1990

Dissolved Oxygen Conditions in the Machipongo River System near Willis Wharf, VA

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DISSOLVED OXYGEN CONDITIONS IN THE MACHIPONGO RIVER SYSTEM NEAR WILLIS WHARF, VA

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A Report to the American Original Co., Inc.

November 16, 1990

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EXECUTIVE SUMMARY

In 1989 and 1990, water temperature, salinity, and dissolved oxygen (DO) concentrations were monitored near Willis Wharf on Parting Creek and near the Route 182 bridge to Quinby on the Machipongo River. Although the study periods differed (mid-May to mid-July in 1989 and mid-August to late September in 1990), the temperatures and salinities were in the same ranges.

In 1989 daily average DO's and minimum DO's were lower at Willis Wharf. In 1990, daily averages and minimums tended to be lower at Quinby. In both years at both stations, Virginia's water quality standards were violated. In 1990,however, the daily average DO was less than 5 mg/l for equal portions of the study period at the two sites; DO values below 4mg/l were observed more frequently at Quinby than at Willis Wharf.

The changes in water quality appear to be due to reduced wastewater loadings from the American Original facility. By several measures, the data suggest that conditions in late summer of 1990 in Parting Creek were as good as or better than those in the Machipongo River, indicating that the current discharge rate was not having a measurable impact on water quality.

I. STUDY DESIGN

Water temperature, salinity, and dissolved oxygen concentrations were monitored at two sites in the Machipongo River system in early summer of 1989 and late summer of 1990. The two study sites have been designated as "Willis Wharf" and "Quinby." The Machipongo River system and the two sampling locations are shown in Figure 1.

In 1989 the "Willis Wharf" monitoring occurred from a dock along the western shore of Parting Creek, just upriver of the American Original facility in the town of Willis Wharf, VA. In 1990, the monitoring was from the dock of the American Original facility. The two locations are within 100 meters of each other. The "Quinby" monitoring in the Machipongo River occurred from a dock at a crab shedding operation located just downriver of the Route 182 crossing of the river and was the same for both 1989 and 1990. The purpose of the monitoring was to determine whether the discharge from the American Original facility was impacting water quality in Parting Creek. The Quinby station was used as the control site for the system.

Hydrolab datasondes equipped with temperature, salinity, and dissolved oxygen sensors were deployed at each location. The instruments were programmed to take readings every 30 minutes. Instruments were calibrated prior to each deployment and checked upon return to VIMS. Calibration procedures and the results of the pre- and post-deployment calibrations are given in Appendix I.

Deployments in 1989 ranged from one to two weeks. Data recovery for this period was less than desired (see Table 1). During two periods, portions of the data are compromised because the tide range was unusually large and the instrument was out of the water near times of low water. A malfunction of the circuitry caused the data files from another period to be lost. And finally, fouling became a problem at higher water temperatures.

During 1990, when deployments were for one week periods, data recovery was greatly improved and fouling was not a problem. Anomalous data for dissolved oxygen, spikes of extremely high concentrations measured at different times during the day, were recorded for the period 30 August to 3 September, 1990. In 1989 when the instrument came out of the water, the records for all three variables were affected. For the period in 1990, the temperature and salinity records show no spikes comparable to those in the DO records. We have no explanation for the erratic DO readings.

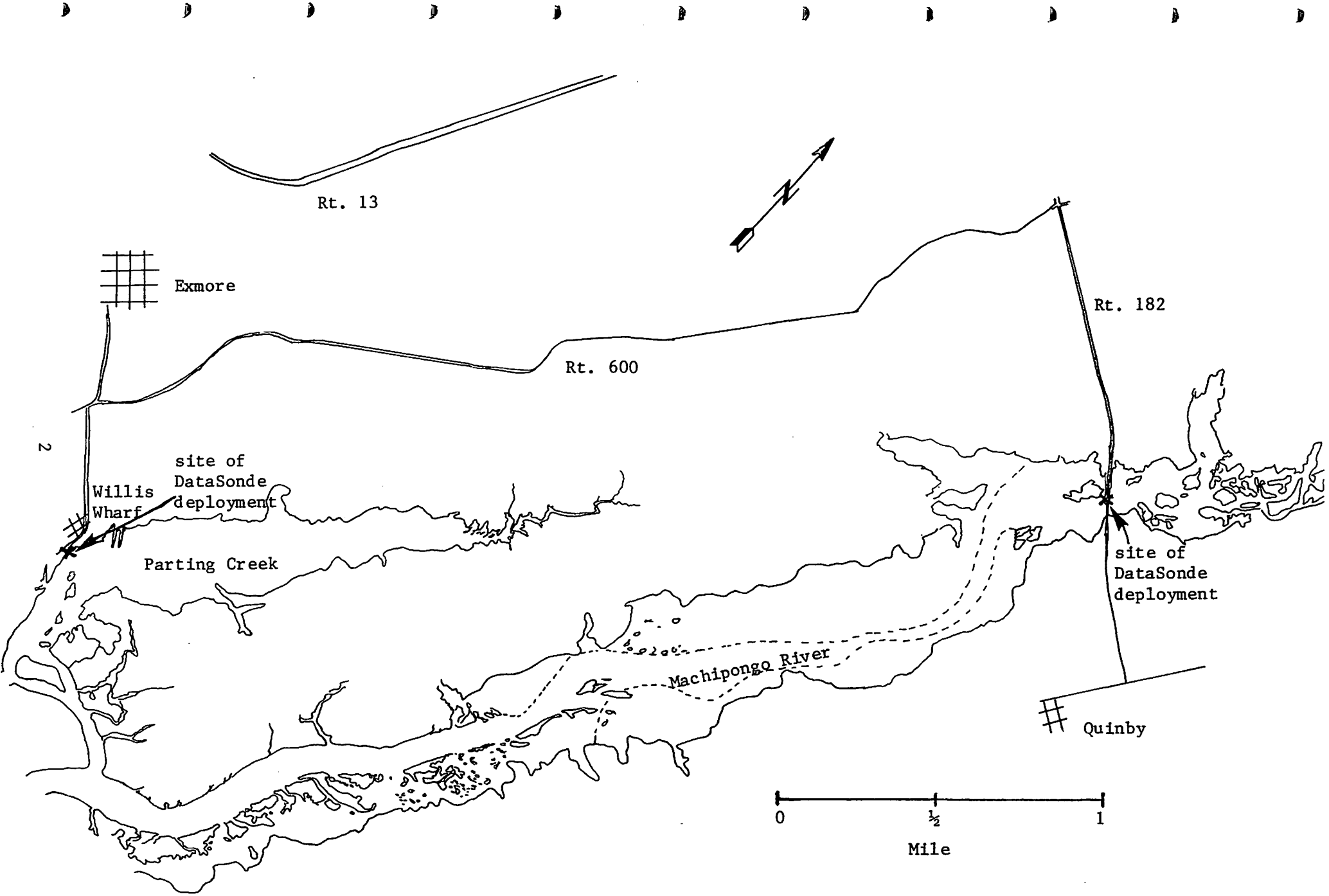


Figure 1. Location of deployment sites, Willis Wharf and Quinby, VA

TABLE I. Deployment Notes

1989

Date	Willis Wharf	Quinby
11 May - 16 May	Good data	Good data
16 May - 31 May	DataSonde coming out of water on low tide, 29-31 May.	Good data
31 May - 16 June	DataSonde coming out of water on low tide, 1-5 June.	Good data
16 June - 3 July	Good data	No data, DS lost all data
3 July - 18 July	Good data, extreme fouling may have caused low salinity data on last two days.	Good data

1990

Date	Willis Wharf	Quinby
9 August - 17 August	Good data	Good data
17 August - 23 August	Good data, 9 inches of rain on 22 August.	Good data, 9 inches of rain on 22 August.
23 August - 29 August	Good data	Good data
29 August - 6 Sept	Good data	Unexplained spikes in D.O. data, 30 August - 3 Sept.
6 Sept - 13 Sept	Good data	Good data
13 Sept - 19 Sept	Good data	Good data
19 Sept - 26 Sept	Good data	Good data

** Very little fouling on the instruments for 1990, probably due to shorter deployment period. **

II. RESULTS

All data are presented as time-concentration plots in Appendix II. Daily averages were calculated and have been tabulated along with daily minimum values; these tables are in Appendix III. Note that all data have been presented in these plots and tables. Periods when records are suspect are noted in the tables, as are times of deployment and retrieval.

A striking feature of the data is the large variability. Water temperatures, for example, vary by several degrees Celsius over the daily light-dark cycle and also vary with the seasons. For both study periods, temperatures ranged from about 20 C to 30 C (Fig. 2). In addition to the annual and daily cycles, there are irregular variations due to meteorological conditions. For example, average daily temperatures in 1989 (see Figure 2a) show the warming trend, but superimposed on that trend are shorter term variations when temperatures rise rapidly or fall below those for previous days.

Average daily salinity in 1989 increased over the study period, presumably due to reduced runoff (see Figure 3). One unusual feature in the 1990 data is the large drop in salinity in late August. There was a major summer thunderstorm with 9" of rain reported for some areas of the Eastern Shore. The drop in salinity presumably is due to the influx of stormwater runoff.

The salinity records show the effect of the semi-diurnal tides (Figure 4a). The magnitude of the salinity range varies with larger differences occurring when there is runoff from the land. The tides also can affect dissolved oxygen values; there is a minimum DO occurring for each minimum salinity observation in the May 11 - 18, 1989 period (Figure 4 a & b). At other times, the tidal influence is small and the daily cycle is pronounced (Figure 5). Oxygen concentrations rise during the day because plants produce oxygen as a byproduct of photosynthesis. Respiration by the algae and plants occurs both day and night; during periods of significant sunlight, the oxygen produced by photosynthesis is greater than that lost to respiration. Daily DO minimums typically occur in early morning, just before sunrise. Daily DO maximums occur in late afternoon. At times the range between these two extremes can be quite large (Figure 6).

In addition to changes over time, water quality varies spatially. A companion field study, conducted by Environmental Consulting Services, Inc., documents the spatial patterns.

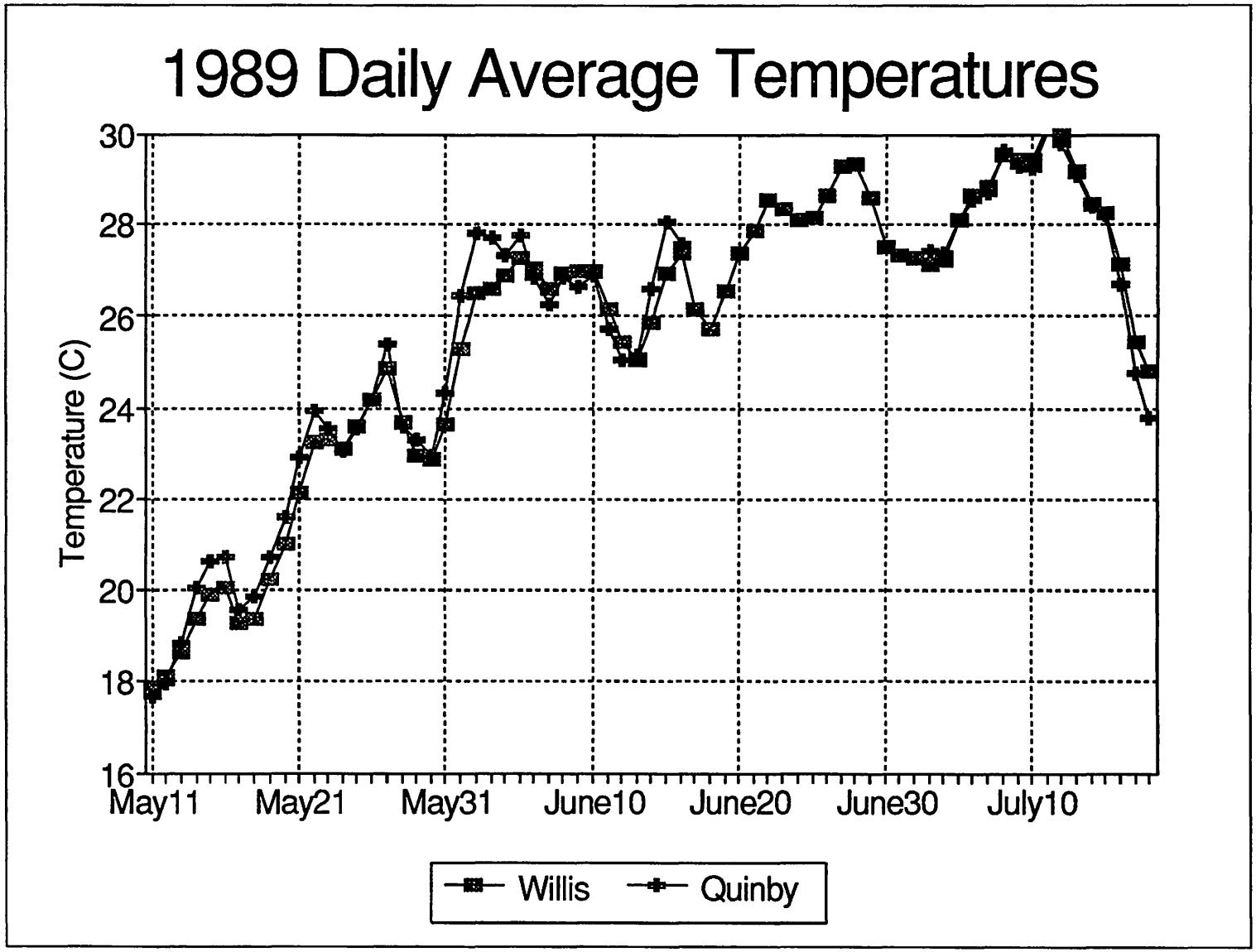


Figure 2a. Time variation of daily average temperature in the early summer of 1989.

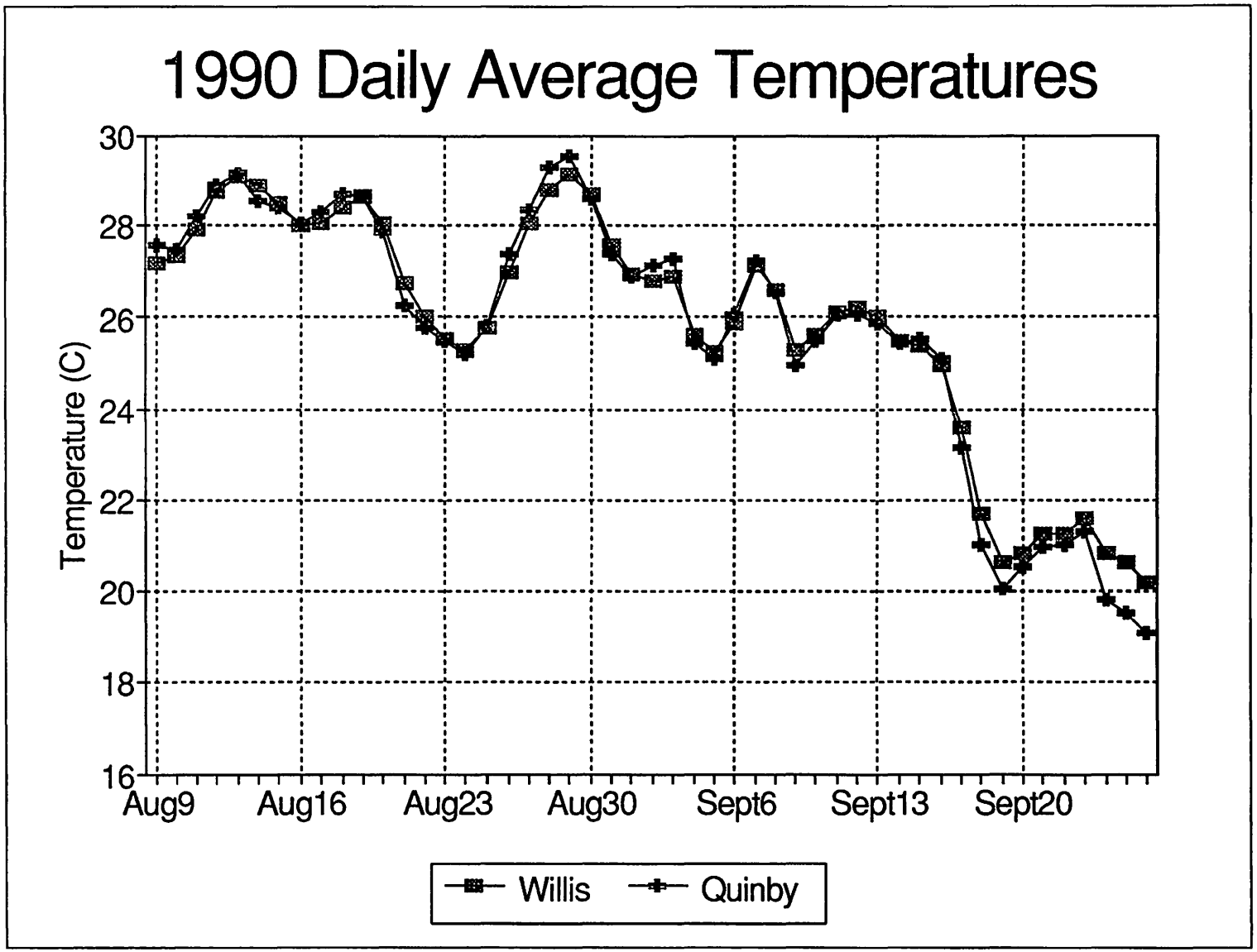


Figure 2b. Time variation of daily average temperature in the late summer of 1990.

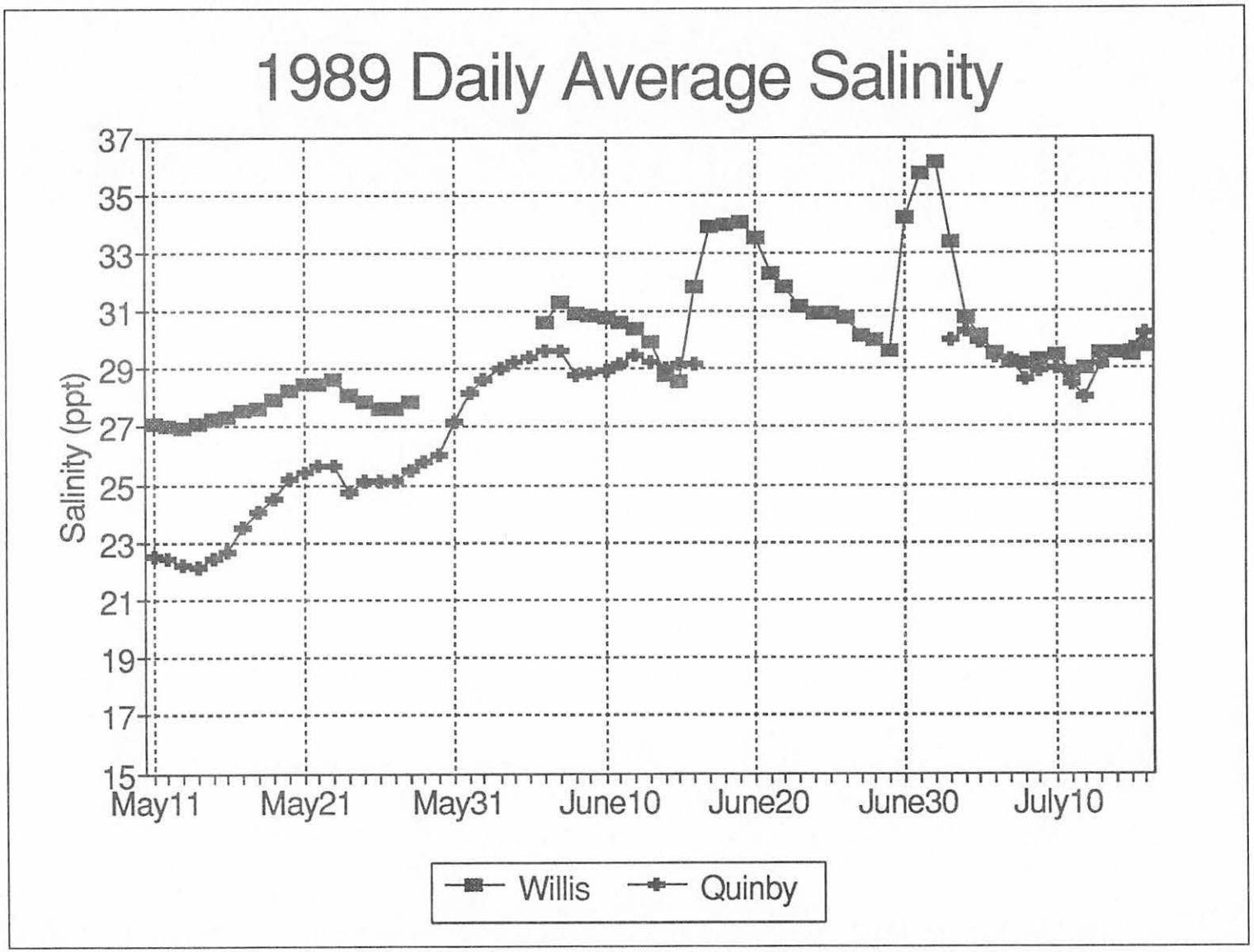


Figure 3a. Time variation of daily average salinity in the early summer of 1989.

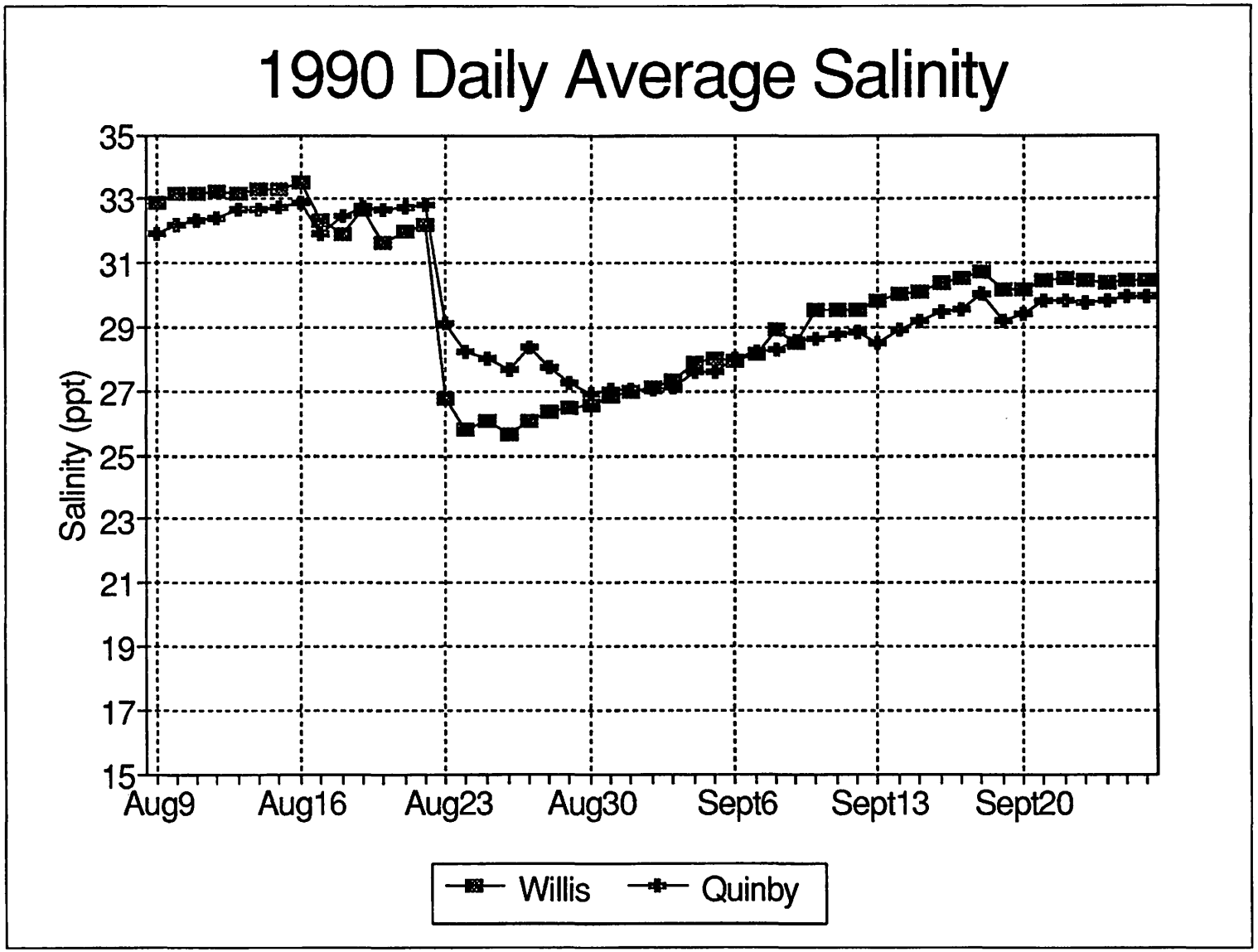


Figure 3b. Time variation of daily average salinity in the late summer of 1990.

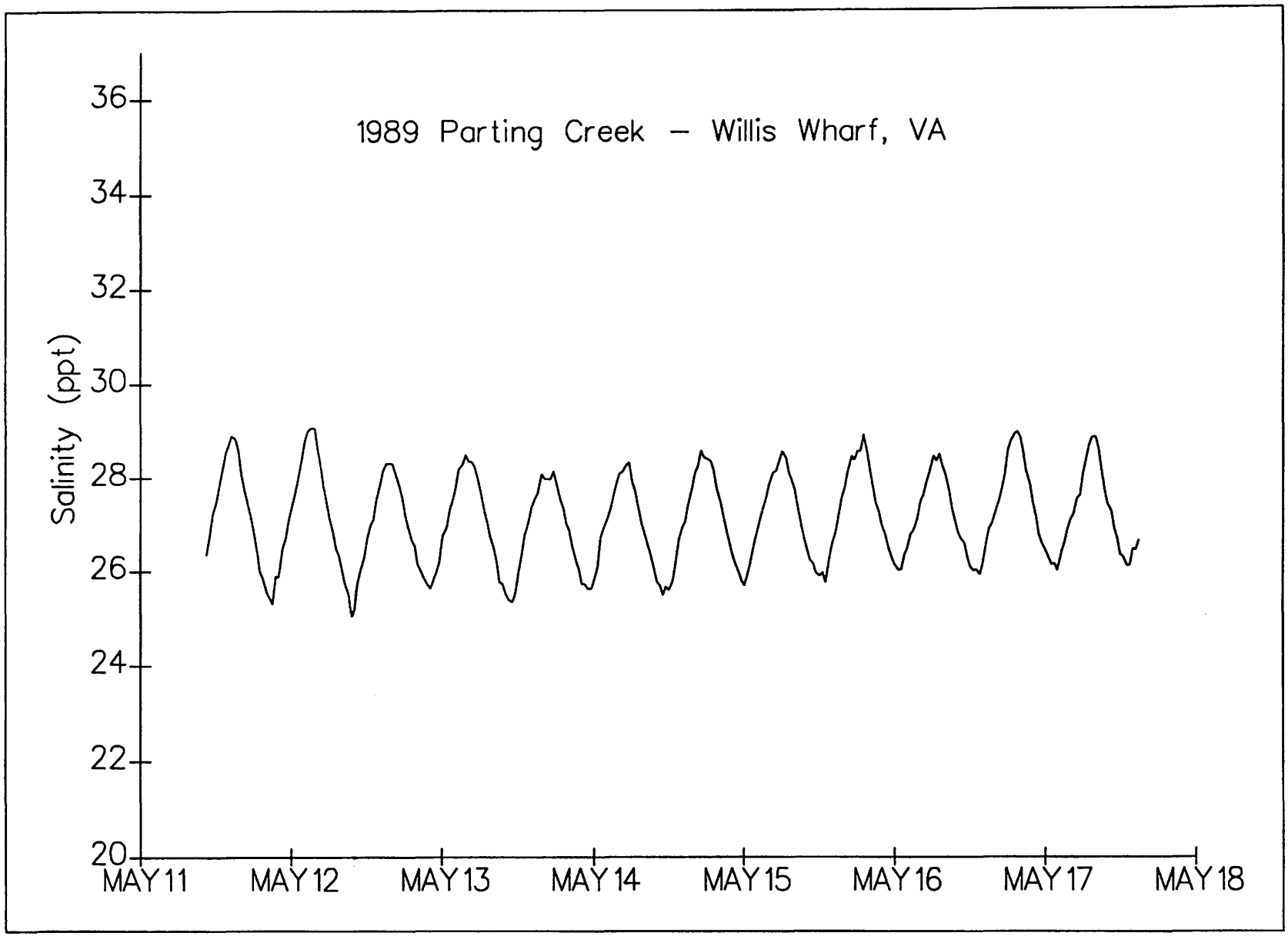


Figure 4a. Time variation of salinity in Parting Creek in mid-May, 1989.

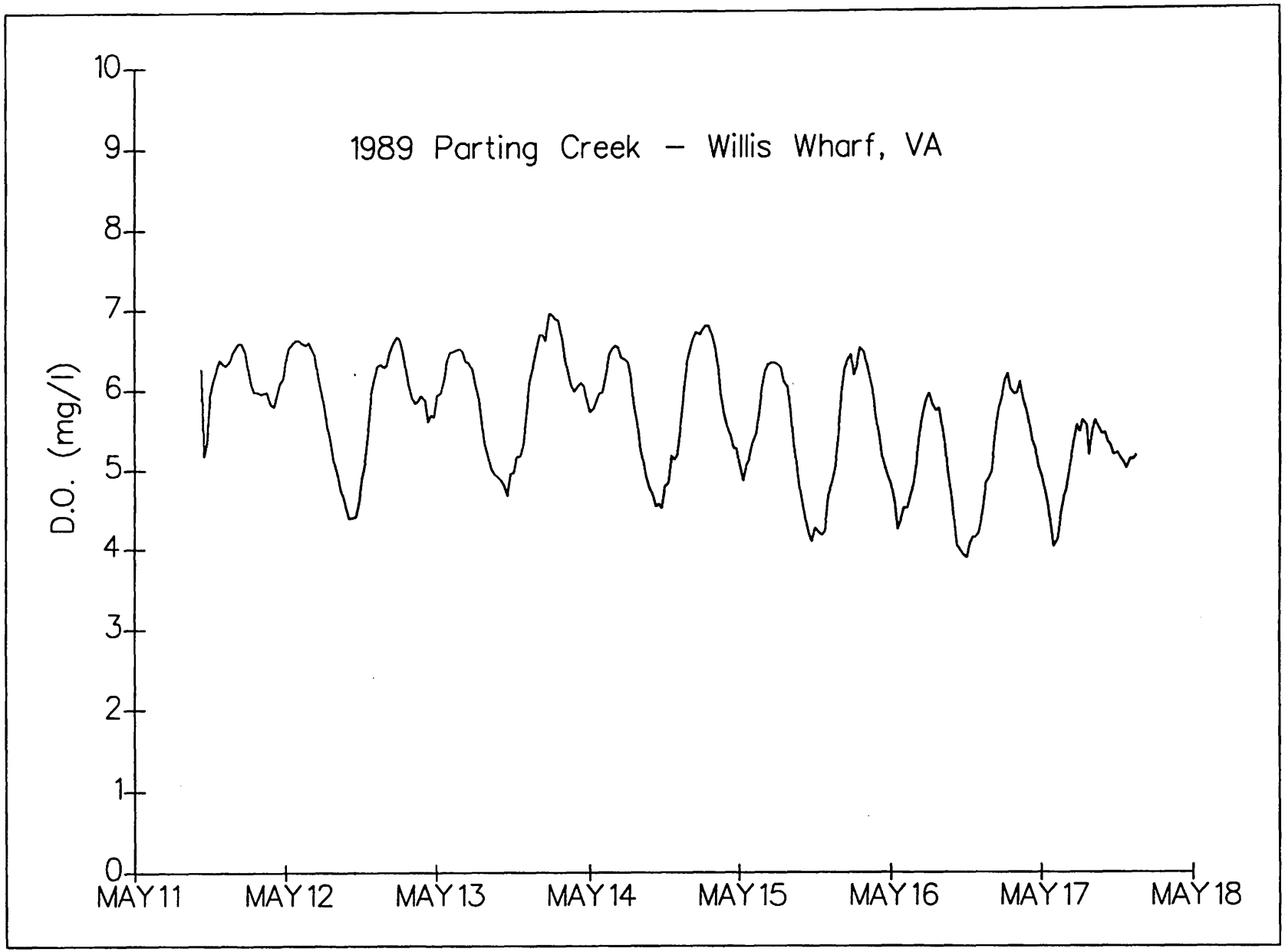


Figure 4b. Time variation of dissolved oxygen concentration in Parting Creek in mid-May, 1989.

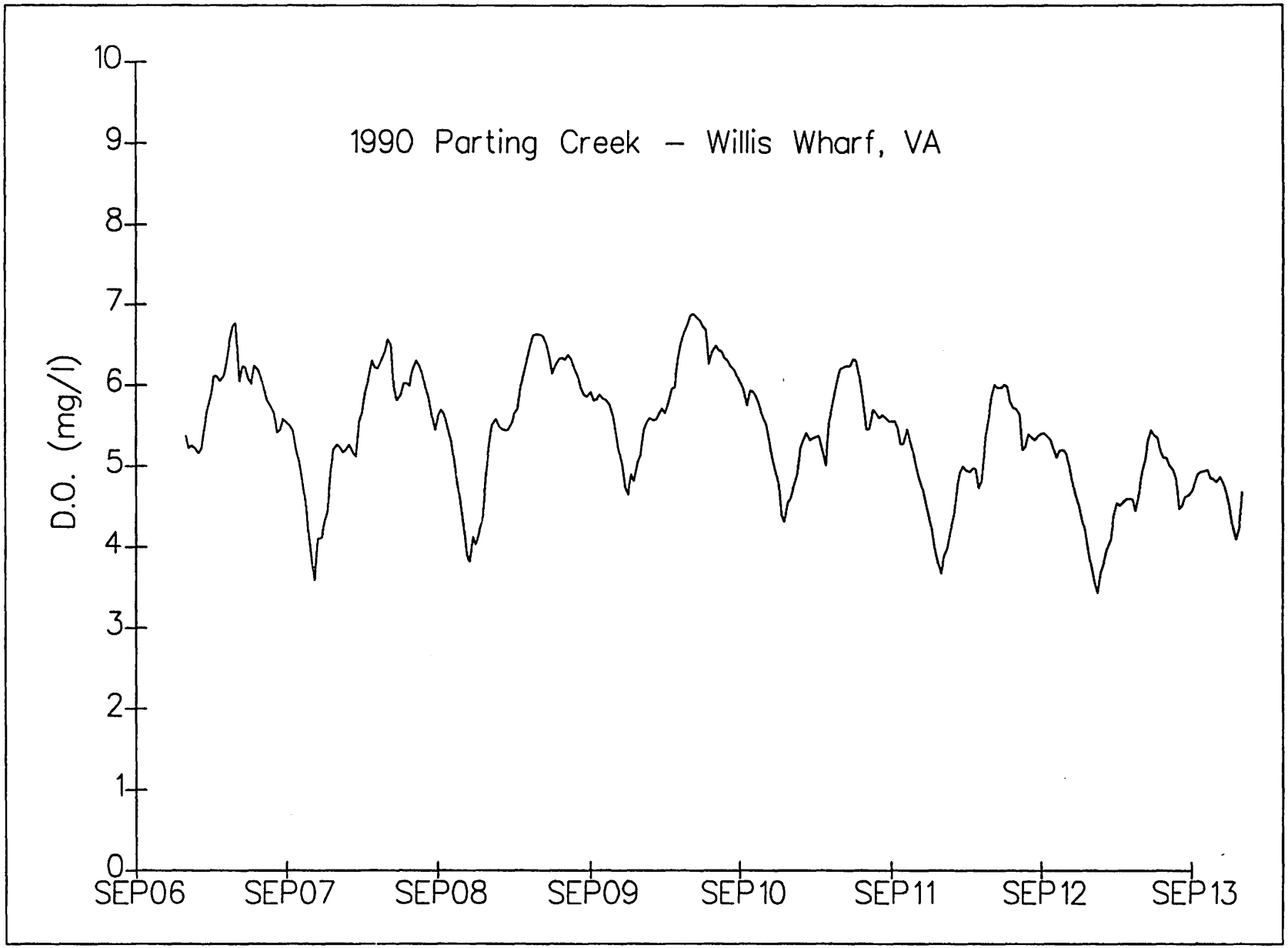


Figure 5. Time variation in dissolved oxygen concentration in early September, 1990.

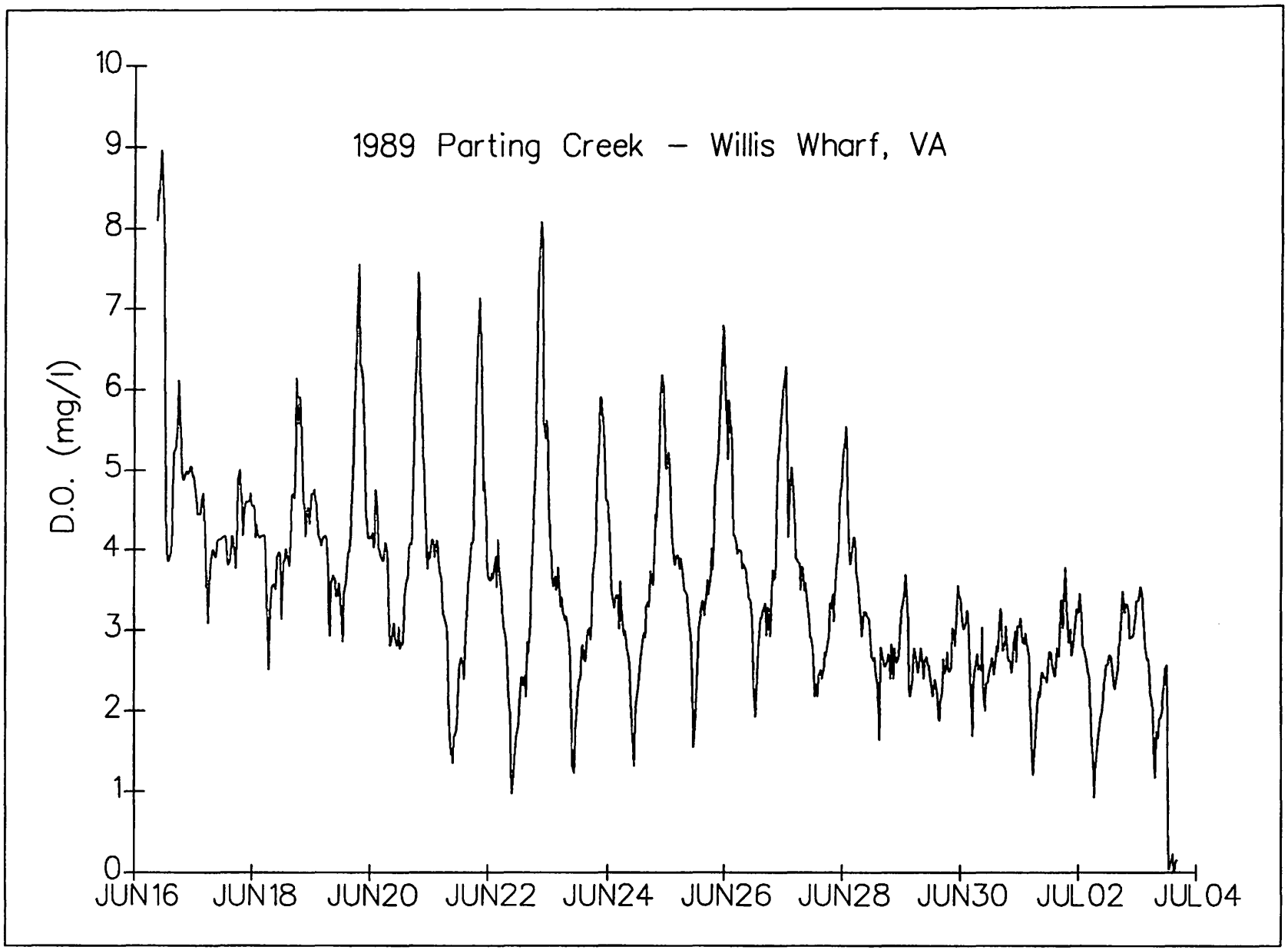


Figure 6. Time variation in dissolved oxygen concentration in Parting Creek in mid-June, 1989, a period with large daily fluctuations.

III. COMPARISON OF CONDITIONS IN 1989 AND 1990

The daily average and minimum dissolved oxygen concentrations have been plotted for each station and each year (see Figure 7). The values have been tabulated and are included in Appendix III. If the average values at the two stations are compared, one can see that in 1989, daily average DO's at the two stations were similar (Figure 8). About half of the time DO's were higher at Willis Wharf, and they were higher at Quinby about 30% of the time. About 20% of the time there was no significant difference between the two (i.e., the symbol on the plot touches the zero line).

In 1990, the pattern had changed. Dissolved oxygen concentrations, on a daily average basis, at Willis Wharf tended to be higher than or equal to those at Quinby. The only time Quinby readings were substantially higher was a period in late August and early September. Note that this is the deployment with anomalous spikes in the DO record for Quinby; data for four days (August 30 - September 2) have been removed from the plot, but the data for August 29 and September 3- 6 have been included. One must consider the possibility that the DO data for the entire deployment is faulty. Even if one does include the first and last days of the deployment, one still comes to the conclusion that oxygen concentrations in 1990 were higher at Willis Wharf than at the Quinby bridge in the Machipongo River.

When the daily minimums are compared (Figure 9), one can see a similar pattern. Daily minimum DO's in 1989 were higher at Quinby but were higher at Willis Wharf in 1990.

The magnitude of the daily variation in dissolved oxygen concentrations provides another measure of water quality conditions. Some diurnal variability is natural and there is no reason to believe that eliminating all variability is desirable. Very large daily swings in DO's, however, would appear to indicate an unstable situation and therefore be undesirable. It is difficult to quantitate these perceptions. In some respects, the water quality standards suggest that a diurnal variation on the order of 2 mg/l is acceptable. For example, if the maximum DO were 6.01 mg/l and the minimum DO were 4.01 mg/l, then the daily average would be 5.01 mg/l and both standards would be met. A larger variation about 5 mg/l would result in minimum DO's below 4 mg/l. At the opposite extreme, a daily range of the same magnitude as the saturation concentration probably is excessive.

During 1989 the differences between the daily maximum and minimum DO observations at Willis Wharf were significantly larger than those observed at Quinby (see Table II and Appendix IV). During a one-week period in early June, the average daily variation was nearly 6 mg/l and was nearly 8 mg/l on one day (June 8, 1989). In 1990 the daily differences at Willis Wharf were smaller than those observed in 1989 and were of the same order of magnitude as those observed at Quinby. The mean difference and the range of values observed at Quinby was essentially the same in 1989 and 1990.

TABLE II. Difference between daily maximum and minimum dissolved oxygen concentrations (in mg/l) at Willis Wharf and Quinby in early summer of 1989 and late summer of 1990.

Time Period	Number of * Observations	Willis Wharf	Quinby
May 1989	16	2.78	2.25
June 1989	11	4.73	2.45
July 1989	16	3.81	2.41
1989 Average	43	3.66	2.36
August 1990	21	2.45	2.43
September 1990	24	1.94	2.20
1990 Average	45	2.18	2.31

* Only days when observations were available for both stations were used in the calculations.

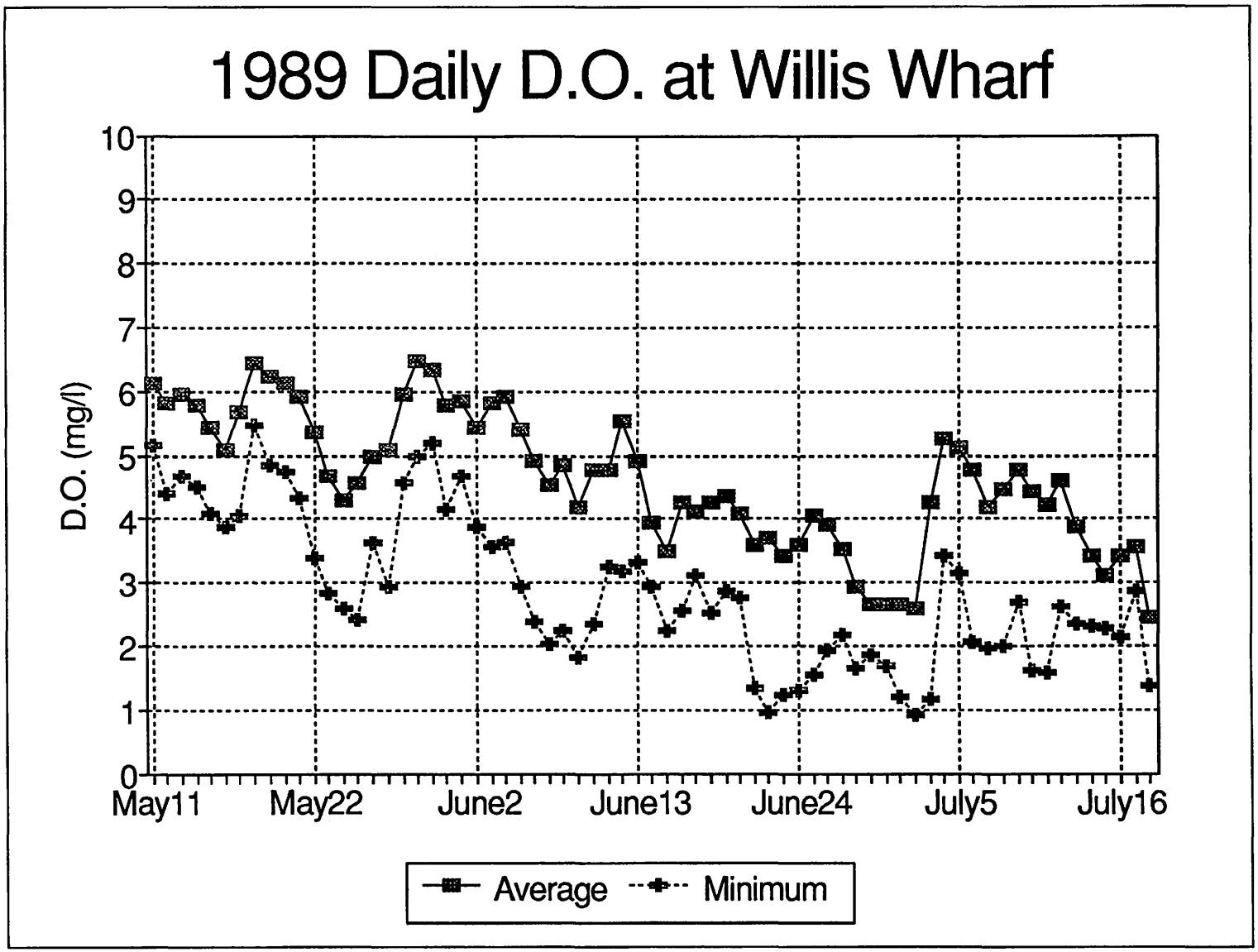


Figure 7a. Daily average and daily minimum concentrations of dissolved oxygen at Willis Wharf in the early summer of 1989.

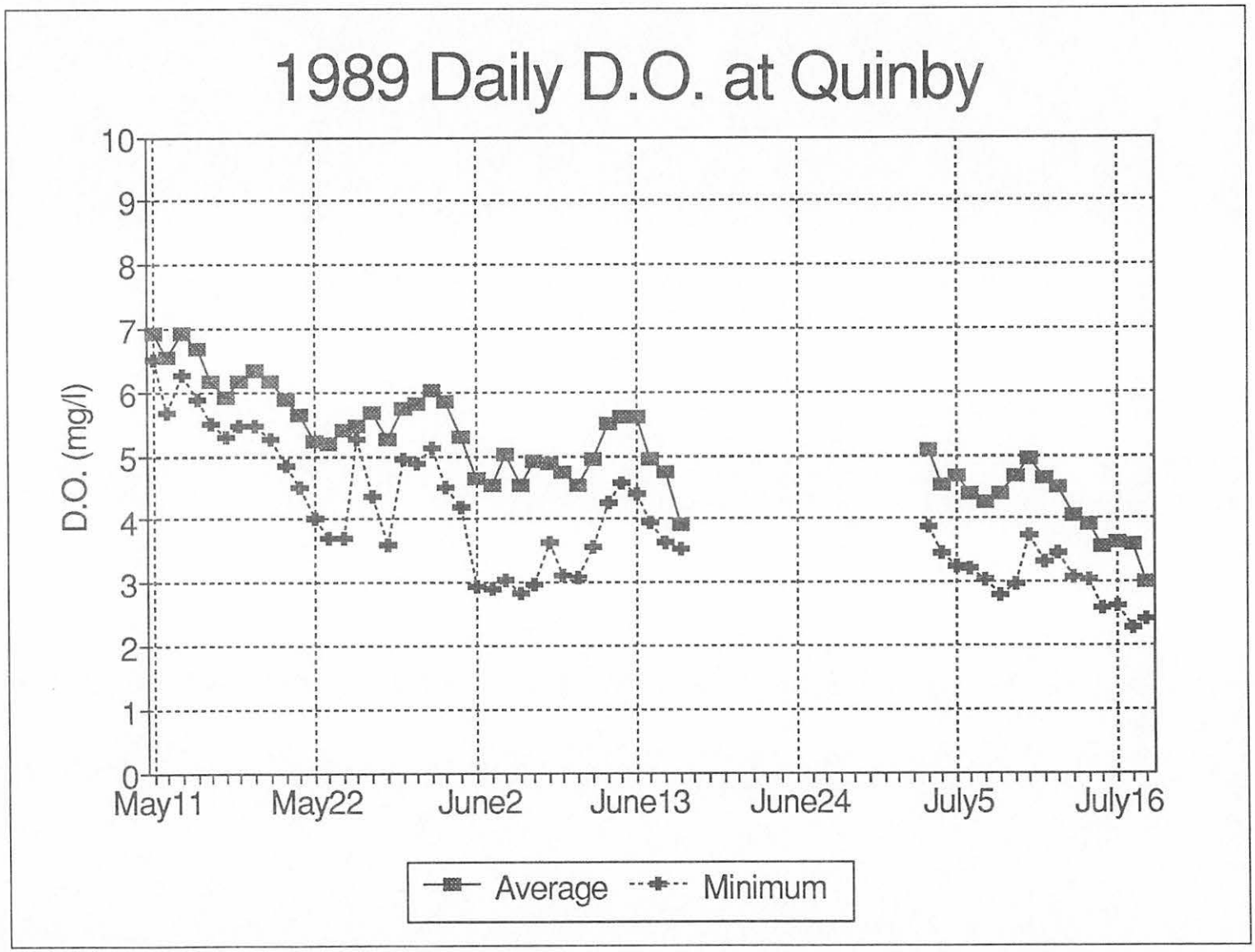


Figure 7b. Daily average and daily minimum concentrations of dissolved oxygen at Quinby in the early summer of 1989.

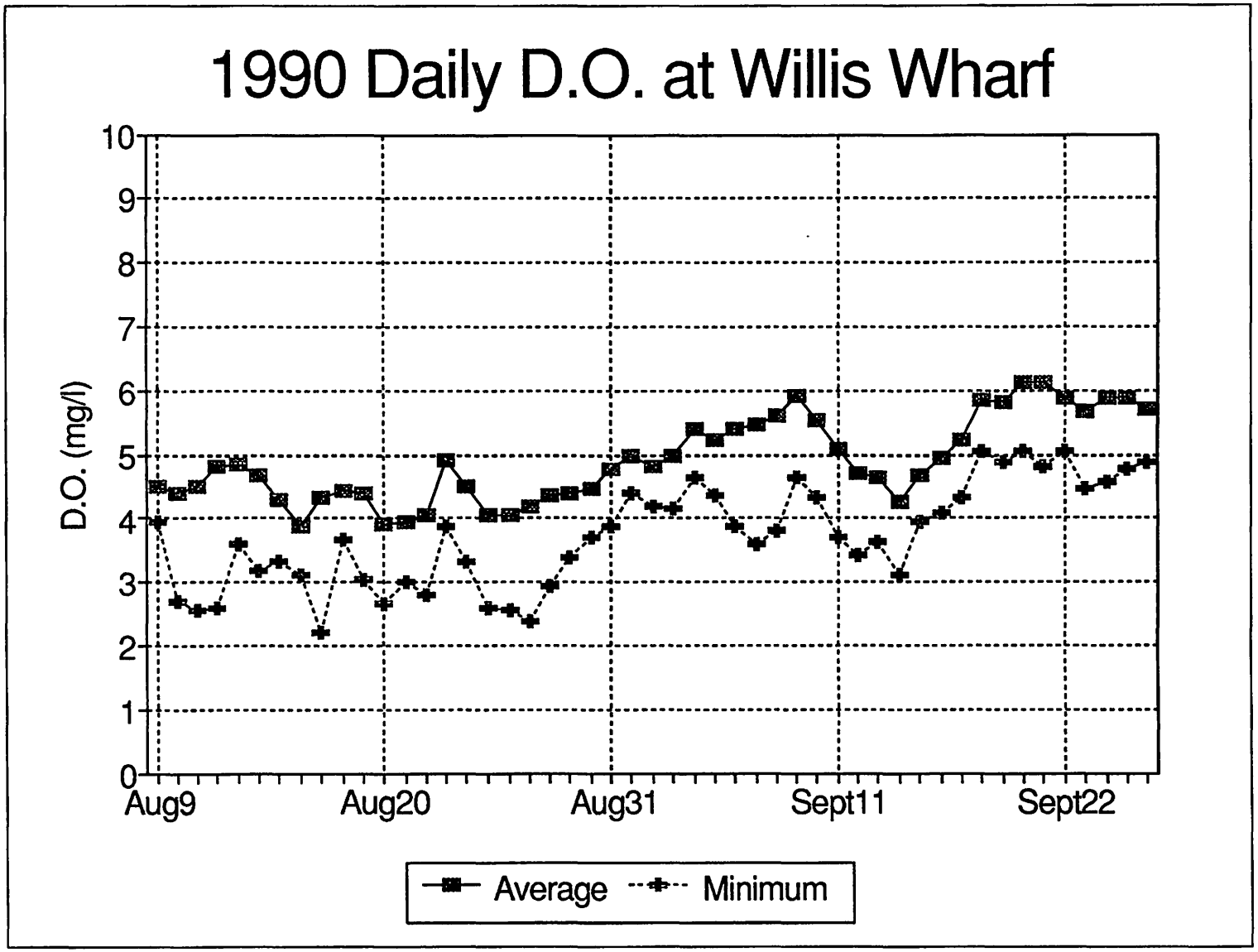


Figure 7c. Daily average and daily minimum concentrations of dissolved oxygen at Willis Wharf in the late summer of 1990.

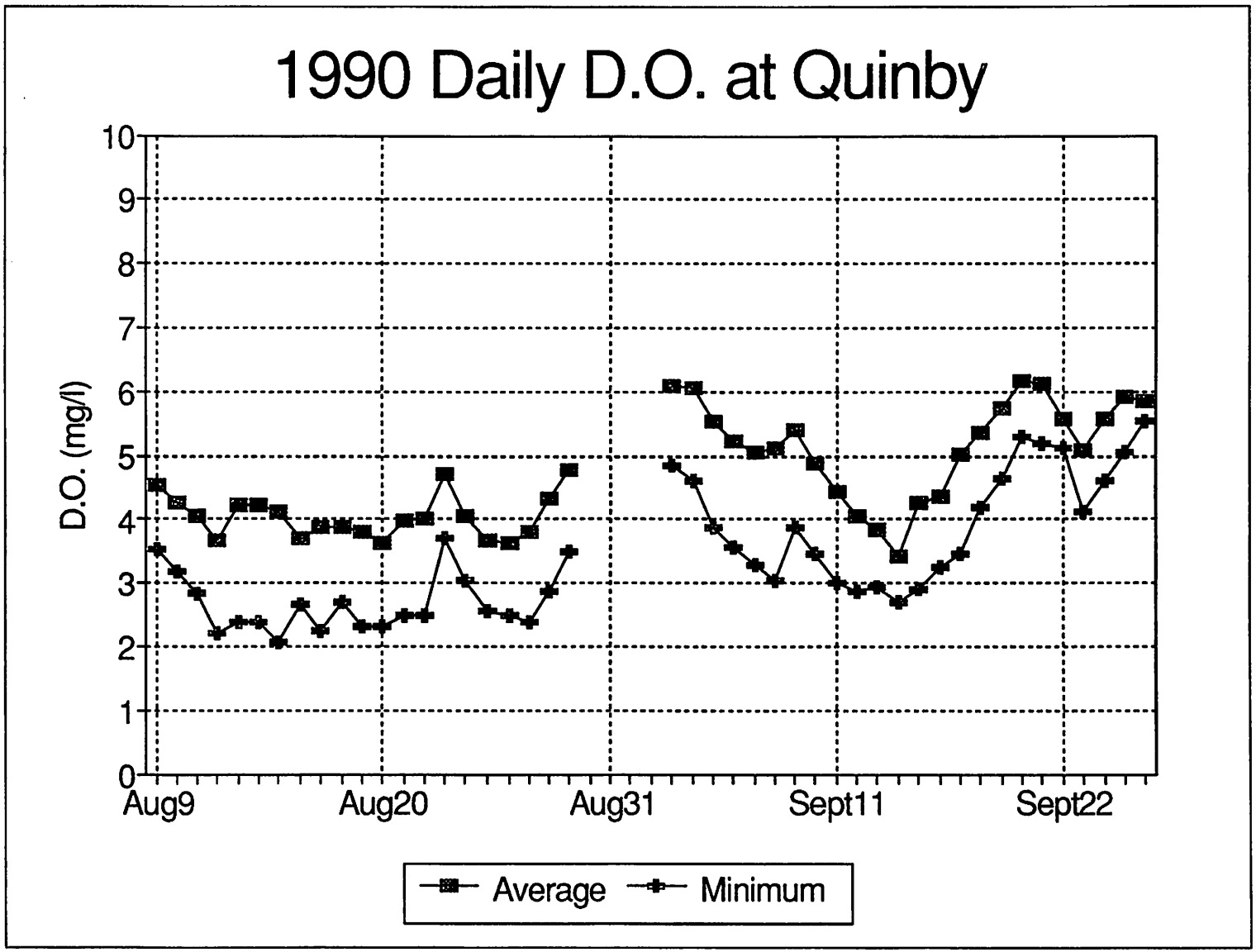


Figure 7d. Daily average and daily minimum concentrations of dissolved oxygen at Quinby in the late summer of 1990.

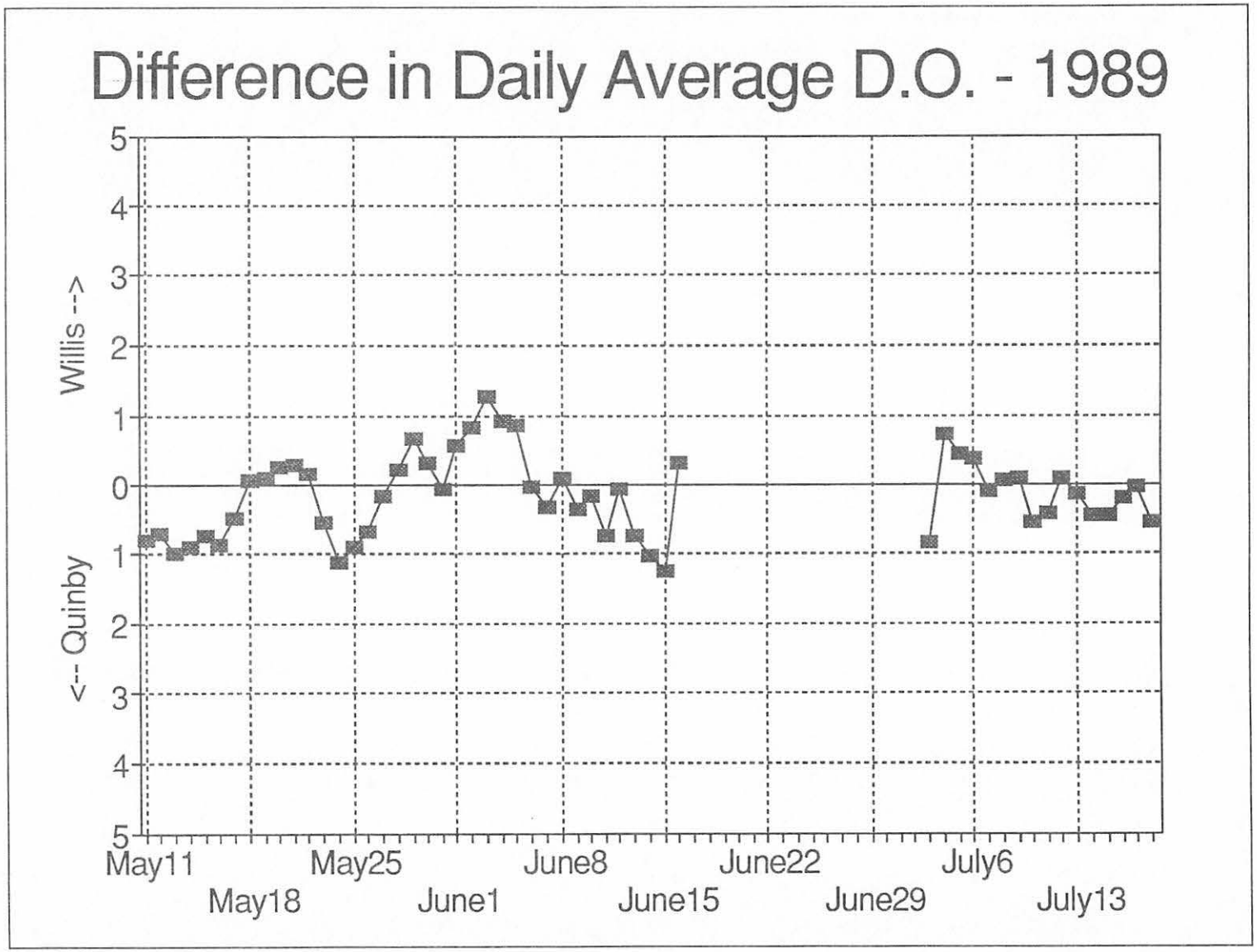


Figure 8a. The difference in daily average dissolved oxygen concentrations at Willis Wharf and Quinby in the early summer of 1989.

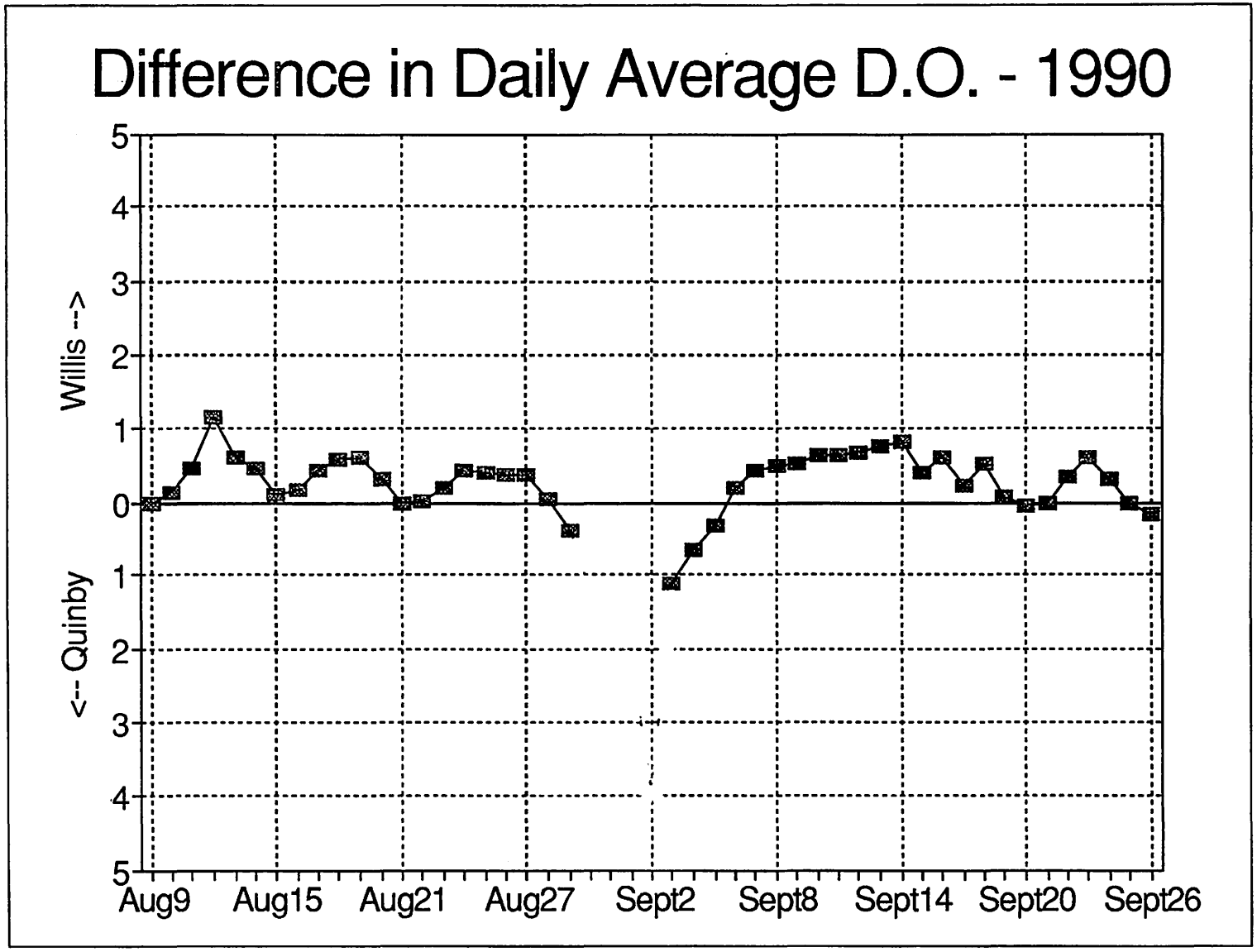


Figure 8b. The difference in daily average dissolved oxygen concentrations at Willis Wharf and Quinby in the late summer of 1990.

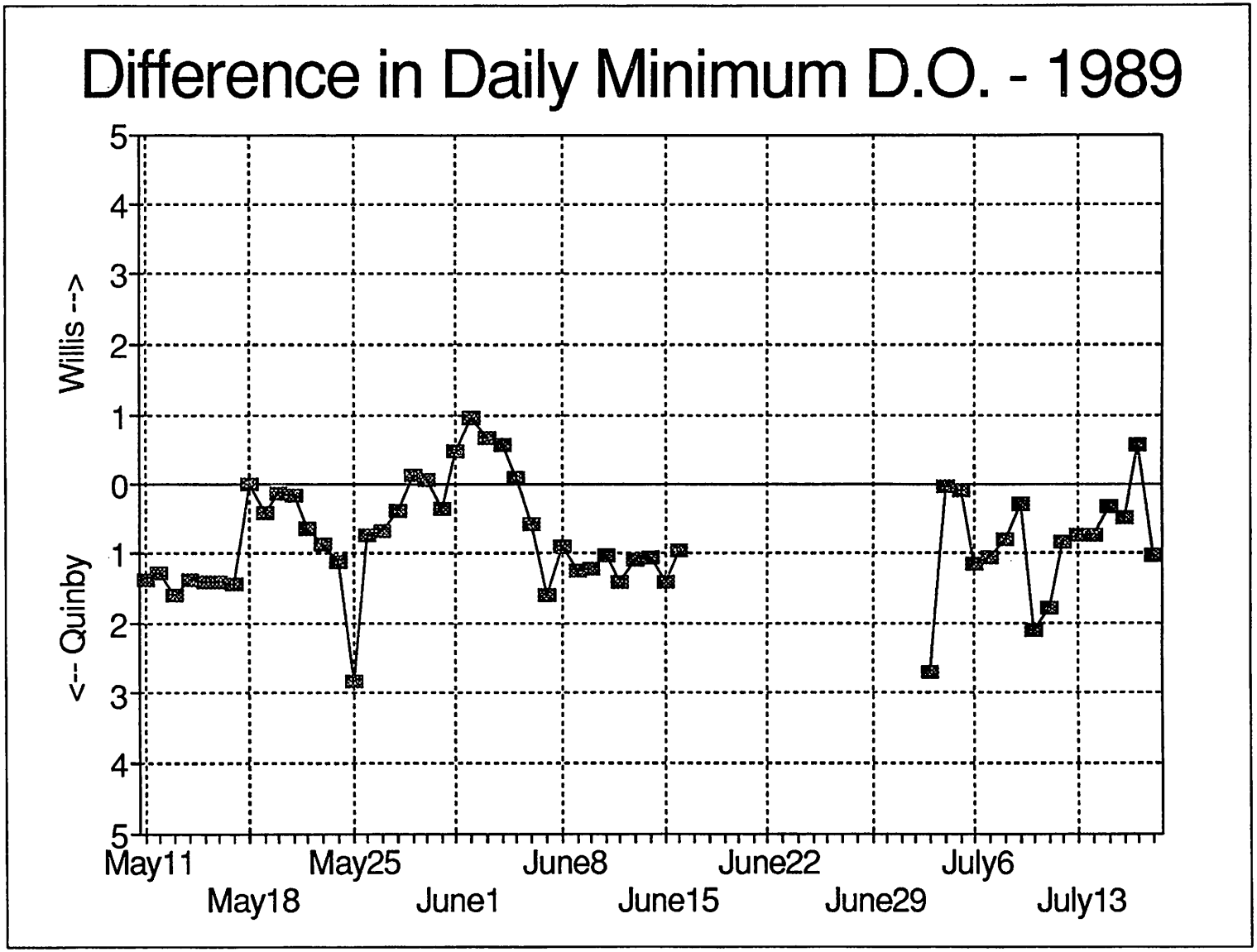


Figure 9a. The difference in daily minimum dissolved oxygen concentrations at Willis Wharf and Quinby in the early summer of 1989.

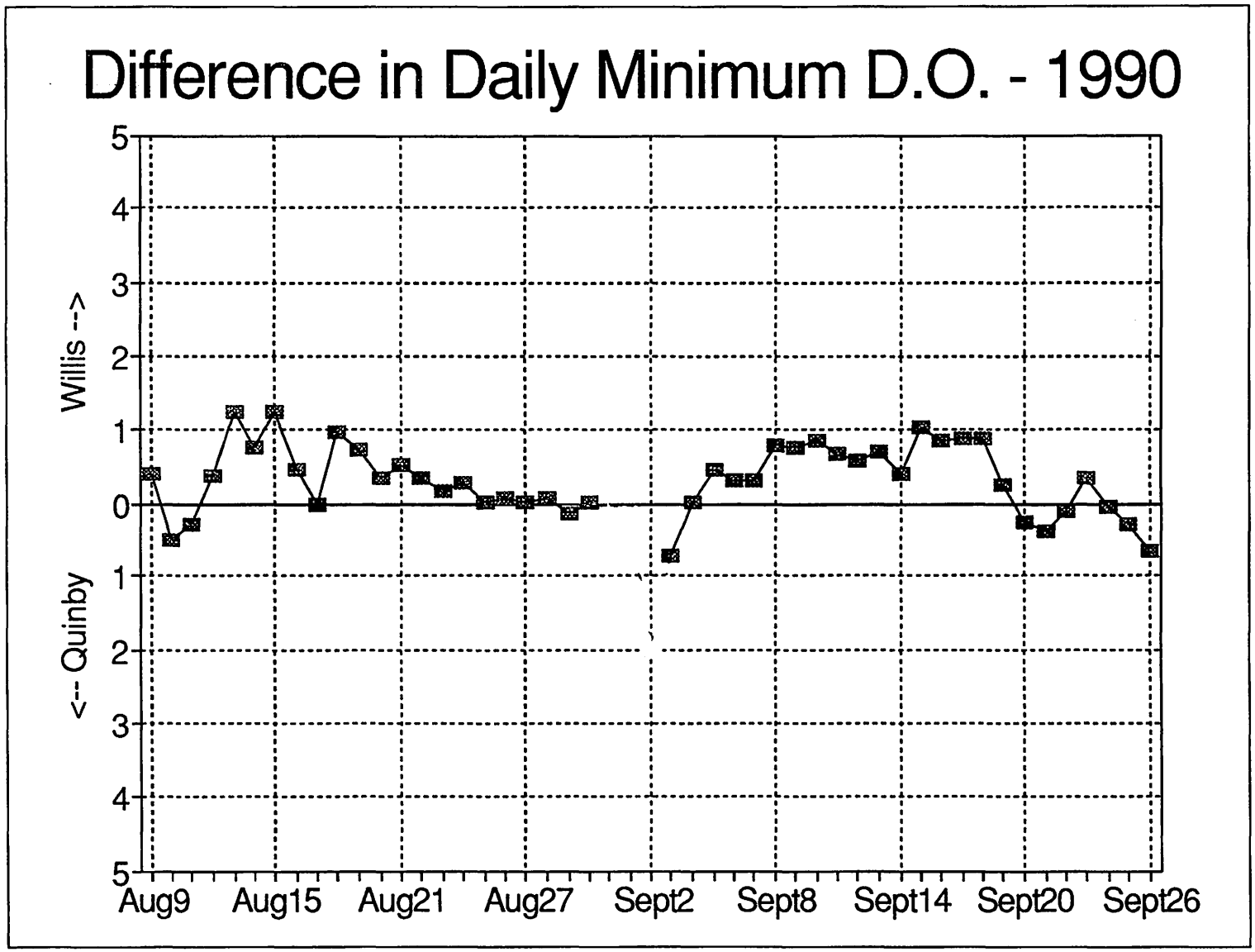


Figure 9b. The difference in daily minimum dissolved oxygen concentrations at Willis Wharf and Quinby in the late summer of 1990.

IV. DISCUSSION AND CONCLUSIONS

Virginia water quality standards for coastal waters include two measures of dissolved oxygen (DO) conditions. Daily average DO concentrations are not supposed to be less than 5 mg/l and no observations are supposed to be below 4 mg/l. The tabulated data in Appendix III show that both parts of the standard were violated at both stations in both years.

For the study period in 1989, the daily average standard was violated 73% of the time at Willis Wharf and 49% of the time at Quinby. For the 1990 deployments, the violations were similar at the two sites; 63% at Willis Wharf and 62% at Quinby. A similar pattern exists for violations of the minimum DO standard. Minimum DO's at Willis Wharf were below 4 mg/l 81% of the time in 1989 but only 63% of the time in 1990. Values less than 4 mg/l were observed at Quinby 58% of the time in 1989 and 75% of the time in 1990.

From several perspectives, it seems clear that water quality conditions at Willis Wharf have improved when contrasted with conditions at Quinby. During 1989 DO's were lower at Willis Wharf in terms of daily average, percent of averages below 5 mg/l, daily minimum, and percent of daily minimums below 4 mg/l. In 1990, conditions at the two sites were very similar and when differences occurred, conditions were better at Willis Wharf than at Quinby.

Conversations with the operator of the crab shedding operation at which the Machipongo River datasonde was deployed indicate no significant differences in operation between 1989 and 1990. Differences between the two years at this site most likely are due to the different seasons (warming in 1989 and cooling in 1990), although the temperatures and salinities encountered were not significantly different. Data gaps also interfere with the comparison. We are not aware of any measurements of the waste loading from a crab shedding operation. We assume that it is small and that conditions at the Quinby site are those which occur naturally in these systems. To support this assumption, we note that crab mortality increases when water quality is poor, so that shedding operations tend to be located where water quality is good.

Wastewater loads in general, and discharge of biochemical oxygen demand (BOD) in particular, from the American Original facility were greatly reduced between the spring of 1989 and the late summer of 1990. The

improvement in DO conditions in Parting Creek must be attributed primarily to this change in plant operations. It is very likely that nutrient loadings also were reduced, which should result in a lower standing stock of algae. This is probably the reason why the daily variation in D.O. at Willis Wharf decreased from about 3.6 mg/l in 1989 to 2.2 mg/l in 1990.

The standards violations at both sites were not unexpected. Shallow estuarine systems with extensive fringing marshes and mudflats often exhibit substandard DO's. This complicates water quality management, since many times no combination of (point source) loads will achieve compliance with the standards. It is relevant to note, however, that conditions in Parting Creek in 1990 were generally the same as, or better than, those in the Machipongo River even though American Original was discharging wastewaters, albeit with greatly reduced loadings. One could conclude that conditions in Parting Creek are essentially the same as those which would occur with no point source loading, or in other words, the discharge is not having a measurable impact on water quality.

Coastal systems, such as the Machipongo River, are complex. It is extremely difficult to model a system that includes mud flats that are exposed at some low tides. The role of tidal wetlands also is difficult to quantitate and simulate. Consequently water quality modelling of such a system would be very expensive and there would be no guarantee that the model could reproduce the observed variations in water quality. Hence mathematical models are not available today, nor are they likely to be available in the near future, which could determine quantitatively the impact of a discharge on ambient DO's. Lacking that tool, the present study has employed a semi-quantitative approach to determining allowable waste loads. That approach indicates that present loadings are not having a significant effect.

Appendix I. Calibration of DataSondes

a) Calibration Procedures

b) Calibration Results

DataSonde Calibration Procedure

For this study, a HydroLab DataSonde I was deployed at each site, Willis Wharf and Quinby, Virginia. The DataSonde was programmed to read time, temperature, conductivity, dissolved oxygen and battery voltage at every half-hour over the deployment period.

The DataSonde is calibrated both before and after it is deployed in the field. The procedure is the same, but in the pre-calibration the instrument is **adjusted** to a standard, whereas in the post-calibration, the instrument is only monitored to see its **change** from the standard. Only conductivity and dissolved oxygen are calibrated. Temperature readings are checked against a platinum thermometer.

A portable DataGeneral I laptop computer runs the calibration program. The computer is connected to the DataSonde through an interfacing unit to establish communication. Software provided by HydroLab is used to calibrate the instrument, as well as to establish the parameters to be measured, the sampling period, and to retrieve the collected data.

In the Physical Oceanography Calibration Lab are vats of varying salinity under constant agitation. The highest salinity vat was used to calibrate the instruments for this study, as it most closely matched salinity at the field site. Also in the lab is a Beckman salinometer, which is calibrated with Copenhagen water weekly and sub-standard seawater daily. A sample of the vat water is collected and read on the salinometer, giving its temperature and conductivity reading. This result is used as the standard for calibration.

The lower end of the DataSonde contains the sensors for temperature, conductivity and dissolved oxygen. A cup is fitted here and filled with water from the high salinity vat. The calibration program then outputs the temperature and conductivity readings. The output can be adjusted higher or lower to meet the standard at the operator's discretion. When the readings become stable, these numbers are set by the operator and stored in the DataSonde.

Calibration for dissolved oxygen occurs much the same way. The sensors of the DataSonde are well-rinsed, and the calibration cup is fitted here, then filled with tap water. The water comes to a level just below the D.O. membrane, so that an air-calibration is performed. The probe is allowed to equilibrate to pertinent saturation values as listed in Standard Methods for the Examination of Water and Wastewater. When the value is reached, the operator sets the calibration.

When the DataSonde is removed from its field site, the sensors are placed in a protective cup filled with the water from which it was just removed. When it arrives back at VIMS, the post-calibration check is performed. The same steps are followed to determine conductivity and oxygen standards as in the pre-calibration procedure, but the DataSonde's output of conductivity and oxygen are only monitored to see how close they are to standard. All pre- and post-calibration measurements are recorded on lab bench sheets.

DataSondes are cleaned of any fouling and mud, D.O. probe membranes and solutions are changed, and battery voltage is checked before each deployment.

DataSonde Calibration

1989	Willis Wharf			Quinby		
Date	**DS**	**Cond.**	**D.O.**	**DS**	**Cond.**	**D.O.**
May 9 (pre)	55	-0.02	0.00	53	-0.04	+0.05
May 22 (post)	55	-0.01	-0.49	53	-1.13	+0.31
May 17 (pre)	54	-0.09	+0.05	52	-0.01	-0.03
June 1 (post)	54	-1.17	-0.24	52	-1.00	-0.21
May 30 (pre)	55	-0.03	+0.20	53	-0.03	+0.17
June 16 (post)	55	+1.27	---	53	-0.72	---
June 16 (pre)	54	-0.20	+0.07	52	+0.32	+0.07
July 3 (post)	54	---	---	52	No Data	
June 30 (pre)	55	-0.06	+0.09	53	-0.06	+0.17
July 19 (post)	55	-16.75	+0.08	53	-9.51	-0.45

1990	Willis Wharf			Quinby		
Date	**DS**	**Cond.**	**D.O.**	**DS**	**Cond.**	**D.O.**
August 6 (pre)	52	-0.08	+0.04	55	-0.08	+0.06
August 17 (post)	52	+0.67	-0.19	55	+0.67	+0.53
August 16 (pre)	53	+0.01	+0.08	54	0.00	+0.07
August 24 (post)	53	+0.61	-0.85	54	+0.07	-0.29
August 22 (pre)	52	+0.07	+0.10	55	+0.07	+0.05
August 29 (post)	52	-0.30	+0.08	55	+0.10	+0.13
August 27 (pre)	53	+0.07	+0.04	54	+0.04	+0.06
September 6 (post)	53	-0.01	-0.28	54	-0.91	+0.42
September 5 (pre)	52	+0.03	+0.09	55	+0.03	+0.04
September 14 (post)	52	+0.19	-0.04	55	+0.19	-0.01
September 12 (pre)	53	-0.04	+0.05	54	-0.04	+0.12
September 19 (post)	53	+0.60	-0.02	54	+0.39	-0.20
September 18 (pre)	52	+0.06	+0.21	55	+0.06	+0.15
September 28 (post)	52	-0.54	-0.33	55	-0.14	-0.18

Appendix II. Plots of All Data by Deployment Period

Variation in temperature, salinity and dissolved oxygen concentrations with time at

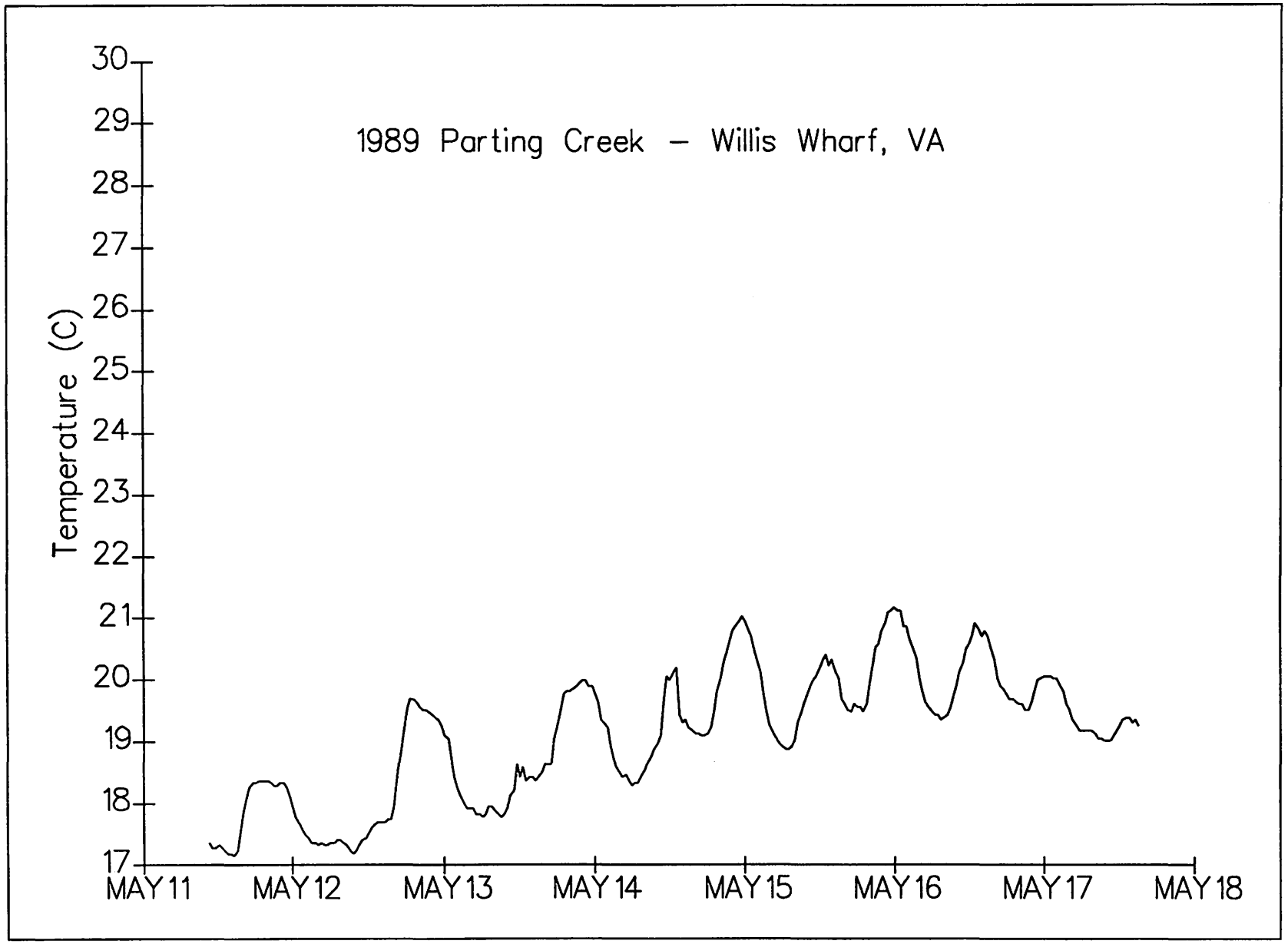
a) Parting Creek - Willis Wharf, in early summer of 1989

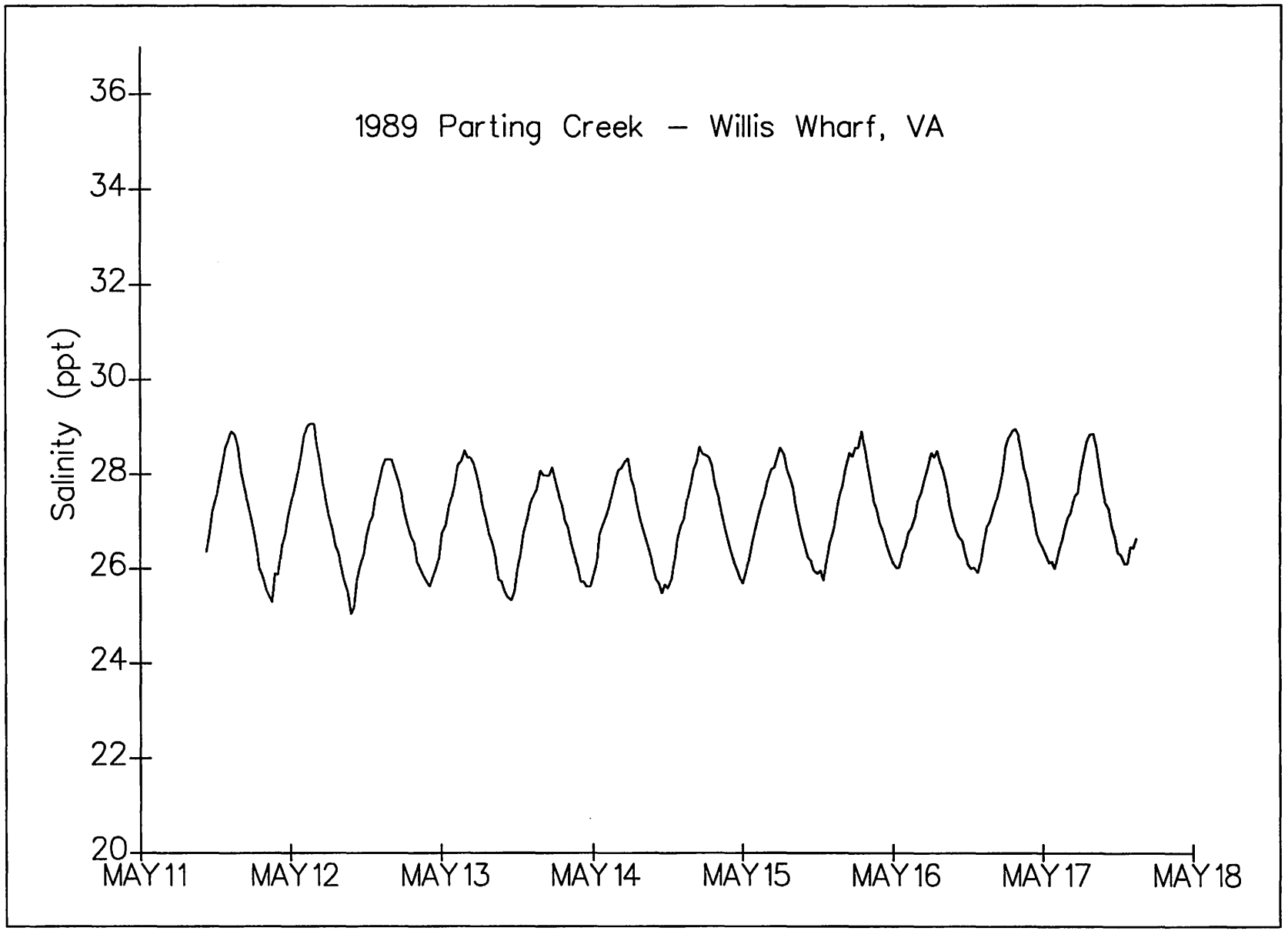
b) Machipongo River - Quinby, in early summer of 1989

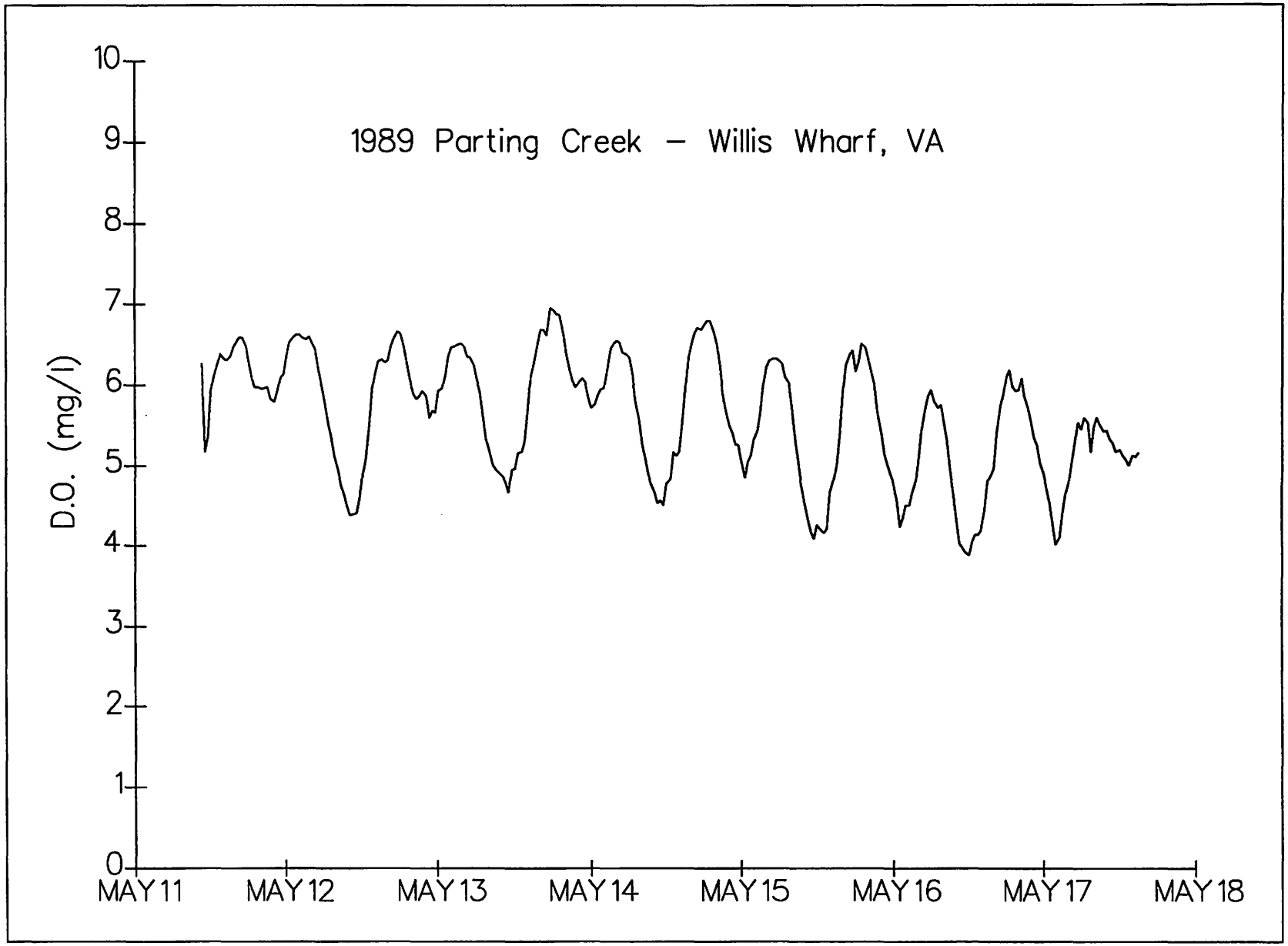
c) Parting Creek - Willis Wharf, in late summer of 1990

d) Machipongo River - Quinby, in late summer of 1990

Note that there has been no censoring of data.


1989 Parting Creek – Willis Wharf, VA
Temperature (C)
30
29
28
27
26
25
24
23
22
21
20
19
18
17
MAY 11
MAY 12
MAY 13
MAY 14
MAY 15
MAY 16
MAY 17
MAY 18


1989 Parting Creek – Willis Wharf, VA
Salinity (ppt)
36
34
32
30
28
26
24
22
20
MAY 11
MAY 12
MAY 13
MAY 14
MAY 15
MAY 16
MAY 17
MAY 18


1989 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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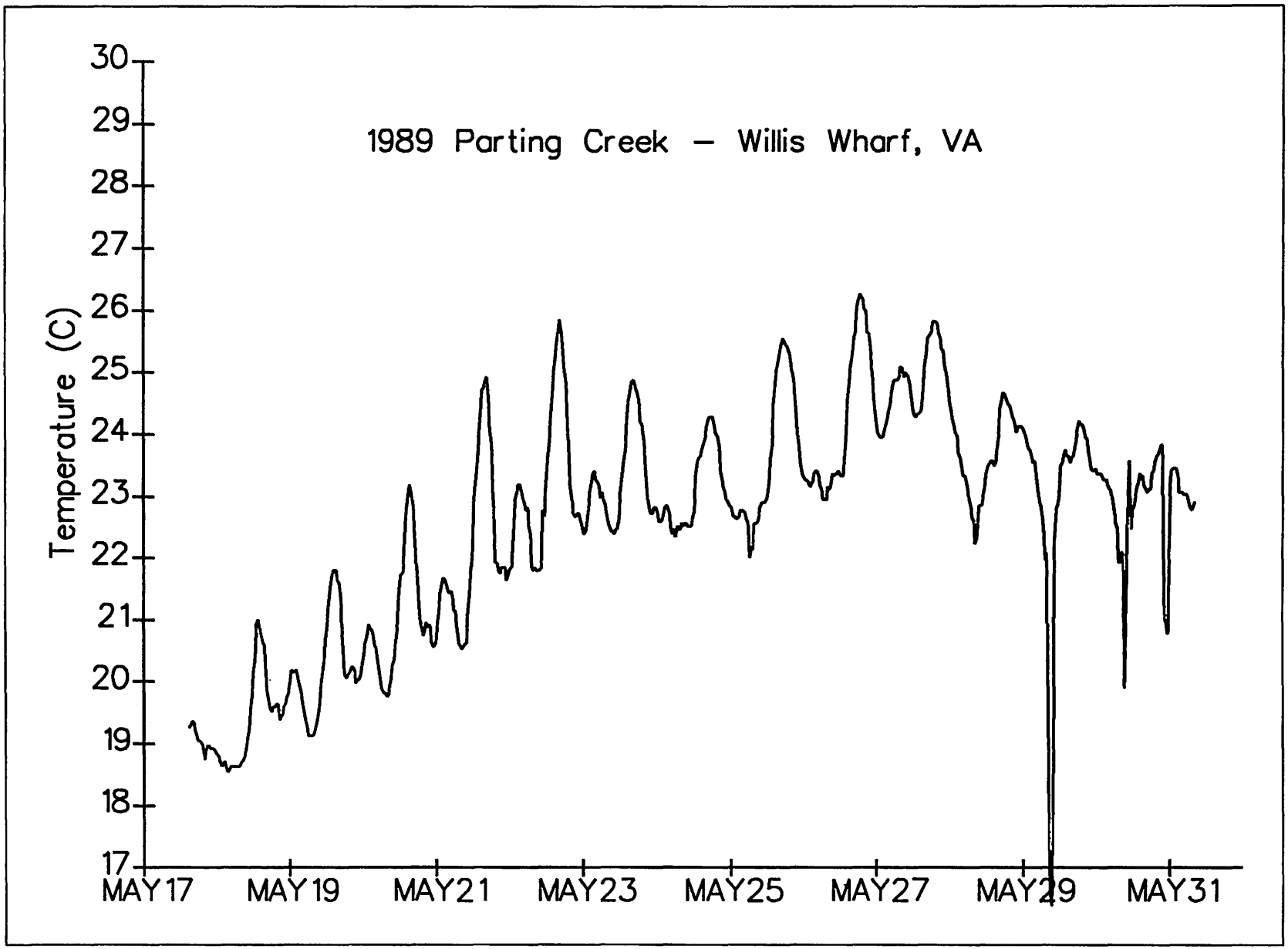
MAY 17
MAY 18


1989 Parting Creek – Willis Wharf, VA
Temperature (C)
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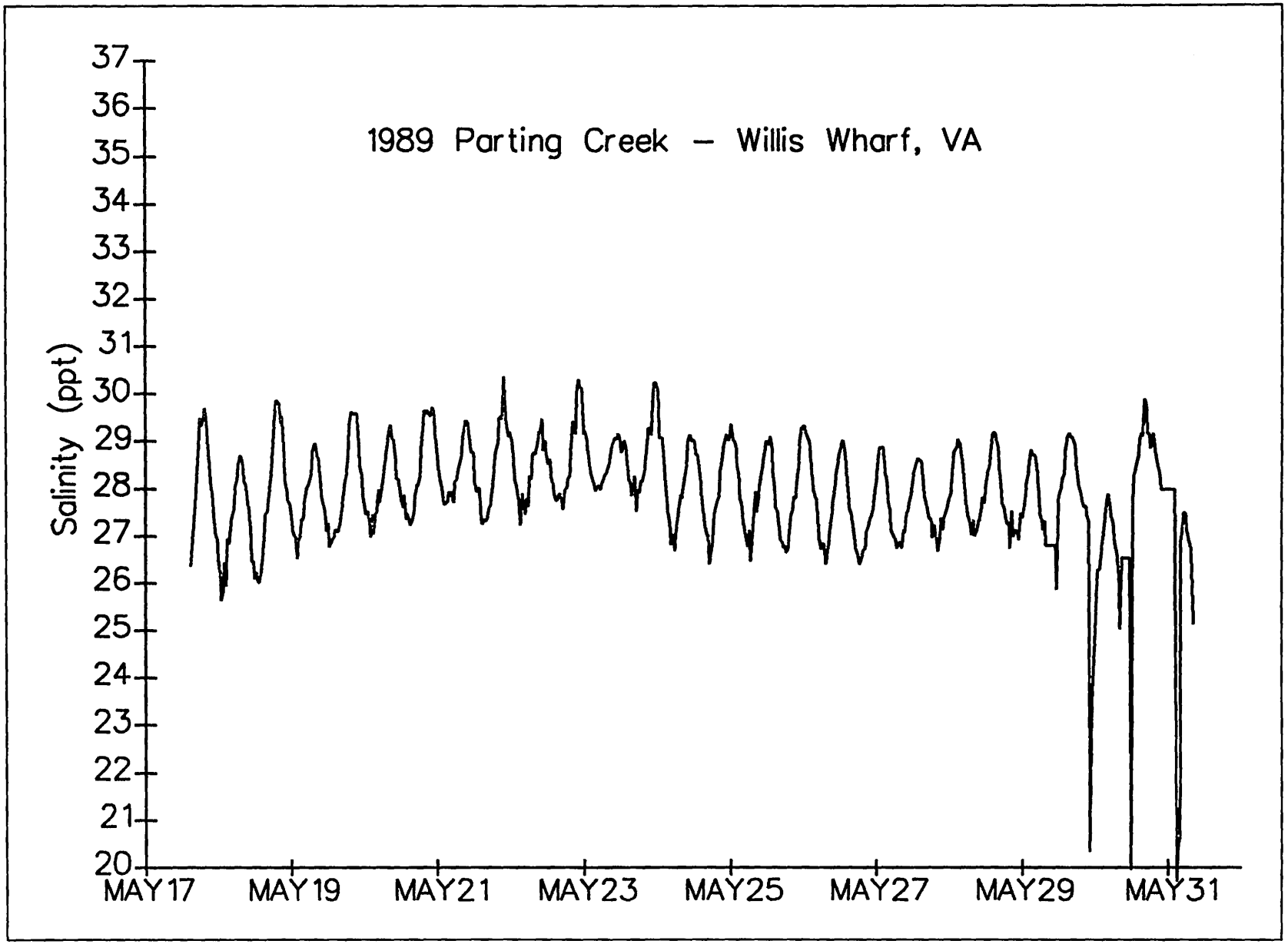
MAY31


1989 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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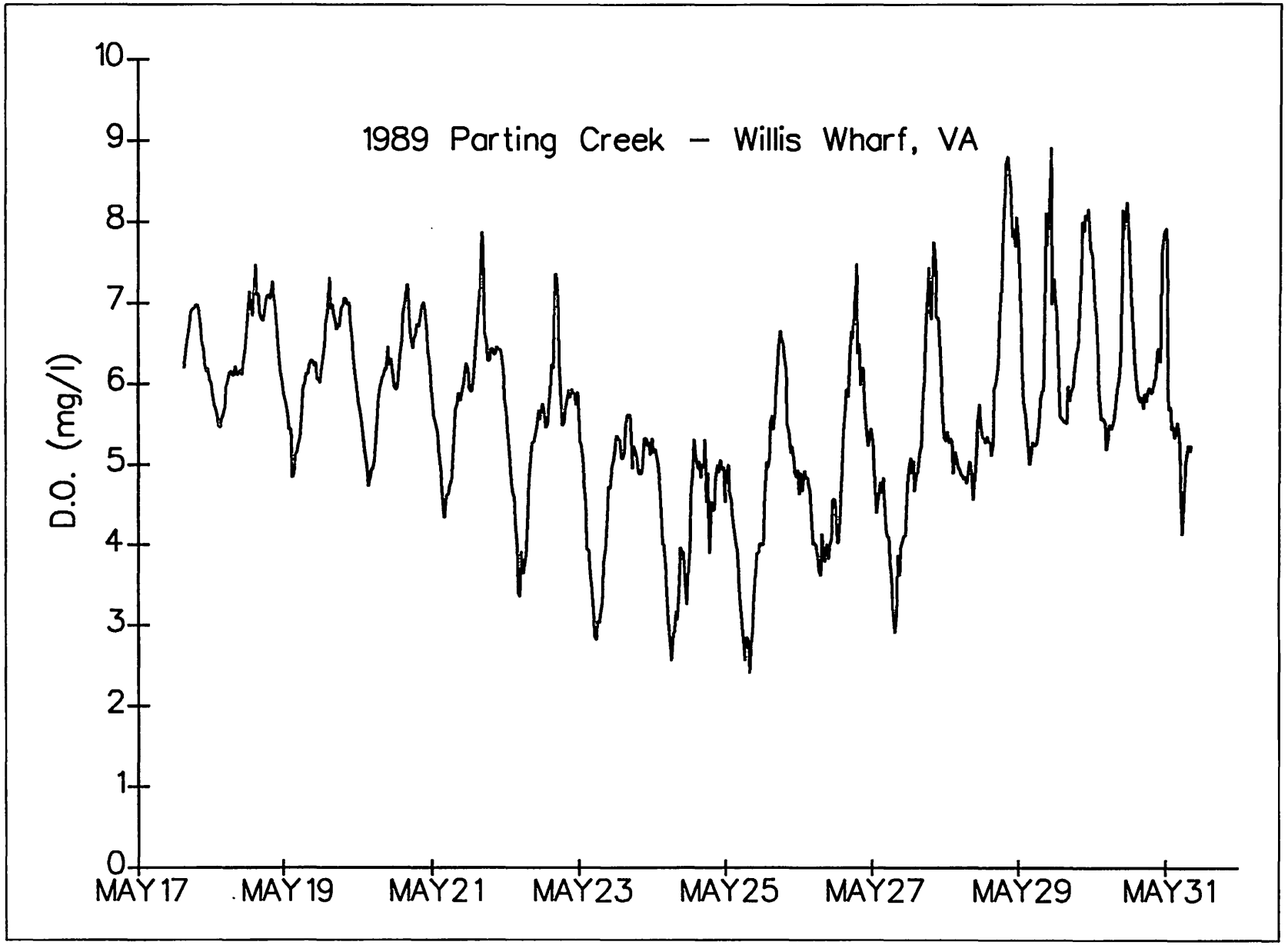
1989 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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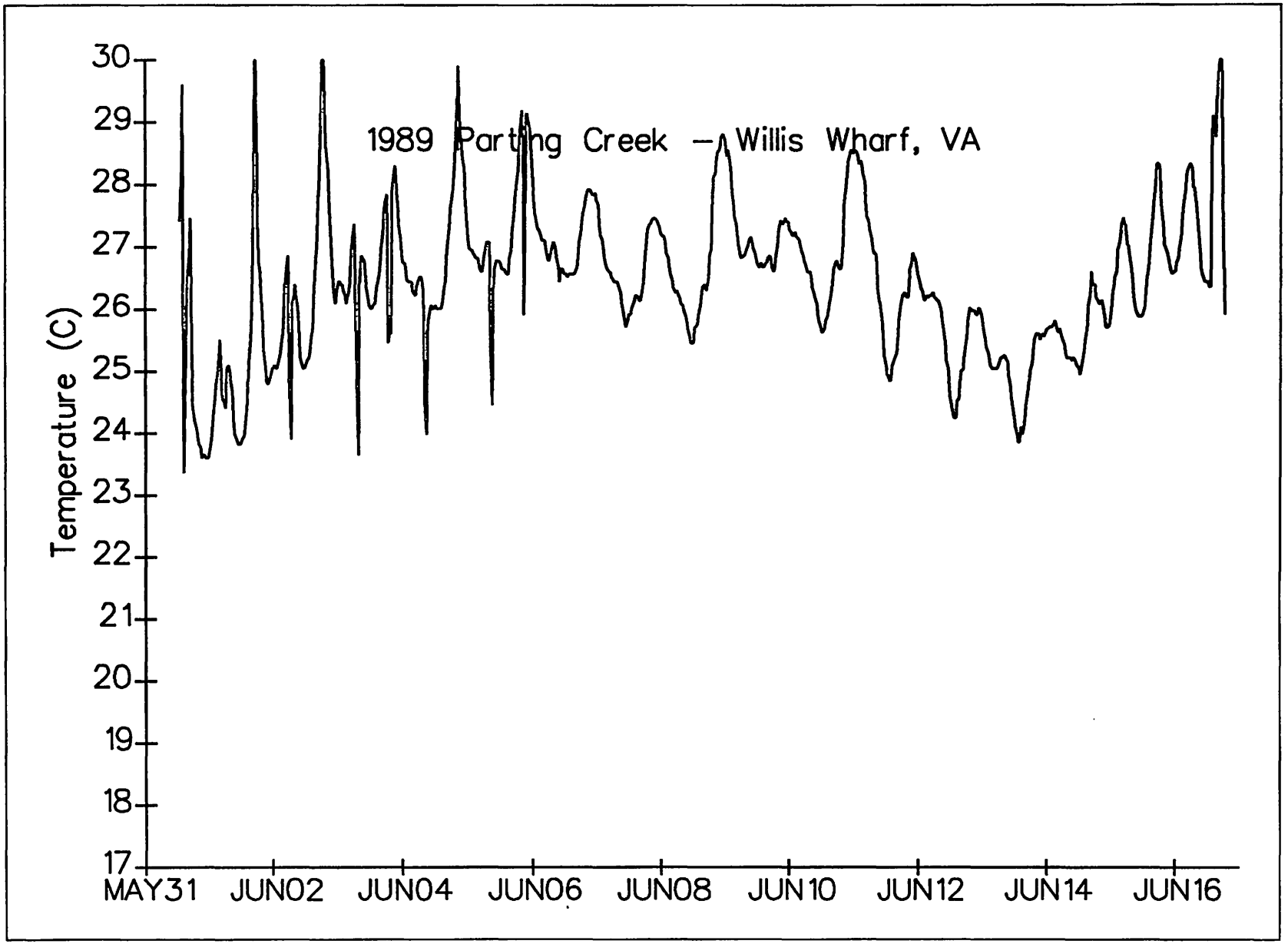
1989 Parting Creek – Willis Wharf, VA
Temperature (C)
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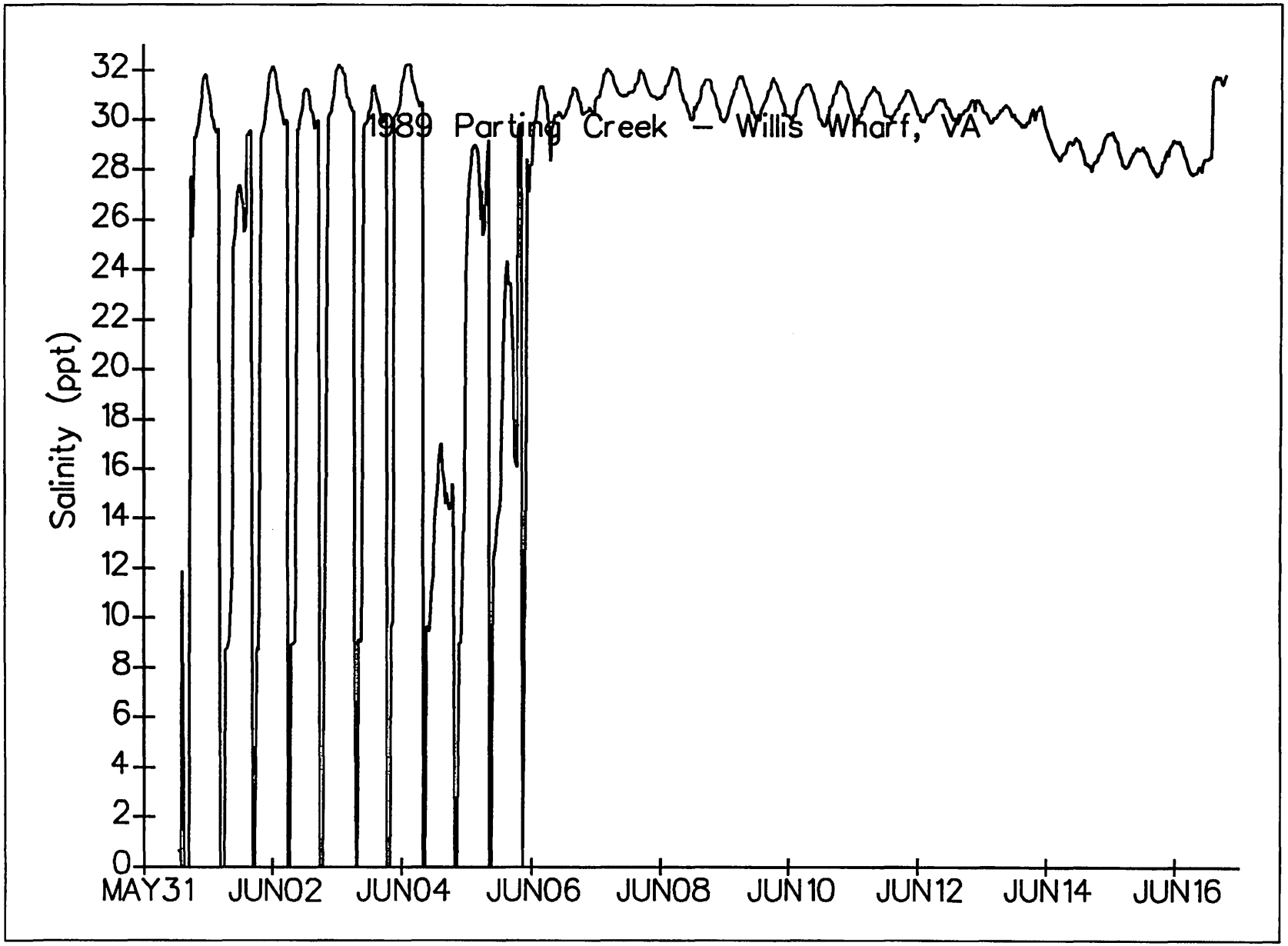
1989 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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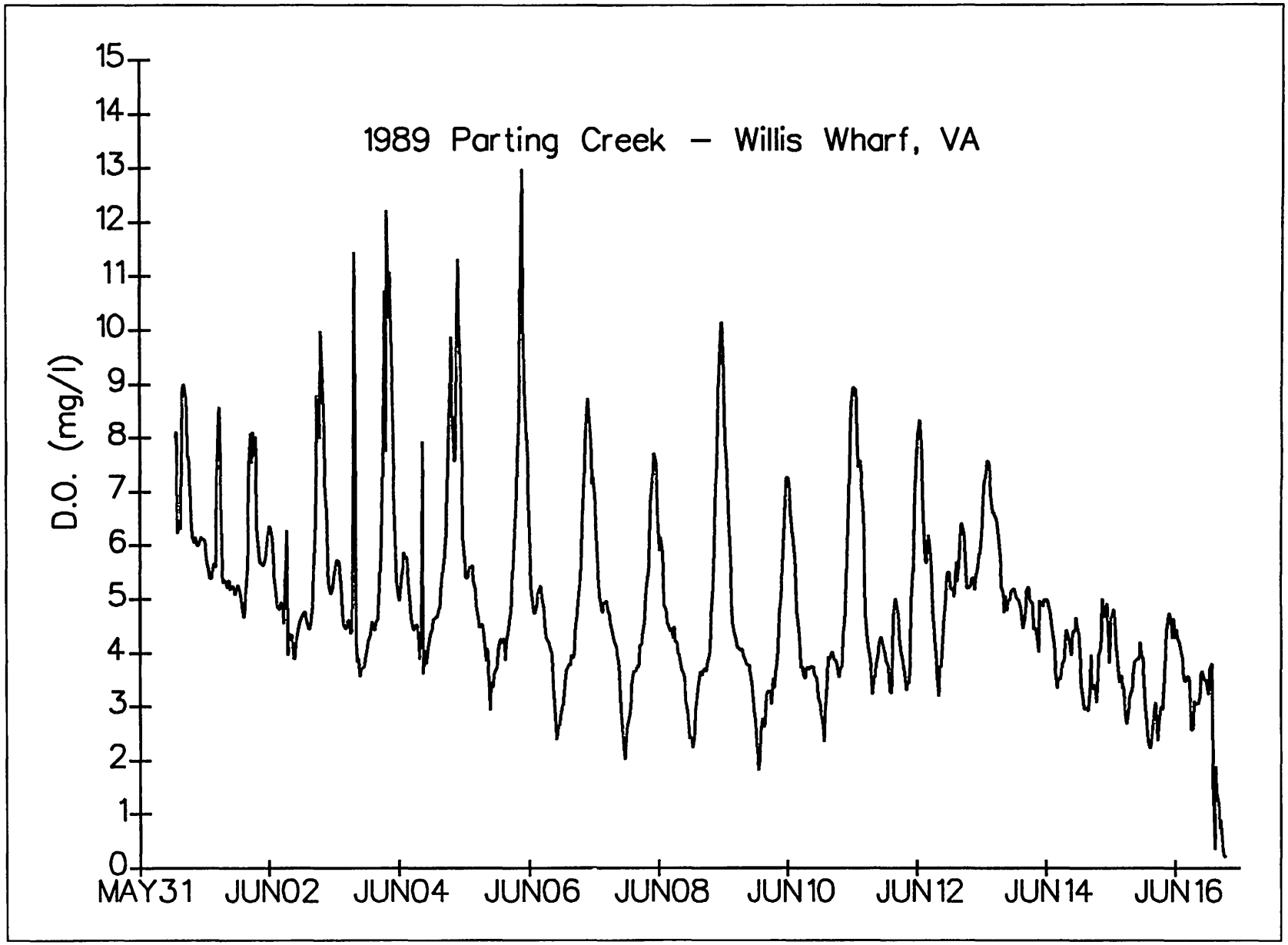
1989 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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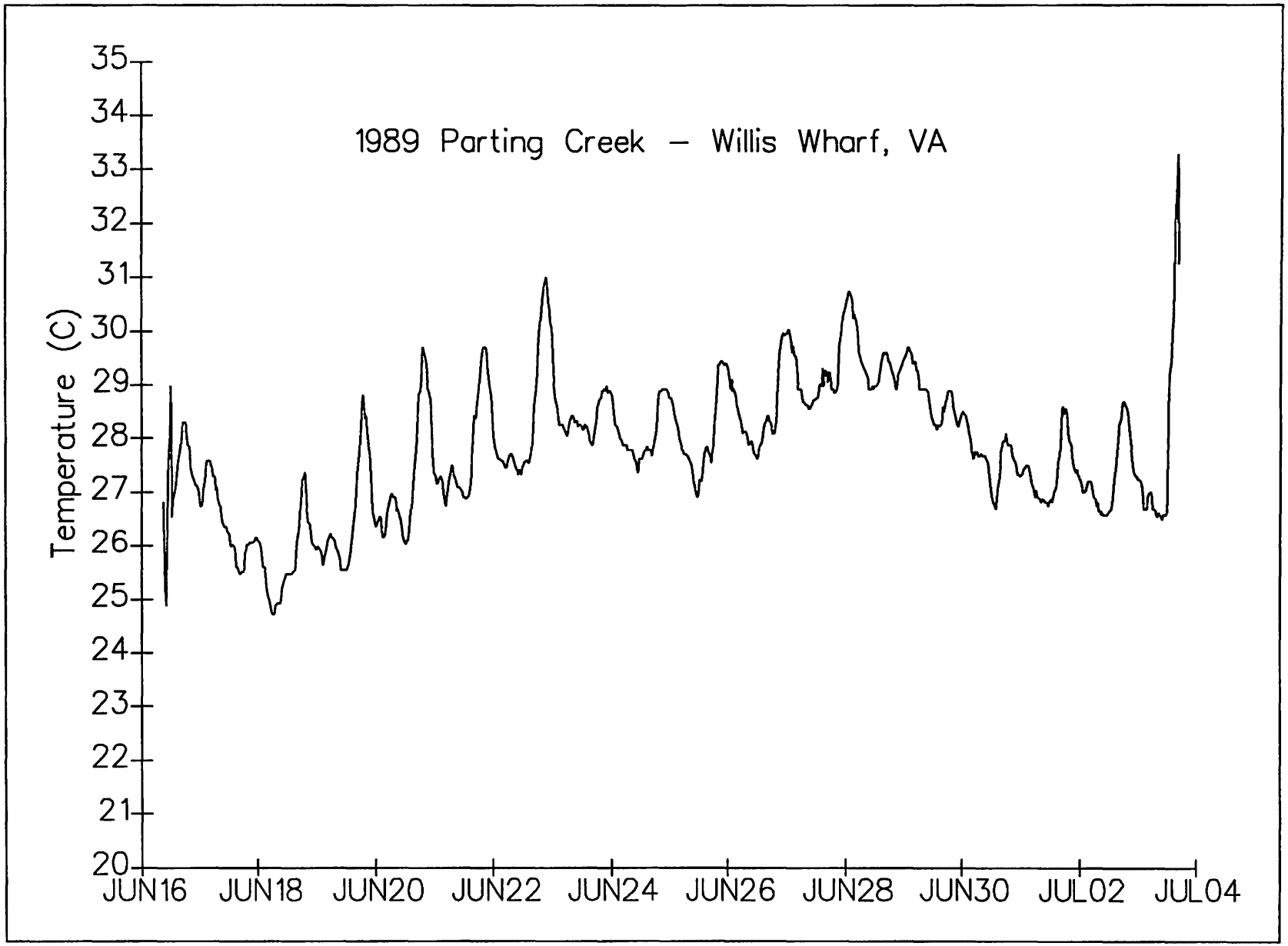
1989 Parting Creek – Willis Wharf, VA
Temperature (C)
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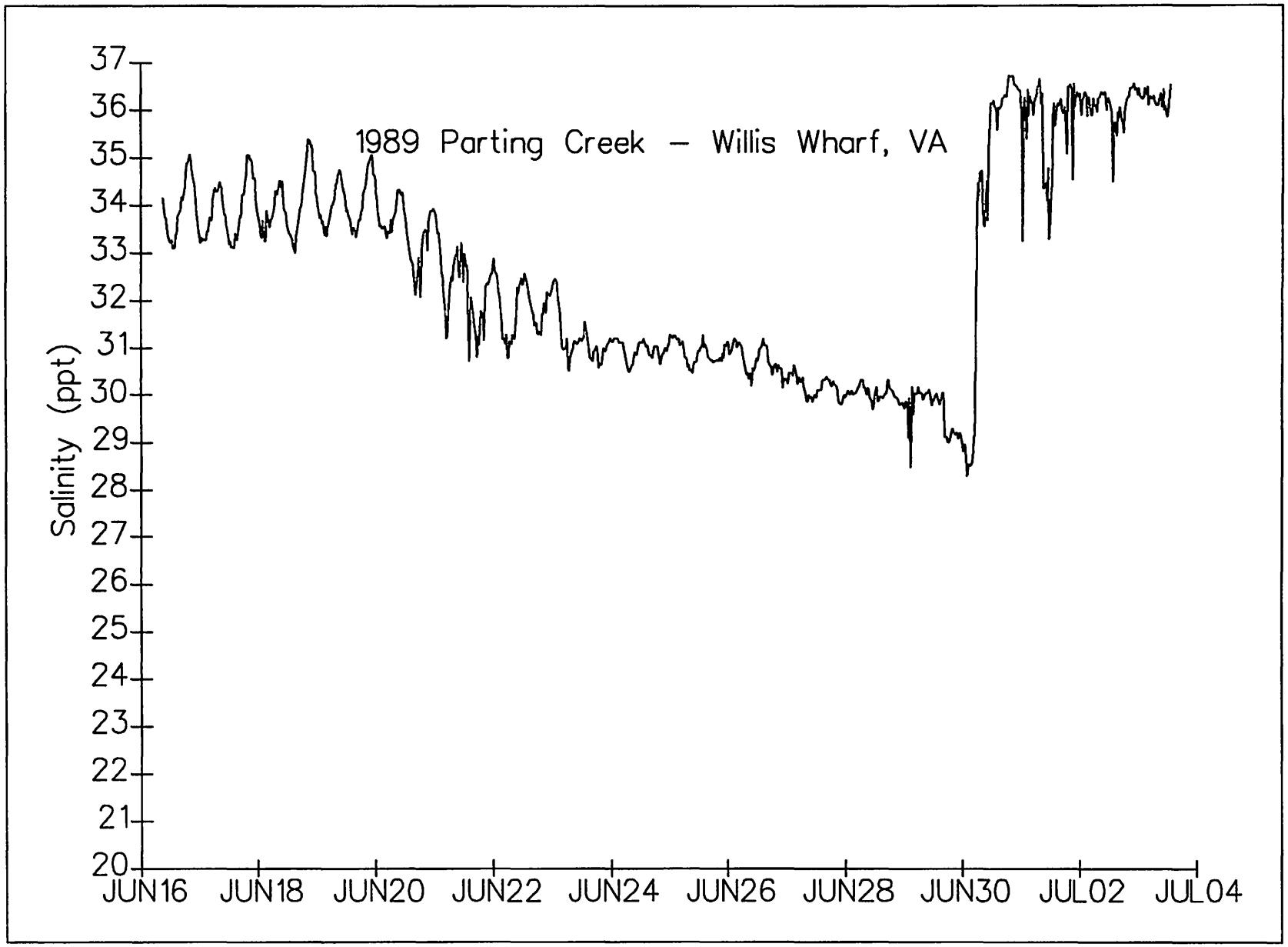
1989 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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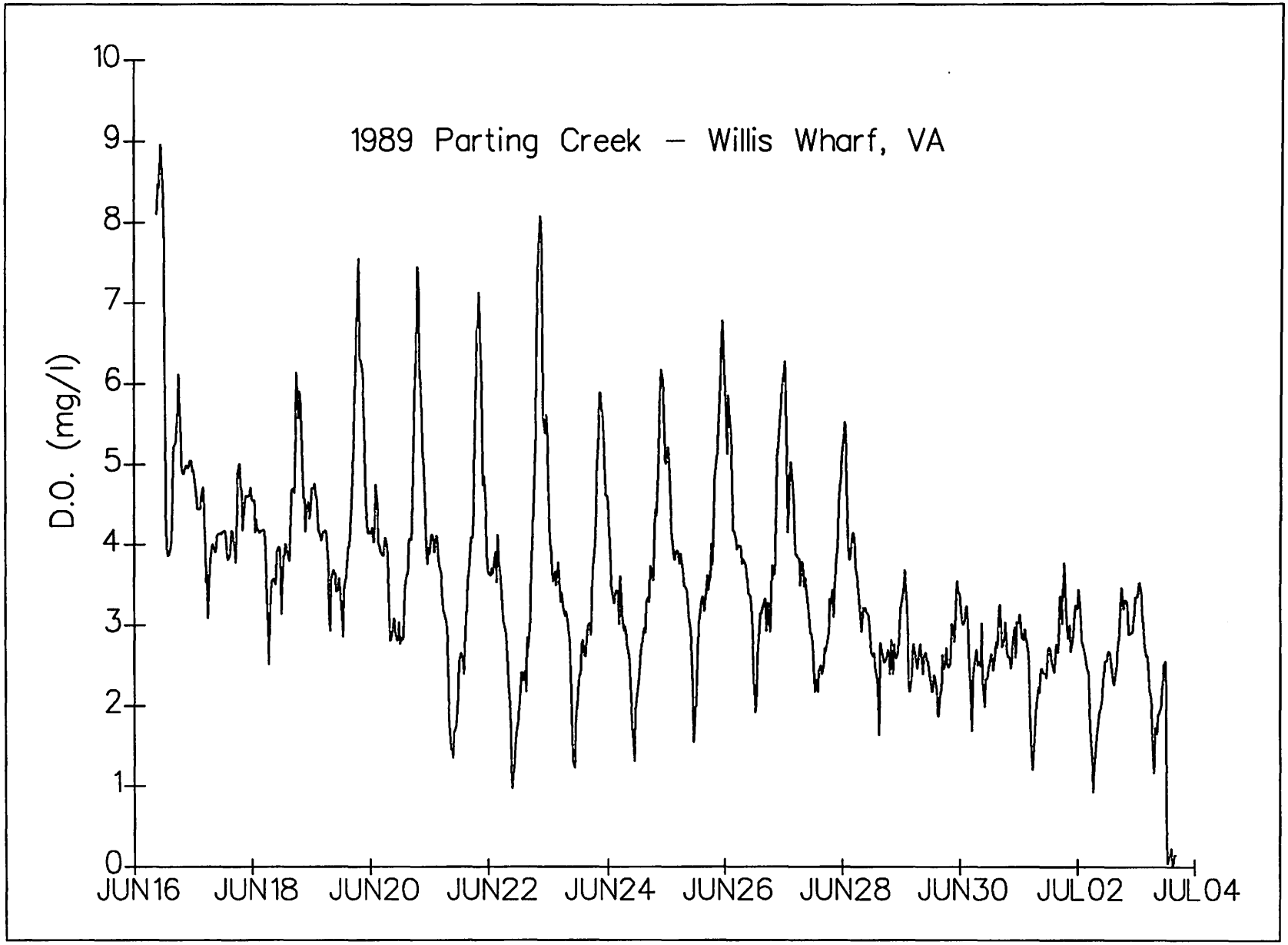
1989 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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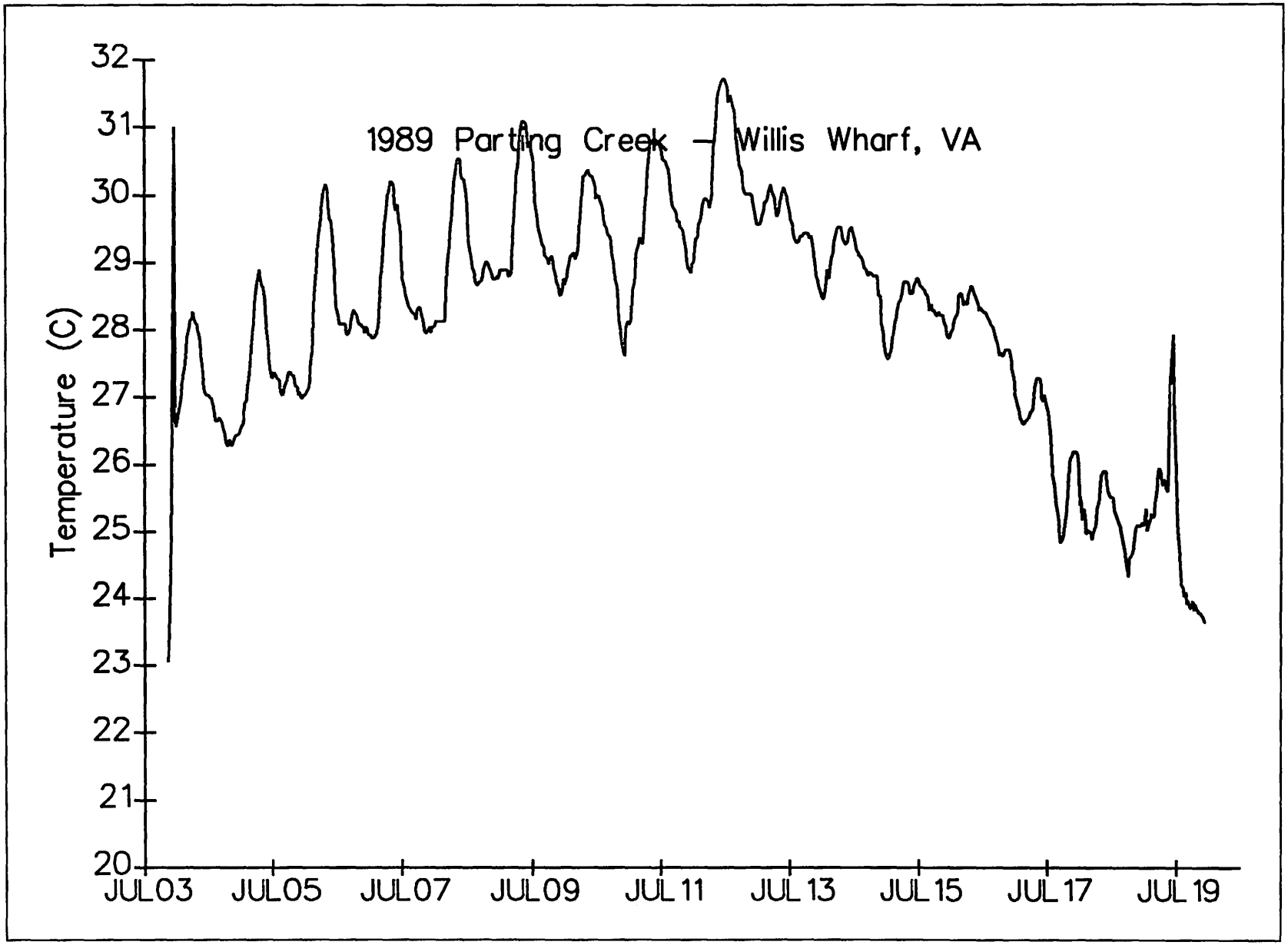
1989 Parting Creek — Willis Wharf, VA
Temperature (C)
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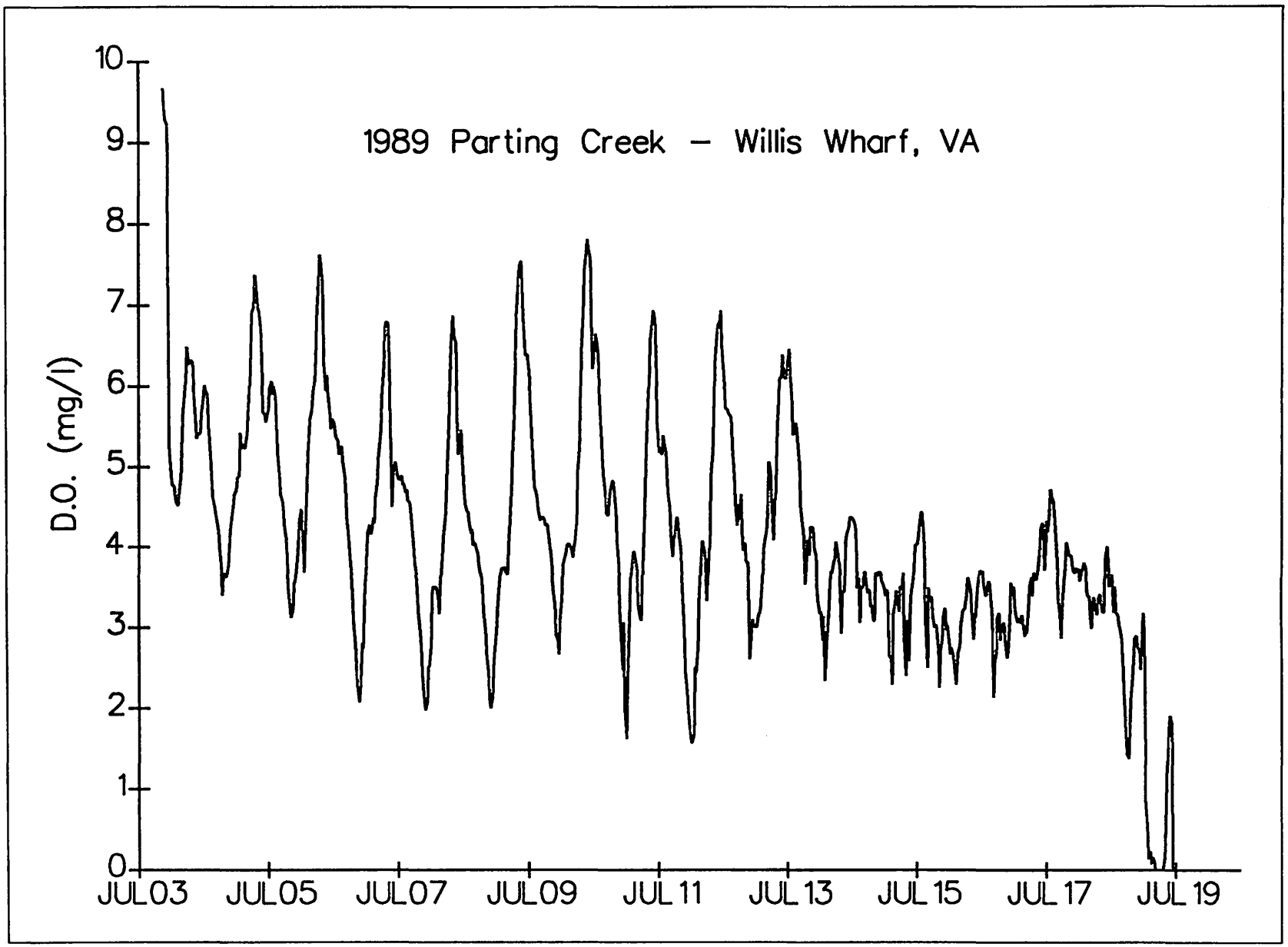
1989 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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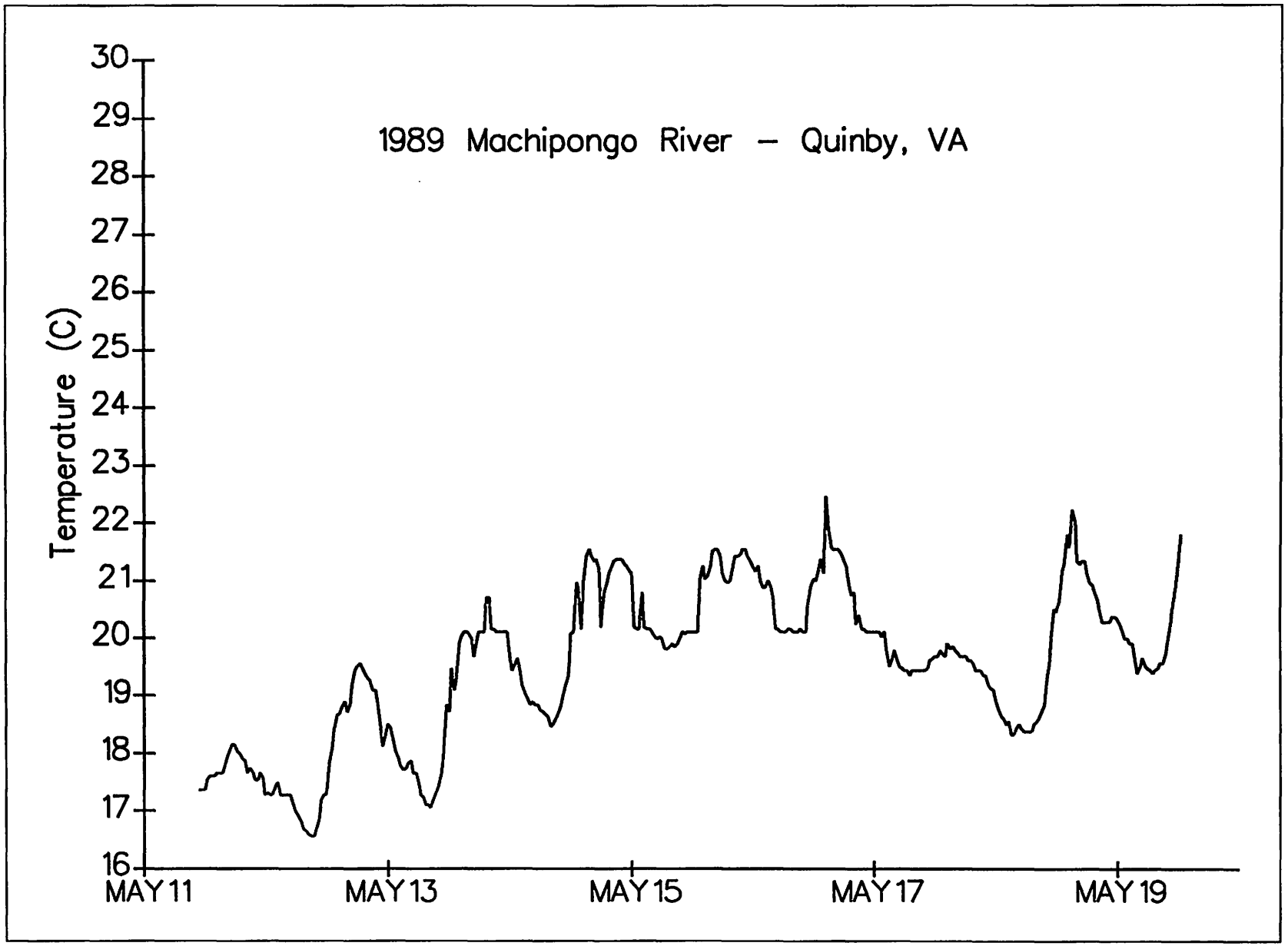
1989 Machipongo River – Quinby, VA
Temperature (C)
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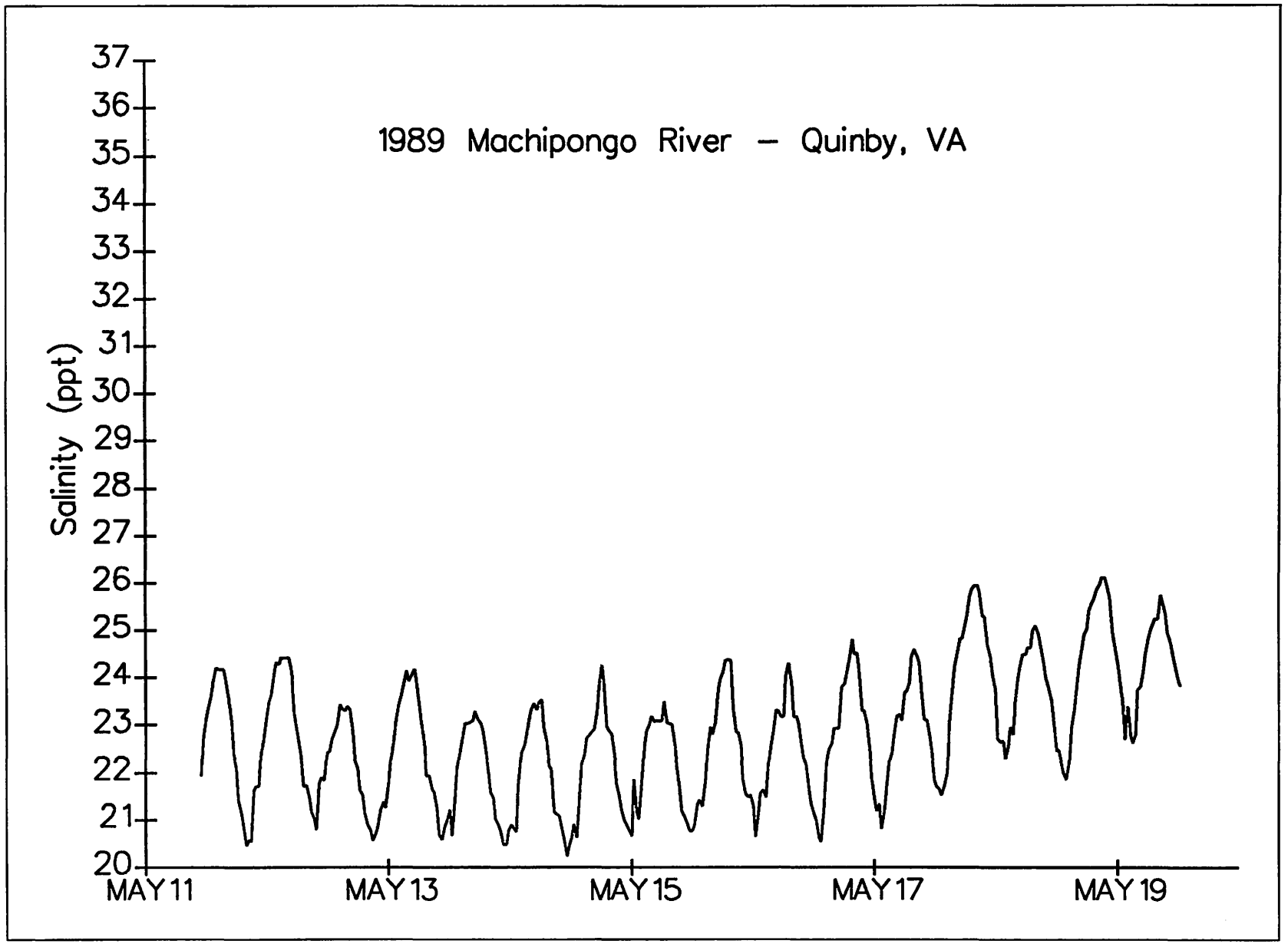
1989 Machipongo River – Quinby, VA
Salinity (ppt)
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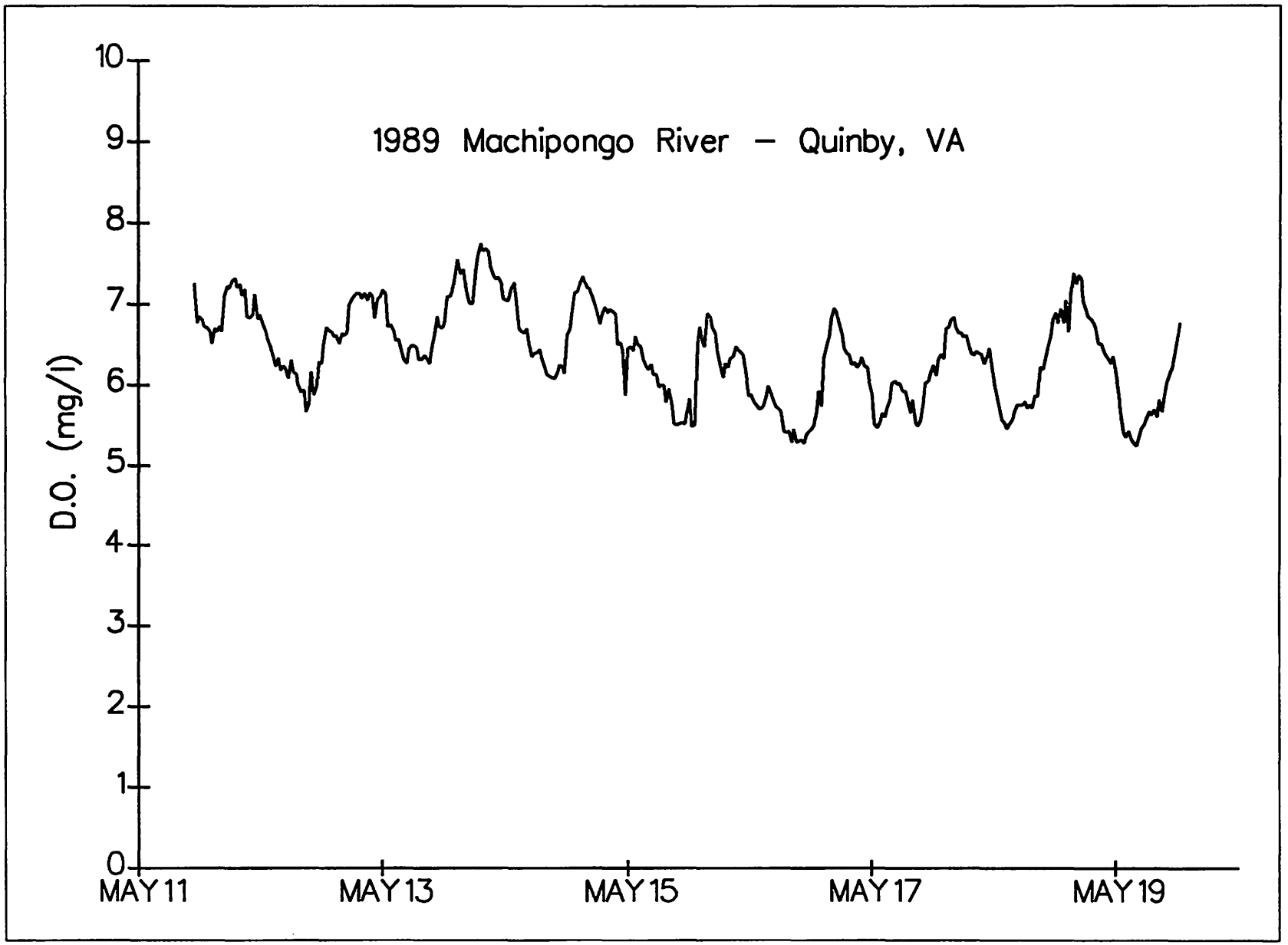
1989 Machipongo River – Quinby, VA
D.O. (mg/l)
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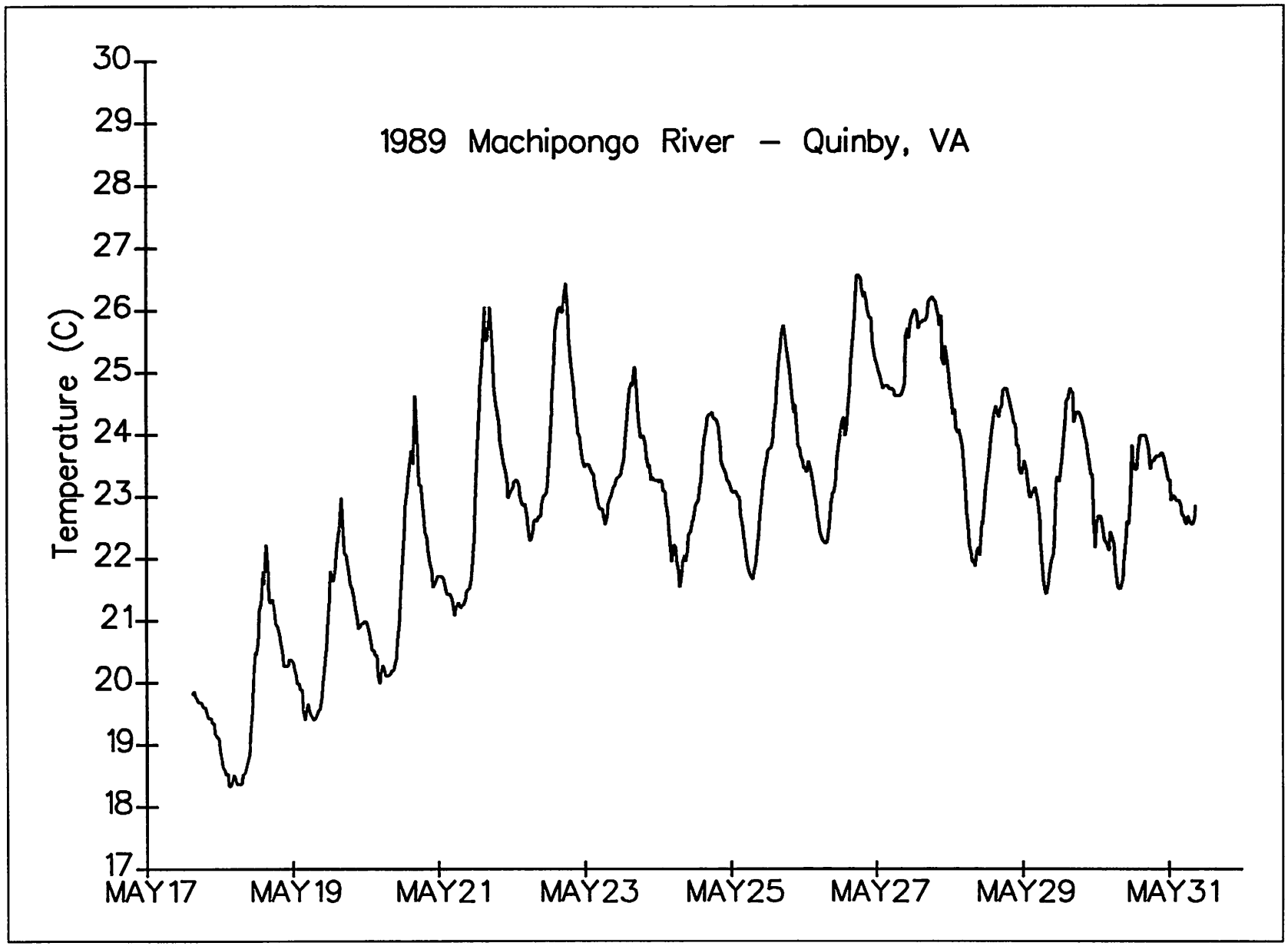
1989 Machipongo River – Quinby, VA
Temperature (C)
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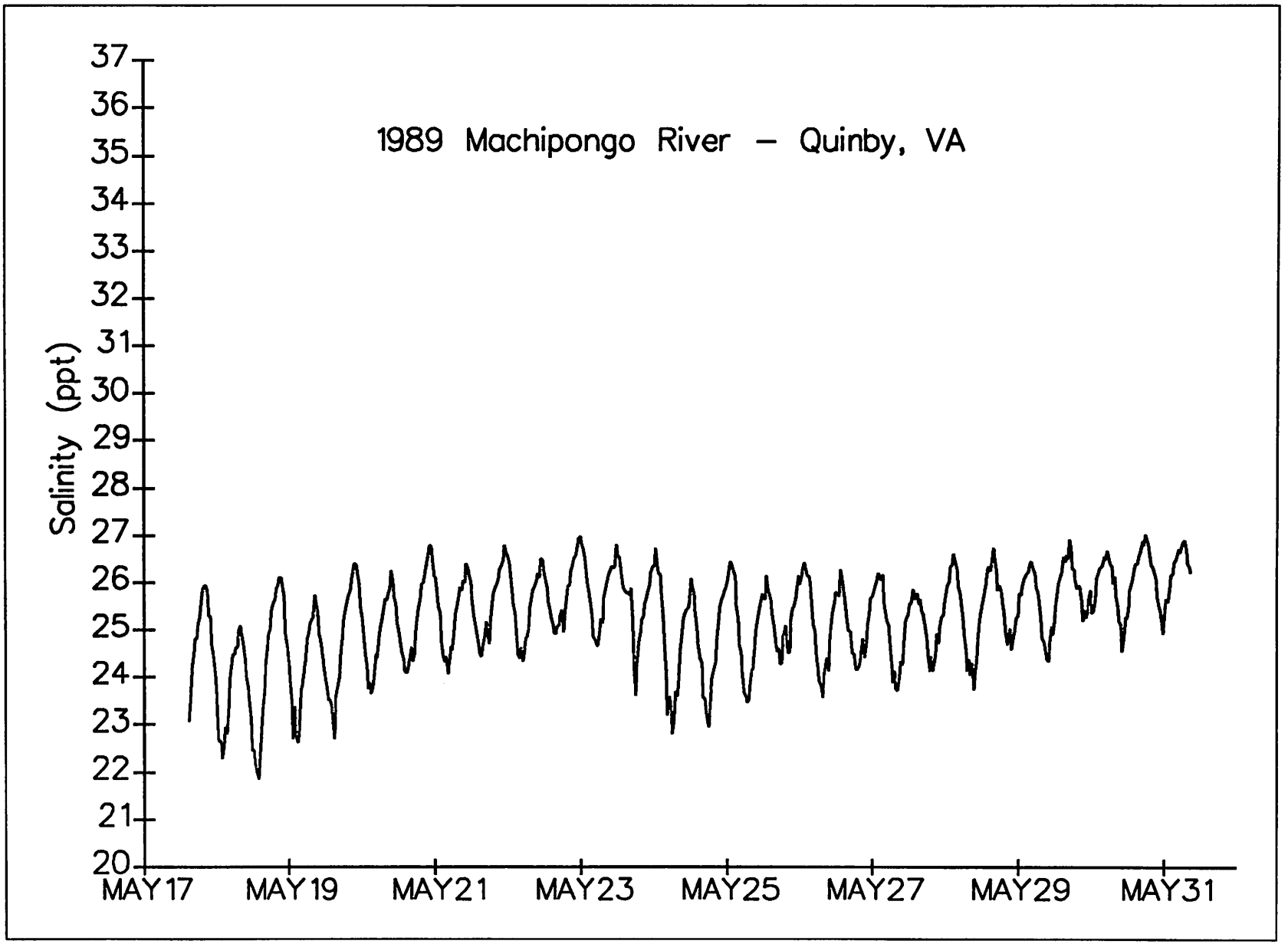
1989 Machipongo River – Quinby, VA
Salinity (ppt)
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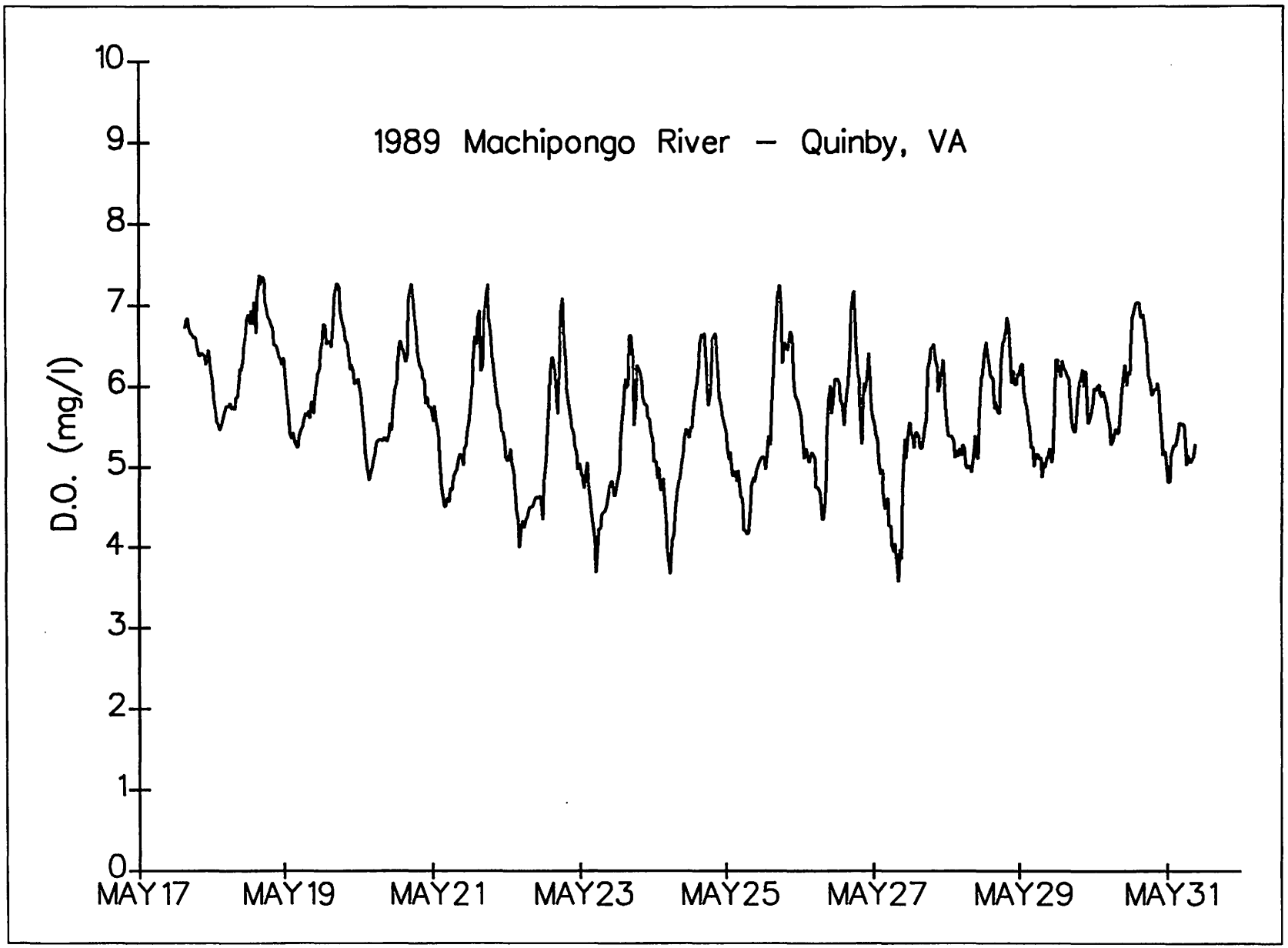
1989 Machipongo River – Quinby, VA
D.O. (mg/l)
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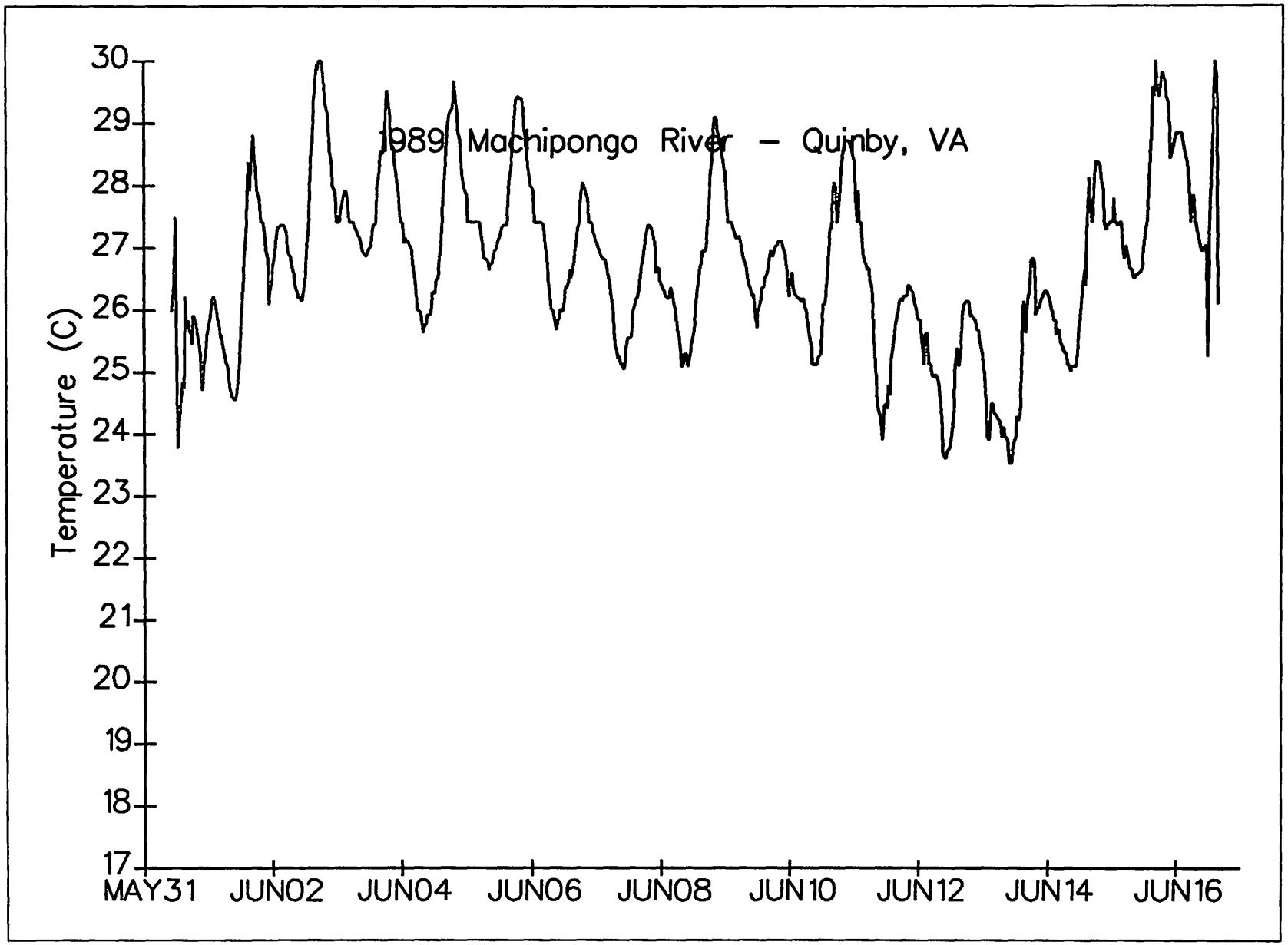
1989 Machipongo River – Quinby, VA
Temperature (C)
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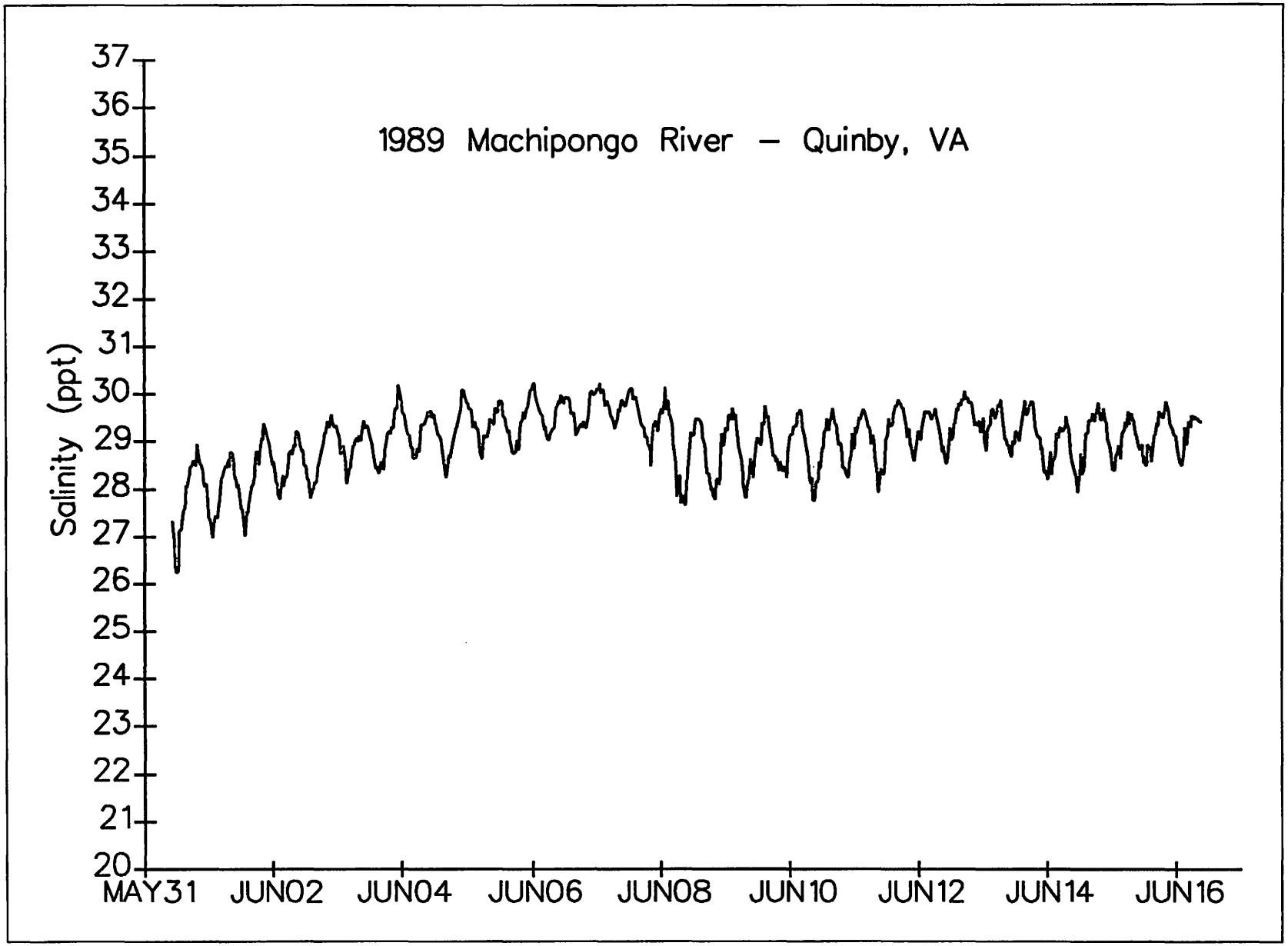
1989 Machipongo River – Quinby, VA
Salinity (ppt)
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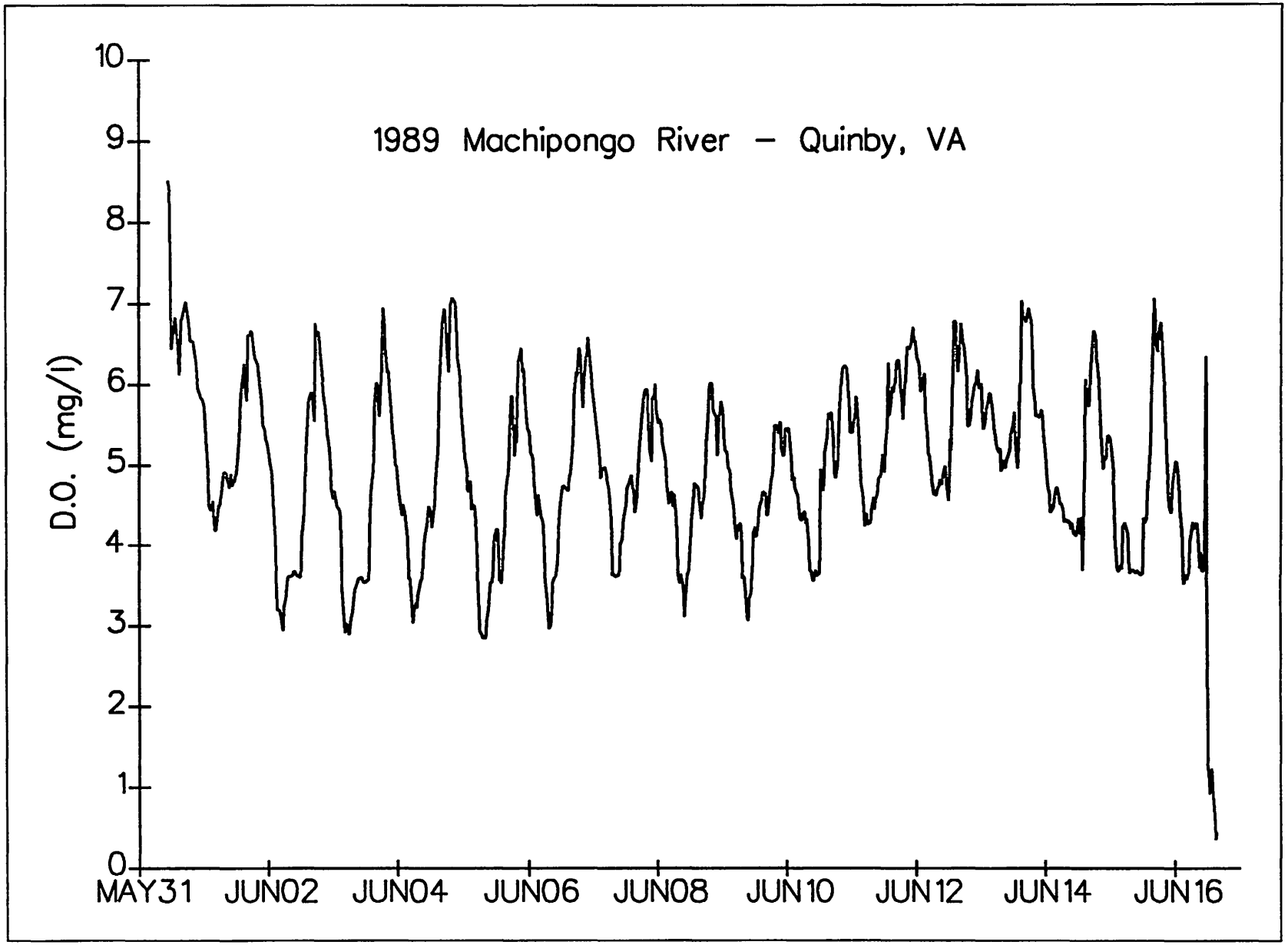
1989 Machipongo River – Quinby, VA
D.O. (mg/l)
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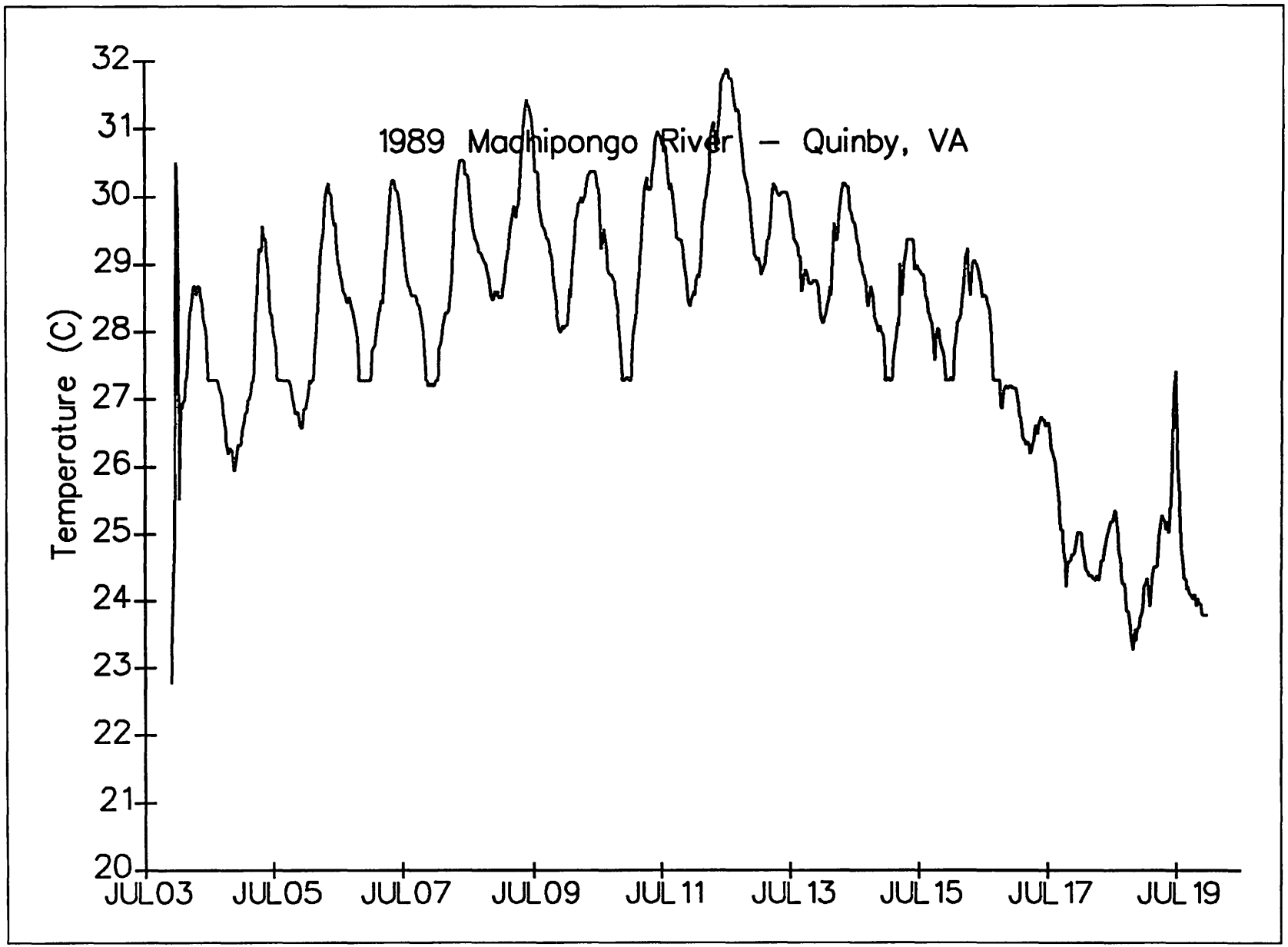
1989 Machipongo River – Quinby, VA
Temperature (C)
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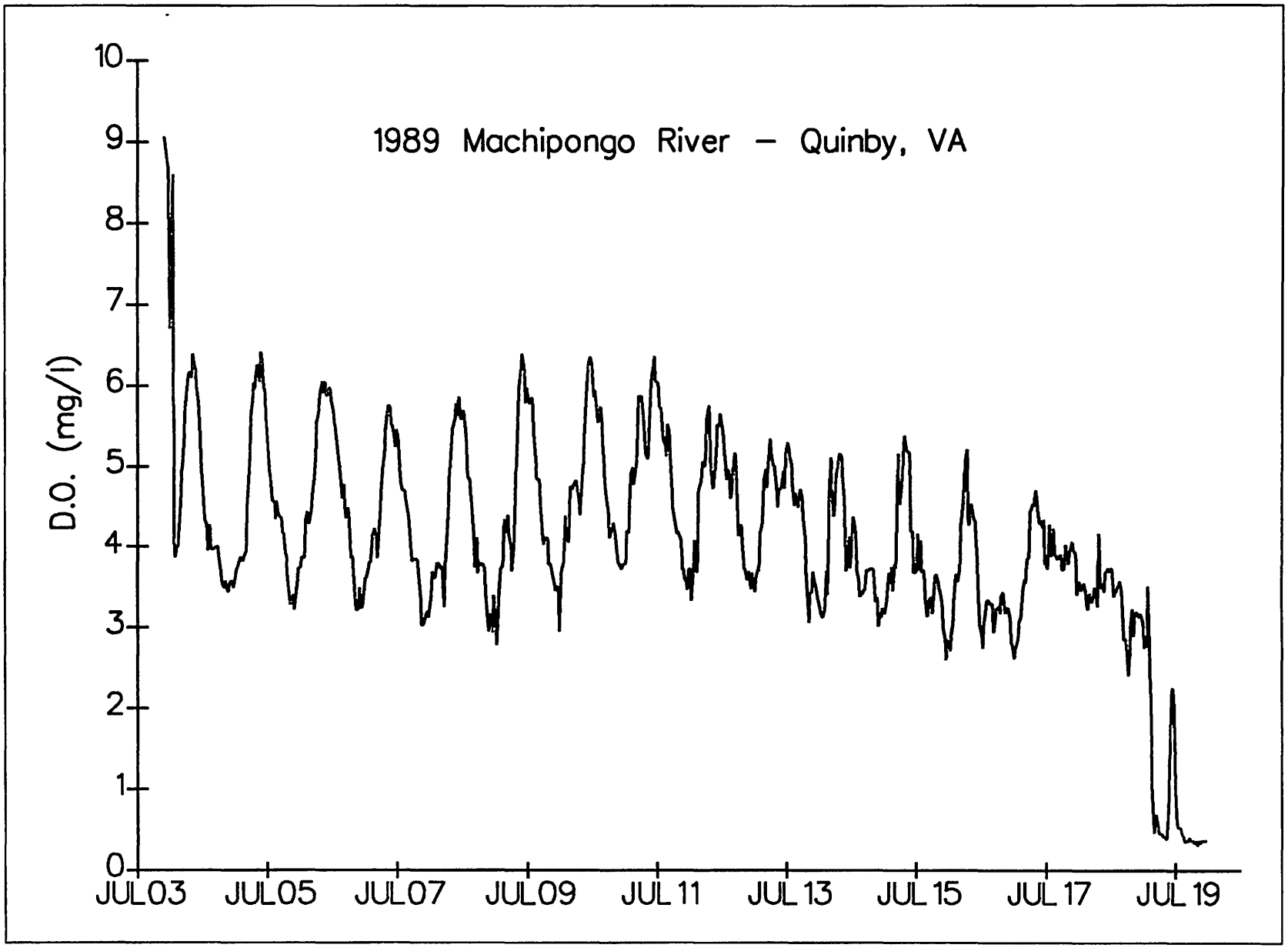
1989 Machipongo River – Quinby, VA
D.O. (mg/l)
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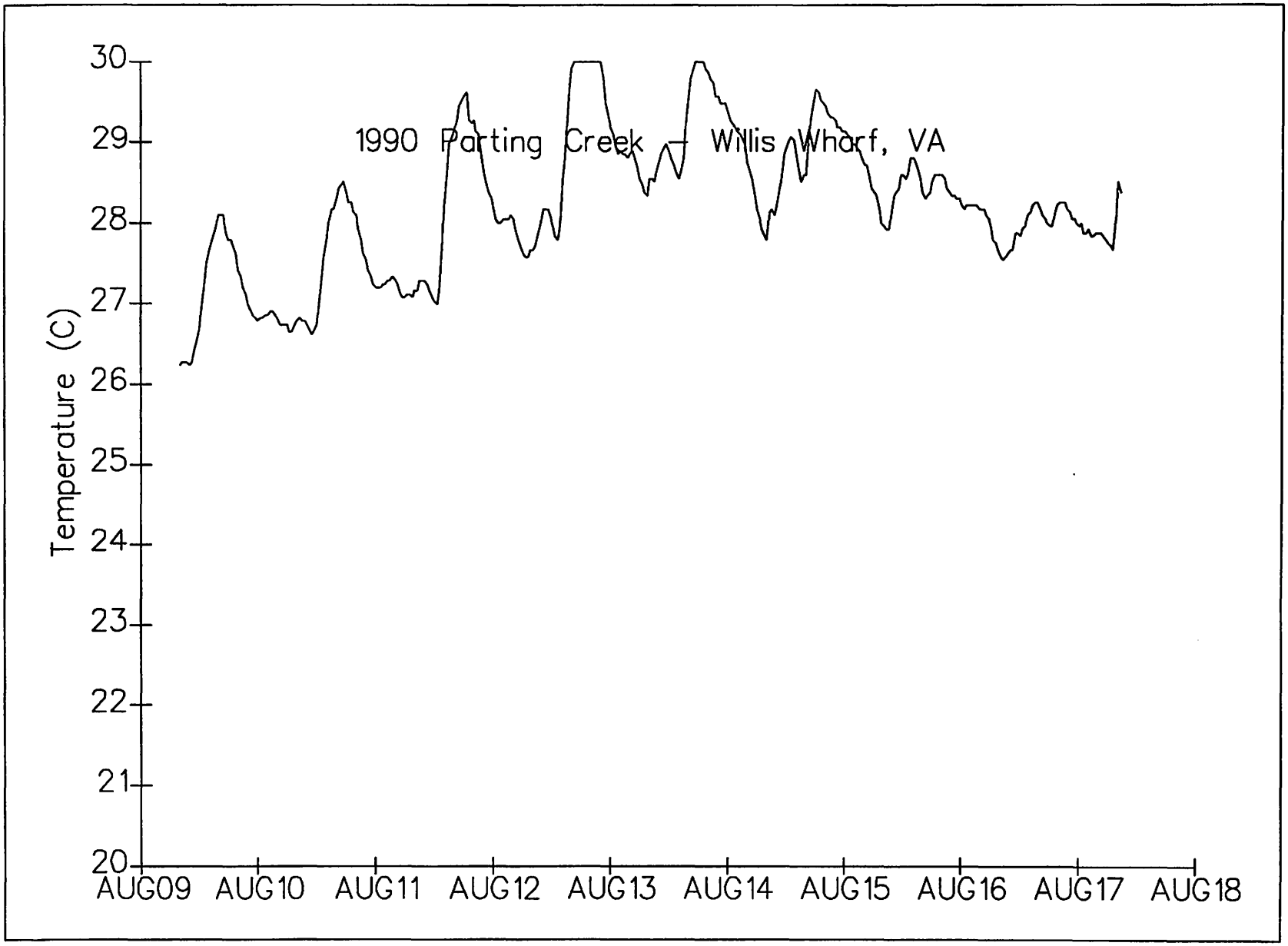
1990 Parting Creek - Willis Wharf, VA
Temperature (C)
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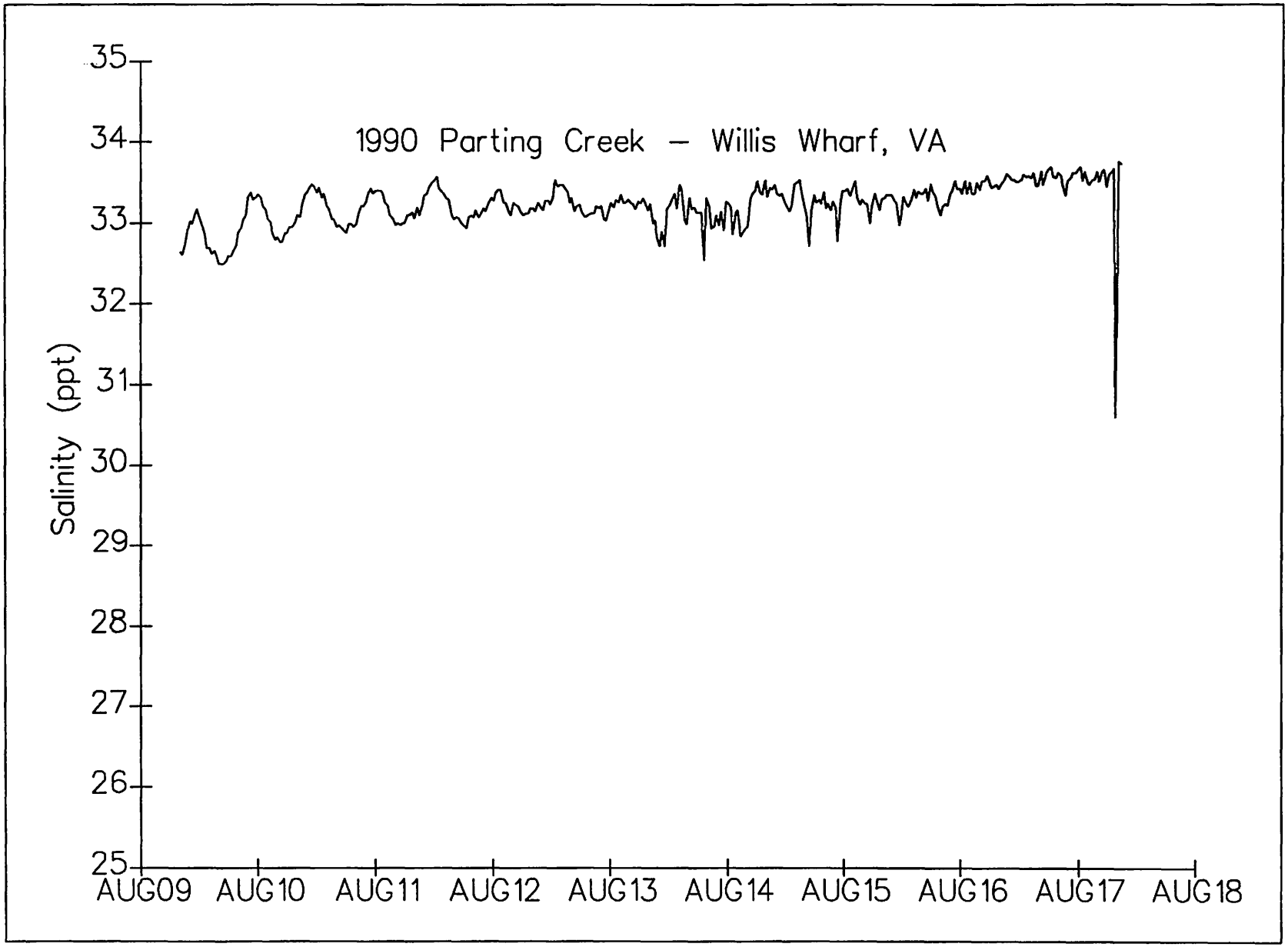
1990 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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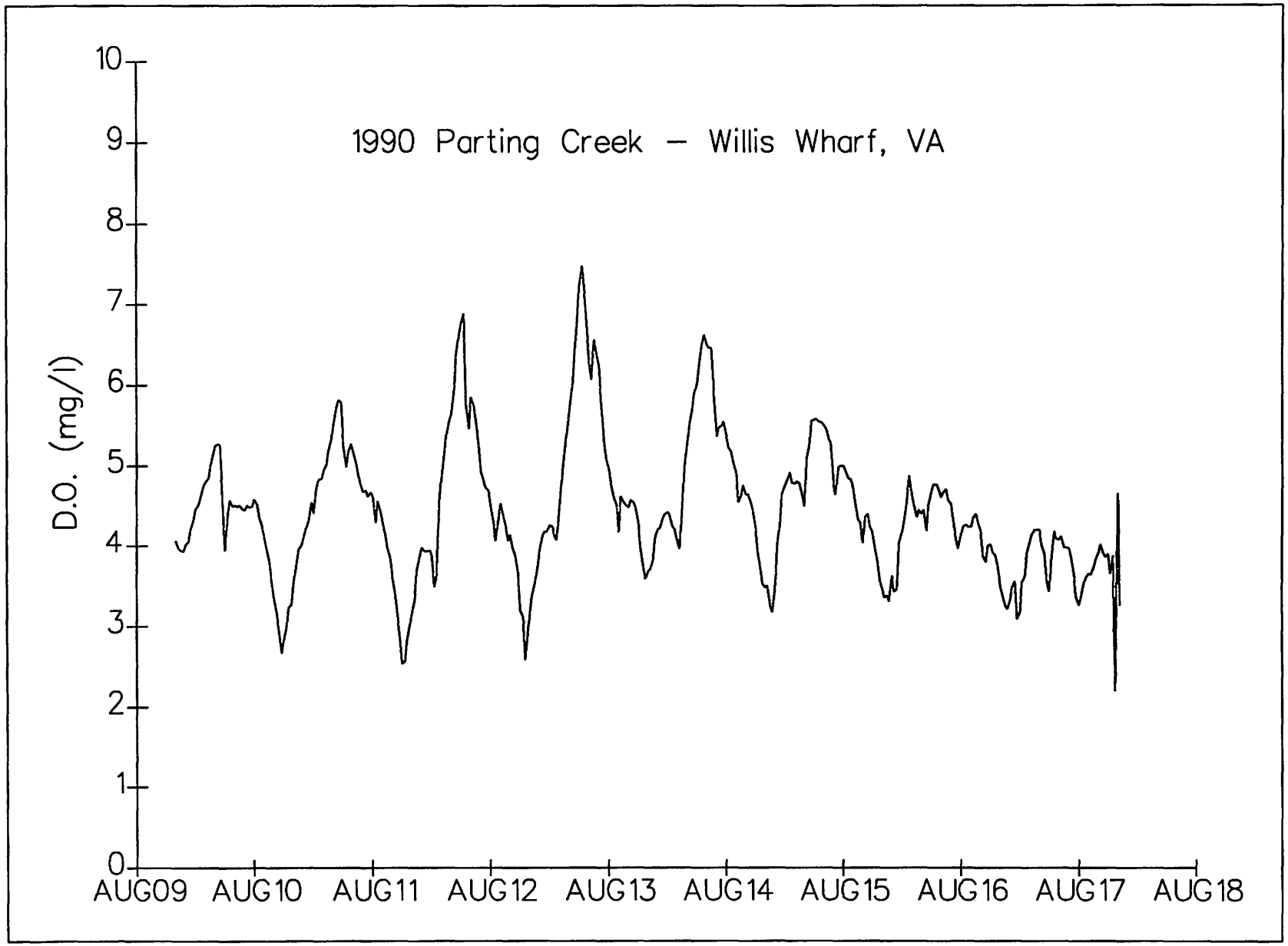
1990 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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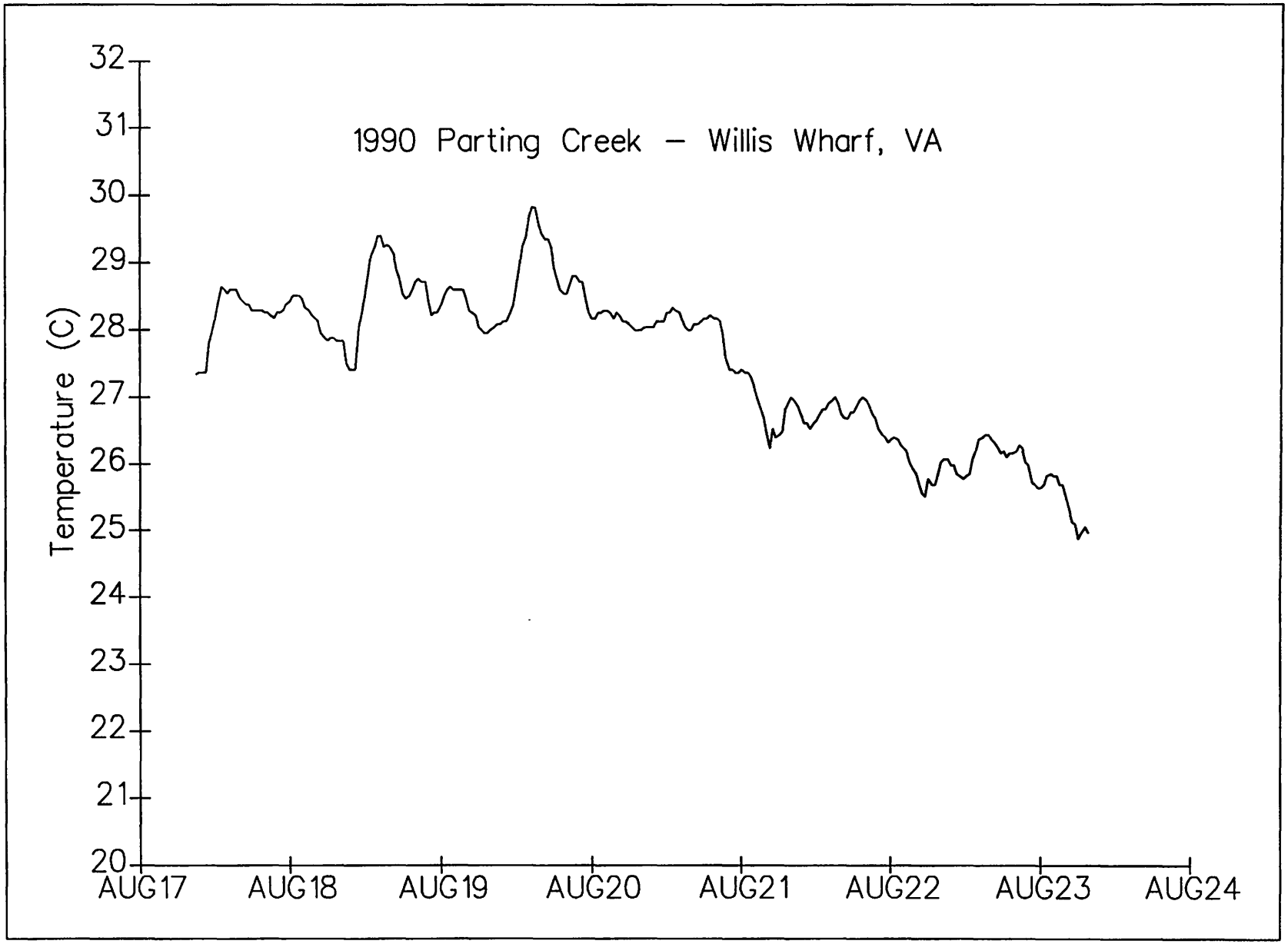
1990 Parting Creek – Willis Wharf, VA
Temperature (C)
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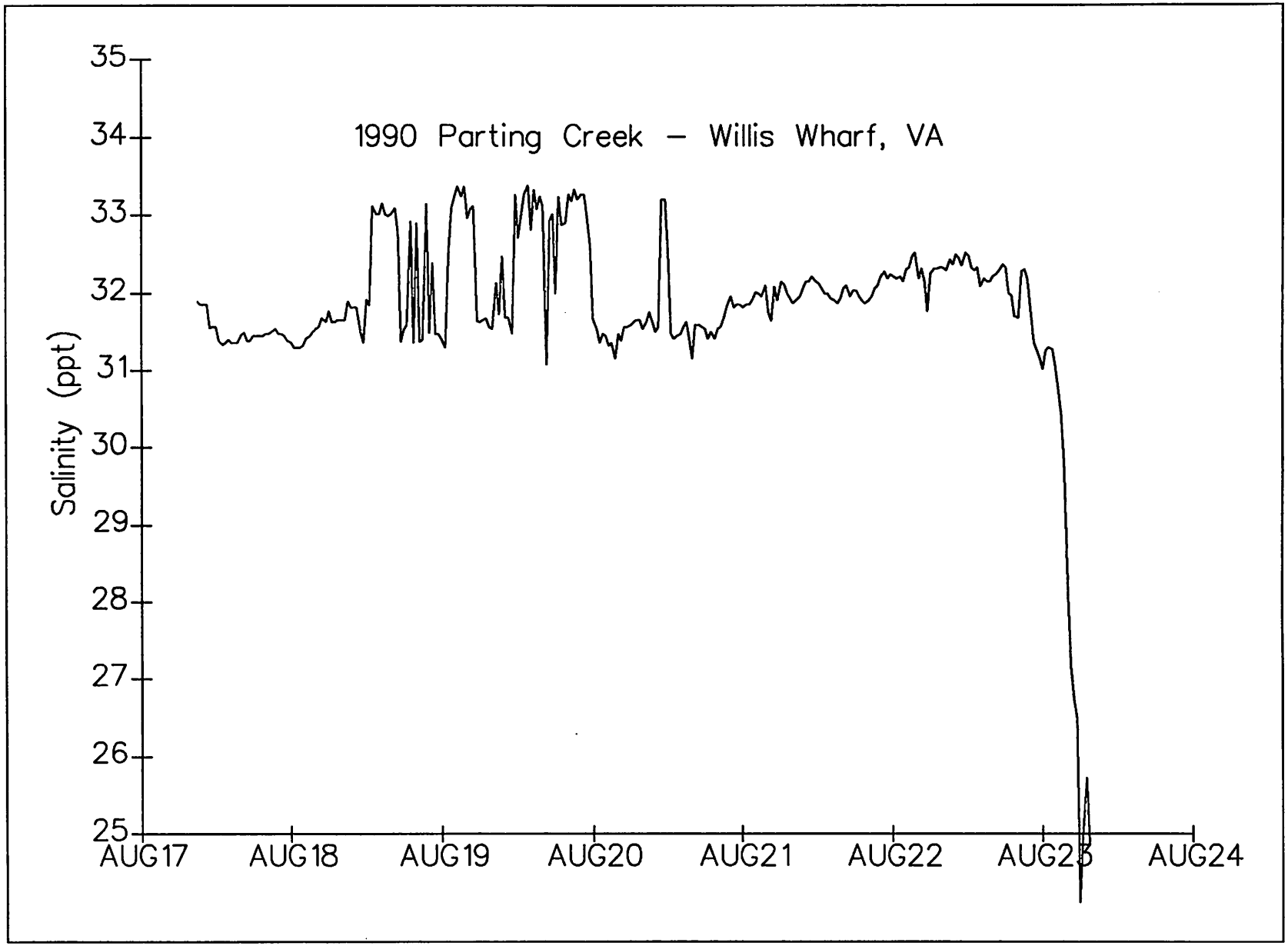
1990 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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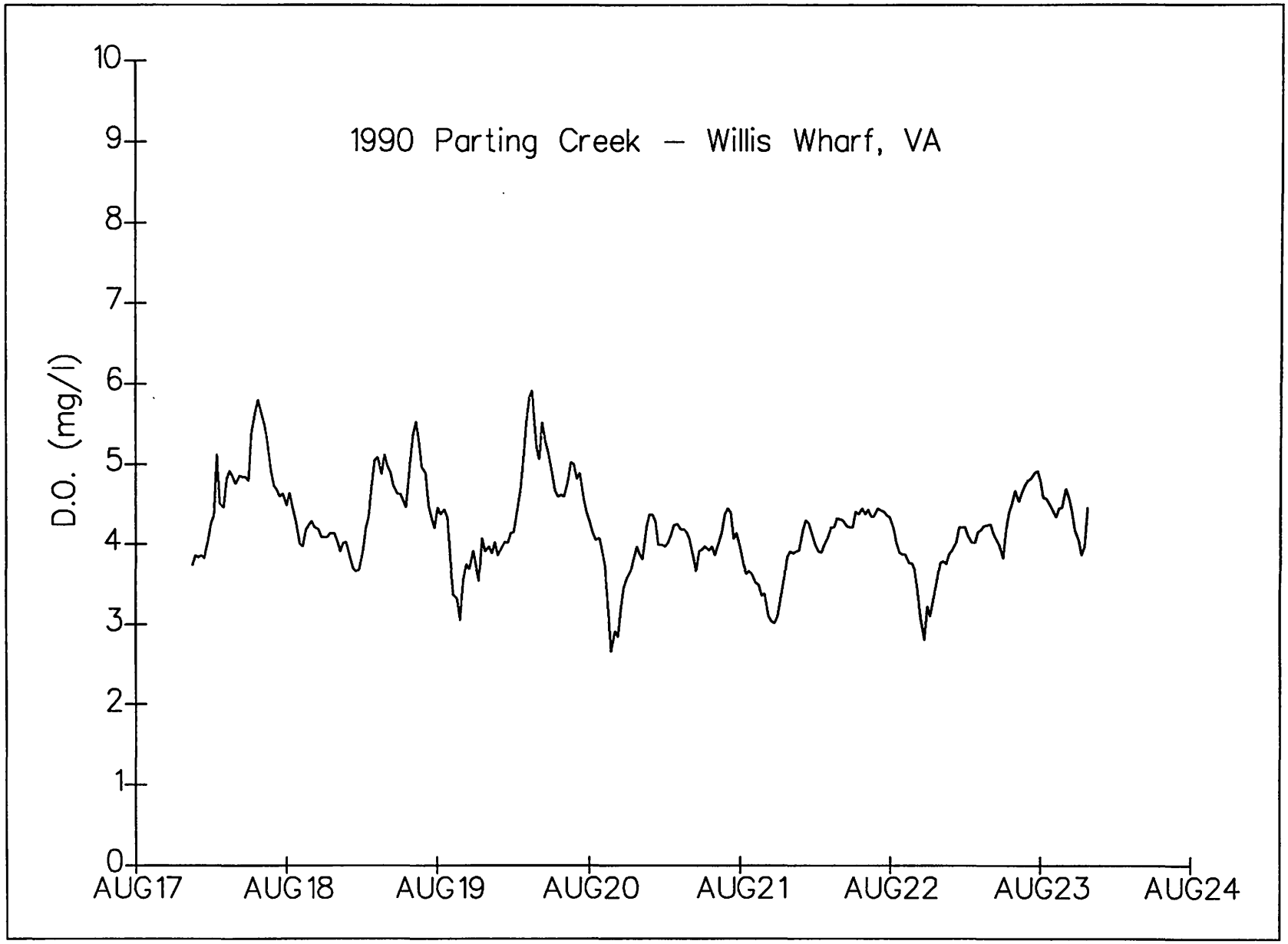
1990 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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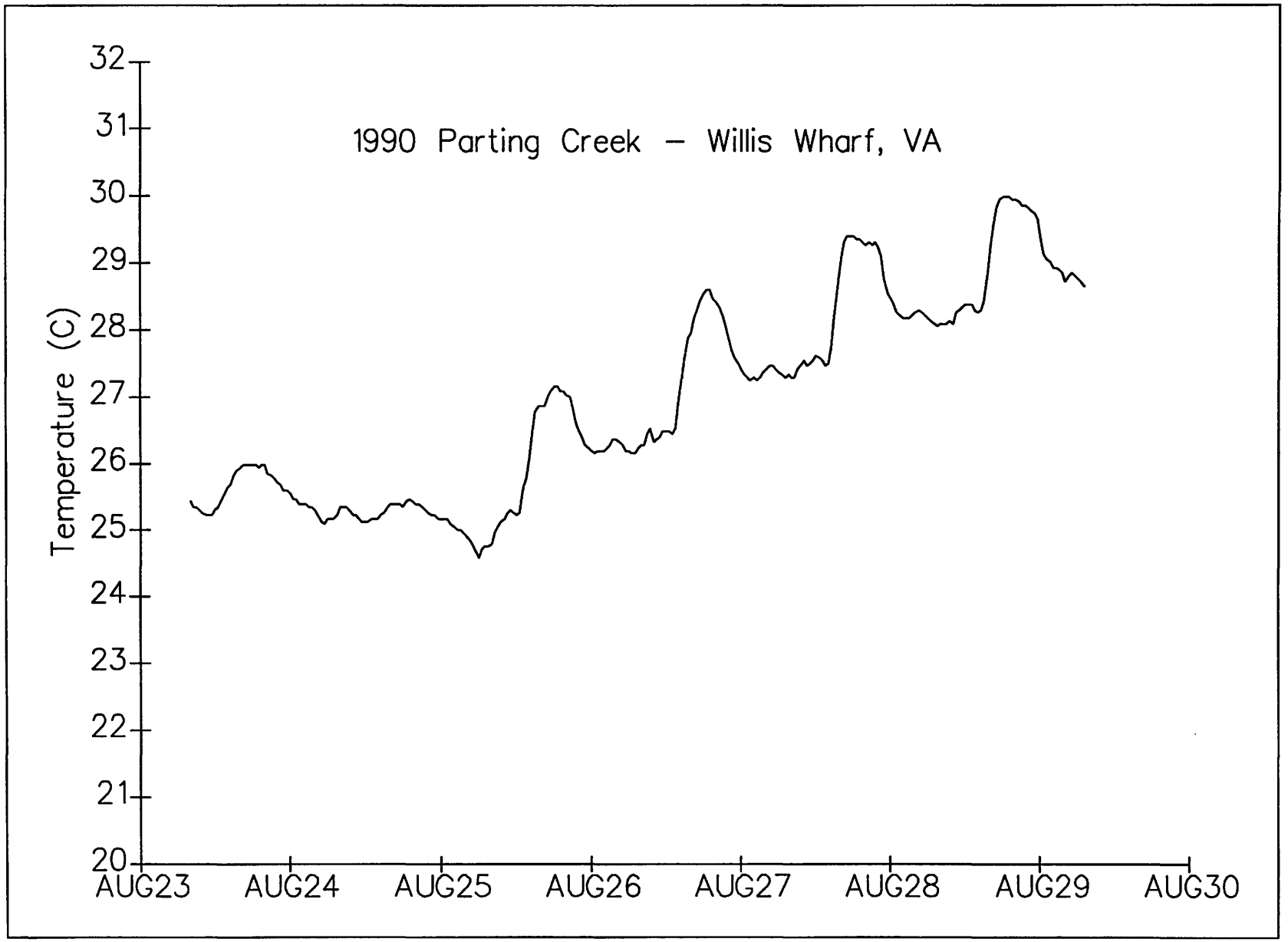
1990 Parting Creek – Willis Wharf, VA
Temperature (C)
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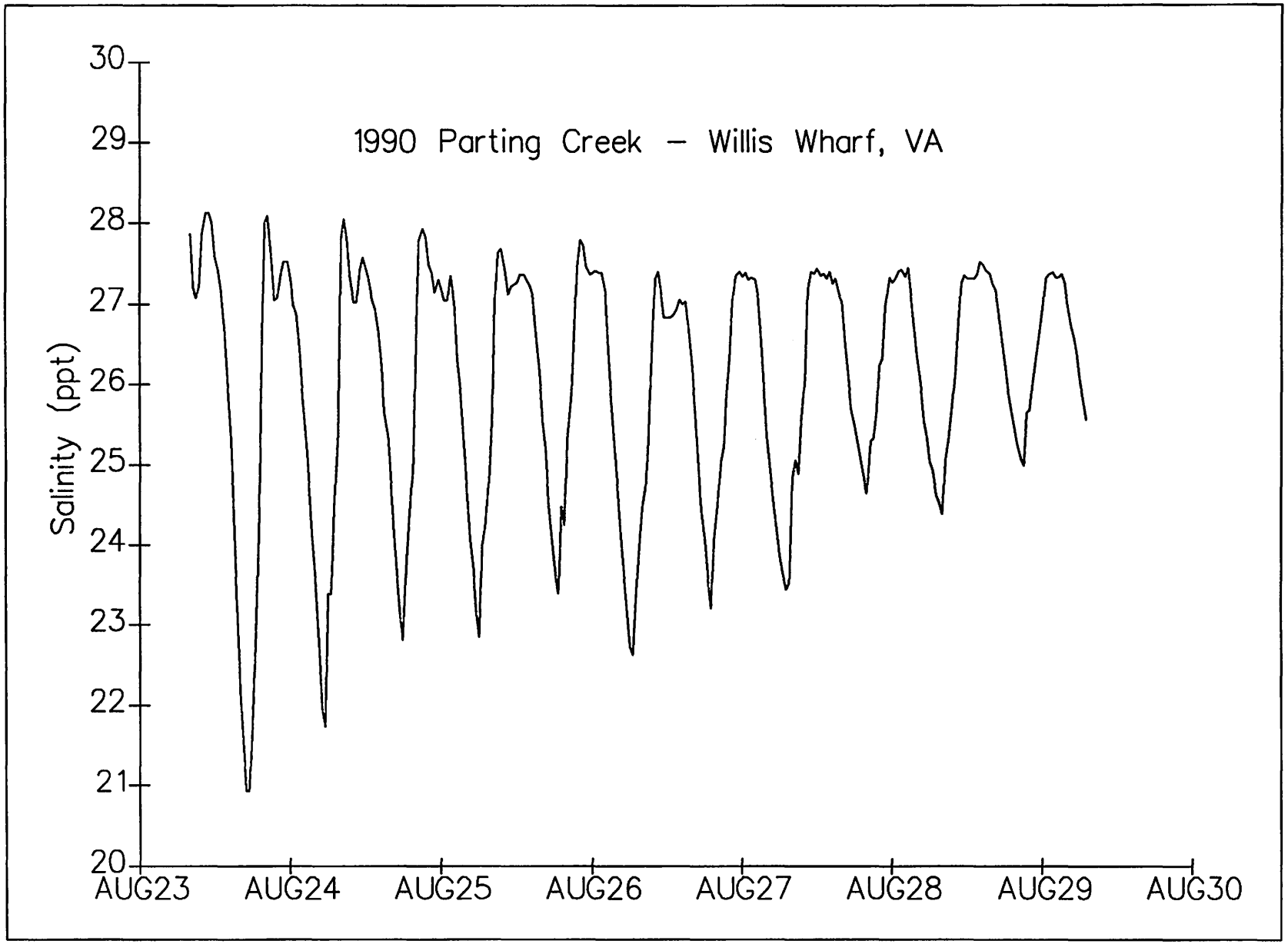
1990 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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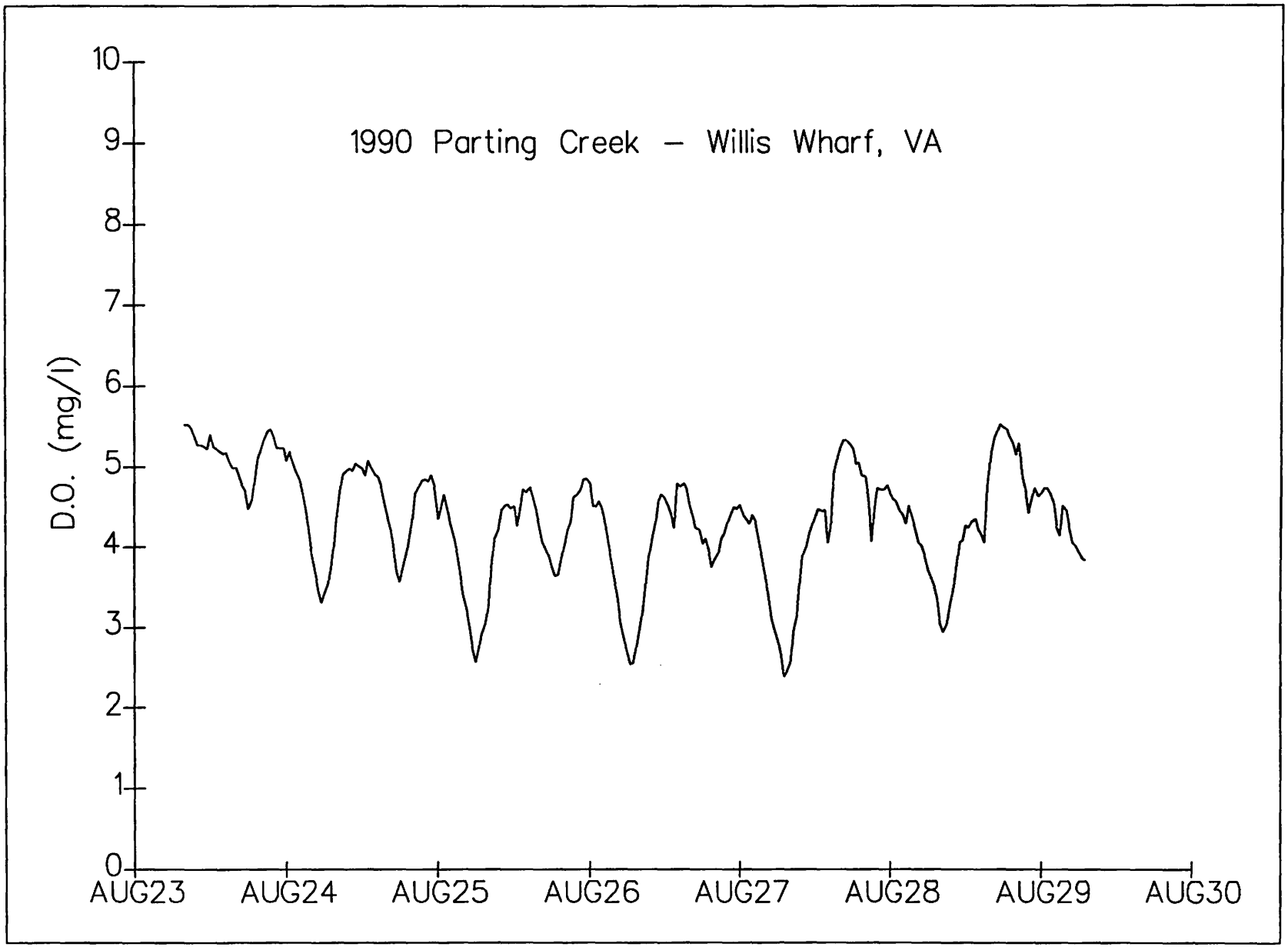
1990 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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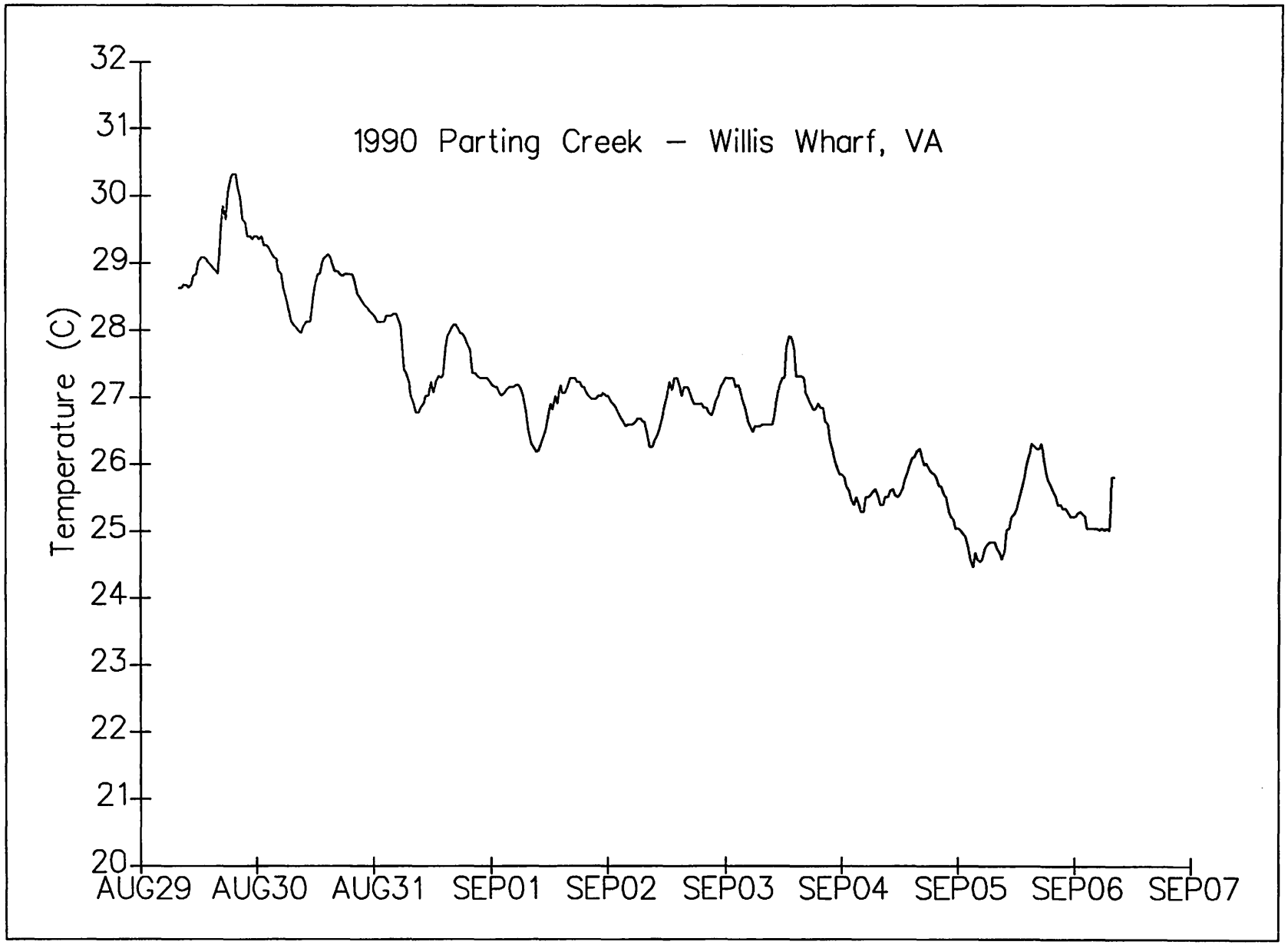
1990 Parting Creek – Willis Wharf, VA
Temperature (C)
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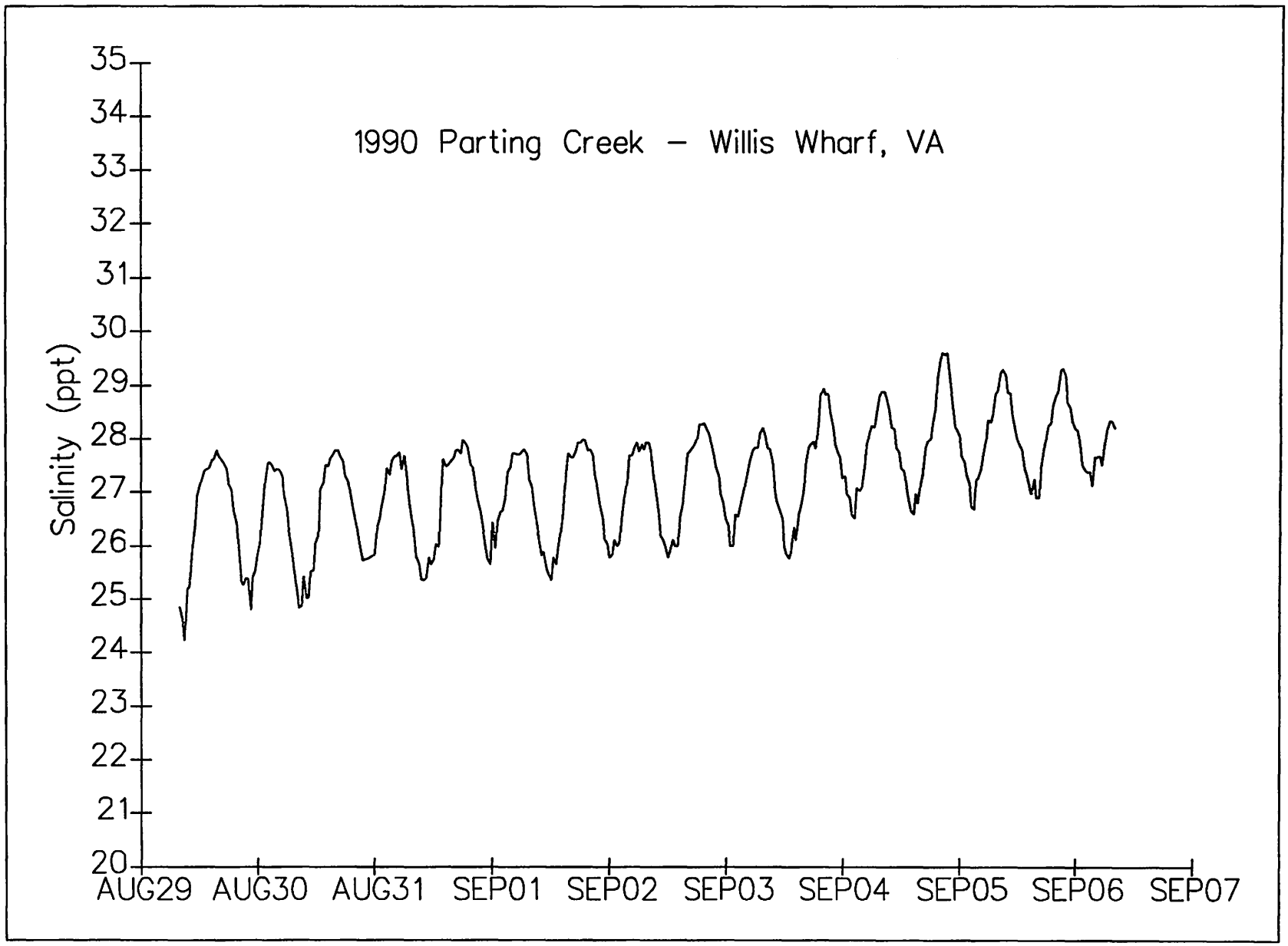
1990 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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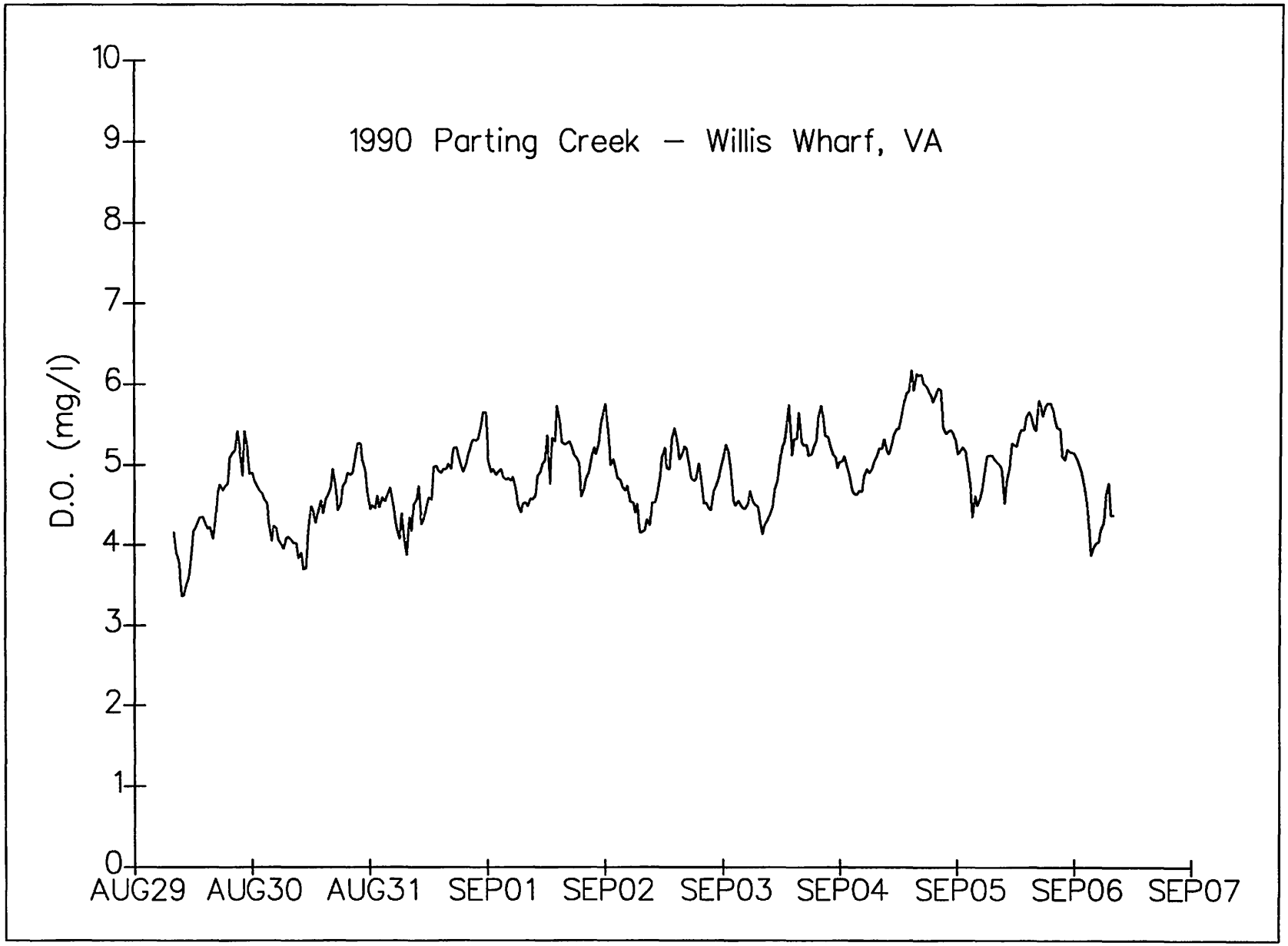
1990 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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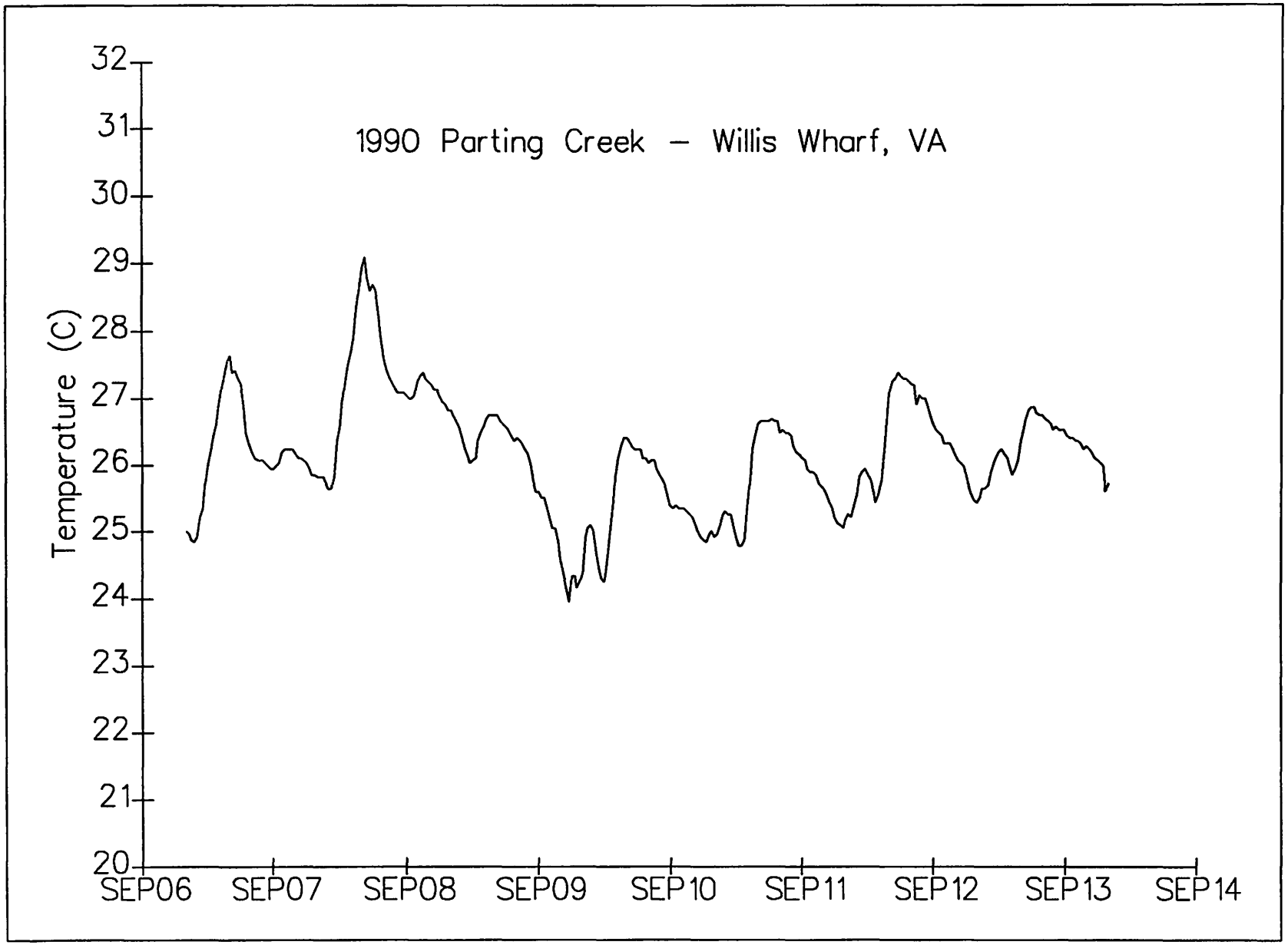
1990 Parting Creek – Willis Wharf, VA
Temperature (C)
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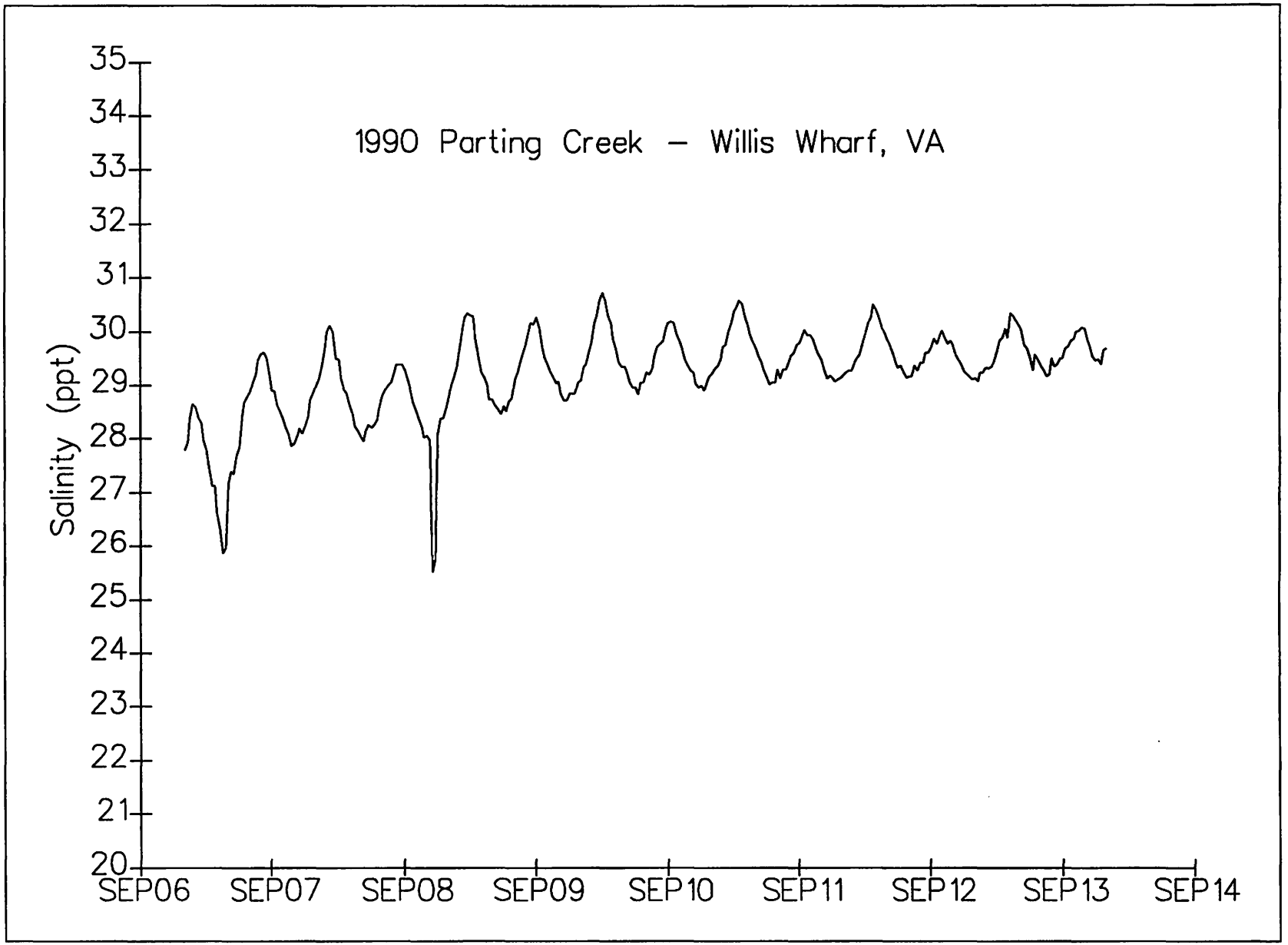
1990 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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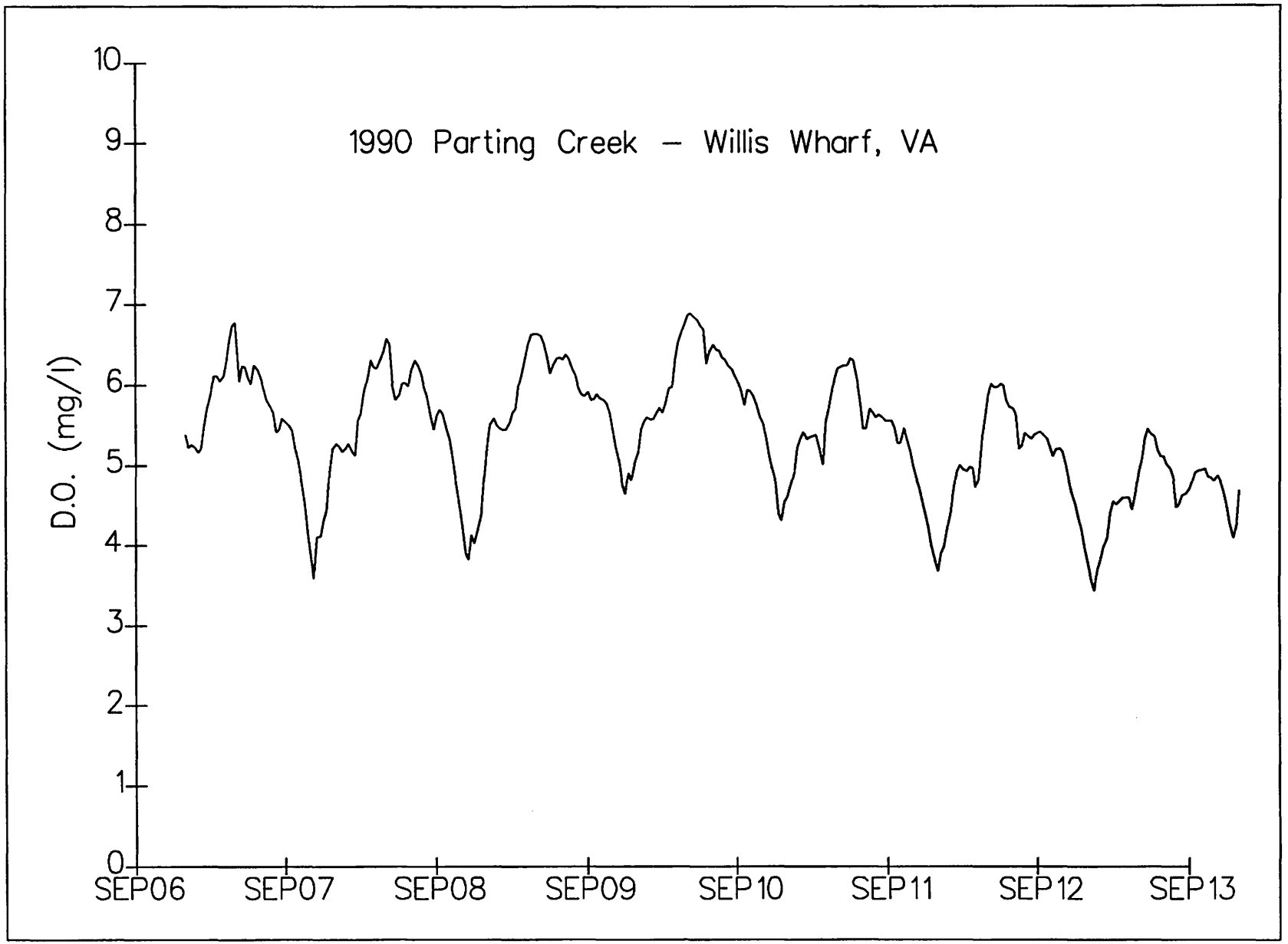
1990 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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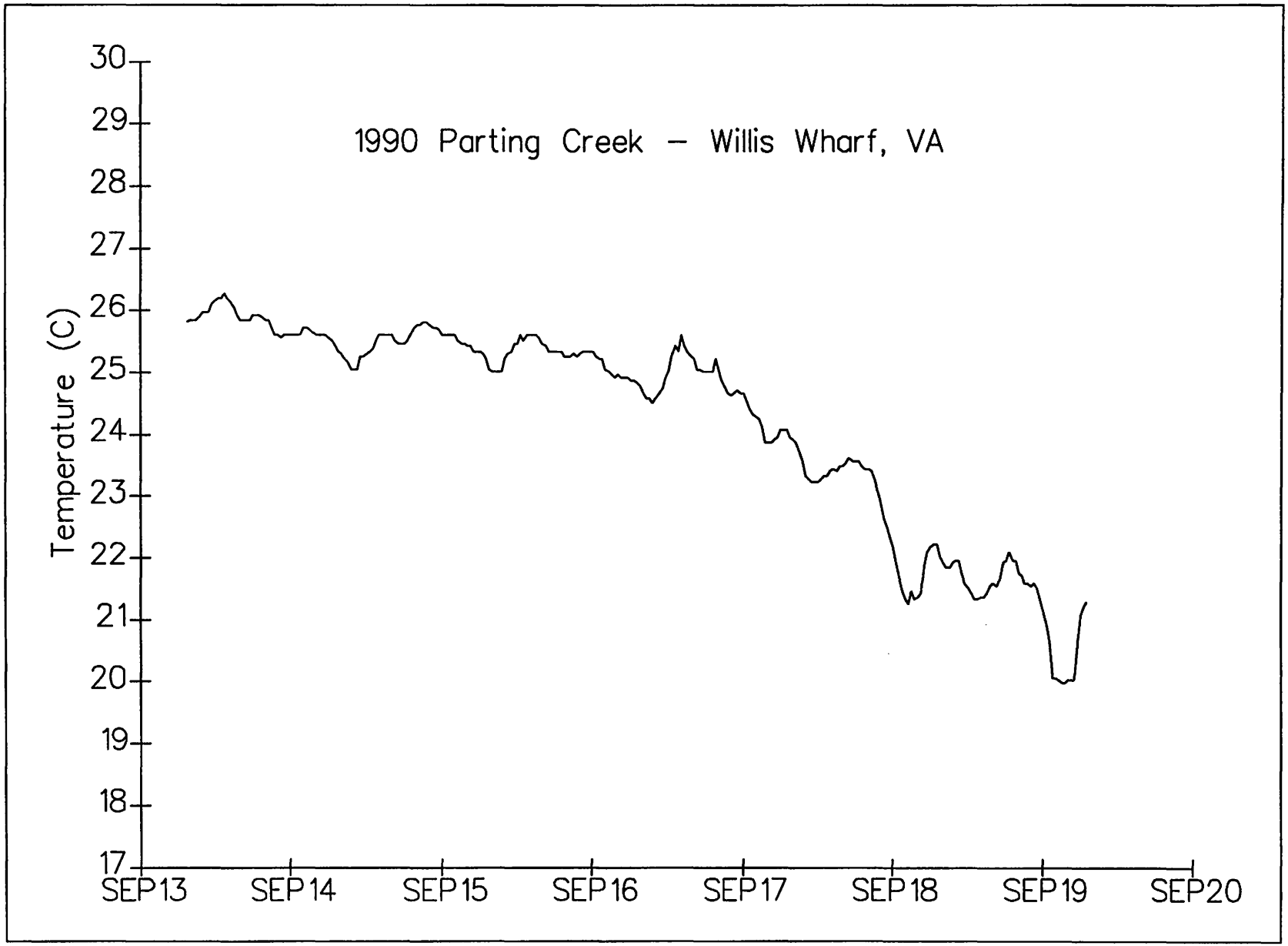
1990 Parting Creek – Willis Wharf, VA
Temperature (C)
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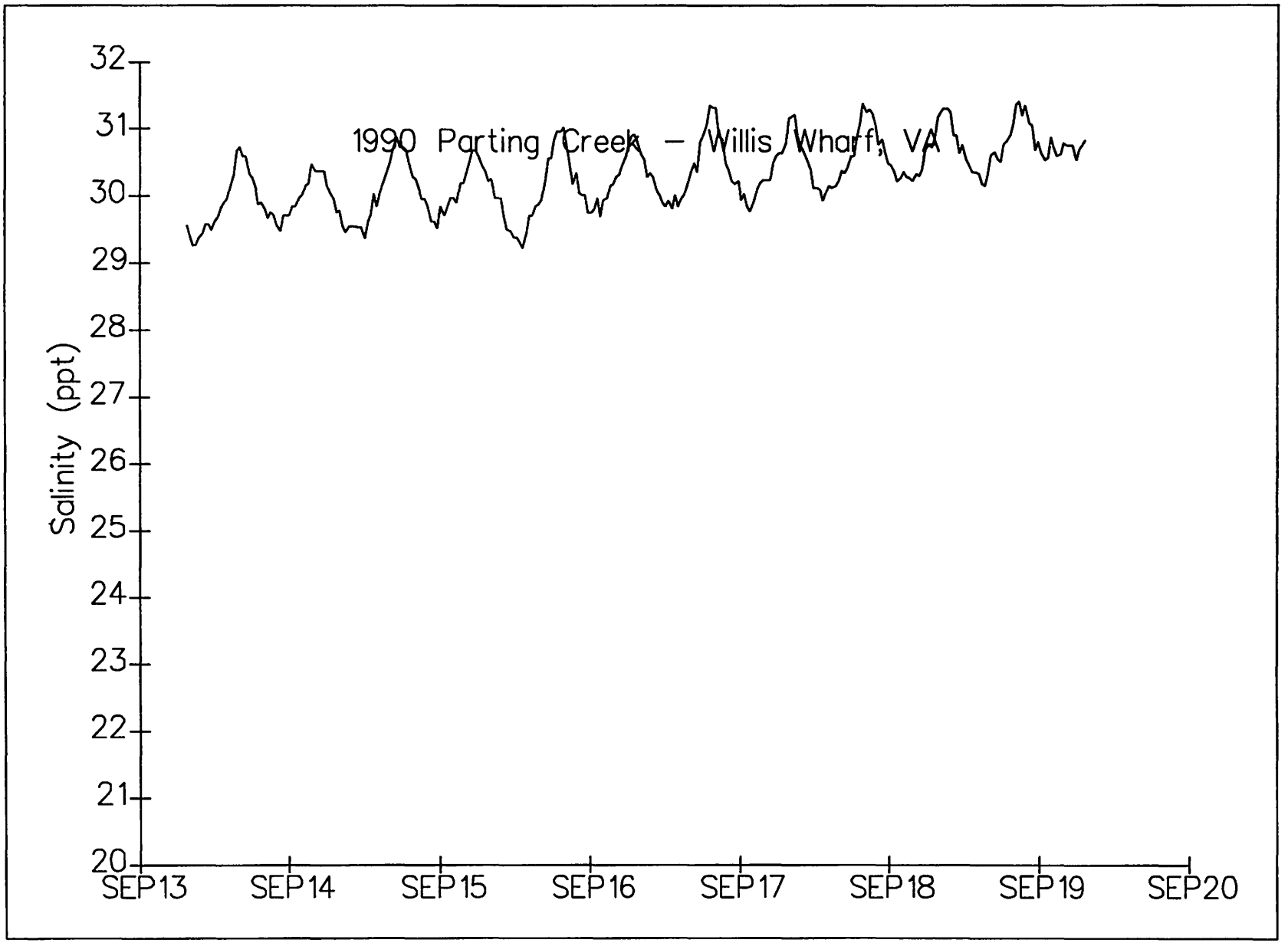
1990 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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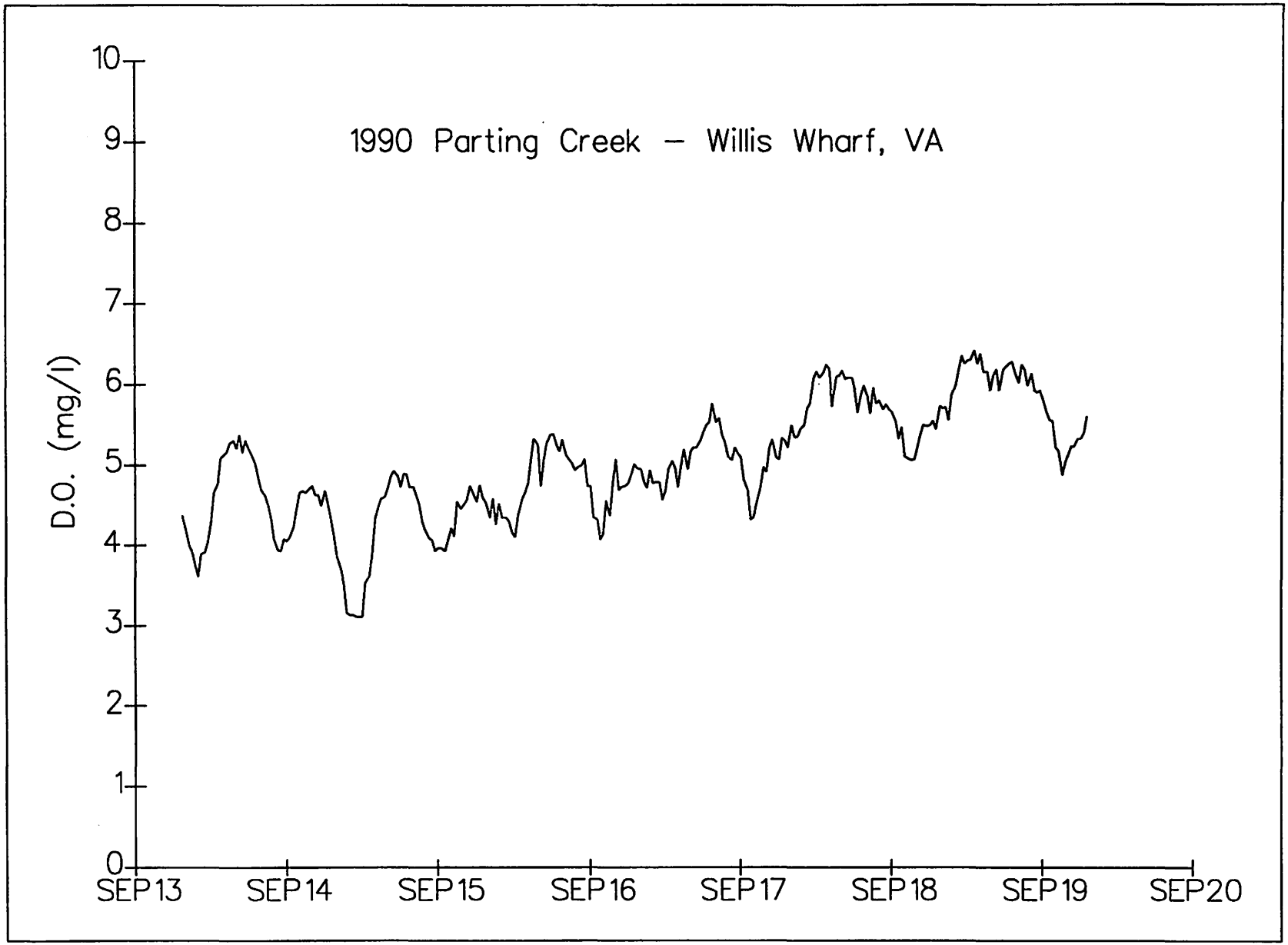
1990 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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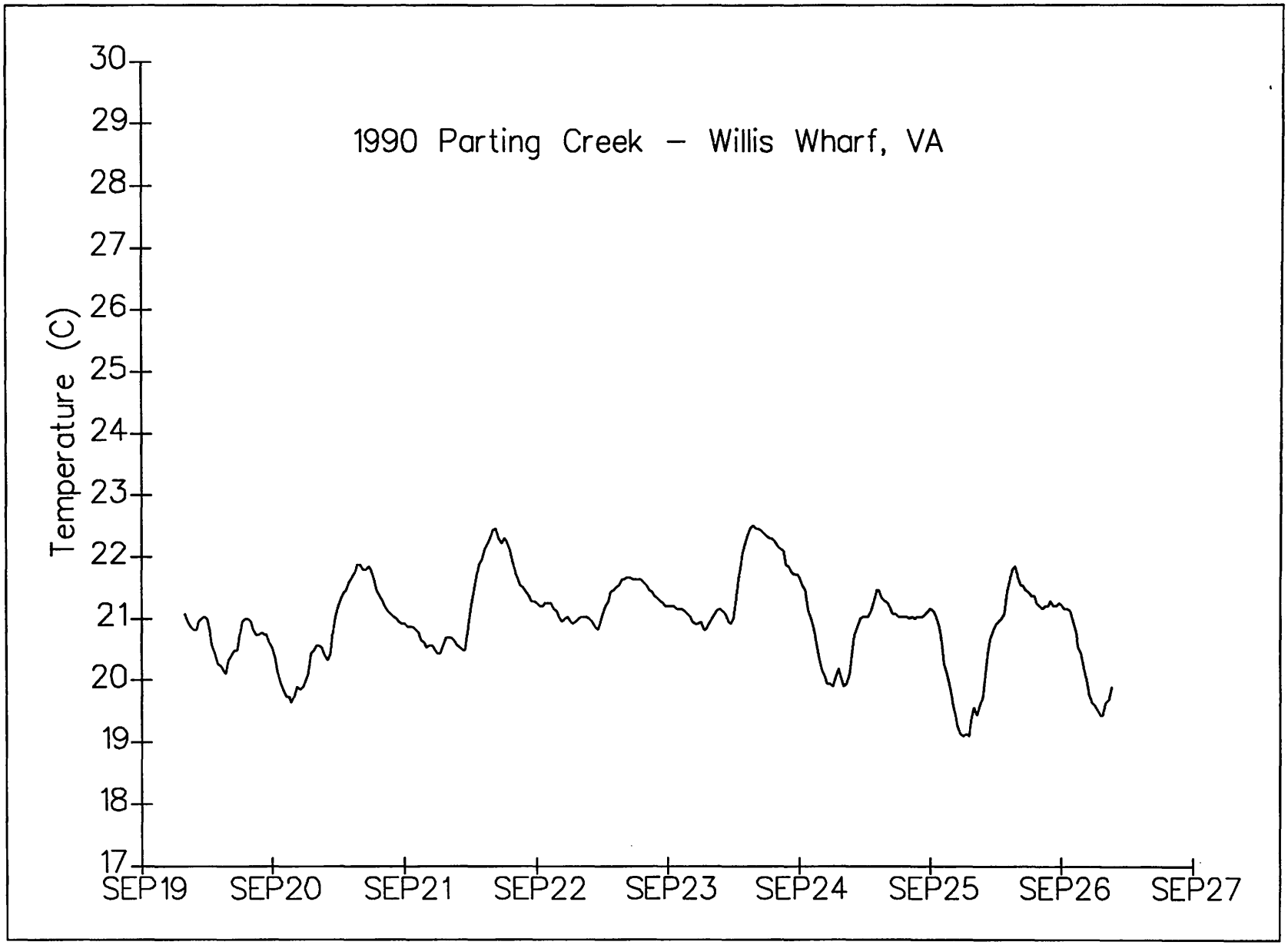
1990 Parting Creek – Willis Wharf, VA
Temperature (C)
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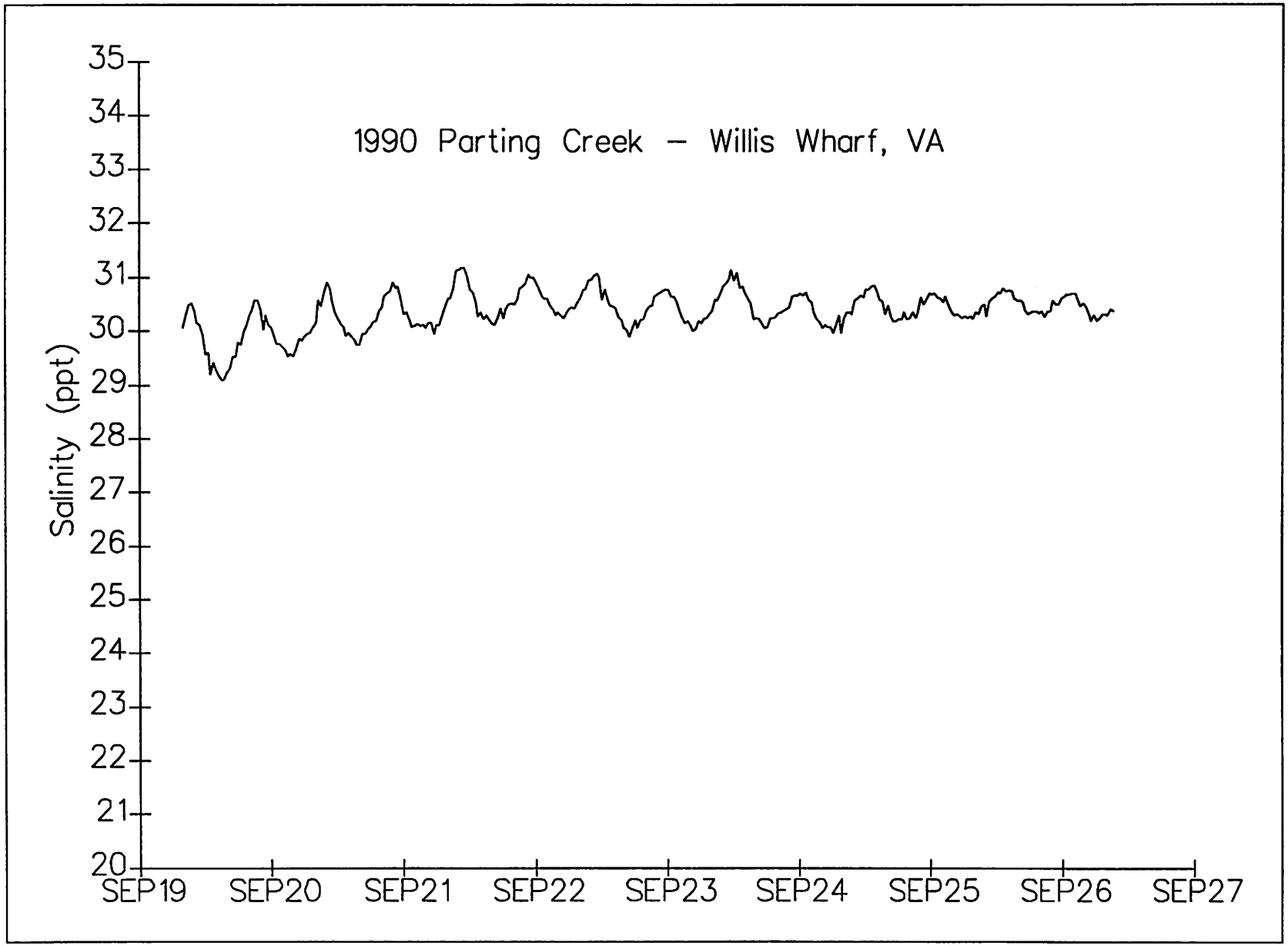
1990 Parting Creek – Willis Wharf, VA
Salinity (ppt)
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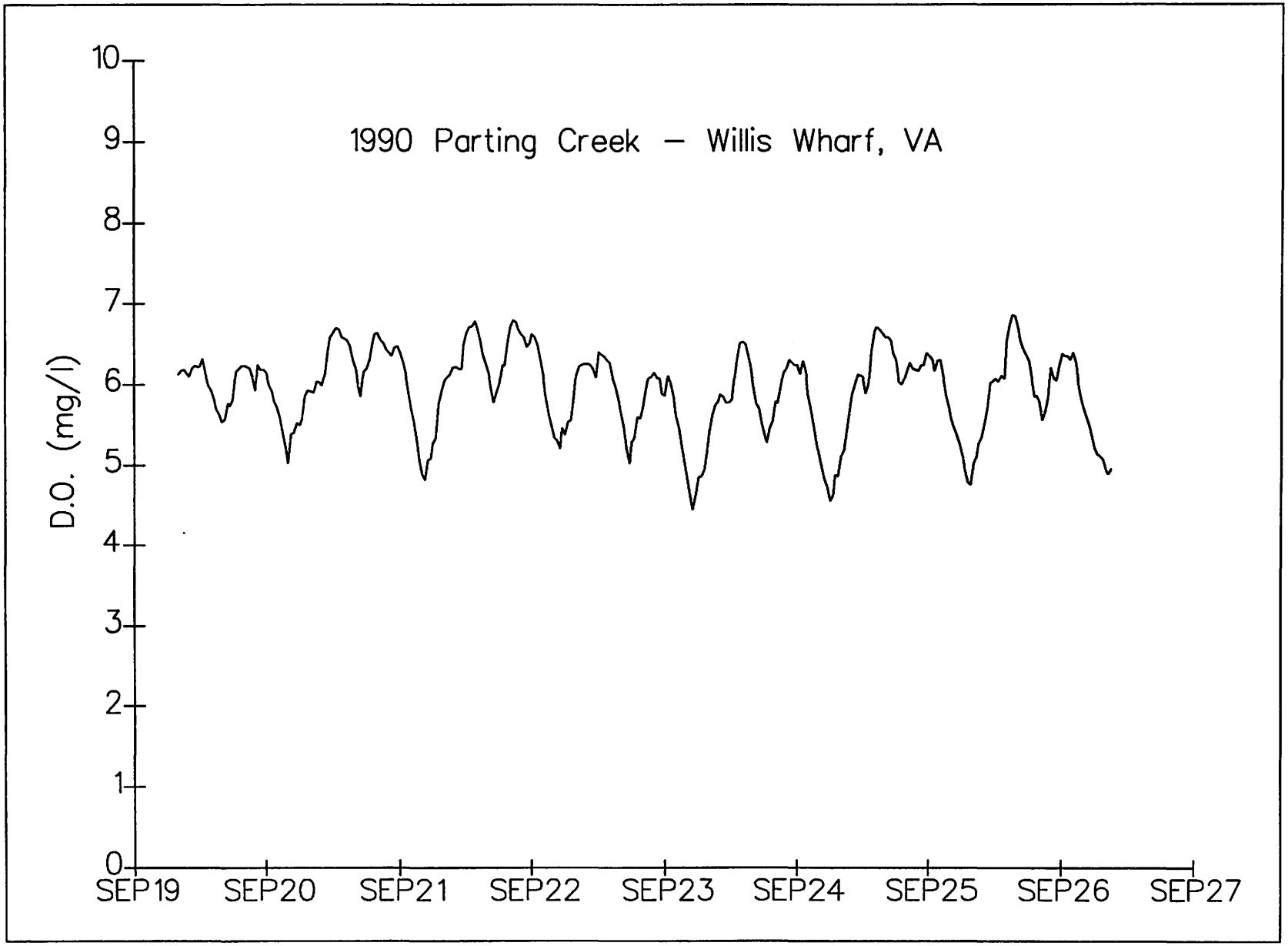
1990 Parting Creek – Willis Wharf, VA
D.O. (mg/l)
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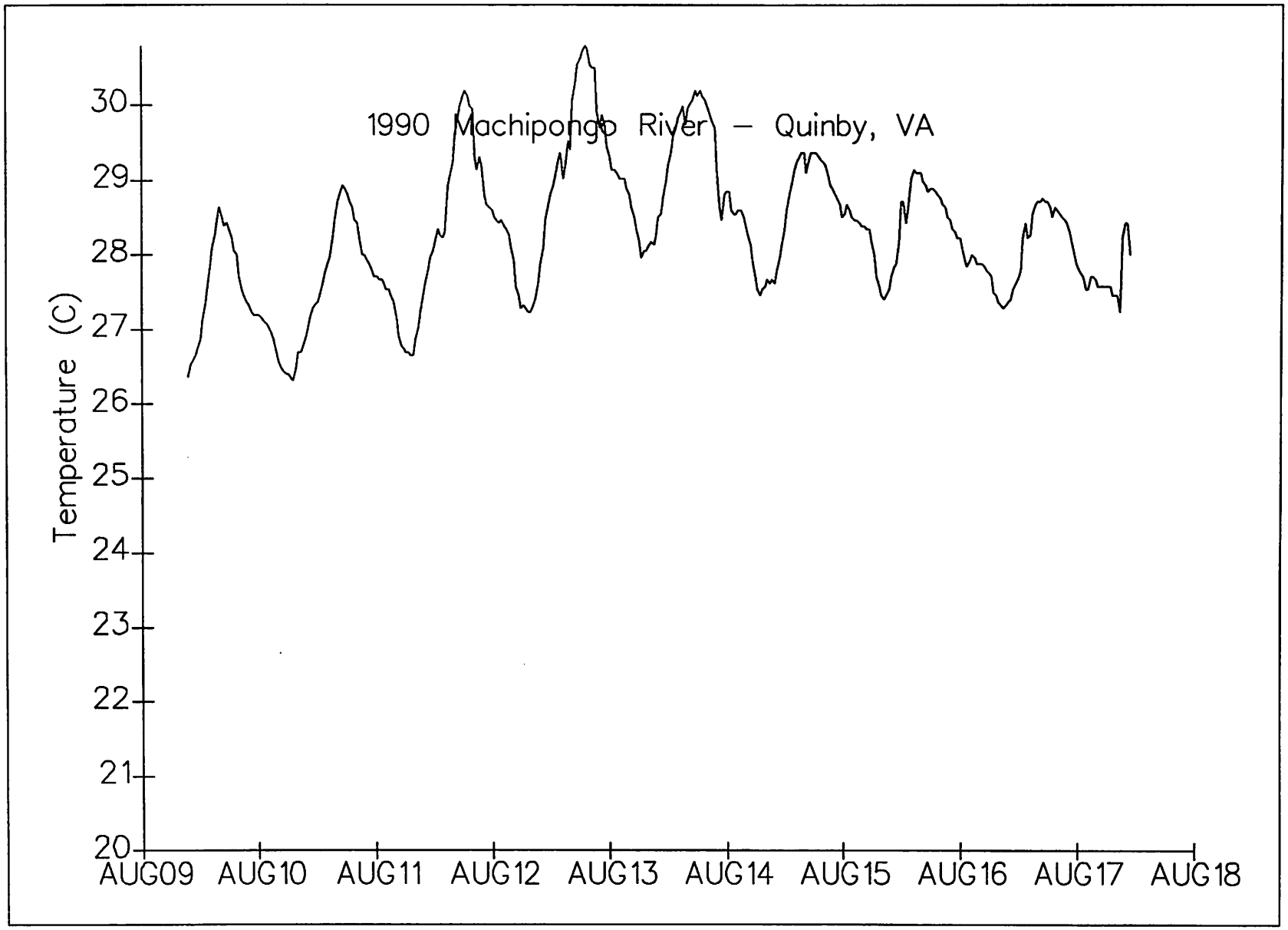
1990 Machipongo River – Quinby, VA
Temperature (C)
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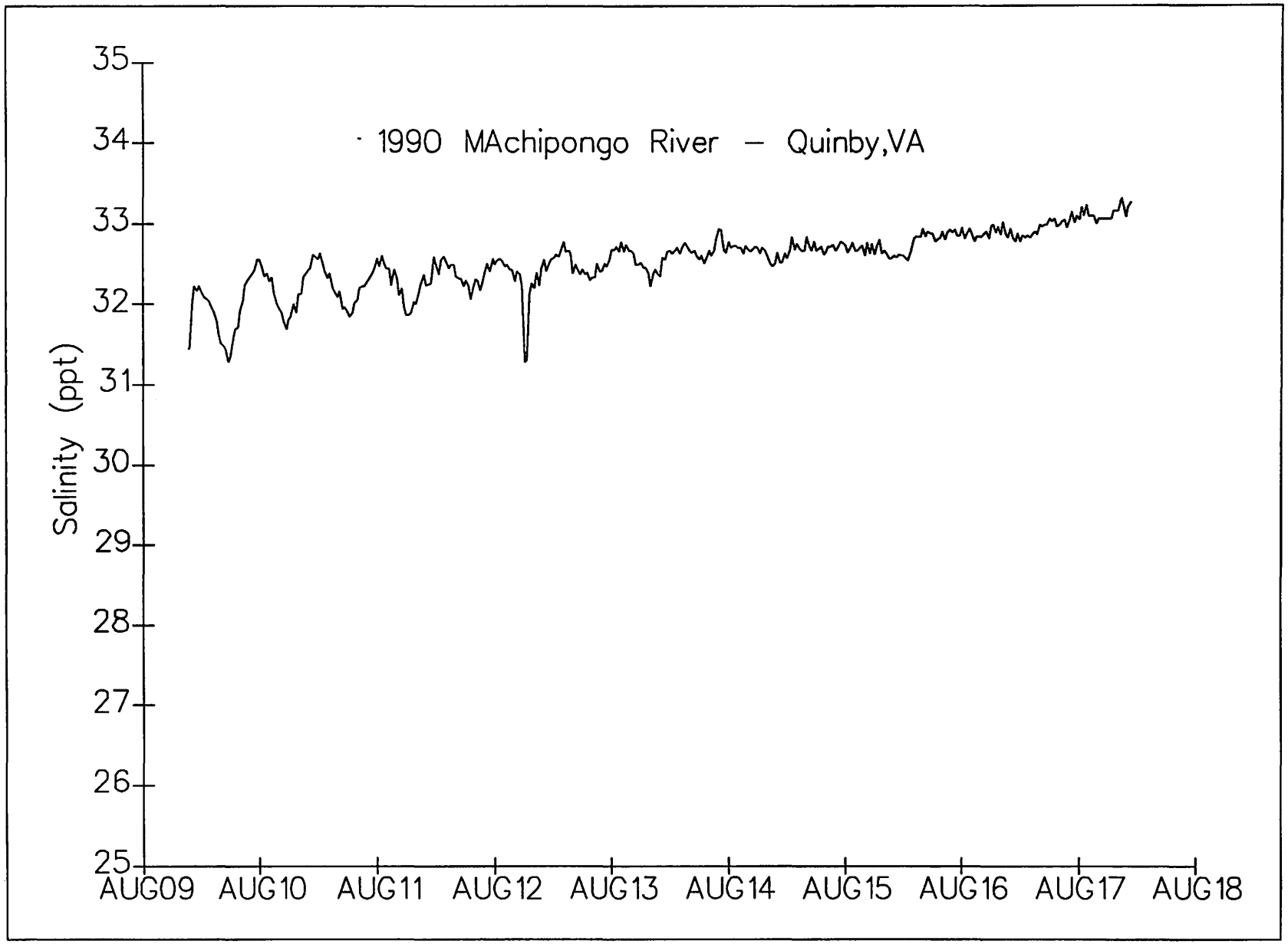
1990 MAchipongo River – Quinby,VA
Salinity (ppt)
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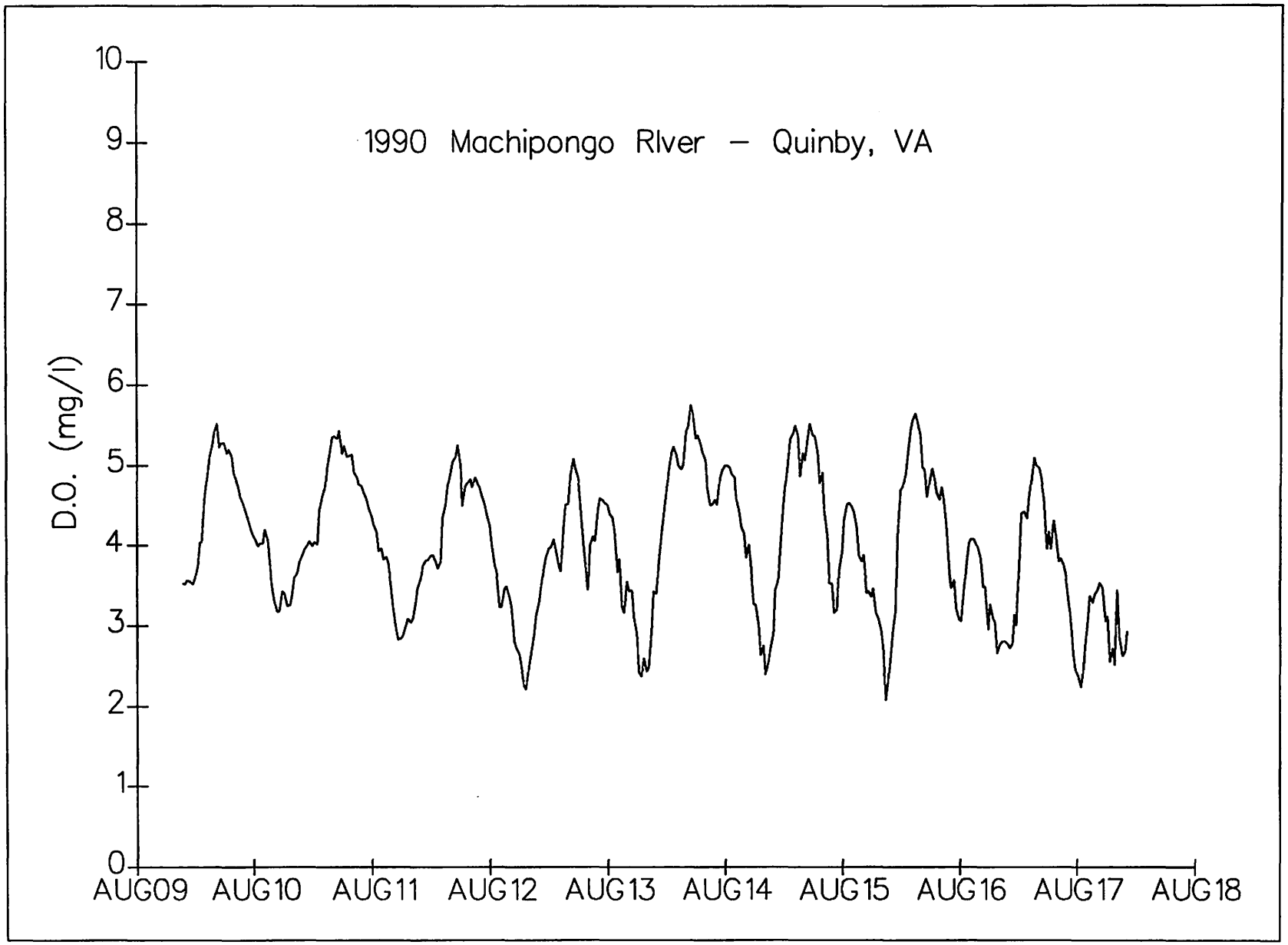
1990 Machipongo RIver – Quinby, VA
D.O. (mg/l)
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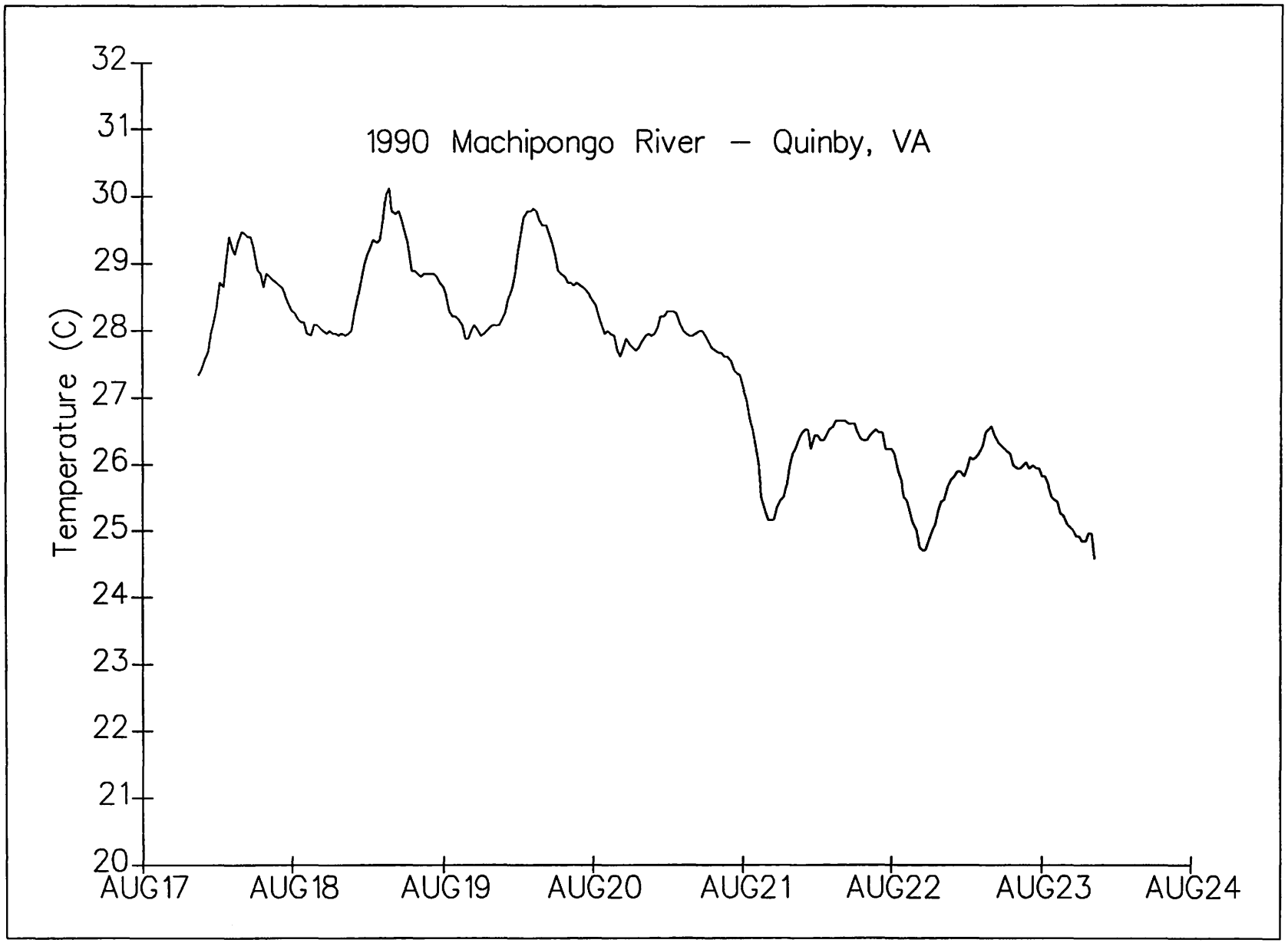
1990 Machipongo River – Quinby, VA
Temperature (C)
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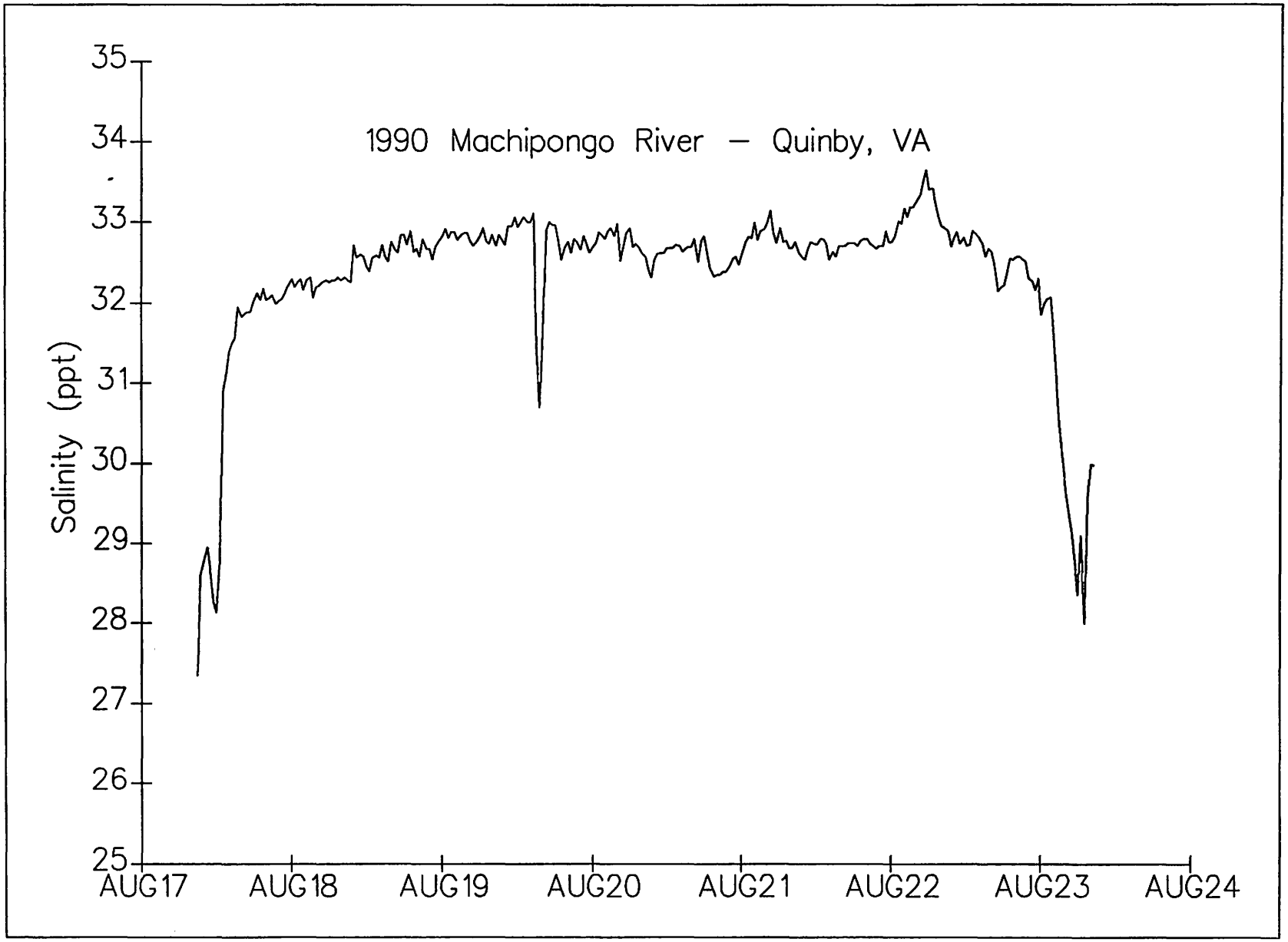
1990 Machipongo River – Quinby, VA
Salinity (ppt)
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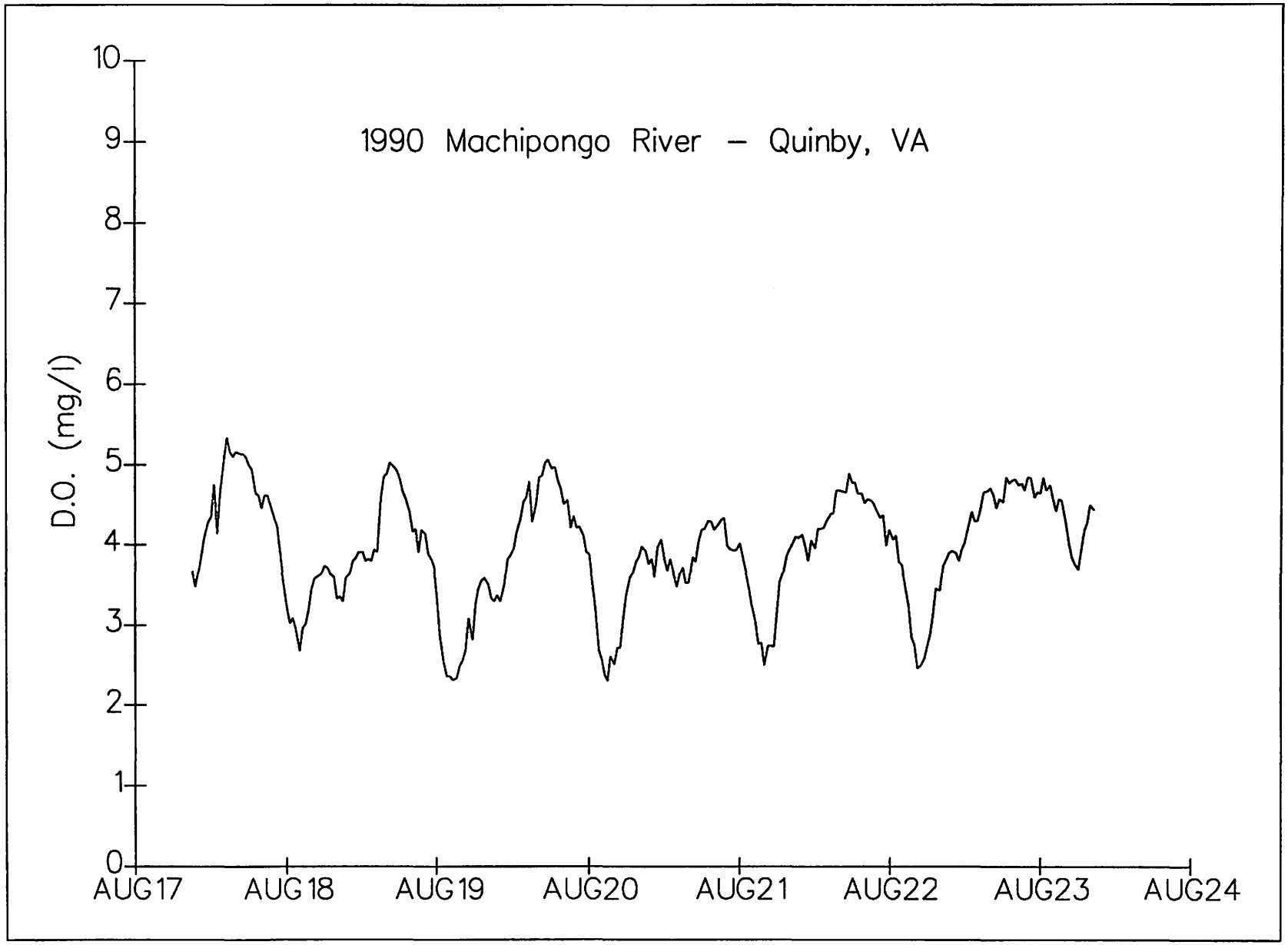
1990 Machipongo River – Quinby, VA
D.O. (mg/l)
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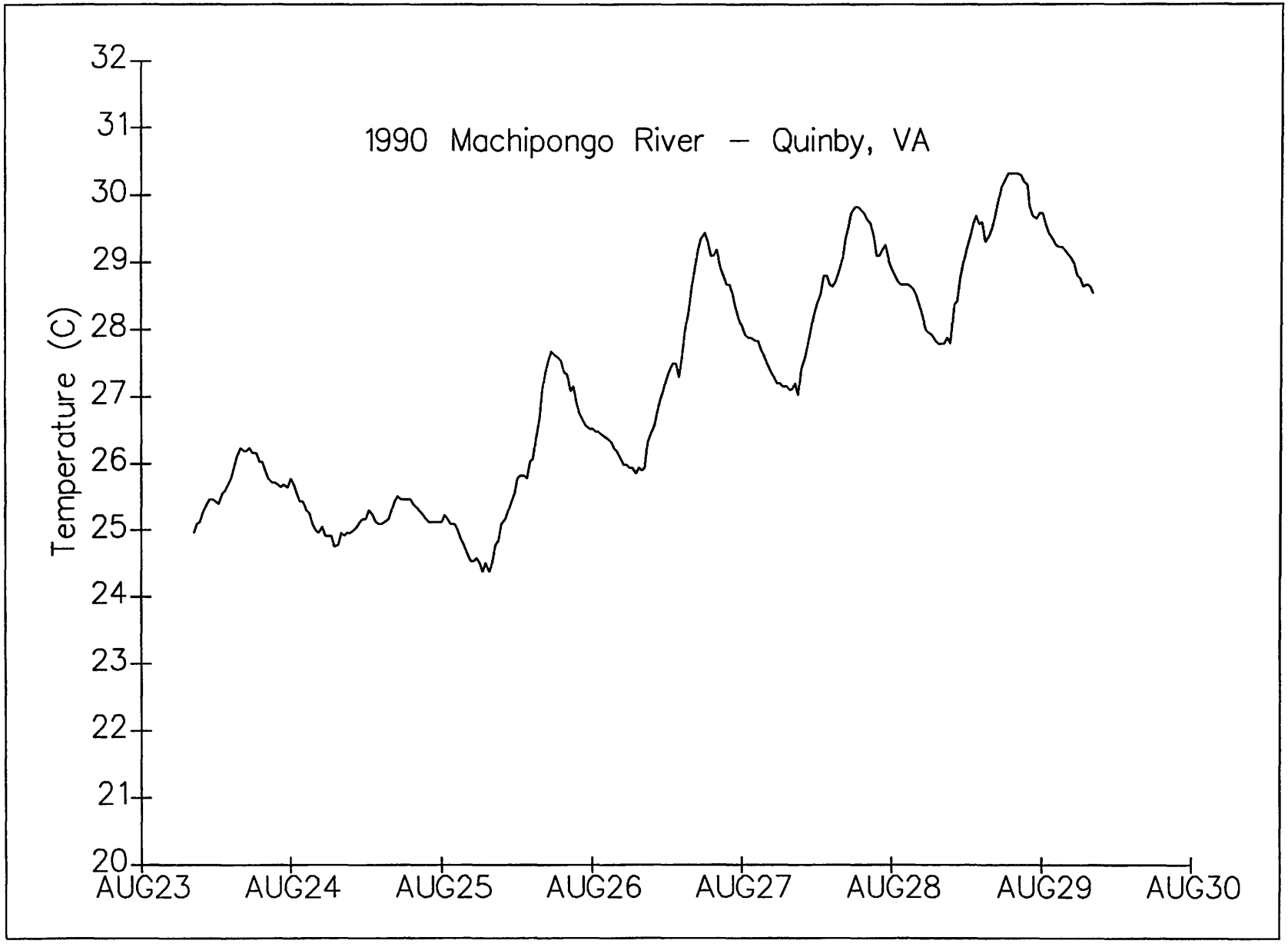
1990 Machipongo River – Quinby, VA
Temperature (C)
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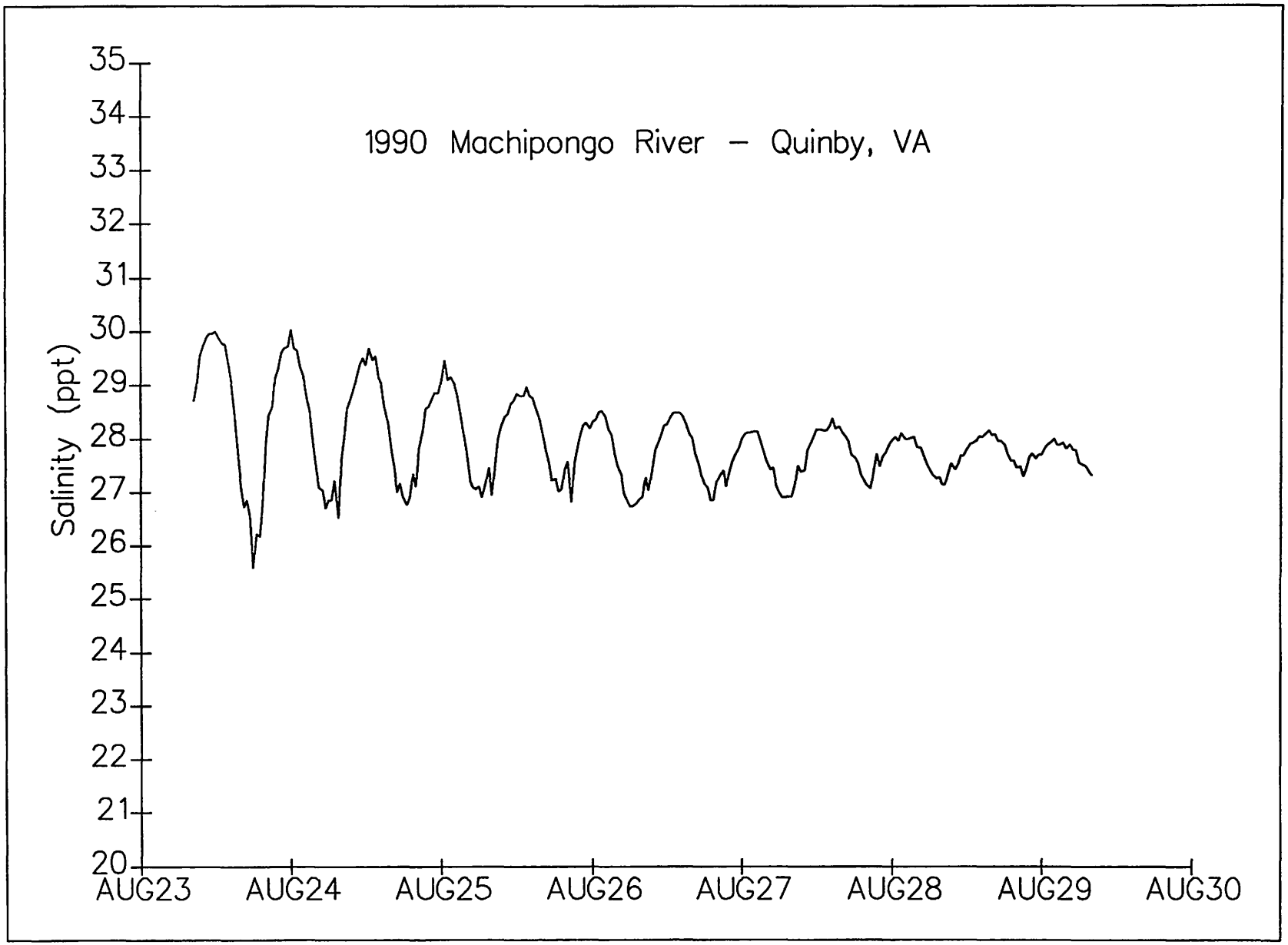
1990 Machipongo River – Quinby, VA
Salinity (ppt)
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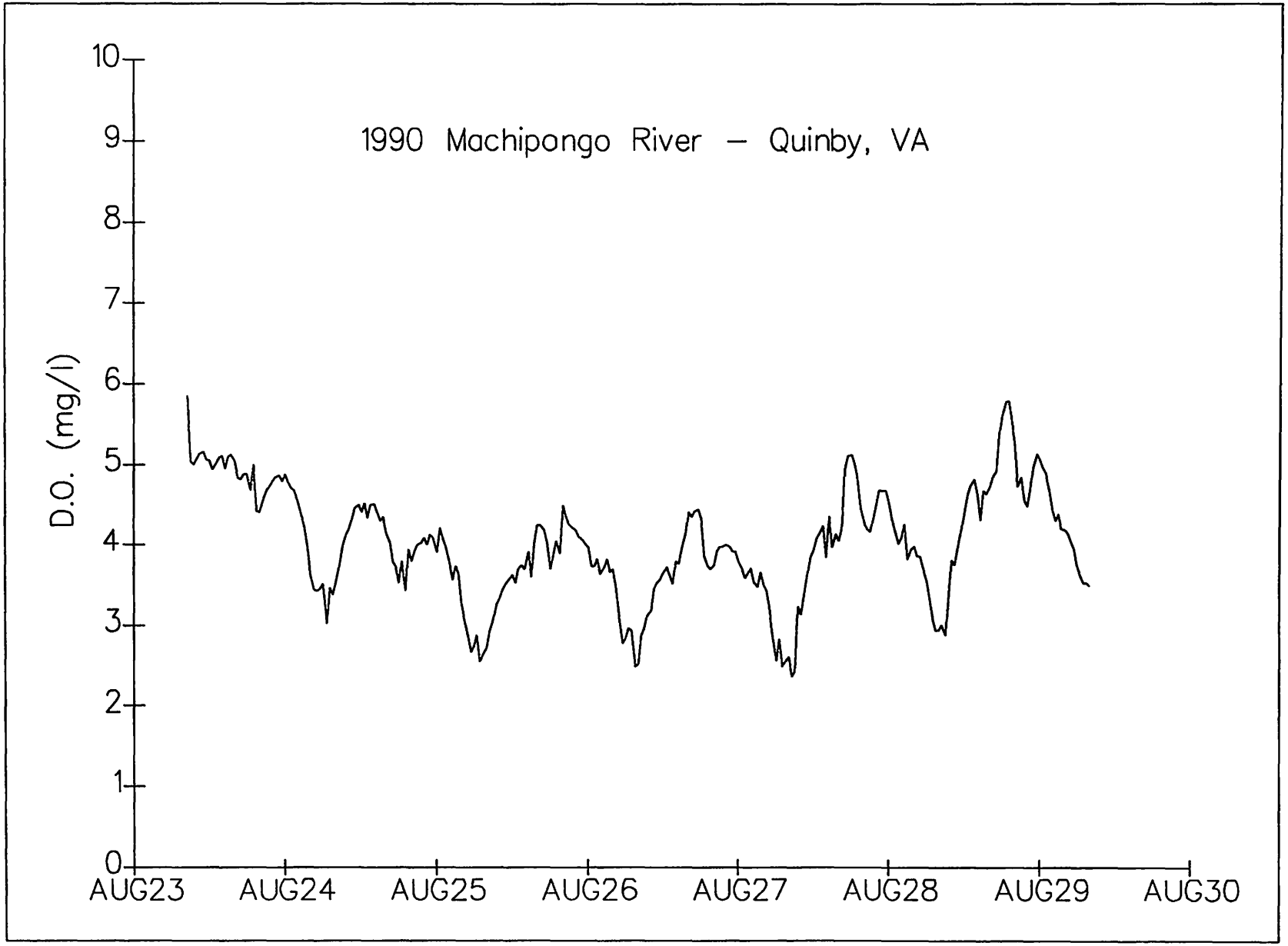
1990 Machipongo River – Quinby, VA
D.O. (mg/l)
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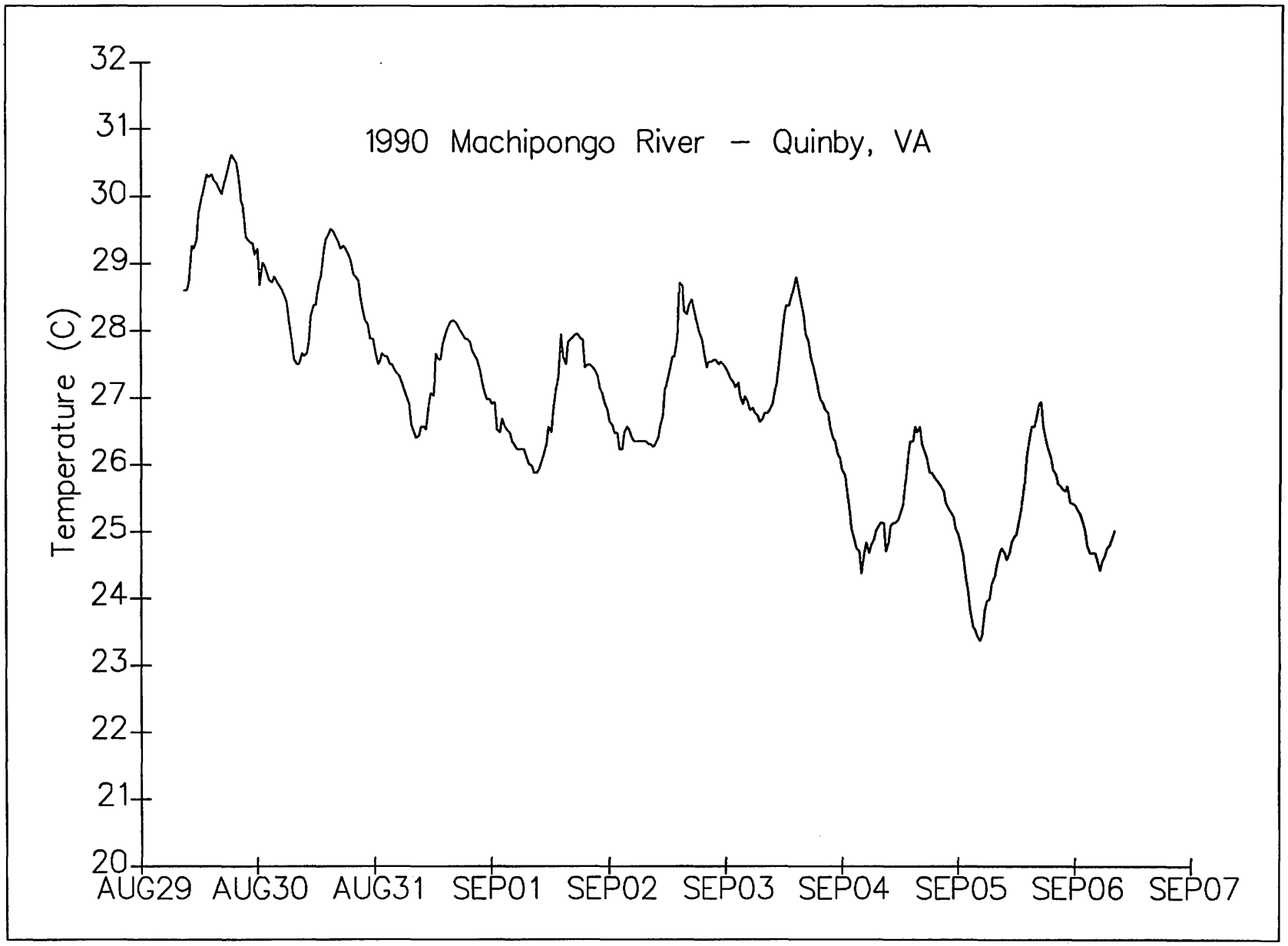
1990 Machipongo River – Quinby, VA
Temperature (C)
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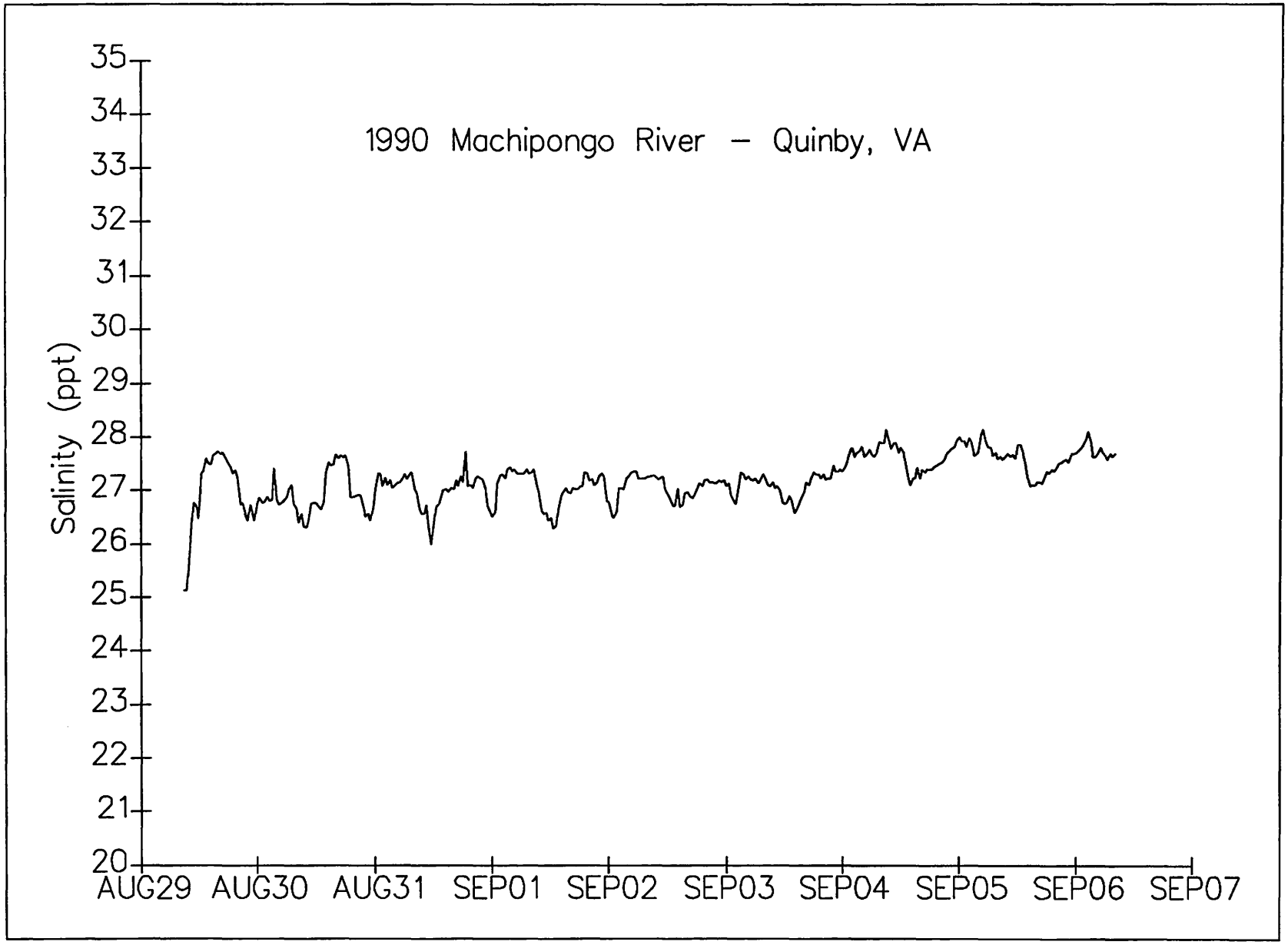
1990 Machipongo River – Quinby, VA
Salinity (ppt)
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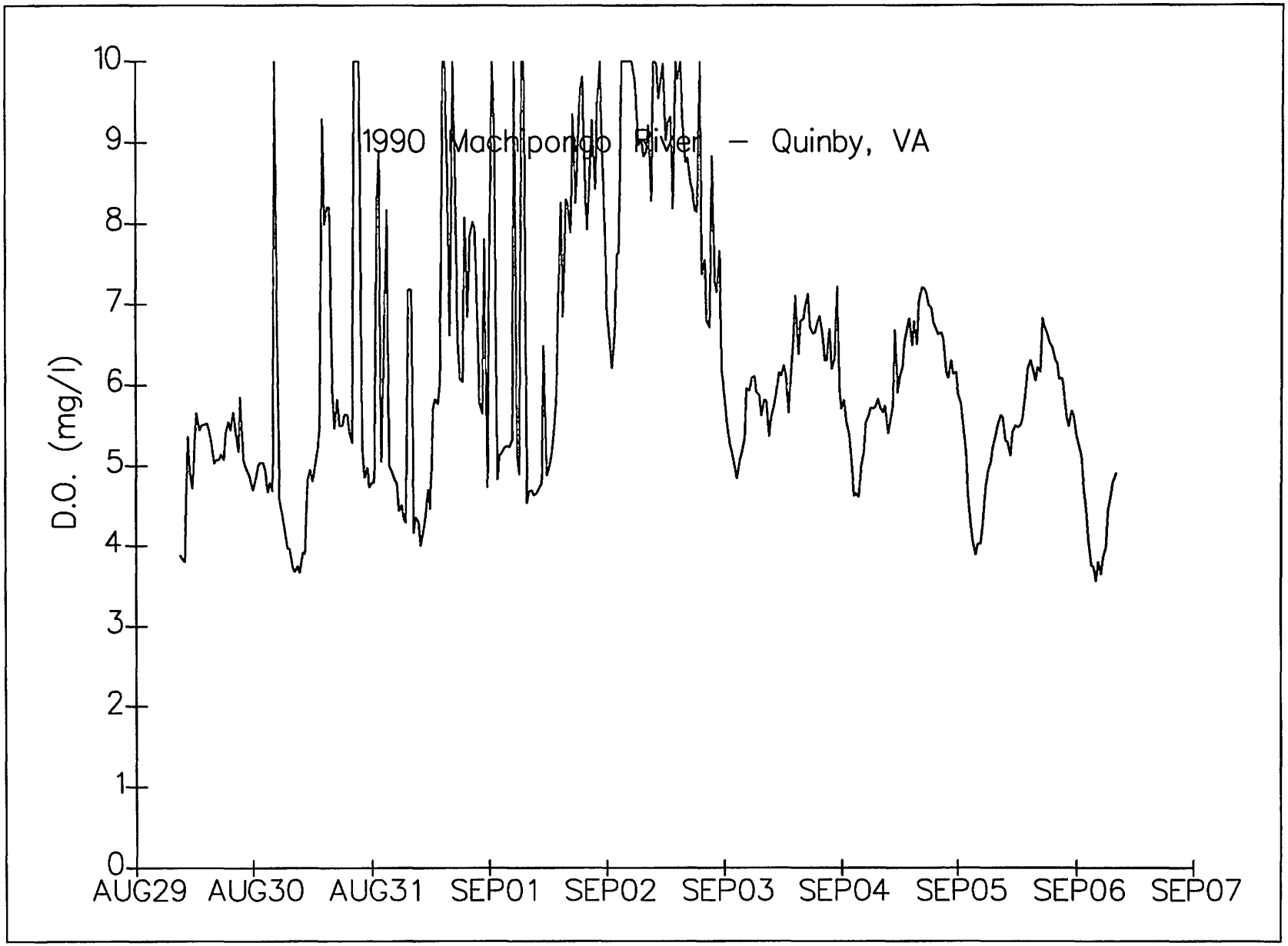
1990 Machipongo River – Quinby, VA
D.O. (mg/l)
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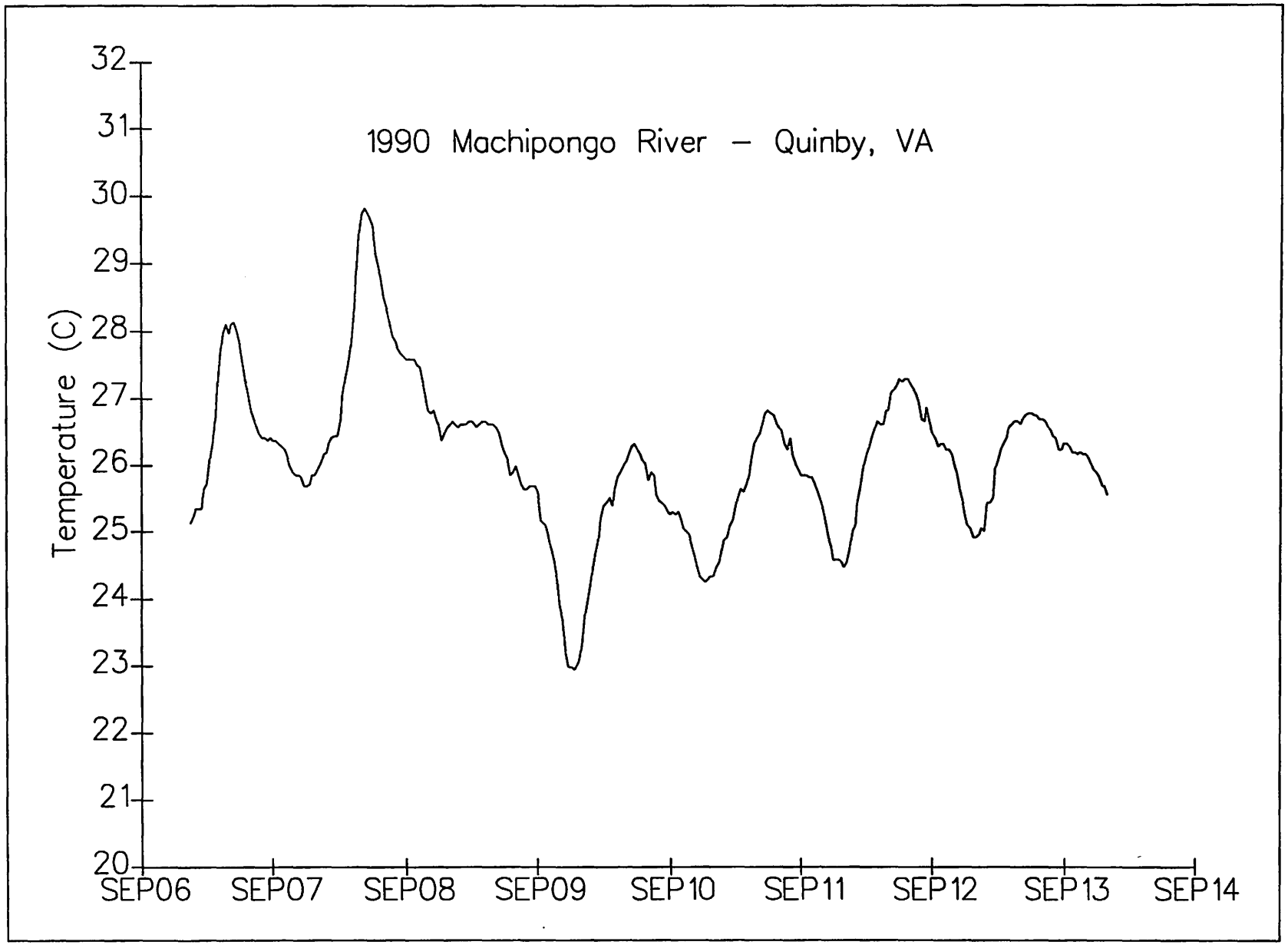
1990 Machipongo River – Quinby, VA
Temperature (C)
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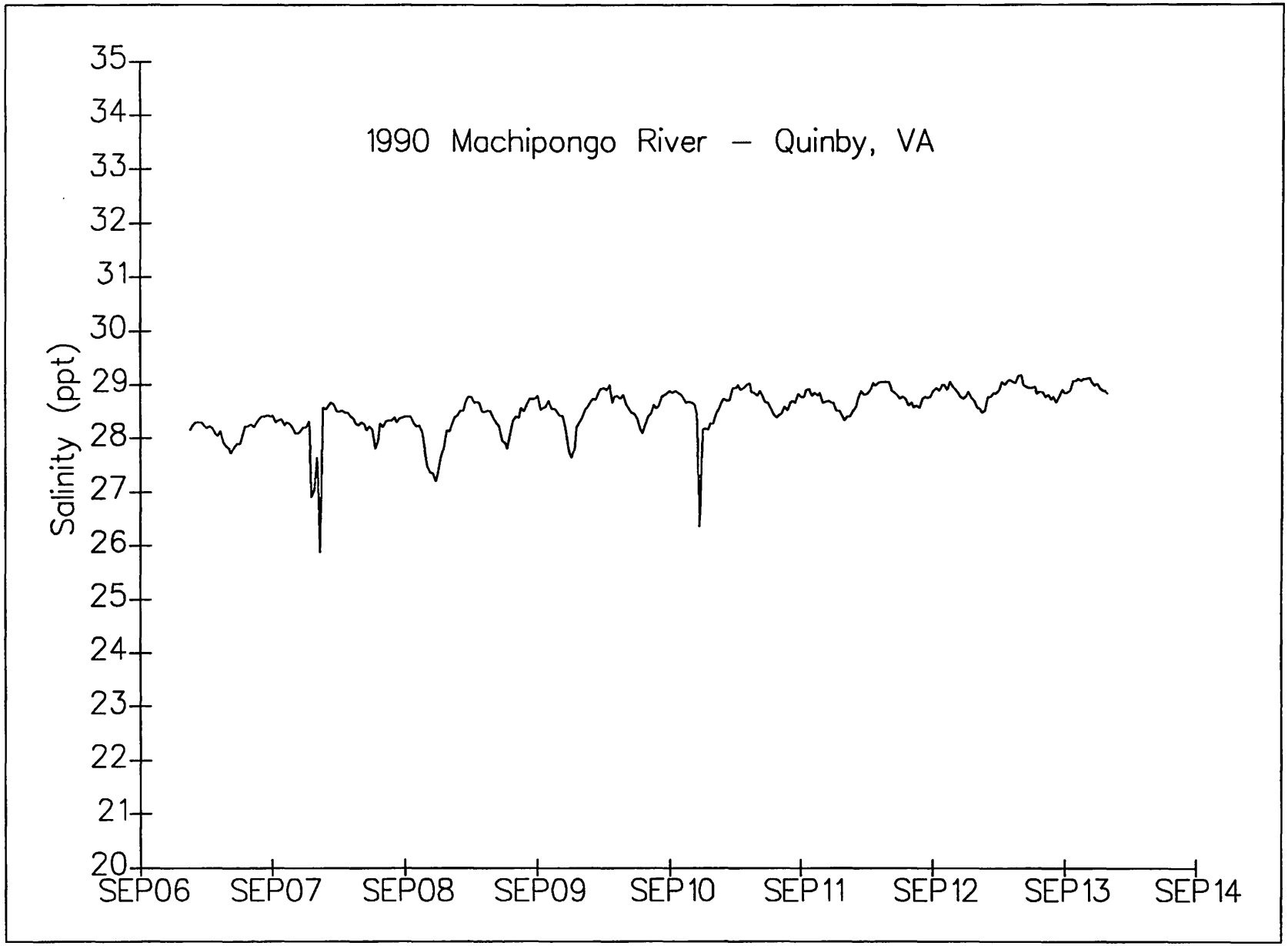
1990 Machipongo River – Quinby, VA
Salinity (ppt)
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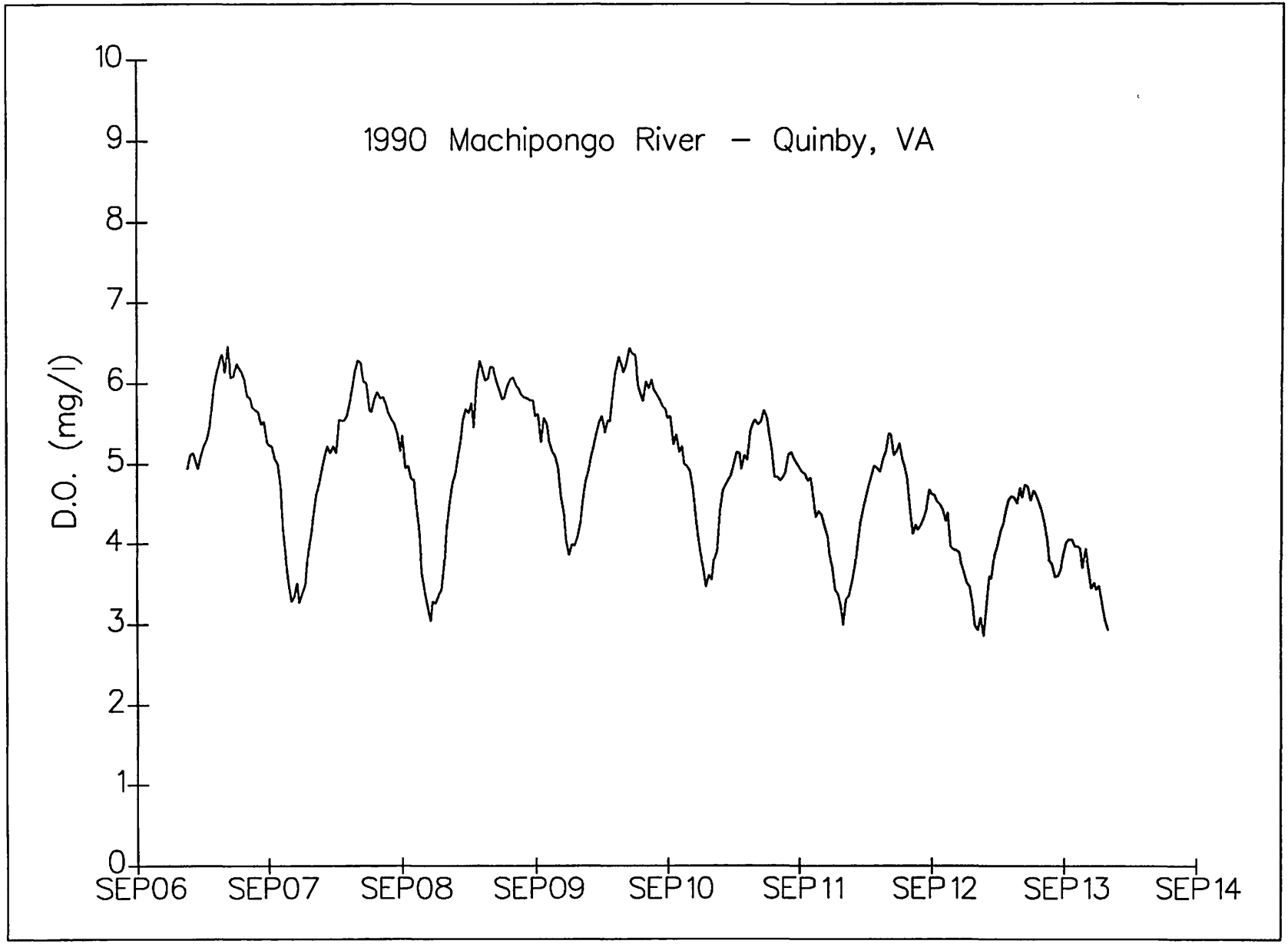
1990 Machipongo River – Quinby, VA
D.O. (mg/l)
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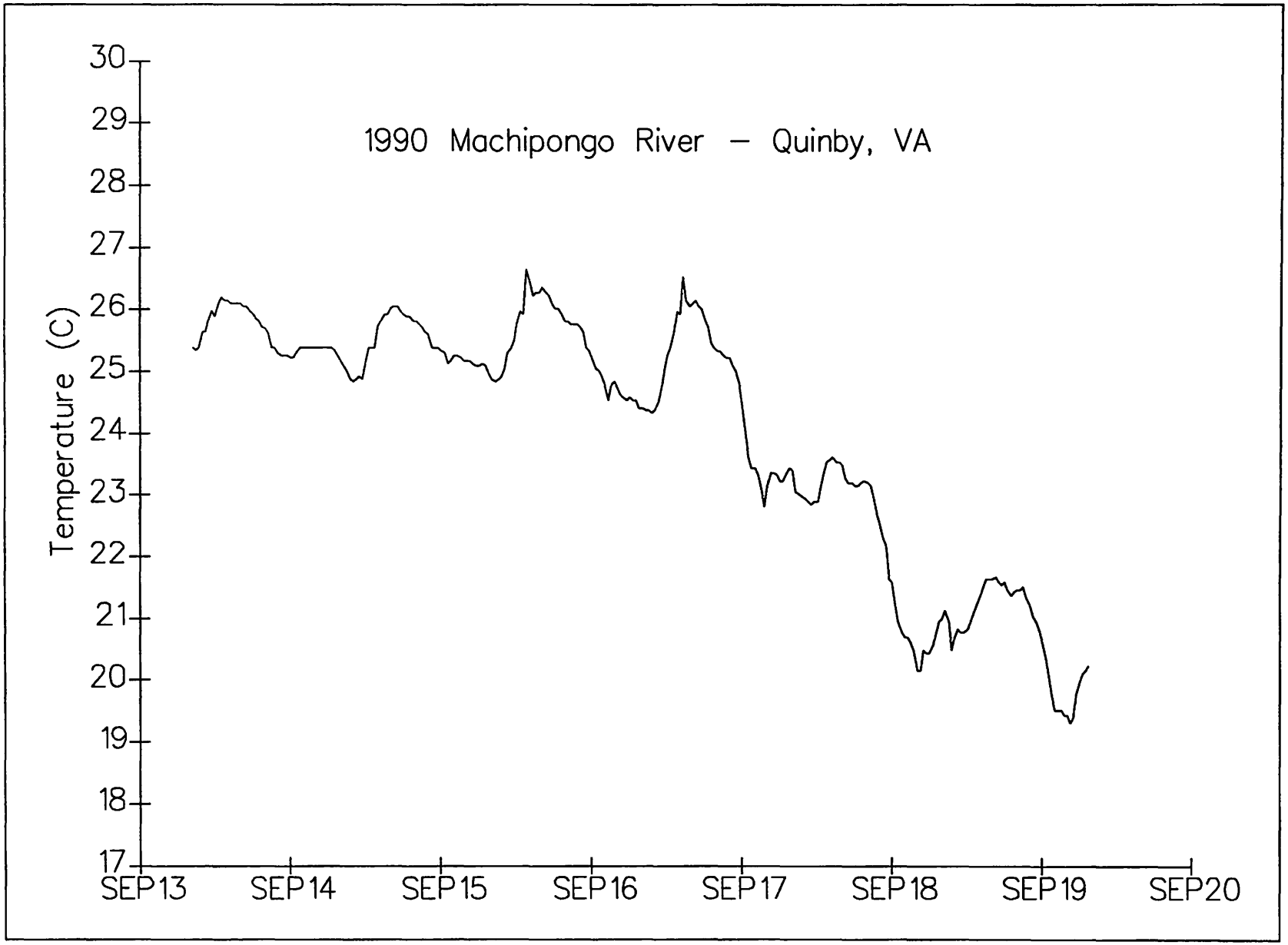
1990 Machipongo River – Quinby, VA
Temperature (C)
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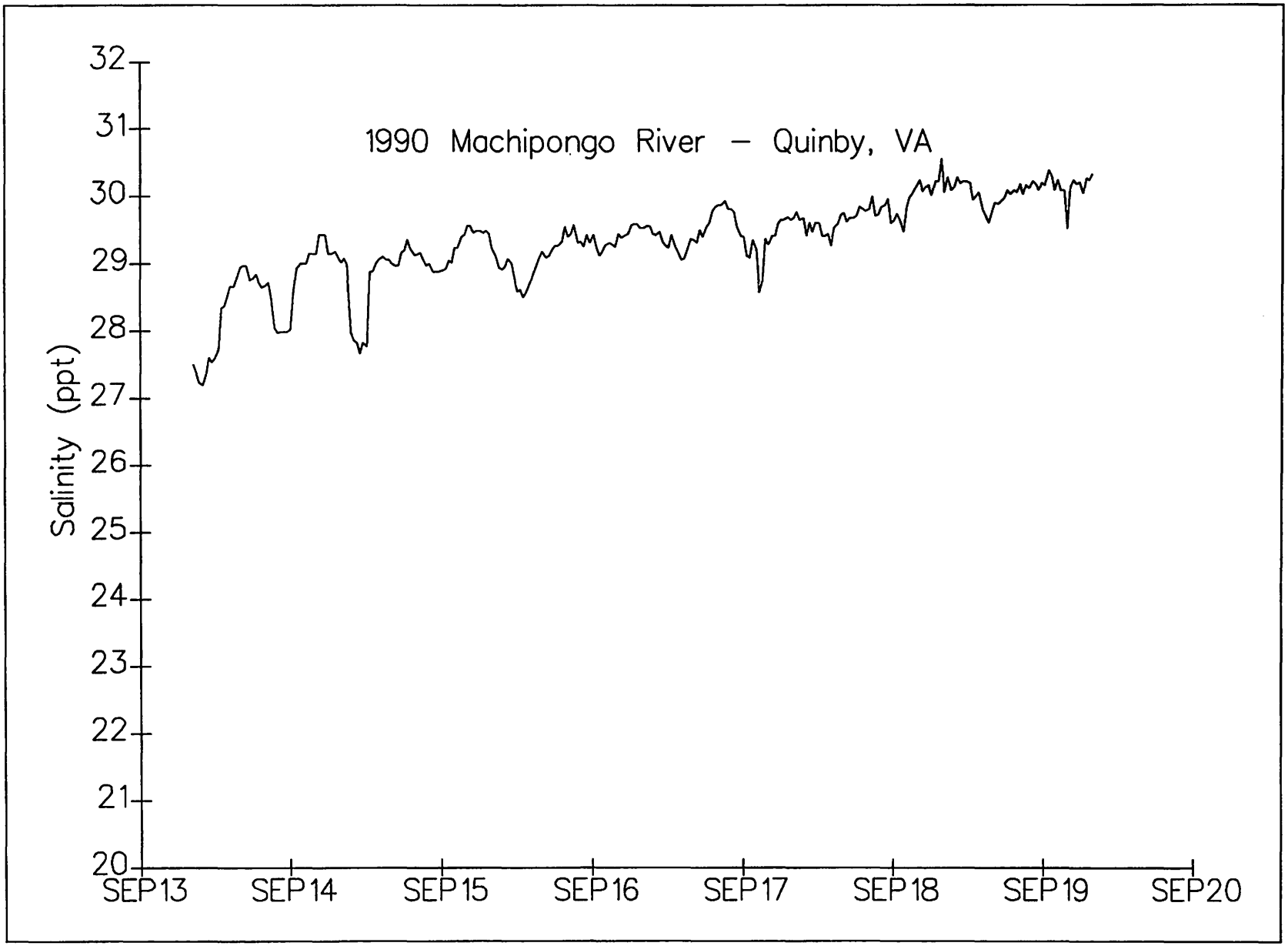
1990 Machipongo River – Quinby, VA
Salinity (ppt)
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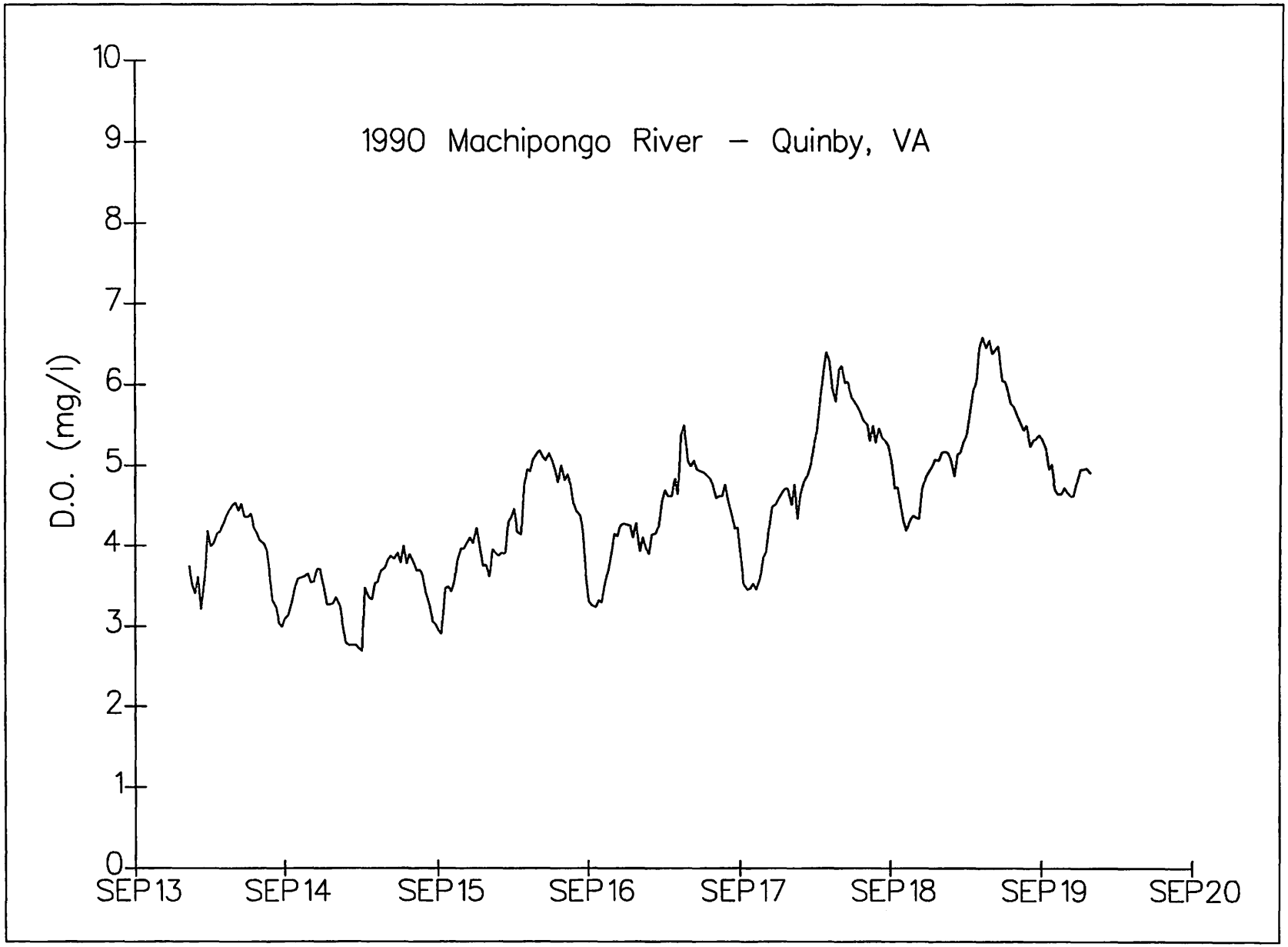
1990 Machipongo River – Quinby, VA
D.O. (mg/l)
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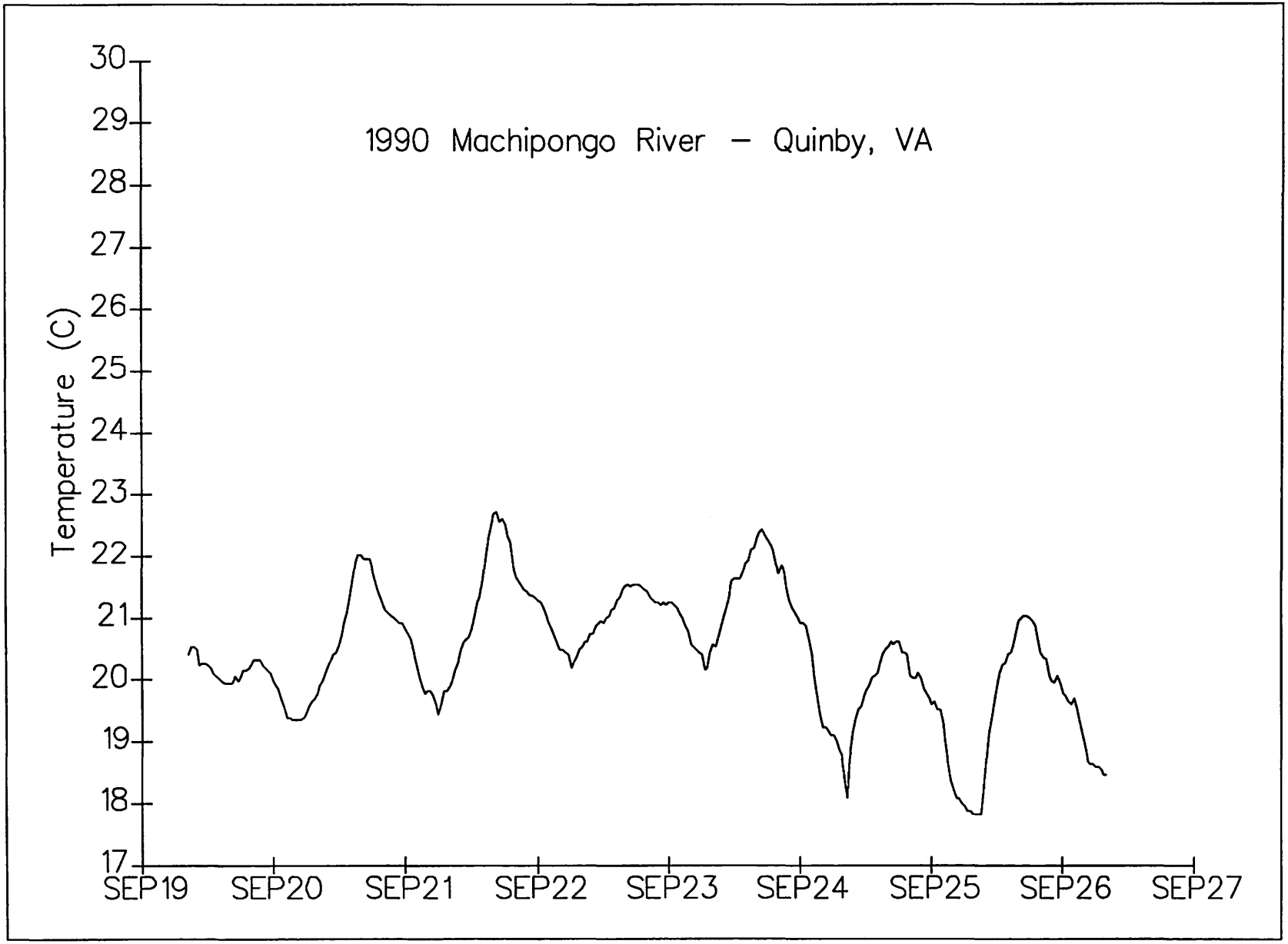
1990 Machipongo River – Quinby, VA
Temperature (C)
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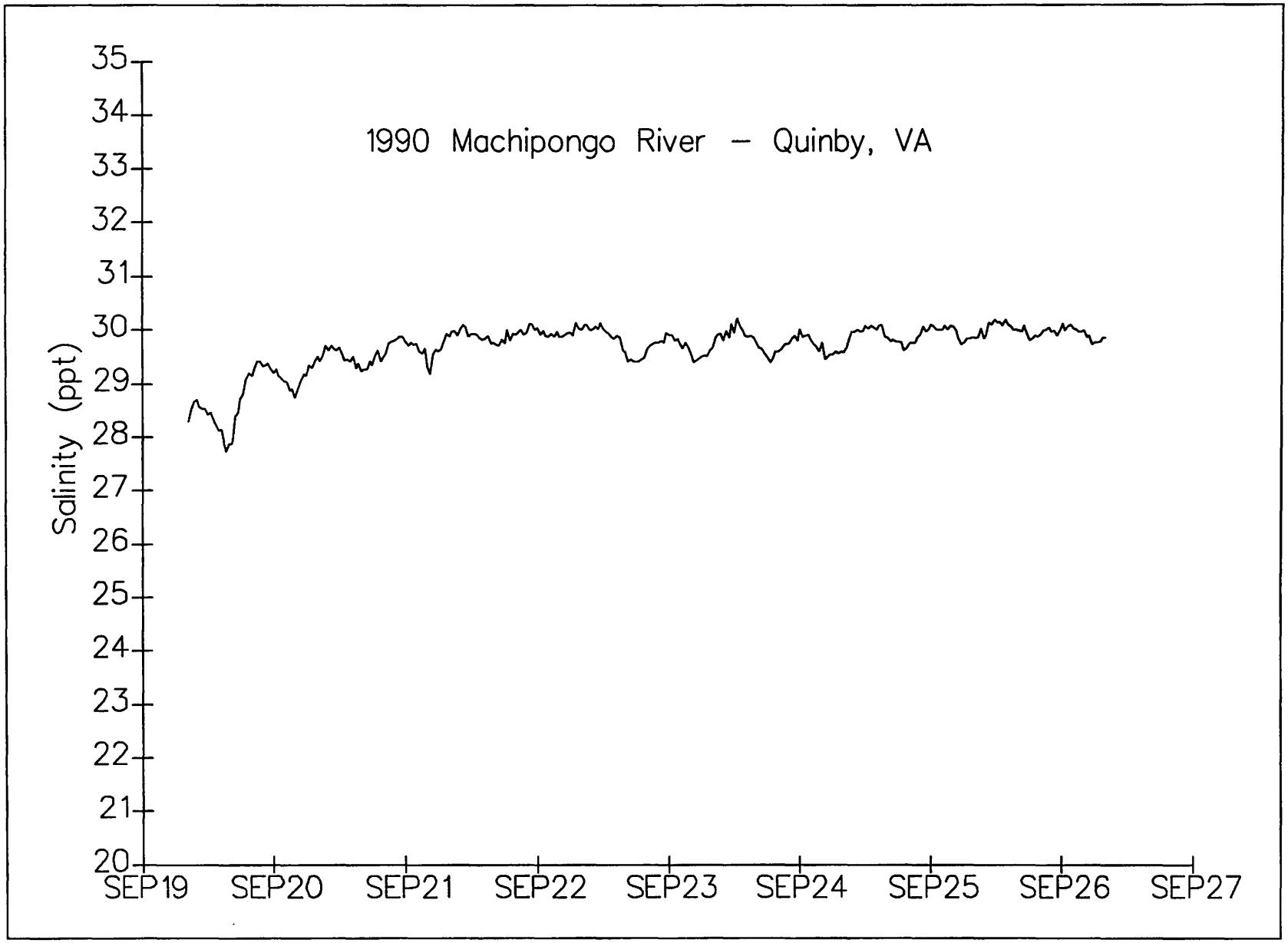
1990 Machipongo River – Quinby, VA
Salinity (ppt)
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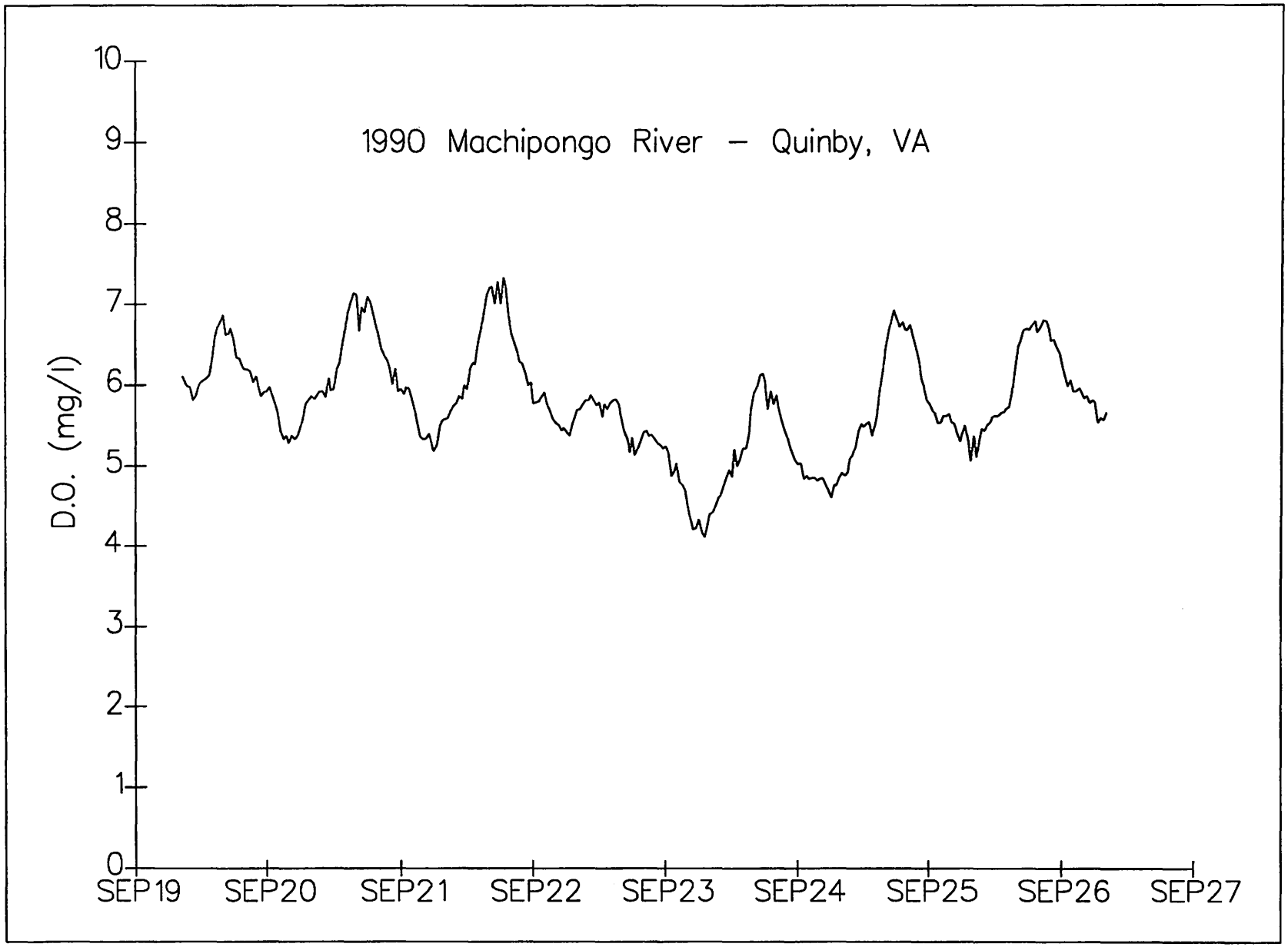
1990 Machipongo River – Quinby, VA
D.O. (mg/l)
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Appendix III. Daily Average and Minimum Readings

Daily average and daily minimum readings at Willis Wharf Quinby during early summer of 1989 and late summer of 1990 for

a) Dissolved Oxygen

b) Water Temperature

c) Salinity

Dissolved Oxygen for the 1989 DataSonde Deployment				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
May 11*	6.13	5.16	6.93	6.51
May 12	5.82	4.38	6.53	5.67
May 13	5.95	4.66	6.93 **H**	6.26 **H**
May 14	5.77	4.50	6.68	5.87
May 15	5.45	4.09	6.17	5.48
May 16	5.08	3.88	5.94	5.28
May 17*	5.65	4.02	6.14	5.47
May 18	6.42	5.46 **H**	6.35	5.46
May 19	6.23	4.84	6.15	5.24
May 20	6.12	4.73	5.87	4.84
May 21	5.93	4.33	5.64	4.50
May 22	5.35	3.36	5.20	4.00
May 23	4.65	2.82	5.18	3.69
May 24	4.29	2.57	5.41	3.68
May 25	4.56	2.41	5.47	5.24
May 26	4.99	3.61	5.66	4.35
May 27	5.09	2.91	5.24	3.58
May 28	5.96	4.55	5.76	4.93
May 29	6.46 **H**	4.99	5.81	4.87
May 30	6.34	5.18	6.02	5.12
May 31*	5.78	4.13	5.84	4.49
June 1	5.86	4.66	5.30	4.19
June 2	5.44	3.88	4.61	2.94
June 3	5.81	3.56	4.52	2.90

* dates of retrieval/deployment

Shade - DataSonde was coming out of water on low tide

Dissolved Oxygen for the 1989 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
June 4	5.92	3.61	5.01	3.04
June 5	5.38	2.94	4.52	2.84
June 6	4.89	2.39	4.91	2.97
June 7	4.54	2.02	4.88	3.62
June 8	4.83	2.23	4.73	3.11
June 9	4.17	1.82	4.54	3.07
June 10	4.78	2.34	4.93	3.55
June 11	4.75	3.22	5.50	4.24
June 12	5.53	3.18	5.59	4.56
June 13	4.89	3.33	5.62	4.41
June 14	3.93	2.92	4.95	3.96
June 15	3.49	2.22	4.73	3.63
June 16*	4.24	2.56	3.92	3.52
June 17	4.10	3.08	No Data	No Data
June 18	4.24	2.51	|	|
June 19	4.37	2.85	|	|
June 20	4.08	2.76	|	|
June 21	3.60	1.34	|	|
June 22	3.68	0.96	|	|
June 23	3.42	1.22	|	|
June 24	3.59	1.31	|	|
June 25	4.02	1.54	|	|
June 26	3.90	1.91	|	|
June 27	3.52	2.16	v	v

* dates of retrieval/deployment

Shade - DataSonde was coming out of water on low tide

Dissolved Oxygen for the 1989 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
June 28	2.92	1.63	No Data	No Data
June 29	2.66	1.86	|	|
June 30	2.66	1.67	|	|
July 1	2.66	1.20	|	|
July 2	2.59 **L**	0.92 **L**	v	v
July 3*	4.26	1.16	5.08	3.87
July 4	5.26	3.41	4.53	3.44
July 5	5.10	3.12	4.66	3.22
July 6	4.76	2.07	4.39	3.21
July 7	4.17	1.98	4.26	3.03
July 8	4.46	2.00	4.39	2.79
July 9	4.78	2.68	4.68	2.95
July 10	4.43	1.62	4.95	3.72
July 11	4.21	1.57	4.63	3.33
July 12	4.59	2.61	4.49	3.44
July 13	3.88	2.34	4.02	3.07
July 14	3.43	2.30	3.89	3.02
July 15	3.11	2.26	3.56	2.60
July 16	3.41	2.14	3.61	2.61
July 17	3.55	2.87	3.59 **L**	2.28 **L**
July 18*	2.45	1.38	3.00	2.41

* dates of retrieval/deployment

Dissolved Oxygen for the 1990 DataSonde Deployment				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
August 9*	4.50	3.93	4.53	3.51
August 10	4.40	2.67	4.27	3.17
August 11	4.49	2.53	4.03	2.83
August 12	4.79	2.58	3.65	2.20
August 13	4.84	3.59	4.23	2.36
August 14	4.68	3.17	4.23	2.39
August 15	4.29	3.31	4.11	2.06 **L**
August 16	3.86 **L**	3.08	3.69	2.63
August 17*	4.31	2.19 **L**	3.88	2.22
August 18	4.43	3.66	3.85	2.68
August 19	4.41	3.05	3.79	2.31
August 20	3.92	2.65	3.62	2.30
August 21	3.95	3.01	3.98	2.49
August 22	4.03	2.80	4.01	2.46
August 23*	4.90	3.85	4.70	3.68
August 24	4.48	3.30	4.04	3.02
August 25	4.05	2.57	3.65	2.55
August 26	4.02	2.54	3.63	2.48
August 27	4.17	2.39	3.81	2.36
August 28	4.36	2.94	4.32	2.88
August 29*	4.39	3.36	4.78	3.49
August 30	4.47	3.69	5.66	3.66
August 31	4.75	3.86	6.21	4.00
September 1	4.98	4.40	7.27	4.53
September 2	4.81	4.16	8.76 **H**	6.17 **H**

* dates of retrieval/deployment

Shade - unexplained spikes in D.O. data

Dissolved Oxygen for the 1990 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
September 3	4.97	4.13	6.09	4.84
September 4	5.40	4.63	6.06	4.60
September 5	5.20	4.34	5.54	3.88
September 6*	5.39	3.87	5.21	3.55
September 7	5.47	3.59	5.04	3.27
September 8	5.61	3.82	5.13	3.03
September 9	5.92	4.64	5.40	3.86
September 10	5.52	4.31	4.87	3.46
September 11	5.09	3.67	4.43	2.99
September 12	4.71	3.42	4.04	2.85
September 13*	4.61	3.61	3.84	2.92
September 14	4.24	3.11	3.42 **L**	2.69
September 15	4.68	3.93	4.26	2.90
September 16	4.94	4.07	4.34	3.23
September 17	5.23	4.32	5.01	3.45
September 18	5.86	5.05 **H**	5.34	4.18
September 19*	5.82	4.87	5.76	4.61
September 20	6.10 **H**	5.02	6.14	5.28
September 21	6.10 **H**	4.81	6.13	5.18
September 22	5.90	5.02	5.57	5.13
September 23	5.68	4.44	5.07	4.11
September 24	5.89	4.55	5.58	4.60
September 25	5.90	4.75	5.91	5.05
September 26*	5.69	4.88	5.86	5.53

* dates of retrieval/deployment Shade - unexplained spikes in D.O. data

Temperature for the 1989 DataSonde Deployment				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
May 11*	17.86	17.15	17.70	17.28
May 12	18.13	17.19	17.95	16.56
May 13	18.66	17.78	18.85	17.06
May 14	19.40	18.29	20.04	18.46
May 15	19.90	18.88	20.62	19.81
May 16	20.05	19.35	20.73	20.11
May 17*	19.24	18.75	19.59	19.09
May 18	19.39	18.54	19.85	18.33
May 19	20.23	19.13	20.74	19.39
May 20	21.00	19.77	21.59	19.98
May 21	22.13	20.53	22.94	21.08
May 22	23.26	21.80	23.93	22.30
May 23	23.30	22.39	23.55	22.56
May 24	23.11	22.34	23.04	21.54
May 25	23.61	22.01	23.56	21.67
May 26	24.16	22.94	24.17	22.26
May 27	24.84	23.95	25.39	24.63
May 28	23.68	22.22	23.63	21.88
May 29	22.98	16.39	23.30	21.42
May 30	22.85	19.89	22.95	21.50
May 31*	23.65	20.82	24.34	22.56
June 1	25.28	23.82	26.44	24.54
June 2	26.54	23.91	27.84	26.15
June 3	26.63	23.65	27.73	26.86

* dates of retrieval/deployment

Shade - DataSonde was coming out of water on low tide

Temperature for the 1989 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
June 4	26.90	23.99	27.33	25.64
June 5	27.30	24.46	27.78	26.65
June 6	27.06	26.44	26.86	25.68
June 7	26.61	25.72	26.26	25.05
June 8	26.97	25.47	26.85	25.09
June 9	27.00	26.61	26.66	25.72
June 10	27.03	25.64	26.91	25.13
June 11	26.17	24.84	25.74	23.91
June 12	25.46	24.25	25.04	23.61
June 13	25.08	23.86	25.15	23.53
June 14	25.88	24.96	26.64	25.01
June 15	26.97	25.89	28.09	26.53
June 16*	27.37	26.36	27.56	26.95
June 17	26.19	25.22	No Data	No Data
June 18	25.74	24.71	|	|
June 19	26.59	25.55	|	|
June 20	27.39	26.02	|	|
June 21	27.88	26.74	|	|
June 22	28.55	27.33	|	|
June 23	28.38	27.88	|	|
June 24	28.12	27.37	|	|
June 25	28.15	26.91	|	|
June 26	28.63	27.62	|	|
June 27	29.30	28.55	v	v

* dates of retrieval/deployment

Shade - DataSonde was coming out of water on low tide

Temperature for the 1989 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
June 28	29.35	28.93	No Data	No Data
June 29	28.62	27.96	|	|
June 30	27.53	26.69	|	|
July 1	27.32	26.74	|	|
July 2	27.30	26.57	v	v
July 3*	27.14	26.48	27.46	22.77
July 4	27.23	26.27	27.40	25.93
July 5	28.12	26.99	28.12	26.57
July 6	28.66	27.88	28.57	27.29
July 7	28.86	27.96	28.73	27.20
July 8	29.51	28.68	29.64	28.47
July 9	29.41	28.51	29.31	28.00
July 10	29.43	27.62	29.22	27.29
July 11	30.16	28.85	30.13	28.38
July 12	29.96	29.31	29.77	28.85
July 13	29.18	28.47	29.11	28.13
July 14	28.47	27.58	28.43	27.29
July 15	28.29	27.88	28.21	27.29
July 16	27.14	25.68	26.71	25.77
July 17	25.44	24.84	24.75	24.20
July 18*	24.82	24.33	23.82	23.27

* dates of retrieval/deployment

Temperature for the 1990 DataSonde Deployment				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
August 9*	27.18	26.23	27.58	26.36
August 10	27.31	26.61	27.50	26.31
August 11	27.94	26.99	28.23	26.65
August 12	28.74	27.58	28.91	27.24
August 13	29.10	28.34	29.14	27.96
August 14	28.88	27.79	28.57	27.46
August 15	28.52	27.92	28.42	27.41
August 16	28.02	27.54	28.06	27.29
August 17*	28.10	27.33	28.30	27.24
August 18	28.41	27.41	28.70	27.92
August 19	28.65	27.96	28.68	27.88
August 20	28.07	27.37	27.91	27.33
August 21	26.78	26.23	26.26	25.17
August 22	26.04	25.51	25.79	24.71
August 23*	25.57	24.88	25.52	24.58
August 24	25.29	25.09	25.19	24.75
August 25	25.78	24.58	25.84	24.37
August 26	27.02	26.15	27.38	25.85
August 27	28.06	27.24	28.37	27.03
August 28	28.78	28.05	29.29	27.79
August 29*	29.17	28.64	29.54	28.55
August 30	28.70	27.96	28.60	27.50
August 31	27.60	26.78	27.40	26.40
September 1	26.96	26.19	26.89	25.89
September 2	26.84	26.27	27.16	26.23

Temperature for the 1990 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
September 3	26.92	25.85	27.29	26.10
September 4	25.64	25.05	25.44	24.37
September 5	25.27	24.46	25.12	23.36
September 6*	25.88	24.84	26.05	24.41
September 7	27.12	25.68	27.24	25.68
September 8	26.63	25.60	26.55	25.64
September 9	25.31	23.95	24.97	22.94
September 10	25.65	24.79	25.51	24.25
September 11	26.14	25.05	26.05	24.46
September 12	26.22	25.43	26.10	24.92
September 13*	26.00	25.55	25.86	25.26
September 14	25.52	25.05	25.47	24.84
September 15	25.38	25.01	25.56	24.84
September 16	24.97	24.50	25.14	24.33
September 17	23.61	22.34	23.17	21.63
September 18	21.69	21.25	21.04	20.15
September 19*	20.63	19.98	20.06	19.30
September 20	20.82	19.64	20.55	19.35
September 21	21.26	20.44	20.98	19.43
September 22	21.25	20.82	21.01	20.19
September 23	21.59	20.82	21.33	20.15
September 24	20.83	19.89	19.83	18.08
September 25	20.65	19.09	19.53	17.82
September 26*	20.22	19.43	19.09	18.46

*** dates of retrieval/deployment**

Salinity for the 1989 DataSonde Deployment				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
May 11*	27.08	25.29	22.54	20.46
May 12	27.03	25.04	22.43	20.56
May 13	26.96	25.33	22.23	20.47
May 14	27.05	25.48	22.08	20.23
May 15	27.27	25.75	22.40	20.76
May 16	27.31	25.92	22.68	20.53
May 17*	27.56	25.99	23.53	20.80
May 18	27.60	25.62	24.05	21.85
May 19	27.93	26.52	24.53	22.61
May 20	28.27	26.98	25.14	23.66
May 21	28.42	27.24	25.43	24.33
May 22	28.50	27.23	25.63	24.33
May 23	28.61	27.52	25.67	23.61
May 24	28.08	26.39	24.74	22.81
May 25	27.87	26.46	25.10	23.47
May 26	27.66	26.39	25.07	23.56
May 27	27.66	26.66	25.07	23.71
May 28	27.88	26.73	25.45	23.74
May 29	25.00	0.25	25.75	24.33
May 30	23.25	0	26.02	24.54
May 31*	25.95	0	27.20	24.92
June 1	21.90	0	28.20	26.97
June 2	24.76	0	28.65	27.78
June 3	24.92	0	29.00	28.12

* dates of retrieval/deployment

Shade - DataSonde was coming out of water on low tide

Salinity for the 1989 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
June 4	17.34	0	29.21	28.25
June 5	21.71	0	29.38	28.63
June 6	30.62	28.37	29.61	29.03
June 7	31.31	30.85	29.61	28.50
June 8	30.89	29.92	28.77	27.65
June 9	30.81	29.93	28.85	27.81
June 10	30.71	29.76	28.91	27.76
June 11	30.59	29.92	29.17	27.94
June 12	30.40	29.85	29.44	28.54
June 13	29.90	28.41	29.24	28.19
June 14	28.80	27.92	29.00	27.94
June 15	28.53	27.74	29.13	28.38
June 16*	31.81	27.80	29.17	28.49
June 17	33.92	33.09	No Data	No Data
June 18	34.01	32.99	|	|
June 19	34.06	33.32	|	|
June 20	33.47	32.08	|	|
June 21	32.26	30.72	|	|
June 22	31.81	30.78	|	|
June 23	31.13	30.52	|	|
June 24	30.95	30.49	|	|
June 25	30.90	30.46	|	|
June 26	30.73	30.15	|	|
June 27	30.17	29.81	v	v

* dates of retrieval/deployment

Shade - DataSonde was coming out of water on low tide

Salinity for the 1989 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
June 28	30.03	29.69	No Data	No Data
June 29	29.64	28.47	|	|
June 30	34.22	28.29	|	|
July 1	35.72	33.23	|	|
July 2	36.09	34.49	v	v
July 3*	33.36	29.82	29.99	29.37
July 4	30.71	29.51	30.34	28.50
July 5	30.12	28.74	29.89	27.94
July 6	29.53	27.02	29.39	27.91
July 7	29.27	26.35	29.32	27.68
July 8	29.11	27.97	28.61	26.99
July 9	29.33	28.67	28.92	27.90
July 10	29.42	28.46	29.01	27.38
July 11	28.89	27.87	28.44	26.98
July 12	28.98	28.17	28.03	25.80
July 13	29.55	29.19	29.13	27.94
July 14	29.58	29.28	29.51	28.75
July 15	29.48	29.11	29.70	28.90
July 16	29.74	25.56	30.22	27.41
July 17	25.38	19.31	22.15	15.08
July 18*	25.90	22.20	20.04	14.35

* dates of retrieval/deployment

Salinity for the 1990 DataSonde Deployment				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
August 9*	32.85	32.50	31.93	31.28
August 10	33.12	32.76	32.20	31.68
August 11	33.19	32.94	32.31	31.87
August 12	33.23	33.03	32.40	31.28
August 13	33.13	32.54	32.61	32.23
August 14	33.24	32.72	32.68	32.47
August 15	33.30	32.97	32.74	32.54
August 16	33.53	33.34	32.92	32.77
August 17*	32.33	30.59	31.90	28.13
August 18	31.93	31.29	32.48	32.06
August 19	32.62	31.08	32.74	30.70
August 20	31.63	31.15	32.65	32.31
August 21	32.00	31.64	32.76	32.54
August 22	32.17	31.15	32.79	32.15
August 23*	26.78	20.93	29.15	25.57
August 24	25.78	21.73	28.24	26.51
August 25	26.06	22.85	28.04	26.82
August 26	25.66	22.62	27.65	26.74
August 27	26.05	23.43	28.37	26.90
August 28	26.34	24.38	27.72	27.15
August 29*	26.51	24.22	27.23	25.12
August 30	26.54	24.83	26.91	26.30
August 31	26.82	25.34	27.01	26.00
September 1	26.94	25.34	27.05	26.28
September 2	27.14	25.77	27.06	26.49

Salinity for the 1990 DataSonde Deployment, cont'd.				
Date	*Willis Wharf*		*Quinby*	
	Daily Avg.	*Daily Min.*	*Daily Avg.*	*Daily Min.*
September 3	27.31	25.75	27.10	26.59
September 4	27.90	26.50	27.62	27.10
September 5	28.05	26.68	27.60	27.07
September 6*	27.97	25.86	28.01	27.57
September 7	28.15	27.86	28.20	25.87
September 8	28.94	27.90	28.26	27.19
September 9	28.48	28.72	28.54	27.64
September 10	29.58	28.90	28.63	26.36
September 11	29.58	29.08	28.75	28.34
September 12	29.58	29.07	28.87	28.49
September 13*	29.81	29.27	28.50	27.20
September 14	30.03	29.37	28.89	27.66
September 15	30.10	29.23	29.17	28.51
September 16	30.36	29.70	29.46	29.06
September 17	30.51	29.77	29.55	28.58
September 18	30.69	30.15	30.04	29.47
September 19*	30.14	29.08	29.16	27.72
September 20	30.15	29.52	29.40	28.74
September 21	30.48	29.94	29.82	29.17
September 22	30.51	29.90	29.84	29.42
September 23	30.46	29.90	29.74	29.40
September 24	30.41	29.96	29.82	29.45
September 25	30.48	30.23	29.98	29.73
September 26*	30.44	30.18	29.93	29.73

*** dates of retrieval/deployment**

Appendix IV. Daily Variations in Dissolved Oxyxgen

Tables of differences between daily minimum and daily maximum D.O. readings at Willis Wharf and Quinby in early summer of 1989 and late summer of 1990

1989 Differences in Daily Maximum and Minimum Dissolved Oxygen		
Date	*Willis Wharf*	*Quinby*
May 11*	1.43	0.81
May 12	2.28	1.50
May 13	2.30	1.28
May 14	2.30	1.40
May 15	2.42	1.41
May 16	2.06	1.67
May 17*	2.82	1.42
May 18	1.91	2.01
May 19	2.43	1.82
May 20	2.54	2.39
May 21	2.94	3.38
May 22	3.74	3.36
May 23	4.16	1.93
May 24	4.09	1.63
May 25	4.42	1.41
May 26	3.57	3.14
May 27	3.61	4.17
May 28	2.30	3.93
May 29	1.46	4.04
May 30	1.85	3.02
May 31*	2.85	3.42
June 1	3.91	2.47
June 2	6.11	3.72
June 3	7.88	4.05

* dates of retrieval/deployment

Shade - DataSonde was coming out of water on low tide

1989 Differences in Daily Maximum and Minimum Dissolved Oxygen, cont'd		
Date	*Willis Wharf*	*Quinby*
June 4	7.70	4.03
June 5	10.04	3.61
June 6	6.35	3.48
June 7	5.69	2.24
June 8	7.91	2.91
June 9	5.45	2.43
June 10	6.59	2.68
June 11	5.12	2.26
June 12	4.39	2.14
June 13	3.22	2.62
June 14	2.09	2.10
June 15	2.41	3.43
June 16*	2.90	0.76
June 17	1.63	No Data
June 18	3.63	|
June 19	4.70	|
June 20	4.70	|
June 21	5.80	|
June 22	7.12	|
June 23	4.68	|
June 24	4.87	|
June 25	5.26	|
June 26	4.37	|
June 27	3.37	V

* dates of retrieval/deployment

Shade - DataSonde was coming out of water on low tide

1989 Differences in Daily Maximum and Minimum Dissolved Oxygen, cont'd		
Date	*Willis Wharf*	*Quinby*
June 28	2.52	No Data
June 29	1.69	|
June 30	1.46	|
July 1	2.24	|
July 2	2.54	V
July 3*	5.13	2.52
July 4	3.96	2.81
July 5	4.50	2.82
July 6	4.72	2.54
July 7	4.90	2.83
July 8	5.54	3.60
July 9	5.14	3.00
July 10	5.31	2.64
July 11	5.36	2.42
July 12	3.85	1.85
July 13	3.20	2.08
July 14	2.13	2.16
July 15	1.45	2.60
July 16	2.57	2.09
July 17	1.53	1.78
July 18*	1.66	0.78

* dates of retrieval/deployment

1990 Differences in Daily Maximum and Minimum Dissolved Oxygen		
Date	*Willis Wharf*	*Quinby*
August 9*	1.34	1.77
August 10	3.15	2.19
August 11	4.36	2.42
August 12	4.90	2.88
August 13	3.04	3.40
August 14	2.41	3.13
August 15	1.69	3.58
August 16	1.31	2.46
August 17*	3.61	2.94
August 18	1.87	2.34
August 19	2.86	2.71
August 20	1.79	1.99
August 21	1.43	2.40
August 22	2.11	2.37
August 23*	1.61	1.44
August 24	1.88	1.85
August 25	2.17	1.79
August 26	2.25	1.96
August 27	2.94	2.32
August 28	2.58	2.91
August 29*	2.06	2.16
August 30	1.58	8.13
August 31	1.80	6.48
September 1	1.34	9.96
September 2	1.60	5.50

* dates of retrieval/deployment Shade - unexplained spikes in D.O. data

1990 Differences in Daily Maximum and Minimum Dissolved Oxygen, cont'd		
Date	*Willis Wharf*	*Quinby*
September 3	1.62	2.39
September 4	1.55	2.61
September 5	1.46	2.95
September 6*	2.90	2.91
September 7	2.99	3.01
September 8	2.82	3.16
September 9	2.25	2.58
September 10	2.02	2.21
September 11	2.34	2.38
September 12	2.03	1.89
September 13*	1.77	1.61
September 14	1.81	1.31
September 15	1.46	2.28
September 16	1.70	2.26
September 17	1.92	2.95
September 18	1.37	2.41
September 19*	1.45	2.26
September 20	1.68	1.86
September 21	1.97	2.15
September 22	1.60	0.78
September 23	2.09	2.03
September 24	2.16	2.33
September 25	2.10	1.76
September 26*	1.50	0.69

* dates of retrieval/deployment