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LIMNOLOGICAL DATABASE FOR PAR POND: 1959-1980

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ABSTRACT

A limnological database for Par Pond, a cooling reservoir for hot reactor effluent water at the Savannah River Plant, is described. The data are derived from a combination of research and monitoring efforts on Par Pond since 1959. The approximately 24,000-byte database provides water quality, primary productivity, and flow data from a number of different stations, depths, and times during the 22-year history of the Par Pond impoundment. The data have been organized to permit an interpretation of the effects of twenty years of cooling system operations on the structure and function of an aquatic ecosystem.

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INTRODUCTION

Limnological data on the reactor water cooling impoundment, Par Pond, have been collected by several groups at the Savannah River Plant (SRP) since 1959. These data were reviewed, and some categories were judged to be of sufficient duration to be useful in providing background for interpreting ecological or limnological events of significance in the 22-year history of the approximately 1100-hectare Par Pond system. These records were prepared for computer storage, access, and manipulation in a format useful for subsequent interpretation and amenable to augmentation. It is the purpose of this report to describe the database available in the Savannah River Laboratory (SRL) computer files, the method by which it is organized, assumptions made in generating observations, and the physical/chemical methods involved in the reported measurements. Another report (Tilly, 1980) interprets these and related data in terms of the effects of years of cooling system operations on the Par Pond reservoir system.

THE LIMNOLOGICAL DATABASE

General Description

The major categories of data are water quality and primary productivity. Water quality, as defined here, includes the relatively standard limnological items in Table 1. Primary productivity data (Table 2) include ^{14}C fixation measurements for plankton and for periphyton (attached algae), chlorophyll measurements, and dry weights.

Water quality and primary productivity data have been further organized as surface, column, or profile observations. Surface observations are simply a record of measurements usually made in the upper 25-cm of the water column, but always within the upper meter. Profile measurements include not only a surface measurement, but also a contemporaneous set of observations from a series of lower depths at the same station. Column observations are measurements which, because of their mode of collection, must be regarded as representing the entire column rather than any discrete depth.

Several synthetic data sets and a "Flow" data set are also available. Synthetic data sets were created by averaging daily observations to yield monthly records and by averaging contemporaneous paired replicate measurements to create single daily estimates. The "Flow" data set includes rainfall-runoff estimates

TABLE 1

Water Quality Data

Dataset Parameter	Units	Database Name	Method Reference*
Alkalinity	mg/L	Alk	S Potentiometric titration
Aluminum	mg/L	Al	S (AA)
Bicarbonate	mg/L	HCO_3	S Nomographic
Calcium	mg/L	Ca	S (AA)
Chloride	mg/L	Cl	S Mercuric Nitrate
Cobalt	mg/L	Co	S (AA)
Color	Pt-Co units	Color	S - Hellige comparator
Conductivity	μmhos/cm^2	Cond.	S - Bridge
Cesium-137, dissolved	pCi/L	^{137}Cs-d	Alberts, Tilly, and Vigerstad, 1979
Cesium-137, total	pCi/L	^{137}Cs-t	Alberts, Tilly, and Vigerstad, 1979
Flow	m^3/min	Flow	Tilly, 1980
Hardness	mg/L	Hard.	S Titration or calculation
Iron	mg/L	Fe	S (AA)
Light, surface fraction		SLF	S - meter
Magnesium	mg/L	Mg	S (AA)
Manganese	mg/L	Mn	S (AA)
Nitrate	μg/L	NO_3	S Cadmium reduction
Nitrite	μg/L	NO_2	S Cadmium reduction
Oxygen	mg/L	Do	S Winkler/galv. cell analy.
pH		pH	S meter in field
Phosphate, ortho	μg/L	PO_4	S Molybdate
Potassium	mg/L	K	S (AA)
Secchi depth	meters	Secchi	S
Seston, net 10	mg/L	N Ses.-10	Tilly, 1975
Seston, net 20	mg/L	N Ses.-20	Tilly, 1975
Seston, total	mg/L	T Ses	Tilly, 1975
Silicate	mg/L	Si	S (AA)
Sodium	mg/L	Na	S (AA)
Solids dissolved:			
total	mg/L	TDS	Marshall and Tilly, 1971
volatile	mg/L	VS	Marshall and Tilly, 1971
non-volatile	mg/L	NVDS	Marshall and Tilly, 1971
Sulfate	mg/L	SO_4	S - turbidimetric
Temperature	°C	Temp.	S - temperature
Turbidity	mg/L	Turb.	S - Hach. turbidimetric
Zinc	mg/L	Zn	S (AA)

* S = APHA (1955, et seq.); Standard Methods.
(AA) = Atomic Absorption.

TABLE 2

Primary Productivity Data

Dataset	Units	Parameter	Database Name	Method Reference
Plankton productivity	mgC/m^3	^{14}C uptake per unit volume	^{14}C Plnk	Tilly, 1975
Plankton productivity	mgC/m^2	^{14}C uptake per unit area	Int. Prod.	Tilly, 1980
Periphyton productivity	mgC/g	^{14}C uptake per unit weight	^{14}C Peri	Tilly, 1980
Periphyton productivity	mgC/m^2	^{14}C uptake per unit area	^{14}C Area	Tilly, 1980
Periphyton productivity	mgC/mg	^{14}C uptake per unit chlorophyll	^{14}C Chla	Tilly, 1975
Plankton chlorophyll	mg/L	per unit volume	Chla Plnk	*
Periphyton chlorophyll	mg/g	per unit weight	Chla Peri	Tilly, 1980
Periphyton chlorophyll	mg/m^2	per unit area	Chla Area	Tilly, 1980
Periphyton pheophytin	mg/g	per unit weight	Pheo Peri	Tilly, 1980
Periphyton pheophytin	mg/m^2	per unit area	Pheo Area	Tilly, 1980
Periphyton biomass	mg/m^2	per unit area	Peri Area	Tilly, 1980

* Strickland and Parsons, 1968; Lorenzen, 1967.

for the Par Pond basin, estimates of discharge over the Cold Dam to Lower Three Runs Creek, make-up water additions from the Savannah River to P reactor, and total cooling water flows for P and R reactors.

Methods and Assumptions

Specific references for the methods and/or assumptions involved are available for most data. Tables 1 and 2 indicate the primary references. The potential user of the data set must be aware, however, that even "standard" methods have changed progressively with time, so that "standard" methods should be referenced to the particular time of origin in cases where the details of procedure may be important.

It is reasonable to assume that the precision and accuracy of the original data are those commonly associated with the standard methods involved. However, the extent to which errors in data input due to keypunch and machine problems contaminate the approximately 24,000 byte data set is unknown. About 90% of the time, series data have been visually screened for consistency, and such problems as scale errors and impossible outliers have been largely eliminated. The correspondence between the original data and the computerized version was estimated by sampling records representative of the main data types during the interpretive phase of the analysis.

For water quality measurements (other than Flow), Table 1 should provide an adequate key to the methods employed. For Flow (Table 1) and Primary Productivity (Table 2), further explanations are required. The parameter Flow is a water discharge or input which differs in character and in method of determination according to the station in question. The different flows are described below:

Flow 0 - the rainfall-runoff inputs to the entire Par Pond basin as computed from rainfall-discharge relationships corrected for seasonal differences in infiltration and evapotranspiration effects.

Flow 5 - the discharge to Lower Three Runs Creek over the Cold Dam near Station 5. The discharge was computed from water elevation-discharge relationships provided for the Par Pond impoundment by the U. S. Corps of Engineers and from daily measurements of Par Pond water level recorded by SRP Power Department.

Flow 8 - the pumped flow of water from the Savannah River to Par Pond as "makeup" via the P-Area "186" basins. The volume was recorded by the SRP Power Department based on operating information on the number of pumps in use, their rated capacities and efficiencies, and flow-meter readings.

Flow 9 - the total pumped flow of water from Par Pond to the P-Area "186" basin or (during years prior to 1964 when R-reactor was retired from service) the total pumped flow from Par Pond to P and R areas as determined and recorded by SRP Power Department (see Flow 8).

Flow R - the total cooling water flow within R reactor from pumping records of SRP Reactor Technology and Power Departments.

Flow P - the total cooling water flow within P reactor from pumping records of SRP Reactor Technology and Power Departments.

Flow V - the flow representing storage of water in the Par Pond basin as calculated from the daily increase in water level. The water-level measurements are averaged for each month and multiplied by the Par Pond area. Par Pond area is assumed constant at 10.6×10^7 square meters within the normal range of water levels recorded by the SRP Power Department.

A major emphasis in the database is upon primary productivity and related factors. Methods for plankton productivity estimation are described in Tilly (1975) and Marshall and Tilly (1971). For periphyton productivity, however, no adequate description exists in a single source; hence Appendix II is provided here.

ACCESS TO THE DATABASE

The Par Pond data are currently (as of June, 1980) in the SRL computer as the major part of JOSHUA dataset name "LAKE3277." For further information on the JOSHUA system and how to access data sets managed by it, the user is referred to JOSHUA System, Volume 2, User's Guide by Honeck, 1975. To display the data, the user requests function "DD" by record name. The pattern of these names is:

LAKES.?TIMEINT.?LAKE.?STATION.?BIOPHYS.?REGIME.?PARAM

"LAKES" is the fixed qualifier in the name string. The variable qualifiers (? name) have the following meaning:

TIMEINT - the time interval associated with an observation; Replica, Daily, or Monthly. The time interval is expressed in Julian days for which Julian day 00001 = January 1, 1950. Subsequent dates are obtained by multiplying 365.25 times the number of years.

LAKE - the name of the lake or pond; Par Pond.

STATION - the name of the Station; e.g., 2, 5, 6, etc.

BIOPHYS - the biological or physical data; Quality or P-Prod.

REGIME - the method of measurement; Profile, Surface, or Column.

PARAM - the name of the data item value; e.g., Temp, pH, C14 PLNK CHLAPERI.

Appendix I gives examples of the access procedure employed and representative records which may be displayed.

A prototype data management system available with JOSHUA enables a number of manipulations of the data to be made. Noteworthy for the environmental scientist is the ability to create a data set, to test it with a standard statistical package, and to construct time-series plots or water-column profiles. Examples of such data presentations and manipulations are displayed in Appendix I.

DATA COLLECTING STATIONS AT PAR POND

For purposes of this document, the Par Pond system is regarded as including all the stations listed in Table 3. Note that the Savannah River pumphouse, the cooling canals, the reactors, and the reservoir proper are regarded as parts of the system. Figure 1 shows the stations for which data are available in the computer. The longest records are "quality column" observations for Stations 8 and 9, which are the Savannah River Pumphouse and Par Pond Pumphouse, respectively. Most of these data were collected by SRP personnel under the guidance of the SRP Works Technical staff. Extensive data for "Flow" at Stations R, P, 5, and 8 were available or derivable from the SRP Power Department records. Table 4 summarizes the general kinds of data available by station and source.

SUMMARY AND PROJECTIONS

An extensive data base has been computerized for the Par Pond system. This report identifies the content and organization of these data so that they may be made available to others interested in the time sequence of the course of events in a reactor effluent cooling reservoir. In the next phase, these and other data will be examined to determine what may be hypothesized about the effects of continuous cooling system operations upon the limnological and ecological features of such an aquatic system.

TABLE 3

Stations in the Par Pond System

Station Designation	Description and Comments	Location
0	Station defined to be the recipient of computed rainfall-runoff discharge from the Par Pond drainage basin.	Par Pond Drainage Basin
1	Beyers Bay Station - Primarily quality surface and P-Area production data collected in periphyton studies.	33:15:52.8 W 81:32:43.2 N
2	Hot Dam (Station A) - Quality data and P-Area production data.	33:15:55.0 W 81:32:26 N
3	Warm Arm (Mid Arm) - Mostly quality surface and P-Area production periphyton data.	33:15:32.0 W 81:32:06 N
4	Warm Arm Mouth - Mostly quality surface and P-Area production periphyton data.	33:15:19.5 W 81:31:34.0 N
5	Cold Dam - Deepest; longest limnological record; quality and P-Area production data.	33:14:18 W 81:31:04 N
6	Pumphouse Arm (West Arm)* - Mostly quality surface and P-Area production periphyton data.	33:14:41 W 81:32:39.6 N
7	Cold Arm (North Arm) - Mostly quality surface and P-Area production periphyton data; shorter record.	33:16:49.2 W 81:30:56.0 N
8	Savannah River Pumphouse - SRP quality column from 3G Pumphouse; flow data from SRP Power Dept.	
9	Par Pond Pumphouse (5G) - SRP quality column from 5G Pumphouse; flow data from SRP Power Dept.	
P	Internal cooling water flows for P Reactor; data from Power Dept.	
R	Internal cooling water flows for R Reactor; data from Power Dept.	
V	Station defined for purpose of computing changes in volume of Par Pond associated with changes in water-level elevations.	

* Not the same as Par Pond Pumphouse, but is located in same arm of the reservoir (see Figure 1).

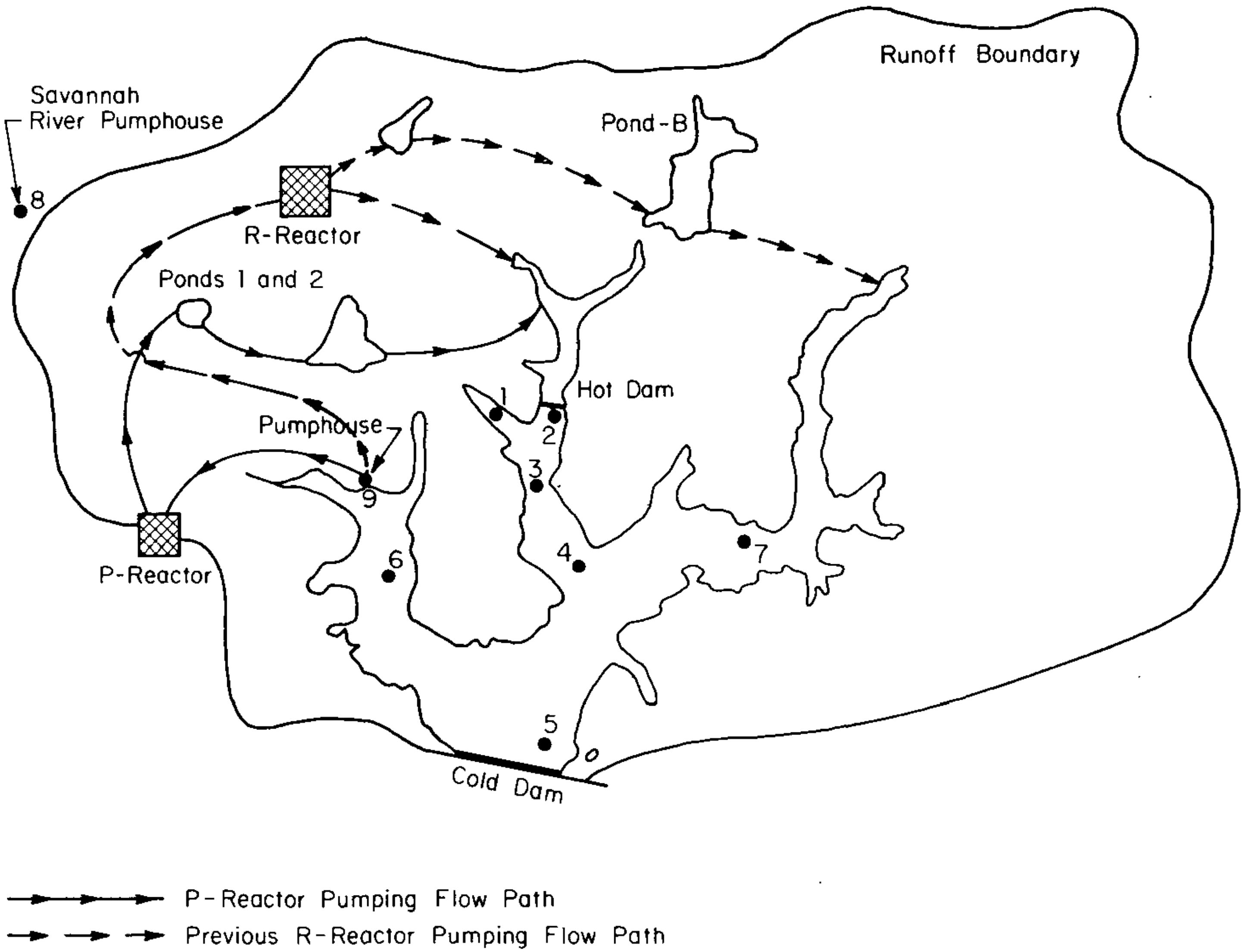


FIGURE 1. Par Pond Sampling Stations (1 through 9) and Rainfall-Runoff Area

TABLE 4

Station of Origin and Source Group

TYPE OF DATA[1,2]	STATION[3]										
	0	1	2	3	4	5	6	7	8	9	V
Water Quality:											
Surface		LIM	LIM	LIM	LIM	LIM	LIM	LIM			
Profile			LIM			LIM	LIM	LIM			
Column			LIM			LIM	LIM		POWR REAC		
Flow:	POWR					POWR			REAC POWR PTEC	REAC POWR PTEC	LIM/POWR
Primary Productivity:											
Plankton			LIM			LIM	LIM	LIM			
Periphyton		LIM	LIM	LIM	LIM	LIM	LIM	LIM			

1. Key: Word in box indicates data of that kind are available and originated from the source symbolized by abbreviations as follows:

   LIM = SRL Limnology Group
   POWR = SRP Power Department
   REAC = SRP Reactor Department
   PTEC = SRP Power Technology and Works Technical Group

2. Some data collected and available in computer may not show here.

3. See Table 3 and Figure 1 for station description and location.

APPENDIX I. Representative Examples of Data Retrieval and Display

The following are examples of computer displays obtained with the "LIST" program.

A. Typical "Select" Frame

B. Representative Data Record

C. Representative Time Series Displays

1. Temperature of Surface Water at Stations 2 and 5 between 1972 and 1976.

2. Chloride Content of Surface Water at Stations 2 and 5 between 1972 and 1977.

3. Water Level at Par Pond in 1969 and 1976.

D. Representative Profile Displays

1. Conductivity Values with Depth at Stations 2 and 5 on October 9, 1972.

2. Light Penetration with Depth at Stations 2 and 5 on July 14, 1971.

3. Carbon-14 Uptake (per Unit Volume) with Depth at Stations 2 and 5 on December 14, 1970.

4. Dissolved Oxygen Concentrations with Depth at Stations 2 and 5 on July 29, 1974.

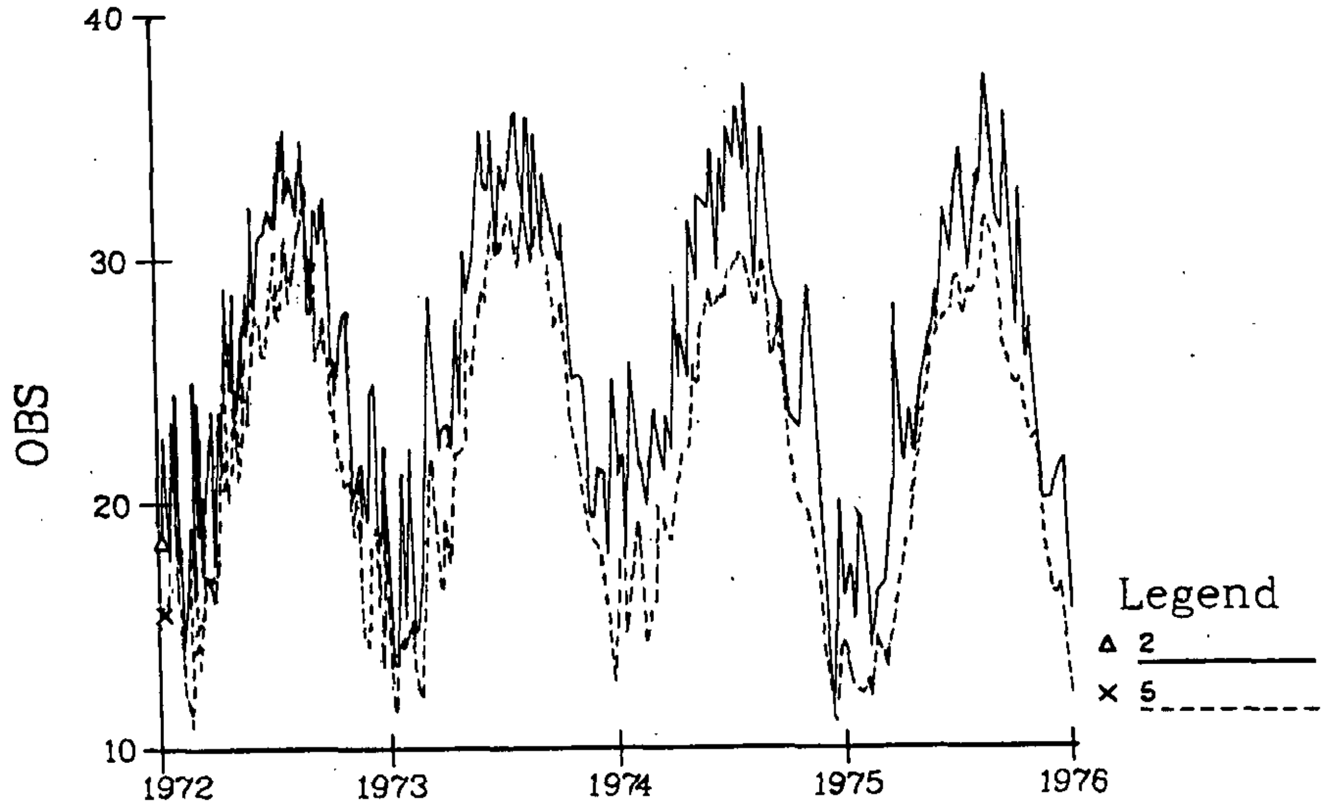
"LIST" in the Time Series and Profile Displays is the generic surrogate for Station labels, e.g., Stations 2 and 5 in these examples.

A. Typical "Select" Frame

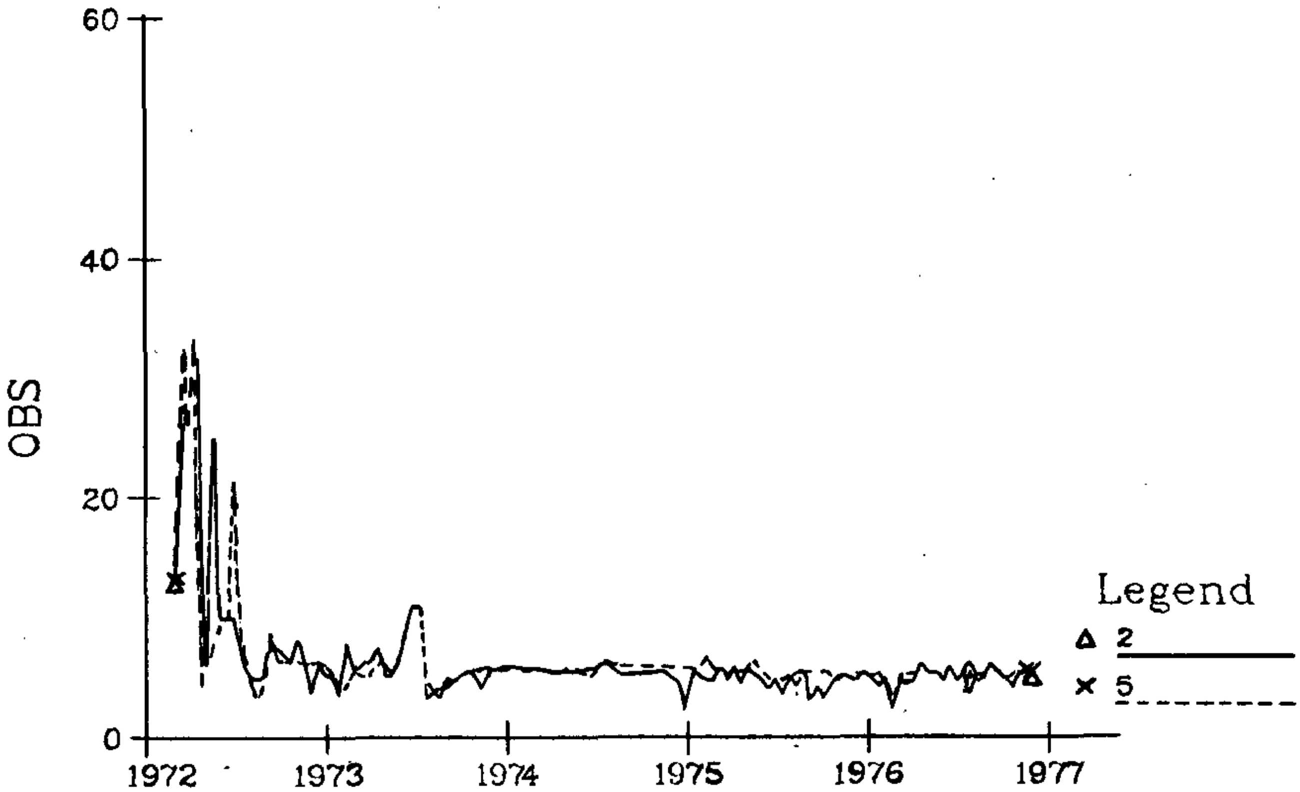
```
LAKE3277 - LAKE - STD ---- LAKE3277                  TUBE 035
DD      --FUNCTION
LAKES.DAILY.PARPOND 2.QUALITY PROFILE.TEMP.........................
...................................................................
```

B. Representative Data Record

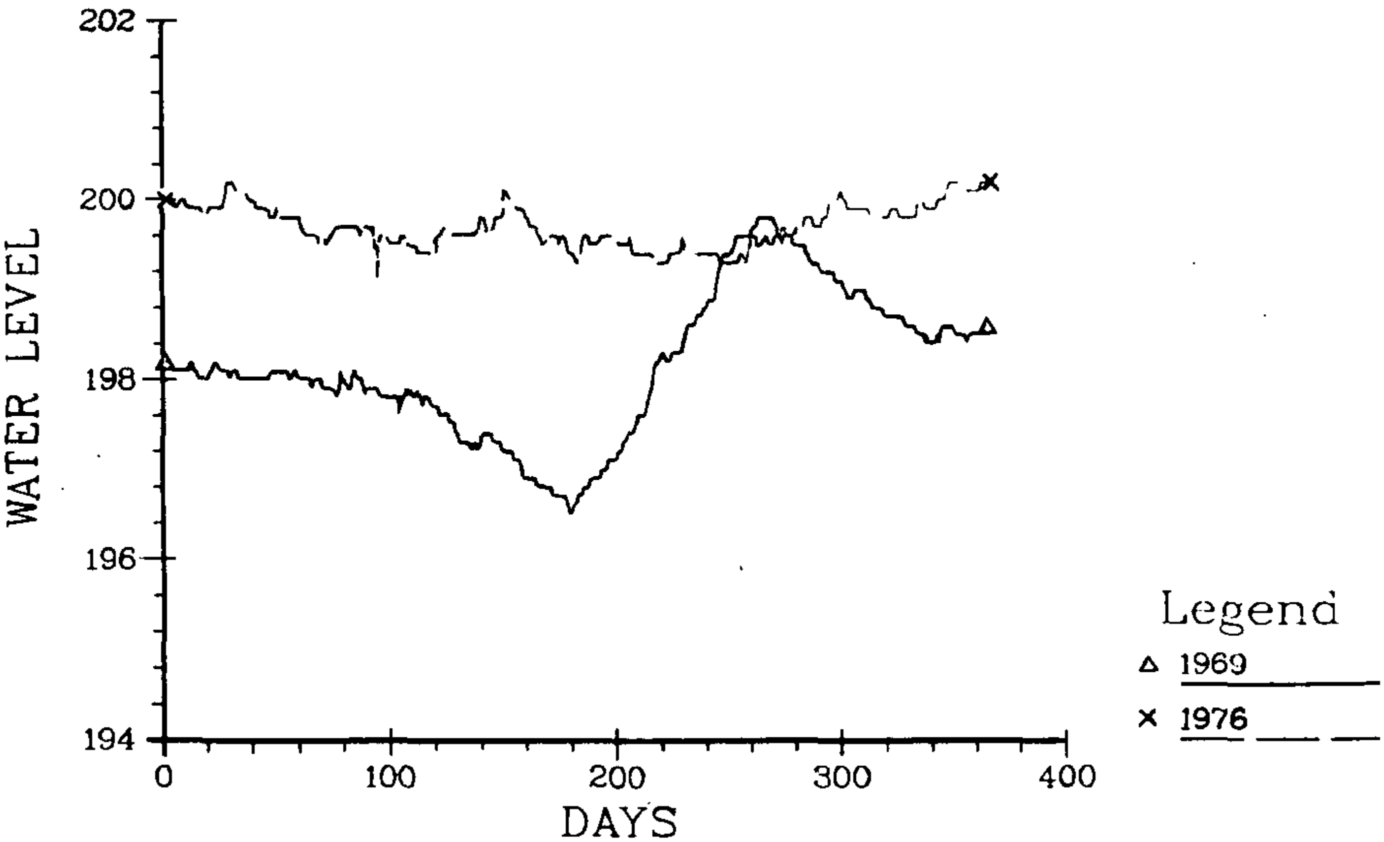
```
:      LAKE3277.LAKES.DAILY.PARPOND.2.QUALITY.PROFILE.TEMP

NUMBER OF OBSERVATIONS :1653
JULIAN DATE      DEPTH        VALUE
:       7620    : 0.00    :2.149997E 01
:       7620    :  .25    :2.149997E 01
:       7620    :  .50    :2.149997E 01
:       7620    :  .75    :2.149997E 01
:       7620    : 1.00    :2.149997E 01
:       7620    : 1.25    :2.119997E 01
:       7620    : 1.50    :2.069997E 01
:       7620    : 1.75    :1.979997E 01
:       7620    : 2.00    :1.899997E 01
:       7620    : 2.25    :1.909998E 01
:       7620    : 2.50    :1.869998E 01
:       7620    : 2.75    :1.849997E 01
:       7620    : 3.00    :1.829997E 01
:       7620    : 3.50    :1.819998E 01
:       7620    : 4.00    :1.799997E 01
:       7620    : 4.50    :1.799997E 01
:       7620    : 5.00    :1.799997E 01
:       7620    : 5.50    :1.789997E 01
```



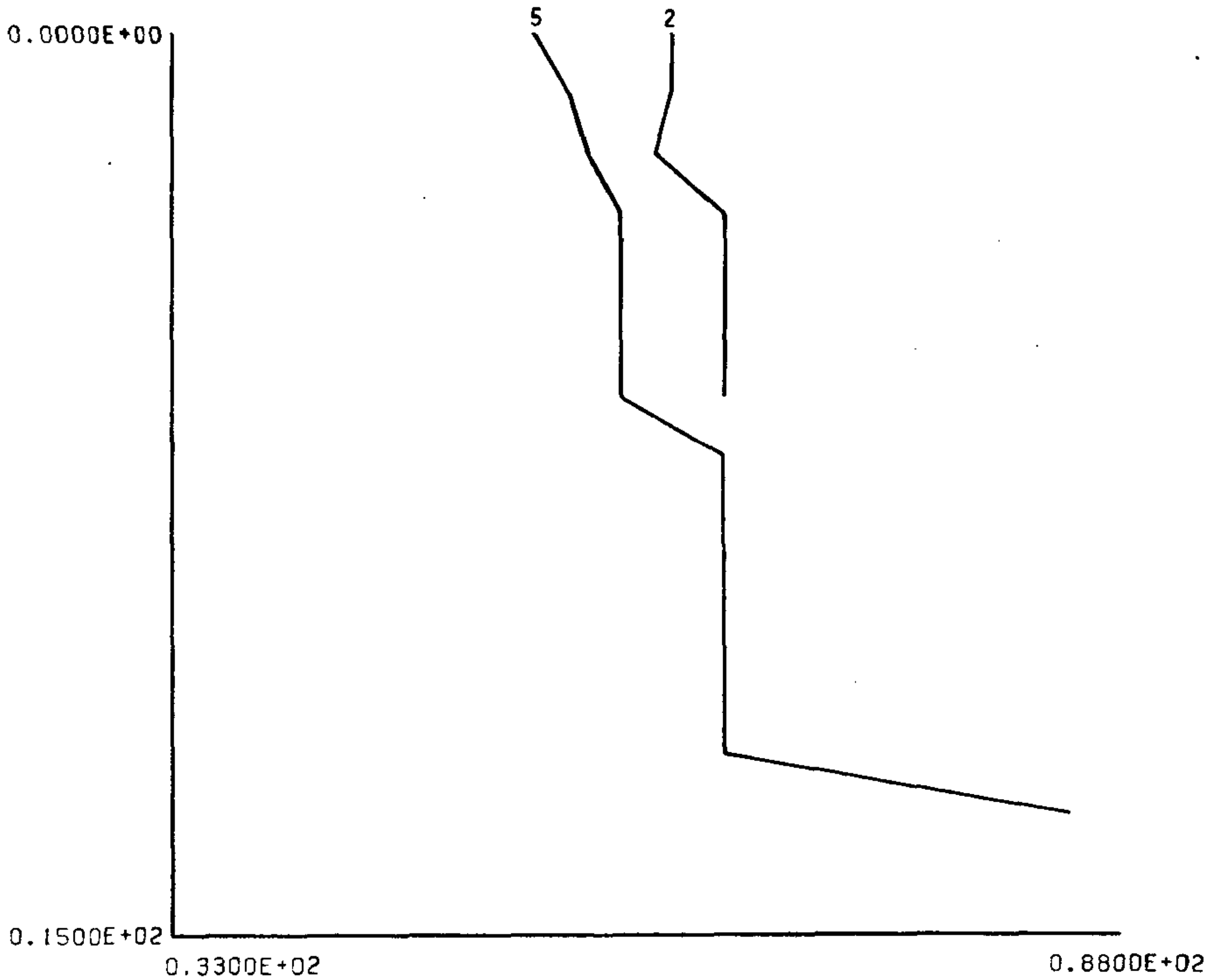
Time Series Display C-1. Temperature of Surface Water (°C) at Stations 2 and 5 between 1972 and 1976



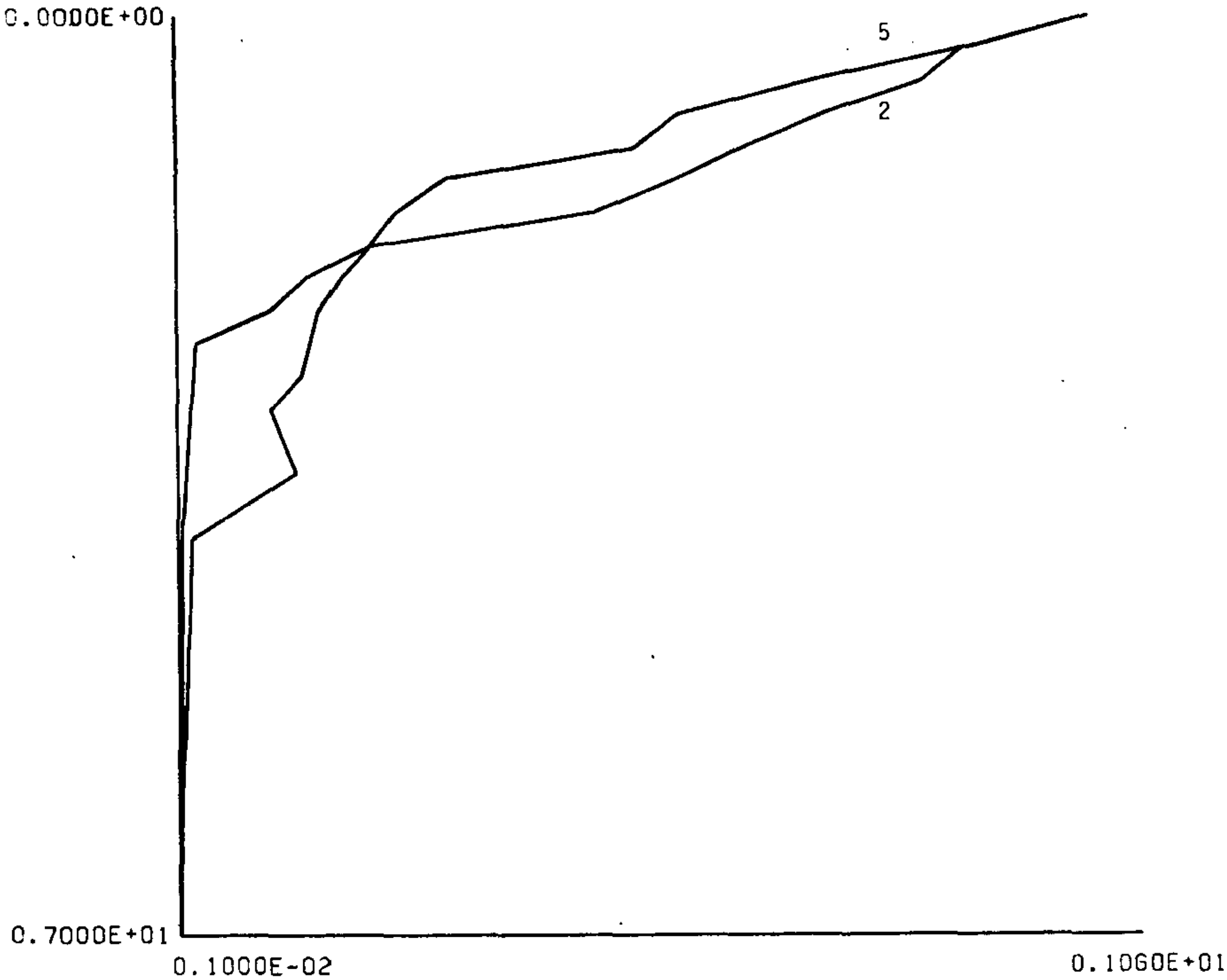
Time Series Display C-2. Chloride Content of Surface Water (ppm) at Stations 2 and 5 between 1972 and 1977



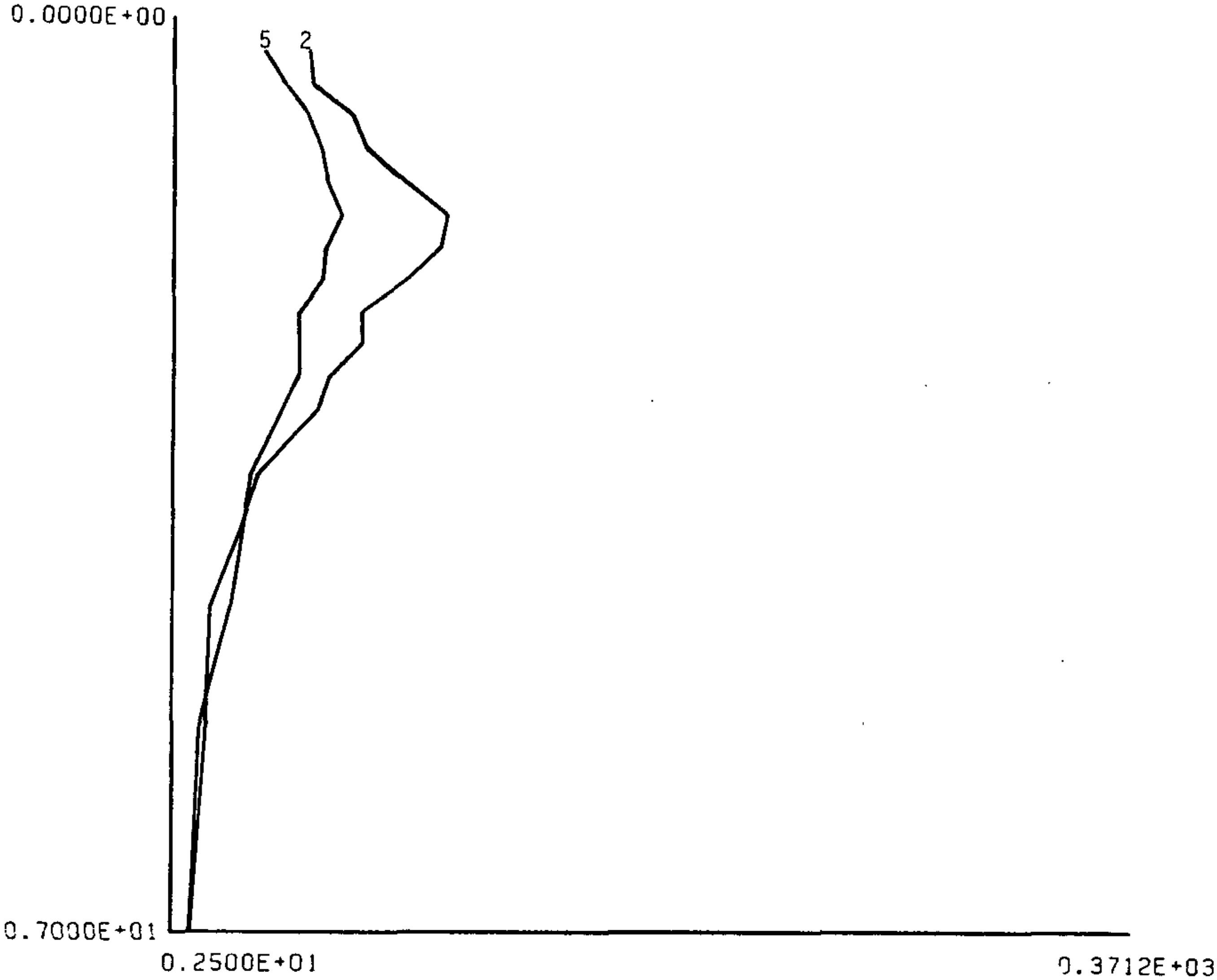
Time Series Display C-3. Water Level (feet) at Par Pond in 1969 and 1976



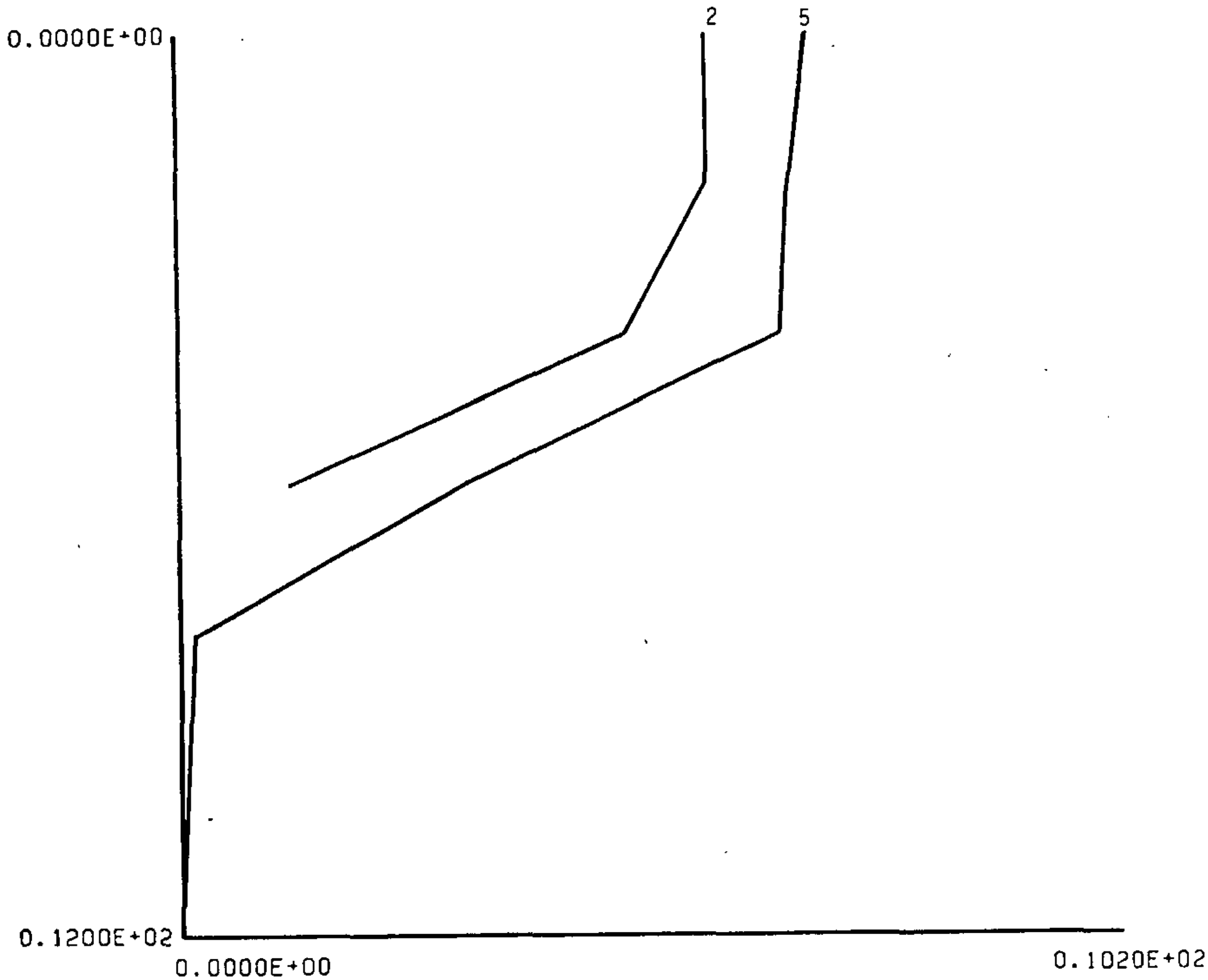
Profile Display D-1. Conductivity Values (abscissa, in µmho/cm^2) with Depth (ordinate, meters) at Stations 2 and 5 on October 9, 1972



Profile Display D-2. Light Penetration (abscissa, as intensity at a given depth relative to intensity at the surface) with Depth (ordinate, meters) at Stations 2 and 5 on July 14, 1971



Profile Display D-3. Carbon-14 Uptake (abscissa, as mg total carbon/m^3) with Depth (ordinate, meters) at Stations 2 and 5 on December 14, 1970



Profile Display D-4. Dissolved Oxygen Concentrations (abscissa, in mg/L) with Depth (ordinate, meters) at Stations 2 and 5 on July 29, 1974

APPENDIX II. Periphyton Productivity: Methods Description

As noted in the text, the methods associated with the periphyton productivity measurements are not described completely elsewhere and have been included here for convenience.

Periphyton Productivity Methods

Periphyton productivities were estimated from the gravimetric accumulation of periphyton on glass microscope slides (exposed to surface lake conditions in Catherwood diatometers) by measuring the ^{14}C uptake, and from the chlorophyll and pheophyton concentrations extractable from periphyton assemblages on such slides. At the end of each two-week period of exposure for colonization and growth, replicate slides were removed for incubation with ^{14}C prior to gravimetric analyses and chlorophyll extractions. A minimum of two, and as many as four, slides constituted the replicates.

^{14}C Uptake

Immediately upon removal from diatometers, colonized slides were placed in 130-mL, wide-mouthed, borosilicate-glass reagent bottles filled with surface water taken from the station of colonization. The water was filtered through 28-μm mesh phytoplankton netting. A known volume (50 to 100 μL) of 20 μCi/mL sodium bicarbonate-^{14}C solution was injected by micropipet into the incubation bottle. The bottle was then capped and suspended with snap fasteners from an aluminum bar supported at each end by a floating polystyrene foam block so that negligible shading from the apparatus occurred, and the bottle remained within the upper 25 cm of the water column. Dark bottles, made of wrapping layers of white over black polyvinyl chloride tape, were used for incubation of slides to determine the magnitude of ^{14}C uptake in the absence of light. (Generally, dark uptake was only a few percent of that in the light and no correction was ever applied). After incubations of three hours, bottles and slides were removed from the lake, placed in light-proof, insulated containers, and transported within 30 minutes to the lake-shore laboratory for immediate processing. ^{14}C-labeled periphyton was carefully scraped from the slides (with the edge of a clean glass slide) into a filter funnel outfitted with a membrane (0.45 μm pore size) filter. To be sure any detached periphyton was recovered, the remaining water from the incubation bottle was poured through the filter. A final rinse with 2 to 3 mL of acid-free, filtered, lake water was found to be adequate to free the sample from inorganic ^{14}C.

Filters were oven-dried at 60°C, stored in a desiccator, then combusted in a commercial analyzer. ^{14}C was recovered with carbon dioxide-absorbing scintillant and counted with standard quench correction measures. Having previously verified that Par Pond water nomographic carbon dioxide values agreed with carbon analyzer measurements, available carbon concentrations were computed from temperature-pH-alkalinity relationships (Saunders, et al., 1962). Carbon uptake per sample was corrected for bottle volume differences to enable computation of carbon uptake per unit of periphyton. This uptake was expressed in terms of dry weight, chlorophyll, or slide area occupied.

Biomass

Periphyton biomass was determined by weighing colonized slides dried at 60°C. Tare weights for slides were determined after rinsing and scrubbing off the accumulated growth. This method was found to provide sufficient material to measure ash content also, and to give more precise estimates of the material accumulated per slide than could methods involving only wet-scraping of fresh slides.

Chlorophyll and Pheophytin

To determine chlorophyll content, periphyton was scraped off newly collected slides following the same methods as for ^{14}C sample preparation. The filter and periphyton from single slides were placed in a standard tapered glass centrifuge tube for extraction with acetone according to procedures outlined in Vollenweider (1969). The extractant was concentrated, diluted, and the absorbance determined on a recording spectrophotometer. The amount of pigment present was calculated by the methods of Strickland and Parsons (1968) and Lorenzen (1967).

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