WATER QUALITY EVALUATION OF
LAKE MUNSON,
LEON COUNTY, FLORIDA

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NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Water Resources Assessment 88-1

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NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

GOVERNING BOARD

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ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Lake Munson is a shallow man-made lake located south of the City of Tallahassee, in Leon County, Florida. The 255-acre lake was originally a cypress swamp which was reportedly impounded in 1950 in an effort to alleviate flooding problems downstream. Since its creation, the lake has been impacted by the discharge of both stormwater and effluent from municipal wastewater treatment plants in amounts exceeding its natural assimilative capacity. As a result, it has experienced severe water quality and ecologic problems including fish kills, algal blooms, floating aquatic vegetation, high nutrient and bacteria levels, low game fish productivity, and depressed oxygen levels. The first reports of massive algal blooms and fish kills date as early as 1956. Although the lake experienced significant improvements in water quality after the elimination of all effluent discharges in 1984, it continues to exhibit degraded conditions due to stormwater discharges from the City of Tallahassee and urban areas in Leon County.

Lake water quality data for the period 1966 to 1980 indicated a lake in an advanced state of eutrophication. In a 1982 study of Florida lakes, for example, Lake Munson was classified as hypereutrophic and ranked the seventh most degraded lake in the state. At the time, most of the nutrient loading originated from wastewater effluent. In 1978-1979, when treatment plants were discharging into the lake at their peak historical rate, it was estimated that they contributed at least 66 percent of the biochemical oxygen demand (BOD), 88 percent of the phosphorus, and 91 percent of the nitrogen loads into Lake Munson. Since effluent discharges were eliminated in 1984, however, the lake experienced significant improvements in water quality. As a result, Lake Munson may now be classified as eutrophic and ranked the fifty-second most degraded lake in the state. Such recovery is a direct result of the wastewater cleanup efforts by the City of Tallahassee, and offers proof of the tangible benefits that stem from lake restoration efforts. More work will be required, however, in order to address the problem of stormwater discharges which continue to affect lake water quality.

Except for accidental sewage spills which occasionally discharge into Munson Slough, stormwater runoff currently accounts for virtually all of the pollutant and sediment loads entering the lake. Stormwater discharges originate from an area of 23,393 acres which includes 51 percent of the City of Tallahassee. A lake water quality sampling program was implemented as part of this project in order to determine the current status of the lake and evaluate the impacts of stormwater discharges. Biweekly water quality samples were obtained at seven stations in the lake for the period November 1986 to October 1987. These data indicated a lake with enriched nutrient levels, algal blooms, elevated pH levels, toxic concentrations of un-ionized ammonia, depressed oxygen levels, and radical diurnal fluctuations in dissolved oxygen. Several parameters were found to exceed Class III water quality standards of the Florida Department of Environmental Regulation. These included nutrients, dissolved oxygen, alkalinity, pH, un-ionized ammonia, total coliforms, and fecal coliforms.

Nitrogen was identified as the limiting nutrient for algal growth in the lake. The abundance of nitrogen relative to phosphorus was evident in the very low ratios of soluble inorganic nitrogen to soluble reactive phosphorus (SIN:SRP) observed in lake waters. The SIN:SRP ratio of Lake Munson was consistently below 2.5:1 during the entire data collection period, with near zero values observed on several sampling dates. Even total nitrogen to total phosphorus ratios showed lakewide average values below 10:1 over the sampling period. The lake's nitrogen limitation status was further verified by algal growth potential and limiting nutrient assays conducted by the Florida Department of Environmental Regulation from November 1986 to October 1987. Analyses of monthly lake samples for that period consistently showed nitrogen limitation during all sampling dates at all stations.

The present loads from stormwater inflows are estimated at 35,762 pounds per day (lbs/day) of suspended solids, 1,558 lbs/day of BOD, 274 lbs/day of nitrogen, 156 lbs/day of phosphorus, 7.8 lbs/day of lead, 2 lbs/day of copper, and 0.8 lbs/day of chromium. Of these incoming loads, the lake is estimated to retain 95 percent of the suspended solids, 20 percent of the BOD, 31 percent of the nitrogen, 64 percent of the phosphorus, 91 percent of the lead, 72 percent of the copper, and 78 percent of the chromium. The effluent from the lake discharges downstream into Eight Mile Pond and eventually into Ames Sink and the Floridan Aquifer.

Nutrients and pollutants captured by the lake accumulate in the bottom sediments as deposits which may adversely impact aquatic life. Lake sediments were found to release significant amounts of orthophosphorus to the water column, thus contributing to algal blooms. In addition, chemical analyses of bottom sediments revealed higher metal concentrations in the main body of the lake than in some of the more isolated locations, which are not as heavily impacted by stormwater. In previous investigations, lake sediments were found to contain pesticides and metal concentrations in quantities 10 to 100 times greater than amounts found in other local lakes, including Lake Miccosukee, Lake Iamonia, and Lake Jackson. The impact on aquatic habitats was recently documented in a 1987 fish survey of the lake which found very low species diversity and a 75 percent drop in fish biomass since the last fish surveys were conducted in 1976 and 1979. The degradation was attributed to poor sediment and water quality as well as to the shallow depths in the lake, which were estimated to average 3 feet. A recent biological study of sediments in Lake Munson documented a macroinvertebrate community typical of systems enriched with nutrients and organic matter.

Future restoration efforts should address techniques for stabilizing bottom sediments in Lake Munson. However, prior to undertaking any in-lake restoration work, it will be advisable to focus on upland alternatives for stormwater treatment. Otherwise, lake restoration efforts will provide only temporary and partial relief, and the need for expensive cleanups will persist. State of the art stormwater treatment facilities such as wet detention or retention/detention systems may be an effective upland alternative to capture a significant fraction of nutrients and other pollutants prior to entering Lake Munson. The effectiveness of these facilities will have to be carefully evaluated, particularly in light of the nitrogen limitation status of Lake Munson. Most stormwater treatment systems, for example, are very effective at removing total phosphorus but only moderately effective at removing total nitrogen. These systems, however, can be very effective at removing total suspended solids as well as metals, pesticides, and other toxic substances which attach to suspended material.

In summary, the trophic status of Lake Munson has shown remarkable improvements since the majority of the nutrient loads were eliminated in 1984 by diverting wastewater treatment plant effluent to spray irrigation fields. However, stormwater discharges continue to adversely impact water and sediment quality by introducing nutrients and toxic substances which are detrimental to aquatic life. This situation is expected to worsen as development continues to occur in the Lake Munson watershed. Therefore, steps must be taken to both reduce the existing load of pollutants into the lake and prevent the impacts from future development.

INTRODUCTION

Lake Munson is a shallow man-made lake located south of the City of Tallahassee. The lake has a history of severe water quality and ecologic problems including fish kills, algal blooms, floating aquatic vegetation, high nutrient and bacteria levels, low game fish productivity, and depressed oxygen levels. Such degradation resulted from the discharge of both stormwater and effluent from municipal wastewater treatment plants in amounts which exceeded the lake's natural assimilative capacity. Although the lake experienced significant improvements in water quality after the elimination of all effluent discharges in 1984, it continues to exhibit degraded conditions due to stormwater discharges from the City of Tallahassee and urban areas in Leon County.

This investigation was designed to assess the current status of the biology and water quality in Lake Munson, determine the impact of nutrient and pollutant loadings from stormwater, and propose restoration alternatives which may contribute to further enhancing conditions in the lake. The project represents a cooperative effort between the Northwest Florida Water Management District (NWFWMD) and the Florida Department of Environmental Regulation (FDER). The NWFWMD was responsible for all the hydrologic and water quality evaluations, and the Biology Section of the FDER conducted the biological sampling and analyses. Although the results from the biological studies were published in a separate report (FDER, 1988), their findings were referenced herein to provide an understanding of the relationships between the biologic, hydrologic, and water quality characteristics of the lake.

The principal tasks accomplished as part of this investigation included the implementation of a data collection program to monitor water quality, sediment chemistry, and biological conditions in the lake; an assessment of nutrient and pollutant loadings from stormwater; a detailed evaluation of the hydrologic characteristics of stormwater runoff entering the lake; a comprehensive statistical analysis of current and historical data; comparisons between nutrient contributions from wastewater effluent and stormwater; estimates of the pollutant retention capacity of the lake; and discussions and suggestions concerning restoration alternatives with potential for successful implementation.

The Lake Munson sampling program was designed to run concurrently with another data collection effort intended to monitor stormwater flows and quality in the Lake Munson watershed. The stormwater program, funded jointly by the City of Tallahassee, Leon County, and the Northwest Florida Water Management District, is part of a project to develop a comprehensive stormwater management plan for the watershed. The stormwater investigation provided a significant amount of information used as part of this study, including lake water level fluctuations, rainfall, lake inflows and outflows, detailed water quality data for six storms upstream and three storms downstream of the lake, and long-term runoff statistics generated by a fully calibrated hydrologic model of the watershed.

Study Area

Lake Munson presently receives the bulk of its stormwater drainage and pollutant loading from a 23,393 acre watershed which contains about 51 percent of the City of Tallahassee (Figure 1). In addition, the lake drains a large rural area west of Tallahassee. This latter subwatershed contributes a small but undetermined amount of runoff that discharges from Lake Bradford during very wet periods. The Lake Bradford chain of lakes serves to attenuate or store stormwater flows and it is also suspected to have active sinks which divert surface water into the Floridan Aquifer. The lakes are known to be in a high recharge area to the Floridan Aquifer.

The area currently occupied by Lake Munson was originally a cypress swamp which was reportedly impounded in 1950 in an effort to alleviate flooding problems downstream (Bocz and Hand, 1985). Impoundment of the swamp created a 255-acre cypress lake with an average depth of about 5 feet. The outfall structure is located at the lake's southeast corner and consists of four swing arm gates with fixed weirs on each side (Figures 2 and 3). The elevation of the side weirs is 26.75 feet NGVD (National Geodetic Vertical Datum) with the bottom of the gates at 19.25 feet NGVD.

Although the lake does not currently receive effluent from wastewater treatment plants in the watershed, it was very heavily impacted in the past. The first wastewater treatment plant to discharge effluent into a tributary of Lake Munson was built in 1934 (Bocz and Hand, 1985). Other major treatment plants were added to the system and their capacities increased in subsequent years, with total effluent discharge peaking in 1978-1979. Prior to that time, however, the City of Tallahassee began diverting wastewater effluent to spray irrigation fields and, by 1984, all effluent discharges into tributaries of Lake Munson had been eliminated.

Figure 1 shows the locations of the three major wastewater treatment plants as well as the major spray irrigation field which currently receives almost all of Tallahassee's wastewater effluent. Spray irrigation of effluent from the T. P. Smith treatment plant began in 1966 and by 1980 all of the effluent from this plant was routed to spray fields. Later, in 1982, the Dale Mabry plant was completely shut down and, in 1984, the Lake Bradford plant began discharging its effluent into the spray irrigation fields (Bocz and Hand, 1985).

Previous Investigations

As a result of the historical nutrient loads from wastewater effluent and stormwater, the lake's water quality has displayed signs of severe degradation for many years. Problems with massive algae blooms were documented as early as 1956 and 1963 (Beck, 1963). In 1963, a survey of the conditions that led to a fish kill indicated the occurrence of elevated pH levels and radical diurnal fluctuations in dissolved oxygen concentrations (Haney, 1963). Other reports described the lake as hypereutrophic, with recurring fish kills, decreased reproduction of game fish, heavy phytoplankton blooms in the summer months, and floating aquatic vegetation, including water hyacinths and duckweed, which required periodic spraying to prevent major coverage of the lake (Ketelle and Uttomark, 1971; and Young and Crew, 1977).

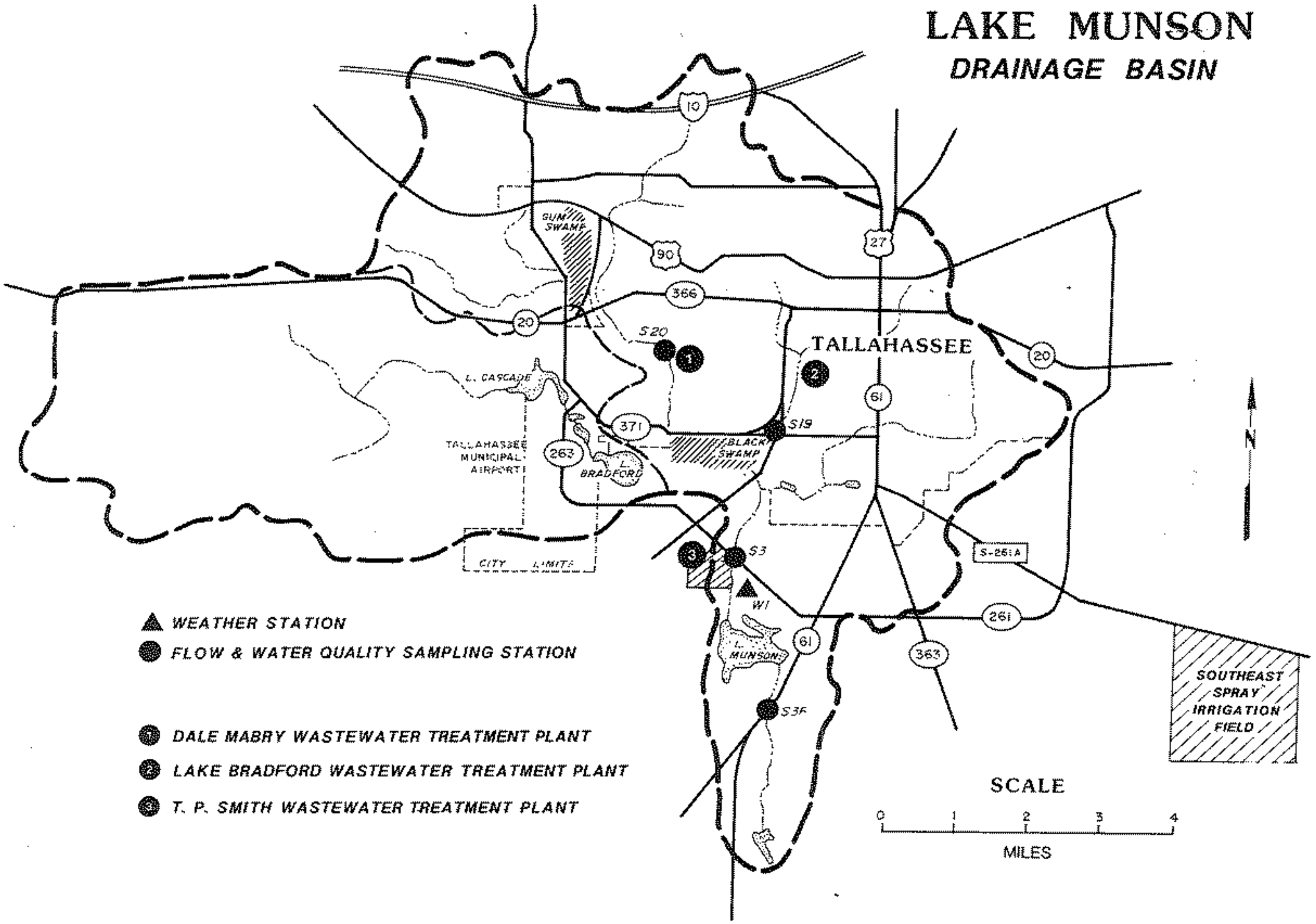
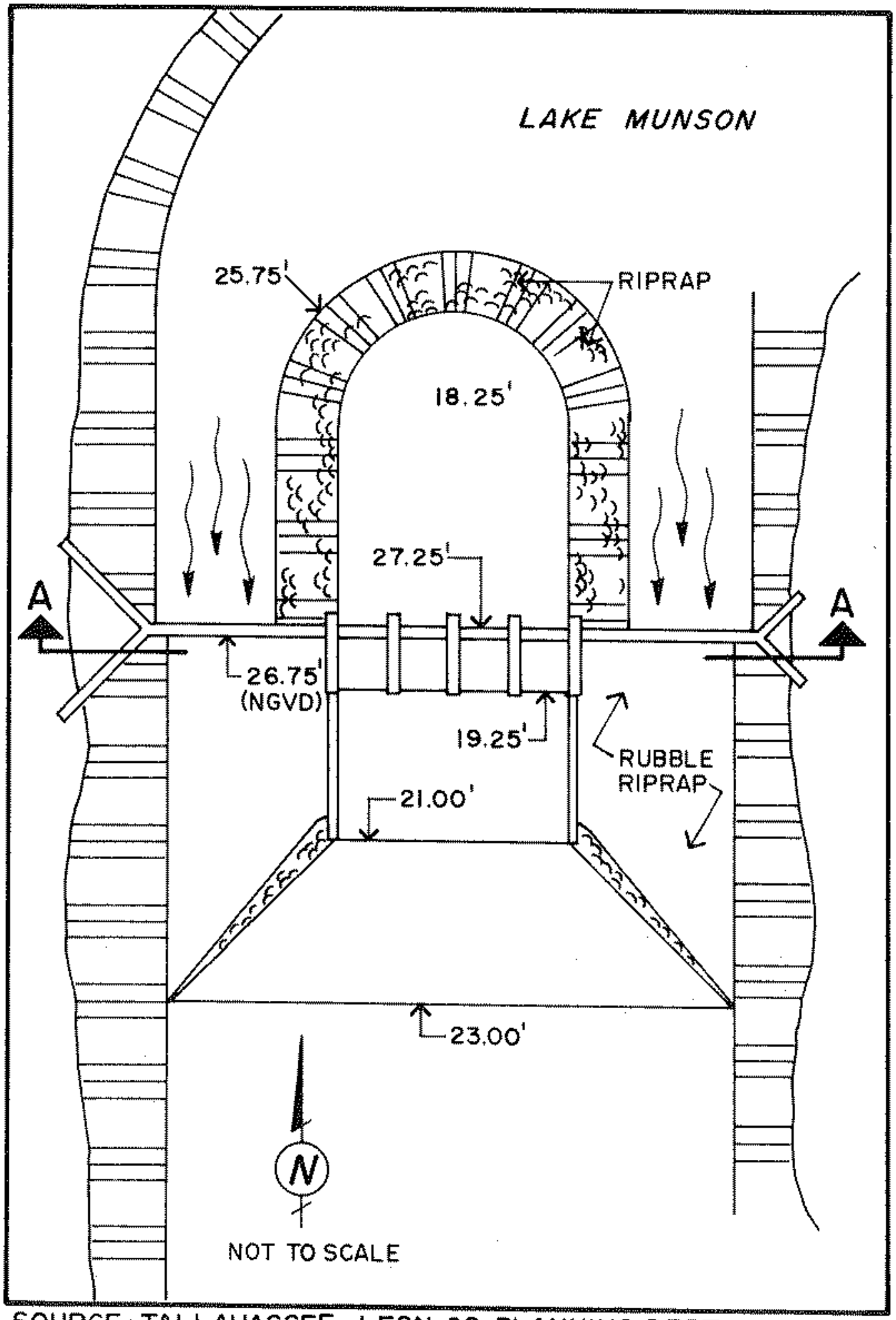


Figure 1. Lake Munson Watershed and Stormwater Monitoring Stations



SOURCE: TALLAHASSEE-LEON CO. PLANNING DEPT.

Figure 2. Plan View of Lake Munson's Outfall Structure

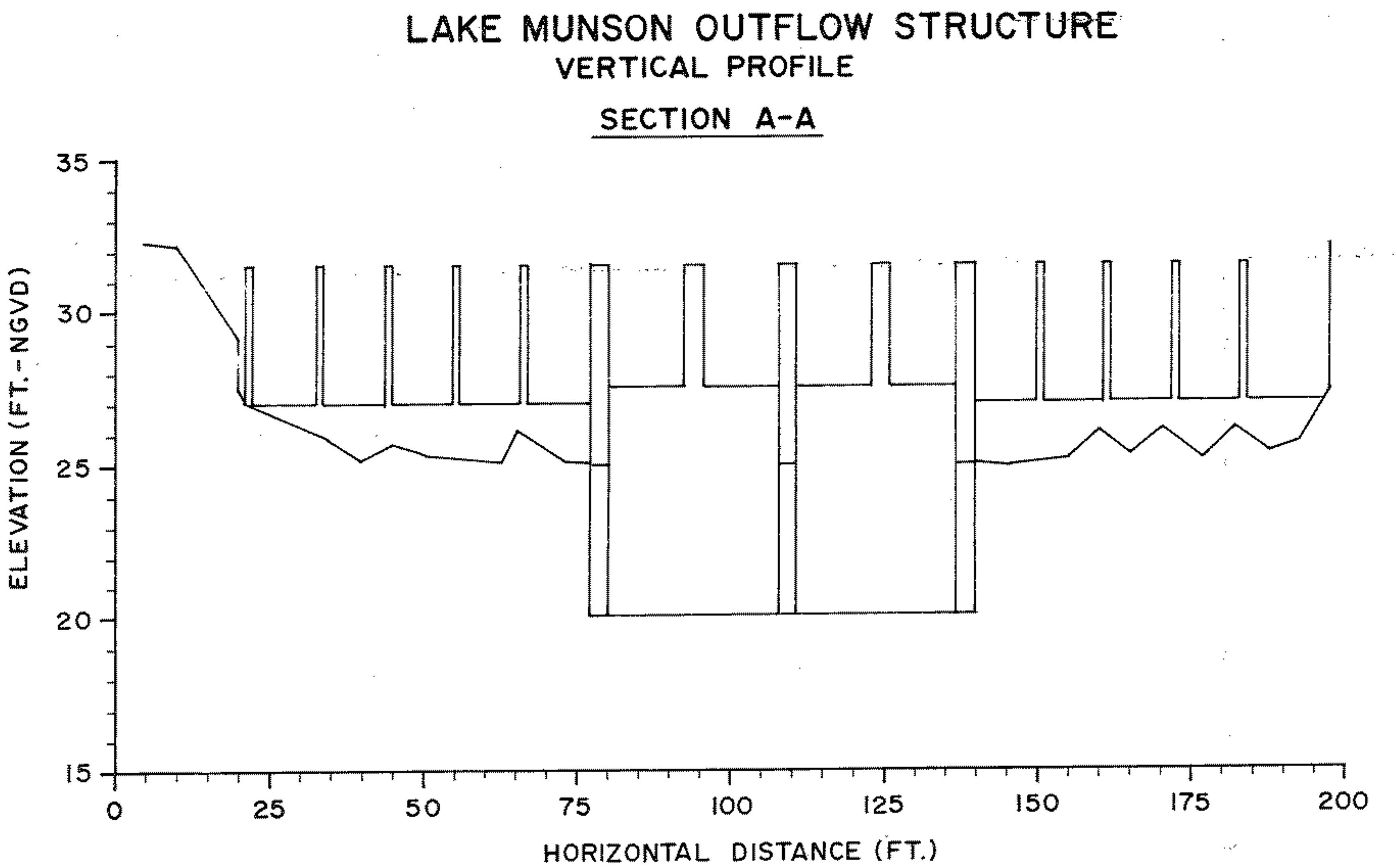


Figure 3. Vertical Section of Lake Munson's Outfall Structure

In 1973 the U. S. Environmental Protection Agency (EPA) conducted a water quality survey of Lake Munson as part of the National Eutrophication Survey (U. S. EPA, 1977). The data indicated a lake in an advanced state of eutrophication. Dissolved oxygen levels fluctuated between 2.8 and 17.1 mg/l, chlorophyll_a ranged from 108.2 to 179.2 ug/l, pH varied from 8.2 to 10.5, total nitrogen ranged from 3.08 to 10.46 mg/l, and total phosphorus was measured at between 1.14 and 4.11 mg/l. Algal assays indicated nitrogen limitation at all stations and sampling times. The study concluded that non-point sources were responsible for about 54 percent of the total phosphorus and 56 percent of the total nitrogen load to the lake, with the remainder being contributed by Tallahassee's wastewater treatment plants.

In an effort to improve water and sediment quality in the lake, a major dewatering program was coordinated by the Tallahassee-Leon County 208 Program in April of 1977. Water levels in the lake were lowered approximately 5 feet, resulting in an exposure of about 70 percent of lake bottom sediments. Some erosion of sediment floc and sludge appearing in the outflow stream was observed during the drawdown period (Leseman, 1977). Also, a dense stand of vegetation grew rapidly on the fertile lake bottom (Young and Crew, 1977). Harvesting, however, was not feasible due to the inability of the soft bottom sediments to support men and equipment (Bocz and Hand, 1985).

Following reflooding of the lake in December of 1977, the Game and Fresh Water Fish Commission stocked the lake with catfish in December of 1977, and later with largemouth bass in the spring of 1978 (Young and Crew, 1979). A fish survey conducted the following year revealed that only 6 percent of the supplemental bass population had survived due to the low tolerance of largemouth bass to poor water quality (Young and Crew, 1980). The Game Commission recommended to discontinue fish monitoring until water quality was improved to the extent that the lake could support a balanced and self-sustaining fish population.

Another study was conducted by the Florida Department of Environmental Regulation in 1985 for the purpose of evaluating the water quality effects of eliminating the discharge of wastewater effluent into Lake Munson. Limited data collected by the FDER from April through August of 1985 indicated substantially improved water quality in the lake. Chlorophyll_a averaged 34 ug/l, secchi depth: 3.9 feet, total nitrogen: 0.5 mg/l, and total phosphorus: 0.4 mg/l. In addition, the FDER estimated the total nutrient load into the lake on the basis of compliance monitoring data for the wastewater treatment plants as well as stormwater data from EPA's National Eutrophication Survey. Results showed that wastewater effluent contributed 20 percent of the hydraulic load, 70 percent of the nitrogen load, and 90 percent of the phosphorus load to the lake in 1973. After examining sediment chemistry data collected by the U. S. Geological Survey (USGS) in 1981, the FDER also concluded that high concentrations of pesticides and toxic materials were being introduced into the lake via stormwater inflows. PCB, Chlordane, DDD, DDE, DDT, Dieldrin, lead, copper, and zinc in Lake Munson sediments were found to occur in quantities 10 to 100 times greater than amounts found in other local lakes, including Lake Miccosukee, Lake Iamonia, and Lake Jackson (Bocz and Hand, 1985).

Although the water quality in Lake Munson appeared to have improved considerably after eliminating the discharge of wastewater effluent, a recent study by the Game Commission indicates no improvement in the lake's fish population. A comparison between fishery values in 1987 and those documented in the surveys of 1976 and 1979 indicated a 75 percent decrease in overall fish biomass (Young and Crew, 1987). In addition, species diversity was found to be quite low as a result of the lake's very limited habitat types. On this basis and results from a recent bathymetric survey of the lake, the Commission concluded that Lake Munson was becoming too shallow to support a viable fish population. The bathymetric survey revealed the existence of thick deposits of organic sediments averaging 2.35 feet lakewide, with maximum accumulations of nearly 8 feet. The average depth of water was calculated at 3 feet and the delta at the lake's inflow point was estimated to cover an area of 15.2 acres. The Commission recommended the complete removal of organic sediments once the problems associated with stormwater runoff and siltation were identified and corrected (Williams and others, 1987).

Data Collection

A comprehensive data collection program was undertaken for Lake Munson in order to monitor seasonal fluctuations in water quality over a one-year period. The program was designed to run concurrently with another data collection effort implemented as part of the aforementioned project to develop a stormwater management plan for the Lake Munson Watershed. The stormwater data collection program provided information on lake inflows and outflows, stormwater quality, precipitation, and lake level fluctuations while the lake water quality was monitored. In this manner, it was possible to establish a direct connection between lake water quality and stormwater inflows.

Lake Sampling

Seven stations were sampled for lake water quality data and up to fifteen stations were sampled for sediment chemistry and physical characteristics, as shown in Figure 4. Sample sites were selected with consideration to previous study locations, inflow/outflow locations, and typical flow patterns in the lake. Water quality samples were obtained biweekly at stations S42 through S48 for the one-year period from November 16, 1986 to November 2, 1987. Sediment sampling was undertaken on four separate occasions during 1987. Stations S42 to S48 (7 sites) were sampled in March and October, and stations S42 to S56 (15 sites) in August and December. Particle size distributions were performed on the sediment samples at all 15 sites. Lake level fluctuations were monitored continuously from mid January through December 1987 using a Handar 550B water level recorder located on the lake's northeast shore just off Tom Still Road (S2 in Figure 4).

Field measurements included data on pH, dissolved oxygen (DO), secchi depth, specific conductance, total depth, and temperature. In addition, dissolved oxygen was monitored continuously for a three-week period in August 1987. A Stevens minimonitor recorder was located on the eastern end of the lake (S64 in Figure 4) and used to log hourly sensor readings for surface and benthic DO, as well as mid-depth water temperature. The minimonitor was routinely recalibrated and DO probes checked and serviced.

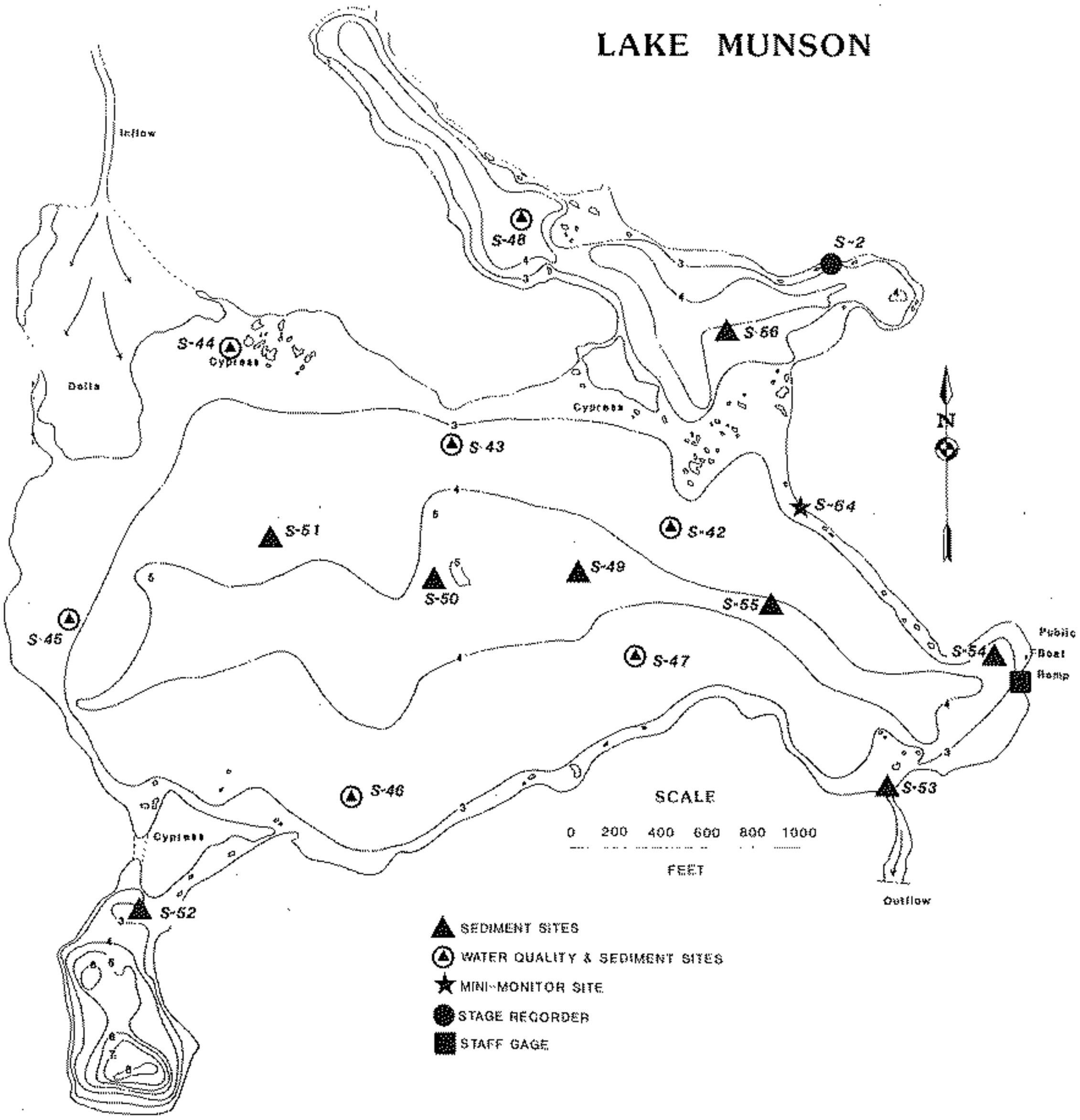


Figure 4. Lake Munson Monitoring Stations

Table 1 includes a list of all parameters analyzed, method reference, storet number, detection limit, and units of expression. All sampling and laboratory analyses were carried out in accordance with the quality assurance plan submitted to FDER as part of the plan of study by the Northwest Florida Water Management District (NWFWMD, 1986), and City of Tallahassee Water Quality Laboratory, using QAMS-005-80 Interim Guidelines and Specifications.

Water samples were retrieved using a peristaltic pump with teflon tubing inserted inside a PVC tube. The tubing was placed at mid-depth in the water column and purged before sample withdrawal. Chlorophyll and microbiological samples were hand grabbed just below the water surface. Microbiological samples were taken with Whirlpak container bags. Laboratory supplied field blanks and replicate samples were analyzed on each field trip for quality control purposes. Sediment samples were retrieved using a PVC coring device with two-foot sections of acrylic plastic tubing inserted into the device. All samples were immediately iced and kept cool throughout the custody period. Bottles were marked with the appropriate identification, and field sheets were provided with each sampling. Samples were delivered to the lab on the day of sample collection.

Temperature and dissolved oxygen measurements were taken at one-foot depth intervals at the seven lake stations (S42-S48). A YSI Model 51B DO meter, which was calibrated on-site and checked periodically for drift, was used for the DO measurements. Measurements of pH were originally taken at mid-depth with an Orion Model 211/Digital pH meter. After noticing some fluctuations in pH values at different depths, profiles were also done with the pH meter. Temperature profiles as well as specific conductance measurements at mid-depth were taken with a YSI Model 33 S-C-T meter. Conductance values were corrected for temperature at 25 degrees C.

All phosphorus and nitrogen species are reported as mg/l of P and N, respectively, throughout this report. Total nitrogen values were calculated by summing total Kjeldahl nitrogen and nitrate-nitrite nitrogen. Also, nitrate values were calculated by subtracting nitrite from nitrate-nitrite values.

Stormwater Sampling

Concurrent with the lake sampling program, stormwater flows and quality in the Lake Munson Basin were monitored as part of the District's project to develop a stormwater management plan for the City of Tallahassee and Leon County. Lake inflows and outflows were monitored continuously using Handar 550B water level recorders located in Lake Munson (S2 in Figure 4) and in Munson Slough just upstream of the lake (S3 in Figure 1). Water level readings were converted to flow values on the basis of ratings developed from flow measurements conducted during significant storm events. Rainfall was monitored with a tipping bucket rain gage (W1 in Figure 1).

TABLE 1

METHODS OF WATER QUALITY ANALYSIS

Parameter	Method Reference	Storet Number	Detection Limit	Units
		Nutrients		
NO3+NO2-N	USGS I-4545-78	00630	0.025	mg/l
NO2-N	USGS 4540-78	00615	0.02	mg/l
Total P	USGS I-4603-78	00665	0.05	mg/l
Ortho P	EPA 365.1	00671	0.024	mg/l
Ammonia-N total	EPA 350.1	00610	0.025	mg/l
Ammonia-N diss.	EPA 350.1	00608	0.025	mg/l
TKN	EPA 351.2	00625	0.07	mg/l
TKN diss.	EPA 351.2	00623	0.07	mg/l
		Mineral and Physical		
Chloride	USGS I-2187-78	00940	0.19	mg/l
Turbidity	EPA 180.1	00076	0.05	NTU
Total Residue	EPA 160.3	00500	1	mg/l
Residue nonfilt.	EPA 160.3	00530	1	mg/l
Residue volatile nonfilt.	EPA 160.4	00535	1	mg/l
Alkalinity	Std Meth 403	00410	3.1	mg/l CaCO3
Color	EPA 110.3		00080	1 ---
Sp cond (lab)	EPA 120.1		00095	4.74 umhos
Sp cond (field)	Std Meth 205	00094	4.74	umhos
pH	Std Meth 423	00400	0.048	---
Temp	Std Meth 205	00010	---	Celsius
DO	Std Meth 421F	00300	---	mg/l
Secchi		00077	---	in
		Metals		
Aluminum diss.	EPA 202.2	01106	3.0	ug/l
Arsenic total	EPA 206.2	01002	3.48	ug/l
Cadmium diss.	EPA 213.2	01025	0.38	ug/l
Cadmium total	EPA 213.2	01027	0.38	ug/l
Chromium diss.	EPA 218.2	01030	0.63	ug/l
Chromium total	EPA 218.2	01034	0.63	ug/l
Copper diss.	EPA 220.2	01040	0.27	ug/l
Copper total	EPA 220.2	01042	0.27	ug/l
Lead diss.	EPA 239.2	1049	0.65	ug/l
Lead total	EPA 239.2	01051	0.65	ug/l
Mercury total	EPA 245.1	71900	0.52	ug/l
Nickel total	EPA 249.2	01067	2.87	ug/l
Zinc total	EPA 289.1	01092	61.5	ug/l
Silver total	EPA 272.1	01077	0.66	ug/l

TABLE 1

METHODS OF WATER QUALITY ANALYSIS
(continued)

Parameter	Method Reference	Storet Number	Detection Limit	Units
		Demand		
BOD 5day & carbonaceous	Std Meth 507 (Electrode)	00310	2.0	mg/l
COD	Oceanographic	00340	4.5	mg/l
TOC	EPA 415.1	00680	0.15	mg/l
		Microbiological		
Fecal Coliform	EPA 600/8-78-017	31625	1	#/100ml
Total Coliform	EPA 600/8-78-017	31501	1	#/100ml
Fecal Strep	EPA 600/8-78-017	31673	1	#/100ml
Chlorophyll_a	Strickland (1972)	32211		ug/l
Phaeophytin	Strickland (1972)	32218		ug/l
		Organics		
Organics	EPA 601;602		(See Table 4)	
		Sediments		
Nitrogen	EPA 351.3	80111	0.5	mg/kg
Phosphorus	USGS I-4603-78	61546	5.0	mg/kg
Aluminum	USGS I-5051-78	01108	10.0	mg/kg
Chromium	EPA 218.2	61513	0.21	mg/kg
Copper	EPA 220.2	61507	0.09	mg/kg
Lead	EPA 239.2	61504	0.22	mg/kg

Stormwater quality was collected at stations S3 and S36 (Figure 1) using Isco model 2700 automatic samplers. A total of six storm events were sampled at station S3, and three at station S36. The samplers were activated by an actuator tip which engaged the peristaltic pump when the water level rose to a predetermined site-specific stage. The samplers were programmed to take up to six water quality samples during each storm event. The typical sampling sequence began with purging of the suction line. The sample volume was then delivered to the appropriate bottle and the line purged to avoid cross-contamination of the next sample.

STORMWATER HYDROLOGY

Short-term records of stormwater flows were available at several locations in the Lake Munson watershed. However, these data were not sufficient to determine the long-term distribution of stormwater flows into the lake. It was necessary, therefore, to apply a calibrated stormwater model to the entire watershed in order to generate a sufficiently long period record from which accurate statistics could be calculated . EPA's Stormwater Management Model (SWMM) (Huber and others, 1981) was the principal tool used in this effort.

The SWMM model was calibrated and verified on the basis of concurrent rainfall and runoff data from 16 subwatersheds in the general vicinity of the City of Tallahassee. A total of 108 different storms were used to test the accuracy of the model against observed data. Figures 5 and 6 show the accuracy of the model in simulating peak flows and runoff volumes, respectively. From the figures, the line of equality represents a perfect match between observed and simulated data. Therefore, the closer the symbols are to that line, the higher the accuracy of each individual storm. The absolute average error for all 108 storms was estimated at 40 percent for peak flows and 25 percent for runoff volumes.

Once calibrated, model parameters were related to each of the watershed's physical characteristics by means of regression equations. The resulting equations enabled the extrapolation of model parameters to ungaged basins, thereby permitting the model to be applied to the entire Lake Munson watershed. Predictive equations were developed for the width parameter of the kinematic wave equation, the resistance factor or Manning's n, and both the saturated hydraulic conductivity and the capillary suction parameters of the Green-Ampt infiltration equation. The correlation coefficients associated with the different equations ranged from 0.83 to 0.99, and standard errors of estimate varied from 3.4 percent to 38 percent.

For the purposes of this study, the Lake Munson watershed was defined as the large urban area which drains approximately 51 percent of the City of Tallahassee. The watershed area is 23,393 acres and the extent of current development is estimated at 20 percent impervious. The large rural area west of Tallahassee which drains into Lake Bradford was not included in the simulations. As discussed earlier, the Lake Bradford chain of lakes functions as a large reservoir for stormwater flows and volumes, so that its outflows are small relative to the more significant flow rates generated from the more developed subbasins in the watershed.

The calibrated model was used to simulate stormwater inflows into Lake Munson based on historical rainfall data. Long-term rainfall data used for this purpose were obtained from records available at the Tallahassee Municipal Airport (NOAA's station no. 08-8758). Hourly rainfall for the 28.5-year period from June 1958 to December 1986 were used to generate a record of stormwater flows for present basin conditions.

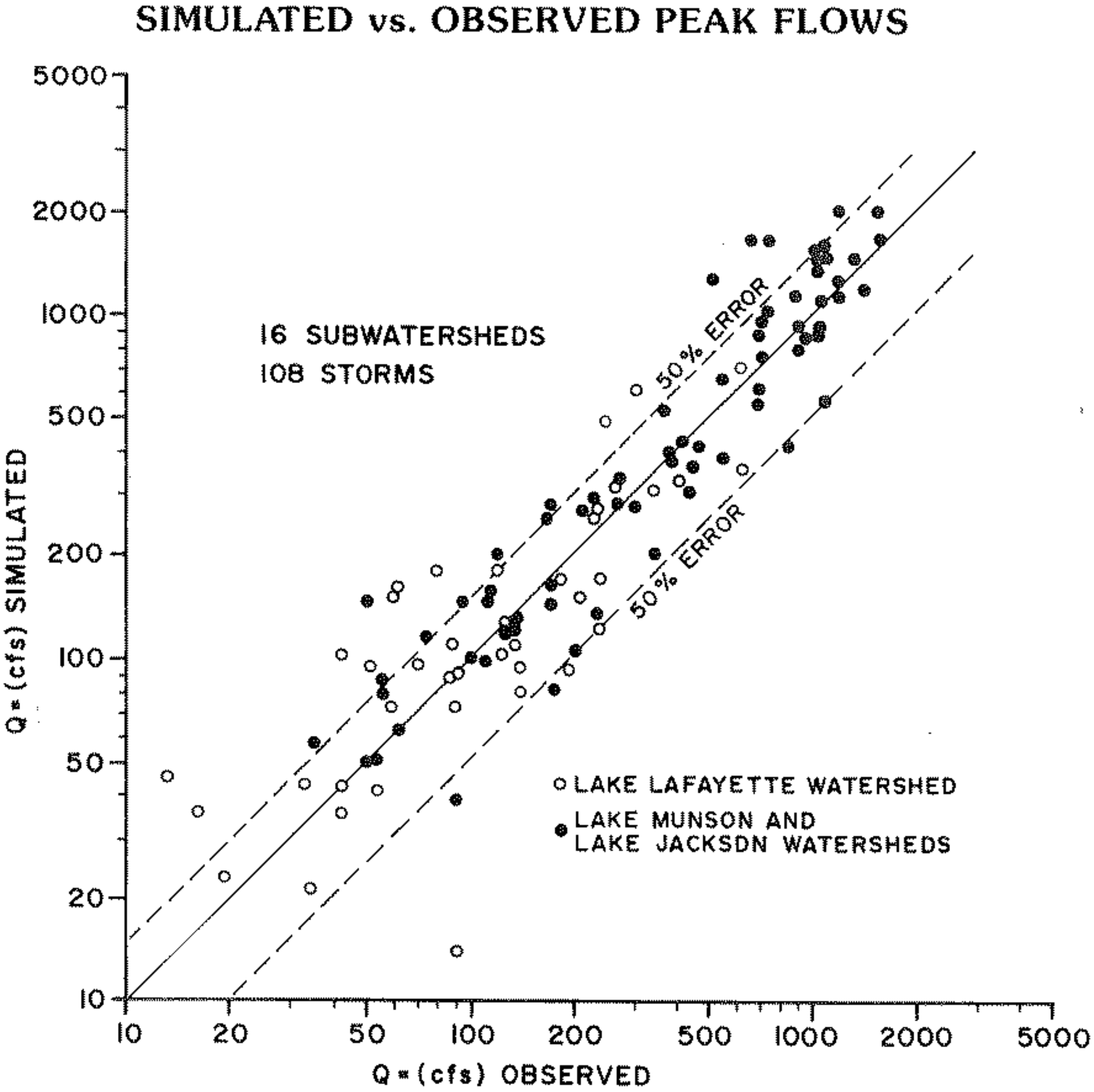


Figure 5. Accuracy of Stormwater Model in Simulating Peak Flows

SIMULATED vs. OBSERVED STORM VOLUMES

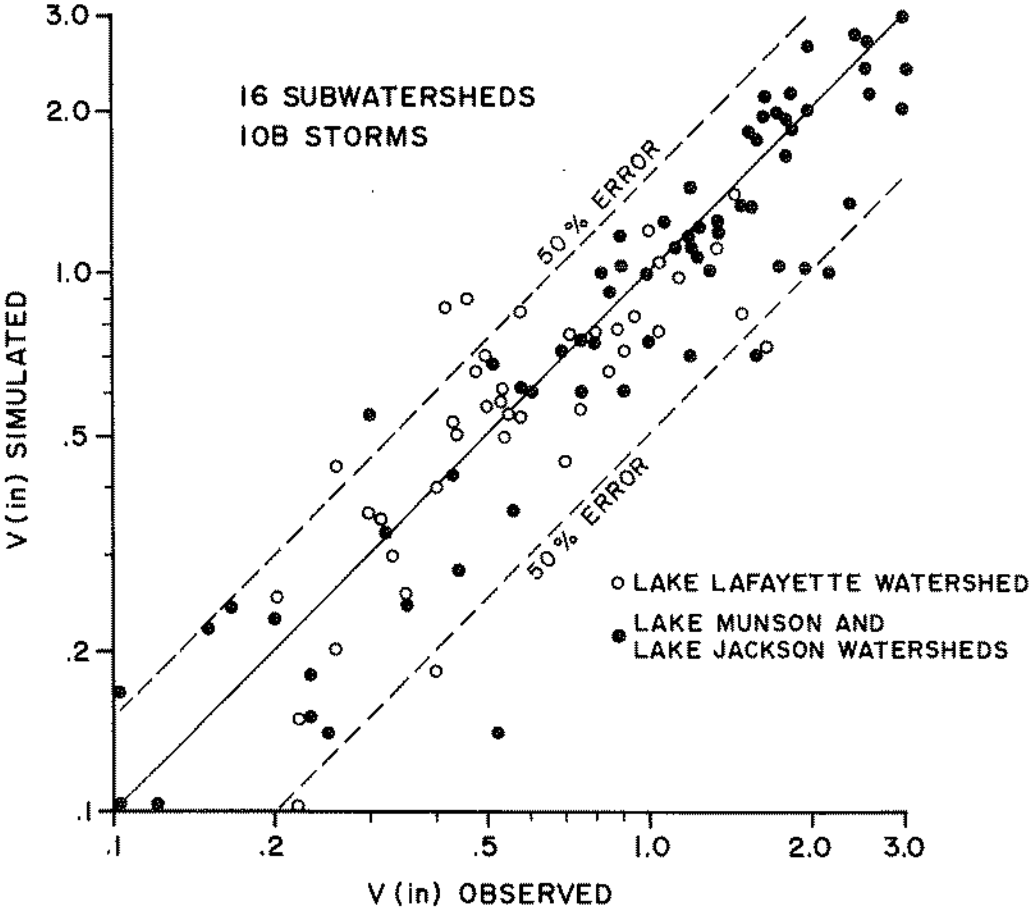


Figure 6. Accuracy of Stormwater Model in Simulating Runoff Volumes

The resulting runoff histories were analyzed statistically to determine the distribution of storm events. The SWMM model was applied initially in order to divide the runoff record into a series of independent storm events and compute their respective statistics on peak flows, average flows, total volumes, event durations, and intervening times. Subsequently, the largest annual flood peaks and volumes were selected and analyzed to determine their frequency distribution. Flood frequencies were calculated by fitting the data to a Log-Pearson Type III distribution following the guidelines recommended by the U. S. Department of the Interior Hydrology Subcommittee (USGS, 1981). The Corps of Engineers' FREQFLO program (U. S. Army Corps of Engineers, 1982) was used to calculate all flood statistics.

Table 2 presents the storm summaries for both rainfall and runoff at Lake Munson. From the table, the average rainstorm generates 0.83 inches of water at a mean peak intensity of about 0.38 inches per hour (in/hr). The mean time between the end of one storm and the beginning of another is 100 hours, with the average storm lasting approximately 9.6 hours. Similarly, the average runoff hydrograph has a duration of 121 hours, an intervening time of 115 hours, and produces about 774 acre-ft of water at a mean peak flow rate of 48 cubic feet per second (cfs). Comparing the average runoff volume (774 acre-ft) with the volume of water in Lake Munson (763 acre-ft, Young and Crew, 1987), it becomes evident that the average storm is basically retained in.the lake for a period of approximately 115 hours before being displaced by the next storm. Settling of suspended solids as well as biochemical treatment of stormwaters occur during that period, providing for some treatment prior to release from the lake.

Figures 7 through 10 show the distributions and flood frequencies of stormwater flows and volumes. From Figures 7 and 8, the median storm has a volume of about 150 acre-ft, a peak flow of 200 cfs, and an average flow of 100 cfs. Half of the storms draining into Lake Munson will be larger than or smaller than the median storm. Figure 8 also indicates that only 20 percent of the storms will have volumes exceeding the capacity of the lake.

In addition to computing flood flow frequencies, the HEC-2 backwater model (U. S. Army Corps of Engineers, 1982) was applied to the computed peak flows in order to calculate the frequency of flooding in the lake. The results are presented in Figure 11 which shows the flooding elevations associated with various return period storms. The figure indicates that a 25-year storm will produce a water surface elevation of 30.3 feet NGVD or a depth of 3.55 feet above the normal pool elevation of about 26.75 feet NGVD.

Hydrologic Conditions During Study Period

Hydrologic data in the Lake Munson Watershed were evaluated to determine the prevailing climatological conditions during the data collection period. This was accomplished by comparing long-term rainfall records at the Tallahassee Municipal Airport with rainfall amounts during the study period.

TABLE 2

SUMMARY OF RAINFALL AND RUNOFF STATISTICS AT LAKE MUNSON

(June 1958 to December 1986)

Rain Storm Statistics at NOAA's Station No. 08-8758 at the Tallahassee Municipal Airport

Storm Parameter	Mean	Coefficient of Variation[1]
Storm Volume (in)	0.83	1.416
Storm Average Intensity (in/hr)	0.14	1.282
Storm Peak Intensity (in/hr)	0.38	1.125
Event Duration (hrs)	9.63	1.367
Interevent Duration (hrs)	100.0	1.017

Simulated Runoff Storm Statistics at Lake Munson Inflow Station S3

Storm Parameter	Mean	Coefficient of Variation[1]
Storm Volume (acre-ft)	774.4	2.028
Storm Average Flow (cfs)	42.7	0.955
Storm Peak Flow (cfs)	220.0	0.903
Event Duration (hrs)	121.0	1.417
Interevent Duration (hrs)	115.0	1.006

[1] - Standard deviation divided by the mean.

DISTRIBUTION OF STORM RUNOFF AT LAKE MUNSON

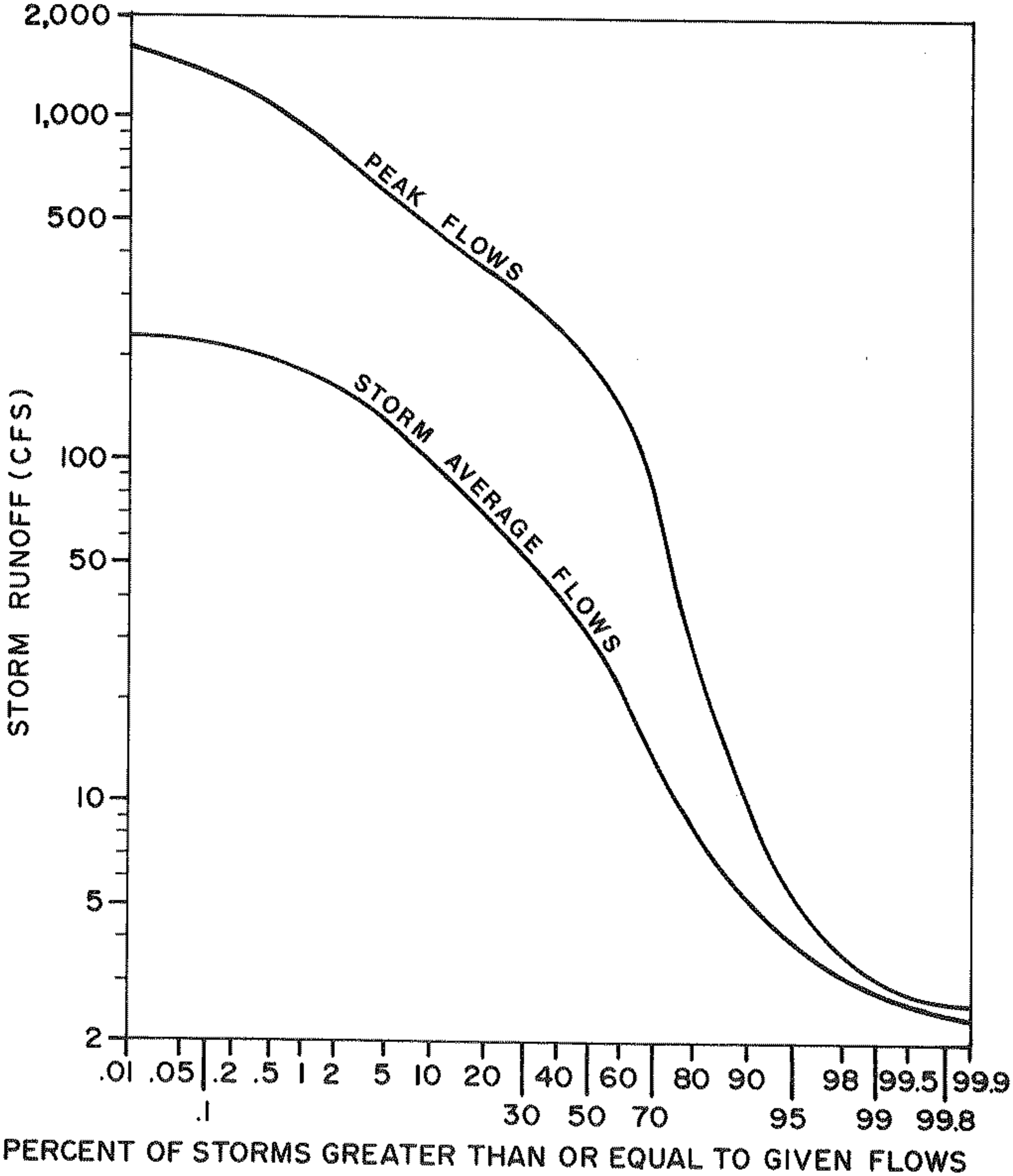


Figure 7. Distribution of Storm Runoff at Lake Munson

DISTRIBUTION OF STORM VOLUMES
AT LAKE MUNSON

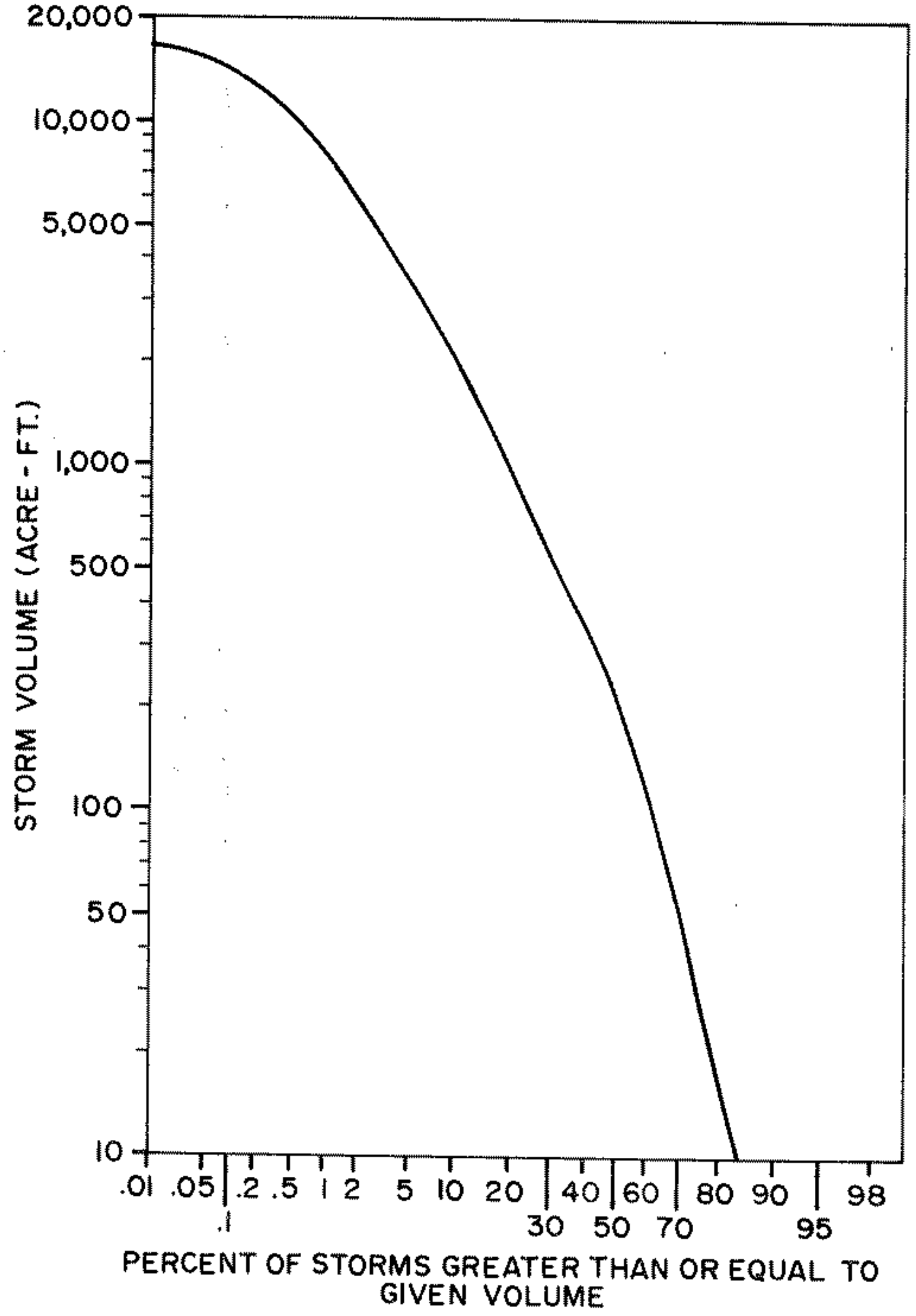


Figure 8. Distribution of Storm Volume at Lake Munson

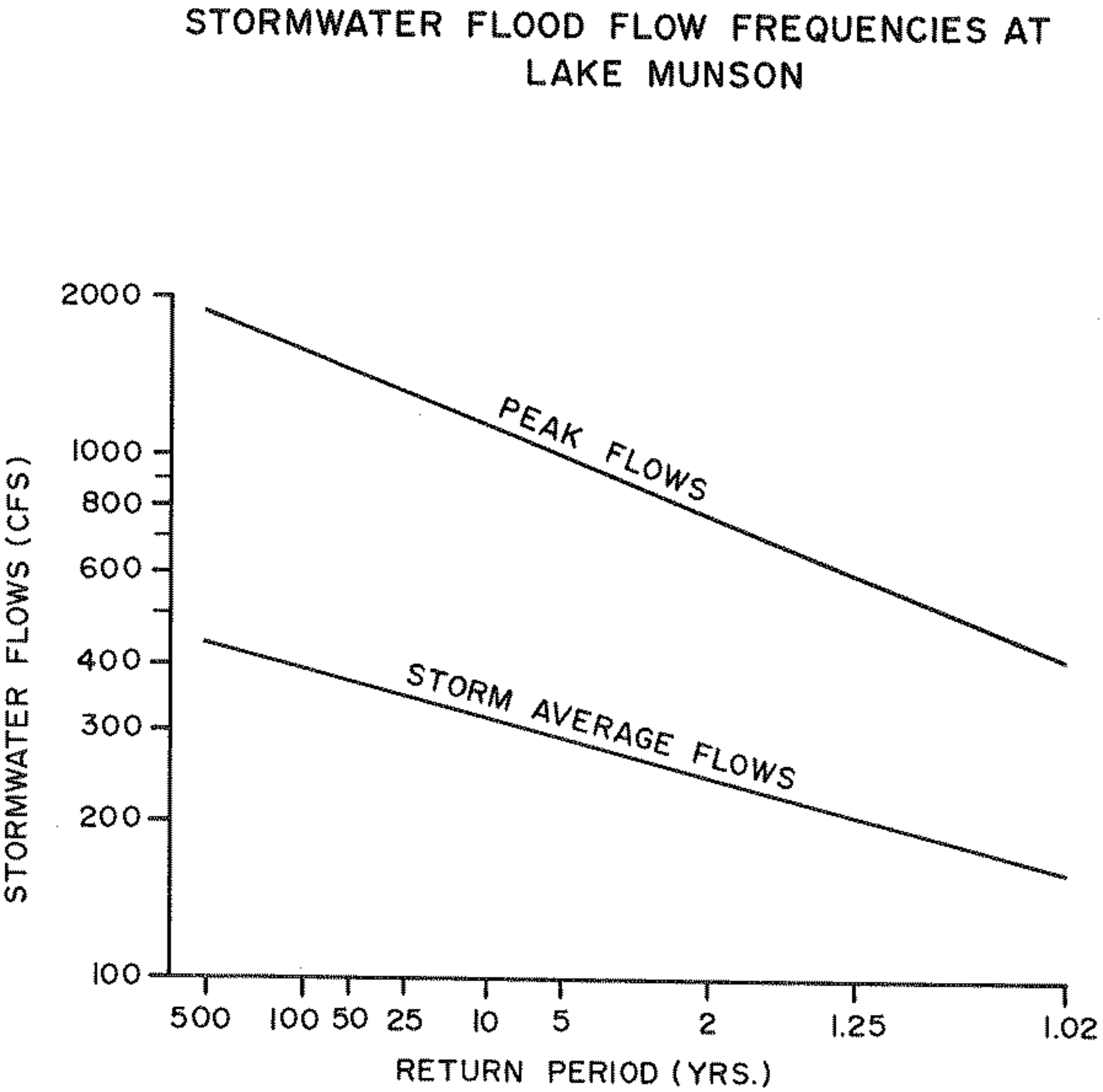


Figure 9. Flood Flow Frequencies at Lake Munson

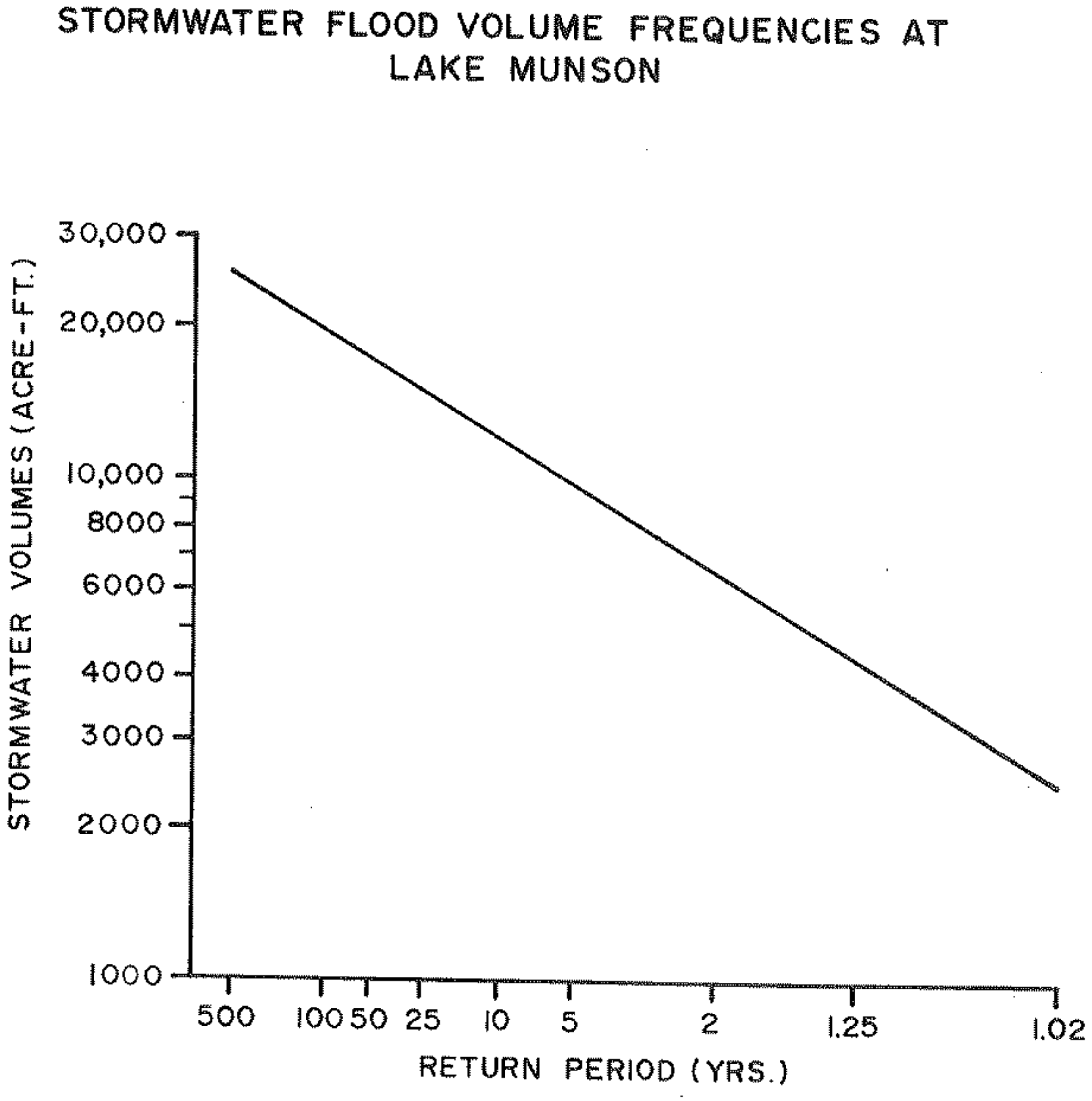


Figure 10. Flood Volume Frequencies at Lake Munson

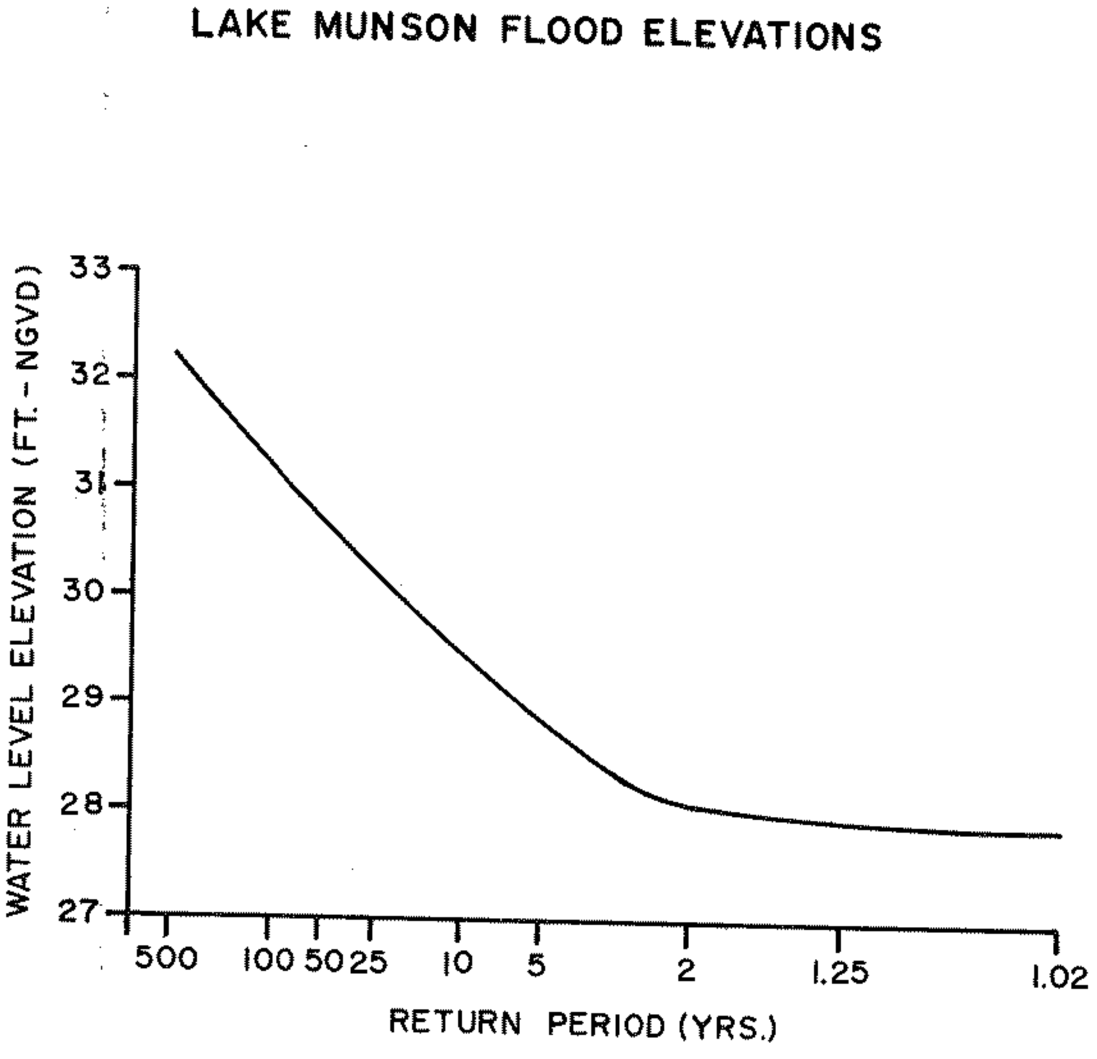


Figure 11. Flood Water Surface Elevations at Lake Munson

Figure 12 gives monthly rainfall totals from November 1986 to November 1987 as well as average and extreme monthly rainfall amounts for the 50-year period from 1938 to 1987. A comparison of the two sets of data indicates that winter and summer rainfall during the study period was slightly above normal, while Spring and Fall rainfall amounts were below normal with dry periods occurring in April and October.

Continuous rainfall data collected at the Lake Munson weather station (station W1 in Figure 1) since January 1987 gives a more detailed account of the occurrence of rain storm events during the study period. Five-minute rainfall data presented in Figure 13 shows that the most intense storm activity as well as the largest storms occurred during the period from late June to early July. The dry periods experienced during April, late May, and October are also well documented. This data compares very favorably with data obtained at the Tallahassee Municipal Airport.

Continuous flow records upstream of the lake on Munson Slough (station S3 in Figure 1) and corresponding lake level fluctuations at station S2 (Figure 4) are provided in Figures 14 and 15, respectively. As would be expected, lake levels respond instantaneously to stormwater inflows, except following dry periods when very small storms would only elicit small changes in lake levels. Inflow and outflow hydrographs display very small time lags, with peak flows practically occurring simultaneously. Outflow hydrographs were flatter and more elongated due to the storage effect of the lake. Since the average storm volume is approximately equal to the storage volume in the lake, lake waters are completely replaced after average or above average storm events.

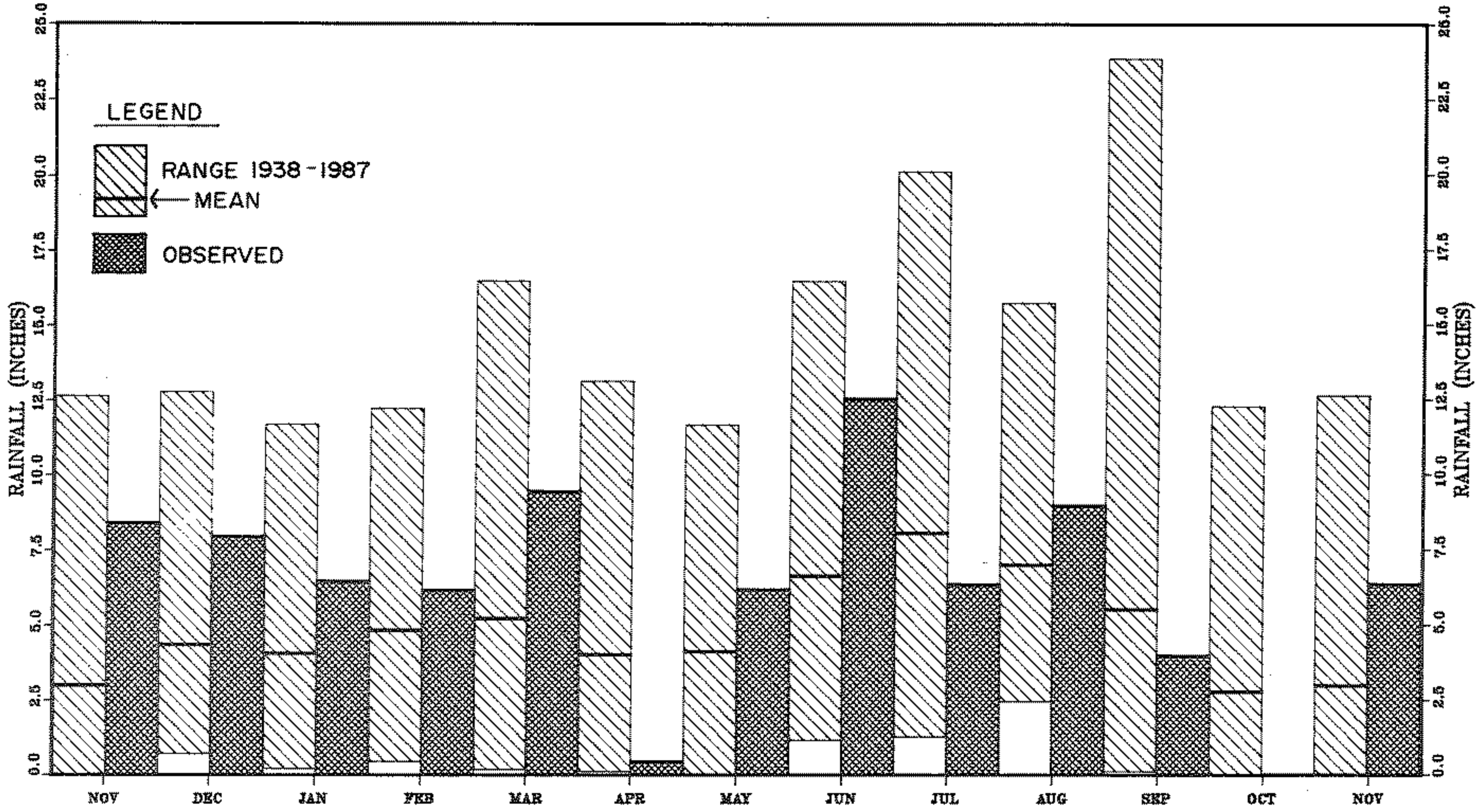


Figure 12. Comparison of Rainfall Data During Study Period and Historical Conditions

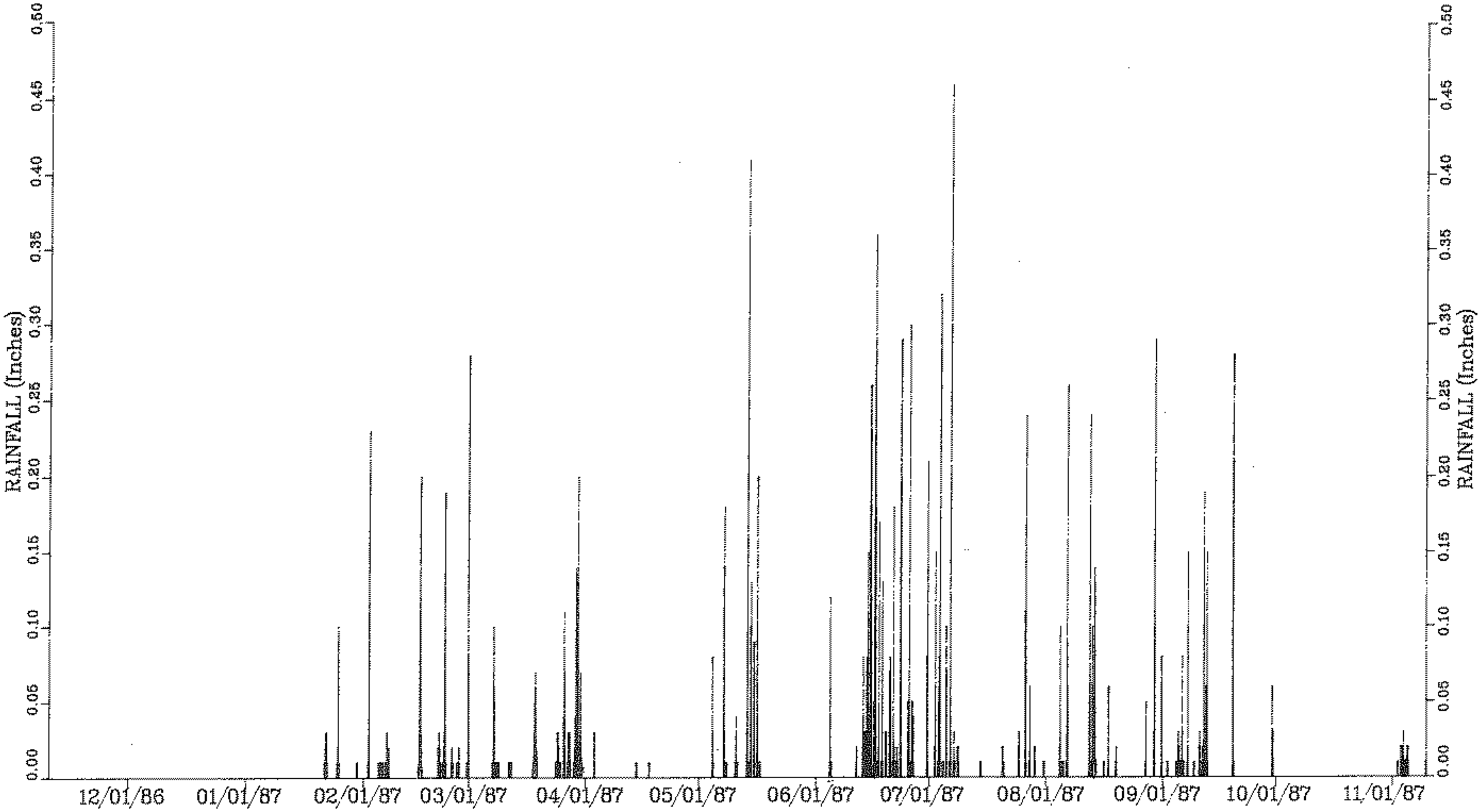


Figure 13. Record of Rainfall Storms During Study Period

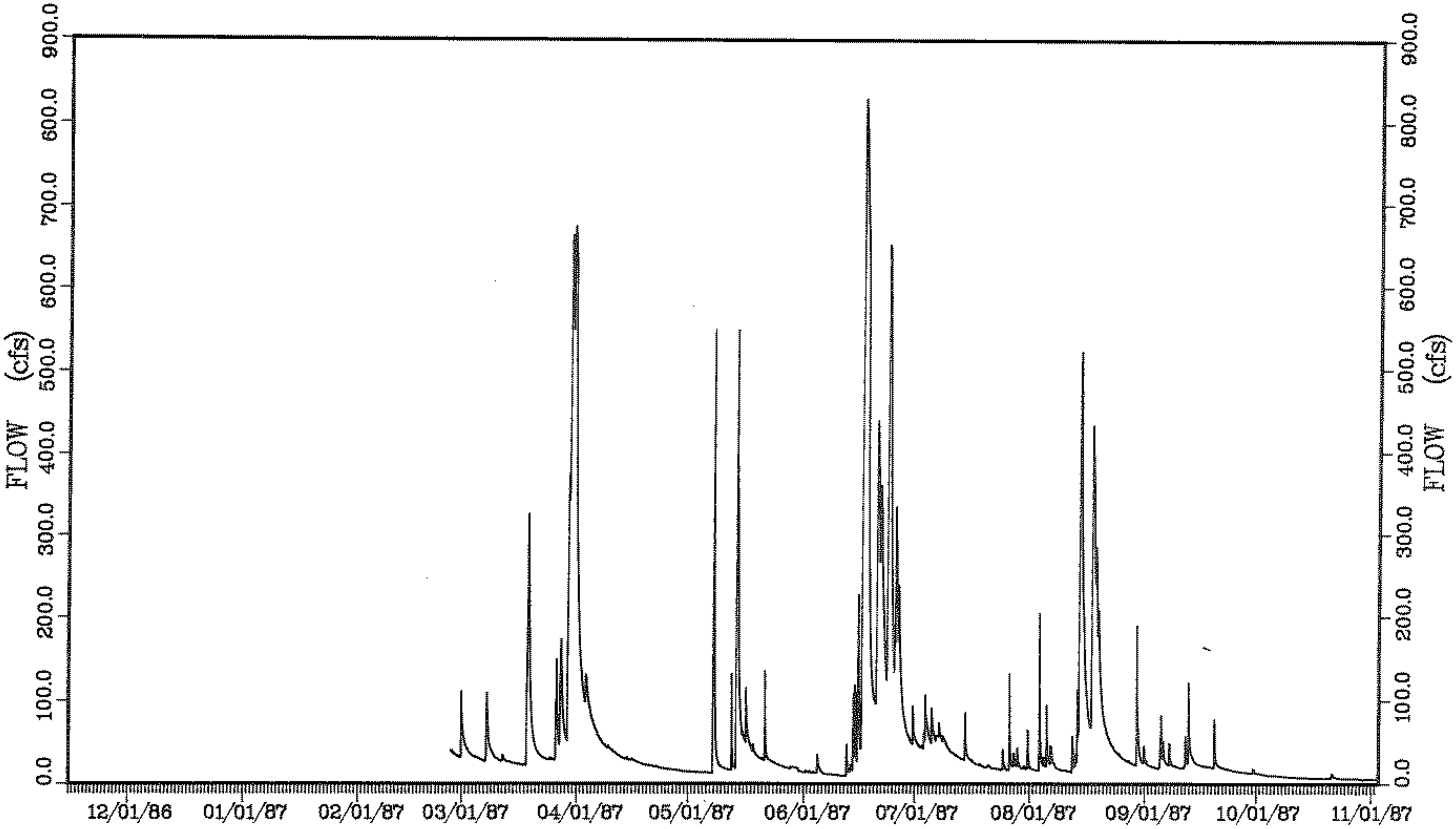


Figure 14. Record of Stormwater Inflows During Study Period

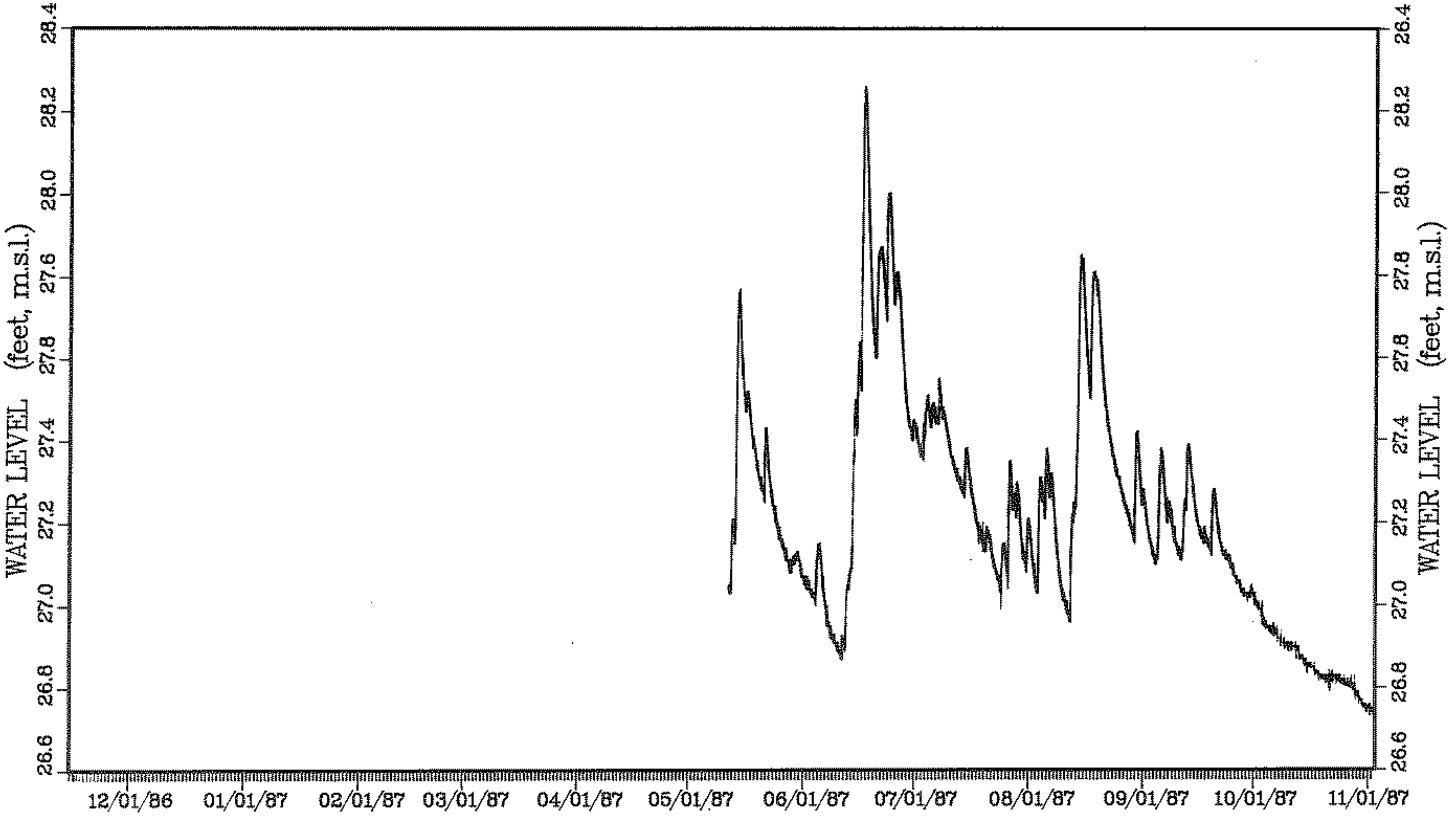


Figure 15. Record of Lake Water Levels During Study Period

STORMWATER LOADS AND QUALITY

In order to monitor the quality of stormwaters entering and exiting Lake Munson, ISCO Model 2700 automatic water quality samplers were installed upstream and downstream of the lake at stations S3 and S36 (Figure 1), respectively. Stations S3 and S36 were in operation during the same period of time as the lake sampling program, thus providing important information on the hydrologic and nutrient/pollutant loading conditions affecting lake water quality.

The water quality samplers were designed to collect up to six samples during each storm event, with shorter time intervals programmed between samples during the first part of the storm, and longer intervals during the receding limb of the hydrograph. This approach allowed for an accurate computation of total storm loads while also providing information on the degree of first flush effect. The samplers' optimal timing sequence was determined on the basis of a computer optimization program that searched all possible time combinations and identified the most appropriate for the expected range of storm events. A water level actuator was used to trigger the first sample. Thereafter, sample intervals were preset to obtain samples at 4:00, 8:10, 13:50, 22:30, and 35:50 hours after the first sample. Fewer than six samples were obtained during small storm events.

A total of six storms were sampled upstream of the lake at station S3 and three downstream at station S36. Three storm events were sampled concurrently at both stations in order to evaluate the pollutant retention capacity of the lake. Each storm hydrograph was recorded by measuring stage at five minute intervals with an automatic water level recorder. Stage data were subsequently converted to flow values by applying a rating equation developed from recent discharge measurements. Inflow and outflow hydrographs for the largest storm sampled are presented in Figure 16. The hydrographs are shown only over the period of time during which water quality samples were obtained. The storm was larger in volume (978 acre-ft) and average flow (330 cfs) than the average stormwater inflow volume (774 acre-ft) and average flow (43 cfs) into Lake Munson. Therefore, the storm provided the most useful information on storm water quality and loads.

In order to estimate loads over the entire hydrograph period, water quality data points were interpolated linearly between sampling intervals. Figures 17 to 19 show linearly interpolated pollutographs (concentration vs. time) for selected parameters at both the inflow and outflow sites. It is interesting to note that pollutograph concentrations at the start of the storm event were substantially lower than peak concentrations. This typically occurs in relatively large watersheds with significant baseflow and/or channel storage. Watershed outflows are initially comprised of higher quality waters displaced from channel storage by stormwater runoff. Subsequently, outflow quality deteriorates as storage is depleted and stormwater runoff becomes an increasing fraction of outflows.

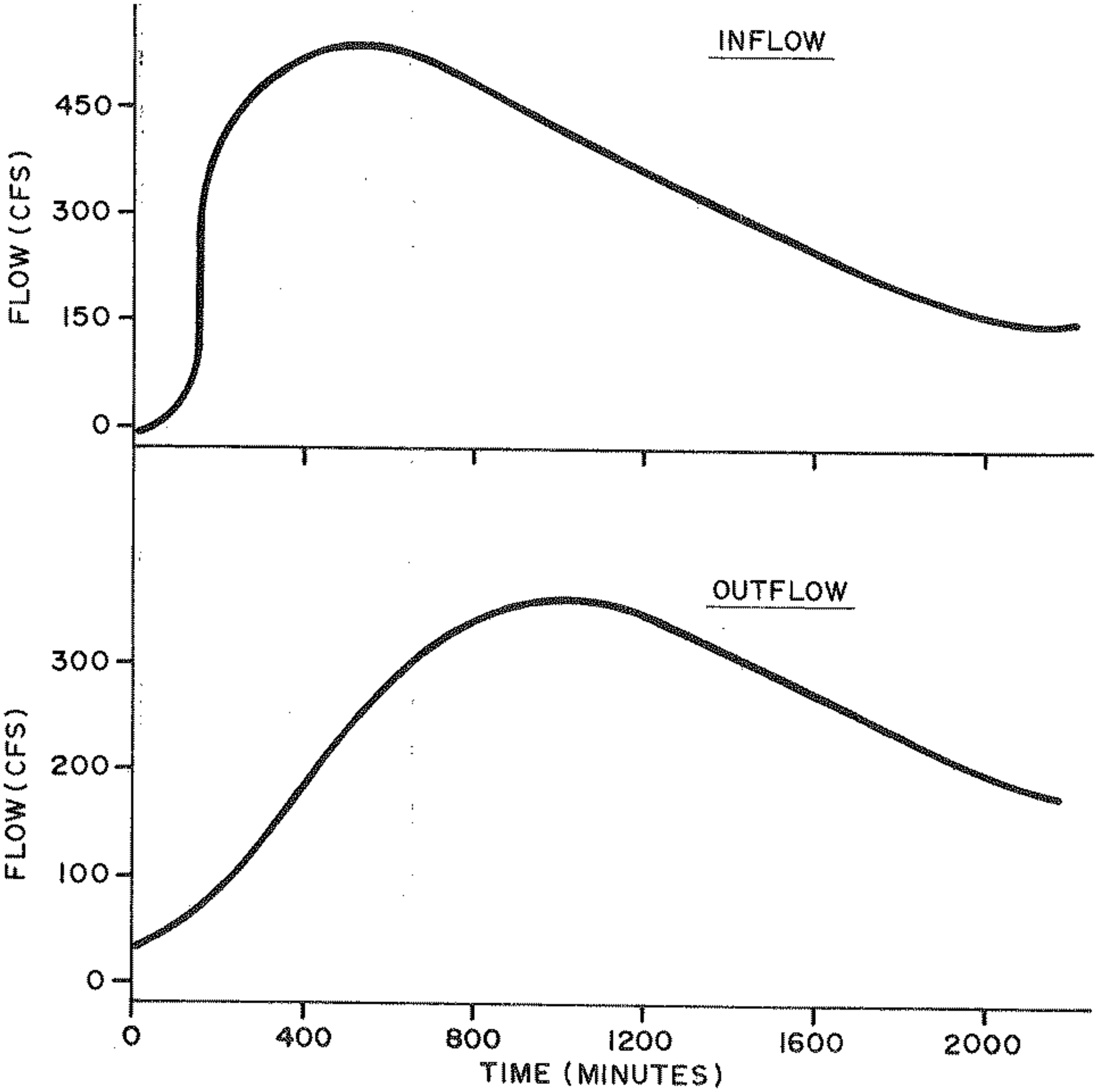


Figure 16. Inflow and Outflow Hydrographs for Largest Storm Sampled

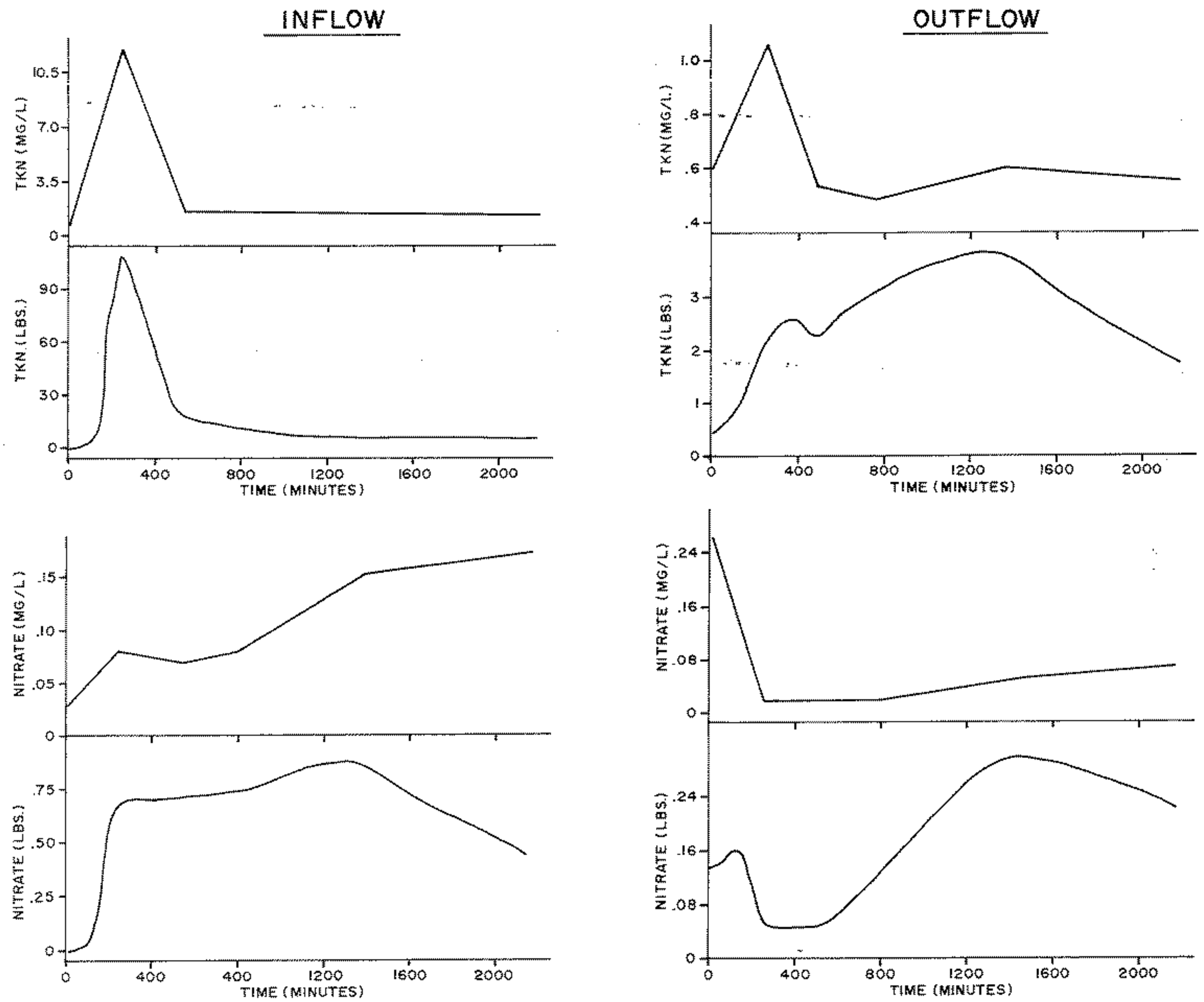


Figure 17. Inflow and Outflow Loads of Total Kjeldahl Nitrogen and Nitrate for Largest Storm Sampled

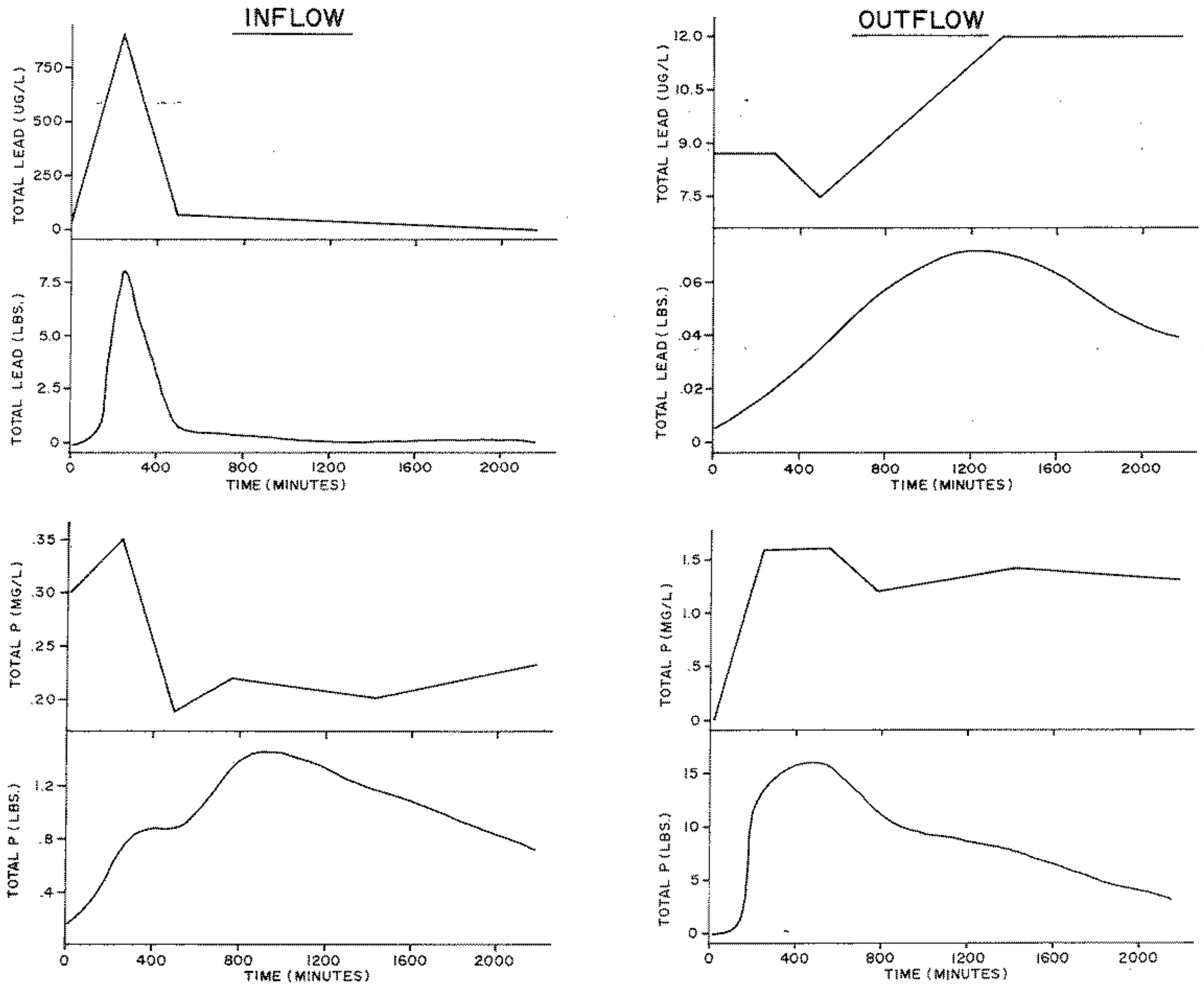


Figure 18. Inflow and Outflow Loads of Total Lead and Total Phosphorus for Largest Storm Sampled

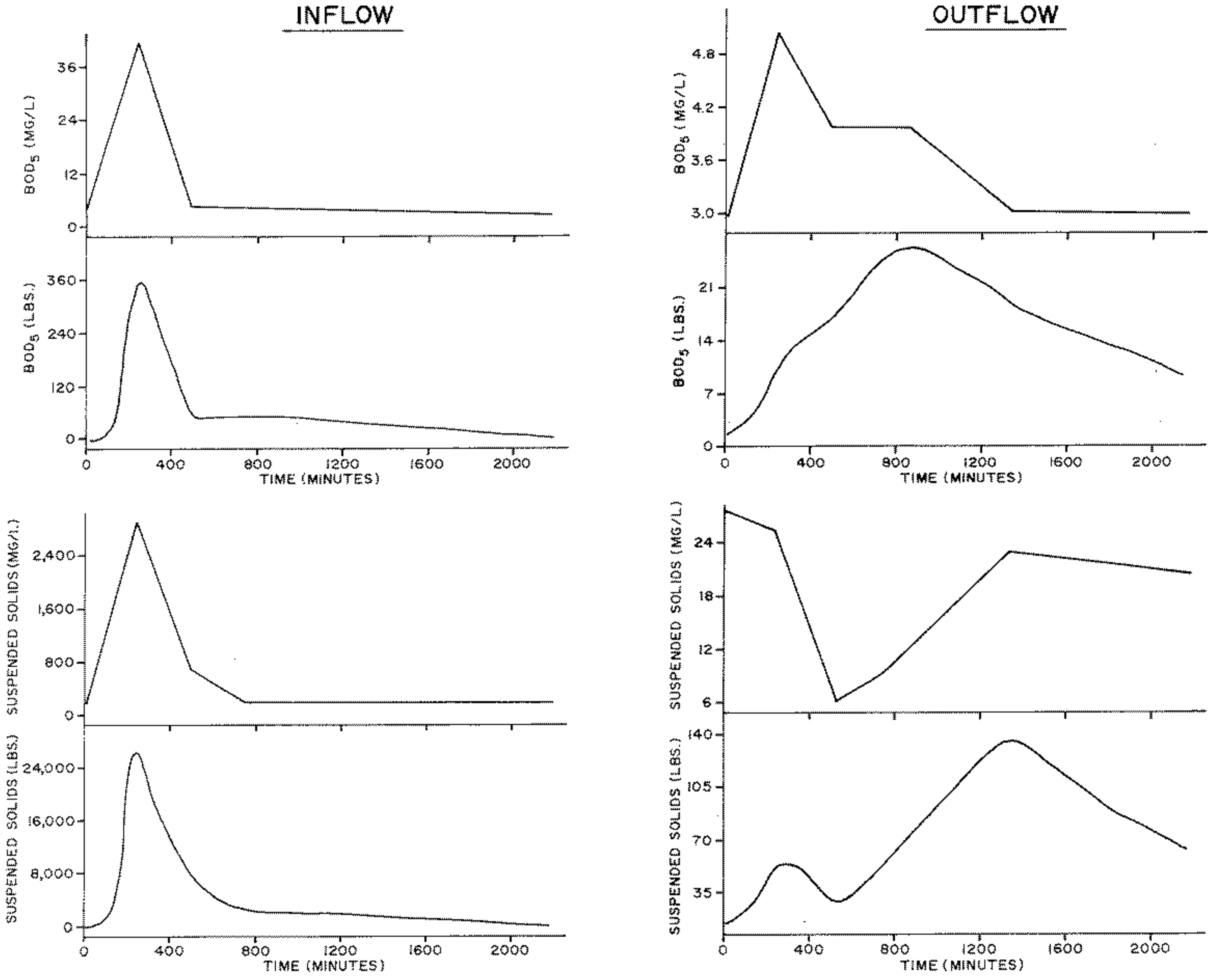


Figure 19. Inflow and Outflow Loads of BOD-5 and Suspended Solids for Largest Storm Sampled

Summaries of the highest parameter concentrations found at stations S3 and S36 are given in Table 3. Most of the parameter concentrations were found to be higher in incoming stormwaters. Lake outflows were of much higher quality and resembled very closely the parameter levels measured in lake waters. However, nitrate was found in higher concentrations at the outflow station than in both the lake and incoming stormwaters. This may be explained by the oxidation of other forms of nitrogen in the lake waters. Examination of Table 3 also indicates that stormwater metal concentrations for mercury, zinc, lead, and copper occasionally exceeded criteria for Class III waters (FDER, 1987).

Stormwater loads were computed by integrating the flow data with the interpolated water quality data (pollutograph) over each 5-minute flow interval. Resulting loadographs (load vs. time) for selected parameters are included in Figures 17 through 19. Inspection of these loadographs indicates that while peak inflow loads frequently occurred in the early part of the storm, peak outflow loads occurred in the middle of the storm. In addition, whereas the peak inflow loads appear to be more related to the first flush effect, peak outflow loads are more a function of the volume of lake water discharged. Comparing total storm inflow and outflow loads reveals that outflow loads are significantly lower, thus reflecting the level of water quality treatment provided by the lake.

Loadograph ordinates were accumulated and related to their respective volumes of stormwater runoff. Figure 20 provides cumulative loadographs for selected parameters at both the inflow and outflow sites. These graphs show the percent of total load leached from the basin due to a given amount of stormwater runoff. The impact of the first flush effect is evident in the curved shape of the inflow graphs which show a large fraction of the total pollutant load occurring early in the storm event. Conversely, cumulative loadographs at the outflow site are basically linear and devoid of the first flush effect. Phosphorus, however, failed to display the pronounced curve at the inflow site. Both its inflow and outflow cumulative loadographs were very similar and more volume related.

Cumulative loadographs were prepared for all six storm events sampled at the inflow site in order to provide a basis for comparing loading characteristics among different size storm events. Figures 21 and 22 show the cumulative loadographs for selected water quality parameters. Only five of the six storms sampled are represented in the graphs, since two storms had identical load distributions. Inspection of the plots indicates that, compared to larger storms, the smaller storms carried a larger fraction of the total load earlier in the storm event. However, total loads were typically higher during larger storms due to the higher concentrations and volumes associated with the large storms. The first flush effect was more pronounced during larger storms, since they generate higher peak concentrations and produce sufficient runoff volume to cause concentrations to drop later in the storm event.

TABLE 3

SUMMARY OF MAXIMUM PARAMETER CONCENTRATIONS IN STORMWATER INFLOWS AND OUTFLOWS TO LAKE MUNSON

Storet Number	Parameter	Station S3	Station S36	Class III Criteria	Units
00076	Turbidity	637.00	39.20	Δ29	NTU
00080	Color	223.00	105.40		CU
00095	Spec cond, lab	420.00	119.00		umhos
00310	BOD, 5-Day	42.00	9.00		mg/l
00314	BOD, Carbonaceous	23.00	10.00		mg/l
00340	COD	178.00	39.00		mg/l
00410	Alkalinity	118.00	28.60	>20.0	mg/l
00500	TDS	2731.00	93.00		mg/l
00530	Suspended Solids	2870.00	27.00		mg/l
00535	Nonfilterable Vol Res	610.00	11.00		mg/l
00608	Ammonia, Dissolved	0.43	0.25		mg/l
00610	Ammonia Nitrogen	0.56	0.27		mg/l
00615	Nitrite	0.06	0.00		mg/l
00623	DKN	0.77	0.93		mg/l
00625	TKN	12.10	1.30		mg/l
00630	Nitrate + Nitrite	0.32	0.26		mg/l
00665	Phosphorus, Total	1.81	0.35		mg/l
00671	Orthophosphate	0.18	0.21		mg/l
00680	Total Organic Carbon	154.00	21.00		mg/l
00940	Chloride	62.20	12.50		mg/l
01034	Chromium, Total	17.40	1.43	50.0	ug/l
01042	Copper, Total	*118.60	25.80	30.0	ug/l
01051	Lead, Total	*889.40	12.00	30.0	ug/l
01067	Nickel, Total	40.40	1.10	100.0	ug/l
01092	Zinc, Total	*940.00	*50.00	30.0	ug/l
71900	Mercury, Total	* 1.88	* 0.25	0.2	ug/l

* - Parameter exceeds standards for Class III waters.

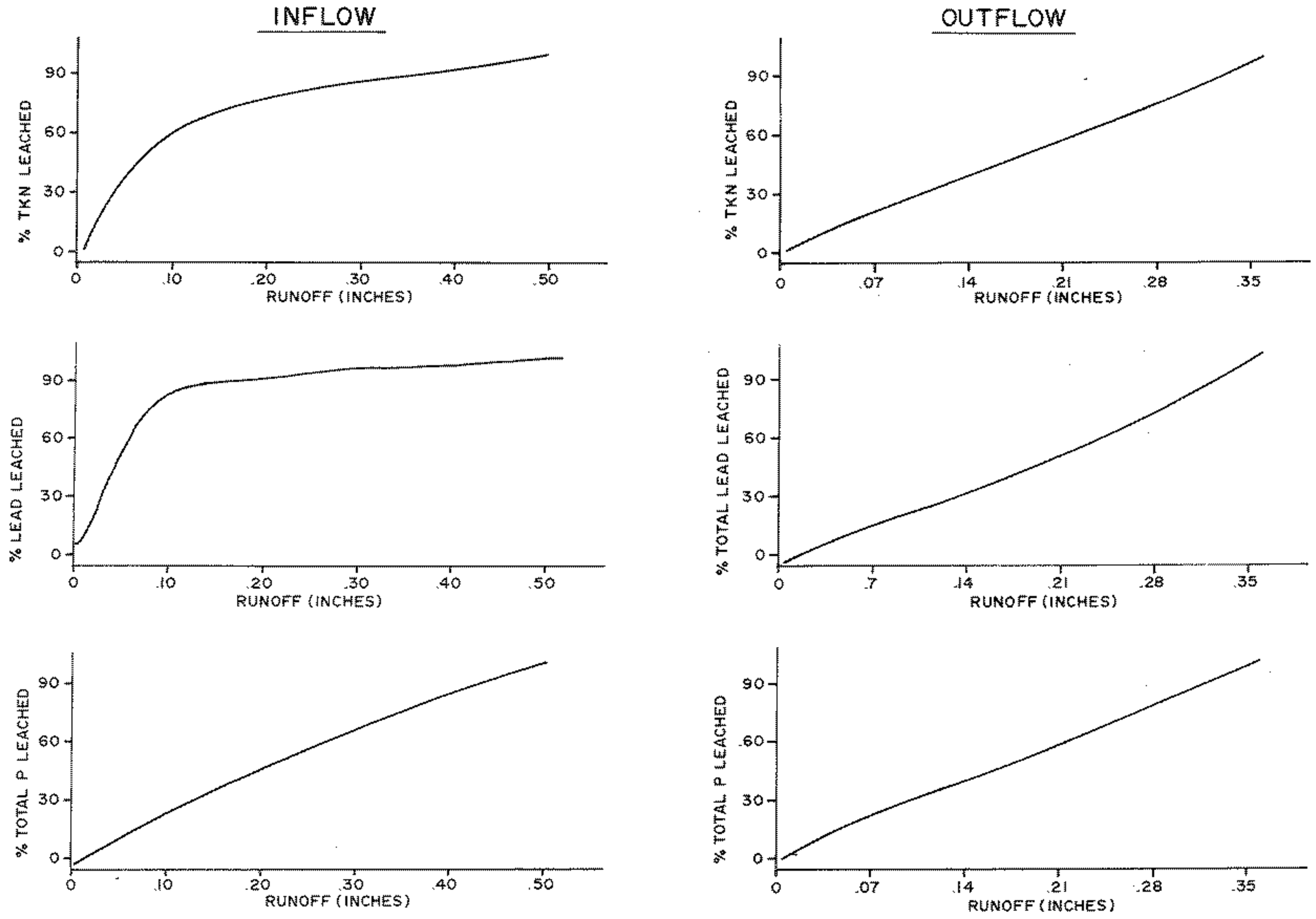


Figure 20. Inflow and Outflow Cumulative Loads of Total Kjeldahl Nitrogen, Total Lead, and Total Phosphorus for Largest Storm Sampled

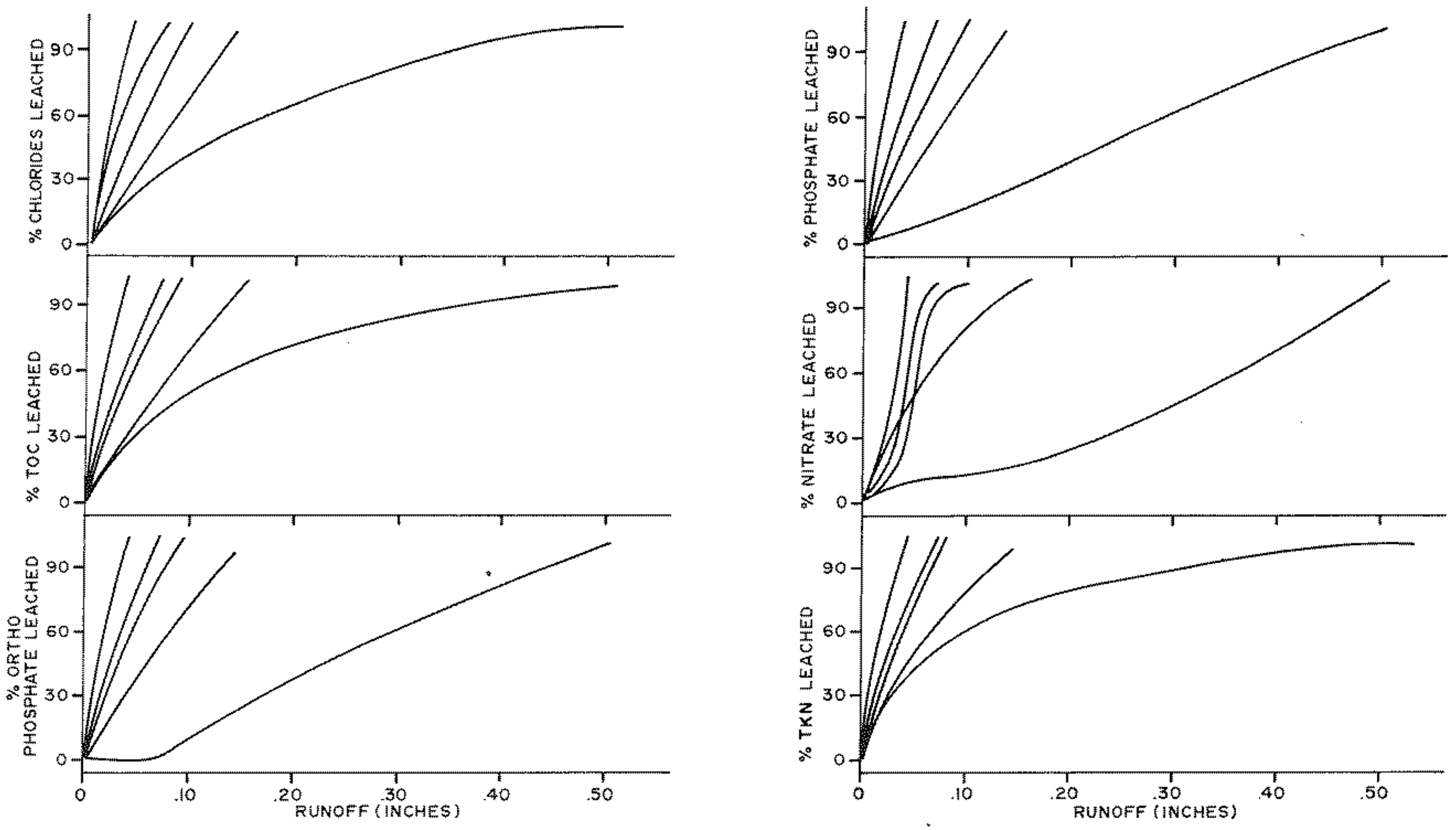


Figure 21. Cumulative Inflow Loads of Total Chlorides, Total Organic Carbon (TOC), Orthophosphate, Total Phosphorus (P), Nitrate, and Total Kjeldahl Nitrogen for all Storms Sampled

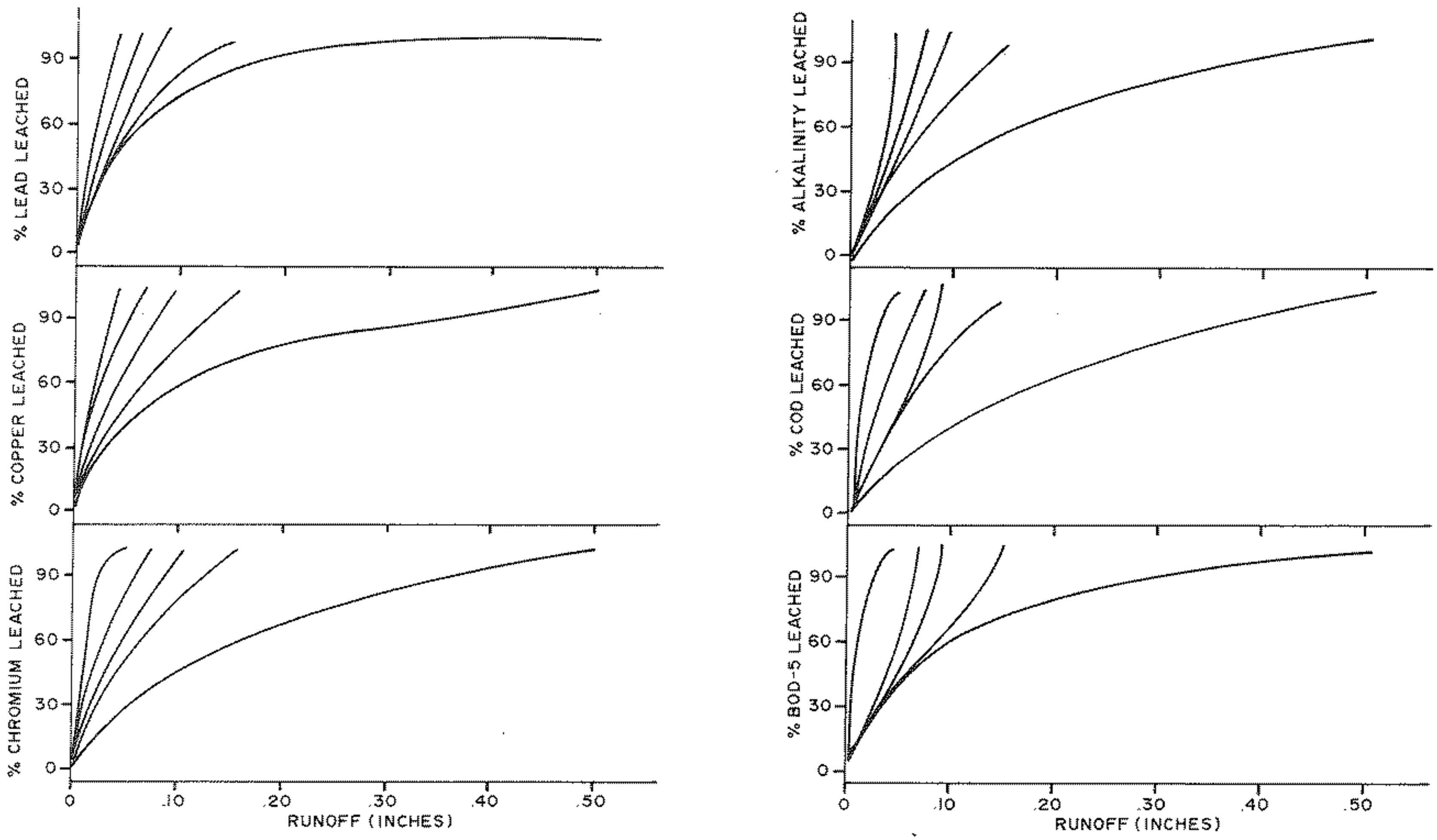


Figure 22. Cumulative Inflow Loads of Total Lead, Total Copper, Total Chromium, Alkalinity as CaCO3, Chemical Oxygen Demand (COD) , and Biological Oxygen Demand (BOD-5) for all Storms Sampled

History of Nutrient and Sediment Loads

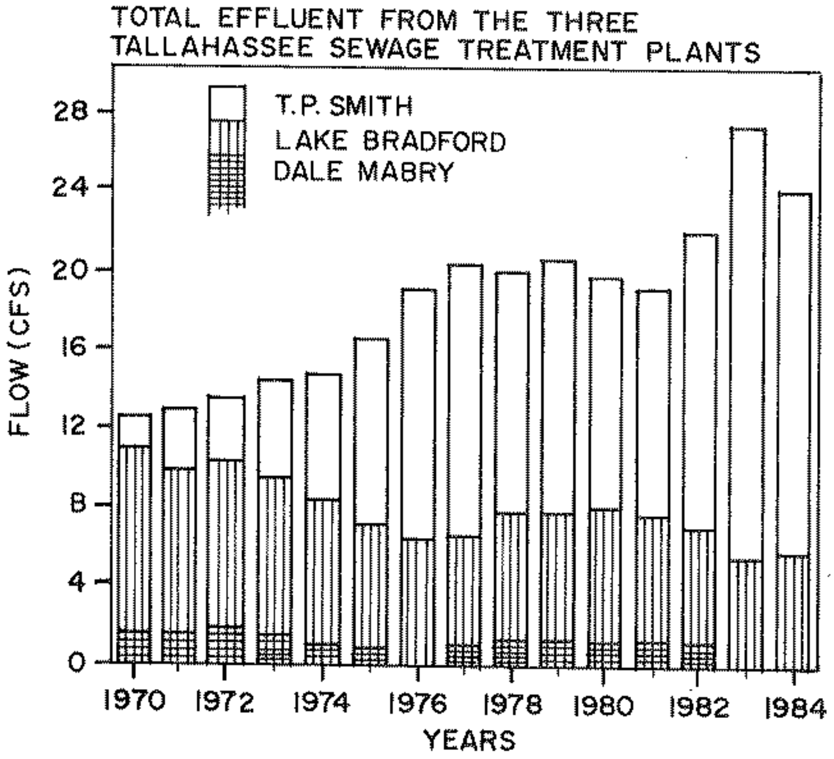
Except for accidental sewage spills which occasionally discharge into Lake Munson, stormwater currently accounts for virtually all the nutrient and sediment loads to the lake. In the past, however, effluent from Tallahassee's wastewater treatment plants contributed a significant portion of the total nutrient load. Following is a discussion of past and present loads as well as estimates of the relative load fractions from stormwater and wastewater.

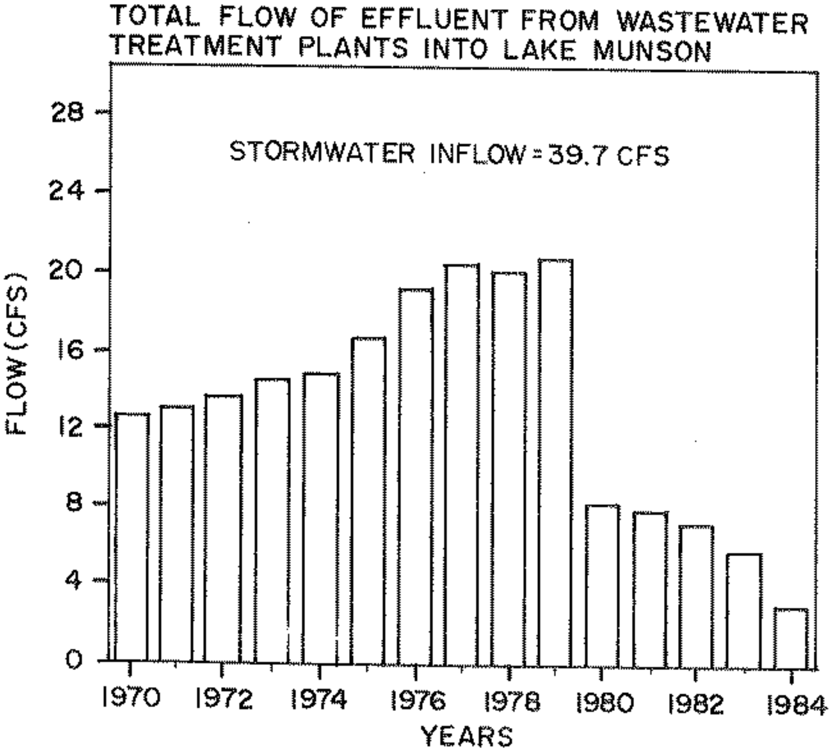
Stormwater inflow loads were estimated as the product of the average stormwater inflow into Lake Munson and the average flow-weighted concentrations of the six storms monitored during this investigation. The long-term average stormwater inflow into the lake was computed to be 39.7 cfs. Histories of wastewater effluent discharges and loads were obtained from a previous study (Bocz and Hand, 1985). Figure 23 shows the combined effluent from all treatment plants for the period 1970 to 1984. It also gives the amount of effluent actually discharging into the lake. At the peak effluent discharge in 1977-1979, treatment plants contributed about 21 cfs or 35 percent of the total hydraulic load (61 cfs) to the lake. After 1979, however, wastewater effluent was incrementally diverted to spray irrigation fields and, by 1984, all discharges to Lake Munson had been eliminated.

As shown in Figure 24, the impact of wastewater on nutrient loads was particularly dramatic. Using the peak effluent loads for the period 1970 to 1984 as the basis for comparison, wastewater discharges were responsible for 66 percent of the biological oxygen demand (BOD), 88 percent of the total phosphorus, and 91 percent of the total nitrogen loads into Lake Munson. On the other hand, stormwaters were responsible for 92 percent of the load of total suspended solids, with the wastewater having minimal impact. The present loads from stormwater inflows were estimated at 35,762 lbs/day of total suspended solids, 1,558 lbs/ day of BOD, 274 lbs/day of total nitrogen, 156 lbs/day of total phosphorus, 7.8 lbs/day of total lead, 2 lbs/day of total copper, and 0.8 lbs/day of total chromium.

In order to compare nutrient loads in the Lake Munson watershed with typical loads from other urban areas in Florida, the loads were converted to export coefficients expressed as load per unit of drainage area. The resulting coefficients for total nitrogen and total phosphorus were 4.3 and 2.4 lbs/acre/year, respectively. By comparison, median coefficients for urban areas in Florida have been estimated at 5.1 lbs/acre/year for total nitrogen and 0.7 lbs/acre/year for total phosphorus. In addition, the rate of atmospheric deposition in Florida (wetfall and dryfall) was calculated at 6.7 lbs/acre/year of total nitrogen and 0.5 lbs/acre/year of total phosphorus (Huber and others, 1982).

Although nitrogen export values from the Lake Munson watershed are comparable to those of other urban areas in Florida, the watershed yields phosphorus at about three times the state median rate. Similar comparisons with atmospheric deposition rates indicate that the land phase of the hydrologic cycle results in the release of significant amounts of phosphorus

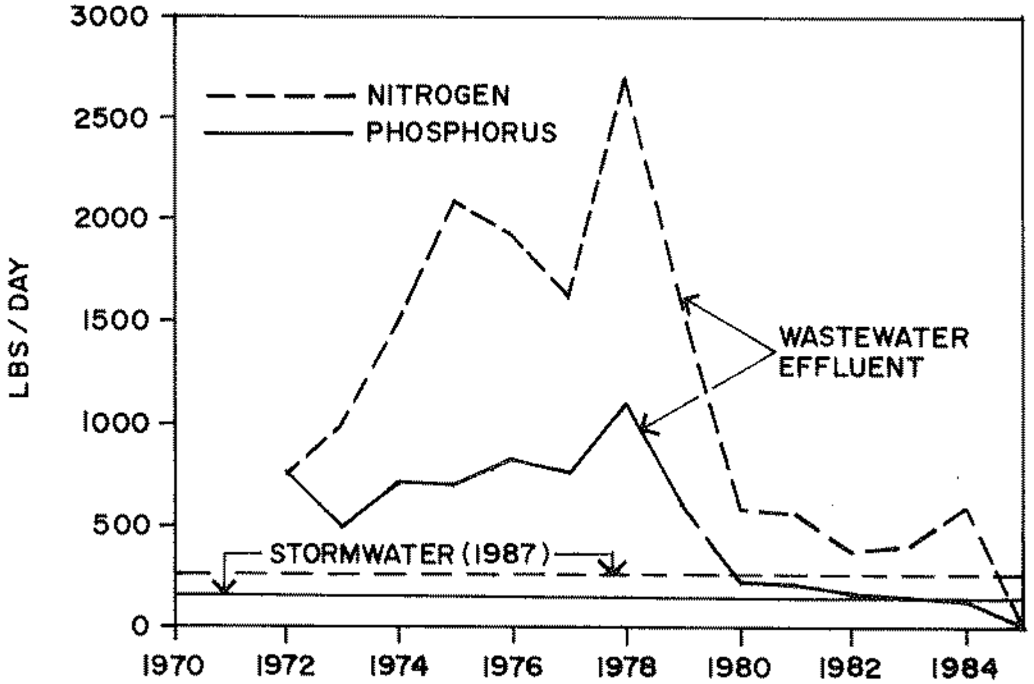

TOTAL EFFLUENT FROM THE THREE TALLAHASSEE SEWAGE TREATMENT PLANTS


TOTAL FLOW OF EFFLUENT FROM WASTEWATER TREATMENT PLANTS INTO LAKE MUNSON

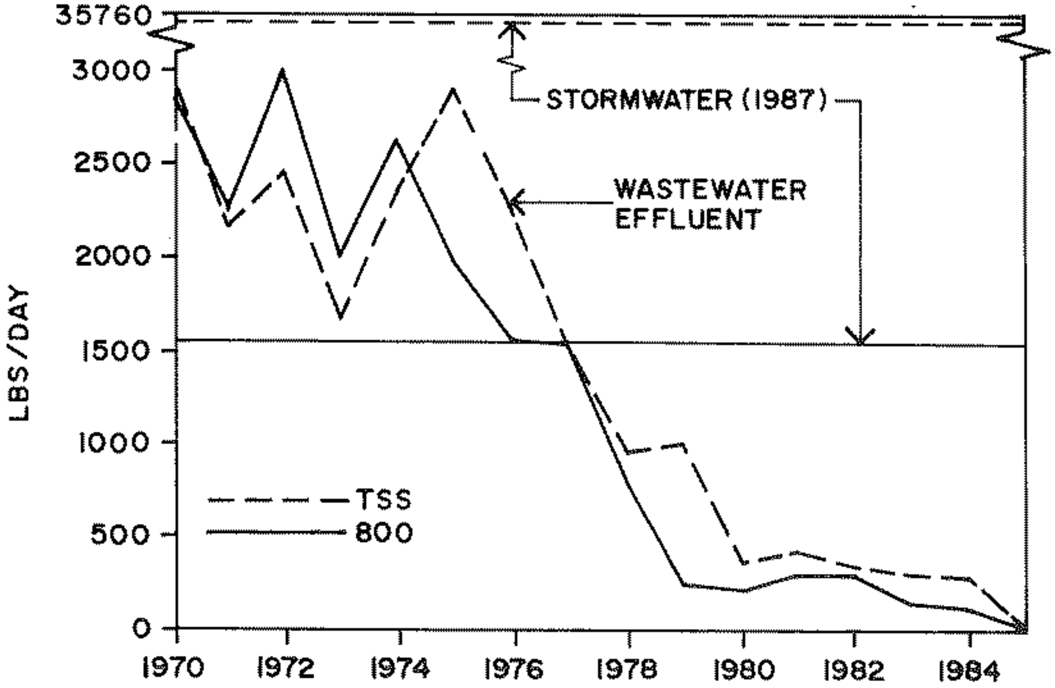
ADAPTED FROM: BOCZ AND HAND, 1985

Figure 23. History of Effluent Discharges from Wastewater Treatment Plants

TOTAL PHOSPHORUS & NITROGEN LOADS TO LAKE MUNSON



BOD & TSS LOADS TO LAKE MUNSON



ADAPTED FROM : BOCZ AND HAND, 1985

Figure 24. History of Nutrient Loads from Wastewater Treatment Plants

into stormwaters. While the ratio of nitrogen to phosphorus in atmospheric fallout is approximately 14.6, the ratio in stormwaters from a typical urban area in Florida is 7, and for Lake Munson is about 1.8. Such high yields of phosphorus relative to nitrogen in the study area help explain the phenomenon of nitrogen limitation in Lake Munson.

Organic Pollutants in Stormwater

This section presents a summary of results from an organic scan of stormwaters conducted as part of the ongoing stormwater project in the Lake Munson Watershed. Stations S19 and S20 (Figure 1) were sampled by the NWFWMD on January 20, 1988. Table 4 shows the list of organic constituents analyzed, including detection limits, and identifies organic pollutants found above detection limits. Examination of the table indicates that few organic chemical constituents were found in concentrations above detection limits. Detectable levels of toluene occurred at both stations in equal concentrations of 0.76 ug/l, while chloroform was measured at 1.15 ug/l and 0.90 ug/l, respectively, at stations S19 and S20. S20 sample results also showed detectable levels of di-n-octy phthalate at 55 ug/l, bis(2-ethylhexyl) phthalate at 20.7 ug/l, and xylene at 5.62 ug/l.

Toluene and xylene are compounds commonly found in petroleum products, phthalate is commonly leached from plastics, and chloroform is typically used as a fumigant. Chloroform and phthalate are also commonly found in laboratory blanks. Several of these compounds can be volatilized or metabolized by aquatic organisms and removed by aerobic biodegradation over a period of several days. Phthalate levels in stormwaters exceeded the Class III water quality standard (3 ug/l) of the Department of Environmental Regulation (FDER, 1987). Phthalate concentrations above 3 ug/l have been shown to interfere with the reproduction of various aquatic organisms.

Although organic constituent concentrations found in stormwaters may be at toxic levels, it is not possible to estimate their impact on the lake since the stations were located upstream in the watershed. Further, stormwater concentrations were based on a single sample and would require verification from additional samples before their actual levels can be accurately determined.

TABLE 4

LIST OF ORGANIC CHEMICALS SAMPLED AT SELECTED STORMWATER SITES UPSTREAM OF LAKE MUNSON

PESTICIDES

Description	Det. Lim. ug/l	Description	Det. Lim. ug/l
Aldrin	.092	a-BHC	.006
b-BHC	.011	Lindane	.0025
d-BHC	.005	Chlordane	.192
4,4'-DDD	------	4,4'-DDE	------
4,4'-DDT	------	Dieldrin	.072
Endosulfan I	.013	Endosulfan II	.013
Endosulfan Sulfate	.036	Ethion	------
Trithion	------	o,p-DDT,DDE,DDD	------
Tedion	------	Endrin Aldehyde	0.03
Heptachlor	.052	Heptachlor Epoxide	.050
Toxaphene	.176	Arochlor 1016	0.25
Arochlor 1221	0.25	Arochlor 1232	0.25
Arochlor 1242	0.25	Arochlor 1248	0.25
Arochlor 1254	0.5	Arochlor 1260	0.5
Aldicarb	------	Diazinon	------
Malathion	0.2	Parathion	0.07
Guthion (Azinophos Methyl)	2.0	Kelthane (Dicofal)	------
Mirex	0.03	Endrin	.0062
Methoxychlor	.0093	Demeton	------

CHLORINATED VOLATILES

Description	Det. Lim. ug/l	Description	Det. Lim. ug/l
Acrolein	0.7	Acrylonitrile	0.5
Bromodichloromethane	.099	Bromoform	.118
Bromomethane	5	Chlorobenzene	------
Chloroethane	5	2-Chloroethylvinyl ether	5
Chloroform *	.647	Chloromethane	5
Dibromochloromethane	.121	Dichlorodifluoromethane	5
1,1-Dichloroethane	------	1,1-Dichloroethene	------
trans-1,3-Dichloropropene	5	trans-1,2-Dichloroethene	------
cis-1,2-Dichloroethylene	------	1,2-Dichloropropane	5
cis-1, 3-Dichloropropene	5	Methylenechloride	1.42
1,1,2-Trichloroethane	------	Trichlorofluoromethane	5
1,2-Dichlorobenzene	10	1,2-Dichlorobenzene	10
1,4-Dichlorobenzene	10	1,2-Dibromo-3-Chloropropane	------
1,1,2,2-Tetrachloroethane	------	Trichloroethene	0.11
Tetrachloroethene	0.05	Carbon Tetrachloride	0.08
Vinylchloride	5	1,1,1-Trichloroethene	0.12
1,2-Dichloroethane	2.7		

TABLE 4

LIST OF ORGANIC CHEMICALS SAMPLED AT SELECTED STORMWATER SITES UPSTREAM OF LAKE MUNSON
(continued)

ACID EXTRACTABLES

Description	Det. Lim. ug/l	Description	Det. Lim. ug/l
2-Chlorophenol	15	2,4-Dichlorophenol	10
2,4-Dimethylphenol	5	2,4-Dinitrophenol	30
2-Methyl-4,6-dinitrophenol	20	4-Nitrophenol	10
Pentachlorophenol	30	Phenol	5
2,4,6-Trichlorophenol	20	4-Chloro-3-methylphenol	10
2-Nitrophenol	20		

BASE/NEUTRAL EXTRACTABLES

Description	Det. Lim. ug/l	Description	Det. Lim. ug/l
Acenaphthene	10.0	Acenaphthylene	10.0
Anathracene	10.0	Benzo(a)anthracene	10.0
Benzo(b)fluoranthene	10.0	Benzo(k)fluoranthene	10.0
Benzo(a)pyrene	10.0	Benzo(g,h,j)perylene	-----
Benzidine	44	BIS(chloroethyl)ether	10
BIS(2-chloroethoxy)methane	10	BIS(2-ethylhexyl)phthalate*	10
BIS(2-chloroisopropyl)ether	10	4-Bromophenyl phenyl ether	10
Benzyl butyl phthalate	10	2-chloronaphthalene	10
4-Chlorophenyl phenyl ether	10	Chrysene	10.0
Dibenzo(a,h)anthracene	25.0	Di-n-butyl phthalate	10
1,3-Dichlorobenzene	10	1,4-Dichlorobenzene	10
1,2-Dichlorobenzene	10	3,3-Dichlorobenzidine	16.5
Diethyl phthalate	10	Dimethyl phthalate	10
2,4-Dinitrotolvene	10	2,6-Dinitrotolvene	10
Di-n-octyl phthalate *	10	1,2-Diphenylhydrazine	-----
Fluoranthene	10.0	Fluorene	10.0
Hexachlorobenzene	10	Hexachlorobutadiene	10
Hexachloroethane	10	Hexochlorocyclopentadiene	10
Indeno(1,2,3-cd)pyrene	------	Isophorone	10
Naphthalene	10.0	Nitrobenzene	10
N-Nitrosodimethylamine	------	N-Nitrosodi-n-propylamine	-----
N-Nitrodsodiphenylamine	1.9	Phenanthrene	10.0
Pyrene	10.0	2,3,7,8-TCDD (Dioxin)	0.05
1,2,4 Trichlorobenzene	10		

TABLE 4

LIST OF ORGANIC CHEMICALS SAMPLED AT SELECTED STORMWATER SITES UPSTREAM OF LAKE MUNSON
(continued)

AROMATIC PURGEABLES

Description	Det. Lim. ug/l	Description	Det. Lim. ug/l
Benzene	------	Toluene *	------
Ethylbenzene	5	Xylene(ortho.meta,para) *	5
Styrene	5	o-Chlorotolvene	5
n-Propylbenzene	5	n-Butylbenzene	5
135-Trimethylbenzene	5		

* - indicates parameter detected above detection limits.

HYDROGEOLOGY

Lake Munson and perimeter areas are located in the Lake Munson hills of the Woodville Karst plain (Hendry and Sproul, 1966). This physiographic subdivision is characterized by a thin layer of quartz sands interbedded with discontinuous clay layers which overlie the limestones of the Floridan Aquifer. Overall, the surficial sediments in this area have a relatively low permeability that restrict the downward percolation of ground water to the Floridan Aquifer. The formation of the original depression which is now the lake bottom may be the remnant of an ancient sink hole or sink-hole dismemberment of a former stream valley. Hendry and Sproul describe the scars of a stream meander that can be traced southward from the lake to its junction with the Wakulla River. Munson Slough, which flows into and out of Lake Munson, is one of the few streams in the area. This stream disappears underground into Ames Sink approximately four miles south of the lake.

To the northwest of Lake Munson lies Lake Bradford and an accompanying chain of lakes. These lakes are higher in elevation than Lake Munson and have been reported to have active sinks. Since lake levels are slightly higher than the potentiometric levels in the Floridan Aquifer, and the lower permeability sediments have been breached, the potential exists for direct recharge from the Bradford chain of lakes to the Floridan. In the case of Lake Munson, an outflow structure maintains lake levels at higher elevations than the potentiometric surface of the Floridan Aquifer. However, the potential for recharge from Lake Munson is not as high since there has been no evidence of recent sink activity. According to lithologic logs, well drillers logs, and geophysical logs available in the immediate vicinity of Lake Munson, the sediments above the Floridan contain fine grained sands, silts, and clays which function as a leaky confining bed.

A representative hydrogeologic cross section of Lake Munson is shown in Figure 25. Soils around the lake consist of fine loamy sands predominantly of the Rutlege series (USDA, 1981) to a depth of 80 inches or more. In some locations the clays beneath these soils may be discontinuous, as indicated by their absence at a few well sites. Even if clays are absent at some locations, the finer grained sands and silts would still restrict the recharge of lake waters into the Floridan. In addition, it has been estimated that the more recently deposited lake bottom sediments have a thickness averaging 2.5 feet, with maximum observed values of eight feet. These fine grained sediments and organic materials function like the lower lying clays by restricting recharge to the limestone. In summary, the overall low hydraulic conductivity of the lake bottom sediments, coupled with the small head differential, results in little direct recharge from the lake.

Ground Water Quality

Ground water which contributes to the base flow of Munson Slough and Lake Munson is discharged from thin surficial sand layers and sand seeps within the lower permeability beds overlying the Floridan Aquifer. These sediments are principally silica based, with a very small percentage of calcium carbonate. Due to their very low carbonate content, these soils are

REPRESENTATIVE HYDROGEOLOGIC SECTION FOR LAKE MUNSON

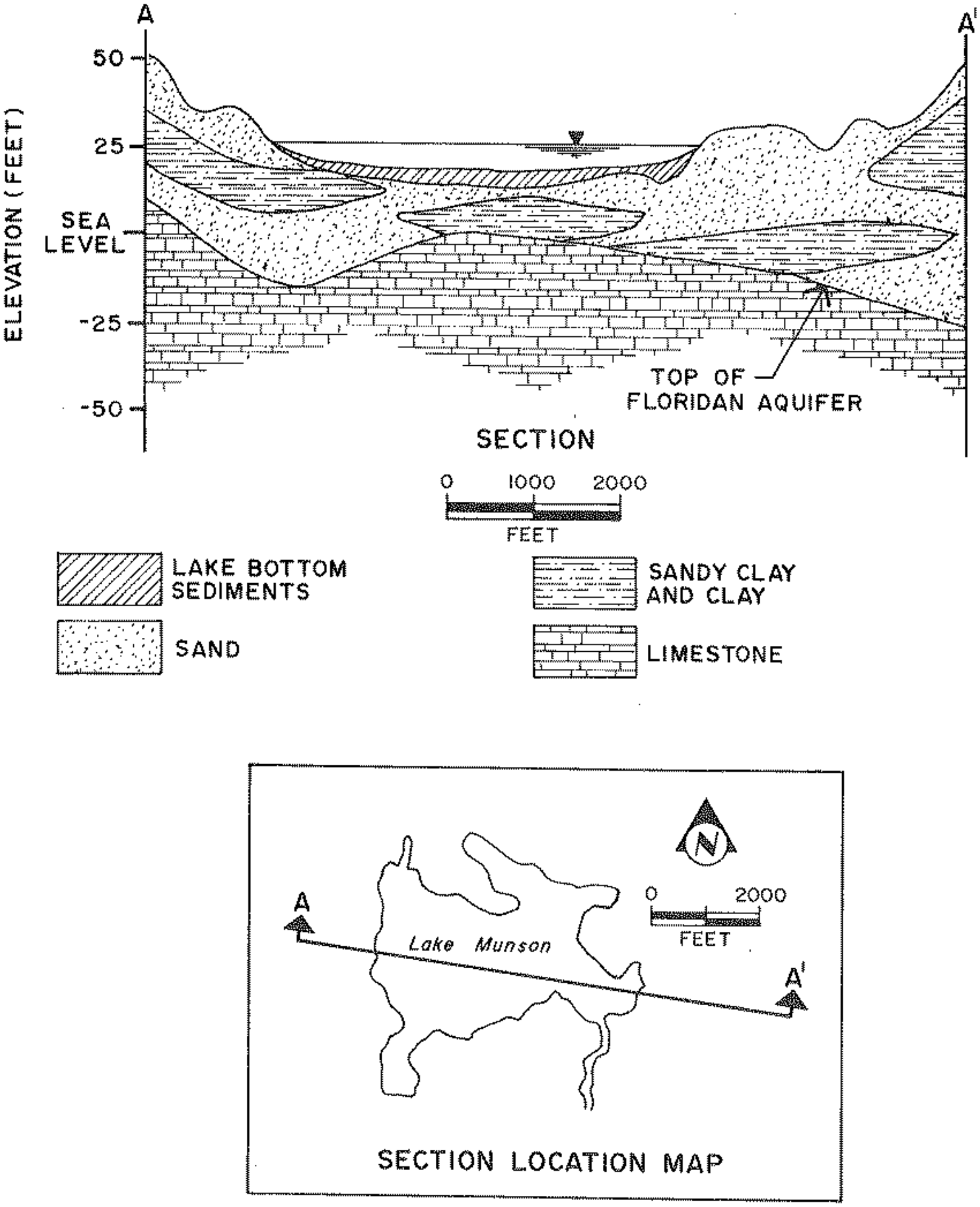


Figure 25. Representative Hydrogeologic Section for Lake Munson

classified as strongly acidic fine sands (USDA, 1981). As a result, surficial ground water is characterized by low alkalinity. Since little alkalinity is contributed by ground water discharges, and average stormwater alkalinity is also relatively low, the lake is a weakly buffered system.

The potential for pollutant loads originating from discharges of contaminated ground waters into Lake Munson was evaluated and compared to the contributions from stormwater inflows. Seepage from spray irrigation of treated wastewater effluent as well as discharges from domestic septic tanks have been documented as potential nutrient sources (Yurewicz and Rosenau, 1986). Another potential source of contamination is an old landfill located north of the lake and adjacent to the spray irrigation field. Although these sources have the potential for contaminating the lake, their actual contributions were estimated to be quite small compared to the more significant loads from stormwater inflows.

An evaluation of nutrient loads from Tallahassee's southwest spray irrigation field provides an example of the limited impact of contaminated ground water discharges. Spray irrigation of treated effluent began as early as 1966 in order to provide land treatment to effluent discharges diverted from Munson Slough. Recent groundwater monitoring of the 68-acre irrigation field along Munson Slough indicated increased nitrate concentrations in the wells sampled (Yurewicz and Rosenau, 1986). For the purpose of this example, it was estimated that nitrate in the ground water beneath the sprayfield area was at a concentration of 3.0 mg/l. Using a worst-case approach, it was assumed that ground water flow to Munson Slough was equal to the recharge rate over half of the sprayfield area adjacent to Munson Slough. The spray volume over this area was based on a maximum application rate of four inches per week. This resulted in a calculated nitrate load of 12.5 pounds per day (lbs/day) or less than 5.0 percent of the estimated daily nitrogen load from stormwater. In reality, nitrate loadings would be much less due to lower irrigation rates and preferential ground water flow to the Floridan Aquifer. While the implications of this analysis are that nutrient contributions from ground water are possible, the actual expected loads from such sources, if any, would be very small.

LAKE WATER QUALITY

The extensive lake water quality data obtained as part of this investigation were organized and analyzed using a variety of techniques in order to facilitate their interpretation. These data were collected biweekly at seven stations for the period November 17, 1986 to November 2, 1987. Initially, all data were carefully examined, verified, and entered into the District's water quality data base. Subsequently, the data were analyzed statistically to explain the water quality characteristics of the lake as well as identify any interaction between parameters. In addition, all historic lake data were obtained and compared to the more recent data in order to identify long-term changes in water quality. This section presents tabular summaries of the data at each individual station, bar charts depicting seasonal changes in parameter concentrations, results from tests of significance between sites, correlations among parameters, and historic plots of lake water quality.

Statistical Summary

A summary of water quality data by parameter and station is given in Table 5. It gives the mean, standard deviation, maximum, minimum, and number of samples (N) per parameter. Replicate sample results obtained at station S42 were not included in the table to prevent giving excessive weight to that station's computed statistics. An F-test on the difference in the two means between all replicated parameters showed no significant differences at the 95 percent confidence level. Values reported below detection limits were included in the analysis since they are considered statistically meaningful. However, when all the values of a given parameter were reported below detection limit, statistical tests were not performed.

A one-way analysis of variance (ANOV) employing an F-test was initially applied to identify any significant differences in average water quality between sites. For any given parameter, the test compares the variability of the site means (spatial variations) to the variability of the entire data set. The results indicated that, except for total phosphorus and pH, no significant differences between station means occurred at the 0.01 significance level. In other words, the spatial variability of total phosphorus and pH was significant compared to the unexplained variability of these parameters. The results are not surprising since, for most parameters, the variability of data collected over time was expected to be much greater than spatial variations.

In the one-way ANOV, seasonal or temporal variations were taken as "random error". In order to correct this problem, a two-way analysis of variance was employed to remove the temporal variations from the random error term in the ANOV model. This approach more accurately identifies differences between sites by comparing the variability between sites to random error that excludes temporal variability. As part of the two-way ANOV, residual

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
10 Temperature, @ surface, (deg. Celsius)	S42	26	21.48	6.79	32.00	11.00
	S43	26	21.57	6.63	31.00	11.01
	S44	26	21.60	6.48	31.00	11.00
	S45	26	21.79	6.80	31.50	11.00
	S46	26	21.96	6.82	32.00	11.00
	S47	26	22.02	6.98	32.00	11.00
	S48	26	22.37	6.77	32.00	11.00
10 Temperature, @ 1 ft. depth (deg. Celsius)	S42	26	21.36	6.82	32.00	11.00
	S43	26	21.33	6.71	31.00	11.00
	S44	26	21.23	6.35	31.00	11.00
	S45	26	21.40	6.65	31.50	11.00
	S46	26	21.69	6.65	32.00	11.00
	S47	26	21.83	6.83	32.00	11.00
	S48	26	22.08	6.67	31.50	11.00
10 Temperature, @ 2 ft. depth (deg. Celsius)	S42	26	21.16	6.68	31.00	11.00
	S43	26	21.17	6.63	31.00	11.00
	S44	26	20.85	6.11	30.00	11.00
	S45	26	21.19	6.51	31.00	11.00
	S46	26	21.40	6.52	31.50	11.00
	S47	26	21.42	6.66	32.00	11.00
	S48	26	21.65	6.49	31.50	11.00
76 Turbidity (ntu)	S42	26	10.65	4.66	20.00	3.80
	S43	26	11.39	6.28	34.00	4.30
	S44	26	9.95	6.74	37.00	4.00
	S45	26	11.25	4.83	27.00	2.70
	S46	26	11.10	5.36	27.00	3.40
	S47	26	11.04	5.48	30.00	3.80
	S48	26	8.23	3.52	16.00	3.20
77 Secchi Disk (inches)	S42	26	27.92	7.65	42.00	14.40
	S43	25	27.50	8.88	57.60	14.40
	S44	26	25.15	5.47	36.00	12.00
	S45	26	26.12	6.07	36.00	15.60
	S46	26	26.69	6.70	39.60	16.80
	S47	26	28.13	9.65	58.80	12.00
	S48	26	31.29	10.54	51.60	14.40

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE (continued)

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
80 Color (cobalt platinum units)	S42	24	89.18	24.36	128.50	35.40
	S43	24	94.21	24.81	128.30	37.70
	S44	24	100.99	24.85	146.50	52.60
	S45	24	92.28	24.45	141.00	44.20
	S46	24	95.48	23.31	141.40	62.00
	S47	24	90.53	28.48	131.30	8.00
	S48	24	76.27	24.82	125.20	13.00
94 Field Specific Conductance (umhos)	S42	26	76.65	20.50	150.00	48.00
	S43	26	78.81	23.71	171.00	48.00
	S44	26	76.65	24.92	169.00	47.00
	S45	26	80.23	25.44	178.00	46.00
	S46	26	76.81	23.05	167.00	47.00
	S47	26	77.62	23.86	170.00	48.00
	S48	26	78.00	23.33	163.00	49.00
95 Lab Specific Conductance (umhos)	S42	26	76.97	21.22	151.00	32.00
	S43	26	78.37	20.06	151.00	49.00
	S44	26	77.61	22.69	152.00	49.00
	S45	26	79.75	20.90	153.00	51.00
	S46	26	77.06	19.92	152.00	49.00
	S47	26	77.96	20.31	152.00	49.00
	S48	26	78.92	20.04	151.00	59.00
300 Dissolved Oxygen, near surface (mg/l)	S42	26	7.35	1.36	11.80	5.20
	S43	26	7.28	1.71	11.40	3.30
	S44	26	6.44	1.96	12.20	2.60
	S45	26	6.84	2.30	13.40	2.00
	S46	26	7.27	2.28	14.60	3.00
	S47	26	7.48	1.89	12.00	1.40
	S48	26	7.51	2.18	14.80	2.30
300 Dissolved Oxygen, @ 1 ft. depth (mg/l)	S42	26	7.09	1.44	11.00	4.10
	S43	26	6.97	1.61	9.80	3.00
	S44	25	6.14	1.77	8.40	2.40
	S45	26	6.70	2.35	12.40	1.40
	S46	26	6.95	2.28	13.00	2.00
	S47	26	7.43	1.49	11.80	5.20
	S48	26	7.17	1.55	11.00	3.80

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE (continued)

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
300 Dissolved Oxygen @ 2 ft. depth (mg/l)	S42	26	6.82	1.62	10.00	3.50
	S43	26	6.72	1.77	9.30	2.80
	S44	25	5.58	2.18	8.80	2.00
	S45	26	6.51	2.70	13.20	0.60
	S46	26	6.92	2.11	11.60	2.70
	S47	26	6.95	1.86	10.40	3.10
	S48	26	6.77	1.55	9.00	3.00
310 Biological Oxygen Demand, 5-day (mg/l)	S42	26	5.88	3.12	13.00	1.00
	S43	26	5.77	2.92	11.00	1.00
	S44	26	5.08	2.73	11.00	1.00
	S45	26	6.08	3.20	13.00	1.00
	S46	26	5.62	2.53	10.00	1.00
	S47	26	5.54	3.02	12.00	1.00
	S48	26	6.65	3.37	13.00	1.00
314 Biological Oxygen Demand, Carbonaceous (mg/l)	S42	24	4.46	2.60	10.00	0.00
	S43	24	4.12	2.35	8.00	1.00
	S44	24	3.83	2.28	9.00	1.00
	S45	24	4.37	2.70	11.00	1.00
	S46	24	4.08	2.47	9.00	0.00
	S47	24	4.29	2.48	9.00	0.00
	S48	24	4.87	2.88	11.00	0.00
340 Chemical Oxygen Demand (mg/l)	S42	26	38.77	9.73	61.00	13.00
	S43	26	38.54	8.02	58.00	20.00
	S44	26	38.38	8.63	59.00	22.00
	S45	26	39.38	7.90	55.00	20.00
	S46	26	37.58	11.04	64.00	8.00
	S47	26	39.38	9.33	71.00	21.00
	S48	26	38.92	9.59	65.00	21.00
400 pH (standard units)	S42	26	7.05	0.84	9.90	5.89
	S43	26	7.01	0.84	9.82	5.87
	S44	26	6.80	0.63	9.04	5.80
	S45	26	6.92	0.74	9.98	5.82
	S46	26	7.01	0.83	9.69	5.88
	S47	26	7.11	0.87	9.88	5.55
	S48	26	7.13	0.80	9.56	5.28

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE (continued)

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
410	S42	26	26.26	8.38	56.00	14.00
Alkalinity,	S43	26	26.69	8.23	56.00	14.80
as Calcium Carbonate	S44	26	26.14	9.72	58.00	12.00
(mg/l)	S45	26	27.20	8.81	56.00	16.80
	S46	26	26.13	7.73	52.00	16.00
	S47	26	26.33	8.63	56.00	15.20
	S48	26	26.99	8.35	54.00	19.20
500	S42	26	79.92	16.88	128.00	55.00
Total Solids	S43	26	82.04	15.34	127.00	59.00
(mg/l)	S44	26	82.15	17.41	135.00	58.00
	S45	26	82.27	15.72	132.00	60.00
	S46	26	80.19	13.76	126.00	64.00
	S47	26	81.46	15.41	132.00	53.00
	S48	26	80.31	19.35	129.00	54.00
510	S42	26	72.27	15.09	117.00	49.00
Total Dissolved	S43	26	73.92	13.94	117.00	54.00
Solids	S44	26	75.08	16.08	126.00	55.00
(mg/l)	S45	26	74.23	13.78	121.00	55.00
	S46	26	72.62	11.94	114.00	58.00
	S47	26	73.54	13.88	122.00	48.00
	S48	26	72.31	16.12	114.00	49.00
530	S42	26	7.65	4.66	20.00	0.00
Total Suspended	S43	26	8.12	4.67	23.00	2.00
Solids	S44	26	7.08	5.21	20.00	0.00
(mg/l)	S45	26	8.04	4.46	21.00	2.00
	S46	26	7.58	4.41	19.00	0.00
	S47	26	7.92	4.60	21.00	2.00
	S48	26	8.00	5.84	23.00	1.00
535	S42	26	6.38	4.12	17.00	0.00
Nonfilterable Volatile	S43	26	6.38	4.24	20.00	2.00
Solids	S44	26	5.15	3.95	18.00	0.00
(mg/l)	S45	26	6.27	4.16	20.00	1.00
	S46	26	5.88	3.69	17.00	0.00
	S47	26	5.96	4.13	18.00	2.00
	S48	26	7.35	5.42	21.00	1.00

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE
(continued)

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
600 Nitrogen, Total as N (mg/l)	S42	26	0.93	0.58	3.45	0.55
	S43	26	0.85	0.38	1.88	0.49
	S44	26	0.77	0.36	1.97	0.00
	S45	26	0.92	0.37	2.05	0.46
	S46	26	0.83	0.27	1.59	0.46
	S47	26	0.85	0.35	1.84	0.50
	S48	26	1.01	0.58	2.92	0.47
608 Dissolved Ammonia, as N (mg/l)	S42	26	0.05	0.03	0.13	0.00
	S43	26	0.04	0.03	0.14	0.00
	S44	26	0.06	0.05	0.20	0.00
	S45	26	0.06	0.05	0.18	0.00
	S46	26	0.05	0.05	0.21	0.00
	S47	26	0.05	0.05	0.21	0.00
	S48	26	0.06	0.06	0.25	0.00
610 Ammonia Nitrogen, as N (mg/l)	S42	26	0.05	0.03	0.13	0.01
	S43	26	0.04	0.03	0.14	0.00
	S44	26	0.06	0.05	0.20	0.01
	S45	26	0.06	0.05	0.17	0.00
	S46	26	0.05	0.05	0.22	0.00
	S47	26	0.05	0.05	0.20	0.00
	S48	26	0.06	0.06	0.25	0.00
615 Nitrite Nitrogen, as N (mg/l)	S42	26	0.00	0.00	0.00	0.00
	S43	26	0.00	0.00	0.00	0.00
	S44	26	0.00	0.00	0.00	0.00
	S45	26	0.00	0.00	0.00	0.00
	S46	26	0.00	0.00	0.00	0.00
	S47	26	0.00	0.00	0.00	0.00
	S48	26	0.00	0.00	0.00	0.00
623 Dissolved Kjeldahl Nitrogen, as N (mg/l)	S42	26	0.44	0.13	0.85	0.23
	S43	26	0.44	0.11	0.64	0.16
	S44	26	0.52	0.19	1.18	0.23
	S45	26	0.46	0.12	0.76	0.25
	S46	26	0.48	0.15	0.83	0.23
	S47	26	0.47	0.12	0.76	0.22
	S48	26	0.48	0.13	0.73	0.24

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE
(continued)

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
625 Total Kjeldahl Nitrogen, as N (mg/l)	S42	26	0.89	0.60	3.45	0.49
	S43	26	0.80	0.39	1.82	0.43
	S44	26	0.72	0.36	1.91	0.00
	S45	26	0.88	0.38	1.99	0.41
	S46	26	0.79	0.28	1.53	0.39
	S47	26	0.82	0.36	1.78	0.43
	S48	26	0.97	0.57	2.85	0.47
630 Nitrate + Nitrite, as N (mg/l)	S42	26	0.04	0.06	0.22	0.00
	S43	26	0.04	0.06	0.22	0.00
	S44	26	0.05	0.07	0.24	0.00
	S45	26	0.04	0.05	0.20	0.00
	S46	26	0.04	0.05	0.20	0.00
	S47	26	0.04	0.05	0.21	0.00
	S48	26	0.04	0.07	0.30	0.00
665 Phosphorus, Total, as P (mg/l)	S42	26	0.26	0.07	0.44	0.17
	S43	26	0.27	0.08	0.42	0.15
	S44	26	0.20	0.10	0.38	0.00
	S45	26	0.29	0.09	0.49	0.13
	S46	26	0.26	0.09	0.51	0.14
	S47	26	0.26	0.11	0.49	0.02
	S48	26	0.27	0.11	0.50	0.10
666 Total Nitrogen/ Total Phosphorus Ratio (dimensionless)	S42	26	3.54	1.37	8.62	2.31
	S43	26	3.14	0.92	5.53	1.83
	S44	25	4.26	1.68	8.75	1.84
	S45	26	3.32	1.21	6.61	2.04
	S46	26	3.36	0.99	5.56	1.71
	S47	26	4.45	5.56	31.00	1.63
	S48	26	3.94	1.57	8.60	1.90
671 Orthophosphate, as P (mg/l)	S42	26	0.15	0.06	0.31	0.05
	S43	26	0.16	0.06	0.30	0.07
	S44	26	0.12	0.06	0.29	0.05
	S45	26	0.17	0.07	0.40	0.06
	S46	26	0.16	0.07	0.30	0.06
	S47	26	0.17	0.07	0.33	0.07
	S48	26	0.16	0.06	0.30	0.05

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE (continued)

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
680 Total Organic Carbon (mg/l)	S42	26	17.55	3.77	26.00	8.30
	S43	26	17.22	3.83	27.40	11.20
	S44	26	18.20	3.13	24.20	10.10
	S45	26	17.77	3.85	26.90	10.00
	S46	26	16.74	3.39	23.70	8.00
	S47	26	17.15	3.77	24.10	7.90
	S48	26	17.47	3.96	25.30	9.40
777 Inorganic Nitrogen/ Orthophosphate Ratio (dimensionless)	S42	26	0.32	0.51	2.00	0.00
	S43	26	0.34	0.50	2.00	0.00
	S44	26	0.49	0.69	2.33	0.00
	S45	26	0.30	0.45	1.67	0.00
	S46	26	0.32	0.48	2.11	0.00
	S47	26	0.30	0.48	2.10	0.00
	S48	26	0.30	0.56	2.00	0.00
940 Dissolved Chlorides (mg/l)	S42	26	5.99	1.76	10.60	3.98
	S43	26	6.09	1.79	10.80	3.84
	S44	26	6.12	2.04	10.90	3.90
	S45	26	6.13	1.85	10.60	4.07
	S46	26	5.95	1.84	10.70	4.00
	S47	26	5.98	1.79	10.40	4.02
	S48	26	5.78	1.63	10.00	3.37
1030 Chromium, Dissolved (ug/l)	S42	22	0.76	0.75	3.15	0.00
	S43	22	0.81	0.78	3.03	0.00
	S44	22	0.71	0.79	3.24	0.00
	S45	22	0.69	0.66	2.53	0.00
	S46	21	0.67	0.57	1.89	0.00
	S47	22	0.59	0.63	2.47	0.00
	S48	22	0.45	0.52	2.14	0.00
1034 Chromium, Total (ug/l)	S42	26	0.92	0.74	3.82	0.00
	S43	26	1.06	0.89	3.26	0.00
	S44	26	1.03	0.96	3.64	0.00
	S45	26	0.85	0.68	2.76	0.00
	S46	26	0.79	0.64	2.46	0.00
	S47	26	0.82	0.70	2.71	0.00
	S48	26	0.45	0.36	1.23	0.00

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE
(continued)

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
1040	S42	22	2.93	1.92	7.12	0.00
Copper, Dissolved	S43	22	2.56	1.53	5.95	0.65
(ug/l)	S44	22	2.59	1.72	7.97	0.30
	S45	22	2.48	1.65	6.25	0.12
	S46	22	2.09	1.22	4.29	0.22
	S47	22	2.27	1.45	4.95	0.00
	S48	22	2.26	1.29	5.80	0.15
1042	S42	26	2.62	1.48	6.29	0.50
Copper, Total	S43	26	2.54	1.49	6.27	0.33
(ug/l)	S44	26	2.34	1.29	5.81	0.33
	S45	26	2.62	1.92	8.82	0.27
	S46	26	2.64	2.02	11.20	0.33
	S47	26	2.27	1.26	6.25	0.00
	S48	26	2.08	1.76	8.94	0.00
1049	S42	22	2.52	2.64	10.20	0.00
Lead, Dissolved	S43	22	2.24	2.29	7.47	0.00
(ug/l)	S44	22	1.95	2.46	8.58	0.00
	S45	22	1.89	2.02	7.21	0.00
	S46	22	1.73	2.21	8.10	0.00
	S47	22	2.37	2.66	8.30	0.00
	S48	22	1.55	1.79	6.60	0.00
1051	S42	26	3.61	2.42	12.20	0.00
Lead, Total	S43	26	3.50	2.45	8.95	0.00
(ug/l)	S44	26	3.16	2.54	9.56	0.00
	S45	26	3.18	2.28	7.68	0.00
	S46	26	3.16	2.44	7.84	0.00
	S47	26	2.91	2.48	8.46	0.00
	S48	26	2.07	2.05	7.08	0.00
31501	S42	26	1083.	2648.	13100.	0.
Coliforms	S43	26	1710.	5100.	26200.	0.
(colonies/100 ml)	S44	26	1065.	1610.	5800.	0.
	S45	26	1191.	2896.	13700.	0.
	S46	26	1131.	2562.	12600.	0.
	S47	26	1249.	2779.	14000.	0.
	S48	26	179.	267.	1000.	0.

TABLE 5

SUMMARY OF LAKE WATER QUALITY STATISTICS BY SAMPLING SITE (continued)

Parameter/ Storet Code	Station Number	N	Mean	Std Dev	Maximum	Minimum
31625 Fecal Coliform (colonies/100 ml)	S42	26	66.	101.	352.	0.
	S43	26	108.	176.	800.	2.
	S44	26	95.	107.	360.	2.
	S45	26	83.	120.	500.	2.
	S46	26	85.	140.	550.	0.
	S47	26	67.	109.	510.	1.
	S48	26	16.	21.	100.	2.
31673 Streptococci (colonies/100 ml)	S42	26	27.	56.	250.	1.
	S43	26	36.	86.	400.	1.
	S44	26	44.	89.	450.	1.
	S45	26	29.	80.	400.	1.
	S46	26	28.	53.	230.	1.
	S47	26	35.	91.	450.	1.
	S48	26	5.	7.	28.	1.
3221 Chlorophyll_a (ug/l)	S42	25	30.57	25.26	80.40	3.98
	S43	25	33.95	29.08	98.50	1.12
	S44	25	28.16	25.86	81.02	1.59
	S45	25	25.20	16.55	56.70	3.30
	S46	25	30.51	23.41	92.59	4.79
	S47	25	30.67	23.91	78.20	3.40
	S48	25	32.27	22.71	72.67	2.80
3228 Phaeophytin (ug/l)	S42	25	1.24	2.52	11.62	0.00
	S43	25	2.38	4.38	13.41	0.00
	S44	25	2.21	4.48	18.69	0.00
	S45	25	1.39	2.92	11.29	0.00
	S46	25	3.64	7.77	31.19	0.00
	S47	25	1.86	4.18	19.86	0.00
	S48	25	4.75	12.40	59.89	0.00
72025 Depth of Lake (feet)	S42	26	4.50	0.31	5.10	4.00
	S43	26	4.31	0.32	4.80	3.30
	S44	26	2.62	0.56	4.60	1.80
	S45	26	4.22	0.34	4.70	3.40
	S46	26	4.18	0.36	4.70	3.00
	S47	26	4.41	0.39	5.00	3.00
	S48	26	4.77	0.33	5.40	4.00

plots were used to verify that the error was randomly distributed. Two outliers were detected using this technique and removed after consultation with the City of Tallahassee Water Quality Laboratory. The results, given in Table 6, indicate that a number of parameters were significantly different between sites.

Having established global differences between sites, a Student's t-test was employed to compare the differences in means between individual sites. The t-test was conducted in a manner that assumes the standard deviations between sites are not equal. The results, shown in Table 6, indicate that many parameters at stations S44 and S48 are significantly different than at several other stations. Station S44 is located near the lake inflow, and station S48 is located in the more isolated waters in the northern arm of the lake. Station S44 showed significantly higher levels of color and lower levels of transparency, dissolved oxygen, BOD, pH, nonfilterable volatile residue, TKN, total phosphorus, orthophosphate, and lake depth than several other stations. Similarly, station S48 had significantly lower values of turbidity, color, chromium, lead, and coliforms, and higher values of pH, BOD, nonfilterable volatile residue, TKN, transparency, and lake depth than several other stations. Although significant from a statistical viewpoint, the magnitude of these differences is relatively small as indicated in Table 5.

Biweekly variations of parameter means, highs, lows, and upper and lower quartiles over the entire data collection period are shown in Figures 26 through 72. Nitrite data were not shown because all values were reported below detection limits. Just prior to the first sample date, weather conditions were dry and warm. At that time, lake levels were low and specific conductance, an indicator of ions in solution, was higher than at any other time during the monitoring period. Total dissolved solids, total residue, alkalinity, orthophosphate, total phosphate, ammonia, chlorides, and chlorophyll were also high at that time. Conversely, nitrate levels were very low throughout this period. Another dry period occurred from September to November 1987, resulting in a slight rise in specific conductance, total dissolved solids, and chlorides.

Nitrogen and Phosphorus

Nitrogen and phosphorus are the major macronutrients affecting the growth of aquatic plants and algae. Normally, algae will readily take up these nutrients in the form of nitrate and orthophosphate. The relative abundance of these nutrients in the water column is the primary factor limiting algal growth potential in a lake environment. One indicator used to identify the nutrient limitation status of a lake system is the ratio of soluble inorganic nitrogen (nitrate) to soluble reactive phosphorus (orthophosphate), or the SIN:SRP ratio. A ratio of less than 10:1 clearly indicates nitrogen limitation, a ratio greater than 20:1 indicates phosphorus limitation, and an intermediate ratio indicates mixed nutrient limitation (Porcella and Bishop, 1975).

TABLE 6

RESULTS FROM TESTS OF SIGNIFICANCE ON LAKE WATER QUALITY STATIONS

Parameter		ANOV on site means F-test	Two sample t-test comparing differences between sites
Code	Description	Results[1]	Means Results[2]
00010	Temperature, 0 ft h	S(.01)	NS
00010	Temperature, 1 ft h	S(.01)	NS
00010	Temperature, 2 ft h	S(.01)	NS
00076	Turbidity	S(.01)	s48 vs. all other sites(.05)
00077	Secchi Depth	S(.05)	s44 vs. s48(.05)
00080	Color	S(.01)	s48 vs. all other sites(.05)
00094	Spec cond, field	NS	NS
00095	Spec Cond, lab	NS	NS
00300	DO, near surface	S(.01)	s44 vs. s42,43,47,48(.10)
00300	DO, 1 ft h	S(.01)	s44 vs. s42,43,47,48(.09)
00300	DO, 2 ft h	S(.01)	s44 vs. s42,43,46,47,48(.06)
00310	BOD, 5-Day	S(.01)	s48 vs. s46,s44(.05)
00314	BOD, Carbonaceous	S(.05)	NS
00340	COD	NS	NS
00400	pH	S(.01)	s48 vs. s44(.10)
00410	Alkalinity	NS	NS
00500	Total Solids	NS	NS
00530	Suspended Solids	NS	NS
00535	Nonfilterable Vol. Res.	S(.01)	s44 vs. s48(.10)
00600	Nitrogen, Total	S(.01)	NS
00610	Ammonia Nitrogen	NS	NS
00615	Nitrite	NS	NS
00625	TKN	S(.01)	s44 vs. s48(.06)
00630	Nitrate	NS(o)	NS
00665	Phosphorus, Total	S(.01)	s44 vs. all(.05)
00671	Orthophosphate	S(.01)	s44 vs. all(.05)
00680	Total Organic Carbon	NS	NS
00940	Chloride, Dissolved	NS	NS
01002	Arsenic, Total	NS	NS
01027	Cadmium, Total	NS	NS
01034	Chromium, Total	S(.05)	s48 vs. all(.05)
01040	Copper, Dissolved	NS	NS
01042	Copper, Total	NS	NS
01049	Lead, Dissolved	NS	NS
01051	Lead, Total	S(.01)	s48 vs. s42,s43(.05)
01067	Nickel, Total	samples below detection limit	
01077	Silver, Total	samples below detection limit	
01092	Zinc, Total	NS	NS

TABLE 6

RESULTS FROM TESTS OF SIGNIFICANCE ON LAKE WATER QUALITY STATIONS (continued)

Parameter		ANOV on site means F-test	Two sample t-test comparing differences between sites
Code	Description	Results[1]	Means Results[2]
31501	Coliform	S(.01)	s48 vs. s42,s44(.05)
31625	Fecal Coliform	S(.01)	s48 vs. all(.02)
31673	Streptococci	S(.05)	s48 vs. all(.10)
71900	Mercury, Total	NS	NS
72025	Depth of Lake	S(.01)	s44 vs. all(.01) s48 vs. all(.01) s42 vs. s43,44,45,46,48(.03) s46 vs. s47(.05)

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[1] The highest significance level is reported as "S(.01)". When no significant difference was found at or below "S(.05)", "NS" is reported. The letter "o" means a possible outlier was detected.

[2] The lowest significance level chosen for this analysis is .10 (corresponding to 90 percent confidence). Values above this level are reported as "NS". The lowest significance level attained is reported as "(.10)", the highest as "(.01)".

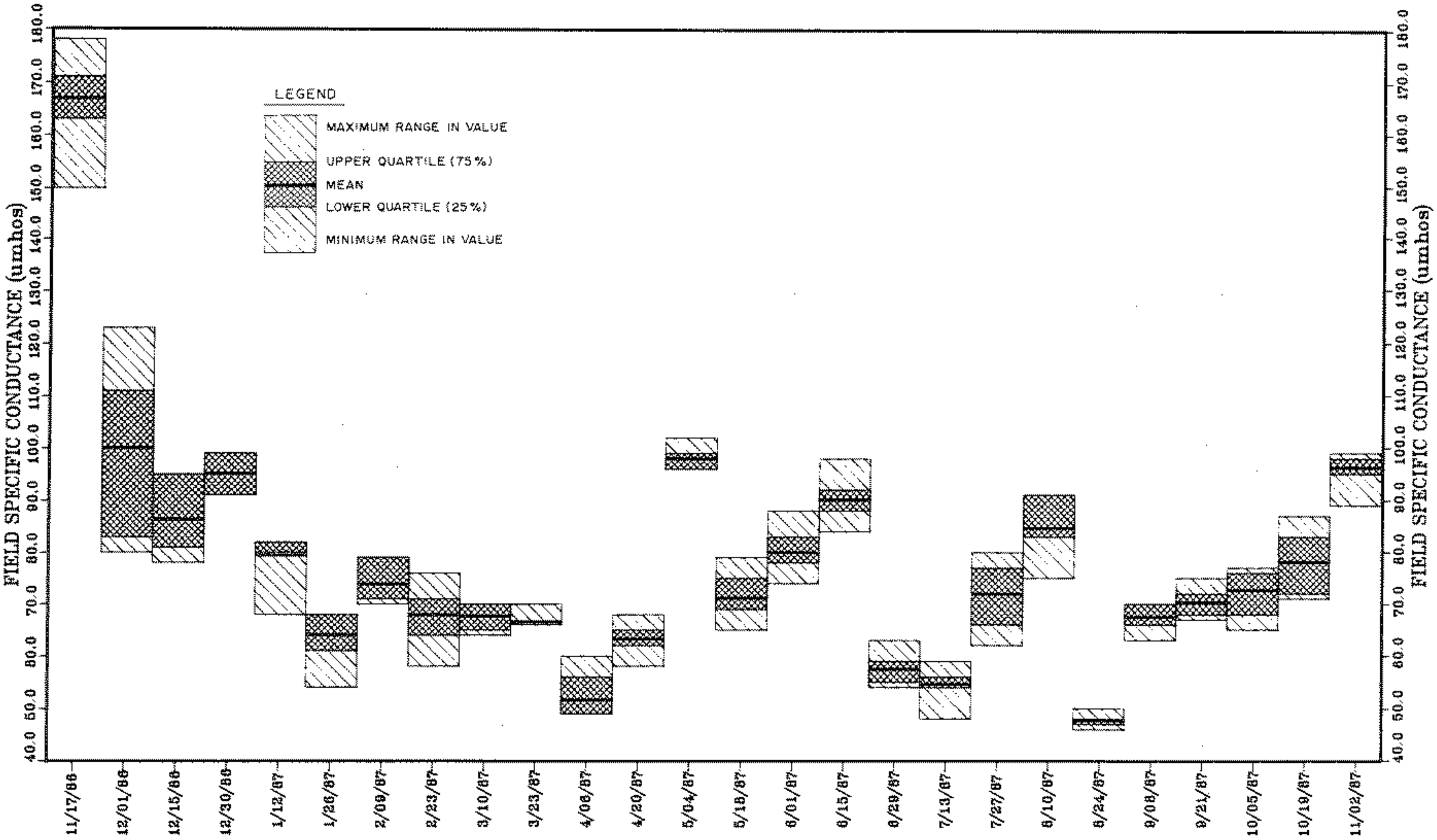


Figure 26. Statistical Summary of Field Specific Conductance Data for Lake Sampling Stations

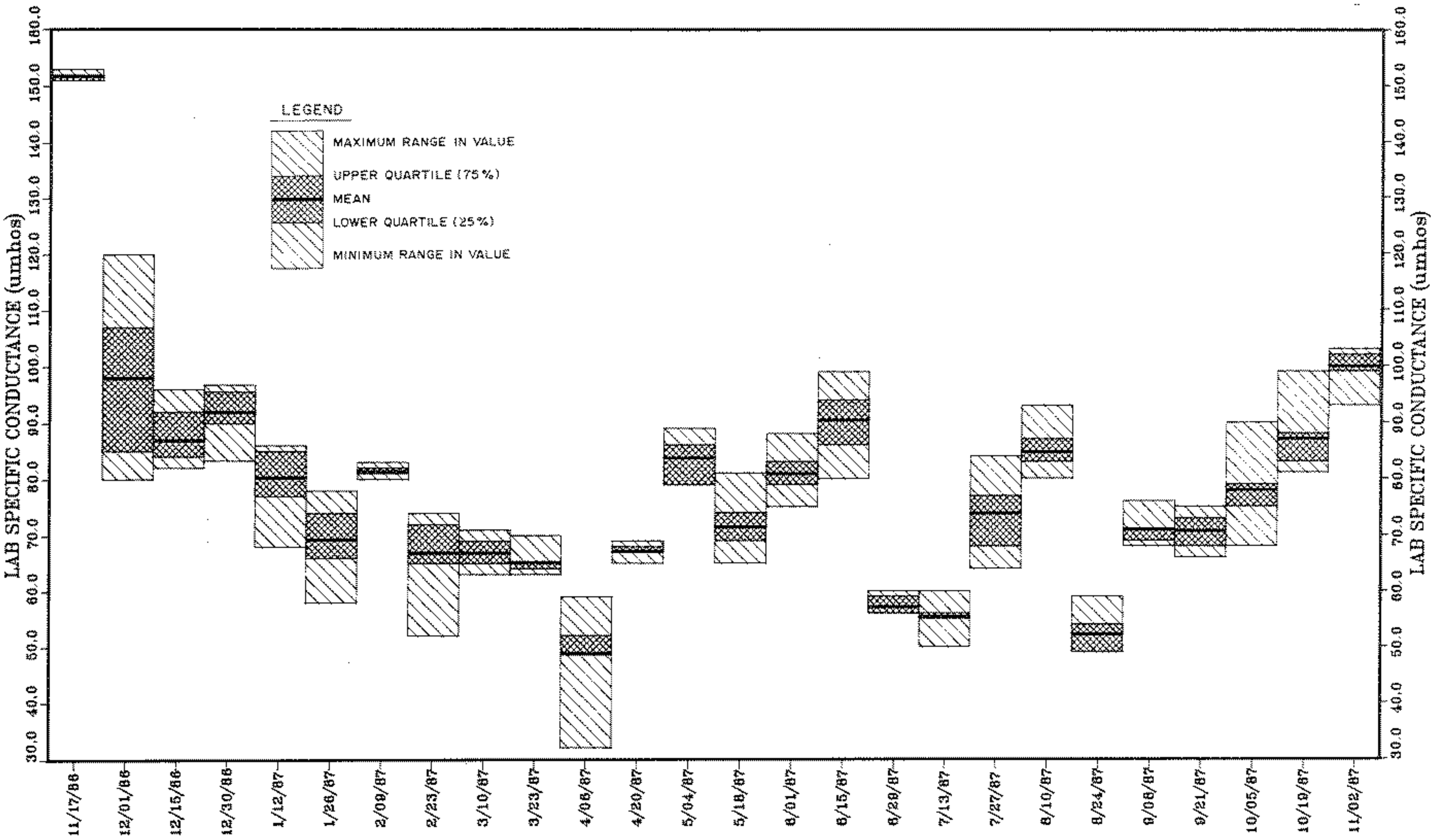


Figure 27. Statistical Summary of Lab Specific Conductance Data for Lake Sampling Stations

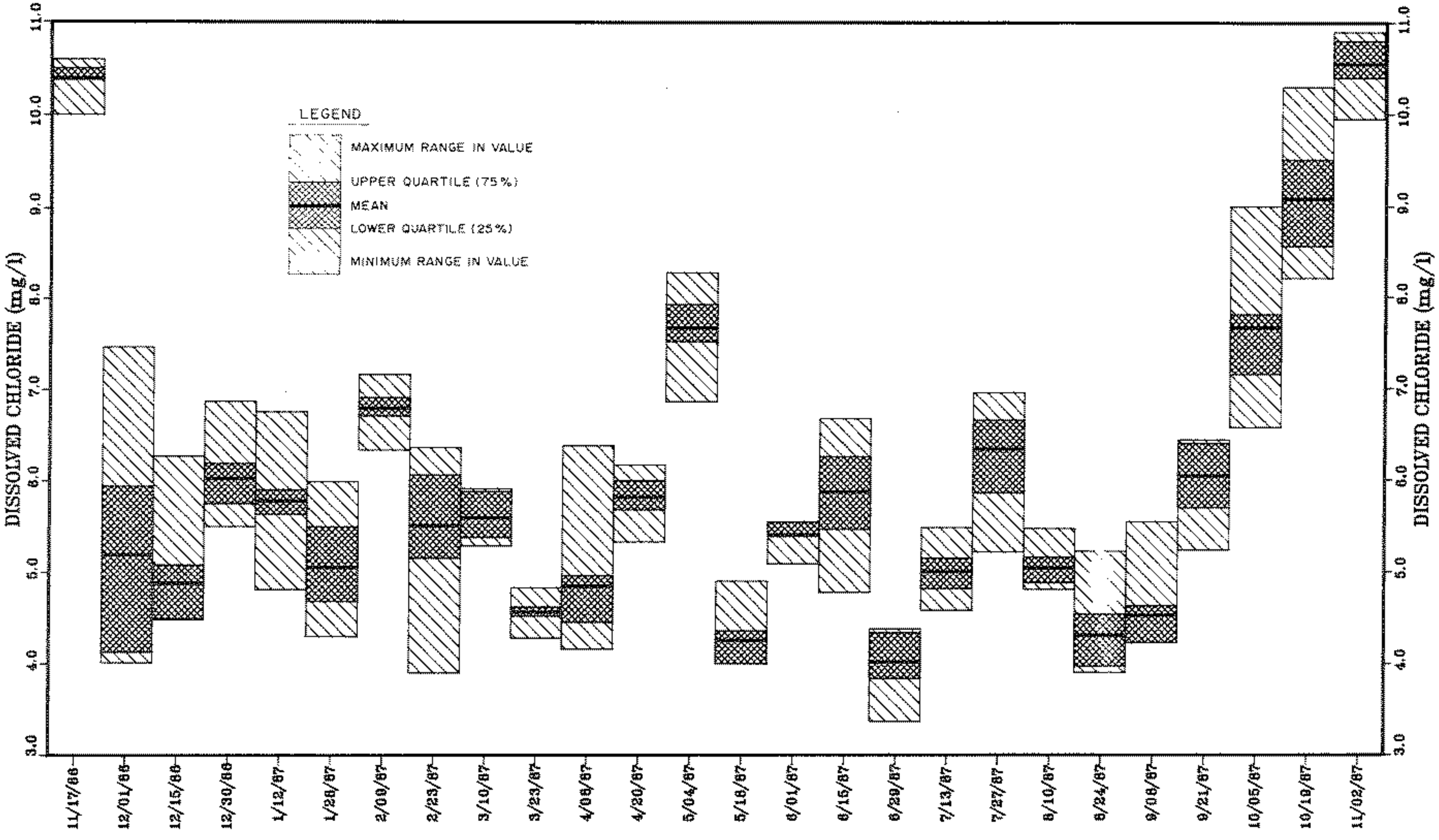


Figure 28. Statistical Summary of Dissolved Chloride Data for Lake Sampling Stations

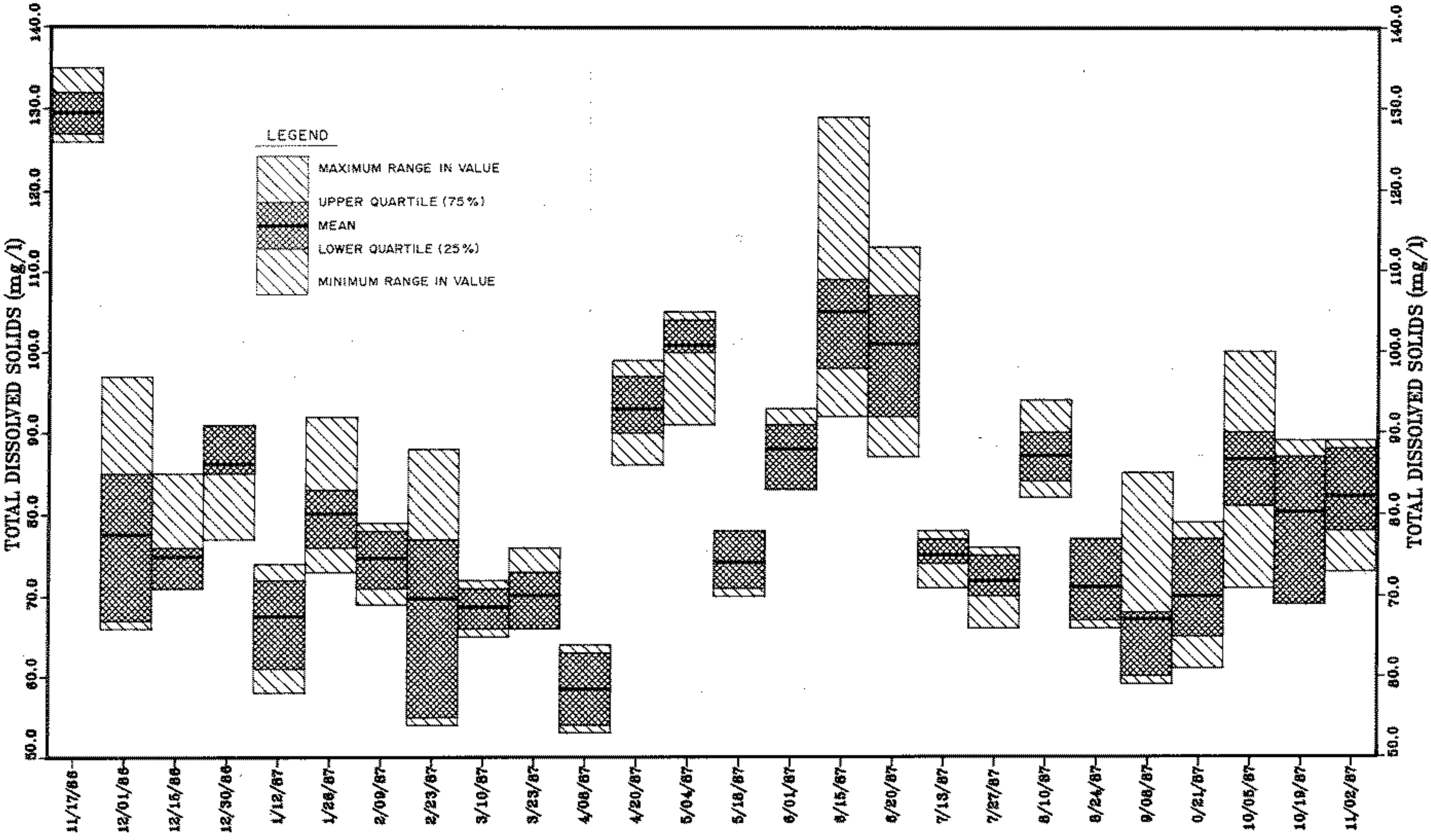


Figure 29. Statistical Summary of Total Dissolved Solids Data for Lake Sampling Stations

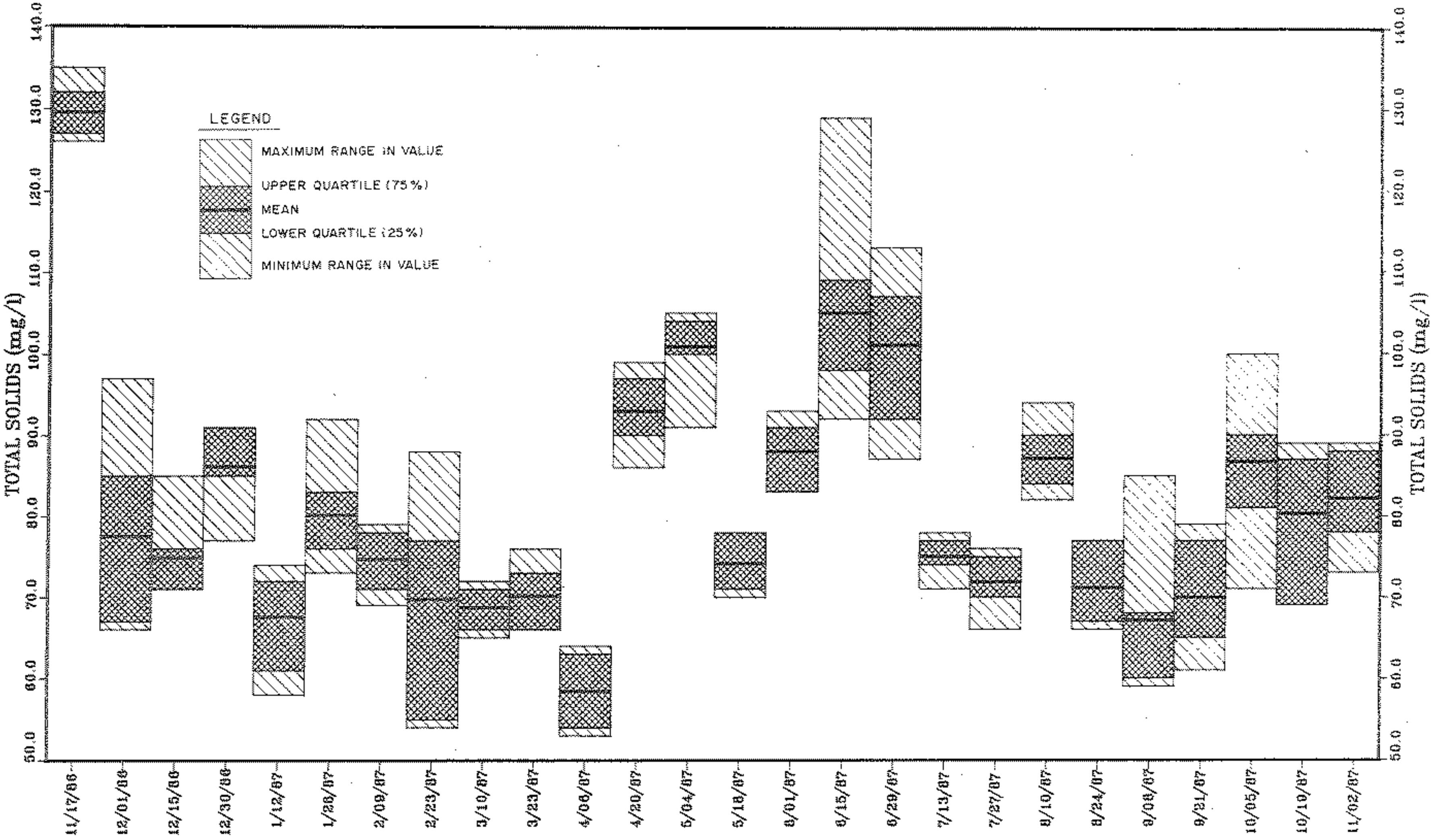


Figure 30. Statistical Summary of Total Solids Data for Lake Sampling Stations

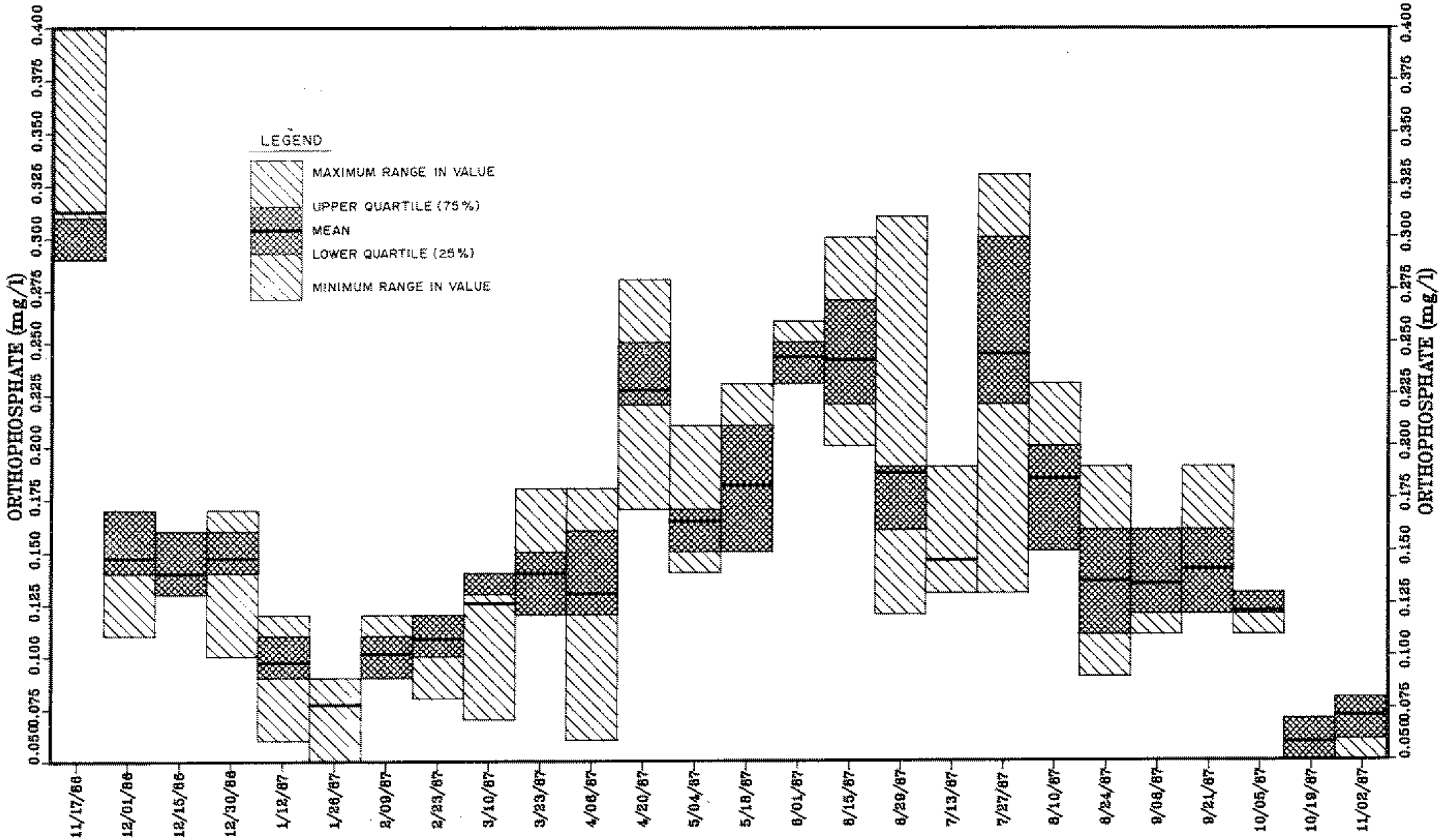


Figure 31. Statistical Summary of Orthophosphate Data for Lake Sampling Stations

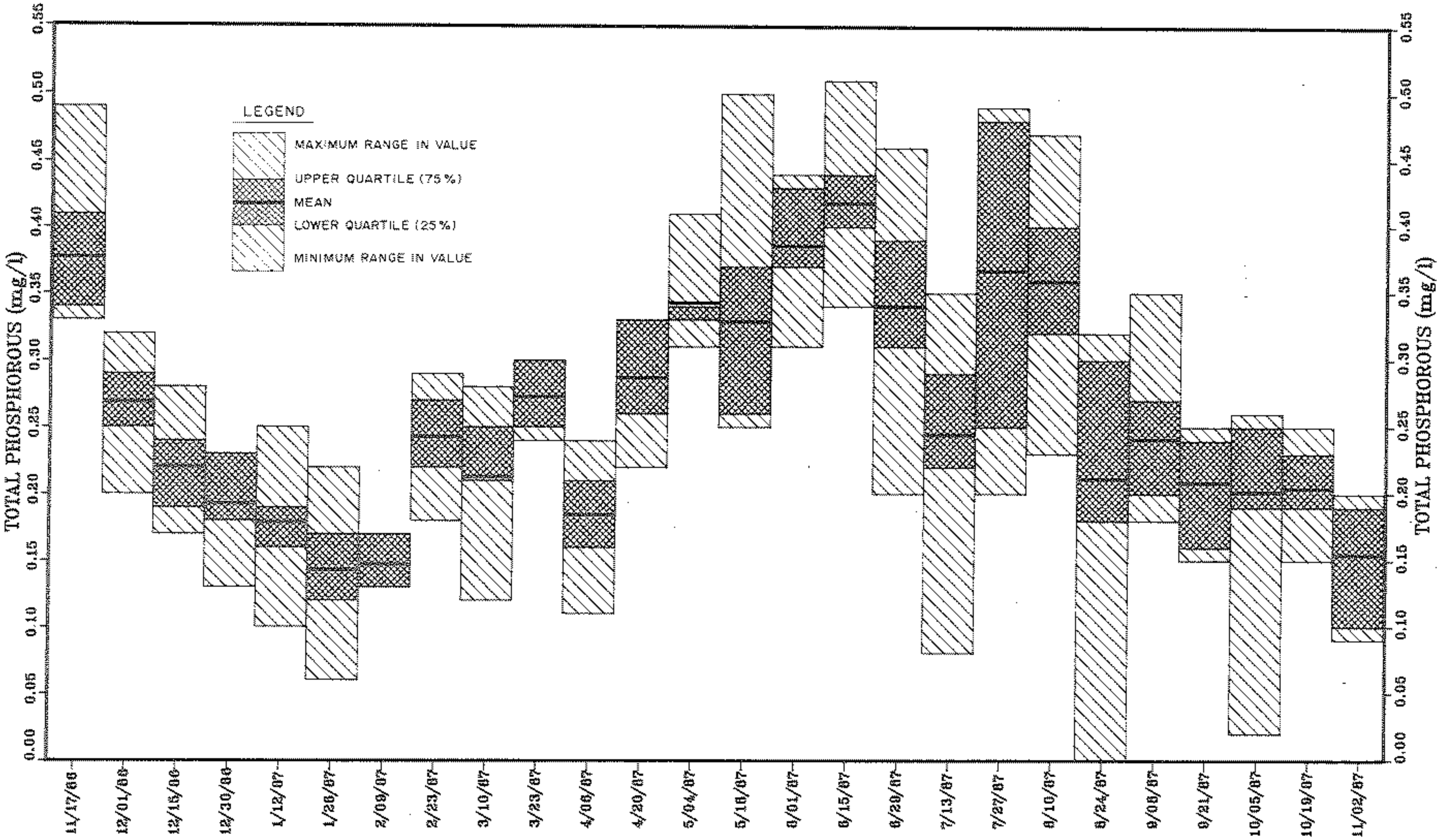


Figure 32. Statistical Summary of Total Phosphorus Data for Lake Sampling Stations

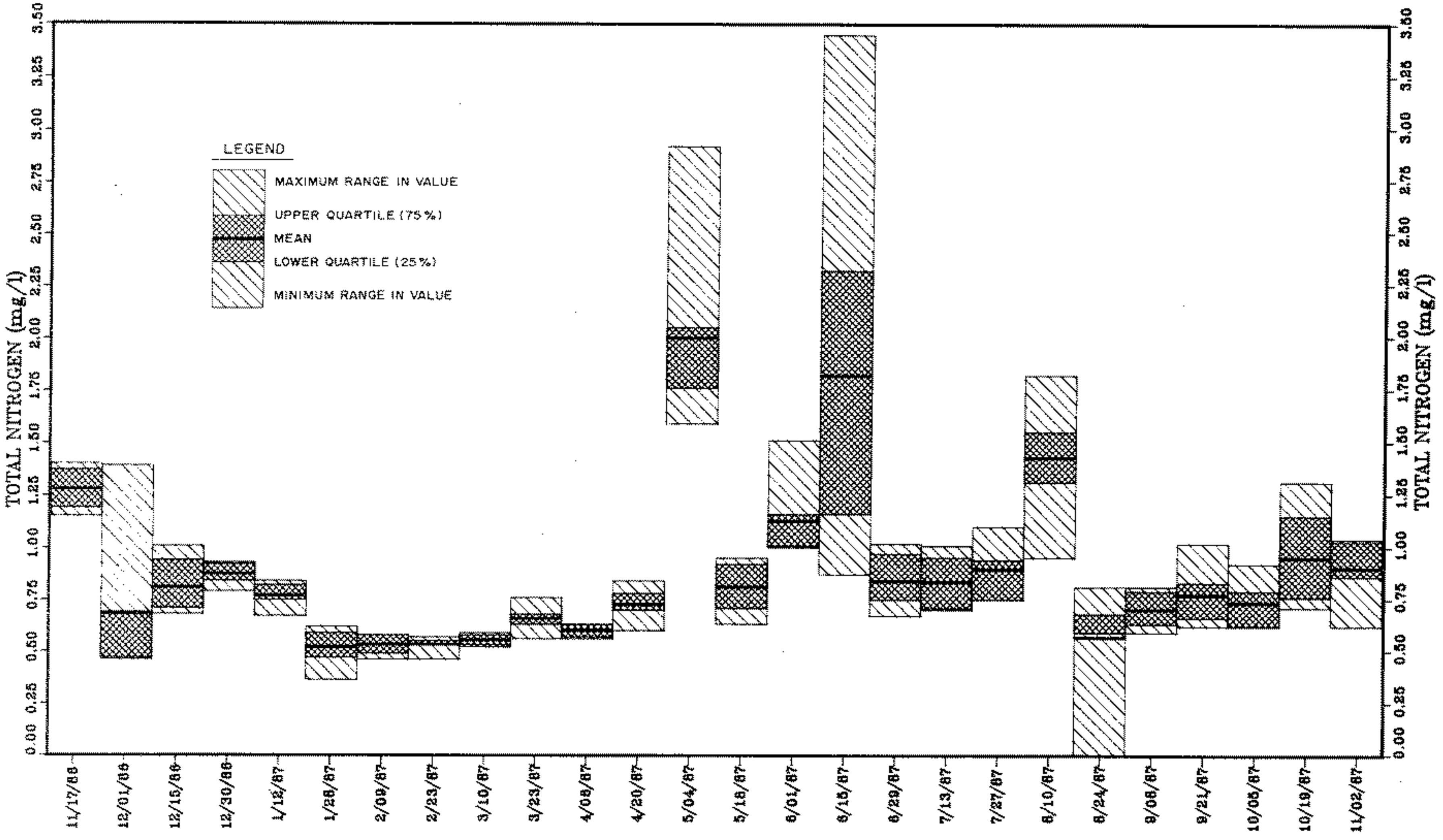


Figure 33. Statistical Summary of Total Nitrogen Data for Lake Sampling Stations

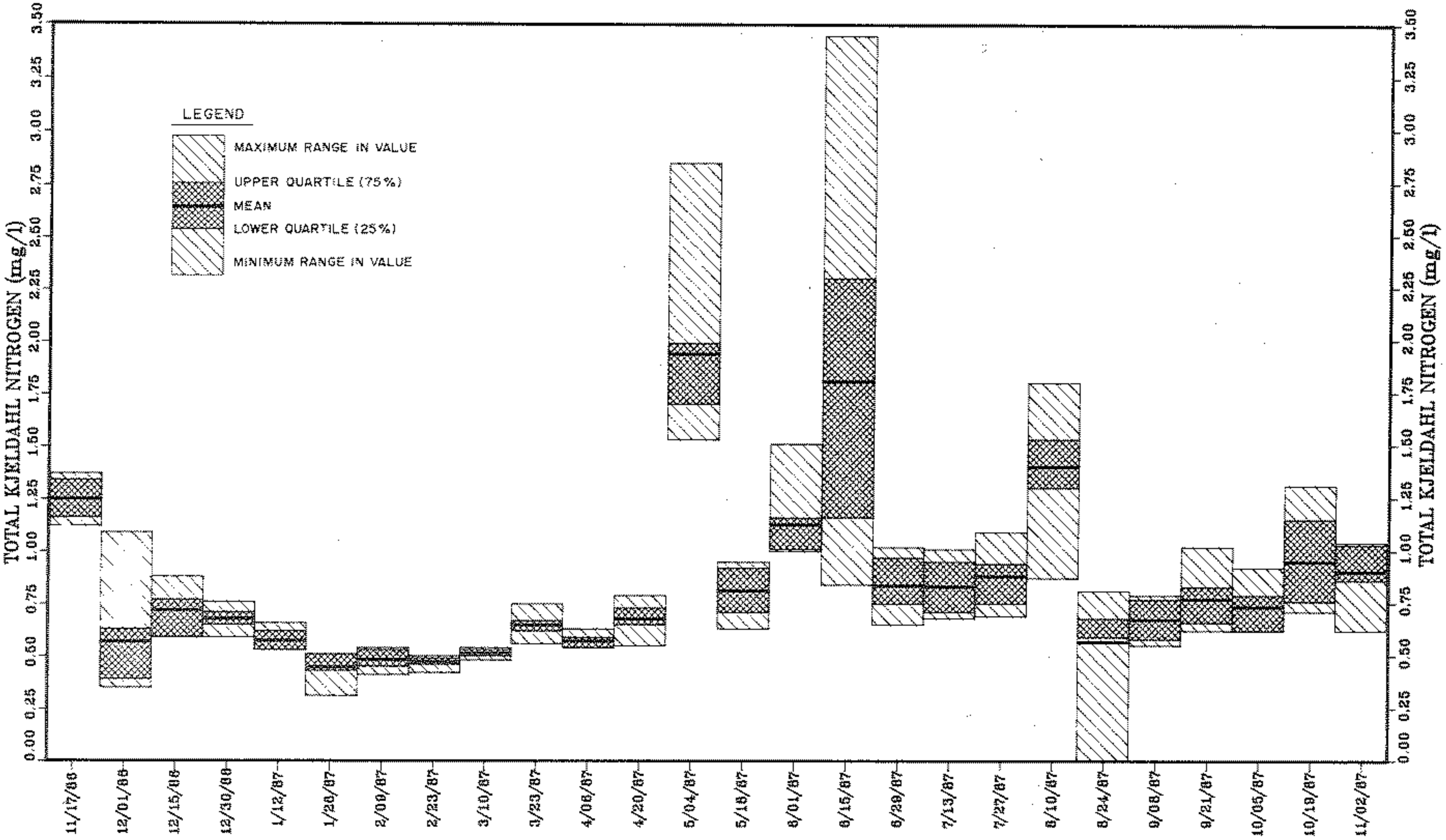


Figure 34. Statistical Summary of Total Kjeldahl Nitrogen Data for Lake Sampling Stations

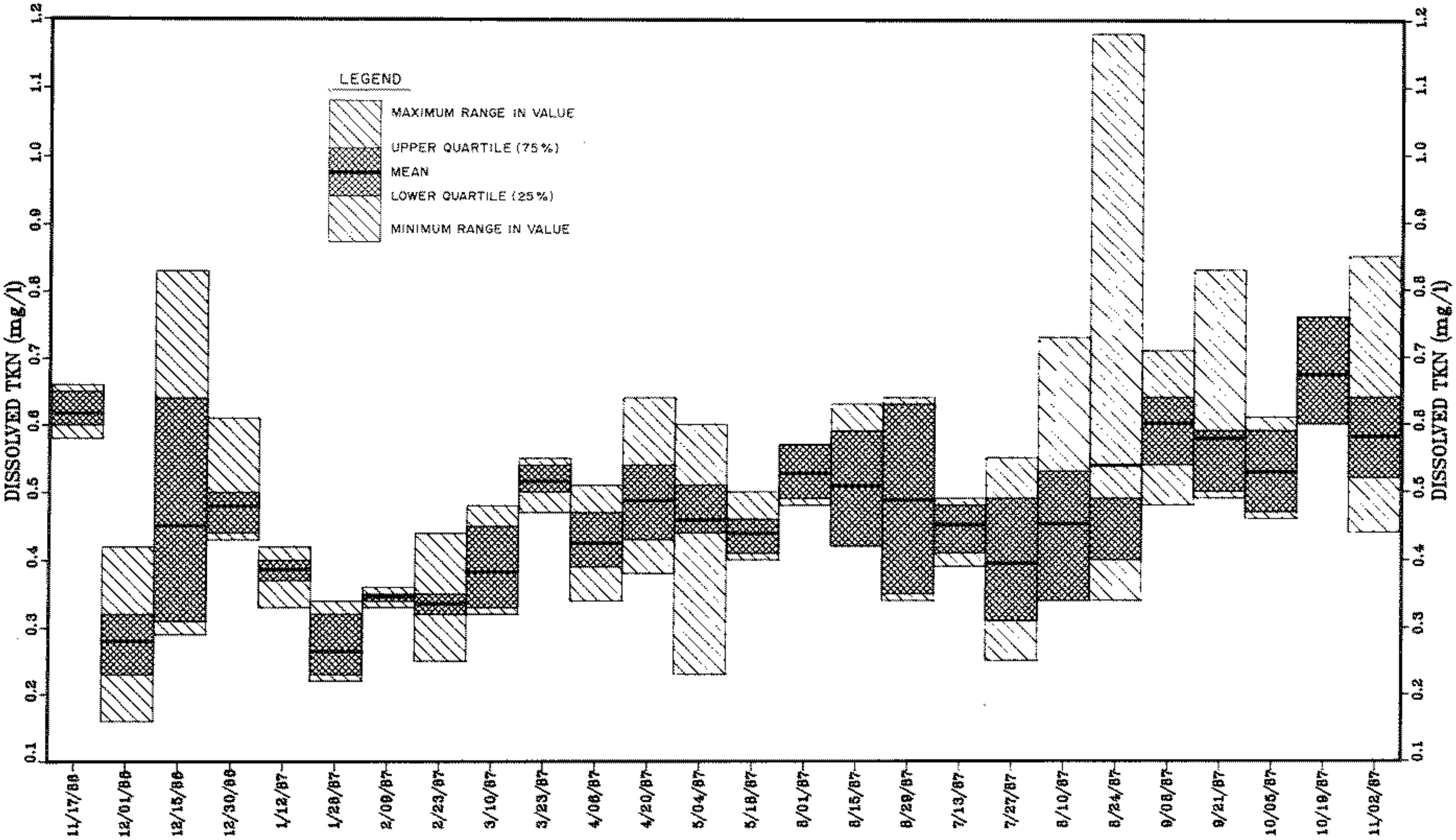


Figure 35. Statistical Summary of Dissolved Kjeldahl Nitrogen Data for Lake Sampling Stations

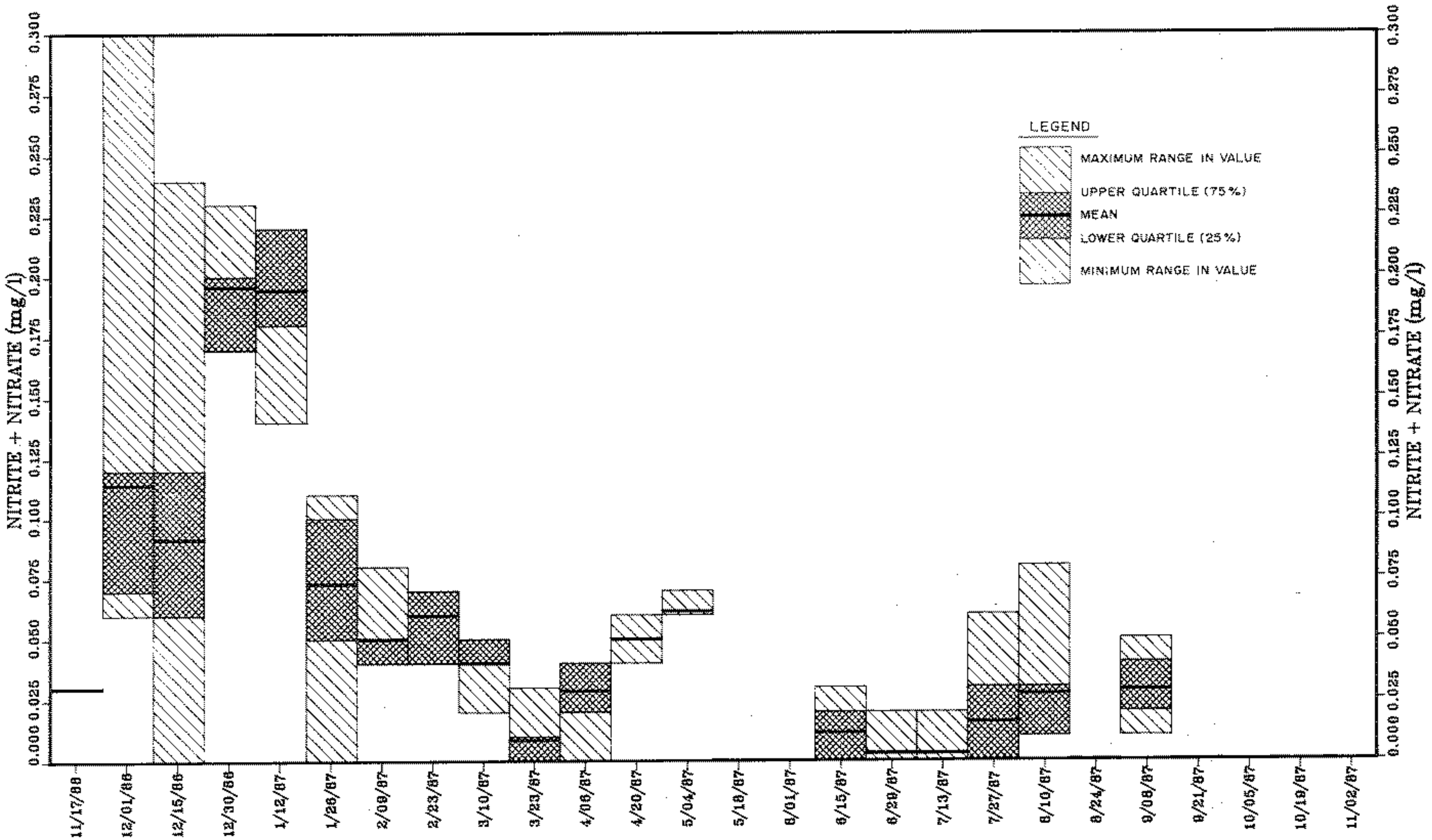


Figure 36. Statistical Summary of Nitrate Plus Nitrite Data for Lake Sampling Stations

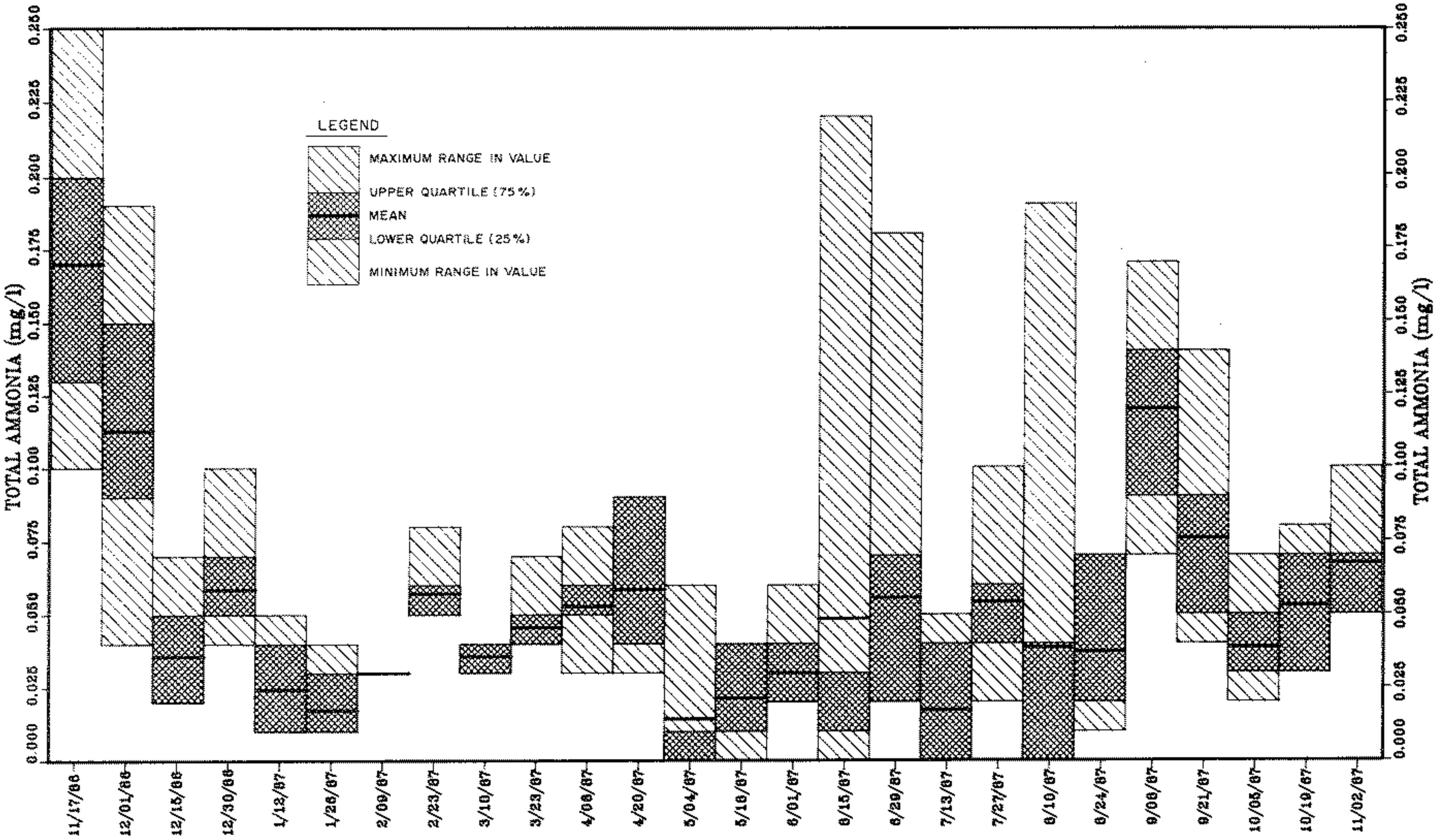


Figure 37. Statistical Summary of Total Ammonia Data for Lake Sampling Stations

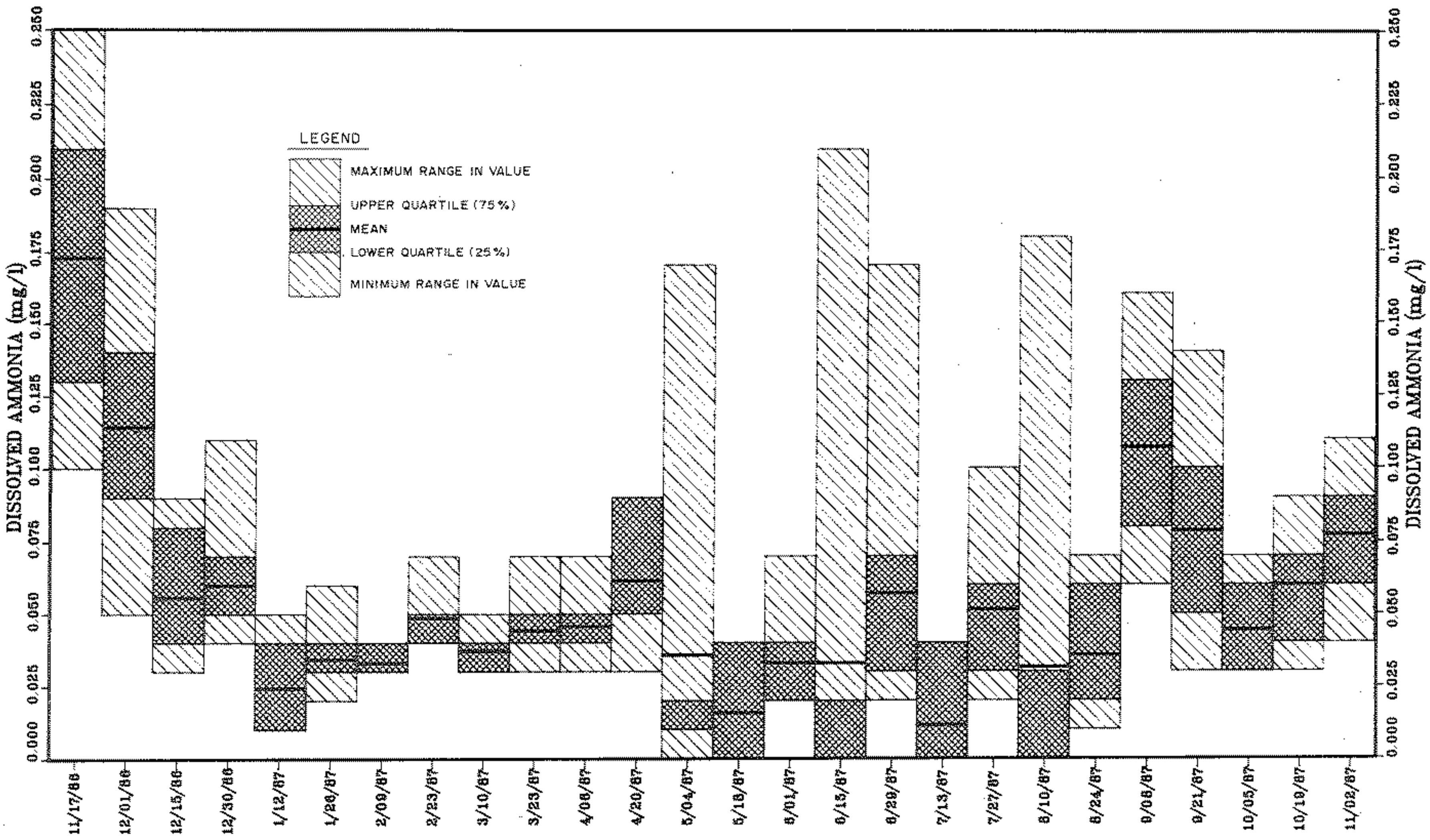


Figure 38. Statistical Summary of Dissolved Ammonia Data for Lake Sampling Stations

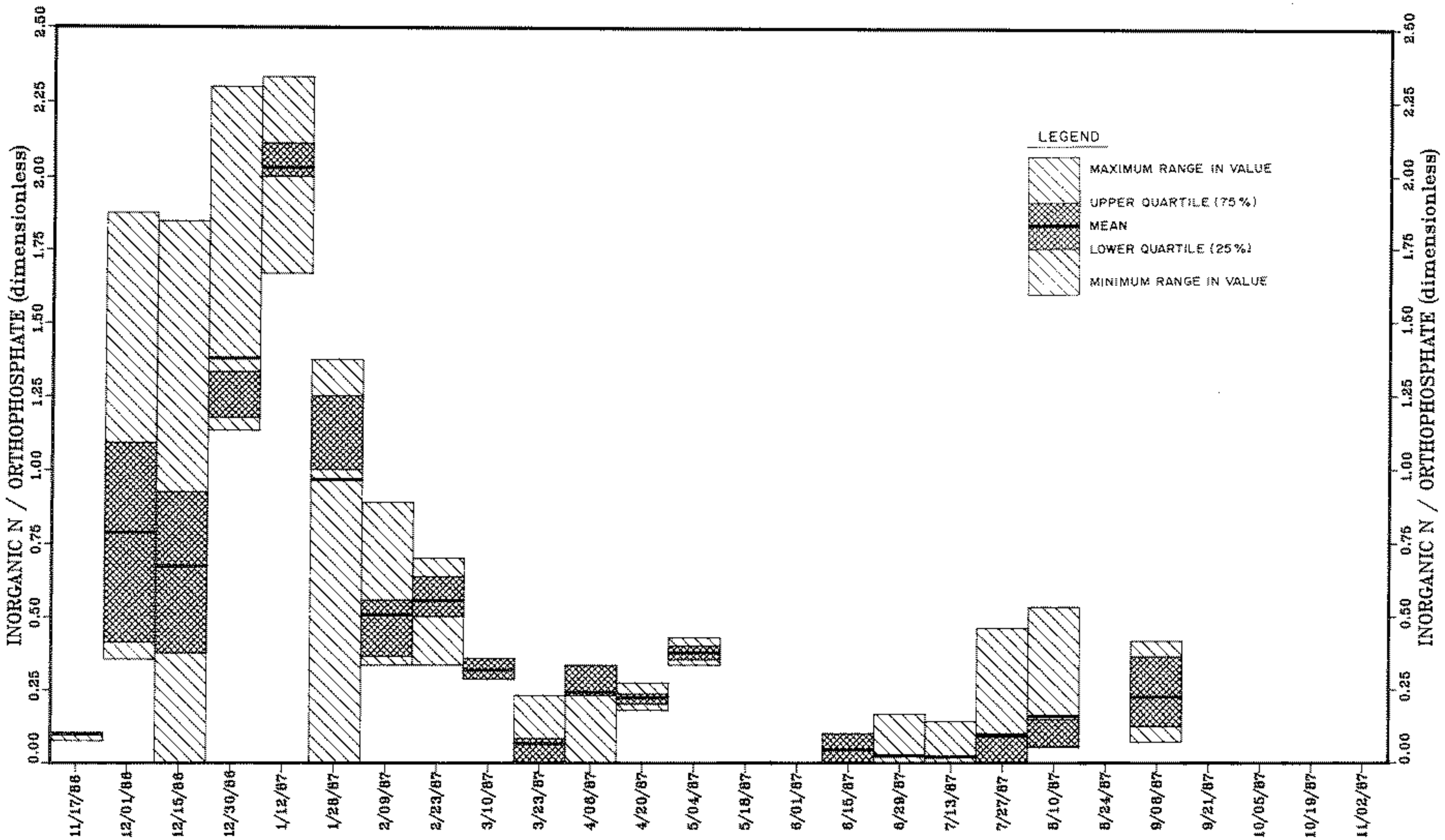


Figure 39. Statistical Summary of Inorganic N/P Ratio Data for Lake Sampling Stations

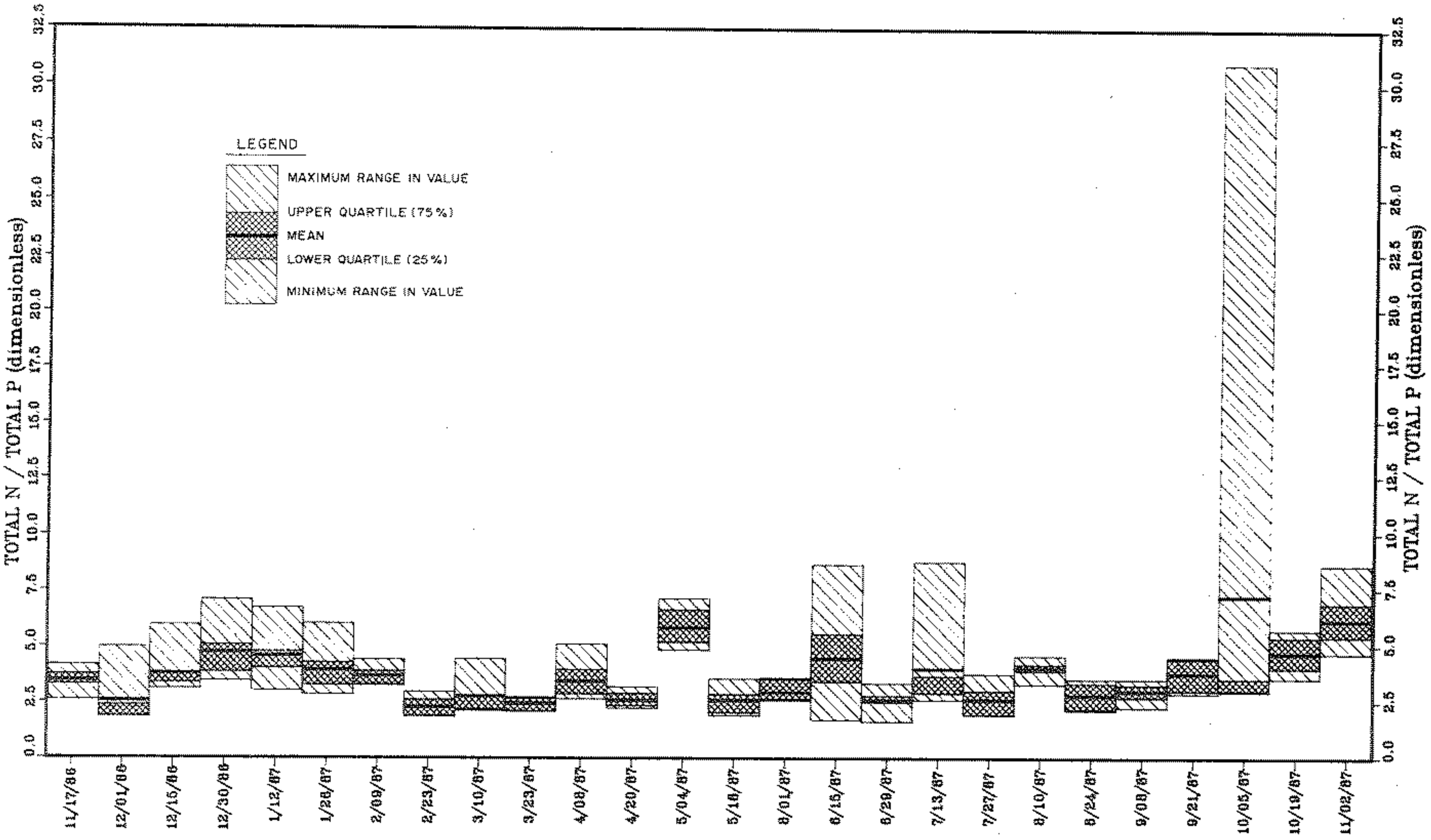


Figure 40. Statistical Summary of Total N/P Ratio Data for Lake Sampling Stations

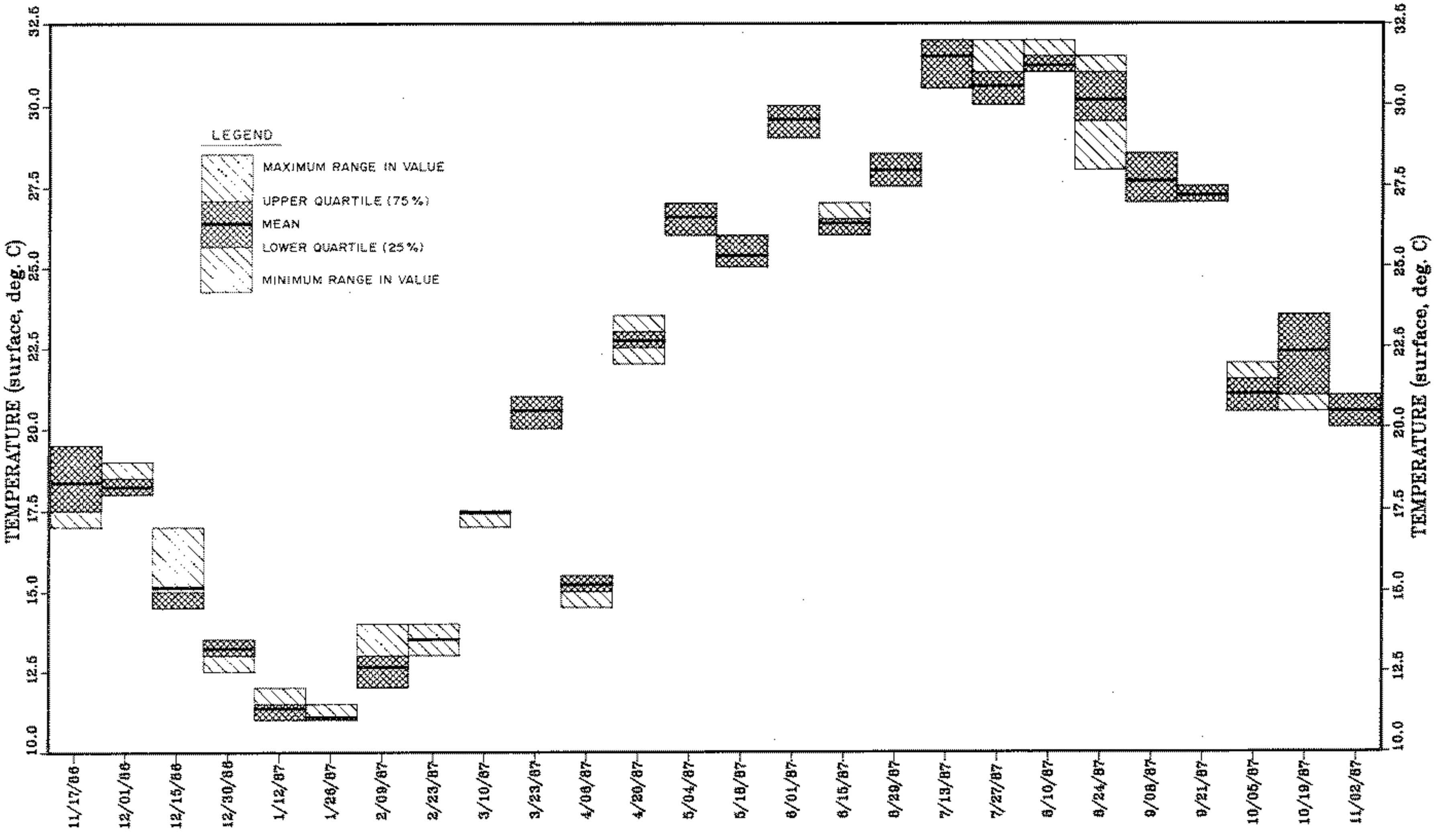


Figure 41. Statistical Summary of Near Surface Temperature Data for Lake Sampling Stations

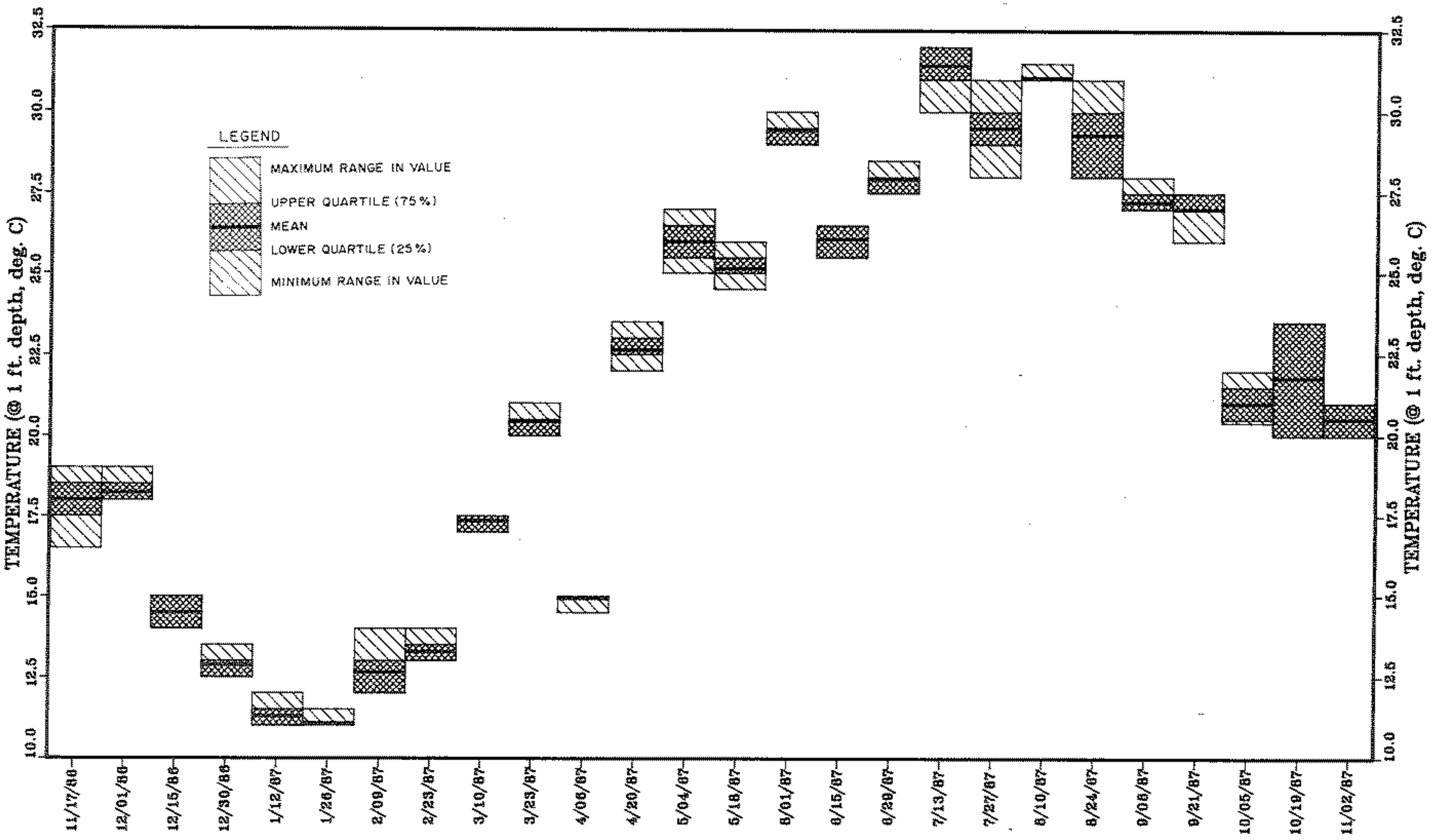


Figure 42. Statistical Summary of Temperature Data at One-Foot Depth for Lake Sampling Stations

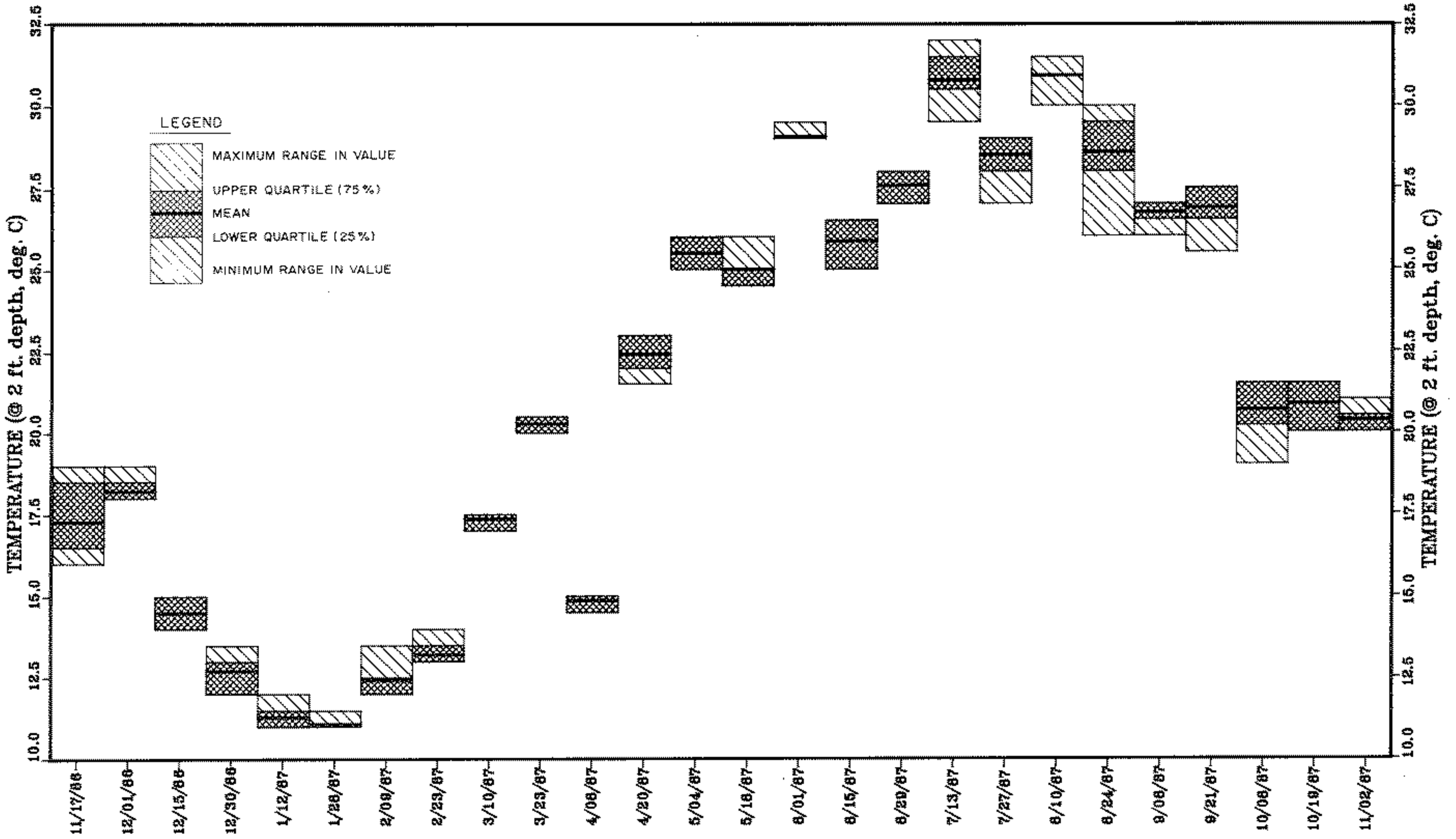


Figure 43. Statistical Summary of Temperature Data at Two-Foot Depth for Lake Sampling Stations

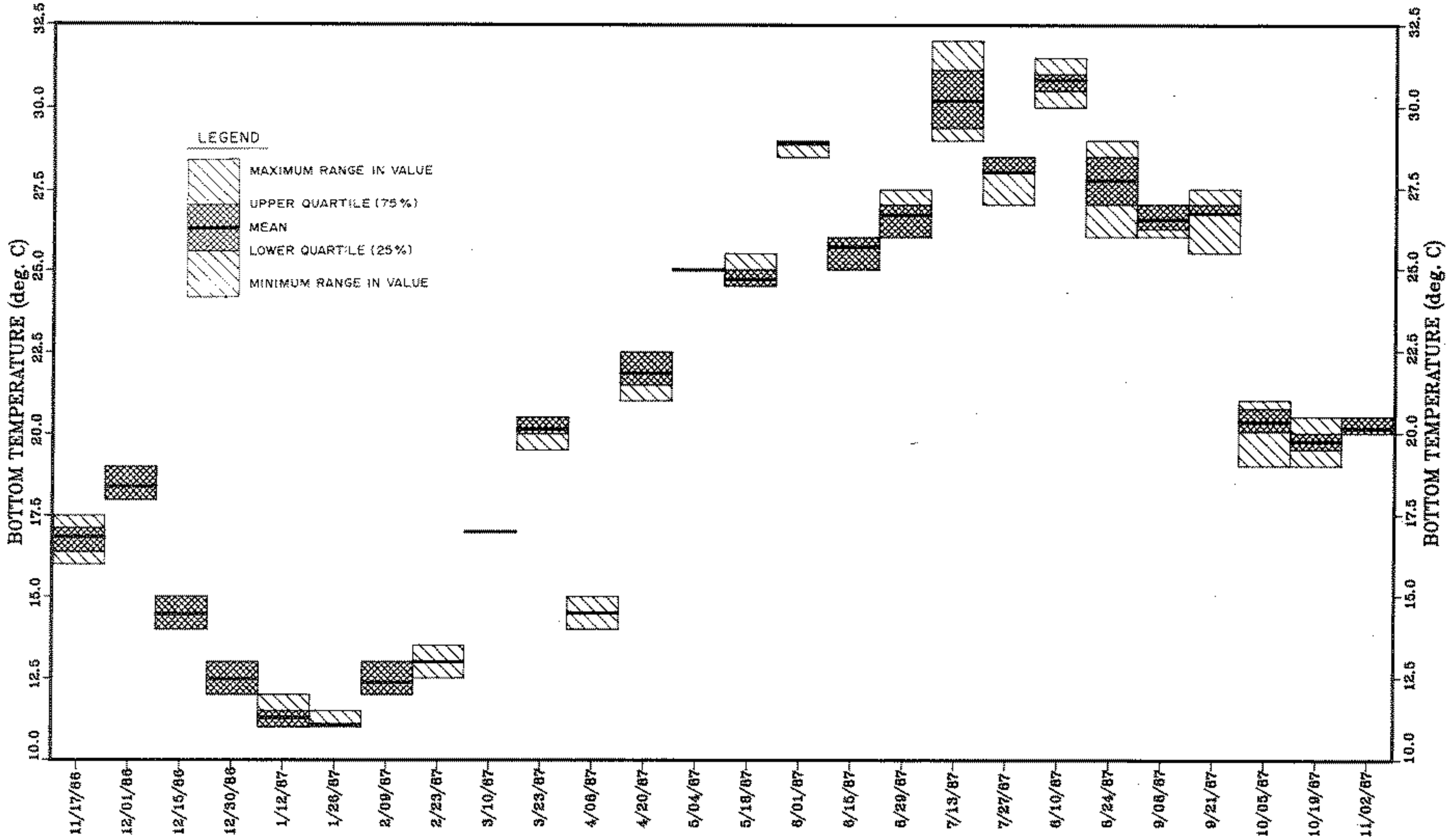


Figure 44. Statistical Summary of Near Bottom Temperature Data for Lake Sampling Stations

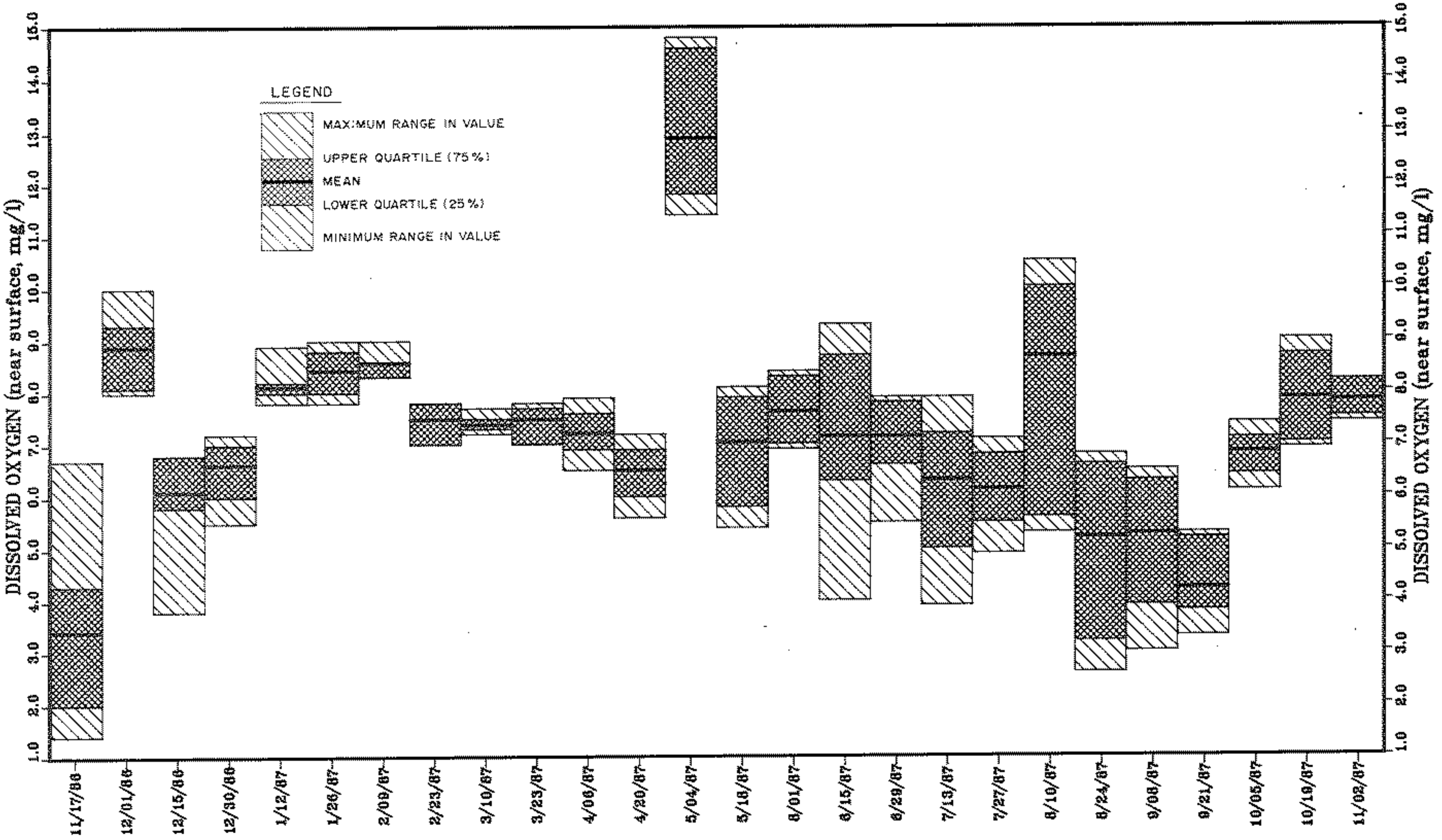


Figure 45. Statistical Summary of Near Surface Dissolved Oxygen Data for Lake Sampling Stations

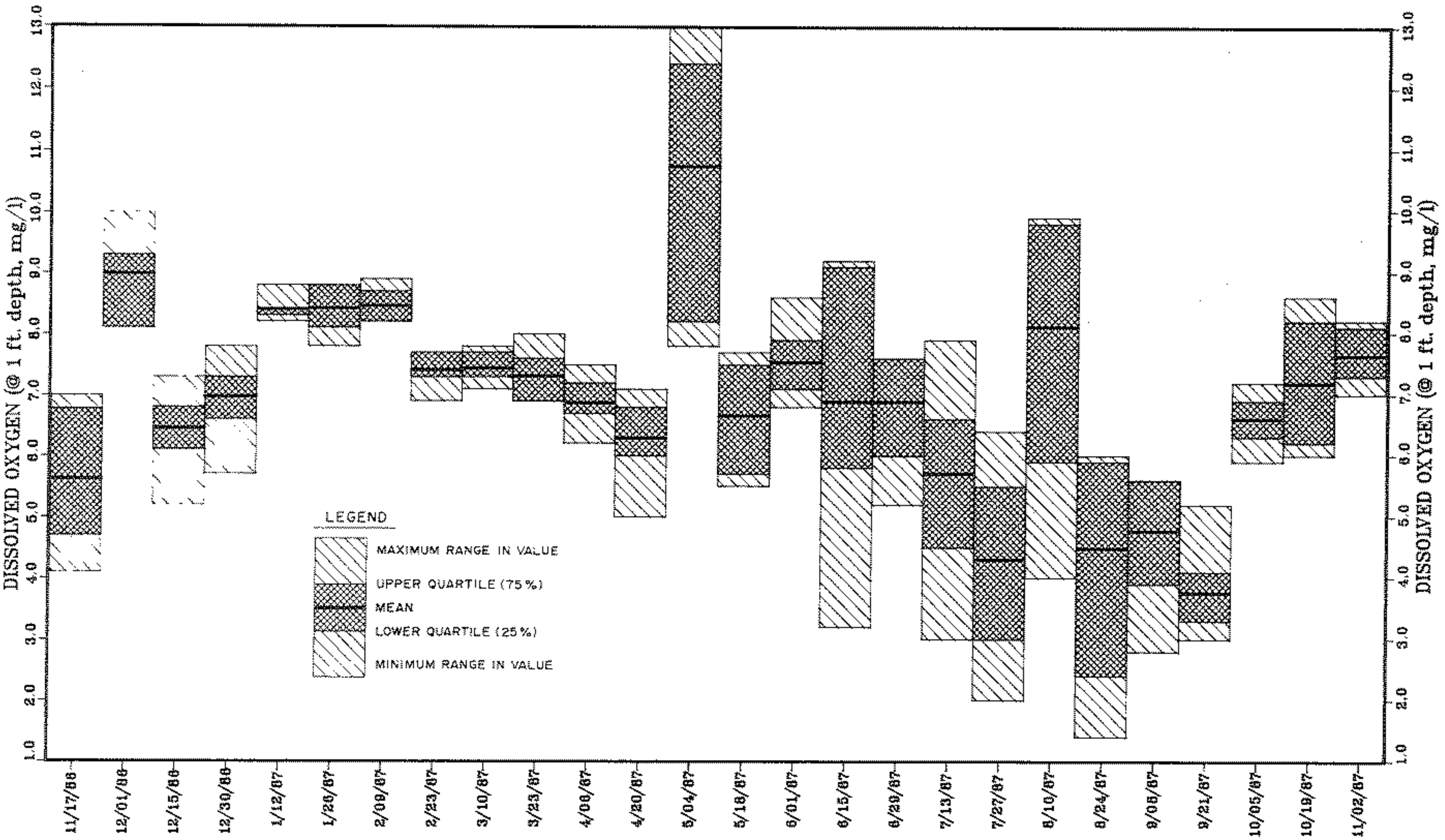


Figure 46. Statistical Summary of Dissolved Oxygen Data at One-Foot Depth for Lake Sampling Stations

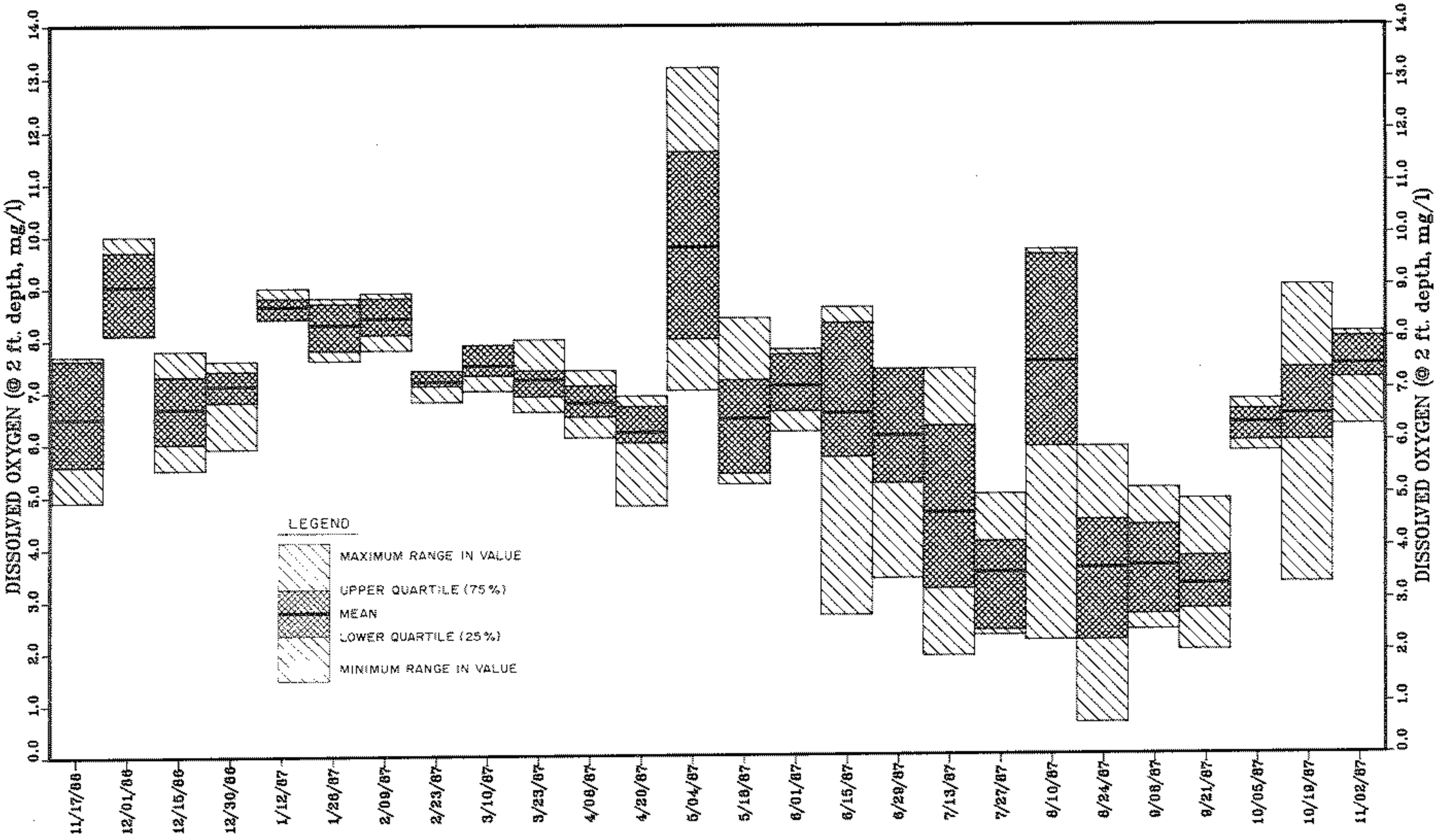


Figure 47. Statistical Summary of Dissolved Oxygen Data at Two-Foot Depth for Lake Sampling Stations

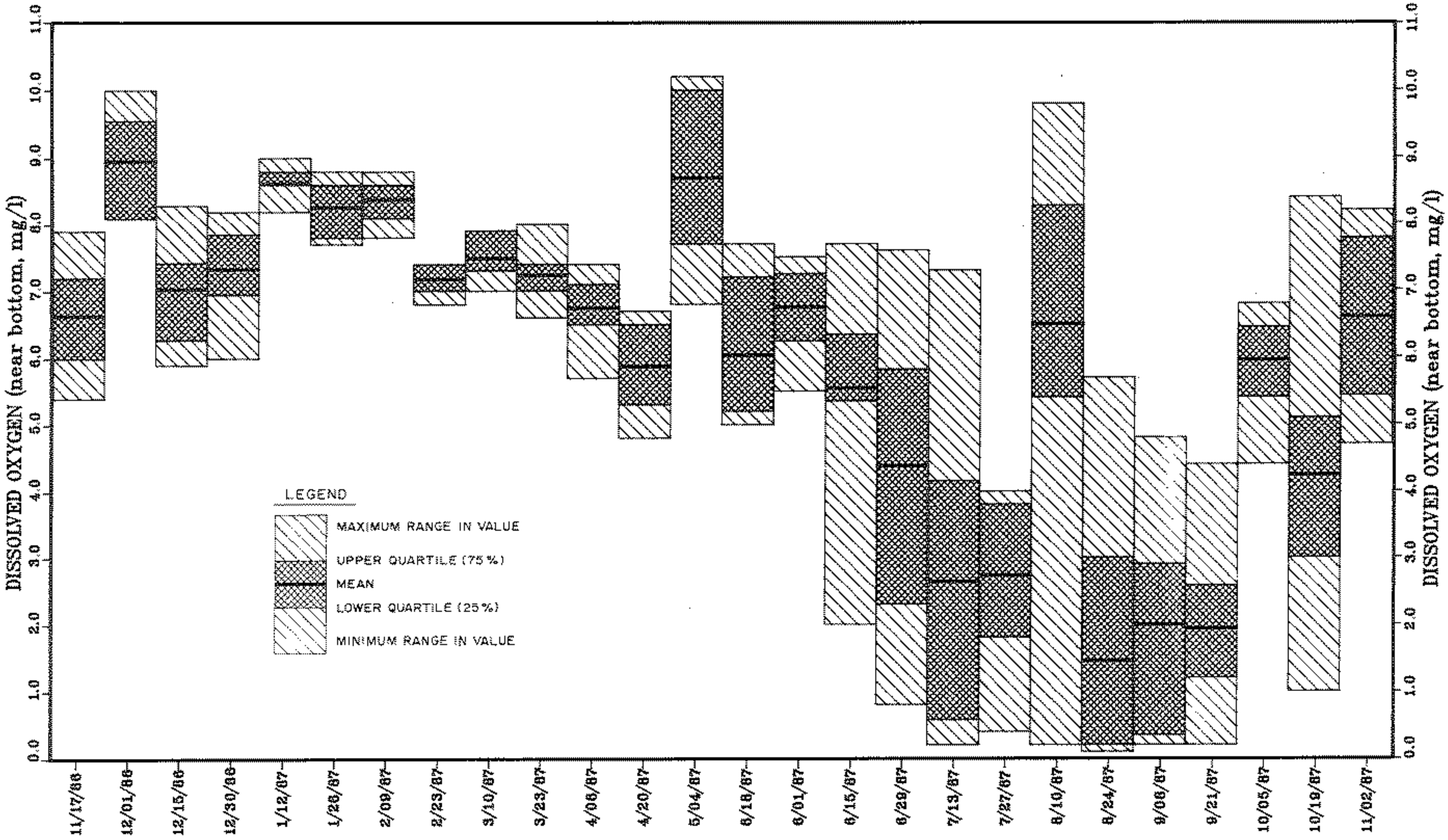
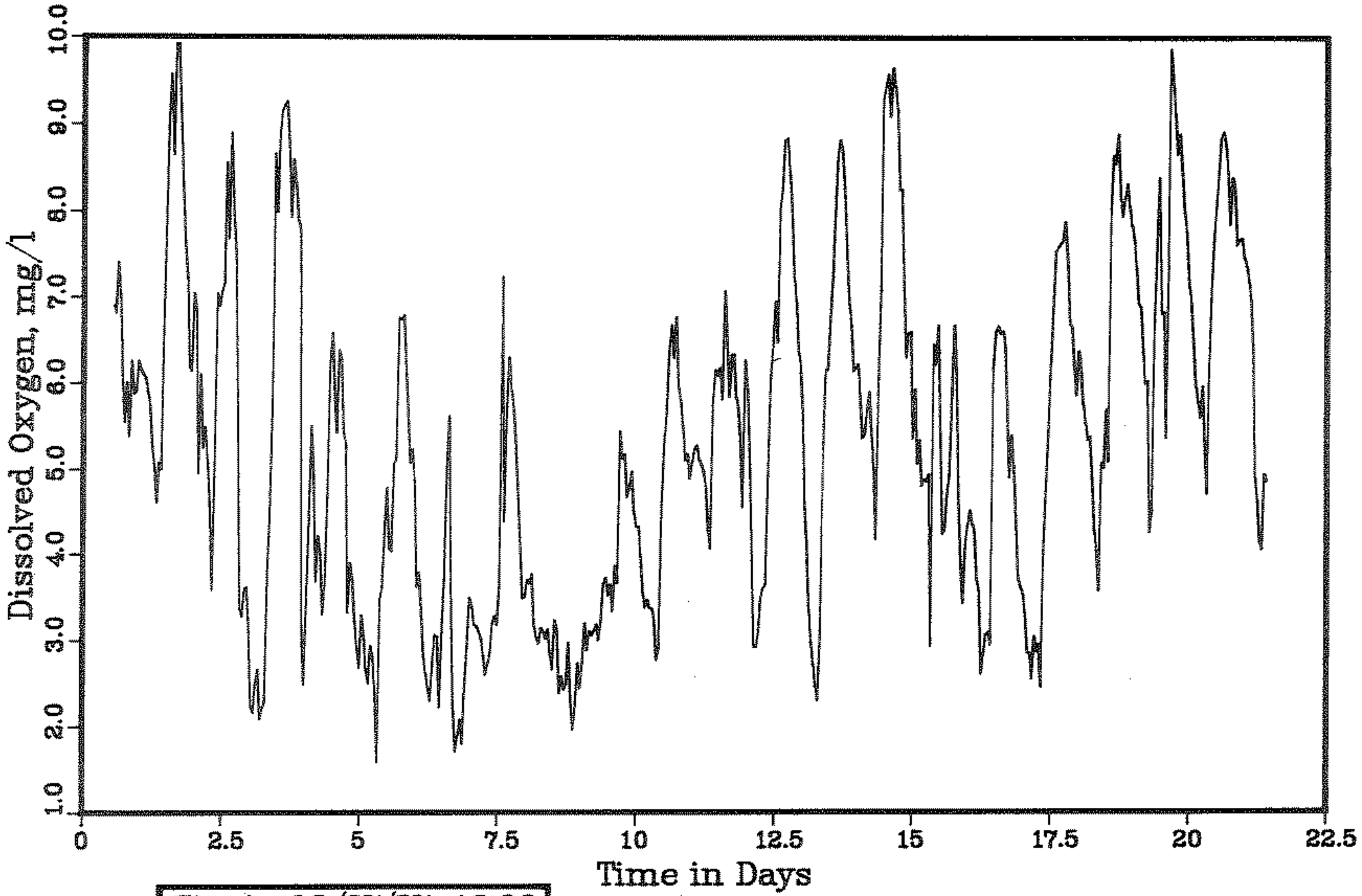


Figure 48. Statistical Summary of Near Bottom Dissolved Oxygen Data for Lake Sampling Stations



Start : 08/27/87 13:00
End : 09/17/87 10:00

Figure 49. Hourly Fluctuations of Dissolved Oxygen at One-Foot Depth

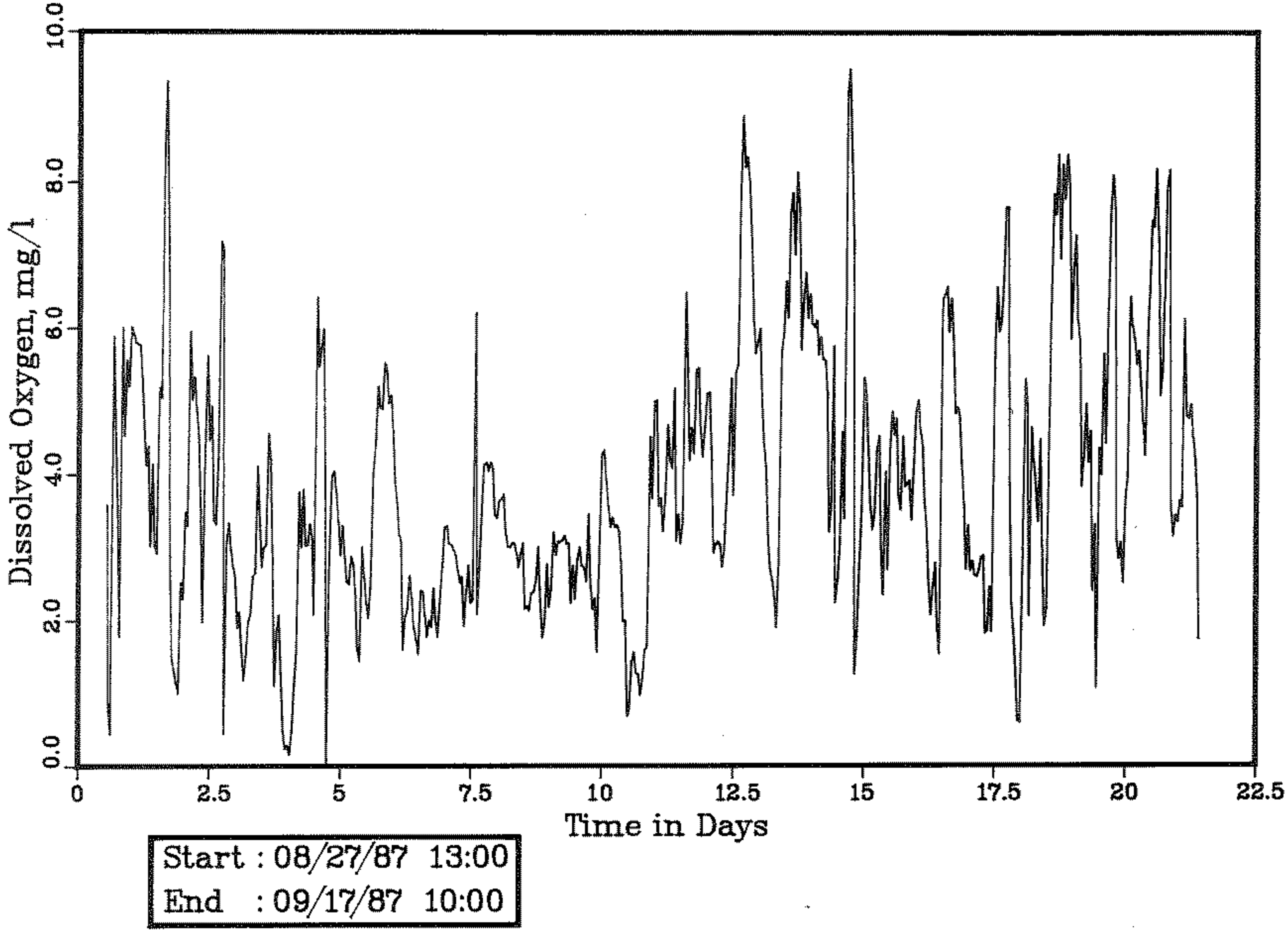


Figure 50. Hourly Fluctuations of Dissolved Oxygen at 2.5-Foot Depth

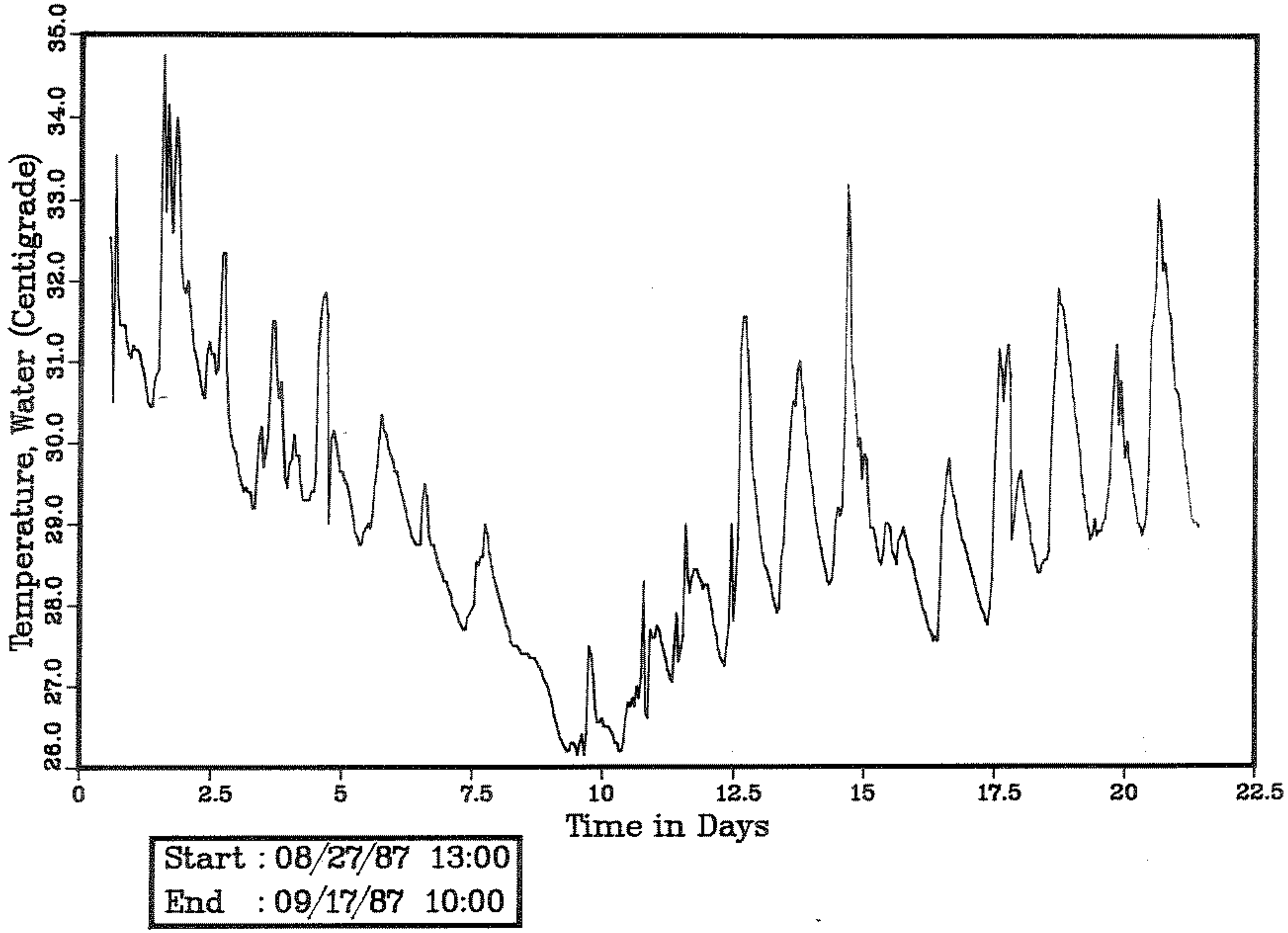


Figure 51. Hourly Fluctuations of Water Temperature at Mid-Depth

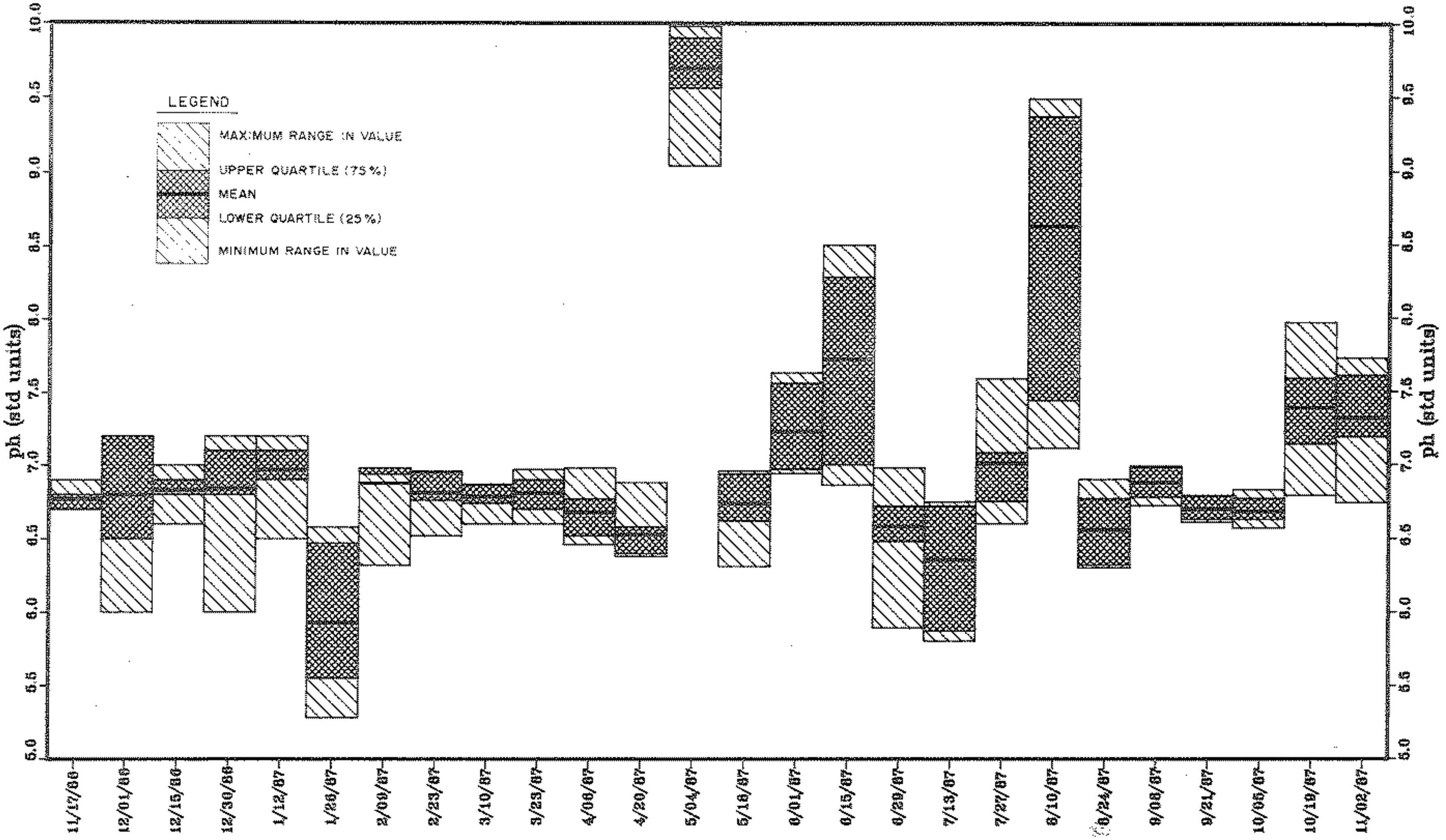


Figure 52. Statistical Summary of pH Data for Lake Sampling Stations

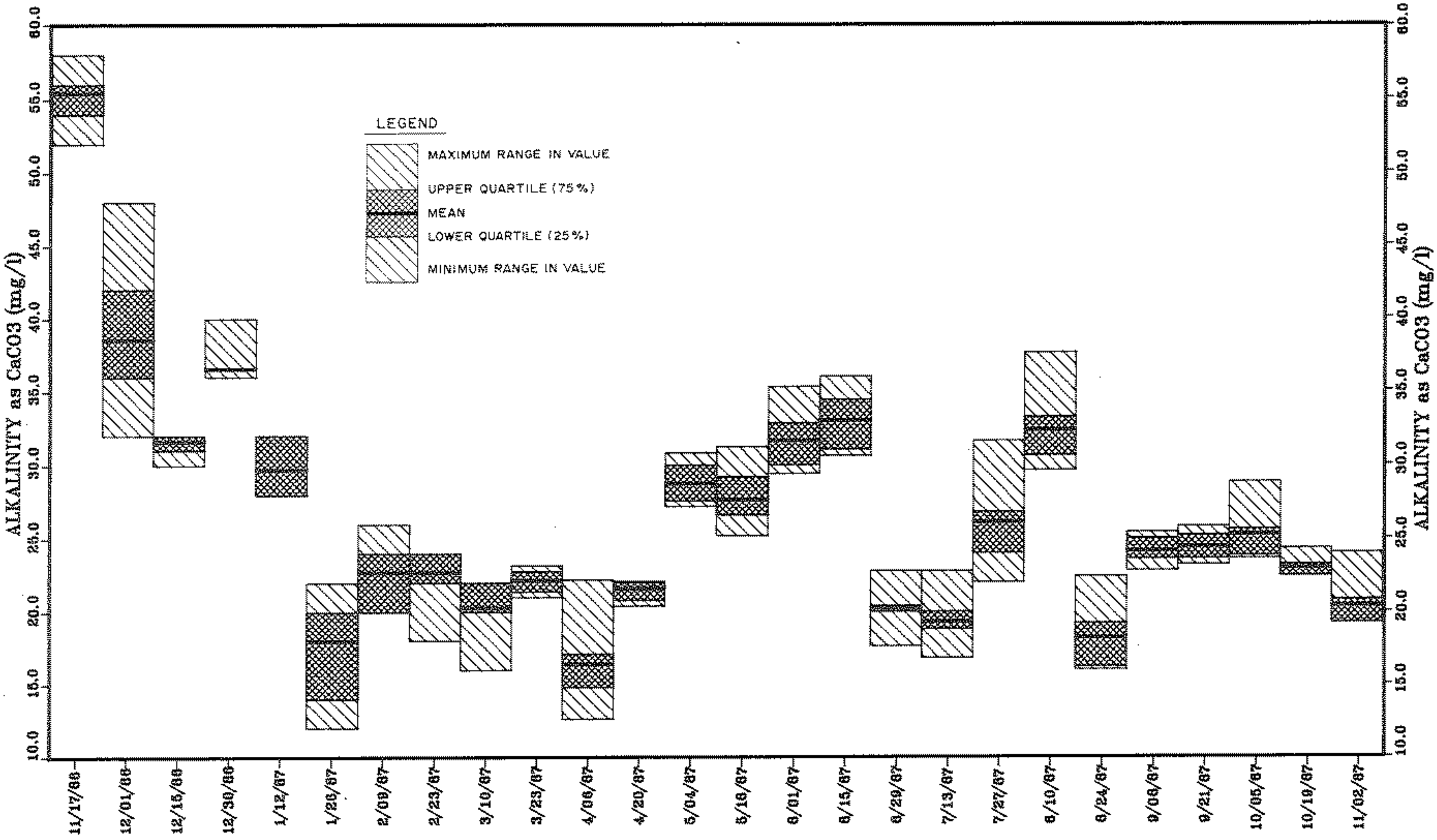


Figure 53. Statistical Summary of Alkalinity Data for Lake Sampling Stations

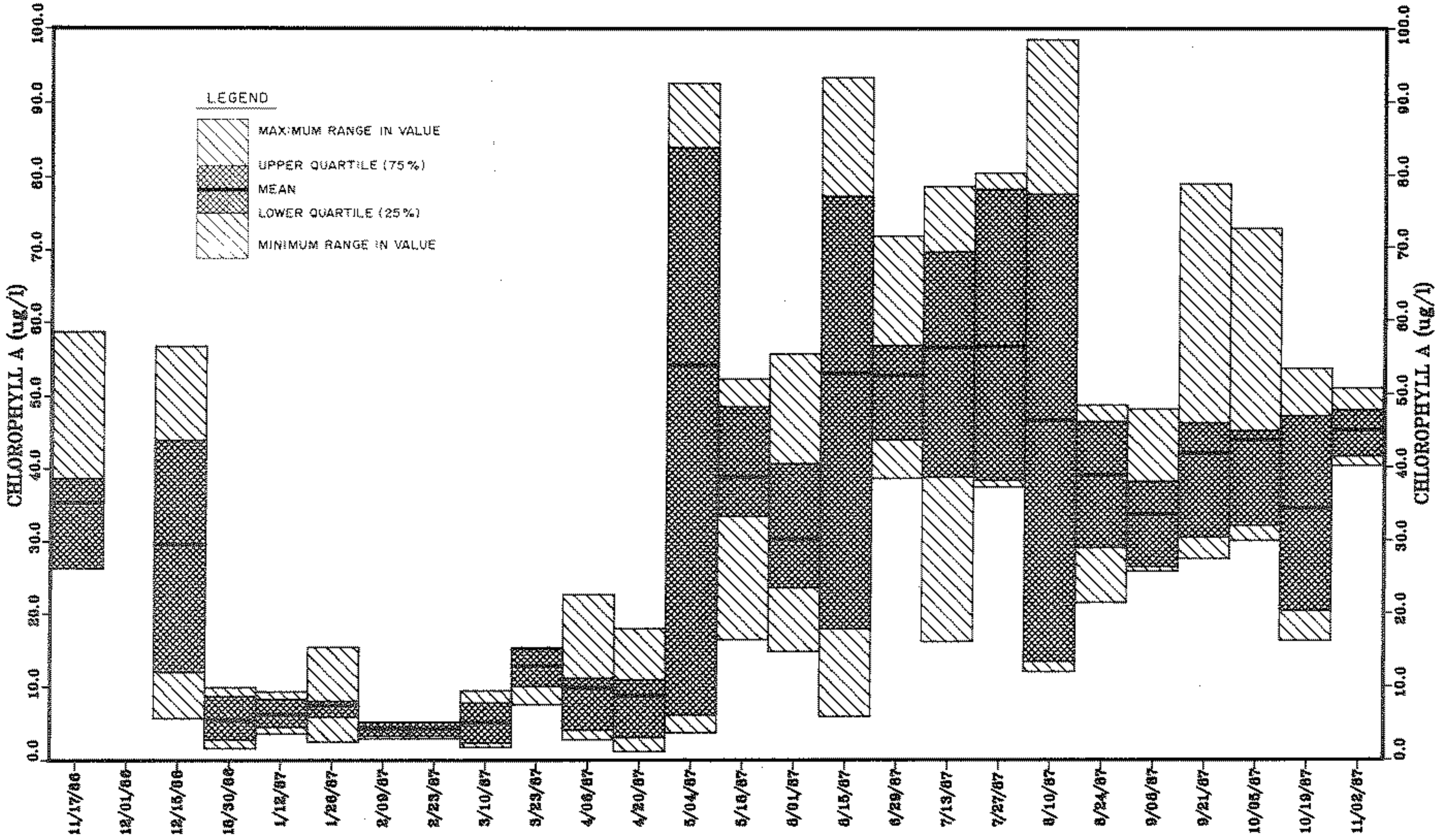


Figure 54. Statistical Summary of Chlorophyll_a Data for Lake Sampling Stations

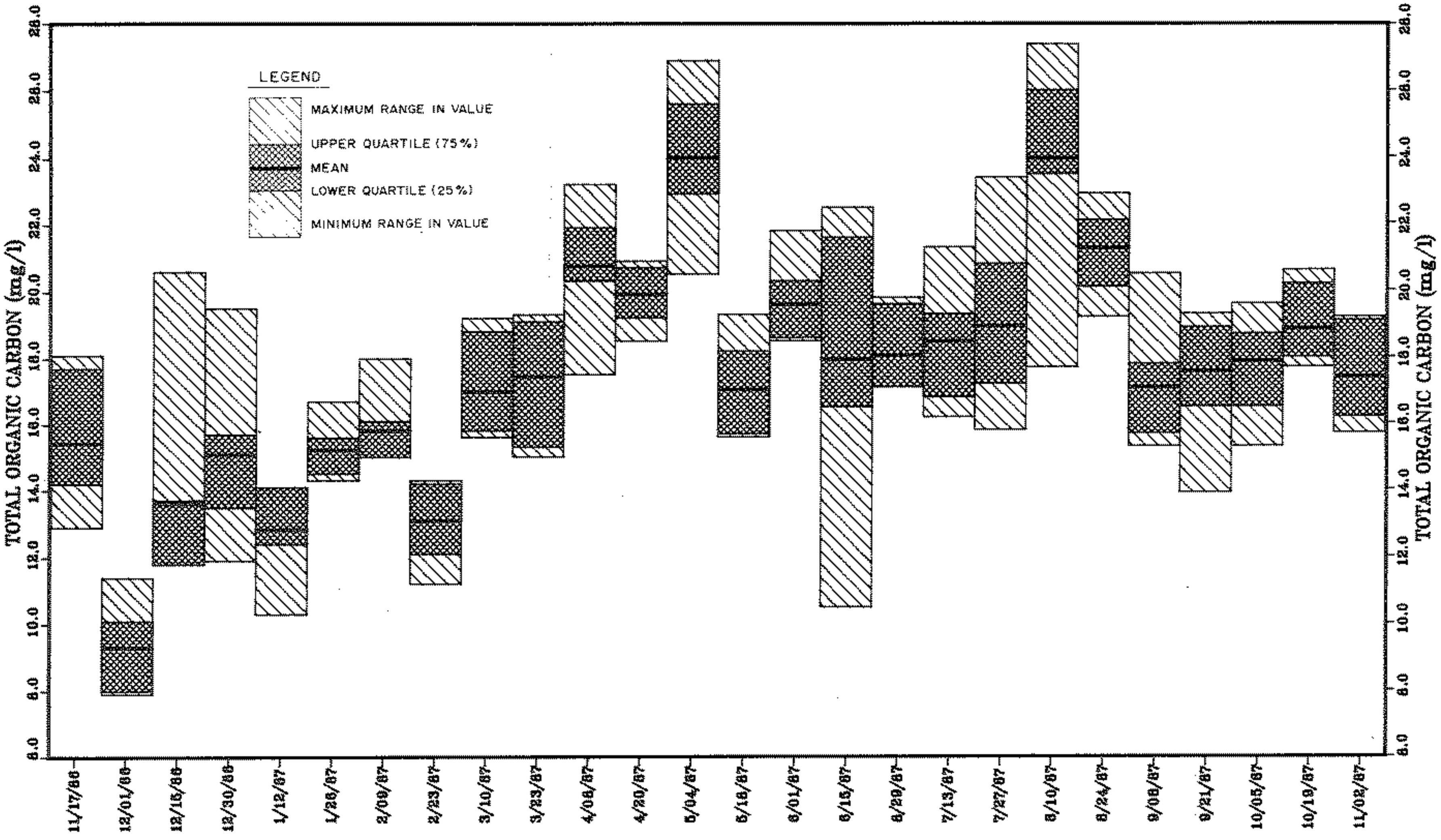


Figure 55. Statistical Summary of Total Organic Carbon Data for Lake Sampling Stations

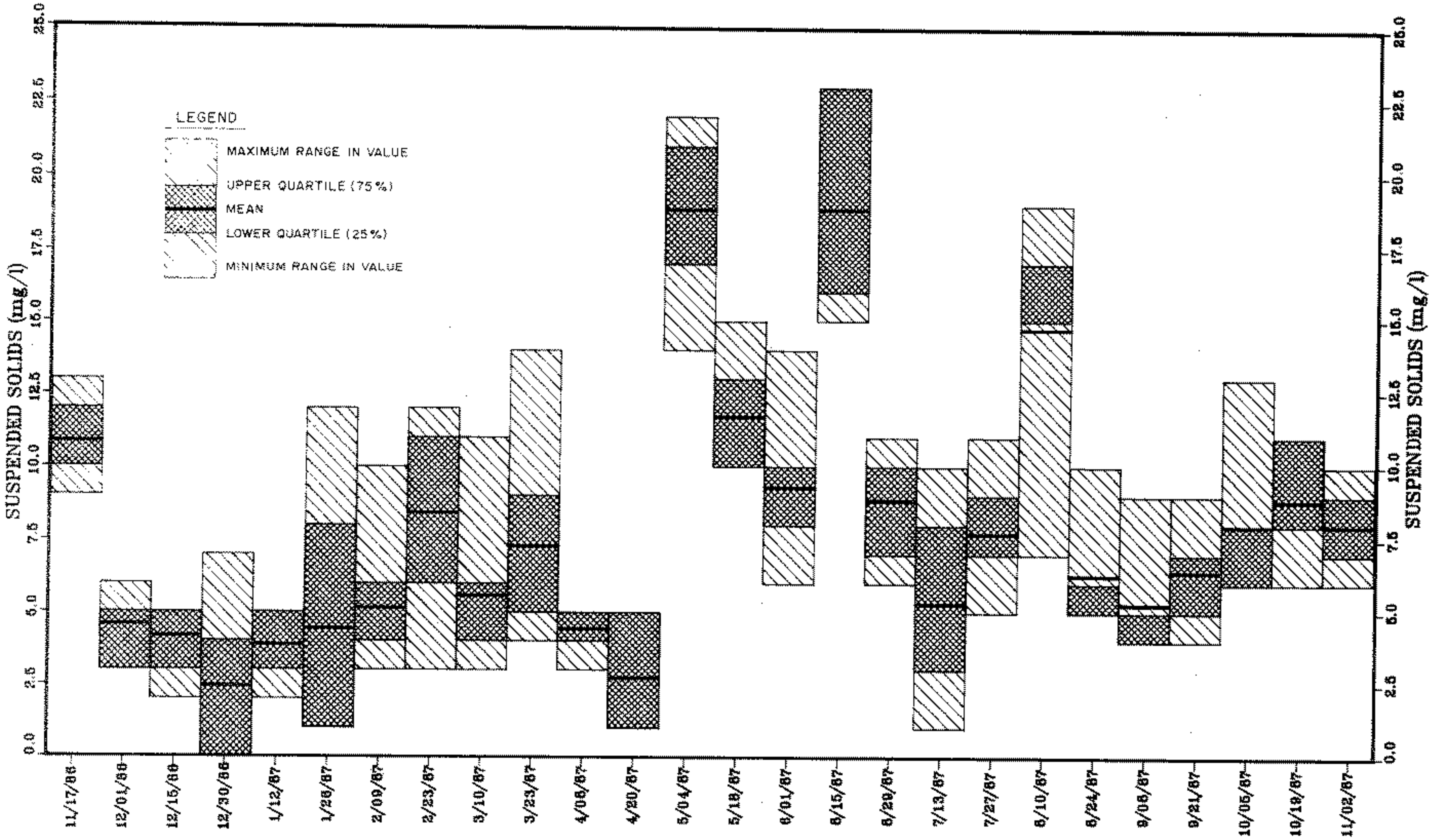


Figure 56. Statistical Summary of Suspended Solids Data for Lake Sampling Stations

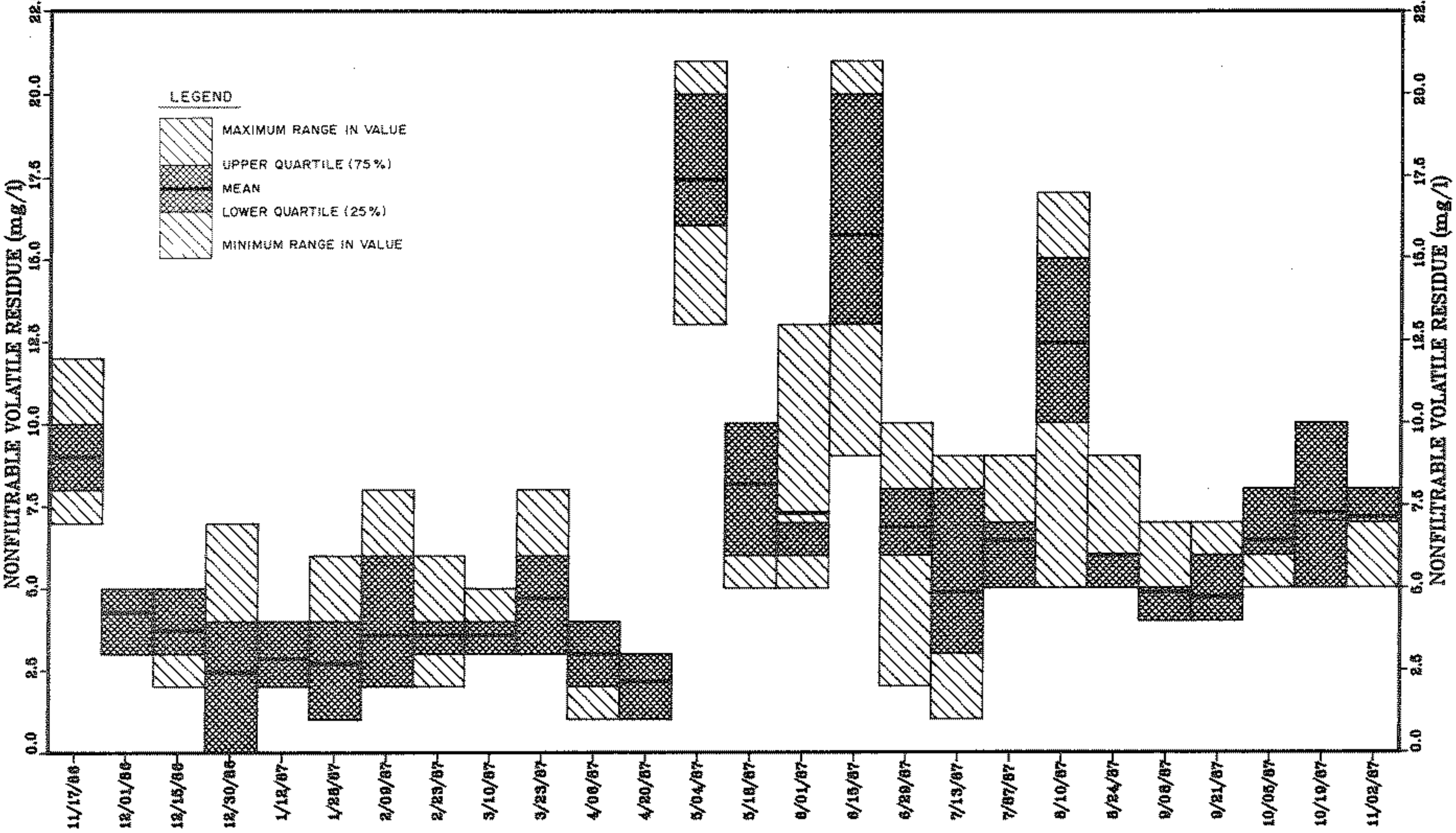


Figure 57. Statistical Summary of Nonfilterable Volatile Solids Data for Lake Sampling Stations

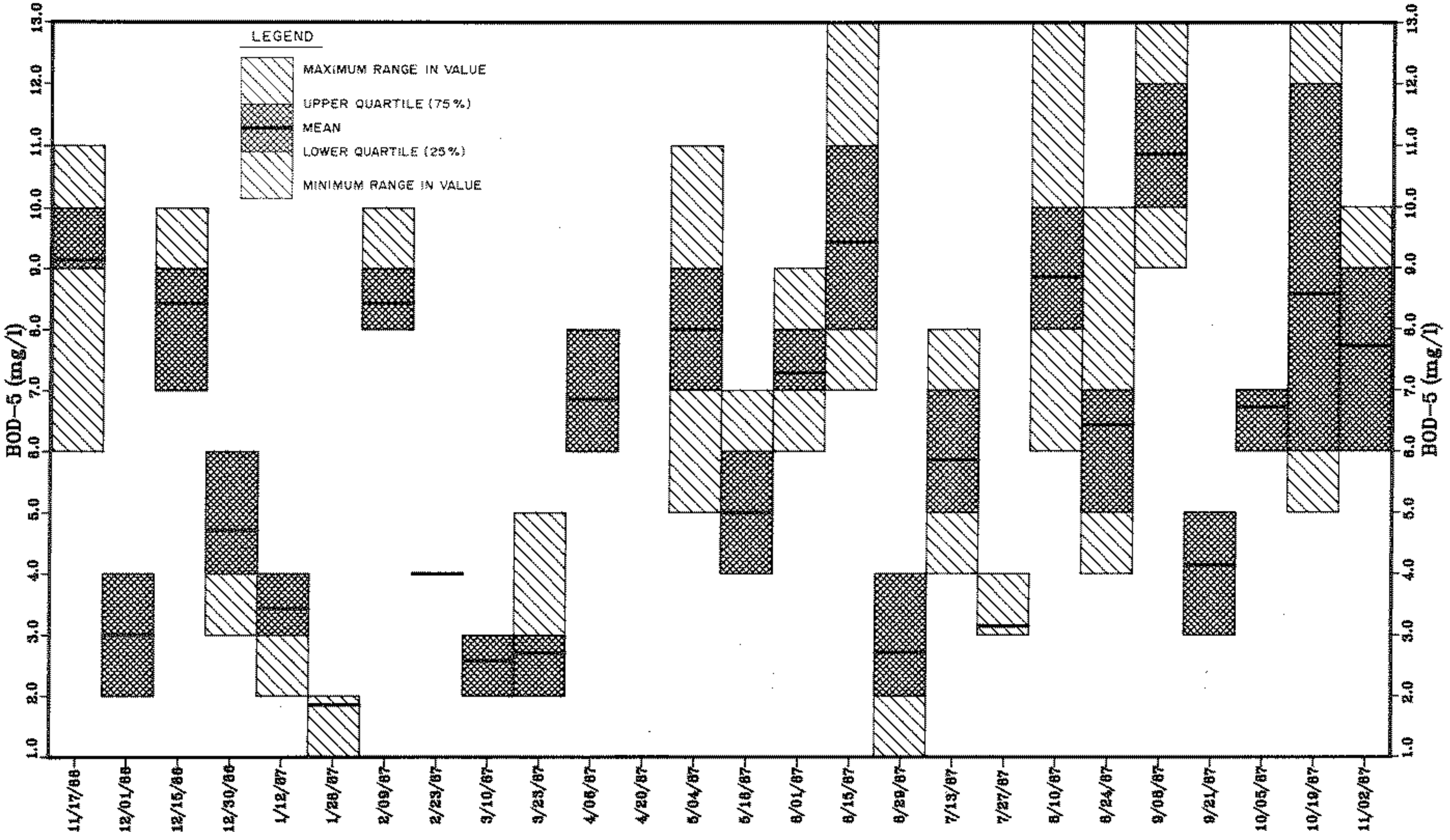


Figure 58. Statistical Summary of BOD-5 Data for Lake Sampling Stations

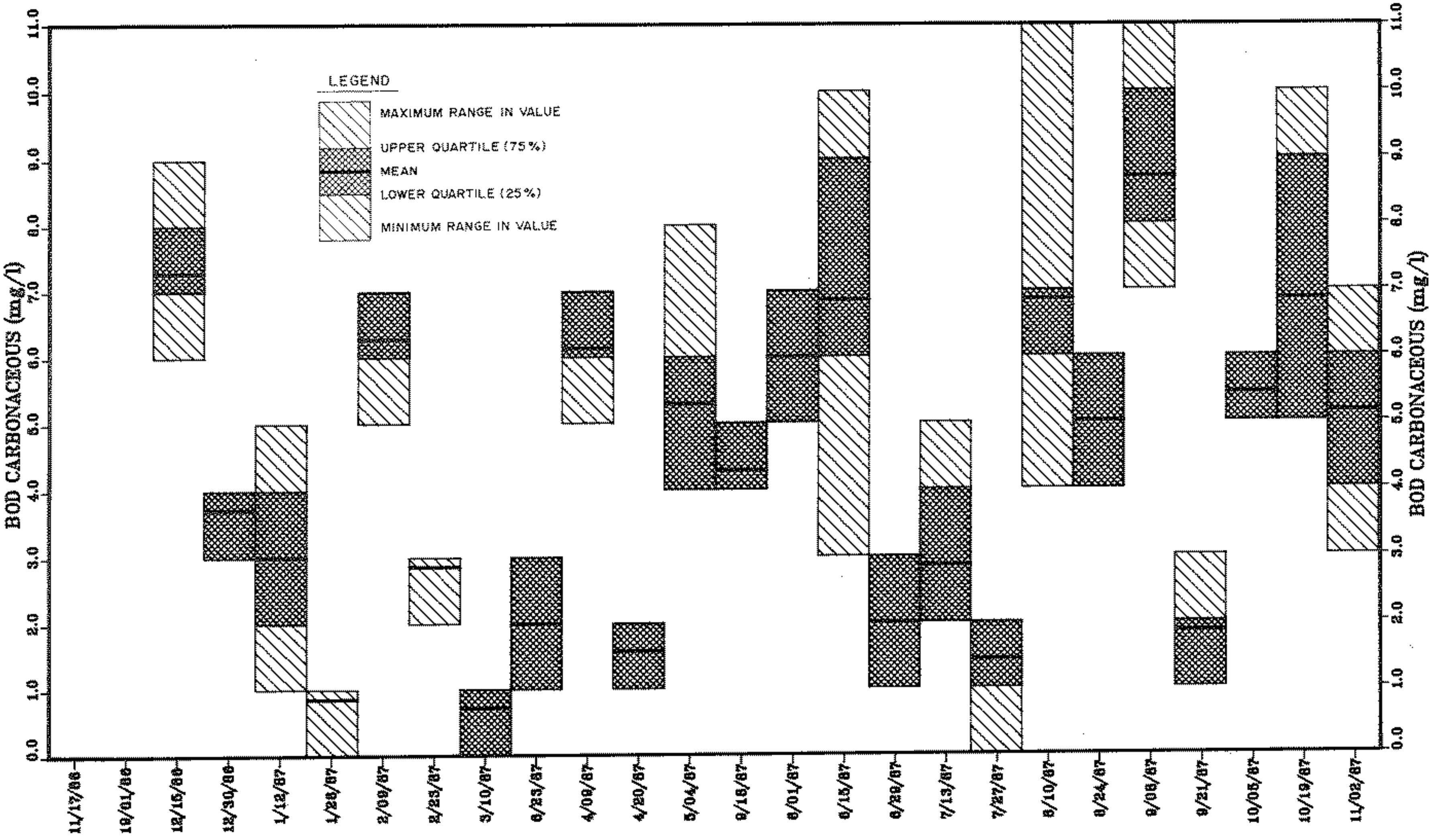


Figure 59. Statistical Summary of Carbonaceous BOD-5 Data for Lake Sampling Stations

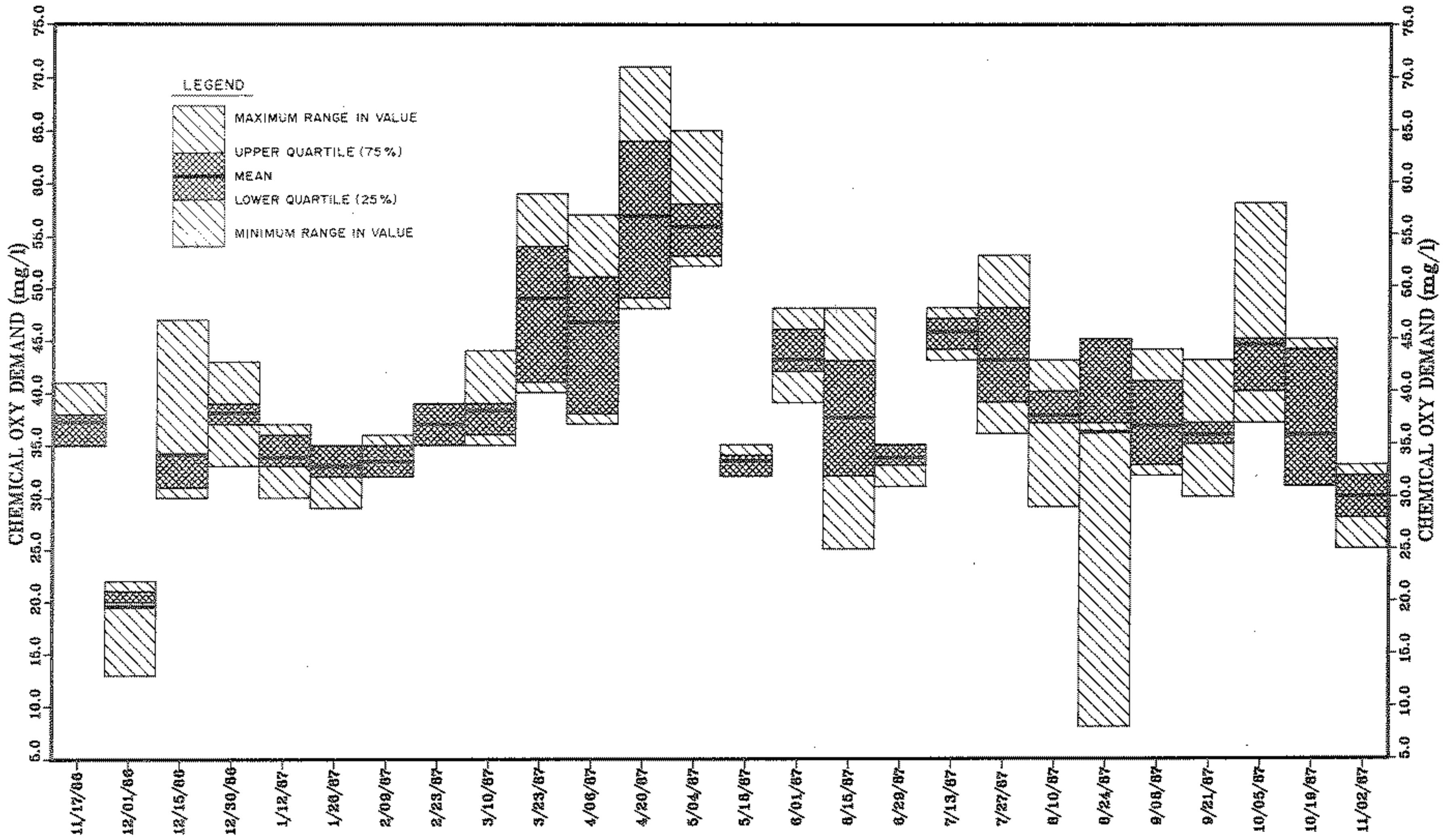


Figure 60. Statistical Summary of Chemical Oxygen Demand Data for Lake Sampling Stations

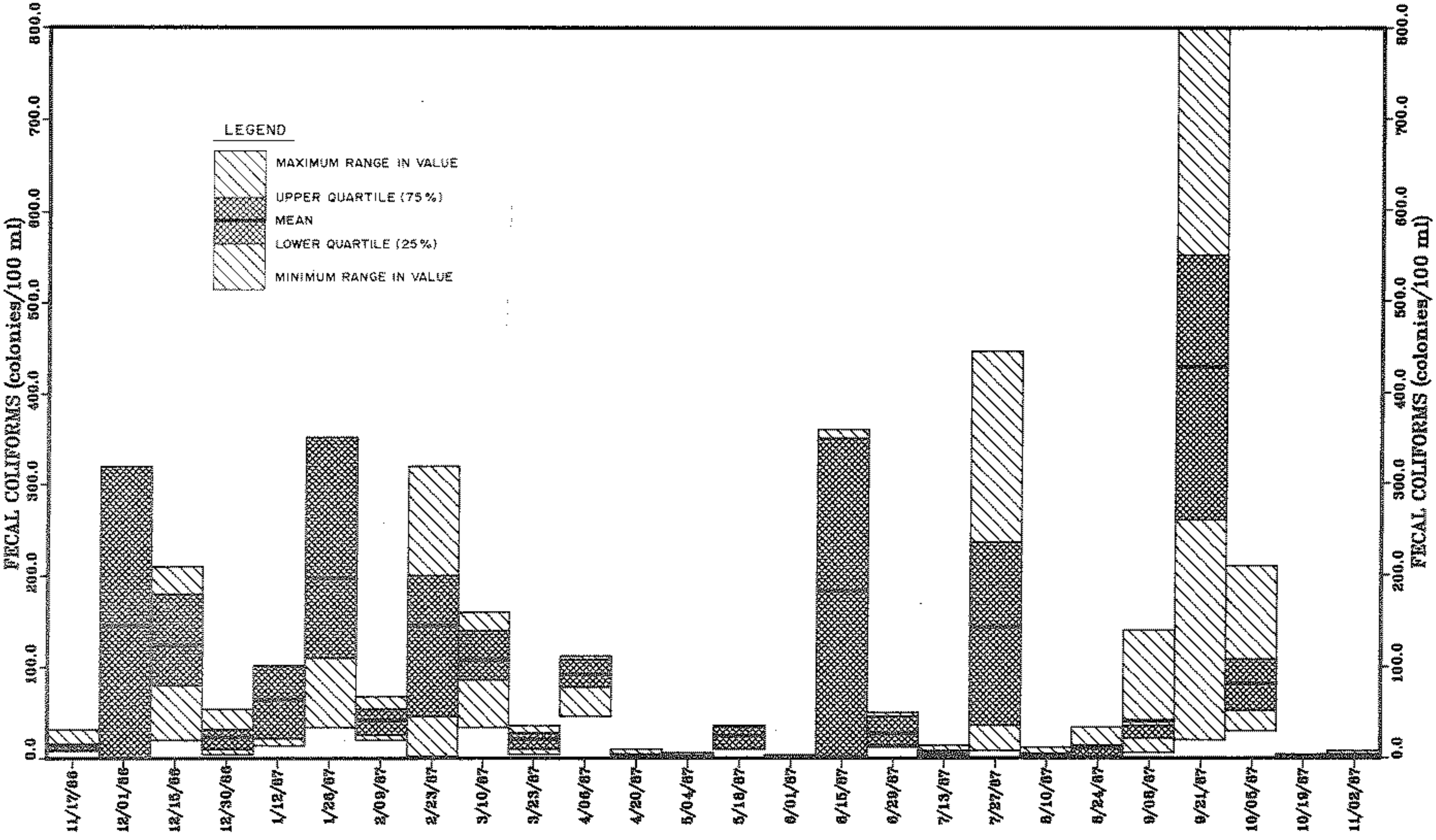


Figure 61. Statistical Summary of Fecal Coliform Bacteria Data for Lake Sampling Stations

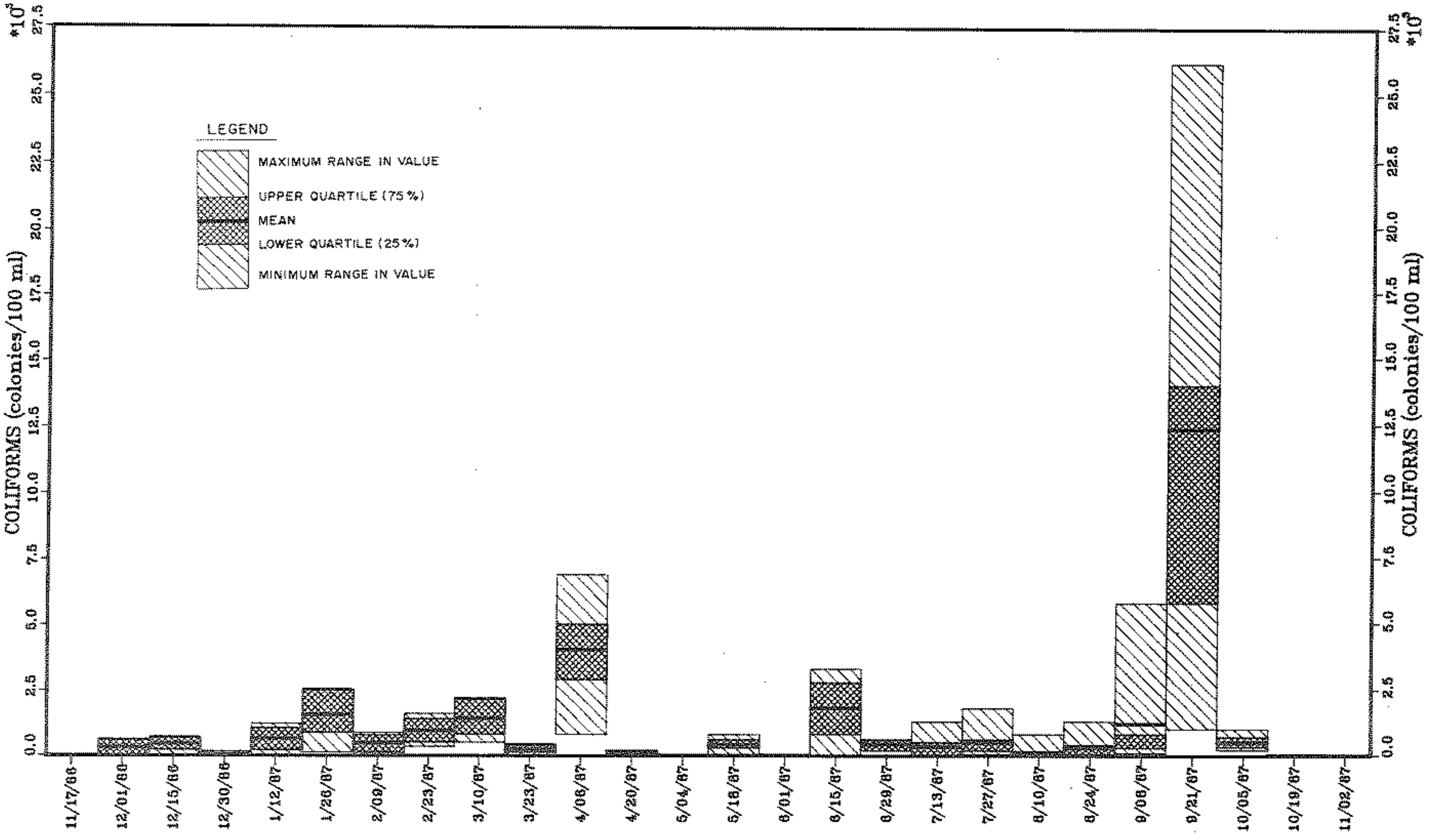


Figure 62. Statistical Summary of Total Coliform Bacteria Data for Lake Sampling Stations

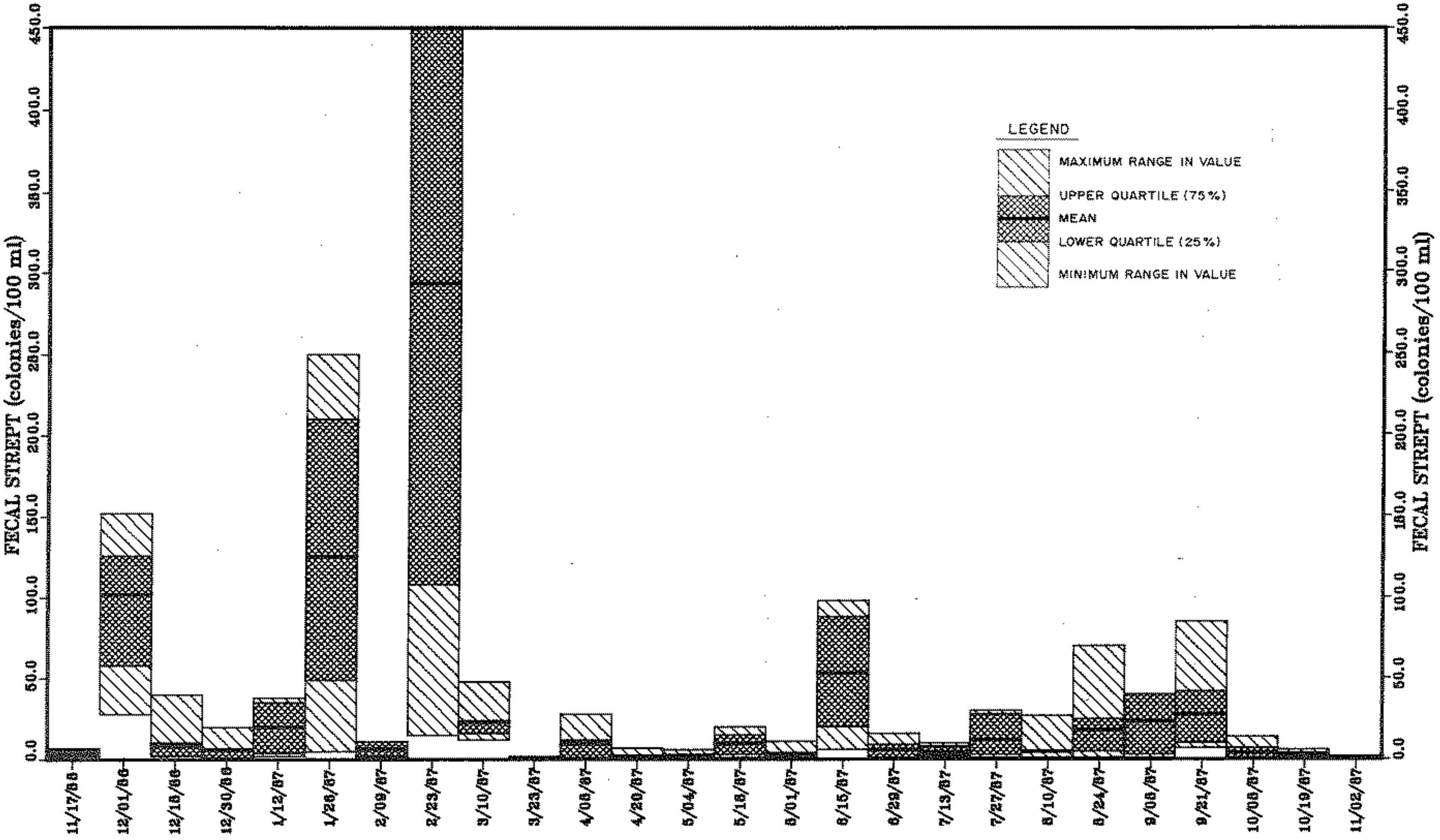


Figure 63. Statistical Summary of Fecal Streptococci Bacteria Data for Lake Sampling Stations

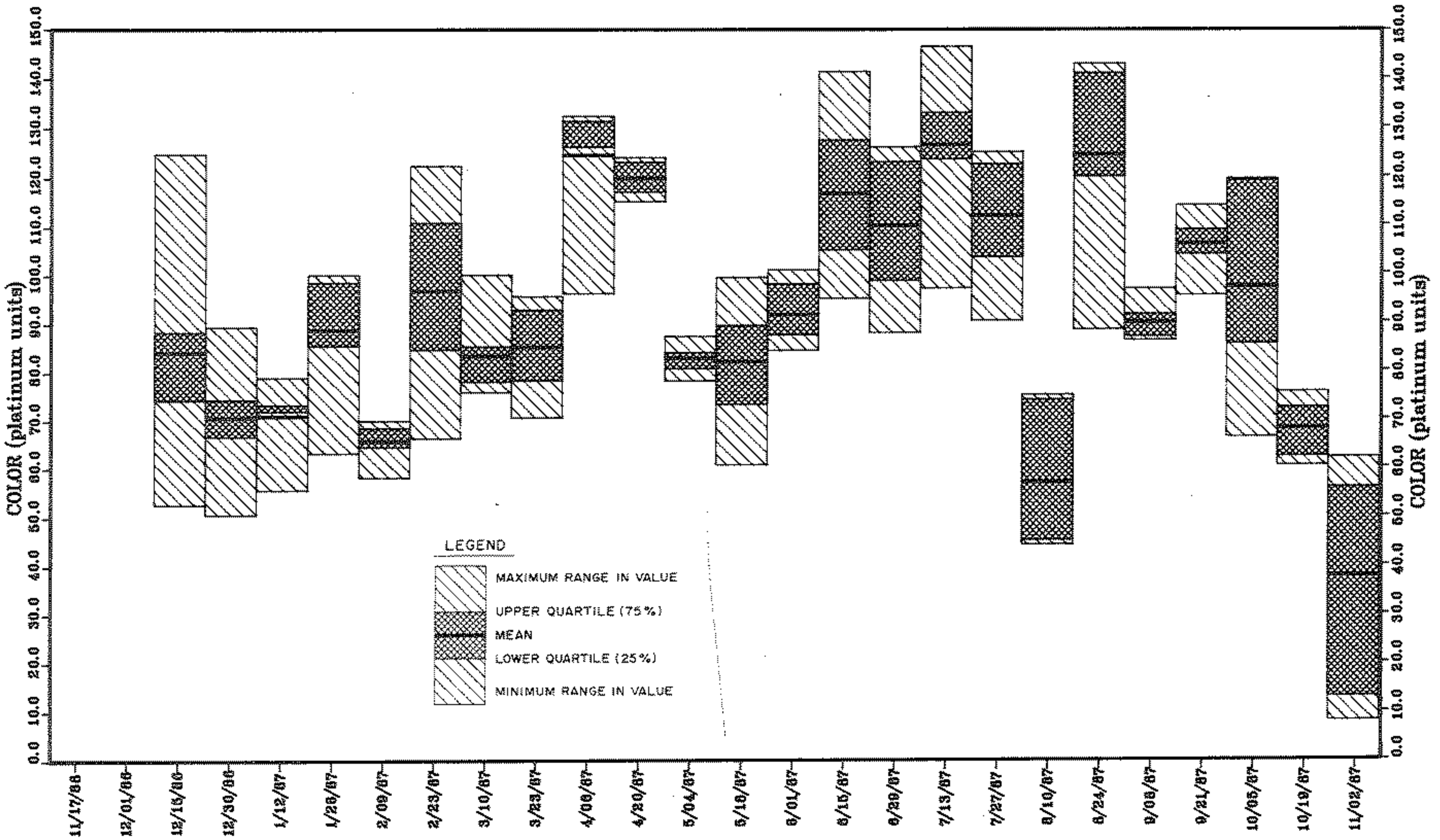


Figure 64. Statistical Summary of Color Data for Lake Sampling Stations

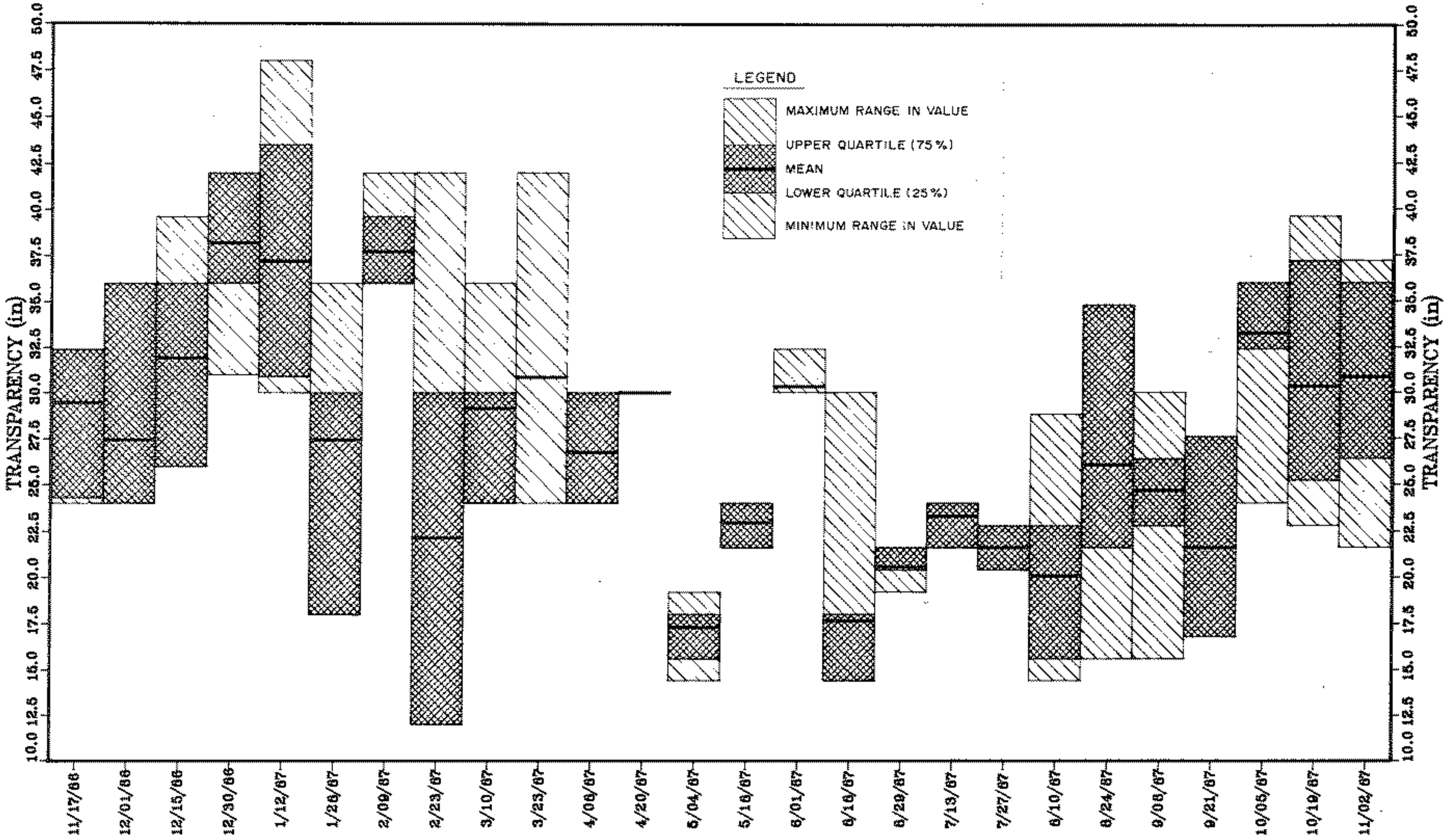


Figure 65. Statistical Summary of Secchi Depth Data for Lake Sampling Stations

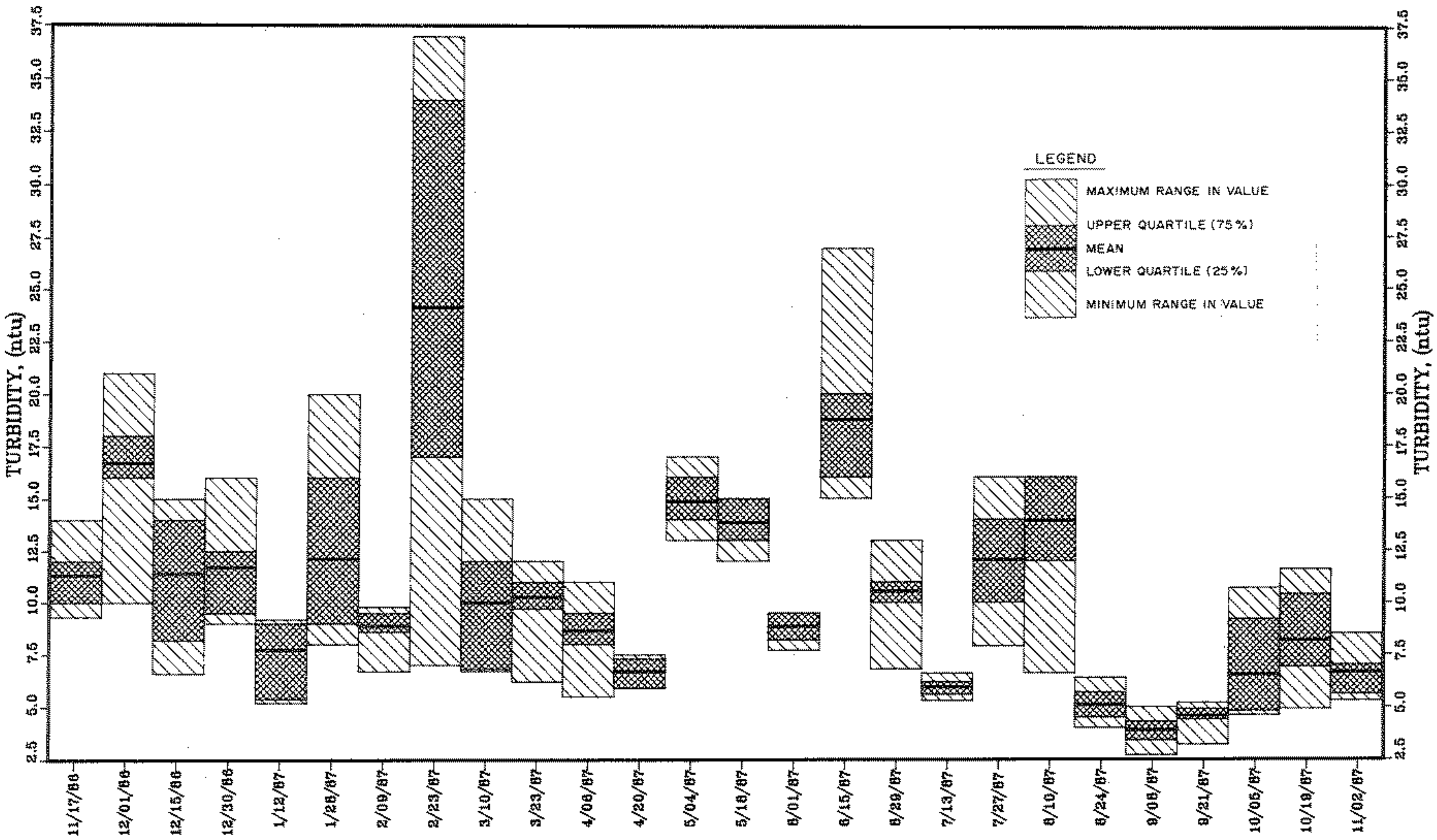


Figure 66. Statistical Summary of Turbidity Data for Lake Sampling Stations

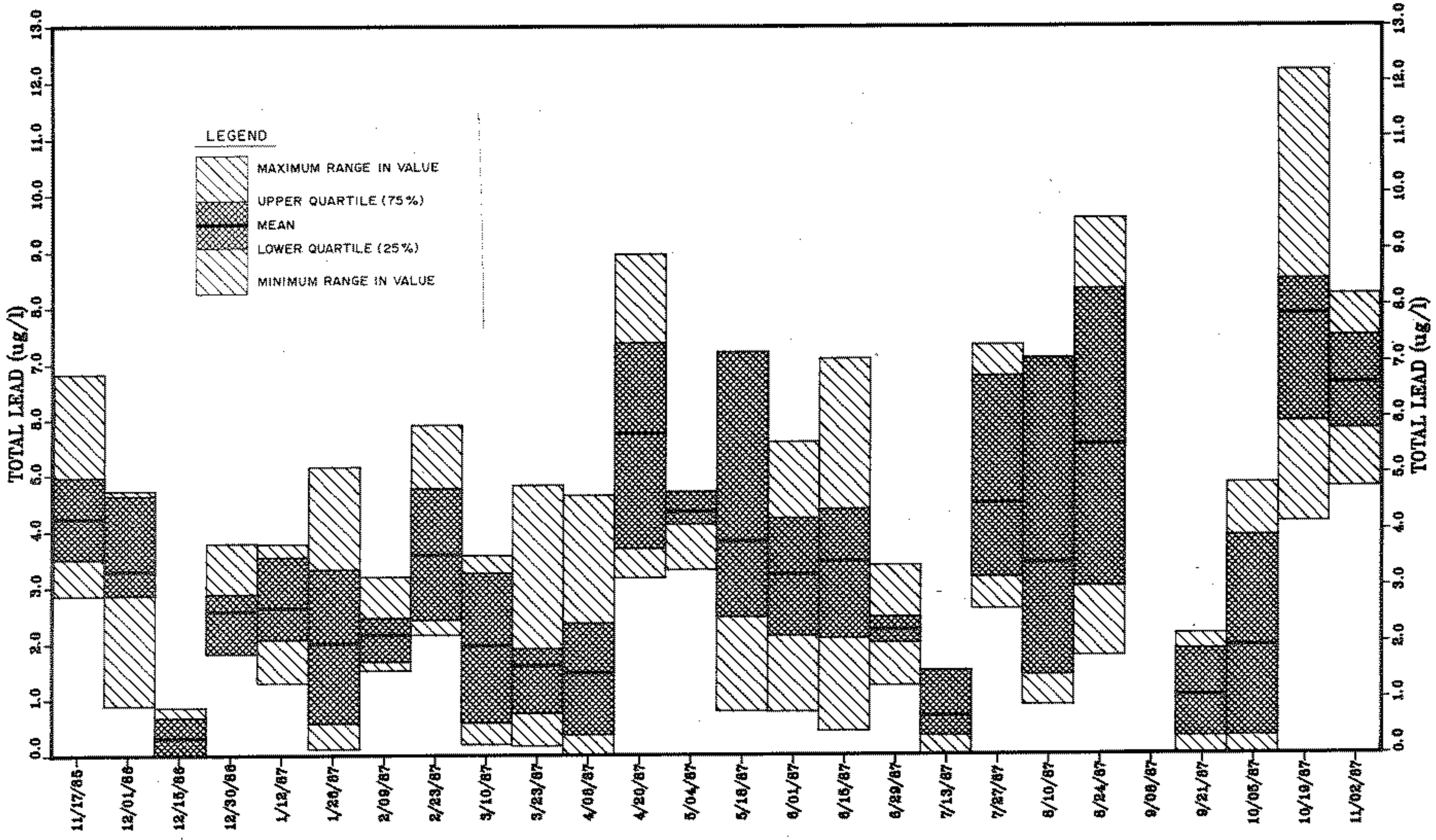


Figure 67. Statistical Summary of Total Lead Data for Lake Sampling Stations

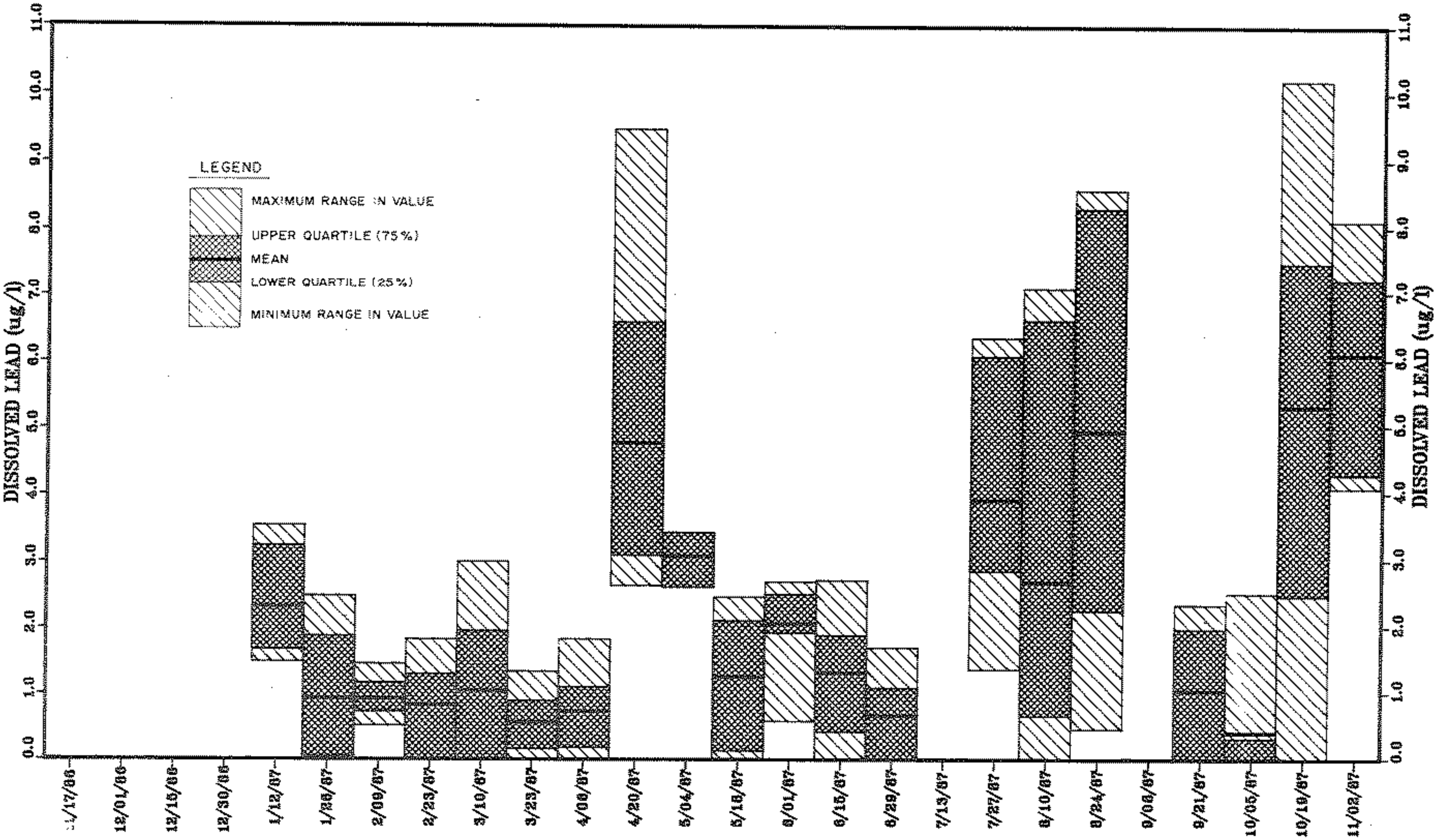


Figure 68. Statistical Summary of Dissolved Lead Data for Lake Sampling Stations

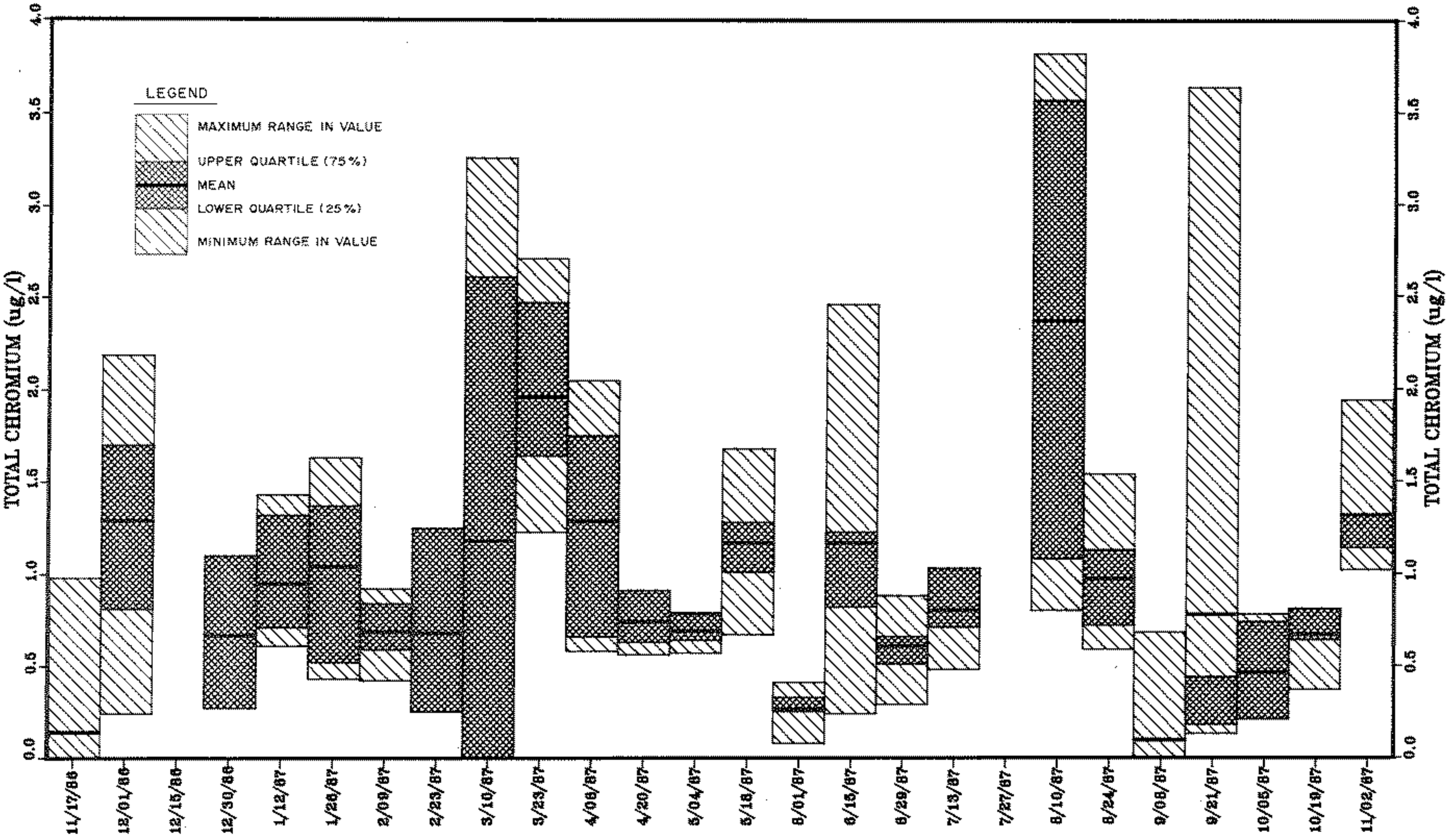


Figure 69. Statistical Summary of Total Chromium Data for Lake Sampling Stations

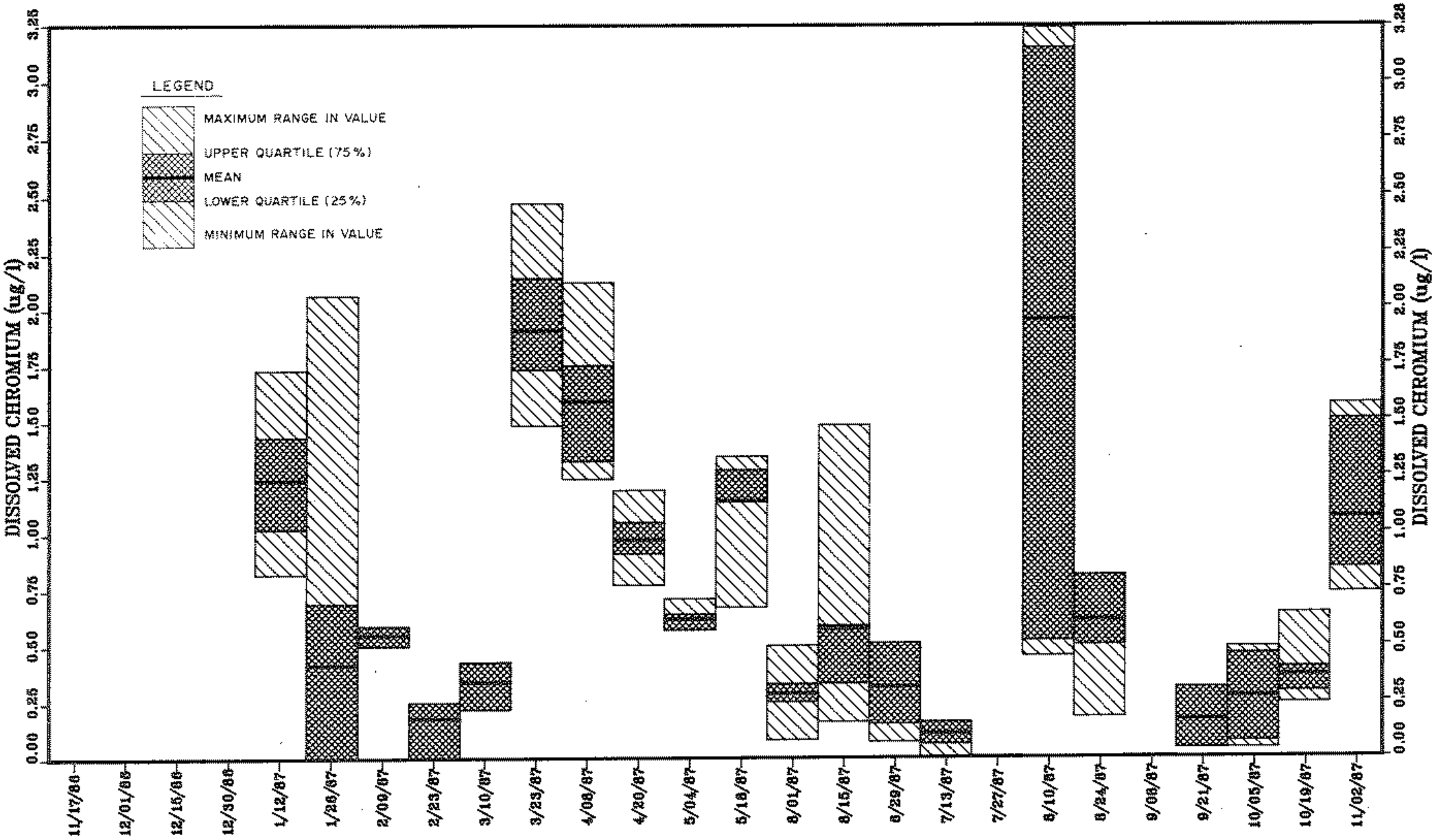


Figure 70. Statistical Summary of Dissolved Chromium Data for Lake Sampling Stations

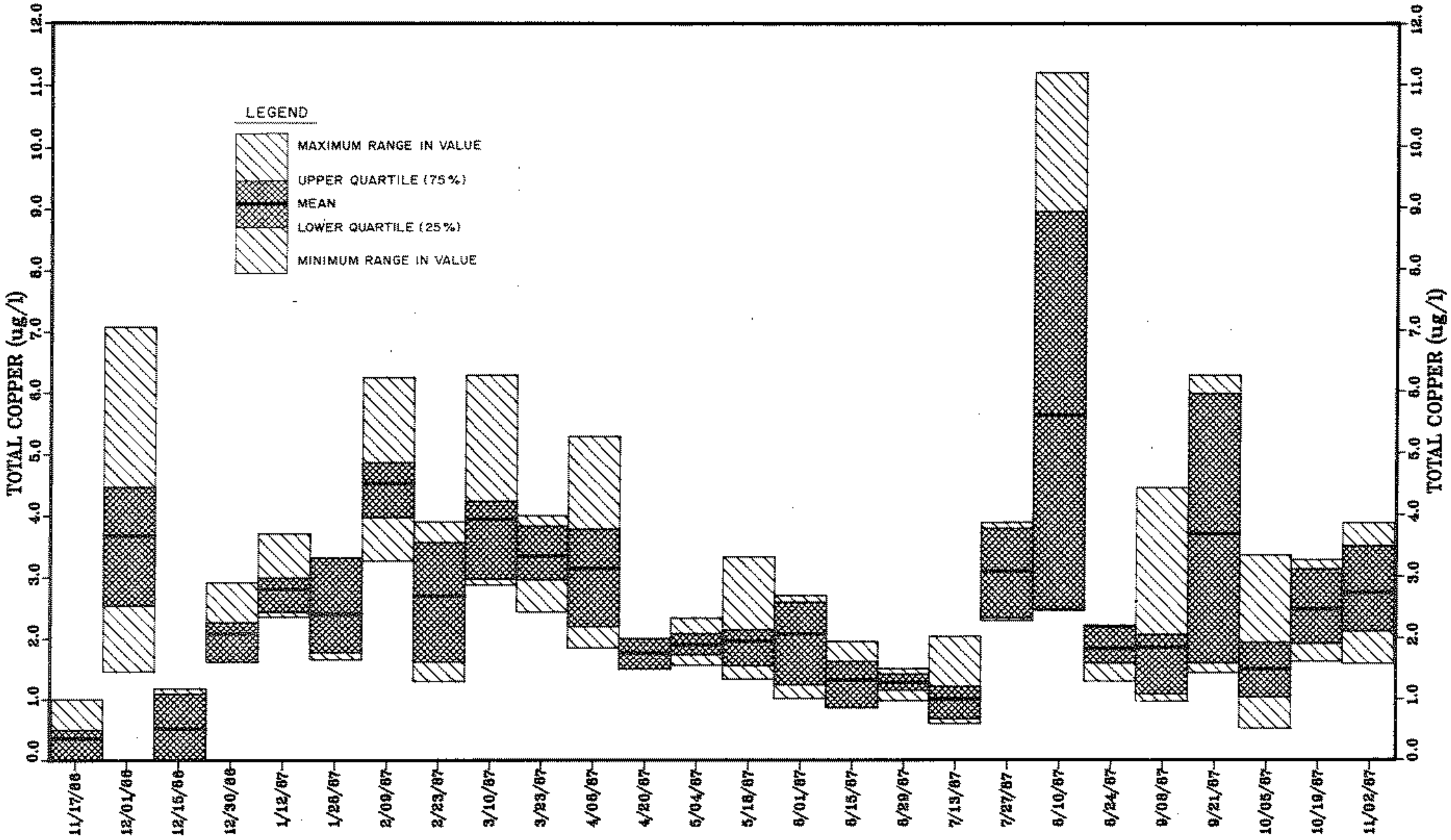


Figure 71. Statistical Summary of Total Copper Data for Lake Sampling Stations

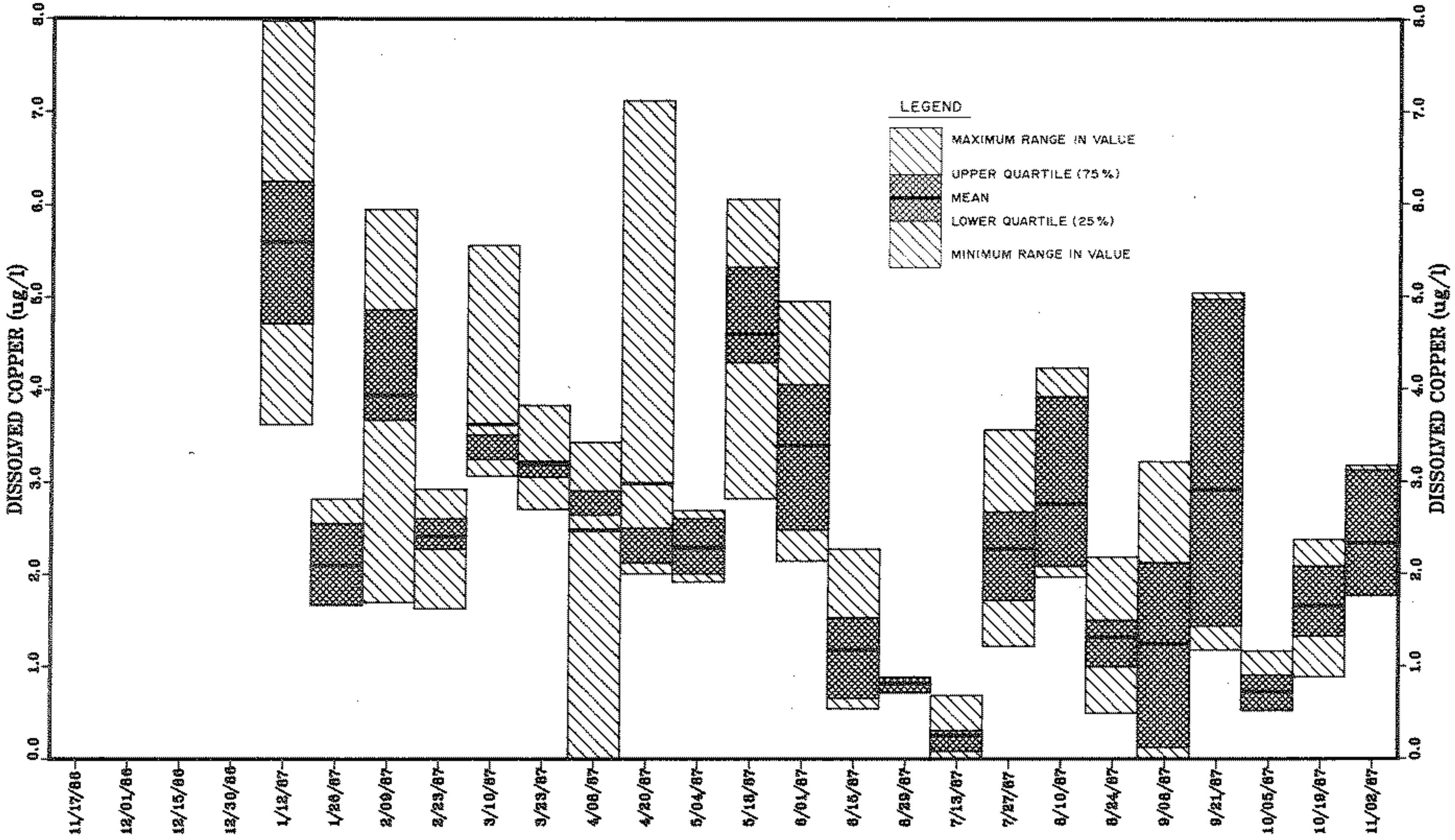


Figure 72. Statistical Summary of Dissolved Copper Data for Lake Sampling Stations

Examination of Figure 39 shows that the SIN:SRP ratio of Lake Munson was consistently below 2.5:1 during the entire data collection period, with near zero values observed on several sampling dates. Even total nitrogen to total phosphorus ratios showed average values below 10:1 during that one-year period (Figure 40). These data reflect an abundance of total phosphorus and orthophosphate relative to total nitrogen and nitrate, thereby suggesting that the lake is nitrogen limited. Lake Munson's nitrogen limitation status was further verified by algal growth potential and limiting nutrient assays conducted by the FDER from November 1986 to October 1987. Analyses of monthly lake samples for that period consistently showed nitrogen limitation on all sampling dates at all stations (FDER, 1988).

Biweekly fluctuations in the various forms of nitrogen and phosphorus during the one-year data collection period are given in Figures 31 through 38. Trends in orthophosphate and total phosphorus are shown in Figures 31 and 32, respectively. Levels of both phosphorus species showed a strong tendency to increase during the hot summer months and drop during the cold winter season. The exceptionally high phosphorus levels observed in November of 1986 apparently occurred due to unseasonally warm and dry weather conditions. Increases in phosphorus concentrations were generally marked by periods of high algal growth and elevated chlorophyll_a levels (Figure 54). High phosphorus levels were also associated with depressed oxygen conditions in the lake, particularly near the bottom (Figure 48). Such a strong relationship with bottom oxygen levels coupled with the abundance of orthophosphate during periods of no stormwater inflows (November 1986 and May 1987) clearly indicates that significant amounts of orthophosphate were released from bottom sediments during the warm summer months. This was also substantiated by the occurrence of higher average levels of orthophosphate in lake waters (0.15 mg/l) compared to average flow-weighted concentrations in stormwaters (0.10 mg/l). In spite of the recycling of phosphorus within the lake, however, the sediments were a net sink for phosphorus, as indicated by the lake's ability to retain 64 percent of the incoming phosphorus load (see section on Lake's pollutant retention capacity).

In regard to nitrogen cycling within Lake Munson, the most significant trend was the tendency for nitrate concentrations (Figure 36) to drop substantially in the summer, and in some instances become completely depleted, in response to high algal growth rates. Favorable conditions for denitrification in the bottom sediments were apparent. Higher average concentrations of nitrate in the stormwaters (0.10 mg/l) than in the lake (0.04 mg/l) also suggest that nitrate was consumed at a faster rate than it was produced. This was particularly the case both during the summer and in the algal bloom that occurred in November 1986. At those times, nitrate levels were very low and ammonia levels relatively high (Figure 37), apparently indicating that the process of nitrification was inhibited, most likely as a result of depressed dissolved oxygen levels over time and depth. The highest levels of nitrate were observed immediately following the decline in algal abundance from December, 1986 through January, 1987. This was likely due to a combination of higher oxygen levels and reduced algal growth rates, conditions which favor nitrate production (nitrification) over consumption.

The predominant form of nitrogen present in lake waters was organic. This is reflected in the high concentrations of total kjeldahl nitrogen (TKN, Figure 34) relative to the other species. This was also the case in stormwaters. Average concentrations of TKN in lake and stormwaters were 0.84 mg/l and 1.18 mg/l, respectively. The higher levels of TKN in stormwaters indicates that the lake system serves as a net sink for organic nitrogen. This explains the accumulation of organic sediments in the lake bottom.

Temperature, Dissolved Oxygen, pH, and Alkalinity

Aside from stormwater inputs of the major nutrients, a major driving force for algal growth in the lake was related to lake water temperature. Contingent upon the availability of nutrients, seasonal increases in lake water temperature are associated with significantly higher levels of biochemical and photosynthetic activity. From Figure 41, for example, it is apparent that increases in water temperature during the summer season closely paralleled the higher concentrations in TKN (Figure 34), the decrease in dissolved oxygen (DO, Figures 45 through 48), and the peaks in chlorophyll_a (Figure 54) and total organic carbon (Figure 55). The lower DO concentrations resulted from the high oxygen uptake rate brought about by the combination of increased temperatures and an abundant supply of nutrients.

In order to evaluate diurnal fluctuations in dissolved oxygen (DO) and and lake water temperature, an automated DO monitoring station (mini-monitor site, Figure 4) was installed in the lake during late summer. DO probes were set near the water surface and lake bottom, and a temperature probe was set at mid-depth. The mini-monitor was programmed to record data on an hourly basis during the three-week period from August 27 to September 17, 1987. The resulting data (Figures 49 through 51) clearly show a strong diurnal cycle in DO due to the processes of photosynthesis and respiration. This cycle produced radical fluctuations in DO, with supersaturated conditions observed in the afternoon and depleted conditions late at night. DO depressions were more severe near the lake bottom than near the water surface due to oxygen uptake from the sediments. The lack of DO daily peaks at about eight days into the test reflects lower levels of photosynthetic activity during a rainy period with intense cloud cover and lower air and water temperatures. Comparing fluctuations in DO and water temperature, it is apparent that diurnal peaks in water temperature coincide with peaks in DO as a result of photosynthetic activity.

For the entire data collection period from November 17, 1986 to November 2, 1987, waters closer to the surface generally remained more oxygenated and experienced less DO variability than deeper waters (Figures 45 through 48). The highest DO was observed in May when photosynthetic activity was high and water temperatures were relatively cool. The low DO near the surface in November 1986 was probably due to high concentrations of oxidizable material floating on the surface. At that time, bottom DO levels were higher than at the surface.

Generally, the pH of lake waters remained fairly stable during the one-year data collection period, ranging from about 6.0 to 7.0, except during periods of high photosynthetic activity when relatively high levels of pH were observed (Figure 52). Uptake of carbon dioxide by plants tends to accelerate during periods of high growth, resulting in less free hydrogen ions in solution and, therefore, increased pH. Values of pH as high as 10.0 were recorded on several occasions when DO was also quite high. Fluctuations in pH exceeded FDER Class III water quality standards which require that pH not vary by more than one unit above or below background levels, and range between 6 and 8.5 (FDER, 1987). During the months of June and August, episodes of high pH were accompanied by high water temperature and elevated ammonia concentrations. At those times, computed equilibrium values of un-ionized ammonia were near or at toxic levels for freshwater aquatic life (U. S. Environmental Protection Agency, 1976), exceeding the Class III water quality standard of 0.02 mg/l (FDER, 1987).

Benthic macroinvertebrate abundance samples obtained by the FDER (1988) during this study did not reveal any unusual sensitivity to environmental stresses, such as depressed DO, or high temperature. Although leeches were reduced in numbers in the warmer months, it was reported that the lower numbers could have been attributed to increased predation by fish. In general, however, invertebrates found in the benthos were typical of those found in nutrient enriched waters, and would typically tolerate the observed stressful conditions.

Alkalinity concentrations shown in Figure 53 displayed a tendency to rise slightly during periods of warm dry weather. These increases may be due to noncarbonate contributions to alkalinity as well as carbonate alkalinity. Alkalinity usually decreased following wet periods. Alkalinity values in Lake Munson were generally low, on occasion falling below the Class III water quality standard of 20 mg/l (FDER, 1987). However, these alkalinities are similar to levels found in other local lakes, such as Lake Jackson.

Chlorophyll_a, Total Organic Carbon, and Other Organic Constituents

Chlorophyll_a is an algal biomass indicator representing 1.5 percent of the dry weight of algae (APHA; Standard Methods, 1985), on average. Figure 54 shows that concentrations of chlorophyll_a were high in the warmer summer months and low in the cooler months. Chlorophyll_a levels rose from near zero in the winter months to average concentrations near 60 ug/l and peak concentrations near 100 ug/l during late spring and summer. These values are equivalent to algal biomass concentrations of 4.0 mg/l and 6.7 mg/l, respectively. Chlorophyll_a fluctuations as well as biomass estimates compared favorably with algal growth potential and grab sample estimates (FDER, 1988). Phytoplankton sampling conducted by the FDER (1988) indicated a peak abundance of algae in November 1986, followed by considerably lower densities from December to April. A bloom of blue-green algae was observed in early May, followed by elevated but gradually declining densities for the remainder of the sampling program. In summary, higher concentrations of Chlorophyll_a were associated with the blue-green algal bloom in May, high algal densities throughout the summer season, and generally depressed dissolved oxygen conditions. It is apparent from these results that algal growth continues to be a problem in the lake.

Total organic carbon (Figure 55) also rose slightly in the warmer months. This increase in concentration may be attributed to the increase in algal biomass. The average concentration of TOC in the winter months is probably a result of decomposing organic matter in the lake and organic matter in stormwater.

Suspended solids concentrations were generally low, particularly in in the winter when concentrations usually were below the detection limit (9.6 mg/l). As depicted in Figure 56, peak concentrations were observed in late spring and summer. Although not a precise estimate, nonfilterable volatile residue may be interpreted as the fraction of the organic matter in the suspended solids. The nonfilterable volatile residue concentrations in Figure 57 follow a very similar pattern to that of suspended solids. Again the winter values were below detection limit. Average concentrations of total suspended solids in lake waters (7.77 mg/l) were much lower than in stormwaters (167.11 mg/l), thereby indicating that the lake traps substantial amounts of suspended solids which accumulate in the lake bottom.

BOD-5 and carbonaceous BOD (Figures 58 and 59) were relatively low, on occasion dropping below detection limit (2 mg/l), and frequently only 2 or 3 times higher than detection levels. Chemical oxygen demand (Figure 60) was also low, remaining fairly constant at levels between 30 and 50 mg/l. On two occasions, values below the detection limit of 22 mg/l were reported. The highest values were observed in the spring and the lowest in the winter. Chemical oxygen demand is widely used as an aid to characterize organic pollutant loads in natural waters. Since it is a measure of the amount of oxygen required for chemical oxidation of organic matter to carbon dioxide and water, it is a broader quantitative measure than BOD.

Fecal coliform bacteria are used as an indicator of disease to determine the safety of water for swimming and drinking. These bacteria are found in the feces or intestines of various warm blooded animals. Although coliform samples were not taken over a 5-day period as required by FDER bathing safety standards, Figure 61 shows fecal coliform levels exceeding the Class III water quality standard of 400 colonies/100 ml on several occasions. In September 1987, the maximum coliform count at one station was equal to 800 colonies/100 ml, coinciding with the maximum level allowed by the FDER on any one sample. Even total coliform counts (Figure 62) exceeded the one time maximum criteria of 2400 colonies/100 ml on many occasions. With respect to fecal streptococci (Figure 63), the highest levels were observed on February 23, 1987, when turbidity was also recorded at high levels. The source of these coliforms may be related to sewage discharges, but a further investigation into the actual occurrence, quality, and quantity of sewage sources would be needed to determine their origin.

Color, Transparency, and Turbidity

Color normally results from the leaching of both living and dead organic particulate matter (Reid and Wood, 1976). From Figure 64, color levels were slightly higher during the growing season, except for one observation in August when color was lower. There was also a tendency for color to drop during dry periods. Transparency, as measured by Secchi depth (Figure 65), ranged from one to four feet. Lower readings typically occurred in the summer months when algal counts were also high. Low winter readings may be due to a combination of high color and high suspended solids from stormwater discharges. Turbidity (Figure 66) displayed patterns similar to Secchi depth, except that turbidity was less variable than Secchi measurements. This is to be expected since secchi readings are affected by a series of factors which are difficult to control (i.e. wave action, cloudy skies, etc.). The highest values of turbidity were obtained on the day after a 2-inch rainfall event in late winter, February 23, 1987.

Trace Metals

Initially, lake waters were sampled for total lead, chromium, copper, mercury, cadmium, arsenic, nickel, and zinc. However, those metals measured below detection limit were eliminated from future samples after the fourth sampling date. Instead, metal sampling for the remainder of the data collection period was directed at measuring dissolved and total fractions of lead, chromium, and copper, which showed concentrations above detection limits. Fluctuations in metal concentrations over the one-year period are given in Figures 67 through 72. As the figures indicate, levels of lead, copper, and chromium never exceeded FDER water quality criteria for class III waters. Differences in metal concentrations between sites were small, with only one station (S48), located in the deeper and more isolated waters of the lake, showing significantly lower concentrations than the rest of the stations. Frequently, the dissolved metal fractions accounted for a large portion of the total (unfiltered) metal content.

Lake water concentrations of all three metals were significantly lower than levels observed in the incoming stormwaters. Concentrations of total lead, copper, and chromium in lake waters averaged 3.08 ug/l, 2.44 ug/l, and 0.85 ug/l, respectively. In contrast, levels in stormwaters averaged 36.38 ug/l of lead, 9.34 ug/l of copper, and 3.64 ug/l of chromium. Accordingly, the majority of the incoming metal loads are retained in the lake, adsorbed onto soil particles which settle on the lake bottom.

Correlation Analysis

Correlation analysis was used as a preliminary screening tool to identify any significant relationships among the various water quality parameters sampled during the period November 1986 to November 1987. Prior to conducting the correlations, all parameters were averaged in space, thereby assuming that the lake was a well mixed system. This was justified on the basis that spatial differences in water quality constituents were found to be too small to impact the results of the correlation analysis. Preliminary correlation computations were performed between water quality components at each individual site and compared to the correlations obtained by spatial averaging. Although differences were found when computing correlations on an individual site basis, these were very small and did not significantly impact the correlation coefficient.

In addition to using straight linear correlation, the three most common curvilinear transformations were also used in the correlations, including the log, square root, and negative inverse. Overall, these transformations did not significantly improve the correlations. Only the log transformation was occasionally more useful than the straight linear form. Appendix A provides a table with the results of all linear and log-linear correlations. The parameter names in the table are labeled with acronyms to facilitate ease of cross referencing.

A summary of results from the correlation analysis is presented in Table 7. The table reports the correlation coefficient (r) for all possible combinations of parameter pairs. Correlation coefficients enclosed in parenthesis represent parameter pairs which exhibited relatively high correlations and which were considered useful in elucidating cause-effect relationships in lake water quality. The correlation coefficient represents the percent deviation in one parameter that is explained by a linear or curvilinear relationship with another parameter. The higher the magnitude of the coefficient, the greater the strength of the relationship between parameters. A positive r value indicates a parameter relationship that is directly proportional (increases in one parameter result in increases in another). Conversely, the correlation is negative, or inversely proportional, if one parameter tends to decrease as another increases.

In accordance with the U. S. EPA (1982), correlation coefficients for the sample size (n) used are significant when r is greater than about 0.2. The sample size (n) used in the correlations was the product of the number of stations and the number of samples taken over time. However, since parameter variability over time was significantly higher than over space, it is more appropriate to use the number of samples over time as an indicator of sample size (and variability), instead of using the number of samples over both time and space. In that case, the sample size is divided by the number of stations (seven), and the level at which correlations become statistically significant increases to 0.5.

Table 7 indicates that many statistically significant correlations ($r \geq 0.5$) exist among water quality parameters, several of which were expected. For example, total nitrogen (TN) is highly correlated with total organic nitrogen and ammonia (TKN) because a large portion of TN is made up of TKN. One of the more commonly found relationships was between inorganic nutrients and organics. Nitrates (NO3) tended to decrease as chlorophyll_a (growth indicator) increased. The log of the ratio of inorganic nitrogen to phosphorus (LIN/OP) was also highly correlated to nitrate and also tended to decrease as chlorophyll_a (CHLA) increased. The log of temperature (LTSURF) correlated with all of the above constituents, most likely as a result of the higher growth that typically occurs during warm weather.

Total phosphorus (TP) tended to increase with increasing chlorophyll_a and temperature. Orthophosphate (OP), which is highly correlated with TP, makes up a large fraction of TP. This is most likely due to the release of orthophosphate from the bottom sediments and its uptake into organic particulate matter following periods of warm weather and stagnation.

TABLE 7

CORRELATION MATRIX OF SELECTED WATER QUALITY PARAMETERS

	COND	BOD5	BODC	ALK	TS	TDS	SS	NVR
BOD5	0.349							
BODC	0.329	(0.910)						
ALK	(0.861)	0.270	0.296					
TS	(0.633)	0.238	0.118	(0.592)				
TDS	(0.635)	0.125	-0.001	(0.591)	(0.957)			
SS	0.235	0.427	0.321	0.234	(0.511)	0.242		
NVR	0.276	0.503	0.404	0.272	(0.526)	0.281	(0.932)	
TN	0.387	0.470	0.397	0.418	(0.585)	0.412	(0.742)	(0.820)
DNH3	0.489	0.086	0.016	(0.438)	0.276	0.354	-0.126	-0.109
NH3	0.460	0.088	0.018	(0.449)	0.246	0.321	-0.126	-0.129
TKN	0.352	0.492	0.406	0.369	(0.579)	0.394	(0.773)	(0.846)
NO3	0.212	-0.215	-0.118	0.311	-0.019	0.082	-0.307	-0.277
TP	0.226	0.182	0.107	0.413	0.474	0.333	(0.602)	(0.551)
OP	0.338	0.076	-0.054	(0.544)	(0.520)	(0.478)	0.324	0.314
IN/OP	0.110	-0.258	-0.163	0.176	-0.122	-0.025	-0.335	-0.327
CL	(0.703)	0.308	0.146	0.346	0.465	0.458	0.198	0.232
PH	0.224	0.409	0.381	0.205	0.284	0.092	(0.680)	(0.749)
LCHLA	0.134	0.361	0.261	0.146	0.240	0.138	0.398	0.468
LTSURF	-0.155	0.215	0.147	-0.051	0.178	0.059	(0.423)	(0.483)

	TN	DNH3	NH3	TKN	NO3	TP	OP	IN/OP
DNH3	0.005							
NH3	-0.036	(0.960)						
TKN	(0.991)	-0.007	-0.043					
NO3	-0.041	0.088	0.054	-0.176				
TP	0.574	0.088	0.125	(0.598)	-0.239			
OP	0.394	0.266	0.306	0.411	-0.168	(0.801)		
IN/OP	-0.126	-0.023	-0.057	-0.252	(0.943)	-0.341	-0.304	
PH	(0.718)	-0.150	-0.178	(0.710)	-0.018	0.360	0.124	-0.078
LCHLA	0.365	0.099	0.099	0.429	(-0.540)	0.402	0.307	-0.572
LTSURF	0.370	-0.034	0.020	0.450	(-0.622)	(0.513)	(0.408)	(-0.688)
LT1FT	0.367	-0.038	0.016	0.447	(-0.627)	(0.511)	(0.405)	(-0.690)
LT2FT	0.366	-0.052	0.003	0.445	(-0.625)	(0.513)	(0.400)	(-0.686)

	CL	COLI	FECAL	LIN/OP	LCHLA	LTSURF
COLI	-0.059					
FECAL	-0.077	(0.748)				
PH	0.257	-0.124	-0.196			
LCHLA	0.114	0.031	-0.048	(-0.664)		
LTSURF	-0.092	0.048	-0.114	(-0.663)	(0.703)	
LT2FT	-0.113	0.058	-0.107	(-0.663)	(0.695)	0.996

Values in parenthesis () are correlations of interest. Parameter prefix "L" is the log of the parameter. The sample size (n) was 182 for most parameters.

Biological activity correlated better with inorganic nitrogen species than with phosphorus species due to the abundance of phosphorus relative to nitrogen. Total organic nitrogen and ammonia (TKN) as well as total nitrogen (TN) were correlated highest with suspended solids (SS) and nonfilterable volatile residue (NVR). This is indicative of the uptake of nitrogen by biological activity, which produces suspended matter with high organic content. TKN, TN, SS, and NVR were also correlated with pH. Increases in pH are common as carbon is fixed into organic matter via photosynthetic activity. Since phosphorus was the more abundant nutrient with regard to biological consumption, it was less correlated with suspended solids.

Specific conductance (COND), which serves as an indicator of ions in water, was positively correlated with alkalinity. It is interesting to note that specific conductance was more highly correlated with alkalinity than with total dissolved solids (TDS). Whether changes in alkalinity were related to stormwater inflows or biochemical activity, the more commonly expected form of alkalinity contributed from these sources is carbonic acid. In determinations of TDS, however, Hem (1985) notes that half of the bicarbonate ions are converted to carbon dioxide and water. It is possible, therefore, that while changes in alkalinity were more closely related to ion concentrations, TDS analysis was less accurate due to a loss of bicarbonate ions. Other weak acids and anions to which alkalinity was weakly correlated included orthophosphate and ammonia. Alkalinity also displayed a weak positive correlation with pH, which was particularly more erratic than alkalinity during periods of high growth. Due to the extreme variability in pH and relatively low values of alkalinity, Lake Munson may be considered a weakly buffered system.

Other correlations of interest were coliforms (COLI) vs. fecal coliforms (FECAL), 5-day biochemical oxygen demand (BOD5) vs. carbonaceous BOD (CBOD), TDS vs. COND, and TDS vs. total solids (TS). Since BOD was generally low, only one of these parameters may be needed for future monitoring of the lake. Likewise, the more general coliform data could be a useful indicator in lieu of the more specific fecal coliform data. In general, all of the highly correlated parameters could be used as key indicators of water quality in future monitoring efforts.

Historical Summary of Lake Water Quality

All historical water quality available for Lake Munson was compiled, summarized, and compared to data collected as part of this investigation in order to detect any significant historical trends in lake water quality. Historical data were primarily obtained from EPA's STORET data base and unpublished data collected by the City of Tallahassee Water Quality Laboratory (Leseman, 1977). Figures 73 through 76 provide, respectively, annual histories of total phosphorus, total nitrogen, ammonia, inorganic nitrogen, chlorophyll_a, transparency, alkalinity, and pH of lake waters for the period 1968 to 1987. The figures show annual averages and ranges for only those parameters and years for which data were available. Although some years are missing and the number of annual samples is sometimes very low, the figures provide an indication of historic trends in lake water quality based on the best available information.

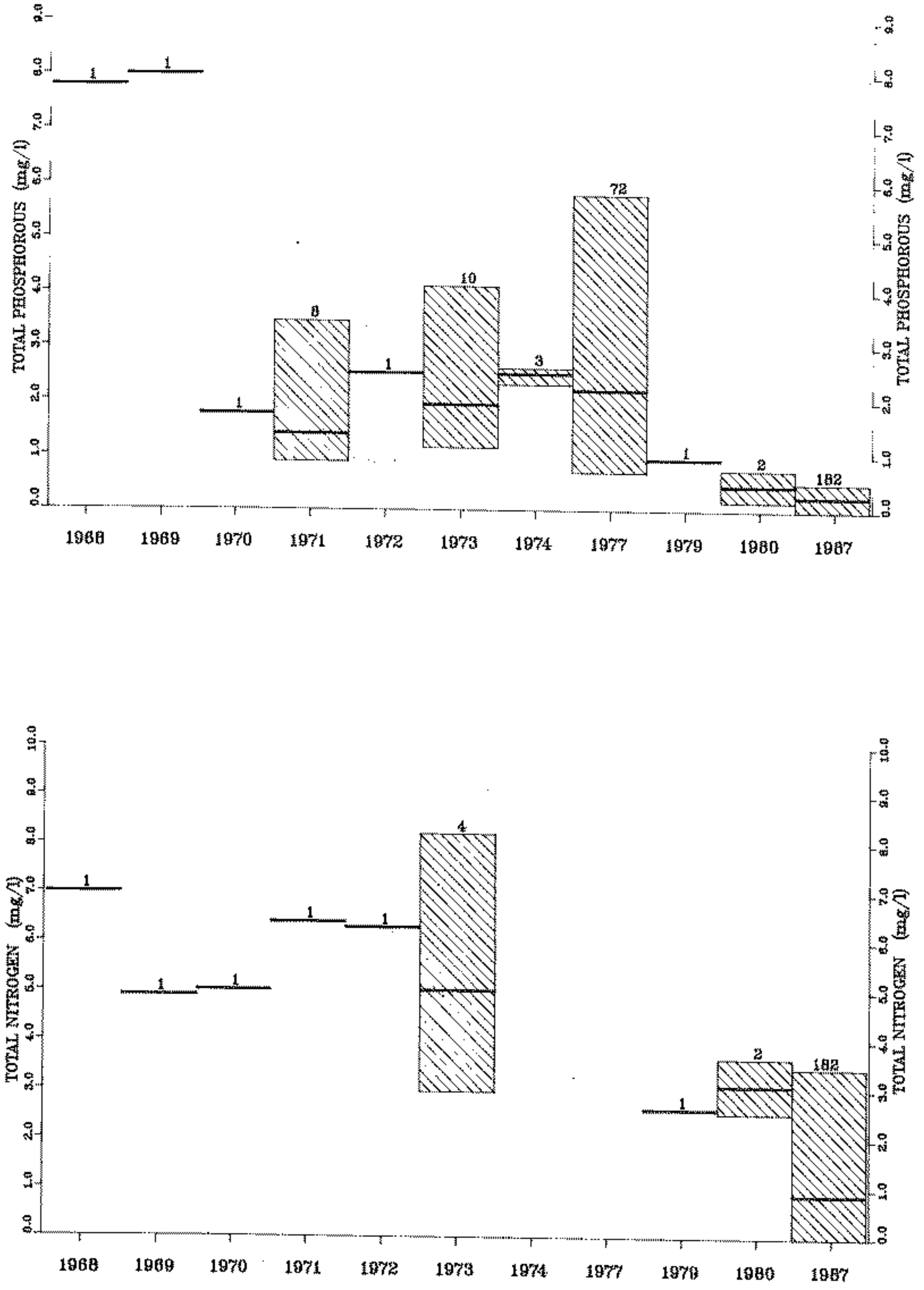
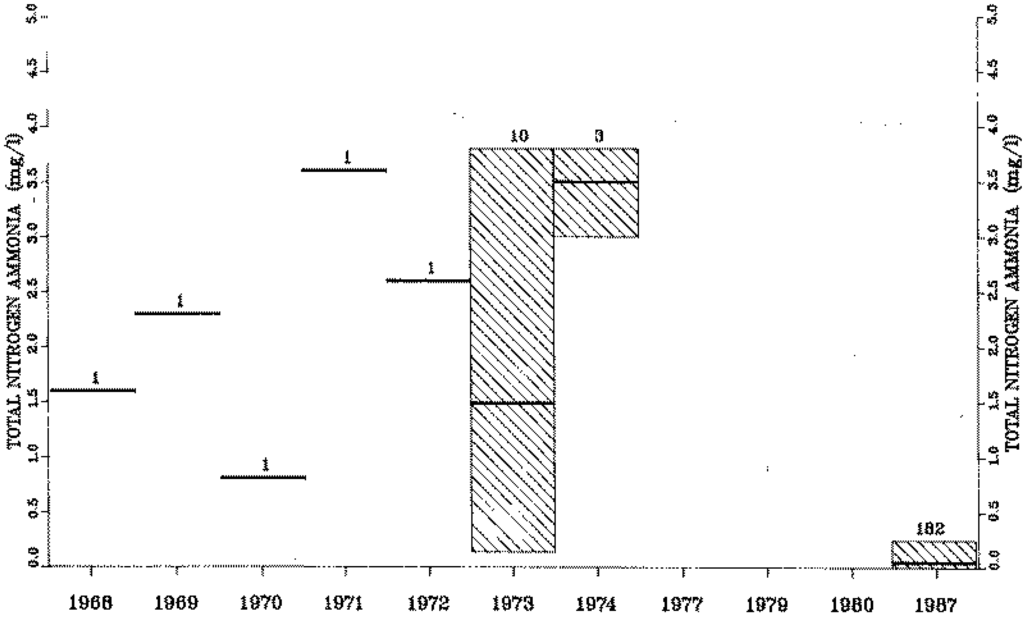


Figure 73. Historic Changes in Total Phosphorus and Total Nitrogen of Lake Waters



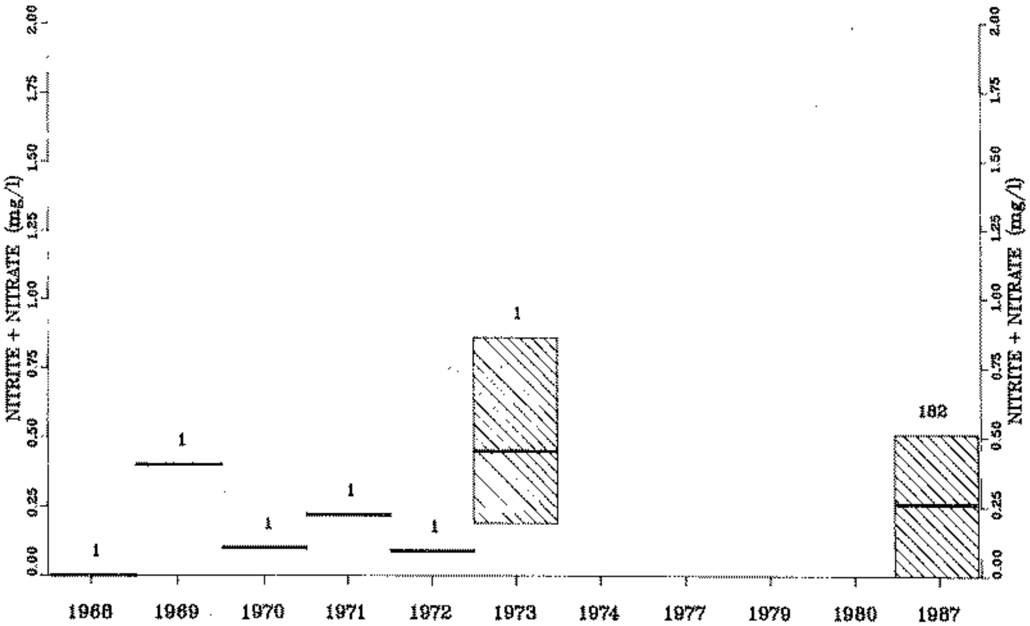


Figure 74. Historic Changes in Total Ammonia and Inorganic Nitrogen of Lake Waters

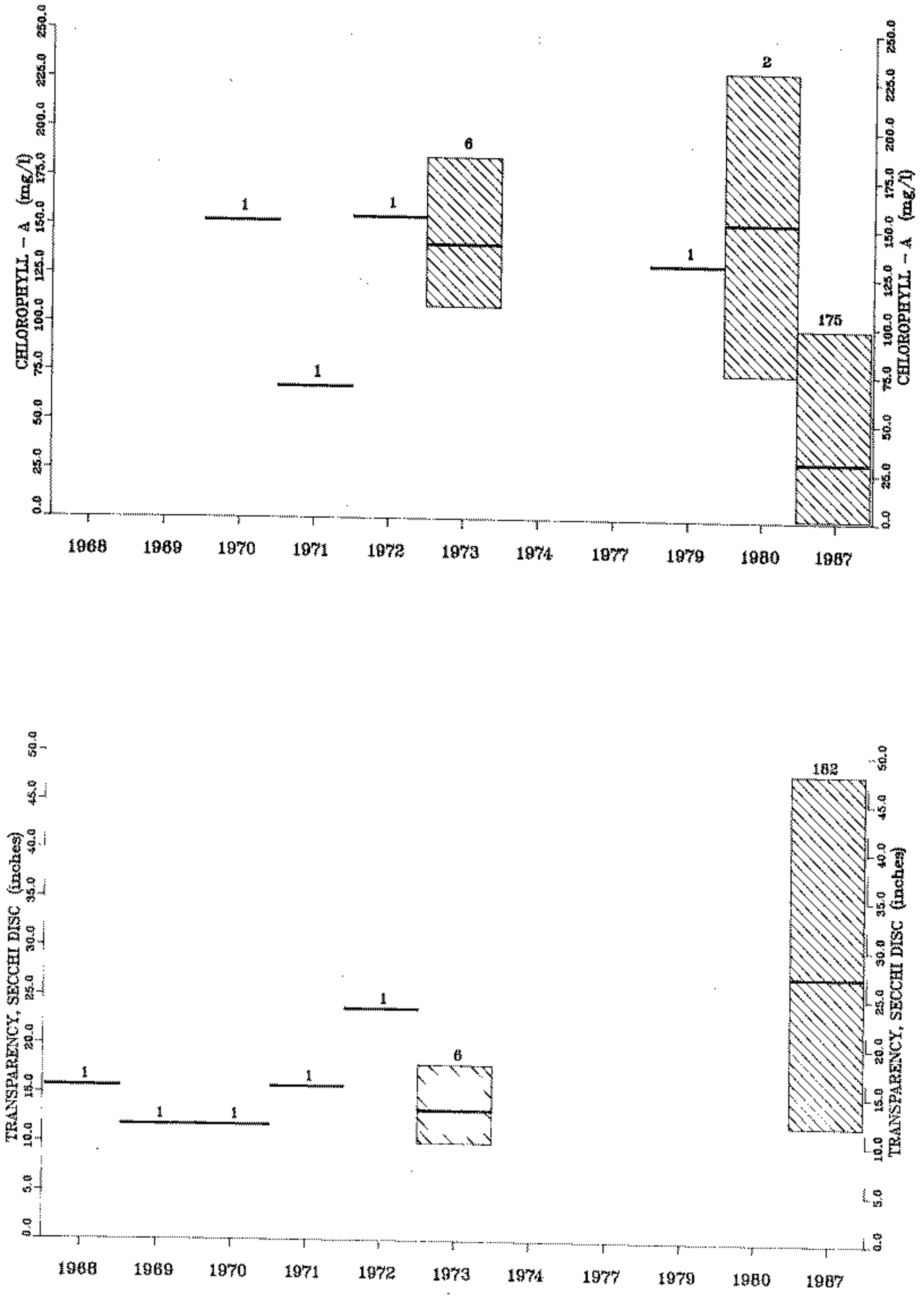


Figure 75. Historic Changes in Chlorophyll_a and Transparency of Lake Waters

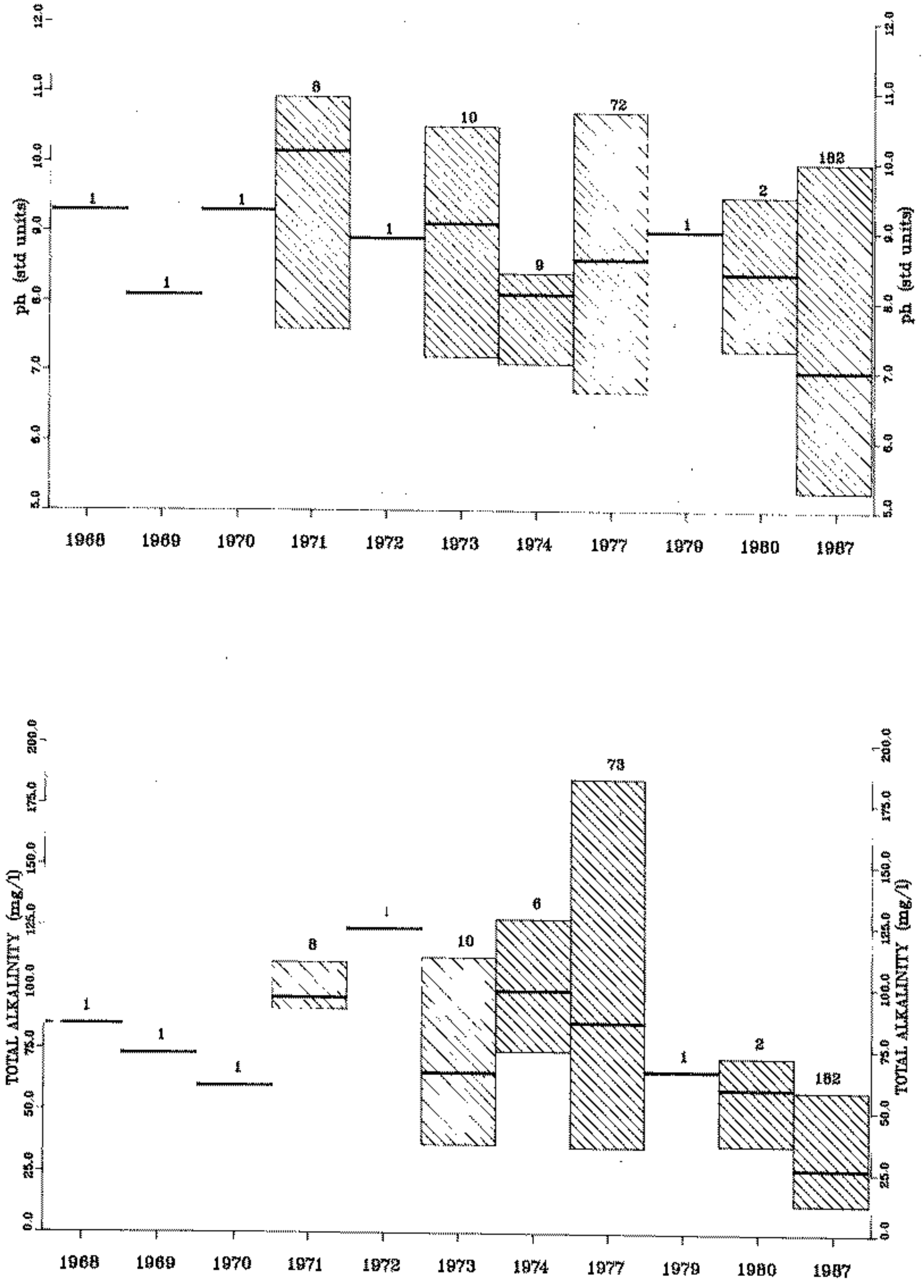


Figure 76. Historic Changes in Alkalinity and pH of Lake Waters

Figures 73 through 75 provide a dramatic representation of the significant improvements in water quality that resulted from the elimination of wastewater effluent discharges into Lake Munson. Since effluent discharges were responsible for about 90 percent of the total nitrogen and phosphorus loads into the lake, it is not surprising to see a substantial drop in total phosphorus (Figure 73), total nitrogen (Figure 73), and total ammonia (Figure 74) in lake waters. It is interesting, however, that the levels of inorganic nitrogen (nitrate + nitrite, Figure 74) displayed a much more subdued downward trend, at times exhibiting very low values. This fact suggests that, historically, the lake may have been nitrogen limited. A comparison of total nitrogen and phosphorus abundance also reveals historically high levels of phosphorus relative to nitrogen. Ammonia levels (Figure 74) are generally higher than inorganic nitrogen, indicating impairment of nitrification due to high productivity and low oxygen levels.

Improvements in lake nutrient status are also reflected in lower chlorophyll_a concentrations (Figure 75) and higher water transparency (Figure 75). Alkalinity (Figure 76) showed a tendency to drop from the relatively higher levels of the past due to the gradual reduction and eventual elimination of wastewater effluent discharges into the lake. Since the source of Tallahassee's water supply is the high alkalinity waters of the Floridan Aquifer, wastewaters have higher alkalinity than stormwater discharges. This is also apparent from Figure 76, which shows a tendency for the pH of lake waters to drop as effluent discharges were gradually eliminated from the lake. However, excessively high pH values continue to occur as a result of high photosynthetic activity in the lake.

LAKE SEDIMENTS

A total of fifteen lake sediment stations were established throughout Lake Munson as shown in Figure 4. Seven sites were sampled quarterly for total nitrogen, total phosphorus, and total volatile solids. All fifteen sites were sampled once for particle size distribution and twice for total aluminum, copper, lead, and chromium. The chemistry samples were extracted from approximately the first four inches of the sediment column.

Physical Properties

In order to examine the particle size composition of bottom sediments, all fifteen sediment sites were analyzed using standard sieve and hydrometer procedures. All organic matter was burned off prior to conducting the analyses. Gradation curves as well as moisture and organic contents for all fifteen sites are presented in Appendix B.

The lake sediments are characterized by silts and clays with high moisture and organic content. Expressed in percent of total sample weight, organic content ranged from 1 to 13 percent, moisture content varied from 16.7 to 88.3 percent, and total solids ranged from 5.3 to 82.8 percent. The average figure reflects a typical sediment sample made up of 64.7 percent water, 4.4 percent organics, and 30.9 percent solids by weight. With respect to the gradation curves, total solids composition ranged from medium sands to fine clays. The average sample was approximately 60 percent silts and clays, 30 percent fine sands, and 10 percent medium sands. Stations with very high content of silts and clays (80 percent or greater by weight) were primarily located along the southern part of the lake, apparently tracking the path of the stormwater sediment plume. These stations were S45, S46, S47, S51, S54, and S55.

When sampling for the sediment cores, it became apparent that the sediment column was comprised of three soil horizons separated by two distinct interfaces. The surficial layer was observed as a brownish to gray gel-like muck of silts and clays. The second horizon contained mostly peat and other organic debris resting over unconsolidated fine sands with very little silts, clays or organics. In order to identify their physical properties, samples of each of the horizons were taken at five stations including S48, S49, S51, S53, and S54. The samples were analyzed for sands, fines (passing the no. 230 sieve), organics, and moisture content. In addition, the upper soil horizons were measured to determine their depths.

The depths of the first sediment layer ranged from 5.5 to 13.5 inches, with a five station average of 9.3 inches. The second layer was much thicker, ranging from 1 inch to 4.25 feet, and averaging 2.4 feet. The thickness of the second horizon was particularly high at stations S49 (3.5 ft), S51 (4.25 ft), and S54 (3.55 ft). The results from the soil analyses indicated a surface horizon with a greater fraction of fines and a lesser amount of organics. The first horizon was characterized by an average organic content of 29 percent, and fines of 69 percent by weight. Conversely, the second horizon was comprised of 12 percent fines and 75 percent organics. The wet unit weight of the surface layer was calculated to average 71.5 pounds per cubic foot.

Clearly, the two upper horizons were created under very different deposition environments. The first horizon, with a much higher content of fines relative to organics, seems to be the product of lake inflows laden with high suspended solids. Stormwater has been documented to have total suspended solids concentrations which are several orders of magnitude greater than those found in wastewater effluent. Therefore, it would appear that the interface between the two layers, located about 9.3 inches below the sediment surface, marks the time when stormwater sediment loads began impacting the lake in a significant way. That time may also coincide with the impoundment or creation of Lake Munson in 1950, since the deposition of fine sediments such as silts and clays require quiescent conditions.

Sediment Accumulation

The first bathymetric map of Lake Munson was developed by the Water Management District in 1976 (Figure 77). An examination of the map shows a large area in the central part of the lake with depths of about five feet. The lakewide average depth was calculated at 3.43 feet. A more recent contour map was developed by the Game and Fish Commission in 1987 (Williams and others, 1987). The map, shown in Figure 78, shows much shallower depths as well as a larger delta at the mouth of the lake. The Game Commission estimated the average lake depth at 3 feet. In addition to the bathymetric map, the Commission measured the depth of organic sediment deposition throughout the lake and prepared two contour maps, one showing the distribution of organic sediments (Figure 79) and another displaying the bathymetry of the lake if all organic sediments were removed (Figure 80). Total depths of organic sediments were calculated to average 2.35 feet lakewide, with maximum observed depths of up to eight feet.

As discussed earlier, sediment analyses conducted as part of this investigation revealed two types of organic sediments separated by a distinct interface. The top layer is composed of mostly silts and clays with some organic matter, whereas the underlying layer is mostly a deposit of peat and other organic debris. Since accretion in the surface layer is primarily associated with stormwater sediment deposition, the stormwater data collected as part of this investigation can be used to estimate rates of sediment build up.

The load of total suspended solids was estimated at 35,762 lbs/day based on 1987 water quality data. Also, the long-term sediment retention capacity of the lake was calculated at approximately 94 percent of the total inflow load. Using these figures as well as a wet unit weight of 71.5 lbs/cu-ft and a moisture content of 65 percent for the surface sediments, it was estimated that surface layer deposition would occur at an average rate of 0.53 inches per year. At that rate, the average depth of the lake would decrease by about 5.83 inches or 0.48 feet in eleven years. This figure compares very favorably with the difference in average depths between the 1976 and 1987 bathymetric surveys: 0.43 feet or 5.2 inches.

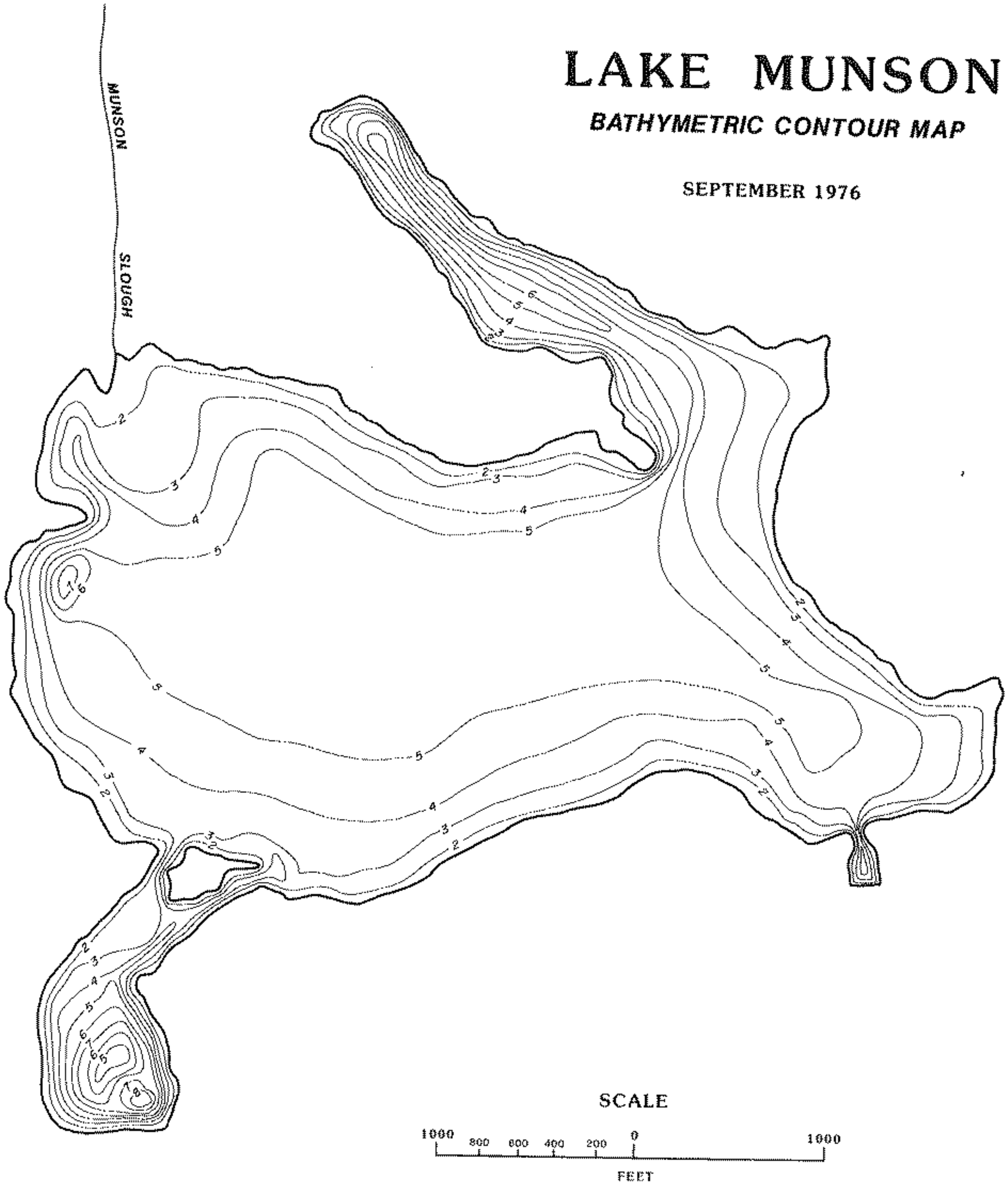


Figure 77. 1976 Bathymetric Map of Lake Munson

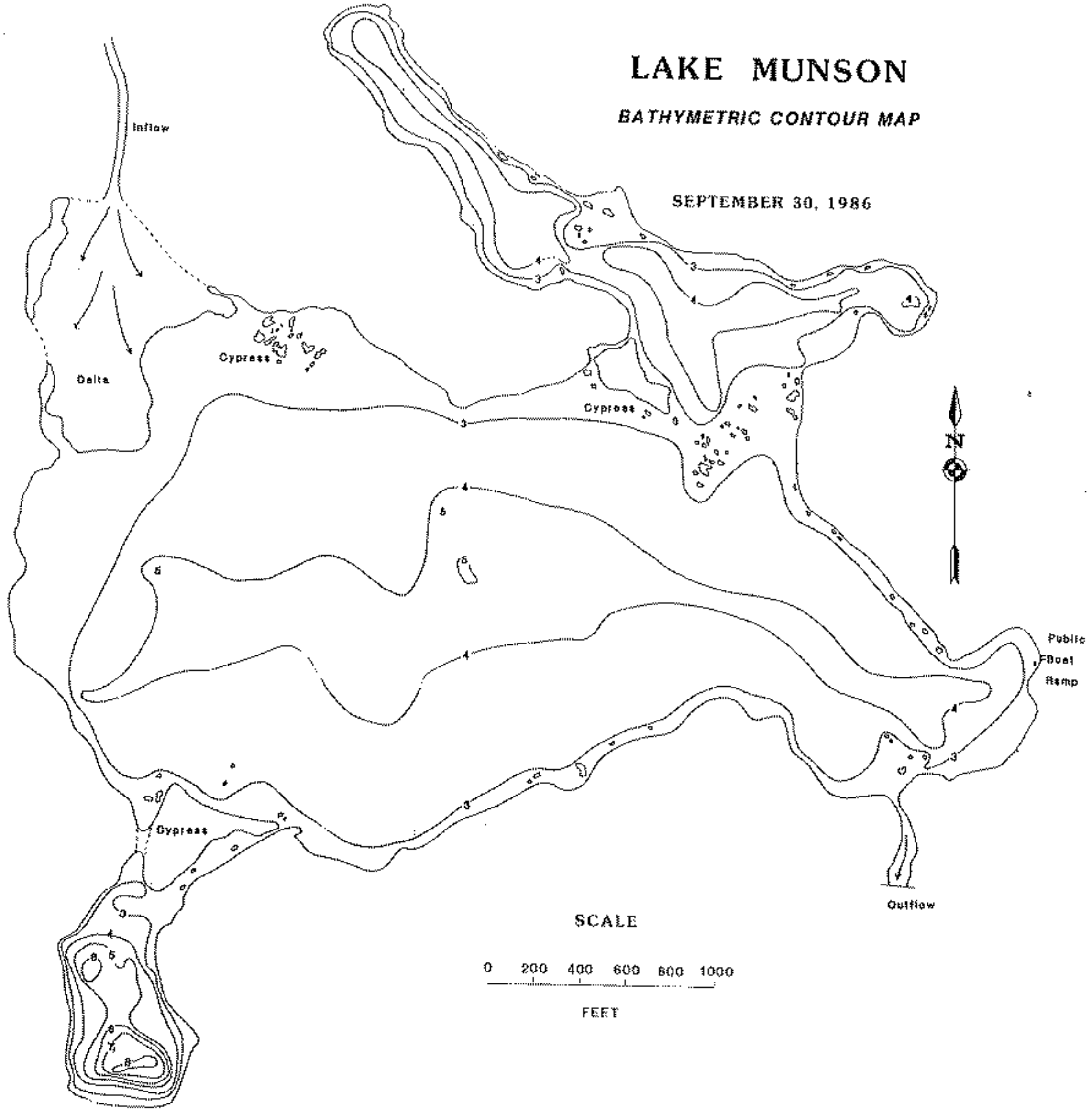


Figure 78. 1986 Bathymetric Map of Lake Munson

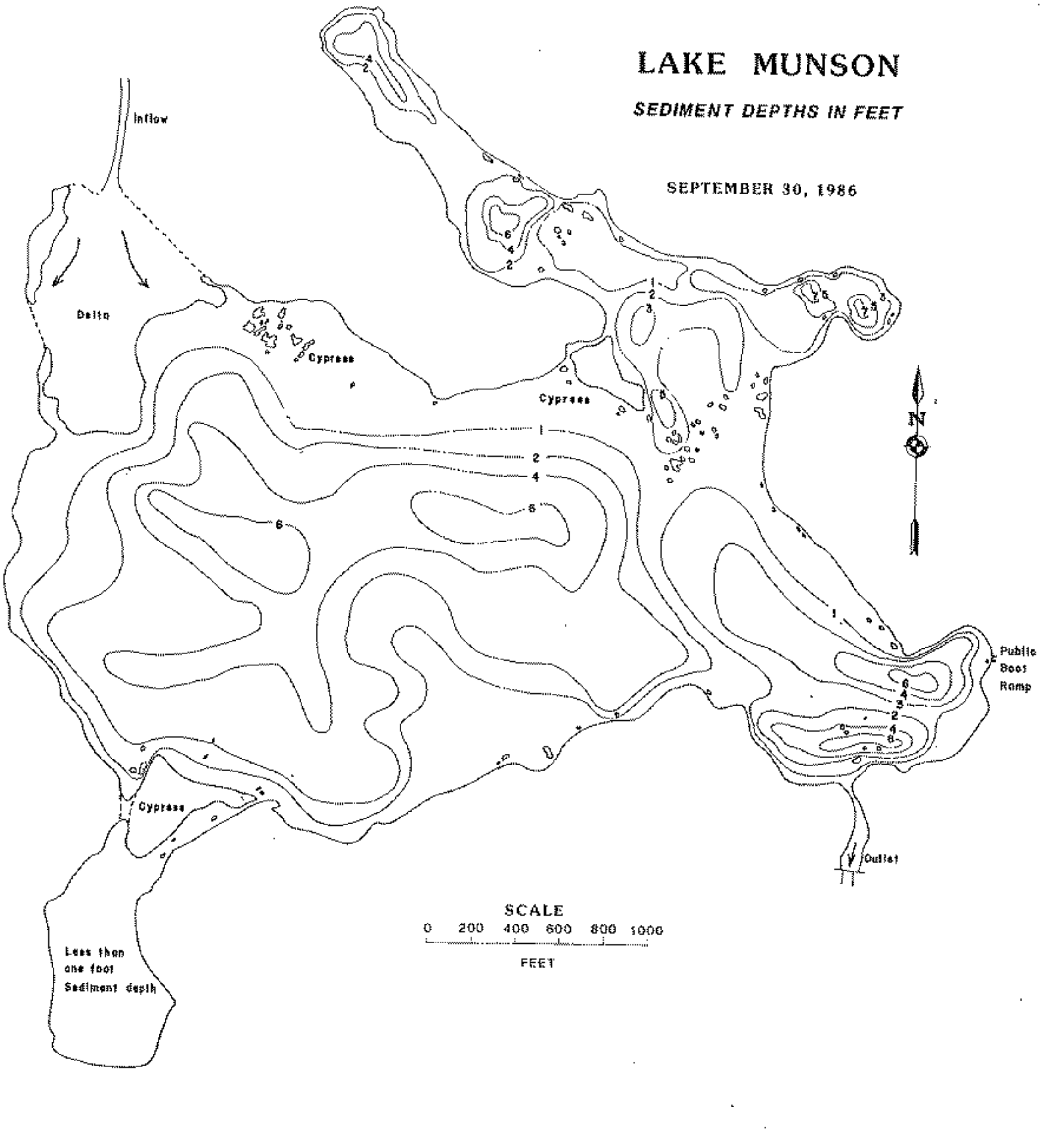


Figure 79. Total Depth of Organic Sediment Deposits in Lake Munson

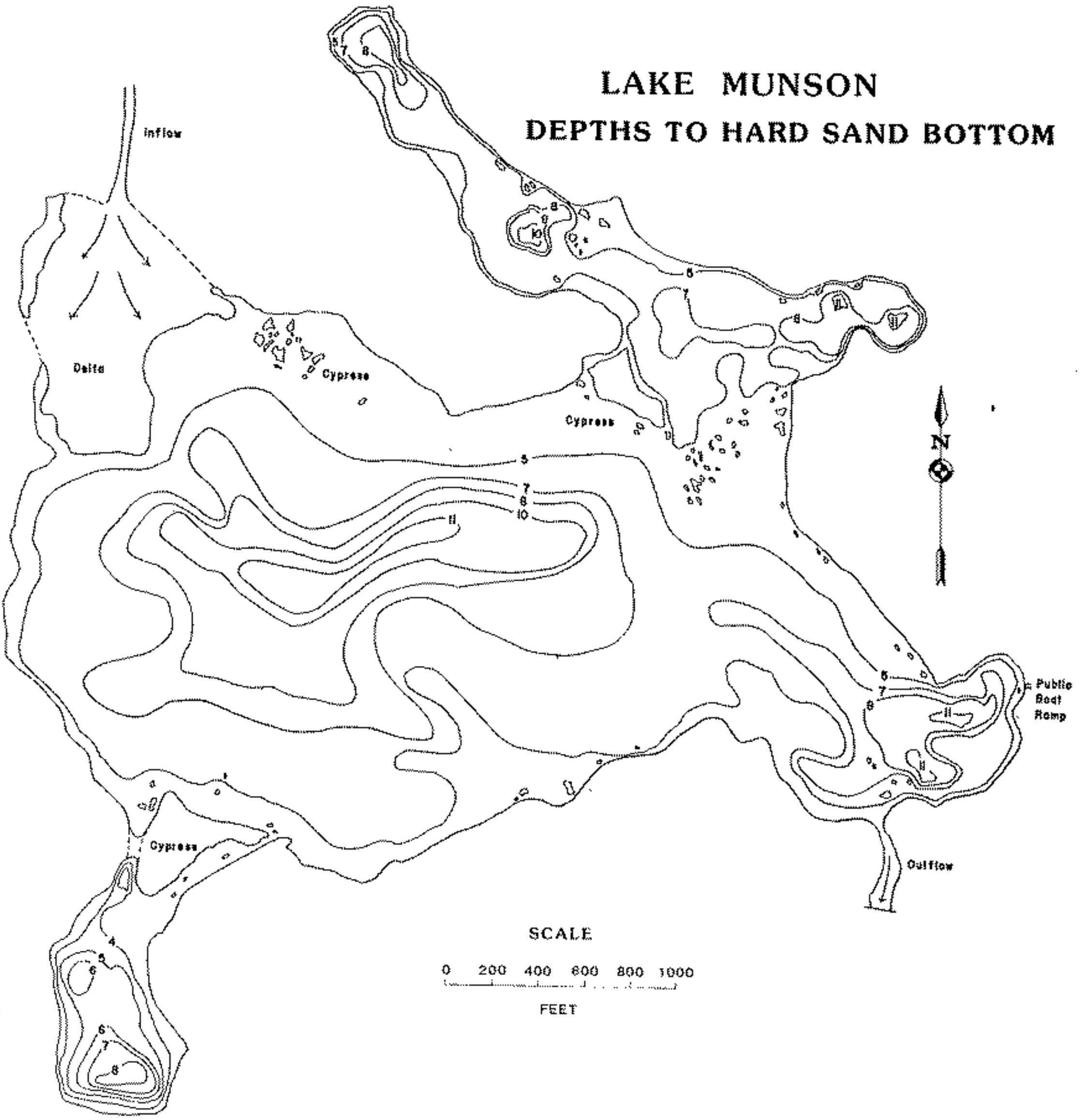


Figure 80. Lake Bathymetry After Complete Removal of Organic Sediments

Based on the results above and the fact that stormwater is responsible for at least 92 percent of the historic load of suspended solids into Lake Munson, it is safe to conclude that the accretion of the surface sediment layer was primarily due to stormwater impacts. Therefore, the thicker peat deposits underlying the surface layer must have been deposited prior to any significant stormwater discharges, perhaps even before the creation of the lake in 1950. As mentioned earlier, settling of silts and clays requires quiescent conditions such as those found in a lake.

Sediment Chemistry

Total Phosphorus and Total Nitrogen

Sediment samples for total nitrogen and total phosphorus were obtained on March 23, August 28, October 19, and December 9, 1987 at stations S42 through S48. The results showed a wide range of values for these parameters. The reported values for total phosphorus ranged from a minimum of 1,471 mg/kg to a maximum of 75,540 mg/kg. Total nitrogen analysis resulted in minimum values of 1,504 mg/kg and maximum values of 22,578. The average value for total phosphorus content was 10,382 mg/kg, exceeding the mean value of 7,868 mg/kg for total nitrogen. Minimum values for both parameters were recorded on August 28 at inflow site S44. Similarly, maximum values were reported on March 23 at site S48, which is located in a more removed and deeper part of the lake compared to the other sampling sites. Higher concentrations were typically reported from samples taken in the early spring. A summary of these parameters is included in Table 8.

The relative contents of nitrogen and phosphorus in the bottom sediments agree with estimates of their accumulation based on the lake's capacity to retain stormwater nutrients. The ratio of total nitrogen to total phosphorus (TN/TP) in stormwaters was calculated at 1.75. Recomputing the ratio based on the amount of nutrients retained in the lake, estimated at 64 percent for phosphorus and 31 percent for nitrogen, the resulting TN/TP ratio is 0.85. This figure is comparable to the ratio of 0.76 calculated from the average nutrient concentrations in the sediments. Such good agreement indicates that most sediment nutrient accumulation originates from stormwater discharges, and suggests that, if some degree of denitrification does occur in the lake, it is not significant to affect nutrient levels in the sediments.

Trace Metals

Metals were sampled on August 28 and December 9, 1987 at fifteen sites (S42-S56). These sites were chosen to provide a representative coverage of the entire lake system. Parameters sampled included chromium, copper, lead, and aluminum. A summary of trace metal concentrations is given in Table 9. Averaging the results from both sampling dates, chromium concentrations ranged from 2.45 mg/kg to 180.90 mg/kg, while copper had a minimum of 1.40 mg/kg and a maximum of 20.76. Similarly, the reported lowest average value for lead was 1.14 mg/kg, with a maximum of 83.00 mg/kg. Being the most abundant metal under natural conditions, aluminum concentrations were the highest. They ranged from 1,172 mg/kg to 119,594 mg/kg, having an overall mean of 71,176 mg/kg. The means for chromium, copper, and lead were, respectively, 96.73 mg/kg, 13.39 mg/kg, and 44.96 mg/kg.

TABLE 8

SUMMARY OF TOTAL PHOSPHORUS AND TOTAL NITROGEN CONCENTRATIONS IN LAKE BOTTOM SEDIMENTS

Parameter Storet Code/ Description	Map Ref. No.	Date			
		3/23	8/28	10/19	12/09
80111 Nitrogen, Total (mg/kg)	S42	9960	10912	10163	9520
	S43	8254	7262	6951	10639
	S44	5391	1504	4535	4205
	S45	5832	3801	6132	4733
	S46	6564	7520	4155	7349
	S47	8154	7520	6474	10229
	S48	22578	15338	6468	8162
61546 Phosphorus, Total (mg/kg)	S42	7392	9160	6285	9257
	S43	10324	8602	9302	12432
	S44	5735	1471	4467	5432
	S45	7515	12280	7720	9420
	S46	9078	11688	5208	11585
	S47	10984	7493	6925	11822
	S48	75540	4082	5709	3784

TABLE 9

SUMMARY OF SELECTED TRACE METAL CONCENTRATIONS IN LAKE BOTTOM SEDIMENTS

Parameter Storet Code/ Description	Map Ref. No.	Date 8/28	12/09	Parameter Storet Code/ Description	Date 8/28	12/09
01108	S42	69804	157000	61504	52	18
Aluminum,	S43	54187	185000	Lead,	99	16
Total	S44	48489	129000	Total	73	30
(mg/kg)	S45	63428	91000	(mg/kg)	78	18
	S46	39563	112000		71	38
	S47	61584	129000		39	37
	S48	60996	32095		20	18
	S49	47848	65940		36	53
	S50	69627	100000		44	112
	S51	57781	83824		52	114
	S52	80517	3183		66	8
	S53	2029	315		1	2
	S54	130000	57030		31	89
	S55	59037	19847		43	35
	S56	95464	29679		40	26
61507	S42	10	10	61513	190	147
Copper,	S43	10	25	Chromium,	110	218
Total	S44	9	33	Total	91	158
(mg/kg)	S45	7	9	(mg/kg)	156	206
	S46	8	9		84	155
	S47	9	19		43	153
	S48	19	6		35	64
	S49	7	7		68	90
	S50	17	13		96	165
	S51	30	10		107	96
	S52	22	1		32	15
	S53	3	0		1	3
	S54	29	6		52	124
	S55	38	2		106	34
	S56	34	2		66	37

The results show fluctuating metal concentrations along the flow path up to the area near the boat landing in the southeast corner, where a slight relative increase in metal concentrations was noted. Some non-point source pollutants may have heightened metal levels at that site. With respect to site location and typical flow patterns, concentrations showed no noteworthy trends in the main body of the lake. However, lower concentrations of all metals typically occurred in the lake's southwest corner, the northeast section, and near the outlet. In all cases, the minimum concentrations were reported at the outlet site (S53). This site was in close proximity to the control structure and may be disturbed by scour.

LAKE POLLUTANT RETENTION CAPACITY

Pollutant retention capacities for Lake Munson were estimated by comparing flow weighted inflow and outflow concentrations for different size storm events. Using average concentrations instead of total loads was justified in this particular case because Lake Munson has practically no detention capacity and is little influenced by groundwater interactions so that, for most practical purposes, outflow and inflow volumes are equal.

Lake Munson functions as a wet detention pond with its permanent pool at the elevation of the emergency spillway. Although the lake is capable of holding a significant volume of water at normal pool level, it has practically no detention storage capacity above permanent pool. As discussed previously, the volume capacity below the permanent pool is only exceeded by about 20 percent of the storm events, so that most of the incoming storms are captured by the lake, displacing an equal volume of lake water downstream. The captured volume undergoes treatment by settling of suspended solids and biochemical activity until such a time as all or part of that storm volume is displaced downstream by the next storm event. The period of time between the end of one storm and the beginning of the next was estimated to average about 115 hours. This is the approximate length of time available for natural treatment of the captured storm volumes.

Two sets of retention capacities were calculated for Lake Munson, one based on the average of flow weighted pollutant concentrations from the three outflow storms (Table 10), and another based on the lakewide average concentrations for the one-year sampling period (Table 11). The latter approach is based on the assumption that the long-term average outflow concentrations are equal to the long-term average concentrations in lake waters. This is justified on the basis that 80 percent of the storm events are captured by the lake and, as a result, 80 percent of the storm outflows represent displaced lake waters. In fact, this approach may be considered more accurate since lake concentrations are representative of a wider range of storm events (one year of data) than the figures obtained from only three storm events.

Table 12 gives the flow weighted average inflow concentrations for the six storms sampled, and Table 13 presents lake removal efficiencies for all water quality parameters monitored. In general, the results indicate that the lake is very effective at retaining particulate material from the incoming stormwaters. Using the removal figures based on lake concentrations, for example, the lake is capable of removing 87 percent of the turbidity and 95 percent of the suspended solids. The particulate fractions of other water quality parameters are also effectively removed. Total phosphorus removal is 64 percent, total nitrogen is 31 percent, biological oxygen demand is 20 percent, total organic carbon is 24 percent, total chromium is 78 percent, total copper is 72 percent, and total lead is 91 percent. Dissolved organic nitrogen and orthophosphate show negative removal rates of -15 percent and -50 percent, respectively, indicating that the sediments appear to release these nutrients to the water column. The impact on orthophosphate is particularly important since the sediments seem capable of supplying a significant amount of phosphorus necessary for algal growth, thus making nitrogen the limiting lake nutrient. In fact, while dissolved phosphorus is added to the water

TABLE 10

FLOW WEIGHTED CONSTITUENT CONCENTRATIONS IN LAKE OUTFLOW

Parameter Description	Storet Code	Storm of 9/05	Storm of 11/09	Storm of 11/17	All Storm Average
Turbidity	76	3.574	5.939	21.990	10.501
Color	80	98.528	38.686	32.196	56.470
Specific Conductance	95	71.084	117.639	103.573	97.432
BOD.5	310	8.280	5.289	3.509	5.693
BOD.C	314	8.772	3.927	1.920	4.873
COD	340	31.064	34.166	28.753	31.328
Alkalinity	410	24.945	27.951	26.004	26.300
Total Solids	500	71.625	88.741	87.654	82.673
Total Dissolved Solids	510	66.100	79.800	70.800	72.200
Total Suspended Solids	530	5.503	8.909	16.871	10.428
Nonfilt. Volatile Solids	535	4.344	6.430	6.520	5.765
Total Nitrogen	600	1.160	0.810	0.630	0.870
Dissolved Ammonia	608	0.236	0.045	0.092	0.124
Ammonia	610	0.254	0.064	0.086	0.135
Nitrite	615	0.000	0.000	0.000	0.000
Dissolved TKN	623	8.846	0.530	0.390	0.589
TKN	625	1.051	0.792	0.584	0.809
Nitrate and Nitrite	630	0.111	0.016	0.041	0.056
Phosphorus	665	0.283	0.205	0.218	0.235
Orthophosphate	671	0.188	0.110	0.096	0.131
TOC	680	18.227	17.614	14.201	16.681
Dissolved Chloride	940	5.261	12.352	10.626	9.413
Chromium Total	1034	0.152	0.226	0.782	0.387
Copper Total	1042	16.747	4.326	6.170	9.081
Lead Total	1051	2.183	8.631	10.353	7.056
Nickel Total	1067	0.454	0.430	0.455	0.446
Zinc Total	1092	0.000	5.108	31.570	12.226
Mercury Total	7900	0.000	0.158	0.246	0.135
Storm Volume (MG)	--	32.2	8.7	238.0	93.0
Ave. Flow (cfs)	--	52.9	23.2	246.1	107.0

TABLE 11

SUMMARY OF LAKE WATER QUALITY STATISTICS

Code	Parameter Description (units)	N	Mean	Std Dev	Maximum	Minimum
10	Temperature, surface (C)	182	21.83	6.65	32.00	11.00
10	Temperature, @ 1 ft. (C)	182	21.56	6.56	32.00	11.00
10	Temperature, @ 2 ft. (C)	182	21.26	6.41	32.00	11.00
76	Turbidity (ntu)	182	10.51	5.37	37.00	2.70
77	Secchi Disk (inches)	181	27.55	8.11	58.80	12.00
80	Color (cobalt plt)	168	91.28	25.61	146.50	8.00
94	Field Specific Cond. (umhos)	182	77.82	23.23	178.00	46.00
95	Lab Specific Cond. (umhos)	182	78.09	20.43	153.00	32.00
300	DO, surface (mg/l)	182	7.17	1.98	14.80	1.40
300	DO, @ 1 ft. (mg/l)	181	6.93	1.83	13.00	1.40
300	DO, @ 2 ft. (mg/l)	181	6.62	2.02	13.20	0.60
310	BOD, 5-Day (mg/l)	182	5.80	2.98	13.00	1.00
314	BOD, Carbonaceous (mg/l)	168	4.29	2.52	11.00	0.00
340	COD, (mg/l)	182	38.71	9.10	71.00	8.00
400	pH (std.)	182	7.00	0.79	9.98	5.28
410	Alkalinity as CaCO3 (mg/l)	182	26.53	8.44	58.00	12.00
500	Total Solids (mg/l)	182	81.19	16.10	135.00	53.00
510	Total Dissolved Solids (mg/l)	182	73.42	14.26	126.00	48.00
530	Total Suspended Solids (mg/l)	182	7.77	4.79	23.00	0.00
535	Nonfilter. Vol. Res. (mg/l)	182	6.20	4.25	21.00	0.00
600	Nitrogen, Total (mg/l)	182	0.88	0.43	3.45	0.00
608	Dissolved Ammonia (mg/l)	182	0.05	0.05	0.25	0.00
610	Ammonia Nitrogen (mg/l)	182	0.05	0.05	0.25	0.00
615	Nitrite (mg/l)	182	0.00	0.00	0.00	0.00
623	Dissolved TKN (mg/l)	182	0.47	0.14	1.18	0.16
625	TKN (mg/l)	182	0.84	0.43	3.45	0.00
630	Nitrate + Nitrite (mg/l)	182	0.04	0.06	0.30	0.00
665	Phosphorus, Total (mg/l)	182	0.26	0.10	0.51	0.00
671	Orthophosphate (mg/l)	182	0.15	0.07	0.40	0.05
680	Total Organic Carbon (mg/l)	182	17.44	3.65	27.40	7.90
940	Dissolved Chloride (mg/l)	182	6.01	1.79	10.90	3.37
1030	Chromium, Dissolved (ug/l)	153	0.67	0.68	3.24	0.00
1034	Chromium, Total (ug/l)	182	0.85	0.74	3.82	0.00
1040	Copper, Dissolved (ug/l)	154	2.45	1.55	7.97	0.00
1042	Copper, Total (ug/l)	182	2.44	1.61	11.20	0.00
1049	Lead, Dissolved (ug/l)	154	2.03	2.29	10.20	0.00
1051	Lead, Total (ug/l)	182	3.08	2.39	12.20	0.00
31501	Coliform (colonies/100 ml)	182	1087.	2870.	26200.	0.
31625	Fecal Coli (colonies/100 ml)	182	74.	120.	800.	0.
31673	Streptococci (col./100 ml)	182	29.	71.	450.	1.
32211	Chlorophyll_a (ug/l)	175	30.19	23.81	98.50	1.12
32218	Phaeophytin (ug/l)	175	2.49	6.39	59.89	0.00
72025	Depth of Lake (feet)	182	4.15	0.75	5.40	1.80

TABLE 12

FLOW WEIGHTED CONSTITUENT CONCENTRATIONS IN STORMWATER INFLOW

Parameter Description	Storet Code	Storm of 2/28	Storm of 5/08	Storm of 6/23	Storm of 9/05	Storm of 11/09	Storm of 11/17	Average All 6
Turbidity	76	34.09	43.95	40.03	21.98	148.42	230.96	86.57
Color	80	103.51	68.72	215.68	74.71	97.52	109.65	111.63
Specific Cond.	95	72.92	81.37	67.63	84.74	121.79	95.80	87.38
BOD.5	310	3.52	5.57	4.25	9.06	12.17	9.09	7.28
BOD.C	314	5.47	2.99	3.25	8.71	7.46	5.09	5.50
COD	340	43.26	44.21	33.53	28.70	53.92	65.54	44.86
Alkalinity	410	22.19	30.29	24.65	31.12	43.95	35.53	31.29
Total Solids	500	121.29	124.59	184.49	96.54	283.19	673.25	247.23
Total Diss. Sol.	510	82.20	86.40	82.55	58.10	119.90	52.60	80.12
Total Susp. Sol.	530	40.12	38.24	101.98	38.42	163.25	620.61	167.11
Nonfil. Vol. Sol.	535	11.87	8.10	24.16	10.04	35.91	127.74	36.30
Total Nitrogen	600	0.73	---	1.02	0.70	1.03	2.74	1.28
Dissolved Ammonia	608	0.05	---	0.12	0.06	0.05	0.16	0.09
Ammonia	610	0.04	---	0.13	0.09	0.08	0.22	0.11
Nitrite	615	0.00	0.02	0.01	0.00	0.01	0.03	0.01
Dissolved TKN	623	0.36	---	0.61	0.43	0.35	0.31	0.41
TKN	625	0.65	---	0.95	0.62	1.03	2.63	1.18
Nitrate + Nitrite	630	0.08	0.24	0.07	0.08	0.00	0.11	0.10
Phosphorus	665	0.32	0.52	0.69	0.36	1.12	1.38	0.73
Orthophosphate	671	0.09	0.11	0.15	0.06	0.14	0.07	0.10
TOC	680	20.08	14.32	17.62	15.69	30.62	39.60	22.99
Diss. Chloride	940	9.23	3.38	3.20	5.52	11.59	9.08	7.00
Chromium Total	1034	4.03	1.64	2.09	6.00	3.19	4.85	3.64
Copper Total	1042	4.15	3.10	10.67	8.13	5.29	24.67	9.34
Lead Total	1051	13.62	10.77	23.54	2.25	29.71	138.41	36.38
Nickel Total	1067	0.21	0.25	0.00	0.44	0.33	---	0.26
Zinc Total	1092	0.82	2.20	0.00	0.00	7.79	197.20	34.67
Mercury Total	7900	0.00	0.00	0.00	0.00	0.27	0.30	0.09
Flow Volume (MG)	--	44.9	60.4	93.9	46.6	27.7	318.8	98.7
Ave. Flow (cfs)	--	119.8	99.3	422.8	76.6	21.5	329.6	178.3

TABLE 13

CONSTITUENT REMOVAL EFFICIENCIES FOR LAKE MUNSON[1]

Parameter Description	Storet Code	Storm of 9\05	Storm of 11/09	Storm of 11/17	Average All Storms	Average Lake Conc.[2]
Turbidity	76	83.74	96.00	90.48	90.07	86.6
Color	80	- 31.89	60.33	70.64	33.03	18.0
Specific Conditions	95	16.12	3.41	- 8.12	3.80	10.4
BOD.5	310	8.57	56.54	61.38	42.16	20.3
BOD.C	314	- 0.66	47.38	62.28	36.33	21.8
COD	340	- 8.24	36.64	56.13	28.18	14.0
Alkalinity	410	19.83	36.41	26.81	27.68	15.3
Total Solids	500	25.01	68.66	86.98	60.49	67.1
Total Dissolved Solids	510	- 14.00	33.00	-34.00	- 5.00	8.0
Total Suspended Solids	530	85.68	94.54	97.28	92.50	95.4
Nonfilt. Volatile Solids	535	56.73	82.09	94.90	77.91	83.0
Total Nitrogen	600	- 65.70	21.33	77.00	10.88	31.3
Dissolved Ammonia	608	-280.65	10.00	42.14	-76.17	44.0
Ammonia	610	-197.66	18.99	60.55	-39.37	54.5
Dissolved TKN	623	- 95.70	-49.30	-26.62	-57.21	-14.6
TKN	625	- 68.94	22.81	77.79	10.55	28.8
Nitrate and Nitrite	630	- 31.56	----	61.32	14.88	60.0
Phosphorus	665	22.14	81.70	84.25	62.69	64.0
Orthophosphate	671	-195.91	24.14	-39.13	-70.30	-50.0
TOC	680	- 16.16	42.48	64.14	30.15	24.3
Dissolved Chloride	940	4.63	- 6.59	-17.00	- 6.32	14.0
Chromium Total	1034	97.47	92.92	83.88	91.42	77.5
Copper Total	1042	-106.04	18.30	74.99	- 4.25	72.0
Lead Total	1051	2.99	70.95	92.52	55.49	91.3
Nickel Total	1067	- 2.76	-31.50	----	-17.13	68.0
Zinc Total	1092	----	34.41	83.99	59.20	84.9
Mercury Total	7900	----	41.04	17.45	29.25	----

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[1] Efficiencies expressed as percent removal: 100*(Input-Output)/Input.

[2] Storm outflow concentrations assumed equal to annual average lake water quality concentrations.

column, nitrate levels are reduced by 60 percent, from the relatively low levels of 0.10 mg/l down to 0.04 mg/l. This would suggest that orthophosphate is released to the water column at a greater rate than it is removed.

In order to further explore the pollutant retention characteristics of Lake Munson, two different techniques were applied to calculate retention capacities of wet detention ponds for total phosphorus and total suspended solids. The method used for computing retention of suspended solids was developed by the EPA (1986), and is based on a statistical technique which uses specific storm characteristics and pond dimensions. Total phosphorus removal was similarly calculated using an empirical approach developed for Corps of Engineers' reservoirs (Walker, 1987) and which is found to apply to urban detention ponds. In addition to storm statistics and pond dimensions, the technique for estimating phosphorus removal also requires input concentrations of orthophosphate and total phosphorus.

The aforementioned techniques were applied to Lake Munson using data generated by this investigation. Removal efficiencies were calculated for different lake dimensions by varying both the lake surface area and depth. The results (Figure 81) were also compared to the observed removal rates for Lake Munson and found to be in excellent agreement, thus verifying the accuracy and applicability of the techniques. Further examination of Figure 81 reveals some interesting relationships between removal rates and pond dimensions. In the case of suspended solids, for example, the results indicate that efficiencies improve considerably with increasing pond area up about 1 percent of the watershed area. Beyond that point, removal rates improve little with increasing pond area. In addition, removal of suspended material seems relatively insensitive to increasing pond depths. On the other hand, phosphorus removal rates seem very sensitive to increasing pond depths, particularly for pond areas larger than 1.5 percent to 2 percent of the watershed, when efficiencies respond more to greater depths than to increased pond area.

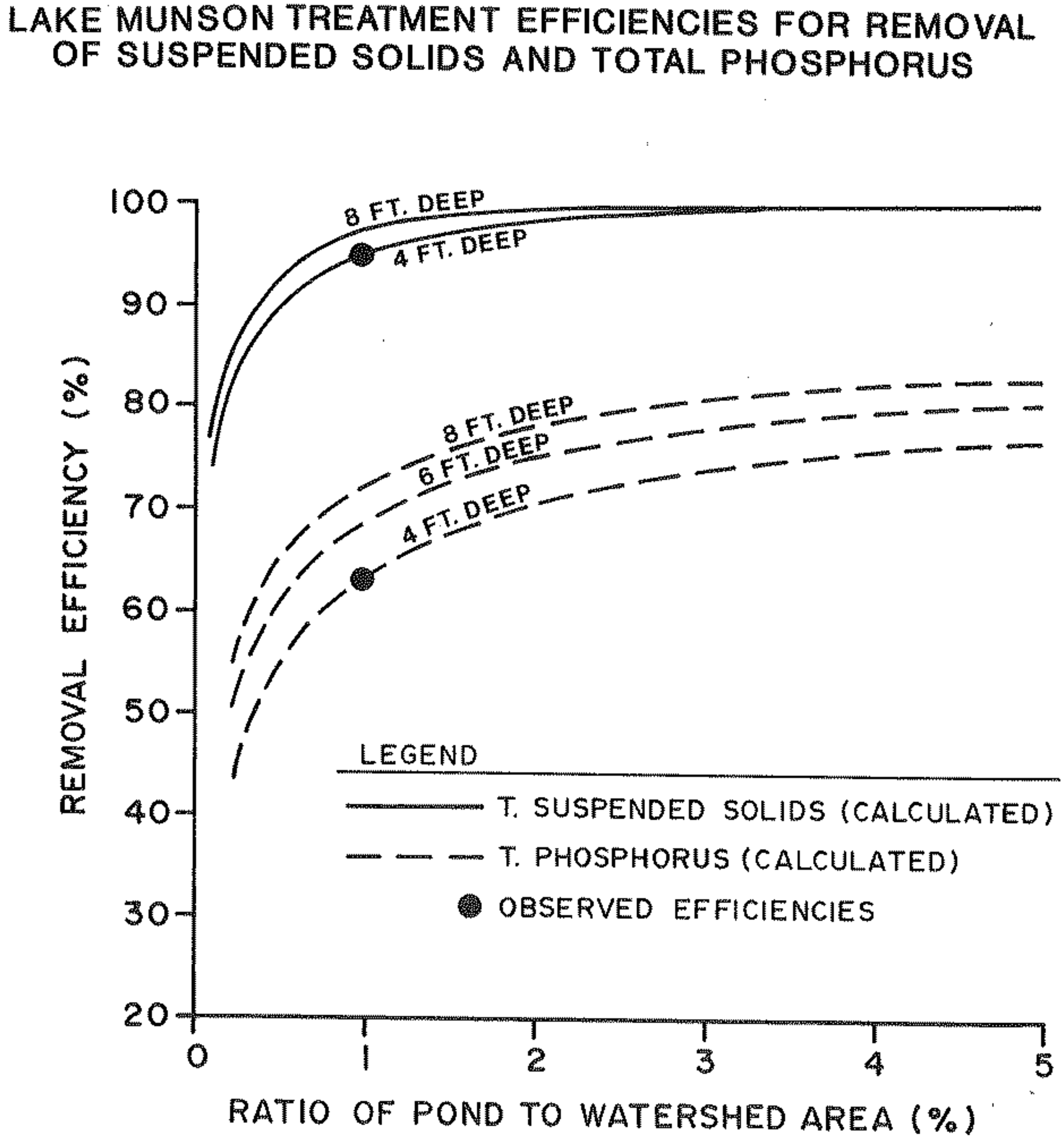

Figure 81. Lake Treatment Efficiencies for Removal of Total Phosphorus and Suspended Solids

LAKE TROPHIC STATE INDEX

It is often useful to express the trophic or nutritional status of a water body in terms of a single value or indicator. Not only does it serve to compare changes in lake trophic conditions with time, but it also provides a means of classifying, comparing, and ranking different lakes on the basis of a single index which reflects the degree of trophic degradation.

A trophic state index (TSI) was developed and used to rank Florida lakes, including Lake Munson, as part of EPA's Clean Lakes Program (Huber and others, 1982). The index is calculated on the basis of lake water quality data including chlorophyll_a, secchi depth, total nitrogen, and total phosphorus. It is designed so that a TSI of 50 would be equivalent to a chlorophyll_a concentration of 10 ug/l, which is generally accepted as the approximate concentration dividing eutrophic and non-eutrophic lakes. A TSI of 60, equivalent to a chlorophyll_a of 20 ug/l, is the desirable upper limit adopted by the Florida DER to define problem lakes.

The Florida trophic index was recalculated for Lake Munson on the basis of data collected as part of this investigation in order to assess the changes that have occurred since the elimination of the wastewater effluent discharges. Since the lake is nitrogen controlled as indicated by an average ratio of total nitrogen to phosphorus of 3.4, the TSI equations for nitrogen controlled lakes were used. Following is a summary of the results for both the 1982 study (Huber and others, 1982) and current data. The 1982 values were developed from a total of 23 lake samples obtained for the period 1966 to 1980. The results are summarized below:

Parameter	1982 Study	1987 Study
Chlorophyll_a (ug/l)	127.1	30.2
Total Nitrogen (mg/l)	4.9	0.89
Total Phosphorus (mg/l)	2.2	0.26
TN/TP Ratio	2.3	3.4
Secchi Depth (ft)	1.3	2.3
TSI	89.5	66.3

An examination of the figures reveals that the trophic status of Lake Munson has improved substantially since the diversion of the wastewater effluent in 1984. The sharp reductions in chlorophyll_a, nitrogen, and phosphorus levels are indicative of a lake which changed from hypereutrophic to eutrophic in a relatively short period time. In fact, whereas in 1982 the lake was ranked as the 7th most degraded lake in the State of Florida, it would currently rank 52nd. In spite of these improvements, however, Lake Munson continues to have trophic problems as evidenced by a TSI greater than 60 and average chlorophyll_a concentrations above 20 ug/l. Nonetheless, the results are proof that restoration measures can have a significant impact in reversing lake degradation.

ALTERNATIVES FOR LAKE RESTORATION

This section offers a brief and general discussion of restoration strategies for Lake Munson. It is not intended to provide an exhaustive analysis of alternatives but rather to present some potentially viable strategies in light of the results from this investigation. A detailed feasibility study of alternatives will be required in order to explore important issues related to economic considerations, engineering and technical feasibility, and environmental impacts.

Prior to undertaking any in-lake restoration work such as sediment removal/stabilization and/or modifications to the hydraulic structure of the lake, it will be advisable to focus on upland alternatives for stormwater treatment. Otherwise, lake restoration efforts will be no more effective than stop-gap measures which are both expensive and provide only temporary and partial relief. State of the art stormwater treatment facilities such as wet detention or retention/detention systems may be implemented at strategic locations in the watershed in order to capture nutrients and toxic substances prior to entering Lake Munson. The effectiveness of these facilities will have to be carefully evaluated, particularly in light of the nitrogen limitation status of Lake Munson. Wet detention systems, for example, are very effective at removing total phosphorus but only moderately effective at removing total nitrogen. Total or partial retention, on the other hand, may not be very effective due to the low percolation capacity of the soils in this area. These systems, however, can be very effective at removing total suspended solids as well as metals, pesticides, and other toxic substances which adsorb to suspended material.

Once lake inflows are improved to a significant degree, in-lake restoration strategies will probably be necessary in order to mitigate the impact of the sediments on the aquatic flora and fauna. The presence of relatively high concentrations of nutrients, metals, pesticides, and other toxic substances in the sediments may short-circuit the food chain and cause imbalances in the ecology of the lake. Restoration of the sediments may be accomplished either totally or partially by chemical stabilization, removal, burial, drawdowns, and flushing with clean oxygenated waters. Some important technical issues associated with the above methods include long and short-term impacts on aquatic life, method of disposal, ability to obtain environmental permits, water quality effects on groundwaters, and impact on lake water levels.

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APPENDIX A

CORRELATION MATRIX OF LAKE WATER QUALITY DATA

Legend:

ALK - Alkalinity, Total
BOD5 - BOD, 5 day
BODC - BOD, Carbonaceous
CHLA - Chlorophyll_a
CL - Chloride, Total
COD - Chemical Oxygen Demand
COLI - Coliform, Total
COLOR - Color
COND - Conductivity, Lab
CR - Chromium, Total
CU - Copper, Total
DCR - Chromium, Dissolved
DCU - Copper, Dissolved
DEEP - Depth of Lake
DNH3 - Nitrogen, Ammonia, Dissolved
DO00 - Oxygen, Dissolved, 0 ft
DO1FT - Oxygen, Dissolved, 1 ft
DO2FT - Oxygen, Dissolved, 2 ft
DPB - Lead, Dissolved
DTKN - Nitrogen, Kjeldahl, Dissolved
FCOND - Conductivity, Field
FECAL - Coliform, Fecal
IN/OP - Ratio of Inorganic Nitrogen to Orthophosphate
NH3 - Nitrogen, Ammonia, Total
NO32 - Nitrite plus Nitrate, Total
N/P - Ratio of Total Nitrogen to Total Phosphorus
NVR - Residue, Volatile, Nonfiltrable
OP - Orthophosphate
PB - Lead, Total
PH - ph
PHYT - Phaeophytin
SECI - Secchi
SS - Residue, Total, Nonfiltrable
STREP - Streptococci, Fecal
TDS - Filterable Residue, Total
TKN - Nitrogen, Kjeldahl, Total
TN - Nitrogen, Total
TOC - Carbon, Total Organic
TS - Total Solids
TSURF - Temperature, Water, Surface
TP - Phosphorus, Total
TURB - Turbidity
T1FT - Temperature, Water, 1 ft
T2FT - Temperature, Water, 2 ft

Note: Prefix L indicates log of data.

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA

	TURB	SECI	COLOR	FCOND	COND	BOD5	BODC	COD	ALK	TS	TDS	SS	NVR	TN
SECI	-0.407													
COLOR	0.032	-0.357												
FCOND	0.192	0.102	-0.601											
COND	0.140	0.164	-0.648	0.964										
BOD5	-0.047	-0.053	-0.254	0.315	0.349									
BODC	-0.022	0.020	-0.244	0.287	0.329	0.910								
COD	-0.120	-0.149	0.327	-0.165	-0.246	0.011	-0.030							
ALK	0.240	0.095	-0.323	0.885	0.861	0.270	0.296	-0.186						
TS	0.218	-0.192	0.035	0.659	0.633	0.238	0.118	0.140	0.592					
TDS	0.086	-0.029	0.063	0.651	0.635	0.125	-0.001	0.095	0.591	0.957				
SS	0.478	-0.558	-0.050	0.279	0.235	0.427	0.321	0.187	0.234	0.511	0.242			
NVR	0.313	-0.469	-0.101	0.318	0.276	0.503	0.404	0.197	0.272	0.526	0.281	0.932		
TN	0.231	-0.350	-0.100	0.442	0.387	0.470	0.397	0.279	0.418	0.585	0.412	0.742	0.820	
N/P	-0.155	0.100	-0.198	0.119	0.133	0.178	0.166	0.069	0.014	0.126	0.120	0.068	0.163	0.227
DNH3	-0.060	0.090	0.032	0.508	0.489	0.086	0.016	-0.210	0.438	0.276	0.354	-0.126	-0.109	0.005
NH3	-0.048	0.045	0.102	0.478	0.460	0.088	0.018	-0.233	0.449	0.246	0.321	-0.126	-0.129	-0.036
DTKN	-0.335	-0.075	0.060	0.161	0.186	0.329	0.264	0.154	0.096	0.256	0.239	0.148	0.199	0.205
TKN	0.206	-0.386	-0.075	0.404	0.352	0.492	0.406	0.298	0.369	0.579	0.394	0.773	0.846	0.991
NO32	0.155	0.310	-0.184	0.228	0.212	-0.215	-0.118	-0.166	0.311	-0.019	0.082	-0.307	-0.277	-0.041
TP	0.387	-0.426	0.186	0.289	0.226	0.182	0.107	0.197	0.413	0.474	0.333	0.602	0.551	0.574
OP	0.176	-0.187	0.361	0.406	0.338	0.076	-0.054	0.224	0.544	0.520	0.478	0.324	0.314	0.394
TOC	-0.229	-0.314	0.189	-0.206	-0.250	0.271	0.224	0.565	-0.264	0.161	0.048	0.398	0.471	0.443
IN/OP	0.118	0.294	-0.187	0.111	0.110	-0.258	-0.163	-0.198	0.176	-0.122	-0.025	-0.335	-0.327	-0.126
CL	-0.096	0.117	-0.408	0.655	0.703	0.308	0.146	0.010	0.346	0.465	0.458	0.198	0.232	0.290
DCR	0.071	0.078	-0.168	0.095	0.045	-0.024	0.049	0.069	0.096	-0.049	-0.082	0.056	0.005	0.031
CR	0.158	-0.111	-0.092	-0.155	-0.162	-0.143	-0.116	-0.072	-0.166	-0.141	-0.194	0.104	0.038	-0.057
DCU	0.067	0.181	-0.324	0.162	0.173	-0.172	-0.112	-0.039	0.225	-0.208	-0.214	-0.084	-0.150	-0.090
CU	0.124	-0.068	-0.241	-0.150	-0.134	-0.093	-0.016	-0.084	-0.160	-0.282	-0.329	0.030	-0.038	-0.109
DPB	-0.069	0.059	-0.158	0.244	0.278	-0.024	-0.024	0.008	-0.030	0.141	0.142	0.063	0.114	0.097
PB	0.155	-0.077	-0.101	0.177	0.205	-0.055	-0.063	-0.011	0.026	0.215	0.173	0.207	0.191	0.116
COLI	-0.126	-0.195	0.231	-0.140	-0.159	-0.092	-0.148	-0.035	-0.134	-0.189	-0.198	-0.046	-0.108	-0.095
FECAL	0.186	-0.229	0.237	-0.061	-0.061	-0.199	-0.243	-0.178	-0.030	-0.145	-0.158	-0.019	-0.122	-0.104
STREP	0.673	-0.303	0.162	-0.093	-0.102	-0.219	-0.185	-0.207	-0.085	-0.077	-0.105	0.054	-0.123	-0.196
CHLA	-0.028	-0.384	0.099	0.088	0.088	0.308	0.204	0.008	0.110	0.252	0.139	0.433	0.505	0.426

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

	TURB	SECI	COLOR	FCOND	COND	BOD5	BODC	COD	ALK	TS	TDS	SS	NVR	TN
PHYT	0.175	-0.200	0.106	0.086	0.031	0.110	0.129	0.175	0.121	0.320	0.226	0.404	0.412	0.384
DEEP	0.084	0.095	-0.042	-0.210	-0.228	-0.029	-0.008	0.003	-0.135	-0.210	-0.228	-0.027	-0.020	-0.003
TSURF	-0.185	-0.452	0.295	-0.173	-0.196	0.206	0.134	0.232	-0.074	0.152	0.033	0.412	0.473	0.366
T1FT	-0.191	-0.449	0.288	-0.177	-0.198	0.200	0.128	0.230	-0.078	0.153	0.035	0.410	0.469	0.364
T2FT	-0.186	-0.456	0.281	-0.183	-0.206	0.193	0.125	0.228	-0.081	0.147	0.028	0.412	0.471	0.365
DO00	0.307	-0.097	-0.387	-0.073	-0.089	0.040	0.146	0.143	-0.142	-0.003	-0.117	0.339	0.375	0.334
DO1FT	0.337	0.041	-0.444	0.158	0.142	0.057	0.145	0.033	0.073	0.136	0.061	0.267	0.296	0.286
DO2FT	0.349	0.131	-0.472	0.265	0.243	0.007	0.100	-0.009	0.175	0.155	0.106	0.200	0.210	0.216
PH	0.252	-0.283	-0.314	0.283	0.224	0.409	0.381	0.236	0.205	0.284	0.092	0.680	0.749	0.718
LTURB	0.943	-0.333	-0.051	0.272	0.221	-0.063	-0.033	-0.083	0.317	0.295	0.169	0.489	0.348	0.298
LSECI	-0.472	0.978	-0.343	0.097	0.164	-0.079	-0.011	-0.145	0.086	-0.205	-0.027	-0.607	-0.517	-0.401
LCOLOR	0.067	-0.324	0.927	-0.539	-0.587	-0.266	-0.242	0.324	-0.198	0.032	0.055	-0.039	-0.099	-0.070
LFCOND	0.230	0.113	-0.620	0.974	0.952	0.312	0.269	-0.185	0.864	0.607	0.583	0.305	0.341	0.472
LCOND	0.161	0.176	-0.651	0.913	0.976	0.340	0.297	-0.268	0.824	0.579	0.570	0.252	0.292	0.403
LBOD5	-0.022	-0.032	-0.264	0.309	0.330	0.947	0.834	-0.076	0.280	0.151	0.032	0.413	0.476	0.414
LBODC	-0.051	0.050	-0.157	0.215	0.234	0.643	0.761	0.004	0.302	0.089	0.020	0.196	0.283	0.276
LCOD	-0.118	-0.113	0.266	-0.149	-0.215	0.048	-0.027	0.959	-0.170	0.133	0.090	0.180	0.176	0.255
LALK	0.261	0.091	-0.341	0.824	0.812	0.272	0.290	-0.180	0.975	0.532	0.512	0.266	0.303	0.447
LTS	0.230	-0.196	0.010	0.616	0.600	0.214	0.102	0.138	0.554	0.991	0.947	0.513	0.525	0.579
LTDS	0.094	-0.030	0.037	0.608	0.602	0.109	0.002	0.096	0.550	0.950	0.990	0.245	0.287	0.418
LTSS	0.255	-0.419	0.008	0.095	0.090	0.298	0.216	0.046	0.044	0.245	0.037	0.711	0.640	0.364
LNVR	0.162	-0.369	-0.024	0.138	0.138	0.354	0.273	0.038	0.092	0.283	0.086	0.697	0.713	0.432
LTN	0.167	-0.226	-0.181	0.428	0.398	0.379	0.301	0.190	0.419	0.478	0.351	0.562	0.622	0.810
LN/P	-0.259	0.135	-0.344	0.221	0.244	0.322	0.290	0.063	0.062	0.172	0.155	0.117	0.265	0.399
LDNH3	-0.146	0.230	0.007	0.309	0.310	-0.056	-0.060	-0.181	0.212	0.081	0.207	-0.343	-0.345	-0.235
LNH3	-0.112	0.135	0.088	0.319	0.322	0.001	-0.012	-0.207	0.276	0.085	0.192	-0.286	-0.301	-0.190
LDTKN	-0.368	-0.057	0.066	0.159	0.180	0.339	0.271	0.205	0.101	0.267	0.243	0.175	0.222	0.249
LTKN	0.130	-0.268	-0.147	0.392	0.364	0.413	0.320	0.223	0.371	0.482	0.340	0.606	0.663	0.813
LNO32	0.282	0.210	-0.134	0.250	0.207	-0.181	-0.104	-0.069	0.288	0.012	0.098	-0.252	-0.247	-0.049
LTP	0.357	-0.342	0.104	0.255	0.205	0.137	0.084	0.153	0.370	0.360	0.243	0.486	0.434	0.503
LOP	0.180	-0.209	0.376	0.315	0.235	0.045	-0.045	0.254	0.505	0.449	0.402	0.312	0.309	0.380
LTOC	-0.288	-0.280	0.204	-0.229	-0.265	0.263	0.201	0.577	-0.302	0.150	0.049	0.357	0.419	0.391
LIN/OP	0.285	0.170	-0.118	0.173	0.129	-0.174	-0.094	-0.045	0.193	-0.054	0.023	-0.251	-0.259	-0.094
LCL	-0.092	0.127	-0.375	0.630	0.679	0.285	0.122	0.050	0.338	0.440	0.433	0.189	0.223	0.303

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

	TURB	SECI	COLOR	FCOND	COND	BOD5	BODC	COD	ALK	TS	TDS	SS	NVR	TN
LDCR	0.110	0.121	-0.168	0.158	0.105	-0.007	0.065	0.071	0.062	0.137	0.090	0.173	0.120	0.111
LCR	0.119	-0.081	-0.062	-0.304	-0.293	-0.216	-0.144	-0.002	-0.325	-0.113	-0.162	0.104	0.045	-0.042
LDCU	0.177	0.104	-0.332	0.235	0.295	-0.146	-0.095	-0.069	0.216	-0.031	-0.068	0.071	-0.004	0.005
LCU	0.075	-0.115	-0.112	-0.379	-0.361	-0.245	-0.175	-0.008	-0.387	-0.372	-0.413	-0.021	-0.080	-0.158
LDPB	0.101	0.067	-0.189	0.304	0.288	-0.082	-0.073	0.011	0.145	0.185	0.168	0.124	0.138	0.148
LPB	0.308	-0.106	-0.052	0.188	0.180	-0.244	-0.269	0.035	0.095	0.290	0.247	0.240	0.185	0.140
LCOLI	-0.029	-0.120	0.443	-0.676	-0.665	-0.293	-0.269	-0.034	-0.589	-0.562	-0.564	-0.213	-0.299	-0.332
LFECAL	0.121	-0.045	0.259	-0.128	-0.135	-0.207	-0.254	-0.155	-0.079	-0.217	-0.179	-0.196	-0.302	-0.278
LSTREP	0.400	-0.246	0.303	-0.100	-0.107	-0.272	-0.232	-0.390	-0.035	-0.194	-0.186	-0.099	-0.222	-0.246
LCHLA	-0.134	-0.306	0.071	0.116	0.134	0.361	0.261	-0.037	0.146	0.240	0.138	0.398	0.468	0.365
LPHYT	0.156	-0.154	0.130	0.047	-0.035	-0.153	-0.118	0.194	0.098	0.271	0.238	0.205	0.145	0.161
LDEEP	0.087	0.099	-0.048	-0.194	-0.213	-0.012	0.008	0.005	-0.124	-0.199	-0.219	-0.017	-0.009	0.004
LTSURF	-0.186	-0.443	0.284	-0.132	-0.155	0.215	0.147	0.241	-0.051	0.178	0.059	0.423	0.483	0.370
LT1FT	-0.192	-0.442	0.278	-0.137	-0.159	0.207	0.139	0.238	-0.058	0.178	0.059	0.421	0.480	0.367
LT2FT	-0.189	-0.448	0.274	-0.147	-0.170	0.198	0.134	0.235	-0.064	0.168	0.048	0.419	0.479	0.366
LDO00	0.264	-0.027	-0.414	-0.224	-0.208	-0.032	0.128	0.099	-0.253	-0.135	-0.225	0.216	0.232	0.193
LDO1FT	0.300	0.113	-0.446	0.145	0.143	0.048	0.151	0.015	0.069	0.119	0.066	0.198	0.215	0.225
LDO2FT	0.320	0.181	-0.452	0.253	0.239	0.009	0.101	-0.000	0.164	0.155	0.119	0.165	0.158	0.185
LPH	0.246	-0.267	-0.325	0.294	0.240	0.425	0.403	0.219	0.220	0.277	0.087	0.673	0.738	0.710

	N/P	DNH3	NH3	DTKN	TKN	NO32	TP	OP	TOC	IN/OP	CL	DCR	CR	DCU
DNH3	-0.049													
NH3	-0.101	0.960												
DTKN	0.196	0.325	0.324											
TKN	0.215	-0.007	-0.043	0.237										
NO32	0.064	0.088	0.054	-0.255	-0.176									
TP	-0.348	0.088	0.125	0.058	0.598	-0.239								
OP	-0.211	0.266	0.306	0.122	0.411	-0.168	0.801							
TOC	0.176	-0.265	-0.267	0.335	0.491	-0.404	0.225	0.150						
IN/OP	0.086	-0.023	-0.057	-0.303	-0.252	0.943	-0.341	-0.304	-0.410					
CL	0.301	0.320	0.266	0.353	0.290	-0.033	-0.046	0.010	0.054	-0.077				
DCR	-0.046	-0.010	0.021	-0.023	0.012	0.187	0.023	-0.011	0.161	0.146	-0.075			
CR	-0.056	-0.100	-0.068	-0.103	-0.050	-0.042	-0.050	-0.161	0.099	-0.000	-0.166	0.703		
DCU	-0.097	-0.174	-0.184	-0.192	-0.131	0.424	-0.078	-0.058	-0.189	0.427	-0.031	0.316	0.178	

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

	N/P	DNH3	NH3	DTKN	TKN	NO32	TP	OP	TOC	IN/OP	CL	DCR	CR	DCU
CU	-0.097	-0.188	-0.156	-0.183	-0.109	0.012	-0.071	-0.206	0.092	0.054	-0.068	0.180	0.348	0.477
DPB	0.029	0.048	-0.015	0.247	0.098	-0.022	0.021	0.014	0.236	-0.072	0.460	0.055	0.015	0.081
PB	-0.040	0.053	0.037	0.205	0.131	-0.119	0.152	0.075	0.148	-0.148	0.434	0.055	0.110	0.030
COLI	-0.037	-0.011	-0.000	0.052	-0.080	-0.101	-0.104	-0.062	0.014	-0.071	-0.059	-0.086	-0.016	0.061
FECAL	-0.061	0.024	0.032	-0.123	-0.110	0.055	-0.054	-0.049	-0.225	0.101	-0.077	-0.165	0.026	0.046
STREP	-0.137	-0.024	-0.004	-0.303	-0.215	0.160	-0.065	-0.192	-0.352	0.226	-0.142	-0.138	0.038	-0.024
CHLA	0.054	0.018	0.021	0.254	0.477	-0.447	0.398	0.276	0.300	-0.470	0.099	-0.133	-0.021	-0.355
PHYT	0.030	-0.115	-0.112	0.089	0.391	-0.096	0.357	0.271	0.185	-0.131	-0.063	-0.044	-0.051	0.001
DEEP	-0.248	-0.176	-0.147	-0.278	-0.003	-0.004	0.202	0.119	-0.126	-0.043	-0.302	-0.057	-0.120	-0.004
TSURF	-0.046	-0.081	-0.026	0.312	0.441	-0.589	0.508	0.399	0.567	-0.638	-0.144	-0.148	-0.006	-0.374
T1FT	-0.045	-0.084	-0.029	0.313	0.439	-0.594	0.506	0.398	0.563	-0.640	-0.147	-0.142	0.001	-0.372
T2FT	-0.045	-0.099	-0.042	0.295	0.441	-0.592	0.511	0.394	0.561	-0.637	-0.164	-0.132	0.014	-0.363
DO00	0.127	-0.432	-0.503	-0.336	0.311	0.133	0.038	-0.261	0.165	0.154	0.010	0.135	0.172	0.146
DO1FT	0.125	-0.324	-0.388	-0.343	0.249	0.244	-0.001	-0.226	-0.012	0.266	0.102	0.181	0.151	0.207
DO2FT	0.133	-0.297	-0.347	-0.367	0.170	0.315	-0.050	-0.197	-0.118	0.330	0.149	0.234	0.134	0.289
PH	0.195	-0.150	-0.178	0.102	0.710	-0.018	0.360	0.124	0.466	-0.078	0.257	0.138	0.093	0.022
LTURB	-0.149	-0.110	-0.117	-0.361	0.267	0.196	0.436	0.244	-0.184	0.144	-0.048	0.155	0.183	0.153
LSECI	0.088	0.120	0.079	-0.046	-0.434	0.286	-0.446	-0.181	-0.315	0.271	0.133	0.092	-0.089	0.184
LCOLOR	-0.223	0.003	0.058	0.003	-0.056	-0.101	0.217	0.348	0.131	-0.103	-0.464	-0.172	-0.118	-0.235
LFCOND	0.147	0.443	0.407	0.128	0.427	0.278	0.280	0.342	-0.229	0.160	0.645	0.076	-0.134	0.190
LCOND	0.154	0.417	0.380	0.154	0.363	0.246	0.215	0.278	-0.267	0.149	0.677	0.014	-0.154	0.207
LBOD5	0.186	0.034	0.045	0.288	0.433	-0.188	0.132	0.017	0.217	-0.226	0.303	-0.031	-0.135	-0.159
LBODC	0.162	-0.008	0.011	0.233	0.283	-0.081	0.022	-0.070	0.170	-0.127	0.108	0.099	-0.071	-0.103
LCOD	0.072	-0.220	-0.235	0.175	0.274	-0.167	0.180	0.211	0.533	-0.181	0.028	0.037	-0.094	-0.010
LALK	0.019	0.357	0.366	0.078	0.396	0.326	0.439	0.518	-0.262	0.189	0.292	0.059	-0.167	0.226
LTS	0.134	0.234	0.198	0.242	0.572	-0.010	0.470	0.490	0.168	-0.116	0.449	-0.047	-0.123	-0.199
LTDS	0.136	0.307	0.266	0.222	0.398	0.095	0.324	0.443	0.058	-0.012	0.442	-0.083	-0.177	-0.209
LTSS	-0.052	-0.037	-0.031	0.111	0.421	-0.459	0.435	0.199	0.216	-0.440	0.130	0.065	0.082	-0.055
LNVR	0.010	-0.019	-0.025	0.158	0.486	-0.449	0.427	0.213	0.260	-0.450	0.153	0.001	0.045	-0.146
LTN	0.193	0.015	-0.008	0.018	0.799	-0.007	0.586	0.378	0.284	-0.087	0.276	0.042	-0.085	-0.051
LN/P	0.845	-0.057	-0.131	0.261	0.370	0.166	-0.432	-0.333	0.251	0.196	0.440	-0.006	-0.058	-0.060
LDNH3	-0.063	0.884	0.820	0.256	-0.247	0.119	-0.126	0.061	-0.305	0.034	0.275	-0.057	-0.128	-0.071
LNH3	-0.122	0.869	0.901	0.302	-0.194	0.047	-0.017	0.169	-0.283	-0.057	0.238	-0.004	-0.069	-0.099
LDTKN	0.188	0.296	0.304	0.972	0.281	-0.265	0.115	0.171	0.368	-0.321	0.356	0.013	-0.101	-0.182

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

	N/P	DNH3	NH3	DTKN	TKN	NO32	TP	OP	TOC	IN/OP	CL	DCR	CR	DCU
LTKN	0.178	0.012	-0.005	0.078	0.823	-0.161	0.617	0.406	0.355	-0.238	0.284	0.023	-0.083	-0.105
LNO32	-0.011	0.142	0.110	-0.337	-0.169	0.883	-0.187	-0.106	-0.368	0.831	-0.055	0.163	-0.010	0.346
LTP	-0.556	0.063	0.097	-0.103	0.516	-0.149	0.899	0.644	0.117	-0.253	-0.060	0.044	-0.040	-0.021
LOP	-0.233	0.191	0.237	0.066	0.392	-0.132	0.786	0.967	0.155	-0.290	-0.134	0.008	-0.129	-0.043
LTOC	0.170	-0.279	-0.277	0.360	0.444	-0.436	0.192	0.138	0.985	-0.430	0.070	0.127	0.065	-0.205
LIN/OP	-0.023	0.104	0.081	-0.363	-0.202	0.804	-0.227	-0.169	-0.329	0.786	-0.102	0.150	0.016	0.321
LCL	0.315	0.282	0.228	0.327	0.296	0.017	-0.055	0.007	0.064	-0.031	0.988	-0.097	-0.179	-0.002
LDCR	0.024	-0.174	-0.196	0.022	0.098	0.126	-0.004	-0.067	0.161	0.088	0.095	0.764	0.571	0.349
LCR	0.033	-0.315	-0.301	-0.126	-0.040	-0.009	-0.153	-0.316	0.128	0.051	-0.121	0.543	0.741	0.166
LDCU	-0.070	-0.123	-0.163	-0.126	-0.024	0.290	-0.006	-0.017	-0.070	0.277	0.101	0.272	0.162	0.780
LCU	-0.061	-0.323	-0.280	-0.162	-0.163	0.057	-0.135	-0.286	0.160	0.108	-0.145	0.255	0.357	0.575
LDPB	-0.053	-0.089	-0.145	-0.009	0.130	0.169	0.099	0.102	0.150	0.124	0.301	0.222	0.144	0.319
LPB	-0.040	-0.089	-0.100	-0.030	0.137	0.007	0.181	0.133	0.087	-0.006	0.331	0.180	0.247	0.203
LCOLI	-0.044	-0.331	-0.289	-0.185	-0.332	0.035	-0.283	-0.353	-0.036	0.126	-0.494	-0.079	0.115	0.026
LFECAL	-0.040	0.024	0.054	-0.166	-0.300	0.186	-0.212	-0.128	-0.299	0.255	-0.174	-0.130	-0.034	0.108
LSTREP	-0.143	0.054	0.096	-0.276	-0.278	0.260	-0.175	-0.189	-0.415	0.337	-0.240	-0.211	0.026	0.012
LCHLA	0.039	0.099	0.099	0.345	0.429	-0.540	0.402	0.307	0.269	-0.572	0.114	-0.129	-0.086	-0.355
LPHYT	-0.007	-0.030	-0.039	-0.006	0.169	-0.083	0.308	0.320	0.097	-0.124	-0.157	0.000	-0.012	0.088
LDEEP	-0.232	-0.175	-0.149	-0.271	0.004	-0.005	0.203	0.124	-0.119	-0.045	-0.287	-0.046	-0.116	-0.003
LTSURF	-0.039	-0.034	0.020	0.355	0.450	-0.622	0.513	0.408	0.557	-0.688	-0.092	-0.131	-0.002	-0.382
LT1FT	-0.038	-0.038	0.016	0.354	0.447	-0.627	0.511	0.405	0.554	-0.690	-0.095	-0.128	0.006	-0.379
LT2FT	-0.038	-0.052	0.003	0.337	0.445	-0.625	0.513	0.400	0.551	-0.686	-0.113	-0.120	0.017	-0.372
LDO00	0.093	-0.526	-0.571	-0.390	0.173	0.126	-0.030	-0.332	0.097	0.163	-0.091	0.152	0.190	0.175
LDO1FT	0.111	-0.322	-0.373	-0.335	0.190	0.232	-0.029	-0.231	-0.065	0.256	0.091	0.181	0.120	0.208
LDO2FT	0.124	-0.277	-0.323	-0.327	0.144	0.281	-0.050	-0.171	-0.146	0.292	0.149	0.205	0.069	0.271
LPH	0.188	-0.135	-0.156	0.125	0.702	-0.020	0.370	0.132	0.445	-0.082	0.270	0.146	0.088	0.037

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

	CU	DPB	PB	COLI	FECAL	STREP	CHLA	PHYT	DEEP	TSURF	T1FT	T2FT	DO00	DO1FT
DPB	0.029													
PB	0.045	0.823												
COLI	0.202	-0.157	-0.203											
FECAL	0.214	-0.156	-0.133	0.748										
STREP	0.099	-0.122	0.058	0.091	0.348									
CHLA	-0.245	0.170	0.130	0.004	-0.032	-0.224								
PHYT	-0.164	-0.046	0.030	-0.091	-0.130	-0.086	0.107							
DEEP	0.051	-0.142	-0.161	0.042	-0.011	0.029	-0.072	0.037						
TSURF	-0.069	0.127	0.103	0.048	-0.107	-0.309	0.640	0.216	-0.030					
T1FT	-0.063	0.112	0.094	0.053	-0.107	-0.310	0.634	0.219	-0.025	0.998				
T2FT	-0.054	0.101	0.082	0.061	-0.101	-0.309	0.630	0.228	-0.017	0.995	0.997			
DO00	0.231	0.071	0.082	-0.259	-0.205	0.049	0.011	0.254	0.142	-0.103	-0.094	-0.085		
DO1FT	0.170	-0.026	0.018	-0.301	-0.254	0.091	-0.159	0.210	0.132	-0.322	-0.307	-0.298	0.890	
DO2FT	0.172	-0.027	0.013	-0.272	-0.185	0.103	-0.278	0.160	0.146	-0.462	-0.449	-0.438	0.755	0.920
PH	0.138	0.216	0.199	-0.124	-0.196	-0.143	0.295	0.271	-0.006	0.295	0.291	0.293	0.601	0.500
LTURB	0.141	-0.045	0.162	-0.192	0.114	0.476	-0.031	0.216	0.088	-0.219	-0.223	-0.218	0.390	0.437
LSECI	-0.070	0.035	-0.089	-0.200	-0.249	-0.359	-0.389	-0.210	0.058	-0.447	-0.441	-0.449	-0.137	0.010
LCOLOR	-0.192	-0.236	-0.164	0.207	0.233	0.158	0.030	0.111	-0.012	0.224	0.218	0.213	-0.312	-0.363
LFCOND	-0.090	0.207	0.175	-0.138	-0.030	-0.085	0.085	0.119	-0.191	-0.188	-0.190	-0.193	0.033	0.232
LCOND	-0.083	0.244	0.204	-0.165	-0.036	-0.097	0.089	0.057	-0.212	-0.195	-0.196	-0.201	-0.001	0.196
LBOD5	-0.074	-0.039	-0.060	-0.046	-0.150	-0.186	0.324	0.071	-0.022	0.192	0.184	0.178	0.033	0.038
LBODC	-0.097	-0.046	-0.057	-0.118	-0.308	-0.176	0.198	0.087	-0.086	0.123	0.119	0.118	0.104	0.133
LCOD	-0.074	-0.038	-0.040	-0.014	-0.145	-0.197	-0.012	0.158	0.003	0.195	0.197	0.195	0.089	-0.000
LALK	-0.120	-0.025	0.012	-0.134	-0.017	-0.096	0.137	0.159	-0.102	-0.031	-0.035	-0.035	-0.070	0.103
LTS	-0.259	0.164	0.237	-0.201	-0.145	-0.067	0.266	0.312	-0.212	0.175	0.176	0.172	0.035	0.151
LTDS	-0.308	0.156	0.186	-0.209	-0.155	-0.098	0.155	0.227	-0.228	0.053	0.055	0.049	-0.068	0.087
LTSS	0.062	0.077	0.142	0.028	0.038	0.064	0.368	0.214	0.008	0.373	0.376	0.377	0.160	0.095
LNVR	0.000	0.150	0.152	-0.033	-0.030	-0.049	0.441	0.233	-0.010	0.444	0.446	0.448	0.162	0.091
LTN	-0.100	-0.017	0.008	-0.072	-0.106	-0.244	0.333	0.297	0.068	0.296	0.292	0.303	0.276	0.258
LN/P	-0.101	0.103	-0.024	-0.028	-0.105	-0.255	0.074	0.033	-0.297	-0.083	-0.084	-0.086	0.206	0.216
LDNH3	-0.114	0.076	0.060	0.038	0.064	0.018	-0.186	-0.176	-0.186	-0.237	-0.242	-0.255	-0.423	-0.341
LNH3	-0.090	0.025	0.055	0.057	0.081	0.019	-0.117	-0.168	-0.152	-0.122	-0.124	-0.137	-0.522	-0.426
LDTKN	-0.197	0.221	0.171	0.058	-0.161	-0.369	0.281	0.110	-0.235	0.348	0.349	0.334	-0.333	-0.348
LTKN	-0.109	-0.007	0.029	-0.056	-0.123	-0.281	0.406	0.312	0.064	0.396	0.392	0.402	0.246	0.207

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

	CU	DPB	PB	COLI	FECAL	STREP	CHLA	PHYT	DEEP	TSURF	T1FT	T2FT	D000	DO1FT
LNO32	0.083	-0.077	-0.118	-0.117	0.075	0.259	-0.506	-0.057	-0.011	-0.632	-0.636	-0.634	0.191	0.297
LTP	-0.033	-0.057	0.058	-0.057	-0.033	-0.048	0.295	0.276	0.267	0.384	0.381	0.391	0.097	0.068
LOP	-0.177	-0.072	-0.034	-0.029	-0.030	-0.192	0.272	0.288	0.170	0.430	0.429	0.431	-0.223	-0.211
LTOC	0.067	0.226	0.131	0.031	-0.214	-0.374	0.301	0.180	-0.128	0.550	0.546	0.543	0.100	-0.071
LIN/OP	0.137	-0.134	-0.157	-0.103	0.086	0.298	-0.542	-0.069	-0.024	-0.637	-0.640	-0.638	0.215	0.310
LCL	-0.032	0.436	0.416	-0.029	-0.034	-0.131	0.068	-0.054	-0.274	-0.160	-0.163	-0.180	0.040	0.116
LDCR	0.171	0.173	0.240	-0.073	-0.179	-0.150	-0.141	0.078	-0.098	-0.203	-0.195	-0.182	0.271	0.343
LCR	0.298	0.064	0.203	0.022	-0.031	0.088	-0.101	0.053	-0.019	-0.067	-0.048	-0.033	0.386	0.343
LDCU	0.414	0.166	0.168	0.033	0.077	0.049	-0.298	0.050	-0.070	-0.321	-0.319	-0.312	0.199	0.214
LCU	0.714	0.114	0.135	0.148	0.153	0.133	-0.226	-0.069	0.018	-0.009	0.004	0.015	0.333	0.169
LDPB	0.144	0.733	0.650	-0.073	-0.044	-0.037	0.042	0.009	-0.028	-0.040	-0.055	-0.060	0.206	0.139
LPB	0.168	0.550	0.734	-0.101	-0.030	0.097	0.006	0.079	-0.098	-0.023	-0.023	-0.030	0.219	0.209
LCOLI	0.207	-0.409	-0.304	0.452	0.511	0.206	-0.146	-0.127	0.123	-0.070	-0.069	-0.056	-0.036	-0.199
LFECAL	0.097	-0.375	-0.318	0.425	0.715	0.270	-0.223	-0.171	-0.023	-0.340	-0.344	-0.342	-0.271	-0.266
LSTREP	0.088	-0.208	-0.082	0.258	0.526	0.710	-0.224	-0.102	-0.062	-0.288	-0.292	-0.291	-0.131	-0.097
LCHLA	-0.259	0.176	0.113	0.031	-0.048	-0.310	0.911	0.095	-0.056	0.691	0.686	0.681	-0.116	-0.266
LPHYT	-0.075	-0.194	0.006	-0.021	-0.076	-0.026	-0.079	0.616	0.012	0.093	0.108	0.122	0.096	0.118
LDEEP	0.057	-0.133	-0.151	0.041	-0.014	0.023	-0.067	0.029	0.993	-0.025	-0.019	-0.012	0.143	0.139
LTSURF	-0.087	0.142	0.129	0.048	-0.114	-0.327	0.642	0.227	-0.052	0.991	0.989	0.986	-0.117	-0.325
LT1FT	-0.078	0.131	0.123	0.051	-0.113	-0.328	0.637	0.230	-0.048	0.989	0.991	0.989	-0.107	-0.311
LT2FT	-0.071	0.124	0.112	0.058	-0.107	-0.326	0.633	0.237	-0.042	0.987	0.989	0.991	-0.098	-0.305
LD000	0.253	0.031	0.035	-0.256	-0.189	0.064	-0.051	0.191	0.181	-0.127	-0.116	-0.102	0.952	0.825
LDO1FT	0.135	-0.086	-0.033	-0.316	-0.287	0.082	-0.188	0.169	0.142	-0.367	-0.346	-0.337	0.818	0.963
LDO2FT	0.133	-0.073	-0.019	-0.261	-0.185	0.090	-0.285	0.143	0.162	-0.476	-0.455	-0.444	0.683	0.865
LPH	0.144	0.223	0.205	-0.122	-0.196	-0.147	0.296	0.268	-0.001	0.293	0.289	0.291	0.574	0.480

	DO2FT	PH	LTURB	LSECI	LCOLOR	LFCOND	LCOND	LBOD5	LBODC	LCOD	LALK	LTS	LTDS	LTSS
PH	0.393													
LTURB	0.458	0.289												
LSECI	0.110	-0.335	-0.380											
LCOLOR	-0.388	-0.286	0.007	-0.311										
LFCOND	0.327	0.362	0.314	0.102	-0.544									
LCOND	0.281	0.280	0.242	0.169	-0.574	0.945								
LBOD5	-0.002	0.395	-0.046	-0.064	-0.266	0.309	0.320							

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

	DO2FT	PH	LTURB	LSECI	LCOLOR	LFCOND	LCOND	LBOD5	LBODC	LCOD	LALK	LTS	LTDS	LTSS
LBODC	0.077	0.271	-0.067	0.025	-0.168	0.189	0.200	0.636						
LCOD	-0.033	0.205	-0.080	-0.114	0.283	-0.165	-0.231	-0.024	-0.008					
LALK	0.187	0.271	0.335	0.074	-0.209	0.844	0.814	0.290	0.308	-0.161				
LTS	0.160	0.296	0.307	-0.211	0.008	0.582	0.566	0.129	0.079	0.129	0.509			
LTDS	0.120	0.114	0.178	-0.033	0.030	0.559	0.556	0.018	0.019	0.087	0.488	0.957		
LTSS	0.037	0.393	0.236	-0.435	-0.008	0.090	0.085	0.296	0.110	0.040	0.054	0.237	0.028	
LNVR	0.025	0.437	0.154	-0.386	-0.047	0.131	0.134	0.343	0.163	0.023	0.104	0.276	0.079	0.964
LTN	0.204	0.566	0.253	-0.258	-0.131	0.468	0.422	0.335	0.216	0.176	0.460	0.473	0.351	0.271
LN/P	0.217	0.335	-0.222	0.121	-0.370	0.258	0.269	0.322	0.273	0.075	0.060	0.175	0.172	-0.094
LDNH3	-0.301	-0.298	-0.196	0.265	-0.018	0.264	0.259	-0.101	-0.084	-0.191	0.145	0.048	0.169	-0.177
LNH3	-0.380	-0.312	-0.185	0.168	0.038	0.267	0.259	-0.035	-0.021	-0.214	0.210	0.042	0.143	-0.141
LDTKN	-0.375	0.137	-0.383	-0.027	0.006	0.128	0.148	0.303	0.250	0.225	0.088	0.252	0.223	0.123
LTKN	0.143	0.570	0.208	-0.296	-0.112	0.423	0.381	0.367	0.232	0.208	0.408	0.475	0.339	0.338
LNO32	0.370	0.041	0.306	0.189	-0.046	0.284	0.225	-0.212	-0.147	-0.088	0.281	0.004	0.096	-0.368
LTP	0.016	0.312	0.408	-0.364	0.167	0.262	0.207	0.096	0.014	0.131	0.408	0.354	0.232	0.354
LOP	-0.192	0.130	0.243	-0.210	0.382	0.263	0.187	0.005	-0.043	0.232	0.502	0.425	0.373	0.180
LTOC	-0.171	0.388	-0.241	-0.275	0.142	-0.258	-0.285	0.211	0.146	0.562	-0.303	0.156	0.057	0.192
LIN/OP	0.374	0.037	0.295	0.151	-0.031	0.203	0.145	-0.214	-0.157	-0.061	0.179	-0.067	0.018	-0.335
LCL	0.162	0.278	-0.044	0.140	-0.420	0.635	0.668	0.282	0.078	0.064	0.296	0.429	0.424	0.104
LDCR	0.402	0.210	0.208	0.116	-0.187	0.125	0.064	-0.001	0.122	0.024	0.028	0.139	0.091	0.158
LCR	0.299	0.082	0.132	-0.077	-0.101	-0.270	-0.269	-0.199	0.029	-0.044	-0.312	-0.078	-0.126	0.022
LDCU	0.297	0.103	0.264	0.091	-0.256	0.249	0.341	-0.162	-0.113	-0.041	0.212	-0.021	-0.063	0.108
LCU	0.128	0.088	0.066	-0.108	-0.088	-0.300	-0.287	-0.215	-0.176	-0.019	-0.325	-0.332	-0.375	-0.001
LDPB	0.164	0.253	0.177	0.045	-0.213	0.279	0.264	-0.080	-0.088	-0.034	0.130	0.201	0.182	0.120

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

	DO2FT	PH	LTURB	LSECI	LCOLOR	LFCOND	LCOND	LBOD5	LBODC	LCOD	LALK	LTS	LTDS	LTSS
LPB	0.226	0.182	0.390	-0.110	-0.095	0.186	0.168	-0.208	-0.169	-0.002	0.069	0.313	0.264	0.116
LCOLI	-0.228	-0.270	-0.106	-0.132	0.438	-0.615	-0.605	-0.242	-0.278	-0.001	-0.528	-0.532	-0.530	-0.095
LFECAL	-0.184	-0.380	0.079	-0.053	0.274	-0.131	-0.142	-0.145	-0.296	-0.076	-0.095	-0.235	-0.197	-0.086
LSTREP	-0.065	-0.268	0.270	-0.265	0.301	-0.094	-0.105	-0.219	-0.269	-0.375	-0.051	-0.200	-0.187	-0.075
LCHLA	-0.364	0.205	-0.137	-0.299	0.003	0.099	0.128	0.378	0.231	-0.056	0.168	0.247	0.144	0.422
LPHYT	0.136	0.015	0.213	-0.140	0.167	0.047	-0.042	-0.184	-0.112	0.182	0.109	0.273	0.237	0.101
LDEEP	0.162	0.005	0.093	0.064	-0.022	-0.176	-0.196	-0.008	-0.070	0.002	-0.092	-0.200	-0.217	0.020
LTSURF	-0.455	0.300	-0.218	-0.433	0.209	-0.147	-0.158	0.196	0.134	0.198	-0.012	0.199	0.075	0.390
LT1FT	-0.444	0.296	-0.223	-0.430	0.204	-0.151	-0.160	0.185	0.127	0.197	-0.018	0.198	0.076	0.395
LT2FT	-0.436	0.296	-0.219	-0.436	0.201	-0.158	-0.169	0.177	0.124	0.195	-0.022	0.189	0.066	0.395
LDO00	0.697	0.453	0.343	-0.062	-0.334	-0.102	-0.105	-0.038	0.080	0.055	-0.169	-0.087	-0.168	0.086
LDO1FT	0.891	0.396	0.405	0.091	-0.362	0.215	0.191	0.021	0.156	-0.009	0.094	0.131	0.086	0.052
LDO2FT	0.952	0.306	0.429	0.167	-0.366	0.311	0.272	-0.013	0.066	-0.020	0.172	0.156	0.125	0.017
LPH	0.377	0.996	0.281	-0.318	-0.299	0.375	0.297	0.413	0.282	0.192	0.287	0.287	0.106	0.401

	LNVR	LTN	LN/P	LDNH3	LNH3	LDTKN	LTKN	LNO32	LTP	LOP	LTOC	LIN/OP	LCL	LDCR
LTN	0.329													
LN/P	0.001	0.372												
LDNH3	-0.177	-0.187	-0.097											
LNH3	-0.148	-0.151	-0.172	0.907										
LDTKN	0.167	0.135	0.252	0.216	0.277									
LTKN	0.396	0.987	0.331	-0.195	-0.148	0.196								
LNO32	-0.383	-0.034	0.060	0.172	0.085	-0.362	-0.175							
LTP	0.341	0.706	-0.554	-0.111	-0.016	-0.007	0.715	-0.100						
LOP	0.197	0.357	-0.372	-0.005	0.110	0.119	0.382	-0.075	0.653					
LTOC	0.229	0.256	0.244	-0.302	-0.279	0.399	0.332	-0.412	0.092	0.135				
LIN/OP	-0.364	-0.081	0.045	0.149	0.061	-0.392	-0.213	0.980	-0.137	-0.138	-0.371			
LCL	0.125	0.277	0.456	0.245	0.208	0.334	0.278	-0.003	-0.071	-0.127	0.077	-0.050		
LDCR	0.087	0.064	0.085	-0.202	-0.186	0.065	0.053	0.055	0.005	-0.056	0.137	0.019	0.073	
LCR	-0.020	-0.097	0.052	-0.301	-0.269	-0.118	-0.100	-0.066	-0.135	-0.284	0.101	-0.057	-0.118	0.735
LDCU	0.008	-0.009	-0.035	0.014	-0.047	-0.140	-0.046	0.268	0.011	-0.035	-0.087	0.246	0.123	0.311
LCU	-0.054	-0.158	-0.085	-0.178	-0.142	-0.169	-0.173	0.053	-0.100	-0.257	0.145	0.094	-0.106	0.229
LDPB	0.132	0.072	0.036	-0.043	-0.087	-0.014	0.054	0.121	0.058	0.034	0.127	0.062	0.303	0.325
LPB	0.082	0.067	-0.041	-0.097	-0.092	-0.042	0.062	0.009	0.113	0.056	0.063	-0.028	0.331	0.434

APPENDIX A - CORRELATION MATRIX OF LAKE WATER QUALITY DATA (continued)

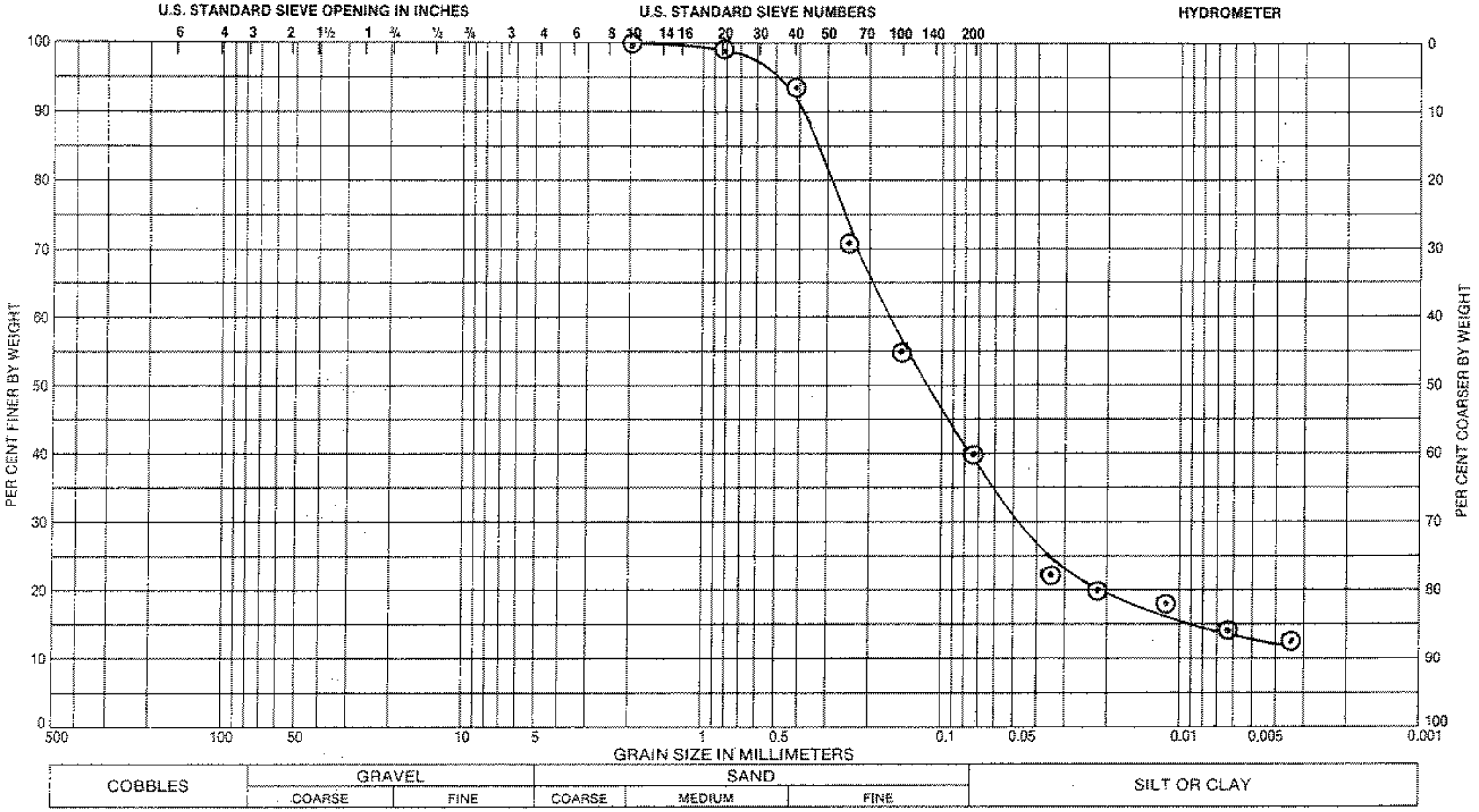
	LNVR	LTN	LN/P	LDNH3	LNH3	LDTKN	LTKN	LNO32	LTP	LOP	LTOC	LIN/OP	LCL	LDCR
LCOLI	-0.171	-0.316	-0.111	-0.199	-0.177	-0.180	-0.323	0.003	-0.235	-0.259	0.004	0.062	-0.438	-0.170
LFECAL	-0.170	-0.267	-0.100	0.097	0.116	-0.188	-0.298	0.200	-0.193	-0.101	-0.249	0.233	-0.140	-0.214
LSTREP	-0.156	-0.321	-0.195	0.060	0.091	-0.350	-0.371	0.322	-0.167	-0.175	-0.432	0.361	-0.214	-0.262
LCHLA	0.500	0.303	0.027	-0.083	-0.028	0.368	0.391	-0.620	0.302	0.302	0.277	-0.664	0.063	-0.159
LPHYT	0.075	0.162	-0.110	-0.045	-0.060	0.019	0.175	-0.048	0.242	0.342	0.110	-0.065	-0.153	0.157
LDEEP	0.004	0.078	-0.282	-0.186	-0.155	-0.230	0.074	-0.011	0.265	0.171	-0.122	-0.024	-0.260	-0.087
LTSURF	0.462	0.302	-0.087	-0.185	-0.067	0.392	0.408	-0.656	0.393	0.435	0.540	-0.663	-0.113	-0.164
LT1FT	0.466	0.296	-0.088	-0.190	-0.070	0.390	0.403	-0.659	0.389	0.433	0.537	-0.665	-0.116	-0.160
LT2FT	0.467	0.302	-0.091	-0.202	-0.082	0.375	0.408	-0.658	0.395	0.433	0.533	-0.663	-0.134	-0.151
LDO00	0.076	0.206	0.142	-0.455	-0.532	-0.375	0.174	0.149	0.066	-0.285	0.047	0.178	-0.059	0.279
LDO1FT	0.042	0.249	0.192	-0.322	-0.389	-0.328	0.199	0.266	0.070	-0.222	-0.106	0.279	0.097	0.337
LDO2FT	-0.003	0.204	0.198	-0.267	-0.329	-0.326	0.147	0.325	0.027	-0.174	-0.182	0.328	0.157	0.372
LPH	0.443	0.568	0.323	-0.281	-0.282	0.165	0.572	0.031	0.323	0.135	0.370	0.026	0.291	0.219

	LCR	LDCU	LCU	LDPB	LPB	LCOLI	LFECAL	LSTREP	LCHLA	LPHYT	LDEEP	LTSURF	LT1FT	LT2FT
LDCU	0.160													
LCU	0.462	0.547												
LDPB	0.185	0.385	0.280											
LPB	0.390	0.309	0.261	0.689										
LCOLI	0.156	-0.049	0.344	-0.261	-0.248									
LFECAL	-0.154	0.072	0.044	-0.224	-0.198	0.665								
LSTREP	-0.011	-0.009	0.145	-0.116	-0.017	0.405	0.490							
LCHLA	-0.182	-0.286	-0.274	-0.006	-0.060	-0.207	-0.251	-0.301						
LPHYT	0.111	0.121	0.001	-0.018	0.123	-0.061	-0.086	-0.037	-0.092					
LDEEP	-0.018	-0.062	0.017	-0.025	-0.092	0.105	-0.031	-0.072	-0.047	0.011				
LTSURF	-0.071	-0.312	-0.032	-0.037	-0.015	-0.100	-0.353	-0.315	0.703	0.115	-0.047			
LT1FT	-0.052	-0.309	-0.015	-0.048	-0.011	-0.097	-0.355	-0.316	0.699	0.127	-0.042	0.998		
LT2FT	-0.040	-0.304	-0.004	-0.052	-0.019	-0.082	-0.353	-0.313	0.695	0.139	-0.037	0.996	0.998	
LDO00	0.420	0.212	0.415	0.185	0.180	0.089	-0.220	-0.113	-0.166	0.066	0.174	-0.143	-0.131	-0.118
LDO1FT	0.316	0.197	0.129	0.085	0.165	-0.191	-0.251	-0.131	-0.284	0.130	0.145	-0.362	-0.346	-0.339
LDO2FT	0.246	0.270	0.087	0.114	0.184	-0.212	-0.159	-0.109	-0.358	0.171	0.173	-0.460	-0.445	-0.437
LPH	0.067	0.109	0.088	0.263	0.182	-0.271	-0.378	-0.270	0.211	0.005	0.009	0.302	0.298	0.298

APPENDIX B

SEDIMENT PARTICLE SIZE DISTRIBUTIONS

Particle size distributions of all 15 sediment sites in Lake Munson were performed by Southern Earth Sciences, Inc., Tallahassee, Florida



Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-42		MOISTURE 65.3				
		SOLIDS 28.8				
		ORGANICS 5.9				

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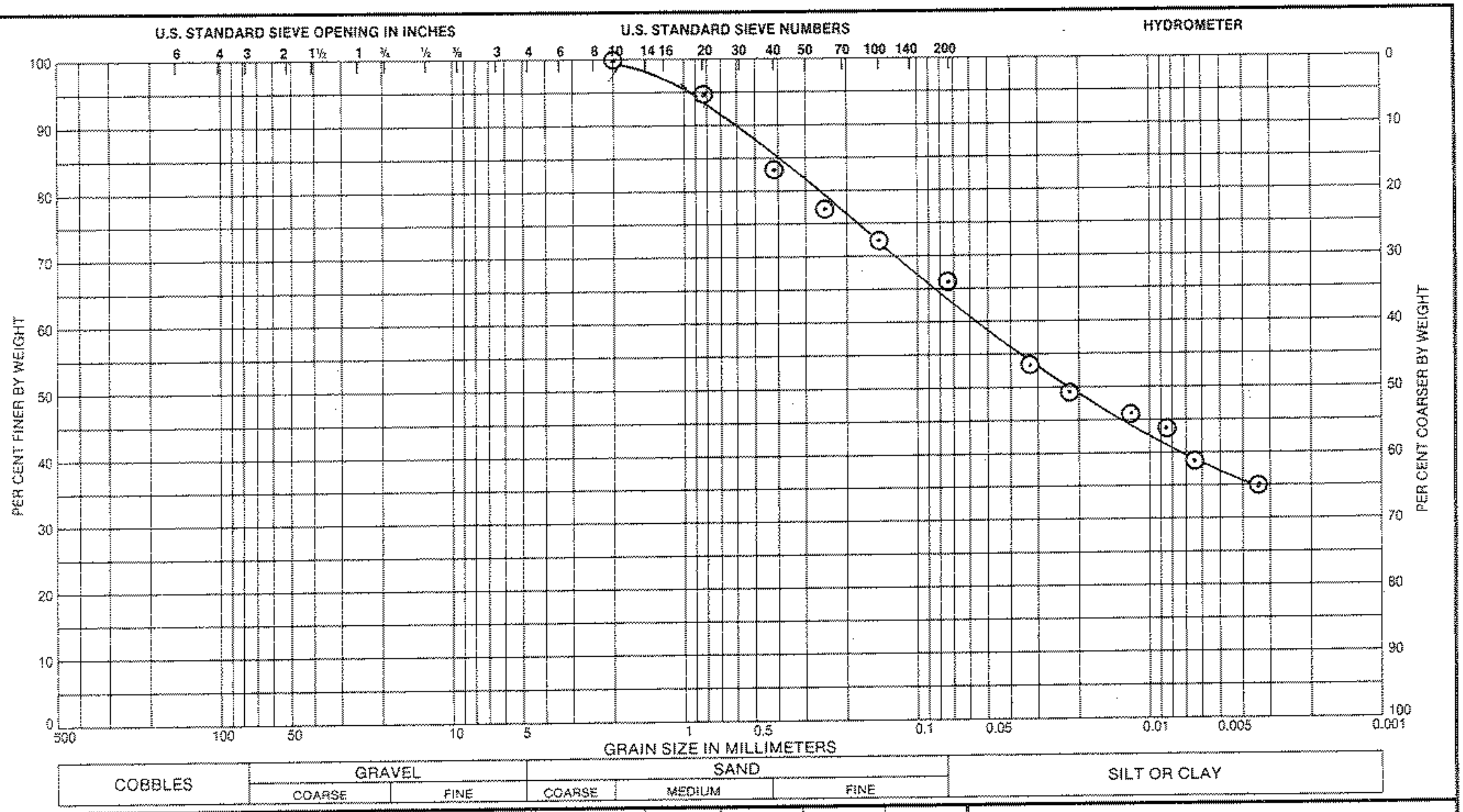

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-43		Moisture - 78.7				
		Solids - 13.7				
		Organics - 7.6				

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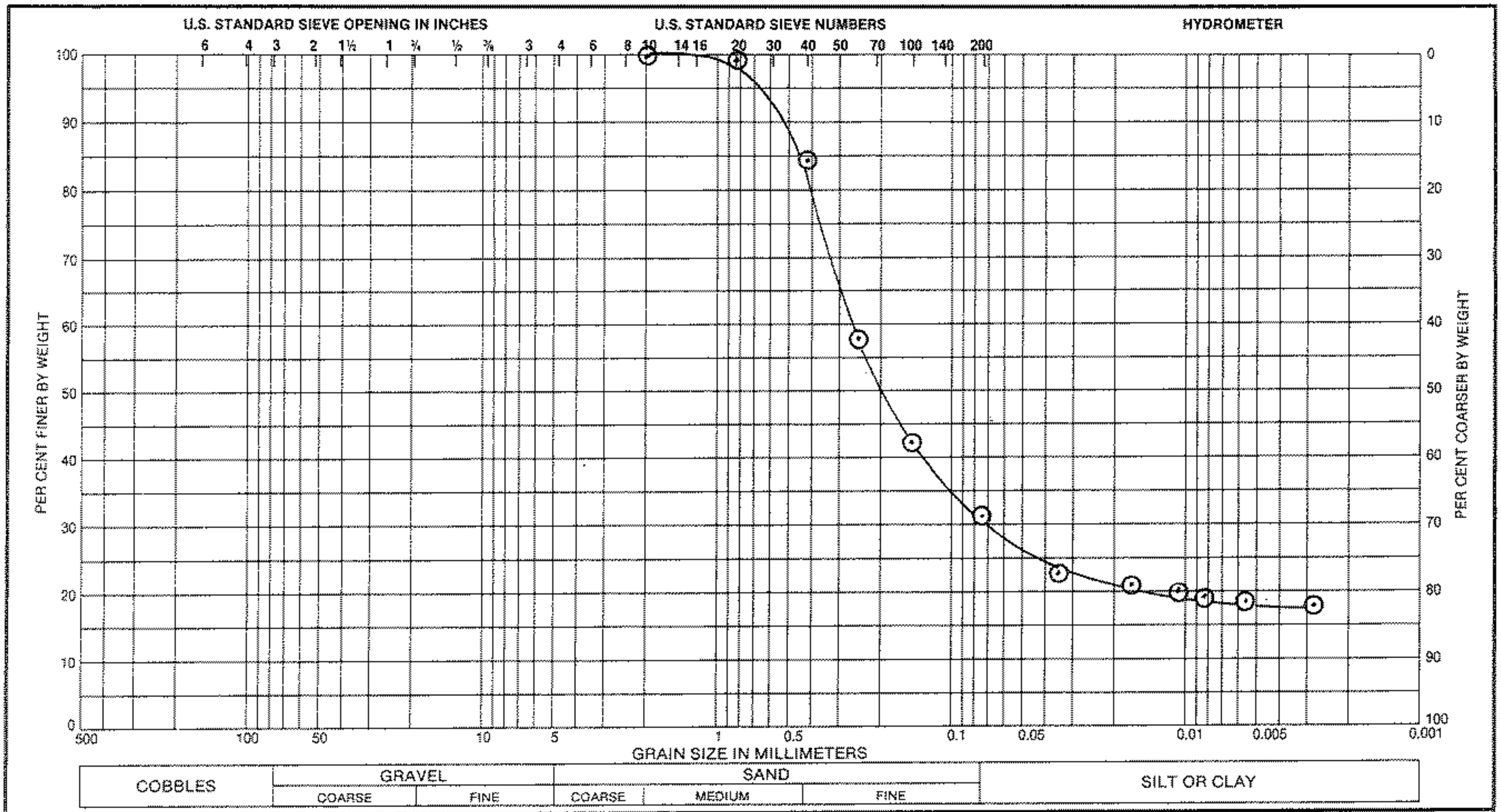

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-44		Moisture - 47.9				
		Solids - 51.1				
		Organics - 1.0				

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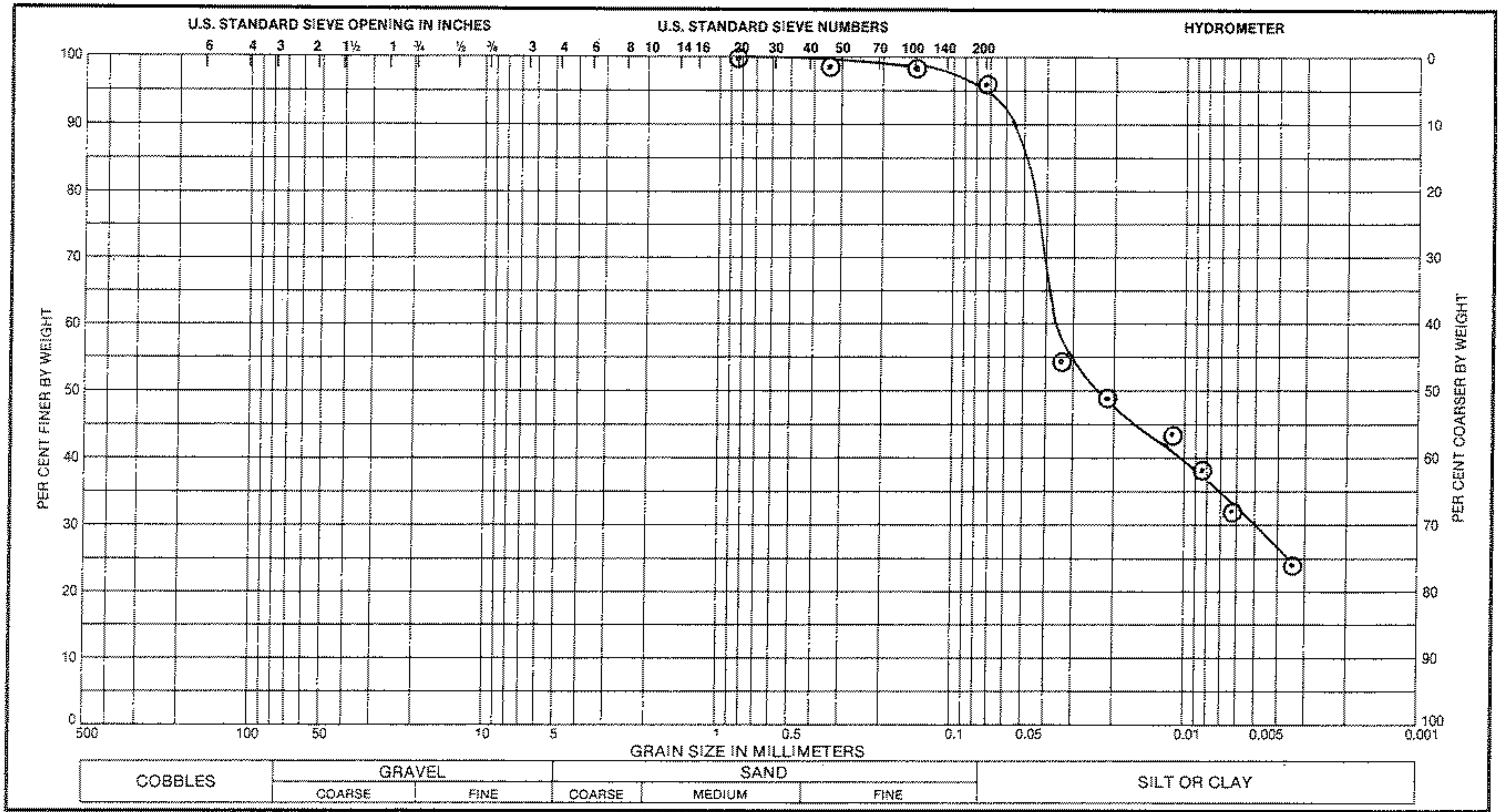

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-45		Moisture - 76.8				
		Solids - 20.1				
		Organics - 3.1				

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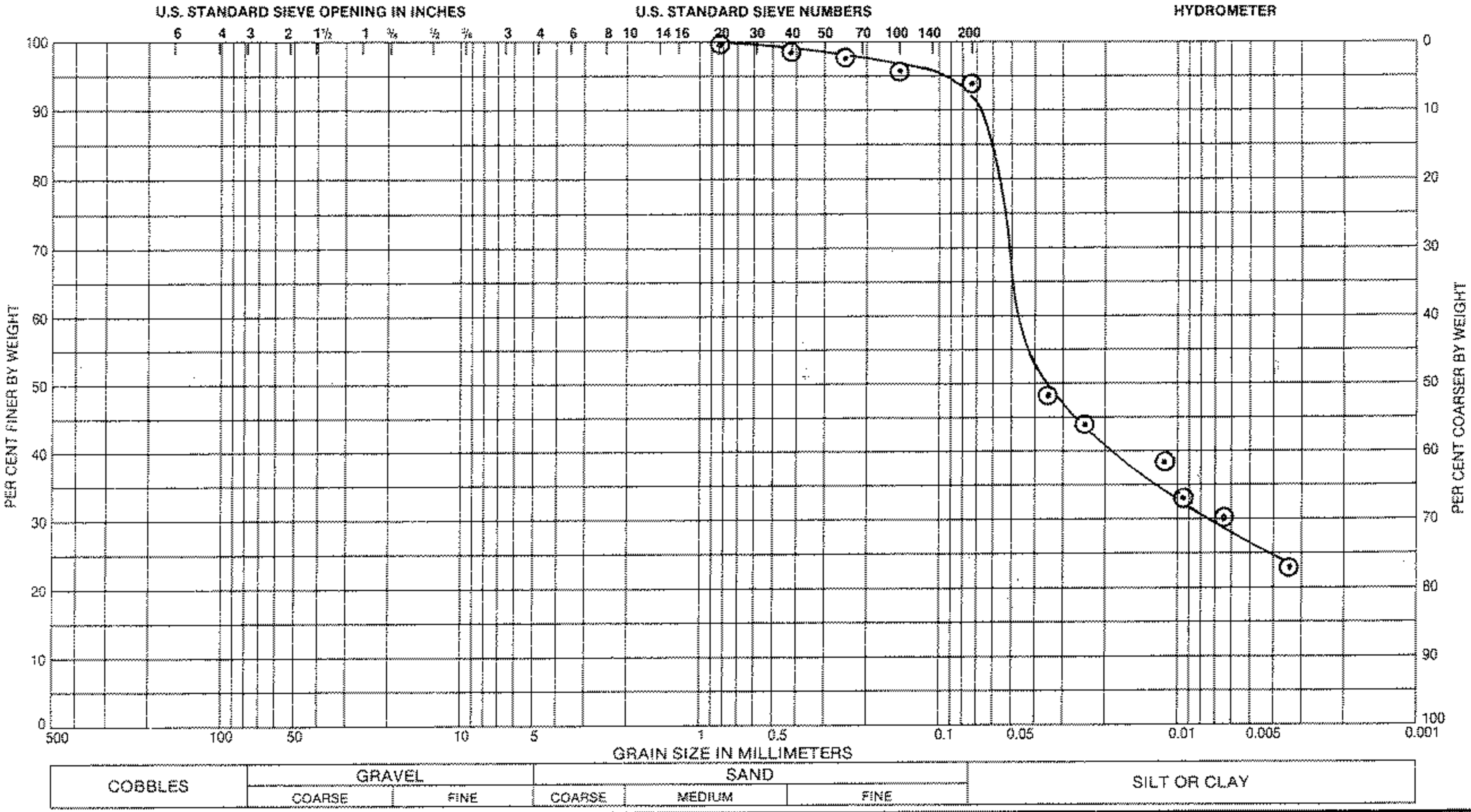

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S- 46		Moisture - 80.5				
		Solids - 15.9				
		Organics - 3.6				

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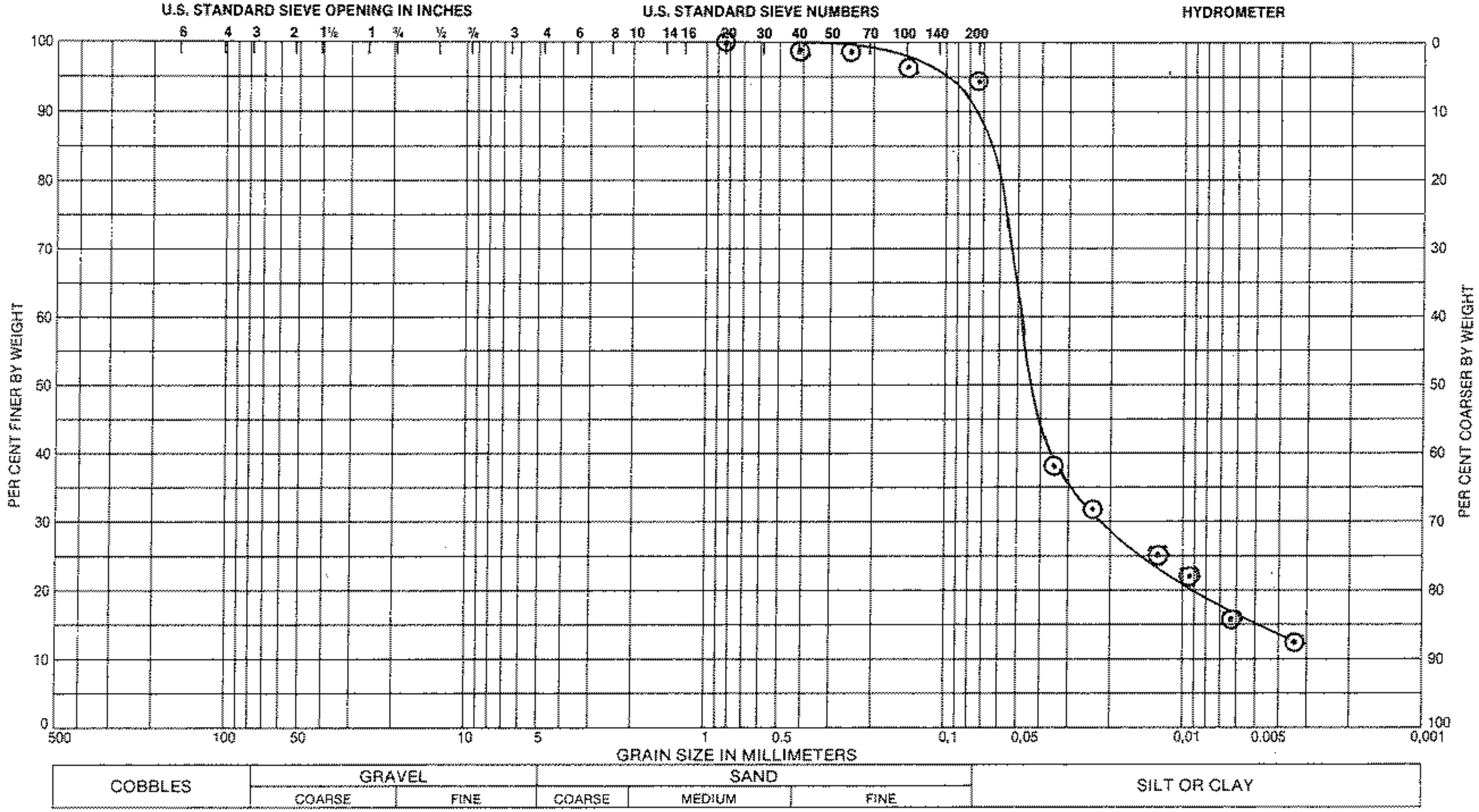

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-47		Moisture - 80.7				
		Solids - 17.6				
		Organics - 1.7				

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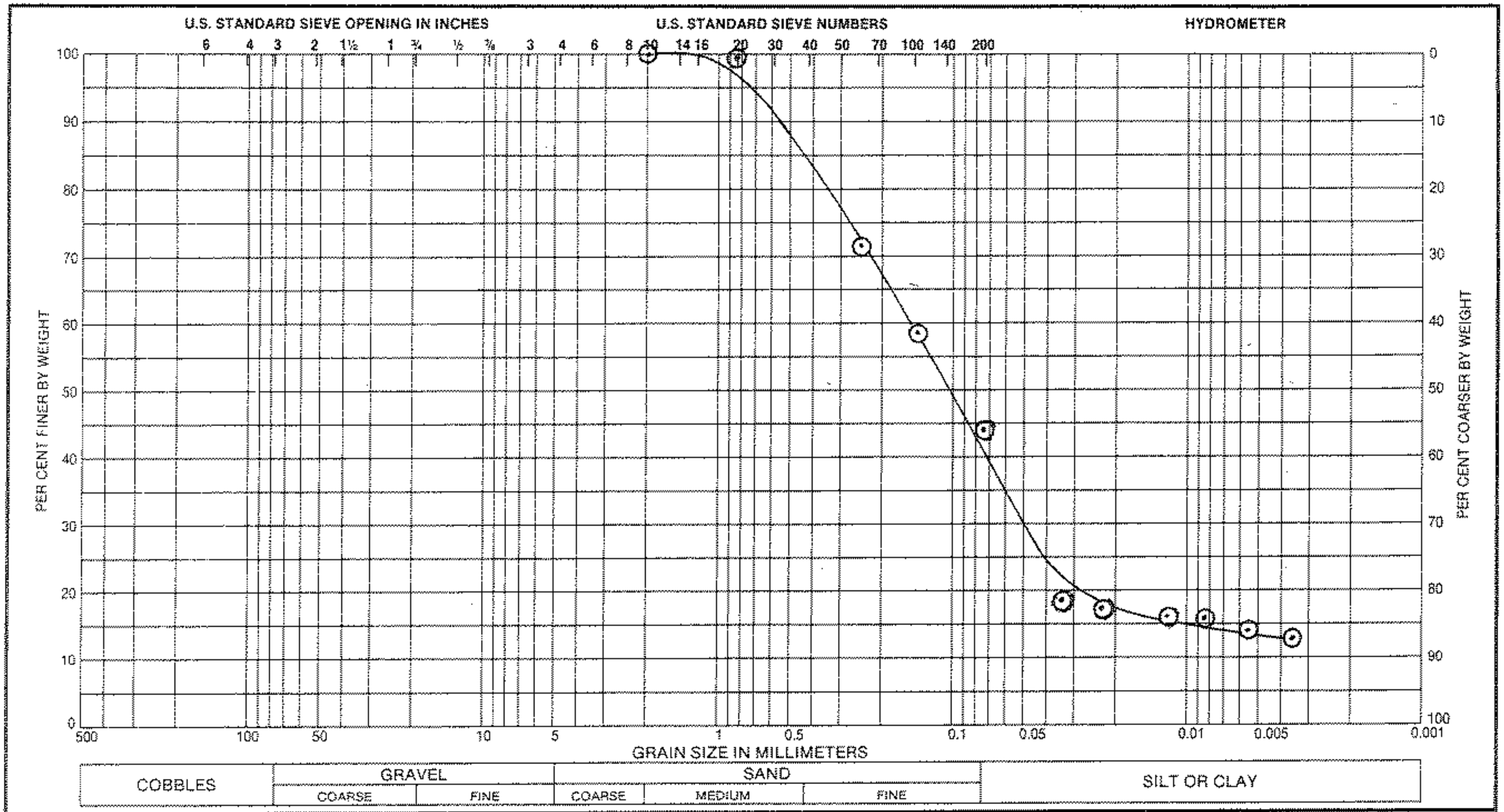

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S- 48		Moisture - 58.4				
		Solids - 38.1				
		Organics - 3.5				

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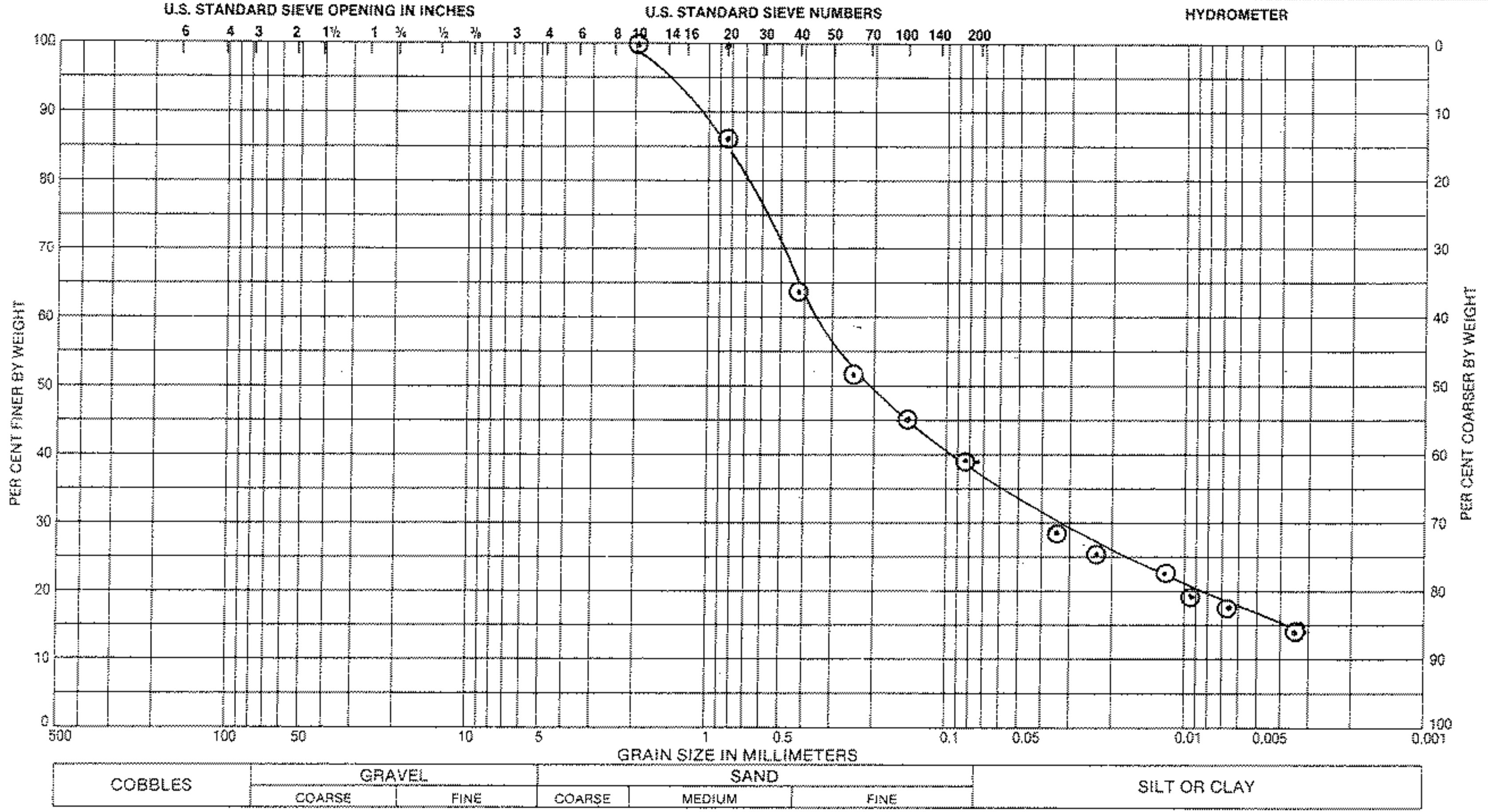

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S- 49		Moisture - 75.7				
		Solids - 11.3				
		Organics - 13.0				

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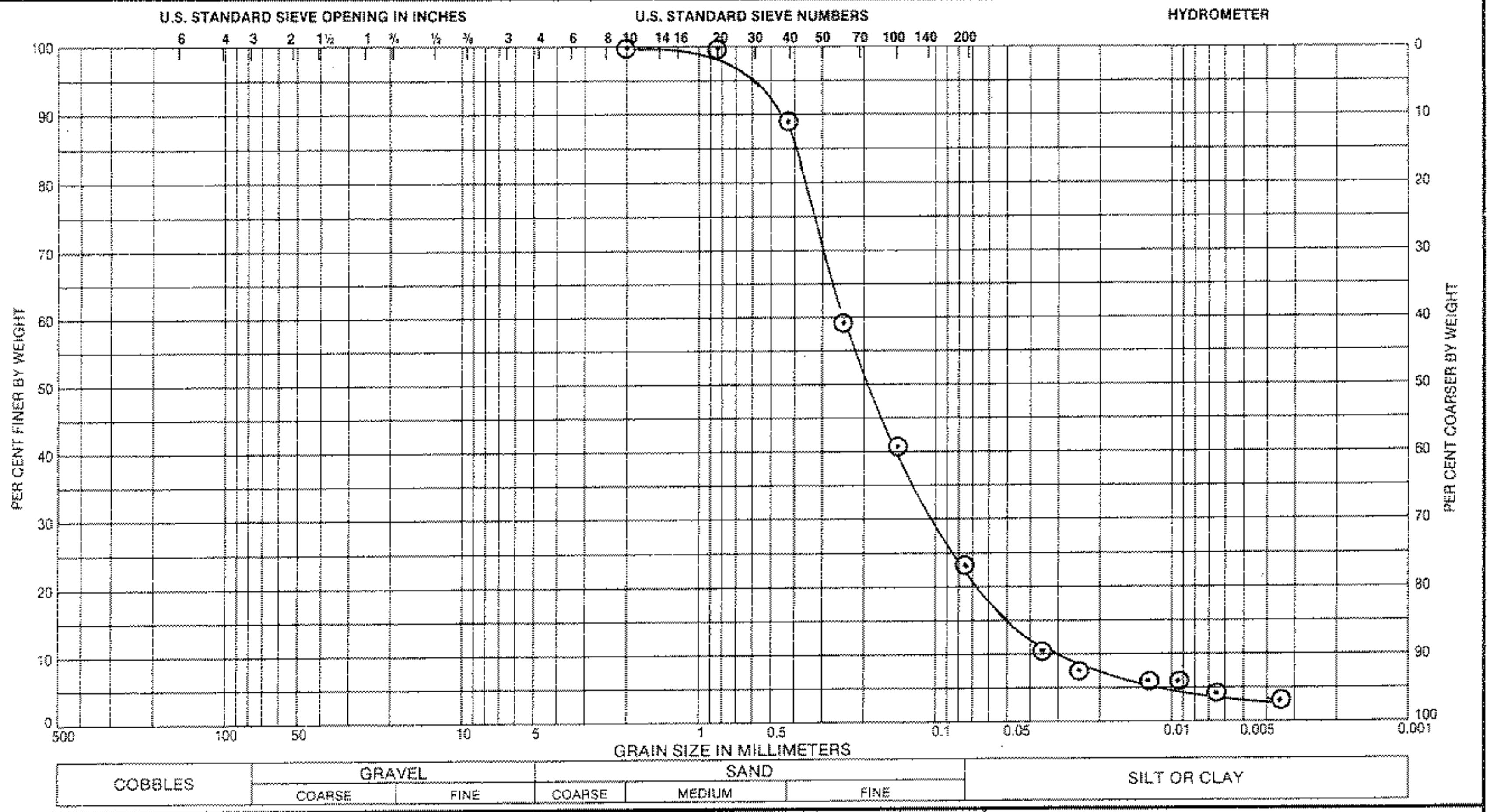

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S- 50		Moisture - 55.7				
		Solids - 41.0				
		Organics - 3.3				

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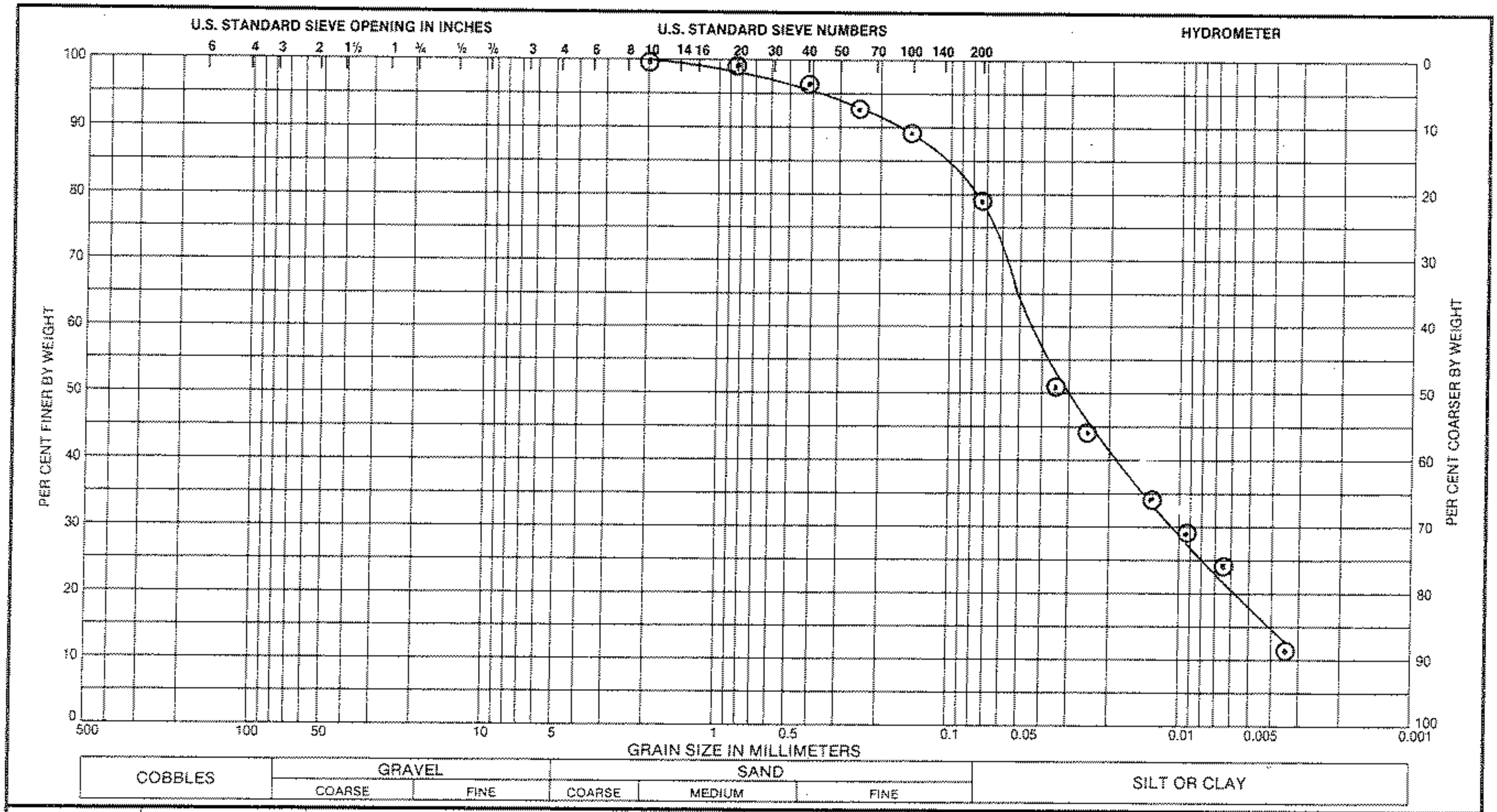

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-51		Moisture - 88.3				
		Solids - 5.31				
		Organics - 6.39				

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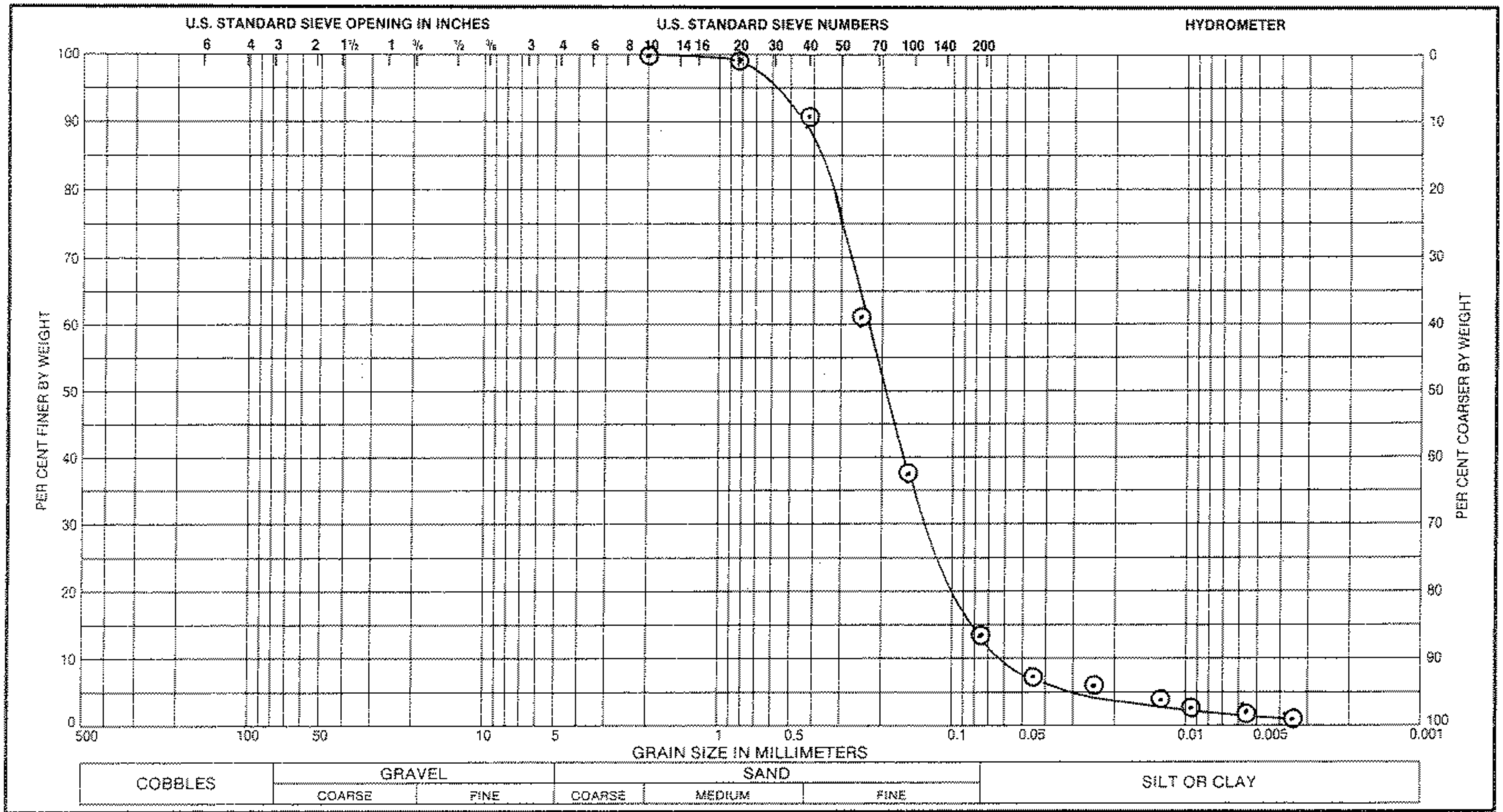

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-52		Moisture - 19.4				
		Solids - 79.5				
		Organics - 1.1				

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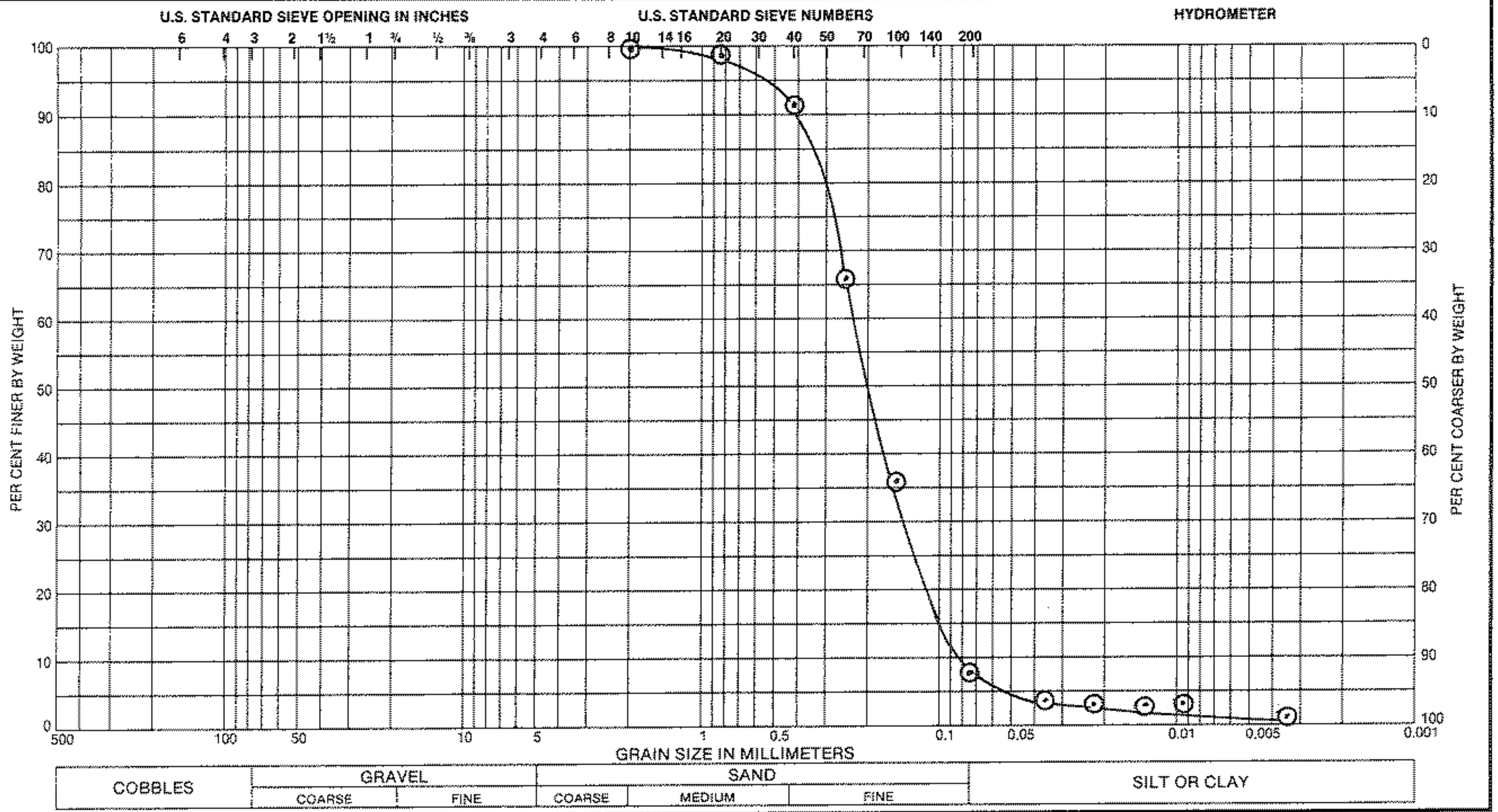

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-53		Moisture - 16.7				
		Solids - 82.8				
		Organics - 0.5				

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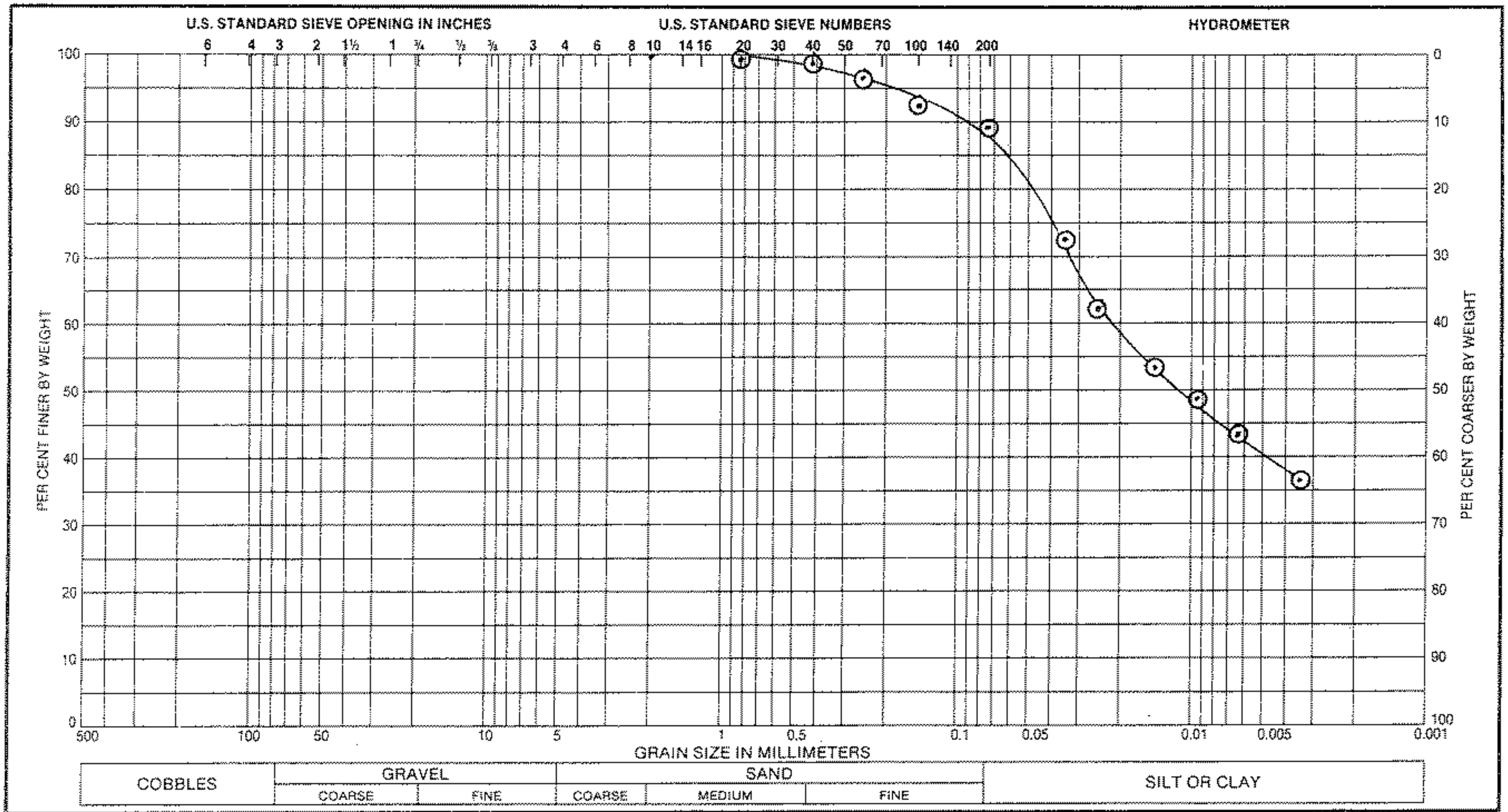

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S- 54		Moisture - 82.2				
		Solids - 11.3				
		Organics - 6.5				

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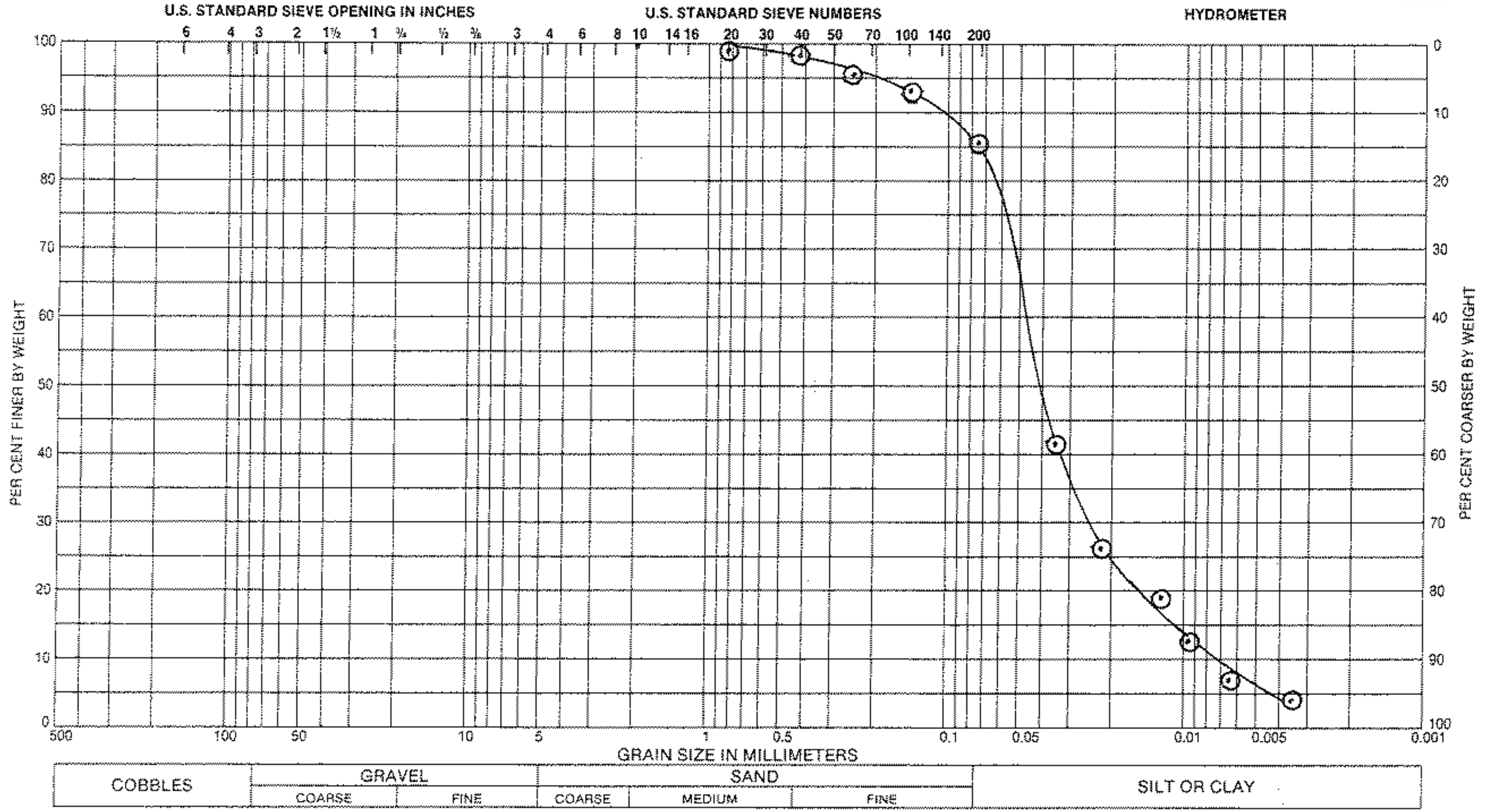

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S-55		Moisture - 82.7				
		Solids - 11.1				
		Organics - 6.2				

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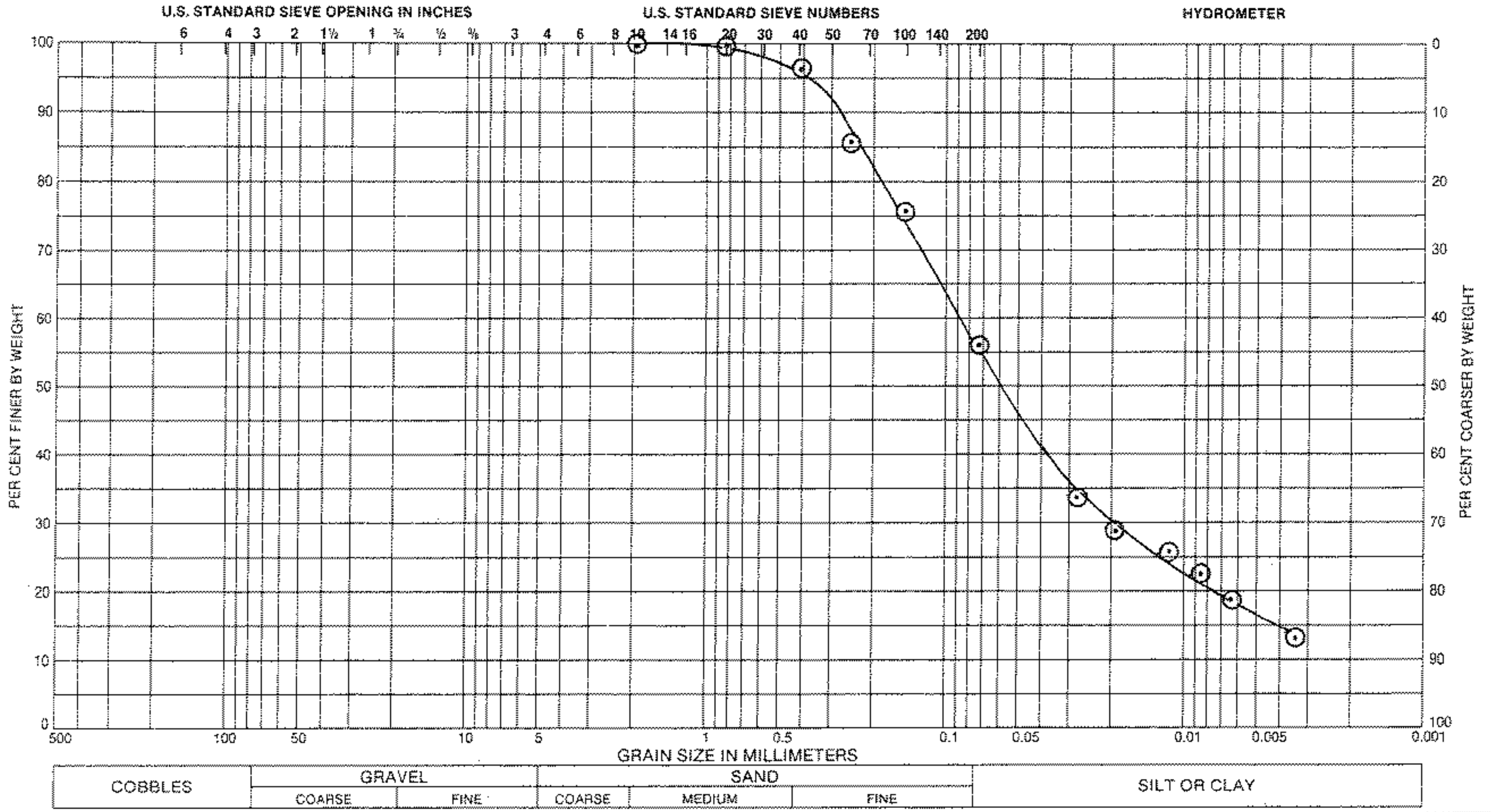

Sample No.	Elev. or Depth	Classification	Nat. w %	LL	PL	PI
S- 56		Moisture - 62.3				
		Solids - 35.6				
		Organics - 2.1				

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