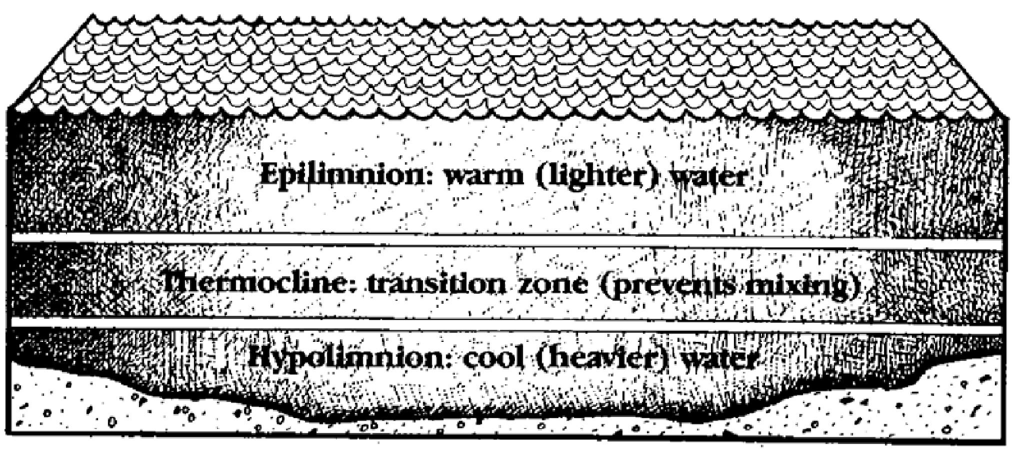
In-lake Conditions-1991

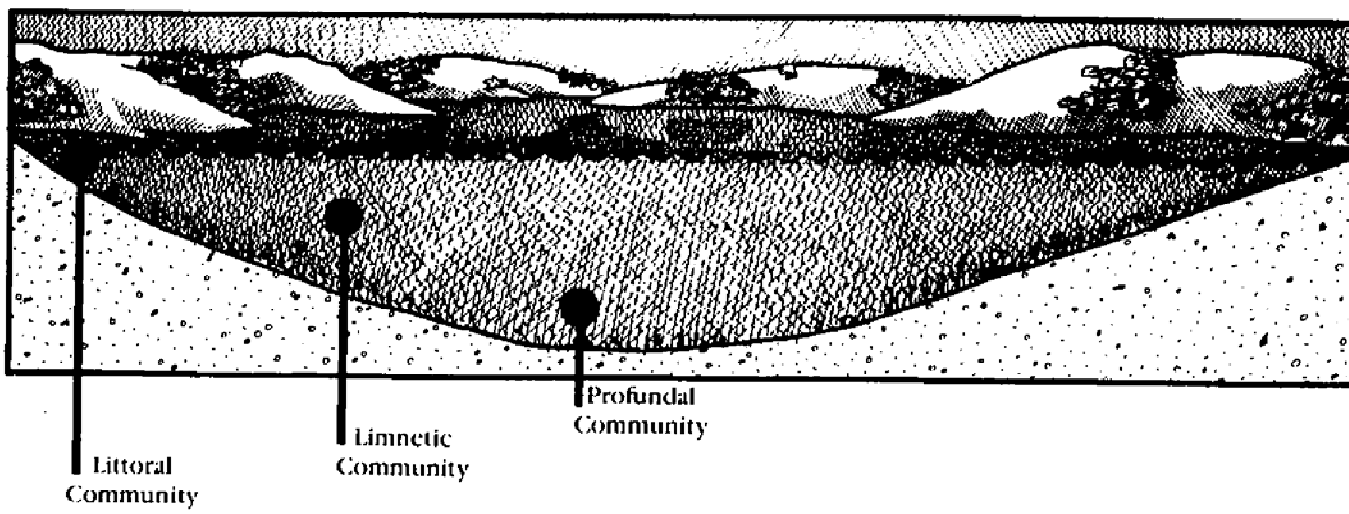
Dissolved oxygen and temperature profiles were taken at the point of maximum depth in each basin. Only the deepest site--site 101--was recorded on the first sampling date of June 3. Data from all three sites is presented in Table 4. Lake temperatures remained stable at 70-71°F during June, July and August before dropping off to 66°F in September and 46°F in October. Lake temperatures were nearly constant from the top to the bottom waters on all five summer monitoring dates. Maple Lake's data for the July 2 sampling date is plotted in Figure 10 along with data from Union Lake's site 101 to illustrate a typical thermocline. No thermal stratification occurred over the testing period for Maple Lake. This is significant in that the lake will mix from top to bottom with the passage of summer weather fronts, i.e., it is polymictic. The fact that Maple Lake is a long, shallow lake combined with the frequent strong winds in the area promotes mixing of the lake from top to bottom. This contributes to decreased water clarity due to sediment being stirred up which 1) increases suspended solids in the water column and 2) makes phosphorus contained in the bottom sediment available for algae growth.

STRATIFICATION: LAKES FORM LAYERS



Lakes in the temperate climates tend to form layers. The **epilimnion** is roughly equivalent to the zone of light penetration where the bulk of productivity, or growth, occurs. The **thermocline** is a narrow band of transition which helps to prevent mixing between the layers. The **hypolimnion** is the zone of decomposition, where plant material either decays or sinks to the bottom and accumulates.

LAKE COMMUNITIES



A lake can be divided into zones or communities. Extending from the shoreline is the **littoral community**, where aquatic plants are dominant. The area of open water is the **limnetic community**, the habitat of algae, microscopic animals and fish. The **profundal community**, where light does not penetrate, is the habitat of bacteria and fungi.

Table 4.

Maple Lake Temperature and Dissolved Oxygen-1991									
	Site 101(NE end)			**Site 102 (middle)**			**Site 103 (SW end)**		
	Temp (°C)	D.O. (mg/L)	Secchi/Col P.Con/Rec	Temp (°F)	D.O. (mg/L)	Secchi (ft.)	Temp (°F)	D.O. (mg/L)	Secchi (ft.)
6/3/91									
0 meters	21.9	8.1	**3.5**			**3**			**3**
1 meter	21.9	8.1	**Green**			**Green**			**Green**
2 meters	21.8	8.2	**P.Con. 4**			**P.Con. 4**			**P.Con. 4**
3 meters	21.3	7.9	**Rec.S. 2**			**Rec.S. 3**			**Rec.S. 3**
4 meters	20.8	1.7							
7/2/91									
0 meters	21.0	7.4	**2.5**	20.8	7.7	**2.5**	20.8	7.7	**2.5**
1 meter	21.0	7.5	**Green**	20.8	7.7	**Green**	20.8	7.7	**Green**
2 meters	21.0	7.5	**P.Con. 3**	20.8	7.7	**P.Con. 3**	20.8	7.7	**P.Con. 3**
3 meters	21.0	7.5	**Rec.S. 3**			**Rec.S. 3**	20.8	7.5	**Rec.S. 3**
4 meters	21.0	7.5							
8/7/91									
0 meters	21.1	8.35	**2.5**	21.5	8.8	**2.3**	21.5	8.6	**2.6**
1 meter	21.1	8.6	**Green**	21.5	8.5	**Green**	21.5	8.6	**Green**
2 meters	21.0	8.3	**P.Con. 4**	21.5	8.3	**P.Con. 4**	21.5	8.5	**P.Con. 4**
3 meters	21.0	8.3	**Rec.S. 3**	21.3	7.4	**Rec.S. 3**	21.5	8.4	**Rec.S. 3**
4 meters	21.0	8.25							
9/11/91									
0 meters	19.0	8.2	**2.5**	19.2	8.6	**2.5**	19.2	9	**2.5**
1 meter	19.0	8.5	**Green**	19.2	8.6	**Green**	19.2	8.8	**Green**
2 meters	19.0	8.5	**P.Con. 4**	19.2	8.8	**P.Con. 4**	19.2	8.8	**P.Con. 4**
3 meters	19.0	8.5	**Rec.S. 3**	19.2		**Rec.S. 3**	19.1	8.5	**Rec.S. 3**
4 meters									
10/8/91									
0 meters	8.0	11.0	**4**	9.0	10.2	**3.5**	9.0	10.8	**3.5**
1 meter	8.0	11.0	**Green**	9.0	10.0	**Green**	9.0	10.8	**Green**
2 meters	8.0	11.0	**P.Con. 3**	9.0	10.0	**P.Con. 3**	8.5	10.4	**P.Con. 3**
3 meters	8.0	11.0	**Rec.S. 3**	9.0	8.0	**Rec.S. 3**	8.5	10.2	**Rec.S. 3**
4 meters	8.0	11.0							

Secchi disk measurements are in feet. Color, physical condition, and recreation suitability are subjective measures taken by citizen monitors.

Secchi disc-ft.

Observed Color

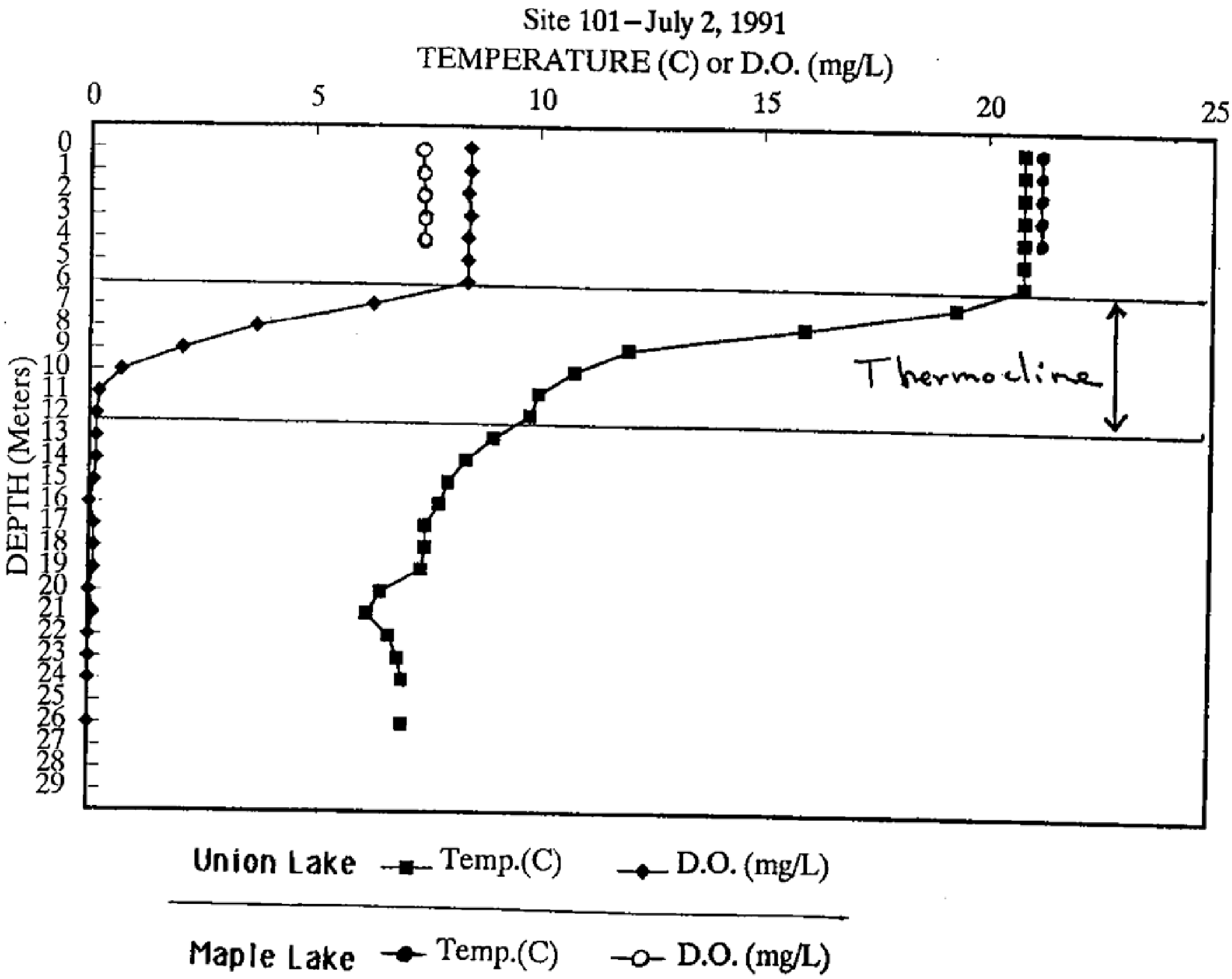
A. Please circle the one number that best describes the physical condition of the lake water today:

1. Crystal clear water.
2. Not quite crystal clear, a little algae present/visible.
3. Definite algal green, yellow, or brown color apparent.
4. High algal levels with limited clarity and/or mild odor apparent.
5. Severely high algal levels with one or more of the following: massive floating scums on lake or washed up on shore, strong foul odor, or fish kill.

B. Please circle the one number that best describes your opinion on how suitable the lake water is for recreation and aesthetic enjoyment today:

1. Beautiful, could not be any nicer.
2. Very minor aesthetic problems; excellent for swimming, boating, enjoyment.
3. Swimming and aesthetic enjoyment slightly impaired because of algal levels.
4. Desire to swim and level of enjoyment of the lake substantially reduced because of algal levels (would not swim, but boating is okay).
5. Swimming and aesthetic enjoyment of the lake nearly impossible because of algal levels.

Figure 10. Maple Lake and Union Lake D.O. and Temperature Profiles



In terms of dissolved oxygen, the only major oxygen difference from the top to the bottom waters appeared on the June 3rd testing date as DO dropped from 7.9 mg/L at 3 meters to only 1.7 mg/L at a depth of 4 meters. This latter low level is due to the probe taking the reading just off the lake's bottom where fungi and bacteria are consuming oxygen as they decompose dead plants and animals that settle out of the lake's upper waters. This latter oxygen concentration would be too low for most game fish, which typically require a concentration of 5 mg/L or greater. While DO concentrations may decline to less than 5 mg/L by the end of winter, monitored summer oxygen levels are more than adequate throughout the entire lake to support game fish. As noted the depletion of oxygen in the lake will be most severe along the bottom sediment-water interface as oxygen is used in the decomposition of organic matter in the sediments. As lakes become more productive or receive more nutrients from their watersheds, more oxygen will be depleted in the bottom waters. This phenomenon, in turn, is related to the release of phosphorus by the lake sediments and is called internal loading.

Phosphorus and nitrogen are essential nutrients for plant life. Excessive amounts of these nutrients allow algae to grow to undesirable levels. Besides the negative aesthetic effect of algae, it may also lead to oxygen depletion and subsequent fish kills, as heavy growths decompose. The forms of these nutrients that are the most available to plants are orthophosphorus, nitrate and ammonia nitrogen. Total phosphorus and total kjeldahl nitrogen are also important, but are utilized by the algae more slowly. In northern Minnesota, phosphorus functions as a "growth-limiting" factor because it is usually present in very low concentrations. Nitrogen, in its various forms is usually more abundant than phosphorus in the aquatic environment; therefore, nitrogen rarely limits plant growth as does phosphorus. Any unattached or "free" phosphorus, in the form of inorganic phosphates, is rapidly taken up by algae and larger aquatic plants. Because algae only require small amounts of phosphorus to live, excess phosphorus causes extensive algal growth called algal blooms. Algal blooms color the water a pea-soup green and are a classic symptom of cultural eutrophication.

Total phosphorus (TP) concentrations averaged approximately 47 ug/L (micrograms per liter or parts per billion) in the lake's surface waters (Table 3) during the summer of 1991. This value is at the upper end of the range of concentrations found in a set of representative minimally impacted lakes in the North Central Hardwood Forests ecoregion. Phosphorus concentrations were highest in the early part of the summer and also were higher at site 102 in the middle of the lake although there was considerable variability from site to site and from month to month in some instances. See Table 5 to compare monthly variations of various variables between testing sites within Maple Lake. Site 101 generally had the lowest phosphorus levels, perhaps due to the flushing action from the inlet and outlet both being in this bay and the fact that this bay is deeper and thus boat action and high winds don't disturb the bottom sediments as readily. Sources of phosphorus are human wastes, animal wastes, industrial wastes, and human disturbance of the land and its vegetation.

Total nitrogen (TN) concentration, which consists of total Kjeldahl nitrogen (TKN) plus nitrite and nitrate-N, averaged 1.3 mg/L over the summer of 1991, which is slightly higher than that found in minimally impacted lakes in this ecoregion. Nitrite and nitrate-N concentrations were less than 0.01 mg/L, which is typical for lakes in this region. TKN levels remained fairly constant throughout the summer and showed no significant difference between the three sampling sites, though site 101 again tended to have somewhat lower levels. Sources of nitrates are the atmosphere, inadequately treated wastewater from sewage treatment plants, agricultural runoff, storm drains, and poorly functioning septic tanks.

The ratio of TN:TP can give an indication as to which nutrient is limiting the production of algae in the lake. For Maple Lake, the TN:TP ratio is about 28:1. This suggests that phosphorus is the

Table 5. Maple Lake In-Lake Variations by Sample Site

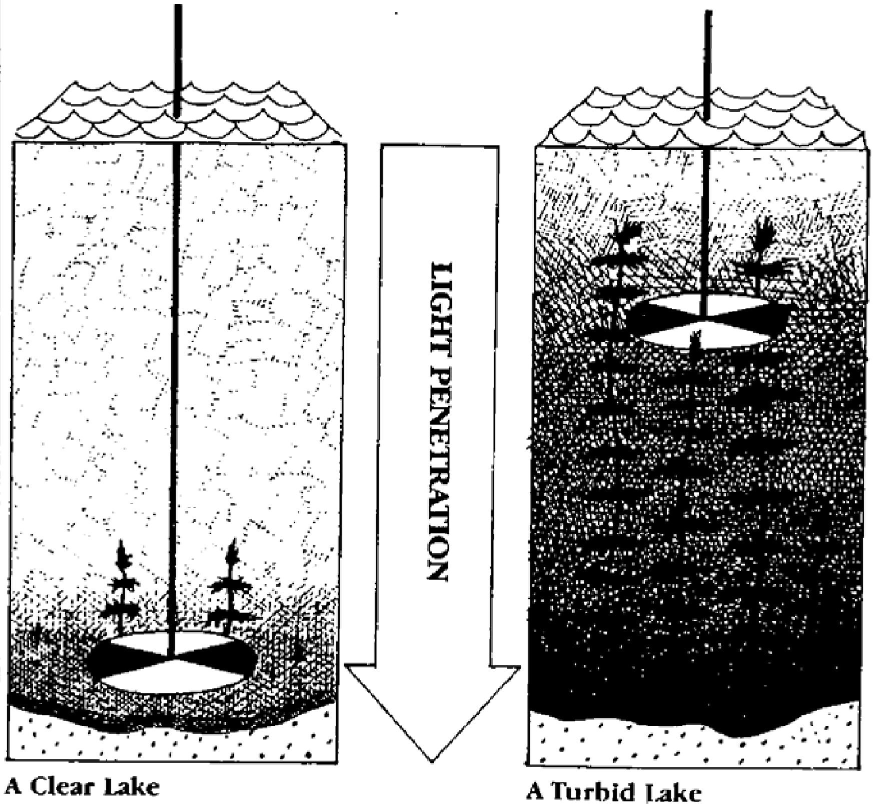
	Sampling Dates					
	6/3/91	7/2/91	8/7/91	9/12/91	10/9/91	Average
Total Phosphorus						
Site 101	.045	.054	.033	.042	.039	**.043**
Site 102	.062	.069	.034	.038	.057	**.052**
Site 103	.039	.069	.045	.038	.040	**.046**
Average	**.049**	**.064**	**.037**	**.039**	**.045**	**.047**
Chlorophyll a						
Site 101	18	10	22	17	9	**15.2**
Site 102	25	16	22	14	6	**16.6**
Site 103	26	14	24	13	10	**17.4**
Average	**23**	**13**	**23**	**15**	**8**	**16.4**
Total Kjeldahl Nitrogen						
Site 101	1.42	1.30	1.34	1.23	1.35	**1.33**
Site 102	1.60	1.55	1.37	2.20	1.02	**1.55**
Site 103	1.54	1.36	1.36	1.27	1.57	**1.42**
Average	**1.52**	**1.40**	**1.36**	**1.57**	**1.31**	**1.43**
Secchi Disk						
Site 101	3.5	2.5	2.5	2.5	4.0	**3.0**
Site 102	3.0	2.5	2.3	2.5	3.5	**2.8**
Site 103	3.0	2.5	2.6	2.5	3.5	**2.8**
Average	**3.2**	**2.5**	**2.5**	**2.5**	**3.7**	**2.9**

limiting nutrient in Maple Lake. Generally, phosphorus is the least abundant nutrient and therefore is the limiting nutrient for biological productivity in a lake. Thus, any additional phosphorus entering the lake will provide the needed ingredient for accelerated algae production. The TN:TP ratio is within the typical range found in minimally impacted lakes in this ecoregion.

Chlorophyll is a pigment produced by algae. Measured concentrations of chlorophyll a provide an estimate of the amount of algal production in a lake. During the summer of 1991, chlorophyll a concentrations ranged from 6 ug/L to 26 ug/L with an average of 16.4 ug/L. Concentrations from 10-20 ug/L may be perceived as a mild algal bloom, while concentrations greater than 30 mg/L may be perceived as a severe nuisance (Heiskary and Walker, 1988). Both the mean and maximum chlorophyll a concentrations for Maple Lake are in the middle of the range of values typically found for this ecoregion.

Secchi disk transparency is a measure of water clarity and is generally a function of the amount of algae in the water. Secchi disk readings for Maple Lake ranged from 2.3 to 4.0 feet over the summer of 1991 with a mean of 2.9 feet which is less than the ecoregion range of about 5-10 feet. The deepest readings were in early spring which is typical for Minnesota lakes. This is often due to the normally low algal productivity in the cooler water and higher zooplankton (small invertebrates that feed upon the algae in the water) populations. Zooplankton populations frequently decline later in the spring due to predation by young fish. Algae make more efficient use of available nutrients and their populations increase and transparency declines. In productive (nutrient rich) lakes such as Maple Lake, transparency may decline rapidly and remain low throughout the summer. During the course of the summer, surface blooms of algae may appear.

MEASURING WATER CLARITY WITH A SECCHI DISC



Water clarity governs the depth of light penetration in lakes. Periodic testing with a secchi disc may show seasonal variations in clarity.

Using a Secchi Disk

The secchi disk is used to measure water clarity. The disc is a 9-inch white circular plate attached to a cord marked at half-foot intervals. Measurements are taken by lowering the disc over the side of a boat and noting the depth at which it is no longer visible. The secchi disc reading provides a good index of lake water quality by indirectly estimating the presence of suspended algae or other material that might interfere with water transparency.

Suspended solids or color due to dissolved organics may also reduce water transparency by affecting the absorption of light. Color was measured at 13 Pt-Co Units (platinum-cobalt units) indicating low coloration. Total suspended solids averaged 12.1 mg/L over the summer which is considerably higher than the ecoregion range of 2-6 mg/L. The turbidity level of 7.0 NTU (nephelometric turbidity units)recorded in August was also considerably higher than the ecoregion range of 1-2. Turbidity in water is caused by suspended matter (soils, organic matter, algae and other microscopic organisms). Several factors may contribute to the higher suspended solids and turbidity including the wind action on this relatively shallow lake, heavy boat traffic stirring up the lake bottom, sediment laden runoff and bottom feeding fish stirring up sediment.

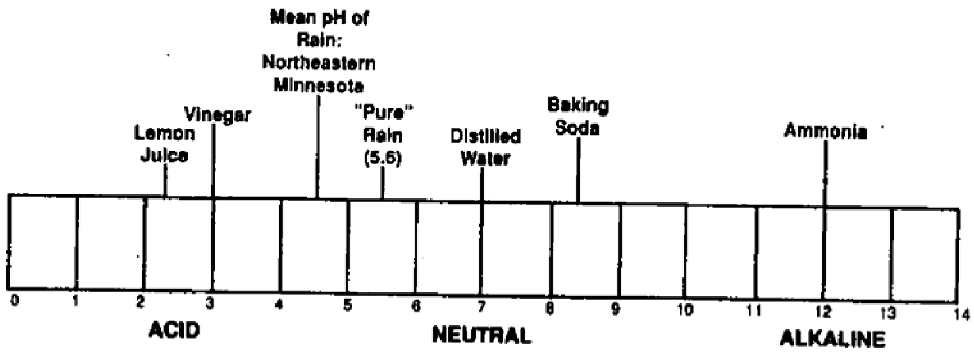
Oxygen levels decrease in turbid water as the water becomes warmer as the result of heat absorption from the sunlight by the suspended particles and as decreased light penetration results in decreased photosynthesis. Suspended solids can clog fish gills, reduce growth rates and disease resistance, and prevent egg and larval development. Settled particles can accumulate and smother fish eggs and aquatic insects. Thus, while algae may be the dominant cause of decreased water clarity, other factors and their causes also need to be considered when setting lake management goals for water clarity.

Along with the transparency measurements subjective measures of Maple Lake's "physical appearance" and recreational suitability" were made by the citizen monitors. Physical appearance ratings range from "crystal clear" (class 1)... to "dense algal blooms, odor, etc." (class 5) and recreational suitability ratings range from "beautiful, could not be any nicer" (class 1)... to "no recreation possible" (class 5) in this rating system (Heiskary and Wilson, 1988).

The "physical appearance" and "recreational suitability" ratings were nearly identical for all three sites on Maple Lake during the summer of 1991 (See Table 4.). Lake conditions were typically characterized as "definite algae present (class 3) to "high algal color" (class 4) and "swimming slightly impaired" (class 3) throughout the entire summer period. It must be kept in mind that these ratings reflect the subjective opinion of the citizen monitors at the time of the secchi disk measurement. As such, many factors may influence the citizen's perception at the time of measurement such as: amounts of algae and types, weather conditions (windy or calm), soil suspensions in the water, water coloration, and the individual's preferences.

The pH for Maple Lake averaged 8.9, which indicates that the lake is basic, as would be expected for this region. This indicates that Maple Lake has good buffering capacity to counteract impacts such as acid rain. Water is basic if the pH is greater than 7; water with pH of less than 7 is considered acidic. For every one unit change in pH there is approximately a ten-fold change in how acidic or basic the sample is. Immature stages of aquatic insects and immature fish are extremely sensitive to low pH values. Future monitoring should include periodic pH measurements. Consideration should be given to taking pH measurements not just of the lake water, but also of rainwater to monitor possible acid rain changes in the area.

THE pH SCALE



One means to evaluate the trophic status of a lake and to interpret the relationship between total phosphorus, chlorophyll a and Secchi disk readings is Carlson's Trophic State Index (TSI, Carlson 1988). This index was developed from the interrelationships of summer Secchi disk transparency and the concentrations of surface water chlorophyll a and total phosphorus. TSI values are calculated as follows:

Total phosphorus TSI (TSIP) = 14.42 ln(TP)+ 4.15
Chlorophyll a TSI (TSIC) = 9.81 ln(Chl a) + 30.6
Secchi disk TSI (TSIS) = 60 - 14.41 ln(SD)

TP and chlorophyll a are in ug/L and Secchi disk transparency is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of 10 units represents a doubling of algal biomass.

The trophic scale typically indicates how increases in the concentration of phosphorus influences chlorophyll a concentration, which is a direct measure of lake productivity. Chlorophyll a and total phosphorus are also related to transparency, the ability of the lake water to transmit light. This relationship makes possible the substitution of secchi disc transparency as a measurement of water quality. Of the three factors, secchi disc is most easily monitored and, in most cases, provides usable information on the other two factors. When setting water quality goals, lake managers should be aware of their lake's position on these scales and the amount of nutrient reduction that may be necessary to reach a desired goal.

A significant understanding of lake water quality can be acquired through use of the secchi disc, a weighted white disc which, when lowered into the water, disappears at a depth related to the amount of dissolved and particulate organic matter in the water. This measurement of transparency is an estimate of the density of phytoplankton (algae) populations, in other words, the nutrient richness or trophic state of the lake. The evaluation of trophic status is simply a beginning. By itself, the trophic status of a lake says nothing about possible sources of nutrient pollution, the knowledge of which is necessary to the decision-making process. Once it has been determined that problems do exist, other models can be used to identify the cause of the problems.

The Carlson trophic state index values for Maple Lake are listed in Table 3 and illustrated in Figure 11. Based on these values Maple Lake would be considered to be eutrophic in condition. Another means for comparing these variables is graphically on scatterplots. Values for Maple Lake are shown on Figure 12. The bottom scatterplot in Figure 12 shows that it would take a rather significant decrease in total phosphorus levels in Maple Lake to bring about an appreciably improved secchi disk reading. In general, the total phosphorus-chlorophyll a-secchi transparency relationships in Maple Lake are comparable to those observed in other Minnesota lakes.

Water Quality Trends

Limited data is available for determining long-term trends in the quality of Maple Lake. Secchi disk readings are available for 1989 and 1990 with mean depths being 2.9 and 2.5 feet respectively. This compares to the 1991 mean secchi disk transparency of 2.9 feet. During the 1989 sampling period the monitors rated the physical condition and recreation suitability somewhat better than the readings from 1991. As noted before, these measures are very subjective according to the perceptions of the observers.

Some previous testing data for Maple Lake is reported in Minnesota Lake Quality Assessment Report-Second Edition, (MPCA 1990). This data was recorded in 1989. It is presented below along with 1991 test results for comparison. The column headings are as follows. TP=mean total phosphorus (ppb); TSP=Carlson's trophic state index for phosphorus; SDM=mean secchi disk (meters); TSS=Carlson's trophic state index for secchi disk; CHLa=mean chlorophyll a (ppb); TSC=Carlson's trophic state index for chlorophyll a; TSI=average of all Carlson trophic status indexes.

Time Period	TP	TSP	SDM	TSS	CHLa	TSC	TSI
1989	49	60	0.9	62	17.6	59	60.2
1991	47	60	0.9	61	16.4	57	59.3

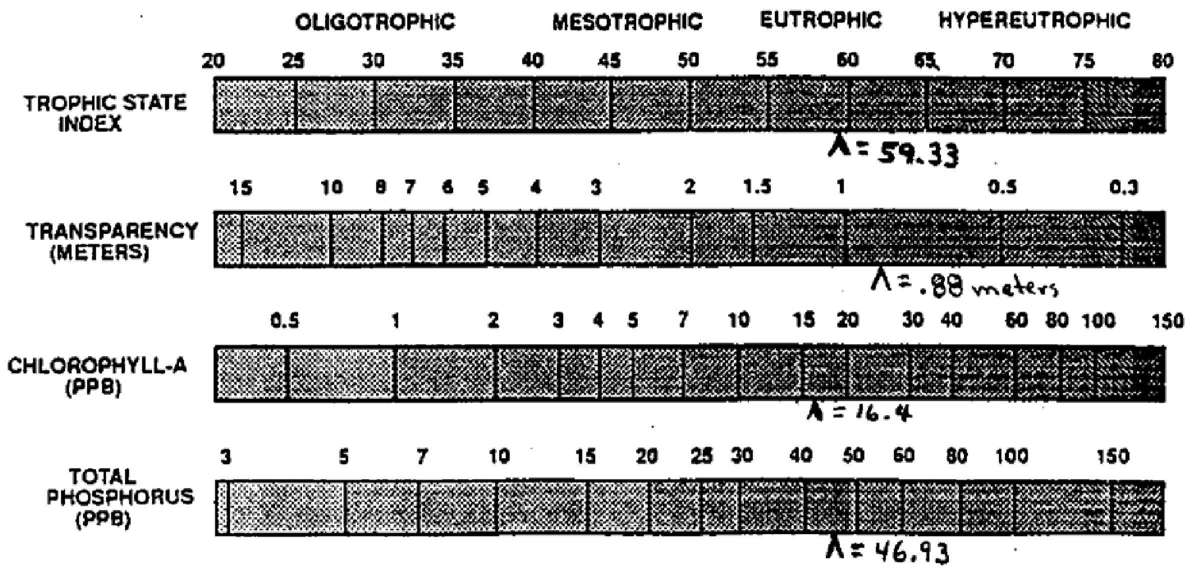
As can be seen, the two sets of test results are nearly identical indicating that Maple Lake has remained quite stable over this relatively short period of time.

Modeling Summary

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternately, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow of amount of water that enters the lake.

To analyze the 1991 quality of Maple Lake, the Minnesota Lake Eutrophication Analysis Procedures (MINLEAP) model was used. This model was developed by MPCA staff based on an analysis of data collected from a set of representative minimally impacted lakes for each ecoregion. It is intended to be used as a screening tool for estimating lake conditions with minimal input data. It must be kept in mind that values for chlorophyll a and the secchi disk are dependant on the value used for phosphorus. Thus, while comparisons can be made between these variables and the

Figure 11. Carlson's Trophic State Index Values For Maple Lake

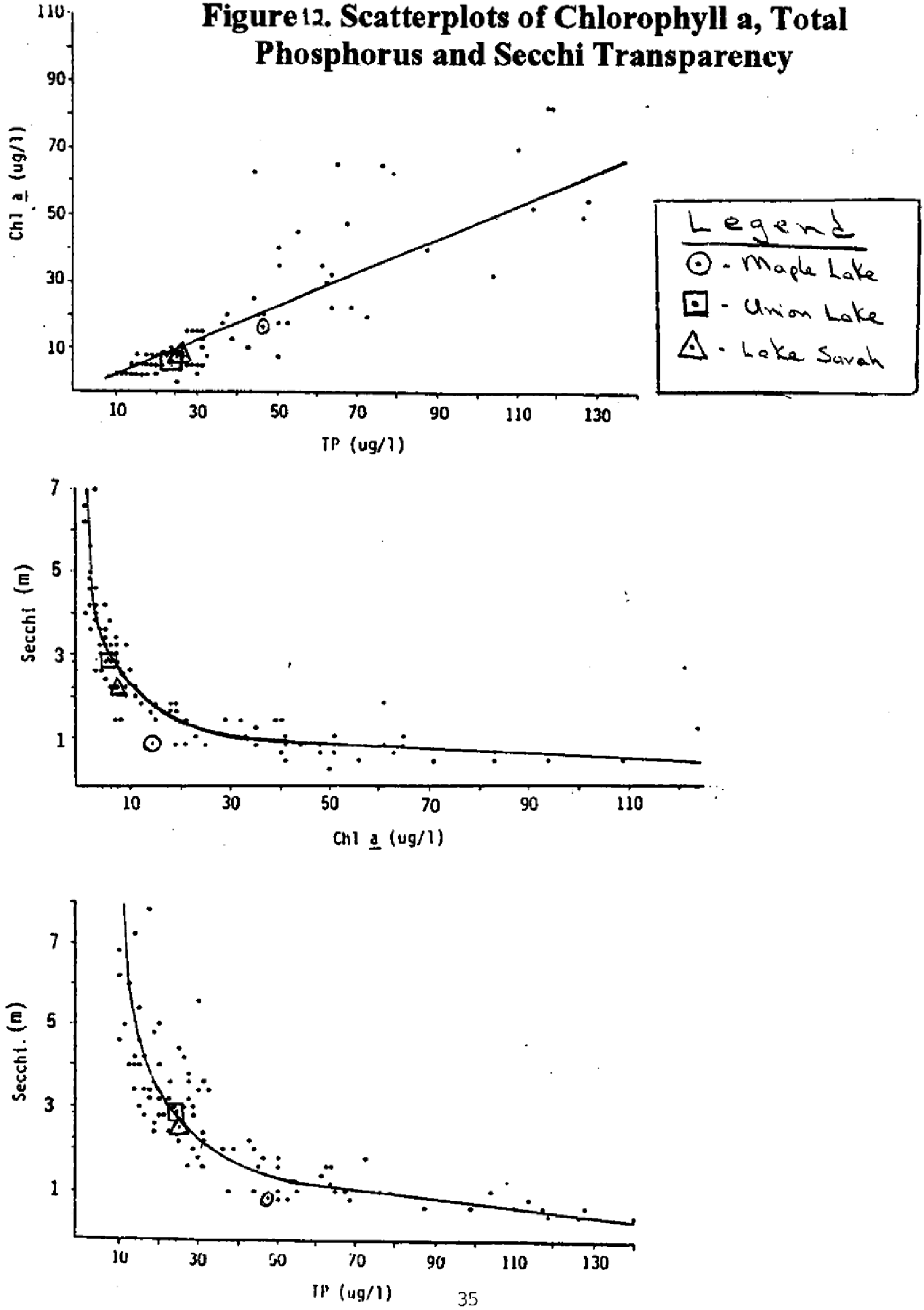


Changes in the Biological Condition of Lakes With Changes in Trophic State

R.E. Carlson

TSI < 30	Classical oligotrophy: Clear water, oxygen throughout the year in hypolimnion, salmonid fisheries in deep lakes.
TSI 30 - 40	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
TSI 40 - 50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer..
TSI 50 - 60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60 - 70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI 70 - 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypertrophic..
TSI > 80	Algal scums, summerfish kills, few macrophytes, dominance of rough fish.

Figure 12. Scatterplots of Chlorophyll a, Total Phosphorus and Secchi Transparency



respective ecoregion average, caution should be used in comparing single variables in isolation from the model in its entirety.

A summary of the results of the MINLEAP model for Maple Lake are presented in Table 6. Following is an explanation of some of the results. Based on MINLEAP, the water residence time (average time it would take to replace the entire volume of the lake) for Maple Lake is approximately seven-tenths of a year. Water residence time relates to the ability of a lake to "flush" itself of algal biomass and contaminated materials. Lakes with short residence times may become quickly polluted but they often quickly respond to remedial actions. It needs to be kept in mind that although Maple Lake has a large total watershed coverage with over 38,000 acres, the functional watershed area that drains into Maple Lake each year will generally be less due to a variety of factors including dry conditions upstream, beaver dams holding water back upstream, or other factors.

Maple Lake retains about 57 percent of the phosphorus that enters the lake. The MINLEAP model predicted an average total phosphorus concentration of 66 ug/l versus the observed average of 47 ug/l. Chlorophyll a levels were predicted at 30 ug/l versus the observed 16 ug/l. In regard to these two variables, Maple Lake is "behaving" much better than would be expected. While these differences are not statistically significant, they are at the edge of the range of expected values compared to ecoregion norms. The observed secchi disk reading of .88 meters was very near the predicted value of 1.04 meters.

Chlorophyll a is a means of assigning a number to the level of algae in the water. Chlorophyll a levels higher than 20 ug/l are considered to be a nuisance with levels above 30 ug/l identified as a severe nuisance. In 1991, the chlorophyll a levels for Maple Lake were observed to be greater than 20 ug/l 26 percent of the time and over 30 ug/l about 7 percent of the time compared to predictions of exceeding these chlorophyll a levels 65 percent and 44 percent respectively. Again, Maple Lake is behaving better than would be expected for a lake with its watershed characteristics. The observed chlorophyll a levels may be lower than predicted but the secchi disk still is near its predicted level because of the higher than normal level of suspended solids and turbidity of Maple Lake which negatively impact the lake's transparency.

Table 6. MINLEAP Model Summary-Maple Lake-1991

```
Minnesota Lake Eutrophication Analysis Procedure
ENTER INPUT VARIABLES
LAKE NAME ? MAPLE LAKE
ECOREGION NUMBER 1=NLF,2=CHF,3=WCP,4=NGP ? 2
WATERSHED AREA (HA)            ? 15410
LAKE SURFACE AREA (HA)         ? 585
LAKE MEAN DEPTH (M)            ? 2.44
OBSERVED MEAN LAKE TP (UG/L)   ? 46.93
OBSERVED MEAN CHL-A (UG/L)     ? 16.4
OBSERVED MEAN SECCHI (M)       ? .88

INPUT DATA:
LAKE NAME =MAPLE LAKE          ECOREGION=CHF
LAKE AREA = 585  HA
WATERSHED AREA (EXCLUDING LAKE) = 15410  HA
MEAN DEPTH = 2.44  METERS
OBSERVED MEAN TP = 46.93  UG/L
OBSERVED MEAN CHL-A = 16.4  UG/L
OBSERVED MEAN SECCHI = .88  METERS

<press ENTER to view results>
```

```
LAKE = MAPLE LAKE                          ECOREGION = CHF
AVERAGE INFLOW TP = 154.9506  UG/L         TOTAL P LOAD       = 3140.384  KG/YR
LAKE OUTFLOW      = 20.267  HM3/YR         AREAL WATER LOAD   = 3.464444 M/YR
RESIDENCE TIME    = .7042978  YRS          P RETENTION COEF   = .5743407

VARIABLE   UNITS     OBSERVED  PREDICTED  STD ERROR  RESIDUAL   T-TEST
TOTAL P    (UG/L)    46.93     65.96      19.68      -0.15      -1.00
CHL-A      (UG/L)    16.40     29.94      16.82      -0.26      -0.97
SECCHI     (METERS)  0.88      1.04       0.40       -0.07      -0.42
NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
      T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

CHLOROPHYLL-A INTERVAL FREQUENCIES (%)
CHL-A              PREDICTED  PREDICTED  PREDICTED
  PPB   OBSERVED    CASE A     CASE B     CASE C
  10     78.57      97.96      97.05      90.03
  20     25.64      72.64      71.08      64.73
  30      6.69      40.31      41.04      43.86
  60      0.16       4.56       5.95      14.47
CASE A = WITHIN-YEAR VARIATION CONSIDERED
CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED
CASE C = CASE B + MODEL ERROR CONSIDERED
Ok
```

SUMMARY AND GOAL SETTING

Objectives of this project were to generate citizen involvement in lake management and provide baseline data for present goal setting and future comparisons. Following are some summary observations related to the current project and preliminary considerations for goal setting. This information is provided as a preliminary discussion of lake management considerations and is intended to be used as the basis for discussion and decisions from lake residents as goals and management guidelines for Maple Lake and its watershed are defined.

As is the case for nearly all lakes in this ecoregion, phosphorus is the limiting nutrient for increased algae production. Thus, the majority of discussion and management efforts related to lake water quality is directed at controlling phosphorus loading in the lake. Overall, the good news is that Maple Lake is behaving better than what would be expected for a lake with its physical characteristics and the land use in its watershed. However, the caution is that any change in conditions in and around Maple Lake and its watershed that would cause an increase in phosphorus concentrations would likely quickly and significantly worsen the condition of Maple Lake.

One reason why Maple Lake may be performing better than expected could be due to the amount of groundwater that is feeding Maple Lake. Generally, groundwater is expected to be of better quality than surface water runoff into a lake. However there may be degradation of lake water quality if the groundwater moves through areas of high phosphorus such as in areas where feedlots are present, excess fertilizers are applied or non-performing septic systems are present. Phosphorus moves horizontally through saturated soils virtually unimpeded in areas where the water table is high.

Maple Lake also has numerous lakes and wetlands in its watershed that serve to filter nutrients out before they reach Maple Lake. It is projected that these wetland areas play a significant role in helping to keep Maple Lake in a better condition than would be expected. If these are drained or reduced in any manner, in-lake water quality can be expected to diminish.

Due to the shallow nature of Maple Lake, there tends to be weed growth throughout much of the lake. While many residents may view this as aesthetically unappealing, these weeds are actually consuming nutrients and tieing them up, thus not making them available for algae production. While some of these nutrients are released when the weeds die, the net effect is to help reduce nutrient--especially phosphorus--availability to algae. Thus, a large scale weed harvesting and removal program could actually significantly decrease water clarity in Maple Lake. Weeds are also beneficial as food and habitat for fisheries.

It may have been expected that water quality would have been better in the east bay of Maple Lake due to this bay being deeper and the flushing action due to the inlet and outlet both being in this end of the lake. However, there was not a significant difference in water quality from one end of Maple Lake to the other. Perhaps this is due to a greater sediment and nutrient load entering the lake via the inlet at the east end which counteracts the flushing action. The increased boating activity at the east end may also keep sediment stirred up to a greater degree. The middle and west end of the lake may also be receiving more groundwater of better quality and the shallower nature of this part of the lake also generates more weed growth which takes up nutrients.

It was noted earlier in this report that the turbidity and suspended solids in Maple Lake were both higher than normal for this ecoregion. In addition to wind action and sediment from erosion and runoff, other factors related to these variables which need to be kept in mind as lake management goals are set include the impact of boating activity and sediment stirred up by bottom-feeding rough fish. Emergent vegetation such as cattails and bulrushes help to neutralize wave action from wind and boats that cause shoreline erosion and sediment disturbance.

A reasonable phosphorus goal for Maple Lake would likely be in the 40-45 ug/l range, considering its morphometry and land use in its watershed. In order to maintain the fisheries and full support for recreation and aesthetic uses, phosphorus levels below 40 ug/l are desirable (Heiskary and Wilson, 1988). This may be difficult for Maple Lake to achieve given its current levels.

Sources of nutrients near the lake should be addressed first. This primarily relates to lake resident's septic systems, lawn care practices and other items such as burning near the lake. "Lakescaping" by individuals around the lake can be both beneficial to Maple Lake and provide a variety of wildlife and aesthetic benefits. (See Figure 13 for "Lakescaping" example). Due to the large watershed area of Maple Lake, efforts need to be made to minimize the amount of nutrients that reach Maple Lake from its contributing watershed. In-lake total phosphorus values could dramatically increase over time if nutrient reduction measures are not implemented in the watershed of Maple Lake. Increasing in-lake nutrient concentrations will result in accelerated degradation of Maple Lake. It must be remembered that cleanup of a degraded lake can be very expensive.

Opportunities should be expanded to allow for more citizen involvement in lake monitoring and management. A systematic program to collect basic information at very low cost should be continued. This would include data collection of secchi disk readings, water temperatures, lake levels, rainfall, physical condition and recreational suitability ratings. Sharing of equipment to cover upgrades and maintenance should be considered with neighboring lake associations--an example would be to share a dissolved oxygen/temperature meter with the Union Lake Sarah Improvement Association to allow collection of D.O./temperature profiles throughout the summer. Improving working relationships between citizens and local and state agencies is essential as all sides have a stake in stewardship of our land and water resources and all sides have something to bring to the table to contribute to improved management. A list of some of the resource agencies and contacts are included in Appendix C.

Continued education efforts are also essential to raise the awareness of water quality issues. Five issues of the "Lake Leader" newsletter were produced and distributed during the duration of the project. This communication tool allowed for delivery of specific and timely information that was of use to lake residents. Options of continuing this type of forum should be pursued. For all education efforts, it must be kept in mind that even though the number of year-round residents is increasing, Maple Lake is till primarily a "summer lake" in that the vast majority of activity occurs from Memorial Day weekend in late May to Labor Day weekend in early September. Thus, information targeted to lake residents must be offered primarily during this time. The option of coordinating a local lake management seminar or series of programs over the summer with the Union Lake Sarah I.A. and other nearby interested parties should be explored. Educational programs via a "naturalist's program series" presented over the summer could also be done.

Future goals set by the Maple Lake Improvement District and its members could include but are not limited to; water quality conditions, fisheries, physical cleanup around the lake, septic system survey and compliance, plans for further citizen monitoring, educational efforts, and coalition building. Efforts should be made to cure lake watershed ills where necessary, but plan as much as possible with prevention in mind. Lake protection should be the dominant theme of future lake management efforts.

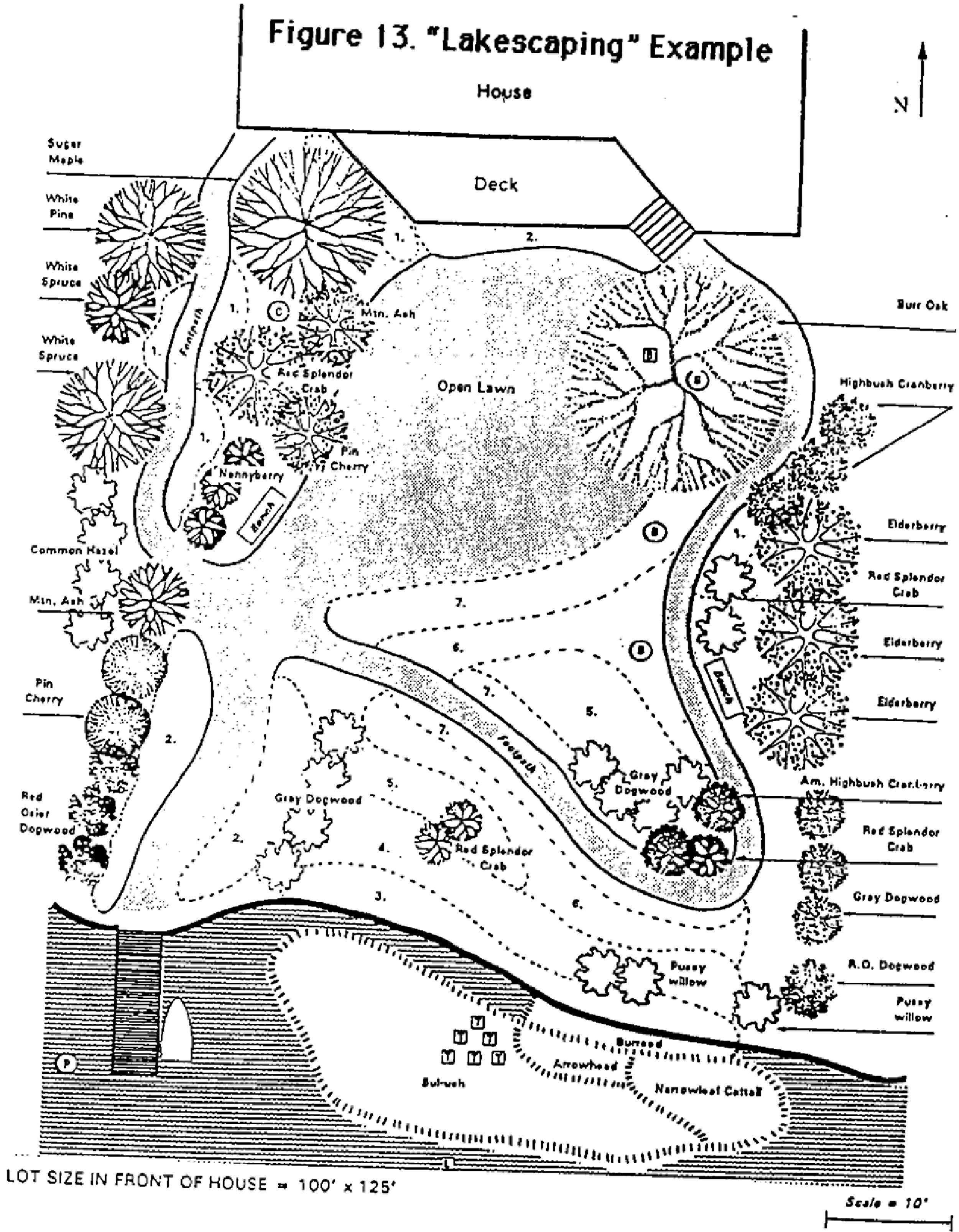


Figure 13. "Lakescaping" Example

Key to Gardens
1. Woodland flower garden
2. Sunny site butterfly/hummingbird garden
3. Wet site garden - short height
4. Moist site garden - medium height
5. Moist site garden - tall height
6. Dry site butterfly garden - medium height
7. Butterfly/hummingbird garden - short height

Key to Nest Boxes/Platforms
- (B) Bluebird nest box
- (P) Purple martin house
- [L] Loon nest platform
- [T] Tern nest platform
- (C) Chickadee nest box
- (S) Screech owl nest box
- [B] Bat house