A Comparison of Nutrient Concentrations and Trophic Conditions in Clear and McCann Lakes, 1991 and 1994

Submitted by:

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Introduction

McCann and Clear Lakes are part of the Island Chain of Lakes which are located in Rusk County, Wisconsin. In 1991, the Island Chain of Lakes Management District and property owners around the lake expressed concerns that increasing development of lake shores and failing septic systems might be affecting water quality of the lakes. The Association and property owners then applied for and received funding from the Wisconsin DNR through a Lakes Planning Grant. This funding was to examine three topics: 1.) the current trophic status of the lakes; 2.) potential sources of nutrients to the lakes; and 3.) the concentrations of bacteria in shoreline areas (Brakke, 1992).

The report for the 1991 project and a specific proposal submitted at the request of the Island Chain of Lakes Management District made recommendations for future monitoring of the lake. The primary reason for these recommendations related to the potential for development surrounding Clear Lake, which may influence its trophic status. In addition, some elevated levels of bacteria had been found in 1991 in two areas.

The primary goal of the sampling in the summer of 1994 was to compare results with conditions observed in 1991. Further, the results would continue to establish a baseline for future comparisons.

The 1991 study examined conditions in all four of the lakes comprising the Island Chain of Lakes drainage network. Three of the lakes, Chain, McCann and Island Lakes, are located along a direct flow path and are drainage lakes having an inlet and an outlet. Clear Lake is physically connected to the other lakes, but it is a drained lake, having no inlet but deriving its input water largely from ground water seepage. Clear Lake drains into McCann Lake, but because of the lack of a surface water inlet that drains a large surface area, it has a much longer water residence time than the other lakes. As a consequence of its clarity and phosphorus levels, as well as it longer residence time, any changes in nutrient concentrations may influence the trophic status of Clear Lake.

Chain Lake is relatively deep and receives inlet water from a large area. Chain Lake empties into McCann, which is half as deep as Chain and it has a relatively short water residence time (Brakke 1992; Table 1). McCann is the shallowest in the Island Chain and it is the most eutrophic. Given the differences in characteristics among the lakes, and the need to streamline monitoring to lower the analytical costs, McCann and Clear were chosen for monitoring (Brakke 1992).

Methods

Main sampling locations were identical to those used for sampling in 1991 and they were located at the deepest part of each lake basin (Figure 1-2). The sites were sampled during the period that would represent the maximum period of thermal stratification, and hence potential for anoxic conditions in the water column. In addition, because of an interest expressed by the Island Chain of Lakes Management District, sampling was shifted from earlier in the summer to later in the summer to include bacterial sampling following a major period of lake usage related to late summer and Labor Day.

Thermal structure and water column dissolved oxygen concentrations were measured on five dates: 6 August, 13 August, 20 August, and 6 September. More extensive sampling, which included the collection of water samples at the surface and in the hypolimnion of Clear and McCann Lakes was done during August of 1994. The August 20, 1994 data was used as the primary comparison for conditions with earlier results, because this period coincided with a well-stratified water column and the time period was comparable to the most extensive sampling in 1991. A further consideration in determining the sampling dates was the restricted availability of the State Lab of Hygiene for receiving samples. Samples had to be received within 24 hours of collection and only on Monday through Thursday.

All methods used in 1994 were identical to the field sampling and analytical procedures used in 1991. The deepwater sampling locations were located on each day of sampling by depthfinder and an anchor was lowered to maintain position. A Secchi disc was used to measure transparency of the water column by lowering the disc over the shaded side of the boat until it disappeared and then raising it until it appeared. The Secchi disc depth was the average of these two readings. A Yellow Springs Instruments (YSI) meter was used to measure oxygen and temperature in the water column. The meter was calibrated prior to and following each use by calibration with the atmosphere. The calibration also was compared with results of a modified Winkler titration. The YSI meter was used at one meter increments to determine the temperature and oxygen profile.

On August 20, three specially prepared Nalgene plastic bottles of different sizes were filled at each site at a depth of 0.5 m. These bottles had been quality assured by the State Laboratory of Hygiene for specific analysis requiring different preservation steps and analytical procedures. Immediately upon filling the samples were placed in a cooler containing ice and freezer packs. Upon returning from each field trip, samples were prepared for shipment to the State Laboratory of Hygiene using standardized procedures. Samples were cooled to 4^0C if they had not reached that temperature and sulfuric acid was added as a preservative to one of the bottles to stabilize the constituents. Bottles were packed in coolers with ice and sent with the via next day mail to the State Laboratory of Hygiene (Brakke, 1992).

A synoptic survey of coliform bacterial concentrations was conducted in August 1994 in the previously mentioned areas. Samples were collected in sterilized bottles from the in-shore areas of each lake. These samples were cooled and shipped overnight to the State Lab for analysis (Brakke, 1992).

Analyses conducted at the State Lab followed standard protocols and the results are supported by extensive quality control/quality assurance procedures (Wisconsin State Lab of Hygiene 1993). Results from the State Lab also can be compared to other lake sampling projects supported by the Lakes Planning Grant Program. Analytical results were reported from the State Lab to the WI DNR in Spooner and then forwarded to UW-Eau Claire. Data for the project were entered into a spreadsheet (Lotus 1-2-3) and graphed.

Results and Discussion

Temperature and dissolved oxygen

Temperature and dissolved oxygen readings were taken for McCann Lake on August 6,13,20, and September 6, 1994. These results are shown in Figures 3-6. Clear Lake temperatures and D.O. were taken on August 20 and September 6, 1994 and the results are found on figures 7 and 8. McCann Lake was stratified on the first sampling date of August 6. Maximum surface temperatures were reached on this day, but the water column remained stratified into September. The thickness of the epilimnion varied between two and five meters in McCann. Oxygen in the hypolimnion was <1 mg/L on all samplings, and oxygen decreased rapidly below 4 m.

Clear Lake was stratified in August and the thickness of the epilimnion was between five and seven meters. The difference in thickness of the epilimnion was likely due to its increased transparency compared to McCann (cf. Brakke 1992). In Clear Lake, dissolved oxygen concentrations in the hypolimnion also were below 1 mg/L. Conditions in both lakes confirmed the patterns observed in 1991, when anoxic conditions were found in all four of the lakes (Brakke 1992).

Chemical conditions in McCann and Clear Lakes

Sample collected was designed to allow for a comparison of Clear and McCann Lakes using data from August 1991 and August 1994 (Tables 3 and 4). This comparison can be made using surface concentrations to one another in the two periods and from the deepwater samples in each period. Earlier data for the lakes was summarized by Brakke (1992).

Surface water conductivity has been similar in all periods of measurement (Table 2). This measurement indicates that the ionic strength of the water, related to the concentrations of all ionic species, has not changed over the period. Some constituents do show variations between years. For example, the measured color of surface water in Clear Lake was higher in 1994 than in 1991, which may be partially responsible for the lower secchi depth transparency in 1994. Alkalinity and pH also were slightly lower than observed in 1991. Concentrations of nitrate and ammonia at the surface were comparatively high in Clear Lake compared to McCann Lake but they were at slightly lower concentrations than in 1991. This difference between the lakes was observed in 1991 (Brakke 1992).

The measured total phosphorus concentration in Clear Lake was similar to that found in 1991. The slightly higher value (15 vs. 13 µg/L) was close to measurement error. Concentrations of nitrates and ammonia remained high in Clear Lake surface waters compared to the other lakes, because algal growth in the lake is limited by phosphorus (Brakke 1992). Nitrogen concentrations at the surface were slightly lower than observed in 1991. Chlorophyll a concentrations (a measure of algal biomass) remained low.

The deepwater sample from Clear Lake had similar color as did the surface sample. Alkalinity increased with depth as it did in 1991, while pH decreased with depth. Ammonia and nitrate concentrations showed some differences with those observed in 1991 but were apparently related to enhanced nitrification in 1994.

Hypolimnetic total phosphorus concentrations reported from the State Lab were half those found in 1991 concentrations. These results are anomolous and may be related to problems in the State Lab in 1994. The lab was receiving more samples than they could process and some analyses were completed only after designated storage times. The lab did not notify anyone of these problems until after the problem occurred and no alternative sampling dates could be arranged. The influence of this situation on the results is discussed later in the report.

McCann Lake surface concentrations showed several differences between 1994 and 1991 (Table 4). Surface concentrations of chlorophyll *a* were nearly twice those observed in 1991. Associated with the higher chlorophyll concentrations was a lower water column transparency as indicated by the Secchi disc measurements. Surface concentrations of some paramenters, color, pH, and alkalinity, were still very similar to 1991. Total phosphorus concentrations were nearly double those found in 1991.

The deepwater concentrations in McCann Lake were similar to those found in 1991 (Table 4). Color was dramatically higher at depth, which is related to the source of humic compounds originating from wetland drainages around the Island Chain. The differences in the source of water influent to McCann and Clear Lakes are reflected in color measured for the deepwater samples (Table 4). Total nitrogen, ammonia and nitrate concentrations also increased substantially with depth. These concentrations were much higher in McCann Lake than in Clear Lake. However, as in Clear Lake, deepwater total phosphorus decreased substantially from 1991, presumably related to the problems at the State Lab, which apparently greatly affected some phosphorus measurements.

Trophic state evaluation

Trophic state of the lakes was evaluated in several ways, but especially by using Carlson's Trophic State Index (TSI)(Carlson 1977). This index can be calculated separately for Secchi disc transparency, total phosphorus, and chlorophyll *a* concentrations (Carlson 1977; Reckhow and Chapra 1983). TSI values are most often calculated for the period of mid- to late-summer when lakes are stratified. In this region, late-July through August is the most common period of reference. Comparable dates in mid-August of 1991 and 1994 were used to calculate TSI. For Secchi disc meaurements, we averaged two values from different sampling dates.

For Clear Lake, the two measurements were 1.6 m and 2.6 m. For McCann Lake, four values were used: 1.6 m, 1.8 m, 1.2 m, and 1.6 m. Addditional measurements of Secchi disc were made on McCann Lake in mid- to late-September. These measurements ranged from 0.7 m to 1.3 m, also indicating conditions of reduced transparency in the water column.

The basis for TSI values related to the three parameters is as follows. Many lakes, except for those with very high phosphorus concentrations, appear to have algal populations whose growth is limited by total phosphorus concentrations (cf. Downing and McCauley 1992). An increase of 10 TSI units represents a doubling of total phosphorus concentrations, roughly tripling algal biomass (as measured by chlorophyll *a*) and reducing transparency by one-half. Therefore, the indices should be compared to one another to see if changes in one parameter are reflected in changes in other measurements.

Calculated TSI values based on Secchi disc, total phosphorus and chlorophyll *a* measurements are shown for McCann and Clear Lakes for 1991 and 1994 in Figures 9-12. Compared with 1991, TSI values based on chlorophyll *a* remained the same for Clear Lake, but total phosphorus and Secchi disc TSI values have increased and are now in the lower portion of the mesotrophic range. The greatest change in estimated TSI was for measurements based on Secchi disc measurements. In 1991, all of the TSI values for McCann Lake were in the middle to upper mesotrophic range, while in 1994 all of the values are in the eutrophic range, indicating increased eutrophic conditions.

All of the TSI data suggest increasingly enriched conditions in both lakes. Nonetheless, there are several possible influence on these results and caution is advised in extrapolating beyond the meaurements and time period of this study. First, the results are for two similar time periods in two different years. Some of the differences in results from 1991 to 1994 could be associated with year-to-year fluctuations in conditions. In particular, some of the variation in water color would influence Secchi disc measurements and TSI values without affecting algal biomass. Second, the results for 1994 include some measurements that were not analyzed by the State Lab within the stated holding times. The influence of laboratory problems on the analyses is not known, but surface water concentrations appear to have been influenced less than samples collected in deeper waters. However, the results indicate the possibility that nutrient concentrations may have increased in the lakes leading to decreases in transparency and increased frequency of algal blooms. Further evidence of algal blooms was found in mid- to late-September for McCann Lake.

Survey of in-shore bacterial concentrations

Samples were collected at several locations to determine whether there was any evidence of unsafe conditions for swimming or any evidence of leaking septic systems. In particular, samples were collected at two locations that had shown elevated bacterial levels in 1991. These locations were offshore of the Arrowhead Bible Camp and along the north shore of McCann lake. Other locations included the shoreline of Clear Lake and along Chain Lake. No samples recorded numbers higher than 10 colonies/100ml, a concentration that is considered safe for human contact. Both of the locations that had elevated concentrations in 1991 showed lower concentrations equivalent to other sites.

Summary and Conclusions

Clear and McCann lakes located in Rusk County are popular recreation lakes. There is increasing human settlement and disturbance of the shoreline. Moreover, some of the development around Clear Lake was related to a sale of land by Rusk County. As pointed out in the report by Brakke in 1992, Clear Lake is especially sensitive to changes in nutrient concentrations.

Anoxic conditions were found in both lakes. Concentrations of surface water phosphorus may have increased slightly in Clear Lake and were considerably higher in McCann Lake. Those results should be verified by future measurements because of the possibility of laboratory error influencing the results. Chlorophyll *a* concentrations were higher in McCann Lake and transparency was lower. Those results appear to confirm that nutrient concentrations were higher in 1994. Algal blooms were observed on several dates and they extended into September. Clear Lake transparency was lower than observed in 1991, which could indicate an increasing trend of nutrients in the lake.

McCann Lake should also be a good indicator of changes that may have occurred in Island and Chain lakes, because of their connected flowpaths of water. Consequently, similar changes in nutrient concentrations, chlorophyll *a* concentrations and transparency might be inferred for the other lakes from the measurements in McCann Lake.

The potential increase in nutrient concentrations in the Island Chain of Lakes is consistent with other observations. For example, Long Lake, which is contributary to Chain Lake, has experienced increased anoxia in deeper waters as development of the shoreline has increased over the last two decades (Sorge, WI DNR, personal communication). Results from Long Lake should be compared with results from the Island Chain to determine whether there is evidence of a long-term change in the lakes, including an analysis of the rates of hypolimnetic oxygen depletion.

The apparent increases in nutrient concentrations in McCann Lake suggest increased vigilance by watershed residents to attempt to minimize impacts on the lakes. Moreover, increasing development of the shoreline of Clear Lake may result in increased nutrient concentrations and changes in lakewater transparency. Given present levels of nutrients, increases in nutrients would be expected to result in perceptible changes in lakewater transparency.

Some of the samples collected in this study were not analyzed by the State Lab of Hygiene within their published holding times. This factor has an unknown influence on the values presented. It appears that the influence was minimal for surface waters, but considerable for deepwater samples that had higher dissolved color. Because of the load of samples submitted to the State Lab and projected cuts in their operating budget, there may be reduced availability of the lab for monitoring work. The results of this study and the one conducted in 1991 suggest that monitoring of nutrient conditions is warranted and an alternate laboratory should be explored.

Monitoring of the lakes should focus on nutrient concentrations, transparency and algal biomass. It also should measure dissolved oxygen profiles during mid- to late-summer. Clear Lake should have a high priority for continued monitoring and McCann Lake can serve as a reference for the other two lakes, Chain and Island. Periodic sampling of those two lakes also should be accomplished.

Bacterial levels do not appear to present hazardous conditions for lakeshore residents. Nonetheless, in order to prevent further increases in nutrient concentrations, lake shore zoning should be enforced and septic systems should be periodically inspected and evaluated. All potential sources of nutrients to the lakes should be evaluated and attempts made to minimize their impact on the lakes.

References

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Table 1. Physical characteristics of Clear and McCann Lakes.

	Clear	McCann
Watershed area (ha)[a]	c	3432
Lake area (ha)	38.4	53.8
Volume (X $10^6 m^3$)	3.4	2.4
Maximum depth (m)	22.5	11.5
Mean depth (m)	9.1	4.4
Water residence (yr)[b]	25	0.4

[a] includes Lower Long Lake drainage area

[b] estimated by WI DNR (1981)

c Recieves some water exchange from Chain Lake; is fed mainly by seepage.

* all information regarding Chain and McCann Lakes has been obtained from the Summary Report for the WI DNR Lakes Planning Grant on the Island Chain of Lakes by Brakke (1992).

Table 2. Specific conductance of surface waters, Clear and McCann Lakes.

	Specific conductance (uS/cm)		
	April 1975	July 1991	August 1994
Clear	168	168	168
McCann	125	124	129

* April 1975 and July 1991 data from the Summary Report for the WI DNR Lakes Planning Grant on the Island Chain of Lakes by Dr. David F. Brakke.

Table 3. Surface concentrations August 1991 vs. August 1994.

	Clear	McCann
Sample Depth (m)	0.5	0.5
°C	'91- 23.0 '94- 22.5	'91- 23.0 '94- 19.2
Secchi (m)	'91- 4.5 '94- 3.0	'91- 2.5 '94- 1.8
Color (PCU)	'91- 15 '94- 25	'91- 25 '94- 25
pH	'91- 8.5 '94- 8.30	'91- 8.2 '94- 8.24
Alk (mg/L)	'91- 90 '94- 87	'91- 63 '94- 64
O_2 (mg/L)	'91- 9.0 '94- 8.2	'91- 9.2 '94- 8.9
Total P (ug/L)	'91- 13 '94- *15	'91- 18 '94- *31
Total N (mg/L)	'91- 0.6 '94- *0.42	'91- 0.5 '94- *0.72
NH_3-N (ug/L)	'91- 582 '94- 500	'91- 7 '94- n.d.
NO_3-N (ug/L)	'91- 54 '94- 90	'91- <7 '94- n.d.
Chlorophyll *a* (ug/L)	'91- 3.0 '94- *2.67	'91- 7.0 '94- 13.8
SiO_2 (mg/L)	'91- 3.2 '94- n.d.	'91- 4.5 '94- n.d.

- all August 1991 data from the Summary Report for the WI DNR Lakes Planning Grant on the Island Chain of Lakes by Dr. David F. Brakke.

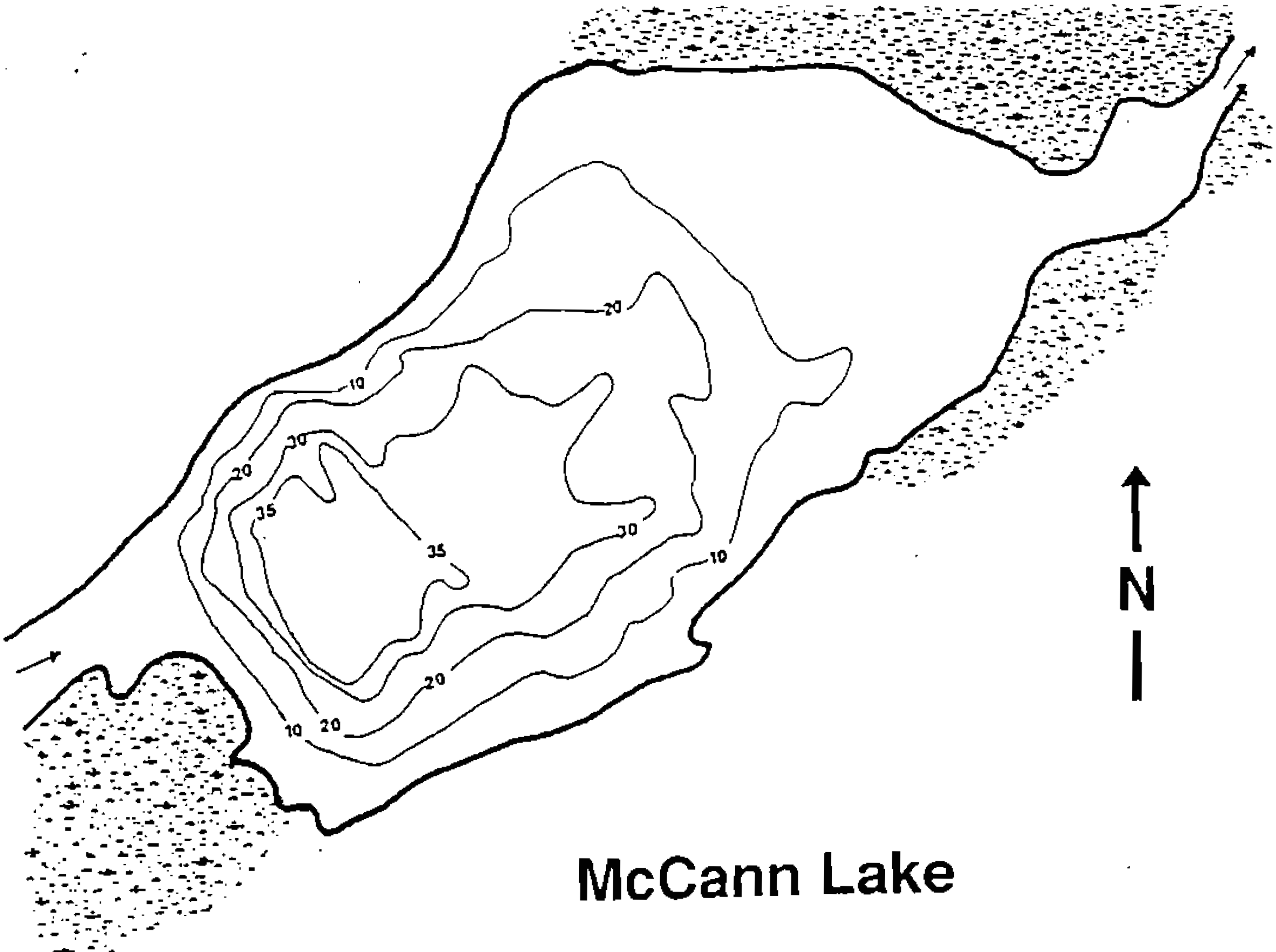
* Result approximate, low absorbance.

Table 4. Deepwater concentrations August 1991 vs. August 1994.

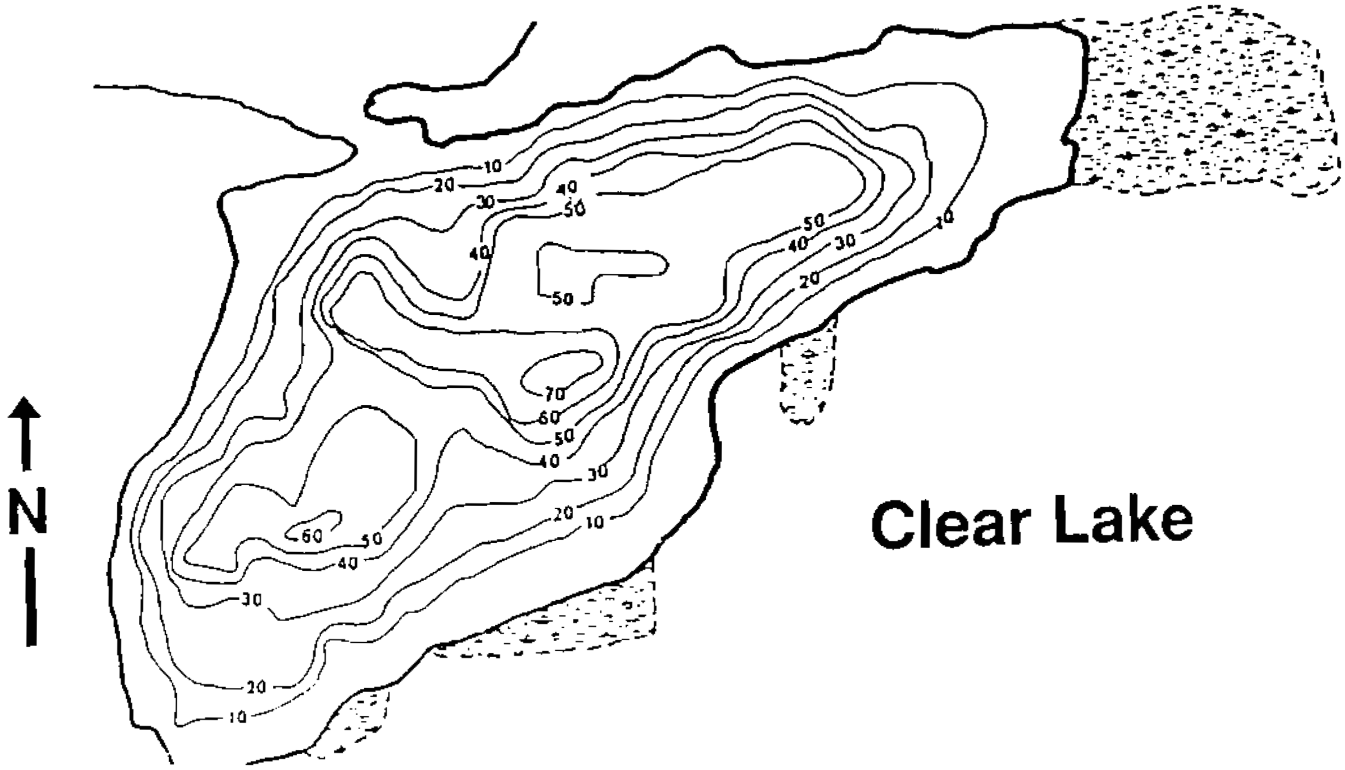
	Clear	McCann
Depth (m)	'91- 16 '94- 19	'91- 10 '94- 10
^0C	'91- 5.5 '94- 6.5	'91- 8.5 '94- 9.8
Color (PCU)	'91- 15 '94- 25	'91- 130 '94- 120
pH	'91- 7.8 '94- 7.57	'91- 7.5 '94- 7.38
Alk (mg/L)	'91- 108 '94- 100	'91- 90 '94- 83
O_2 (mg/L)	'91- 0.2 '94- 0.8	'91- <0.2 '94- 1.1
Total P (ug/L)	'91- 140 '94- *70	'91- 172 '94- *42
Dissolved P (ug/L)	'91- 24 '94- 26	'91- 94 '94- 13
Total N (mg/L)	'91- 1.0 '94- *0.72	'91- 2.2 '94- *1.74
NH_3-N (ug/L)	'91- 593 '94- 304	'91- 1280 '94- 1130
NO_3-N (ug/L)	'91- 54 '94- 76	'91- 32 '94- 20

- all 1991 figures came from the Summary Report on the Chain of Lakes for the WI DNR by Dr. Brakke.

* Holding time exceeded or analysis approximate because of low levels.



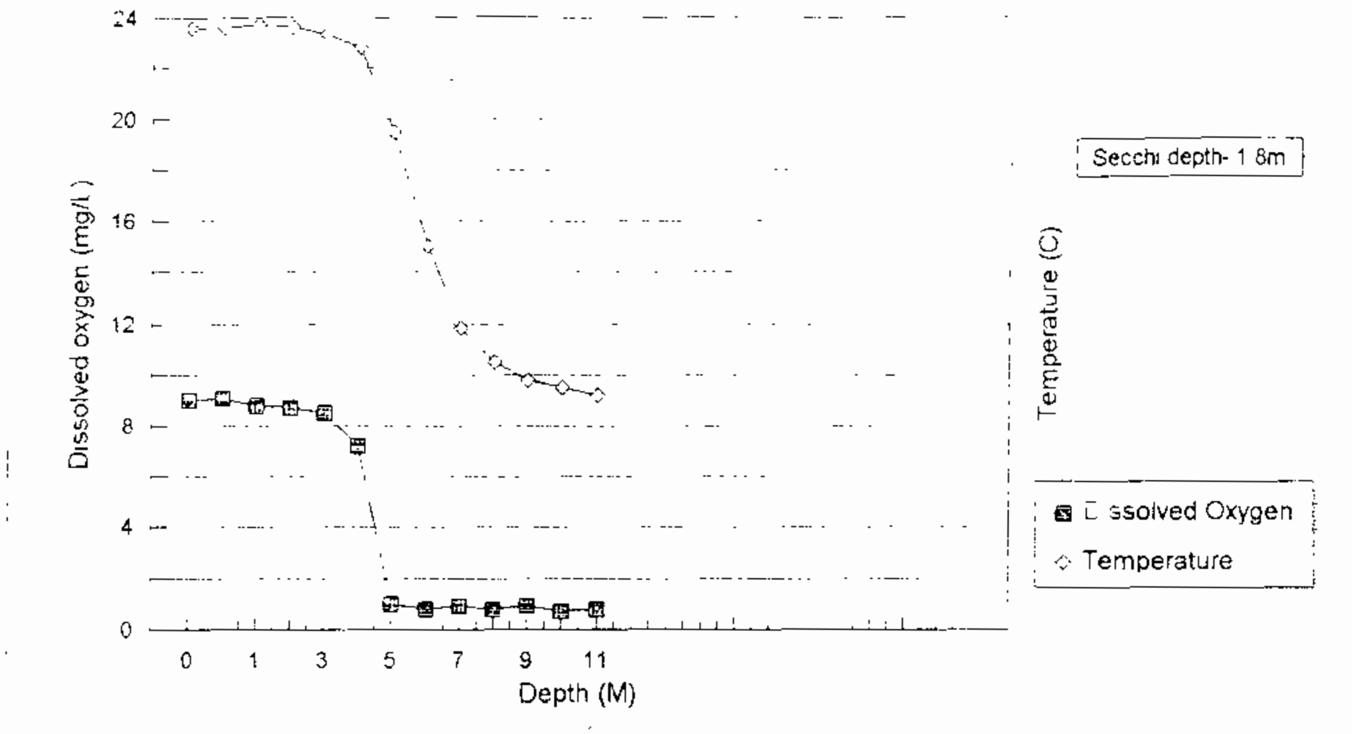
McCann Lake



Clear Lake

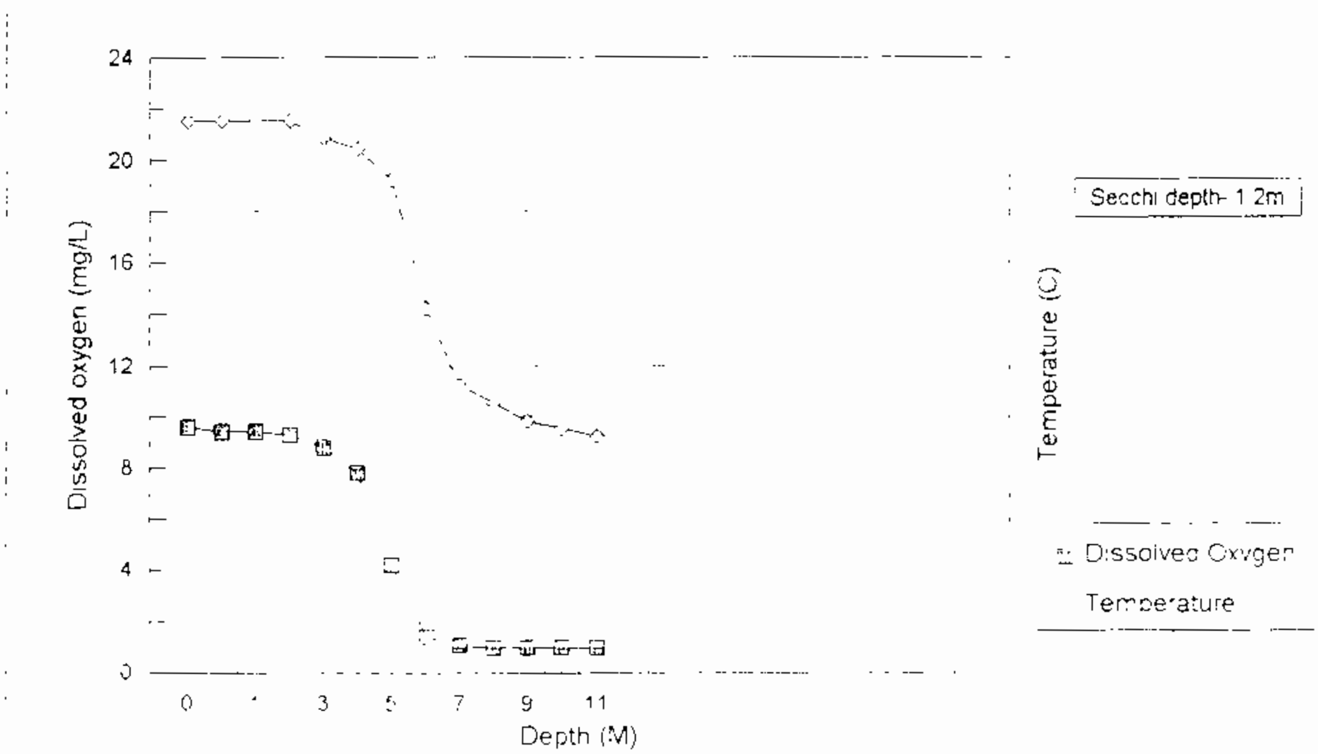
McCann Temp/D.O.

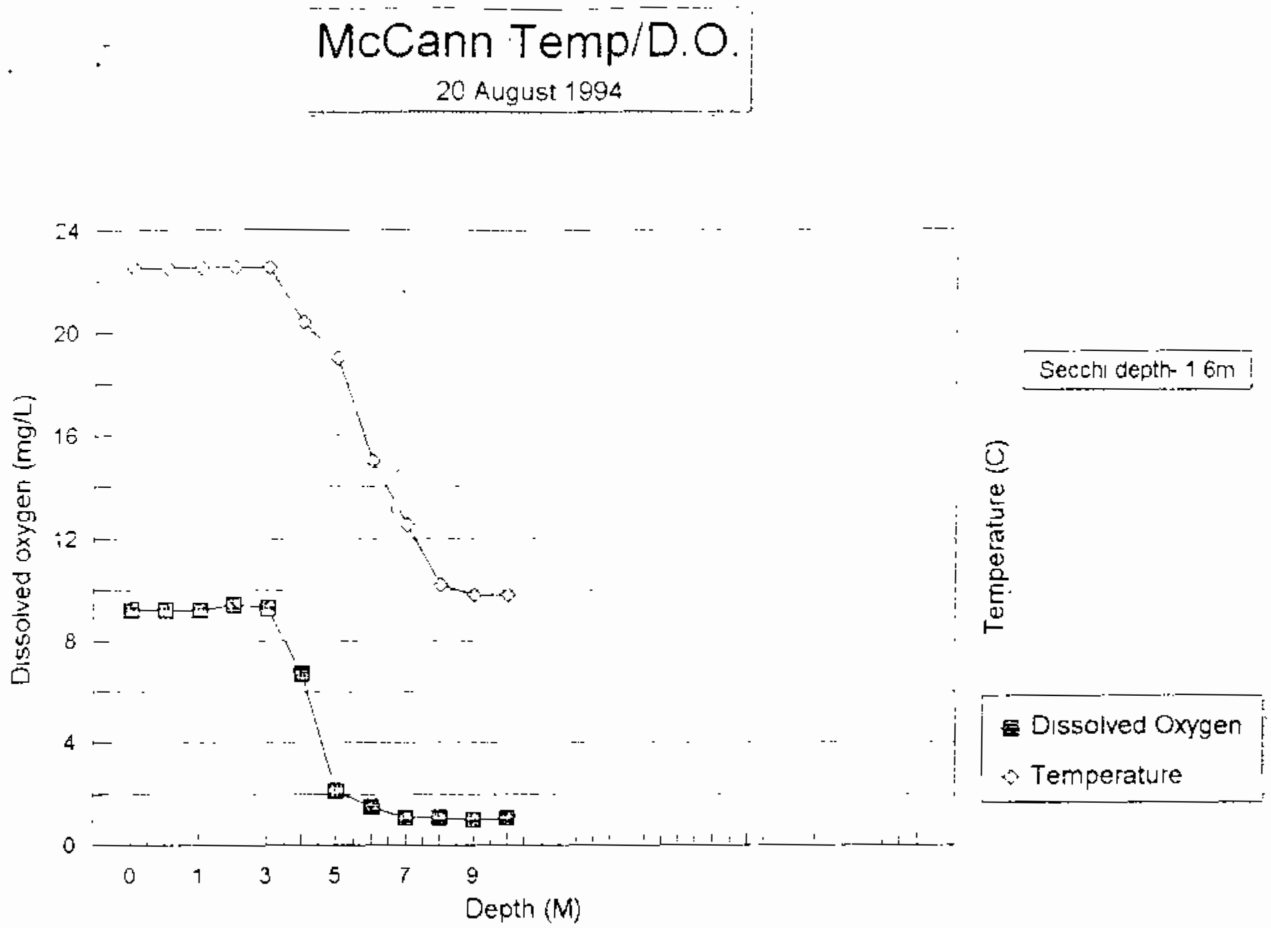
6 August 1994



McCann Temp/D.O.

13 August 1994




McCann Temp/D.O.
20 August 1994
24
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16
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Dissolved oxygen (mg/L)
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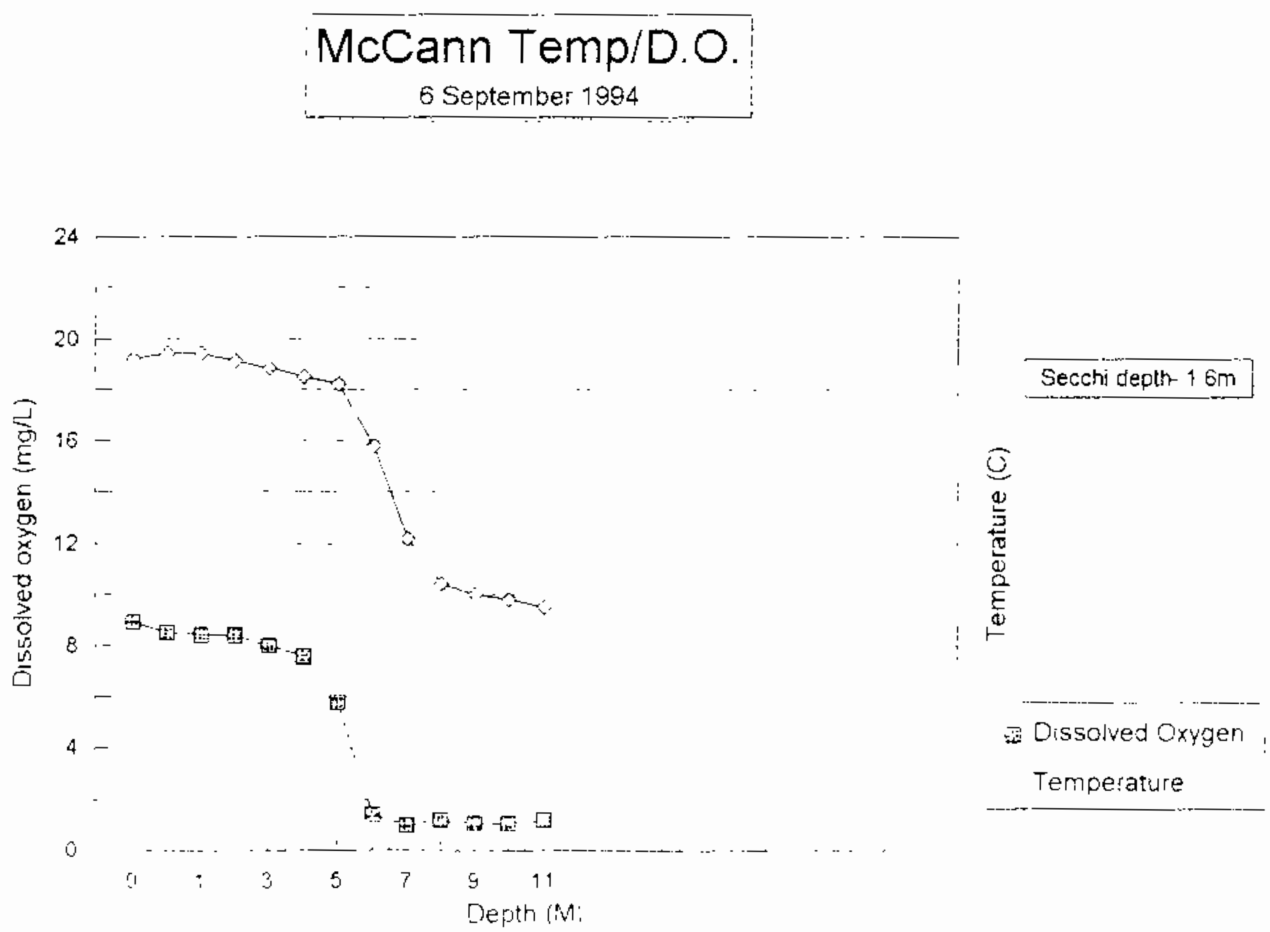
Depth (M)
Temperature (C)
Secchi depth- 1 6m
Dissolved Oxygen
Temperature


McCann Temp/D.O.
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Temperature (C)
Secchi depth- 1 6m
Dissolved Oxygen
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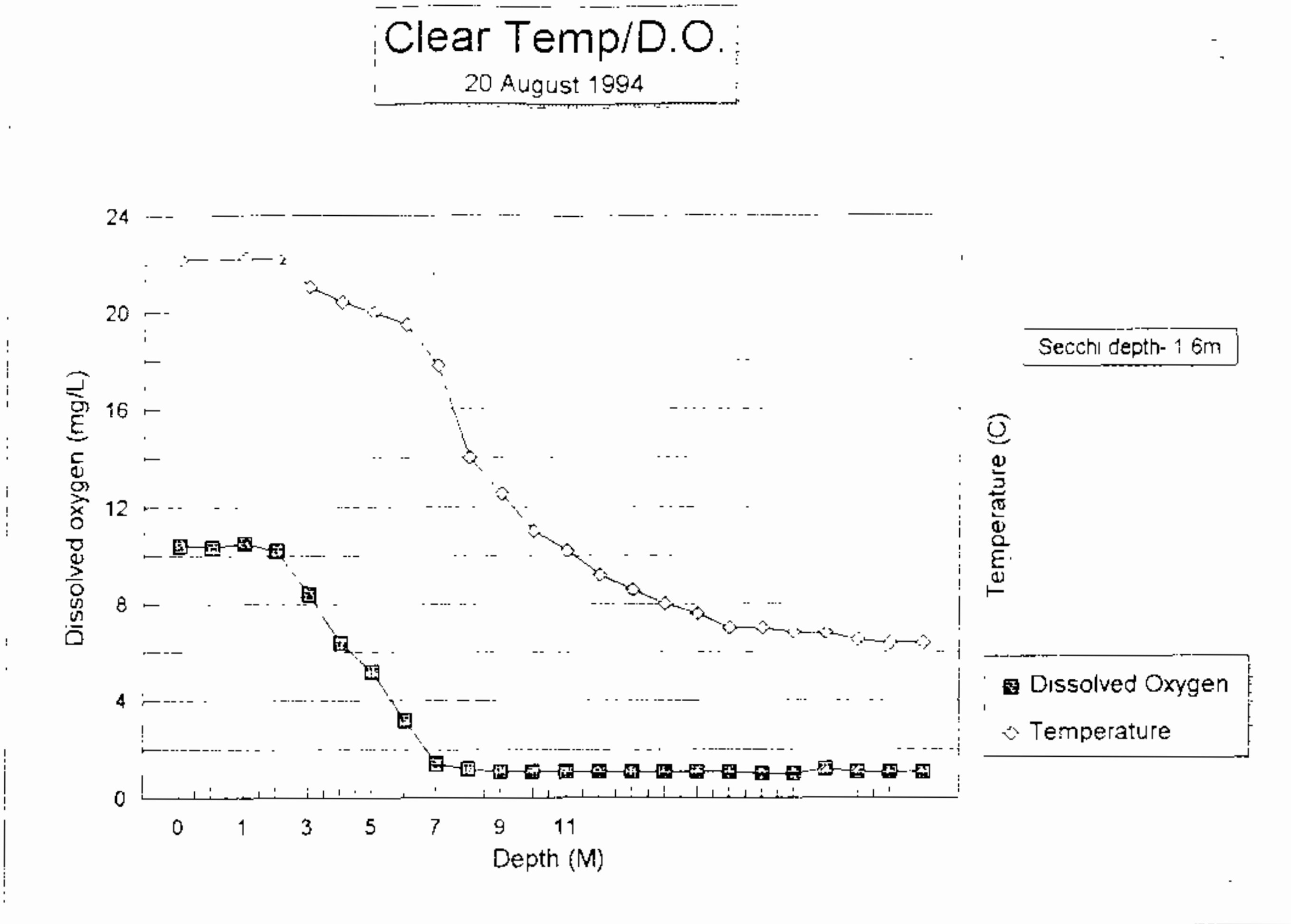
Clear Temp/D.O.
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Secchi depth- 1 6m
Dissolved Oxygen
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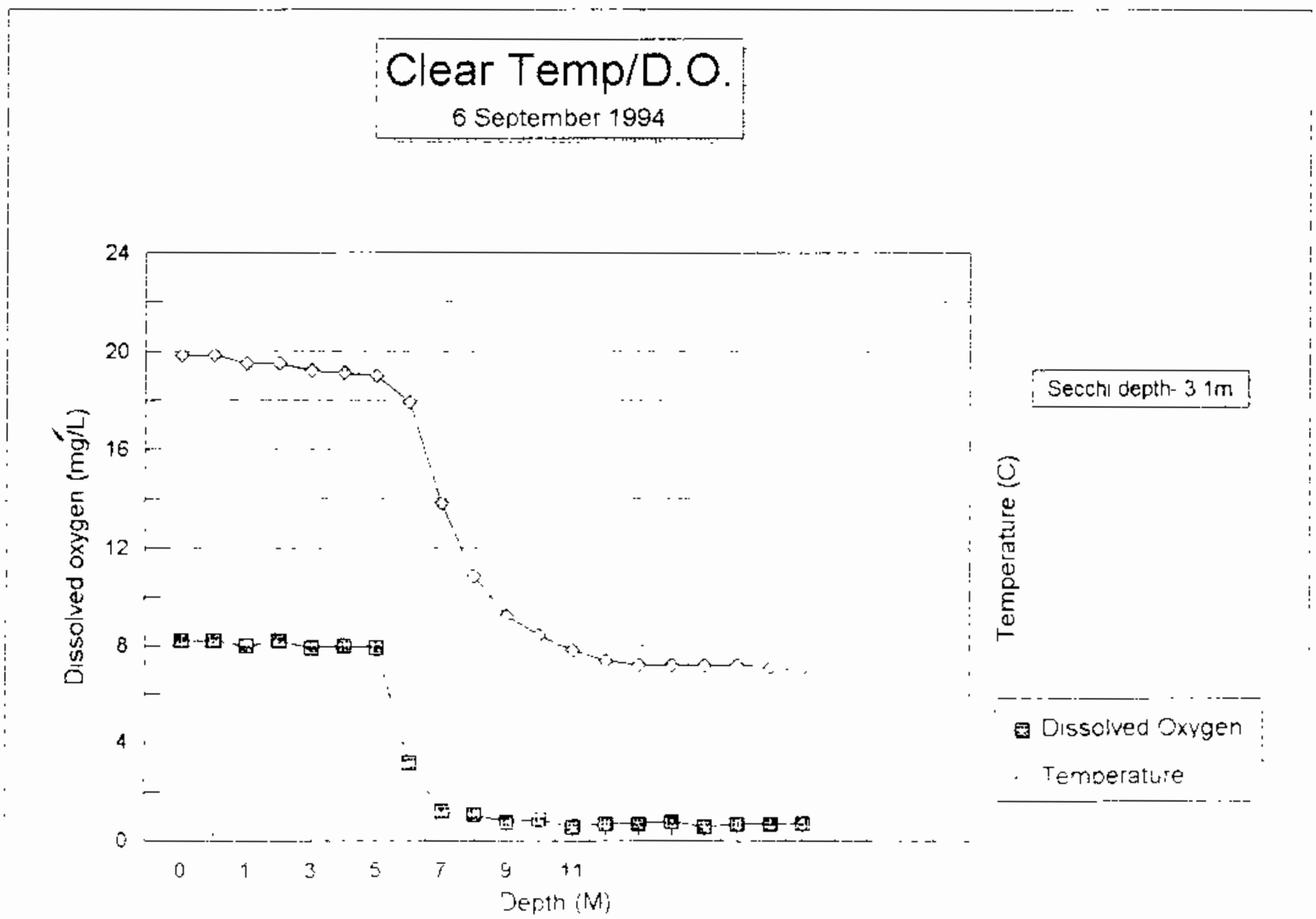
Clear Temp/D.O.
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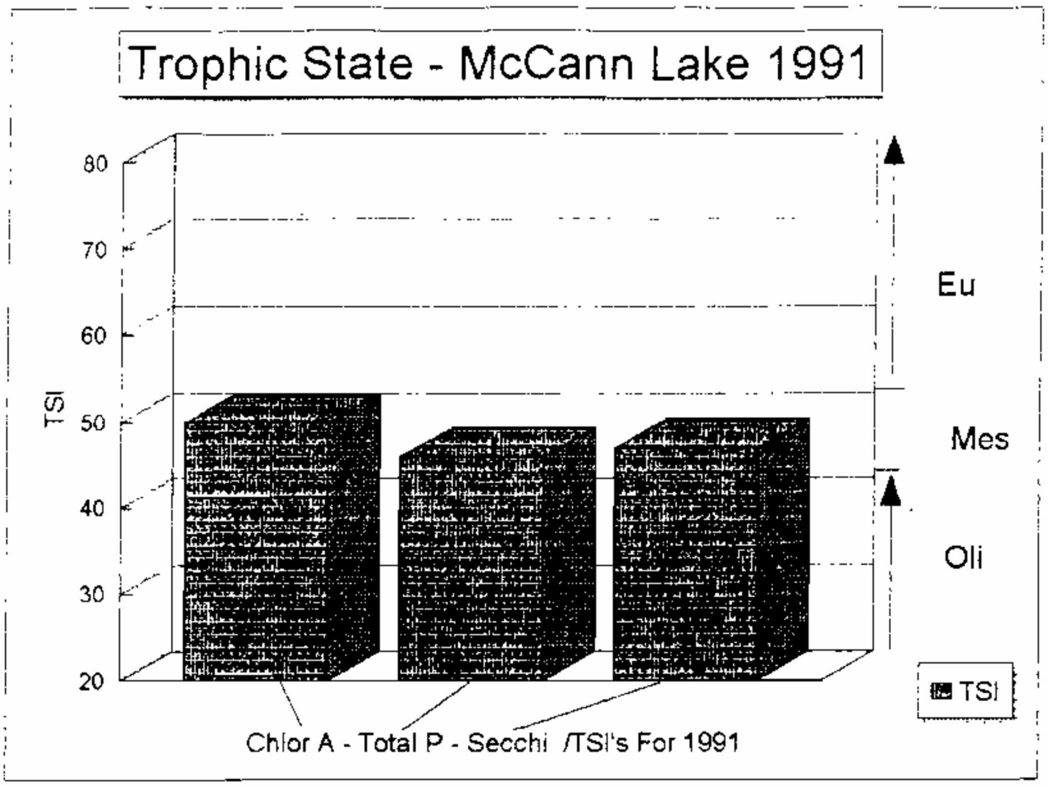
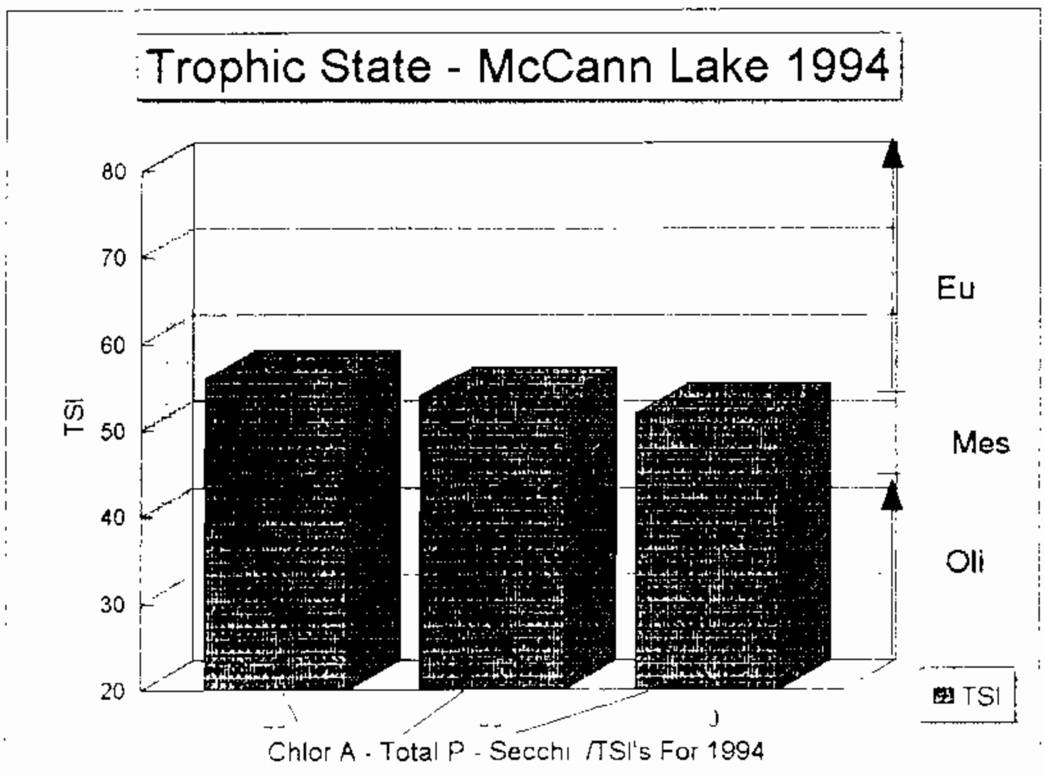
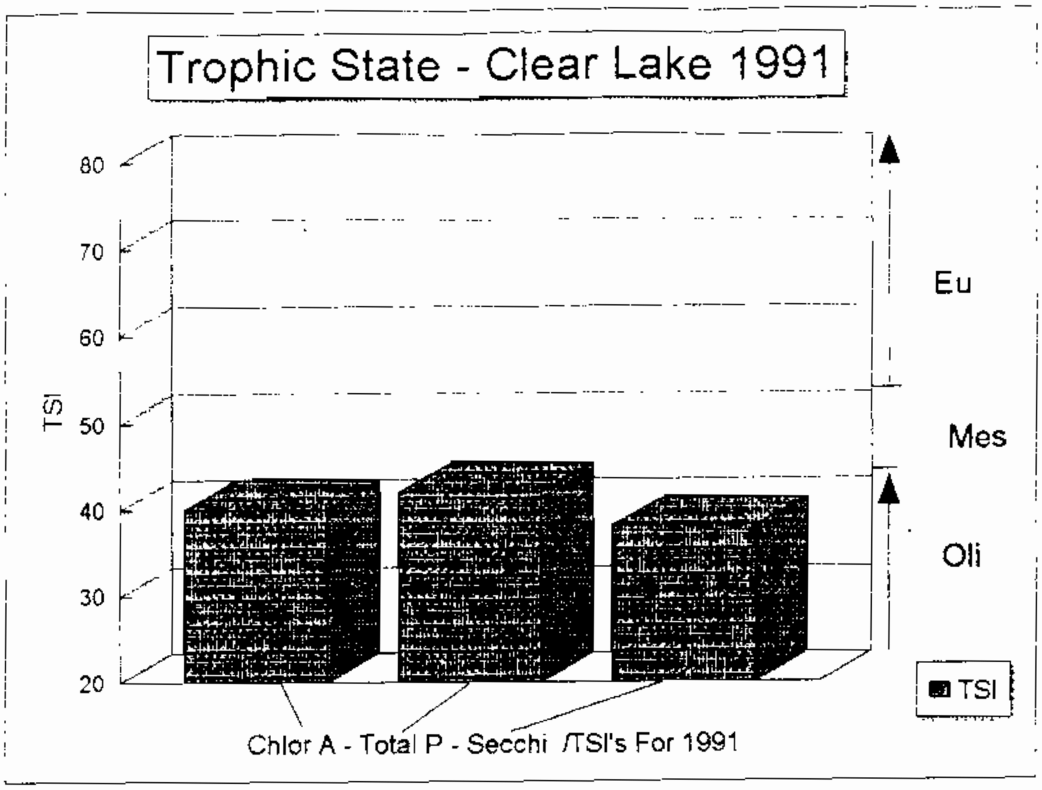


* All 1991 values were obtained from the Summary Report on the Island Chain of Lakes by Brakke (1992).





* All 1991 values were obtained from the Summary Report on the Island Chain of Lakes by Brakke (1992).