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WATER QUALITY AND PHOSPHORUS DYNAMICS AS AFFECTED BY AN ALUM TREATMENT IN LONG LAKE, KITSAP COUNTY

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INTRODUCTION

This report summarizes the changes in the quality of Long Lake, Kitsap County (137 ha, 2 m mean depth), over the past eleven years, with special emphasis over the last three years. Work on the lake during 1984-1987 was supported by a research contract with the Washington Department of Ecology (WDOE) and Kitsap County (KC). Previous work from 1976-1981 was supported by the U. S. Environmental Protection Agency (EPA) through a research grant. Limited data were collected during the intervening years, 1982-1983, without direct funding.

The effort by University of Washington students and faculty over the past eleven years has been aimed at understanding the nutrient (especially phosphorus) dynamics in Long Lake and the role of rooted macrophytes and bottom sediments in controlling lake concentrations of phosphorus (P). The impetus for this effort was a plan by Entranco Engineers to lower the water level to control macrophte abundance and add alum (aluminum sulfate) to control the release of P from sediments. When the plan to lower the water level was funded by EPA, WDOE and KC in 1976, a P budget had not yet been developed and the role P release from sediments (internal loading) and macrophyte decay were unknown. In fact, lake P models and restoration success stories had been developed from data sets from primarily deep lakes, and the realization of the more difficult problems with macrophytes and internal loading in shallow lakes had only begun. In fact, 1976 was the first year of EPA's Clean Lakes program and Long Lake was one of the first lakes to receive some of those funds.

In retrospect, a different approach to the restoration of Long Lake may have been taken if a thorough nutrient budget and a sediment profile of P had been available. Lake Trummen in Sweden, a lake of about the same dimensions

(100 ha, 1 m mean depth) as Long Lake but with much worse water quality, had been dredged in 1970-1971. The lake showed rapid and dramatic improvement in quality and its condition has remained so (Bjork, 1985). One meter of bottom sediment was removed from Lake Trummen because it had not improved during ten years since sewage effluent diversion and the upper 0.5 m of its sediments were known to be rich in P and were the source of its continued problems. That project cost about 0.5 million in 1974 U.S. Dollars. While surficial sediments are much less enriched than in Lake Trummen, internal loading from Long Lake sediments has nonetheless been determined as the principal source of P for spring-summer blooms of algae, and sediment profiles have shown that much of that P could be removed by dredging the top 0.5 m of sediment (see sediment results).

The water level in Long Lake was drawn down from June to October, 1979 with the maximum level reduction of 1.8 m reached in August. As a result, about 40% of the lake's sediment and macrophytes were exposed to drying (Entranco, 1980). Although the exposed leaves and stems of plants died through desiccation (except the water lilies), the sediments remained wet and plant roots were relatively unaffected (Lynch, 1982). Moreover, the highly organic sediment which shrunk by 50% when 30 cm deep samples were exposed outside in styrofoam picnic coolers (Plotkin, 1979), compacted only slightly when exposed in the lake (Lynch, 1982). As a result, abundance was back to normal by the summer of 1981, even though the crop had decreased by 84% in 1980 following the drawdown (Welch et al., 1982).

Once it was known that internal loading was the cause for high P concentrations and blue green algal blooms in summer, and not external loading, Entranco Engineers developed a plan to treat the sediments with alum.

The lake and its sediments were dosed with alum (70 mg/L, 5.6 mg/L Al) in September, 1980.

Alum addition is one of six lake treatments designed to reduce inlake nutrient content by inactivating P in sediments (Cooke et al., 1986). Because of its effectiveness, it has become one of the most popular in-lake treatments. Except for two cases in the U. S., Pickerel Lake, Wisconsin (Garrison and Knauer, 1984) and Long Lake, Washington (Welch et al., 1982), and three cases in Europe (Welch et al., 1988), treatments prior to 1980 had been applied only to stratified lakes (thermoclines persisting all summer). Treatments in stratified lakes have been effective and relatively long lasting; 10 and 12 years for two Wisconsin lakes and five and six for two Ohio lakes (Garrison and Knauer, 1984; Cooke and Kennedy, 1981). Treatment effectiveness in polymictic Pickerel Lake and the European lakes, however, lasted less than a year. In Pickerel Lake the failure was due to the unstratified condition and firm bottom which apparently permitted redistribution of the alum floc to the center of the lake (Garrison and Knauer, 1984). The failure in European lakes was due to continued high external loading.

Long lake was only the second shallow (mean depth 2 m), unstratified lake with low external loading to be treated with alum. No permanent thermocline between surface and bottom has been detected. There was fear that the same process that occurred in Pickerel Lake would also occur in Long Lake. However, Long Lake bottom sediments are flocculent and organic in nature, compared to those in Pickerel Lake and may have limited alum mobility horizontally. Nevertheless, this treatment was considered to be highly successful (Welch et al., 1982, 1986) and was persistent for four years. High summer P content and blue green algal blooms returned the fifth year, but subsided in the succeeding two years. The experimental design for the evaluation of an alum treatment was not ideal because there were two successive treatments to the lake. The alum treatment was preceded by lake level drawndown, and substantial improvement in water quality was observed after the drawdown and before the alum treatment (Welch et al., 1982, 1986).

Interpretation of field data, laboratory experiments and P modelling suggests that summer P input to Long Lake is dominated by anaerobic P release from warm sediments during short periods of partial stratification followed by wind events. Due to the large supply of P, the amount of P accumulating in the water column in the form of algae is probably limited by the rate of nitrogen fixation by blue-green algae. However, increases in pH due to photosynthesis assists in solubilizing P and maintaining it in the water column. Direct release of P from macrophytes to the open water during growth and decay is considered less significant to the blooming of blue-green algae in summer than is sediment P release. The primary effect of macrophyte decay may be the production of detritus loading to increased bacterial activity and lower sediment redox potential, which eventually leads to conditions in the sediments that enhance the release of P. Remineralization of P from sedimented phytoplankton may also contribute to the elevated P concentrations. As the alum layer becomes dispersed and fresh organic and inorganic sediments are deposited over the alum, reducing conditions in the sediments should again result in renewed release of P. A return of sediment P release is followed by enhanced algal growth, elevated pH and sedimentation of algal detritus leading to further P release by redox and possibly pH mechanisms in this positive feedback system. Therefore, once P release from sediments is inhibited and algal productivity is reduced, removal of macrophyte biomass might delay the return of reducing conditions in the sediments.

The benefits of restoration were evaluated through review of data from 1976 through 1983 compared with data collected during this investigation (1984-1987). The return of large scale internal loading in 1985 and the accumulated data base of 11 years (1976-1987), allowed for some interpretation of the P cycling processes in this shallow, productive lakes. An evaluation of the affects of macrophyte removal on lake P through harvesting, as proposed in the contract, was not accomplished because unforseen problems prevented the initiation of an adequate harvesting program.

The objectives of the project were as follows: 1) Summarize and critically evaluate historical data collected since 1976 and relate changes to the various restoration techniques; 2) Determine the longevity of the alum treatment and if diminished effectiveness was indicated by sediment chemical content; 3) Demonstrate that anaerobic release of P is a plausible mechanism to explain summer internal loading of P; and 4) Develop a nonsteady state P model to increase the understanding of P cycling in the lake and provide a tool for future predictions of restoration treatments; and 5) Suggest recommend the future use of alum in shallow lakes.

SITE DESCRIPTION

Long Lake, Kitsap County, Washington is a shallow lake located in the Puget Sound lowlands. The lake is long (2.8 km), narrow (0.25 km) and shallow (mean depth = 2.0 m) (Figure 1). Soils of the drainage basin are composed mostly of a gravelly loam sand and a variety of peat, alluvium and various combinations of silt, loam, sand and gravel (Bortleson et al., 1976).

Salmonberry Creek is the main inflow and contributes 53% of the total hydraulic load to the lake and 62% of the total surface inflow (Lynch, 1982). Groundwater input is usually relatively small, but could be significant during wet periods. The lake flushing rate is rather high and variable, ranging from 3.6/yr in a dry year (76-77 water year) to 7.7 in a wet year (77-78 water year) (Lynch, 1982). External phosphorus loading has averaged about 930 kg/yr (1976-1978), but this was probably underestimated due to lack of information on storm water inputs. Through sediment core analyses (lead, aluminum and cesium-157), the sedimentation rate in the lake since 1950 has averaged 415 g/m^2-yr, or 0.43 cm/yr (Perkins et al., 1979).

In 1973 it was estimated that 69% of the drainage area was forest or undeveloped land, 5% surburban residential and 20% agricultural (Bortleson et al., 1976). The nearshore was 67% developed with 121 nearshore homes. The lake surface represented about 6% of the drainage basin. Basic morphometric features are given in Figure 1.

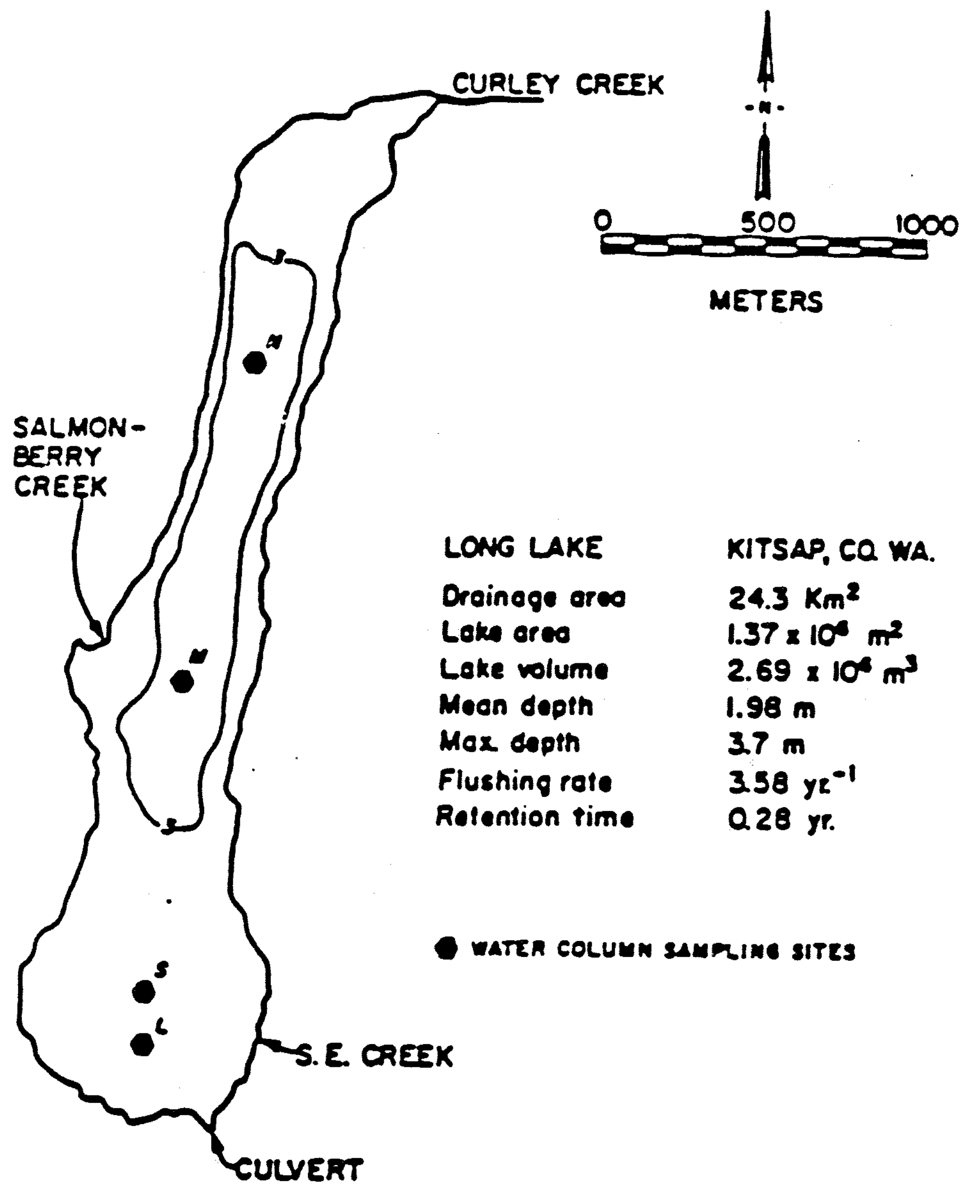


Figure 1. Water column sampling locations and morphometric characteristics of Long Lake, Kitsap County, Washington. Flushing rate was estimated at 3.6 yr^{-1} in 1977 water year and 7.6yr^{-1} in 1978 (Bortleson et al. 1976)

MATERIALS AND METHODS

Water sample collection and analysis

The sampling design used in previous studies of Long Lake was followed (Welch et al., 1982). Twice monthly sampling took place in spring and summer. In fall and winter samples were taken monthly. A local resident was employed to take inflow samples and read a staff gauge following rainstorms. In-lake sampling was performed at four stations (Figure 1). The North station (N) was sampled at 0.5, 1.5 and 2.5 m for total phosphorus (TP), soluble reactive phosphorus (SRP), chlorophyll *a* (chl *a*) alkalinity, pH, dissolved oxygen (DO), temperature and Secchi transparency. These observations were also made at the same depths at the Midlake station (M) and at depths of 0.5 and 1.5 m at the South station. Samples at the Lilies Station (L) were collected at 0.5 m for most variables except DO which was determined at 1.5 m.

Salmonberry Creek and Curley Creek were the only inflow and outflows sampled although two smaller inflow creeks and a groundwater source were monitored in the past (Lynch, 1982). Sample analysis on creek water included TP, SRP, pH, temperature and flow estimated by a calibrated staff gauge, which was read on each sampling trip.

Temperature profiles indicated little stratification of the lake during most sampling trips and therefore all data were summarized as whole lake, weighted means. This was done by weighting the arithmetic average of N and M values and the arithmetic average of S and L values by their respective lake volume fractions. This resulted in a whole lake volume-weighted mean. The formula used is as follows:

(North + Midlake samples)/6*.67 + (South + Lilies)/3*.33

Temperature was determined in the field with a YSI 57 oxygen meter and probe. The pH as measured in the field using a field pH meter with a combination glass electrode standardized at pH 7 and 10.

TP was determined using unfiltered water samples decanted in the laboratory and subjected to persulfate digestion under pressure. SRP was determined colorimetrically by the ascorbic acid method (APHA,1985). Water samples were filtered through 0.45 μm Millipore filter previously soaked in deionized water, and were then frozen for later analysis of SRP. All P analyses were performed with 10 cm and 5 cm cells at 885 nm on a Perkin-Elmer Lambda 3 spectrophotometer. Quality assurance samples were analyzed on three separate occasions. For samples in the 10-100 μg/L ranges, determined TP was 93%, 106% and 95% of the mean true values, and well within the 95% confidence range for the USEPA QA samples.

Chl a was determined by filtration of up to 500 ml of sample through a 27 mm glass fiber filter (Gelman A-E) containing two drops of saturated $MgCO_3$ solution. Filters were frozen and desiccated in aluminum pouches before analysis. Samples were then ground in 90% acetone and extracted overnight at -5^{0} C, filtered through glass fiber filters and diluted to 15 ml with 90% acetone. The extract was then read on a Perkin-Elmer Lambda 3 spectrophotometer at 750 nm and 665 nm and/or a Turner Designs model 111 fluorometer (APHA, 1985). Chl a concentration was calculated using the monochromatic equation of Lorenzen (1967) or an appropriate calibration factor for the fluorometer, each with a correction for phaeophytin. Quality assurance samples were analyzed on one occasion. Determined chl a was 94% of the true mean value and well within the 95% confidence range for the USEPA sample.

Alkalinity was determined by titrating 200 ml of lake sample with standardized 0.02 N H_2SO to an endpoint pH of 4.8 (APHA, 1985). DO was determined by the azide modification of the Winkler method (APHA, 1985). In the summers of 1986 and 1987, DO profiles were determined with a YSI model 57 oxygen probe, which was calibrated with water in equilibrium with the atmosphere and analyzed by the Winkler method.

Secchi transparency was measured with a standard (20 cm) black and white disc on the shady side of the boat at all four stations. Measurements were made to 0.1 m.

During February through June 1986, 60 ml subsamples from all sampling locations were acidified with 2 drops of concentrated reagent grade nitric acid and analyzed for total dissolvable iron (TFe) and total dissolvable manganese (TMn) using acetylene-air atomic absorption spectrophotometry (AA) (Instrumentation Laboratories 551 AA, EPA, 1979). From July through September 1986, samples returned to the laboratory were subsampled and filtered through 0.45 μm Millipore filters and the filtrate was acidified. AA analyses gave total soluble iron (TSFe) at the time of filtration.

<u>Macrophyte biomass</u>

Macrophyte surveys were conducted in a fashion similar to those in the past (Gabrielson, 1978; Lynch, 1982; Jacoby, 1981; Michaud, 1983). Surveys in late August or early September of 1984 to 1987 were timed to assess peak biomass, although <u>Potamogeton praelongus</u>, an abundant macrophyte in the lake, peaks, flowers and senesces by late July. Stalks of <u>P. praelongus</u> remain through late summer, however. The dominant macrophyte (often 95% of summer biomass) <u>Elodea densa</u> (also known as <u>Egeria densa</u>; Hutchinson 1957) is an exotic species introduced from South America. <u>E. densa</u> biomass peaks in lake August or September. Surveys were performed in April (1986) and June (1985) to determine of-peak biomass and to provide information on seasonal distribution patterns and estimates of overwintering biomass.

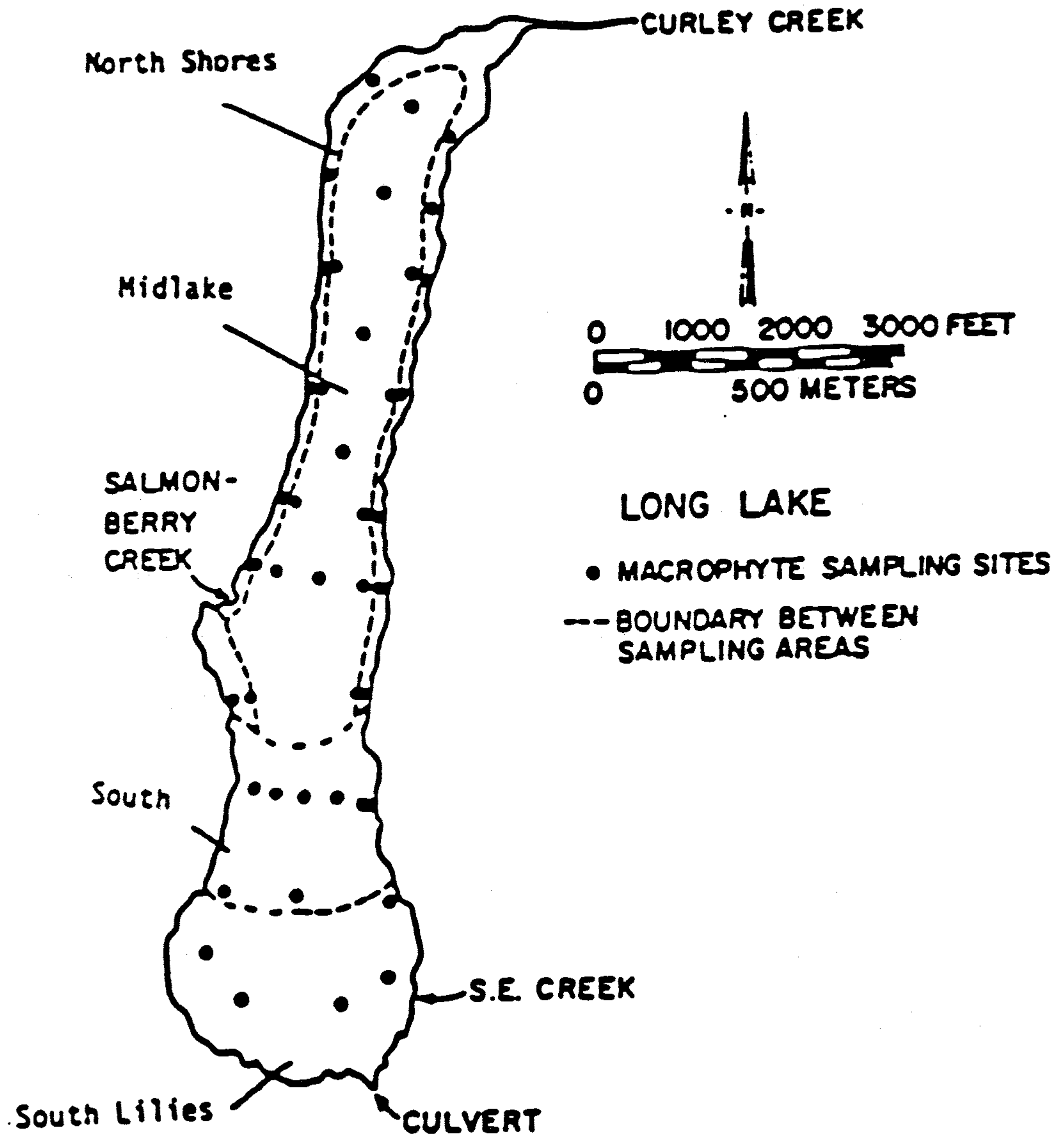


Figure 2. Macrophyte survey stations in Long Lake used in this study (Jacoby et al. 1982).

The sampling area was stratified into four seasons according to depth and sediment type (Jacoby, 1981; Figure 2). The same weighting scheme was used by Lynch (1982), but with slightly different section boundaries. Lynch also convereted early biomass estimates based on a three areas (Gabrielson, 1978; Hufschmidt, 1978; Perkins et al., 1979) to four area estimates. Discrepancies produced by the use of the three maps is thought to be small relative to that due to actual sampling of the plants.

A sectioned, 55-gallon drum served as a 0.255 m^2 quadrat, which was lowered from a boat and placed over the plants. Plants were then removed by a diver and placed in a net attached to the sampler. The selection of a sampling site was not wholly random. The bias of the sampler was removed as much as possible by preselecting a sampling site, approaching it by motor, slowing and anchoring. When the boat came to rest the sample was taken from a predetermined side of the boat. Samples were rinsed free of mud and placed in numbered bags. Water depth at each site was also recorded. Samples were washed with tap water in the laboratory, separated and identified to species, placed on foil in a drying oven (70^0 C) for 24 hours, and weighed.

Sample weights of species were combined on a quadrat basis. The mean density for each lake section was then calculated. A weighted mean density was determined by summing the products of section mean densities and percent areas for the four sections. The 95% confidence for the weighted mean was estimated as follows (Perkins et al., 1979).

$$95\%\ \text{CONFIDENCE INTERVAL} = 2\sqrt{\sum_{1}^{i} S_i^2 / N}$$

where S_i^2 is the variance of the ith section and N is the number of sections.

A significant portion of plant biomass lies in the emergent stand of <u>Nuphar</u> at the southern end of the lake. <u>Nuphar</u> is normally not sampled in the quadrats. An estimate of their contribution to biomass was made by Gabrielson (1978), who estimated that they covered 5% of the lake area and averaged 730 g dry wt./m^2. In August of 1985 a few stalks of Nuphar were collected from their root base and the number of stalks per m^2 and the percent of lake coverage was visually estimated. The stalks were dried and weighed in order to estimate Nuphar biomass.

Sediment collection

Sediments were collected by a diver using 30 cm polycarbonate tubes inserted by hand into the soft sediments. While the tube was still in place a #7 rubber stopper was placed in the lower end of the tube and the core was transferred upright to the boat and stopper at the top to exclude air bubbles. Cores were returned to the laboratory on ice to be sectioned for fractionation analysis or prepared for P-release experiments. Earlier cores were collected by a piston corer (Lynch, 1982; Jacoby et al., 1983).

Sediment analysis

A short core was collected from station M in September 1985. The core was sectioned and the upper few mm of sediment, as well as all 1 cm sections below this surficial sediment to a depth of 15 cm, were placed in an aluminum dish for drying. Dry sediments were ground with a mortar and pestle and about 0.1 g subsamples from the surface sediment, and subsequent depths of 1,2,3,4,5 and 15 cm, were digested in teflon cups by successive treatments with hot concentrated HNO_3, HF, HNO_3 and 1:1 HNO_3:$HClO_3$ (Jackson, 1960). The crucible was washed with a warm solution of 1 ml concentrated HCl and deionized water and decanted into a 50 m volumetric flask and diluted with deionized water to volume. Appropriate aliquots were analyzed for SRP to give sediment TP and by acetylene flame AA to give TS-Fe and TS-Mn. The method of standard additions was used to detect possible matrix effects. Analyses of approximately 5 mg samples with a Carlo Erba CHN analyzer model 1106 and acetanylide standards yielded total sediment carbon and nitrogen (Hedges and Stern, 1984).

Sediment phosphorus fractionation

P fractionation of sediment was performed at three depth intervals (0-2, 2-5 and 5-15 cm) and at two stations (M and S) in late summer of 1984, April and August of 1985 and March 1986 and at the Lilies station in March 1986. The method followed the fractionation procedure of Chang and Jackson (1957) as modified by Williams et al. (1967) (Table 1). This procedure has been used in the past on Long Lake sediments by Lynch (1982).

Cores collected for fractionation were separated into three segments (0-2, 2-5 and 5-15 cm) by securing a core in a buret stand, replacing the lower rubber stopper with one of cork, and with the aid of a glass rod the sediment was then extruded thorugh the top of the tube. When the sediment surface was flush with the top of the tube the upper few millimeters of sediment slurry were carefully removed and discarded. Each depth interval extruded and removed was placed in a predried and weighed aluminum dish, weighed, dried at 70^{o} C and weighed again for determination of water content. The sample was then ground with mortar and pestle and dried again before extraction. The 0-2 cm layer tended to be very fluid. The 2-5 cm layer was less fluid, but still required slow extrusion. The 5-15 cm, layer was quite compact and could be extruded easily.

Fractionation required 0.5 g of dried sediment, which was placed in 50 ml plastic centrifuge tubes with screw caps. The first treatment consisted of 25 ml of 1.0 N NH_4Cl solution (pH adjusted to 7.0 with 4 N NH_4OH) and held for 30 minutes on a shaker table. Although the Williams et al. (1967) procedure calls for the use of 0.5 N NH_4Cl, the original Chang and Jackson (1957) procedure used 1.0 N NH_4Cl. A 1.0 N solution was used here to be consistent

Table 1. Sediment fractionation procedure for total inorganic phosphorus (AI-P) following scheme of Williams et al. (1967), but with further modification (see text).

STEP	EXTRACTION REAGENT(S)	NOMENCLATURE	METHOD OF P DETERMINATION OF EXTRACT
1	1.0 N NH_4Cl pH=7.0 30 minutes (but see text)		APHA 1985
2	0.5 N NH_4F pH=8.2 24 hours	-	APHA 1985
3	0.1 N NaOH 17 hours	P COMPLEXED TO SHORT RANGE ORDER IRON-RICH COMPLEX	Dickman and Bray 1940
4	dithionite-citrate-bicarbonate "CDB" (but see text)	-	Watanabe and Olsen 1962

with previous work (Lynch, 1982; Jacoby et al., 1983). Although neutralization at this step was not mentioned by Lynch (1982) or Jacoby et al. (1983) and is apparently not part of the Chang and Jackson (1957) or Williams et al. (1967) procedure, it is recommended by Bostrom (1984) and was used here.

The tubes were centrifuged at about 1600 G for 15 minutes in an International Clinical Centrifuge, model CL. The pellet was stable and enabled the supernatant to be decanted into a 50 ml volumetric flask and diluted to 50 ml with deionized water. This fraction was analyzed for SRP by the ascorbic acid method (APHA 1985) using reagent and color blanks when necessary. Sample size was generally 20 ml diluted to 40 ml.

The second fractionation involved treatment of the pellet from the previous extraction with 0.5 N NH_4F (pH adjusted to 8.2 with 4.0 N NH_4OH) for 24 hours on a shaker machine. These were centrifuged and decanted as before. This was followed by a 20 ml washing with saturated NaCl solution which was added to the 50 ml volumetric flask and diluted to 50 ml. Sample size was generally 2 ml diluted to 40 ml followed by SRP analysis.

Color development in the 0.5 N NH_4F extract was very slow (up to 2 hours), but was stable for 24 hours. This phenomenon is believed to be due to the fluoride because NH_4^+ in the previous extract had shown no effect on color development. The standards prepared with the lowest concentrations of NH_4F showed no delay in color reactions. Color effects were observed with NH_4F concentrations as low as 0.02 N NH_4F (1 ml 0.5 N NH_4F diluted to 40 ml with standard). At this concentration of NH_4F, color development was not complete even after 22 hours. At concentrations at and below 0.02 N NH_4F, no delay in color development was observed after 1 hour. This effect was not reported by

Lynch (1982) or Jacoby et al. (1983). Its significance will be discussed later.

The third extraction required a 17-hour extraction on a shaker machine with 25 ml of 0.1 N NaOH. The samples were decanted and washed with 20 ml NaCl, centrifuged and the washings discarded. The supernatant was diluted to 50 ml in a volumetric flask and analyzed for SRP by the stannous chloride method of Dickman and Bray (1940). Aliquot size was usually 2 ml diluted to 35 ml.

The fourth extraction, "CDB", was originally thought to remove "reductant" soluble P and was referred to as "reductant soluble P" by Williams et al. (1967). Further study indicated that P extracted from non-calcareous sediments removed P from a ferrous iron-rich gel complex and the term "reductant" became redundant. This fraction will be called CDB here, but is not to be confused with CDB if not preceded by other extractions, as in Williams et al. (1971).

The pellet was suspended in a solution of 20 ml of 0.3 M sodium citrate and 2.5 ml of 1 M sodium bicarbonate followed by the addition of 1 g of solid sodium dithionite. Heating the suspension in a water bath at 80-90^{o} C is recommended with stirring for 15 minutes. Lacking a water bath, the sodium citrate solution was preheated to 80^{o} C and the plastic tubes were placed in a tub of water at 80^{o} C with continued heating on a hot plate. The citrate solution was then added followed by the bicarbonate and dithionite. The reduction rection was allowed to proceed for 15 minutes using a glass rod for occasional stirring. The tubes were then centrifuged and the supernatant decanted into 50 ml volumetric flasks. A 20 ml washing of saturated NaCl was also added to each flask and diluted to 50 ml with deionized water. SRP analysis was performed with a 2 ml aliquot diluted to 25 ml in reagent grade ethyl alcohol by the method of Watanabe and Olsen (1962), which requires a solvent extraction of P from the highly reduced sample. An attempt was made to reoxidize the samples by bubbling air, followed by analysis via the simpler ascorbic acid method (Weaver, 1974), but this procedure did not sufficiently oxidize the sample.

Together these fractions were summed and referred to as "Available Inorganic Phosphorus" (AI-P) by Lynch (1982). However, Williams et al. (1967) referred to this sum as total inorganic P because the portion that is "available" is not determined. Lynch may have associated this scheme with a further modification of the Williams et al. (1967) procedure by Mayer and Williams (1981) who identified AI-P as apatite bound inorganic P derived by extraction with 0.5 N HCl. For consistency, AI-P will still refer to the sum of NH_4Cl, NH_4F, NaOH and CDB-P extractions according to Williams et al. (1971). This quantity supposedly represents P bound to a "short range order iron-rich gel complex."

All P analyses were performed with extraction reagent blanks, and color blanks were used when necessary. Samples that were highly colored (typical of NaOH extractions) were diluted for analysis. The procedure to precipitate the color by acid addition failed, so color blanks were carried through when color was significant in the NaOH fractions.

Alum effect on sediment P release

An experiment was performed to locate the "layer" of alum in the sediments. Determining the fate of the alum layer following an in-lake treatment could greatly enhance the interpretation of the benefits derived from the treatment and could help explain the decline of its beneficial effects. If present, anaerobic P release rates from various depths in the sediments might vary depending on the presence or absence of an alum layer.

An experiment was also designed to compare P release rates from two intact cores treated with different alum doses and P release rates from cores in which the alum floc was dispersed into the top 2 cm of the sediment. P release rate was determined by incubating sealed cores at 20^{o} C. The overlying water was sampled 8, 16, 32 and 64 days after the start of incubation. Replicate cores were sacrificed for P analysis on each sampling day for each experimental treatment.

Sixty, 30-cm cores were collected from station M as described previously. Eight cores were sealed with a rubber stopper (taking care to exclude air bubbles) and then the top was wrapped tightly with electrical tape (undisturbed sediments = CONTROL). The rubber stopper at the core top was fitted with a glass sampling port and serum stopper. Eight cores from which the top 2 cm of sediment was removed were filled with unfiltered lake water and sealed as before (2 CM REMOVED). Eight cores had the top 5 cm of sediments removed, were filled with lake water and sealed as before (5 CM REMOVED). Eight cores were treated with 2.0 ml of the prepared alum solution described above (5.5 g Al/m^2). Another eight cores were treated with a 5.5. g Al/m^2 dose, after which the settled floc was gently mixed to a depth of about 2 cm with a glass rod (5.5 g Al/m^2 MIXED). Eight cores were also dosed at twice the first level (11 g Al/m^2), to approximate the original lake dose.

All cores were then placed in anaerobic incubation chambers and maintained at 20^{o} C for the duration of the experiment. At 8, 16, 32 and 64 days two cores from each treatment were placed in a nitrogen purged, glove box. Samples were removed with a syringe through the serum stopper, placed in 60 ml plastic bottles and treated with 2 drops of concentrated nitric acid. Replicate samples were immediately filtered through 0.45 μm Millipore filters followed by the same nitric acid treatment. Analysis of the samples followed the perchloric acid digestion method yielding TP and total soluble phosphorus (TSP), respectively (APHA, 1985). After sampling cores, the top stopper was removed and pH and DO of the overlying water were determined electrometrically.

Depth of overlying water was also measured to determine volumes and calculate P release on an areal basis. A plot of the TP and TSP concentration (corrected for volume) over time yields a straight line and the slope is an estimate of the P release rate. These release rates were then compared to examine the fate of alum after treatment and its ability to prevent release of P.

Water and Phosphorus Budgets

Water and TP budgets for October 1, 1976 to September 13, 1977, were obtained from Lynch (1982), and for September 9, 1980, to August 27, 1981 from Michaud (1983). The methods and assumptions used to calculate the budgets for both were identical with the single exception that Michaud used 2 week time steps between measurements and Lynch used time steps which varied from 2-5 weeks. The water and TP budgets for September 14, 1984, to September 24, 1987 were determined in this study.

Pan evaporation data from the Puyallup Weather Station (U.S. Climatological Data for Washington, 1984-1987), 35 km southeast of Long Lake, were multiplied by 0.7 to obtain lake evaporation (Linsley et al., 1982). Precipitation on the lake was taken as the average of the Bremerton and Wauna Weather Stations located 11 km north and 12 km south of Long Lake, respectively (U.S. Climatological Data for Washington, 1984-1987). Lake storage was determined according to Lynch (1982), by calculating lake volumes from Curley Creek stages before and after each time step. The surface area of the lake was assumed to remain constant. The only unknown in the water budget, ungauged terrestrial input, was calculated by difference from the following equation:

Ungauged Terrestrial Input = Curley Cr. Outflow + Evap. Losses - Salmonberry Cr. Inflow - Lake Precip. + Change in Lake Storage

Assumptions about partitioning the ungauged terrestrial input into surface runoff and groundwater were the same as those used by Lynch (1982) and Michaud (1983), as follows:

1) When input from the ungauged catchment is equivalent to 50% of the Salmonberry Creek inflow, it is attributed all to surface water inflow. Groundwater inputs are assumed to be negligible;

2) When input from the ungauged catchment drops below an amount equivalent to 50% of the Salmonberry Creek contribution, it is assumed the ungauged surface input is 50% of Salmonberry Creek and that groundwater recharge from the lake accounts for the difference;

3) When the input from the ungauged catchment exceeds 50% of Salmonberry Creek, it is assumed the ungauged surface input is equal to 50% of Salmonberry Creek plus one half of the amount in excess of 50%. Groundwater is assumed to account for the other half of the excess.

The following mass balance equation was used to determine the term net sedimentation (if +), or net internal loading from sediments (if -), as the only unknown:

Net Sedimentation or Internal Loading = Salmonberry Creek Input + Ungauged Surface Input + Groundwater Input + Bulk Atmospheric Input + Septic Tank Input - Change in Lake TP Storage - Curley Creek Output

TP concentrations used in the budgets were from Salmonberry Creek, Curley Creek, and a volume-weighted mean of the whole lake. Salmonberry Creek input and Curley Creek output were taken as the mean of measured TP at the beginning and end of each time period. Change in lake TP storage is the final minus initial lake TP. TP of the ungauged surface input was assumed to be the same as that of Salmonberry Creek. This obviously introduces some error to the budget; however, the land uses in the Salmonberry Creek catchment are similar to those in the ungauged catchment.

The water budget provides information about the lake's gain or loss of groundwater. The groundwater TP is assumed to contain 120 μg/l, as determined in 1977 by a seepage meter (Lynch, 1982). During times of groundwater recharge, it is assumed that the lake is losing water with a TP equal to the average lake concentration at the time.

The atmospheric deposition rate determined by Lynch (1982) of 0.23 kg P/day was used. This value was assumed to remain constant and independent of rainfall.

The septic tank leachate loading rate of 0.88 kg P/home-yr, determined by Gilliom (1978), was used. Assuming 120 nearshore homes, this amounts to a septic TP loading rate of 0.29 kg/day.

The final term in the TP mass balance is "Net Sedimentation or Internal Loading" is unknown and can be calculated by difference. If negative, net internal loading is taking place, and if positive, net sedimentation is occurring.

<u>Model Development</u>

A non-steady state, mass balance TP model used to predict Long Lake's volume-weighted mean TP concentration and to obtain an estimate of the gross internal loading and gross sedimentation rates. The model used was first developed by Vollenweider (1969) and modified by Larson et al. (1979) and is as follows:

$$\frac{d(TP)}{dt} = \frac{L'ext}{V} - \frac{Q(TP)}{V} - \sigma\ (TP) + \frac{L'int}{V}$$

where L'ext is the combination of septic, atmospheric, groundwater, stream, and ungauged surface loading; Q is outflow, V is lake volume, σ is the sedimentation rate coefficient, and L'int is internal loading. Water and TP budgets were necessary as input data to calibrate and verify the model.

This non-steady state model was chosen because: 1) it separates gross sedimentation and gross internal loading, allowing the investigator to learn more about the factors affecting each; 2) complete data sets are available for several years on Long Lake, including years with known high and low internal loading; and 3) it separates events seasonally, allowing inspection of the timing and magnitude of internal loading.

There were five years of sufficient data available: October 1, 1976 to September 13, 1977; September 9, 1980 to August 27, 1981; and September 14, 1984 to September 24, 1987. Treatment of the lake with alum in early September of 1980 presented a unique opportunity. Michaud (1983) showed that gross internal loading the summer after alum treatment (1981) was approximately 20% of L'int in 1977. This evidence was based on measured sediment flux rates and a gross sedimentation rate of 0.90 mg P/m^2-day. Therefore, the 1981 summer L'int was assumed to equal 20% of the 1977 summer L'int, and the 1980-1981 year was used to calibrate the above model for an appropriate gross sedimentation rate coefficient.

Assuming that the 1981 summer L'int was equal to 20% of the 1977 summer value, the gross sedimentation rate coefficient could be calibrated using an iterative process if sedimentation were known. Other researchers have found a relationship between sedimentation rate and flushing rate, a more easily measured value (Dillon, 1975; Larsen and Mercier, 1976; Shuster, 1985; and Butkus, 1987). A similar relationship of the form $\sigma = x\rho^y$ was assumed for Long Lake. The constants x and y were calibrated by successively varying each until the sum of squares (SS) of the difference between measured and calculated TP during 1981 was minimized:

$$SS = \mathrm{Sum}(j=1,n)\ (TP_j\ \mathrm{measured} - TP_j\ \mathrm{calculated})^2,$$

where j increases from 1 to n, which is the total number of time steps

After calibration of the sedimentation rate coefficient was complete, that relationship was used in the model for the time period October 1, 1976 to September 13, 1977. L'int was unknown for that period, but because all the other terms in the above equation were known, L'int could be calculated by difference. A relationship was sought between L'int and several other easilty measured parameters, including wind speed and direction, water temperature, season, and flushing rate, either individually or combined in order to better understand the cause for internal loading. The most satisfactory formulation was between L'int and season. That is, internal loading appeared to be time dependent only. A similar scheme was used by Larsen et al. (1979). The summer rate of L'int lasted from June until mid-September. There was also a winter rate which lasted from mid-September through May. Again, the calibrated rates for summer and winter L'int during 1976-1977 were determined by varying their magnitude until a minimum SS was obtained.

The model was then adjusted using 20% of the 1977 summer L'int to calibrate a sedimentation rate coefficient for 1980-1981. This new sedimentation rate coefficient was then used to calibrate the model for L'int, and the cycle was repeated until a minimum SS was obtained in each calibration year.

The model was verified using the years September 14, 1984 to September 24, 1987. The values of x and y from the sedimentation coefficient calibration, and the seasonal values of L'int from other years, were used in the verification of the model. This was not a completely valid verification because it was known from mass balances that internal loading was less than during pre alum years, but it gave an indication of the effect of alum on internal loading, relative to pre-alum years.

A statistical analysis was performed on the model output for the three verification years. The test consisted of a student's t test with $H_O: d=0$, $H_A: d=0$, and $\alpha(2)=0.05$, where d = Predicted (TP) - Measured (TP) (Zar 1984).

RESULTS

In-lake water quality

Location of the four stations along the long axis (North-South) of Long Lake allowed the detection of gradients in water quality constituents in earlier studies. However, the pattern of TP and chl *a*, observed in past studies of Long Lake (Hufschmidt, 1978; Michaud, 1983), was not observed here during 1984 through 1986 (Figures 3 and 4, Appendix A). Earlier in-lake concentration during the non-growing season was generally related to winter storms, which frequently yielded high TP content. However, on the average, TP from 11 storms during 1984-1986 was the same as that for routine samples (42 μg/L $\pm$ 50%). Biological and chemical processes in the lake during the growing season (February-October) also resulted in high TP, which was related to algal biomass (e.g. summer 1985; Figures 3 and 4). SRP in the lake was generally less than that in the inflow (23 $\pm$ 12 μg/L), and during summer SRP was depleted, relative to that in the inflow. However, it was still detectable during June-September (mean = 5.4 $\pm$ 3.3, 1985) with lowest concentrations occurring typically in June.

Although nitrogen species were not determined as part of this study, past observations of seasonal changes in nitrogen forms are instructive. Coupled with data on phosphorus (both TP and SRP), the nutritional status of phytoplankton through a "typical" year can be inferred and the relationship between inflow and in-lake TP, which indicates net internal loading of phosphorus in summer, can be illustrated.

Typically, the concentration of ammonia nitrogen was elevated in the inflow and in-lake in winter and then decreased to detection limit levels (< 15 μg/L) during the summers of 1977, 1979 and 1980 (Figures 5, 6 and 7). Total nitrogen (TN) is elevated in winter and is similar in the inflow and in-

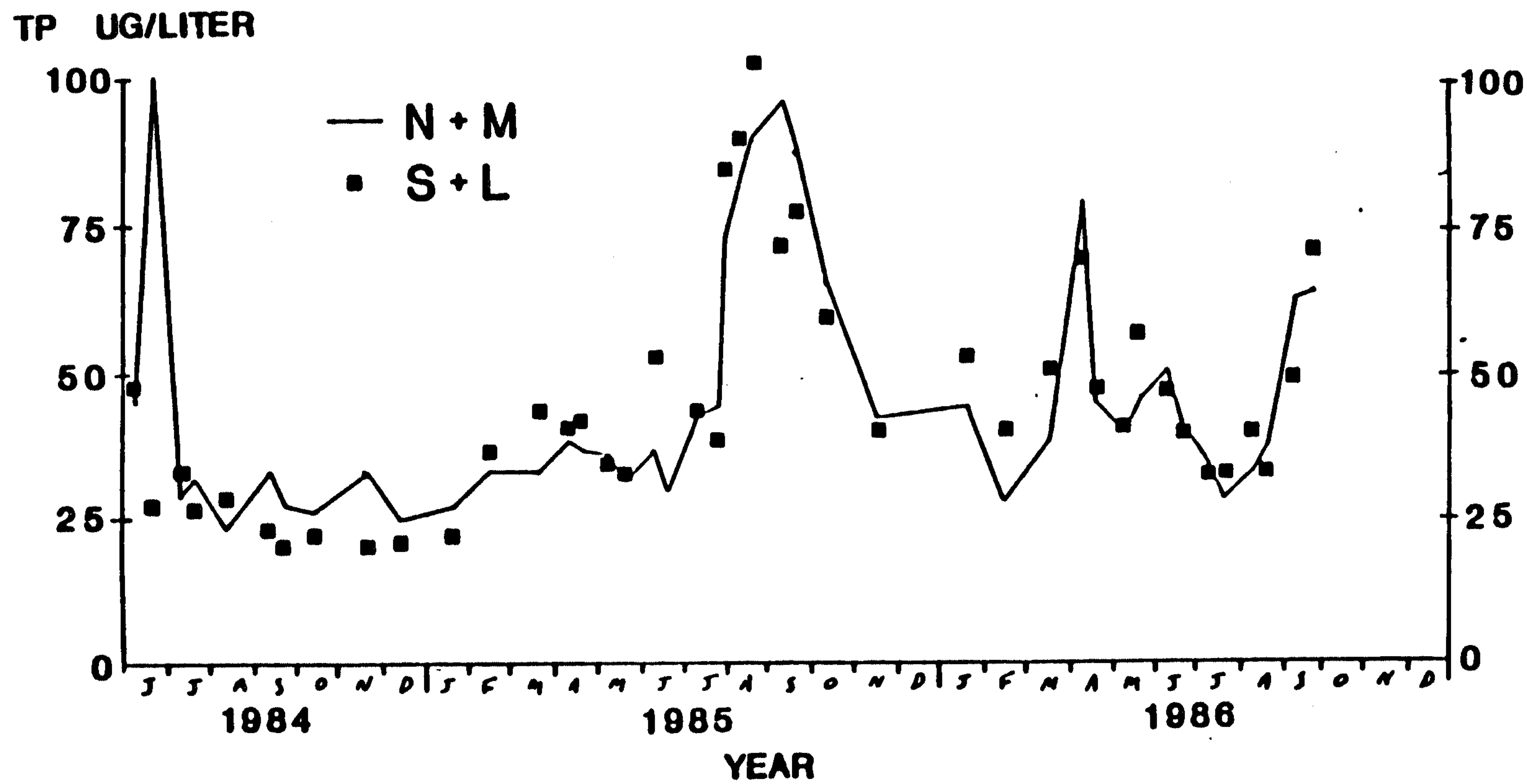


Figure 3. Total phosphorus (TP) volume-weighted means of North and Midlake (N+M), and South and Lilies (S+L) in Long Lake June 1984 to December 1986.

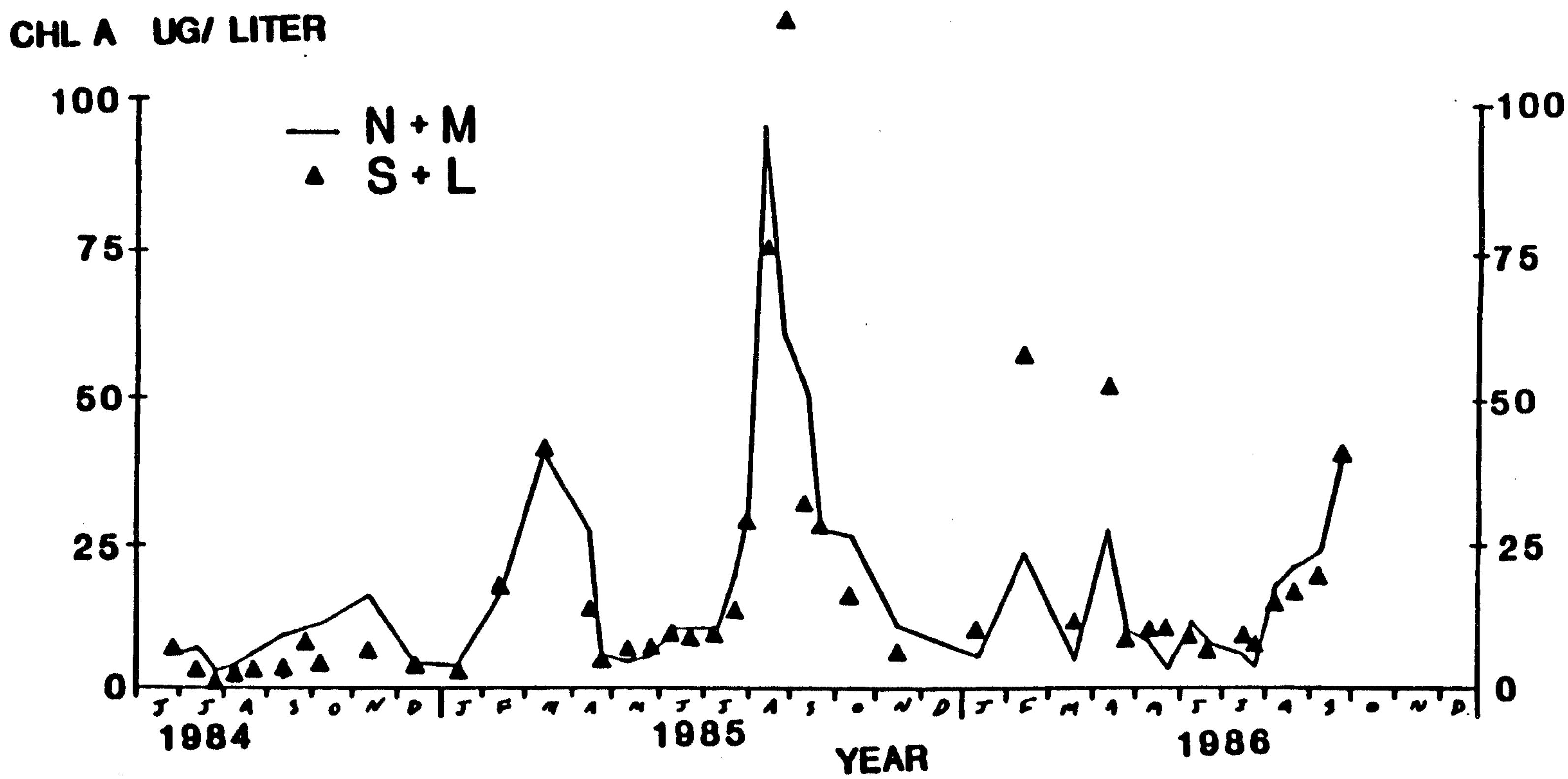


Figure 4. Chlorophyll _a_ (Chl _a_) volume-weighted means of North and Midlake (N+M), and South and Lilies (S+L) in Long Lake June 1984 to December 1986.

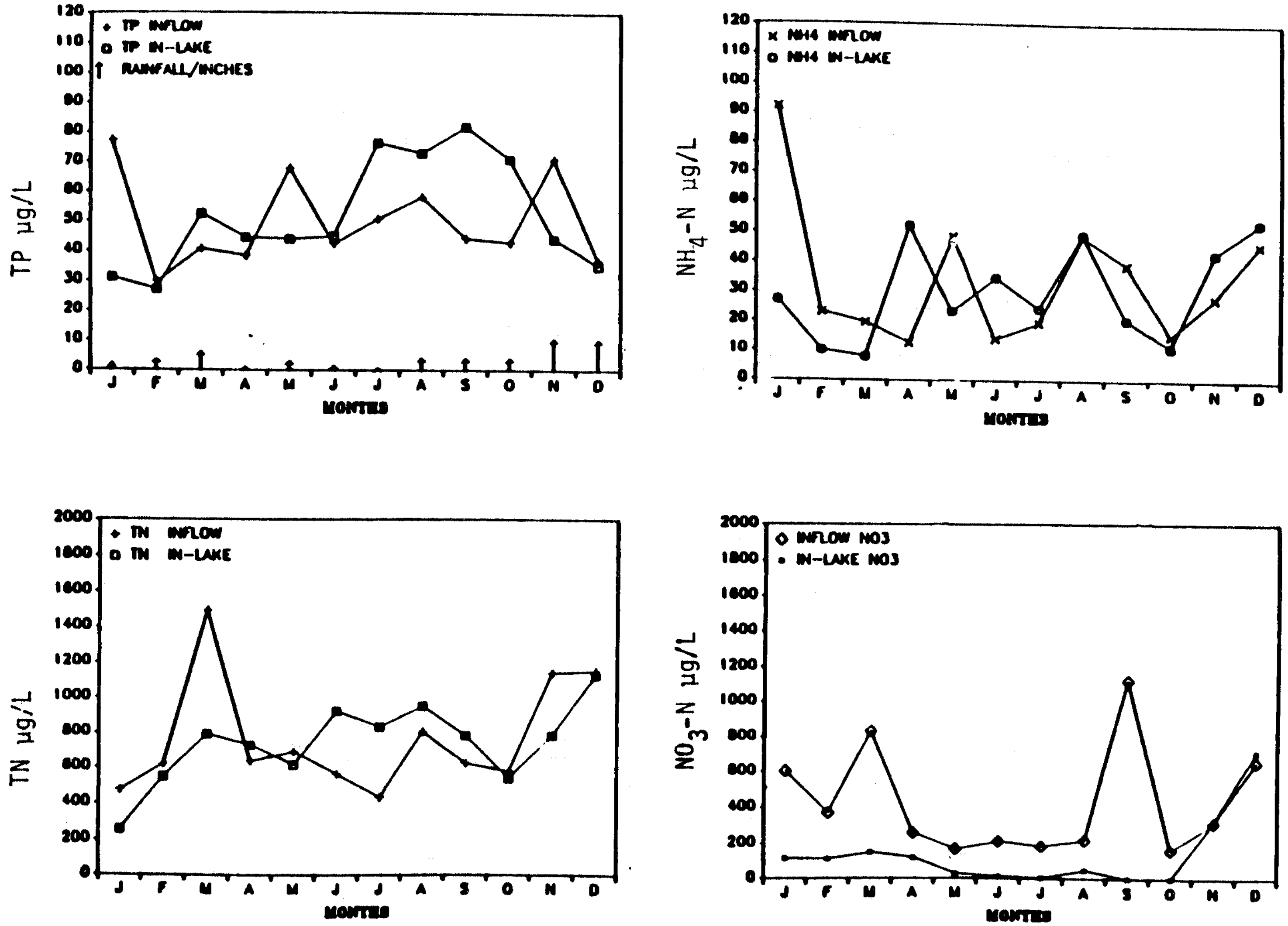


Figure 5 . Long Lake monthly mean inflow and in-lake concentrations of TP, NH_4-N, NO_3-N and TN in 1977. ↑ denotes monthly rainfall with the scale in inches.

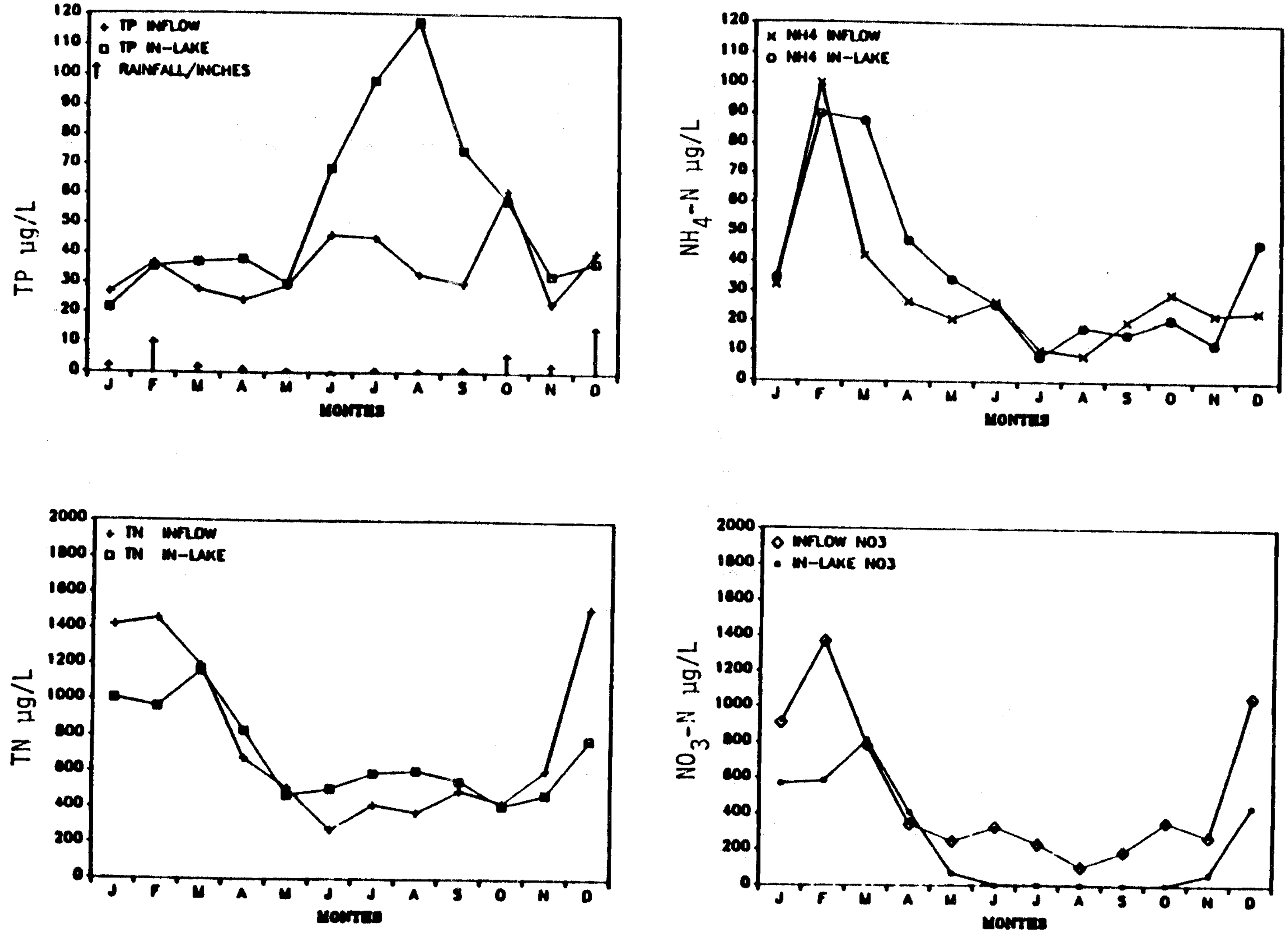


Figure 6 . Long Lake monthly mean inflow and in-lake concentrations of TP, NH_4-N, NO_3-N and TN in 1979. ↑ denotes monthly rainfall with the scale in inches.

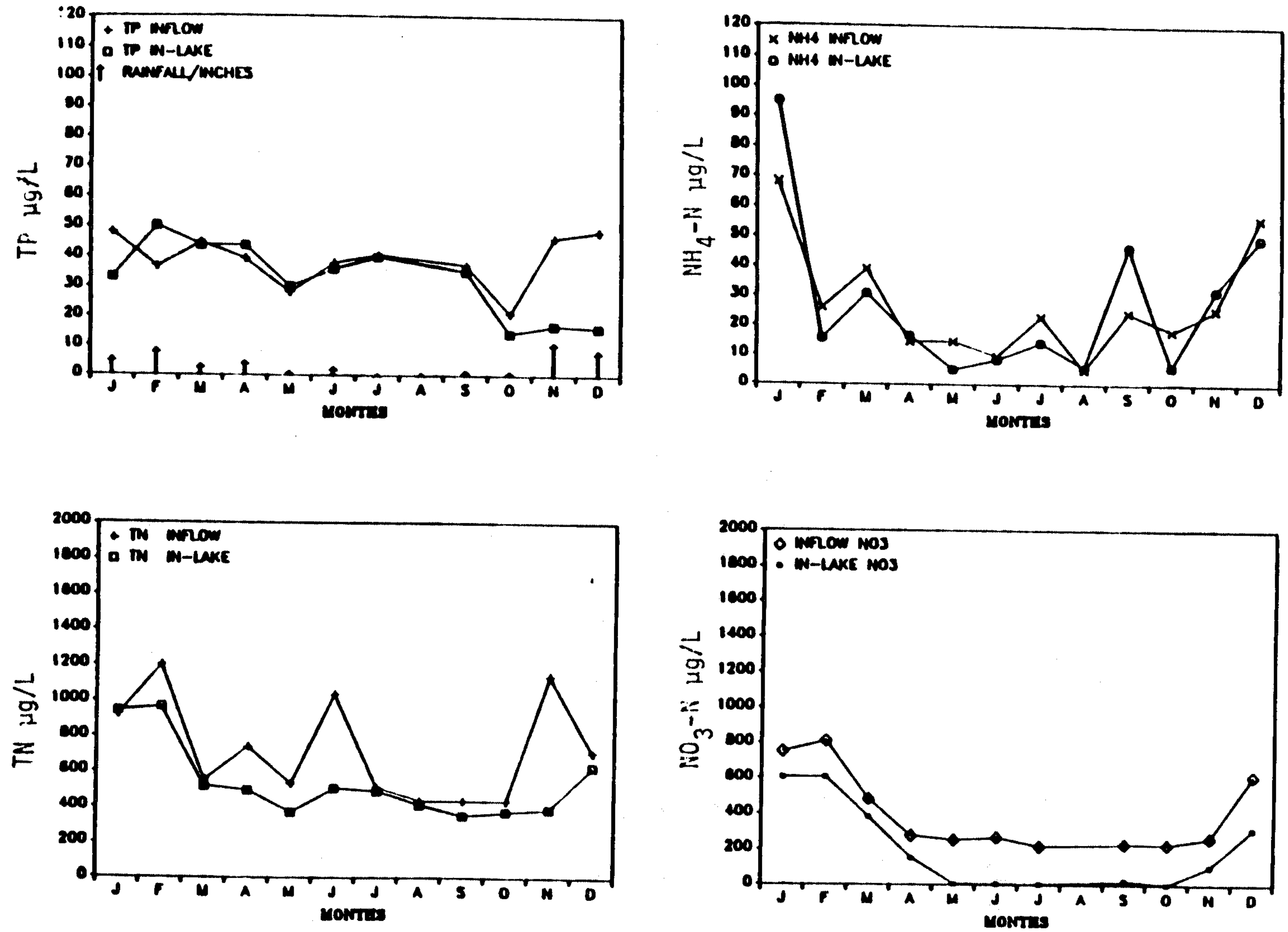


Figure 7. Long Lake monthly mean inflow and in-lake concentrations of TP, NH_4-N, NO_3-N and TN in 1980. ↑ denotes monthly rainfall with the scale in inches.

lake throughout the year. Inflow TN is composed largely of NO_3-N and organic nitrogen. During summer, inflow soluble nitrogen is quickly converted to algae or if nitrate, some portion may be denitrified in the sediments. In-lake nitrate is depleted to undetectable levels which may indicate that sediments are competing with phytoplankton for nitrate (Ripl and Lindmark, 1979).

Patterns of inflow and in-lake TP in 1977 and 1979 demonstrate that between June and October, when inflow is low and rainfall is slight, large increases of in-lake TP may have occurred. This TP was primarily in the form of phytoplankton. A detailed mass balance on TP during these periods indicates that almost half of the in-lake TP was derived either from the sediments or the macrophytes. A similar episode of internal P loading occurred in March during the bloom of a mixture of diatoms and cryptomonads (Lynch, 1982). In 1980, however, the year following drawdown, a P mass balance indicated that there was no net internal loading that summer (Jacoby 1981). This is also shown by an excess in inflow TP over in-lake TP (Figure 7).

Alum was added to the lake in September of 1980 and the following summer there was still no net internal loading observed (Michaud 1983). Inflow TP was even higher than in-lake TP in 1981 (Figure 8). The effect on TP from these manipulations was not observed for nitrogen, however.

Nutrient limitation to algae was assessed by combining in-lake NO_3-N and NH_3-N (SN) and comparing that to SRP (Michaud, 1983; Figure 9). SN varied seasonally with peaks occurring during winter and minimums during maximum biological activity in summer. SRP, on the other hand, showed no seasonal trend prior to drawdown. This alone indicates that phytoplankton were

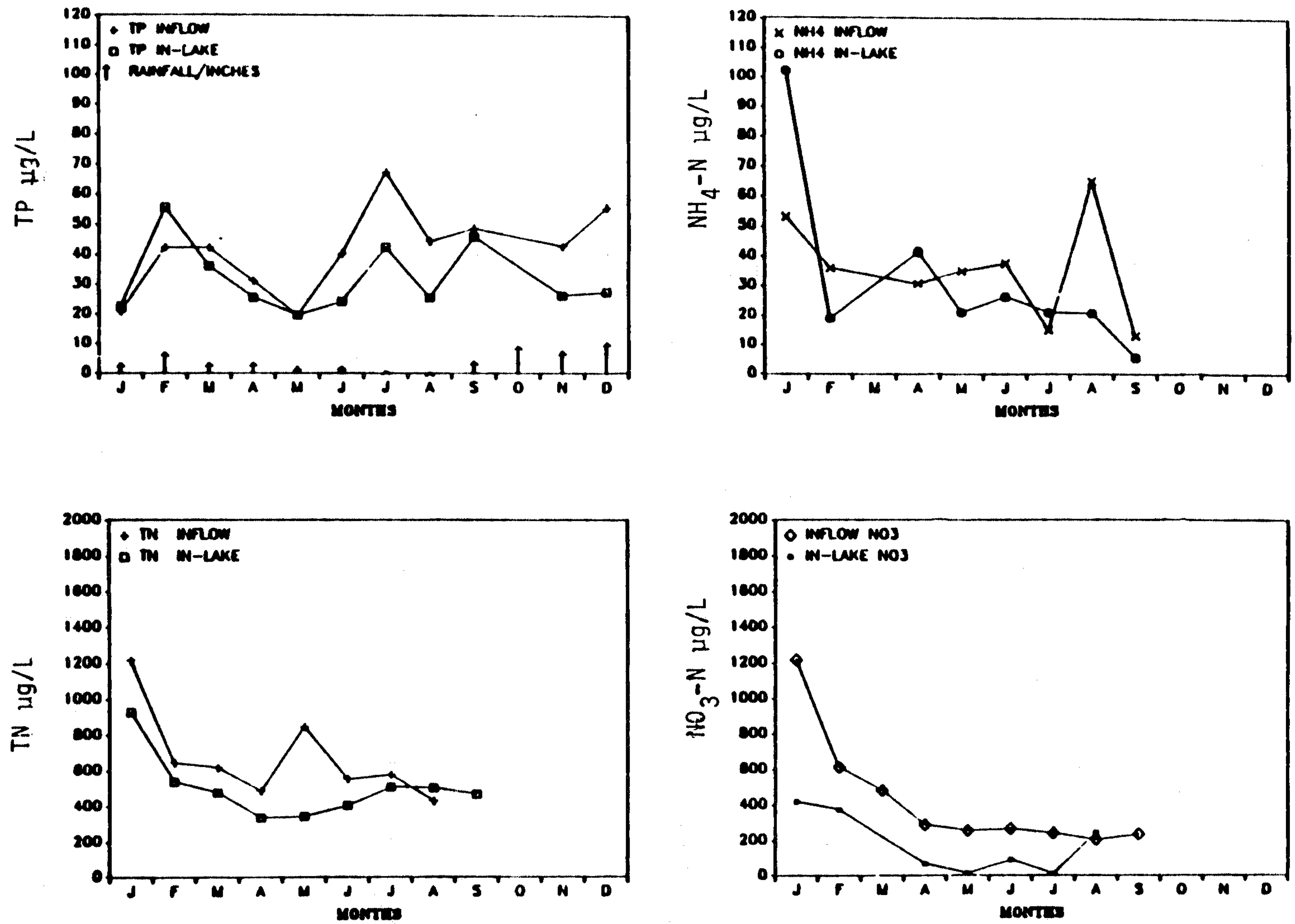


Figure 8. Long Lake monthly mean inflow and in-lake concentrations of TP, NH_4-N, NO_3-N and TN in 1981. ↑ denotes monthly rainfall with the scale in inches.

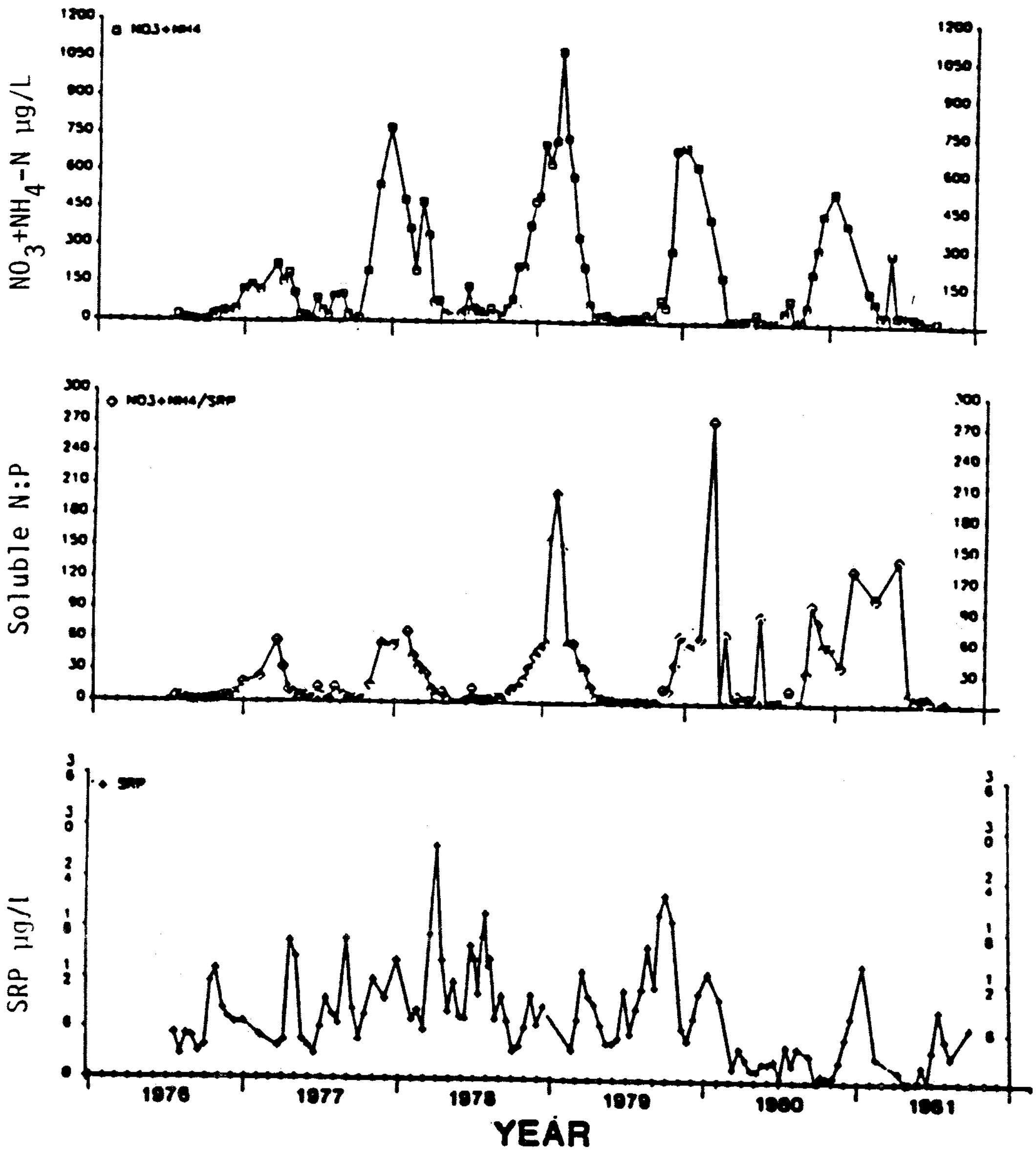


Figure 9 . Long Lake whole-lake volume-weighted mean concentrations of soluble nitrogen (SN= NO_3 + NH_4-N), soluble reactive phosphorus (SRP) and the ratio of SN:SRP 1976-1981.

nitrogen limited prior to treatment. The ratio of SN:SRP also indicates that N was limiting in summer: SN:SRP $\leq$ 10 (Figure 9).

In-lake TP and TN concentrations from earlier years are shown in Figure 10. TN tended to be higher during winter and lowest in summer while TP concentrations varied in the reverse pattern, as indicated previously, except for the post-drawdown and alum years (1980, 1981). The summer TN:TP ratio was rather low and constant for 1978-1980, suggesting N limitation. The higher and more variable TN:TP ratio in summer 1977 is apparently due to high and variable TN values. TN:TP after treatment was higher than in pretreatment years, indicating a change in limitation.

Summer TN:TP and SN:SRP means for June-September are shown in Table 2. Although not conclusive, because 1977 TN:TP was not different than TN:TP in 1981, TN:TP following drawdown and alum suggests a trend toward P limitation following N limited summers of 1978 and 1979. SN:SRP data are less suggestive.

In-lake alkalinity followed trends in inflow alkalinity (9-58 mg/L) and ranged from 15 mg $CaCO_3$/L in December 1985 to 49 mg/L in October of 1985 (Appendix A). The mean for 1985 was 36 $\pm$ 9 mg/L (n = 26). Alkalinity was generally uniform throughout the lake.

The distribution of hydrogen ion concentration, as pH, was generally low in winter and increased throughout the summer as phytoplankton productivity increased. A peak pH of 8.0 was observed in the southern portion of the lake in September of 1986 indicating that peak production occurred in late summer that year. Inflow pH ranged from 6.4 to 7.8 and followed the pattern of inflow alkalinity.

Secchi transparency was highly variable throughout all years. The greatest consistency in transparency at station M was observed in the summer

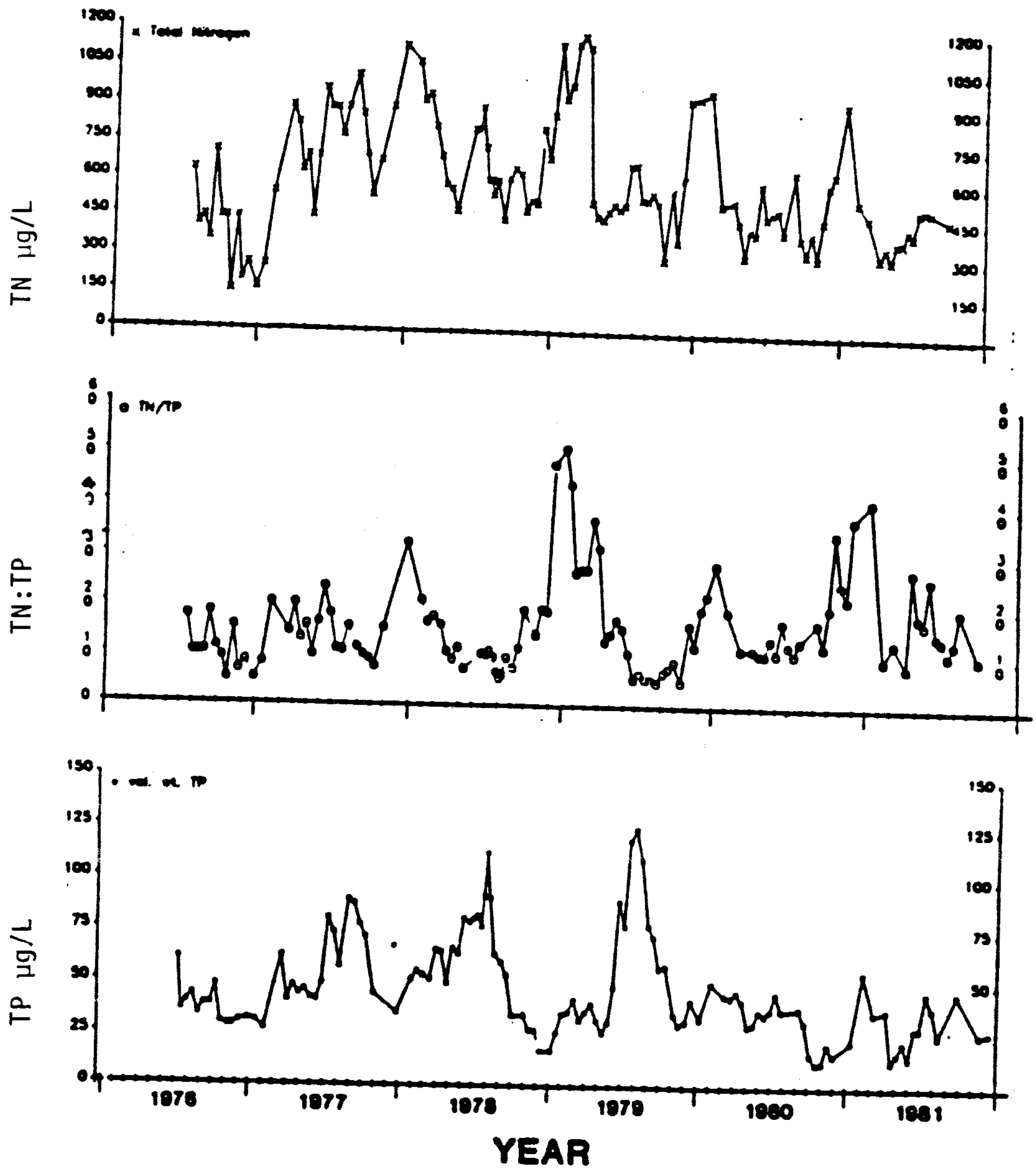


Figure 10. Long Lake whole-lake volume-weighted mean concentrations of total nitrogen (TN), total phosphorus (TP) and the ratio of TN:TP 1976-1981.

Table 2. Summer (June-September) mean TN:TP ratio and SN:SRP ratio in Long Lake 1976-1981 (SN= NO_3-N + NH_3-N). Means of whole lake ratios during summer.

YEAR	JUN-SEPT TN:TP ($\bar{x}$ ± s.d.)	n	JUN-SEPT SN:SRP ($\bar{x}$ ± s.d.)	n
1976	13 ± 4	6	2 ± 2	6
1977	14 ± 8	8	6 ± 5	8
1978	9 ± 10	10	4 ± 3	10
1979	7 ± 8	8	2 ± 1	8
1980	13 ± 3	7	5 ± 5	6
1981	16 ± 6	7	6 ± 3	6

of 1984 with a mean of 2.5 ± 0.3 (n = 8). A maximum of 3.4 m was recorded at M in May, 1985. Winter (December-February, 1985-1986) transparency was generally low (mean = 1.2 ± 0.2, n = 5) due to the inflow of dissolved humic substances. Beginning in November, the lake quickly turned to a dark tea color, which persisted until about February. The lake lost the color quickly through the spring and fluctuations in transparency throughout summer and fall were primarily controlled by particulate matter.

The seasonal pattern of phytoplankton biomass, that was typical during pretreatment years, was more evident again in 1985, although there were still two peaks observed each year (Figure 4). The spring peak (40 µg/L in March, 1985) consisted primarily of the diatom Asterionella and a motile cryptomonad. The summer peak (89 µg/L in August, 1985) occurred in late summer and consisted of a mixture of blue-green algae (Anabaena, Aphanizomena, Microcystis, Coelosphaerium and Gleotrichia), green algae, diatoms and the same motile cryptomonad observed in spring.

Productivity (as ^{14}C uptake) was determined by Hufschmidt in 1977-1978. In late February, 1978 productivity reached a high of about 500 mg C/m^2-d. The rate declined in April to 50 mg C/m^2-d and then rapidly rose to a peak of 1000 mg C/m^2-d in July, coinciding with the peak in chl a. The average summer rate of productivity was 536 ± 250 mg C/m^2-d (n=8). Post-treatment productivity was not determined.

Oxygen concentration, determined by titration, indicated that oxygen throughout the year was generally near saturation. However, oxygen concentrations, determined with a YSI probe at more discrete depth intervals throughout the summer of 1986-1987 indicated that gradients of oxygen concentration developed at times immediately above the sediments (Figures 11-12). However, temperature data indicated that very little gradient in density

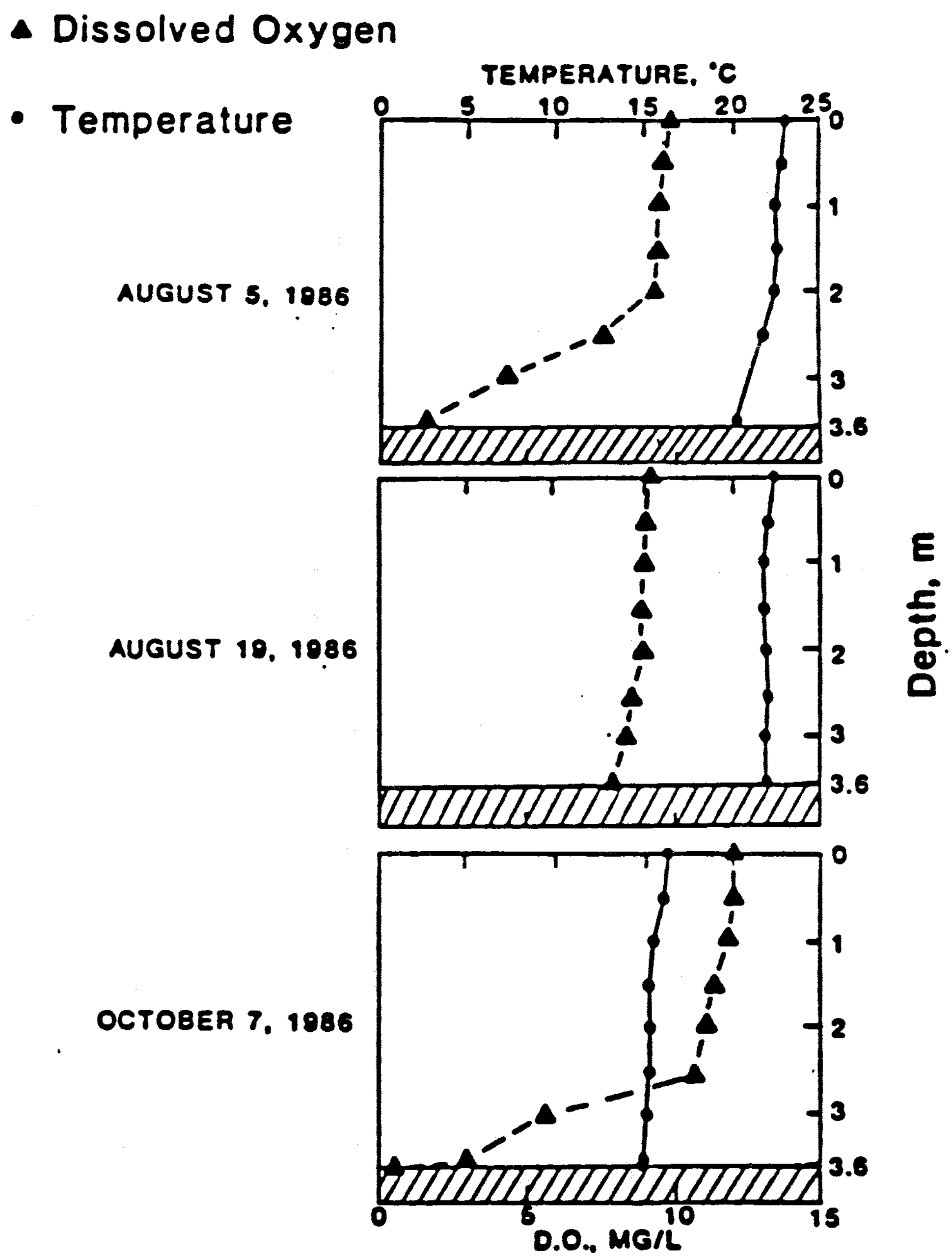


Figure 11. Selected profiles of dissolved oxygen and temperature at Midlake in Long Lake Summer of 1986.

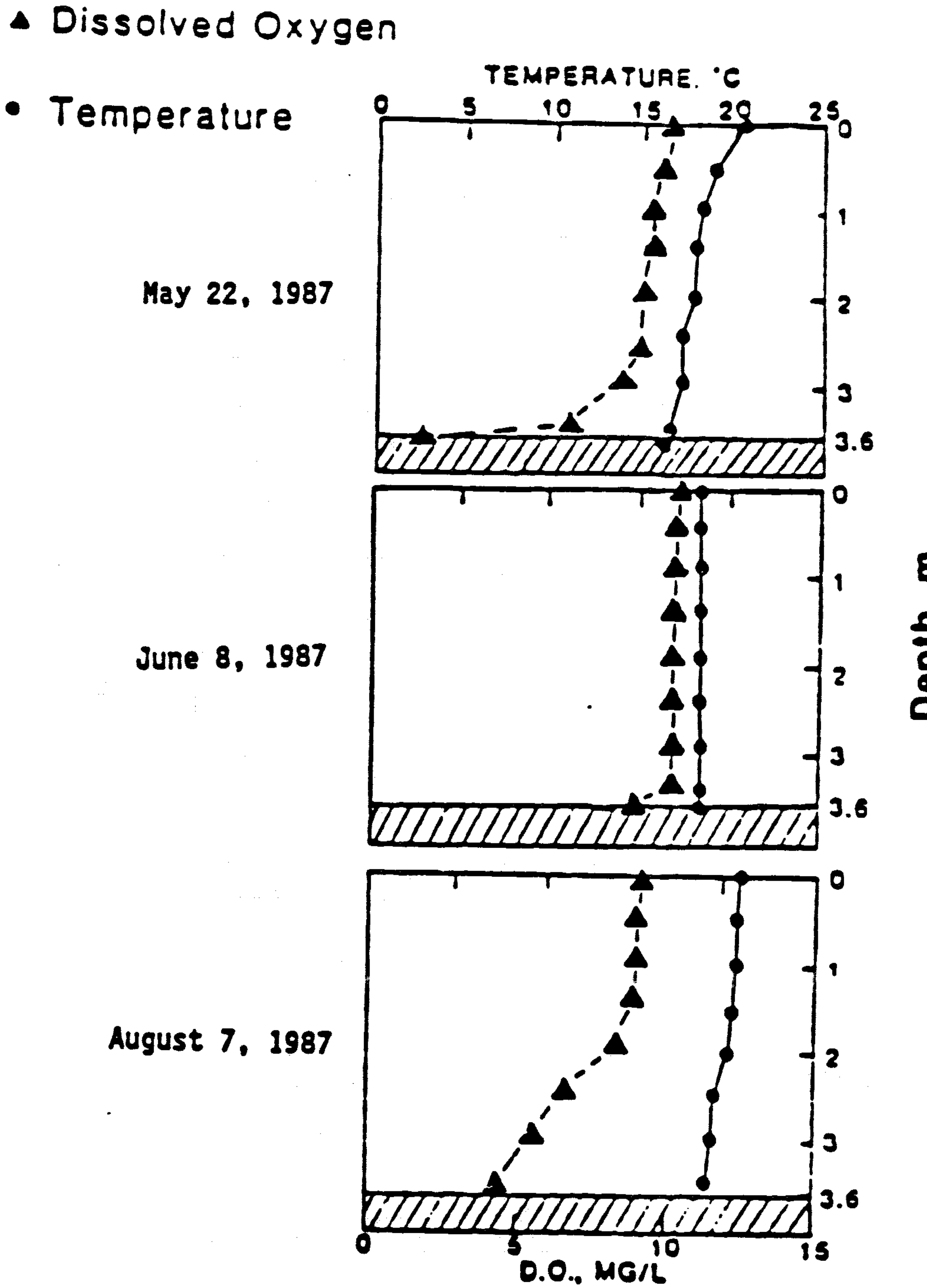


Figure 12. Representative DO and temperature profiles.

developed with depth existed. DO as low as 1.6 mg/L (5 August 1986) was observed just above the sediment at station M at mid-day.

Water concentrations of iron and manganese

To assess the importance of oxidation-reduction reactions at the sediment water surface, in-lake concentrations of TFe and TMn were compared to inflow concentrations (Figure 13). Inflow TFe ranged from 490 to 218 μg/L (mean = 368 ± 90 μg/L, n = 13) between February 1986 and September 1986. This was slightly higher than the average inflow iron content reported for Issaquah Creek, the inflow to Lake Sammamish, Washington (mean = 290 ± 316 μg/L, n = 31) between June 1974 to June 1975 (Felmy, 1981). TMn varied from 58 to 26 μg/L (mean = 43 ± 13, n = 13), which is also higher than that reported by Felmy (mean = 20 ± 14, n = 31).

Soluble iron (TSFe) was also determined on six occasions from 8 July, 1986 to 16 September, 1986 and averaged 73% of the inflow TFe and 56% of the TFe in-lake. Although the of TSFe fraction is rather high, TSFe is separated operationally: that iron which pases through the 0.45 μm Millipore filter, a large portion of which may be colloidal material (Delfino and Lee 1968; Delfino and Lee 1971; Howard and Chisholm 1975).

TFe:TMn ratios, along with concentration data, can indicate the oxidation-state of the sediments. In-lake water was enriched in Mn relative to Fe throughout the year (i.e., lower TFe:TMn ratio), relative to the inflow (Figure 13). This is not due to the resuspension of sediments rich in Mn, because sediments had an Fe:Mn ratio of over 20. The inflow, however, was enriched in Mn only in February and again in July through September. The summer increase in Mn in the inflow was accompanied by a decrease in Fe. This result is difficult to explain, although it may indicate partitioning of Fe and Mn upstream.

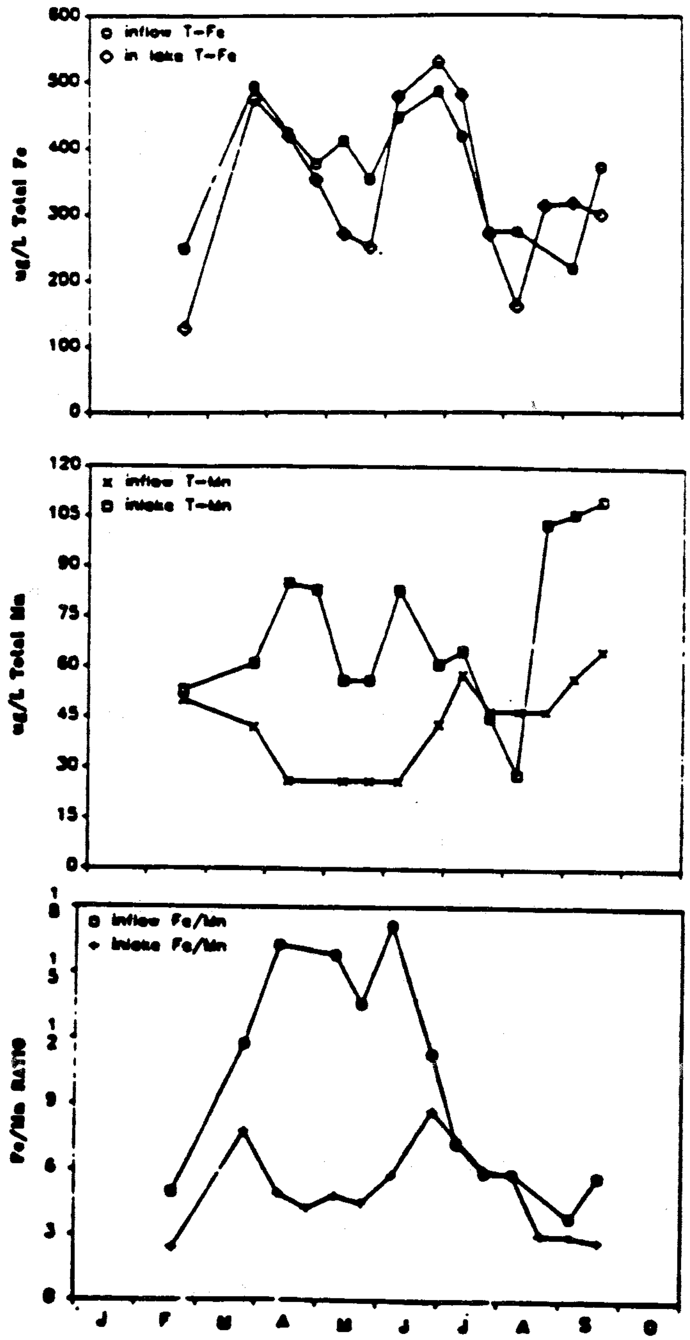


Figure 13. Salmonberry (Inflow) total iron (TFe) and whole-lake volume-weighted in-lake mean TFe (top). Inflow total manganese (TMn) and In-lake TMn (middle). Inflow and In-lake TFe:TMn ratio (bottom). 1986.

Generally, in-lake TMn was greater than inflow TMn throughout the year while little difference was discerned between inflow and in-lake TFe. Source sampling and flow data are inadequate to compute a mass balance on Fe and Mn that would show the relative magnitude of net sedimentation or release. However, assuming that Salmonberry Creek is characteristic of fluvial inputs and aeolian inputs are small, the inflow-lake concentration differences suggest that net Mn release from sediments occurred throughout the year except for one date in July. Periods of net sedimentation and release of Fe may have occurred throughout the year.

Fe, Mn, P, C and N in sediments at Midlake

To clarify sediment processes, sediment Fe, Mn, P, C and N content was determined at 1 cm intervals in the top 5 cm and again at 15 cm in a core collected at station M in September 1985. The concentration of Fe, Mn and P rises rapidly above the 5 cm depth to maximum concentrations of 0.22, 0.27 and 4.74% of dry wt. for Mn, P and Fe, respectively (Figure 14 and Table 3). These values are generally consistent with those from Lake Sammamish (Felmy, 1981), Lake Washington (Wallace, 1973; Barnes, 1976), Lake Mendota (Delfino et al., 1969) and other Wisconsin lakes (Bortleson and Lee, 1974).

Lynch (1982) also analyzed Fe and P at 1 cm intervals at station M and observed the same higher concentrations of Fe and P in the top 5 cm of the core (Table 4). Similar profiles in the south section of the lake were suggested to be due to macrophyte "mining" of P from deeper sediments. These were similar to results from Lake Wingra sediments and apparent effects of macrophytes (Prentki, 1979).

Sediment C and N were analyzed to evaluate the role of sedimentation in determining changes of Fe and P in the sediments (Table 5). The concentration of C and N is fairly constant in the top 5 cm of sediment (mean % C =

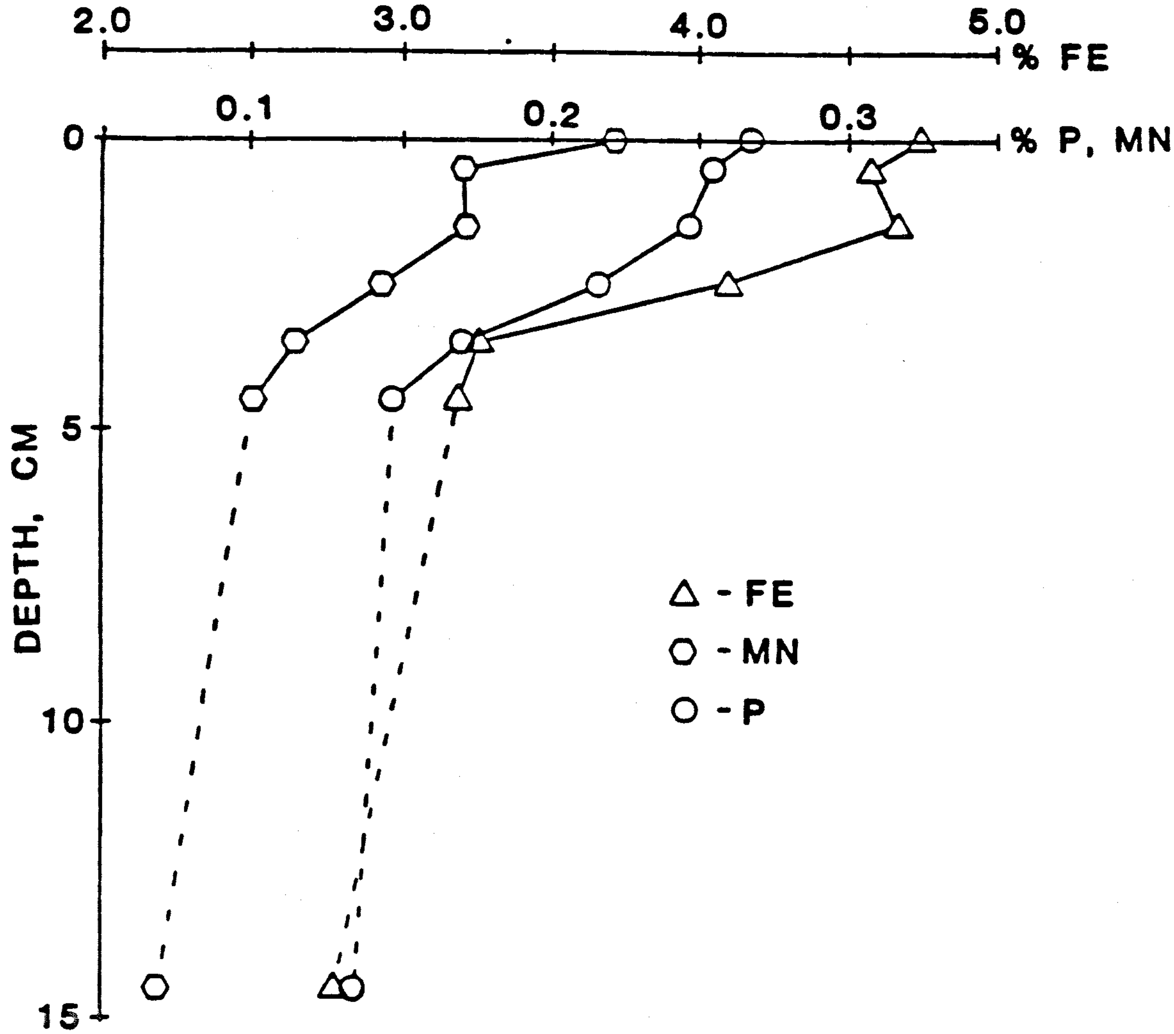


Figure 14. Sediment profile at Midlake of iron, manganese and phosphorus (mg/gm dry sediment) in sections of the top 5 cm of sediment and 14-15 cm depth. Core collected September 1985.

Table 3. Iron, manganese and phosphorus in the surficial sediments and 1 cm sections to 5 cm and one sample from 14-15 cm of sediment collected at Midlake station, Long Lake in September 1985. Concentration is as mg/gm dry sediment.

depth (cm)	----mg/gm------			Corrected by method of standard additions	
	P	Fe	Mn	Fe	Mn
surface	2.67	47.4	2.22	50.3	3.04
0-1	2.54	45.8	1.71	48.5	2.34
1-2	2.47	46.7	1.72	49.5	2.35
2-3	2.15	41.0	1.44	43.5	1.97
3-4	1.70	32.6	1.15	34.5	1.55
4-5	1.46	31.8	1.01	33.8	1.39
-					
-					
-					
14-15	1.34	27.8	0.69	29.5	0.94

Table 4. Iron, phosphorus and organic matter concentrations in 1 cm sections of sediment collected at Midlake by Lynch (1982). Date of collection between 1976-1978. Concentration as mg/gm dry sediment.

depth (cm)	-----mg/gm-----		
	P	Fe	% ORG
0-1	2.35	34.9	25.0
1-2	1.90	29.5	25.9
2-3	1.51	25.3	26.1
3-4	1.53	26.8	26.4
4-5	1.73	28.8	27.9
-			
-			
-			
14-15	1.18	19.3	28.4

Table 5. Percent total carbon and nitrogen of dry Midlake sediments collected in September of 1985.

depth (cm)	-----percent dry wt---		
	C	N	C:N
surface	12.6	1.4	9.0
0-1	12.3	1.3	9.2
1-2	12.3	1.3	9.3
2-3	11.9	1.2	9.6
3-4	12.3	1.3	9.6
4-5	12.6	1.3	9.5
-			
-			
-			
14-15	11.9	1.1	10.4

12.3 ± 0.3 and mean % N = 1.3 ± 0.1; C:N = 9.4), in contrast to the upward increase shown by Fe, Mn and P. Lynch's (1982) data at station M indicate that the organic matter decreased steadily toward the surface in the top 10 cm of sediment (Table 4).

Macrophytes

The pattern of macrophyte distribution, both spatially and temporally has been highly variable in the last 10 years. Perkins et al. (1979) indicated that macrophyte sampling was rather accurate due to the dense and uniform distribution of the dominate macrophyte, *Elodea densa*. However, following drawdown and alum addition, macrophyte cover has become more variable and less evenly distributed (Michaud 1983; this study). The southern end of Long Lake was essentially filled with *E. densa* and this macrophyte was quite abundant at station M prior to drawdown. There have also been some complications due to variation in areas used for sample weighting, bias due to visually selecting sample sites and variable life cycles of the plants to be sampled.

Peak macrophyte biomass occurred in September of 1976 and 1984 (whole lake means = 242 and 193 g dry wt/m^2, respectively) during the 10 years of data, while the minimum summer whole lake biomass was observed in August 1985 (30 g dry wt/m^2) and in August of 1980 (88 g dry wt/m^2), the year following drawdown (Figure 15 and Table 6). Dense cover of the filamentous alga *Mougeotia* was observed on macrophytes throughout the summer of 1985.

Species composition changed dramatically between 1978 and 1986. Hufschmidt (1978) reported that in August, 1978, *E. densa* comprised 95% of the biomass. Jacoby (1981) reported that in June, 1980, *E. densa* comprised 60% of the biomass. Results of the September, 1984 survey indicate that *E. densa* again comprised 96% of the total biomass, which was 242 metric tons of dry

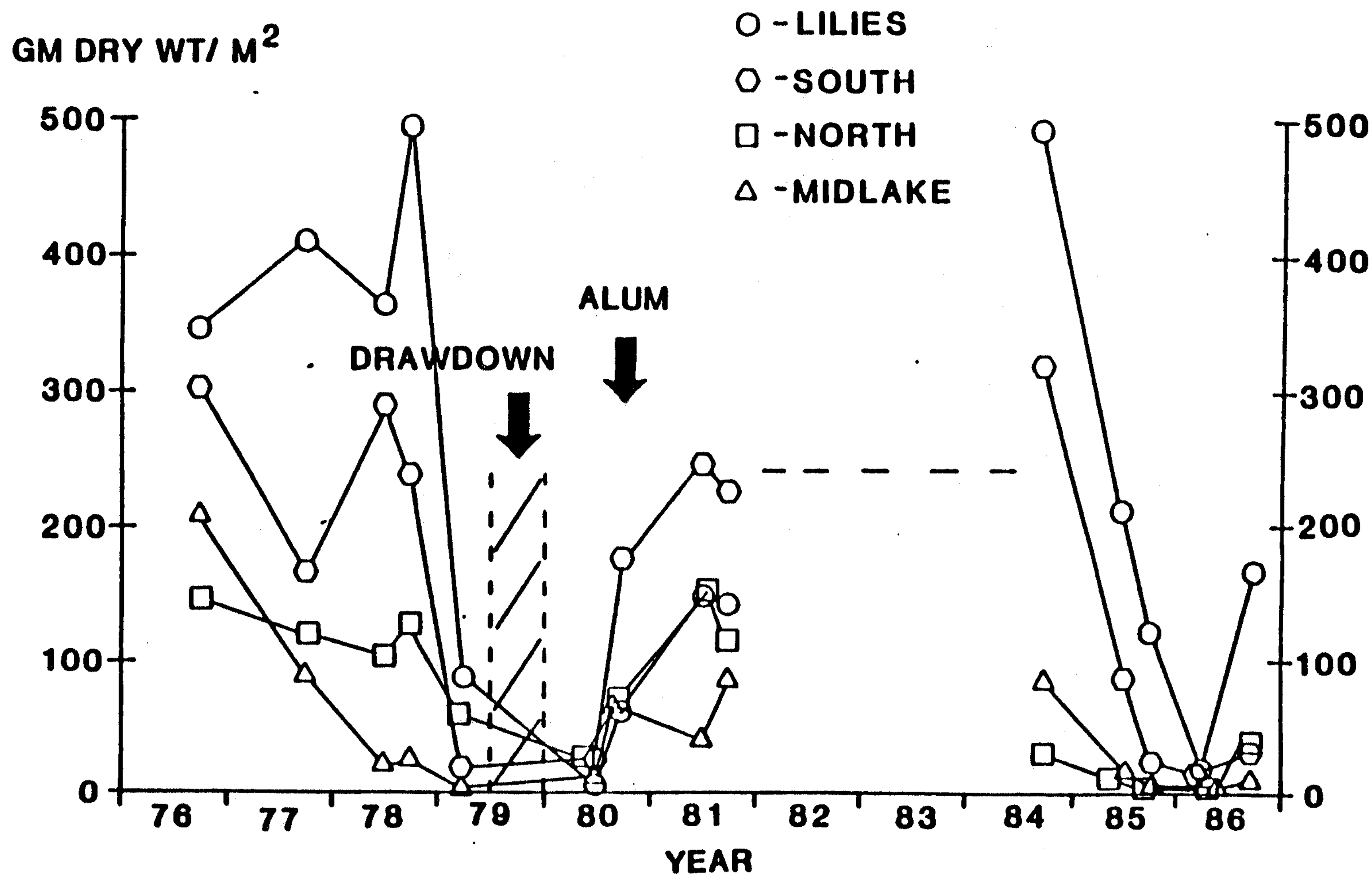


Figure 15. Macrophyte biomass in Long Lake in the four samping areas 1976-1986. Biomass as g dry weight/m².

Table 6. Macrophyte density in Long Lake, Kitsap County, Washington (1976-1987)

Summer peak density estimate (gm dry weight/m2 ± 95% CI).

DATE	n	North(.14)	n	Midlake(.51)	n	South(.17)	n	Lilies (.18)	n	wt. mean
21-Sep-76	?	149 ± 54	?	211 ± 93	?	303 ± 83	?	347 ± 125	44	242 ± 92
21-Oct-77	?	120 ± 50	?	91 ± 54	?	201 ± 53	?	413 ± 116	23	172 ± 64
24-Aug-78	9	140 ± 83	11	27 ± 17	8	240 ± 95	6	496 ± 69	34	160 ± 59
23-Aug-80	9	74 ± 56	17	70 ± 43	8	177 ± 91	6	62 ± 72	40	87 ± 54
24-Aug-81	9	116 ± 100	11	89 ± 106	5	227 ± 115	9	141 ± 46	34	125 ± 135
19-Sep-84	14	33 ± 26	13	87 ± 40	8	322 ± 150	5	497 ± 118	40	193 ± 93
06-Aug-85	14	2 ± 3	15	6 ± 8	8	24 ± 19	6	124 ± 52	43	30 ± 23
04-Sep-86	15	41 ± 25	13	14 ± 25	8	33 ± 44	8	168 ± 94	44	49 ± 42
19-AUG-87	14	42 ± 32	14	36 ± 35	9	107±71	5	206±183	42	125±29

June macrophyte density in Long Lake.

DATE	n	North(.14)	n	Midlake(.51)	n	South(.17)	n	Lilies (.18)	n	wt. mean
28-Jun-78	9	117 ± 76	12	18 ± 15	8	179 ± 39	6	366 ± 100	35	122 ± 49
26-Jun-80	8	29 ± 24	12	19 ± 13	8	29 ± 25	6	6 ± 16	34	20 ± 17
23-Jun-81	9	153±100	11	41 ± 118	6	249 ± 177	8	150 ± 90	34	112 ± 128
18-Jun-85	14	13 ± 10	13	18 ± 14	8	85 ± 26	5	216 ± 65	40	64 ± 28

Spring biomass in Long Lake.

DATE	n	North(.14)	n	Midlake(.51)	n	South(.17)	n	Lilies (.18)	n	wt. mean
14-Apr-79	?	50 ± 31	?	6 ± 5	?	19 ± 12	?	87 ± 15	?	29 ± 12
29-Mar-86	13	6 ± 12	13	5 ± 11	8	14 ± 20	6	20 ± 26	40	9 ± 11

matter in the lake (Table 7). However, in August, 1985, E. densa had declined to 60% of the total biomass, which was only 40 metric tons (Table 8).

The loss in biomass can be attributed completely to E. densa as the biomass of Potamogeton praelongus appears to have remained constant (Table 7 and 8). Losses occurred in all sections of the lake, but losses were most striking in the Lilies, where E. densa predominated prior to 1985. In 1986 (September) total biomass was nearly as low as in 1985 and E. densa had declined to an all time low contribution of 34%. E. densa was being replaced by larger masses of Ceratophyllum demersum and P. praelongus (Table 9). However, by September, 1987, E. densa had recovered to 70% and the total biomass had returned to near "normal" levels (171 tons; Table 10).

Although not included in our estimate of whole lake biomass, the coverage of Nuphar sp. (24 stalks/m^2, 29.8 g dry wt./stalk) was estimated at 720 g dry wt./m^2 in August, 1985. Assuming a 5% coverage of the lake by Nuphar, which is found almost exclusively in the South end, total biomass of Nuphar is estimated at 49 metric tons. Obviously, the neglect of Nuphar underestimated macrophyte biomass in the lake, but if included its relative stability from year-to-year would also tend to obscure fluctuations in other species, which are considered more pertinent to lake dynamics.

Sediment fractionation

Fractionation of Long Lake sediments was performed several times at Midlake and South stations between 1978 and 1986. The results of this time series for Midlake illustrates that P fractions (NH_4Cl, NH_4F and CDB) have changed dramatically over the years (Figure 16). However, because P fractionation is a complex, time consuming process, some of the year-to-year variation may be due to different investigators: 1978 by Lynch (1982), 1982 by Jacoby et al. (1983) and 1984-1986 by DeGasperi (1987).

Table 7. Macrophyte biomass in Long Lake, Kitsap County, Washington on 18-20 September 1984 (kg dry weight).

SPECIES	BIOMASS (KG)	% OF TOTAL
E. densa	232,106	96
P. praelongus	7,548	3
C. demersum	2,045	0.8
E. canadensis	474	0.2
P. crispus	20	trace
	242,193	100

LOCATION (% area)	BIOMASS (KG)	P (KG)	% ELODEA	% TOTAL
NORTH (.14)	21,360	64	96	9
MIDLAKE (.51)	23,310	70	98	10
SOUTH (.17)	75,070	225	91	30
LILIES (.18)	122,460	365	99	51
	242,200	727	96	100

Table 8. Macrophyte biomass in Long Lake, Kitsap County, Washington on 5,7 August 1985 (kg dry weight). Phosphorus content of macrophytes based on an estimate of 0.3 % P content of dry plants.

SPECIES	BIOMASS (KG)	% OF TOTAL
E. densa	24,251	60
P. praelongus	8,789	22
C. demersum	7,618	18
P. crispus	-	trace
	40,658	100

LOCATION (% area)	BIOMASS (KG)	P (KG)	% ELODEA	% TOTAL
NORTH (.14)	1,650	5	13	4
MIDLAKE (.51)	3,480	10	15	9
SOUTH (.17)	5,600	17	63	14
LILIES (.18)	29,950	90	67	73
	40,680	122	60	100

NOTE: An estimate of *Nuphar* biomass indicated an above sediment standing stock of 48,960 kg dry mass based on 720 gm dry wt/m^2 and 5 % coverage of total lake area. An esimate of 730 gm dry wt/m^2 was made by Gabrielson (1978), but no coverage estimate.

Table 9. Macrophyte biomass in Long Lake, Kitsap County, Washington on 4,5 September 1986 (kg dry weight).

SPECIES	BIOMASS (KG)	% OF TOTAL
C. demersum	22,848	34
P. praelongus	20,807	31
E. densa	16,605	25
Nitella	2,832	4
E. canadensis	2,661	4
P. berchtoldii ??	1,141	2
	66,893	100

LOCATION (% area)	BIOMASS (KG)	P (KG)	% ELODEA	% TOTAL
NORTH (.14)	7,866	24	trace	12
MIDLAKE (.51)	9,925	30	12	15
SOUTH (.17)	7,761	23	0	12
LILIES (.18)	41,526	125	37	61
	66,893	727	96	100

Table 10. 1987 Macrophyte survey summary.

	PERCENT AREA	DRY WT. g/sq.m.	STD DEV	SAMPLE SIZE		E. densa g/sq.m.	P. prae-longus g/sq.m.	P. pusilus g/sq.m.	E. canad-ensis g/sq.m.	Cerato-phylluc g/sq.m.
NORTHSHORE	14%	42.14	58.94	n = 14		16.04	21.28	2.85	0.48	1.49
MIDLAKE	51%	36.19	64.90	n = 14		5.28	13.69	14.96	1.77	0.49
SOUTH	17%	170.74	106.70	n = 9		99.28	38.63	14.54	9.48	8.81
LILLIES	18%	396.92	205.52	n = 5		366.08	0.00	30.84	0.00	0.00
	TOTAL =	124.83		n = 42	TOTAL =	87.71	16.53	16.05	2.58	1.96
	TOTAL KG =	171,014			TOTAL KG =	120,163	22,644	21,991	3,537	2,680
					% OF TOTAL =	70.3%	13.2%	12.9%	2.1%	1.6%

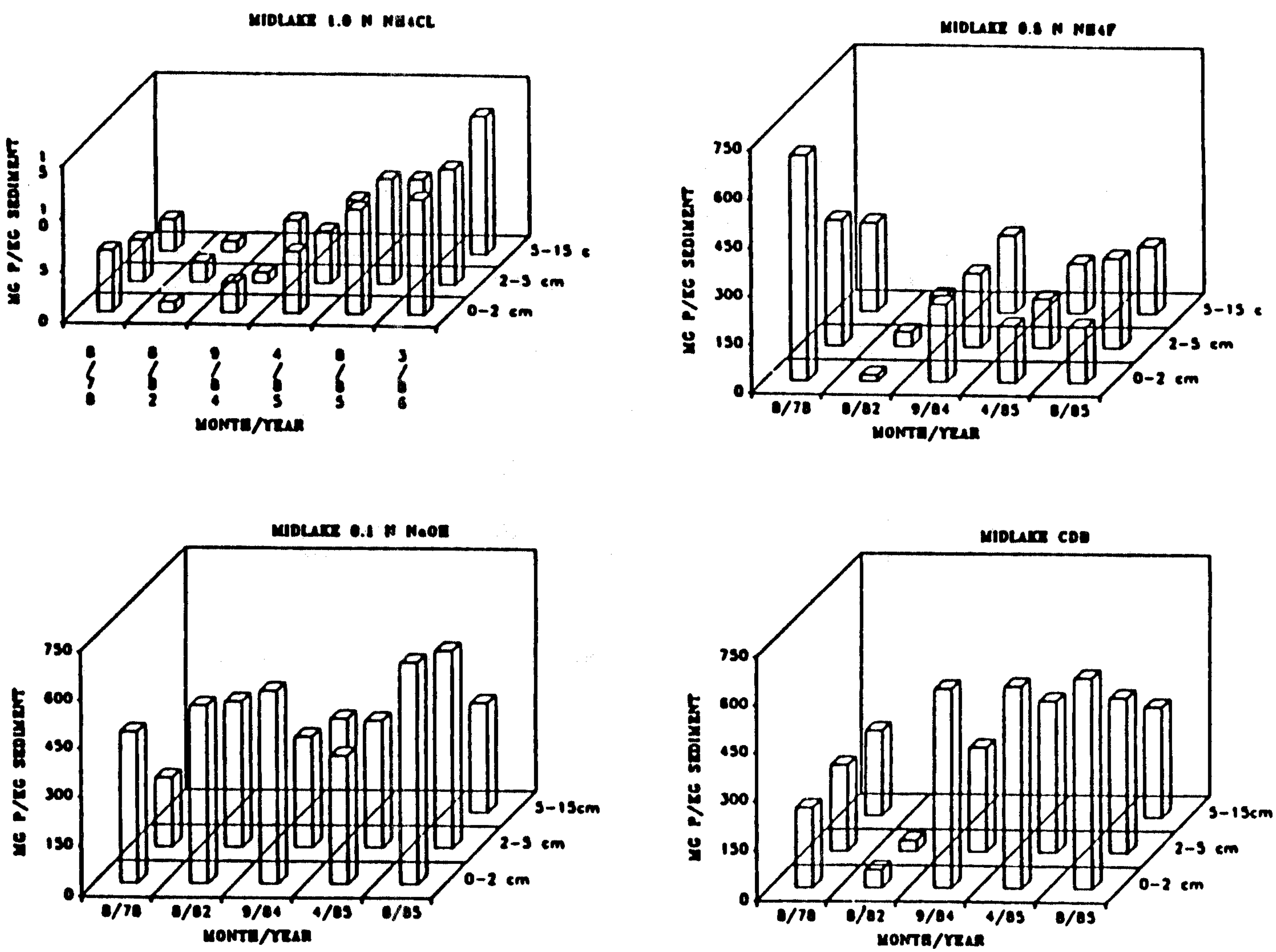


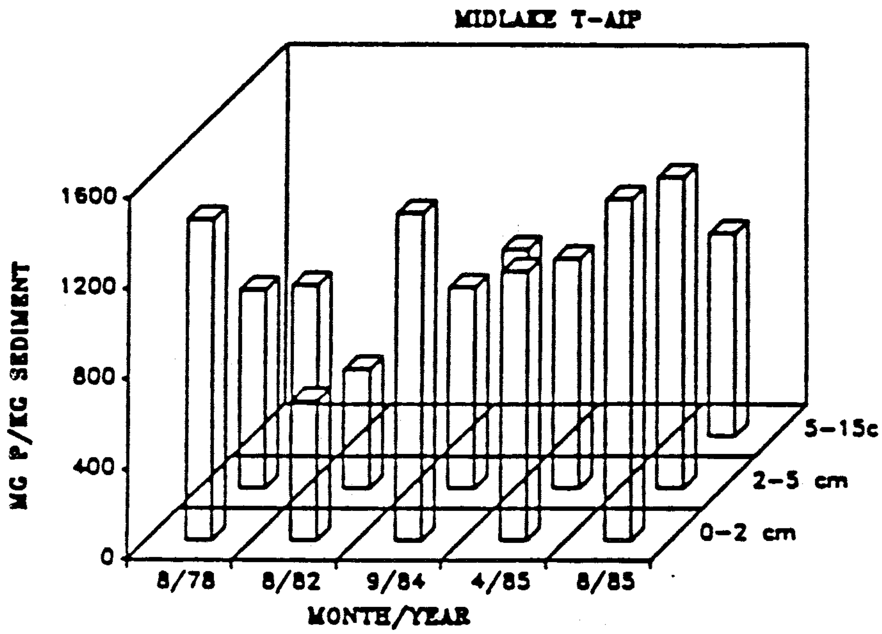
Figure 16. Results of P fractionation of Long Lake sediments at Midlake 1978-1986. Results as mg P extracted/kg dry sediment.

The difficulties involved in sediment fractionation have been discussed in Methods. Some inconsistencies have occurred in the procedures, especially prior to 1984 so there will be minimal discussion of the apparent patterns displayed over the nine-year period.

However, two points are evident. The first extraction (NH_4Cl) demonstrates a strikingly smooth trend over the years with the lowest NH_4Cl fraction observed the summer following alum addition to Long Lake. This is the first step in the fractionation procedure, thus, the year-to-year trend in this case is probably significant. According to Bostrom (1984), it represents the easily exchangable or loosely bound P in the sediment.

The second point concerns the interpretation by Jacoby et al. (1983) of the reduction of AI-P following alum addition. Figures 16 and 17 clearly demonstrate that, except for the NaOH extraction, P fractionation in 1982 at station M yielded very little AI-P. Reduction in the NH_4Cl fraction may not be an experimental artifact, but such large reductions in the NH_4F and CDB fraction as observed in 1982 seem unlikely. The result is suspect since P bound in an alum floc should still be found in the inorganically bound P pool and would be released in this series of extractions resulting in an increase in AI-P.

Two experiments were performed to test that hypothesis. Experiment I employed dry alum (approximately equal to the Long Lake dose) applied to wet sediment. Experiment II involved a wet alum floc of an equivalent dose. A one-sided paired t-test (Sokal and Rohlf, 1981) was employed to determine if treatment with alum affected any P fraction. In only one fraction and one treatment (wet alum addition = Experiment II, NH_4Cl) was there a significant reduction ($P < .05$) in extractable P with the addition of alum (Table 11).



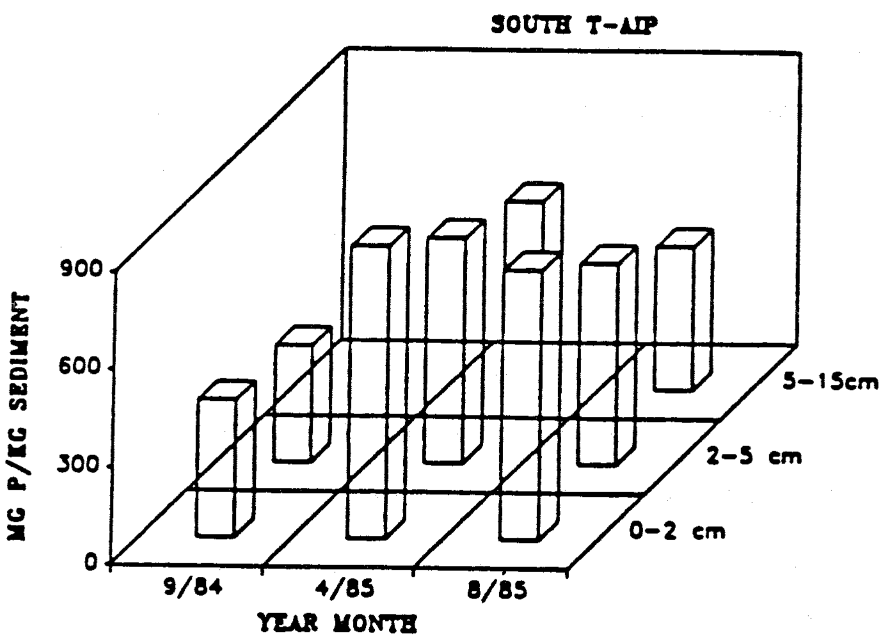


Figure 17 . Sum of inorganic P extractions (AI-P) at Midlake and South 1978-1986.

Table 11. Results of fractionation experiments. EXPERIMENT I (dry alum) and EXPERIMENT II (wet alum floc). Values are given as mg P/kg dry sed ± s.d. (n=2).

------------------ EXPERIMENT I --------------------

TREATMENT	NO ALUM	250 MG ALUM	1000 MG ALUM
1.0 N NH_4Cl	5 ±3	2 ±1	2 ±2
0.5 N NH_4F	88 ±20	74 ±25	50 ±1
0.1 N NaOH	149 ±42	174 ±28	178 ±28
CDB	248 ±140	241 ±111	95 ±17
AI-P	490 ±148	491 ±117	325 ±33

-------------------EXPERIMENT II --------------------

TREATMENT	NO ALUM	500 MG ALUM
1.0 N NH_4Cl	4 ±1	1 ±1 *******
0.5 N NH_4F	151 ±1	233 ±69
0.1 N NaOH	330 ±111	231 ±110
CDB	265 ±104	214 ±90
AI-P	679 ±160	750 ±152

******* Significantly different (P<0.5) from NO ALUM

These experimental results suggest that the 1982 data may have been subject to procedural errors. In addition, results indicate that complete fractionation may have little utility in the evaluation of an alum treatment. However, it appears that the use of the NH_4Cl extraction may be a simple method to monitor loosely sorbed P in sediment, which may be significantly controlled by an alum treatment. The difference between surficial sediment NH_4Cl extractable P and SRP concentrations above the sediment have been used to estimate the diffusional gradient of PO_4 between sediment and water (Golterman et al, 1969).

The close relation between interstitial P and NH_4Cl extractable P may be illustrated by imagining 50 cm^3 of surficial sediment containing 95% water, 700 μg P/L interstitial P and 10 μg P/g dry sediment of NH_4Cl extractable P. The interstitial P contained in this volume of sediment equals 35 μg P while NH_4Cl extractable P would amount to 25 μg P. Although it is realized that interstitial P concentration determines the flux of P between P bound to sediment and interstitial water and the diffusion and advection of P to the overlying water, the observed patterns of NH_4Cl extractable P may be important in the P dynamics of Long Lake.

Individual fractionation results for station S are available only between 1984 to 1986 (Figure 18). Although all of these fractionations were performed by one individual (DeGasperi, 1987), the difficulty in replicating results is apparent from the low values for the September 1984 fraction (Figures 17 and 18).

The fractionation data have been combined in Table 12, excluding those from 1982, to illustrate differences in the distribution of P in various fractionations with depth and along the gradient among stations M, S and L. Pooling of the fractionation data indicate that about half of the total

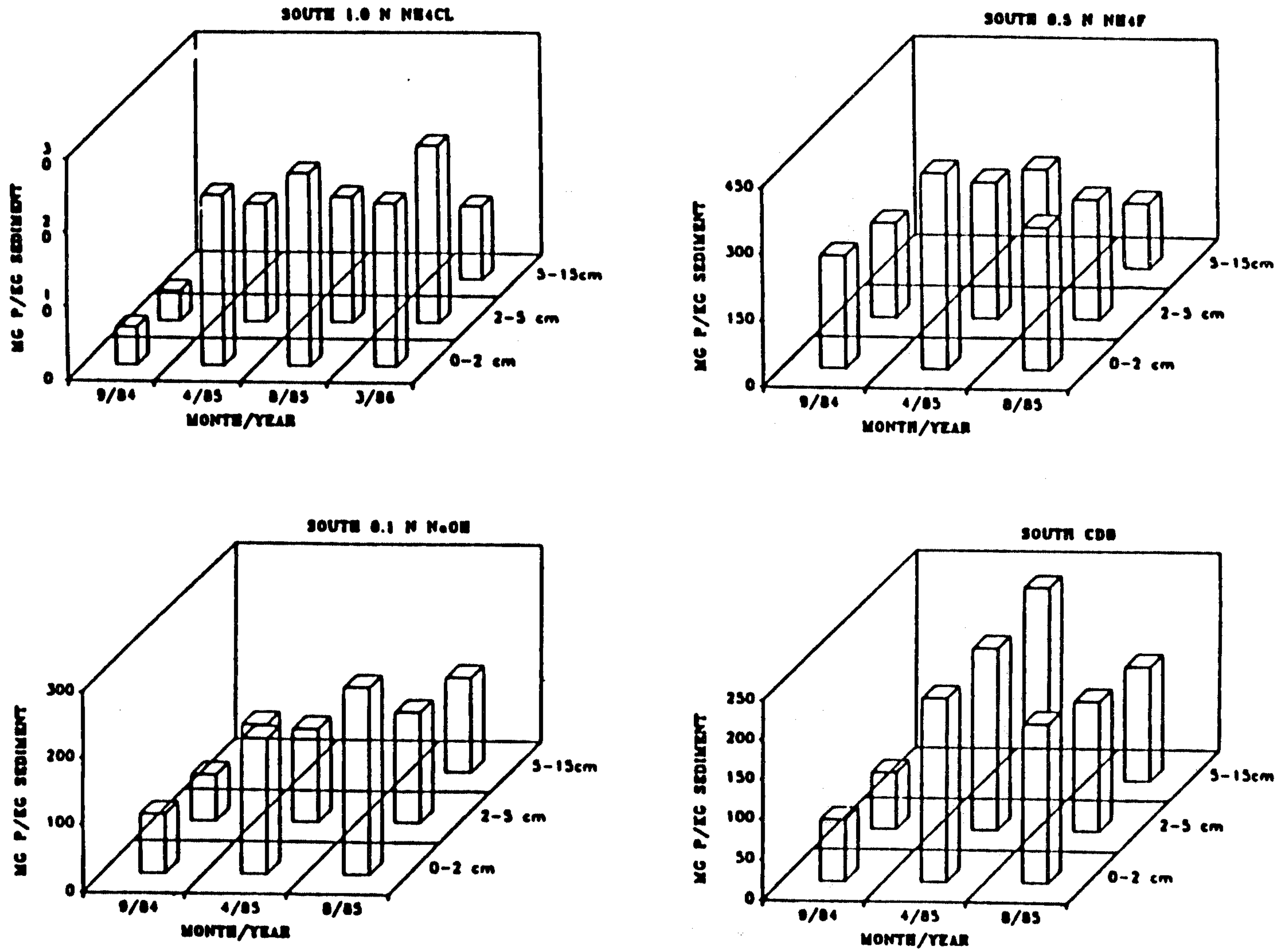


Figure 18. Results of P fractionation of Long Lake sediments at South 1978-1986. Results as mg P extracted/kg dry sediment.

Table 12. Average (mean±s.d.) of fractionation results of Lynch (1982) on sediments from 1978 and results of this study. Percent water, organic content and sediment phosphorus data are from Lynch. Fractionation results are expressed as mg P/kg dry sed.

MIDLAKE	NH4CL n=5		NH4F n=4		NaOH n=4		CDB n=4		T-AIP		TOTAL P	% WATER	% ORGANIC
depth	X̄±s.d.	% AI-P	X̄±s.d.	% AI-P	X̄±s.d.	% AI-P	X̄±s.d.	% AI-P	Σ	% TOT-P	mg/kg		
0-2 cm	7 ± 3	0.5	321 ± 2	26	531 ± 131	43	531 ± 195	36	1390	65	2125	94	26
2-5 cm	6 ± 4	0.6	264 ± 9	25	388 ± 164	37	384 ± 107	37	1042	66	1590	93	27
5-15 cm	6 ± 4	0.8	221 ± 5	29	251 ± 86	33	285 ± 48	37	763	56	1352	91	28

SOUTH	NH4CL n=4		NH4F n=3		NaOH n=3		CDB n=3		T-AIP		TOTAL P	% WATER	% ORGANIC
depth	X̄±s.d.	% AI-P	X̄±s.d.	% AI-P	X̄±s.d.	% AI-P	X̄±s.d.	% AI-P	Σ	% TOT-P	mg/kg		
0-2 CM	19 ± 9	3	340 ± 9	47	191 ± 98	27	169 ± 82	23	719	56	1275	96	35
2-5 CM	15 ± 8	3	264 ± 4	47	126 ± 51	23	155 ± 79	28	560	49	1147	94	33
5-15 CM	7 ± 3	2	177 ± 4	40	107 ± 37	24	147 ± 94	34	438	43	1010	93	32

LILIES	n=1		T-AIP		TOTAL P	% WATER	% ORGANIC
depth	X̄±s.d.	%AI-P	Σ	% TOT-P	mg/kg		
0-2 CM	62 ± 19	18	342	32	1083	95	34
2-5 CM	44 ± 1	13	328	31	1057	93	35
5-15 CM	14 ± 2	5	287	29	993	92	35

surface sediment (0-2 cm) phosphorus (65%) is AI-P at station M. The absolute amount and percent of total sediment P as AI-P decreases with depth in the sediment and horizontally from station M to L (Table 12). This horizontal trend is inversely related to the abundance of macrophytes and probably represents the removal by macrophyte roots. In fact, Lynch (1982) showed that the seasonal removal of AI-P was similar to internal loading calculated by mass balance.

Unfortunately, data for the individual fractions at station L were not presented by Lynch (1982) and only one NH_4Cl fraction was performed at this station on sediments collected in March 1986 (Table 12). Therefore, general north-south trends for the remaining three fractions are suggested by differences between stations M and S only.

The NH_4Cl fraction at station M is quite low (0.5% of total sediment P) and typical of lakes that have not received significant amounts of sewage or agricultural runoff (Bostrom 1984). Interestingly, this fraction increases towards the southern end of the lake (3% at station S and 18% at the 0-2 cm level at station L).

The NH_4F fraction was thought to remove primarily Al-bound P, but that fraction also probably includes Fe-bound P in non-calcareous sediments (Williams et al., 1971). Williams et al. claimed that the NH_4F extraction could not selectively remove Al-bound P and also suggested that evidence of Al-bound P in non-calcareous sediments was not demonstrated. Analytical precision was greatest for this fraction and results show an interesting pattern. On a dry-weight basis, the amount in this fraction was roughly the same at both stations, but on a percentage basis the NH_4F fraction at station S holds twice the amount as at station M (Table 12). This is interesting and may suggest that the portion of sediment contributing to this fraction, perhaps fine clays, is evenly distributed throughout the lake.

NaOH extractable P has been related to P available to algae in several studies (e.g., Sonzogni et al. 1982), and is thought to represent both Fe and Al bound P (Williams et al. 1971). This fraction has also been observed to decrease following periods of internal P loading (Wildung and Schmidt 1973; Lynch 1982) in Long Lake. Therefore, its relative distribution may be of some significance. Unfortunately, variability in the results among investigators (mean percent error = 38% during 1984-1986) precludes detailed analysis of the NaOH extractable P profile. Clearly, however, station M surface sediments contained more than twice the amount in this fraction than at station S (531 vs. 191 mg P/kg). Also, a higher portion of total sediment P was contributed by this fraction (43 vs. 27%) at station M, so the difference is not strictly due to higher concentrations of P at station M.

Distribution of the CDB fraction, as was the case with the NaOH fraction, was complicated by variability of past results. However, as with NaOH extractable P, distinct differences are apparent between stations M and S. CDB fraction amounts were very similar to those of NaOH at each station and again CDB was about twice as abundant at station M (0-2 cm depth, 531 vs. 169 mg P/kg sed), as well as being relatively more abundant (36 vs. 23%). The distribution pattern of the NaOH and CDB fractions is probably strongly influenced by sediment depositional patterns in the lake.

<u>Alum effect on sediment P release</u>

Incubation of sediment cores from station M under quiescent, anaerobic conditions, in the dark and at 20^{o} C resulted in a substantial release of P from Long lake sediments (Figure 19). The similar results of TSP and TP indicated that all P was soluble. The cause for TSP to slightly exceed TP is

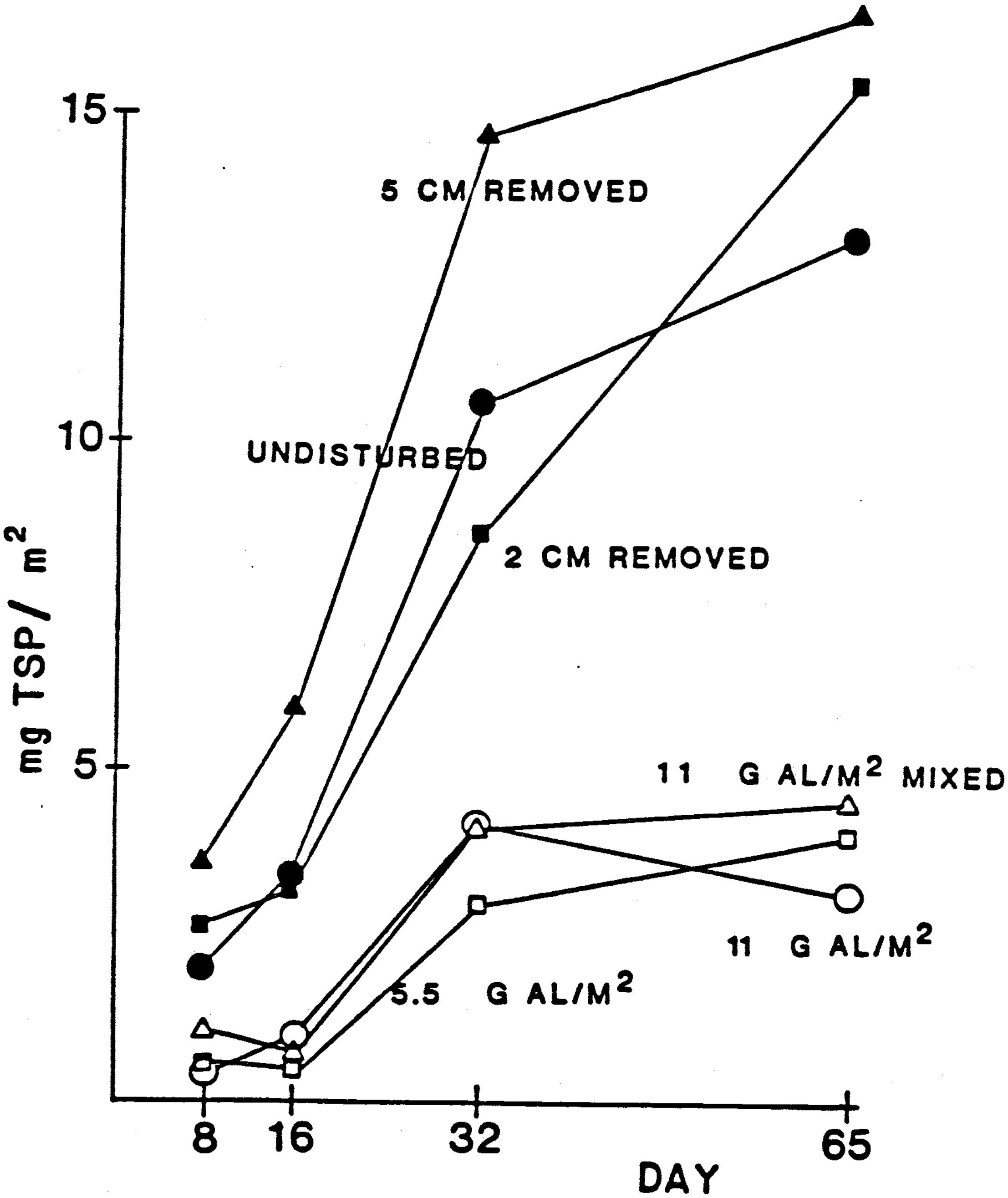


Figure 19. Mass of P (mg/m²) over cores plotted against time during the anaerobic P release experiment.

unknown. Regression of the mass of TSP above the sediments against the day since the beginning of incubation (8, 16 and 32) gave an estimated release rate of 3.8 mg TSP/m^2-d (r = .98) from the intact core (CONTROL; Table 13). This rate is not exceptionally high and is similar to that from other non-calcareous, anoxic sediments in the Puget Sound region (Welch et al., 1986). However, rates of P release under similar anaerobic, quiescent conditions have exceeded 30 mg P/m^2-d (Theis and McCabe, 1978).

Although this experiment was designed to locate the alum "layer," the small number of cores sampled and large variation among cores sampled on the same day indicated that the regression slopes between CONTROL, 2-CM-REMOVED and 5-CM-REMOVED cores are not statistically different. However, the release rate from the 5-CM-REMOVED core (4.8 mg TSP/m^2-d, r = 99) was nearly double that from the intact core of from the 2-CM-REMOVED core (2.6 mg TSP/m^2-d, r = .96), suggesting that the alum may have been residing below 2 cm in the sediment, but above 5 cm (Figure 19).

The experiment involving various additions of alum indicates that alum treatment is an effective inhibitor of P release from anaerobic Long Lake sediment (Figure 19 and Table 14). Due to the same limitations in core-to-core variability as in the sediment removal experiment, the results are not too clear, although there is the suggestion that fresh alum mixed into the top 2 cm of sediment provides little improvement over a surface applied floc.

<u>Longevity of the drawdown/alum treatment</u>

Summer (June-September) statistics for chl <u>a</u>, TP and Secchi transparency for 1976 to 1987 are shown in Table 15. As noted in earlier studies (Jacoby 1981; Michaud 1983; Jacoby et al. 1982; Jacoby et al. 1983), drawdown in 1979 resulted in less TP the following summer and a reduction in net internal P loading, but little observable improvement in chl <u>a</u> or Secchi transparency.

Table 13. Mass of P in water in anaerobic cores over a 65 day period. Intact core (CONTROL), 2 cm of sediment dredged and 5 cm of sediment dredged. All values are as mg P/m² ± s.d., n=2. Both total soluble P and TP above cores are presented here.

mg TSP/m²			
DAY	CONTROL	2 CM REMOVED	5 CM REMOVED
8	2.0 ±*	2.7 ±0.3	3.6 ±*
16	3.4 ±1.9	3.2 ±2.4	5.9 ±0.8
32	10.7 ±0.9	8.6 ±0.3	14.7 ±5.2
65	13.1 ±3.8	15.5 ±3.3	16.6 ±1.9
P release rate (8-32) mg TSP/m²*d	3.76 r=.98	2.58 r=.96	4.75 r=.99

mg TP/m²			
DAY	CONTROL	2 CM REMOVED	5 CM REMOVED
8	3.0 ±0.1	2.9 ±1.8	1.9 ±0.8
16	5.3 ±0.4	5.4 ±0.5	6.8 ±0.6
32	12.0±1.5	10.2 ±0.1	14.6 ±4.9
65	12.2 ±3.8	14.0 ±3.0	15.1 ±0.7

*lost replicate

Table 14. Mass of P in water in anaerobic cores over a 65 day period. Alum undisturbed (11 g Al/m^2), half dose alum (5.5 g Al/m^2) and half dose alum mixed into top 2 cm sediment (5.5 g Al/m^2). All values are as mg P/m^2 ± s.d., n=2. Both total soluble P and TP above cores are presented here.

DAY	mg TSP/m^2		
	11 g Al/m^2	5.5 g Al/m^2	5.5 g Al/m^2 mixed
8	0.3 ±*	0.5 ±0.4	1.2 ±0.1
16	0.9 ±0.3	0.4 ±0.1	0.7 ±0.1
32	4.3 ±1.9	3.0 ±0.2	4.3 ±0.6
65	3.3 ±1.1	4.0 ±1.6	4.6 ±1.9

DAY	mg TP/m^2		
	11 g Al/m^2	5.5 g Al/m^2	5.5 g Al/m^2 mixed
8	0.8 ±0.4	1.1 ±0.4	2.0 ±0.4
16	1.3 ±0.6	0.9 ±0.2	1.0 ±0.4
32	3.0 ±1.7	1.5 ±0.5	3.0 ±0.9
65	1.5 ±0.8	1.4 ±0.3	3.2 ±1.4

* lost replicate

Table 15. Summer (Jun-Sept) mean chlorophyll a (CHL a), total phosphorus (TP) and Secchi transparency. CHL a and TP are based on whole-lake volume-weighted means and Secchi on Midlake values (mean ±s.d., n).

YEAR	---- whole lake ----- CHL a	TP	MIDLAKE SECCHI
	--------ug/Liter-----		m
1976	12.5 ± 4.6 n=7	41.8 ± 9.0 n=7	1.8 ±0.2 n=6
1977	29.4 ±18.7 n=8	69.1 ±17.9 n=8	1.4 ±0.6 n=9
1978	23.5 ±12.0 n=10	78.2 ±17.3 n=10	1.7 ±0.5 n=9
1979	16.4 ±11.4 n=8	89.7 ±26.4 n=8	1.1 ±0.6 n=7
1980	18.3 ±11.8 n=6	37.5 ± 4.1 n=7	1.8 ±0.7 n=8
1981	17.3 ± 9.2 n=6	32.7 ±11.5 n=7	2.2 ±0.7 n=6
1982	3.7 ± 1.6 n=2	30.9 ± 6.2 n=6	3.0 ±0.3 n=6
1983	11.0 ± 3.4 n=4	31.5 ±13.5 n=4	2.1 ±0.5 n=5
1984	5.8 ± 2.4 n=8	36.4 ±17.0 n=9	2.5 ±0.3 n=8
1985	35.6 ±30.1 n=9	65.5 ±25.2 n=9	1.1 ±0.8 n=11
1986	16.3 ±10.9 n=8	44.5 ±13.0 n=8	1.9 ±0.4 n=9
1987	10.6 ± 3.3 n=9	30.0 ± 8.9 n=9	2.1 ± 0.2 n=9

SRP concentration was also substantially reduced that year (Figure 9). Following alum application in September 1980, TP remained even lower the following summer, mean transparency exceeded 2.0 m and mean chl a was still similar to pretreatment levels. In 1981, 1982, 1983 and 1984 summer TP continued to remain low, transparency was greater than 2.0 m and mean chl a was less than 11 μg/L.

In 1985, summer transparency averaged 1.1 m and TP and chl a averaged 66 and 36 μg/L. The lake had apparently returned to the pretreatment level of quality with the highest chl a and lowest transparency in the eight previous summers (drawdown year excluded). In 1986, average transparency was still less than 2.0 m, but TP and chl a had decreased to 45 and 16 μg/L. In 1987 the trend to higher quality continued and low TP and chl a and relatively high transparency, that were typical during the four, post-alum years, again prevailed. The alum treatment may still be effective, although its longevity had previously been reported as four years (1981-1984; Welch et al., 1986; Welch et al., 1988). The apparent termination of the alum treatment may have been related to weather conditions in 1985 as will be discussed later.

Water and Phosphorus Budgets

Water and TP budgets for 1976-1977 and 1980-1981 were obtained from Lynch (1982) and Michaud (1983), respectively. These budgets are included in Appendix B, along with those for the years 1984-1985, 1985-1986, and 1986-1987. Summaries of the water and TP budgets for these five years are provided in Tables 16 and 17. Calendar year 1976-77 was fairly dry (1.1 million m^3 of precipitation on the lake) and 1980-1981 was a relatively wet year with more than double the precipitation falling on the lake surface. Because of the added hydraulic loading in 1980-1981, the external loading was proportionately higher. The high groundwater addition in 1980-1981 was also probably related

Table 16. Water budget summary.

YEAR	TOTAL SALMON-BERRY FLOW cu.m. x 10**5	TOTAL PRECIPI-TATION cu.m. x 10**5	TOTAL CURLEY FLOW cu.m. x 10**5	TOTAL EVAPORA-TION cu.m. x 10**5	AVERAGE LAKE VOLUME cu.m. X 10**5	TOTAL UNGAGED SURFACE INFLOW cu.m. X 10**5	GROUND-WATER cu.m. X 10**5
76-77	59	11	97	6.8	27.7	34	-1.0
77-78	109	21	216	5.9	28.3	75	17.0
80-81	67	24	258	3.4	28.9	102	68.0
84-85	74	14	117	6.9	28.3	45	-9.5
85-86	81	16	127	6.3	29.0	59	-22.1
86-87	111	18	194	9.9	28.6	73	2.7

Table 17. Phosphorus budget summary. All values in kg.

YEAR	SALMON-BERRY ADDITION	UNGAGED STREAM ADDITION	GROUND-WATER ADDITION	ATMOSPHER-IC AND SEPTIC ADDITION	EXTERNAL LOADING	CURLEY LOSSES
76-77	278	157	30	188	653	426
77-78	501	297	222	193	1,213	1,123
80-81	246	304	816	183	1,549	572
84-85	314	184	36	189	723	390
85-86	396	367	35	191	989	774
86-87	358	230	158	194	940	655

Periods (PLPs). The summer of 1977 had only 5 PLPs and a TP of 69 μg/L, followed in 1978 by 7 PLPs and a TP of 78 μg/L. PLPs decreased from 7 in 1985 to 6 in 1986, and finally 5 in 1987. This coincided with a decrease in TP from 66 μg/L in 1985 to 45 μg/L in 1986, and to 30 μg/L in 1987. Internal loading appears to be correlated, in a general way with PLPs.

Alum use in shallow lakes

The use of alum in shallow, unstratified lakes has not been as dependable as in stratified lakes. Five of ten shallow lake treatments, for which data are available, were unsuccessful. That is, the treatment controlled P for a few months at most. In four of those "failures," there were other sources of either external or internal P that were not controlled (Welch et al., 1988). Because control of external loading is always a prerequisite to ensure success of in-lake treatments, these cases may not have been "failures" had external inputs been reduced prior to alum application. The other five treatments are all Washington State lakes and were initially successful, but the Long Lake (Kitsap) treatment is the only one for which longevity is known. Two lakes were followed for one year and the other two for two years.

The treatment in Long Lake (Kitsap) lasted for four years because, based on P-release experiments, the alum layer was no longer at the sediment surface, but had been covered over by new P-yielding sediment and/or dispersed downward by bioturbation. However, some alum effect still persisted because the surface sediment was not as P active as deeper sediment. Much of the new P-yielding sediment probably originated from macrophytes, because algal production was greatly reduced following treatment. This would be consistent with the original hypothesis for the origin of internal P loading in Long Lake, i.e. loading comes directly from open water sediments (mid lake), and not the weedy south end, and the source of organic matter that promotes reducing conditions and P release is transported from the south end macrophytes during the winter die-back period (Jacoby et al., 1982). That is also consistent with the south-north gradient of AI-P in surficial sediments shown here and the greater depletion of sediment pore water SRP in the south end macrophyte beds (Lynch, 1982).

Actually, Long Lake TP and chl a returned to pretreatment levels in the fifth year after treatment but then were much less than pretreatment levels during the sixth and seventh years after treatment. Overall, the treatment may be considered to have lasted longer than four years. The recovery (TP reduction) in 1986 and 1987 may have been related to the crash of macrophytes in 1985 and 1986. In addition to alum maintaining some effect in the sediments, the lack of a wintertime reinoculation of surficial sediments with macrophyte organic matter following the poor crop summers of 1985 and 1986 may have been a partial cause for low internal loading in 1986 and 1987. The relationship between those events would also be consistent with the role of macrophytes in Long Lake hypothesized above.

The extensive presence of macrophytes may represent a limitation for alum use in shallow lakes. The alum treatment does not curtail macrophyte production because they take nearly all of their nutrients from sediments through their roots. If anything, their growth is enhanced by alum, because algal control clears the water allowing more light to reach deeper extending the depth of colonization. This may explain in part why the alum treatment of Horseshoe and Snake Lakes in Wisconsin lasted over 12 years, in spite of the alum layer "sinking" (Garrison and Knauer, 1984). With algal control and fewer macrophytes, and greater depth (both stratify) and capacity for decomposition, the deposition of organic matter was no doubt substantially reduced compared to that in a shallow lake with extensive macrophyte beds. If this relationship between macrophyte organic matter and sediment-P release is valid, then there may be a ratio of macrophyte biomass-to-lake volume or depth (or whole-lake average biomass) beyond which the cost effectiveness of alum is greatly reduced. Under such conditions, dredging of the littoral macrophyte beds to limit that source of organic matter may be required before alum is applied. The biomass in Long Lake ranged from 160 to 242 g/m^2 before treatment and was 30 and 49 g/m^2 during the posttreatment crash years. If the suspected relationship between macrophyte biomass and sediment P release is valid, then some form of macrophyte removal may be needed prior to alum treatment in lakes with macrophyte biomass exceding a whole-lake mean approaching 100 g/m^2.

Redistribution of the alum floc, which occurred in Pickerel Lake, Wisconsin, apparently was not a serious problem in the five successfully treated Washington State lakes, including Long Lake (Kitsap). P was controlled for only a month or two in Pickerel Lake but was controlled for at least four years in Long Lake and possibly for a similar period in the other four lakes; however, monitoring was terminated after one year in two lakes and after two years in the other two.

SUMMARY AND CONCLUSIONS

1. Treatment of Long Lake by drawdown in 1979 and alum in 1980 changed the seasonal patterns of nutrients.

   a. High TP content did not result from winter storms after treatment as occurred before treatment.

   b. Inflow TP, which was generally less than inlake TP before treatment, was higher than inlake TP after treatment, indicating a reduction in internal loading of P.

   c. Inflow, relative to inlake, concentrations of SRP, TN and NO_3-N did not reverse following treatment, although inlake SRP tended to be more depleted and NO_3-N less depleted during summer after treatment. This was due to a change in nutrient limitation from N before treatment to P after treatment, indicated by a slightly higher TN:TP ratio during the summers after treatment.

2. Inflow pH is usually low (6.4-7.8) but increases in the lake in summer due to photosynthesis. The maximum observed during 1984-1987 was 8.0, whereas the maximum reached 9 to 10 during pretreatment years.

3. Transparency in winter is generally low (mean 1.2 m) and controlled by humic substances in the inflow, while phytoplankton controls it in summer-fall. Summer mean transparency exceeded 2 m after treatment, whereas it was always less than 2 m before treatment.

4. DO determinations at 0.5 m depth intervals have shown depletion to as low as 1.6 mg/L in water overlying the sediment, in spite of no or very slight thermal stratification. This suggests that anoxic conditions probably occur intermittently at the sediment-water interface allowing mobilization of P from sediments.

5. Net internal loading of Mn occurred, indicating that reducing conditions were present in surficial sediments allowing Mn release; but inflow-inlake data for Fe, which control P release, were too variable to demonstrate internal loading.

6. Concentrations of Fe, Mn and Fe in surficial sediment were similar to other lakes. The high correlation between Fe and P (and decreasing organic matter toward the sediment surface) indicates that the increase in P in the top 5 cm of sediment is due to increased influx of inorganic sediment to the lake and not entirely to diffusion from greater depths.

7. Drawdown reduced spring macrophyte biomass from 122 to 20 g/m^2 (whole lake mean) and summer biomass from levels of 160 to 242 g/m^2 before to 87 g/m^2 after treatment. While biomass quickly recovered to predrawdown levels near 200 g/m^2, macrophytes (especially the dominant, _Elodea densa_) crashed in 1985 to 30 g/m^2 and was still low in 1986 (49 g/m^2). Recovery had occurred in 1987 to 125 g/m^2. The cause for the crash is unexplained.

8. The alum treatment lowered the loosely sorbed fraction of P in surficial sediments, but had no effect on other fractions. That was demonstrated in experiments also. In addition to forming a floc barrier over sediments, alum may control P by converting loosely sorbed P to Al and Fe bound fractions, especially in lakes with high levels of the former fraction.

9. Sediment release experiments, with and without surficial sediment layers removed, suggest that sediment P release rates may have been reduced by about 50% (5 cm-removed versus 2 cm-removed layers). A higher release rate in the intact core indicates that the alum layer has been covered by more recent, active sediment. Variability among replicates was so great that differences were not statistically significant, however.

10. Longevity of the alum treatment was at least four years. In 1985, the fifth summer following the September 1980 treatment, TP, chl a and transparency reached pretreatment levels presumably marking an end to the high lake quality that had resulted from the treatment. However, high lake quality returned in 1987, suggesting that either 1985 or 1987 was atypical year.

11. A relationship is suspected between macrophyte organic matter transported from the south end to more open-water areas in the northern two-thirds of the lake and sediment-P release from sediments in that open-water area. Such a relationship may have contributed to the relatively short-lived effectiveness of alum in Long Lake and may well be influential in other weedy, shallow lakes. If such a relationship is suspected, some method

for reducing that macrophyte source of enrichment prior to alum treatment in shallow lakes may be needed. Judging from the sequence of events in Long Lake after treatment (see discussion), a whole-lake biomass of macrophytes approaching 100 g/m^2 may indicate an abundance where macrophyte removal should be considered.

12. A non-steady state TP model was calibrated and tested to evaluate lake response to manipulation. Gross sedimentation rate was determined, as a function of flushing rate, during reduced internal loading in 1981, and gross internal loading during pretreatment in 1977, using the 1981 sedimentation rate. A statistically acceptable fit between observed and predicted TP in 1985 and 1986, which included the pretreatment internal loading rate, indicates a termination of the alum effect. However, the fit was not acceptable in 1987, as lake TP was greatly overestimated, indicating a resumption of internal loading control.

13. Using the model to estimate gross internal loading showed an inverse relationship with macrophyte abundance during the pretreatment years of 1976-1978 and the post-alum effect years 1984-1987. Lake TP during those years was also inversely related to macrophyte abundance. This suggests that macrophytes may protect surficial sediments from wind mixing and hence entrainment of sediment released P.

14. Wind data also showed that more events of calm periods followed by high wind speeds ("potential loading periods") occurred in summer 1985, when macrophyte abundance (and protection of surficial sediment) was also lowest. Thus, that combination may account in part for the exceptionally

poor lake quality that year, and that the alum effect has not completely terminated as previously believed.

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Appendix A

Long Lake Water Quality Data, 1976-1987

	Chl a ug/l			TP ug/l			SRP ug/l			TN ug/l		
DATE	N+R	S+L	wt. mean	N+R	S+L	wt. mean	N+R	S+L	wt. mean	N+R	S+L	wt. mean
07/13/76	28.7	3.6	20.4	44.3	44.3	60.9	-	-	-	-	-	-
07/20/76	9.3	3.4	7.4	47.4	24.3	36.1	6.8	2.2	5.3	672	551	632
08/03/76	14.0	1.9	10.0	47.8	24.3	40.1	3.5	1.3	2.8	402	434	412
08/17/76	13.1	2.5	9.6	51.3	27.7	43.5	6.8	1.8	5.2	484	345	445
08/31/76	13.1	3.0	9.8	40.8	20.4	34.0	4.7	5.2	4.9	453	400	356
09/14/76	22.0	3.8	16.0	48.9	18.2	38.8	3.7	2.0	3.1	659	803	707
09/30/76	17.6	6.7	14.0	52.7	26.8	39.0	4.3	3.2	3.9	464	395	441
10/14/76	7.3	3.7	6.1	55.4	33.5	48.2	15.0	4.5	11.5	455	425	445
10/26/76	4.1	2.4	3.5	50.8	21.8	30.0	17.2	4.7	13.1	170	114	152
11/11/76	2.6	4.1	3.1	31.2	23.7	25.7	9.9	4.9	8.3	445	443	444
11/23/76	3.4	3.6	3.5	31.4	22.9	29.0	8.3	5.0	7.2	205	179	196
12/09/76	6.1	5.0	5.7	33.9	21.7	31.0	6.6	6.5	6.6	238	316	264
12/30/76	4.7	36.3	15.1	29.0	44.3	32.0	7.0	6.1	6.7	196	93	162
01/18/77	4.4	13.6	7.4	31.9	37.2	31.0	-	-	-	261	246	256
02/08/77	3.6	15.4	7.5	24.2	42.3	27.0	5.5	4.1	5.0	529	581	546
03/01/77	23.4	63.5	36.6	40.5	52.6	43.0	5.5	5.4	5.5	733	606	691
03/22/77	104.0	62.9	90.4	62.4	59.9	62.0	3.6	4.1	3.8	940	789	890
04/05/77	13.6	15.2	14.1	40.4	44.9	41.0	5.0	3.7	4.6	863	742	823
04/19/77	1.0	1.5	1.2	49.3	36.8	48.0	19.0	11.1	16.4	695	501	631
05/03/77	1.7	2.7	2.0	41.4	54.9	44.0	13.5	16.5	14.5	702	685	696
05/17/77	8.9	11.2	9.7	45.4	51.8	46.0	5.0	3.8	4.6	439	471	450
05/31/77	20.1	6.8	15.7	42.3	37.4	42.0	3.9	3.7	3.8	699	670	689
06/14/77	27.5	36.0	30.3	41.9	37.2	41.0	3.2	2.4	2.9	990	891	957
06/28/77	11.1	2.8	8.4	52.0	33.1	49.0	8.2	1.8	6.1	963	725	884
07/12/77	60.9	26.2	49.4	85.4	46.8	80.0	13.3	1.8	9.5	937	777	884
07/26/77	68.6	55.2	64.2	74.4	69.1	73.0	8.6	5.8	7.7	826	677	777
08/09/77	15.3	5.6	12.1	64.2	38.3	57.0	8.6	2.4	6.6	917	826	887
08/30/77	31.2	9.8	24.1	96.7	52.1	89.0	22.5	4.8	16.7	1110	817	1,013
09/13/77	29.8	11.2	23.7	100.6	43.0	87.0	10.9	2.9	8.3	908	771	863
09/27/77	27.4	13.0	22.6	81.0	54.3	77.0	5.6	2.8	4.7	768	565	701
10/11/77	18.8	4.5	14.1	72.1	52.4	71.0	9.2	4.4	7.6	609	393	538
11/01/77	6.5	5.0	6.0	46.9	28.9	44.0	14.7	6.1	11.9	752	524	677
11/29/77	7.6	18.2	11.1	-	-	-	10.3	8.0	9.5	927	818	891
12/27/77	5.3	6.3	5.6	34.7	37.6	35.0	13.4	15.6	14.1	1154	1076	1,129
01/31/78	31.5	46.6	36.5	48.1	58.1	51.0	6.5	8.1	7.0	1107	987	1,067
02/14/78	46.8	50.1	47.9	52.2	64.0	55.0	7.7	9.2	8.2	965	815	916
02/28/78	21.6	32.9	25.3	51.3	64.2	53.0	5.5	6.5	5.8	935	962	944
03/17/78	8.0	1.6	5.9	50.4	50.8	51.0	13.9	23.9	17.2	828	794	817
04/01/78	3.8	4.3	4.0	62.4	70.6	65.0	29.0	25.0	27.7	734	621	697
04/14/78	33.5	13.1	26.8	65.4	54.7	64.0	14.7	13.1	14.2	602	542	582
04/28/78	9.0	8.3	8.8	48.8	45.2	49.0	8.4	7.2	8.0	586	525	566
05/12/78	9.4	9.4	9.4	67.5	63.0	66.0	12.0	10.6	11.5	461	510	477
06/23/78	46.7	17.4	37.0	82.8	57.5	78.0	17.3	13.0	15.9	843	732	806
07/03/78	64.7	22.6	50.8	90.2	58.8	79.8	16.0	10.7	14.3	883	641	803
07/11/78	33.6	5.1	24.2	96.8	50.7	81.6	11.3	7.7	10.1	975	723	892
07/21/78	23.5	31.5	26.1	84.0	50.8	76.0	19.9	10.7	16.9	763	667	731
07/28/78	21.9	5.3	16.4	112.2	47.3	90.8	26.2	6.5	19.7	615	576	602

	Chl a ug/l			TP ug/l			SRP ug/l			TN ug/l		
DATE	N+M	S+L	wt. mean	N+M	S+L	wt. mean	N+M	S+L	wt. mean	N+M	S+L	wt. mean
08/04/78	19.0	10.8	16.3	119.8	78.7	112.0	15.5	9.3	13.5	634	533	601
08/11/78	23.7	6.8	18.1	110.4	67.5	89.6	18.7	5.4	14.3	586	449	541
08/21/78	24.7	10.3	19.9	67.9	43.4	63.0	8.5	4.2	7.1	618	562	600
09/06/78	18.0	8.4	14.8	66.5	44.1	59.1	11.6	6.3	9.9	488	348	442
09/19/78	15.4	4.5	11.8	54.4	44.6	53.0	8.0	4.6	6.9	628	564	607
10/03/78	30.3	21.2	27.3	33.1	33.5	34.0	3.5	3.0	3.3	593	760	648
10/17/78	12.9	11.6	12.5	-	-	-	4.1	3.6	3.9	608	664	626
10/31/78	3.9	2.2	3.3	34.5	25.0	34.0	7.0	4.6	6.2	502	432	479
11/14/78	2.4	2.8	2.5	26.7	21.1	27.0	10.7	8.7	10.0	543	478	522
11/28/78	2.5	2.8	2.6	29.3	27.2	27.0	6.6	6.3	6.5	557	406	508
12/14/78	2.1	2.0	2.1	-	-	17.0	8.8	8.4	8.7	812	-	812
12/30/78	2.0	-	2.0	23.8	-	-	10.6	-	10.6	692	-	692
01/09/79	3.1	-	3.1	16.2	-	17.0	9.8	-	9.8	867	-	867
01/23/79	3.7	-	3.7	24.0	-	26.0	12.0	-	12.0	1141	-	1,141
02/06/79	7.9	-	7.9	32.0	-	35.0	4.0	-	4.0	930	-	930
02/20/79	16.2	16.0	16.1	34.7	40.0	36.0	3.3	4.1	3.6	1007	940	985
03/06/79	4.7	2.5	4.0	40.7	53.5	42.0	5.6	10.5	7.2	1175	1084	1,145
03/20/79	4.6	3.3	4.2	31.5	35.2	32.0	12.3	14.5	13.0	1121	1295	1,178
04/03/79	1.8	2.2	1.9	36.5	36.2	36.0	9.6	10.8	10.0	1170	1060	1,134
04/17/79	6.4	5.7	6.2	40.1	45.9	40.0	8.8	9.7	9.1	474	612	520
05/01/79	3.1	7.6	4.6	29.5	46.7	32.0	6.0	7.8	6.6	443	506	464
05/15/79	4.7	8.2	5.9	25.8	32.6	26.0	4.3	4.6	4.4	446	460	451
05/29/79	13.1	12.0	12.7	31.3	39.4	31.0	4.4	4.4	4.4	483	484	483
06/12/79	15.2	20.8	17.0	47.1	56.2	48.0	4.3	6.7	5.1	485	568	512
06/26/79	6.8	36.6	16.6	95.7	75.7	89.1	8.8	14.6	10.7	462	554	492
07/10/79	13.7	15.0	14.1	74.9	81.2	77.0	5.1	6.5	5.6	461	606	509
07/24/79	47.3	32.7	42.5	110.3	137.3	119.2	7.7	10.4	8.6	736	537	670
08/07/79	8.2	8.3	8.2	130.9	112.6	124.9	8.7	15.5	10.9	680	662	674
08/21/79	16.5	17.2	16.7	114.6	99.5	109.6	10.1	28.0	16.0	581	435	533
09/06/79	12.8	9.0	11.5	80.9	70.3	77.4	11.2	11.1	11.2	551	489	531
09/18/79	5.8	2.6	4.7	84.3	47.0	72.0	18.4	22.6	19.8	595	491	561
10/02/79	6.3	5.3	6.0	55.2	60.3	56.9	24.2	18.0	22.2	476	608	520
10/18/79	8.9	1.4	6.4	69.8	34.6	58.2	22.6	11.8	19.0	295	297	296
11/08/79	9.7	9.2	9.5	35.8	33.2	34.9	8.0	2.7	6.3	591	538	574
11/20/79	5.1	11.7	7.3	27.7	34.9	30.1	5.9	2.5	4.8	365	370	367
12/06/79	4.3	7.3	5.3	31.1	33.4	31.9	7.9	6.7	7.5	617	621	622
12/19/79	1.6	1.9	1.7	42.2	41.0	41.8	10.1	11.3	10.5	978	846	934
01/10/80	2.8	6.5	4.0	29.6	40.0	33.0	11.7	15.3	12.9	945	936	942
02/07/80	12.5	28.9	17.9	43.2	64.5	50.2	7.5	14.4	9.8	1046	805	966
03/10/80	22.6	13.1	19.5	45.3	42.5	44.4	1.5	1.5	1.5	485	577	515
03/25/80	22.6	6.2	17.2	40.6	48.6	43.2	3.7	4.4	3.9			
04/08/80	8.4	7.4	8.1	43.9	50.1	45.9	2.0	4.1	2.7	532	538	534
04/22/80	37.1	28.5	34.3	39.0	47.1	41.7	1.1	2.0	1.4	445	455	448
05/06/80	8.9	8.6	8.8	27.3	34.6	29.7	0.7	2.2	1.2	322	298	315
05/20/80	6.0	6.7	6.2	28.6	35.1	30.7	2.5	1.9	2.3	382	502	422
06/03/80	15.0	14.3	14.8	34.2	42.5	36.9	2.1	2.0	2.1	382	444	402
06/17/80	-	-	-	30.2	45.0	35.1	2.5	2.7	2.6	741	326	604
07/01/80	23.2	31.0	25.8	37.4	37.5	37.4	0.5	0.3	0.4	456	496	469
07/15/80	13.9	17.0	14.9	40.4	55.4	45.4	3.8	5.1	4.2	455	556	489
07/29/80	12.3	17.2	13.9	36.4	39.2	37.3	2.2	1.5	2.0	470	561	[illegible]
08/12/80	-	-	-	-	-	-	4.0	4.1	4.0	396	438	410

	Chl a ug/l			TP ug/l			SRP ug/l			TN ug/l		
DATE	N+R	S+L	wt. mean	N+R	S+L	wt. mean	N+R	S+L	wt. mean	N+R	S+L	wt. mean
09/09/80	34.8	43.0	37.5	37.6	39.8	38.3	2.9	3.8	3.2	681	504	555
09/23/80	-	9.4	3.1	12.9	70.1	31.8	0.0	0.0	0.0	316	543	39[illegible]
10/07/80	6.5	8.8	7.3	14.8	19.6	16.4	-	2.6	0.9	323	338	329
10/21/80	8.7	24.2	13.8	7.0	21.7	11.9	-	1.5	0.5	295	383	[illegible]
11/04/80	2.3	5.3	3.3	8.6	20.7	12.6	1.0	-	0.7	320	292	311
11/18/80	2.7	5.2	3.5	22.7	17.9	21.1	2.9	1.7	2.5	515	322	461
12/02/80	-	-	-	16.6	15.1	16.1	5.6	4.5	5.2	704	395	502
12/16/80	-	-	-	-	-	-	7.3	8.7	7.8	700	539	647
01/13/81	0.8	0.5	0.7	21.0	25.9	22.6	13.4	15.2	14.0	979	830	929
02/13/81	24.6	20.7	23.3	46.4	74.0	55.5	3.6	1.8	3.0	603	407	538
03/10/81	11.4	30.1	17.6	32.0	44.4	36.1	-	-	-	532	364	477
04/09/81	8.7	9.1	8.8	30.1	53.6	37.9	1.8	0.1	1.2	350	246	316
04/23/81	3.1	5.7	4.0	11.7	15.5	13.0	0.0	0.0	0.0	354	361	356
05/07/81	5.7	17.5	9.6	12.4	25.9	16.9	0.0	0.2	0.0	298	334	310
05/21/81	4.0	20.0	9.3	6.5	54.4	22.3	0.0	0.0	0.0	369	396	378
06/04/81	5.5	5.1	5.4	10.4	23.4	14.7	1.9	2.2	2.0	366	408	380
06/18/81	8.8	12.2	9.9	25.2	36.3	28.9	0.4	0.2	0.0	462	362	429
06/30/81	14.6	7.6	12.3	31.0	25.2	29.1	3.7	4.1	3.8	441	333	405
07/16/81	14.2	62.5	30.1	29.4	79.9	46.1	6.8	12.5	8.7	437	640	504
07/30/81	9.1	38.4	18.8	28.6	59.3	38.7	3.5	8.4	5.1	486	563	511
08/13/81	3.2	14.3	6.9	18.8	39.2	25.5	2.7	3.6	3.0	523	463	503
09/27/81	4.2	69.7	25.8	35.7	66.5	45.9	7.4	4.9	6.6	447	509	467
11/21/81	1.0	2.3	1.4	27.1	24.4	26.2	-	-	-			
12/15/81	6.0	11.0	7.7	28.7	24.5	27.3	-	-	-			
02/04/82	2.9	3.4	3.1	30.0	28.2	29.4	-	-	-			
02/25/82	10.0	14.2	11.4	45.1	46.1	45.4	-	-	-			
03/22/82	19.1	31.0	23.0	35.0	43.8	37.9	-	-	-			
04/28/82	4.0	5.4	4.5	23.2	40.2	28.8	-	-	-			
06/10/82	2.5	2.9	2.6	33.7	50.0	39.1	-	-	-			
06/25/82	3.8	6.8	4.8	33.6	41.5	36.2	-	-	-			
07/09/82	-	-	-	23.2	25.7	24.0	-	-	-			
07/23/82	-	-	-	26.0	34.7	28.9	-	-	-			
08/06/82	-	-	-	27.4	44.4	33.0	-	-	-			
08/17/82	-	-	-	22.2	28.5	24.3	-	-	-			
06/09/83	8.5	9.1	8.7	22.0	17.2	20.4	-	-	-			
06/24/83	15.0	12.0	14.0	26.4	16.0	23.0	-	-	-			
07/15/83	-	-	-	-	-	-	-	-	-			
08/05/83	12.1	17.5	13.9	32.8	31.0	32.2	-	-	-			
09/07/83	7.7	7.1	7.5	52.0	46.7	50.3	-	-	-			
06/06/84	-	-	-	40.6	48.7	43.3	-	-	-			
06/25/84	5.7	5.9	5.8	100.1	27.2	76.0	-	-	-			
07/12/84	7.1	3.0	5.7	28.9	32.6	30.1	-	-	-			
07/25/84	3.0	1.7	2.6	31.6	27.0	30.1	-	-	-			
08/08/84	4.4	3.3	4.0	24.4	28.7	25.8	-	-	-			
08/30/84	5.7	3.7	5.0	34.1	22.3	30.2	10.6	12.8	11.3			
09/14/84	9.8	3.5	7.7	34.3	24.4	31.0	2.7	4.1	3.2			
09/27/84	10.7	7.2	9.5	27.1	19.6	24.6	2.4	2.4	2.4			
10/09/84	12.0	4.3	9.5	25.7	21.0	24.1	3.3	2.7	3.1			
11/10/84	17.3	5.8	13.3	32.7	19.6	28.4	3.9	4.4	4.1			

DATE	Chl a ug/l B+M	S+L	wt. mean	TP ug/l B+M	S+L	wt. mean	SRP ug/l B+M	S+L	wt. mean
12/09/84	4.5	4.1	4.4	24.9	20.6	23.5	6.1	5.5	5.9
01/13/85	3.4	2.4	3.1	27.2	22.1	25.5	8.4	8.9	8.6
02/16/85	17.3	18.4	17.7	34.2	37.1	35.2	5.3	4.2	4.9
03/09/85	45.0	46.4	45.5	33.5	44.1	37.0	3.7	4.6	4.0
04/06/85	25.7	14.0	21.8	38.9	40.9	39.6	4.8	8.4	5.8
04/23/85	6.0	5.8	5.9	37.4	42.4	39.1	6.8	10.1	7.9
05/04/85	5.3	8.0	6.2	37.2	35.0	36.5	4.4	4.5	4.4
05/18/85	6.0	6.1	6.0	31.6	32.6	31.9	-	-	-
06/02/85	10.4	9.6	10.1	37.6	52.9	42.6	3.5	5.7	4.2
06/14/85	10.0	8.3	9.4	29.7	31.6	30.3	1.4	1.4	1.4
07/01/85	11.4	11.2	11.3	42.5	43.7	42.9	3.0	3.2	3.1
07/15/85	19.6	14.5	17.9	44.7	39.1	42.9	3.9	4.4	4.1
07/26/85	31.1	30.6	30.9	73.7	85.1	77.5	4.6	5.1	4.8
08/07/85	-	-	-	-	-	-	-	-	-
08/12/85	96.3	75.5	89.4	82.0	90.2	84.7	4.4	6.5	5.1
08/19/85	-	-	-	-	-	-	-	-	-
08/26/85	61.2	117.7	79.8	90.8	103.9	95.1	6.4	7.1	6.6
09/09/85	-	-	-	-	-	-	-	-	-
09/13/85	50.8	32.1	44.6	97.2	72.1	88.9	16.1	6.9	13.1
09/23/85	27.7	26.6	27.3	87.9	77.8	84.6	7.3	4.6	6.4
10/19/85	25.9	17.1	23.0	65.9	59.9	63.9	27.4	32.1	29.0
11/16/85	11.6	6.7	10.0	43.1	40.3	42.2	29.9	29.7	29.8
12/18/85	-	-	-	-	-	-	-	-	-
01/23/86	6.7	10.2	7.9	45.1	54.0	48.0	26.9	26.3	26.7
02/17/86	24.4	58.8	35.8	28.0	41.2	32.4	25.3	25.5	25.4
03/25/86	5.5	12.7	7.9	39.1	53.4	43.8	14.2	14.1	14.2
04/11/86	26.2	52.8	35.0	55.9	79.9	65.9	-	-	-
04/25/86	11.5	8.2	10.4	46.0	47.9	46.7	-	-	-
05/09/86	8.5	10.5	9.2	40.9	40.5	40.8	15.1	14.7	15.0
05/23/86	4.3	12.0	6.8	46.6	58.4	50.5	12.1	11.8	12.0
06/06/86	12.8	10.4	12.0	50.6	48.4	49.9	20.6	20.8	20.7
06/26/86	8.5	7.4	8.1	42.2	40.1	41.5	7.0	5.3	6.4
07/08/86	7.4	9.6	8.1	35.3	33.5	34.7	2.8	2.8	2.8
07/22/86	4.1	8.2	5.5	28.6	33.3	30.2	2.6	4.3	3.2
08/05/86	16.6	14.7	16.0	34.1	42.0	36.7	2.0	3.0	2.3
08/19/86	21.1	15.9	19.4	38.2	33.7	36.7	4.0	3.8	3.9
09/02/86	23.6	19.6	22.3	63.4	49.5	58.8	-	-	
09/16/86	38.7	40.2	39.2	65.1	72.0	67.4	-	-	
10/07/86	27.7	39.3	31.5	38.3	47.2	41.2	1.4	2.3	1.7
11/06/86	12.1	11.6	11.9	36.3	45.0	39.2	2.3	3.6	2.7
12/04/86				32.7	28.2	31.2	9.6	7.4	8.9
01/02/87	3.8	9.5	5.7	31.1	33.5	31.9	10.9	9.7	10.5
02/07/87	3.4	4.3	3.7	37.5	43.6	39.5	7.8	10.3	8.6
03/07/87	10.3	11.4	10.7	31.4	32.4	31.7	6.6	6.5	6.6
04/11/87	13.8	17.8	15.1	28.1	28.8	28.3	4.8	7.2	5.6
04/25/87	3.5	2.6	3.2	32.4	31.2	32.0	3.5	2.6	3.2
05/08/87	2.7	4.4	3.3	25.4	27.7	26.2	3.7	3.6	3.7
05/22/87	4.1	3.6	3.9	24.6	25.8	25.0	3.0	3.9	3.3
06/08/87	8.3	4.7	7.1	28.4	29.6	28.8	3.9	4.1	4.0
06/18/87	8.2	12.1	9.5	29.1	32.6	30.3	1.9	2.6	2.1

	Chl a ug/l			TP ug/l			SRP ug/l		
DATE	N+M	S+L	wt. mean	N+M	S+L	wt. mean	N+M	S+L	wt. mean
07/01/87	10.3	12.4	11.0	24.2	26.6	25.0	1.8	2.1	1.9
07/16/87	8.3	4.9	7.2	24.1	22.6	23.6	1.7	1.4	[illegible]
07/30/87	16.7	4.3	12.6	31.7	23.9	29.1	2.0	2.0	2.0
08/13/87	21.5	6.5	16.5	48.1	36.5	44.3	2.5	3.6	2.9
08/27/87	15.6	4.8	12.0	17.3	9.3	14.7	2.1	2.5	2.2
09/10/87	15.0	9.9	13.3	42.1	30.6	38.3	2.5	2.5	2.5
09/24/87	7.4	5.2	6.6	36.5	35.5	36.2	1.8	2.8	2.2

	P inflow		P outflow		pH				SECCHI (m)
DATE	TP_i	SRP_i	TP_o	SRP_o	N+R	S+L	wt. mean	lillies	midlake
07/13/76					-	-	-	-	-
07/20/76	36.3	16.9	43.5	10.4	8.9	10.1	9.7	10.0	1.8
08/03/76	53.2	13.9	44.7	9.8	8.2	10.2	9.7	10.1	2.0
08/17/76	58.8	18.2	45.6	9.7	7.9	8.8	8.4	8.9	2.0
08/31/76	37.3	17.8	35.1	10.1	9.0	9.8	9.4	9.8	1.8
09/14/76	60.1	16.4	39.3	7.9	9.4	9.5	9.4	9.5	1.5
09/30/76	62.6	16.3	55.4	10.3	9.6	10.1	9.8	9.9	1.3
10/14/76	41.9	11.1	48.4	12.3	8.3	9.4	9.0	9.4	2.4
10/26/76	45.4	16.4	37.8	13.0	8.2	9.2	8.8	9.3	3.0
11/11/76	32.9	10.9	30.2	9.7	7.9	8.8	8.4	8.7	3.0
11/23/76	39.4	12.0	28.9	7.4	7.6	7.4	7.5	7.4	3.0
12/09/76	37.8	15.0	27.4	7.2	7.6	7.7	7.6	7.7	3.0
12/30/76	41.0	13.9	25.4	7.1	7.4	7.6	7.5	7.8	2.2
01/18/77	77.3	-	31.2	-	7.3	7.2	7.3	7.0	3.0
02/08/77	29.7	11.5	28.0	4.6	7.1	8.2	7.8	8.2	3.0
03/01/77	45.2	13.4	33.8	5.5	-	-	-	-	2.0
03/22/77	36.3	11.6	62.2	3.6	8.3	8.1	8.2	8.1	1.4
04/05/77	42.4	12.5	58.2	5.5	7.7	7.9	7.8	7.9	3.0
04/19/77	34.4	10.7	44.6	14.2	7.5	7.5	7.5	7.5	3.0
05/03/77	81.2	13.3	44.5	11.9	7.8	7.6	7.7	7.7	2.7
05/17/77	33.6	12.1	43.8	6.3	7.9	7.8	7.9	7.7	2.0
05/31/77	89.1	15.6	50.9	3.8	9.1	8.6	9.0	8.2	1.7
06/14/77	37.9	19.3	39.5	2.5	9.8	9.6	9.7	9.3	1.0
06/28/77	47.0	18.4	42.5	12.3	8.6	9.6	9.2	8.8	2.6
07/12/77	40.5	15.8	64.2	5.6	9.0	9.6	9.3	-	0.9
07/26/77	61.0	23.0	61.9	6.9	9.4	9.6	9.5	8.6	0.9
08/09/77	55.3	23.9	69.2	12.4	8.2	9.1	8.7	9.4	1.9
08/30/77	61.0	19.0	89.6	18.4	7.7	7.4	7.6	8.4	1.8
09/13/77	43.9	20.4	74.0	12.3	8.1	8.4	8.2	8.5	0.9
09/27/77	44.7	16.3	64.0	7.2	7.4	7.8	7.6	7.5	1.2
10/11/77	42.9	17.5	53.9	11.7	7.2	7.3	7.2	7.5	1.8
11/01/77	104.7	11.4	112.6	14.7	7.4	7.4	7.4	7.0	-
11/29/77	37.0	7.8	33.0	10.8	6.5	6.6	6.5	6.5	1.0
12/27/77	36.8	10.7	36.1	13.2	6.5	6.1	6.4	6.0	1.6
01/31/78	41.0	11.1	44.6	5.6	7.1	7.0	7.1	7.0	1.4
02/14/78	35.1	13.1	43.4	7.9	7.2	7.3	7.2	7.3	1.1
02/28/78	38.4	9.6	42.8	6.4	6.4	6.4	6.4	6.4	1.5
03/17/78	31.5	11.2	34.9	15.7	6.6	6.7	6.6	6.7	2.3
04/01/78	40.0	27.5	63.4	27.6	7.1	7.2	7.1	7.3	1.8
04/14/78	38.2	9.9	59.0	14.1	7.9	7.5	7.8	7.2	1.5
04/28/78	46.2	10.0	44.9	11.2	7.7	7.4	7.6	7.3	2.4
05/12/78	34.9	14.0	53.1	10.8	7.6	7.4	7.5	7.4	1.6
06/23/78	38.6	19.7	95.3	14.0	8.7	7.1	8.5	7.1	1.1
07/03/78	41.1	23.1	-	-	8.7	8.0	8.6	-	1.1
07/11/78	52.1	20.7	-	-	-	-	-	7.1	-
07/21/78	42.5	26.5	-	-	8.4	9.1	8.8	8.9	1.8
07/28/78	42.6	22.7	-	-	-	-	-	7.3	2.2

	P inflow		P outflow		pH			SECCHI(m)	
DATE	TPi	SRPi	TPo	SRPo	B+R	S+L	wt. mean	lillies	midlake
08/04/78	53.5	22.1	-	-	8.5	8.9	8.7	8.1	1.4
08/11/78	-	-	-	-	-	-	-	7.3	1.3
08/21/78	44.3	20.7	-	-	-	-	-	7.5	1.6
09/06/78	56.9	19.1	-	-	-	-	-	7.6	2.5
09/19/78	32.5	17.4	57.5	7.7	8.5	8.9	8.7	7.2	2.0
10/03/78	15.8	13.4	36.1	4.1	-	-	-	-	1.2
10/17/78	40.0	15.1	48.0	5.8	7.4	8.1	7.8	8.8	2.6
10/31/78	78.5	12.7	-	6.8	6.7	6.6	6.7	6.6	3.1
11/14/78	-	12.1	-	8.8	7.6	7.6	7.6	7.5	3.1
11/28/78	-	9.0	-	7.7	7.2	7.3	7.2	7.3	3.1
12/14/78	-	9.0	-	6.8	7.5	7.4	7.5	-	2.5
12/30/78	-	10.0	-	12.1	7.3	-	-		-
01/09/79	22.8	10.5	17.9	9.5	7.0	7.0	7.0		3.1
01/23/79	30.7	12.3	33.1	8.8	6.7	6.7	6.7		1.6
02/06/79	42.5	9.6	40.5	6.0	6.6	6.6	6.6		-
02/20/79	31.0	4.6	35.3	4.4	7.0	7.0	7.0	7.0	2.1
03/06/79	29.5	8.3	32.7	5.5	6.6	6.6	6.6	6.6	2.0
03/20/79	25.9	9.3	32.9	10.2	6.5	6.5	6.5	6.6	2.7
04/03/79	19.3	7.7	19.8	8.9	6.5	6.5	6.5	6.7	2.8
04/17/79	29.0	13.1	32.0	8.8	6.2	6.2	6.2	6.3	2.2
05/01/79	30.7	11.5	21.1	5.8	6.7	6.7	6.7	7.0	2.7
05/15/79	25.5	13.4	23.2	3.4	-	-	-	7.2	2.6
05/29/79	30.9	19.6	47.3	5.7	-	-	-	7.2	2.4
06/12/79	41.9	23.0	50.1	4.4	-	-	-	7.2	2.2
06/26/79	50.1	34.8	45.1	10.6	8.2	8.4	8.3	-	)
07/10/79	53.0	16.5	68.1	6.1	7.1	7.2	7.1		1.0
07/24/79	37.2	24.0	101.7	5.3	-	-			0.6
08/07/79	34.3	18.4	91.0	8.0	8.1	9.2	8.5		0.6
08/21/79	31.3	20.6	76.3	10.4	7.2	8.0	7.5		0.5
09/06/79	32.6	20.2	61.6	10.9	7.6	7.8	7.7		1.1
09/18/79	26.8	20.8	56.9	19.6	8.1	9.7	8.6		1.4
10/02/79	23.2	15.4	37.2	17.7	8.7	10.1	9.2		)
10/18/79	98.9	21.6	68.6	27.5	8.1	9.1	8.4		)
11/08/79	26.0	9.4	26.0	7.9	7.5	6.7	7.2	6.7	2.2
11/20/79	19.9	9.4	25.9	8.0	7.8	7.2	7.6	7.2	)
12/06/79	34.0	10.1	35.0	9.1	7.1	7.1	7.1	7.1	1.9
12/19/79	47.0	8.2	44.1	10.4	7.9	7.6	7.8	7.2	1.0
01/10/80	48.1	7.1	30.6	9.9	6.2	6.2	6.2	6.3	2.0
02/07/80	36.8	5.0	37.4	4.7	6.8	6.7	6.8	6.7	1.8
03/10/80	51.3	8.6	45.3	2.5	6.3	6.7	6.4	6.8	1.5
03/25/80	38.0	9.6	39.4	3.5	-	-	-		-
04/08/80	33.9	5.8	31.7	1.1	6.7	7.2	6.9	7.1	1.9
04/22/80	44.8	9.0	34.2	2.0	7.4	7.4	7.4	7.7	0.9
05/06/80	24.0	10.5	43.4	2.4	-	-			1.7
05/20/80	32.4	11.7	29.8	4.4	7.1	7.0	7.1	7.2	1.9
06/03/80	37.4	16.0	33.0	2.4	7.1	7.0	7.1	7.2	1.6
06/17/80	39.0	15.3	29.1	2.2	7.4	6.6	7.1	6.3	1.0
07/01/80	29.4	12.5	27.6	2.1	8.1	7.5	7.9	7.1	1.7
07/15/80	51.1	17.7	36.4	7.7	6.7	6.5	6.6	6.7	1.3
07/29/80	42.1	20.8	36.1	9.1	7.9	-	5.3	5.9	2.1
08/12/80	-	21.4	-	6.3	7.7	7.5	7.6	7.1	2.2

	P	inflow	P outflow		pH				SECCHI(m)
DATE	TP_i	SRP_i	TP_o	SRP_o	N+A	S+L	wt. mean	lillies	midlake
09/09/80	38.1	18.7	28.7	18.7	8.6	8.3	8.5	7.9	1.3
09/23/80	36.4	15.9	-	-	6.4	6.5	6.4	6.9	>
10/07/80	24.8	14.3	25.7	0.5	6.7	7.4	6.9	6.9	3.1
10/21/80	17.2	10.0	8.8	1.1	7.9	9.0	8.3	8.8	3.1
11/04/80	56.5	14.6	16.0	1.4	6.9	6.7	6.8	6.7	3.3
11/18/80	36.6	10.5	17.2	4.3	7.1	7.2	7.1	7.2	1.9
12/02/80	48.8	8.3	24.8	7.1	6.7	6.5	6.6	-	1.3
12/16/80	-	12.9	-	9.6	7.0	6.9	7.0	6.8	2.5
01/13/81	20.9	10.6	16.9	10.9	6.8	6.7	6.8	6.7	1.6
02/13/81	42.4	7.9	39.2	3.0	6.9	7.0	6.9	7.0	1.1
03/10/81	42.2	-	26.8	-	6.8	7.2	6.9	7.3	1.6
04/09/81	42.9	5.5	30.8	1.5	6.8	6.8	6.8	6.8	1.9
04/23/81	19.2	6.3	19.7	0.0					2.2
05/07/81	15.4	5.8	11.2	0.4					2.0
05/21/81	23.8	10.2	5.0	0.0					2.3
06/04/81	33.3	23.2	9.9	2.8	6.9	7.4	7.1	6.9	2.3
06/18/81	42.8	16.3	25.6	0.6	6.0	6.1	6.0	5.7	1.9
06/30/81	44.9	21.0	34.3	4.3	8.7	9.1	8.8	9.1	1.4
07/16/81	90.0	49.3	32.6	10.6	9.3	10.4	9.7	10.4	1.5
07/30/81	44.5	29.3	22.2	9.6	8.5	9.5	8.8	9.2	2.6
08/13/81	44.4	24.8	38.7	13.0	7.3	8.9	7.8	8.6	>
09/27/81	48.7	31.8	27.9	12.1	7.3	8.9	7.8	8.5	-
11/21/81	42.7	-	23.3	-	6.5	6.3	6.4	6.2	-
12/15/81	55.4	-	34.3	-	5.6	6.1	5.8	6.0	1.2
02/04/82	38.6	-	36.8	-	6.3	6.2	6.3	6.1	1.8
02/25/82	61.0	-	43.8	-	6.8	6.7	6.8	6.7	1.8
03/22/82	52.3	-	35.3	-	7.8	7.5	7.7	7.5	1.6
04/28/82	79.5	-	25.4	-	7.5	7.3	7.4	7.1	>
06/10/82	67.8	-	42.4	-	7.5	7.7	7.6	7.4	>
06/25/82	71.6	-	42.5	-	8.0	7.7	7.9	7.4	>
07/09/82	67.3	-	28.4	-	8.0	7.6	7.9	7.1	3.0
07/23/82	54.2	-	22.3	-	8.6	7.6	8.3	7.1	3.0
08/06/82	68.2	-	34.4	-	8.7	7.4	8.3	6.9	3.0
08/17/82	56.2	-	23.6	-	8.7	7.6	8.3	7.1	2.4
06/09/83	-	-	-	-	8.2	8.5	8.3	9.0	2.3
06/24/83	-	-	-	-	8.5	8.7	8.6	8.7	2.0
07/15/83	-	-	-	-	8.3	8.2	8.3	8.0	1.3
08/05/83	-	-	-	-	7.7	8.3	7.9	8.9	2.5
09/07/83	-	-	-	-	7.0	6.5	6.8	6.4	2.5
06/06/84	-	-	-	-	6.7	7.3	6.9	7.3	2.6
06/25/84	-	-	-	-	6.9	7.1	7.0	-	2.9
07/12/84	-	-	-	-	6.7	7.1	6.8	7.2	3.0
07/25/84	-	-	-	-	6.9	7.8	7.2	8.5	2.6
08/08/84	-	-	-	-	7.2	7.6	7.3	8.5	2.4
08/30/84	29.9	25.4	24.9	7.9	6.7	7.6	7.0	7.8	2.5
09/14/84	28.3	20.1	28.9	4.9	7.6	7.6	7.6	6.7	2.0
09/27/84	24.8	23.4	34.8	7.1	7.2	8.0	7.5	8.5	2.5
10/09/84	37.0	15.8	33.6	3.8	7.9	6.4	7.4	6.5	2.2
11/10/84	85.6	19.7	40.7	4.4	7.0	6.8	6.9	6.8	1.4

	P inflow		P outflow		pH				SECCHI(m)
DATE	TPi	SRPi	TPo	SRPo	N+M	S+L	wt. mean	lillies	midlake
12/09/84	32.5	9.1	26.9	5.4	6.6	6.4	6.5	6.3	1.4
01/13/85	23.9	8.5	17.5	5.8	6.9	7.0	6.9		1.4
02/16/85	27.4	9.3	36.0	3.3	6.7	6.8	6.7	6.7	1.2
03/09/85	25.1	9.4	39.1	2.1	7.2	7.4	7.3	7.4	0.9
04/06/85	37.6	13.9	37.9	14.6	8.0	7.7	7.9	7.5	1.1
04/23/85	43.0	3.8	46.2	6.9	7.0	7.2	7.1	7.2	2.0
05/04/85	33.5	8.3	33.7	4.2	6.8	7.0	6.9	7.0	1.9
05/18/85	34.3	25.2	30.0	22.3					3.4
06/02/85	49.9	20.1	44.4	13.4	7.0	7.0	7.0	7.0	3.0
06/14/85	36.7	19.8	30.2	1.4	7.1	7.0	7.1	7.0	2.0
07/01/85	31.3	18.2	38.1	6.2	7.7	7.7	7.7	8.0	1.5
07/15/85	39.1	21.6	42.0	4.0	7.2	7.4	7.3	7.9	1.2
07/26/85	51.9	24.5	62.9	12.6	7.4	8.0	7.6	7.9	0.8
08/07/85	47.3	-	73.4	-					0.6
08/12/85	47.8	23.9	78.8	4.8	8.8	8.7	8.8	8.8	0.5
08/19/85	40.3	-	71.6	-					-
08/26/85	36.4	22.0	100.6	13.6	8.4	9.1	8.6	9.4	0.7
09/09/85	47.2	-	93.3	-					0.7
09/13/85	32.0	24.7	78.5	11.4	8.3	8.0	8.2	7.8	0.7
09/23/85	35.3	19.8	79.7	7.1	7.3	8.0	7.5	8.5	0.8
10/19/85	78.4	43.1	87.5	34.1	7.4	7.5	7.4	7.4	1.1
11/16/85	45.8	34.9	40.6	25.9	6.8	6.8	6.8	6.8	2.4
12/18/85	24.5	18.7	28.9	10.2					-
01/23/86	31.3	26.9	54.7	28.7	7.0	7.0	7.0	7.1	0.8
02/17/86	27.8	26.5	27.5	27.5	7.1	7.1	7.1	7.1	1.3
03/25/86	32.4	29.1	37.4	21.5	7.2	7.2	7.2	7.2	1.7
04/11/86	37.1	45.0	51.0	33.5	7.1	7.4	7.2	7.4	0.9
04/25/86	?133.2	54.5	48.6	30.5	7.6	7.4	7.5	7.3	1.0
05/09/86	34.6	21.6	41.7	12.8	7.3	7.4	7.3	7.3	2.0
05/23/86	?81.0	20.1	54.3	12.1	7.5	7.7	7.6	7.6	2.3
06/06/86	59.2	42.5	39.2	24.4	7.8	7.7	7.8	7.4	1.7
06/26/86	53.6	41.6	39.5	7.8	7.3	7.8	7.5	8.1	2.1
07/08/86	33.2	18.8	28.4	4.9	7.6	7.5	7.6	7.4	2.3
07/22/86	31.9	16.8	27.0	4.5	7.6	7.8	7.7	7.7	2.2
08/05/86	37.8	23.8	30.8	6.5	8.2	8.3	8.2	9.4	2.1
08/19/86	-	23.0	27.0	4.7	7.3	7.5	7.4	8.3	1.6
09/02/86	29.5	26.5	48.9	9.3	7.8	8.1	7.9	8.2	1.5
09/1[illegible]/86	43.1	-	44.4	11.3	8.5	9.1	8.7	9.0	1.4
10/07/86	20.3	19.3	26.6	1.2	9.0	9.5	9.2	9.6	0.9
11/06/86	38.4	16.5	34.3	3.7	7.2	7.0	7.1	7.2	2.2
12/04/86	26.6	18.1	30.5	7.8	7.2	6.8	7.1	6.8	1.9
01/02/87	33.7	15.0	31.9	9.1					1.6
02/07/87	34.1	11.0	45.2	6.3	7.4	6.8	7.2	6.8	1.7
03/07/87	34.7	14.1	13.7		7.0	6.9	7.0	6.9	1.7
04/11/87	30.0	17.0	22.1	4.3	7.2	7.1	7.2	7.0	1.4
04/25/87	28.7	18.0	36.8	3.5	7.2	7.2	7.2	7.2	1.9
05/08/87	42.8	21.3	36.4	10.1	7.8	9.0	8.2	9.3	3.4
05/22/87	29.0	15.0	30.1	4.4	7.5	8.6	7.9	8.6	3.0
06/08/87	31.6	22.4	30.0	5.7	8.1	8.7	8.3	8.8	2.4
06/18/87	33.0	14.2	40.8	3.2	8.3	8.6	8.4	8.9	1.9

	P inflow		P outflow		pH				SECCHI(m)
DATE	TPi	SRPi	TPo	SRPo	B+M	S+L	wt. mean	lillies	midlake
07/01/87	34.3	18.8	31.2	2.1	8.5	9.3	8.8	9.4	2.4
07/16/87	32.6	17.5	29.3	2.0	8.5	8.7	8.6	8.6	2.3
07/30/87	30.2	17.7	28.5	2.2	9.4	9.3	9.4	9.6	1.8
08/13/87	27.3	14.6	36.3	2.3	9.2	8.1	8.8	7.6	1.8
08/27/87	12.9	14.2	19.7	3.6	8.7	9.1	8.9	9.4	2.1
09/10/87	25.3	18.2	201.1	8.7	8.7	9.1	8.8	7.8	2.0
09/24/87	27.1	16.2	35.1	6.9	8.3	8.9	8.4	8.8	2.3

DATE	NO3+NO2-N ug/l N+R	NO3+NO2-N ug/l S+L	NO3+NO2-N ug/l wt. mean	NH4-N ug/l N+R	NH4-N ug/l S+L	NH4-N ug/l wt. mean	NO3+NH3	% INFLOW NH4	% INFLOW NO3	TN/TP	SN/SRP
7/13/76	-	-	-	-	-	-					
07/20/76	-	-	-	28.0	15.0	23.7	23.7	16	-	17.51	119.25
08/03/76	-	-	-	11.0	11.0	11.0	11.0	28	-	10.30	147.50
08/17/76	8.0	trace	3.0	5.0	6.0	5.3	8.3	18	-	10.23	85.58
08/31/76	trace	trace	0.0	3.0	4.0	3.3	3.3	9	159	10.47	72.65
09/14/76	trace	trace	0.0	2.0	3.0	2.3	2.3	8	207	18.24	228.06
09/30/76	trace	trace	0.0	4.0	5.0	4.3	4.3	7	147	11.31	112.07
10/14/76	20.0	trace	13.4	14.0	6.0	11.4	24.8	9	154	9.24	38.59
10/26/76	27.0	trace	18.1	16.0	8.0	13.4	31.5	14	194	5.05	11.59
11/11/76	34.0	trace	22.8	20.0	13.0	17.7	40.5	13	19	15.47	53.86
11/23/76	24.0	6.0	18.1	17.0	11.0	15.0	33.1	11	218	6.76	27.19
12/09/76	47.0	16.0	36.8	11.0	10.0	10.7	47.4	15	241	8.51	40.16
12/30/76	167.0	5.0	113.5	10.0	6.0	8.7	122.2	23	487	5.06	24.17
01/18/77	157.0	23.0	112.8	33.0	15.0	27.1	139.8	92	601	8.26	
02/08/77	157.0	15.0	110.1	12.0	6.0	10.0	120.2	23	368	20.23	108.41
03-01-77	155.0	trace	103.9	11.0	6.0	9.4	113.2	27	976	16.07	126.41
03/22/77	236.0	109.0	194.1	8.0	3.0	6.4	221.0	12	686	14.36	236.43
04/05/77	140.0	13.0	98.1	68.0	25.0	53.8	151.9	15	285	20.07	180.06
04/19/77	173.0	62.0	136.4	58.0	35.0	50.4	186.8	10	230	13.15	38.49
05/03/77	96.0	32.0	74.9	33.0	31.0	32.3	107.2	24	265	15.83	48.06
05/17/77	trace	trace	0.0	25.0	23.0	24.3	24.3	101	172	9.77	97.65
05/31/77	7.0	7.0	7.0	13.0	13.0	13.0	20.0	20	60	16.42	179.82
06/14/77	trace	trace	0.0	6.0	6.0	6.0	6.0	16	212	23.35	326.07
06/28/77	32.0	5.0	23.1	90.0	10.0	63.6	86.7	12	207	18.05	145.28
07/12/77	13.0	trace	8.7	36.0	21.0	31.1	39.8	28	187	11.05	93.02
07/26/77	trace	trace	0.0	8.0	37.0	17.6	17.6	11	178	10.64	101.20
08/09/77	23.0	8.0	18.1	100.0	25.0	75.2	93.3	74	228	15.56	135.33
08/30/77	111.0	10.0	77.7	26.0	18.0	23.4	101.0	23	209	11.39	60.83
09/13/77	trace	trace	0.0	29.0	21.0	26.4	26.4	44	245	9.92	104.45
09/27/77	trace	trace	0.0	14.0	16.0	14.7	14.7	34	1,992	9.10	149.92
10/11/77	trace	trace	0.0	10.0	13.0	11.0	11.0	15	163	7.57	70.60
11/01/77	216.0	34.0	155.9	48.0	18.0	38.1	194.0	20	533	15.38	57.05
11/29/77	540.0	392.0	491.2	41.0	61.0	47.6	538.8	36	100		93.39
12/27/77	737.0	663.0	712.6	48.0	64.0	53.3	765.9	46	654	32.24	79.87
01/31/78	523.0	312.0	453.4	27.0	23.0	25.7	479.1	13	514	20.93	151.88
02/14/78	385.0	241.0	337.5	23.0	31.0	25.6	363.1	19	553	16.65	111.71
02/28/78	175.0	116.0	155.5	43.0	39.0	41.7	197.2	36	270	17.81	161.91
03/17/78	353.0	312.0	340.8	121.0	148.0	129.9	470.7	72	438	16.02	47.69
04/01/78	317.0	242.0	292.3	43.0	52.0	46.0	338.2	22	318	10.72	25.17
04/14/78	53.0	10.0	38.8	37.0	27.0	33.7	72.5	32	297	9.10	41.08
04/28/78	80.0	67.0	75.7	6.0	3.0	5.0	80.7	4	271	11.55	70.70
05/12/78	8.0	5.0	7.[illegible]	26.0	22.0	24.7	31.7	32	213	7.23	41.36
06/23/78	8.0	36.0	17.2	10.0	25.0	15.0	32.2	22	24	10.34	50.78
07/03/78	14.0	22.0	16.6	22.0	37.0	27.0	43.6	25	164	10.06	56.34
07/11/78	82.0	19.0	61.2	80.0	65.0	75.0	136.3	46	275	10.93	88.29
07/21/78	25.0	6.0	18.7	28.0	14.0	23.4	42.1	23	69	9.62	43.37
07/28/78	29.0	9.0	22.4	32.0	28.0	30.7	53.1	19	239	6.63	30.57

	NO3+NO2-N ug/l			NH4-N ug/l				N INFLOW	N INFLOW		
DATE	N+M	S+L	wt. mean	N+M	S+L	wt. mean	NO3+NH3	NH4	NO3	TN/TP	SN/SRP
08/04/78	12.0	12.0	12.0	15.0	16.0	15.3	27.3	20	199	5.36	44.[illegible]
08/11/78	14.0	12.0	13.3	28.0	22.0	26.0	39.4	-	-	6.03	37.79
08/21/78	11.0	5.0	9.0	12.0	14.0	12.7	21.7	15	228	9.52	84.6[illegible]
09/06/78	36.0	10.0	27.4	24.0	25.0	24.3	51.8	15	231	7.47	44.85
09/19/78	10.0	10.0	10.0	18.0	22.0	19.3	29.3	16	244	11.45	88.23
10/03/78	trace	trace	0.0	19.0	25.0	21.0	21.0	11	205	19.06	194.34
10/17/78	41.0	7.0	29.8	26.0	14.0	22.0	51.8	14	186		159.2[illegible]
10/31/78	67.0	25.0	53.1	41.0	19.0	33.7	86.9	7	251	14.09	77.14
11/14/78	184.0	148.0	173.5	44.0	39.0	42.4	215.8	24	357	19.32	51.9[illegible]
11/28/78	185.0	112.0	160.9	60.0	42.0	54.1	215.0	36	523	18.81	78.11
12/14/78	419.0	303.0	380.7	-	. .	-	380.7	-	821	47.76	93.68
12/30/78	453.0	-	453.0	23.0	-	23.0	476.0	26	653		65.28
01/09/79	471.0	-	471.0	27.0	-	27.0	498.0	23	573	51.00	88.47
01/23/79	661.0	-	661.0	42.0	-	42.0	703.0	41	1,238	43.88	95.08
02/06/79	517.0	-	517.0	110.0	-	110.0	627.0	144	839	26.57	232.50
02/20/79	660.0	628.0	649.4	72.0	65.0	69.7	719.1	56	1,097	27.36	276.34
03/06/79	1,034.0	895.0	988.1	70.0	115.0	84.8	1,073.0	52	1,017	27.26	158.65
03/20/79	645.0	627.0	639.1	91.0	89.0	90.3	729.4	32	551	36.83	90.47
04/03/79	520.0	468.0	502.8	78.0	66.0	74.0	576.9	18	360	31.49	113.42
04/17/79	339.0	261.0	313.3	16.0	28.0	20.0	333.2	35	315	12.99	57.11
05/01/79	168.0	130.0	155.5	56.0	65.0	59.0	214.4	17	200	14.49	70.34
05/15/79	48.0	22.0	39.4	34.0	17.0	28.4	67.8	25	253	17.33	102.44
05/29/79	6.0	7.0	6.3	15.0	14.0	14.7	21.0	20	279	15.59	109.85
06/12/79	trace	trace	0.0	15.0	46.0	25.2	25.2	19	311	10.67	100.63
06/26/79	4.3	3.3	4.0	23.5	30.5	25.8	29.8	34	336	5.53	45.95
07/10/79	3.3	4.4	3.7	8.6	14.6	10.6	14.2	10	206	6.61	91.49
07/24/79	trace	trace	0.0	6.3	4.4	5.7	5.7	11	251	5.62	78.03
08/07/79	trace	trace	0.0	11.9	28.8	17.5	17.5	5	0	5.40	61.59
08/21/79	trace	trace	0.0	21.8	11.0	18.2	18.2	12	204	4.86	33.29
09/06/79	<5	<5	0.0	16.8	26.0	19.8	19.8	25	187	6.85	47.51
09/18/79	trace	trace	0.0	17.5	12.0	15.7	15.7	15	-	7.79	28.34
10/02/79	<8.5	9.0	3.0	34.5	16.0	28.4	31.4	28	-	9.13	23.45
10/18/79	<9.5	<5	5.0	12.8	14.0	13.2	18.2	31	350	5.08	15.53
11/08/79	108.0	13.0	76.6	12.0	12.7	12.2	88.9	28	-	16.41	91.75
11/20/79	71.0	-	47.6	13.5	11.7	12.9	60.5	17	268	12.19	76.74
12/06/79	263.8	237.0	255.0	20.7	44.0	28.4	283.3	29	-	19.51	82.84
12/19/79	679.0	500.7	620.2	53.8	86.7	64.7	684.8	18	1,050	22.35	89.03
01/10/80	625.2	557.5	602.9	81.2	123.0	95.0	697.9	68	2,027	28.52	73.09
02/07/80	627.3	560.7	605.3	15.7	15.0	15.5	620.8	26	810	19.24	98.85
03/10/80	322.5	495.5	379.6	24.5	44.0	30.9	410.5	39	479	11.61	343.57
03/25/80	-	-		-	-			-	-		0.00
04/08/80	153.8	145.0	150.9	19.7	47.0	28.7	179.6	12	321	11.62	198.28
04/22/80	<5	<5		6.3	<5	4.2	4.2	17	227	10.76	320.90
05/06/80	5.0	5.0	5.0	5.0	5.0	5.0	10.0	13	232	10.59	263.39
05/20/80	5.0	5.7	5.2	5.0	5.0	5.0	10.2	16	270	13.71	183.15
06/03/80	5.0	5.0	5.0	7.3	6.7	7.1	12.1	19	518	10.90	194.71
06/17/80	3.7	3.0	3.4	11.4	6.0	9.6	13.0	0	14	17.22	235.39
07/01/80	6.7	5.0	6.0	37.9	16.7	30.9	36.9	20	221	12.53	1,080.65
07/15/80	0.0	0.0	0.0	10.7	6.7	9.4	9.4	21	206	10.76	115.39
07/29/80	0.0	0.0	0.0	0.0	7.0	2.3	2.3	28	221	13.40	253.94
08/12/80	-	-	-	6.3	4.7	5.8	5.8	5	-		101.66

	NO3+NO2-N ug/l			NH4-N ug/l				% INFLOW	% INFLOW		
DATE	N+M	S+L	wt. mean	N+M	S+L	wt. mean	NO3+NH3	NH4	NO3	TN/TP	SN/SRP
09/09/80	32.8	15.0	26.9	19.0	11.7	16.7	43.6	27	227	17.09	204.28
09/23/80	18.5	8.7	15.3	71.8	85.7	76.3	91.6	22	227	12.30	
10/07/80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27	222	20.02	382.28
10/21/80	0.0	0.0	0.0	0.0	16.9	11.7	15.2	9	228	34.68	830.30
11/04/80	36.5	27.0	33.4	31.7	20.0	31.1	64.5	29	4924	24.70	464.18
11/18/80	229.0	13.0	166.4	34.3	29.0	32.6	199.0	22	342	21.83	184.11
12/02/80	322.0	95.3	247.2	41.0	56.3	46.1	293.3	47	779	37.38	114.95
12/16/80	478.0	169.0	376.0	50.9	57.0	52.8	428.8	65	442		83.35
01/13/81	472.5	306.0	417.6	96.3	114.0	102.1	519.7	53	1,217	41.08	66.40
02/13/81	453.5	207.0	372.2	20.0	17.0	19.0	391.2	36	611	9.70	179.38
03/10/81	-	-	-	-	-			-	480	13.20	
04/09/81	115.5	29.5	87.1	46.7	25.3	39.6	126.8	38	282	8.34	254.79
04/23/81	57.0	11.8	41.8	47.7	33.7	43.1	84.9	23	287	27.51	
05/07/81	10.6	5.0	8.8	29.9	16.5	25.5	34.2	28	240	18.39	
05/21/81	11.7	19.5	14.3	17.1	16.0	16.7	31.0	42	270	16.94	
06/04/81	29.5	706.0	252.7	28.7	22.0	26.5	279.2	27	287	25.86	190.03
06/18/81	8.9	5.0	7.6	27.5	23.3	26.1	33.7	40	267	14.86	
06/30/81	8.3	5.0	7.2	29.5	31.0	30.0	37.2	46	253	13.94	105.78
07/16/81	7.0	6.0	6.7	22.3	23.5	22.7	29.4	24	234	10.94	58.06
07/30/81	10.5	15.0	12.0	24.7	8.0	19.2	31.2	6	244	13.20	99.94
08/13/81	20.8	11.9	17.9	26.3	9.5	20.8	38.6	65	202	19.71	167.90
09/27/81	447.0	509.0	467.5	5.7	5.0	5.5	15.6	13	233	10.19	71.10

Appendix B

Long Lake Water and TP Budgets

1976-1977 WATER BUDGET

DATE 10/1/76-9/27/77	AVG SALMON BERRY FLOW cu.m. x 10**5	PRECIP-ITATION cu.m. x 10**5	CURLEY CREEK FLOW cu.m. X 10**5	EVAPORA-TION cu.m. X 10**5	LAKE VOLUME START cu.m. x 10**6	LAKE VOLUME START cu.m. X 10**6	VOLUME CHANGE cu.m. X 10**4	AVERAGE LAKE VOLUME cu.m. X 10**6	UNGAGED SURFACE INFLOW cu.m. X 10**5	GROUND-WATER cu.m. X 10**5	TIME STEP (WEEKS)
10/1/76-10/27	4.45	0.55	8.27	0.05	2.753	2.753	0.000	2.75	2.77	0.55	3.7
10/27-11/11	2.43	0.29	5.09	0.00	2.753	2.807	5.400	2.78	2.07	0.85	2.1
11/11-11/23	1.88	0.50	3.08	0.00	2.807	2.786	-2.100	2.80	0.94	-0.45	1.7
11/23-12/9	2.04	0.10	3.17	0.00	2.786	2.719	-6.700	2.75	1.02	-0.66	2.3
12/9-12/30	3.29	0.83	5.55	0.00	2.719	2.832	11.300	2.78	2.10	0.46	3.0
12/30-1/18/77	3.44	0.57	6.04	0.00	2.832	2.840	0.800	2.84	1.92	0.20	2.7
1/18-2/8	3.13	0.25	5.76	0.00	2.840	2.774	-6.600	2.81	1.63	0.07	3.0
2/8-3/1	5.96	1.21	8.22	0.00	2.774	2.920	14.600	2.85	2.98	-0.47	3.0
3/1-3/22	10.28	1.85	16.24	0.00	2.920	2.836	-8.400	2.88	5.14	-1.87	3.0
3/22-4/5	2.06	0.38	4.69	0.10	2.836	2.782	-5.400	2.81	1.42	0.39	2.0
4/5-4/19	1.71	0.20	3.15	0.30	2.782	2.732	-5.000	2.76	0.95	0.09	2.0
4/19-5/3	2.19	0.30	3.12	0.33	2.732	2.765	3.300	2.75	1.19	0.09	2.0
5/3-5/17	2.16	0.23	3.22	0.47	2.765	2.732	-3.300	2.75	1.08	-0.11	2.0
5/17-5/31	4.42	0.61	4.35	0.47	2.732	2.970	23.800	2.85	2.21	-0.04	2.0
5/31-6/14	1.68	0.51	3.63	0.67	2.970	2.711	-25.900	2.84	0.84	-1.32	2.0
6/14-6/28	1.37	0.00	1.34	0.70	2.711	2.665	-4.600	2.69	0.69	-0.48	2.0
6/28-7/12	1.37	0.22	1.58	0.63	2.665	2.665	0.000	2.67	0.69	-0.07	2.0
7/12-7/26	0.69	0.02	0.75	0.64	2.665	2.636	-2.900	2.65	0.37	0.02	2.0
7/26-8/9	0.55	0.01	0.58	0.74	2.636	2.623	-1.300	2.63	0.46	0.19	2.0
8/9-8/30	1.28	1.39	2.06	0.95	2.623	2.790	16.700	2.71	1.32	0.68	3.0
8/30-9/13	1.37	0.31	3.43	0.42	2.790	2.753	-3.700	2.77	1.23	0.55	2.0
9/13-9/27	1.54	0.80	3.43	0.31	2.753	2.753	0.000	2.75	1.08	0.31	2.0

1977-1978 WATER BUDGET

DATE 9/27/77-10/3/78	AVG SALMON BERRY FLOW cu.m. x 10**5	PRECIP-ITATION cu.m. x 10**5	CURLEY CREEK FLOW cu.m. X 10**5	EVAPORA-TION cu.m. X 10**5	LAKE VOLUME START cu.m. x 10**6	LAKE VOLUME START cu.m. X 10**6	VOLUME CHANGE cu.m. X 10**4	AVERAGE LAKE VOLUME cu.m. X 10**6	UNGAGED SURFACE INFLOW cu.m. X 10**5	GROUND-WATER cu.m. X 10**5	TIME STEP (WEEKS)
9/27/-10/11/77	1.54	0.37	4.11	0.03	2.753	2.774	2.100	2.76	1.60	0.83	2.0
10/11-11/1	4.68	1.54	6.89	0.00	2.774	2.912	13.800	2.84	2.34	-0.29	3.0
11/1-11/29	19.46	3.41	30.56	0.00	2.912	3.192	28.000	3.05	10.11	0.38	4.0
• 11/29-12/27	20.90	3.37	43.30	0.00	3.192	2.941	-25.100	3.07	13.49	3.04	4.0
12/27-1/31/78	15.50	2.47	37.00	0.00	2.941	2.941	0.000	2.94	13.39	5.64	5.0
1/31-2/14	6.03	1.46	15.79	0.00	2.941	3.024	8.300	2.98	6.08	3.06	2.0
2/14-2/28	4.35	0.45	7.78	0.00	3.024	2.941	-8.300	2.98	2.18	-0.04	2.0
2/28-3/17	4.49	0.66	8.28	0.00	2.941	2.849	-9.200	2.90	2.25	-0.04	2.4
3/17-4/1	3.97	0.73	9.28	0.00	2.849	2.920	7.100	2.88	3.64	1.65	2.0
4/1-4/14	2.39	0.42	5.63	0.29	2.920	2.832	-8.800	2.88	1.72	0.52	2.0
4/14-4/28	5.04	1.25	10.65	0.24	2.832	2.958	12.600	2.90	4.19	1.67	2.0
4/28-5/12	1.88	0.14	5.14	0.39	2.958	2.795	-16.300	2.88	1.41	0.47	2.0
5/12-5/26	2.30	0.63	4.52	0.41	2.795	2.786	-0.900	2.79	1.54	0.39	2.0
5/26-6/9	1.78	0.31	3.73	0.68	2.786	2.744	-4.200	2.77	1.40	0.51	2.0
6/9-6/23	1.47	0.14	3.25	0.58	2.744	2.728	-1.600	2.74	1.39	0.66	2.0
6/23-7/7	1.44	0.10	3.01	0.53	2.728	2.744	1.600	2.74	1.44	0.73	2.0
7/7-7/21	1.47	0.10	2.47	0.58	2.744	2.698	-4.600	2.72	0.87	0.14	2.0
7/21-8/4	1.51	0.24	2.09	0.68	2.698	2.682	-1.600	2.69	0.80	0.05	2.0
8/4-8/21	1.75	0.14	1.33	0.66	2.682	2.631	-5.100	2.66	0.87	-1.27	2.4
8/21-9/6	1.76	1.11	2.08	0.34	2.631	2.711	8.000	2.67	0.88	-0.55	2.1
9/6-9/19	2.32	0.84	4.17	0.24	2.711	2.807	9.600	2.76	1.69	0.53	1.9
9/19-10/3/78	3.01	0.90	5.10	0.22	2.807	2.711	-9.600	2.76	1.51	-1.07	2.1

1980-1981 WATER BUDGET

DATE 1980-1981	AVG SALMON BERRY FLOW cu.m. x 10**5	AVG CUR-LEY FLOW cu.m. x 10**5	PRECIPI-TATION cu.m. x 10**4	EVAPORA-TION cu.m. x 10**4	LAKE VOLUME START cu.m. x 10**6	LAKE VOLUME START cu.m. X 10**6	VOLUME CHANGE cu.m. X 10**4	AVERAGE LAKE VOLUME cu.m. X 10**6	UNGAGED SURFACE INFLOW cu.m. X 10**5	GROUND-WATER cu.m. X 10**5	TIME STEP (WEEKS)
9/9-9/23	0.51	3.94	2.33	1.70	2.71	2.72	1.00	2.72	1.87	1.62	2.0
9/23-10/7	0.96	4.15	1.64	1.22	2.72	2.71	-1.00	2.72	1.75	1.27	2.0
10/7-10/21	1.03	4.11	2.68	0.73	2.71	2.73	2.00	2.72	1.81	1.29	2.0
10/21-11/4	1.88	5.82	9.36	0.73	2.73	2.90	17.00	2.82	2.85	1.90	2.0
11/4-11/18	3.63	14.97	17.02	0.00	2.90	2.98	8.00	2.94	6.15	4.33	2.0
11/18-12/2	4.11	18.43	18.65	0.00	2.98	3.27	29.00	3.13	8.70	6.64	2.0
12/2-12/16	1.82	15.38	5.50	0.00	3.27	2.90	-37.00	3.09	5.12	4.22	2.0
12/16-12/30	9.04	17.95	29.20	0.00	2.90	3.37	47.00	3.14	7.58	3.05	2.0
12/30-1/13	7.09	21.65	29.20	0.00	3.37	3.19	-18.00	3.28	6.72	3.17	2.0
1/13-1/27	2.60	17.92	15.14	0.00	3.19	3.05	-14.00	3.12	6.82	5.52	2.0
1/27-2/13	2.70	16.97	15.14	0.00	3.05	3.02	-3.00	3.04	6.91	5.56	2.4
2/13-2/27	9.42	19.39	29.16	0.00	3.02	3.16	14.00	3.09	6.59	1.88	2.0
2/27-3/10	2.05	14.32	29.16	0.00	3.16	2.96	-20.00	3.06	4.19	3.16	1.6
3/10-3/26	2.31	10.45	4.45	0.00	2.96	2.88	-8.00	2.92	4.03	2.87	2.3
3/26-4/9	3.60	12.30	4.45	0.00	2.88	2.98	10.00	2.93	5.53	3.73	2.0
4/9-4/23	3.08	14.18	0.49	2.67	2.98	2.92	-6.00	2.95	6.16	4.62	2.0
4/23-5/7	1.64	7.74	4.56	2.19	2.92	2.84	-8.00	2.88	2.92	2.10	2.0
5/7-5/21	1.58	7.74	8.04	2.19	2.84	2.86	2.00	2.85	3.27	2.48	2.0
5/21-6/4	1.34	6.48	1.25	2.67	2.86	2.77	-9.00	2.82	2.53	1.85	2.0
6/4-6/18	1.51	6.27	4.00	1.70	2.77	2.80	3.00	2.79	2.81	2.06	2.0
6/18-6/30	1.00	4.38	1.57	2.43	2.80	2.72	-8.00	2.76	1.56	1.06	1.7
6/30-7/16	1.18	4.35	2.02	4.62	2.72	2.69	-3.00	2.71	1.88	1.30	2.3
7/16-7/30	0.99	3.36	0.00	3.40	2.69	2.65	-4.00	2.67	1.39	0.90	2.0
7/30-8/13	0.96	2.81	0.00	4.13	2.65	2.62	-3.00	2.64	1.25	0.77	2.0
8/13-8/27	1.03	2.64	0.00	3.15	2.62	2.62	0.00	2.62	1.19	0.66	2.0

1984-1985 WATER BUDGET

DATE 9/14/84-9/13/85	AVG SALMON BERRY FLOW cu.m. x 10**5	PRECIP-ITATION cu.m. x 10**5	CURLEY CREEK FLOW cu.m. X 10**5	EVAPORA-TION cu.m. X 10**5	LAKE VOLUME START cu.m. x 10**6	LAKE VOLUME END cu.m. X 10**6	VOLUME CHANGE cu.m. X 10**4	AVERAGE LAKE VOLUME cu.m. X 10**6	UNGAGED SURFACE INFLOW cu.m. X 10**5	G.W. INFLOW cu.m. X 10**5	TIME STEP (weeks)
9/14/84-9/27	0.86	0.12	2.80	0.32	2.741	2.733	-0.835	2.74	1.24	0.81	1.86
9/27-10/9	0.85	0.14	2.85	0.23	2.733	2.762	2.923	2.75	1.40	0.98	1.71
10/9-11/10	12.53	2.91	15.11	0.23	2.762	3.259	49.692	3.01	6.26	-1.39	4.57
11/10-12/9	17.31	2.69	22.21	0.00	3.259	3.280	2.088	3.27	8.66	-6.24	4.14
12/9-1/13/85	14.13	1.63	21.84	0.00	3.280	3.004	-27.560	3.14	7.06	-3.74	5.00
1/13-2/16	9.40	1.53	16.14	0.00	3.004	3.125	12.110	3.06	5.56	0.86	4.86
2/16-3/9	4.45	0.32	9.73	0.00	3.125	2.862	-26.307	2.99	2.28	0.06	3.00
3/9-4/6	4.66	1.36	5.69	0.04	2.862	2.653	-20.879	2.76	2.33	-4.71	4.00
4/6-4/23	2.83	0.47	3.58	0.33	2.653	2.875	22.132	2.76	2.12	0.70	2.43
4/23-5/4	1.16	0.41	3.42	0.26	2.875	2.866	-0.835	2.87	1.30	0.72	1.57
5/4-5/18	1.47	0.10	2.64	0.44	2.866	2.766	-10.022	2.82	0.74	-0.24	2.00
5/18-6/2	0.70	0.76	1.76	0.48	2.766	2.712	-5.428	2.74	0.35	-0.10	2.14
6/2-6/14	0.82	0.23	2.11	0.39	2.712	2.850	13.780	2.78	1.62	1.21	1.71
6/14-7/1	0.79	0.16	2.50	0.76	2.850	2.657	-19.208	2.75	0.40	-0.02	2.43
7/1-7/15	0.65	0.00	1.06	0.92	2.657	2.616	-4.176	2.64	0.62	0.29	2.00
7/15-7/26	0.30	0.00	0.30	0.64	2.616	2.599	-1.670	2.61	0.31	0.16	1.57
7/26-8/12	0.50	0.18	0.58	0.65	2.599	2.741	14.198	2.67	1.11	0.86	2.43
8/12-8/26	0.38	0.00	0.69	0.68	2.741	2.607	-13.362	2.67	0.19	-0.53	2.00
8/26-9/13	0.48	0.55	1.59	0.53	2.607	2.683	7.516	2.64	1.04	0.90	2.57

1985-1986 WATER BUDGET

DATE 9/13/85-9/16/86	AVG SALMON BERRY FLOW cu.m. x 10**5	PRECIPITATION cu.m. x 10**5	CURLEY CREEK FLOW cu.m. X 10**5	EVAPORATION cu.m. X 10**5	LAKE VOLUME START cu.m. x 10**6	LAKE VOLUME END cu.m. X 10**6	VOLUME CHANGE cu.m. X 10**4	AVERAGE LAKE VOLUME cu.m. X 10**6	UNGAGED SURFACE INFLOW cu.m. X 10**5	G.W. INFLOW cu.m. X 10**5	TIME STEP (weeks)
9/13/85-9/23	0.27	0.20	1.44	0.16	2.683	2.691	0.835	2.69	0.67	0.54	1.43
9/23-10/19	3.88	0.26	4.26	0.45	2.691	2.724	3.341	2.71	1.94	-1.04	3.71
10/19-11/16	4.18	3.41	8.22	0.16	2.724	3.025	30.065	2.87	2.94	0.85	4.00
11/16-1/23/86	37.77	5.24	26.95	0.00	3.025	3.793	76.834	3.41	18.88	-27.25	9.71
1/23-2/17	14.50	1.56	17.06	0.00	3.793	3.184	-60.966	3.49	7.25	-12.33	3.57
2/17-3/25	6.51	2.41	22.54	0.00	3.184	3.067	-11.692	3.13	7.85	4.60	5.14
3/25-4/11	1.79	0.45	9.36	0.21	3.067	2.958	-10.857	3.01	3.57	2.67	2.43
4/11-4/25	1.47	0.39	5.93	0.22	2.958	2.941	-1.670	2.95	2.43	1.69	2.00
4/25-5/9	1.47	0.72	5.04	0.30	2.941	2.941	0.000	2.94	1.94	1.20	2.00
5/9-5/23	1.03	0.61	4.97	0.36	2.941	2.875	-6.681	2.91	1.77	1.25	2.00
5/23-6/6	0.99	0.06	4.76	0.31	2.875	2.741	-13.362	2.81	1.59	1.09	2.00
6/6-6/26	1.08	0.35	3.87	0.89	2.741	2.737	-0.418	2.74	1.91	1.38	2.86
6/26-7/8	0.79	0.22	2.29	0.44	2.737	2.741	0.418	2.74	1.08	0.68	1.71
7/8-7/22	1.03	0.14	2.71	0.48	2.741	2.741	0.000	2.74	1.26	0.75	2.00
7/22-8/5	1.03	0.00	2.43	0.62	2.741	2.699	-4.176	2.72	1.05	0.55	2.00
8/5-9/2	2.06	0.02	3.56	1.20	2.699	2.674	-2.505	2.69	1.73	0.70	4.00
9/2-9/16	1.10	0.18	2.02	0.45	2.674	2.712	3.758	2.69	1.05	0.51	2.00

1986-1987 WATER BUDGET

DATE 9/13/85-9/16/86	AVG SALMON BERRY FLOW cu.m. x 10**5	PRECIP-ITATION cu.m. x 10**5	CURLEY CREEK FLOW cu.m. X 10**5	EVAPORA-TION cu.m. X 10**5	LAKE VOLUME START cu.m. x 10**6	LAKE VOLUME END cu.m. X 10**6	VOLUME CHANGE cu.m. X 10**4	AVERAGE LAKE VOLUME cu.m. X 10**6	UNGAGED SURFACE INFLOW cu.m. X 10**5	G.W. INFLOW cu.m. X 10**5	TIME STEP (weeks)
9/16-10/7	1.75	0.63	4.57	0.29	2.712	2.808	9.604	2.76	2.16	1.29	3.00
10/7-11/6	4.55	1.65	9.76	0.21	2.808	3.067	25.890	2.94	4.32	2.04	4.29
11/6-12/4	8.22	3.77	15.07	0.00	3.067	3.213	14.615	3.14	4.33	0.22	4.00
12/4-1/2/87	17.52	2.11	23.77	0.00	3.213	3.484	27.142	3.35	8.76	-1.92	4.14
1/2-2/7	24.04	3.80	33.47	0.00	3.484	3.317	-16.703	3.40	12.02	-8.07	5.14
2/7-3/7	17.76	2.87	28.26	0.04	3.317	3.610	29.230	3.46	9.73	0.85	4.00
3/7-4/11	17.13	1.49	26.97	0.73	3.610	3.138	-47.186	3.37	8.56	-4.19	5.00
4/11-4/25	3.56	0.28	6.92	0.40	3.138	3.025	-11.275	3.08	2.06	0.28	2.00
4/25-5/8	2.42	0.37	5.53	0.50	3.025	3.025	0.000	3.02	2.23	1.02	1.86
5/8-5/22	1.64	0.20	5.21	0.74	3.025	2.879	-14.615	2.95	1.73	0.91	2.00
5/22-6/8	1.71	0.60	5.78	0.91	2.879	2.941	6.264	2.91	2.93	2.08	2.43
6/8-6/18	1.93	0.00	3.23	0.58	2.941	2.837	-10.439	2.89	0.97	-0.14	1.43
6/18-7/1	2.07	0.06	3.50	0.98	2.837	2.808	-2.923	2.82	1.55	0.51	1.86
7/1-7/16	0.99	0.11	3.82	0.82	2.808	2.795	-1.253	2.80	1.95	1.46	2.14
7/16-7/30	1.13	0.09	3.49	0.76	2.795	2.795	0.000	2.80	1.80	1.24	2.00
7/30-8/13	1.16	0.04	3.73	0.94	2.795	2.837	4.176	2.82	2.24	1.65	2.00
8/13-8/27	1.23	0.12	3.60	0.72	2.837	2.774	-6.264	2.81	1.48	0.86	2.00
8/27-9/10	1.16	0.00	3.25	0.77	2.774	2.783	0.835	2.78	1.83	1.18	2.00
9/10-9/24	1.23	0.09	3.63	0.50	2.783	2.837	5.428	2.81	1.99	1.36	2.00

1976-1977 TP BUDGET

DATE 10/1/76-9/27/77	SALMON-BERRY ADDITION (kg P)	UNGAGED STREAM ADDITION (kg P)	GROUND-WATER ADDITION (kg P)	ATMOSPHER-IC AND SEPTIC ADDITION (kg P)	EXTERNAL LOADING (kg/wk)	CURLEY LOSSES (kg P)	STARTING LAKE CONTENT (kg P)	ENDING LAKE CONTENT (kg P)	NET SEDIMEN-TATION (kg P)
10/1/76-10/27	22.3	17.8	6.6	13.5	16.2	39.0	131.6	106.8	-46.0
10/27-11/11	9.5	7.5	10.2	7.8	16.3	17.3	106.8	84.2	-40.3
11/11-11/23	6.8	3.6	-1.3	6.2	8.9	9.2	84.2	81.1	-9.2
11/23-12/9	8.0	3.8	-2.0	8.3	7.9	8.9	81.1	85.4	-4.9
12/9-12/30	12.8	6.9	5.5	10.9	12.0	14.4	85.4	89.2	-17.9
12/30-1/18/77	20.3	8.8	2.4	9.9	15.2	16.9	89.2	88.6	-25.1
1/18-2/8	16.9	6.7	0.8	10.9	11.8	17.3	88.6	75.2	-31.4
2/8-3/1	22.1	8.6	-1.7	10.9	13.3	25.5	75.2	126.1	36.5
3/1-3/22	42.1	18.5	-9.8	10.9	20.6	78.0	126.1	176.1	66.3
3/22-4/5	8.0	6.2	4.7	7.3	13.1	28.1	176.1	113.8	-60.4
4/5-4/19	6.5	4.4	1.1	7.3	9.6	16.1	113.8	129.8	12.8
4/19-5/3	12.7	5.8	1.1	7.3	13.4	14.0	129.8	120.3	-22.4
5/3-5/17	12.3	5.2	-0.5	7.3	12.1	14.2	120.3	126.2	-4.2
5/17-5/31	27.0	15.5	-0.2	7.3	24.8	20.4	126.2	124.7	-30.7
5/31-6/14	10.8	5.9	-5.5	7.3	9.2	16.3	124.7	110.8	-16.1
6/14-6/28	5.9	3.4	-2.2	7.3	7.2	5.5	110.8	130.1	10.4
6/28-7/12	6.0	3.7	-0.5	7.3	8.2	8.4	130.1	212.7	74.5
7/12-7/26	3.5	2.4	0.2	7.3	6.7	4.7	212.7	193.0	-28.4
7/26-8/9	3.2	3.4	2.3	7.3	8.1	3.8	193.0	150.3	-55.1
8/9-8/30	7.4	8.3	8.2	10.9	11.6	16.3	150.3	248.6	79.8
8/30-9/13	7.1	5.8	6.6	7.3	13.4	28.1	248.6	240.6	-6.7
9/13-9/27	6.8	4.5	3.7	7.3	11.1	23.6	240.6	210.6	-28.7

1977-1978 TP BUDGET

DATE 9/27/77-10/3/78	SALMON-BERRY ADDITION (kg P)	UNGAGED STREAM ADDITION (kg P)	GROUND-WATER ADDITION (kg P)	ATMOSPHER-IC AND SEPTIC ADDITION (kg P)	EXTERNAL LOADING (kg/wk)	CURLEY LOSSES (kg P)	STARTING LAKE CONTENT (kg P)	ENDING LAKE CONTENT (kg P)	NET SEDIMEN-TATION (kg P)
9/27/77-10/11	6.8	6.9	10.0	7.3	15.5	24.2	210.6	196.1	-21.3
10/11-11/1	34.6	17.1	-1.7	10.9	20.3	57.2	196.1	127.8	-72.0
11/1-11/29	138.2	73.8	4.6	14.6	57.8	223.1	127.8	127.7	-8.2
11/29-12/27	77.3	35.1	36.5	14.6	40.9	151.6	127.7	103.8	-35.8
12/27-1/31/78	60.5	40.2	67.7	18.2	37.3	148.0	103.8	148.5	6.1
1/31-2/14	22.9	17.6	36.7	7.3	42.2	69.5	148.5	165.1	1.6
2/14-2/28	16.1	6.3	-0.2	7.3	14.7	33.5	165.1	156.5	-4.6
2/28-3/17	15.7	7.9	-0.2	8.8	13.3	32.3	156.5	144.7	-11.7
3/17-4/1	14.3	12.4	19.8	7.3	26.9	45.5	144.7	187.5	34.5
4/1-4/14	9.3	6.0	6.2	7.3	14.4	34.3	187.5	181.8	-0.2
4/14-4/28	21.2	15.1	20.0	7.3	31.8	55.4	181.8	146.1	-43.9
4/28-5/12	7.7	5.2	5.6	7.3	12.9	22.6	146.1	185.0	35.7
5/12-5/26	8.7	6.6	4.7	7.3	13.6	26.7	185.0	176.1	-9.5
5/26-6/9	7.3	6.3	6.1	7.3	13.5	23.9	176.1	219.8	40.6
6/9-6/23	5.9	5.6	7.9	7.3	13.3	25.7	219.8	213.9	-6.9
6/23-7/7	5.9	6.5	8.7	7.3	14.2	28.0	213.9	302.9	88.6
7/7-7/21	7.8	4.3	1.7	7.3	10.5	23.2	302.9	205.3	-95.5
7/21-8/4	5.3	3.1	0.6	7.3	8.1	21.5	205.3	300.7	100.6
8/4-8/21	8.6	4.1	-11.1	8.8	4.3	13.2	300.7	166.5	-131.4
8/21-9/6	9.0	4.4	-3.5	7.8	8.3	13.9	166.5	170.5	0.2
9/6-9/19	10.4	7.3	6.4	6.8	16.6	25.9	170.5	148.8	-26.7
9/19-10/3/78	7.2	4.8	-4.6	7.8	7.1	24.0	148.8	90.8	-49.2

1980-1981 TP BUDGET

DATE 1980-1981	SALMON-BERRY ADDITION (kg P)	UNGAGED STREAM ADDITION (kg P)	GROUND-WATER ADDITION (kg P)	ATMOSPHER-IC AND SEPTIC ADDITION (kg P)	EXTERNAL LOADING (kg/wk)	CURLEY LOSSES (kg P)	STARTING LAKE CONTENT (kg P)	ENDING LAKE CONTENT (kg P)	NET SEDIMEN-TATION (kg P)
9/9-9/23	1.9	6.8	19.4	7.3	17.7	11.3	103.5	57.1	-70.5
9/23-10/7	3.5	6.5	15.2	7.3	16.2	3.8	57.1	42.0	-43.8
10/7-10/21	2.6	8.2	15.5	7.3	16.8	10.6	42.0	25.4	-39.6
10/21-11/4	3.2	6.1	22.8	7.3	19.7	5.1	25.4	30.2	-29.5
11/4-11/18	20.5	17.2	52.0	7.3	48.5	16.5	30.2	67.1	-43.6
11/18-12/2	15.0	23.4	79.7	7.3	62.7	31.7	67.1	53.3	-107.5
12/2-12/16	8.9	20.7	50.6	7.3	43.7	38.1	53.3	58.3	-44.4
12/16-12/30	29.0	17.7	36.6	7.3	45.3	32.5	58.3	67.7	-48.7
12/30-1/13	22.8	15.7	38.0	7.3	41.9	39.2	67.7	70.2	-42.1
1/13-1/27	5.4	10.5	66.2	7.3	44.7	30.3	70.2	67.1	-62.2
1/27-2/13	5.6	10.6	66.7	8.8	37.8	28.7	67.1	148.9	18.8
2/13-2/27	39.9	19.6	22.6	7.3	44.7	76.0	148.9	155.8	-6.5
2/27-3/10	8.7	12.4	37.9	5.7	41.2	56.1	155.8	100.3	-64.1
3/10-3/26	9.8	11.8	34.4	8.3	29.1	28.0	100.3	97.6	-39.0
3/26-4/9	15.2	16.2	44.8	7.3	41.7	33.0	97.6	101.9	-46.2
4/9-4/23	13.2	24.6	55.4	7.3	50.2	43.7	101.9	35.3	-123.4
4/23-5/7	3.2	5.0	25.2	7.3	20.3	15.2	35.3	41.8	-19.0
5/7-5/21	2.4	5.0	29.8	7.3	22.2	8.7	41.8	42.6	-35.0
5/21-6/4	3.2	8.6	22.2	7.3	20.6	3.2	42.6	34.6	-46.1
6/4-6/18	5.0	19.7	24.7	7.3	28.3	6.2	34.6	74.8	-10.3
6/18-6/30	4.3	8.1	12.7	6.2	18.3	11.2	74.8	86.0	-8.9
6/30-7/16	5.3	9.3	15.6	8.4	16.8	14.9	86.0	101.7	-8.0
7/16-7/30	8.9	8.7	10.8	7.3	17.8	11.0	101.7	85.9	-40.5
7/30-8/13	4.3	7.2	9.2	7.3	14.0	6.4	85.9	55.5	-52.0
8/13-8/27	4.6	4.8	7.9	7.3	12.3	10.2	55.5	105.6	35.7

1984-1985 TP BUDGET

DATE 9/14/84-9/13/85	SALMON-BERRY ADDITION (kg P)	UNGAGED STREAM ADDITION (kg P)	GROUND-WATER ADDITION (kg P)	ATMOSPHER-IC AND SEPTIC ADDITION (kg P)	EXTERNAL LOADING (kg/wk)	CURLEY LOSSES (kg P)	STARTING LAKE CONTENT (kg)	ENDING LAKE CONTENT (kg)	NET SEDIMEN-TATION (kg P)
9/14/84-9/27	2.3	3.3	9.8	6.8	11.9	8.9	85.0	67.2	-30.9
9/27-10/9	2.6	4.3	11.7	6.2	14.5	9.7	67.2	66.6	-15.8
10/9-11/10	76.8	38.4	-3.4	16.6	28.1	56.2	66.6	92.5	-46.3
11/10-12/9	102.3	51.2	-17.7	15.1	36.4	75.1	92.5	77.1	-91.2
12/9-1/13/85	39.8	19.9	-8.8	18.2	13.8	48.5	77.1	76.6	-21.2
1/13-2/16	24.2	14.3	10.3	17.7	13.7	43.2	76.6	110.0	10.2
2/16-3/9	11.7	6.0	0.7	10.9	9.8	36.6	110.0	105.9	3.2
3/9-4/6	14.6	7.3	-17.4	14.6	4.8	21.9	105.9	105.1	2.0
4/6-4/23	11.4	8.5	8.5	8.8	15.3	15.1	105.1	112.4	-14.8
4/23-5/4	4.4	5.0	8.7	5.7	15.2	13.7	112.4	104.6	-17.9
5/4-5/18	5.0	2.5	-0.9	7.3	6.9	8.4	104.6	88.2	-21.9
5/18-6/2	2.9	1.5	-0.3	7.8	5.5	6.6	88.2	115.5	21.9
6/2-6/14	3.6	7.0	14.5	6.2	18.3	7.9	115.5	86.3	-52.7
6/14-7/1	2.7	1.3	0.0	8.8	5.3	8.5	86.3	114.0	23.4
7/1-7/15	2.3	2.2	3.5	7.3	7.6	4.3	114.0	112.2	-12.8
7/15-7/26	1.3	1.4	1.9	5.7	6.6	1.6	112.2	201.4	80.4
7/26-8/12	2.5	5.5	10.3	8.8	11.2	4.2	201.4	232.2	7.7
8/12-8/26	1.6	0.8	-4.5	7.3	2.6	5.7	232.2	248.0	16.4
8/26-9/13	1.7	3.6	9.6	9.4	9.4	14.2	248.0	238.5	-19.4

1985-1986 TP BUDGET

DATE 9/13/85-9/16/86	SALMON-BERRY ADDITION (kg P)	UNGAGED STREAM ADDITION (kg P)	GROUND-WATER ADDITION (kg P)	ATMOSPHERIC AND SEPTIC ADDITION (kg P)	EXTERNAL LOADING (kg/wk)	CURLEY LOSSES (kg P)	STARTING LAKE CONTENT (kg)	ENDING LAKE CONTENT (kg)	NET SEDIMENTATION (kg P)
9/13/85-9/23	0.9	2.3	6.5	5.2	10.4	11.4	238.5	227.6	-14.3
9/23-10/19	22.1	11.0	-8.8	13.5	10.2	35.6	227.6	174.1	-55.8
10/19-11/16	26.0	18.3	10.3	14.6	17.3	52.7	174.1	127.7	-62.8
11/16-1/23/86	145.8	72.9	-115.0	35.4	14.3	111.6	127.7	182.1	27.0
1/23-2/17	42.9	81.5	-59.2	13.0	5.1	70.1	182.1	101.9	-28.2
2/17-3/25	19.6	23.6	55.2	18.7	22.8	73.2	101.9	134.3	-11.4
3/25-4/11	23.8	47.6	32.1	8.8	46.3	103.9	134.3	194.9	52.1
4/11-4/25	35.2	58.0	20.3	7.3	60.4	108.0	194.9	137.4	-70.4
4/25-5/9	22.5	29.6	14.4	7.3	36.9	59.9	137.4	120.0	-31.3
5/9-5/23	7.3	12.5	15.0	7.3	21.1	27.9	120.0	145.2	10.9
5/23-6/6	10.5	16.8	13.1	7.3	23.9	36.3	145.2	136.8	-19.9
6/6-6/26	14.5	25.7	13.8	10.4	22.5	34.1	136.8	113.6	-53.5
6/26-7/8	6.8	9.2	8.4	6.2	17.9	12.2	113.6	95.1	-35.9
7/8-7/22	3.3	4.1	9.9	7.3	12.3	7.5	95.1	82.5	-29.8
7/22-8/5	3.6	3.7	10.0	7.3	12.3	7.0	82.5	99.3	-0.7
8/5-9/2	6.9	5.8	4.0	14.6	7.8	12.9	99.3	157.2	39.5
9/2-9/16	4.0	3.8	5.1	7.3	10.1	9.4	157.2	182.8	14.7

1986-1987 TP BUDGET

DATE 9/16/86-9/24/87	SALMON-BERRY ADDITION (kg P)	UNGAGED STREAM ADDITION (kg P)	GROUND-WATER ADDITION (kg P)	ATMOSPHER-IC AND SEPTIC ADDITION (kg P)	EXTERNAL LOADING (kg/wk)	CURLEY LOSSES (kg P)	STARTING LAKE CONTENT (kg)	ENDING LAKE CONTENT (kg)	NET SEDIMEN-TATION (kg P)
9/16/86-10/7	5.5	6.9	15.5	10.9	12.9	16.2	182.8	115.7	-89.6
10/7-11/6	13.4	12.7	24.5	15.6	15.4	29.8	115.7	120.2	-31.9
11/6-12/4	26.7	14.1	2.6	14.6	14.5	48.8	120.2	100.2	-29.1
12/4-1/2/87	52.9	26.5	-6.0	15.1	21.4	74.2	100.2	111.1	-3.4
1/2-2/7	81.5	40.8	-25.7	18.7	22.4	129.2	111.1	131.0	33.8
2/7-3/7	61.1	33.5	10.2	14.6	29.8	83.4	131.0	114.4	-52.6
3/7-4/11	55.5	27.7	-13.3	18.2	17.6	48.3	114.4	88.8	-65.5
4/11-4/25	10.5	6.1	3.4	7.3	13.6	20.4	88.8	96.8	1.2
4/25-5/8	8.7	8.0	12.2	6.8	19.2	20.3	96.8	79.3	-32.9
5/8-5/22	5.9	6.2	10.9	7.3	15.2	17.3	79.3	72.0	-20.3
5/22-6/8	5.2	8.9	25.0	8.8	19.7	17.3	72.0	84.1	-18.4
6/8-6/18	6.2	3.1	-0.4	5.2	9.9	11.4	84.1	86.0	-0.9
6/18-7/1	7.0	5.2	6.2	6.8	13.5	12.6	86.0	70.2	-28.3
7/1-7/16	3.3	6.5	17.5	7.8	16.4	11.5	70.2	66.0	-27.9
7/16-7/30	3.5	5.7	14.8	7.3	15.7	11.8	66.0	81.5	-4.0
7/30-8/13	3.4	6.4	19.8	7.3	18.5	14.0	81.5	125.6	21.2
8/13-8/27	2.5	3.0	10.3	7.3	11.5	10.1	125.6	40.7	-97.9
8/27-9/10	2.2	3.5	15.0	7.3	14.0	35.9	40.7	106.5	73.7
9/10-9/24	3.2	5.2	16.4	7.3	16.0	42.9	106.5	102.6	6.9

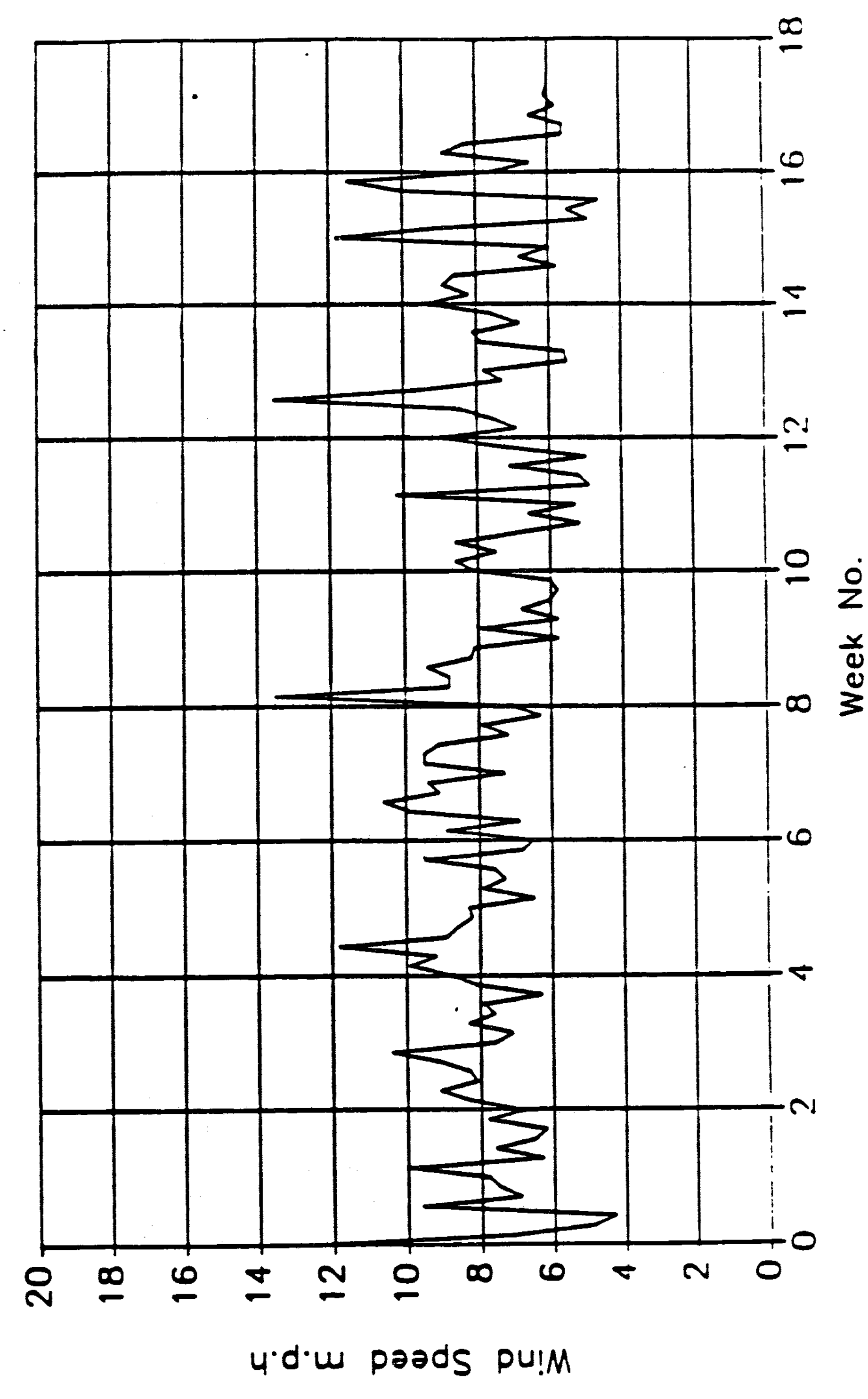
Appendix C

Average Daily Wind Speed

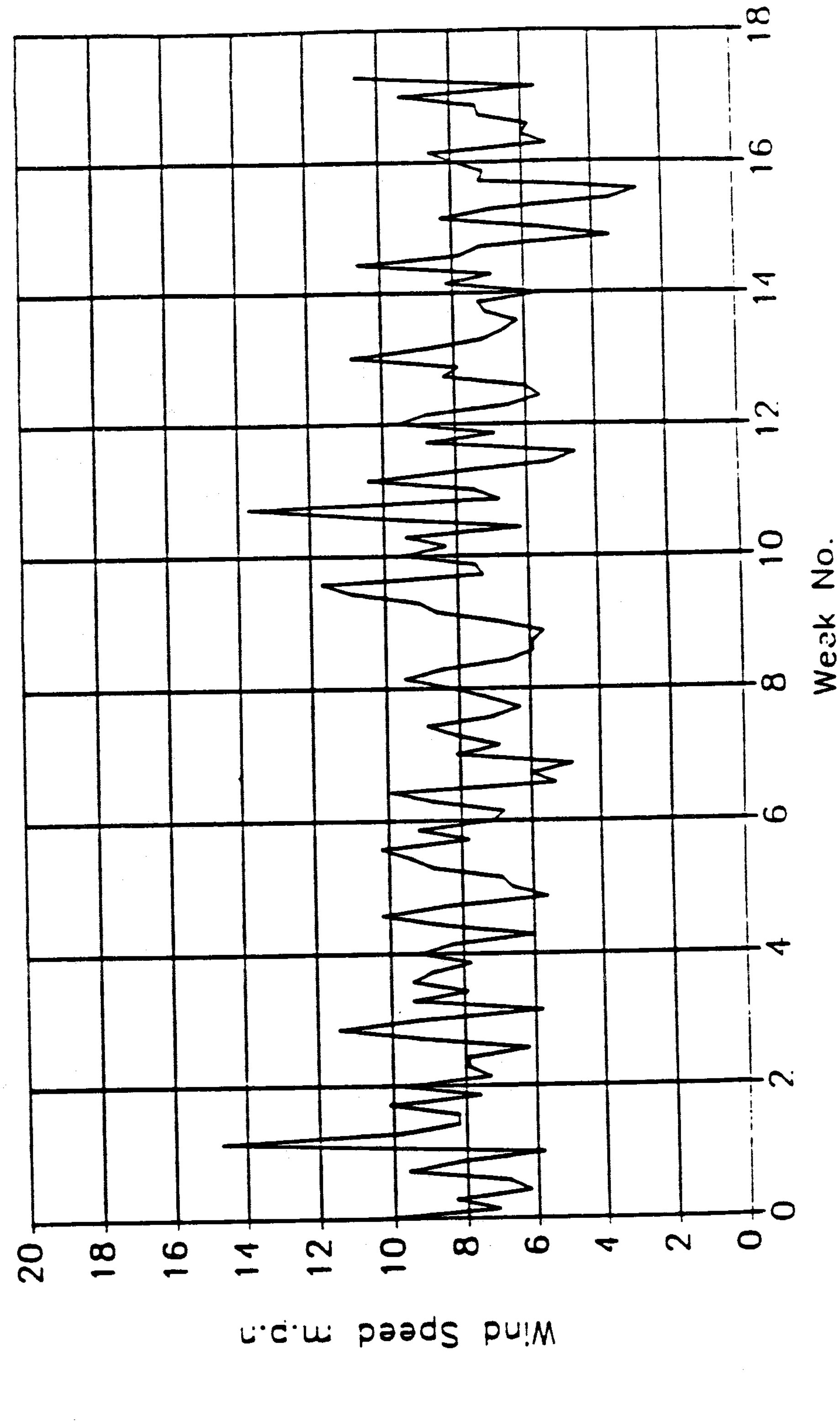
June-September

1977, 1978, 1985, 1986, 1987

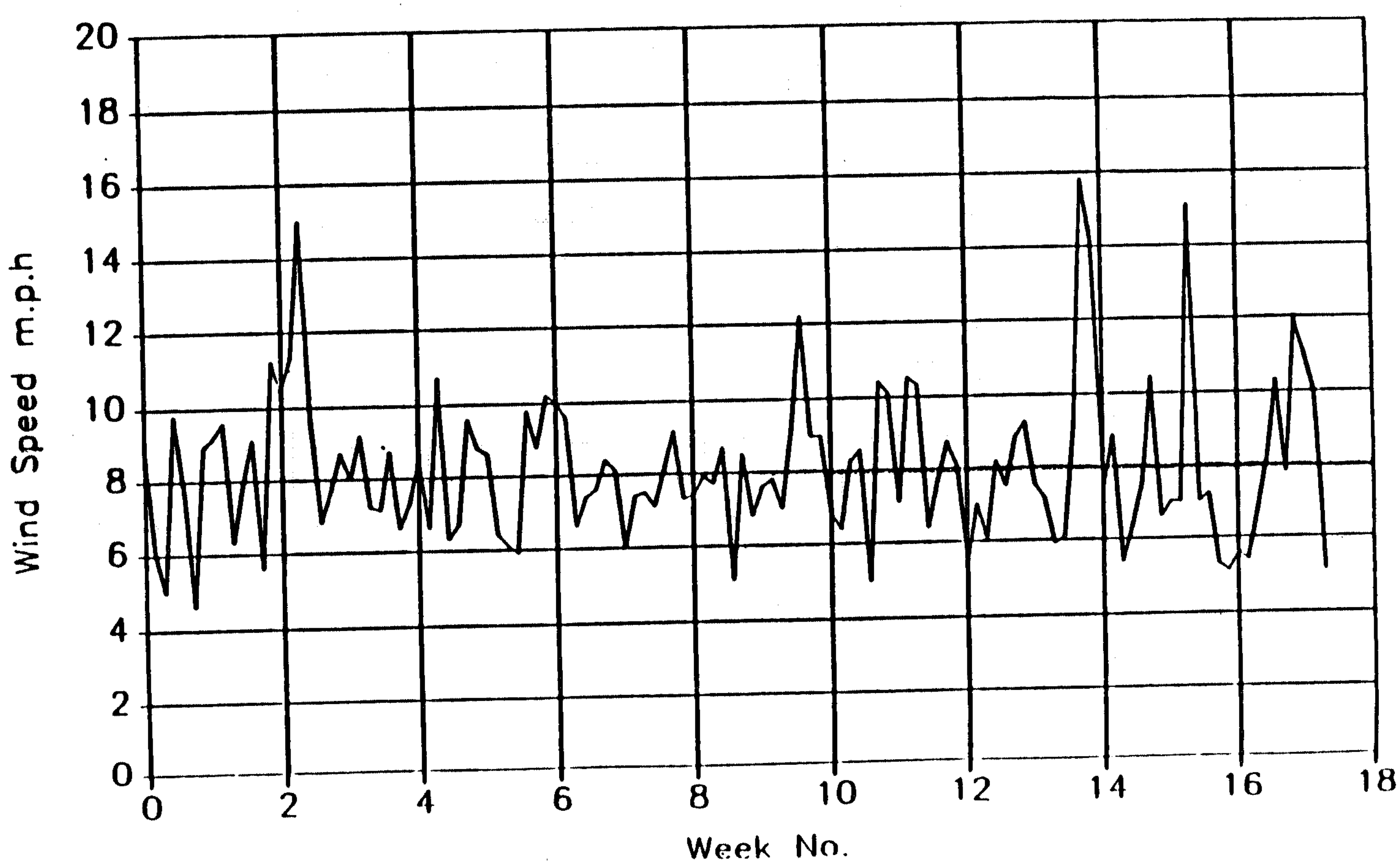
AVERAGE DAILY WIND SPEED
JUNE 1 – SEPTEMBER 30, 1977



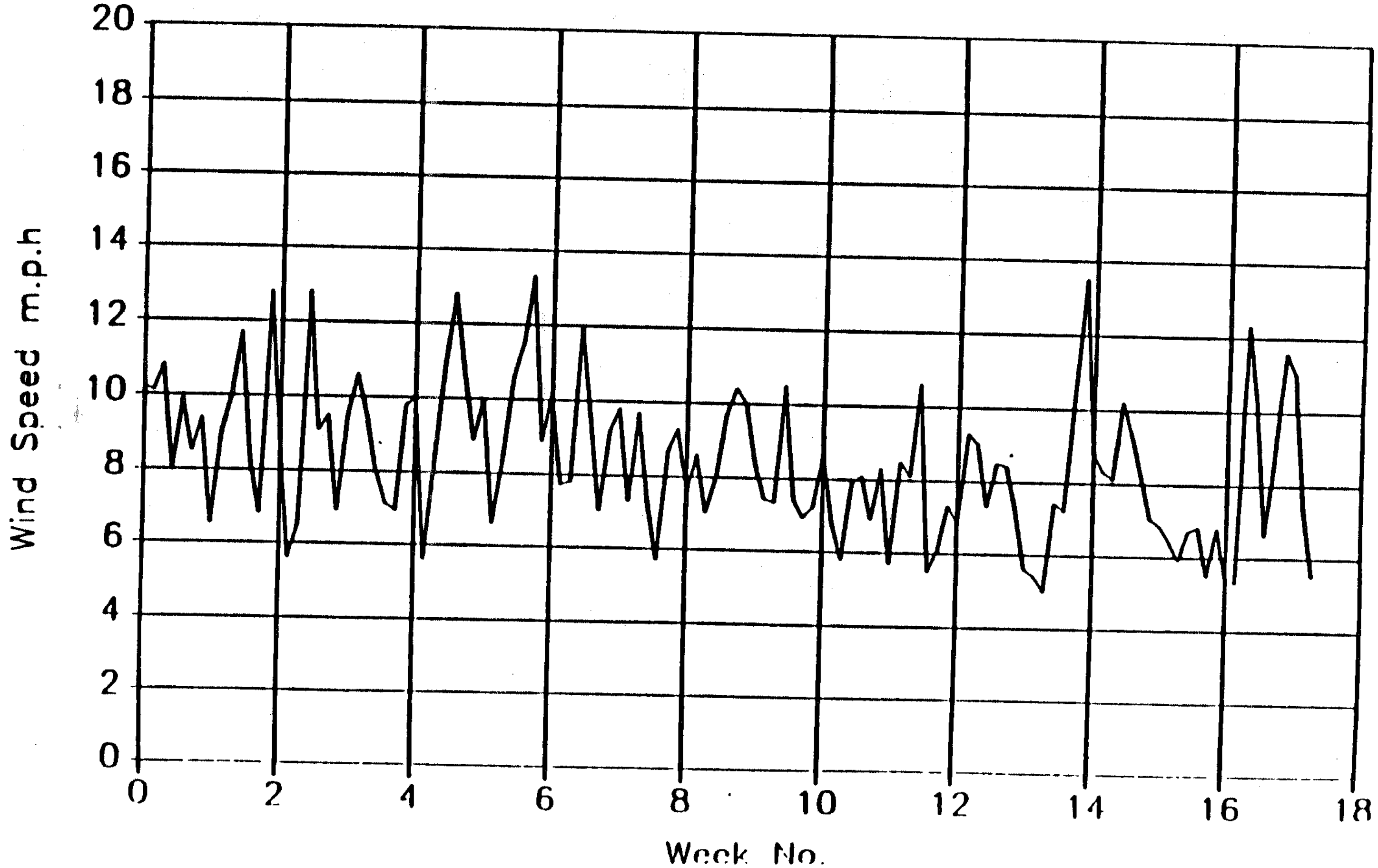
AVERAGE DAILY WIND SPEED
JUNE 1 – SEPTEMBER 30, 1978

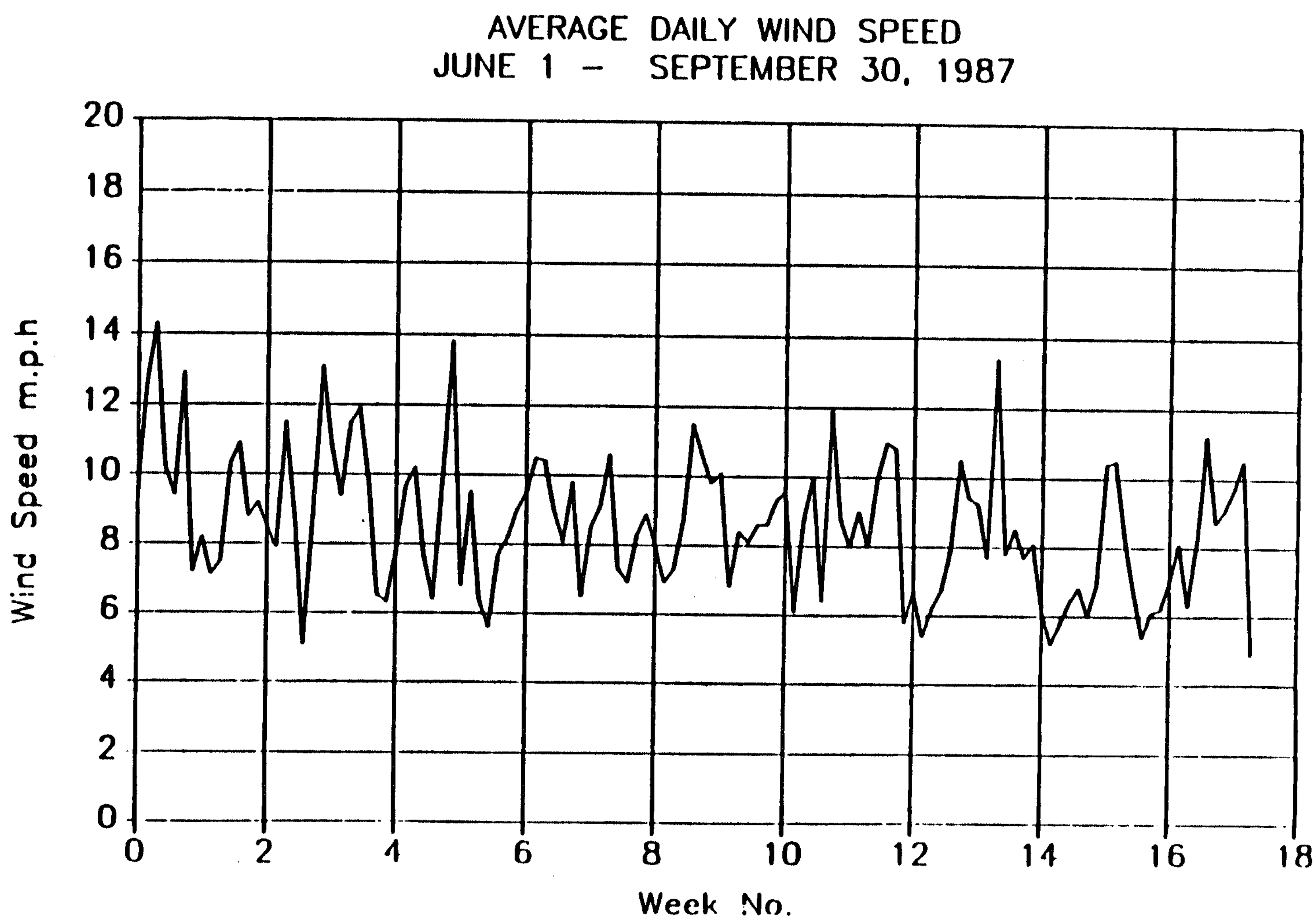


AVERAGE DAILY WIND SPEED
JUNE 1 – SEPTEMBER 30, 1985



AVERAGE DAILY WIND SPEED
JUNE 1 – SEPTEMBER 30, 1986




AVERAGE DAILY WIND SPEED
JUNE 1 - SEPTEMBER 30, 1987
Wind Speed m.p.h
20
18
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
16
18
Week No.