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Field Studies in the Lynnhaven River for Calibration of a Tidal Prism Water Quality Model

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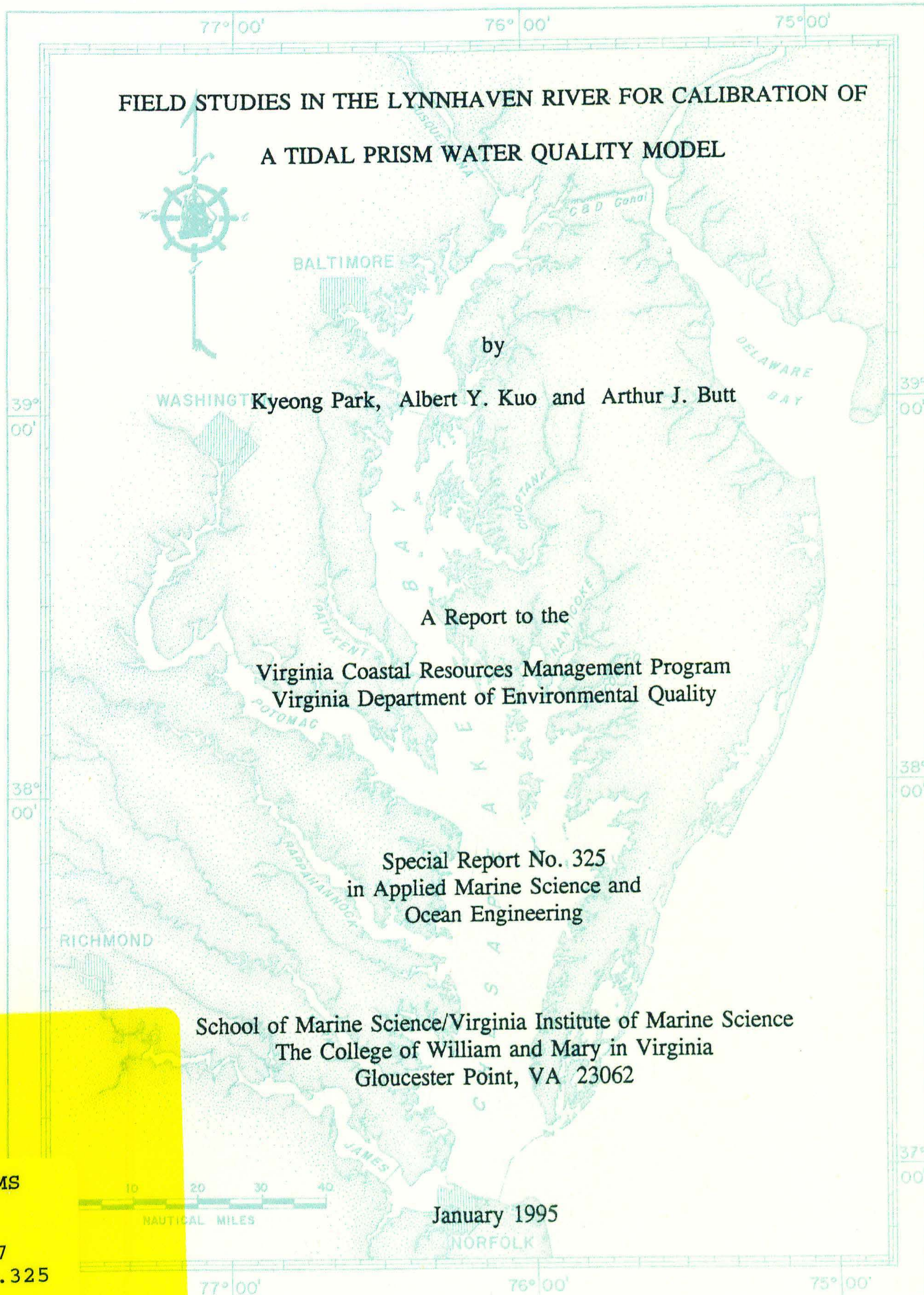

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by

Kyeong Park, Albert Y. Kuo and Arthur J. Butt

A Report to the

Virginia Coastal Resources Management Program
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School of Marine Science/Virginia Institute of Marine Science
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I. Introduction

Under the Virginia Coastal Resources Management Program Grants (VCRMPG) for FY '93, a tidal prism water quality model has been developed for small coastal basins and tidal creeks. The rationale of the model development is provided and the model is described in detail in Kuo & Park (1994). The tidal prism model uses the concept of tidal flushing for physical transport processes. The nutrient and phytoplankton kinetics are mostly from the Chesapeake Bay three-dimensional water quality model (Cerco & Cole 1994), and the model also includes the sediment process model of the main Bay (DiToro & Fitzpatrick 1993). The model has twenty four water column and twenty seven sediment state variables (Table I-1). The model, being a generic model applicable to any small coastal basins and tidal creeks, and operational on a personal computer, should provide a tool to state and local agencies for water quality management of Virginia's small coastal basins.

The application of the tidal prism water quality model to the Lynnhaven River is being conducted in a project "Development of a Water Quality Model for Small Coastal Basins to Address Management Needs" under VCRMPG for FY '94. The model calibration and verification requires extensive data set. Since 1975, the Tidewater Regional Office of the Department of Environmental Quality (DEQ) has been monitoring bimonthly the water quality conditions in the Lynnhaven River. Table I-2 lists the water quality parameters measured by this DEQ monitoring program. Although the DEQ monitoring program has produced extensive data set for the Lynnhaven River, it does not include several water quality parameters that are essential for model calibration and verification. For example, algal biomass plays a central role in the model affecting almost all other state variables, and thus measurements of algal biomass, which are not included in the DEQ monitoring program, are indispensable for model calibration and verification.

A supplemental field study, which measures the water quality parameters not covered by the existing DEQ monitoring program, was conducted in the Lynnhaven River in June-December, 1994. The field surveys, which hereafter are referred to as the VIMS (Virginia Institute of Marine Science) surveys, include four longitudinal surveys and one intensive survey. The VIMS surveys supplement the existing DEQ monitoring program and produce a more complete data set for the Lynnhaven River.

This report documents the results of the VIMS surveys and some of the DEQ monitoring program. Chapter II describes the field and laboratory procedures employed in the VIMS surveys. The data for June-December, 1994, i.e., the data from the VIMS surveys supplemented by the DEQ monitoring data, are presented and discussed in Chapter III. The data from the VIMS surveys are also presented in tabular format in Appendix A. The long-term DEQ monitoring data between 1976-1994 are presented for the inlet of the Lynnhaven River in Chapter IV. The DEQ data at the remaining eight stations are presented in Appendix B. The primary purpose of this study is to produce and identify data sets for the application of the tidal prism water quality model to the Lynnhaven River. As a conclusion, suggestion for the uses of data, including the VIMS survey data, the DEQ data and others, for the application of the tidal prism water quality model is given in Chapter V.

Table I-1. Model state variables[a].

WATER COLUMN:	
1) salinity	2) temperature
3) cyanobacteria (blue-green algae)	4) diatoms
5) green algae	
6) refractory particulate organic carbon	7) labile particulate organic carbon
8) dissolved organic carbon	
9) refractory particulate organic phosphorus	10) labile particulate organic phosphorus
11) dissolved organic phosphorus	12) total phosphate
13) refractory particulate organic nitrogen	14) labile particulate organic nitrogen
15) dissolved organic nitrogen	16) ammonium nitrogen
17) nitrite+nitrate nitrogen	
18) particulate biogenic silica	19) available silica
20) dissolved oxygen	21) chemical oxygen demand
22) total suspended solid	
23) total active metal[b]	
24) fecal coliform bacteria	
SEDIMENT:	
1-3) particulate organic carbon, G_1, G_2 and G_3 classes in Layer 2	
4-6) particulate organic nitrogen, G_1, G_2 and G_3 classes in Layer 2	
7-9) particulate organic phosphorus, G_1, G_2 and G_3 classes in Layer 2	
10) particulate biogenic silica in Layer 2	
11-12) sulfide/methane[c], Layer 1 and 2	
13-14) ammonium nitrogen, Layer 1 and 2	15-16) nitrate nitrogen, Layer 1 and 2
17-18) phosphate phosphorus, Layer 1 and 2	
19-20) available silica, Layer 1 and 2	
21) ammonium nitrogen flux	22) nitrate nitrogen flux
23) phosphate phosphorus flux	24) silica flux
25) sediment oxygen demand	26) release of chemical oxygen demand
27) sediment temperature	

[a] The tidal prism water quality model is described in Kuo & Park (1994).

[b] Total active metal may not be modeled by using total suspended solid as sorption site for phosphate and dissolved silica.

[c] Sulfide is modeled for salt water while methane is modeled for fresh water.

Table I-2. Parameters[a] measured by the DEQ monitoring program in the Lynnhaven River.

salinity	temperature
total organic carbon	
total phosphorus	phosphate phosphorus
total Kjeldahl nitrogen	ammonium nitrogen
nitrite+nitrate nitrogen	
silica	
dissolved oxygen	chemical oxygen demand
suspended solids (total, fixed and volatile)	
fecal coliform bacteria	
turbidity	

[a] Only those parameters that are relevant to the application of the tidal prism water quality model (Kuo & Park 1994) are listed.

II. Description of the VIMS Surveys

Two types of field surveys were conducted in June-December, 1994 at the Lynnhaven River (Fig. II-1): longitudinal and intensive surveys.

II-1. Field Surveys

A. Longitudinal survey: The DEQ monitoring program has nine stations in the Lynnhaven River system (Table II-1 and Fig. II-1). The water quality parameters measured by the DEQ program are listed in Table I-2. The "longitudinal survey" was to enhance the existing DEQ monitoring program. For four times in 1994 (June 21, August 23, October 4 and December 7), the VIMS field personnel collected samples from the existing nine stations in the Lynnhaven River on the same dates as the DEQ monitoring program. Since the VIMS surveys were to collect supplemental data to the DEQ monitoring program, the sampling times were synchronized with the DEQ monitoring program, rather than following a certain tidal phase. It took approximately 2 to 2½ hours to cover all nine stations.

Stations L1 to L7 are water stations approached by boat, and Stations LBC and TC are land stations sampled from the bridges. At seven water stations, water samples were taken from a 23-ft open boat using a Frautchii bottle. Surface (1 m below surface) and bottom (1 m above bottom) samples were taken at Station L4 (inlet), and only surface samples were taken at the remaining water stations because of shallow depths (Table II-1). At two land stations, a Frautchii bottle was lowered from the bridges to collect water samples. The water samples were filtered within 2 to 2½ hours of collection to separate the dissolved and particulate fractions. For particulate biogenic silica, 47 mm Milpore filters were used and for total particulate carbon/nitrogen, 13 mm Whatman GF/F glass fiber filters were used. For all other parameters, a 47 mm Whatman GF/F glass fiber filters were used. The filters and filtrates were prepared for the parameters listed in Table II-2, stored on ice, brought back to, and analyzed at the Nutrient Analysis Laboratory (NAL), VIMS.

For all four longitudinal surveys, bottom sediment cores were taken using a Phleger gravity corer at Stations L2 and L6 (Fig. II-1). From a sediment core, two samples were prepared. The oxic top portion (about 1 cm) and the lower anoxic portion of the core were removed and placed into plastic tubes. When removing anoxic portion, care was taken not to take sediment samples deeper than 10 cm, below which the sediment is believed to be inactive (DiToro & Fitzpatrick 1993). The plastic tubes were stored in ice, brought back to the NAL, and analyzed for parameters listed in Table II-2.

In addition to the water and bottom sediment sampling, the longitudinal surveys also included the followings. At the water stations, vertical profiles of salinity and temperature were obtained using an Applied MicroSystem CTD (Conductivity-Temperature-Depth) on the first two surveys (June 21 and August 23). On the last two surveys (October 4 and December 7), temperature was measured *in situ* using a pH meter (Beckman). From two depths (surface and bottom) at Station L4 and one depth (surface) at the remaining water stations, four Winkler bottle samples were taken using a Frautchii bottle. Two Winkler bottle samples were analyzed for dissolved oxygen and the other two were for salinity at the NAL. Secchi disk depths were also recorded at the water stations. At the land stations, which were accessed from the bridges, water temperature was measured *in situ* using a pH meter (Beckman), and four Winkler bottle samples were taken, two for dissolved oxygen and the other two for salinity measurements. All parameters measured, either *in situ* or at the laboratory, are listed in Table II-2. Some parameters were measured by both the longitudinal surveys and the DEQ program, and are used for consistency check between two surveys (Table II-2).

B. Intensive survey: Another type of field survey conducted was an "intensive survey." Large variations within a tidal cycle or a day may exist for chlorophyll 'a', dissolved oxygen and suspended solid concentrations. Hence, tidal cycle or daily averages and ranges for these parameters cannot be estimated from the bimonthly DEQ program or longitudinal surveys. One intensive survey, every 2.5-hour sampling over 25 hours at Stations L2 and L6, was conducted on August 9-10, 1994 using a 23-ft open boat. Samples from Station L6 were taken over 25 hours from 17:00 August 9 till 18:00 August 10, while samples from Station L2 were taken only for 10 hours during daylight hours of

August 10.

All samples were taken from the surface (1 m below surface) at both stations. Water temperature and dissolved oxygen were measured using a YSI (Yellow Strings Instrument) DO meter. Four Winkler bottle samples were taken using a Frautchii bottle. Two Winkler bottle samples were analyzed for salinity and the other two were for dissolved oxygen at the NAL to check the performance of the YSI DO meter and probe. Secchi disk depths were recorded during daylight hours. The water samples upon collection were filtered on board through a 47 mm Whatman GF/F glass fiber filter to separate the dissolved and particulate fractions. The filters were prepared for the parameters listed in Table II-3, stored in ice, brought back to, and analyzed at the NAL, VIMS. All parameters measured, either *in situ* or at the laboratory, are listed in Table II-3.

II-2. Laboratory Analysis

The water and bottom sediment samples collected in longitudinal and intensive surveys were analyzed for the water quality parameters listed in Tables II-2 and II-3 at the NAL. The analytical methods, which are briefly described in this section, generally follow the methods in EPA (1979), NAL Procedures Manual (1994) and Standard Methods (1992).

A. Salinity and dissolved oxygen: Salinity was measured using a salinometer and is reported in parts per thousand (ppt). Dissolved oxygen was measured using Winkler titration method and is reported in mass per unit volume of water (g m^{-3}).

B. Filter: The residue retained on the pre-weighted and pre-muffled filter was dried to a constant weight at 103 to 105°C to measure total suspended solid. Then, the filter was further muffled to a constant weight at 500±50°C to measure total fixed solid. The weight lost on ignition is total volatile solid.

Total particulate carbon and total particulate nitrogen were measured using a Carlo Erba NA1500 C/N analyzer following the procedure in NAL Procedures Manual (1994), which is an adaptation of the method in Menzel & Vaccaro (1964). Total particulate phosphorus was measured using the method in Aspila et al. (1976), which muffles the filter followed by the extraction with hydrochloric acid. Particulate (sorbed) inorganic phosphorus was measured using the same method as total particulate phosphorus except that the filter was not muffled before extraction with acid. The extracts, after dilution, were analyzed for dissolved phosphate using a continuous flow analyzer. Milpore filters (0.45 μm pore size) prepared for particulate biogenic silica were digested with NaOH in a 100°C water bath, and analyzed for silica on a Technicon Autoanalyzer using the method in Paasche (1973). The filters for chlorophyll 'a' and phaeophytin were treated with $MgCO_3$ upon filtering, and then ground, extracted with 90% acetone and measured using a scanning spectrophotometer. All particulate parameters are reported in mass per unit volume of water (g m^{-3} except chlorophyll 'a' and phaeophytin in mg m^{-3}).

B. Filtrate: The samples for dissolved organic carbon, which were acidified with 6 N HCl to pH 2 upon filtering, were bubbled with ultra pure air for 6 minutes to remove inorganic carbon. Dissolved organic carbon then was measured using a Shimadzu Total Organic Carbon Analyzer, Model TOC-5000. Total dissolved nitrogen and total dissolved phosphorus were measured using alkaline persulfate digestion method, which is an adaptation of the method in D'Elia et al. (1977). Dissolved phosphate was measured using a colorimetric method with ascorbic acid reduction. The procedure for determination of dissolved silica is based on the reduction of a silicomolybdate in acidic solution to molybedenum blue by ascorbic acid. All dissolved parameters, which were measured using continuous flow analyzers, are reported in mass per unit volume of water (g m^{-3}).

C. Bottom sediment: The sediment samples were dried to a constant weight at 103 to 105°C. Total solid was measured in percentage from the weight difference before and after drying at 103 to 105°C. Total solid is reported in percent, i.e., mass per mass of sediment (0.01 g g^{-1}).

All other parameters for sediment samples were measured using a known mass of dried sediment samples. The mass of total carbon/nitrogen was measured by employing the same method used for total particulate carbon/nitrogen for water column filters. The total inorganic phosphorus samples were directly extracted with hydrochloric acid. The total phosphorus samples were muffled in a furnace for approximately 2 hours at 550°C, and then the phosphorus was extracted with hydrochloric acid. The extracts, after dilution, were analyzed for dissolved phosphate using a continuous flow analyzer. Total carbon, total nitrogen, total phosphorus and total inorganic phosphorus are reported in mass per mass of dry solid (mg g^{-1}).

Table II-1. Stations for both the DEQ monitoring program and the VIMS surveys.

Station ID	km from Inlet	Depth[a] (m)	Remarks	Sampling Depth
INLET:				
L4	km 0.0	9.5 m	Rt. 60 at inlet	T and B[c]
WESTERN BRANCH:				
L1	km 6.45	1.8 m	Buoy 34 (old 40)	T[c]
L2[b]	km 4.72	2.5 m	Buoy 26	T[c]
L3	km 3.05	1.8 m	Buoy 20 (old 18)	T[c]
TC	km 9.19		Bridge on Rt. 58	*[d]
EASTERN BRANCH:				
L5	km 2.77	2.5 m	Mapps Point	T[c]
L6[b]	km 4.76	2.0 m	Off Trants Point	T[c]
L7	km 7.08	1.7 m	Off Wolfsnare Point	T[c]
LBC	km 9.65		Old London Bridge on Potters Road	*[d]

[a] Water depth at low tide.
[b] Bottom sediment core stations and intensive survey stations.
[c] T = 1 m below surface and B = 1 m above bottom.
[d] At the land stations (LBC and TC), the water samples were collected by lowering a Frautchii bottle from the bridges.

Table II-2. Water quality parameters measured for water and bottom sediment samples collected at longitudinal surveys.

A. *IN SITU*:	
	salinity (S)[a]
	temperature (T)[a]
	secchi disk depth (SD)
B. LABORATORY:	
1. Winkler Bottle:	salinity (S)[a]
	dissolved oxygen (DO)[a]
2. Filter:	total particulate carbon (PC)
	total particulate nitrogen (PN)
	total particulate phosphorus (PP)
	particulate (sorbed) inorganic phosphorus (PO4p)
	particulate biogenic silica (PSi)
	chlorophyll 'a' (Chl)/phaeophytin
3. Filtrate:	dissolved organic carbon (DOC)
	total dissolved nitrogen (TDN)
	total dissolved phosphorus (TDP)
	dissolved phosphate (PO4d)
	dissolved silica (DSi)
4. Bottom Sediment:	total solid (STS)[b]
	total carbon (STC)
	total nitrogen (STN)
	total phosphorus (STP)
	total inorganic phosphorus (SPO4p)

[a] These parameters also are measured by the DEQ monitoring program in June-December, 1994, and thus will be used for consistency check between the DEQ program and the VIMS surveys.

[b] The first character "S" indicates the parameters measured for the sediment cores.

Table II-3. Water quality parameters measured for water samples collected at intensive survey.

A. *IN SITU*:	
	temperature (T)
	dissolved oxygen (DO)
	secchi disk depth (SD)
B. LABORATORY:	
1. Winkler Bottle:	salinity (S)
	dissolved oxygen (DO)
2. Filter:	total suspended solid (TSS)
	total fixed solid (TFS)
	chlorophyll 'a' (Chl)/phaeophytin

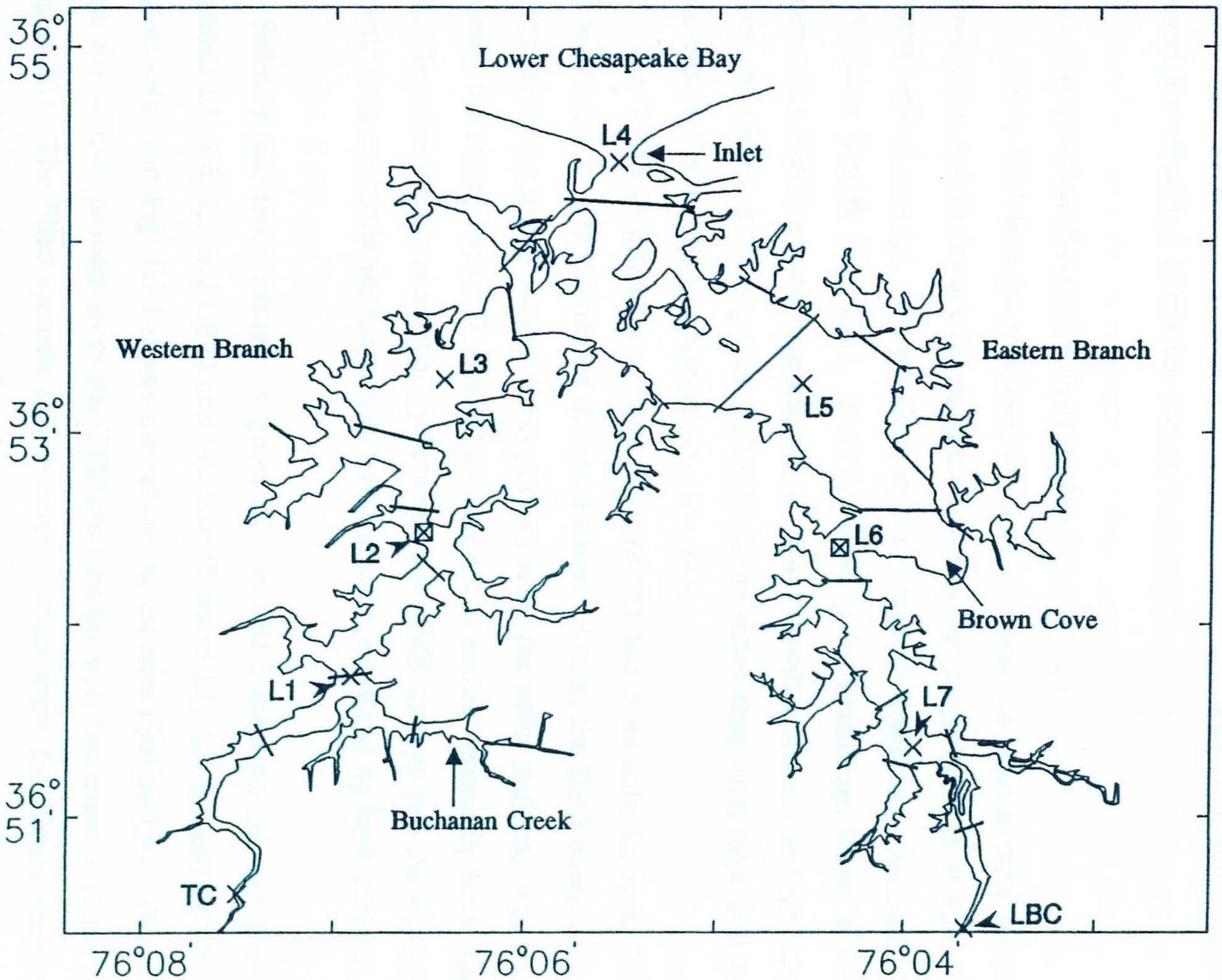


Figure II-1. The Lynnhaven River showing the station locations for 1994 VIMS surveys: longitudinal stations (×) and intensive stations (☐). Solid lines are model transects.

III. Results from the VIMS Surveys: Conditions in June-December, 1994

Since the VIMS longitudinal surveys were to collect supplemental data to the DEQ monitoring program, the longitudinal survey data are combined with the DEQ monitoring data taken on the same dates, and are presented in Section III-1. The data from the VIMS intensive survey follow in Section III-2. The data from both longitudinal and intensive surveys are presented in tabular format in Appendix A.

III-1. Longitudinal Surveys with DEQ Monitoring Data

Table III-1 lists the predicted times of high and low tides at three locations (Inlet, Brown Cove and Buchanan Creek Entrance), and the sampling times at nine stations for all longitudinal surveys. Brown Cove is in the Eastern Branch and Buchanan Creek is in the Western Branch (Fig. II-1). The tidal wave in the Lynnhaven River, which is a small system, has standing wave characteristics. Water floods from low to high tide with slack-before-ebb (SBE) occurring near high tide, while water ebbs from high to low tide with slack-before-flood (SBF) occurring near low tide.

The VIMS longitudinal surveys collected the data from both the land (LBC and TC) and water (L1 to L7) stations on the same dates, whereas the DEQ monitoring program visited the land stations on the different dates from the water stations. For the land stations, therefore, the DEQ monitoring data are presented separately from the VIMS data. To examine the compatibility between the VIMS surveys and the DEQ program, comparisons are made for the parameters that were measured by both surveys.

A. Salinity and temperature: Figures III-1 and III-2 show the salinity in the Eastern (Stations L5, L6, L7 and LBC) and Western (Stations L1, L2, L3 and TC) branches respectively, and Fig. III-3 shows the salinity at the inlet (Station L4). The open symbols show the vertical profiles from the CTD casts on the first two surveys (June 21 and August 23). The filled symbols at 1 m below surface show the salinity measured from the Winkler bottle samples: the bottle salinity also was taken from the bottom of the inlet (Fig. III-3). Good agreement exists between the CTD casts and the bottle samples, and the vertical profiles from the first two surveys show that the system is vertically well-mixed. On the last two surveys (October 4 and December 7), therefore, only the bottle samples were taken 1 m below the surface: the bottle samples also were taken from the bottom of the inlet (Fig. III-3). The filled symbols at the top of figures show the salinity measured by the DEQ monitoring program at 1 m depth.

Figures III-4 and III-5 show the temperature in the Eastern and Western branches respectively, and Fig. III-3 shows the temperature at the inlet. As in salinity, the vertical profiles of temperature (open symbols), taken using the CTD casts on the first two surveys, show that the system is vertically well-mixed. On the last two surveys, therefore, the near surface temperature was measured *in situ* (filled symbols at 1 m below surface): the bottom temperature also was measured at the inlet (Fig. III-3). The filled symbols at the top of figures show the temperature measured by the DEQ monitoring program.

Figures III-1 to III-5 show that the system is vertically well-mixed. The Lynnhaven River system, a small and narrow coastal basin, exhibits one-dimensional sectionally-homogeneous behavior. Salinity changes in response to tide, increasing as seawater coming in (during flooding current from low to high tide) and decreasing as seawater going out (during ebbing current from high to low tide). The survey on June 21 was conducted during ebb, i.e., from high to low tide (Table III-1), resulting in low salinity at all water stations (Figures III-1 to III-3). The August 23 survey was conducted around SBE (Table III-1), resulting in high salinity at all water stations (Figures III-1 to III-3). Salinity also is affected by freshwater discharge, as it limits the intrusion of seawater. At land stations (LBC and TC), salinity is the highest at the survey on October 4 and the lowest at the survey on December 7, suggesting that freshwater discharge be relatively the lowest at the October 4 survey and the highest at the December 7 survey. At all water stations, salinity at the October 4 survey, which was conducted during ebb and low freshwater discharge, was higher than that at the December 7 survey, which was conducted during flood and high freshwater discharge. At all nine stations, temperature decreased from June to December, with one exception at the inlet, which is discussed in Section III-1E.

B. Spatial distribution: Figure III-6 shows the spatial distributions on June 21 for salinity, dissolved oxygen, chlorophyll, particulate and total dissolved phosphorus, particulate inorganic phosphorus, particulate and total dissolved nitrogen, ammonium and nitrate nitrogen, total suspended and fixed solids, particulate and dissolved organic carbon, dissolved and biogenic particulate silica, and secchi depth. Among these parameters, ammonium and nitrate nitrogen, and total suspended and fixed solids were measured by the DEQ monitoring program. Figures III-7 to III-9 show the corresponding data from the remaining three longitudinal surveys on August 23, October 4 and December 7, respectively.

Figures III-6 to III-9 show that the concentrations of organic and inorganic matter, and suspended solids, most of the time, increased landward and were diluted seaward by the seawater entering from the inlet. Chlorophyll concentration increased landward and dissolved oxygen increased seaward. Inorganic phosphorus was present as much in particulate form as in dissolved form, indicating the importance of phosphate sorption-desorption process in the water column. In the DEQ program, the detection limits for ammonium and nitrate nitrogen are 0.04 and 0.05 g m^{-3}, respectively. The water column concentrations for these inorganic nitrogen were, most of the time, lower than the detection limits.

C. Sediment: Figure III-10 shows the sediment conditions for total solid, total carbon, total nitrogen, total phosphorus and total inorganic phosphorus. The sediment contents are within the ranges observed in main Chesapeake Bay, which are 10-60, 1-5 and 0.1-1 mg g^{-1}, respectively, for carbon, nitrogen and phosphorus (DiToro & Fitzpatrick 1993: Fig. 8-7). More than half of total phosphorus was present in particulate inorganic phosphorus, indicating the importance of phosphate sorption/desorption process in the sediment.

The ratios of carbon-to-nitrogen, carbon-to-phosphorus and nitrogen-to-phosphorus in sediment are compared to the Redfield ratio in Fig. III-11. The carbon-to-nitrogen ratio was enriched in carbon relative to the Redfield ratio. The ratios of carbon-to-phosphorus ratio and nitrogen-to-phosphorus were enriched in phosphorus, which may be due to the settling of sorbed inorganic phosphorus to the sediment (DiToro & Fitzpatrick

1993). Figure III-11 generally follow the behavior observed in main Chesapeake Bay (DiToro & Fitzpatrick 1993: Fig. 8-1).

D. DEQ data at land stations: At the land stations (LBC and TC), the DEQ monitoring program had sampled six times in June-November, 1994: June 8, July 13, August 3, September 7, October 5 and November 8. These sampling dates were different from the VIMS longitudinal surveys. Figure III-12 shows the DEQ monitoring data at Stations LBC for salinity, temperature, dissolved oxygen, ammonium and nitrate nitrogen, and total suspended and fixed solids. For salinity, temperature and dissolved oxygen, the VIMS data from the longitudinal surveys are also included. Figure III-13 shows the corresponding data at Station TC.

At both land stations, salinity fluctuation was quite large ranging from zero to almost 25 ppt, which was due to the dominance by freshwater discharge. Temperature generally decreased from June to December. Lowest dissolved oxygen was observed in August at both land stations. Ammonium and nitrate nitrogen concentrations were, most of the time, lower than the detection limits (0.04 and 0.05 g m^{-3} for ammonium and nitrate nitrogen, respectively).

E. Comparison between VIMS and DEQ data: The following parameters were measured by both the VIMS surveys and the DEQ program: salinity, temperature and dissolved oxygen. The data from two surveys are compared for these parameters in Fig. III-14. The data at the land stations (LBC and TC) are not included in Fig. III-14 since the sampling dates are different between two surveys.

The DEQ program data have slightly higher salinity than the VIMS survey data. The salinity data that are rounded to the first digit are stored in the DEQ database, which may be, at least in part, responsible for the discrepancy (Fig. III-14). Good agreement exists for temperature between the VIMS surveys and the DEQ program, with one exception. On October 4, the temperature at the surface of the inlet was 13°C from the VIMS survey and 19.1°C from the DEQ program (see Fig III-3). At the October 4 survey, the VIMS temperature data (except the measurements at the inlet) ranged 16.8-

19°C, and the DEQ data ranged 17.2-19.5°C. Moreover, this discrepancy is the only exception to the tendency in temperature, which decreased from June to December at all nine stations (Figures III-3 to III-5). Hence, the VIMS temperature at the inlet from the October 4 survey (13°C) seems too low. The DEQ program data have slightly lower dissolved oxygen than the VIMS survey data. It should be noted that the duplicate Winkler bottles taken in the VIMS surveys gave consistent readings of dissolved oxygen (Figures III-6 to III-9).

Figure III-15 compares the DEQ data and the VIMS data for total phosphorus, total nitrogen and organic carbon. As in Fig. III-14, the data at the land stations are not included in Fig. III-15. The DEQ program measured total phosphorus (TP), and the VIMS surveys measured particulate phosphorus (PP) and total dissolved phosphorus (TDP), which have a relationship:

$$TP = PP + TDP \qquad (3\text{-}1)$$

The total phosphorus measured by the DEQ program was higher than that by the VIMS surveys (Fig. III-15). In the DEQ program, the detection limit for total phosphorus is 0.1 g m^{-3}. The VIMS data indicate that the water column concentrations were, most of the time, less than the detection limit, which may be responsible for the overestimation of total phosphorus in the DEQ data compared to the VIMS data.

The DEQ program measured total Kjeldahl nitrogen (TKN), which is defined as:

$$TKN = ON + NH4 + ANC \cdot CChl \cdot Chl \qquad (3\text{-}2)$$

ON & NH4 = organic and ammonium nitrogen (g m^{-3}) respectively
ANC = nitrogen-to-carbon ratio in algae (g N per g C)
CChl = carbon-to-chlorophyll ratio in algae (g C per mg Chl)
Chl = chlorophyll concentration (mg m^{-3}).
Then, total nitrogen (TN) can be estimated using TKN and nitrate nitrogen (NO3):

$$TN = TKN + NO3 \qquad \textit{from DEQ Program} \qquad (3\text{-}3)$$

or using particulate nitrogen (PN) and total dissolved nitrogen (TDN):

$$TN = PN + TDN + ANC \cdot CChl \cdot Chl \qquad \textit{from VIMS Surveys} \qquad (3\text{-}4)$$

The DEQ program measured TKN and NO3 (Eq. 3-3), and the VIMS surveys measured

PN, TDN and Chl (Eq. 3-4). Figure III-15 compares TN estimated using Equations 3-3 and 3-4: the ratios in Kuo & Park (1994), ANC (0.167 g N per g C) and CChl (0.06 g C per mg Chl), were used in Equations 3-3 and 3-4. Considerable scatter exists in one-to-one correspondence in Fig. III-15. Since the method of estimating TN using PN and TDN has superior precision and accuracy to the TKN method, the Chesapeake Bay Program has adopted this method in the monitoring of the mainstem Cheasepeake Bay since 1987.

The DEQ program measured total organic carbon (TOC), and the VIMS surveys measured dissolved organic carbon (DOC), which have a relationship:

$$TOC = POC + DOC \qquad (3\text{-}5)$$

where POC = particulate organic carbon. Then, DOC should not be larger than TOC. However, the comparison in Fig. III-15 shows that DOC from the VIMS surveys was, most of the time, larger than TOC from the DEQ program.

Figures III-14 and III-15 indicate that the VIMS surveys and the DEQ program have produced comparable salinity, temperature and dissolved oxygen. However, they suggest that some discrepancies do exist between two surveys for organic and inorganic matter, which may be due to the differences in analytical methods and detection limits. Hence, one should be cautious when combining the data from two surveys.

III-2. Intensive Survey

Every 2.5-hour sampling from the surface (1 m below surface) was conducted at Stations L2 and L6 on August 9-10, 1994. Figure III-16 shows the predicted tide at three locations (Fig. II-1) and the sampling times in intensive survey. The sampling at Station L6 started near low tide (17:00 August 9) and lasted two tidal cycles till 18:00 August 10. The sampling at Station L2 started near low tide (06:55 August 10) and lasted one tidal cycle till 16:55 August 10.

Figure III-17 shows the intra-tidal variations in salinity and dissolved oxygen at Stations L2 and L6. The vertical bar indicates overall maximum, mean and minimum: for dissolved oxygen, these statistics were estimated using duplicate Winkler readings only. Salinity shows semidiurnal variation in response to tide (Figures III-16 and III-17), increasing during flood (from low to high tide) and decreasing during ebb (from high to low tide). Dissolved oxygen shows diurnal variation, decreasing after sunset because of no photosynthesis at night and reaching minimum near the time of sunrise (Fig. III-17). Since dissolved oxygen increases seaward (Figures III-6 to III-9), the high dissolved oxygen in the incoming seawater replenishes dissolved oxygen during flood. On August 10, low tide occurred around the time of sunrise, so that the above two factors combined to contribute to the reduction in dissolved oxygen around the time of sunrise.

Figure III-18 shows the intra-tidal variations in temperature, chlorophyll, total suspended and fixed solids, and secchi depth at Stations L2 and L6. Temperature shows diurnal variation with the lowest value occurring near the sunrise. Since chlorophyll and inorganic nutrients increase landward (Figures III-6 to III-9), their concentrations at a given location increase during ebb. The phase lag between tidal transport and time of sunrise results in semidiurnal variation in chlorophyll in Fig. III-18. Chlorophyll at Station L6 decreases after sunset until midnight (Hour 0-7), because of both no light and flooding current (Fig. III-16) that transports low-chlorophyll saltier water landward (Figures III-6 to III-9). Chlorophyll increases from midnight until sunrise (Hour 7-14), because of ebbing current that transports high-chlorophyll fresher water seaward. Chlorophyll decreases again from sunrise till noon (Hour 14-19), because dilution by flooding current overcomes the growth due to sunlight. Note that the local minimum around noon is higher than that around midnight, for which both no light and dilution by flooding current reduce the chlorophyll concentration. After noon, chlorophyll increases again, because of light and ebbing current. Total solids, both suspended and fixed, reach local maxima near maximum flood or ebb (Fig. III-18).

Table III-1. Predicted tide at three locations[a] and sampling times at nine stations in longitudinal surveys.

A. Predicted Tide

		Buchanan Creek Entrance[a]	Inlet[a]	Brown Cove[a]
June 21	High tide	07:49	06:40	07:35
	Low tide	14:42	12:57	14:34
August 23	Low tide	05:58	04:13	05:50
	High tide	11:19	10:10	11:05
	Low tide	18:22	16:37	18:14
October 4	High tide	08:52	07:43	08:38
	Low tide	16:03	14:18	15:55
December 7	Low tide	07:57	06:12	07:49
	High tide	13:24	12:15	13:10

B. Sampling Times

	TC[a]	L1	L2	L3	L4	L5	L6	L7	LBC
June 21	11:10	10:33	10:52	11:04	09:57	11:23	11:40	12:05	10:10
August 23	10:15	09:56	10:14	10:40	09:07	11:03	11:20	11:50	09:25
October 4	10:52	10:25	10:40	10:55	09:47	11:15	11:30	11:50	10:10
December 7	10:10	09:27	09:40	10:00	08:50	10:18	10:28	10:52	09:25

[a] See Fig. II-1 for locations: Buchanan Creek is in the Western Branch, and Brown Cove is in the Eastern Branch.

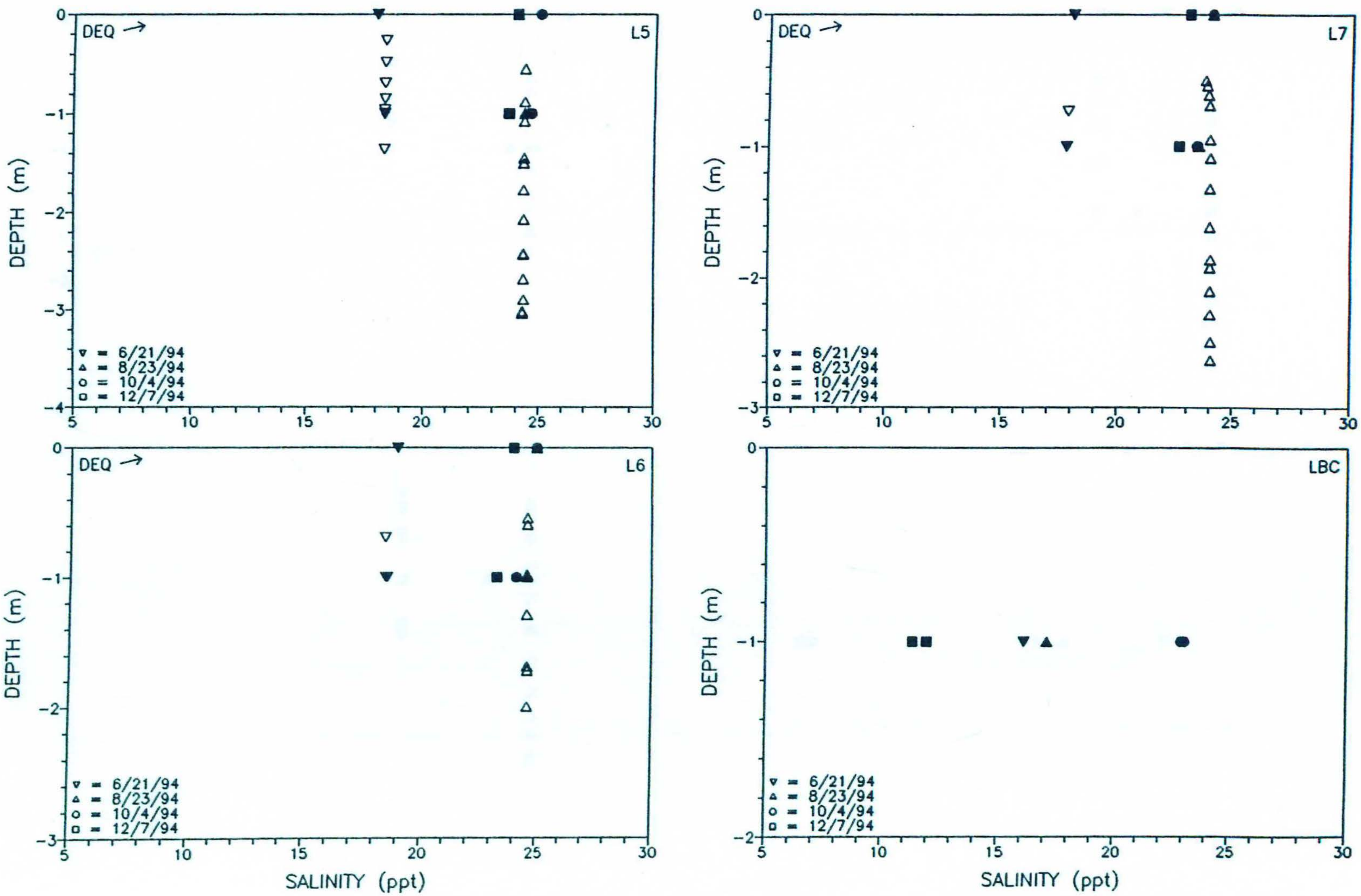


Figure III-1. Salinity in the Eastern Branch from four longitudinal surveys and the DEQ monitoring program.

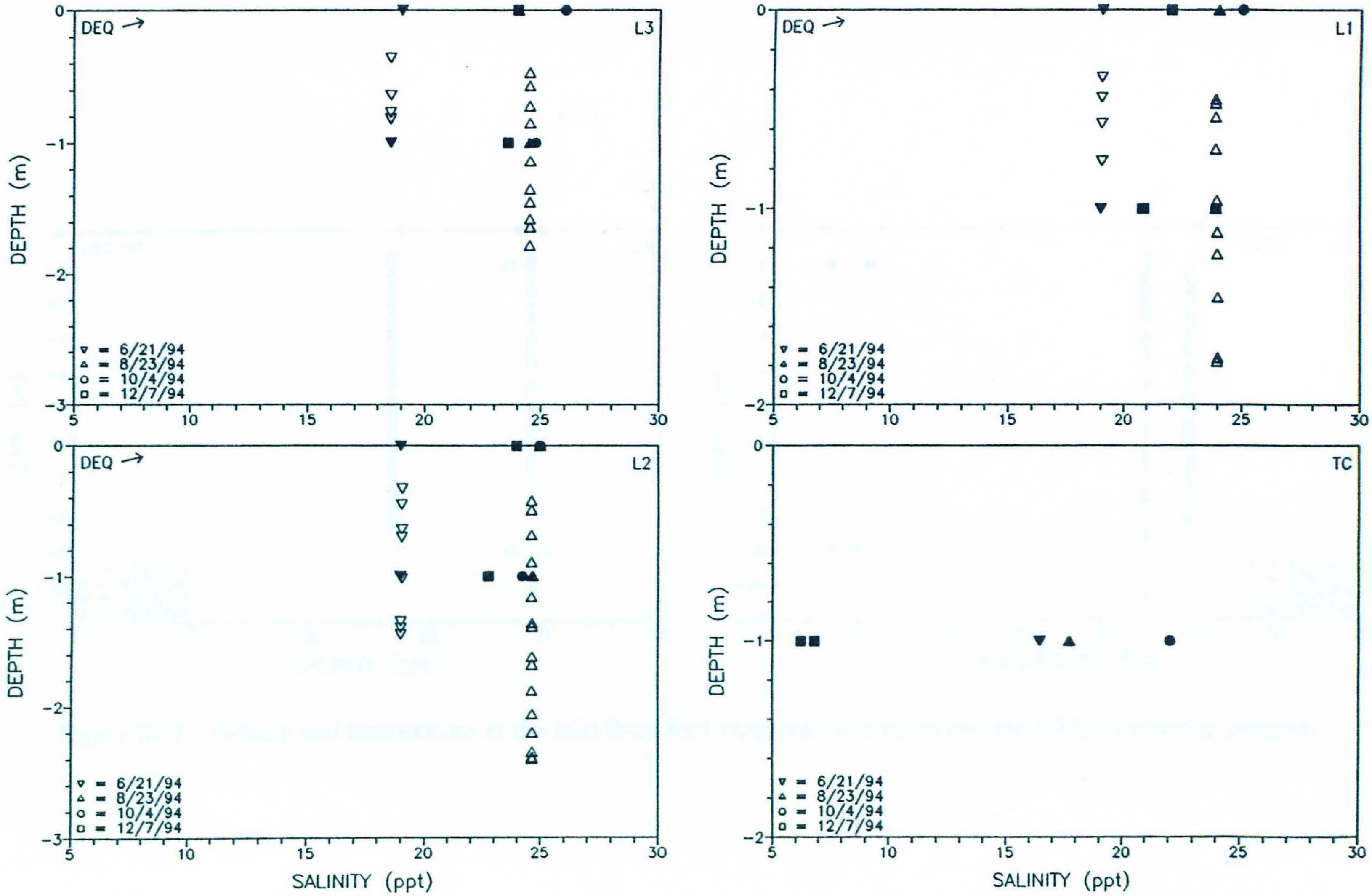


Figure III-2. Salinity in the Western Branch from four longitudinal surveys and the DEQ monitoring program.

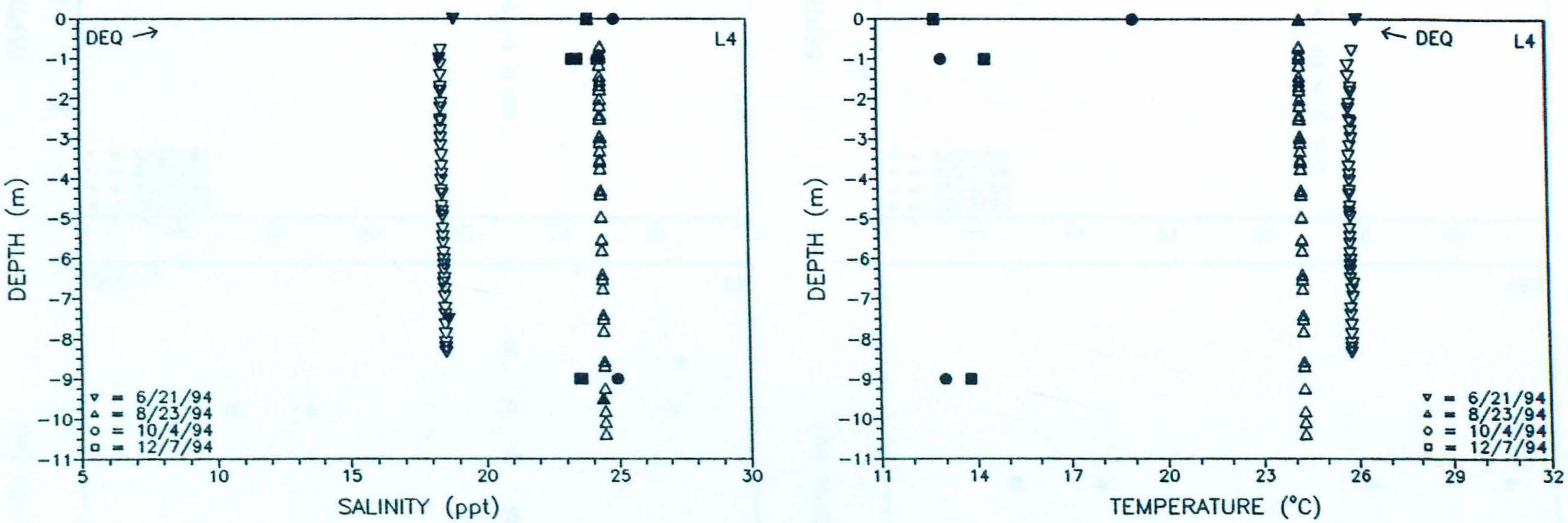


Figure III-3. Salinity and temperature at the inlet from four longitudinal surveys and the DEQ monitoring program.

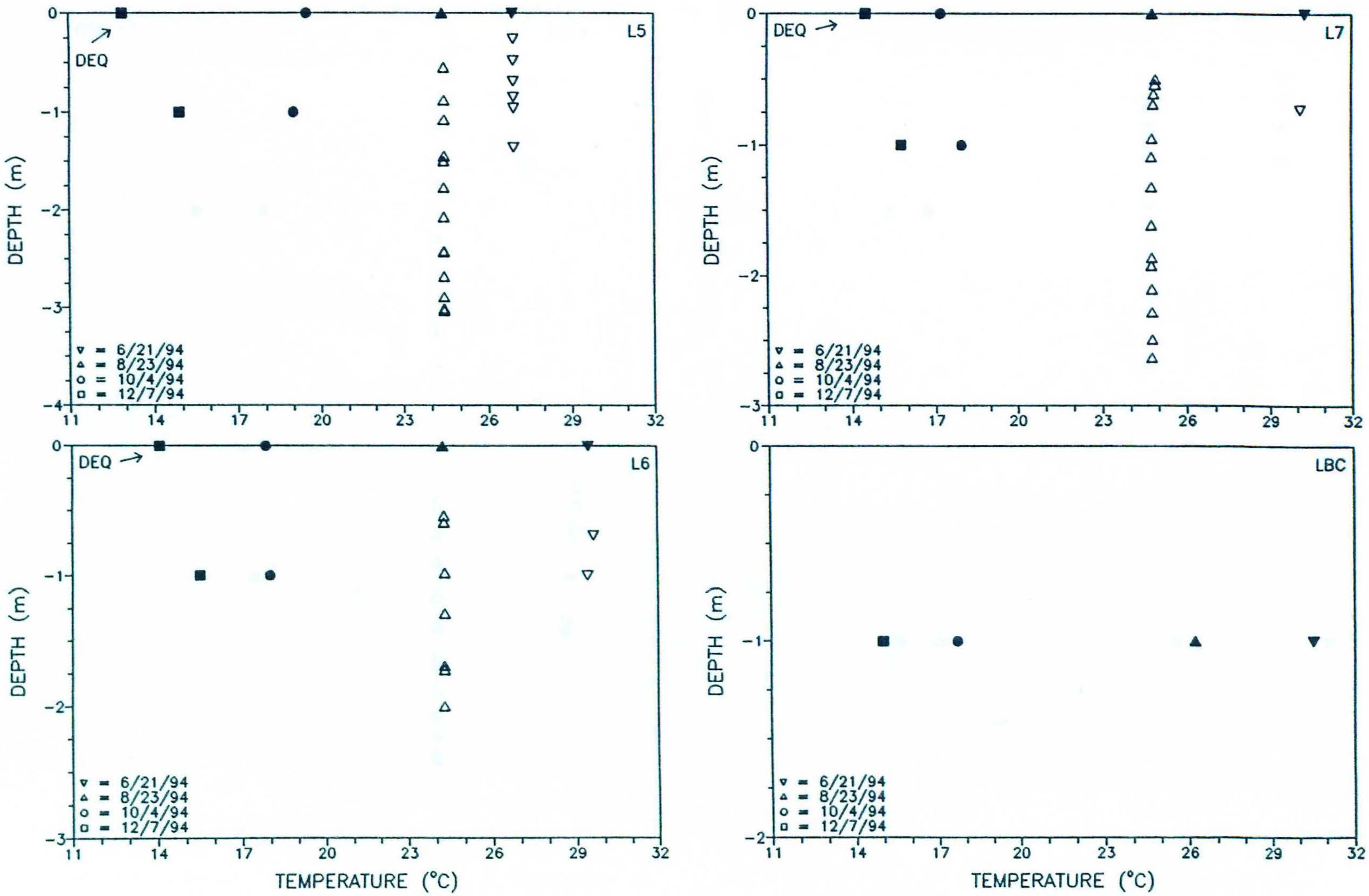


Figure III-4. Temperature in the Eastern Branch from four longitudinal surveys and the DEQ monitoring program.

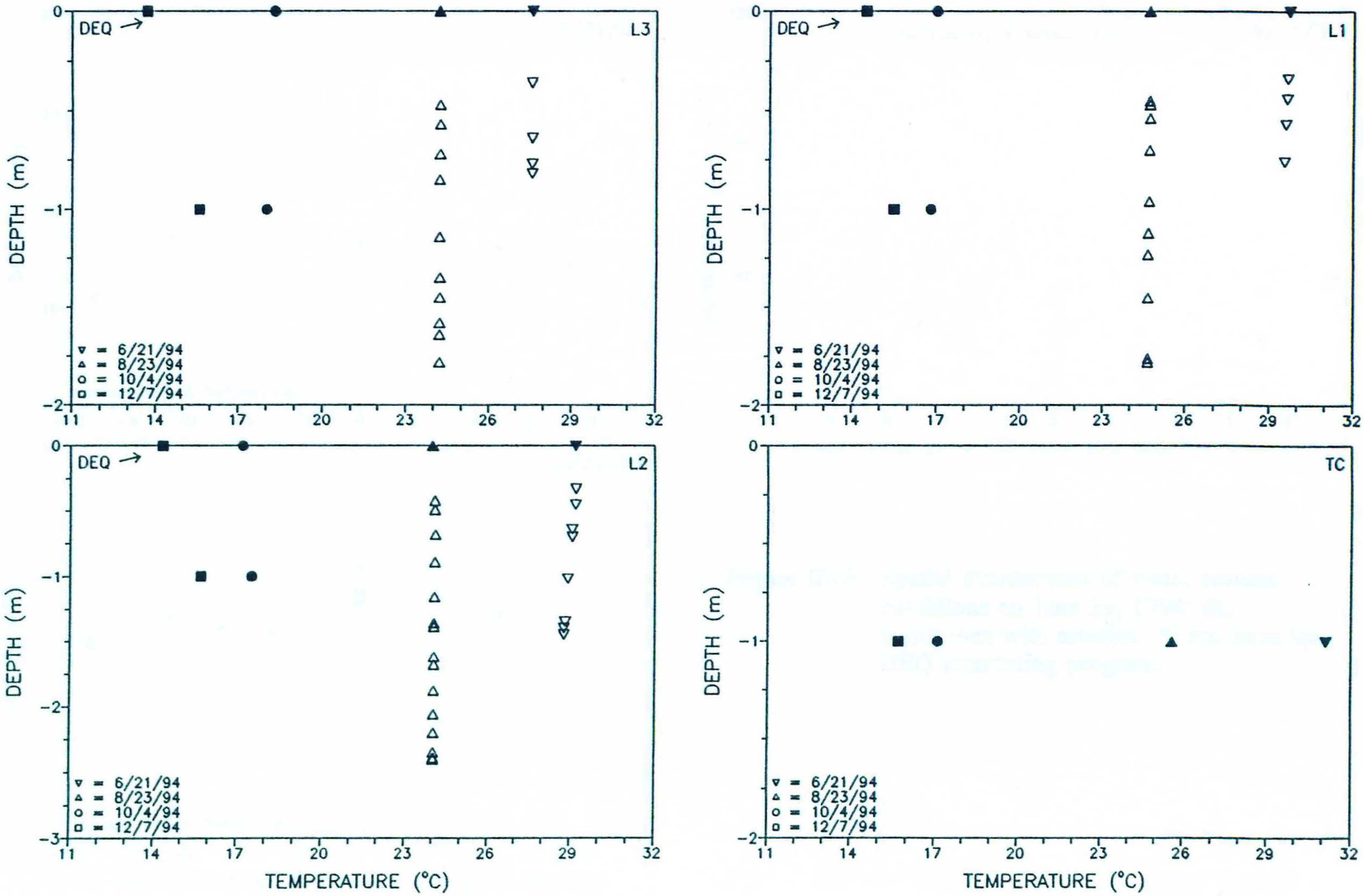
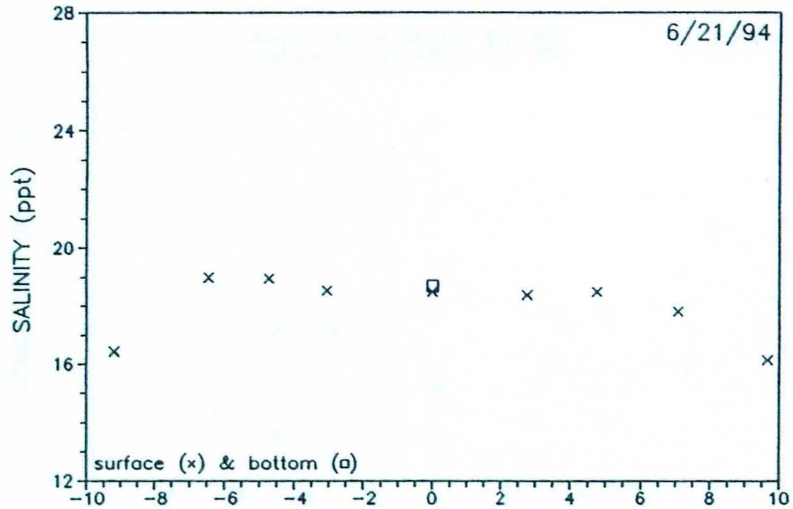
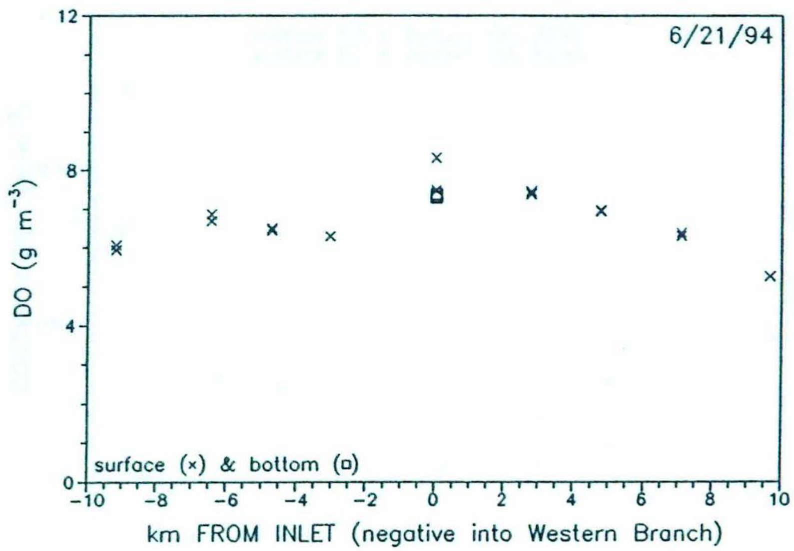


Figure III-5. Temperature in the Western Branch from four longitudinal surveys and the DEQ monitoring program.





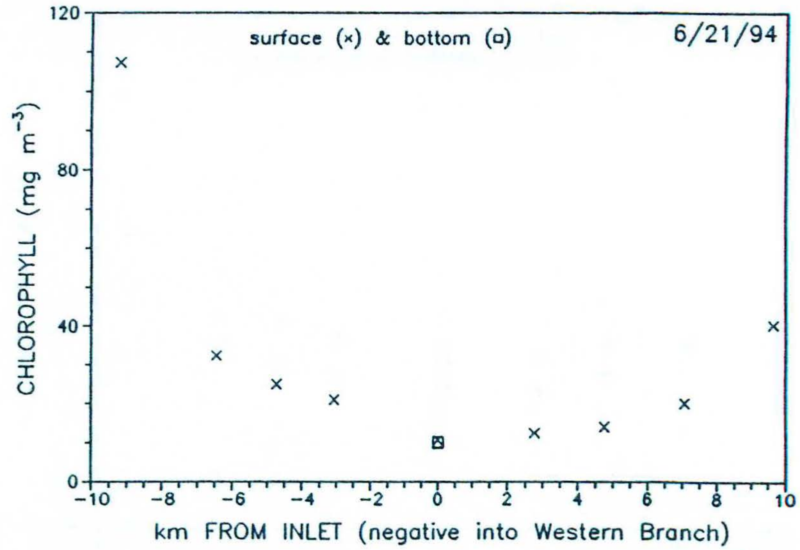


Figure III-6. **Spatial distributions of water column conditions on June 21, 1994: the parameters with asterisk (*) are from the DEQ monitoring program.**

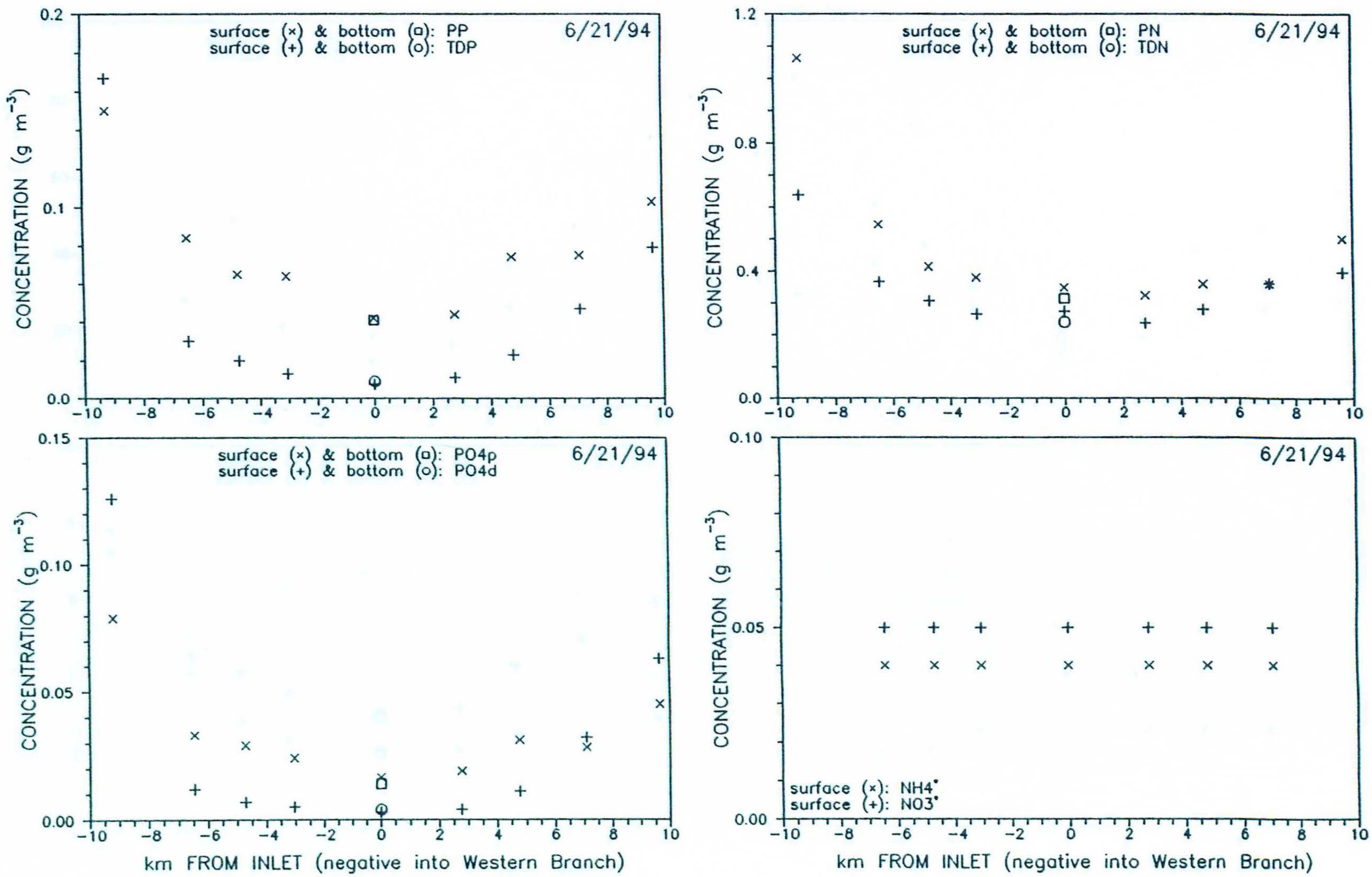


Figure III-6. (continued.)

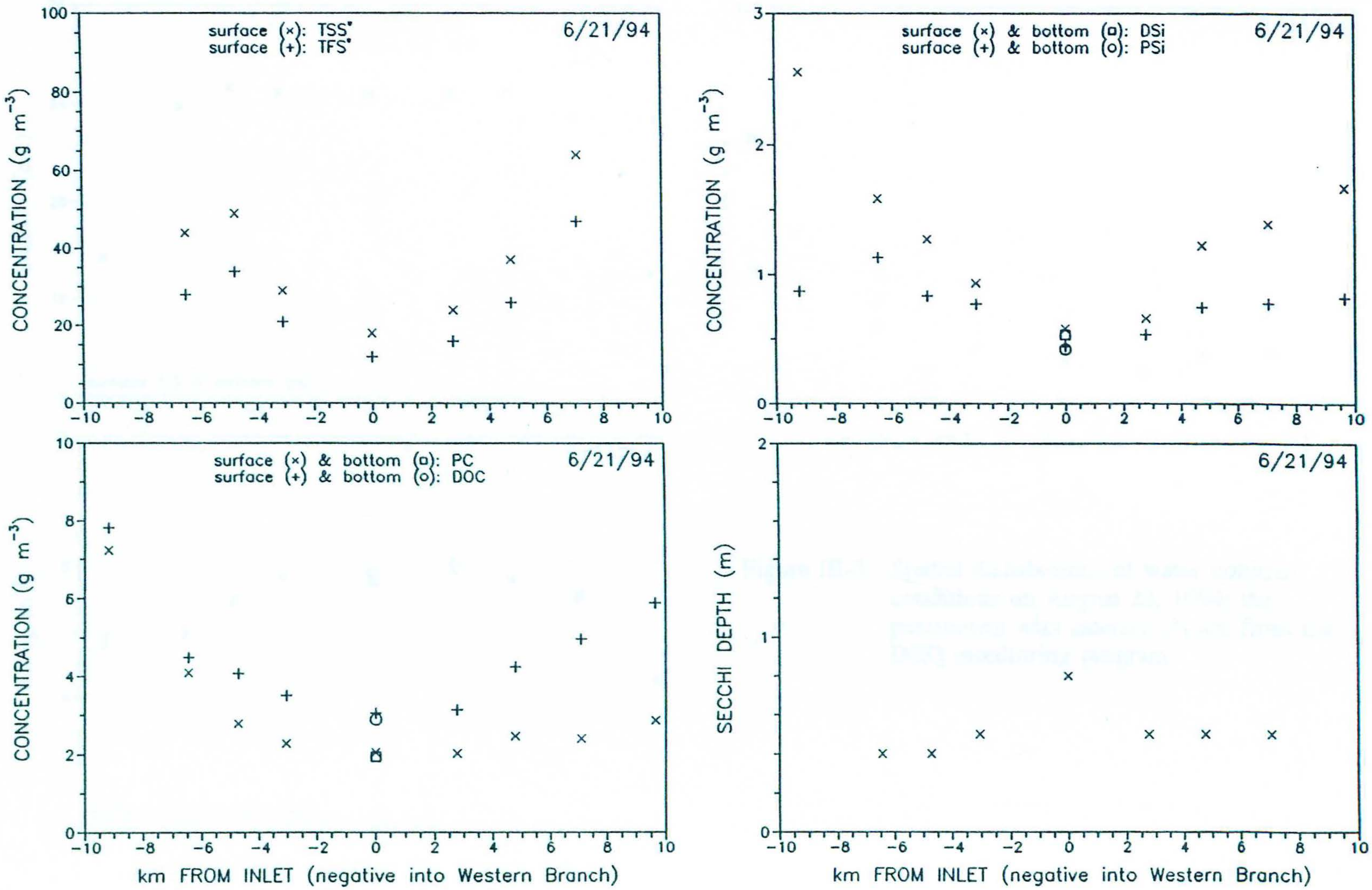


Figure III-6. (continued.)

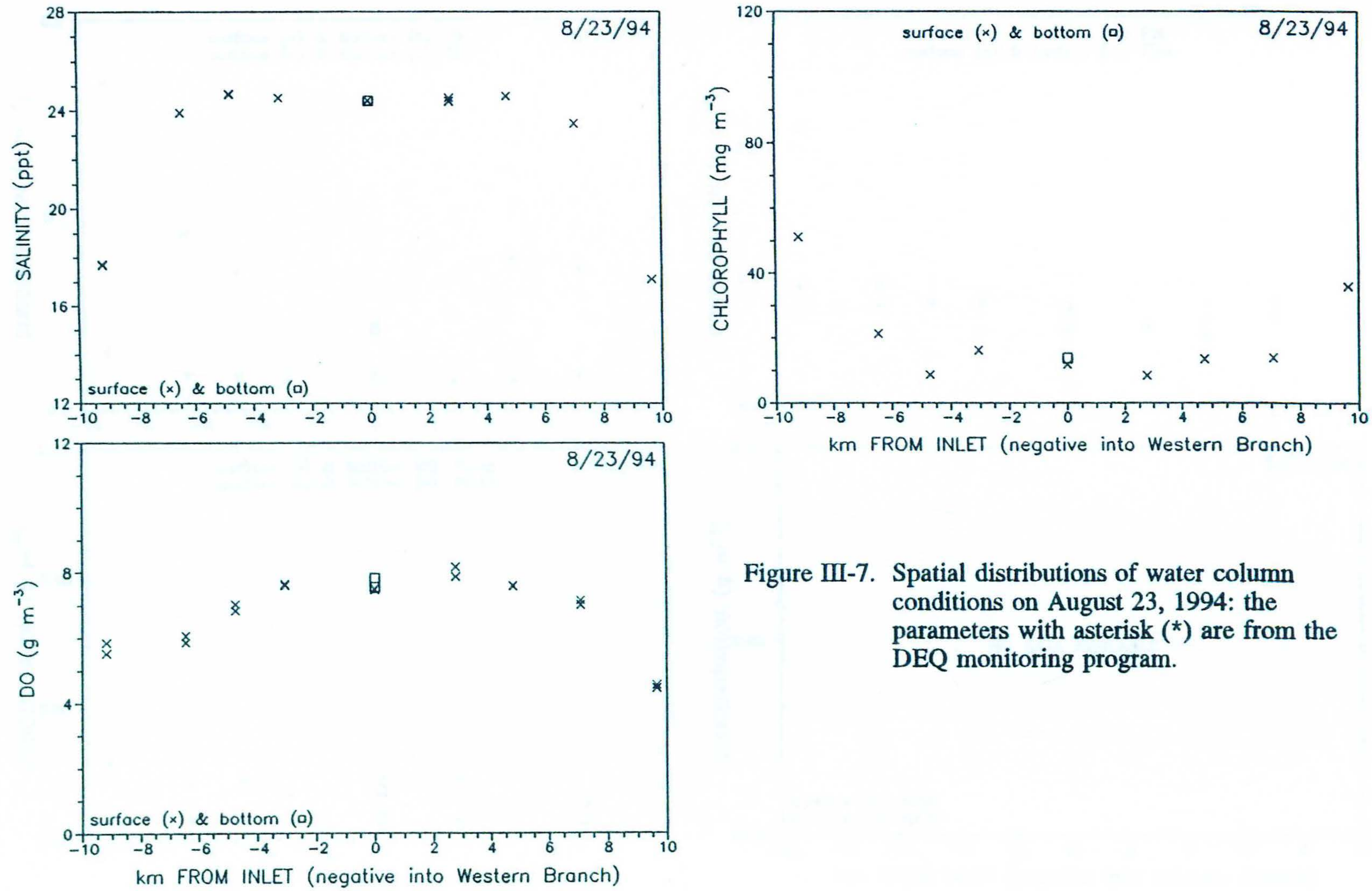


Figure III-7. Spatial distributions of water column conditions on August 23, 1994: the parameters with asterisk (*) are from the DEQ monitoring program.

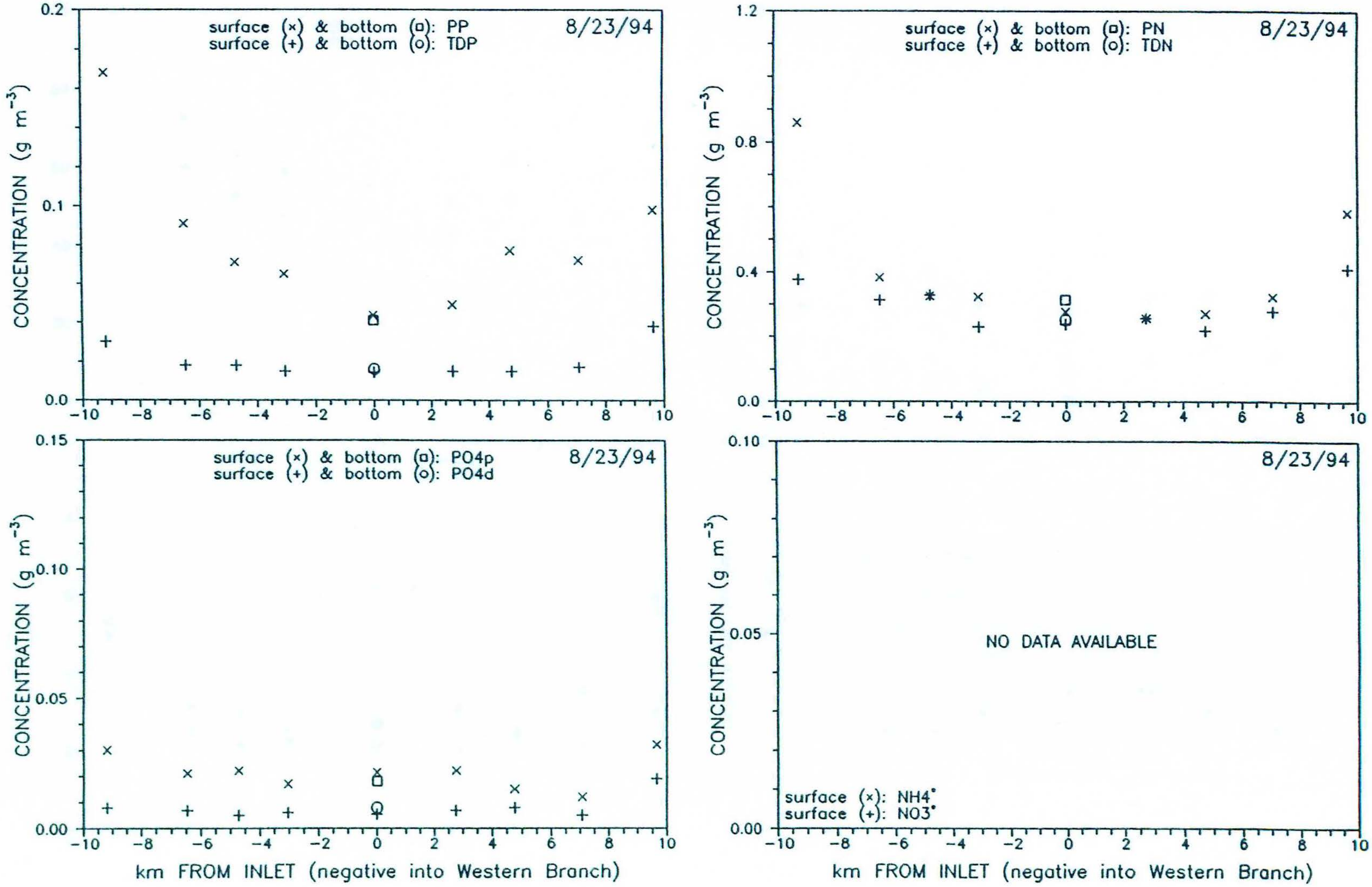


Figure III-7. (continued.)

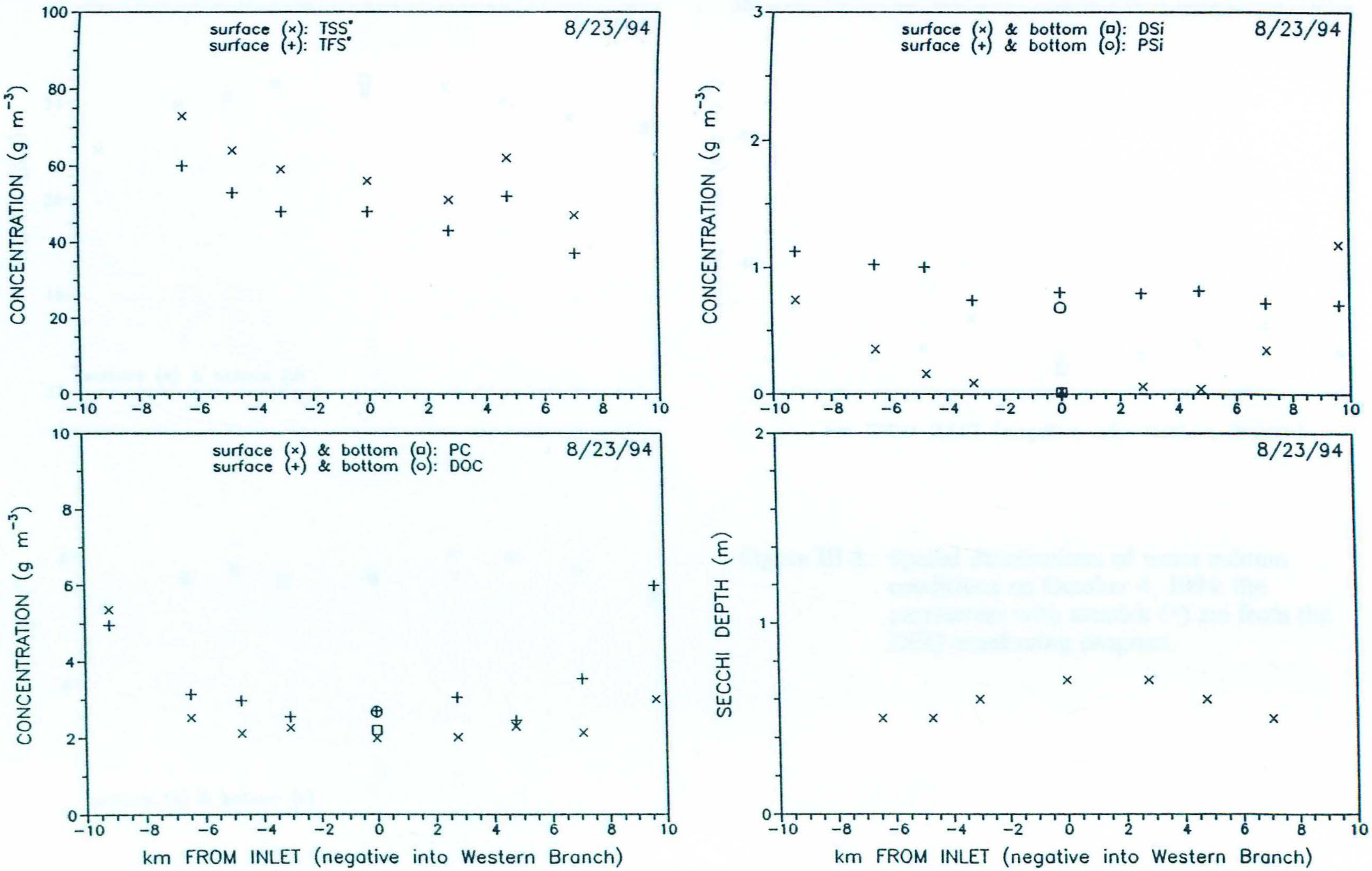
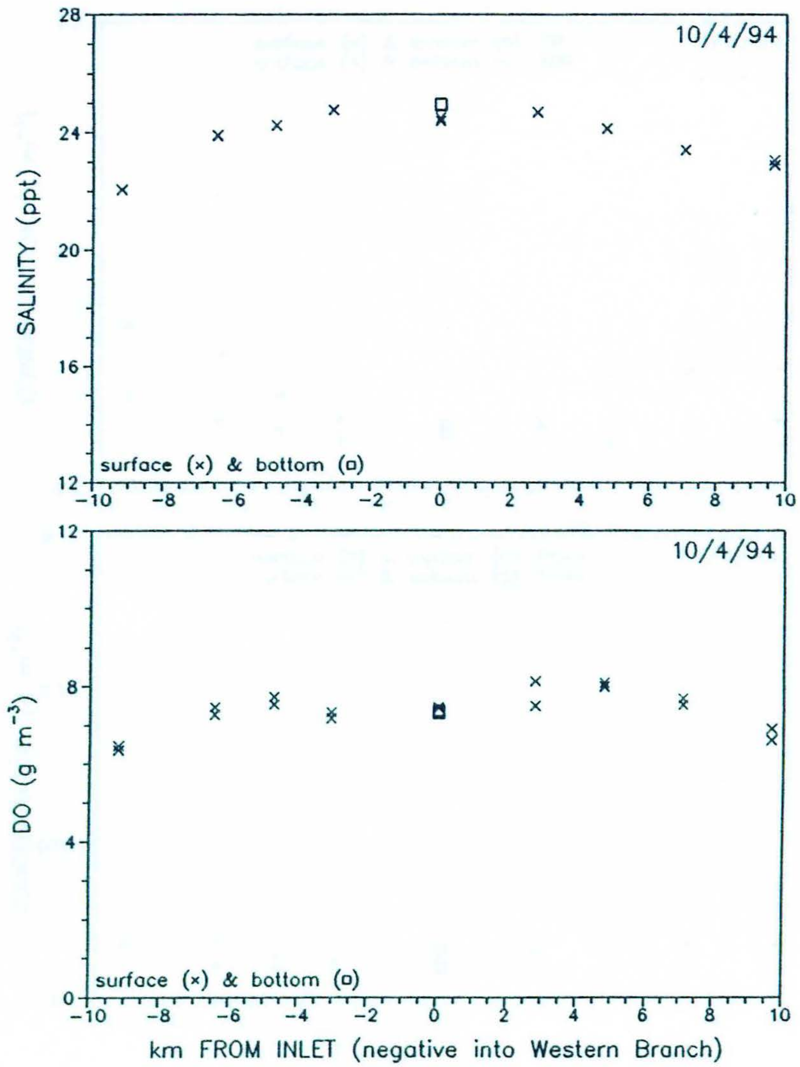


Figure III-7. (continued.)



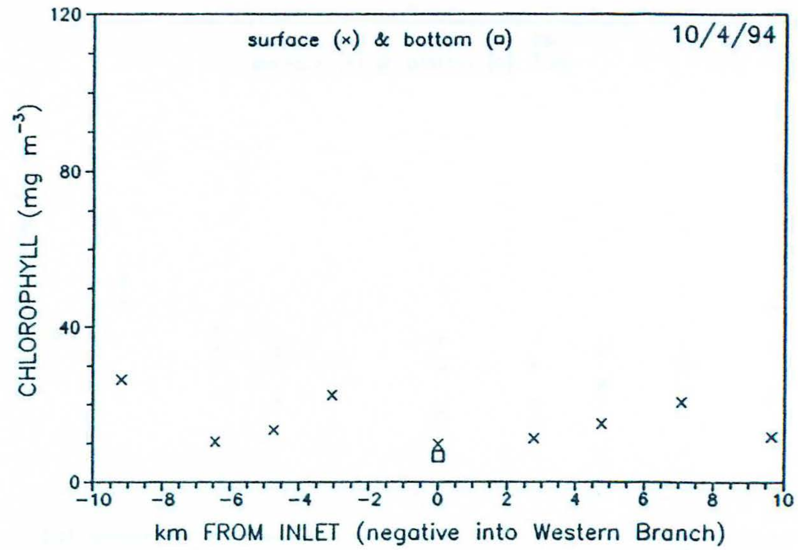


Figure III-8. Spatial distributions of water column conditions on October 4, 1994: the parameters with asterisk (*) are from the DEQ monitoring program.

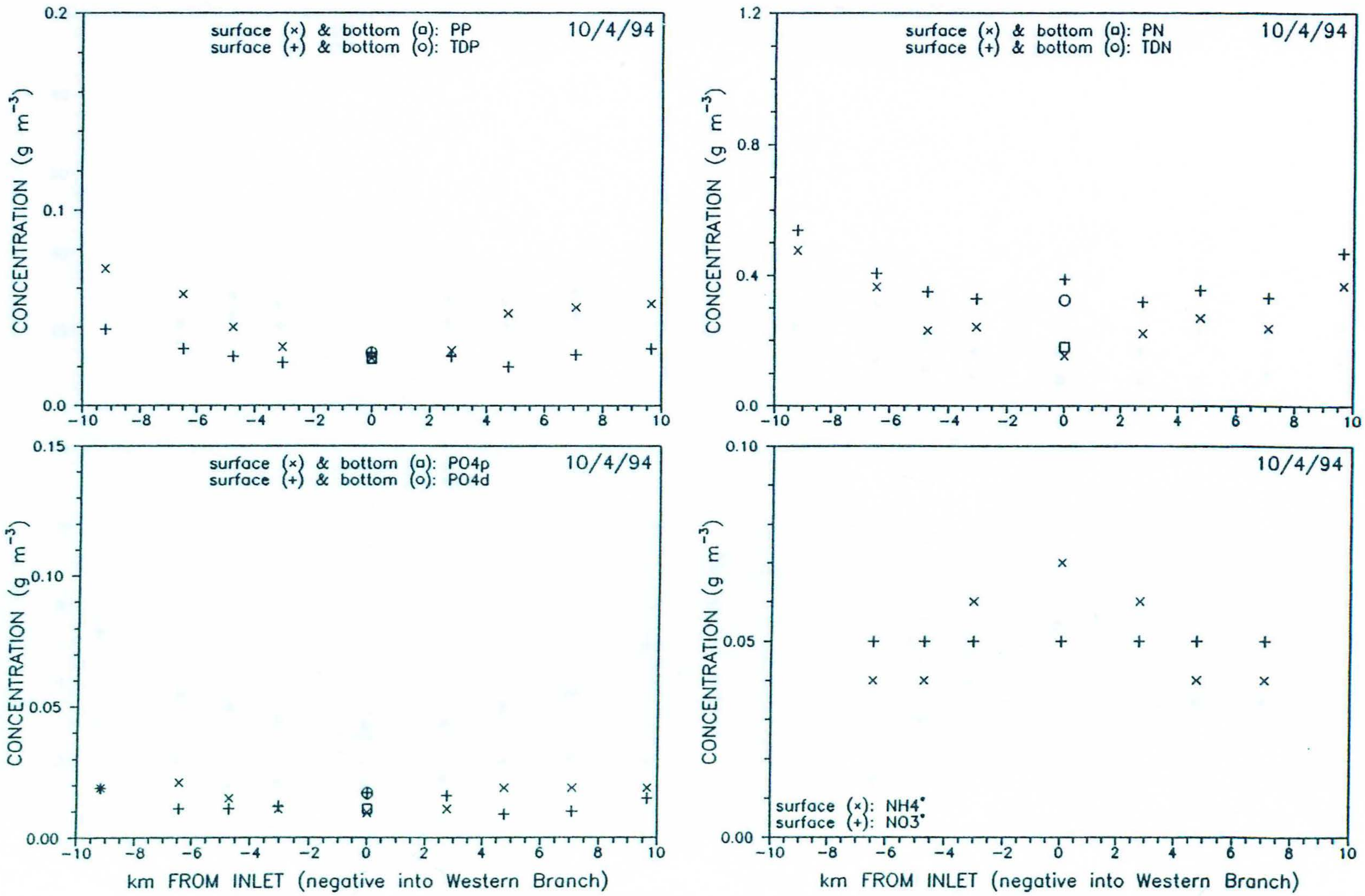


Figure III-8. (continued.)

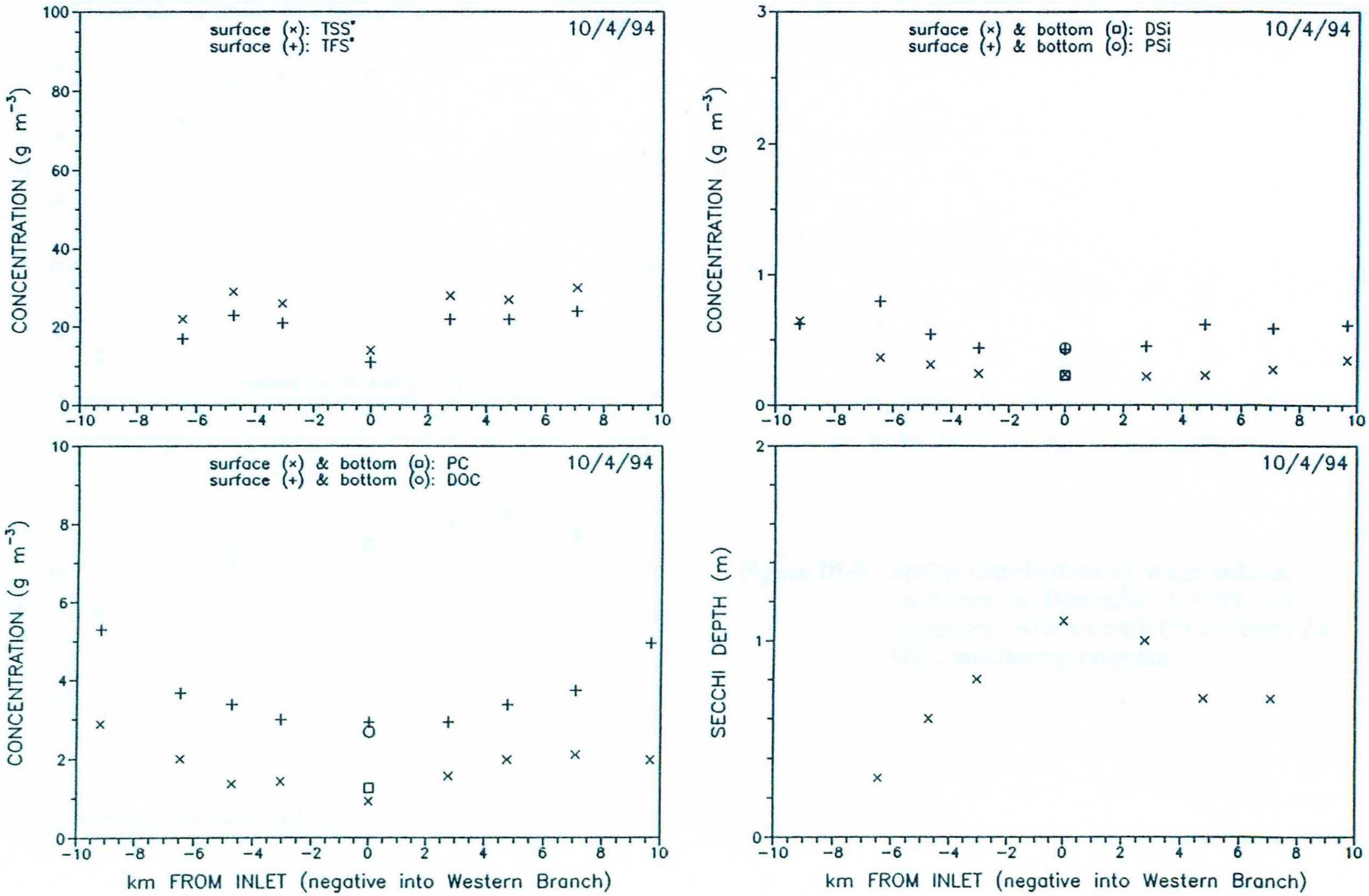
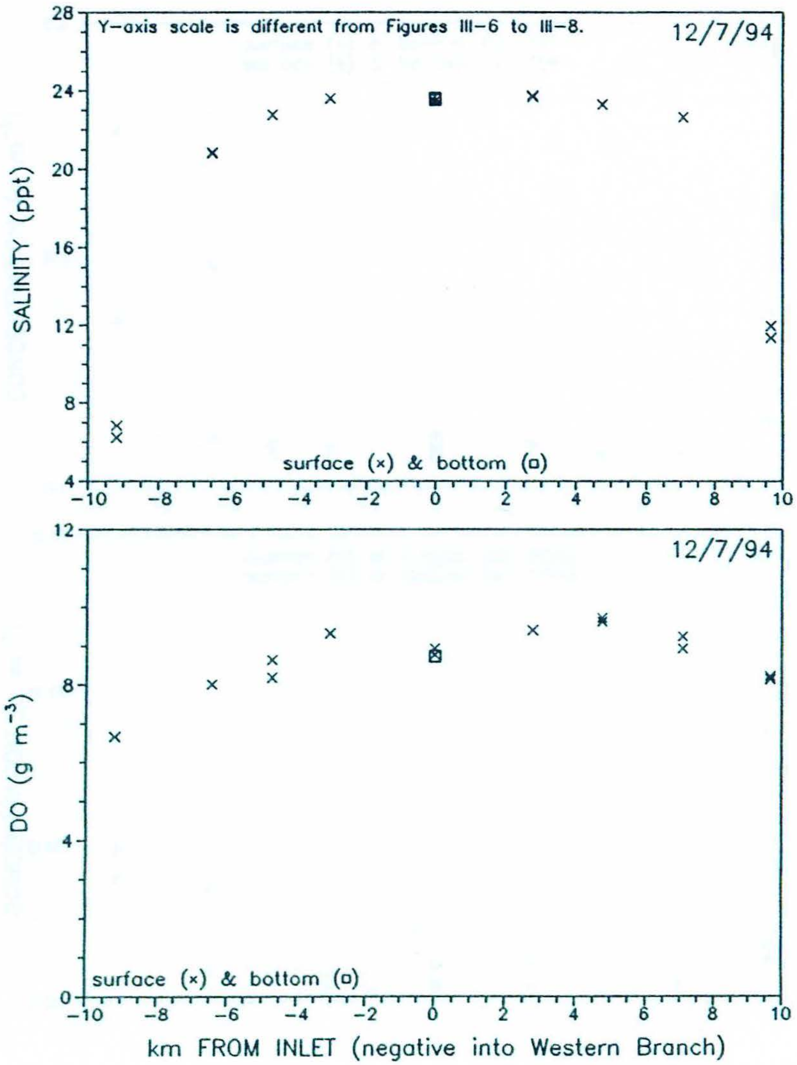


Figure III-8. (continued.)



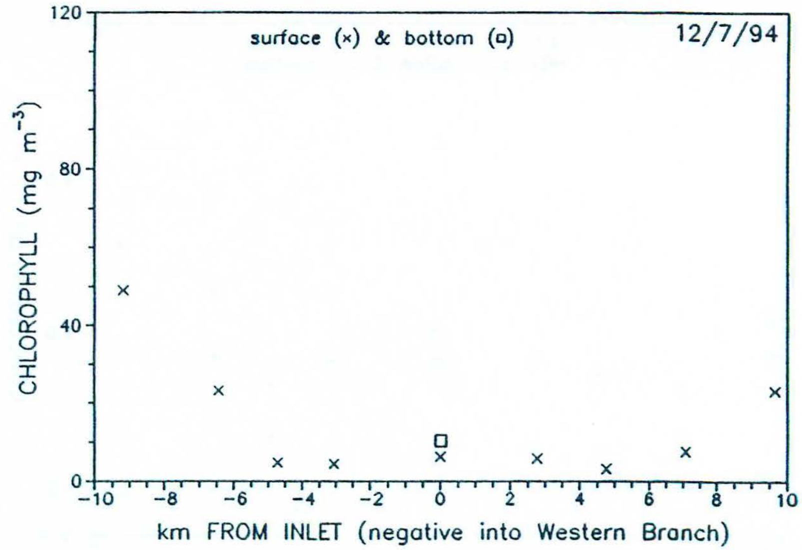


Figure III-9. Spatial distributions of water column conditions on December 7, 1994: the parameters with asterisk (*) are from the DEQ monitoring program.

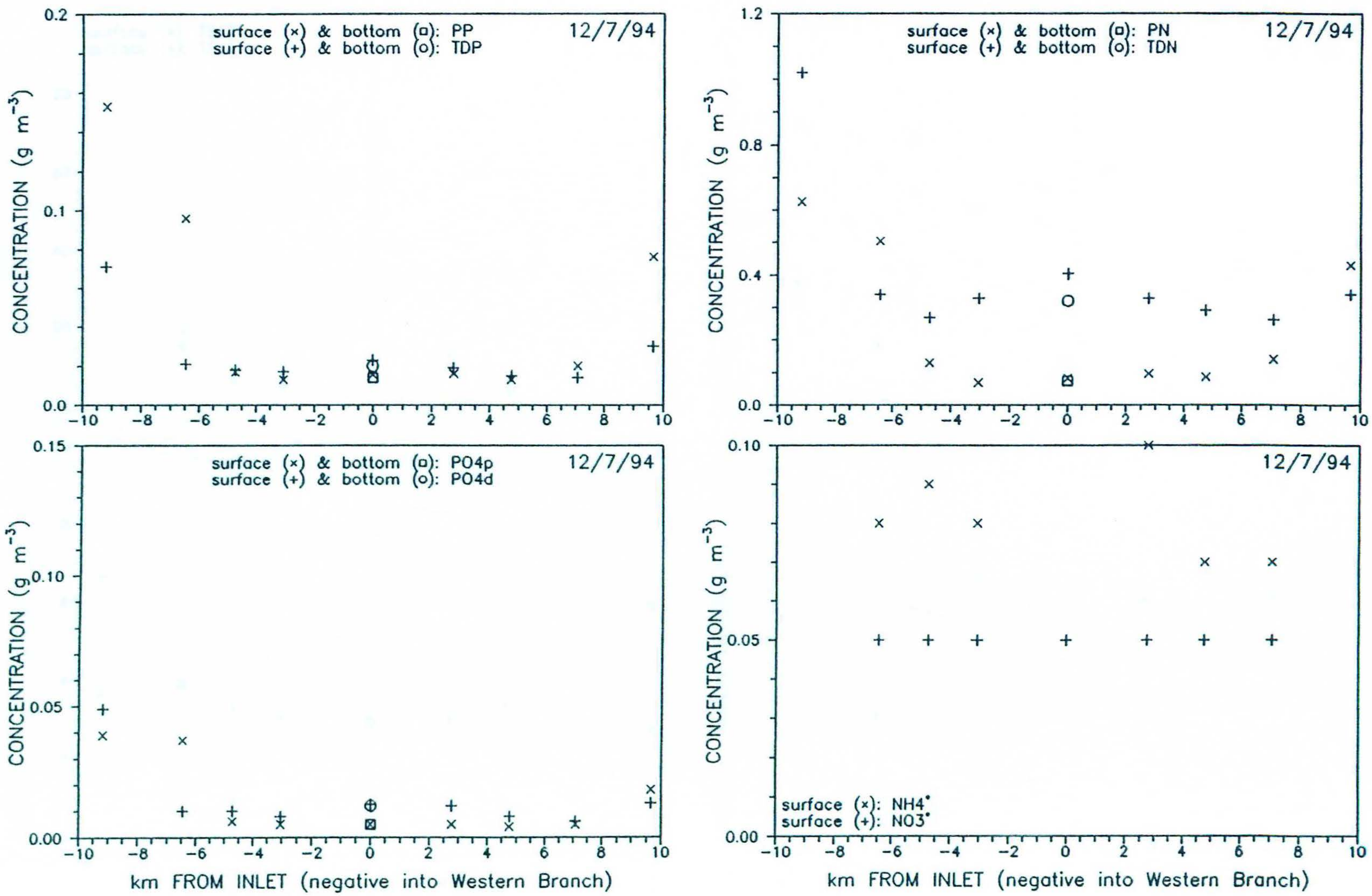


Figure III-9. (continued.)

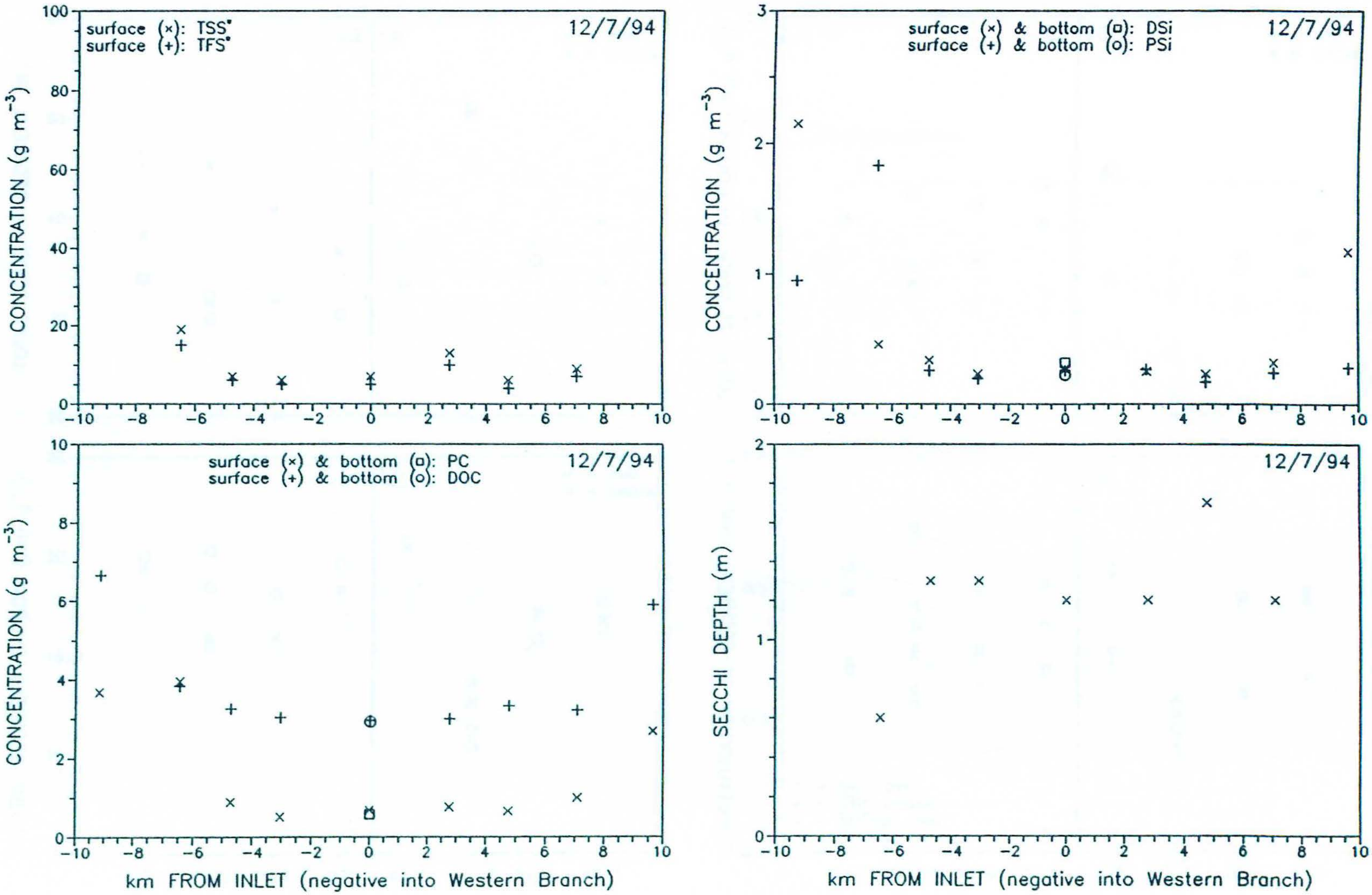


Figure III-9. (continued.)

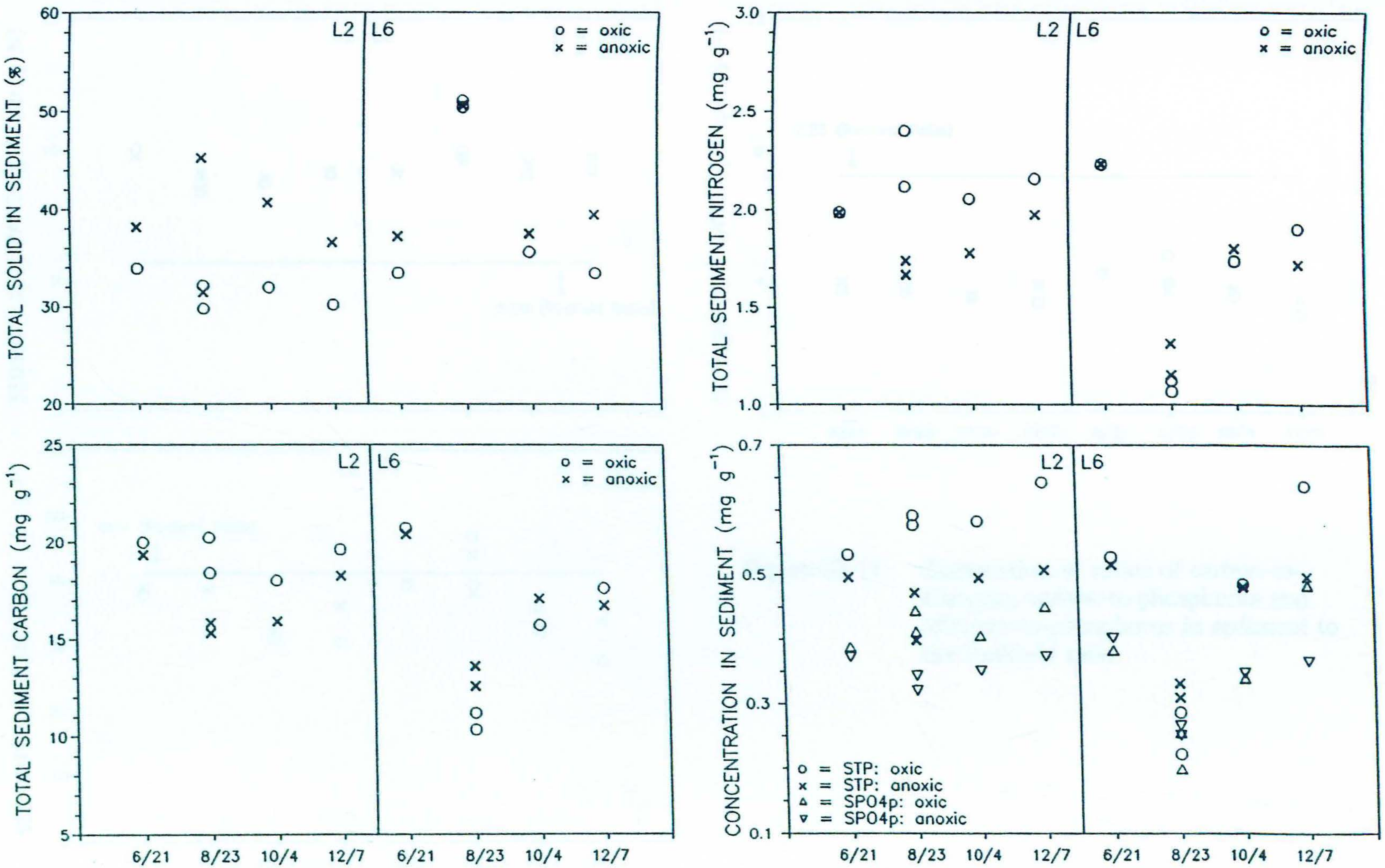
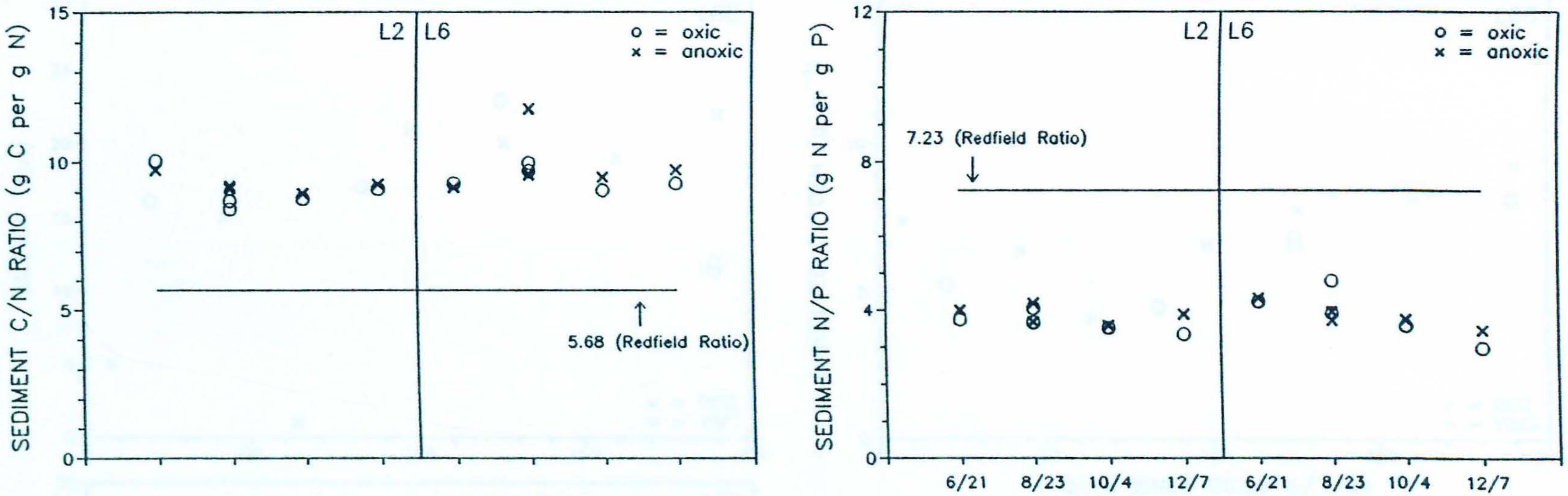


Figure III-10. Sediment conditions at Stations L2 and L6 from four longitudinal surveys.



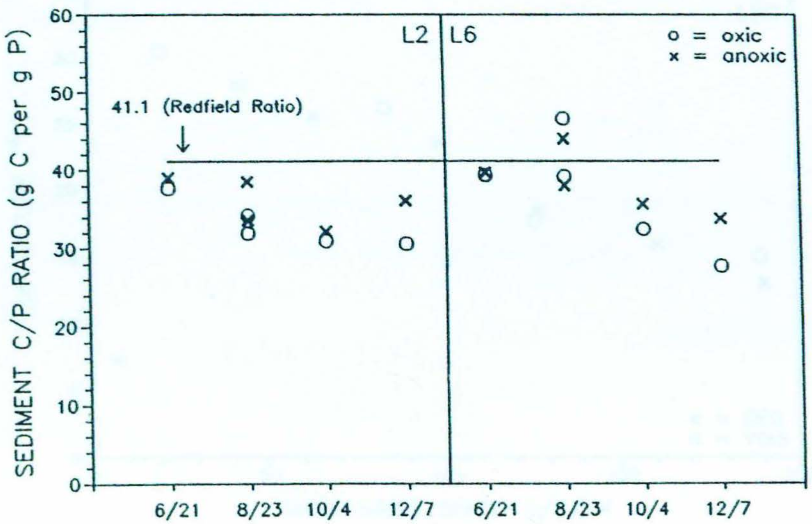
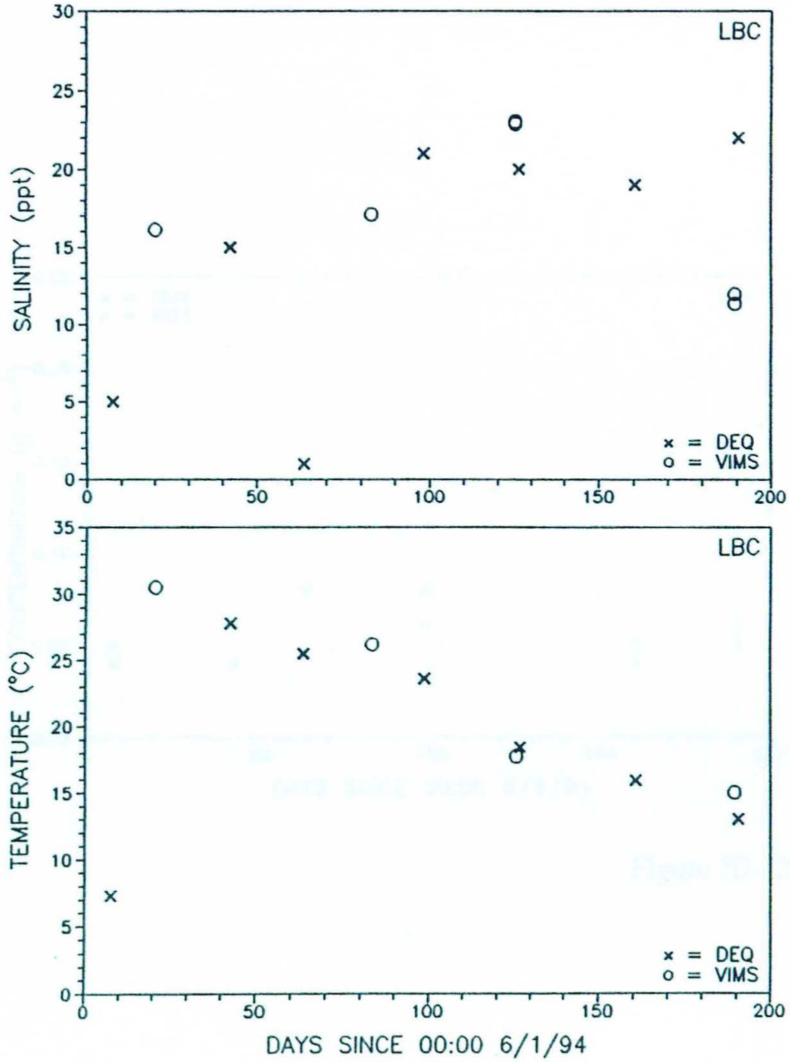


Figure III-11. Comparison of ratios of carbon-to-nitrogen, carbon-to-phosphorus and nitrogen-to-phosphorus in sediment to the Redfield ratio.



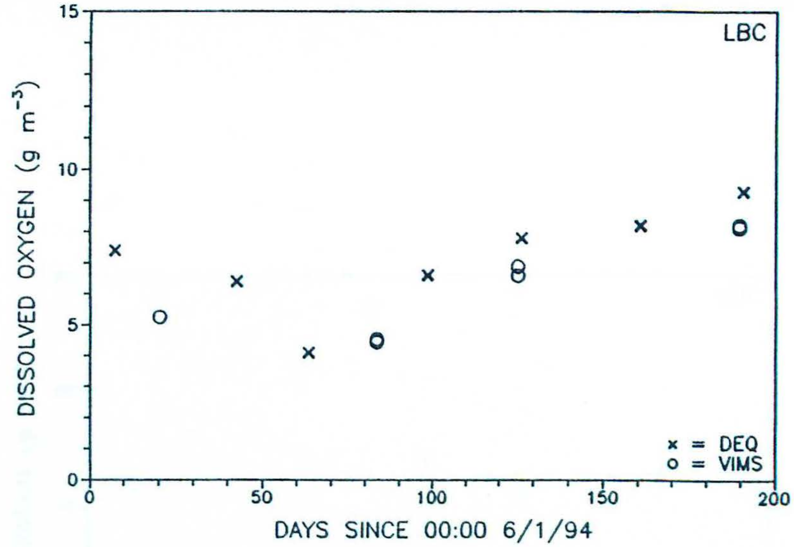


Figure III-12. **Water column conditions at Station LBC from the DEQ monitoring program.**

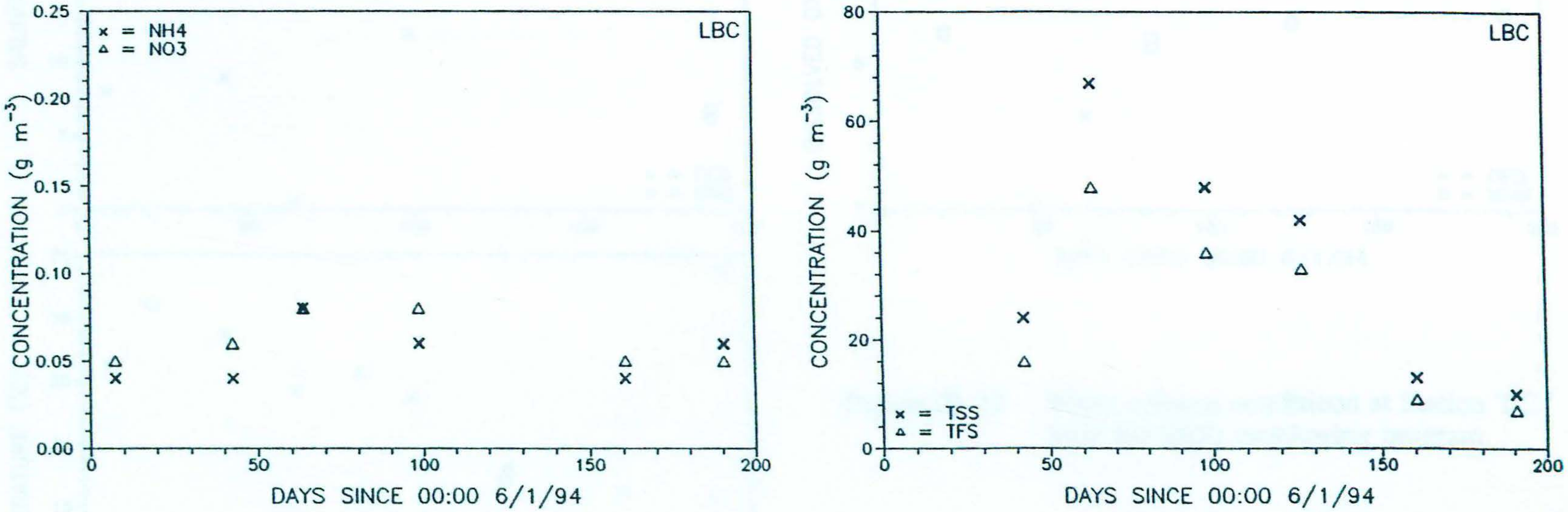


Figure III-12. (continued.)

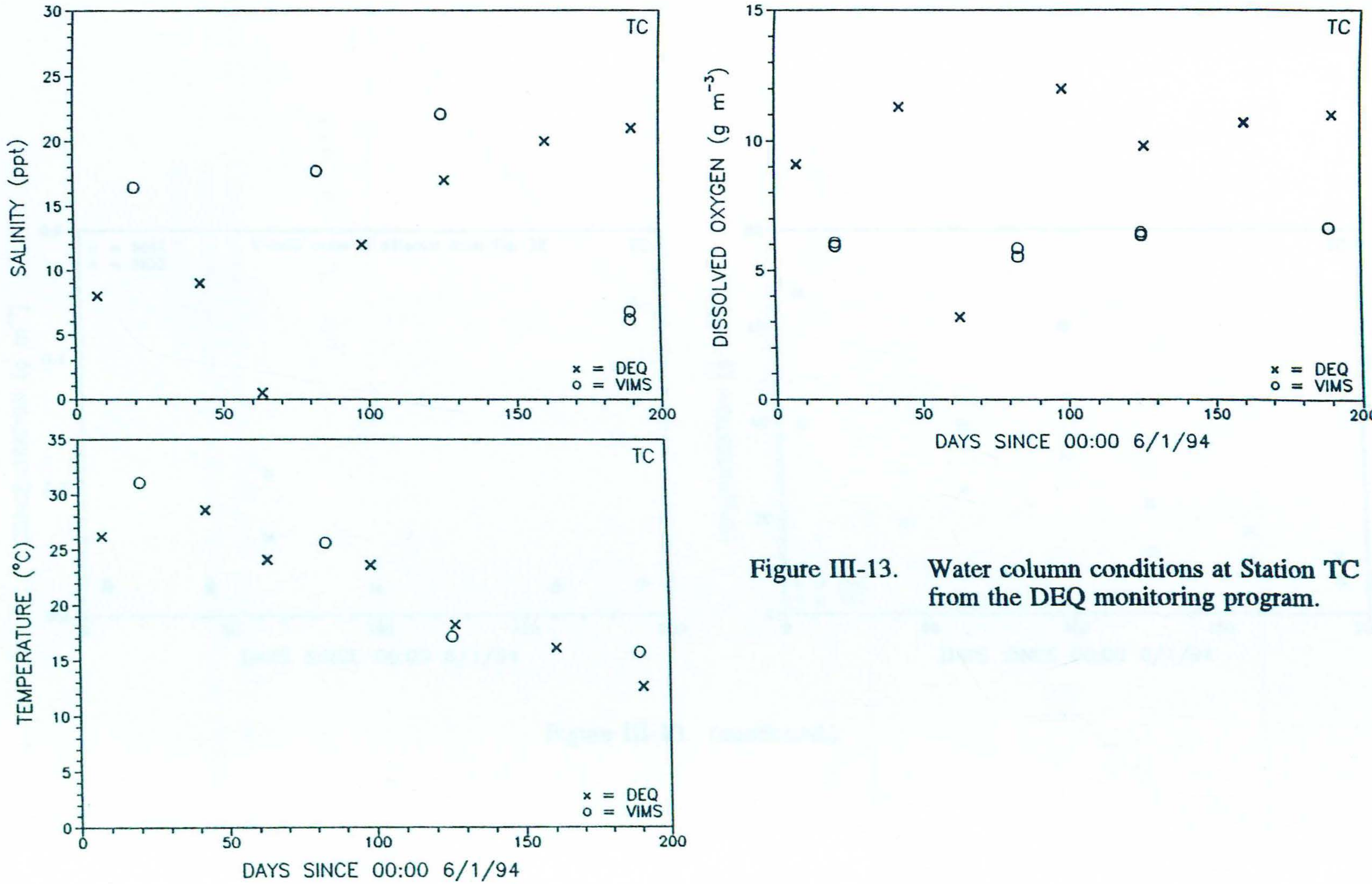


Figure III-13. Water column conditions at Station TC from the DEQ monitoring program.

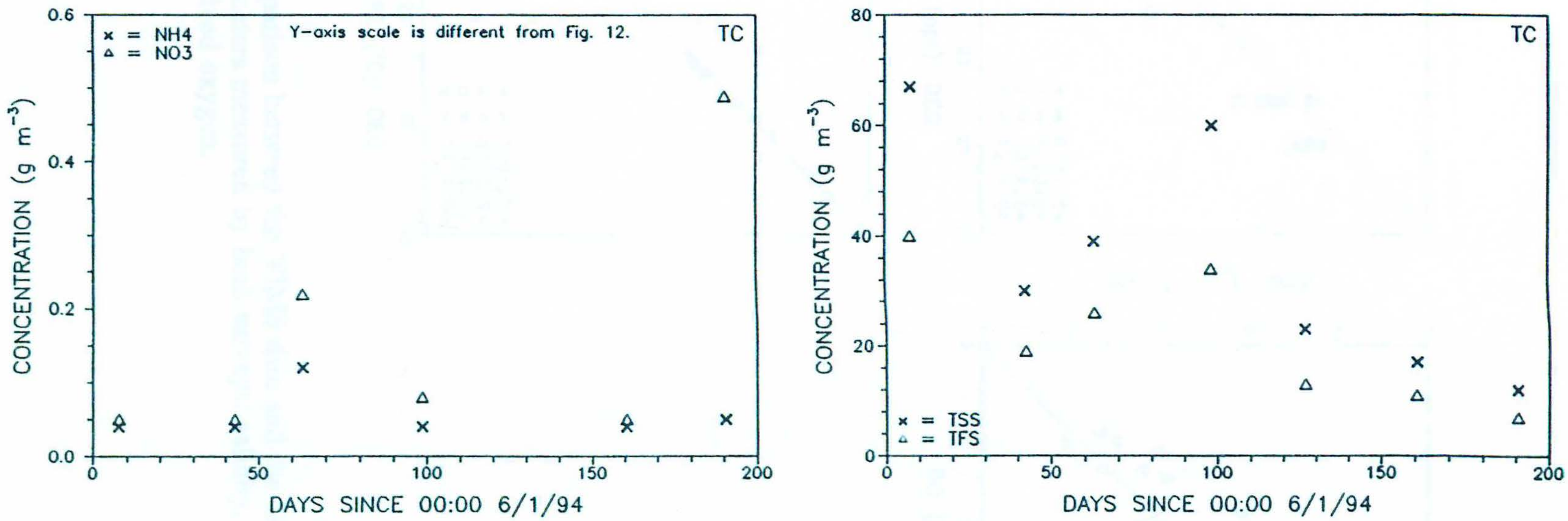


Figure III-13. (continued.)

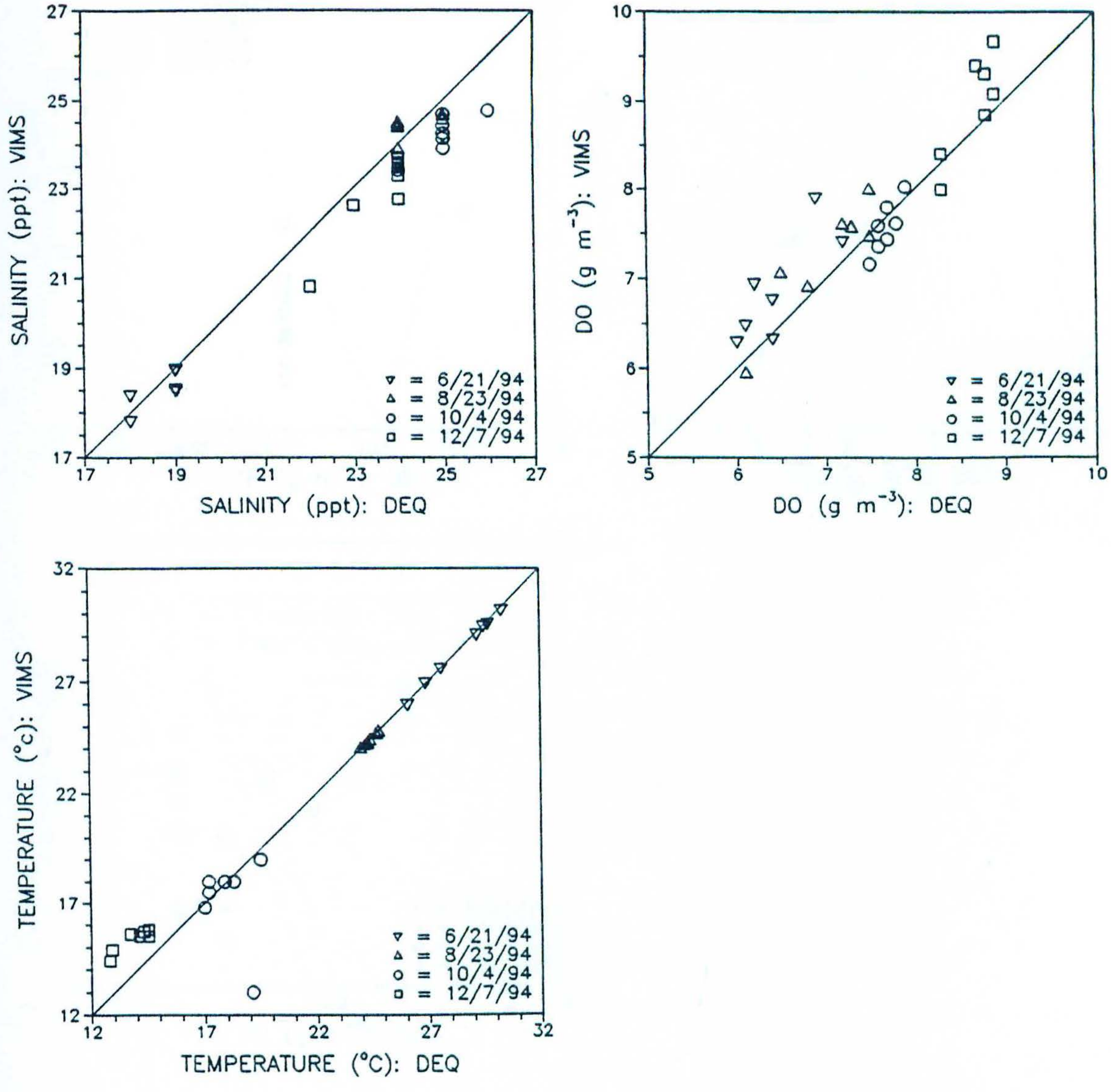


Figure III-14. Comparison between the VIMS data and the DEQ data for the parameters measured by both surveys: salinity, temperature and dissolved oxygen.

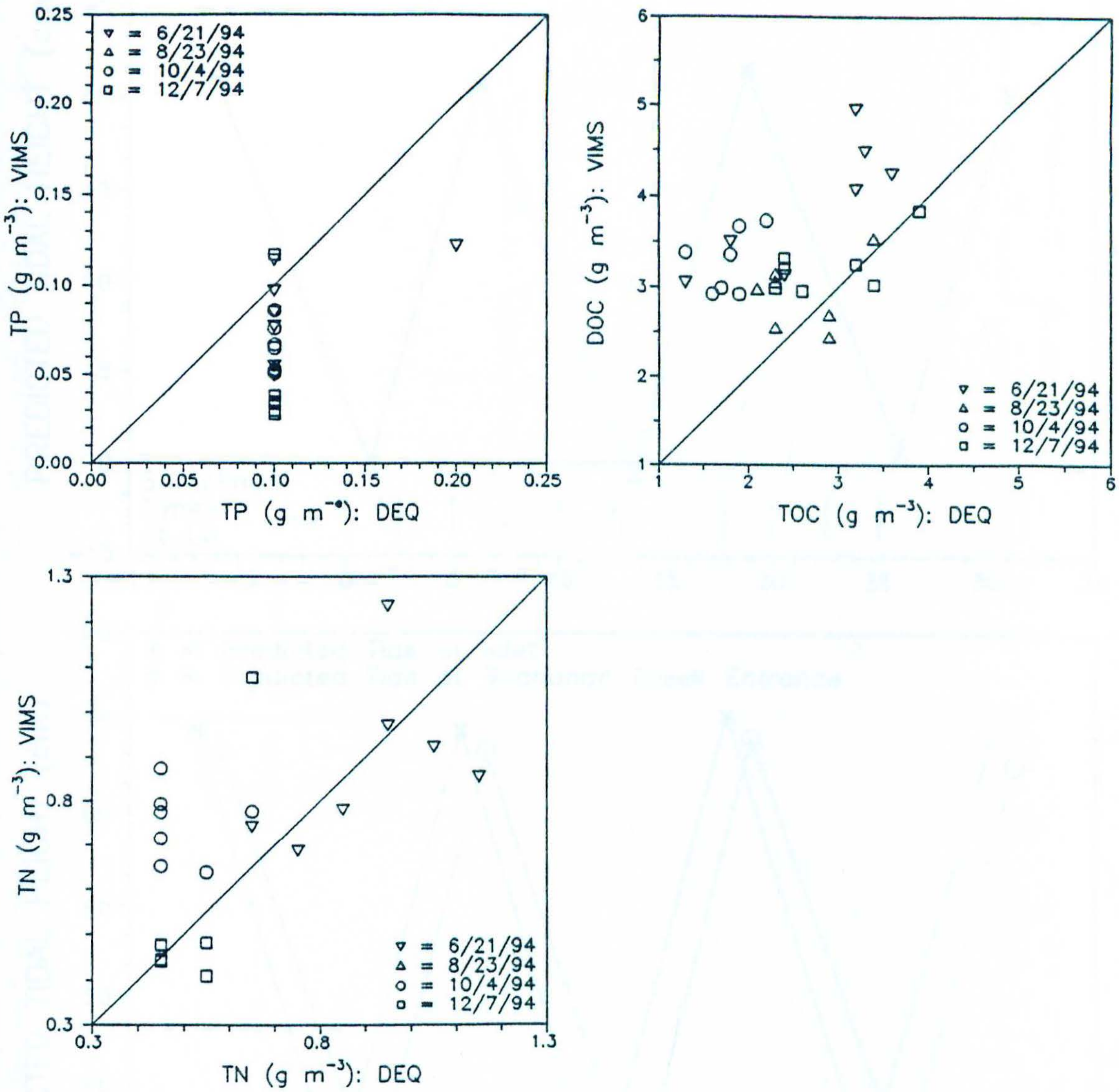


Figure III-15. Comparison between the VIMS data and the DEQ data for total phosphorus, total nitrogen and organic carbon.

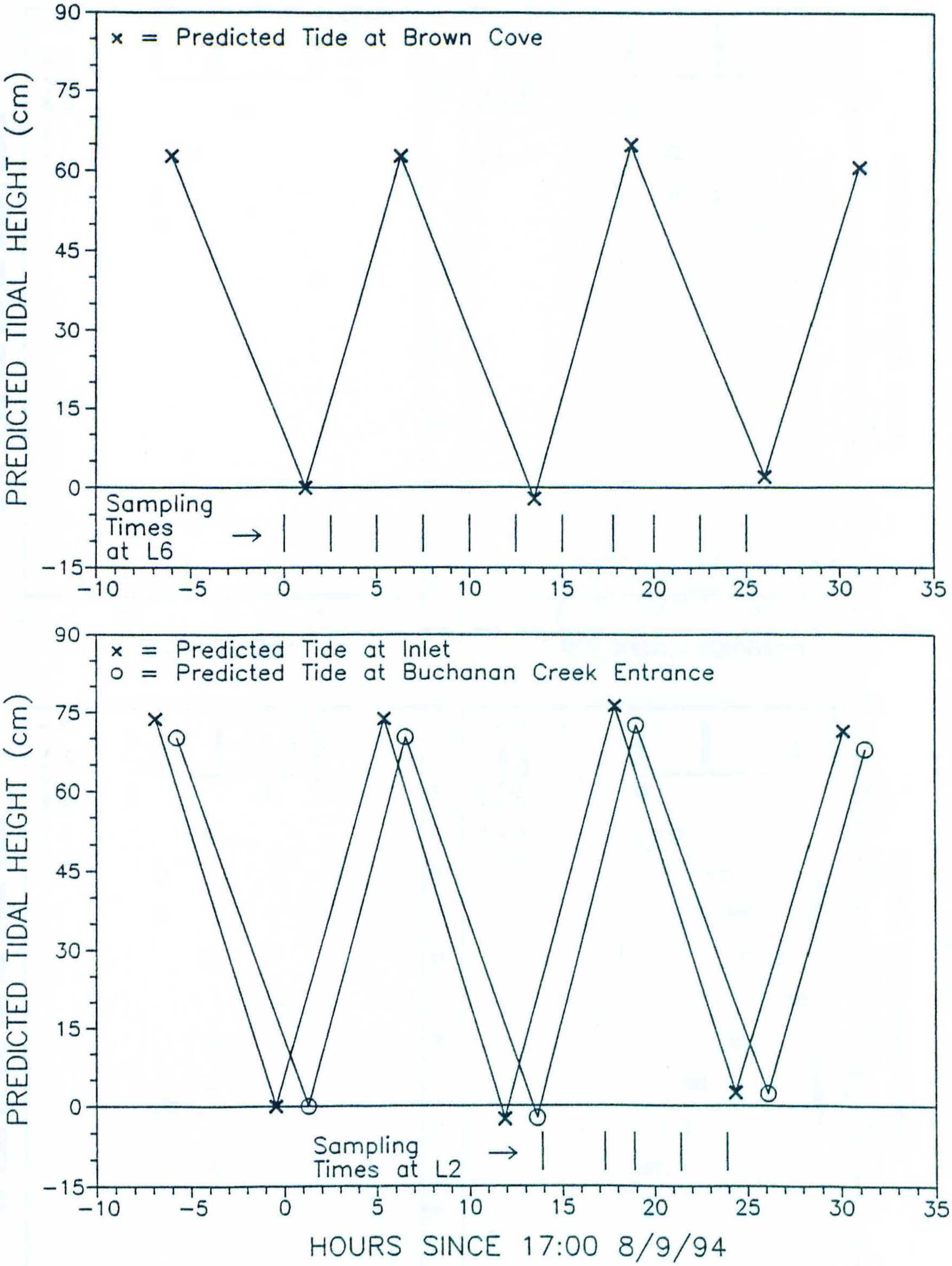


Figure III-16. Predicted tide at Inlet, Brown Cove and Buchanan Creek Entrance, and sampling times at Stations L2 and L6 in intensive survey.

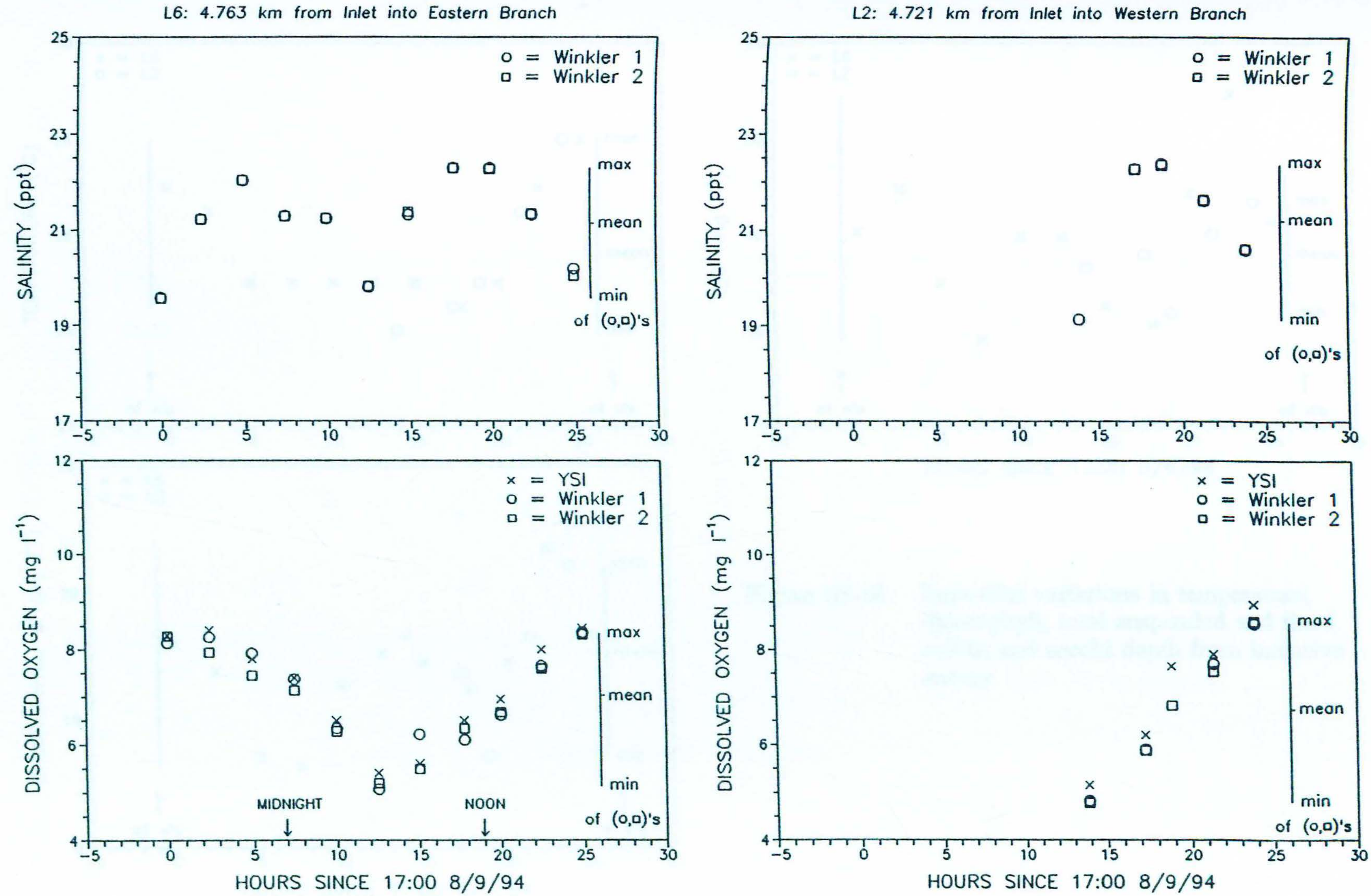
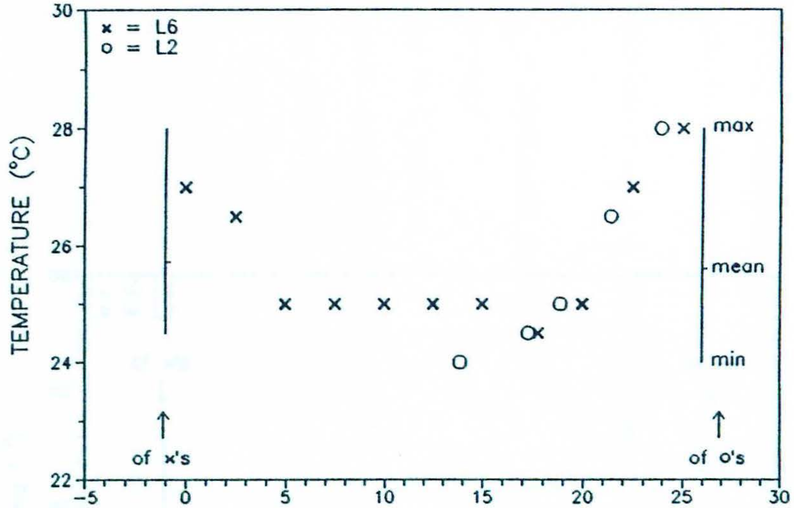
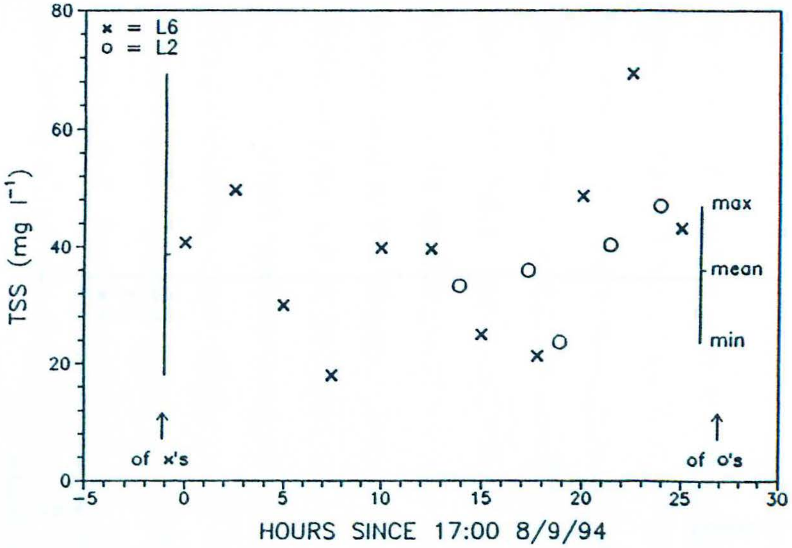


Figure III-17. Intra-tidal variations in salinity and dissolved oxygen from intensive survey.





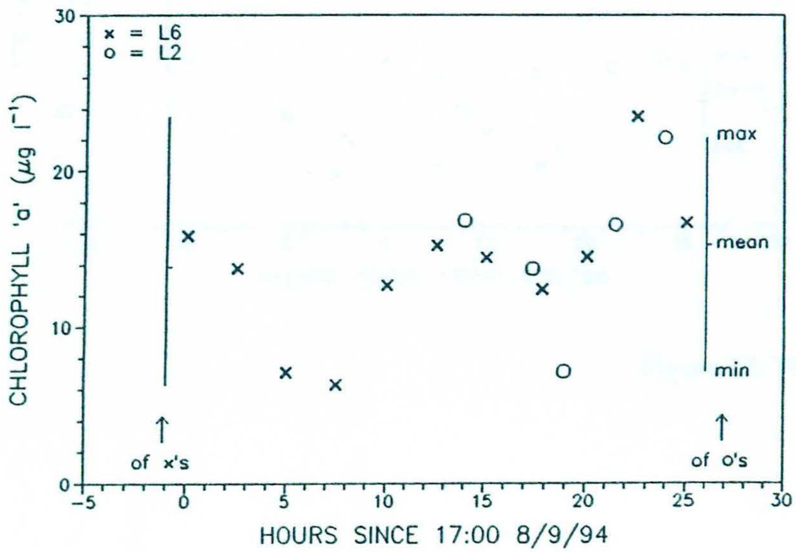


Figure III-18. Intra-tidal variations in temperature, chlorophyll, total suspended and fixed solids, and secchi depth from intensive survey.

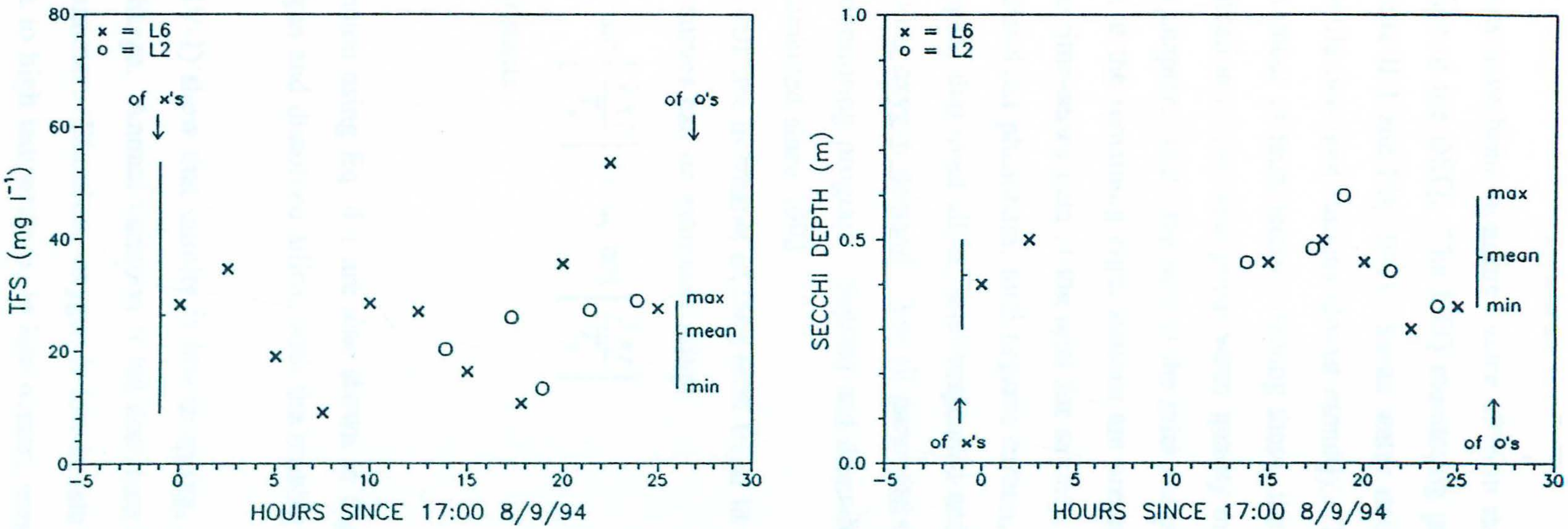


Figure III-18. (continued.)

IV. Results from the DEQ Monitoring Program: Long-term Trend at Inlet

Water quality conditions have been monitored since 1976 in the Lynnhaven River by the Tidewater Regional Office of the DEQ. The DEQ monitoring program has nine stations in the Lynnhaven River (Table II-1 and Fig. II-1). Seven water stations have been sampled approximately bimonthly, while two land stations almost monthly. The DEQ monitoring program have measured a number of parameters. Among these, the parameters (Table I-2) that are relevant to the application of the tidal prism water quality model (Kuo & Park 1994) are briefly discussed in this chapter. Only the data at the inlet are presented in this chapter as an example, and the data at the remaining eight stations are presented in Appendix B.

Figure IV-1 shows the time-series data at the inlet for salinity, temperature, dissolved oxygen, total phosphorus, dissolved phosphate, total organic carbon, total Kjeldahl nitrogen, ammonium and nitrate nitrogen, dissolved silica, total suspended and fixed solids, fecal coliform bacteria, and chemical oxygen demand. Not all parameters have been measured from the beginning of the monitoring program. Salinity and dissovled oxygen measurements, for example, has been implemented since 1992.

The DEQ monitoring data are indicative of long-term trend in water quality conditions. Annual multiple regression curves can be estimated using:

$$Concentration = a_0 + a_1 \cdot \sin\left[\frac{2\pi t}{T_p}\right] + a_2 \cdot \cos\left[\frac{2\pi t}{T_p}\right] \tag{4-1}$$

a_0, a_1 & a_2 = regression constants

t = time in year

T_p = period = 1 year.

The regression curves estimated using Eq. 4-1 are also shown in Fig. IV-1 for salinity, temperature, dissolved oxygen and dissolved silica, with the number of observations (n) used to estimate three constants.

The DEQ data (Fig. IV-1) show that salinity is low in spring, probably due to high spring-time freshwater discharge. Annual variation is the dominant signal for temperature, low in winter and high in summer. Dissolved oxygen is low in late summer indicating active decay of organic matter due to high temperature, in late winter, temperature is low and dissolved oxygen is high. For the above three parameters, the annual regression curves fit the corresponding data fairly well.

Total phosphorus is lower than the detection limit (0.1 g m^{-3}) most of the time (Fig. IV-1). For dissolved phosphate, more than half of the data also is lower than the detection limit (0.01 g m^{-3}). Before 1988, the detection limit for ammonium nitrogen (0.1 g m^{-3}) was too high, with no single measurement higher than 0.1 g m^{-3}. Even with the improved detection limit since 1988 (0.04 g m^{-3}), half of the data is still lower than 0.04 g m^{-3}. Nitrate nitrogen shows that most of the data are lower than the detection limit, which has been changed twice since 1976. Dissolved silica is shown in Fig. IV-1 with the annual regression curve estimated using Eq. 4-1. Low silica concentration in early part of each year may be due to the growth of diatoms, which indicates that diatoms may be an important contributor for spring bloom in saline water at the inlet of the Lynnhaven River. No non-zero measurement was obtained for chemical oxygen demand at the inlet.

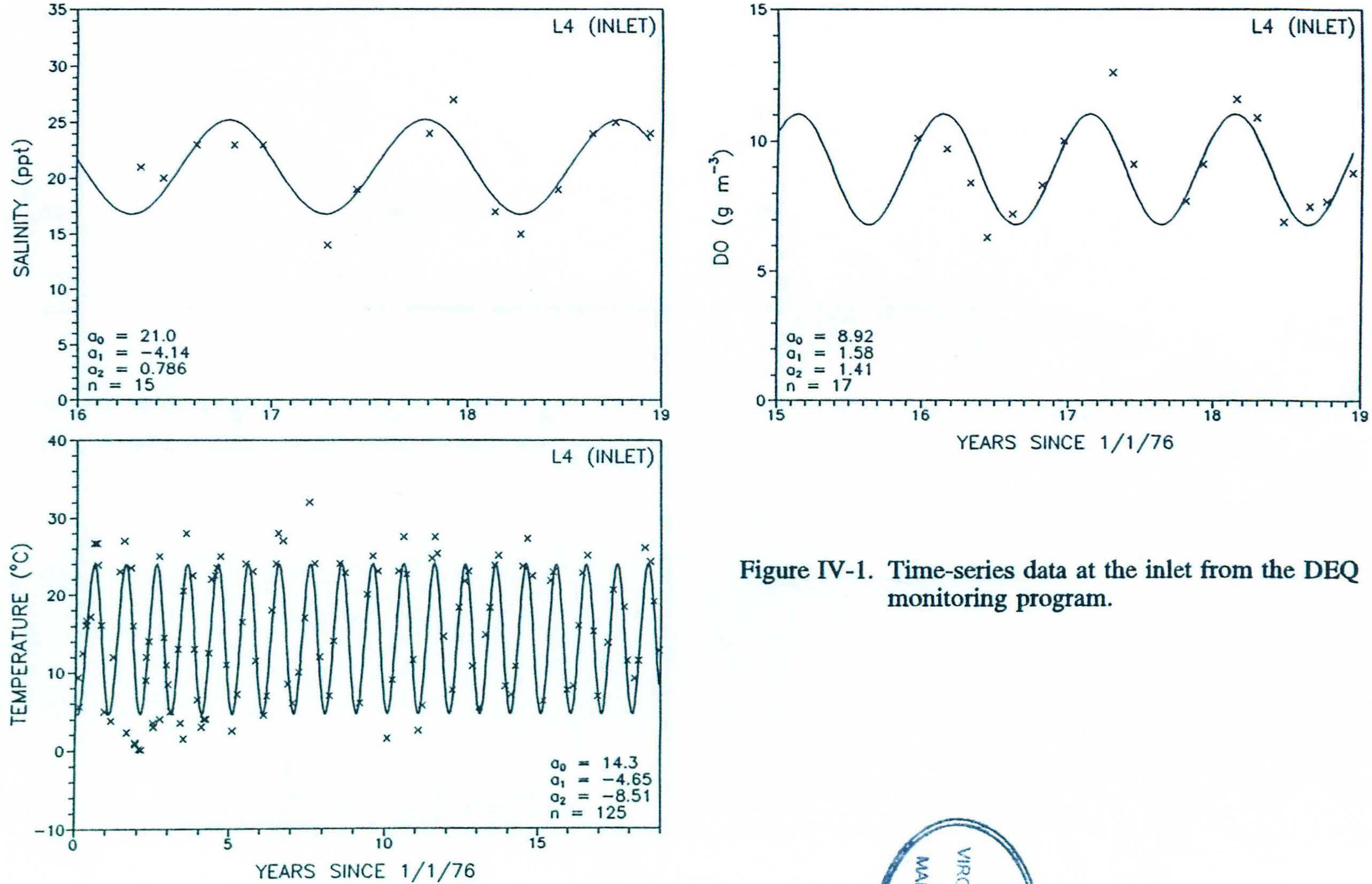


Figure IV-1. Time-series data at the inlet from the DEQ monitoring program.

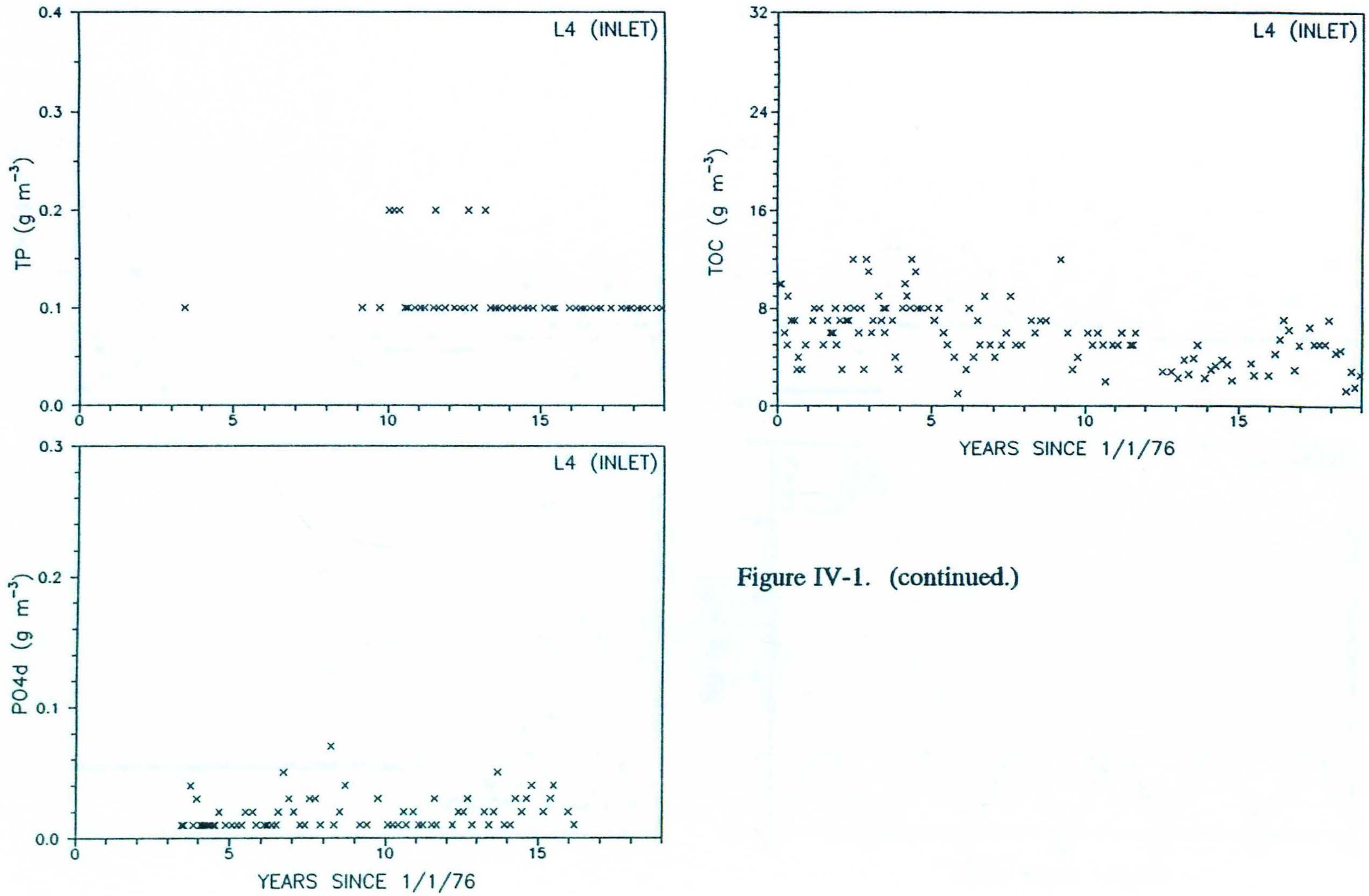


Figure IV-1. (continued.)

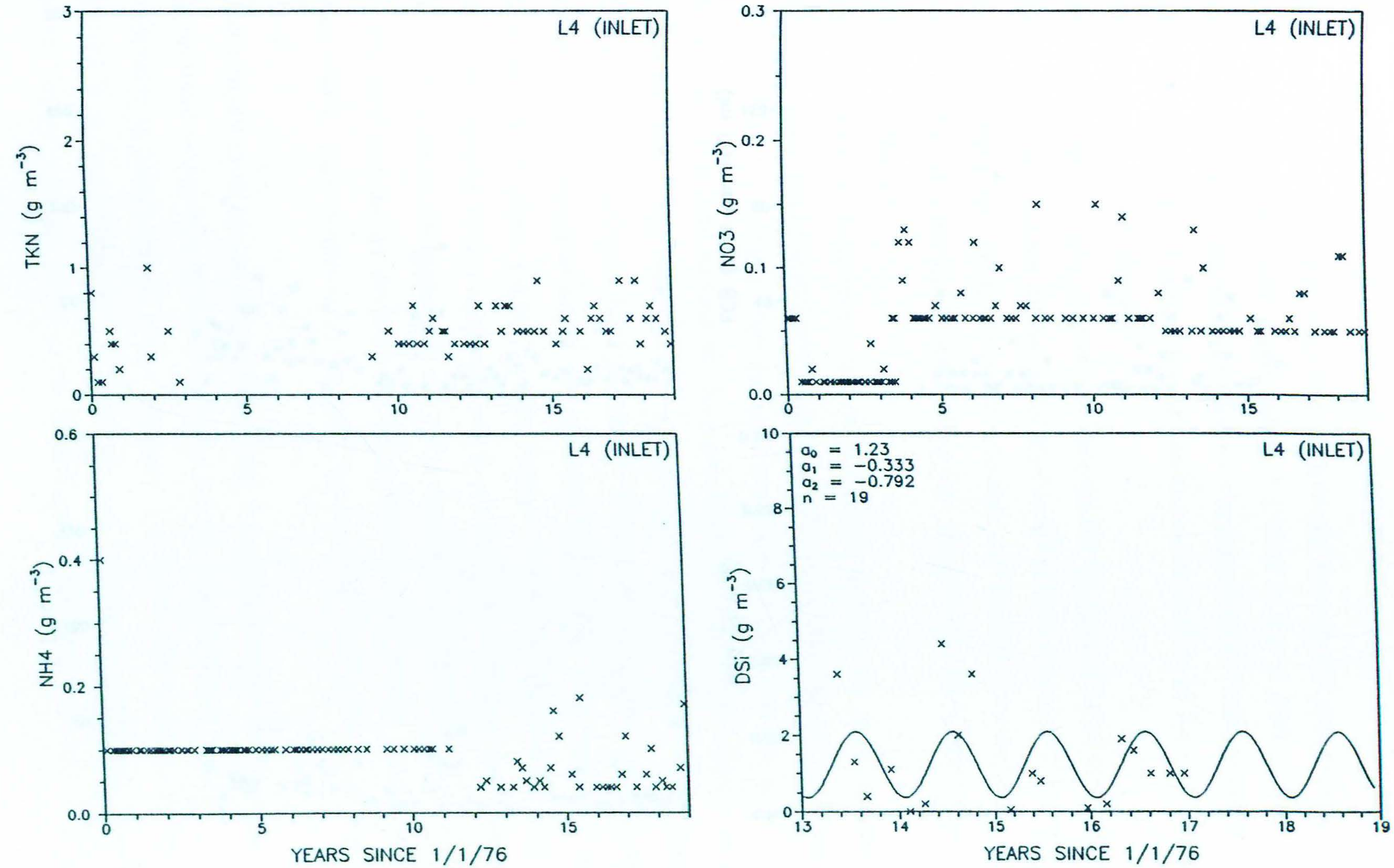


Figure IV-1. (continued.)

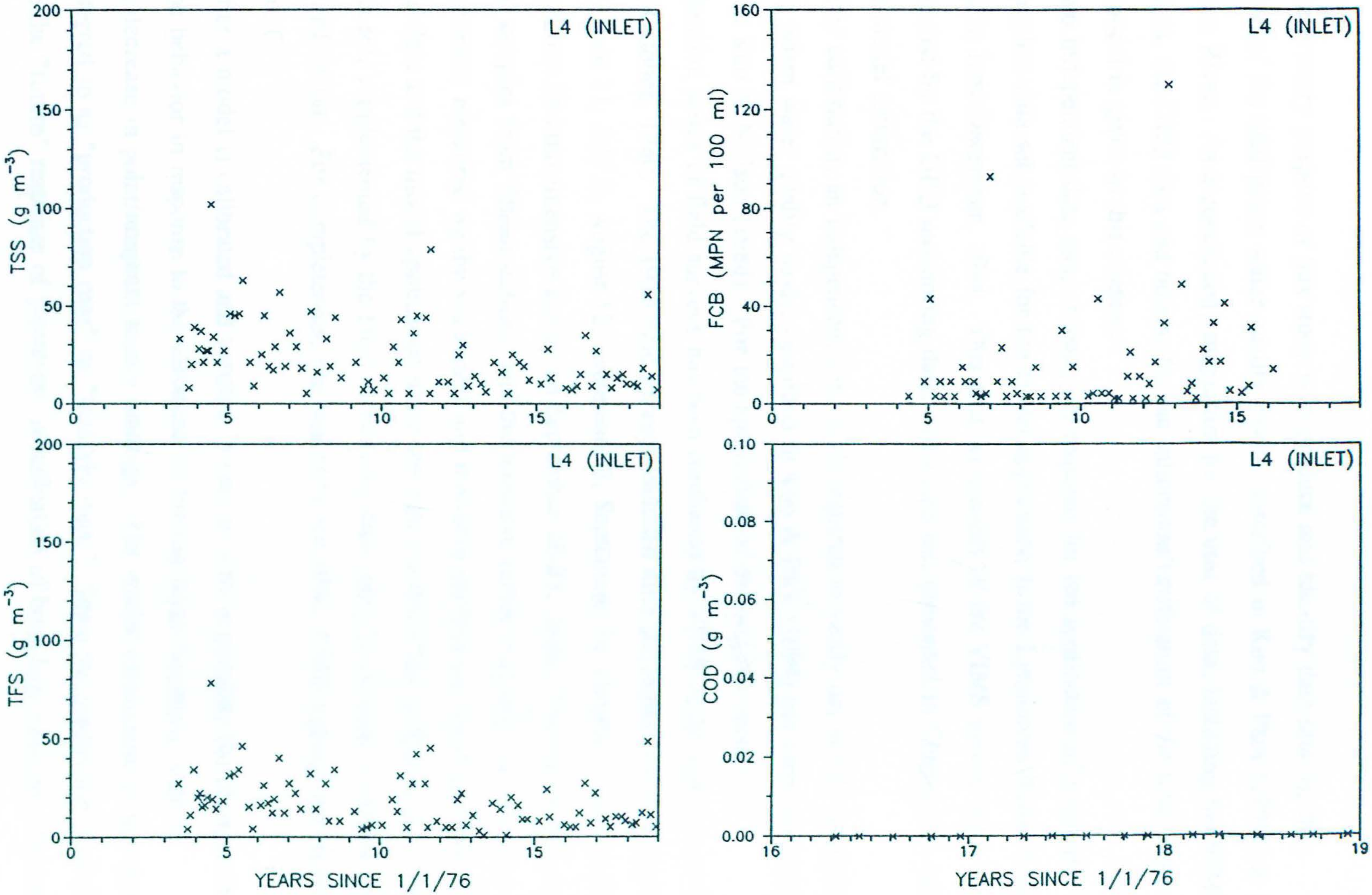


Figure IV-1. (continued.)

V. Identification of Data for Model Application

The primary purpose of this study is to produce and identify data sets for the application of the tidal prism water quality model, described in Kuo & Park (1994), to the Lynnhaven River. As a conclusion, suggestion for the uses of data, including the VIMS survey data, the DEQ data and others, for the calibration/verification of the tidal prism water quality model is given in this chapter.

Two independent data sets, at least, are required for the application of a model. The most complete data set available for the model application at the Lynnhaven River is the data collected in June-December, 1994. This data set consists of the VIMS survey data, supplemented by the DEQ monitoring data. This data set, presented in Chapter III, may be used for model calibration.

After calibration, an independent data set is required to verify the model calibration. The tidal prism water quality model described in Kuo & Park (1994) has been evolved from the one in Kuo & Neilson (1988). For the application of the original version, a comprehensive series of field surveys has been conducted by VIMS at the Lynnhaven River in April-October, 1980. The 1980 field surveys included nine slackwater surveys (April 28, May 27, June 11, July 8, August 12, September 8, September 29, October 1 and October 7, 1980) and one 26-hour intensive survey on September 26-27, 1980. The slackwater surveys collected samples from fifteen stations, and the intensive survey had nine stations (Fig. V-1). The parameters measured by the slackwater and intensive surveys are listed in Table V-1. The field data and the model application using the data are described in Kuo et al. (1982). This data set, supplemented by the DEQ monitoring data, may be an ideal candidate for model verification. For completeness, the data from the 1980 VIMS surveys are listed in Appendix C.

After a model is calibrated and verified, it can be used to simulate the changes in prototype behavior in response to the variations in forcing input functions, such as increase/decrease in point/nonpoint source loadings. The model simulations of this type are often referred to as "production runs" or "scenario runs." Since the production runs are to simulate the "future" response of prototype, specification of boundary conditions becomes critical. The water column conditions of the incoming seawater through the inlet are an example. The long-term DEQ monitoring data will provide an excellent basis to evaluate "average" annual conditions at the inlet. The annual regression curves shown in Fig. IV-1 are examples of this effort.

The tidal prism water quality model, described in Kuo & Park (1994), has twenty four water column and twenty seven sediment state variables (Table I-1). It is not likely that any past data set, or any one in near future, may include measurements of all state variables listed in Table I-1. Then, data conversion, such as that in Eq. 3-3, may be inevitable. The long-term DEQ monitoring data, which are presented in Chapter IV and Appendix B, will be very useful for this purpose.

Table V-1. Water quality parameters measured by the VIMS slackwater and intensive surveys in April-October, 1980.

salinity
temperature
dissolved oxygen
carbonaceous biochemical oxygen demand (5-day and ultimate)[a]
chlorophyll
total phosphorus
dissolved phosphate
total Kjeldahl nitrogen
ammonium nitrogen
nitrate+nitrite nitrogen
fecal coliform bacteria
secchi disk depth

[a] Ultimate carbonaceous biochemical oxygen demand was measured only at the slackwater surveys.

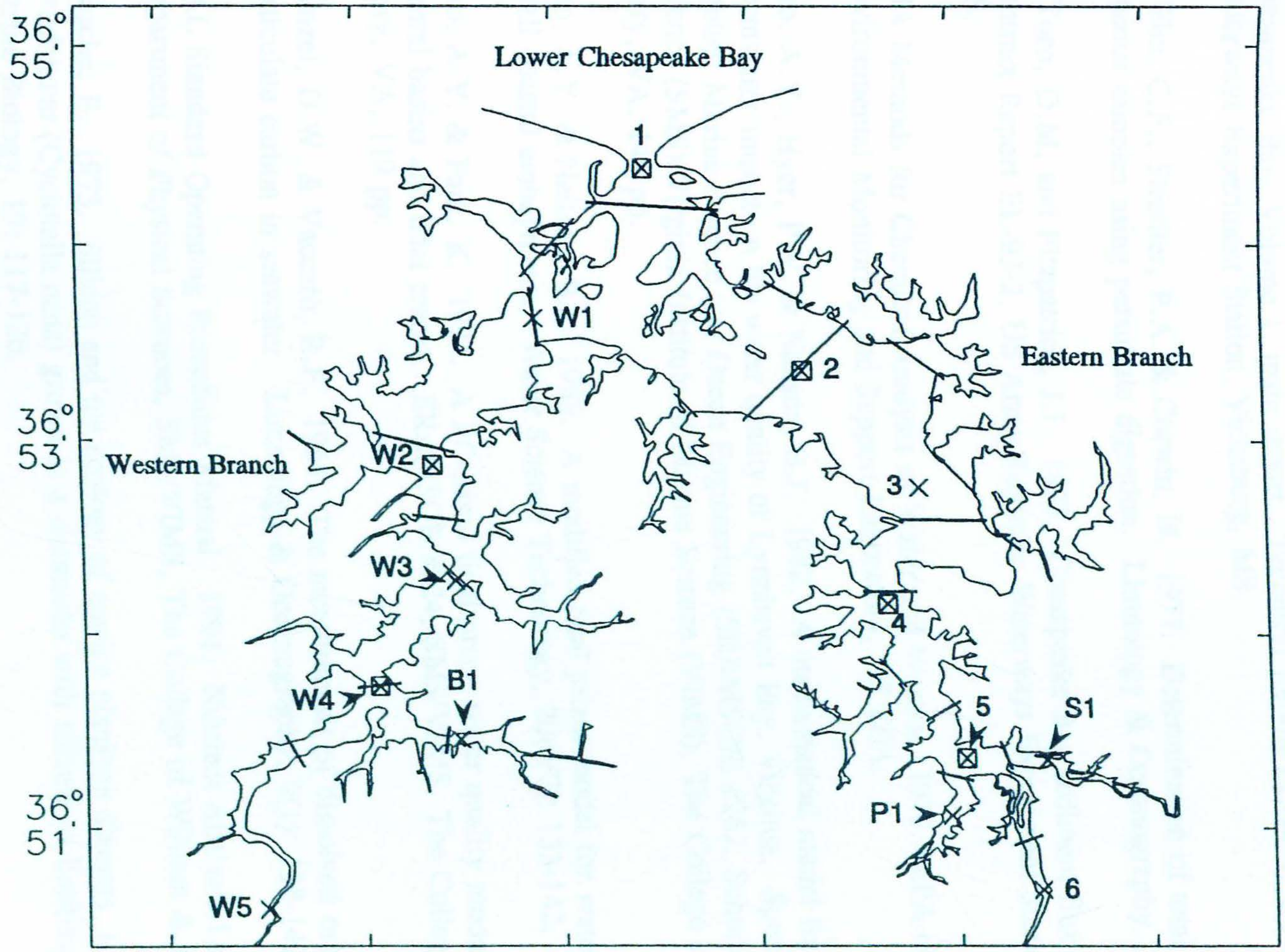


Figure V-1. The Lynnhaven River showing the station locations for 1980 VIMS surveys: slackwater stations (×) and intensive stations (⊠). Solid lines are model transects.

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Appendix A. The Data from the VIMS surveys in June-December, 1994

The data from the VIMS surveys, both longitudinal and intensive, in June-December, 1994 are presented in tabular format in this appendix. The salinity and temperature from CTD casts at the first two longitudinal surveys on June 21 and August 23 are not included here.

Table A-1. Results from the first longitudinal survey on 6/21/94.

1. WATER COLUMN

	km	PC (mg/l)	DOC (mg/l)	PN (mg/l)	TDN (mg/l)	PP (mg/l)	TDP (mg/l)	PO4p (mg/l)	PO4d (mg/l)	DSi (mg/l)	PSi (mg/l)	CHL (ug/l)	DO (mg/l)	DO-dup (mg/l)	S (ppt)	S-dup (ppt)
: DTL		0.097	0.200	0.019	0.026	0.001	0.002	0.001	0.001	0.013	0.000	0.950	0.080		0.000	
TC	-9.186	7.227	7.810	1.063	0.639	0.150	0.167	0.079	0.126	2.554	0.871	107.334	5.939	6.076	16.438	16.428
L1	-6.451	4.086	4.485	0.546	0.367	0.084	0.030	0.033	0.012	1.585	1.134	32.296	6.860	6.684	18.978	
L2	-4.721	2.782	4.070	0.414	0.307	0.065	0.020	0.029	0.007	1.273	0.833	24.959	6.507	6.448	18.950	
L3	-3.045	2.275	3.500	0.380	0.265	0.064	0.013	0.024	0.005	0.933	0.770	21.000	6.292		18.537	
L4	0.0	1.987	2.870	0.340	0.280	0.040	0.008	0.017	0.003	0.582	0.446	12.180	8.310	7.468	18.483	
L4-duplicate		2.104	3.220	0.356	0.267	0.044	0.007	0.016	0.003	0.573	0.438	9.080				
L5	2.768	2.015	3.130	0.324	0.237	0.044	0.011	0.019	0.004	0.658	0.534	12.496	7.448	7.370	18.375	
L6	4.763	2.452	4.240	0.359	0.280	0.074	0.023	0.031	0.011	1.225	0.747	14.098	6.958	6.919	18.490	
L7	7.080	2.388	4.950	0.360	0.361	0.075	0.047	0.028	0.032	1.389	0.773	20.132	6.370	6.292	17.799	
LBC	9.653	2.850	5.880	0.501	0.396	0.103	0.079	0.045	0.063	1.669	0.819	40.384	5.253	5.253	16.125	16.125
L4-bottom		1.931	2.880	0.314	0.240	0.041	0.009	0.014	0.004	0.532	0.422	10.093	7.291	7.370	18.678	

2. SEDIMENT

	STS (%)	STC (mg/g)	STN (mg/g)	STP (mg/g)	SPO4p (mg/g)
L2-top	33.924	19.988	1.988	0.531	0.388
L2-bottom	38.186	19.340	1.985	0.496	0.372
L6-top	33.474	20.711	2.231	0.527	0.382
L6-bottom	37.244	20.402	2.232	0.515	0.402

Table A-2. Results from the second longitudinal survey on 8/23/94.

1. WATER COLUMN

	km	PC	DOC	PN	TDN	PP	TDP	PO4p	PO4d	DSi	PSi	CHL	DO	DO-dup	S	S-dup
		(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(ug/l)	(mg/l)	(mg/l)	(ppt)	(ppt)
: DTL		0.097	0.200	0.019	0.026	0.001	0.002	0.001	0.001	0.013	0.000	0.950	0.080		0.000	
TC	-9.186	5.359	4.950	0.860	0.377	0.168	0.030	0.030	0.008	0.743	1.127	51.264	5.858	5.535	17.723	17.673
L1	-6.451	2.522	3.150	0.383	0.313	0.091	0.018	0.021	0.007	0.355	1.025	21.307	6.060	5.858	23.909	23.916
L2	-4.721	2.115	2.980	0.326	0.329	0.071	0.018	0.022	0.005	0.159	1.004	8.677	6.828	7.030	24.693	24.648
L3	-3.045	2.257	2.550	0.323	0.231	0.065	0.015	0.017	0.006	0.088	0.743	16.153	7.636	7.595	24.521	24.521
L4	0.0	2.246	2.570	0.302	0.233	0.043	0.014	0.022	0.006	0.051	0.796	11.121	7.494	7.474	24.409	24.397
L4-duplicate		1.706	2.820	0.251	0.245	0.044	0.015	0.021	0.005	(0.012)	0.809	12.616				
L5	2.768	2.008	3.060	0.257	0.257	0.049	0.015	0.022	0.007	0.058	0.796	8.411	8.161	7.858	24.521	24.371
L6	4.763	2.293	2.450	0.271	0.219	0.077	0.015	0.015	0.008	0.040	0.817	13.564	7.575	7.595	24.584	24.588
L7	7.080	2.129	3.540	0.323	0.278	0.072	0.017	0.012	0.005	0.346	0.719	13.884	7.009	7.151	23.474	23.466
LBC	9.653	3.004	5.990	0.584	0.412	0.098	0.038	0.032	0.019	1.179	0.704	35.925	4.444	4.545	17.103	17.099
L4-bottom		2.200	2.680	0.314	0.252	0.041	0.016	0.018	0.008	0.015	0.684	13.777	7.535	7.817	24.390	24.394

2. SEDIMENT

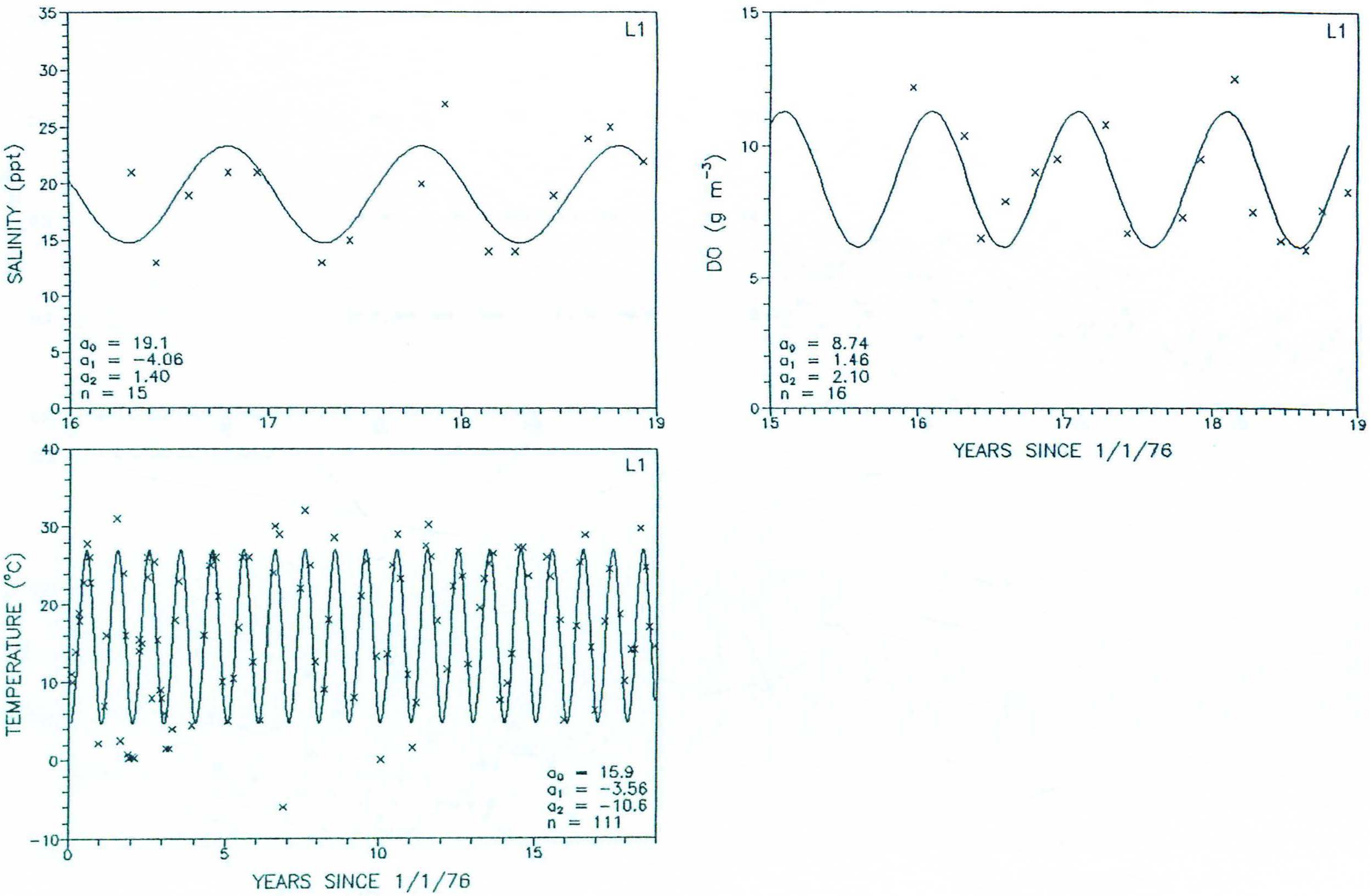
	STS	STC	STN	STP	SPO4p
	(%)	(mg/g)	(mg/g)	(mg/g)	(mg/g)
L2-top	29.802	20.237	2.401	0.592	0.444
L2-top: dup	32.178	18.421	2.117	0.577	0.411
L2-bottom	31.487	15.323	1.666	0.398	0.320
L2-bottom: dup	45.290	15.846	1.738	0.472	0.343
L6-top	51.085	11.195	1.123	0.286	0.255
L6-top: dup	50.421	10.345	1.066	0.222	0.199
L6-bottom	50.533	12.571	1.314	0.331	0.266
L6-bottom: dup	50.588	13.589	1.153	0.309	0.251

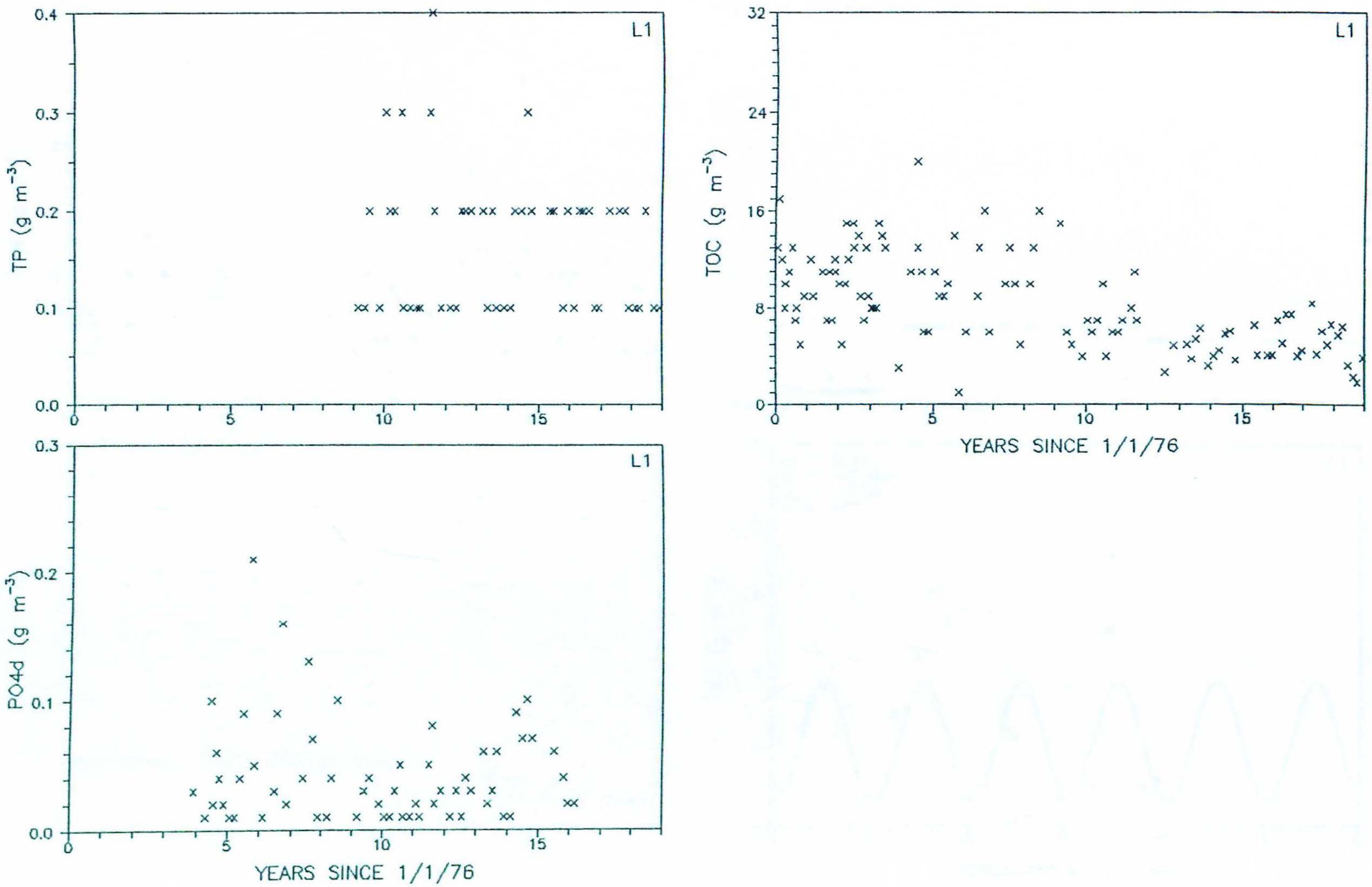
Table A-5. Results from the intensive survey on August 9-10, 1994.

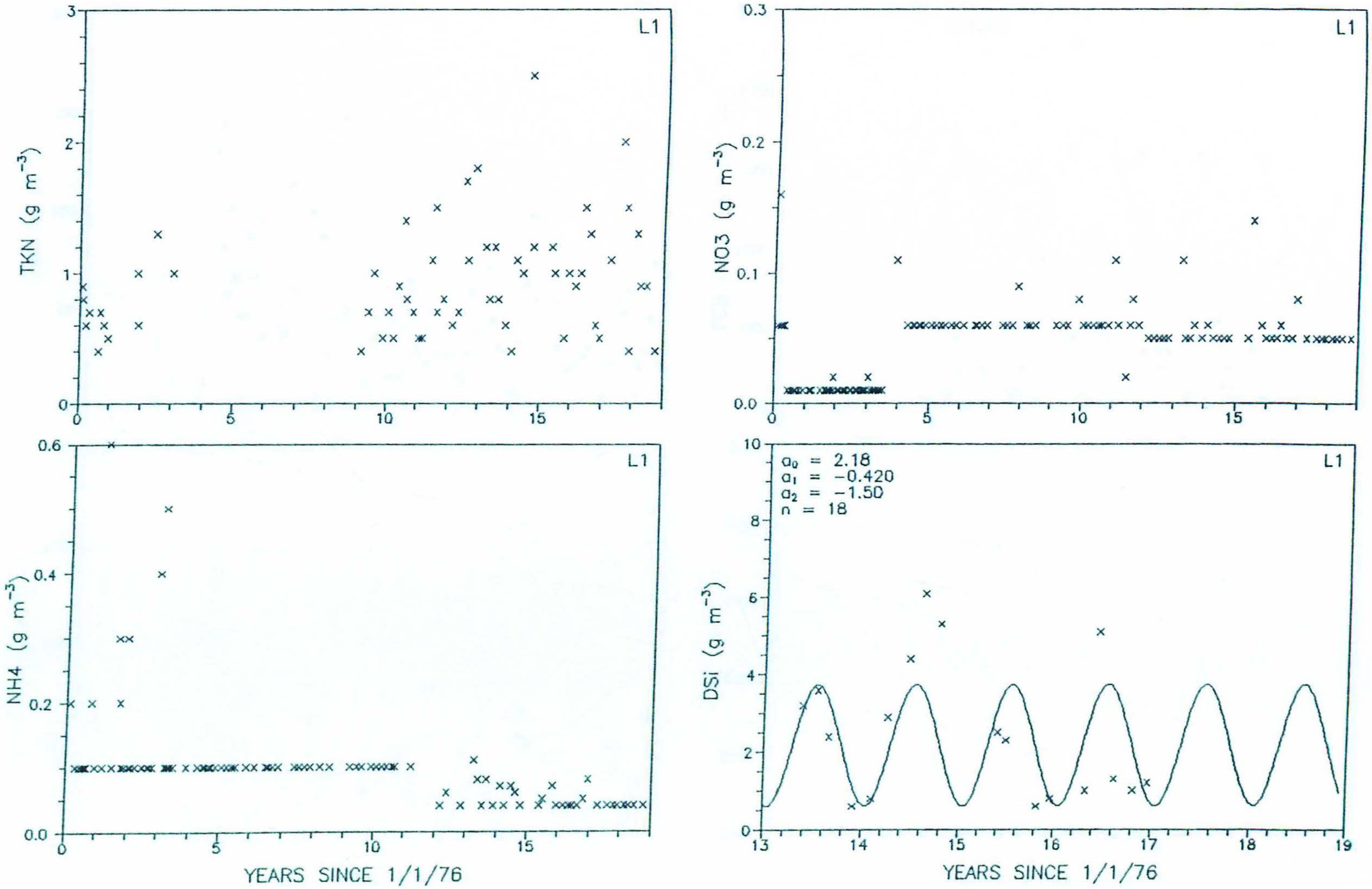
Station	Day	Hr	Min	Time (hr)	Chl (ug/l)	TSS (mg/l)	TFS (mg/l)	T (oC)	SD (m)	S (ppt) Wink-1	S (ppt) Wink-2	DO (mg/l) Wink-1	DO (mg/l) Wink-2	YSI
				: DTL =	0.950	2.000	0.000			0.000		0.080		
L6	8/9	17	0	0.00	15.860	40.750	28.250	27.0	0.40	19.581	19.566	8.140	8.281	8.30
		19	30	19.50	13.777	49.667	34.667	26.5	0.50	21.225	21.221	8.261	7.939	8.40
		22	0	22.00	7.102	30.000	19.000	25.0		22.030	22.034	7.919	7.457	7.80
	8/10	0	30	24.50	6.301	18.000	9.000	25.0		21.294	21.291	7.377	7.135	7.40
		3	0	27.00	12.638	39.833	28.500	25.0		21.239	21.247	6.332	6.271	6.50
		5	30	29.50	15.201	39.667	27.000	25.0		19.802	19.832	5.065	5.186	5.40
		8	0	32.00	14.418	25.000	16.333	25.0	0.45	21.313	21.375	6.211	5.487	5.60
		10	45	34.75	12.371	21.333	10.667	24.5	0.50	22.292	22.292	6.090	6.332	6.50
		13	0	37.00	14.454	48.667	35.667	25.0	0.45	22.292	22.267	6.613	6.673	6.95
		15	30	39.50	23.496	69.330	53.667	27.0	0.30	21.317	21.338	7.658	7.598	8.00
		18	0	42.00	16.652	43.167	27.667	28.0	0.35	20.197	20.051	8.362	8.321	8.45
				maximum =	23.496	69.330	53.667	28.00	0.500		22.292		8.362	
				mean =	13.843	38.674	26.402	25.73	0.421		21.141		7.032	
				minimum =	6.301	18.000	9.000	24.50	0.300		19.566		5.065	
L2	8/10	6	55	30.92	16.803	33.333	20.333	24.0	0.45	19.138	21.375	4.824	4.784	5.15
		10	15	34.25	13.706	36.000	26.000	24.5	0.48	22.270	22.263	5.889	5.869	6.20
		11	55	35.92	7.102	23.667	13.333	25.0	0.60	22.381	22.348		6.814	7.65
		14	25	38.42	16.518	40.333	27.333	26.5	0.43	21.614	21.625	7.698	7.537	7.90
		16	55	40.92	22.108	47.000	29.000	28.0	0.35	20.595	20.606	8.542	8.583	8.95
				maximum =	22.108	47.000	29.000	28.00	0.600		22.381		8.583	
				mean =	15.247	36.067	23.200	25.60	0.462		21.422		6.727	
				minimum =	7.102	23.667	13.333	24.00	0.350		19.138		4.784	

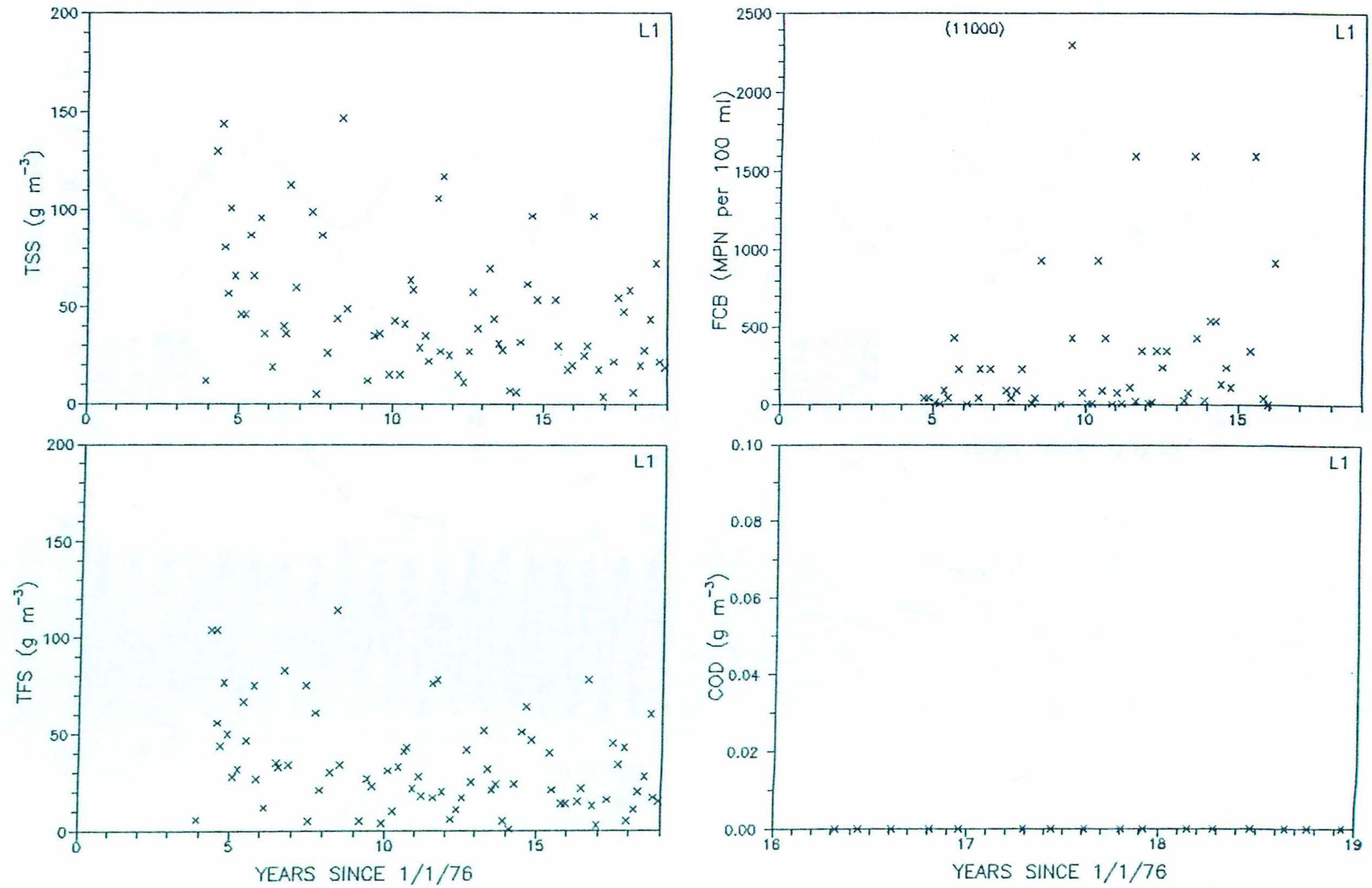
Appendix B. The DEQ Monitoring Data in the Lynnhaven River (1976-1994)

The DEQ monitoring data at the inlet (Station L4) are presented in Fig. IV-1. The DEQ data from the remaining eight stations (Stations L1, L2, L3 and TC in the Western Branch, and Stations L5, L6, L7 and LBC in the Eastern Branch) are presented for 1976-1994 in this appendix, following the same format as Fig. IV-1.

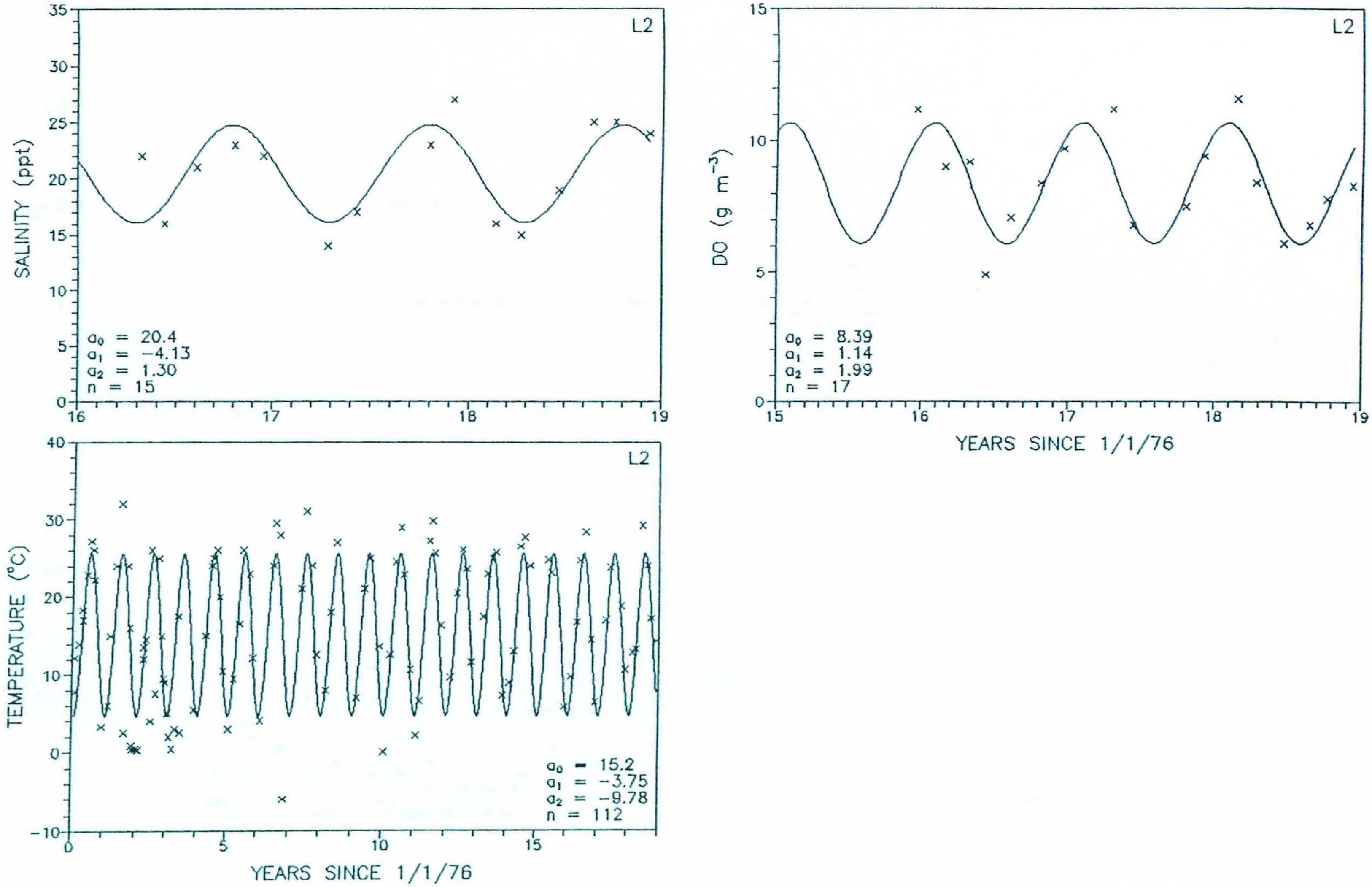

L1
SALINITY (ppt)
a0 = 19.1
a1 = −4.06
a2 = 1.40
n = 15
L1
DO (g m−3)
a0 = 8.74
a1 = 1.46
a2 = 2.10
n = 16
YEARS SINCE 1/1/76
L1
TEMPERATURE (°C)
a0 = 15.9
a1 = −3.56
a2 = −10.6
n = 111
YEARS SINCE 1/1/76

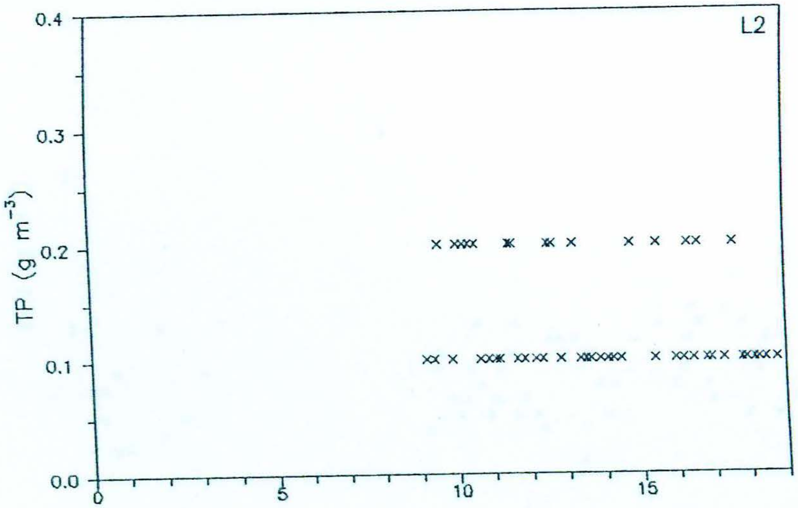

L1
TP (g m-3)
0.0
0.1
0.2
0.3
0.4
L1
TOC (g m-3)
0
8
16
24
32
0
5
10
15
YEARS SINCE 1/1/76
L1
PO4d (g m-3)
0.0
0.1
0.2
0.3
0
5
10
15
YEARS SINCE 1/1/76

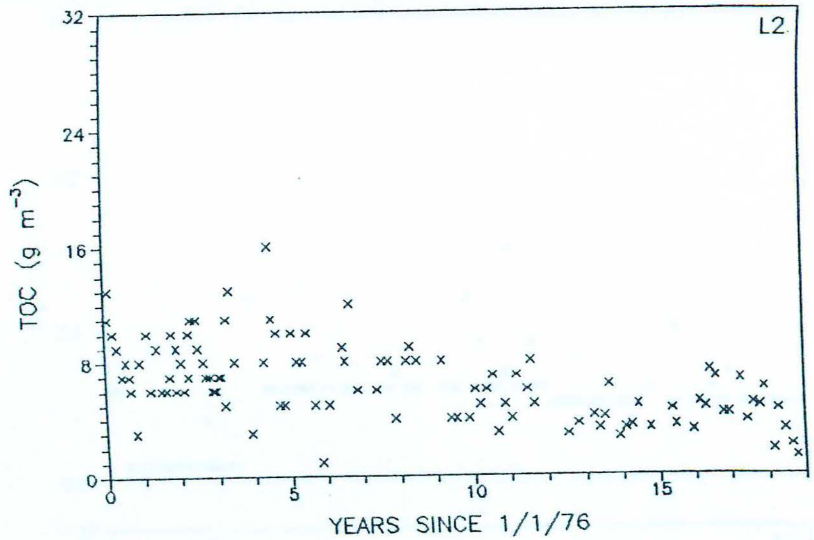

L1
TKN (g m^-3)
NO3 (g m^-3)
NH4 (g m^-3)
DSi (g m^-3)
a0 = 2.18
a1 = -0.420
a2 = -1.50
n = 18
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76

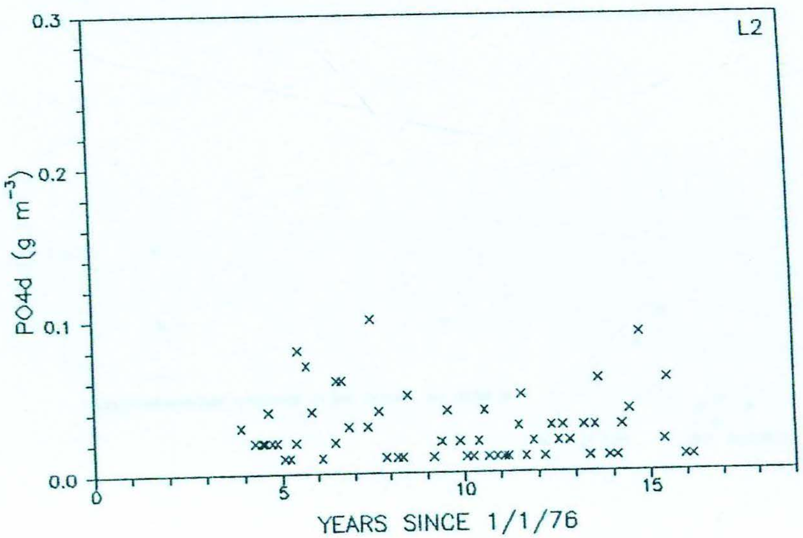


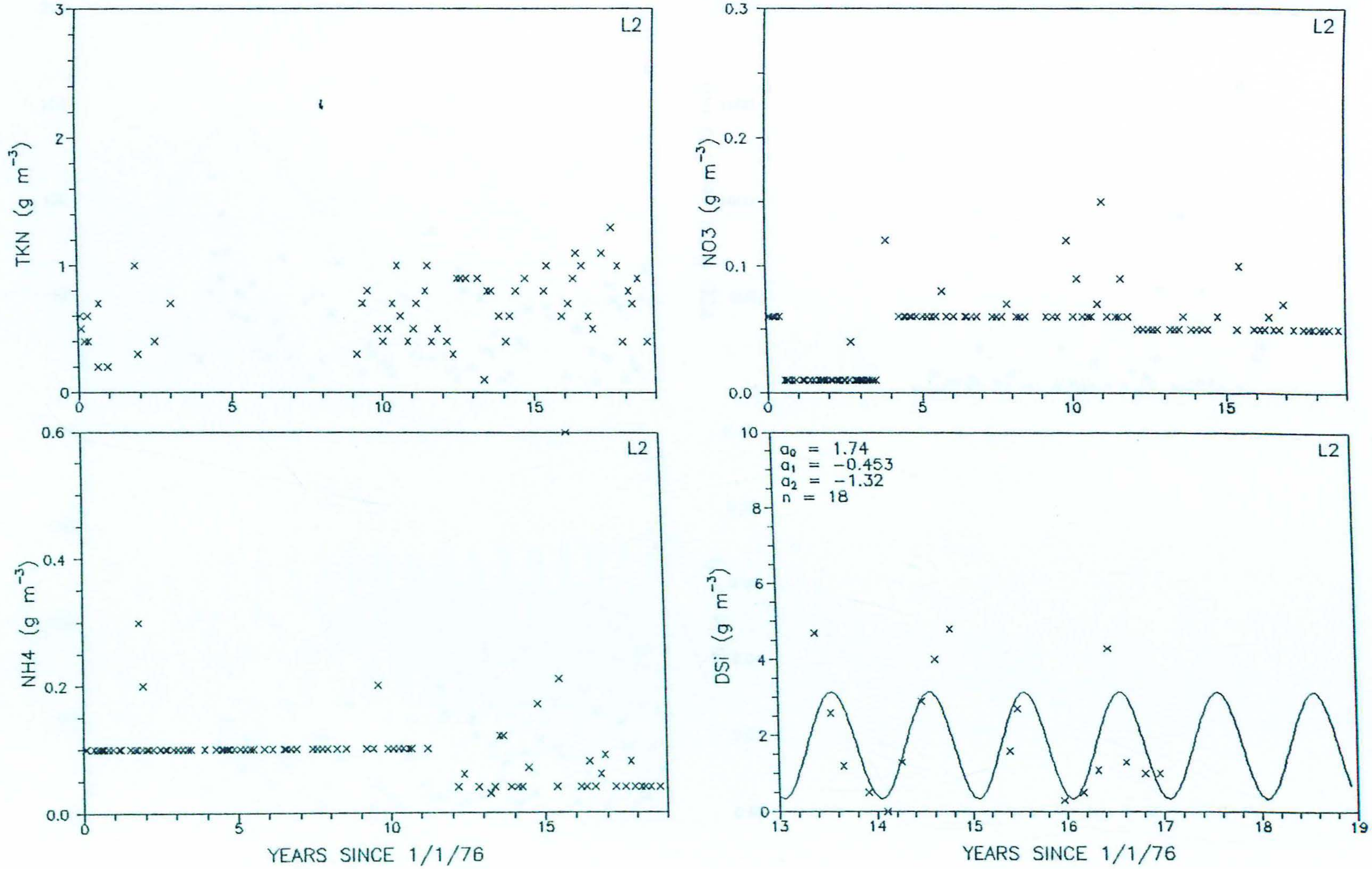
L1
TSS (g m⁻³)
FCB (MPN per 100 ml)
(11000)
TFS (g m⁻³)
COD (g m⁻³)
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76

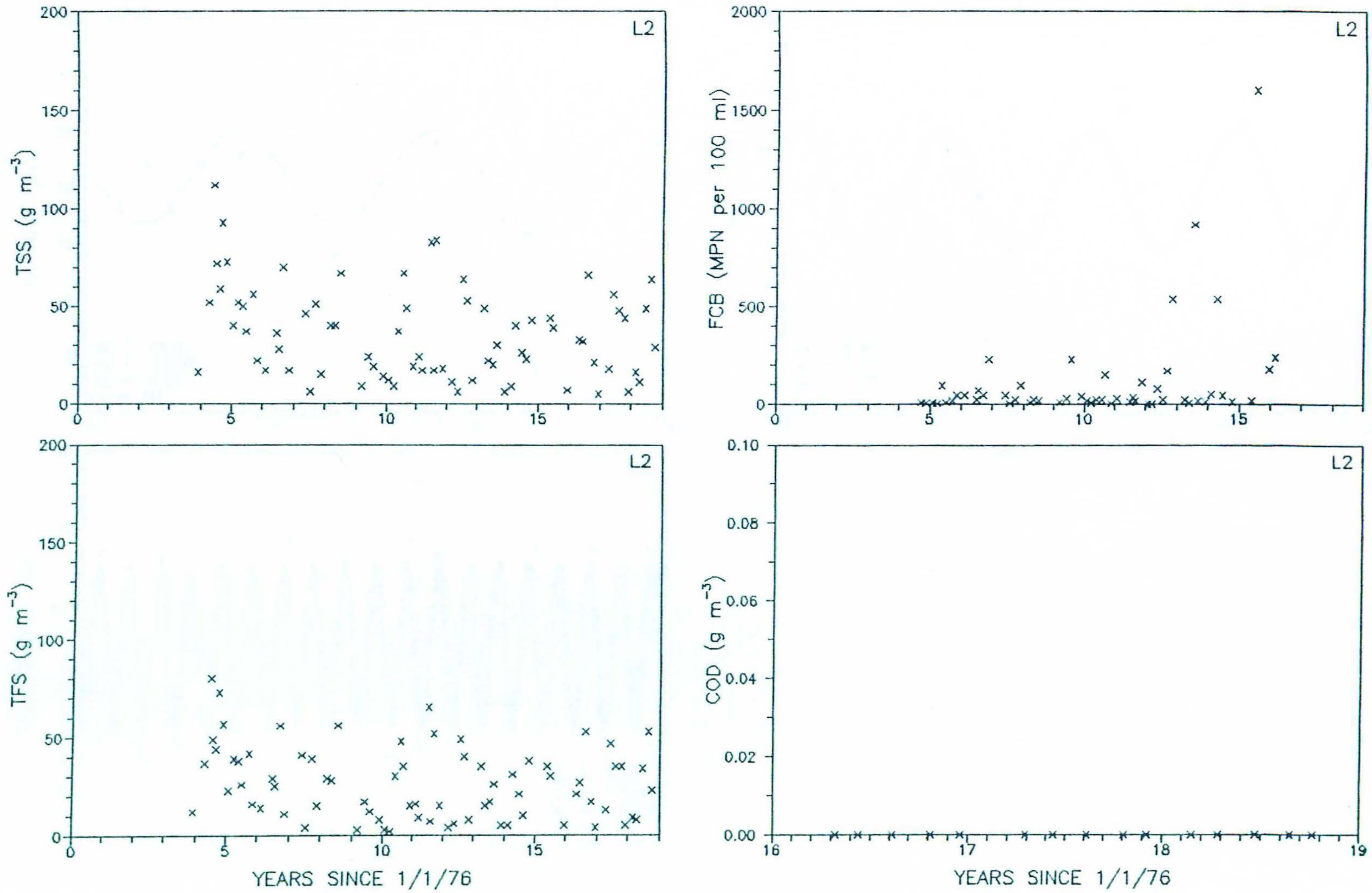

L2
SALINITY (ppt)
a₀ = 20.4
a₁ = −4.13
a₂ = 1.30
n = 15
L2
DO (g m⁻³)
a₀ = 8.39
a₁ = 1.14
a₂ = 1.99
n = 17
YEARS SINCE 1/1/76
L2
TEMPERATURE (°C)
a₀ = 15.2
a₁ = −3.75
a₂ = −9.78
n = 112
YEARS SINCE 1/1/76

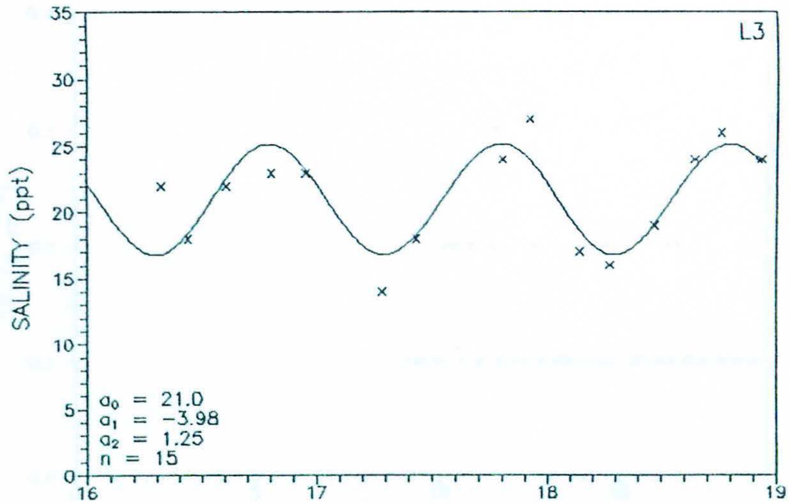

L2
TP (g m^-3)
0.0
0.1
0.2
0.3
0.4
0
5
10
15

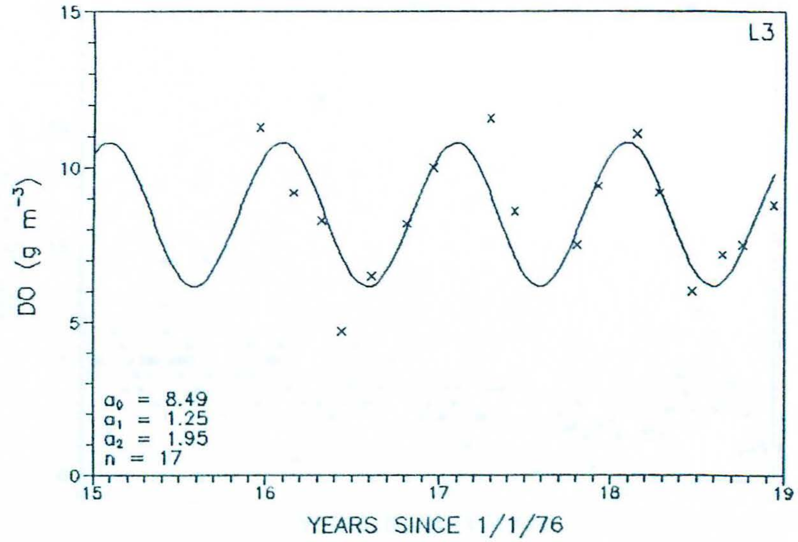

L2
TOC (g m^-3)
0
8
16
24
32
0
5
10
15
YEARS SINCE 1/1/76

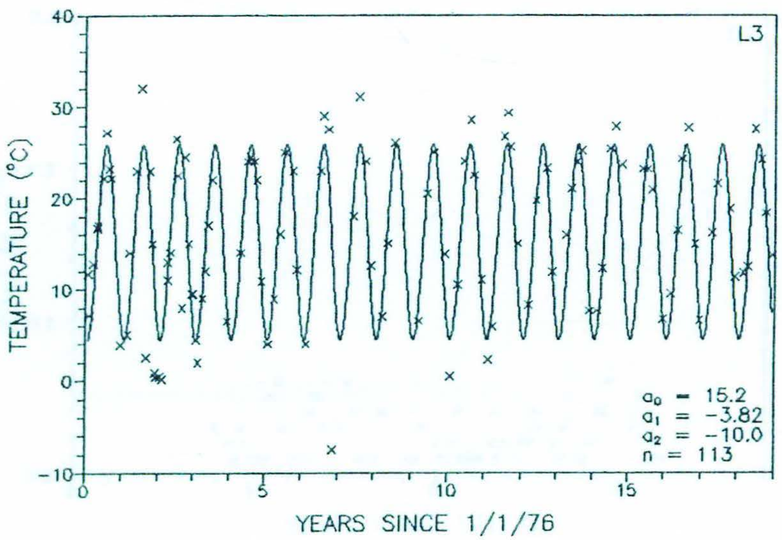

L2
PO4d (g m^-3)
0.0
0.1
0.2
0.3
0
5
10
15
YEARS SINCE 1/1/76

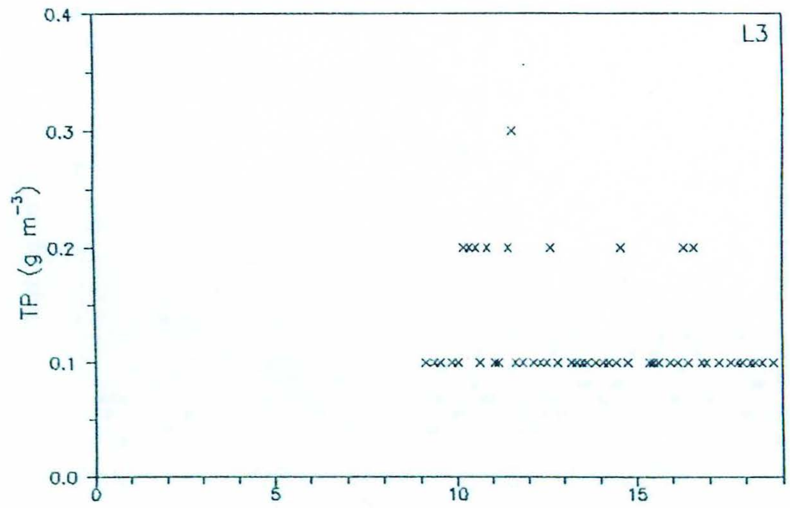

L2
TKN (g m^{-3})
NO3 (g m^{-3})
NH4 (g m^{-3})
DSi (g m^{-3})
a_0 = 1.74
a_1 = −0.453
a_2 = −1.32
n = 18
YEARS SINCE 1/1/76

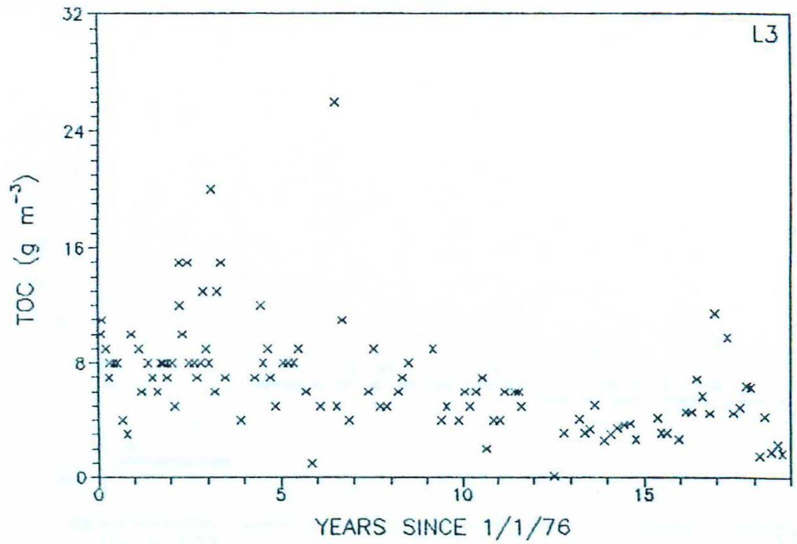

L2
TSS (g m^-3)
FCB (MPN per 100 ml)
TFS (g m^-3)
COD (g m^-3)
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76

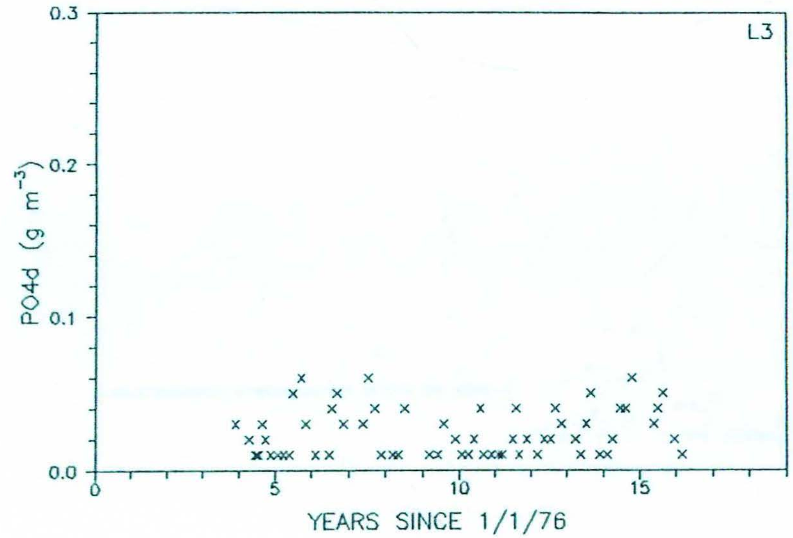

L3
SALINITY (ppt)
a_0 = 21.0
a_1 = −3.98
a_2 = 1.25
n = 15

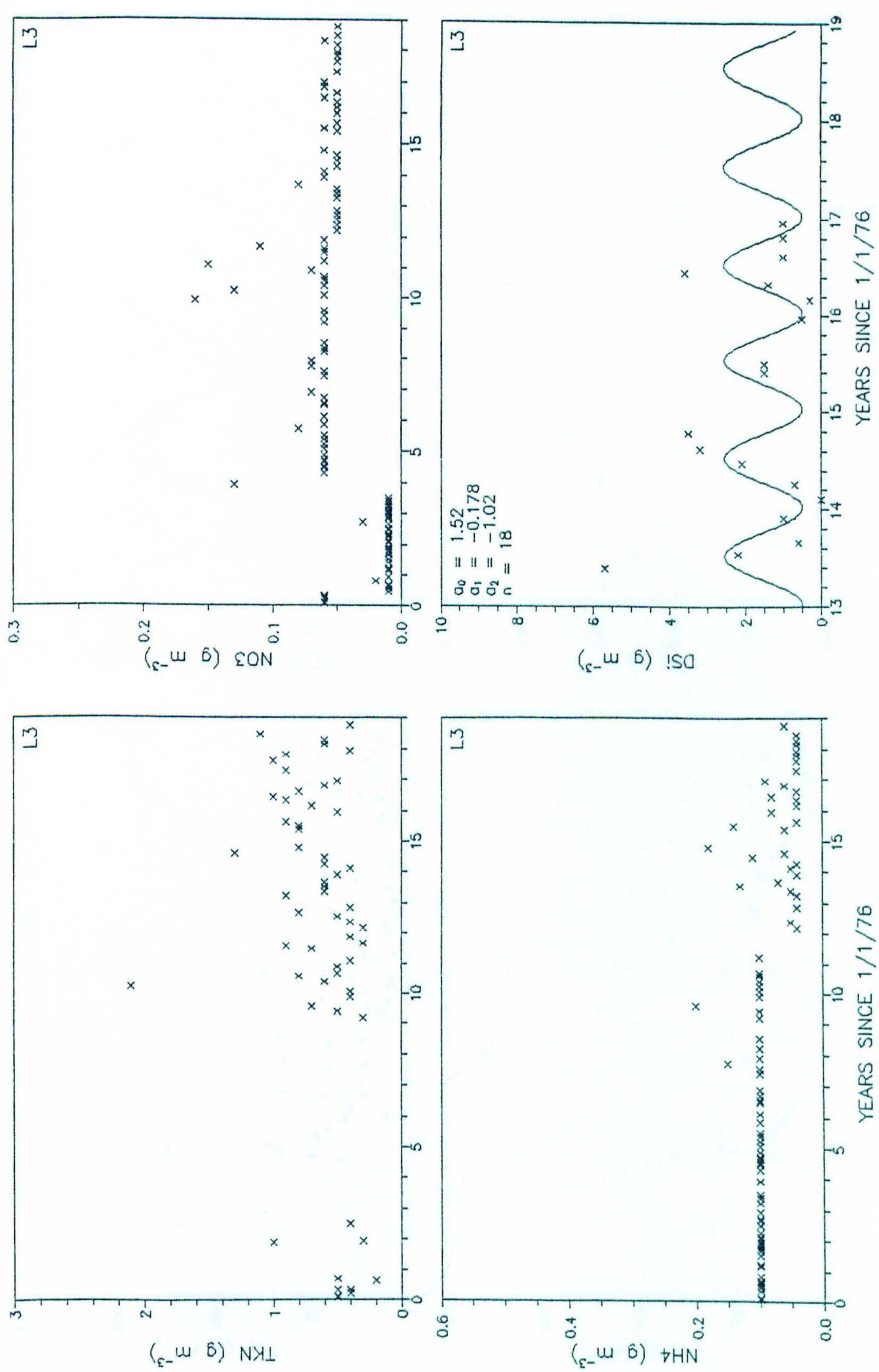

L3
DO (g m^{-3})
a_0 = 8.49
a_1 = 1.25
a_2 = 1.95
n = 17
YEARS SINCE 1/1/76


L3
TEMPERATURE (°C)
a_0 = 15.2
a_1 = −3.82
a_2 = −10.0
n = 113
YEARS SINCE 1/1/76

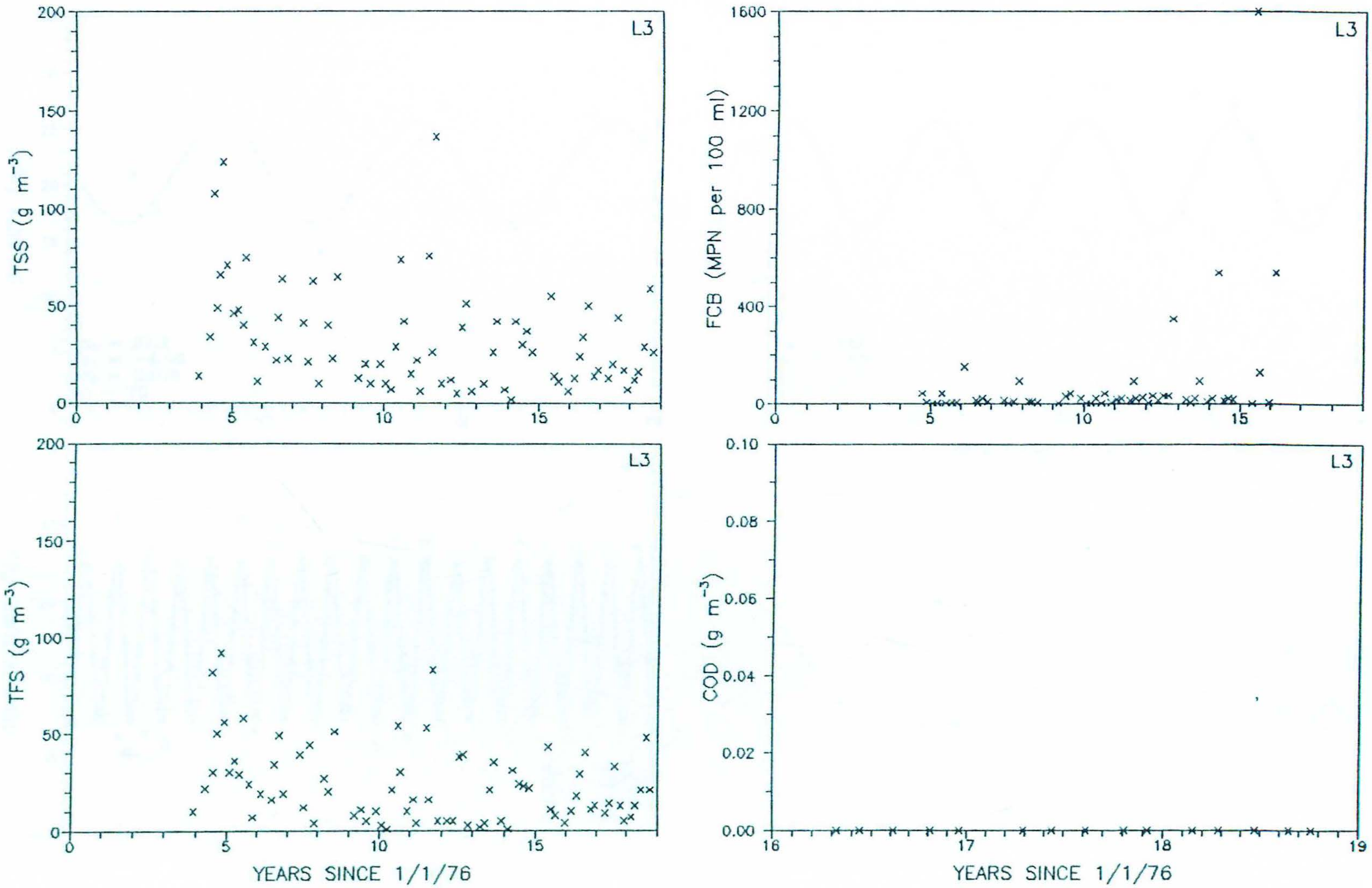

L3
TP (g m^{-3})
0.0
0.1
0.2
0.3
0.4
0
5
10
15

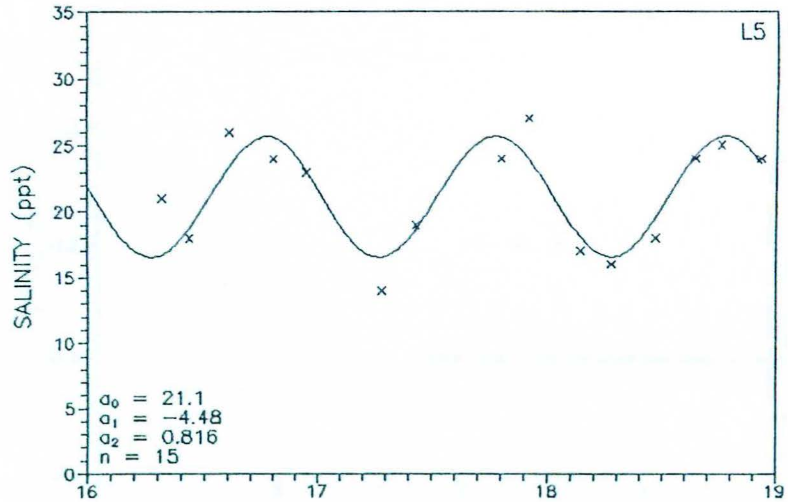

L3
TOC (g m^{-3})
0
8
16
24
32
0
5
10
15
YEARS SINCE 1/1/76

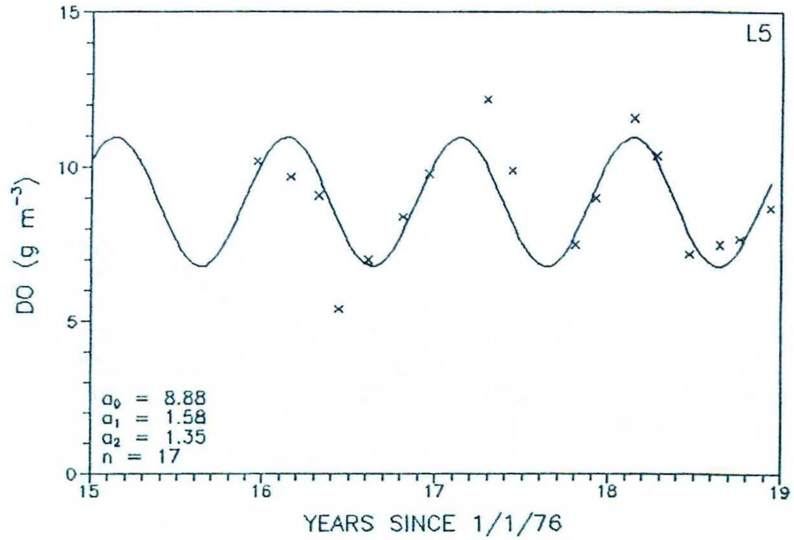

L3
PO4d (g m^{-3})
0.0
0.1
0.2
0.3
0
5
10
15
YEARS SINCE 1/1/76

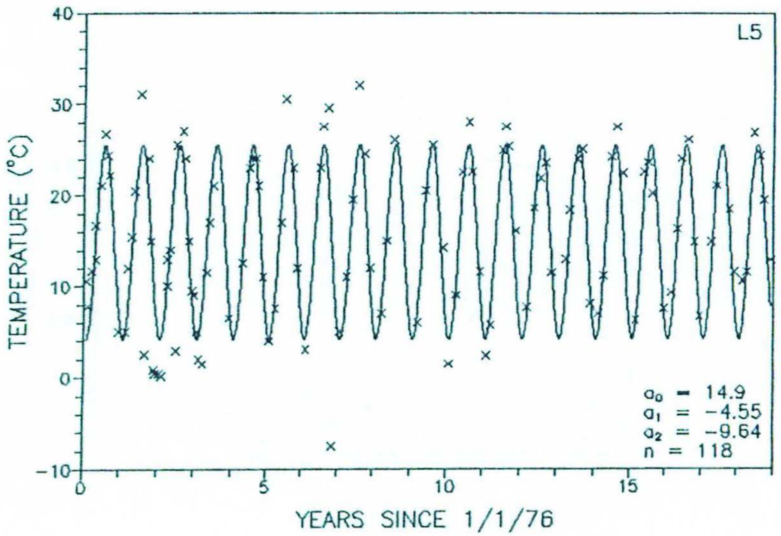


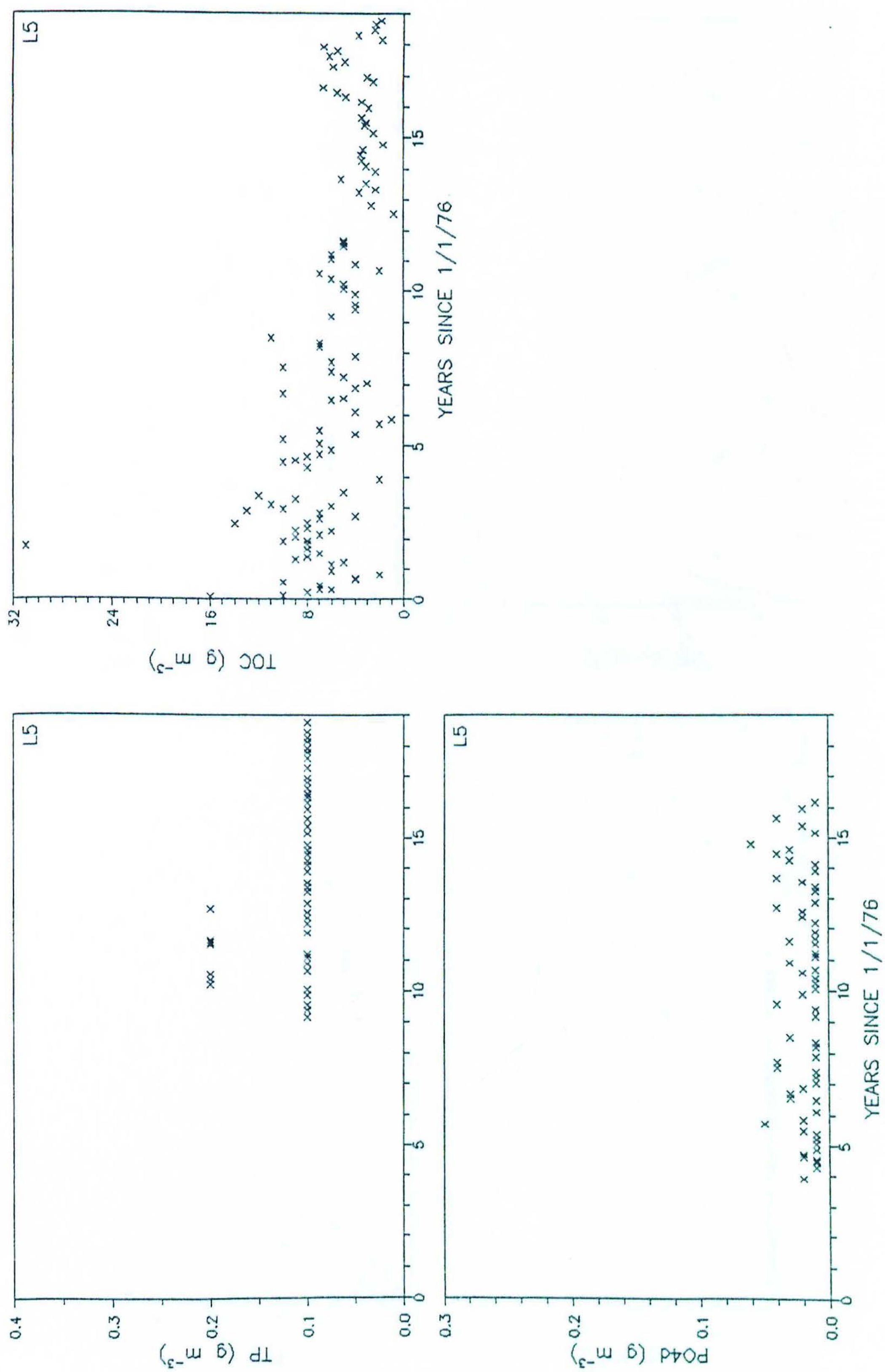
L3
TKN (g m⁻³)
NO3 (g m⁻³)
NH4 (g m⁻³)
DSi (g m⁻³)
a_0 = 1.52
a_1 = −0.178
a_2 = −1.02
n = 18
YEARS SINCE 1/1/76

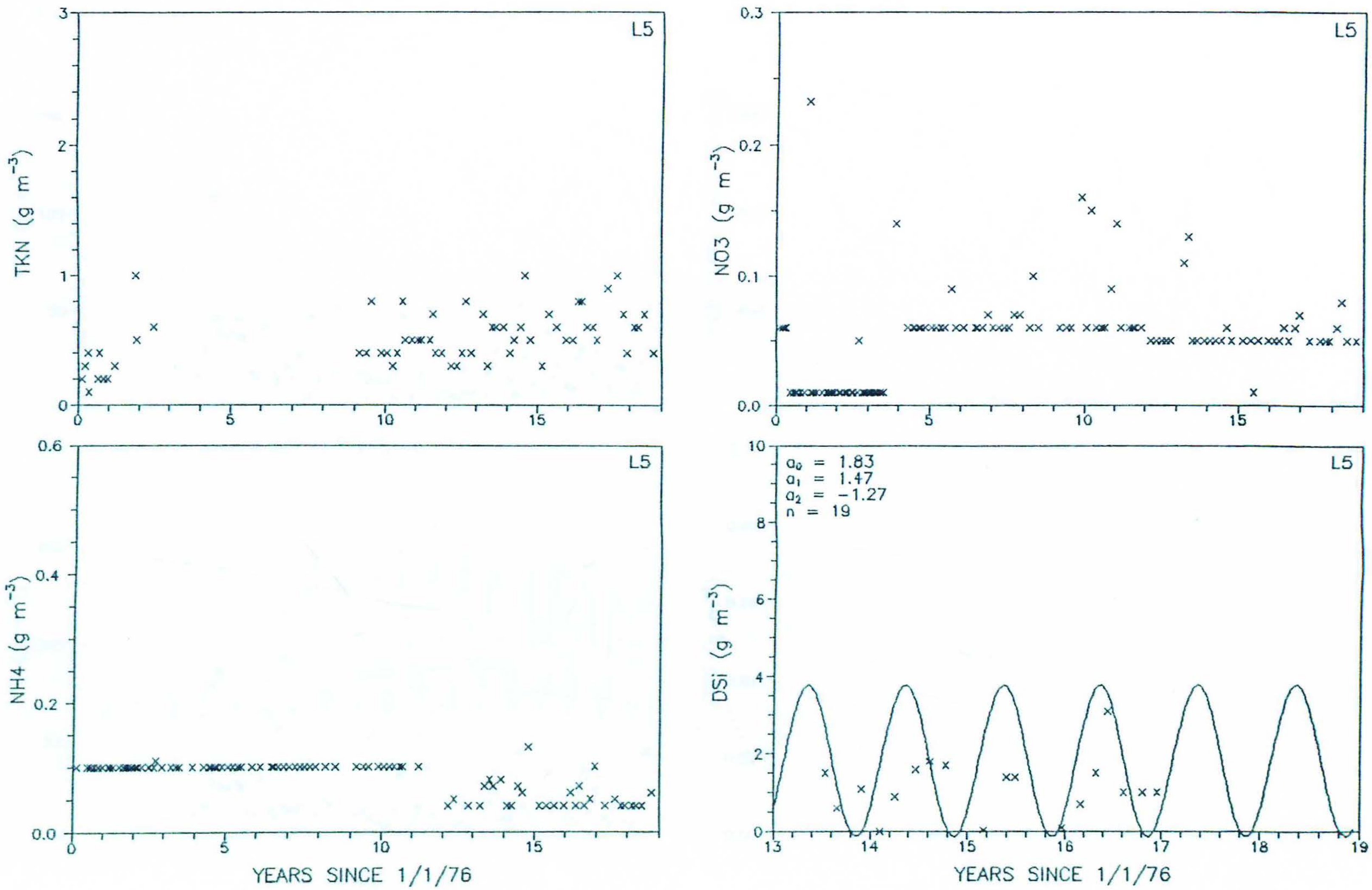

L3
TSS (g m⁻³)
0
50
100
150
200
0
5
10
15
L3
FCB (MPN per 100 ml)
0
400
800
1200
1600
0
5
10
15
L3
TFS (g m⁻³)
0
50
100
150
200
0
5
10
15
YEARS SINCE 1/1/76
L3
COD (g m⁻³)
0.00
0.02
0.04
0.06
0.08
0.10
16
17
18
19
YEARS SINCE 1/1/76

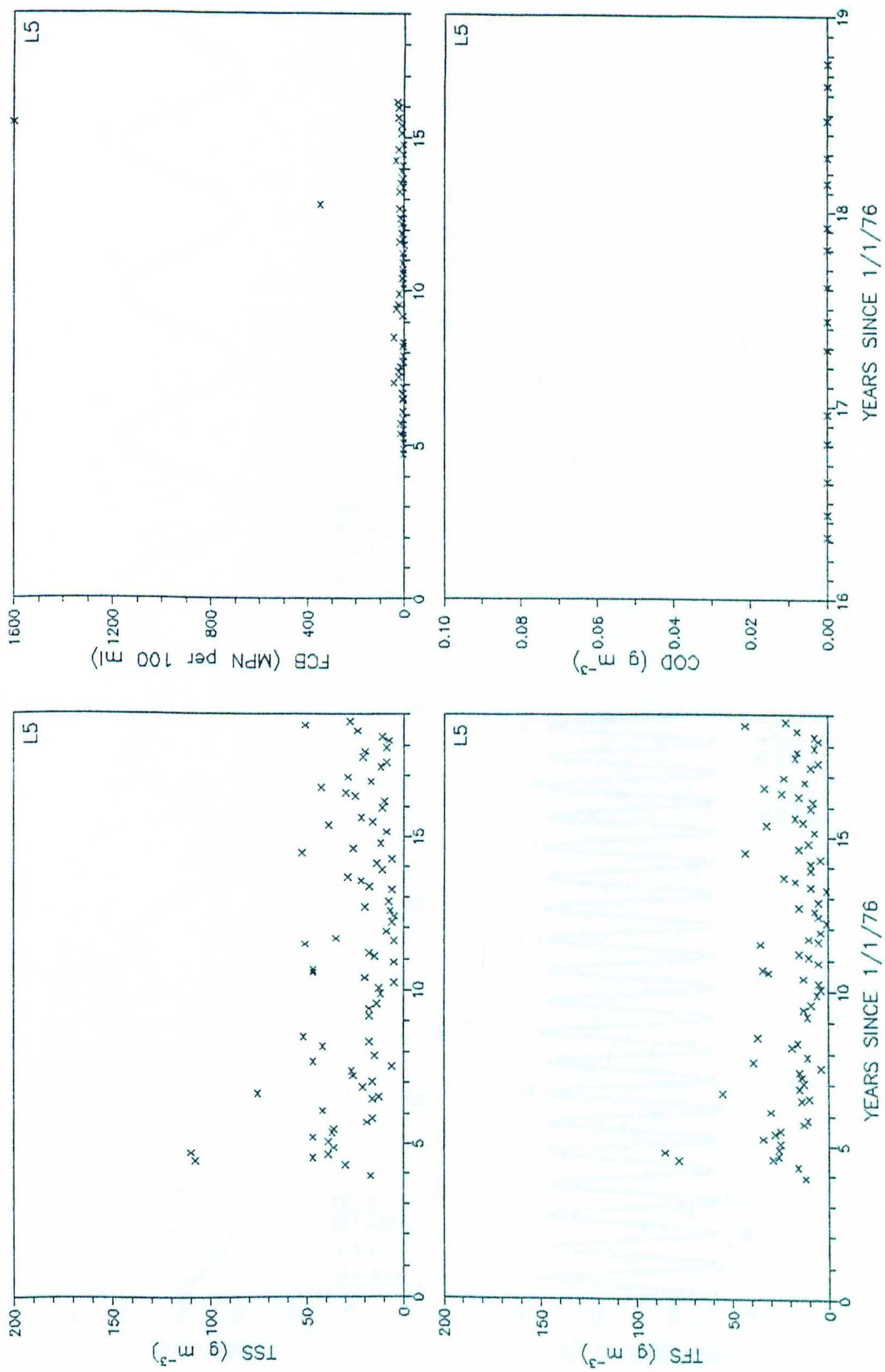

L5
SALINITY (ppt)
a_0 = 21.1
a_1 = −4.48
a_2 = 0.816
n = 15


L5
DO (g m^{-3})
a_0 = 8.88
a_1 = 1.58
a_2 = 1.35
n = 17
YEARS SINCE 1/1/76

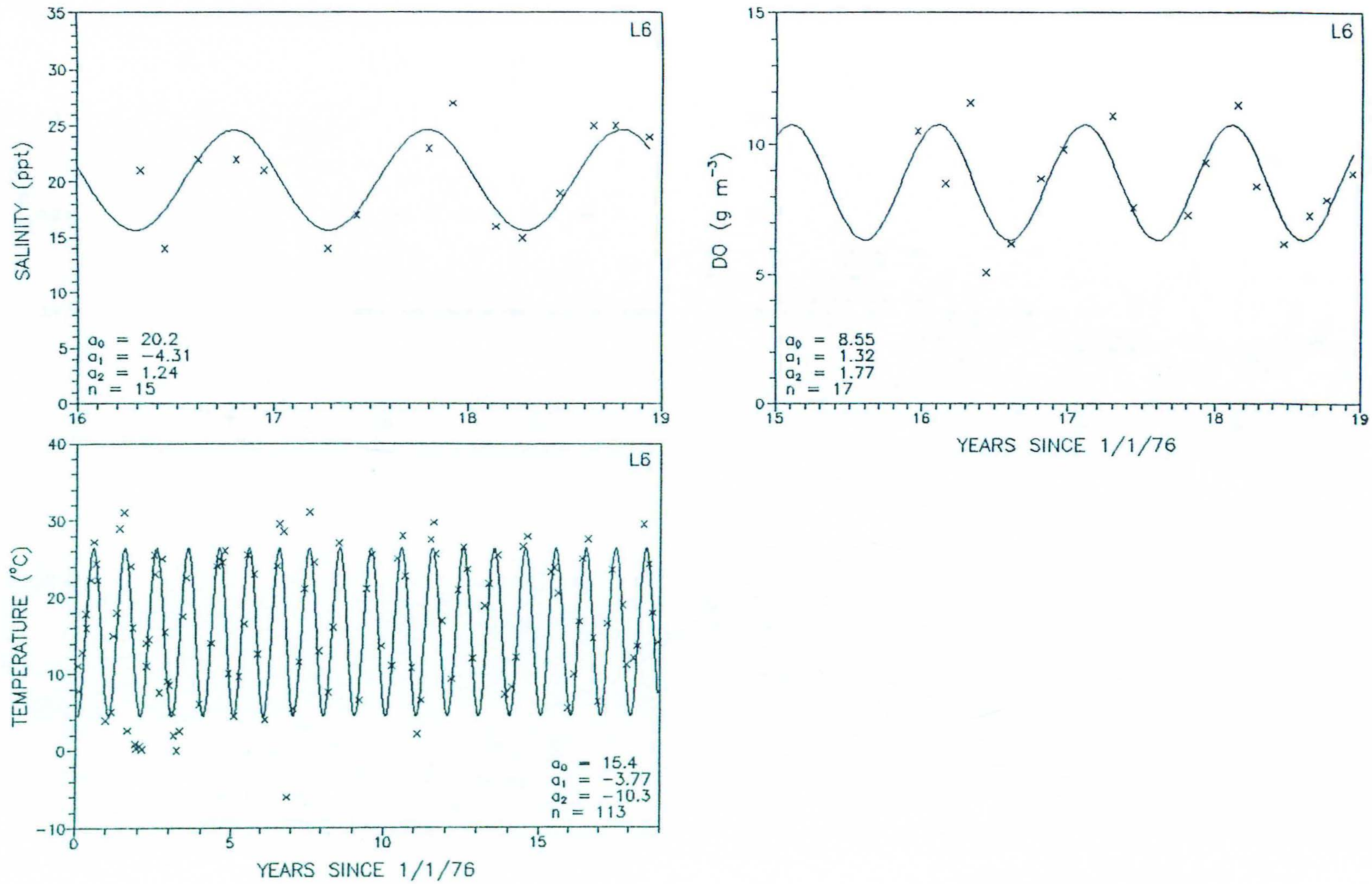

L5
TEMPERATURE (°C)
a_0 = 14.9
a_1 = −4.55
a_2 = −9.64
n = 118
YEARS SINCE 1/1/76

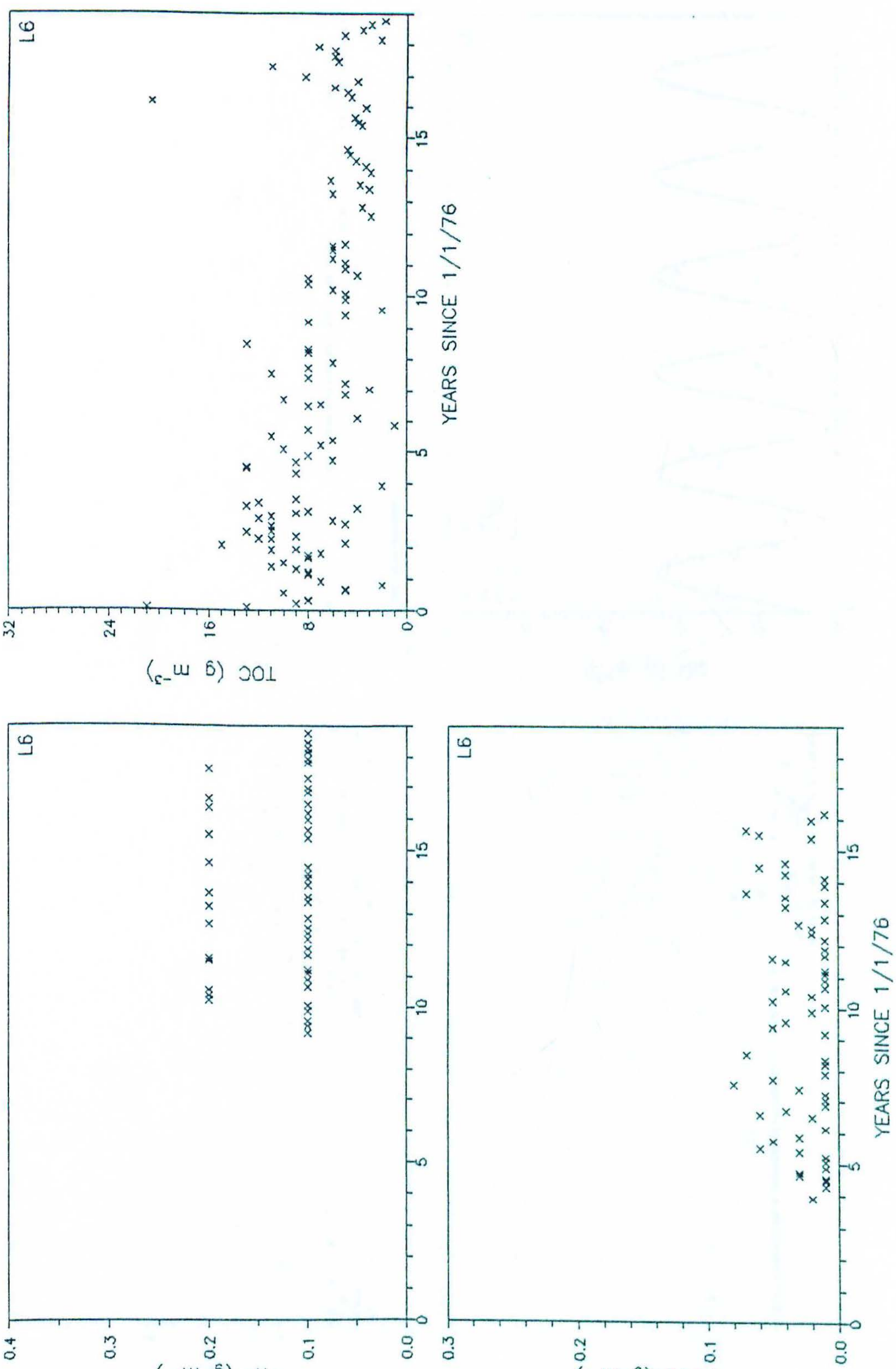

L5
TOC (g m^-3)
32
24
16
8
0
0
5
10
15
YEARS SINCE 1/1/76
L5
TP (g m^-3)
0.4
0.3
0.2
0.1
0.0
0
5
10
15
L5
PO4 (g m^-3)
0.3
0.2
0.1
0.0
0
5
10
15
YEARS SINCE 1/1/76

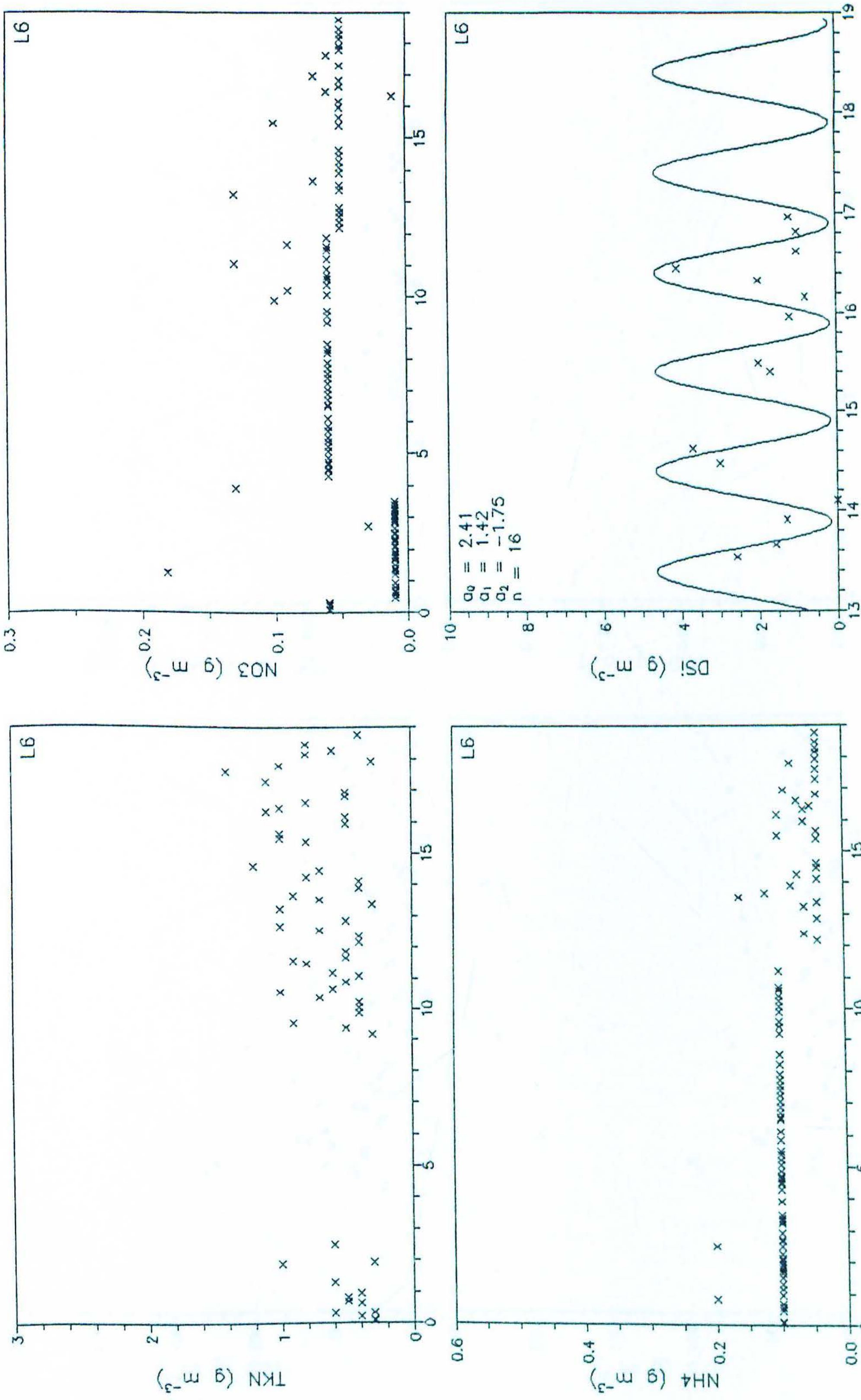

L5
TKN (g m^-3)
NO3 (g m^-3)
NH4 (g m^-3)
DSi (g m^-3)
a0 = 1.83
a1 = 1.47
a2 = -1.27
n = 19
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76



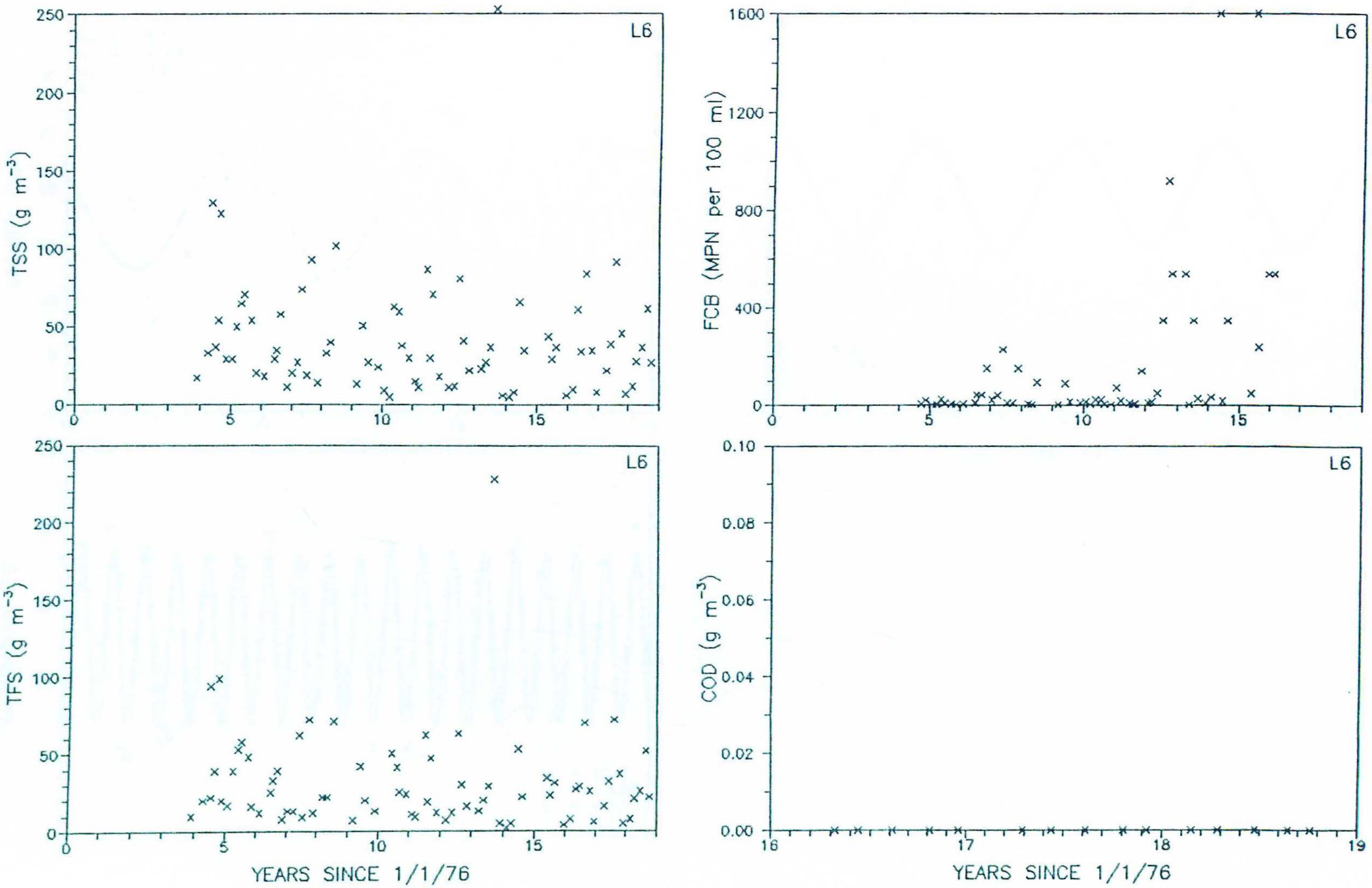
L5
TSS (g m^-3)
FCB (MPN per 100 ml)
TFS (g m^-3)
COD (g m^-3)
YEARS SINCE 1/1/76

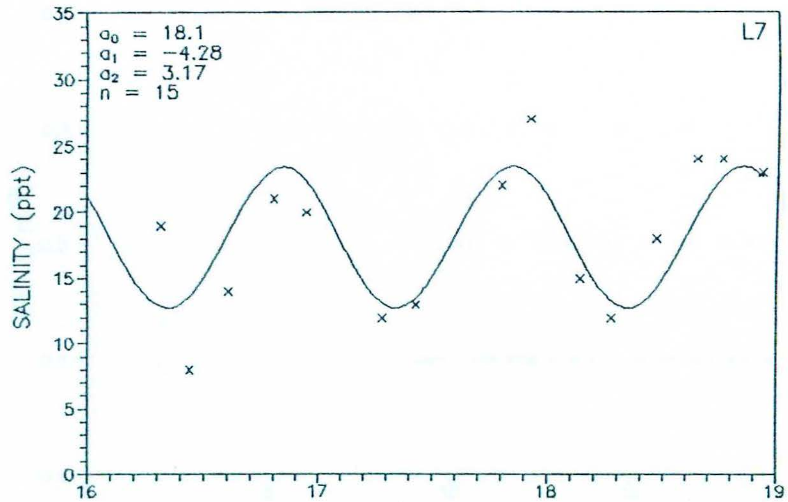

L6
SALINITY (ppt)
a0 = 20.2
a1 = −4.31
a2 = 1.24
n = 15
L6
DO (g m−3)
a0 = 8.55
a1 = 1.32
a2 = 1.77
n = 17
YEARS SINCE 1/1/76
L6
TEMPERATURE (°C)
a0 = 15.4
a1 = −3.77
a2 = −10.3
n = 113
YEARS SINCE 1/1/76

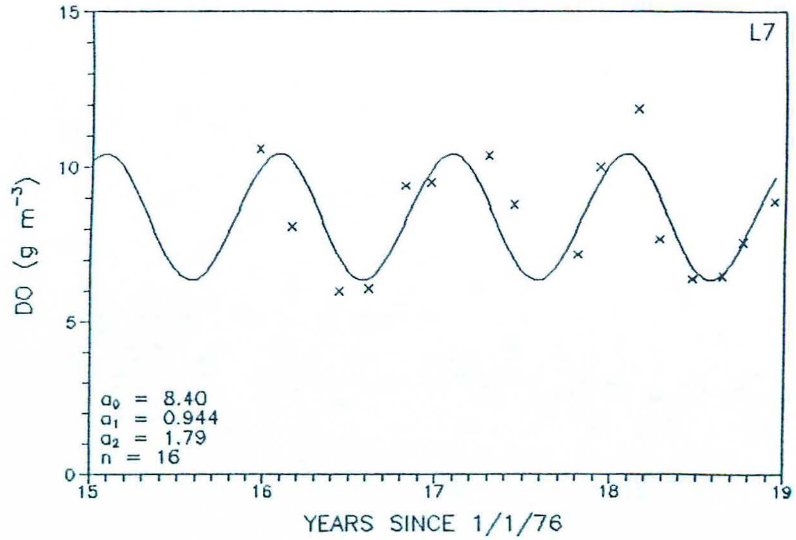

L6
TOC (g m-3)
YEARS SINCE 1/1/76
L6
TP (g m-3)
L6
PO4 (g m-3)
YEARS SINCE 1/1/76

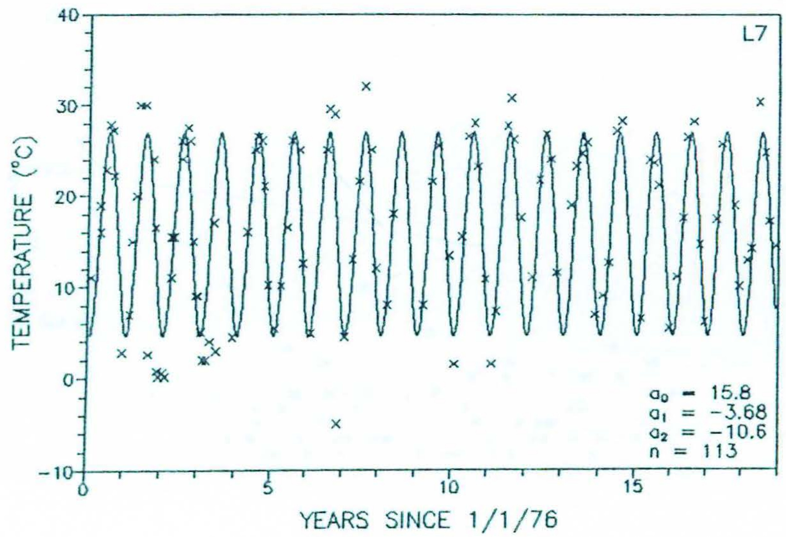


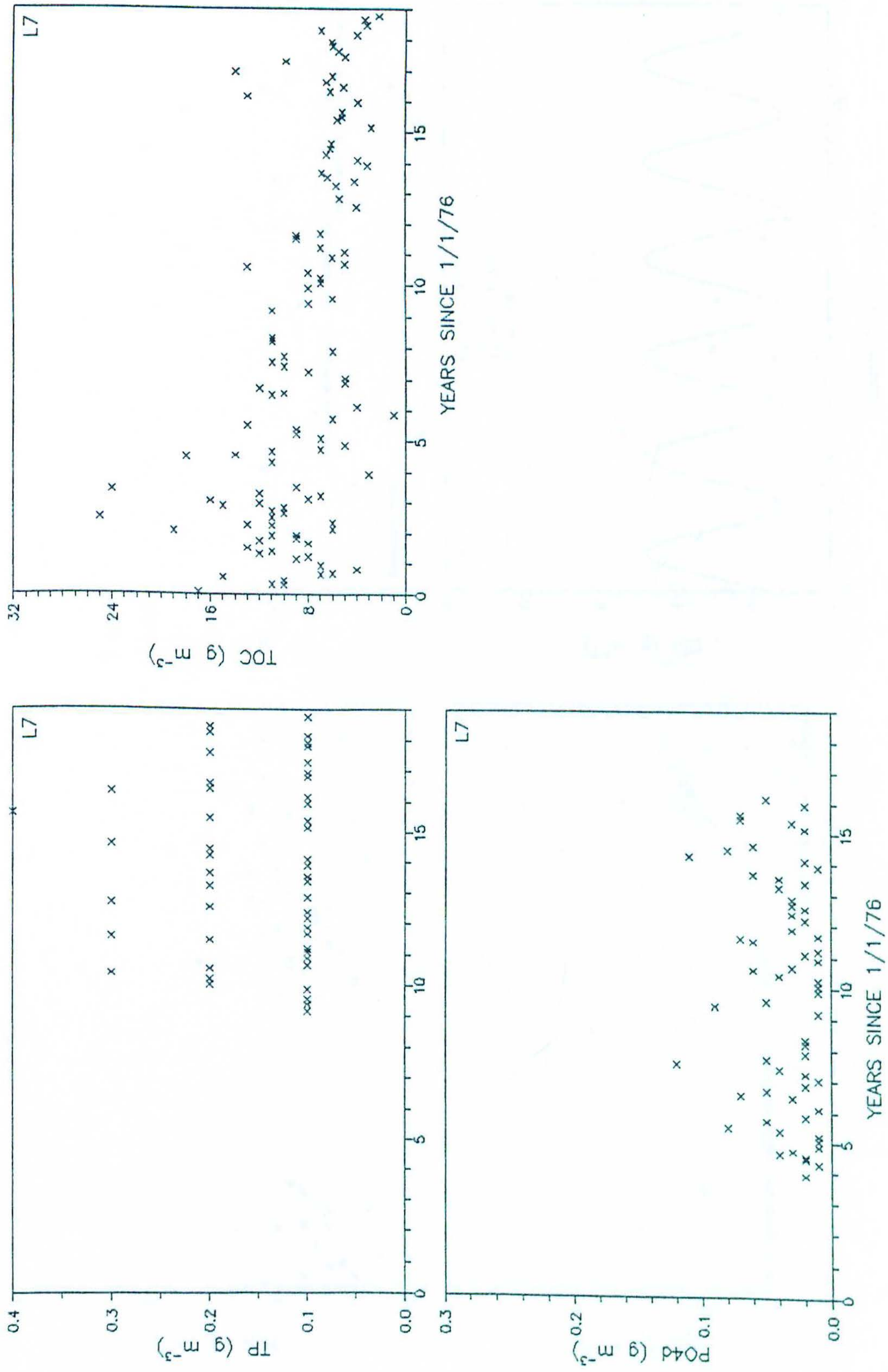
L6
TKN (g m^-3)
YEARS SINCE 1/1/76
L6
NH4 (g m^-3)
YEARS SINCE 1/1/76
L6
NO3 (g m^-3)
L6
a0 = 2.41
a1 = 1.42
a2 = -1.75
n = 16
DSi (g m^-3)
YEARS SINCE 1/1/76

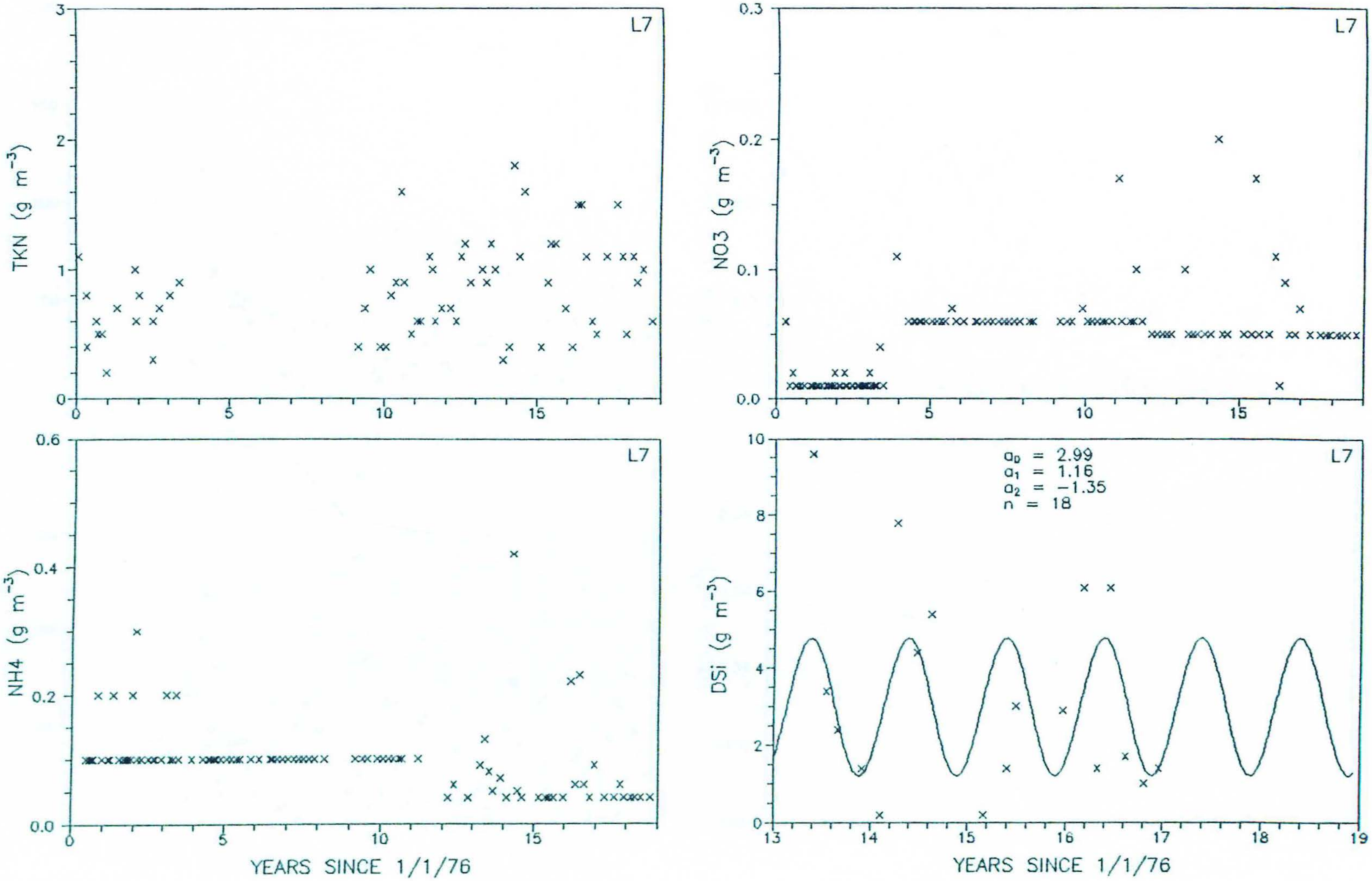

L6
TSS (g m^-3)
TFS (g m^-3)
FCB (MPN per 100 ml)
COD (g m^-3)
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76

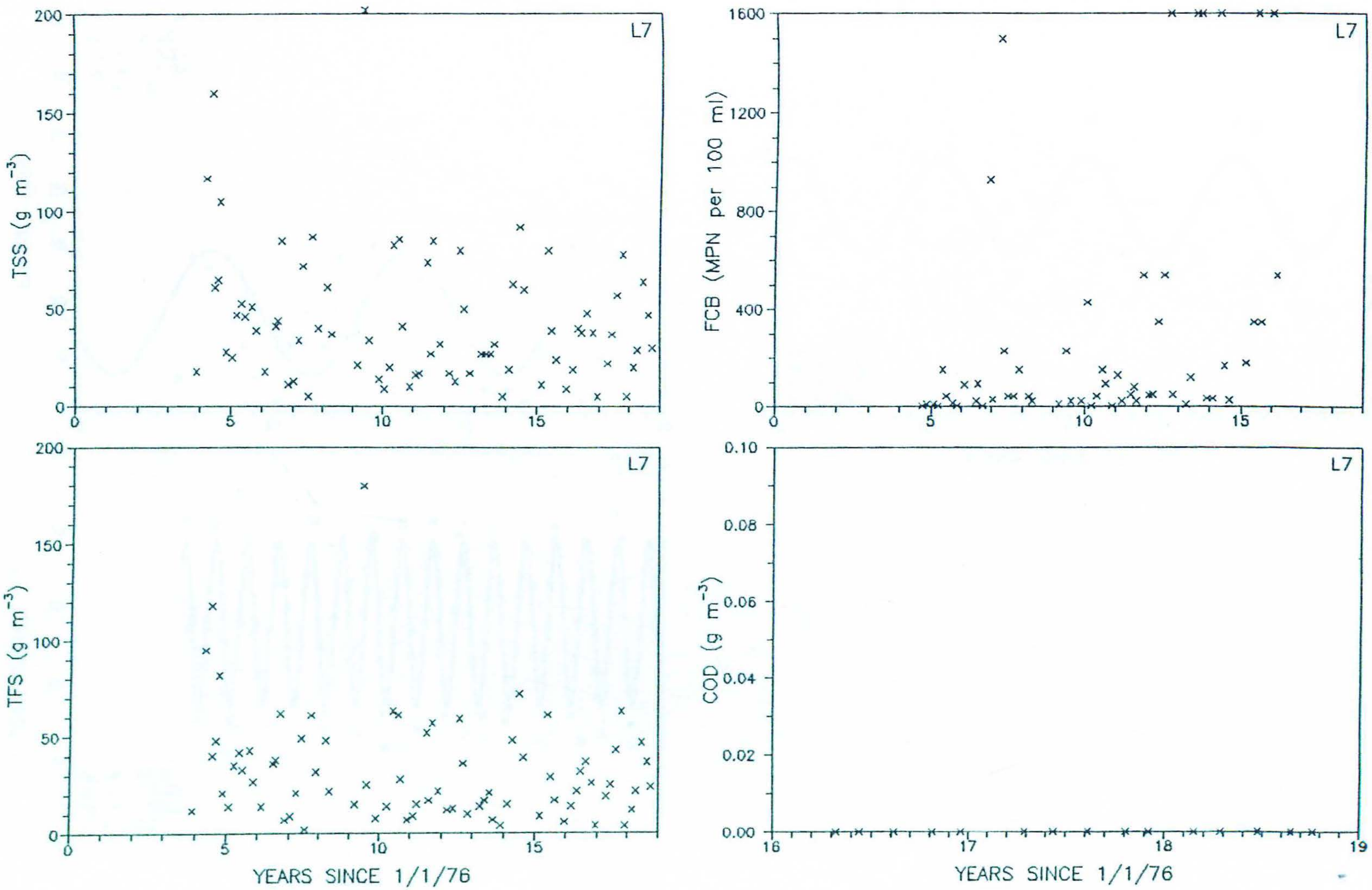

L7
a_0 = 18.1
a_1 = −4.28
a_2 = 3.17
n = 15
SALINITY (ppt)

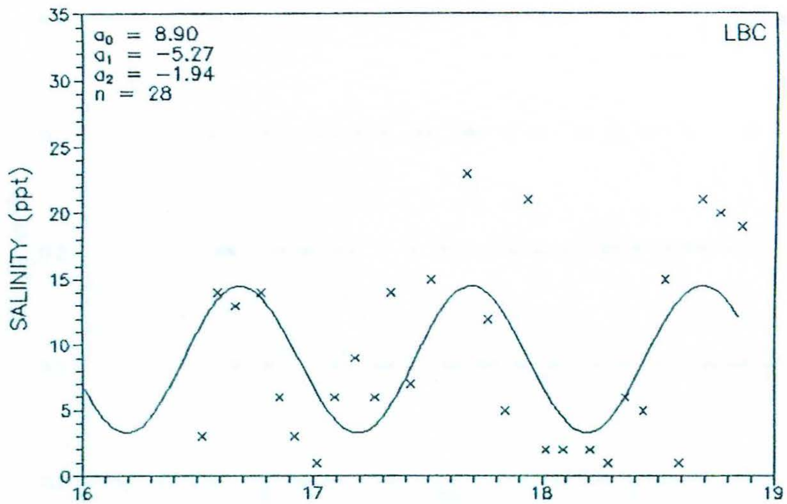

L7
a_0 = 8.40
a_1 = 0.944
a_2 = 1.79
n = 16
DO (g m^{-3})
YEARS SINCE 1/1/76


L7
a_0 = 15.8
a_1 = −3.68
a_2 = −10.6
n = 113
TEMPERATURE (°C)
YEARS SINCE 1/1/76

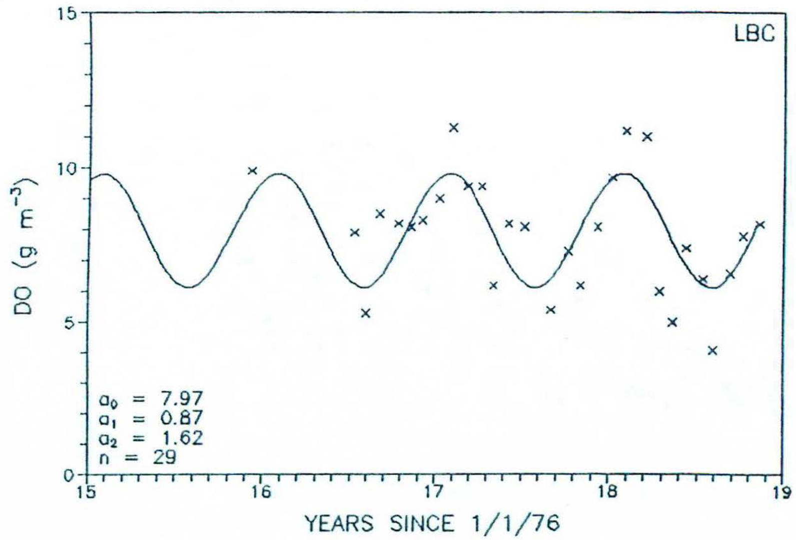

L7
TOC (g m^-3)
YEARS SINCE 1/1/76
L7
TP (g m^-3)
L7
PO4 (g m^-3)
YEARS SINCE 1/1/76


L7
TKN (g m^{-3})
L7
NO3 (g m^{-3})
L7
NH4 (g m^{-3})
YEARS SINCE 1/1/76
a_0 = 2.99
a_1 = 1.16
a_2 = −1.35
n = 18
L7
DSi (g m^{-3})
YEARS SINCE 1/1/76

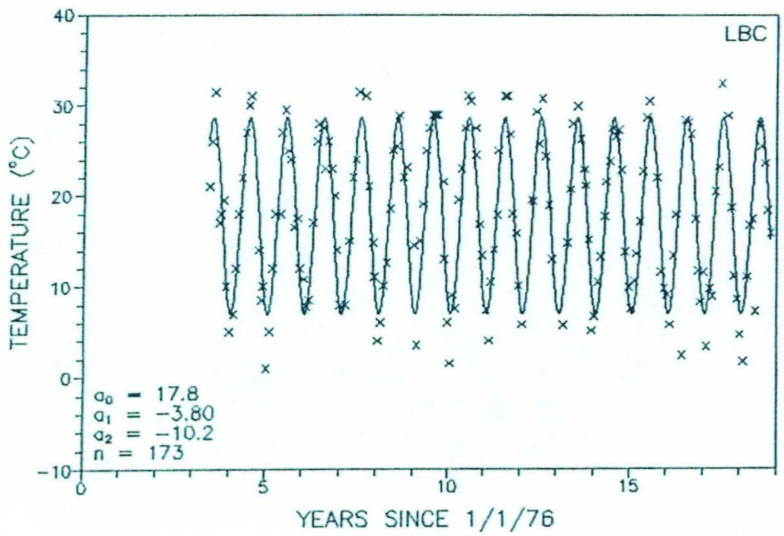

L7
TSS (g m^-3)
TFS (g m^-3)
FCB (MPN per 100 ml)
COD (g m^-3)
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76



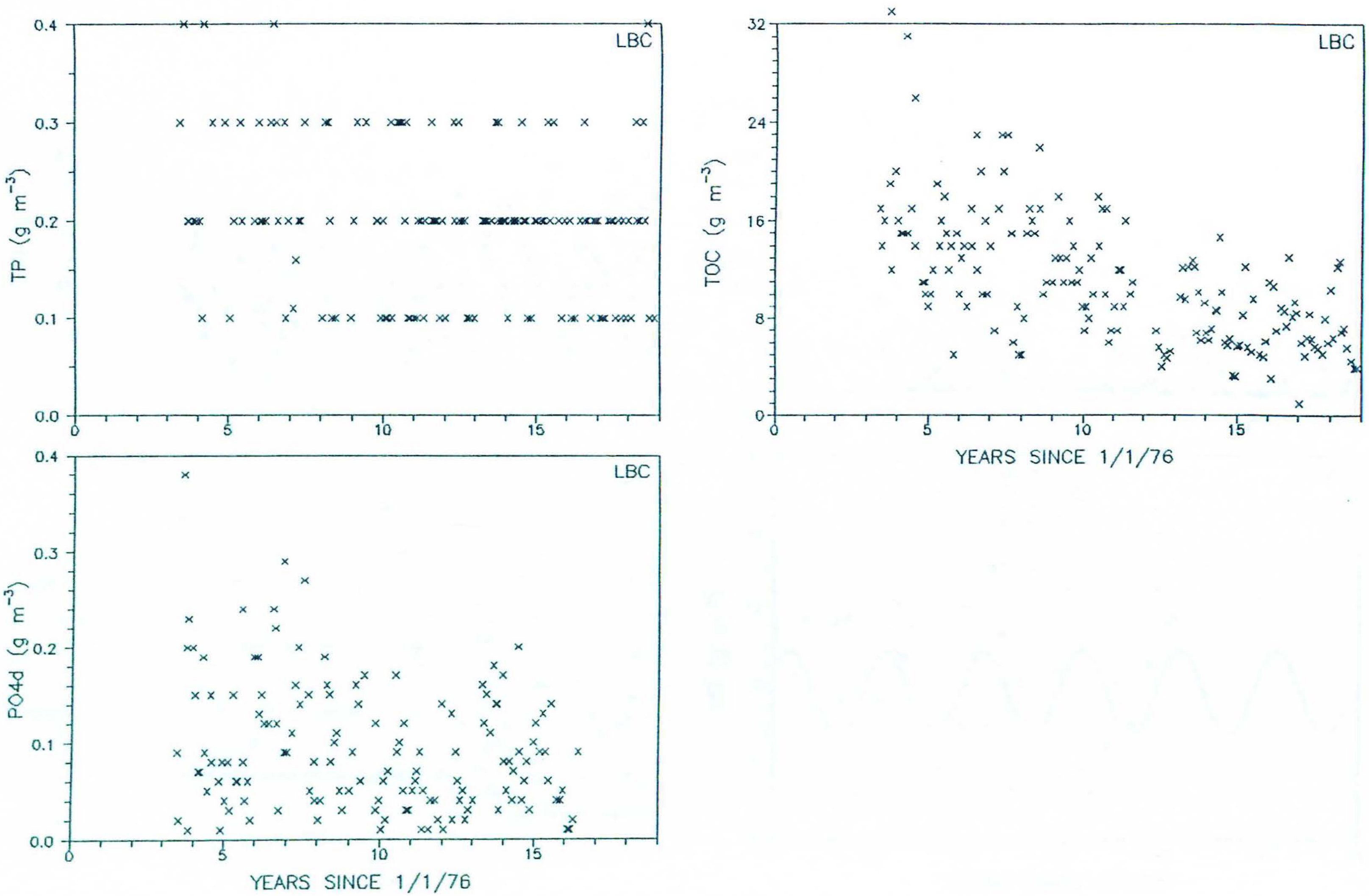
a_0 = 8.90
a_1 = −5.27
a_2 = −1.94
n = 28
LBC
SALINITY (ppt)

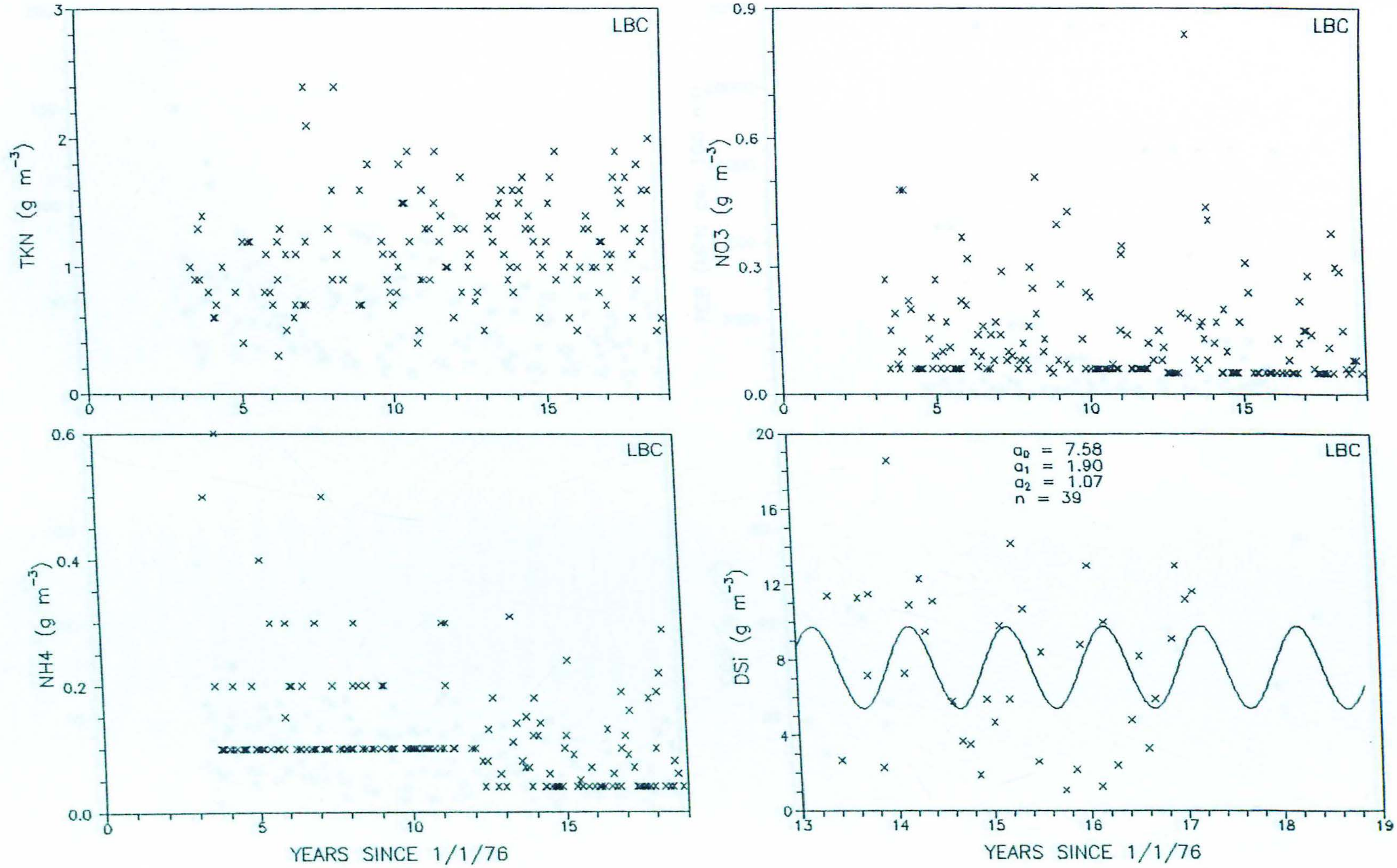


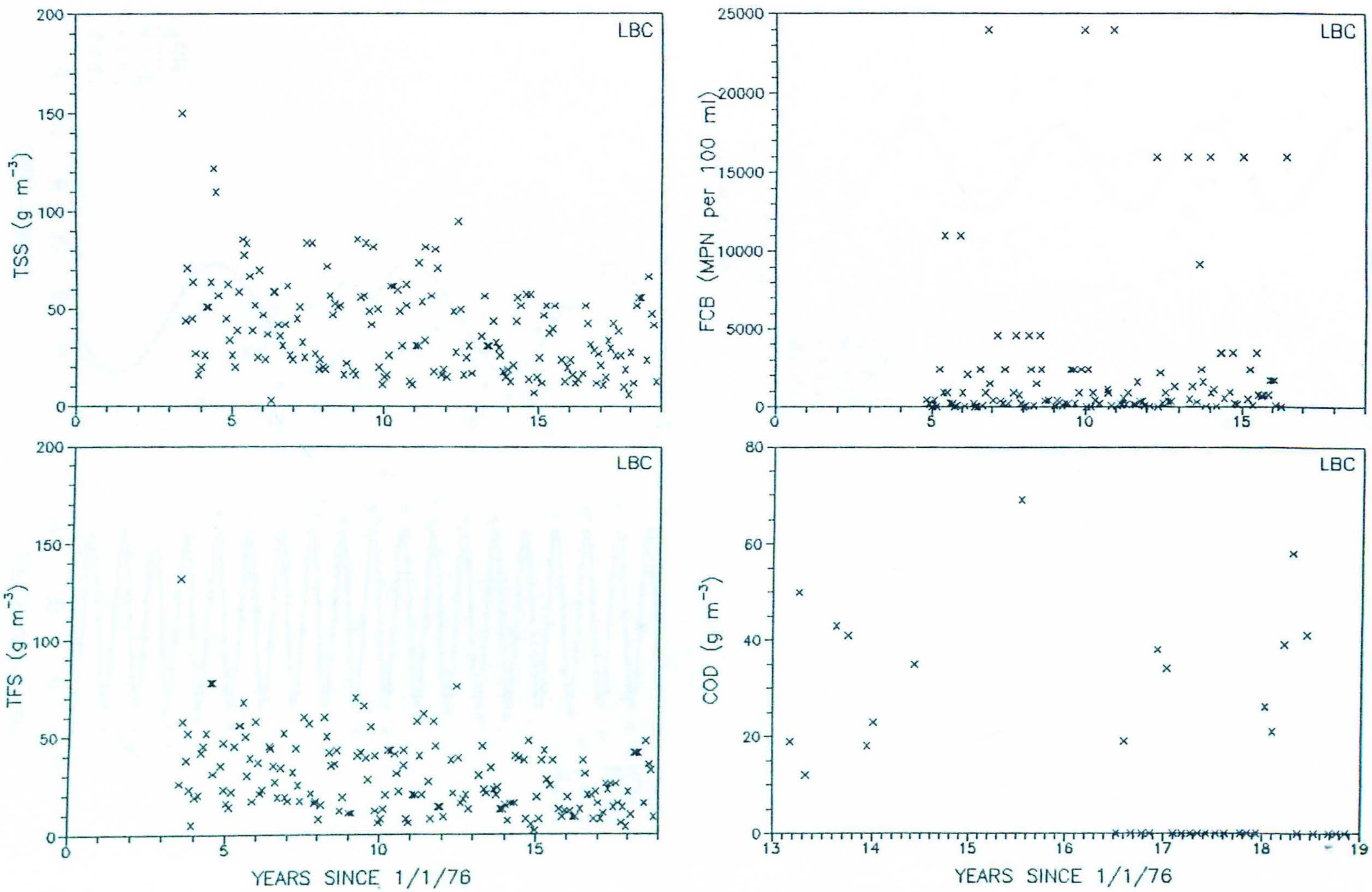
LBC
DO (g m^{-3})
a_0 = 7.97
a_1 = 0.87
a_2 = 1.62
n = 29
YEARS SINCE 1/1/76

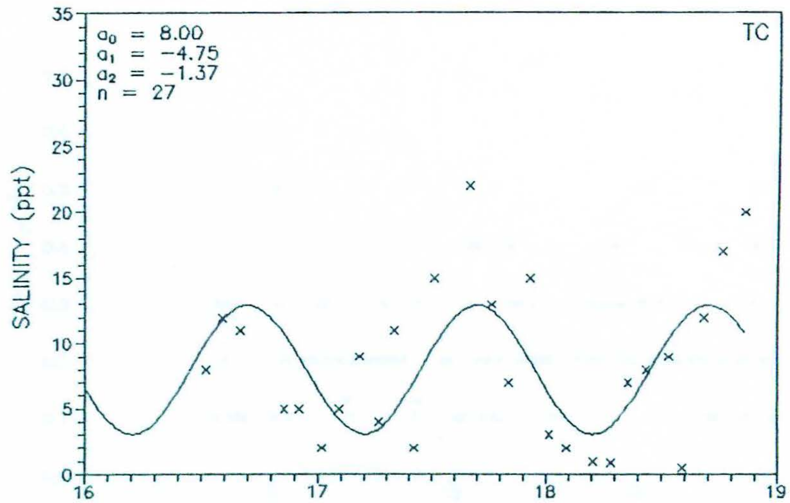


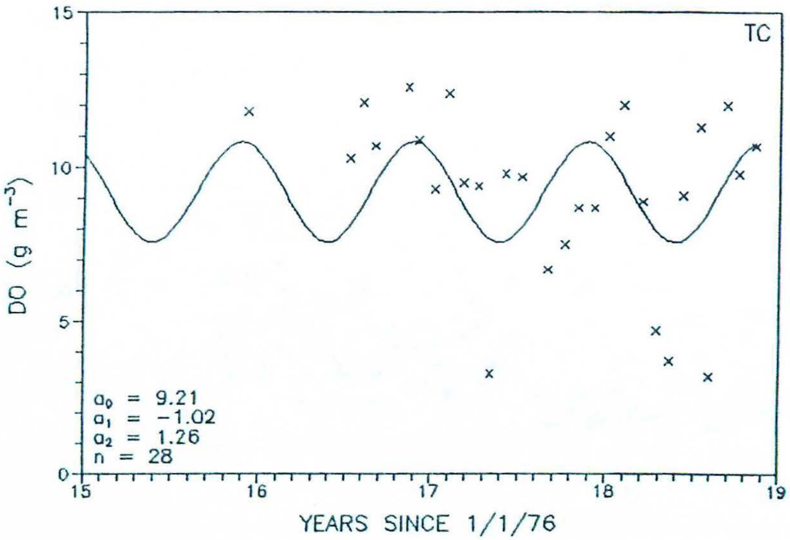
LBC
TEMPERATURE (°C)
a_0 = 17.8
a_1 = −3.80
a_2 = −10.2
n = 173
YEARS SINCE 1/1/76

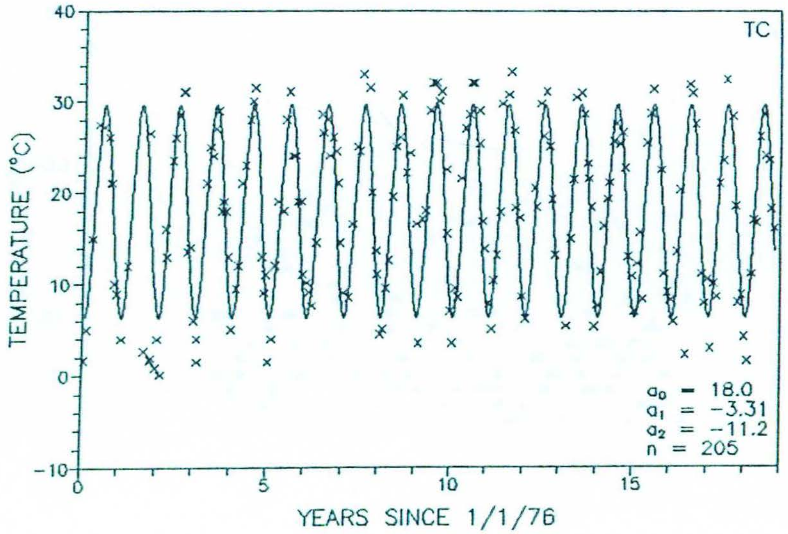

TP (g m-3)
LBC
TOC (g m-3)
LBC
PO4d (g m-3)
LBC
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76

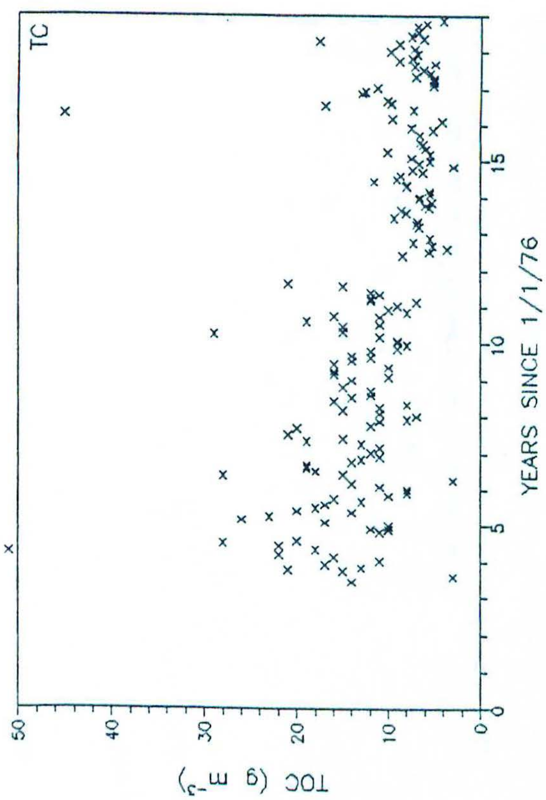

LBC
TKN (g m^{-3})
NO3 (g m^{-3})
NH4 (g m^{-3})
DSi (g m^{-3})
a_0 = 7.58
a_1 = 1.90
a_2 = 1.07
n = 39
YEARS SINCE 1/1/76


LBC
TSS (g m^-3)
FCB (MPN per 100 ml)
TFS (g m^-3)
COD (g m^-3)
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76

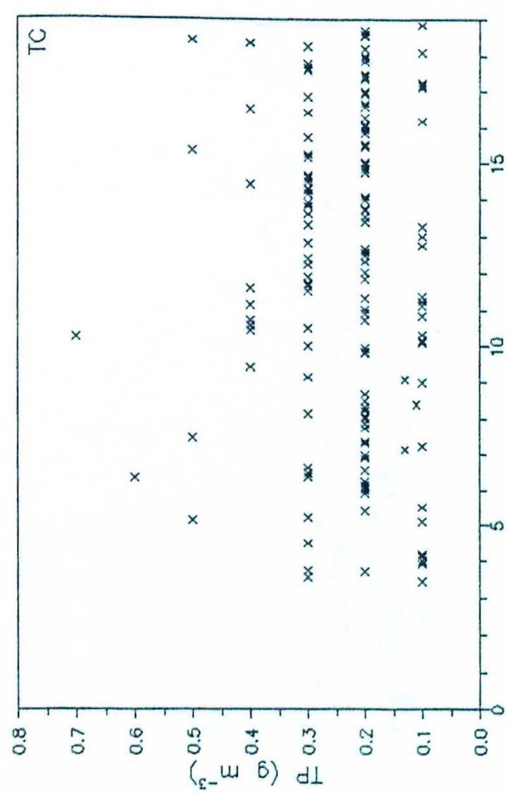

TC
a_0 = 8.00
a_1 = −4.75
a_2 = −1.37
n = 27
SALINITY (ppt)


TC
a_0 = 9.21
a_1 = −1.02
a_2 = 1.26
n = 28
DO (g m^{-3})
YEARS SINCE 1/1/76

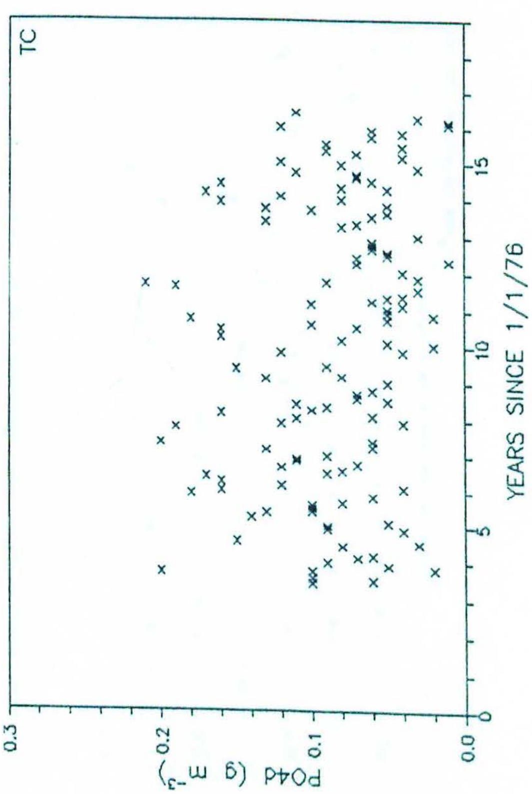

TC
a_0 = 18.0
a_1 = −3.31
a_2 = −11.2
n = 205
TEMPERATURE (°C)
YEARS SINCE 1/1/76



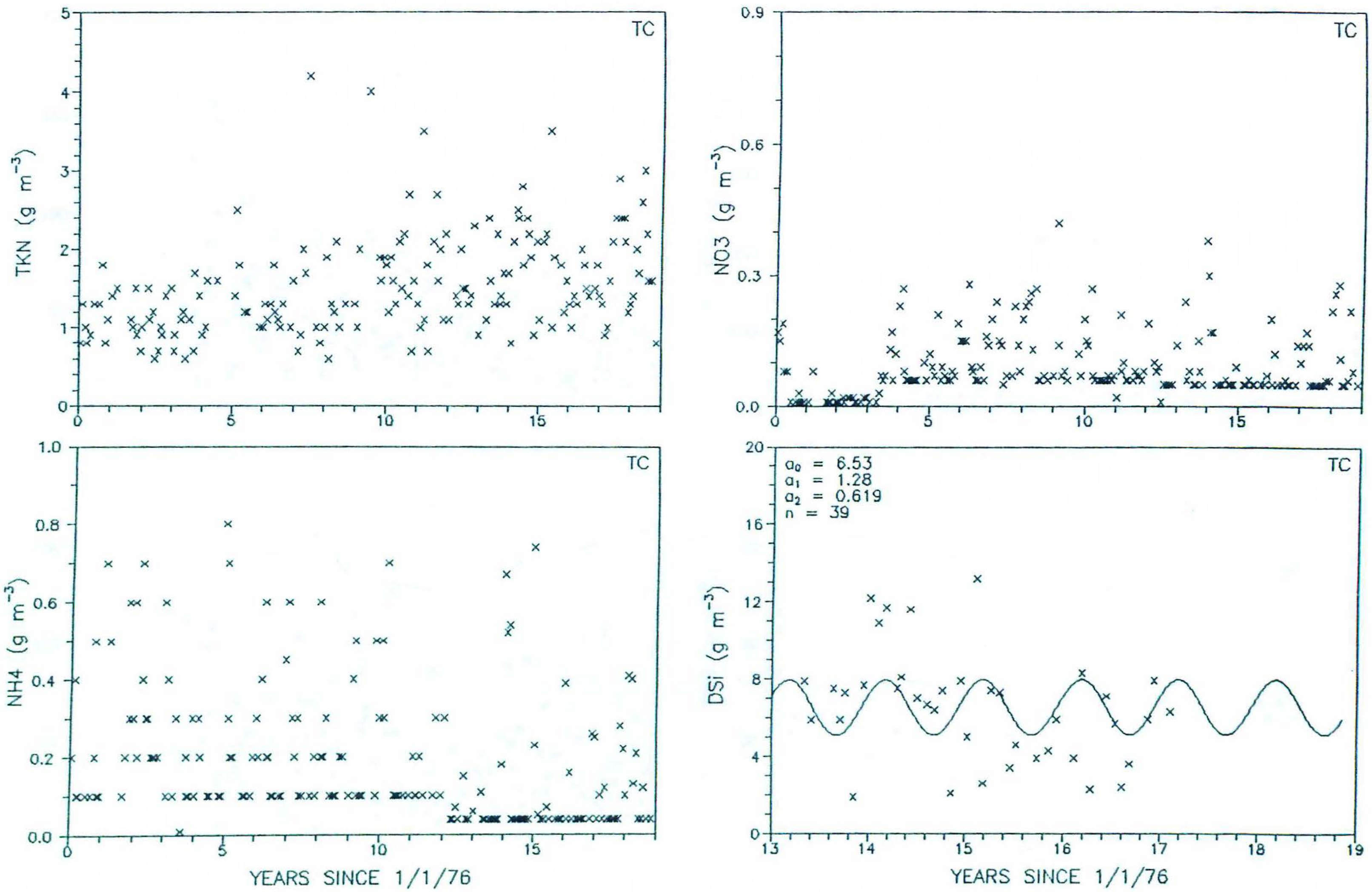
TC
TOC (g m^{-3})
YEARS SINCE 1/1/76

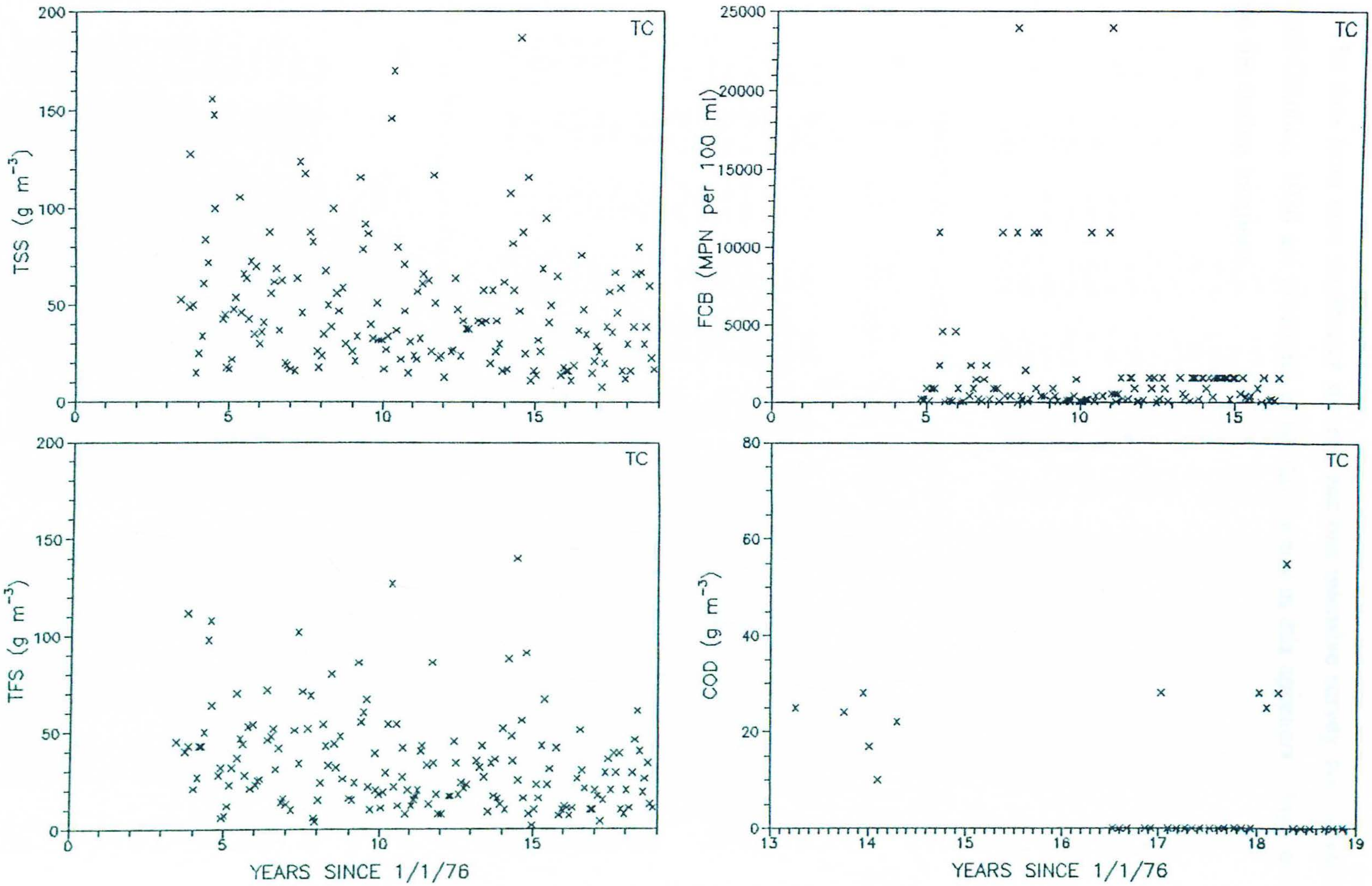


TC
TP (g m^{-3})



TC
PO4 (g m^{-3})
YEARS SINCE 1/1/76


TC
TKN (g m^{-3})
TC
NO3 (g m^{-3})
TC
NH4 (g m^{-3})
YEARS SINCE 1/1/76
a_0 = 6.53
a_1 = 1.28
a_2 = 0.619
n = 39
TC
DSi (g m^{-3})
YEARS SINCE 1/1/76


TC
TSS (g m⁻³)
TC
FCB (MPN per 100 ml)
TC
TFS (g m⁻³)
TC
COD (g m⁻³)
YEARS SINCE 1/1/76
YEARS SINCE 1/1/76

Appendix C. The Data from Field Surveys Conducted by VIMS in 1980

The data from nine slackwater surveys and one intensive survey conducted by VIMS in April-October, 1980 are presented in tabular format in this appendix. Figure V-1 shows the station locations.

Table C-1. Results from the slackwater survey conducted on 4/28/80 (08:58-11:00).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	16.05	18.31	9.70	0.05	0.01	0.28	0.05	0.05	9.60	2.0	1.80	1.80	
1B	0.0	16.83	18.61	13.40	0.05	0.01	0.28	0.05	0.05	8.60	7.8		1.50	
2	2.253	16.54	18.50	12.90	0.05	0.01	0.30	0.05	0.05	9.20	2.0	1.80	1.60	3.02
3	3.843	17.92	18.68	9.50	0.08	0.01	0.40	0.05	0.05	9.60	23.0	0.60	1.40	
4	5.310	19.29	17.92	19.00	0.05	0.01	0.58	0.12	0.05	6.00	6.8	0.60	1.50	
5	7.080	19.98	17.18	36.70	0.20	0.01	0.85	0.29	0.05	6.30	490.0	0.60	2.20	5.65
6	9.010	20.08	11.35	37.80	0.15	0.01	1.15	0.05	0.05		470.0	0.30	3.05	
P1	6.919	19.69	12.25	26.30	0.10	0.01	0.88	0.05	0.05	5.70	17000.0	0.30	2.35	
S1	7.080	20.87	15.14	43.50	0.12	0.01	1.10	0.05	0.05	6.30	490.0	0.30	3.25	
W1	-2.026	17.72	18.93	9.90	0.05	0.01	0.35	0.05	0.05	8.00	17.0	1.10	1.20	
W2	-3.701	18.80	18.51	9.30	0.06	0.01	0.65	0.08	0.05	6.10	33.0	0.50	1.35	9.33
W3	-5.083	19.98	17.85	8.50	0.06	0.01	0.70	0.15	0.05	5.50	27.0	0.50	0.85	
W4	-6.436	20.87	16.09	17.00	0.14	0.03	1.12	0.24	0.05	4.70	490.0		2.25	
W5	-9.186	19.00		17.20	0.22	0.07	1.42	0.05	0.26	5.10	24000.0		3.80	
B1	-6.934	20.68	15.21	25.20	0.48	0.07	2.30	0.34	0.05	3.20	3300.0	0.40	4.60	9.33

Table C-2. Results from the slackwater survey conductedd on 5/27/80 (07:24-09:24).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	21.95	17.54	5.90	0.05	0.01	0.28	0.04	0.01	9.10		1.10	1.95	
1B	0.0	21.90	17.61	6.40	0.05	0.01	0.35	0.04	0.01	9.20	2.0		2.15	
2	2.253	21.95	16.47	7.20	0.05	0.01	0.32	0.01	0.01	9.60	6.8	1.40	2.50	5.14
3	3.843	23.04	15.93	7.50	0.06	0.01	0.50	0.01	0.06	6.20	23.0	0.50	1.20	
4	5.310	23.84	13.76	9.50	0.10	0.01	0.68	0.01	0.01	6.20	33.0	0.30	1.45	
5	7.080	23.94	13.92	14.40	0.16	0.01	0.81	0.04	0.01	6.50	79.0		1.90	5.51
6	9.010	22.44	11.88		0.37	0.01	0.92	0.03	0.01	6.10	110.0		3.80	
P1	6.919	23.94	12.91	16.80	0.14	0.01	0.86	0.62	0.01	6.40	170.0	0.30	2.40	
S1	7.080	23.84	17.22	24.50	0.16	0.01	0.95	0.04	0.01	6.30	49.0	0.40	2.40	
W1	-2.026	22.25	16.02		0.09	0.01	0.52	0.02	0.01	6.70	33.0	0.50	1.45	
W2	-3.701	23.04	15.28	9.60	0.14	0.01	0.80	0.04	0.01	6.30	130.0	0.50	1.30	3.71
W3	-5.083	23.74	13.71	14.40	0.18	0.01	0.85	0.06	0.01	6.10	130.0	0.40	1.70	
W4	-6.436	24.34	11.91	21.40	0.19	0.01	0.99	0.02	0.01	7.20	490.0	0.40	2.80	
W5	-9.186	21.65	1.91	46.50	0.32	0.05	1.62	0.02	0.01	5.80	95.0	0.30	4.40	
B1	-6.934	24.14		29.50	0.28	0.01	1.15	0.01	0.01	7.80	790.0	0.40	3.50	8.66

Table C-3. Results from the slackwater survey conducted on 6/11/80 (07:48-10:24).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	21.45	23.84	4.40	0.05	0.01	0.85	0.01	0.01	7.40	4.5	1.20	0.30	
1B	0.0	21.55	23.94	4.80	0.06	0.01	0.28	0.01	0.01	7.40	2.0		0.50	
2	2.253	22.15	23.31	4.40	0.06	0.01	0.40	0.07	0.01	7.10	23.0	0.90	0.30	
3	3.843	22.54	22.24	7.60	0.11	0.01	0.55	0.01	0.01	6.40	7.8	0.50	0.65	
4	5.310	23.24	21.32	11.40	0.11	0.01	0.66	0.01	0.01	6.10	33.0	0.40	1.30	
5	7.080	23.63	20.44	16.60	0.14	0.01	0.75	0.01	0.01	5.80	33.0	0.30	1.10	
6	9.010	22.70		24.70	0.17	0.01	0.98	0.01	0.01	5.40	220.0	0.30	1.80	
P1	6.919	23.44	19.06	19.40	0.14	0.01	0.78	0.05	0.01	6.70	79.0	0.10	1.40	4.18
S1	7.080	23.94	17.62	22.60	0.17	0.01	0.75	0.01	0.01	6.50	170.0	0.30	1.90	
W1	-2.026	22.34	23.21	4.80	0.07	0.01	0.32	0.27	0.01	6.70	4.5	0.70	0.50	
W2	-3.701	23.14	22.16	8.10	0.11	0.01	0.55	0.01	0.01	6.10	49.0	0.50	0.85	2.69
W3	-5.083	23.74	21.73	12.20	0.16	0.01	0.75	0.01	0.01	6.00	23.0	0.50	1.35	
W4	-6.436	24.34	20.87	21.20	0.17	0.01	0.85	0.01	0.01	6.80	79.0	0.40	2.20	
W5	-9.186	23.54		45.20	0.35	0.02	1.82	0.01	0.01	5.90	33.0	0.30	4.70	
B1	-6.934	24.64	20.38	26.50	0.26	0.05	1.12	0.01	0.01	6.40	170.0	0.30	3.20	7.38

Table C-4. Results from the slackwater survey conducted on 7/8/80 (05:30-07:48).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	24.10	23.34	4.40	0.042	0.018	0.35	0.04	0.01	9.20		1.50	0.50	
1B	0.0	24.35	23.25	3.70	0.041	0.014	0.38	0.01	0.01	8.30	2.0		0.50	
2	2.253	23.40	23.32	4.30	0.047	0.014	0.32	0.01	0.01	8.50		1.40	0.35	1.86
3	3.843	25.60	22.90	9.00	0.111	0.014	0.48	0.01	0.01	7.20		0.40	0.25	
4	5.310	25.80	21.92	6.90	0.130	0.018	0.60	0.08	0.01	7.80	13.0	0.30	0.30	
5	7.080	25.70	21.22	12.40	0.215	0.027	1.08	0.01	0.01	4.80	130.0	0.30	1.10	4.50
6	9.010	25.60	18.88	17.90	0.205	0.042	1.08	0.02	0.01	4.40	280.0	0.50	1.35	
P1	6.919	25.25	20.60	13.10	0.206	0.035	0.85	0.01	0.01	4.60	33.0	0.10	1.35	
S1	7.080	25.20	19.29	18.10	0.406	0.038	1.62	0.01	0.01		49.0	0.10	2.15	
W1	-2.026	24.30	23.17	5.30	0.072	0.014	0.42	0.01	0.01	6.00	4.0	0.50	0.15	
W2	-3.701	25.40	22.74	6.40	0.087	0.027	0.55	0.04	0.01	5.40	7.8	0.50	0.30	1.90
W3	-5.083	26.20	22.55	9.60	0.149	0.032	0.58	0.02	0.01	5.10	11.0		0.45	
W4	-6.436	26.20	21.96	16.60	0.219	0.059	0.85	0.03	0.01	5.10	490.0	0.40	1.45	
W5	-9.186	22.70	18.23	32.10	0.446	0.086	1.65	0.01	0.01	2.30	330.0		5.40	
B1	-6.934	25.60	21.71	23.60	0.351	0.136	1.28	0.01	0.01	5.60	2300.0			9.04

Table C-5. Results from the slackwater survey conducted on 8/12/80 (10:00-11:42).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	25.10	26.34	5.60	0.044	0.011	0.40	0.01	0.01	7.30		1.60	0.50	
1B	0.0	25.00	26.40	7.00	0.042	0.011	0.40	0.01	0.01	7.30			0.15	
2	2.253	24.90	26.60	3.90	0.047	0.014	0.34	0.01	0.01	7.20		1.30	0.20	2.80
3	3.843	26.80	25.17	8.00	0.071	0.017	0.52	0.01	0.01	6.60	6.1	0.70	0.25	
4	5.310	28.20	23.70	11.70	0.104	0.048	0.65	0.02	0.01	7.80	330.0	0.60	1.00	
5	7.080	28.80	20.74	19.20	0.150	0.035	0.98	0.01	0.01	6.80	13.0		1.60	6.85
6	9.010	30.10	14.46	27.50	0.233	0.046	1.32	0.04	0.01	6.30	110.0	0.50	2.50	
P1	6.919	28.90	20.63	19.20	0.152	0.030	0.90	0.01	0.01	5.90	49.0	0.40	1.80	
S1	7.080	29.90	16.73	29.70	0.235	0.046	1.18	0.01	0.01	6.80	230.0	0.30	2.15	
W1	-2.026	25.20	26.85	6.30	0.069	0.015	0.40	0.05	0.01	7.40	2.0	1.10	0.55	
W2	-3.701	25.80	26.50	8.30	0.078	0.019	0.48	0.05	0.01	7.00	7.8	0.60	0.50	5.21
W3	-5.083	28.30	24.38	10.00	0.129	0.034	0.75	0.05	0.01	6.60	6.8	0.40	1.50	
W4	-6.436	29.30	23.16	27.80	0.200	0.066	1.04	0.01	0.01	7.80	11.0	0.30	3.35	
W5	-9.186	30.10	15.59	62.70	0.475	0.140	2.25	0.02	0.01	10.20	79.0	0.50		
B1	-6.934	30.30	22.37	35.60	0.260	0.091	1.12	0.01	0.01	8.80	33.0	0.30	5.90	11.01

Table C-6. Results from the slackwater survey conducted on 9/8/80 (08:06-09:42).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	26.17	25.77	7.30	0.050	0.016	0.41	0.028	0.01	6.60	2.0	1.10	1.45	
1B	0.0	26.07	25.89	8.10	0.064	0.018	0.46	0.011	0.01	6.80			0.80	
2	2.253	26.17	25.70	5.99	0.068	0.026	0.40	0.052	0.01	6.70	1.8	0.80	0.80	2.49
3	3.843	26.96	25.13	7.50	0.070	0.034	0.45	0.084	0.01	6.70	7.8	0.70	0.95	
4	5.310	27.07	24.93	14.40	0.115	0.029	0.80	0.129	0.01	5.40	7.8		1.35	
5	7.080	27.26	24.36	17.50	0.121	0.024	0.80	0.010	0.01	5.30	79.0	0.40	1.90	4.95
6	9.010	26.70	23.92	19.40	0.156	0.027	0.92	0.068	0.01	5.50	130.0	0.50	2.70	
P1	6.919	27.36	24.38	15.40	0.127	0.043	0.74	0.060	0.01	5.40	17.0	0.40	1.50	
S1	7.080	27.07	24.06	15.30	0.455	0.031	0.22	0.010	0.01		49.0	0.30	3.20	
W1	-2.026	26.07	25.68	7.00	0.052	0.018	0.48	0.023	0.01		2.0	1.40	1.10	
W2	-3.701	26.17	25.49	4.70	0.070	0.021	0.63	0.163	0.01	6.90	17.0	1.00	0.95	2.20
W3	-5.083	27.07	24.86	11.80	0.105	0.023	0.76	0.010	0.01	6.10	13.0	0.50	1.60	
W4	-6.436	27.66	24.62	18.80	0.182	0.042	0.79	0.010	0.01	7.40	70.0	0.30	2.35	
W5	-9.186	26.50	23.06	36.00	0.341	0.071	1.76	0.004	0.01	5.10	49.0	0.30	5.95	
B1	-6.934	27.66	24.22	28.20	0.231	0.066	1.19	0.010	0.01	7.30	49.0	0.30	4.20	8.47

Table C-7. Results from the slackwater survey conducted on 9/29/80 (14:30-15:36).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	22.50	26.33	9.90	0.085	0.020	0.60	0.10	0.02	7.40	13.0	0.70	1.30	
1B	0.0	22.70	26.34	14.20	0.100	0.016	0.65	0.05	0.02	9.40	7.8		1.50	
2	2.253	22.30	26.32	11.80	0.069	0.017	0.60	0.08	0.02	7.20	13.0	0.90	1.35	5.48
3	3.843	22.10	26.25	11.80	0.089	0.009	0.64	0.03	0.02	7.40	4.5	0.60	1.70	
4	5.310	22.10	26.12	14.20	0.096	0.010	0.68	0.01	0.02	7.60	33.0	0.60	1.70	
5	7.080	21.70	25.84	14.80	0.077	0.013	0.71	0.01	0.01	8.30	11.0	0.60	1.90	4.94
6	9.010	21.60	25.09	22.50	0.110	0.019	0.80	0.01	0.01	8.20	70.0	0.60	2.90	4.72
P1	6.919	21.50	25.37	21.00	0.091	0.017	0.76	0.01	0.01	8.20	11.0		2.15	
S1	7.080	21.50	24.94	21.40	0.124	0.016	0.77	0.01	0.01	8.90	49.0	0.40	2.85	
W1	-2.026	22.65	26.18	10.00	0.096	0.027	0.64	0.07	0.02	8.10	13.0	0.60	1.70	
W2	-3.701	22.20	26.06	10.90	0.100	0.016	0.66	0.05	0.02	7.60	79.0	0.60	1.60	
W3	-5.083	21.70	25.92	14.20	0.100	0.020	0.69	0.02	0.01	7.50	13.0	0.70	1.75	
W4	-6.436	21.60	25.44	20.50	0.153	0.032	0.82	0.01	0.01	8.70	33.0	0.70	2.35	
W5	-9.186	21.40	20.65	56.80	0.287	0.084	1.38	0.01	0.01	13.20	170.0	0.60	6.70	
B1	-6.934	21.50	24.60	27.70	0.159	0.050	0.92	0.01	0.01	10.20	130.0	0.70	4.05	6.46

Table C-8. Results from the slackwater survey conducted on 10/1/80 (16:00-17:30).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	22.50		5.70	0.062	0.019	0.56	0.09	0.021	7.60	6.8	1.00	0.70	
1B	0.0	22.40		5.00	0.068	0.027	0.50	0.11	0.021	7.40	17.0		0.90	
2	2.253	22.40		4.60	0.070	0.024	0.64	0.11	0.022	7.20		0.90	0.70	2.77
3	3.843	21.70		8.10	0.124	0.027	0.67	0.08	0.019	6.60	33.0	0.90	1.25	
4	5.310	21.60		7.00	0.107	0.027	0.71	0.08	0.019	6.80	49.0	0.70	1.55	
5	7.080	21.50		13.10	0.105	0.024	0.68	0.05	0.016	7.20	79.0	0.60	1.50	4.42
6	9.010	21.60		14.40	0.099	0.029	0.74	0.03	0.021	6.90	330.0	0.80	1.40	
P1	6.919	21.60		11.80	0.101	0.032	0.70	0.06	0.015	8.00	230.0	0.60	1.65	
S1	7.080	21.70		14.80	0.132	0.055	0.80	0.04	0.016	7.30	1300.0	0.60	1.75	
W1	-2.026	22.10		4.40	0.066	0.037	0.53	0.15	0.018	7.10	17.0	1.00	0.85	
W2	-3.701	21.60		7.20	0.095	0.047	0.64	0.12	0.021	6.90	33.0	0.70	1.15	3.88
W3	-5.083	21.50		7.40	0.124	0.043	0.75	0.19	0.024	8.00	23.0	0.70	1.00	
W4	-6.436	21.50		7.40	0.143	0.068	0.73	0.06	0.017	7.10	330.0	0.80	1.70	
W5	-9.186	21.80		37.60	0.256	0.057	1.23	0.01	0.021	7.70	2800.0	0.40	5.25	
B1	-6.934	21.60		19.20	0.209	0.114	0.94	0.07	0.022	6.90	490.0	0.60	2.30	5.06

Table C-9. Results from the slackwater survey conducted on 10/7/80 (07:12-09:06).

	km	T (C)	S (ppt)	CHL (ug/L)	TP (mg/L)	PO4d (mg/L)	TKN (mg/L)	NH4 (mg/L)	NO3 (mg/L)	DO (mg/L)	FCB (MPN /100 ml)	SD (m)	BOD5 (mg/L)	BODu (mg/L)
1T	0.0	19.30		3.90	0.053	0.019	0.60	0.17	0.029	6.90	4.0	0.90	0.40	
1B	0.0	19.30			0.053	0.023	0.67	0.16	0.028	6.90	13.0		0.60	
2	2.253	18.80		4.10	0.042	0.031	0.48	0.14	0.037	7.40	6.8	0.90	0.45	
3	3.843	18.40		6.10	0.069	0.016	0.68	0.16	0.043	7.00	17.0	0.70	0.65	
4	5.310	17.50		8.40	0.075	0.018	0.78	0.15	0.027		6.8	0.70	0.95	
5	7.080	16.80		12.40	0.152	0.023	0.82	0.01	0.005	7.00	14.0	0.50	2.10	
6	9.010	16.80		13.30	0.081	0.016	0.77	0.01	0.005	7.20	79.0	0.70	2.10	
P1	6.919	16.80		14.40	0.130	0.010	1.00	0.10	0.005	7.30	49.0	0.60	1.60	
S1	7.080	16.60		14.40	0.095	0.010	0.84	0.07	0.005	6.20	79.0	0.50	2.20	
W1	-2.026	18.10		3.70	0.055	0.027	0.60	0.16	0.042	7.00	11.0	1.00	0.65	
W2	-3.701	17.50		6.60	0.065	0.023	0.63	0.14	0.044	7.00	49.0	0.90	1.00	
W3	-5.083	17.40		7.60	0.077	0.030	0.64	0.08	0.008	7.40	33.0	0.80	1.15	
W4	-6.436	17.70		10.70	0.122	0.046	0.84	0.08	0.006	7.80	79.0	0.50	1.75	
W5	-9.186	16.50			0.194	0.056	1.41	0.01	0.005	7.00	110.0	0.70	3.60	
B1	-6.934	17.20		15.90	0.179	0.065	1.18	0.10	0.005	8.00	110.0	0.50	3.10	

Table C-10. Temperature (oC) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				26.8			25.5			
7	30	24.8	25.3			26.5					
8	0			25.1	27.0	26.8			25.6		
8	30	25.0	25.3	24.9							
9	0	24.8	24.9	24.9	27.1	25.5					
10	0	24.9	24.9	24.8	25.4	25.5					
11	0	24.9	24.7	24.9	25.6	25.8		25.6			
12	0	25.3	25.1	25.1	25.9	25.9					
13	0	25.5	25.4		26.2	26.2		25.6			
13	30			25.2							
14	0	25.7	26.9	25.4	26.4	26.4			26.1		
15	0	25.8	25.5	25.3	26.6	26.4		25.9			
16	0	25.7	25.9	25.5	26.6	26.3			26.2		
17	0	25.3	25.2	25.5	26.2	25.9		25.9			
18	0	25.4	25.2	25.3	25.9	25.6			25.4		
19	0	25.0	24.8	25.0	25.8	25.5		25.1			
20	0	24.4	24.6	24.5	26.4						
20	30					25.4			25.4		
21	0	24.3	24.3	24.1	25.1	25.1		24.0			
22	0	24.2	24.3	24.6	24.6	24.8			24.1		
23	0	24.2	24.2	24.5	24.5			23.7			
23	30					23.9					
0	0	23.9	24.4	24.1	23.9	24.1			24.1		
1	0	23.6	23.5	23.9	23.8	23.3		23.3			
2	0	23.9	22.9	23.7	24.7	24.7			23.3		
3	0	22.8	22.7	23.3	24.6			22.7			
4	0	23.1	22.5	22.9	22.6	22.2			22.2		
5	0	23.3	22.4	22.6	22.2			22.3			
5	30					21.9					
6	0	23.2	23.4	22.1	21.5	21.0			21.8		
7	0				21.5			22.5			
7	30	22.0	21.8	22.5		21.1					
8	0	23.1	23.0	23.4	21.8	21.4			22.2		
9	0	23.5	23.4	23.6	22.0	21.7		21.8			
9	30									21.2	
10	0						21.4				
maximum =			26.9	25.5	27.1	26.8	21.4	25.9	26.2	21.2	
minimum =			21.8	22.1	21.5	21.0	21.4	21.8	21.8	21.2	
mean =			24.34	24.32	24.84	24.57	21.40	24.15	24.22	21.20	

Table C-11. Salinity (ppt) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				25.5			26.0			
7	30	23.5	25.3			23.8					
8	0			25.9	25.3	25.4			25.1		
8	30	23.6	23.6	21.0							
9	0	26.3		23.6	26.0	26.3					
10	0		26.3	26.2	27.9	27.0					
11	0	26.3	26.2	26.5	26.2	25.5		27.4			
12	0	26.3	26.3	26.2	25.9	25.4					
13	0	26.3	26.2		25.4	25.2		26.1			
13	30			26.1							
14	0	26.1	25.2	26.0	25.0	24.5			24.7		
15	0	25.9	25.9	25.6	24.6	24.1		25.3			
16	0	25.4	25.3	25.3	24.0	23.3			23.3		
17	0	25.7	25.6	25.2	23.5	21.7		25.0			
18	0	25.5	26.0	25.5	23.4	21.8			22.3		
19	0	25.9	26.1	26.1	24.5	22.5		25.4			
20	0	26.3	25.7	26.3	25.1						
20	30					24.9			24.8		
21	0	26.4	25.8	26.2	25.4	24.9		26.1			
22	0	26.4	25.4	25.9	26.1	25.3			25.5		
23	0	26.4	25.9	25.7	26.3			26.6			
23	30					25.0					
0	0	26.3	25.8	25.9	25.6	25.1			25.4		
1	0	26.5	26.1	25.9	25.5	24.8		26.1			
2	0	26.4	25.6	25.2	25.1	24.6			24.6		
3	0	26.2	25.8	25.4	24.8	23.5		25.7			
4	0	26.4	25.8	25.7	24.4	23.2			23.3		
5	0	26.3	25.6	25.2	24.9			25.1			
5	30					22.8					
6	0	26.4	26.0	27.0	23.6	22.1			22.1		
7	0				24.2			25.3			
7	30	25.9	26.0	26.0		22.6					
8	0	26.3	25.8	23.5	25.1	23.5			24.6		
9	0	26.1	25.9	25.5	25.3	25.2		26.0			
9	30									14.3	
10	0						22.9				
maximum =			26.5	27.0	27.9	27.0	22.9	27.4	25.5	14.3	
minimum =			23.5	21.0	23.4	21.7	22.9	25.0	22.1	14.3	
mean =			25.85	25.50	25.13	24.22	22.90	25.85	24.15	14.30	

Table C-12. 5-day CBOD (mg/l) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				1.15			2.10			
7	30	0.70	0.90			1.80					
8	0			0.80					1.60		
8	30										
9	0	0.90	0.75	0.80							
10	0	0.85	1.00	1.10	1.20	1.40					
11	0							1.25			
12	0										
13	0	1.60	1.45		1.95	2.50		1.40			
13	30			1.30							
14	0								2.30		
15	0							1.70			
16	0	1.55	1.45	1.55	3.00	2.80			4.10		
17	0							2.50			
18	0								4.35		
19	0	1.65	1.40	1.35	2.30	3.10		1.65			
20	0										
20	30								2.80		
21	0							1.10			
22	0	0.85	0.85	0.95	1.35	1.20			1.65		
23	0							1.30			
23	30										
0	0								1.35		
1	0				2.20	1.50		1.10			
2	0								2.10		
3	0							1.10			
4	0	1.35	2.15	1.15	1.80	2.20			1.90		
5	0							1.50			
5	30										
6	0								3.90		
7	0				2.20			1.75			
7	30	1.05	1.10	1.00		2.45					
8	0								2.60		
9	0							1.25			
9	30									6.20	
10	0						2.95				
maximum =			2.15	1.55	3.00	3.10	2.95	2.50	4.35	6.20	
minimum =			0.70	0.80	1.15	1.20	2.95	1.10	1.35	6.20	
mean =			1.197	1.111	1.906	2.106	2.950	1.515	2.605	6.200	

Table C-13. Dissolved oxygen (mg/l) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				5.27			4.90			
7	30	7.82	5.54			4.62					
8	0			5.90	5.11	5.77			4.70		
8	30	6.66	5.58	5.90							
9	0	6.04	5.98		6.83	5.57		6.08			
10	0	6.08	7.00	6.32	6.53	6.87			5.04		
11	0	7.12	5.72	6.60	7.12	7.42		6.24			
12	0	6.60	6.56	5.30	7.58	8.04			6.74		
13	0	7.02	8.04		7.62	8.70		7.80			
13	30										
14	0	7.46	7.66		8.66	8.96			7.94		
15	0	7.44	6.98	7.12	9.49	8.44		8.64			
16	0	7.58	7.46	6.70	9.07	7.48			9.80		
17	0	7.30	7.22	7.62	8.96	6.71		8.30			
18	0	7.46	7.14	7.36	8.36	6.93			9.60		
19	0	7.20	7.28	7.04	8.38	7.36		6.74			
20	0	6.22	7.28	6.82	7.46						
20	30					7.30			7.46		
21	0	5.46		6.12	7.10	8.04		6.54			
22	0	6.20	6.26	6.68	7.10	7.12			6.60		
23	0	7.14	7.54	6.50	7.60			6.44			
23	30					7.06					
0	0	6.10	6.56	6.38	7.56	6.86			6.68		
1	0	8.26	7.96	5.60	6.61	7.10		6.46			
2	0	6.14	7.94	6.60	6.89	6.35			6.50		
3	0	6.38	6.12	6.40	6.98	6.57		6.90			
4	0	6.20	6.16	6.72	6.43	5.65			7.04		
5	0	6.24	7.96	6.08	5.51			6.32			
5	30										
6	0	6.20	8.08	6.06	5.79	5.05			6.54		
7	0	6.38	6.38		5.23			6.62			
7	30			6.82		4.80					
8	0	6.76	6.58	6.42	6.13	6.43					
9	0	6.36	6.44	6.50	6.40	6.60					
9	30									8.36	
10	0						6.06				
maximum =			8.26	7.62	9.49	8.96	6.06	8.64	9.80	8.36	
minimum =			5.46	5.30	5.11	4.62	6.06	4.90	4.70	8.36	
mean =			6.816	6.482	7.103	6.838	6.060	6.768	7.053	8.360	

Table C-14. TKN (mg/l) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				0.93			0.86			
7	30		0.56			0.45					
8	0			0.62					0.90		
8	30										
9	0		0.62	0.65	0.77	0.98					
10	0										
11	0	0.60	0.68	0.57	0.61	0.69		0.68			
12	0										
13	0		0.64		0.76	0.77		0.72			
13	30			0.71							
14	0								0.87		
15	0	0.65	0.71	0.68	0.85	1.02		0.78			
16	0				0.81	1.10			1.24		
17	0	0.64	0.65	0.63	0.88	1.47		0.77			
18	0								1.29		
19	0	0.72		0.64	0.82	1.14		0.78			
20	0								0.76		
20	30										
21	0	0.84	0.72	0.62	0.83	0.85		0.96			
22	0								0.64		
23	0	0.75	0.79	0.66	0.53			0.63			
23	30					0.71					
0	0								0.73		
1	0	0.55	0.56	0.53	0.68	0.69		0.64			
2	0								0.74		
3	0	0.62	0.54	0.66	0.80	0.85		0.91			
4	0								0.64		
5	0	0.57	0.74	0.72	0.94			1.03			
5	30					0.94					
6	0								0.90		
7	0				0.86			1.40			
7	30	0.68	0.74	0.72		0.77					
8	0								0.81		
9	0	0.70	0.66	0.63	0.92	0.88		0.72			
9	30									1.74	
10	0						1.10				
maximum =			0.84	0.72	0.94	1.47	1.10	1.40	1.29	1.74	
minimum =			0.54	0.53	0.53	0.45	1.10	0.63	0.64	1.74	
mean =			0.664	0.646	0.799	0.887	1.100	0.837	0.865	1.740	

Table C-15. Ammonium nitrogen (mg/l) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				0.06			0.14			
7	30	0.08	0.06			0.07					
8	0			0.07					0.14		
8	30										
9	0		0.08	0.07	0.05	0.06					
10	0										
11	0	0.04	0.09	0.08	0.04	0.01		0.07			
12	0										
13	0	0.09	0.10		0.01	0.01		0.05			
13	30			0.06							
14	0								0.05		
15	0	0.05	0.07	0.01	0.01	0.03		0.06			
16	0				0.01				0.01		
17	0	0.01	0.04	0.01	0.01	0.01		0.02			
18	0								0.12		
19	0	0.09	0.02	0.01	0.01	0.01		0.06			
20	0								0.01		
20	30										
21	0	0.15	0.14	0.11	0.03	0.01		0.02			
22	0								0.06		
23	0	0.20	0.18	0.12	0.03			0.02			
23	30					0.02					
0	0								0.03		
1	0	0.15	0.08	0.16	0.01	0.02		0.04			
2	0								0.06		
3	0	0.15	0.15	0.04	0.03	0.03		0.03			
4	0								0.03		
5	0	0.04	0.10	0.02	0.02			0.01			
5	30					0.10					
6	0								0.04		
7	0				0.05			0.01			
7	30	0.10	0.14	0.15		0.08					
8	0								0.03		
9	0	0.14	0.20	0.09	0.05	0.05		0.10			
9	30									0.01	
10	0						0.01				
maximum =			0.20	0.16	0.06	0.10	0.01	0.14	0.14	0.01	
minimum =			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
mean =			0.101	0.071	0.028	0.036	0.010	0.048	0.053	0.010	

Table C-16. Nitrate nitrogen (mg/l) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				0.030			0.040			
7	30	0.020	0.010			0.060					
8	0			0.010					0.050		
8	30										
9	0		0.010	0.010	0.020	0.030					
10	0										
11	0	0.010	0.010	0.010	0.020	0.020		0.020			
12	0										
13	0	0.010	0.020		0.020	0.030		0.030			
13	30			0.01							
14	0								0.050		
15	0	0.020	0.020	0.010	0.010	0.030		0.040			
16	0				0.010	0.030			0.060		
17	0	0.020	0.020	0.010	0.010	0.060		0.040			
18	0								0.060		
19	0	0.020	0.020	0.010	0.010	0.040		0.040			
20	0										
20	30								0.030		
21	0	0.020	0.020	0.020	0.010	0.010		0.040			
22	0								0.031		
23	0	0.020	0.020	0.020	0.020			0.040			
23	30					0.020					
0	0								0.030		
1	0	0.020	0.020	0.020	0.010	0.020		0.040			
2	0								0.040		
3	0	0.020	0.020	0.010	0.010	0.030		0.040			
4	0								0.030		
5	0	0.010	0.020	0.010	0.020			0.040			
5	30					0.040					
6	0								0.040		
7	0				0.020			0.040			
7	30	0.020	0.020	0.010		0.040					
8	0								0.040		
9	0	0.020	0.020	0.020	0.020	0.020		0.030			
9	30									0.003	
10	0						0.030				
maximum =			0.020	0.020	0.030	0.060	0.030	0.040	0.060	0.003	
minimum =			0.010	0.010	0.010	0.010	0.030	0.020	0.030	0.003	
mean =			0.0178	0.0129	0.0160	0.0320	0.0300	0.0369	0.0419	0.0030	

Table C-17. Total phosphorus (mg/l) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				0.19			0.15			
7	30	0.09	0.07			0.20					
8	0			0.09					0.20		
8	30										
9	0		0.10	0.09	0.12	0.17					
10	0										
11	0	0.07	0.09	0.09	0.10	0.11		0.10			
12	0										
13	0	0.08	0.08		0.10	0.12		0.12			
13	30			0.09							
14	0								0.18		
15	0	0.08	0.09	0.10	0.14	0.18		0.14			
16	0				0.17	0.17			0.22		
17	0	0.09	0.09	0.10	0.17	0.26		0.17			
18	0								0.27		
19	0	0.11	0.12	0.08	0.15	0.20		0.14			
20	0								0.15		
20	30										
21	0	0.14	0.11	0.09	0.16	0.17		0.19			
22	0								0.12		
23	0	0.13	0.12	0.09	0.09			0.12			
23	30					0.11					
0	0								0.11		
1	0	0.07	0.07	0.07	0.10	0.12		0.13			
2	0								0.17		
3	0	0.10	0.09	0.08	0.12	0.13		0.16			
4	0								0.12		
5	0	0.08	0.11	0.11	0.16			0.20			
5	30					0.17					
6	0								0.17		
7	0				0.14			0.24			
7	30	0.10	0.10	0.10		0.20					
8	0								0.15		
9	0	0.08	0.11	0.10	0.18	0.16		0.11			
9	30									0.34	
10	0						0.17				
maximum =			0.14	0.11	0.19	0.26	0.17	0.24	0.27	0.34	
minimum =			0.07	0.07	0.09	0.11	0.17	0.10	0.11	0.34	
mean =			0.095	0.091	0.139	0.165	0.170	0.152	0.169	0.340	

Table C-18. Dissolved phosphate (mg/l) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				0.03			0.06			
7	30	0.02	0.02			0.04					
8	0			0.02					0.09		
8	30										
9	0		0.02	0.02	0.03	0.03					
10	0										
11	0	0.02	0.04	0.02	0.02	0.02		0.03			
12	0										
13	0	0.02	0.02		0.02	0.02		0.03			
13	30			0.02							
14	0								0.07		
15	0	0.02	0.02	0.02	0.03	0.02		0.05			
16	0				0.02	0.02			0.10		
17	0	0.02	0.03	0.02	0.02	0.03		0.06			
18	0								0.12		
19	0	0.02	0.02	0.02	0.02	0.02		0.05			
20	0								0.05		
20	30										
21	0	0.03	0.03	0.03	0.02	0.02		0.06			
22	0								0.05		
23	0	0.03	0.03	0.03	0.02			0.05			
23	30					0.03					
0	0								0.03		
1	0	0.03	0.02	0.03	0.02	0.02		0.05			
2	0								0.07		
3	0	0.03	0.04	0.02	0.03	0.03		0.06			
4	0								0.05		
5	0	0.02	0.02	0.03	0.02			0.07			
5	30					0.03					
6	0								0.06		
7	0				0.02			0.08			
7	30	0.02	0.02	0.02		0.02					
8	0								0.05		
9	0	0.02	0.03	0.03	0.02	0.02		0.04			
9	30									0.06	
10	0						0.02				
maximum =			0.04	0.03	0.03	0.04	0.02	0.08	0.12	0.06	
minimum =			0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.06	
mean =			0.024	0.024	0.023	0.025	0.020	0.053	0.067	0.060	

Table C-19. Chlorophyll 'a' (ug/l) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				8.5			7.4			
7	30	5.0	8.1			16.6					
8	0			10.0					13.5		
8	30										
9	0	7.6	7.9	8.0	17.3	21.0					
10	0										
11	0	10.7	9.6	9.6	13.5	22.3		11.6			
12	0										
13	0	7.4	9.2		17.5	24.9		13.1			
13	30			13.5							
14	0								25.8		
15	0	13.5	11.6	18.0	24.5	28.2		20.1			
16	0				26.2	27.3			35.6		
17	0	10.9	11.4	14.4	26.2	24.5		21.8			
18	0								34.9		
19	0	14.6	15.4	12.1	19.2	24.0		14.0			
20	0								21.2		
20	30										
21	0	6.8	6.6	7.4	13.1	14.8		7.4			
22	0								9.4		
23	0	6.8	7.2	8.7	10.3			9.0			
23	30					12.2					
0	0								11.8		
1	0	5.7	7.0	5.9	11.4	12.7		8.5			
2	0								18.3		
3	0	8.3	9.4	8.7	12.7	15.3		9.6			
4	0								25.6		
5	0	6.1	8.8	7.6	14.4			12.9			
5	30					12.4					
6	0								34.1		
7	0				14.2			14.2			
7	30	8.5	8.3	8.5		16.4					
8	0								24.9		
9	0	8.1	8.3	8.1	16.8	16.8		8.3			
9	30									59.0	
10	0						24.0				
maximum =			15.4	18.0	26.2	28.2	24.0	21.8	35.6	59.0	
minimum =			5.0	5.9	8.5	12.2	24.0	7.4	9.4	59.0	
mean =			8.89	10.04	16.39	19.29	24.00	12.15	23.19	59.00	

Table C-20. Fecal coliform bacteria (MPN/100 ml) from the intensive survey conducted on 9/26

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				230			1300			
7	30					4900					
8	0	7.8	7.8	23					3300		
8	30										
9	0	13	6.8	6.8				490			
10	0				49	170			220		
11	0							130			
12	0								330		
13	0				130	700		330			
13	30	49	33	33							
14	0								490		
15	0							330			
16	0	49	130	460	790	2800			790		
17	0							330			
18	0								3300		
19	0			31	330	2300		230			
20	0										
20	30								1100		
21	0							70			
22	0	4.5		2	130	170			130		
23	0							46			
23	30										
0	0								330		
1	0			230	110	330		230			
2	0								1100		
3	0							130			
4	0	23	49	230	490	330			3300		
5	0							230			
5	30										
6	0								3300		
7	0	33	33	79	460			330			
7	30					490					
8	0								790		
9	0							46			
9	30									790	
10	0						790				
maximum =			130	460	790	4900	790	1300	3300	790	
minimum =			4.5	2	49	170	790	46	130	790	
mean =			33.8	121.6	302.1	1354.4	790.0	301.6	1421.5	790.0	

Table C-21. Secchi depth (m) from the intensive survey conducted on 9/26-27/80.

hr	min	1T	1B	2	4	5	6	W2	W4	W5	
		(0.0)	(0.0)	(2.253)	(5.310)	(7.080)	(9.010)	(-3.701)	(-6.436)	(-9.186)	= km from inlet
7	0				0.4			0.4			
7	30	1.0				0.3					
8	0			0.8	0.4	0.3			0.4		
8	30	0.7		0.9							
9	0	0.8		0.8	0.4	0.4					
10	0			0.9	0.6	0.4					
11	0	0.7		0.9	0.5	0.5		0.5			
12	0	0.7		0.7	0.5	0.5					
13	0	0.8		0.6	0.5	0.5		0.5			
13	30										
14	0	0.7		0.5	0.4	0.3					
15	0	0.6		0.5	0.4	0.3		0.4			
16	0	0.6		0.5	0.4	0.3			0.3		
17	0	0.7		0.5	0.4	0.2		0.4			
18	0					0.2					
19	0										
20	0										
20	30										
21	0										
22	0										
23	0										
23	30										
0	0										
1	0										
2	0										
3	0										
4	0										
5	0										
5	30										
6	0										
7	0										
7	30					0.2					
8	0	0.5		0.8	0.2	0.3					
9	0	0.6		0.8	0.4	0.3		0.5			
9	30									0.4	
10	0										
maximum =			1.0	0.9	0.6	0.5		0.5	0.4	0.4	
minimum =			0.5	0.5	0.2	0.2		0.4	0.3	0.4	
mean =			0.70	0.71	0.42	0.33		0.45	0.35	0.40	