Lake Assessment Program
1991

Fishhook Lake
(I.D. #29-242)

Hubbard County, Minnesota

Hubbard County Environmental Services
Beltrami County Soil and Water Conservation District
Fishhook Lake Association
Minnesota Pollution Control Agency
Headwaters Regional Development Commission

June, 1992

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Conversion Factors

This report's discussions assume that the reader is familiar with basic water quality terminology as used in the "Citizens' Guide to Lake Protection". Commonly used abbreviations in this report include:

ug/l = micrograms per liter = parts per billion [These are the "normal" units for phosphorus and chlorophyll (algae) and are the smallest units of measure in this report.]

mg/l = milligrams per liter = parts per million [These are the next largest units of measure and are typically used for alkalinity, nitrogen, total solids and chloride concentrations.]

m = meters = 3.3 feet

km = kilometer = 3,280 feet, which is about 0.6 miles

ha = hectare = 2.5 acres

1 square mile = 2.6 RM

1 square mile = 640 acres

1 acre-foot = 1 foot of water over one acre

Executive Summary, Conclusions, and Recommendations

Fish Hook Lake is located approximately one-half mile north of Park Rapids, Minnesota in Hubbard County. Its surface area is 1,634 acres, maximum depth is approximately 76 feet and average depth is about 26 feet.

It has a large watershed area of 129,252 acres and is connected upstream via the Potato River to Potato Lake which is connected in turn to large lakes such as Eagle and Island. Portage Lake, a shallow lake basin drains into Fish Hook along the western shore. The Fish Hook River drains to the south through the City of Park Rapids where it connects with the Straight River.

Total phosphorus concentrations measured during the open water season of 1991 averaged 18.4 ug/l (migrograms per liter) +/- 7.13 ug/l. Chlorophyll-a concentrations averaged 3.77 +/- 1.47 ug/l. Secchi disk transparency averaged 10.3 +/- 2.2 feet over the monitoring period. Average TSI using Carlson's Trophic State Index was 44.5 which indicates a mesotrophic condition.

In general, considering the large size of the watershed, water quality in Fish Hook Lake is somewhat better than computer models such as MINLEAP and the Reckhow-Simpson model would indicate. This may in part be due to the fact that upstream lakes and wetlands act as nutrient sinks, trapping phosphorus before it can be transported to Fish Hook. It is important, therefore, to protect the existing water quality in the face of continuing development.

Watershed and lakeshore protection should begin with educational efforts aimed at both lakeshore residents and landowners within the watershed. Enforcement of current shoreland regulations and careful land use planning should help to protect the water quality in Fish Hook Lake.

Conclusions:

The water quality in Fish Hook Lake, based on 1991 sampling, is consistent with what would be expected for lakes in the Northern Lakes and Forests Ecoregion. The lake generally has better water quality than would be expected based on computer models such as MINLEAP and Reckhow-Simpson. This may in part be due to the fact that the models overestimate the amount of phosphorus loaded directly into the lake from the large watershed. Upstream lakes and wetlands may act as sinks and intercept this phosphorus load before it reaches Fish Hook. Extremely wet years, with more water moving through the upstream lakes and wetlands, may transport nutrients into Fish Hook and cause a decrease in water quality. These fluctuations in water quality on a year-to-year basis are to be expected and only continued monitoring will determine the limits of those fluctuations. If water quality changes exceed those limits, then corrective measures will have to be initiated before water quality is severely degraded. Continued participation in the CLMP program will provide a cost-effective monitoring system. Basic water chemistry could be sampled every 3-5 years in order to assure the accuracy of Secchi Disk transparency readings.

Recommendations:

The following recommendations are based on conclusions developed as a result of this study:

1. The Fish Hook Lake Association should continue to gather information on the water quality in Fish Hook Lake by continuing Secchi disk transparency monitoring and lake level monitoring as

they have done in the past. Volunteer monitoring efforts such as CLMP and lake level monitoring are cost-effective and can provide information on trends in water quality. This information can be used to initiate corrective measures before the lake water quality has been too severely degraded.

2. The Fish Hook Lake Association should continue to work with its members and other lake management groups including local and state agencies and the Hubbard County Coalition of Lake Associations to provide information and education materials to lakeshore members and other landowners within the watershed for the lake. This may be an opportunity to work closely with other lake associations on lakes upstream from Fish Hook. As the computer models suggest, these lakes may act as "sinks" for some of the phosphorus loading that would normally reach Fish Hook. Protecting these upstream lakes will help assure the water quality in Fish Hook Lake.

   Educational materials are available from the MPCA, MNDNR, and County offices such as Soil and Water Conservation District, Environmental Services and County Extension. These agencies may provide assistance in this educational effort.

3. The Fish Hook Lake Association conducted a septic survey in conjunction with this lake assessment. Efforts should be made to continue the effort to bring non-complying systems into compliance with state and county codes. The lake association may wish to request assistance from the Hubbard County Environmental Services Office to accomplish this goal. To place the potential impact from septic systems on the lake in perspective, if there were a large percentage of poor systems, then leaking septic tanks could contribute as much as 5-20 percent of the current estimated phosphorus income to the lake.

4. Development within the watershed should procede in such a manner as to minimize water quality degradation in the lake. Major shifts in current land use patterns must be studied carefully for their impact on Fish Hook Lake and the lakes upstream. Wetlands can serve as "filters" for surface and groundwater quality and should not be drained. These natural filters can be overloaded, however, and use of these ecosystems as "sinks" and "filters" should be limited to their natural capacity. The Hubbard County Planning Commission and Hubbard County Board of Commissioners will have a significant impact in this area, as they make decisions regarding land use controls.

5. Protection of groundwater quality from toxic materials and other pollutants such as excess fertilizer and chemical usage is not only important from the standpoint of drinking water quality but is also important because there is undoubtedly some groundwater flow into and out of Fish Hook Lake. Pollutants could be transmitted to the lake waters which could affect fish and other aquatic life. Use of the lake could be affected and this would have a detrimental effect on the economy in the Park Rapids area.

6. The Fish Hook Lake Association can help state agencies such as the Department of Natural Resources by educating its members about exotic species such as Eurasian Water Milfoil, Purple Loosestrife and Zebra Mussels. Volunteering to conduct inspections at boat landings will help to raise awareness about exotic species. In many cases the only time that infestations of exotic species can be eradicated is during the initial invasion stage. Regular checks for exotics such as Eurasian Water Milfoil may allow for its detection in time for control actions to be effective. The lake association members may want to conduct regular examinations for the presence of exotic species.

7. Future water monitoring efforts should include:

   a. CLMP participation
   b. Water level monitoring
   c. Aquatic plant surveys
   d. Basic water chemistry every 3-5 years — unless routine Secchi disk monitoring as mentioned above indicates a dramatic change.
   e. Monitor inflows into the lake to more accurately determine the actual nutrient loading.
   f. Continue refinement of computer models based on additional data.

FISH HOOK LAKE

(I.D. #29-242)

INTRODUCTION

Fish Hook Lake was sampled for water quality parameters during the summer of 1991 as part of an innovative program that combined Fish Hook Lake Association efforts with those of several public agencies. The sampling was similar to that of a Lake Assessment Program (LAP) usually conducted by the Minnesota Pollution Control Agency (MPCA). In the case of Fish Hook Lake the Hubbard County Environmental Services Office, the Hubbard County Soil and Water Conservation District (SWCD), the Beltrami County Soil and Water Conservation District (SWCD), the Headwaters Regional Development Commission (HRDC), and the MPCA worked together to conduct a LAP. LAPs are designed to assist lake associations collect and analyze baseline water quality in order to assess the current condition (e.g., trophic status) of their lake. The general work plan for a LAP includes participation in the MPCA's Citizen Lake Monitoring Program (CLMP), examination of land use and drainage in the watershed, and assessment of the collected data.

Fish Hook Lake was sampled on five occasions by either the MPCA or the Beltrami County SWCD and the Hubbard County Environmental Services Office with the assistance of the lake association in 1991. Participants in the sampling included Jeff Hrubes from the Beltrami SWCD, Laird Hensel from Hubbard County Environmental Services, Steve Heiskary and Bruce Paakh from MPCA, and Deane Wilson from the Fish Hook Lake Association. Deane Wilson was also responsible for collecting Citizen's Lake Monitoring Program data and water level data over the past several years. Other lake association efforts included compiling and writing the historical narrative (Carolyn Spangler) and organizing the household septic survey (Joyce Wilson). Information of land use and areas in the watershed was assembled by Bill Alden of the Hubbard County SWCD.

Study Limitations

The study is designed to provide basic water quality data and an assessment of 1991 lake conditions. All parties should understand that additional information may need to be collected and analyzed prior to implementation of restorative/abatement strategies. In addition, pollution abatement strategies would have to be defined by more detailed studies. For example, LAP studies generally estimate water and nutrient budgets and these estimates are subject to a fair amount of uncertainty (e.g., +/- 25-200%). Detailed studies, by contrast, would include sampling of the main inlets and outlets, gauging the streams and generating statistically valid estimates of nutrient loading. Detailed lake and stream measurements are usually extended over the course of one year and may cost several thousand dollars.

OVERVIEW

Fish Hook Lake is located one-half mile north of the town of Park Rapids, Minnesota in Hubbard County (see Figures 1 and 3). The lake's watershed covers an area of 129,252 acres in Hubbard and Becker Counties. It is the fourth lake in a chain of developed lakes which includes Island, Eagle, and Potato Lakes. In addition, an inlet from Portage Lake ot the northwest provides for drainage from the western area of the watershed. The lake covers an area of 1,634 acres and has a maximum depth of approximately 80 feet. Compared to other lakes in this part of the state, it would be considered fairly typical in terms of surface area and maximum depth.

Soils

Fish Hook Lake is located in a primarily level area resulting from Wisconsin Glaciation. Soils in the watershed are classified as Menahga-Marquette-Nebish, which are characterized as well to excessively well drained soils formed in outwash sand and gravel. Droughtiness and wind erosion are area management concerns.

Ecoregions

As land use affects water quality, it can be useful to divide the state into regions where the land use and water resources are similar. For Minnesota, this results in seven regions, referred to as "ecoregions", as defined by soils, land surface form, natural vegetation and current land use. Fish Hook Lake is located in the Northern Lakes and Forests ecoregion (Figure 3).

Watershed Land Use

Fish Hook Lake has a large watershed relative to its surface area (e.g., a ratio of 79 acres of watershed : 1 acre of lake). Forested land use dominates Fish Hook Lake's watershed (73 percent). The next most prevalent land uses are water and wetlands (12 percent) and cultivated (7 percent).

METHODS

Water quality data was collected from May through September of 1991. Specific sampling dates were May 14, June 14, July 17, August 15, and September 19. Sampling was conducted jointly by MPCA and SWCD/Environmental Services personnel in May, July, and September. SWCD and Environmental Services personnel conducted the sampling in June and August.

As in most Lake Assessment Program sampling systems, two sites were sampled on each date. The primary site (site 101) was near the location of maximum depth of the lake toward the eastern end of the lake. The secondary site (site 102) was located in a secondary basin toward the western end of the lake (Figure 1).

A full range of water quality parameters was collected in May, July, and September and analyzed by the Minnesota Department of Health laboratory in St. Paul, Minnesota.

Samples were analyzed for nutrients (total phoshporus, total Kjeldahl nitrogen, and nitrate + nitrite nitrogen), total suspended solids, total inorganic suspended solids, alkalinity, pH, chlorides, turbidity, color, and chlorophyll (Table 1). Physical parameters measured in the field included Secchi disk measurements plus temperature and dissolved oxygen profiles.

Additional total phosphorus and chlorophyll a samples were collected by local personnel in conjunction with the samples collected by the MPCA. Only total phosphorus and chlorophyll a samples were collected by local personnel during the June and August sampling dates. All the samples collected by local personnel were analyzed at ERA Laboratories in Duluth, MN, using EPA-approved methods. Secchi disk measurements, temperature and D.O. profiles were also taken during the June and August sampling runs.

Equipment used for sampling and field measuremnts included a Secchi disk, 2-meter integrated sampler (Figure 2) for surface samples, a one or two-liter Van Dorn samplers for near-bottom samples, YSI model 51 temperature/dissolved oxygen meter and a Hydrolab model SVR2 multi-parameter meter.

1991 LAKE ASSESSMENT PROGRAM (LAP) SAMPLING SITES

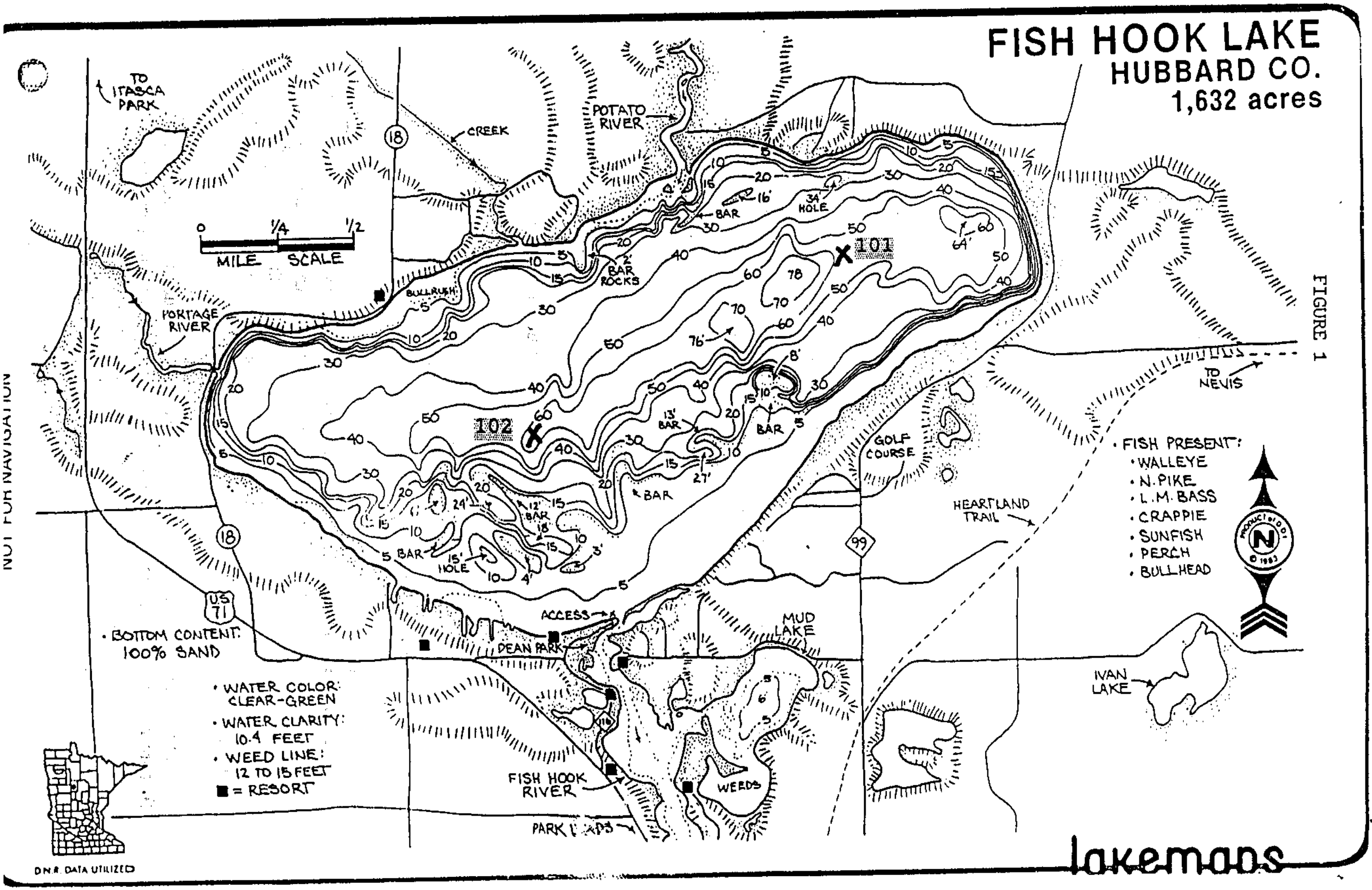


Table 1. Average Summer Water Quality and Trophic Status Indicators. Based on summer epilimnetic data.

Lake Fish Hook Year 1991

Parameter	Units	Mean	n	Min	Max	Std Dev	Typical Range[1] of Summer Means for Ecoregion
Total Phosphorus	ppb	18.4	8	8	24	7.13	14-17
Chlorophyll a	ppb	3.77	8	2	6.09	1.47	<10
Secchi disk	ft	10.3	8	8.5	15.4	2.2	8-15
Total Kjeldahl N	ppm	0.43	4	0.39	0.46	0.029	<0.75
Nitrite + Nitrate-N	ppm	0.03	2	0.01	0.05	0.023	<0.01
Alkalinity	ppm	140	2	130	150	14.14	40-140
Color	Pt-Co Units	---	-	---	---	-----	-----
pH	SU	8.5	2	8.5	8.5	0	7.2-8.3
Chloride	ppm	1.65	2	1.6	1.7	0.07	<2
Total Suspended Solids	ppm	2.2	2	2.0	2.39	0.28	<1-2
Total Suspended Inorganic Solids	ppm	0.9	2	0.8	1.0	0.14	<1-2
Turbidity	NTU	1.85	2	1.7	2.0	0.21	<2
Conductivity	umhos/cm	270	1	270	270	0	50-250

TN:TP ratio 40:1 25:1--35:1

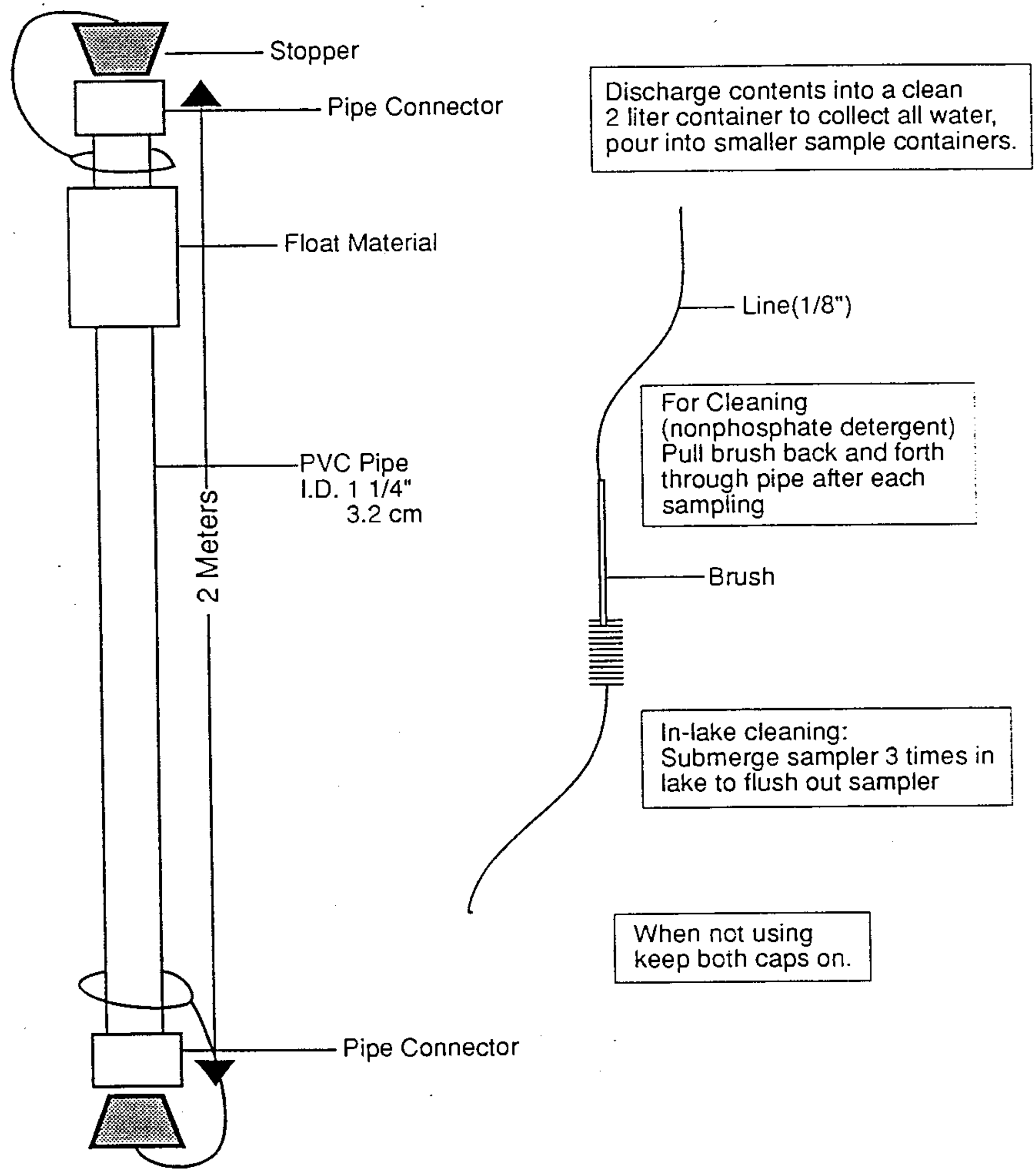
TSIP (TP) 46.4
TSIC (Chl-a) 43.6
TSIS (Secchi) 43.5
TSI (Mean) 44.5
Percentile[2] 51 %

1. Heiskary and Wilson. 1990. Minnesota Lake Water Quality Assessment Report. Appendix II, page 43.

2. Percentile ranking of mean TSI value for the lake relative to the ecoregion it is located in. Extrapolate from Appendix 1 in Heiskary and Wilson (1990).

FIGURE 2

Integrated Sampler



Note: We ccould provide rubber stoppers (the green stoppers in the lab)

DISCUSSION

Temperature and dissolved oxygen profiles taken during the summer of 1991 indicate thermal stratification already beginning as of the June 14 sampling date. A dissolved oxygen profile on that date indicates well oxygenated water (above 5 milligrams per liter mg/l) down to a depth of about 60 feet. By the July 17 sampling date, there is a well defined thermocline formed in the 30 to 40 foot range and the hypolimnion (that area of the lake below the thermocline) has become oxygen depleted. Gamefish require concentrations of dissolved oxygen at least 3 mg/l which would limit their habitat to about the upper 28 feet of the lake.

The temperature and dissolved oxygen profiles taken on August 15 show that the thermocline has moved up to about 26 feet. The hypolimnion continues to be anoxic (oxygen depleted) below about 28 feet.

As cooler temperatures arrive in the fall, the surface waters have cooled which causes them to become more dense and begin to sink. The temperature/dissolved oxygen profiles taken on September 17 show the top of the thermocline has dropped to about 33 feet. Some mixing of the lake has started, although fall turnover is not complete. There is some dissolved oxygen (about 2 ppm) down to the bottom, but the lower limit of the thermocline (about 39 feet) is also the lower limit of oxygen concentrations greater than 3 mg/l.

Organic matter decomposition is likely the reason for oxygen depletion in the hypolimnion. Once the thermocline has formed and effectively "sealed off" the hypolimnion from the epilimnion, there is little oxygen produced and dissolved oxygen levels fall below the limits which can support fish and other aquatic organisms.

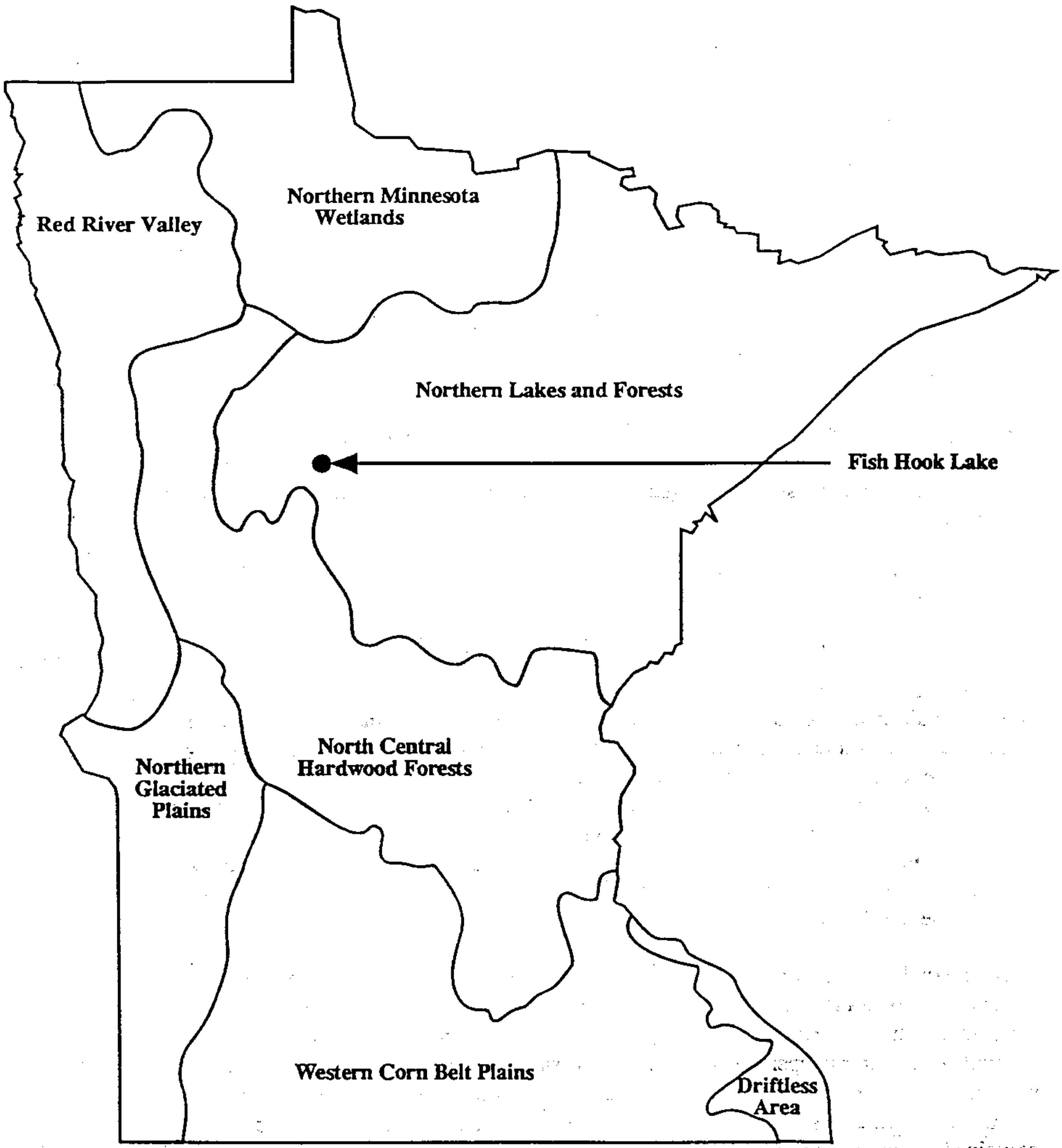
Mean total phosphorus concentrations in the surface waters were 18.6 micrograms per liter (ug/l or parts per billion ppb). This is somewhat higher than typical values of 14 to 17 ppb found in a set of minimally-affected lakes in the Northern Lakes and Forests Ecoregion (Figure 3).

Mean total phosphorus concentrations in samples collected near th bottom were 39 ug/l. Under anoxic conditions, phosphorus is liberated from bottom sediments and released into the water column. While the thermocline is present, the phosphorus dissolved in the hypolimnetic water is generally unavailable to plants, particularly algae. However, when the lake "turns over" in the fall, that dissolved phosphorus is redistributed throughout the water column. Turnover in northern lakes such as Fish Hook occurs when water temperatures are cool enough to inhibit algal growth. There may still be some dissolved phosphorus left in the water column after ice-out and spring turnover, but cool spring water temperatures inhibit algal growth and allow much of the remaining phosphorus to settle out below the thermocline that is forming.

This "internal loading", or recycling of nutrients within the lake, can be the engine that drives rapid water quality degradation. Under the right conditions, that release of nutrients into the water column can lead to a sudden increase in algae growth (blooms). If enough phosphorus remains in the water column when water temperatures increase in the summer and conditions become favorable for growth, severe, early blooms can be the result. In addition, shallow lakes with weak thermal stratification can be destratified by strong winds during the summer months and the dissolved phosphorus that is contained below the thermocline will be distributed throughout the lake and become available for algal growth.

FIGURE 3. FISH HOOK LAKE LOCATION MAP

Minnesota's econregions noted



Total nitrogen (TN) concentration, estimated by adding total Kjeldahl nitrogen (TKN) plus nitrite and nitrate (NO_2 + no_3), averaged 0.46 mg/l over the summer. Nitrate + Nitrite concentrations averaged 0.03 mg/l which is slightly above the value of 0.01 mg/l which is typical for the ecoregion.

The ratio of TN:TP can give an indication of the limiting nutrient in a lake. The limiting nutrient is generally the least abundand and its lack of availability limits the biological productivity of the lake. In Fish Hook Lake, the TN:TP ratio is 40:1, which is very similar to the TN:TP ratio for minimally affected lakes in this ecoregion (25:1 to 35:1). This strongly suggests that phosphorus is the limiting nutrient and controlling phosphorus will control algal blooms within the lake.

Chlorophyll-a concentrations give an estimate of the algal productivity in a lake. Chlorophyll is the green pigment present in both aquatic and terrestrial plants. Concentrations of chlorophyll-a between 10 and 20 ug/l are generally considered to indicate mild algal blooms. Concentrations between 20 and 30 ug/l generally indicate a bloom which would be perceived as a nuisance and concentrations over 30 ug/l would be perceived as a severe nuisance.

In Fish Hook Lake, the maximum concentration of chlorophyll-a measured during the summer of 1991 was 6.08 ug/l and the mean concentration during the summer months was 3.77 ug/l. Both of these values are substantially below the 10 ug/l limit which would indicate mild algal blooms. It is possible that mild blooms do occur infrequently, but were not present on sampling dates during the summer of 1991.

Secchi disk transparency is generally a good indication of the relative abundance of algae present in the water. Large amounts of suspended sediments or heavily colored water (as from bog drainage) can influence the Secchie disk readings in certain situations. The total suspended solids were very close to the typical values found in the Ecoregion and probably do not greatly influence the Secchi disk readings. Transparency measured over the summer of 1991 ranged from 8.5 to 15.4 feet and corresponds almost exactly with the typical values for this ecoregion.

The trophic state index (TSI) is a means of rating the biological productivity of a lake. The relationship among Secchi disk transparency, total phosphorus concentration and chlorophyll-a concentration can be calculated and expressed as a single number. One method of stating this relationship is by Carlson's Trophic State Index (Carlson, 1977). TSI values are calculated using the following formulas:

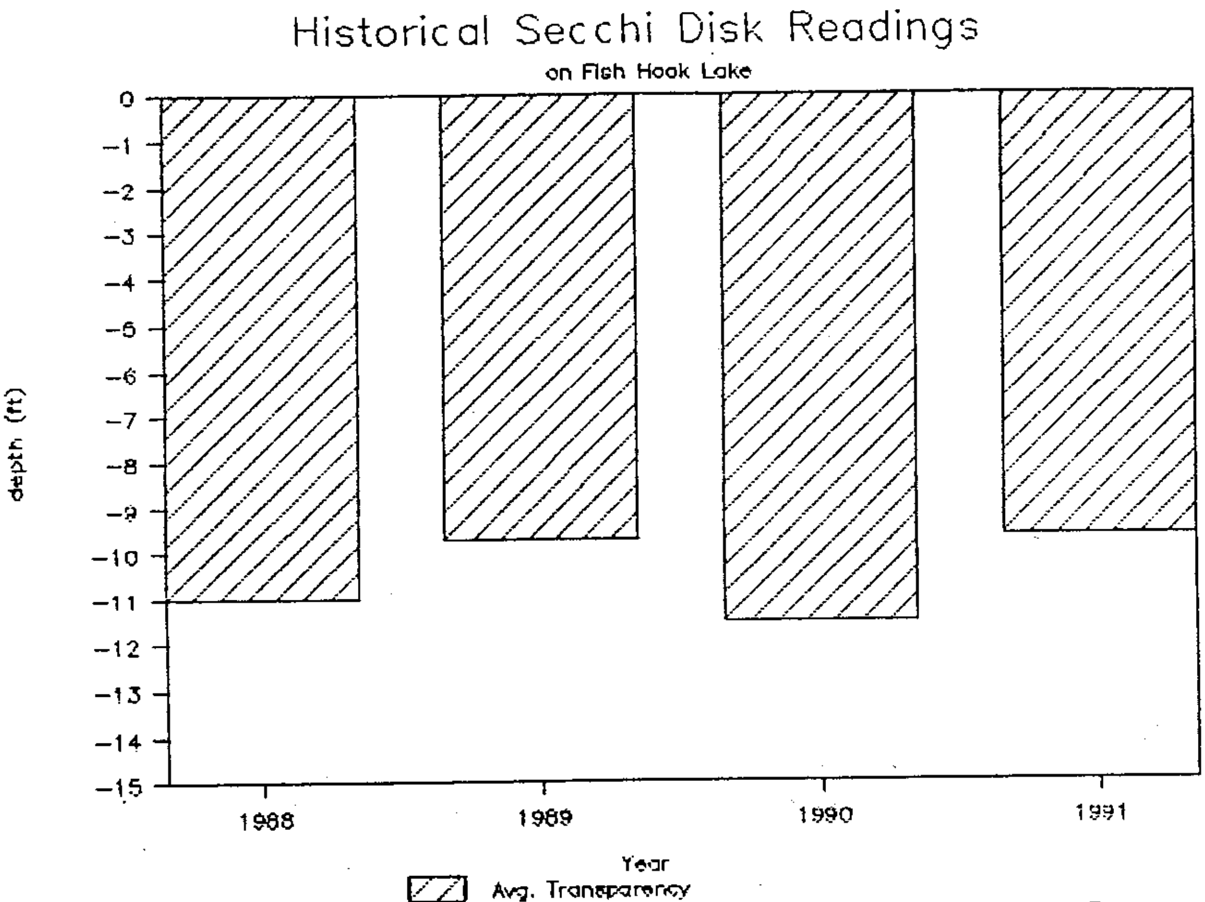
Total Phosphorus TSI (TSIP) — 14.42 * In(TP) + 4.15
Chlorophyll-a TSI (TSIC) — 9.81 * In(Chl-a) + 30.6
Secchi Disk TSI (TSIS) — 60 - 14.41 * In(SD)

In these formulas, summer averages for TP and chlorophyll-a are used and expressed in ug/l. TSI is calculated by using summer averages for Secchi disk transparency expressed in meters.

This system allows a more precise comparison of lakes than using the three classical limnological terms of oligotrophic, mesotrophic and eutrophic. Carlson's TSI values range from 0 (ultra-oligotrophic and unproductive) to 100 (hypereutrophic and extremely productive). Each increase of 10 units along the scale represents a doubling of the algal biomass present in the lake.

Average values for TSI variables are presented in Table 2. These figures indicate that Fish Hook Lake is mesotrophic. The mean TSI of 44.5 would rank it in the 51st percentile relative to about 700 other lakes in the Northern Lakes and Forests Ecoregion. That means that the TSI value for Fish Hook is

FIGURE 4



	Avg. Physical Condition	Avg. Recreational Suitability
1988	2.0	2.0
1989	2.2	2.0
1990	1.7	2.0
1991	2.0	2.0

Each Citizen Lake Monitoring Program (CLMP) participant also provides a subjective rating of physical condition and recreational suitability at the same time as the secchi disk transparency measurement. Physical appearance ratings range from "crystal clear" (#1) to "dense algal blooms, etc." (#5). Recreational suitability ratings range from "beautiful, could not be any better" (#1) through "swimming slightly impaired" (#3) to "no recreation possible" (#5).

Long term observation of secchi disk transparency is a very useful tool for monitoring the water quality within a lake. The lake association should be encouraged to continue with the CLMP program. This low-cost program can provide information on trends in water quality and allow corrective actions to be initiated before the lake is severely degraded.

Table 2. Morphometric, Watershed and Fishery Characteristics

Lake Name Fish Hook

MDNR I.D. # 29-0242

Area (lake)	1,634 acres (661.5 ha)[1]	
Mean depth	26.7 feet (8.1 m)	
Maximum depth	76 feet (23.2 m)	
Volume	43,652 acre-feet (53.8 HM3)	
Littoral area	15 %	
Fetch	2.96 mile (4.76 km)	

Watershed area 129,252 acres (52,329 ha)

Watershed: lake surface ratio 79 : 1

Estimated average water residence time 0.44 years

Fisheries - Ecological Classification Centrarchid - Walleye
- Management Classification Walleye - Centrarchid

Public accesses (#): 2 + 1
Inlets: 2 Outlets: 1

Land Use (percentage/area):

	Forest	Water	Marsh	Pasture	Cultivated	Urban-Res.
Project (percent)[2]	73.4 %	8.5	3.4	4.0	7.1	2.0
(acre)	97,628 acre	11,244	4541	7187	9455	2548
Ecoregion (NLF) (percent)[3]	54-81	14-31 (combined)		0-6	0-7	0-7

Shoreland zoning: natural, recreational or general

Development (homes)[4]	Seasonal	Permanent	Total
1967	74	53	127
1982	81	90	171
Current (1991)	55	109	164

1. Pertinent conversions: acres divided by 2.47 = hectare; feet divided by 3.28 = meters; acre-feet divided by 811 = HM3.
2. Derived from most current assessment.
3. Derived from Heiskary and Wilson (1988 or 1990) Minnesota Lake Water Quality Assessment Report Table 6.
4. DNR or Land Management Information Center records.

higher (more eutrophic) than 49 percent of the lakes assessed by the MPCA in this ecoregion. Or, put another way, Fish Hook is currently about average for the lakes in this ecoregion.

Graphic comparison of scatterplot data is another method of comparing the variables total phosphorus, chlorophyll-a and Secchi disk. Figure 5 shows the variables plotted on the X and Y axis with the "line of best fit" depicting the relationship between the variables.

In Fish Hook, the relationship among total phosphorus, chlorophyll-a and Secchi disk is very similar to other Minnesota lakes and falls very close to the line of best fit. This indicates a close relationship among the variables and changes in one, total phosphorus for example, will have a definite effect on the other variables (chlorophyll-a and Secchi disk).

There are many mathematical computer models available for predicting nutrient loading and water budgets for lakes. As with any model, the more data that can be collected, the more accurate those predictions will be. These models can also be used to predict what could happen to water quality should some variables such as land use, population, development, etc., undergo substantial changes.

MINLEAP or the "Minnesota Lake Eutrophication Analysis Procedure" (Wilson, 1988) was one of the modesl used to analyze conditions in Fish Hook Lake in 1991. This model is intended to be used as a primary screening tool for estimating lake conditions with minimal data input. The model was based on data collected fro a set of minimally affected lakes for each ecoregion in the state and uses regional coefficients for precipitation, runoff, evaporation, etc.

The full printout of model results is presented in Table 3. Lake-specific information includes lake size and volume, watershed size, and observed values for total phosphorus, chlorophyll-a and Secchi disk. MINLEAP predicts total phosphorus concentrations of 32 +/- 8 ug/l, chlorophyll-a concentrations of 10.4 +/- 5 ug/l and Secchi disk transparency of 1.95 +/- .7 M. This prediction is considerably worse than the observed values of 19 +/- 7 ug/l total phosphorus, 3.77 +/- 1.47 ug/l chlorophyll-a, and 3.4 +/- .7 M Secchi disk. This comparison is summarized below:

	Observed	MINLEAP Prediction
Total Phosphorus	19.0 +/- 7 ug/l	32.0 +/- 8 ug/l
Chlorophyll-a	3.77 +/- 1.47 ug/l	10.4 +/- 5 ug/l
Secchi Disk	3.4 +/- 0.7 M	1.95 +/- 0.7 M

Since the observed values are so much better than the values predicted by the model, it suggests that Fish Hook Lake is a very valuable resource with water quality somewhat better than what would be expected. Lake management efforts should be aimed at maintaining the current water quality in spite of likely changes in population density and land use.

In addition to predictions of water quality parameters, MINLEAP also predicts the percent of summer (based on a 100-day season) that chlorophyll-a concentrations resulting from mild (10 ug/l), nuisance (20 ug/l), and severe (30 ug/l) algal blooms would be likely to occur. Table 3 shows that mild blooms would be expected to occur roughly 45% of the time, with nuisance blooms occurring about 15% of the time and severe blooms occurring about 5% of the time.

Figure 5. SCATTERPLOTS OF CHLOROPHYL-a, TOTAL PHOSPHORUS AND SECCHI TRANSPARENCY.
Based on summer data from a set of representative lakes from four ecoregions in Minnesota.
Values for Fish Hook Lake in Hubbard County

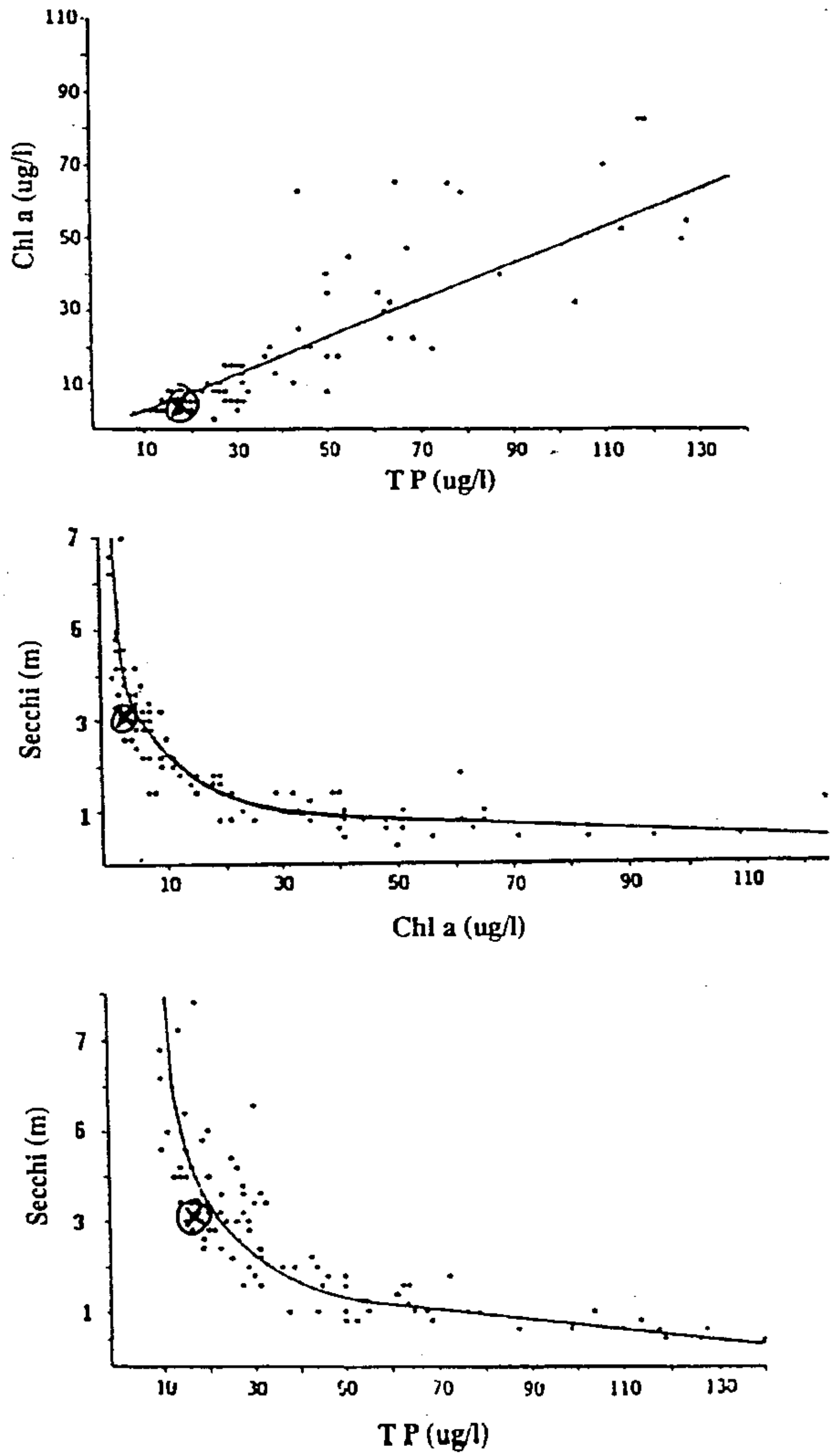


Table 3: MINLEAP MODEL RESULTS FOR FISHHOOK LAKE

LAKE = FISH HOOK		ECOREGION = NLF	
AVERAGE INFLOW TP	= 52.39462 UG/L	TOTAL P LOAD	= 6345.428 KG/YR
LAKE OUTFLOW	= 121.1084 HM3/YR	AREAL WATER LOAD	= 20.88076 M/YR
RESIDENCE TIME	= .4070733 YRS	P RETENTION COEF	= .3789151

VARIABLE	UNITS	OBSERVED	PREDICTED	STD ERROR	RESIDUAL	T-TEST
TOTAL P	(UG/L)	18.40	32.54	7.74	-0.25	-1.97
CHL-A	(UG/L)	3.77	10.67	5.30	-0.45	-1.85
SECCHI	(METERS)	3.12	1.92	0.68	0.21	1.29

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	1.15	45.80	46.11	47.17
20	0.01	6.07	7.64	15.05
30	0.00	0.84	1.36	5.50
60	0.00	0.01	0.02	0.52

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

Again, this indicates that water quality is better than would be expected and should be protected in order to maintain that quality.

Models are only one tool for lake analysis and should be viewed as a tool rather than as an end product. The large watershed area relative to the lake size (79:1) can 'fool' the model into predicting much worse conditions than are actually there. In addition, the fact that a good deal of the runoff from the watershed enters other basins (lakes) before entering Fish Hook, probably affects the runoff characteristics.

Another watershed and lake water quality model that was used in analyzing Fish Hook Lake was the Reckhow-Simpson model. This model attempts to predict in-lake total phosphorus concentrations and frequency of algae blooms. By using a range of export coefficients from various land uses, the model predicts a range of TP concentrations from a low value to a most likely value to a high value. The model also takes the breakdown of land use in a watershed into account and attempts to predict the amount of total phosphorus that each type of land use contributes to the total.

Using the land use total from Appendix 6, the model predicts a low total phosphorus concentration of 17 ug/l which agrees quite well with the observed values of 19 ug/l. The model predicts the most likely total phosphorus concentration as 45 ug/l which is substantially higher than the observed values. These numbers also indicate that Fish Hook is a lake wth somewhat better water quality than would be expected and the resource should be preserved. Based on the observed values for total phosphorus, chlorophyll-a and Secchi disk, the model predicts that chlorophyll-a concentrations greater than 10 ug/l would occur about 6% of the time (or 6 days per summer). Even though there were no observed instances of algal blooms, the sampling runs were scheduled monthly and may not have coincided with any algae blooms that did occur.

The complete printout of the model inputs and results are presented in Table 4.

Both models predict a water residence time of 0.4 years (146 days). Predicted values for average phosphorus inflow concentrations into the lake for MINLEAP and the Reckhow-Simpson model agree quite well at 52 ug/l. Total phosphorus loading to the lake is also quite comparable between the two models, 6,345 kg — MINLEAP vs 6,872 kg. — Reckhow-Simpson.

able 4. Reckhow-Simpson Models

s software was developed by Bruce Wilson for research use by the
nesota Pollution Control Agency, 520 Lafayette Road, St.Paul, MN 55155
s software should be considered draft and not used for commercial applications.
il, 1989. version NALMS. Use this at your own risk.
ARE RESPONSIBLE FOR CHECKING THE ACCURACY OF CALCULATIONS.
S IS A DRAFT DOCUMENT TO DEMONSTRATE SPREADSHEET USAGE, ONLY.
2)296-9210

The first model is described in:
khow,K.H. J.T. Simpson.1980. A Procedure using modeling and error
lysis for the prediction of lake phosphorus concentration from land
information. Can.J.Fish.Aq.Sci.37(9):1439-1448.

ershed Area (ha	52329		1.3E+08	=EST Q	130.82	=HM3	0.4 =Water Residence (year)
e Area (ha)	562		19.76	=EST qs			
er Runoff (m)	0.25	NOTE: 1HM3 = 1,000,000 M3					
ecipitation(m)	0.45		0.019	=Observed TP (mg/l)			
aporation(m)	0.45		0.01549	=Observed TP StDev			
lume (HM3)	53.8		10	=N			
unty capitas/cab	2.9						
mber Seasonal Ca	74						
mber Perm. Cabin	30						

	Before	After	Delta
rest Area (ha)	39065	39065	0
ric Area (ha)	3443	3443	0
ban Area (ha)	1028	1028	0
tland Area (ha)	1615	1615	0
sture/Open (ha)	2713	2713	0

port Values		Low	Most Like	High	Before LOW	Before MOST LIKE	Before HIGH		After LOW	After MOST LIKE	After HIGH
rest P Export		0.1	0.15	0.2	3906.5	5859.75	7813	=Forested Flux :	3906.5	5859.75	7813
ric P Export		0.5	0.75	1	1721.5	2582.25	3443	=Ag flux :	1721.5	2582.25	3443
ban P Export		0.5	1	1.25	514	1028	1285	=Urban flux :	514	1028	1285
tland P Export		0.025	0.05	0.075	40.375	80.75	121.125	=wetland flux :	40.375	80.75	[illegible]
sture/open Export		0.2	0.3	0.4	542.6	813.9	1085.2	=Pasture/Open flux=	542.6	813.9	[illegible]
mospheric Export		0.2	0.3	0.4	132.4	198.6	254.8	=Ppt flux :	132.4	198.6	264.8
il Retention Coef		0.35	0.8	0.5							
int Source Befor	kg/yr	0	0	0							
int Source After	kg/yr	0	0	0	14.92054	59.66219	149.2054	=Septic flux :	14.92054	59.68219	149.2054
lta Point Source	kg/yr	0	0	0							
pita Years		298.4109	298.4109	298.4109	0	0	0	=Point Souce :	0	0	0
					6572.295	10622.93	14161.33	=Total P Flux =	6872.295	10622.93	12955.00
					1038.111	1604.672	2139.173	= P LOAD =	1038.111	1604.672	1956.949
					52.53245	81.20266	108.2505	= Inflow P ug/l	52.53245	81.20266	99.02924
					0.029	0.045	0.061	=PREDICTED TP =	0.029	0.045	0.055

	Before		After
	-1.34678	=LOG Pml =	-1.34678
	0.015424	= + MODEL ERROR =	0.015424
	-0.01148	= - MODEL ERROR =	-0.01148
	0.008	= + LOADING ERROR =	0.005
	0.008	= - LOADING ERROR =	0.008
	0.017375	=TOTAL + UNCERTAIN =	0.016214
	0.013998	=TOTAL - UNCERTAIN =	0.013998

Reckhow/Simpson	ug P/l	31	45	62	55% CONFIDENCE LIMITS	19	45	61
		17	45	80	90% CONFIDENCE LIMITS	17	45	77
[illegible]		[illegible]	47	59	CANFIELD/BACHMAN	33	47	55

. The second model is described in:
:khow. 1983 A Method for the Reduction of Lake Model Prediction Error". Water Res 17(8):911-916

Former -	New +	Net TP		Pred Boun -	Pred Boun +	Projected TP Change Incr/Decr	+/-
-0.00034	0	-0.00034	0.000345	0.000257	0.000463	-0.00034	0.000103

Lake Data

Lake TP	StDev	St Error	Pred Error	Obs TP	Net Change		Predicted P	+/- Pred Error
0.019	0.0114	0.002327	0.002329	0.019	-0.00034	=	0.019	+/- 0.002329
						=	19	+/- 2

[. Predicted changes in frequency of Secchi and Chlorophyll

lker, 1984. "Statistical Bases for Mean Chlorophylla Criteria" NALMS 4:57-62.

		BEFORE Observed	AFTER Predicted
(E TP	mg/l	0.019	0.019
(E CHLA	ug/l	4.9	4.9
(E SECCHI	m	3	3
eq chla > 10	% SUMMER	6	6
eq chla > 20	% SUMMER	0	0
eq chla > 30	% SUMMER	0	0
eq chla > 60	% SUMMER	0	0

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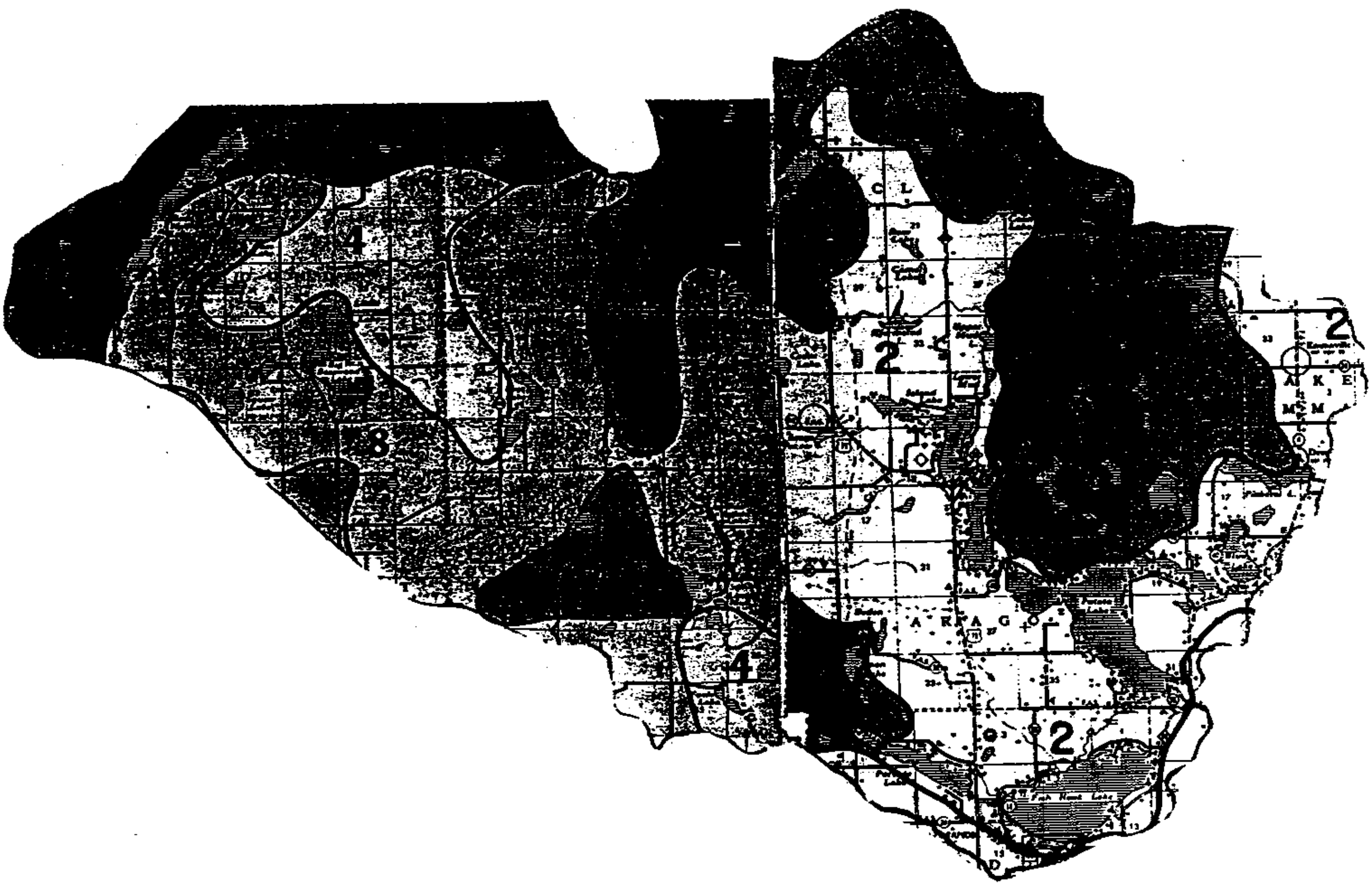
FIGURE 6

FISH HOOK LAKE WATERSHED

General Soils Map



2 MEHAHGA-MARQUETTE ASSOCIATION: Excessively drained,
8 nearly level to steep sandy soils, formed in outwash
sand and gravel under forest vegetation.

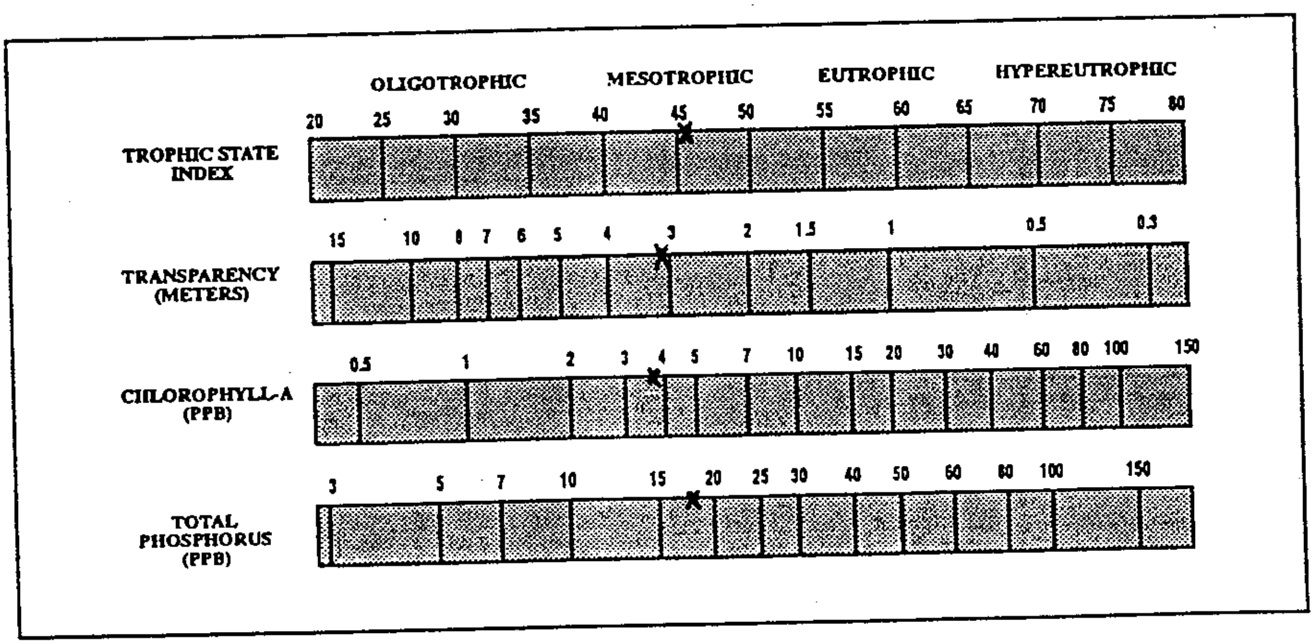
1 NEBISH VARIANT-UNNAMED ASSOCIATION: Well to somewhat
3 excessively drained, gentle sloping to steep loamy and
4 sandy soils, formed in sandy loam till and gravelly
7 sand morainic deposits under forest vegetation.

Figure 7. Trophic Status Index Values for FishHook Lake
TSI Relationships based on mean summer data for 1991.

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.



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

FIGURE 8

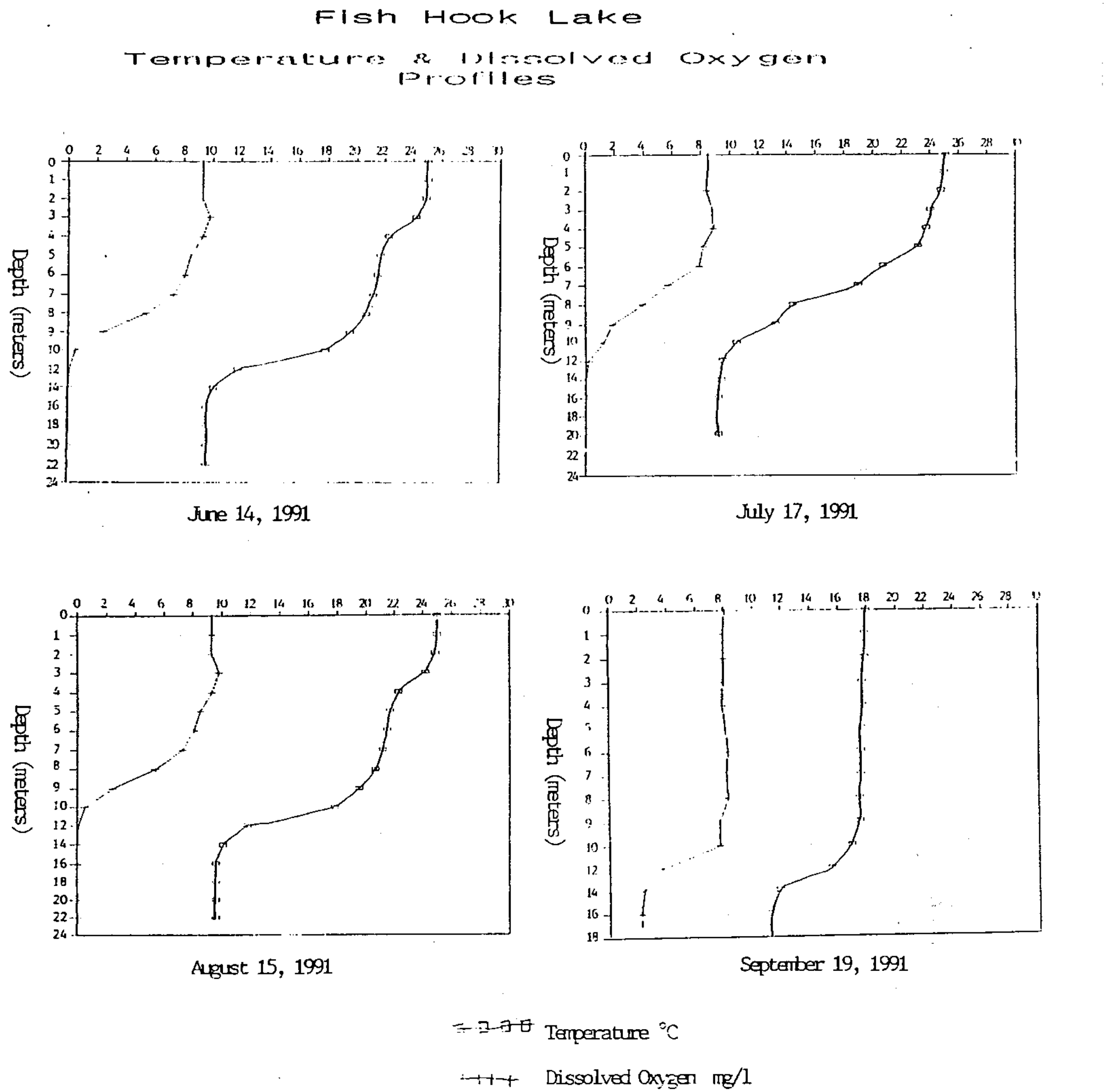
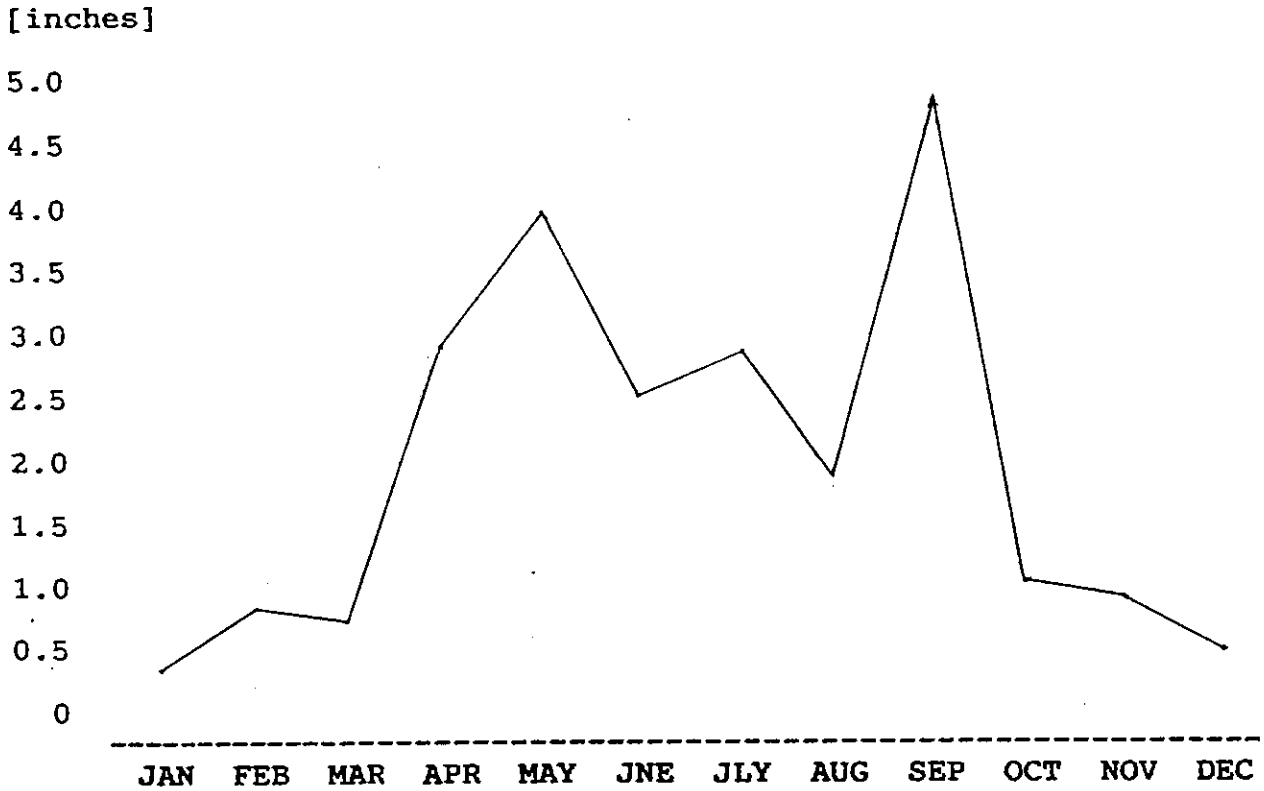

Fish Hook Lake
Temperature & Dissolved Oxygen Profiles
Depth (meters)
June 14, 1991
July 17, 1991
August 15, 1991
September 19, 1991
Temperature °C
Dissolved Oxygen mg/l

FIGURE 9

1991 HUBBARD COUNTY MONTHLY PRECIPITATION TOTALS



* Data from The State Climatology Office, Division of Waters, Minn. Department of Natural Resources.

January	0.41 in.
February	0.92 in.
March	0.78 in.
April	2.99 in.
May	4.07 in.
June	2.46 in.
July	2.94 in.
August	1.87 in.
September	4.67 in.
October	1.12 in.
November	1.08 in.
December	0.62 in.

ANNUAL PRECIPITATION 24.24 in.

FISHHOOK LAKE

ONSITE SEWAGE TREATMENT SYSTEM SURVEY

1991 SURVEY

43 systems were installed since 1980. 39 of these systems contain septic tanks and drainfields. 4 contain septic tanks and seepage pits.

74 systems are pre-1980. 16 of these contain a septic tank and drainfield. The rest of the systems contain cesspools,seepage tanks, or seepage tanks with drainfields.

11 systems are unknown, and 3 people refused the survey.

Data for this survey was collected using a survey sheet that was distributed to property owners. The sheet contained 8 diagrams of systems, and instructed the property owner to choose 1 of the 8 selections that best described their system. No technical assistance was provided in the selection process. In order to validate the results of the survey, extensive research and ground truthing would have to be done.

164 surveys were distributed to property owners on Fishhook Lake. 131 of these were completed for a 79.8% return rate. These results do not give a complete representation of the lake, but they do give a broad overview of the sewage treatment systems that are around the lake.

APPENDIX 2

HISTORY OF FISH HOOK LAKE

COMPILED AND WRITTEN BY CAROLYN SPANGLER

Sources of Information:

Centennial Edition of the **Park Rapids Enterprise**

"**LEST WE FORGET**" A history of Park Rapids commemorating the centennial-1880-1980.

Hubbard County Highway Department

Hubbard County Records Office

DNR

Margaret Nygaard

Lester Sheldon

Harris Walsh

Bob McClelland

Norm Fulton

Harry Jones

Disney's of White City Resort

Pauline Schleicher, granddaughter of Dr. Stone

1871---A Military road skirting the south side of Fish Hook Lake was used by the government for transporting soldiers and supplies from Leech Lake to the White Earth Reservation.

1881--Two years after the first settlers arrived Frank D. Rice, owner of the townsite, named Park Rapids. The park like groves on the second prairie and the rapids on the Fish Hook River, undammed at that time, provided the impetus for the name.

1881--The Rice brothers built the first dam on Fish Hook River west of the foot bridge. The dam powered their rolling stone and grist mill.

1881--The first sawmill, started by Mr. Meyers, was located by the Rice grist mill. The sawmill turned out rough lumber used for window, door frames, floor boards and boards for roofs. When the dam broke in 1885 the lumber mill was destroyed.

1886--A new dam was built where the present dam exists. A new flour and feed mill was built beside this dam.

1885--The dam at Park Rapids was the only developed water power in the county.

1885--A wooden bridge financed by private donations was built across Fish Hook River. (highway 34)

1886--Peter Turnbull settled 40 acres on the northwest of the lake. During this year he received receipt from the government to live on the property before buying in 1887. This property is now the Zinniel farm. A story is told that Zinniel claims that he drove his cattle across the lake near the present boat access before the dam was built. Harry Jones, a retired farmer living on Fish Hook Lake next to the Portage Creek said this story is possible because there is a ridge across the lake covered with 15 feet of water in the area Zinniel claims to have crossed.

1889-The long desired railroad came to Park Rapids.

1890-1910-The "Lottie Lee excursion boat operated on the Fish Hook River.

1890--Logging began in the area when one of the biggest logging companies, the Red River Logging Company, drove pilings for a saw mill in Akeley. In these days Fish Hook lake was used primarily for logging. The Pine Tree Logging company logged Norway and White Pines from acreage near Itasca Park where steam haulers traveling along ice roads carried the huge lumbering logs to ice covered lakes. In the spring a boom was formed around the logs by a circle of logs chained end to end to keep the logs in order and pulled by barge down the rivers and lakes. Men called "river pigs", who were very skilled on their feet, would run on the logs with spiked shoes to break up jammed logs. Logs from the Two Inlets area traveled through Island, Eagle, Potato and Fish Hook Lakes for a destination of Little Falls.

Circa. 1900--The lumber people changed the mouth of Fish Hook River in order for the logs to flow more freely down the river. The mouth originally took a sharp turn and made the transport of logs down the river difficult.

1891--The Eagles Nest Plat was owned by the Northern Pacific

Railroad prior to 1891. In March 1891 it was sold to Frederick Wayerhauser, M. G. Norton and Peter Musser. the corporation was named the Immigration Land Co. of Little Forks, MN. In 1904 the property was sold to J.C. Peabody and in 1914 he surveyed and platted the property and designated it as Eagles Nest. (Areage North of Potato River and part of Peabody bay)

1892-93--A single circular sawmill built by Ellersick and Sons on the east side of the river was later converted to a band mill by new owners, Sawyer and Burnet in 1897. This mill operated until 1911 when it was dismantled.

1892--The Great Northern Brick Company, a company partially responsible for economic growth of the area, bought 40 acres on the east end of the lake from Libby Kindred for $400. Bricks manufactured by the Brick Company were delivered to Park Rapids by river barge. The barge was also used for pumping and hauling sand from the lake to a concrete block plant located on the river. The barge, propelled by a paddle wheel, was turned by a four cylinder gasoline engine.

1892--The Timber Act made possible the purchase of land and tree removal to lumber companies. Timber land was purchased for $1.25-$2.50 an acre.

1896--A Homestead Patent of 145 acres NE and NW of Portage Creek on the west of Fish Hook Lake was sold to Henry and Harriet Rose. One of two farms on the lake changed ownership several times until Harry Jones, present owner, bought the farm (excluding part of the original property: the Pine Park

Acreage) from his parents for $2000 in 1945.

1901-1918--Logging days--at times the entire surface of the lake was covered with logs.

1902--Dr. Stone built the first hospital in Park Rapids, on the site of the present Park Terrace. Known as Park Sanitarium, the wooden building burned on Christmas Day and was replaced by a brick structure in 1903 according to Pauline Schleicher, grandaughter of Dr. Stone. While the hospital was being built, Dr. Stone secured the Germania Hall on North Park Avenue as a temporary hospital. The hospital later became the Rainbow Inn, a club house or resort where per person weekly rates were $5 or $1 per night. The Rainbow Inn was named for the Rainbow Division in which Herbert Stone, a son of Dr. Stone, served during WWI. Sons of Dr. Stone A. W. and Herbert managed the Inn. The property was in the Stone family until 1962.

Dr. Stone also operated a health sanitarium on a 45 acre plot now owned by the Methodist Church Northern Pines Campground. The lake resort consisted of three buildings: a lodge, a girl's dormitory and one cabin. These were used to house patients from his hospital in Park Rapids who were recuperating and other guests. Cottages rented for $1 a day, $20 a month or $ 50 a season. Dr. Stone sold his sanitarium for $4000 to a group of Methodist ministers and laymen who were looking for a campsite to serve people of the districts in a camping program. The church then sold lots to ministers, laymen and churches to pay back money borrowed to pay for the property. Lots were sold for $100 to $200. In later years some of the lots were given back or sold back to the Assembly Grounds.

--Margaret Nygaard, a Park Rapids resident since 1904, says a road existed next to the lake on the south side across from Deane Park. Folk lore from logging days indicates the road may be a remnant of a road around the lake used to transport loggers and supplies to supply boats, or Wannigans in peak logging years. The existing road, built during Franklin Roosevelt's Work Progress Administration project, is between the cabins and Deane Park.

1908--At the peak of logging activity, 4 or 5 thousand men were employed in the woods.

1912--the bridge across Fish Hook River (highway 34) was replaced by a steel bridge with plank flooring. The clatter of the loose planks could be heard in the quiet of summer evenings, and became known as a "rattling good bridge".

1914--A launch service was provided to carry supplies, fishermen and passengers to local lakes. A Page from the log book of Captain Oscar Thomas says it took seven hours to travel from Fish Hook Lake to Island Lake for a day excursion. The journey cost $5 for 7 people.

1917--Bill Taber gave property on Fish Hook River to the city in memory of his son Deane, who died during WWI.

Circa. 1918---After rampant and indiscriminate logging depleted the big logs of Norway and White Pine, river and lake logging ended and the big saw mill on the river was dismantled.

1920--After the cessation of big tree logging, the industry changed. Small logging companies started logging smaller trees such as Jackpine and Birch and moving around the area with their own mills after milling three or four-hundred thousand feet of lumber. A process called dead-heading where drowned logs were picked out of the water by barge became popular. This was not profitable and didn't last long. The saw mills on the river were used by farmers or local loggers who brought their logs by truck for cutting into rough lumber in later years. The logging industry still brightens the economy of Park Rapids, and logs are now sold for studs and planks. Potlatch owns much of the logging land in the area.

1923-Fred Fulton bought the Fish Hook Resort, now White City, on the lake, from a Mr. Knap. Fulton added the dance hall, restaurant and eventually 15 cabins for tourists. The resort was a popular place in Big Band days when an 8 piece band entertained locals two nights a week. This is the only resort that exists today on Fish Hook Lake. Fulton sold the resort in 1947.

1928-29-30--A box factory across from the present Heartland Park on Fish Hook River provided jobs for local people.

Circa. 1930s-- When Mrs. Higgs, who owned one of the first cabins on the lake wanted to sell her property on the east shore for $3.75 a front foot people thought she was crazy to sell for so much.

1933--When a wider more heavily constructed bridge was constructed over the Fish Hook River (highway 34) there was opposition to the large amount of fill used to shorten the span.

1937--Permits were required to fill public wetlands. Wetlands on Fish Hook Lake filled before 1976 were not considered public wetlands and allowed to fill.

1938---The dam on Potato River was built by highway 18 as a Work Progress Administration project.

1938 and 1940--County Road 18 on the west end of the lake was moved into the lake to straighten out the original curvy and dangerous road. The new road was filled with 30 ft of dirt cut from a nearby hill. Horses pulled rail ore cars to the dirt pit to be filled with two tons of dirt, and then it rolled down to the lake with a brake man riding in back to stop the car. Being a winter project, the pit was covered with straw on weekends to prevent freezing and dynamite was used to break up again if needed. The construction was done by Work Progress Administration project instituted during Franklin Roosevelt's administration to employ men for little money. The road originally had water on either side, but homeowners on the road have filled in the area between their lawns and the road.

1940--Matt Michaels sold his farm (one of two on lake) to Harry Jones (present owner) father. The foundation of the present Jones house is made from hand-hewn logs.

1940-1945-During WW11--Barges roamed the lake searching for sunken logs to be hoisted out for lumbering. It was usually the but cut--the best part of a log that sank while being driven down the lake during logging days. Logs were grabbed from the bottom of the lake with ice pik like grappling hooks and then towed to shore to be milled into lumber.

1945 and after WW11---Tourism opened up in Hubbard with the advent of bulldozers to the area and the building of roads. Without bulldozers and heavy equipment, access to lakes was difficult. Before this time lake cottage owners were local people.

1950's-A 50 foot bank was bulldozed to build homes on the North side of the lake.

1976 (circa)--The core of engineers formulated regulations that required permits to fill in wetlands of certain characteristics.

1976---Hogs from a local farm bathed in Portage creek.

1991--A mobile home park was built on property south of the lake and across from the Heartland Gold Course. Originally a wetland, this property was filled in the early 1970's.

1991---Fishing in Portage creek is almost impossible with the rampant weed growth, unlike the 40's when boats easily trolled the clear creek.

1991---The Wetland Conservation Act enacted state laws designed to protect wetlands not covered under previous regulations.

1992-- Can still see logs in bottom of lake in Peabody Bay on the North side of the lake.

--A New dam was built in the summer of 1982. The dam broke in October 12 of '82 after heavy rains and the upper river receded 10 feet. (unofficial footage) Soome say one million dollars worth of damage was done but the dam was repaired by October 16.

--Flour mill stones were discovered in the river near the city park when the new dam was being built. They had been left in the bottom of the river with the destruction of the mill and probably covered naturally over the years. The mill stones can be seen at the Hubbard County Historical Society.

--The housing development property North of White City Resort was once a wetland and cow pasture. This was filled in during the '60's.

---While the plan was to build an amphitheater by Heartland Park, an abundance of saw dust on the bank north of the foot bridge deemed the project unsafe and impossible. This is near where a planer and saw mill existed in the early 1900's and an estimated 100,000 feet of lumber travelled through the mills each day. The planer mill continued operation until 1935.

---Albert's Bay was one of the first resorts on the lake.

YR=91

Variable	N	Mean	Std Dev	Minimum	Maximum
TP	10	0.0227000	0.0194082	0.0080000	0.0610000
TKN	4	0.4275000	0.0298608	0.3900000	0.4600000
N2N3	2	0.0300000	0.0282843	0.0100000	0.0500000
CHLA	12	3.5041664	1.7012959	1.0000000	6.0599992
COLOR	2	10.0000000	0	10.0000000	10.0000000
SD	8	3.3249996	0.8310923	2.0999998	4.6999998
SDF	8	10.9125000	2.7189481	8.9500000	15.4500000
TSS	2	2.1999998	0.2828424	2.0000000	2.3999996
TSIN	2	0.9000001	0.1414212	0.8000002	1.0000000
PH	0	.	.	.	.
PHF	6	7.8999998	0.5019962	7.3999996	8.5000000
CL	2	1.6499996	0.0707109	1.5999994	1.6999998
COND	1	270.0000000	.	270.0000000	270.0000000
CONDF	0	.	.	.	.
ALK	2	140.0000000	14.1421356	130.0000000	150.0000000
TURB	2	1.8499999	0.2121322	1.6999998	2.0000000

FISH HOOK LAKE WATER QUALITY DATA. All data stored in STORET under MPCA code.
LAKEID=29-0242

DATE	SITE	D	TP	RTP	TKN	N2N3	RN2N3	TSS	TSIN	ALK	PHF	CL	COND	CONDF	TURB	COLOR	CHLA	PHEO	SDF
910514	101	0	.024		0.35	0.03		3.0	1.0	170	.	1.9	280	.	1.5	10	2.16	.	11.0
910514	101	65	.034		0.59	0.04		.	.	.	.	.	.	.	.	.	.	.	.
910514	102	0	.010		0.62	0.02		3.6	1.6	160	.	1.9	280	.	1.8	10	1.76	.	10.4
910514	102	39	.033		0.56	0.02		.	.	.	.	.	.	.	.	.	.	.	.
910514	14801	3	.019		.	.		.	.	.	.	.	.	.	.	.	4.00	.	.
910514	14801	72	.052		.	.		.	.	.	.	.	.	.	.	.	.	.	.
910514	14802	3	.023		.	.		.	.	.	.	.	.	.	.	.	3.00	.	.
910614	14801	3	.008		.	.		.	.	.	7.7	.	.	.	.	.	3.00	.	15.4
910614	14801	65	.034		.	.		.	.	.	.	.	.	.	.	.	.	.	.
910614	14802	3	.009		.	.		.	.	.	7.9	.	.	.	.	.	2.00	.	15.1
910717	101	0	.017		0.44	0.01	K	2.4	1.0	130	.	1.7	270	.	2.0	10	3.89	0.23	9.5
910717	101	62	.017		0.62	.		.	.	.	.	.	.	.	.	.	.	.	.
910717	102	0	.015		0.46	.		.	.	.	.	.	.	.	.	.	2.98	0.23	10.5
910717	14801	3	.013		.	.		.	.	.	.	.	.	.	.	.	6.00	.	.
910717	14801	65	.035		.	.		.	.	.	.	.	.	.	.	.	.	.	.
910717	14802	3	.014		.	.		.	.	.	.	.	.	.	.	.	3.00	.	.
910919	101	0	.061		0.42	.		.	.	.	8.5	.	.	.	.	.	6.09	0.64	9.2
910919	102	0	.057		0.39	0.05		2.0	0.8	150	8.5	1.6	.	.	1.7	10	6.09	0.96	9.2
910919	102	45	.070		0.52	.		.	.	.	.	.	.	.	.	.	.	.	.
910919	14801	3	.018		.	.		.	.	.	.	.	.	.	.	.	3.00	.	.
910919	14802	3	.015		.	.		.	.	.	.	.	.	.	.	.	3.00	.	.

The SAS System

SITE=14801

OBS	DATE	D	NDM	DO	TEMP
39	910514	3	-1	.	.
40	910514	72	-22	.	.
41	910614	0	0	9.2000	22.3000
42	910614	3	-1	9.3000	22.0000
43	910614	6	-2	9.8000	21.6000
44	910614	9	-3	9.4000	21.6000
45	910614	13	-4	10.4000	19.8000
46	910614	16	-5	10.7000	18.6000
47	910614	19	-6	10.6000	18.2000
48	910614	22	-7	8.2000	17.4000
49	910614	26	-8	8.8000	16.6000
50	910614	29	-9	8.5000	15.5000
51	910614	32	-10	8.3000	15.2000
52	910614	39	-12	7.3000	14.5000
53	910614	45	-14	6.0000	14.0000
54	910614	52	-16	5.3000	12.3000
55	910614	59	-18	5.3000	10.3000
56	910614	65	-20	2.9000	9.9000
57	910614	65	-20	.	.
58	910717	3	-1	.	.
59	910717	65	-20	.	.
60	910814	0	0	9.3000	25.0000
61	910814	3	-1	9.3000	25.0000
62	910814	6	-2	9.3000	24.9000
63	910814	9	-3	9.8000	24.2000
64	910814	13	-4	9.3000	22.3000
65	910814	16	-5	8.5000	21.7000
66	910814	19	-6	8.1000	21.5000
67	910814	22	-7	7.3000	21.2000
68	910814	26	-8	5.4000	20.7000
69	910814	29	-9	2.4000	19.5000
70	910814	32	-10	0.5000	17.8000
71	910814	39	-12	0.1000	11.8000
72	910814	45	-14	0.0000	10.1000
73	910814	52	-16	0.0000	9.6000
74	910814	59	-18	0.0000	9.6000
75	910814	65	-20	0.0000	9.6000
76	910814	65	-20	.	.
77	910814	72	-22	0.0000	9.7000
78	910814	78	-24	0.0000	9.9000
79	910919	3	-1	.	.

Dear Data Gatherers and Users,

The data listed here were received and put into computer file by the State Climatology Office on or before 03-28-1992. Hopefully, these data will be beneficial to the individual locations who provide the observations as well as provide a weather history for your area, town, or county.

1991 HUBBARD Monthly Precipitation, Totals

TTTRRSSN	OOOOOOO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AGR	HYD	ANN	GRO
13932 87	GACK HER				3.12	3.70	2.97	3.77	2.24	4.09	0.93						16.77
13933167	NASENIUS				2.82	3.42	2.92	2.34	1.54	4.19	0.56						14.41
13934 37	BRANHAM				2.39	5.10	2.84	2.33	1.49	3.68	0.73	0.91	0.31				15.44
13934297	RUYRODEN					4.51	3.04	1.93	1.74	4.17							15.39
13935148	UDEAN VI	0.33	0.82	0.84	3.45	4.65	2.52	2.51	2.04	5.02	1.14	0.81	0.53	22.92	26.89	24.66	16.74
13935157	HOEFS ED	0.95	1.50	0.70	3.65	4.60	2.60	1.65	2.08	5.25	1.20	1.35	0.70	24.27	28.44	26.23	16.18
14033 27	ALDEN WM				3.00	3.97	2.49	3.09	1.88	4.53							15.96
14033288	JAMES JE	0.38	0.80	0.81	2.89	3.49	2.59	2.95	1.76	4.31	1.02	1.58	0.74	21.77	24.86	23.32	15.10
14034 27	BERRY LY				3.35	4.35	2.42	3.47	1.58	4.22	1.12						16.04
14034237	KRUFT E	0.36	0.76	0.62	3.35	4.26	2.24	2.33	1.64	3.97	1.00	1.25	0.44	22.19	24.69	22.22	14.44
14034317	JOHNSRUD				3.72	5.07	2.53	2.50	1.64	5.54	1.26						17.28
14035 98	PETERSON	0.23	0.82	0.96	3.14	4.14	2.84	1.49	1.90	3.88	0.84	0.87	0.37	21.27	24.17	21.48	14.25
14035231	PARK RAP	0.31	0.87	0.84	3.39	4.06	2.64	2.36	1.53	5.04	1.31	0.86	0.45	21.84	25.88	23.66	15.63
14035232	PARK RAP	0.27	0.50	0.52	3.43	4.25	2.67	2.46	1.50	5.01		0.57	0.52	21.12	24.97		15.89
14035267	GLATZMAI				2.72	3.84	1.94	2.98	1.41	4.69	1.08						14.86
14132207	KRAMER N					3.66	1.90	4.60	2.03	5.33							17.52
14132248	MARTIG M						2.10	3.20	1.97	5.13							
14135197	GARTNER				2.81	4.67	2.30	2.65	2.45	3.52	1.29						15.59
14232 48	SNEBY RO	0.36	0.63	1.31	1.76	4.91	1.40	3.25	1.59	5.43	1.34	0.86		22.17	25.46		16.58
14233297	FISHER					2.50	1.80	3.53	1.49	5.38	1.28						14.70
14235177	MITCHELL	0.24	0.89	0.74	2.97	5.01	1.25	3.51	1.80	3.87	1.23	0.94	0.74			23.19	15.44
14332 37	SCHMIDT	1.00	1.40	0.85	2.60	3.72	1.28	2.93	2.14	5.52	1.32	1.30	1.30	24.65	27.86	25.36	15.59
14334 27	LESSMAN				3.15	4.58	2.88	3.38	1.25	4.64	1.23						16.73
14433147	DAVIS TO				2.49	3.36	2.38	3.61	1.47	5.89							16.71
14433291	GUTHRIE	0.14	0.96	0.66	3.07	4.05	3.89	3.05	2.30	5.57	1.43	1.26	0.52	27.14	31.12	26.90	18.86
14533127	HOFF ART	0.40	1.07	0.46	2.34	3.80	2.68	3.27	3.52	4.49	1.09	1.46	0.81	24.14	26.84	25.39	17.76
14534 67	DIFFLEY				3.05	2.20	3.42	4.14	2.38	3.73	1.20						15.87
county averages		0.41	0.92	0.78	2.99	4.07	2.46	2.94	1.87	4.67	1.12	1.08	0.62	23.04	26.47	24.24	15.99
# of obs		12	12	12	23	26	27	27	27	27	21	13	12	11	11	10	26

Abbreviations denote the following: CC=county #; TTT=township #; RR=range #; SS=section #; N=network #
(networks: 1 = Minn DNR Forestry; 2 = National Weather Service; 3 = Metro Mosquito Control; 4 = Back Yard Rain Gauge; 5 = Future Farmers of America;
6 = KSTP-TV; 7 = Soil & Water Conservation Districts; 8 = Deep Portage Conservation Reserve, Minnesota Association of Watersheds, Minnesota Power & Light)
JAN-DEC = monthly total precipitation; AGR = agricultural year (Sep 90 thru Aug 91) precip; HYD = hydrologic year (Oct 90 thru Sep 91) precip;
ANN = annual (Jan 91 thru Dec 91) precip; GRO = growing season (May 91 thru Sep 91) precip;

Prepared by: The State Climatology Office, Division of Waters, Minn DNR.
For further information contact Jim Zandlo or Greg Spoden at 612-296-4214

APPENDIX 5

MDNR FISHERIES SUMMARY FROM SWIM

PHYSICAL CHARACTERISTICS FOR LAKE: FISH HOOK

Dominant forest/soil type: CONIFER/SAND
Size of lake: 1432 Acres   Shorelength: 7.0 Miles.
Maximum depth: 80.0   Median depth: 26.0

Minnesota Pollution Control Agency   Data from 1983-1989
Secchi disk reading (water clarity): 9.7 feet.
Lake contour map number: B0131 (available at cost from Documents Division)
(phone: 612-297-3000)

DEVELOPMENT CHARACTERISTICS FOR LAKE: FISH HOOK

Shoreland zoning classification: GENERAL DEVELOPMENT
Public accesses in 1988: 3

Development	Seasonal Homes	Permanent Homes	Total Homes
1967	74	53	127
1982	81	90	171

*** PUSH RETURN TO CONTINUE ***

DNR SECTION OF FISHERIES INFORMATION FOR LAKE FISH HOOK

WATER CHEMISTRY   SURVEY DATE: 07/05/1988

Secchi disk: 7.0
Water color: DARK GREEN   % Littoral: 41
Cause of water color: ALGAE

LAKE DESCRIPTION

Surface water area: 1632
Management class: WALLEYE-CENTRARCHID
Ecological type: CENTRARCHID-WALLEYE

Accessibility: VILLAGE OWNED IN SEC. 14, SOUTH SHORE, ALSO
HEARTLAND PARK, LOCATED ON RIVER.

Area fisheries supervisor: DENNIS ERNST   (218) 732-4153
301 S. GROVE AVE   PARK RAPIDS   56470

*** PUSH RETURN FOR CATCH DATA ***

NET CATCH DATA

GILL NETS   No. of sets: 6   Gill net survey date: 7/05/1988

species	# fish	# per set	total pounds	pounds per set
Northern Pike	69	11.5	171.50	28.58
White Sucker	20	3.3	30.80	5.13
Shorthead Redhorse	2	0.3	4.20	0.70
Black Bullhead	3	0.5	3.30	0.55
Yellow Bullhead	8	1.3	6.40	1.07
Rock Bass	32	5.3	10.70	1.78
Pumpkinseed Sunfish	20	3.3	3.70	0.62
Bluegill Sunfish	33	5.5	3.80	0.63
Largemouth Bass	8	1.3	12.20	2.03
Black Crappie	1	0.2	0.10	0.02
Yellow Perch	14	2.3	1.60	0.27
Walleye	25	4.2	36.60	6.10

*** PUSH RETURN FOR TRAP DATA ***

TRAP NETS No. of sets: 15 Trap survey date: 7/05/1988

species	# fish	# per set	total pounds	pounds per set
Northern Pike	2	0.1	5.60	0.37
Black Bullhead	2	0.1	1.10	0.07
Yellow Bullhead	16	1.1	9.80	0.65
Rock Bass	23	1.5	8.00	0.53
Pumpkinseed Sunfish	57	3.8	7.10	0.47
Bluegill Sunfish	944	62.9	101.50	6.77
Largemouth Bass	32	2.1	4.20	0.28
Black Crappie	1	0.1	0.10	0.01
Yellow Perch	4	0.3	0.30	0.02
Walleye	1	0.1	4.20	0.28

*** PUSH RETURN FOR FISH COMMENTS ***

FISH POPULATION COMMENTS

GILLNET CATCH COMPARED TO REGIONAL AVERAGE ARE FOR NORTHERN PIKE 11.5 COMPARED TO 4.18 REGIONAL

More (Y/N):

FISH POPULATION COMMENTS cont.

AVERAGE, WALLEYE 4.17 COMPARED TO 4.09 AVERAGE. YELLOW PERCH 2.33 COMPARED TO 16.50 AVERAGE. WHITE SUCKER HIGH AT 3.33 COMPARED TO 1.83 AVERAGE. TRAP NET CATCH COMPARED TO REGIONAL AVERAGE WAS: BLUE-GILL WAS 62.93 COMPARED TO 15.25 AVERAGE, BLACK CRAPPIE LOW AT .07 COMPARED TO 1.49 AVERAGE. LARGEMOUTH BASS 2.13 COMPARED TO 0.80 AVERAGE.

*** PUSH RETURN FOR STOCKING DATA ***

FISH STOCKING DATA

year	species	size	# released
80	Walleye	FRY	1066000

80	Walleye	YEARLING	2070
80	Walleye	FINGERLING	4320
81	Walleye	FRY	800000
81	Walleye	FINGERLING	18500
82	Walleye	FRY	450000
82	Northern Pike	ADULT	200
83	Northern Pike	YEARLING	1560
83	Northern Pike	ADULT	67
84	Walleye	FINGERLING	13275
85	Walleye	FRY	585250
86	Walleye	FINGERLING	9654
88	Walleye	FINGERLING	6792
90	Walleye	FINGERLING	8400

*** PUSH RETURN FOR PERMIT DATA ***

PERMIT DATA FOR LAKE FISH HOOK

SUMMARY OF DNR PERMIT
APPLICATIONS ISSUED OR DENIED AS OF MAY 1990 FOR LAKE: FISH HOOK

PERMIT TYPES:	NUMBER ISSUED	NUMBER DENIED
PUBLIC (PROTECTED) WATERS PERMITS		
Pipeline	1	0
Structural Encroachment	1	0
Excavation	18	1
Shore protection	1	0
GENERAL APPROPRIATION PERMITS		
Irrigation	1	1

Enter the report or MENU:

FISHHOOK LAKE WATERSHED LANDUSE 1990

APPENDIX 6

```
'ee memory = 500272 bytes.
mmand: cou 1 fishhook hubluse
unt output file:
unt of C:\EPPL7\WATERSHD\FISHHOOK.EPP
TIRE FISHHOOK WATERSHD 10M
```

lass	Count	Percent	Cumulative	Area	Legend
1	3950962	73.37	73.37	97628.271	FOREST
2	382640	7.11	80.48	9455.034	CULTIVATED
3	455031	8.45	88.93	11243.816	WATER
4	183756	3.41	92.34	4540.611	MARSH
5	103130	1.92	94.25	2548.342	URBAN/RESIDENTIAL
7	290837	5.40	99.65	7186.582	PASTURE/OPEN
8	7205	0.13	99.79	178.036	URBAN/NON RESIDENTIAL
9	10300	0.19	99.98	254.513	TRANSPORTATION
10	658	0.01	99.99	16.259	ACTIVE FEEDLOT
12	445	0.01	100.00	10.996	ABANDONED FEEDLOT

```
 5384964 cells are onsite.
 5806194 cells are offsite.

mmand:
HELP - general help      ? - prompt specific help      MENU - menu mode
```

FISHHOOK SUB-WATERSHED LANDUSE 1990

memory = 436560 bytes.
and: COU 1 FISHSUB HUBLUSE
t output file:
t of C:\EPPL7\WATERSHD\FISHSUB.EPP
hook subwatrshd luse 10m

ss	Count	Percent	Cumulative	Area	Legend
1	363521	59.21	59.21	8982.6039	FOREST
2	68308	11.13	70.34	1687.8907	CULTIVATED
3	87929	14.32	84.66	2172.7256	WATER
4	30328	4.94	89.60	749.4049	MARSH
5	22142	3.61	93.21	547.1288	URBAN/RESIDENTIAL
7	37126	6.05	99.25	917.3835	PASTURE/OPEN
8	3495	0.57	99.82	86.3614	URBAN/NON RESIDENTIAL
10	658	0.11	99.93	16.2592	ACTIVE FEEDLOT
12	421	0.07	100.00	10.4029	ABANDONED FEEDLOT

613928 cells are onsite.
610212 cells are offsite.

and:
LP - general help ? - prompt specific help MENU - menu mode

Glossary

Acid Rain: Rain with a higher than normal acid range. Caused when polluted air mixes with cloud moisture. Can make lakes devoid of fish.

Algal Bloom: An unusual or excessive abundance of algae.

Alkalinity: Capaçity of a lake to neutralize acid.

Bioaccumulation: Build-up of toxic substances in fish flesh. Toxic effects may be passed on to humans eating the fish.

Biomanipulation: Adjusting the fish species composition in a lake as a restoration technique.

Ecosystem: A community of interaction among animals, plants, and microorganisms, and the physical and chemical environment in which they live.

Epilimnion: Most lakes form three distinct layers of water during summertime weather. The epilimnion is the upper layer and is characterized by warmer and lighter water.

Eutrophication: The aging process by which lakes are fertilized with nutrients. **Natural eutrophication** will very gradually change the character of a lake. **Cultural eutrophication** is the accelerated aging of a lake as a result of human activities.

Eutrophic Lake: A nutrient-rich lake — usually shallow, "green" and with limited oxygen in the bottom layer of water.

Fall Turnover: Cooling surface waters, activated by wind action, sink to mix with lower levels of water. As in spring turnover, all water is now at the same temperature.

Hypolimnion: The bottom layer of lake water during the summer months. The water in the hypolimnion is denser and much colder than the water in the upper two layers.

Lake Management: A process that involves study, assessment of problems, and decisions on how to maintain a lake as a thriving ecosystem.

Lake Restoration: Actions directed toward improving the quality of a lake.

Lake Stewardship: An attitude that recognizes the vulnerability of lakes and the need for citizens, both individually and collectively, to assume responsibility for their care.

Limnetic Community: The area of open water in a lake providing the habitat for phytoplankton, zooplankton and fish.

Littoral Community: The shallow areas around a lake's shoreline, dominated by aquatic plants. The plants produce oxygen and provide food and shelter for animal life.

Mesotrophic Lake: Midway in nutrient levels between the eutrophic and oligotrophic lakes.

Nonpoint Source: Polluted runoff — nutrients and pollution sources not discharged from a single point: e.g. runoff from agricultural fields or feedlots.

Oligotrophic Lake: A relatively nutrient-poor lake, it is clear and deep with bottom waters high in dissolved oxygen.

pH Scale: A measure of acidity. (See diagram on page 5.)

Photosynthesis: The process by which green plants produce oxygen from sunlight, water and carbon dioxide.

Phytoplankton: Algae — the base of the lake's food chain. it also produces oxygen.

Point Sources: Specific sources of nutrient or polluted discharge to a lake: e.g. stormwater outlets.

Profundal Community: The area below the limnetic zone where light does not pentrate. This area roughly corresponds to the hypolimnion layer of water and is home to organisms that break down or consume organic matter.

Respiration: Oxygen consumption

Secchi Disc: A device measuring the depth of light penetration in water.

Sedimentation: The addition of soils to lakes, a part of the natural aging process, makes lakes shallower. The process can be greatly accelerated by human activities.

Spring Turnover: After ice melts in spring, warming surface water sinks to mix with deeper water. At this time of year, all water is the same temperature.

Thermocline: During summertime, the middle layer of lake water. Lying below the epilimnion, this water rapidly loses warmth.

Trophic Status: The level of growth or productivity of a lake as measured by phosphorus content, algae abundance, and depth of light penetration.

Water Density: Water is most dense at 39°F and expands (becomes less dense) at both higher and lower temperatures.

Watershed: The surrounding land area that drains into a lake, river or river system.

Zooplankton: Microscopic animals