Section VI - STATISTICAL ANALYSIS

The following statistical analyses are based upon comparisons of annual datasets gathered from the 21 selected lakes. For each parameter, the datasets from each lake were combined for each year. Descriptive tests were performed to determine basic statistics, and to analyze for skewness, kurtosis and normality. One Way Analysis of Variance (One Way ANOVA) and Pairwise Multiple Comparison Procedures were run to test for significant difference between years and to isolate those years that significantly differ from others.

Total Phosphorus

The total phosphorus trend in 21 Hamilton County Lakes is shown graphically in Figure A. Several data points have been removed from these analyses, including reported values of 0.000 mg/L and reported values greater than 0.100 mg/L. Skewness (a measure of how symmetrically observed values are distributed about the mean) and kurtosis (measure of how peaked or flat the distribution is compared to a normal distribution) dropped considerably once the outlying data points were removed. Skewness and kurtosis would equal 0 in a normally distributed data set. Descriptive statistics are presented in Table 1. Total phosphorus data for the Hamilton County lakes tended to be positively skewed (more high values), with skewness ranging from 1.1 to 2.7. Kurtosis was also positive ("peaky" data), with values ranging from 1.4 to 10.9. None of the data sets (all seasonal values arranged by years) were 5 normally distributed, as determined by the Kolmogorov-Smirnov distance ("K-S Dist" in Table 1).

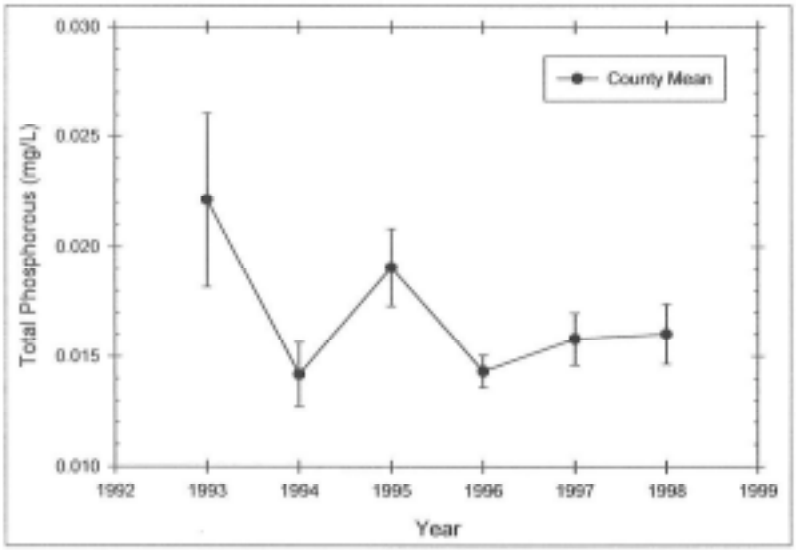

Figure A Total phosphorus trend in 21 Hamilton County Lakes

A Kruskal-Wallis One Way ANOVA on Ranks was performed on the phosphorus dataset since the annual groups failed a normality test. The differences in the median values among the years were greater than would be expected by chance and there was a statistically significant difference ($P = < 0.001$). A Pairwise Multiple Comparison Procedure (Dunn' Method) was used to determine which years were significantly different. Based upon this test, the median values for

following years are significantly different from each other with a P value < 0.05, meaning that the likelihood of being incorrect in concluding that there is a significant difference is less than 5 percent. These values are sorted by the Difference of Ranks, which provides a gauge of the size of the difference between years.

1995 vs. 1994, Diff of Ranks = 133.9
1993 vs. 1994, Diff of Ranks = 124.3
1995 vs. 1996, Diff of Ranks = 87.7
1997 vs. 1994, Diff of Ranks = 82.1

If one were to eliminate 1993 and 1995 from the analysis as anomalous points, there was a significant trend towards increasing phosphorus levels in the Hamilton County lakes. Average 1997 total phosphorus concentrations were significantly higher than 1994 ($P < 0.05$), with mean 1996 levels falling between 1994 and 1997 and 1998 levels similar to 1997. This trend is shown graphically in Figure B. Bear in mind that here may not be a basis for eliminating 1993 and 1995 from the trend analysis.

None of the individual lakes exhibited annual means that were significantly different from the county means at the $P < 0.05$ level.

Table 1 – Descriptive Statistics for Total Phosphorus in 21 Hamilton County Lakes

Year	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
93	132	37	0.0221	0.0195	0.00200	0.00397
94	132	12	0.0142	0.00802	0.000732	0.00145
95	132	14	0.0191	0.00968	0.000891	0.00176
96	132	14	0.0143	0.00404	0.000372	0.000736
97	132	5	0.0158	0.00670	0.000595	0.00118
98	131	17	0.0160	0.00735	0.000688	0.00136

Year	Range	Max	Min	Median	25%	75%
93	0.0960	0.0970	0.001000	0.0170	0.0113	0.0250
94	0.0520	0.0550	0.00300	0.0120	0.01000	0.0160
95	0.0490	0.0550	0.00600	0.0170	0.0120	0.0250
96	0.0230	0.0310	0.00800	0.0140	0.0120	0.0170
97	0.0520	0.0550	0.00300	0.0150	0.0120	0.0170
98	0.0520	0.0580	0.00600	0.0140	0.0110	0.0190

Year	Skewness	Kurtosis	K-S Dist.	K-S Prob.	Sum	Sum of Square
93	2.056	4.526	0.211	<0.001	2.102	0.0822
94	2.656	9.322	0.201	<0.001	1.702	0.0318
95	1.120	1.440	0.115	<0.001	2.249	0.0538
96	1.191	2.251	0.143	<0.001	1.691	0.0261
97	2.709	10.964	0.206	<0.001	2.006	0.0373
98	2.560	9.897	0.171	<0.001	1.827	0.0354

See Appendix I for parameter definitions

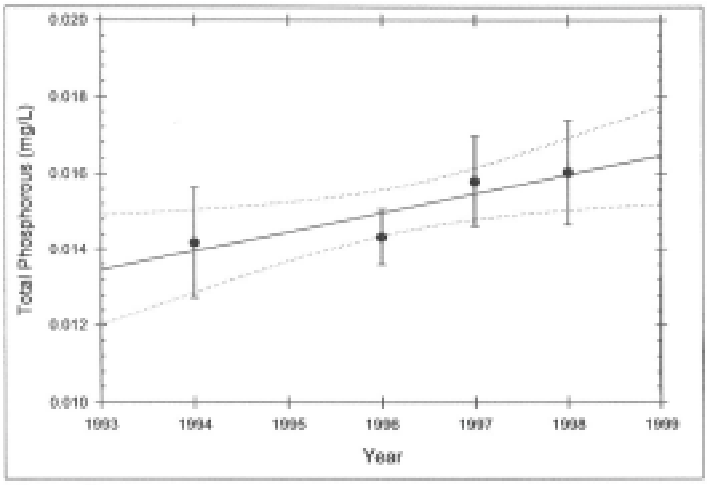

Figure B Total phosphorus trend in 21 Hamilton County Lakes with 1993 & 1995 data removed. Fit line is first order regresssion (solid) with 95 % confidence intervals (dotted).

The Secchi disk transparency trend for the 21 Hamilton County Lakes is shown graphically in Figure C. Descriptive statistics for the transparency data set is presented in Table 2. The transparency data were less skewed than the phosphorus dataset, indicating a more normal distribution of samples about the mean.

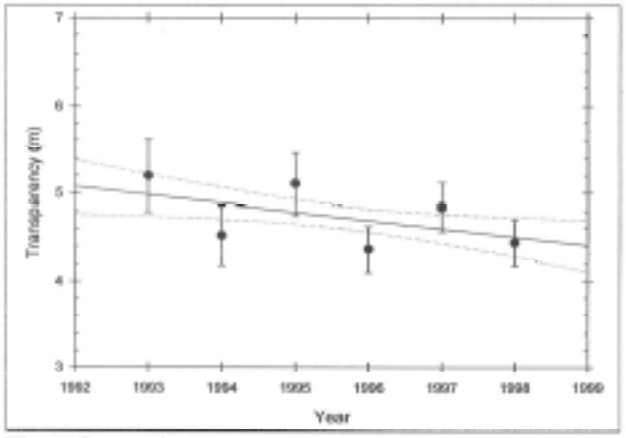

Figure C Transparency trend in 21 Hamilton County lakes. Fit line is first order regresssion (solid) with 95 % confidence intervals (dotted).

A Kruskal-Wallis One Way ANOVA on Ranks was performed on the transparency dataset since the annual groups failed a normality test. The differences in the median values among the years were greater than would be expected by chance and there was a statistically significant difference ($P = < 0.001$). A Pairwise Multiple Comparison Procedure (Dunn' Method) was used to determine which years were significantly different. Based upon this test, the median values for following years are significantly different from each other with a P value < 0.05, meaning that the likelihood of being incorrect in concluding that there is a significant difference is less than 5 percent. These values are sorted by the Difference of Ranks, which provides a gauge of the size of the difference between years.

1993 vs. 1996, Diff of Ranks = 87.1
1993 vs. 1998, Diff of Ranks = 86.5
1993 vs. 1994, Diff of Ranks = 81.7

Based upon this analysis, it can be stated that there was a trend of decreasing transparency in the 21 Hamilton County Lakes, with mean transparencies in 1994, 1996, and 1998 being significantly lower than in 1993 at $P < 0.05$ level.

Table 2 – Descriptive Statistics for Transparency in 21 Hamilton County Lakes

Year	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
93	132	35	5.201	2.021	0.205	0.407
94	132	13	4.521	1.864	0.171	0.338
95	132	13	5.109	1.997	0.183	0.363
96	132	13	4.363	1.442	0.132	0.262
97	132	5	4.840	1.596	0.142	0.280
98	131	9	4.439	1.456	0.132	0.261

Year	Range	Max	Min	Median	25%	75%
93	13.18	15.00	1.820	5.150	3.753	6.400
94	10.50	11.80	1.300	4.300	3.500	5.275
95	10.20	12.10	1.900	4.850	3.672	6.300
96	6.400	8.050	1.650	4.250	3.363	5.400
97	8.780	10.00	1.220	4.720	3.730	5.940
98	7.910	9.710	1.800	4.100	3.500	5.070

Year	Skewness	Kurtosis	K-S Dist.	K-S Prob.	Sum	Sum of Squares
93	1.290	4.505	0.0771	0.163	504.500	3015.853
94	1.278	2.663	0.134	<0.001	538.000	2842.103
95	0.899	1.352	0.0702	0.157	608.030	3577.359
96	0.296	-0.288	0.0565	0.439	519.170	2510.406
97	0.404	-0.0201	0.0598	0.313	614.720	3296.296
98	1.048	1.504	0.111	<0.001	541.540	2660.409

See Appendix for parameter definitions

Several lakes exhibited annual means that were significantly lower than county annual mean values based upon a Dunn's Method Pairwise Multiple Comparison Procedure ($P < 0.05$).

The lakes and the years that the lake mean was significantly lower than the county mean were Lake Adirondack (1995), Lake Algonquin (1995), and Lake Durant (each year, 1993 - 1998). Several lakes also exhibited annual means that were significantly higher than the county annual means by the same analysis. The lakes and the years that the lake mean was significantly higher than the county mean were Blue Mountain Lake (1994) and Limekiln Lake (1998).

Chlorophyll a

The chlorophyll a trend for the 21 Hamilton County Lakes is shown graphically in Figure D. Descriptive statistics for the transparency data set is presented in Table 3. The chlorophyll a data were positively skewed in 1997 and more normally distributed about the mean in 1998.

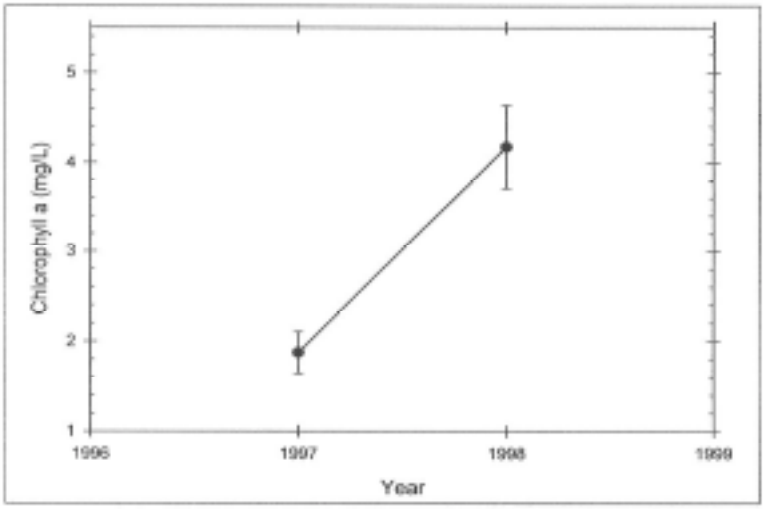

Figure D Chlorophyll *a* trend in 21 Hamilton County Lakes

A Kruskal-Wallis One Way ANOVA on Ranks was performed on the chlorophyll *a* dataset since the annual groups failed a normality test. The differences in the median values among the years were greater than would be expected by chance and there was a statistically significant difference ($P = < 0.001$). A Pairwise Multiple Comparison Procedure (Dunn' Method) was used to determine which years were significantly different. Based upon this test, the median values for the two years of data, 1997 and 1998, are significantly different from each other with a P value < 0.05, meaning that the likelihood of being incorrect in concluding that there is a significant difference is less than 5 percent.

Based upon this analysis, it can be stated that there was a trend of increasing chlorophyll *a* in the 21 Hamilton County Lakes. However, there was also a change between laboratories and analytical techniques between 1997 and 1998.

Lake Eaton exhibited an annual mean in 1998 that was significantly lower than county annual mean value for that year based upon a Dunn's Method Pairwise Multiple Comparison Procedure ($P < 0.05$).

Table 3 – Descriptive Statistics for Chlorophyll *a* in 21 Hamilton County Lakes

Year	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
97	132	7	1.873	1.318	0.118	0.233
98	131	8	4.176	2.597	0.234	0.463

Year	Range	Max	Min	Median	25%	75%
97	8.740	9.130	0.390	1.630	1.055	2.228
98	11.060	11.690	0.630	3.400	2.032	6.372

Year	Skewness	Kurtosis	K-S Dist.	K-S Prob.	Sum	Sum of Squares
97	2.157	7.423	0.148	<0.001	234.100	653.706
98	0.658	-0.649	0.143	<0.001	513.690	2967.910

See Appendix for parameter definitions

pH

The pH trend for the 21 Hamilton County Lakes is shown graphically in Figure E. Descriptive statistics for the pH data set is presented in Table 4. The pH data exhibited low skewness and kurtosis, indicating a more normal distribution of samples about the mean.

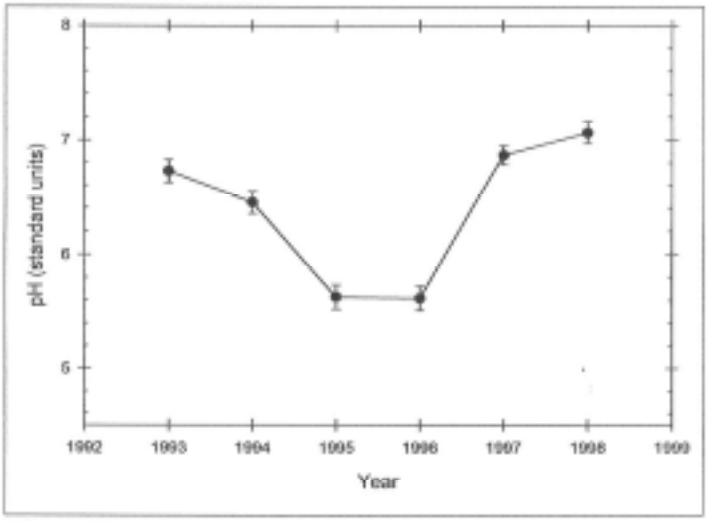

Figure E pH trend in 21 Hamilton County Lakes

A Kruskal-Wallis One Way ANOVA on Ranks was performed on the pH dataset since the annual groups failed a normality test. The differences in the median values among the years were greater than would be expected by chance and there was a statistically significant difference (P = < 0.001). A Pairwise Multiple Comparison Procedure (Dunn' Method) was used to determine which years were significantly different. Based upon this test, the median values for following

years are significantly different from each other with a P value < 0.05, meaning that the likelihood of being incorrect in concluding that there is a significant difference is less than 5 percent. The Difference of Ranks values are reported to provide a gauge of the size of the difference between years.

1993 vs. 1994, 1995 & 1996, Diff of Ranks = 85.5, 286.8, & 289.0, respectively.
1997 vs. 1994, 1995 & 1996, Diff of Ranks = 129.1, 330.4, & 332.6, respectively.
1998 vs. 1993, 1994, 1995 & 1996, Diff of Ranks = 92.0, 177.6, 378.8 & 381.1, respectively

Table 4 – Descriptive Statistics for pH in 21 Hamilton County Lakes

Year	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
93	132	34	6.725	0.514	0.0520	0.103
94	132	12	6.450	0.533	0.0487	0.0964
95	132	12	5.630	0.590	0.0539	0.107
96	132	14	5.619	0.583	0.0537	0.106
97	132	5	6.869	0.470	0.0417	0.0825
98	131	9	7.064	0.514	0.0465	0.0921

Year	Range	Max	Min	Median	25%	75%
93	2.860	7.910	5.050	6.795	6.370	7.110
94	2.910	7.830	4.920	6.520	6.220	6.825
95	3.130	7.200	4.070	5.680	5.270	6.050
96	3.300	7.070	3.770	5.645	5.330	5.920
97	3.250	8.340	5.090	6.920	6.602	7.155
98	3.420	8.640	5.220	7.050	6.760	7.360

Year	Skewness	Kurtosis	K-S Dist.	K-S Prob.	Sum	Sum of Squares
93	-0.535	0.259	0.0878	0.060	659.050	4457.782
94	-0.732	0.828	0.113	<0.001	773.960	5025.646
95	-0.359	-0.138	0.0946	0.010	675.560	3844.604
96	-0.405	0.859	0.0754	0.096	663.020	3765.207
97	-0.683	2.305	0.0710	0.116	872.360	6020.013
98	0.0132	1.102	0.0470	0.674	861.850	6120.350

See Appendix for parameter definitions

Based upon this analysis, it can be stated that there was a significant trend of decreasing pH in the 21 Hamilton County Lakes between 1993 and 1996 and a significant trend of increasing pH between 1996 and 1998 (P < 0.05 level). The Difference of Ranks increases as one compares years that are not consecutive (multiple years apart from one another), showing that the mean difference increases with time.

Morehouse Lake exhibited annual means in 1994 and 1997 that were significantly lower than county annual mean value for those years based upon a Dunn's Method Pairwise Multiple Comparison Procedure (P < 0.05).

Alkalinity

The alkalinity trend for the 21 Hamilton County Lakes is shown graphically in Figure F. Descriptive statistics for the alkalinity data set is presented in Table 5. The alkalinity data exhibited a positive skew and kurtosis, indicating a bias towards higher values (fewer low alkalinities).

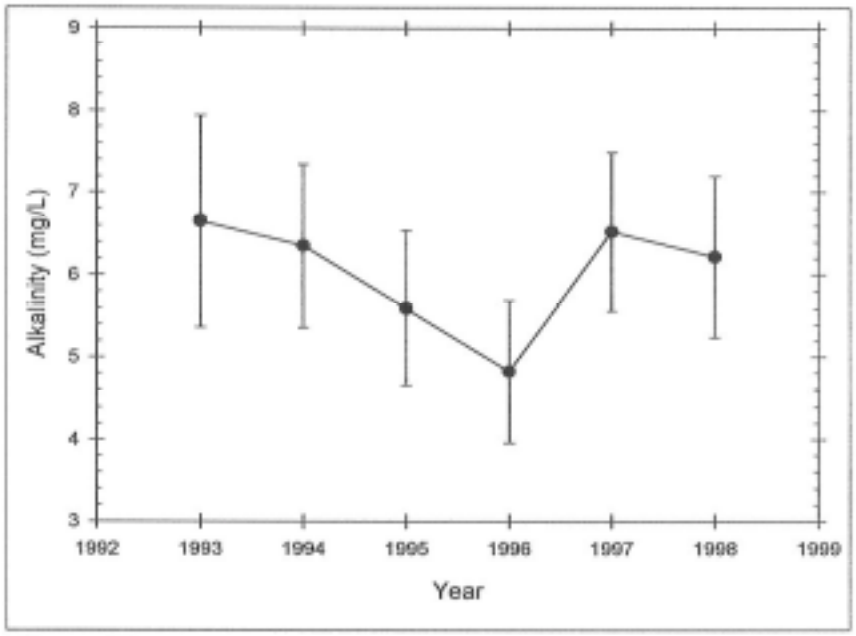

Figure F Alkalinity trend in 21 Hamilton County lakes

A Kruskal-Wallis One Way ANOVA on Ranks was performed on the alkalinity dataset since the annual groups failed a normality test. The differences in the median values among the years were greater than would be expected by chance and there was a statistically significant difference (P = < 0.004). A Pairwise Multiple Comparison Procedure (Dunn's Method) was used to determine which years were significantly different. Based upon this test, the median values for following years are significantly different from each other with a P value < 0.05, meaning that the likelihood of being incorrect in concluding that there is a significant difference is less than 5 percent. These values are sorted by the Difference of Ranks, which provides a gauge of the size of the difference between years.

1993 vs. 1996, Diff of Ranks = 99.4
1997 vs. 1996, Diff of Ranks = 80.9

Based upon this analysis, it can be stated that mean alkalinity in 1996 was significantly lower than in 1993 and 1997 (P < 0.05 level). The apparent trend is similar to pH, with decreasing alkalinity between 1993 and 1995/1996, followed by increasing alkalinity.

Table 5 – Descriptive Statistics for alkalinity in 21 Hamilton County Lakes

Year	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
93	131	42	6.65	6.110	0.648	1.287
94	131	11	6.354	5.484	0.501	0.991
95	131	11	5.596	5.229	0.477	0.945
96	131	12	4.823	4.754	0.436	0.863
97	131	6	6.528	5.439	0.486	0.963
98	130	7	6.220	5.498	0.496	0.981

Year	Range	Max	Min	Median	25%	75%
93	42.500	25.700	-16.800	5.500	3.400	8.400
94	27.600	26.800	-0.800	5.300	2.800	8.050
95	26.300	24.500	-1.800	4.150	2.200	7.550
96	25.500	23.100	-2.400	3.500	1.600	6.550
97	25.300	25.300	0.000	5.200	2.800	8.025
98	27.800	26.700	-1.100	5.400	2.525	7.975

Year	Skewness	Kurtosis	K-S Dist.	K-S Prob.	Sum	Sum of Squares
93	0.718	4.151	0.160	<0.001	592.100	7224.770
94	1.866	4.249	0.152	<0.001	762.500	8423.890
95	1.532	2.984	0.121	<0.001	671.500	7010.970
96	1.805	3.798	0.135	<0.001	573.900	5434.070
97	1.715	3.199	0.154	<0.001	816.000	8995.400
98	1.808	3.961	0.151	<0.001	765.100	8446.950

See Appendix for parameter definitions

Several lakes exhibited annual means that were significantly different than county annual mean values based upon a Dunn's Method Pairwise Multiple Comparison Procedure ($P < 0.05$). Lake Adirondack had an alkalinity that was significantly higher than the county mean in 1995 and 1996. Morehouse Lake had an alkalinity that was significantly lower than the county mean in 1993, 1994, 1995, and 1997.

Relationship between Trophic Variables (SD and TP, CHL and NO_3)

An examination of the relationship between transparency (SD) and total phosphorus (TP) and chlorophyll *a* (CHL) concentrations was performed using linear and multiple regression techniques and by determining the Pearson product-moment correlation.

A linear regression between TP and SD was performed on a combined data set of all years. CHL could not be included in this analysis for a multiple regression since CHL data only exists for 1997 and 1998. This resultant regression equation was: SD = 5.163 - 25.821 x TP, with an r^2 = 0.023. Most of the transparency values were clumped around TP . 0.02 mg/L, yielding the extremely poor regression correlation (Figure G). Based upon the dataset, there was a positive

relationship between TP and SD, but the degree of correlation was negligible.
A multiple linear regression was performed to predict 1998 SD from TP, CHL and NO_3. The analysis determined that although there is a relationship between SD and the other three variables, NO_3 contributes the greatest to the relationship. The combined multiple regression equation was: SD = 4.272 - 33.047 x TP - 0.0254 x CHL + 7.577 x NO_3, with a resultant r^2 = 0.15. Only NO_3 significantly contributed to the relationship $P < 0.001$. The P values for TP and CHL were 0.07 and 0.64, respectively. There was a positive relationship between SD and the three independent variables, but the degree of correlation was low.

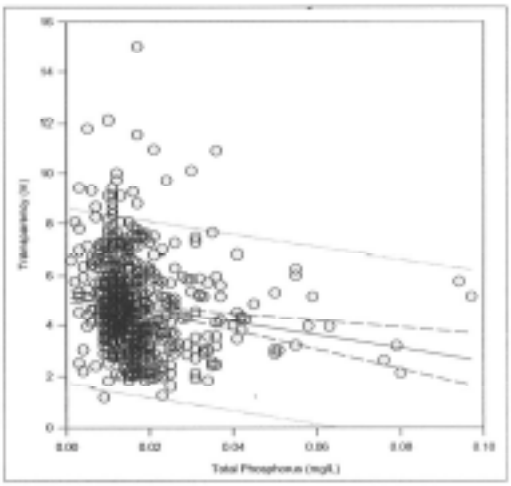

Figure G Relationship between TP and SD in Hamilton County lakes

A linear regression was run between SD and NO_3, since the multiple regression analysis indicated the strongest relationship between these two parameters. The resultant equation was: SD = 3.595 + 8.098 x NO_3, with a r^2 = 0.126, indicating a positive relationship but a low degree of correlation.

In summary, although there is a relationship between SD and other water quality parameters, the relationship is weak at best. This is probably due to the wide cross-section of lakes presently in the Hamilton County monitoring program.

Temperature

A comparison between years of mean monthly surface temperature (1 M depth) for the 21 Hamilton County lakes was conducted to identify any trends in lake temperatures. The 1 meter depth was selected since it is more stable than this depth would provide a more stable reading than at the immediate lake surface. A One Way ANOVA was conducted for each month to determine if significant differences exist between years. Since the May and June data were normally distributed, a Pairwise Multiple Comparison Procedure (Tukey Test Method) was conducted to isolate which, if any years, were significantly different. The K-W ANOVA of Ranks and Dunn's Pairwise Comparison Method was used for July - October, since these datasets failed either the normality or equal variance tests. The results are presented graphically in Figure H. Note that too few 1 meter data points existed for 1993 to include that year in this analysis.

Overall, the monthly lake surface temperature curves for each of the study years were similar to one another. No consistent trend was apparent in these data. A month by month analysis follows. The average lake surface temperature (1 m depth) of the 21 Hamilton County lakes was significantly warmer in 1998 than in 1994, 1995, 1996 and 1997 ($P < 0.05$). In June, the average lake surface temperatures in 1998 and 1994 were significantly cooler than in 1995, 1996 and 1997. In July, the average lake surface temperatures in 1994, 1995, and 1998 were significantly warmer than in 1996 and 1997. In August, the average lake surface temperature in 1994 was significantly cooler than in 1995 and 1998. The average lake surface temperature in August 1995 was significantly warmer than in 1996 and 1997. In September, the average lake surface temperature in 1994 was significantly cooler in 1995, 1996, 1997 and 1998. In October, the average lake surface temperatures in 1994 and 1996 were significantly cooler than in 1997 and 1998. The 1996 October temperature was also significantly cooler than in 1995.

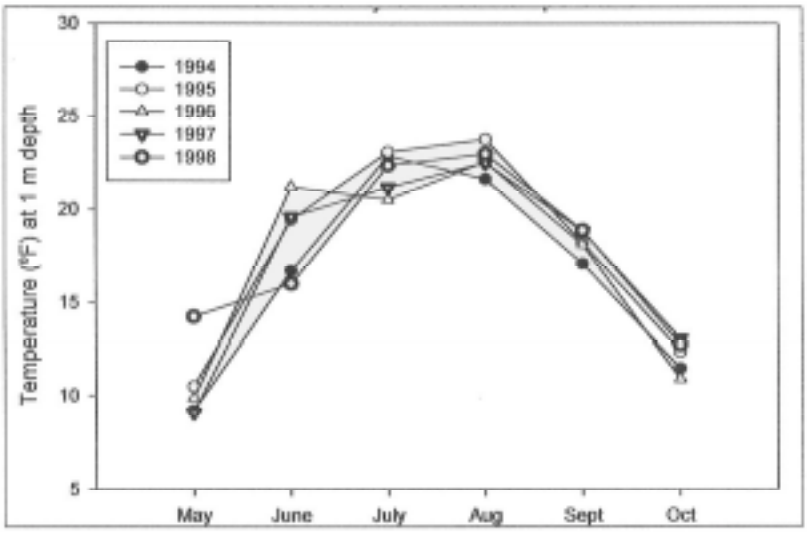

Figure H Monthly mean temperature at 1 m depth in 21 Hamilton County lakes

Section VII – REFERENCES

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