Four lakes (Weaver, Fish, Jubert and Champlin Mill Pond) were sampled by the Commission in 1991 (Figures 2 and 3). Critical lake drainage basins as defined in the Elm Creek Watershed Management Plan are shown in Figure 4. Lake morphometry, watershed area and land use data are summarized for each lake in Table 2. Land uses with potentially adverse effects on water quality include, row crops, commercial, industrial and medium and high density residential uses. These land uses are classified as deleterious uses in the Elm Creek watershed plan. Land uses with potentially positive effects on water quality include grasslands, wetlands, woods and parks. These uses are classified as sustaining uses. The percentages of deleterious and sustaining use were determined from 1980 aerial photos.

The Champlin Mill Pond is an impoundment created by a dam on Elm Creek before it enters the Mississippi River. It consists of 3 basins known as the upper, middle and lower basins. Samples are collected in the lower basin. Because the Mill Pond is a reservoir rather than a lake, it has different characteristics than lakes. It is fairly well mixed due to continuous water movement of Elm Creek through the Mill Pond.

Water quality parameters monitored for in 1991 are summarized in Table 3. Fish and Weaver Lakes and the Mill Pond were sampled monthly from May through September on the following dates. May 14, June 11, July 16, August 13 and September 17. Analyses of lake samples for alkalinity and chloride were conducted in May. All other parameters were monitored or analyzed monthly. Jubert Lake was sampled in July and August. May, June and September monitoring was not possible due to access problems. Samples were collected and delivered to the laboratory that same day. All samples were analyzed within the specified holding times.

Phosphorus is a chemical element that is essential for plant growth. Concentrations of total phosphorus (TP) indicate the maximum growth potential for algae in a lake and may be used to classify a lake's trophic status. Weaver and Fish Lakes had their maximum concentrations of total phosphorus in May (Figure 5a). The Mill Pond had its maximum total phosphorus of 532 ug/L in June. Jubert Lake had high phosphorus concentrations in both samples, but August (720 ug/L) was about double that of July (349 ug/L). Minimum total phosphorus concentrations were recorded in September for Weaver and Fish Lakes, and in June for the Mill Pond. Jubert Lake had the highest mean concentration of total phosphorus, and Weaver Lake had the lowest (Figure 6a). Both epilimnetic (surface) and hypolimnetic (bottom) samples were collected for each lake (Figure 7). Generally hypolimnetic samples were substantially higher in phosphorus than epilimnetic samples. The hypolimnetic phosphorus increased throughout the monitoring season. September samples had hypolimnetic TP up to 15 times greater than epilimnetic samples. High TP in the hypolimnion is indicative of internal loading of phosphorus from the sediments.

Chlorophyll a is a photosynthetic pigment found in all green plants. The concentration of chlorophyll a is a measure of algal abundance. The concentration of chlorophyll a in Weaver Lake peaked in June and was lowest in May (Figure 5b). Fish Lake chlorophyll a peaked in August and was at its lowest in June. Mill pond had it s highest chlorophyll a concentration in May and its lowest in June. The chlorophyll a concentration in the August sample for Jubert Lake was about double that of the July sample. Both samples were high, as expected based upon the"pea green" look of the lake. The Mill Pond exhibited the lowest mean chlorophyll a concentration (Figure 6b). Jubert Lake had the highest mean and median concentration.

Secchi disk transparency is a measure of water clarity. Higher Secchi disk transparency indicates greater water clarity. The maximum Secchi disk transparency occurred in May in Weaver Lake (Figure 5c). Maximum transparency for Fish Lake occurred in July. The Mill Pond had its maximum transparency in September. Minimum transparency occurred in June in Weaver,August in Fish and May in the Mill Pond. Transparency was very low in Jubert for both July and August. Weaver and Fish Lakes had average transparency values in excess of 5 feet (Figure 6c). Weaver Lake had the highest average at 7.1 feet. The average was influenced by the very high May transparency reading of 11.2 feet. Fish Lake's transparency remained about the same throughout the monitoring season.

Temperature and dissolved oxygen measurements were taken from all four lakes. Dissolved oxygen concentrations generally mirrored temperature profiles with a rapid decrease in dissolved oxygen below the thermocline during stratification. Dissolved oxygen conditions varied from lake to lake. Temperature profiles show that Fish and Weaver Lakes were stratified throughout the monitoring season (Figures 8 & 9). In May Fish Lake was fairly well oxygenated to the bottom. However, profiles for the remainder of the season showed anoxia below approximately 18 feet. Weaver Lake was well oxygenated throughout the water column in May. The June profile showed oxygen concentrations dropping off at a depth of 30 feet. By July, oxygen dropped below 5 mg/L at a depth of only 11 feet and dropped to zero at 24 feet. The August and September profiles indicated low oxygen concentrations below 18 feet and anoxia below 30 to 40 feet. Since the Mill Pond is part of the Elm Creek, it remains fairly well mixed and is only slightly stratified as shown in the dissolved oxygen and temperature profiles (Figure 10). The Mill Pond exhibited poor oxygen concentrations with its highest concentration at approximately 7 mg/L. Below three feet of depth, oxygen concentrations remained under 5 mg/L. Oxygen concentrations should remain above 5 mg/L for long-term fish survival. Profiles for July and August in Jubert Lake are available (Figure 11). Jubert Lake was strongly stratified, with very low dissolved oxygen concentrations. The lake was anoxic below a depth of 6 feet. This condition severely limits the fishery of a lake.

Lakes may be classified as to their trophic state based on Carlson’s Trophic State Index (Carlson 1977). This index indicates nutrient enrichment and is calculated based on measured values for total phosphorus, chlorophyll a and Secchi disk transparency. Trophic state index values for the lakes sampled in 1991 are shown in Figure 12. Weaver and Fish Lakes are considered eutrophic. Phosphorus concentrations for the Mill Pond would classify it as hypereutrophic. However, the chlorophyll a and transparency of the Pond are not characteristic of a hypereutrophic status due to the extensive weed growth in the Pond, and the fact that it is a flow through system. Movement of water through the pond prevents the buildup of algae. The above normal runoff which occurred in 1991 likely increased the flushing action experienced in the Pond With less algae, the transparency is higher than expected based upon the phosphorus concentration. The TSI for phosphorus indicates the potential trophic state for the Mill Pond. Its high phosphorus concentration suggests that either the Mill Pond will have dense macrophyte beds or heavy algal blooms throughout the summer in the more stagnant areas. Water movement prevents the buildup of algae in areas near the stream channel. Although only two samples were collected from Jubert Lake, its very high phosphorus concentrations and conditions observed in the lake indicate it would be classified as hypereutrophic.

It is difficult to determine trends when extensive data is not available for a lake. The accuracy of these evaluations increases with increasing number of samples. The following trend analysis is based on limited data and therefore may not be an accurate assessment of water quality trends for the lakes. The Elm Creek Watershed District, in its Management Plan, established water quality goals for lakes within the watershed. These numerical goals differ depending upon lake classification. In order to simplify the meaning of these goals, they are referred to as upper or lower limits in this report. Weaver and Fish Lakes are category I lakes and have the most stringent water quality goals. Jubert Lake is a category II lake and has somewhat less stringent goals. The Mill Pond is a category III lake and has the least stringent goals. Since it is also an impoundment, it has different characteristics than lakes and therefore has different goals than category III lakes.

The phosphorus concentration for Fish Lake is above the upper limit listed in the Plan. Mean concentrations of chlorophyll a and mean concentrations of total phosphorus (Figure 13) have increased since 1989. The chlorophyll a concentration remains below the upper limit. Mean Secchi disk transparency for Fish Lake has remained fairly stable since 1987 (Figure 13). The Minnesota Pollution Control Agency (MPCA) lists a mean transparency of 5.2 feet for Fish Lake. This value is based on 75 measurements from 1977-1989 and is quite comparable to recent transparency measurements for Fish Lake. The MPCA (1977-89) mean concentration of total phosphorus is well below the mean concentration observed in 1991. The MPCA mean is based on 24 samples.

Mean total phosphorus for Weaver Lake appears to be increasing over time and has exceeded the upper limit specified in the Plan since 1989 (Figure 14). However, the chlorophyll concentration appears to be decreasing over time and remains well below the upper limit. This may be due in part to the chemical treatments used to control the algal blooms and increase transparency. Mean Secchi disk transparency in Weaver Lake was slightly higher in 1991 compared to 1990 and remains above the lower limit specified in the Plan (Figure 14).

The mean concentration of total phosphorus in the Mill Pond has increased since 1988 (Figure 15). However, the chlorophyll concentration was substantially lower than measured in 1988. Mean Secchi disk transparency in the Mill Pond was much higher than that observed in 1988, but similar to the 1985 mean (Figure 15). Differences in flow from 1988 and 1991 also would account for the increase in chlorophyll a concentration. Runoff for 1991 was almost ten times greater than for 1998. With increased flow, algae could not build up and create nuisance conditions. Also the differences may be attributed to the differences in macrophyte growth with drawdown occurring prior to the 1988 monitoring season. Areas with dense macrophyte growth tend to have high transparency.

The total phosphorus concentration in Jubert Lake has increased over time (Figure 16). It should be rioted that the means for Jubert Lake are based on only 2 samples taken mid summer. Although the 1991 mean is based on only 2 samples, it is substantially higher at 535 ug/L than means from previous years (highest was under 300 ug/L). The chlorophyll a concentration was also high. As expected based upon the chlorophyll a concentration, transparency in Jubert Lake was very poor and substantially lower than in the past. This time of the year, often referred to as the "dog days of summer" is typically when the worst water quality is observed for a lake. All three parameters for Jubert Lake were beyond the limits specified in the Plan (i.e. poor water quality).

There were many large and small storm events in 1991. Rainfall was above normal. The increase in rainfall for 1991 resulted in increased runoff and likely increased nutrient loading to the lakes. All four lakes had mean total phosphorus concentrations that exceeded the Plan limits and were the highest on record.

The water quality of Fish and Weaver Lakes, as measured by total phosphorus, appears to be declining. The commission has taken steps in the past to reduce nutrient loading through erosion control and other practices. It is apparent that additional management practices or improvement projects are needed to reverse the trend in water quality for the Elm Creek Watershed.

The water quality of Elm Creek Watershed lakes may be compared to that of lakes that should be similar in water quality based on location, land use, soils, land form and potential natural vegetation. The MPCA in cooperation with the Environmental Protection Agency (EPA) has developed a means to group Minnesota Lakes based on the above characteristics. These areas are called aquatic ecoregions. There are seven of these ecoregions in the state (Figure 17) (Wilson and Walker 1989). The Twin Cities Metropolitan area is within the ecoregion known as the North Central Hardwood Forests (NCHF). Lakes within an ecoregion should be somewhat similar to each other. Elm Creek Watershed lakes may be compared with other NCHF lakes. The MPCA rankings for Fish, Weaver and Jubert Lakes and the Mill Pond are 57, 54, 43 and 20 percentile respectively. These rankings are based on limited data and may change somewhat with additional data. The rankings are percentile values with a value of 0 indicating the poorest water quality and 100 indicating the best water quality in comparison with other lakes in the ecoregion. Jubert Lake is ranked as having very poor water quality in comparison with other NCI-IF lakes. The Mill Pond is also below the median for water quality. Fish and Weaver were both ranked approximately at midrange for the ecoregion.

Ecoregions also provide a means for gathering useful information for setting water quality goals. The potential water quality of a lake may be estimated based on data for the lakes having the best water quality for the ecoregion. The MPCA refers to these lakes as minimally impacted lakes. Mean values for monitored lakes may be compared to interquartile ranges for the NCHF lakes (Table 5). Fish and Weaver have mean total phosphorus concentrations at the upper end of the interquartile range. This indicates the potential water quality of these lakes is much better than existing conditions. Mean total phosphorus for the Mill Pond and Jubert Lake is 7 to 11 times greater than the 75th percentile value for the ecoregion. These water bodies would not be considered minimally impacted. They are definitely impacted by pollutant loading from the watershed. The remainder of the water quality parameters listed in Table 5 are generally within the interquartile range for the ecoregion except for chlorides. The high chlorides may be due to high concentrations of chloride left behind from road salting and carried in snowmelt runoff. The samples for chloride were collected in May when chloride concentrations in runoff are probably near their peak.

The three main parameters, total phosphorus, chlorophyll a and Secchi disk transparency are all interrelated. For most lakes in this area, phosphorus is the nutrient that determines the amount of algae and macrophyte growth in a lake. High phosphorus concentrations will generally result in either dense macrophyte growth or algal blooms. The frequency and severity of these algal blooms is dependent upon phosphorus concentrations. Chlorophyll is a measure of the amount of algae in a lake and Secchi disk transparency is dependent upon chlorophyll a concentrations. Transparency may also be limited by other dissolved or suspended materials in the lake.

The interrelationships described above are shown graphically on scatterplots in Figure 18. The 1991 mean data are plotted. The phosphorus concentrations of Jubert Lake and the Mill Pond are so high they are beyond the boundaries of the graph. However, data from Fish and Weaver Lakes do fit the general relationship shown in the graphs.

Probably the most important information that can be taken from Figure 18 is noting the critical points for TP and chlorophyll a as they affect transparency. On the middle graph, the "critical area" is at a concentration of about 5 to 10 ug/L. When concentrations exceed this range and up to a concentration of about 30 ug/L, the result is a substantial reduction in transparency. Once concentrations exceed about 30 ug/L, there is only a small decrease in transparency with increases in chlorophyll a. Similarly, at TP concentrations greater than 10 ug/L there is a rapid decrease in transparency with increases in TP up to a concentration of about 60 ug/L. Weaver Lake falls within this "critical range" for phosphorus and chlorophyll a. Any increases in phosphorus and chlorophyll a concentrations are likely to result in noticeable decreases in transparency. For example, if mean chlorophyll a was increased from 11 to 20 ug/L, mean transparency is expected to drop from its existing 7 feet down to about 4.5 feet. Jubert Lake and the Mill Pond's TP concentrations are already beyond the critical point. Any increases in TP will result in increases in the frequency and severity of algal blooms and reduced transparency or increases in macrophyte density and coverage, however they will likely not be dramatic changes. Weaver Lake is at the tail end of the critical range. Increases in phosphorus will result in only minor reductions in transparency.

Regressions of several parameters were completed for Fish and Weaver Lakes and the Mill Pond. It was not appropriate to use regression with the limited data available for Jubert Lake. The r-squared values (percent variance explained) are presented in Table 6. Only the Mill Pond showed a significant relationship between phosphorus and chlorophyll a. Fish Lake had a significant relationship between total nitrogen and chlorophyll a. This indicates that it may be nitrogen that is controlling the growth of macrophytes and algae in the lake. However, the total nitrogen to total phosphorus ratio (TN:TP) indicates that phosphorus is the limiting nutrient for Fish and Weaver Lakes. For the Mill Pond and Jubert Lake, the TN:TP ratio suggests that nitrogen may be the limiting nutrient, but the regression results show no relationship between TN and chlorophyll or transparency.

Fish and Weaver Lakes had r-squared values of 0.69 and 0.64 respectively for the regression of chlorophyll a and Secchi disk transparency. The r-squared values were increased using Log values. This indicates the transparency of these lakes is limited mainly by algae and the data fit more of a curvilinear than linear relationship. Some of the variance in transparency is not explained by the chlorophyll a concentrations. Other dissolved or suspended materials are limiting transparency. For the Mill pond, less than 50 % of the variance in transparency was explained by chlorophyll a concentration. This is not surprising for a flow-through system. Sediments, both inorganic and organic materials, are carried with the movement of the water and reduce transparency.

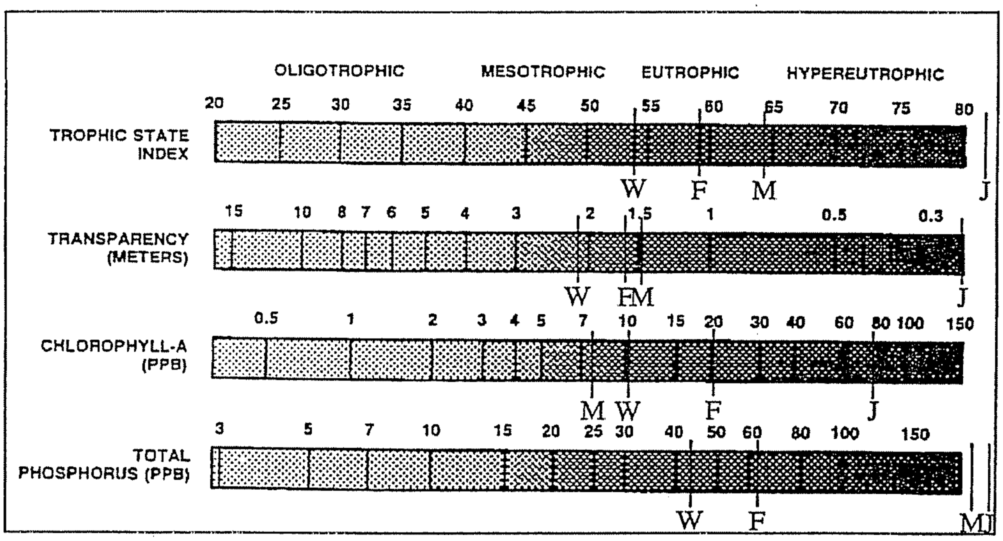
The computer model "MINLEAP" was used to compare the 1991 . data to water quality values expected for minimally impacted lakes in the ecoregion (Wilson 1988). The modeling results also provided predictions of lake conditions in terms of algal blooms. The results are presented in Table 7. The predicted parameters for both Fish and Weaver Lakes indicated potentially improved water quality compared to observed values. The model predicted statistically significant differences for all three parameters for the Mill Pond. However it predicted lower phosphorus and higher chlorophyll a than observed. It also predicted poorer transparency than observed.

WEAVER LAKE

	SDT ft.	TP ug/L	HYPO TP ug/L	CHL ug/L	NO2 + N03 mg/L	NH3 mg/L	TKN mg/L	HYPO TKN mg/L	TN mg/L	pH	COND umhos/ cm	ALK mg/L	CL mg/L
MAY	11.2	60	88	5.8	0.73	0.18	0.6	1.1	1.3	8.15	311	126	54
JUNE	4.0	51	234	19.3	0.10	0.03	0.6	1.2	0.7	8.35	330		
JULY	5.5	47	253	8.7	0.63	<.03	0.2	0.9	0.9	8.40	337		
AUGUST	8.0	34	370	8.9	0.86	<.03	1.0	1.8	1.9	7.65	338		
SEPTEMBER	7.0	28	414	9.9	0.11	0.15	1.5	3.5	1.6	7.10	290		
Mean	7.1	44	272	10.5	0.49	0.12	0.8	1.7	1.3	7.93	321		
Median	7.0	47	253	8.9	0.63	0.15	0.6	1.2	1.3	8.15	330		
STD Dev.	2.7	13	128	5.1	0.36	0.08	0.5	1.1	0.5	0.55	21		
TSI 54	49	59		54									

	Ecoregion*	Fish	Weaver	Mill Pond	Jubert
TP (ug/L	23 - 50	65	44	341	535
CHL a (ug/L)	5 - 22	20.4	10.5	8.3	74.5
SDT (ft)	4.9 - 10.5	5.4	7.1	4.9	0.5
Chloride (mg/L)	4 - 10	31	54	39	21
Alkalinity (mg/L)	75 - 150	159	126	158	126
TKN (mg/L)	<.6 - 1.2	0.8	0.8	1.0	1.4
NO2 + NO3 (mg/L)	<.01	0.43	0.49	0.47	0.81
pH	8.6 - 8.8	8.2	7.93	7.41	8.8
Conductivity	300 - 400	333	319	293	279
TN:TP	25:1 - 35:1	20:01	30:1	4:01	4:01

*Interquartile (25th to 75th percentile) values for minimally impacted lakes



After Moore, L. and K. Thornton, [Ed.] 1988. Lake and Reservoir Restoration Guidance Manual. USEPA. EPA 440/5-88-002.

F-Fish Lake W-Weaver Lake M-Mill Pond J-Jubert Lake

LAKE = WEAVER ECOREGION = CHF
AVERAGE INFLOW TP = 221.7552 UG/L TOTAL P LOAD = 46.55308 KG/YR
LAKE OUTFLOW = .20993 HM3/YR AREAL WATER LOAD = .3264852 M/YR
RESIDENCE TIME = 19.60272 YRS P RETENTION COEF = .9060706

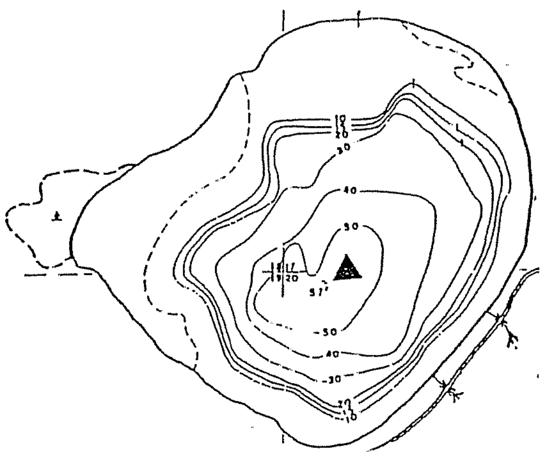
VARIABLE	UNITS	OBSERVED	PREDICTED	STD ERROR	RESIDUAL	T-TEST
TOTAL P	(UG/L)	44.00	20.83	8.87	0.32	1.64
CHL-A	(UG/L)	10.50	5.57	3.98	0.28	0.83
SECCHI	(METERS)	2.16	2.82	1.31	-0.12	-0.55

NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

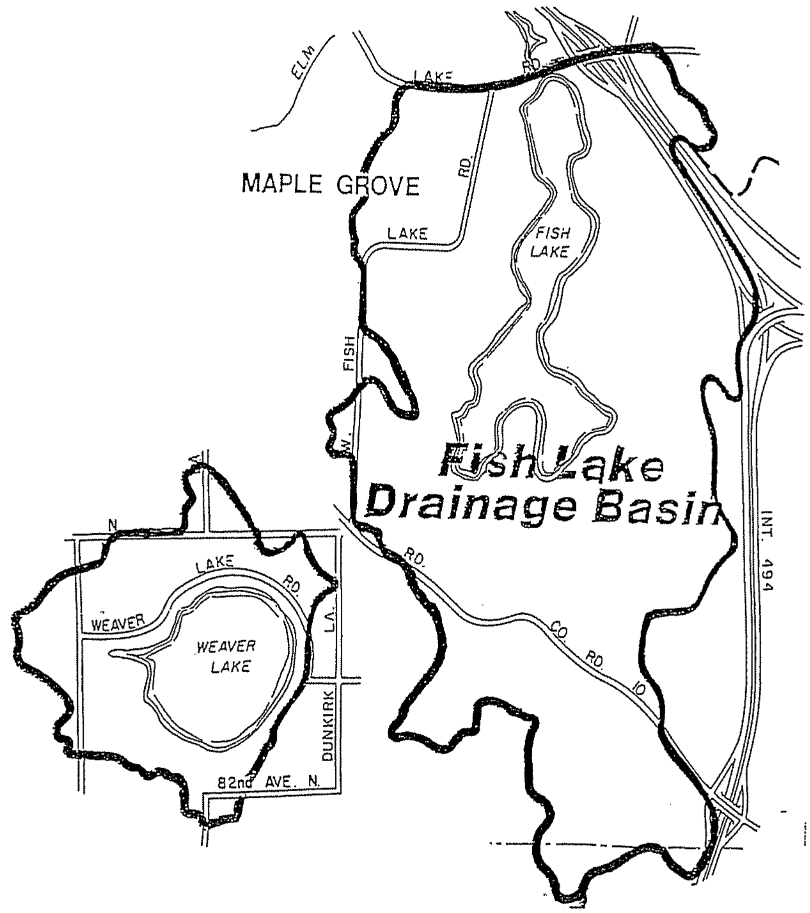
CHLOROPHYLL-A INTERVAL FREQUENCIES (%)

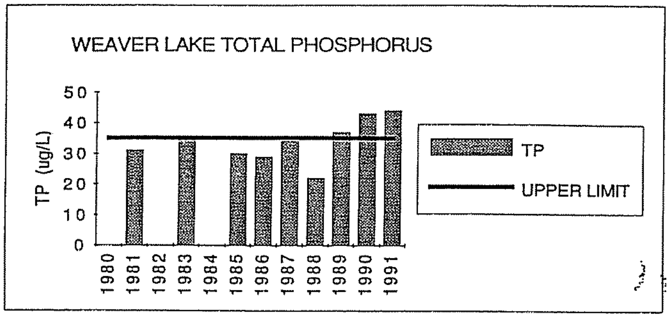
CHL-A PPB	OBSERVED	PREDICTED CASE A	PREDICTED CASE B	PREDICTED CASE C
10	44.44	7.19	8.86	21.37
20	5.67	0.18	0.37	5.74
30	0.76	0.01	0.03	2.09
60	0.01	0.00	0.00	0.24

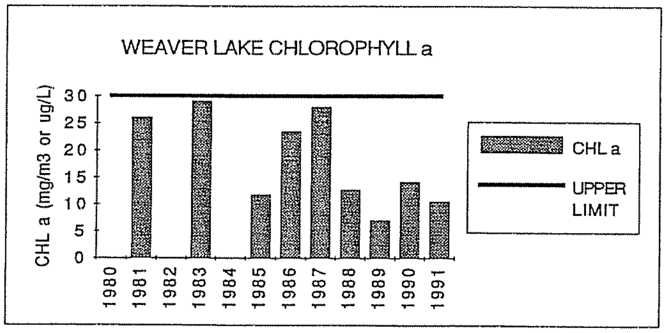
CASE A = WITHIN-YEAR VARIATION CONSIDERED
CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED
CASE C = CASE B + MODEL ERROR CONSIDERED
0

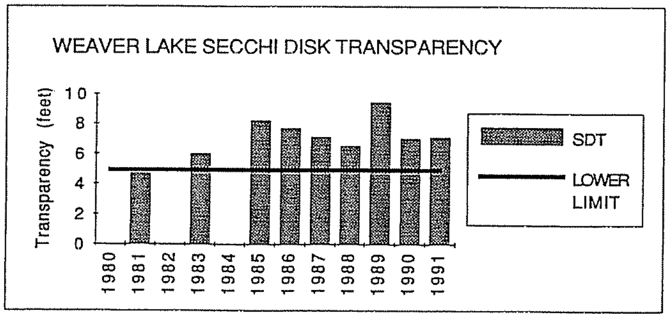


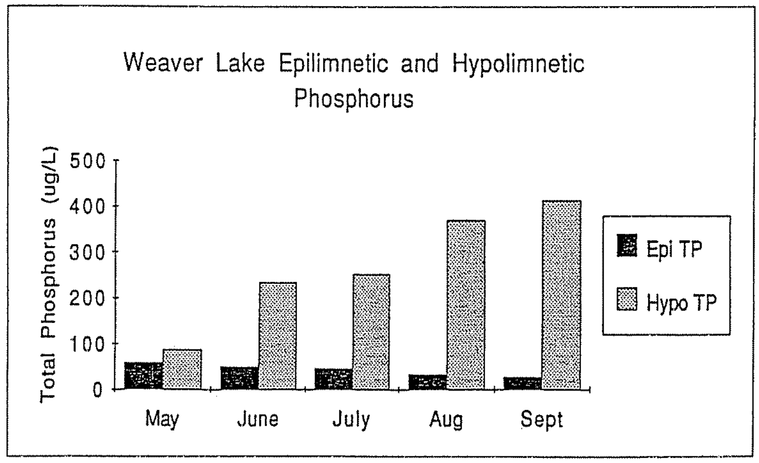
WEAVER LAKE

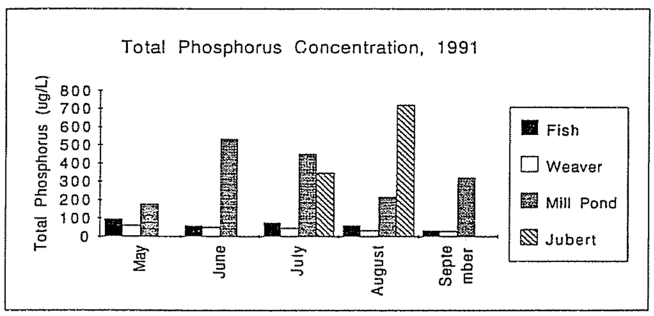


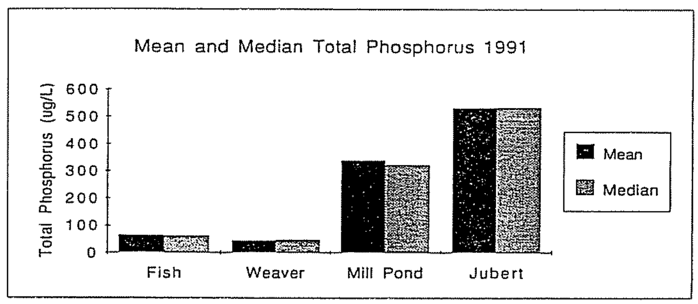

WEAVER LAKE TOTAL PHOSPHORUS
TP (ug/L)
50
40
30
20
10
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
TP
UPPER LIMIT

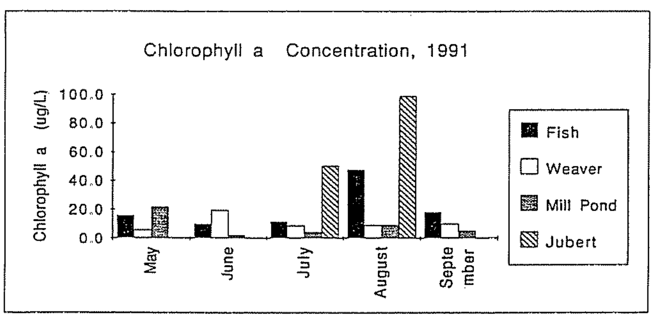

WEAVER LAKE CHLOROPHYLL a
CHL a (mg/m3 or ug/L)
30
25
20
15
10
5
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
CHL a
UPPER LIMIT

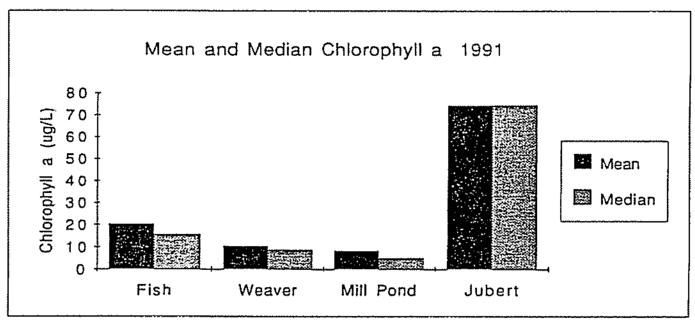

WEAVER LAKE SECCHI DISK TRANSPARENCY
Transparency (feet)
10
8
6
4
2
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
SDT
LOWER LIMIT

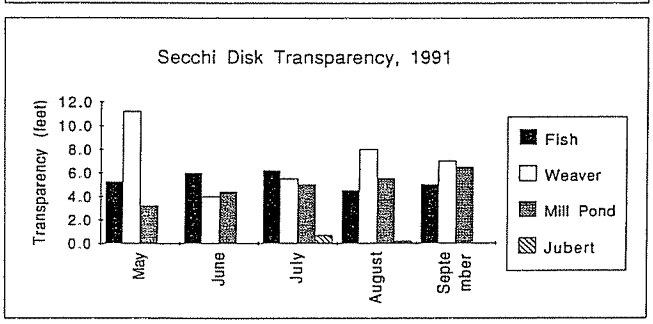

Weaver Lake Epilimnetic and Hypolimnetic Phosphorus
Total Phosphorus (ug/L)
500
400
300
200
100
0
May
June
July
Aug
Sept
Epi TP
Hypo TP

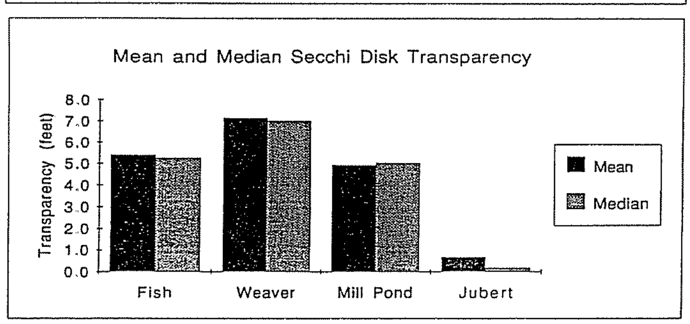

Total Phosphorus Concentration, 1991
Total Phosphorus (ug/L)
800
700
600
500
400
300
200
100
0
May
June
July
August
September
Fish
Weaver
Mill Pond
Jubert

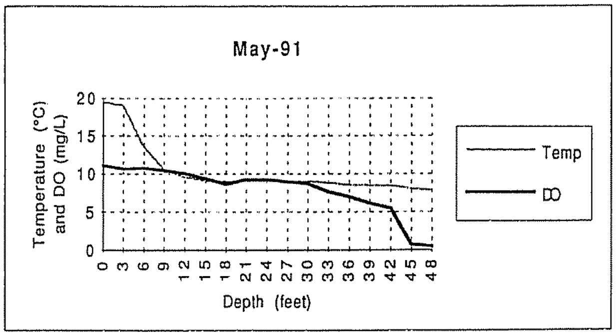

Mean and Median Total Phosphorus 1991
Total Phosphorus (ug/L)
600
500
400
300
200
100
0
Fish
Weaver
Mill Pond
Jubert
Mean
Median

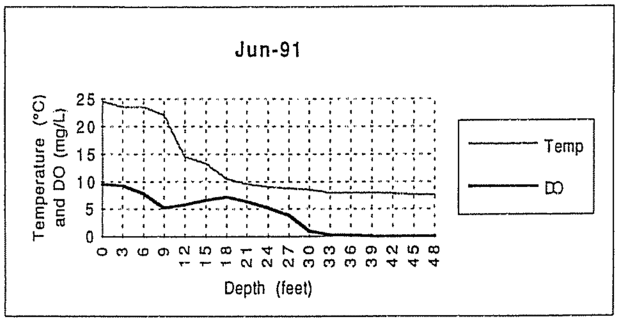

Chlorophyll a Concentration, 1991
Chlorophyll a (ug/L)
100.0
80.0
60.0
40.0
20.0
0.0
May
June
July
August
September
Fish
Weaver
Mill Pond
Jubert

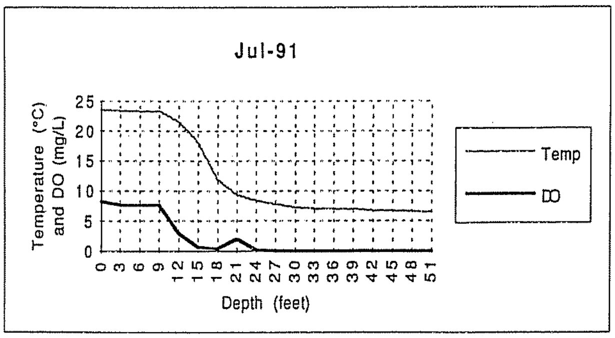

Mean and Median Chlorophyll a 1991
Chlorophyll a (ug/L)
80
70
60
50
40
30
20
10
0
Fish
Weaver
Mill Pond
Jubert
Mean
Median

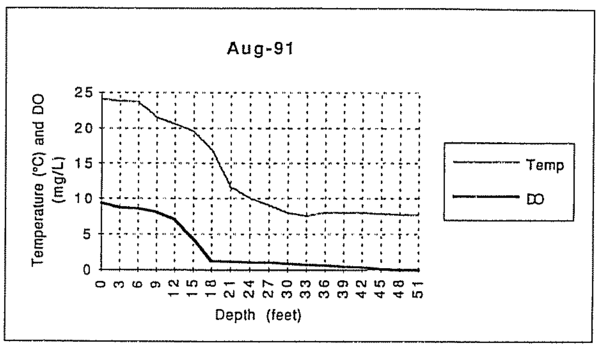

Secchi Disk Transparency, 1991
Transparency (feet)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
May
June
July
August
September
Fish
Weaver
Mill Pond
Jubert

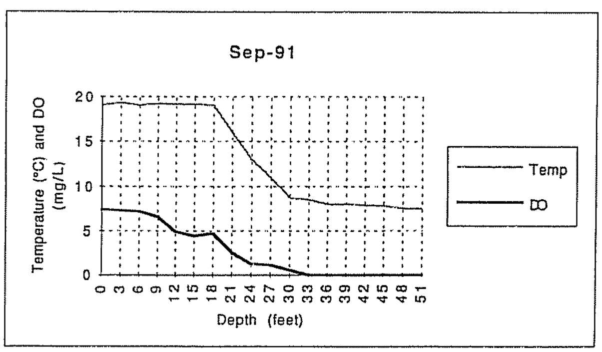

Mean and Median Secchi Disk Transparency
Transparency (feet)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Fish
Weaver
Mill Pond
Jubert
Mean
Median

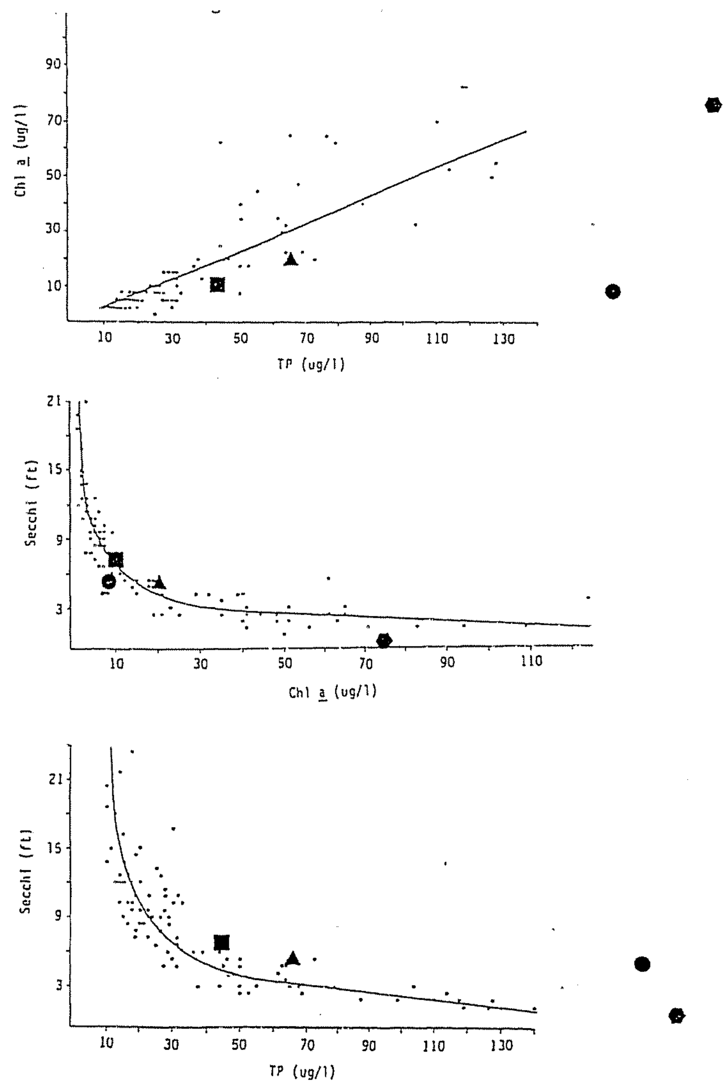












SCATTERPLOTS OF CHLOROPHYLL-a, SECCHI TRANSPARENCY, AND TOTAL PHOSPHORUS. Based on summer mean concentrations for ecoregion lakes.

▲ FISH ■ WEAVER ● MILL POND ⬣ JUBERT

Weaver Lake R-squared Values

		Dependent Variable			
		CHL	SDT	LOG(CHL)	LOG(SDT)
Independent Variable	TP	<.01	0.05	0.02	0.01
	CHL		0.64		0.75
	TN	0.31	0.31	0.22	0.43
	LOG(CHL)				0.82