MITIGATION OF NON-POINT SOURCE WATER QUALITY POLLUTION USING RIPARIAN RESTORATION

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ABSTRACT. To determine whether beaver ponds improve the quality of water flowing through them, water samples taken above, within, and below several beaver pond complexes along Currant Creek were analyzed for several water quality parameters. The role of periphytic algae in affecting nutrient concentrations was investigated by comparing measurements of algal productivity and standing crop to the water quality data. Concentrations of suspended solids, total phosphorus, NaOH-extractable phosphorus, total Kjeldahl nitrogen and nitrate were reduced in water flowing through the beaver pond complexes. The results of the periphyton studies indicate that while nutrient concentrations appear to affect algal growth and standing crop, periphyton has little affect on nutrient concentrations in Currant Creek. Periphyton may play a minor role in reducing concentrations of nitrate in the stream by removing nitrate from the water.

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CHAPTER I

INTRODUCTION

Flaming Gorge Reservoir, formed by damming the Green River, is located in southwestern Wyoming and eastern Utah. The upstream portion of the reservoir is exhibiting symptoms of eutrophication (Parker et al., 1984). It is estimated that approximately eighty percent of all nutrients entering the reservoir originate from non-point sources (Fannin, 1983). The purpose of this research is to determine whether beaver ponds on lower order streams in the drainage reduce nutrient loads carried by the streams, thereby decreasing the nutrient load to the reservoir.

A review of the literature reveals that while little knowledge exists concerning the effect of beaver ponds on water quality, there is a large amount of information on related topics, including stream nutrient dynamics, erosion control, riparian vegetation, and wetlands.

Naiman and Melillo (1984) found that stream sections modified by beaver accumulated 1000 times more nitrogen than before modification. Beaver ponds trapped sediments and organic matter and were important in nutrient retention. Francis et al. (1984) reported that nitrogen accumulation in sediments is enhanced nine to 44-fold by beaver damming a section of stream, with the enhancement being proportional to the volume of sediment trapped by the dams. They suggested that beaver ponds may act as sinks for phosphorus and nitrogen. Smith (1984) discovered that suspended solid concentrations in Currant Creek were reduced in water flowing through beaver pond complexes. Skinner et al. (1984) noted that beaver ponds trapped coliform bacteria, and that younger ponds had a higher trapping efficiency than older ponds. Working with a small flood detention reservoir, Schreiber et al. (1980) determined that concentrations of dissolved phosphorus were reduced by 8 to 50 percent and concentrations of total sedimentary phosphorus were reduced by 43 to 79 percent in water flowing through the reservoir.

Heede (1982,1984), studying gully erosion, determined that events in larger channels control those of smaller channels. If base level is lowered by downcutting a headcut develops and moves upstream, while if the base level is raised gradient decreases and causes reduced sediment transport rates. Beaver ponds reduce erosion, raise soil depths, and cause deposition of sediments (Munther, 1981). According to Smith (1983) and Apple (1983) beaver ponds reduce erosion and collect sediments. Beaver dams also can reverse gullying (Stabler, 1983).

Riparian vegetation and wetlands can play an important role in nutrient removal and bank stability. Schlosser and Karr (1980) detected that suspended solid concentrations in their study streams were highest where riparian vegetation had been removed. Wooded floodplains often play an important role in trapping suspended sediments during floods (Wilkens and Hebel, 1982). Narrow buffer strips of riparian vegetation between agricultural land and streams can be effective at removing nitrate in runoff before it reaches the stream (Jacobs and Gilliam, 1983). Lowrance (1981), studying nutrient imports and exports for the riparian zone, noted that both nitrogen and phosphorus accumulated in the riparian zone. In addition, inorganic nitrogen was converted to organic nitrogen. According to Brinson et al. (1981), riverine swamps provide an opportunity for nutrient exchange between surface water and bottom sediments. Nitrogen is converted to its gaseous form within the sediments via the nitrification-denitrification pathway. Phosphate accumulates in the sediments, but because no escape pathway exists (e.g., such as denitrification), and because there is a limit to which sediment can accumulate phosphorus, the capacity of the swamp for phosphate assimilation is limited. Aquatic vegetation within wetlands improves water quality by removing phosphorus and nitrogen from the water and transferring them into plant tissue (Sloey et al., 1978). Beaver dams raise the water table and improve bank stability, thereby creating riparian communities and expanding the riparian zone (Stabler, 1983; Call, 1980; Apple, 1983; Smith, 1983; Munther, 1981). Beaver ponds also increase the water-sediment interface.

Phosphorus dynamics in streams have been studied fairly extensively. Meyer and Likens (1979) suggest that in Bear Brook there is no annual net retention of of phosphorus. During most days phosphorus imports exceeded exports, but during episodes of high stream discharge accumulated phosphorus was flushed from the stream section. Imports of dissolved and coarse particulate phosphorus exceeded exports, while exports of fine particulate phosphorus exceeded imports. Thus there was a net conversion of other forms of phosphorus to the fine particulate form, which composed 62 percent of all phosphorus exported downstream. Forty six percent of all phosphorus removal occurred during discharges of greater than 50 liters/second, which accounts for only nine percent of water output. Debris dams contribute to phosphorus retention by forming ponds where sediments collect and provide sites for phosphorus adsorption. Areas with a high sediment-water interface also contributed to phosphorus retention by providing more area for adsorption to sediments.

Johnson et al. (1976) observed that 75 percent of phosphorus in Fall Creek was transported during the highest flows, which occurred ten percent of the time. In the Maumee River Basin suspended sediments contained more total phosphorus than either soils or bottom sediments (Green et al., 1978). The authors attributed this to selective erosion of fine particles and adsorption of phosphorus during fluvial transport. Hill (1982) reports that during low summer flow phosphorus is retained within a stream section, and that this phosphorus is exported downstream during storm flows either as part of the sediment load or in solution following desorption from sediments. Fine sediments from pools had a greater buffering capacity than coarser sediments.

Hill speculated that benthic algae and macrophytes might account for a portion of the phosphorus removal in a stream. Algal growth can rapidly remove dissolved nutrients from solution (La Point et al., 1983). However, Meyer (1979) determined that the microbial community in Bear Brook played a minor role in phosphorus dynamics in relation to sediment adsorption.

To study the effects of beaver dams on water quality, Currant Creek was chosen as a study area. Currant Creek is a second order stream that flows into the northeast corner of Flaming Gorge Reservoir. Three null hypotheses were tested: 1) Water quality is unaffected by beaver pond complexes; 2) The location of the beaver pond complexes on the stream (e.g., headwaters, etc.) does not affect water quality; and 3) periphytic algae within the pond complexes do not affect nutrient concentrations. The first hypothesis was tested directly, while the other hypotheses were tested indirectly by making inferences from the collected data.

CHAPTER II

DESCRIPTION OF STUDY AREA AND SAMPLING LOCATIONS

Research was performed on Currant Creek, located in southwestern Wyoming. Currant Creek is a second order stream, as determined from a 1:62500 USGS map (Currant Creek Ranch Quadrangle) and visual inspection of the stream headwaters. The stream originates on Little Mountain (elevation 9000 ft or 2745 m) and flows approximately 20 mi (32 km) before emptying into Flaming Gorge Reservoir (elevation ca. 6000 ft or 1830 m).

The area drained by Currant Creek is 51 mi^2 (132 km^2). The drainage is fairly narrow, having a maximum width of 3.5 mi (5.6 km), and steep sides rise up to 1000 ft (305 m) above the valley bottom over a distance of 0.4 mi (0.6 km). As the stream approaches Flaming Gorge Reservoir, the steep sides subside and the flood plain widens.

The study area includes Currant Creek Ranch and several miles of stream below the ranch. The length of the entire study area is about 8 mi (12.9 km). The downstream end of the study area is about 2 mi (3.2 km) above the stream outlet into Flaming Gorge. On the ranch the valley floor is about 0.2 mi (0.3 km) across, with a gradient of about one to three percent. Below the ranch the valley floor widens slightly.

On the ranch there are three large beaver pond complexes which vary in length from 0.2 to 0.4 mi (0.3 to 0.6 km). There are also individual beaver ponds scattered along the stream. Besides these pond complexes, the valley floor is occupied by subirrigated hay meadows. In the downstream 2.5 mi (4.0 km) of the study area there are no beaver dams and the stream is downcut. The vegetation in this area is composed mostly of sagebrush (<u>Artemisia</u>) and greasewood (<u>Sarcobatus</u>).

The entire drainage is grazed by cattle. Grazing occurs at the headwaters during the summer, and at lower elevations during the winter. The meadows on the ranch are harvested for hay, and during the summer water occasionally is diverted for irrigation.

The headwater area of Currant Creek is characterized by very loose soils, which in combination with the steep terrain cause a high incidence of landslides and slumping (Case, 1985). These loose soils may contribute to the high sediment loads carried by the stream.

A total of eleven sampling stations were set up on Currant Creek. There were two types of sampling stations, and these are described in detail below. Five stations with an automatic water sampler were located on stream sections, while six stations without an automatic water sampler were located within beaver ponds and on stream sections immediately above the ponds. The point where the unimproved road crosses the stream was designated mile 0.0 (Figure 1).

Automatic water samplers were placed at five stations designated 1 through 5 (upstream to downstream) and located 1.7, 3.7, 5.7, 7.7, and 8.0 mi (2.7, 6.0, 9.2, 12.4, and 12.9 km; measured on the road) downstream from mile 0.0. Station 1 is upstream from all beaver ponds, station 2 is situated downstream from the first two beaver pond complexes and directly upstream from the ranch house and corrals, station 3 is just downstream from the final beaver pond complex, station

4 is situated downstream from a two mile stretch of stream containing no beaver ponds, and station 5 is located directly downstream from a small beaver pond complex in an exclosure constructed by the Bureau of Land Management (unfortunately the dams in the exclosure area were washed out during spring runoff). These stations all are located on stream sections (rather than pond sections) of Currant Creek. The stream bottom at all locations is firm with a composition of small cobbles, gravel, and fine sediments (Platts et al., 1983), except at station 2, which has a soft substrate of fine sediment. Station 2 also is characterized by deeper water and lower water velocity than the other stations.

At the six additional stations (those not serviced by an automatic water sampler) grab samples were taken for chemical analysis. These stations are located 1.9, 2.1, 2.2, 2.5, 4.1, and 4.5 road miles (3.1, 3.4, 3.5, 4.0, 6.6, and 7.2 km) downstream from mile 0.0. These three pairs of stations are referred to (from upstream to downstream) as UBC 1 and UBC 2 (upper beaver pond complex), MBC 1 and MBC 2 (middle beaver pond complex), and LBC 1 and LBC 2 (lower beaver pond complex). The upstream station of each pair (e.g., UBC 1) is located on a stream section, while the downstream station of each pair is a lentic site within a beaver pond. LBC 1 is located immediately downstream from the ranch house and corrals. It differs from the UBC 1 and MBC 1 stations by having a soft substrate of fine sediment (in contrast to a firm substrate composed of small cobbles, gravel, and fine sediment). Also, the water is deeper and has a lower velocity than at the other stream stations. The LBC pond complex is the largest pond complex, followed in decreasing order by the MBC and UBC pond complexes. Water movement is quite evident at the UBC 2 station, which has a noticeable flow through the pond. Aquatic vegetation is common in the LBC and MBC ponds. Areas of heavily vegetated marsh and willow (Salix) thickets were present in all of the pond complexes.

Several changes took place between the 1984 and 1985 sampling periods that should be noted. The upstream section of the UBC pond complex was deserted by beaver (probably because the ponds were practically filled with deposited sediment), and new ponds were constructed at the downstream end. Several of the dams in the upstream area deteriorated during spring runoff 1985, and the stream cut a new channel through the previously deposited sediments. When last observed, terrestrial vegetation (mostly grasses) was rapidly colonizing the newly exposed area that only recently had been the bottom of several beaver ponds.

Sediment deposition within the ponds at MBC complex caused them to become noticeably more shallow by the 1985 sampling season. Beaver activity was evident at the downstream end of the MBC pond complex, which had several new ponds at the beginning of the 1985 season. New ponds also were evident a short distance upstream from station 3.

Another change between sampling periods occurred at the LBC 1 sampling location. A section of bank slumped into the stream, causing an alteration in bottom substrate and water depth. The stream became shallower and the bottom composition changed from a soft substrate of fine sediment to a firm substrate composed of small cobbles, gravel and fine sediment.

The Currant Creek Ranch changed ownership late in 1984, and most of the cattle were removed. The number of cattle on the ranch during the 1985 runoff season was considerably less than in 1984.

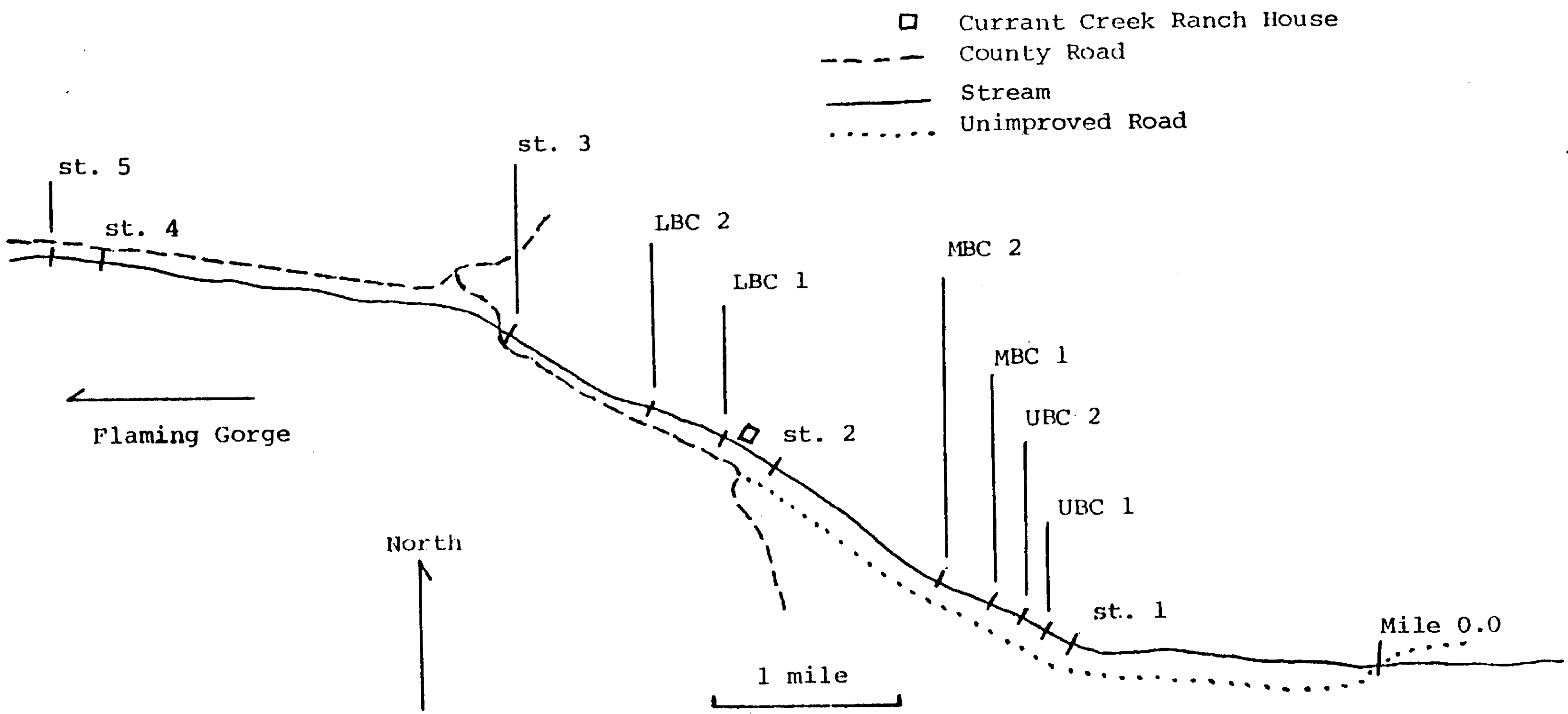

Figure 1: Map of Currant Creek study area (from USGS Currant Creek Ranch Quadrangle).

CHAPTER III

METHODS

In May 1984, five automatic water samplers were placed on Currant Creek at stations 1 through 5. The samplers were set to collect 250 to 500 ml at intervals of 5.5 to 8 hr. The samplers were serviced weekly, with a composite sample taken for chemical analyses from each sampler. At the same time, a grab sample was taken from the stream and volume flow was determined at each of these stations. Flows were determined from measured velocities using the method outlined by Platts et al. (1983). The composite samples were analyzed for suspended and dissolved solids, total phosphorus, total Kjeldahl nitrogen and conductivity. The grab samples were analyzed for nitrate, ammonia, ortho-phosphate, sodium hydroxide extractable phosphorus and pH. These parameters were chosen to measure concentrations of phosphorus and nitrogen that might be utilizable by algae, as well as total concentrations. Recent work has suggested that sodium hydroxide extractable phosphorus may be a good measure of biologically available phosphorus (Messer et al., 1984). All analyses were performed by the U.S.E.P.A.-certified Water Quality Laboratory at Western Wyoming College (methods are described in Appendix A). Sampling continued through early August, 1984.

Additional sampling began at the three pairs of stations in the beaver complexes during July 1984. Weekly grab samples were taken at each of these sites, and analyses were performed as described above. Flows were determined (Platts et al., 1983) at stations UBC 1 and MBC 1. Sampling continued at these stations through early October, 1984.

In early April 1985, sampling was resumed at all six beaver complex stations, and stations 2, 3, and 4. The sampling location at UBC 2 and MBC 2 was moved a short distance downstream from the 1984 sampling point to sample at the downstream end of the pond complex (which had been expanded during the fall or winter). Sampling was discontinued at station 1 because the sample taken at UBC 1 was considered to represent the the water quality at station 1. Sampling was discontinued at station 5 because, as described earlier, the beaver ponds between stations 4 and 5 washed out during spring runoff of 1984. Grab samples were taken at all stations, and were analyzed for suspended solids, total phosphorus, total Kjeldahl nitrogen, ortho-phosphate, sodium hydroxide-extractable phosphorus, nitrate, and ammonia. Discharge was determined at UBC 1, MBC 1, station 3, and station 4 (Platts et al., 1983). Sampling continued through the middle of June, 1985.

Periphytometers were constructed by cutting the top and bottom out of plastic microscope slide boxes (25 slide capacity). A strip of styrofoam was glued to both of the long sides and a wire was connected to one of the short sides (the front) of each box. Eight microscope slides were placed in each box, leaving five empty slots at each end and an empty slot between each slide. The slides were separated by a distance of 0.4 in (1.0 cm). The two halves of the slide box were then wired together. The periphytometers were secured in place by attaching them with wire to iron bars driven into the stream or pond bottom. In undisturbed water, they floated with the top of the slides 0.08 to 0.16 in (2 to 4 mm) below the surface of the water.

Periphytometers were placed into the stream and ponds during the period from June 28 to August 30, 1984. They were placed at stations 2, 3, 6, UBC 1, UBC 2, MBC 1, MBC 2, LBC 1, and LBC 2. Two or three periphytometers were installed at each location. On August 2, the replicate periphytometers at UBC 2 and LBC 1 were moved closer together to minimize differences in water velocity.

Initially slides were collected after incubations of 7-21 days, but because sloughing of material was observed after seven days the incubation period was shortened to seven days. Accumulation on slides within a given periphytometer appeared to be the same, except for the first (farthest forward) and last (farthest back) slides. For this reason data from the first and last slides were not included in the analyses. When slides were collected from the periphytometers, they were replaced with new slides. Before being placed in the periphytometers, all slides were soaked in concentrated sulfuric acid for a minimum of six hr, rinsed with distilled water, and dried at 200°C for at least 30 min. If periphytometers were lost (or used by beavers in their dam construction), they were replaced during the next collecting period.

When slides were removed from the periphytometers, they were placed into microscope slide cases and returned to the laboratory. The accumulated material was rewetted with distilled water and scraped into preweighed 10 ml porcelain crucibles. The crucibles were dried at 105°C to a constant mass, cooled in a dessicator, and weighed to the nearest 0.1 mg. The crucibles then were heated to 500°C for one hour, allowed to cool, and the ashed material was rewetted with distilled water. The crucibles then were dried at 105°C to a constant mass, cooled in a dessicator, and weighed. Total accumulation rate (dry mass) and organic accumulation rate (ash free dry mass) were computed as mg/(m^2 of slide)·(day). Percent organic accumulation (percent loss on ignition) was calculated as (ash free dry mass/dry mass)·100.

When chlorophyll accumulation was determined from incubated slides, two slides were placed in a 75 ml glass jar and broken immediately after removal from the periphytometer. Ninety percent acetone was added to cover the slide fragments, and and the samples were placed on ice and steeped in the dark for a minimum of 12 hr. The samples then were poured into 15 ml centrifuge tubes and centrifuged for 20 min at about 4000 RPM in a Model CL International Clinical centrifuge. Chlorophyll determination was performed using a Beckman DU model 2400 spectrophotometer following standard methods (APHA-AWWA-WPCF, 1975). Chlorophyll accumulation was computed as mg/(m^2 of slide)·(day) and was determined from August 2 through August 31, 1984.

The standing crop of chlorophyll on bottom substrates (rock, wood, sediment) was determined weekly from July 4 to August 31, 1984 at stations 2, 4, 5, UBC 1, UBC 2, MBC 1, MBC 2, LBC 1, and LBC 2. Percent of bottom composed of rock, sediment, and wood was estimated by visual examination.

Samples from wood were obtained by carefully removing periphyton with a brush and rinsing the material into a glass jar with distilled water. The surface area of the wood then was calculated by assuming the piece of wood was a cylinder. Samples from rock were obtained by placing a 1.1 in (28 mm) internal diameter hollow plastic cylinder with a 0.25 in (6 mm) foam rubber gasket firmly against the surface of a rock, removing the periphyton from the area within the cylinder with a brush, adding distilled water to the cylinder, and suctioning the water and periphyton into a glass jar. These steps were repeated until all the periphyton appeared to be removed. Sediment samples were obtained with a corer made from a 1.1 in (28 mm) internal diameter plastic syringe with the needle end cut off. The corer was pushed into the sediment while the plunger was lifted; then the corer was removed from the sediment. The sediment in the corer was rinsed into a 75 ml jar with distilled water. All samples were filtered through a GF/C glass fiber filter, either in the field or after being placed on ice and returned in darkness to the lab. Several drops of magnesium carbonate suspension were added during filtration. The filter and residue were placed in a 15 ml centrifuge tube, about 8 ml of 90 percent acetone were added to the tube, and the tube was topped with PERIFILM and shaken violently by hand for 60 sec. The samples were placed on ice and steeped in darkness for a minimum of 12 hr. Chlorophyll concentration was computed as mg/m^2 of sampled substrate or total bottom (APHA-AWWA-WPCF, 1975). Standing crop was determined from July 4 through August 31, 1984.

Statistical analyses were performed on a microcomputer using the software package SYSTAT. All models used are linear, and include two sample and paired t-tests, analysis of variance, and simple and multiple regressions. When appropriate, residuals were plotted against the estimates to check for fit of the model. Pearson correlation matrices were examined for high correlations among variables ($r \geq 0.7$ was considered high). When choosing among such highly correlated variables, the independent variable having the most direct cause-effect relation to the dependent variable was used in the regression equation. For example, date and flow had a large negative correlation. When describing changes in chemical concentrations, flow was the factor most directly affecting concentration so flow, rather than date, was used in the equation that was reported. The multiple regressions reported for the periphyton data are the product of an attempt to explain the most variance in the dependent variable with the least number of independent variables. When trying to explain the variance in periphyton accumulation rates and standing crop, equations were produced using either physical parameters (such as season or distance downstream) or chemical parameters as independent variables. In these cases, separate regressions were reported for each. All references in this paper to "significant differences" reflect the probabilities obtained from analysis of variance and contrasts, while "explained variance" comes from the adjusted r^2 value obtained from a regression. A level of significance of 0.05 was used for all tests.

CHAPTER IV

RESULTS

Water Chemistry

During 1984, water samples were collected either as composite samples from automatic water samplers (stations 1 through 5) or as grab samples (beaver pond complex stations). During 1985, all water samples taken were grab samples. Samples from stations 1-5 (1-4 during 1985) were analyzed separately from samples collected at the beaver pond complex stations. Data from different years also were analyzed separately. Results from statistical analyses of the data are presented in Table I.

During both 1984 and 1985, data were divided into groups representing spring runoff and summer flow. This division was made on the basis of decreasing flow and nutrient concentrations. In 1984, sampling at stations 1-5 did not start until well into spring runoff. Samples from May 22 through June 5 were designated as being from spring runoff while samples from June 12 through August 7 were designated as data from summer flow. Sample collection at the beaver pond complex stations did not begin until well after spring runoff and ran from July 3 through October 6. During 1985, sampling at all stations began very early during spring runoff. Spring runoff was designated as being from April 20 through May 20, and data from May 27 through June 19 was considered as being collected during summer flow.

<u>Data From Spring Runoff, 1984 and 1985</u>:

During spring runoff in 1984 (three analyses), concentrations of suspended solids (SS), total phosphorus (TP), total Kjeldahl nitrogen (TKN) and nitrate were significantly less at stations between and directly downstream from beaver pond complexes (2 and 3) than at stations upstream from and several miles downstream from beaver pond complexes (1, 4, and 5; Figures 2-5). Concentrations of sodium hydroxide-extractable phosphorus (NaOH-P) were fairly constant upstream from and within the areas of beaver ponds, but increased downstream (stations 4 and 5), although not significantly (Figure 6). There was no noticeable trend for concentrations of ortho-phosphate (OP).

During spring runoff in 1985 (eight analyses), concentrations of SS, TP, NaOH-P, OP, and TKN were less at stations between and directly downstream from beaver pond complexes (2 and 3) than at stations upstream from and several miles downstream from beaver pond complexes (1 and 4; Figures 7-11). For SS, TP, and NaOH-P this difference was statistically significant. Concentrations of nitrate decreased in a downstream direction (mostly between station 1 and 3), and distance below mile 0.0 explained 27 percent of the variance in nitrate (Figure 12). At the beaver pond complex stations (UBC 1, UBC 2, MBC 1, MBC 2, LBC 1, LBC 2), concentrations of SS, NaOH-P, TP, and TKN were lower at the pond sites than at the stream sites immediately upstream. For SS and NaOH-P, this difference was significant.

Data From Summer Flow, 1984 and 1985:

During summer 1984 at stations 1-5 (eight analyses), concentrations do not decrease in pond complexes as during spring runoff. Rather, concentrations of OP, SS, TP, TKN and NaOH-P appear to increase generally in a downstream direction. The increase in concentration is most noticable downstream from the beaver pond complexes (between stations 3 and 5) for all parameters except OP (Figures 13-17). Distance below mile 0.0 explains 26 percent of the variance in OP, 11 percent of the variance in SS, 14 percent of the variance in TP, and nine percent of the variance in NaOH-P. The trend for TKN is not significant. Nitrate displays the same tendency as it did during spring runoff (decreasing concentration in the area with beaver ponds followed by increased concentrations downstream, Figure 18), but this difference is not significant. At the beaver pond complex stations during summer and early fall (July 3 through October 6; nine analyses), concentrations of SS are significantly lower at the pond sites than at the stream sites immediately upstream. TP exhibits the same trend as SS, but differences are not significant.

During early summer in 1985 (four analyses) at stations 1-4, SS demonstrates the same trend as during spring (lower concentrations at stations between and directly downstream from beaver pond complexes than at stations upstream from and several miles downstream from beaver pond complexes), but differences are not significant (Figure 19). Concentrations of TP and TKN increase downstream (with most of the increase occurring downstream from the beaver pond complexes) and distance below mile 0.0 explains 31 percent of the variance in TP and 56 percent of the variance in TKN (Figures 20, 21). Concentrations of nitrate decrease downstream (with most of the decrease occurring in the area of the beaver pond complexes) and distance below mile 0.0 explains 80 percent of the variance (Figure 22). No significant differences occur for NaOH-P or OP, although concentrations of NaOH-P appear to increase slightly downstream (Figure 23). At the beaver pond complex stations, concentrations of nitrate, SS, and TP appear to be lower at the pond sites than at the corresponding stream sites upstream. However, this difference is statistically significant only for nitrate.

Data From All Analyses, 1984 and 1985:

During 1984, some water samples were analyzed for conductivity, total dissolved solids, pH, and ammonia. Both conductivity and concentration of total dissolved solids increased downstream. No trend was evident for pH. Concentrations of ammonia almost always were at or near the level of detection, and no trend was evident.

Concentrations of several parameters decreased through the sampling season, as did average discharge. For stations 1 through 5 (automatic sampler stations) during 1984 (May 22 through August 7), average discharge explains 18 percent of the variance in SS, 16 percent of the variance in TP, 11 percent of the variance in TKN, and 46 percent of the variance in nitrate concentration. For the beaver pond complex stations (grab samples only) during 1984 (July 3 through October 7), average discharge explains 38 percent of the variance in TP, 66 percent of the variance in NaOH-P, 19 percent of the variance in OP, and 21 percent of the variance in nitrate concentration. For all stations during 1985 (grab samples only, April 2 to June 19), average discharge explains 39 percent of the variance in SS and TP, 38 percent of the variance in TKN, 46 percent of the variance in NaOH-P, and 58 percent of the variance in OP.

During spring runoff 1984, a high correlation existed between SS and TP and TKN. As the season progressed in 1984, less of the variance in

TP and TKN was explained by SS. For stations 1 through 5 during spring runoff (May 22 through June 5), SS explains 72 percent of the variance in TP and 79 percent of the variance in TKN. For the same stations during summer flow (June 12 through August 7), SS explains 52 percent of the variance in TP and 54 percent of the variance in TKN. For the beaver complex stations later in the summer (July 3 through October 6), SS explains 33 percent of the variance in TP and 28 percent of the variance in TKN. During spring runoff in 1985, a high correlation existed between concentrations of SS and TP and TKN, as in 1984. But during runoff in 1985 there was also a high correlation between SS and NaOH-P. The variance in TP, TKN, and NaOH-P explained by SS decreased through the season. For all stations during spring runoff (April 2 through May 20), SS explains 96 percent of the variance in TP, 92 percent of the variance in TKN, and 90 percent of the variance in NaOH-P. During summer flow (May 7 through June 19), SS explains 91 percent of the variance in TP, 40 percent of the variance in TKN, and 23 percent of the variance in NaOH-P.

Nutrient Loading

By combining flow data with chemical data from stations 1 through 5, loading budgets were produced for SS, TP, TKN, and nitrate for 1984 (Figures 24-27). To calculate annual loads (Figures 28-31), an estimate of flow was needed for periods not sampled (i.e., fall, winter, early spring). This was done by regressing measured flows from Currant Creek against the logs of the average flow (1978 to 1980) for these same dates at Salt Wells Creek near South Baxter, Wyoming (USGS Station 09216565).

This resulted in an equation for estimating flows on Currant Creek. Logs of SS, TP, TKN, and nitrate daily loadings were regressed against flow to develop equations for estimating nutrient loads for the periods not sampled (i.e., fall, winter, early spring). It should be emphasized that these estimates may not be very accurate for a given year. Both the calculated loads for the sampling season (Figures 24-27) and the estimated annual loads (Figures 28-31) decrease as water flows through the beaver pond complexes, followed by increasing loads downstream.

Because the sampling season in 1985 was shorter than 1984 (and only included spring runoff and a few weeks of summer flow), no loading estimates were produced for 1985. Since 1984 was a very wet year and since it appears that 1985 will be a very dry year, the loading values for 1985 should be much lower. The basic trend of decreasing loads in the area of the beaver ponds, followed by increased loads downstream, should be the same in both years.

Periphyton Productivity

Data on rates of accumulation on glass microscope slides were calculated either as grams ash free dry mass/(m^2)·(day) (AFDM) or as grams chlorophyll a/(m^2)·(day). Data on ash free dry mass were obtained from June 28 through August 31, and chlorophyll a data were obtained from August 2 through August 31. The chlorophyll a values used in the analyses have been corrected for pheophyton (APHA-AWWA-WPCF, 1975). Rates of accumulation (either as AFDM or chlorophyll a) were used as indices of productivity. Results of statistical analyses are presented in Table 2.

Differences in the duration of incubation and individual variation among periphytometers at a single site had no significant effect on AFDM. However, since sloughing was observed on slides after seven days, only incubations of seven to nine days were used in the analysis. Due to differences between stream and pond sites, data from these sites were analyzed separately.

A difference exists between stream and pond locations for rate of accumulation in relation to distance downstream. At the stream sites AFDM increased downstream, and distance below mile 0.0 explained 52 percent of the variance. For pond sites there was no significant relationship between distance downstream and AFDM.

A decrease in accumulation rate was noticed beginning July 24 which seemed to correspond to a decrease in both flow and suspended solids. Dates before July 24 were classified as early summer, and dates after and including July 24 were classified as late summer. This difference between seasons explains 25 percent of the variance in AFDM for stream sites and 20 percent of the variance for pond sites (see Figures 32-34 for differences between stations and seasons).

Several chemical parameters appear to be important in affecting the accumulation rate at the stream locations. OP, NaOH-P, and SS have a positive relationship with AFDM at the stream sites, and explain 61 percent of the variance. However, at the pond sites there is no significant relationship between these chemical parameters and AFDM.

Within the beaver ponds percent organic matter increases downstream, with distance below mile 0.0 explaining 68 percent of the variance. At the stream sites, there is no significant relationship between distance downstream and percent loss on ignition.

The rate of chlorophyll a accumulation increases downstream for both stream and pond locations. Distance below mile 0.0 explains 82 percent of the variance in chlorophyll a for the stream sites and 40 percent of the variance for the pond sites. Several chemical parameters appear to be important in affecting chlorophyll a accumulation rate. OP and NaOH-P explain 63 percent of the variance at the stream sites, while OP explains 37 percent of the variance at the pond sites. At the stream locations, SS explains 72 percent of the variance in chlorophyll a, while at the pond sites there is no significant relationship between SS and chlorophyll a.

A negative relationship exists between the rate of chlorophyll a accumulation and nitrate concentration. While the rate of chlorophyll a accumulation increases downstream, nitrate concentration decreases. It appears that primary productivity may be affecting nitrate concentrations, so chlorophyll a accumulation rate is considered the independent variable. Chlorophyll a explains 40 percent of the variance in nitrate concentration at the stream sites and 19 percent of the variance at the pond sites.

A positive relationship exists between rates of accumulation of chlorophyll a and AFDM. Chlorophyll a explains 53 percent of the variance in AFDM at the stream sites and 34 percent of the variance at the pond sites. At the pond sites chlorophyll a appears to be closely related to percent organic matter, and explains 52 percent of the variance. There is no significant relationship between chlorophyll a and percent loss on ignition at the stream locations.

The ratio of AFDM to chlorophyll a was calculated as an index of the autotrophic composition of the periphyton community (the lower the ratio, the higher the autotrophic composition; Weber and McFarland, 1969). At the pond sites, distance downstream and date have a negative relationship with this ratio, and explain 44 percent of the variance. At the stream sites, there is no significant relationship between distance downstream and date and this ratio.

Periphyton Standing Crop

Standing crop data are recorded both as grams chlorophyll a/m2 sampled substrate and as grams chlorophyll a/m2 stream or pond bottom. Once again, stream sites were separated from pond sites for analyses. Results of statisical analyses may be found in Table 2. There is a significant difference in standing crop among the substrates sampled (wood, bottom sediments, rock). Since wood made up a very small fraction of substrate available for algal colonization, it was deleted from the remaining analyses.

The data on chlorophyll a/m2 of sampled substrate was compared with the water quality data. OP and SS appear to have some affect on standing crop at the stream sites, as they explain 32 percent of the variance in chlorophyll a/m2. There is no significant relationship between OP and SS and chlorophyll a/m2 at the pond sites. Average discharge and date have no significant affect on chlorophyll a/m2 at either stream or pond sites.

The data on chlorophyll a/m2 bottom also were compared to the water quality data. OP may have some affect on standing crop, as it explains

13 percent of the variance in chlorophyll a/m2 at the stream sites and 25 percent of the variance at the pond sites. Standing crop at stream sites increases downstream, with distance below mile 0.0 explaining 42 percent of the variance in chlorophyll a/m2. There is no significant relationship between distance downstream and chlorophyll a/m2 for the pond stations. Average discharge and date have no significant effect on chlorophyll a/m2.

A negative relationship exists between chlorophyll a/m2 bottom and nitrate concentration at the stream sites, with chlorophyll a/m^2 explaining 33 percent of the variance. There is no relationship between chlorophyll a/m^2 bottom and nitrate at the pond sites.

Table I. Results from statistical analyses of data on water quality. For t-tests, the stations that were compared are listed. Abbreviations used are: Dist. 0.0, distance downstream from mile 0.0; BPC, data from all six stations in beaver pond complexes (grab samples only); 1-5, data from the stations with an automatic water sampler (1984); 1-4, data from stations 1-4 (grab samples only, 1985); SS, suspended solids; TP, total phosphorus; TKN, total Kjeldahl nitrogen; OP, orthophosphate; NaOH-P, NaOH-extractable phosphorus.

INDEPENDENT VARIABLE(S)	DEPENDENT VARIABLE	TEST	STATIONS	TIME PERIOD	PROBABILITY	ADJUSTED R2
STATION	SS	2 SAMPLE T (STS 2,3 V. 1,4,5)	1-5	MAY 22-JUNE 5 84	0.001	
STATION	TP	2 SAMPLE T (STS 2,3 V. 1,4,5)	1-5	MAY 22-JUNE 5 84	0.002	
STATION	TKN	2 SAMPLE T (STS 2,3 V. 1,4,5)	1-5	MAY 22-JUNE 5 84	0.002	
STATION	NO3	2 SAMPLE T (STS 2,3 V. 1,4,5)	1-5	MAY 22-JUNE 5 84	0.034	
STATION	SS	2 SAMPLE T (STS 2,3 V. 1,4)	1-4	APRIL 2-MAY 20 85	0.007	
STATION	TP	2 SAMPLE T (STS 2,3 V. 1,4)	1-4	APRIL 2-MAY 20 85	0.038	
STATION	NaOH-P	2 SAMPLE T (STS 2,3 V. 1,4)	1-4	APRIL 2-MAY 20 85	0.009	
DIST. 0.0	NO3	REGRESSION	1-4	APRIL 2-MAY 20 85	0.001	0.266
STATION	SS	PAIRED T (STREAM V. POND)	BPC	APRIL 2-MAY 20 85	0.036	
STATION	NaOH-P	PAIRED T (STREAM V. POND)	BPC	APRIL 2-MAY 20 85	0.003	
DIST. 0.0	OP	REGRESSION	1-5	JUNE 12-AUG 7 84	0.001	0.258
DIST. 0.0	SS	REGRESSION	1-5	JUNE 12-AUG 7 84	0.036	0.106
DIST. 0.0	TP	REGRESSION	1-5	JUNE 12-AUG 7 84	0.020	0.135
DIST. 0.0	NaOH-P	REGRESSION	1-5	JUNE 12-AUG 7 84	0.035	0.091
STATION	SS	PAIRED T (STREAM V. POND)	BPC	JULY 3-OCT 6 84	0.036	
DIST. 0.0	TP	REGRESSION	1-4	MAY 27-JUNE 19 85	0.015	0.306
DIST. 0.0	TKN	REGRESSION	1-4	MAY 27-JUNE 19 85	0.001	0.555
DIST. 0.0	NO3	REGRESSION	1-4	MAY 27-JUNE 19 85	0.001	0.796
STATION	NO3	PAIRED T (STREAM V. POND)	BPC	MAY 27-JUNE 19 85	0.020	
DISCHARGE	SS	REGRESSION	1-5	MAY 22-AUG 7 84	0.002	0.179
DISCHARGE	TP	REGRESSION	1-5	MAY 22-AUG 7 84	0.003	0.159
DISCHARGE	TKN	REGRESSION	1-5	MAY 22-AUG 7 84	0.013	0.109
DISCHARGE	NITRATE	REGRESSION	1-5	MAY 22-AUG 7 84	0.001	0.459
DISCHARGE	TP	REGRESSION	BPC	JULY 3-OCT 6 84	0.001	0.382
DISCHARGE	NaOH-P	REGRESSION	BPC	JULY 3-OCT 6 84	0.001	0.661
DISCHARGE	OP	REGRESSION	BPC	JULY 3-OCT 6 84	0.001	0.189
DISCHARGE	NITRATE	REGRESSION	BPC	JULY 3-OCT 6 84	0.001	0.214
DISCHARGE	SS	REGRESSION	ALL	APRIL 2-JUNE 19 85	0.001	0.386
DISCHARGE	TP	REGRESSION	ALL	APRIL 2-JUNE 19 85	0.001	0.391
DISCHARGE	TKN	REGRESSION	ALL	APRIL 2-JUNE 19 85	0.001	0.384
DISCHARGE	NaOH-P	REGRESSION	ALL	APRIL 2-JUNE 19 85	0.001	0.463
DISCHARGE	OP	REGRESSION	ALL	APRIL 2-JUNE 19 85	0.001	0.582
SS	TP	REGRESSION	1-5	MAY 22-JUNE 5 84	0.001	0.724
SS	TKN	REGRESSION	1-5	MAY 22-JUNE 5 84	0.001	0.793
SS	TP	REGRESSION	1-5	JUNE 12-AUG 7 84	0.001	0.519
SS	TKN	REGRESSION	1-5	JUNE 12-AUG 7 84	0.001	0.542
SS	TP	REGRESSION	BPC	JULY 3-OCT 6 84	0.001	0.327
SS	TKN	REGRESSION	BPC	JULY 3-OCT 6 84	0.001	0.279
SS	TP	REGRESSION	ALL	APRIL 2-MAY 20 85	0.001	0.964
SS	TKN	REGRESSION	ALL	APRIL 2-MAY 20 85	0.001	0.923
SS	NaOH-P	REGRESSION	ALL	APRIL 2-MAY 20 85	0.001	0.901
SS	TP	REGRESSION	ALL	MAY 27-JUNE 19 85	0.001	0.911
SS	TKN	REGRESSION	ALL	MAY 27-JUNE 19 85	0.001	0.904
SS	NaOH-P	REGRESSION	ALL	MAY 27-JUNE 19 85	0.001	0.226

Table II. Results from statistical analyses of data on periphyton accumulation rate and standing crop. Dry weight, AFDW, and Chlor A represent rates of accumulation ($mg/m^2/day$) for total accumulation, ash free dry weight, and chlorophyll a. Other abbreviations used are: Dist. 0.0, distance downstream from mile 0.0; % Loss, percent loss on ignition; Chlor A/m^2 S, standing crop of chlorophyll a per square meter of sampled substrate; Chlor A/m^2 B, standing crop of chlorophyll a per square meter of total bottom; OP, ortho-phosphate; NaOH-P, NaOH-extractable phosphorus; SS, suspended solids.

INDEPENDENT VARIABLE(S)	DEPENDENT VARIABLE	TEST	LOCATION	TIME PERIOD	PROBABILITY	ADJUSTED R2
DIST. 0.0	AFDW	REGRESSION	STREAM	JUNE 28-AUG 31	0.001	0.521
SEASON	AFDW	REGRESSION	STREAM	JUNE 28-AUG 31	0.001	0.248
SEASON	AFDW	REGRESSION	POND	JUNE 28-AUG 31	0.001	0.196
OP,NaOH-P,SS	AFDW	REGRESSION	STREAM	JUNE 28-AUG 31	0.001	0.606
DIST. 0.0	% LOSS	REGRESSION	POND	JUNE 28-AUG 31	0.001	0.682
DIST. 0.0	CHLOR A	REGRESSION	STREAM	AUG 2-AUG 31	0.001	0.816
DIST. 0.0	CHLOR A	REGRESSION	POND	AUG 2-AUG 31	0.001	0.396
OP,NaOH-P	CHLOR A	REGRESSION	STREAM	AUG 2-AUG 31	0.001	0.633
OP	CHLOR A	REGRESSION	POND	AUG 2-AUG 31	0.001	0.365
SS	CHLOR A	REGRESSION	STREAM	AUG 2-AUG 31	0.001	0.716
CHLOR A	NITRATE	REGRESSION	STREAM	AUG 2-AUG 31	0.001	0.404
CHLOR A	NITRATE	REGRESSION	POND	AUG 2-AUG 31	0.021	0.193
CHLOR A	AFDW	REGRESSION	STREAM	AUG 2-AUG 31	0.001	0.534
CHLOR A	AFDW	REGRESSION	POND	AUG 2-AUG 31	0.013	0.341
CHLOR A, SS	DRY WEIGHT	REGRESSION	STREAM	AUG 2-AUG 31	0.001	0.884
CHLOR A	% LOSS	REGRESSION	POND	AUG 2-AUG 31	0.001	0.520
DIST.0.0,DATE	AFDW/CHLOR A	REGRESSION	POND	AUG 2-AUG 31	0.012	0.443
SUBSTRATE	CHLOR A/M2 S	ANOVA		JULY 4-AUG 31	0.001	
OP, SS	CHLOR A/M2 S	REGRESSION	STREAM	JULY 4-AUG 31	0.001	0.316
OP	CHLOR A/M2 B	REGRESSION	STREAM	JULY 4-AUG 31	0.039	0.125
OP	CHLOR A/M2 B	REGRESSION	POND	JULY 4-AUG 31	0.034	0.248
DIST. 0.0	CHLOR A/M2 B	REGRESSION	STREAM	JULY 4-AUG 31	0.001	0.423

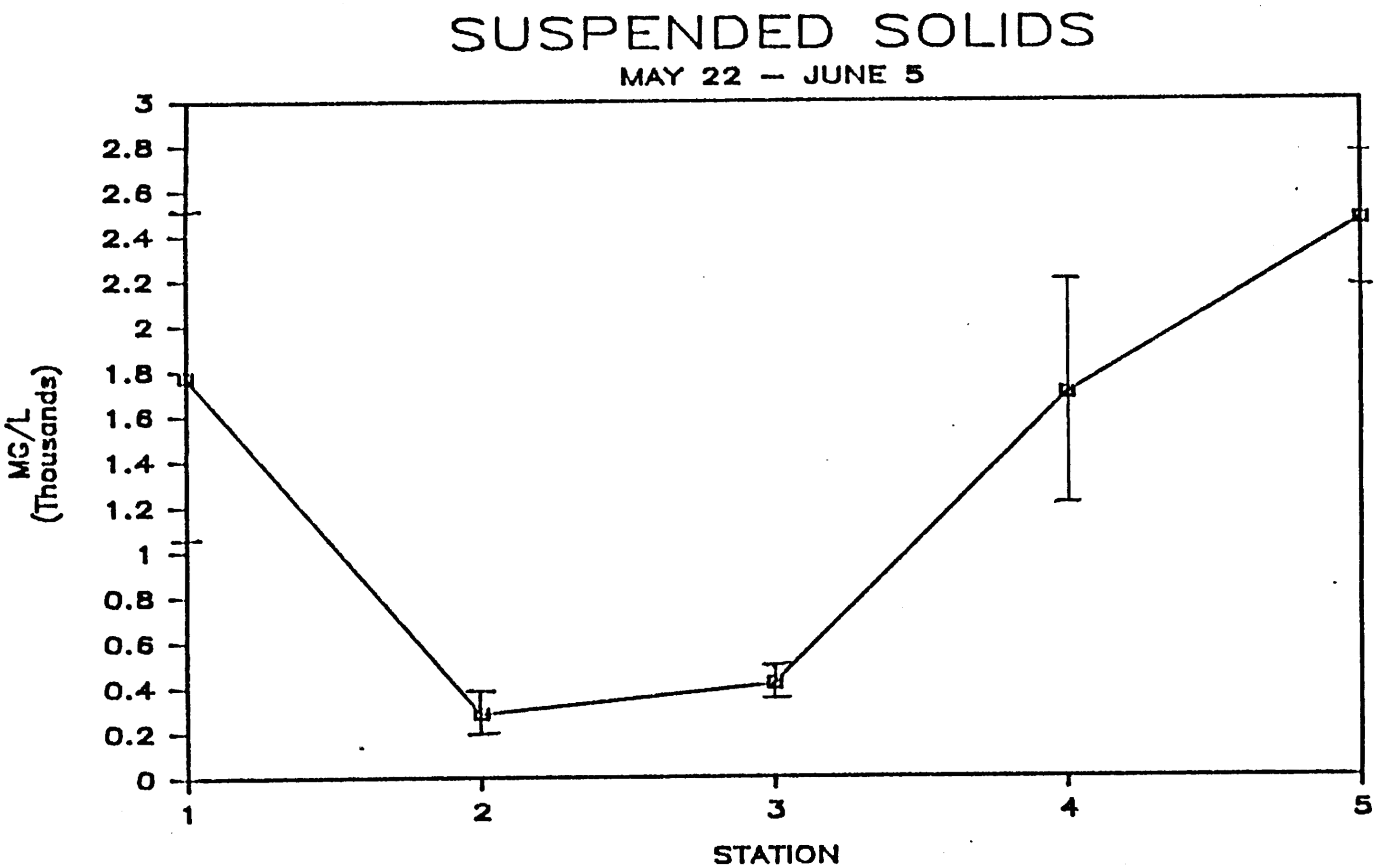

Figure 2: Concentrations of suspended solids for stations serviced by an automatic water sampler (1-5). Each point represents an average from three analyses performed between May 22 and June 5, 1984. Bars represent + or - one standard error. X axis is not to scale.

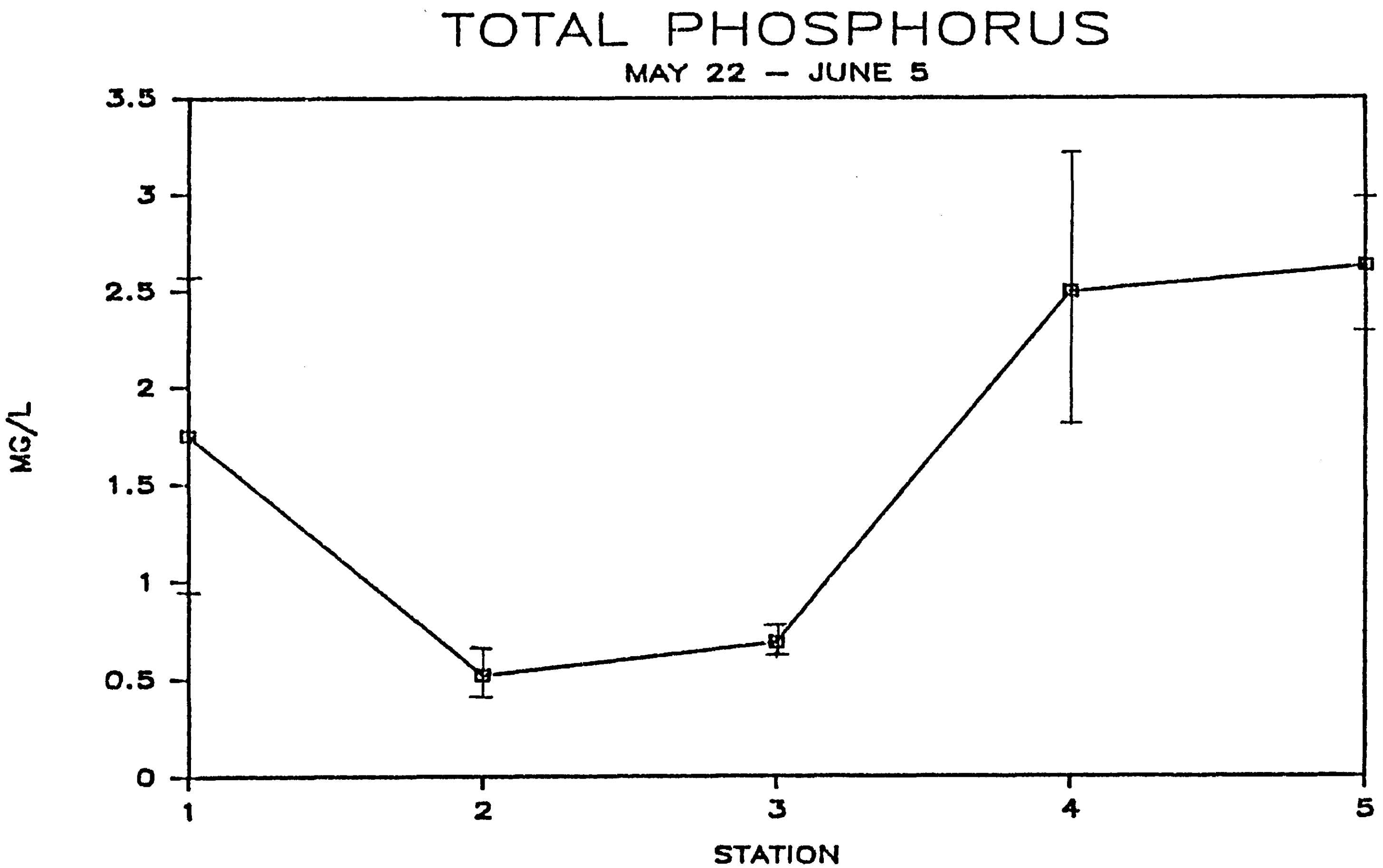

Figure 3: Concentrations of total phosphorus for stations serviced by an automatic water sampler (1-5). Each point represents an average from three analyses performed between May 22 and June 5, 1984. Bars represent + or - one standard error. X axis is not to scale.

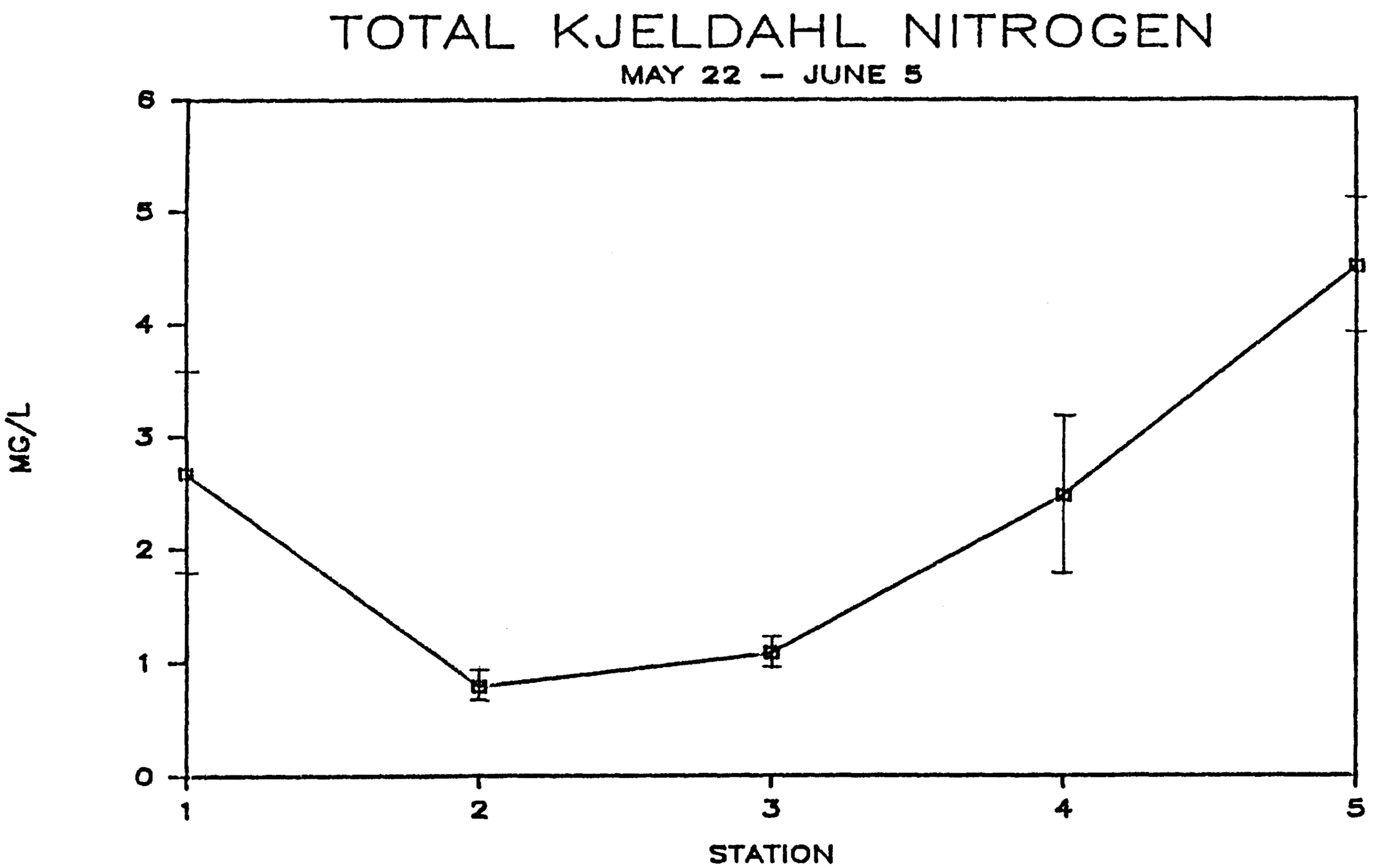

Figure 4: Concentrations of total Kjeldahl nitrogen for stations serviced by an automatic water sampler (1-5). Each point represents an average from three analyses performed between May 22 and June 5, 1984. Bars represent + or - one standard error. X axis is not to scale.

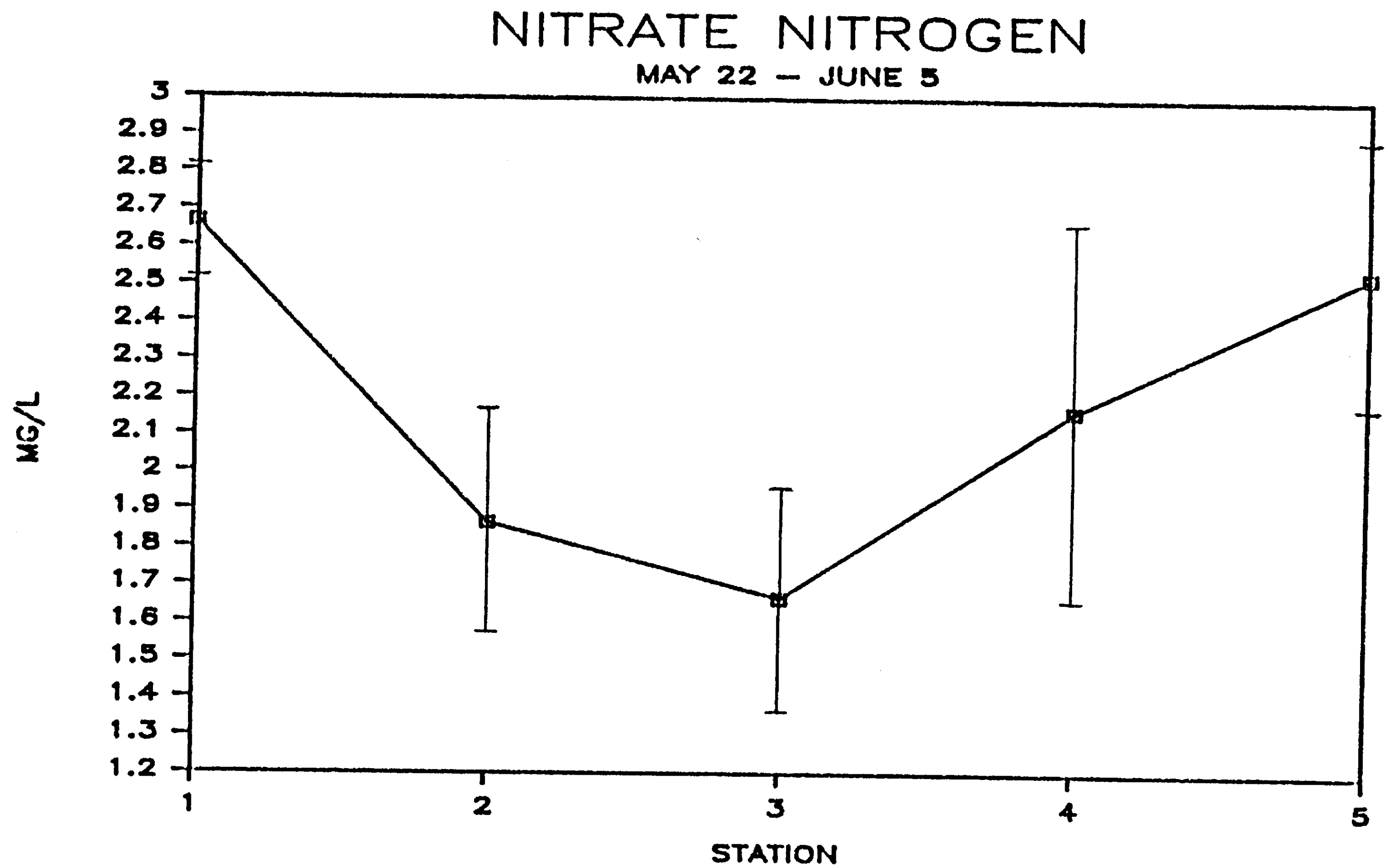

Figure 5: Nitrate nitrogen concentrations for stations serviced by an automatic water sampler (1-5). Each point represents an average from three analyses performed between May 22 and June 5, 1984. Bars represent + or - one standard error. X axis is not to scale.

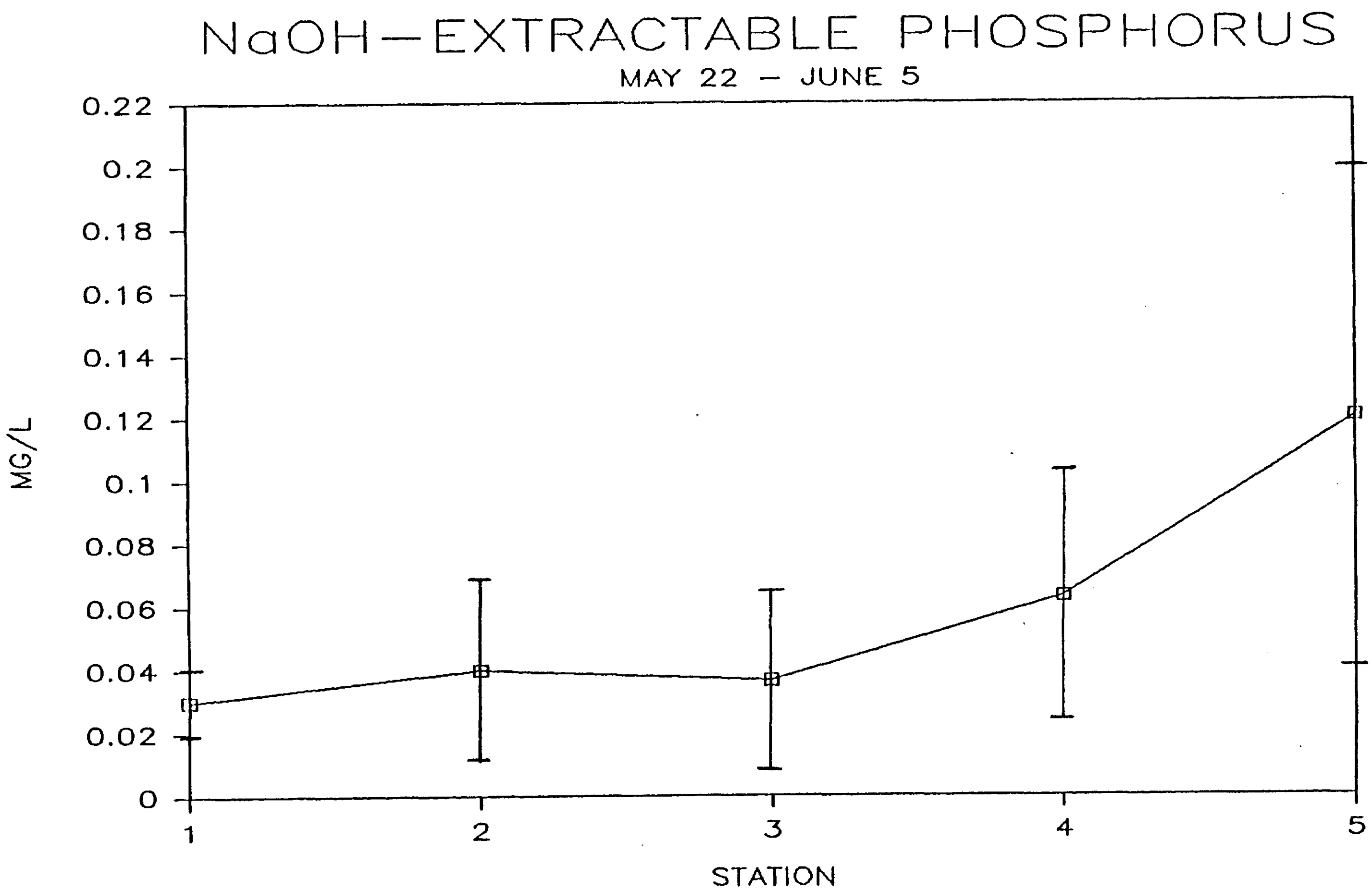

Figure 6: Concentrations of NaOH-extractable phosphorus for stations serviced by an automatic water sampler (1-5). Each point represents an average from three analyses performed between May 22 and June 5, 1984. Bars represent + or - one standard error. X axis is not to scale.

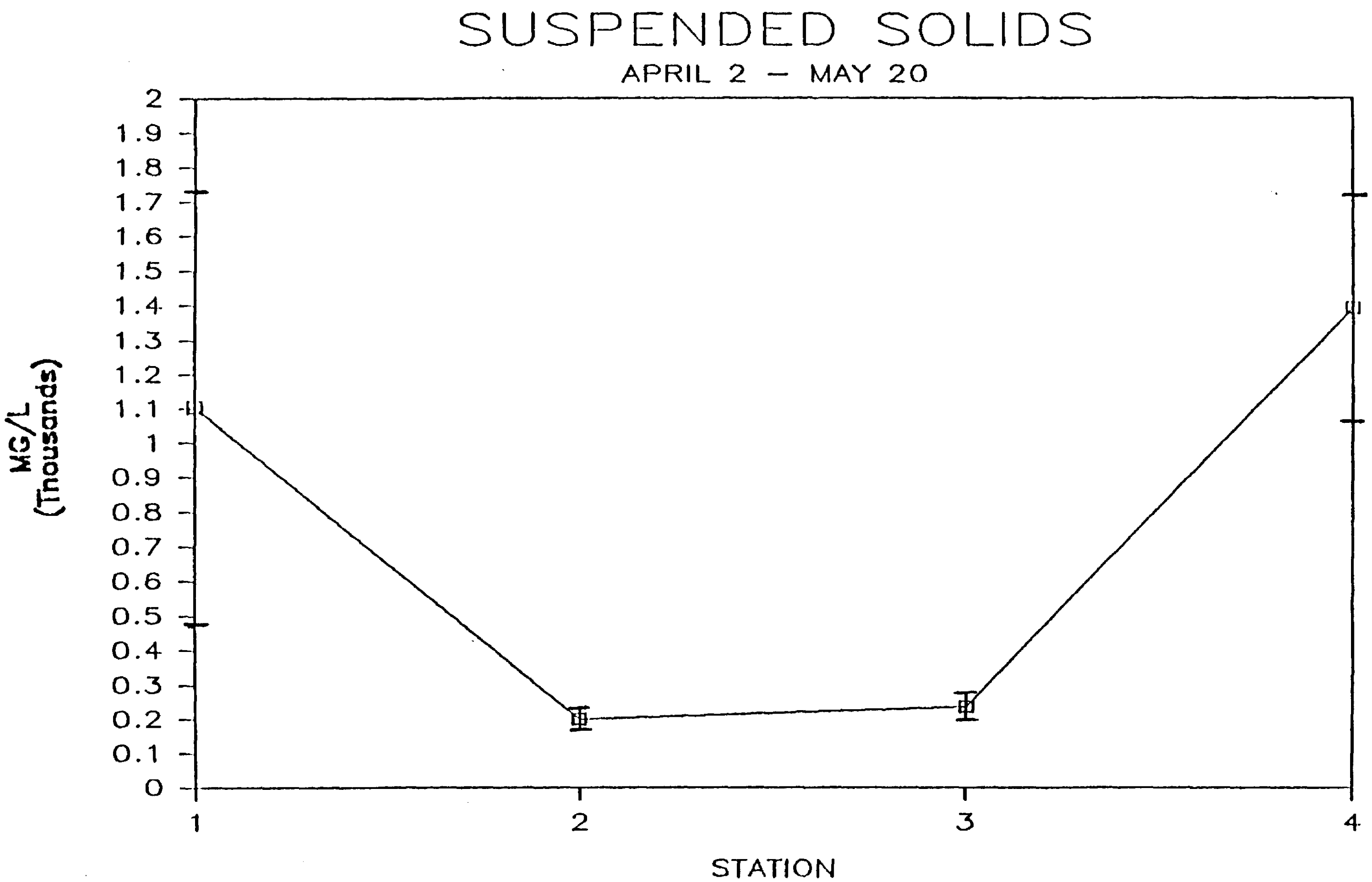

Figure 7: Concentrations of suspended solids for stations 1 through 4. Each point represents an average from eight analyses performed between April 2 and May 20, 1985. Bars represent + or – one standard error. X axis is not to scale.

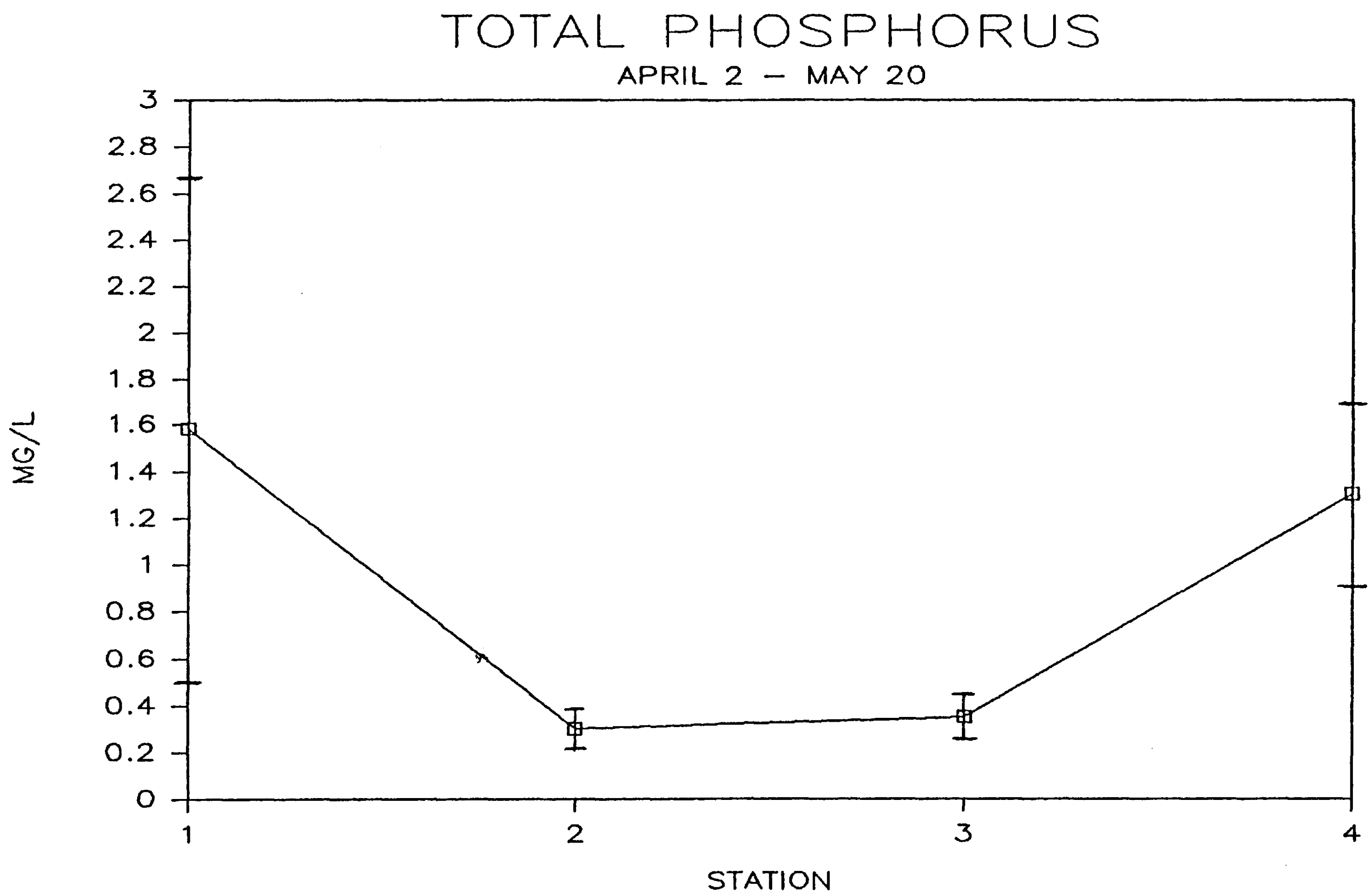

Figure 8: Concentrations of total phosphorus for stations 1 through 4. Each point represents an average from eight analyses performed between April 2 and May 20, 1985. Bars represent + or - one standard error. X axis is not to scale.

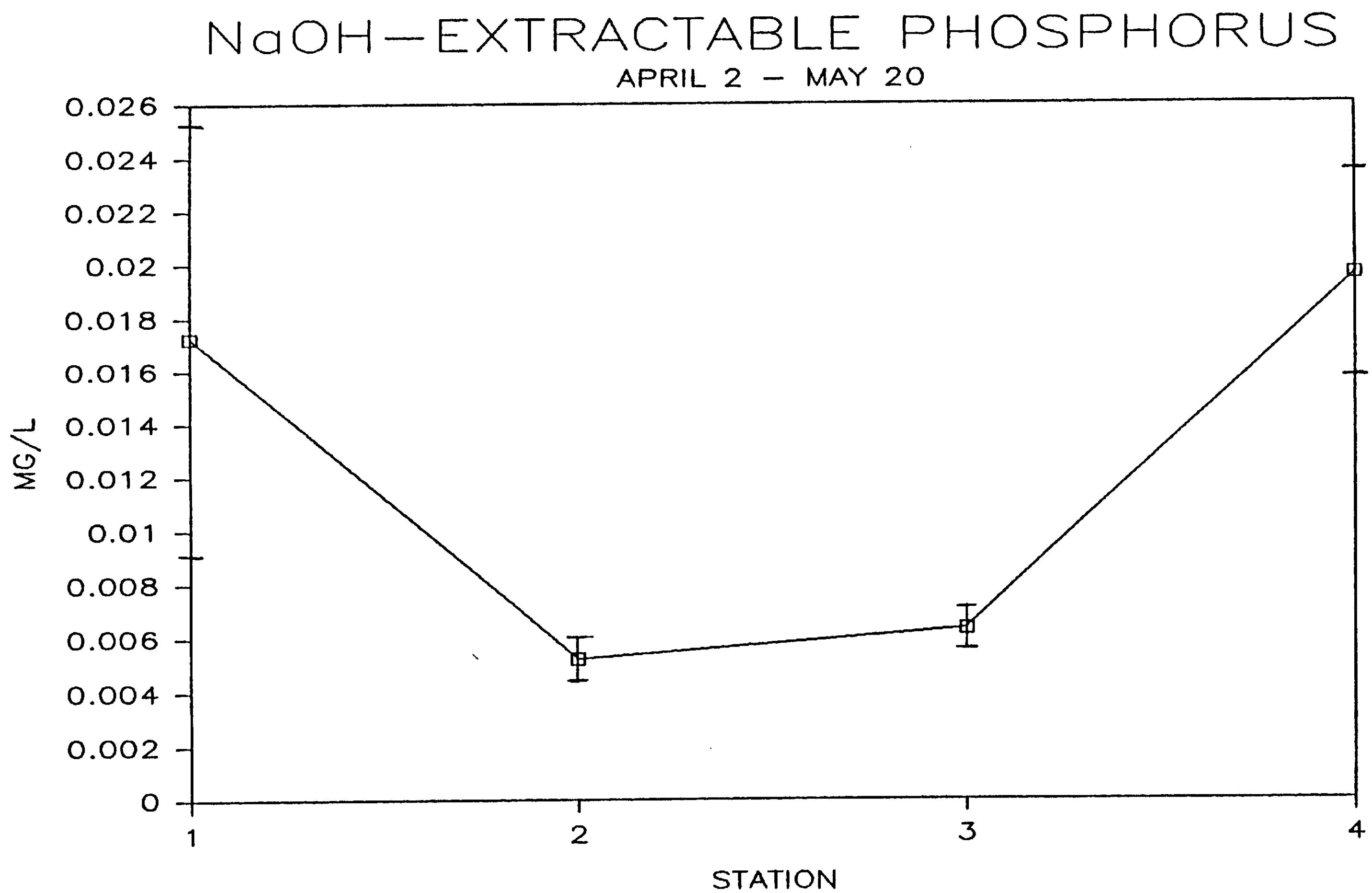

Figure 9: Concentrations of NaOH-extractable phosphorus for stations 1 through 4. Each point represents an average from eight analyses performed between April 2 and May 20, 1985. Bars represent + or - one standard error. X axis in not to scale.

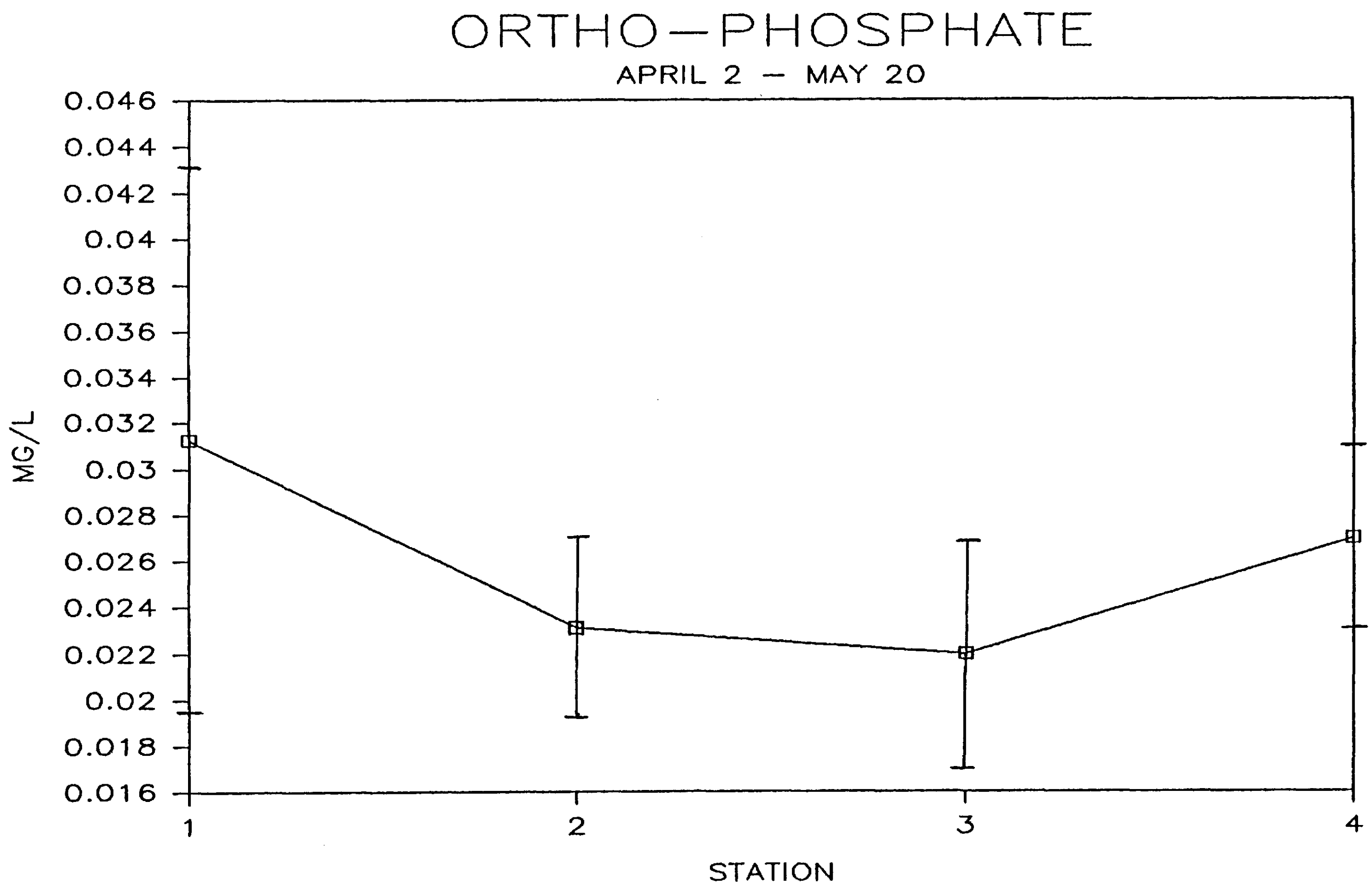

Figure 10: Concentrations of ortho-phosphate for stations 1 through 4. Each point represent an average from eight analyses performed between April 2 and May 20, 1985. Bars represent + or - one standard error. X axis is not to scale.

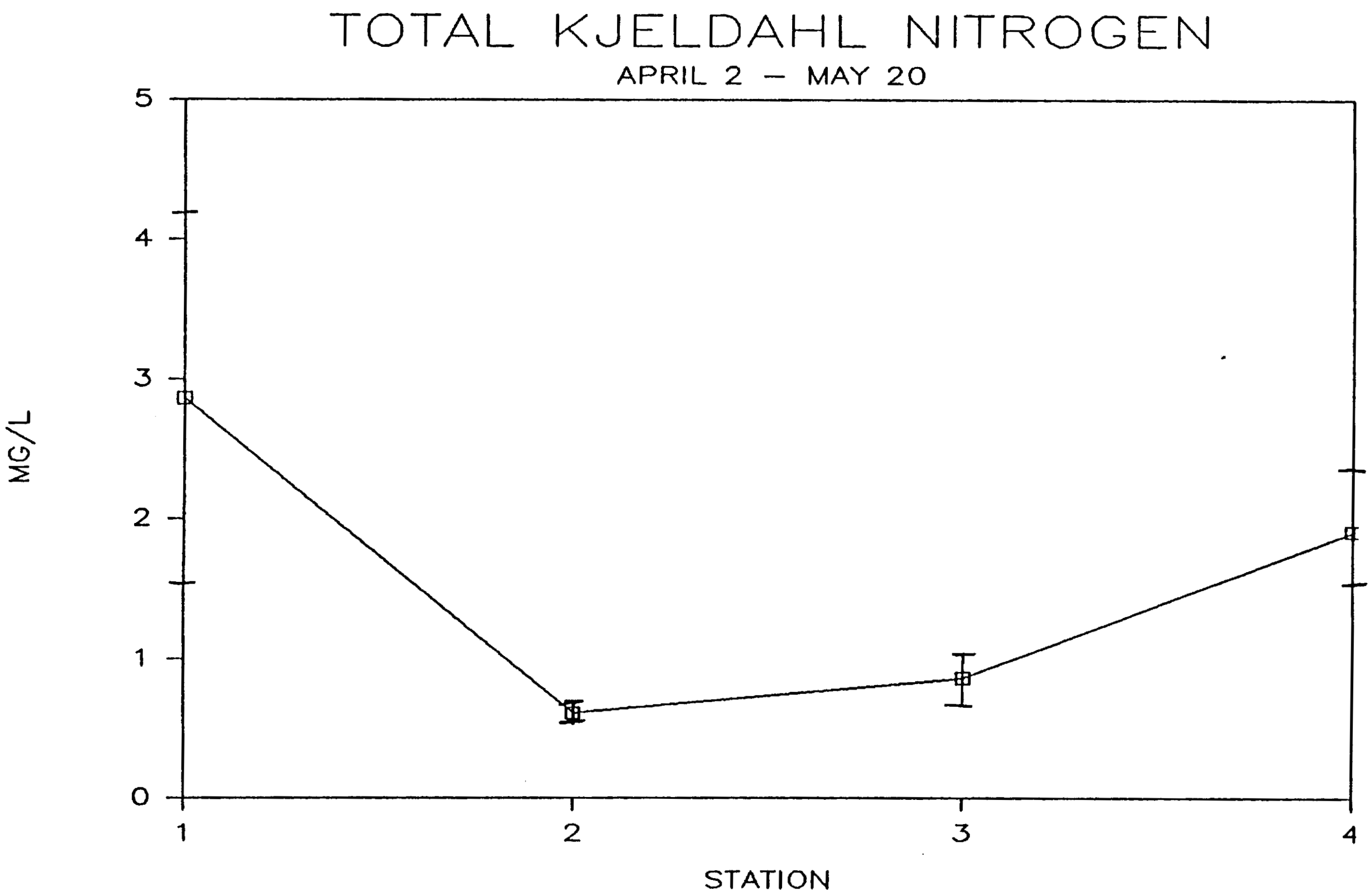

Figure 11: Concentrations of total Kjeldahl nitrogen for stations 1 through 4. Each point represents an average from eight analyses performed between April 2 and May 20, 1985. Bars represent + or − one standard error. X axis is not to scale.

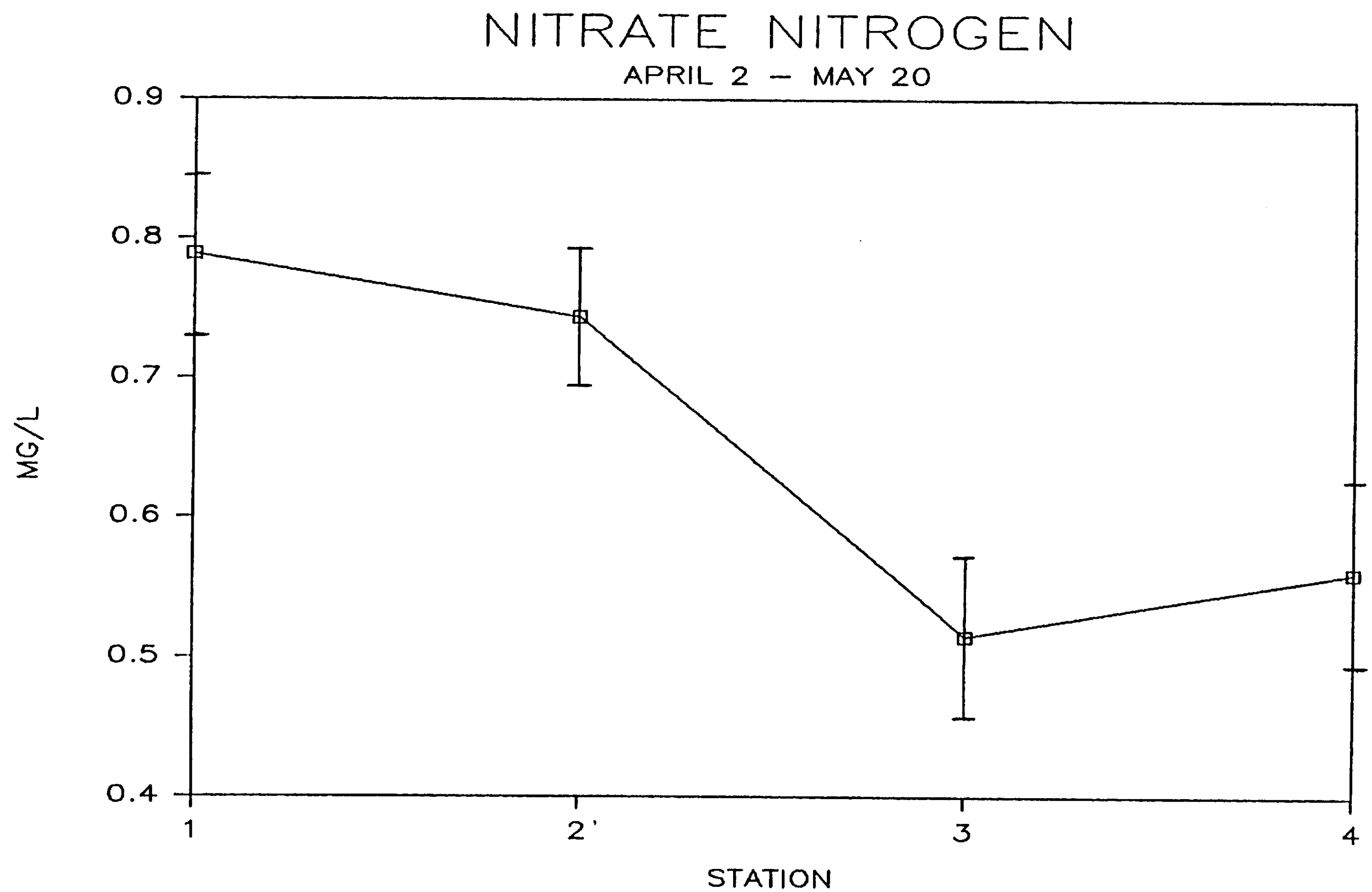

Figure 12: Concentrations of nitrate nitrogen for stations 1 through 4. Each point represents an average from eight analyses performed between April 2 and May 20, 1985. Bars represent + or - one standard error. X axis in not to scale.

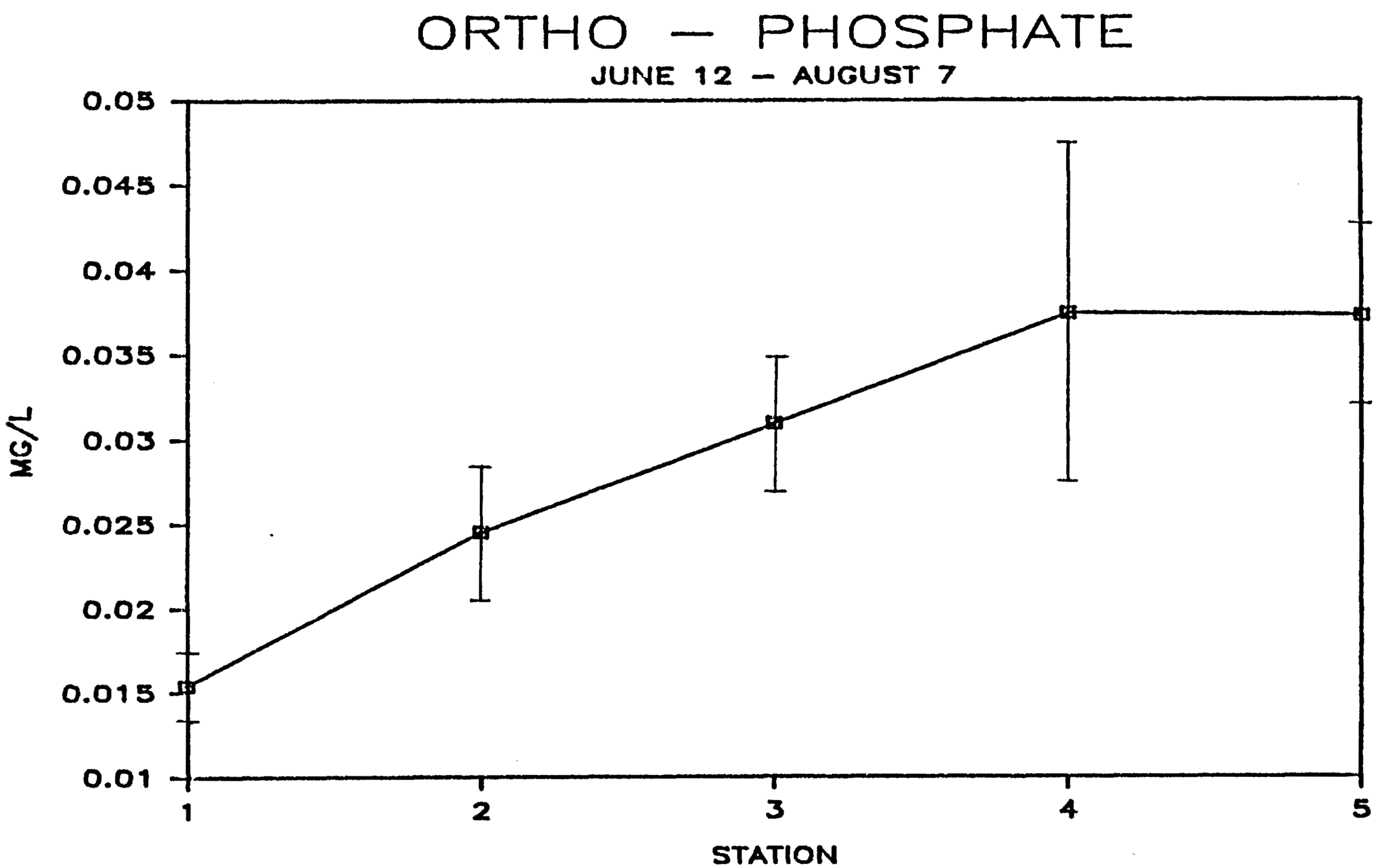

Figure 13: Concentrations of ortho-phosphate for stations serviced by an automatic water sampler (1-5). Each point represents an average from eight analyses performed between June 12 and August 7, 1984. Bars represent + or - one standard error. X axis is not to scale.

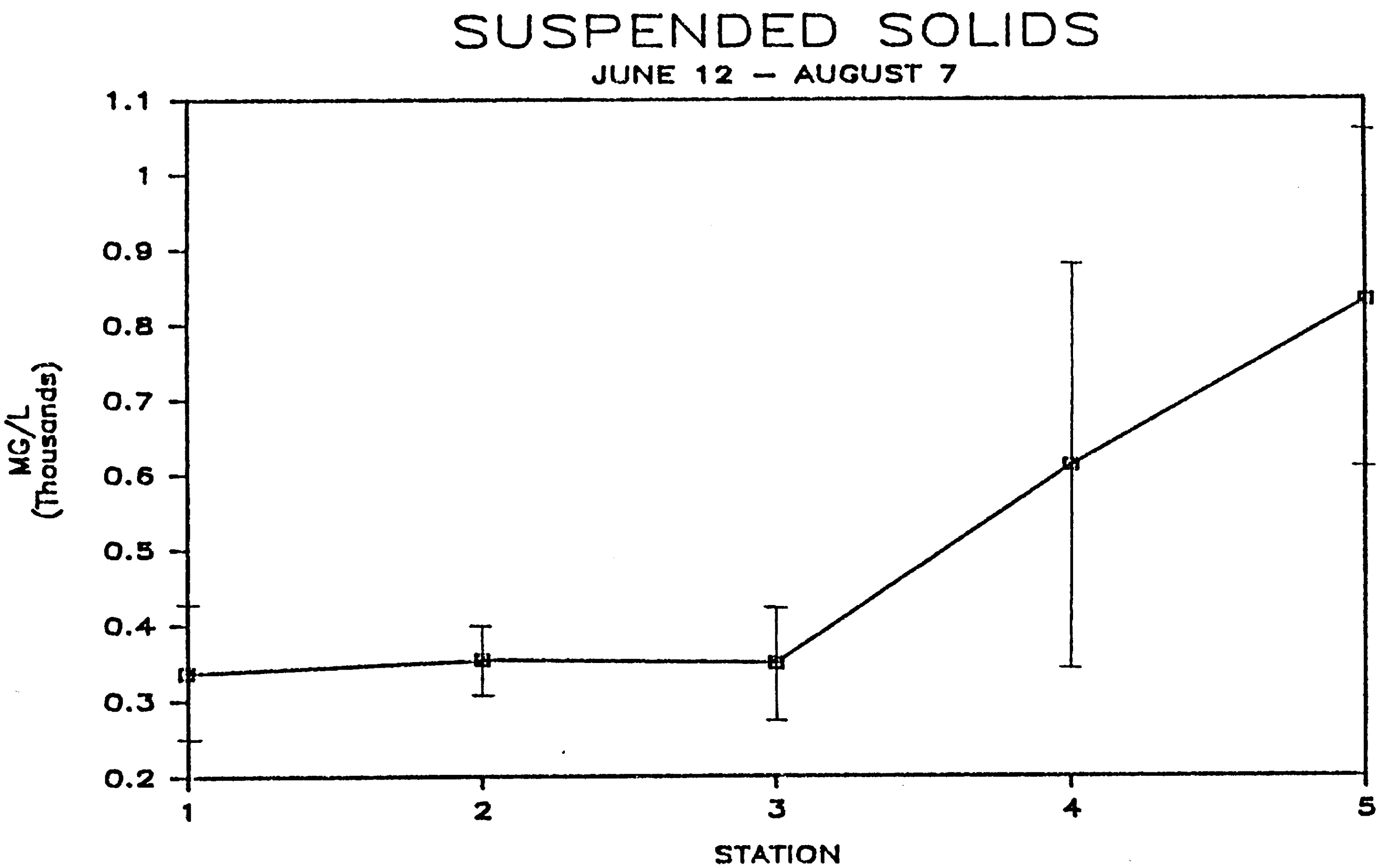

Figure 14: Concentrations of suspended solids for stations serviced by an automatic water sampler (1-5). Each point represents an average from eight analyses performed between June 12 and August 7, 1984. Bars represent + or - one standard error. X axis is not to scale.

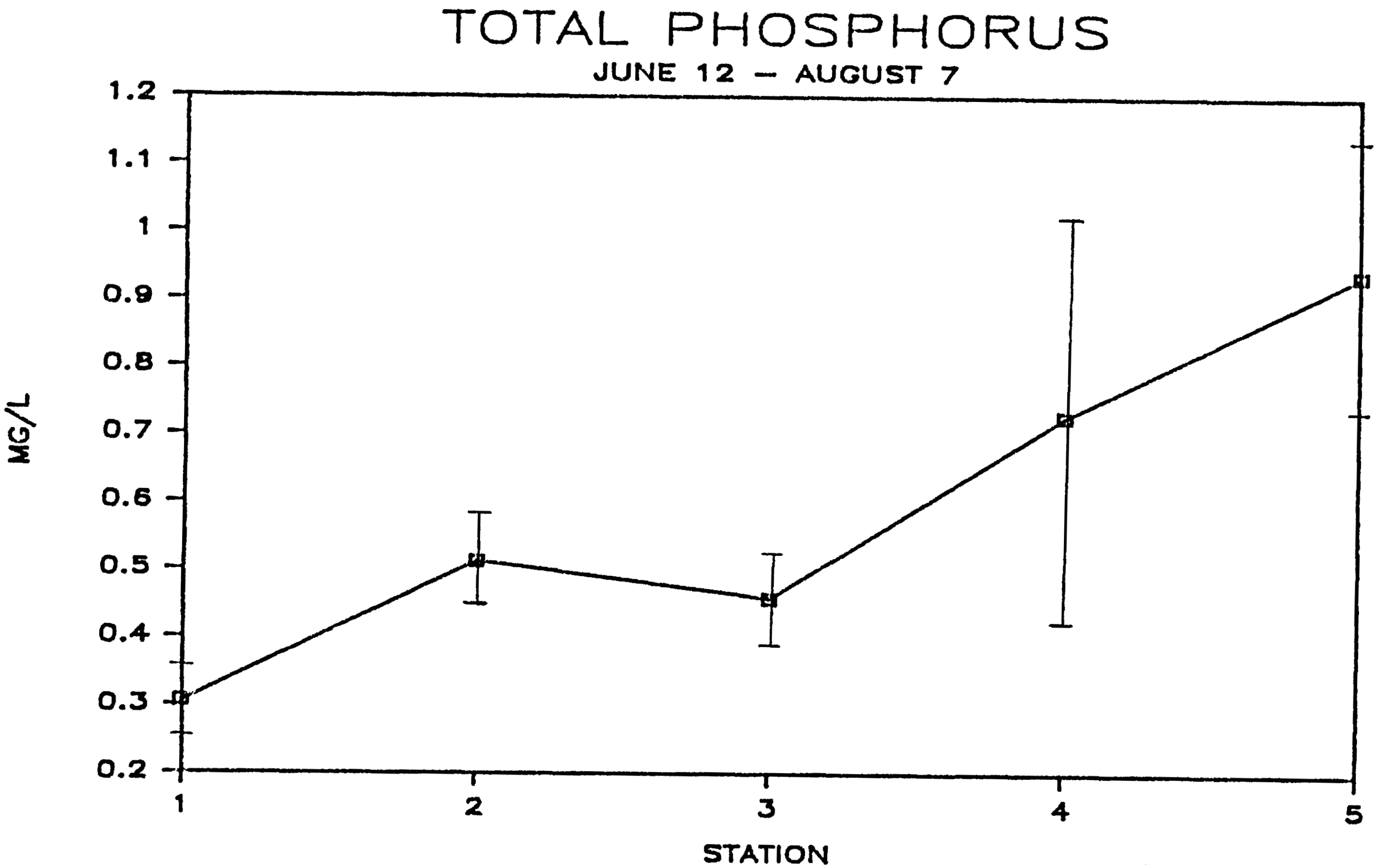

Figure 15: Concentrations of total phosphorus for stations serviced by an automatic water sampler (1-5). Each point represents an average from eight analyses performed between June 12 and August 7, 1984. Bars represent + or - one standard error. X axis is not to scale.

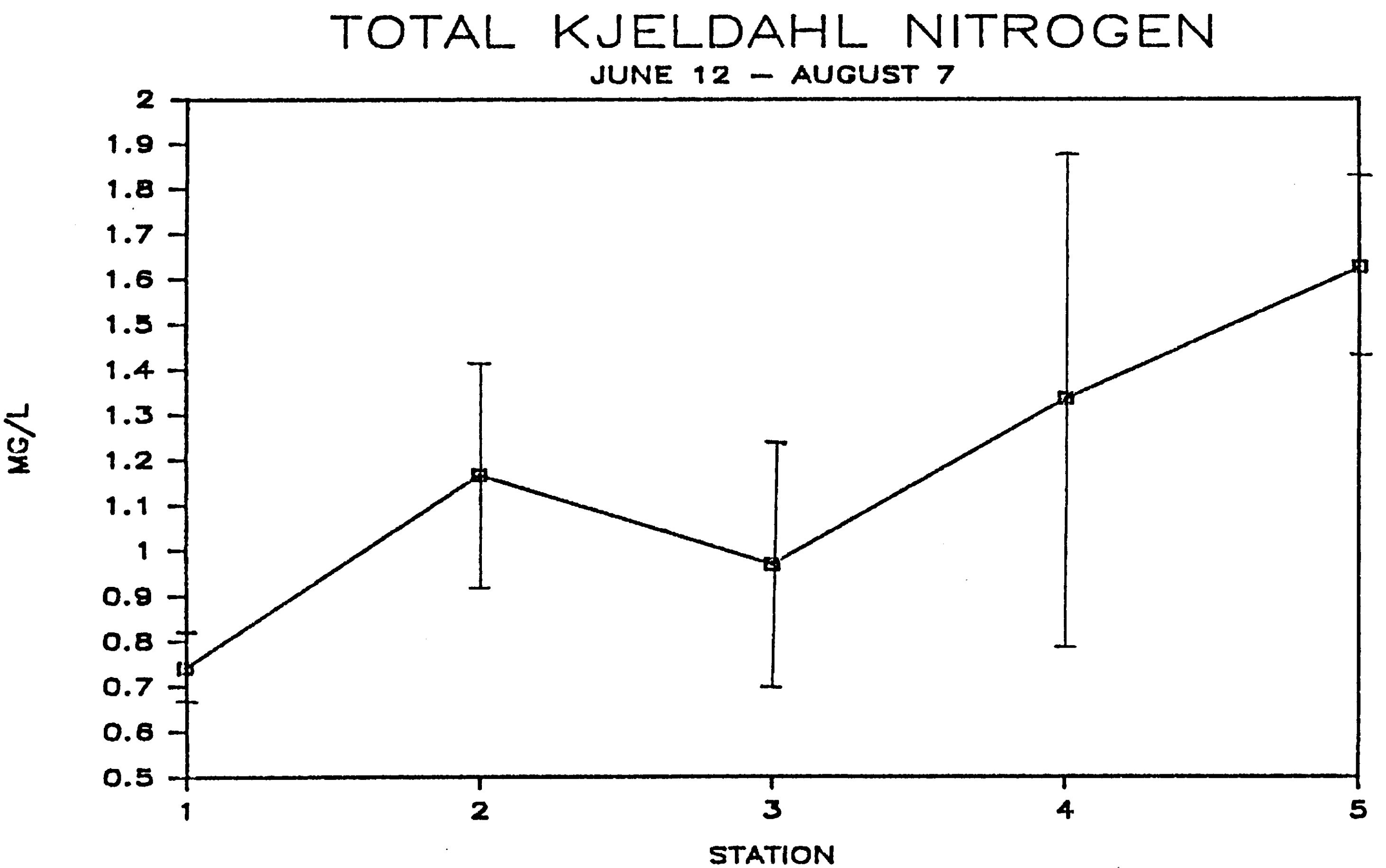

Figure 16: Concentrations of total Kjeldahl nitrogen for stations serviced by an automatic water sampler (1-5). Each point represents an average from eight analyses performed between June 12 and August 7, 1984. Bars represent + or - one standard error. X axis is not to scale.

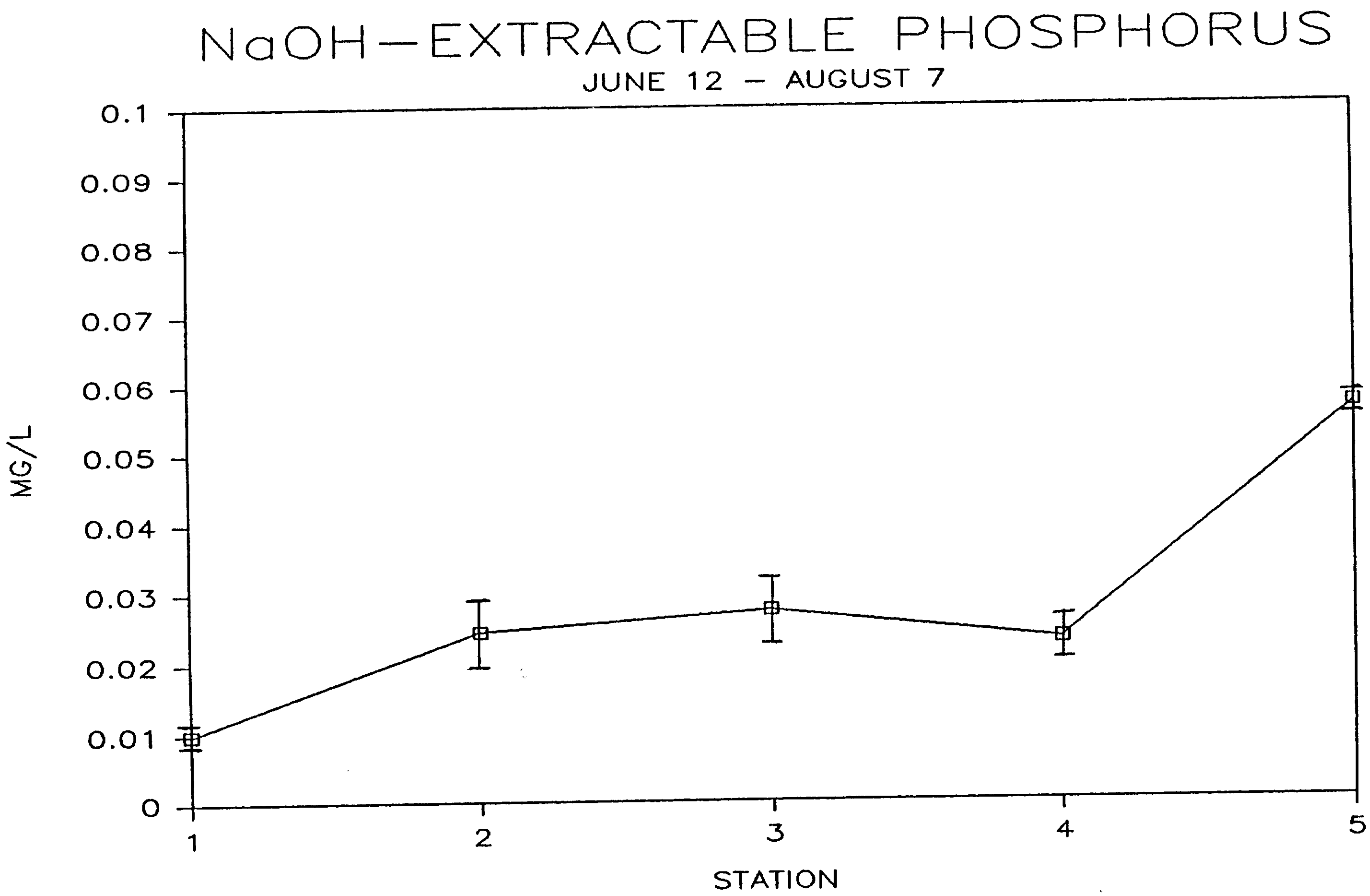

Figure 17: Concentrations of NaOH-extractable phosphorus for stations serviced by an automatic water sampler (1-5). Each point represents an average from eight analyses performed between June 12 and August 7, 1984. Bars represent + or - one standard error. X axis is not to scale.

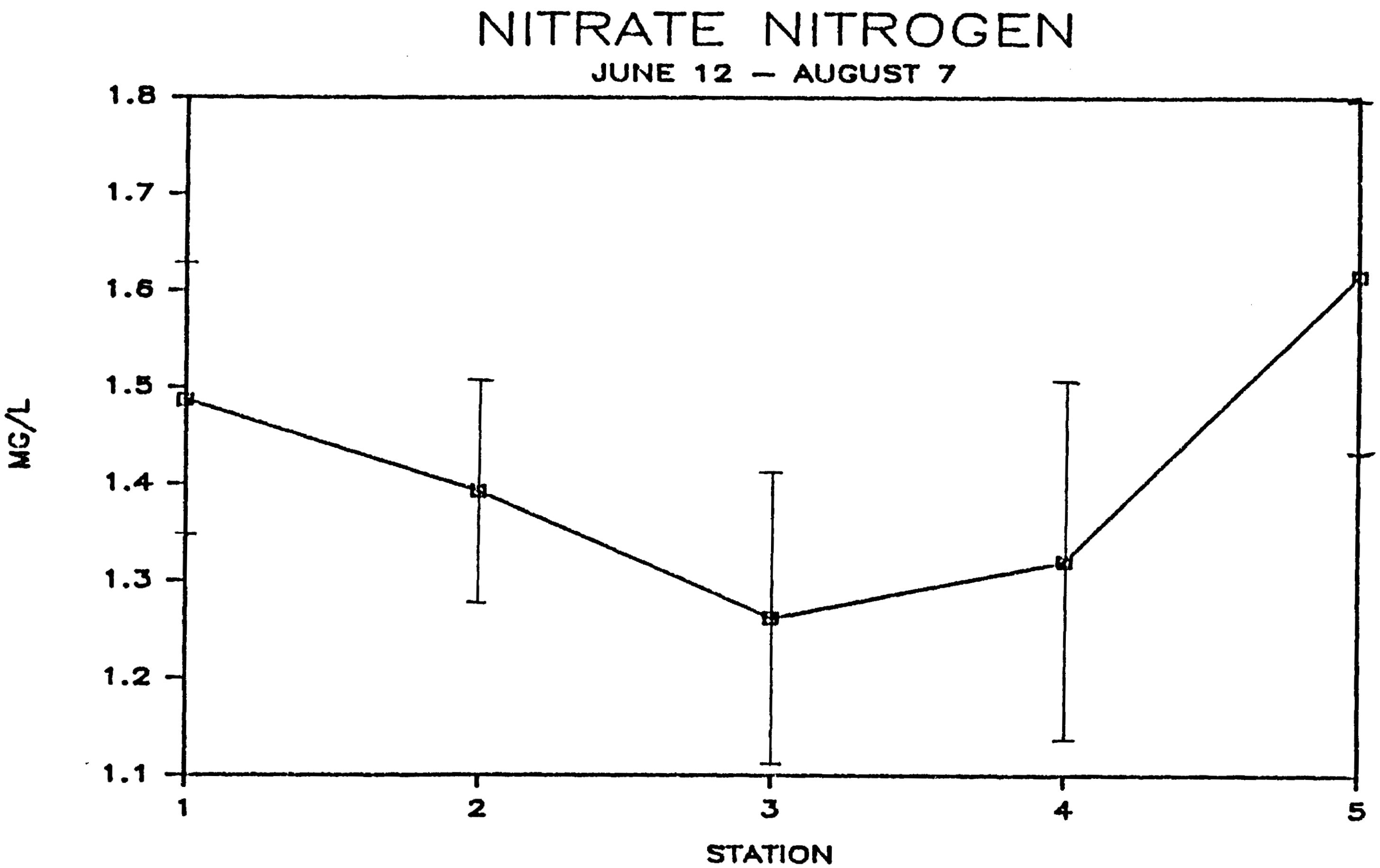

Figure 18: Concentrations of nitrate concentration for stations service by an automatic water sampler (1-5). Each point represents an average from eight analyses performed between June 12 and August 7, 1984. Bars represent + or − one standard error. X axis is not to scale.

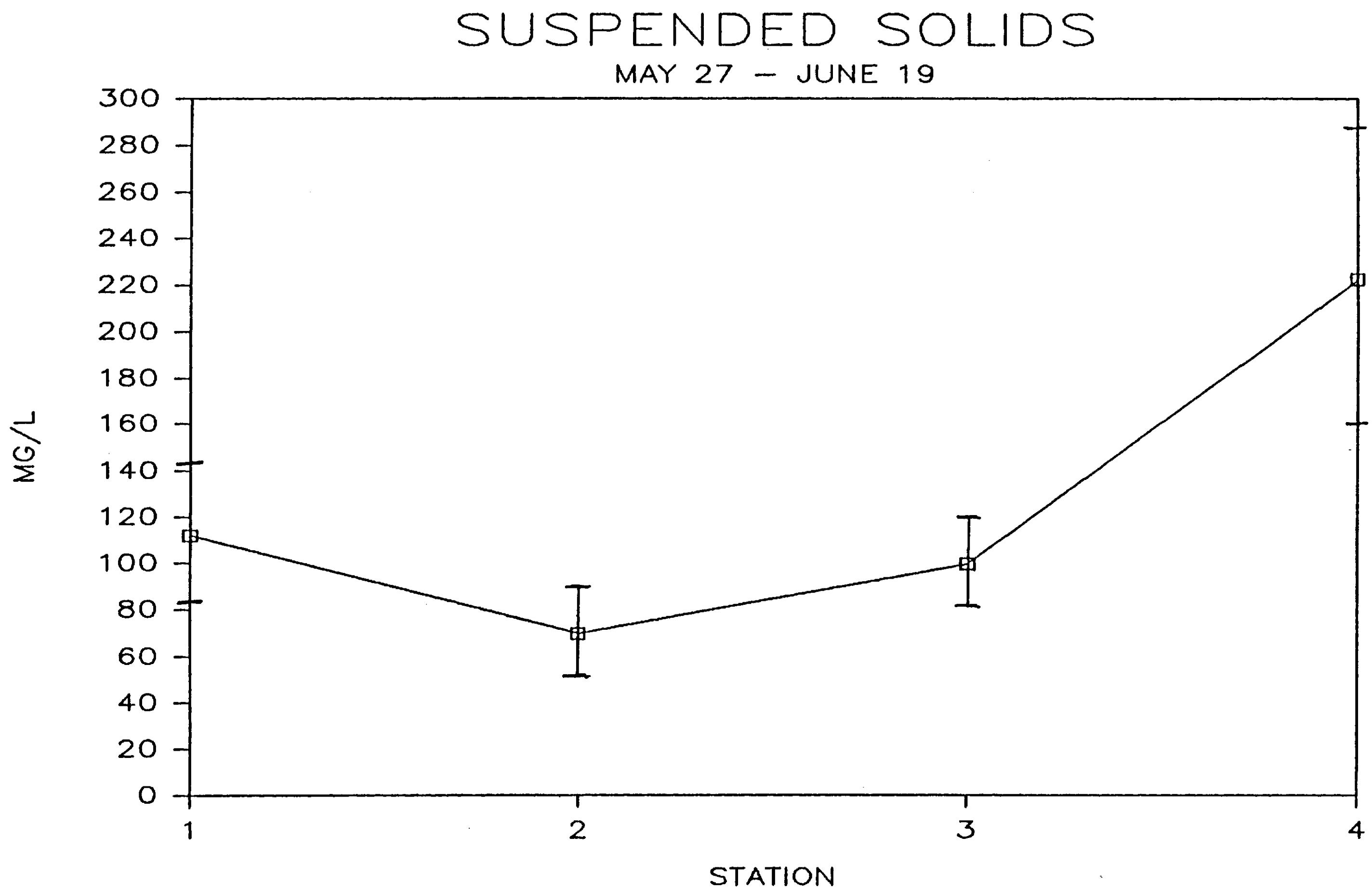

Figure 19: Concentrations of suspended solids for stations 1 through 4. Each point represents an average from four analyses performed between May 27 and June 19, 1985. Bars represent + or - one standard error. X axis is not to scale.

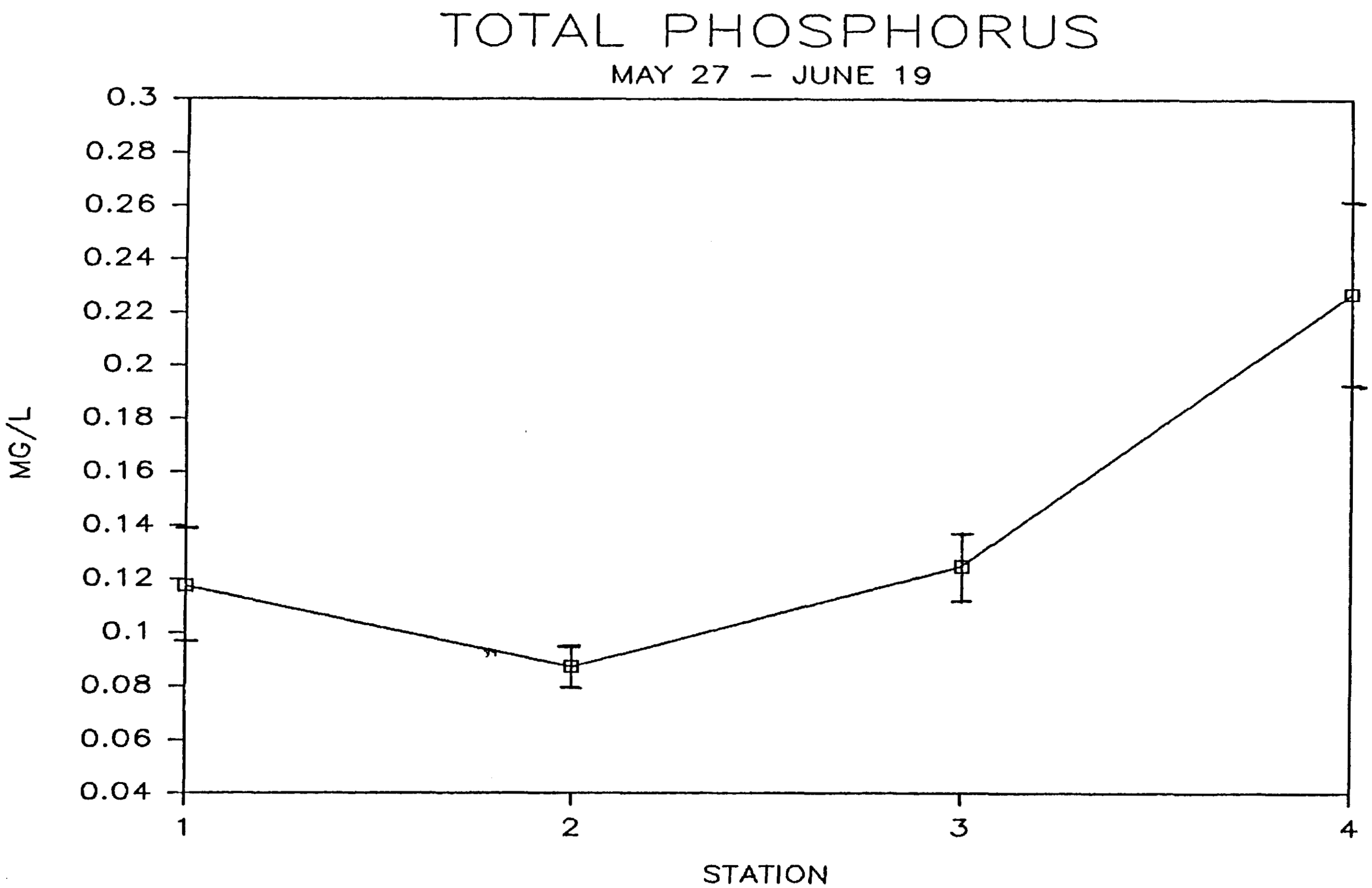

Figure 20: Concentrations of total phosphorus for stations 1 through 4. Each point represents an average from four analyses perrformed between May 27 and June 19, 1985. Bars represent + or – one standard error. X axis is not to scale.

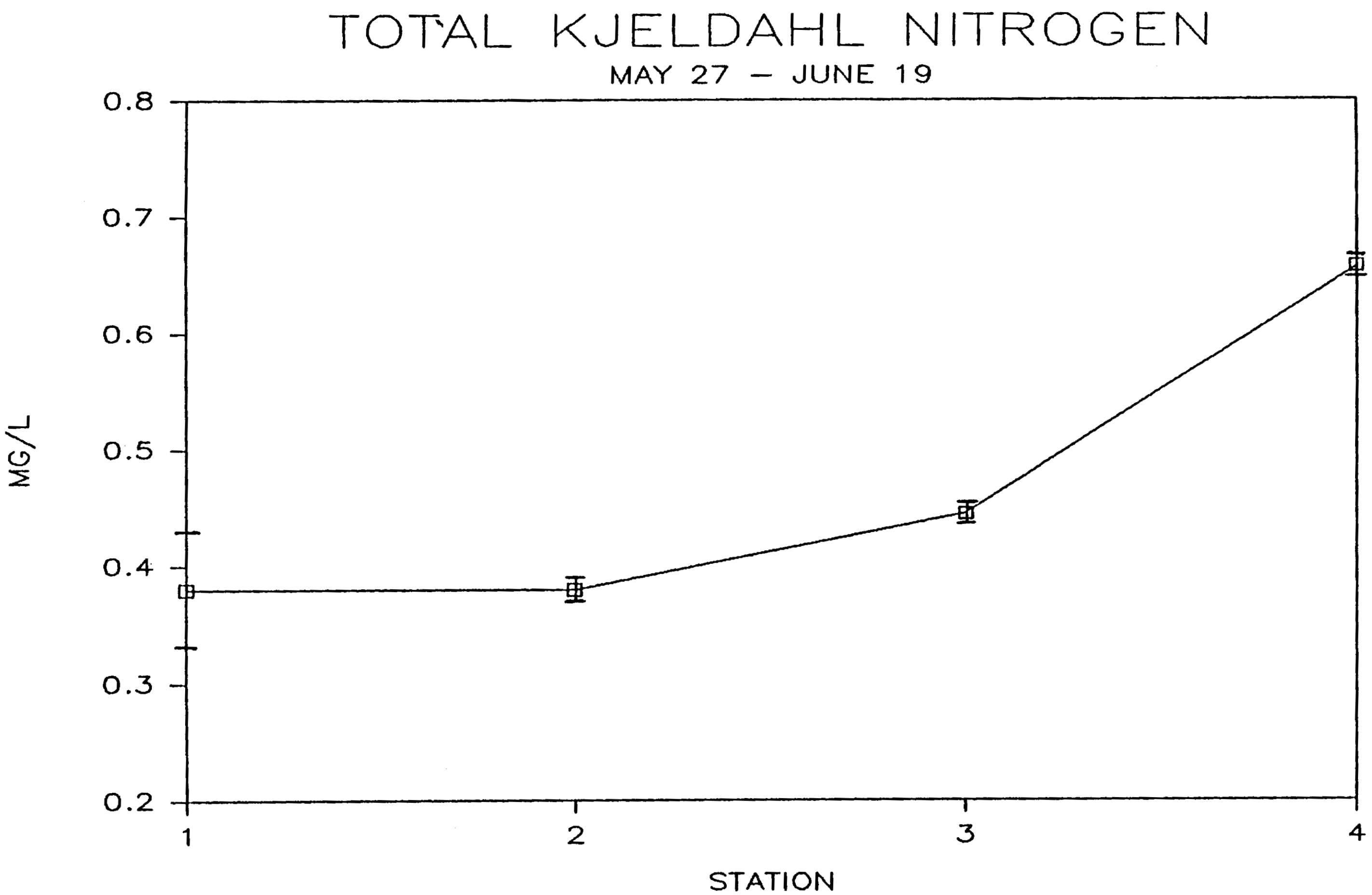

Figure 21: Concentrations of total Kjeldahl nitrogen for stations 1 through 4. Each point represents an average from four analyses performed between May 27 and June 19, 1985. Bars represent + or – one standard error. X axis is not to scale.

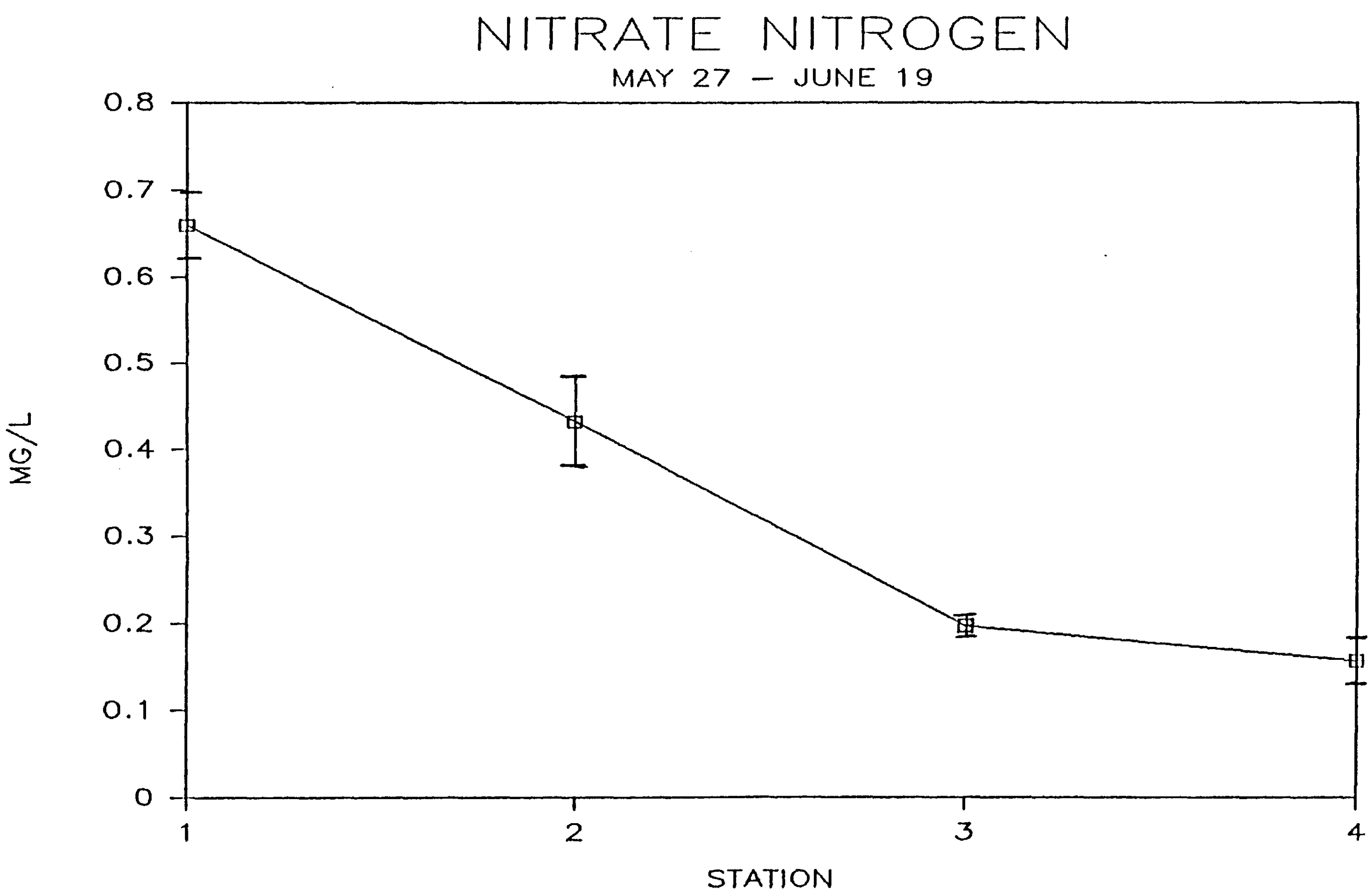

Figure 22: Concentrations of nitrate nitrogen for stations 1 through 4. Each point represents an average from four analyses performed between May 27 and June 19, 1985. Bars represent + or − one standard error. X axis is not to scale.

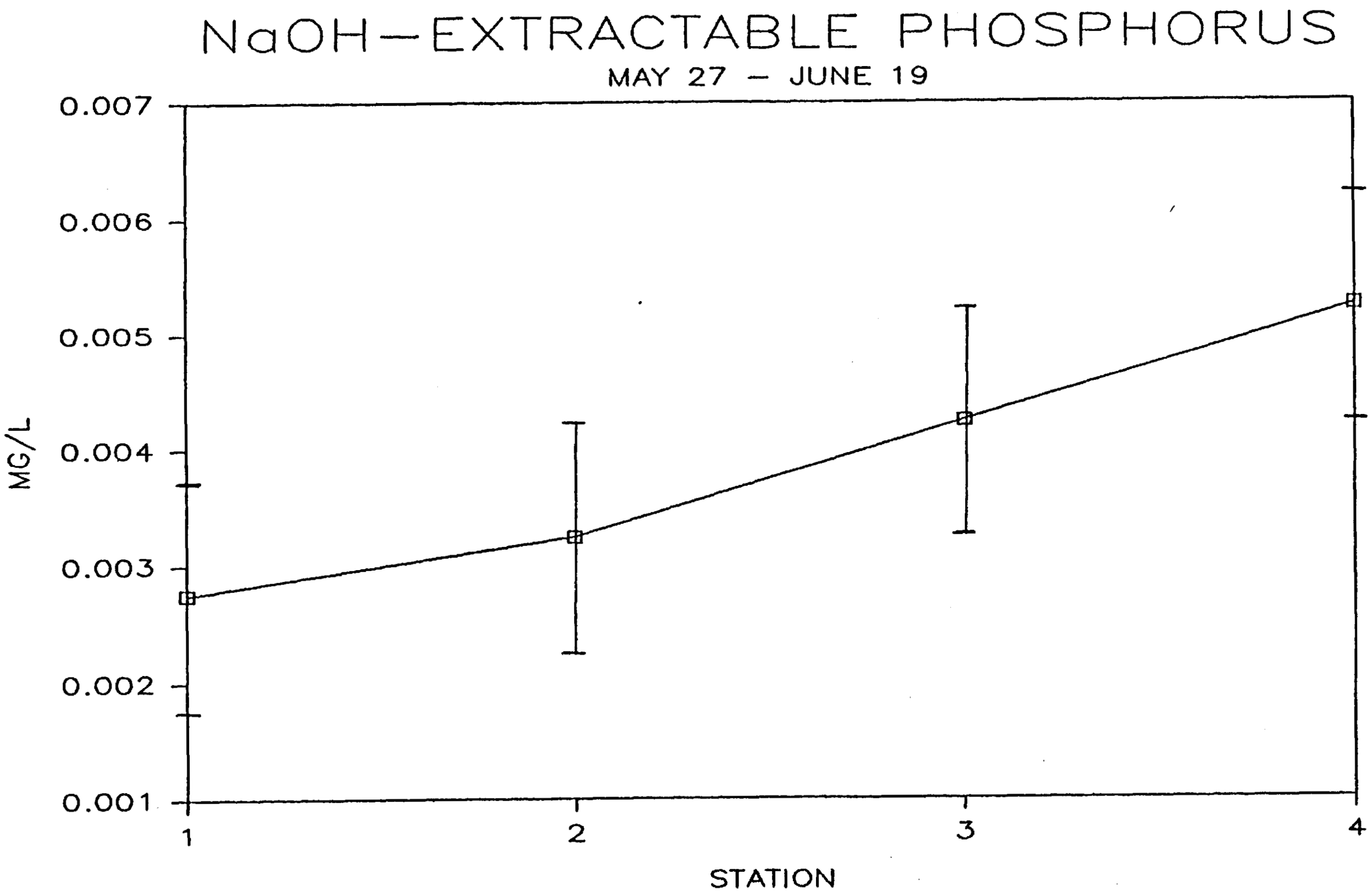

Figure 23: Concentrations of NaOH-extractable phosphorus for stations 1 through 4. Each point represents an average from four analyses performed between May 27 and June 19, 1985. Bars represent + or - one standard error. X axis is not to scale.

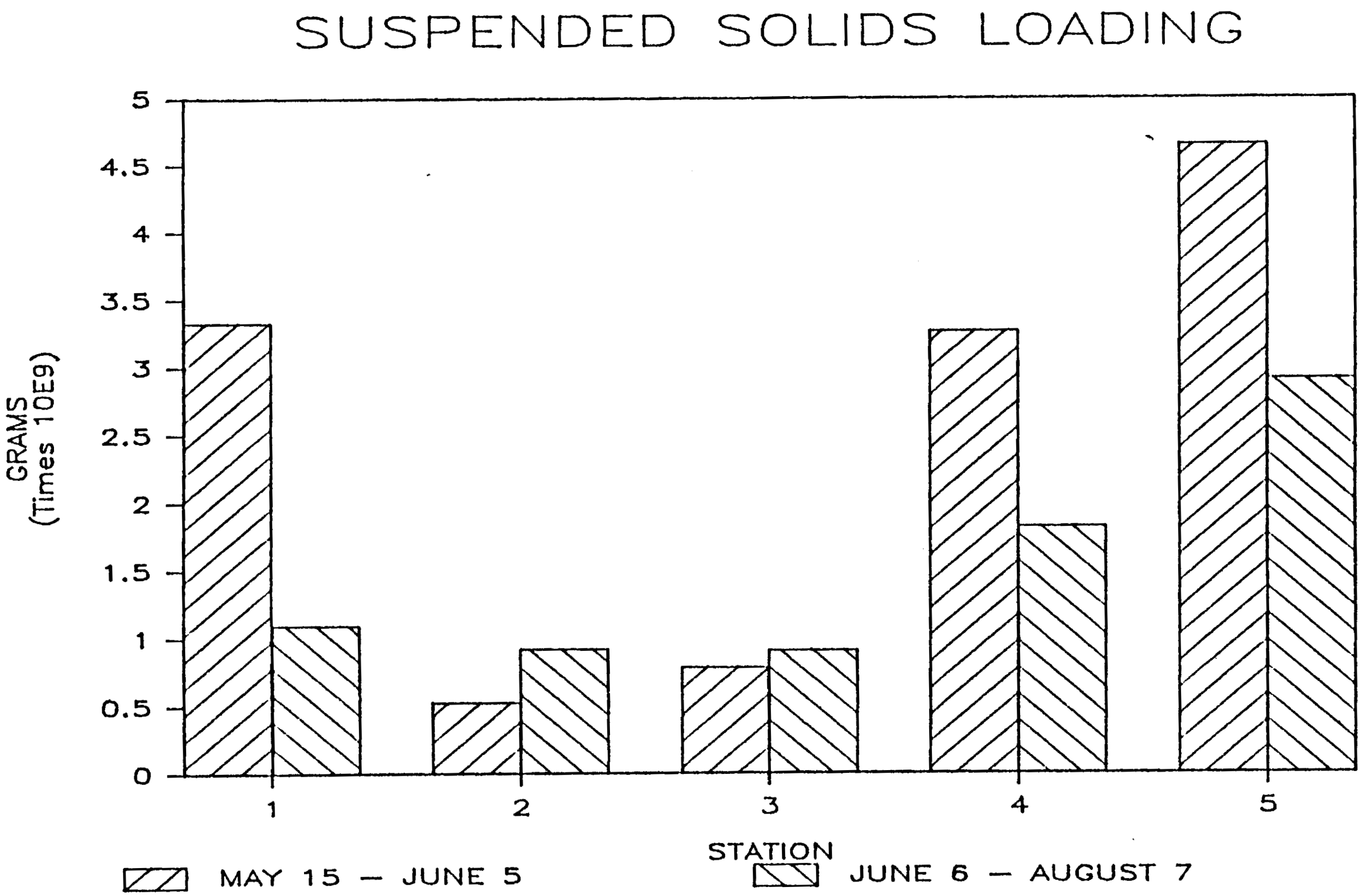

Figure 24: Loads of suspended solids from stations serviced by an automatic water sampler (1-5) for 1984. Values are presented both for spring (May 15-June 5) and summer (June 6-August 7) periods. X axis is not to scale.

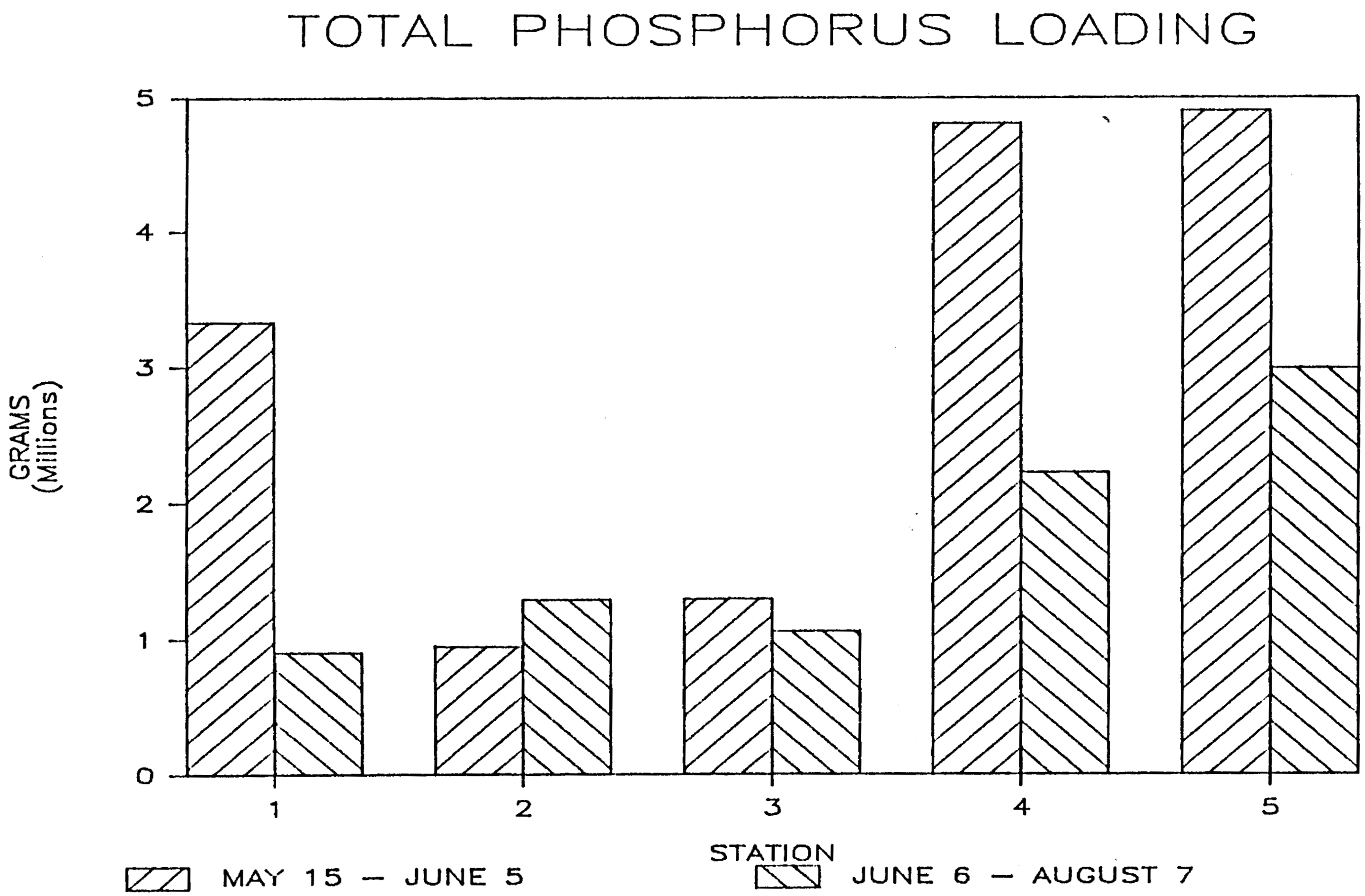

Figure 25: Loads of total phosphorus from stations serviced by an automatic water sampler (1-5) for 1984. Values are presented both for spring (May 15-June 5) and summer (June 6-August 7) periods. X axis is not to scale.

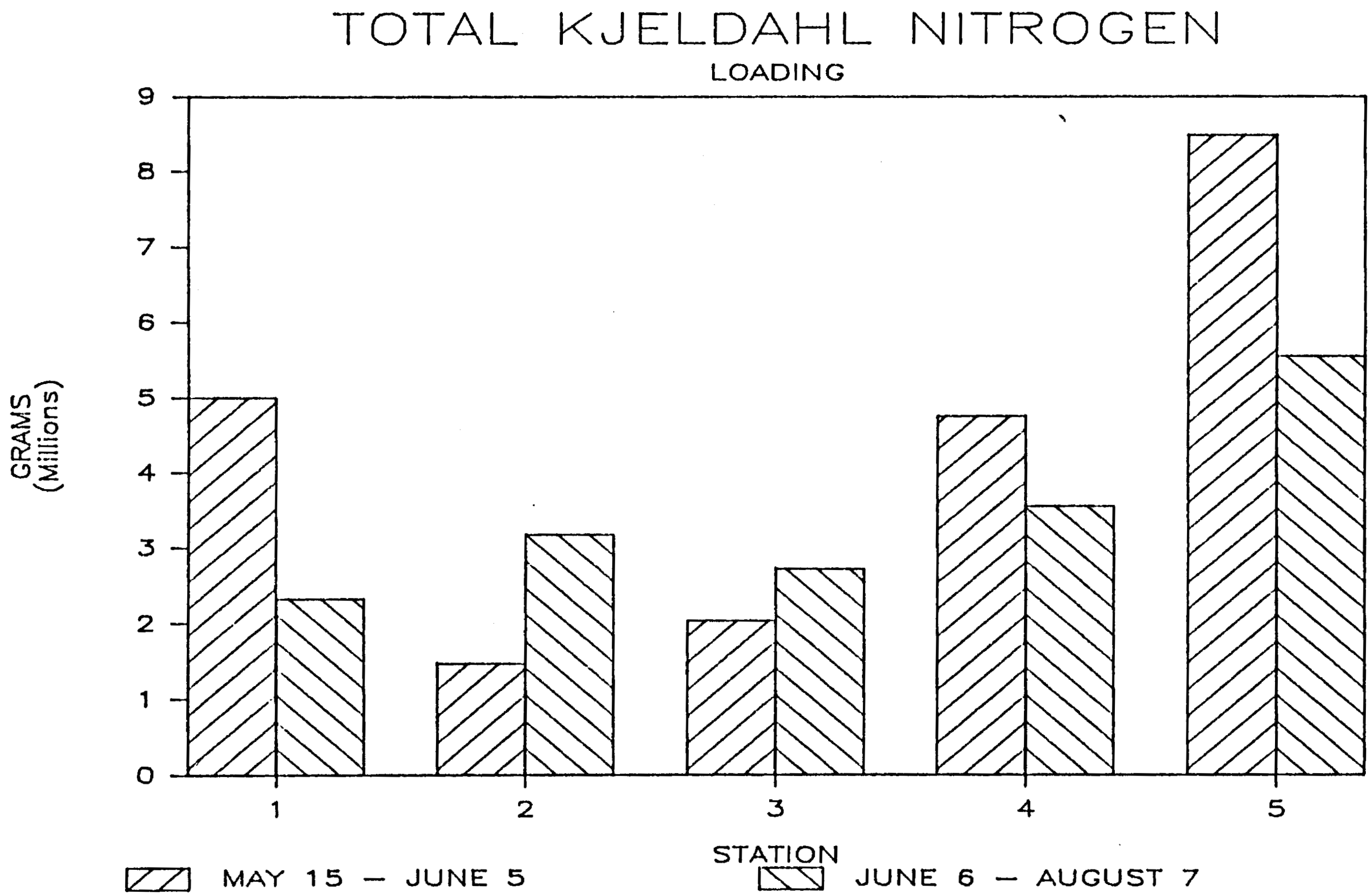

Figure 26: Loads of total Kjeldahl nitrogen from stations serviced by an automatic water sampler (1-5) for 1984. Values are presented both for spring (May 15-June 5) and summer (June 6-August 7) periods. X axis is not to scale.

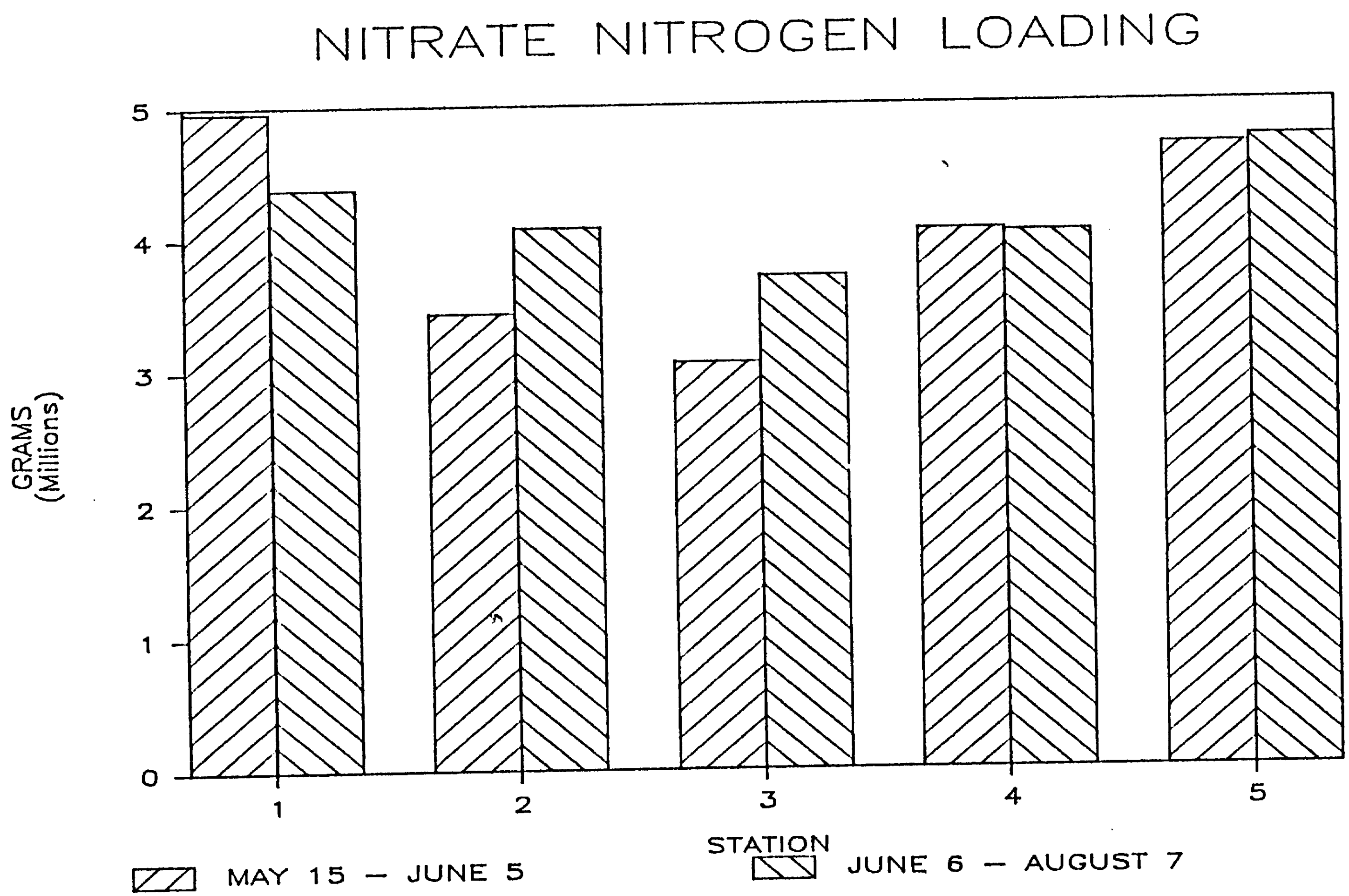

Figure 27: Loads of nitrate nitrogen from stations serviced by an automatic water sampler (1-5) for 1984. Values are presented both for spring (May 15-June 5) and summer (June 6-August 7) periods. X axis is not to scale.

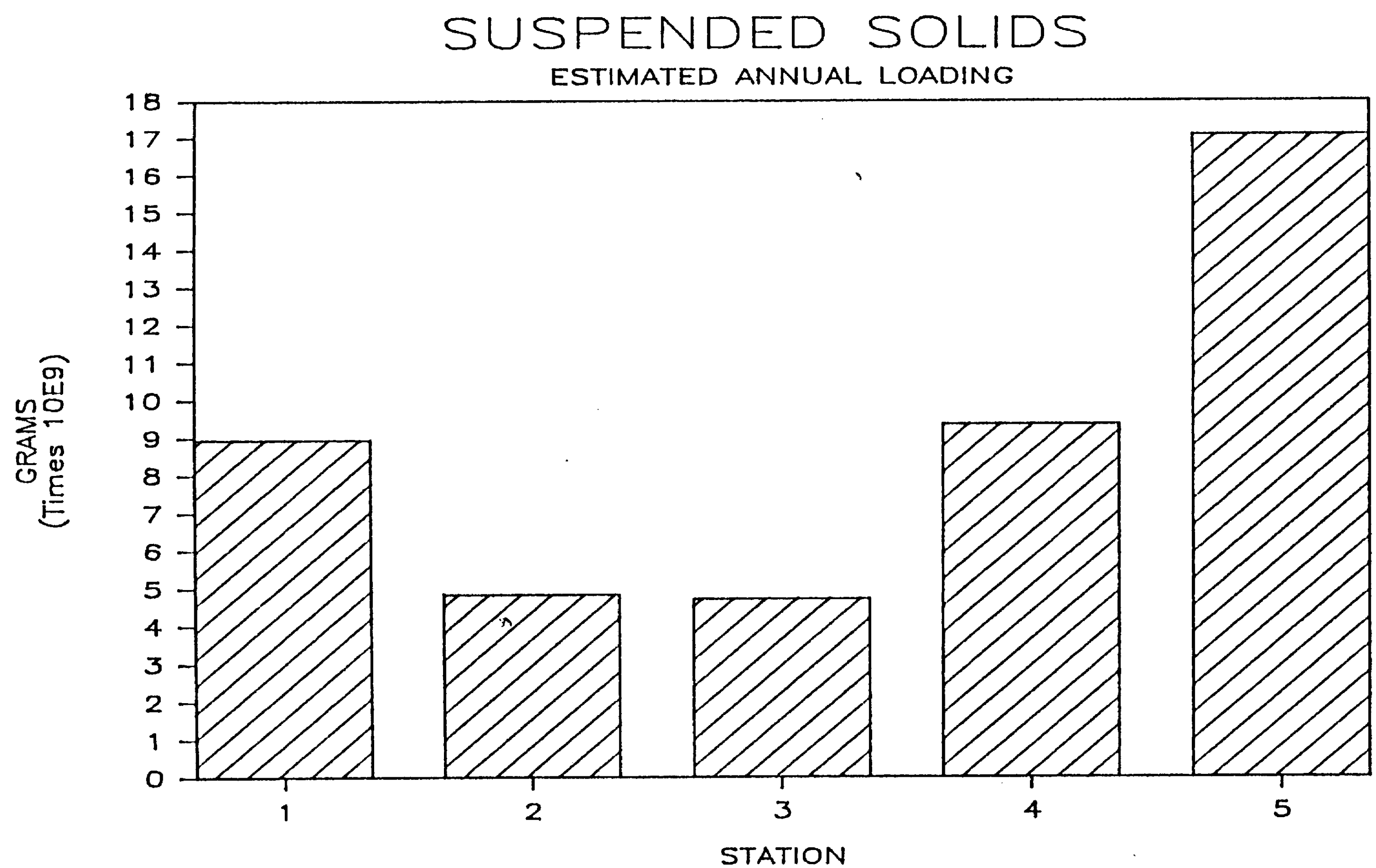

Figure 28: Estimated annual loads (1984) of suspended solids from stations serviced by an automatic water sampler (1-5). X axis is not to scale.

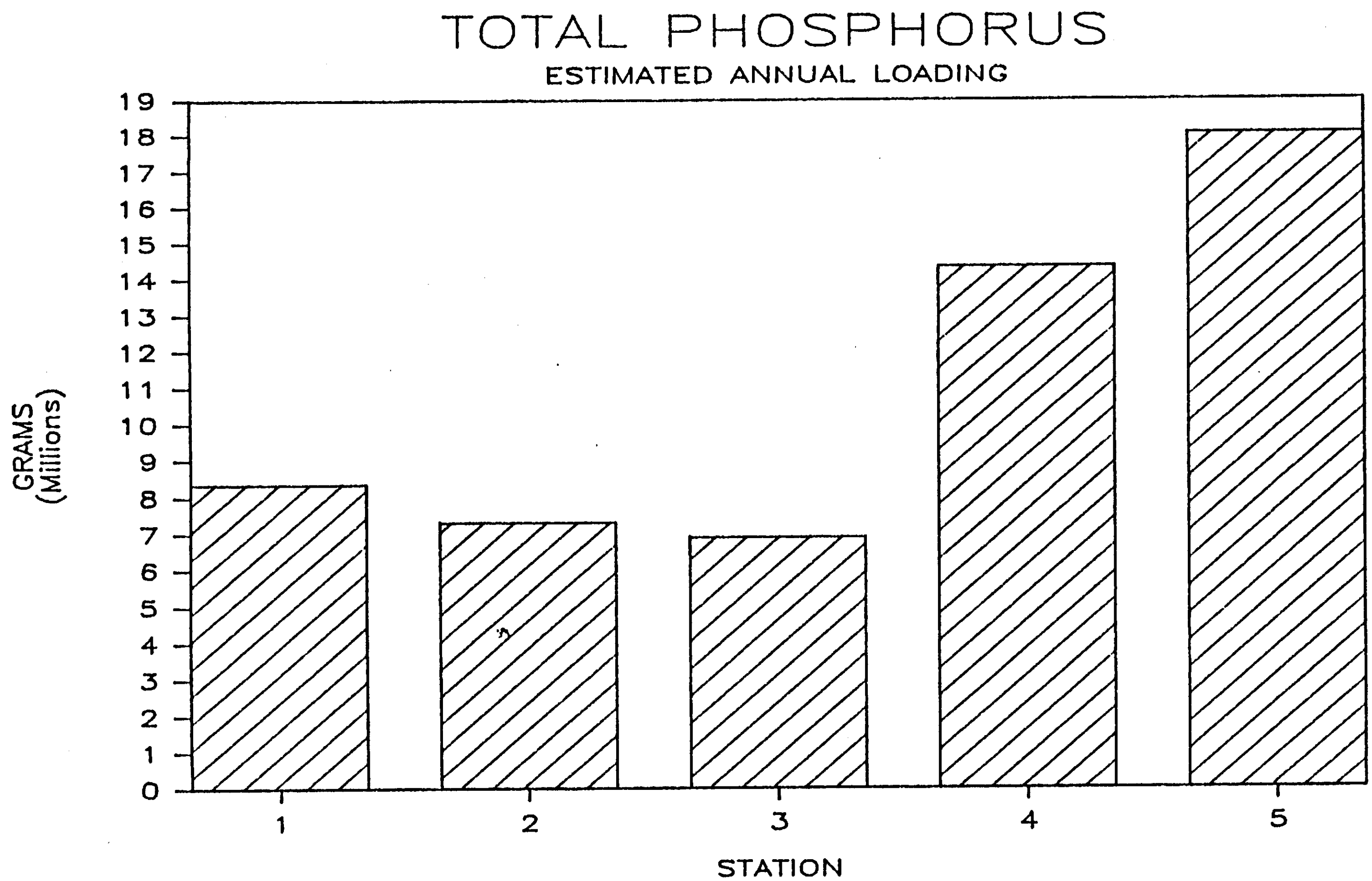

Figure 29: Estimated annual loads (1984) of total phosphorus from stations serviced by an automatic water sampler (1-5). X axis is not to scale.

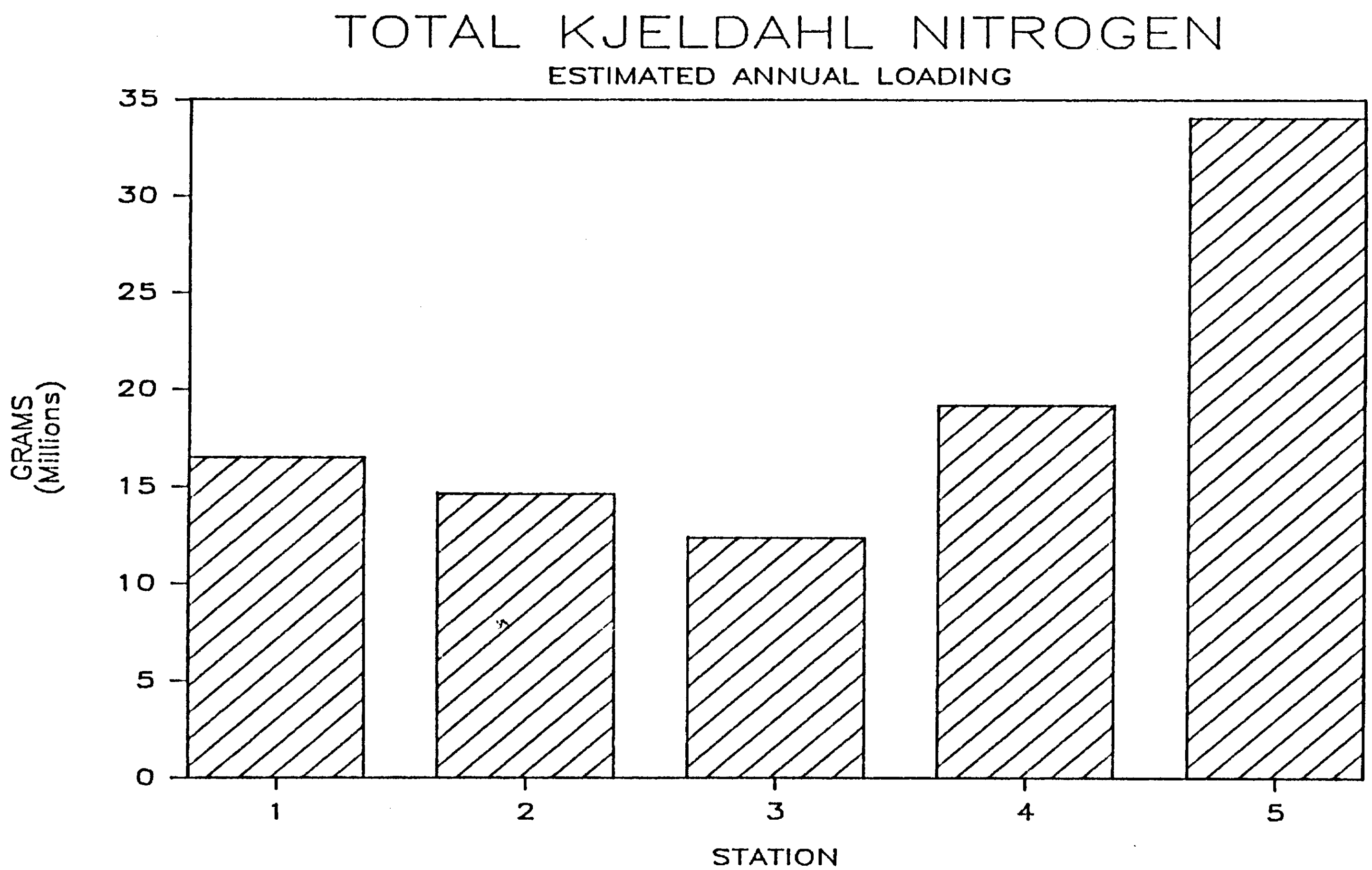

Figure 30: Estimated annual loads (1984) of total Kjeldahl nitrogen from stations serviced by an automatic water sampler (1-5). X axis is not to scale.

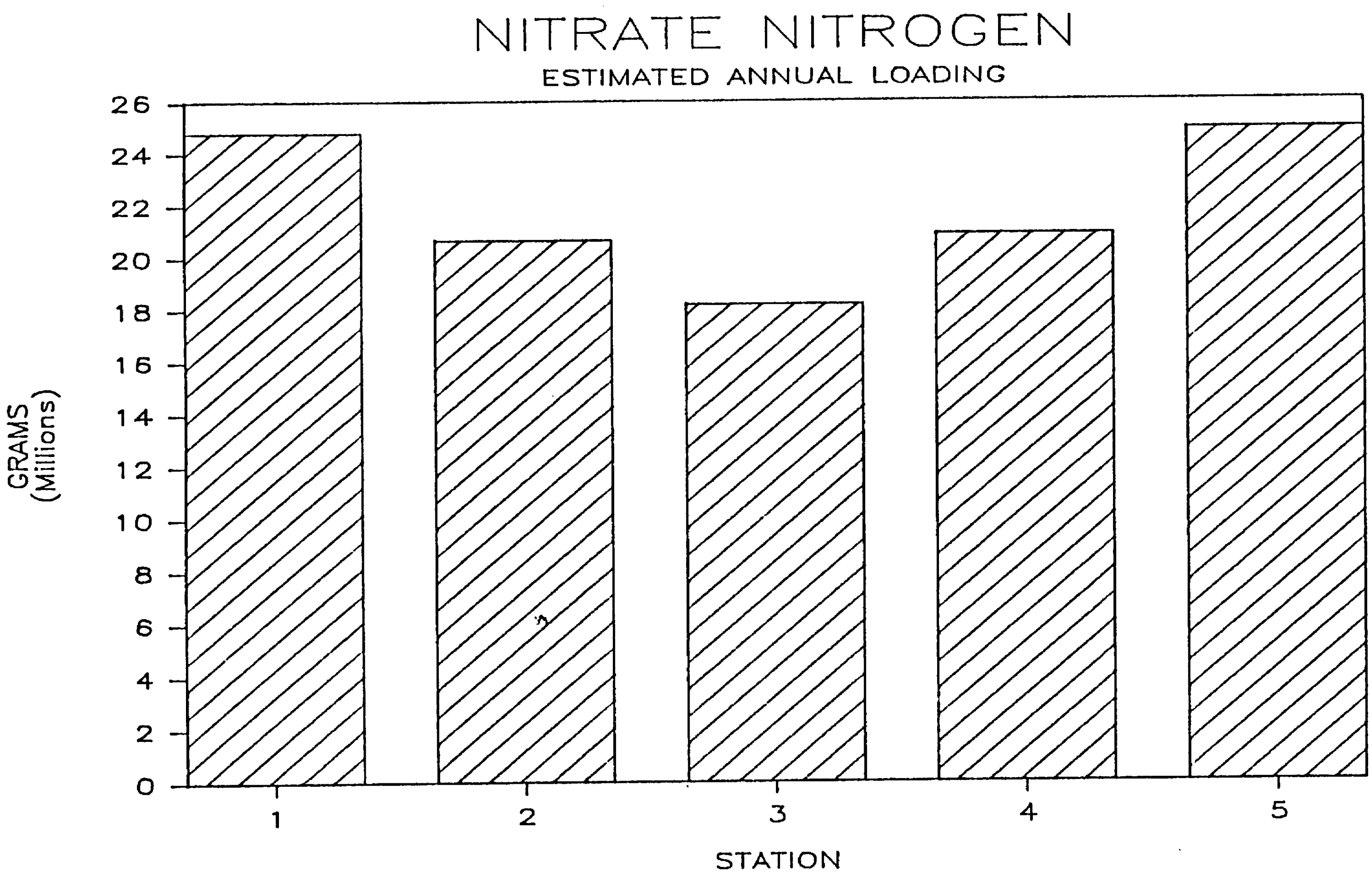

Figure 31: Estimated annual loads (1984) of nitrate nitrogen from stations serviced by an automatic water sampler (1-5). X axis is not to scale.

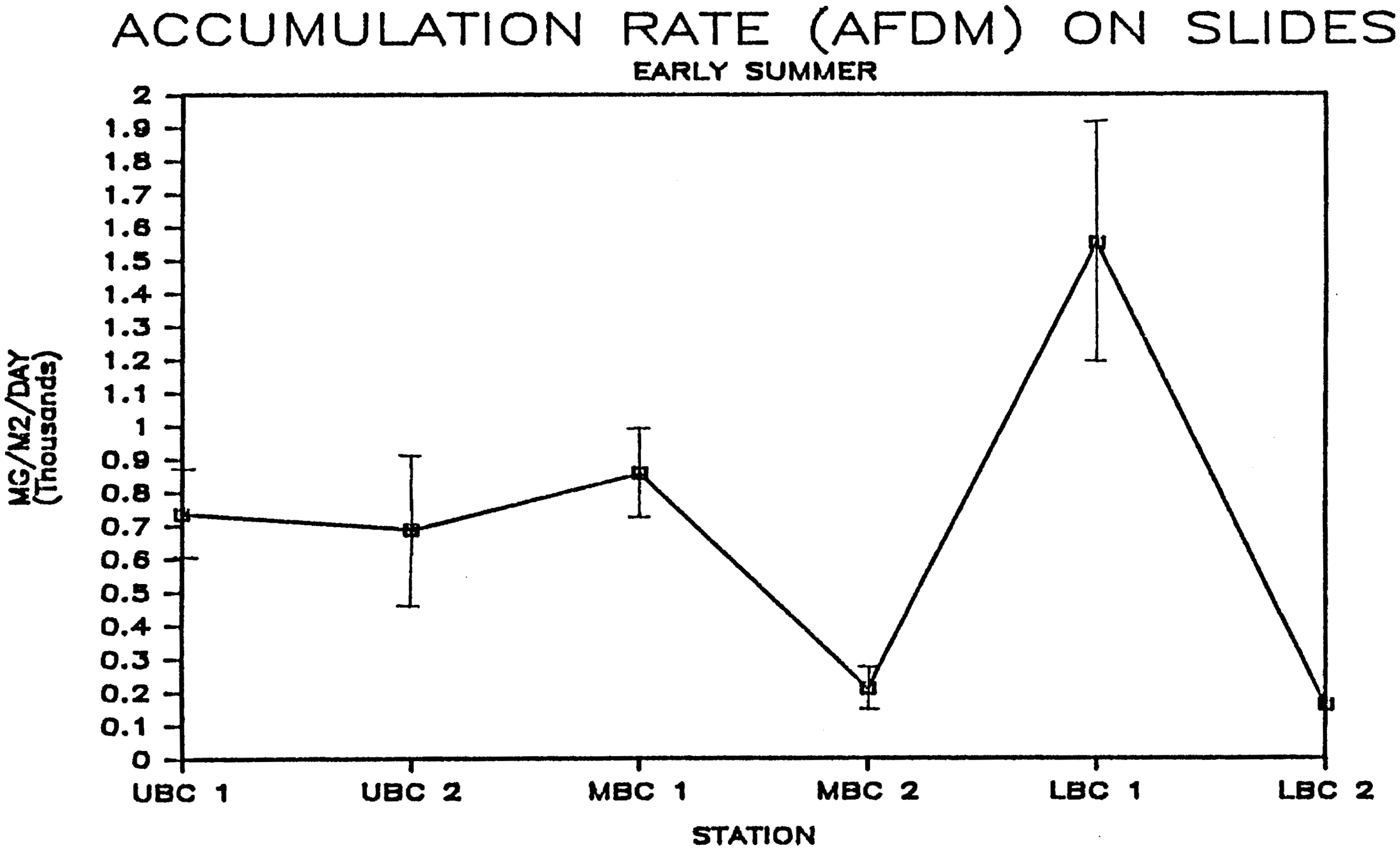

Figure 32: Accumulation rate (mg AFDW/m2/day) for stations in beaver pond complexes. Each point represents an average from 2 analyses performed between July 3 and July 17. Bars represent + or - one standard error. X axis is not to scale.

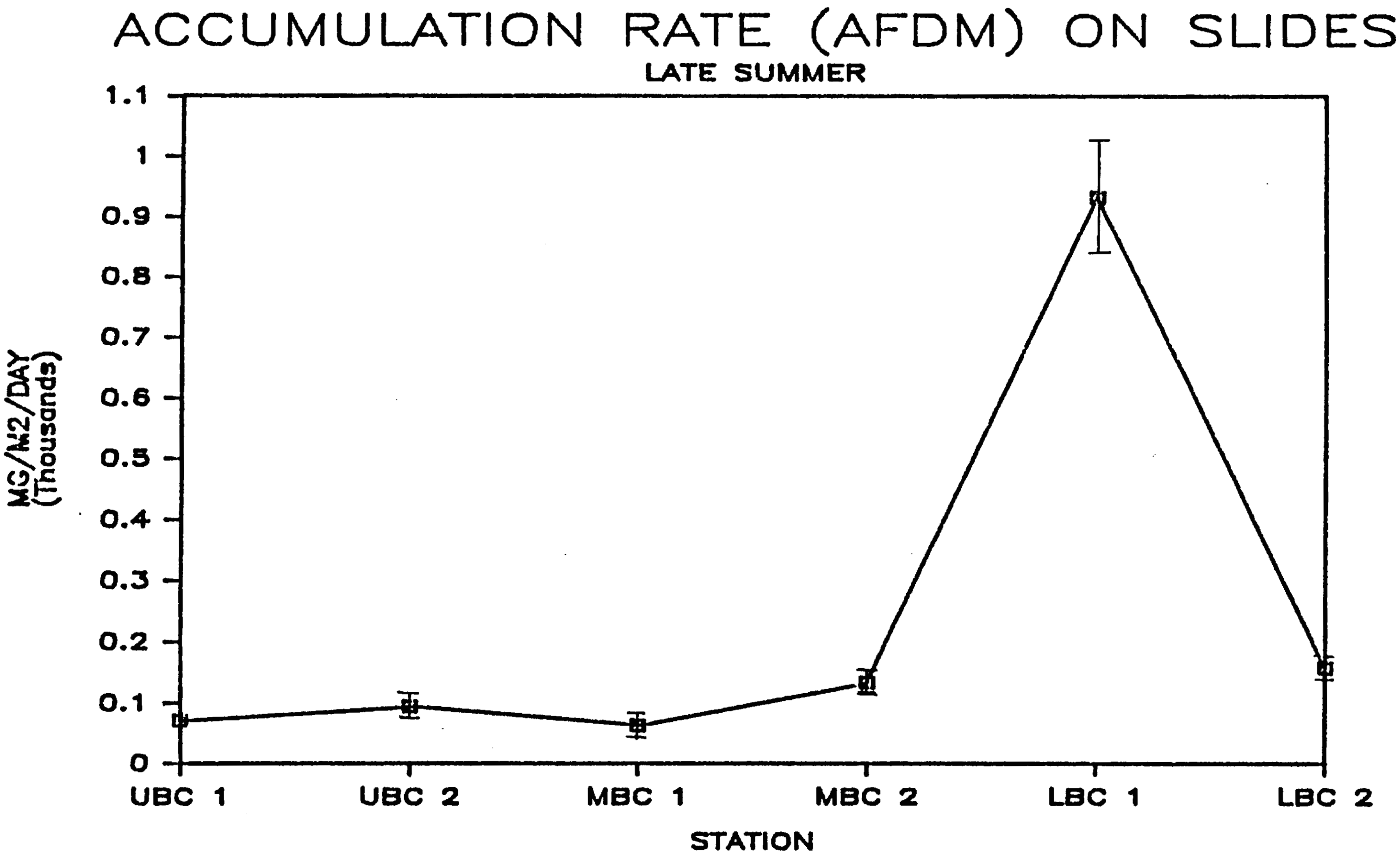

Figure 33: Accumulation rate (mg AFDW/m2/day) for stations in beaver pond complexes. Each point represents an average from six analyses performed between July 24 and August 31. Bars represent + or − one standard error. X axis is not to scale.

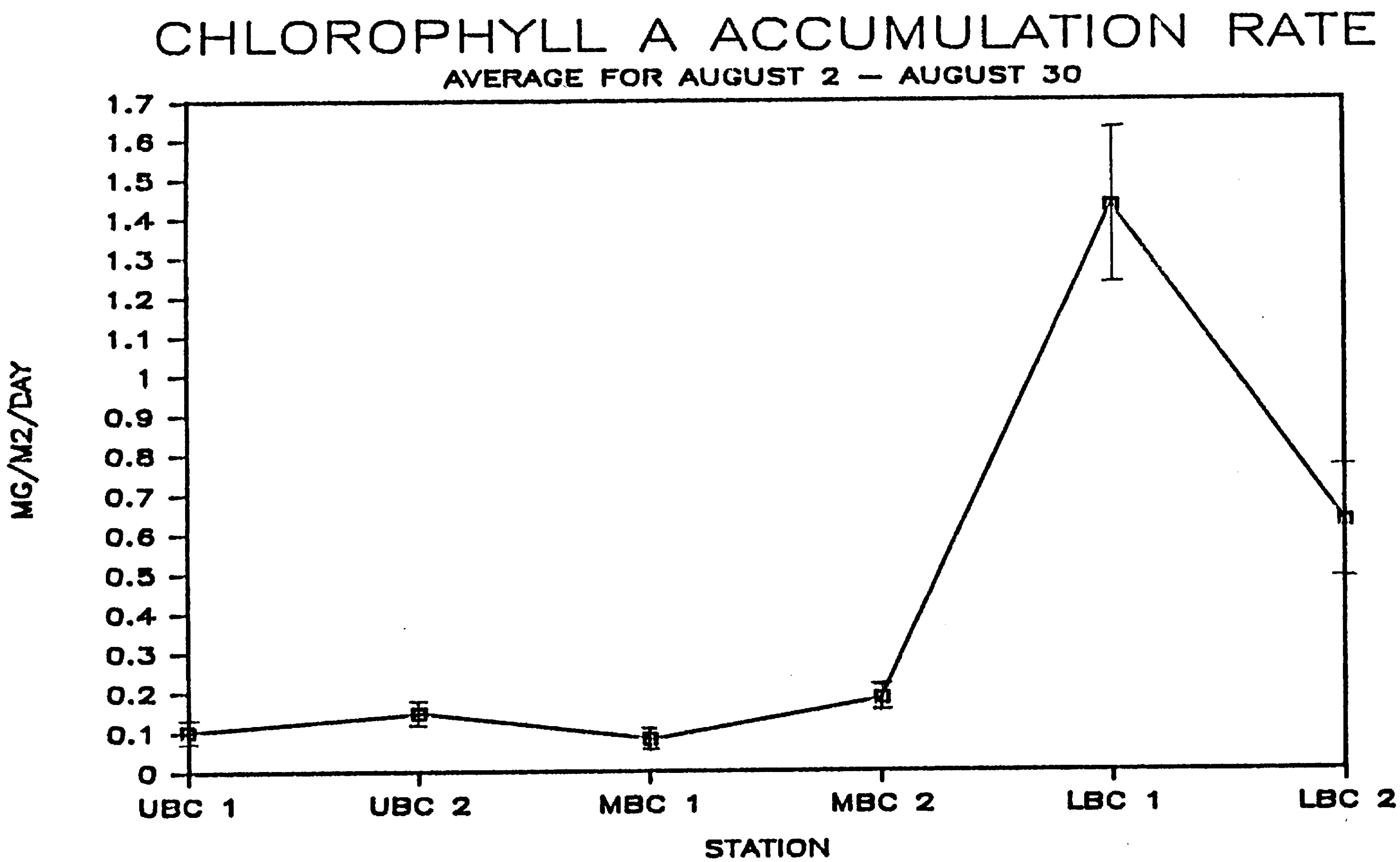

Figure 34: Chlorophyll a accumulation rate (mg/m2/day) for stations in beaver pond complexes. Each point represents an average from four analyses performed between August 2 and August 31. Bars represent + or - one standard error. X axis is not to scale.

CHAPTER V

DISCUSSION

Water Quality and Nutrient Loading

Beaver pond complexes do have a definite effect on water quality in Currant Creek. The effect is much more pronounced during spring runoff, and the trend during runoff in both years will be discussed first. During the 1984 runoff, concentrations of suspended solids, total phosphorus, total Kjeldahl nitrogen, and nitrate are significantly reduced in water flowing through the pond complexes (Figures 2-5). Concentrations of these parameters increase dramatically downstream from the pond complexes. During 1985 runoff, concentrations of suspended solids, total phosphorus and NaOH-extractable phosphorus were significantly reduced in water flowing through the pond complexes, followed by increased concentrations downstream (Figures 7-9). Total Kjeldahl nitrogen and ortho-phosphate demonstrated the same trend (Figures 10, 11), although differences were not statistically significant. Nitrate concentrations were reduced in water flowing through the ponds, as in 1984, but concentrations did not increase considerably downstream (Figure 12).

A proposed reason for these observations is as follows. During runoff, erosion upstream from the pond complexes provides the stream with large amounts of suspended solids. The suspended solids are transported downstream, where they are deposited within the beaver pond complexes. Several factors probably cause this deposition of sediment. Water flowing into the beaver ponds is spread out over a greater area, velocity decreases, and sediments settle out of suspension. Aquatic macrophytes, marsh vegetation, and willow thickets also cause water velocity to decrease, and serve as sediment traps. Thus the fine particulates that typically are transported during high flow events (Meyer and Likens, 1979) are prevented from moving downstream.

Soluble phosphorus and organic nitrogen may sorb strongly to fine clay and organic matter particles (Walter et al., 1979). Because of the deposition of particulates within the ponds, phosphorus and nitrogen concentrations also are reduced in water flowing through the beaver pond complexes.

The increase in concentrations of suspended solids and associated nutrients in water downstream from the beaver pond complexes must be due to stream bank and channel erosion. Downcutting of the stream channel below the pond complexes supports this conclusion. If erosion were occurring primarily in the uplands and the headwater region, an increase in concentrations downstream would not be encountered. Thus, it appears that bank and channel erosion are major sources of suspended solids to the stream. Wilken and Hebel (1982) and Lowham et al. (1982) also found that bank and channel erosion contributed greatly to sediment load in a stream.

Because nitrate is highly soluble and does not sorb readily to sediment particles, a reduction in sediment concentrations should not necessarily lead to a reduction in nitrate concentrations. The primary factor causing the decrease in nitrate concentrations in water flowing through the ponds is probably denitrification within the sediments of the ponds and associated wetlands. Brinson et al. (1981) found that the sediments in riverine swamps play an important role in accumulating nitrate, followed by the conversion of nitrate to nitrogen gas. Riparian vegetation, aquatic macrophytes, and benthic algae also may play a role in removing nitrate from the water. The reason for the increase in concentrations of nitrate downstream from the ponds in 1984 and not in 1985 is not known.

The reason why beaver ponds had no effect on concentrations of NaOH-extractable phosphorus during 1984, but had a very significant effect in 1985 is not understood. There was a very significant relationship between suspended solids and NaOH-extractable phosphorus during spring 1985, but not during spring 1984. A possible reason for the differences between years is the presence of cattle during 1984 but not during 1985. NaOH-extractable phosphorus may consist of both a dissolved and a particulate fraction. If cattle provided a large source of the dissolved fraction during 1984, and if the relative contribution from other sources was small, then variation in the non-bovine source would not have been detected. Since cattle were practically absent in 1985, changes in concentration of the particulate (non-bovine) fraction (due to the deposition within the ponds) would be apparent. The increase in concentration of NaOH-extractable phosphorus downstream from the area with ponds during both years probably is due to stream channel and bank erosion (plus inputs from cattle for 1984).

During the summer, beaver ponds do not improve water quality to the same extent as they do during runoff. This probably occurs for several reasons. The water entering the ponds in the summer carries fewer sediments, and therefore upon slowing down a smaller percentage of its sediment load is deposited. During high flows water is spread out over a large area, but during the lower summer flows it seeks out channels and erodes through previously deposited sediments. Activity by beaver, ducks, and fish stirs up water in the ponds and keeps sediments there in suspension. During higher flows, this stirring up of the sediments is insignificant compared to the large amounts of sediment entering the ponds. Diversion of water for irrigation also may confound the effects of beaver ponds in our study area. The increase in concentrations of suspended solids, total phosphorus, total Kjeldahl nitrogen, and NaOH-extractable phosphorus downstream from the beaver pond complexes (Figures 14-17, 19-23) must be (as during runoff) due to stream bank and channel erosion.

During spring runoff in both years, there was a strong correlation between concentrations of suspended solids and total phosphorus and total Kjeldahl nitrogen. During spring runoff 1985, there was also a strong correlation between suspended solids and NaOH-extractable phosphorus. During both years, as the season progressed the variance in these chemical parameters explained by suspended solids decreased. Both Meyer (1979) and Johnson et al. (1976) report that the sorption of phosphorus to sediments is an equilibrium process and that when concentrations in the surrounding water are lower than in the sediment, phosphorus is released from the sediments. This may explain why the correlation between suspended solids and phosphorus decreases through the summer. That is, as concentrations of phosphorus in the water decrease to lower levels, phosphorus is released into the water. Thus, since sorbed phosphorus is released into solution through the summer, the relationship between suspended solids and phosphorus decreases. If the sorption-desorption of organic nitrogen acts similarly to phosphorus, then the desorption of organic nitrogen from sediment particles during the summer may contribute to the decreased amount of variance in total Kjeldahl nitrogen explained by suspended solids.

During both summers, concentrations of suspended solids and total phosphorus were higher at stream locations than at pond locations just downstream (this was only statistically significant for suspended solids during 1984). This suggests that beaver ponds play some role in trapping sediments even during low summer flows although not to the same extent as during spring runoff. The reason concentrations of total Kjeldahl nitrogen and NaOH-extractable phosphorus are not similarly affected may be due to desorption from sediment particles as concentrations in the water decrease. Since these desorbed nutrients are in solution, they are not trapped within the beaver ponds.

The decrease in concentration of nitrate nitrogen in water flowing through the ponds during both summers should be due to the same causes as during the spring (i.e., denitrification within the sediments and possibly some uptake by marsh and aquatic vegetation).

The decrease in concentrations of various chemical parameters through the summer almost certainly is due to loss of erosive ability of the water during lower flows. As water velocity decreases, so does its ability to erode and carry materials. If bank and channel erosion are the primary sources of these chemical parameters (as discussed earlier), then it would be expected that concentrations would decrease as flow decreased.

The data on nutrient loading (1984) are important in several respects. First, they show that beaver ponds may be important in reducing the downstream export of suspended solids, total phosphorus, total Kjeldahl nitrogen, and nitrate (Figures 24-31). Secondly, they provide insight into the importance of location of the beaver ponds along the stream in improving water quality. Below the pond complexes on Currant Creek, bank and channel erosion apparently contribute markedly to increases in sediment and nutrients. Concentrations in this area equaled or exceeded concentrations in the water upstream from the pond complexes. If water quality is going to be improved downstream, contribution of sediment and nutrients to the stream below the ponds must be minimal. This can occur either if the channel downstream from the ponds is stable, or if the ponds are close to the stream outlet.

The estimated loads (both summer and annual) show that beaver ponds reduce the downstream export of sediment and nutrients (Figures 24-31). Actual values for total loads probably are higher than my estimates because storm events that were not sampled contribute greatly to total loads. However, the relative effect of beaver ponds is underestimated because during the unsampled storm events beaver ponds should play the same important role in trapping sediments and associated nutrients that they play during the higher flows of spring runoff. Meyer and Likens (1979) warn against predicting mass balances from one year of data owing to the variability between years. We feel quite confident that in general sediment and nutrient loads will be reduced by beaver ponds during all years, although actual loads will vary.

The available water quality data from 1985 provide additional insight into the variability of nutrient loads between years and the affect of beaver ponds on these loads. While 1984 was an extremely wet year (both in terms of snow melt and summer rain events), 1985 was quite dry. During both years beaver ponds did reduce sediment and nutrient concentrations. So while exports of sediment and nutrients would be much higher for 1984 than for 1985, beaver ponds should reduce loads during both years.

In addition to collecting sediments and associated nutrients, beaver dams should play an important role in preventing erosion within the stream channel. By reducing the stream gradient, both erosion and sediment transport rates are reduced (Heede, 1978, 1982). With less erosion, the potential for sediment and nutrient transport downstream is decreased.

Another factor determining whether beaver ponds affect water quality in the long run is the stability of the dams and of the collected sediments. If the beaver dams wash out every few years, the sediments and nutrients that were collected in the ponds will be washed downstream. If the dams do not wash out every few years and vegetation has a chance to stabilize the collected sediments, over the long term aggradation will take place and water quality will be improved. The pond complexes in the study area appear to be quite stable, and vegetation is stabilizing the collected sediments. Therefore, on Currant Creek, the beaver ponds do prevent the downstream movement of sediment and associated nutrients.

Periphyton

Productivity:

It is quite evident from the results of the periphyton accumulation studies that different mechanisms are affecting productivity in the stream and pond sections. At the stream locations accumulation rates of both chlorophyll a and organic matter increase downstream as does ortho-phosphate concentration. Ortho-phosphate and NaOH-extractable phosphorus both explain some variance in both chlorophyll a and organic accumulation rates, and therefore may affect productivity. If so, then the forms of phosphorus usable by algae may be limiting growth in the upstream areas, where both productivity and concentrations of these forms of phosphorus are low.

Suspended solids also were important in explaining the variance in accumulation rates at the stream locations. Naiman and Sedell (1980) found that microalgae associated with detritus accounted for up to 45 percent of the chlorophyll in their study streams. If this is the case in Currant Creek, the detrital component of the sediments that collected on the glass slides contribute to chlorophyll a concentrations. The decrease in accumulation rate on the slides noted between early and late summer corresponds to a reduction in suspended solid concentrations due to a reduction in flow.

Several parameters that were not measured may be important in affecting productivity and may account for the unexplained variance in the accumulation rates of chlorophyll a and organic matter. For example, the increase in accumulation rate downstream may be due partially to gradual warming of the water. On August 15 in the early afternoon, water temperature at station 2 was 15°C while the water temperature at station 4 was 17°C. Another factor affecting accumulation may be high flows due to summer rain storms. Tett et al. (1978) and Stockner and Shortreed (1976) both found that high flows encountered during heavy rain storms controlled algal biomass because of the scouring action that occurred. Horner and Welch (1981) reported that elevated flows during storms caused a larger reduction in biomass of the producers in the periphytic community than in the consumers.

Different factors appear to be affecting productivity in the ponds than at stream locations. In ponds there is no increase in the rate of organic accumulation downstream, none of the chemical parameters explained a significant amount of the variance in the rate of organic accumulation, and ortho-phosphate explains only 37 percent of the variance in chlorophyll a accumulation. Increased flows due to storm events should have a minimal effect on accumulation within the ponds. It appears that some unmeasured factor is important in controlling productivity at the pond sites.

We suspect that grazing by snails may be affecting productivity in the ponds. Elwood and Nelson (1972) reported that grazing by herbivores reduced standing crop and productivity of periphyton in their study stream, while Hunter (1979) found that grazing by snails reduced both periphyton productivity and standing crop in ponds. Hunter also noted that grazing by snails increased the ratio of chlorophyll a to dry mass. From a visual examination of the ponds, snails are abundant at the LBC sampling location, present in fewer numbers at the MBC location, and rare at the UBC location. In the LBC pond, small snails often had to be removed from the glass slides when they were collected.

While the rate of organic accumulation is not lower at the locations with more snails and the rate of chlorophyll a accumulation actually shows an increase downstream, there is a very significant increase in percent organic matter for downstream stations. Chlorophyll a explains a significant portion of the variance in percent organic matter. Distance downstream and date both have a negative relationship with the ratio of organic matter to chlorophyll a, and explain a significant portion of the variance in this ratio. Thus, these data indicate that mg chlorophyll a per mg AFDM increases downstream. This increase seems to correspond to an increase in the number of snails.

The high ratio of chlorophyll a to AFDM in the beaver ponds with the most snails suggests that snail grazing may be influencing productivity within these ponds. A possible reason why a corresponding downstream decrease in accumulation rates was not seen is because of the downstream increase in the concentration of ortho-phosphate. The increase in ortho-phosphate concentrations causes an increase in algal growth (as seen at the stream locations), which partially counters the effects of grazing by snails.

Standing Crop:

Before discussing the results for periphyton standing crop, it should be noted that collecting methods are rather crude, and sample sizes were small while variation (for example, among rocks at the same location) was high. Sediment samples were not separated into categories (such as sand, silt, etc.), which according to Tett et al. (1978) should support significantly different standing crops. Substrate composition was estimated by visual examination and only applies to the small area where the samples were collected. Thus, we have the least confidence in the interpretation of the standing crop results.

It appears that algal standing crop at the stream locations is partially influenced by ortho-phosphate and suspended solids, with an increase in standing crop occurring downstream. Ortho-phosphate may influence standing crop at the pond sites, but most of the variance at the pond sites is unexplained. There is no significant change in standing crop through the summer. Elevated flows during storm events may be important in determining standing crop at the stream locations (Tett et al., 1978; Stockner and Shortreed, 1976). After several storm events, it was noted that rocks had been flipped over so that the side covered by algae was on the bottom. Also, the hypothesis that snail grazing is influencing standing crop cannot be rejected with the available data.

Effect of Periphyton on Water Quality:

Both periphyton accumulation rate and standing crop have a negative relationship with nitrate concentration. This relation is significant at both stream and pond sites for accumulation rate, and at stream sites for standing crop. This suggests that periphyton may play some role in reducing the concentration of nitrate in the water. While periphyton productivity may play a minor role in affecting concentrations of nutrients such as ortho-phosphate, the affects of ortho-phosphate on productivity appear to be much more dominant.

Conclusions

Beaver ponds complexes on Currant Creek significantly improve water quality. If beaver ponds are to be used to mitigate water quality pollution, location of the ponds along the stream is important. Although the dominant processes involved appear to be physical in nature, the hypothesis that periphytic algae affect nutrient concentrations cannot be rejected.

This investigation was concerned with only one aspect of beaver ponds: their effect on water quality. The benefits of beaver ponds go far beyond improving water quality and decreasing erosion. Beaver ponds can be important in improving fisheries, increasing the riparian zone, and providing habitat for wildlife. Beaver ponds also have beneficial effects on the hydrology of a stream, as they tend to dissipate peak discharges and increase base flows. The manager may be interested in beaver for a combination of the above reasons.

It is important to note that beaver have been present on Currant Creek historically, and that the ponds studied in this research occurred naturally as the work of native beavers. In the arid west, many formerly "healthy" streams have become severely downcut. These streams provide only marginal beaver habitat at best. Some work has been done with reintroducing beaver into such areas, in hopes that beaver ponds will help restore these streams to their former state. S.B.L.M. in Rock Springs, Wyoming. While these attempts have met with some success, much remains to be learned about establishing beaver colonies along downcut streams. The reintroduction of beaver shows promise both for improving water quality and restoring streams, but it is not a quick and easy solution.

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APPENDICES

APPENDIX A

Methods used in chemical analysis of water samples.

Parameter	Method	Reference
Total Dissolved Solids	Gravimetric-residue upon evaporation at 180°C.	EPA (1983)
Suspended Solids	Total nonfilterable residue dried at 103-105° C.	EPA (1983)
Total Phosphorus	Persulfate digestion, colorimetric-ascorbic acid	EPA (1983)
Ortho-phosphate	Direct colorimetric-ascorbic acid	EPA (1983)
NaOH-extractable Phosphorus	NaOH/NaCl extraction, colorimetric-ascorbic acid	Messer, et al. (1984)
Nitrate	Devarda alloy reduction-distillation and titration	APHA-AWWA-WPCF (1980)
Total Kjeldahl Nitrogen	Distillation-titrimetric	EPA (1983)
Ammonia	Distillation-titrimetric	EPA (1983)
Conductivity	Instrumental-umhos/cm	APHA-AWWA-WPCF (1980)
pH	Instrumental-hydrogen ion electrode	EPA (1983)

APPENDIX B

Chemical data for stations with an automatic water sampler (1984).

DAY OF STUDY		1	8	15	22	29	36	43	50	64	71	78
DATE OF SAMPLE		522	529	605	612	619	626	703	710	724	731	807
CONDUCTIVITY	1	650	600	700	670	550	520	540	590	560	590	550
uMHOS/CM2	2	610	650	700	670	580	590	610	625	590	650	640
	3	650	650	800	670	590	640		660	610	700	680
	4	650	680	800	720	600	600	610	650	610	700	700
	5	650	660	800	720	600	600	610	650	630	710	700
TOTAL	1	520	500	472	456	480	512	368	408	464	420	460
DISSOLVED	2	520	510	460	480	492	528	464	476	532	460	536
SOLIDS	3	530	520	472	456	528	536		468	540	476	564
MG/L	4	540	520	488	484	548	476	440	524	488	480	664
	5	540	540	476	488	544	548	432	500	492	492	584
SUSPENDED	1	980	3250	1100		290	290	580				190
SOLIDS	2	200	340	320	220	350	300	340	432	206	472	515
MG/L	3	480	410	370	200	670	250		174	302	572	281
	4	2580	1530	990	950		410	200	168	2110	184	266
	5	3060	1940	2400		1150	1885	1000	188	880	296	432
TOTAL	1	1.400	3.200	0.660		0.270	0.370	0.390				0.198
PHOSPHORUS	2	0.250	0.500	0.820	0.500	0.150	0.400	0.525	0.655	0.345	0.620	0.918
MG/L	3	0.800	0.670	0.600	0.300	0.200	0.400		0.300	0.533	0.640	0.836
	4	3.700	2.500	1.300	1.200		0.570	0.280	0.240	2.250	0.240	0.312
	5	2.000	3.300	2.600		0.450	1.100	1.520	1.320	1.370	0.260	0.548
ORTHO-	1	0.040	0.060		0.020		0.020	0.020	0.010	0.012	0.021	0.005
PHOSPHORUS	2	0.020	0.020		0.020		0.030	0.030	0.020	0.008	0.037	0.027
MG/L	3	0.020	0.040		0.020		0.030		0.030	0.029	0.048	0.029
	4	0.020	0.030		0.090		0.030	0.010	0.030	0.025	0.049	0.028
	5	0.020	0.070		0.040		0.030	0.060	0.030	0.026	0.046	0.029
NaOH-	1	0.010	0.040	0.040	0.010	0.010	0.010	0.020	0.010	0.005	0.010	0.004
EXTRACTABLE	2	0.010	0.010	0.100	0.010	0.020	0.020	0.020	0.050	0.011	0.043	0.022
PHOSPHORUS	3	0.010	0.010	0.090	0.020	0.050	0.020		0.030	0.015	0.036	0.021
MG/L	4	0.030	0.010	0.150	0.050	0.020	0.020	0.020	0.020	0.028	0.015	0.013
	5	0.050	0.030	0.280	0.220	0.060	0.030	0.020	0.060	0.027	0.018	0.018

APPENDIX B (Continued)

DAY OF STUDY		1	8	15	22	29	36	43	50	64	71	78
DATE OF SAMPLE		522	529	605	612	619	626	703	710	724	731	807
TOTAL	1	1.73	4.40	1.89		0.77	0.77	0.90				0.53
KJELDAHL	2	0.63	0.90	0.86	0.33	0.86	0.88	1.44	2.60	0.84	0.99	1.40
NITROGEN	3	1.24	1.10	0.92	0.20	2.46	0.60		0.76	1.10	1.10	0.57
MG/L	4	3.80	2.30	1.33	0.99		1.00	0.46	0.84	4.60	0.70	0.77
	5	4.30	5.60	3.64		2.53	1.60	1.75	1.80	1.80	0.81	1.10
NITRATE	1	2.50	2.50	3.00	2.20	2.00	1.50	1.20	1.30	1.30	1.20	1.20
NITROGEN	2	1.60	1.50	2.50	1.70	2.00	1.30	1.60	1.20	1.20	1.20	0.94
MG/L	3	1.30	1.40	2.30	1.90	1.80	1.30		0.97	1.00	1.00	0.87
	4	2.70	1.20	2.60	2.40	1.90	1.30	1.00	1.20	0.94	1.00	0.83
	5	2.10	2.30	3.20	1.90	2.10	1.30	3.00	1.10	1.70	1.00	0.83
AMMONIA	1	0.03	0.01	0.01	0.03	0.03	0.05	0.05	0.05	0.05	0.05	0.05
MG/L	2	0.02	0.03	0.01	0.03	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	3	0.03	0.02	0.01	0.05	0.03	0.05		0.05	0.05	0.05	0.05
	4	0.01	0.02	0.02	0.03	0.02	0.05	0.05	0.05	0.05	0.05	0.05
	5	0.03		0.02	0.03	0.05	0.05	0.05	0.05	0.05	0.05	0.05
pH	1	8.01	8.07	8.16	7.95	8.15	8.28	7.94	8.22	8.17	8.22	8.62
	2	8.32	8.16	8.43	8.07	8.36	8.21	8.14	8.02	8.21	8.27	8.58
	3	8.09	8.30	8.48	8.04	8.32	8.24		8.24	8.28	8.27	8.45
	4	8.12	8.19	8.28	8.01	8.29	8.19	7.96	8.14	8.36	8.33	8.52
	5	8.06	8.04	8.34	8.01	8.32	8.17	8.04	8.12	8.32	8.37	8.51
VOLUME	1		37.9	31.4	27.6	28.7	23.6	17.7	14.2	10.0	11.9	9.2
DISCHARGE	2		35.2	28.9	27.3	28.3	17.6	19.1	16.5	10.5	10.6	10.9
CFS	3		37.1	35.0	29.9	28.7	22.1	16.7	17.6	14.5	13.0	9.3
	4		36.7	37.1	27.4	29.1	21.1	21.7	19.6	16.4	14.1	10.4

APPENDIX C

Chemical data for stations in beaver pond complexes (grab samples only, 1984).

DAY OF STUDY		43	50	64	71	78	93	101	122	138
DATE OF SAMPLE		703	710	724	731	807	822	830	920	1006
CONDUCTIVITY	UBC 1	560	590	550	560	570				
uMHOS/CM2	UBC 2	580	720	560	670	610				
	MBC 1	590	610	570	620	610				
	MBC 2	580	610	580	610	610				
	LBC 1	620	660	590	670	680				
	LBC 2	840	700	630	920	830				
TOTAL	UBC 1	380	400	416	397	492				
DISSOLVED	UBC 2	388	516	416	444	556				
SOLIDS	MBC 1	368	448	412	400	508				
MG/L	MBC 2	480	428	440	412	504				
	LBC 1	492	436	456	456	540				
	LBC 2	692	480	468	656	720				
SUSPENDED	UBC 1	100	55	74	78	73	74	33	29	19
SOLIDS	UBC 2	93	23	42	35	29	42	22	46	5
MG/L	MBC 1	91	60	64	74	50	62	28	22	4
	MBC 2	68	29	44	90	156	105	82	30	15
	LBC 1	97	64	100	162	221	145	87	35	16
	LBC 2	10	24	88	18	51	54	43	22	12
TOTAL	UBC 1	0.470	0.125	0.127	0.180	0.078	0.289	0.055	0.055	0.068
PHOSPHORUS	UBC 2	0.470	0.035	0.105	0.120	0.050	0.100	0.054	0.083	0.038
MG/L	MBC 1	0.520	0.075	0.125	0.190	0.079	0.108	0.058	0.047	0.036
	MBC 2	0.500	0.110	0.127	0.260	0.109	0.167	0.128	0.077	0.050
	LBC 1	0.460	0.160	0.233	0.450	0.287	0.228	0.153	0.110	0.063
	LBC 2	0.280	0.168	0.263	0.130	0.116	0.138	0.105	0.072	0.052
ORTHO-	UBC 1	0.030	0.030	0.017	0.014	0.017	0.015	0.009	0.010	0.015
PHOSPHORUS	UBC 2	0.030	0.020	0.014	0.019	0.020	0.018	0.011	0.014	0.008
MG/L	MBC 1	0.030	0.010	0.016	0.021	0.023	0.016	0.011	0.011	0.008
	MBC 2	0.030	0.020	0.021	0.031	0.022	0.023	0.014	0.016	0.012
	LBC 1	0.030	0.030	0.030	0.044	0.027	0.027	0.026	0.040	0.021
	LBC 2	0.020	0.030	0.029	0.017	0.014	0.030	0.025	0.017	0.013

APPENDIX C (Continued)

DAY OF STUDY		43	50	64	71	78	93	101	122	138
DATE OF SAMPLE		703	710	724	731	807	822	830	920	1006
NaOH-	UBC 1	0.010	0.020	0.008	0.007	0.006	0.005	0.005	0.001	0.001
EXTRACTABLE	UBC 2	0.020	0.020	0.015	0.010	0.007	0.005	0.005	0.001	0.001
PHOSPHORUS	MBC 1	0.030	0.030	0.005	0.006	0.007	0.005	0.005	0.001	0.002
MG/L	MBC 2	0.020	0.020	0.005	0.013	0.008	0.005	0.005	0.004	0.001
	LBC 1	0.030	0.030	0.010	0.014	0.016	0.005	0.005	0.003	0.001
	LBC 2	0.020	0.050	0.008	0.008	0.010	0.005	0.005	0.001	0.001
TOTAL	UBC 1	0.15	0.15	0.34	0.35	0.25	0.27	0.35	0.02	0.19
KJELDAHL	UBC 2	0.22	0.15	0.25	0.31	0.22	0.23	0.27	0.01	0.18
NITROGEN	MBC 1	0.28	0.10	0.35	0.38	0.24	0.25	0.16	0.08	0.18
MG/L	MBC 2	0.18	0.21	0.30	0.46	0.32	0.41	0.18	0.29	0.23
	LBC 1	0.53	0.27	0.50	0.63	0.67	0.43	0.47	0.27	0.31
	LBC 2	0.17	0.10	0.55	0.71	0.45	0.37	0.46	0.23	0.27
NITRATE	UBC 1	1.30	1.30	2.00	1.10	1.00	1.07	1.03	0.90	1.20
NITROGEN	UBC 2	1.40	1.80	1.30	1.40	1.30	1.31	1.19	1.10	0.88
MG/L	MBC 1	1.10	1.50	0.34	1.20	1.10	1.03	1.09	0.88	1.00
	MBC 2	1.20	1.40	1.30	1.20	0.98	0.98	0.98	0.90	0.76
	LBC 1	1.20	1.20	1.40	1.10	1.00	0.98	0.98	0.59	0.45
	LBC 2	0.90	1.00	1.20	0.43	0.58	0.78	0.82	0.35	0.25
AMMONIA	UBC 1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MG/L	UBC 2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	MBC 1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	MBC 2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	LBC 1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	LBC 2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
pH	UBC 1	8.15	8.20	8.20	8.21	8.46				
	UBC 2	8.14	8.04	8.20	8.08	8.31				
	MBC 1	8.12	8.26	8.20	8.24	8.42				
	MBC 2	8.13	8.27	8.22	8.28	8.42				
	LBC 1	8.23	8.18	8.17	8.22	8.45				
	LBC 2	8.08	8.11	8.18	7.96	8.03				
VOLUME	UBC 1	17.4	13.6	11.2	8.4	9.0	8.3	6.3	5.0	5.4
DISCHARGE	MBC 1	19.9	20.8	11.8	11.5	8.6	7.6	6.1	5.4	5.5
CFS										

APPENDIX D

Chemical data for stations 1 through 4 (grab samples only, 1985).

DAY OF STUDY		1	9	17	21	28	35	42	49	56	63	71	79
DATE OF SAMPLE		402	410	418	422	429	506	513	520	527	603	611	619
SUSPENDED	1	5550	968	594	310	348	398	410	252	206	100	54	88
SOLIDS	2	276	368	236	156	129	258	109	69	124	46	48	62
MG/L	3	536	516	266	154	102	108	127	86	112	60	66	162
	4	3060	1510	2660	1210	710	830	596	583	396	252	112	130
TOTAL	1	9.00	1.20	0.78	0.38	0.40	0.36	0.37	0.19	0.18	0.11	0.08	0.10
PHOSPHORUS	2	0.47	0.63	0.37	0.25	0.20	0.26	0.14	0.10	0.11	0.07	0.08	0.09
MG/L	3	0.74	0.87	0.40	0.24	0.16	0.14	0.16	0.11	0.15	0.10	0.10	0.15
	4	3.20	2.00	2.50	1.20	0.13	0.58	0.47	0.35	0.34	0.27	0.15	0.15
ORTHO-	1	0.110	0.031	0.023	0.024	0.025	0.014	0.014	0.009	0.006	0.005	0.016	0.005
PHOSPHATE	2	0.041	0.033	0.031	0.023	0.021	0.015	0.013	0.008	0.011	0.005	0.010	0.011
MG/L	3	0.043	0.035	0.033	0.024	0.015	0.008	0.012	0.006	0.009	0.004	0.009	0.009
	4	0.035	0.038	0.043	0.026	0.026	0.016	0.018	0.014	0.010	0.002	0.008	0.004
NaOH-	1	0.076	0.016	0.009	0.006	0.007	0.008	0.009	0.007	0.003	0.003	0.001	0.004
EXTRACTABLE	2	0.007	0.008	0.004	0.005	0.004	0.005	0.003	0.006	0.003	0.003	0.001	0.006
PHOSPHORUS	3	0.011	0.011	0.006	0.007	0.003	0.004	0.003	0.006	0.004	0.003	0.002	0.008
MG/L	4	0.041	0.017	0.030	0.022	0.013	0.011	0.012	0.011	0.008	0.006	0.003	0.004

APPENDIX D (Continued)

DAY OF STUDY		1	9	17	21	28	35	42	49	56	63	71	79
DATE OF SAMPLE		402	410	418	422	429	506	513	520	527	603	611	619
TOTAL	1	15.00	2.30	1.40	0.86	0.70	1.10	0.91	0.62	0.45	0.45	0.23	0.39
KJELDAHL	2	1.00	0.93	0.70	0.31	0.48		0.49	0.35	0.37	0.37	0.39	0.39
NITROGEN	3	1.40	1.60	1.00	0.73	0.54	0.62	0.54	0.47	0.45	0.45	0.45	0.43
MG/L	4	4.00	2.40	2.90	1.70	1.30	1.30	0.83	0.85	0.68	0.82	0.55	0.58
NITRATE	1	0.43	0.86	0.92	0.97	0.90	0.85	0.78	0.60	0.68	0.56	0.66	0.74
NITROGEN	2	0.70	0.79	0.75	0.92	0.82	0.8	0.74	0.43	0.62	0.43	0.29	0.39
MG/L	3	0.50	0.65	0.62	0.70	0.51	0.43	0.54	0.17	0.18	0.21	0.21	0.19
	4	0.54	0.70	0.77	0.79	0.57	0.43	0.47	0.21	0.16	0.19	0.10	0.18
AMMONIA	1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MG/L	2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	3	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
VOLUME	1	18.3	6.9	7.0	8.0	6.9	7.2	7.1	8.3	7.3	6.3	6.0	4.0
DISCHARGE	3	7.1	9.0	8.0	8.2	8.1	8.1	9.2	6.8	5.6	6.9	4.9	3.8
CFS	4	9.7	9.0	8.3	8.2	9.3	5.7	8.9	6.2	7.1	7.5	8.9	2.5

APPENDIX E

Chemical data for stations in beaver pond complexes (grab samples only, 1985).

DAY OF STUDY		1	9	17	21	28	35	42	49	56	63	71	79
DATE OF SAMPLE		402	410	418	422	429	506	513	520	527	603	611	619
SUSPENDED	UBC 1	5550	968	594	310	348	398	410	252	206	100	54	88
SOLIDS	UBC 2	2600	528	294	190	274	1630	562	302	188	158	60	54
MG/L	MBC 1	3880	592	398	219	258	418	286	175	122	80	32	34
	MBC 2	1650	360	270	158	148	232	158	58	88	72	50	66
	LBC 1	284	756	198	134	150	328	104	75	88	164	114	102
	LBC 2	248	564	104	132	74	128	50	46	70	24	18	70
TOTAL	UBC 1	9.00	1.20	0.78	0.38	0.40	0.36	0.37	0.19	0.18	0.11	0.08	0.10
PHOSPHORUS	UBC 2	3.30	0.72	0.39	0.24	0.34	1.60	0.49	0.30	0.18	0.17	0.08	0.07
MG/L	MBC 1	5.80	0.86	0.51	0.30	0.34	0.43	0.29	0.19	0.12	0.11	0.06	0.05
	MBC 2	2.30	0.67	0.40	0.20	0.23	0.29	0.18	0.09	0.10	0.11	0.09	0.09
	LBC 1	0.50	1.10	0.34	0.22	0.24	0.61	0.14	0.12	0.13	0.21	0.17	0.13
	LBC 2	0.48	0.96	0.23	0.24	0.16	0.18	0.10	0.10	0.12	0.07	0.07	0.12
ORTHO-	UBC 1	0.110	0.031	0.023	0.024	0.025	0.014	0.014	0.009	0.006	0.005	0.016	0.005
PHOSPHATE	UBC 2	0.110	0.030	0.026	0.023	0.025	0.010	0.016	0.009	0.007	0.005	0.014	0.007
MG/L	MBC 1	0.110	0.031	0.024	0.022	0.021	0.016	0.016	0.011	0.008	0.005	0.010	0.007
	MBC 2	0.070	0.031	0.026	0.026	0.019	0.013	0.014	0.007	0.008	0.008	0.017	0.012
	LBC 1	0.044	0.037	0.028	0.026	0.022	0.024	0.013	0.011	0.013	0.014	0.017	0.011
	LBC 2	0.045	0.037	0.033	0.026	0.019	0.013	0.016	0.008	0.016	0.006	0.013	0.014
NaOH-	UBC 1	0.076	0.016	0.009	0.006	0.007	0.008	0.009	0.007	0.003	0.003	0.001	0.004
EXTRACTABLE	UBC 2	0.061	0.009	0.005	0.005	0.004	0.028	0.013	0.012	0.005	0.004	0.001	0.007
PHOSPHORUS	MBC 1	0.074	0.010	0.006	0.005	0.008	0.009	0.013	0.007	0.003	0.003	0.001	0.001
MG/L	MBC 2	0.051	0.010	0.006	0.004	0.003	0.006	0.005	0.003	0.003	0.004	0.002	0.005
	LBC 1	0.010	0.024	0.004	0.003	0.006	0.015	0.004	0.006	0.003	0.006	0.003	0.007
	LBC 2	0.007	0.016	0.004	0.006	0.006	0.005	0.003	0.006	0.004	0.003	0.003	0.008

APPENDIX E (Continued)

DAY OF STUDY		1	9	17	21	28	35	42	49	56	63	71	79
DATE OF SAMPLE		402	410	418	422	429	506	513	520	527	603	611	619
TOTAL	UBC 1	15.00	2.30	1.40	0.86	0.70	1.10	0.91	0.62	0.45	0.45	0.23	0.39
KJELDAHL	UBC 2	5.40	1.30	0.82	0.53	0.74	4.70	1.10	0.70	0.44	0.48	0.35	0.28
NITROGEN	MBC 1	8.50	1.30	0.86	0.75	0.73	1.00	0.62	0.50	0.35	0.35	0.35	0.25
MG/L	MBC 2	3.80	1.20	0.79	0.29	0.62	0.70	0.33	0.35	0.35	0.35	0.60	0.33
	LBC 1	1.00	1.80	0.66	0.70	0.53	1.00	0.19	0.38	0.37	0.50	0.45	0.43
	LBC 2	1.00	0.55	0.64	0.64	0.51	0.45	0.35	0.47	0.41	0.41	0.39	0.52
NITRATE	UBC 1	0.43	0.86	0.92	0.97	0.90	0.85	0.78	0.60	0.68	0.56	0.66	0.74
NITROGEN	UBC 2	0.59	1.00	1.20	1.00	1.10	0.82	0.81	0.64	0.68	0.62	0.72	0.72
MG/L	MBC 1	0.45	0.83	0.86	0.97	0.90	0.82	0.81	0.72	0.64	0.60	0.66	0.68
	MBC 2	0.56	0.81	0.84	0.92	0.79	0.78	0.64	0.47	0.58	0.50	0.60	0.62
	LBC 1	0.65	0.65	0.76	0.90	0.76	0.50	0.76	0.52	0.35	0.37	0.41	0.40
	LBC 2	0.58	0.70	0.71	0.82	0.68	0.66	0.52	0.27	0.27	0.19	0.21	0.21
AMMONIA	UBC 1	0.13	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MG/L	UBC 2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	MBC 1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	MBC 2	0.11	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	LBC 1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	LBC 2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
VOLUME	UBC 1	18.3	6.9	7.0	8.0	6.9	7.2	7.1	8.3	7.3	6.3	6.0	4.0
DISCHARGE	MBC 1	23.8	6.2	5.4	5.4	5.4	7.2	7.9	8.2	6.9	6.3	4.20	4.3
CFS													

APPENDIX F

Nutrient loadings for stations with an automatic water sampler. Underlined values from August 8 through May 14 represent estimates obtained from regression equations. Underlined values from May 15 through August 7 represent estimates for missing data.

TIME PERIOD		JANUARY	FEBRUARY	MARCH	APRIL	MAY 1-14	MAY 15-22	MAY 23-29
SUSPENDED	1	2491609	6531907	19835356	53161839	100925289	94704108	292045108
SOLIDS	2	8558152	11110664	15010322	19604239	23321152	19327369	30552411
LOADING	3	4794684	8081277	14749592	25159383	35604099	46385686	36842614
(GM/DAY)	4	4571934	9232089	20751524	42584348	67959473	249323060	137485851
	5	4688133	12793813	40691153	113631830	221564410	295708745	174328464

TIME PERIOD		MAY 30- JUNE 5	JUN 6-12	JUN 13-19	JUN 19-26	JUNE 27- JULY 3	JUL 4-10	JUL 11-24
SUSPENDED	1	89077152	47693953	20362239	14970148	26605714	14933206	9131326
SOLIDS	2	25913353	15097366	24575117	15486360	15596453	18019958	6249346
LOADING	3	29962315	13724878	47043795	12905300	9724847	7258039	9161662
(GM/DAY)	4	80169437	65193173	47745941	21164692	9174384	7007761	64010289
	5	194350151	121808296	80746812	97305963	45871920	7842019	26696234

TIME PERIOD		JUL 25-31	AUG 1-7	AUG 8-31	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
SUSPENDED	1	6946966	4443827	4560789	4944017	5745926	3813116	3486583
SOLIDS	2	13383542	12045110	10080684	10303386	10731489	9603510	9373461
LOADING	3	16219039	6572186	6652425	6949603	7538109	6037540	5751750
(GM/DAY)	4	5217313	6221358	7104770	7535290	8408141	6235194	5841172
	5	8393069	10103859	8800351	9571941	11194379	7302978	6652731

APPENDIX F (Continued)

TIME PERIOD		JANUARY	FEBRUARY	MARCH	APRIL	MAY 1-14	MAY 15-22	MAY 23-29
TOTAL	1	2151	5755	17884	48927	94135	135292	287552
PHOSPHORUS	2	13587	17289	22822	29201	34277	24159	44930
LOADING	3	9020	13477	21409	32284	42170	77309	60206
(GM/DAY)	4	3622	9885	31441	87081	171198	357556	224650
	5	8519	19019	47995	109144	186208	193274	296538

TIME PERIOD		MAY 30- JUNE 5	JUN 6-12	JUN 13-19	JUN 19-26	JUNE 27- JULY 3	JUL 4-10	JUL 11-24
TOTAL	1	53446	31910	18958	19100	17890	12389	7979
PHOSPHORUS	2	66403	34312	10532	20648	24083	27322	10466
LOADING	3	48588	20587	14043	20648	16055	12514	16169
(GM/DAY)	4	105273	82349	62140	29424	12844	10011	68257
	5	210546	104652	31597	56783	69725	55061	41561

TIME PERIOD		JUL 25-31	AUG 1-7	AUG 8-31	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
TOTAL	1	6550	4631	3988	4330	5048	3322	3032
PHOSPHORUS	2	17580	21471	15804	16125	16743	15112	14777
LOADING	3	18147	19553	11604	12000	12776	10770	10375
(GM/DAY)	4	6805	7297	6800	7396	8650	5642	5140
	5	7372	12817	14099	15080	17092	12145	11272

APPENDIX F (Continued)

TIME PERIOD		JANUARY	FEBRUARY	MARCH	APRIL	MAY 1-14	MAY 15-22	MAY 23-29
TOTAL	1	6949	16149	42683	101135	177215	167182	395384
KJELDAHL	2	30662	37480	47239	58010	66298	60881	80874
NITROGEN	3	13039	21112	36789	60228	82985	119830	98846
LOADING	4	13345	25372	53206	102659	157398	367220	206678
(GM/DAY)	5	14631	34051	92106	222767	395594	415538	503216

TIME PERIOD		MAY 30- JUNE 5	JUN 6-12	JUN 13-19	JUN 19-26	JUNE 27- JULY 3	JUL 4-10	JUL 11-24
TOTAL	1	153051	91270	54065	39748	41285	31702	20629
KJELDAHL	2	69642	22646	60385	45427	66056	108453	25483
NITROGEN	3	74501	13725	172728	30973	31193	31702	33370
LOADING	4	107702	67938	70215	51621	21101	35039	139548
(GM/DAY)	5	294764	212049	177643	82594	80276	75083	54606

TIME PERIOD		JUL 25-31	AUG 1-7	AUG 8-31	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
TOTAL	1	17297	12396	11794	4039	14436	10083	9324
KJELDAHL	2	28071	32744	34778	35367	36492	33504	32885
NITROGEN	3	31190	13331	17641	18367	19801	16130	15424
LOADING	4	19848	18009	19969	21073	23294	17722	16695
(GM/DAY)	5	22968	25727	24682	26533	30357	21024	19404

APPENDIX F (Continued)

TIME PERIOD		JANUARY	FEBRUARY	MARCH	APRIL	MAY 1-14	MAY 15-22	MAY 23-29
NITRATE	1	17292	34223	75166	151112	237958	241592	224650
NITROGEN	2	19155	33607	64245	114183	165959	154619	134790
LOADING	3	15979	28604	55959	101520	149537	125628	125804
(GM/DAY)	4	13680	27625	62094	127424	203353	260919	107832
	5	18138	35184	75507	148713	231073	202937	206678

DATE OF SAMPLE		MAY 30- JUNE 5	JUN 6-12	JUN 13-19	JUN 19-26	JUNE 27- JULY 3	JUL 4-10	JUL 11-24
NITRATE	1	242938	150974	140429	77432	55046	54227	39438
NITROGEN	2	202448	116661	140429	67108	73395	50055	36404
LOADING	3	186252	130386	126386	67108	51835	40461	30337
(GM/DAY)	4	210546	164699	133408	67108	45872	50055	28516
	5	259134	130386	147451	67108	137616	45884	51572

DATE OF SAMPLE		JUL 25-31	AUG 1-7	AUG 8-31	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
NITRATE	1	34026	28066	26535	28095	31252	23376	21938
NITROGEN	2	34026	21985	27255	28568	31186	24552	23302
LOADING	3	28355	20348	23023	24173	26472	20663	19574
(GM/DAY)	4	28355	19413	21259	22548	25159	18657	17478
	5	28355	19413	27485	29052	32215	24310	22851

APPENDIX G

Data from periphytometers. Averages represent the average value per slide in a periphytometer. Rates are expressed as $mg/m^2/day$. Rates and average percent loss on ignition were calculated from data on days of incubation, average dry weight, and average loss on ignition.

MILES BELOW 0.0	DAYS SINCE JUNE 26	DAYS INCUBATION	AVERAGE DRY WEIGHT GRAMS	AVERAGE LOSS ON IGNITION GRAMS	DRY WEIGHT MG/M2/ DAY	AFDW MG/M2/ DAY	AVERAGE PERCENT LOSS ON IGNITION
1.73	7	7	0.0677	0.0042	2582	159	6.2
2.53	7	7	0.0327	0.0035	1246	132	10.7
2.53	7	7	0.0185	0.0026	706	98	13.9
2.53	7	7	0.0187	0.0023	715	89	12.5
3.73	7	7	0.5866	0.0326	22376	1242	5.6
3.73	7	7	0.5454	0.0338	20804	1288	6.2
7.98	7	7	0.8803	0.0325	33577	1238	3.7
7.98	7	7	0.4053	0.0220	15458	839	5.5
1.73	14	7	0.1666	0.0137	6355	523	9.0
1.73	14	14	1.5560	0.0780	29675	1488	5.1
1.90	14	7	0.2548	0.0134	9720	512	5.2
1.90	14	7	0.2452	0.0131	9353	501	5.4
2.09	14	7	0.5051	0.0244	19266	929	4.8
2.09	14	7	0.1497	0.0091	5710	346	6.1
2.23	14	7	0.4206	0.0264	16042	1006	6.3
2.23	14	7	0.4369	0.0237	16663	903	5.5
2.53	14	7	0.1488	0.0101	5676	385	6.8
2.53	14	7	0.1782	0.0110	6796	418	6.2
2.53	14	7	0.0999	0.0075	3810	287	7.7
2.53	14	14	0.2673	0.0240	5097	458	9.0
2.53	14	14	0.0780	0.0104	1488	199	13.4
3.73	14	7	0.4023	0.0334	15345	1275	8.3
3.73	14	14	0.7490	0.0537	14284	1024	7.2
4.08	14	7	0.3851	0.0280	14689	1067	7.3
4.48	14	7	0.0371	0.0041	1415	156	11.0
7.98	14	7	0.5380	0.0233	20521	889	4.3
7.98	14	14	0.6497	0.0277	12390	527	4.3
1.90	21	7	0.4418	0.0283	16853	1081	6.4
1.90	21	14	0.9986	0.0485	19045	925	4.8
1.90	21	14	2.8230	0.1270	53839	2423	4.5
1.90	21	7	0.4122	0.0223	15724	852	5.5
2.09	21	7	0.6441	0.0325	24569	1238	5.0
2.09	21	14	2.0876	0.1077	39814	2053	5.1
2.09	21	7	0.0745	0.0064	2842	243	8.6
2.09	21	14	0.1744	0.0166	3327	317	9.5
2.23	21	7	0.2792	0.0175	10651	668	6.4
2.23	21	14	0.2522	0.0169	4809	322	6.9
2.53	21	7	0.0256	0.0019	978	72	7.3
2.53	21	14	0.2576	0.0181	4913	345	8.0
2.53	21	14	0.0633	0.0066	1208	126	10.5

APPENDIX G (Continued)

MILES BELOW 0.0	DAYS SINCE JUNE 26	DAYS INCUBATION	AVERAGE DRY WEIGHT GRAMS	AVERAGE LOSS ON IGNITION GRAMS	DRY WEIGHT MG/M2/ DAY	AFDW MG/M2/ DAY	AVERAGE PERCENT LOSS ON IGNITION
3.73	21	14	0.1725	0.0143	3289	273	8.3
3.73	21	21	0.2688	0.0204	3418	259	7.8
4.08	21	14	0.8988	0.0608	17141	1160	6.8
4.08	21	7	0.5232	0.0342	19956	1303	6.5
4.08	21	7	0.7668	0.0600	29248	2287	7.8
4.48	21	14	0.1043	0.0157	1990	299	15.0
4.48	21	7	0.0251	0.0043	956	164	17.2
4.48	21	7	0.0270	0.0042	1031	160	15.5
7.98	21	7	0.4473	0.0266	17063	1016	6.0
7.98	21	7	0.6168	0.0337	23528	1287	5.5
7.98	21	14	0.7046	0.0320	13438	611	4.5
7.98	21	21	0.7916	0.0376	10065	478	4.8
1.90	28	7	0.0468	0.0030	1785	113	6.5
1.90	28	7	0.0441	0.0031	1682	120	7.3
1.90	28	21	0.1168	0.0081	1485	103	7.1
1.90	28	7	0.0251	0.0018	957	69	7.2
1.90	28	21	0.0592	0.0042	753	53	7.2
2.09	28	7	0.1123	0.0066	4282	253	5.9
2.09	28	21	0.5755	0.0356	7317	452	6.2
2.09	28	7	0.0151	0.0014	576	53	9.3
2.09	28	21	0.1584	0.0122	2014	155	7.9
2.23	28	7	0.0655	0.0056	2500	214	8.7
2.23	28	14	0.0823	0.0073	1570	139	8.9
2.23	28	7	0.0221	0.0023	842	88	10.5
2.23	28	21	0.0353	0.0027	448	34	7.5
2.53	28	14	0.0442	0.0057	844	109	13.0
2.53	28	14	0.0578	0.0068	1102	130	11.8
2.53	28	7	0.0422	0.0034	1610	130	8.1
2.53	28	7	0.0221	0.0019	843	71	8.6
4.08	28	7	0.2785	0.0203	10622	773	7.3
4.08	28	14	0.4281	0.0314	8165	599	7.4
4.48	28	14	0.0802	0.0152	1530	290	19.0
4.48	28	7	0.0304	0.0053	1161	203	17.5
4.48	28	7	0.0320	0.0072	1222	277	22.6
4.48	28	14	0.0913	0.0173	1742	330	18.9
7.98	28	7	0.1150	0.0059	4385	224	5.1
7.98	28	14	0.1623	0.0081	3095	154	5.1
1.90	37	16	0.0139	0.0009	232	14	5.9
1.90	37	9	0.0112	0.0009	331	28	8.1
1.90	37	9	0.0673	0.0012	1997	37	4.8
2.09	37	16	0.0463	0.0046	772	76	10.3
2.09	37	9	0.0422	0.0033	1252	98	7.8
2.09	37	16	0.0441	0.0031	736	52	7.3

APPENDIX G (Continued)

MILES BELOW 0.0	DAYS SINCE JUNE 26	DAYS INCUBATION	AVERAGE DRY WEIGHT GRAMS	AVERAGE LOSS ON IGNITION GRAMS	DRY WEIGHT MG/M2/ DAY	AFDW MG/M2/ DAY	AVERAGE PERCENT LOSS ON IGNITION
2.09	37	9	0.0569	0.0047	1689	139	8.3
2.09	37	9	0.0200	0.0015	595	44	7.1
2.53	37	16	0.0977	0.0113	1630	188	11.6
2.53	37	9	0.0425	0.0035	1261	104	8.3
2.53	37	16	0.1659	0.0160	2768	268	9.7
2.53	37	9	0.0893	0.0085	2650	253	10.1
2.53	37	9	0.0617	0.0058	1831	173	9.6
4.08	37	9	0.5998	0.0352	17793	1045	5.9
4.48	37	9	0.0305	0.0075	904	221	24.6
4.48	37	9	0.0467	0.0102	1386	302	21.8
4.48	37	23	0.1612	0.0256	1871	298	15.9
4.48	37	16	0.1128	0.0204	1883	340	18.1
1.90	44	7	0.0465	0.0026	1774	100	5.9
1.90	44	7	0.0330	0.0023	1259	87	7.0
1.90	44	7	0.0176	0.0015	670	56	8.6
2.09	44	7	0.0091	0.0009	345	34	10.8
2.09	44	7	0.0123	0.0014	468	53	11.5
2.09	44	7	0.0092	0.0013	352	50	14.6
2.23	44	7	0.0059	0.0007	223	27	12.7
2.23	44	7	0.0136	0.0007	520	27	5.3
2.53	44	7	0.0447	0.0029	1704	112	6.6
2.53	44	7	0.0261	0.0017	997	65	6.5
4.08	44	7	0.5620	0.0302	21437	1151	5.4
4.08	44	7	0.2066	0.0146	7880	558	7.2
4.08	44	7	0.3589	0.0226	13689	861	6.3
4.48	44	7	0.0152	0.0021	579	79	13.7
4.48	44	7	0.0249	0.0039	951	147	15.5
4.48	44	7	0.0265	0.0029	1012	110	12.7
7.98	44	7	0.4166	0.0250	15891	952	6.0
1.90	51	7	0.0161	0.0017	615	65	10.7
1.90	51	7	0.0247	0.0025	944	96	10.5
1.90	51	7	0.0143	0.0019	547	71	13.1
2.09	51	7	0.0213	0.0021	812	80	10.0
2.09	51	7	0.0253	0.0023	966	87	9.1
2.23	51	7	0.0116	0.0015	442	56	12.8
2.53	51	7	0.0232	0.0023	886	88	9.9
2.53	51	7	0.0380	0.0035	1449	132	9.2
2.53	51	7	0.0385	0.0035	1468	133	9.1
4.08	51	7	0.5154	0.0384	19658	1463	7.5
4.08	51	7	0.2928	0.0239	11166	910	8.2
4.08	51	7	0.4448	0.0343	16967	1307	7.7
4.48	51	7	0.0167	0.0027	636	104	16.6
4.48	51	7	0.0131	0.0023	499	88	17.6

APPENDIX G (Continued)

MILES BELOW 0.0	DAYS SINCE JUNE 26	DAYS INCUBATION	AVERAGE DRY WEIGHT GRAMS	AVERAGE LOSS ON IGNITION GRAMS	DRY WEIGHT MG/M2/ DAY	AFDW MG/M2/ DAY	AVERAGE PERCENT LOSS ON IGNITION
4.48	51	7	0.0175	0.0030	666	114	17.1
7.98	51	7	0.2037	0.0166	7768	633	8.1
1.90	59	8	0.0110	0.0010	369	34	12.0
1.90	59	8	0.0212	0.0018	706	60	8.9
2.09	59	8	0.0297	0.0031	990	102	10.4
2.09	59	8	0.0354	0.0028	1180	93	7.9
2.23	59	8	0.0082	0.0012	275	41	15.6
2.23	59	8	0.0050	0.0009	167	32	19.2
2.53	59	8	0.0413	0.0044	1379	147	10.8
2.53	59	8	0.0279	0.0032	932	106	11.4
4.08	59	8	0.2174	0.0173	7256	578	8.0
4.08	59	8	0.5111	0.0370	17057	1233	7.2
4.48	59	8	0.0313	0.0052	1045	175	16.8
4.48	59	8	0.0367	0.0066	1225	221	18.0
1.90	66	7	0.0081	0.0009	310	32	10.9
1.90	66	7	0.0354	0.0028	1350	107	8.1
1.90	66	15	0.0535	0.0041	952	74	7.8
2.09	66	7	0.0498	0.0039	1901	148	8.0
2.09	66	7	0.0353	0.0025	1345	97	7.4
2.09	66	15	0.0390	0.0041	694	72	10.8
2.23	66	7	0.0106	0.0010	403	40	10.3
2.23	66	7	0.0152	0.0013	579	51	9.0
2.53	66	7	0.0660	0.0054	2516	206	8.2
2.53	66	7	0.0464	0.0045	1770	170	9.8
2.53	66	15	0.0909	0.0122	1618	217	13.6
4.08	66	7	0.1284	0.0127	4897	484	9.9
4.08	66	7	0.2707	0.02195	10325	837	8.2
4.08	66	15	0.7615	0.0605	13554	1076	8.0
4.48	66	7	0.0152	0.0027	580	101	17.6
4.48	66	7	0.0124	0.0022	472	82	17.4
4.48	66	15	0.0862	0.0143	1535	255	16.6

APPENDIX H

Data from analyses of chlorophyll accumulation on periphytometers. Measurements were made after incubations of 7-8 days. Rates are expressed as mg/m^2/day. Acidified Chlor A represents the accumulation rate of chlorophyll *a* after correction for pheophyton. Phaeo represents the accumulation rate of pheophyton.

MILES BELOW 0.0	DAYS SINCE JUNE 26	CHLOR A MG/M2 /DAY	CHLOR B MG/M2 /DAY	CHLOR C MG/M2 /DAY	ACIDIFIED CHLOR A MG/M2 /DAY	PHAEO MG/M2 /DAY
1.90	44	0.110	0.083	0.001	0.092	0.039
1.90	44	0.097	0.086	0.016	0.077	0.046
2.09	44	0.078	0.042	0.011	0.071	0.015
2.09	44	0.064	0.063	0.000	0.056	0.020
2.23	44	0.031	0.022	0.005	0.029	0.006
2.23	44	0.057	0.042	0.091	0.046	0.025
2.53	44	0.221	0.149	0.033	0.188	0.071
2.53	44	0.180	0.196	0.013	0.158	0.062
4.08	44	2.440	1.344	0.221	2.316	0.327
4.08	44	2.100	1.548	0.168	1.823	0.638
4.48	44	0.326	0.196	0.018	0.261	0.128
4.48	44	0.271	0.229	0.002	0.183	0.175
7.98	44	4.207	2.742	0.172	3.801	0.962
7.98	44	4.524	2.280	0.371	4.799	0.000
1.90	51	0.056	0.053	0.046	0.036	0.040
1.90	51	0.048	0.058	0.000	0.036	0.029
2.09	51	0.124	0.138	0.000	0.094	0.068
2.09	51	0.107	0.119	0.005	0.091	0.043
2.23	51	0.091	0.088	0.000	0.081	0.028
2.23	51	0.067	0.073	0.000	0.053	0.033
2.53	51	0.148	0.174	0.034	0.123	0.067
2.53	51	0.149	0.179	0.008	0.103	0.103
4.08	51	1.237	0.789	0.146	1.118	0.279
4.48	51	0.547	0.634	0.070	0.463	0.228
4.48	51	0.542	0.558	0.030	0.515	0.117
7.98	51	0.951	0.395	0.727	1.082	0.000
7.98	51	2.121	1.823	0.031	1.808	0.744
1.90	59	0.116	0.077	0.006	0.105	0.026
2.09	59	0.246	0.127	0.009	0.227	0.042
2.09	59	0.224	0.154	0.000	0.193	0.069
2.23	59	0.122	0.075	0.007	0.103	0.041
2.23	59	0.120	0.068	.000	0.107	0.028
2.53	59	0.247	0.133	0.015	0.231	0.038
2.53	59	0.223	0.141	0.025	0.205	0.045
4.08	59	1.568	1.105	0.169	1.221	0.705
4.08	59	1.476	1.177	0.108	0.786	1.306
4.48	59	1.701	1.514	0.140	1.435	0.634
4.48	59	1.438	1.384	0.112	1.226	0.532

APPENDIX H (Continued)

MILES BELOW 0.0	DAYS SINCE JUNE 26	CHLOR A MG/M2 /DAY	CHLOR B MG/M2 /DAY	CHLOR C MG/M2 /DAY	ACIDIFIED CHLOR A MG/M2 /DAY	PHAEO MG/M2 /DAY
1.90	66	0.250	0.178	0.009	0.214	0.080
1.90	66	0.199	0.177	0.000	0.171	0.069
2.09	66	0.259	0.231	0.011	0.232	0.073
2.09	66	0.242	0.220	0.000	0.220	0.063
2.23	66	0.147	0.131	0.000	0.124	0.056
2.23	66	0.146	0.125	0.000	0.118	0.061
2.53	66	0.353	0.352	0.002	0.292	0.148
4.08	66	1.516	1.277	0.175	1.279	0.551
4.08	66	1.673	1.364	0.144	1.478	0.488
4.48	66	0.618	0.719	0.050	0.500	0.297
4.48	66	0.544	0.622	0.040	0.440	0.260

APPENDIX I

Standing crop of chlorophyll in Currant Creek on three types of natural substrate (1=rock, 2=sediment, 3=wood).

MILES BELOW 0.0	DAYS SINCE JUNE 26	SUBSTRATE TYPE	FRACTION OF BOTTOM	CHLOR A MG/M2	CHLOR B MG/M2	CHLOR C MG/M2	ACIDIFIED CHLOR A MG/M2	PHAEO MG/M2
1.73	7	1	0.5	13.84	12.09	0.00	11.15	5.97
5.44	7	1	0.2	36.94	29.95	0.00	27.98	18.54
7.69	7	1	0.33	6.28	5.53	0.00	4.43	3.79
1.90	14	1	0.60	7.78	7.37	0.00	5.68	4.45
2.09	14	3	0.02	17.11	14.46	0.00	12.68	9.20
2.23	14	1	0.9	25.27	25.88	0.00	19.12	13.68
2.53	14	3	0.02	2.49	2.28	0.00	2.15	0.86
1.90	21	1	0.60	14.87	9.27	0.00	14.76	1.05
1.90	21	1	0.60	1.63	1.52	0.54	1.49	0.42
2.09	21	3	0.02	22.15	18.29	0.00	14.94	14.32
2.09	21	3	0.02	4.51	3.53	0.87	3.53	2.06
2.23	21	1	0.90	4.16	3.72	0.00	3.07	2.30
2.23	21	1	0.90	3.66	2.43	0.00	3.34	0.79
2.53	21	3	0.02	1.92	1.27	0.00	1.72	0.46
2.53	21	3	0.02	0.31	0.23	0.05	0.24	0.13
4.08	21	1	0.01	19.61	12.85	1.39	12.92	12.65
4.08	21	2	0.01	0.94	0.67	0.00	0.55	0.73
4.48	21	2	0.02	5.12	3.53	0.27	5.36	0.00
4.48	21	2	0.02	7.08	6.41	1.03	5.59	3.32
5.44	22	1	0.60	16.97	9.57	0.53	16.92	0.92
5.44	22	1	0.60	76.41	53.99	0.00	67.91	20.06
5.44	22	1	0.60	92.68	67.42	0.00	78.72	30.88
7.69	22	1	0.85	7.20	5.82	0.67	5.86	2.94
7.69	22	1	0.85	12.29	9.30	1.55	10.95	3.31
7.69	22	1	0.85	33.59	30.89	0.22	25.61	17.31
7.69	22	1	0.85	34.54	18.70	1.16	32.69	4.69
1.73	28	1	0.70	2.13	1.50	0.00	2.87	0.00
1.73	28	1	0.70	7.42	4.85	0.00	6.21	2.53
1.90	28	1	0.60	3.92	3.33	0.00	3.58	0.97
1.90	28	1	0.60	17.20	13.13	0.00	15.27	4.70
2.09	28	3	0.02	4.69	4.28	0.03	3.39	2.74
2.23	28	1	0.90	35.26	18.31	0.00	29.87	10.59
2.23	28	1	0.90	82.60	39.58	1.99	69.19	25.59
2.53	28	3	0.02	6.83	5.72	0.00	6.13	1.85
2.53	28	3	0.02	12.11	7.73	0.00	10.75	3.06
4.08	28	3	0.01	25.60	13.95	2.85	23.32	5.06
4.08	28	3	0.01	21.03	11.98	1.19	19.33	3.93
4.48	28	3	0.02	32.11	26.36	1.54	24.08	16.68

APPENDIX I (Continued)

MILES BELOW 0.0	DAYS SINCE JUNE 26	SUBSTRATE TYPE	FRACTION OF BOTTOM	CHLOR A MG/M2	CHLOR B MG/M2	CHLOR C MG/M2	ACIDIFIED CHLOR A MG/M2	PHAEO MG/M2
5.44	28	1	0.60	44.33	32.68	0.00	37.27	15.47
5.44	28	1	0.60	58.07	30.22	0.87	48.44	18.75
1.73	38	1	0.70	3.43	2.51	0.00	2.79	1.36
1.73	38	1	0.70	6.01	3.83	0.00	5.01	2.06
1.73	38	2	0.30	7.99	4.57	0.00	6.29	3.29
1.90	38	1	0.60	10.89	5.48	0.00	10.23	1.54
1.90	38	1	0.60	2.59	0.96	0.00	2.67	0.00
1.90	38	2	0.40	2.19	1.35	0.23	2.01	0.44
2.09	38	2	0.50	20.32	13.32	2.68	23.20	0.00
2.09	38	2	0.50	40.96	21.44	4.93	28.11	23.59
2.23	38	1	0.90	44.78	11.42	0.00	51.15	0.00
2.23	38	1	0.90	19.03	6.22	0.91	17.63	2.50
2.23	38	2	0.10	37.39	21.24	0.00	24.32	24.04
2.53	38	2	0.40	33.36	20.49	0.87	25.48	15.31
2.53	38	2	0.40	36.65	24.20	0.00	23.39	24.93
2.53	38	3	0.02	3.55	1.96	0.00	3.09	0.95
4.08	38	2	0.30	154.25	109.76	0.00	89.89	120.77
4.08	38	2	0.30	87.61	64.68	0.00		
4.08	38	3	0.01	32.62	22.48	0.80	25.69	14.09
4.48	38	2	0.15	196.59	133.56	0.00	90.72	193.42
4.48	38	2	0.15	75.05	32.17	26.79	52.97	39.62
4.48	38	3	0.02	7.24	4.02	0.00	4.78	4.52
5.44	38	1	0.60	12.98	8.02	0.00	11.69	2.94
5.44	38	1	0.60	14.46	11.22	0.30	13.12	3.52
5.44	38	2	0.40	59.81	35.34	2.85	39.54	37.68
7.69	38	1	0.85	43.93	30.90	0.00	34.42	19.38
7.69	38	1	0.85	27.52	20.02	0.00	22.92	9.92
1.73	45	1	0.70	9.84	8.64	0.00	8.51	3.28
1.73	45	1	0.70	3.47	2.11	0.00	3.19	0.67
1.73	45	2	0.30	6.19	3.47	0.08	4.54	3.09
1.90	45	1	0.60	1.28	0.68	0.00	1.53	0.00
1.90	45	1	0.60	1.61	1.20	0.00	1.13	0.95
1.90	45	2	0.40	16.46	12.52	0.43	10.33	11.79
2.09	45	2	0.50	52.89	26.85	27.50	43.94	17.50
2.09	45	2	0.50	32.18	22.05	5.40	23.06	17.81
2.23	45	1	0.90	50.52	49.27	0.00	42.73	19.33
2.23	45	1	0.90	42.48	47.62	0.00	32.37	23.36
2.23	45	2	0.10	24.62	19.38	8.21	19.77	10.48
2.53	45	2	0.40	38.38	22.13	3.09	25.67	23.59

APPENDIX I (Continued)

MILES BELOW 0.0	DAYS SINCE JUNE 26	SUBSTRATE TYPE	FRACTION OF BOTTOM	CHLOR A MG/M2	CHLOR B MG/M2	CHLOR C MG/M2	ACIDIFIED CHLOR A MG/M2	PHAEO MG/M2
2.53	45	2	0.40	31.19	33.92	6.37	24.47	15.87
2.53	45	3	0.02	1.75	1.96	0.00	1.14	1.30
4.08	45	2	0.30	96.01	70.22	24.58	83.83	28.41
4.08	45	2	0.30	142.27	119.80	0.00	98.56	88.17
4.08	45	3	0.01	6.62	6.60	0.00	4.64	4.18
4.48	45	2	0.15	79.71	74.67	8.54	48.42	62.37
4.48	45	2	0.15	86.82	85.23	9.74	57.24	60.98
4.48	45	3	0.02	28.42	35.60	6.01	22.29	15.30
5.44	45	1	0.60	29.82	35.17	0.00	21.83	18.26
5.44	45	1	0.60	28.27	20.28	1.36	30.32	0.00
5.44	45	2	0.40	68.68	46.32	0.47	58.30	22.32
7.69	45	1	0.85	65.15	69.30	0.00	56.84	22.90
7.69	45	1	0.85	54.64	42.48	0.00	51.27	10.42
7.69	45	2	0.15	15.42	11.11	0.00	10.59	9.35
1.73	50	1	0.70	4.90	4.15	0.00	3.81	2.32
1.73	50	1	0.70	5.69	4.76	0.00	4.65	2.29
1.73	50	2	0.30	9.27	7.23	6.04	7.67	3.58
1.90	50	1	0.60	1.15	0.88	0.00	1.02	0.33
1.90	50	1	0.60	31.78	16.67	0.00	27.06	9.35
1.90	50	2	0.40	6.42	3.92	3.71	5.87	1.34
2.09	50	2	0.50	25.79	21.32	4.26		
2.09	50	2	0.50	32.95	28.39	2.78	22.44	21.21
2.23	50	1	0.90	19.99	17.73	0.00	8.82	21.08
2.23	50	1	0.90	44.22	31.25	0.00	33.03	22.27
2.23	50	2	0.10	7.67	5.67	0.70	4.19	6.54
2.53	50	2	0.40	71.44	46.56	0.00	53.52	34.92
2.53	50	2	0.40	44.71	34.49	3.78	32.23	25.04
4.08	51	2	0.30	119.71	85.25	9.07	80.77	75.22
4.08	51	2	0.30	190.78	160.49	0.00	150.00	87.70
4.48	51	2	0.15	209.89	171.75	0.00	99.33	207.53
4.48	51	2	0.15	121.28	109.03	1.49	52.97	129.19
5.44	51	1	0.60	35.65	32.34	0.00	30.36	12.86
5.44	51	1	0.60	38.43	43.68	1.00	27.09	25.02
5.44	51	2	0.40	61.59	50.07	1.46	33.03	54.24
7.69	51	1	0.85	84.63	68.67	9.05	71.87	29.57
7.69	51	1	0.85	128.68	130.61	0.00	92.34	78.13
1.90	59	1	0.60	18.29	8.81	0.00	16.90	2.95
1.90	59	1	0.60	1.63	1.51	0.00	1.44	0.50
1.90	59	2	0.40	30.68	27.10	10.20	14.17	31.37

APPENDIX I (Continued)

MILES BELOW 0.0	DAYS SINCE JUNE 26	SUBSTRATE TYPE	FRACTION OF BOTTOM	CHLOR A MG/M2	CHLOR B MG/M2	CHLOR C MG/M2	ACIDIFIED CHLOR A MG/M2	PHAEO MG/M2
2.09	59	2	0.50	17.56	17.71	1.04	12.14	11.46
2.09	59	2	0.50	42.67	44.81	5.56	33.81	20.84
2.23	59	1	0.90	34.10	26.03	0.00	28.45	12.42
2.23	59	1	0.90	34.40	18.69	0.00	30.08	8.87
2.23	59	2	0.10	4.28	4.51	0.07	2.84	3.03
2.53	59	2	0.40	47.25	41.40	0.00	30.44	33.45
2.53	59	2	0.40	49.96	43.25	0.00	27.69	42.93
4.08	59	2	0.30	122.67	105.94	0.00	76.73	90.44
4.08	59	2	0.30	109.06	79.19	6.55	77.47	62.16
4.48	59	2	0.15	152.92	118.50	0.00	82.77	132.28
4.48	59	2	0.15	89.75	53.25	2.94	57.63	59.45
5.44	59	1	0.60	31.47	32.42	0.00	24.42	16.05
5.44	59	1	0.60	73.03	58.64	0.00	55.80	35.83
5.44	59	2	0.40	30.27	15.23	13.51	17.37	23.20
7.69	59	1	0.85	34.27	29.11	1.03	27.52	14.88
7.69	59	1	0.85	25.35	24.27	0.00	22.26	8.20
7.69	59	2	0.15	66.58	25.03	5.46	45.00	37.75
1.90	66	1	0.60	1.55	1.08	0.00	1.31	0.51
1.90	66	1	0.60	2.59	1.80	0.00	2.21	0.83
1.90	66	2	0.40	22.99	15.17	8.05	17.96	10.14
2.09	66	2	0.50	63.01	42.64	7.00	50.06	26.37
2.09	66	2	0.50	171.34	55.18	40.43	163.26	15.12
2.23	66	1	0.90	52.01	37.35	0.33	39.76	24.77
2.23	66	1	0.90	66.40	33.17	0.00	53.25	24.82
2.53	66	2	0.40	56.14	37.23	7.24	45.06	22.60
2.53	66	2	0.40	101.73	54.97	10.12	92.09	20.99
4.08	66	2	0.30	115.78	64.01	27.88	100.08	32.33
4.08	66	2	0.30	194.50	80.82	12.41	129.44	115.06
4.48	66	2	0.15	42.63	22.23	14.72	34.67	15.42
4.48	66	2	0.15	81.93	28.14	19.67	60.18	37.94
5.44	66	1	0.60	52.66	57.43	2.17	45.96	18.85
5.44	66	1	0.60	67.15	66.43	0.00	60.89	18.89
5.44	66	2	0.40	29.26	15.53	6.86	12.08	30.51
7.69	66	1	0.85	21.86	13.17	0.00	19.07	5.93
7.69	66	1	0.85	75.89	32.41	0.30	68.64	14.18

APPENDIX J

Aquatic macrophytes found within the Currant Creek study area.

Species	Location collected
Hipparus vulgaris	LBC 2
Ranunculus aquatilus	MBC 2
Ranunculus sp.	LBC 2
Persicaria amphibia	MBC 2
Potamogeton sp.	LBC 1, LBC 2