CHICKAWAUKIE LAKE STUDY

prepared for

Chickawaukie Lake Association
Rockland / Rockport, Maine

by

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INTRODUCTION

Development of nuisance algal blooms in recent years has interfered with uses of Chickawaukie Lake for recreation and water supply. In response to this problem, intensive lake monitoring, watershed monitoring, and watershed management programs have been undertaken. The purposes of this report are as follows:

(1) to assess existing lake water quality with respect to algae, nutrients, and related factors;

(2) to identify and describe cause-effect relationships which control lake conditions; and

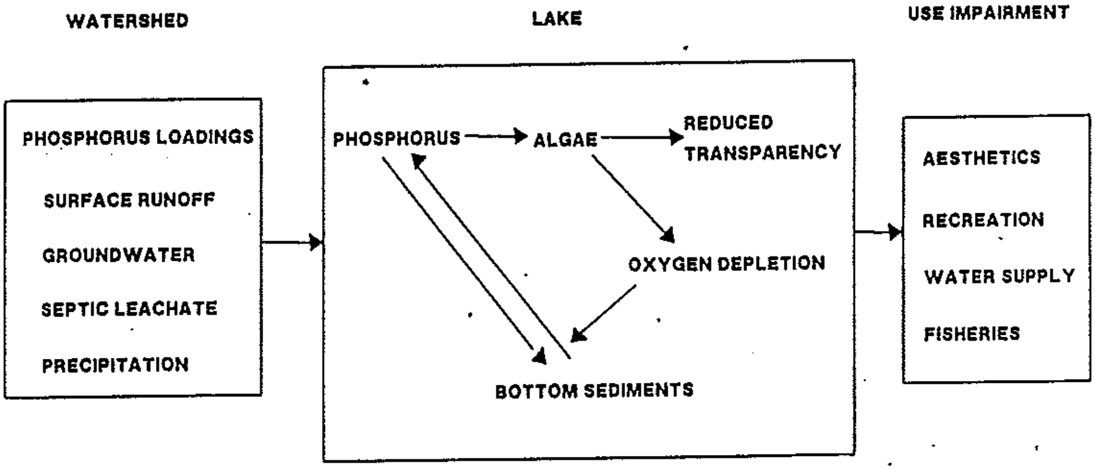
(3) to evaluate and recommend additional diagnostic, protection, and restoration measures.

Results are described below, following a brief discussion of basic concepts pertaining to lake algae problems.

BASIC CONCEPTS

Algal blooms are symptomatic of eutrophication, a process involving enrichment of water bodies with nutrients (e.g., nitrates and phosphates), which originate from various natural and cultural(man-induced) sources. As illustrated in Figure 1, this process has several direct and indirect influences on lake water quality conditions and uses.

Figure 1
Lake Eutrophication Process



and human activity. For example, regional watershed studies have shown that conversion of forested land into urban land without special controls typically increases phosphorus export by five- to twenty-fold (Reckhow et al.,1980, Meta Systems, 1982, Dennis, 1986). These increases partially reflect increased surface runoff, which has a much higher potential for transporting phosphorus, as compared with water which percolates through the soil column before reaching a pond or tributary stream. Phosphorus concentration in stormwater runoff from residential areas typically averages from 250 to 600 ppb (Athayede et al.,1983). In the absence of specific point-source contributions, groundwater phosphorus levels in this region are usually less than 15 ppb. In lake environments, average phosphorus concentrations exceeding 20-25 ppb are usually accompanied by eutrophic conditions. These comparisons reveal the importance of minimizing direct runoff and promoting infiltration as a means of protecting lakes from nutrient enrichment and resulting algal blooms.

Aside from runoff, domestic sewage represents another potentially significant phosphorus source in urban watersheds. Phosphorus in domestic sewage from a typical household (2-3 lbs/capita-year) usually exceeds phosphorus loading in urban runoff by more than a factor of ten. For this reason, it is desirable to avoid discharge of untreated (or treated) domestic sewage to lakes or to their tributaries. In many watersheds, onsite soil treatment systems are employed for sewage disposal. Because of filtration, chemical precipitation, and adsorption mechanisms, soil systems usually have high capacities for removing phosphorus in domestic wastewaters and preventing it from reaching lakes in significant quantities. Phosphorus removal efficiency depends upon many factors, including leach field size, depth to groundwater, hydraulic loading rate, loading patterns (seasonal vs. year-round), soil texture and chemical composition, permeability, groundwater movement, soil moisture and oxygen content, distance from lake or tributary, slope, vegetation, maintenance practices, and system age (Reckhow et al.,1980; Sawney and Starr,1977; Meta Systems,1982). For the purposes of estimating lake phosphorus budgets, removal efficiencies of 90% or more are typically assumed for onsite systems in proper working order.

Agricultural land uses can also contribute to lake phosphorus loadings (Omernik,1977). Such impacts depend strongly upon the intensities and types of agriculture, cropping and management practices, watershed topography, soil types, and climate. Agricultural activities involving less disturbance of the soil generally have lower impacts on phosphorus export (e.g., pastures vs. row crops). Soil particles, fertilizers, and animal wastes transported in surface runoff can be potent nutrient sources. As in urban watersheds, the general objective of minimizing surface runoff applies to management of agricultural watersheds for protecting lake water quality.

The amount of phosphorus loading which a lake can tolerate without causing eutrophic conditions depends upon a number of lake-specific factors, including volume, surface area, depth, and water budget. For these reasons, diagnosis of eutrophication problems requires a fundamental understanding of lake hydrology and watershed characteristics, in addition to water quality monitoring data from the

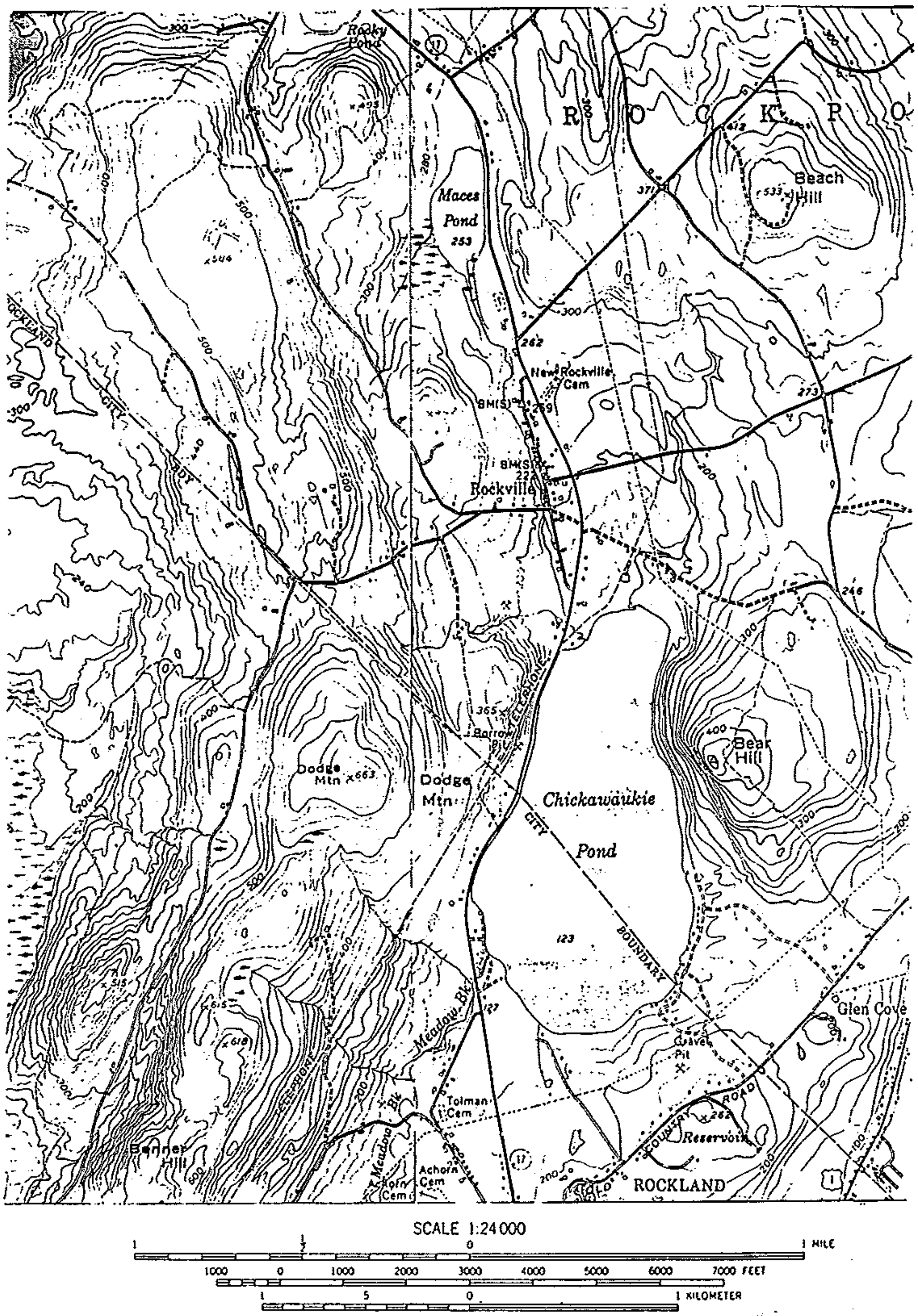
Table 1
Chickawaukie Lake Morphometric and Hydrologic Characteristics

Pool Elevation		Full	3.3-ft Drawdown
Surface Elevation	feet msl	123.2	119.9
Surface Area	acres	362	341
Volume	acre-ft	7639	6485
Maximum Depth	feet	33.1	29.8
Mean Depth	feet	21.1	19.0
Hydraulic Residence Time	years	1.48	1.26
Surface Overflow Rate	feet/yr	14.3	15.1

Watershed Areas	Acres	%
Undeveloped	1373	52.3%
Golf Course	23	0.9%
Agricultural	458	17.5%
Urban	368	14.0%
Maces Pond	40	1.5%
Chickawaukie Lake	362	13.8%
Total	2624	100.0%

Estimated Water Budget	Area acres	Flow ac-ft/yr	Flow %	Yield in/yr
Watershed Inflows	2262	4411	75.6%	23.4
Direct Precipitation	362	1422	24.4%	47.1
Total Inflows	2624	5833	100.0%	26.7
Evaporation	362	694	11.9%	23.0
Outflow	2624	5138	88.1%	23.5

Figure 3
Watershed Topographic Map



weather and from the northeast during storms. These directions are roughly in line with the main axis of the lake. Whitecaps are not uncommon and the lake is very popular with wind surfers. Intense winds and resulting water turbulence can have important impacts on vertical mixing and nutrient cycling.

Annual and seasonal variations in precipitation at Rockland are shown in Figure 5. Annual average precipitation is 47.1 inches. The 1982-1987 study period included a range of hydrologic conditions. Annual precipitation was below normal in 1982 and 1985, near normal in 1986 and 1987, and above normal in 1983 and 1984. Primarily as a result of storms which occurred in November, annual precipitation during 1983 (76 inches) was the highest on record since 1914.

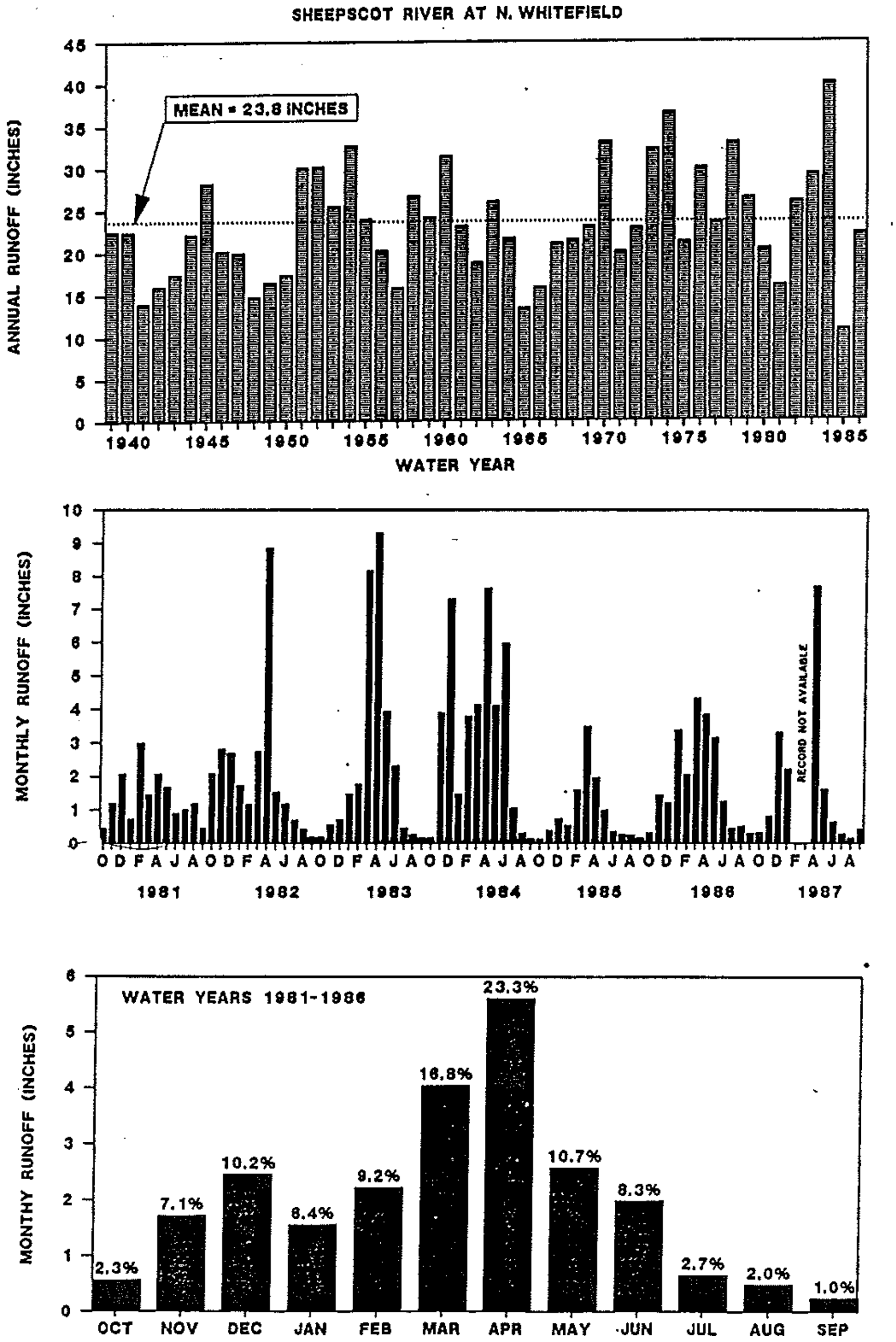
There are no operating streamflow gauges in the watershed. Figure 6 plots annual and seasonal variations in watershed runoff measured by the U.S. Geological Survey on the Sheepscot River near North Whitefield. This gage (Station Number 01038000) has a continuous, unregulated record since 1939 and is located approximately 20 miles west-north-west of Chickawaukie Lake. Although it is not in the Chickawaukie watershed, the data provide reasonable perspectives on regional runoff rates. The average annual runoff, 23.8 inches,' is typical of other watersheds in coastal Maine, which range from 20 to 25 inches (Linsley et al.,1975).

Lake elevation is partially regulated by a small dam at the outlet to Meadow Brook (southwestern corner), which has been under the control of the Camden and Rockland Water Company since 1985. During the fall and winter of 1985-86 and 1986-87, the lake level was drawn down by approximately 3 feet. This drawdown range can be compared with the maximum lake depth of approximately 34 feet at full pool. Based upon the lake basin profile (Figure 4), a drawdown of 3 feet would reduce the total lake volume by approximately 15%. Drawdown was accomplished by removing planks in the dam at Labor Day and replacing them at the end of the spring runoff season, so that lake level reached full pool by the beginning of summer. The objective of this drawdown was to increase the flushing rate of the lake during the fall period, when lake phosphorus and algal levels were elevated.

Regulation of lake levels also occurred prior to 1985, but according to no known rationale and no records are available. Approximate estimates of lake level variations can be derived from lake monitoring data collected by the Camden and Rockland Water Company. Figure 7 plots the maximum depth of vertical temperature and oxygen profiles taken in the center of the lake over the 1982-1987 period. Since the profiles were generally extended to within 1 foot of the lake bottom, the maximum profile depth provides a relative indicator of lake elevation. The seasonal drawdown patterns discussed above are evident for 1985 and 1986. The data suggest that average lake levels were lower by .5-1 meter (1.6-3.3 feet) during 1982-1984, especially in summer.

Watershed land uses, estimated from a map provided by McNelly (1988), include agriculture (458 acres), golf course (23 acres), urban (368 acres), undeveloped areas (1373 acres), Maces Pond (40 acres), and Chickawaukie Lake (362 acres). Agricultural uses are of relatively low

Figure 6


SHEEPSCOT RIVER AT N. WHITEFIELD
ANNUAL RUNOFF (INCHES)
0
5
10
15
20
25
30
35
40
45
MEAN = 23.8 INCHES
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
WATER YEAR
MONTHLY RUNOFF (INCHES)
0
1
2
3
4
5
6
7
8
9
10
O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A O D F A J A
1981
1982
1983
1984
1985
1986
1987
RECORD NOT AVAILABLE
MONTHY RUNOFF (INCHES)
0
1
2
3
4
5
6
WATER YEARS 1981-1986
2.3%
7.1%
10.2%
6.4%
9.2%
16.8%
23.3%
10.7%
8.3%
2.7%
2.0%
1.0%
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP

intensity (pasture, hay fields). There is a general trend towards increased urban development in the watershed. Much of this is occurring at relatively low density (>5-10 acres/lot).

Historical nonpoint source pollution problems generated by agricultural and urban land uses in the watershed are described by Brown(1985):

(1) general increasing trend in residential construction;

(2) erosion of steep, unpaved roads on the eastern shore;

(3) erosion caused by poor residential construction practices;

(4) leaching from exposed manure piles on the eastern shore (dairy farm);

(5) fertilizer usage (agricultural, residential, golf course);

(6) contributions from onsite sewage disposal systems;

(7) use of phosphate detergent products.

With the possible exception of (4), none of the above problems alone could be described as having a "major" impact on the lake. Cumulative impacts are of major concern, however, and are probably responsible for the development of nuisance algal growths in the early 1980's.

In response to these identified problems, watershed management activities have been undertaken by the Chickawaukie Lake Association, Towns of Rockport and Rockland, and Camden and Rockland Water Company. Problems associated with inadequate manure storage facilities have been eliminated. Impacts of future residential construction activities will be limited by land use ordinances enacted in Rockport (northern watershed) and Rockland (southern watershed).

MONITORING PROGRAMS

In response to algal blooms which were first reported in 1980, a preliminary water quality survey was conducted by Camden and Rockland Water Company in 1981 (McNelly and Hunt,1984). Water quality was good in spring and early summer. A transparency of 23 feet was recorded in mid June, although the bottom of the pond below 30 feet was depleted of dissolved oxygen. Analysis of turbidity, pH, and chlorophyll-a data indicated that an algal bloom was present from the middle of August through the middle of November of 1981. Severe algal blooms in late summer of 1982 and 1983 are reflected by turbidity and pH measurements taken at the water supply intake (Figure 8). In September of 1982, when intake turbidity peaked at 34 ntu, lake chlorophyll-a concentration peaked at 71 ppb. Based upon these results, intensive lake and watershed monitoring studies were initiated in 1983 and have been continued at various frequencies through 1987.

A tributary monitoring program was conducted by the Camden and Rockland Water Company in 1983 to identify significant nutrient inputs and watershed sources (McNelly and Hunt,1984). A subsequent report by Hunt (1985) described specific problem areas in the watershed, as outlined above.

This report focuses on lake monitoring data which were collected between 1982 and 1987. Inlake mechanisms regulating algal blooms and potential control methods are evaluated. Details of the monitoring program design and sample inventories are summarized in Table 2. A computer data base (Appendix A), has been established to facilitate reporting, analysis, and display of the information.

VERTICAL PROFILES

Vertical profiles of temperature, dissolved oxygen, and total phosphorus contain important diagnostic information on lake condition and processes controlling phosphorus cycling. Three formats have been selected to display these data:

(1) concentration vs. depth plots (Appendix B).

(2) depth vs. season contour plots (Appendix C).

(3) time series plots by depth interval (Figure 9).

These displays are referenced in the discussion below.

The vertical temperature structure of deep lakes is usually described as consisting of three distinct zones during the summer:

epilimnion: relatively warm, well-mixed, surface layer of the pond, where temperature is fairly uniform with depth;

metalimnion or **thermocline**: intermediate layer, where temperature declines sharply with depth; and

hypolimnion: cool, bottom layer, of relatively uniform temperature, which is essentially isolated from the surface waters and the atmosphere during the summer season.

Because water density varies with temperature, the thermocline acts as a barrier to vertical mixing. The thermocline generally starts out near the surface in the late spring and migrates downward as the lake heats and then cools later in the summer. Wind-induced mixing can have major influences on thermocline movement by causing entrainment of cool metalimnetic or hypolimnetic waters into the surface layer. Fall turnover occurs when the thermocline reaches the bottom and the lake mixes vertically. Northern lakes may also stratify in winter, with warmer waters (approaching 4 deg C) on the bottom and cooler waters (approaching 0 deg C, in equilibrium with surface ice temperature).

Typical of lakes of this depth and region, Chickawaukie stratifies

Figure 9
Temperature, Dissolved Oxygen, and Total Phosphorus Time Series

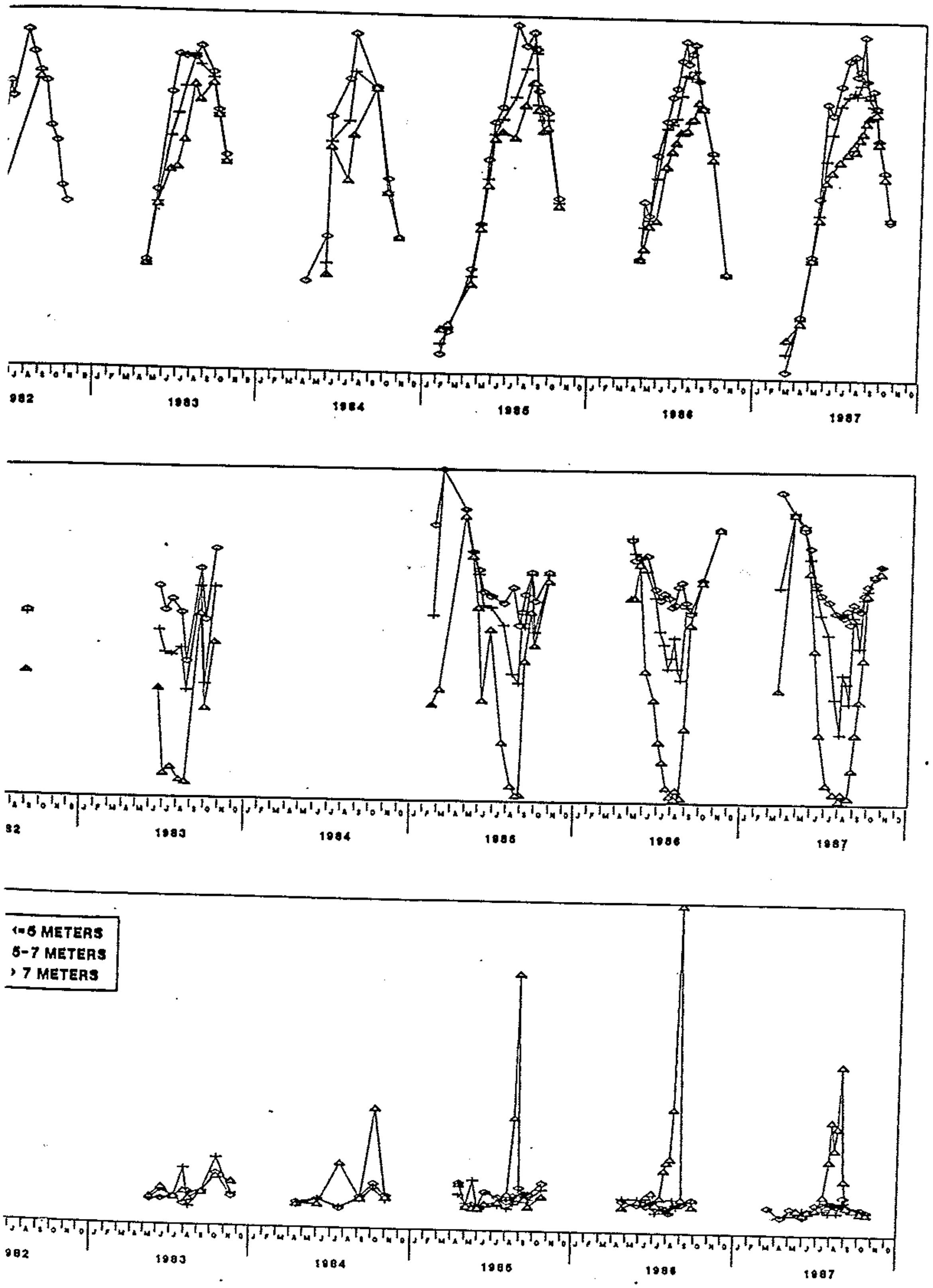


Figure 10
General Impacts of Wind on Thermocline Tilt and Water Currents

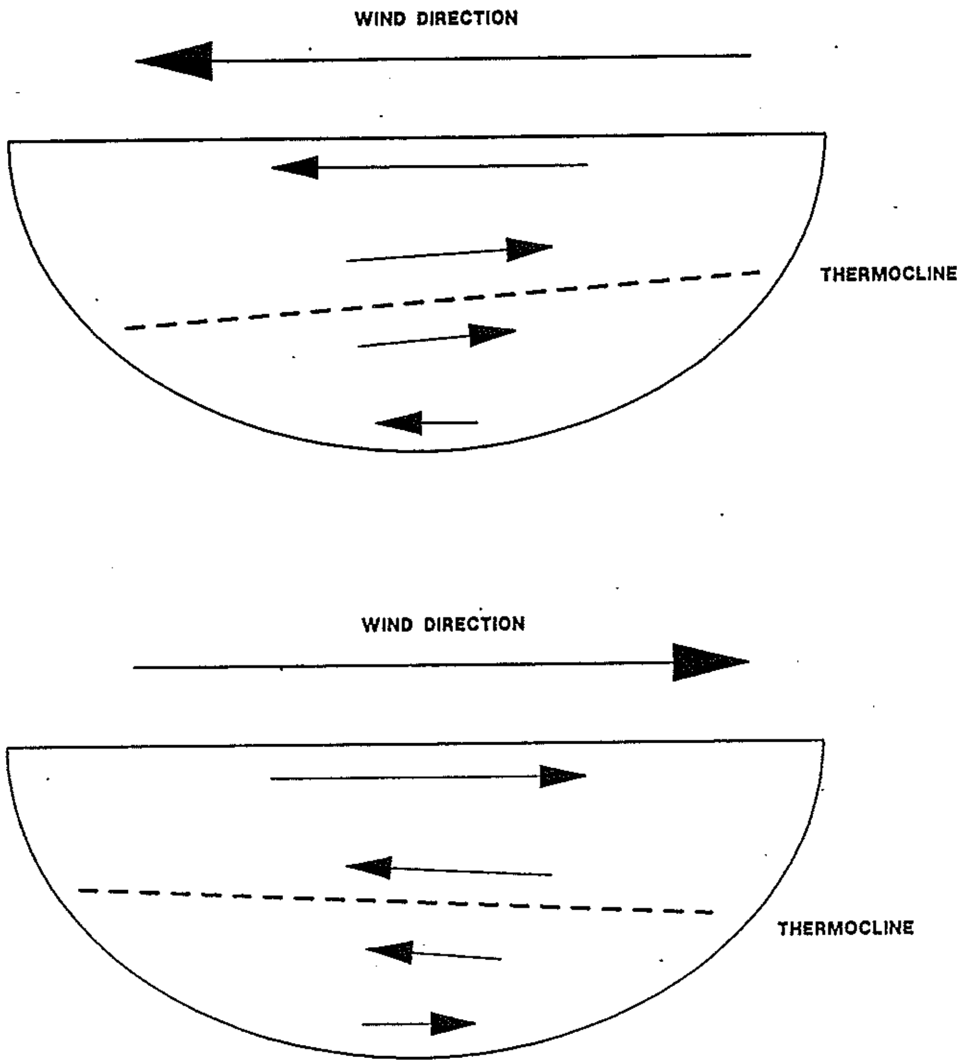


Figure 11
Bottom Dissolved Oxygen Variations

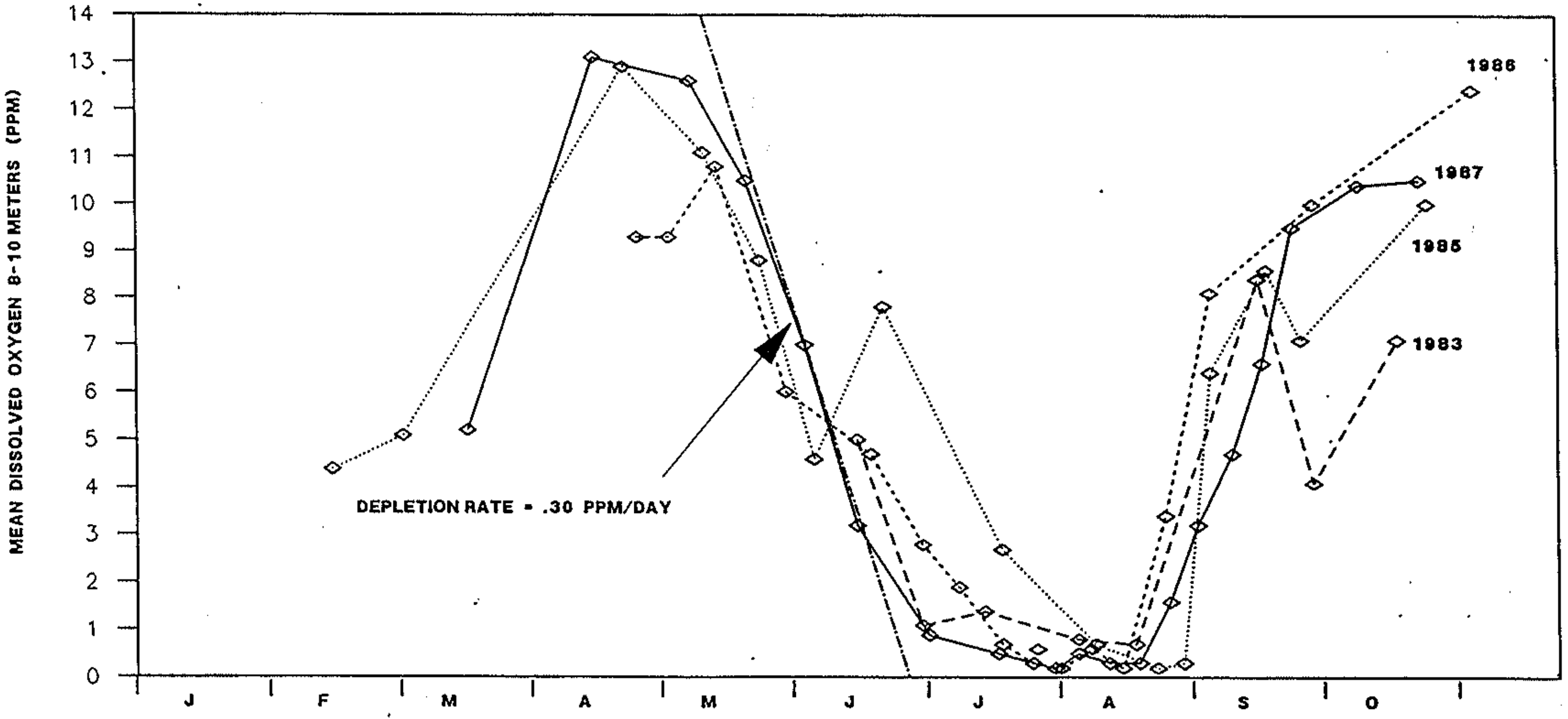


Table 3
Dominant Algal Types in 1987

Date	3/16	5/7	6/15	7/1	7/17	7/30	8/5	8/19	8/26	9/2	9/10	9/24	10/9
Detritus	XX												
Anabaena		X	X	XX	X	XX	XX	XX	XX	XX	XX	XX	XX
Aphanizomenon	X		X		X								
Asterionella	X	X	XX	X	X								X
Ceratium					X				X				
Dinobryon			X										
Fragillaria		X			X	X	X	X	X		X		X
Spirogyra					X								
Staurastrum			X										
Synura			X		X								
Tabellaria		XX	X	X	XX	X	X	X	X		X		X
Ulothrix		X			X				X				
Volvox		X			X	X			X			X	

XX Dominant
X Present

Table 4
Statistical Summary of Chickawaukie Lake Phosphorus, Chlorophyll-a, and Transparency Data

Year	N	Mean	Standard Dev.	Standard Error	Minimum	Maximum
		Total Phosphorus (ppb)			0-5 meters	
1982	1	19.0			19.0	19.0
1983	6	18.8	2.9	1.2	14.4	22.6
1984	4	17.8	2.9	1.5	13.4	21.2
1985	12	22.8	4.8	1.4	15.7	32.0
1986	13	18.4	2.2	0.6	13.7	22.7
1987	15	19.0	3.5	0.9	12.0	25.8
ALL	51	19.6	3.9	0.5	12.0	32.0
		Chlorophyll-a (ppb)			Epilimnion	
1982	10	15.1	22.3	7.1	2.4	71.0
1983	5	11.0	10.3	4.6	2.8	30.6
1984	3	11.6	10.8	6.2	3.7	26.9
1985	10	14.8	10.5	3.3	2.0	34.0
1986	8	8.6	2.4	0.8	5.3	12.2
1987	13	11.6	6.1	1.7	4.5	24.7
ALL	49	12.4	12.6	1.8	2.0	71.0
		Transparency (meters)			Surface	
1982	11	3.2	1.3	0.4	1.1	5.1
1983	9	3.2	1.6	0.5	1.4	6.4
1984	8	3.5	1.1	0.4	1.4	5.0
1985	13	2.2	1.1	0.3	0.9	4.4
1986	15	3.5	0.6	0.2	2.6	4.5
1987	16	2.4	1.0	0.3	1.2	4.5
ALL	72	2.9	1.1	0.1	0.9	6.4

N = Number of Sampling Dates
Values for April-September of Each Year

ppb) during each year. "Severe nuisance" (>30 ppb) levels were detected in September of 1982, 1983 and 1985. Recent studies in Minnesota (Heiskary and Walker,1987) have shown that Walmsley's nuisance criteria are highly correlated with subjective evaluations of physical appearance and suitability for recreational use. Transparency cycled between 4-5 meters in spring and 1-2 meters in late summer and fall. Based upon modeling results described below, seasonal reductions in transparency can be attributed primarily to increases in algal density, driven by phosphorus recycled from lake bottom sediments.

The surface-layer time series in Figure 12 suggest that lake conditions were improved in later years of the survey (1986-1987), as compared with 1982-1985, particularly with respect to seasonal maximum chlorophyll-a and phosphorus concentrations. These "improvements" may be partially attributed to effects of ongoing watershed management programs, winter flushing, and/or increases in lake level (Figure 7). A longer monitoring period is needed, however, to determine whether these observed changes are "real" or whether they reflect random climatologic variations.

The phosphorus, chlorophyll-a, and transparency data clearly indicate that 1986 was "different" from the other years. Seasonal increases in phosphorus and chlorophyll-a did not occur and the transparency remained above 2.5 meters. One hypothesis is that there was less vertical transport of phosphorus from the bottom waters into the surface waters during this year. This hypothesis is supported by two observations:

(1) Peak phosphorus concentrations in the bottom waters were highest during 1986 (Figure 9). The June 18, 1986 sample at 10 meters also had a phosphorus concentration of 2380 ppb, the highest recorded value in the lake survey data base. More of the phosphorus contributed by bottom sediments and settled algal cells apparently remained below the thermocline and less was transported into the surface layer during 1986.

(2) Thermal stratification was more pronounced during 1986, particularly in late spring. Figure 13 compares vertical temperature profiles taken in late May of 1983, 1985, 1986, and 1987. The thermocline was much stronger in May 1986 and had a maximum temperature gradient of about 2 deg-C/meter, vs. .5 deg-C/meter for other years. The stronger thermocline would have the effect of "trapping" phosphorus released from bottom sediments and from decay of the spring diatom bloom and other organic particles. The bottom temperature was also slightly cooler in 1986 (10 deg-C vs. 10.5-12 deg-C), despite the later sampling date (May 29 vs. May 19-23).

The stronger thermocline and cooler bottom temperatures during May 1986 may reflect differences in the timing and magnitude of spring runoff, air temperatures, and/or wind speeds. Based upon maximum sampled depths (Figure 7), lake levels may have been higher in spring 1986. A higher l level in early spring would increase the initial storage of cold er and promote thermal stability later in the season.

August 1987 monitoring also included analyses for nitrogen species, three depths (Appendix A). Nitrate levels were at or below the ection limit (100 ppb) in all samples. Ammonia concentrations were s than 10 ppb in surface and between 80 and 150 ppb in bottom waters. is possible that algal populations were influenced by nitrogen itation during this period, although low resolutions of the nitrate kjeldahl nitrogen analyses preclude an accurate determination of iting nutrient during this period.

SPHORUS RECYCLING DYNAMICS

Figure 14 overlays seasonal variations in epilimnetic (0-5 meter) sphorus, epilimnetic chlorophyll-a, hypolimnetic (8-10 meter) solved oxygen, and hypolimnetic total phosphorus. These plots strate the coupling of processes occurring in surface and bottom rs and eventually leading to algal bloom development:

(1) During each year, the period of maximum algal growth (as measured by rate of increase in chlorophyll-a) occurred when bottom waters were anaerobic. This suggests that anaerobic sediment processes (e.g., reduction and solubilization of iron phosphate compounds, (Stauffer, 1981)) and subsequent phosphorus transport into the mixed layer contribute to algal bloom development.

(3) In 1983 and 1984, hypolimnetic phosphorus accumulations were small, although increases in epilimnetic phosphorus and chlorophyll-a were substantial. This is consistent with sediment phosphorus release and relatively high vertical transport rates during these years.

(4) In 1985, 1986, and 1987, peak rates of phosphorus increase in the hypolimnion also coincided with anaerobic periods. Rates of phosphorus increase accelerated during anaerobic periods, especially after development of significant chlorophyll-a concentrations. In 1986 and 1987, peak hypolimnetic phosphorus concentrations followed peak chlorophyll-a concentrations. Both redox-mediated sediment phosphorus release and decay of settling algal cells contribute to hypolimnetic phosphorus accumulations. In a sense, however, both of these processes are driven by algal sedimentation, which supplies the organic matter (energy) necessary to drive sediment redox reactions.

(5) During the peak algal bloom in late summer of each year, the epilimnetic chlorophyll-a and total phosphorus concentrations were approximately equal. Since the phosphorus/chlorophyll-a ratio of algal biomass is typically 1:1 by weight (Bowie et al., 1985), most of the phosphorus in the mixed layer was incorporated into algal

cells and relatively little existed in dissolved or detrital form. This relationship is used below is as a crude model for predicting algal responses at fall turnover based upon phosphorus mass balance.

(6) Algal peaks were observed before and after fall turnover in 1985 and 1987. In 1985, the fall peak was more severe. In 1987, the summer peak was more severe. Weather conditions (light, temperature) and iron-phosphate precipitation likely control algal response to phosphorus mixed into the surface layer at fall turnover. Generally, an earlier turnover period would be more conducive to an algal bloom, particularly one which interferes with recreational uses of the lake.

(7) The July 1987 bloom occurred earlier in the season than in other years and coincided with a period of maximum anoxia. The depth of the anoxic layer dropped from approximately 6.5 (shallowest recorded) to 7.5 meters between July 30 to August 5. It is possible that this bloom was driven by phosphorus released from shallow metalimnetic sediments. Stauffer and Armstrong (1984) reported that a similar mechanism was responsible for epilimnetic phosphorus loading in Shagawa Lake, Minnesota.

Accumulations of iron (680-1,940 ppb), manganese (2,560-3,100 ppb), and total phosphorus (48-230 ppb) were observed in the lake bottom waters during August 1987. These reflect reduction and dissolution of metals from bottom sediments under anaerobic conditions. Iron can have important impacts on phosphorus recycling from lake sediments (Stauffer, 1981). Under aerobic conditions, formation of insoluble ferric hydroxy-phosphates can immobilize soluble phosphorus. Under anaerobic conditions, the iron is chemically reduced, releasing soluble ferrous and phosphate ions. These processes often lead to accumulation of soluble iron and phosphorus in the bottom waters of stratified, anoxic lakes. When these compounds are transported via diffusion or thermocline erosion to lake surface waters (aerobic), the iron is oxidized and ferric hydroxy-phosphates are reformed. Algae compete with this process to utilize soluble phosphorus transported from anaerobic bottom waters. Results of this competition depend upon several factors, including pH, temperature, light.

As described by Stauffer (1981), iron to phosphorus ratios exceeding 3.2 to 1 by weight are required to immobilize soluble phosphorus, based upon typical composition of iron hydroxide precipitates. Recent feasibility studies of ortho phosphate immobilization in the hypolimnion of a Minnesota lake via ferric chloride addition indicate that iron to phosphorus ratios of approximately 20 to 1 are required to achieve ortho phosphorus concentrations below 10 ppb (Walker,1987). The iron to phosphorus ratio ranged from 8 to 30 in the bottom waters of Chickawaukie Lake during August 1987, based upon four samples at 9 meters depth. Given the observed development of algal blooms in Chickawaukie during periods of

Table 5
Eutrophication Model Predictions

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LAKE EUTROPHICATION ANALYSIS PROCEDURE REPORT ON:   CHICKAWAUKIE LAKE, MAINE

                                               ---PREDICTED CONDITIONS---
LAKE CONDITION...           UNITS              Existing Pristine Full Dev
spring phosphorus           ppb                   17.7      8.7     56.8
summer chlorophyll-a        ppb                    4.7      1.7     25.2
summer transparency         m                      3.8      5.2      1.3

fall overturn phosphorus    ppb                   26.5     13.0     84.8
overturn chlorophyll-a      ppb                   26.5     13.0     84.8
overturn transparency       m                      1.2      2.1      0.4

ALGAL NUISANCE FREQUENCIES...
"no problems"               chl-a < 10 ppb        93.8%    99.9%    11.9%
"algae visible "            chl-a 10-20 ppb        6.2%     0.1%    88.1%
"nuisance conditions"       chl-a 20-30 ppb        0.4%     0.0%    52.5%
"severe nuisance"           chl-a > 30 ppb         0.0%     0.0%    27.7%

HYPOLIMNETIC OXYGEN DEPLETION...
areal depletion rate        mg/m2-day              358      185     1046
vol. depletion rate         mg/m3-day              336      174      980
days of oxygen supply       days                    36       69       12

EXISTING WATER AND PHOSPHORUS BUDGETS...                Water      Total Phosphorus
                            Area     Flow      Flow    Yield    Load    Load   Export     Conc
Item                       acres  ac-ft/yr       %     in/yr   lbs/yr     % lbs/ac-yr     ppb
undeveloped area            1413   2755.4     47.2%    23.4    112.6   20.5%   0.080     15.0
agric untilled               481    937.9     16.1%    23.4     76.6   14.0%   0.159     30.0
urban area                   368    717.6     12.3%    23.4    271.7   49.5%   0.738    139.0
shoreline sewage disposal                                       23.1    4.2%
precipitation                362   1420.9     24.4%    47.1     65.2   11.9%   0.180     16.8
total inflow                2624   5831.8    100.0%    26.7    549.2  100.0%   0.209     34.6
evaporation                  362    693.8     11.9%    23.0
sedimentation                                                  301.4   54.9%
outflow                     2624   5137.9     88.1%    23.5    247.8   45.1%   0.094     17.7
overturn recycle                                               180.8   32.9%


LAKE MORPHOMETRIC AND HYDROLOGIC VARIABLES...
surface area               362.0 acres    hydraulic residence time      1.48 years
mean depth                  21.0 feet     surface overflow rate        14.19 ft/yr
maximum depth               33.1 feet     phosphorus residence time     0.67 years
shoreline septic sys. use    105 people   mean hypolimnetic depth        3.5 feet
septic p removal effic.       90 %        hypolimnetic surface area    141.0 acres
fall overturn p recycle      0.6 fraction
```

15 ppb) for the pond surface.

Spring phosphorus concentrations are estimated from external phosphorus loading, water budget, and lake volume using the empirical phosphorus retention model developed by Larsen and Mercier (1976). This model is routinely employed in analyses of Maine lakes (Dennis and Dennis,1987). Summer chlorophyll-a level (prior to late summer phosphorus recycling) is estimated using Dillon and Rigler's (1974) spring phosphorus/summer chlorophyll-a regression. Chlorophyll-a frequencies (early summer) corresponding to Walmsley's (1984) nuisance categories are predicted using a lognormal frequency distribution model (Walker,1984). Late spring areal hypolimnetic oxygen depletion rate is estimated based upon spring phosphorus and mean depth using a model developed from northern lake data (Walker,1979).

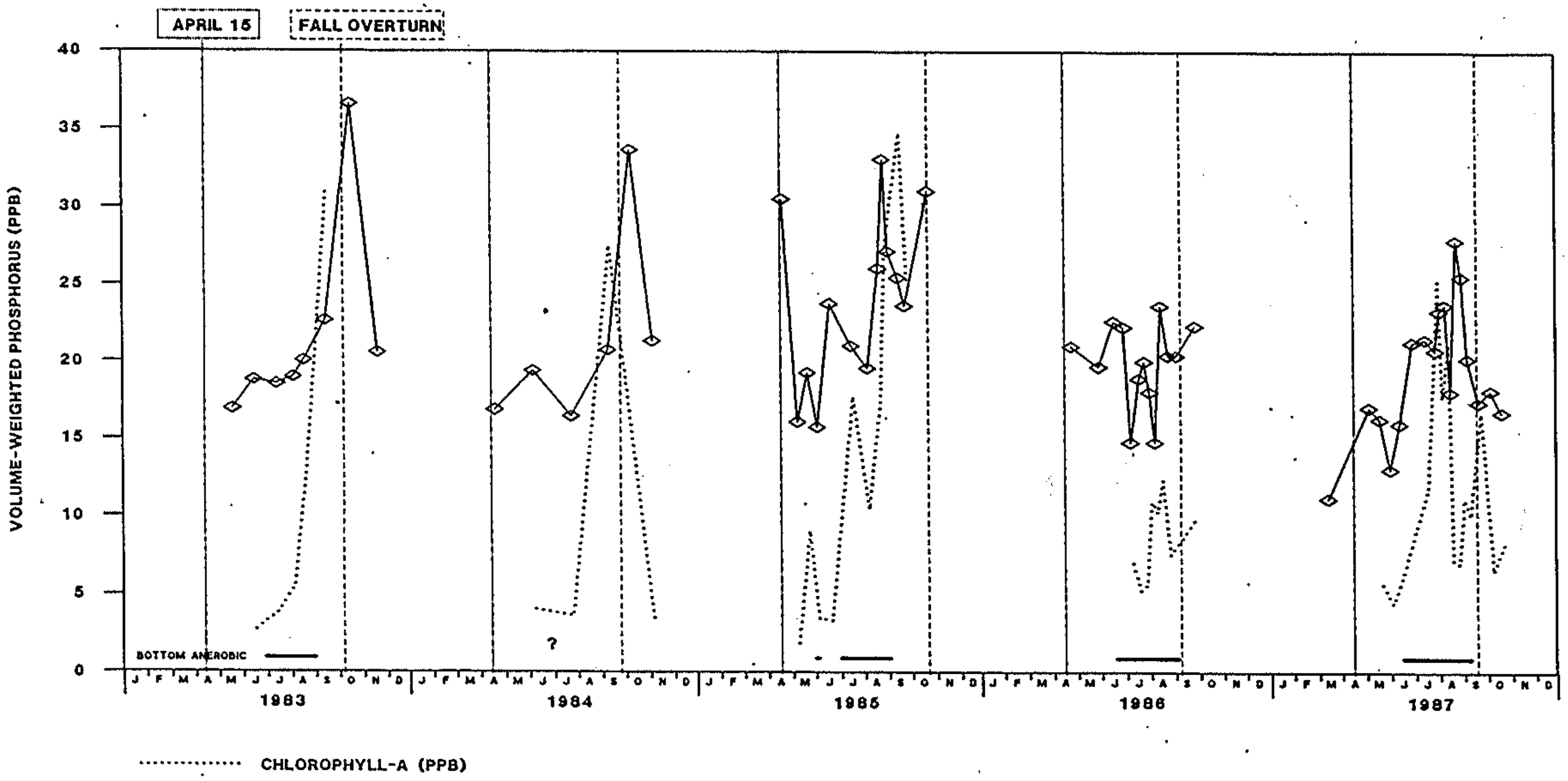
Figure 16 shows that inverse transparency (proportional to light extinction coefficient) can be modeled as a linear function of chlorophyll-a over a concentration range of 0 to 50 ppb. The slope of the relationship (.025 m^2/mg) is identical to that employed in similar models developed for Vermont lakes (Walker,1982b) and Corps of Engineer reservoirs (Walker,1985). The intercept (.15 m^{-1}) is a calibrated value which reflects light extinction by inorganic particles and color. The data and model indicate that transparency in Chickawaukie is controlled primarily by variations in algal density.

Effects of internal phosphorus recycling on phosphorus and productivity late in the summer are predicted using a modified version of the model suggested by Nurnberger(1984). An additional term is added to the phosphorus balance equation to account for summer internal recycling which accounts for the observed seasonal increases in surface-layer phosphorus concentration. This internal recycling term is calculated as a fraction of the estimated annual net phosphorus sedimentation, as predicted using the Larsen-Mercier model. The recycle fraction (0.6) has been calibrated to predict peak mixed-layer phosphorus concentrations in late summer 1987 (Figure 12). Fall overturn phosphorus concentration is calculated by adding the recycle term (recycled load divided by lake volume) to the predicted phosphorus concentration at spring turnover.

Because of algal uptake and co-precipitation with iron, fall recycled phosphorus is assumed not to influence lake conditions the following spring. Time-series of volume-weighted phosphorus concentrations (Figure 17) show relatively rapid reductions in water column phosphorus concentrations following fall overturn in 1983, 1984 and 1987. Net internal recycling during 1986 was small and the lake was not sampled after overturn in 1985. With this assumption, a spring phosphorus concentration of 17.7 ppb is predicted based upon the external phosphorus budget. This value appears reasonable in relation to observed time series (Figure 12).

Algal responses at fall turnover are predicted by assuming a chlorophyll-a/phosphorus ratio of 1 during this period. As discussed above, this amounts to assuming that all of the phosphorus in the water column is incorporated into algal cells. Observed time series (Figures

Figure 17
Volume-Weighted Phosphorus Concentrations



Year	1983	1984	1985	1986	1987	MODEL
Spring P Conc. ppb	17	17	17	21	18	17.7
Peak P Conc. ppb	37	34	34	26	28	26.5
Net P Increase ppb	20	17	17	5	10	8.8
Net P Increase lbs	413	351	351	103	207	182

Lake Volume = 7602 acre-feet

Table 6
Unit Impacts on Lake Phosphorus Concentration

CHICKAWAUKIE LAKE, MAINE		Lake P	Lake P	Units-Required	
UNIT IMPACTS ON LAKE PHOSPHORUS...	P Load	Conc	Conc	10%	1 ppb
	lbs/yr	ppb	%	Impact	Impact
acre undeveloped land	0.08	0.003	0.01%	689	388
acre pasture	0.16	0.005	0.03%	345	194
acre row crop	0.30	0.010	0.06%	181	102
acre urban land	0.74	0.024	0.13%	74	42
acre impervious surface	1.78	0.058	0.32%	31	17
typical urban lot	0.55	0.018	0.10%	100	56
person input to shoreline septic system	2.20	0.071	0.40%	25	14
person output from shoreline septic system	0.22	0.007	0.04%	250	141
5-lb box tide detergent	0.49	0.016	0.09%	112	63
50-lb bag lawn fertilizer	0.65	0.021	0.12%	84	47
cubic yard top soil	1.11	0.036	0.20%	49	28
ton fresh cow manure	4.00	0.129	0.73%	14	8
ton dried cow manure	36.00	1.163	6.55%	2	1
ton fresh horse manure	4.00	0.129	0.73%	14	8
ton guano	160.00	5.169	29.13%	0	0
ton pine needles	2.00	0.065	0.36%	27	15
ton oak leaves	8.00	0.258	1.46%	7	4
ton alfalfa hay	10.00	0.323	1.82%	5	3
ton cornstalks	8.00	0.258	1.46%	7	4
ton phosphate rock	400.00	12.923	72.83%	0	0
ton wood ashes	30.00	0.969	5.46%	2	1
cubic yard fresh cow manure	3.37	0.109	0.61%	16	9
cow - year	38.72	1.251	7.05%	1	1
hog - year	7.11	0.230	1.29%	8	4
sheep - year	3.23	0.104	0.59%	17	10
person - year	2.20	0.071	0.40%	25	14
turkey - year	0.86	0.028	0.16%	64	36
goose - year	0.62	0.020	0.11%	89	50
duck - year	0.38	0.012	0.07%	146	82
chicken (layer) - year	0.35	0.011	0.06%	156	88
chicken (broiler) - year	0.20	0.006	0.04%	277	156
seagull - year	0.09	0.003	0.02%	595	335

of only 6% of the phosphorus stored in bottom sediments would account for the observed increases in volume-weighted phosphorus concentration in late summer. The gross release of 903 lbs, estimated above based upon an assumed anoxic release rate of 12 mg/m^2-day, would be 29% of the sediment stored phosphorus.

Modeling results indicate that spring and early summer phosphorus, chlorophyll-a, and transparency levels in Chickawaukie Lake are in reasonable agreement with expectations based upon lake morphometry, land uses, and regional factors. These **mesotrophic** conditions are also reasonably compatible with existing lake uses. **Eutrophic** conditions in late summer and fall, however, result from internal recycling mechanisms which, in turn, reflect historical watershed abuses (causing enrichment of bottom sediments) and lake hydrodynamics (promoting phosphorus recycling from bottom sediments during periods of high algal growth potential).

CONTROL STRATEGIES

Continuation of the ongoing watershed management program is required to protect the lake from further increases in external phosphorus loading. Lake profile data analysis and modeling results indicate that reductions in internal phosphorus recycling are clearly required to reduce the frequency and severity of late summer algal blooms. Approaches to achieving the latter objective are discussed below.

Based upon review of recent literature on inlake management techniques for controlling internal phosphorus cycling (Cooke et al.,1986, NALMS,1988) and upon consideration of lake-specific conditions, the following methods are discussed:

(1) **flushing**

(2) **lake level increase**

(3) **destratification**

(4) **hypolimnetic aeration**

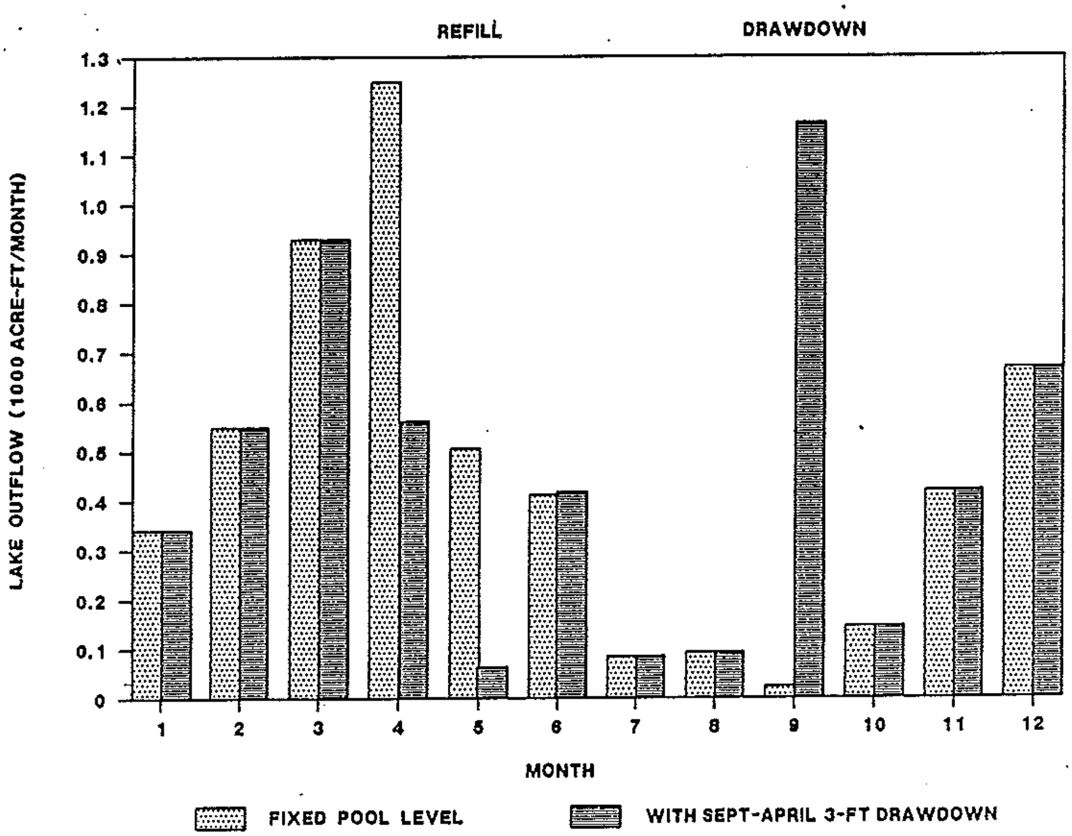
(5) **sediment phosphorus inactivation**

The features, potential effectiveness, and limitations of these techniques are discussed below. For more comprehensive reviews of these techniques, the reader is referred to the above references. The following discussion focuses on aspects which are relevant to Chickawaukie Lake and which could provide some degree of long-term control.

In this context, **flushing** refers to lowering of the lake water level during the fall season, when relatively high phosphorus concentrations have been observed in the surface waters. As discussed above, this technique was practiced during the fall/winter seasons of 1985-86 and 1986-87. In each of these periods, the lake level was drawn

Figure 18

Effects of Lake Level Regulation on Outflow



BASED UPON MONTHLY WATER BALANCE CALCULATIONS
AVERAGE RUNOFF AND PRECIPITATION 1981-1985

of algal blooms, during the worst possible period from a water supply perspective. Thus, while an increase in lake level may improve water quality during average or high-flow years, a potential for algal blooms would remain if water supply uses involve seasonal drawdown during dry years. Higher water levels would reduce, but not eliminate, the risk of algal blooms following major wind events during summer.

Destratification systems are designed to eliminate thermal stratification and thereby prevent development of anaerobic conditions in lake bottom waters. As indicated above, periods of maximum algal growth rate coincide with periods of bottom anoxia as a result of phosphorus released from bottom sediments. Destratification is generally achieved with air injection or various types of mechanical devices. This technique was suggested by Whitman and Howard (1986) as a possible method for controlling algal blooms in Chickawaukie Lake.

Because of lake morphometry, it would be technically feasible, if not relatively easy, to destratify the lake with aerators or mechanical devices (especially with a little help from the wind). This would, in turn, prevent the development of anaerobic conditions in the bottom waters and reduce redox-mediated phosphorus recycling. It would tend to increase aerobic phosphorus recycling, however, by mixing phosphorus released from settled algal cells and other detritus back into the surface layer during the growing season. Another problem is that anaerobic processes can still occur in the surficial sediments and release phosphorus, even when the overlying water column is aerobic (Ripl,1985). As described by Lorenzen and Mitchell (1974), destratification has the highest potential for reducing algal productivity when light-limited conditions can be induced by mixing algal cells over greater depths. Lake depths and non-algal turbidity levels in Chickawaukie are too low to expect that mixing would induce light limitation during the summer.

While destrafication is effective for dealing with such problems as iron and manganese, the technique has a rather nebulous track record for controlling nutrient and algae problems. A review of 20 case studies by Patsorak et al, (1982) indicates that reductions in total phosphorus were achieved following destratification in only 30% of the cases. Transparency decreased more frequently (53%) than it increased (21%). Total and bluegreen algal density were reduced in 42% and 52% of the cases, respectively.

Hypolimnetic aeration systems are designed to introduce oxygen below the thermocline without destratifying the lake (Ashley,1985). Since oxygen levels are maintained in the hypolimnion and the thermocline is not destroyed, such systems can potentially reduce phosphorus recycling attributed to anaerobic processes without increasing aerobic phosphorus recycling. The advantage of trapping nutrients below the thermocline during the summer months is maintained.

Hypolimnetic aeration would be limited use in Chickawaukie Lake. The lake is too shallow and wind-swept (rarely has a true hypolimnion). Recent experience in Minnesota (Walker,1987), indicates that this technique can be effective for increasing hypolimnetic dissolved oxygen

CONCLUSIONS AND RECOMMENDATIONS

(1) Spring and early summer phosphorus, chlorophyll-a, and transparency levels in Chickawaukie Lake are in reasonable agreement with expectations based upon lake morphometry, land uses, and regional factors. These mesotrophic conditions are also reasonably compatible with existing lake uses.

(2) Eutrophic conditions in late summer and fall result from internal phosphorus recycling mechanisms which, in turn, reflect historical watershed abuses (causing enrichment of bottom sediments) and lake hydrodynamics (promoting phosphorus recycling from bottom sediments during periods of high algal growth potential).

(3) Monitoring data suggest that lake conditions were improved in 1986 and 1987, as compared with 1982 through 1985, particularly with respect to seasonal maximum chlorophyll-a and phosphorus concentrations. These "improvements" may be partially attributed to effects of ongoing watershed management programs, fall/winter flushing, and/or increases in lake level. A longer monitoring period is needed, however, to determine whether these observed changes are "real" or whether they reflect random climatologic variations.

(4) Although it promotes oxygen depletion, thermal stratification can be considered beneficial because it helps to trap phosphorus released from settled algae and from bottom sediments below the thermocline until turnover. Higher thermal stability in 1986 probably contributed to the substantially lower phosphorus, lower chlorophyll-a, and higher transparencies measured during that year.

(5) Lake level manipulations should be done with consideration of their effects on temperature stratification and phosphorus recycling. Generally, higher levels are preferred for promoting temperature stratification, deferring the onset of anaerobic conditions during summer and winter stratified periods, and reducing the risk of algal bloom development following major wind events in midsummer.

(6) A control strategy recommended on a trial basis involves maintaining maximum pool level (subject to constraints imposed by outlet structure, shoreline flooding, beach access, etc.) from late winter through the summer stratified period. Although this practice may be cost-effective for reducing the frequency and severity of algal blooms, risk of algal blooms would still exist at fall turnover, after major mid-summer wind events, and/or during lake drawdown periods, if required for water-supply purposes under drought conditions.

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APPENDIX A

DATA LISTINGS

1 - Oxygen, Temperature, Phosphorus, Secchi, Chlorophyll-a

2 - Other Water Quality Data

3 - Comments

CHICKAWAUKIE LAKE WATER QUALITY DATA BASE PAGE 3

STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
C	9/29/83	9.0	17.0	4.1			
C	9/29/83	9.5	17.0	3.4			
C	10/18/83	0.0	14.8	9.9		1.7	
C	10/18/83	1.0	14.2	10.9	32		
C	10/18/83	2.0	14.0	11.5	34		
C	10/18/83	3.0	14.0	11.8	33		
C	10/18/83	4.0	13.9	12.2	38		
C	10/18/83	5.0	14.9	11.4	39		
C	10/18/83	6.0	13.9	10.5	60		
C	10/18/83	7.0	13.9	8.7	32		
C	10/18/83	8.0	13.9	7.8	31		
C	10/18/83	9.0	13.9	6.4	36		
C	10/28/83	0.0				2.1	
C	11/22/83	1.0			13	2.4	
C	11/22/83	2.0					
C	11/22/83	3.0			23		
C	11/22/83	4.0					
C	11/22/83	5.0			24		
C	11/22/83	6.0					
C	11/22/83	7.0			22		
C	11/22/83	8.0					
C	11/22/83	9.0			30		
C	4/20/84	0.0	6.0			3.4	
C	4/20/84	1.0			20		
C	4/20/84	2.0					
C	4/20/84	3.0			17		
C	4/20/84	4.0					
C	4/20/84	5.0			14		
C	4/20/84	6.0					
C	4/20/84	7.0			15		
C	4/20/84	8.0					
C	4/20/84	9.0			16		
C	4/28/84	0.0				2.5	
C	6/03/84	0.0	10.6			3.5	
C	6/03/84	1.5	9.4				
C	6/03/84	3.0	8.3				
C	6/03/84	4.6	7.8				
C	6/03/84	6.1	7.2				
C	6/03/84	7.6	7.2				
C	6/03/84	9.1	6.7				
C	6/03/84	10.4	5.6				
C	6/07/84	1.0	18.0	8.6	20	5.0	4.1
C	6/07/84	2.0	18.0	6.4	22		
C	6/07/84	3.0	17.0	4.8			
C	6/07/84	4.0	16.0	4.0	18		
C	6/07/84	5.0	16.0	3.8	18		
C	6/07/84	6.0	15.5	3.4	23		
C	6/07/84	7.0	15.0	3.2	16		
C	6/07/84	8.0	15.0	2.8	17		
C	6/07/84	9.0	15.0	2.8	15		
C	6/07/84	10.0	15.0	2.6			
C	7/15/84	0.0	21.1			4.0	
C	7/15/84	1.5	20.6				
C	7/15/84	3.0	18.3				
C	7/15/84	4.6	17.8				
C	7/15/84	6.1	16.7				
C	7/15/84	7.6	13.9				
C	7/15/84	9.1	11.7				
C	7/26/84	0.0	23.0	8.0		4.7	3.7
C	7/26/84	1.0	23.0	3.8	20		
C	7/26/84	2.0	22.5	3.8	12		
C	7/26/84	3.0	22.5	2.6	12		
C	7/26/84	4.0	22.5	2.6	12		
C	7/26/84	5.0	22.0	0.8	11		

CHICKAWAUKIE LAKE WATER QUALITY DATA BASE PAGE 4

STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
C	7/26/84	6.0	21.0	0.6	14		
C	7/26/84	7.0	19.0	0.6	15		
C	7/26/84	8.0	16.5	0.6	16		
C	7/26/84	9.0	15.0	0.6	72		
C	8/18/84	0.0				3.5	
C	9/12/84	0.0	19.0	9.3		1.4	26.9
C	9/12/84	1.0	19.0	8.8	20		
C	9/12/84	2.0	19.0	7.7	22		
C	9/12/84	3.0	19.0	5.9	28		
C	9/12/84	4.0	19.0	5.0	18		
C	9/12/84	5.0	18.9	4.5	18		
C	9/12/84	6.0	18.9	4.0	18		
C	9/12/84	7.0	18.9	3.5	21		
C	9/12/84	8.0	18.9	2.7	20		
C	10/11/84	0.0	15.0	10.2		1.4	
C	10/11/84	1.0	13.0	11.2	34		
C	10/11/84	2.0	13.0	9.8	31		
C	10/11/84	3.0	12.2	4.8	29		
C	10/11/84	4.0	12.1	5.5	28		
C	10/11/84	5.0	12.0	4.9	30		
C	10/11/84	6.0	12.0	4.0	26		
C	10/11/84	7.0	12.0	3.7	28		
C	10/11/84	8.0	12.0	3.2	32		
C	10/11/84	9.0	12.0	3.1	130		
C	11/08/84	0.0	9.0	14.2		2.6	3.4
C	11/08/84	1.0	9.0	14.4	20		
C	11/08/84	2.0	9.0	12.0	25		
C	11/08/84	3.0	9.0	10.4	22		
C	11/08/84	4.0	9.0	8.0	22		
C	11/08/84	5.0	9.0	4.7	22		
C	11/08/84	6.0	9.0	5.0	18		
C	11/08/84	7.0	9.0	3.7	20		
C	11/08/84	8.0	9.0	4.3	22		
C	11/08/84	9.0	9.0	4.3	20		
C	11/27/84	0.0				3.4	
C	2/15/85	0.0	0.2	14.9		4.0	
C	2/15/85	1.0	1.0	14.5			
C	2/15/85	2.0	1.5	13.2			
C	2/15/85	3.0	1.5	11.2			
C	2/15/85	4.0	1.5	10.8			
C	2/15/85	5.0	1.8	10.6			
C	2/15/85	6.0	2.0	8.8			
C	2/15/85	7.0	2.0	7.9			
C	2/15/85	8.0	2.5	7.2			
C	2/15/85	9.0	3.0	3.2			
C	2/15/85	10.0	3.5	2.8			
C	3/01/85	0.0	2.0	14.8		2.9	
C	3/01/85	1.0	3.0	14.8			
C	3/01/85	2.0	3.0	15.1			
C	3/01/85	3.0	3.0	15.1			
C	3/01/85	4.0	3.0	15.2			
C	3/01/85	5.0	3.0	15.2			
C	3/01/85	6.0	3.0	15.0			
C	3/01/85	7.0	3.0	15.0			
C	3/01/85	8.0	3.0	7.4			
C	3/01/85	9.0	3.5	5.1			
C	3/01/85	9.5	3.5	2.7			
C	4/12/85	0.0				2.7	
C	4/22/85	0.0	7.0	13.2		2.8	
C	4/22/85	1.0	7.0	13.2	29		
C	4/22/85	2.0	7.0	13.2			
C	4/22/85	3.0	7.0	13.2	35		
C	4/22/85	4.0	7.0	13.2			
C	4/22/85	5.0	7.0	13.2	32		

CHICKAWAUKIE LAKE WATER QUALITY DATA BASE PAGE 7

STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
C	4/25/86	0.0	8.0	11.8		2.7	
C	4/25/86	1.0	8.0	11.8	23		
C	4/25/86	2.0	8.0	11.8			
C	4/25/86	3.0	8.0	11.8	16.		
C	4/25/86	4.0	8.0	12.0			
C	4/25/86	5.0	7.5	11.9	24		
C	4/25/86	6.0	7.9	12.0			
C	4/25/86	7.0	7.9	12.0	23		
C	4/25/86	8.0	7.9	12.1			
C	4/25/86	9.0	7.9	12.1	17		
C	4/25/86	10.0	7.9	3.6			
C	5/02/86	0.0	12.0	10.8		4.0	
C	5/02/86	1.0	12.0	10.8			
C	5/02/86	2.0	12.0	10.8			
C	5/02/86	3.0	12.0	11.0			
C	5/02/86	4.0	11.5	11.0			
C	5/02/86	5.0	10.5	11.4			
C	5/02/86	6.0	10.2	11.3			
C	5/02/86	7.0	9.8	11.2			
C	5/02/86	8.0	9.0	10.6			
C	5/02/86	8.5	8.8	10.0			
C	5/02/86	9.0	8.8	9.9			
C	5/02/86	9.5	8.5	9.1			
C	5/02/86	10.0	8.2	8.8			
C	5/02/86	10.5	8.0	7.2			
C	5/13/86	0.0	11.0	11.1		4.3	
C	5/13/86	1.0	11.0	11.0			
C	5/13/86	2.0	11.0	11.0			
C	5/13/86	3.0	10.5	11.0			
C	5/13/86	4.0	10.5	11.2			
C	5/13/86	5.0	10.5	11.2			
C	5/13/86	6.0	10.5	11.2			
C	5/13/86	7.0	10.5	11.2			
C	5/13/86	8.0	10.5	11.2			
C	5/13/86	8.5	10.2	11.2			
C	5/13/86	9.0	10.0	11.2			
C	5/13/86	9.5	10.0	11.2			
C	5/13/86	10.0	10.0	9.1			
C	5/29/86	0.0	14.8	11.0		4.5	
C	5/29/86	1.0	14.8	11.1	17		
C	5/29/86	2.0	14.8	11.2			
C	5/29/86	3.0	14.8	11.2	20		
C	5/29/86	4.0	14.8	11.2			
C	5/29/86	5.0	14.8	11.3	20		
C	5/29/86	6.0	14.5	11.2			
C	5/29/86	7.0	12.2	10.2	23		
C	5/29/86	8.0	11.2	9.6			
C	5/29/86	8.5	11.0	8.8			
C	5/29/86	9.0	10.1	5.0	21		
C	5/29/86	9.5	10.1	3.8			
C	5/29/86	10.0	10.0	3.1			
N	5/29/86	0.0	15.0	11.0			
N	5/29/86	1.0	14.9	11.0			
N	5/29/86	2.0	14.9	11.2			
N	5/29/86	3.0	14.9	11.2			
N	5/29/86	4.0	14.9	11.3			
N	5/29/86	5.0	14.9	11.4			
N	5/29/86	6.0	14.8	11.4			
N	5/29/86	7.0	14.2	11.2			
N	5/29/86	8.0	11.8	9.7			
N	5/29/86	8.5	11.2	9.7			
N	5/29/86	9.0	10.9	8.3			
N	5/29/86	9.5	10.2	5.7			
N	5/29/86	10.0	10.0	3.5			
S	5/29/86	0.0	14.8	11.2			
S	5/29/86	1.0	14.8	11.2			
S	5/29/86	2.0	14.8	11.2			

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STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
S	5/29/86	3.0	14.8	11.3			
S	5/29/86	4.0	14.8	11.3			
S	5/29/86	5.0	14.0	11.1			
S	5/29/86	6.0	12.9	10.3			
S	5/29/86	7.0	11.3	8.7			
S	5/29/86	8.0	10.5	7.8			
S	5/29/86	8.5	10.1	4.9			
S	5/29/86	9.0	10.0	3.6			
S	5/29/86	9.5	10.0	3.3			
S	5/29/86	10.0	10.0	3.2			
C	6/18/86	0.0	17.5	9.6	12	3.4	
C	6/18/86	1.0	17.5	9.7	22		
C	6/18/86	2.0	17.4	9.8	21		
C	6/18/86	3.0	17.0	9.8	13		
C	6/18/86	4.0	17.0	9.8	16		
C	6/18/86	5.0	17.0	9.8	24		
C	6/18/86	6.0	17.0	9.4	24		
C	6/18/86	7.0	16.0	8.8	18		
C	6/18/86	8.0	14.5	6.4	29		
C	6/18/86	8.5	14.3	5.8			
C	6/18/86	9.0	14.0	4.8	21		
C	6/18/86	9.5	13.0	2.7			
C	6/18/86	10.0	13.0	1.7	2380		
N	6/18/86	0.0	17.0	9.7			
N	6/18/86	1.0	17.0	9.7			
N	6/18/86	2.0	17.0	9.7			
N	6/18/86	3.0	17.0	9.8			
N	6/18/86	4.0	17.0	9.8			
N	6/18/86	5.0	16.5	9.5			
N	6/18/86	6.0	16.5	9.3			
N	6/18/86	7.0	16.0	8.6			
N	6/18/86	8.0	15.0	7.4			
N	6/18/86	8.5	14.5	6.4			
N	6/18/86	9.0	14.0	5.6			
N	6/18/86	9.5	14.0	3.5			
N	6/18/86	10.0	13.0	1.9			
S	6/18/86	0.0	18.0	9.6			
S	6/18/86	1.0	17.4	9.7			
S	6/18/86	2.0	17.0	9.7			
S	6/18/86	3.0	17.0	9.7			
S	6/18/86	4.0	17.0	9.8			
S	6/18/86	5.0	17.0	9.9			
S	6/18/86	6.0	17.0	9.8			
S	6/18/86	7.0	17.0	9.8			
S	6/18/86	8.0	16.0	8.2			
S	6/18/86	8.5	15.0	6.3			
S	6/18/86	9.0	14.0	4.4			
S	6/18/86	9.5	13.5	2.7			
S	6/18/86	10.0	13.0	2.0			
C	6/30/86	0.0	19.1	9.2		3.6	
C	6/30/86	1.0	19.0	9.2	38		
C	6/30/86	2.0	19.0	9.3	6		
C	6/30/86	3.0	18.9	9.3	25		
C	6/30/86	4.0	18.0	9.1	14		
C	6/30/86	5.0	17.0	8.7	19		
C	6/30/86	6.0	17.0	8.2	25		
C	6/30/86	7.0	16.5	7.3	16		
C	6/30/86	8.0	16.0	5.2	29		
C	6/30/86	9.0	15.0	2.9	26		
C	6/30/86	10.0	14.1	0.8			
N	6/30/86	0.0	19.7	9.2			
N	6/30/86	1.0	19.4	9.2			
N	6/30/86	2.0	19.1	9.3			
N	6/30/86	3.0	18.5	9.4			
N	6/30/86	4.0	17.8	9.2			
N	6/30/86	5.0	17.2	8.4			
N	6/30/86	6.0	17.0	8.1			
N	6/30/86	7.0	16.5	6.8			

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STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
N	7/25/86	9.0	16.0	0.1	34		
S	7/25/86	0.0	22.2	8.7			
S	7/25/86	1.0	22.0	8.8	20		
S	7/25/86	2.0	22.0	8.9			
S	7/25/86	3.0	22.0	9.0	14		
S	7/25/86	4.0	22.0	9.0			
S	7/25/86	5.0	21.9	9.1	17		
S	7/25/86	5.5	21.4	9.1			
S	7/25/86	6.0	20.4	8.4			
S	7/25/86	6.5	18.7	4.2			
S	7/25/86	7.0	18.2	3.1	16		
S	7/25/86	7.5	17.0	0.3			
S	7/25/86	8.0	16.5	0.1			
S	7/25/86	8.5	15.9	0.1			
S	7/25/86	9.0	15.4	0.1	48		
C	8/01/86	0.0	21.0	9.0	14	3.1	10.8
C	8/01/86	1.0	21.1	9.0	16		
C	8/01/86	2.0	21.0	9.1	20		
C	8/01/86	3.0	21.0	9.1	18		
C	8/01/86	4.0	20.9	9.1	16		
C	8/01/86	5.0	20.8	9.1	18		
C	8/01/86	5.5	20.6	9.1			
C	8/01/86	6.0	20.7	9.1	12		
C	8/01/86	6.5	20.3	8.7			
C	8/01/86	7.0	19.8	4.8	15		
C	8/01/86	7.5	18.1	0.3			
C	8/01/86	8.0	17.1	0.2	27		
C	8/01/86	8.5	16.9	0.1			
C	8/01/86	9.0	16.0	0.1	43		
C	8/01/86	9.5	15.5	0.1			
C	8/01/86	10.0	15.1	0.1			
N	8/01/86	0.0	21.0	9.0			
N	8/01/86	1.0	21.0	9.0	21		
N	8/01/86	2.0	21.0	9.1			
N	8/01/86	3.0	20.9	9.1	17		
N	8/01/86	4.0	20.9	8.9			
N	8/01/86	5.0	20.9	8.8	12		
N	8/01/86	5.5	20.8	8.7			
N	8/01/86	6.0	20.8	8.9			
N	8/01/86	6.5	20.6	8.7			
N	8/01/86	7.0	20.1	8.0	14		
N	8/01/86	7.5	18.5	1.4			
N	8/01/86	8.0	17.5	0.2			
N	8/01/86	8.5	16.8	0.1			
N	8/01/86	9.0	16.0	0.1	40		
N	8/01/86	9.5	15.7	0.1			
N	8/01/86	10.0	14.9	0.1			
S	8/01/86	0.0	21.3	9.0			
S	8/01/86	1.0	21.2	9.0	13		
S	8/01/86	2.0	21.0	9.1			
S	8/01/86	3.0	21.0	9.1	13		
S	8/01/86	4.0	20.9	9.1			
S	8/01/86	5.0	20.5	9.1	13		
S	8/01/86	5.5	20.3	8.7			
S	8/01/86	6.0	20.1	7.9			
S	8/01/86	6.5	19.8	4.8			
S	8/01/86	7.0	18.7	2.1	15		
S	8/01/86	7.5	17.8	0.2			
S	8/01/86	8.0	17.0	0.1			
S	8/01/86	8.5	16.6	0.1			
S	8/01/86	9.0	16.0	0.1	82		
S	8/01/86	9.5	15.9	0.1			
S	8/01/86	10.0	15.2	0.1			
C	8/08/86	0.0	22.1	9.9	12	3.0	10.1
C	8/08/86	1.0	22.0	10.0	10		
C	8/08/86	2.0	22.0	10.0	12		
C	8/08/86	3.0	21.8	10.2	21		
C	8/08/86	4.0	21.1	9.9	12		

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STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
C	8/08/86	5.0	21.0	9.8	14		
C	8/08/86	5.5	20.3	8.0			
C	8/08/86	6.0	20.0	6.5	15		
C	8/08/86	6.5	19.5	4.6			
C	8/08/86	7.0	18.9	2.3	14		
C	8/08/86	7.5	18.1	0.8			
C	8/08/86	8.0	18.0	0.6	16		
C	8/08/86	8.5	17.8	0.2			
C	8/08/86	9.0	16.9	0.1	41		
C	8/08/86	9.5	16.1	0.1			
C	8/08/86	10.0	15.2	0.1			
N	8/08/86	0.0	22.0	9.8			
N	8/08/86	1.0	22.0	9.8	12		
N	8/08/86	2.0	22.0	9.8			
N	8/08/86	3.0	21.9	9.9	12		
N	8/08/86	4.0	21.7	9.9			
N	8/08/86	5.0	21.1	9.5	15		
N	8/08/86	5.5	21.1	9.4			
N	8/08/86	6.0	20.2	6.7			
N	8/08/86	6.5	20.0	6.1			
N	8/08/86	7.0	19.9	5.4	13		
N	8/08/86	7.5	19.1	3.6			
N	8/08/86	8.0	18.8	1.7			
N	8/08/86	8.5	18.0	0.1			
N	8/08/86	9.0	17.2	0.1	24		
N	8/08/86	9.5	17.0	0.1			
N	8/08/86	10.0	16.2	0.1			
S	8/08/86	0.0	21.8	9.9			
S	8/08/86	1.0	21.8	9.9	11		
S	8/08/86	2.0	21.8	10.0			
S	8/08/86	3.0	21.8	10.0	18		
S	8/08/86	4.0	21.1	9.8			
S	8/08/86	5.0	21.0	9.1	15		
S	8/08/86	5.5	20.8	8.7			
S	8/08/86	6.0	20.0	6.5			
S	8/08/86	6.5	19.8	5.4			
S	8/08/86	7.0	19.0	3.2	15		
S	8/08/86	7.5	18.6	1.9			
S	8/08/86	8.0	17.6	0.2			
S	8/08/86	8.5	16.6	0.1			
S	8/08/86	9.0	16.0	0.1	120		
S	8/08/86	9.5	16.0	0.1			
S	8/08/86	10.0	15.6	0.1			
C	8/15/86	0.0	22.2	9.9	12	2.6	12.2
C	8/15/86	1.0	22.2	10.0	22		
C	8/15/86	2.0	22.2	10.0	23		
C	8/15/86	3.0	22.2	10.1	17		
C	8/15/86	4.0	22.2	10.1	14		
C	8/15/86	5.0	21.9	9.8	19		
C	8/15/86	5.5	21.8	9.5			
C	8/15/86	6.0	21.1	8.7	17		
C	8/15/86	6.5	20.1	4.7			
C	8/15/86	7.0	19.1	0.9	41		
C	8/15/86	7.5	18.8	0.2			
C	8/15/86	8.0	17.9	0.1	37		
C	8/15/86	8.5	17.2	0.1			
C	8/15/86	9.0	16.9	0.1	87		
C	8/15/86	9.5	16.9	0.1			
C	8/15/86	10.0	16.0	0.1			
N	8/15/86	0.0	22.8	9.9			
N	8/15/86	1.0	22.8	10.0	14		
N	8/15/86	2.0	22.8	10.0			
N	8/15/86	3.0	22.6	10.2	15		
N	8/15/86	4.0	22.3	10.2			
N	8/15/86	5.0	22.2	10.2	22		
N	8/15/86	5.5	21.9	9.3			
N	8/15/86	6.0	21.2	8.8			
N	8/15/86	6.5	20.0	4.3			
N	8/15/86	7.0	18.9	0.3	17		

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STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
C	5/20/87	1.0	12.4	11.6	17		
C	5/20/87	2.0	12.1	11.7			
C	5/20/87	3.0	12.0	11.7	15		
C	5/20/87	4.0	12.0	11.6			
C	5/20/87	5.0	11.6	11.2	16		
C	5/20/87	6.0	11.1	11.2			
C	5/20/87	7.0	10.9	11.0	17		
C	5/20/87	8.0	10.9	11.0			
C	5/20/87	9.0	10.8	10.6	17		
C	5/20/87	10.0	10.5	10.0			
C	6/03/87	0.0	19.8	10.0		4.5	4.5
C	6/03/87	1.0	19.8	10.0	11		
C	6/03/87	2.0	19.4	10.0			
C	6/03/87	3.0	18.0	10.2	11		
C	6/03/87	4.0	17.1	10.1			
C	6/03/87	5.0	16.0	9.9	15		
C	6/03/87	6.0	14.9	9.9			
C	6/03/87	7.0	14.2	9.6	17		
C	6/03/87	8.0	13.8	8.7			
C	6/03/87	9.0	13.1	6.7	14		
C	6/03/87	10.0	12.8	5.6			
C	6/15/87	0.0	18.2	9.5	12	3.9	6.1
C	6/15/87	1.0	18.1	9.5	16		
C	6/15/87	2.0	18.0	9.5	20		
C	6/15/87	3.0	17.8	9.7	19		
C	6/15/87	4.0	17.0	9.4	17		
C	6/15/87	5.0	17.0	9.2	14		
C	6/15/87	6.0	16.8	9.0	13		
C	6/15/87	7.0	16.1	8.6	13		
C	6/15/87	8.0	14.1	4.9	16		
C	6/15/87	9.0	14.8	4.2	15		
C	6/15/87	9.5			17		
C	6/15/87	10.0	12.8	1.7			
N	6/15/87	0.0	18.8	9.4			
N	6/15/87	1.0	18.0	9.5	12		
N	6/15/87	2.0	18.0	9.6			
N	6/15/87	3.0	17.9	9.5	12		
N	6/15/87	4.0	17.0	9.5			
N	6/15/87	5.0	16.5	9.3	24		
N	6/15/87	6.0	16.2	8.6			
N	6/15/87	7.0	16.0	8.0	13		
N	6/15/87	8.0	13.8	3.7			
N	6/15/87	9.0	12.6	1.8	20		
N	6/15/87	10.0	12.3	1.1			
N	6/15/87	10.0	12.3	1.1			
S	6/15/87	0.0	18.1	9.5			
S	6/15/87	1.0	18.0	9.5	14		
S	6/15/87	2.0	18.0	9.6			
S	6/15/87	3.0	18.0	9.6	15		
S	6/15/87	4.0	17.9	9.6			
S	6/15/87	5.0	17.0	9.3	23		
S	6/15/87	6.0	16.8	9.1			
S	6/15/87	7.0	16.2	8.5	21		
S	6/15/87	8.0	15.4	7.3			
S	6/15/87	9.0	15.0	6.3	13		
S	6/15/87	10.0	14.8	1.3			
S	6/15/87	10.0	14.8	1.3			
C	7/01/87	0.0	20.0	9.2	15	2.0	9.0
C	7/01/87	1.0	19.8	9.4	25		
C	7/01/87	2.0	19.8	9.3	23		
C	7/01/87	3.0	19.5	9.3	18		
C	7/01/87	4.0	19.2	9.2	37		
C	7/01/87	5.0	19.0	8.7	17		
C	7/01/87	6.0	18.6	8.2	17		
C	7/01/87	7.0	18.0	7.3	19		
C	7/01/87	8.0	15.5	2.1	16		
C	7/01/87	9.0	14.0	0.3	16		
C	7/01/87	10.0	13.8	0.2			

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STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
N	7/01/87	0.0	20.2	9.3			
N	7/01/87	1.0	20.0	9.3	18		
N	7/01/87	2.0	19.8	9.3			
N	7/01/87	3.0	19.8	9.3	20		
N	7/01/87	4.0	19.5	9.3			
N	7/01/87	5.0	19.0	8.6	18		
N	7/01/87	6.0	18.8	8.6			
N	7/01/87	7.0	18.2	7.9	18		
N	7/01/87	8.0	14.9	0.3			
N	7/01/87	9.0	13.9	0.3	21		
N	7/01/87	10.0	13.8	0.2			
S	7/01/87	0.0	20.0	9.3			
S	7/01/87	1.0	19.9	9.3	16		
S	7/01/87	2.0	19.6	9.3			
S	7/01/87	3.0	19.5	9.2	18		
S	7/01/87	4.0	19.2	9.2			
S	7/01/87	5.0	19.2	9.2	22		
S	7/01/87	6.0	18.7	8.0			
S	7/01/87	7.0	17.5	6.4	15		
S	7/01/87	8.0	16.2	3.6			
S	7/01/87	9.0	15.0	1.3	17		
S	7/01/87	10.0	14.2	0.2			
C	7/17/87	0.0	22.0	8.8	19	2.0	11.6
C	7/17/87	1.0	21.8	8.8	23		
C	7/17/87	2.0	21.2	8.8	24		
C	7/17/87	3.0	21.1	8.9	22		
C	7/17/87	4.0	21.0	8.9	19		
C	7/17/87	5.0	20.6	8.4	22		
C	7/17/87	5.5	19.5	5.7			
C	7/17/87	6.0	19.0	4.9	29		
C	7/17/87	6.5	18.5	4.7			
C	7/17/87	7.0	17.4	2.9	15		
C	7/17/87	7.5	16.5	1.6			
C	7/17/87	8.0	15.6	0.3	12		
C	7/17/87	8.5	15.1	0.2			
C	7/17/87	9.0	14.2	0.2	27		
C	7/17/87	9.5	14.0	0.2	31		
C	7/17/87	10.0	13.8	0.2			
N	7/17/87	0.0	22.2	8.8		2.0	
N	7/17/87	1.0	21.9	8.8	16		
N	7/17/87	2.0	21.5	8.9			
N	7/17/87	3.0	21.3	9.0	25		
N	7/17/87	4.0	21.2	9.0			
N	7/17/87	5.0	20.0	6.4	18		
N	7/17/87	5.5	19.8	6.0			
N	7/17/87	6.0	19.3	5.1			
N	7/17/87	6.5	19.0	4.8			
N	7/17/87	7.0	18.2	4.1	12		
N	7/17/87	7.5	17.0	2.3			
N	7/17/87	8.0	16.0	0.3			
N	7/17/87	8.5	15.1	0.3			
N	7/17/87	9.0	15.0	0.2	19		
N	7/17/87	9.5	14.6	0.2			
N	7/17/87	10.0	14.0	0.2			
O	7/17/87	0.0			27		
S	7/17/87	0.0	22.4	8.8		2.0	
S	7/17/87	1.0	22.0	8.8	17		
S	7/17/87	2.0	21.8	8.9			
S	7/17/87	3.0	21.5	9.0	25		
S	7/17/87	4.0	21.1	9.0			
S	7/17/87	5.0	21.0	8.8	18		
S	7/17/87	5.5	21.0	8.5			
S	7/17/87	6.0	19.2	5.0			
S	7/17/87	6.5	18.8	3.8			
S	7/17/87	7.0	17.6	2.5	13		
S	7/17/87	7.5	17.0	1.5			
S	7/17/87	8.0	15.8	0.3			

CHICKAWAUKIE LAKE WATER QUALITY DATA BASE PAGE 19

STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
S	8/12/87	0.0	21.0	9.0		1.2	
S	8/12/87	1.0	21.0	9.0	18		
S	8/12/87	2.0	20.8	8.8			
S	8/12/87	3.0	20.6	8.6	22		
S	8/12/87	4.0	20.6	8.2			
S	8/12/87	5.0	20.6	8.2	19		
S	8/12/87	5.5	20.5	8.2			
S	8/12/87	6.0	20.5	8.2			
S	8/12/87	6.5	19.8	3.8			
S	8/12/87	7.0	19.0	3.1	22		
S	8/12/87	7.5	17.8	0.7			
S	8/12/87	8.0	16.2	0.2			
S	8/12/87	8.5	16.0	0.1			
S	8/12/87	9.0	15.3	0.1	80		
S	8/12/87	9.5	15.0	0.1			
S	8/12/87	10.0	15.0	0.1			
C	8/19/87	0.0	24.1	9.0	18	1.2	7.1
C	8/19/87	1.0	24.0	9.0	19		
C	8/19/87	2.0	24.0	8.8	20		
C	8/19/87	3.0	22.9	8.3	18		
C	8/19/87	4.0	21.9	7.3	16		
C	8/19/87	5.0	21.1	6.7	13		
C	8/19/87	5.5	21.0	6.2			
C	8/19/87	6.0	20.3	5.5	12		
C	8/19/87	6.5	20.0	4.2			
C	8/19/87	7.0	19.2	2.8	13		
C	8/19/87	7.5	18.5	1.0			
C	8/19/87	8.0	17.8	0.2	23		
C	8/19/87	8.5	17.0	0.1			
C	8/19/87	9.0	16.3	0.1	48		
C	8/19/87	9.5	16.0	0.1			
C	8/19/87	10.0	15.1	0.1			
N	8/19/87	0.0	24.0	9.1		1.2	
N	8/19/87	1.0	24.0	9.1	30		
N	8/19/87	2.0	23.9	9.1			
N	8/19/87	3.0	22.9	7.9	30		
N	8/19/87	4.0	21.9	7.4			
N	8/19/87	5.0	21.1	6.7	13		
N	8/19/87	5.5	21.0	6.4			
N	8/19/87	6.0	20.8	5.8			
N	8/19/87	6.5	20.0	4.2			
N	8/19/87	7.0	19.1	2.2	18		
N	8/19/87	7.5	18.7	1.1			
N	8/19/87	8.0	17.2	0.2			
N	8/19/87	8.5	16.8	0.2			
N	8/19/87	9.0	16.2	0.1	28		
N	8/19/87	9.5	15.9	0.1			
N	8/19/87	10.0	15.0	0.1			
O	8/19/87	0.0			22		
S	8/19/87	0.0	24.0	9.0		1.2	
S	8/19/87	1.0	24.0	9.0	19		
S	8/19/87	2.0	24.0	9.0			
S	8/19/87	3.0	23.0	8.4	24		
S	8/19/87	4.0	21.8	7.4			
S	8/19/87	5.0	20.8	6.7	20		
S	8/19/87	5.5	20.8	6.3			
S	8/19/87	6.0	20.2	5.3			
S	8/19/87	6.5	19.8	3.7			
S	8/19/87	7.0	19.1	2.7	18		
S	8/19/87	7.5	18.2	0.8			
S	8/19/87	8.0	17.0	0.2			
S	8/19/87	8.5	16.1	0.1			
S	8/19/87	9.0	15.9	0.1	190		
S	8/19/87	9.5	15.1	0.1			
S	8/19/87	10.0	15.0	0.1			
C	8/26/87	0.0	19.9	9.2	13	2.3	7.0
C	8/26/87	1.0	20.0	9.1	22		
C	8/26/87	2.0	20.0	9.0	24		

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STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
C	8/26/87	3.0	20.0	9.0	17		
C	8/26/87	4.0	20.0	9.0	21		
C	8/26/87	5.0	20.0	9.0	22		
C	8/26/87	5.5	20.0	9.0			
C	8/26/87	6.0	20.0	8.9	16		
C	8/26/87	6.5	20.0	8.9			
C	8/26/87	7.0	20.0	8.9	23		
C	8/26/87	7.5	19.1	5.0			
C	8/26/87	8.0	18.2	0.4	33		
C	8/26/87	8.5	16.9	0.2			
C	8/26/87	9.0	16.2	0.2	230		
C	8/26/87	9.5	16.0	0.2			
C	8/26/87	10.0	15.5	0.2			
N	8/26/87	0.0	20.0	9.2		2.2	
N	8/26/87	1.0	20.1	9.0	20		
N	8/26/87	2.0	20.1	9.0			
N	8/26/87	3.0	20.1	9.0	19		
N	8/26/87	4.0	20.1	8.8			
N	8/26/87	5.0	20.0	8.9	17		
N	8/26/87	5.5	20.0	8.9			
N	8/26/87	6.0	20.0	8.9			
N	8/26/87	6.5	19.9	7.2			
N	8/26/87	7.0	19.8	4.1	24		
N	8/26/87	7.5	18.9	1.1			
N	8/26/87	8.0	17.6	0.3			
N	8/26/87	8.5	16.6	0.2			
N	8/26/87	9.0	16.1	0.2	110		
N	8/26/87	9.5	16.0	0.2			
N	8/26/87	10.0	15.8	0.2			
O	8/26/87	0.0			20		
S	8/26/87	0.0	20.0	9.2		2.3	
S	8/26/87	1.0	20.0	9.2	15		
S	8/26/87	2.0	20.0	9.2			
S	8/26/87	3.0	20.0	9.2	27		
S	8/26/87	4.0	20.0	9.2			
S	8/26/87	5.0	20.0	9.2	19		
S	8/26/87	5.5	20.0	9.2			
S	8/26/87	6.0	20.0	9.2			
S	8/26/87	6.5	20.0	9.2			
S	8/26/87	7.0	20.0	9.2	20		
S	8/26/87	7.5	20.0	9.2			
S	8/26/87	8.0	19.8	9.2			
S	8/26/87	8.5	18.0	1.5			
S	8/26/87	9.0	16.9	0.4	80		
S	8/26/87	9.5	16.1	0.2			
S	8/26/87	10.0	15.9	0.2			
C	9/02/87	0.0	19.0	9.3	21	2.5	11.0
C	9/02/87	1.0	19.0	9.2	28		
C	9/02/87	2.0	19.0	9.1	29		
C	9/02/87	3.0	18.9	8.8	27		
C	9/02/87	4.0	18.9	8.7	25		
C	9/02/87	5.0	18.9	8.7	20		
C	9/02/87	5.5	18.9	8.7			
C	9/02/87	6.0	18.8	8.7	23		
C	9/02/87	6.5	18.8	8.6			
C	9/02/87	7.0	18.8	8.6	20		
C	9/02/87	7.5	18.4	6.8			
C	9/02/87	8.0	18.0	3.9	29		
C	9/02/87	8.5	17.9	3.1			
C	9/02/87	9.0	17.8	2.7	39		
C	9/02/87	9.5	17.2	0.5			
C	9/02/87	10.0	16.6	0.1			
N	9/02/87	0.0	19.2	9.4		2.5	
N	9/02/87	1.0	19.2	9.2	38		
N	9/02/87	2.0	19.0	8.9			
N	9/02/87	3.0	19.0	8.7	21		
N	9/02/87	4.0	18.9	8.7			
N	9/02/87	5.0	18.9	8.6	22		

CHICKAWAUKIE LAKE WATER QUALITY DATA BASE PAGE 23

STA	DATE	DEPTH METERS	TEMP DEG-C	D.O. PPM	TOTAL P PPB	SECCHI METERS	CHL-A PPB
S	9/24/87	8.0	15.8	9.8			
S	9/24/87	8.5	15.8	9.7			
S	9/24/87	9.0	15.8	9.7	20		
S	9/24/87	9.5	15.8	9.6			
S	9/24/87	10.0	15.8	9.1			
C	10/09/87	0.0	14.0	10.4	15	4.4	6.5
C	10/09/87	1.0	14.0	10.2	16		
C	10/09/87	2.0	14.0	10.2	23		
C	10/09/87	3.0	14.0	10.2	23		
C	10/09/87	4.0	14.0	10.4	17		
C	10/09/87	5.0	14.0	10.4	17		
C	10/09/87	6.0	14.0	10.4	18		
C	10/09/87	7.0	14.0	10.4	16		
C	10/09/87	8.0	13.8	10.6	15		
C	10/09/87	9.0	13.8	10.5	15		
C	10/09/87	10.0	13.5	10.2			
N	10/09/87	0.0	13.9	10.4		4.5	
N	10/09/87	1.0	13.9	10.2	13		
N	10/09/87	2.0	13.9	10.2			
N	10/09/87	3.0	13.9	10.2	22		
N	10/09/87	4.0	13.9	10.2			
N	10/09/87	5.0	13.8	10.2	16		
N	10/09/87	6.0	13.8	10.3			
N	10/09/87	7.0	13.8	10.3	16		
N	10/09/87	8.0	13.5	10.4			
N	10/09/87	9.0	13.5	10.4	14		
N	10/09/87	10.0	13.5	10.4			
O	10/09/87	0.0			23		
S	10/09/87	0.0	13.8	10.6		4.2	
S	10/09/87	1.0	13.9	10.4	14		
S	10/09/87	2.0	13.9	10.5			
S	10/09/87	3.0	13.9	10.5	19		
S	10/09/87	4.0	13.9	10.5			
S	10/09/87	5.0	13.8	10.5	17		
S	10/09/87	6.0	13.8	10.6			
S	10/09/87	7.0	13.5	10.4	19		
S	10/09/87	8.0	13.5	10.5			
S	10/09/87	9.0	13.4	10.4	17		
S	10/09/87	9.5	13.2	10.3			
C	10/23/87	0.0	10.1	11.0	13	4.4	8.3
C	10/23/87	1.0	10.2	10.6	14		
C	10/23/87	2.0	10.6	10.6	20		
C	10/23/87	3.0	10.8	10.8	21		
C	10/23/87	4.0	10.8	10.8	17		
C	10/23/87	5.0	10.8	10.9	17		
C	10/23/87	6.0	10.8	10.8	15		
C	10/23/87	7.0	10.8	10.8	17		
C	10/23/87	8.0	10.8	10.8	14		
C	10/23/87	9.0	10.8	10.8	15		
C	10/23/87	10.0	10.8	10.0			
O	10/23/87	0.0			12		

CHICKAWAUKIE LAKE WATER QUALITY DATA BASE

STA	DATE	DEPTH METERS	TURBIDITY NTU	ALKALINITY PPM	PH SU	TKN PPB	NO3N PPB	NH34N PPB	IRON PPB	MANGANESE PPB	SULFATE PPM	CONDUCTIVITY UMHOS
C	8/15/86	0.0	2.1	13	9.0							78
C	8/25/86	0.0	0.7		6.8							68
C	9/05/86	0.0	0.7	16	7.1							74
C	9/29/86	0.0	0.6	18	7.5							70
C	11/05/86	0.0	0.4	15	6.8							68
C	11/18/86	0.0	0.4	15	6.7							32
C	11/25/86	0.0	0.6	15	6.8							34
C	3/16/87	0.0	0.3									
C	3/16/87	1.0			6.8							77
C	4/15/87	0.0	0.6	13	6.9							73
C	5/07/87	0.0	0.4	13	7.3							76
C	6/03/87	0.0	0.5	14	6.9							75
C	6/15/87	0.0		16	7.5							75
C	7/01/87	0.0	1.7	15	7.8							84
C	7/17/87	0.0	2.7	17	8.2							
C	7/30/87	0.0		16	9.3							81
C	8/05/87	0.0		15	8.3							72
C	8/05/87	1.0		15	7.9	1000	100	10	120	130	4.7	71
C	8/05/87	6.0		16	7.2	1000	100	10	130	170	4.1	71
C	8/05/87	9.0		26	6.9	2000	100	140	1100	2560	4.1	84
C	8/12/87	1.0		16	7.6	1000	100	10	80	140	5.8	71
C	8/12/87	7.0		18	6.9	1000	100	10	100	400	4.7	71
C	8/12/87	9.0		30	6.7	2000	100	80	1660	2760	4.9	86
C	8/19/87	1.0		17	8.3	1000	100	10	60	80	5.1	78
C	8/19/87	3.0		16	7.4	1000	100	10	80	80	4.9	82
C	8/19/87	9.0		27	6.6	2000	100	150	680	2840	4.5	93
C	8/26/87	1.0		18	7.4	1000	100	10	90	130	5.8	74
C	8/26/87	8.0		22	6.8	1000	10	10	260	1300	4.1	78
C	8/26/87	9.0		29	6.9	2000	10	150	1940	3100	2.5	87
C	9/02/87	0.0		18	7.5							76
C	9/17/87	0.0	4.4	19	7.2							75
C	9/24/87	0.0		17	7.6							72
C	10/09/87	0.0		16	7.3							65
C	10/23/87	0.0		16	7.4							76

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CHICKAWAUKIE LAKE WATER QUALITY DATA BASE     PAGE   2

STA      DATE  COMMENTS

C     5/13/86  40 MPH WINDS THE PREVIOUS DAY

C     5/29/86   SURFACE NTU = 0.55.

C     6/30/86  SURFACE = 0.53 NTU.

C     7/08/86  8.5 CHL A CORE = 7.0 PPB.

C     7/18/86  7.5 METER CHL A CORE = 5.3 PPB.

C     7/25/86  7 METER CHL A CORE = 5.7PPB.

C     8/01/86  SURFACE = 0.85 NTU ; 7 METER CHL A CORE = 10.8 PPB.

C     8/08/86  SURFACE = 0.94 NTU. 7 METER CHL A CORE = 10.1 PPB.

C     8/15/86  6.5 METER CHL A CORE = 12.2 PPB ; SURFACE = 2.1 NTU.

C     8/25/86  8 METER CHL A CORE = 7.5 PPB ; SURFACE = 0.74 NTU.

C     9/05/86   SURFACE = 0.74 NTU.

C     9/29/86  9 METER CHL A CORE = 9.9 PPB ; SURFACE = 0.64 NTU

C    11/05/86  ALGAE DIE-OFF THROUGHOUT THE LAKE ; 600-800 GULLS ON LAKE.;surface=.44 ntu

C    11/18/86  SURFACE = 0.40 NTU.

C    11/25/86  SURFACE = 0.56 NTU ; WATER LEVEL 36 IN. FROM TOP OF DAM.;est 800 gulls on lake

C     3/16/87  SURFACE = 0.31 NTU;ALGAL SAMPLE OVER INTAKE: ASTERIONELLA, APHANIZOMENON
C     3/16/87  APHANIZOMENON - DETRITUS MORE COMMON THAN LIVE ALGAE.
C     3/16/87  ICE COVER.

C     4/15/87   SURFACE = 0.64 NTU.

C     5/07/87   SURFACE = 0.44 NTU. TABELLARIA VERY DOMINANT, FRAGILLARIA & ASTERIONELLA
C     5/07/87  & ASTERIONELLA VERY COMMON, ULOTHRIX COMMON, ANABAENA OCCASIONAL,
C     5/07/87  OCCASIONAL, VOLVOX RARE.

C     5/20/87   9 M CHL A CORE = 5.68 PPB

C     6/03/87   SURFACE = 0.45 NTU. WATER LEVEL 31 IN. BELOW TOP OF DAM.
C     6/03/87   9 M CHL A CORE = 4.51 PPB.

C     6/15/87   WINDY (DIFFICULT TO DO PROFILE). WATER LEVEL 29 IN. BELOW TOP OF
C     6/15/87  OF DAM. ABUNDANT & DIVERSE ALGAL COMMUNITY; ASTERIONELLA & TABELLARIA
C     6/15/87  TABELLARIA MOST ABUNDANT, WITH DINOBRYON, SYNURA,ANABAENA,APHANIZOMENON
C     6/15/87  APHANIZOMENON & STAURASTRUM PRESENT.
C     6/15/87   9 M CHL A CORE = 6.13 PPB.

C     7/01/87   SURFACE = 1.7 NTU. ANABAENA DOMINANT WITH TABELLARIA AND
C     7/01/87  ASTERIONELLA COMMON.
C     7/01/87   7 M CHL A CORE = 9.02 PPB.

C     7/17/87   SURFACE = 2.7 NTU; 100 - 150 GULLS ON LAKE.
C     7/17/87  TABELLARIA MOST ABUNDANT, ANABAENA AND APHANIZOMENON VERY ABUNDANT,
C     7/17/87  CERATIUM, ASTERIONELLA, ULOTHRIX, VOLVOX, AND FRAGILLARIA
C     7/17/87  COMMON, SPIROGYRA AND SYNURA OCCASIONAL.
C     7/17/87   7 M CHL A CORE = 11.55 PPB.

C     7/30/87   ANABAENA DOMINANT, SOME TABELLARIA, VOLVOX & FRAGILLARIA.
C     7/30/87  200 GULLS ON LAKE.
C     7/30/87  6 M CHL A CORE = 24.71 PPB.

C     8/05/87   WATER LEVEL 28 IN. FROM TOP OF DAM. ANABAENA DOMINANT; TABELLARIA
C     8/05/87  & FRAGILLARIA ALSO PRESENT. 7 M CHL A CORE
C     8/05/87  OUTLET = 0.025 PPM TOT P.

C     8/12/87   WATER LEVEL 28.5 IN. BELOW TOP OF DAM. 6.5 M CHL A
C     8/12/87  OUTLET SAMPLE = 0.025 PPM. 6.5 M CHL A CORE
```
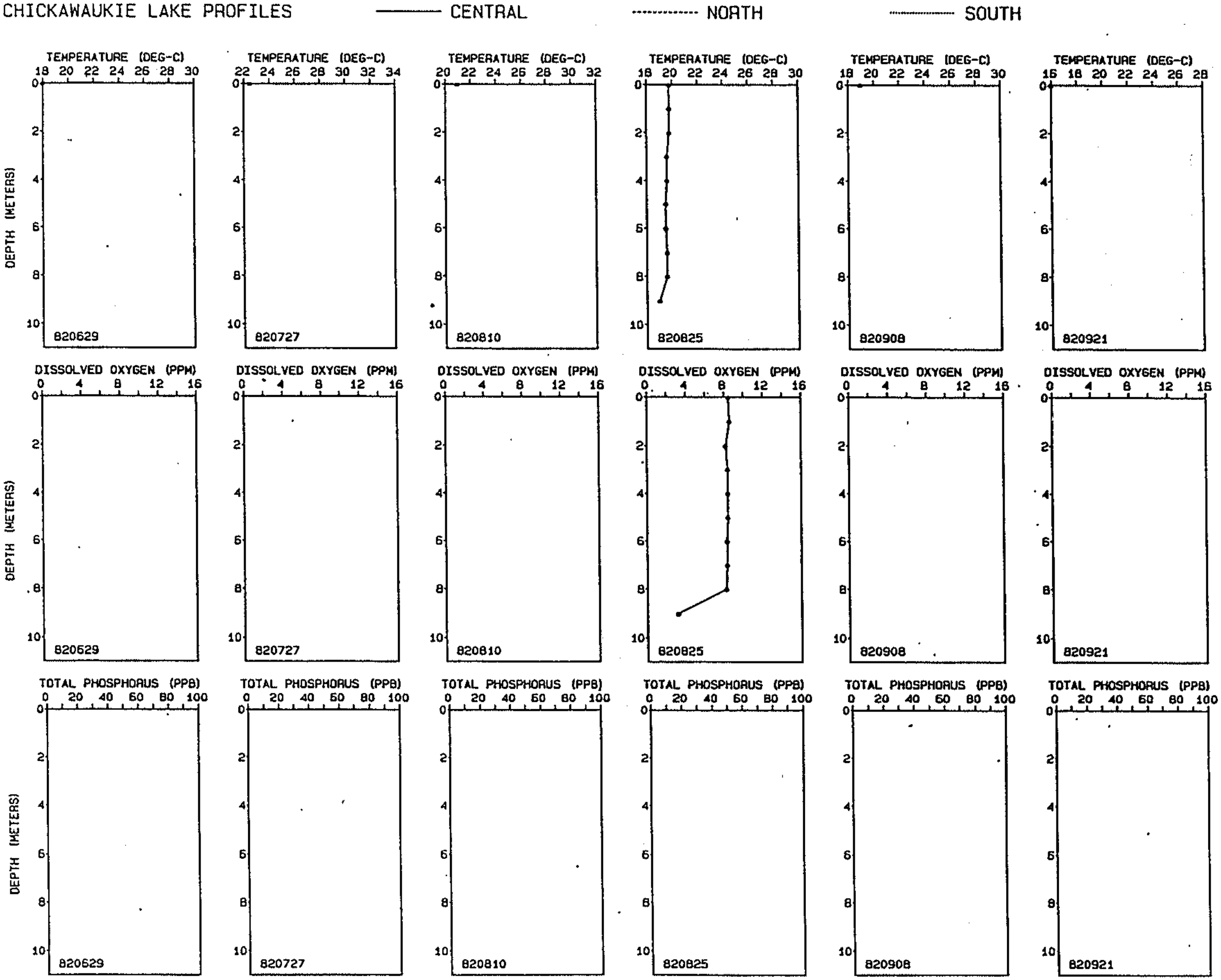

APPENDIX B

VERTICAL PROFILES

Note: A scale maximum of 100 ppb is used in the total phosphorus displays. Values greater than 100 ppb are plotted as 100 ppb.

CHICKAWAUKIE LAKE PROFILES

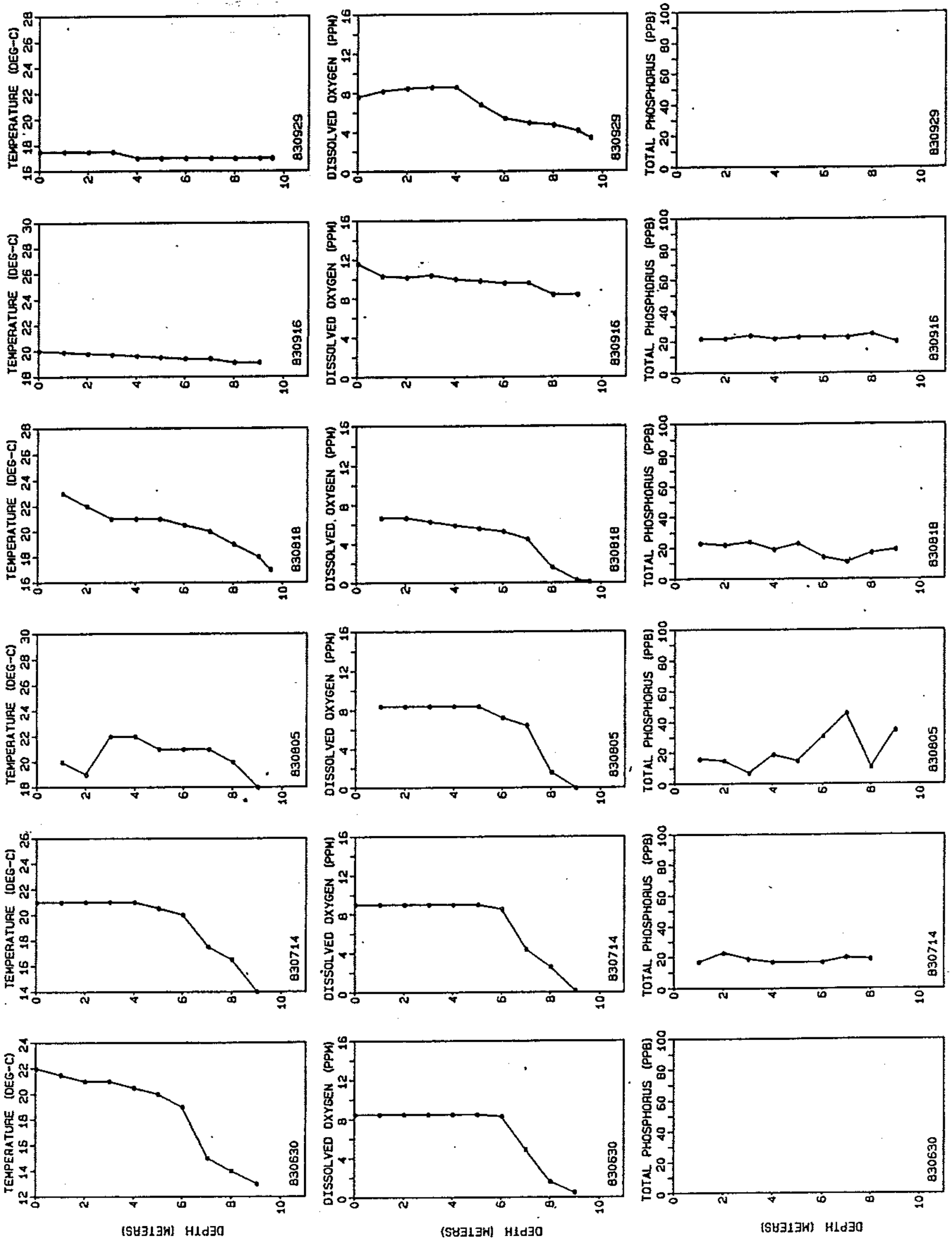


CHICKAWAUKIE LAKE PROFILES

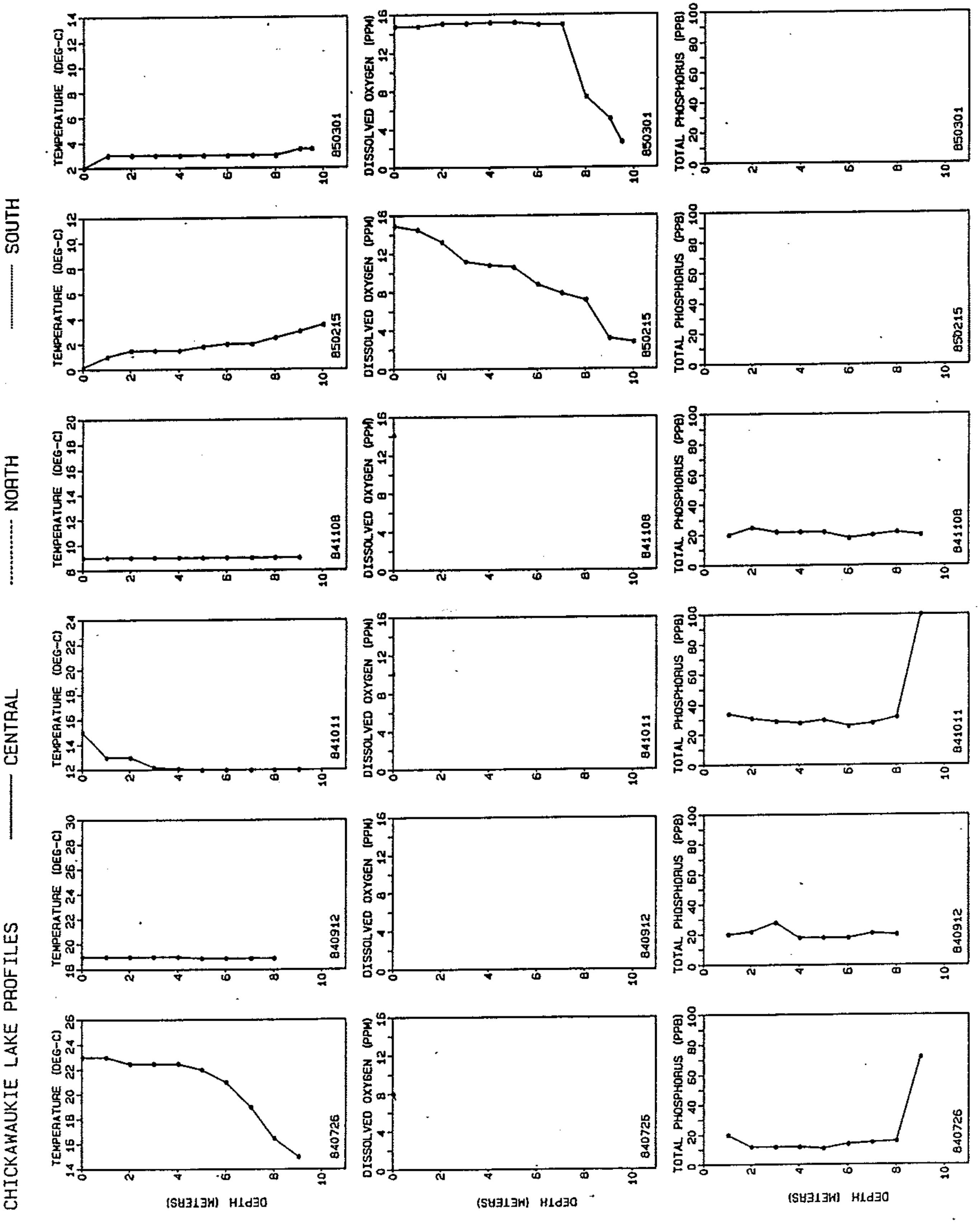
—— CENTRAL

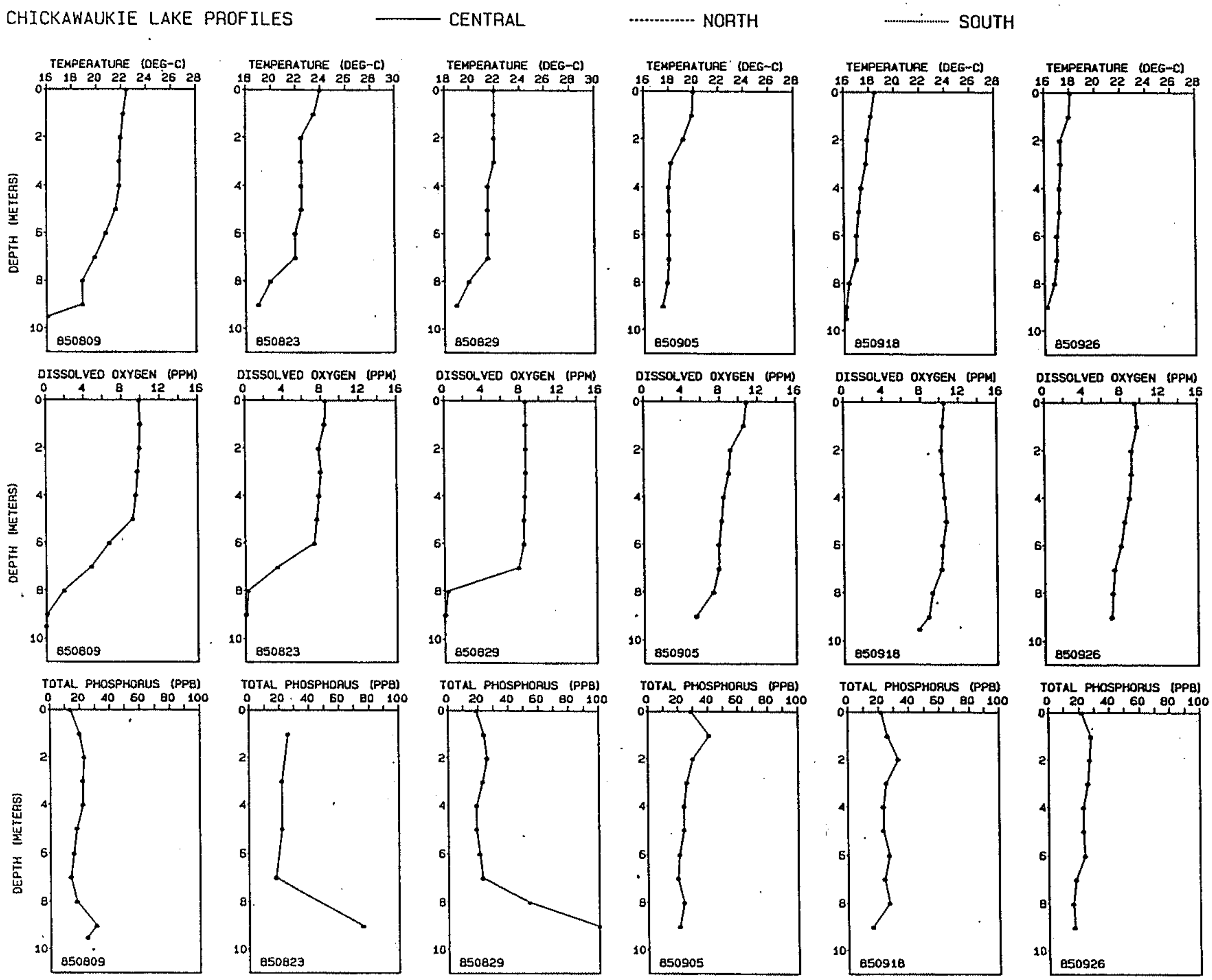
-------- NORTH

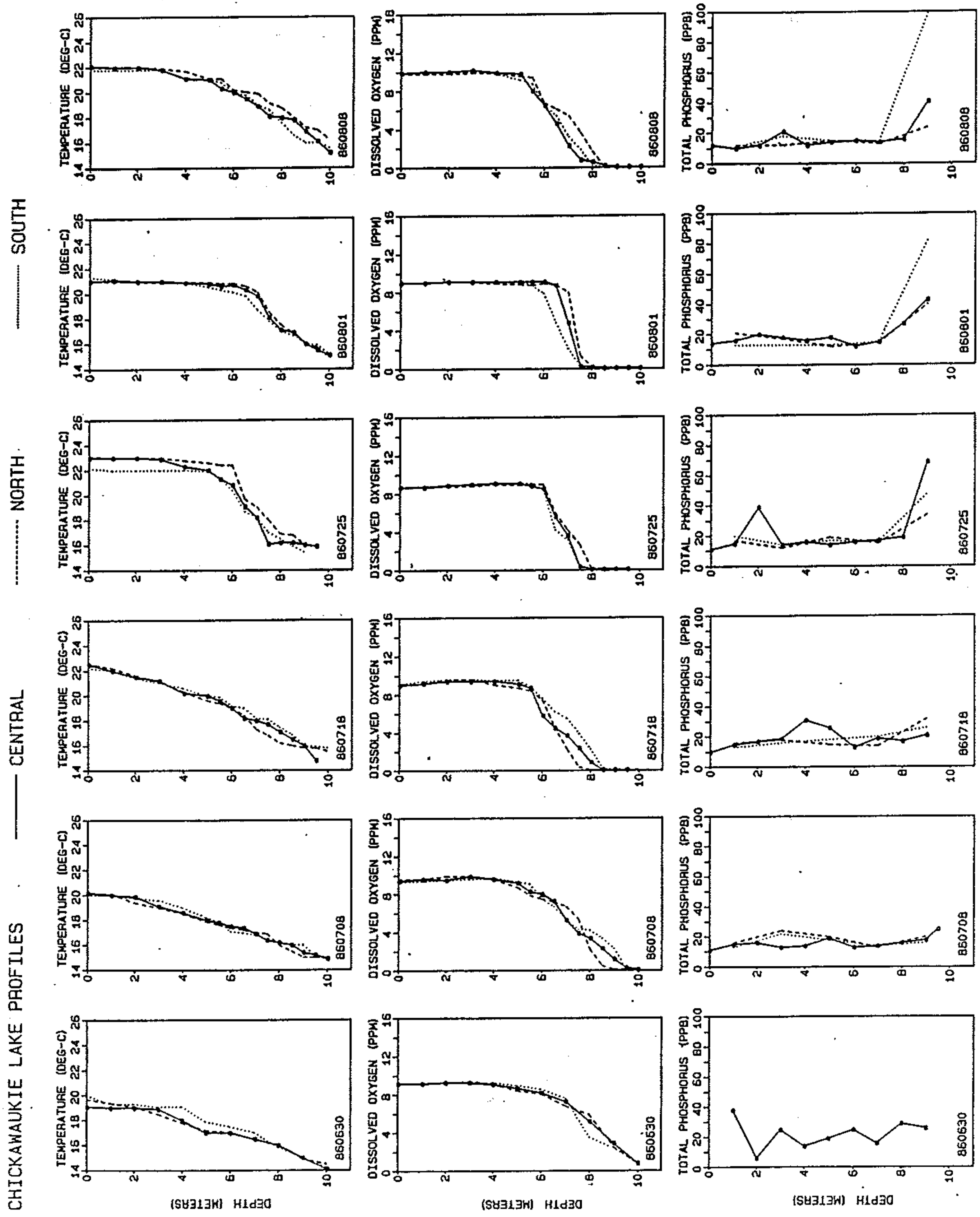
.... SOUTH



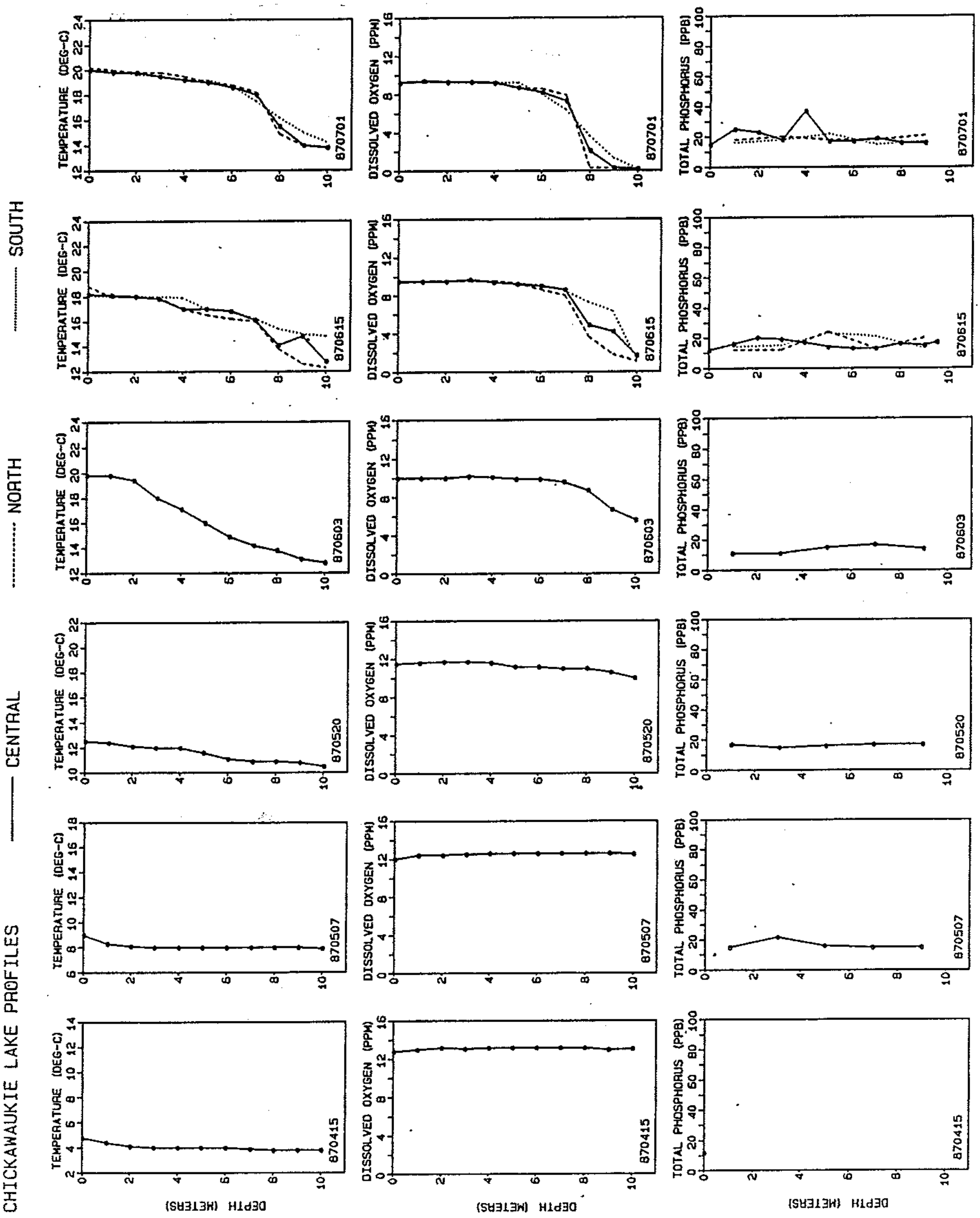
CHICKAWAUKIE LAKE PROFILES



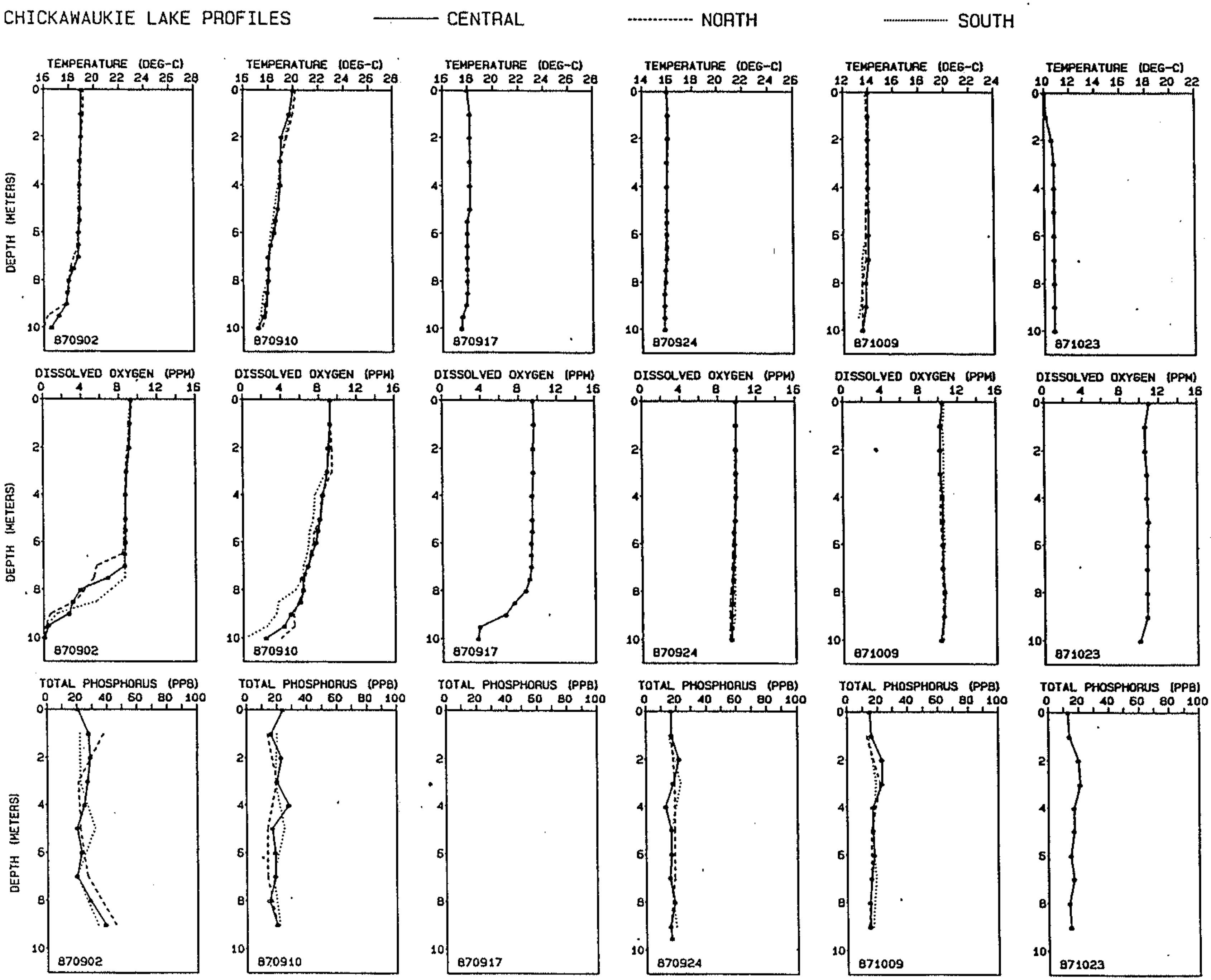

CHICKAWAUKIE LAKE PROFILES

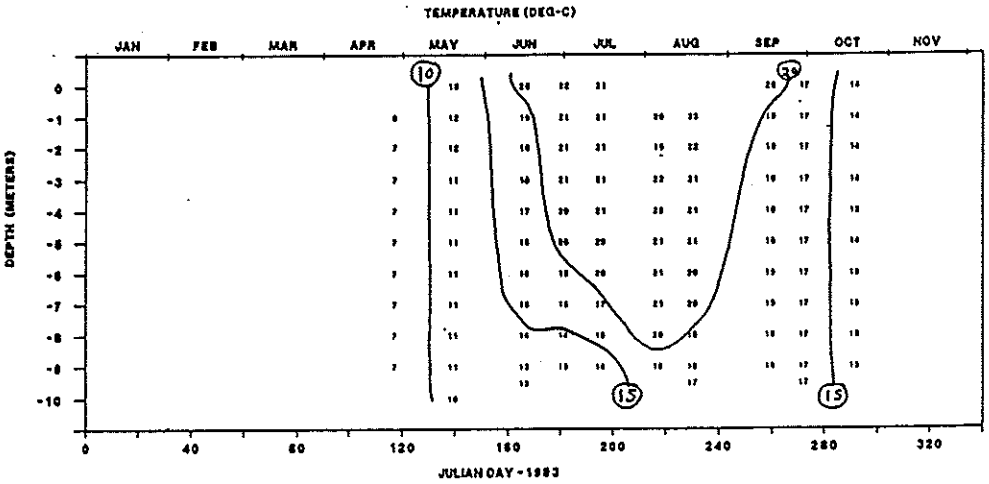


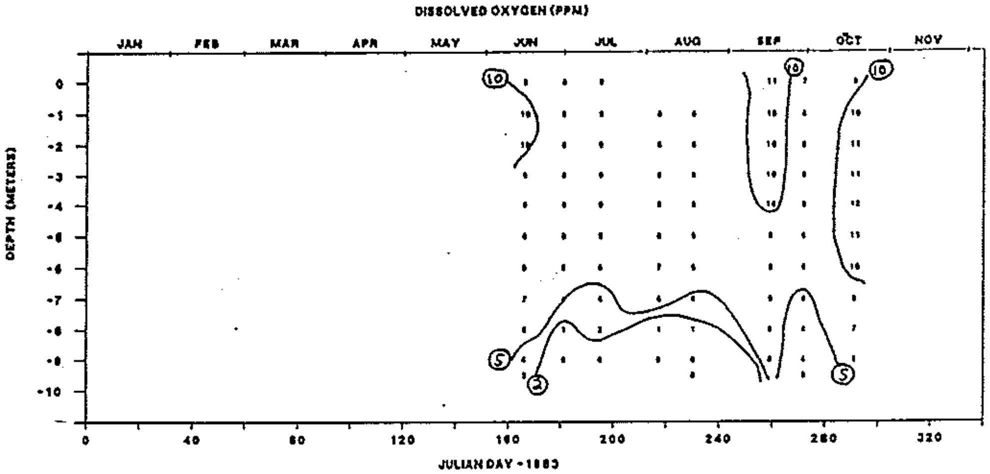
CHICKAWAUKIE LAKE PROFILES

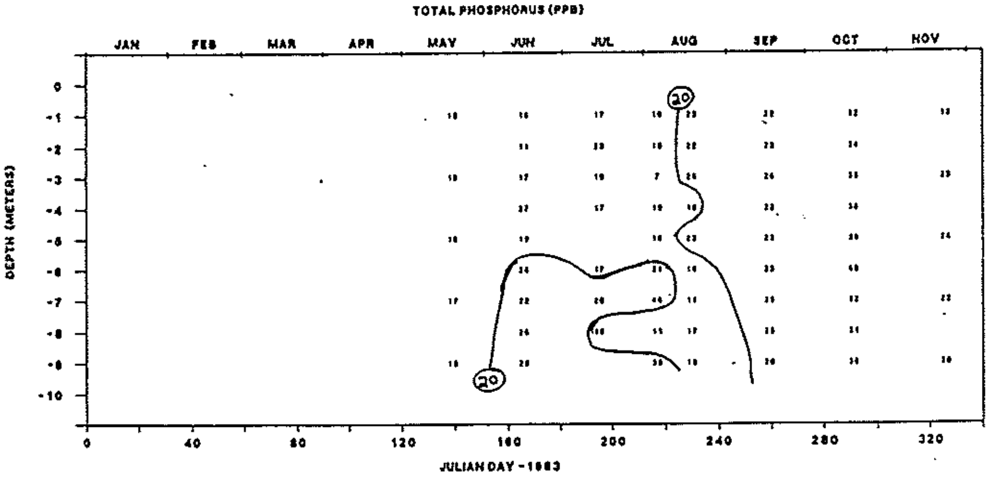

CHICKAWAUKIE LAKE PROFILES
——— CENTRAL
··········· NORTH
- - - - - - SOUTH
TEMPERATURE (DEG-C)
DISSOLVED OXYGEN (PPM)
TOTAL PHOSPHORUS (PPB)
DEPTH (METERS)
870701
870615
870603
870520
870507
870415
0
2
4
6
8
10
12
14
16
18
20
22
24
40
60
80
100

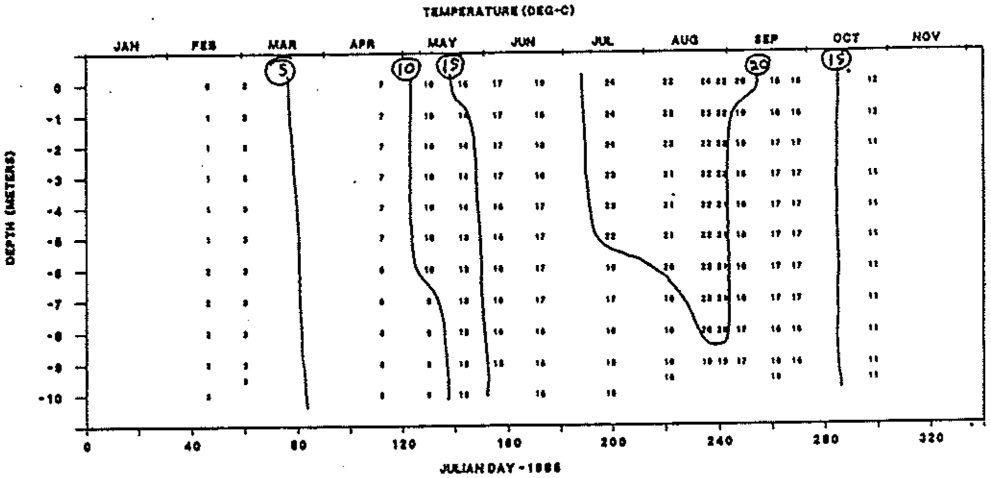
CHICKAWAUKIE LAKE PROFILES

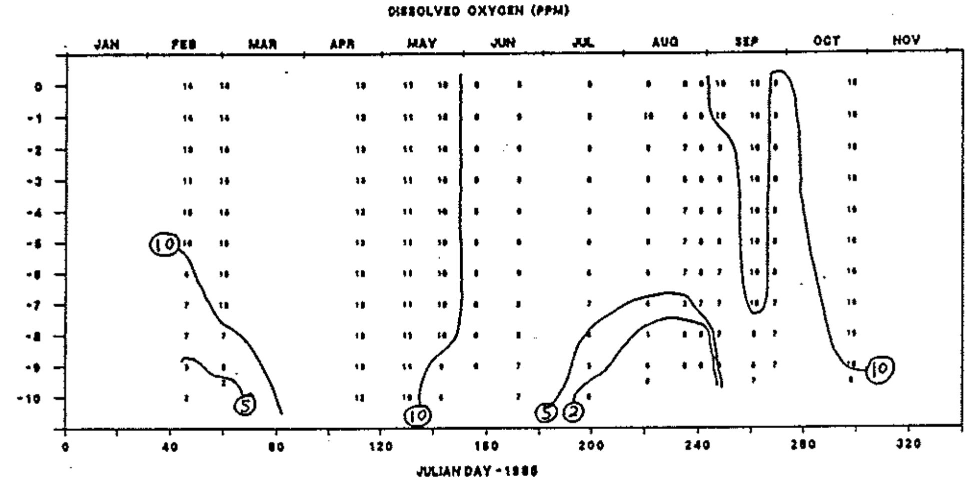


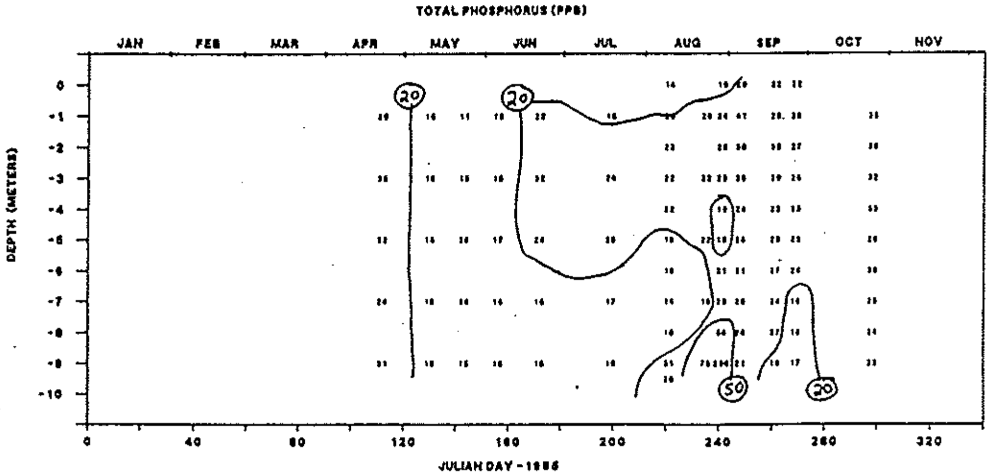

TEMPERATURE (DEG-C)

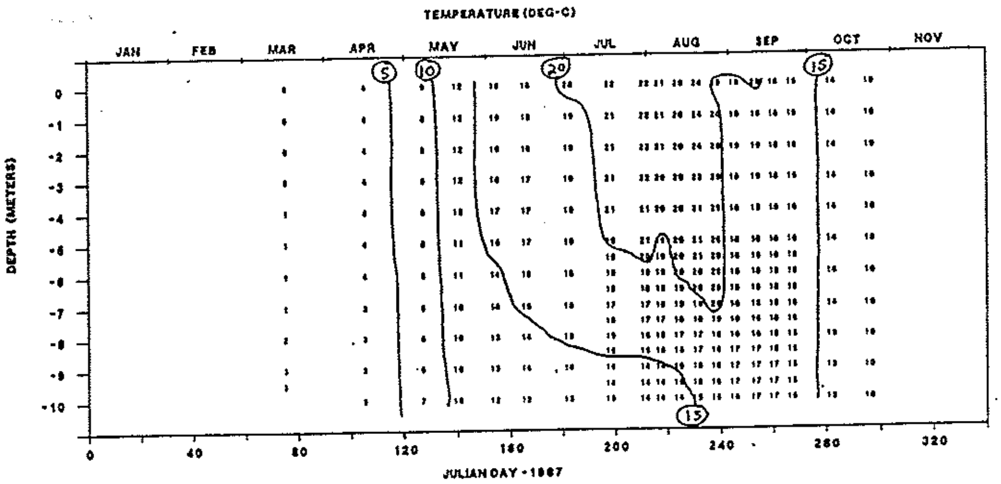

DISSOLVED OXYGEN (PPM)

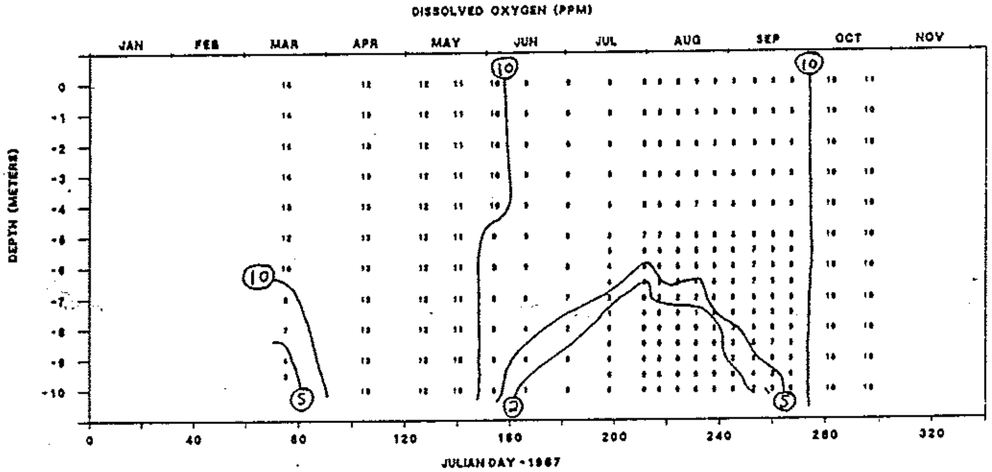

TOTAL PHOSPHORUS (PPB)

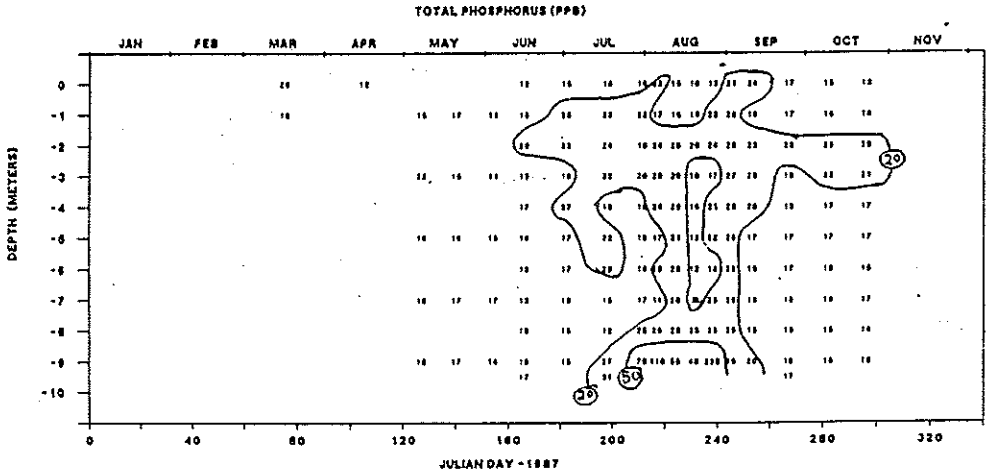

TEMPERATURE (DEG-C)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEPTH (METERS)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
5
10
15
20
15
0
40
80
120
160
200
240
280
320
JULIAN DAY - 1986


DISSOLVED OXYGEN (PPM)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
10
5
10
5
2
10
0
40
80
120
160
200
240
280
320
JULIAN DAY - 1986


TOTAL PHOSPHORUS (PPB)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEPTH (METERS)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
20
20
50
20
0
40
80
120
160
200
240
280
320
JULIAN DAY - 1986


TEMPERATURE (DEG-C)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEPTH (METERS)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
5
10
20
15
15
0
40
80
120
160
200
240
280
320
JULIAN DAY - 1987


DISSOLVED OXYGEN (PPM)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEPTH (METERS)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
10
10
10
5
2
5
0
40
80
120
160
200
240
280
320
JULIAN DAY - 1987


TOTAL PHOSPHORUS (PPB)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEPTH (METERS)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
20
20
50
0
40
80
120
160
200
240
280
320
JULIAN DAY - 1987