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The Association of Water Quality Parameters, Geological Substrates and Periphyton Community Structure

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THE ASSOCIATION OF WATER QUALITY PARAMETERS, GEOLOGICAL SUBSTRATES AND PERIPHYTON COMMUNITY STRUCTURE

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Arkansas Water Resources Research Center
University of Arkansas
Fayetteville, Arkansas 72701

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Research Project Technical Completion Report

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ABSTRACT

THE ASSOCIATION OF WATER QUALITY PARAMETERS, GEOLOGICAL SUBSTRATES AND PERIPHYTON COMMUNITY STRUCTURE

This research was designed to understand the structure of epilithic diatom assemblage of a first-to-third order stream system which has minimal variance in nutrient concentration, but significant differences in geomorphological character. The primary objective was to determine the importance of geological substrate on the structure of the diatom assemblages. The second objective was to examine the effect of flow on these assemblages, and the third part of the research was to develop a seasonal model of temporal and spatial annual succession.

The temporal and spatial models represent the effect of seasons, stream order, substrate characteristics, storm events, and periods of lesser flow on diatom assemblages.

Also, a compilation of the diatoms reported in the Ozark Highlands is included along with a determination of the similarity of the diatom flora in the study reach on the Middle Fork of the White River and other regional streams.

Richard L. Meyer and Julia Christensen Eichman

Completion Report to the U.S. Department of the Interior, Geological Survey, Reston, VA, June 1990.

Keywords--Periphyton/Water Quality/Streams/Substrate/Flow

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The contributions of the White River Environmental Protection Association and the residents of the Middle Fork valley are particularly noteworthy. Their interest, contributions of rain and flow data, and financial contribution indicates a strong public interest in the activities of environmental science.

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INTRODUCTION

Flowing water poses significant problems for study because of its continuum properties (Cummins 1974; Vannote et al. 1980), and its patchiness (Pringle et al. 1988).

Studies involving water quality and organism interaction have spanned several decades (Myers 1898; Fritsch 1929; Shelford and Eddy 1929; Hustedt 1930; Preston 1948; Gumtow 1955; Blum 1956; Odum 1957; Douglas 1958; Hohn et.al 1963; Patrick and Reimer 1966, 1975; Edwards 1972; Lowe 1974; Moore 1977; Clark 1977; Jones 1978; Schoeman 1973; Weber and Corliss 1978; Woomer 1986; DeSeve 1981; Keithan 1988). Identification of the diatoms and analytical techniques for water quality parameters have improved during the last one hundred years. As early as 1929 studies recognized that a permanent stream sub-community exists and undergoes successional development. This sub-community attains and maintains a quasi-stable condition approximately comparable to land climaxes and manifests seasonal and annual differences (Fritsch 1929; Eddy and Shelford 1929). The topography of the stream bottom and individual rocks were recognized as important, but only as anchors, and protection from variable flow rates (Blum 1956). Flow rate studies were important because scouring as a disturbance factor might keep assemblages immature, or as pioneer sere (Douglas 1958; Patrick 1962). Further stream studies introduced the idea that as water flows over and through the landscape to the stream channel it acquires and integrates characteristics from the land, especially the soils, topography, and vegetation (Hynes 1970; Whitton 1975; Likens and Borman 1974). Even with the availability of this information there have been very few attempts to treat streams and rivers holistically, as discrete ecological systems. It is easy to visualize a pond, lake, or forest as a discrete entity, but it is not as easy with a stream because it changes size and covers a continuous area (Minshall et al. 1983).

A. Purpose and Objectives

The purposes of this research were focused primarily on the influence of geological substrate characteristics on the associated diatom assemblages, as well as to determine if flow provided not only a continuous supply of nutrients and removal of waste, but induces mechanical stress so as to act as a selective force on the assemblages. The primary objective focused on determining the importance of geological substrate characteristics on the associated epilithic diatom assemblage. The secondary objective was the development of a seasonal model of diatom assemblages for a first through third order ecosystem. Correlation of the seasonal assemblage structure with flow patterns would permit the determination of the importance of storm events and cessation of flow on the assemblages. The recovery of the organisms may give insight into the role of surviving populations in secondary succession.

This research concentrates on the influences of selected chemical, physical and geologic parameters resulting in the differentiation of diatom assemblages along a spatial gradient during an annual cycle. Also, a comparison of the stream diatom assemblages of this study area with those stream assemblages in other areas of the Ozark Highlands/Boston Mountains was compiled in order to provide a comprehensive survey of the diatoms from this ecoregion (Rippey 1977; Woomer 1986).

B. Related Research and Activities

The holistic approach brought about the introduction of ecoregions (Lotspeich 1980). Ecoregions are defined as areas of relatively homogeneous types of land-surface form, soil, potential natural vegetation, and land use (Rohm et al. 1987).

This research was conducted in the Ozark Highland ecoregion of Arkansas. The reference stream for this area is the Buffalo River (Rippey and Meyer 1976), because it is a stream with minimal human populations and disturbance. It has been suggested that other streams should be selected for analysis in each of the eco-regions to insure the representativeness of the reference stream (Rohm et al. 1987). Documentation shows that within a given region there are subtle differences that should be recognized, not only with regard to geology, but water quality, nutritional element availability, flow rates, and seasonal changes as well (Keithan et al. 1988). All of these parameters play a part in the community present and the changes that may occur if disturbance increases (Hughes and Larsen 1988).

Diatoms were selected as the research organisms because they are the dominant organisms of Ozark Highland streams, and in the studied reach (Robinson 1951; Rippey 1977; Woomer 1986). Much is known about their specific nutritional needs, and their assemblage response to various changes in the micro-environment (Fee 1967; Lowe 1972). Hohn (1961) states, "The total species observed in natural "healthy" rivers of similar chemical quality is the same in widely separated geographical areas although the number of specimens observed in securing these species may be quite different." If the chemical quality is different when comparing streams, then a judgement on their relative health probably should not be made (Hohn 1961).

The effect of fluctuating water levels and seasons on invertebrates and fish is well documented (Fisher et al. 1982; Kroger 1973; Legendra et al. 1984). Studies of diatoms indicate seasonal distribution so species tend to follow the same general pattern year after year. "The most important generalizations we can make are that a flora at a particular season is related more to water quality (mineral, content, pH, etc...) and current speed than to any other factor. We can conclude that variation in flora with seasons results chiefly from changes in water temperature, but changes in total incident light are important for some species" (Whitford and Schumacher 1963). The highest production rates generally occur in spring or early summer, and the lowest production rates occur in late summer, with fewer species present (Castenholz 1960; Holland 1969; Main 1977, 1988; Muller-Haeckel et al. 1978; Whitford et al. 1963).

The Middle Fork of the White River is located in Madison and Washington counties of northwest Arkansas. It is a first-to-third order stream located in the Ozark Highlands, but its drainage is from the Boston Mountains. This stream was selected as the study reach because it has steep-to-shallow slope, ephemeral portions, riffle pool segments and traverses seven geological formations. Also it is moderately populated, with a minimal amount of disturbance, and because preliminary observations indicated significant differences between it and the Buffalo River (Meyer, personal communication). Also, the Middle Fork is one of the three major drainage areas which supplies Beaver Lake, the major drinking water resource for northwest Arkansas.

The drainage basin is narrow and surrounded by rugged plateaus (Bishop 1961; Taylor 1964). There is some agricultural disturbance in the form of cattle pastures, hog operations, and chicken operations. Only minimal field plowing is done in the area. The agricultural activities occur at least 200 meters from the stream and there is usually riparian forest 40 meters wide along the stream margins. The major steam-bed disturbance is gravel removal. During high water periods in the spring and fall the stream is used for recreational activities such as canoeing.

The study area was unique because the geomorpholgy of the area includes five different formations, with six of their members, from two different ages exposed to the stream flow (Figure 1 & 2). Seven distinct lithological formations (rock types) are exposed within the watershed.

The typical riffle-pool pattern allows for mixing of various water quality types. The flow patterns were altered by bimodal annual rainfall distribution. There were dry periods in the summer and winter when obvious surface flow ceases. The standing pools during these periods were through gravel and/or spring-fed.

Previous studies have compared natural versus artificial substrates (Blinn 1980; Brown 1976; Cox 1988; Woomer 1986; Fontaine 1983; Lay et al. 1987; Lowe et al. 1980; Siver 1977; Tippet 1970; Tuchman et al. 1980), as well as flow rates and succession (Fisher et al. 1982; Fritsch 1929; Guntow 1955; Jones 1978; Kroger

Upper Reach Formations

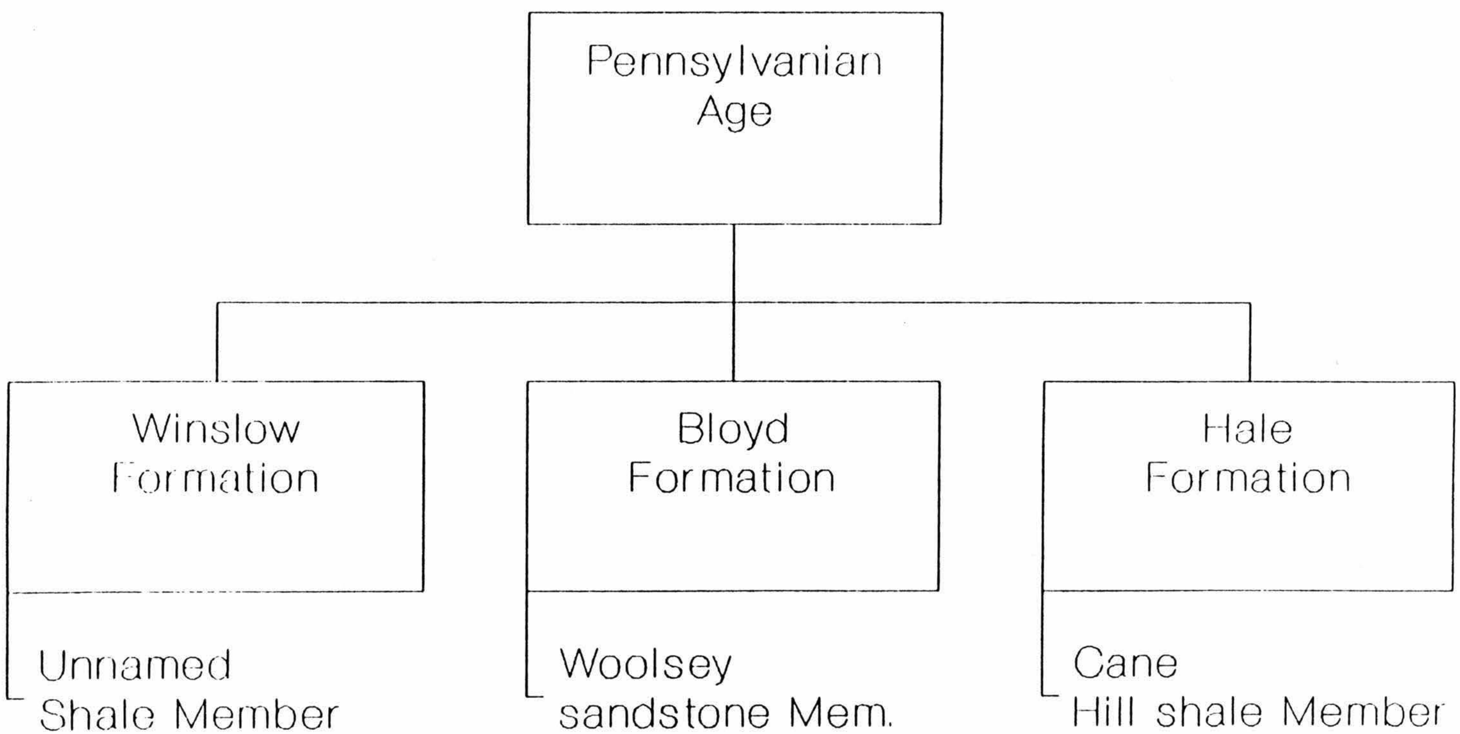


Figure 1

Lower Reach Formations

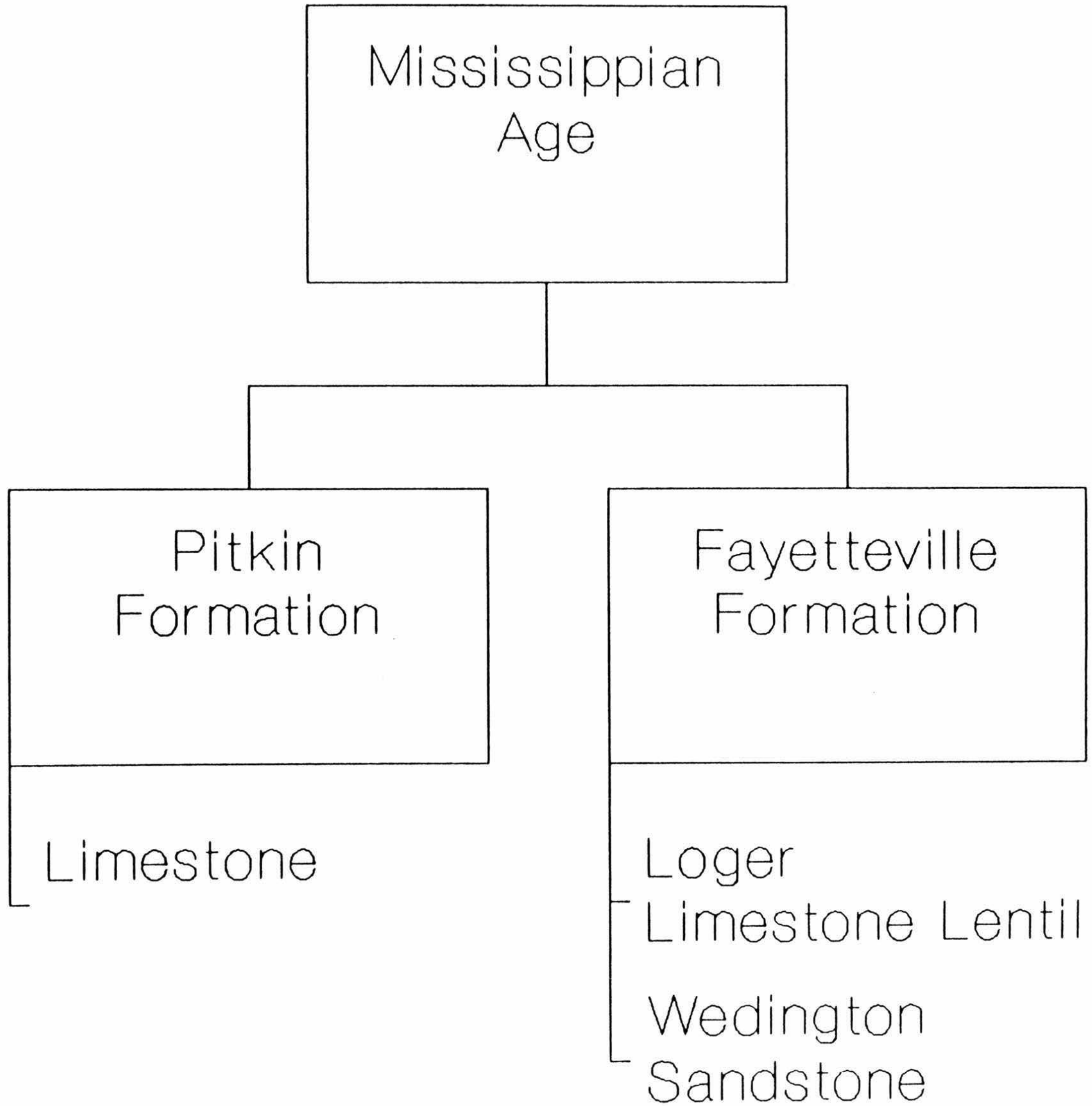


Figure 2

1973). Seasonal cycles of streams have been examined by Holland (1969); Main (1988); Muller-Haeckel et al. (1978); Whitford et al. (1963). Earlier comparison of water quality with diatom assemblages were conducted by Lowe (1974); Schoeman (1973); Weber et al. (1978); Hustedt (1930); Dodd (1971). Only a few studies integrated all of these parameters in their research (Eminson 1980; Tuchman et al. 1979; Patrick 1962; Patrick and Strawbridge 1963). An analysis of the interaction of nutrient composition of the water, the geological substrate to which the organisms are attached and the flow characteristics of the stream system may provide a characterization of the diatom community through an annual cycle, the diatom assemblage associated with each substrate type and the influence of flow. One obstacle of the project was the shortage of research done on low conductivity, low pH, low nutrient streams (Christensen and Archibald 1976, Camburn et al. 1978, Winterbourne et al. 1985).

METHODS AND PROCEDURES

A. Site Descriptions

Nine permanent river collection stations on the Middle Fork of the White River were selected for analysis of the diatom assemblage, selected physical measurements, chemical water quality analysis, and identification of the geologic formations exposed to

Figure 3

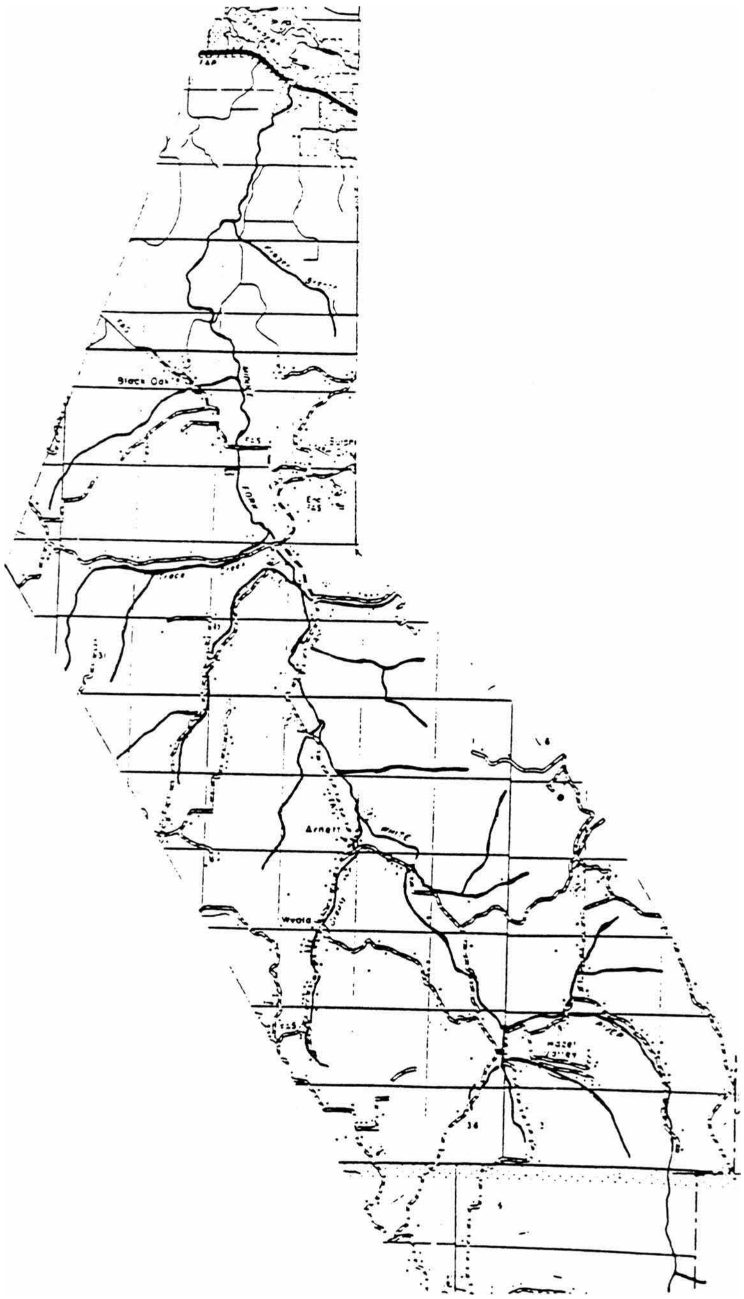


Figure 3 Middle Fork of the White River Drainage Basin, and Study Sites

Stream Profile

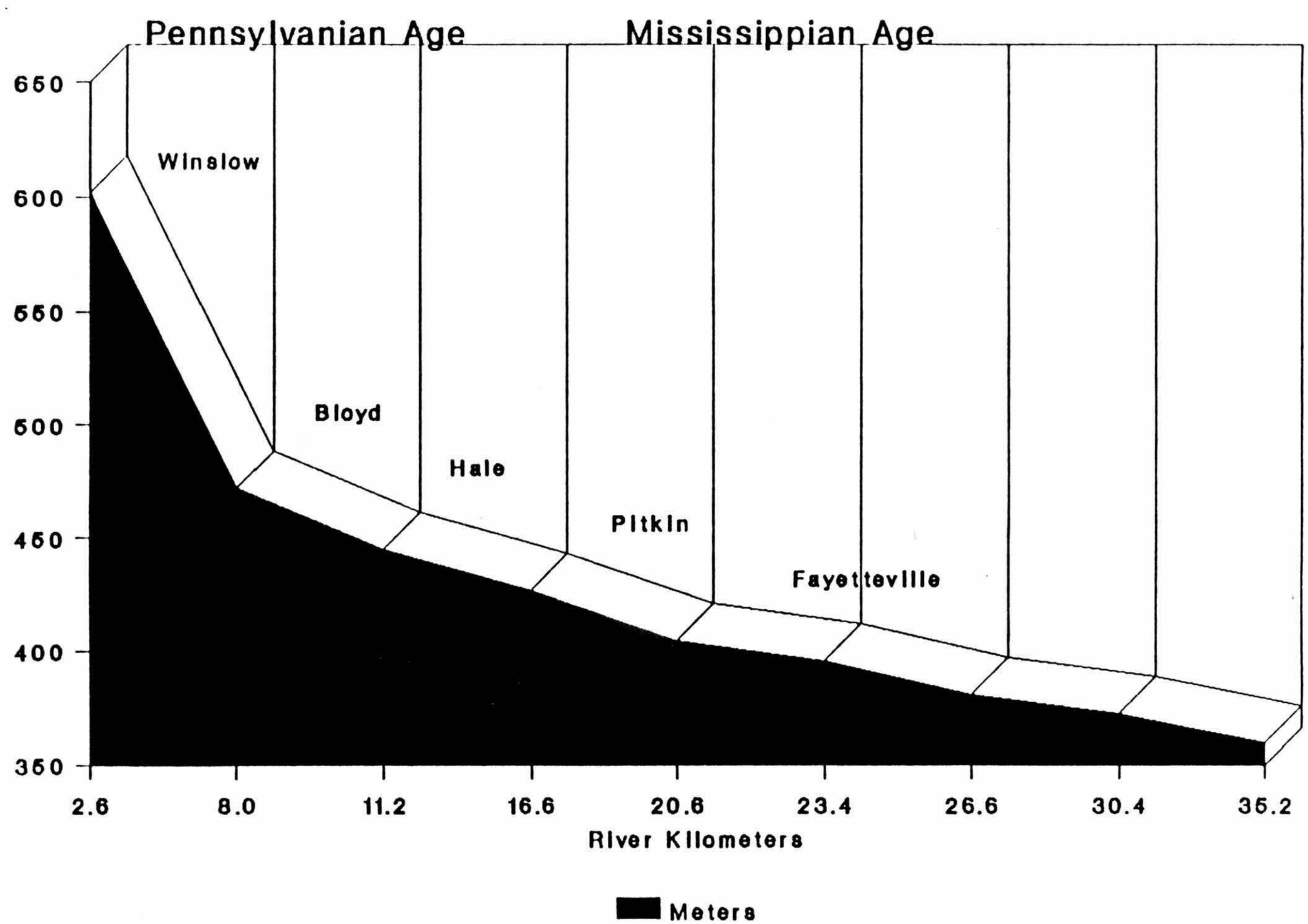


Figure 4

water flow. (Figure 3). The geological information about the area was obtained from U.S. Geological Survey 7 1/2′ maps, and by on site observations. Soil types and characteristics were obtained from the Washington County, Arkansas Soil Survey (1969).

The river drainage system bisects the north face of the Boston Mountain peneplain resulting in hilly terrain with valley flats along the streams. The valley flats at the lower portion are built of alluvial deposits several feet thick which are probably post-Pleistocene in age (Taylor 1964). The entire basin is composed of the typical "v" shaped valleys with the hills widely forested and the rocks covered with soil and colluvium. The sandstone and limestone of the lower half form bluffs whereas the siltstone and shale of the upper portions form gentle slopes.

The five geological formations with six of its members are exposed along the river course. Figure 4 depicts the stratigraphy of the substrate characteristics with sampling locations along the stream profile. Detailed descriptions are given for each sampling site.

River Kilometer 2.6 [R28W, T14N NE 1/4 of Section 4]

The exposed substrate at 602 meters is very friable shale, an unnamed member of the Winslow Formation. The stream is narrow, 2 meters wide with exposed bedrock slabs. The riparian zone is pasture surrounded by oak-hickory stands of the Ozark National

Forest.

River Kilometer 8.0 [R28W, T14N NE 1/4 of Section 30]

Elevation has decreased to 472 meters. The sandstone bedrock is the Woolsey member of the Bloyd Formation. The four meter wide stream bottom is covered by cobble and gravel. Pastures and small chicken operations adjoin the western margin while the forest is adjacent to the eastern rim.

River Kilometer 11.2 [R29W, T14N Center of Section 24]

At 445 meters elevation the substrate is composed of slab shale from the Cane Hill Member of the Hale Formation. The area adjacent to the eight meter wide stream is wooded with minimal pasturing.

River Kilometer 16.6 [R29W, T14N SW 1/4 of Section 11]

The area is surrounded by limestone bluffs of the Pitkin formation. The 20 meter wide stream is exposed to the Pitkin limestone formation and the elevation is 427 meters. The little true soil is found only along the stream margin which supports minimal pasturing of cattle.

River Kilometer 20.6 [R29W, T15N SW 1/4 of Section 34]

At 405 meters the ten meter wide stream is exposed to the sandstone slab of the Wedington Member from the Fayetteville Formation. There are extensive pastures and several chicken operations, but forested stream margins are being maintained.

River Kilometer 23.4 [R24W, T15N NE 1/4 of Section 28]

This sampling area is on massive sandstone slabs of the Wedington Member at an elevation of 396 meters. On the east side of the ten meter wide stream at the top of the bluff is a cemetery, and beyond the forested west margin is a cattle feed lot.

River Kilometer 26.6 [R29W, T15N SW 1/4 of Section 16]

This area is pasture at an elevation of 381 meters. The bedrock formation is the Loger limestone lentil of the Fayetteville Formation. The 100 meter wide streambed is gravel and cobble, with through gravel flow and during the dry periods.

River Kilometer 30.4 [R29W, T15N NE 1/4 of Section 5]

The elevation of this heavily pastured 60 meter wide site is 373 meters. Its bedrock is compose of sandstone of the Wedington Member of the Fayetteville Formation and it is covered with gravel and cobble; although flooding may expose it to water flow.

River Kilometer 35.2 [R29W, T15N NW 1/4 of Section 33]

The elevation at this site is 360 meters with the Fayetteville Formation buried under several meters of alluvium and cobble. This area is of very reduced slope, 60 meters wide and is used as a pasture for cattle. At the beginning of this project a beaver was actively maintaining a dam across the stream at this point.

B. Sampling and Data Collection

Diatom samples were collected by gathering plant materials, picking up obvious grazers, and scraping rocks. Epipelic of organisms on mud surfaces were collected by pipetting. All possible substrates at each sampling site were included. These samples were placed in individual virgin glass vials.

Raw samples were split. Half of the sample was observed untreated to establish the live-to-dead ratio, with 90% live establishing the sample's acceptability (Slock 1979). This portion was later preserved and archived as a reference sample. The other portion was cleaned by a modified Van der Werff (1958) method. The cleaned material was dried on coverslips and mounted on slides with Hyrax (n=1.65).

The mounted diatom material was observed with a Nikon light microscope containing a Nikon 100X plan achromat (1.30) oil objective and Nikon 10X occulars. Species were identified to species with the help of the following works: Hustedt (1930, 1937, 1949); Cleve-Euler (1951-1955); Camburn et al. (1978); Petersen (1950); Czarnecki et al. (1978); Hansmann (1973); Christensen (1969, 1976); Patrick and Reimer (1966, 1975). Nomenclature was updated using Vanlandingham (1973). To determine the proportional representation of the diatom assemblages found at each site 1000 valves were identified and counted. Slides were scanned for additional taxa.

Chemical and physical parameters were monitored in the field from September, 1989 through October, 1990. Field measurement of temperature was made using a field thermometer, flow was measured with a General Oceanics, Inc. flow meter and pH using a Marksen pH meter. Water samples for laboratory analysis were collected five centimeters below the water surface, and maintained at or below stream temperature. In the laboratory turbidity was determined with a Hach Turbidimeter Model 2100 using unfiltered water samples. Conductivity was ascertained with a YSI Model 54 conductivity meter. The determination of orthophosphate, ammonia nitrogen, nitrate nitrogen, alkalinity, and total hardness were done in accordance with Standard Methods, Edition 16 (APHA 1985).

Data compilation, graphs and calculations were preformed by an IBM-XT computer using Lotus 123 (2.2) and Harvard Graphics (2.3).

PRINCIPAL FINDINGS AND SIGNIFICANCE

The results were compiled in five categories. First the annual mean distribution of each measured parameter was considered by river kilometer. Second, physical and chemical parameters were analyzed for each site. Third, the general longitudinal distribution of the diatom taxa was described. Fourth, a seasonal distribution of diatoms for each site was examined. Fifth, a comprehensive list of taxa for the Ozark/Boston ecoregion was compiled.

A. Mean Annual Water Quality Parameters

There is a relationship between the change of the geomorphology, the stream order, and certain water chemistry at the study sites. The stream order impact, however, may be a factor of the volume and quality of water the tributaries contribute to the system.

There is a direct relationship between hardness, alkalinity, and conductivity (Figure 5). The upper reaches of the stream have low values, with a large change between RKm 8.0 and RKm 11.2 for each parameter (20 mg/l hardness, 20 mg/l alkalinity, and 20 uS conductivity change). There is a formation shift from the sandstone Woolsey member of the Bloyd formation to the shale Cane Hill member of the Hale Formation at RKm 11.2 (Figure 4). A large change, of 20 mg/l hardness, 30 mg/l alkalinity, and 30 uS, occurs between RKm 16.6 and RKm 23.4. The area at RKm 16.6 is the Pitkin limestone formation, before RKm 23.4 there are several tributaries that drain this formation into the stream (Figure 3). There would be an increase in the calcium carbonate and an observed increase in associated parameters. The rest of the sites reach a plateau, but at a slightly lower level of 38.00 mg/l alkalinity, 31.00 mg/l

Mean Hardness Parameters
September 1989 - October 1990

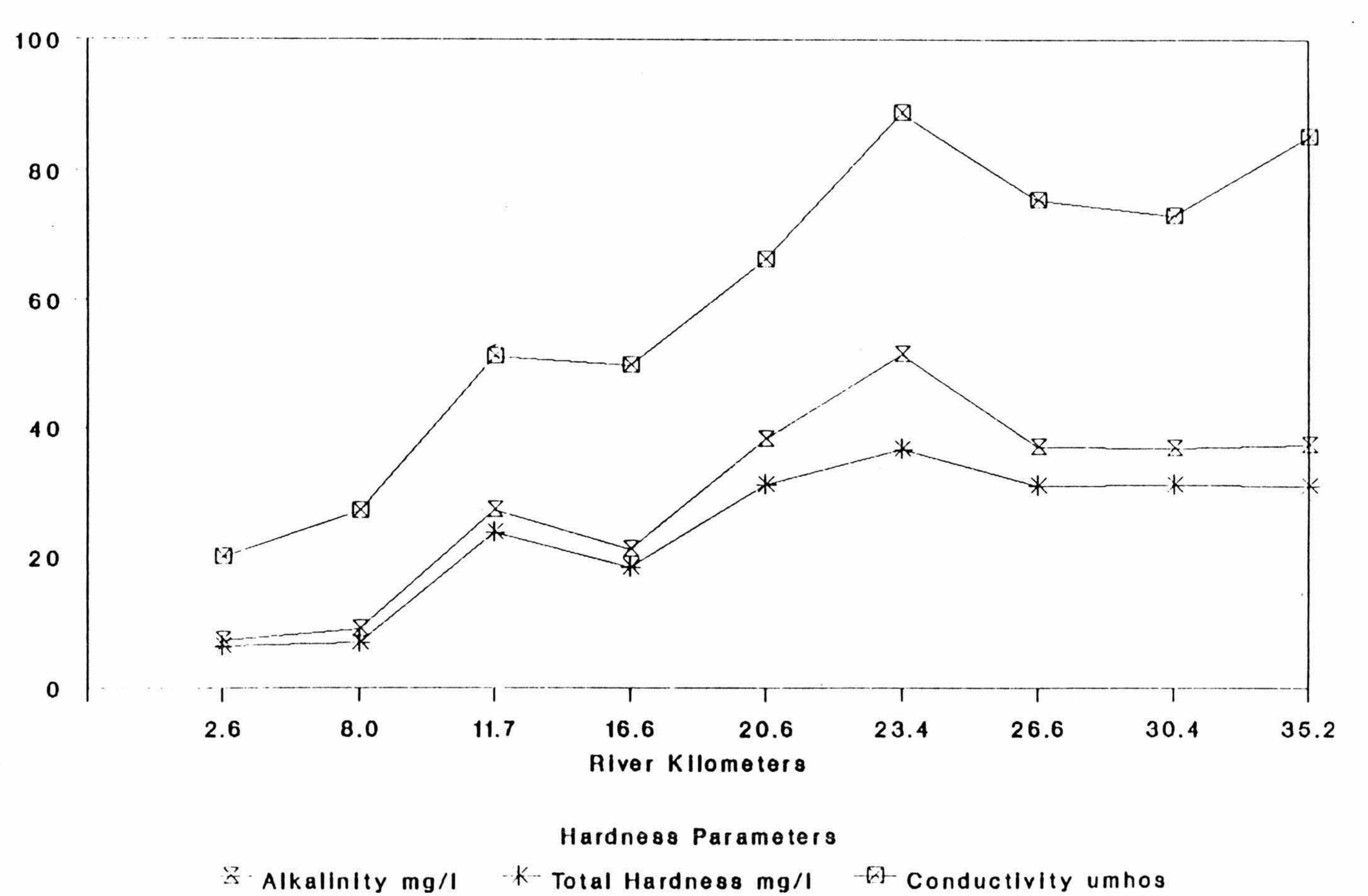


Figure 5

hardness, and 75.0 uS.

There appeared to be a greater buffering capacity exhibited in the lower reaches which was the result of extensive exposure to the limestone at the midreaches (Figure 4). This area has one of the major tributaries, Greasy Creek, entering into the system. This stream traverses the limestone exposure, and the runoff adds dissolved calcium carbonate to the system. The pH of the water also increases the ability of the water to leach ions from the exposed limestone (Wetzel 1983). There was also some effect of dilution because the volume of the stream was increased with the increasing stream order.

There was not a significant variation in the quantity of orthophosphate or ammonia nitrogen along the entire study reach. Both parameters averaged less than one milligram per liter (Figure 6). The nitrate concentrations fluctuate with increased flow and corresponding runoff from the riparian area. There was a noticeable increase in association with additional human disturbance. RKm 2.6 surrounded by the Ozark National Forest had a mean nitrate nitrogen of 1.34 mg/l compared to 5.03 mg/l at the RKm 35.2 which is surrounded by a cow pasture.

Without the influence of major volume increase due to rain runoff from the entire basin, the turbidity was normally less than 10 NTUs at the lower end, with an average of 5 NTUs (Figure 7).

Mean Chemical Parameters
September 1989 - October 1990

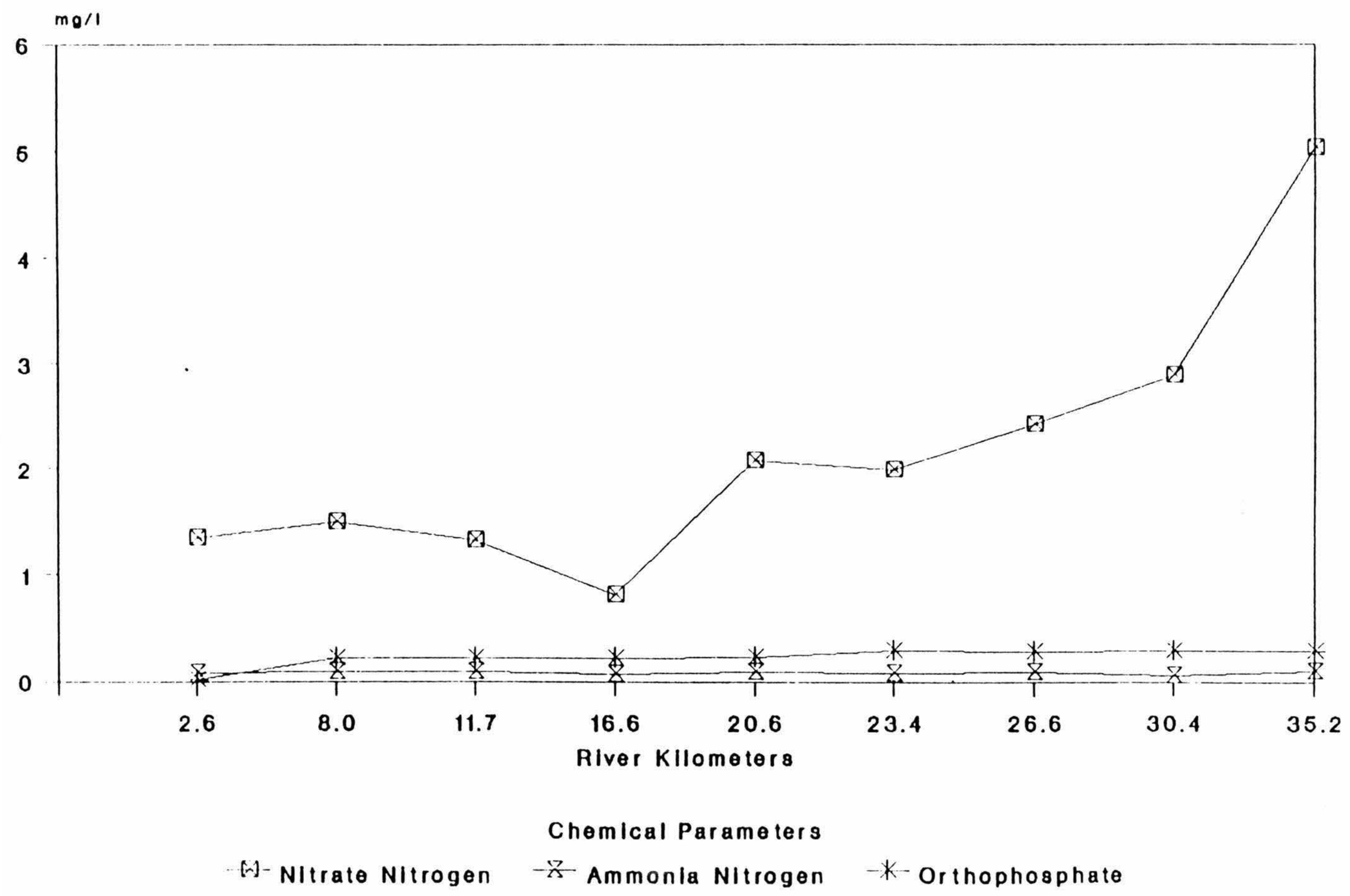


Figure 6

Mean Turbidity
September 1989 - 1990

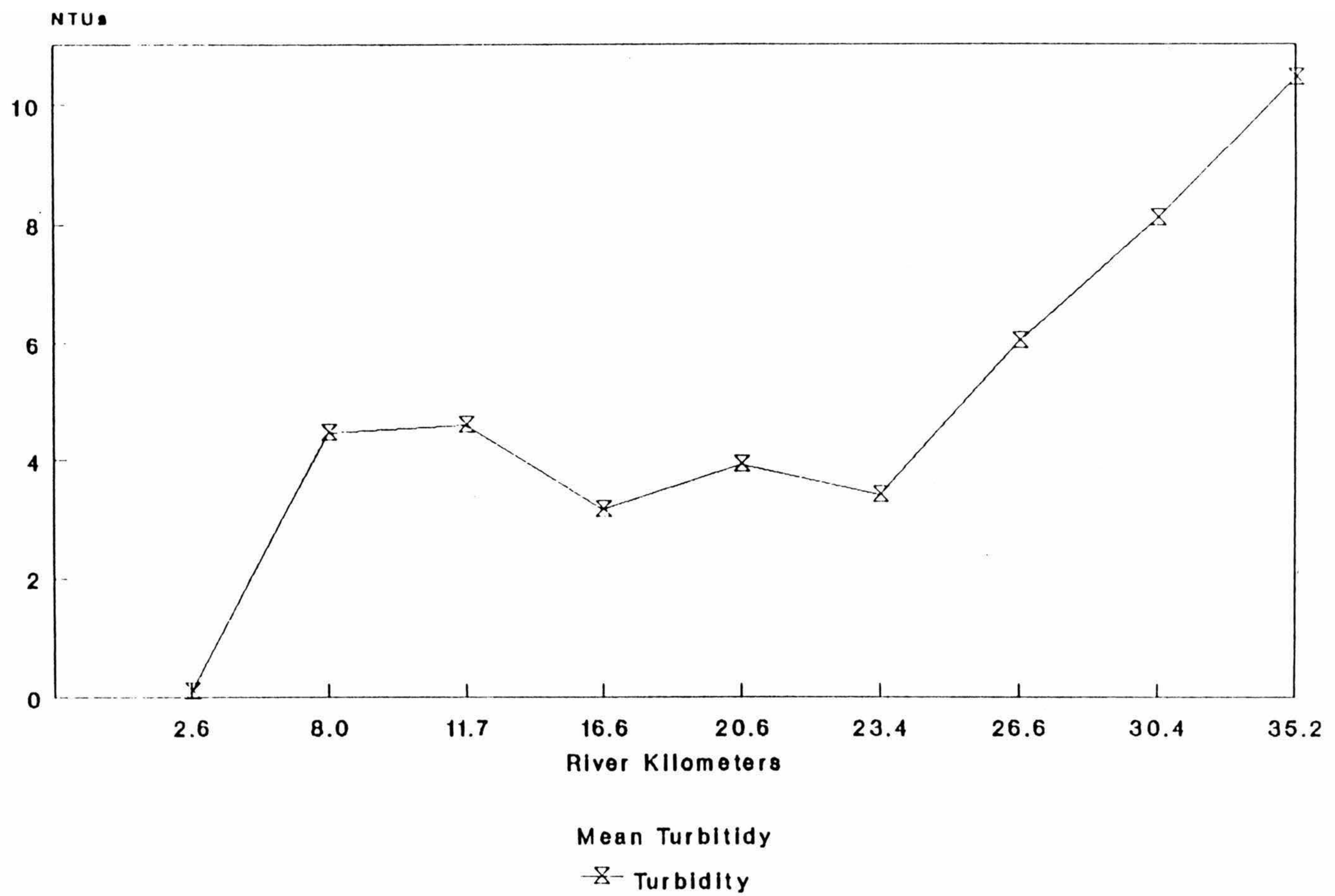


Figure 7

With minimal runoff the upper reaches seldom had turbidities more than 5 NTUs. As the order of the stream changed so did the turbidity load. This was associated with an increase in alluvium and debris transport, but algae and zooplankton had little or no effect (Figure 3).

Mean flow rates were the most erratic of the parameters measured (Figure 8). They were affected by changes in the elevation, rainfall amounts and the stream width and depth, as well as the number, volume and area of the drainage basins of tributaries. (Figures 3 & 4).

Temperature also followed the pattern of the rest of the parameters (Figure 9). The lowest mean temperature of 14.2°C was at RKm 2.6 where the stream was narrow and first order. When the order of the stream changed from first to second order before RKm 11.7 the temperature rose to 16.4°C. The next change in order occurred after RKm 20.6 and again there was a sharp upward trend to 16.9°C. Temperature reached a plateau of 17.8°C at RKm 30.4. Temperature was affected by seasons and also appeared to be affected by stream order. The temperature changes at the lower reaches were more gradual than those of the upper reaches, and where volume and exposure increased while flow rate decreased.

Mean pH for the study area was 6.52 at RKm 2.6 with a slight increase to 6.90 at RKm 8.0 (Figure 10). There was a change of

Mean Flow

September 1989 - 1990

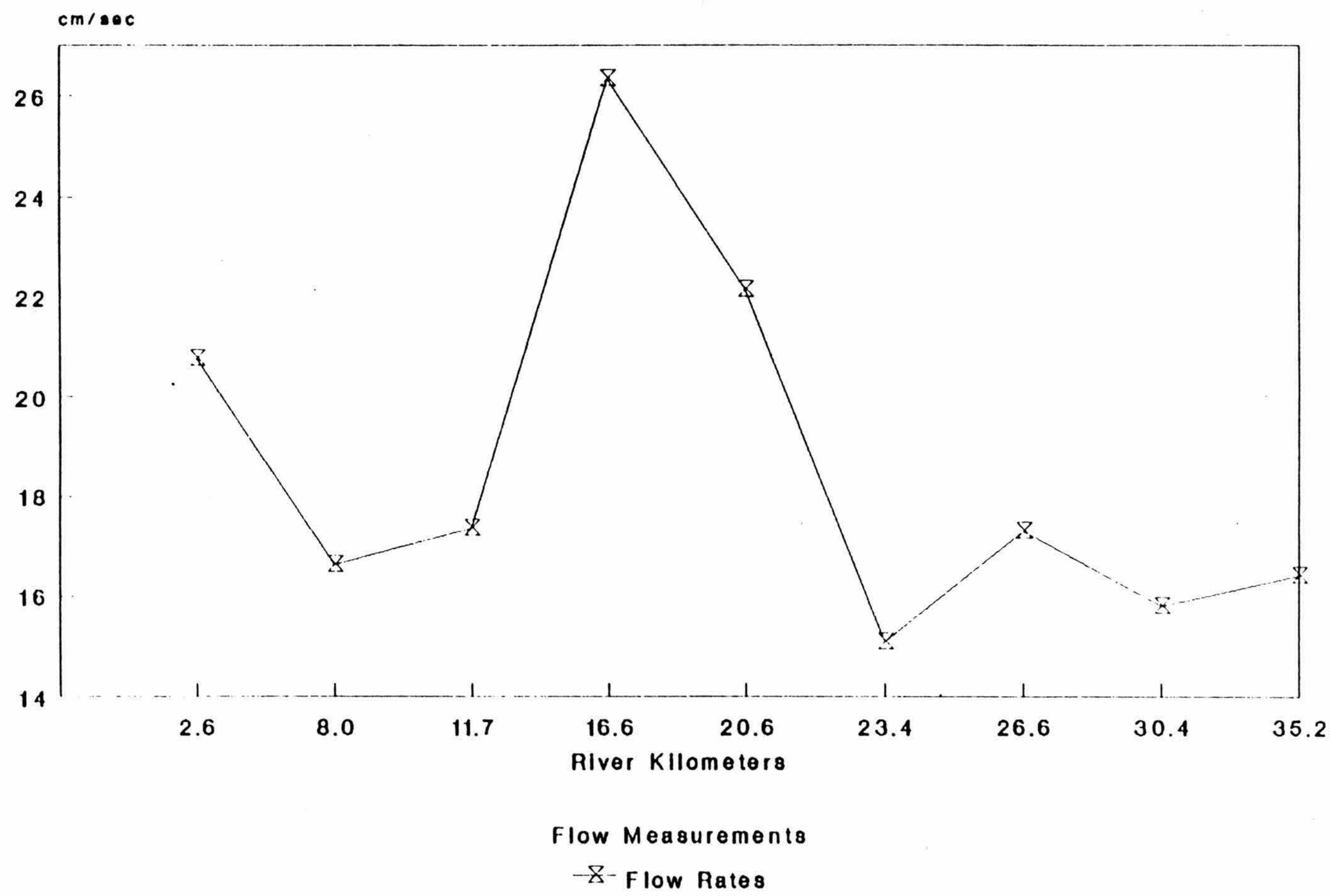


Figure 8

Mean Temperatures
September 1989 - October 1990

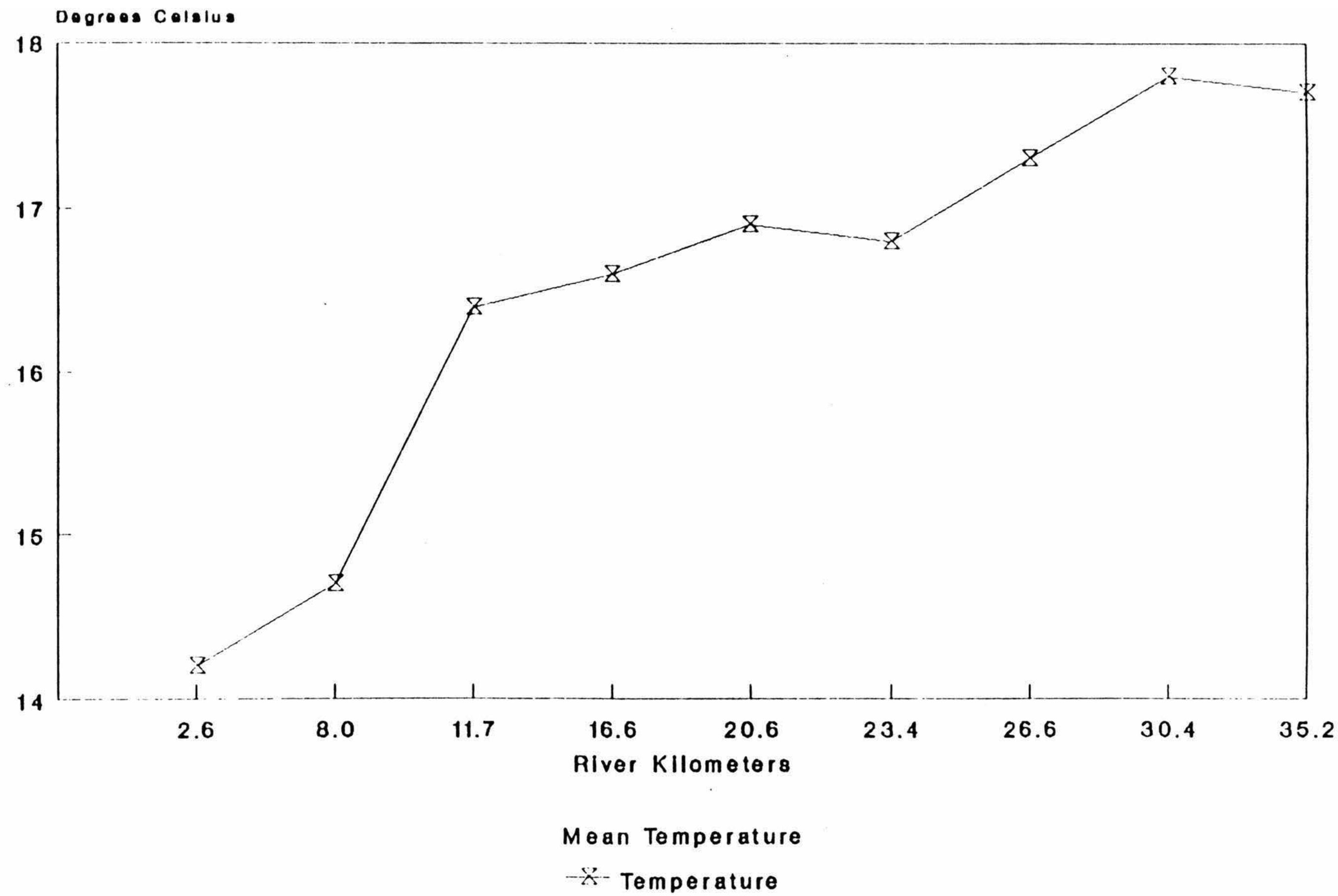


Figure 9

Mean pH
September 1989 - October 1990

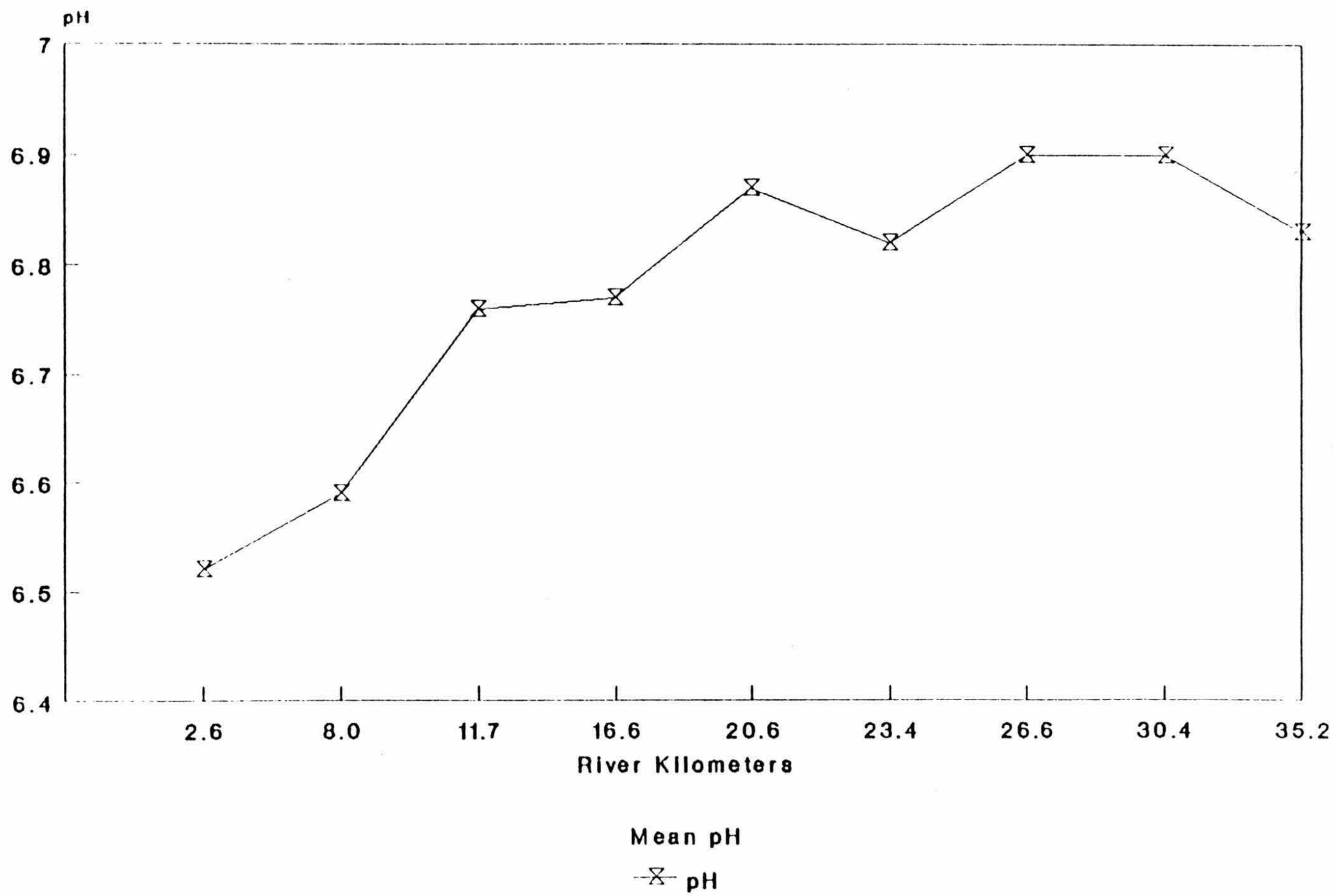


Figure 10

0.17 between RKm 8.0 and RKm 11.7. This was associated with change of formations and stream order between those two sites. The next large change from 6.77 to 6.87 occurred between RKm 16.6 and RKm 20.6. This increase was associated with a formation change. A decrease of pH to 6.82 occurred at RKm 23.4. The next change was marked by an increase to 6.90 as the stream order changed from second to third, and the formations are covered by a thick layer of cobble and alluvium. (Figures 1 & 2).

B. Temporal Analysis of Water Quality by Site

All of the parameters at each site appear to have an annual cycle. This cycle may be an affect of the flow and seasonal climate changes, as well as length of exposure to the various substrates.

A site-by-site description of the water quality parameters measured yielded information necessary to suggest explanations for the diatom assemblages present. It also provided information about if and when microenvironments underwent seasonal change. This in turn assisted in the development of a seasonal model for diatom assemblages. The information also assisted in the explanation of why some taxa were present.

RKm 2.6

Flow, Turbidity, Chemical, and Hardness Parameters

Conductivity, hardness, and alkalinity (hardness parameters) were at the highest level in November of 1989 (Figure 11). There was little or no flow and the turbidity was 5 NTUs (Figures 12 & 13, respectively). The chemical parameters were also low (Figure 14). The December measurements were not collectable because the stream was frozen solid. The early January measurements showed an increase in flow to, and the hardness parameters had dropped to 4.00 mg/l hardness, 5.00 mg/l alkalinity, and 30.00 uS conductivity. In late January the parameters held relatively steady with the exception of turbidity which had decreased from 6 NTUs to 0 NTUs. The rains began in February. Conductivity dropped sharply to 1.00 uS, while turbidity increased to 1 NTU. The rest of the parameters were constant. In March the flow increased to 38.7 and the chemical parameters declined significantly (0.04 mg/l nitrate nitrogen, 0.00 mg/l ammonia nitrogen, and 0.19 mg/l orthophosphate). The conductivity increased to normal levels of 15 uS quickly. During April through September there was a steady increase in the hardness parameters to 10.00 mg/l alkalinity, 8.00 mg/l hardness, and 20.00 uS, a gradual decline in flow to 7.0 cm/sec, but the chemical parameters remained at constant levels

Hardness Parameters
September 1989 - October 1990

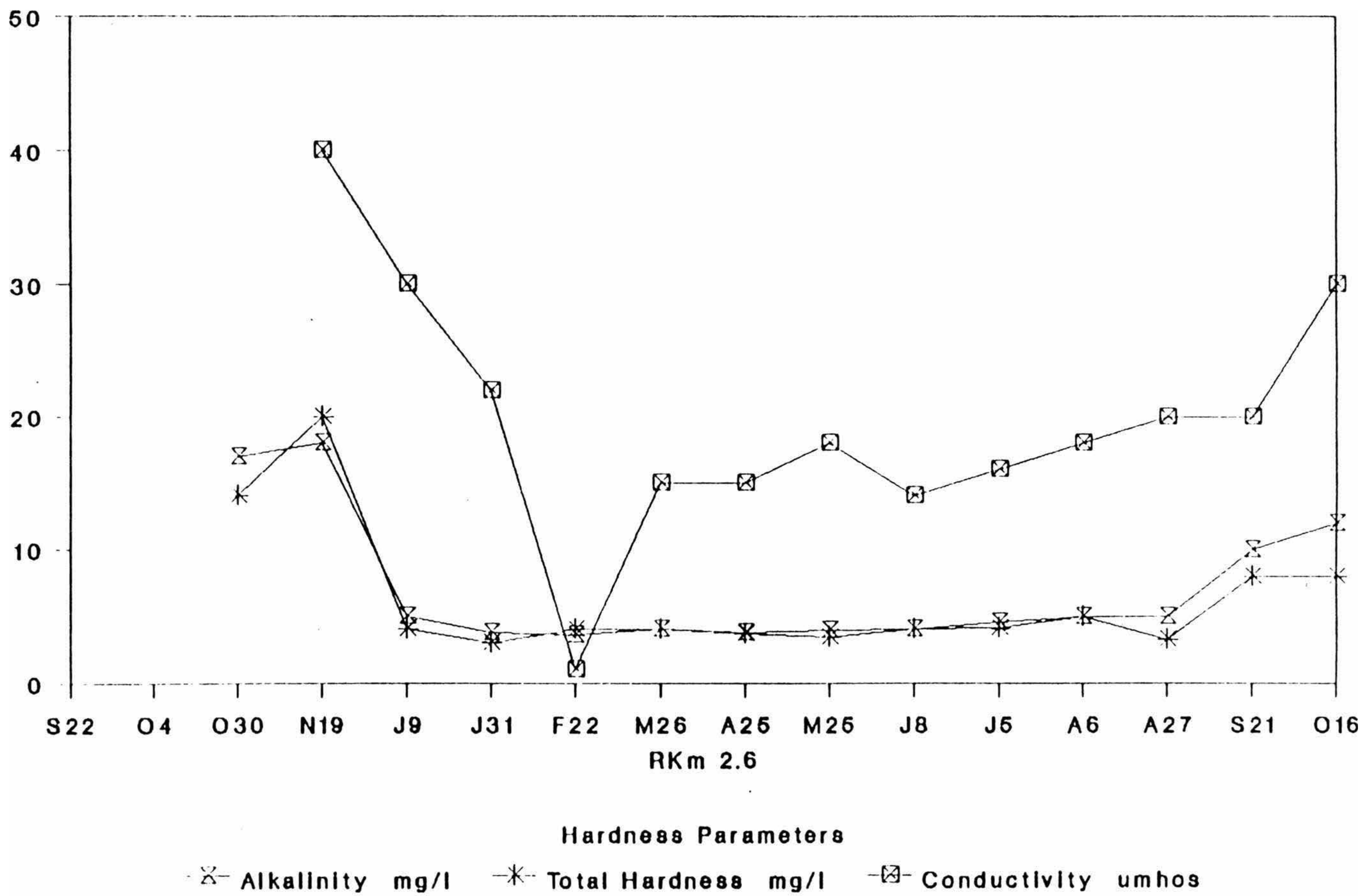


Figure 11

Flow
September 1989 - October 1990

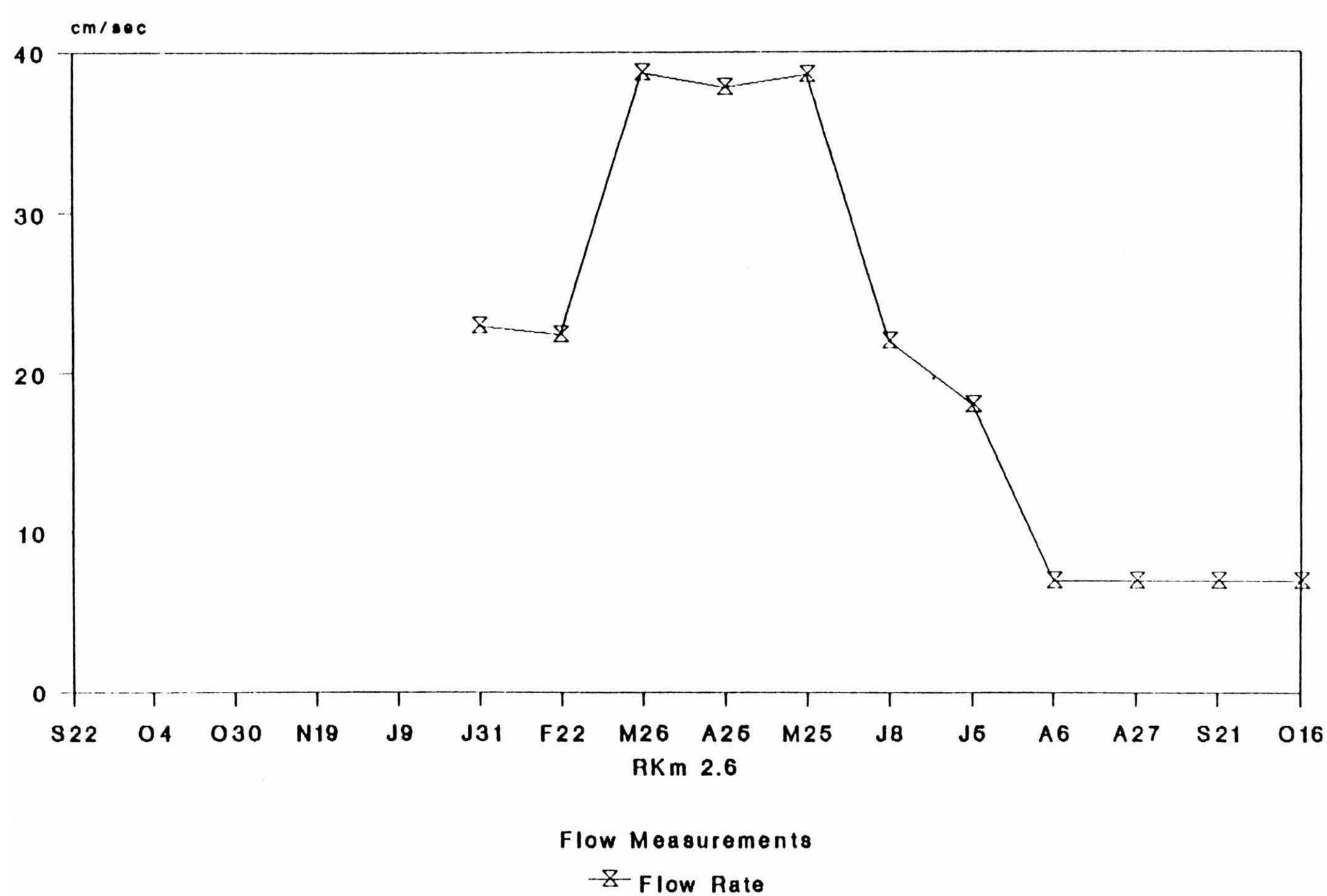


Figure 12

Turbidity
September 1989 - October 1990

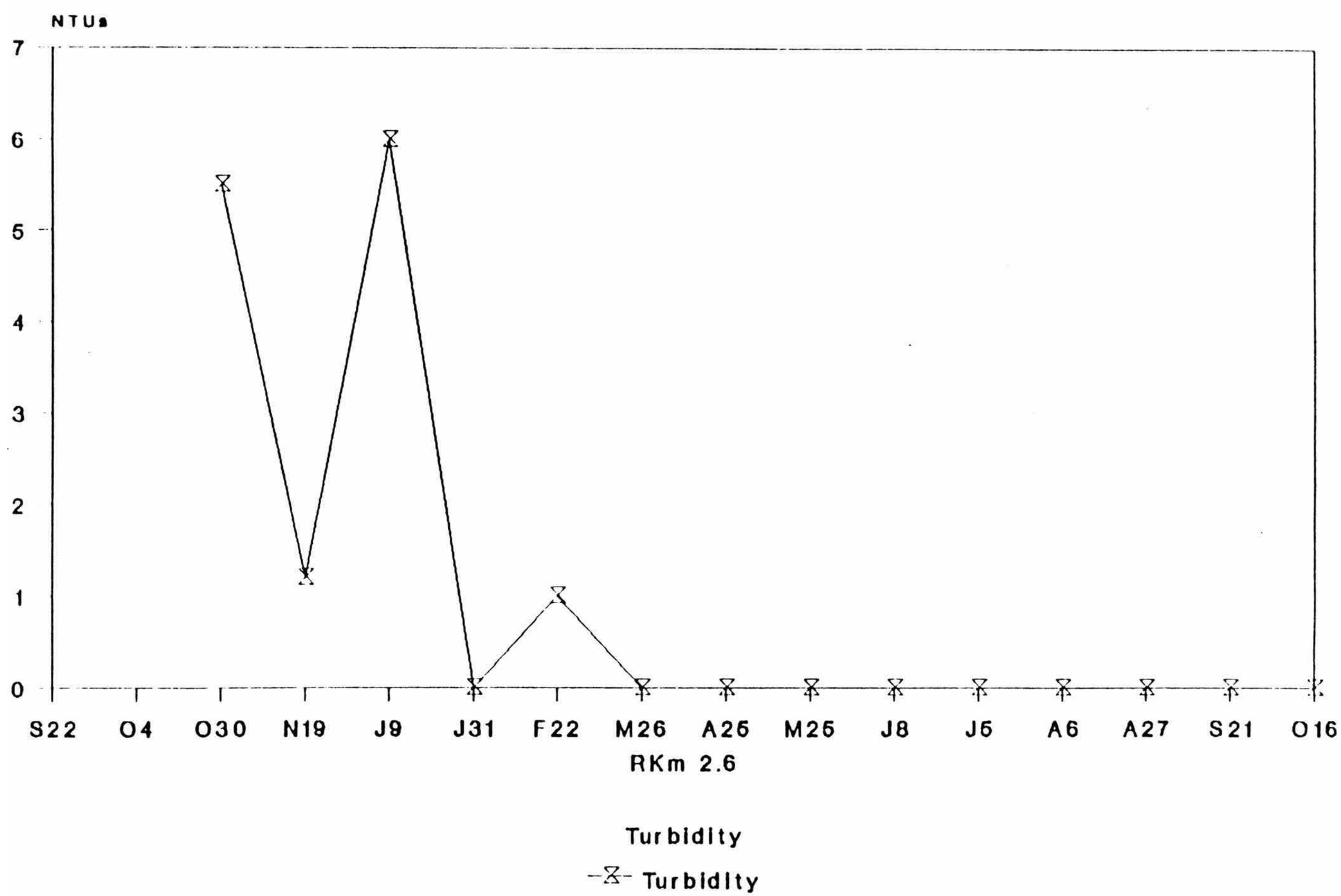


Figure 13

Chemical Parameters
September 1989 - October 1990

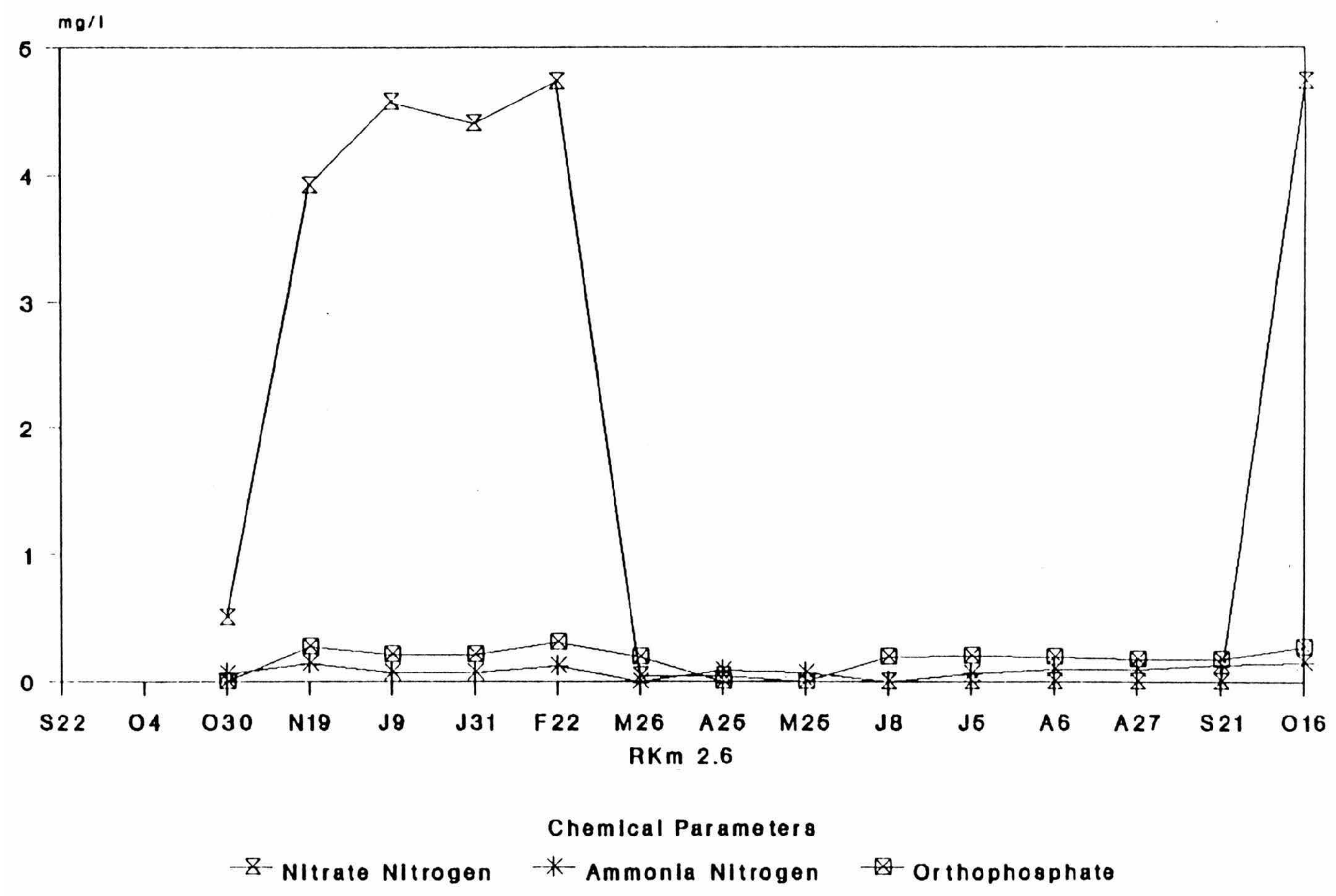


Figure 14

because of the lack of human activities above this point. Between the sampling in September and October, 1990, the weather changed, leaf-fall occurred, and the fall rains began. During this same period frame there was an increase in the hardness and chemical parameters while the flow and turbidity remained constant at 7.00 cm/sec, and 0 NTUs, respectively.

Temperature and pH

The November sampling had the highest hardness parameters, but the lowest pH of 6.36 (Figure 11 & 15 respectively). In early January the pH had increased to 6.48 and the temperature had returned to 10 °C (Figure 16). The pH and temperature were the same in late January, but associated with mid-February rains the pH increased sharply to 6.50 and the temperature dropped to 7 °C. From March through September the temperature increased steadily to 27 °C and the pH under went 0.02 shifts constantly. In October the temperature dropped sharply to 12 °C, but again the pH shift was slight at 0.01.

RKm 8.0

Flow, Turbidity, Chemical, and Hardness Parameters

Alkalinity of 18.00 mg/l, and hardness of 12 mg/l in late October were the highest readings (Figure 17). All of the hardness parameters began to decline with alkalinity reaching its

pH
September 1989 - October 1990

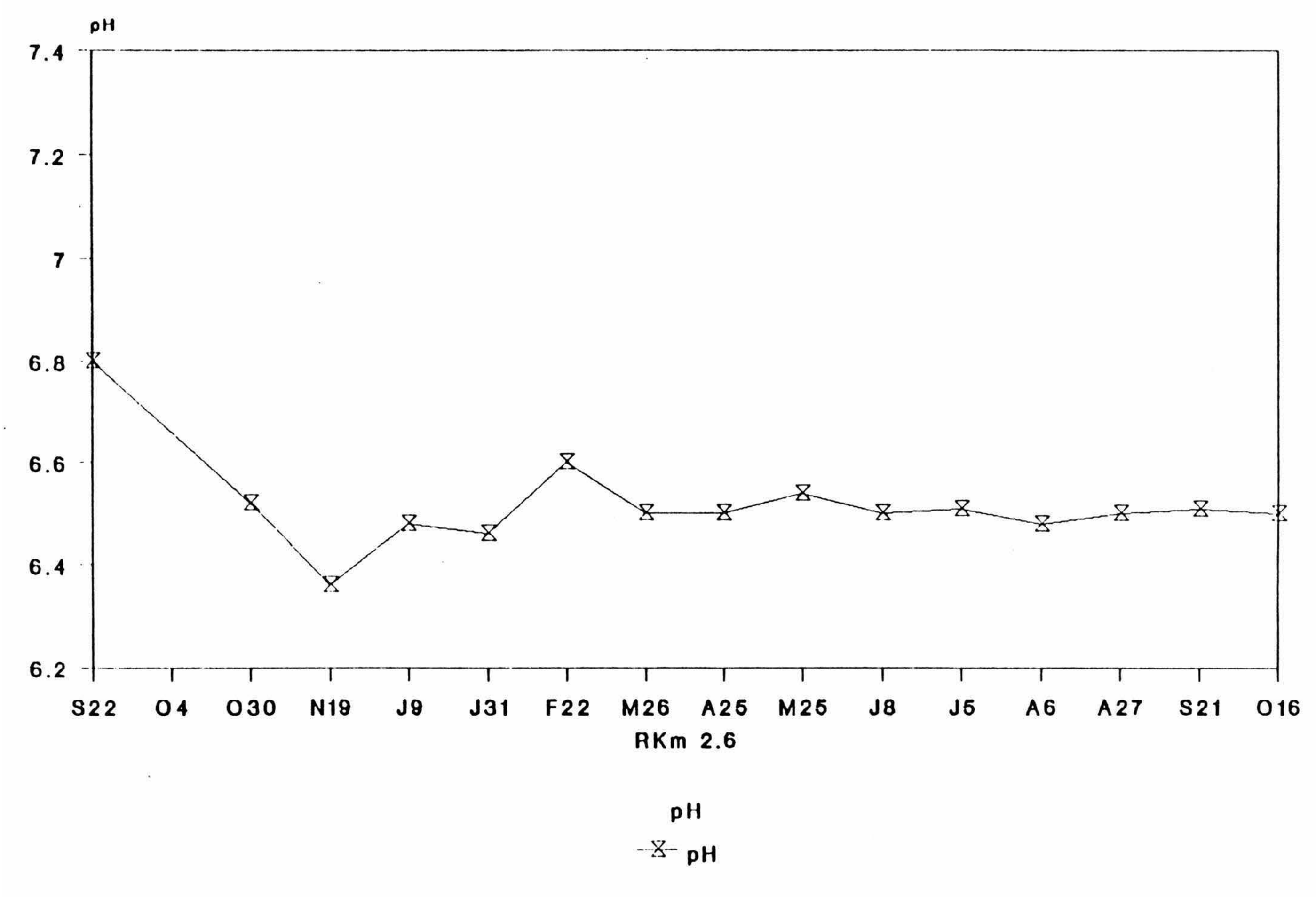


Figure 15

Temperature
September 1989 - October 1990

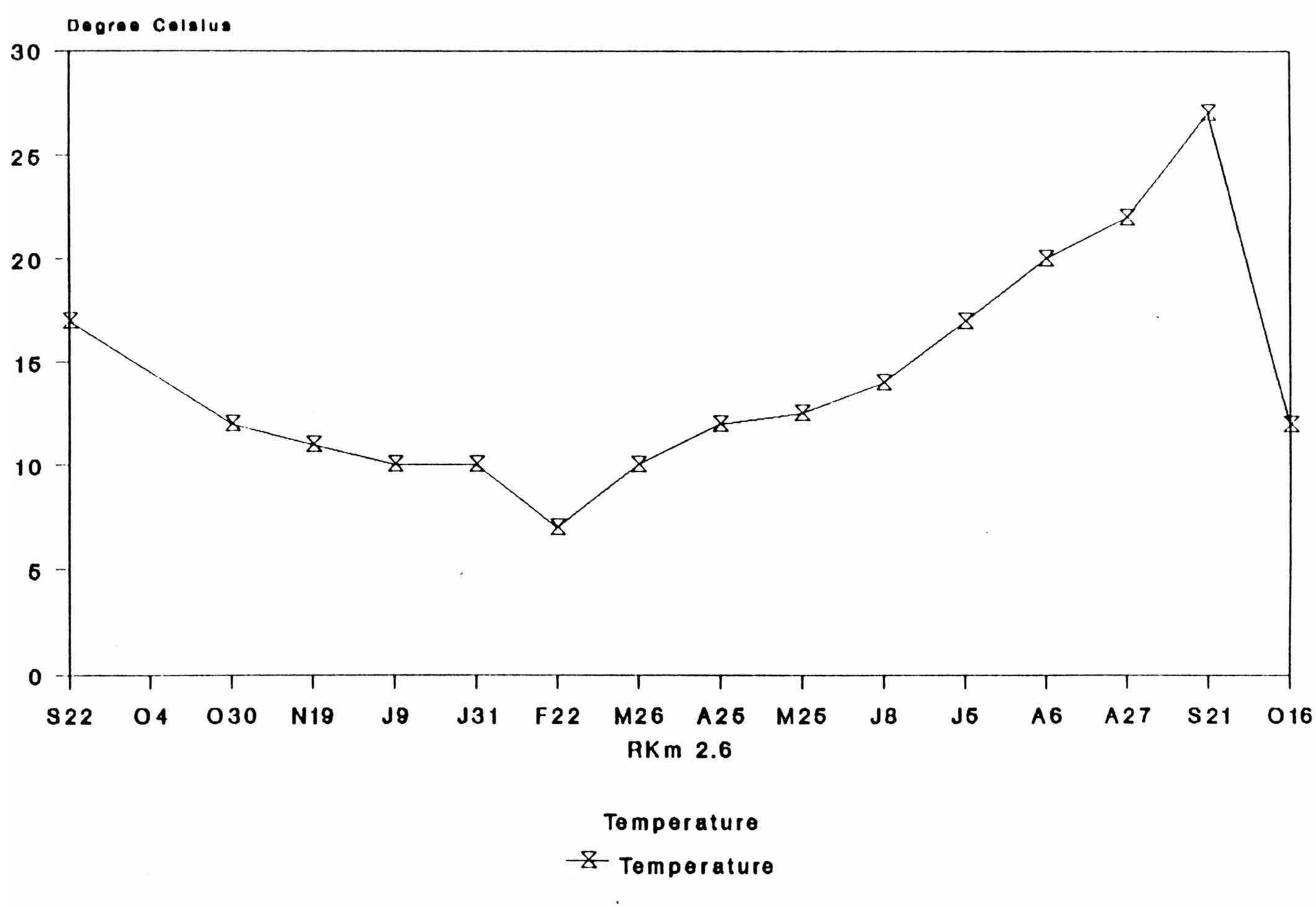


Figure 16

Hardness Parameters
September 1989 - October 199o

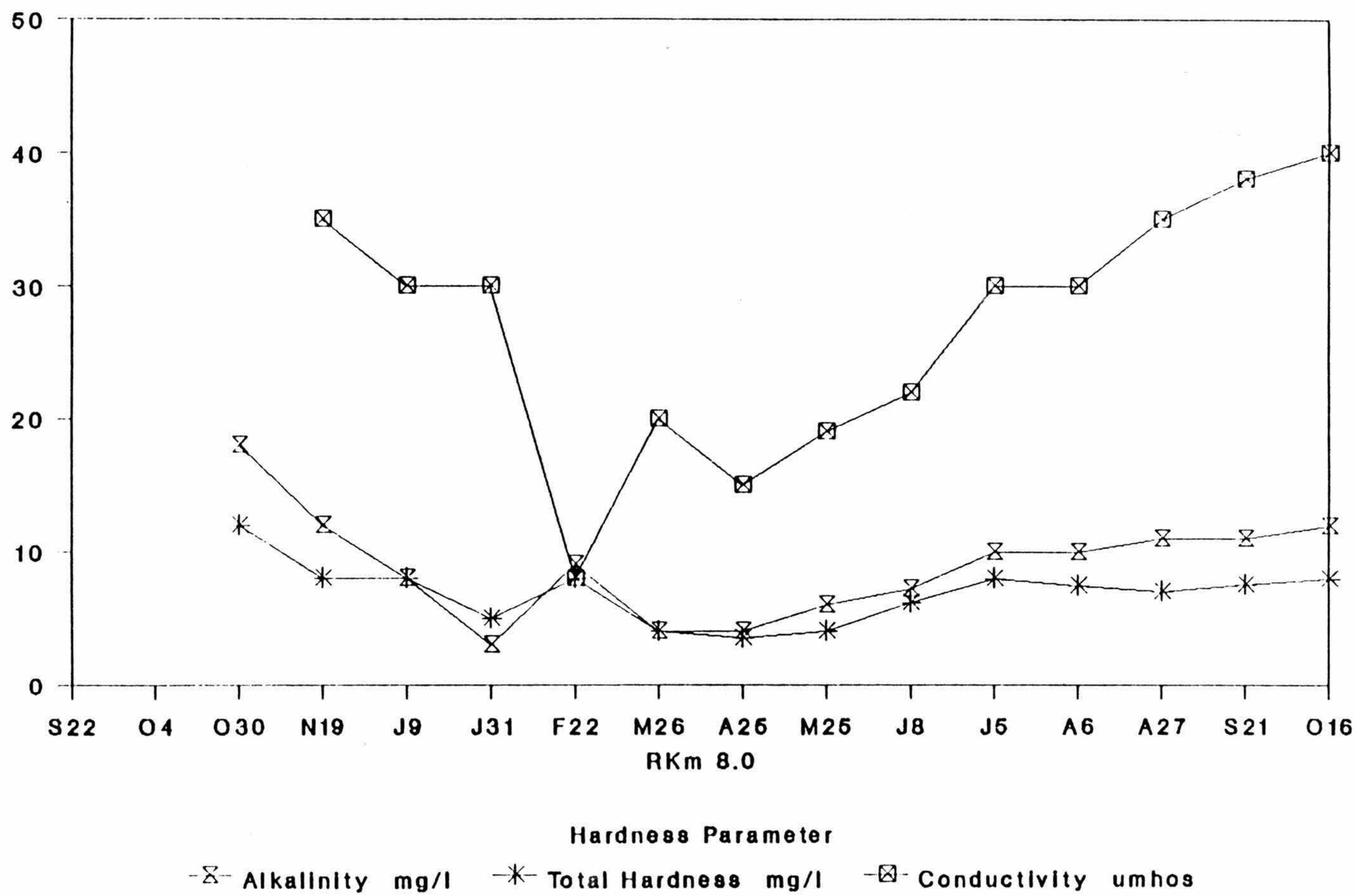


Figure 17

lowest point in late January at 3.00 mg/l, conductivity reaching its lowest point of 8.00 uS in February, and hardness at 3.50 mg/l in April. After April there was a general increase through the last measurement in October, 1990 of alkalinity 12.00 mg/l, hardness 8.00 mg/l, and conductivity of 40.00 uS.

Flow was a trickle till February when the spring rains produced rates as great as 61.1 cm/sec (Figure 18). It quickly subsided to a more normal rate of 7 cm/sec. It remained at that rate through October. 1991. Turbidity was only increased to 28 NTUs during November as a result of the new bridge construction (Figure 19). The ammonia nitrogen, nitrate nitrogen, and ortho-phosphate remained low at less than 0.20 mg/l, 5.00 mg/l, and 0.30 mg/l respectively, from September, 1989, through October, 1990 (Figure 20). There was little other anthropogenic activity to have any impact on this area.

<u>Temperature and pH</u>

The highest pH of 6.91 was in September, 1989 (Figure 21). The site dried in early October, but began to flow at a very low volume again by late October (Figure 18). The pH at that time was 6.64 where it remained through November. In early January the pH had increased to 6.30 and the temperature had returned to 12 °C (Figure 22). The pH increased to 6.43, but the temperature was the same at the end of January. With the rains in February the pH

Flow
September 1989 - October 1990

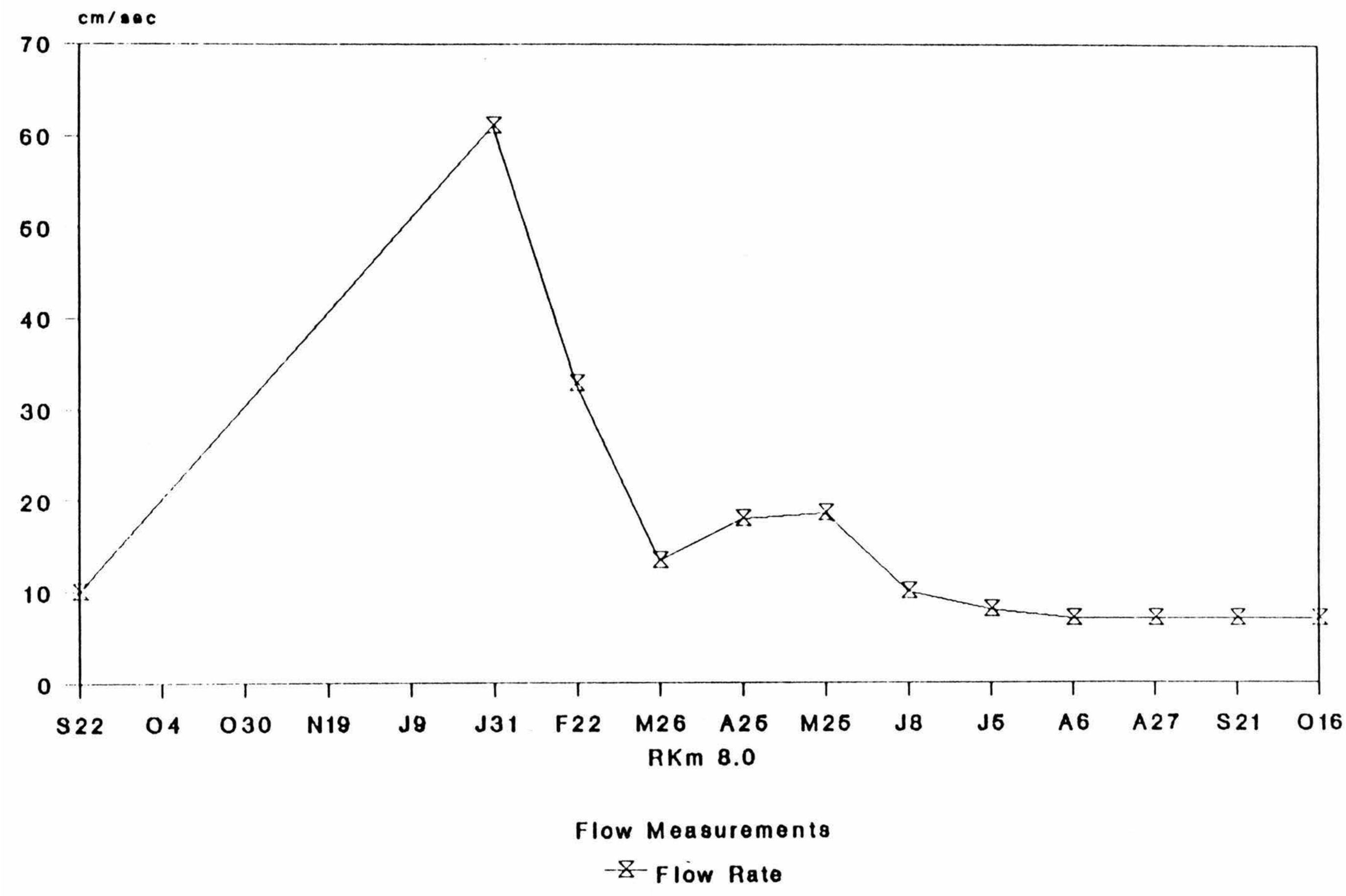


Figure 18

Turbidity
September 1989 - October 1990

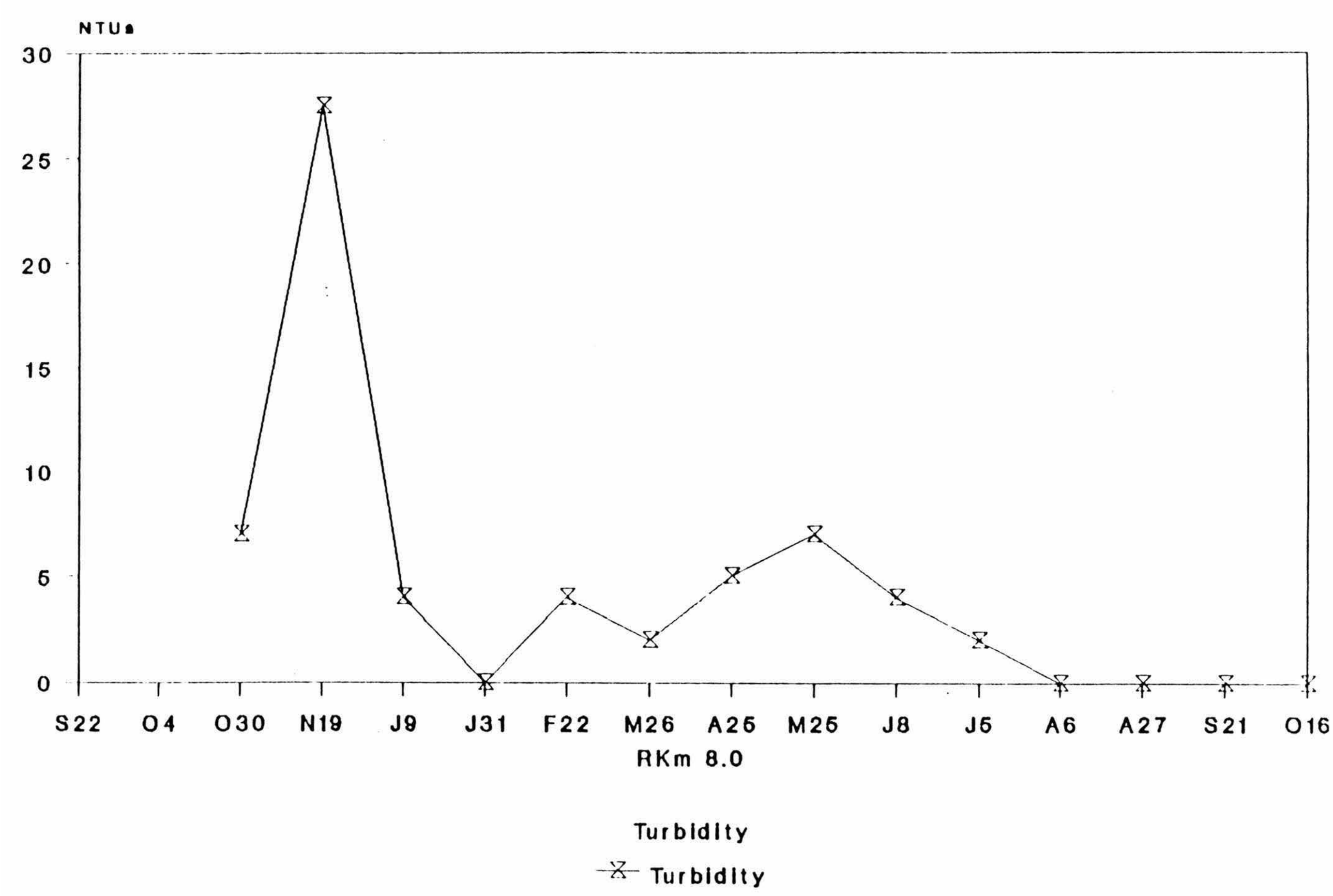


Figure 19

Chemical Parameters
September 1989 - October 1990

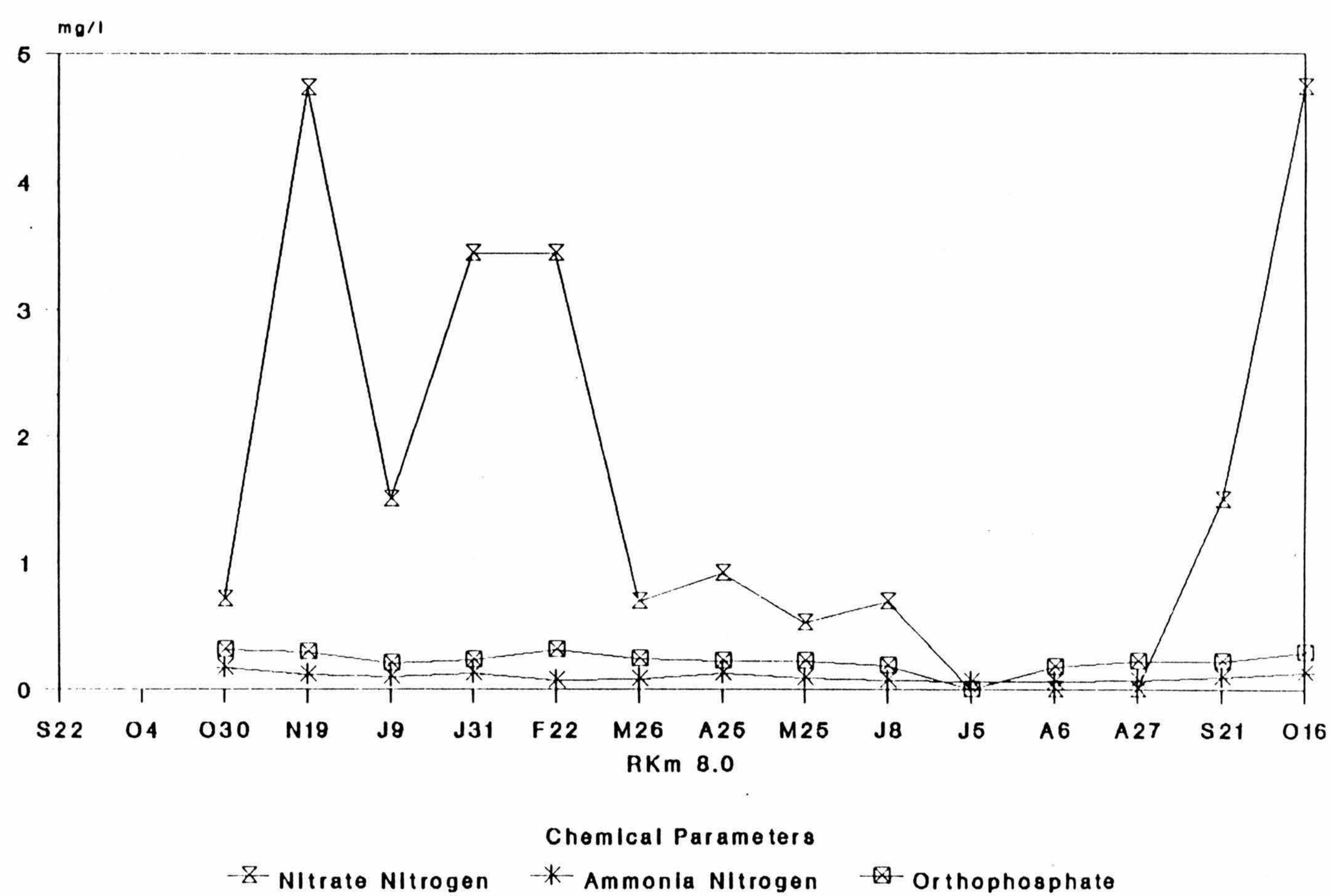


Figure 20

pH
September 1989 - October 1990

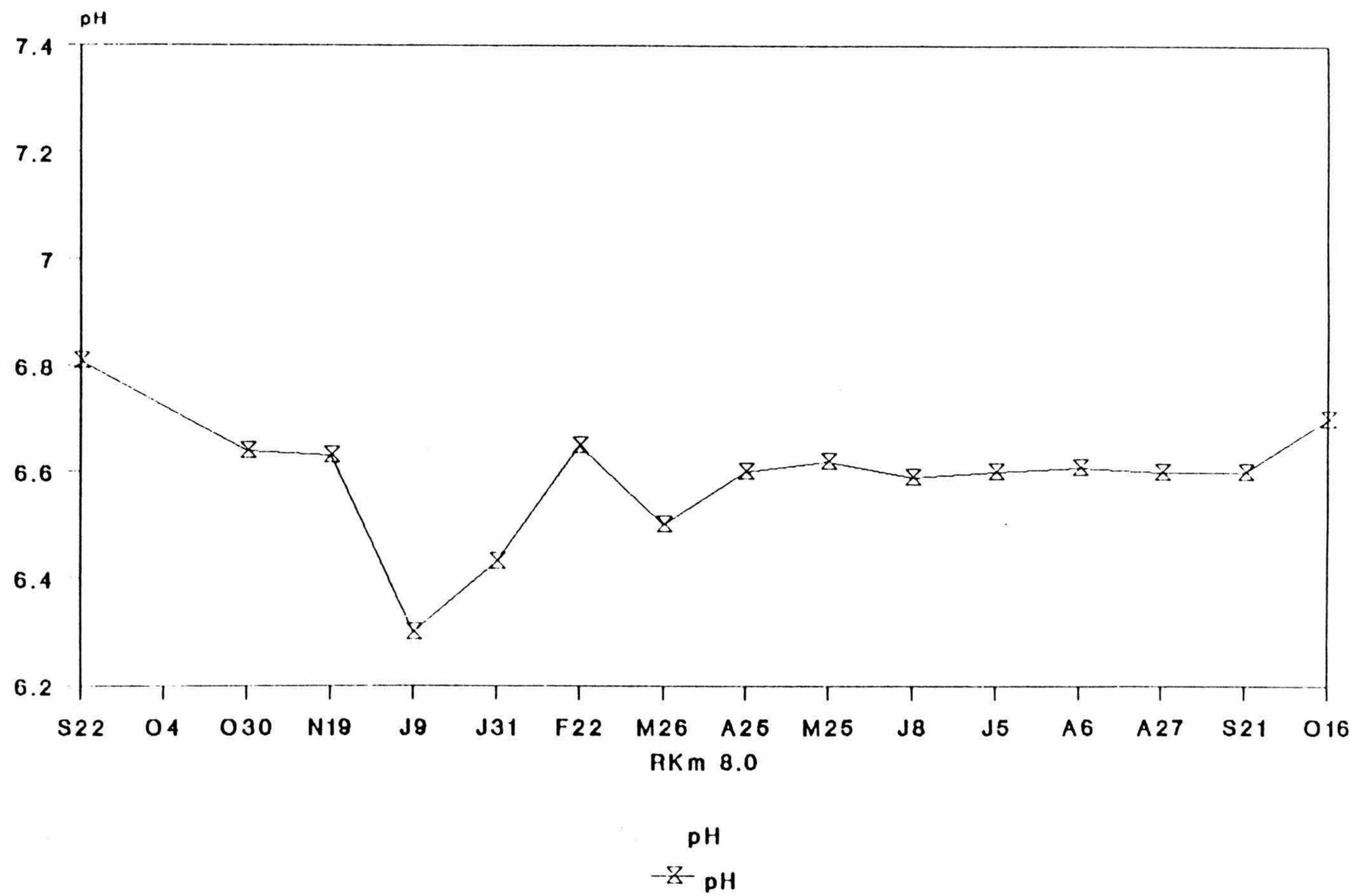


Figure 21

Temperature
September 1989 - October 1990

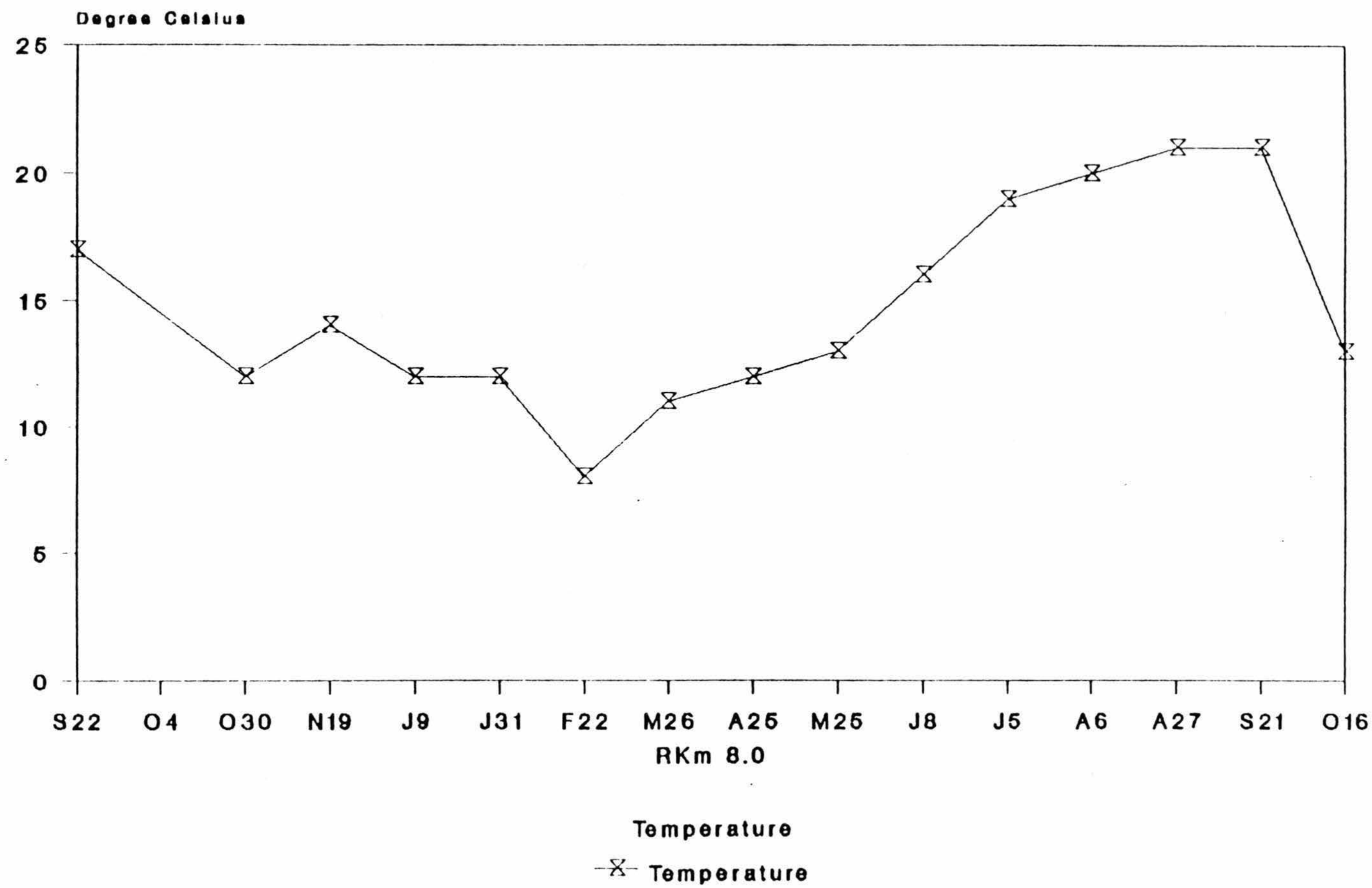


Figure 22

increased sharply to 6.65 and the temperature dropped just as sharply to 8 °C. From March through September the temperature increased gradualy to 21 °C and the pH displayed only ±0.02 variations. In October the temperature dropped sharply to 13°C, but the pH increased to 6.70.

RKm 11.2

Flow, Turbidity, Chemical, and Hardness Parameters

The alkalinity, hardness and conductivity all peaked at 90.00 mg/l, 83.00 mg/l, and 215.0 uS respectively, in November (Figure 23). Flow was unmeasurably low (Figure 24). The turbidity was 20 NTUs during period (Figure 25). In January the hardness parameters decreased to alkalinity 26.00 mg/l, hardness 26.00 mg/l and conductivity 35.00 uS, and flow increased to 28.4 cm/sec. The February rains increased the flow rate to a maximum of 53.9 cm/sec and the volume of the stream. After the waters receded in March the hardness parameters increased steadily to alkalinity 26.00 mg/l, hardness 26.00 mg/l, and conductivity 50.00 uS in October of 1991. The nitrate nitrogen was 4.41 mg/l in October with great fluctuation through February, after which there was a sharp decline to 1.49 mg/l (Figure 26). The other chemical parameters remained constant at ammonia nitrogen less than 0.10 mg/l and orthophosphate at less than 0.31 mg/l.

Hardness Parameters
September 1989 - October 1990

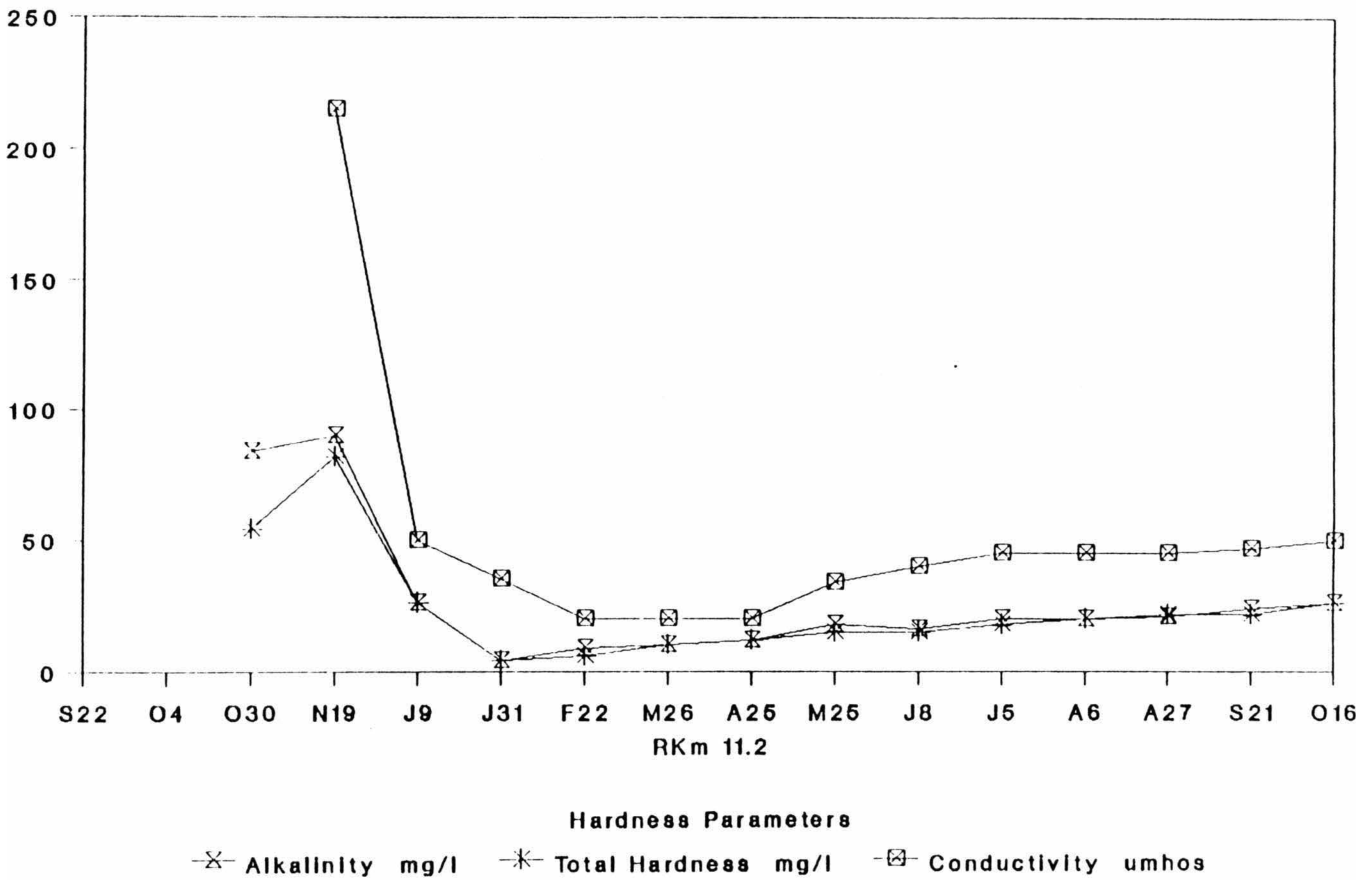


Figure 23

Flow
September 1989 - October 1990

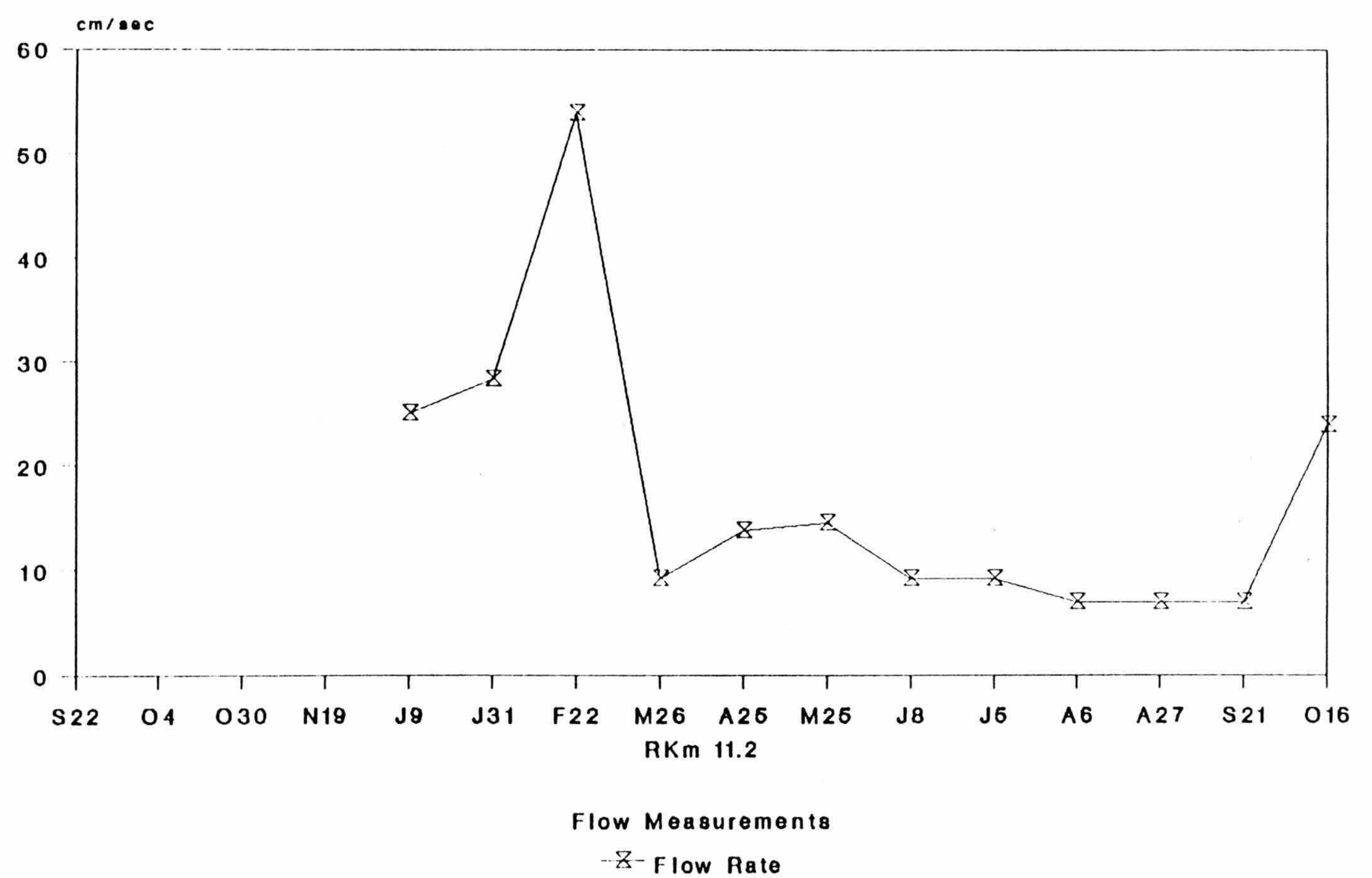


Figure 24

Turbidity
September 1989 - October 1990

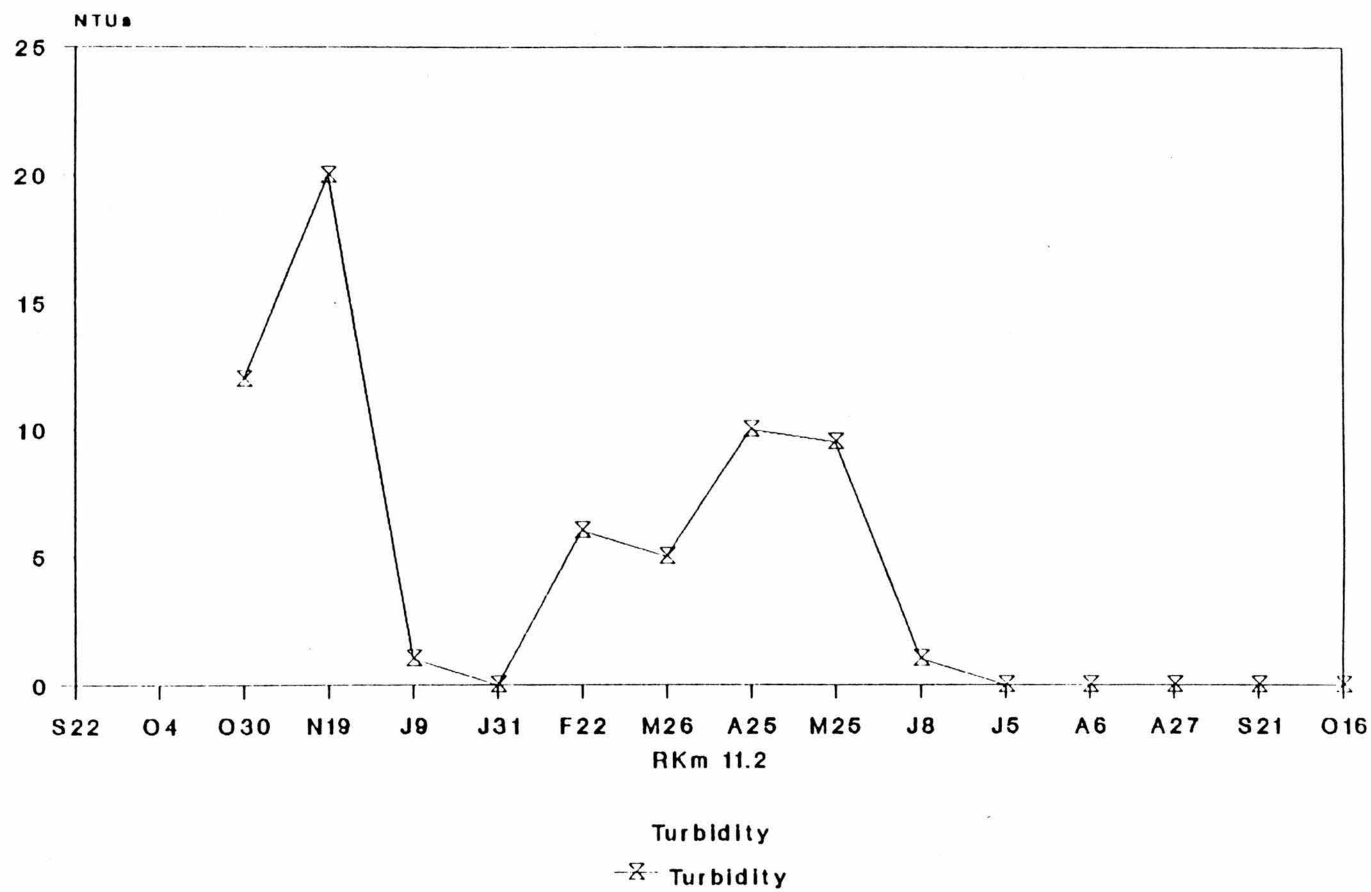


Figure 25

Chemical Parameters
September 1989 - October 1990

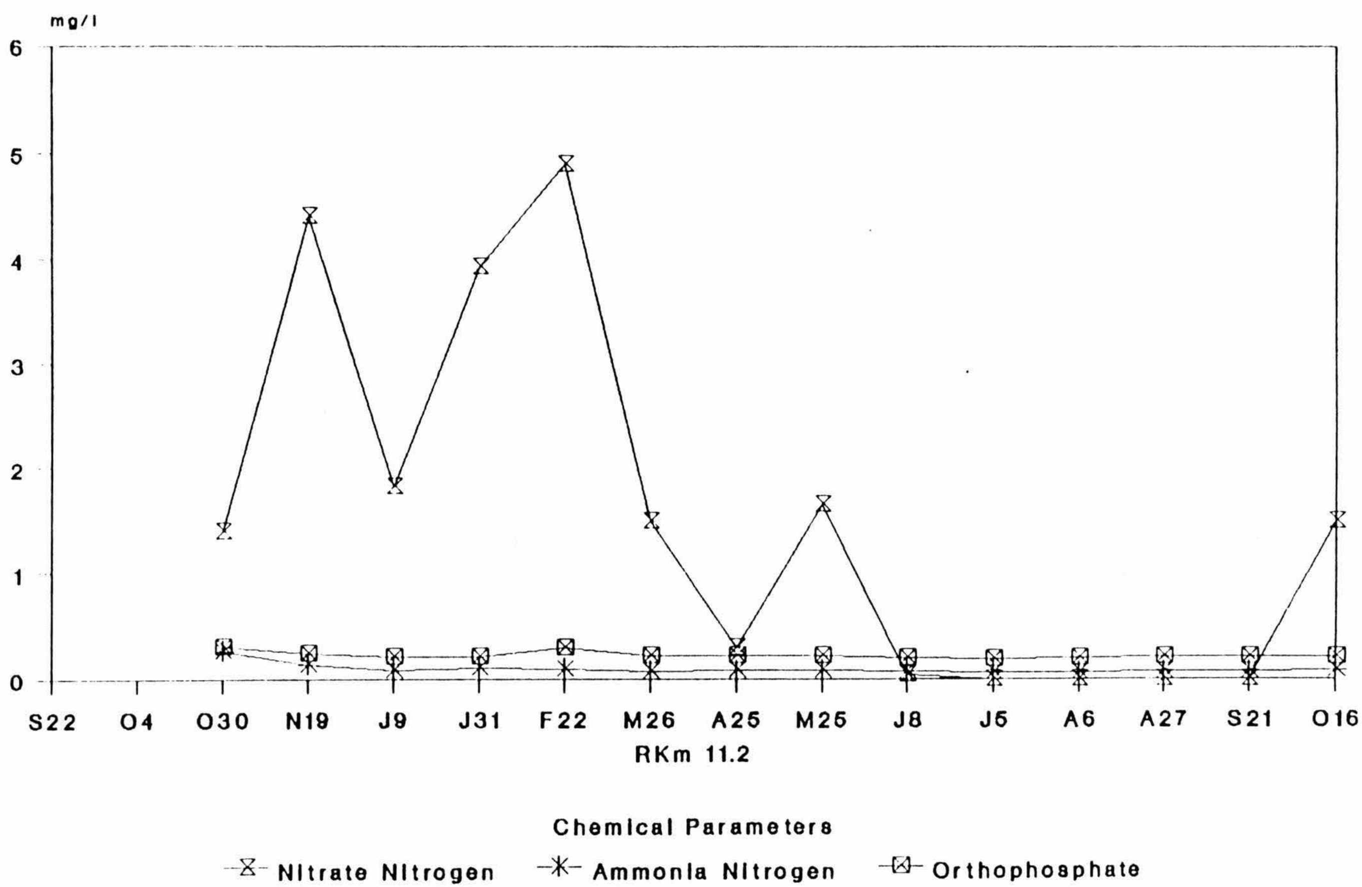


Figure 26

Temperature and pH

The highest pH of 7.05 was in late October of 1989 (Figure 27). The pH declined through the end of January reaching its lowest point of 6.54. With the rains in February the pH increased to 6.77 and the temperature decreased to 8 °C (Figure 28). From March through September the temperature increased steadily to 24 °C and the pH under went slight 0.04 shifts. In October the temperature decreased to 14 °C, but the pH shift caused a decrease to 6.7.

RKm 16.6

Flow, Turbidity, Chemical, and Hardness Parameters

This site was dry mid-September, late October, and November (Figure 29). The alkalinity, hardness, and conductivity were 38.00 mg/l, 32.00 mg/l, and 72.00 uS respectively in early January, but in late January decreased to an alkalinity of 8.00 mg/l, hardness of 10.00 mg/l and conductivity of 40.00 uS (Figure 30). In February the flow was 25.68 and turbidity was 6 NTUs (Figure 31). The chemical parameters of ammonia nitrogen, nitrate nitrogen, and orthophosphate were 0.08 mg/l, 4.895 mg/l, and 40.00 uS (Figure 32). From March through October all hardness parameters increased steadily, the turbidity decreased to 5 NTUs and chemical parameters returned to their low, but steady levels of less than 5 mg/l.

pH
September 1989 - October 1990

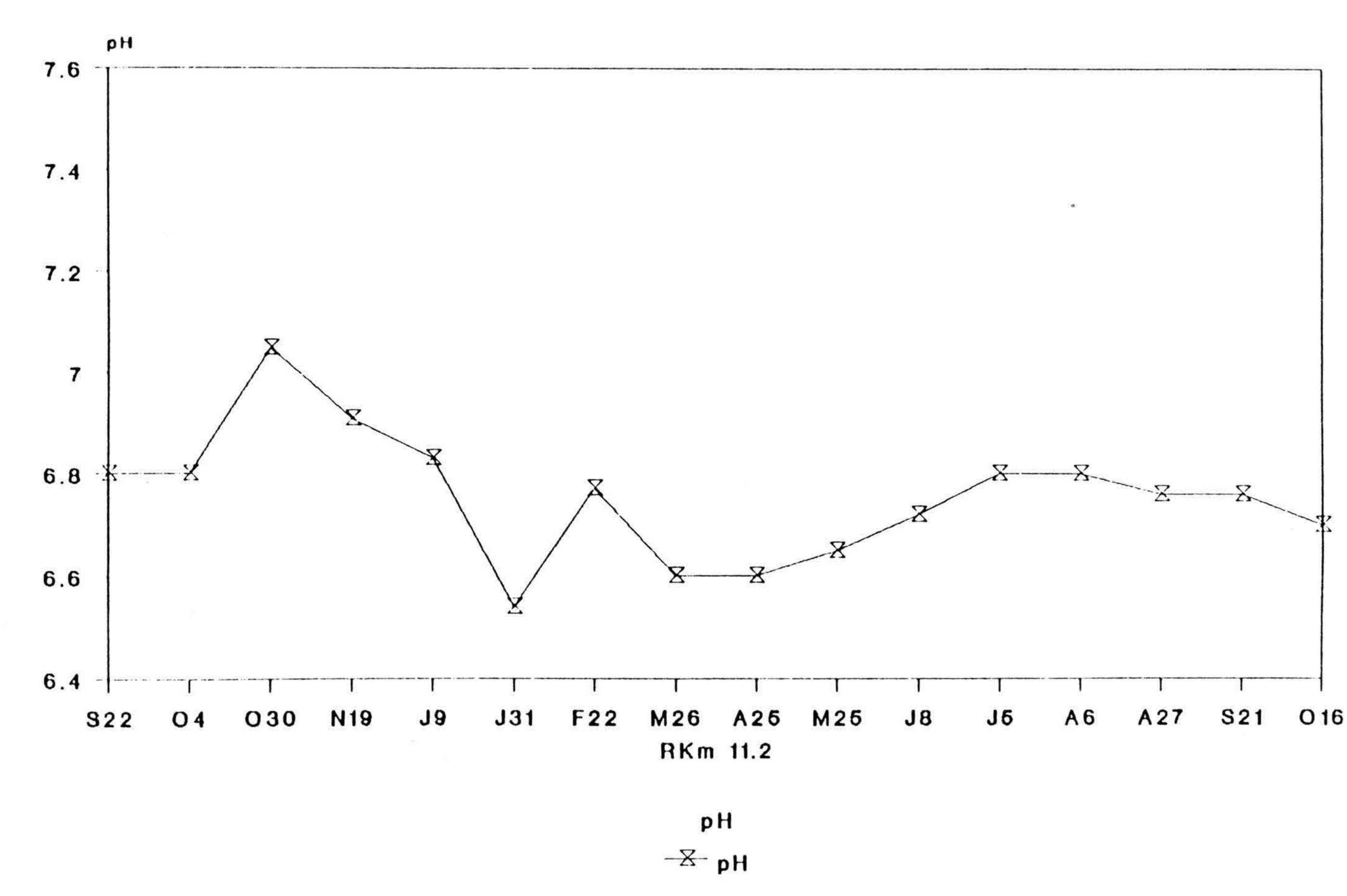


Figure 27

Temperature
September 1989 - October 1990

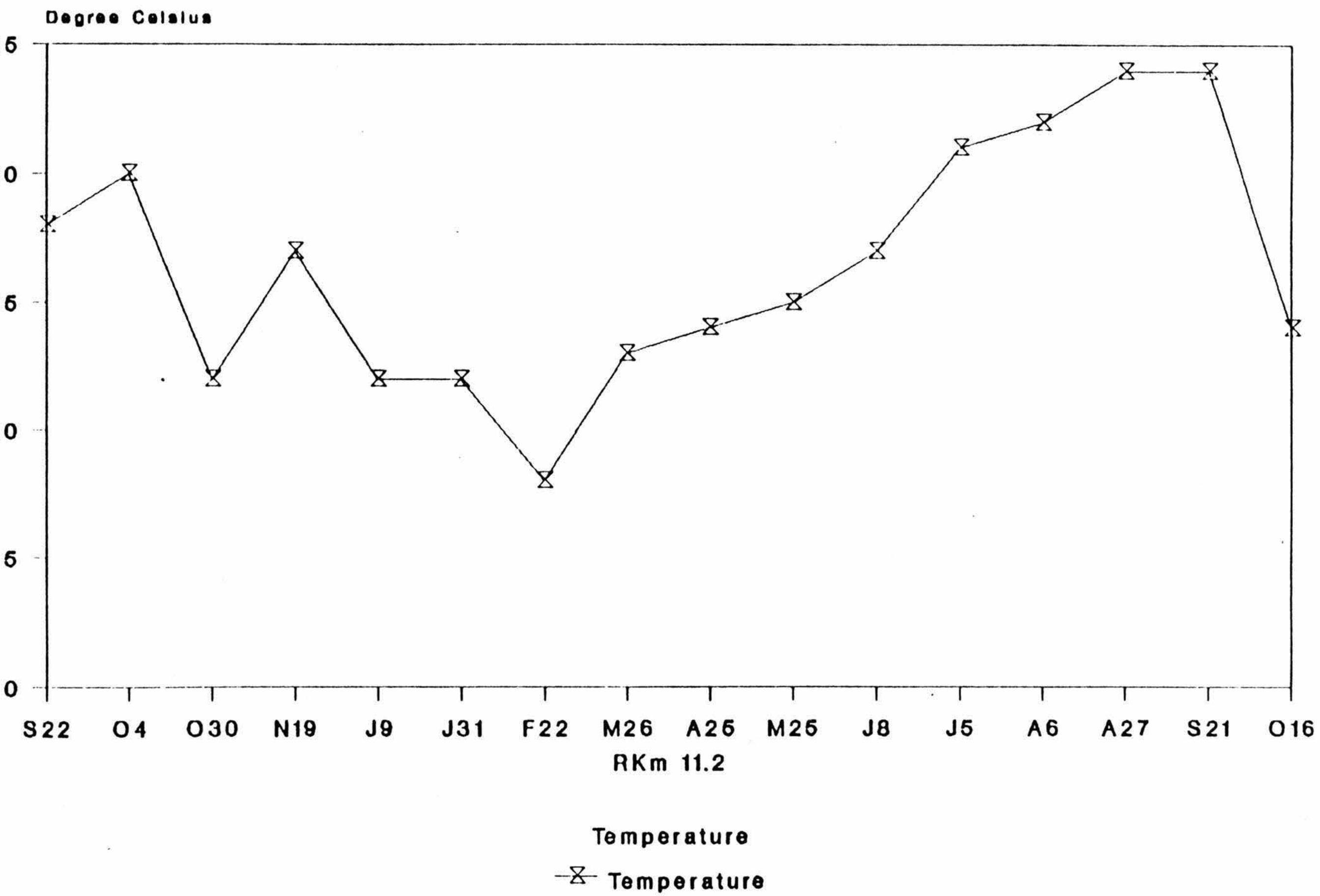


Figure 28

Flow
September 1989 - October 1990

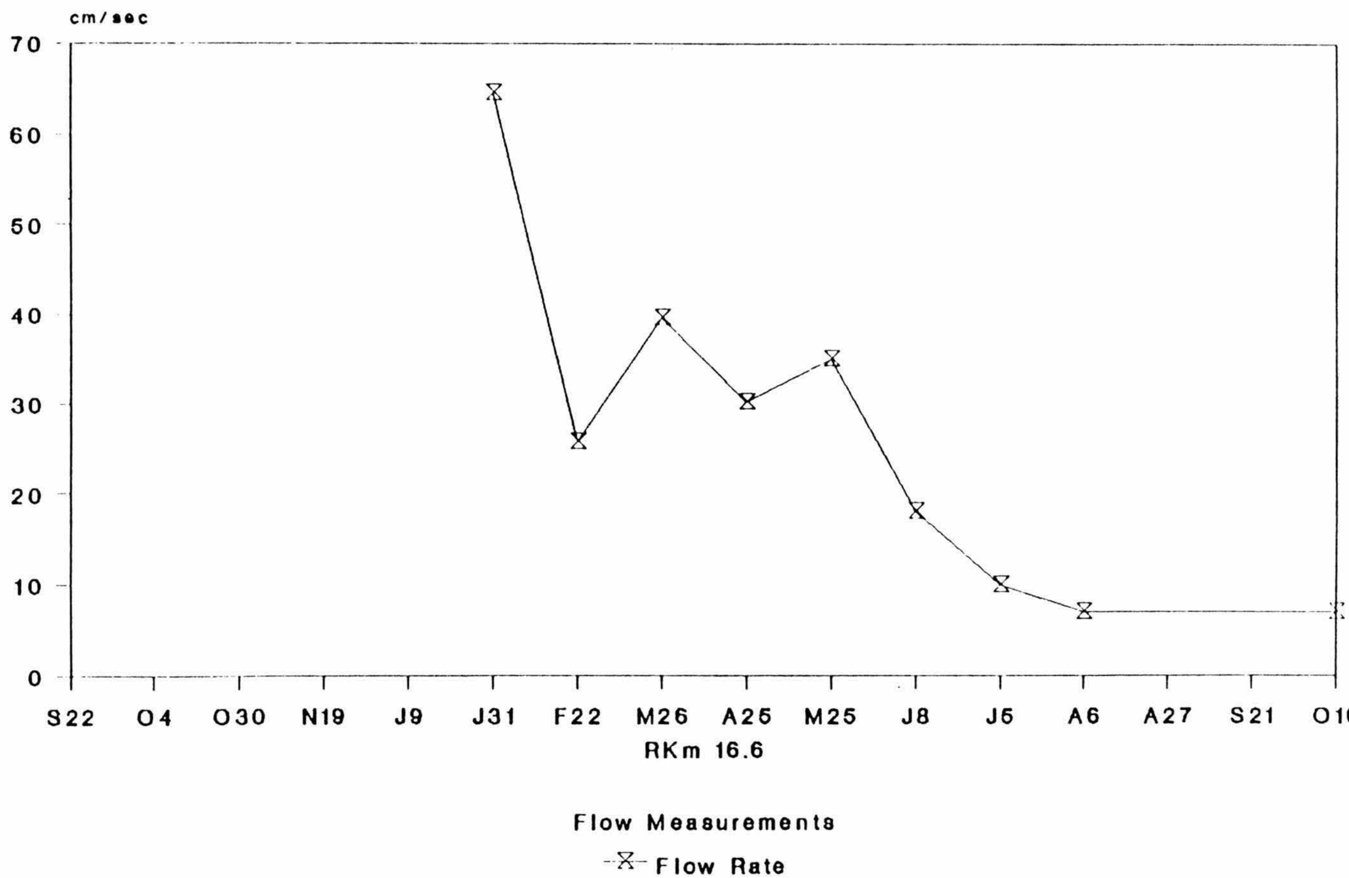


Figure 29

Hardness Parameters
September 1989 - October 1990

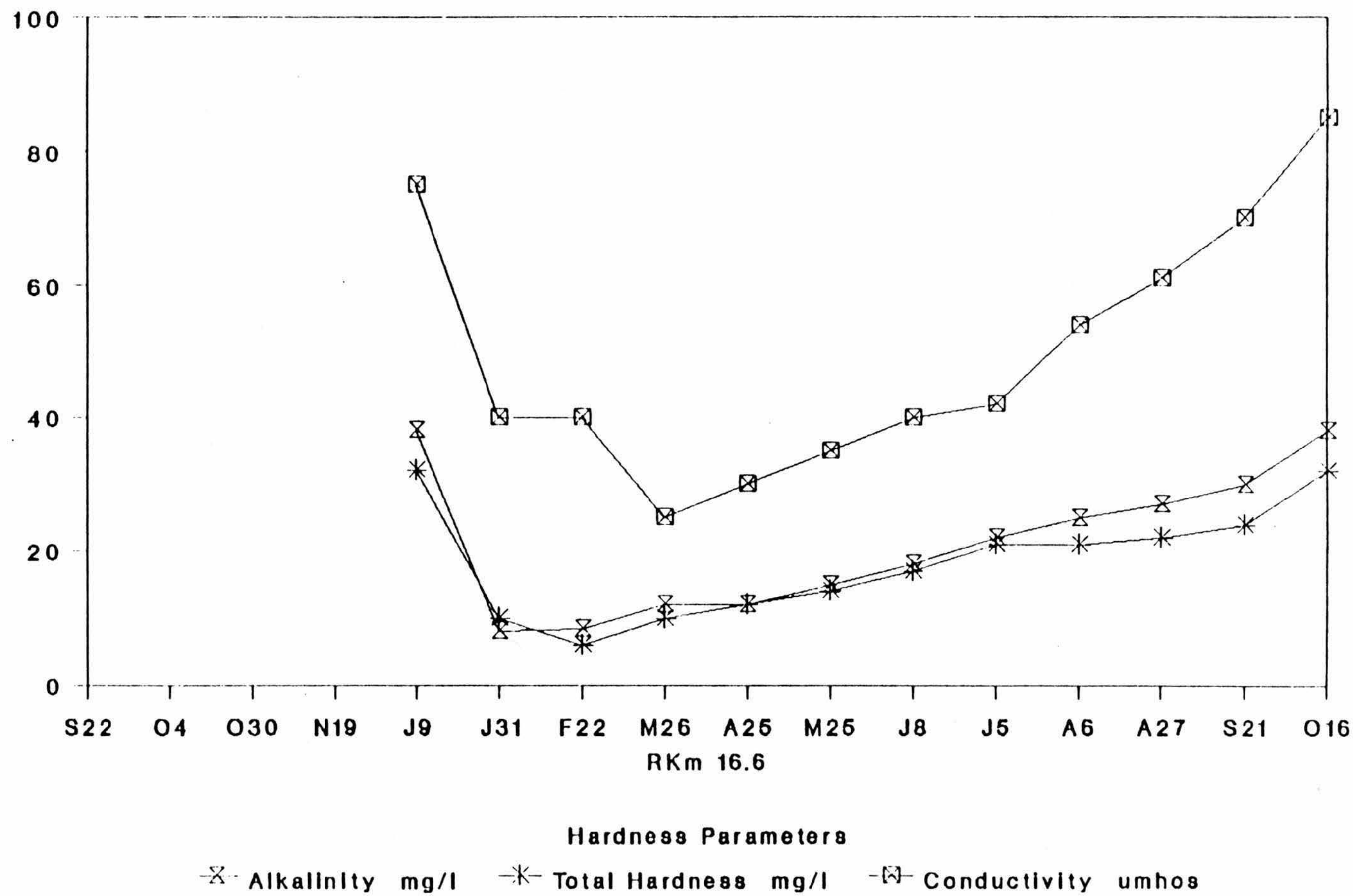


Figure 30

Turbidity
September 1989 - October 1990

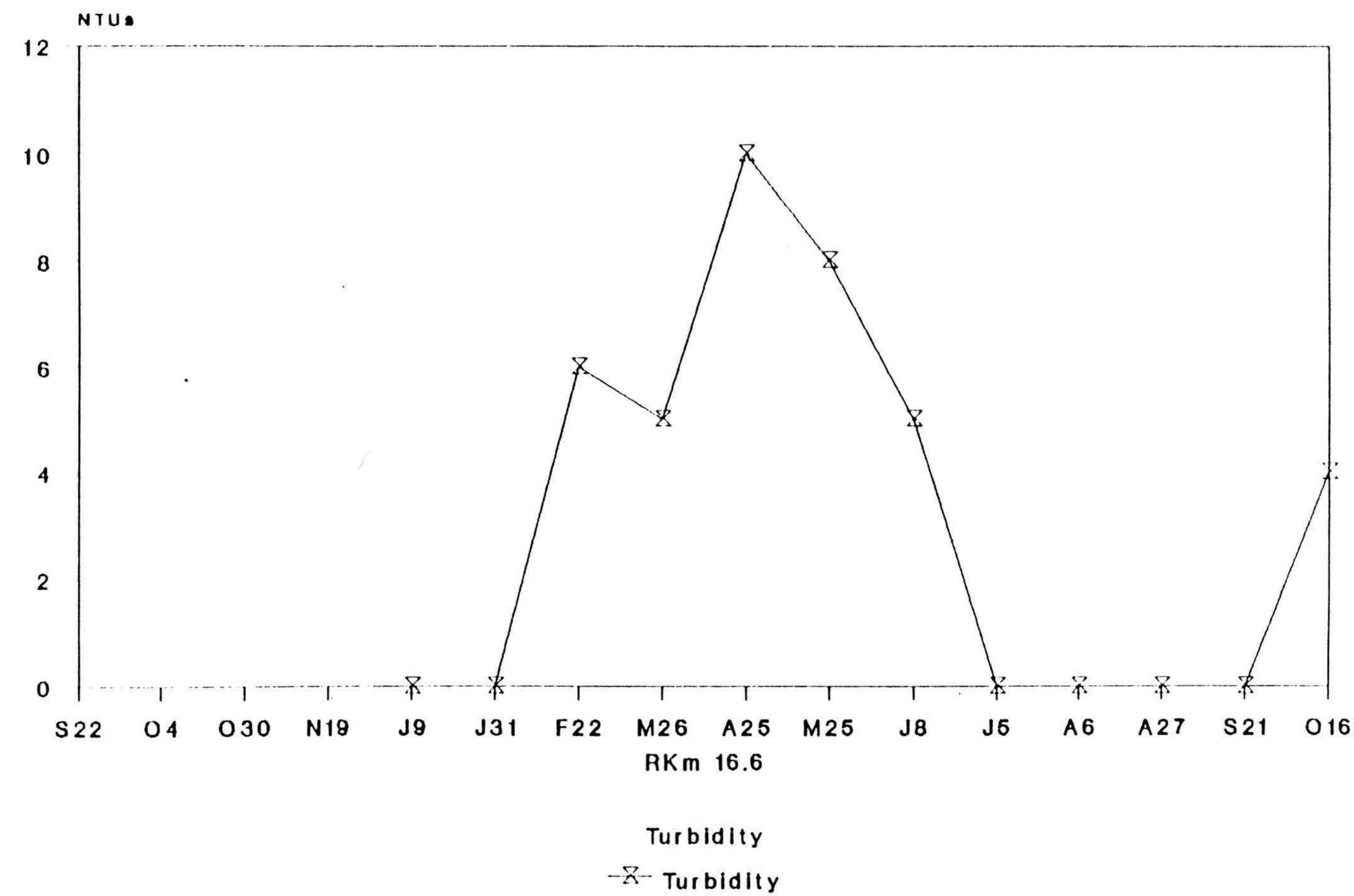


Figure 31

Chemical Parameters
September 1989 - October 1990

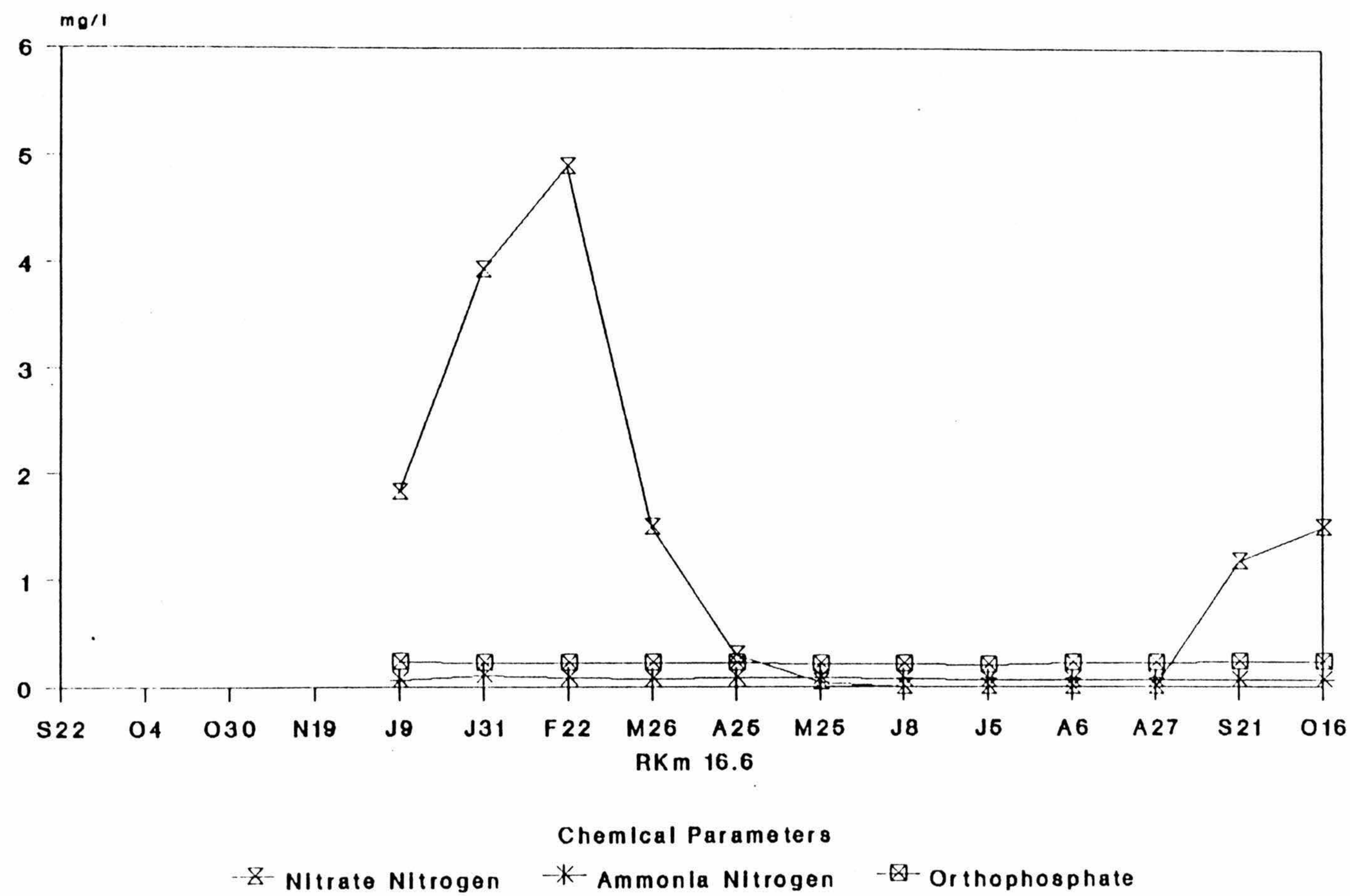


Figure 32

Temperature and pH

In early October there was one small pool on a limestone shelf; also there was a small seep along the stream margin. The pH was 7.30 (Figure 33), and the temperature was 22 °C (Figure 34). The entire area dried till early January when the pH was 6.80, and the temperature was 10 °C. The pH dropped to 6.68 but the temperature increased to 12 °C, in late January. The February pH was 6.75 and the temperature decreased to 7 °C. The pH dropped to 6.60 in March and remained there through April after which it gradually increased to a plateau at 6.80 through September. Temperature began to increase in March and rose to 25 °C in September. In October the temperature and pH decreased to 17 °C and 6.70, respectively.

RKm 20.6

Flow, Turbidity, Chemical, and Hardness Parameters

The hardness parameters were high in November, conductivity 105.00 uS, alkalinity 58.00 mg/l, and total hardness 42.00 mg/l (Figure 35). They reach their lowest in late January, conductivity 40.00 uS, alkalinity 8.00 mg/l, and total hardness 10.00 mg/l. There was a gradual increase of alkalinity and conductivity through mid-October, but hardness reached a plateau in June at 42.00 mg/l.

pH
September 1989 - October 1990

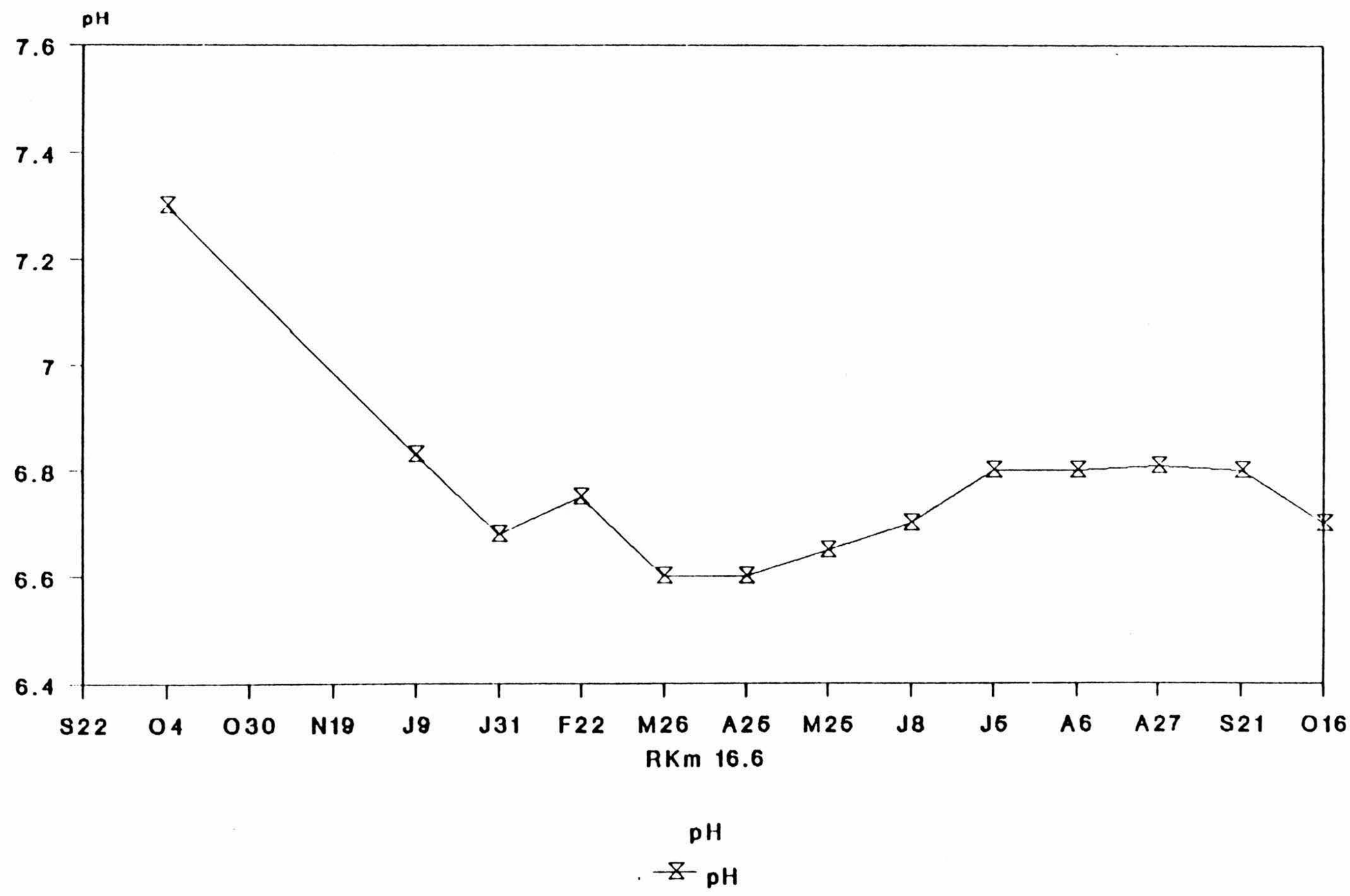


Figure 33

Temperature
September 1989 - October 1990

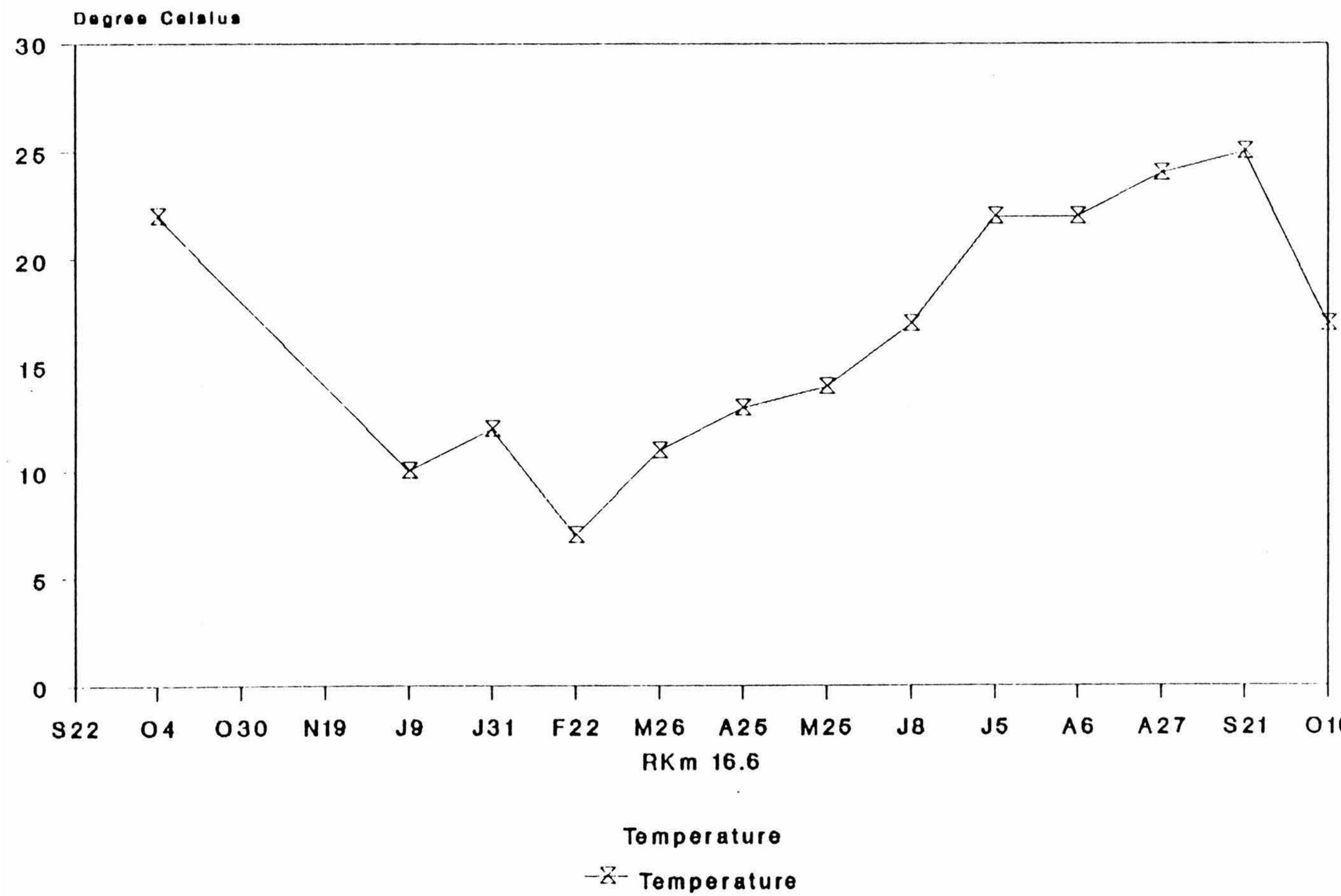


Figure 34

Hardness Parameters
September 1989 - October 1990

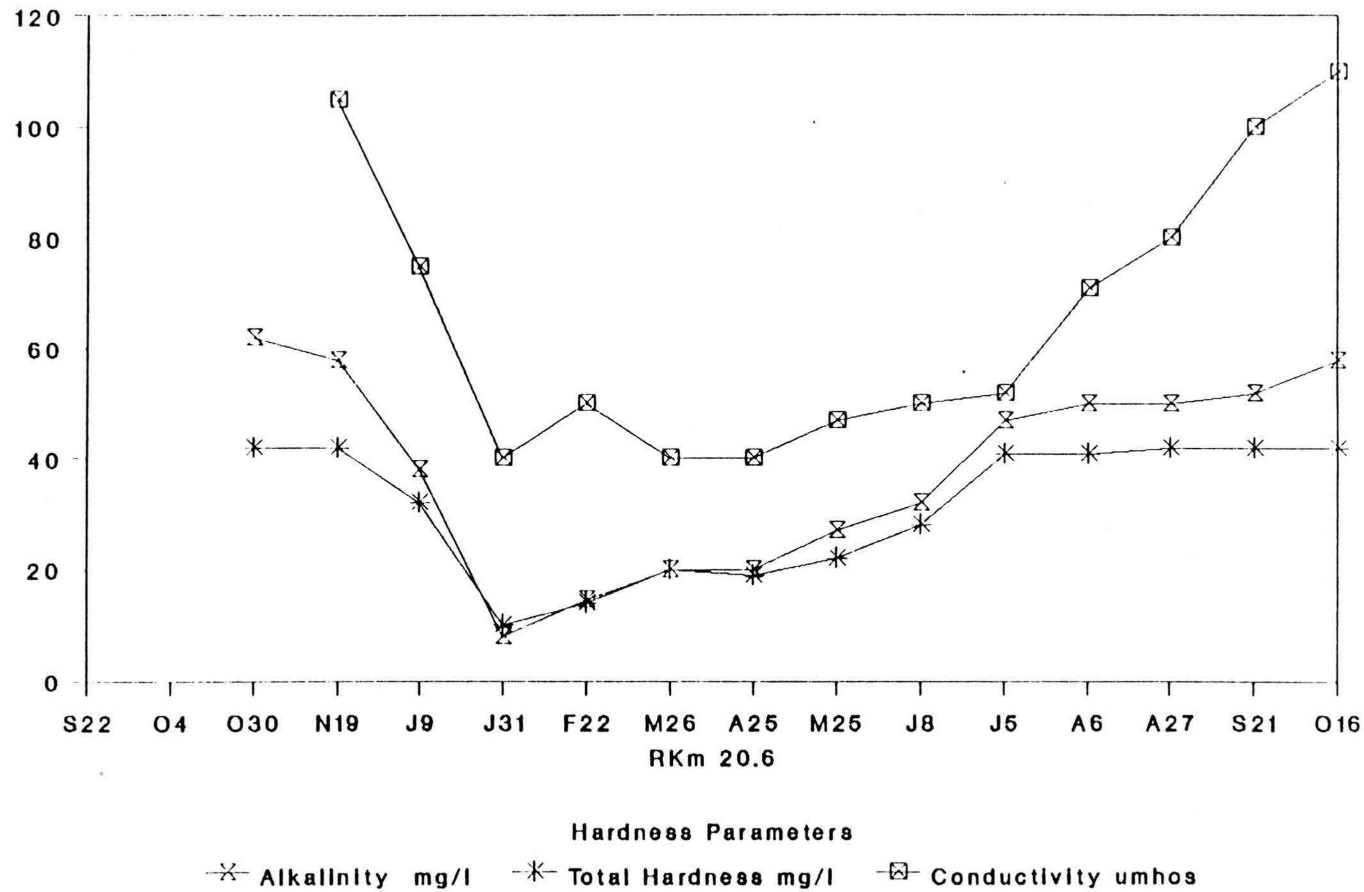


Figure 35

Nitrate nitrogen was measured to be 3.11 mg/l in November (Figure 36). It fell slightly in early January. There was a increase to 4.57 mg/l by late January. It remained high till May then it dropped to 1.66 mg/l. Measurements were low till September. The other chemical parameters remained constant.

Flow was not measurable till the end of January when it was 64.5 cm/sec (Figure 37). Turbidity increased from 0 NTUs at the end of January to 12.5 NTUs in mid-May (Figure 38). Flow and turbidity decreased to 10.0 cm/sec, and 5 NTUs respectively in June.

Temperature and pH

Late September, 1989, temperature and pH reached a peak of 26 °C and 7.13 respectively (Figure 39 & 40 respectively). There was a general decline in both through January, when the pH was 6.83, and the temperature was 10 °C. With the spring rains in February the temperature decreased to 8 °C and the pH decreased to 6.68. The temperature from March through early August gradually increased to peak at 24 °C. Late August the temperature began to decline. Mid-October it made a significant decline from 21 °C to 14 °C. The pH began at 6.68 in March, and had increased to 7.0 by mid-October.

Chemical Parameters
September 1989 - October 1990

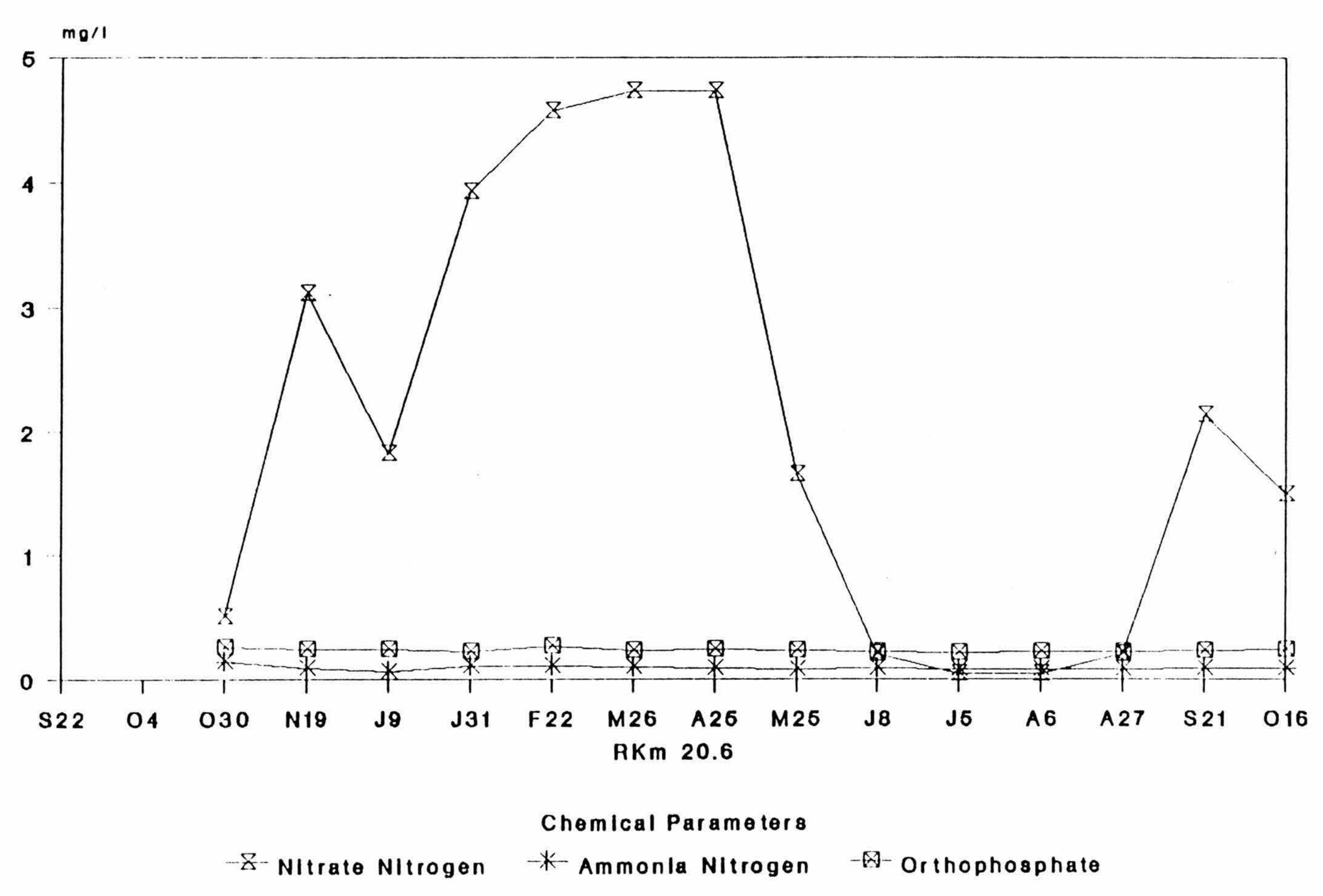


Figure 36

Flow
September 1989 - October 1990

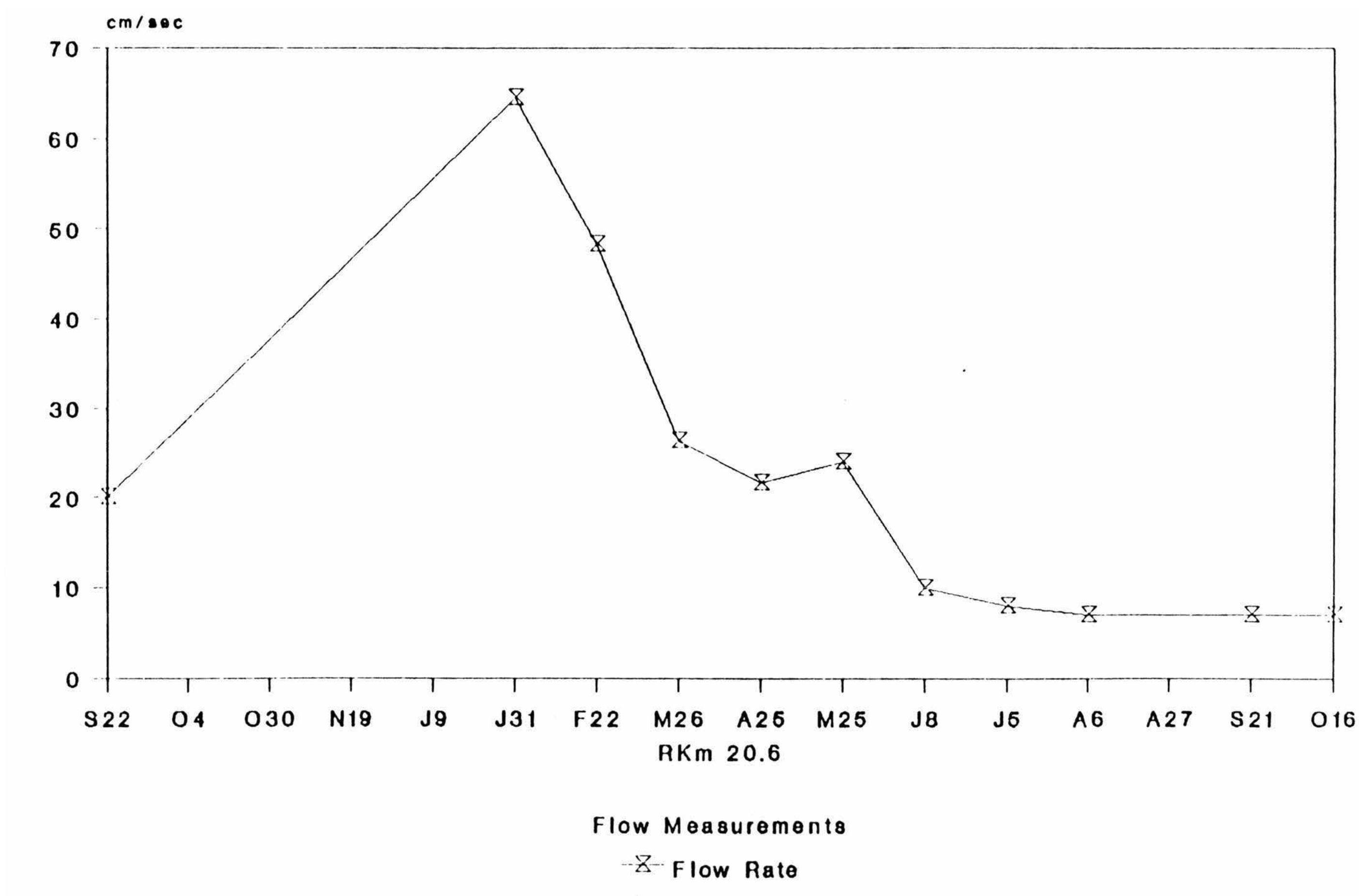


Figure 37

Turbidity
September 1989 - October 1990

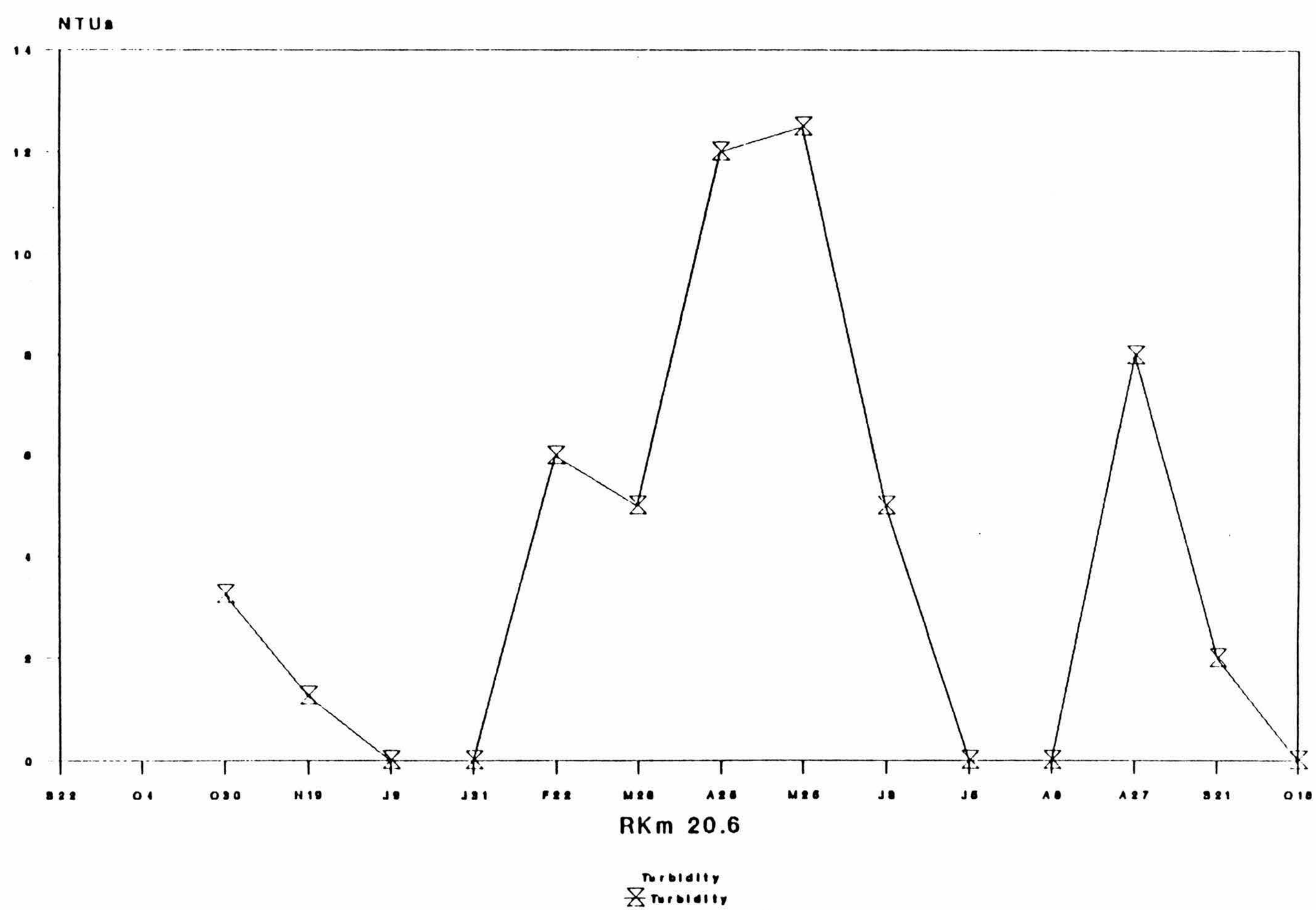


Figure 38

Temperature
September 1989 - October 1990

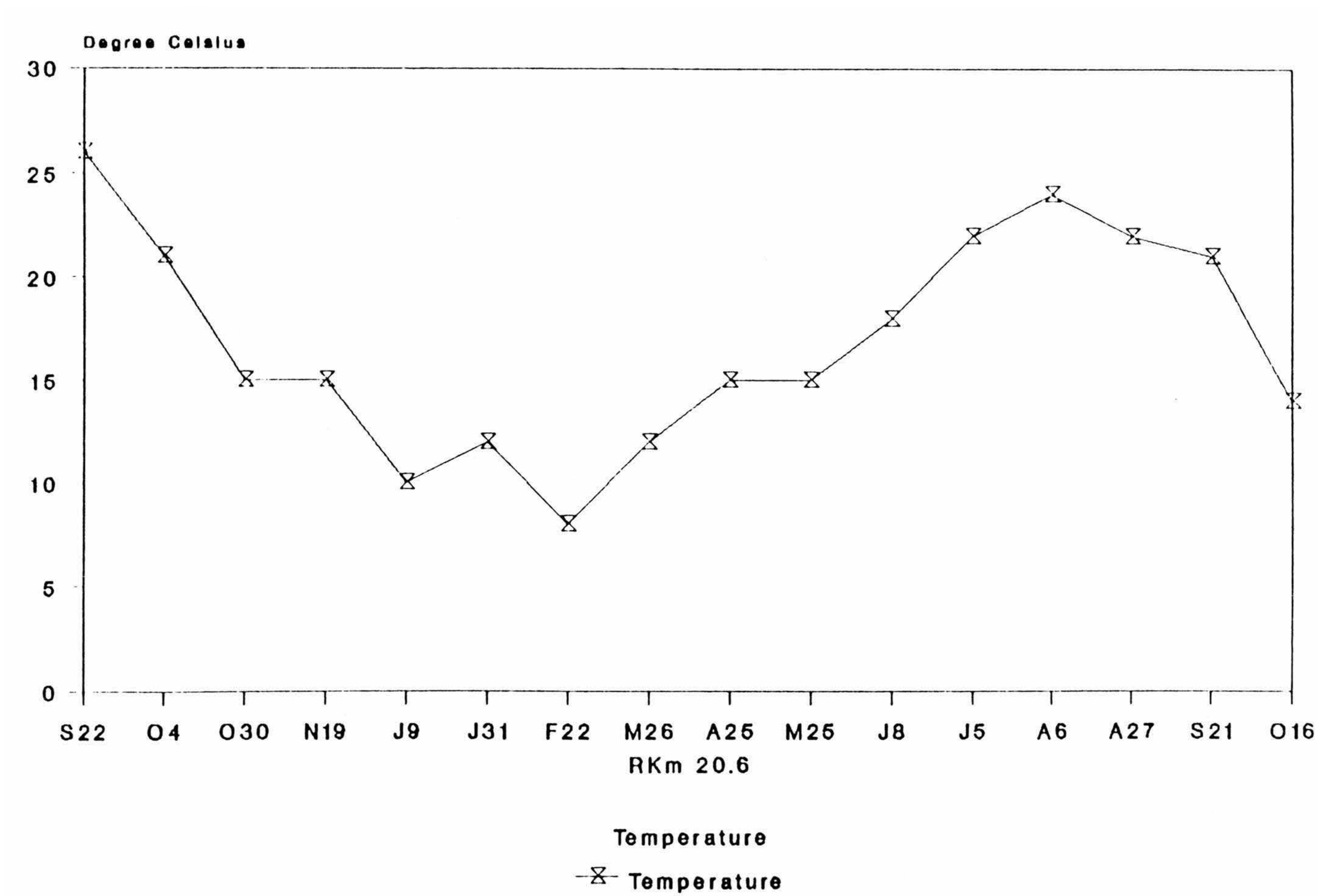


Figure 39

pH
September 1989 - October 1990

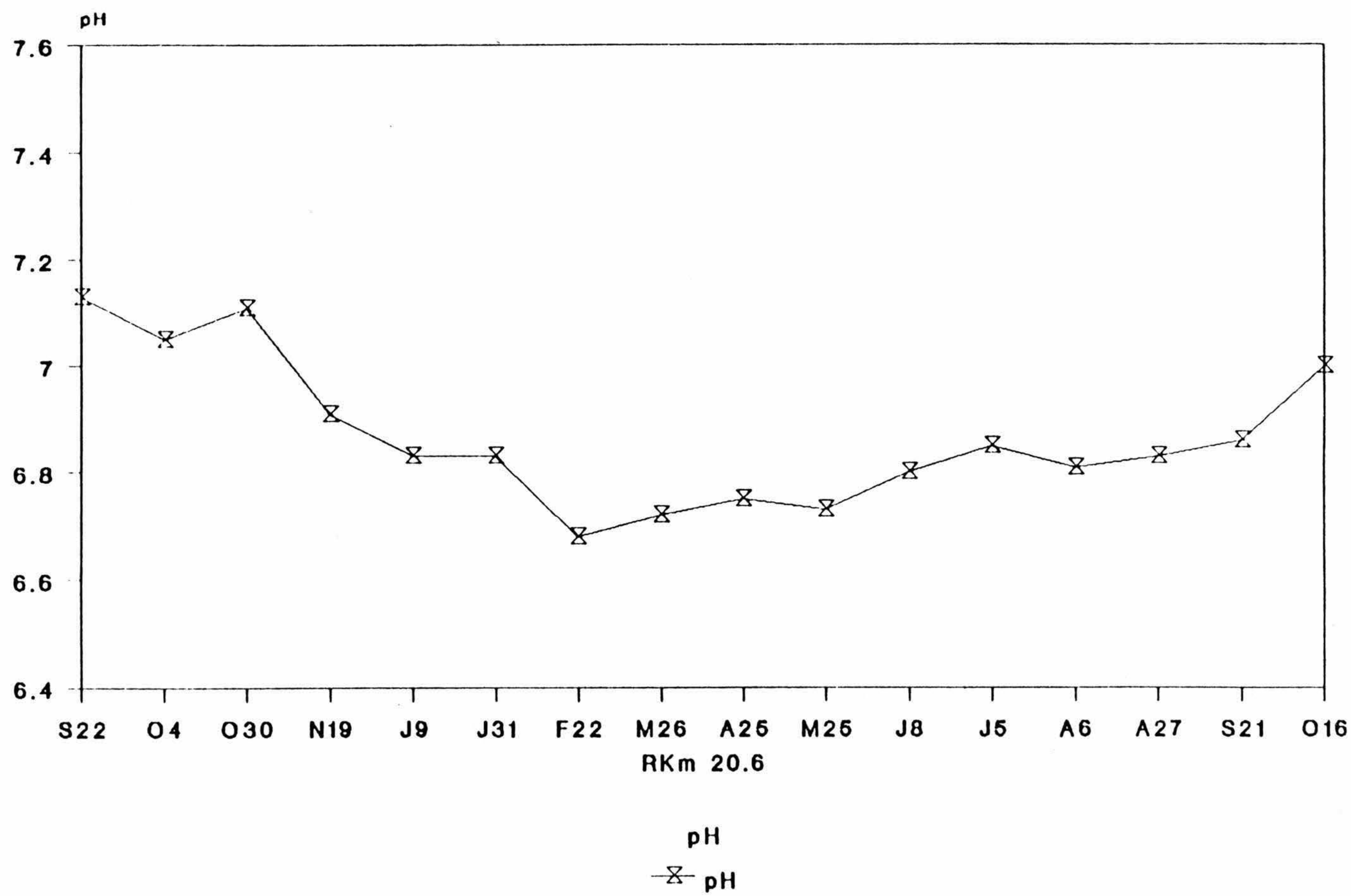


Figure 40

RKm 23.4

Flow, Turbidity, Chemical, and Hardness Parameters

Alkalinity 70.00 mg/l, hardness 48.00 mg/l, and conductivity were highest in November and lowest in February (30.00 mg/l, 23.00 mg/l, and 45.0 uS, respectively) (Figure 41). In March a gradual increase of these parameters began and was maintained through mid-October when they were 80.00 mg/l, 54.00 mg/l, and 130.0 uS.

Nitrate nitrogen at 6.35 mg/l was high in late October, but decreased to 2.30 mg/l in mid-November (Figure 42). It peaked at 6.68 mg/l in February, then decreased to 1.49 mg/l and lower through early August when it began to increase. The other chemical parameter remained low throughout the study.

Flow ceased in late October, and didn't return until late January at which the maximum flow of 46.0 cm/sec occurred (Figure 43). It receded in March and maintained a constant 7.00 cm/sec flow through to mid-October. The turbidity increased to 10 NTUs in February and did not decrease until June when it was 5 NTUs (Figure 44).

Temperature and pH

The temperature in September, 1989 was 21 °C and maintained a general decline through early January to 11 °C (Figure 45). In late January it increased to 15 °C, but it decreased in February. March through early August the temperature increased gradually

Hardness Parameters
September 1989 - October 1990

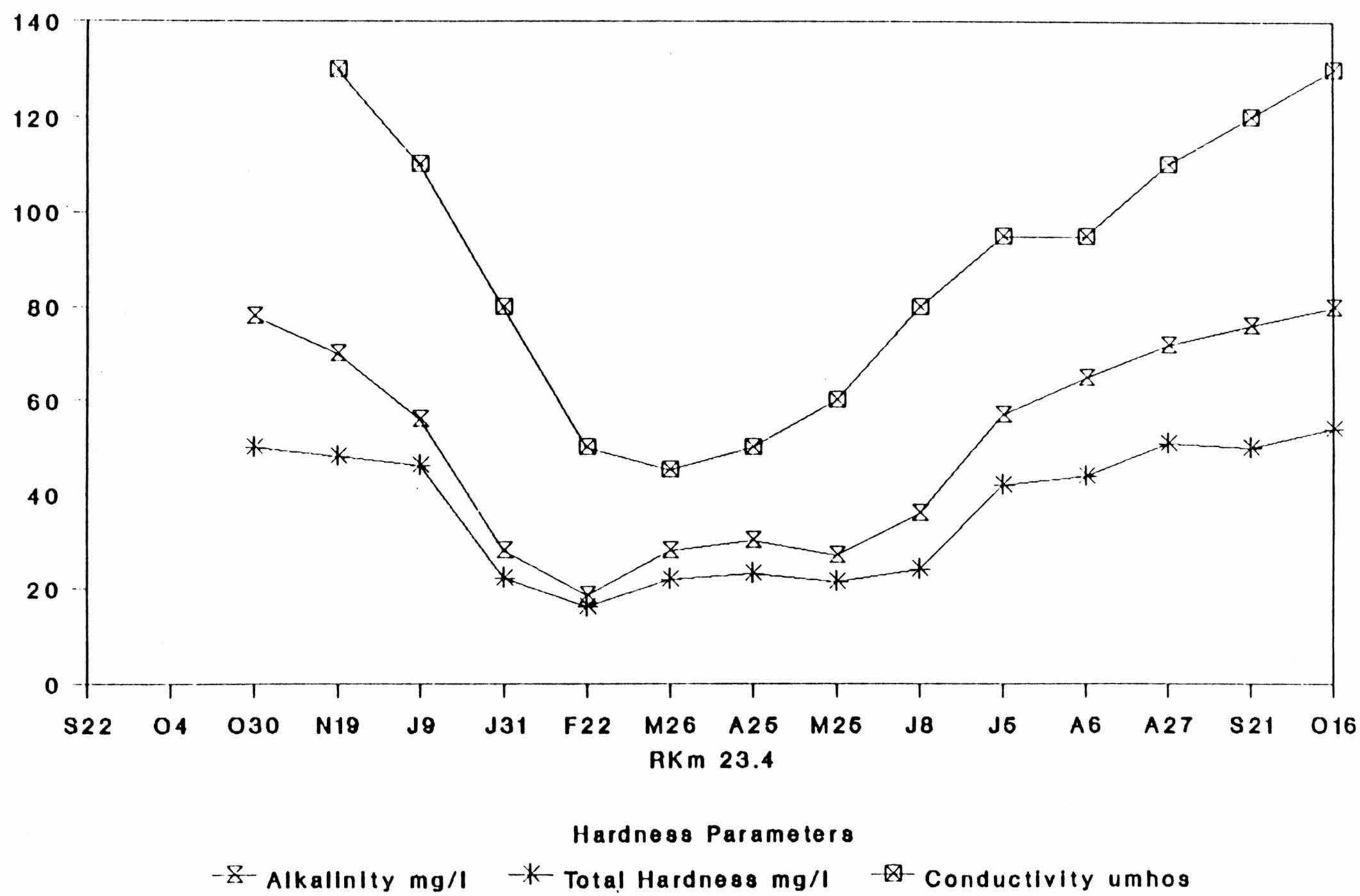


Figure 41

Chemical Parameters
September 1989 - October 1990

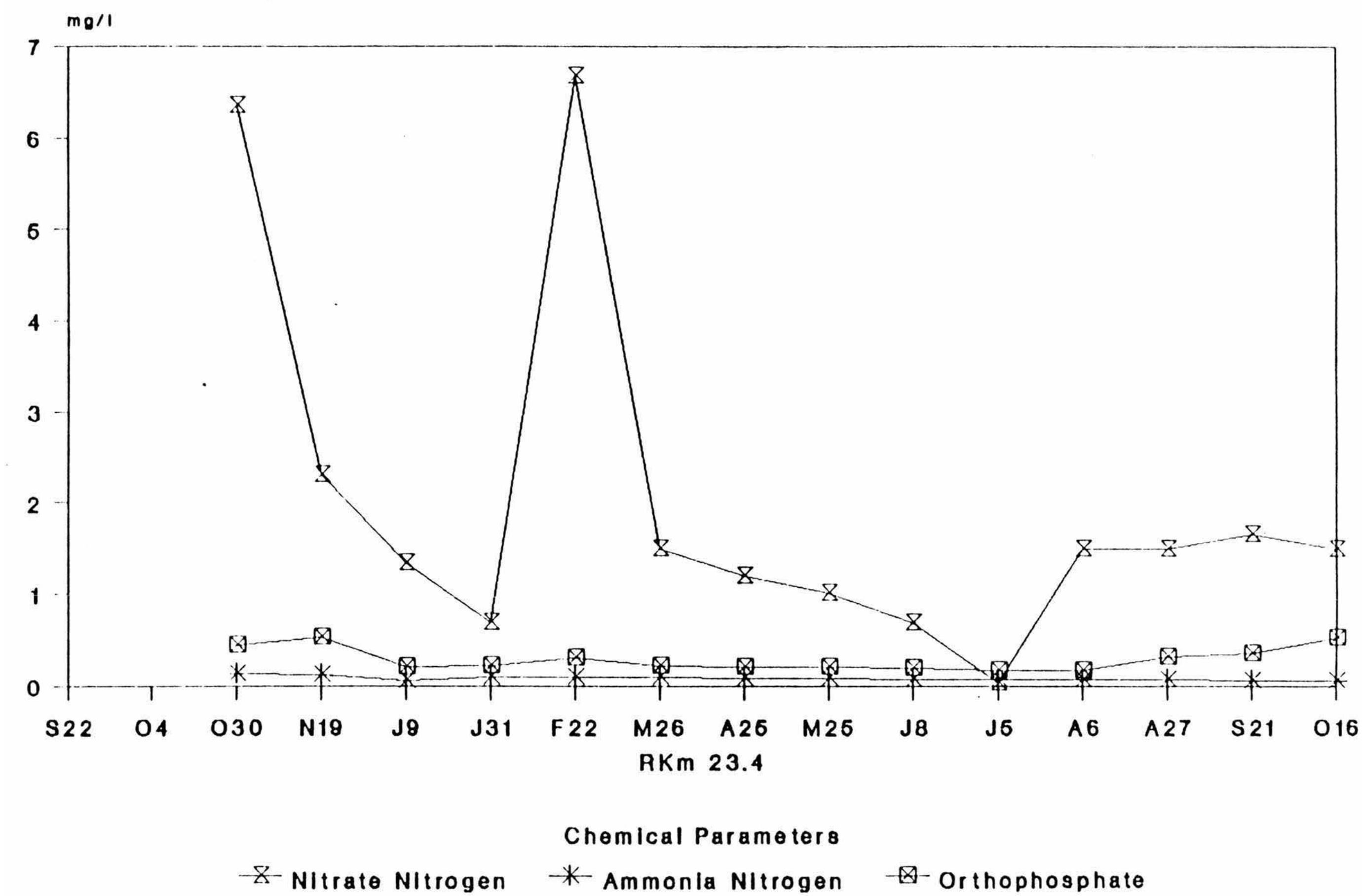


Figure 42

Flow
September 1989 - October 1990

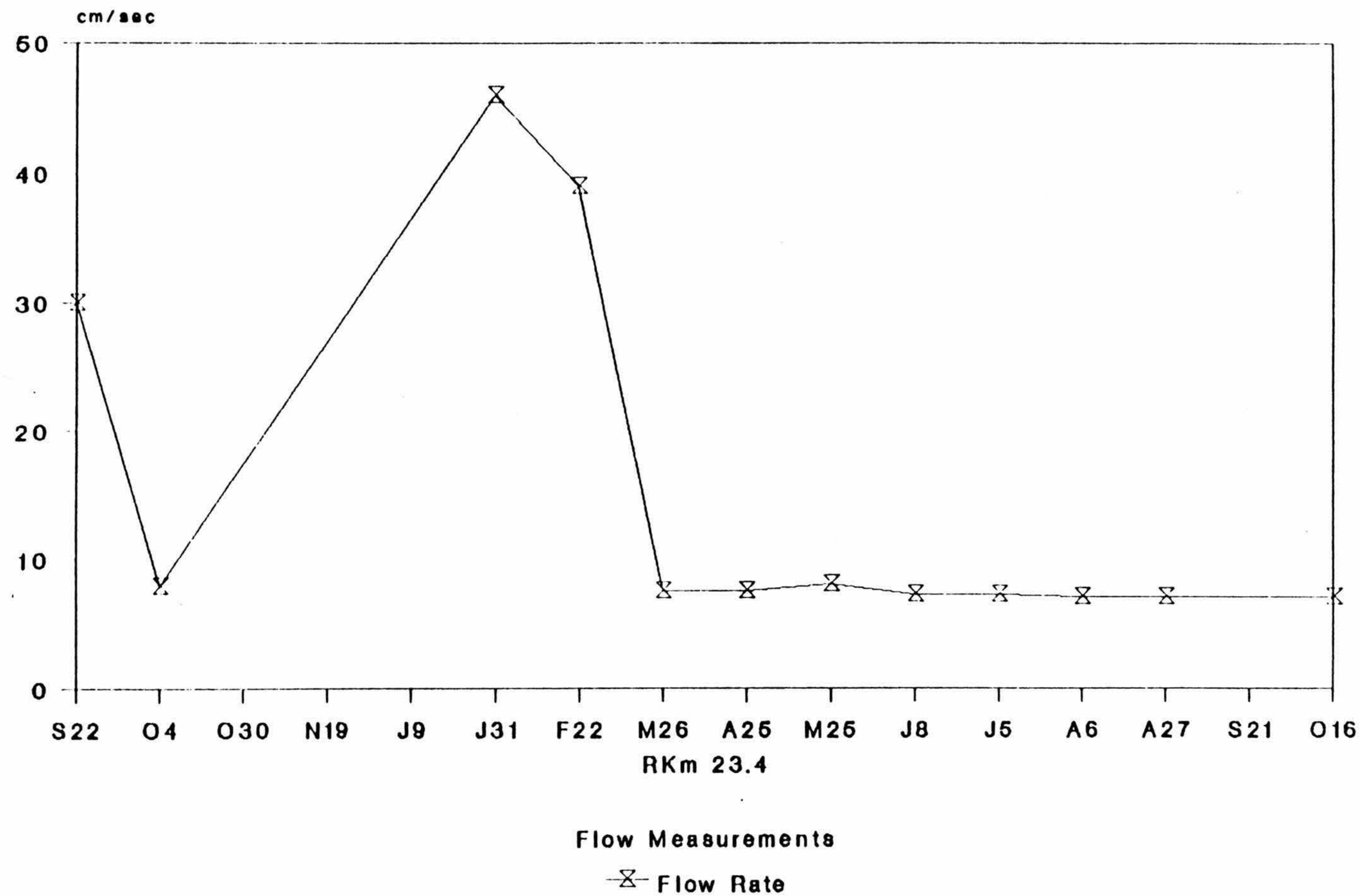


Figure 43

Turbidity
September 1989 - October 1990

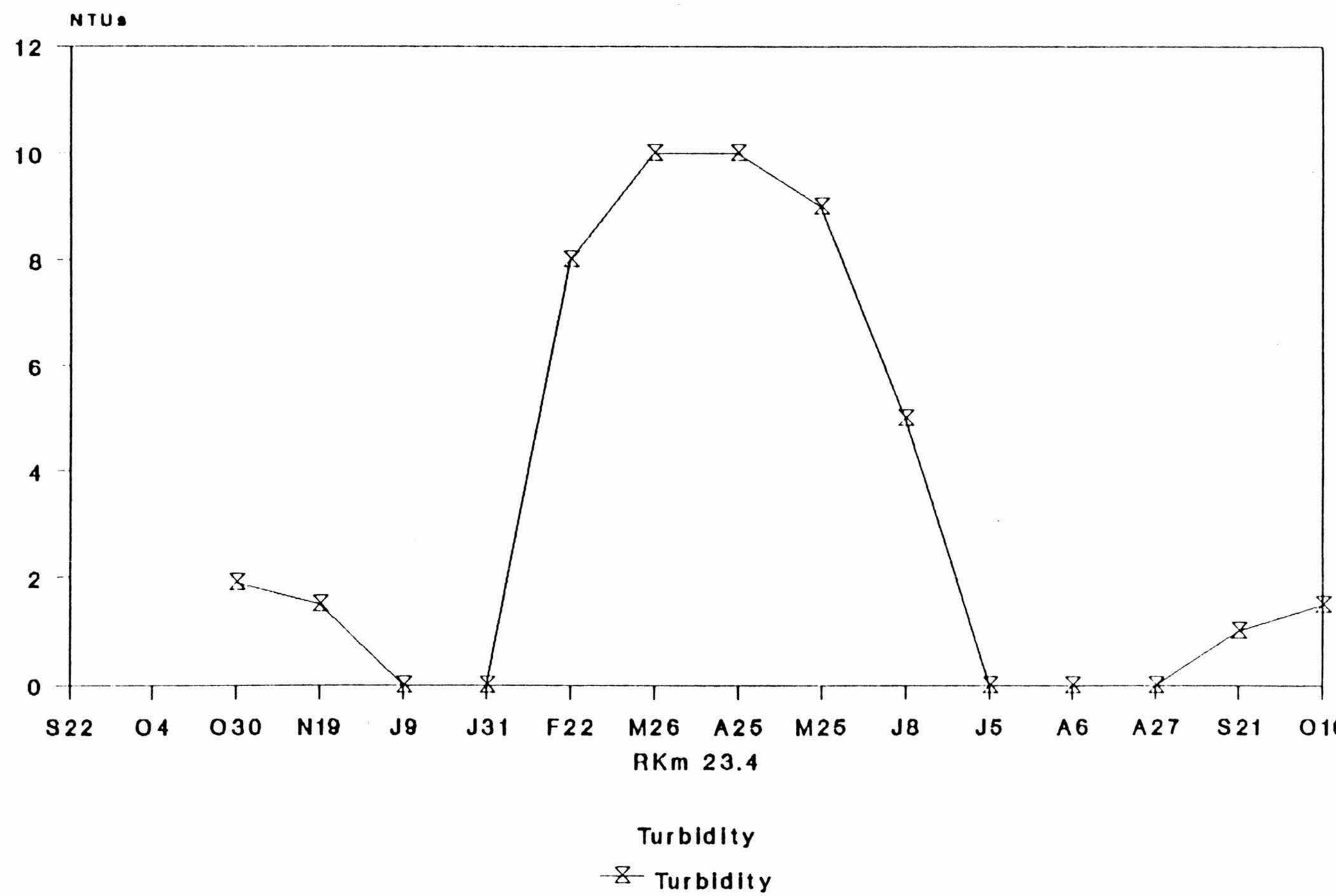


Figure 44

Temperature
September 1989 - October 1990

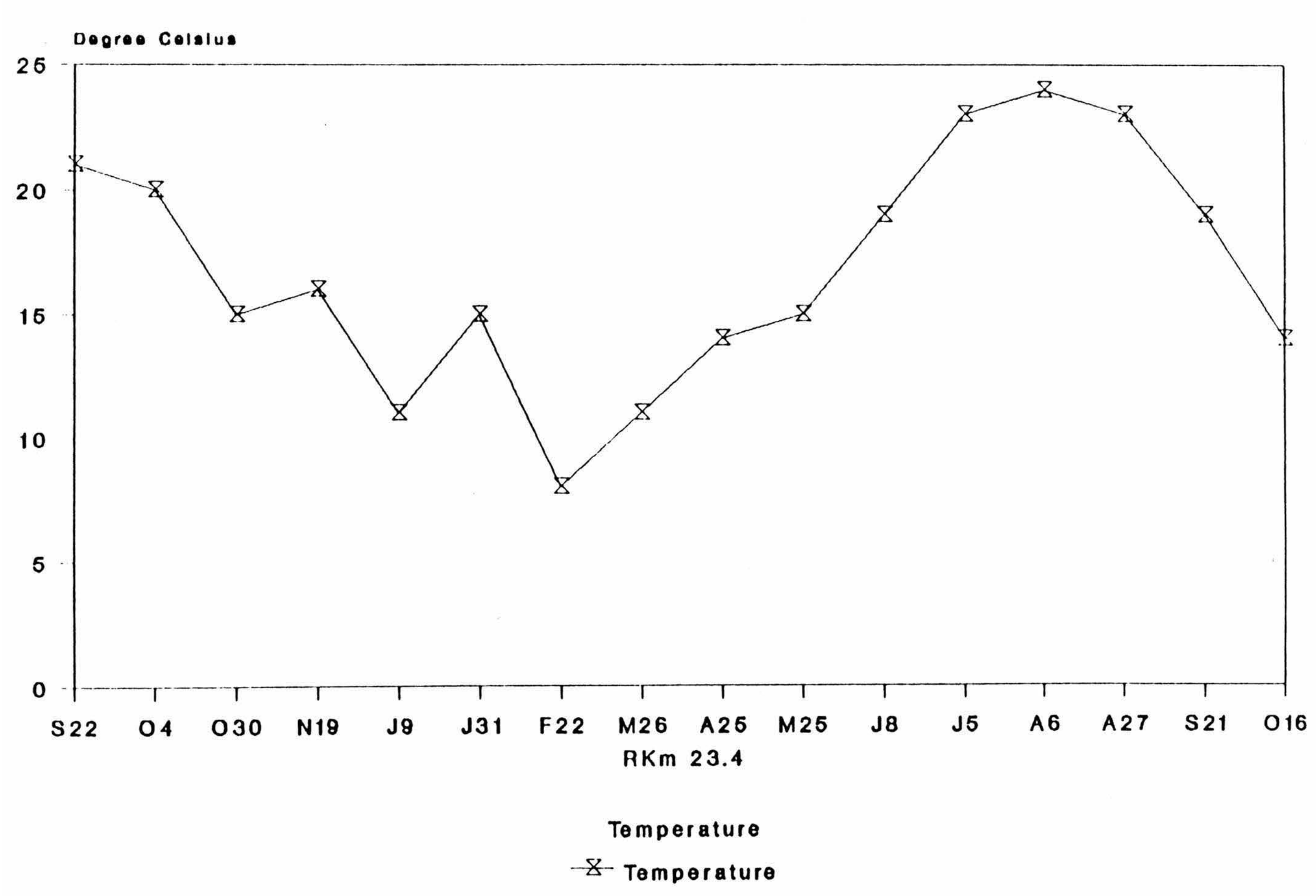


Figure 45

from 11 °C to 24 °C. The temperature began to decline in late August.

Late September, 1989, the pH reached a peak of 7.10 (Figure 46). From that point there was a general decline to a pH of 6.76 at the end of October. November the pH increased to 6.96, but returned to 6.75 in January. There was a significant increase in pH, to 7.00, at this site during February, but it decreased to 6.70 in late March.

RKm 26.6

Flow, Turbidity, Chemical, and Hardness Parameters

Conductivity, alkalinity, and total hardness were 100.00 uS, 43.00 mg/l, and 36.00 mg/l respectively in November (Figure 47). These hardness parameters gradually decreased to 25.00 mg/l, 23.00 mg/l, 58.00 uS, respectively in May. In July they began and continued upward to peak in October at 45.00 mg/l, 36.00 mg/l, 100.00 uS, respectively. Flow was not measurable until late January when it was 11.3 cm/sec (Figure 48). The flow increased steadily to 25.9 in May, then it declined just as gradually to 7.00 cm/sec in early August. Measurable flow ceased in late August. Turbidity followed the same pattern as flow beginning at 10 NTUs in January, increasing to 18 NTUs in April and decreasing to 0 NTUs in October (Figure 49).

pH
September 1989 - October 1990

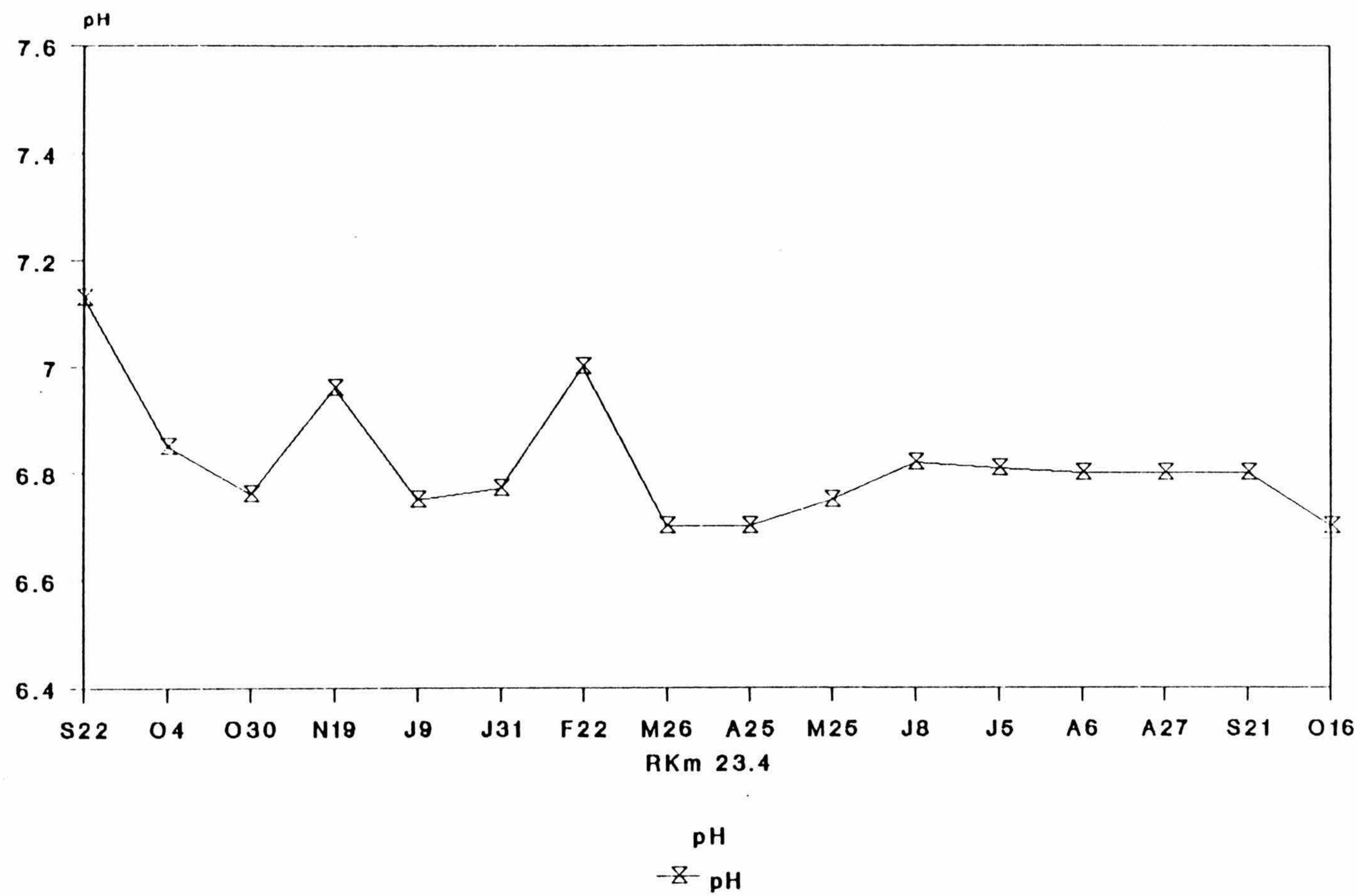


Figure 46

Hardness Parameters
September 1989 - October 1989

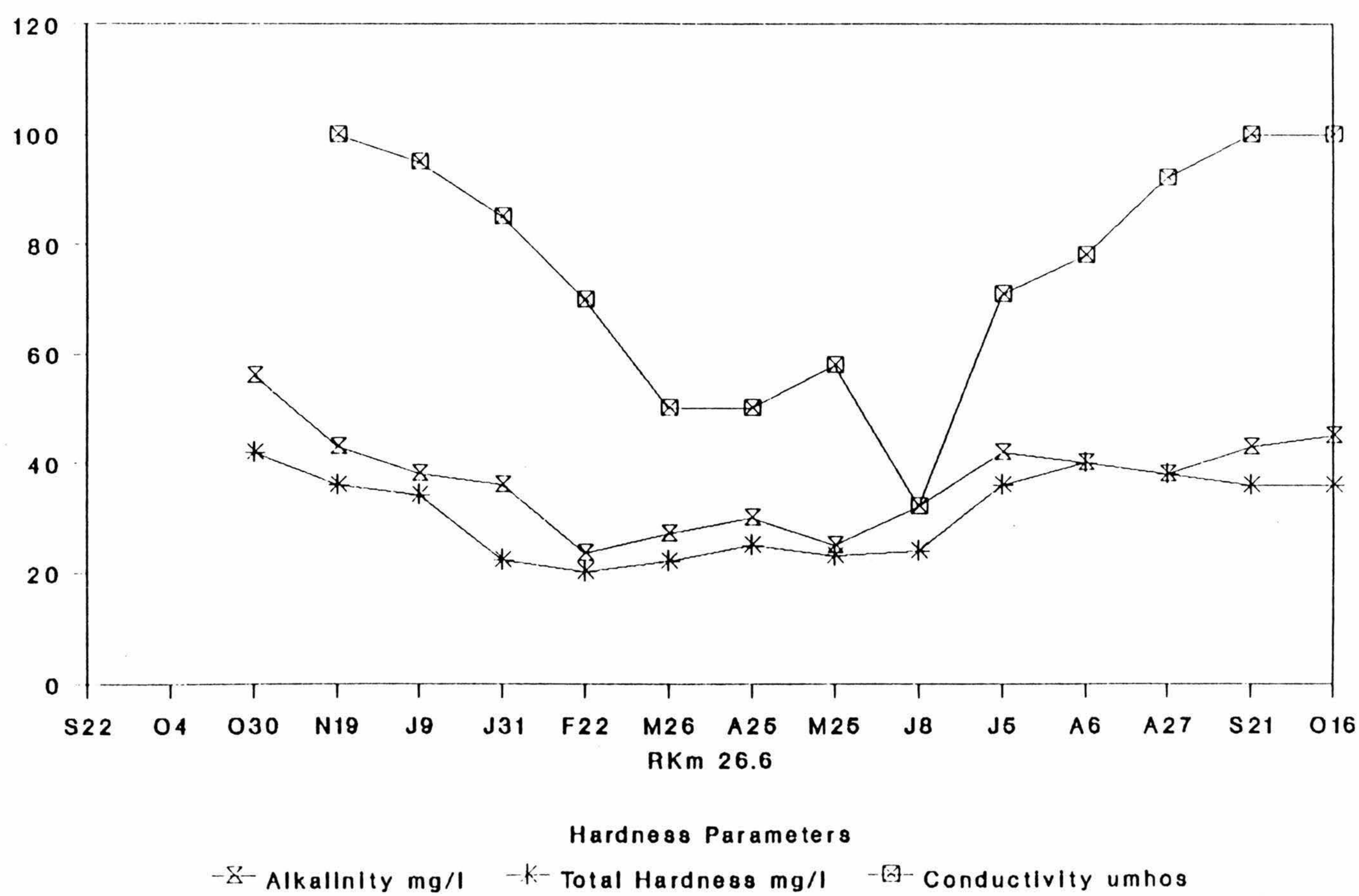


Figure 47

Flow
September 1989 - October 1990

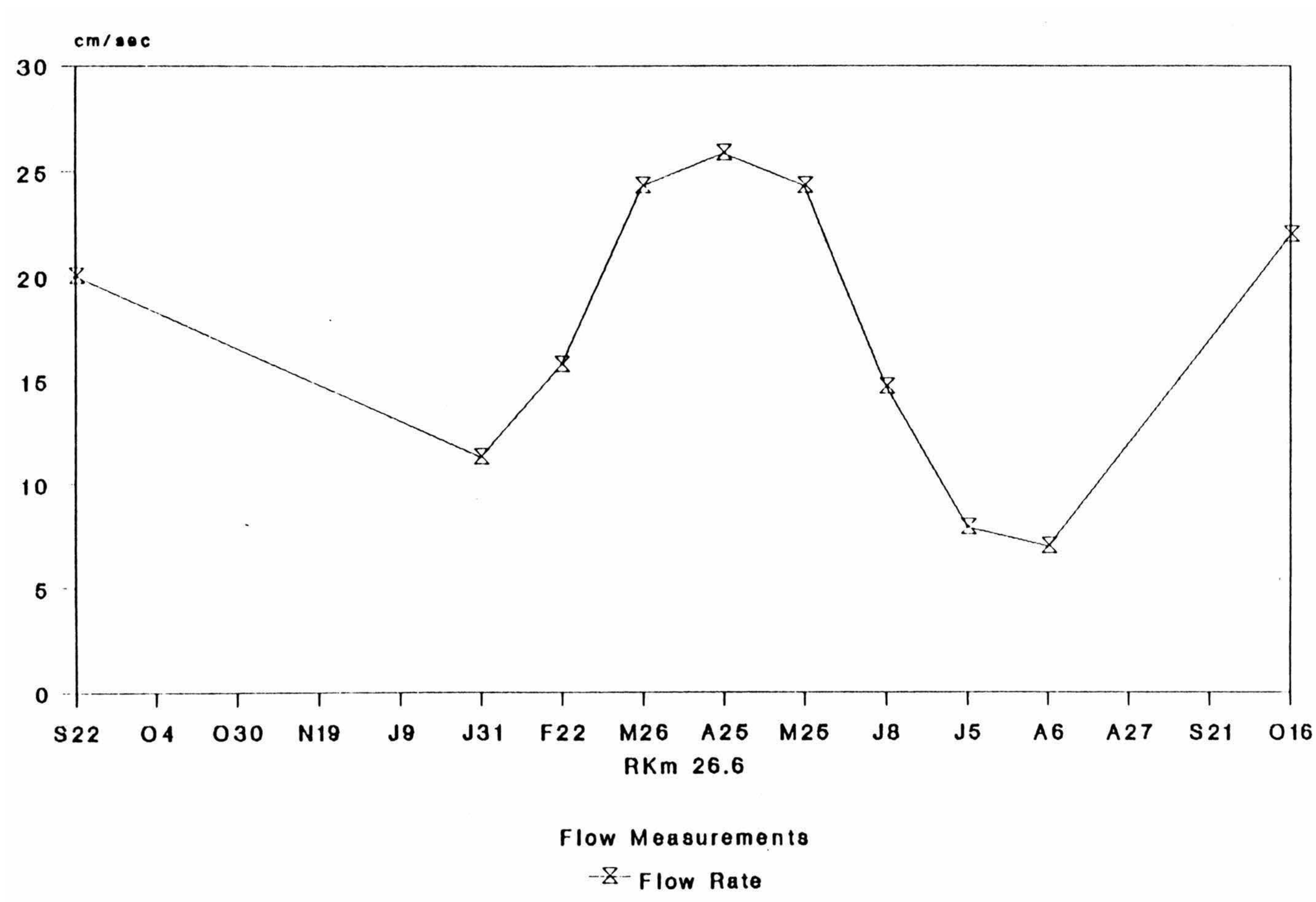


Figure 48

Turbidity
September 1989 - October 1990

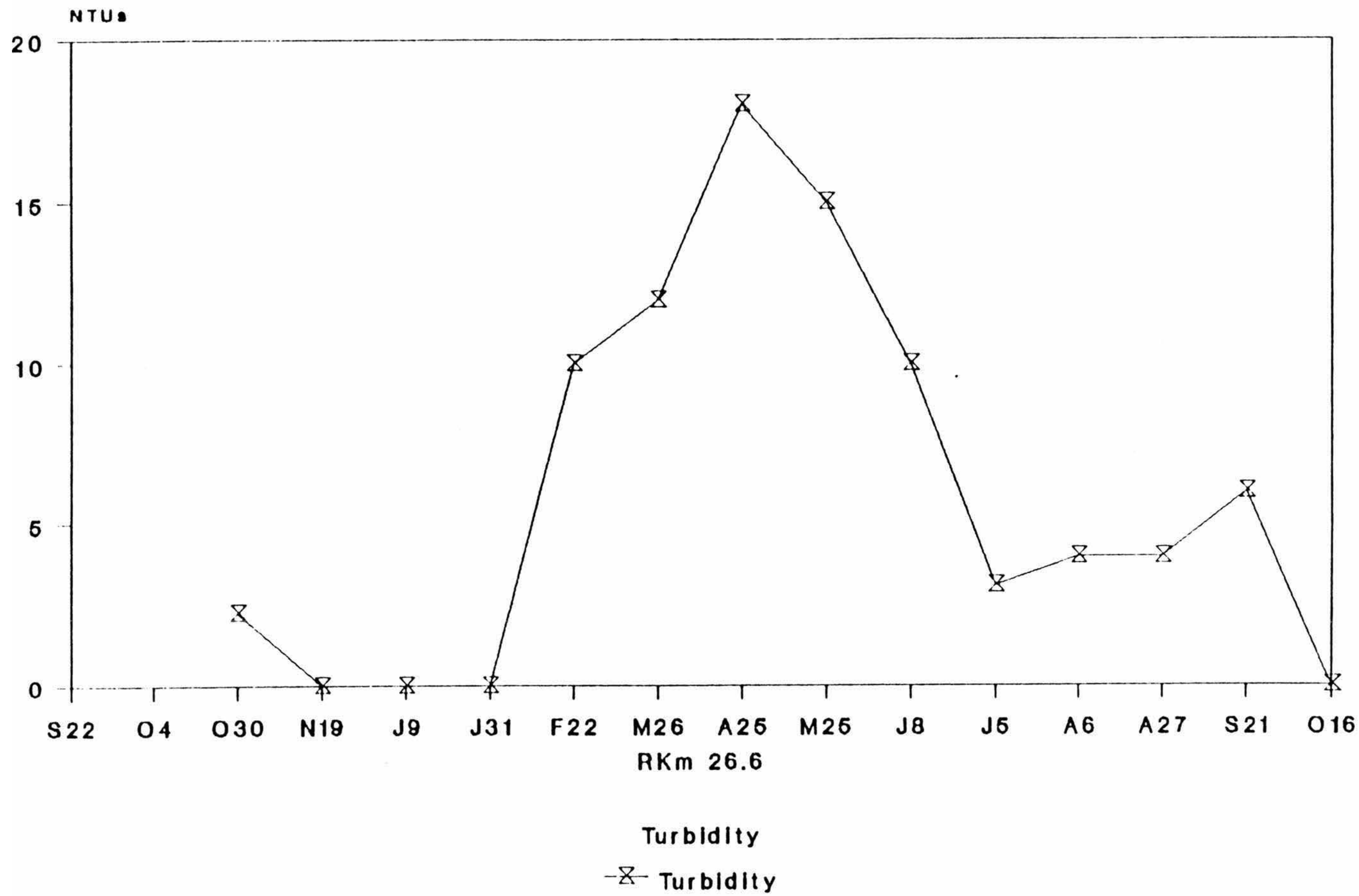


Figure 49

The nitrate nitrogen, ammonia nitrogen, and orthophosphate were 6.35 mg/l, 0.127 mg/l, and 0.446 mg/l, respectively, in late October (Figure 50). They decrease in early January, but nitrate nitrogen peaked at 6.54 mg/l in late January. In late February the chemical parameters began to decline, and maintained low levels of nitrate nitrogen 1.49 mg/l, 0.061 mg/l, and 0.524 through mid-October 1990.

<u>Temperature and pH</u>

Late September, 1989, the pH was 7.10 (Figure 51). There was a general decline through late October to 6.87. In November it had increased to 7.01, but by late January it had declined to 6.70. In late February it had increased to 6.97. In late March it dropped off slightly to 6.80 and then it remained constant until June. It reached a peak of 7.00 in early August. In late August it had dropped to 6.80, but increased to 7.10 by mid-October.

The temperature fluctuated a great deal (Figure 52). The trend from early October, 1989, with a temperature of 23 °C, was downward to the lowest temperature of 8 °C in February. March through early August it increased to a peak temperature of 25 °C. In late August the temperature began to decline. It was 14 °C in mid-October, 1990.

Chemical Parameters
September 1989 - October 1990

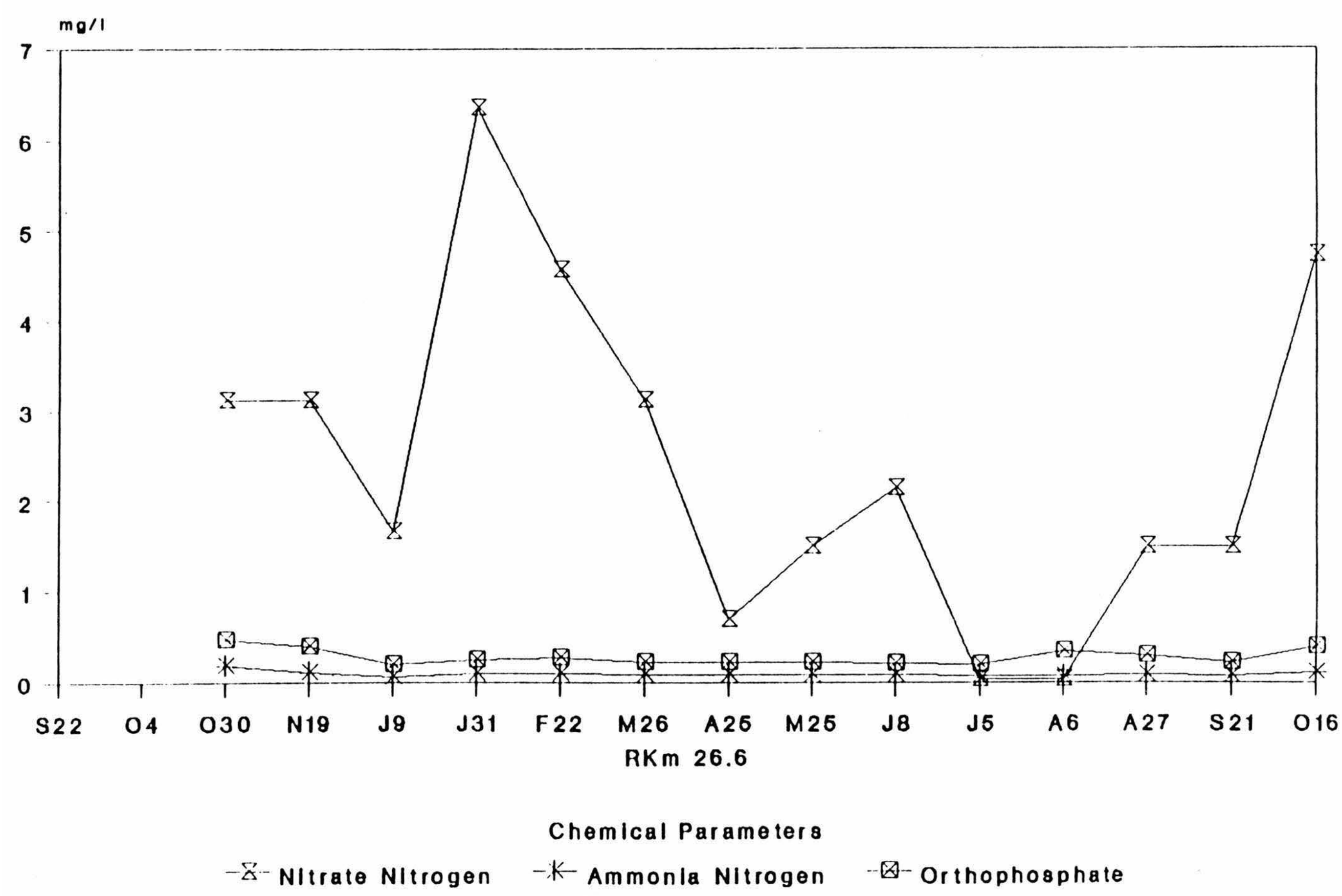


Figure 50

pH
September 1989 - October 1990

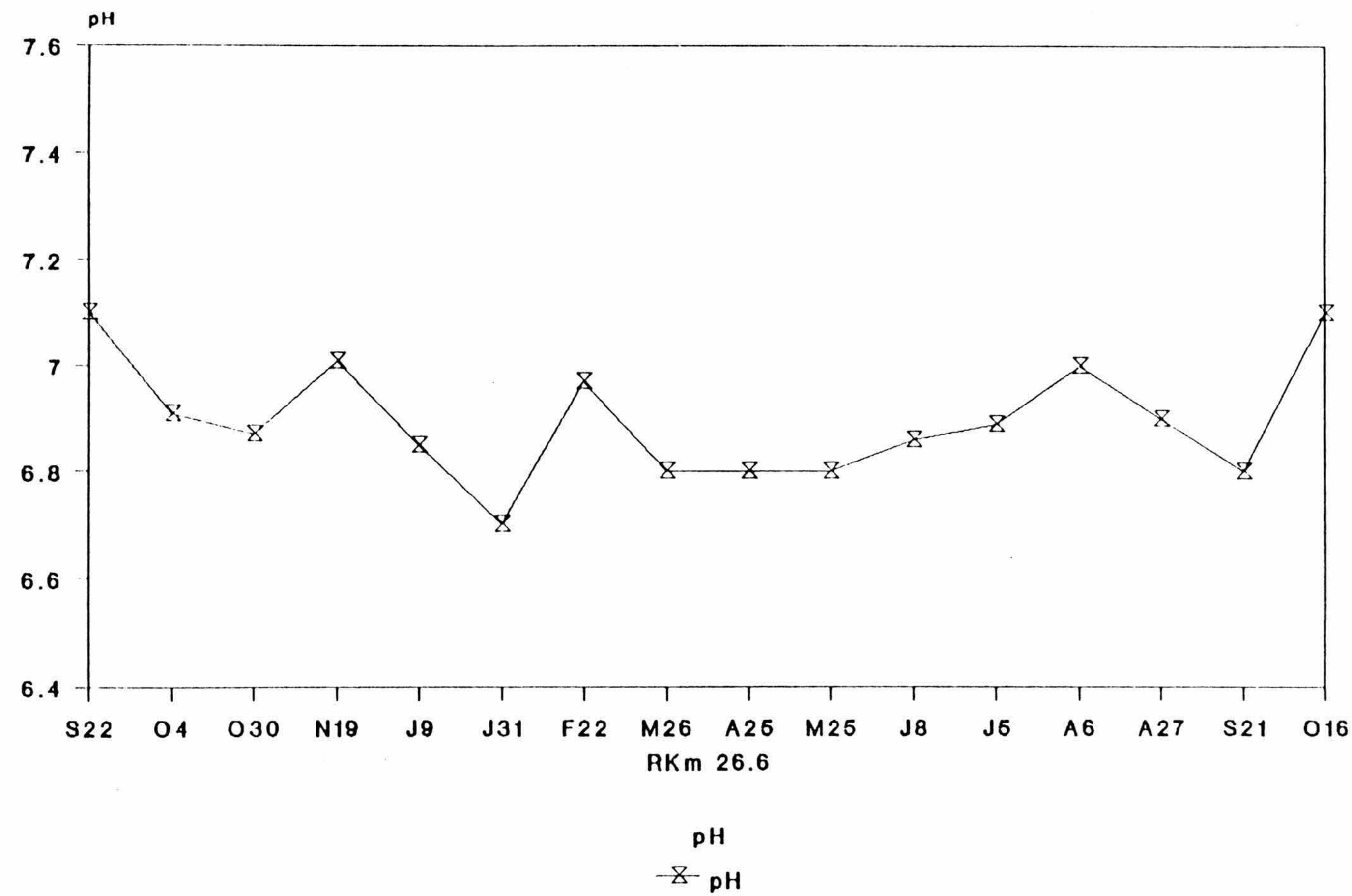


Figure 51

Temperature
September 1989 - October 1990

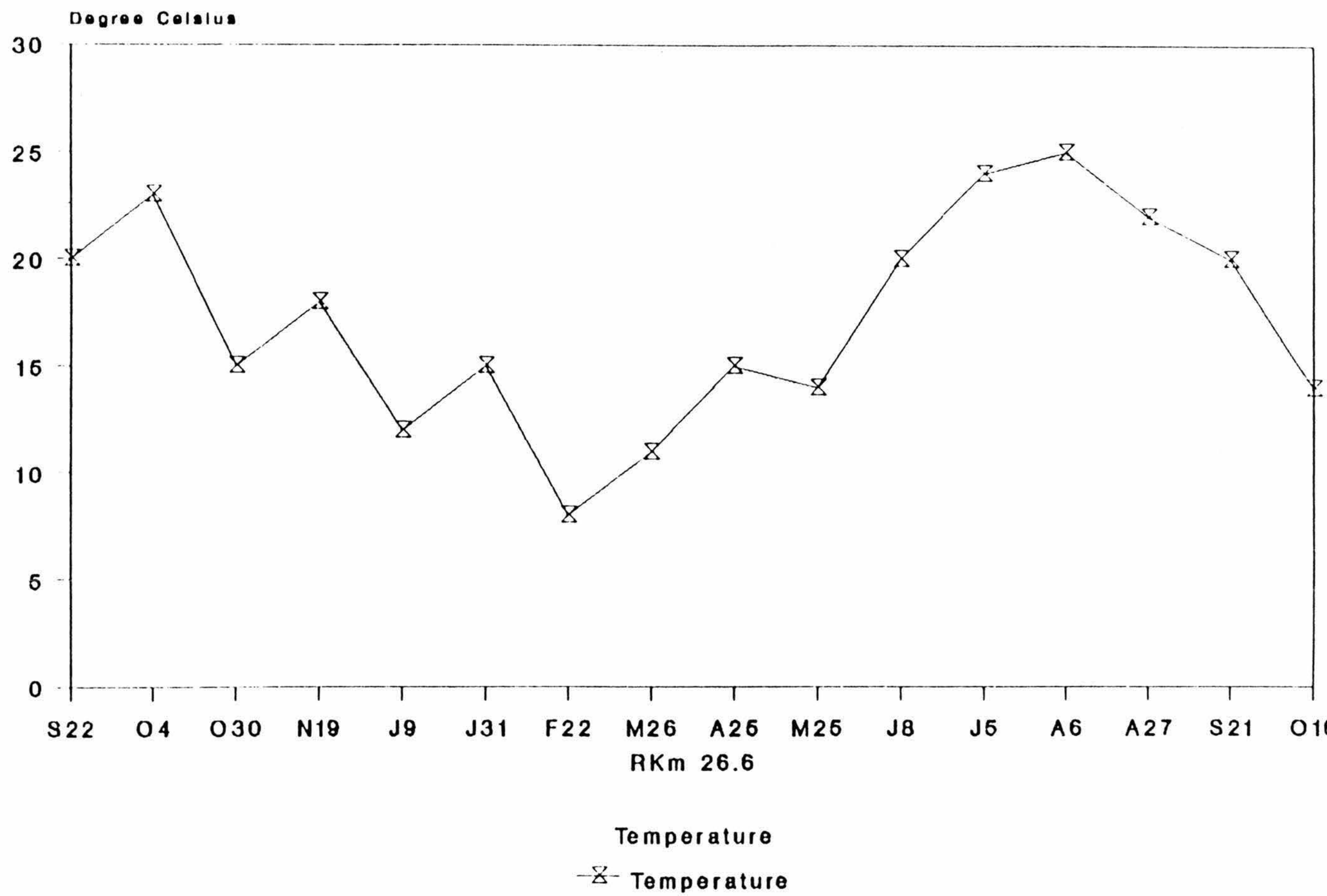


Figure 52

RKm 30.4

Flow, Turbidity, Chemical, and Hardness Parameters

Alkalinity, hardness, and conductivity were 52.00 mg/l, 42.00 mg/l, 93.00 uS, respectively in mid-November, 1989 (Figure 53). There was a general decline in February to 22.20 mg/l, 22.2 mg/l, 45.0 uS, respectively. These parameters remained relatively constant until July. Then each increased steadily to 50.00 mg/l, 40.00 mg/l, and 120.00 uS, respectively by mid-October.

The chemical parameters fluctuated a great deal but nitrate nitrogen remained less than 5.00 mg/l, ammonia nitrogen remained less than 0.20 mg/l, and orthophosphate remained less than 0.70 mg/l (Figures 54). Turbidity was 0 NTUs in January and had a peak of 22 NTUs in April (Figure 55). Flow was intermittent till January when it was 13.2 cm/sec (Figure 56). It peaked in February at 37.5 cm/sec and then declined to 7.0 cm/sec in September. There was an increase to 22.0 cm/sec in mid-October.

Temperature and pH

Late September, 1989, the pH was 7.40, but by early October it had decreased to 6.81 (Figure 57). In late October it increased and continued to increase in November to 6.97. There was a general decline through January to 6.40. It returned to 6.90 in February, but decreased in March to 6.80. The pH remained relatively constant till May. There was an increase in May, June, and

Hardness Parameters
September 1989 - October 1990

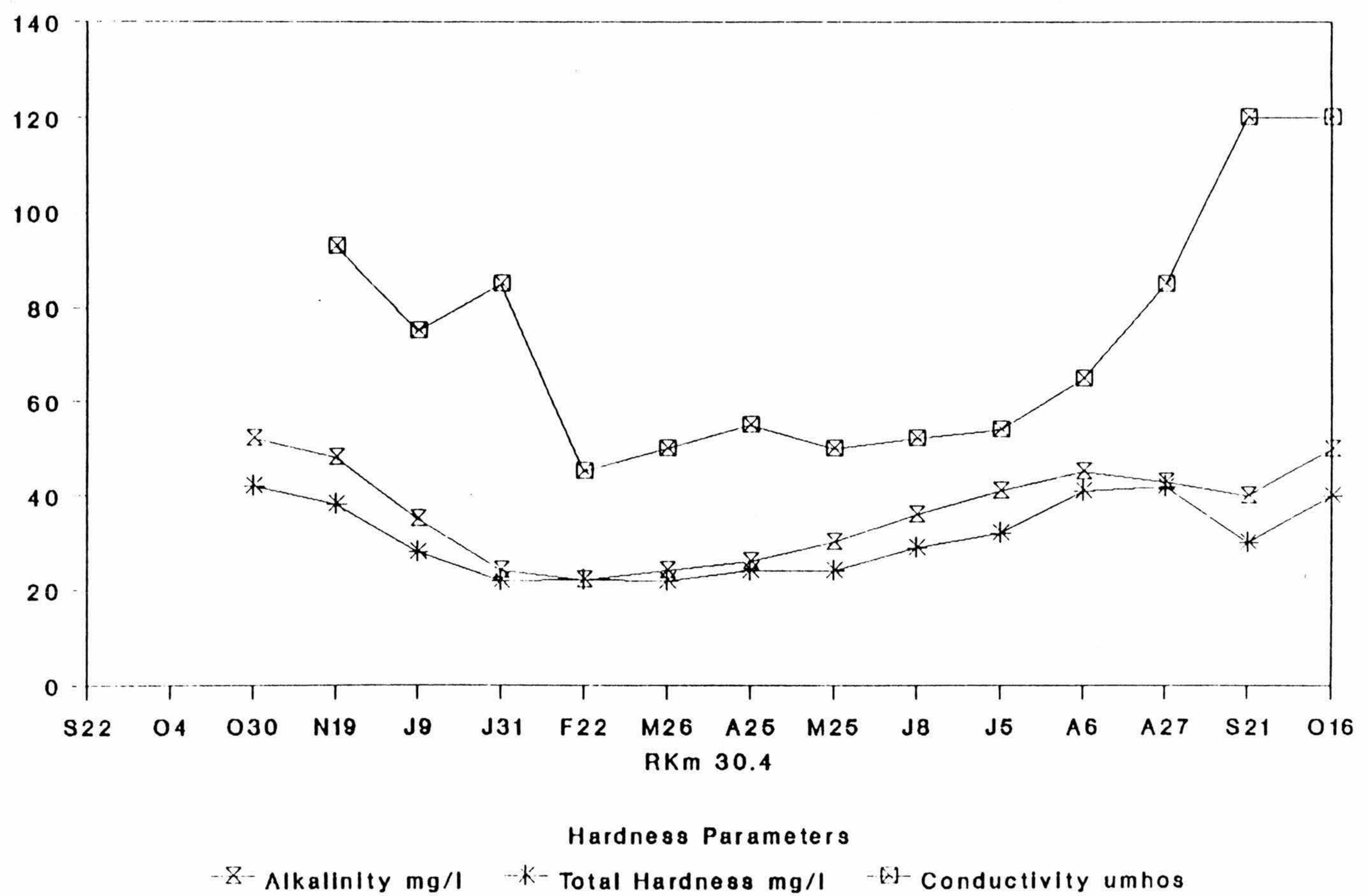


Figure 53

Chemical Parameters

September 1989 - October 1990

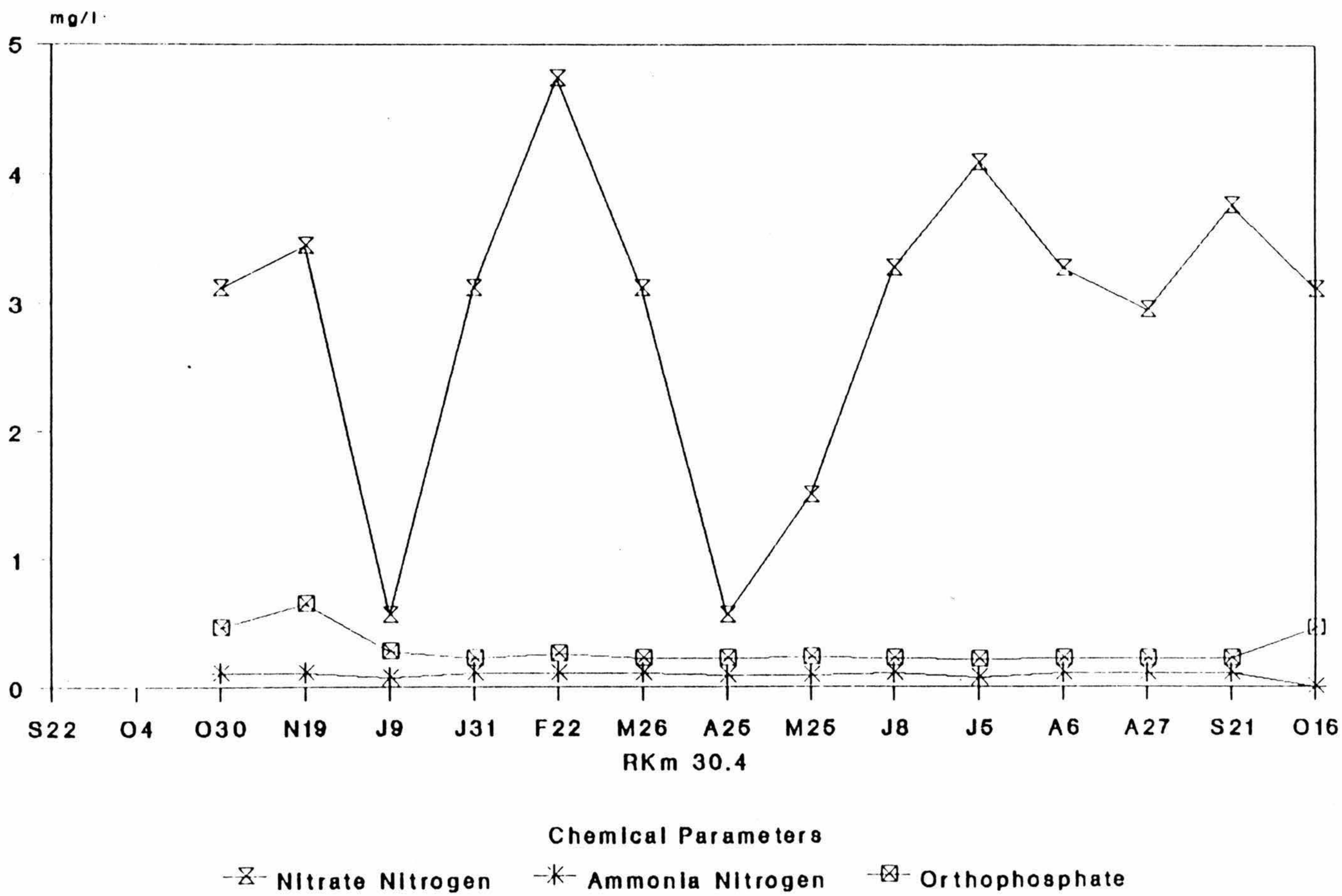


Figure 54

Turbidity
September 1989 - October 1990

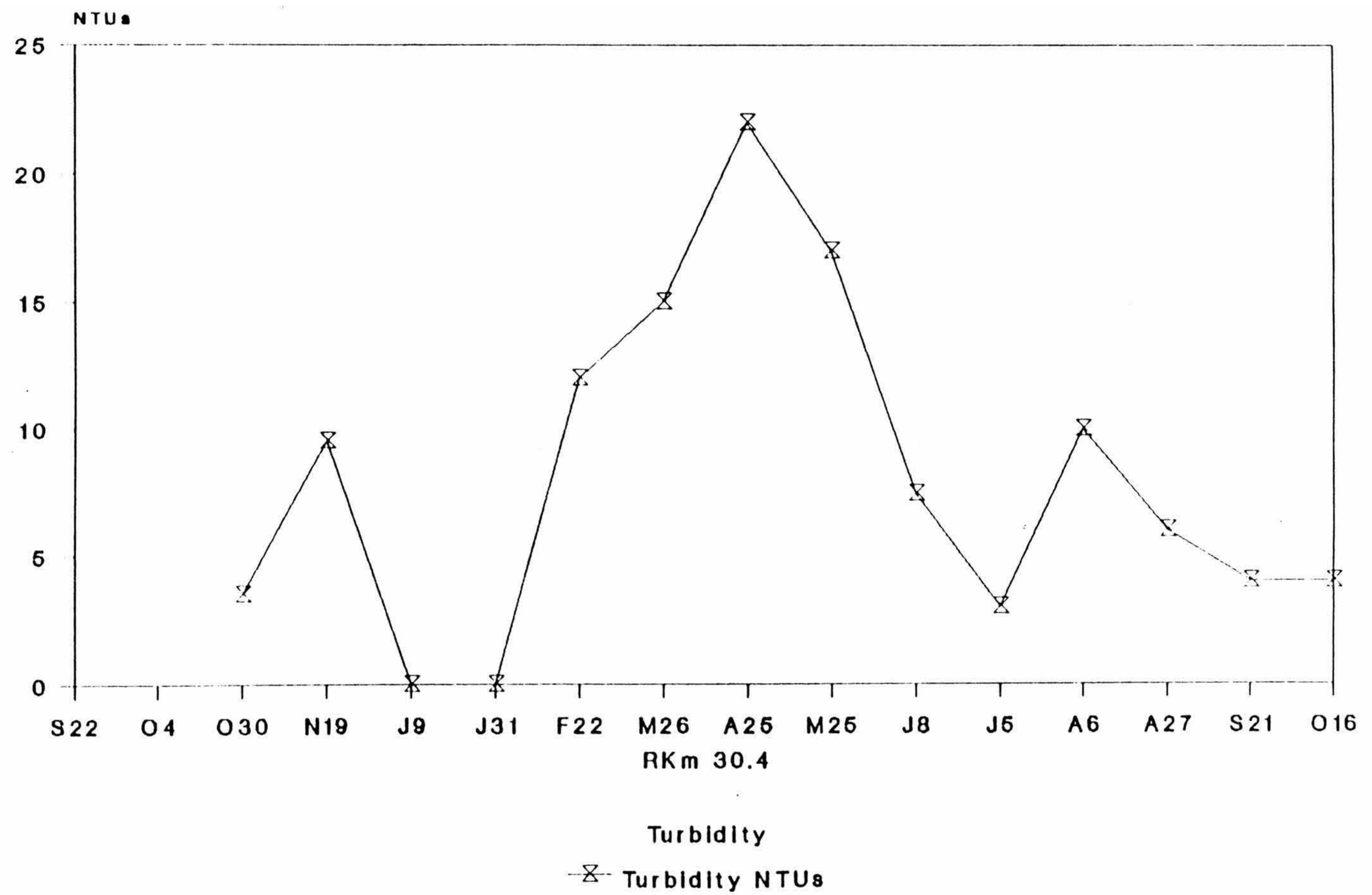


Figure 55

Flow
September 1989 - October 1990

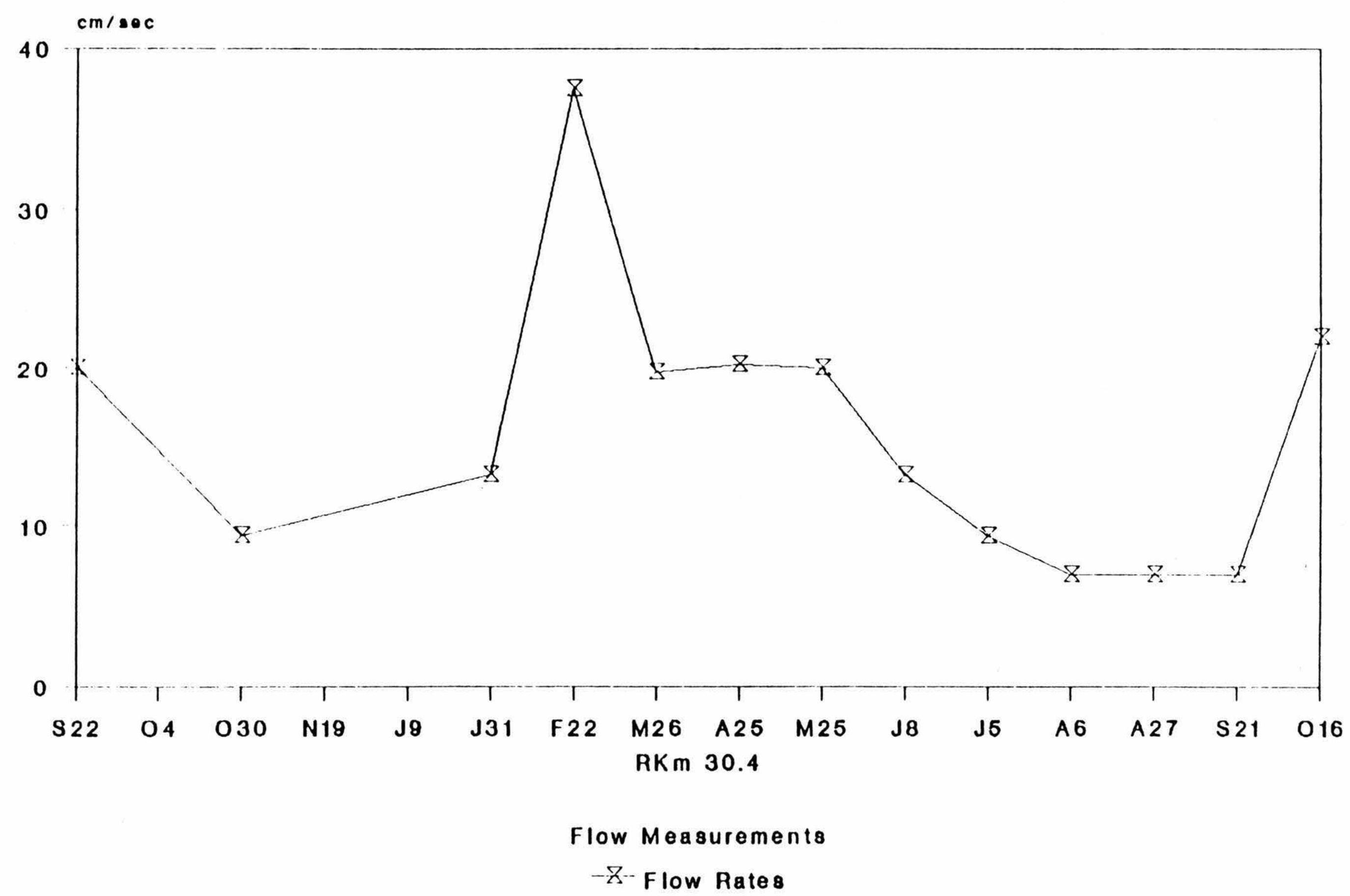


Figure 56

pH
September 1989 - October 1990

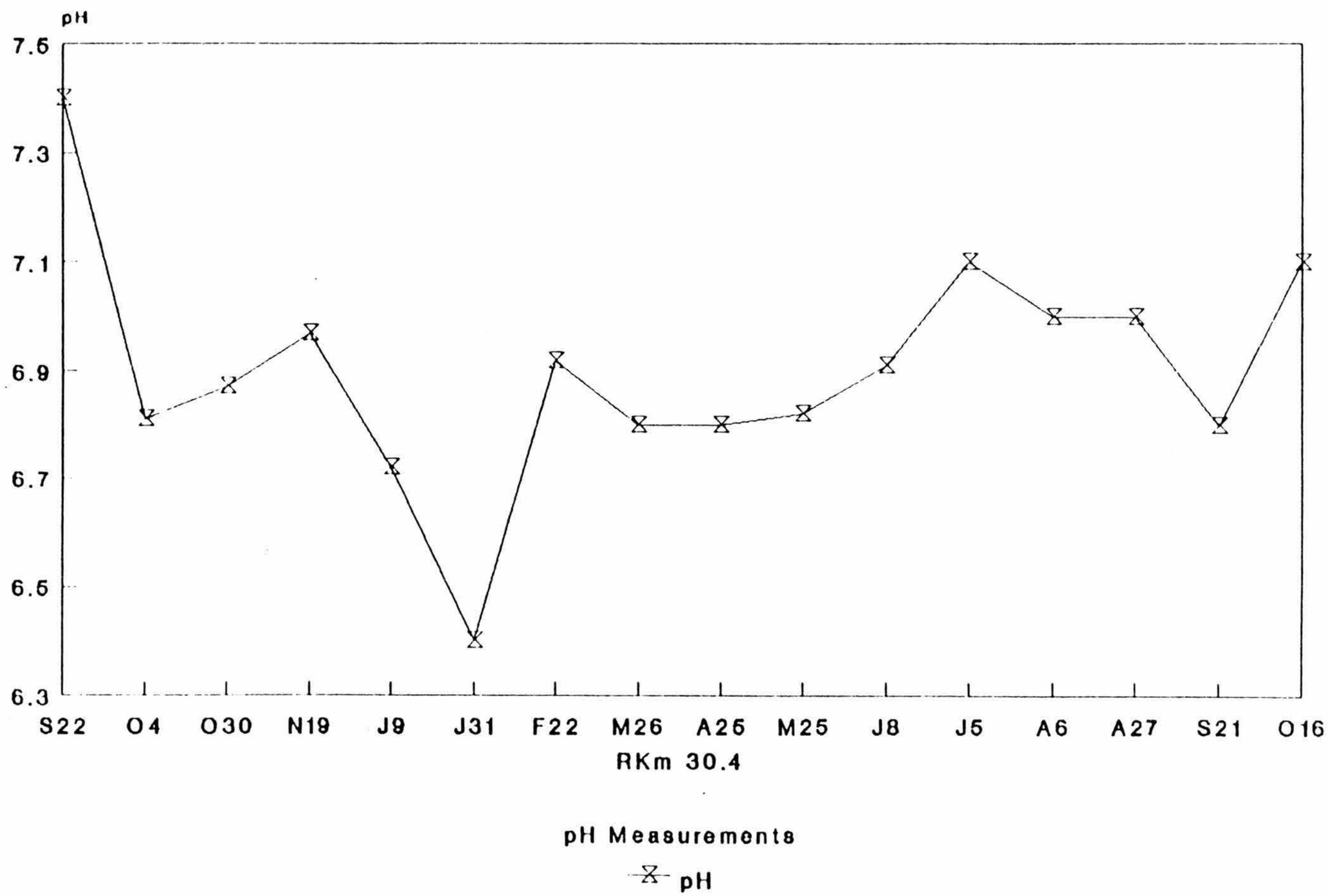


Figure 57

July to 7.10. In August the pH was 7.00, but decreased to 6.80 in September. The final measurement in October was 7.10.

The temperature was 26 °C in September, 1989 (Figure 58). It had a gradual decline through January to 12 °C. The temperature in February was 7 °C then it increased through early August to a peak at 26 °C. By late August the decline pattern of the temperature had begun and the last temperature measured was 14 °C.

RKm 35.2

Flow, Turbidity, Chemical, and Hardness Parameters

Alkalinity, hardness, and conductivity were 54.00 mg/l, 46.00 mg/l, 105.00 uS, respectively, in November (Figure 59). They began a general decline until March. A gradual increase began in late April and continued to mid-October when they were 52.00 mg/l, 44.00 mg/l, 120.00 uS, respectively. Nitrate nitrogen fluctuated monthly, but remained less than 10.00 mg/l. The other chemical parameters remained constant and low with ammonia nitrogen less than 0.20 mg/l, and orthophosphate less than 0.70 mg/l (Figure 60). Flow wasn't measurable after early October when it was 7.8 cm/sec (Figure 61). In early January measurable flow returned to 7.0 cm/sec, and there were only minor fluctuations through October of 1990. Turbidity peaked at 44 NTUs in late April, then gradually declined to 1 NTU in late August. It

Temperature
September 1989 - October 1990

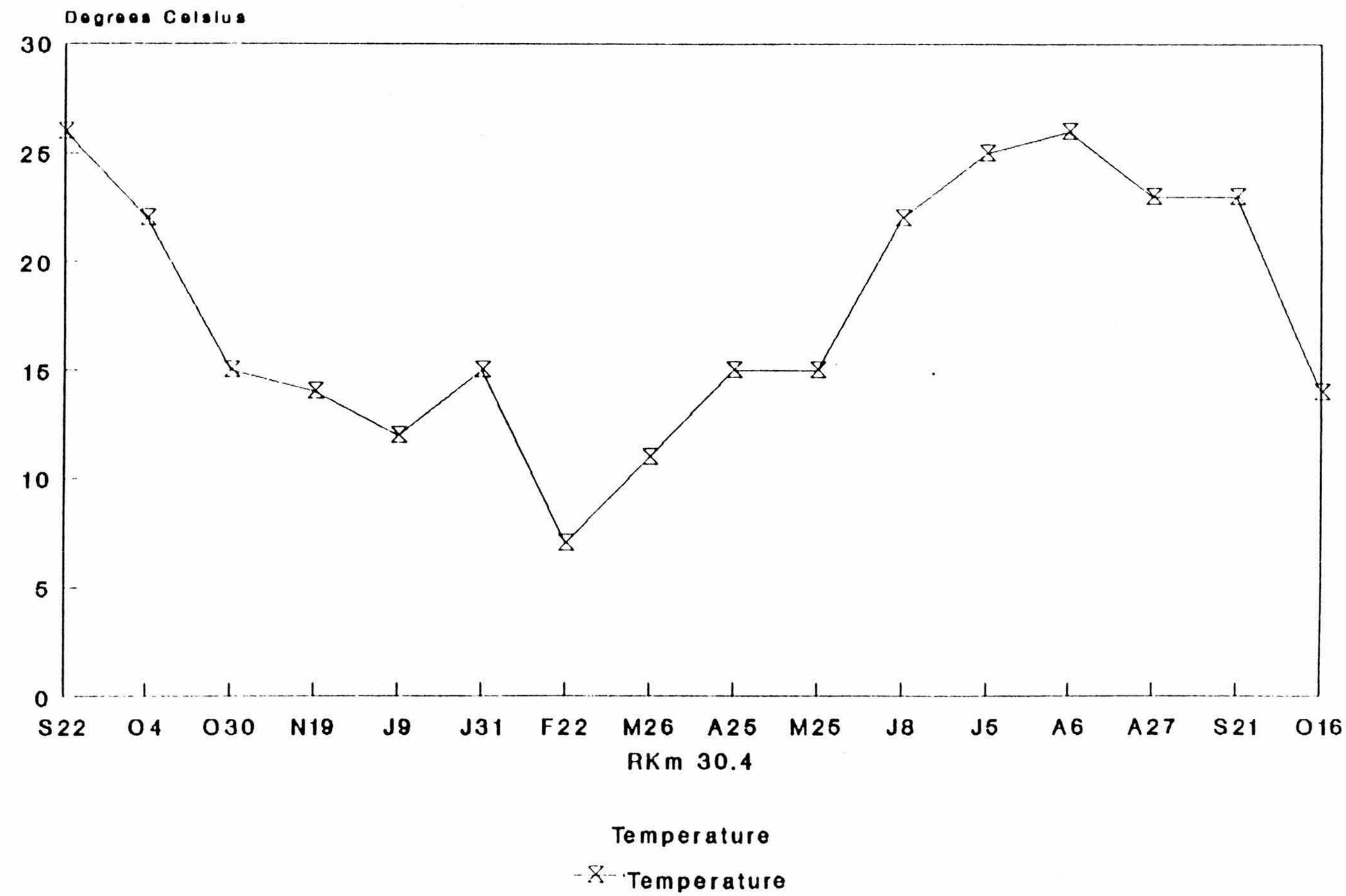


Figure 58

Hardness Parameters
September 1989 - October 1990

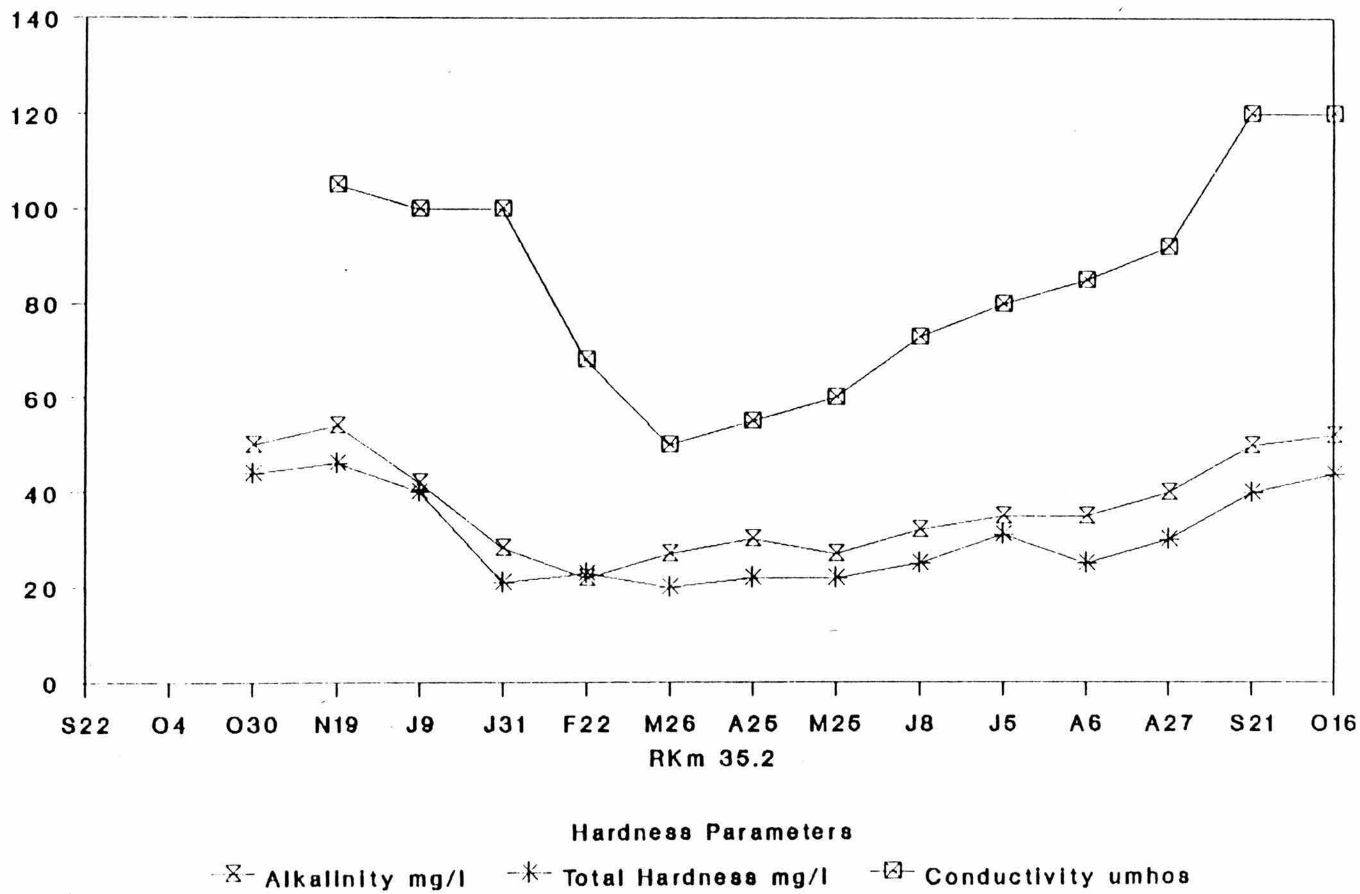


Figure 59

Chemical Parameters
September 1989 - 1990

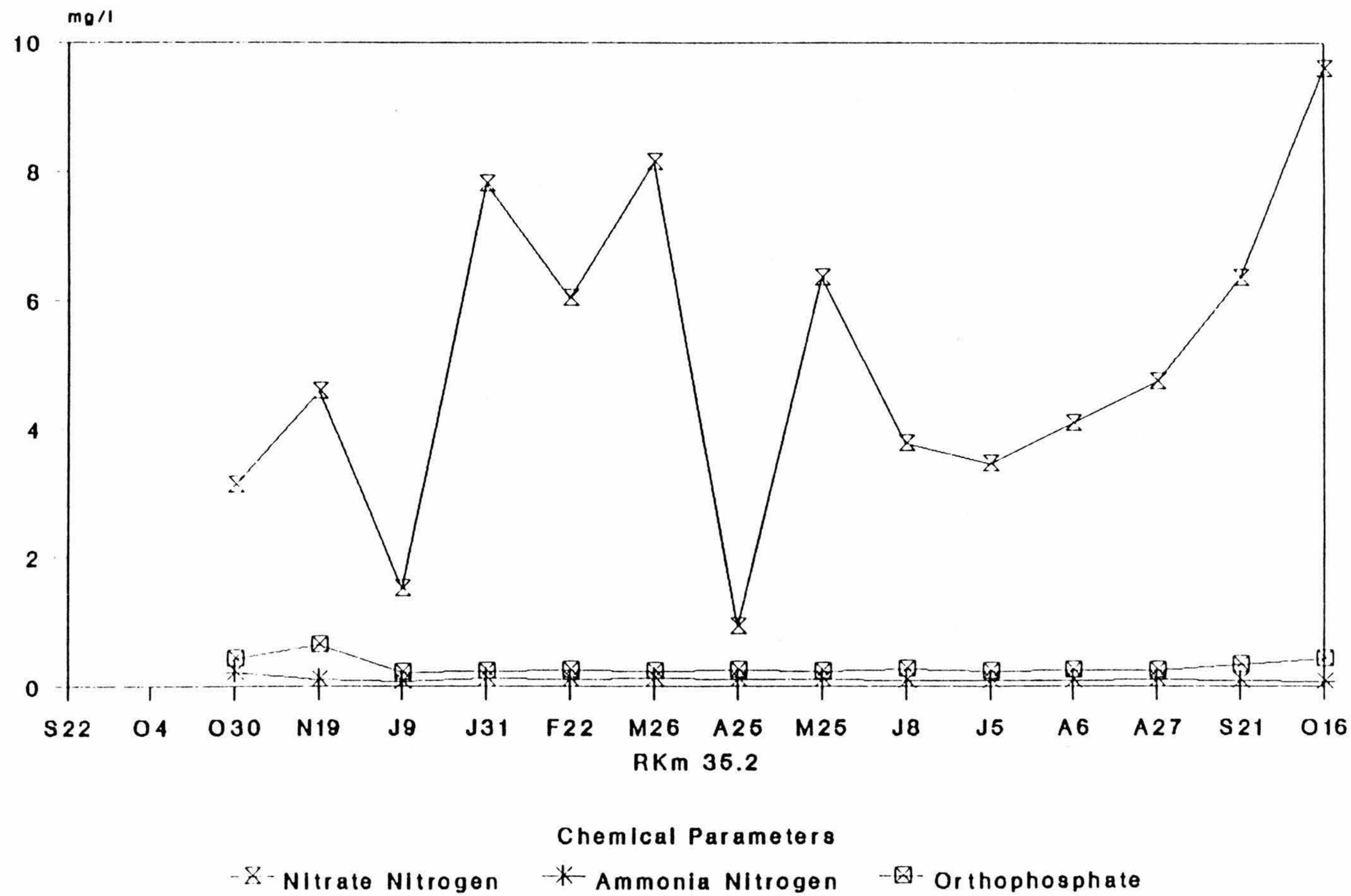


Figure 60

Flow Measurements
September 1989 - October 1990

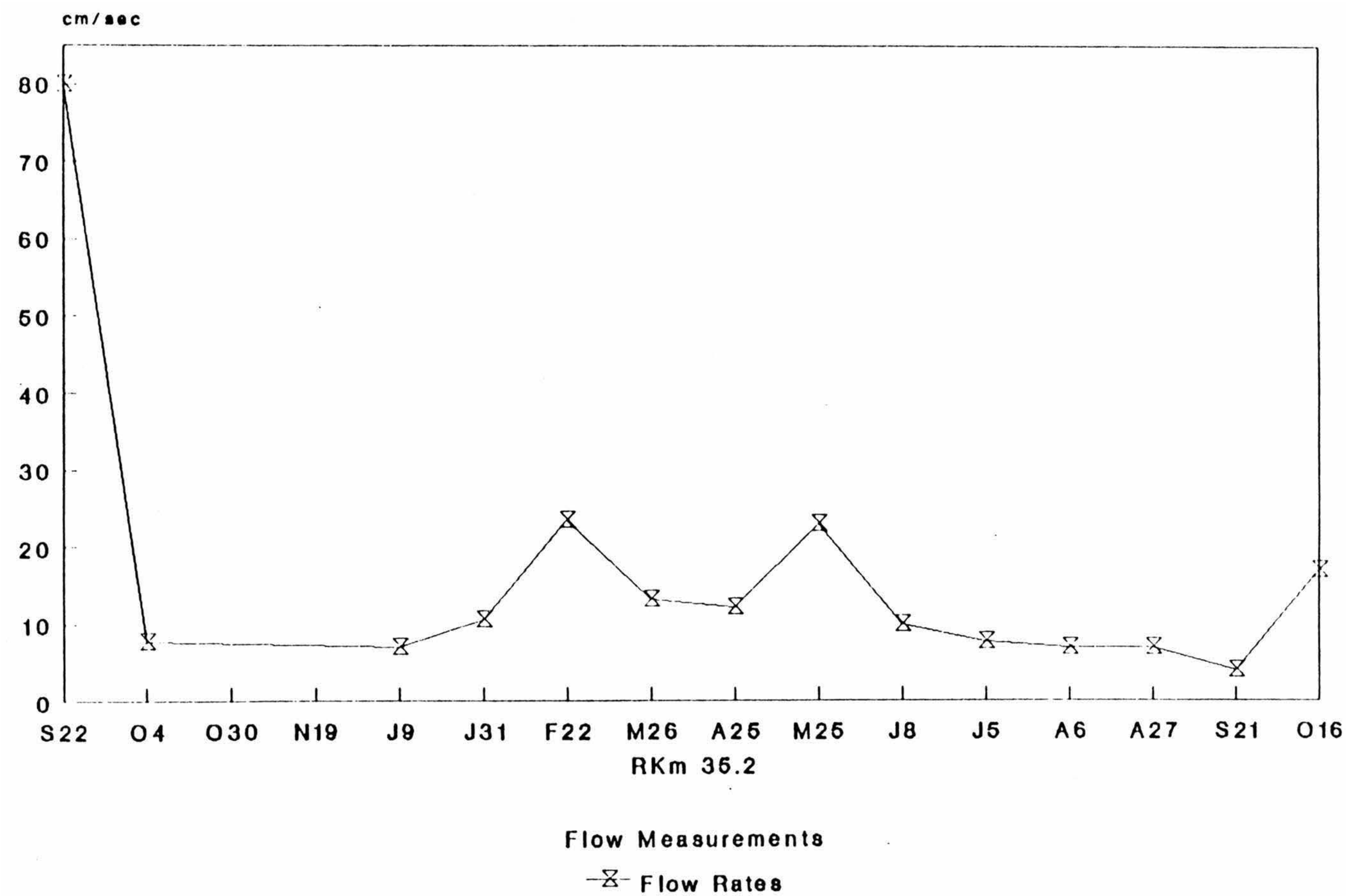


Figure 61

increased to 6 NTUs in October (Figure 62).

Temperature and pH

Late September, 1989, pH was 6.69, but in early October it dropped to 6.63 (Figure 63). There was an increase in late October to 6.80 and it decreased through late January when it reached 6.26. In February the pH was 6.92 and it remained between that reading and 6.80 through July. During August the pH increased to 7.10, and dropped to 6.80 in September, and then increased to 7.40 in October, 1990.

The temperature was 20 °C in September, 1989 (Figure 64). It gradually declined through January to 11 °C. The lowest temperature was in February when it was 8 °C, after which it gradually increased reaching a 25 °C plateau in July which was maintained through September. The last temperature in October was 15 °C.

Turbidity
September 1989 - October 1990

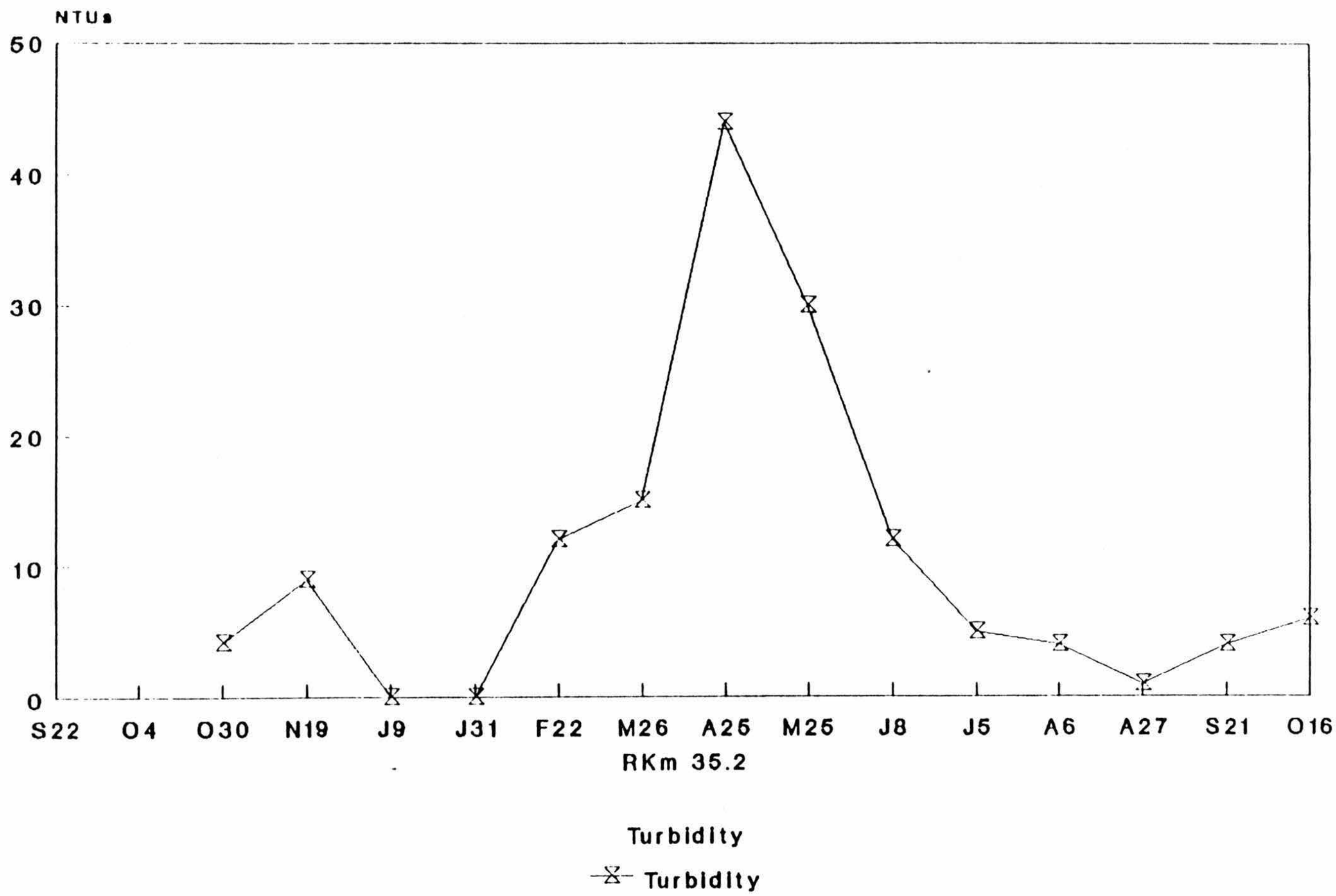


Figure 62

pH Measurements
September 1989 - 1990

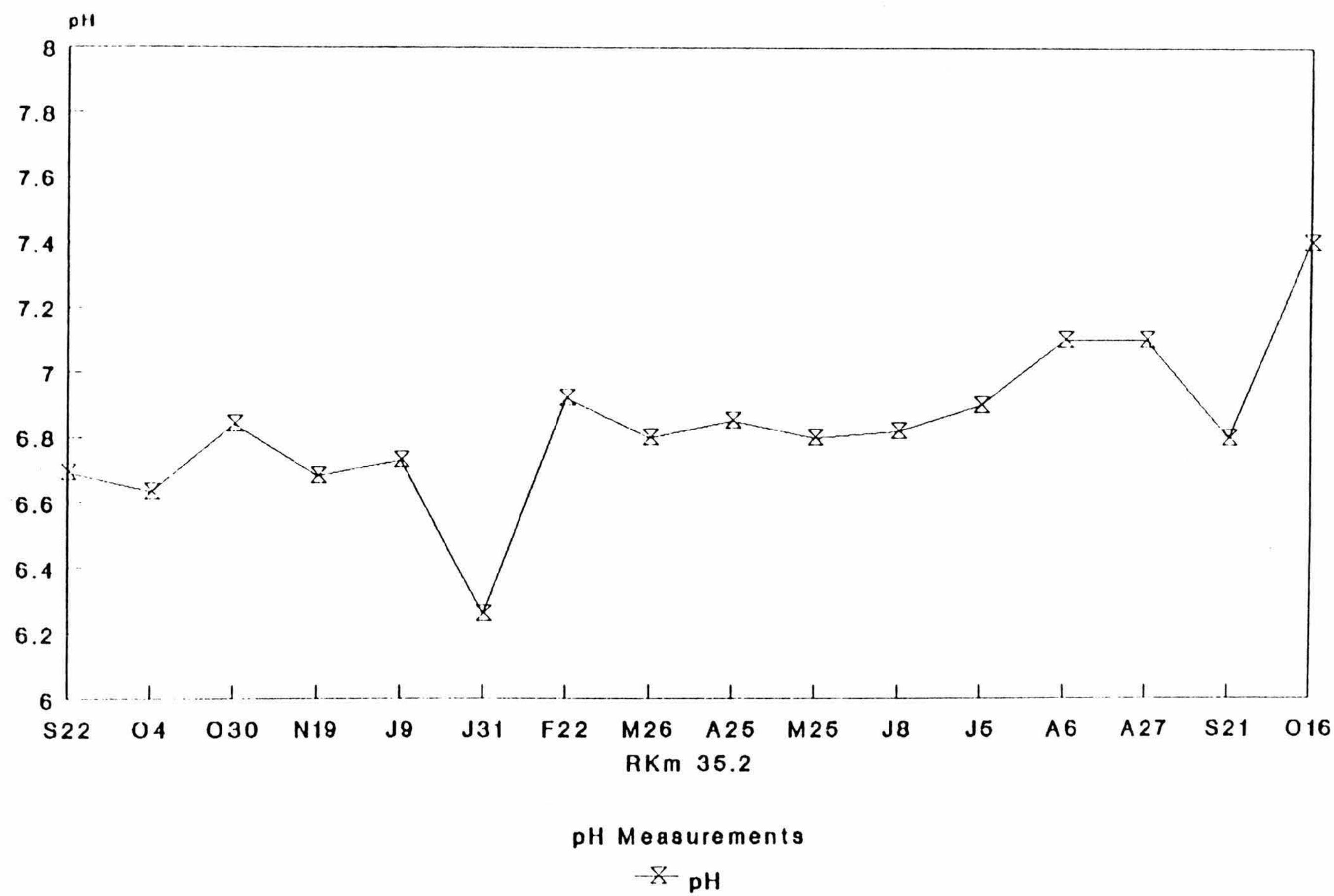


Figure 63

Temperatures
September 1989 - October 1990

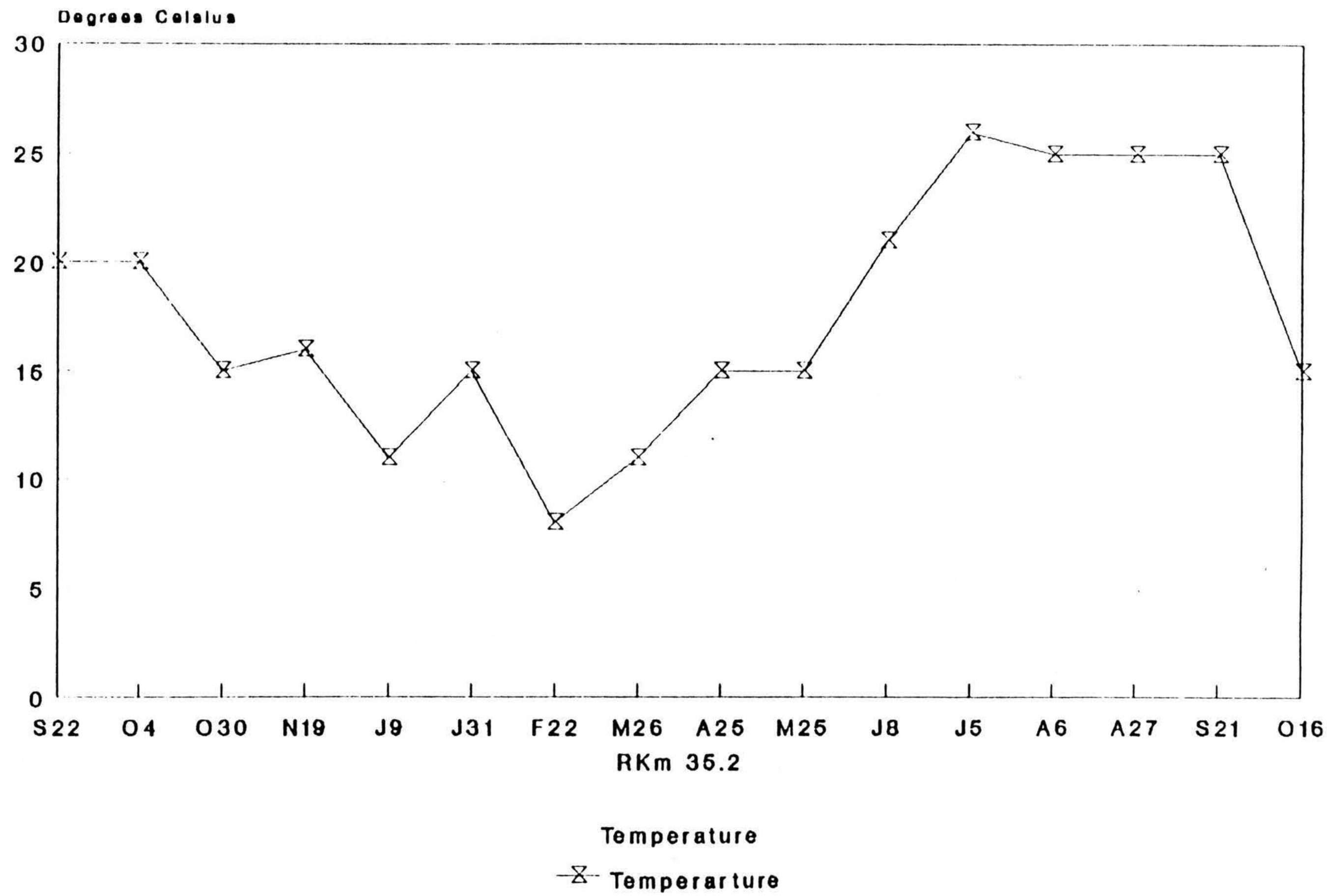


Figure 64

C. Longitudinal Distribution of Diatom Taxa

An examination of the longitudinal distribution of the diatom taxa will give a site by site overview of assemblages located at each site. It will also indicate if there are any differences between those sites. (A complete taxa list is in Meyer and Eichman, in press).

RKm 2.6

At this site there were five site specific genus species (Table 1). There were six dominant taxa that occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage at RKm 2.6 (Table 2). Four taxa occurred with a frequency of greater than 60%, but were present in less than 10% of the assemblage during the study period (Meyer and Eichman, in press). No taxa had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were five taxa with a frequency of between 18% and 60%, and that made up between 5% and 10% of the assemblage at some time during the annual cycle. Nineteen taxa were present with a frequency of between 18% and 60%, and contributed greater than 1% but less than 5% of the assemblage. Nine taxa were present with a frequency of between 6% and 18%, and contributed at least 1% to the diatom assemblage. There were seventy-eight taxa that occurred with a

Taxa Limited to a Specific Sampling Site

Table 1

Taxa	Location
Achnanthes coarctata	RKm 2.6
Achnanthes marginulata	RKm 11.2
Achnanthes saxonica	RKm 35.2
Cymatopleura elliptica	RKm 35.2
Cymbella cistula var gibbosa	RKm 23.4
Cymbella lunata	RKm 2.6
Cymbella naviculiformis	RKm 8.0
Eunotia maior var. ventricosa	RKm 2.6
Fragilaria capucina var mesolepta	RKm 35.2
Gomphonema acuminatum var elongatum	RKm 30.4
Navicula longicephala	RKm 11.2
Navicula luzonenis	RKm 30.4
Navicula mutica	RKm 11.2
Navicula pupula var rectangularis	RKm 11.2
Nitzschia tryblinella var levidensis	RKm 35.2
Pinnularia biceps	RKm 2.6
Pinnularia brebissonii var. diminuta	RKm 8.0
Pinnularia maior var. transverrsa	RKm 8.0
Rhizosolenia longiseta	RKm 35.2
Stauroneis anceps	RKm 11.2
Stauroneis ignorata	RKm 2.6

Number of Relative Dominant Taxa
River Kilometers

Frequency/ % of Assemblage	2.6	8.0	11.2	16.6	20.6	23.4	26.6	30.4	35.2
>60% / ≥10%	6	8	7	4	8	7	8	8	6
>60% / <10%	4	9	7	3	9	11	14	15	21
>60% / <1%						2	1		1
<60% >18% / >10%		2	2	3	2	1	2		5
<60% >18% / <10% >5%	5	4	4	8	4	3	8	2	3
<60% >18% / <5% >1%	19	12	17	13	20	21	16	29	21
<18% >6% / >1%	9	4	8	5		2	5	3	9
<60% / <1%	78	68	67	54	63	55	50	75	72

Table 2

frequency of less than 60%, and they were always less than 1% of the diatom assemblage for this site.

RKm 8.0

At this site there were two site specific taxa found (Table 1). There were eight taxa that occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage for this site (Table 2). Seven taxa occurred with a frequency of greater than 60%, but less than 10% of the assemblage during the annual cycle (Meyer and Eichman, in press). Two taxa had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were four taxa with a frequency of between 18% and 60%, and that made up between 5% and 10% of the assemblage at some time during the project. Twelve taxa were present with a frequency of between 18% and 60%, and a contribution of greater than 1% but less than 5% of the assemblage. Four taxa were present with a frequency of between 6% and 18%, and contributed at least 1% to the diatom assemblage. There sixty-eight taxa that occurred with a frequency of less than 60%, and were always less than 1% of the diatom assemblage for this site.

RKm 11.2

At this site there were five site specific taxa found (Table 1). There were seven taxa that occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage for this site (Table 2). Seven taxa occurred with a frequency of greater than 60%, but less than 10% of the assemblage during the study period (Meyer and Eichman, in press). Two taxa had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were four taxa with a frequency of between 18% and 60%, and that made up between 5% and 10% of the assemblage at some time during the project. Seventeen taxa were present with a frequency of between 18% and 60%, and a contribution of greater than 1% but less than 5% of the assemblage. Eight taxa were present with a frequency of between 6% and 18%, and contributed at least 1% to the diatom assemblage. There were sixty-seven taxa that occurred with a frequency of less than 60%, and they were always less than 1% of the diatom assemblage for this site.

RKm 16.6

At this site there were no site specific taxa found. There were four taxa that occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage for this site (Table 2). Three taxa occurred with a frequency of greater than 60%, but less than 10% of the assemblage during the study period (Meyer and Eichman, in press). Three taxa had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were eight taxa with a frequency of between 18% and 60%, and that made up between 5% and 10% of the assemblage at some time during the project. Thirteen taxa were present with a frequency of between 18% and 60%, and a contribution of greater than 1% but less than 5% of the assemblage. Five taxa were present with a frequency of between 6% and 18%, and contributed at least 1% to the diatom assemblage. There were fifty-four taxa that occurred with a frequency of less than 60%, and they were always less than 1% of the diatom assemblage for this site.

RKm 20.6

At this site, there were no site specific taxa found. There were eight taxa that occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage for this site (Table 2). Nine taxa occurred with a frequency of greater than 60%, but less than 10% of the assemblage during the study period (Meyer and Eichman, in press). Two taxa had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were four taxa with a frequency of between 18% and 60%, and that made up between 5% and 10% of the assemblage at some time during the project. Twenty taxa were present with a frequency of between 18% and 60%, and a contribution of greater than 1% but less than 5% of the assemblage.
No taxa were present with a frequency of between 6% and 18%, and they contributed at least 1% to the diatom assemblage. There were sixty-three taxa that occurred with a frequency of less than 60%, and they were always less than 1% of the diatom assemblage for this site.

RKm 23.4

At this site, one site specific taxon, _Cymbella_ _cistula_ var. _gibbosa_ was found (Table 1). Seven taxa occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage for this site (Table 2). Eleven taxa occurred with a frequency of greater than 60%, but less than 10% of the assemblage during the study period (Meyer and Eichman, in press). Only two taxa had a frequency greater than 60%, but they were less than 1% of the assemblage for the site. One taxon had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were three taxa with a frequency of between 18% and 60%, and that made up between 5% and 10% of the assemblage at some time during the project. Twenty-one taxa were present with a frequency of between 18% and 60%, and a contribution of greater than 1% but less than 5% of the assemblage. Two taxa were present with a frequency of between 6% and 18%, and contributed at least 1% to the diatom assemblage. There were fifty-five taxa that occurred with a frequency of less than 60%, and they were always less than 1% of the diatom assemblage for this site.

RKm 26.6

At this site there were no site specific taxa found. There were ten taxa that occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage for this site (Table 2). Twelve taxa occurred with a frequency of greater than 60%, but never made up more than 10% of the assemblage (Meyer and Eichman, in press). At this site there was one taxon with a frequency greater than 60%, but it was less than 1% of the assemblage. Two taxa had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were eight taxa with a frequency of between 18% and 60%, and they made up between 5% and 10% of the assemblage at some time during the project. Sixteen taxa were present with a frequency of between 18% and 60%, and a contribution between 1% and 5% of the assemblage. Five taxa were present with a frequency of between 6% and 18%, and contributed at least 1% to the diatom assemblage. There were fifty taxa that occurred with a frequency of less than 60%, and they were always less than 1% of the diatom assemblage for this site.

RKm 30.4

There was one site specific taxon, Navicula luzonenis found (Table 1). Eight taxa that occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage for this site (Table 2). Fifteen taxa occurred with a frequency of greater than 60%, but less than 10% of the assemblage during the study period (Meyer and Eichman, in press). At this site there were no taxa with a frequency greater than 60% and with concentrations greater than 1% of the assemblage for the site. No taxa had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were two taxa with a frequency of between 18% and 60%, and that made up between 5%

and 10% of the assemblage at some time during the project. Twenty-nine taxa were present with a frequency of between 18% and 60%, and a contribution of greater than 1% but less than 5% of the assemblage. Three taxa were present with a frequency of between 6% and 18%, and contributed at least 1% to the diatom assemblage. Seventy-five taxa occurred with a frequency of less than 60%, and they were always less than 1% of the diatom assemblage for this site.

RKm 35.2

Rkm 35.2 had five site specific taxa found representing five different genera (Table 1). There were six taxa that occurred with a frequency of greater than 60%, and at some time during the annual cycle made up 10% of the diatom assemblage for this site (Table 2). Twenty-one taxa occurred with a frequency of greater than 60%, but less than 10% of the assemblage during the study period (Meyer and Eichman, in press). At this site there was one taxon with a frequency greater than 60%, but it was less 1% of the assemblage for the site. Five taxa had a frequency between 18% and 60% and made up more than 10% of the assemblage. There were three taxa with a frequency of between 18% and 60%, and that made up between 5% and 10% of the assemblage at some time during the project. Twenty-one taxa were present with a frequency of between 18% and 60%, and a contribution of greater than 1% but less than 5% of the assemblage. Nine taxa were present with a frequency of between 6% and 18%, and contributed at least 1% to the diatom assemblage. There were seventy-two taxa that occurred with a frequency of less than 60%, and they were always less than 1% of the diatom assemblage for this site.

D. Seasonal Structure of Diatom Assemblages and Diversities

The seasonal data of diatom assemblages must be taken into consideration when developing an entire diatom stream assemblage model. Past information has shown some taxa of to be seasonal (Edward and Christensen 1972; Fisher et. al 1982; Holland 1969; Main 1988; Whitford and Schumacher 1963) and influencd by climatically variable physical parameters (Hohn 1961; Cox 1988). The dominant taxa that occur in greater than 60% of the samples and whose population makes up greater than or equal to 10% of the assemblage are used to describe the seasonal distribution of the assemblages at the research sites and provide a generalized model.

RKm 2.6 and RKm 8.0

RKm 2.6 and RKm 8.0 followed a parallel course of seasonal development of assemblages (Figure 65 & 66). In the fall there was an increase in *Achnanthes deflexa* until late January when there was an increase in flow (Figures 11 & 18). During this same period of time the *Achnanthes minutissima* increased as did the *Eunotia*, *Gomphonema*, and *Meridion* species (Meyer and Eichman, in press). By mid-May and June *A. deflexa* population returned to large numbers and the other taxa populations decreased. The temperature increased and the other parameters remained

Dominant Taxa
›10% of Assemblage, ›60% of Samples

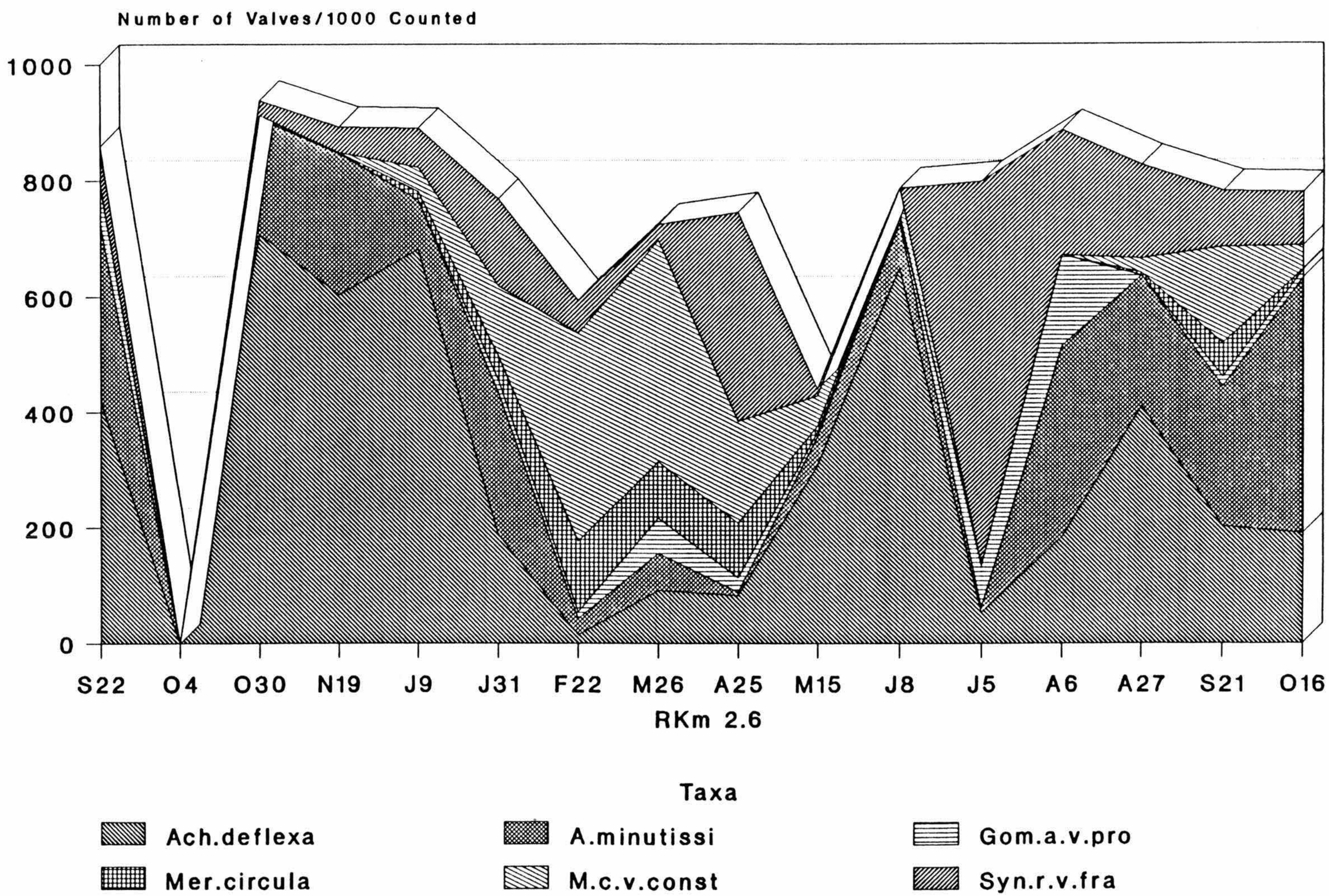


Figure 65

Dominant Taxa

>10% of Assemblage, >60% of Samples

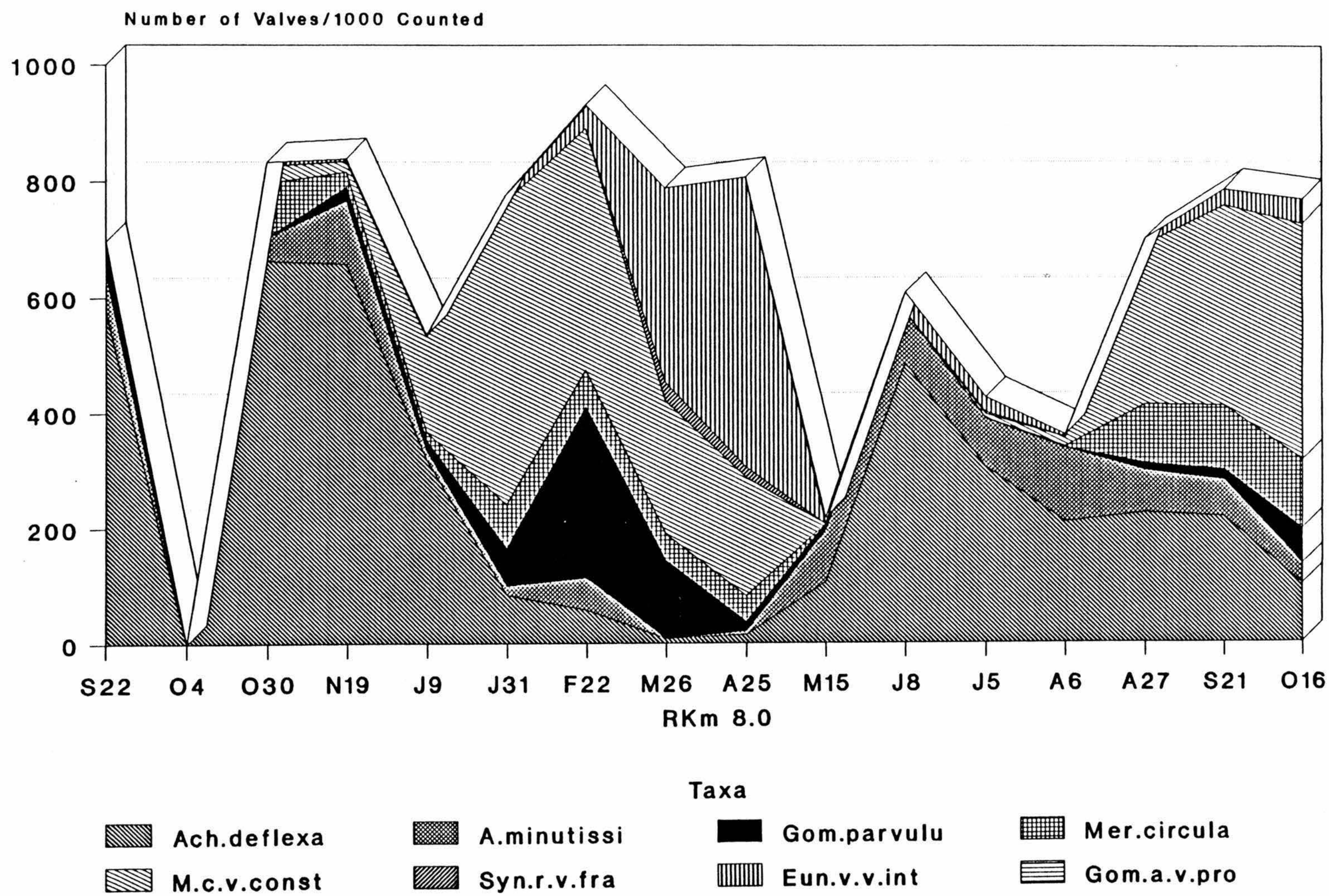


Figure 66

constant (Figures 11 - 22). A. deflexa declined in July and A. minutissima, Synedra rumpens var. fragilariodes, and the Eunotia species increased. The temperature continued to increase. In early August A. deflexa increased, but dropped off when the temperature peaked in September. The A. minutissima population increased as did the Eunotia and Meridion species. When the temperature dropped in October, the hardness parameters increased as did the nitrate nitrogen, and other chemical parameters. A. deflexa, Synedra rumpens var. fragilariodes, Eunotia, and Meridion taxa all decreased during this time, but the A. minutissima reached a peak.

The diversity was low during the winter months (Figures 67 & 68). Temperature and flow increased in late January, and so did the diversity. The diversity dropped in March, and the flow decreased. The diversity increased till July. The temperature increased and flow was constant. Diversity increased in late August, and the temperature was decreased.

RKm 11.2 and RKm 16.6

Rkm 11.2 and Rkm 16.6 follow a parallel course of seasonal development. In the fall there was an increase in Achnanthes deflexa until late January when there was an increase in flow (Figures 69, 70, 24, & 29). During this same period of time the Achnanthes minutissima increased as did the Gomphonema, Nitzschia and Meridion taxa (Figures 69 & 70). By mid-May and June A. deflexa population returned to large numbers and the other taxa

Diversity
September 1989 - October 1990

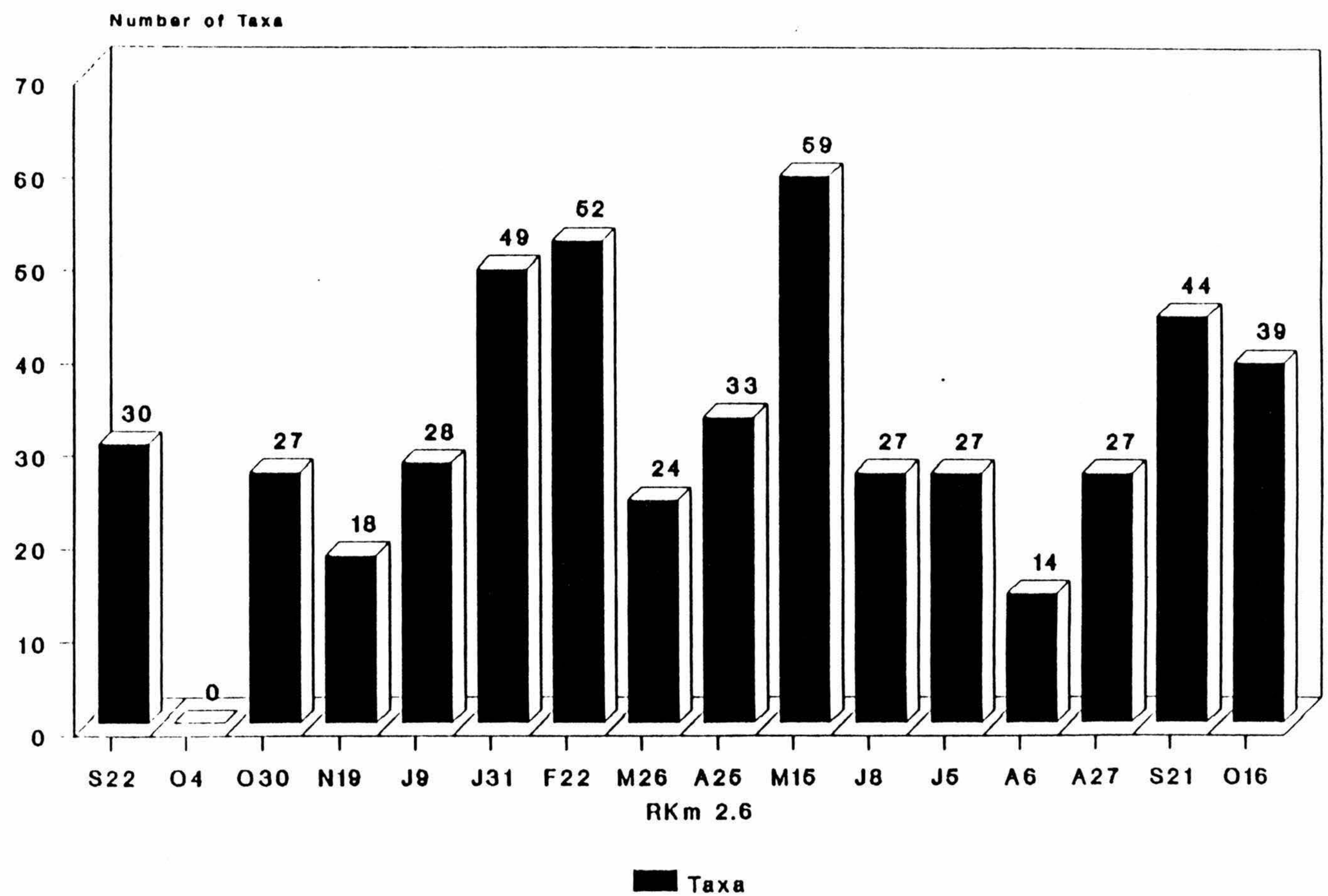


Figure 67

Diversity
September 1989 - October 1990

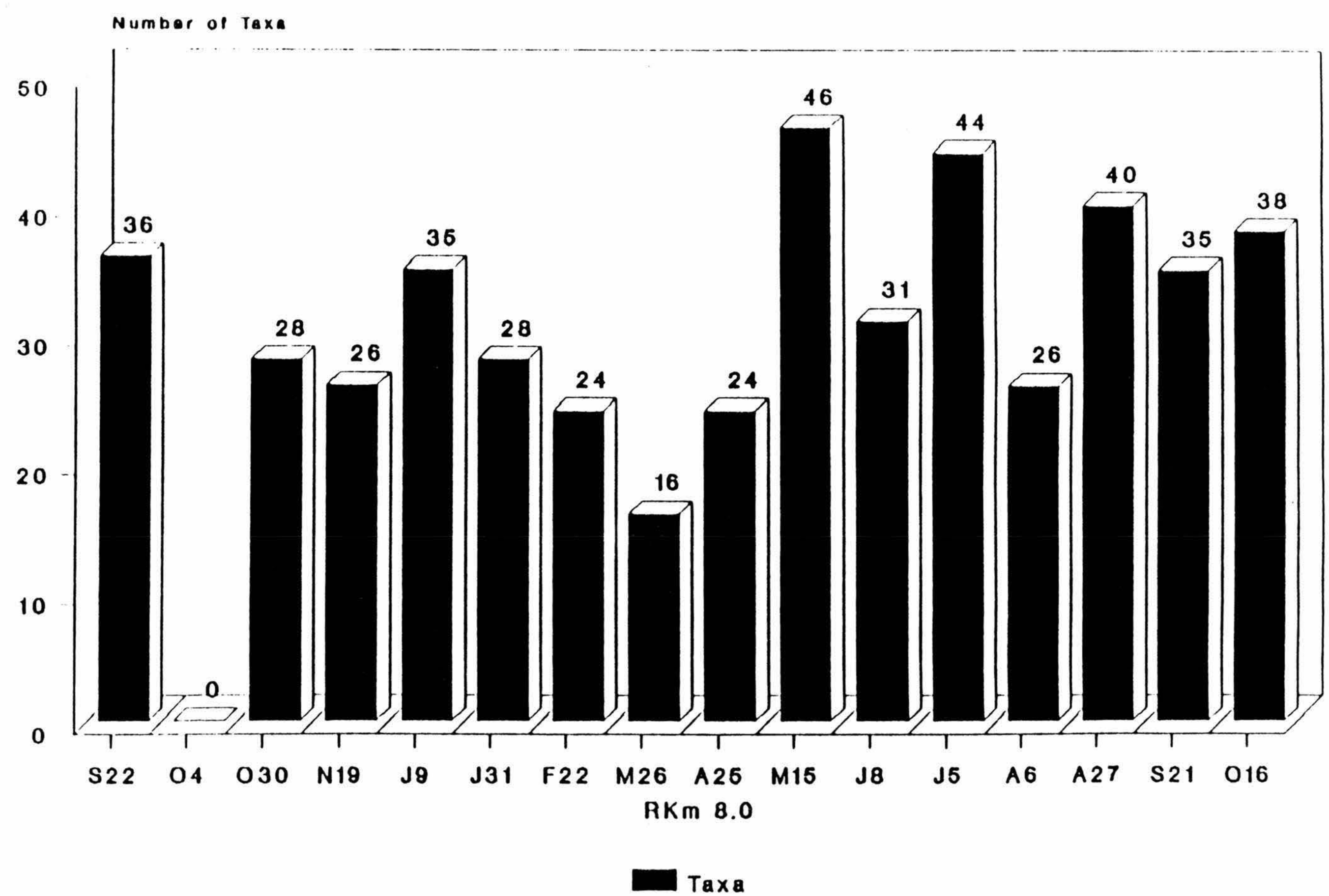


Figure 68

Dominant Taxa
>10% of Assemblage, >60% of Samples

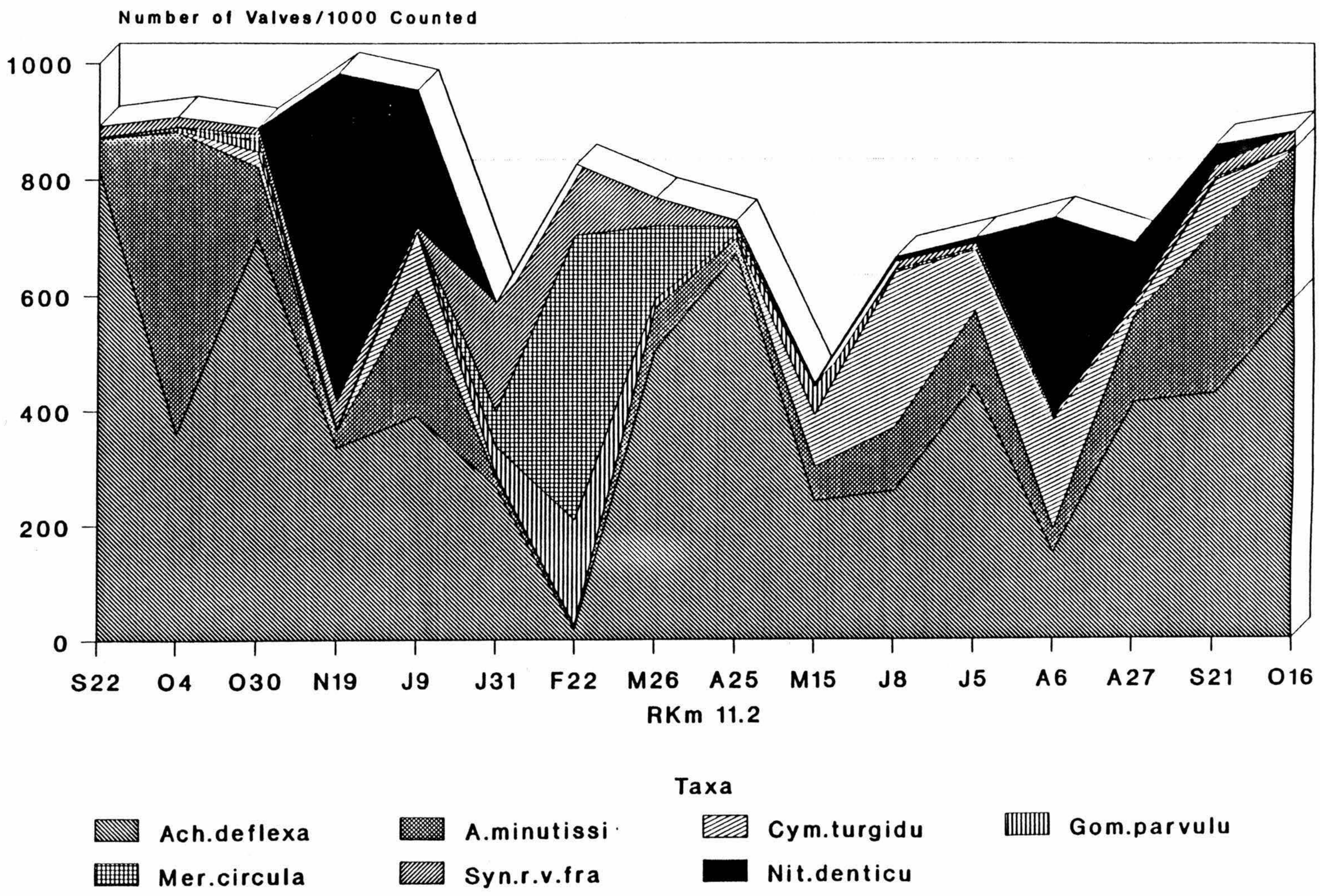


Figure 69

Dominant Taxa
>10% of Assemblage, >60% of Samples

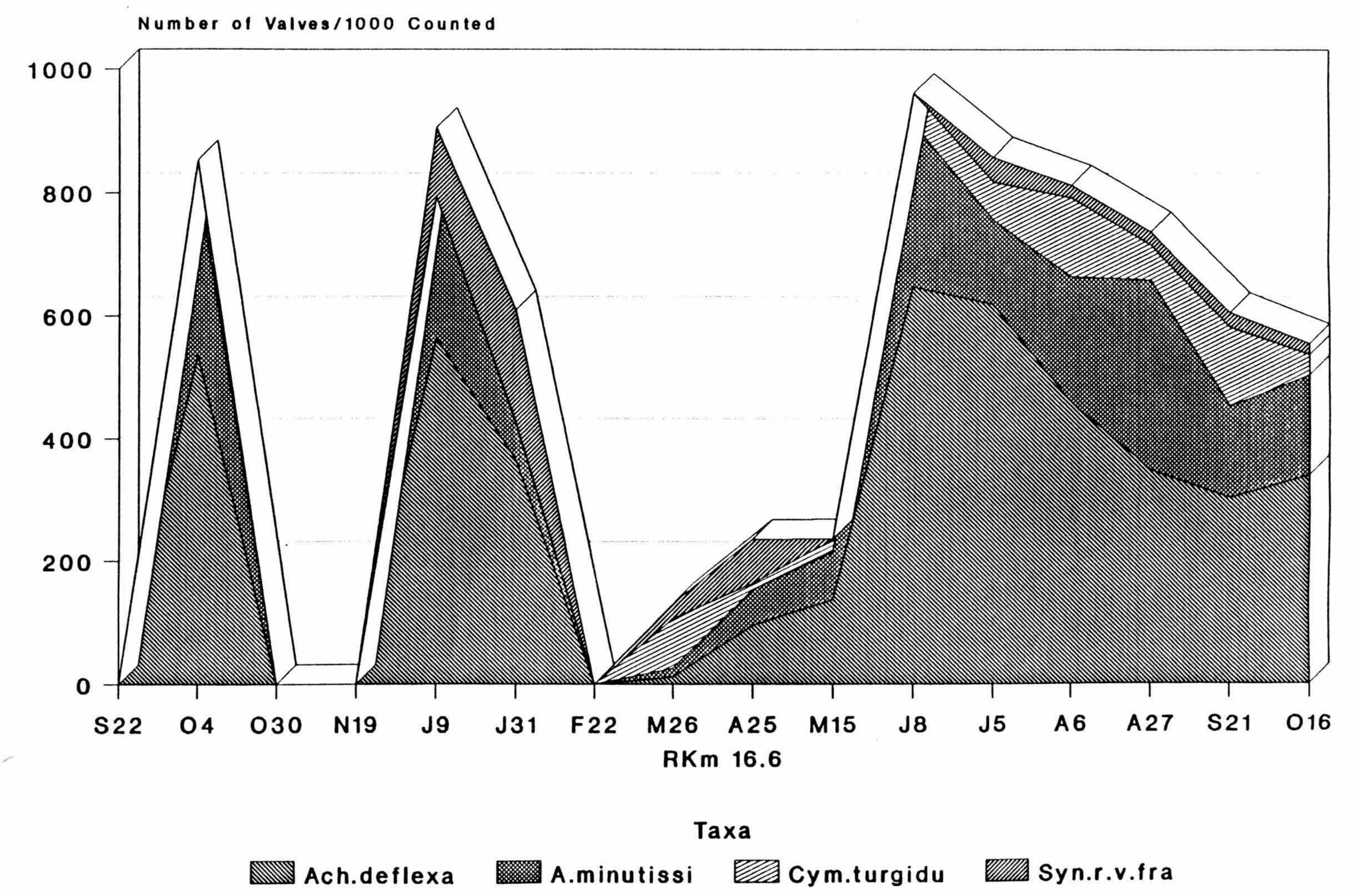


Figure 70

populations decreased. The temperature increased and the other parameters remained constant (Figures 23-34). A. deflexa declined in July and A. minutissima, A. lanceolata, A. lanceolata var. dubia, Surirella linearis and the Cymbella taxa all increased. The temperature continued to increase. In early August A. deflexa and Nitzschia denticula increased, but dropped off in September and the temperature was at its peak. The A. minutissima population was increasing as were the Cymbella and A. lanceolata taxa. When the temperature dropped in October, the hardness parameters increased as did the nitrate nitrogen, and other chemical parameters. A. deflexa and A. minutissima reached a peak in October.

The diversity was low during the winter months (Figure 71 & 72). Temperature and flow increased in late January, as did the diversity. The diversity decreased in February and began increasing in March while flow decreased. The diversity increased till July. The temperature increased during this time while flow was constant. Diversity increased in late August, and the temperature decreased.

RKm 20.6

In the fall there was an increase in Achnanthes deflexa until late January and there was an increase in flow (Figures 73 & 36). During this same period of time the Achnanthes minutissima increased as did the Amphora, Cocconeis, Navicula, Gomphonema, Nitzschia and Meridion taxa. By mid-May and June A. deflexa population returned to large numbers and the other taxa popula-

Diversity
September 1989 - October 1990

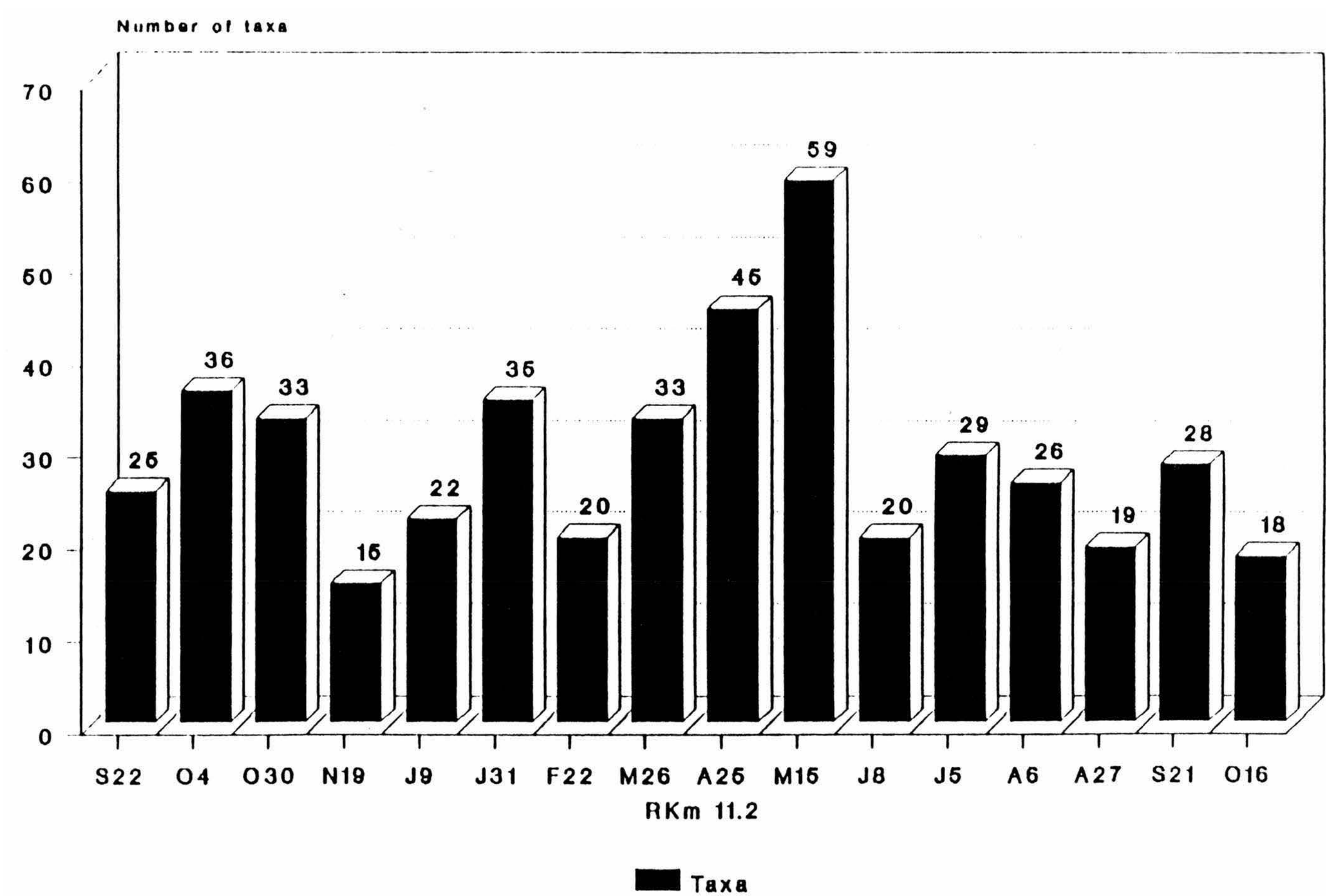


Figure 71

Diversity
September 1989 - October 1990

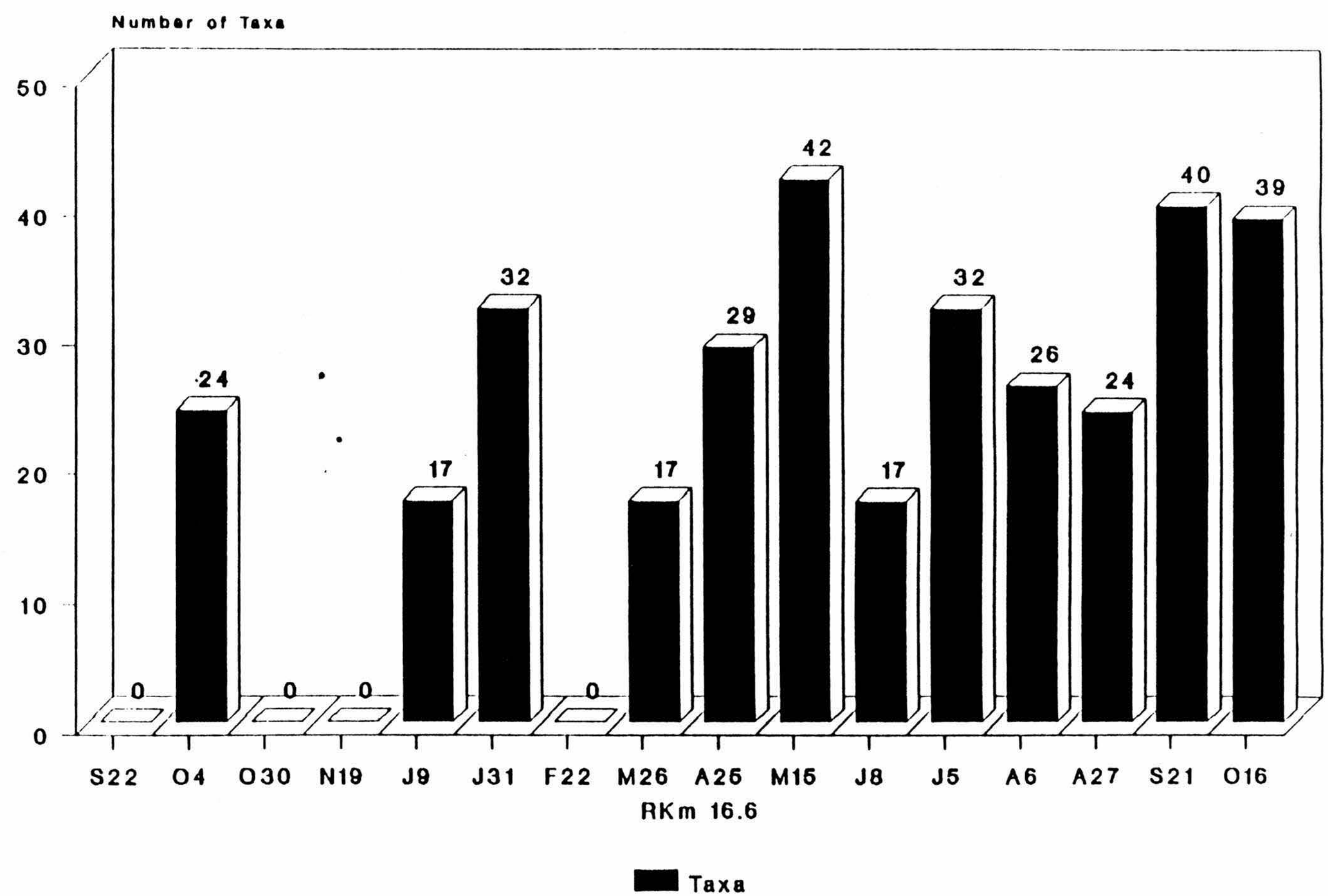


Figure 72

Dominant Taxa
>10% of Assemblage, >60% of Samples

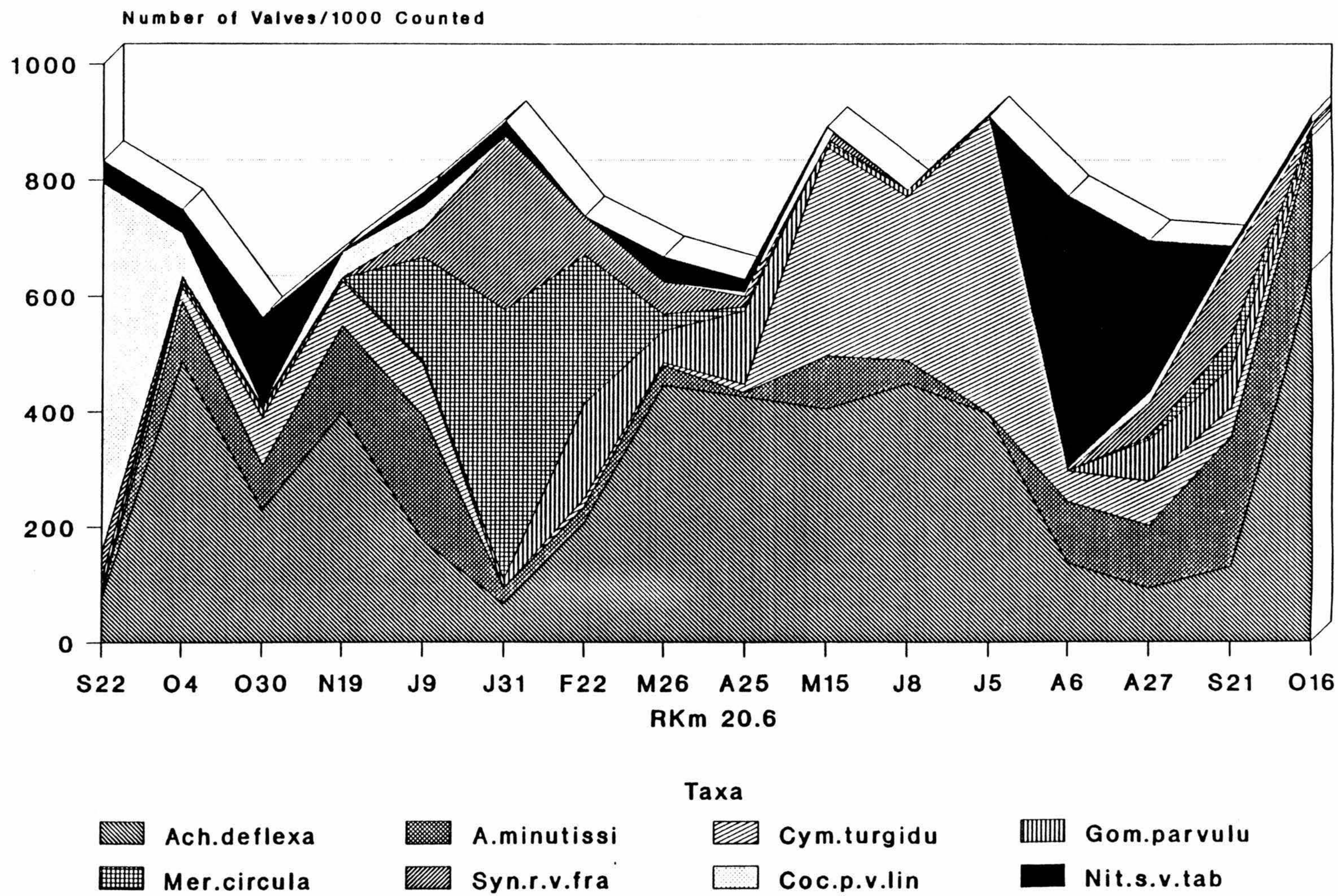


Figure 73

tions decreased. The temperature was increased and the other parameters remained constant in June (Figures 35 - 40). A. deflexa declined in July and A. minutissima, A. lanceolata, A. lanceolata var. dubia, Surirella linearis, Gomphonema, Synedra and Cymbella taxa all increased. The temperature continued to increase. In early August A. deflexa increased, but dropped off in September as the temperature was at its peak. The A. minutissima population increased as did the Cymbella and A. lanceolata taxa. When the temperature dropped in October, the hardness parameters increased as did the nitrate nitrogen, and other chemical parameters. A. deflexa, A. minutissima and Synedra rumpens var. fragilariodes reached a peak.

The diversity was high during the winter months. Temperature and flow increased in late January, but the diversity declined (Figure 74). The diversity increased in March as the flow was decreasing. The diversity dropped till August. The temperature increased during this time while flow was constant. Diversity increased in late August, and the temperature decreased.

RKm 23.6

In the fall there was an increase in Achnanthes deflexa until late January when there was an increase in flow (Figures 75 & 42). During this same period of time the Achnanthes minutissima increased as did the Cocconeis, Navicula, Gomphonema and Nitzschia taxa (Meyer and Eichman, in press). By mid-May and June A. deflexa population returned to large numbers and the other taxa

116

Number of Taxa
September 1989 - October 1990

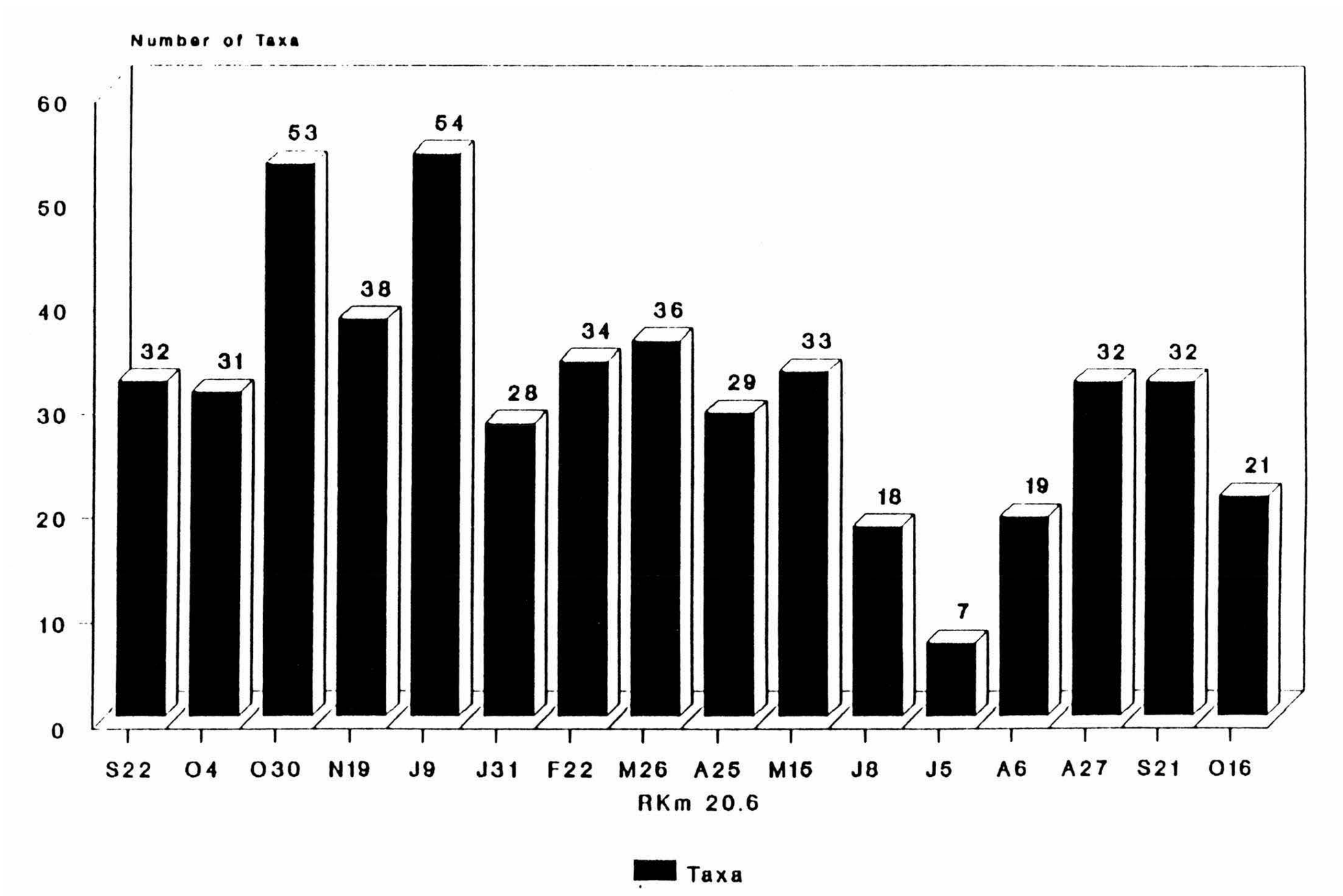


Figure 74

Dominant Taxa

>10% of Assemblage, >60% of Samples

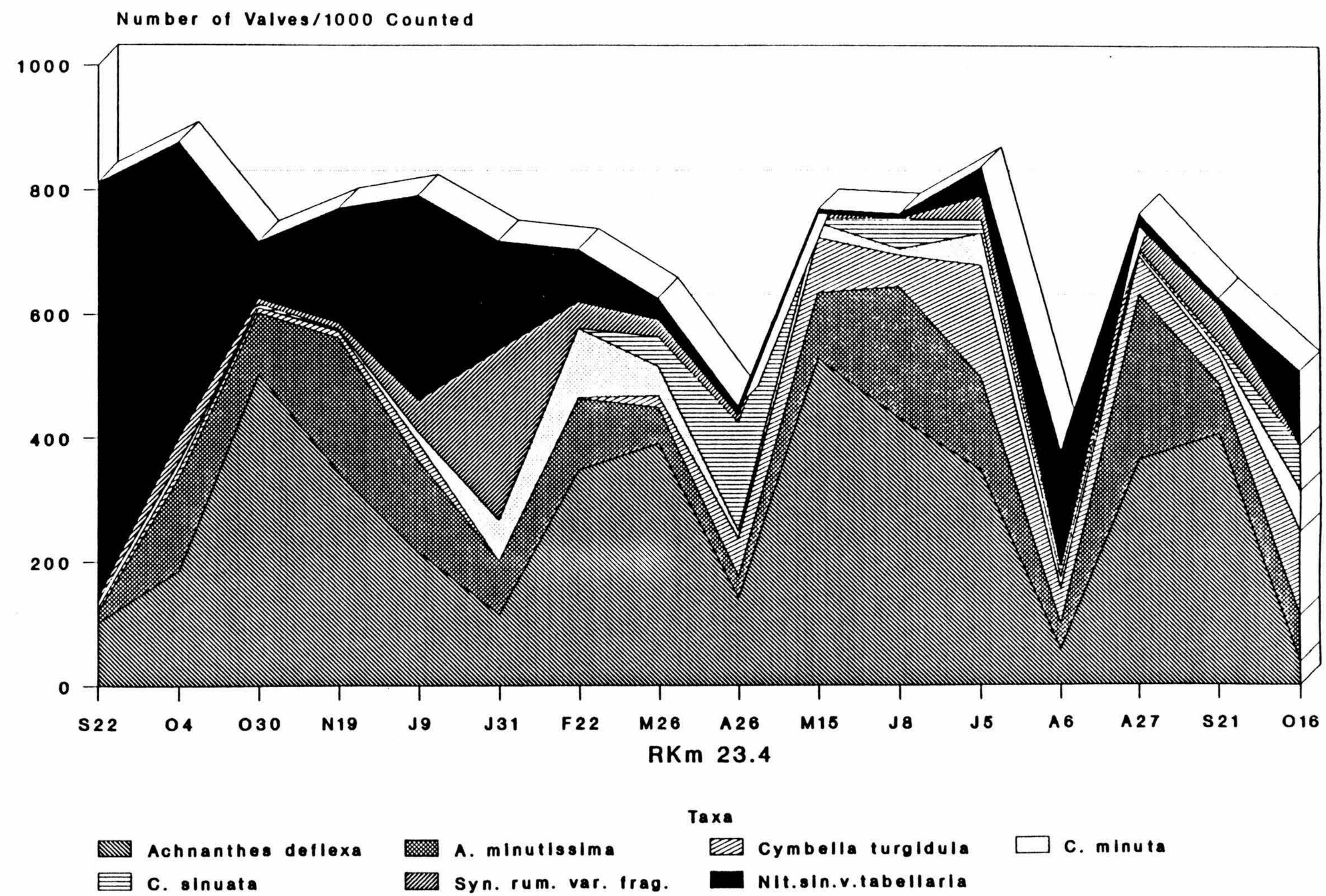


Figure 75

populations decreased. The temperature increased and the other parameters were remaining constant (Figures 41 - 46). A. deflexa declined in July and A. minutissima, A. lanceolata, A. lanceolata var. dubia, Surirella linearis, Gomphonema, Synedra and Cymbella taxa all increased. The temperature continued to increase. In early August A. deflexa increased, but dropped off in September as the temperature was at its peak. The A. minutissima population was increasing as were the Cymbella and A. lanceolata taxa. When the temperature dropped in October, the hardness parameters increased as did the nitrate nitrogen, and other chemical parameters. A. deflexa, A. minutissima and Synedra rumpens var. fragilariodes reached a peak in October.

The diversity was high during the winter months. Temperature and flow increased in February, but the diversity decreased (Figure 76). The diversity increased till May, and the flow decreased. The diversity dropped till August. The temperature increased during this time and flow was constant. Diversity increased in late August, and the temperature decreased.

RKm 26.6 and RKm 30.4

RKm 26.6 and RKm 30.4 followed a parallel course of seasonal development. In the fall there was an increase in Achnanthes deflexa until late January when there was an increase in flow (Figures 77, 78, 48, & 56). During this same period of time the Achnanthes minutissima increased as did the Cocconeis, Navicula, Gomphonema, Meridion and Nitzschia taxa (Meyer and Eichman, in

Diversity
September 1989 - October 1990

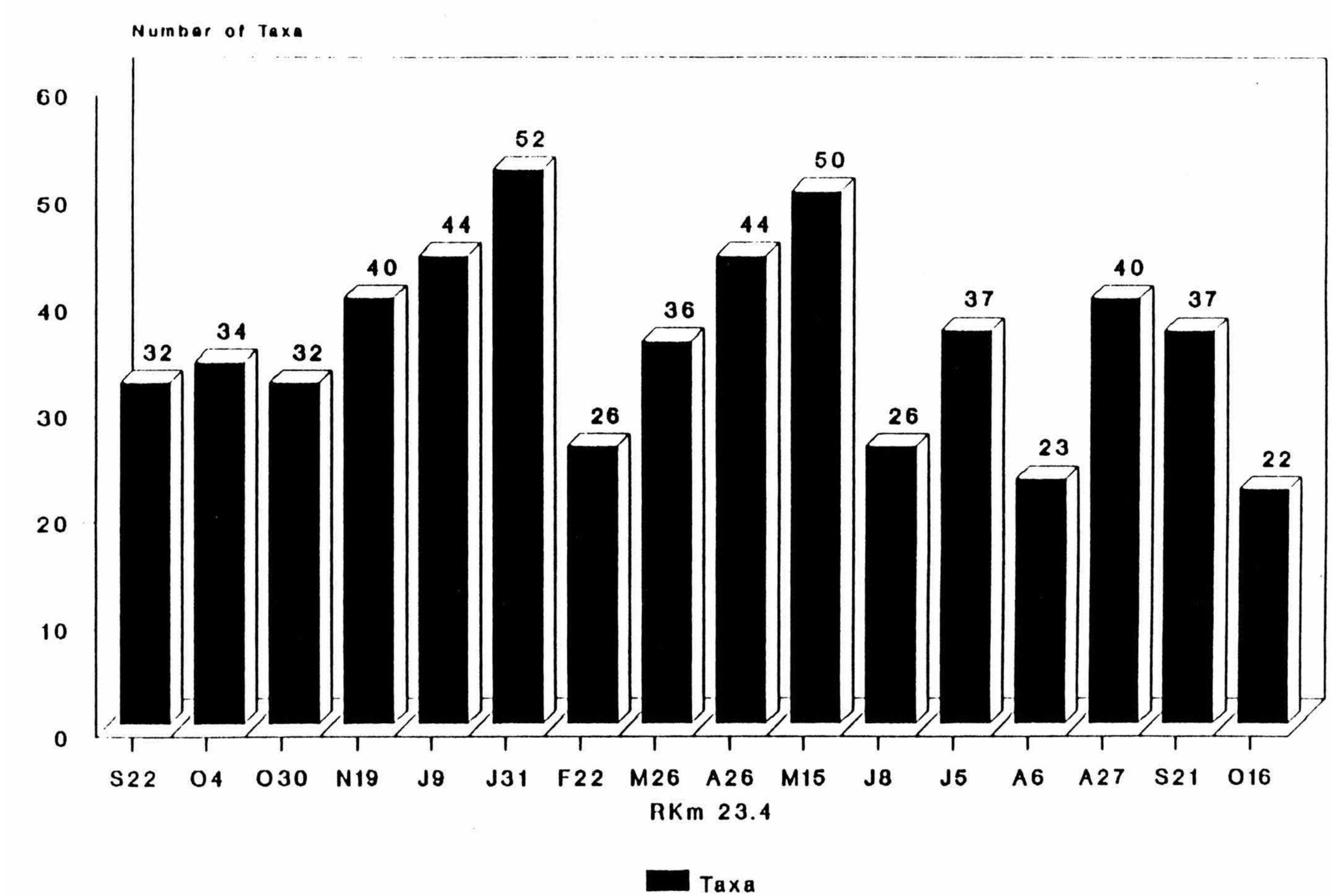


Figure 76

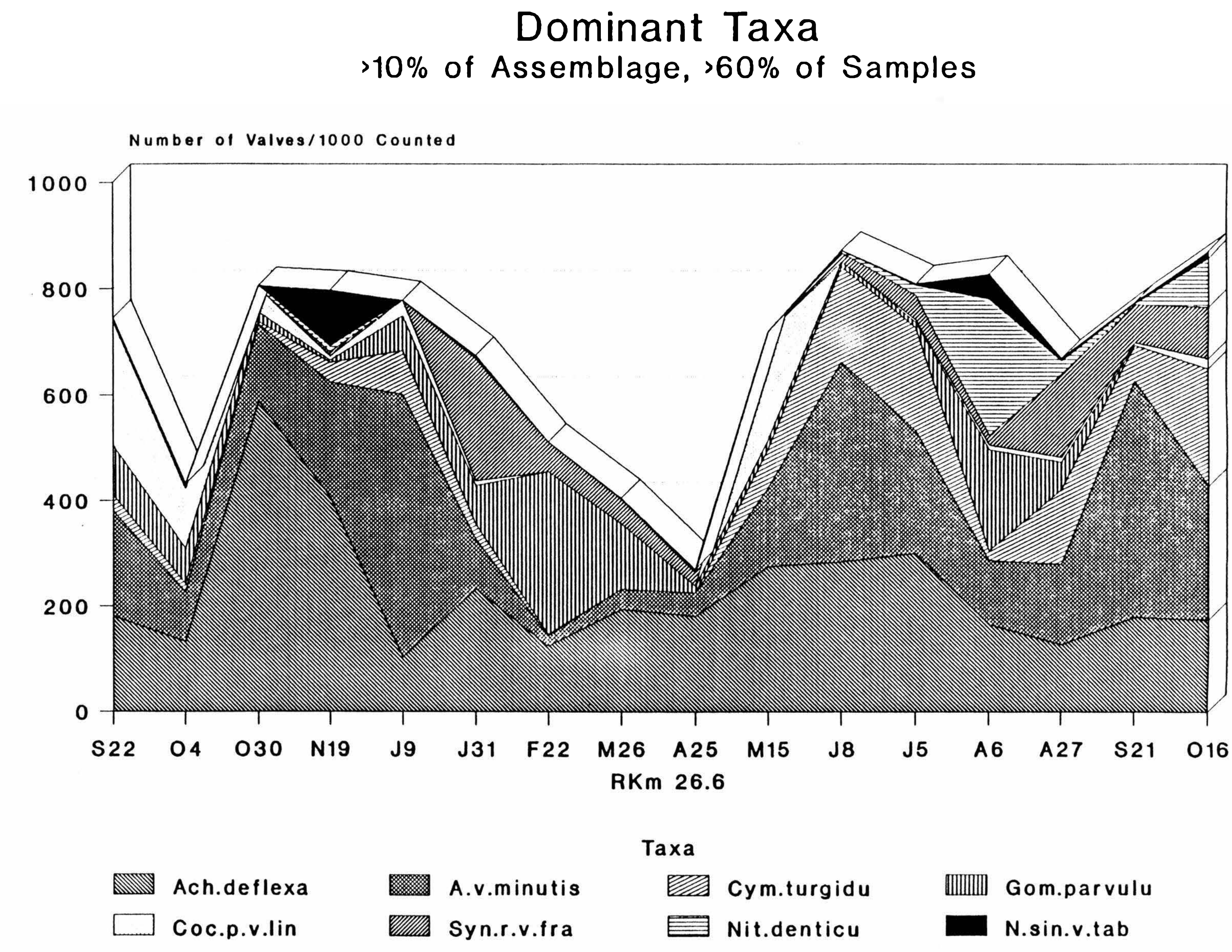

Dominant Taxa
›10% of Assemblage, ›60% of Samples
Number of Valves/1000 Counted
1000
800
600
400
200
0
S22
O4
O30
N19
J9
J31
F22
M26
A25
M15
J8
J5
A6
A27
S21
O16
RKm 26.6
Taxa
Ach.deflexa
A.v.minutis
Cym.turgidu
Gom.parvulu
Coc.p.v.lin
Syn.r.v.fra
Nit.denticu
N.sin.v.tab

Figure 77

Dominant Taxa
>10% of Assemblage, >60% of Samples

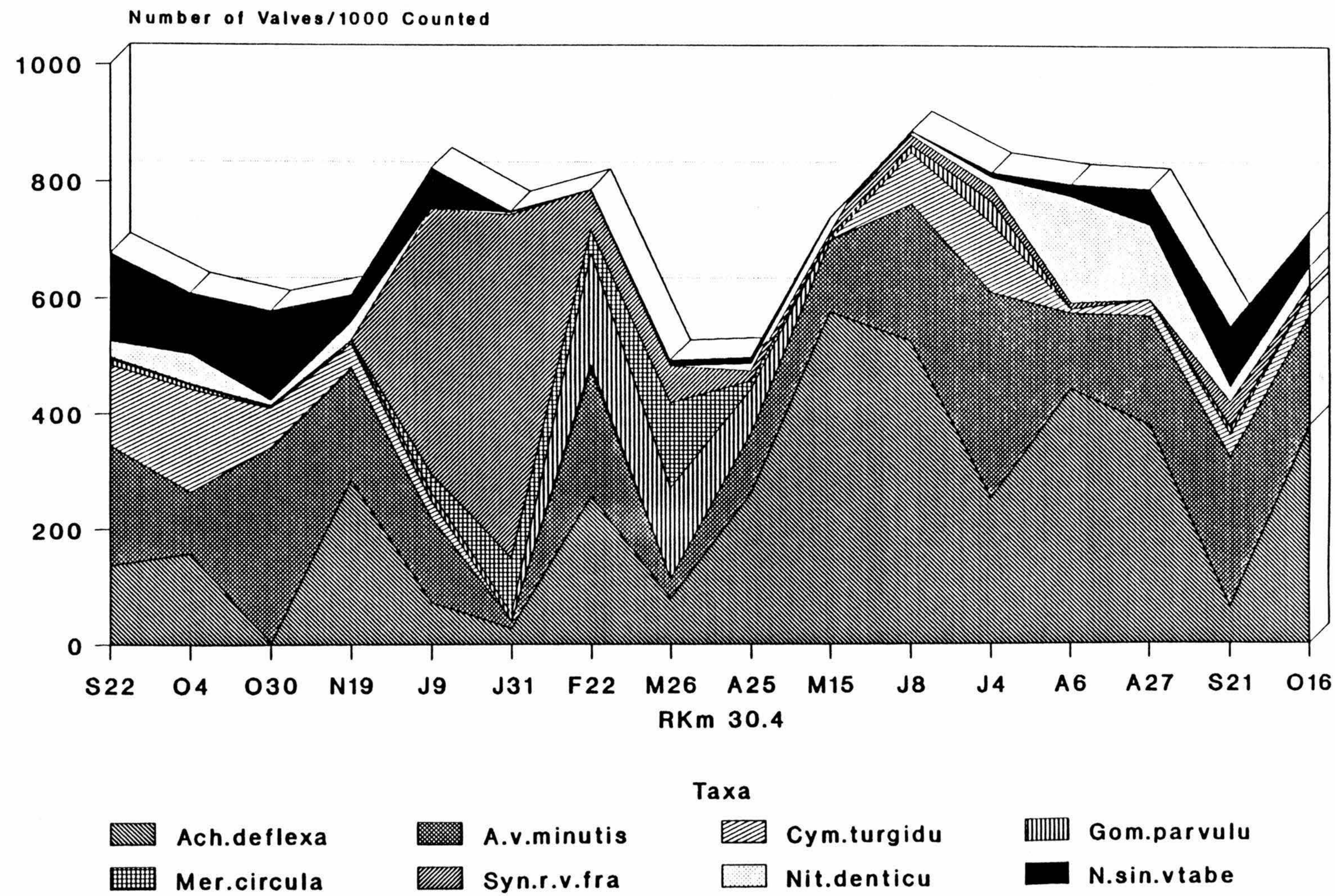


Figure 78

press). By mid-May and June A. deflexa population returned to large numbers and the other taxa populations decreased with the exception fo Rhoicosphenia curvata and Surirella ovata. The temperature increased and the other parameters were remaining constant (Figures 47 - 58). A. deflexa declined in July and A. minutissima, A. lanceolata, A. lanceolata var. dubia, Surirella linearis, Gomphonema, Synedra and Cymbella taxa all increased. The temperature continued to increase. In early August A. deflexa increased, but dropped off in September as the temperature was at its peak. The A. minutissima population was increasing as were the Synedra, Cymbella and A. lanceolata taxa. When the temperature dropped in October, the hardness parameters increased as did the nitrate nitrogen, and other chemical parameters. Cymbella turgidula and A. minutissima reached a peak in October.

The diversity was relatively constant during the winter months. Temperature and flow increased in February (Figures 79 & 80). Diversity dropped sharply in June. The temperature increased during this time and flow was constant. Diversity increased in July and remained relatively constant.

RKm 35.2

In the fall there was an increase in Achnanthes deflexa until late January when there was an increase in flow (Figures 81 & 61). During this same period of time the Achnanthes minutissima increased as did the Melosira, Cocconeis, Navicula, Gomphonema, Meridion and Nitzschia taxa (Meyer and Eichman, in press). By

Diversity
September 1989 - October 1990

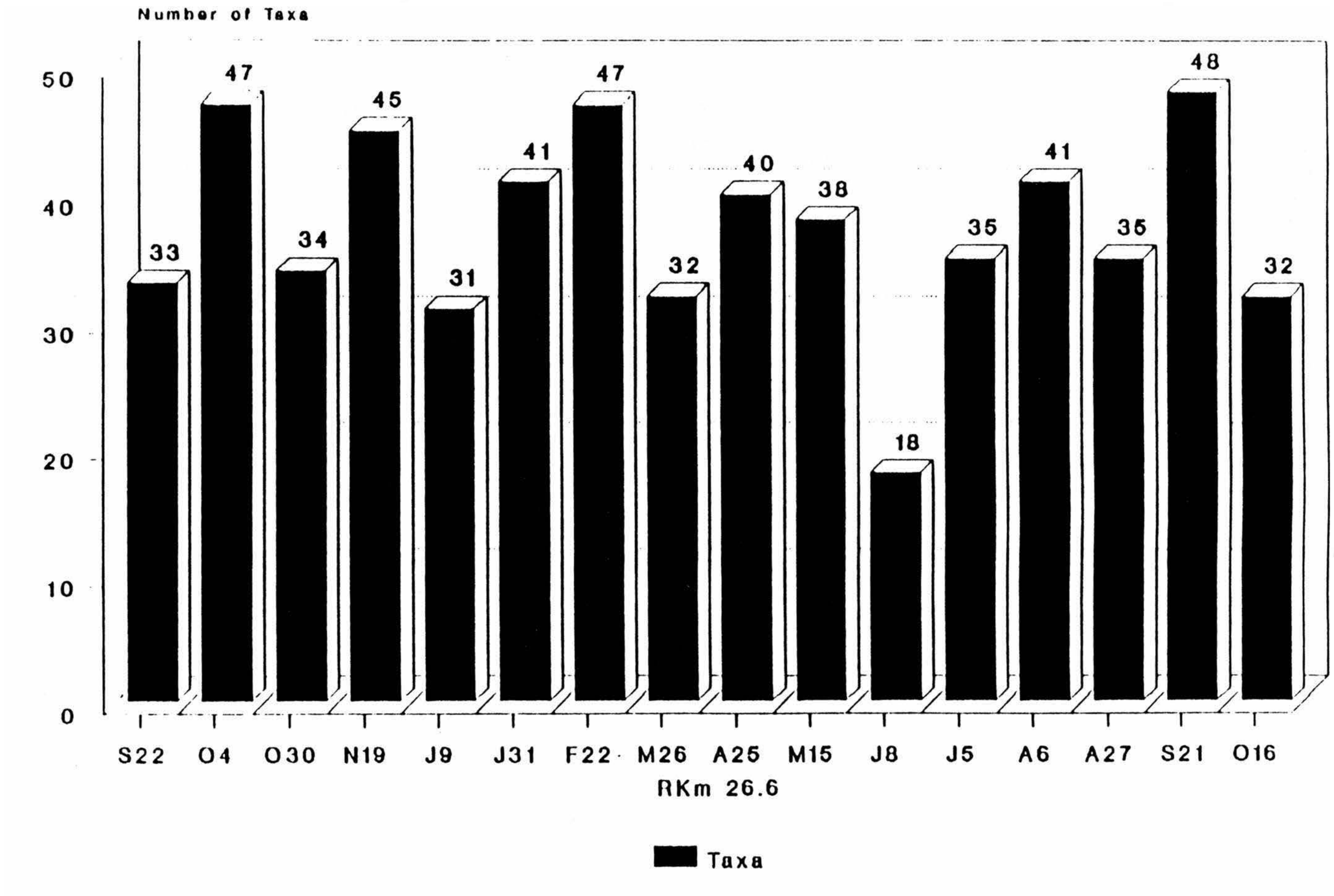


Figure 79

Diversity
September 1989 - October 1990

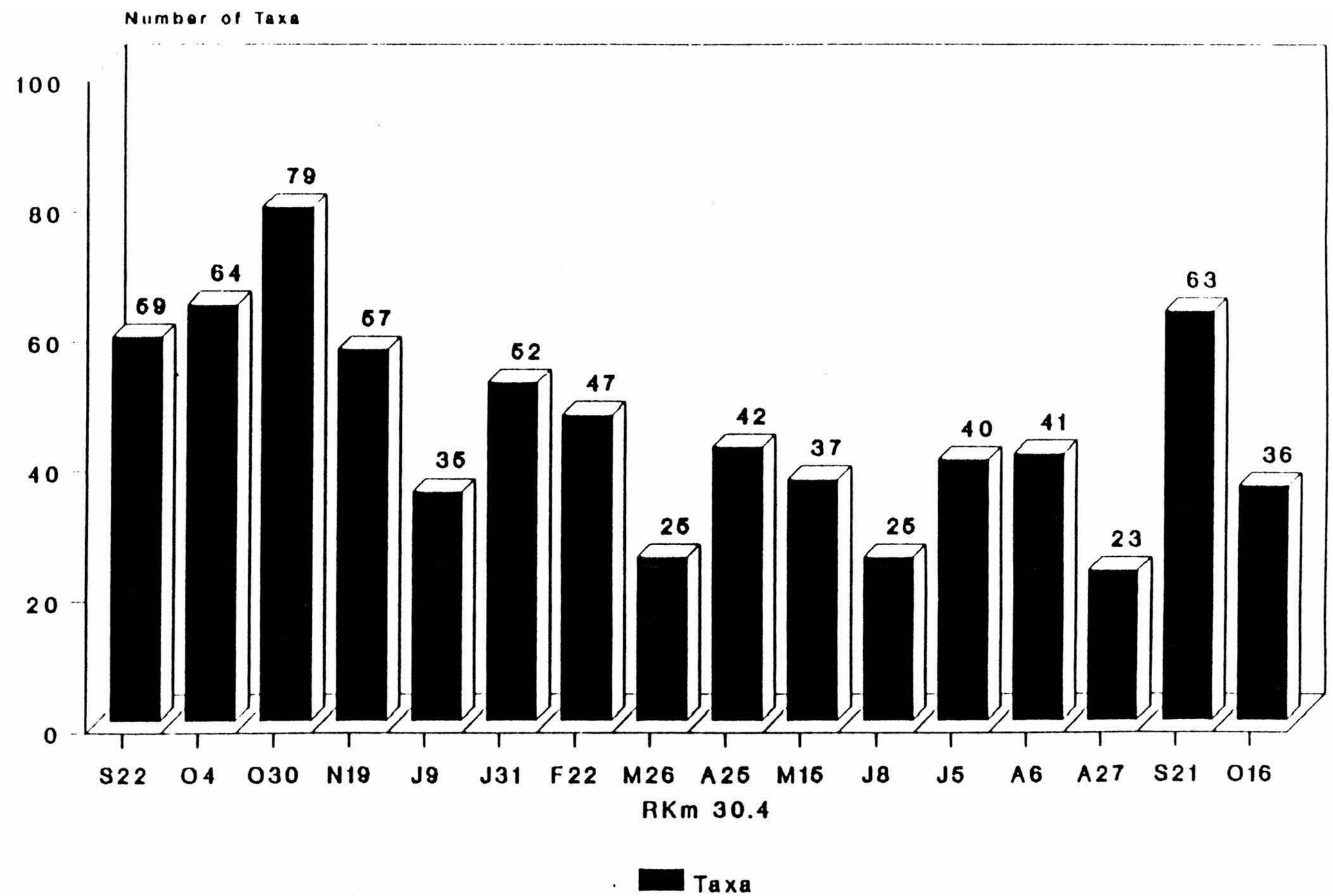


Figure 80

Dominant Taxa
›10% of Assemblage, ›60% of Samples

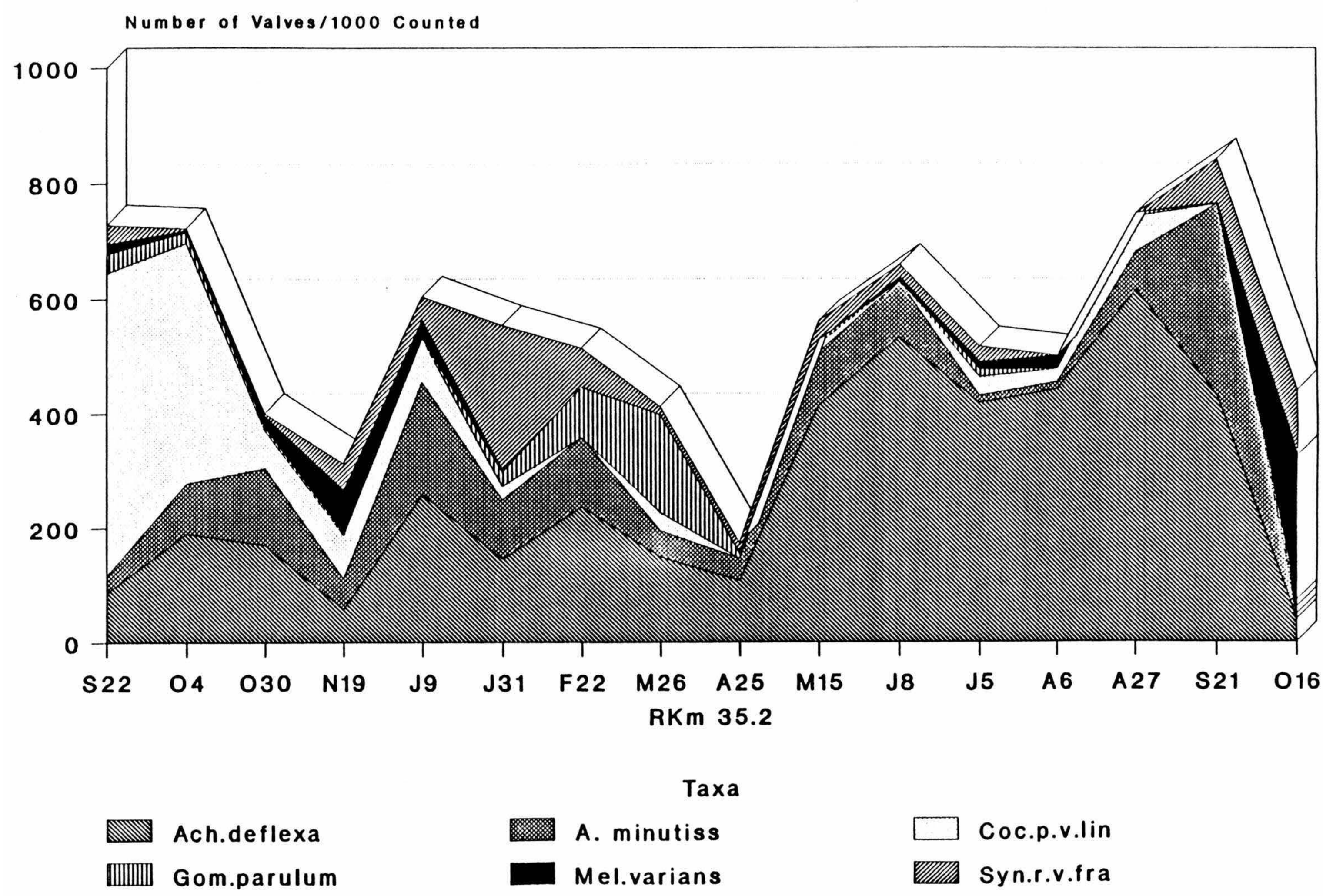


Figure 81

mid-May and June A. deflexa population returned to large numbers and the other taxa populations decreased. The temperature increased and the other parameters remained constant (Figures 59 - 64). A. deflexa declined in July and A. minutissima, A. lanceolata, A. lanceolata var. dubia, Surirella linearis, Gomphonema, Synedra and Cymbella taxa all increased. The temperature was still increasing. In early August A. deflexa increased, but dropped off in September as the temperature was at its maximum. The A. minutissima population was increasing as were the Synedra, Cymbella and A. lanceolata taxa. When the temperature dropped in October, the hardness parameters increased as did the nitrate nitrogen, and other chemical parameters. Melosira taxa and A. minutissima reached a peak in October.

The diversity was very high and relatively constant during the winter months (Figure 82). Temperature and flow increased in February. Diversity dropped sharply in February. The temperature increased during this time and flow was constant. Diversity remained constant through the rest of the study.

Diversity
September 1989 - October 1990

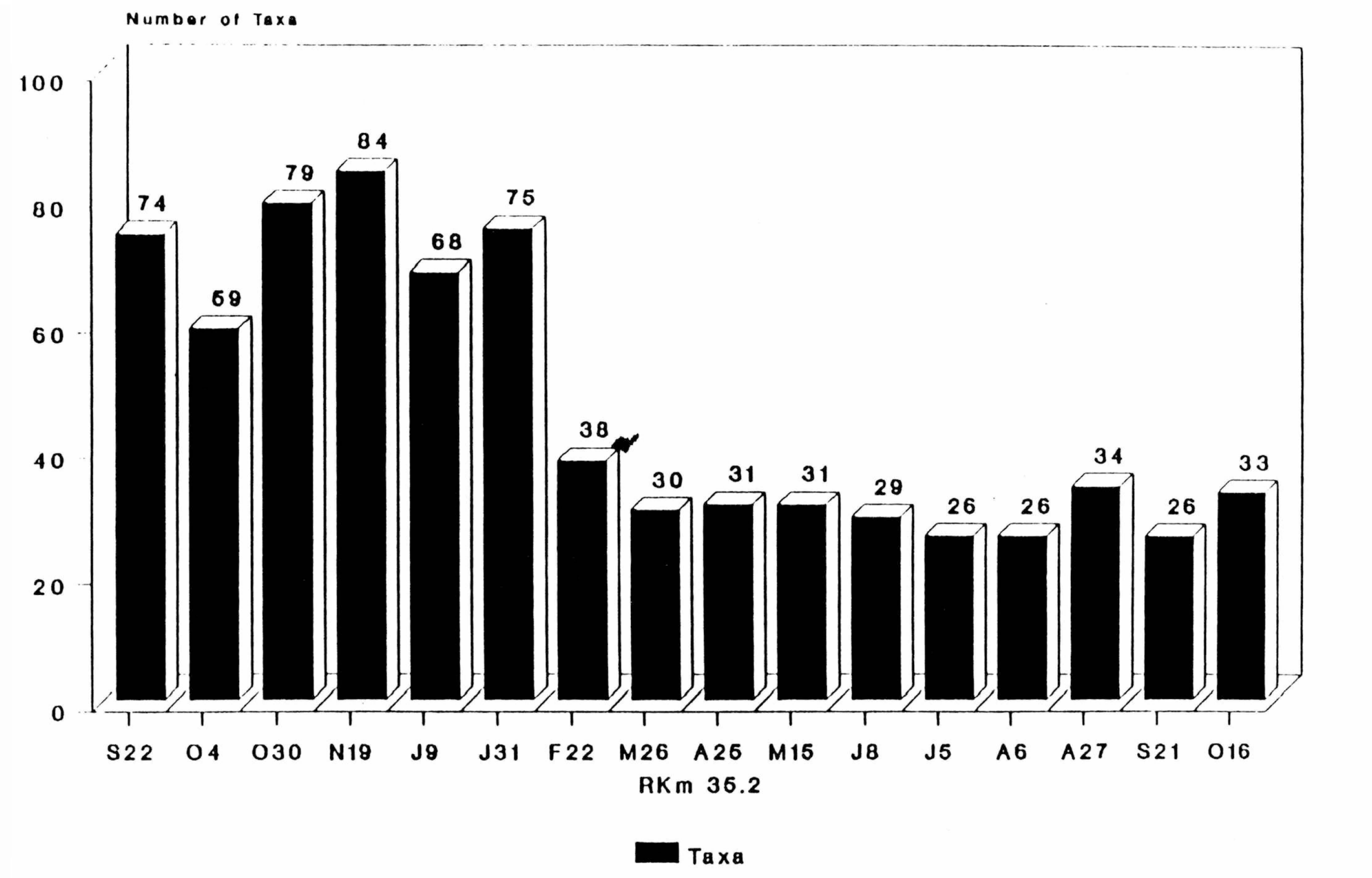


Figure 82

E. Comparison of Streams in the Ozark Highland/Boston Mountain Region

The taxa reported for the Buffalo River (Rippey 1977), Illinois River (Woomer 1986), and Spring Creek (Woomer 1986) were compared for diversity and similarity. The Middle Fork of the White River reported the greatest diversity (195 taxa) (Figure 83). In descending order the Buffalo River, Illinois River, and Spring Creek contained 104, 64, and 48 taxa respectively.

A comparison of the total diatom floras was made to ascertain similarities between these streams by calculating a Jaccard similarity index (1912). Table 3 list the combined floras and the streams in which each taxon occurs. The highest similarity index is between the Illinois River and its tributary Spring Creek (34%) (Figure 84). A comparison between all other streams is less than 15%. The Middle Fork is nearly equal in similarity to the Buffalo and Illinois Rivers (11.5 and 13.0%, respectively). Also, the Buffalo River versus the Illinois River has an index (12.4%) within the range of Middle Fork comparisons.

Ozark Highland/Boston Mountains
Stream Diversities

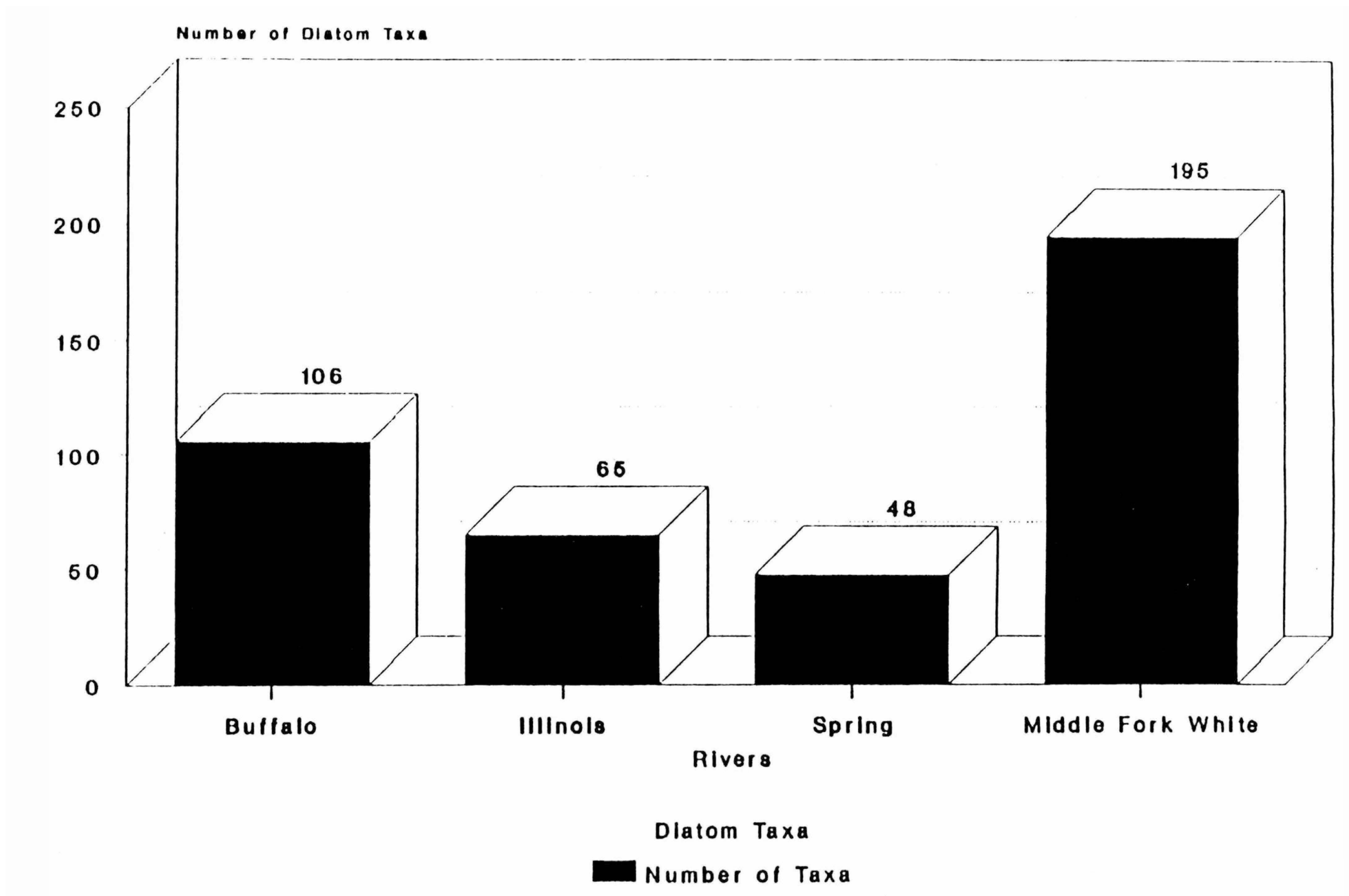


Figure 83

Reported Stream Taxa for the Ozark Highland/Boston Mountains Area

Table 3

B-Buffalo, I-Illinois, S-Spring, W-Middle Fork White	
Taxa	
Achnanthes	
affinis Grun. var. affinis	W
clevei Grun. var. clevei	W
coarctata (Breb. in W. Sm.)Grun. var. coarctata	W
deflexa Reim. var. deflexa	W
exigua var. heterovalva Krasske	W
hauckiana Grun. var. hauckiana	B,W
hauckiana var. rostrata Schulz	W
inflata(Kutz.)Grun.	B
lanceolata (Breb.) Grun. var. lanceolata	B,I,S,W
lanceolata var. dubia Grun.	W
laceolata var. omissa Reim.	I
linearis W. Sm.	I
linearis var. pusilla Grun.	W

marginulata Grun. var marginulata	W
minutissima Kutz. var. minutissima	B,W
pinnata Hust.	I,S
saxonica Krasske var. saxonica	W
sp. 1 jke	W
Amphipleura	
pellucida Kutz. var. pellucida	B,W
Amphora	
ovalis (Kutz.) Kutz. var. ovalis	W
ovalis var. pediculus Kutz.	I
perpusilla (Grun.) Grun. var. perpusilla	I,W
submontana Hust. var. submontana	W
Anomoeoneis	
serians var. brachysira (Breb. ex. Kutz.) Hust.	W
vitrea (Grun.) Ross comb. nov. var vitrea	W

Caloneis	
bacillum (Grun.) Cl. var. bacillum	I,W
ventricosa (Ehr.)Meist. var ventricosa	B,W
ventricosa var. truncatula (Grun.) Meist.	W
Camylodiscus	
echeneis Ehr.	W
Cocconeis	
disculus (Schum.) Cl.	B
pediculus Ehr.	I
placentula Ehr. var. placentula	B,W
placentula var. euglypta (Ehr.) Cleve	I,S
placentula var. lineata (Ehr.) V. N.	I,W
rugosa Sov.	B
scutellum Ehr.	B
Cyclotella	
atomus Hust.	B

glomerata Bachman	B
meneghiniana Kutz.	I,S,W
michiganiana Skvortzow	I
Cymatopleura	
camplodiscus Bail	B
elliptica (Breb.) W.Sm.	B,W
solea (Breb.)W.Sm.	B,I,W
Cymbella	
affinis Kutz.	B,I
angustata (W. Sm.) Cl. var. angustata	W
aspera (Ehr.) H. perag. var. aspera	W
brehmii Hust. var. brehmii	W
cistula (Ehr.) Kirchn. var. cistula	W
cistula var. gibbosa Brun.	W
cymbiformis Ag. var. cymbiformis	W
cymbiformis var. nonpunctata Font.	W
laevis Nag.	B

lunata W. Sm. var. lunata	W
mexicana (Ehr.) Cl. var. mexicana	W
microcephala Grun. var. microcephala	W
minuta Hilse ex. Rabh. var. minuta	I,W
minuta f. latens (Krasske) Reim comb. nov.	W
minuta var. pseudogracilis (Choln.) Reim.	W
minuta var. silesiaca (Bleisch ex Rabh.)Reim.	S
muelleri Hust. var. muelleri	W
naviculaformis Auersw. ex. Heib. var. naviculiformis	W
prostata (Gerk.)Cleve	B,I,S
sinuata Greg. var. sinuata	B,I,W
subaequalis f. Krasskei (Foged) Reim. comb. nov.	W
triangulum (Ehr.) Cl. var. triangulum	W
tumida (Breb. ex. Kutz.) V. H. var. tumida	B,I,W
tumidula Grun. ex. A. S. var. tumidula	W
turgida (Greg.) Cleve	B
turgidula Grun. var. turgidula	I,W
ventricosa Kutz.	B

Denticula	
tenuis var. crassula (Naeg. ex. Kutz.) W. & G. S. West	W
tenuis var. frigida (Kutz.) Grun.	W
Diatoma	
vulgare var. breve Grun.	W
vulgare var. linearis V.H.	W
vulgare Bory	B,I,S
Diploneis	
marginestriata Hust. var. marginestriata	W
ostracodarum (Pant.) Jur.	B
puella (Schus.) Cl. var. puella	I,W
Epithemia	
argus Kutz.	B
smithii Carruthers var. smithii	W
sorex Kutz.	B
turgida(Ehr) Kutz.	B

Eunotia	
acus Ehr.	B
curvata (Kutz.) Lagerst. var. curvata	W
curvata var. capitata (Grun.) Patr. comb. nov.	W
fallax A. Cl. var. fallax	W
flexuosa Breb. ex. Kutz. var. flexuosa	W
incisa Wm. Sm. ex. Greg. var. incisa	W
kocheliensis O. Mull	W
maior var. ventricosa A.Cl.	W
monodon Ehr. var. monodon	W
naegelii Migula var. naegelii	W
parallela Ehr. var. parallela	W
pectinalis var. minor (Kutz) Rabh.	W
pectinalis (O.F. Mull?) Rhbh. var. pectinalis	B,W
soleirolii (Kutz.) Rabh. var. soleirolii	W
sudetica O. Mull. var. sudetica	W
tenella (Grun) Cl. var tenella	W
triodon Ehr. var triodon	W
vanheurckii var. intermedia (Krasske ex. Hust.) Patr.	W

Fragilaria	
brevistriata Grun.	B
capucina Desmaz.	B,I,S
capucina var. mesolepta Rabh.	S,W
crontonensis Kitton var. crontonensis	B,I,W
intermedia Grunow	B
vaucheriae (Kutz.)Peters var. vaucheriae	W
virescens Ralfs. var. virescens	W
Frustulia	
rhomboides var. amphipleuroides (Grun.) Cl.	W
rhomboides var. capitata (A. Mayer) Patr.	W
rhomboides (Ehr.) DeT. var. rhomboides	B,W
rhomboides var. saxonica (Rabh.) DeT.	W
vulgaris (Thwaites) Del. var. vulgaris	B,S,W
weinholdii Hust. var. weinholdii	W
Gomphonema	
abbreviatum Ag.	S

acuminatum Ehr. var. acuminatum	B,W
acuminatum var. elongatum (W. Sm.) Carr.	W
affine Kutz. var affine	W
angustatum (Kutz.) Rabh. var. angustatum	B,I,S,W
angustatum var. productum Grun.	W
augur Ehr. var. augur	B,W
clevei Fricke var. clevei	W
constrictum Ehr.	B
gibba J. Wallace var. gibba	W
gracile Ehr. emend. V. H. var. gracile	S,W
instablis Hohn & Hellerm. var. instablis	W
olivaceum var. calcarea (Cl.) Cl.	I
olivaceum var. minutissima Hust.	S
olivaceum (Lyng.) Kutz	B,I,S
parvulum (Kutz.) var. parvulum	I,S,W
parvulum var. micropus Kutz.	W
sphaerophorum Ehr. var. sphaerophorum	I,W
subclavatum (Grun.) Grun.	I
subclavatum var. commutatum (Grun.) A. Mayer	W

tenellum Kutz. var. tenellum	I,W
tergestinum (Grun.) Fricke var. tergestinum	I,W
truncatum Ehr. var. truncatum	I,W
ventricosum Greg.	I,S
Gyrosigma	
kutzingii (Grun.) Cl.	B
scalproides (Rabh.) Cl. var. scalproides	B,W
spencerii (Quek.) Griff. & Henfr. var. spencerii	B,W
Hantzschia	
amphoixys (Ehr.) Grun.	B
amphioxys fo. capitata Muell.	W
Mastigloia	
braunii Grun.	B
Melosira	
ambigua (Grun.) O. Mull.	I

crenulata Kutz.	B
distans	W
granulata Ehr. (Ralfs.)	I
varians C. A. Ag.	B,I,S,W
Meridion	
circulare (Grev.) Ag. var. circulare	B,S,W
circulare var. constrictum (Ralfs) V. H.	W
Navicula	
accomoda Hust.	S
arvensis Hust. var. arvensis	W
bacillum Ehr.	B
bicephala Hust.	B
caduca Hust.	I,S
capitata Ehr.	I
cincta (Ehr.) Ralfs var. cincta	W
cocconeiformis Greg.	B
commutata (Grun.) A. Schmidt.	B

contenta var. biceps (Arn.) V. H.	W
contenta Grun.	B
cryptocephala Dutz. var. cryptocephala	B,I,S,W
cryptocephala var. venta (Kutz.) Rabh.	I,S,W
exigua Greg.	B
exigua var. capitata Patr.	I,W
festiva Krasske	S
gastrum Ehr.	B
gregaria Donk. var. gregaria	W
guatamalensis Cl. & Grun.	B
gysingensis Foged var. gysingensis	W
halophila (Grun.) Cl.	B
hambergii Hust. var. hambergii	W
hungarica Grun.	B
hustedtii Krasske	I
lacustris Greg. var lacustris	W
lanceolata (Ag.) Kutz. var. lanceolata	W
laevissima Kutz. var. laevissima	W
longicephala Hust.	

luzonenis Hust. var. luzonensis	I,S,W
menisculus var. upsaliensis (Grun.) Grun.	S
minima Grun. var. minima	W
mutica var. cohnii (Hilse) Grun.	W
mutica Kutz. var. mutica	S,W
mutica var. stigma Patr.	I,S
mutica var. undulata (Hilse.) Grun.	W
pennata A. Schmidt	B
peregrina (Ehr.) Kutz. var. peregrina	B,W
placentula Ehr.	B
protracta Grun.	S
pseudoreinhardtii Patr. var. pseudoreinhardtii	I,S,W
pupula var. capitata Skv. & Meyer	W
pupula var. elliptica Hust.	W
pupula var. mutata (Krasske) Hust.	W
pupula Kutz.	B,I,S
pupula var. rectangularis (Greg.) Grun.	W
pygmea Kutz.	B
radiosa Kutz.	B

radiosa var. tenella (Breb. ex Kutz.) Grun.	S
reinhardtii (Grun.) V.H.	B
rhynchocephala Kutz. var. rhynchocephala	W
rhynchocephala var. germainii (Wallace) Patr.	W
salinarum Grun. var. salinarum	W
secreta var. apiculata Patr.	S
seminulum var. intermedia Hust.	I,S
subtilissima Cl.	B
symmetrica Patr. var. symmetrica	W
tripunctata (O. Mull.) Bory.	I
virdula var. avenacea (Breb. ex Grun. V.H.	S
viridula var. linearis Hust.	W
viridula var. rostellata (Kutz?) Cl.	B,W
viridula Kutz.	B,I
Neidium	
affine (Ehr.) Pfitz.	B
affine var. amphirhynchus (Ehr.) Cl.	W
apiculatum Reim.	

dubium (Ehr.) Cl.	B
Nitzschia	
acicularis W. Sm.	B,I,S,W
acuta Hust.	W
amphibia Grun.	I,W
apiculata (Greg.) Grun.	W
clausii Hantzsch	I
denticula Grun.	B,W
disspata (Kutz.) Grun.	B,I,S,W
fasciculata Grun.	E
filiformis (W. Sm.) Schutt	B
fonticola Grun.	B
frustulum (Kutz.) Grun.	I,S
frustulum var. minutula	W
gracilis Hantzsch	W
holsatica Hust.	B
ignorata Krasske	W
intermedia Hantsch ex Cleve et Grunow	S,W

lacunarum Hust.	B
lancettula O. Mull.	W
linearis W. Sm.	S,W
palea (Kutz.) W. Sm.	B,W
paleacea Grun.	I,S
paradoxa (J.F. Gmel.) Grun.	B
parvula W. Sm.	B,W
sigmoidea (Nitz.) W.Sm.	B
sinuata var. tabellaria Grun.	B,W
striolata Hust.	W
subinflata Hust.	W
sublinearis Hust.	W
terricola Lund	I
tryblinella var. levidensis (W. Sm.) Grun.	I,W
Pinnularia	
biceps Greg. var. biceps	W
biceps f. petersenii Ross.	W
borealis var. rectangularis Carlson	W

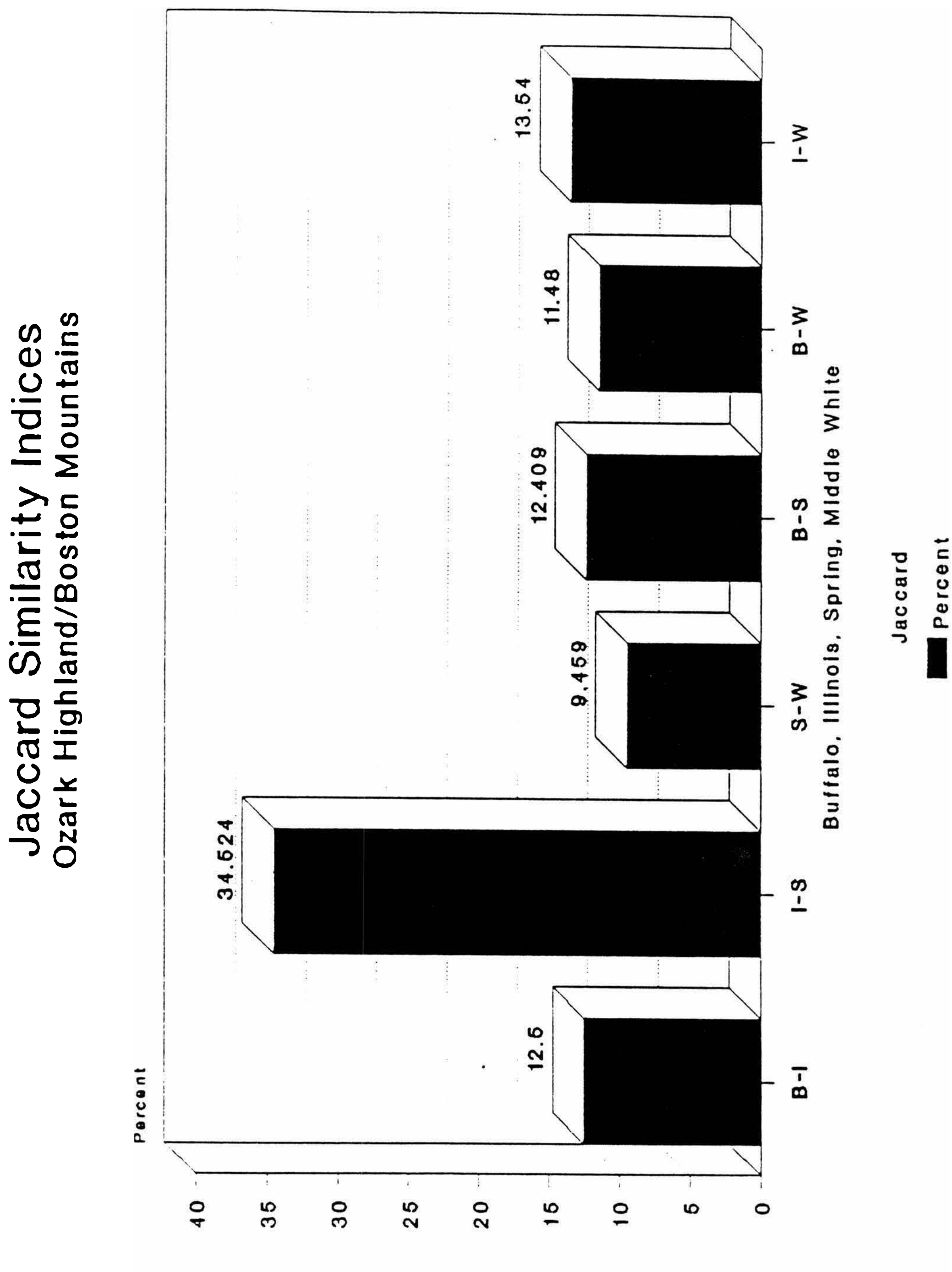
brasiliensis Hust.	B
brebissonii var. diminuta (Grun.) Cl.	W
brevicostata Cl. var. brevicostata	W
capitata var. paucistriata (Grun.) Cl.	W
divergens W. Sm. var. divergens	W
divergens var. bacillaris (M. Perag.) Mills	W
gibba (Kutz.) V.H.	B,S
maior var. transverrsa (A.S.) Cl.	S
microstauron (Ehr.) Cl.	B
nodosa (Ehr.) Wm. Sm. nodosa	W
sublinearis (Grun) Cl. var sublinearis	W
sudetica Hilse	B
termitina (Ehr.) Patr. comb. nov. var. termitina	W
Pleurosigma	
delicatulum W. Sm.	B
Rhoicosphenia	
curvata (Kutz.) Grun. ex pabh. var. curvata	I,S,W

Rhopalodia	
gibba (Ehr.) O. Mull var. gibba	B,W
gibba var. ventricosa (Kutz.) H&M Perag.	W
Rhizosolenia	
longiseta	W
Stauroneis	
anceps Ehr. var. anceps	W
anceps f. gracilis Rabh.	W
crucicula (W. Sm.) Donk.	B
ignorata Hust. var. ignorata	W
livingstonii Reim. var. livingstonii	W
obtusa Lagerst. var. otusa	B,W
phoenicenteron (Nitz.) Ehr.	B
smithii Grun.	B
Stenopterobia	
intermedia (Lewis) V.H.	W

intermedia var. capitata Fontell	W
Stephanodiscus	
astrea (Ehr.) Grun.	B
niagarae Ehr.	W
tenuis Hust.	I
Surirella	
angustata Kutz.	B,I,S
biseriata Breb.	B
brightwilli W. Sm.	B
delicatissima Lewis	W
linearis W.Sm.	W
linearis var. constricta	W
ovalis Breb.	B
ovata Kutz.	B,I,S,W
ovata var. pinnata (W.Sm.) Grun.	E
robusta Ehr.	B,W
splendida (Ehr.) Kutz.	B

seucica Grun.	S
tenera var. nervosa Schmidt.	W
tenera Greg.	B
sp. 1 jke	W
Synedra	
actinastroides Lemm.	B
acus Kutz.	B
amphicephala Kutz. var. amphicephala	W
incisa Boyer var. incisa	W
rumpens var. fragilariodes Grun.	W
rumpens var. meneghiniana Grun.	W
socia Wallace	I
tabulata (Ag.) Kutz.	B
ulna (Nitz.) Ehr. var. ulna	B,I,S,W
ulna var. amphirhynchus (Ehr.) Grun.	W
ulna var. ramesi (Heribaud & Perogallo) Hust.	I

Figure 84



Jaccard Similarity Indices
Ozark Highland/Boston Mountains
Percent
40
35
30
25
20
15
10
5
0
12.5
34.524
9.459
12.409
11.48
13.54
B-I
I-S
S-W
B-S
B-W
I-W
Buffalo, Illinois, Spring, Middle White
Jaccard
Percent

DISCUSSION

The area of the study has the geology of two ages (Pennsylvanian, and Mississippian). A review of the water analysis, and diatom assemblages at the study sites indicate the Middle Fork of the White River basin area may be divided into two ecologic systems. The steeply sloped upper portion of the river including stations RKm 2.6, RKm 8.0, and RKm 11.2 are exposed to geologic formations of the Pennsylvanian age. The lower portion of the river including stations RKm 16.6, RKm 20.6, RKm 23.4, RKm 26.6, RKm 30.4, and RKm 35.2 are exposed to geologic formations of the Mississippian age.

RKm 2.6 is exposed to the unnamed friable shale of the Winslow formation, RKm 8.0 is exposed to the sandstone Woolsey member of the Bloyd formation, and RKm 11.2 is exposed to the shale Cane Hill member of the Hale formation (Figure 3). The chemical analysis of the water from these sites indicate these formations contribute very little to the mineral content of the water. The surrounding soils are acidic (Eichman unpublished report 1990) and there is no limestone to buffer the system. The area is remote, and has very little human disturbance to add to the nutrient content. Therefore, in summary, the water at these sites have low hardness parameters, low pH, and low nutrient levels in common. RKm 11.2 chemical and physical parameters were more variable, but the temporary presence of a beaver impoundment may account for the variability.

An analysis of the diatom assemblages at these sites also indicate greater diversity and variability than the Mississippi segment. Forty taxa were exclusive to the Pennsylvanian segment (Table 4). The main complexes were composed of the genera _Eunotia_, and _Pinnularia_. The ecological distribution of these genera are associated with low mineral content, low organic content, pH below 7.0, cool temperatures, and high oxygen content (Patrick & Reimer 1966, 1975; Schoeman 1973).

With the exception of when the stream was frozen solid in December, 1989 there was flow, but sometimes it was below measurable velocities. Flow impacted on the area when the spring rains caused flooding. The stream channel is narrow causing the water to rise and increase flow rate rapidly. The influence of increased volume and velocity has been shown by Fisher et al. (1982), Reisen & Spencer (1970) to cause scouring. Similar impacts were observed during spring flooding only. Fall flow rates were below the threshold to move substrate and with minimal sheer. Observed assemblage changes are associated with decreasing temperature. The lack of alluvium at these upper reaches decreased the amount of scouring that occurred. The assemblage diversity was not as affected as in the lower reaches during flooding (Figure 74-81).

The lower stations were exposed to the Mississippi age formations and have a reduced stream gradient. RKm 16.6 site is located at the beginning of the Pitkin formation, RKm 20.6 site is exposed to the sandstone Wedington member of the Fayetteville

Taxa Exclusive to the Pennsylvanian Sites

RKm 2.6, RKm 8.0, RKm 11.2

Table 4

Achnanthes
coarctata (Breb. in W. Sm.)Grun. var. coarctata
marginulata Grun. var marginulata
Anomoeoneis
serians var. brachysira (Breb. ex. Kutz.) Hust.
vitrea (Grun.) Ross comb. nov. var vitrea
Cymbella
aspera (Ehr.) H. perag. var. aspera
brehmii Hust. var. brehmii
lunata W. Sm. var. lunata
naviculaformis Auersw. ex. Heib. var. naviculiformis
Eunotia
curvata var. capitata (Grun.) Patr. comb. nov.
fallax A. Cl. var. fallax

flexuosa Breb. ex. Kutz. var. flexuosa
incisa Wm. Sm. ex. Greg. var. incisa
kocheliensis O. Mull
maior var. ventricosa A.Cl.
monodon Ehr. var. monodon
naegelii Migula var. naegelii
parallela Ehr. var. parallela
pectinalis var. minor (Kutz) Rabh.
pectinalis (O.F. Mull?) Rhbh. var. pectinalis
soleirolii (Kutz.) Rabh. var. soleirolii
sudetica O. Mull. var. sudetica
Eunotia
tenella (Grun) Cl. var tenella
triodon Ehr. var triodon
Frustulia
rhomboides var. saxonica (Rabh.) DeT.
vulgaris (Thwaites) Del. var. vulgaris

Gomphonema
affine Kutz. var affine
Navicula
contenta var. biceps (Arn.) V. H.
laevissima Kutz. var. laevissima
longicephala Hust.
mutica Kutz. var. mutica
pupula var. rectangularis (Greg.) Grun.
Pinnularia
biceps Greg. var. biceps
biceps f. petersenii Ross.
borealis var. rectangularis Carlson
brebissonii var. diminuta (Grun.) Cl.
brevicostata Cl. var. brevicostata
capitata var. paucistriata (Grun.) Cl.
maior var. transverrsa (A.S.) Cl.
nodosa (Ehr.) Wm. Sm. var. nodosa

termitina (Ehr.) Patr. var. termitina
Stauroneis
anceps Ehr. var. anceps
anceps f. gracilis Rabh.
ignorata Hust. var. ignorata
livingstonii Reim. var. livingstonii

formation, the site RKm 23.4 is exposed to the same member, site RKm 26.6 is exposed to the Loger limestone lentil of the Fayetteville formation, site RKm 30.4 is cobble overlaid on the sandstone Wedington member of the Fayetteville formation, and RKm 35.4 site is exposed to cobble, alluvium and gravel several meters thick above the Fayetteville formation.

The chemical parameters were different for this portion when compared to the upper reach. The mean pH was 0.35 greater than those of the upper portion. This represents a large difference since a 0.3 change in pH is 100% change in hydrogen ions. The mean hardness parameters for these reaches were at least five times greater at the lower portion than upper portion.

There were 31 taxa that are not found in the upper portion of the stream (Table 5). They are taxa that have an ecological distribution with a greater need for and/or tolerance to a higher nutrient, mineral, and pH level. The stream changed to third order in this portion. There was less slope, the streambed was wider and the pools were much larger. These factors allowed for greater warming, reduced flow rate and moderation of chemical parameter variability. These environmental conditions are markedly different between the upper and lower portions. The differences are reflected by the seventy-one indicator taxa.

Flow was slow and scouring was not as great a factor in these lower reaches, unless a major flooding event occurred and the turbidity increased. The additional nutrients were contributed by the more numerous human activities that occur in this lower

Taxa exclusive to the Mississippian Sites

RKm 16.6, RKm 20.6, RKm 23.4, RKm 26.6, RKm 30.4, RKm 35.2

Table 5

Achnanthes
affinis Grun. var. affinis
clevei Grun. var. clevei
hauckiana var. rostrata Schulz
saxonica Krasske var. saxonica
Amphipleura
pellucida Kutz. var. pellucida
Caloneis
ventricosa (Ehr.)Meist. var ventricosa
Camylodiscus
echeneis Ehr.
Cymatopleura
elliptica (Breb.) W.Sm.

solea (Breb.)W.Sm.
Cymbella
mexicana (Ehr.) Cl. var. mexicana
Diploneis
marginestriata Hust. var. marginestriata
Epithemia
smithii Carruthers var. smithii
Fragilaria
capucina var. mesolepta Rabh.
virescens Ralfs. var. virescens
Gomphonema
acuminatum var. elongatum (W. Sm.) Carr.
sphaerophorum Ehr. var. sphaerophorum
tergestinum (Grun.) Fricke var. tergestinum

Navicula
peregrina (Ehr.) Kutz. var. peregrina
pupula var. elliptica Hust.
pupula var. mutata (Krasske) Hust.
Nitzschia
fasciculata Grun.
sublinearis Hust.
tryblinella var. levidensis (W. Sm.) Grun.
Rhopalodia
gibba (Ehr.) O. Mull var. gibba
gibba var. ventricosa (Kutz.) H&M Perag.
Rhizosolenia
longiseta
Stenopterobia
intermedia var. capitata

Stephanodiscus
niagarae
Surirella
delicatissima Lewis
tenera var. nervosa Schmidt
sp. 1 jke

portion (Figures 74-81). RKm 35.2 site had a number of unusual site specific taxa. Their presence may be explained by a well constructed beaver dam that was in place until the spring floods (Table 1 and Figure 82).

There was a group of cosmopolitan taxa that occurred in the entire stream, as indicated by the similarity in the dominant taxa (Figures 65-73). This group was unique because many of them have an ecological distribution in waters of low organic and high oxygen requirements (Patrick & Reimer 1966, 1975; Schoeman 1973). This research gave support to this information, because of the ecological condition of this particular stream.

The third part of this project was to develop a model of the seasonal assemblages. This stream in that regard was no different than other streams. There were taxa which developed and dominated the assemblage with a parallel reduction in diversity by approximately 50%. Those taxa, *Achnanthes deflexa* and *A. minutissima*, had a spring and fall pulse. After they declined, other taxa, *Cymbella turgidula* and *Navicula cryptocephala*, replaced them and diversity increased.

As Fritsch (1929) and Eddy and Shelford (1929) recognized, in those early years, seasonal, and annual differences occur. Figures 74-82 show changes in diversity through a seasonal cycle with associated conditions. Analysis of dominant taxa figures also indicate a change in population within the assemblages over time. Further research will be necessary to determine the causative factors initiating the observed changes.

Flood events were a significant force resulting in changes that occurred in the system during this research period. The changes were similar to those reported by Whitford and Schumacher (1963), Fisher (1982), and Kroger (1973). There were beaver dams at RKm 35.2 and 11.2 which caused a large impoundment of water. This habitat changed dramatically after the spring floods during late January and early February when the dams were destroyed. This resulted in the release of a large volume of water with increased velocity. The drop in diversity at RKm 11.2 was immediate, but returned to normal levels quickly (Figure 68). The diversity at RKm 35.2 dropped and never recovered to the high levels observed during the months of impoundment (Figure 80). This would indicate there were tychoplanktor taxa present at this site that are not usually present in flowing waters. The atypical species found at the RKm 35.2 site are unusual for flowing water according to Patrick and Reimer (1966, 1975) and Schoeman (1973).

Catastrophic events such as the spring flooding demonstrate the need for the holistic approach to stream studies. The changes to the assemblages were dramatic and progressive. Those taxa at the upper portion of the stream were transported downstream. However, if the taxa were not normally a member of the lower reach assemblage they disappeared and were not collected again at the next sampling date. The Eunotia complex for example, was normally found at RKm 2.6, but after the floods large numbers of this taxa were found at several downstream sites (Meyer and Eichman, in press).

The Middle Fork of the White River had a greater diversity than was reported for the other stream of this ecoregion (Figure 83). The Illinois river and Spring Creek project was a study of the impact of a waste water treatment facility (Woomer 1986). These two streams, unlike the Buffalo National River and the Middle Fork, had a great deal of human disturbance. The disturbance included higher chemical parameter levels, such as nitrate nitrogen (Woomer 1986; Rippey 1977).

Similarity index comparisons of the Middle Fork of the White River with studies of other streams located in the Ozark Highland/Boston Mountain Region were developed using Jaccard'similarity index (1912). The comparisons indicate there is very little similarity among the streams of the region that have been studied (Figure 82). The highest similarity occurred between the Illinois River and Spring Creek. The low similarity indices support Rohm and his coworkers (1987) premise that more than one stream should be selected for study as secondary references in an ecoregion because the primary reference stream may not be representative of all the geology, and water chemistry.

This project expanded the list of reported diatom taxa for this ecoregion by 131 (Table 4). The Middle Fork of the White River had only those taxa which are generally common in all streams i.e. Achnanthes lanceolata, Cyclotella meneghiniana, Cymatopleura solea, Cymbella sinuata C. tumida, Fragilaria crontonensis, Frustulia vulgaris, Gomphonema angustatum, G. parvulum, Melosira varians, Meridion circulare, Navicula cryptocephala, N. cryptocephala var.venta, N. luzonenis, N. pseudoreinhardtii, Nitzschia acicularis, N. disspata and Rhoicosphenia curvata (Patrick & Reimer 1966, 1975; Schoeman 1973).

The data from this research lays the foundation for future studies. Further research is required to select which of the influencing factors are most significant and to determine their importance. This research, however, suggests that ammonia nitrogen, and orthophosphate are probably unimportant parameters for this area while the hardness parameters, pH, geomorphology, other stream biota, temperature, and flow rates should be considered in future research. Perhaps the interaction of all the parameters including the external features of surrounding topography, soils, and vegetation are so intertwined there is not one most significant factor.

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