THE EFFECT OF THREE MARSH MANAGEMENT TECHNIQUES ON THE ECOLOGY OF IRREGULARLY FLOODED CHESAPEAKE BAY WETLANDS.

vegetation & water quality studies

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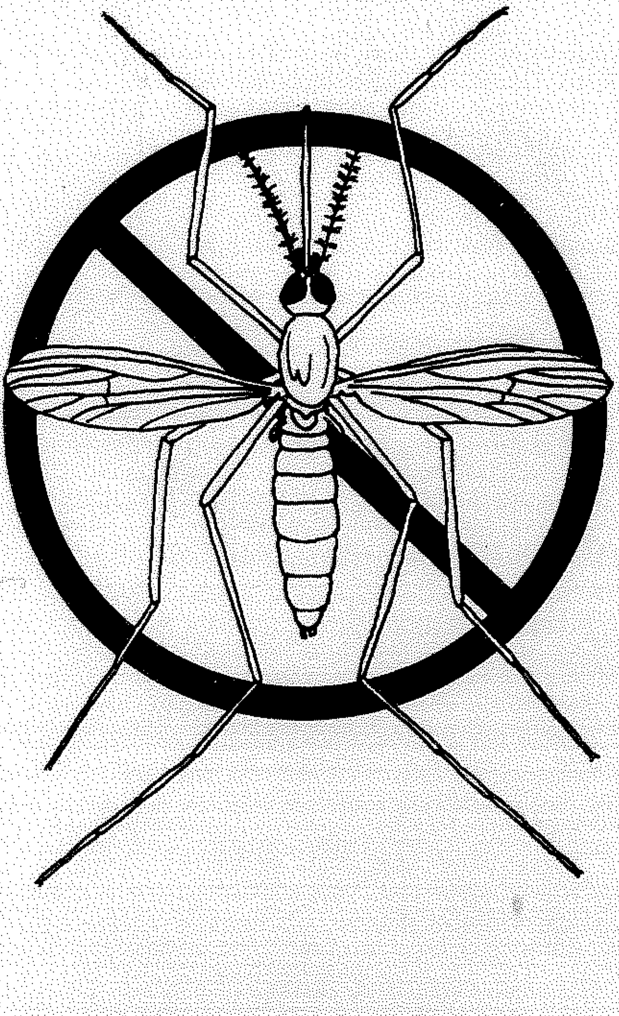

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THE EFFECT OF THREE MARSH MANAGEMENT TECHNIQUES ON THE ECOLOGY OF IRREGULARLY FLOODED CHESAPEAKE BAY WETLANDS

PARTS I and II

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PREFACE

This document contains two reports that were completed for the Maryland Department of Agriculture and Maryland Department of Natural Resources (Tidewater Administration). Part I is a summary of results obtained during the first two years of a study to determine the ecological impacts of ditching on irregularly flooded brackish wetlands on the Deal Island Wildlife Management Area (Maryland). Part II contains results of years 3 and 4 of the same study. Most of the work reported in Part II was obtained during the summer of 1981.

PART I

EXECUTIVE SUMMARY

A two year study was conducted to determine the effects of ditching on the ecology of irregularly flooded Chesapeake Bay wetlands. Three sites on the Deal Island Wildlife Management Area were ditched in 1979. One area (Open Site) received standard Open Water Marsh Management treatment and was coupled to the adjacent estuary to permit complete tidal exchange. Water control structures were used at a second site (Water Control Site) to permit partial tidal coupling. The third ditched area (Closed Site) was not coupled to the estuary. Two unditched areas served as control sites.

Changes in vegetation composition were still ongoing at all sites after two years. *Distichlis spicata* (Salt grass) and *Spartina patens* (Saltmeadow cordgrass) were co-dominant species of the wetlands prior to ditching. After one year *D. spicata* was the dominant species at the Open and Water Control Sites. By the second year *Iva frutescens* (Marsh elder) and *Baccharis halimifolia* (Sea-myrtle) were abundant at the Open Site and by 1981 were also abundant at the Water Control Site. *S. patens* became the dominant species at the Closed Site where there has been no invasion by *I. frutescens* or *B. halimifolia*. Nitrogen and phosphorus concentrations have been higher in plant tissues and decomposition rates of litter have decreased at the three treated sites. Changes in vegetation composition, nutrient concentrations and decomposition rates are attributed to lowering of the water tables at the three treated sites.

No major changes in water quality parameters occurred at any of the sites, and intra-site differences (e.g., shallow ponds versus ditches) in water quality parameters were greater than inter-site differences. Results of tidal cycle studies conducted at the Open Site suggest, compared to the Control Site, that there would be a continuous export of nutrients whenever ditched areas are completely coupled to the estuary.

It is recommended that open sites be avoided and that, where possible, closed systems or water control systems be used for controlling mosquitoes on irregularly flooded wetlands. If it is necessary to permit partial coupling between ditched areas and the estuary, exchange should be minimal so that natural water tables are maintained and shrubby species are discouraged from becoming dominant in the wetlands.

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I. INTRODUCTION

It is generally accepted that mosquito control is desirable because of the pestiferous nature of many species as well as their potential as vectors of diseases (e.g., malaria, yellow fever, and encephalitis) to humans and domestic animals. In recent years many mosquito management programs have been based on the use of larvacides or adulticides which, in addition to having negative impacts on nontarget species (Ward and Howes 1974, Ward and Busch 1976, Ward and Ludwig 1976, Fitzpatrick and Sutherland 1978), may have long-term adverse environmental impacts. Insecticide use also produces resistance in the target species and in recent years it has been shown that the use of chemicals is not as cost effective for abatement as methods that control mosquito populations by managing water levels (Provost 1977, Shisler et al. 1979). In the United States there has been a renewed interest in the use of water management techniques which control mosquitoes, reduce the need for insecticides, and do not significantly alter the ecology of the managed wetlands.

The most widely practiced mosquito control marsh management technique has been ditching. Smith (1904) recommended ditching as a technique for controlling Aedes sollicitans in salt marshes by draining surface water from the marsh so that larvae could not complete development to adulthood (ca. 7-10 days after egg eclosion). Ditching was begun on a small scale in New Jersey in 1906 and by 1912 New Jersey law provided for expansion of a program (Headlee 1945) that consisted of the establishment of ditches that were constructed parallel to one another at a spacing distance of 150-200 feet. Parallel ditching became the principle means of salt marsh mosquito control and its application reached a peak during the Depression when people were employed by state and federal agencies to dig the ditches. It is estimated that by 1938 ninety percent of the tidewater marshes between Maine and Virginia had been ditched (Bourn and Cottam 1950) with little or no consideration having been given to the ecological consequences. Cottam et al. (1938) were first to disagree with the notion of parallel ditching. At about the same time Urner (1935) and Bradbury (1938) reported that many waterfowl and shorebirds were adversely affected by mosquito control projects. Bourn and Cottam (1950) and Cottam and Bourn (1952) advised that parallel ditching caused a decline in the abundance and diversity of salt marsh invertebrates and also caused undesirable changes in the salt marsh plant community structure. Stearns et al. (1940) found parallel ditching to be deleterious to muskrat production due to the elimination of choice food plants. Although its effectiveness in reducing mosquito production has also been challenged (LaSalle and Knight 1973), other authors have suggested that parallel ditching does not always cause the serious ecological consequences attributed to it (Kuenzler and Marshall 1973, Lesser 1976).

A more recent ditching technique, Open Marsh Water Management (OMWM), has been used to control mosquito production (Ferrigno and Jobbins 1968), Burger 1980). In OMWM, a network of ditches is constructed to connect all mosquito breeding sites. The ditch network is coupled to the estuary to enhance tidal circulation and bring larvivorous fish to mosquito breeding areas of the wetland. Modification of standard OMWM have also been proposed (Meredith and Saveikis 1980).

Previous experience with OMWM, primarily in New Jersey, has shown that mosquitoes can be controlled and the use of insecticides can be eliminated or greatly reduced. Ecological effects of various OMWM procedures are not well known. In some instances densities of fiddler crabs (Uca sp.) increased while snail populations (Melampus sp.) declined (Ferrigno 1970, Shisler and Jobbins 1977b). Burger and Shisler (1978) have also shown that OMWM treated areas may no longer be used as breeding sites by gulls. In some instances wetland vegetation changed following OMWM application. Primary production was shown to increase (Shisler and Jobbins 1977a) following OMWM, but undesirable shrubby species such as *Iva frutescens* and *Baccharis halimifolia* may replace herbaceous dominants when the managed areas are coupled to the estuary. In other instances, vegetation of coastal wetlands may not change following OMWM (Robert Berry, Maryland Dept. Agriculture, personal communication) and, in managed systems that are not coupled to the estuary, vegetation changes may not be significant (Burger and Shisler 1978). With the exception of a study of carbon transport in OMWM treated wetlands in New Jersey (Shisler and Jobbins 1977a), there are no data on the impacts of OMWM on nutrient export-import dynamics, water quality parameters, and decomposition processes.

The Deal Island Study

The OMWM techniques that were designed in New Jersey are now being used or modified for use in other states. In addition to the many ecological questions that remain unanswered, it still must be determined whether or not OMWM, or other modifications, will control mosquitoes in other areas. For example, in the Chesapeake Bay, tidal regimes, salinity patterns and wetland vegetation are different from those in New Jersey where OMWM was designed. Particularly striking are differences in the tidal amplitudes. Most of the brackish wetlands in the Maryland portion of Chesapeake Bay are irregularly flooded and the average tidal range is much less than those found in Delaware Bay.

In 1979 a joint project between the Maryland Department of Agriculture and the Smithsonian Institution was initiated to determine the management and ecological effects of OMWM and modifications of OMWM on typical irregularly flooded wetlands of the Chesapeake Bay. The research was conducted on the 10,000

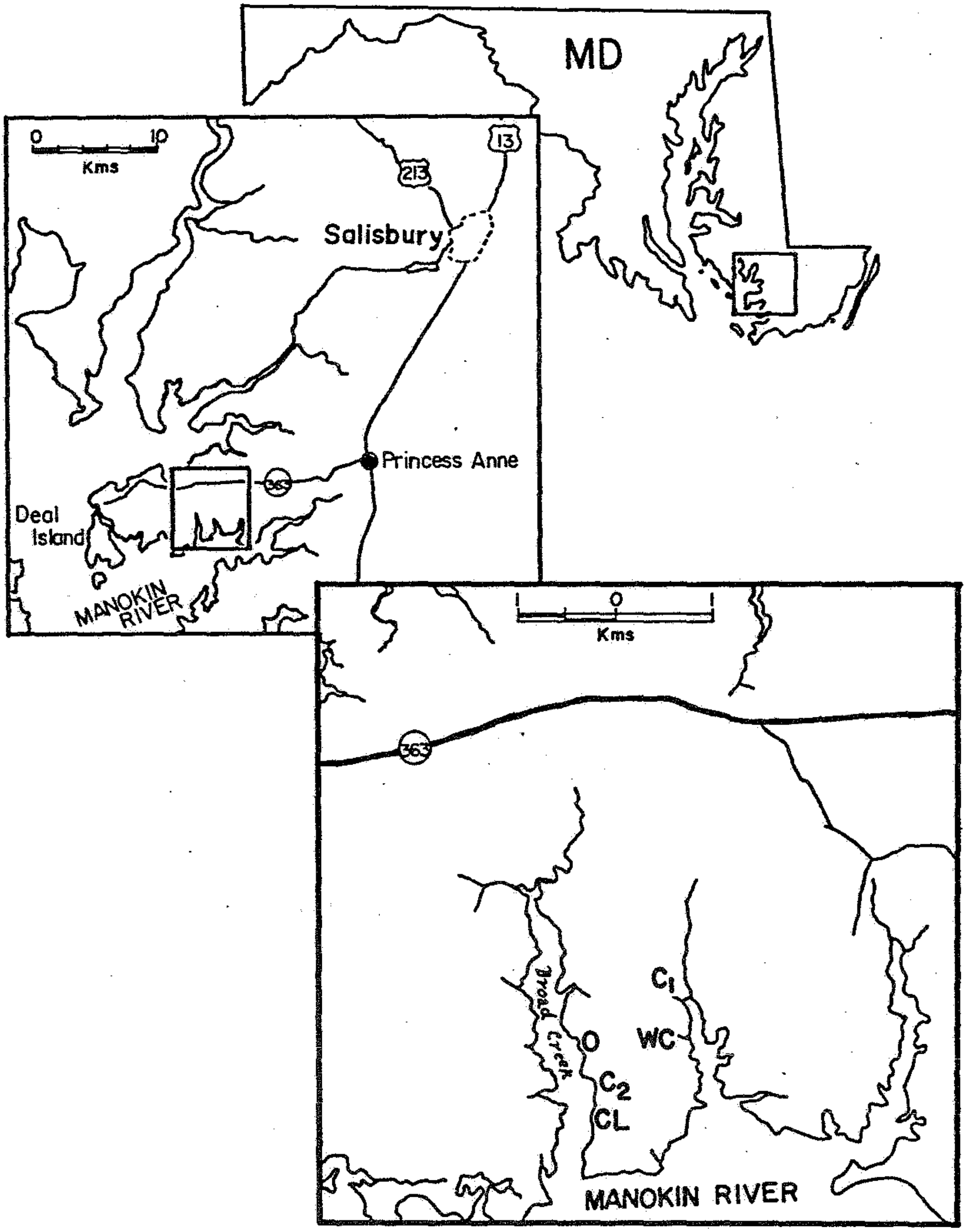


Figure 1. Location of the Deal Island study sites. O = Open Site, CL = Closed Site, WC = Water Control Site, C1 = Control Site used in 1979, C2 = Control Site used in 1980.

acre Deal Island Wildlife Management Area in Somerset County, Maryland (Fig. 1). Wetlands in that area, dominated primarily by Spartina patens and/or Distichlis spicata, contain many potholes that are used by mosquitos as breeding sites.

Four areas were located and three were treated as follows (Fig. 1).

1. Open Site — A 20.23 hectare area was ditched and coupled to the adjacent estuary to provide tidal circulation throughout. This site would be standard OMWM as described by Bruder (1980).
2. Water Control Site — An approximately 10.12 hectare site was ditched and water level control structures were used to permit some tidal water to flood and ebb from the area. A more detailed description of these structures is in Lesser (1982).
3. Closed Site — A 12.14 hectare area was ditched but the site was not connected to the adjacent estuary so that tidal waters exchanged only during spring and/or storm tides.

A 8.09 hectare Control Site was also established. This site proved to be topographically lower than the ditched sites and, consequently, was much wetter than desirable. After 1 year, a second 4.05 hectare Control Site was chosen that was more typical of the ditched sites. The locations of 2 Control Sites are shown in Fig. 1.

Ditches and ponds were excavated with an amphibious rotary ditcher that broadcast a thin layer of spoil for 10 to 15 meters. Ditches were about 0.76 meters wide and from 0.60 to 0.90 meters deep. In addition to the ditches, at least one large shallow pond with pond radials was created in the Open and Water Control sites. Additional details of the ditching procedure are found in Lesser (1982).

II. HYDROLOGY

A major objective of OMWM is to eliminate mosquito breeding sites by removing water from the wetland surface. Although standard OMWM procedures may provide for efficient mosquito control, potential negative impacts may result if the water table is lowered. In particular, there was concern that water tables would be lowered if irregularly flooded Chesapeake Bay wetlands were managed using standard OMWM procedures and that undesirable changes would occur in wetland vegetation. In addition, few data were available to assess the effects that standard OMWM would have on nutrient cycling within the wetlands and on nutrient exchange processes between the wetlands and adjacent estuarine areas. The experimental design used in this study was, consequently, chosen to provide varying degrees of water table manipulations. To monitor water level fluctuations in ditches and to assess the degree and depth of surface flooding at each treated site and in a natural pothole at the Control Sites, Stevens type F water level recorders were used. These instruments provided data on water level fluctuations and data on the frequency and depth of surface flooding that occurred at each site. In addition, personnel of the Maryland Department of Agriculture installed shallow ground water wells and monitored ground water levels throughout the study (Lesser 1982).

The Open Site produced the most dramatic decline in the ground water table and daily (tidal) fluctuations in the ditches were most pronounced at that site (Fig. 2). As an example, water level fluctuations in the ditches at the Open Site averaged 38.6 cm (standard error = 1.9 cm) during the week shown in Fig. 2. Water tables were maintained near the surface at the Closed Site and water level fluctuations typically averaged less than 0.7 cm (standard error = .1 cm) per tidal event during periods of time when the wetland was not flooded (Fig. 2). Water

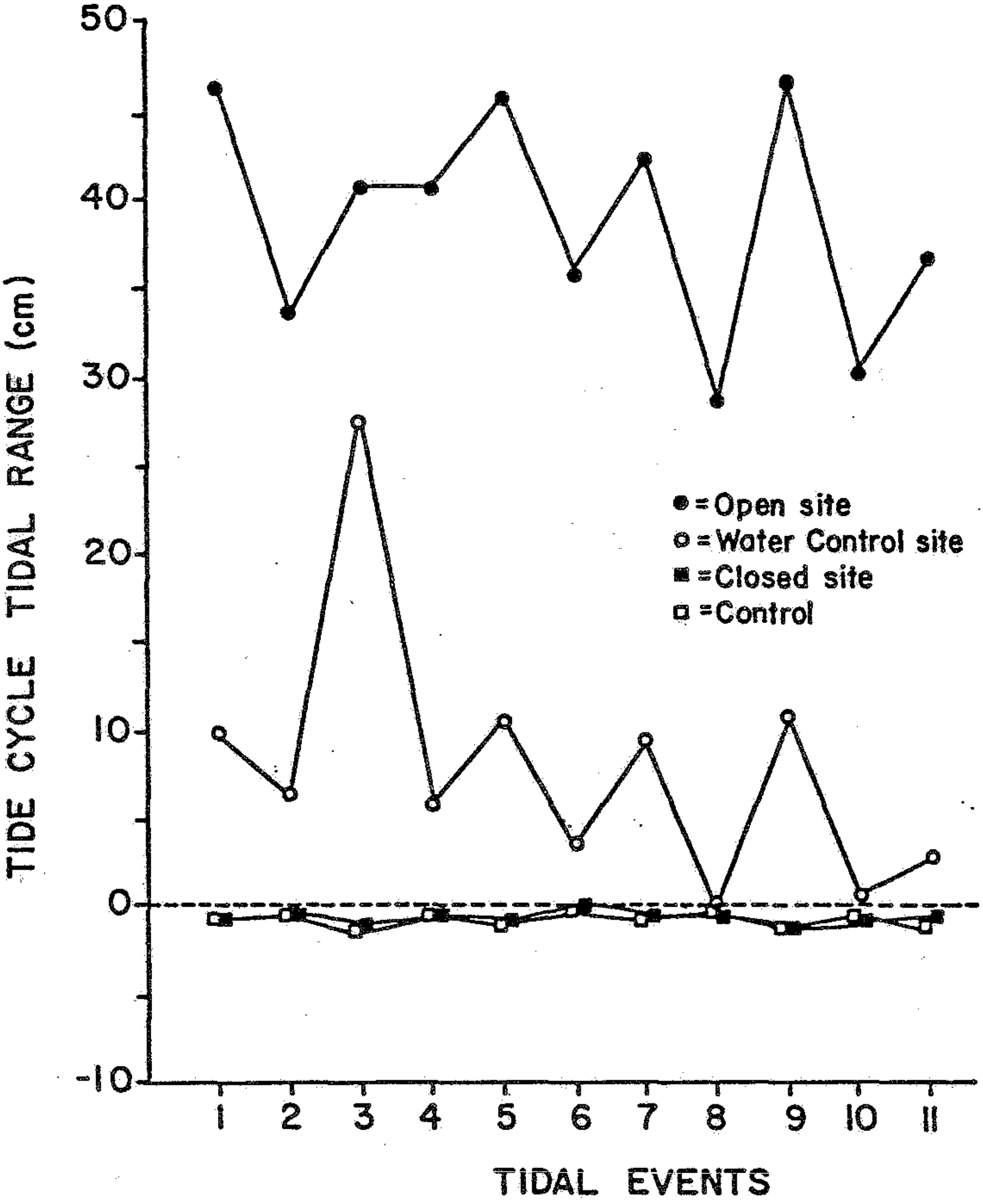


Figure 2. Range (cm) in water level fluctuations in a ditch at each of the 3 treated sites and a natural pothole at Control Site 2. Data were compiled from water level records during the week of May 28 - June 3, 1980. There was no precipitation nor surface tidal flooding during that time period. The range for each tidal cycle is the maximum water level minus the minimum water level.

level fluctuations in the pothole at the Control Site were very similar to those at the Closed Site and averaged only 0.8 cm per tidal event.

Data from the water level recorders showed that the treated sites were irregularly flooded during the two year study period (Fig. 3). Flooding events were more numerous in 1979 with the majority of floods occurring between August and November (Fig. 3). After examining water level, vegetation, and mosquito data for 1979, it was apparent that an atypical control site had been chosen. The site was consistently wetter and produced very few mosquitoes (Lesser 1982). Accordingly, we decided to move the Control Site to another area (Fig. 1) in 1980. Comparing the sites in 1980, very few flooding events occurred at all due to a prolonged drought (Lesser 1982). The Closed Site flooded more often than the other treated areas in both 1979 and 1980, indicating that, relative to the other treated sites, it may have been topographically lower. In addition, the Closed Site was closer to the Manokin River (Fig. 1) and may have been more prone to inundation during strong winds and/or storms.

Data for surface flooding events are summarized in Table 1. The data were compiled from water level recordings which were examined to determine when flooding events occurred and the depth of tidal waters on the wetland surface. Except for September and October 1979, surface flooding usually occurred only during one of the two daily tidal cycles and inundation averaged less than 10 cm at all sites indicating that the flood waters were usually shallower than the litter zone which averaged between 10 and 20 cm. It is clear that these wetlands do not flood often and that they are not deeply flooded when those events occur. One could speculate, therefore, that the managed wetlands in that portion of the Chesapeake Bay would only irregularly have contact with the adjacent estuary. Since there were no noticeable differences in flooding frequency or depth at the treated sites,

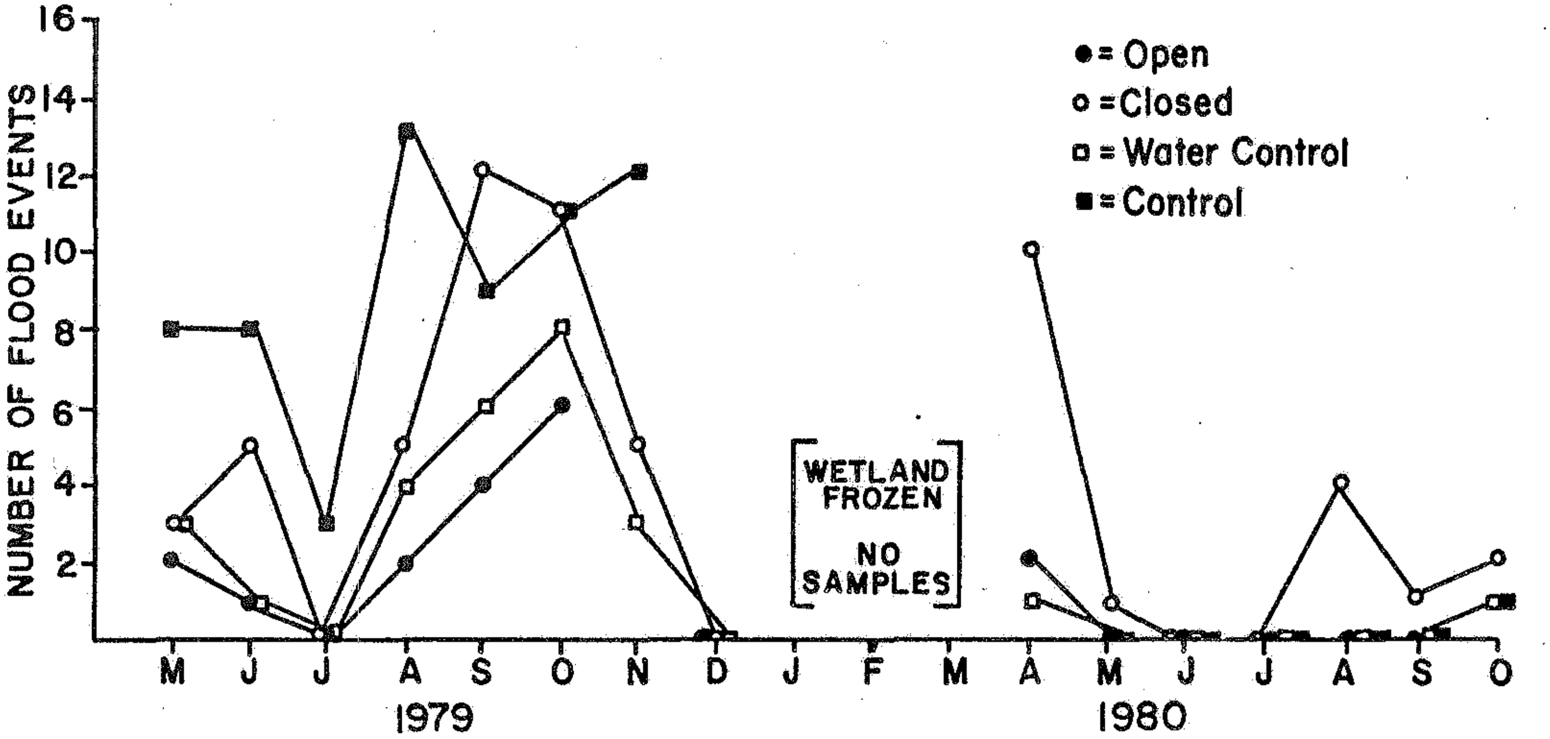


Figure 3. Graphic summary of surface flooding events for each month of the study. The number of tidal flooding events were determined by examining water level data that were monitored continuously, except during the winter when the ditches and potholes were frozen.

Table 1. Summary of hydrologic data for the three treated and two control sites. ND represents malfunction of the water level recorder but the chart trace indicated that at least one flooding event occurred. NS indicates that the site was not sampled. A dash indicates that no or only one flooding event(s) occurred thus mean, maximum, and/or minimum values could not be calculated. Flooding depth is in cm.

	Number of Floods		Number of Days with Floods		Flooding Depths					
					Mean		Maximum		Minimum	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
OPEN										
April	NS	2	NS	1	NS	3.2	NS	3.4	NS	3.1
May	2	0	2	0	2.8	-	3.1	-	2.4	-
June	1	0	1	0	0.6	-	-	-	-	-
July	0	0	0	ND	-	-	-	-	-	-
August	2	0	2	0	6.6	-	11.0	-	2.1	-
September	4	ND	3	ND	3.0	ND	5.8	ND	0.3	ND
October	6	ND	5	ND	5.6	ND	20.4	ND	0.9	ND
November	ND	0	ND	NS	ND	NS	ND	NS	ND	NS
December	0	0	0	NS	-	NS	-	NS	-	NS
CLOSED										
April	NS	10	NS	6	NS	3.0	NS	7.3	NS	0.3
May	3	1	3	1	4.9	3.1	6.7	-	2.4	-
June	5	0	4	0	2.3	-	4.9	-	0.3	-
July	0	0	0	0	-	-	-	-	-	-
August	5	4	5	4	6.5	7.2	16.8	13.4	2.3	1.5
September	12	1	7	1	8.2	10.3	36.6	-	0.6	-
October	11	2	6	2	3.1	10.5	29.0	18.6	3.1	2.4
November	5	0	4	NS	5.7	NS	14.3	NS	2.1	NS
December	0	0	0	NS	-	NS	-	NS	-	NS

Table 1. (continued)

	Number of Floods		Number of Days with Floods		Flooding Depths					
					Mean		Maximum		Minimum	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
					WATER CONTROL					
April	NS	1	NS	1	NS	9.6	NS	-	NS	-
May	3	0	3	0	6.0	-	7.3	-	3.4	-
June	1	0	1	0	2.7	-	-	-	-	-
July	0	0	0	0	-	-	-	-	-	-
August	4	0	4	0	5.7	-	14.0	-	1.2	-
September	6	ND	4	ND	6.3	ND	16.2	ND	2.1	ND
October	8	1	5	1	6.6	1.5	20.4	-	1.5	-
November	3	NS	3	NS	2.2	NS	5.5	NS	0.6	NS
December	0	NS	0	NS	-	NS	-	NS	-	NS
					CONTROL					
April	NS	ND	NS	ND	-	ND	NS	ND	NS	ND
May	8	0	8	0	5.0	-	10.4	-	0.6	-
June	8	0	6	0	3.6	-	7.6	-	0.9	-
July	3	0	2	0	2.3	-	4.0	-	0.6	-
August	13	0	10	0	4.0	-	17.4	-	0.6	-
September	9	ND	6	ND	8.0	ND	17.4	ND	1.5	ND
October	11	1	6	1	9.4	23.5	26.0	-	0.9	-
November	12	NS	11	NS	3.2	NS	7.3	NS	0.0	NS

it appears that ditching does not increase the frequency or intensity of surface flooding.

III. VEGETATION

A. METHODS

1. Biomass and nutrients

Vegetation was sampled monthly, except during winter months when the wetland was frozen, at the three treatment sites and control sites between May of 1979 and October 1980. The sampling design included harvesting all vegetation in 50 x 50 cm quadrates that were located at 0, 5, 10, 15, and 20 meters along each of 3 randomly located transects. The design thus provided for triplicate quadrates that were harvested monthly for each distance. In addition, five randomly chosen quadrates were sampled within each site in areas that were not impacted by spoil deposition during the initial management process.

In the laboratory, vegetation was divided into live and dead components with the live biomass being further subdivided by species. Dead biomass included all litter on the wetland surface. All plant materials were dried at 70° C, weighed, and ground in a Wiley Mill prior to analysis for nitrogen using Macro-Kjeldahl techniques (APHA 1976) and phosphorus using an acid digestion technique (Fiske and Subbarow 1925, King 1932).

Factorial analysis of variance was conducted to test the biomass and nutrient data for significant main effects and interactions among sites (4 levels), distances (5 levels) and times for each variable. The Statistical Analysis System (Helwig and Council 1979) was used in data analysis. The following variables were analyzed:

1. Live Biomass of each species combined (LB) and *S. patens* (LBS) and *D. spicata* (LBD) separately.
2. Dead Biomass (DB) which includes all standing (upright) dead shoot material and all other surface litter.

3. Total Biomass (TB) where TB = LB + DB.
4. Average nitrogen concentrations of all live biomass (NPL).
5. Nitrogen in live biomass (NLB) where NLB = NPL x LB of *D. spicata*, *S. patens* and all species combined.
6. Average phosphorus concentrations of all live biomass (PPL).
7. Phosphorus in live biomass (PLB) where PLB = PPL x LB of *D. spicata*, *S. patens* and all species combined.
8. Nitrogen concentrations of dead biomass (NPD).
9. Nitrogen in dead biomass (NDB) where NDB = NPD x DB.
10. Phosphorus concentrations of dead biomass (PPD).
11. Phosphorus in dead biomass (PDB = PPD x DB).
12. Total nitrogen in biomass (NT = NLB + NDB).
13. Total phosphorus in biomass (PT = PLB + PDB).

When main effects were significant, Duncan's multiple range tests (Duncan, 1955) were used to analyze for specific differences among sites, distances, and times. Interaction effects, however, were so few (Appendix A) that all possible interaction effects were not analyzed separately.

Another objective of the design was to determine: (1) whether there were any overall affects of manipulation in areas of each site that had not been affected by spoil and (2) within each site, were there any differences between the 0-20 meter distances and areas of the site that were not affected by spoil. To answer these questions, 5 random plots (50 cm x 50 cm) were sampled at each site in areas that had not been affected by spoil during the ditching procedure. Those plots were harvested on the same days that the 0, 5, 10, 15, and 20 m distances were harvested. Analysis of variance tests were made on the biomass and nutrient data from the random plots: (1) to test for inter-site differences among the random plots, one-way ANOVA tests were performed for each variable and the means compared using Duncan's multiple range tests; (2) to test for intra-site differences, one-way ANOVA tests were performed on data from the random plots and data from the 5 distances. Duncan's multiple range tests were made to compare means when the ANOVA's tests showed significant effects.

2. Aboveground primary production

Biomass and nutrient data were also used to estimate aboveground primary production and its associated nutrients using three methods (Linthurst and Reimold 1978):

Method 1 — Peak standing crop. Primary production for each site x distance combination was assumed to be equal to the peak live biomass standing crop value for the growing season. Peak standing crop data for each site x distance combination were then used to test for site, distance, and site x distance interactions using factorial ANOVA as described above.

Method 2 — Net aboveground primary production. This method, based on Milner and Hughes (1968), assumes that net production is equal to the sum of all positive increases in live biomass during the study period. Similar to Method 1, net aboveground primary production was calculated for each site x distance combination and the data tested using factorial ANOVA.

Method 3 — Smalley method. This method (Smalley 1959) is similar to Method 2 but includes data for both live and dead biomass. Statistical analyses were similar to those used for Methods 1 and 2.

3. Decomposition

Shoots of *D. spicata* and *S. patens* were collected at the end of the 1979 growing season and air dried for use in decomposition studies. The air dried material was divided into shoot tops and bases and 2.5 g subsamples prepared. The 2.5 g subsamples were then placed into 2 mm mesh nylon litter bags. Each bag thus contained 10 g of material: (1) 2.5 g S. patens shoot tops, (2) 2.5 g S. patens shoot bases, (3) 2.5 g D. spicata shoot tops, (4) 2.5 g D. spicata shoot bases. Litter bags (512) were placed in the field on 18 April, 1979. Within each site, equal numbers of litter bags were placed on top of spoil that had been created during the ditching and in a nearby area where spoil had not been deposited during the ditching process. Duplicate litter bags were collected monthly (four per site) and returned to the laboratory for processing.

Because we were concerned about nutrient changes in the litter, surface materials were removed by gently washing the samples prior to drying at 70° C. Dried samples were then weighed, ground, and analyzed for N and P. During the first few months of the study the original 2.5 g subsamples were ground and analyzed individually. Once shoot tops and bases had decomposed to the point where they could not be differentiated, the two subsamples for each species were combined for nutrient analyses.

Weight and nutrient concentration data were used to calculate the total amounts of N and P in the litter samples. Weight and nutrient data, both concentrations and totals, were tested by factorial ANOVA to determine if there were any site or subsite (spoil or nonspoil) effects. Means were compared using Duncan's multiple range tests. Decay coefficients were calculated from the weight data using a negative exponential model (Olson 1963) of the form $-k = \ln (X/X_0)\ t$, where X_0 is the dry weight initially present and X the dry weight remaining at time t. The k values (e.g., rates of decomposition) were tested for site, location and site x location effects interaction using factorial ANOVA. Means were compared using Duncan's multiple range tests.

4. Density, height, and reproductive phenology

Densities of reproductive and vegetative shoots were monitored throughout the study in permanently marked study plots. Triplicate permanently marked plots were established within each site at 0, 5, 10, 15, and 20 m from the same ditches that were used for biomass studies. The plots, 0.25 x 0.25 m, were sampled monthly and counts made of the number of aerial shoots of each species. The number of reproductive (e.g., flowering or fruiting) shoots was also counted. When suitable numbers of shoots were present, the length (hereafter referred to as height) of five randomly chosen non-reproductive shoots of *D. spicata* and *S. patens* were measured to the nearest tenth of a centimeter. Density and height data for *D. spicata* and *S. patens* were tested by factorial ANOVA to determine if there were site, distance, and site x distance interaction effects. Means were compared using Duncan's multiple range tests.

5. Submersed vegetation

Submersed plants in ponds and ditches were censused in 1979 by randomly walking over the sites and estimating percent cover in 25 potholes and 25 ditches. In 1980, wooden stakes were placed at 25 pond and ditch sites and the areas surveyed several times during the year. Percent cover estimates for the ponds were for the entire pond area which was variable while cover estimates for the ditches were for 2 m linear segments.

B. RESULTS

1. Biomass

Live biomass ranged from an average of 88.8 - 180.0 g of plant biomass per m^2 (hereafter referred to as g m^{-2}) in 1979 and was significantly less at the Control Site (Table 2). We believe that the differences were due to the fact that Control

Table 2. Results of Duncan's Multiple Range Tests for site effects on the fifteen variables listed. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript. N = nitrogen and P = phosphorus.

Site	Total live biomass g m^{-2}		*D. spicata* live biomass g m^{-2}		*S. patens* live biomass g m^{-2}		Total dead biomass g m^{-2}		Total biomass g m^{-2}	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
OPEN	180.0^{A}	152.4^{B}	152.4^{A}	42.8^{B}	25.6^{C}	67.2^{C}	205.2^{A}	566.8^{A}	385.2^{A}	719.2^{AB}
CLOSED	154.0^{B}	210.0^{A}	33.2^{B}	24.8^{C}	118.4^{A}	183.2^{A}	193.6^{A}	462.0^{B}	347.6^{AB}	672.0^{B}
WATER CONTROL	164.4^{AB}	140.8^{B}	144.4^{A}	99.2^{A}	9.6^{D}	24.8^{D}	116.0^{B}	375.6^{C}	280.0^{C}	518.8^{C}
CONTROL	88.8^{C}	187.2^{A}	16.8^{B}	76.4^{B}	46.4^{B}	110.8^{B}	237.2^{A}	589.6^{A}	326.0^{BC}	774.8^{A}

Site	N in live biomass g m^{-2}		% N in live biomass %		P in live biomass g m^{-2}		% P in live biomass %		N in dead biomass g m^{-2}	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
OPEN	1.68^{A}	1.48^{AB}	1.14^{A}	1.05^{AB}	0.16^{A}	0.131^{AB}	0.11^{A}	0.10^{A}	1.12^{B}	3.92^{A}
CLOSED	1.04^{B}	1.52^{AB}	0.88^{C}	0.73^{C}	0.12^{B}	0.146^{A}	0.09^{B}	0.08^{B}	1.00^{BC}	2.56^{B}
WATER CONTROL	1.52^{A}	1.40^{B}	1.18^{A}	1.11^{A}	0.16^{A}	0.127^{AB}	0.11^{A}	0.11^{A}	0.80^{C}	2.72^{B}
CONTROL	0.76^{C}	1.72^{A}	1.01^{B}	0.98^{B}	0.08^{C}	0.121^{B}	0.08^{B}	0.08^{B}	1.48^{A}	4.24^{A}

Site	% N in dead biomass %		P in dead biomass g m^{-2}		% P in dead biomass %		Total nitrogen g m^{-2}		Total phosphorus g m^{-2}	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
OPEN	0.61^{A}	0.71^{A}	0.08^{AB}	0.24^{A}	0.041^{A}	0.044^{A}	2.80^{A}	5.36^{B}	0.24^{A}	0.36^{A}
CLOSED	0.50^{B}	0.56^{B}	0.08^{AB}	0.16^{B}	0.036^{BC}	0.035^{C}	2.04^{B}	4.08^{C}	0.18^{BC}	0.32^{B}
WATER CONTROL	0.64^{A}	0.72^{A}	0.04^{B}	0.16^{B}	0.047^{A}	0.046^{A}	2.28^{B}	4.12^{C}	0.20^{AB}	0.28^{B}
CONTROL	0.62^{A}	0.72^{A}	0.09^{A}	0.24^{A}	0.032^{C}	0.039^{B}	2.24^{B}	5.92^{A}	0.16^{C}	0.36^{A}

Site 1 was much wetter than the other areas because it was more frequently flooded (Fig. 3 and Table 1). The almost continuous presence of standing water may have lowered overall productivity and caused a shortened 1979 growing season at the Control Site. Because of the apparent disparity between the Control and the treated sites, a more comparable control area was used in 1980 (Control Site 2 - Fig. 1). When comparing the ditched sites only, there was significantly less live biomass (LB) at the Closed Site (154.0 g m^{-2}) than at the Open Site (180.0 g m^{-2}) in 1979. After the first growing season following ditching, most of the live biomass at the Open and Water Control Sites was D. spicata whereas most of the live biomass at the Closed and Control Sites (Table 2) consisted of S. patens shoots.

The decrease in live biomass from 1979 to 1980 at the Open and Water Control sites may have been due to drought conditions in 1980 (Lesser 1982). Live biomass at the Open and Water Control Sites in 1980 was significantly less than live biomass at the Control Site (Table 2). In addition, live biomass at the Closed Site increased in 1980 compared to 1979 and most of the increase was in S. patens biomass which increased from an average of 118.4 g m^{-2} to 183.2 g m^{-2} . S. patens live biomass was greater at all sites in 1980 compared to 1979 while D. spicata decreased at the three treated sites. It is unclear at this time whether the decline in D. spicata was due to the drought or simply due to postmanagement changes that are still ongoing.

Average total dead biomass (litter) was greater at all sites in 1980 than in 1979 (Tables 2), although litter biomass near the ditches continued to be less with litter biomass at O m (382 g m^{-2}) and 5 m (444.4 g m^{-2}) being significantly less than at the other distances in 1980 (Table 3). The increase in total biomass (Table 2) between 1979 and 1980 is, therefore, due to increases in total dead biomass and not any significant increase in aboveground live biomass at the treated sites. In 1980, total live biomass and D. spicata live biomass were significantly greater at 0 m (Table 3).

Table 3. Results of Duncan's Multiple Range Tests for distance effects on the fifteen variables listed. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript. N = nitrogen and P = phosphorus.

	Total live biomass		*D. spicata* live biomass		*S. patens* live biomass		Total dead biomass		Total biomass	
	g m^{-2}		g m^{-2}		g m^{-2}		g m^{-2}		g m^{-2}	
Distance	1979	1980	1979	1980	1979	1980	9179	1980	1979	1980
0	153.6^{A}	201.6^{A}	92.8^{A}	102.0^{A}	52.4^{AB}	101.2^{A}	110.0^{B}	382.0^{B}	263.6^{B}	578.4^{B}
5	141.2^{A}	172.0^{B}	94.0^{A}	72.0^{B}	37.2^{B}	97.6^{A}	126.8^{B}	444.4^{B}	268.0^{B}	616.4^{B}
10	156.0^{A}	163.6^{B}	92.4^{A}	60.8^{B}	48.0^{AB}	88.8^{A}	198.4^{A}	549.6^{A}	354.4^{A}	713.2^{A}
15	140.8^{A}	156.4^{B}	78.4^{A}	54.8^{B}	56.0^{A}	96.0^{A}	255.2^{A}	570.4^{A}	396.0^{A}	726.8^{A}
20	142.0^{A}	170.4^{B}	76.8^{A}	60.8^{B}	56.8^{A}	103.6^{A}	249.6^{A}	545.6^{A}	391.6^{A}	728.8^{A}

	N in live biomass		% N in live biomass		P in live biomass		% P in live biomass		N in dead biomass	
	g m^{-2}		%		g m^{-2}		%		g m^{-2}	
Distance	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
0	1.32^{A}	1.84^{A}	1.05^{A}	1.01^{A}	0.12^{A}	0.16^{A}	0.10^{A}	0.08^{B}	0.68^{B}	2.68^{C}
5	1.24^{A}	1.48^{B}	1.10^{A}	0.97^{A}	0.12^{A}	0.12^{A}	0.10^{A}	0.09^{AB}	0.72^{B}	3.08^{BC}
10	1.28^{A}	1.44^{B}	1.03^{A}	0.99^{A}	0.12^{A}	0.12^{A}	0.09^{A}	0.10^{A}	1.16^{A}	3.68^{A}
15	1.20^{A}	1.28^{B}	1.05^{A}	0.93^{A}	0.12^{A}	0.12^{A}	0.10^{A}	0.09^{AB}	1.48^{A}	3.84^{A}
20	1.20^{A}	1.52^{B}	1.00^{A}	0.94^{A}	0.12^{A}	0.12^{A}	0.10^{A}	0.09^{AB}	1.44^{A}	3.48^{AB}

	% N in dead biomass		P in dead biomass		% P in dead biomass		Total nitrogen		Total phosphorus	
	%		g m^{-2}		%		g m^{-2}		g m^{-2}	
Distance	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
0	0.55^{A}	0.69^{A}	0.038^{C}	0.148^{C}	0.04^{A}	0.038^{B}	1.96^{B}	4.48^{B}	0.15^{C}	0.289^{C}
5	0.55^{A}	0.69^{A}	0.048^{C}	0.184^{B}	0.04^{A}	0.041^{AB}	1.96^{B}	4.56^{AB}	0.16^{BC}	0.311^{BC}
10	0.61^{A}	0.68^{A}	0.075^{B}	0.236^{A}	0.04^{A}	0.044^{A}	2.44^{A}	5.12^{A}	0.20^{AB}	0.369^{A}
15	0.63^{A}	0.69^{A}	0.106^{A}	0.241^{A}	0.04^{A}	0.042^{AB}	2.68^{A}	5.16^{A}	0.24^{A}	0.362^{A}
20	0.60^{A}	0.66^{A}	0.098^{AB}	0.218^{AB}	0.04^{A}	0.040^{AB}	2.64^{A}	5.04^{A}	0.24^{A}	0.352^{AB}

2. Nutrients

The total standing stock of nitrogen and phosphorus in live and dead biomass increased at all sites between 1979 and 1980 (Table 2). Total nitrogen values ranged from 2.04 - 2.80 g m^{-2} at the Closed and Open Sites in 1979 and 4.08 - 5.36 g m^{-2} at the same sites in 1980. Total phosphorus standing stocks increased from 0.16 - 0.24 g m^{-2} in 1979 to 0.28 - 0.36 g m^{-2} in 1980.

The increases in total nitrogen and total phosphorus were due to changes in total biomass rather than any significant changes in nutrient concentrations. Concentrations of nitrogen in live biomass were significantly higher at the Open and Water Control Sites in both 1979 and 1980 although there was a slight decrease at all sites in 1980 (Table 2). Phosphorus concentrations in live biomass were also higher at the Open and Water Control Sites during both years but, unlike nitrogen, there were no differences between years (Table 2).

Concentrations of nitrogen in dead biomass increased at all sites in 1980 and ranged from 0.56 - 0.72% in 1980 compared to a range in 1979 of 0.50 - 0.62% (Table 2). Contributions of plant material produced in 1979 that were high in nitrogen to the 1980 dead biomass compartment may have caused this increase. Phosphorus concentrations in dead biomass did not show the same trend, although phosphorus in dead biomass increased from 0.04 - 0.09 g m^{-2} in 1979 to 0.16 - 0.24 g m^{-2} in 1980 because of the overall increase in dead biomass.

Differences in nutrient standing stock as a function of distance from ditches were striking in 1979 and present but not as marked in 1980 (Table 3). There were very few differences in any of the phosphorus variables except that total phosphorus continued to be significantly less at 0 and 5 meters because there was still less dead biomass at those distances. Total nitrogen at 0 m (1.96 g m^{-2}) and 5 m (1.96 g m^{-2}) was also lower than at the other distances because the dead biomass compartment had not fully recovered to predisturbance levels by the end of the second growing season.

There was a general trend for nitrogen and phosphorus concentrations in live biomass to vary seasonally with the highest values occurring in the early part of the growing season (Table 4). Because the two Control Sites were so different, we removed data from those sites and then made additional time x site comparisons for the three treated areas (Table 5). The high N and P concentrations in live biomass in May of 1979 (Table 5) did not occur in 1980 when the three treated sites were compared. Tissue phosphorus concentrations were highest early in the growing season in both 1979 and 1980 (Table 5).

Additional site comparisons for live biomass, live biomass of *D. spicata*, and live biomass of *S. patens* during similar months in 1979 and 1980 are shown in Table 6. A decline in total live biomass occurred between August and September in 1980 and the decrease was particularly striking at the Open and Water Control Sites where the mean values declined 36.3% and 18.7% respectively. *Distichlis spicata* live biomass was less in August of 1980 at all sites as compared to the previous month and compared to September 1979 values. *Spartina patens* increased at all sites in 1980 until August which was followed by a sharp decline at the Open Site. The overall decrease in *D. spicata* biomass and increase in *S. patens* biomass in 1980 may be due to postdisturbance successional changes at the sites or to species responses to the drought conditions that year. Several years of data gathered under different climatological regimes would be required before the causes for those types of changes could be understood.

3. Aboveground primary production

As already noted, site differences in live biomass between 1979 and 1980 were, due primarily to changes in species composition rather than to any overall

Table 4. Results of Duncan's Multiple Range Tests for time effects for the fifteen variables listed. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript.

	Live biomass		*D. spicata* live biomass		*S. patens* live biomass		Dead biomass		Total biomass	
	g m^{-2}		g m^{-2}		g m^{-2}		g m^{-2}		g m^{-2}	
Month	1979	1980	1979	1980	1979	1980	197	1980	1979	1980
MAR		31.2^{E}		4.0^{C}		20.4^{D}		669.6^{A}		700.8^{AB}
APR		29.2^{E}		9.6^{C}		19.2^{D}		354.4^{D}		383.6^{C}
MAY	37.2^{D}	195.6^{C}	18.8^{E}	66.0^{B}	15.2^{E}	126.4^{B}	268.4^{AB}	536.0^{B}	305.6^{BC}	732.0^{AB}
JUN	87.6^{C}	218.4^{C}	54.0^{D}	115.2^{A}	32.0^{DE}	102.4^{BC}	113.2^{E}	424.0^{ED}	201.2^{CD}	642.4^{B}
JUL	140.4^{B}	255.2^{B}	82.0^{C}	119.2^{A}	51.8^{BCD}	132.4^{B}	101.6^{E}	431.6^{CD}	242.4^{CD}	686.8^{AB}
AUG	212.8^{A}	313.2^{A}	117.6^{AB}	113.6^{A}	81.2^{A}	178.4^{A}	126.8^{DE}	385.6^{D}	339.6^{B}	698.8^{AB}
SEP	226.4^{A}	256.4^{B}	138.8^{A}	100.4^{A}	66.0^{AB}	128.0^{B}	204.8^{BC}	516.4^{BC}	431.2^{A}	772.8^{A}
OCT	155.6^{B}		96.8^{BC}		44.4^{CD}		183.6^{CD}		339.2^{B}	
NOV	167.2^{B}		100.0^{BC}		60.0^{BC}		317.2^{A}		484.4^{A}	
DEC		80.0^{D}		28.8^{C}		69.6^{C}		670.0^{A}		756.4^{A}

Table 4. (Continued)

Month	N in live biomass		% N in live biomass		P in live biomass		% P in live biomass		N in dead biomass	
	$g\ m^{-2}$		%		$g\ m^{-2}$		%		$g\ m^{-2}$	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
MAR		0.28^{D}		0.79^{DE}		0.04^{D}		0.084^{C}		4.20^{B}
APR		0.32^{D}		1.46^{A}		0.04^{D}		0.179^{A}		2.12^{F}
MAY	0.68^{D}	2.12^{BC}	1.76^{A}	1.14^{B}	0.075^{C}	0.20^{B}	0.196^{A}	0.104^{B}	1.12^{CB}	3.44^{CD}
JUN	1.12^{C}	1.80^{C}	1.45^{B}	0.89^{CD}	0.096^{CB}	0.16^{C}	0.114^{B}	0.078^{CD}	0.72^{CD}	2.52^{EF}
JUL	1.36^{B}	1.92^{BC}	1.06^{C}	0.83^{CDE}	0.118^{B}	0.16^{C}	0.088^{C}	0.071^{DE}	0.60^{D}	2.84^{DE}
AUG	1.64^{A}	2.88^{A}	0.80^{D}	0.94^{C}	0.165^{A}	0.24^{A}	0.077^{CD}	0.079^{CD}	0.80^{CD}	3.16^{CD}
SEP	1.88^{A}	2.24^{B}	0.85^{D}	0.94^{C}	0.154^{A}	0.16^{C}	0.066^{D}	0.076^{CD}	1.48^{B}	3.64^{BC}
OCT	1.04^{C}		0.71^{D}		0.117^{B}		0.076^{DC}		1.08^{BC}	
NOV	1.04^{C}		0.72^{D}		0.096^{CD}		0.065^{D}		1.88^{A}	
DEC		0.56^{D}		0.76^{E}		0.04^{D}		0.063^{E}		4.92^{A}

Table 4. (Continued)

	% N in dead biomass		P in dead biomass		% P in dead biomass		Total nitrogen		Total phosphorus	
	%		g m^{-2}		%		g m^{-2}		g m^{-2}	
Month	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
MAR		0.64^{D}		0.227^{B}		0.04^{B}		4.48^{B}		0.28^{D}
APR		0.60^{D}		0.135^{E}		0.04^{B}		2.47^{C}		0.16^{E}
MAY	0.41^{D}	0.66^{CD}	0.12^{A}	0.205^{B}	0.044^{AB}	0.04^{B}	1.80^{C}	5.55^{A}	0.20^{B}	0.40^{AB}
JUN	0.60^{BC}	0.61^{D}	0.04^{C}	0.150^{DE}	0.031^{CD}	0.04^{B}	1.84^{C}	4.34^{B}	0.12^{A}	0.32^{CD}
JUL	0.48^{D}	0.66^{CD}	0.04^{C}	0.169^{CDE}	0.025^{D}	0.04^{B}	1.96^{BC}	4.75^{B}	0.16^{A}	0.32^{CD}
AUG	0.68^{AB}	0.82^{A}	0.04^{C}	0.193^{CD}	0.043^{AB}	0.05^{A}	2.40^{B}	6.04^{A}	0.20^{B}	0.44^{A}
SEP	0.77^{A}	0.72^{BC}	0.08^{B}	0.184^{CD}	0.046^{A}	0.04^{B}	3.36^{A}	5.88^{A}	0.24^{B}	0.36^{BC}
OCT	0.59^{C}		0.08^{B}		0.047^{A}		2.12^{BC}		0.20^{B}	
NOV	0.58^{C}		0.12^{A}		0.037^{BC}		2.92^{A}		0.20^{B}	
DEC		0.74^{B}		0.345^{A}		0.05^{A}		5.48^{A}		0.40^{AB}

Table 5. Percent nitrogen and phosphorus of live biomass for the three treated sites. All values (%) are means of fifteen samples.

		NPL		PPL	
Site	Month	1979	1980	1979	1980
OPEN	MAR		0.67		0.09
	APR		1.66		0.18
	MAY	2.14	0.95	0.18	0.11
	JUN	1.51	1.11	0.16	0.09
	JUL	0.99	1.03	0.10	0.09
	AUG	0.89	1.02	0.10	0.07
	SEP	1.04	1.05	0.07	0.11
	OCT	0.78		0.08	
	NOV	0.60		0.05	
	DEC		0.93		0.08
CLOSED	MAR		0.56		0.06
	APR		0.87		0.13
	MAY	1.62	0.98	0.20	0.10
	JUN	1.18	0.55	0.09	0.08
	JUL	0.83	0.59	0.07	0.06
	AUG	0.73	0.90	0.07	0.07
	SEP	0.63	0.77	0.07	0.06
	OCT	0.65		0.06	
	NOV	0.49		0.06	
	DEC		0.61		0.05
WATER CONTROL	MAR		0.92		0.07
	APR		1.59		0.19
	MAY	1.51	1.15	0.20	0.08
	JUN	1.29	0.99	0.06	0.06
	JUL	0.98	0.85	0.07	0.07
	AUG	0.62	0.93	0.05	0.08
	SEP	0.84	0.79	0.05	0.06
	OCT	0.71		0.07	
	NOV	1.08		0.09	
	DEC		0.62		0.05

Table 6. Total plant live biomass and biomass of *S. patens* and *D. spicata* between May and September in 1979 and 1980. All values are g m^{-2}.

	OPEN		CLOSED		WATER CONTROL	
Month	1979	1980	1979	1980	1979	1980
			Total live biomass			
MAY	44.0	222.4	41.6	236.4	15.2	142.4
JUN	110.0	203.6	81.2	234.8	81.2	173.2
JUL	175.2	228.0	160.0	338.8	113.2	217.6
AUG	260.8	288.4	206.8	339.6	201.2	288.4
SEP	222.7	183.6	257.2	322.8	330.4	234.4
			Distichlis live biomass			
MAY	25.2	61.6	21.2	26.0	9.6	128.4
JUN	93.2	176.0	28.0	30.0	78.4	160.0
JUL	142.4	134.0	31.2	63.6	108.4	200.0
AUG	224.4	98.4	31.2	22.4	196.8	185.2
SEP	212.8	112.4	68.4	41.6	268.8	82.8
			Spartina live biomass			
MAY	18.8	159.6	19.2	210.4	2.0	3.2
JUN	16.0	27.2	50.8	204.0	2.0	12.4
JUL	30.8	90.4	126.0	275.2	0.0	6.8
AUG	35.2	180.0	175.6	306.0	3.6	40.4
SEP	8.0	27.6	184.4	274.0	37.6	91.2

community change in aboveground primary production. Even though 1980 was a very dry year, aboveground primary production was higher at almost all sites and distances in 1980 (Tables 7 and 8). For both years there were no differences between the treated sites for any of the production estimates and values in 1980 ranged from a low of 376.8 g m^{-2} for the peak standing crop (Method 1) production estimate at the Water Control Site to 1360.0 g m^{-2} for the Smalley (Method 3) estimate of production at the Open Site. For comparison, production estimates in 1979 ranged from 225.2 g m^{-2} (Method 1 at the Closed Site) to 898.8 g m^{-2} (Method 3 at the Open Site). Similar to results of the biomass and nutrient analyses, several years of additional data would be required to determine if the yearly differences in production estimates were due to climatological variations or to temporal recovery responses following ditching.

4. Inter- and intra-site biomass and nutrient comparisons

As noted earlier, we believe that many of the responses were caused by overall changes within the site rather than changes that occurred only near the ditches. As described in part 1 of the METHODS section, two methods were used to test these assumptions. Comparisons were made between data collected from the random plots at each of the treated sites with data from the Control Site. Since the random plots were not affected by spoil deposition, any differences between them and the Control Site would be due to overall site responses. A second set of comparisons were made to determine if the changes that occurred between 0-20 meters from ditches also occurred in the random plots. These comparisons could provide insight into intra-site variation.

Results of inter-site comparisons of 1980 data from the random plots are shown in Tables 9 and 10). Data from 1979 are not given because, as already stated, we found that the Control Site used that year was very different from the treated

Table 7. Aboveground primary production and nutrient uptake estimates for the 4 study sites in 1979 and 1980. Means, read vertically, that are not significantly different at the 0.05 level of significant share the same superscript. Production estimates and nutrient data are g m^{-2}.

Site	Primary Production		Nitrogen		Phosphorus	
	1979	1980	1979	1980	1979	1980
	PEAK STANDING CROP (METHOD 1)					
OPEN	353.6^{A}	408.0^{A}	3.08^{A}	3.80^{A}	0.32^{A}	0.32^{A}
CLOSED	313.6^{A}	426.0^{A}	1.88^{B}	3.44^{A}	0.20^{B}	0.32^{A}
WATER CONTROL	364.0^{A}	376.8^{A}	3.24^{A}	3.88^{A}	0.32^{A}	0.36^{A}
CONTROL	225.2^{B}	420.0^{A}	1.64^{B}	4.20^{A}	0.16^{C}	0.32^{A}
	NET ABOVEGROUND PRIMARY PRODUCTION (METHOD 2)					
OPEN	421.6^{AB}	502.8^{A}	3.12^{B}	4.88^{A}	0.36^{A}	0.436^{AB}
CLOSED	362.8^{B}	479.2^{A}	1.76^{A}	4.60^{A}	0.20^{A}	0.354^{AB}
WATER CONTROL	498.4^{A}	453.9^{A}	4.56^{C}	4.84^{A}	0.36^{A}	0.452^{A}
CONTROL	233.2^{C}	496.4^{A}	1.60^{A}	4.64^{A}	0.12^{C}	0.349^{B}
	SMALLEY (METHOD 3)					
OPEN	898.8^{A}	1350.4^{A}	5.12^{A}	11.08^{A}	0.44^{A}	0.84^{A}
CLOSED	881.2^{A}	1360.0^{A}	4.20^{A}	10.04^{A}	0.40^{AB}	0.76^{A}
WATER CONTROL	859.2^{A}	1063.2^{B}	7.24^{B}	9.84^{A}	0.52^{A}	0.80^{A}
CONTROL	599.6^{B}	1078.4^{B}	4.72^{A}	8.96^{A}	0.28^{B}	0.72^{A}

Table 8. Results of Duncan's Multiple Range Tests for aboveground primary production and nutrient uptake estimates for the five distances sampled. Means, read vertically, that are not significantly different at the 0.05 significant level share the same superscript. All values are g m^{-2}.

Distance	Primary Production		Nitrogen		Phosphorus	
	1979	1980	1979	1980	1979	1980
PEAK STANDING CROP (METHOD 1)						
0	320.0^{A}	418.8^{A}	2.68^{A}	4.40^{A}	0.24^{AB}	0.32^{AB}
5	291.2^{A}	424.4^{A}	2.36^{A}	4.00^{A}	0.20^{B}	0.32^{AB}
10	334.8^{A}	416.4^{A}	2.40^{A}	3.92^{A}	0.28^{A}	0.36^{A}
15	295.2^{A}	373.2^{A}	2.32^{A}	2.92^{B}	0.24^{AB}	0.28^{B}
20	330.4^{A}	405.2^{A}	2.60^{A}	3.96^{A}	0.28^{A}	0.32^{AB}
NET ABOVEGROUND PRIMARY PRODUCTION (METHOD 2)						
0	379.6^{A}	458.4^{A}	2.96^{AB}	5.28^{A}	0.28^{AB}	0.40^{A}
5	319.2^{A}	485.6^{A}	2.60^{AB}	4.88^{AB}	0.24^{B}	0.40^{A}
10	387.6^{A}	539.2^{A}	2.64^{AB}	5.24^{A}	0.28^{AB}	0.48^{A}
15	377.6^{A}	428.4^{A}	2.28^{A}	3.88^{B}	0.24^{AB}	0.36^{A}
20	431.2^{A}	493.6^{A}	3.32^{AB}	4.40^{AB}	0.32^{A}	0.36^{A}
SMALLEY (METHOD 3)						
0	692.4^{B}	876.0^{C}	4.76^{AB}	8.40^{A}	0.34^{AB}	0.60^{B}
5	608.8^{B}	1083.2^{BC}	4.32^{B}	10.00^{A}	0.32^{B}	0.76^{AB}
10	988.8^{A}	1408.4^{A}	5.76^{AB}	10.92^{A}	0.48^{A}	0.88^{A}
15	888.8^{AB}	1420.4^{A}	5.36^{AB}	11.28^{A}	0.44^{AB}	0.84^{A}
20	870.0^{AB}	1278.0^{AB}	6.44^{A}	9.20^{A}	0.44^{AB}	0.80^{AB}

Table 9. Results of Duncan's Multiple Range Tests for comparison of 1980 data for random plots at the 3 treated sites and the Control Site. All biomass and nutrient standing stock data are in g m^{-2}. Percent (%) N and P in live and dead biomass are as indicated. Means, read horizontally, that are not significantly different at the 0.05 level of significance share the same superscript.

VARIABLE	OPEN	CLOSED	WATER CONTROL	CONTROL
Total biomass	982.4^{A}	920.0^{A}	840.4^{A}	598.4^{B}
Live biomass	214.0^{A}	260.4^{A}	244.8^{A}	144.4^{B}
Dead biomass	768.0^{A}	659.6^{AB}	595.6^{B}	456.4^{C}
% N in live biomass	0.70^{B}	0.74^{B}	0.76^{B}	0.98^{A}
% N in dead biomass	0.63^{B}	0.54^{C}	0.67^{AB}	0.72^{A}
N in live biomass	1.40^{AB}	1.80^{AB}	1.92^{A}	1.28^{B}
N in dead biomass	4.92^{A}	3.60^{B}	4.12^{AB}	3.28^{B}
Total nitrogen	6.32^{A}	5.40^{AB}	6.04^{A}	4.56^{B}
% P in live biomass	0.08^{A}	0.08^{A}	0.08^{A}	0.08^{A}
% P in dead biomass	0.04^{A}	0.03^{A}	0.04^{A}	0.03^{A}
P in live biomass	0.12^{A}	0.16^{A}	0.16^{A}	0.08^{B}
P in dead biomass	0.32^{A}	0.24^{B}	0.24^{B}	0.16^{C}
Total phosphorus	0.48^{A}	0.40^{A}	0.40^{A}	0.24^{B}

Table 10. Results of Duncan's Multiple Range Tests for intra-site comparisons for biomass and nutrient variables. All values are g m^{-2} except for % N and P in live and dead biomass. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript. R = random plots.

	DISTANCES	Total biomass	Live biomass	Dead biomass	% N in live biomass	% N in dead biomass	Total
OPEN	0	603.6^{B}	194.4^{AB}	408.8^{C}	1.18^{A}	0.78^{A}	5.16^{A}
	5	647.2^{B}	162.0^{AB}	481.2^{CB}	1.08^{A}	0.73^{AB}	5.00^{A}
	10	787.2^{B}	154.4^{AB}	632.4^{AB}	0.97^{AB}	0.68^{AB}	5.60^{A}
	15	783.6^{B}	130.0^{B}	653.2^{AB}	1.10^{A}	0.69^{AB}	5.76^{A}
	20	774.0^{B}	120.8^{B}	653.2^{AB}	0.92^{A}	0.66^{B}	5.24^{A}
	R	982.4^{A}	214.4^{A}	768.0^{A}	0.70^{B}	0.63^{B}	6.32^{A}
CLOSED	0	488.8^{C}	226.8^{A}	261.6^{B}	0.71^{A}	0.52^{A}	3.00^{C}
	5	553.2^{C}	227.2^{A}	326.0^{B}	0.73^{A}	0.56^{A}	3.32^{BC}
	10	747.6^{B}	193.2^{A}	554.4^{A}	0.69^{A}	0.53^{A}	4.36^{AB}
	15	760.8^{B}	196.4^{A}	564.4^{A}	0.71^{A}	0.60^{A}	4.72^{A}
	20	808.0^{AB}	205.2^{A}	602.4^{A}	0.79^{A}	0.56^{A}	4.84^{A}
	R	920.0^{A}	260.4^{A}	663.6^{A}	0.74^{A}	0.54^{A}	5.40^{A}
WATER CONTROL	0	466.0^{B}	159.2^{B}	306.8^{B}	1.12^{AB}	0.70^{A}	3.76^{B}
	5	474.8^{B}	126.4^{B}	348.0^{B}	1.09^{AB}	0.69^{AB}	3.80^{B}
	10	555.2^{B}	136.0^{B}	418.8^{B}	1.29^{A}	0.75^{A}	4.56^{B}
	15	551.6^{B}	130.4^{B}	421.3^{B}	0.99^{B}	0.72^{A}	4.08^{B}
	20	546.8^{B}	152.4^{B}	382.4^{B}	1.04^{B}	0.73^{A}	4.28^{B}
	R	842.4^{A}	244.4^{A}	593.6^{A}	0.76^{C}	0.67^{A}	6.04^{A}

Table 10. (Continued)

	DISTANCES	N in live biomass	N in dead biomass	% P in live biomass	% P in dead biomass	P in live biomass	P in dead biomass	Total phosphorus
OPEN	0	2.04^{A}	3.12^{B}	0.09^{A}	0.04^{A}	0.12^{A}	0.16^{C}	0.32^{B}
	5	1.56^{AB}	3.40^{B}	0.10^{A}	0.04^{A}	0.12^{A}	0.20^{CB}	0.36^{B}
	10	1.36^{AB}	4.24^{AB}	0.10^{A}	0.04^{A}	0.12^{A}	0.24^{ABC}	0.36^{B}
	15	1.24^{AB}	4.48^{AB}	0.11^{A}	0.04^{A}	0.12^{A}	0.24^{ABC}	0.36^{B}
	20	1.08^{B}	4.16^{AB}	0.09^{A}	0.04^{A}	0.08^{A}	0.28^{AB}	0.36^{B}
	R	1.40^{AB}	4.92^{A}	0.08^{A}	0.04^{A}	0.12^{A}	0.32^{A}	0.48^{A}
CLOSED	0	1.60^{A}	1.36^{B}	0.06^{A}	0.03^{A}	0.12^{A}	0.08^{C}	0.20^{C}
	5	1.60^{A}	1.72^{B}	0.07^{A}	0.03^{A}	0.12^{A}	0.08^{CB}	0.24^{BC}
	10	1.36^{A}	3.00^{A}	0.08^{A}	0.03^{A}	0.12^{A}	0.20^{A}	0.32^{AB}
	15	1.36^{A}	3.36^{A}	0.08^{A}	0.03^{A}	0.12^{A}	0.20^{A}	0.36^{A}
	20	1.60^{A}	3.24^{A}	0.08^{A}	0.03^{A}	0.12^{A}	0.16^{AB}	0.32^{AB}
	R	1.80^{A}	3.60^{A}	0.08^{A}	0.04^{A}	0.16^{A}	0.24^{A}	0.40^{A}
WATER CONTROL	0	1.56^{A}	2.12^{B}	0.10^{AB}	0.04^{A}	0.12^{A}	0.12^{B}	0.24^{B}
	5	1.28^{A}	2.52^{B}	0.10^{AB}	0.04^{A}	0.08^{A}	0.12^{B}	0.24^{B}
	10	1.48^{A}	3.04^{B}	0.10^{AB}	0.05^{A}	0.12^{A}	0.20^{AB}	0.36^{AB}
	15	1.12^{A}	2.96^{B}	0.10^{AB}	0.04^{A}	0.08^{A}	0.16^{AB}	0.28^{B}
	20	1.40^{A}	2.76^{B}	0.11^{A}	0.04^{A}	0.08^{A}	0.16^{AB}	0.28^{B}
	R	1.92^{A}	4.12^{A}	0.083^{B}	0.04^{A}	0.16^{A}	0.24^{A}	0.40^{A}

sites. In 1980, total biomass, live biomass, and dead biomass were significantly greater in the random plots at the three treated sites compared to the Control Site (Table 9). Nutrient standing stocks for nitrogen and phosphorus in live, dead, and total biomass showed similar patterns (Table 9). Nitrogen concentrations of live and dead biomass, in contrast, were significantly higher at the Control Site.

A comparison of nitrogen concentration in live and dead biomass between the random plots and 0-20 meter distances within each site showed higher nitrogen concentrations in the spoil area (Table 10). These results suggest that the overall site management caused tissue N levels to be less in areas that were removed far enough from ditches so that they were not affected by spoil. Very little spoil was deposited at 20m yet N levels in live biomass were significantly higher at this distance in the Open and Water Control Sites as compared to % N in live biomass in the random plots. There is a distinct trend of increasingly higher tissue nutrient levels towards the ditches (Table 10). Further away, in areas not impacted by spoil, the data suggest that tissue N concentrations may even be suppressed (Table 10). Although phosphorus concentrations in live and dead biomass were less in the random plots, the differences were not significant (Table 10).

There were no differences between the random plots and any of the 5 distances for live biomass, % N, and % P in live and dead biomass at the Closed Site (Table 10). Differences in total biomass, total N and total P were due to the presence of less dead biomass near the ditches.

These data in Table 10 clearly show that biomass, both live and dead, have not yet reached premanagement levels. Live biomass recovery seems to be greatest near the ditches while dead (litter) biomass will not return to premanagement levels for at least one more year.

Aboveground primary production was significantly greater in random plots at the treated sites in 1980 (Table 11) and, in most instances, the amounts of N and P followed the same pattern (Table 11). There were very few significant intra-site differences in aboveground primary production (Table 12) although estimated production was greatest in the random plots at all sites. There were few intra-site differences and no overall pattern in estimated N or P uptake in aboveground production (Table 12)

5. Decomposition

Tables 13 and 14 contain results of the Duncan's multiple range tests for site and location effects on weight loss and nutrient content of decomposing D. spicata and S. patens shoots after 525 days. Average weights of D. spicata shoots remaining in the litter bags was significantly greater at the Open, Closed and Water Control Sites (Table 13). S. patens showed a similar pattern for shoot tops, but not shoot bases nor tops and bottoms combined (Table 14). The data, therefore, indicate that decomposition occurs more slowly in ditched areas.

Except for phosphorus remaining in S. patens tops and bottoms combined (Table 14), litter samples at the Open and Water Control sites contained more nitrogen and phosphorus than samples from Closed and Control Sites. Higher nitrogen values in litter at the Open and Water Control Sites (Tables 13 and 14) were due to slower rates of weight losses (i.e., higher average concentration values of weight remaining after 525 days) and not higher N concentrations of the litter. Litter nitrogen concentration averaged 0.73% and 0.68% for D. spicata and S. patens at the Control Site as compared to a range at the other sites of 0.55 - 0.69% for D. spicata and 0.58 - 0.64% for S. patens.

With the exception of total phosphorus in S. patens shoots (Table 14), there were no location effects for any of the variables tested nor were there any

Table 11. Results of Duncan's Multiple Range Tests of 1980 production estimates and associated nutrient assimilation for random plots at the 3 treated sites and Control Site. All values are g m^{-2}. Means, read horizontally, that are not significantly different at the 0.05 level of significance share the same superscript.

	OPEN	CLOSED	WATER CONTROL	CONTROL
Peak Standing Crop	455.2^{AB}	515.2^{A}	529.2^{A}	314.8^{B}
N in Peak Standing Crop Estimate	3.48^{A}	3.52^{A}	4.80^{A}	3.12^{A}
P in Peak Standing Crop Estimate	0.36^{A}	0.32^{AB}	0.40^{A}	0.24^{B}
Net Aboveground Primary Production Estimate	552.4^{AB}	667.2^{A}	553.2^{AB}	372.0^{B}
N in Net Aboveground Primary Production Estimate	3.96^{A}	4.80^{A}	5.60^{A}	3.48^{A}
P in Net Aboveground Primary Production Estimate	0.44^{A}	0.44^{A}	0.48^{A}	0.24^{B}
Smalley Method	1367.2^{A}	1547.2^{A}	1129.2^{AB}	808.8^{B}
N in Smalley Estimate	6.44^{AB}	9.52^{AB}	11.60^{A}	6.68^{B}
P in Smalley Estimate	0.84^{A}	0.92^{A}	0.84^{A}	0.52^{B}

Table 12. Results of Duncan's multiple range tests of intra-site comparisons for production related variables. All values are g m^{-2} and means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript. R represents random plots, N = nitrogen, P = phosphorus.

	DISTANCE	Peak standing (PSC)	N in PSC estimate	P in PSC estimate	Net aboveground primary production (NAPP)	N in NAPP estimate	P in NAPP estimate	Smalley Method (NPS)	N in NPS estimate	N in NPS estimate
OPEN	0	434.0^{A}	4.88^{A}	0.36^{A}	551.2^{A}	5.80^{A}	0.44^{A}	942.4^{A}	8.04^{A}	0.64^{A}
	5	409.6^{A}	4.36^{A}	0.36^{A}	445.6^{A}	4.92^{A}	0.40^{A}	986.8^{B}	10.60^{A}	0.72^{AB}
	10	470.8^{A}	3.28^{A}	0.32^{A}	578.0^{A}	4.64^{A}	0.40^{A}	1168.0^{B}	8.96^{A}	0.64^{B}
	15	385.6^{A}	3.28^{A}	0.32^{A}	468.4^{A}	4.68^{A}	0.44^{A}	2036.4^{A}	17.24^{A}	1.08^{A}
	20	338.8^{A}	3.24^{A}	0.28^{A}	470.8^{A}	4.32^{A}	0.44^{A}	1614.8^{AB}	10.44^{A}	1.00^{AB}
	R	455.2^{A}	3.48^{A}	0.40^{A}	552.8^{A}	3.96^{A}	0.44^{A}	1367.2^{B}	9.80^{A}	0.84^{AB}
CLOSED	0	420.8^{B}	4.20^{A}	0.28^{A}	412.0^{B}	5.40^{A}	0.32^{A}	908.8^{C}	8.52^{A}	0.44^{B}
	5	499.6^{A}	3.96^{A}	0.32^{A}	535.6^{AB}	5.00^{A}	0.32^{A}	1186.0^{CB}	8.84^{A}	0.60^{AB}
	10	386.4^{B}	3.36^{ABC}	0.32^{A}	502.0^{AB}	4.64^{A}	0.40^{A}	1781.6^{A}	11.32^{A}	1.04^{AB}
	15	398.8^{B}	2.56^{C}	0.28^{A}	407.6^{B}	3.72^{A}	0.32^{A}	1262.8^{BC}	10.16^{A}	0.80^{AB}
	20	424.8^{B}	3.16^{BC}	0.32^{A}	538.0^{AB}	4.26^{A}	0.36^{A}	1661.2^{AB}	11.24^{A}	0.80^{AB}
	R	515.2^{A}	3.52^{AB}	0.36^{A}	667.2^{A}	4.80^{A}	0.44^{A}	1547.2^{AB}	9.52^{A}	0.92^{A}
WATER	0	359.6^{B}	3.60^{AB}	0.32^{B}	398.0^{A}	4.28^{AB}	0.36^{B}	720.0^{B}	8.00^{B}	1.00^{B}
CONTROL	5	368.6^{B}	4.08^{AB}	0.28^{BC}	521.2^{A}	5.84^{A}	0.48^{AB}	969.6^{AB}	10.76^{AB}	0.76^{AB}
	10	427.6^{AB}	5.24^{A}	0.60^{A}	515.2^{A}	6.16^{A}	0.64^{A}	1402.0^{A}	12.96^{A}	1.04^{A}
	15	354.4^{B}	2.80^{B}	0.24^{C}	400.0^{A}	3.32^{B}	0.32^{B}	1270.0^{AB}	6.27^{AB}	0.76^{AB}
	20	373.2^{B}	3.72^{AB}	0.28^{BC}	434.8^{A}	4.44^{AB}	0.32^{B}	954.8^{AB}	8.20^{B}	0.80^{AB}
	R	529.6^{A}	4.80^{A}	0.44^{B}	553.2^{A}	5.60^{A}	0.48^{AB}	1129.2^{AB}	11.60^{AB}	0.92^{AB}

Table 13. Results of Duncan's Multiple Range Tests for sites and location effects on decomposing *D. spicata* litter. Data are means (g) for the 525 day study period. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript.

SITE EFFECTS

	Total Shoot weight	Weight of shoot tops only	Weight of shoot bases only	Total nitrogen in shoots	Total nitrogen in shoots
OPEN	3.95^{A}	1.88^{A}	2.07^{A}	$.027^{A}$	$.0015^{A}$
CLOSED	3.93^{A}	1.90^{A}	2.03^{A}	$.022^{B}$	$.0011^{B}$
WATER CONTROL	4.06^{A}	1.96^{A}	2.10^{A}	$.026^{A}$	$.0012^{C}$
CONTROL	3.58^{B}	1.67^{B}	1.91^{B}	$.024^{B}$	$.0010^{B}$

LOCATION EFFECTS

SPOIL	3.99^{A}	1.92^{A}	2.07^{A}	$.025^{A}$	$.0013^{A}$
NONSPOIL	3.87^{A}	1.84^{A}	2.02^{A}	$.024^{A}$	$.0012^{A}$

Table 14. Results of Duncan's Multiple Range Tests for site and location effects on decomposing S. patens litter. Data are means (g) for the 525 day study period. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript.

SITE EFFECTS

	Total shoot weight	Weight of shoot tops only	Weight of shoot bases only	Total nitrogen in shoots	Total phosphorus in shoots
OPEN	3.52^{A}	1.65^{A}	1.86^{A}	$.023^{A}$	$.0015^{A}$
CLOSED	3.56^{AB}	1.73^{A}	1.84^{A}	$.020^{B}$	$.0014^{B}$
WATER CONTROL	3.76^{B}	1.79^{A}	1.97^{A}	$.024^{A}$	$.0014^{B}$
CONTROL	3.29^{A}	1.51^{B}	1.77^{A}	$.019^{B}$	$.0009^{C}$

LOCATION EFFECTS

	Total shoot weight	Weight of shoot tops only	Weight of shoot bases only	Total nitrogen in shoots	Total phosphorus in shoots
SPOIL	3.62^{A}	1.72^{A}	1.90^{A}	$.022^{A}$	$.0014^{A}$
NONSPOIL	3.53^{A}	1.67^{A}	1.85^{A}	$.021^{A}$	$.0013^{B}$

significant site location interactions. This indicates that differences in decomposition were due to overall site effects.

Figures 4 and 5 compare weight loss data for D. spicata and S. patens at all sites. As can be seen, litter lost weight faster for both species at the Control Site compared to the treated sites. Litter weight data were also used to calculate instantaneous rates of decomposition (Olson 1963). The decomposition rates (k) were then analyzed using two-way factorial analyses of variance to determine if there were site and/or location effects. There were no location and site x location interactions for k but there were significant site effects for both species. The decomposition rate of D. spicata at the Control Site (k=-0.052% day^{-1}) was greater than at the treated sites (k=-0.038% day^{-1} at Open Site, -0.031% day^{-1} at the Closed Site, and -0.036% day^{-1} at the Water Control Site). There were no significant differences between the treated sites when k values were compared using Duncan's multiple range tests. Spartina patens decomposition occurred fastest at the Open (-0.069% day^{-1}) and Control Sites (-0.061 day^{-1}) but the only significant site differences were between the Open Site and the Closed (k= -0.052% day^{-1}) and Water Control (k=-0.049% day^{-1}) Sites.

6. Density, height, and reproductive phenology

A. Density

Monthly sampling of shoot densities in permanent plots clearly demonstrates that the vegetation is still undergoing changes. Density of all species ranged from 714 - 1990 plants m^{-2} in 1979 to 1321 - 3986 plants m^{-2} in 1980 (Tables 15 and 16). Average density of both dominants increased in 1980 (Table 15) , but increases in S. patens were particularly striking. Average S. patens shoot density increased from 36 to 122 plants per m^{2} (339%) at the Open Site, from 19 to 97 plants per m^{2} (510%) at the Water Control Site and from 1445 to 3401 plants per m^{2} (235%) at the Closed

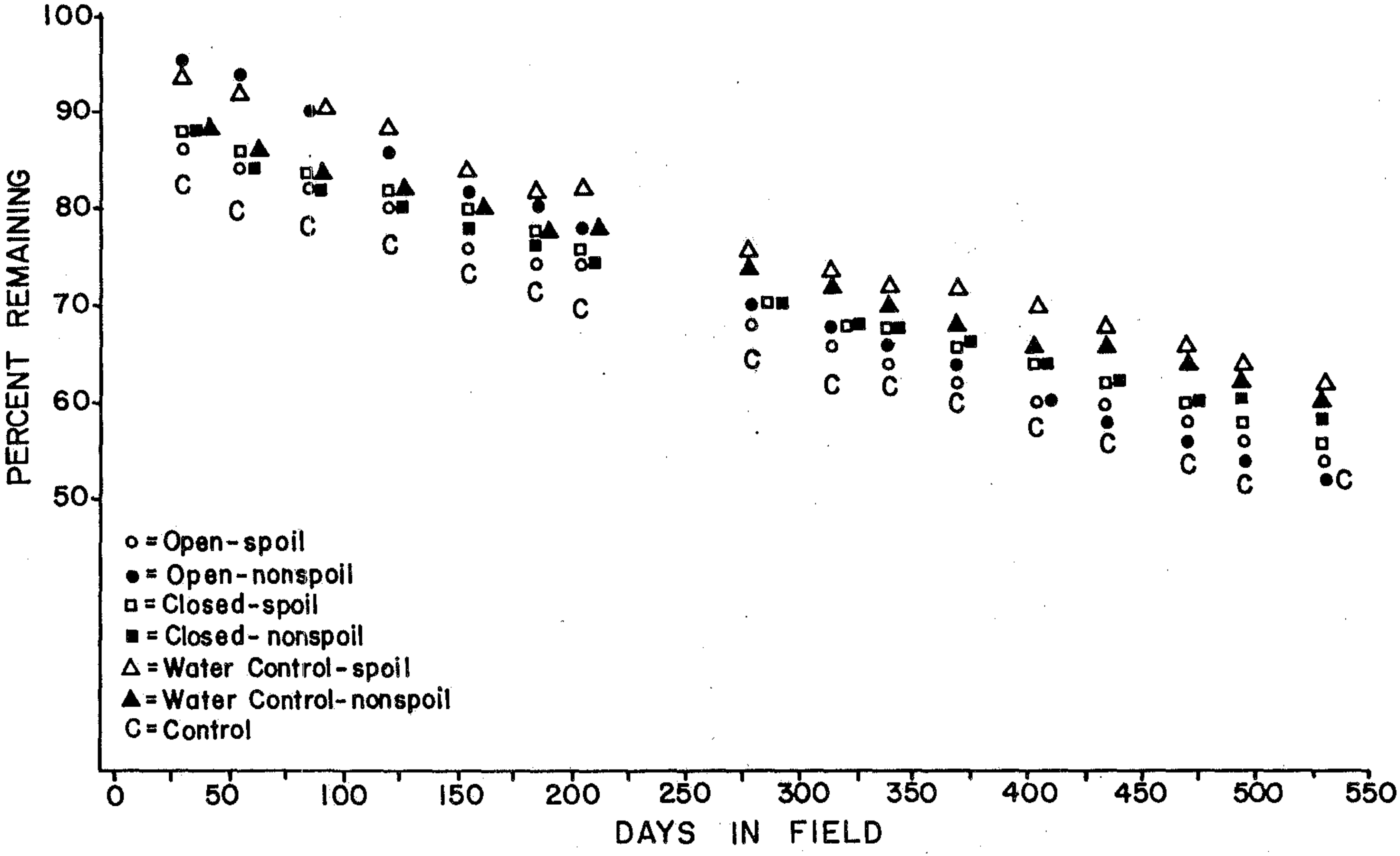


Figure 4. Weight loss data for *D. spicata* shoots at the four study sites. Each point represents the mean of duplicate samples for shoot tops and losses combined.

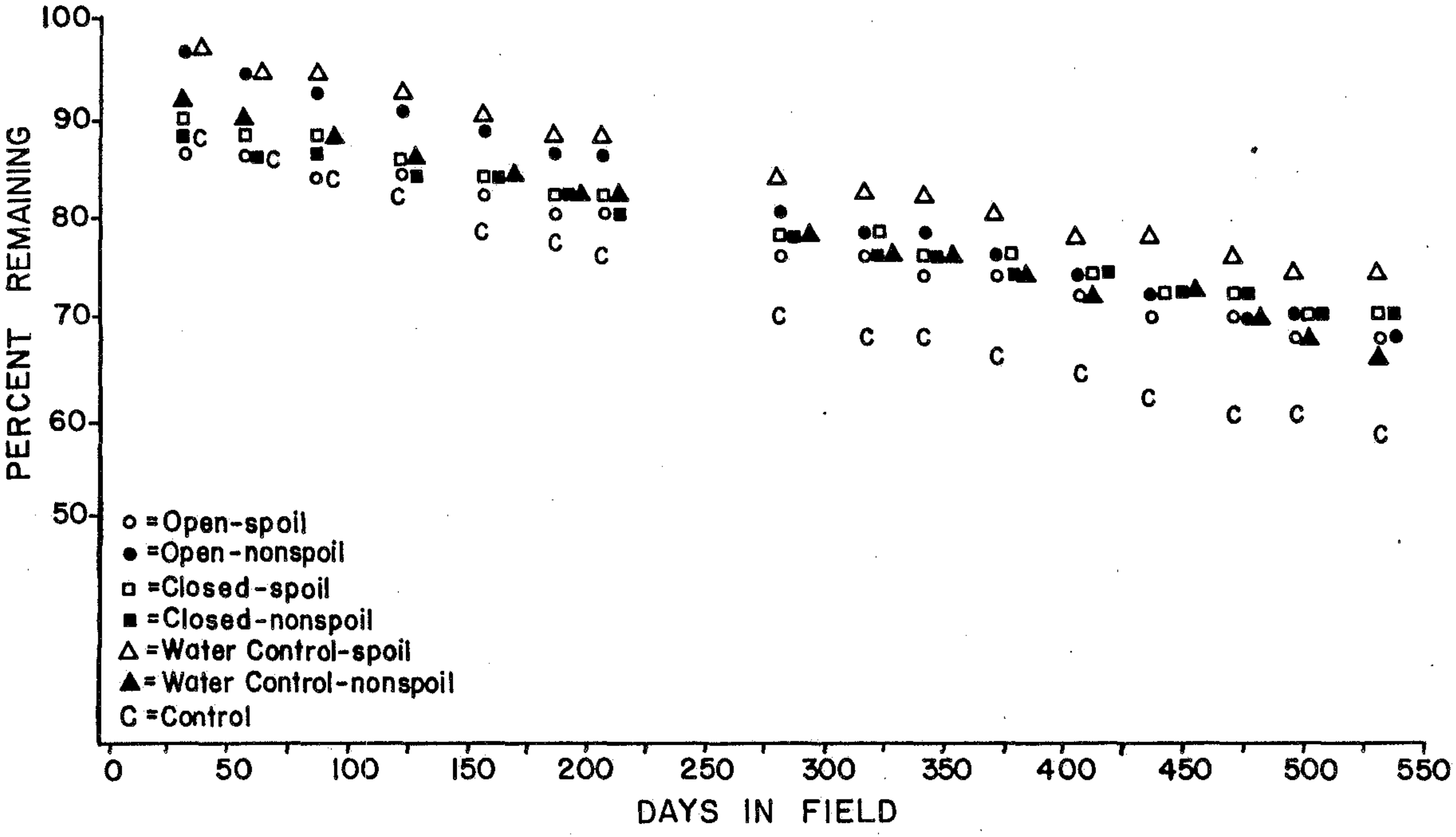


Figure 5. Weight loss data for S. patens shoots at the four study sites. Each point represents the mean of duplicate samples for shoot tops and bottoms combined.

Table 15. Results of Duncan's Multiple Range Tests for site effects on shoot density (plants m^{-2}) of all plants, *D. spicata*, and *S. patens* in permanent plots at the three treated sites and two control sites. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript.

Site	Density of all plants		Density of *D. spicata*		Density of *S. patens*	
	1979	1980	1979	1980	1979	1980
OPEN	1053^{B}	1321^{D}	1016^{A}	1193^{B}	36^{C}	122^{C}
CLOSED	1990^{A}	3986^{A}	544^{B}	583^{C}	1445^{A}	3401^{A}
WATER CONTROL	1085^{B}	1743^{C}	1064^{A}	1635^{A}	19^{C}	97^{C}
CONTROL	714^{C}	2166^{B}	406^{B}	451^{C}	303^{B}	1712^{B}

Table 16. Results of Duncan's Multiple Range Tests for distance effects on shoot density (plants m^{-2}) of all plants, D. spicata, and S. patens in permanent plots. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript.

Distance	Density of all plants		Density of D. spicata		Density of S. patens	
	1979	1980	1979	1980	1979	1980
0	1159^{B}	2103^{B}	791^{AB}	1062^{A}	366^{B}	1035^{B}
5	1415^{A}	2693^{A}	940^{A}	1117^{A}	474^{AB}	1570^{A}
10	1179^{B}	2429^{AB}	726^{B}	972^{ABC}	452^{AB}	1450^{A}
15	1138^{B}	2161^{B}	683^{B}	869^{BC}	451^{AB}	1287^{AB}
20	1163^{B}	2134^{B}	649^{B}	806^{C}	511^{AB}	1324^{AB}

Site. Comparing densities between 0 and 20 meters, *D. spicata* shoot densities were significantly higher near the ditches (Table 16) while *S. patens* showed the opposite trend. Yearly differences were also obvious at all distances (Table 16), with large increases in overall shoot density at all distances and particularly large increases in *S. patens* at all distances.

Because the Control Site was changed after the first year, density data were examined for the three treated sites for 1980 only (Table 17). Density of both species in the permanent plots increased at almost all distances at the three sites, but the increases were most striking for *S. patens*, especially at the Closed Site (Table 17). *D. spicata* changes were not as pronounced (Table 17) and it would appear that *D. spicata* was affected by the dry conditions that existed in 1980 (Table 18). Particularly noteworthy was a sharp decrease in *D. spicata* densities at all sites between August and September after a summer of very little precipitation and almost no surface flooding events.

B. Height

D. spicata and *S. patens* shoots were significantly longer at each of the treated sites in 1979 and the response persisted in 1980 (Table 19). *D. spicata* plants averaged 21.4 cm at the Control Site in 1979 which was significantly less than the range of 24.4 - 25.9 cm for plants at the three treated sites. Plants were also taller at the treated sites in 1980 and ranged from 27.2 - 30.3 cm at the treated sites compared to 24.1 cm at the Control Site.

S. patens shoot lengths at the treated sites were not very different between years, but the average shoot length in both 1979 and 1980 was significantly greater at the treated compared to the Control Sites.

Table 17. Density of D. spicata and S. patens shoots between 0 and 20 meters at the three treated sites in 1980. All values are average number of plants per m^2.

	D. spicata						*S. patens*					
Site	OPEN		CLOSED		WATER CONTROL		OPEN		CLOSED		WATER CONTROL	
Distance	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
0	798	1123	592	540	1086	1517	43	147	1171	2897	0	0
5	1283	1310	571	496	1211	2203	50	228	1633	3638	0	0
10	895	958	562	802	1373	1796	57	155	1624	3942	0	0
15	1157	1218	391	550	984	1427	27	51	1288	3474	1	4
20	951	1294	605	523	664	1153	2	31	1512	3054	95	480

Table 18. Average monthly shoot density of D. *spicata* and *S. patens* at the three treated sites. All values are number of plants per m^2.

	D. spicata						*S. patens*					
Site	OPEN		CLOSED		WATER CONTROL		OPEN		CLOSED		WATER CONTROL	
Month	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
APR		943		285		1330		63		1801		93
MAY	946	1678	757	689	701	2453	4	106	1315	3143	1	106
JUN	972	1409	585	721	778	1844	12	81	1113	3407	9	70
JUL	1084	1345	543	727	969	1502	20	199	1248	3839	0	38
AUG	871	1150	491	622	943	1725	33	119	815	4089	20	156
SEP	1413	629	662	450	1886	955	82	165	2300	4128	45	117
OCT	1117		460		1215		64		1737		25	
NOV	713		310		957		34		1590		35	

Table 19. Results of Duncan's Multiple Range Tests for site and distance effects on the length (cm) of *S. patens* and *D. spicata* shoots measured in permanent plots. Means, read vertically, that are not significantly different at the 0.05 level of significance share the same superscript.

Site	*D. spicata*		*S. patens*	
	1979	1980	1979	1980
OPEN	25.9^{A}	27.2^{B}	32.8^{A}	32.1^{A}
CLOSED	25.3^{AB}	27.4^{B}	30.4^{A}	33.0^{A}
WATER CONTROL	24.4^{B}	30.3^{A}	33.0^{A}	34.1^{A}
CONTROL	21.4^{C}	24.1^{C}	23.6^{B}	28.0^{B}

Distance (m)				
0	24.1^{A}	25.9^{C}	27.1^{A}	31.5^{AB}
5	23.8^{A}	28.0^{AB}	28.8^{A}	30.6^{AB}
10	24.1^{A}	27.6^{AB}	31.0^{B}	30.3^{B}
15	24.9^{A}	28.4^{A}	28.5^{A}	31.1^{AB}
20	24.6^{A}	26.9^{BC}	27.3^{A}	31.8^{A}

C. Reproductive phenology

Permanent plots were sampled monthly to monitor the density of reproductive shoots of *D. spicata* and *S. patens*. No attempt was made to determine whether or not seeds were produced and the data can only be interpreted as a crude measure of overall reproductive effort.

S. patens did not produce flowering shoots at the Water Control and Control Sites in 1979 and reproductive activity was very low in permanent plots at the Open Site (Table 20). There were two peaks in reproductive activity at the Closed Site (August and September) in 1979. *Spartina* reproductive activity in 1980 was similar to that of 1979 but the large range of values measured did not permit any yearly comparisons.

D. spicata flowered later than *S. patens* at all sites and reproductive shoots were present for a shorter period of time. *D. spicata* flowered at each of the treated sites during both years and the greatest number of reproductive shoots occurred at the Open and Water Control sites where *D. spicata* was the dominant species. The large range in numbers of reproductive shoots did not permit any statistical analysis of site effects.

7. Submersed vegetation

Submersed vegetation, primarily *Ruppia*, has invaded ditches and pothole ponds at all sites (Table 21). There are no intra-site differences between ditches and ponds but inter-site comparisons show that more areas have been invaded at the Closed and Water Control Sites. This suggests that invasion will occur faster in managed areas that do not experience frequent and dramatic changes in water levels.

Table 20. Number of reproductive shoots per m^2 ($\pm$ standard error) of S. patens and D. spicata in permanent plots. Plots were sampled monthly throughout the study but data are presented for only those dates during which reproductive shoots were present in at least 1 plot. Values in parentheses are ranges.

	1979				1980			
Site	14 JUN	12 JUL	7 AUG	12 SEP	19 JUN	16 JUL	26 AUG	2 OCT
				S. patens				
OPEN	0	3 ± 2 (0 - 32)	0	2 ± 1 (0 - 16)	0	10 ± 10 (0 - 144)	11 ± 11 (0 - 96)	0
CLOSED	19 ± 10 (0 -128)	59 ± 30 (0 -272)	19 ± 13 (0 -160)	56 ± 22 (0 - 256)	3 ± 2 (0 - 16)	26 ± 10 (0 - 16)	21 ± 11 (0 - 77)	0
WATER CONTROL	0	0	0	0	0	0	0	0
CONTROL	0	0	0	0	16 ± 10 (0 - 77)	50 ± 22 (0 -288)	0	0
				D. spicata				
OPEN	0	0	24 ± 16 (0 -224)	206 ± 62 (0 -704)	0	0	124 ± 30 (0 -368)	0
CLOSED	0	0	0	53 ± 22 (0 - 192)	0	0	13 ± 10) (0 - 144)	0
WATER CONTROL	0	0	0	78 ± 29 (0 -336)	0	0	94 ± 32) (0 -432)	54 ± 16 (0 -192)
CONTROL	0	0	0	0	0	0	37 ± 16 (0 - 192)	0

Table 21. Frequency data for submersed vegetation in ditches and potholes. All values are mean percentages for 25 ditches and 25 potholes that were sampled at each site. There were no ditches at the Control Site and this is indicated with a dash (-). Species (R = *Ruppia*, C = *Chara*, E = *Eleocharis*) are shown in parenthesis.

Site	Ditches	Ponds
Open	16% (R)	16% (R) 8% (E)
Closed	52% (R)	59% (R)
Water Control	92% (R)	56% (R)
Control	-	84% (R) 8% (C)

IV. WATER QUALITY STUDIES

A. METHODS

1. Inter- and intra-site comparisons

Monthly grab samples were collected for a sixteen month period between April 1979 and October 1980 from one pond and ditch at each site. The samples were collected just below the water surface in acid washed polyethylene bottles, acidified immediately, and placed on ice prior to being returned to the laboratory where they were analyzed for nitrate, ammonia, total and dissolved Kjeldahl nitrogen and total and dissolved phosphorus. Phosphorus and nitrogen parameters were analyzed with standard procedures found in APHA (1976), King (1932), Strickland and Parsons (1965), and Richards and Kletsch (1964).

2. Tidal cycle studies

Twelve tidal cycle studies were conducted at the Open Site between May 1979 and October 1980 to monitor nutrient concentrations and patterns of exchange between that manipulated site and the adjacent estuary. Five tidal cycle studies were also conducted at the Control Site between April and October 1980. Water samples and flow data were taken from a ditch that connected the Open Site to the estuary. At the Control Site a wooden flume was constructed to fit into the creek so that a cross-sectional area of constant dimension could be used. Preliminary studies were conducted to determine how often it was necessary to collect water samples and to determine how frequently, and where to take flow measurements that would represent the average flow rate through the two sample sites. As a result of those studies, water was collected every two hours and flow data hourly. Sampling was initiated at either morning high slack or low slack tide and continued until the next high slack or low slack tide occurred. Analysis of the water samples was similar to that stated above for water quality samples. Flow measurements were made with an electromagnetic flow meter. Hourly flow data (m sec^{-1}) were combined with water level (m) and cross-sectional (m^2) data to calculate total hourly water flux (m^3) through the sample sites. Water quality data were then combined with flux data to estimate total amounts of material transported for each time interval, and for each ebb and flood tide.

B. RESULTS

1. Inter- and Intra-site comparisons

Complete listings of the water quality data are found in Appendices B, C, D, and E and only selected data are used in this section of the report to demonstrate typical patterns. Water quality data were analyzed for temporal trends as well as inter- and intra-site comparisons. When comparisons were made between ponds and ditches in the Control Site to similar areas in the treated sites, there were no major differences in water quality parameters monitored between April 1979 and October 1980. At all sites, including control areas, concentrations of all nutrients were generally higher in the ponds and ditches than in the adjacent estuary. Figure 6, as an example, shows temporal patterns for concentration of total Kjeldahl nitrogen and ammonia in ditches at the 3 treated sites with concentrations in the estuary and in creeks at the Control Sites. Comparing the treated sites, concentrations of ammonia and total Kjeldahl nitrogen were higher at the Water Control Site during much of 1979. This may have been a response to the management activity since that site was ditched last and water sampling began almost immediately upon completion of the ditching operation. In contrast, Open and Closed Sites had been recovering for longer periods of time before sampling began and, for ammonia, there were no noticeable differences between those 2 sites and the Control Sites. Lowest concentrations of both forms of nitrogen

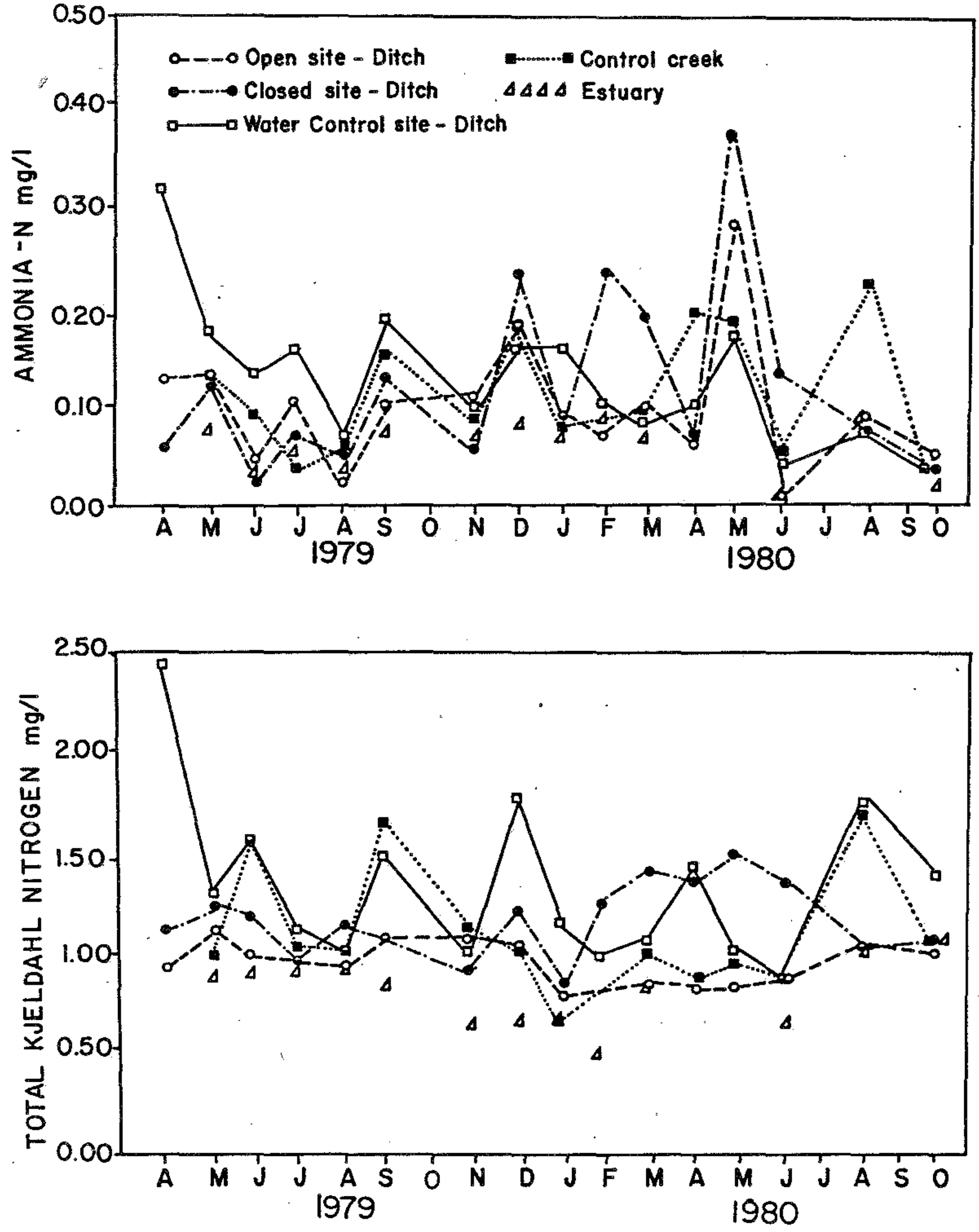


Figure 6. This diagram contains temporal data for total Kjeldahl nitrogen and ammonia for ditches at the three treated sites, natural creeks at the Control Sites, and the adjacent estuary.

occurred in the estuary throughout the study.

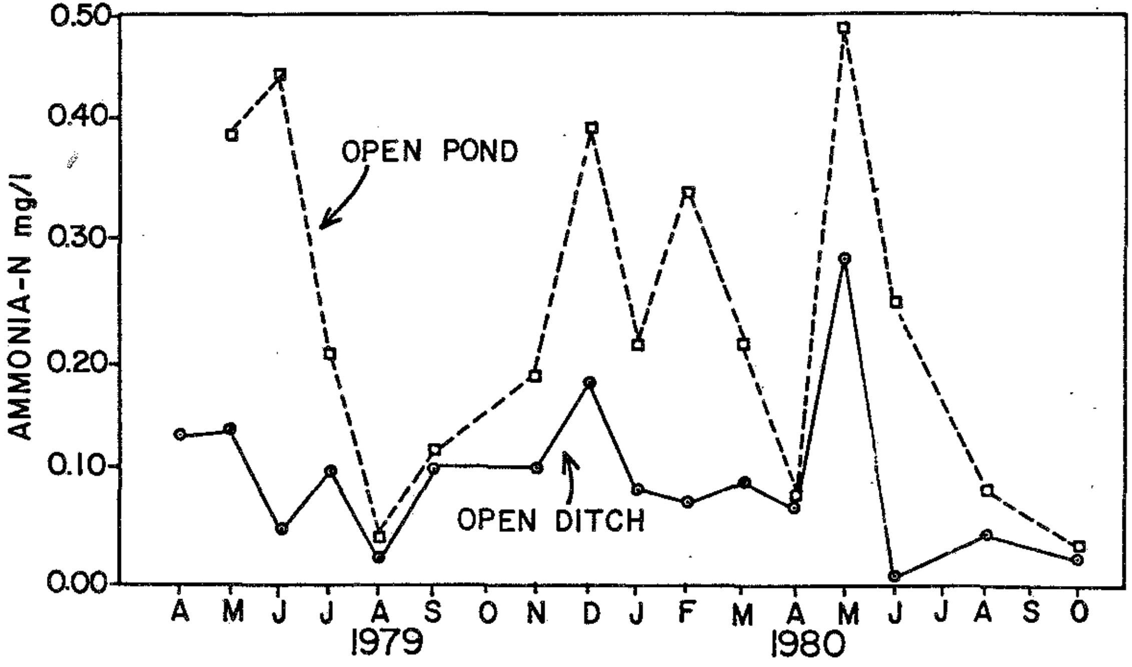
Ditches at the Water Control and Closed Sites, in general usually had higher concentrations of total Kjeldahl nitrogen than the Open Site (Fig. 6). Though both the Open and Control Sites had free tidal exchange with the estuary, the Open Site almost always had lower concentrations of Kjeldahl nitrogen (Fig. 6). Although it is only speculative, this difference could be due to the lack of an established benthic community within the ditches at the Open Site. The Control Site, in comparison, had a greater density of snails and the stream banks contained numerous animal burrows.

Comparing ponds to ditches, concentrations of all forms of nitrogen were usually higher in the ponds (Fig. 7), and especially for ammonia (Fig. 8) were almost always more variable in ponds than in the ditches. Higher concentrations of nutrients and greater variability would be expected to occur in the ponds which are shallow (Lesser 1982) and more susceptible to bioturbation and other forms of agitation (e.g., wind). Another example is shown in Fig. 9 which is a comparison of total and dissolved Kjeldahl nitrogen concentration in the ditch and pond at the Open Site. Concentrations of both nutrients were higher in ponds except between September and November, 1979.

Unlike nitrogen, total and dissolved phosphorus concentrations did not differ significantly between sites nor within sites. As an example, Fig. 10 shows phosphorus data for the pond and ditch at the Open Site. Dissolved phosphorus concentrations were almost always less than 0.05 mg/ℓ and differences between sample sites were minimal. For total phosphorus, there were no within site differences in 1979 and concentrations were slightly lower in the ponds in 1980.

2. <u>Tidal cycle studies</u>

Nutrient concentration data for the tidal cycle studies are in Appendix C and



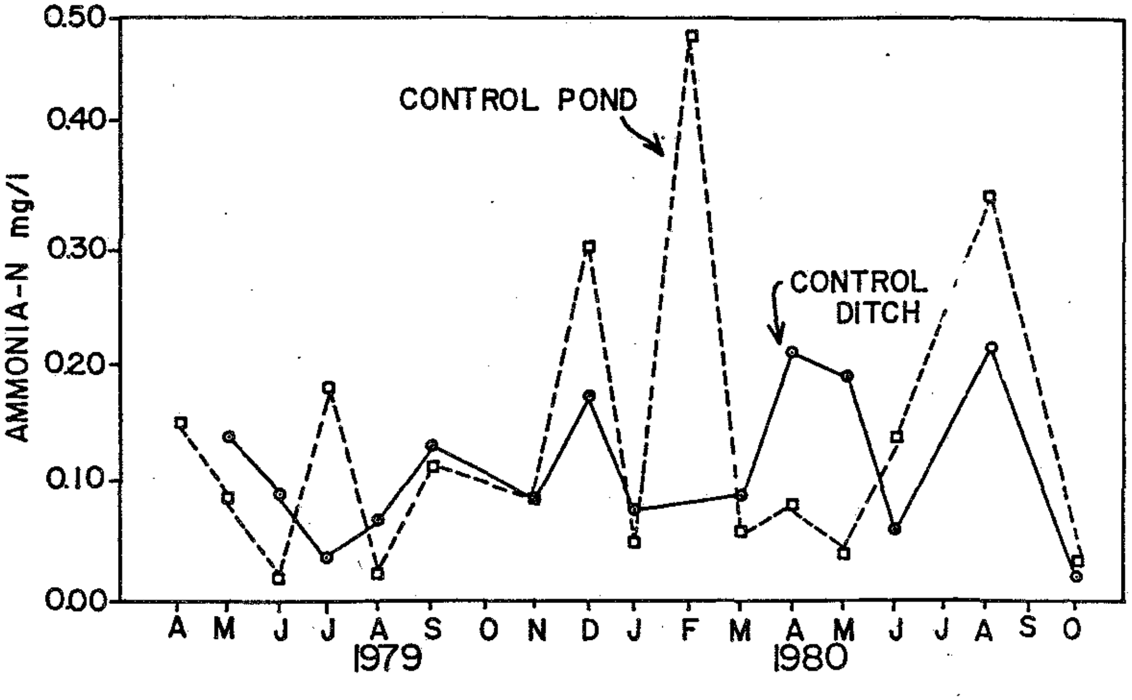


Figure 7. Ammonia concentrations in ponds and ditches at the Open and Control Sites. In this figure, comparisons are made within each of the sites.

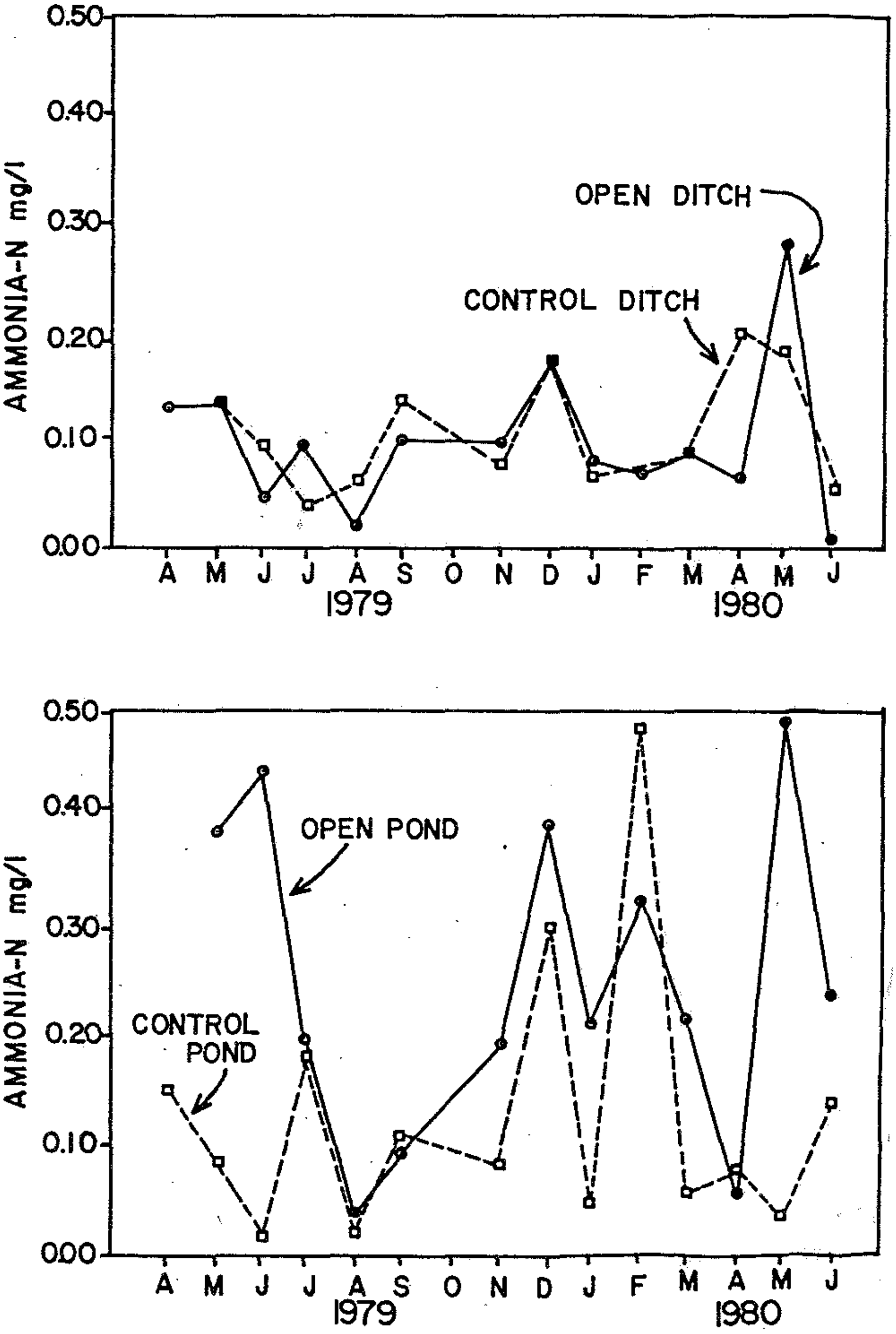


Figure 8. Ammonia concentrations in ponds and ditches at the Open and Control Sites. In this figure, comparisons are made between sites.

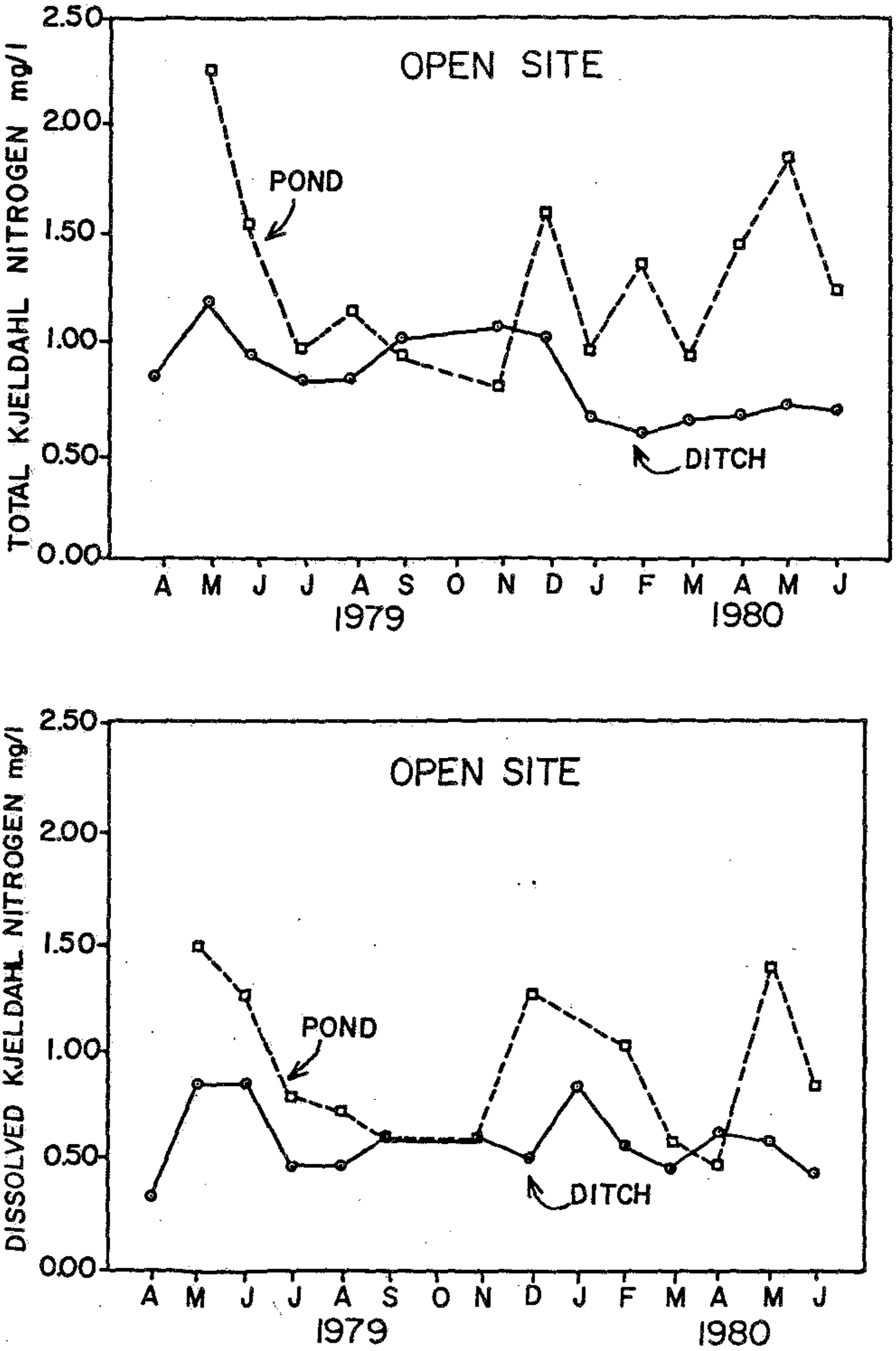


Figure 9. Comparison of dissolved and total Kjeldahl nitrogen concentration in the pond and ditch at the Open Site.

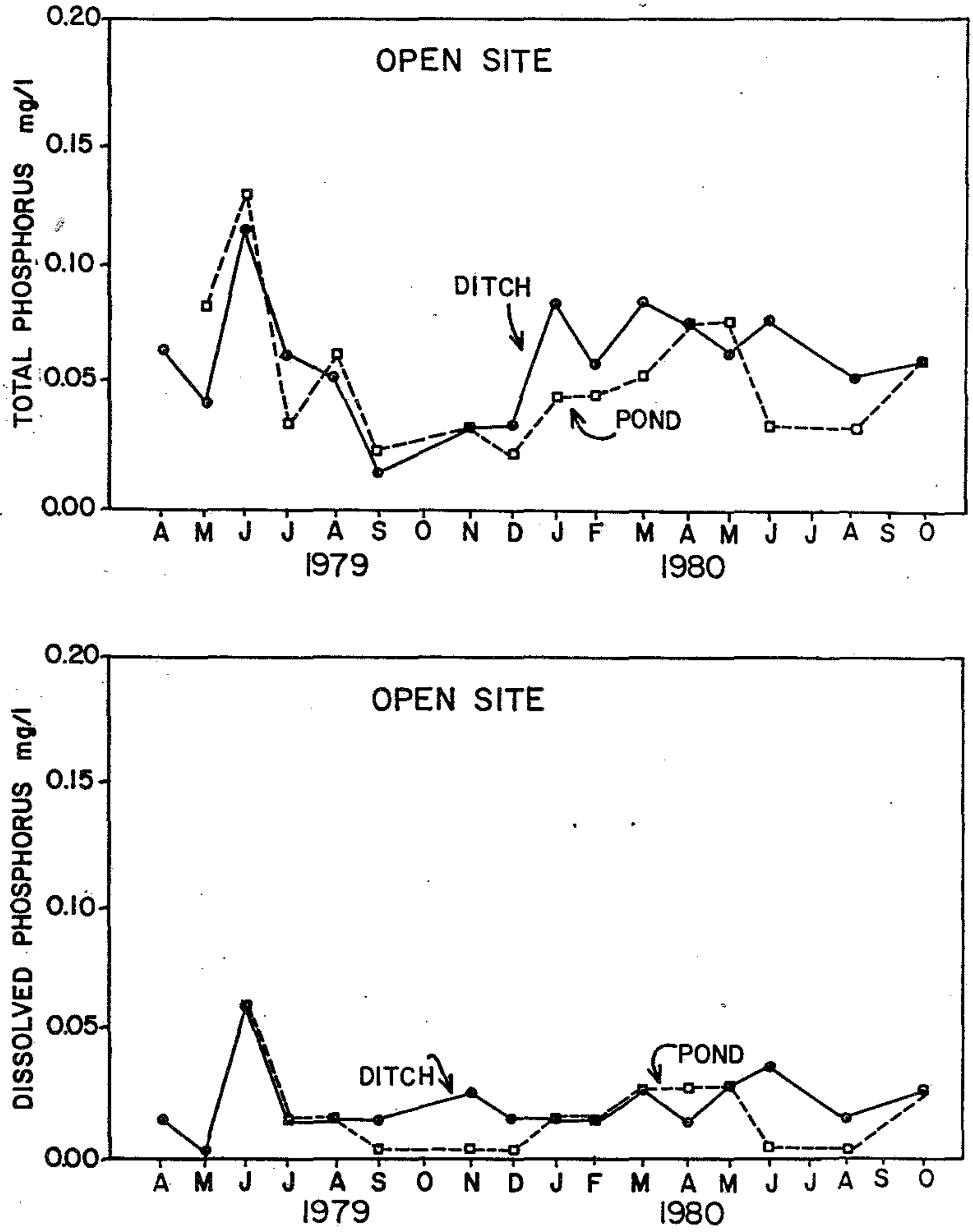


Figure 10. Comparison of total and dissolved phosphorus concentrations in the pond and ditch at the Open Site.

are summarized in Table 22 and Fig. 11. Tidal cycles were categorized into one of the following four general patterns for each nutrient (Fig. 11): (A) concentrations change very little during the tidal cycle, (B) concentrations greater at low tide than high tide, (C) concentrations greater at high tide than low tide, (D) concentrations barely detectable during the tidal cycle. Only patterns A and B were detected for ammonia, total, and dissolved Kjeldahl nitrogen. Eight of the 13 tidal cycles were of type A for ammonia while type B tidal cycles were most common for total and dissolved Kjeldahl nitrogen. Eight of 13 tidal cycles were categorized as type B for total Kjeldahl nitrogen and 11 of 13 were type B for dissolved Kjeldahl nitrogen. Types A, C, and D patterns were observed for nitrate. On 3 occasions, nitrate was barely detectable (Type D) while 6 type C and 4 type A tidal cycles. Phosphorus exhibited all four patterns although one type of tidal cycle was most common for both total and dissolved forms. Nine of the 13 tidal cycles were type A for total phosphorus and 8 were type A for total phosphorus. There were two type 2 tidal cycles for each form of phosphorus. Two type C tidal cycles occurred to total phosphorus, while the remaining two tidal cycles for dissolved phosphorus were type C and D. Nutrient concentration changes were not very large during tidal cycles and although the ranges, in some instances, were rather large, standard errors for mean tidal cycle concentrations were small (Table 22). Except for nitrate-nitrite concentrations of most elements were greatest at low tide (Fig. 11) and the overall patterns were not as variable as has been reported for other areas in the Chesapeake Bay (Axelrad et al. 1976, Heinle and Flemer 1976, Stevenson et al. 1976, Jordan, personal communication).

The range of ammonia concentrations measured during tidal cycles was almost always greater than the range of nitrate concentrations but, for both forms of nitrogen, the standard errors were very small compared to the range (Table 22).

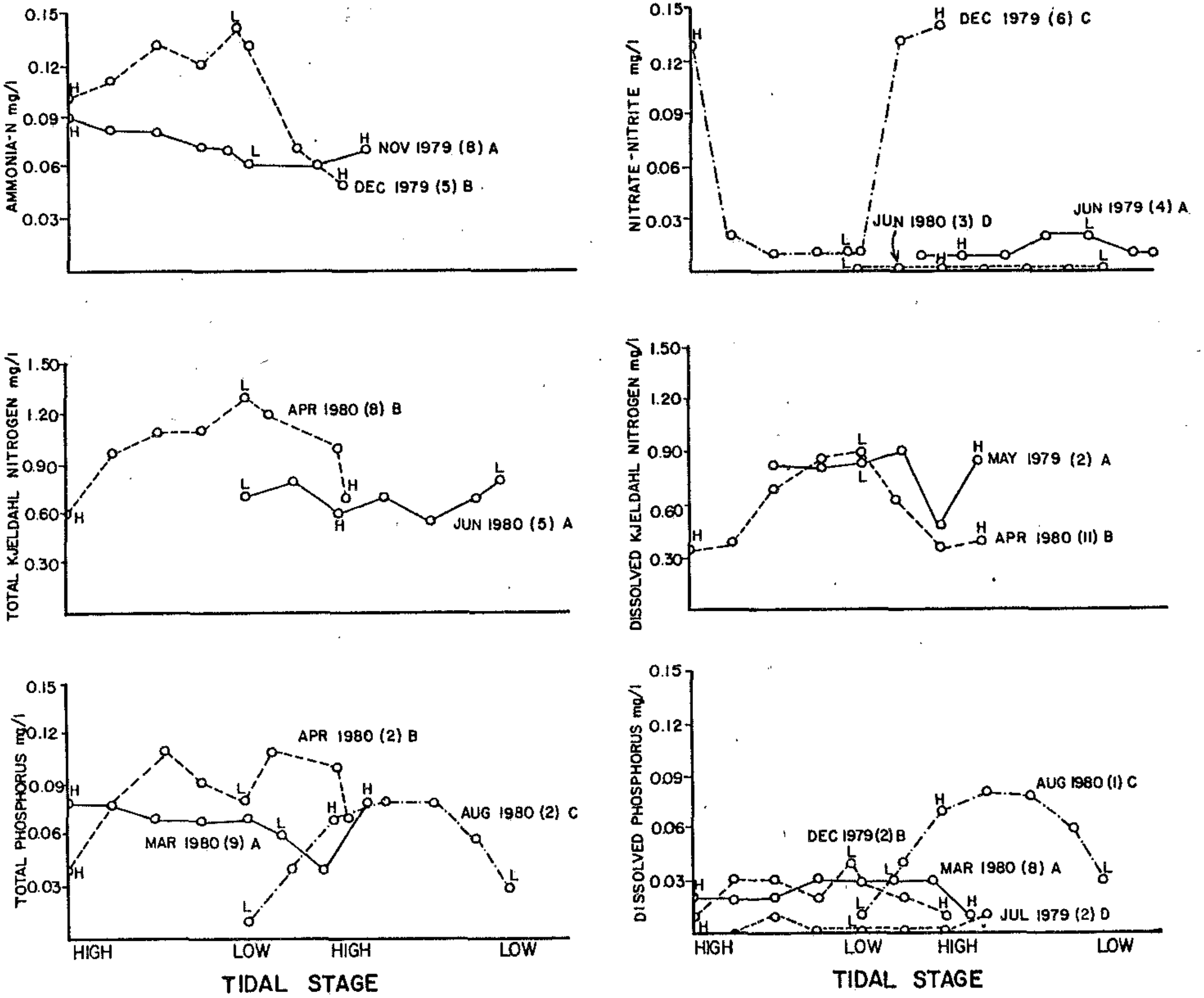


Figure 11. Summary of tidal cycle studies. For each nutrient, the type of tidal cycle pattern was categorized (see text for description of four categories used) and one representative cycle shown for each type. The date chosen is given and the number of tidal cycles of each type is shown in parentheses. Tidal stages are relative and high and low tides are indicated with an H and L respectively.

Table 22. Summary concentration data (mg ℓ^{-1}) for tide cycle studies at the Open Site in 1979 and 1980 and Control Site in 1980. The ranges (max and min) are reported as well as the means and standard errors. Raw data are provided in Appendix C.

I. OPEN SITE

	NITRATE			AMMONIA		
DATE	MAX	MIN	$\bar{X} \pm$ SE	MAX	MIN	$\bar{X} \pm$ SE
			1979			
APR	0.10	0.05	0.07 ± 0.01	0.29	0.07	0.19 ± 0.03
MAY	0.02	0.00	0.01 ± 0.003	0.13	0.07	0.11 ± 0.01
JUN	0.02	0.01	0.01 ± 0.002	0.11	0.00	0.06 ± 0.02
JUL	0	-	0	0.13	0.04	0.08 ± 0.01
AUG	0	-	0	0.06	0.03	0.05 ± 0.004
SEP	0.01	0.01	0.01 ± 0.000	0.11	0.06	0.09 ± 0.006
NOV	0.03	0.01	0.02 ± 0.003	0.10	0.56	0.57 ± 0.004
DEC	0.14	0.01	0.06 ± 0.02	0.13	0.05	0.11 ± 0.01
			1980			
MAR	0.19	0.07	0.11 ± 0.02	0.08	0.05	0.07 ± 0.004
APR	0.16	0.07	0.11 ± 0.01	0.11	0.05	0.08 ± 0.008
MAY	0.04	0.01	0.03 ± 0.004	0.19	0.11	0.16 ± 0.013
JUN	0	-	-	0.04	0.00	0.01 ± 0.005
AUG	0	-	-	0.11	0.06	0.08 ± 0.006
OCT	0.06	0.00	0.02 ± 0.08	0.07	0.01	0.04 ± 0.008

Table 22 (Continued)

	TOTAL KJELDAHL NITROGEN			DISSOLVED KJELDAHL NITROGEN		
DATE	MAX	MIN	$\bar{X} \pm$ SE	MAX	MIN	$\bar{X} \pm$ SE
			1979			
APR	1.20	0.70	0.92 ± 0.09	1.00	0.33	0.63 ± 0.11
MAY	1.20	0.58	1.01 ± 0.11	0.92	0.46	0.76 ± 0.06
JUN	1.30	0.80	1.02 ± 0.0.8	1.12	0.60	0.88 ± 0.08
JUL	1.02	0.81	0.90 ± 0.03	0.75	0.47	0.61 ± 0.04
AUG	1.44	0.90	1.09 ± 0.08	1.05	0.47	0.72 ± 0.08
SEP	1.29	0.94	1.11 ± 0.04	0.97	0.61	0.76 ± 0.05
NOV	1.13	0.06	0.83 ± 0.07	0.77	0.50	0.58 ± 0.04
DEC	1.19	0.60	0.95 ± 0.10	0.96	0.45	0.78 ± 0.09
			1980			
MAR	0.86	0.50	0.70 ± 0.05	0.74	0.36	0.53 ± 0.005
APR	1.30	0.64	1.00 ± 0.08	0.86	0.33	0.59 ± 0.08
MAY	0.83	0.72	0.79 ± 0.01	0.76	0.60	0.65 ± 0.02
JUN	0.83	0.56	0.71 ± 0.04	0.71	0.28	0.48 ± 0.05
AUG	1.50	1.11	1.19 ± 0.06	1.39	0.68	0.94 ± 0.09
OCT	1.08	0.75	0.94 ± 0.04	1.11	0.53	0.68 ± 0.08

Table 22 (Continued)

	TOTAL PHOSPHORUS			DISSOLVED PHOSPHORUS		
DATE	MAX	MIN	$\bar{X} \pm SE$	MAX	MIN	$\bar{X} \pm SE$
			1979			
APR	0.08	0.01	0.05 ± 0.01	0.03	0.01	0.02 ± 0.004
MAY	0.25	0.04	0.12 ± 0.41	0.01	0.00	0.01 ± 0.002
JUN	0.14	0.10	0.12 ± 0.004	0.08	0.06	0.07 ± 0.006
JUL	0.08	0.06	0.07 ± 0.003	0.01	0.00	0.004± 0.002
AUG	0.08	0.07	0.08 ± 0.002	0.06	0.04	0.05 ± 0.002
SEP	0.08	0.01	0.05 ± 0.009	0.01	0.00	0.004± 0.002
NOV	0.07	0.02	0.04 ± 0.005	0.02	0.00	0.02 ± 0.003
DEC	0.07	0.03	0.04 ± 0.004	0.04	0.01	0.02 ± 0.004
			1980			
MAR	0.08	0.04	0.07 ± 0.005	0.03	0.01	0.02 _ 0.003
APR	0.11	0.04	0.08 ± 0.007	0.03	0.01	0.02 ± 0.003
MAY	0.12	0.06	0.08 ± 0.007	0.04	0.01	0.02 ± 0.003
JUN	0.07	0.05	0.06 ± 0.004	0.03	0.00	0.01 ± 0.003
AUG	0.08	0.01	0.05 ± 0.01	0.08	0.01	0.05 ± 0.01
OCT	0.10	0.03	0.07 ± 0.008	0.03	0.02	0.02 ± 0.002

Table 22. (Continued)

II. CONTROL SITE

Date	MAX	MIN	$\bar{X} \pm$ SE	MAX	MIN	$\bar{X} \pm$ SE
		NITRATE			AMMONIA	
APR	0.15	0.02	0.08 ± 0.02	0.06	0.02	0.09 ± 0.02
MAY	0.03	0.00	0.01 ± 0.005	0.31	0.17	0.23 ± 0.02
JUN	0.00	0.00	0.00	0.14	0.00	0.05 ± 0.02
AUG	0.00	0.00	0.00	0.27	0.19	0.22 ± 0.01
OCT	0.005	0.001	0.003 ± 0.001	0.04	0.00	0.02 ± 0.005
		TOTAL KJELDAHL NITROGEN			TOTAL KJELDAHL NITROGEN	
APR	2.57	0.63	1.29 ± 0.31	1.08	0.35	0.59 ± 0.11
MAY	1.55	0.67	0.88 ± 0.10	1.00	0.51	0.69 ± 0.06
JUN	2.68	0.62	1.11 ± 0.28	1.11	0.37	0.64 ± 0.11
AUG	7.54	1.13	3.18 ± 1.05	3.28	0.72	1.40 ± 0.34
OCT	1.31	0.88	1.03 ± 0.06	0.83	0.55	0.63 ± 0.04
		TOTAL PHOSPHORUS			DISSOLVED PHOSPHORUS	
APR	0.26	0.07	0.14 ± 0.03	0.06	0.005	0.02 ± 0.007
MAY	0.08	0.03	0.06 ± 0.006	0.03	0.02	0.02 ± 0.001
JUN	0.14	0.03	0.06 ± 0.01	0.008	0.00	0.01 ± 0.001
AUG	0.57	0.11	0.32 ± 0.07	0.35	0.02	0.10 ± 0.05
OCT	0.10	0.06	0.08 ± 0.004	0.04	0.01	0.02 ± 0.004

This was most likely due to differences in nutrient concentrations of water in Broad Creek at high tide rather than changes in water that ebbed from the Open Site. Nitrate concentrations showed a strong seasonal pattern with maximum values and highest average values occurring in the colder spring months (Table 22). Nitrate values were very low between May and November and nitrate was not detected between June and August. Similar patterns were observed at the Control Site.

Most of the Kjeldahl nitrogen was in the dissolved form and accounted for between 59 - 86% of the total Kjeldahl nitrogen ($\bar{X}$ = 72.9 ± 7.5%) at the Open Site and 45.7 - 92.2% ($\bar{X}$ = 67.3 ± 18.4%) at the Control Site.

During most of the tidal cycle studies, concentrations of total (TP) and dissolved (DP) phosphorus changed very little (Fig. 11, Table 22). There was a tendency for the average concentrations of TP and DP to decline during the summer months and similar to nitrogen, the data indicate that there were no dramatic changes following management. Unlike nitrogen, particulate phosphorus was the dominant form and there were no differences between the Open and Control Sites. Ratios of dissolved phosphorus to total phosphorus averaged 33.2 ± 11.7% at the Control Site and 34.1 ± 26.1% at the Open Site.

Results of the tidal flux studies are shown in Figures 12-14 and complete data are provided in Appendix E. There was almost always a net flux of nitrogen and phosphorus from the Open Site to the estuary and the magnitudes of the fluxes were greatest in 1979. Particularly striking were large fluxes of particulate N and P in 1979 which probably reflects the transport of particulate materials from the newly cut ditches. The decline in transport of particulates in 1980 probably is a reflection of ditch stabilization. Ammonia flux was almost always greater than 50 g per tidal cycle whereas nitrate fluxes were very small (less than 25 g) except for larger fluxes in March 1979 and October 1980 (Fig. 12). The highest nitrate flux

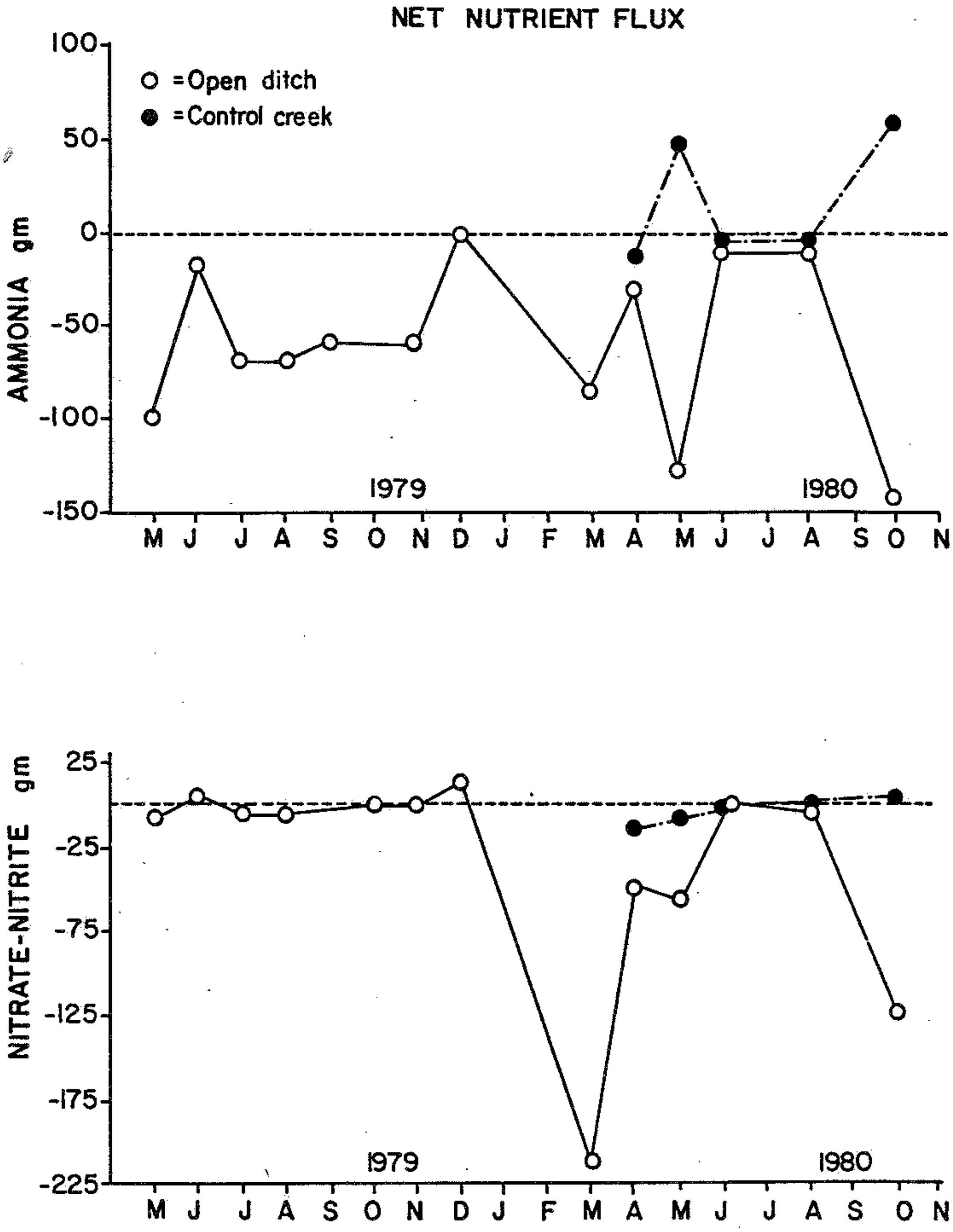


Figure 12. Tidal flux data for ammonia and nitrate. Positive values indicate a net flux into the site while a negative number indicates a net tide cycle export to the estuary.

values were measured between March and May, while ammonia fluxes occurred throughout most of the year.

The efflux of total Kjeldahl nitrogen was usually between 500 g and 1000 g in 1979 and between 250 g and 500 g in 1980 (Fig. 13). The higher total Kjeldahl values in 1979 were due to an efflux of particulate nitrogen from the Open Site because dissolved Kjeldahl nitrogen fluxes were smaller in magnitude and not as variable.

Most of the flux of phosphorus in 1979 was also due to the loss of particulate material (Fig. 14). Dissolved P fluxes were small compared to total phosphorus and the former were not as variable with a range of +13.2 mg to -40.6 mg compared to a range of +42.6 mg to - 165. 4 mg for particulate phosphorus in 1979. The range for both forms of phosphorus were much less in 1980. Dissolved phosphorus flux ranged from -0.6 mg to -35.3 mg in 1980 while the range of total phosphorus was -12.7 mg to -121.7 mg.

Tidal cycle studies were conducted in the creek that entered the second Control Site between April and October 1980. Because of the difficulty in measuring cross-sectional area of that creek, a wooden flume was constructed and installed so that all water was forced through a known cross-sectional area. This permitted more accurate determination of water movement into and out of the site.

For all nutrients, flux patterns were more variable and of smaller magnitude than those measured at the Open Site (Figs. 12-14). It would have been desirable to compare the flux data on an area basis (e.g., amount exported per unit area) but that was not possible because we could not determine the amount of area flooded with each tide at the Control Site. In addition, area comparisons would not be suitable because none of the wetland surface flooded during tidal studies at the Open Site and net fluxes were only measurements of exchanges between incoming

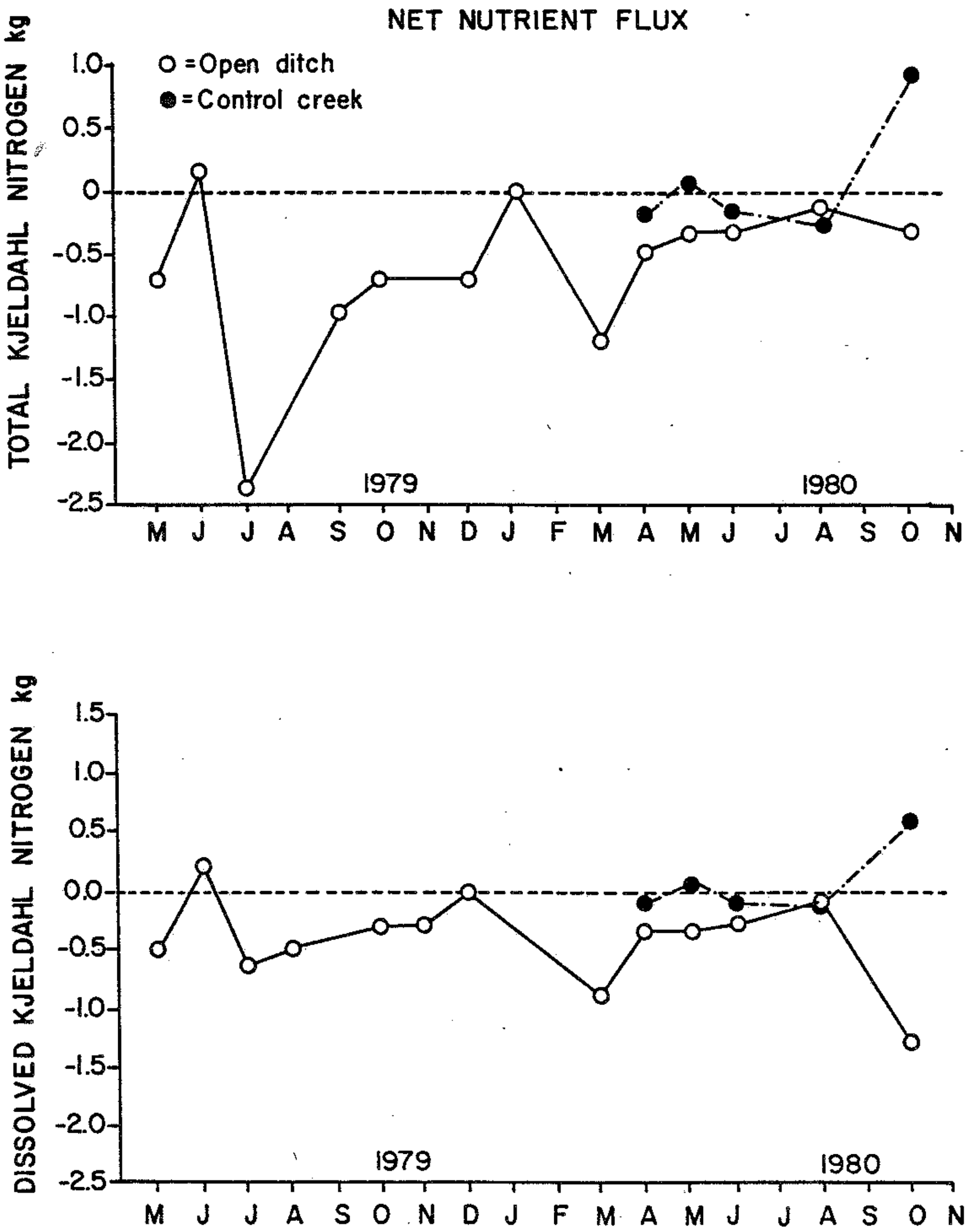


Figure 13. Tidal flux data for total and dissolved Kjeldahl nitrogen. Positive values indicate a net flux into the site while a negative number indicates a net tidal cycle export to the estuary.

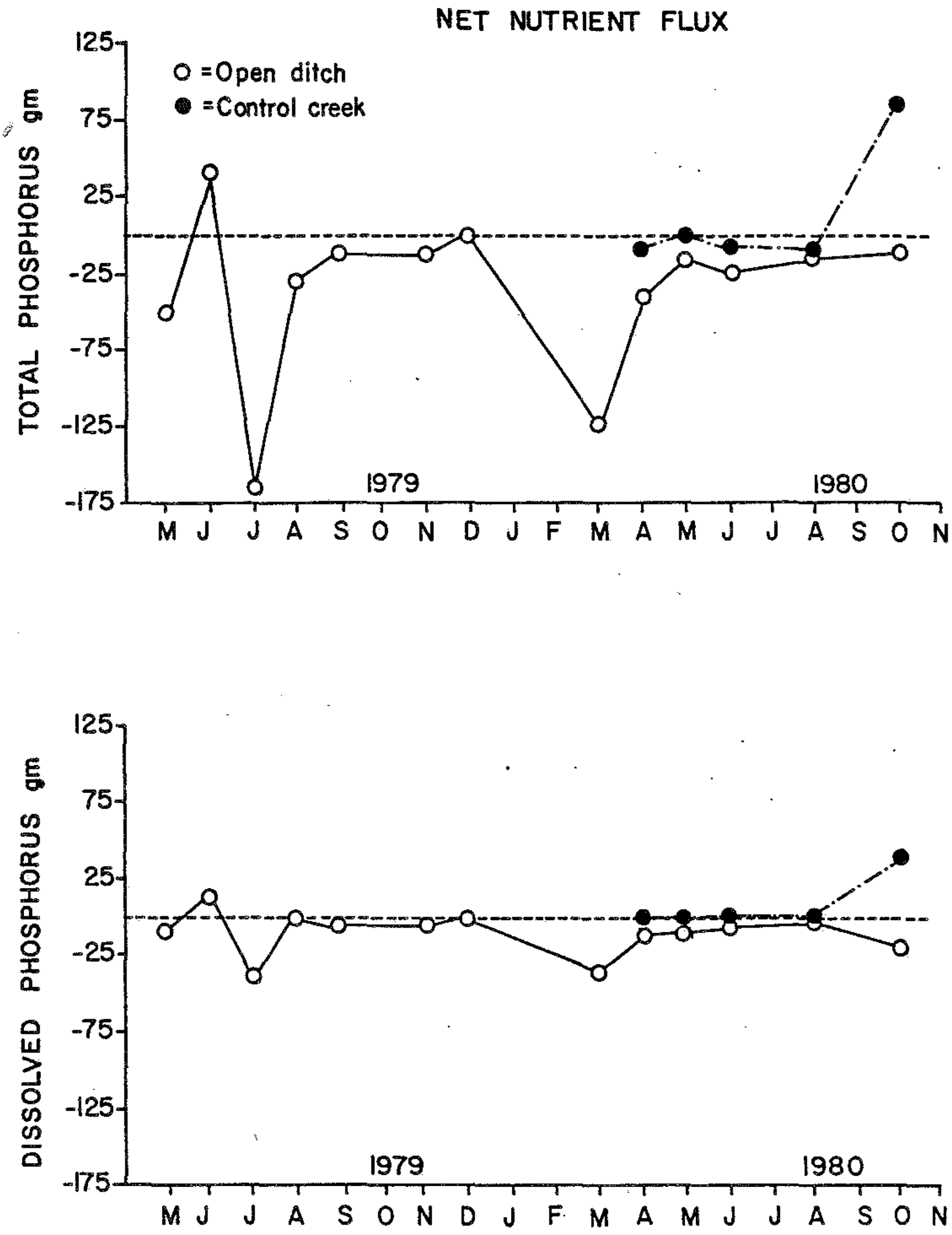


Figure 14. Tidal flux data for dissolved and total phosphorus. Positive values indicate a net flux into the site while a negative number indicates a net tidal export to the estuary.

tidal waters and the network of ditches. On the contrary, net fluxes at the Control Site were measurements of exchange between incoming water, vegetated and unvegetated areas of the creek bank, and some portion of the wetland surface.

Another procedure for comparing sites is to examine concentrations of materials in ebb and flood water. Figure 15 shows data for nitrate, total Kjeldahl N, dissolved Kjeldahl N, and total phosphorus for one representative tidal cycle (April 1980). Clearly, there were differences in concentrations and the concentrations were of greater magnitude at the Control Site. This indicates that the larger fluxes from the Open Site (Figs. 12-14) were due to a greater hydrologic flux rather than higher concentrations of materials in ebbing water.

This type of analysis still does not deal with the problem of tidal assymetry (Boon 1980, Kjerfve and McKellar 1980) which makes it difficult to compare ebb and flood tides that have different volumes of water. We attempted to deal with that problem by examining flux patterns over a relatively long period of time and by sampling tide beginning and ending with high slack tide and tides that began and ended at low slack tide.

Given the inherent variability in seasonal patterns of water flux and variability in the types of tides sampled, the overall pattern was quite consistent. We believe that this lends strong support to our conclusion that ditched Open systems will continuously export materials to the estuary. This is caused by allowing large amounts of water into the ditch network and the transport of particulate and dissolved materials from the ditch network to the adjacent estuary.

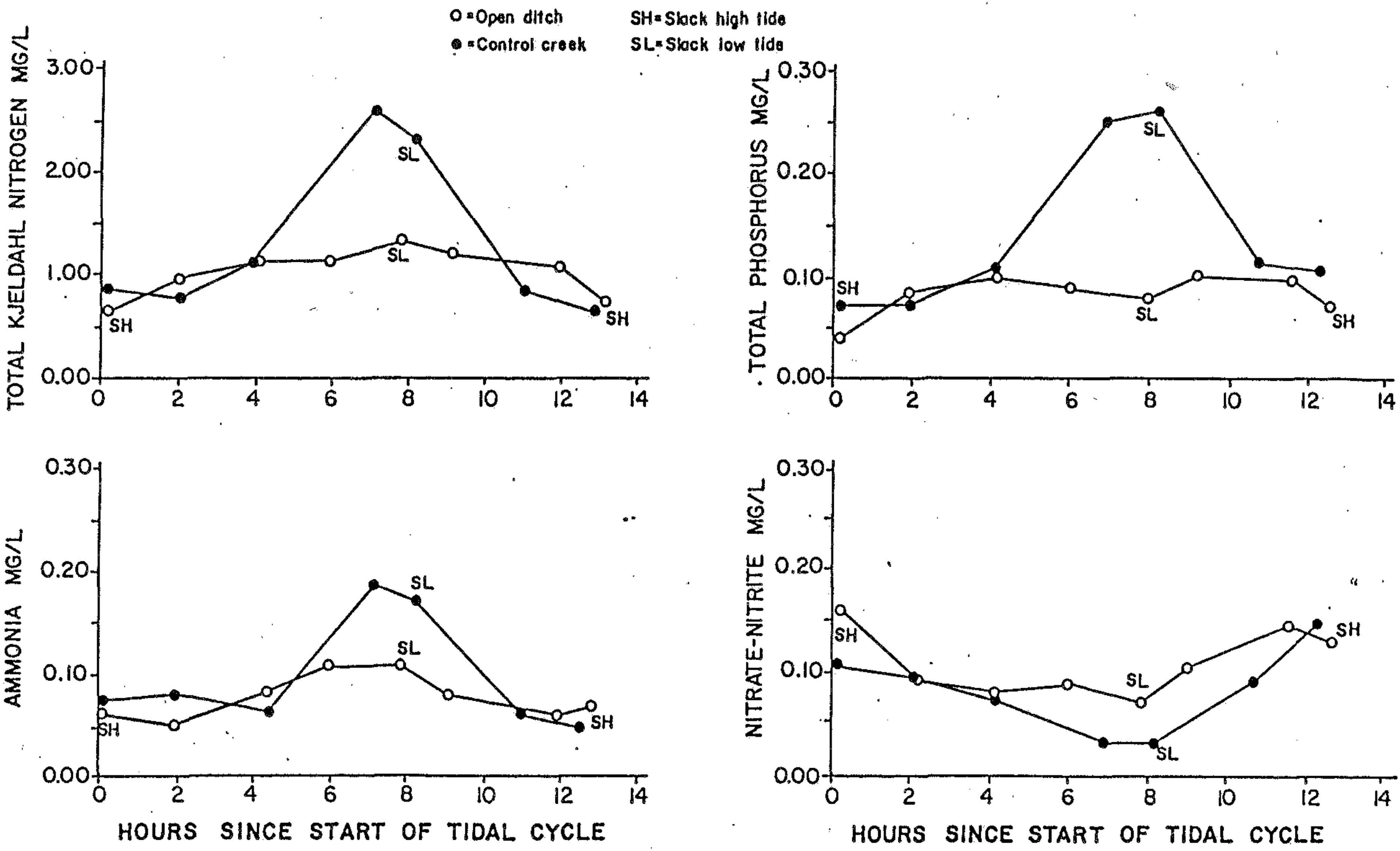


Figure 15. Representative data from the tidal cycle conducted in April 1980. Relative tidal stages are as indicated.

V. DISCUSSION

The purpose of this study was to determine the impacts that selected ditching procedures would have on the ecology of irregularly flooded Chesapeake Bay wetlands. Specifically, the research was designed to determine whether wetland alterations would affect (1) the structure and production of wetland vegetation, (2) the nutrient status of wetland vegetation, (3) rates of decomposition of wetland vegetation, (4) concentrations of selected nutrients in water, and (5) nutrient import-export characteristics of altered wetlands. These objectives will be considered individually in the following discussion.

Structures and production of wetland vegetation

The most obvious management impact of OMWM is the deposition of spoil within a zone of approximately 20 meters from each ditch. Although spoil is broadcast in a rather thin layer, it is deep enough to cover almost all pre-existing vegetation within a zone of 10-15 meters. How fast does vegetation recover? Vegetation recovery was rapid at all sites and within one growing season live aboveground biomass had returned to levels that were almost equal to live aboveground biomass at the Control Site (Table 2) and areas within each site that were unaffected by spoil deposition (Table 3) during the management procedure. After two growing seasons, live aboveground biomass was almost equal to or greater than live aboveground biomass measured at the Control Site and in areas unaffected by spoil.

Dead biomass (litter), on the other hand, had not returned to pre-exisiting levels after 1 growing season, particularly near the ditches where spoil deposition was thickest (Table 3). By the end of the second growing season (Table 3) recovery of litter biomass was almost complete except at 0 and 5 meters.

Further comparisons, however, showed that recovery was effected through different mechanisms at the treated site. At the Open and Water Control sites, where water levels fluctuations were greatest (Fig. 2), D. spicata became the dominant species after one growing season (Table 2); while S. patens became the dominant species at the Closed Site. After two growing seasons, changes were still ongoing and S. patens appeared to be increasing in density relative to D. spicata (Tables 15-18) at all sites. We are not sure, however, whether this response was part of the recovery process following disturbance or whether D. spicata populations were negatively affected by drought conditions that prevailed in 1980. Only additional monitoring of the permanent plots will enable us to determine the long-term recovery patterns.

The short- and long-term effects of altering wetland hydrology have rarely been studied and few quantative data are available on vegetation changes following OMWM. Roman (1978) found that restriction of tidal flushing in Connecticut resulted in long-term increases in D. spicata and declines in S. patens. In one New Jersey wetland, vegetation of a short form S. alterniflora wetlands did not change following implementation of Open Marsh Water Management (Shisler and Jobbins 1977b) while other New Jersey wetlands, ditched areas were invaded by Iva and Baccharis when the sites were coupled to the estuary, while no significant changes resulted when wetlands in the same area were not connected to the estuary (Burger and Shisler 1978).

The proximate factors that cause shifts in vegetation are unknown but changes in the water table are undoubtedly very important. When water tables are lowered or nutrients added, problems associated with anaerobosis are eliminated or reduced (Linthurst 1980, Gallagher 1975, Linthurst and Seneca 1980a and b, Mendelssohn 1979a and b, Mendelssohn and Seneca 1980, Smart and Barko 1978, Sullivan and Daiber 1974, Valiela and Teal 1974, Valiela et al. 1975, Valiela et al. 1976, Buresh et al. 1980) and vegetation growth is enhanced.

In almost every study cited above, addition of nutrients or decreasing the water logging conditions caused S. alterniflora production to increase. Few studies, however, provide insight into the types of changes that would result from altering water levels in irregularly flooded brackish wetlands. Gleason and Zieman (1981) examined internal oxygen supply to S. patens and their data suggest that that species would do best under conditions where the substrate was not waterlogged. In the current study, data show the opposite response (Tables 15-18). Smart and Barko (1978) further suggested that D. spicata would do better than S. patens under conditions of high salinity which would most likely occur in areas that are not frequently flushed such as the Open and Water Control sites. Lesser (personal communication) found no significant differences in interstitial salinity in this study and we can not conclude that salinity differences between sites can account for the observed differences in species composition. It seems clear, however, that D. spicata initially would become more important when irregularly flooded Chesapeake Bay wetlands are ditched and coupled completely (Open Site) or partially (Water Control Site) to the estuary. Our data suggest that S. patens will dominate sites that are closed and may, over the long-term, become increasingly important in all types of ditched wetlands.

A secondary treatment affect was the invasion of two areas by Iva frutescens and Baccharis halimifolia. It has long been known that these semi-shrubs rapidly invade spoil piles that were elevated more than a few centimeters above the wetland surface. In New Jersey, semi-shrubs invaded some OMWM ditched wetlands but not others (Burger and Shisler 1978). In Maryland (Robert Berry, personal communication), very little invasion has occurred on coastal wetlands that have been ditched using standard OMWM procedures. Those coastal wetlands, however, are exposed to a much wider tidal amplitude than are Chesapeake Bay brackish wetlands.

When it became apparent that semi-shrubs were becoming important, we realized that our permanent plots (0.25 x 0.25 m) were not large enough to sample the semi-shrubs adequately. In 1980, we established additional permanent plots (4 m x 4 m) at all sites and determined the density of Iva and Baccharis as well as estimated the cover of seedlings. There were distinct site differences in densities of Iva and Baccharis after two growing seasons (Table 23). Iva was the dominant species at the Open Site while Baccharis was most common at the Water Control Site. Density of these species at the Closed Site is still less than 1 plant per 16 m^2. Estimates of seedling cover also suggest that there are many young plants at the Open and Water Control sites compared to the Closed Site. These results suggest negative impacts associated with the establishment of Open and Water Control sites in irregularly flooded Chesapeake Bay wetlands. It is, however, not possible to make a general prediction that semi-shrubs will invade all Open and Water Control sites, because their establishment may depend on other site factors than depth to the water table. Because nothing is known about the specific germination requirements of Iva and Baccharis, it is suggested that the most appropriate course of action would be to conduct studies on the germination and establishment requirements of both species. The goal of that work should be to determine how germination and establishment are affected by substrate quality (e.g., peat versus clay substrates) and moisture content of the substrate. Only after this information is available will it be possible to predict, with reasonable accuracy, how much the water table could be lowered on any specific marsh that is to be ditched. Based on our data, wetlands that are comparatively young (such as Deal Island wetlands) will

Table 23. Density of *Iva* and *Baccharis* in June 1981. All values are numbers per $16 m^2$. Seedling coverage was estimated as % of total $16 m^2$ area.

Site	IVA Density	BACCHARIS Density	SEEDLING COVER*
Open	3.7 ± 1.7	0.4 + 0.3	33.3 ± 9.2
Closed	0.2 ± 0.2	0	3.3 ± 1.1
Water Control	0.3 ± 0.2	6.9 ± 3.8	21.4 ± 7.0
Control	0	0	8.4 ± 1.9

* (*Iva*, *Baccharis*, and *Pluchea*)

produce spoil with large amounts of inorganic matter mixed with the peat. In these situations, semi-shrub invasion will occur if the water table is lowered more than 5-10 cm.

Biomass data were used to estimate aboveground primary production using three computational methods. No significant statistical site differences occurred for either the peak standing crop or net aboveground primary production estimates of net production in 1980 (Table 7). Neither were there any distance effects on production when the two methods were compared although using the Smalley method of calculating production, production was significantly less at 0 and 5 meters (Table 8). There were also significant site differences when the Smalley method calculations were compared (Table 7). These results, however, do not represent any real differences in net production because unlike the other 2 methods, the Smalley method uses litter biomass as part of the computation and it was shown elsewhere that there were signficant site and distance differences in the amounts of dead biomass.

Although we don't believe that aboveground production was different for any of the treated sites, there may have been an overall site effect. Production was, in general, greater in the random plots at the three treated sites as compared to the Control Site in 1980 (Table 11). The random plots, as stated, were not impacted by the original site manipulations (e.g., not impacted by spoil deposition) but would have been affected by changes in site hydrology. The slight increase in production may have been due to slight lowering of the water table which, as has been shown for S. alterniflora (Linthurst 1980, Linthurst and Seneca 1980b), may cause increased production. When intra-site production comparisons were made (Table 12), the random plots were almost always more productive than any of the 0 to 20 meter distances. The reasons for this are unknown, but the differences may be due to the fact that plant populations within 0 - 20 meters have not yet fully recovered.

Production estimates for Deal wetlands are near the lower end of the range of values reported for other Chesapeake Bay *S. patens/D. spicata* dominated wetlands when peak standing crop estimates are compared (Table 24). Our estimates using the Smalley computational method (248 - 1,360 g m^{-2}) is similar to the 572 g m^{-2} value reported by Mendelssohn and Marcellus (1976).

In summary, the most important changes that resulted from the site manipulations were changes in the dominance pattern of the treated areas and invasion of two sites by Iva and Baccharis. The only significant changes in primary production were higher values measured in the random plots. This suggests that once recovery is complete, that the treated areas may be slightly more productive than natural wetlands. There were, however, no differences in production when Open, Water Control and Closed systems are compared.

Nutrient status of wetland vegetation

Although differences in biomass and primary production were minimal,there were significant changes in the nutrient content of live shoots. The pattern was particularly dramatic for nitrogen which has been shown to be a critical nutrient in estuarine wetlands (Linthurst 1980, Mendelssohn 1979a, Mendelssohn and Seneca 1980, Buresh et al. 1980, Patrick and DeLaune 1976, Valiela et al. 1975 and 1976.

The patterns of nutrient changes are clearly shown in Tables 2 and 3. Nitrogen concentrations were significantly higher in live shoots at the Open and Water Control Sites and the pattern persisted for both years of the study. This suggests that the response was not ephemeral and not simply due to the deposition of nutrient rich oxidized substrate material on the wetland surface. Nitrogen concentrations in live shoots were significantly less at the Closed Site when compared to the Control Site during both years of the study (Table 2). The data

Table 24. Production estimates for several Chesapeake Bay *Spartina patens/ Distichlis spicta* dominated wetlands. Method 1 = Peak Standing Crop, Method 2 = Summation technique, Method 3 = Smalley, Method 4 = infrared gas analysis. All values are g m^2. Data compiled from: 1 (Whigham et al. 1978) and 2 (Drake and Read (1981).

This study	Method 1	426 - 225	(Range)	Source
	Method 2	502 - 233	(Range)	
	Method 3	1360 - 248	(Range)	
McCormick	Method 1	1123		1
Heinle	Method 1	449		1
Flemer et al.	Method 1	1209 - 680	(Range)	1
McCormick et al.	Method 1	1525		1
Mendelssohn and Marcellus	Method 3	572		1
Drake	Method 1	445		1
Drake and Read	Method 4	737		2

clearly suggest that lowering the water table would cause changes in tissue nutrient concentrations and that these changes could be minimized by maintaining the water table near the wetland surface.

Increases in tissue nitrogen concentrations were most likely due to alterations of the waterlogging conditions that are characteristic of irregularly flooded wetlands (Mendelssohn and Seneca 1980). It has been shown that nitrogen can be a limiting nutrient for plant growth in wetlands with saturated substrates (Buresh et al. 1980), and that growth and nitrogen uptake can be enhanced by raising the level of the substrate relative to the water table (Linthurst 1980), or by lowering the water table (Wiegert et al. 1980). Most of the research on this topic has been conducted with S. alterniflora and a large number of variables have been shown to be related to growth of that species. The interactions are complex and not yet clearly understood (Linthurst 1980). Aeration of sediments has been shown to increase production (Mendelssohn and Seneca 1980) because of changes in redox potential. If drainage is extensive and tidal inundation infrequent, however, substrates dry (Linthurst 1980) and production may even be reduced because pH decreases to less than 6 which is suboptimal for S. alterniflora. In one study, Linthurst and Seneca (1980b) showed that pH declined significantly and production was less when pots with S. alterniflora were elevated to 10 cm above the wetland surface. Since the water table changes in this study were, on average, less than 10 cm, the increase in N concentrations may have been due to increases in redox potential but the substrate may not have dried enough to decrease substrate pH to values below 6. An increase in redox potential would account for increased nitrogen uptake due to elimination of the need for "energetically expensive metabolic adjustments" (Linthurst 1980). The decline in tissue N concentrations at the Closed Site may have been due to increased waterlogging because the reservoir of water in the ditches would provide enough water supply to maintain the ground water level near the wetland surface. This was seen in another study in 1981 (Table 25), when we determined substrate moisture content between 11 June and 12 August. Clearly the Open Site substrates were drier, particularly at 0 meters. The Closed Site, at 20 meters, was almost always equal to or greater in moisture content than was the Control Site. In addition, muskrats created small openings between the Closed Site and the estuary that permitted some water to enter at high tide which may have helped in maintaining the water table near the wetland surface.

The effect of lowering the water table on tissue N concentrations can also be seen when intra-site comparisons are made between random plots and samples collected from the 0 - 20 meter distances. Nitrogen concentrations were highest near the ditches and declined with increasing distances from the ditches (Fig. 16) at the Open and Water Control sites. At the Closed Site, water tables were not lowered (Fig. 2) and there were no differences between any of the distances.

In summary, there were significantly higher concentrations of nitrogen in live shoots at two of the sites and slightly lower concentrations at the Closed Site. Higher N concentrations at the Open and Water Control sites were most likely due to a lessening of waterlogging conditions and resultant increase in uptake. Similar or slightly lower values at the Closed Site may be due to increases in waterlogging conditions.

Decomposition of wetland vegetation

The purpose of this portion of the study was to determine if there would be any changes in decomposition rates and whether or not decomposition rates would change if litter was lying on spoil deposits.

There was an overall site response for decomposition of *D. spicata* litter

Table 25. Percent moisture of substrates at 3 of the Deal Island sites between 11 June and 12 August 1981. All values are means of 5 samples ± 1 standard error.

Site	Distance (m)	11 JUN	19 JUN	25 JUN	2 JUL	25 JUL	12 AUG
CONTROL		501 ± 1	403 ± 10	396 ± 29	365 ± 29	395 ± 17	484 ± 52
OPEN	0	147 ± 9	153 ± 37	114 ± 26	144 ± 32	193 ± 29	160 ± 15
	20	444 ± 27	356 ± 92	380 ± 16	365 ± 35	318 ± 44	180 ± 18
CLOSED	0	330 ± 32	464 ± 35	335 ± 25	400 ± 16	412 ± 31	405 ± 16
	20	281 ± 18	406 ± 8	434 ± 8	436 ± 15	452 ± 31	366 ± 26

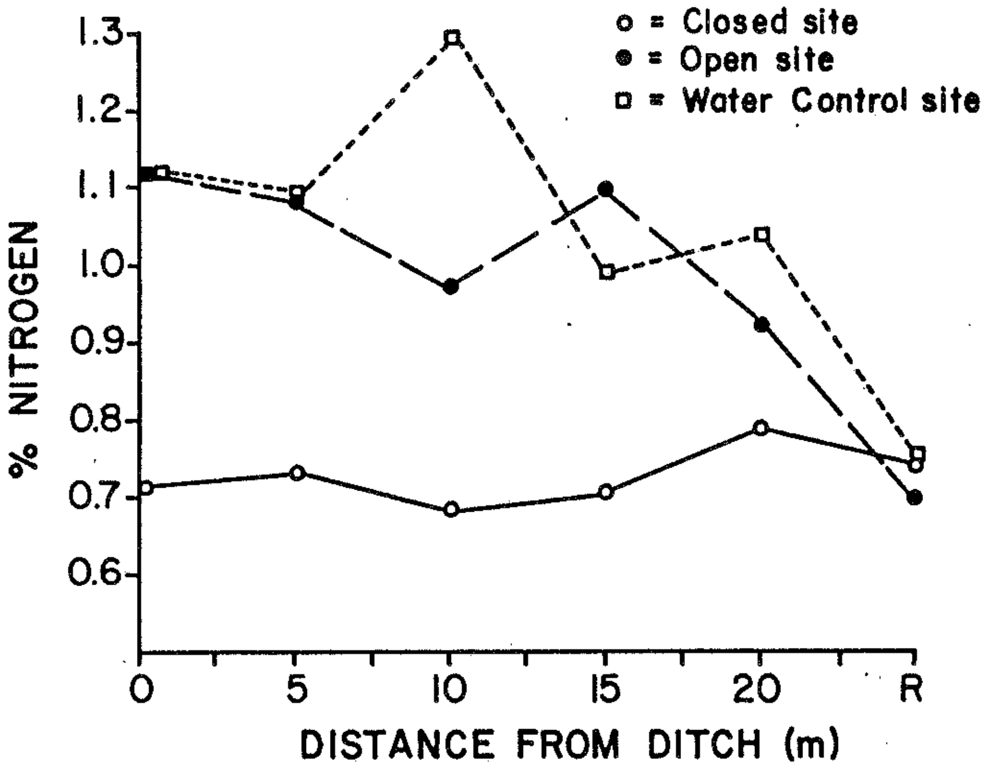


Figure 16. Percent nitrogen in live biomass as a function of distance from the ditch.

which lost weight more slowly at the three treated sites (Table 13). Results were not as clear for *S. patens* when site comparisons were made (Table 14) although there was a tendency for all weight components to be greater at the treated sites even though variation was high enough so that significant differences were only associated with shoot tips. There were no differences between spoil and nonspoil locations for *D. spicata* (Table 13) or *S. patens* (Table 14).

It is known that brackish wetland plants decompose more slowly than freshwater wetland plants (Odum and Heywood 1978). In addition, moisture content of the litter is important and any process that causes water tables to be lowered or causes the surface to be elevated slightly would be expected to cause lower litter moisture content and resultant decreases in decomposition rates.

The ecosystem level effects of lower decomposition rates are unknown, but clearly more biomass will remain in the wetland surface. In addition, the accumulated litter would probably have higher nitrogen concentrations because of increased N levels in live biomass. The long-term effects of increased litter biomass and increased nutrient content are unknown but they would provide additional fuel for fires that are frequently set in these wetlands. Hotter fires could mean a deeper burn into the peat of wetlands with lowered water tables which may, in turn, kill shallow rooted plants such as *S. patens*. Obviously, these possibilities are only speculative but it does suggest one of the potential dangers associated with lowering water water tables on irregularly flooded wetlands.

In summary, litter decomposition rates are lower on wetlands that were ditched, but there does not appear to be any difference when litter is on or off of spoil.

Water quality parameters

The purpose of this portion of the study was to determine if management procedures would produce significant change in water quality parameters. Comparisons of water quality parameters in ditches in the three treated areas with data from the Control Site and adjacent estuary, clearly demonstrate that no significant changes occurred (Figs. 6-10). If changes do occur, they will be noticed shortly after and during ditching. Ammonia and total Kjeldahl N data from the Water Control Site (the last to be ditched) showed that concentrations may be elevated initially but that background levels (compared to the Control Site creek) are reached within six months (Fig. 6). In fact, for most forms of nitrogen (Figs. 7 and 9) concentration are often higher in ponds as compared to ditches and concentration at the Control Site creek were usually higher than in ditches at the treated sites (Fig. 8). There were no patterns for phosphorus when inter- and intra-site comparisons were made (Fig. 10).

Additional comparisons of water quality parameters were made by measuring nutrient concentrations during tidal cycle studies at the Open and Control Sites. Figure 12 contains representative data from one tidal cycle study and demonstrate that nutrient concentrations were, in fact, usually less in water that ebbs from the Open Site as compared to water samples from the Control Site creek.

In summary, no significant changes in selected water quality parameters occurred as a result of management. Any increases in nutrient concentrations that do occur following OMWM management will probably return to background levels after six months.

Import and export studies

The tidal cycle studies were conducted to assess the impact that OMWM might have on the flux of selected nutrients into or from managed wetlands. The impetus for the work was based on concern that coupling irregularly flooded wetlands to the estuary might result in the export of materials to the estuary which, if they occured on a large scale, might cause eutrophication problems. These concerns were based on previous research (Stevenson et al. 1976, Heinle and Flemer 1976, Axelrad et al. 1976, Bender and Correll 1974) which had shown that Chesapeake Bay wetlands, in most instances, export materials to the estuary more often than they import nutrients.

Tidal cycle studies were conducted at the Open Site between May 1979 and October 1980 and at the Control Site between April 1980 and October 1980 (Figs. 12-14). It was not possible to conduct tidal cycle studies in 1979 at the Control Site because of manpower limitations. The studies were conducted either from high slack tide to high slack tide or low slack tide to low slack tide. Detailed data from each study are provided in Appendices C, D, and E.

Examination of Figures 12-14 show that materials were exported from the Open Site during almost all tidal cycles. Import-export patterns were more variable at the Control Site and the quantity of flux material from or into the Control Site was almost always less than the amounts measured at the Open Site. Patterns measured at the Control Site were variable which is similar to results previously reported by Stevenson et al. (1976), Heinle and Flemer (1976), and Axelrad et al. (1976). The seasonal import of nitrate and nitrite (Fig. 12) suggests that these managed wetlands responded very much like the Eastern Shore wetlands studied by Stevenson et al. (1976).

Why were exports large at the Open Site compared to the Control Site? As Nixon (1980) has described, there are many problems associated with the measurement of nutrient flux from wetlands. These issues and result of our studies are presented in the RESULTS section and will only be summarized here: (1) coupling ditched systems to the estuary produced no significant increases in the concentrations of nutrients in ebbing tidal waters. In most instances, nutrient concentrations during tidal cycles were equal to or less than those measured at the Control Site (Table 22), (2) increased concentrations, therefore, did not account for the larger flux of materials from the Open Site. Since concentration differences did not account for the observed pattern, the increased flux from the Open Site was most likely due to the larger influx and efflux of water that we measured. Creating an extensive ditch system, with a large storage capacity, will cause larger amounts of water to enter an Open system than will enter a natural tidal creek of equal size. The long-term consequences of this process are not known. Others (Shisler and Jobbins 1977a) have suggested that Open systems enhance estuarine systems through increases in wetland production, increase the diversity of estuarine organisms that utilize the wetland, and increase food sources for wetland-estuarine organisms. These benefits must, of course, be balanced by any changes that might produce undersirable changes. None of these conclusions have, however, been documented adequately.

In summary, Open systems will export nutrients to the estuary whereas the pattern is more variable for non-ditched wetlands. Ditched wetlands allow more water to enter than would a similar sized non-ditched wetland and, consequently, larger amounts of material will flux from the wetland. The long-term consequences of this are not known.

VI. CONCLUSIONS

1. Hydrologic differences between the treated sites produced different responses within the wetlands.
2. Lowering of the water table produced, at the Open and Water Control Sites, vegetation with significantly higher tissue N and P concentrations.
3. If elevated nutrient levels persist, it can be expected that the litter layer will also become nutrient enriched.
4. It is not expected that the enriched litter layer would be more rapidly decomposed because lowering the water table produced lower decomposition rates at all sites. Consequently, it can be expected that litter biomass will ultimately be greater on managed wetlands.
5. Changes in species composition occurred. The two sites (Open and Water Control) with regular tidal exchange became dominated by <u>D. spicata</u> during the first year and <u>S. patens</u> became dominant in the Closed Site. Changes, however, are still ongoing and the Open and Water Control Sites are becoming invaded by <u>Iva</u> and <u>Baccharis</u>.
6. No significant changes in concentrations of selected water quality resulted from the management. However, the tidal cycle studies indicated that the nutrients measured are exported from the Open Site compared to more variable import-export patterns measured at the Control Site.
7. Ditches and ponds have been invaded by submersed plants primarily <u>Ruppia</u> and it is expected that their aerial coverage will continue to increase.

VII. RECOMMENDATION

Although standard OMWM procedures provide effective mosquito control (Lesser, 1982) on irregularly flooded wetlands in the Chesapeake Bay, negative impacts may result. To minimize detrimental effects, it is recommended that only Closed systems or Water Control systems be used where possible. If some tidal exchange is required to control mosquito populations, water control systems can be used but every effort should be made to keep tidal exchange to a minimum and to maintain natural water table.

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APPENDIX TABLE OF CONTENTS

APPENDIX A: Tables 26 - 30. Summary tables for analysis of variance tests performed on biomass, plant nutrient, production, density and plant height data.

Table 26. Summary results from analysis of variance tests for plant nutrient and biomass parameters. Significance levels are A $\geq$ .05, B $\geq$ .01, C $\geq$ .001. ns indicates non significance. Df = degrees of freedom. F values are shown when there were significant effects.

Effects source	Df.	Live biomass	Live biomass of *S. patens*	Live biomass of *D. spicata*	Dead biomass	Total biomass	N in live biomass	% N in live biomass	P in live biomass	% P in live biomass	N in dead biomass	% N in dead biomass	P in dead biomass	% P in dead biomass	Total nitrogen	Total phosphorus
1979																
Main																
Total	419															
Site (S)	3	26.13^{C}	84.97^{C}	112.61^{C}	8.79^{C}	4.80^{B}	39.16^{C}	9.24^{C}	35.93^{C}	7.45^{C}	7.76^{C}	6.52^{C}	ns	9.47^{C}	6.19^{B}	8.47^{C}
Distance (D)	4	ns	ns	ns	12.11^{C}	8.44^{C}	ns	ns	ns	ns	11.46^{C}	ns	11.58^{C}	ns	6.16^{C}	6.18^{C}
Time (T)	6	41.41^{C}	10.07^{C}	20.23^{C}	12.74^{C}	14.04^{C}	21.35^{C}	49.44^{C}	12.13^{C}	53.25^{C}	10.87^{C}	13.43^{C}	11.74^{C}	9.29^{C}	12.01^{C}	5.76^{C}
Interaction																
S x D	12	ns	ns	ns	2.93^{C}	2.65^{C}	ns	ns	ns	ns	2.44^{B}	ns	ns	ns	2.40^{B}	ns
S x T	18	6.12^{C}	6.11^{C}	7.78^{C}	ns	2.13^{B}	5.32^{C}	2.55^{C}	5.78^{C}	2.51^{C}	ns	2.63^{B}	ns	1.93^{A}	1.69^{B}	3.53^{C}
D x T	24	ns	ns	ns	ns	ns	1.84^{B}	ns	ns	ns	ns	ns	ns	ns	ns	1.71^{A}
1980																
Total	477															
Main																
Site (S)	3	12.91^{C}	65.72^{C}	23.03^{C}	20.02^{C}	22.18^{C}	ns	35.61^{C}	ns	27.66^{C}	31.72^{C}	28.51^{C}	11.64^{C}	17.37^{C}	29.08^{C}	7.43^{C}
Distance (D)	4	3.07^{B}	ns	6.53^{C}	10.86^{C}	6.82^{C}	3.98^{B}	ns	ns	ns	7.75^{C}	ns	9.69^{C}	2.51^{A}	2.63^{A}	5.40^{C}
Time (T)	7	78.34^{C}	24.47^{C}	28.10^{C}	15.19^{C}	14.04^{C}	62.53^{C}	33.45^{C}	52.31^{C}	86.81^{C}	17.74^{C}	12.54^{C}	18.86^{C}	15.83^{C}	22.57^{C}	18.12^{C}
Interaction																
S x D	12	ns	ns	2.13^{B}	2.00^{A}	ns	ns	1.95^{A}	ns	ns	ns	ns	ns	ns	ns	ns
S x T	21	ns	4.81^{C}	4.25^{C}	2.40^{C}	2.37^{C}	ns	4.22^{C}	1.71^{A}	5.35^{C}	2.98^{C}	4.58^{C}	2.47^{C}	3.06^{C}	3.09^{C}	2.88^{C}
D x T	28	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 27. Summary results from analysis of variance tests for production and associated nutrient parameters. F values are shown where there were significant effects. Significance levels are A $\geq$ .05, B $\geq$ .01, C $\geq$ .001. NS indicates no significance. Df = degrees of freedom.

Effects	Df	Peak standing crop (PSC)	N in PSC	P in PSC	Net above-ground primary production (NAPP)	N in NAPP	P in NAPP	Smalley Method (NPS)	N in NPS	P in NPS
					1979					
Total	59									
Main										
Site (S)	3	11.21^C	34.62^C	23.36^C	11.64^C	25.81^C	23.90^C	2.87^A	5.10^B	5.35^B
Distance (D)	4	NS	NS	$2,96^B$	NS	NS	NS	2.77^A	NS	NS
Interaction										
S X D	12	NS	NS	2.59^B	NS	NS	2.27^A	NS	NS	NS
					1980					
Total	59									
Main										
Site (S)	3	NS	NS	NS	NS	NS	NS	3.17^B	NS	NS
Distance (D)	4	NS	NS	NS	NS	NS	NS	5.06^B	NS	2.90^A
Interaction										
S X D	12	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 28. Summary results from analysis of variance tests for plant nutrient, biomass, and production parameters comparing data from the Control Site with data from random plots at the 3 treated sites. F values are shown when there were significant effects. Significance levels are A = .05, B = . 01, C $\geq$ .001. ns indicates no significance. Total degrees of freedom were 273 for biomass parameters and 34 for production parameters.

I. Biomass and nutrients		II. Production	
Variable	Test result	Variable	Test result
Live biomass	8.76^C	Peak standing crop (PSC)	3.98^A
Dead biomass	14.73^C		
Total biomass	21.90^C		
N in live biomass	2.67^A	N in PSC	ns
% n in live biomass	9.50^C	P in PSC	ns
P in live biomass	8.74^C	Net aboveground production (NAPP)	3.57^A
% P in live biomass	ns	N in NAPP	ns
N in dead biomass	5.36^B	P in NAPP	5.48^B
% N in dead biomass	10.41^C	Smalley Method (NPS)	4.11^A
P in dead biomass	12.38^C	N in NPS	ns
% P in dead biomass	ns	P in NPS	4.77^B
Total nitrogen	5.93^C		
Total phosphorus	20.08^C		

Table 29. Summary analysis of variance results for vegetation biomass and nutrient parameters for intra-site comparisons. F values are shown where there were significant effects. Significance levels are A $\geq$ .05, B $\geq$ .01, C $\geq$ .001. ns indicates not significance. Df = degrees of freedom.

Effects	Df	Live biomass	Dead biomass	Total biomass	N in live	% N in live biomass	P in live	% P in live biomass	N in dead	% N in dead biomass	P in dead	% P in dead biomass	Total nitrogen	Total phos-phorus
Total	159													
						OPEN SITE								
Distance	5	ns	4.70^{B}	4.58^{B}	ns	5.59^{C}	ns	ns	2.30^{A}	2.34^{A}	3.78^{B}	ns	nt	2.75^{A}
						CLOSED SITE								
Distance	5	ns	8.54^{C}	9.64^{C}	ns	ns	ns	ns	6.63^{C}	ns	5.09^{B}	ns	6.05^{C}	6.19^{C}
						WATER CONTROL SITE								
Distance	5	2.92^{A}	5.79^{C}	11.51^{C}	ns	6.38^{C}	ns	ns	3.85^{B}	ns	2.74^{A}	2.60^{A}	4.89^{B}	4.47^{B}

Table 30. Summary test results from analysis of variance for *D. spicata* and *S. patens* density and stem height data. F values are given where there were significant effects. Significance levels are A ≥ .05, B ≥ .01, C ≥ .001. NS indicates no significance. Df = degrees of freedom.

Effects	Df	Height of *S. patens*	Df	Height of *D. spicata*	Df	Density of *D. spicata*	Df	Density of *S. patens*	Df	Density of All Plants
					1979					
Main										
Total	1016		1906		419		419		419	
Sites (S)	3	65.08^{C}	3	34.52^{C}	3	44.80^{C}	3	290.39^{C}	3	84.14^{C}
Distance (D)	4	4.33^{B}	4	NS	4	4.30^{B}	4	NS	4	3.01^{A}
Time (T)	6	68.68^{C}	6	87.99^{C}	6	5.08^{C}	6	7.58^{C}	6	12.13^{C}
Interactions										
S X D	9	2.91^{B}	12	19.12^{C}	12	3.93^{C}	12	2.43^{B}	12	3.64^{C}
S X T	17	6.15^{C}	18	21.80^{C}	18	3.39^{C}	18	4.83^{C}	18	3.16^{C}
D X T	24	2.40^{B}	24	2.56^{C}	24	NS	24	NS	24	NS
					1980					
Main										
Total	1104		1175		359		359		359	
Sites (S)	3	34.49^{C}	3	54.06^{C}	3	73.01^{C}	3	199.09^{C}	3	89.95^{C}
Distance (D)	4	NS	4	5.91^{C}	4	3.23^{B}	4	2.59^{A}	4	3.35^{B}
Time (T)	5	223.26^{C}	5	322.75^{C}	5	11.10^{C}	5	7.38^{C}	5	8.52^{C}
Interactions										
S X D	9	9.64^{C}	12	5.45^{C}	12	4.45^{C}	12	NS	12	NS
S X T	15	4.62^{C}	15	4.52^{C}	15	2.19^{B}	15	2.63^{B}	15	3.78^{C}
D X T	20	1.89^{B}	20	NS	20	NS	20	NS	20	NS

APPENDIX B: Tables 31 - 36. Nutrient concentration data for ponds and ditches at the three treated sites, control, Broad Creek, and Geangawkin Creek. Sampling of Geangawkin Creek was terminated in December 1979. All values are mg ℓ^{-1} and a dash indicates that no sample was analyzed.

AMMONIA DATA (mg ℓ^{-1})

	DATE OF COLLECTION														
				1979							1980				
SITE-LOCATION	5-31	6-19	7-17	8-14	9-18	11-9	12-11	1-23	2-28	3-25	4-08	5-08	6-11	8-07	10-02
OPEN-CHANNEL	0.10	0.08	0.07	0.03	0.10	0.07	0.11	0.06	0.06	0.07	0.08	0.23	0.01	0.08	0.03
OPEN-POND	0.40	0.40	0.20	0.04	0.12	0.19	0.40	0.20	0.30	0.20	0.06	0.52	0.22	0.04	0.02
BROAD CREEK	0.08	0.03	0.05	0.03	0.07	0.07	0.08	0.07	0.08	0.06	-	-	0.00	0.08	0.01
CLOSED-CHANNEL	0.12	0.02	0.06	0.04	0.12	0.06	0.24	0.08	0.23	0.17	0.06	0.36	0.13	0.07	0.02
CLOSED-POND	0.16	0.07	0.07	0.03	0.09	0.06	0.24	0.08	0.25	0.20	0.06	0.23	0.06	0.07	0.02
WATER CONT.-CHAN.	0.20	0.11	0.15	0.04	0.15	0.09	0.16	0.15	0.10	0.07	0.09	0.18	0.04	0.07	0.02
WATER CONT.-POND	0.23	0.33	0.26	0.03	0.14	0.28	0.37	0.20	0.53	0.18	0.27	0.23	0.16	0.46	0.14
GEANGAWKIN CREEK	-	0.10	0.09	0.05	0.07	0.07	0.07	0.08	0.08	-	-	-	-	-	-
CONTROL-CHANNEL	0.13	0.09	0.04	0.05	0.16	0.08	0.19	0.07	-	0.08	0.09	0.19	0.05	0.22	0.02
CONTROL-POND	0.09	0.02	0.18	0.04	0.10	0.08	0.29	0.05	0.54	0.06	0.09	0.04	0.14	0.35	0.03

NITRATE-NITRITE DATA (mgℓ^{-1})

	DATE OF COLLECTION														
				1979							1980				
SITE-LOCATION	5-31	6-19	7-17	8-14	9-18	11-9	12-23	1-23	2-28	3-25	4-08	5-08	6-11	8-07	10-02
OPEN-CHANNEL	0.01	0.02	0.00	0.00	0.01	0.02	0.07	0.09	0.16	0.11	0.11	0.03	0.00	0.00	0.02
OPEN-POND	-	0.01	0.00	0.01	0.01	0.01	0.02	0.07	0.13	0.05	0.00	0.00	0.00	0.00	0.01
BROAD CREEK	0.00	0.01	0.00	0.00	0.01	0.03	0.11	0.07	0.12	0.21	-	-	0.00	0.00	0.00
CLOSED-CHANNEL	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.08	0.05	0.03	0.00	0.00	0.05	0.00	0.00
CLOSED-POND	0.02	0.02	0.00	0.00	0.01	0.01	0.00	0.08	0.07	0.01	0.00	0.00	0.00	0.00	0.00
WATER CONT.-CHAN.	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.01
WATER CONT.-POND	0.03	0.01	0.01	0.00	0.01	0.05	0.08	0.09	0.11	0.07	0.07	0.05	0.01	0.00	0.02
GEANGAWKIN CREEK	0.01	0.02	0.00	0.00	0.01	0.05	0.11	-	-	-	-	-	-	-	-
CONTROL-CHANNEL	0.12	0.03	0.00	0.00	0.01	0.01	0.05	0.09	-	0.08	0.08	0.02	0.00	0.00	0.00
CONTROL-POND	0.02	0.01	0.00	0.01	0.01	0.01	0.00	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.00

TOTAL KJELDAHL NITROGEN DATA (mg ℓ^{-1})

DATE OF COLLECTION

				1979							1980				
SITE-LOCATION	5-31	6-19	7-17	8-14	9-18	11-9	12-23	1-23	2-28	3-25	4-08	5-08	6-11	8-07	10-02
OPEN-CHANNEL	1.24	0.99	0.87	0.87	1.11	1.13	1.06	0.68	-	0.74	0.82	0.84	0.80	1.20	0.94
OPEN-POND	2.24	1.56	0.97	1.14	0.97	0.81	1.57	0.98	1.38	0.93	1.51	1.91	1.23	1.36	1.01
BROAD CREEK	0.68	0.81	0.91	0.89	0.74	0.59	0.62	0.62	0.45	0.71	-	-	0.60	1.22	0.96
CLOSED-CHANNEL	1.41	1.26	0.93	1.23	1.15	0.94	1.29	0.82	1.29	1.44	1.29	1.57	1.42	1.25	1.01
CLOSED-POND	1.35	1.68	1.03	1.06	1.20	1.06	1.89	0.89	1.40	1.70	2.45	1.45	1.44	2.61	1.20
WATER CONT.-CHAN.	2.00	1.60	1.00	1.03	1.08	1.00	1.79	1.25	0.93	1.16	1.41	1.07	0.75	1.78	1.55
WATER CONT.-POND	0.98	1.36	1.27	0.98	1.05	0.92	1.28	0.61	1.68	1.47	1.23	1.16	1.04	2.22	1.35
GEANGAWKIN CREEK	0.82	1.12	0.80	0.82	1.02	0.72	0.79	-	-	-	-	-	-	-	-
CONTROL-CHANNEL	0.95	1.55	0.94	1.03	1.71	1.20	0.97	0.61	-	1.89	0.88	0.97	0.81	1.67	1.03
CONTROL-POND	1.05	1.11	1.42	1.09	1.31	1.11	2.50	0.56	2.64	1.17	1.07	1.16	2.10	-	1.21

DISSOLVED KJELDAHL NITROGEN (mg ℓ^{-1})

DATE OF COLLECTION

				1979							1980				
SITE-LOCATION	5-31	6-19	7-17	8-14	9-18	11-9	12-11	1-23	2-28	3-25	4-08	5-08	6-11	8-07	10-02
OPEN-CHANNEL	0.76	0.88	0.61	0.70	0.75	0.57	0.78	0.49	0.35	0.53	0.63	0.64	0.47	0.94	0.68
OPEN-POND	1.50	1.28	0.83	0.79	0.70	0.70	1.35	0.86	1.11	0.71	0.49	1.53	0.93	1.05	0.80
BROAD CREEK	0.44	0.53	0.56	0.56	0.43	0.47	0.46	0.55	0.38	0.37	-	-	0.35	0.85	0.62
CLOSED-CHANNEL	1.18	1.12	0.64	0.81	0.27	0.70	1.62	0.70	1.08	1.16	0.93	1.53	0.96	0.95	0.90
CLOSED-POND	1.25	1.23	0.85	0.70	0.31	0.84	1.43	0.73	1.23	1.24	0.91	1.33	1.03	1.45	1.01
WATER CONT.-CHAN.	2.00	1.00	0.82	0.64	1.00	0.62	1.66	1.22	0.86	0.81	1.29	0.76	0.53	1.02	0.91
WATER CONT.-POND	0.85	0.98	0.94	0.56	0.76	0.97	1.13	0.61	1.53	1.17	0.91	1.11	0.98	1.78	1.05
GEANGAWKIN CREEK	0.72	0.75	0.51	0.54	0.48	0.75	0.51	0.46	-	-	-	-	-	-	-
CONTROL-CHANNEL	0.75	1.02	0.68	0.71	1.31	1.08	0.82	0.55	-	0.51	1.07	0.76	0.63	1.09	0.63
CONTROL-POND	0.88	1.09	1.08	0.91	0.92	0.49	1.99	0.52	2.58	0.82	0.88	0.98	1.68	2.64	0.96

TOTAL PHOSPHORUS DATA (mgℓ $^{-1}$)

	DATE OF COLLECTION														
				1979							1980				
SITE-LOCATION	5-31	6-19	7-17	8-14	9-18	11-9	12-11	1-23	2-28	3-25	4-08	5-08	6-11	8-07	10-02
OPEN-CHANNEL	0.04	0.12	0.06	0.05	0.01	0.03	0.03	0.08	0.05	0.08	0.07	0.06	0.07	0.05	0.06
OPEN-POND	0.08	0.13	0.03	0.06	0.02	0.03	0.02	0.04	0.04	0.05	0.07	0.07	0.03	0.03	0.06
BROAD CREEK	0.05	0.11	0.04	0.06	0.04	0.04	0.04	0.06	0.04	0.06	-	-	0.04	0.07	0.08
CLOSED-CHANNEL	0.08	0.11	0.08	0.06	0.02	0.04	0.05	0.04	0.05	0.05	0.06	0.06	0.03	0.14	0.04
CLOSED-POND	0.05	0.07	0.03	0.04	0.02	0.06	0.05	0.04	0.06	0.06	0.18	0.07	0.07	0.22	0.03
WATER CONT.-CHAN.	0.07	0.12	0.08	0.08	0.07	0.04	0.04	0.05	0.05	0.05	0.04	0.05	0.03	0.12	0.10
WATER CONT.-POND	0.04	0.09	0.06	0.04	0.03	0.04	0.02	0.05	0.04	0.03	0.08	0.04	0.02	0.04	0.03
GEANGAWKIN CREEK	0.04	0.10	0.07	0.06	0.04	0.06	0.02	0.04	-	-	-	-	-	-	-
CONTROL-CHANNEL	0.13	0.17	0.04	0.06	0.10	0.06	0.03	0.06	-	0.15	0.16	0.07	0.04	0.32	0.08
CONTROL-POND	0.03	0.07	0.07	0.04	0.01	0.05	0.09	0.05	0.05	0.06	0.06	0.04	0.17	0.06	0.04

DISSOLVED PHOSPHORUS DATA ($mg \ell^{-1}$)

DATE OF COLLECTION

				1979							1980				
SITE-LOCATION	5-31	6-19	7-17	8-14	9-18	11-9	12-11	1-23	2-28	3-25	4-08	5-08	6-11	8-07	10-02
OPEN-CHANNEL	0.00	0.06	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.01	0.02
OPEN-POND	-	0.06	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.00	0.00	0.02
BROAD CREEK	0.00	0.04	0.03	0.01	0.00	0.01	0.01	0.02	0.00	0.01	-	-	0.00	0.01	0.01
CLOSED-CHANNEL	0.01	0.01	0.04	0.01	0.00	0.01	0.03	0.02	0.01	0.01	0.01	0.02	0.00	0.00	0.02
CLOSED-POND	0.02	0.07	0.02	0.01	0.00	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.03
WATER CONT.-CHAN.	0.03	0.06	0.02	0.05	0.00	0.01	0.01	0.03	0.01	0.02	0.04	0.02	0.00	0.04	0.01
WATER CONT.-POND	0.01	0.06	0.02	0.03	0.00	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.00	0.01	0.02
GEANGAWKIN CREEK	0.01	0.09	0.01	0.04	0.01	0.01	0.01	0.01	0.02	-	-	-	-	-	-
CONTROL-CHANNEL	0.01	0.07	0.00	0.01	0.01	0.01	0.03	0.01	-	0.04	0.01	0.02	0.01	0.06	0.03
CONTROL-POND	0.01	0.07	0.02	0.00	0.01	0.02	0.05	0.02	0.02	0.02	0.02	0.01	0.01	0.03	0.03

APPENDIX C: Nutrient concentration data for tidal cycle studies at the Open (Tables 37 - 42) and Control (Tables 43 - 48) Sites. All values are mg ℓ^{-1}. An H indicates high slack tide and L indicates low slack tide.

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ^{-1}) DURING TIDE CYCLES - OPEN SITE

AMMONIA

04-03-79								
(mg ℓ^{-1})	0.07	0.13	0.18	0.20	0.24	0.29		
TIME	6:45	8:30	10:45	12:45	14:45	16:45		
05-31-79								
(mg ℓ^{-1})	0.08	0.17	0.11	0.12	0.07	0.13		
TIME	10:30	12:38	14:45(L)	16:15	18:15	20.00(H)		
06-19-79								
(mg ℓ^{-1})	0.05	0.04	0.09	0.11	0.11	0.00	0.05	
TIME	9:15	11:10(H)	13:05	15:05	17:00(L)	19:04	20:45	
07-17-79								
(mg ℓ^{-1})	0.13	0.10	0.07	0.07	0.08	0.05	0.04	
TIME	7:50	9:50	11:50	13:50(L)	15:50	17:40	19:50	
08-14-79								
(mg ℓ^{-1})	0.04	0.05	0.04	0.06	0.05	0.06	0.03	
TIME	6:35	8:30(H)	10:30	12:30	14:30	16:30(L)	18:20	
09-18-79								
(mg ℓ^{-1})	0.10	0.11	0.10	0.09	0.10	0.08	0.06	
TIME	9:30	11:30(H)	13:30	15:30	17:30	19:30(L)	21:30	
11-09-79								
(mg ℓ^{-1})	0.10	0.08	0.08	0.07	0.07	0.06	0.06	0.07
TIME	5:15(H)	7:15	9:15	11:15	12:17	13:05(L)	16:15	17:37(H)
12-11-79								
(mg ℓ^{-1})	0.09	0.11	0.13	0.12	0.14	0.13	0.07	0.05
TIME	7:08(H)	9:05	11:00	13:00	14:45(L)	15:00	17:05	18:53(H)
03-25-80								
(mg ℓ^{-1})	0.08	0.08	0.06	0.05	0.08	0.05	0.07	0.07
TIME	8:30(H)	10:30	12:30	14:30	16:30	17:54(L)	19:50	21:40(H)
04-08-80								
(mg ℓ^{-1})	0.06	0.05	0.08	0.11	0.11	0.08	0.06	0.07
TIME	6:45(H)	8:45	11:10	12:45	14:00(L)	15:55	18:00	19:15(H)
05-08-80								
(mg ℓ^{-1})	0.19	0.19	0.19	0.19	0.16	0.11	0.11	0.14
TIME	3:49(L)	6:01	8:02	8:33(H)	10:35	12:25	14:30	16:20(L)
06-11-80								
(mg ℓ^{-1})	0.02	0.00	0.00	0.01	0.01	0.02	0.04	
TIME	9:15(L)	11:15	13:15(H)	15:20	17:15	19:15	20:53(L)	
08-07-80								
(mg ℓ^{-1})	0.11	0.06	0.07	0.08	0.07	0.08	0.08	
TIME	8:00(L)	10:00	11:47(H)	14:00	16:00	18:00	19:24(L)	
10-02-80								
(mg ℓ^{-1})	0.04	0.04	0.06	0.07	0.03	0.01	0.01	0.02
TIME	9:40(H)	11:40	13:40	15:47	16:40(L)	17:50	19:43	22:25(H)

CHANGES IN NUTRIENT CONCENTRATIONS (mgℓ^{-1}) DURING TIDE CYCLES - OPEN SITE

NITRATE-NITRITE

04-03-79								
(mg ℓ^{-1})	0.07	0.07	0.10	0.05	0.05	0.05		
TIME	6:45	8:30	10:45	12:45	14:45	16:45		
05-31-79								
(mg ℓ^{-1})	0.01	0.01	0.02	0.01	0.00	0.01		
TIME	10:30	12:38	14:45(L)	16:15	18:15	20:00(H)		
06-19-79								
(mg ℓ^{-1})	0.01	0.01	0.01	0.02	0.02	0.01	0.01	
TIME	9:15	11:10(H)	13:05	15:05	17:00(L)	19:04	20:45	
07-17-79								
(mg ℓ^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TIME	7:50	9:50	11:50	13:50(L)	15:50	17:40	19:50	
08-14-79								
(mg ℓ^{-1})	0.00	0.00	0.01	0.00	0.00	0.00	0.00	
TIME	6:35	8:30(H)	10:30	12:30	14:30	16:30(L)	18:20	
09-18-79								
(mg ℓ^{-1})	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
TIME	9:30	11:30(H)	13:30	15:30	17:30	19:30(L)	21:30	
11-09-79								
(mg ℓ^{-1})	0.03	0.02	0.02	0.01	0.01	0.02	0.03	0.03
TIME	5:15(H)	7:15	9:15	11:15	12:17	13:05(L)	16:15	17:37(H)
12-11-79								
(mg ℓ^{-1})	0.13	0.02	0.01	0.01	0.01	0.01	0.13	0.14
TIME	7:08(H)	9:05	11:00	13:00	14:45(L)	15:00	17:05	18:53(H)
03-25-80								
(mg ℓ^{-1})	0.19	0.18	0.11	0.11	0.09	0.07	0.07	0.08
TIME	8:30(H)	10:30	12:30	14:30	16:30	17:54(L)	19:50	21:40(H)
04-08-80								
(mg ℓ^{-1})	0.16	0.10	0.08	0.08	0.07	0.10	0.14	0.13
TIME	6:45(H)	8:45	11:10	12:45	14:00(L)	15:55	18:00	19:15(H)
05-08-80								
(mg ℓ^{-1})	0.01	0.03	0.01	0.04	0.04	0.04	0.03	0.03
TIME	3:49(L)	6:01	8:02	8:33(H)	10:35	12:25	14:30	16:20(L)
06-11-80								
(mg ℓ^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TIME	9:15(L)	11:15	13:15(H)	15:20	17:15	19:15	20:53(L)	
08-07-80								
(mg ℓ^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TIME	8:00(L)	10:00	11:47(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ^{-1})	0.01	0.02	0.05	0.06	0.00	0.00	0.00	0.01
TIME	9:40(H)	11:40	13:40	15:47	16:40(L)	17:50	19:43	22:25(H)

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ$^{-1}$) DURING TIDE CYCLES - OPEN SITE

TOTAL KJELDAHL NITROGEN

04-03-79								
(mg ℓ$^{-1}$)	0.73	0.87	0.70	0.87	1.20	1.16		
TIME	6:45	8:30	10:45	12:45	14:45	16:45		
05-31-79								
(mg ℓ$^{-1}$)	1.00	1.15	0.82	1.28	0.58	1.24		
TIME	10:30	12:38	14:45(L)	16:15	18:15	20:00(H)		
06-19-79								
(mg ℓ$^{-1}$)	0.83	0.99	1.18	1.30	1.27	0.80	0.80	
TIME	9:15	11:10(H)	13:05	15:05	17:00(L)	19:04	20:45	
07-17-79								
(mg ℓ$^{-1}$)	0.81	0.87	0.87	0.94	1.02	0.96	0.84	
TIME	7:50	9:50	11:50	13:50(L)	15:50	17:40	19:50	
08-14-79								
(mg ℓ$^{-1}$)	0.80	0.87	1.00	1.01	1.14	1.14	0.94	
TIME	6:35	8:30(H)	10:30	12:30	14:30	16:30(L)	18:20	
09-18-79								
(mg ℓ$^{-1}$)	1.02	1.11	1.17	1.29	1.11	1.12	0.94	
TIME	9:30	11:30(H)	13:30	15:30	17:30	19:30(L)	21:30	
11-09-79								
(mg ℓ$^{-1}$)	0.72	1.13	0.92	1.06	0.84	0.78	0.60	0.57
TIME	5:15(H)	7:15	9:15	11:15	12:17	13:05(L)	16:15	17:37(H)
12-11-79								
(mg ℓ$^{-1}$)	0.60	1.06	1.16	1.14	1.19	1.19	0.64	0.62
TIME	7:08(H)	9:05	11:00	13:00	14:45(L)	15:00	17:05	18:53(H)
03-25-80								
(mg ℓ$^{-1}$)	0.62	0.74	0.69	0.78	0.85	0.86	0.50	0.52
TIME	8:30(H)	10:30	12:30	14:30	16:30	17:54(L)	19:50	21:40(H)
04-08-80								
(mg ℓ$^{-1}$)	0.64	0.97	1.11	1.12	1.30	1.19	0.98	0.69
TIME	6:45(H)	8:45	11:10	12:45	14:00(L)	15:55	18:00	19:15(H)
05-08-80								
(mg ℓ$^{-1}$)	0.80	0.82	0.76	0.72	0.78	0.81	0.82	0.83
TIME	3:49(L)	6:01	8:02	8:33(H)	10:35	12:25	14:30	16:20(L)
06-11-80								
(mg ℓ$^{-1}$)	0.72	0.80	0.62	0.72	0.56	0.69	0.83	
TIME	9:15(L)	11:15	13:15(H)	15:20	17:15	19:15	20:53(L)	
08-07-80								
(mg ℓ$^{-1}$)	1.11	1.02	1.33	1.13	1.15	1.50	1.13	
TIME	8:00(L)	10:00	11:47(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ$^{-1}$)	0.75	0.91	0.93	1.03	1.08	1.00	0.90	0.88
TIME	9:40(H)	11:40	13:40	15:47	16:40(L)	17:50	19:43	22:25(H)

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ^{-1}) DURING TIDE CYCLES - OPEN SITE

DISSOLVED KJELDAHL NITROGEN

04-03-79								
(mg ℓ^{-1})	0.33	0.38	0.55	0.65	0.91	1.00		
TIME	6:45	8:30	10:45	12:45	14:45	16:45		
05-31-79								
(mg ℓ^{-1})	0.74	0.78	0.78	0.92	0.46	0.85		
TIME	10:30	12:38	14:45(L)	16:15	18:15	20:00(H)		
06-19-79								
(mg ℓ^{-1})	0.86	0.86	0.96	1.12	1.11	0.65	0.60	
TIME	9:15	11:10(H)	13:05	15:05	17:00(L)	19:04	20:45	
07-17-79								
(mg ℓ^{-1})	0.48	0.54	0.63	0.75	0.75	0.64	0.47	
TIME	7:50	9:50	11:50	13:50(L)	15:50	17:40	19:50	
08-14-79								
(mg ℓ^{-1})	0.53	0.63	0.64	0.79	0.98	1.05	0.47	
TIME	6:35	8:30(H)	10:30	12:30	14:30	16:30(L)	18:20	
09-18-79								
(mg ℓ^{-1})	0.61	0.70	0.68	0.97	0.85	0.86	0.62	
TIME	9:30	11:30(H)	13:30	15:30	17:30	19:30(L)	21:30	
11-09-79								
(mg ℓ^{-1})	0.50	0.50	0.54	0.74	0.77	0.58	0.50	0.54
TIME	5:15(H)	7:15	9:15	11:15	12:17	13:05(L)	16:15	17:34(H)
12-11-79								
(mg ℓ^{-1})	0.55	0.96	0.99	0.96	0.96	0.94	0.45	0.46
TIME	7:08(H)	9:05	11:00	13:00	14:45(L)	15:00	17:05	18:53(H)
03-25-80								
(mg ℓ^{-1})	0.48	0.50	0.53	0.57	0.74	0.67	0.36	0.40
TIME	8:30(H)	10:30	12:30	14:30	16:30	17:54(L)	19:50	21:40(H)
04-08-80								
(mg ℓ^{-1})	0.34	0.48	0.75	0.84	0.86	0.66	0.33	0.42
TIME	6:45(H)	8:45	11:10	12:45	14:00(L)	15:55	18:00	19:15(H)
05-08-80								
(mg ℓ^{-1})	0.66	0.61	0.60	0.61	0.62	0.64	0.68	0.76
TIME	3:49(L)	6:01	8:02	8:33(H)	10:35	12:25	14:30	16:20(L)
06-11-80								
(mg ℓ^{-1})	0.56	0.37	0.28	0.44	0.40	0.57	0.71	
TIME	9:15(L)	11:15	13:15(H)	15:20	17:15	19:15	20:53(L)	
08-07-80								
(mg ℓ^{-1})	0.96	0.68	0.75	0.86	0.99	1.39	0.94	
TIME	8:00(L)	10:00	11:47(H)	14:00	16:00	18:00	19:25(H)	
10-20-80								
(mg ℓ^{-1})	0.62	0.59	1.11	0.85	0.59	0.53	0.56	0.58
TIME	9:40(H)	11:40	13:40	15:47	16:40(L)	17:50	19:43	22:25(H)

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ^{-1}) DURING TIDE CYCLES - OPEN SITE

TOTAL PHOSPHORUS

04-03-79								
(mg ℓ^{-1})	0.06	0.07	0.08	0.08	0.01	0.01		
TIME	6:45	8:30	10:45	12:45	14:45	16:45		
05-31-79								
(mg ℓ^{-1})	0.09	0.07	0.25	0.18	0.04	0.10		
TIME	10:30	12:38	14:45(L)	16:15	18:15	20:00(H)		
06-19-79								
(mg ℓ^{-1})	0.12	0.13	0.14	0.13	0.13	0.12	0.10	
TIME	9:15	11:10(H)	13:05	15:05	17:00(L)	19:04	20:45	
07-17-79								
(mg ℓ^{-1})	0.06	0.06	0.08	0.08	0.07	0.06	0.07	
TIME	7:50	9:50	11:50	13:50(L)	15:50	17:40	19:50	
08-14-79								
(mg ℓ^{-1})	0.08	0.08	0.08	0.08	0.07	0.07	0.07	
TIME	6:35	8:30(H)	10:30	12:30	14:30	16:30(L)	18:20	
09-18-79								
(mg ℓ^{-1})	0.01	0.05	0.05	0.08	0.07	0.05	0.07	
TIME	9:30	11:30(H)	13:30	15:30	17:30	19:30(L)	21:30	
11-09-79								
(mg ℓ^{-1})	0.04	0.04	0.03	0.04	0.02	0.07	0.04	0.04
TIME	5:15(H)	7:15	9:15	11:15	12:17	13:05(L)	16:15	17:37(H)
12-11-79								
(mg ℓ^{-1})	0.03	0.04	0.04	0.07	0.04	0.04	0.04	0.04
TIME	7:08(H)	9:05	11:00	13:00	14:45(L)	15:00	17:05	18:53(H)
03-25-80								
(mg ℓ^{-1})	0.08	0.08	0.07	0.07	0.07	0.06	0.04	0.08
TIME	8:30(H)	10:30	12:30	14:30	16:30	17:54(L)	19:50	21:40(H)
04-08-80								
(mg ℓ^{-1})	0.04	0.08	0.11	0.09	0.08	0.10	0.10	0.07
TIME	6:45(H)	8:45	11:10	12:45	14:00(L)	15:55	18:00	19:15(H)
05-08-80								
(mg ℓ^{-1})	0.06	0.07	0.09	0.08	0.10	0.12	0.09	0.06
TIME	3:49(L)	6:01	8:02	8:33(H)	10:35	12:25	14:30	16:20(L)
06-11-80								
(mg ℓ^{-1})	0.07	0.07	0.05	0.07	0.06	0.05	0.05	
TIME	9:15(L)	11:15	13:15(H)	15:20	17:15	19:15	20:53(L)	
08-07-80								
(mg ℓ^{-1})	0.01	0.04	0.07	0.08	0.08	0.06	0.03	
TIME	8:00(L)	10:00	11:47(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ^{-1})	0.06	0.08	0.04	0.05	0.10	0.03	0.08	0.08
TIME	9:40(H)	11:40	13:40	15:47	16:40(L)	17:50	19:43	22:25(H)

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ$^{-1}$) DURING TIDE CYCLES - OPEN SITE

DISSOLVED PHOSPHORUS

04-03-79	(mg ℓ$^{-1}$)	0.01	0.03	0.01	0.02	0.02	0.03		
	TIME	6:45	8:30	10:45	12:45	14:45	16:45		
05-31-79	(mg ℓ$^{-1}$)	0.01	0.01	0.01	0.01	0.00	0.01		
	TIME	10:30	12:38	14:45(L)	16:15	18:15	20:00(H)		
06-19-79	(mg ℓ$^{-1}$)	0.06	0.06	0.08	0.10	0.08	0.07	0.06	
	TIME	9:15	11:10(H)	13:05	15:05	17:00(L)	19:04	20:45	
07-17-79	(mg ℓ$^{-1}$)	0.00	0.01	0.00	0.00	0.00	0.01	0.01	
	TIME	7:50	9:50	11:50	13:50(L)	15:50	17:40	19:50	
08-14-79	(mg ℓ$^{-1}$)	0.01	0.02	0.02	0.02	0.01	0.02	0.01	
	TIME	6:35	8:30(H)	10:30	12:30	14:30	16:30(L)	18:20	
09-18-79	(mg ℓ$^{-1}$)	0.01	0.00	0.00	0.01	0.00	0.00	0.01	
	TIME	9:30	11:30(H)	13:30	15:30	17:30	19:30(L)	21:30	
11-09-79	(mg ℓ$^{-1}$)	0.02	0.00	0.02	0.01	0.00	0.00	0.01	0.00
	TIME	5:15(H)	7:15	9:15	11:15	12:17	13:05(L)	16:15	17:37(H)
12-11-79	(mg ℓ$^{-1}$)	0.01	0.03	0.03	0.02	0.04	0.03	0.02	0.01
	TIME	7:08(H)	9:05	11:00	13:00	14:45(L)	15:00	17:05	18:53(H)
03-25-80	(mg ℓ$^{-1}$)	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.01
	TIME	8:30(H)	10:30	12:30	14:30	16:30	17:54(L)	19:50	21:40(H)
04-08-80	(mg ℓ$^{-1}$)	0.01	0.01	0.03	0.02	0.02	0.03	0.01	0.01
	TIME	6:45(H)	8:45	11:10	12:45	14:00(L)	15:55	18:00	19:15(H)
05-08-80	(mg ℓ$^{-1}$)	0.02	0.02	0.01	0.02	0.02	0.03	0.03	0.04
	TIME	3:49(L)	6:01	8:02	8:33(H)	10:35	12:25	14:30	16:20(L)
06-11-80	(mg ℓ$^{-1}$)	0.03	0.00	0.01	0.01	0.01	0.01	0.01	
	TIME	9:15(L)	11:15	13:15(H)	15:20	17:15	19:15	20:53(L)	
08-07-80	(mg ℓ$^{-1}$)	0.01	0.04	0.07	0.08	0.08	0.06	0.03	
	TIME	8:00(L)	10:00	11:47(H)	14:00	16:00	18:00	19:25(L)	
10-02-80	(mg ℓ$^{-1}$)	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.02
	TIME	9:40(H)	11:40	13:40	15:47	16:40(L)	17:50	19:43	22:25(H)

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ^{-1}) DURING TIDE CYCLES - CONTROL SITE

AMMONIA

04-08-80								
(mg ℓ^{-1})	0.06	0.08	0.06	0.18	0.17	0.06	0.05	
TIME	6:50(H)	8:55	10:50	13:10	14:57(L)	17:00	19:05(H)	
05-08-80								
(mg ℓ^{-1})	0.31	0.28	0.17	0.18	0.19	0.20	0.23	0.25
TIME	2:53(L)	3:59	6:11	8:11(H)	10:25	12:15	14:40	16:23(L)
06-11-80								
(mg ℓ^{-1})	0.05	0.00	0.02	0.00	0.05	0.09	0.14	
TIME	9:30(L)	11:30	12:30(H)	14:30	16:25	18:30	21:00(L)	
08-07-80								
(mg ℓ^{-1})	0.11	0.06	0.07	0.08	0.07	0.08	0.08	
TIME	8:00(L)	10:00	11:57(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ^{-1})	0.02	0.01	0.00	0.02	0.03	0.04	0.00	
TIME	9:45(H)	11:50	13:49	15:50(L)	17:42	19:55	22:13(H)	

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ^{-1}) DURING TIDE CYCLES - CONTROL SITE

NITRATE - NITRITE

04-08-80								
(mg ℓ^{-1})	0.02	0.10	0.07	0.02	0.02	0.10	0.15	
TIME	6:50(H)	8:55	10:50	13:10	14:57(L)	17:00	19:05(H)	
05-08-80								
(mg ℓ^{-1})	0.00	0.00	0.01	0.03	0.03	0.03	0.01	0.01
TIME	2:53(L)	3:59	6:11	8:11(H)	10:25	12:15	14:40	16:23(L)
06-11-80								
(mg ℓ^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TIME	9:30(L)	11:30	12:30(H)	14:30	16:25	18:30	21:00(L)	
08-07-80								
(mg ℓ^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TIME	8:00(L)	10:00	11:57(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ^{-1})	0.00	0.01	0.00	0.00	0.00	0.01	0.01	
TIME	9:45(H)	11:50	13:49	15:50(L)	17:42	19:55	22:13(H)	

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ $^{-1}$) DURING TIDE CYCLES - CONTROL SITE

TOTAL KJELDAHL NITROGEN

04-08-80								
(mg ℓ $^{-1}$)	0.88	0.74	1.09	2.57	2.33	0.78	0.62	
TIME	6.50(H)	8:55	10:50	13:10	14:57(L)	17:00	19:05(H)	
05-08-80								
(mg ℓ $^{-1}$)	1.55	0.97	0.74	0.72	0.66	0.79	0.73	0.79
TIME	2:53(L)	3:59	6:11	8:11(H)	10:25	12:15	14:40	16:23(L)
06-11-80								
(mg ℓ $^{-1}$)	0.81	0.63	0.66	0.62	1.06	1.29	2.68	
TIME	9:30(L)	11:30	12:30(H)	14:30	16:25	18:30	21:00(L)	
08-07-80								
(mg ℓ $^{-1}$)	0.11	1.02	1.33	1.13	1.15	1.50	1.13	
TIME	8:00(L)	10:00	11:57(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ $^{-1}$)	1.10	0.91	1.10	1.31	1.01	0.88	0.88	
TIME	9:45(H)	11:50	13:49	15:50(L)	17:42	19:55	22:13(H)	

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ$^{-1}$) DURING TIDE CYCLES - CONTROL SITE

DISSOLVED KJELDAHL NITROGEN

04-08-80								
(mg ℓ$^{-1}$)	0.50	0.41	0.44	1.08	0.96	0.35	0.41	
TIME	6:50(H)	8:55	10:50	13:10	14:57(L)	17:00	19:05(H)	
05-08-80								
(mg ℓ$^{-1}$)	1.00	0.85	0.51	0.51	0.57	0.59	0.73	0.76
TIME	2:53(L)	3:59	6:11	8:11(H)	10:25	12:15	14:45	16:23(L)
06-11-80								
(mg ℓ$^{-1}$)	0.63	0.37	0.38	0.41	0.65	1.11	0.96	
TIME	9:30(L)	11:30	12:30(H)	14:30	16:25	18:30	21:00(L)	
08-07-80								
(mg ℓ$^{-1}$)	0.96	0.68	0.75	0.86	0.99	1.39	0.94	
TIME	8:00(L)	10:00	11:57(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ$^{-1}$)	0.58	0.60	0.65	0.83	0.58	0.60	0.55	
TIME	9:45(H)	11:50	13:49	15:50(L)	17:42	19:55	22:13(H)	

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ$^{-1}$) DURING TIDE CYCLES - CONTROL SITE

TOTAL PHOSPHORUS

04-08-80								
(mg ℓ$^{-1}$)	0.07	0.07	0.11	0.25	0.26	0.11	0.10	
TIME	6:50(H)	8:55	10:50	13:10	14:57(L)	17:00	19:05(H)	
05-08-80								
(mg ℓ$^{-1}$)	0.08	0.08	0.07	0.07	0.04	0.06	0.04	0.03
TIME	2:53(L)	3:59	6:11	8:11(H)	10:25	12:15	14:40	16:23(L)
06-11-80								
(mg ℓ$^{-1}$)	0.04	0.06	0.04	0.05	0.05	0.05	0.14	
TIME	9:30(L)	11:30	12:30	14:30	16:25	18:30	21:00(L)	
08-07-80								
(mg ℓ$^{-1}$)	0.36	0.14	0.11	0.12	0.44	0.51	0.57	
TIME	8:00(L)	10:00	11:57(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ$^{-1}$)	0.08	0.08	0.08	0.07	0.10	0.07	0.06	
TIME	9:45(H)	11:50	13:49	15:50(L)	17:42	19:55	22:13(H)	

CHANGES IN NUTRIENT CONCENTRATIONS (mg ℓ^{-1}) DURING TIDE CYCLES - CONTROL SITE

DISSOLVED PHOSPHORUS

04-08-80								
(mg ℓ^{-1})	0.01	0.01	0.01	0.03	0.06	0.01	0.01	
TIME	6:50(H)	8:55	10:50	13:10	14:57(L)	17:00	19:05(H)	
05-08-80								
(mg ℓ^{-1})	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
TIME	2:53(L)	3:59	6:11	8:11(H)	10:25	12:15	14:40	16:23(L)
06-11-80								
(mg ℓ^{-1})	0.1	0.00	0.00	0.01	0.02	0.01	0.01	
TIME	9:30(L)	11:30	12:30(H)	14:30	16:25	18:30	21:00(L)	
08-07-80								
(mg ℓ^{-1})	0.16	0.02	0.02	0.02	-	0.05	0.10	
TIME	8:00(L)	10:00	11:57(H)	14:00	16:00	18:00	19:25(L)	
10-02-80								
(mg ℓ^{-1})	0.02	0.02	0.02	0.04	0.03	0.03	0.01	
TIME	9:45(H)	11:50	13:49	15:50(L)	17:42	19:55	22:13(H)	

APPENDIX D: Data from APPENDIX C are plotted to graphically show nutrient concentration patterns during tidal cycle studies at the Open and Control Sites. The X axis is hours after initiation of each study. The Y axis are nutrient concentration data in $mg \ell^{-1}$. High and low slack tides are indicated respectively with H and L.

Group	Nutrients	Site	Figure Numbers	Pages
1	Nitrate	Open	17 - 23	126 - 132
2	Nitrate	Control	24 - 26	134 - 136
3	Ammonia	Open	27 - 33	138 - 144
4	Ammonia	Control	34 - 36	146 - 148
5	Dissolved Kjeldahl	Open	37 - 43	150 - 156
6	Dissolved Kjeldahl	Control	44 - 46	158 - 160
7	Total Kjeldahl	Open	47 - 53	162 - 168
8	Total Kjeldahl	Control	54 - 56	170 - 172
9	Dissolved Phosphorus	Open	57 - 63	174 - 180
10	Dissolved Phosphorus	Control	64 - 66	182 - 184
11	Total Phosphorus	Open	67 - 73	186 - 192
12	Total Phosphorus	Control	74 - 76	194 - 196

I. NITRATE - OPEN SITE

Figure 11

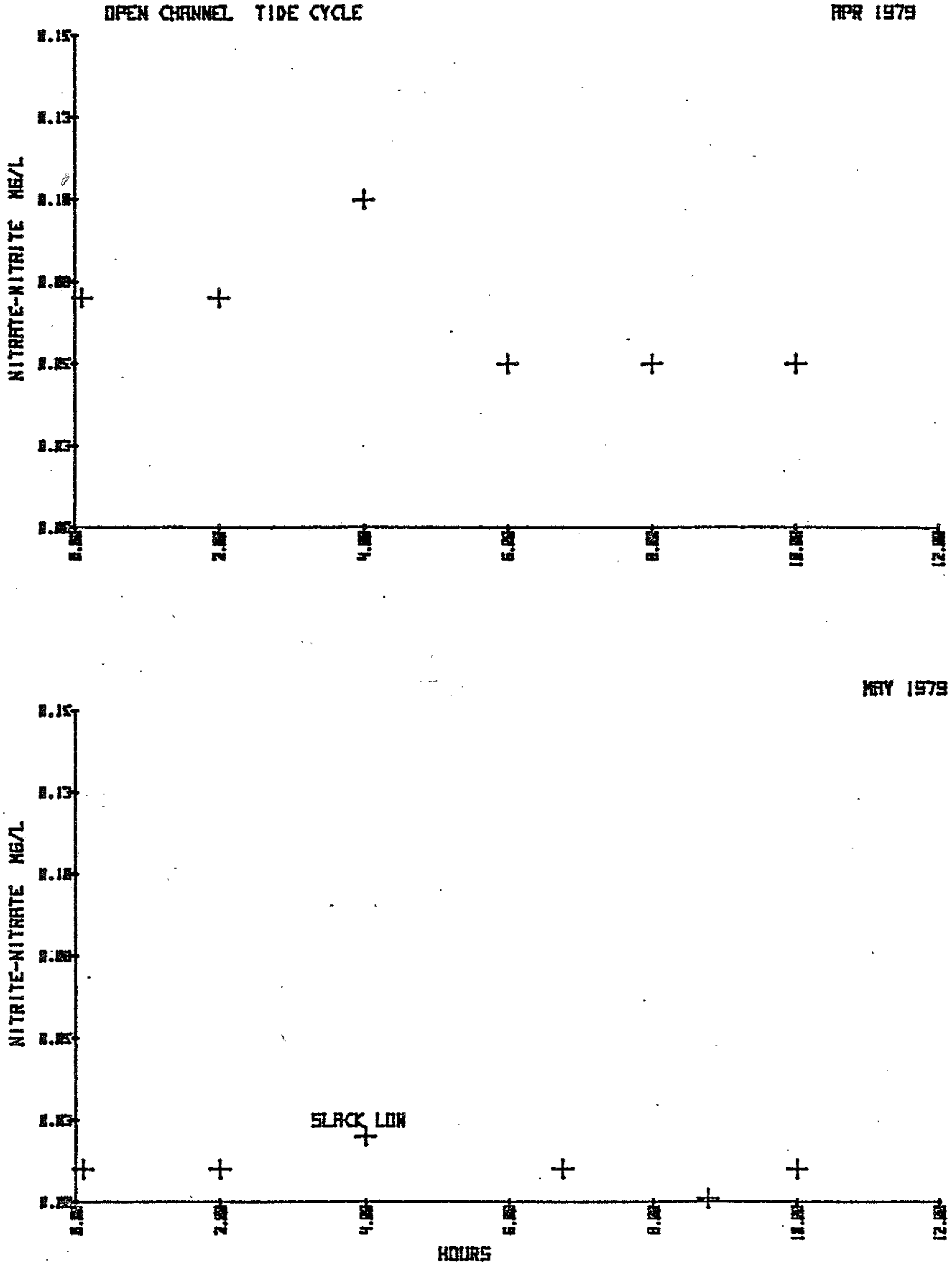

OPEN CHANNEL TIDE CYCLE
APR 1979
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
MAY 1979
NITRITE-NITRATE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 12

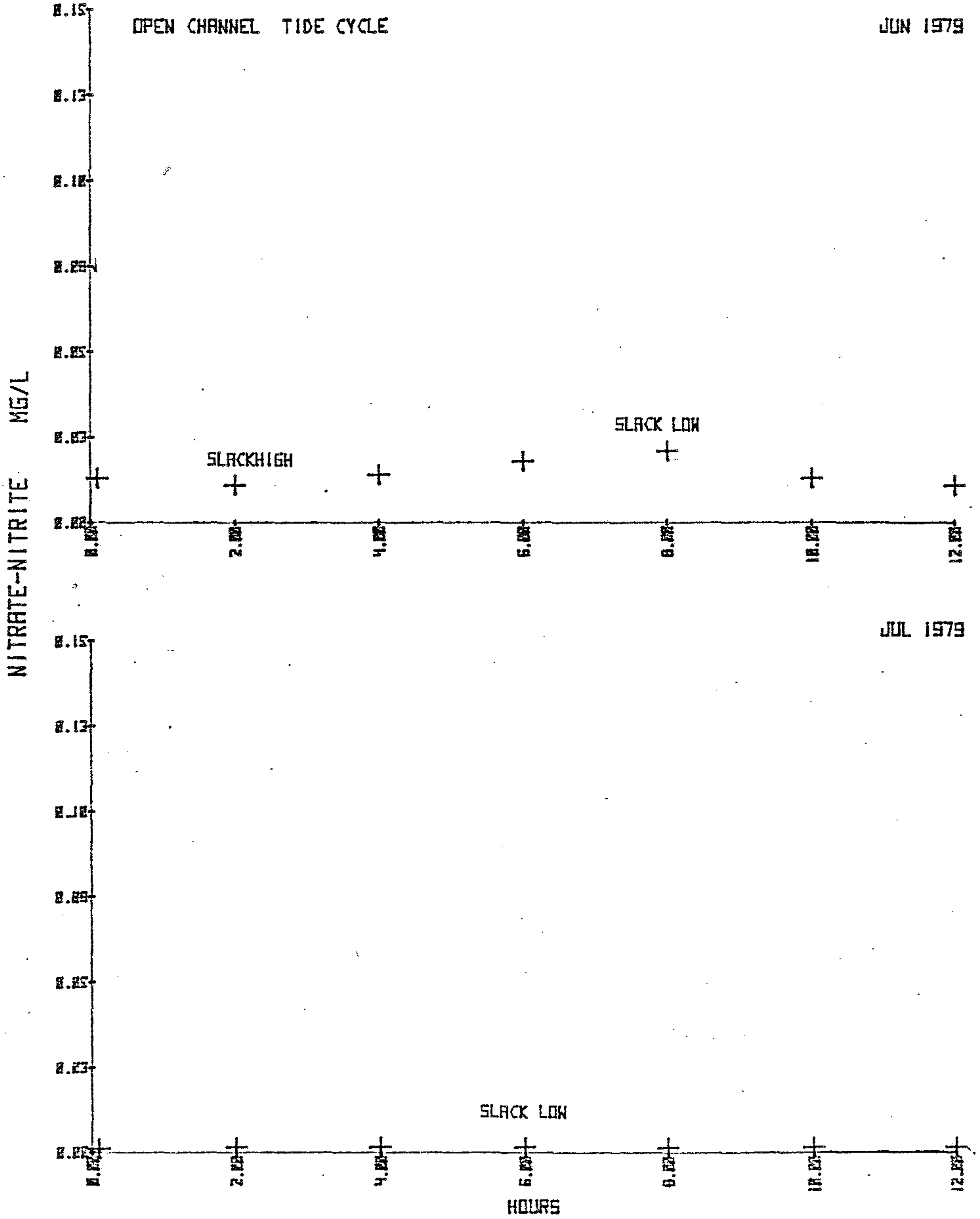

OPEN CHANNEL TIDE CYCLE
JUN 1979
JUL 1979
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACKHIGH
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 13

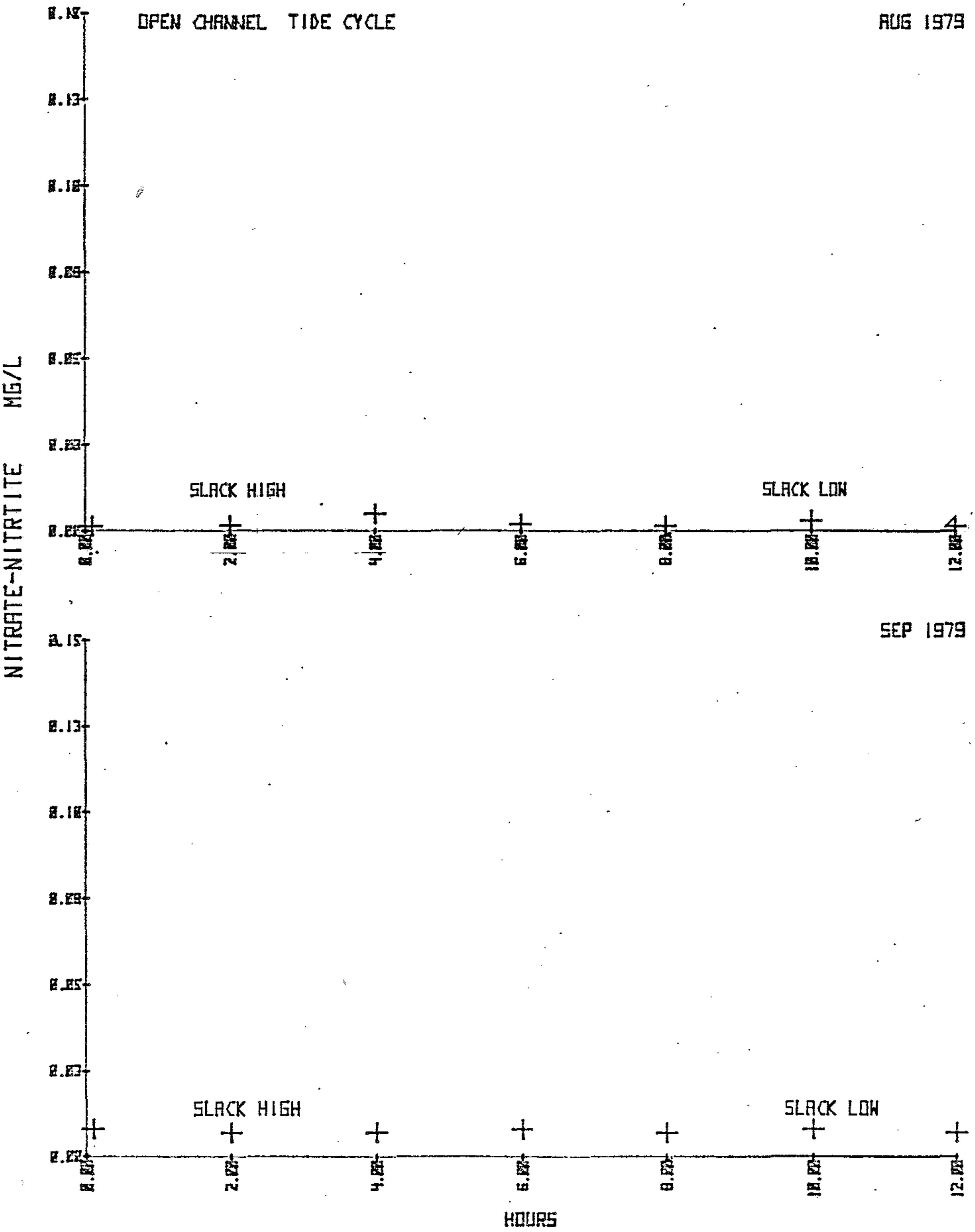

OPEN CHANNEL TIDE CYCLE
AUG 1979
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK HIGH
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
SEP 1979
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK HIGH
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 14

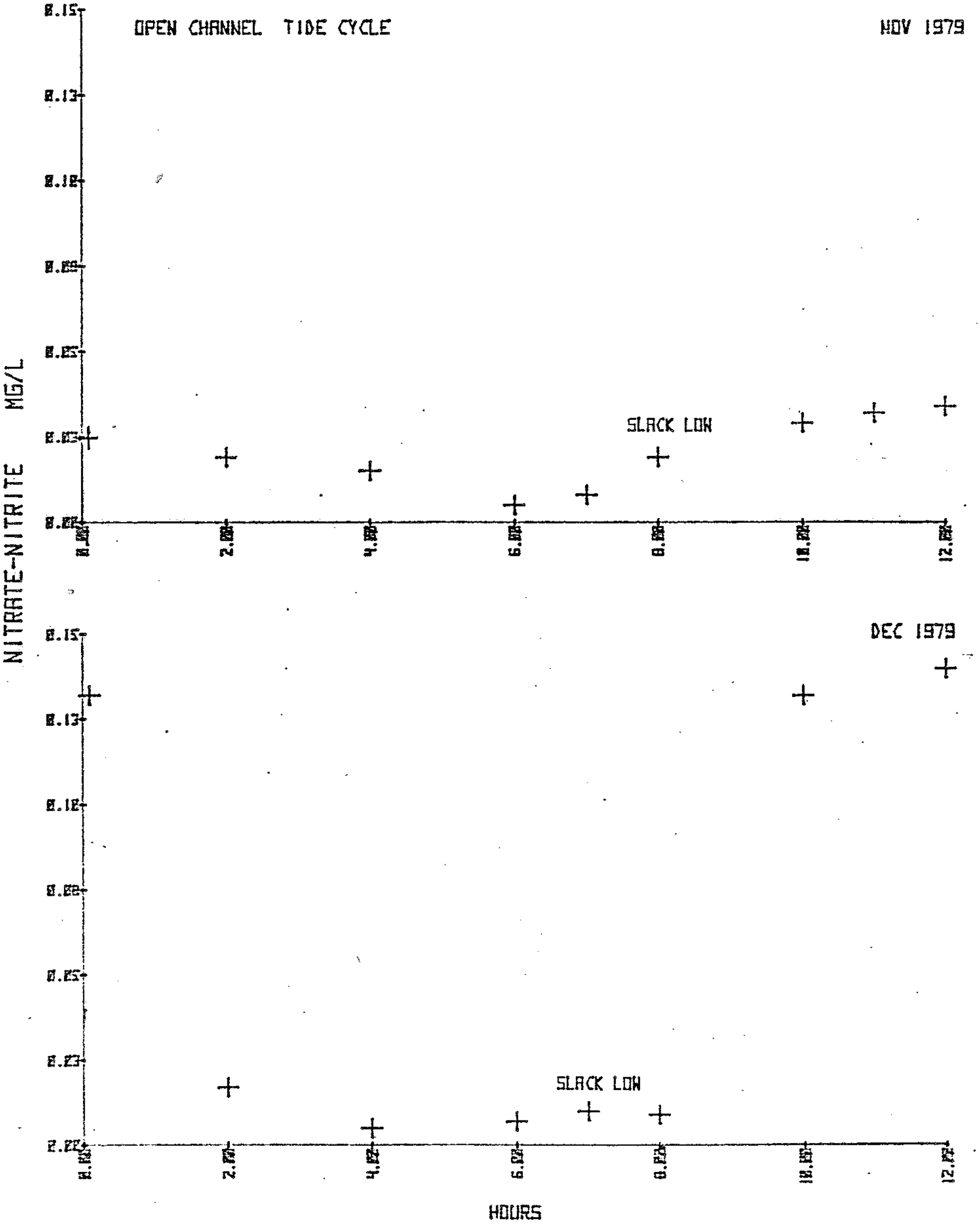

OPEN CHANNEL TIDE CYCLE
NOV 1979
DEC 1979
NITRATE-NITRITE MG/L
SLACK LOW
SLACK LOW
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 15

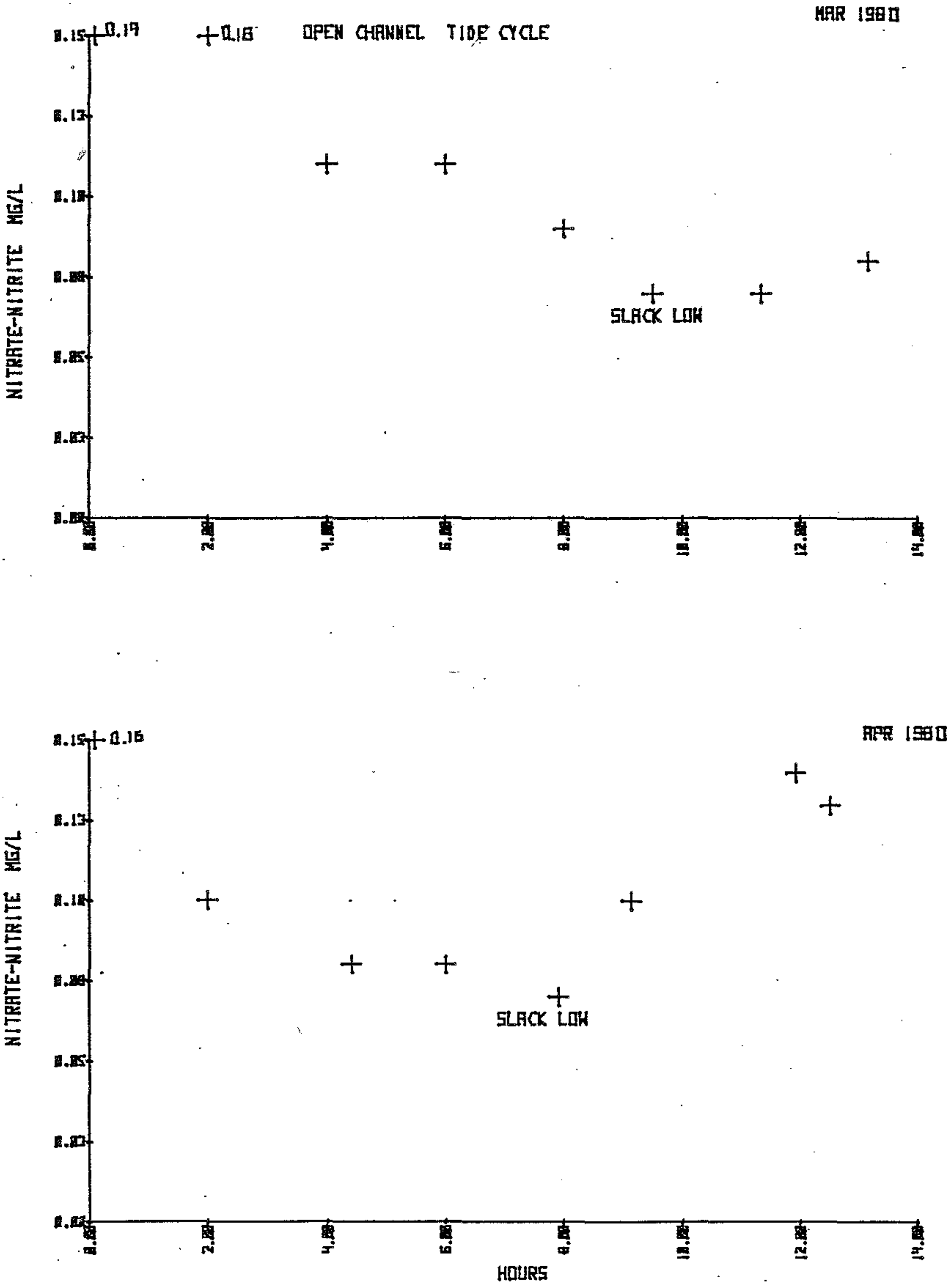

OPEN CHANNEL TIDE CYCLE
MAR 1980
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.19
0.18
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
APR 1980
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.16
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 16

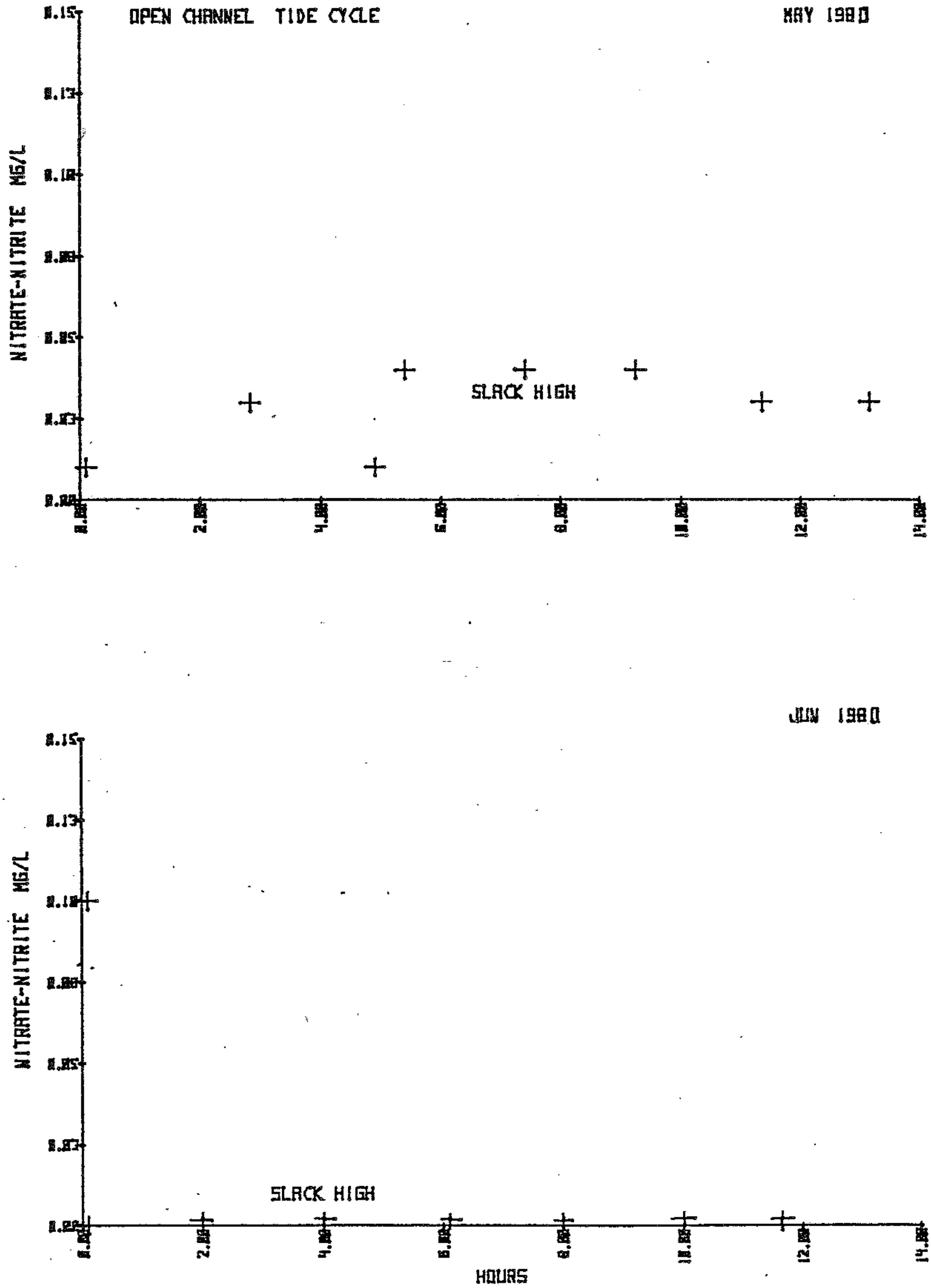
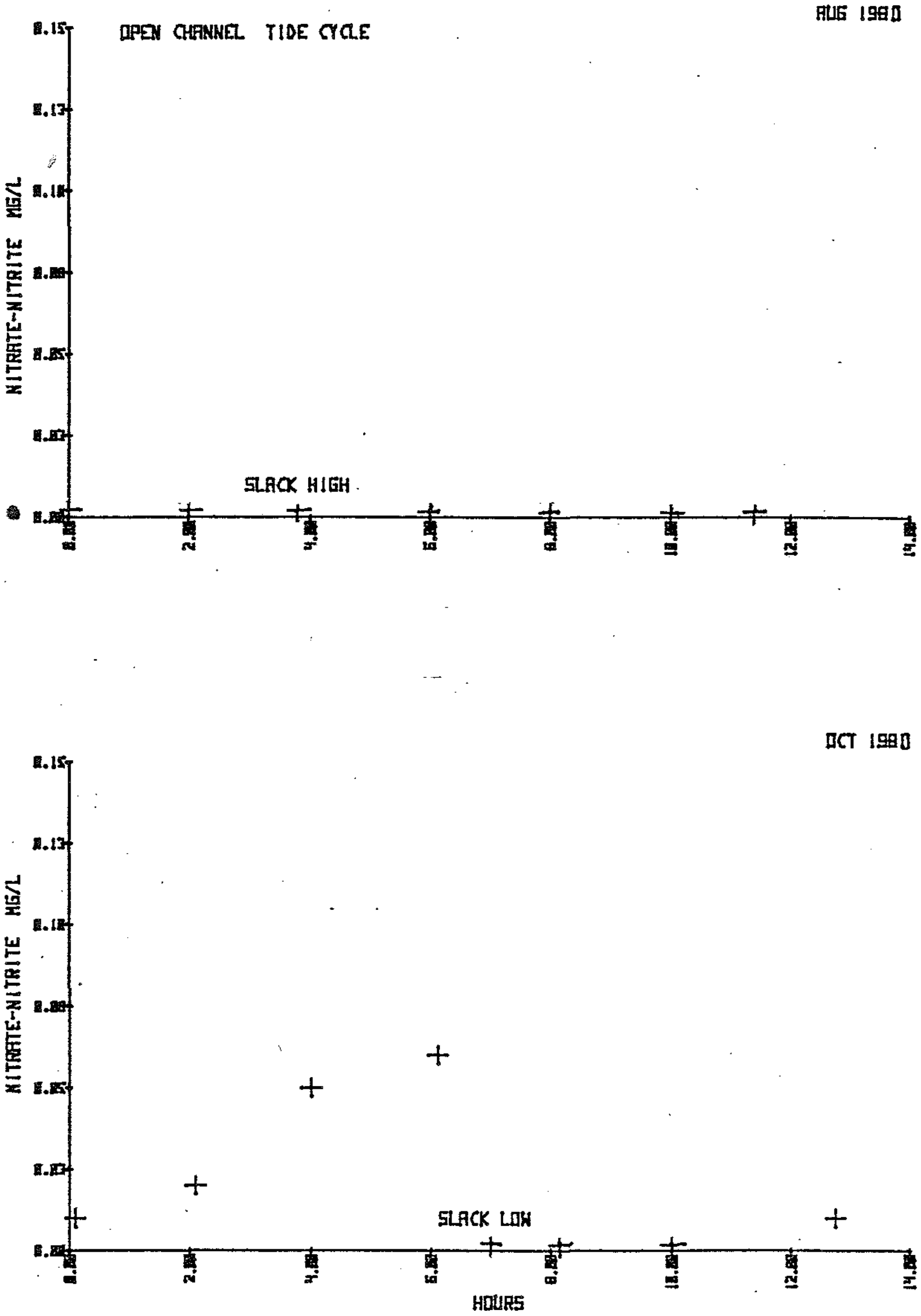

OPEN CHANNEL TIDE CYCLE
MAY 1980
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 17


AUG 1980
OPEN CHANNEL TIDE CYCLE
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1980
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

2. NITRATE - CONTROL SITE

Figure 18

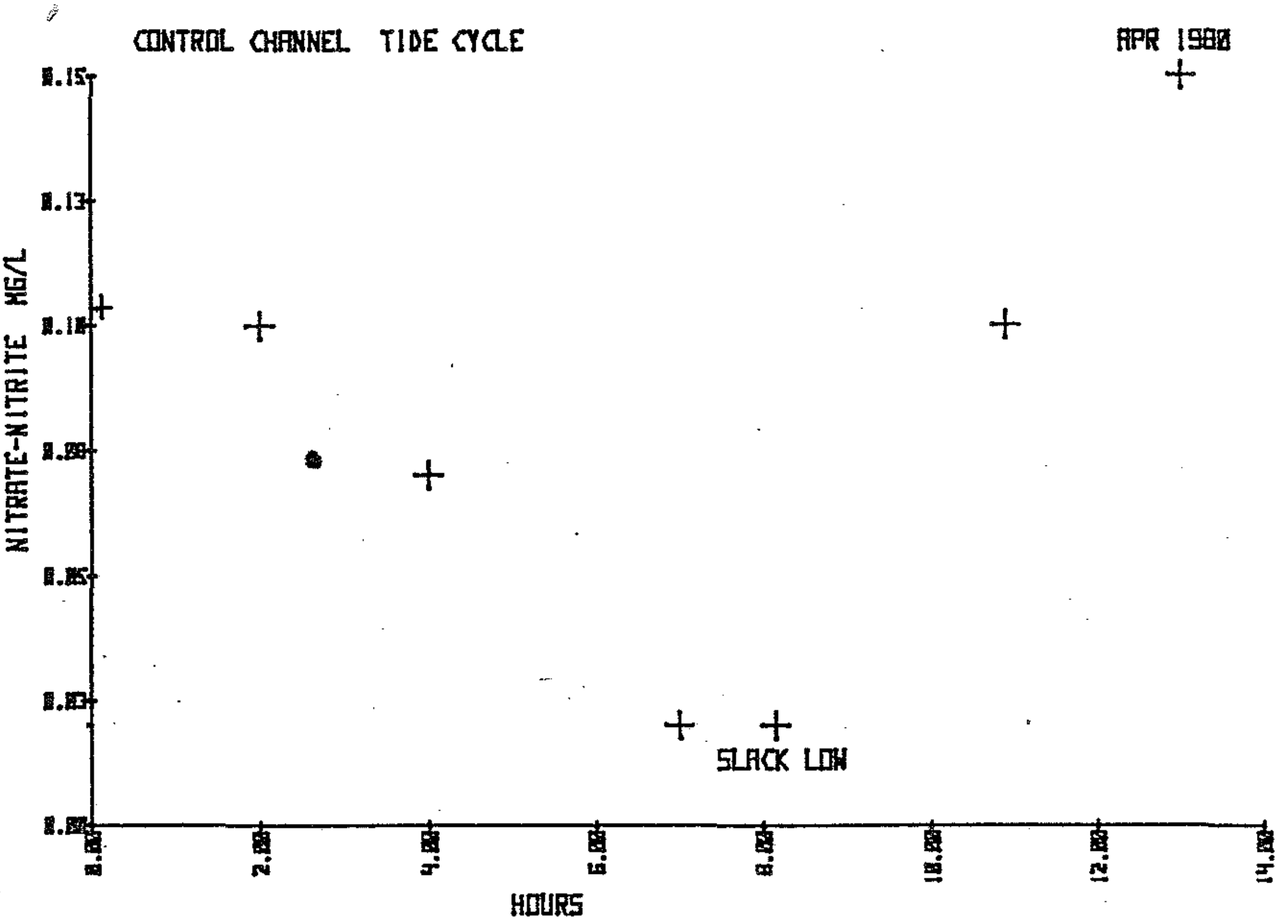

CONTROL CHANNEL TIDE CYCLE
APR 1980
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS
SLACK LOW

Figure 19

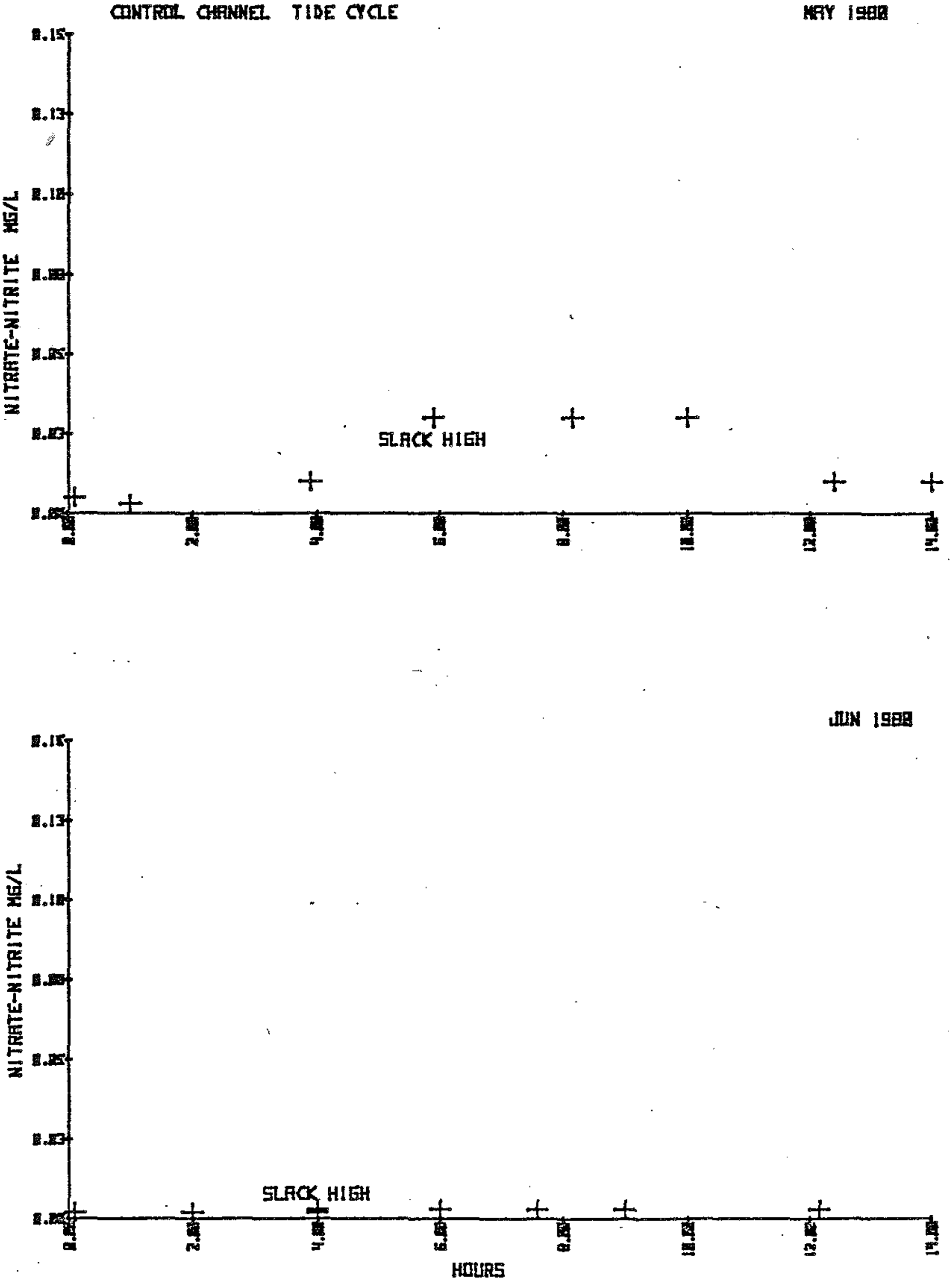
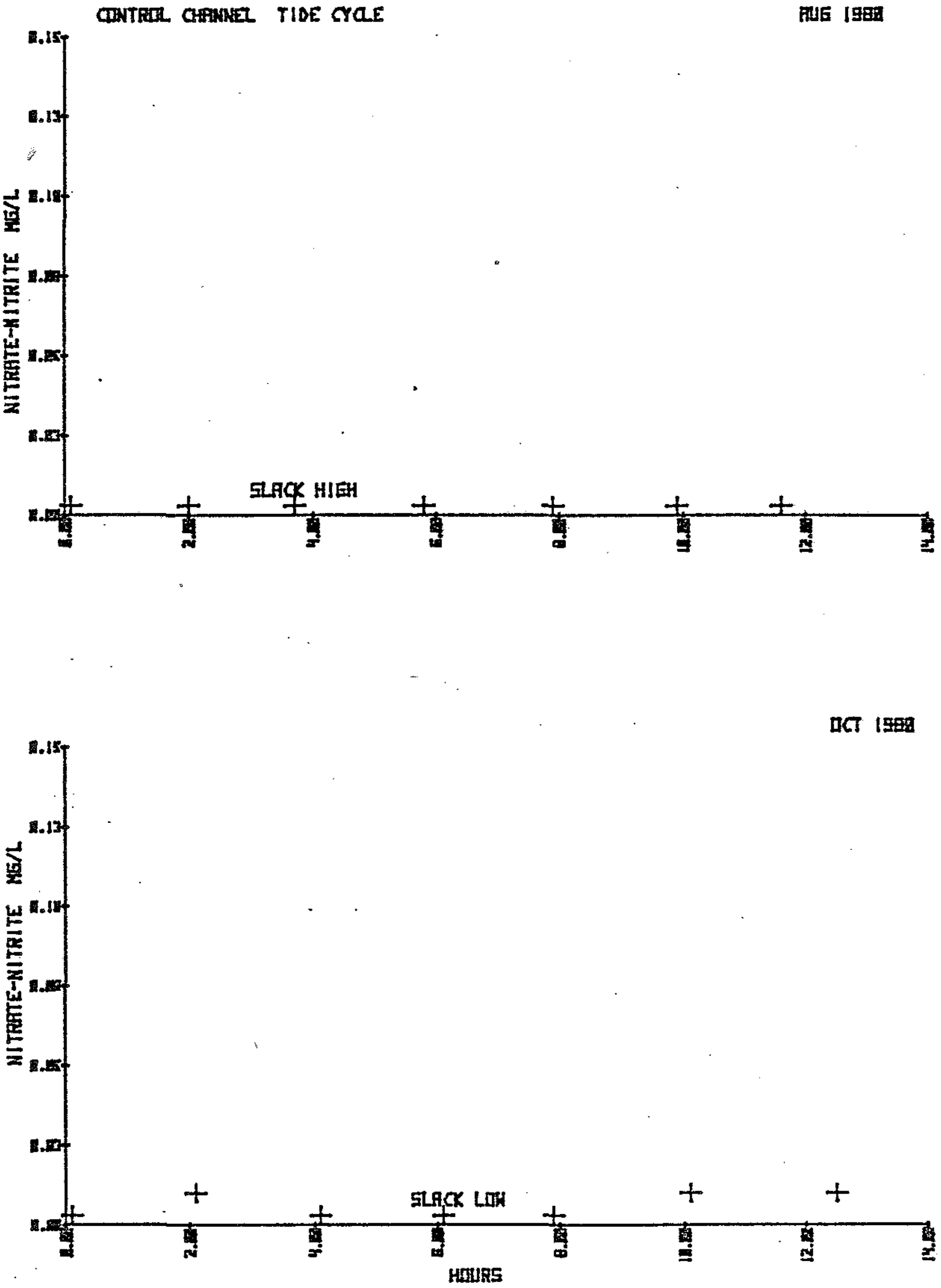

CONTROL CHANNEL TIDE CYCLE
MAY 1980
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 20


CONTROL CHANNEL TIDE CYCLE
AUG 1988
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1988
NITRATE-NITRITE MG/L
0.15
0.13
0.10
0.08
0.05
0.03
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

3. AMMONIA - OPEN SITE

Figure 21

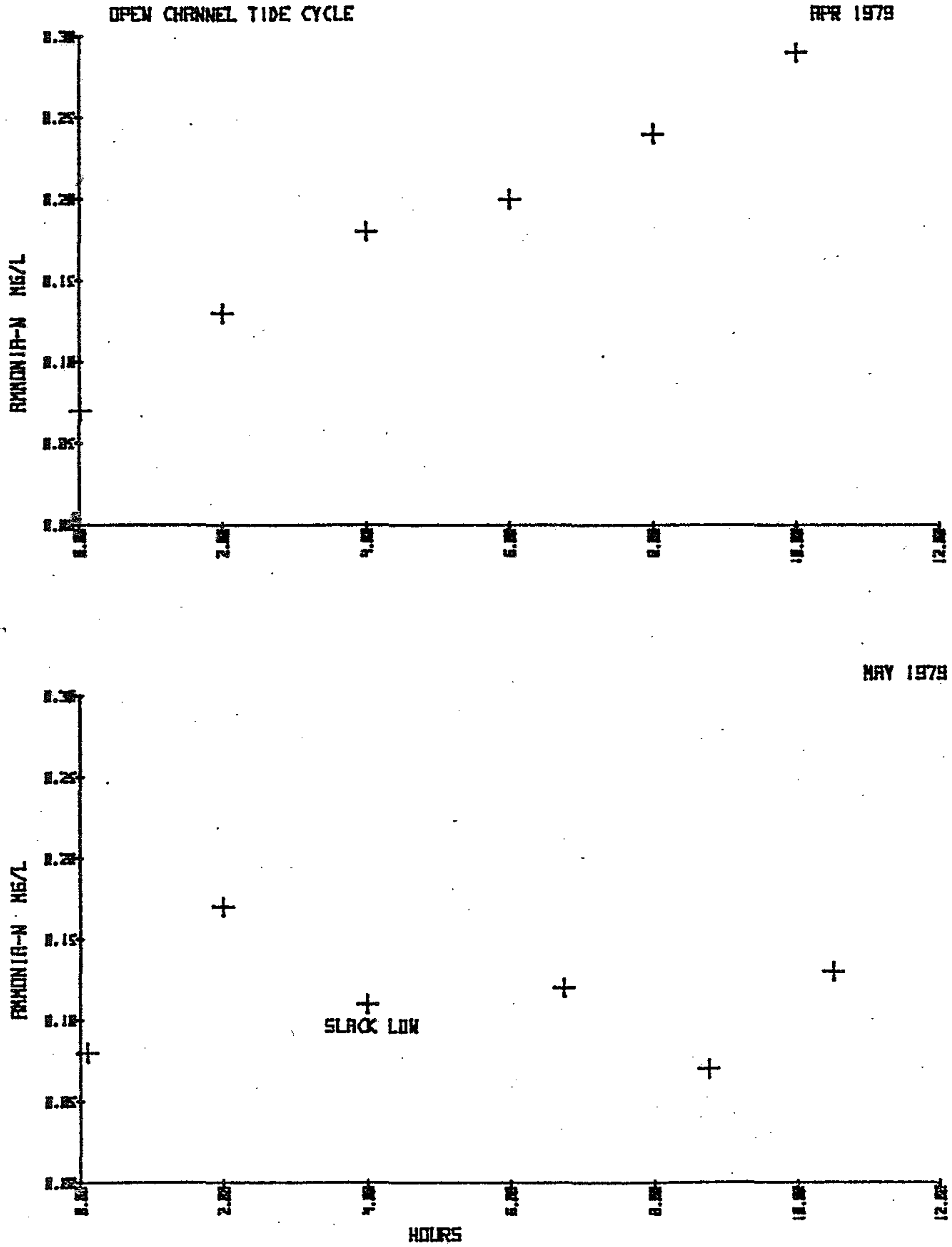

OPEN CHANNEL TIDE CYCLE
APR 1979
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
MAY 1979
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 22

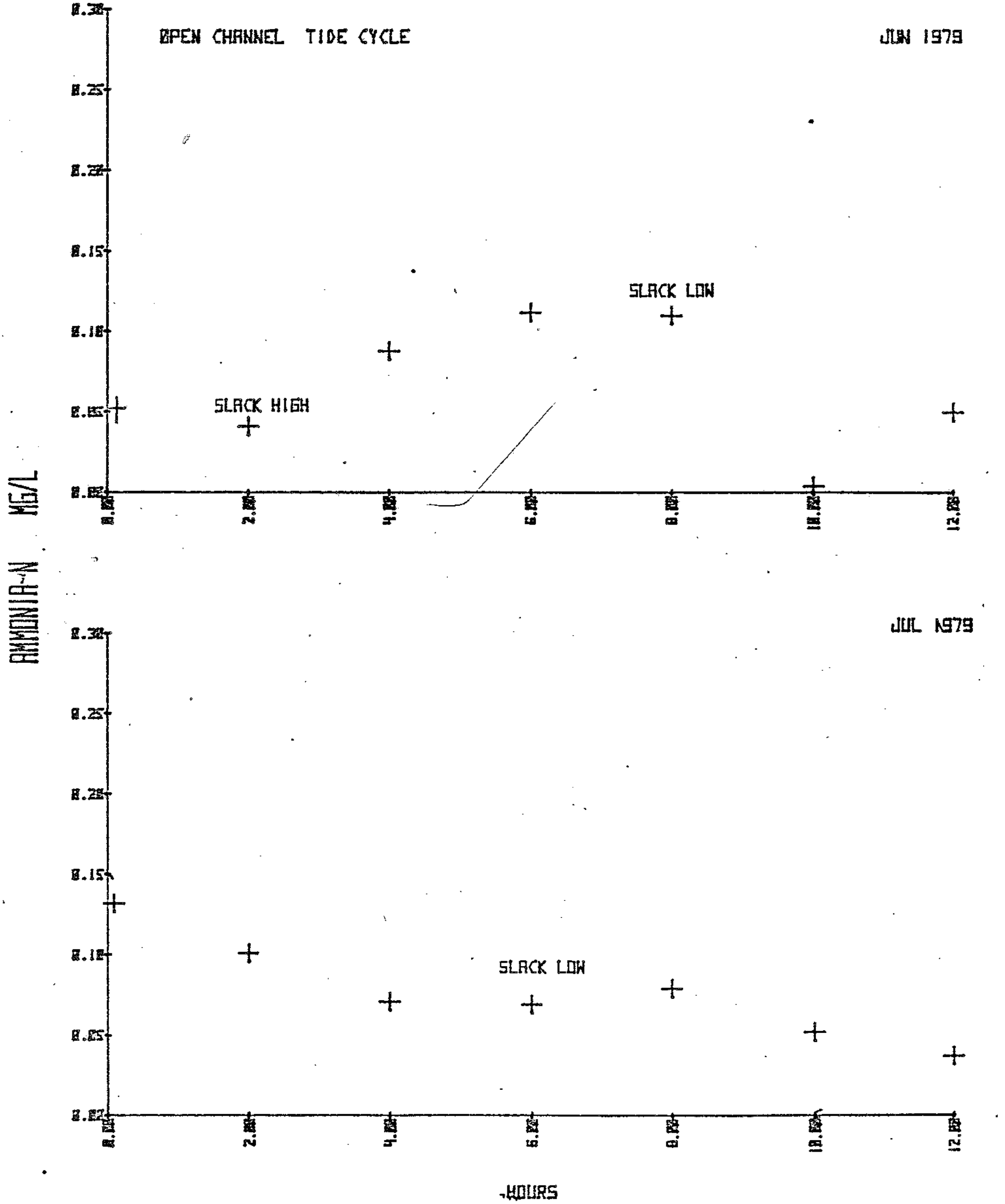

OPEN CHANNEL TIDE CYCLE
JUN 1979
SLACK HIGH
SLACK LOW
JUL 1979
SLACK LOW
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 23

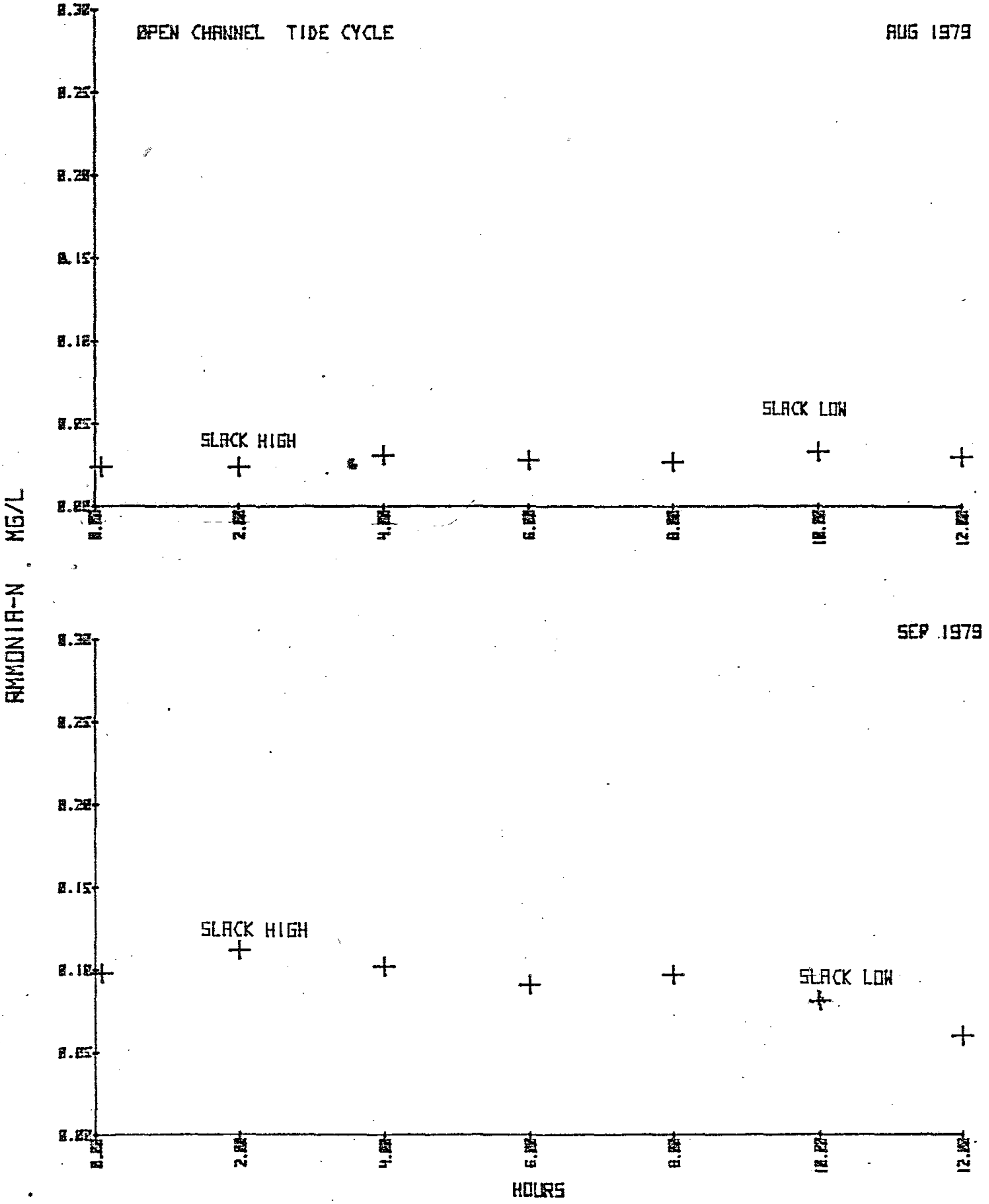

OPEN CHANNEL TIDE CYCLE
AUG 1979
SLACK HIGH
SLACK LOW
SEP 1979
SLACK HIGH
SLACK LOW
AMMONIA-N MG/L
HOURS
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00

Figure 24

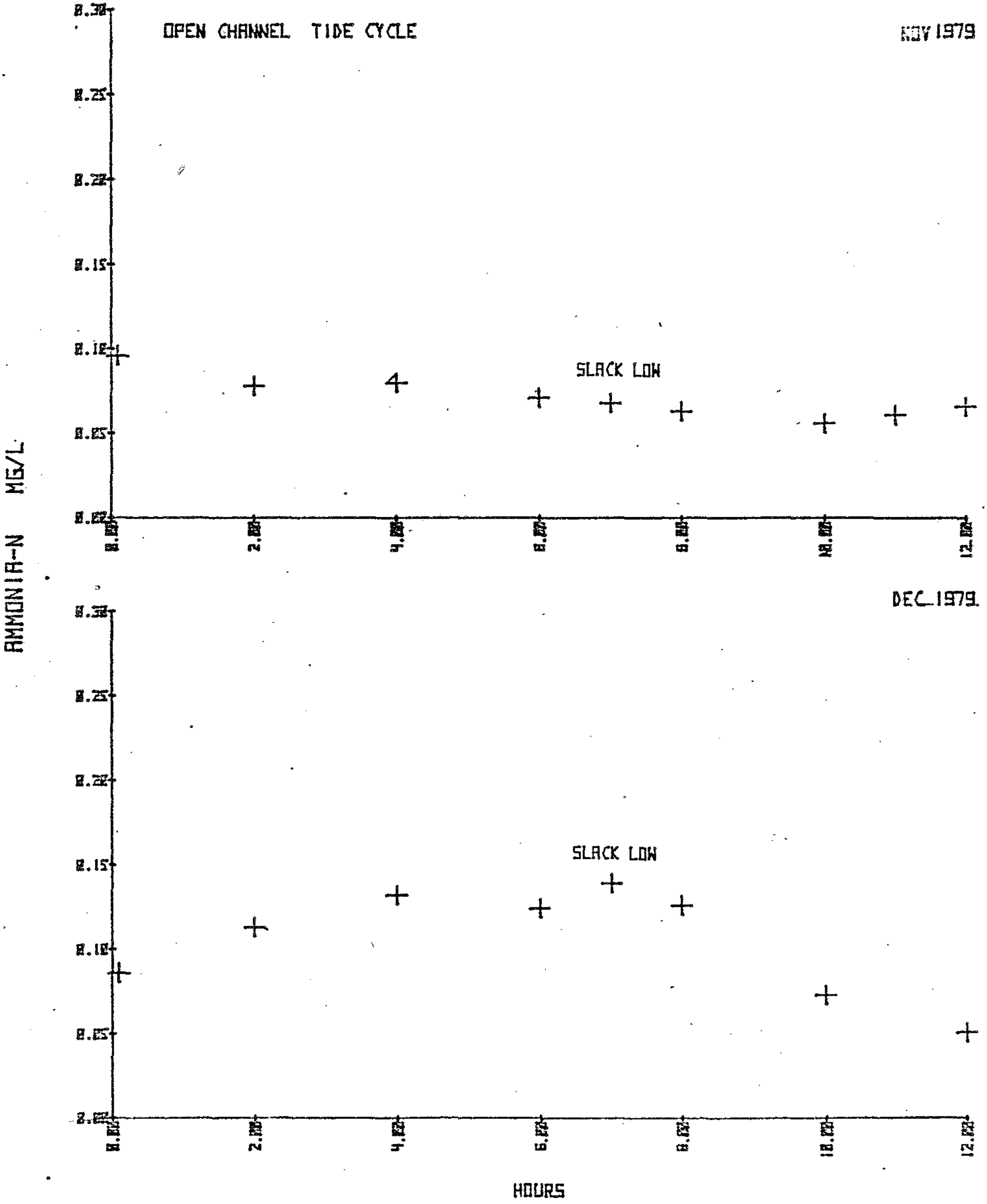

OPEN CHANNEL TIDE CYCLE
NOV 1979
SLACK LOW
DEC 1979
SLACK LOW
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 25

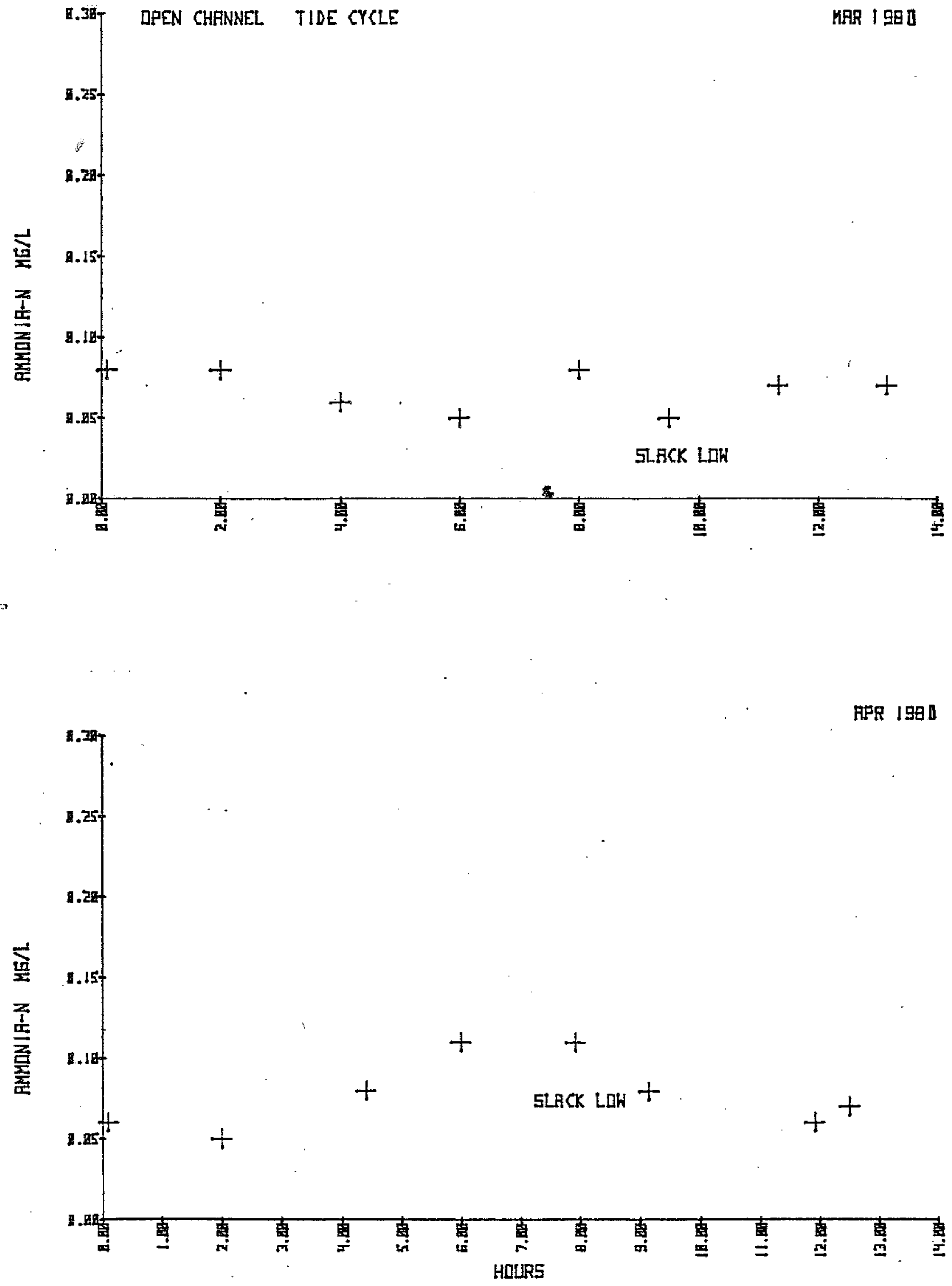

OPEN CHANNEL TIDE CYCLE
MAR 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
SLACK LOW
APR 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
SLACK LOW
HOURS

Figure 26

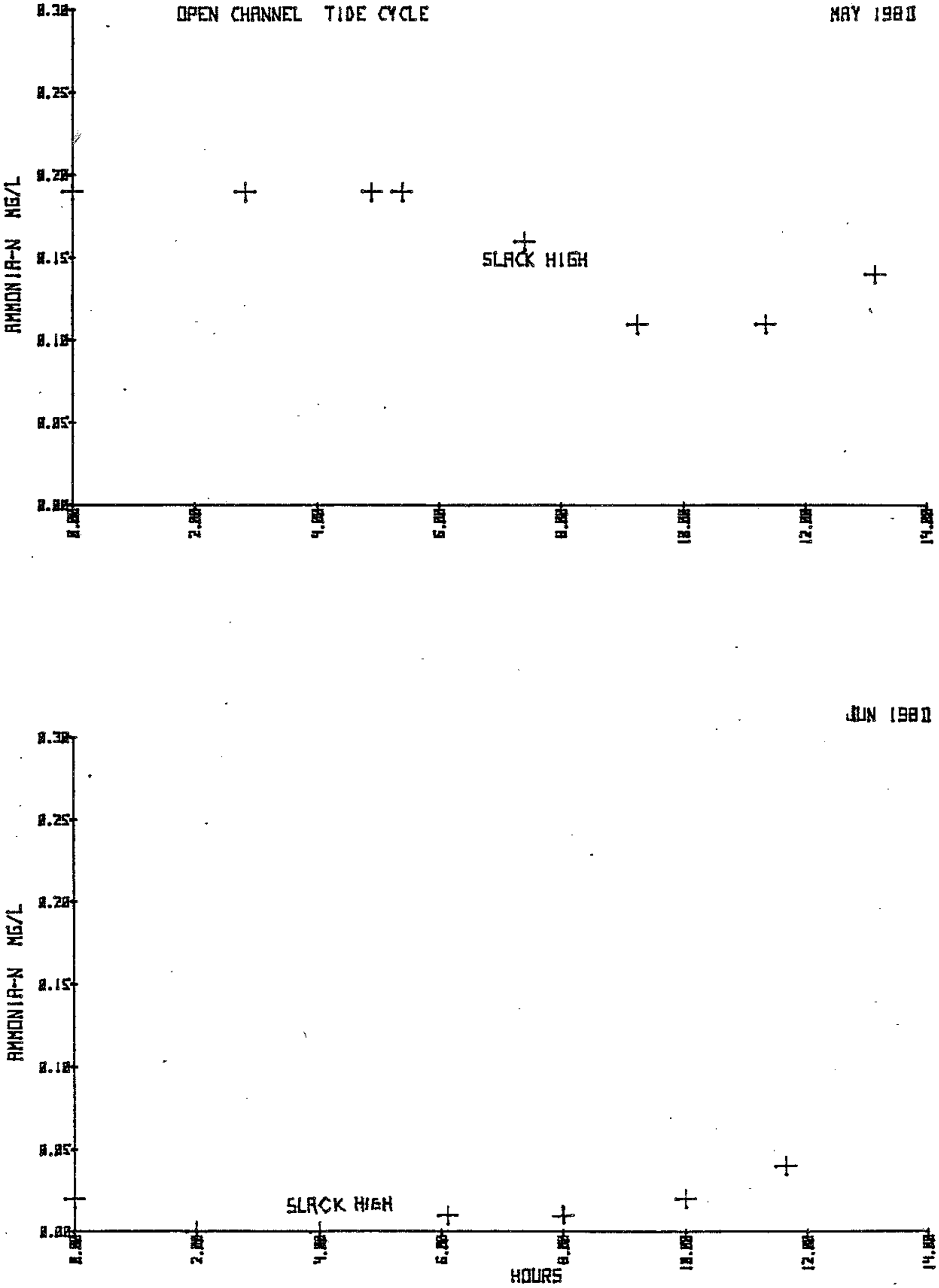
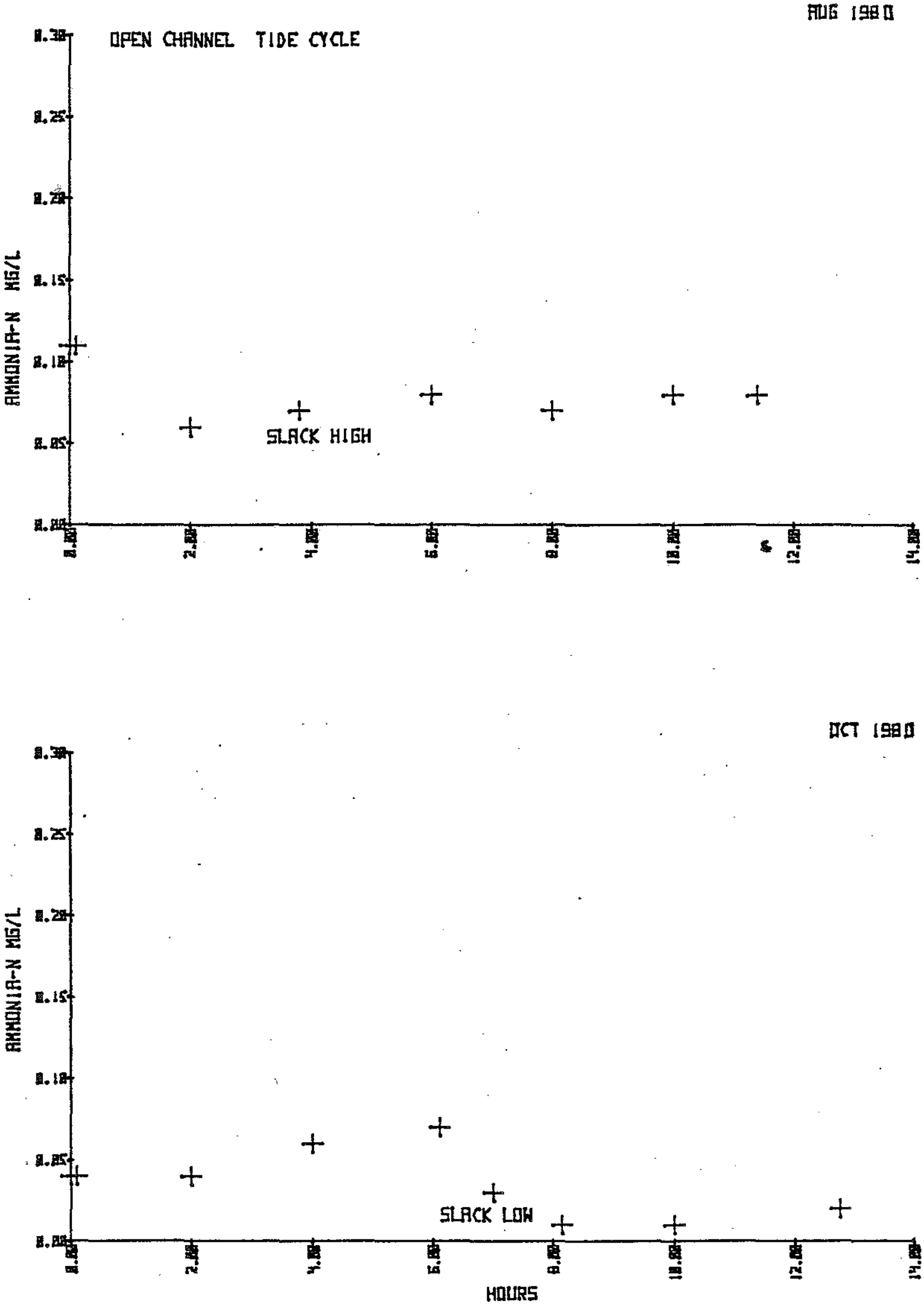

OPEN CHANNEL TIDE CYCLE
MAY 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 27


AUG 1980
OPEN CHANNEL TIDE CYCLE
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

4. AMMONIA - CONTROL SITE

Figure 28

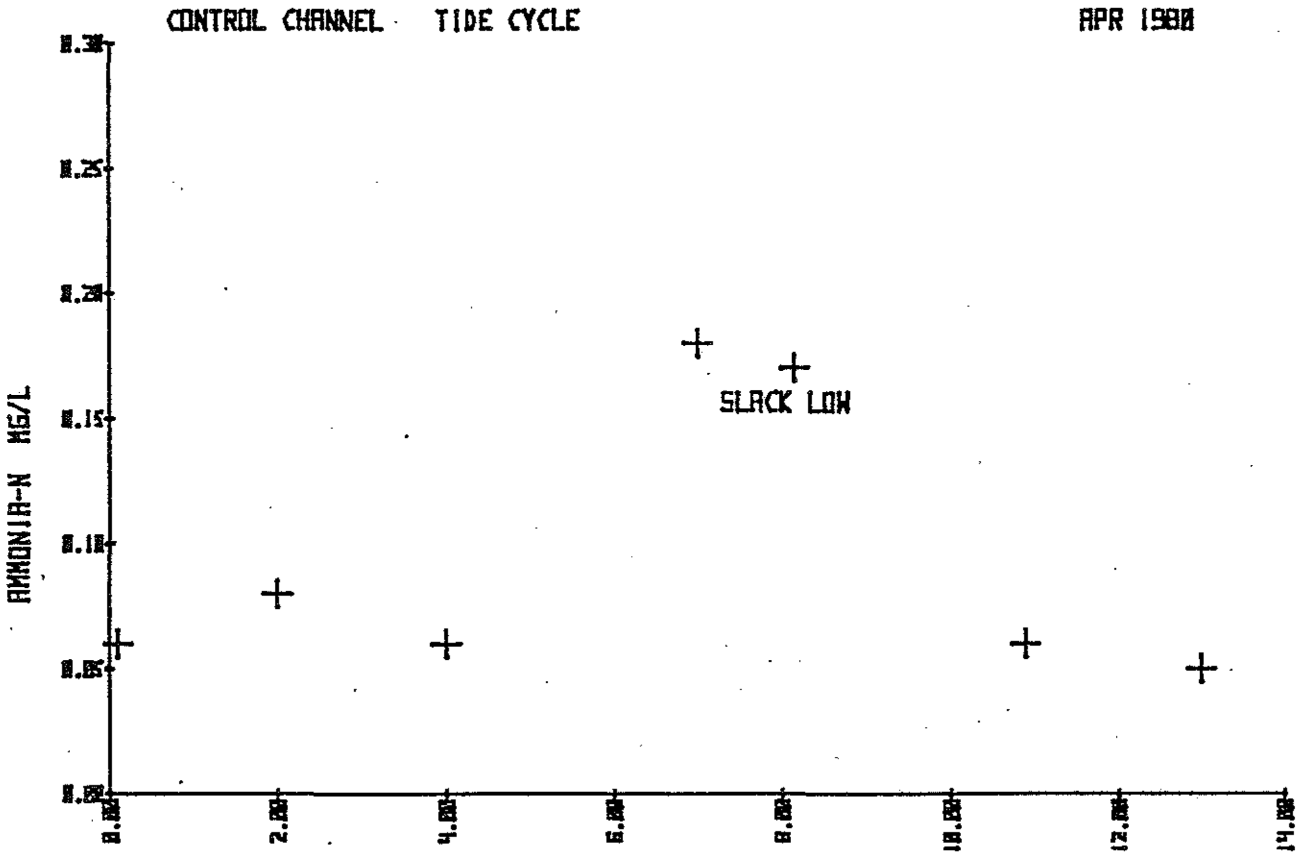

CONTROL CHANNEL TIDE CYCLE
APR 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00

Figure 29

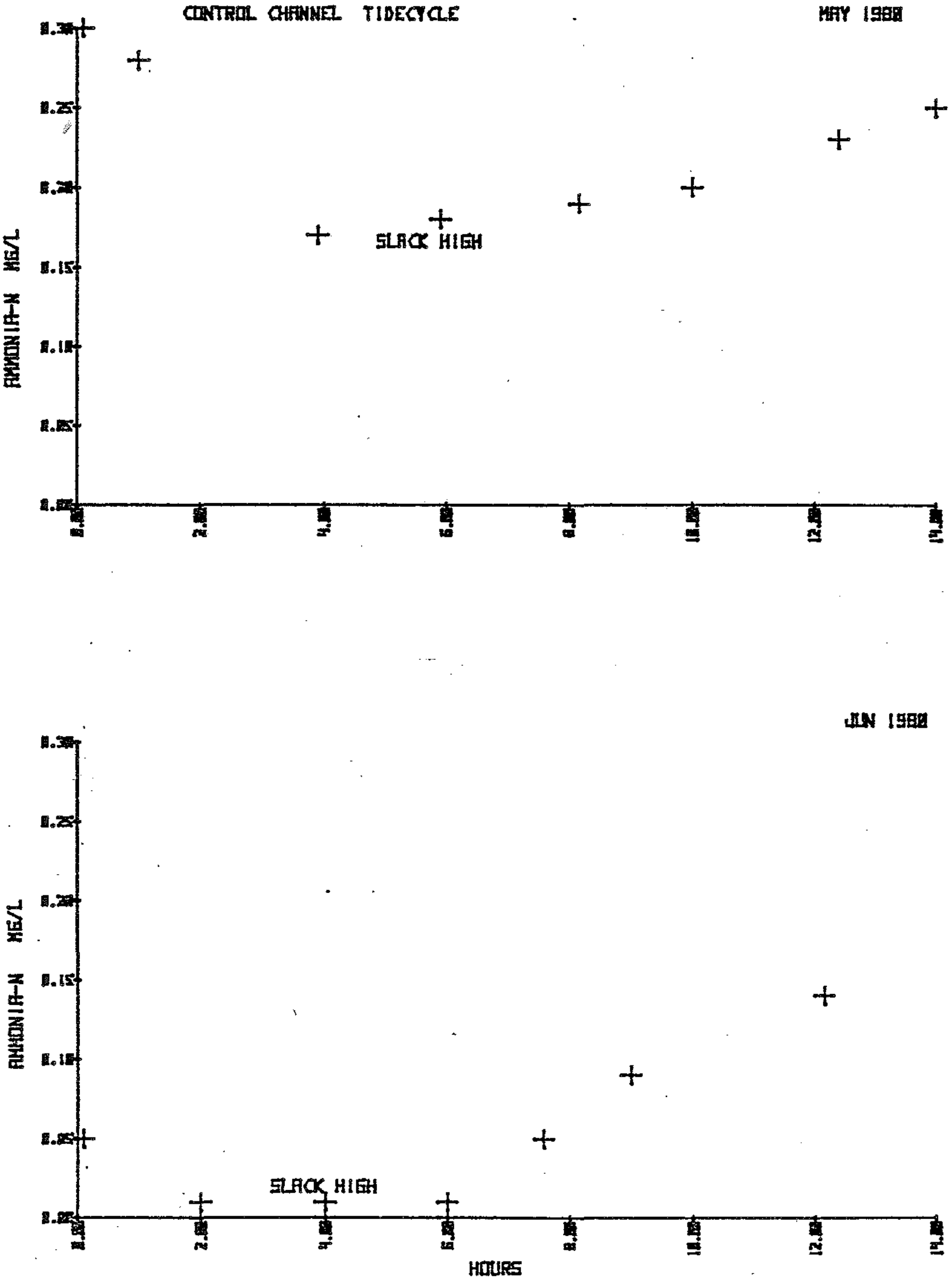
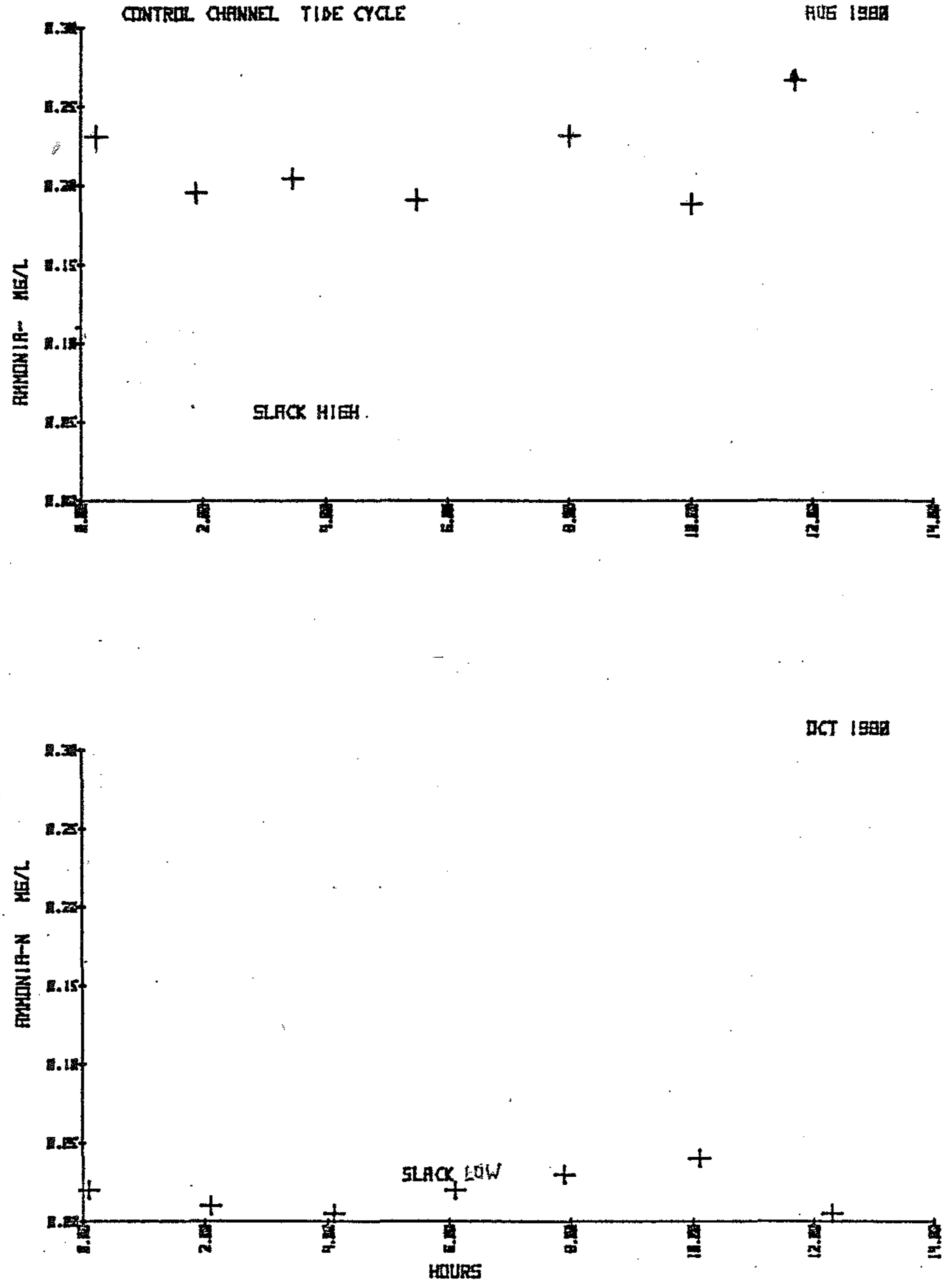

CONTROL CHANNEL TIDECYCLE
MAY 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 30


CONTROL CHANNEL TIDE CYCLE
AUG 1980
AMMONIA- MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1980
AMMONIA-N MG/L
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

5. DISSOLVED KJELDAHL NITROGEN - OPEN SITE

Figure 31

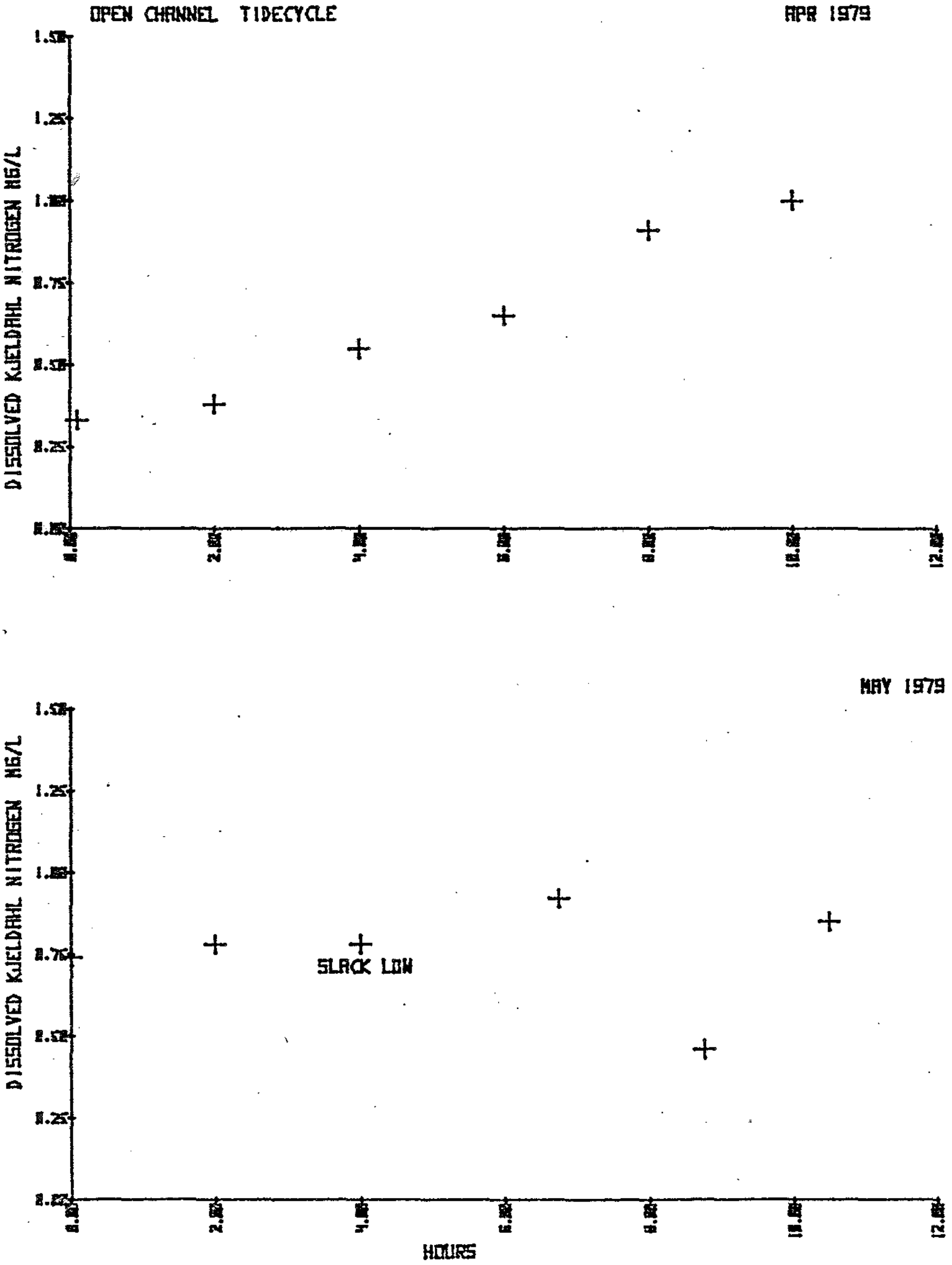

OPEN CHANNEL TIDECYCLE
APR 1979
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
MAY 1979
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 32

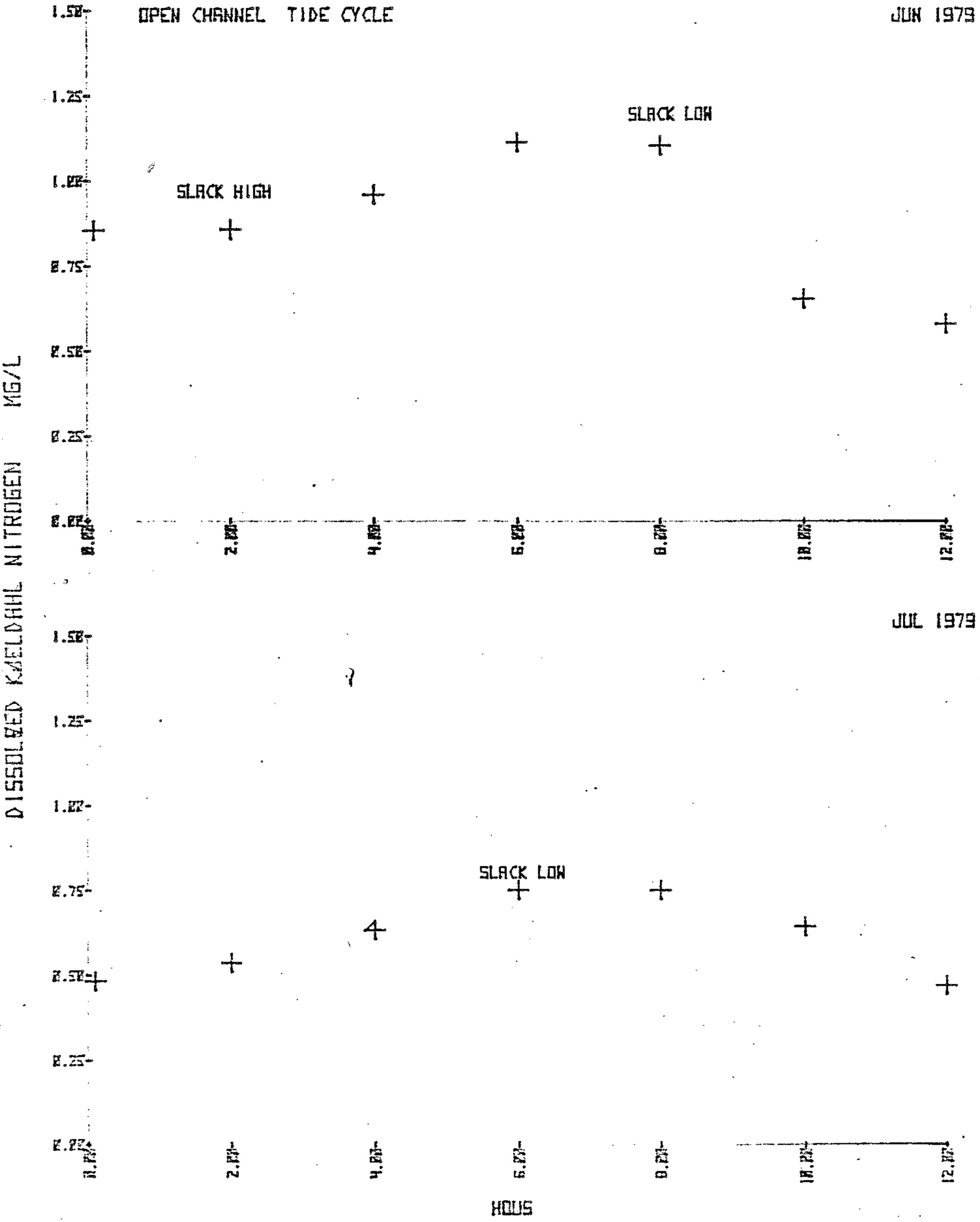

OPEN CHANNEL TIDE CYCLE
JUN 1979
SLACK HIGH
SLACK LOW
JUL 1979
SLACK LOW
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
DISSOLVED KJELDAHL NITROGEN MG/L
HOUS

Figure 33

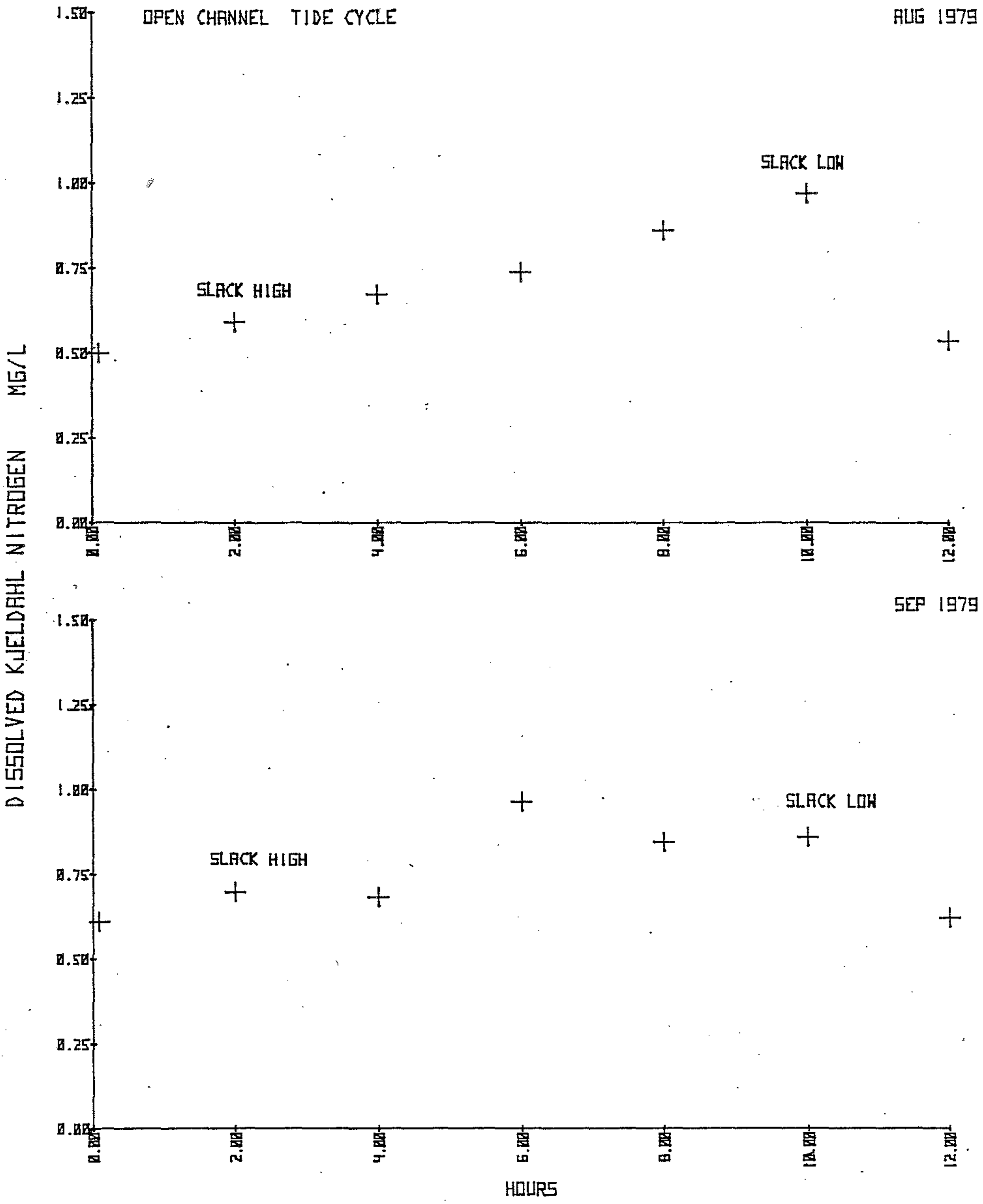

OPEN CHANNEL TIDE CYCLE
AUG 1979
SEP 1979
SLACK HIGH
SLACK LOW
DISSOLVED KJELDAHL NITROGEN MG/L
HOURS
0.00
0.25
0.50
0.75
1.00
1.25
1.50
0.00
2.00
4.00
6.00
8.00
10.00
12.00

Figure 34

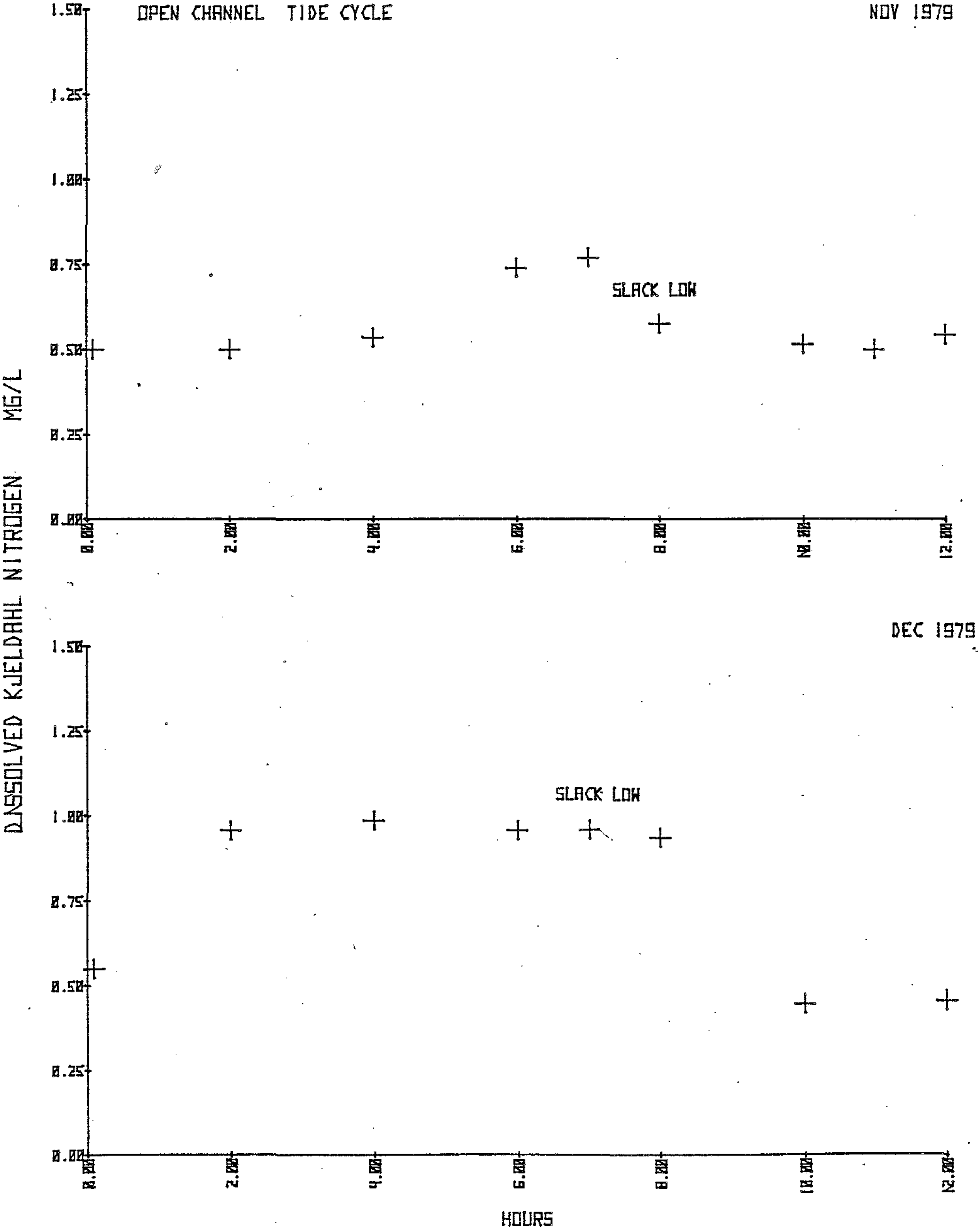

OPEN CHANNEL TIDE CYCLE
NOV 1979
DEC 1979
SLACK LOW
SLACK LOW
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 35

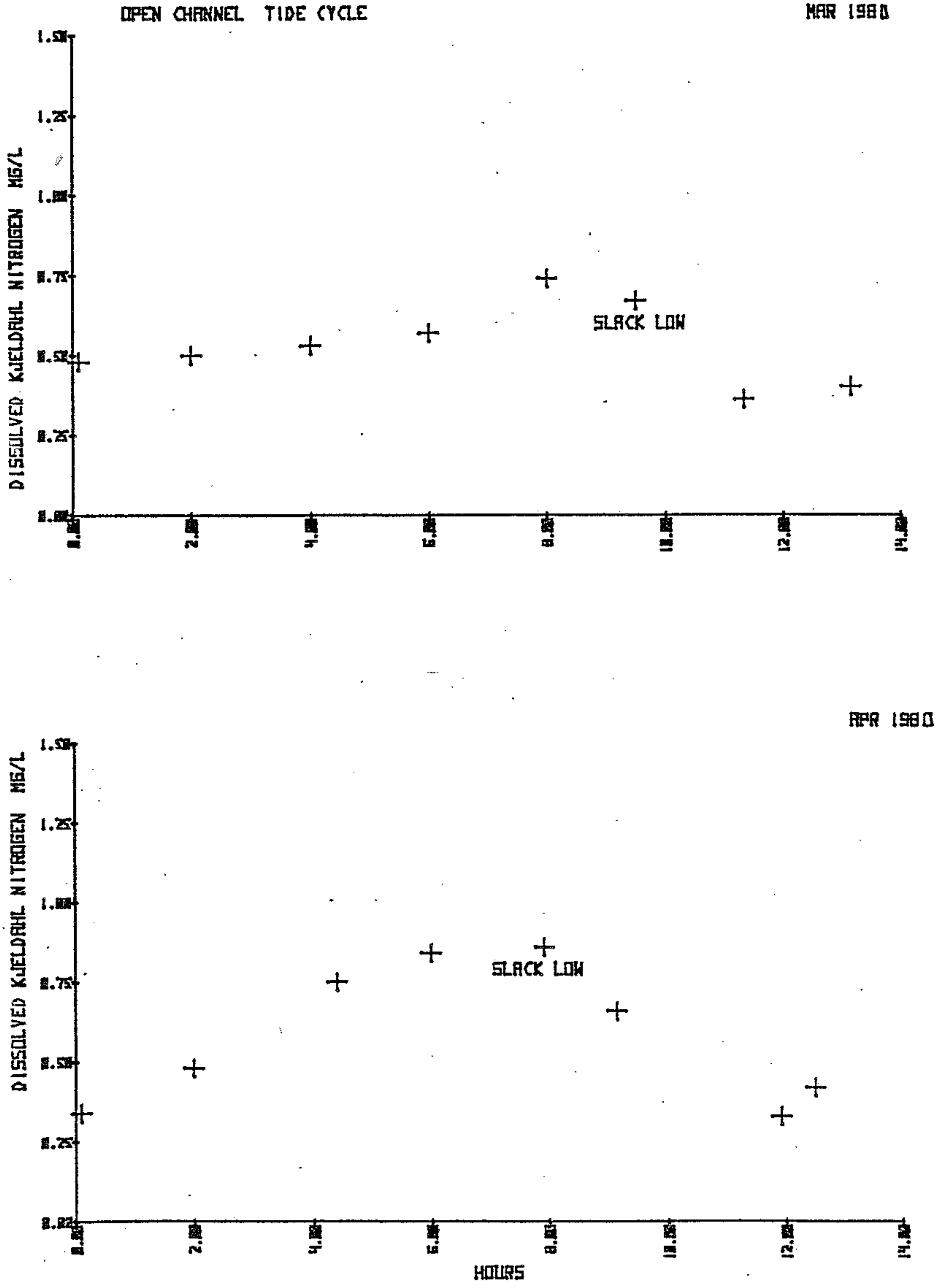

OPEN CHANNEL TIDE CYCLE
MAR 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
APR 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 36

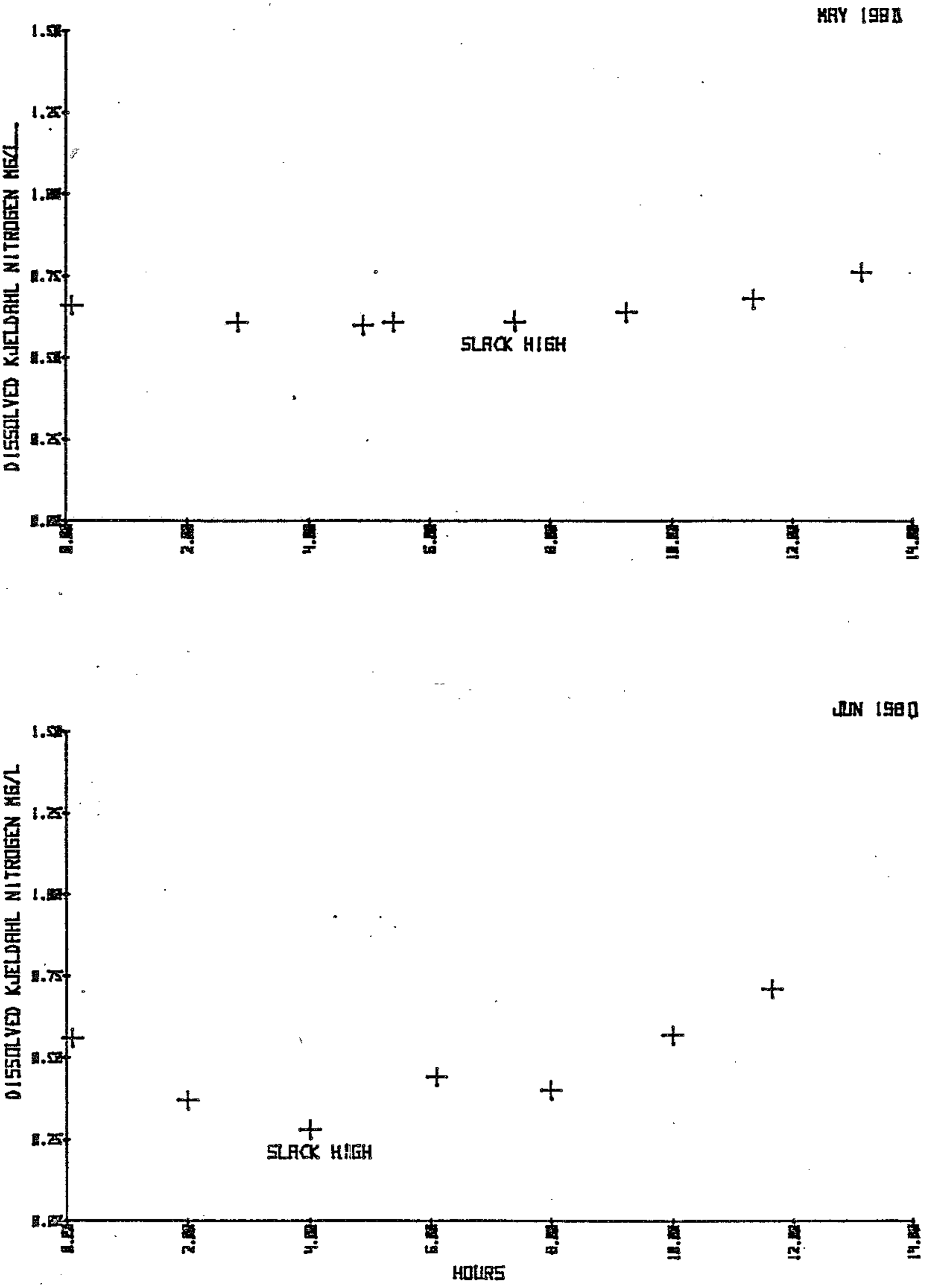
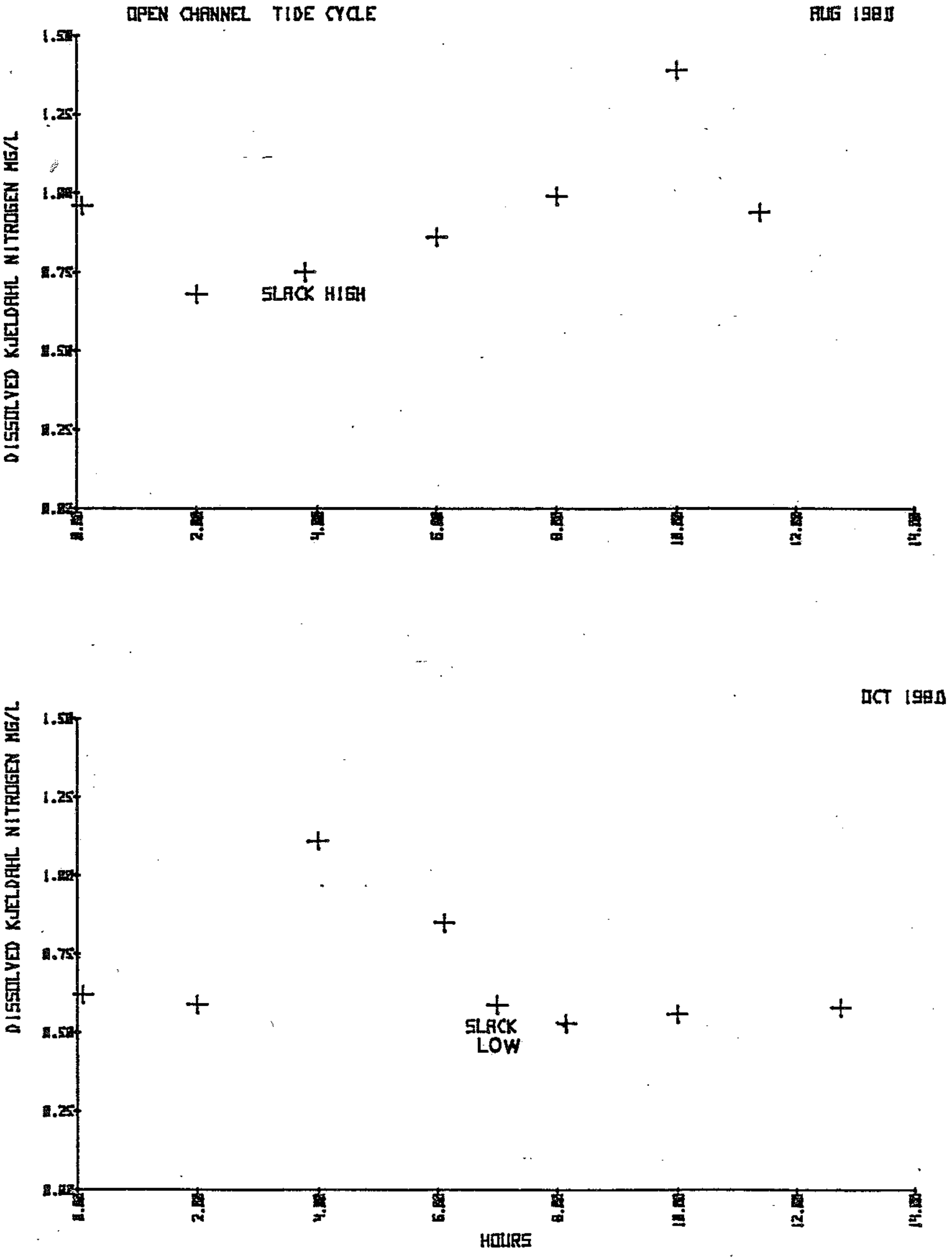

MAY 1980
DISSOLVED KJELDAHL NITROGEN MG/L
0.00
0.25
0.50
0.75
1.00
1.25
1.50
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
DISSOLVED KJELDAHL NITROGEN MG/L
0.00
0.25
0.50
0.75
1.00
1.25
1.50
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 37


OPEN CHANNEL TIDE CYCLE
AUG 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
SLACK HIGH
OCT 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
SLACK
LOW
HOURS

6. DISSOLVED KJELDAHL NITROGEN - CONTROL SITE

Figure 38

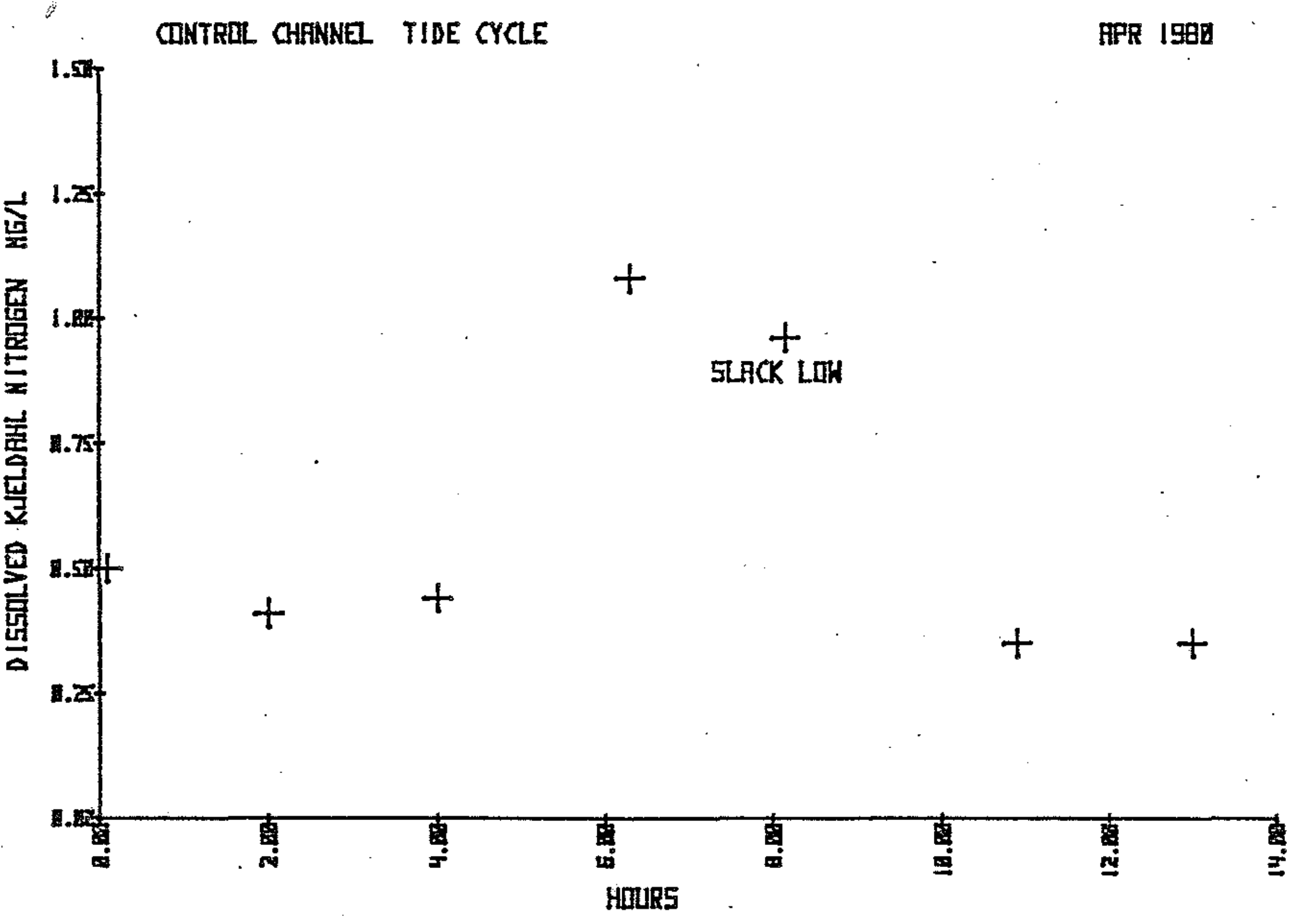

CONTROL CHANNEL TIDE CYCLE
APR 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 39

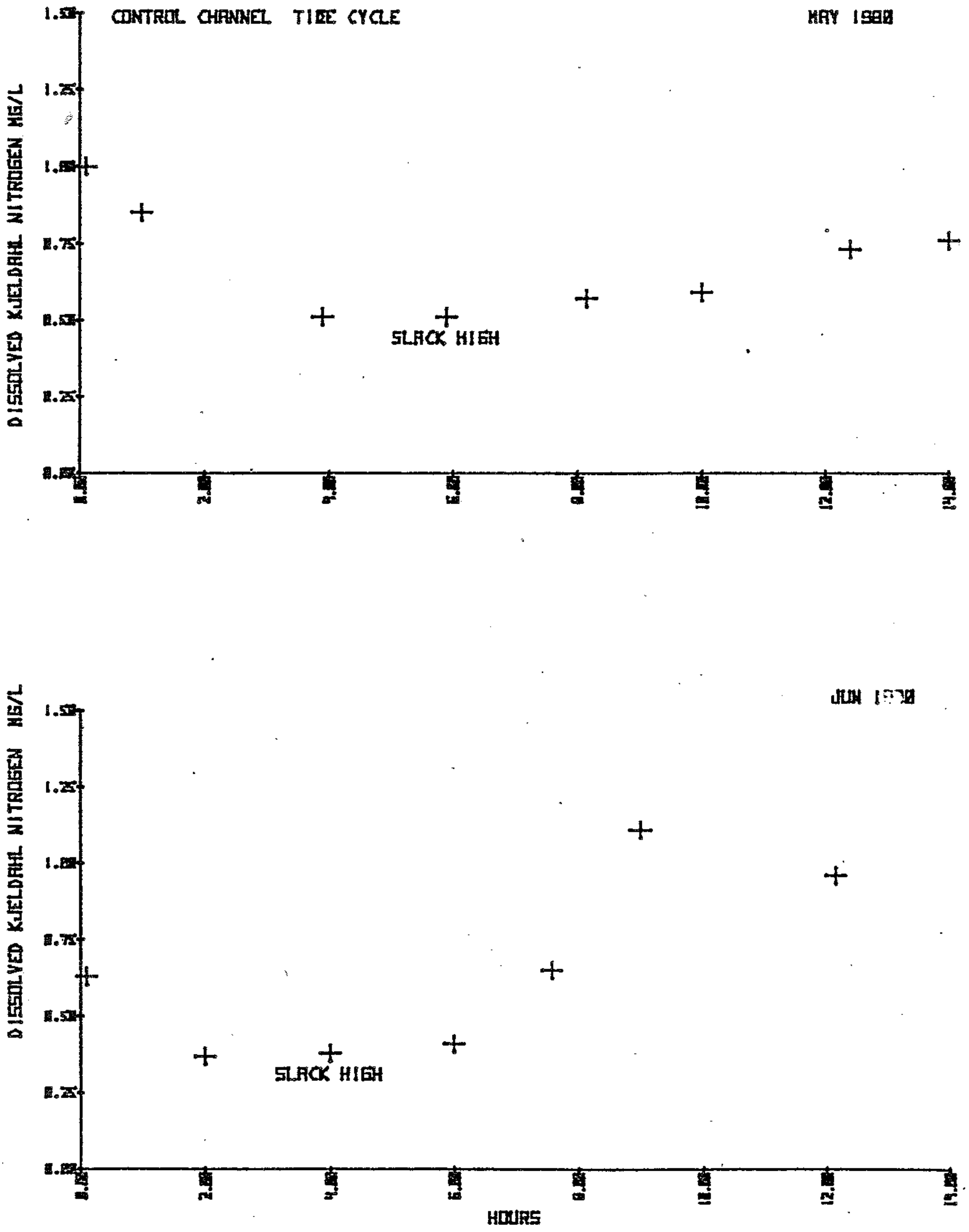
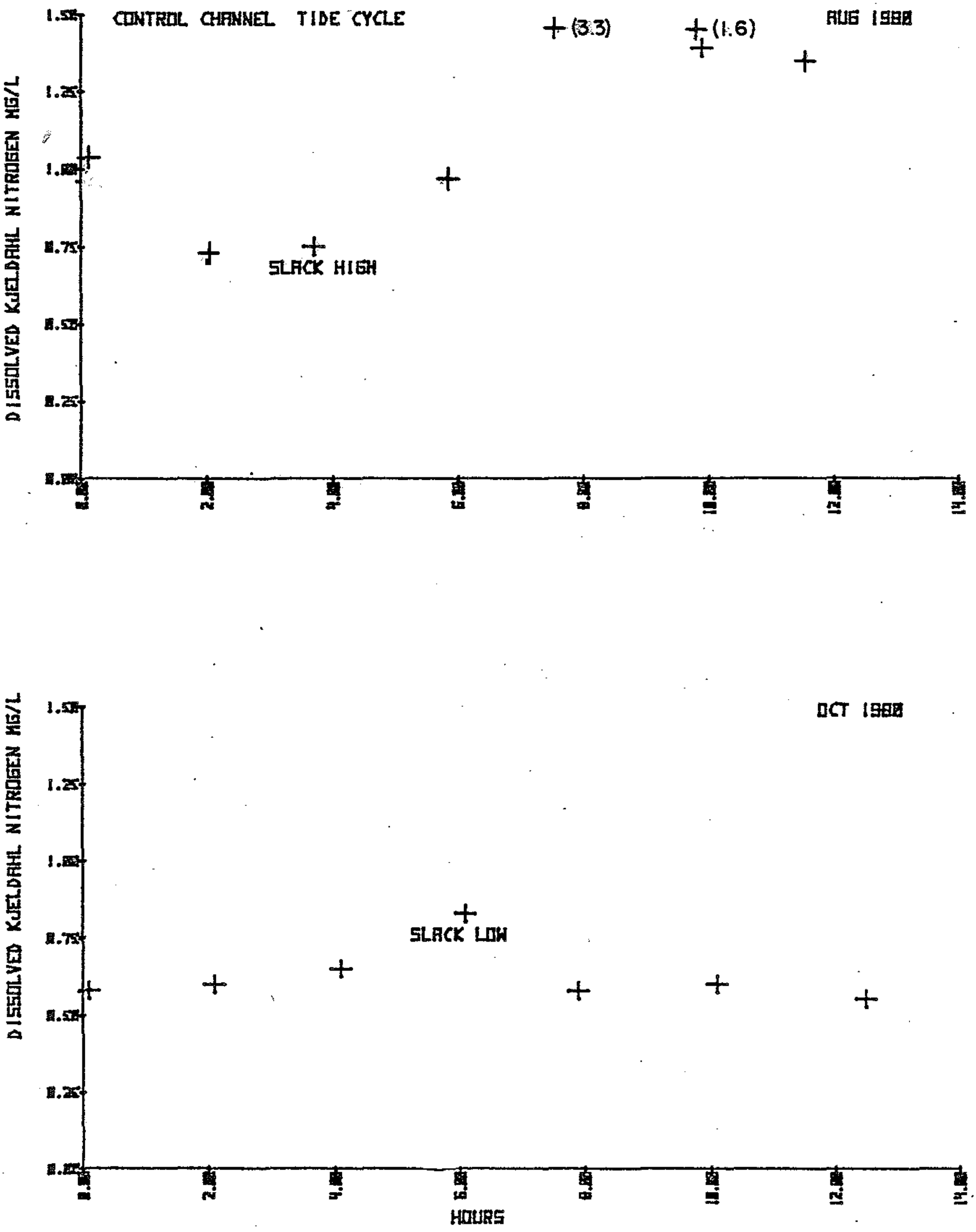

CONTROL CHANNEL TIDE CYCLE
MAY 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 40


CONTROL CHANNEL TIDE CYCLE
AUG 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
(3.3)
(1.6)
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1980
DISSOLVED KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

7. TOTAL KJELDAHL NITROGEN - OPEN SITE

Figure 41

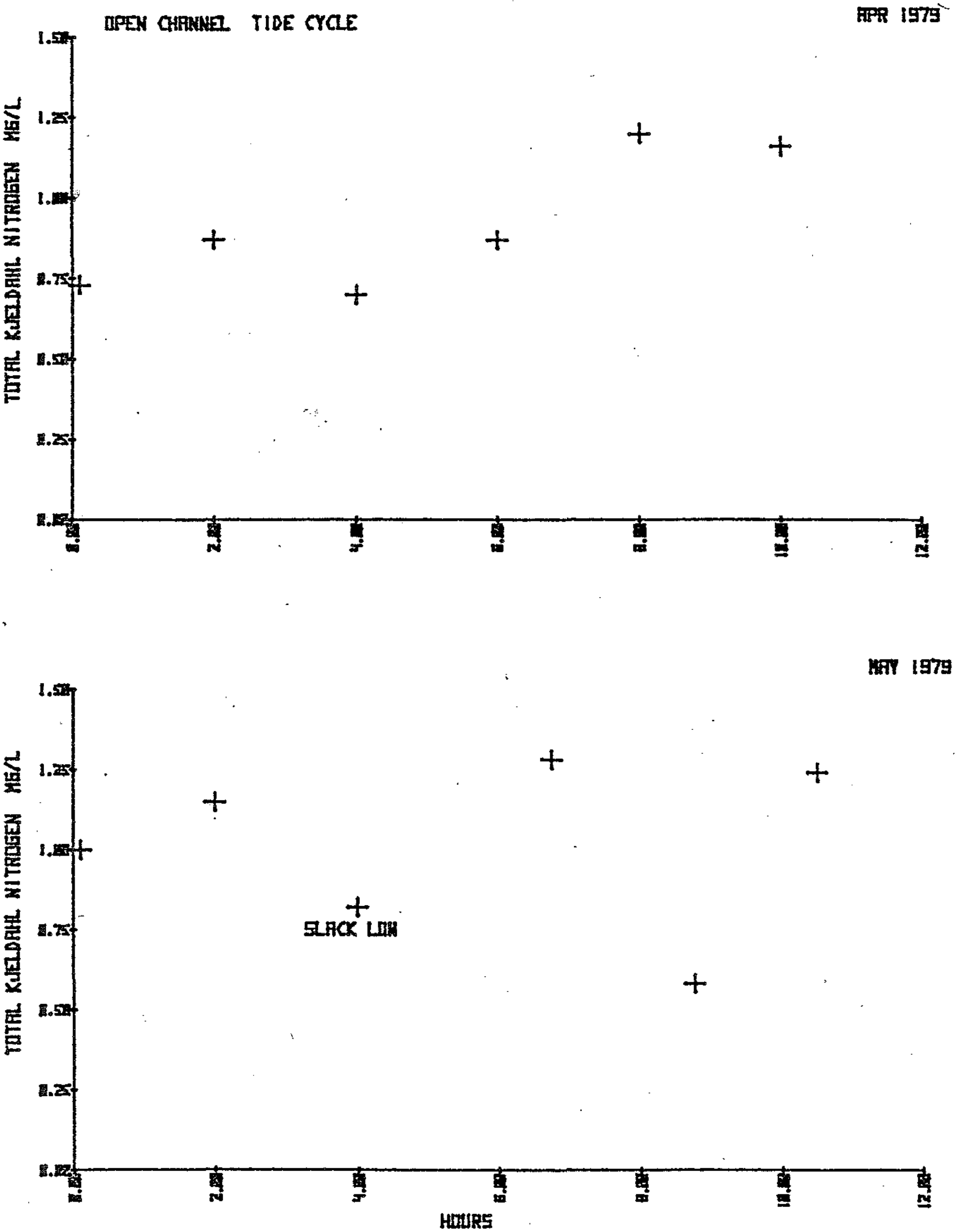
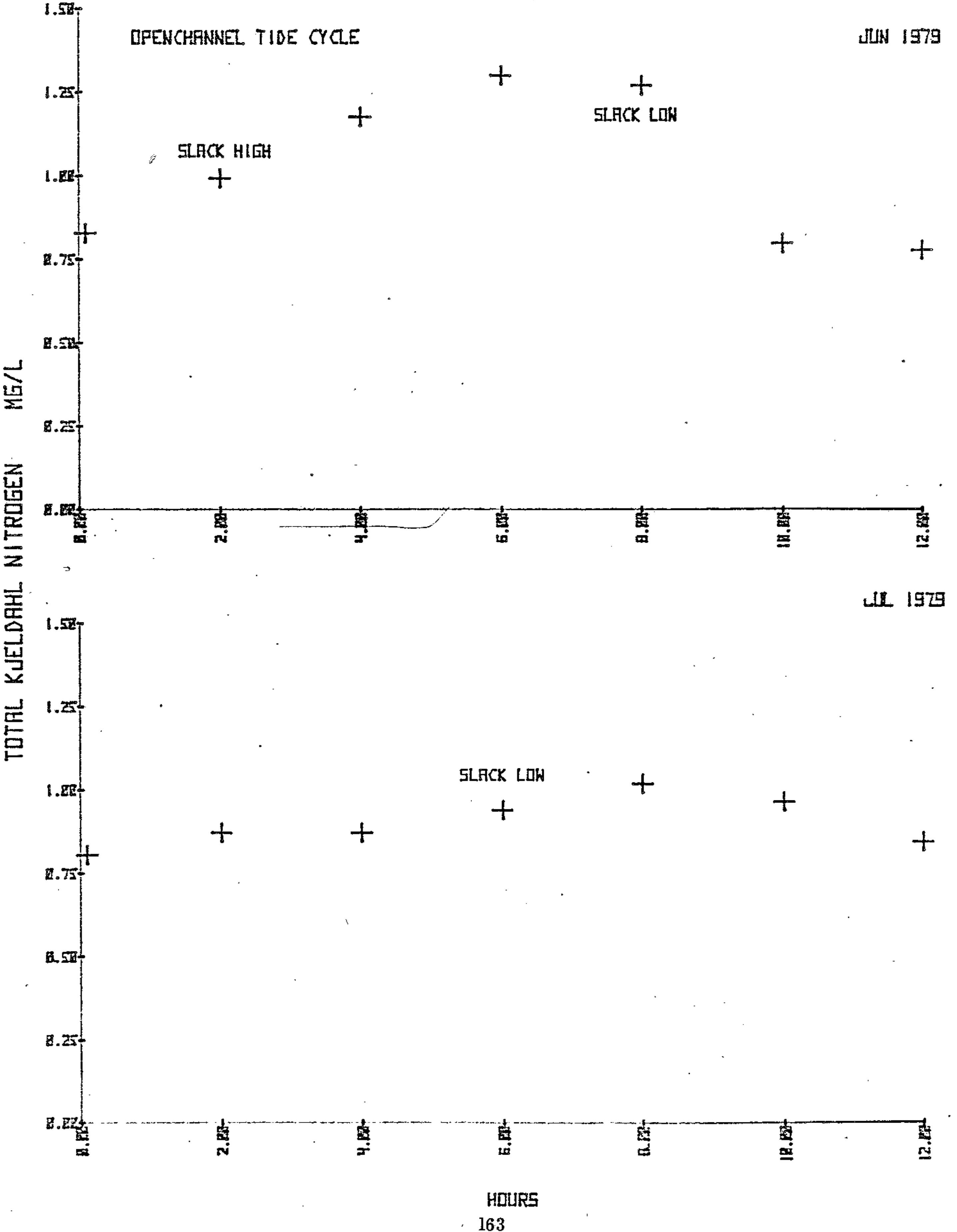

OPEN CHANNEL TIDE CYCLE
APR 1979
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
MAY 1979
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 42



OPENCHANNEL TIDE CYCLE
JUN 1979
SLACK HIGH
SLACK LOW
JUL 1979
SLACK LOW
TOTAL KJELDAHL NITROGEN MG/L
0.00
0.25
0.50
0.75
1.00
1.25
1.50
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 43

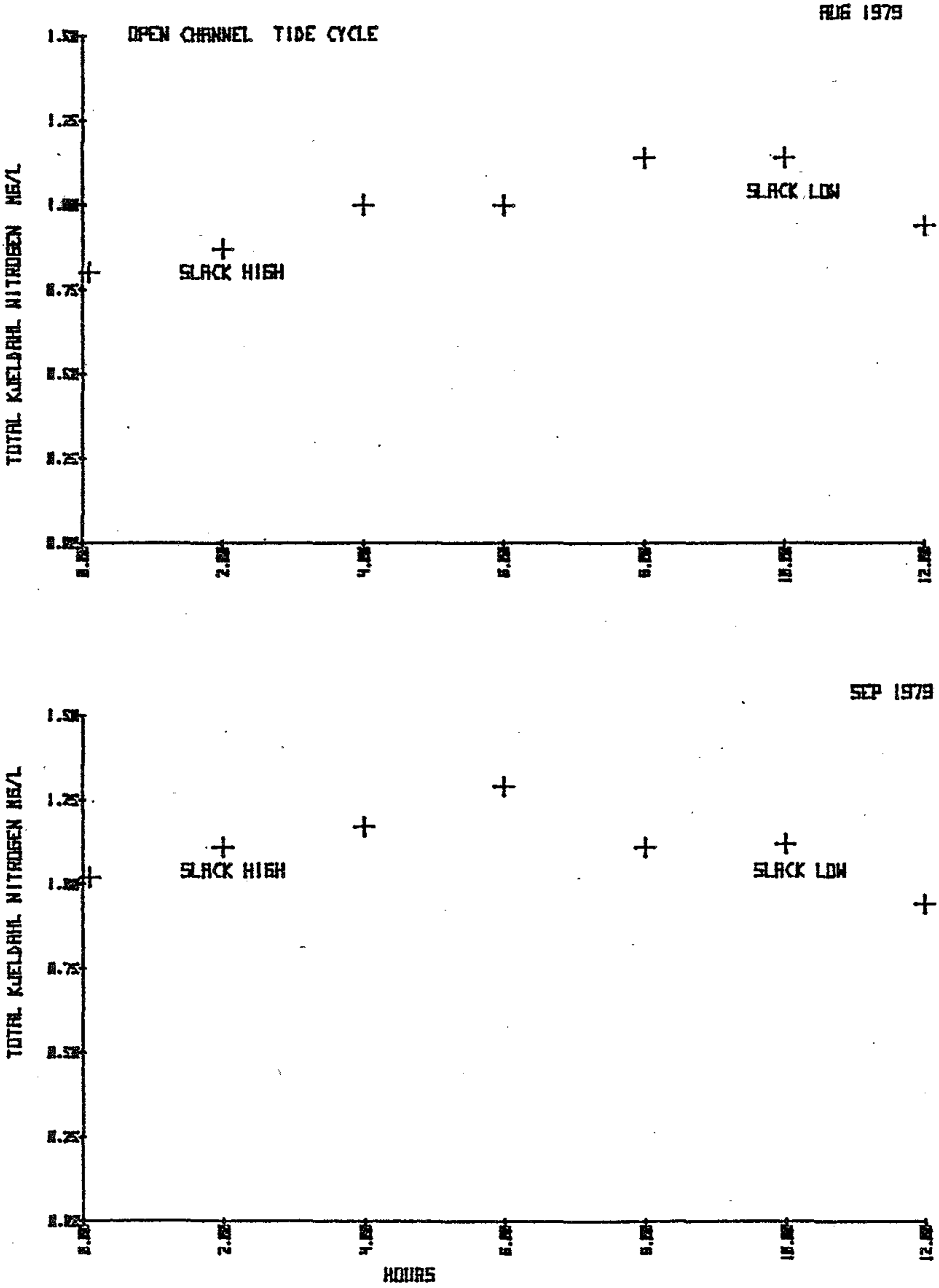

AUG 1979
OPEN CHANNEL TIDE CYCLE
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
SEP 1979
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 44

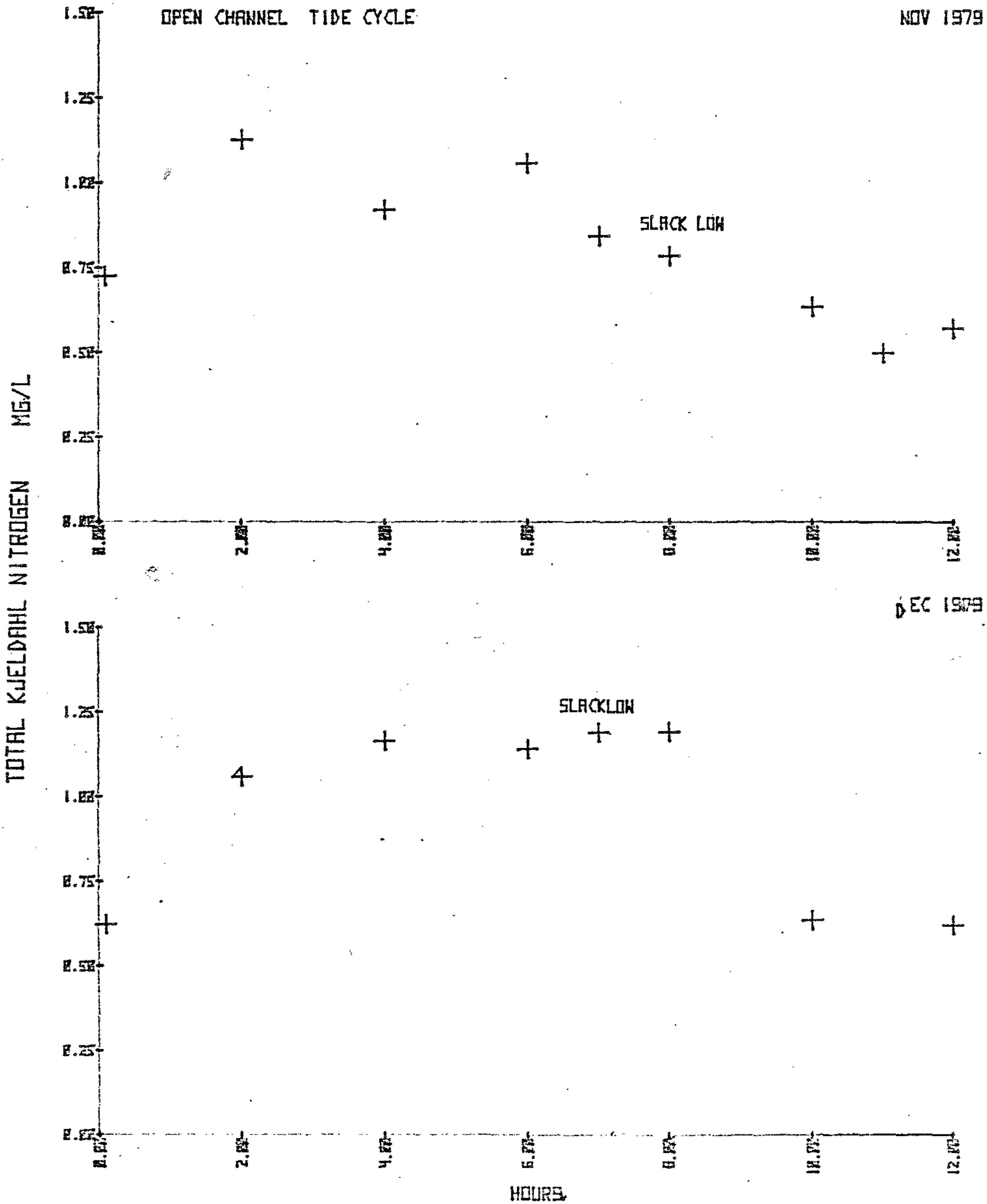

OPEN CHANNEL TIDE CYCLE
NOV 1979
SLACK LOW
DEC 1979
SLACKLOW
TOTAL KJELDAHL NITROGEN MG/L
HOURS
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00

Figure 45

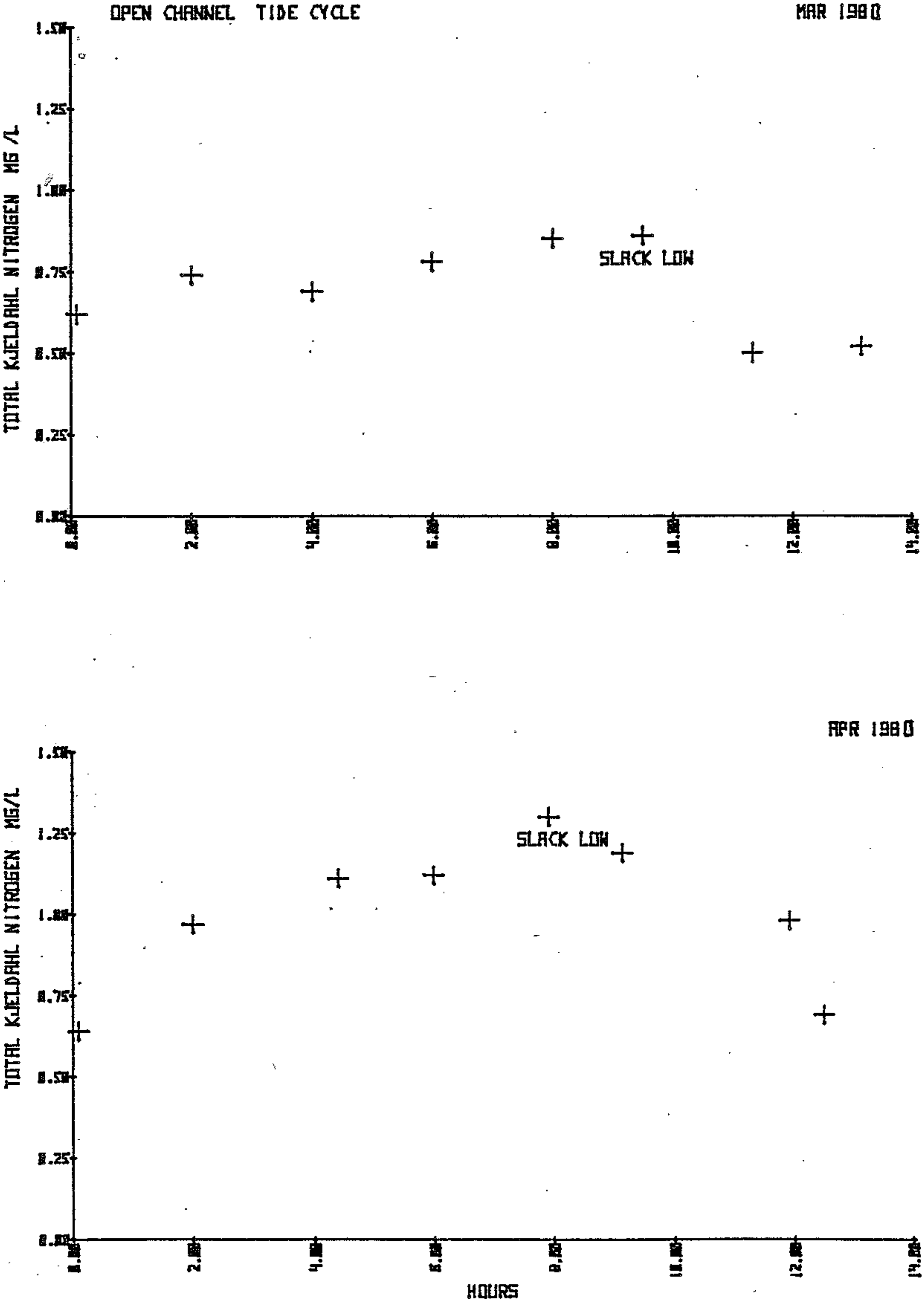

OPEN CHANNEL TIDE CYCLE
MAR 1980
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
APR 1980
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 46

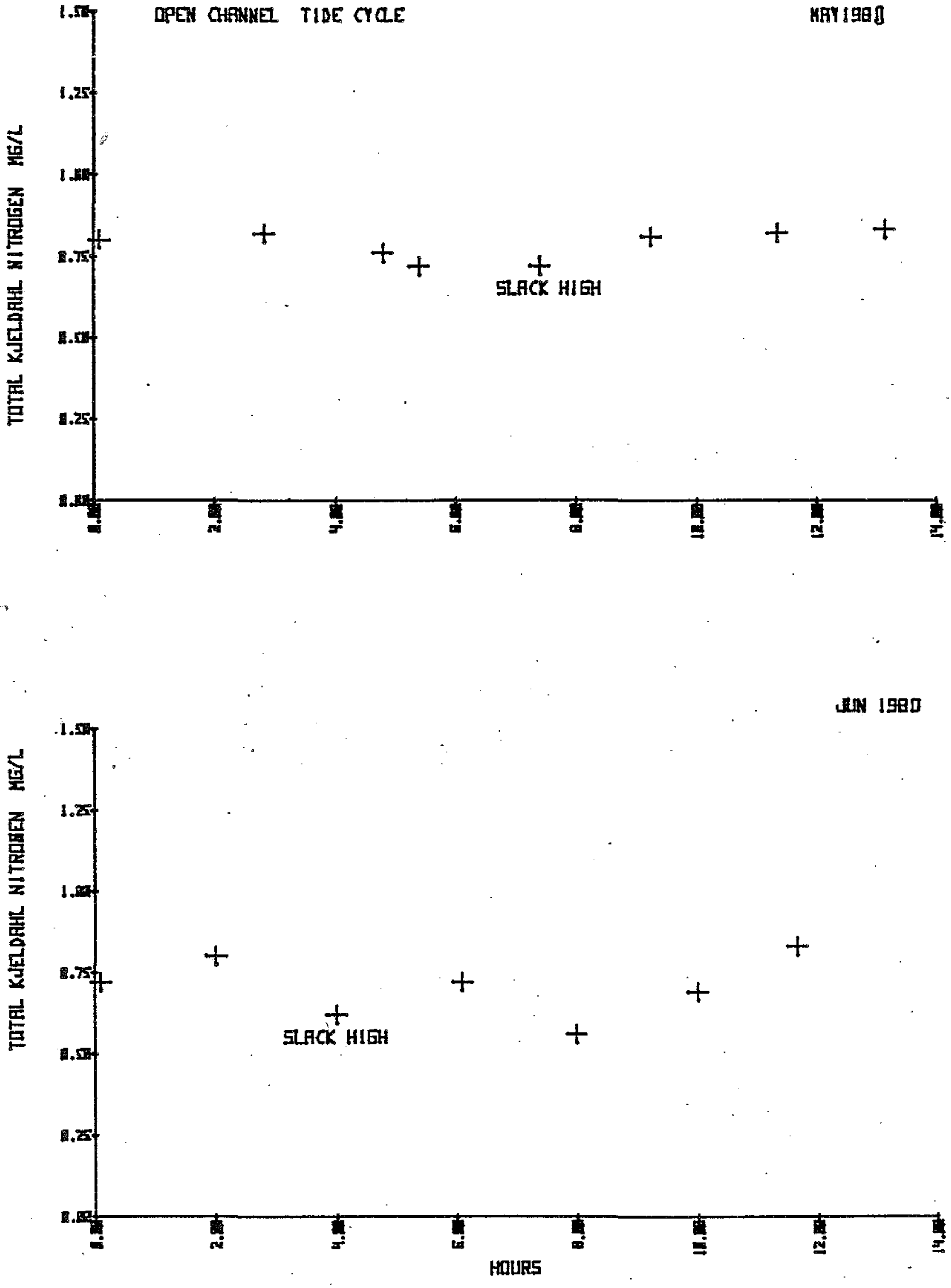
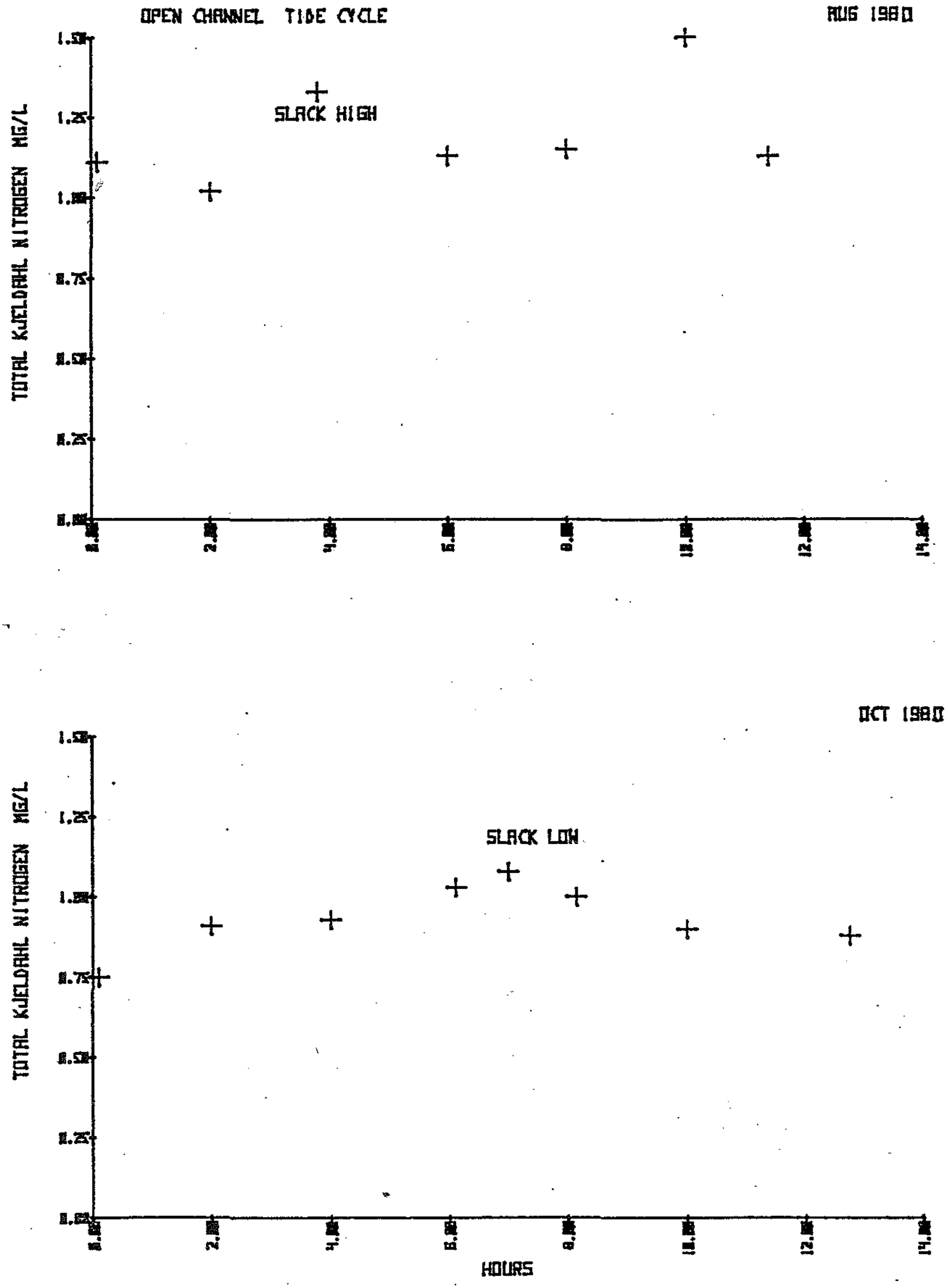

OPEN CHANNEL TIDE CYCLE
MAY 1980
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 47


OPEN CHANNEL TIDE CYCLE
AUG 1980
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1980
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

8. TOTAL KJELDAHL NITROGEN - CONTROL SITE

Figure 48

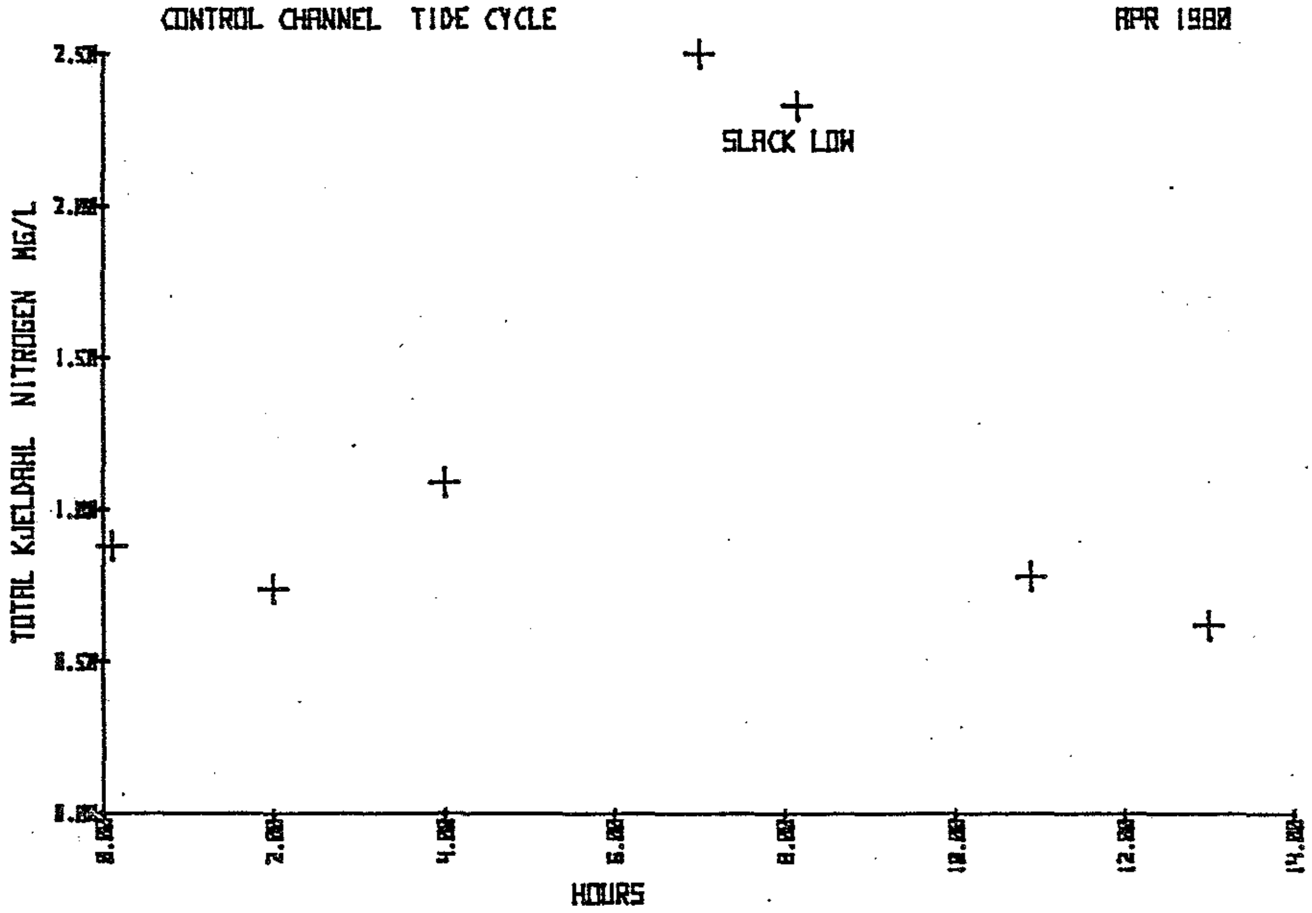

CONTROL CHANNEL TIDE CYCLE
APR 1980
SLACK LOW
TOTAL KJELDAHL NITROGEN MG/L
2.50
2.00
1.50
1.00
0.50
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 49

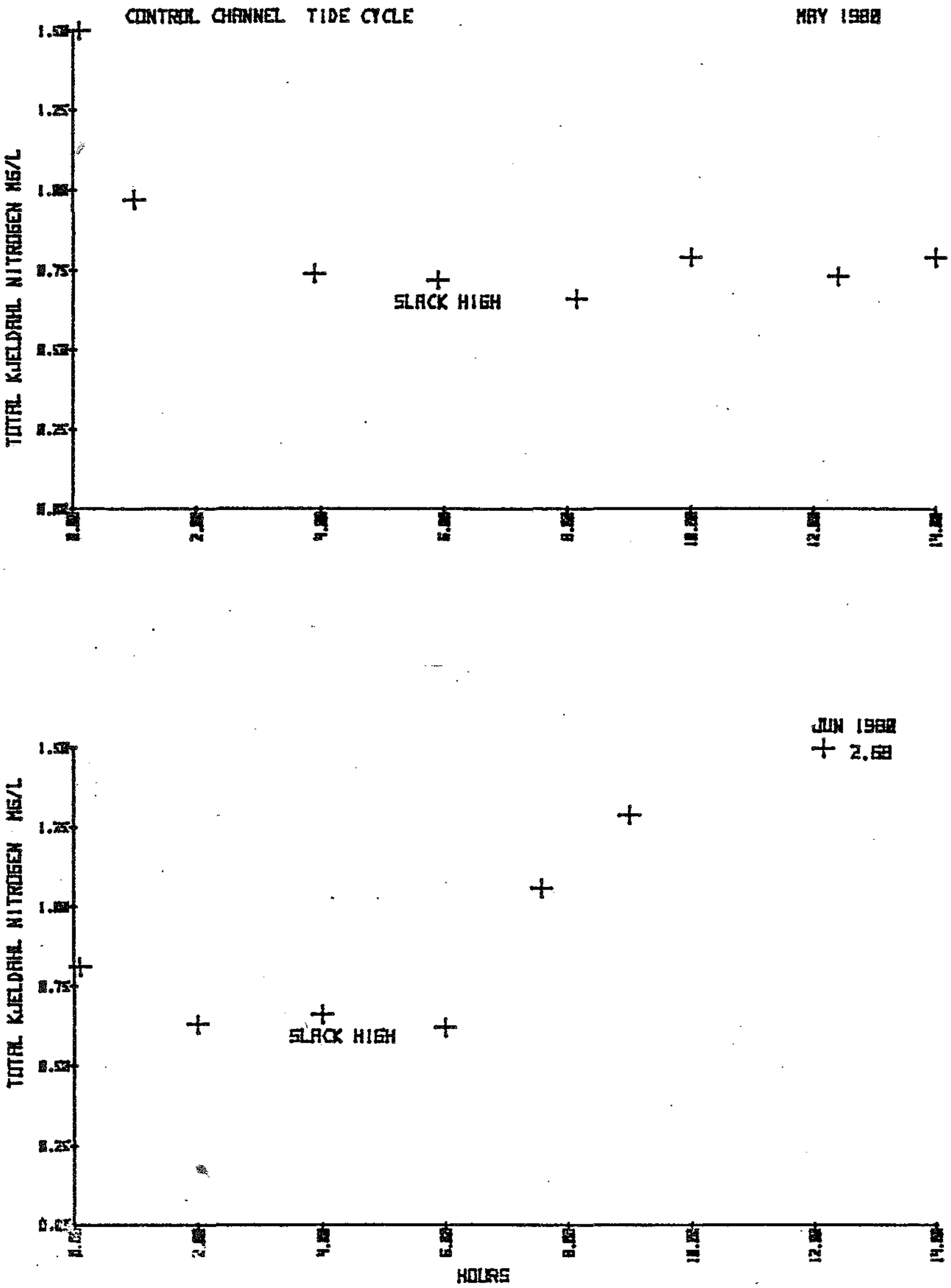
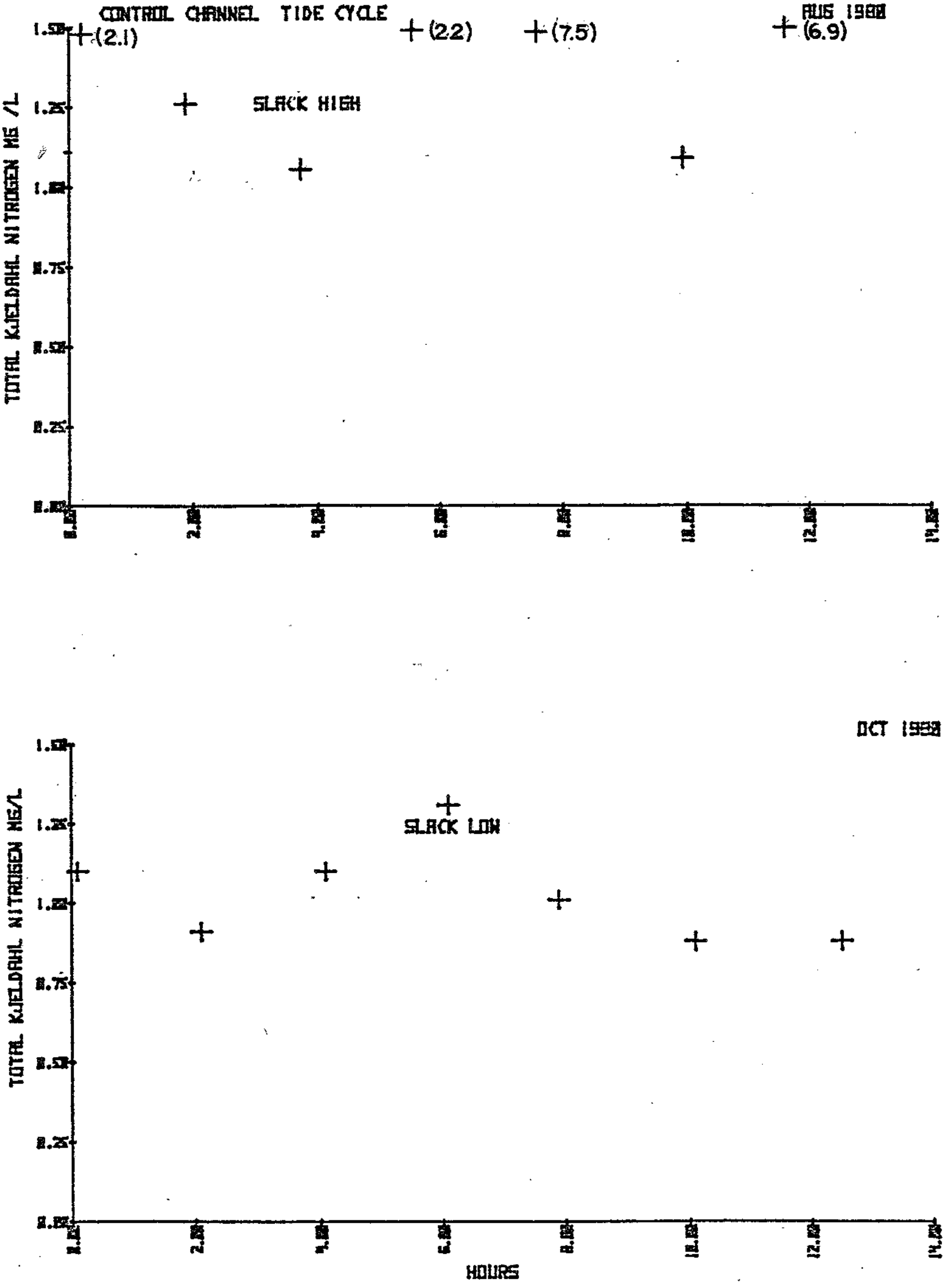

CONTROL CHANNEL TIDE CYCLE
MAY 1980
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
2.68
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 50


CONTROL CHANNEL TIDE CYCLE
AUG 1988
(2.1)
(2.2)
(7.5)
(6.9)
SLACK HIGH
TOTAL KJELDAHL NITROGEN MG /L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1988
SLACK LOW
TOTAL KJELDAHL NITROGEN MG/L
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

9. DISSOLVED PHOSPHORUS - OPEN SITE

Figure 51

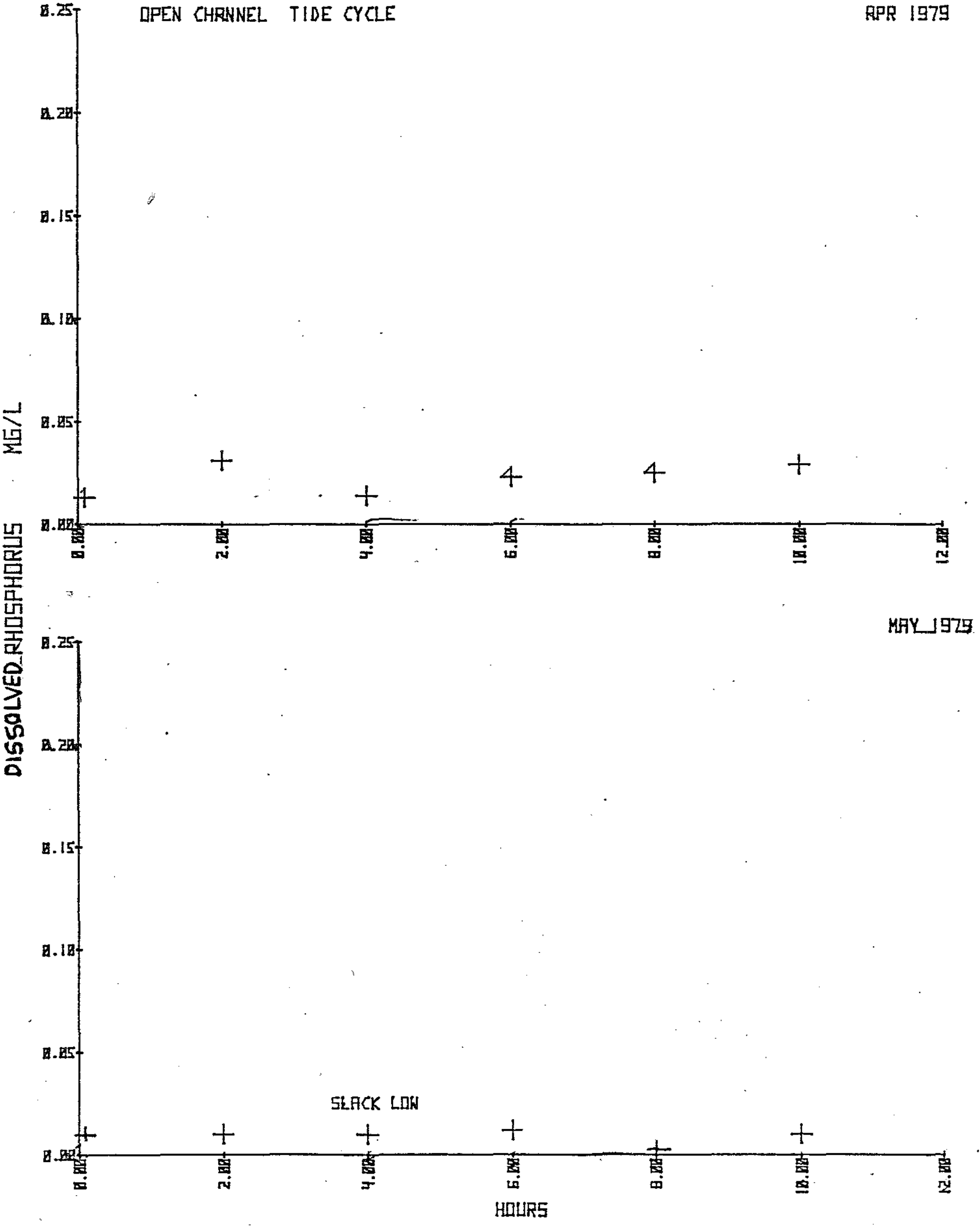

OPEN CHANNEL TIDE CYCLE
APR 1979
MAY 1979
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
SLACK LOW
HOURS

Figure 52

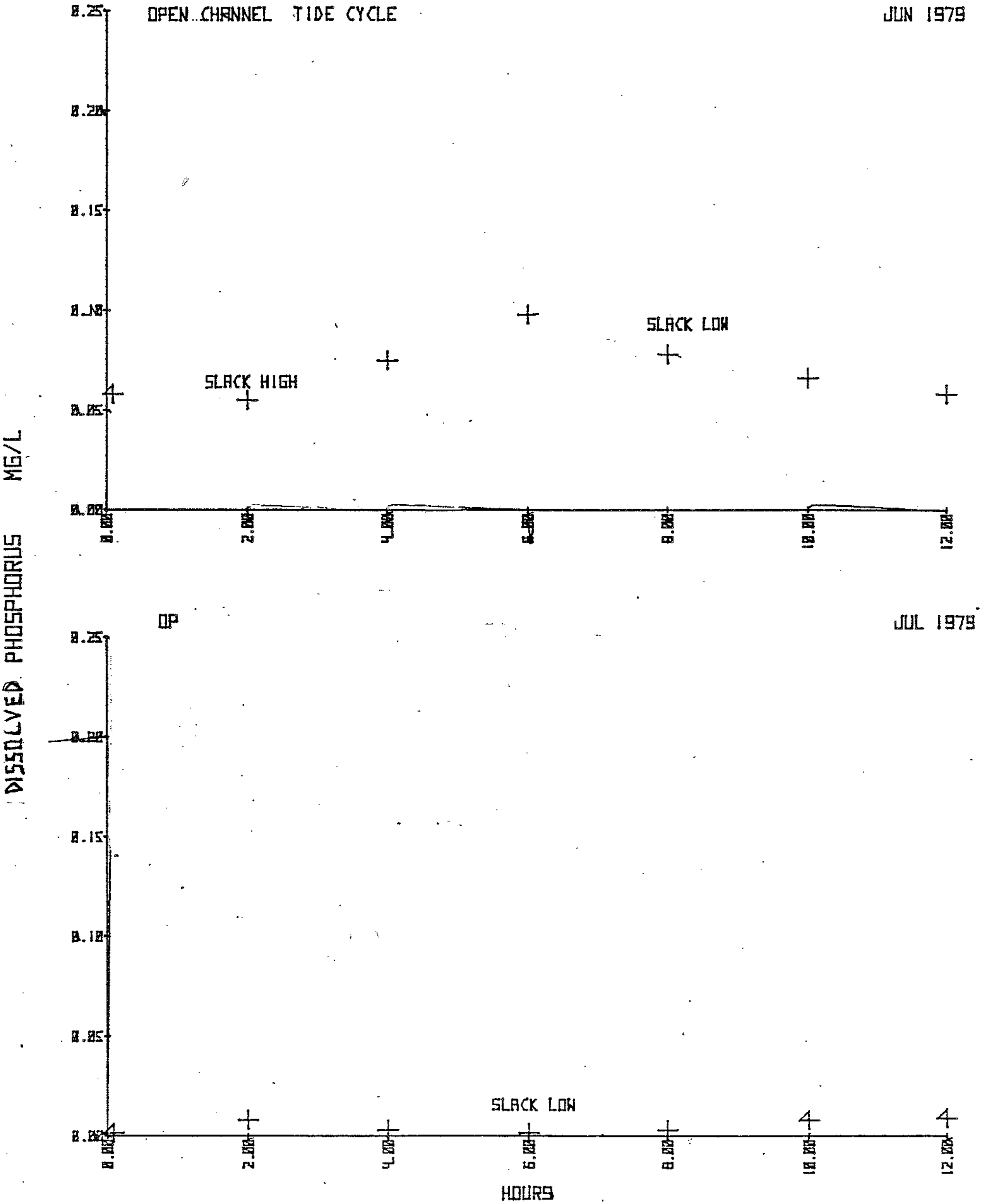

OPEN CHANNEL TIDE CYCLE
JUN 1979
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
OP
JUL 1979
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
DISSOLVED PHOSPHORUS MG/L
HOURS

Figure 53

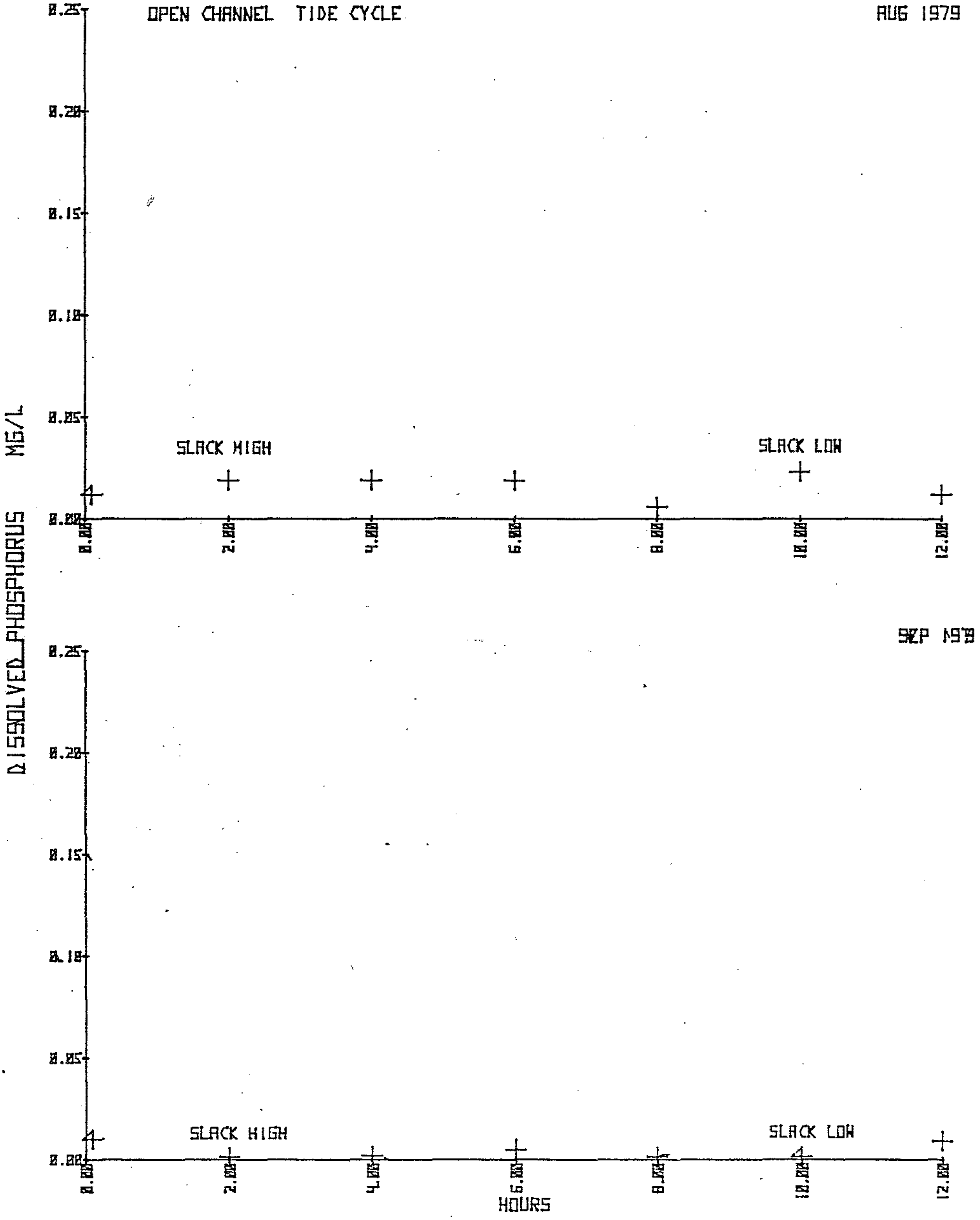

OPEN CHANNEL TIDE CYCLE
AUG 1979
SLACK HIGH
SLACK LOW
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
SEP 1979
SLACK HIGH
SLACK LOW
DISSOLVED PHOSPHORUS MG/L
HOURS

Figure 54

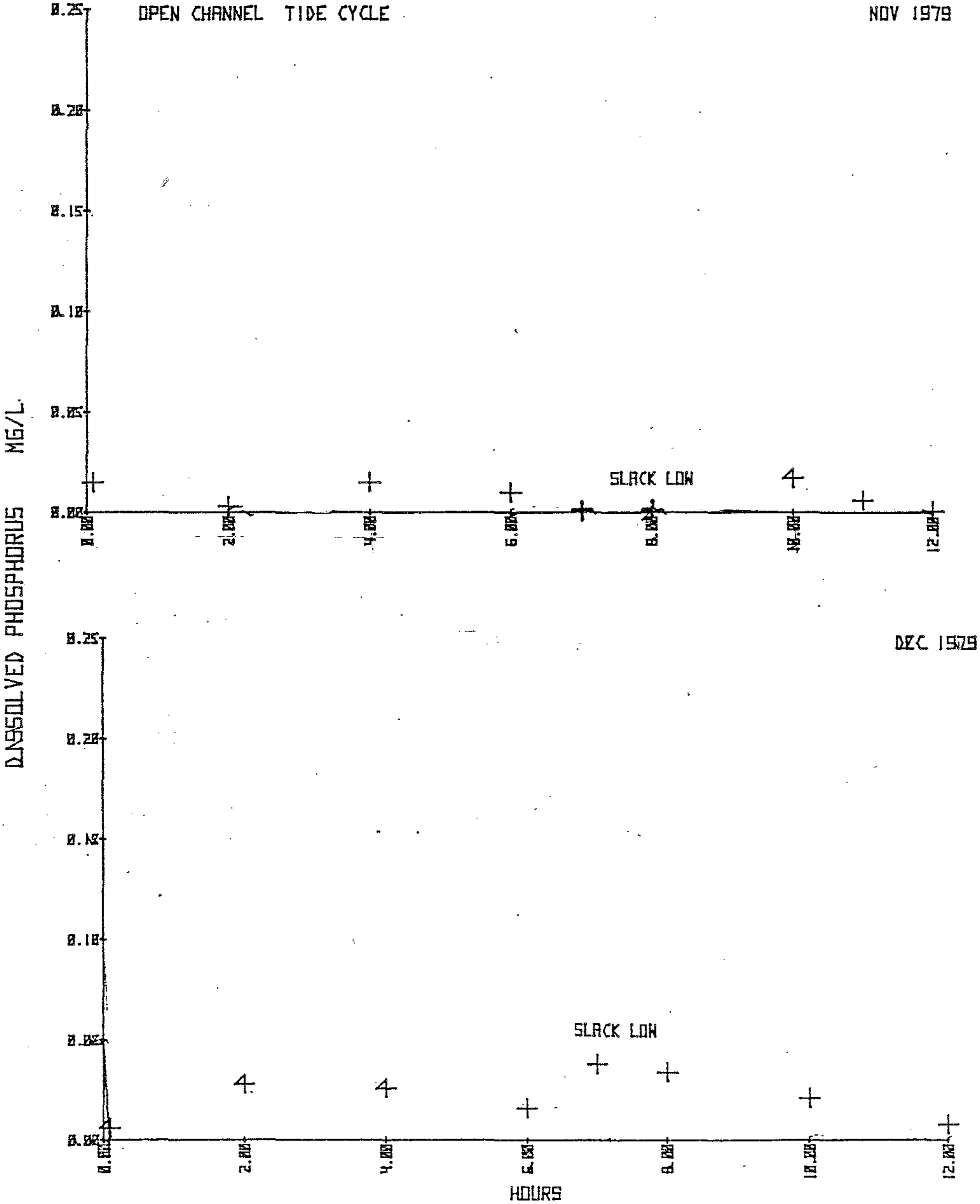

OPEN CHANNEL TIDE CYCLE
NOV 1979
DEC 1979
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 55

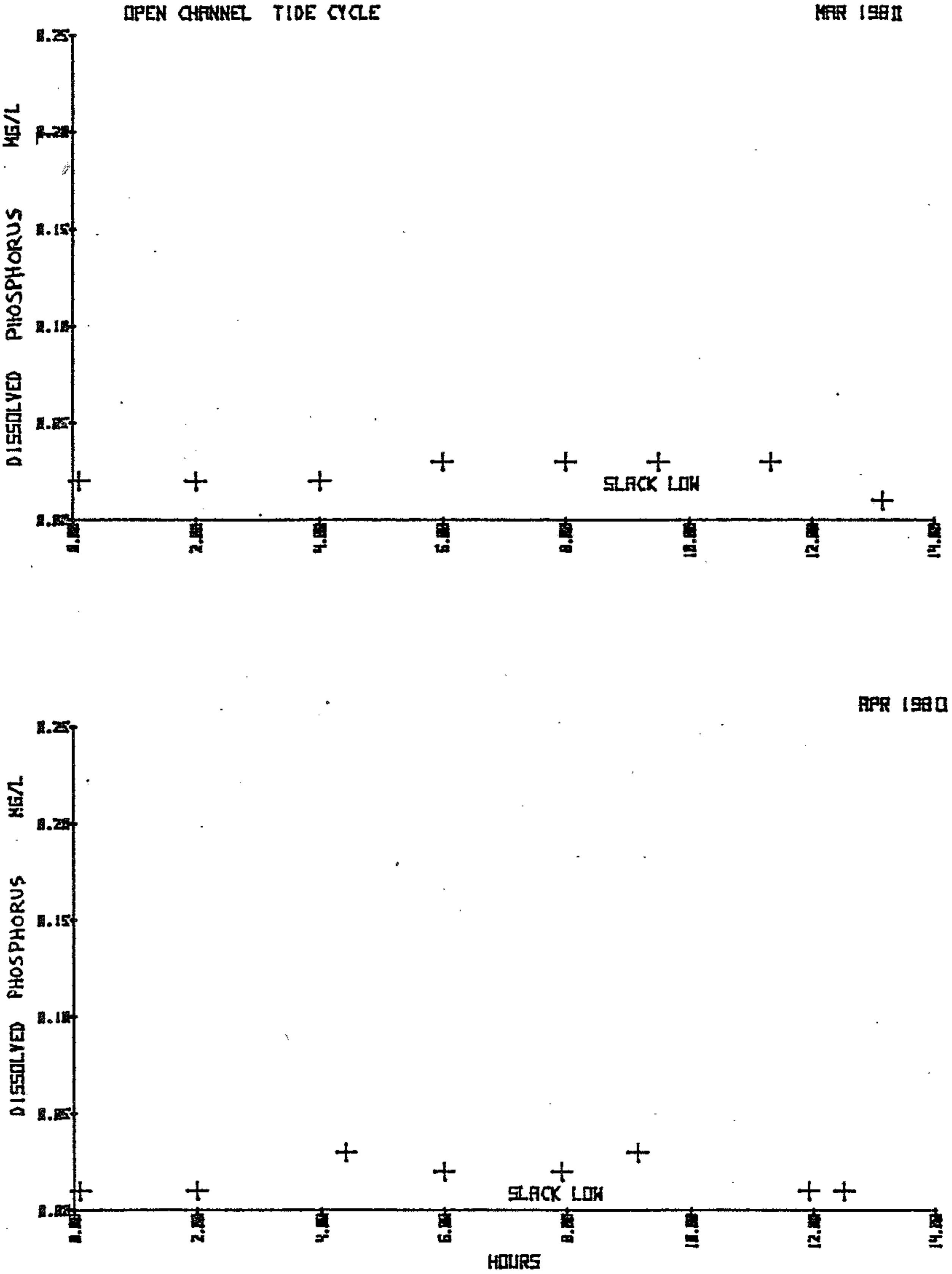

OPEN CHANNEL TIDE CYCLE
MAR 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
APR 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 56

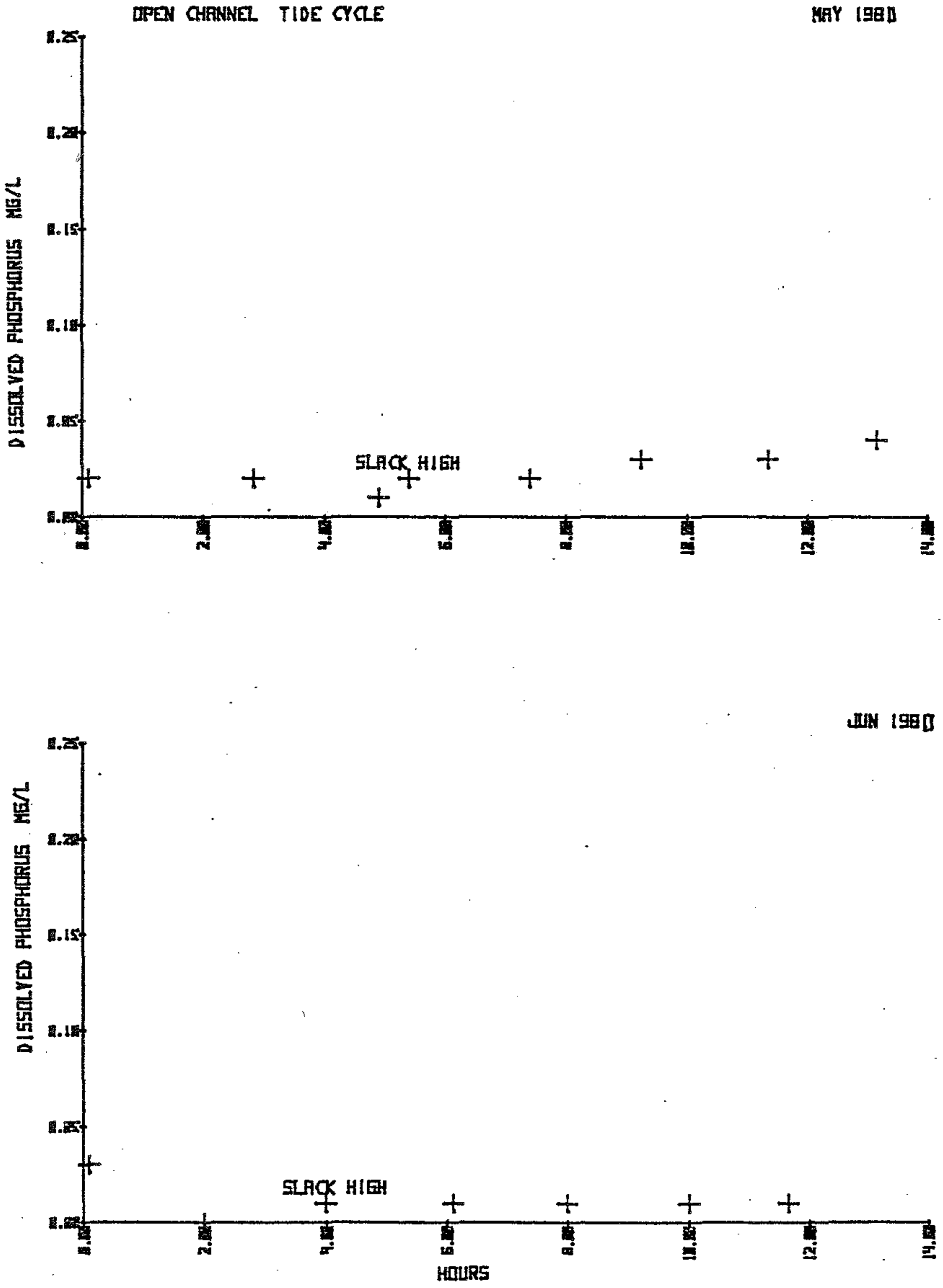
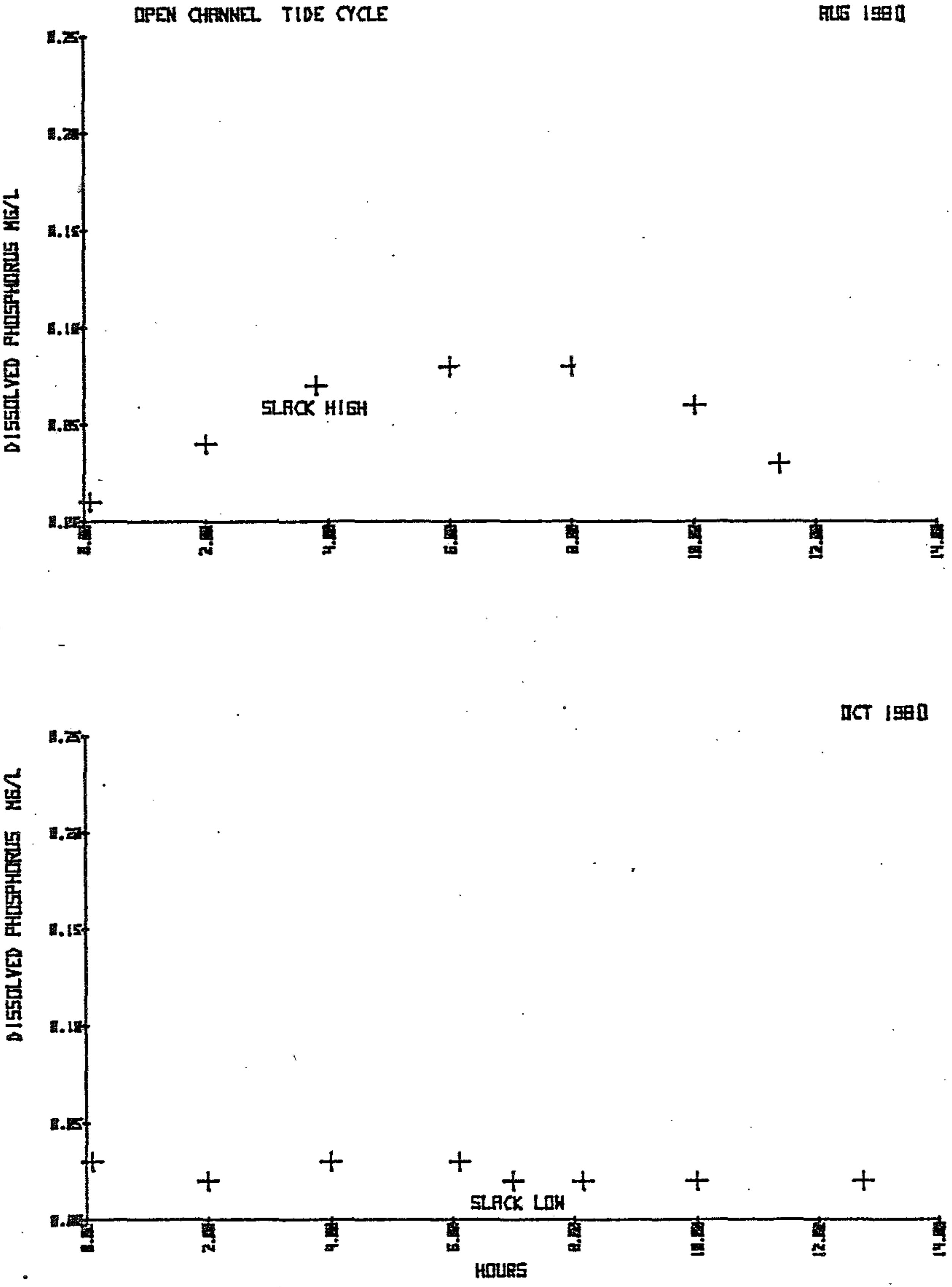

OPEN CHANNEL TIDE CYCLE
MAY 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 57


OPEN CHANNEL TIDE CYCLE
AUG 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

10. DISSOLVED PHOSPHORUS - CONTROL SITE

Figure 58

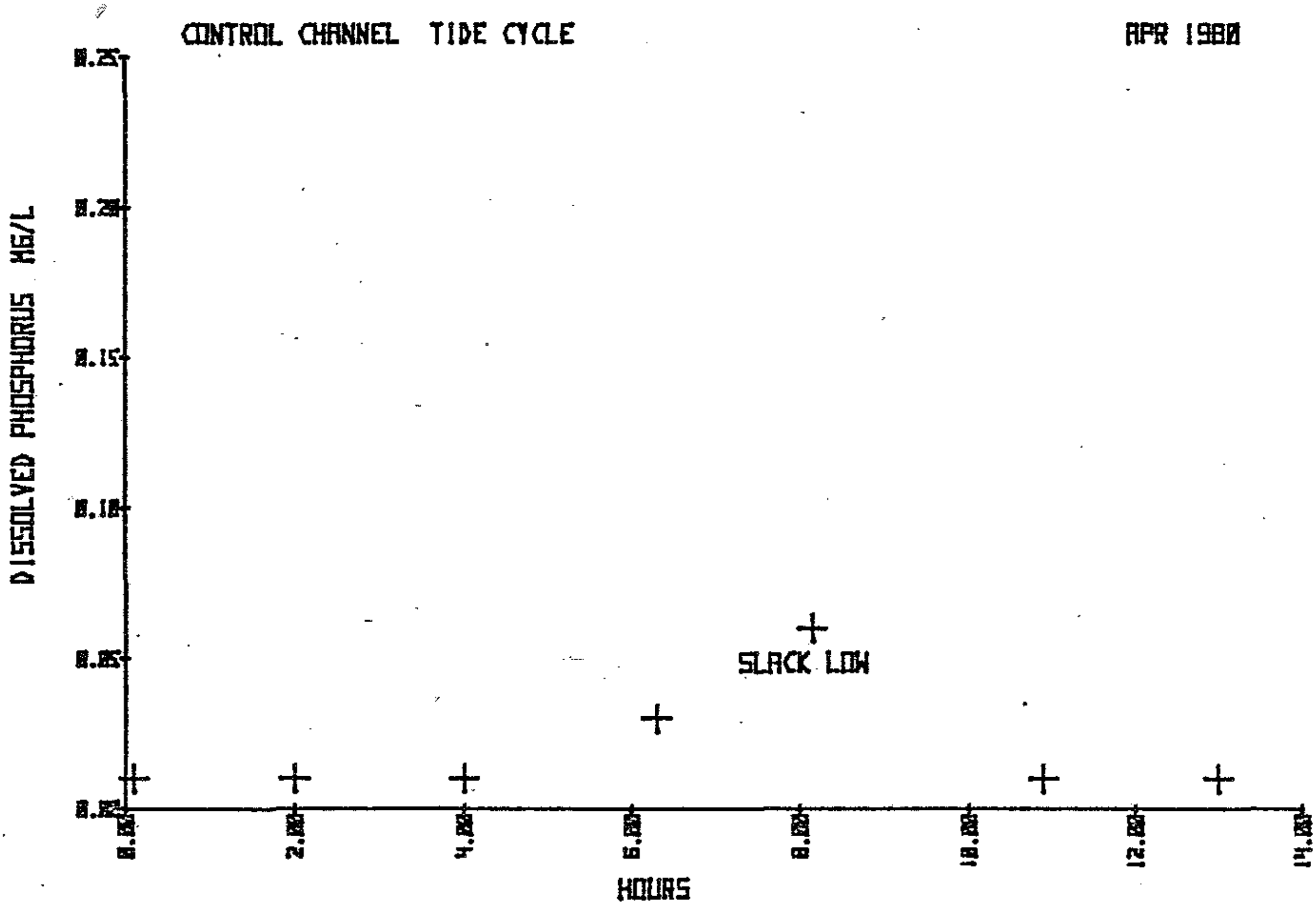

CONTROL CHANNEL TIDE CYCLE
APR 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 59

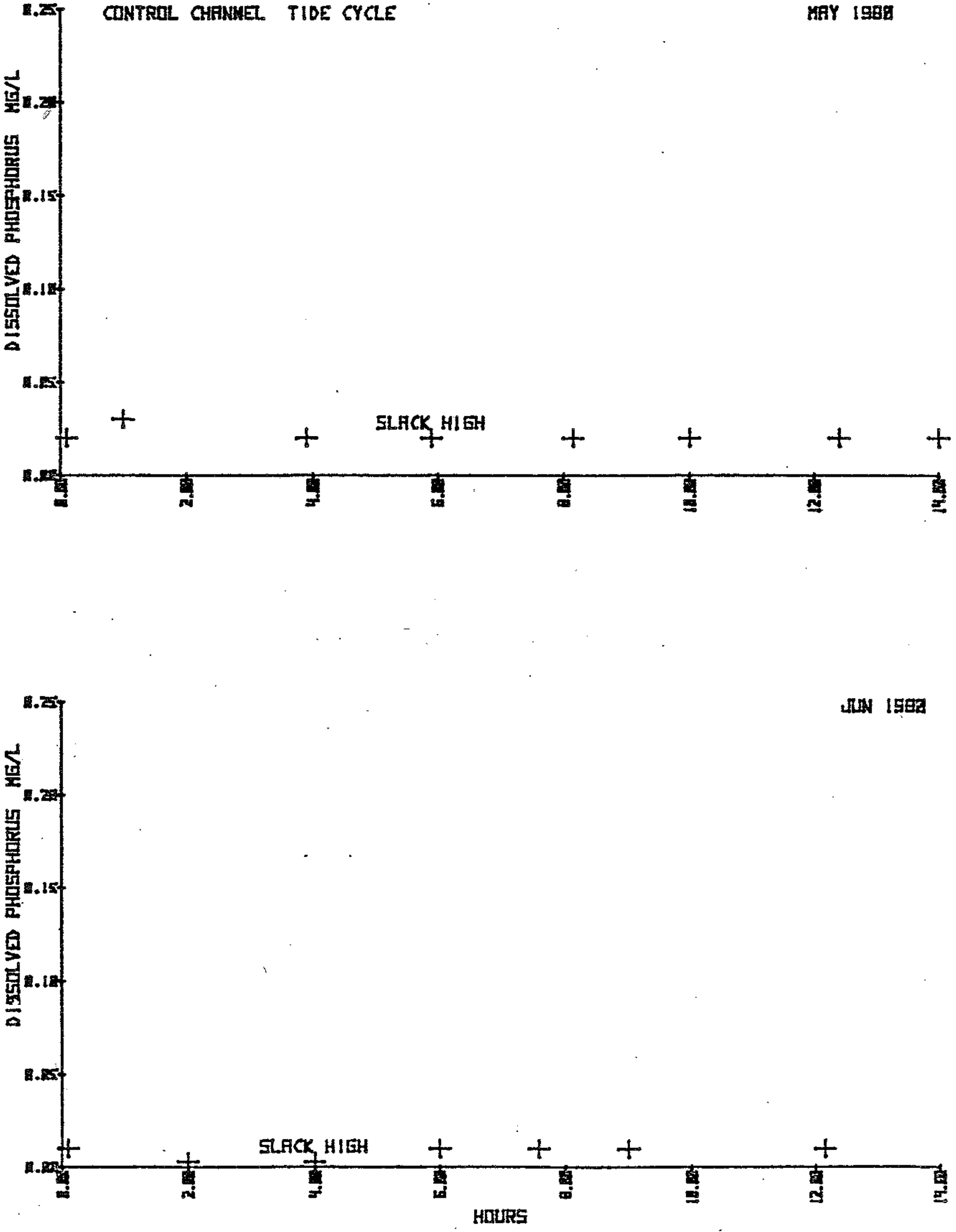
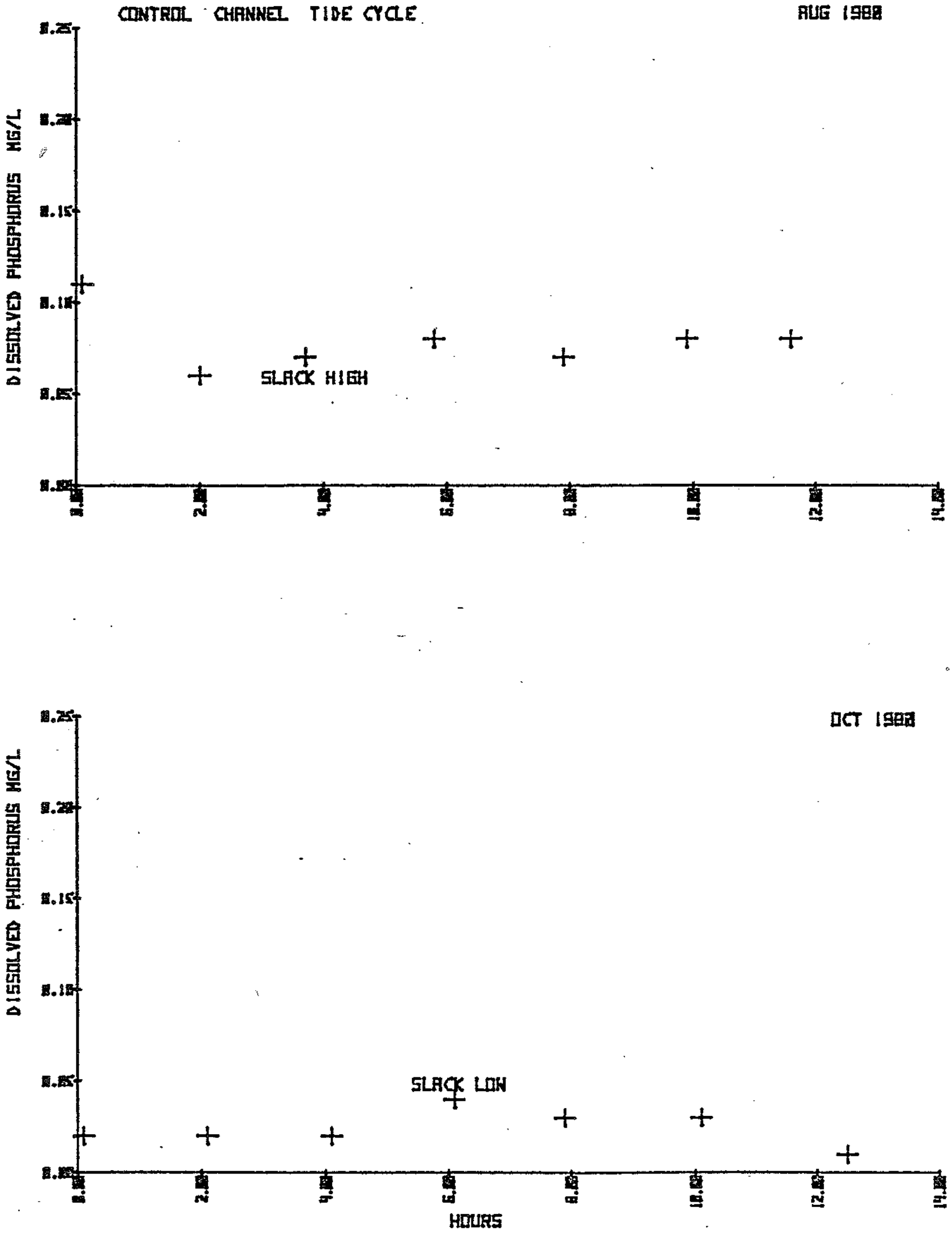

CONTROL CHANNEL TIDE CYCLE
MAY 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 60



CONTROL CHANNEL TIDE CYCLE
AUG 1988
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1988
DISSOLVED PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

11. TOTAL PHOSPHORUS - OPEN SITE

Figure 61

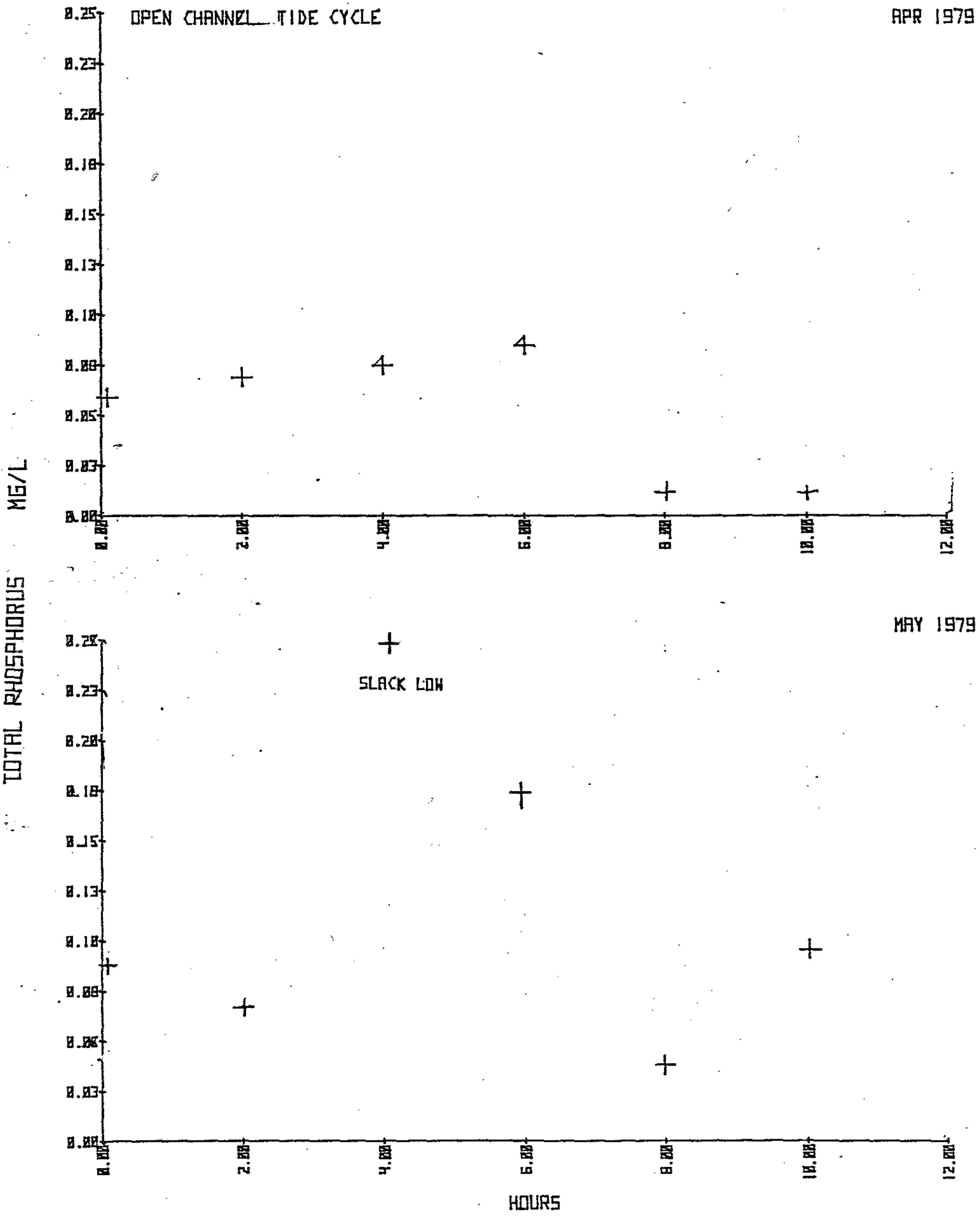

OPEN CHANNEL TIDE CYCLE
APR 1979
0.25
0.23
0.20
0.18
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
MAY 1979
SLACK LOW
0.25
0.23
0.20
0.18
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
TOTAL PHOSPHORUS MG/L
HOURS

Figure 62

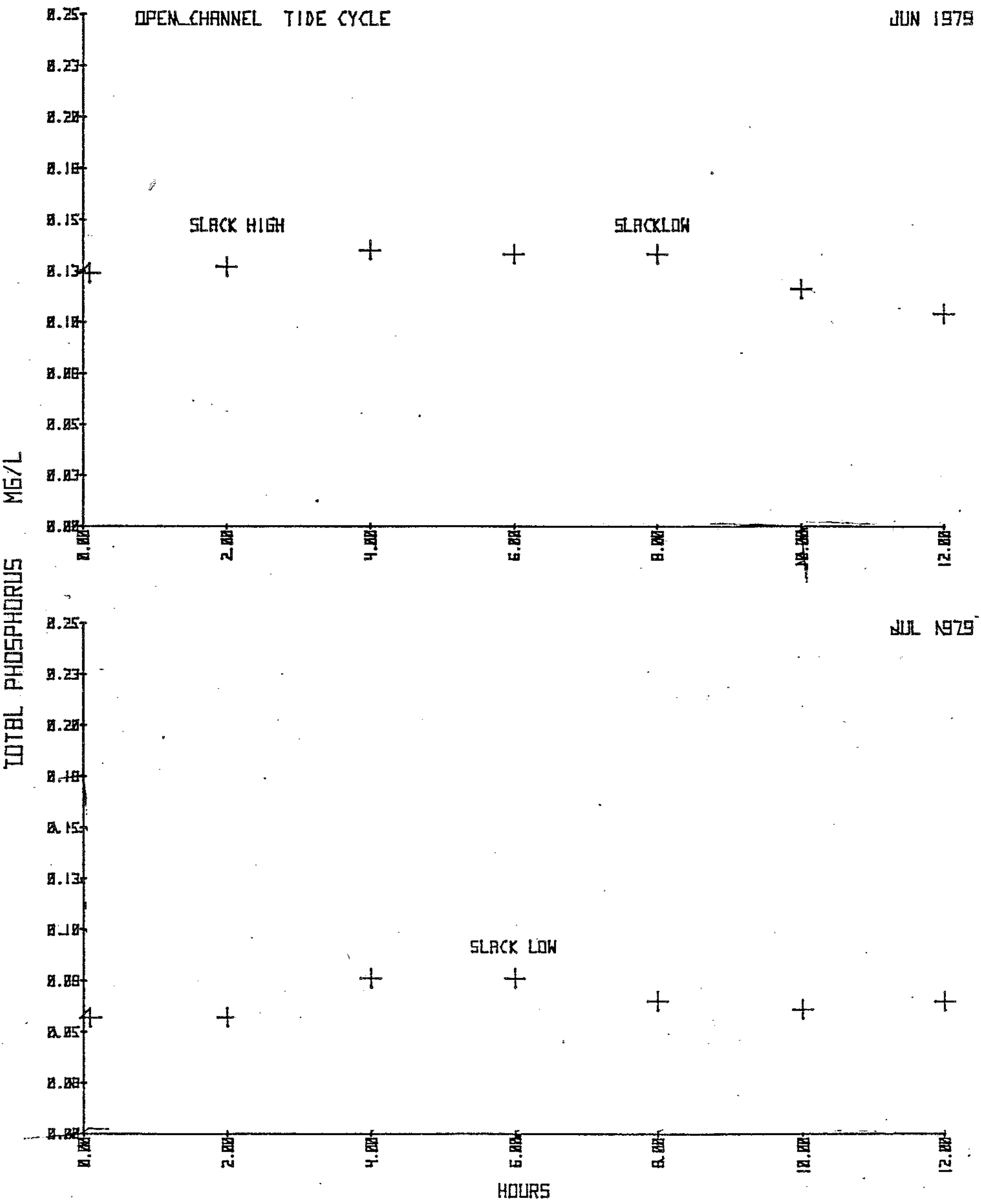

OPEN CHANNEL TIDE CYCLE
JUN 1979
SLACK HIGH
SLACKLOW
JUL 1979
SLACK LOW
TOTAL PHOSPHORUS MG/L
HOURS
0.25
0.23
0.20
0.18
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00

Figure 63

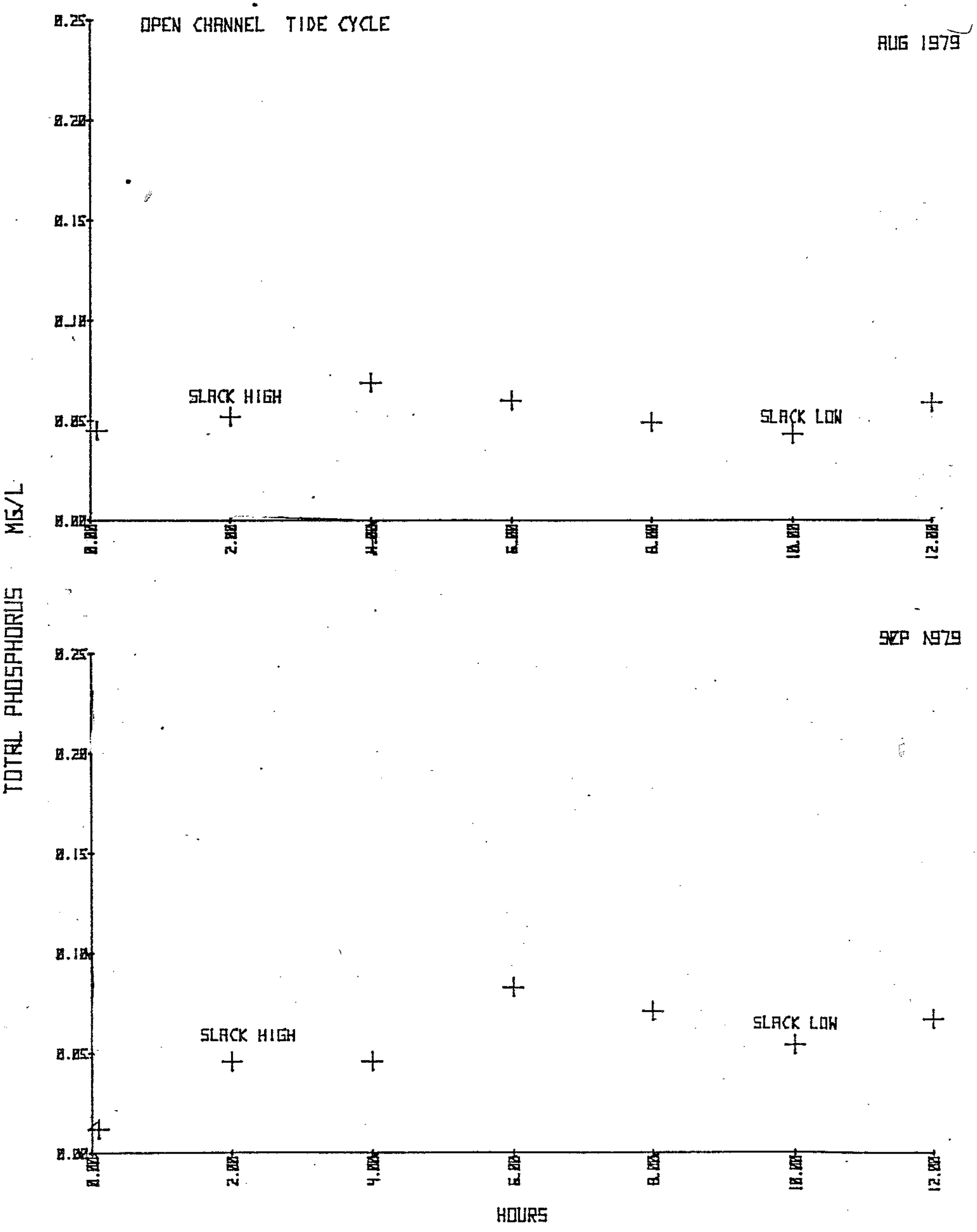

OPEN CHANNEL TIDE CYCLE
AUG 1979
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
SEP 1979
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 64

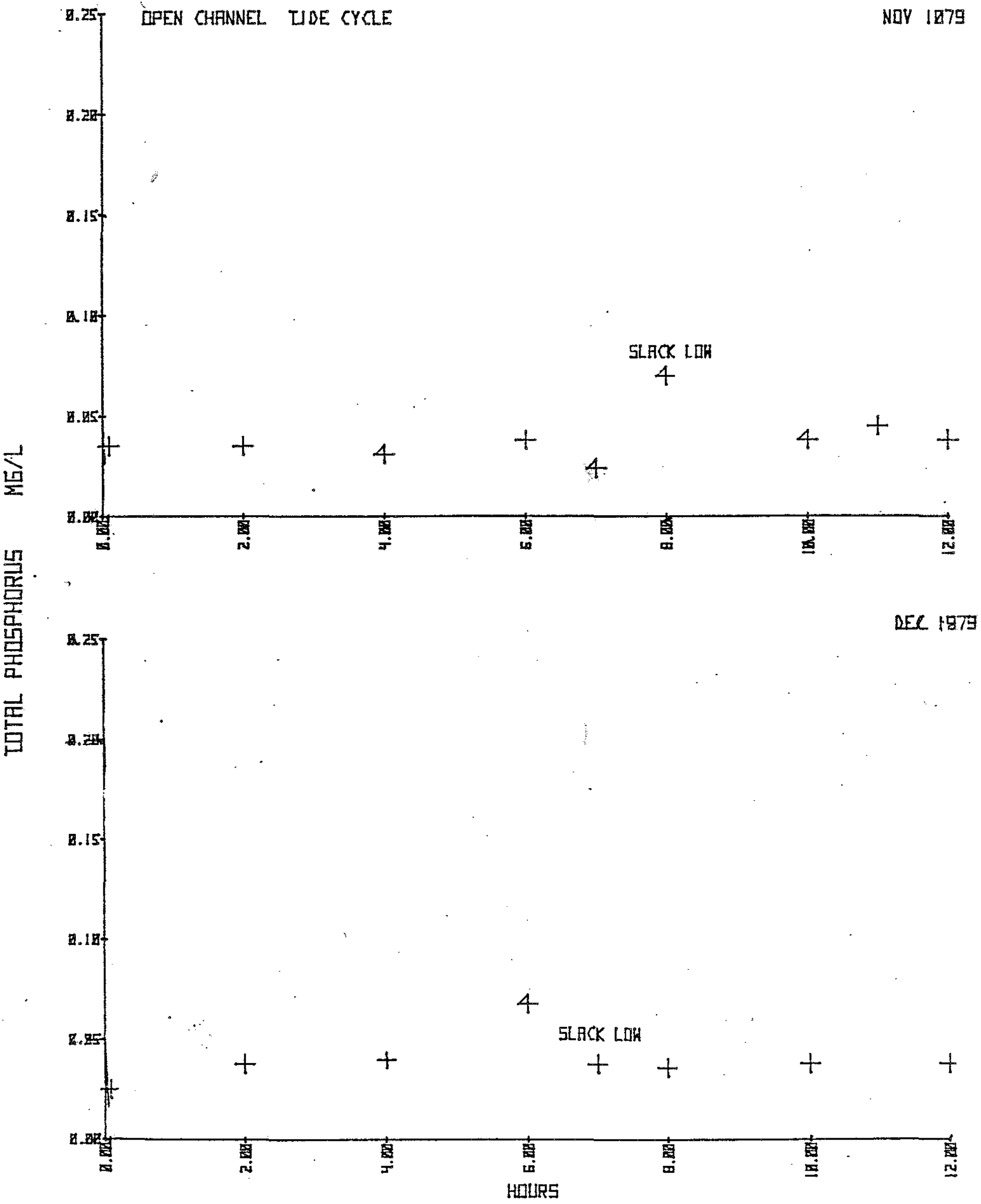
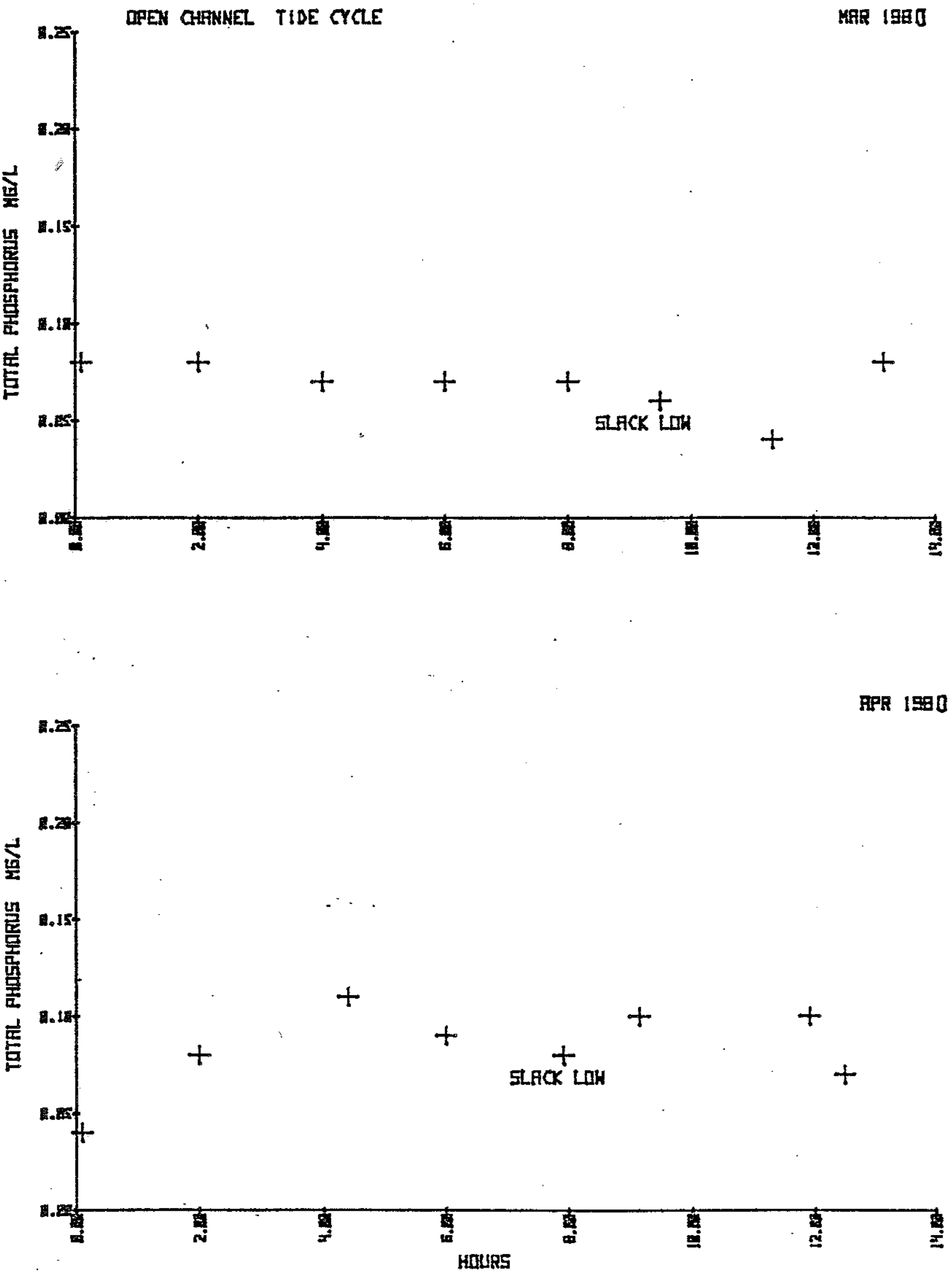

OPEN CHANNEL TIDE CYCLE
NOV 1079
SLACK LOW
DEC 1979
SLACK LOW
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
HOURS

Figure 65



OPEN CHANNEL TIDE CYCLE
MAR 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
APR 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 66

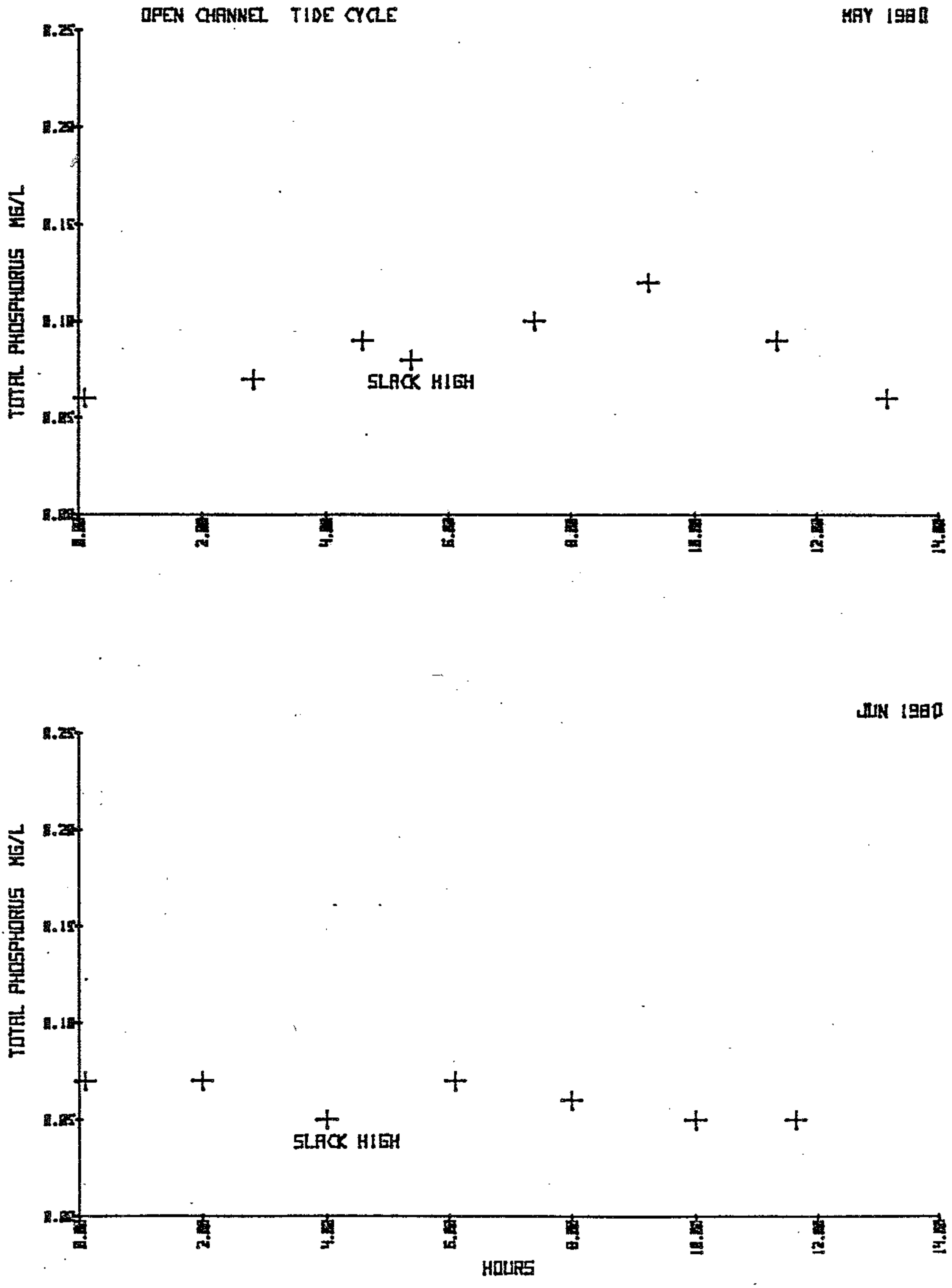
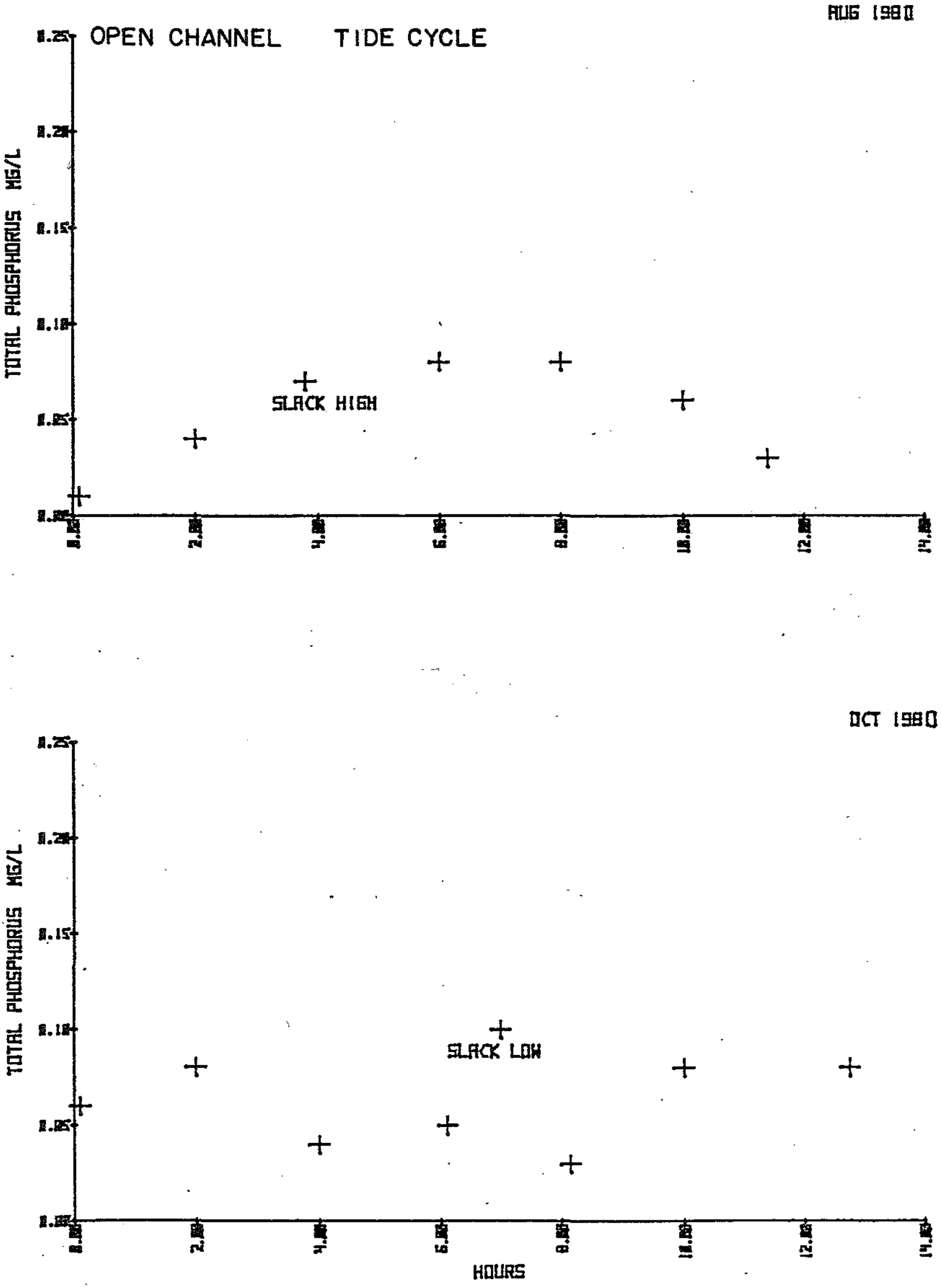

OPEN CHANNEL TIDE CYCLE
MAY 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 67


AUG 1980
OPEN CHANNEL TIDE CYCLE
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

12. TOTAL PHOSPHORUS - CONTROL SITE

Figure 68

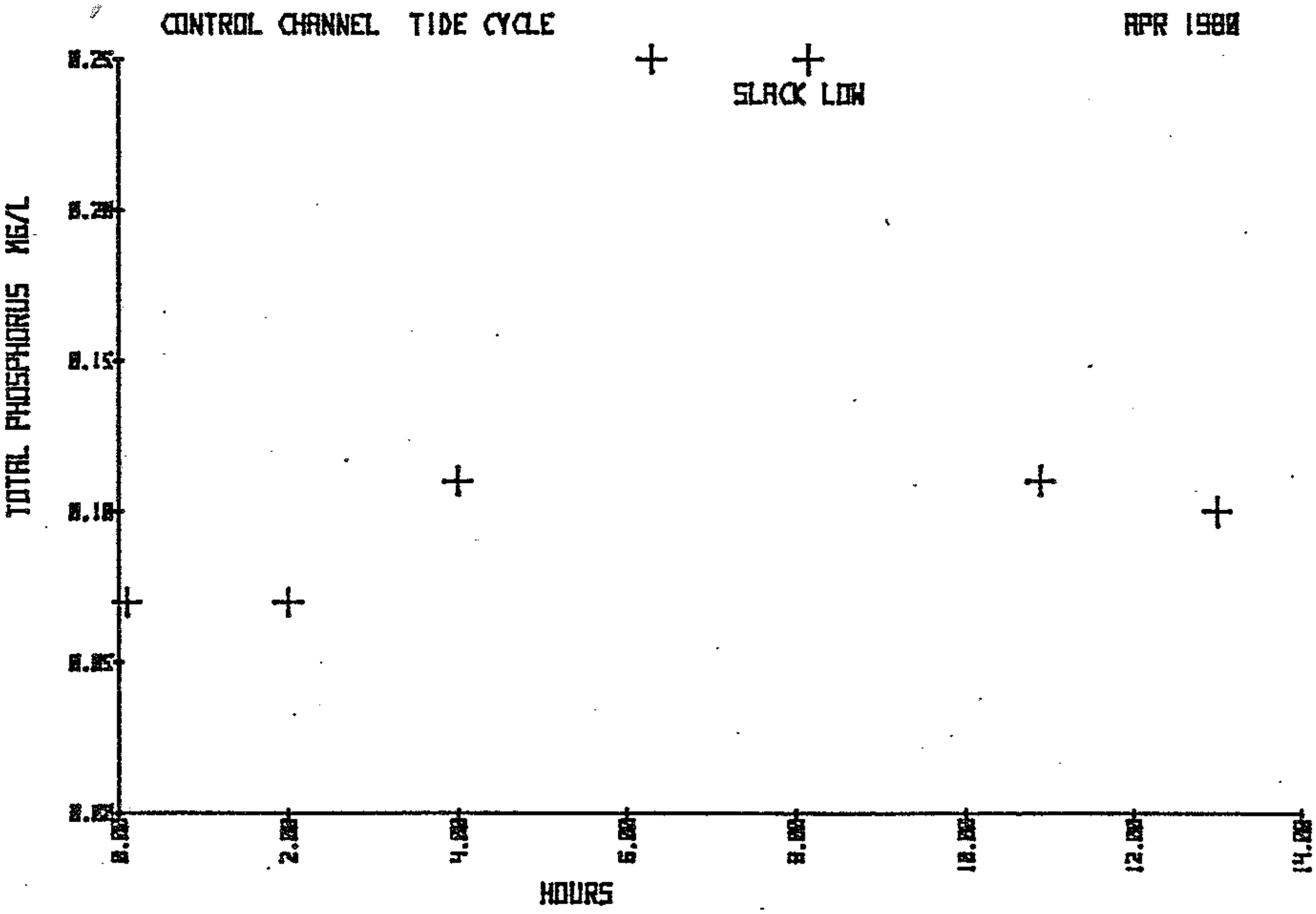
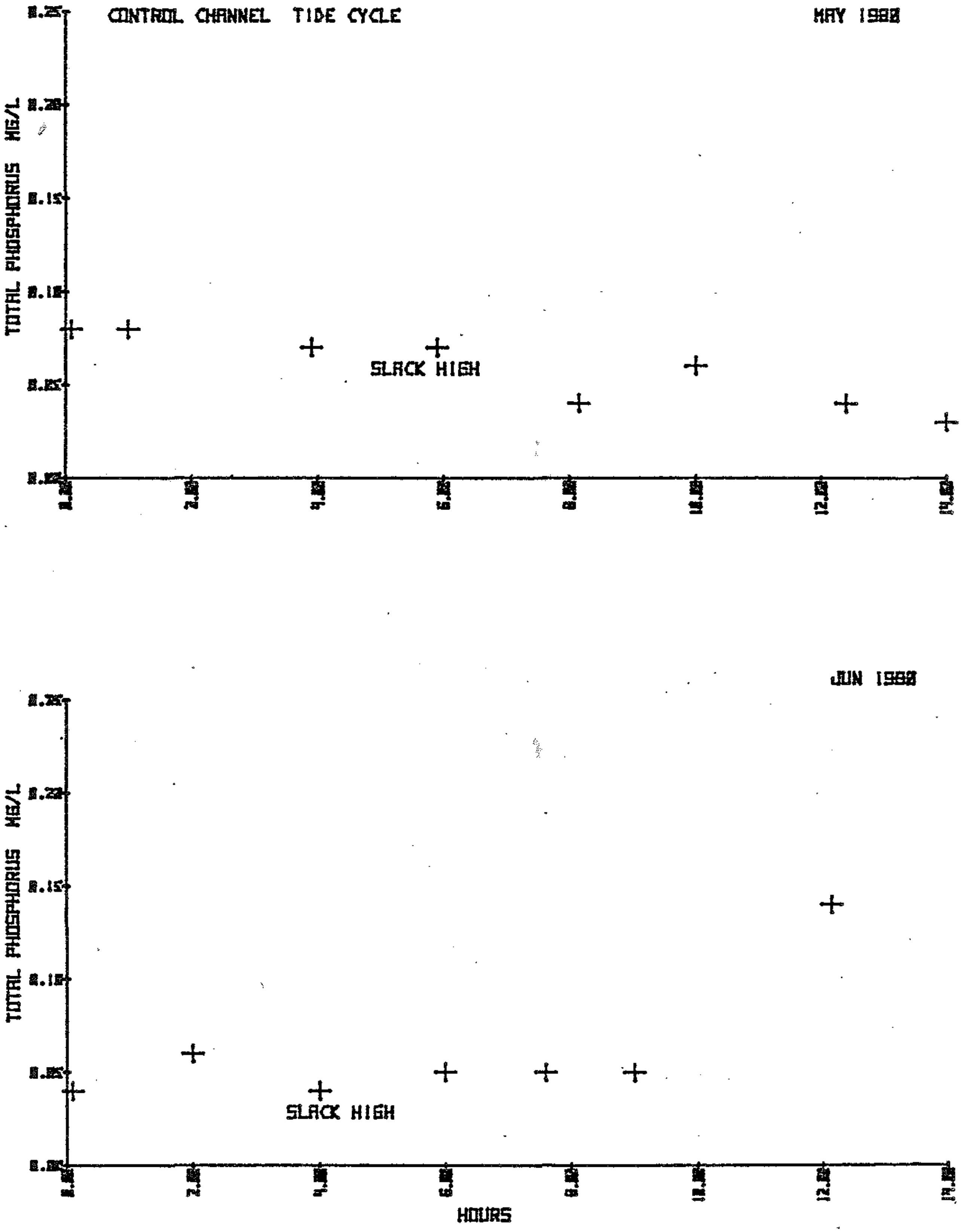
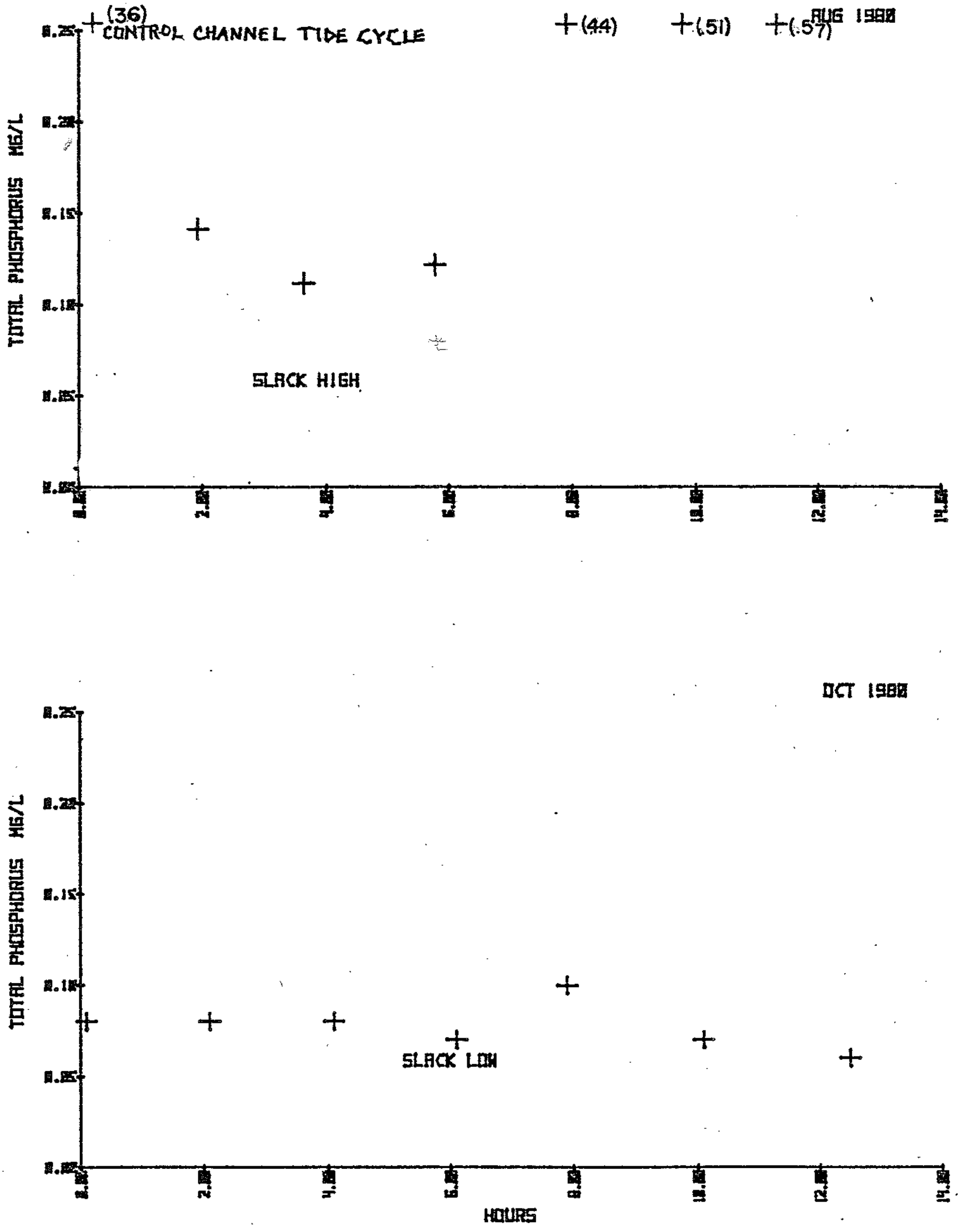

CONTROL CHANNEL TIDE CYCLE
APR 1980
SLACK LOW
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 69



CONTROL CHANNEL TIDE CYCLE
MAY 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
JUN 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

Figure 70


(36)
CONTROL CHANNEL TIDE CYCLE
(44)
(51)
(.57)
AUG 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK HIGH
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
OCT 1980
TOTAL PHOSPHORUS MG/L
0.25
0.20
0.15
0.10
0.05
0.00
SLACK LOW
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS

APPENDIX E. Nutrient flux data are plotted graphically to show patterns of influx on efflux during tidal cycle studies at the Open and Control Sites. The X axis is expressed as hours since slack tide. The Y axis is grams of material that entered (+) or was removed (-) from the site during 2 hour time intervals.

Group	Nutrients	Site	Figure Numbers	Pages
1	Nitrate and ammonia	Open	77 - 88	199 - 210
2	Nitrate and ammonia	Control	89 - 91	212 - 214
3	Total and dissolved Kjeldahl N	Open	92 - 103	216 - 227
4	Total and dissolved Kjeldahl N	Control	104 - 106	229 - 231
5	Total and dissolved phosphorus	Open	107 - 118	233 - 244
6	Total and dissolved phosphorus	Control	119 - 121	246 - 248

1. NITRATE AND AMMONIA - OPEN SITE

Figure 71

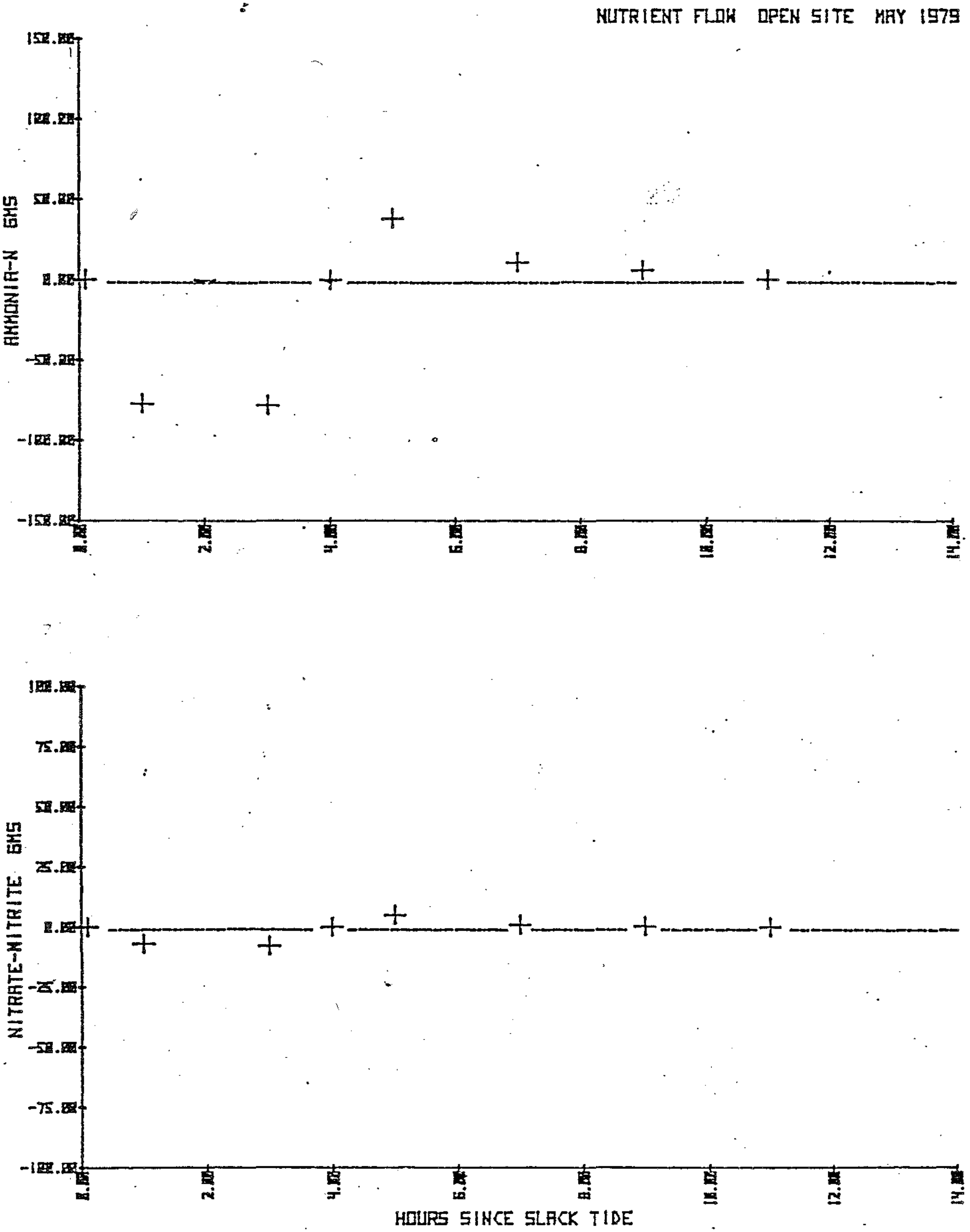

NUTRIENT FLOW OPEN SITE MAY 1979
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 72

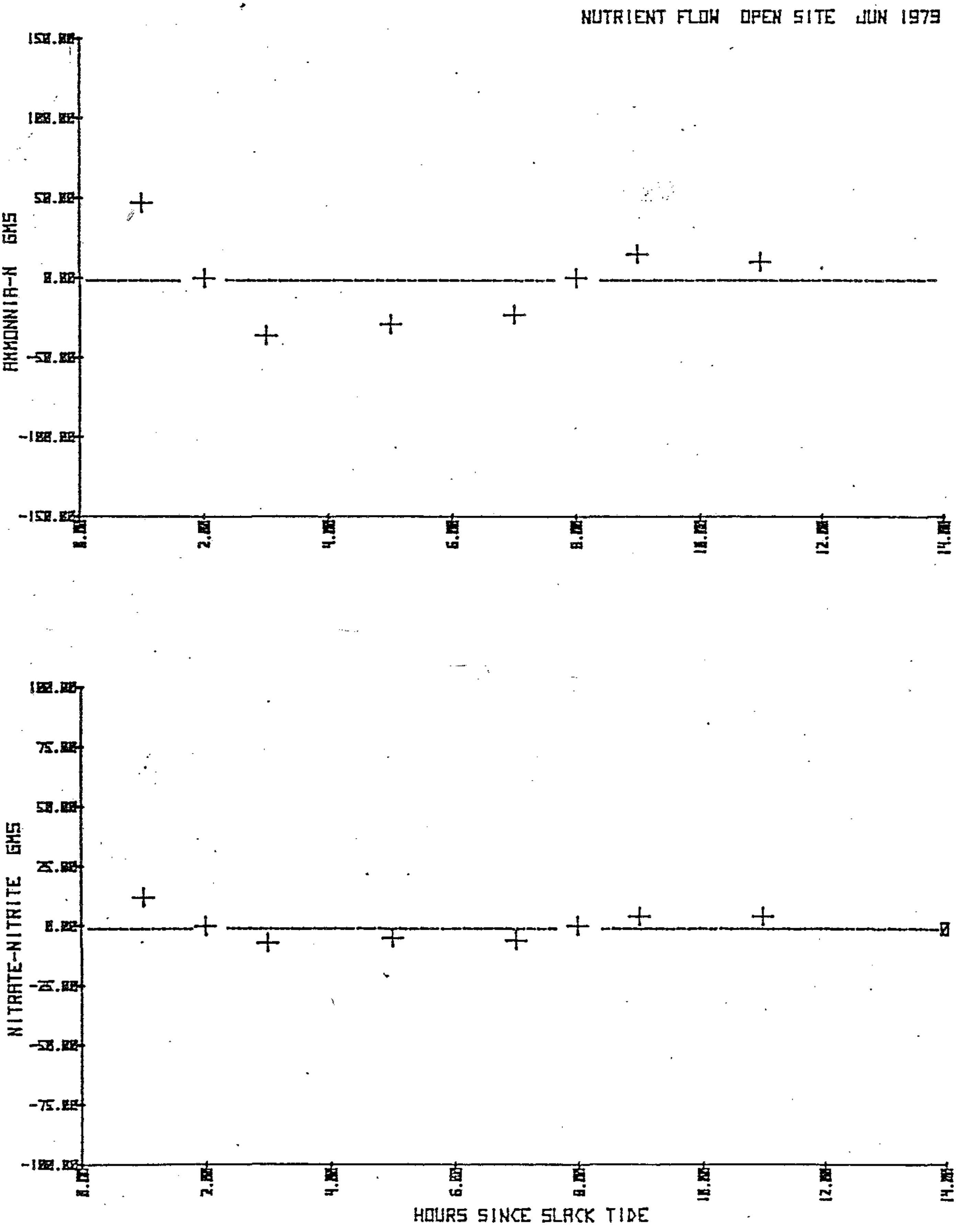

NUTRIENT FLOW OPEN SITE JUN 1979
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
AMMONIA-N GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
NITRATE-NITRITE GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 73

NUTRIENT FLOW OPEN SITE AUG 1979

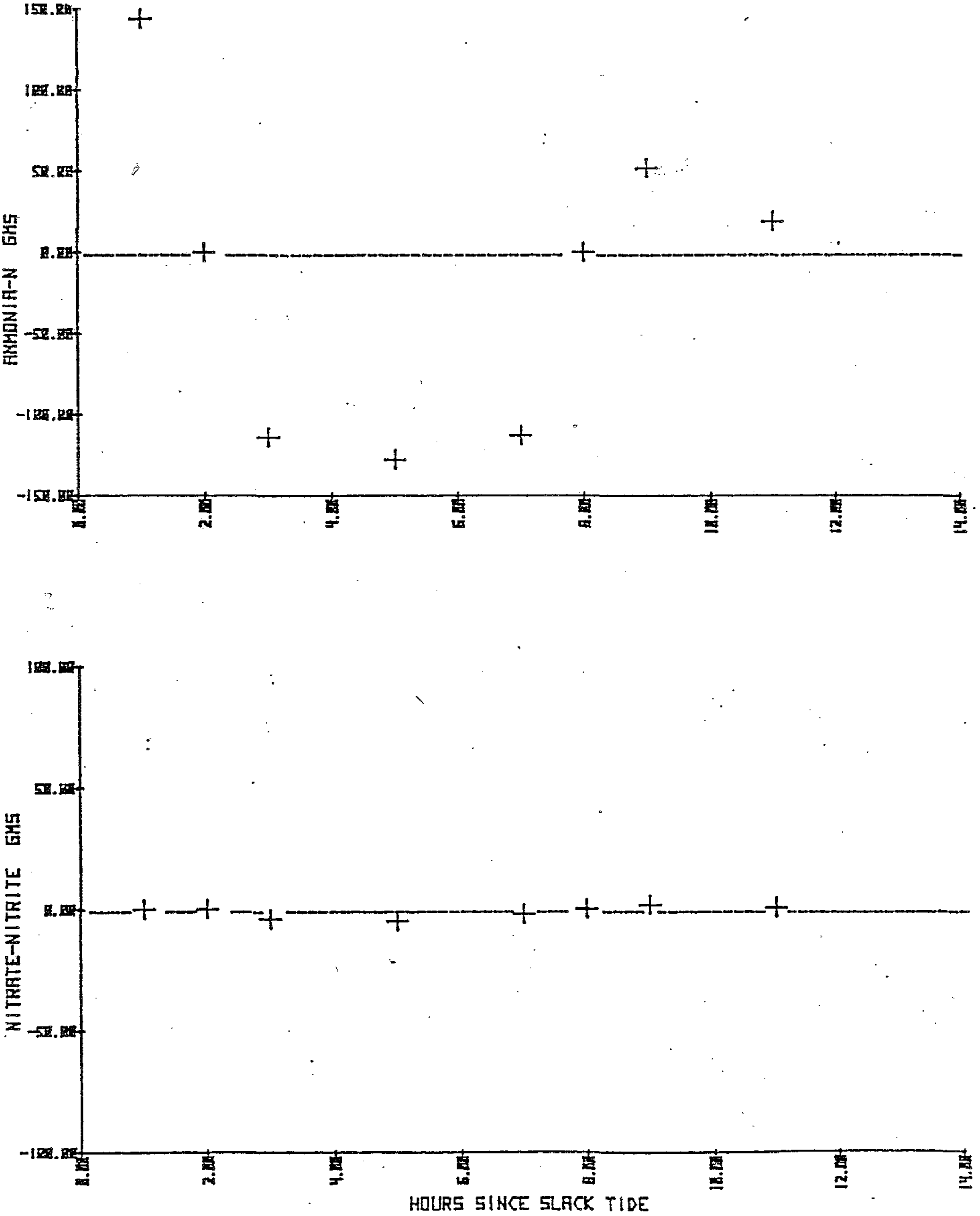
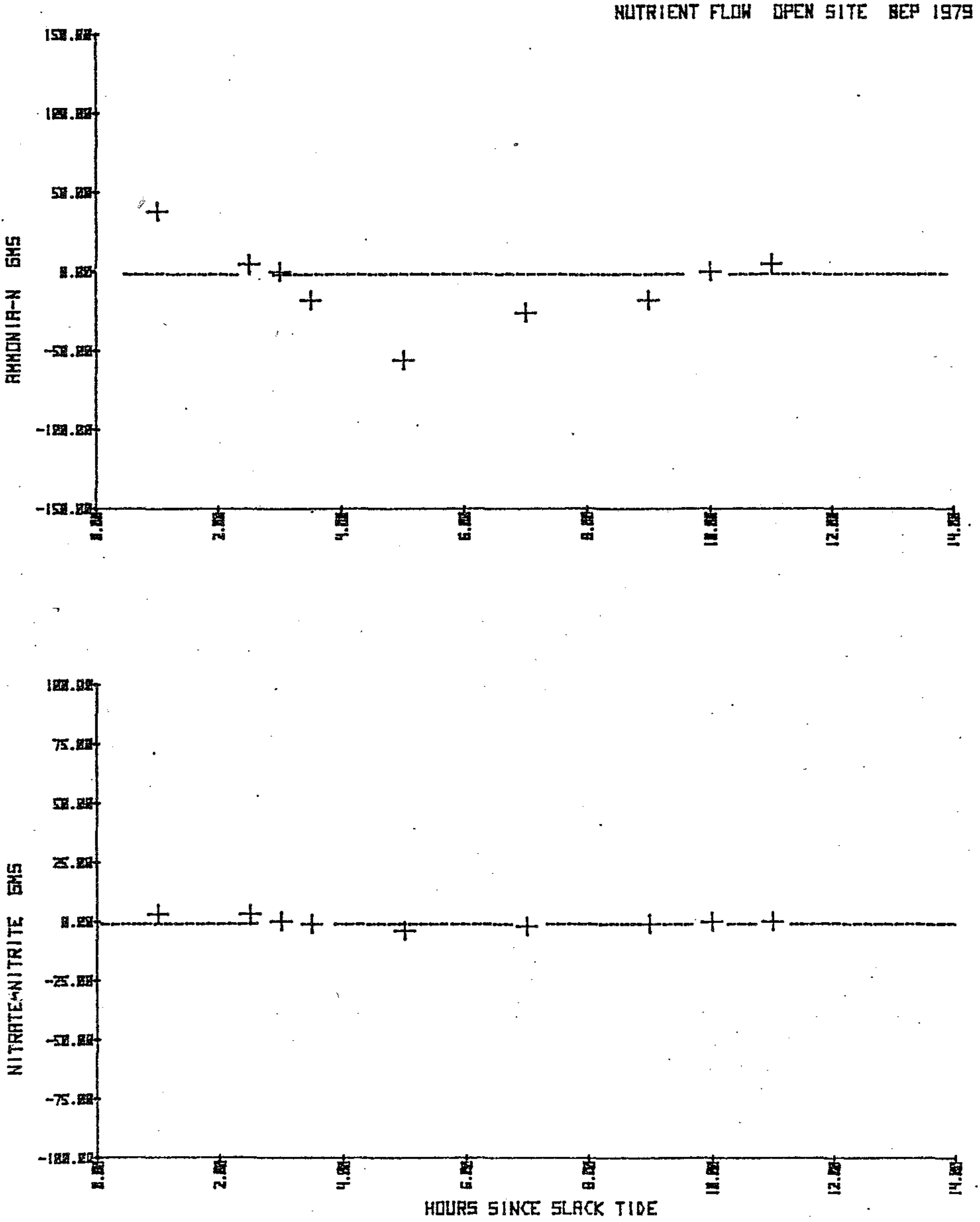


Figure 74


NUTRIENT FLOW OPEN SITE SEP 1979
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE+NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

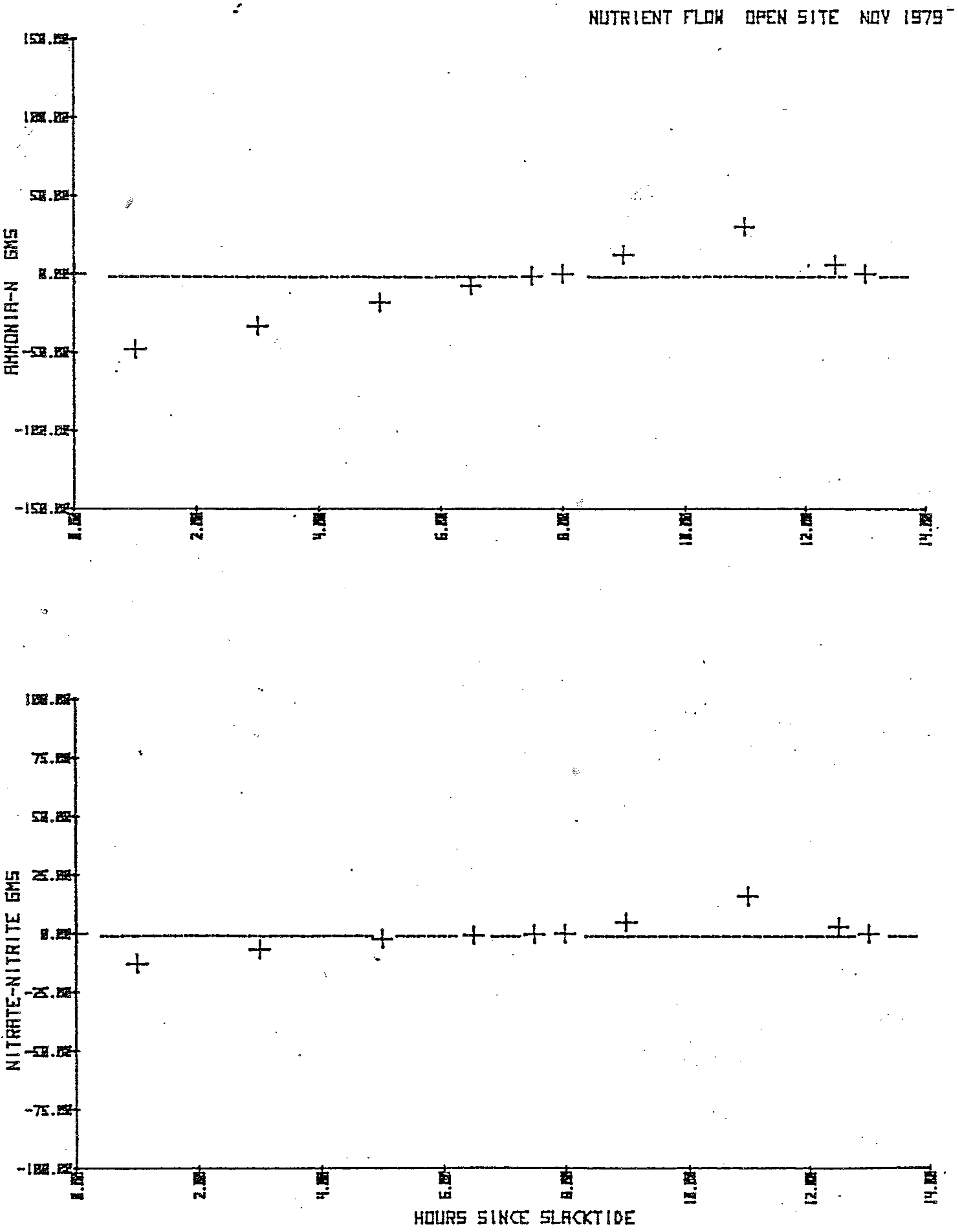


Figure 75

NUTRIENT FLOW OPEN SITE NOV 1979
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACKTIDE

Figure 76

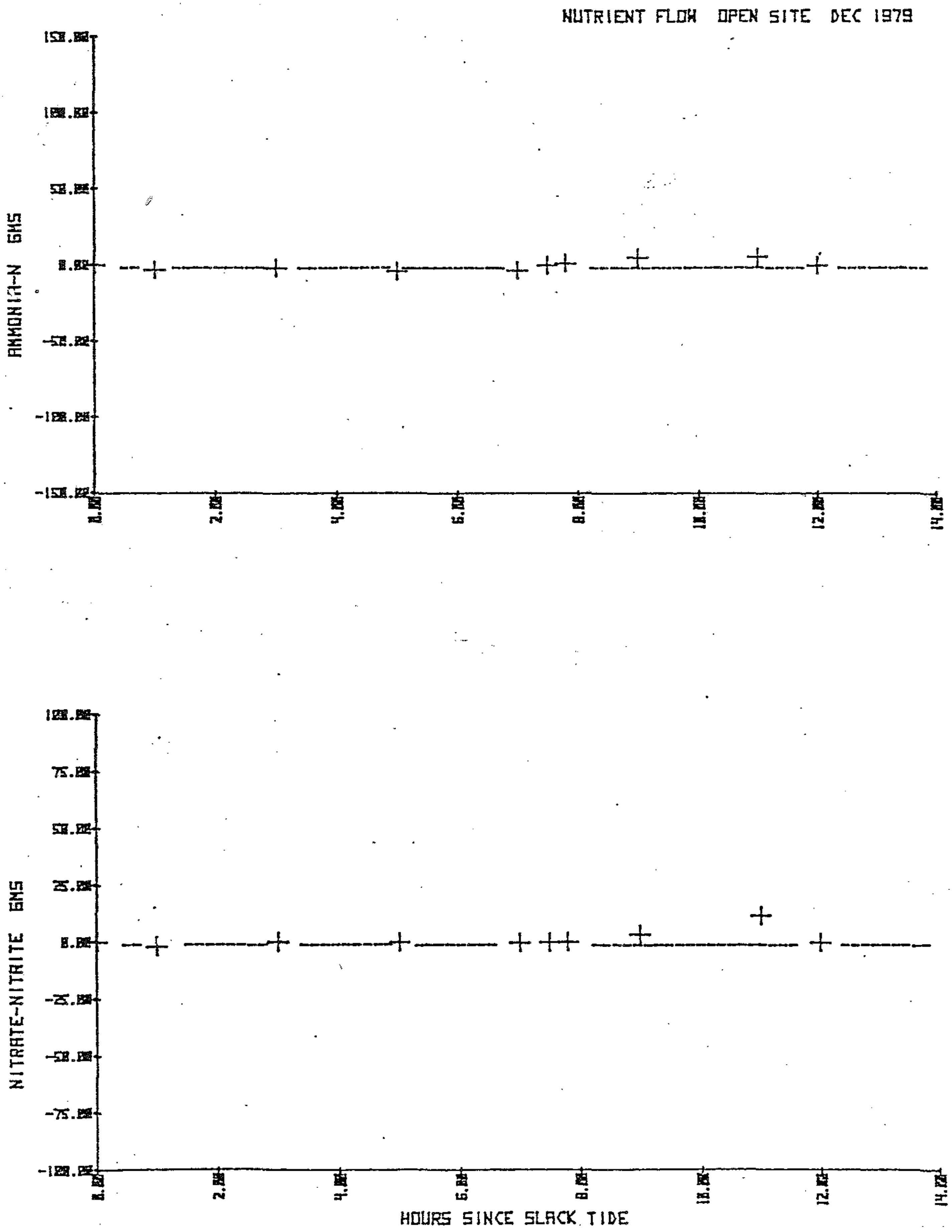

NUTRIENT FLOW OPEN SITE DEC 1979
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 77

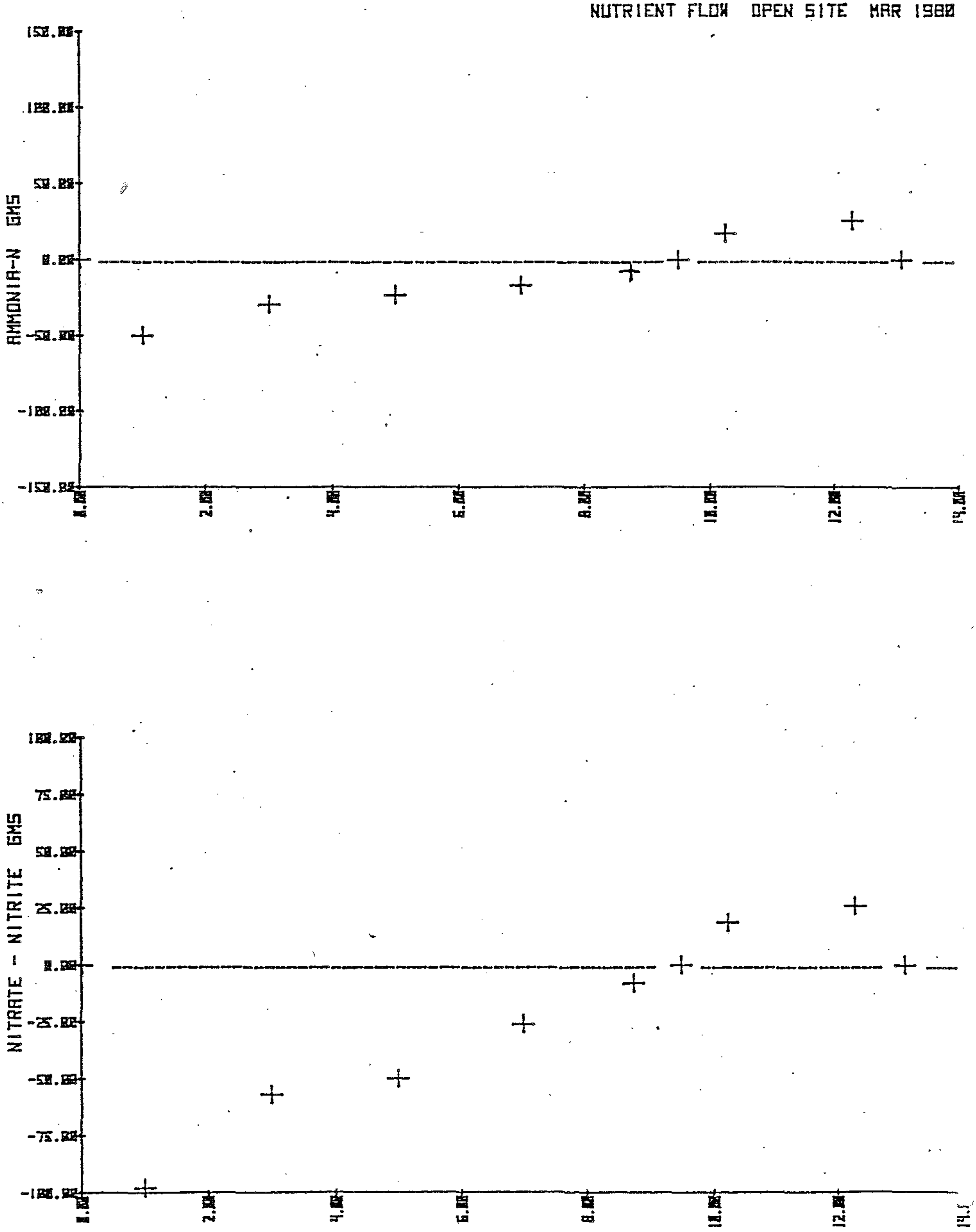
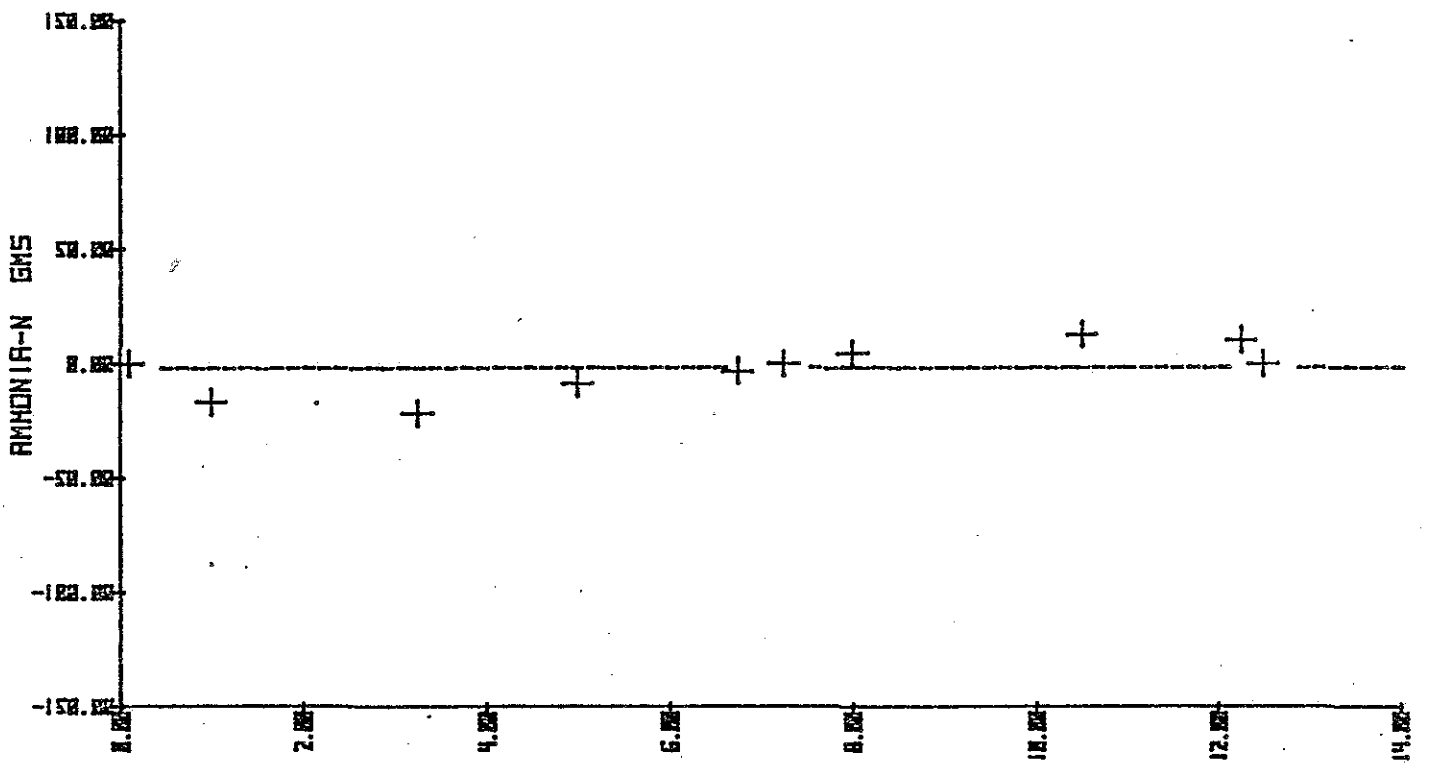
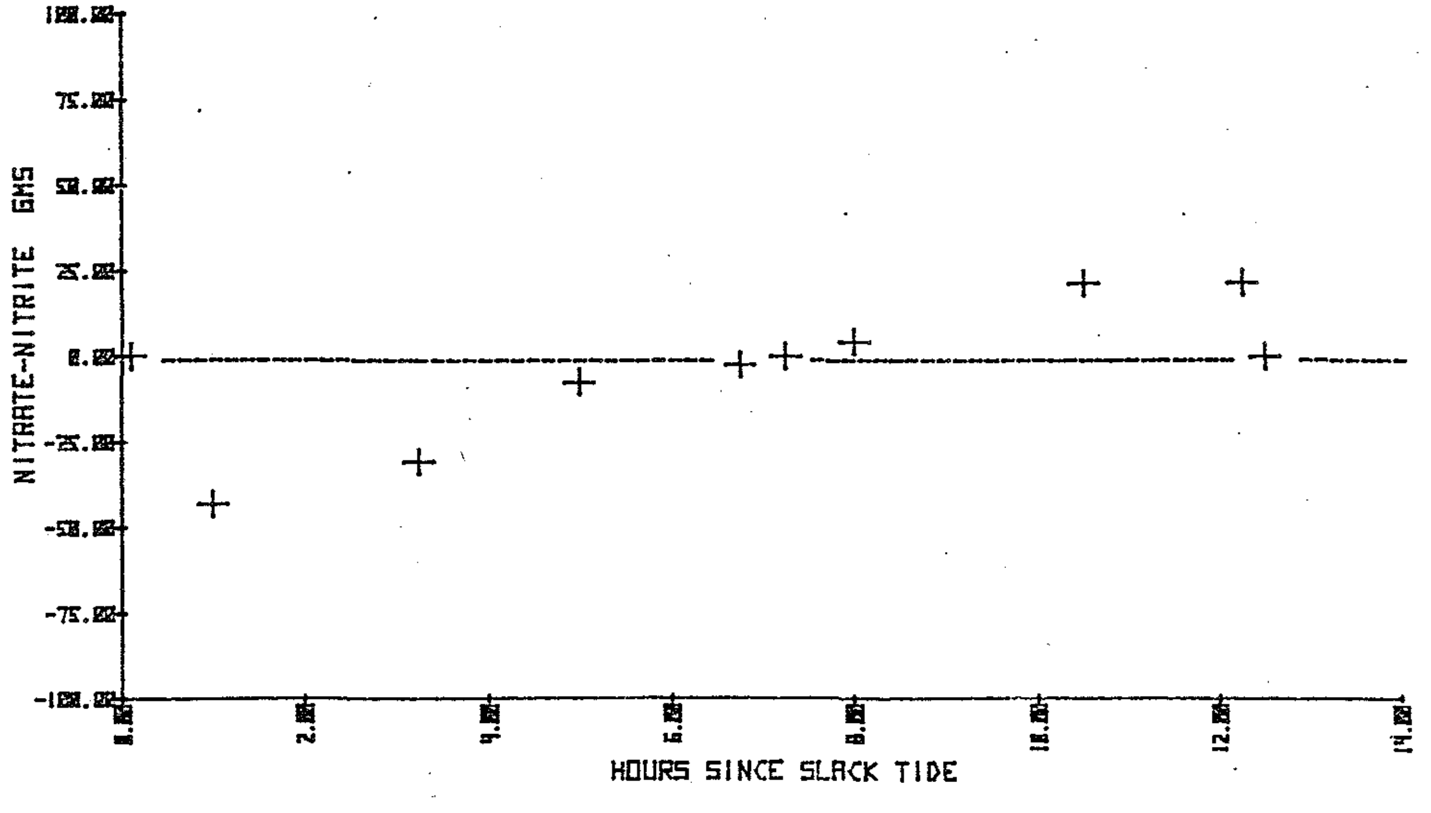

NUTRIENT FLOW OPEN SITE MAR 1980
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE - NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.0
HOURS SINCE SLACK TIDE

Figure 78


NUTRIENT FLOW OPEN SITE APR 1980
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00


NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

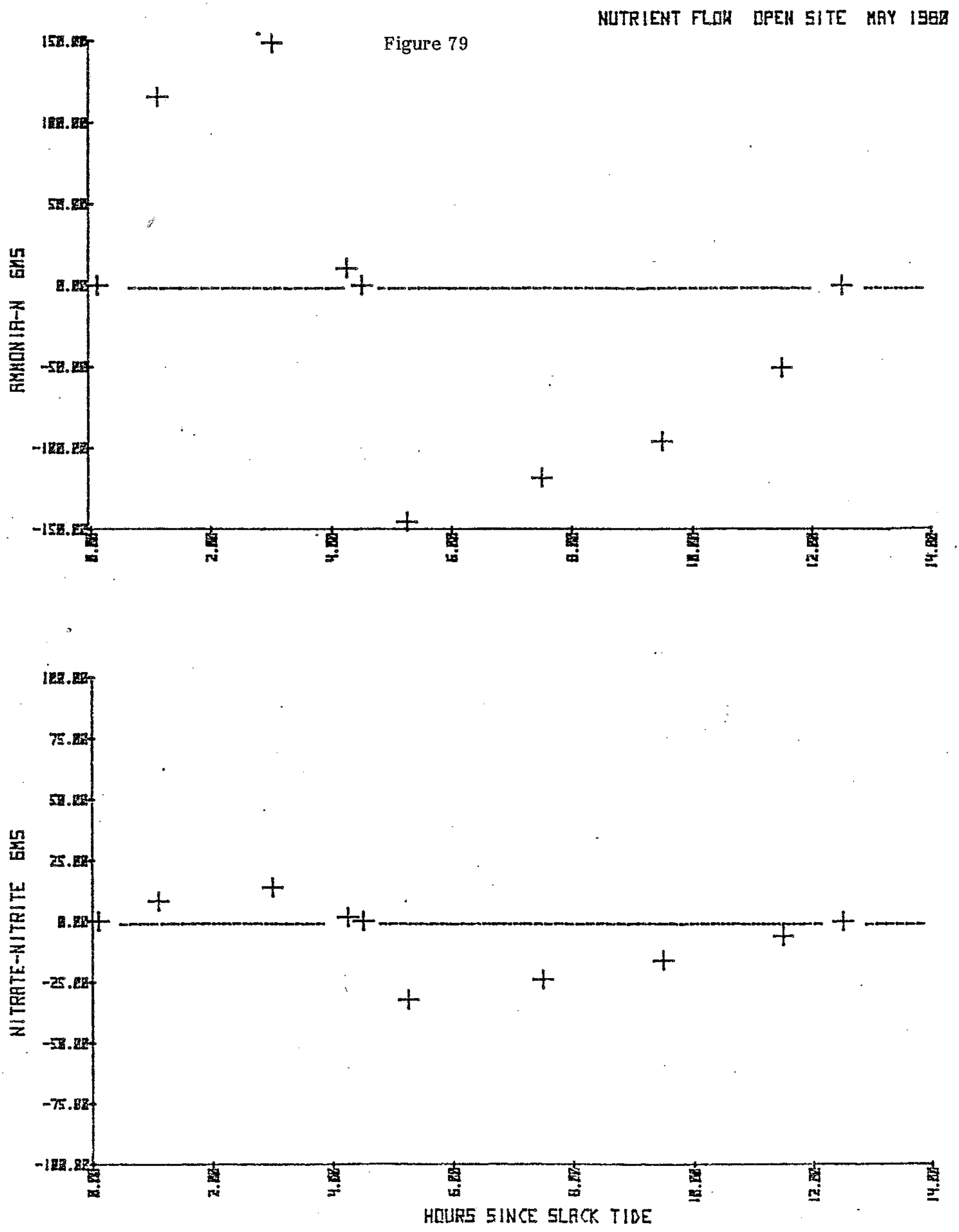

NUTRIENT FLOW OPEN SITE MAY 1980
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 79

Figure 80

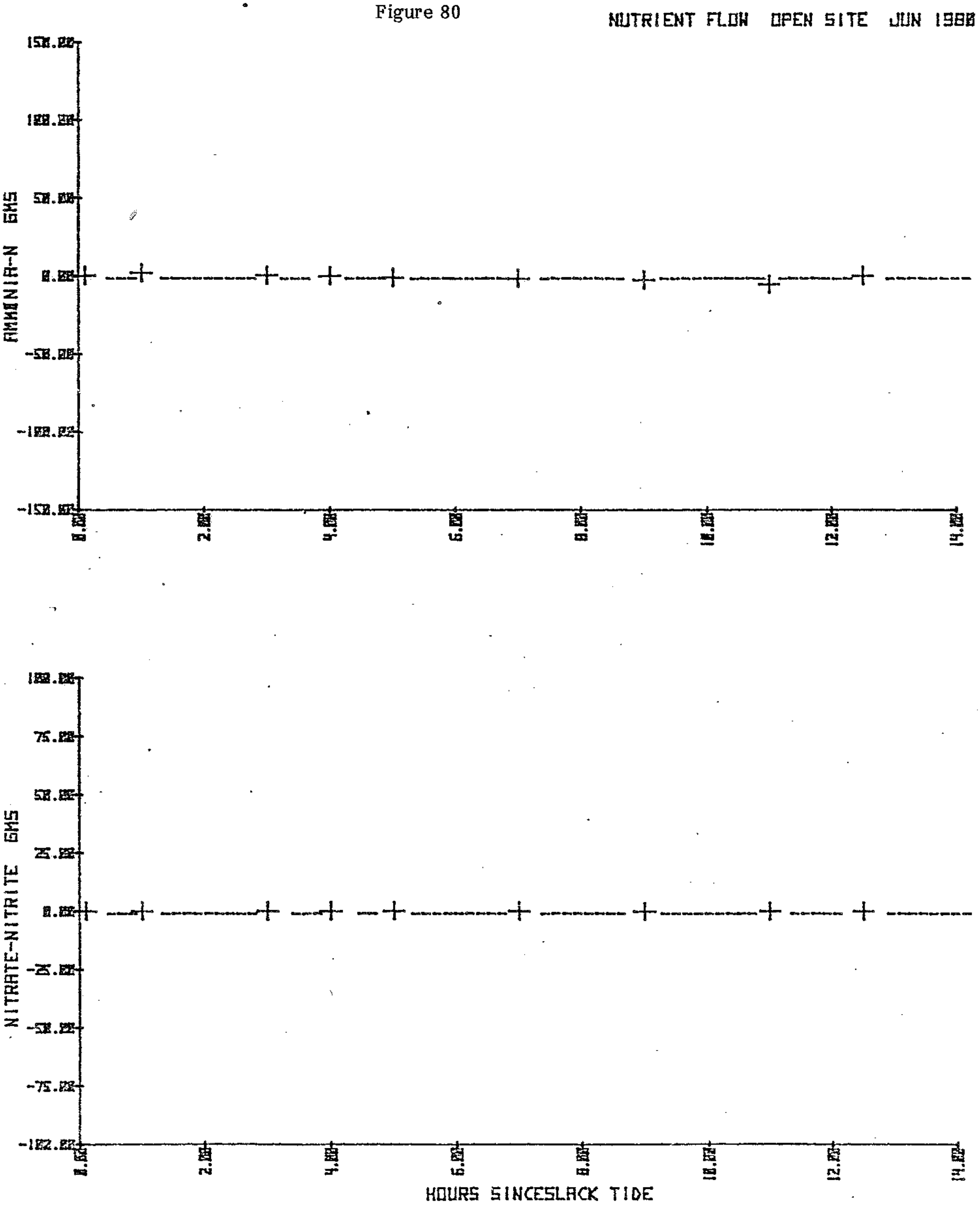
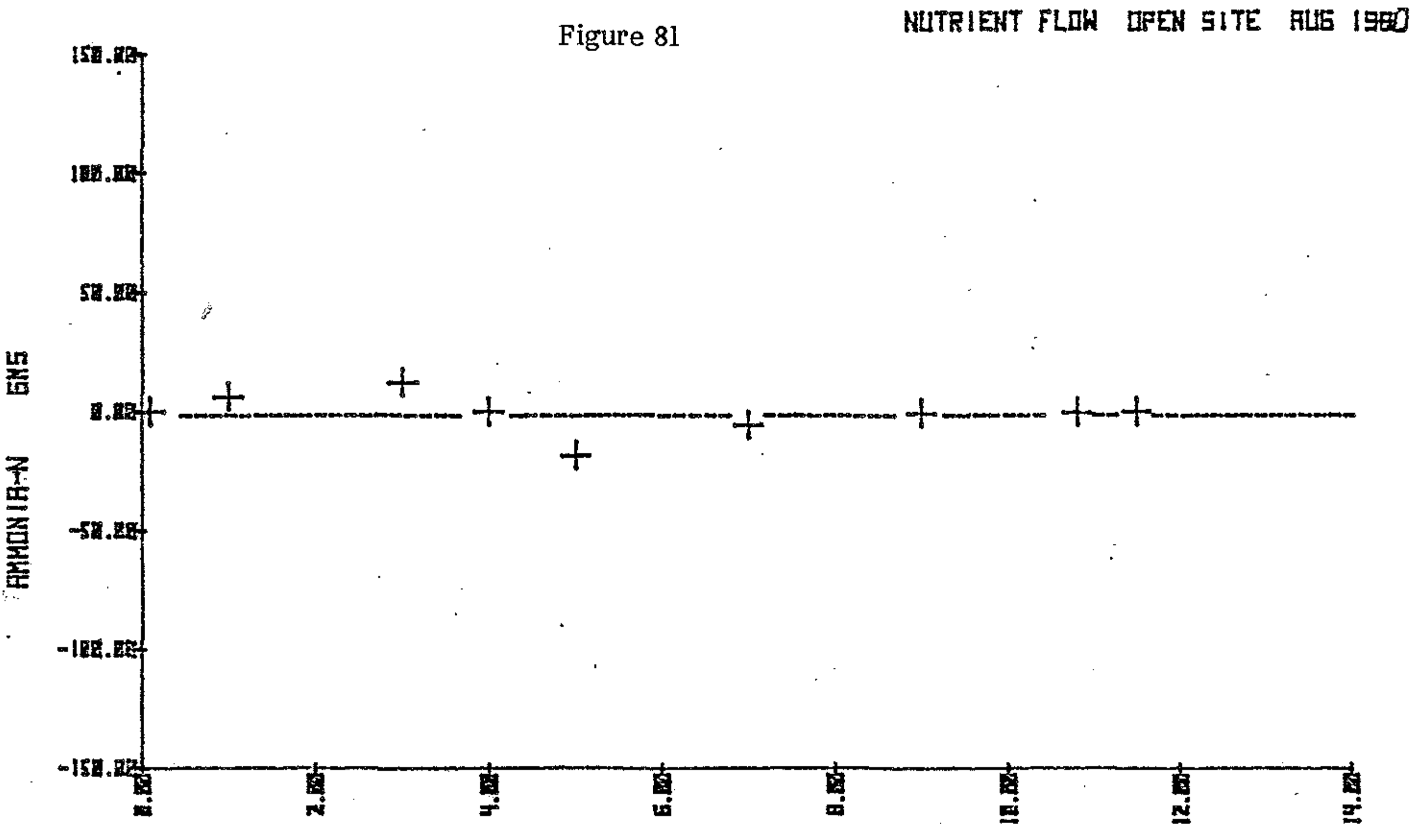

NUTRIENT FLOW OPEN SITE JUN 1980
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCESLACK TIDE

Figure 81


NUTRIENT FLOW OPEN SITE AUG 1980
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
AMMONIA-N GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00

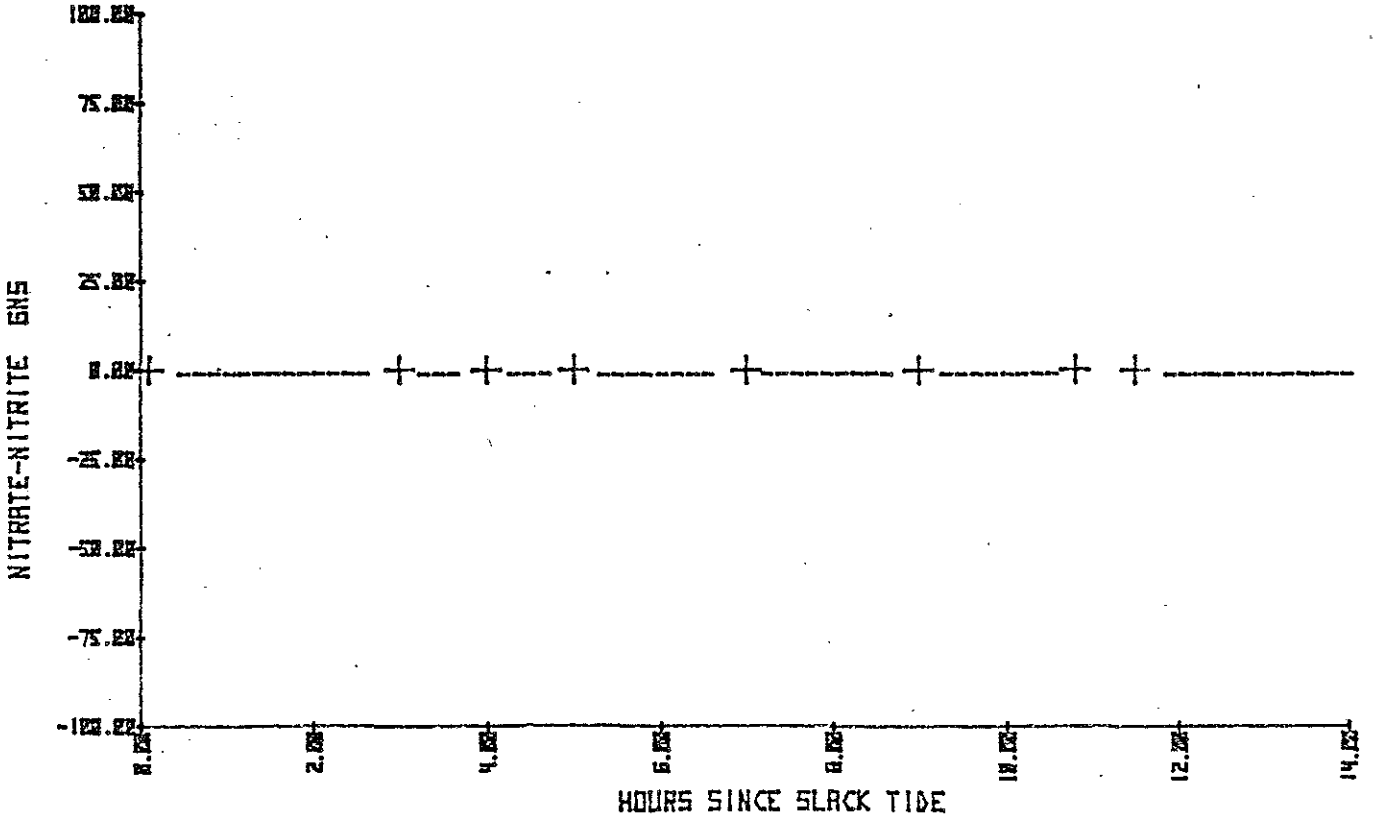
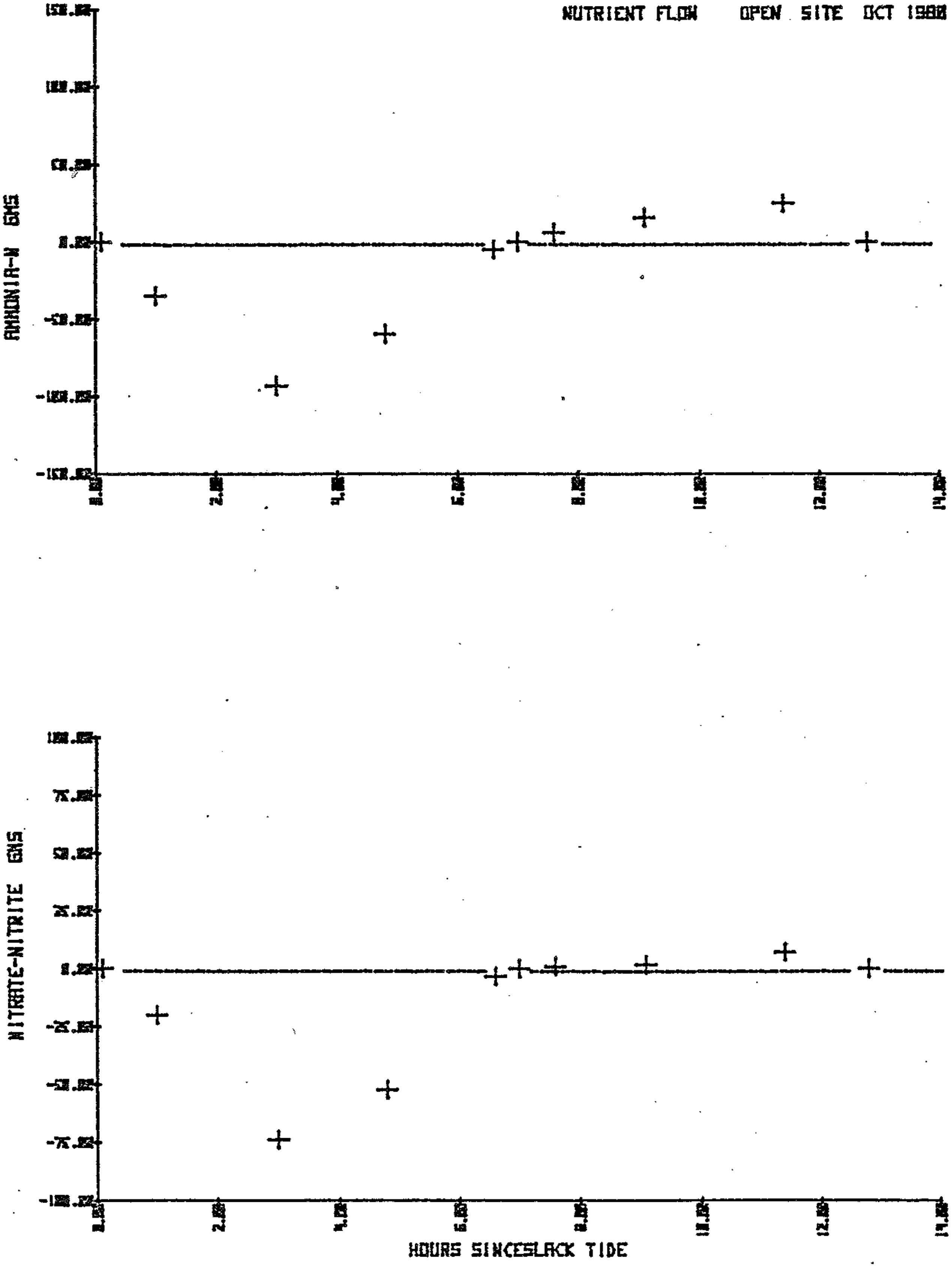

100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
NITRATE-NITRITE GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 82


NUTRIENT FLOW OPEN SITE OCT 1980
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCESLACK TIDE

2. NITRATE AND AMMONIA - CONTROL SITE

Figure 83

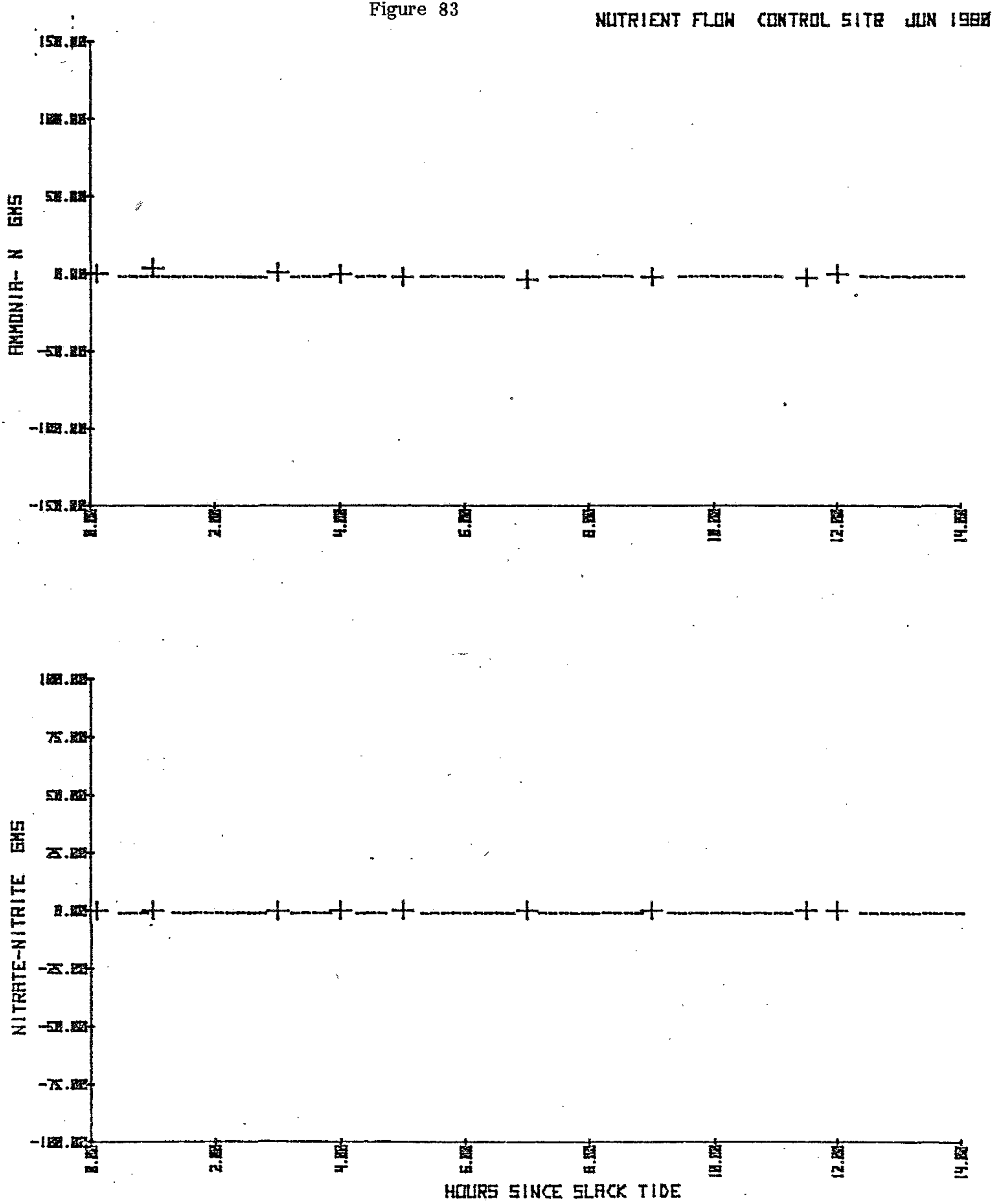

NUTRIENT FLOW CONTROL SITE JUN 1980
AMMONIA- N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 84

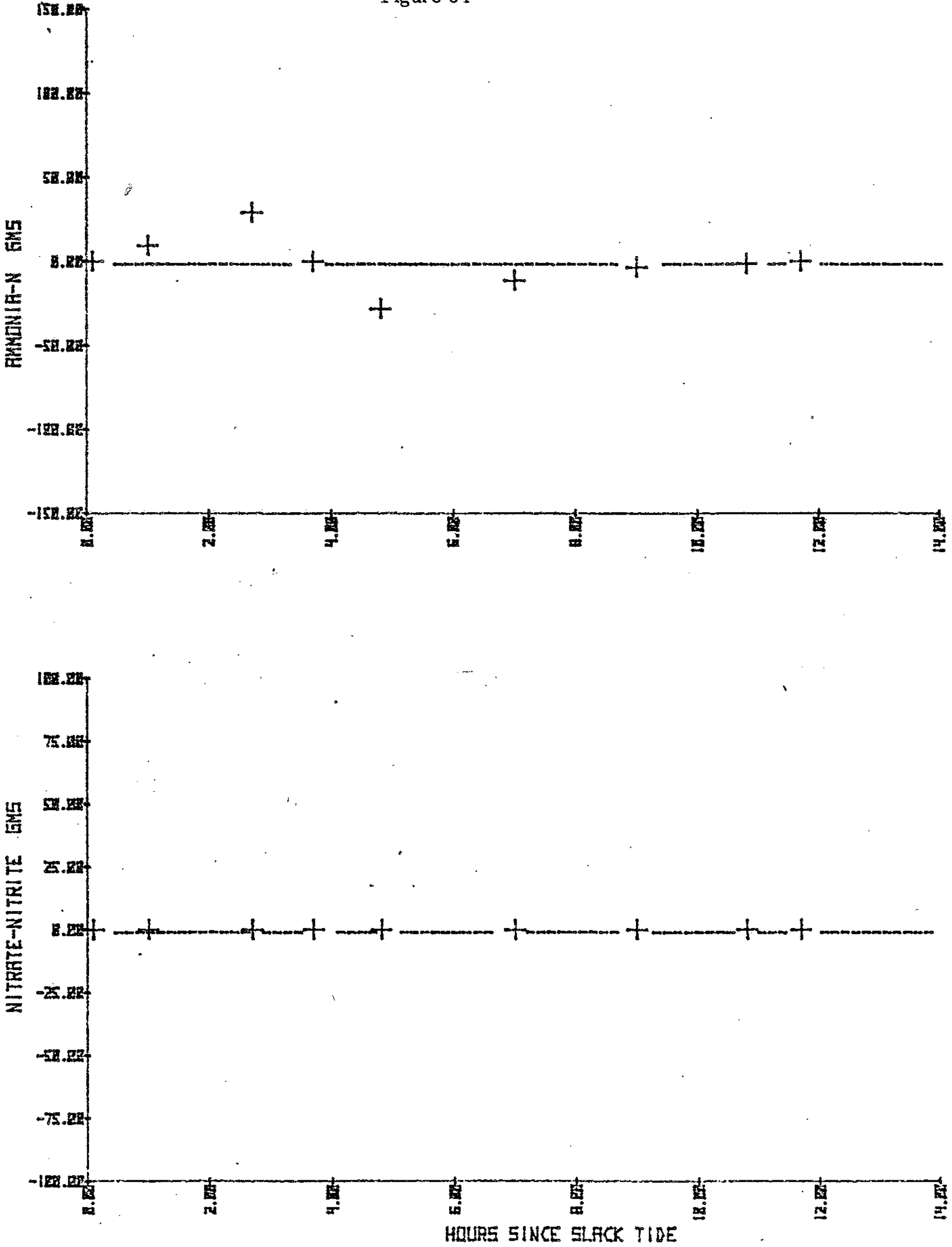
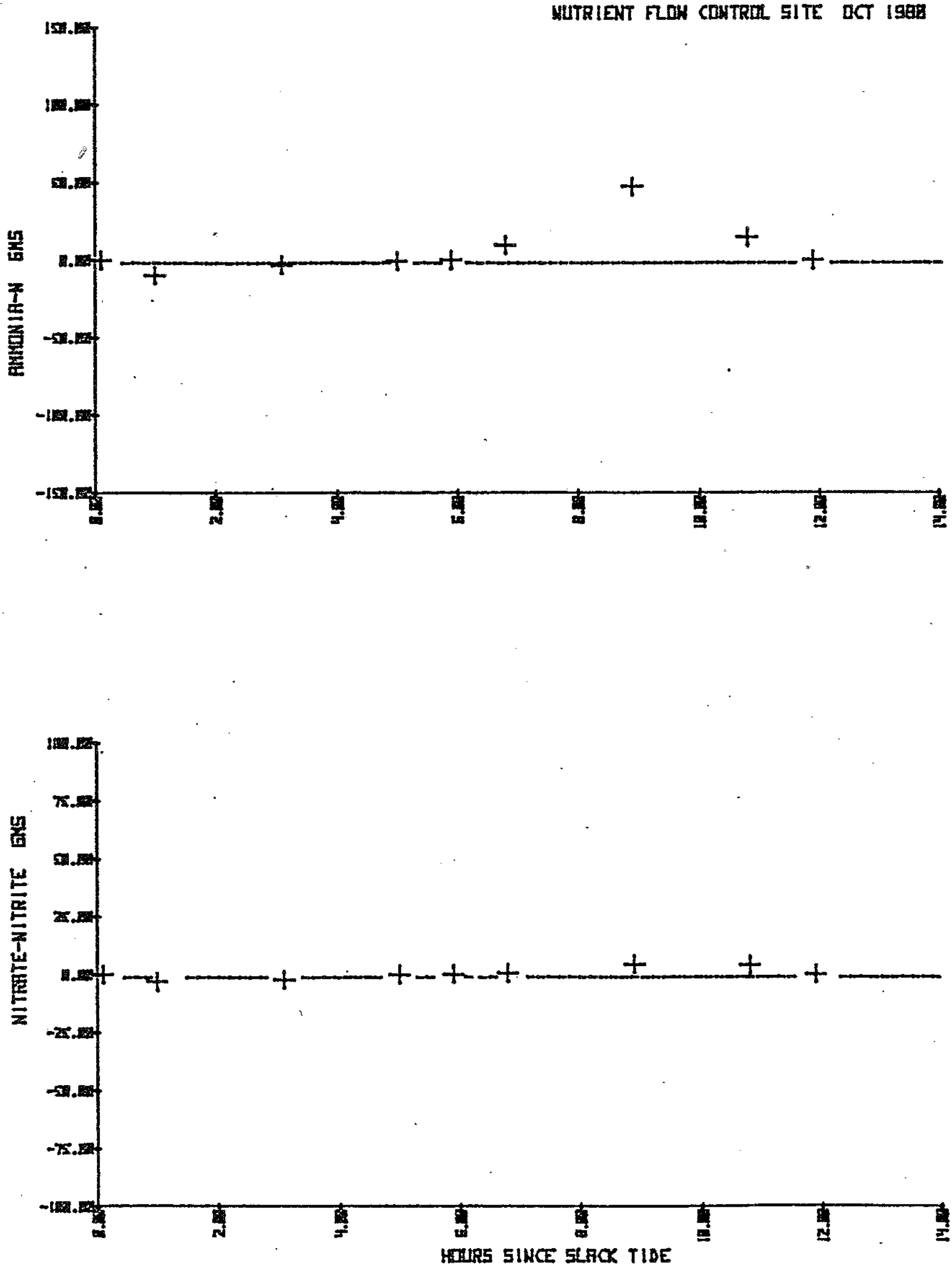

NUTRIENT FLOW CONTROL SITE AUG 1980
AMMONIA-N GMS
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE-NITRITE GMS
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 85


NUTRIENT FLOW CONTROL SITE OCT 1980
AMMONIA-N GMS
150.000
100.000
50.000
0.000
-50.000
-100.000
-150.000
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
NITRATE-NITRITE GMS
100.000
75.000
50.000
25.000
0.000
-25.000
-50.000
-75.000
-100.000
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

3. TOTAL AND DISSOLVED KJELDAHL N - OPEN SITE

Figure 86

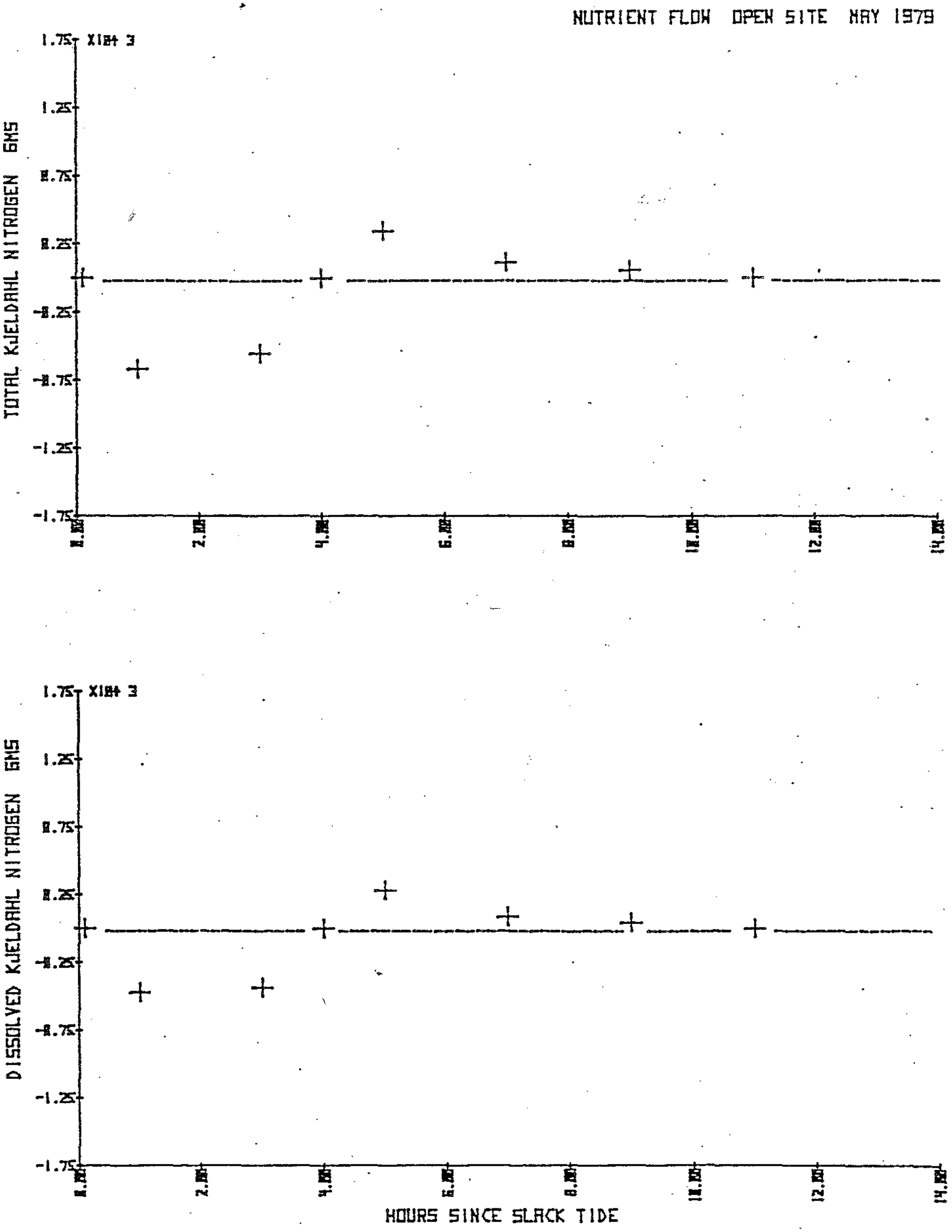

NUTRIENT FLOW OPEN SITE MAY 1979
1.75 X10↑ 3
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
TOTAL KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
1.75 X10↑ 3
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
DISSOLVED KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 87

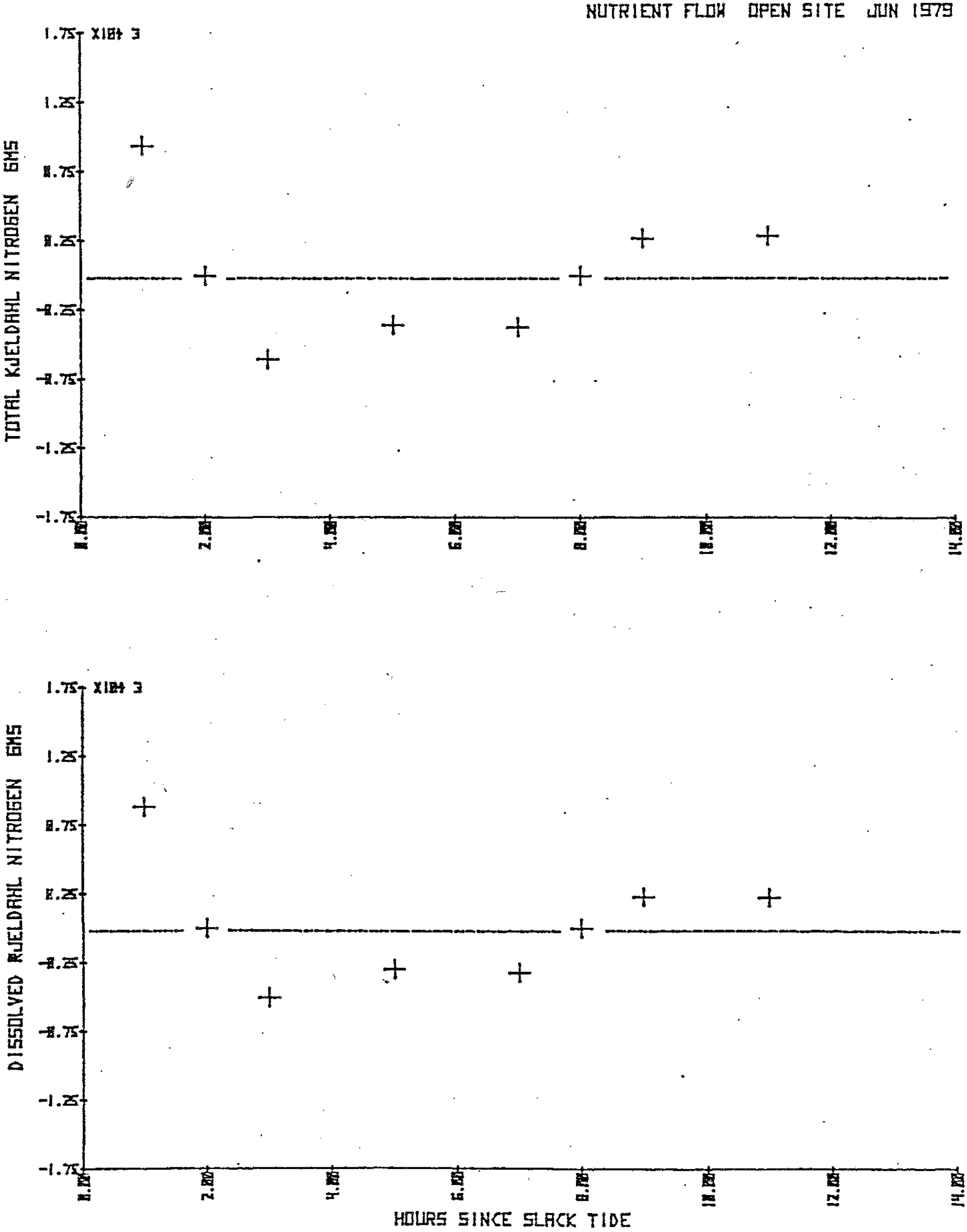

NUTRIENT FLOW OPEN SITE JUN 1979
X10↑ 3
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
TOTAL KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X10↑ 3
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
DISSOLVED KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 88

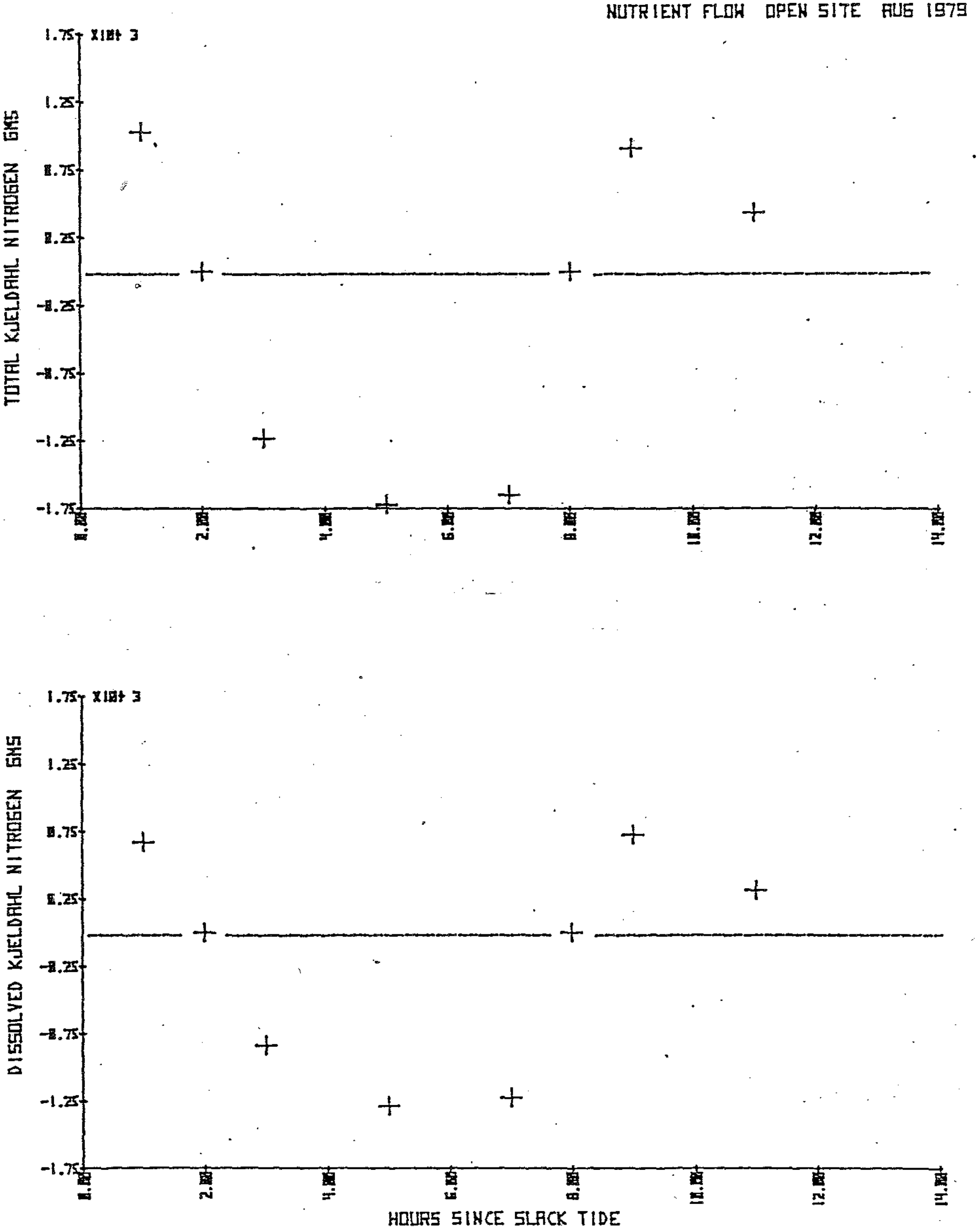

NUTRIENT FLOW OPEN SITE AUG 1979
TOTAL KJELDAHL NITROGEN GMS
1.75 X10↑ 3
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED KJELDAHL NITROGEN GMS
1.75 X10↑ 3
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 89

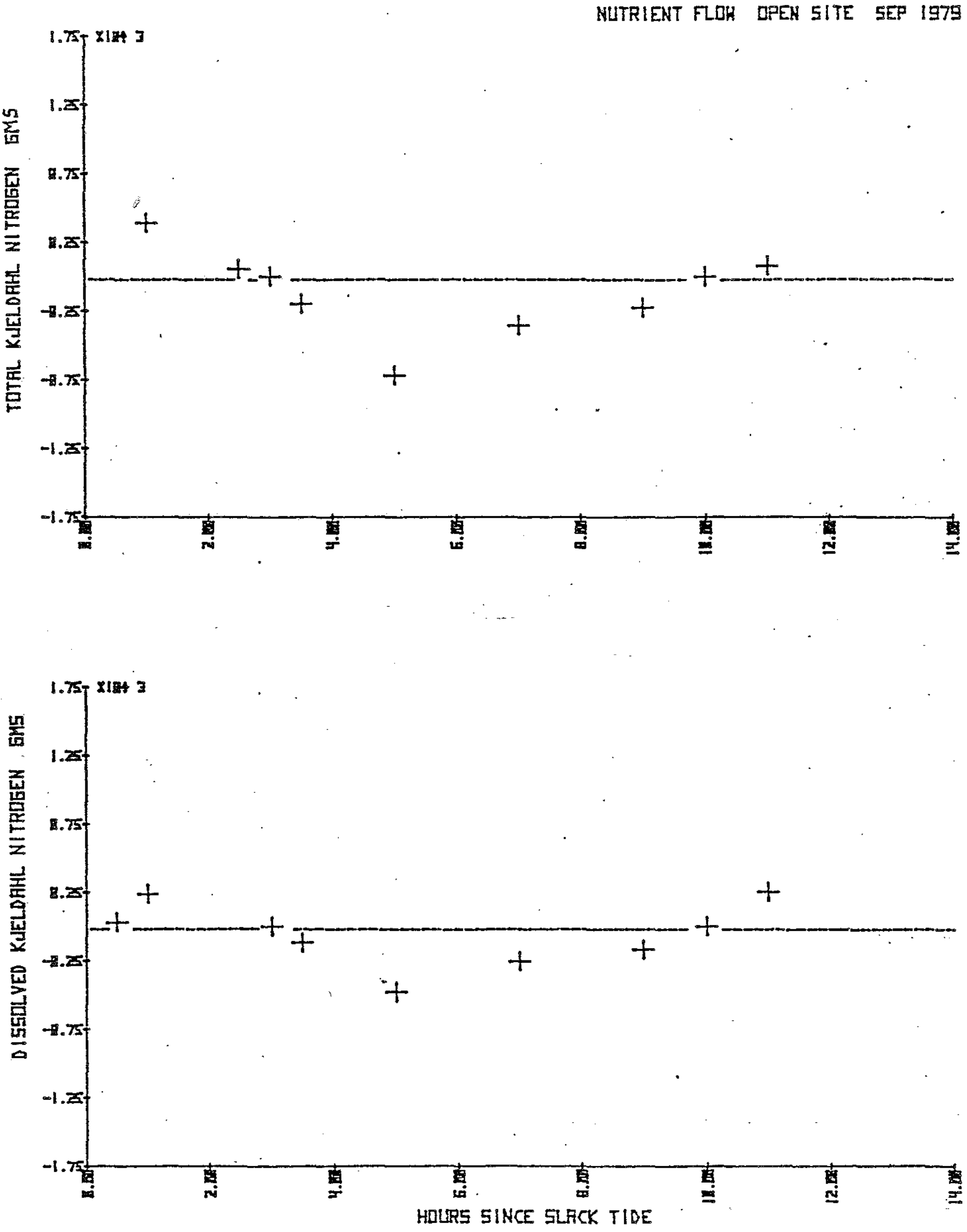

NUTRIENT FLOW OPEN SITE SEP 1979
TOTAL KJELDAHL NITROGEN GMS
X10** 3
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED KJELDAHL NITROGEN GMS
X10** 3
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 90

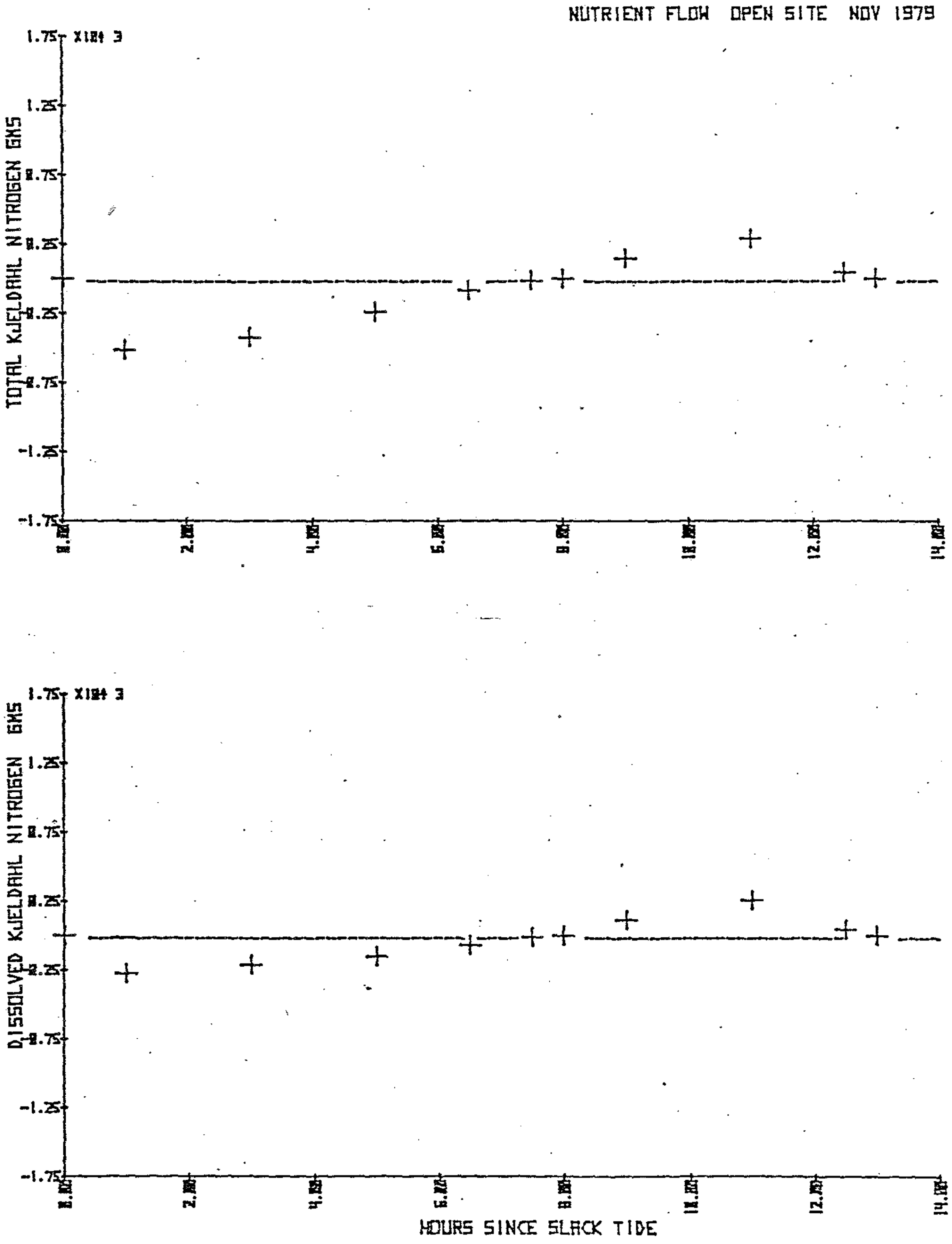

NUTRIENT FLOW OPEN SITE NOV 1979
X10↑ 3
TOTAL KJELDAHL NITROGEN GMS
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X10↑ 3
DISSOLVED KJELDAHL NITROGEN GMS
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 91

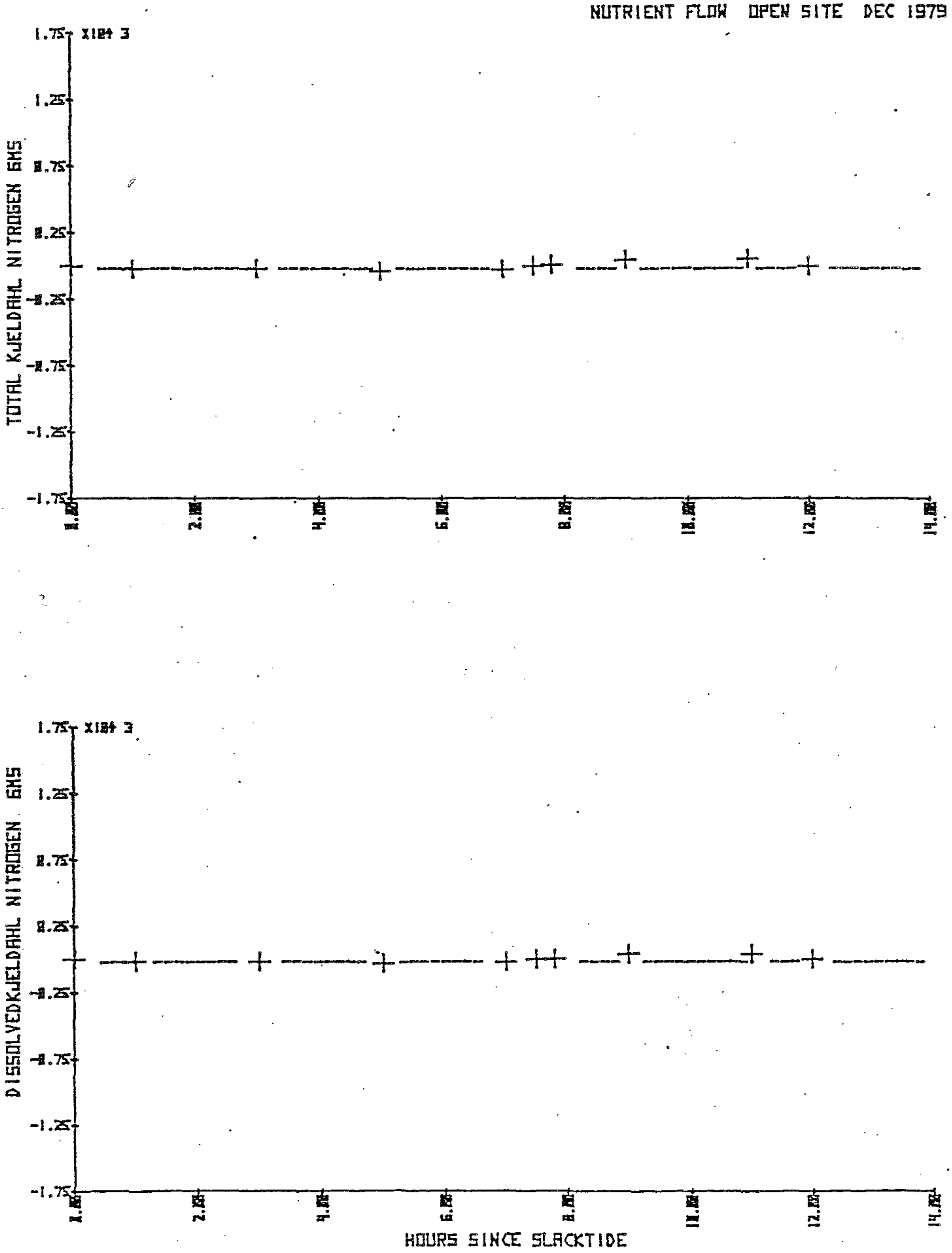

NUTRIENT FLOW OPEN SITE DEC 1979
1.75 X10* 3
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
TOTAL KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
1.75 X10* 3
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
DISSOLVEDKJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACKTIDE

Figure 92

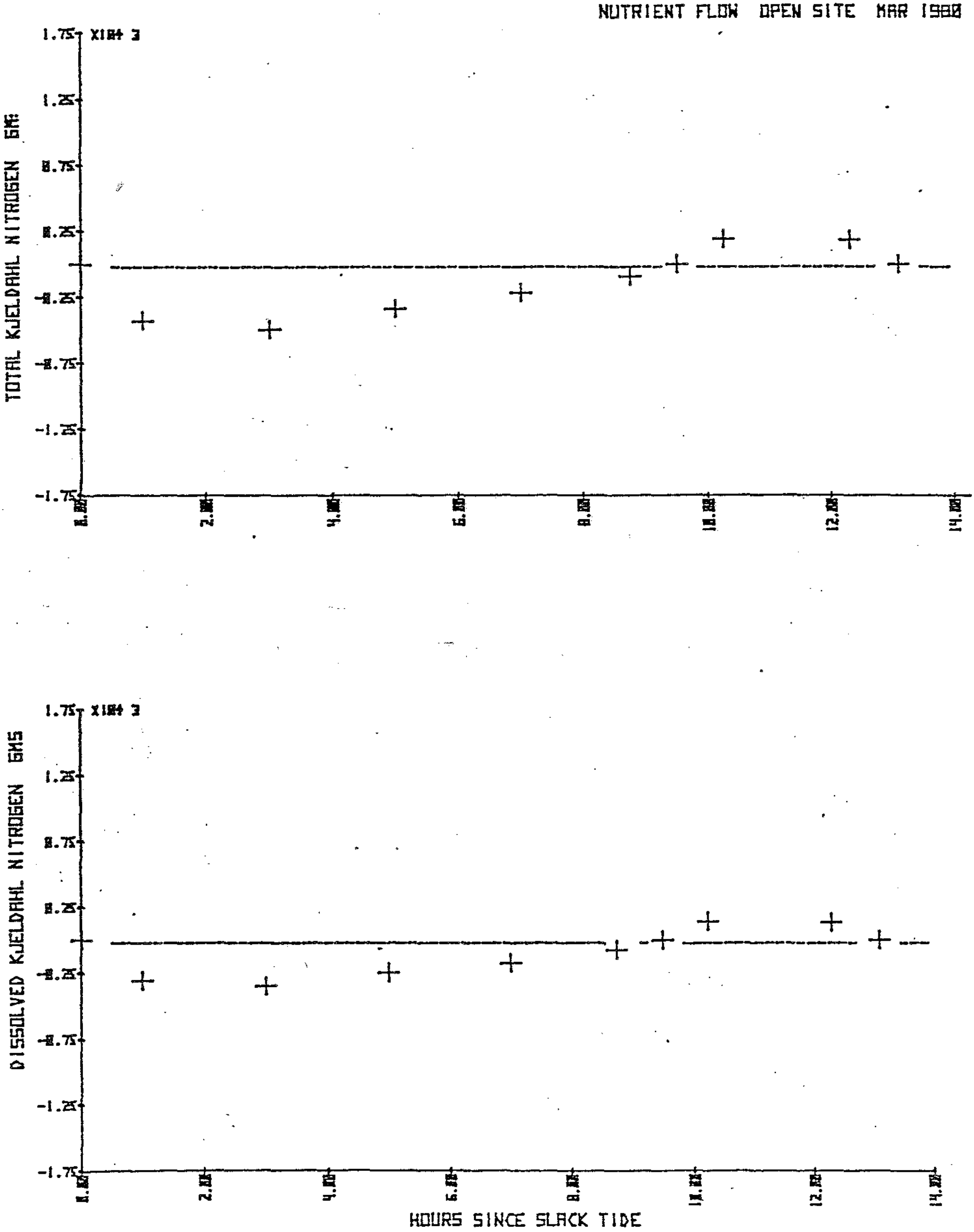
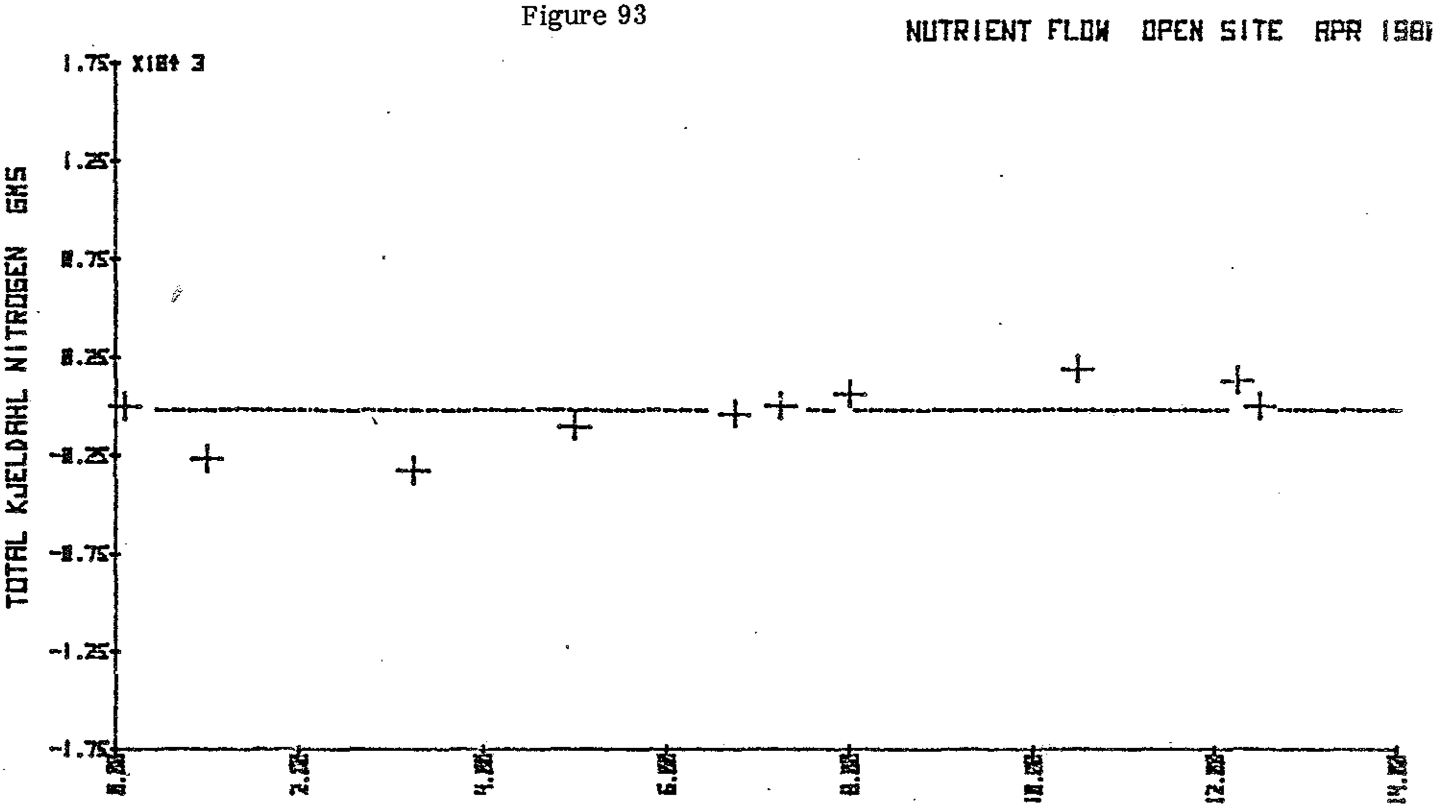
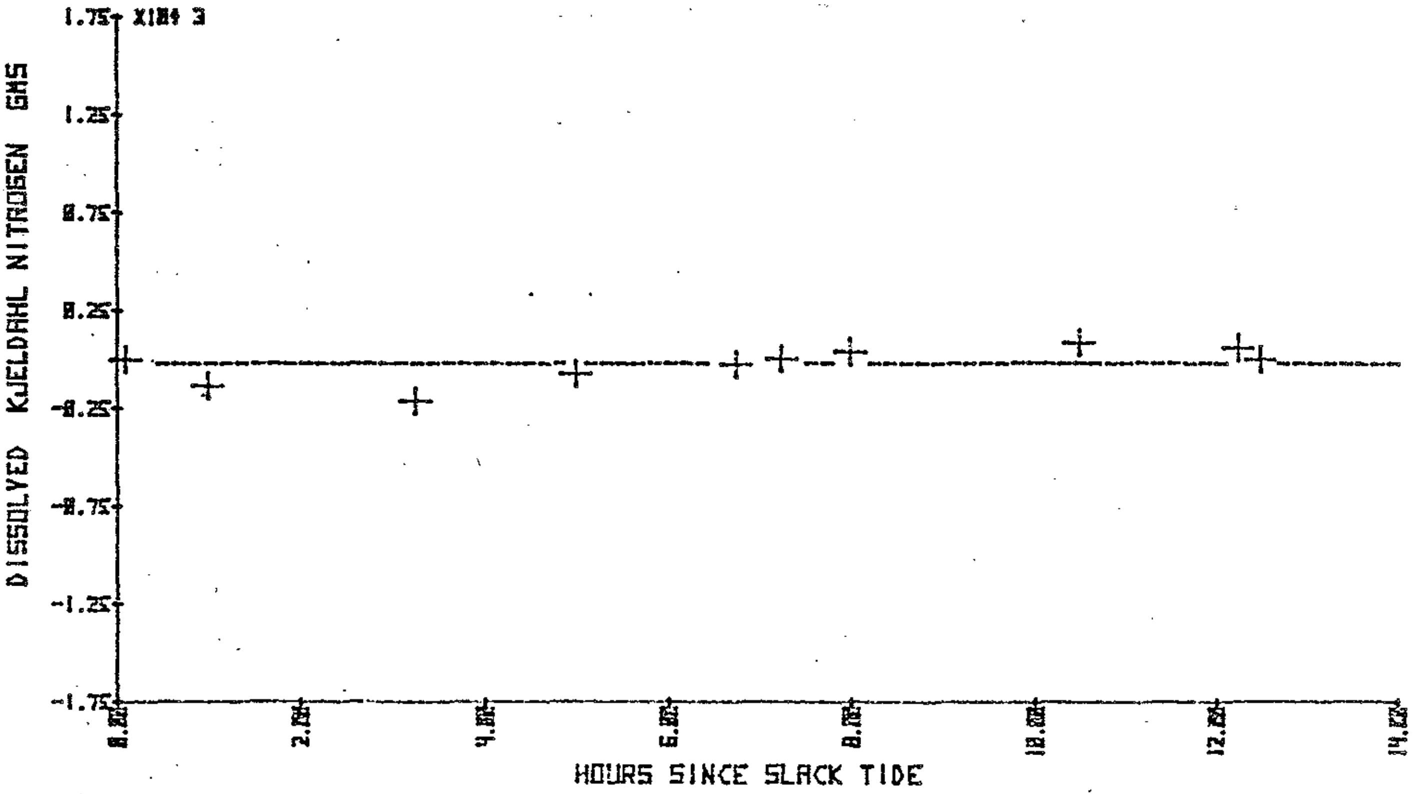

NUTRIENT FLOW OPEN SITE MAR 1980
X10** 3
TOTAL KJELDAHL NITROGEN GMS
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X10** 3
DISSOLVED KJELDAHL NITROGEN GMS
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 93



NUTRIENT FLOW OPEN SITE APR 1981
X10↑ 3
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
TOTAL KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00



X10↑ 3
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
DISSOLVED KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 94

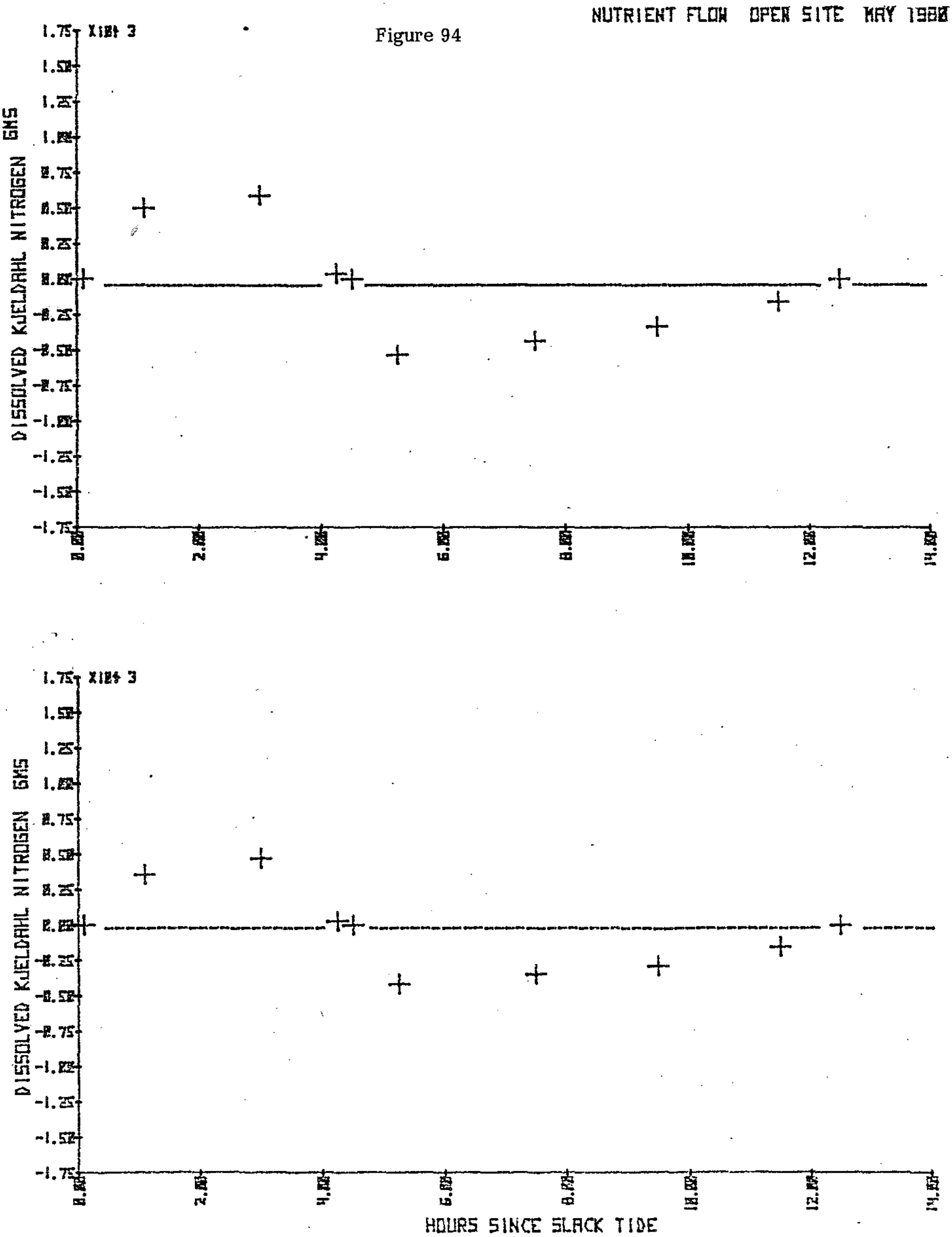

NUTRIENT FLOW OPEN SITE MAY 1980
X10+ 3
DISSOLVED KJELDAHL NITROGEN GMS
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X10+ 3
DISSOLVED KJELDAHL NITROGEN GMS
HOURS SINCE SLACK TIDE

Figure 95

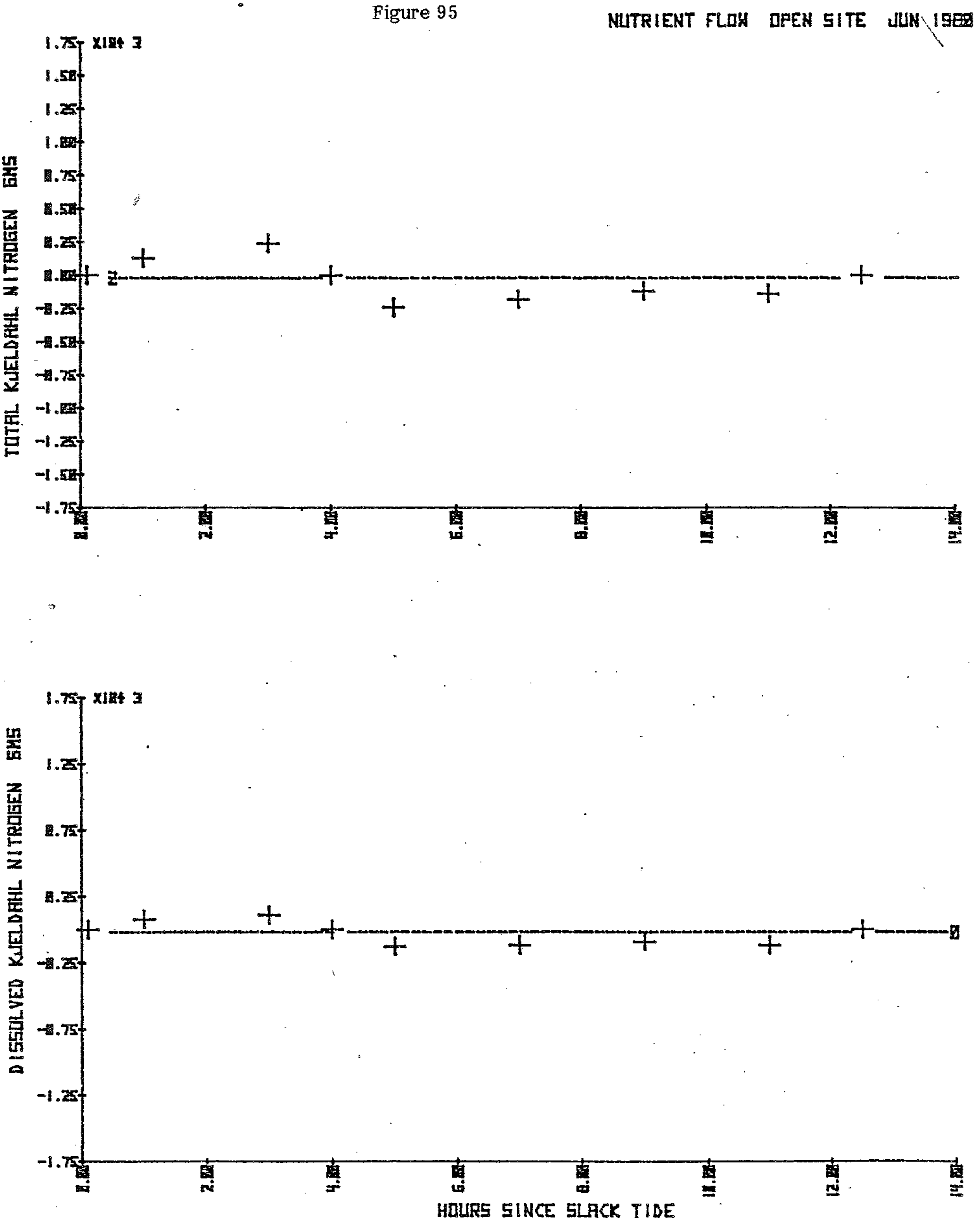

NUTRIENT FLOW OPEN SITE JUN 1980
X10↑ 3
TOTAL KJELDAHL NITROGEN GMS
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X10↑ 3
DISSOLVED KJELDAHL NITROGEN GMS
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 96

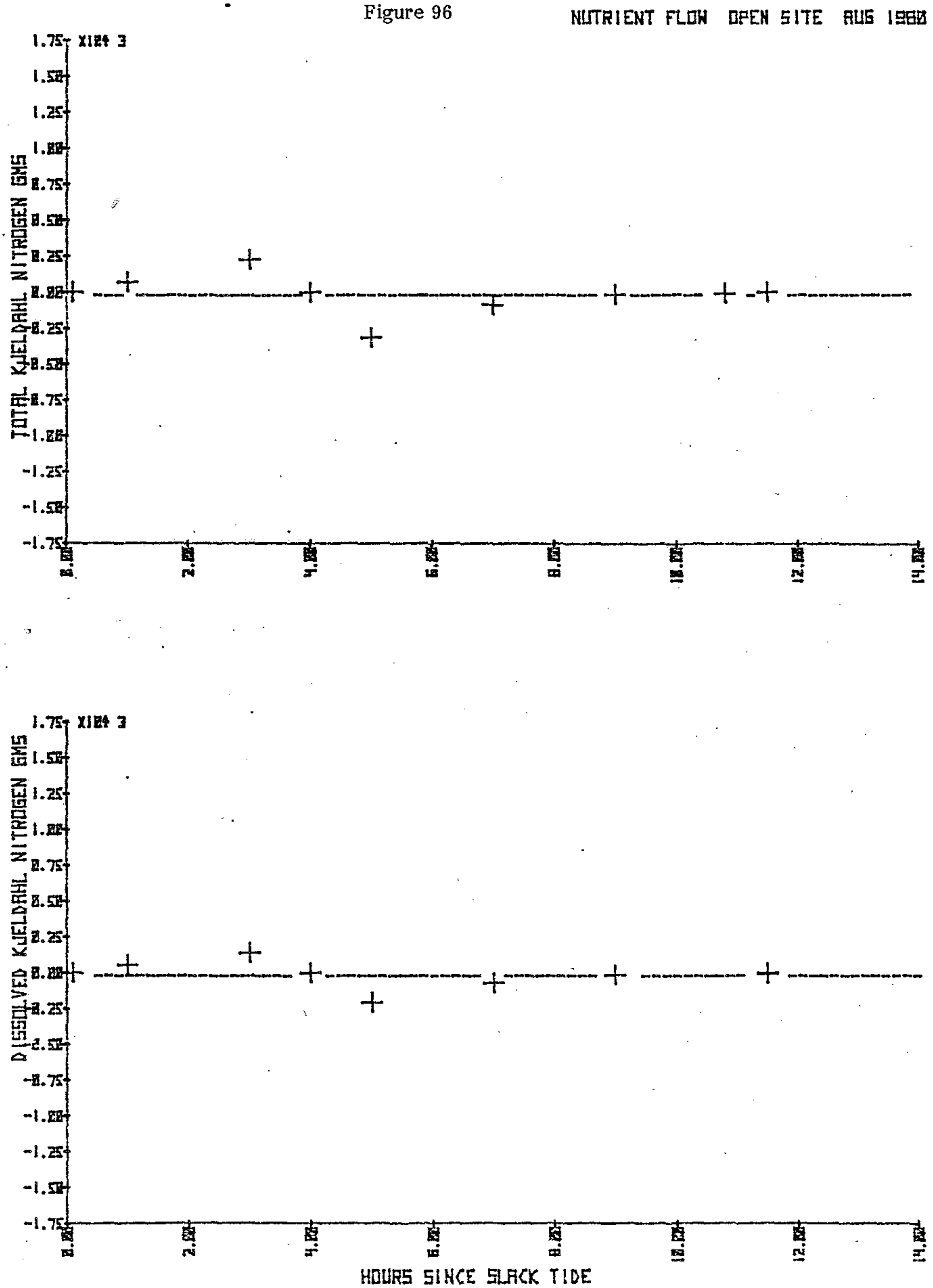
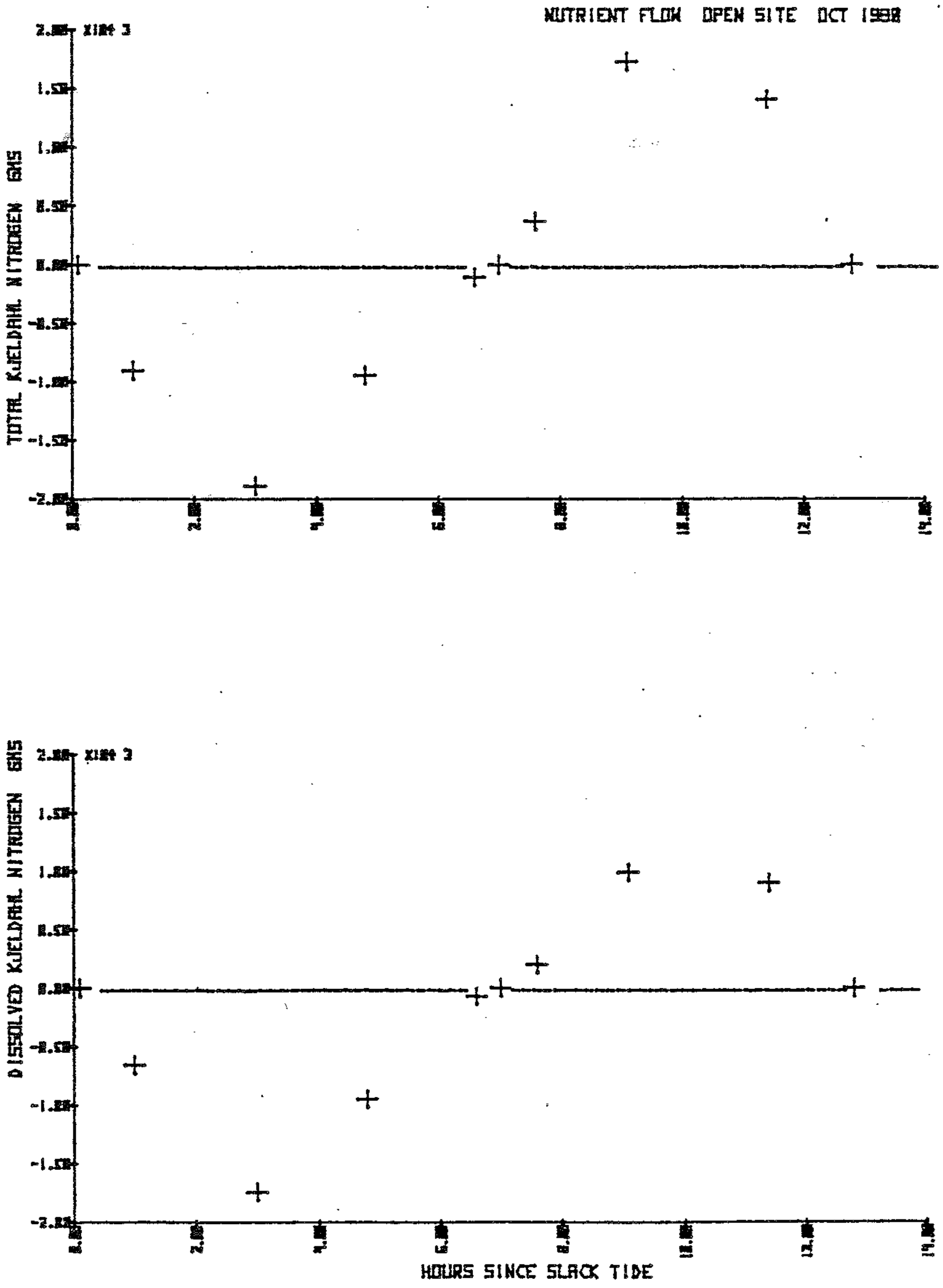

NUTRIENT FLOW OPEN SITE AUG 1980
X10^ 3
TOTAL KJELDAHL NITROGEN GMS
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X10^ 3
DISSOLVED KJELDAHL NITROGEN GMS
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 97


NUTRIENT FLOW OPEN SITE OCT 1988
2.00 X10* 3
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
TOTAL KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
2.00 X10* 3
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
DISSOLVED KJELDAHL NITROGEN GMS
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

4. TOTAL AND DISSOLVED KJELDAHL N - CONTROL SITE

Figure 98

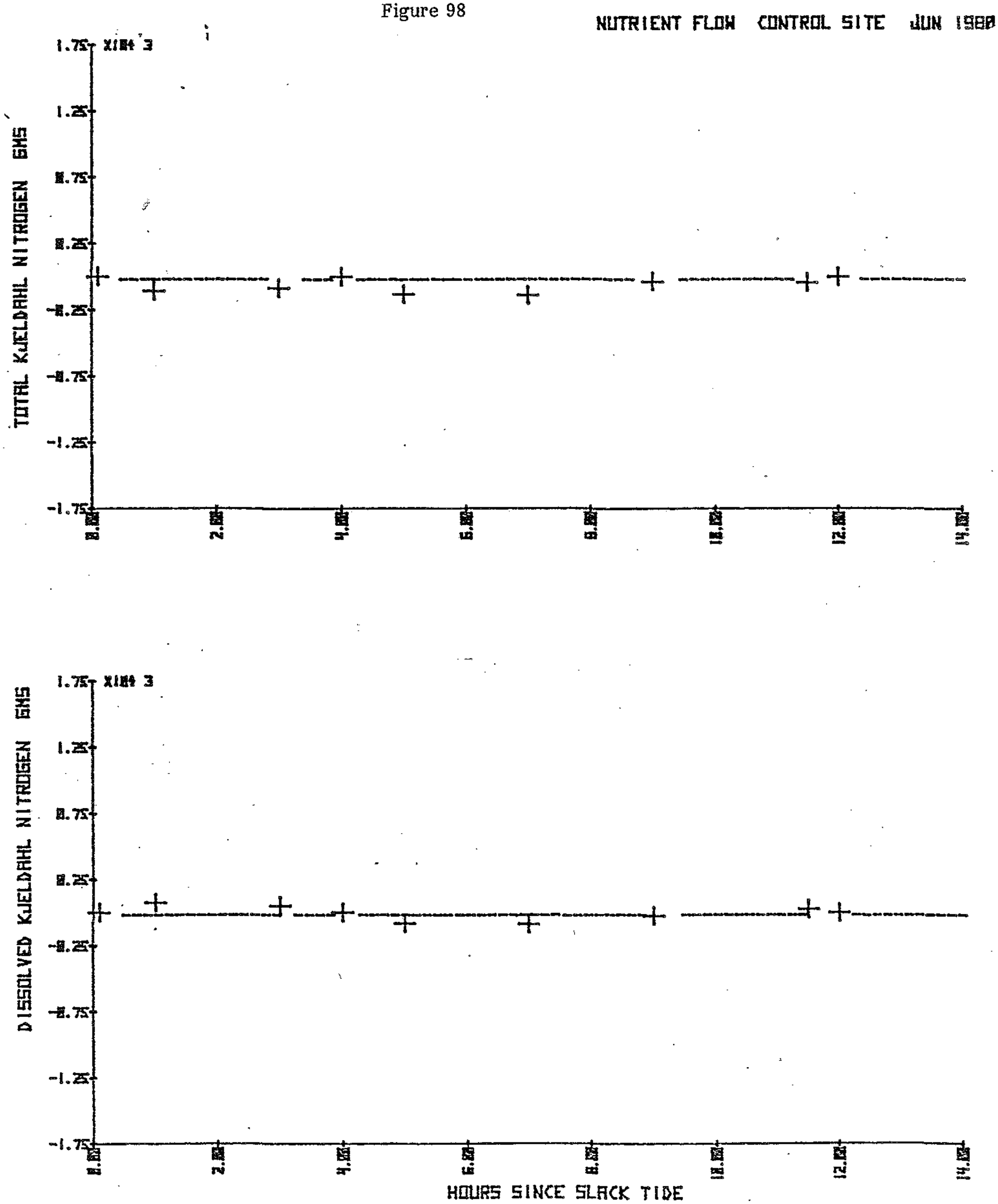

NUTRIENT FLOW CONTROL SITE JUN 1980
TOTAL KJELDAHL NITROGEN GMS
X10⁴ 3
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED KJELDAHL NITROGEN GMS
X10⁴ 3
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 99

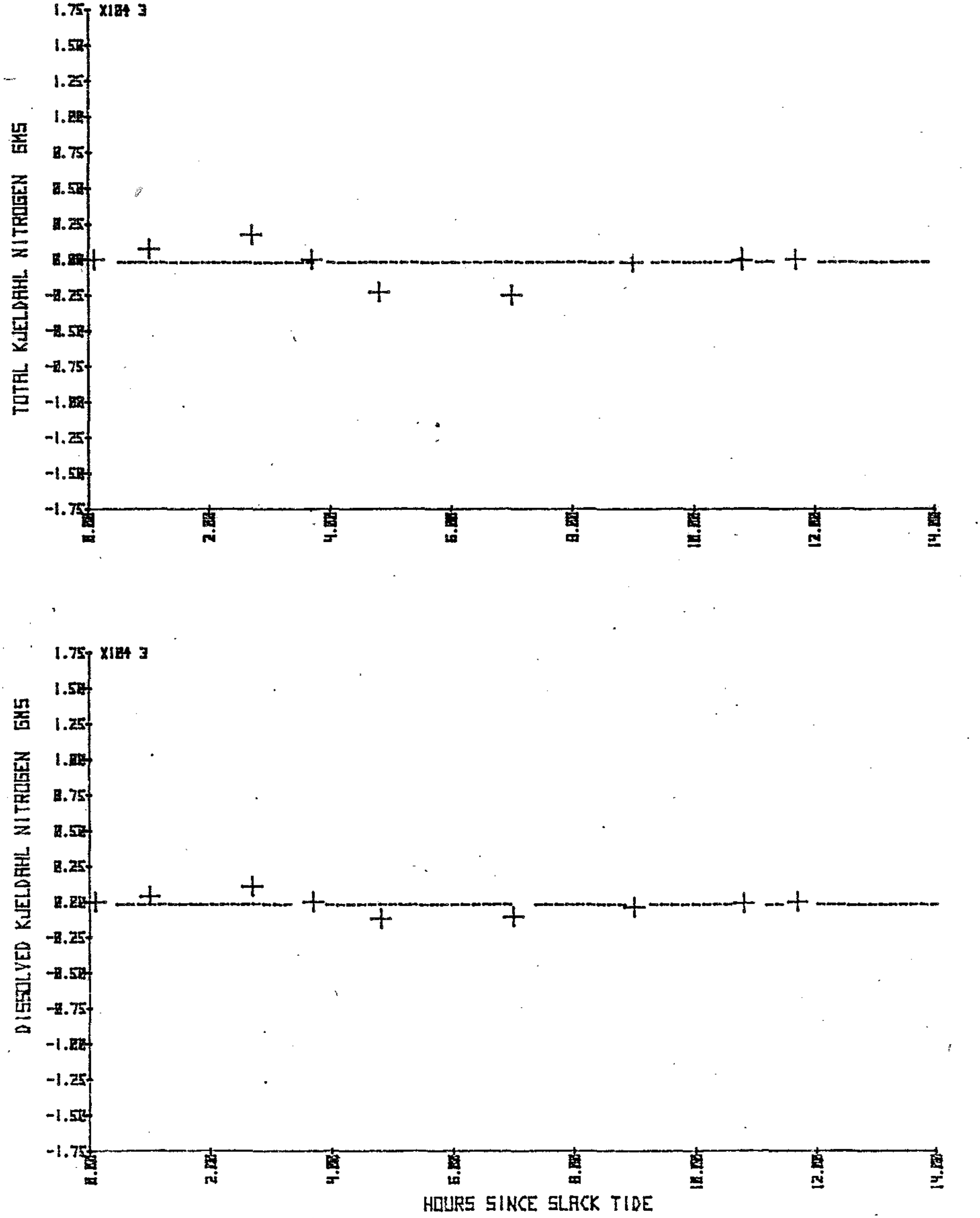
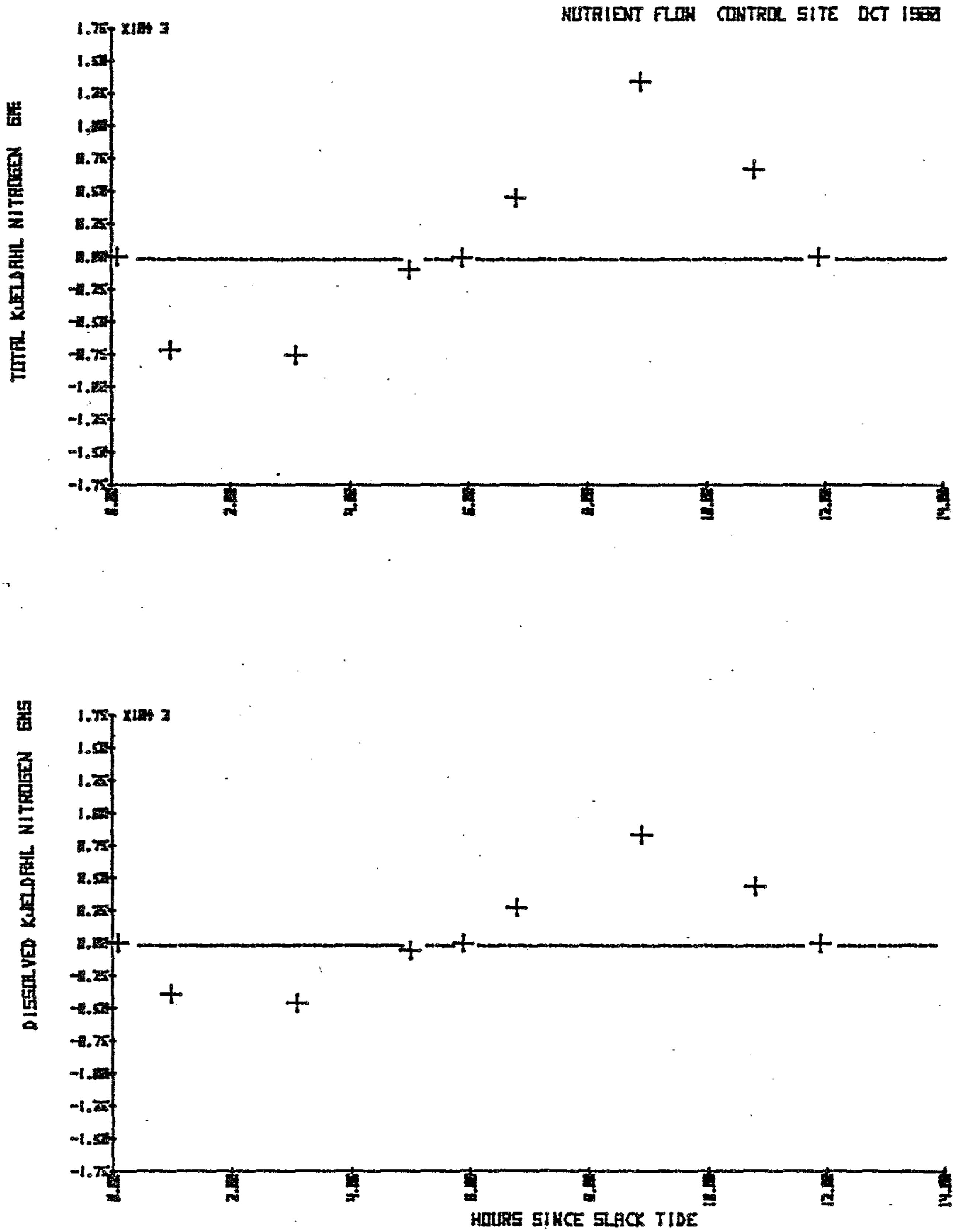

NUTRIENT FLOW CONTROL SITE AUG 1980
X10↑ 3
TOTAL KJELDAHL NITROGEN GMS
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X10↑ 3
DISSOLVED KJELDAHL NITROGEN GMS
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 100


NUTRIENT FLOW CONTROL SITE OCT 1980
X10^ 3
TOTAL KJELDAHL NITROGEN GMS
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
X10^ 3
DISSOLVED KJELDAHL NITROGEN GMS
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

5. TOTAL AND DISSOLVED PHOSPHORUS - OPEN SITE

Figure 101

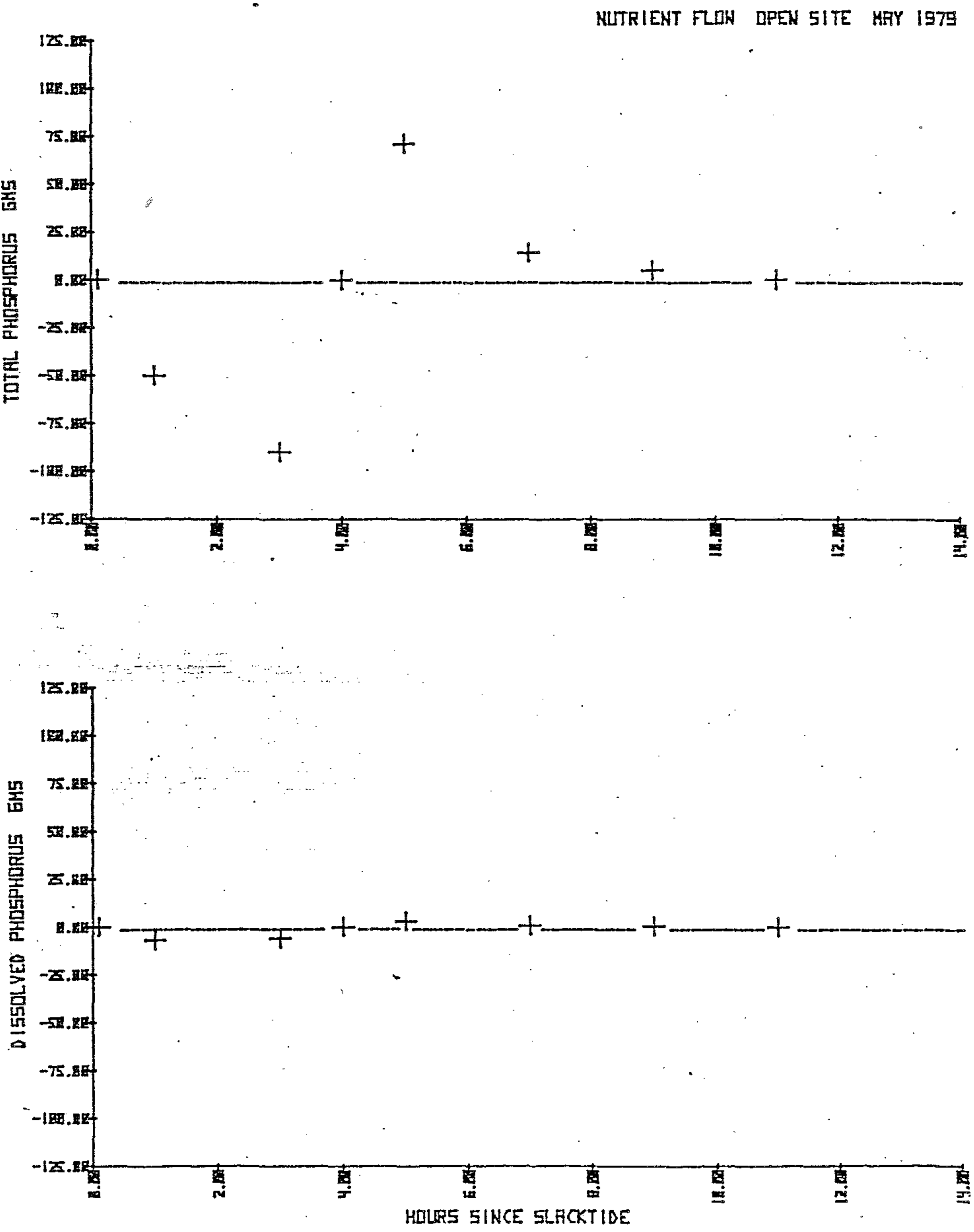
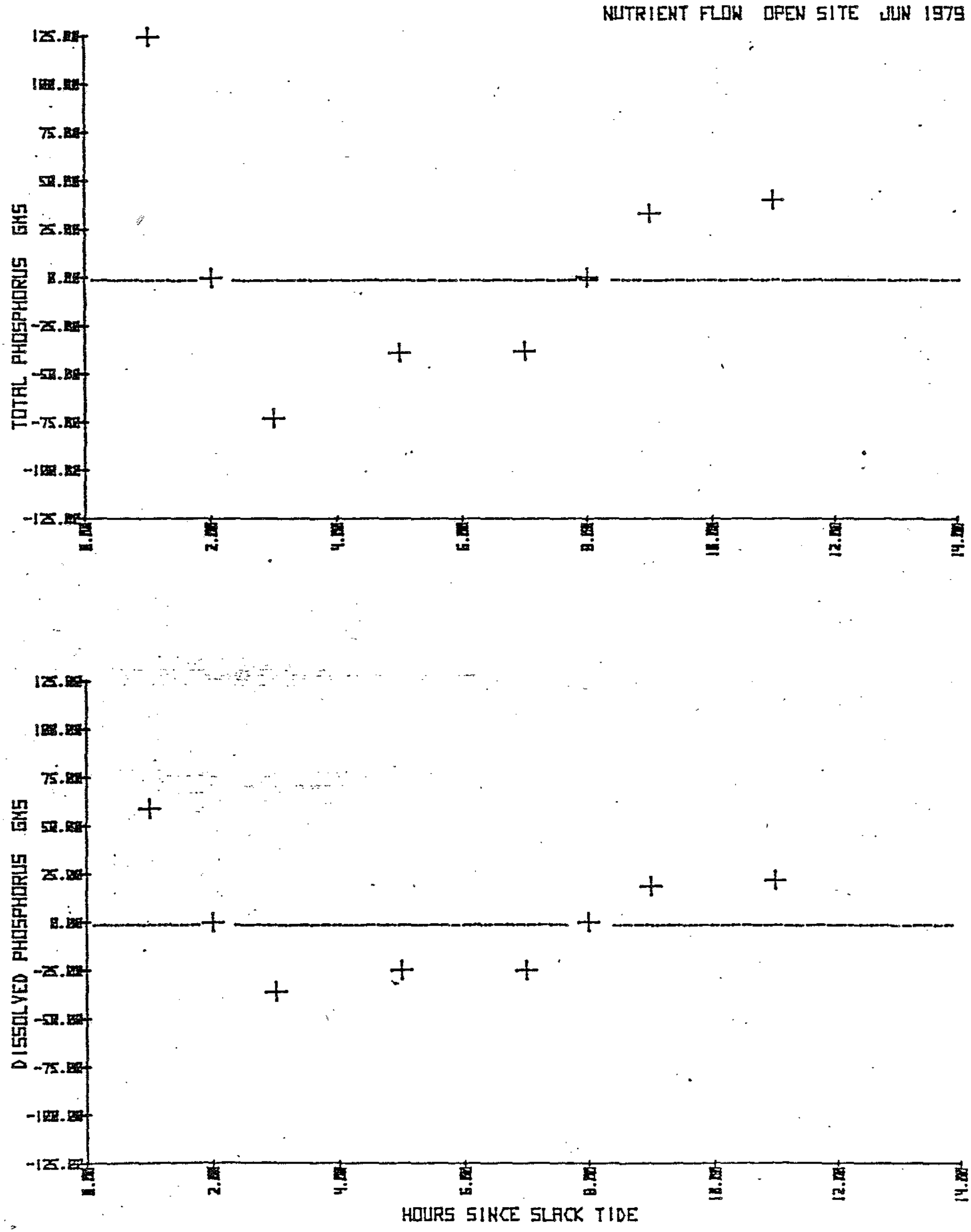
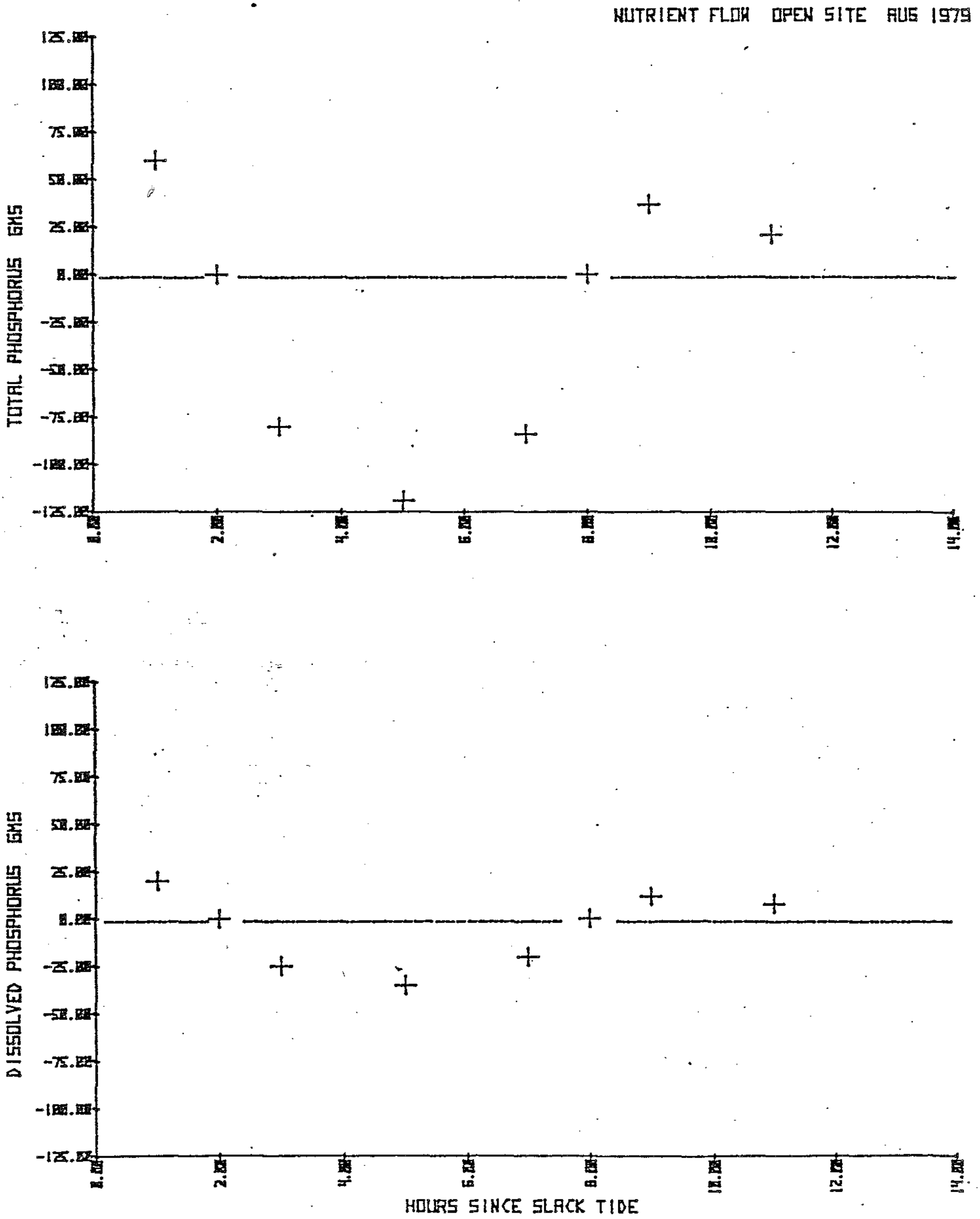

NUTRIENT FLOW OPEN SITE MAY 1979
TOTAL PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACKTIDE

Figure 102



NUTRIENT FLOW OPEN SITE JUN 1979
TOTAL PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 103


NUTRIENT FLOW OPEN SITE AUG 1979
TOTAL PHOSPHORUS GMS
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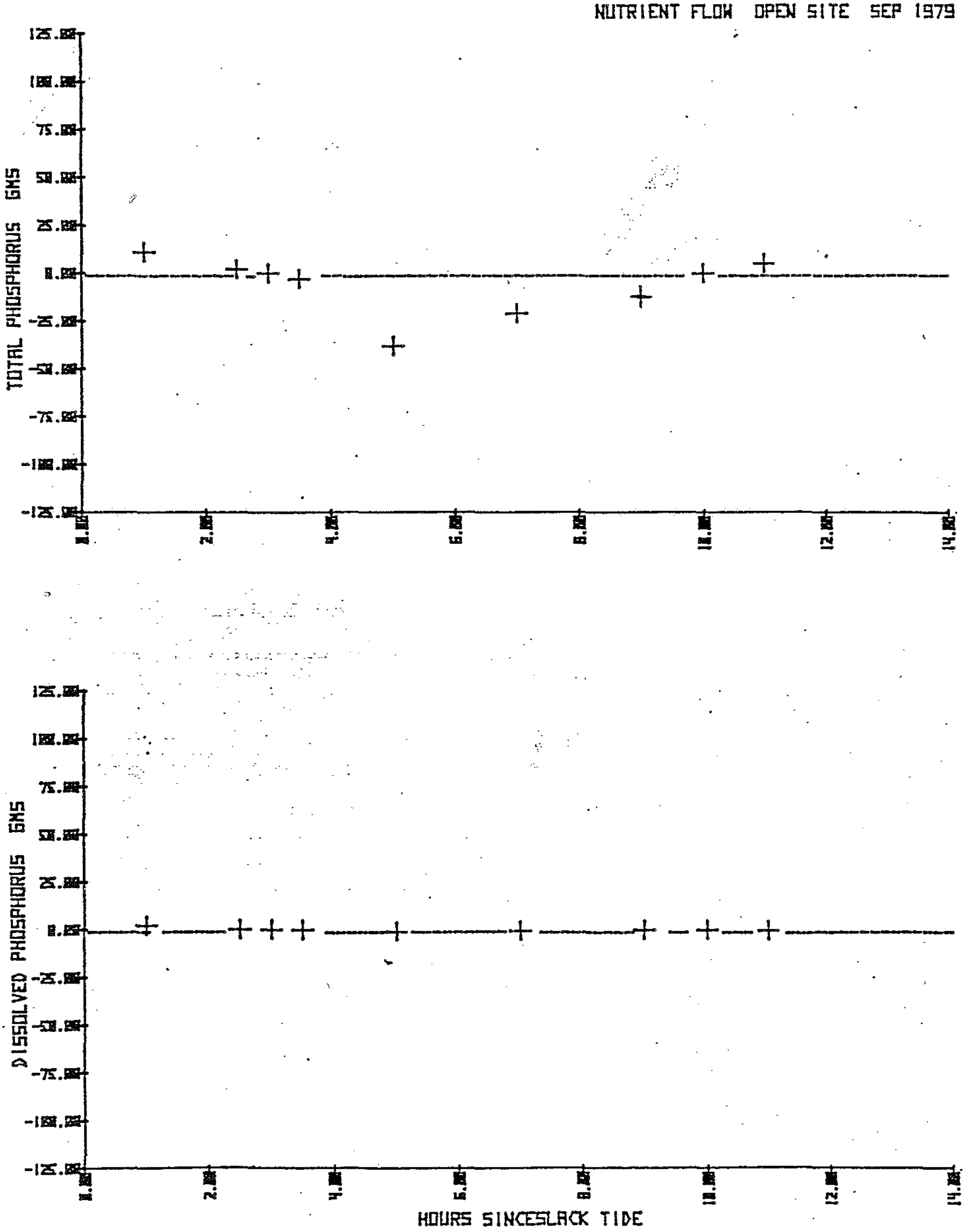
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 104


NUTRIENT FLOW OPEN SITE SEP 1979
TOTAL PHOSPHORUS GMS
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100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCESLACK TIDE

Figure 105

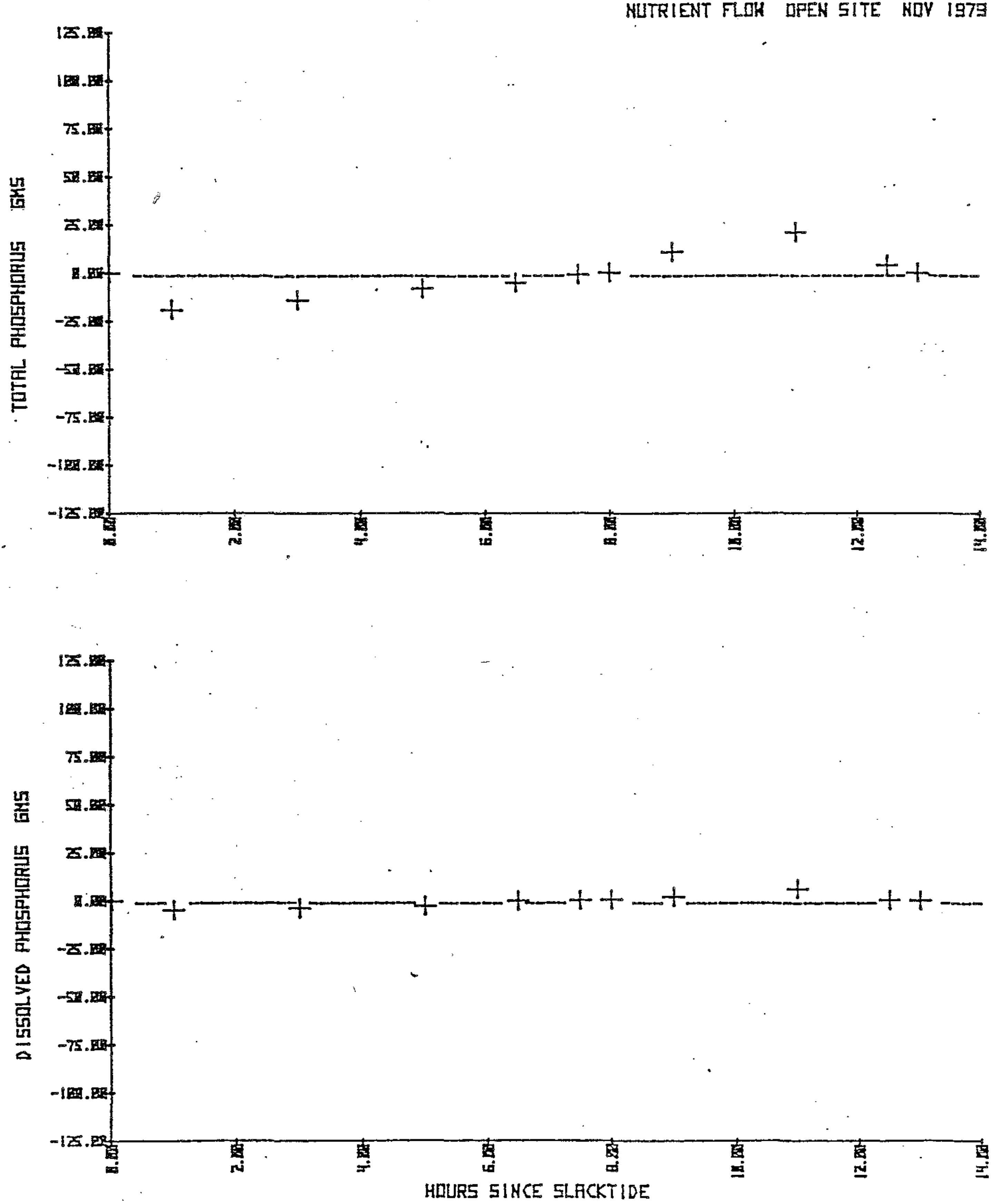

NUTRIENT FLOW OPEN SITE NOV 1979
TOTAL PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACKTIDE

Figure 106

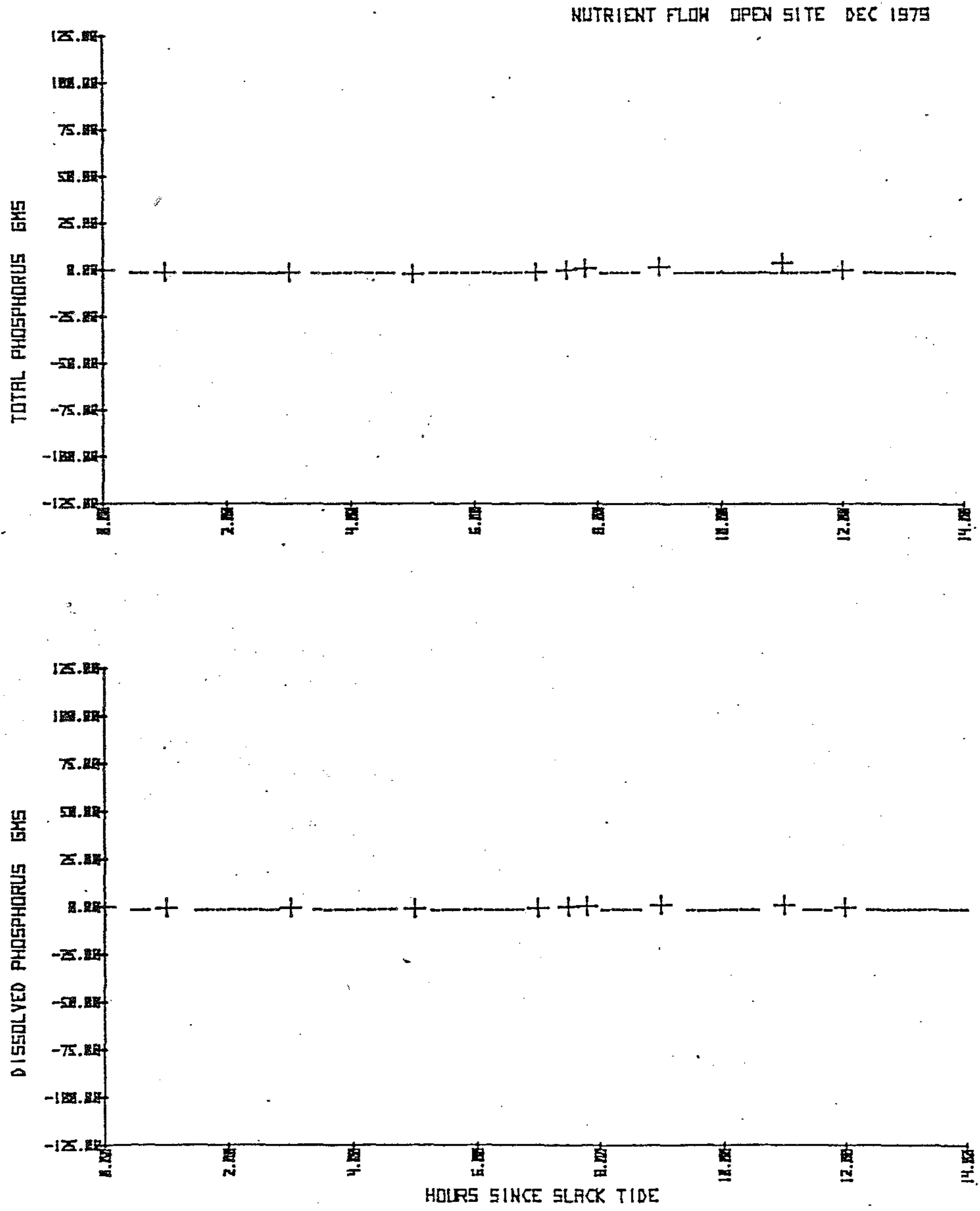
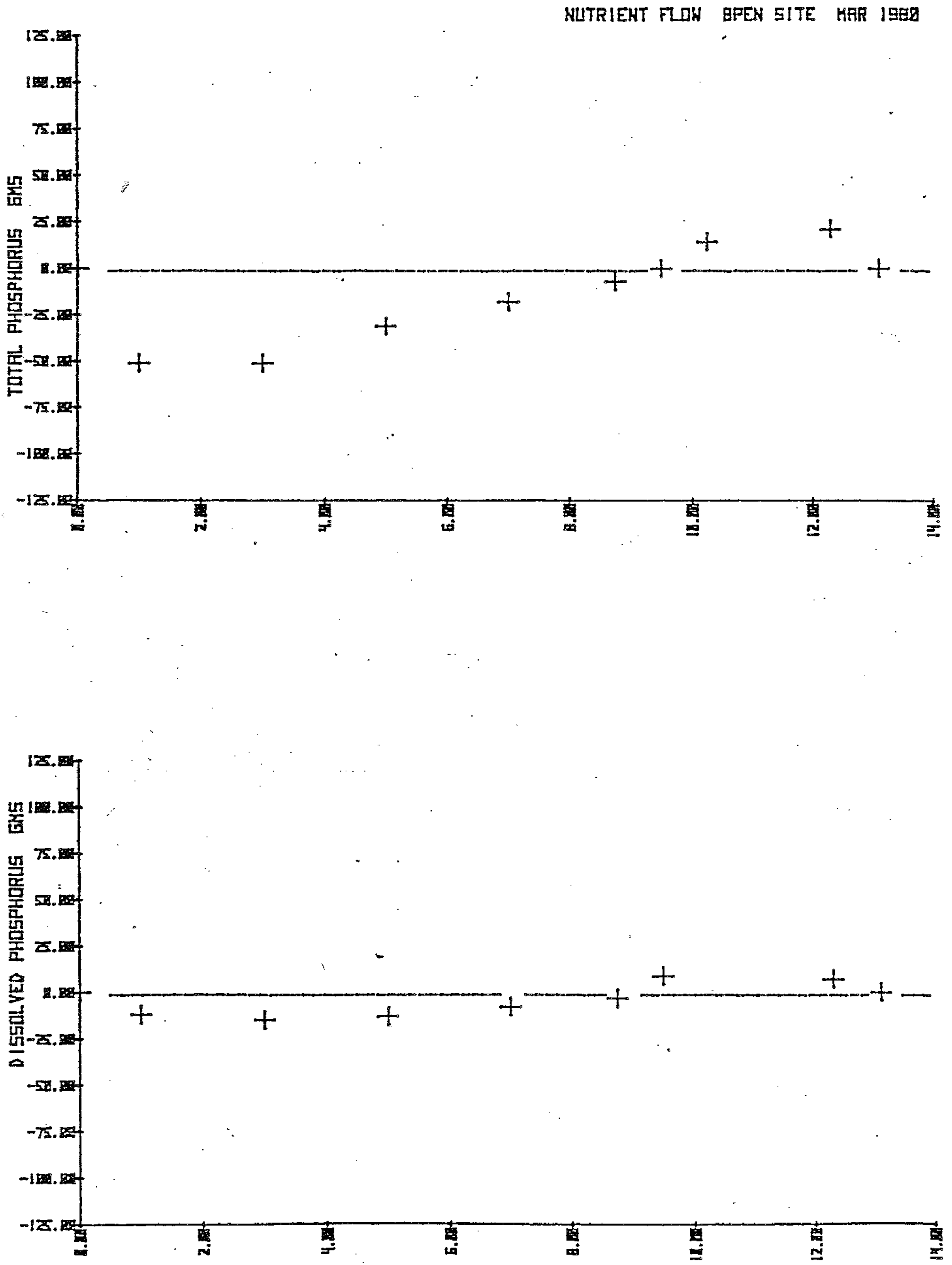

NUTRIENT FLOW OPEN SITE DEC 1979
TOTAL PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 107


NUTRIENT FLOW OPEN SITE MAR 1980
TOTAL PHOSPHORUS GMS
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100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 108

NUTRIENT FLOW OPEN SITE APR 1980

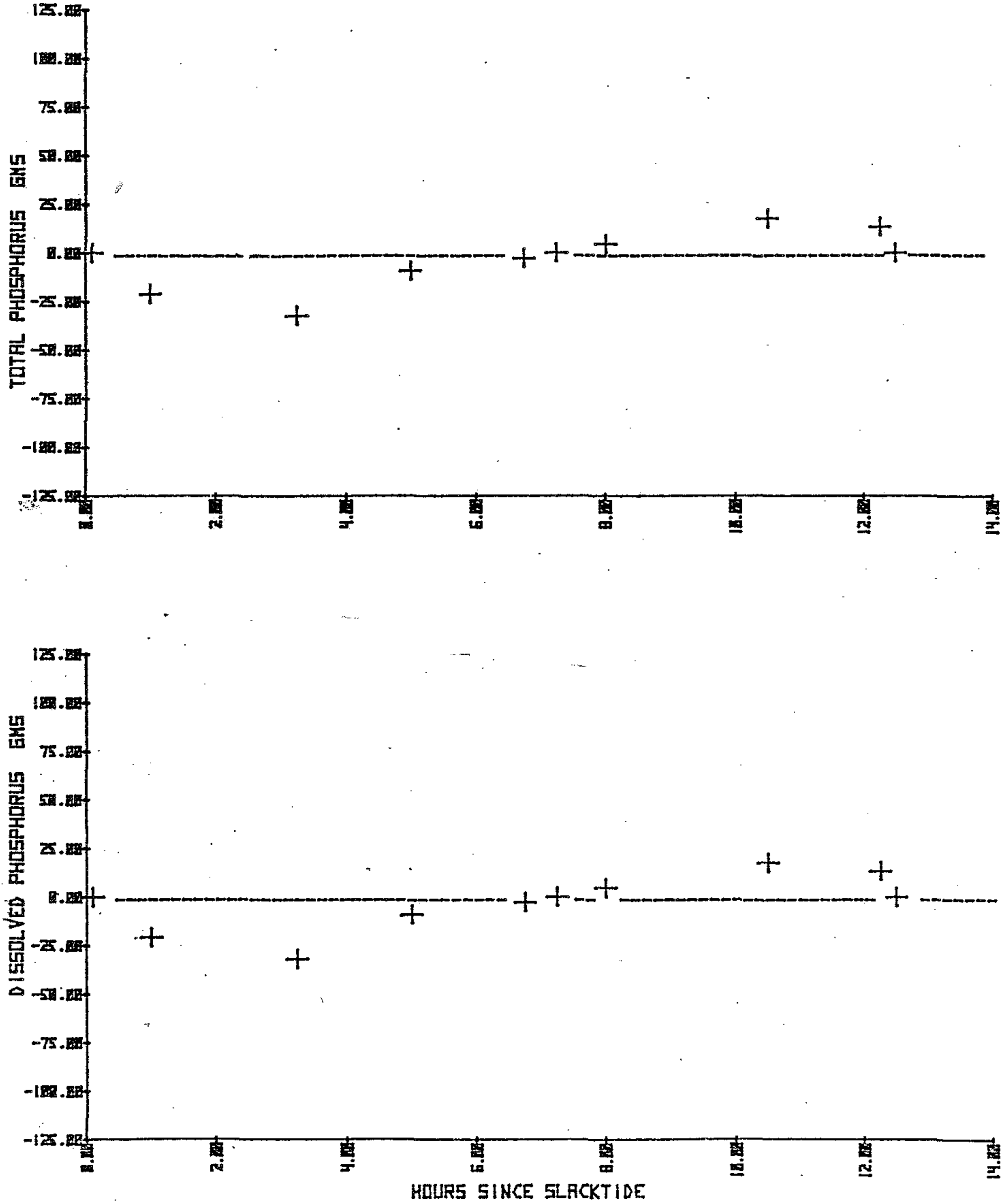


Figure 109

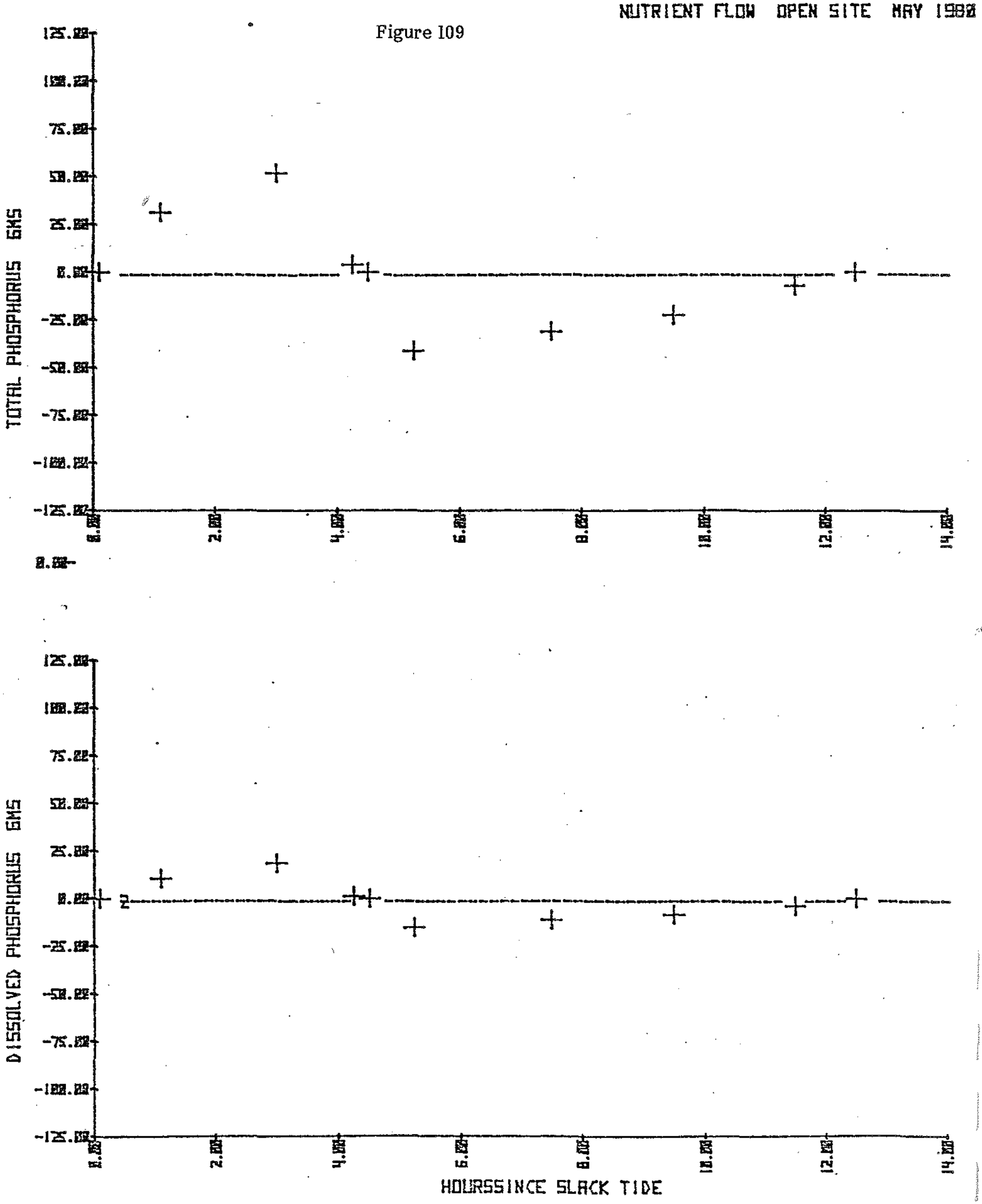

NUTRIENT FLOW OPEN SITE MAY 1980
TOTAL PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
0.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
2
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURSSINCE SLACK TIDE

Figure 110

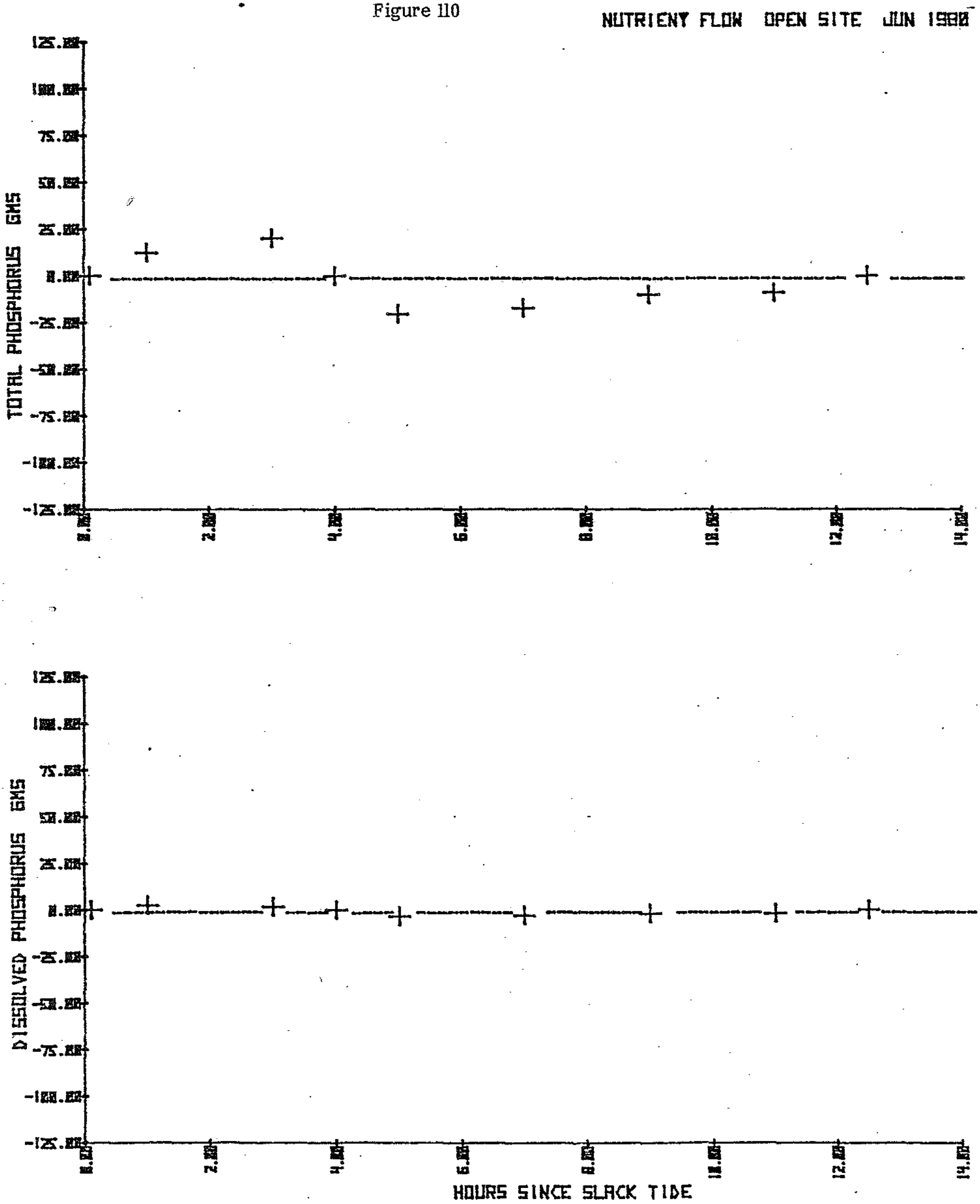

NUTRIENT FLOW OPEN SITE JUN 1980
TOTAL PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 111 NUTRIENT FLOW OPEN SITE AUG 1980

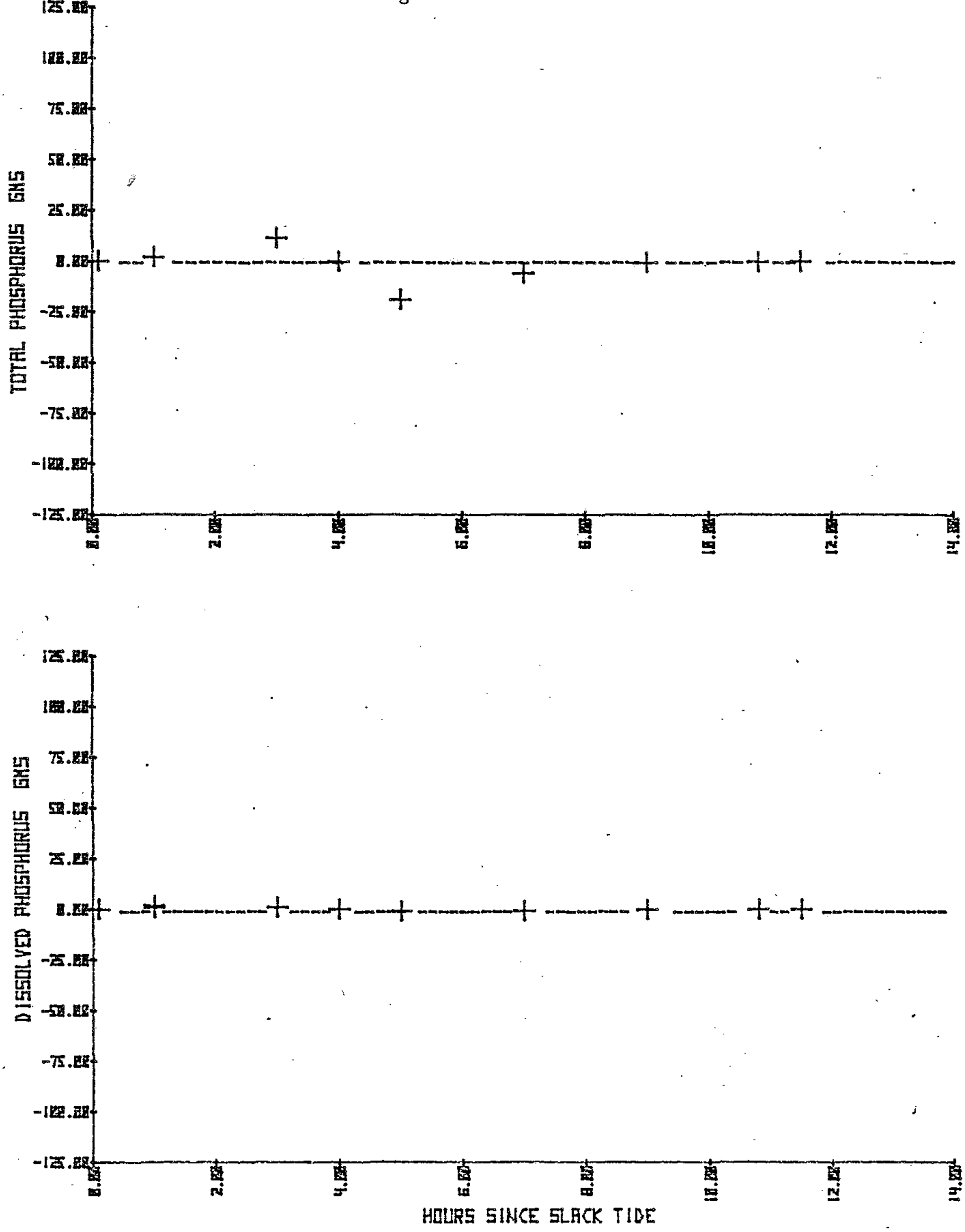
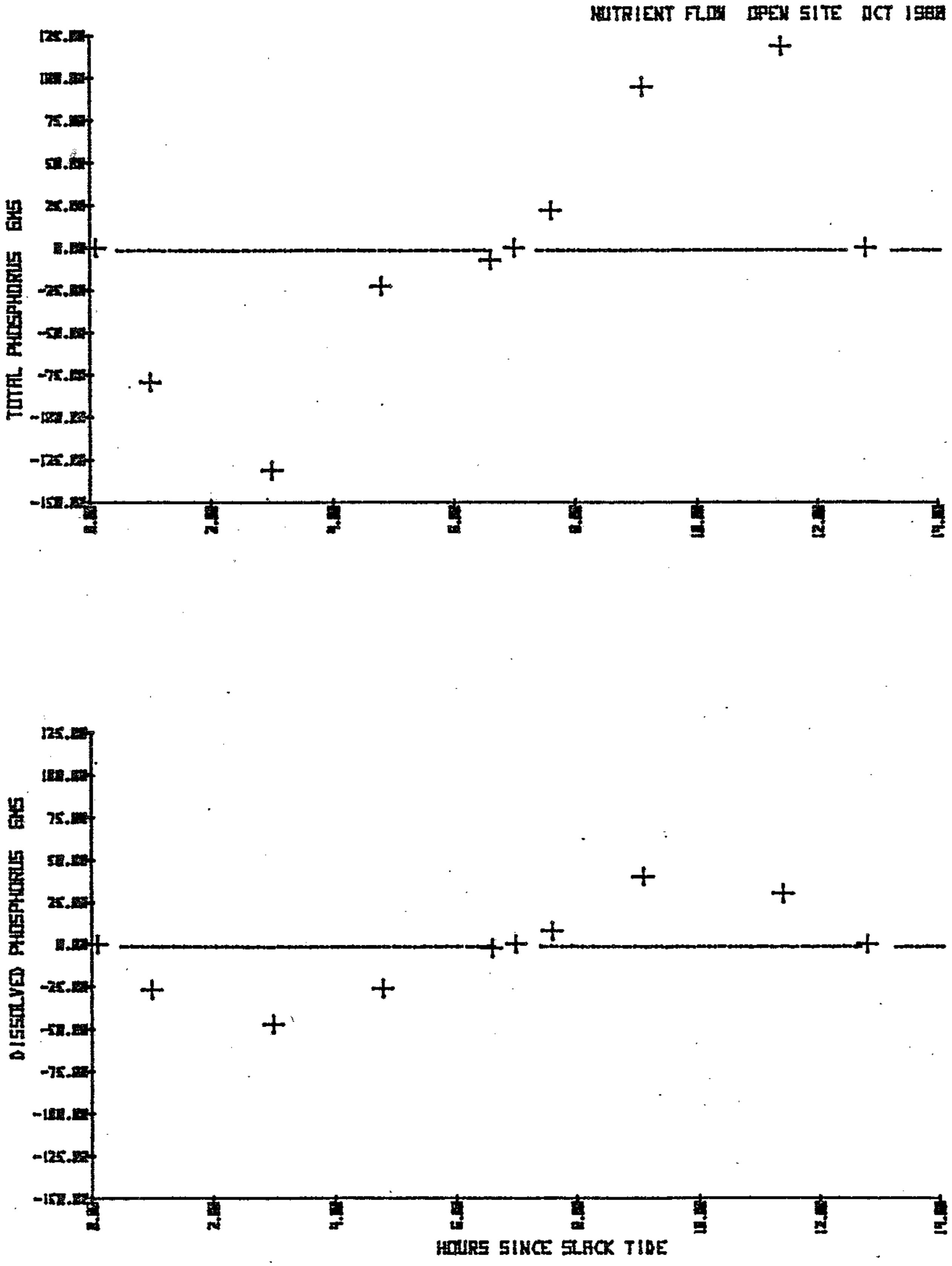


Figure 112


NUTRIENT FLOW OPEN SITE OCT 1980
TOTAL PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
-150.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

6. TOTAL AND DISSOLVED PHOSPHORUS - CONTROL SITE

Figure 113

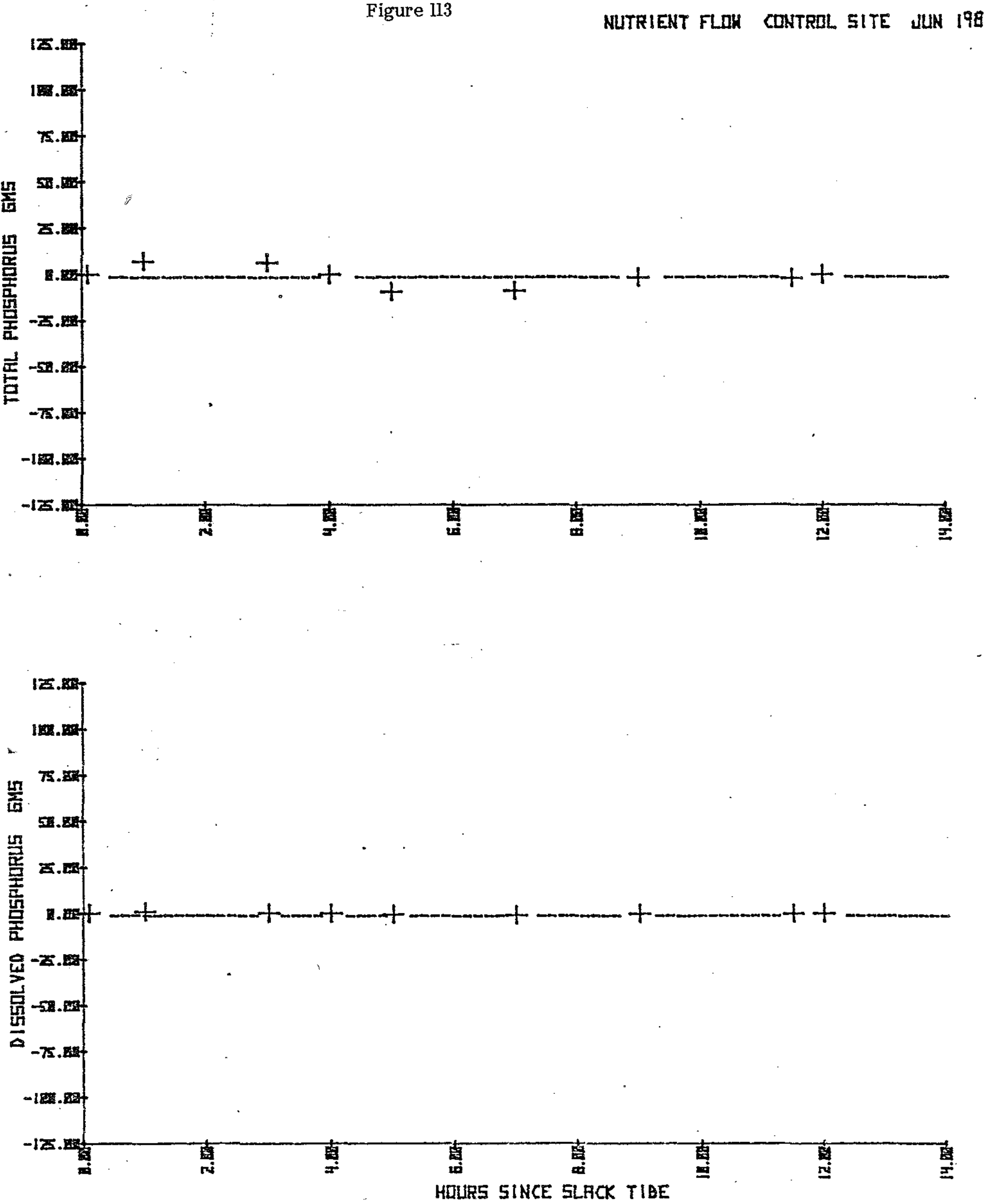

NUTRIENT FLOW CONTROL SITE JUN 198
TOTAL PHOSPHORUS GMS
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 114

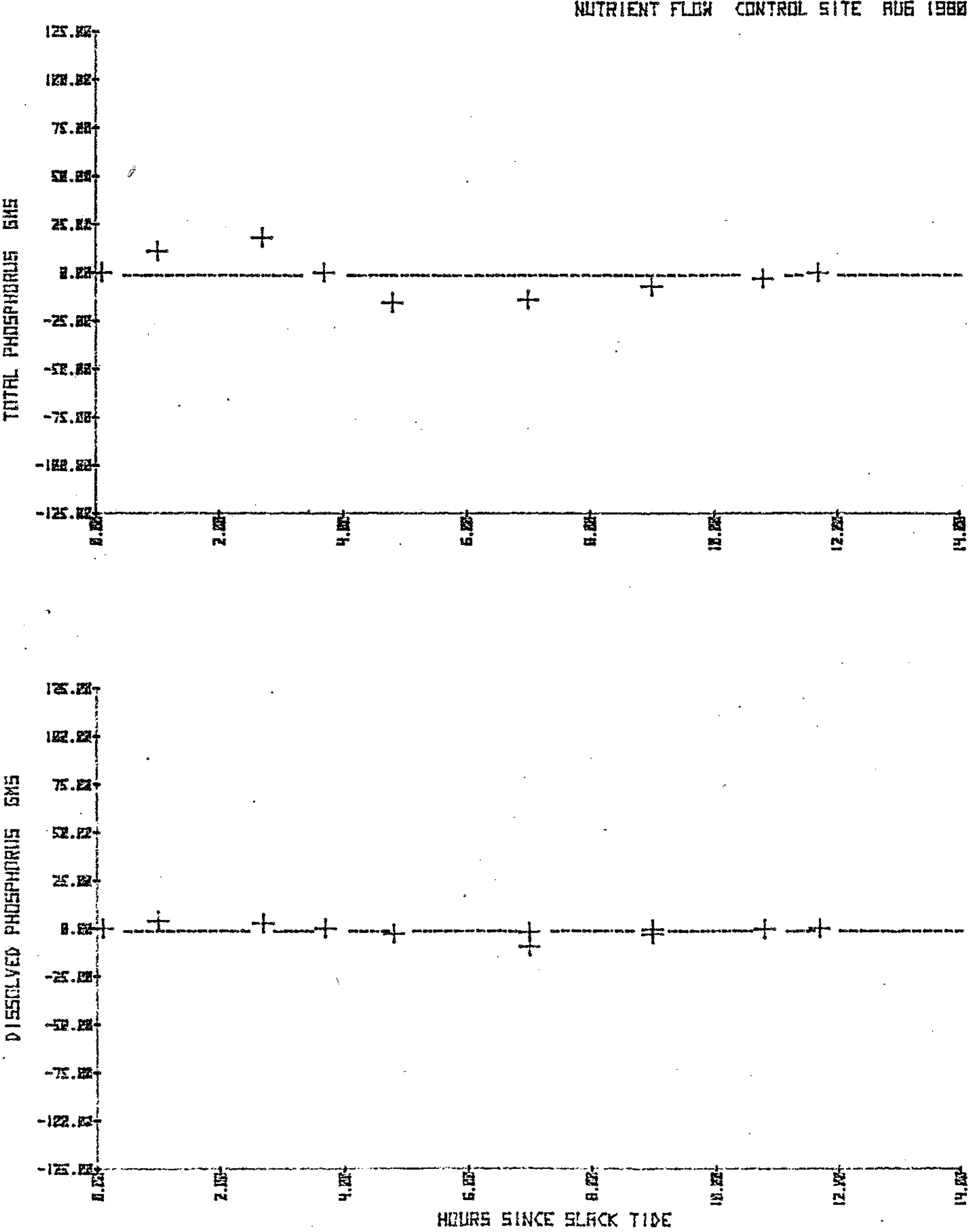
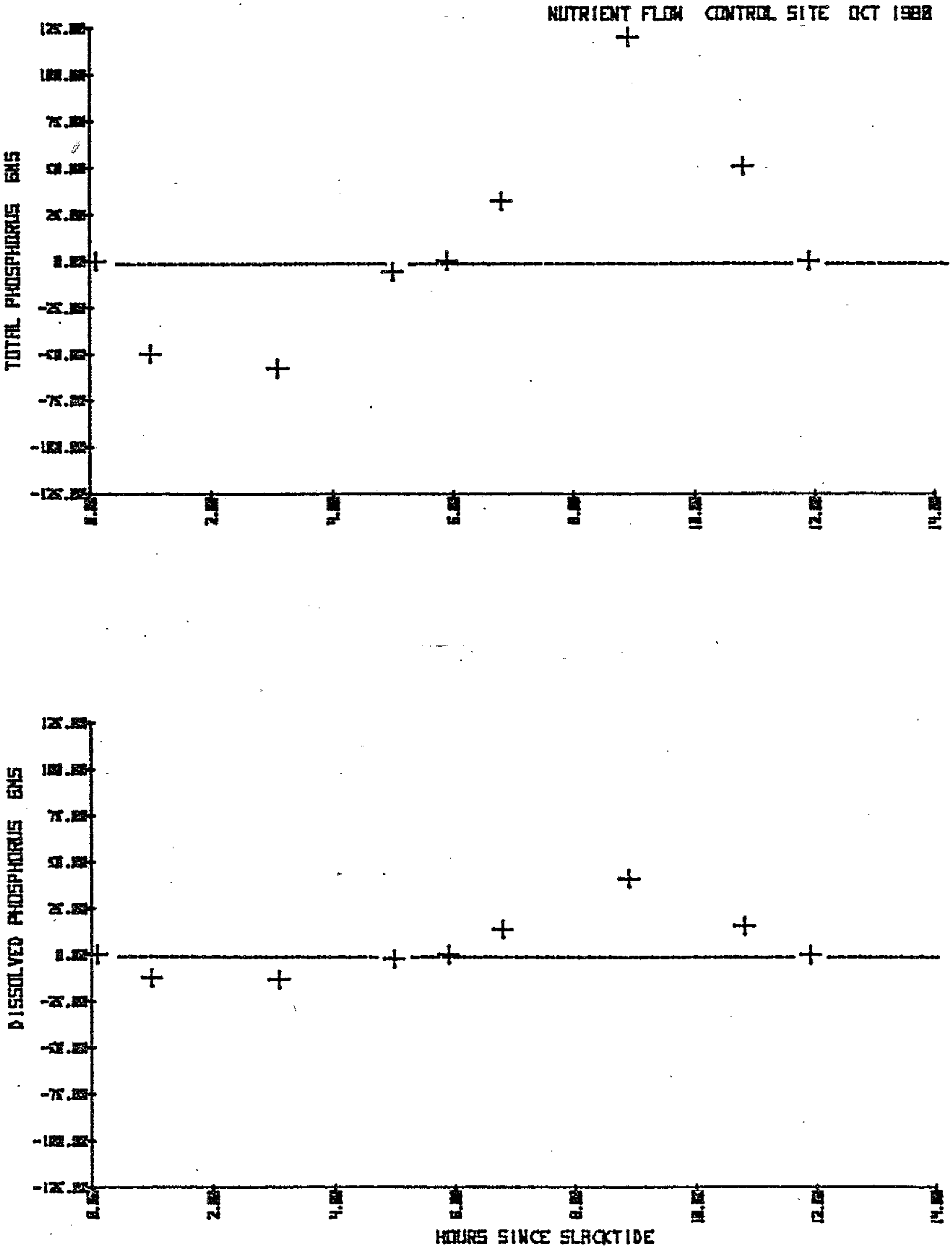

NUTRIENT FLOW CONTROL SITE AUG 1980
TOTAL PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
DISSOLVED PHOSPHORUS GMS
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
HOURS SINCE SLACK TIDE

Figure 115


NUTRIENT FLOW CONTROL SITE OCT 1988
TOTAL PHOSPHORUS GMS
125.000
100.000
75.000
50.000
25.000
0.000
-25.000
-50.000
-75.000
-100.000
-125.000
0.000
2.000
4.000
6.000
8.000
10.000
12.000
14.000
DISSOLVED PHOSPHORUS GMS
125.000
100.000
75.000
50.000
25.000
0.000
-25.000
-50.000
-75.000
-100.000
-125.000
0.000
2.000
4.000
6.000
8.000
10.000
12.000
14.000
HOURS SINCE SLACKTIDE

PART II

INTRODUCTION

This report is an extension of Part I of this document and contains data gathered during the summer of 1981 and fall of 1982. The purpose of the research was to continue the monitoring of plant communities and nutrients in plants at the Deal Island sites during the third and fourth years following management. The project had the following objectives:

1) Measure plant density in permanent plots during the 3rd and 4th years following management.
2) Measure plant biomass after three growing seasons following management.
3) Measure nutrient concentrations in plant tissues after three growing seasons.
4) Determine the response of D. spicata and S. patens shoot nitrogen concentrations to the addition of nitrogen fertilizer in both managed and control areas.

Before presenting results of the work it would be useful to summarize the original experimental design and results from vegetation studies that are presented in Part I.

Experimental Design — Three areas were extensively ditched in 1978 and early 1979 using a rotary ditcher. Details of the procedures can be found in Lesser (1982). One area (Open Site) was coupled to the adjacent estuary to permit flushing during each tidal cycle. A second area (Water Control Site) was similar to the Open Site except that the area was only partially coupled to the estuary. The purpose of this treatment, using water control structures, was to permit some tidal flushing while also maintaining water in the ditches. The third ditched area (Closed Site) was not coupled to the estuary and only received water from precipitation and during flooding events associated with high spring tides and/or storm tides. Two Control Sites were used. The original Control Site, used in 1979, was abandoned in 1980 because it was hydrologically very dissimilar to the three ditched areas. A more appropriate Control Site was selected in 1980 and used throughout the remainder of the study.

Vegetation Sampling — At each site, permanent plots were established along three randomly chosen transects (Fig. 1). The transects were oriented perpendicular to the ditches and permanently marked plots (25 cm x 25 cm) established at 0, 5, 10, 15, and 20 meters. Figure 1 is drawn to demonstrate that spoil, from the ditching, was always encountered between 0 and 15 meters and was found as far as 20 meters. Vegetation in the permanent plots was sampled monthly in 1979 and 1980.

In 1979 and 1980, we also conducted monthly harvests of aboveground tissues of plants and collected plant litter at each site. The sampling design was similar to that shown in Fig. 1 except that three new transects were randomly selected at each site on each harvest date. On each sampling date, all live and dead plant material was removed from triplicate quadrats (50 cm x 50 cm) at 0, 5, 10, 15, and 20 meters from the ditch. In the laboratory, the samples were separated into live and dead components. Each component was weighed after drying and then

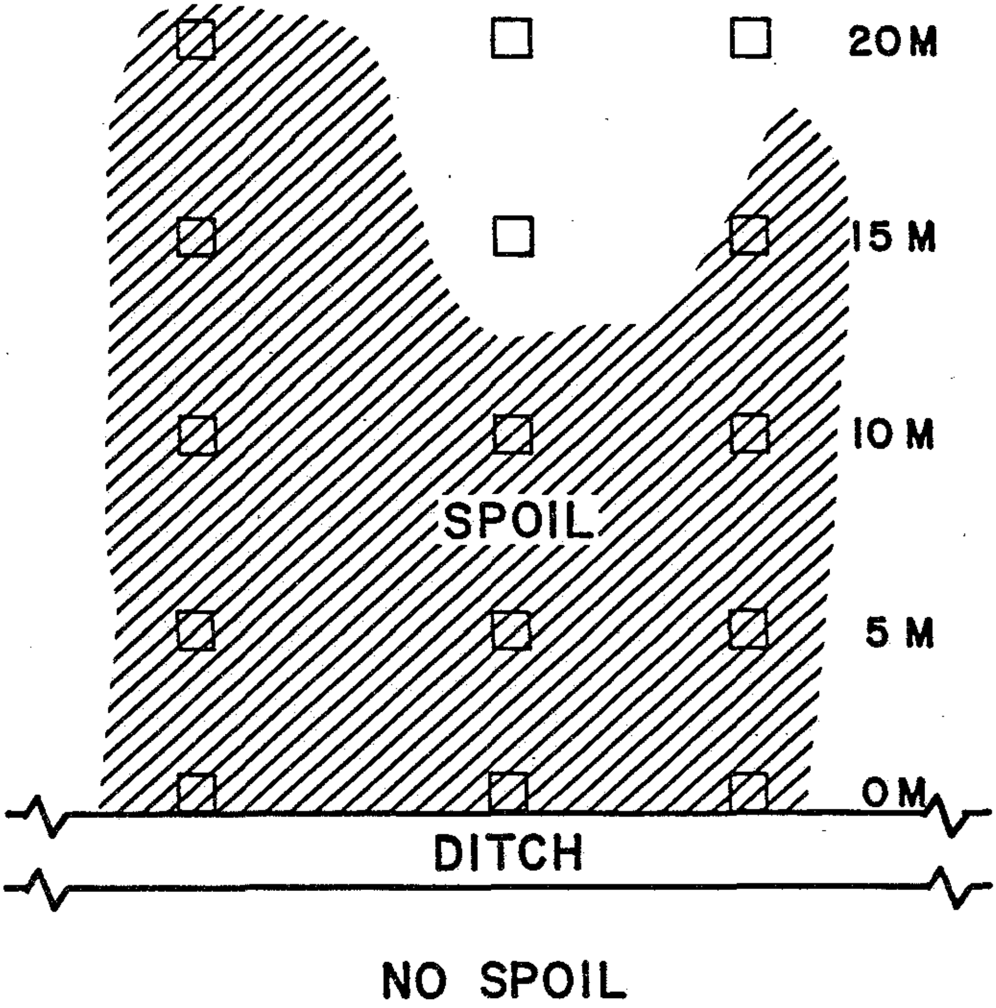


Figure 1. Diagrammatic representation of sampling design used at each site. Three randomly located transects, each 20 meters long, were established perpendicular to a ditch made by the rotary ditcher. Permanent plots were established at 0, 5, 10, 15, and 20 meters for density studies. Spoil, shown as hatched areas, was rather uniform between 0 and 15 meters but was found as far as 20 meters from ditches.

analyzed for nitrogen and phosphorus. This procedure enabled us to monitor recovery of the vegetation as well as determine whether there were any changes in nutrient concentrations due to the different management procedures.

Additional studies conducted in 1979 and 1980 included measurements of litter decomposition and water quality analyses. Details of those studies are not reviewed in this report since they were terminated after the 1980 growing season and results presented in Part I.

SUMMARY OF RESULTS — 1979 and 1980.

1) Net aboveground primary production did not differ significantly when the 3 treated sites were compared to the Control.

2) Live biomass had, on the average, returned to pre-treatment levels at all sites by the end of the second growing season. Near the ditches, however, biomass was still significantly less than at distances of 5, 10, 15, and 20 meters.

3) Litter biomass had not returned to pre-treatment levels at any sites by the end of the second (1980) growing season.

4) The two sites (Open and Water Control) that were coupled to the estuary were still undergoing changes in vegetation by the end of the second year.

   a) The Open and Water Control sites were dominated by *Distichlis spicata* by the end of the first growing season. *Pluchea purpurascens*, *Iva frutescens*, and *Baccharis halimifolia* began to colonize both sites during the first year and expanded their coverage during the second year.

   b) The Closed Site was dominated by *Spartina patens* after the first year following management and there were no major shifts in species composition in 1980.

5) Nitrogen and phosphorus concentrations of plant shoots increased significantly at all three treated sites and there were significant differences between sites.

   a) Concentrations of both nitrogen and phosphorus were highest at the Open and Water Control Sites, intermediate at the Closed Site and lowest at the Control Site.

b) Elevated levels of nitrogen and phosphorus continued during the second year suggesting that the response would be long-term or permanent. Additional data suggested that the changes in nutrients were caused by lowering the water table at the Open and Water Control Sites.

c) By the end of the second growing season, nitrogen concentrations of litter had significantly increased. This response was due to live shoots, which were high in N and P, ultimately becoming incorporated into the litter compartment.

Clearly, two of the managed areas were still undergoing changes after two years and it seemed desirable to continue to monitor the sites.

METHODS - 1981 and 1982

1. Plant densities in permanent plots.

Permanent plots, initially established in 1979, were monitored again in 1981 and 1982. Similar to previous years, the number of live shoots of all species were counted in the 15 plots (25 cm x 25 cm) at each site. Triplicate plots were located at 0, 5, 15, and 20 meters from ditches at each site (Fig. 1). Because seedlings of *P. purpurascens*, *I. frutescens* and *B. halimifolia* were so numerous in 1981 at the Open and Water Control site, aerial coverage (%) was, at times, estimated rather than counting individuals. In 1982, the number of stems of each species was counted.

2. Plant Biomass

Live vegetation and litter was harvested in August 1981 from 9 quadrats at each site. Triplicate samples were collected at 0, 10 and 20 meters from ditches. In the laboratory, *D. spicata* and *S. patens* shoots were separated and dry weights determined for each species. After drying at 60° C the dry weights of all live biomass was determined by summing dry weight values for *D. spicata*, *S. patens*, and all other species. Litter was analyzed separately and dry weights determined. Nitrogen concentrations of *D. spicata* and *S. patens* shoots were then determined using procedures described in Part I.

3. Nutrient enrichment study

Several investigators have suggested that primary production and nutrient assimilation by plants in estuarine wetlands is limited by nitrogen even though interstitial water is very rich in ammonia (Valiela et al. 1982, Mendelssohn et al. 1982, Morris 1980, Mendelssohn and Seneca 1980). Mendelssohn et al. 1982) have recently reviewed the literature on this topic and suggested that nitrogen (ammonium) uptake is inhibited because of physiological stresses associated with waterlogged substrates. In particular, plants in anaerobic environments must overcome anoxia and the presence of toxic chemicals, particularly sulfides. In drained substrates, which occur near streams in natural wetlands, investigators (King et al. 1982) have found that plant growth is more vigorous and that there is more oxygen around the plant roots. Mendelssohn and Postek (1982) have studied both streamside and high marsh forms of Spartina alterniflora and found that sulfides are converted to non-toxic iron precipitates in streamside habitats.

The presence of elevated nitrogen in live shoots at the Open and Water Control Sites suggested that, following ditching, nitrogen was not as limiting to plant growth at those sites. We hypothesized that plants were able to assimilate more nitrogen because the substrates contained less moisture. Figure 2 shows substrate moisture data collected from the Open, Closed and Control Sites between May and August 1981. Clearly there was less water in the substrate near the ditch (0 m) at the Open Site and moisture content at 20 meters was at times also less during the growing season. The differences between substrate moisture content at the Closed Site and Open Site persisted throughout that three month period. In 1980, information was obtained which suggested that plants at the Open Site were more efficiently incorporating nitrogen into belowground tissues (Table 1).

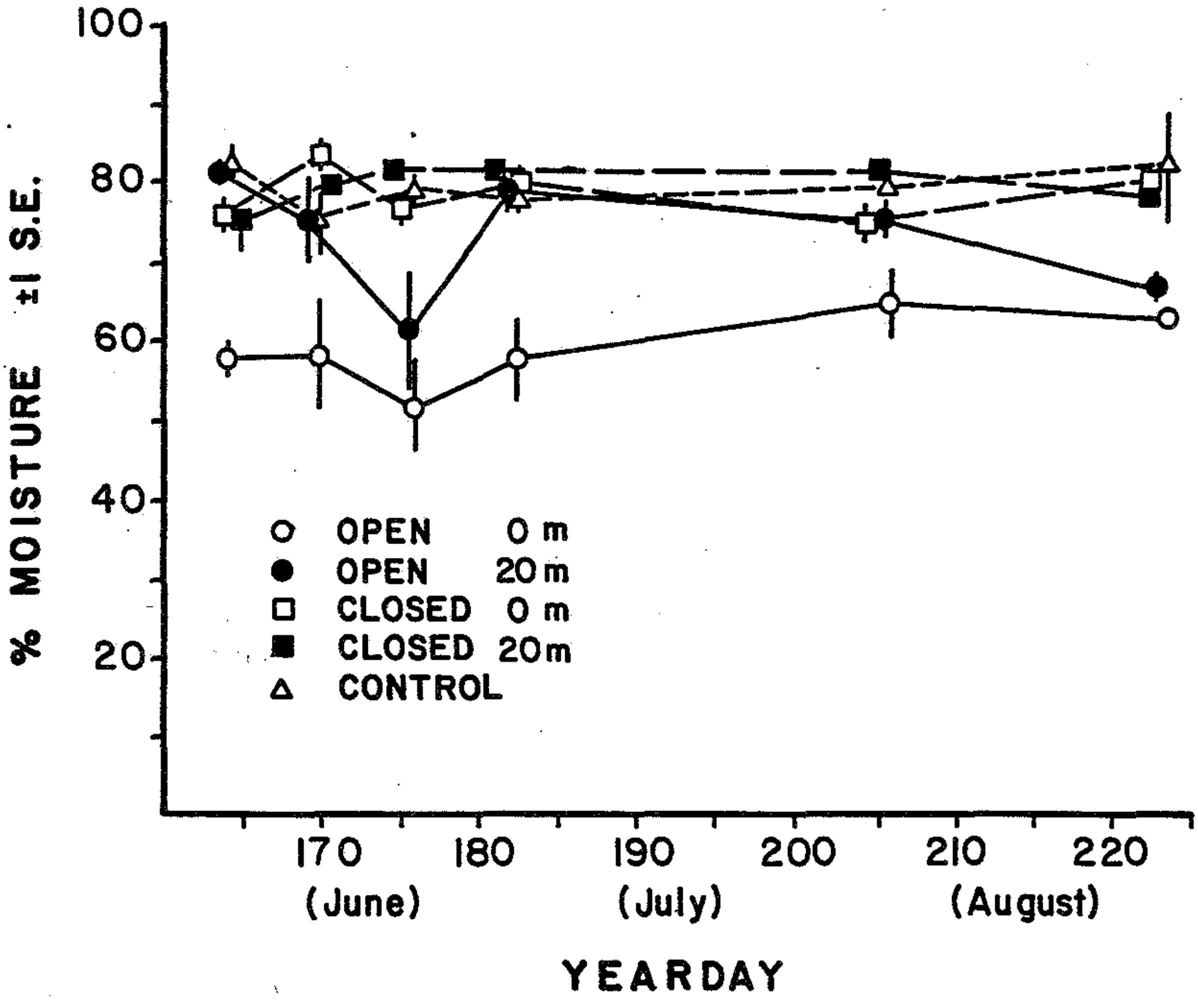


Figure 2. Substrate moisture content at the Open, Closed, and Control Sites between June and August, 1981. All values are means (% of wet weight) ±1 standard error of the mean.

Table 1. Nitrogen concentrations (%) of belowground rhizomes. All values are means of triplicate samples ±1 standard error of the mean. Substrate samples were collected in 1980. In the laboratory they were washed and all live and dead rhizome material removed. Live and dead rhizomes were primarily *S. patens* and *D. spicata*.

SITE	DEAD RHIZOMES	LIVE RHIZOMES
OPEN	0.93 ± 0.11	1.06 ± 0.02
CLOSED	0.69 ± 0.04	0.98 ± 0.03
CONTROL	0.75 ± 0.09	0.99 ± 0.02

Dead and live rhizomes of D. spicata and S. patens collected at the Open Site, had higher concentrations of nitrogen than rhizomes collected at the Closed and Control Sites.

In 1981 an experiment was conducted to test the hypothesis that plants at the Open Site had elevated nitrogen levels because of increased substrate drainage and, consequently, were able to more efficiently assimilate nitrogen. Nitrate fertilizer was added to two randomly located experimental plots at the Open Site, two at the Closed Site, and one at the Control Site. Plot dimensions were 5 m x 10 m and, at the Open and Closed sites, were positioned with the long axis parallel to the ditch. The short axis of the plots were positioned between 0 and 5 meters and 15 and 20 meters at the Open and Closed Sites. Control plots, no fertilizer added, were located 15 meters away from each fertilized plot. The fertilizer was purchased from Sudbury Laboratory (Sudbury, Mass) and was mixed with estuarine water and applied at a rate of 20 gN m^{-2} on June 11, 1981. Shoots of D. spicata and S. patens were collected from the fertilized and unfertilized plots after 7, 14, 28, 41, and 53 days and analyzed for nitrogen content using procedures described in Part I.

RESULTS

Live Biomass

Shoot biomass data from the 1981 sampling are compared with data for 1979 and 1980 in Table 2. There was a significant site affects (F = 10.818, df = 3, Sig. level = 0.0001) in 1981 but no significant differences between Open, Closed and Water Control Sites and all three sites had significantly less shoot biomass than what was measured at the Control Site (Table 2). There is no obvious reason for the high values at the Control Site although, by chance alone, the samples may have been collected in an area where net aboveground production was high. Since biomass was only sampled on one date in 1981, compared to monthly sampling in 1979 and 1980, there would be a higher probability that, due to spatial heterogeneity alone, one sampling site could yield data that were higher. Although there were no differences in total live biomass between treated sites, species differences noted in 1979 and 1980 (see Part I) persisted in 1981 (Table 2). There was a significant site affect on D. spicata shoot biomass (F = 5.463, df = 3, Sig. level = 0.005) with shoot biomass of D. spicata being significantly greater at the Open (97.1 g m^{-2}) and Water Control (114.3 g m^{-2}) Sites (Table 2). There was no significant difference between D. spicata at the Open and Water Control site compared to the Control Site (179.6 g m^{-2}). There was also a significant site affect on S. patens shoot biomass (F = 7.485, df = 3, Sig. level = 0.001). Similar to 1979 and 1980, S.patens shoot biomass was significantly less at the Open (18.6 g m^{-2}) and Water Control (17.4 g m^{-2}) Sites compared to the Closed (178.5 g m^{-2}) Site.

In 1981, there were no significant distance effects for total shoot biomass (F = 0.692, df = 2, Sig. level = 0.692), shoot biomass of D. spicata (F = 1.436, df = 2, Sig. level = 0.258) or S. patens shoot biomass (F = 0.171, df = 2, Sig. level = 0.894).

Table 2. Site and distance effects on total shoot biomass, biomass of *D. spicata* shoots, and biomass of *S. patens* shoots. Statistical analyses of 1981 data were made using SPSS Two-way (site, distance) analysis of variance. Means were compared using Duncan's Multiple Range Tests. Values that share the same superscript are not different at the 0.05 level of significance. Data for 1979 and 1980 are described in Part I. All values are g m^{-2} and comparisons between sites or distances are read vertically.

SITE EFFECTS

SITE	TOTAL BIOMASS			D. SPICATA BIOMASS			S. PATENS BIOMASS		
	1979	1980	1981	1979	1980	1981	1979	1980	1981
OPEN	180.0^{A}	152.4^{B}	145.4^{A}	152.4^{A}	42.8^{B}	97.1^{A}	25.6^{C}	67.2^{C}	18.6^{B}
CLOSED	154.0^{B}	210.0^{A}	191.6^{A}	33.2^{B}	24.8^{C}	7.3^{B}	118.4^{A}	183.1^{A}	178.5^{A}
WATER CONTROL	164.4^{AB}	140.8^{B}	159.9^{A}	144.4^{A}	99.2^{A}	114.3^{A}	9.6^{D}	24.8^{D}	17.4^{B}
CONTROL	88.8^{C}	187.2^{A}	435.9^{B}	16.8^{B}	76.4^{B}	179.6^{A}	46.4^{B}	110.8^{B}	255.7^{A}

DISTANCE EFFECTS

DISTANCE	1979	1980	1981	1979	1980	1981	1979	1980	1981
0 METERS	153.6^{A}	201.6^{A}	245.9^{A}	92.8^{A}	102.0^{A}	130.4^{A}	52.4^{AB}	101.2^{A}	99.8^{A}
10 METERS	156.0^{A}	163.6^{B}	245.9^{A}	92.4^{A}	72.0^{B}	101.1^{A}	48.0^{AB}	88.8^{A}	128.8^{A}
20 METERS	142.2^{A}	170.4^{B}	207.8^{A}	76.8^{A}	54.8^{B}	67.3^{A}	56.8^{A}	103.6^{A}	124.1^{A}

Average shoot biomass (all species combined) was very similar at 0 meters (245.9 g m^{-2}) and 10 meters (245.9 g m^{-2}) in 1981 and only slightly, but not significantly (Table 2), less at 20 meters (207.8 g m^{-2}).

Table 2 only demonstrates that interyear variation was high. At this point, we do not know whether the yearly differences were due to sampling, yearly variation in abiotic parameters (salinity, precipitation, frequency of flooding, etc.), recovery from management, or affects due to competition between species.

Litter Biomass

Litter biomass data for 1979-1981 are given in Table 3. The trend toward a yearly increase in litter biomass continued and there were no significant site (F = 0.800, df = 3, Sig. level = 0.506) or distance (F = 1.872, df = 2, Sig. level = 0.176) effects by 1981. Litter biomass averaged 605.9 g m^{-2} for all sites. In 1979 and 1980 litter biomass at 0 meters was significantly less than at 10 and 20 meters (Table 3). In 1981 there was still slightly less litter at 0 meters (502.9 g m^{-2}) but that value was not significantly greater than at 10 meters (648.7 g m^{-2}) or 20 meters (666.2 g m^{-2}).

Shoot Density

Throughout the study, there have been large inter- and intrasite differences in shoot density. *Spartina patens* dominated the Closed Site since 1979 and *D. spicata* was the dominant at the Open and Water Control Sites (Figure 3). *Distichlis spicata* continued to dominate the Open Site in 1981 and 1982 even though the average shoot density has changed dramatically to a range of 821-181 shoots m^{-2} in 1982 compared to 2203-304 shoots m^{-2} in 1981 (Table 4).

Table 3. Site and distance effects on litter biomass. Statistical analysis of 1981 data were made using SPSS Two-way (site, distance) analysis of variance. Means (g m^{-2}) were compared using Duncan's Multiple Range Tests. Values that share the same superscript, read vertically, are not different at the 0.05 level of significance. Data for 1979 and 1980 are described in Part I.

SITE EFFECTS

SITE	1979	1980	1981
OPEN	205.2^{A}	566.8^{A}	681.6^{A}
CLOSED	193.6^{A}	462.0^{B}	630.1^{A}
WATER CONTROL	116.0^{B}	375.6^{C}	520.9^{A}
CONTROL	237.2^{A}	589.6^{A}	591.2^{A}

DISTANCE EFFECTS

DISTANCE (METERS)	1979	1980	1981
0	110.0^{B}	382.0^{B}	502.9^{A}
10	198.4^{A}	549.6^{A}	648.7^{A}
20	249.6^{A}	545.6^{A}	666.2^{A}

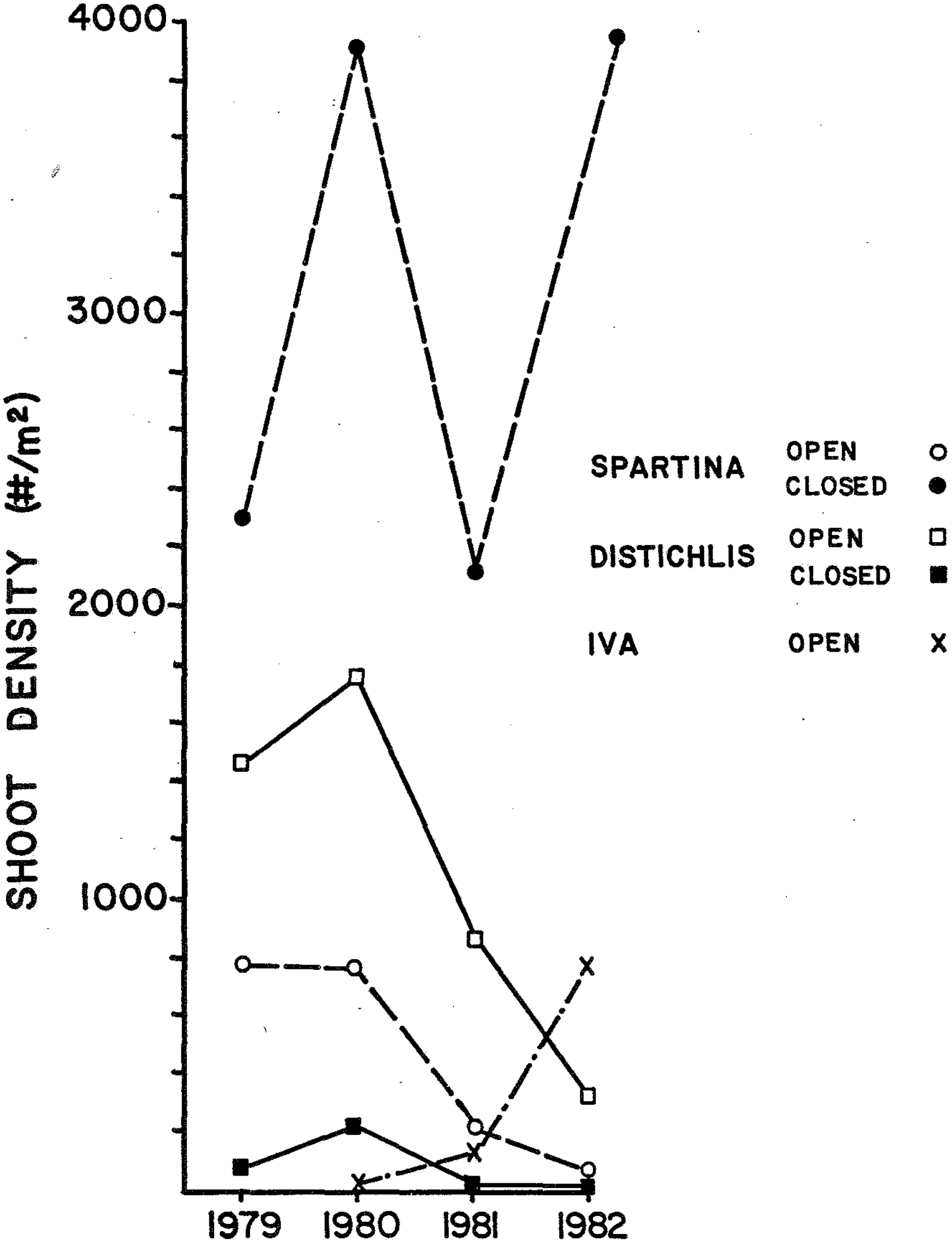


Figure 3. Shoot density data for S. patens, D. spicata, and I. frutescens at the Open and Closed Sites. Values for 1979 and 1980 are from Part I of this report.

Table 4. Density data for all distances at the three treated sites and Control Site in 1981 and 1982. All values are means ±1 standard error of the mean. In 1981, percentage cover estimates were made for seedling in several plots. Those are indicated with a % sign.

DISTANCE (M)	0		5		10		15		20	
SPECIES YEAR	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982
CONTROL SITE										
Distichlis spicata	1024 ± 459	1760 ± 597	122 ± 72	117 ± 69	384 ± 102	352 ± 107	362 ± 267	369 ± 370	197 ± 43	106 ± 162
Spartina patens	1787 ± 1500	1429 ± 719	1584 ± 956	2154 ± 283	2645 ± 315	3440 ±1192	1899 ± 689	1179 ± 246	1483 ± 246	1882 ± 682
Pluchea purpurascens	5% ± 3%		1% ± 1%		5% ± 5%		7% ± 7%			
Seedling?		16 ± 16		4 ± 4						11 ± 11
OPEN SITE										
Distichlis spicata	2203 ± 1017	821 ± 611	304 ± 215	265 ± 100	699 ± 240	181 ± 141	949 ± 145	267 ± 162	954 ± 66	309 ± 285
Spartina patens			485 ± 302	298 ± 154	288 ± 147	410 ± 120	107 ± 107	98 ±181	27 ± 27	101 ± 72
Baccharis halimifolia				21 ± 21						11 ± 11
Iva frutescens	107 ± 107	75 ± 44	213 ± 198	261 ± 261	15% ±8%	208 ± 74	3% ± 2%	53 ± 27	5 ± 5	5 ± 1
Solidago sp.	27 ± 27	5 ± 5	11 ± 11		11 ± 11	5 ± 5		11 ± 11	11 ± 11	
Pluchea purpurascens			33% ±28%						20% ± 15%	
WATER CONTROL SITE										
Distichlis spicata	821 ± 384	107 ±84	347 ± 243	5 ± 5	1179 ± 423	213 ± 160	970 ± 625	203 ± 11	474 ± 227	28 ± 19
Spartina patens							5 ± 5		272 ± 197	251 ± 139
Baccharis halimifolia		58 ±104		59 ±44		30 ± 46		32 ± 16		
Iva frutescens	40% ±27%	267 ± 267	280 ± 70	50 ± 125	21 ± 11	240 ± 240	128 ± 24	75 ± 51	104 ± 189	12 ± 18
Pluchea purpurascens	5% ±5%		20% ±15%		8% ± 8%		8% ± 8%			
CLOSED SITE										
Distichlis spicata	203 ± 84	46 ±37	203 ± 59	22 ± 14	485 ±230	168 ±201	448 ±195	110 ± 53	379 ±108	314 ± 129
Spartina patens	2107 ± 300	3987 ± 73	1976 ± 384	2587 ±409	3856 ± 955	3621 ± 250	3205 ± 1159	2459 ± 267	3045 ± 296	2987 ± 285
Iva frutescens		48 ± 48		11 ± 11		5 ± 5		5 ± 5	5 ± 5	6 ± 6
Pluchea purpurascens						208 ± 208				

Spartina patens continued to dominate the Closed Site in 1981 and 1982 (Fig. 3) and D. spicata also has continued to decline at all distances at the Closed Site (Table 4). Coincident with the decline in D. spicata and S patens at the Open Site has been an increase in the density of Iva frutescens. Iva was present at the Open and Water Control Sites in 1979, but did not appear in the permanent plots until 1980 (Fig. 3). By 1982, I. frutescens density had increased to 261 shoots per m^{-2} in one quadrat and an overall average of almost 80 plants m^{-2} at the Open Site. Iva frutescens seedlings were found in the permanent plots at the Closed Site in 1982 but there is no indication that it will become widespread. Baccharis halimifolia has become common at the Water Control Site (Table 4).

Tissue Nitrogen Concentrations

As noted earlier, nitrogen concentrations in shoots were significantly higher at the Open and Water Control Sites and significantly less at the Closed Site in 1979 and 1980. In 1981, that pattern continued as there were significant differences between the Open and Closed Sites for S. patens (F = 15.394, df = 1, Sig. level = 0.004) and D. spicata (F = 5.093, df = 1, Sig. level = 0.054). In 1981 there were also significant distance effects on S. patens (F = 10.963, df = 1, Sig. level = 0.011), and D. spicata (F = 21.373, df = 1, Sig. level = 0.002).

Distichlis spicata and S. patens shoots had significnatly higher tissue nitrogen concentrations near the ditches (0 meters) compared to 20 meters (Table 5). There were no significant differences for either species when data from the Control Site (Table 5) were compared with 20 meters at either the Open (F = 6.89, df = 1, Sig. level = 0.253) or Closed (F = 2.30, df = 1, Sig. level = 0.606) Sites. Both species had significantly higher tissue nitrogen concentrations at the Open Site.

Table 5. Site and distance affects on the nitrogen concentrations (%) of D. spicata and S. patens in 1981. Means, read vertically, that are not significantly different share the same superscript. Significance levels are, at least, at the 0.05 level. Site and distance affects for the Open and Closed Sites were compared using SPSS Two-way analysis of variance for site (Open and Closed) and distance (0 and 20 meters) effects. Data from all site and distance combinations were compared to means for the Control Site using one-way analysis of variance and T-tests.

SITE EFFECTS

SITE	D. SPICATA	S. PATENS
OPEN	1.02	1.02
CLOSED	0.84	0.67

DISTANCE EFFECTS

SITE	DISTANCE (METERS)	D. SPICATA	S. PATENS
OPEN	0	1.21	1.62
	20	0.83^A	0.41^A
CLOSED	0	1.01	0.99
	20	0.68^A	0.36^A
CONTROL		0.72^A	0.29^A

Nitrogen Fertilization Study

1. Spartina patens

There were significant site, distance, fertilization and time effects on the nitrogen concentrations of *S. patens* shoots when the Open and Closed Sites were compared (Table 6). Mean shoot nitrogen concentrations at the Open Site (1.34%) were significantly higher (Table 6) than at the Closed Site (1.03%). Nitrogen concentrations were also significantly higher at 0 meters (1.23%) than at 20 meters (1.13%) and concentrations at the fertilized sites were significantly greater (1.29%) than the mean of 1.07% at the non-fertilized sites. The significant yearday effects were due to higher concentrations (1.35%) on yearday 90 (28 days after fertilizer added) compared to very similar values on yearday 169 (1.16%), 176 (1.17%), 203 (1.16%), and 2.5 (1.09%).

There were significant 2-way interactions for 3 combinations (Table 6). Nitrogen concentrations were higher in shoots collected from the fertilized plots at both the Open and Closed Sites (Table 7). Significant site x time interactions were due to consistently higher nitrogen concentrations at the Open Site and higher values on yearday 190 at both sites (Table 8). Shoot nitrogen concentrations were also high on yearday 203 at the Open Site (1.42%) but on the same yearday had returned to lower values (0.90%) at the Closed Site. The significant fertilization x time interaction (Table 8) was due to higher nitrogen concentrations, with only one exception, in shoots at the fertilized site and the higher values measured on yearday 190 (1.50%) at the fertilized site and yeardays 190 (1.16%) and 203 (1.28%) at the unfertilized site. There were no significant 3 or 4 way interactions (Table 6).

Table 9 compares shoot nitrogen concentrations at the fertilized and unfertilized Control Site with concentrations at the two ditched sites. With only 3

Table 6. Results of analysis of variance on the nitrogen concentrations of S. patens shoots.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance Level
Main Effects	5.324	7	0.761	17.900	0.001
Site (S)	2.921	1	2.921	68.758	0.001
Distance (D)	0.231	1	0.231	5.435	0.0220
Fertilization (F)	1.208	1	1.208	28.427	0.001
Time (T)	0.833	4	0.208	4.901	0.001
2-Way Interactions	2.714	15	0.181	4.266	0.001
S x D	0.005	1	0.005	0.127	0.723
S x F	0.224	1	0.244	5.753	0.019
S x T	0.445	4	0.111	2.615	0.041
D x F	0.003	1	0.003	0.070	0.793
D x T	0.254	4	0.064	1.496	0.212
F x T	1.754	4	0.439	10.321	0.001
3-Way Interactions	1.293	13	0.099	2.341	0.011
S x D x F	0.114	1	0.114	2.686	0.105
S x D x T	0.307	4	0.077	1.805	0.136
S x F x T	0.313	4	0.078	1.841	0.129
D x F x T	0.263	4	0.066	1.545	0.197
4-Way Interaction	0.245	3	0.820	1.925	0.132
S x D x F x T	0.245	3	0.820	1.925	0.132
Explained Variance	9.581	38	0.252	5.934	0.001
Residual Variance	3.314	78	0.042		
Total	12.896	116	0.111		

Table 7. Comparison of site x fertilization and distance x site x fertilization effects on the nitrogen concentrations (%) of S. patens and D. spicata shoots. F is the symbol for fertilized and NF for unfertilized plots. Values are mean concentrations ±1 standard error of the mean.

SITE x FERTILIZATION EFFECTS

TREATMENT	OPEN	CLOSED	CONTROL
		S. PATENS	
F	1.25 ± 0.04	1.08 ± 0.06	1.07 ± 0.05
NF	1.18 ± 0.06	0.97 ± 0.02	0.95 ± 0.03
		D. SPICATA	
F	1.54 ± 0.07	1.42 ± 0.06	1.53 ± 0.11
NF	1.31 ± 0.06	1.26 ± 0.05	1.29 ± 0.07

DISTANCE x SITE x FERTILIZATION EFFECTS

	OPEN		CLOSED	
	0 METERS	20 METERS	0 METERS	20 METERS
		S. PATENS		
F	1.49 ± 0.09	1.49 ± 0.06	1.17 ± 0.06	1.00 ± 0.09
NF	1.27 ± 0.09	1.06 ± 0.07	0.99 ± 0.03	0.94 ± 0.04
		D. SPICATA		
F	1.64 ± 0.11	1.53 ± 0.07	1.39 ± 0.10	1.45 ± 0.06
NF	1.33 ± 0.08	1.29 ± 0.08	1.33 ± 0.08	1.18 ± 0.05

Table 8. Mean nitrogen concentrations(%) for S.patens shoots for site x time and fertilizer x time interactions.

				TIME		
SITE	YEARDAY	169	176	190	203	215
OPEN		1.29	1.25	1.60	1.42	1.22
CLOSED		1.04	1.09	1.17	0.90	0.96

				TIME		
TREATMENT	YEARDAY	169	176	190	203	215
FERTILIZED		1.30	1.41	1.50	1.04	1.19
UNFERTILIZED		1.03	0.93	1.16	1.28	0.99

Table 9. Nitrogen concentrations (%) in S. patens shoots in fertilized (F) and unfertilized (NF) plots at the two treatment Sites and Control Site. All values are means ± 1 standard error of the mean. Results of statistical tests (T-tests) for each yearday are also provided for within treatment comparisons. All values, read vertically, with a superscript A are not significantly different from the fertilized Control Site and values with superscript B are not different from the unfertilized Control Site.

		YEARDAY DAYS SINCE START	169 7	176 14	190 28	203 41	215 53
SITE	DISTANCE (M)	TREATMENT					
OPEN	0	F	1.65 ± 0.06	1.59 ± 0.06	1.82 ± 0.24	1.77 ± 0.11	1.22 ± 0.06
		NF	1.19 ± 0.09	0.99 ± 0.06^{B}	1.45 ± 0.06	1.17 ± 0.18	0.95 ± 0.05^{B}
OPEN	20	F	1.35 ± 0.02	1.68 ± 0.05	1.51 ± 0.11	1.45 ± 0.26	1.47 ± 0.11
		NF	0.96 ± 0.03	0.75 ± 0.02	No Data	1.31 ± 0.08	1.25 ± 0.12
CLOSED	0	F	1.13 ± 0.10^{A}	1.29 ± 0.01^{A}	1.41 ± 0.11	0.88 ± 0.14	1.15 ± 0.03
		NF	1.10 ± 0.04	1.05 ± 0.06^{B}	1.17 ± 0.04	1.08 ± 0.06^{B}	0.89 ± 0.03^{B}
CLOSED	20	F	1.07 ± 0.45^{A}	1.09 ± 0.05	1.24 ± 0.22^{A}	0.66 ± 0.11^{A}	0.93 ± 0.02^{A}
		NF	0.85 ± 0.02^{B}	0.91 ± 0.05	0.84 ± 0.02^{B}	0.97 ± 0.02^{B}	0.84 ± 0.08^{B}
CONTROL		F	1.23 ± 0.09^{A}	1.30 ± 0.03^{A}	1.06 ± 0.09^{A}	0.83 ± 0.07^{A}	0.93 ± 0.08^{A}
		NF	0.82 ± 0.02^{B}	1.07 ± 0.04^{B}	0.89 ± 0.06^{B}	1.07 ± 0.07^{B}	0.89 ± 0.06^{B}

exceptions, shoot nitrogen concentrations were significantly higher at both 0 and 20 meters at the Open Site compared to fertilized and unfertilized plots at the Control Site. With only two exceptions (0 meters on yearday 203 and 20 meters on yearday 215), concentrations were also higher in fertilized plots at the Closed Site but on only two instances (yearday 176) were concentrations significantly higher than those measured at the Control Site.

2. Distichlis spicata

All main effects were significantly different when D. spicata nitrogen concentrations were compared at the Open and Closed Sites (Table 10) and the patterns were similar to those described for S. patens. Nitrogen concentrations at the Open Site (1.49%) were higher than those measured at the Closed Site (1.34%). Nitrogen concentrations were higher near the ditches (1.45% at 0 meters) than at 20 meters (1.37%) and shoots at fertilized sites had higher nitrogen concentrations (1.53%) than shoots collected from unfertilized plots (1.28%).

Two, 3- and 4-way interactions were much more complex and all but four were significant at the 0.05 level of significance. Shoots at the fertilized plots were higher in nitrogen at both the Open and Closed Sites (Table 11) but shoot concentrations at the unfertilized Closed Site (1.32%) were not very different from those measured at the fertilized Closed Site (1.42%). Site x time and fertilizer x time interactions are similar to those described for S. patens as both fertilized and non-fertilized plots at both sites had higher concentrations measured on yeardays 190 and/or 203 (Table 11). A similar pattern was seen when distance x time comparisons were made (Table 11). Shoot nitrogen concentrations were higher at yearday 190 at both 0 and 20 meters and, in most instances, concentrations were higher at 0 meters.

Table 10. Results of analysis of variance on the nitrogen concentrations of *D. spicata* shoots.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance Level
Main Effects	4.204	7	0.601	28.980	0.001
Sites (S)	0.656	1	0.656	31.659	0.001
Distance (D)	0.176	1	0.176	8.503	0.005
Fertilization (F)	1.613	1	1.613	77.855	0.001
Time (T)	1.586	4	0.396	19.131	0.001
2-Way Interactions	6.444	15	0.430	20.733	0.000
S x D	0.081	1	0.081	3.889	0.052
S x F	0.245	1	0.245	11.826	0.001
S x T	0.524	4	0.131	6.325	0.001
D x F	0.005	1	0.005	0.255	0.615
D x T	1.234	4	0.308	14.882	0.001
F x T	4.418	4	1.105	53.302	0.001
3-Way Interactions	1.075	13	0.083	3.992	0.001
S x D x F	0.255	1	0.255	12.317	0.001
S x D x T	0.466	4	0.117	5.622	0.001
S x F x T	0.197	4	0.049	2.379	0.059
D x F x T	0.140	4	0.035	1.690	0.161
4-Way Interaction	0.416	3	0.139	6.96	0.000
S x D x F x T	0.416	3	0.139	6.96	0.000
Explained Variance	12.140	38	0.319	15.417	
Residual Variance	1.616	78	0.021		
Total	13.756	116	0.119		

Table 11. Two-way interactions for nitrogen concentrations (%) of D. spicata shoots.

I. Site x Fertilization Interaction

	Fertilized	Unfertilized
Open	1.64	1.32
Closed	1.42	1.26

II. Site x Time Interaction

YEARDAY	169	176	190	203	215
Open	1.50	1.41	1.92	1.52	1.20
Closed	1.34	1.33	1.43	1.29	1.31

III. Distance x Time Interaction

YEARDAY	169	176	190	203	215
0 Meters	1.41	1.47	1.76	1.49	1.14
20 Meters	1.44	1.26	1.47	1.32	1.37

IV. Fertilization x Time Interaction

YEARDAY	169	176	190	203	215
Fertilized	1.47	1.64	1.92	1.20	1.43
Unfertilized	1.38	1.09	1.25	1.61	1.08

Table 12 compares D. spicata shoot nitrogen concentrations at the Control Site with nitrogen data from the two ditched sites. Although there was a tendency for nitrogen concentrations to be elevated in the fertilized plots, in only 5 instances were the values significantly higher than those measured at the fertilized Control Site. Three of the higher values occurred at 0 meters at the Open Site and one at 0 meters and one at 20 meters at the Closed Site. There were also very few significant differences when the fertilized plots at the two ditched sites were compared to the unfertilized Control plot. In only three instances were concentrations higher at the Open Site (two at 0 meters and one at 20 meters) and only two instances (one each at 0 and 20 meters) at the Closed Site.

Table 12. Nitrogen concentrations (%) of *D. spicata* shoots in fertilized (F) and unfertilized (NF) plots at the two treatment Sites and Control Site. All values are means ± 1 standard error. Results of statistical tests (T-tests) for each yearday are also provided for within treatment comparisons. All values with superscript A are not significantly different from the fertilized Control Site and values, read vertically, with superscript B are not different from the unfertilized Control Site.

SITE	DISTANCE (M)	TREATMENT	YEARDAY 169 DAYS SINCE START 7	176 14	190 28	203 41	215 53
OPEN	0	F	1.78 ± 0.03	1.89 ± 0.05^{A}	2.39 ± 0.05	1.61 ± 0.12^{A}	1.11 ± 0.03
		NF	1.39 ± 0.03^{B}	1.07 ± 0.06	1.58 ± 0.06	1.71 ± 0.11^{B}	0.91 ± 0.04^{B}
OPEN	20	F	1.38 ± 0.08^{A}	1.69 ± 0.07^{A}	1.78 ± 0.01^{A}	1.13 ± 0.03^{A}	1.65 ± 0.09^{A}
		NF	1.44 ± 0.08	0.97 ± 0.04		1.63 ± 0.05^{B}	1.12 ± 0.11^{B}
CLOSED	0	F	1.13 ± 0.07	1.66 ± 0.04^{A}	1.89 ± 0.01^{A}	0.92 ± 0.16^{A}	1.41 ± 0.01^{A}
		NF	1.44 ± 0.28^{B}	1.27 ± 0.06^{B}	1.19 ± 0.08	1.71 ± 0.05^{B}	1.13 ± 0.10^{B}
CLOSED	20	F	1.58 ± 0.13^{A}	1.33 ± 0.09	1.64 ± 0.06^{A}	1.13 ± 0.06^{A}	1.56 ± 0.01^{A}
		NF	1.33 ± 0.06^{B}	1.05 ± 0.05	0.99 ± 0.07^{B}	1.40 ± 0.04^{B}	1.15 ± 0.08^{B}
CONTROL		F	1.39 ± 0.08^{A}	1.78 ± 0.07^{A}	1.99 ± 0.11^{A}	0.94 ± 0.30^{A}	1.56 ± 0.06^{A}
		NF	1.12 ± 0.05^{B}	1.43 ± 0.09^{B}	1.21 ± 0.09^{B}	1.64 ± 0.19^{B}	1.07 ± 0.09^{B}

DISCUSSION

Years 1979 - 1982

Live biomass and litter standing crop, although variable from year to year, have returned to pretreatment levels at the three ditched sites (Figs. 4 and 5). With the exception of the very large value for total live biomass at the Control Site in 1981, there were no site differences when treated sites were compared. Given that there is intrasite spatial variability in shoot biomass, it seems likely that the high value from the Control Site was probably, by chance alone, due to the fact that we sampled only once in 1981 compared to monthly during 1979 and 1980.

Differences, first noted in 1979, in species composition persisted through 1982. *Spartina patens* is clearly the dominant species at the Closed Site (Fig. 3) and there is no evidence that it will be supplanted by either *I. frutescens* or *B. halimifolia*. *Distichlis spicata* dominated the Open and Water Control Sites between 1979 and 1981 but by 1982 shoot density data from the permanent plots (Fig. 3 and Table 4) demonstrate that it and *S. patens* have declined at the Open Site. Similar changes are ongoing at the Water Control Site (Table 4). At the Open and Water Control Sites, *I. frutescens* has become more abundant and *B. halimifolia* has become established and is widespread at the Water Control Site. If this trend continues, it seems likely that both *D. spicata* and *S patens* will become subordinate species at the Open and Water Control Sites.

Litter biomass returned to pretreatment levels at a slower rate than live shoot biomass and only reached pretreatment levels in 1981 (Fig. 5). Within each site, recovery of the litter compartment was slowest near the ditches, particularly within the first meter (Fig. 6). From our earlier work on decomposition rates (see Part I) it was shown that litter decomposed slower at the ditched

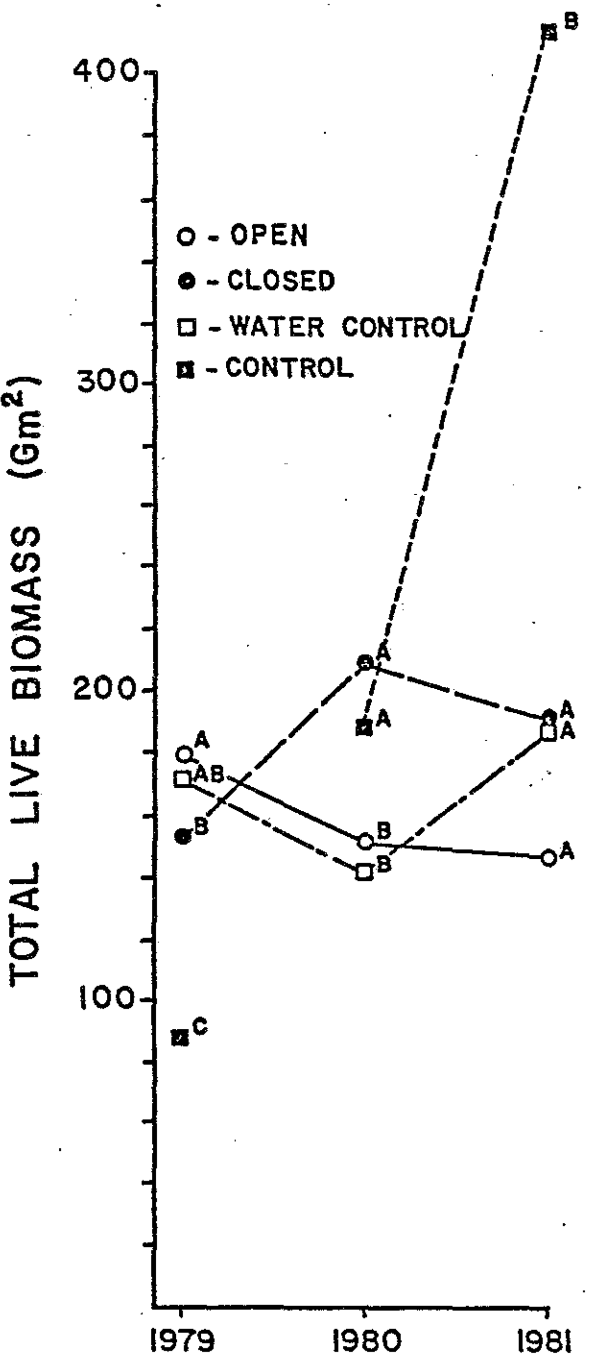


Figure 4. Average total live biomass of all species at the 3 treated sites and Control Site. Data are taken from Table 2. Values that share the same superscript, read vertically within each year, are not significantly different.

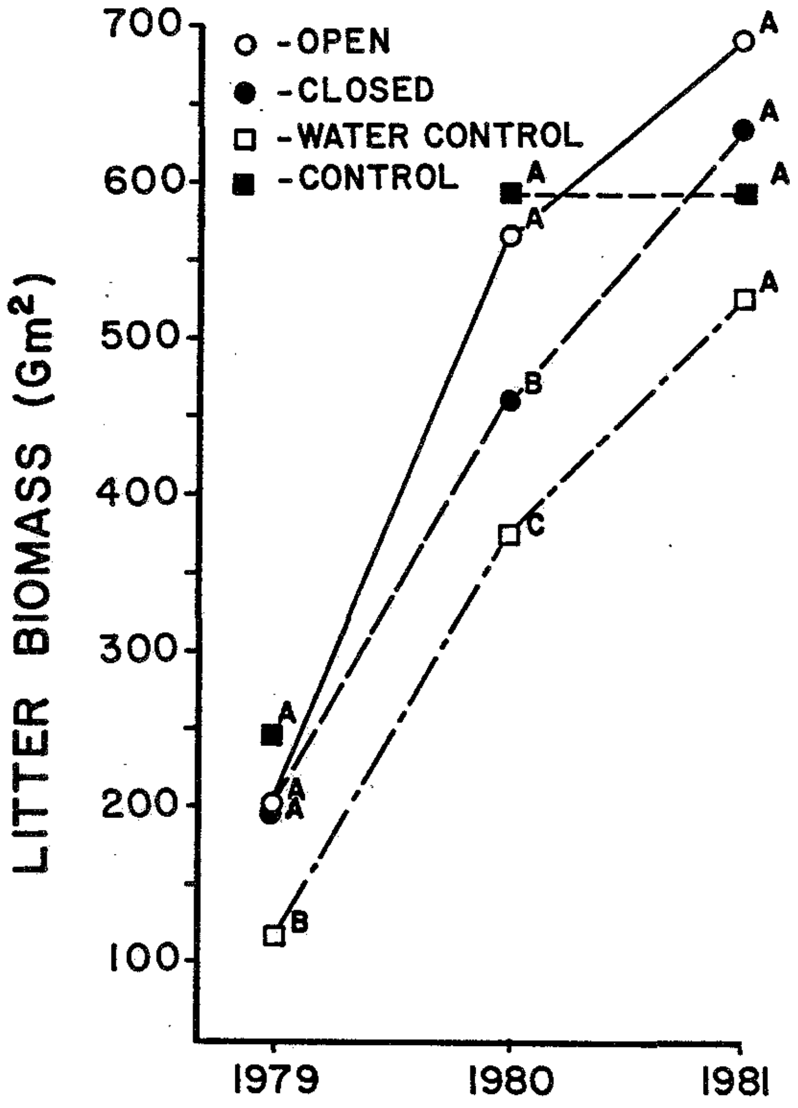


Figure 5. Mean litter biomass at the three treated sites and Control Site from 1979 to 1981. Values are taken from Table 3. Means that share the same superscript, read vertically within each year, are not significantly different.

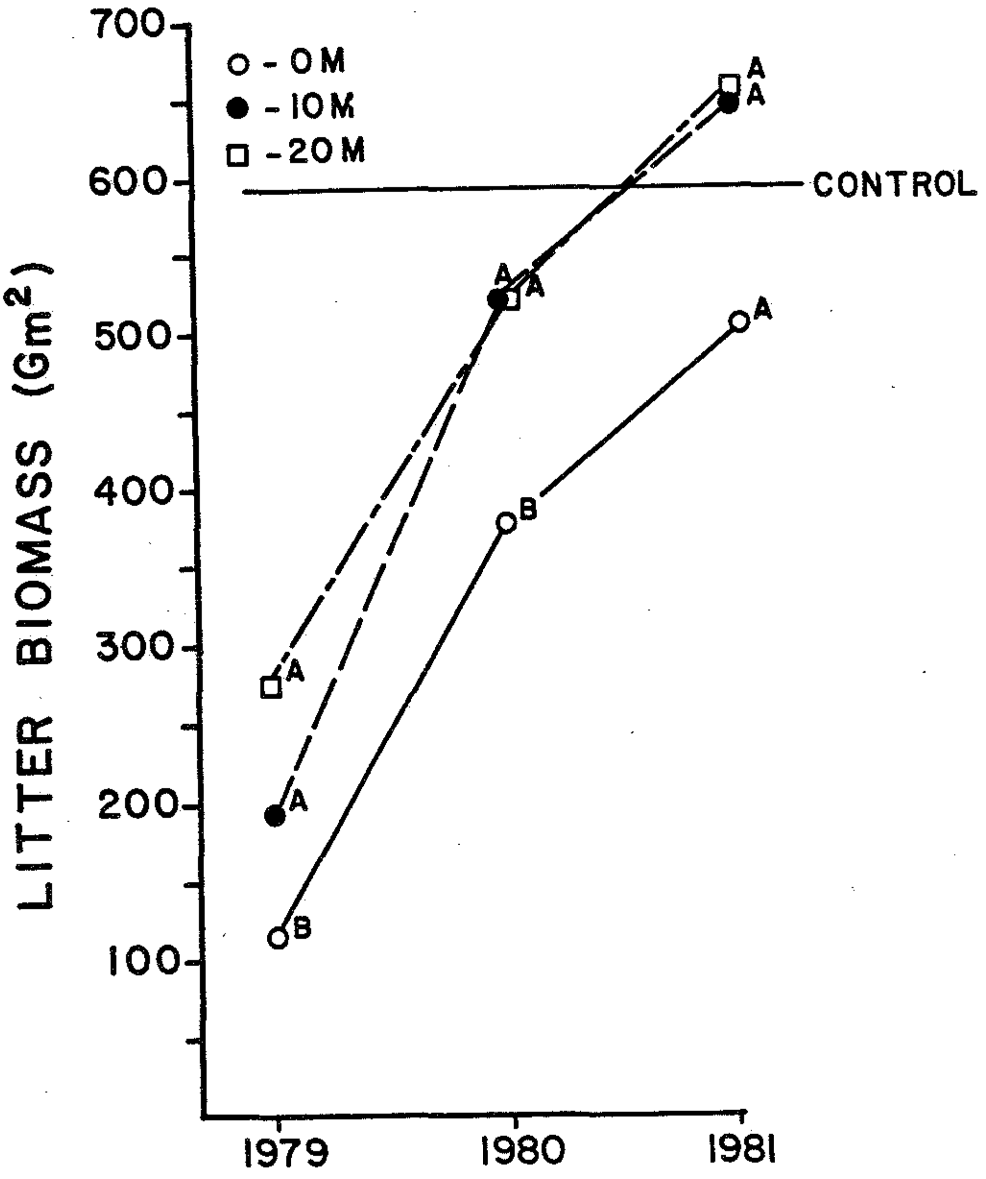


Figure 6. Mean litter biomass at 0, 10, and 20 meters, for the three treated sites combined, from 1979 to 1981. Values are taken from Table 3. Means read vertically, within each year, that share the same superscript are not signifienatly different. Average litter biomass from the Control Site is plotted for comparison.

sites. This lead us to speculate that the size of the litter compartment would ultimately reach a level that would be greater than pretreatment levels. Several years of additional data would be needed to test this hypothesis but we believe that it is an important issue because these wetlands are often burned. If the litter layer is thicker, the fires might be hotter and the resultant burn might be deeper into the peat, especially in sites where the water table has been lowered. This aspect on the study will be discussed further in the Summary and Recommendations section.

In 1979 and 1980, we had determined that there were significantly higher concentrations of nitrogen in live shoots at the Open and Water Control Sites Was that pattern of long-term duration or only temporary?
To answer this question would require several more years of data but our 1981 measurements suggest that the pattern is long-term. Reasons for this are discussed further in the next section. Nitrogen concentrations were still significantly higher at the Open Site (1.02%) and lower at the Closed Site (0.76) in 1981.

Fertilization Study

The hypothesis tested was that plants at the Open Site would have higher shoot nitrogen concentrations following fertilization than plants at the Closed and Control Sites because the substrate moisture content had been lowered enough to make nitrogen more available.

Our prediction was that plants in the fertilized plot at the Open Site would have significantly higher shoot nitrogen concentrations than plants at either the Closed or Control Sites. In addition, because the

the water table is lower nearer the ditches (see Part I) and the substrate contains less water (Fig. 2) we predicted that there would be a distance effect and that plants in fertilized plots near the ditches would have higher tissue nitrogen concentrations than plants located in fertilized plots 20 meters from the ditch. The following sequence was predicted in shoot nitrogen concentration in fertilized and unfertilized plots.

(Open, 0 meters) > (Open, 20 meters) ≥ (Closed,
0 meters) > (Closed, 20 meters) = (Control)

With very few exceptions the predicted and observed results matched.

Figures 7-10 are compilations of data for the 5 sample dates and demonstrate the changes that occurred in fertilized and unfertilized plots. In each diagram, points to the left of the center line indicate that nitrogen concentrations at the ditched sites were higher than at the Control Site. Values to the right of the center line represent nitrogen concentrations that were lower at the ditched sites. In each figure, an * appears next to the symbol when the mean for that site and sample date combination were significantly different from the Control Site.

1. Spartina patens

In the unfertilized plots, the highest shoot nitrogen concentrations were at the Open Site at 0 meters (Fig. 7). Four of the five values plotted are to the left of the center line and each was significantly greater than data from the Control Site. In the fertilized plots, the array of data points for 0 meters at the Open Site was further from the center line (Fig. 8) and all values measured at the fertilized plot were significantly greater than concentrations measured at the Control Site. Shoot nitrogen concentrations increased an average of 40.9 ± 0.07% when fertilized and unfertilized plots were compared for the 0 meter distance at the Open Site.

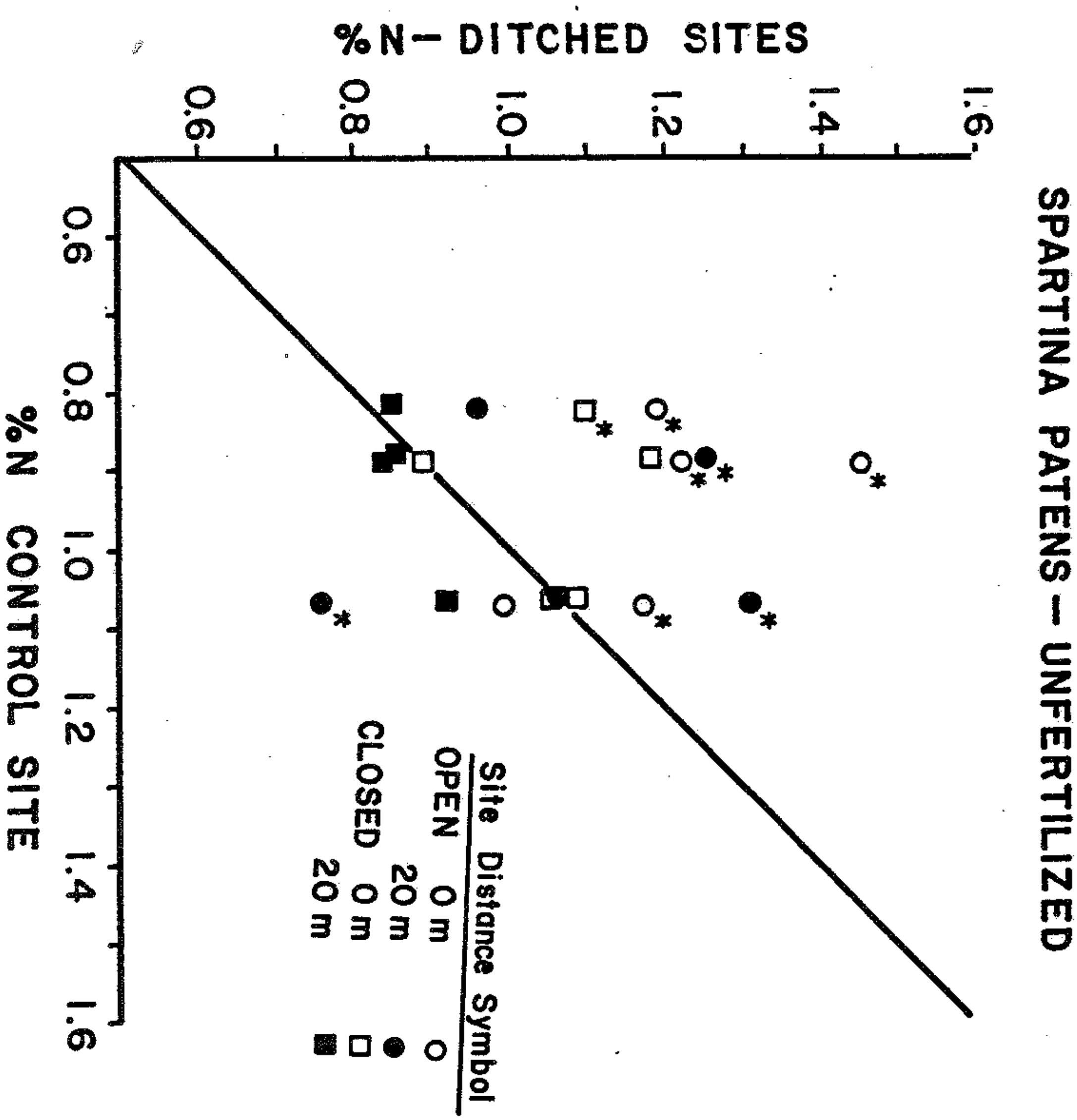
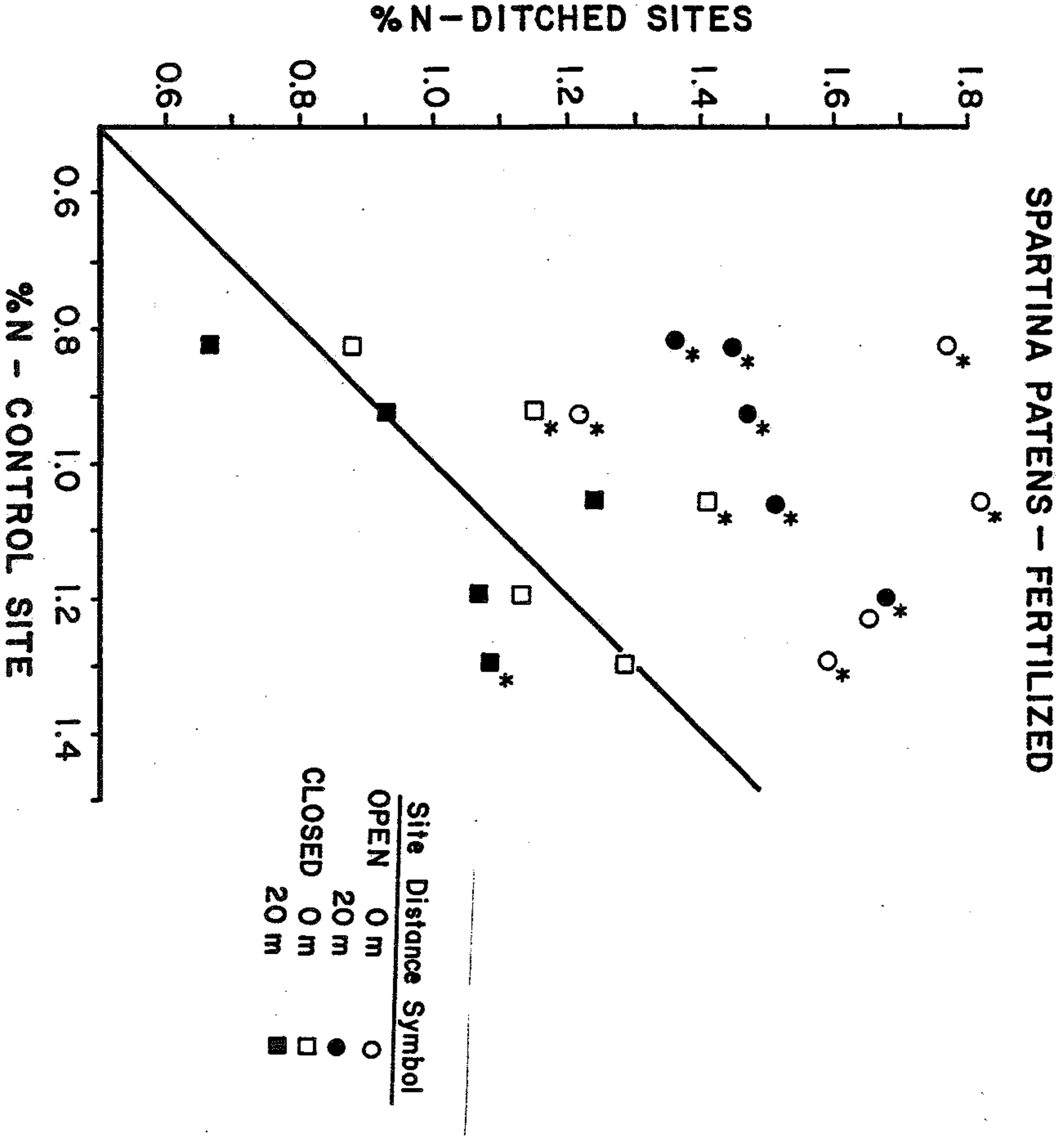


Figure 7. Comparison of nitrogen concentrations (%) of S. patens in unfertilized plots in the Open and Closed Sites with unfertilized plots in the Control Site. Significant differences between the ditched Sites and the Control Site are indicated with a *.

Figure 8. Comparison of nitrogen concentrations (%) of S. patens in fertilized plots in the Open and Closed Sites with fertilized plots in the Control Site. Significant differences between the ditched Sites and the Control Site are indicated with a *.



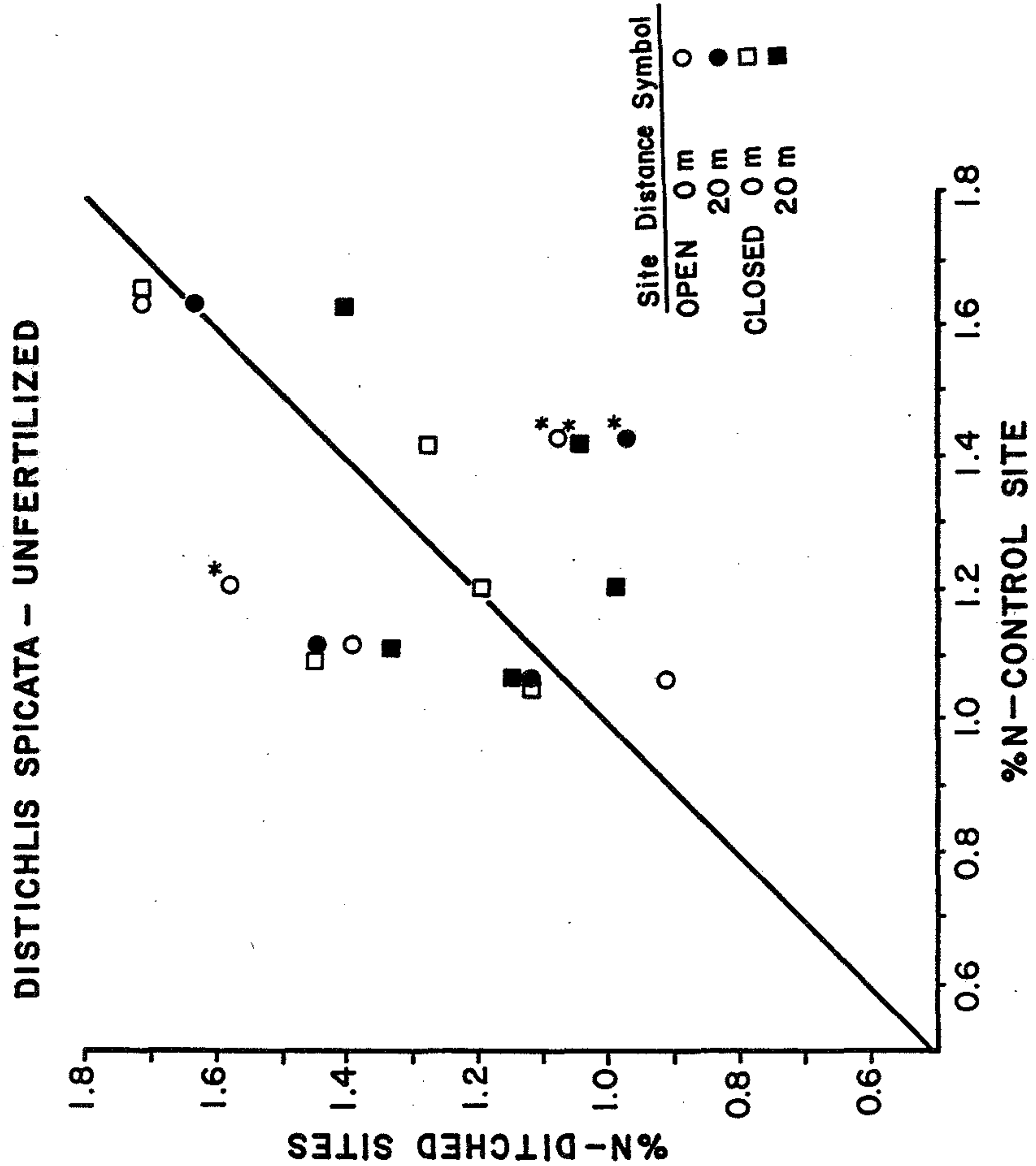
The same response occurred for S. patens at 20 meters at the Open Site. In the unfertilized plots, four of the data points were to the left of the center line (Fig. 7) but only on two sample dates were the values significantly greater than those measured at the Control Site. Following fertilization, shoot nitrogen concentrations were always significantly greater (Fig. 8) and the average increase was 48.5 ± 26.0%.

In only one instance were shoot concentrations of S. patens in the unfertilized plot at the Closed Site significantly greater than shoot concentrations at the Control Site (Fig. 7). In the fertilized plots at the Closed Site, shoot concentrations of S. patens were significantly greater on three sampling dates at 0 meters (Fig. 8). At no time were nitrogen concentrations at 20 meters greater than those measured at the fertilized Control Site. The average increase, when fertilized and unfertilized plots were compared, was 11.4 ± 8.6 and 14.2 ± 13.1% at the Closed Site which was similar to the response measured at the Control Site (14.5 ± 11.8%).

2. Distichlis spicata

The response of D. spicata was more variable (Figs. 9 and 10). An increase in nitrogen concentration, as predicted, occurred at 0 meters at the Open Site but the differences were only significantly different from the fertilized Control Site on two sampling dates. In the unfertilized plots there was no pattern when shoot nitrogen concentrations of D. spicata at 0 meters at the Open Site were compared to data from the unfertilized Control Site. Similarly, there was no positive significant response to fertilization for D. spicata at 20 meters at the Open Site or 0 and 20 meters at the Closed Site.

Figure 9. Comparison of nitrogen concentrations (%) of *D. spicata* in unfertilized plots in the Open and Closed Sites with unfertilized plots in the Control Site. Significant differences between the ditched Sites and the Control Site are indicated with a *.



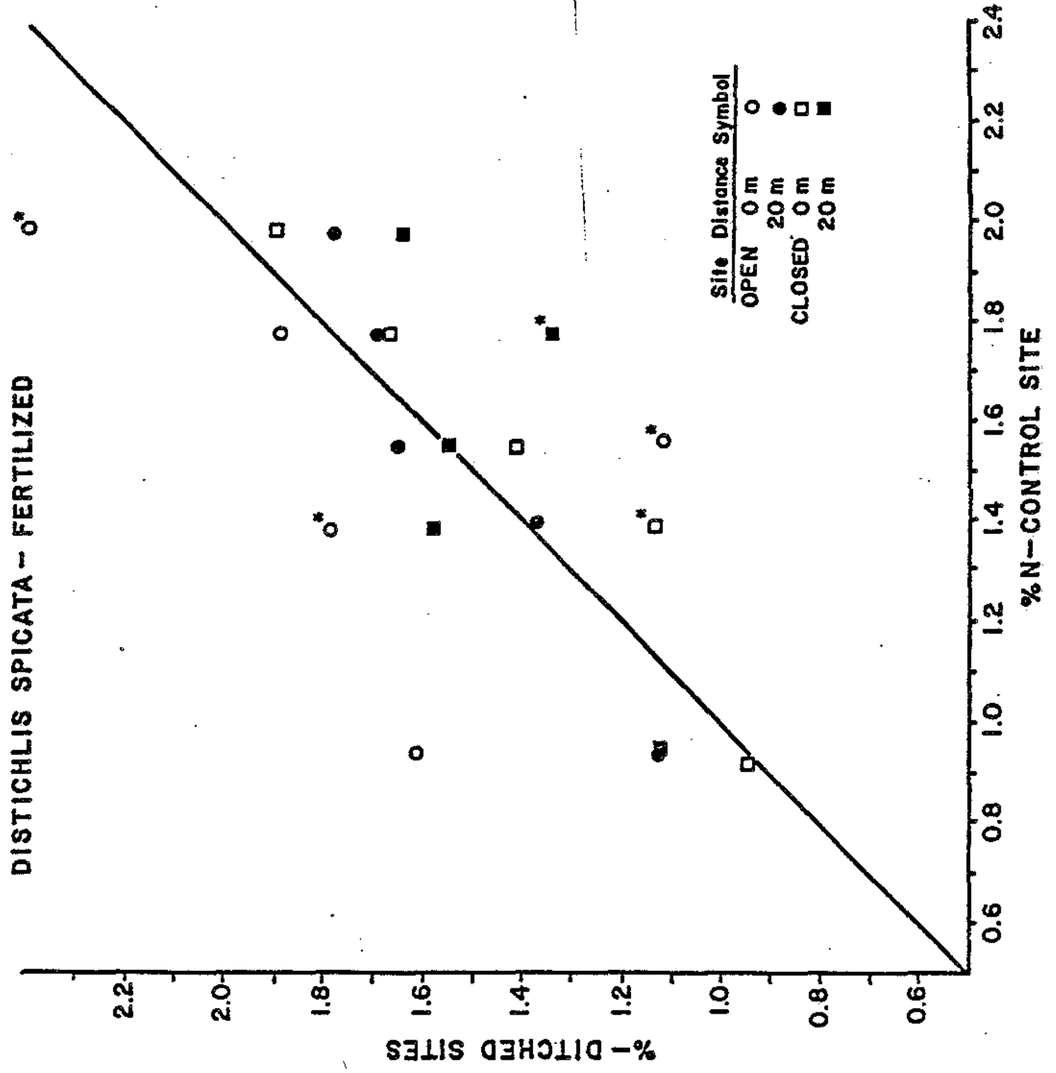


Figure 10. Comparison of nitrogen concentrations (%) of D. spicata in fertilized plots in the Open and Closed Sites with fertilized plots in the Control Site. Significant differences between the ditched Sites and the Control Site are indicated with a *.

Why was the responses of *D. spicata* so different from that of *S. patens*? *Spartina patens* has a much shallower root/rhizome system than *D. spicata*. In 1981, as part of another study (Whigham personal observation) we collected substrate cores at the Open, Closed and Control Sites. The cores, collected near the plots used in this study, were washed and the rhizome biomass determined for *D. spicata* and *S. patens* in 0-5, 5-10, 10-15, and 15-20 cm depth intervals. Figure 11 shows some results of that study. At all sites, the rhizomes of *S. patens* are found near the surface whereas *D. spicata* rhizomes occur throughout the profile. Barber (personal communication) has also shown that *S. patens* has a small rhizome and a very dense root mat near the surface. Since the plots were only fertilized once, it seems likely that most of the fertilizer was absorbed in the surface layers of the peat substrate where the roots and rhizomes of *S. patens* were concentrated. The lack of any clear response of *D. spicata* may have been also due to increased moisture content in the deeper substrate where nitrogen fertilizer may not have reached or may not have been available due to anoxic conditions (Mendelssohn 1979, Valiela et al. 1978). What is clear from the study is that there was a distinct site response with fertilization affects being greatest at the Open Site. These data suport the hypothesis that nitrogen assimilation is primarily controlled by substrate moisture conditions.

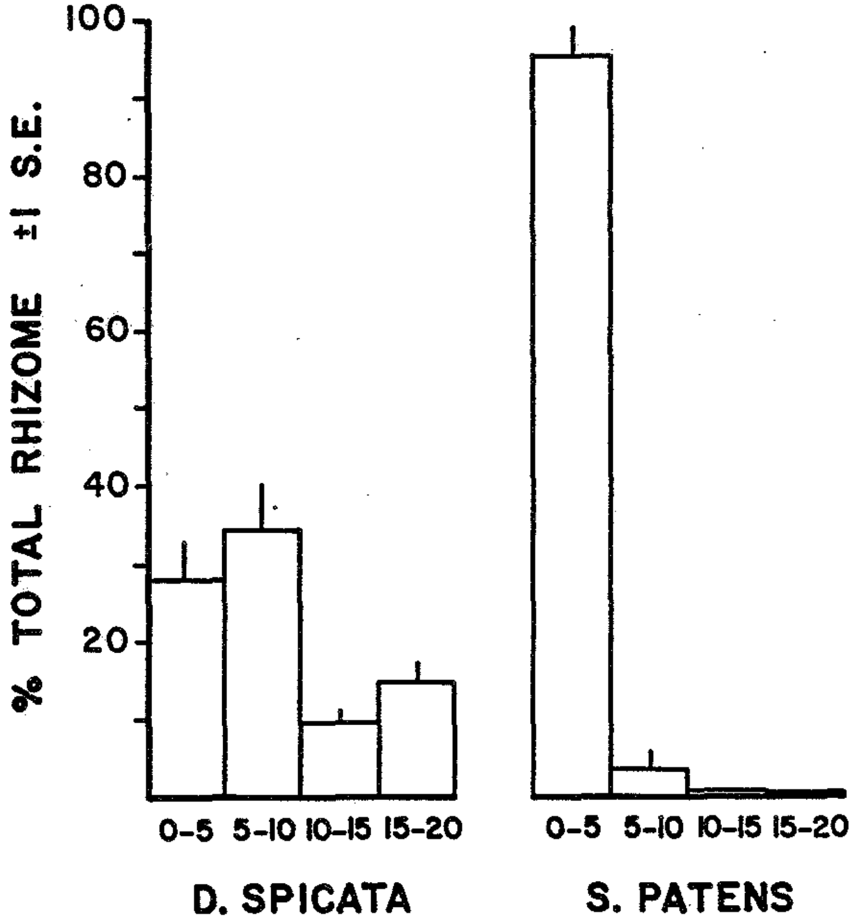


Figure 11. D. spicata and S. patens distribution (%) of rhizome biomass in substrate cores collected at the Open, Closed and Control Sites. Data are means of 9 samples for each depth interval shown.

SUMMARY AND RECOMMENDATIONS

It is clear that the ditched areas have all recovered from the management activities. What is unclear, however, are several issues related to the long-term effects. Our evidence shows clearly that the two sites that are directly coupled to the estuary are still undergoing changes in vegetation composition. It now appears that the Open and Water Control Sites will become almost completely dominated by *I. frutescens* and *B. halimifolia*. Our data also indicate that shoot nitrogen concentrations will continue to be elevated at those sites. The litter compartment has completely recovered to pretreatment levels at all sites and the data from 1979 and 1980 demonstrate that litter may become enriched in nitrogen and that the litter horizon will be thicker due to lower rates of decomposition.

The two questions that seem to be of primary importance are: 1) Can vegetation changes at the Open and Water Control Site be reversed? This may be a very important question because if other areas begin to change following ditching, can the process be stopped and/or reversed so that the ditched areas remain open (dominated by marsh grasses) and more suitable for waterfowl and muskrat use; and 2) If the trend toward increased litter biomass continues, is this a possible threat because the wetlands are frequently burned and a hotter fire (from a greater fuel load) can lead to a deeper peat burn and killing of the plants, particularly the shallow rooted *Spartina patens*?

Like most studies, this one has provided answers to some questions and has created others. I recommend that several other studies, all small in scale and low in cost, should be conducted. The questions presented above need to be addressed and a framework for the research would be as follows:

1) Can the invasion of I. frutescens and B. halimifolia be reversed?

    A. Procedure: Convert 1/3 of the Open Site at Deal Island into a Closed Site and 1/3 into a Water Control Site. Establish permanent plots in each area and monitor vegetation in the plots each year for a period of 3-5 years. Once the manipulations would be completed, the study would only require 2 workdays per year to sample the plots. At the same time, plant tissues of the dominant species could be collected and analyzed for nitrogen content for very little cost.

2) Will the litter layer continue to increase in size and will a deeper burn result in areas where ditched wetlands are coupled to the estuary?

This would require a more detailed study but useful data could be compiled by continuing to sample the litter layer at the 3 Deal Island sites. This project would require 1 day of additional field work and several days of laboratory work. Should it be found, with another year or two of data, that litter is still accumulating, then the issue of possible impact of fires could be addressed.

3) Why does I. frutescens and B. halimifolia invade some areas and not others? It would be important to know the germination requirements of both species. I believe it is particularly important to know the type of substrate that provides optimum germination sites (peat, clay, etc.) and what the moisture content needs to be in order for seedlings to become established. This information would be useful in making decisions about how far the water table can be lowered given the type(s) of substrates found in areas where ditching will be done.

This project would require both field and laboratory experiments. It could be a student project and might take 2 years. Cost would be minimal if funds could be obtained to employ a student from one of the Universities or the local Community College. Laboratory studies on germination ecology could be conducted in the winter and field studies during the spring and summer.

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