HIGGINS LAKE
GERRISH AND LYON TOWNSHIPS
ROSCOMMON COUNTY, MICHIGAN

1998 WATER QUALITY AND BOTTOM SEDIMENTS STUDY

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HIGGINS LAKE, GERRISH AND LYON TOWNSHIPS, ROSCOMMON COUNTY 1998

DESCRIPTION AND LOCATION

Higgins Lake is a 10,480-acre moderately hard-water 135-foot-deep kettle lake located in Sections 5, 6, 7, 8. 9. 10, 17, 18, 20; 21, 27, 8, 29, 32, 33 and 34, Gerrish Township (T24N R3W) and Sections 1, 2, 3, 10, 11, 12, 13, 14, and 15, Lyon Township (T24N R4E) Roscommon County, Michigan. (See location map.)

The lake has a single island, Flynn's Island, which is about 30 acres. Hence the surface area of the lake is about 10,450 acres. The lake, which consists of a 3421-acre 100-foot-deep southeast basin, and a 7056-acre 135-foot-deep west basin, has a water volume 571577 acre feet. (See Hydrographic and sample station map.)

The mean depth (lake volume divided by surface area) is 54.6 feet. The lake has 111,981 feet of shoreline. The surface elevation of the lake is 1154 feet above sea level.

The size of the watershed, which is the land area which contributes water to the lake, but does not include the lake, is 23,806 acres. The drainage area, which includes the watershed and the lake, is 32,486 acres. The watershed to lake ratio is 2.27 to 1, which is on the low side of normal for a Michigan inland lake.

The drainage area map on the enclosed Atlas pages is a line drawing for good reason. To determine the watershed boundaries on any map, enlarge or reduce the size of the line drawing until the lake is the same size as that on the map being used, then make a transparency of the drainage area map. Overlay the drainage area lake figure on the map being used, and make a copy of the map with the transparency overlay. This will provide a map with drainage area boundaries on it.

The lake flushes once every 21.5 years on an average. This also means the lake only gets rid of about 5 percent of the nutrients which enter the lake each year. This means residents need to be careful about what they add to the near lake soils and the lake itself.

There are no inlets. The outlet is located on the east end of the lake.

The approximate location of the 135-foot deep hole in the west basin is latitude (44° 29.845N) and longitude (84° 45.836W).

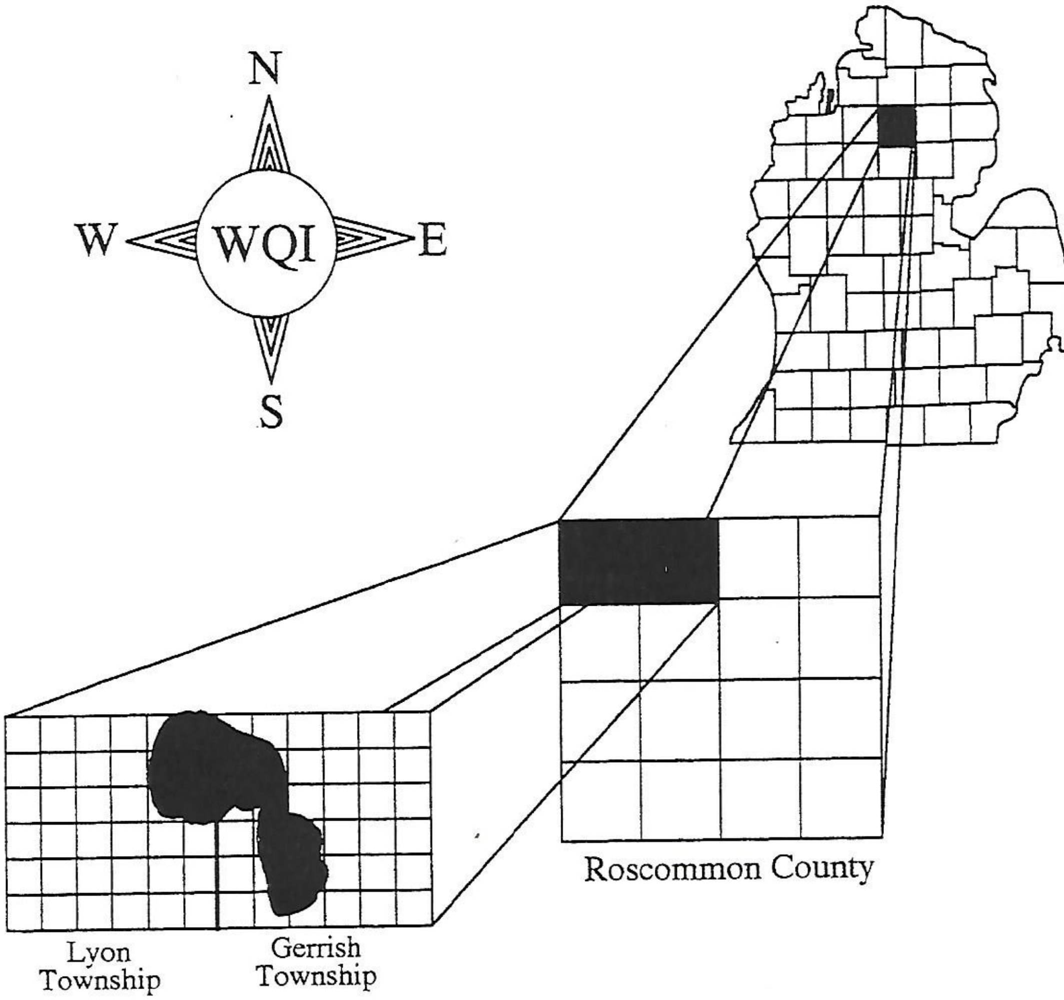
Higgins Lake

1998 Water Quality and Bottom Sediments Study

Errata Page, Prepared by HLPOA

(Refer to Page 1 of the Study)

- Title: Higgins Lake is partially contained in Beaver Creek Twp, Crawford County, MI
- Line 1: The total acreage of Higgins Lake, per the Fisheries Div of the MI DNR, is 9,600 acres
- Line 8: Flynn Island is known today as Treasure Island
- Line 17: The surface elevation (Legal Level) is 1,154.11 feet above sea level
- Line 43: Known inlets include Big Creek and Little Creek



LOCATION MAP

Higgins Lake
Many Sections
Gerrish Township
T24N R3W &
Lyon Township
T24 R4W
Roscommon County

FUSILIER'S ATLAS
AND GAZETTEER
OF MICHIGAN LAKES
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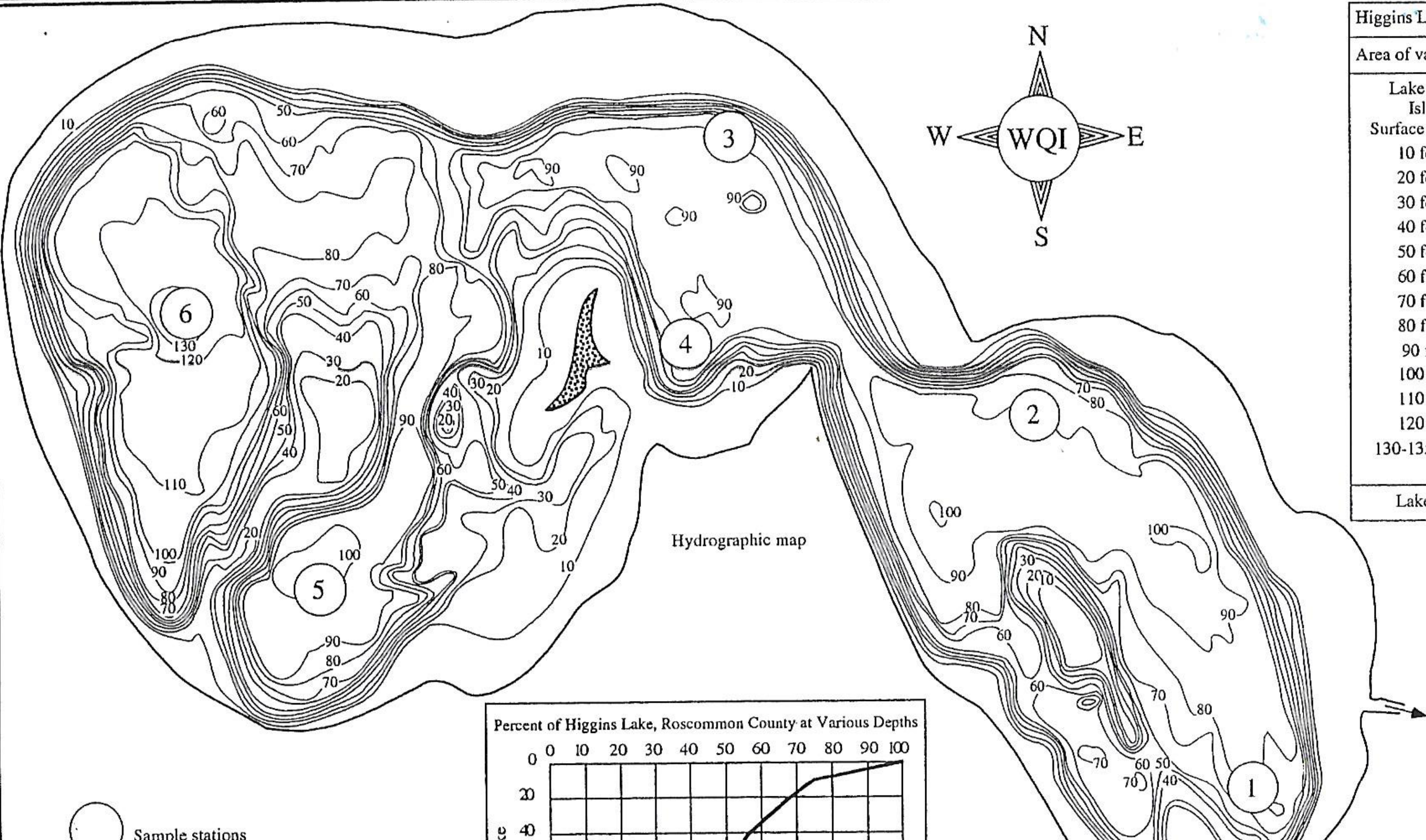
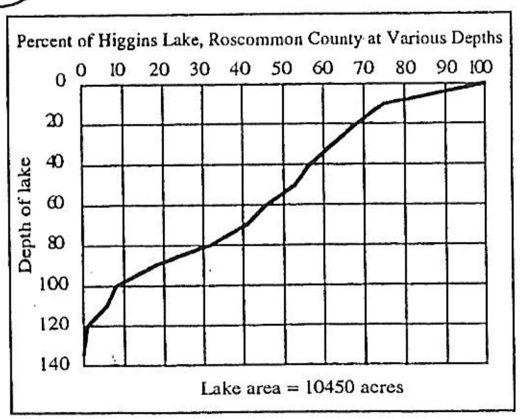


Higgins Lake Contour Areas And Volumes	
Area of various contours	Volume in Acre Feet
Lake area = 10480 acres	
Island area = 30 acres	
Surface area = 10450 acres	91491
10 feet = 7848.25 acres	74890
20 feet = 7129.71 acres	68570
30 feet = 6584.22 acres	62790
40 feet = 5973.73 acres	57820
50 feet = 5590.29 acres	51797
60 feet = 4769.09 acres	45477
70 feet = 4326.25 acres	38333
80 feet = 3340.41 acres	52655
90 feet = 1925.14 acres	14003
100 feet = 875.42 acres	7344
110 feet = 593.30 acres	4047
120 feet = 216.09 acres	1267
130-135 feet = 37.23 acres	93
Lake volume = 571577 acre feet	



Hydrographic and Sample Station Map

Higgins Lake
Many Sections
Gerrish Township
T24N R3W &
Lyon Township
T24 R4W
Roscommon County

THE 1998 WATER QUALITY AND BOTTOM SEDIMENTS STUDY

During certain periods of the year, Michigan lakes have poorer water quality than the remainder of the year. The water quality sampling in this study is designed to look at two of those poor water quality periods, one in early spring when phosphorus which may be released from the bottom sediments is distributed throughout the water column by spring mixing, and a second in late August when the water is warmest, and the lake is stratified (if it stratifies). During most of the remainder of the year, the water quality is better. Thus if the lake gets high marks for water quality during early spring and late summer, it probably has pretty good water quality all year long.

THE SAMPLE STATIONS

The water quality samples were taken from six in-lake sites, shown on the map (above), and were selected as being representative of larger portions of the lake.

Summer top to bottom temperature and dissolved oxygen measurements were taken at various intervals at the 135-foot deep hole to determine if a thermocline occurred, and if dissolved oxygen depletion occurred in the deep water.

SAMPLING DATES

No samples were collected in spring.

Six summer surface samples were collected September 10, 1998 to detect possible high chlorophyll a concentrations, shallow Secchi disk transparencies and bottom water (hypolimnetic) dissolved oxygen depletion which may occur during this period. Bottom sediment samples were collected at the same stations at this time.

THE ANALYSES

In late summer, dissolved oxygen, temperature, and Secchi disk transparency measurements were conducted in the field. Total phosphorus, conductivity, alkalinity, total nitrate, chlorophyll a, and pH tests were performed in the Water Quality Investigators laboratory near Dexter, Michigan. All tests followed the procedures outlined in *Standard Methods for the Examination of Water and Wastewater,* 1989.

THE LAKE WATER QUALITY INDEX

The Lake Water Quality Index (LWQI) (Fusilier, 1982) used in this study to define the water quality of Higgins Lake was developed for two reasons. First, there was no agreement among lake scientists regarding which tests should be used to define the water quality of a lake; and second, there was no agreement among lake scientists regarding the meaning of the data collected during lake studies.

Development of the index involved two questionnaires which were sent to a panel of 555 scientists who were members of the American Society of Limnology and Oceanography. The panel was specifically selected because they were chemists and biologists with advanced degrees who studied lake water quality.

The first questionnaire asked the scientists to select tests which they felt should be used to define lake water quality.

The tests most often selected by the scientists became the index parameters (or tests). They were:

Dissolved oxygen (Percent saturation)	
Total phosphorus	Alkalinity
Chlorophyll a	Temperature
Secchi disk depth	Conductivity
Total nitrate nitrogen	pH

The second questionnaire, sent out after the first was returned, asked the scientists what the results of the tests they selected as good indicators of lake water quality meant.

After the responses to the second questionnaire were returned and tabulated, the nine parameters and the accompanying rating curves were combined into a Lake Water Quality Index.

The index ranges from 1 to 100, with 100 indicating excellent lake water quality. The index rates lakes about the same way teachers rate students: 90-100=A, 80-90=B, 70-80=C, 60-70=D, and below 60=E.

The highest index for a Michigan lake studied by the author was Long Lake in Grand Traverse County at 100 in the spring of 1994. The lowest was 16 (Lake Macatawa in Ottawa County).

The spring Lake Water Quality Indices for Higgins Lake is unknown since no samples were collected.

The summer Lake Water Quality Index values was either 95 or 96 at the 6 in-lake stations, with an average of 96, indicating the 1998 summer water quality for Higgins Lake was in the A range.

Table 1 lists the summer Lake Water Quality Index values for the six Higgins Lake surface stations in 1998.

TABLE 1. SPRING AND SUMMER LAKE WATER QUALITY INDEX VALUES AT SIX HIGGINS LAKE SAMPLE STATIONS		
STATION IDENTIFICATION NUMBER	LAKE WATER QUALITY INDEX	
	SPRING 1998	SUMMER 1998
1	NA	95
2	NA	96
3	NA	96
4	NA	95
5	NA	96
6	NA	96
Average	NA	96

The data shows the water quality of Higgins Lake is high.

A DISCUSSION OF THE INDEX PARAMETERS

The data discussed below can be found in the Atlas pages.

TEMPERATURE (AND DISSOLVED OXYGEN)

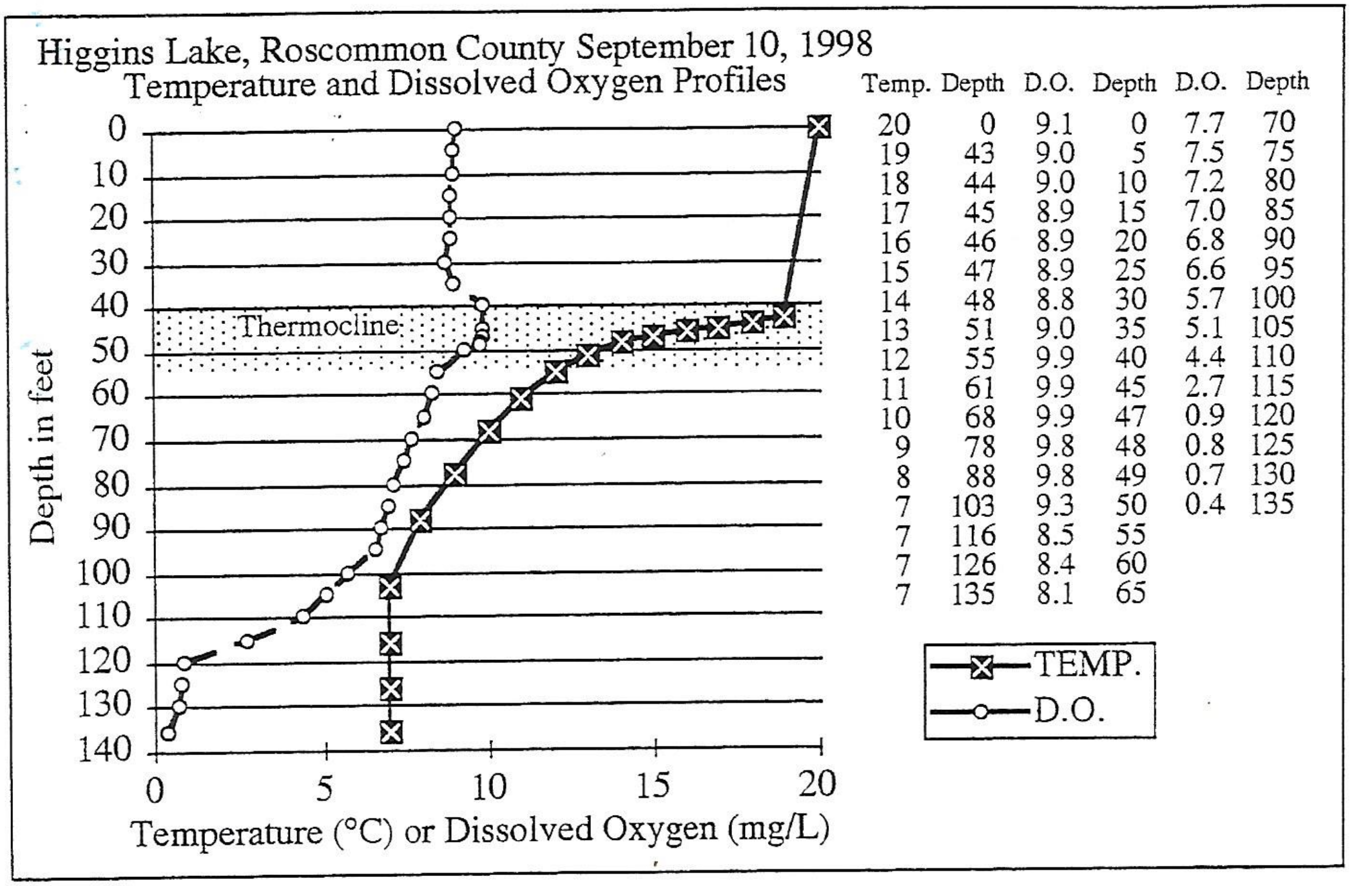
Temperature exerts a wide variety of influences on most lakes, such as the separation of layers of water (stratification), solubility of gases, and biological activity.

Top to bottom temperature and dissolved oxygen measurements were taken at the 135-foot deep hole in summer.

The graph below shows the temperature and dissolved oxygen profiles of Higgins Lake on September 10, 1998. The vertical scale represents the depth, and the horizontal scale represents temperature in degrees centigrade or dissolved oxygen in milligrams per liter. Temperature is shown by the solid line and solid squares, and dissolved oxygen is shown by the dotted line with light circles.

In summer (September 10) a 15-foot-thick thermocline (defined as a layer of water in a lake where the temperature changes more than 1°C per meter of depth) developed, from 40 to 55 feet.

A thermocline is important because it prevents the bottom layers of water in a lake from mixing with the surface waters during the warm months. This prevents nutrients released from the bottom sediments during periods when the bottom water becomes depleted of dissolved oxygen from mixing with the surface water where it could cause algal blooms.



Temp.	Depth	D.O.	Depth	D.O.	Depth
20	0	9.1	0	7.7	70
19	43	9.0	5	7.5	75
18	44	9.0	10	7.2	80
17	45	8.9	15	7.0	85
16	46	8.9	20	6.8	90
15	47	8.9	25	6.6	95
14	48	8.8	30	5.7	100
13	51	9.0	35	5.1	105
12	55	9.9	40	4.4	110
11	61	9.9	45	2.7	115
10	68	9.9	47	0.9	120
9	78	9.8	48	0.8	125
8	88	9.8	49	0.7	130
7	103	9.3	50	0.4	135
7	116	8.5	55		
7	126	8.4	60		
7	135	8.1	65		

On the other hand, the thermocline prevents oxygen from being distributed through-out the water column. If a lake runs out of dissolved oxygen below the thermocline, and if phosphorus has been precipitating to the bottom sediments, that same phosphorus can be released from the bottom sediments, and mixed into the water column when the lake mixes in fall. This can cause additional algae to grow the next year.

The slight increase in dissolved oxygen in the thermocline is probably due to an algal bloom which settled there. Algal blooms in thermoclines are not unusual and are found in all kinds of lakes. They don't indicate anything in particular.

On September 10, 1998 the surface temperature was 19 or 20°C at all surface stations. At the bottom of the 135-foot-deep hole, the temperature was 7°C. This 7 degree bottom water indicates the lake mixed in spring. If the lake hadn't mixed the temperature of the bottom water would have been 4°C or less.

DISSOLVED OXYGEN

Dissolved oxygen is the parameter most often selected by lake water quality scientists as being important. Besides its importance in providing oxygen for aquatic organisms to use, in natural lakes, oxygen is involved in phenomena such as phosphorus precipitation and release from the lake bottom sediments.

In summer, the dissolved oxygen concentration of the surface water at the sample sites ranged from 9.1 to 9.4 milligrams per liter. The data shows the lake did not run out of dissolved oxygen in the 135-foot-deep hole in late summer, although it dropped to only 0.4 milligrams per liter.

These data indicates 100 percent of the lake, on an areal basis, had dissolved oxygen top to bottom in the water column all year long.

Low dissolved oxygen concentrations (below 4 milligrams per liter) are generally insufficient to support fish life. In most southeast Michigan lakes, there is no dissolved oxygen below the thermocline (18 to 22 feet) in summer. [Since we study many Michigan lakes and measure the oxygen depletion below the thermocline in many of them, we are not sure why our depth sounder (and fish finder) shows the presence of fish in the areas devoid of dissolved oxygen.]

However as a limnologist, I like to see some dissolved oxygen in the bottom water of a lake, even if it is almost zero. This is because as long as there is some dissolved oxygen in the water at the bottom of the lake, phosphorus which was precipitated by iron to the bottom sediments, will remain there. Once a lake runs out of dissolved oxygen in the water at the bottom, iron comes back into solution, and when that happens, it releases the phosphorus back into the water. This can cause additional algae to grow when the lake mixes.

LIMITING NUTRIENTS

Before discussing the nutrients in the lake, a short discussion of "limiting nutrients" is in order. Let's take a farmer as an example.

What farmers try to learn when they have the soils in their fields tested is which nutrients are in shortest supply. They know the nutrients in shortest supply are the "limiting nutrients" and if they add more of those nutrients the fields will be more productive, and they will have more crops to sell.

The same thing happens in lakes. They too are "nutrient limited". However, the last thing you would want to do is add more of the "limiting nutrients" unless of course, you want more plants and algae. (Don't laugh. In the past, this was done to lakes to increase the amount of fish in the lake. In fact, many times the nutrients were added in the form of sewage.)

Now for the nutrient discussion.

TOTAL PHOSPHORUS

Although there are several forms of phosphorus found in lakes, the experts selected total phosphorus as being the most important. This is probably because all forms of phosphorus can be converted to the other forms. Currently, most lake scientists feel that phosphorus, which is measured in parts per billion (1 part per billion is one second in 31 years) or micrograms per liter ($\mu g/L$), is the one "limiting nutrient" which might be controlled.

However, based on our studies of many Michigan inland lakes, we've found many lakes were phosphorus limited in spring (so don't add phosphorus) and nitrate limited in summer (so don't add nitrogen).

10 parts per billion in surface water is considered a low concentration of phosphorus in a lake and 50 parts per billion is considered to be a high value by many lake scientists.

The summer surface phosphorus concentrations were either 5 or 6 micrograms per liter at the six surface in-lake stations, with an average of 6 micrograms per liter.

Usually lakes have higher phosphorus concentrations in spring than in summer because phosphorus is precipitated to the bottom sediments in summer. Since we had no spring samples we had no data against which to compare the summer data.

Here's where knowing the number of pounds of water in the lake comes in useful. Using the phosphorus data and knowing the number of billions of pounds of water in the lake (1554 billion pounds) we can calculate the total number of pounds of phosphorus in the lake in summer.

In summer 1998, the lake contained 9324 pounds of phosphorus. The phosphorus concentration is low, but the water volume of the lake is huge.

By applying lawn fertilizers containing phosphorus it is possible for home owners to easily double or triple the amount of phosphorus in the lake. This has the potential of causing water quality problems.

TOTAL NITRATE NITROGEN

Nitrate nitrogen, also measured in the parts per billion range, has traditionally been considered by lake scientists to also be a limiting nutrient. The experts felt any concentration below 200 parts per billion was excellent in terms of lake water quality. The highest value found by the author was 49,000 parts per billion in a stream feeding Lake Macatawa in Ottawa County.

The summer surface nitrate nitrogen concentrations ranged from 6 to 32 micrograms per liter, with an average of 15 micrograms per liter.

These data show the lake in summer is nitrate limited. This means no nitrate fertilizers should be used in the lake watershed, because additional nitrogen will cause more plants and algae to grow.

We're finding many lakes have lower nitrate nitrogen concentrations in summer than in spring. This is probably due to two factors. First, plants and algae growing in lakes as the water warms can remove nitrates from the water column. And second, bacterial denitrification (where nitrates are converted to nitrogen gas) by bacteria also occurs at a much faster rate in summer when the water is warmer.

Generally limnologists feel optimal nitrate nitrogen concentrations (which encourage maximum plant and algal growth) are about 16-17 times higher than phosphorus concentrations. The reason more nitrogen than phosphorus is needed is because nitrogen is one of the chemicals used in the production of proteins in plants, while phosphorus is used as a catalyst in the transfer of energy, but is not used to create plant material. If the nitrate concentration is less than 16-17 times the phosphorus concentration, the lake is considered to be nitrogen limited. If the nitrate concentration is higher than 16-17 times the phosphorus concentration, the lake is considered to be phosphorus limited.

TOTAL ALKALINITY

Alkalinity is a measure of the ability of the water to absorb acids (or bases) without changing the hydrogen ion concentration (pH). It is, in effect, a chemical sponge. In most Michigan lakes, alkalinity is due to the presence of carbonates and bicarbonates which were introduced into the lake from ground water sources. In lower Michigan, acidification of most lakes should not be a problem because of the high alkalinity concentrations.

Most lakes have lower summer than spring alkalinities, for two reasons; first, because plants and algae in the lake remove carbon dioxide from the carbonates, and second, some of the carbonates precipitate as the water warms up. Both of these conditions remove part of the buffer system that helps maintain stable conditions in a lake, and could lead to a shift toward a higher pH.

The alkalinity data (range 102-105 milligrams per liter) indicates Higgins Lake is a moderately hard water lake.

HYDROGEN ION CONCENTRATION (pH)

pH has traditionally been a measure of water quality. Today it is an excellent indicator of the effects of acid rain on lakes. About 99% of the rain events in southeastern Michigan are below a pH of 5.6 and are thus considered acid. However, there seems to be no lakes in southeast Michigan which are being affected by acid rain. Most lakes have pH values between 7.5 and 9.0.

The summer surface pH values were either 8.5 or 8.6. These are normal summer pH values for a high quality inland lake.

pH values often rise in summer as plants and algae use carbonates in the water as a source of carbon, and as carbonates precipitate to the bottom sediments in the warmer water.

CONDUCTIVITY

Conductivity, measured with a meter, detects the capacity of water to conduct an electric current. More importantly however, it measures the amount of materials dissolved in the water, since only dissolved materials will permit an electric current to flow. Theoretically, pure water will not conduct an electric current. It is the perception of the experts that poor quality water has more dissolved materials than does good quality water. We agree.

The conductivity of the waters in Higgins Lake is generally on the low side of normal, being 245 micromhos/cm at the six surface stations summer. We generally see lower conductivities in summer than in spring, again probably related to the removal of some of the dissolved carbonates during the summer months.

SECCHI DISK DEPTH (originally Secchi's disk)

In 1865, Angelo Secchi of Rome, Italy used white disk for studying the transparency of the water in the Mediterranean Sea. Later a limnologist (lake scientist) named Whipple divided the disk into black and white quadrants which many are familiar with today.

The Secchi disk depth is a lake test widely used and accepted by limnologists. The experts generally felt that the greater the Secchi disk depth, the better quality the water. However, one Canadian scientist pointed out acid lakes have very deep Secchi disk values.

Since we've published several atlases (Fusilier, 1991, 1992, 1993 & 1994) which included Secchi disk data sent in by Official Lake Monitors on many inland lakes in Michigan, we've come to realize the Secchi disk measurement may not be an indicator of water quality. It may just be an indicator of a characteristic of the lake.

The literature suggests the proper way to take a Secchi disk depth measurement is to lower the disk into the water on the shaded side of an anchored boat to a point where it disappears. Then raise it to a point where it is visible. The average of these two readings is recorded as the Secchi disk depth.

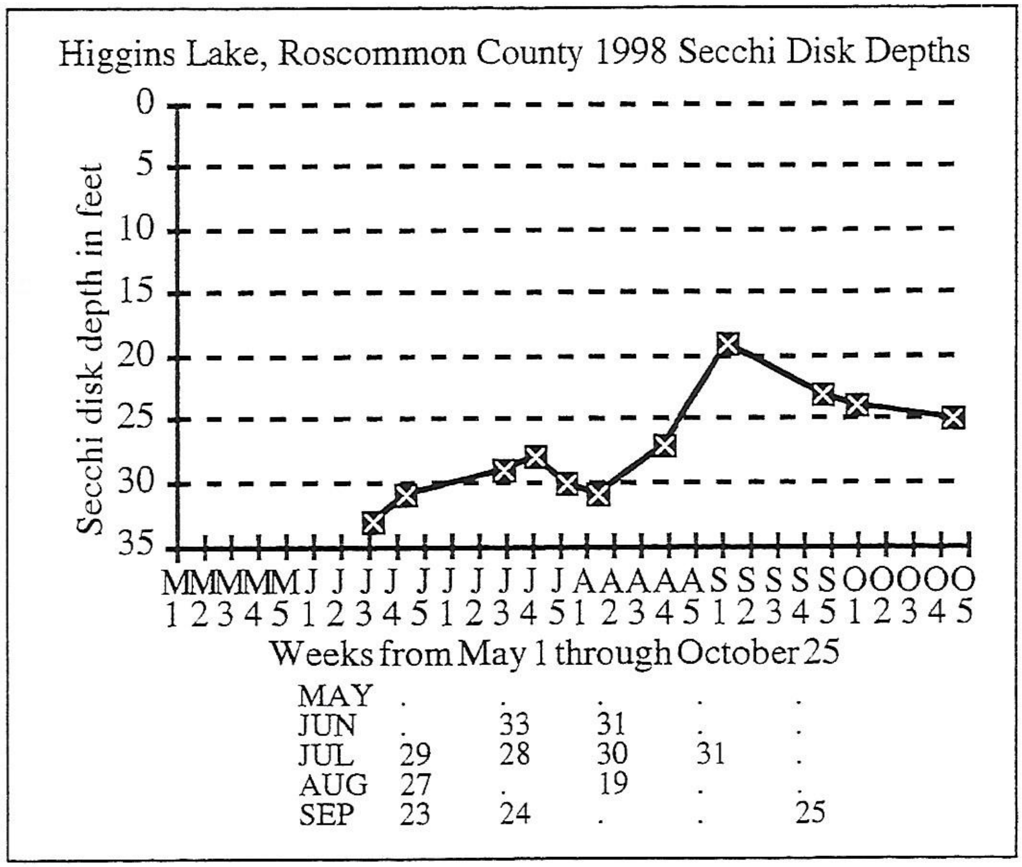
We do it slightly differently. We lower the disk on the shaded side of an anchored boat until the disk disappears, and note the depth, then report the depth to the next deepest foot. For example if the disk disappears at six and a half feet, we report the Secchi disk depth as 7 feet. The reason we do this is that some suggest using a water telescope (a device that works like an underwater mask and eliminates water roughness) to view the disk as it disappears. Since we don't use this device, we compensate for it by noting the slightly deeper depth.

We feel it is only necessary to report Secchi disk measurements to the closest foot. Secchi disk measurements should be taken between 10 AM and 4 PM. Rough water will give slightly shallower readings than smooth water. Sunny days will give slightly deeper readings than cloudy days. However, roughness influences the visibility of the disk more than sunny or cloudy days. Furthermore, it's been reported that most adults can see the Secchi disk disappear at about the same depth, but grand-children see it disappear 3-4 feet deeper than grand-parents.

If there are sample sites where the lake is too shallow and the disk is visible when resting on the bottom, the reading should be taken at a nearby site. Since the sampling procedure is designed to obtain representative samples, the concept of moving the boat to an area where a Secchi disk transparency reading can be properly taken is appropriate. In the case of Secchi disk readings, this procedure is more valid than reporting that the disk is visible on the lake bottom.

Most lakes in southeast Michigan have Secchi disk readings of less than ten feet.

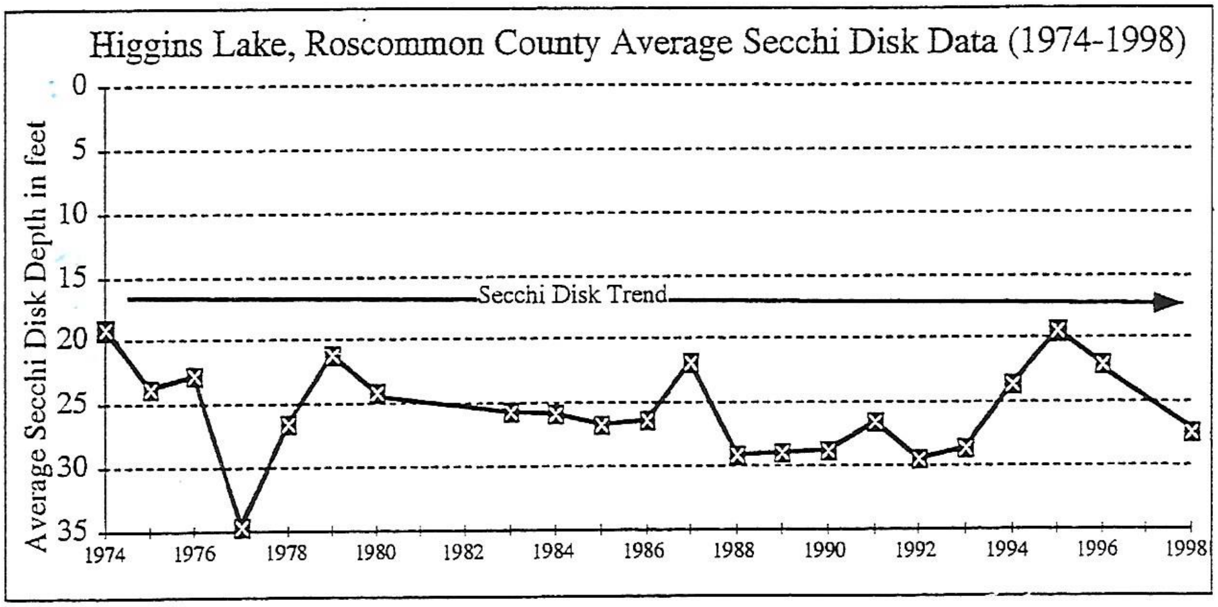
Jeff Tomak did a good job taking Secchi disk readings during 1998. The Secchi disk readings in Higgins Lake were deep (28 to 33 feet) in spring, then dropped to 20 to 25 feet as the lake warmed in summer. The following graph shows the data Jeff collected.



The Average Secchi disk trend graph shows since the program started in 1974, Higgins Lake was getting clearer, although in 1994, 1995 and 1996, the data shows the lake was getting less clear. There was insufficient data to calculate an average for 1997. The graph below shows the Secchi disk trend for Higgins Lake from 1974 to the present.

If more 1998 early spring Secchi disk measurements had been collected the 1998 average Secchi disk data for Higgins Lake would have been better. As it is, data was not collected in May and the first part of June, and that's when Secchi disk measurements would probably have been deepest. This shows why it is important to collect Secchi disk data uniformly over the warm months.

The Higgins Lake Property Owner's Association should continue to take Secchi disk readings through-out the the warm months. These data are extremely useful in following conditions in Higgins Lake.



CHLOROPHYLL a

Chlorophyll a is used by lake scientists as a measure of the biological productivity of the water. Generally, the lower the chlorophyll a, the better. High concentrations of chlorophyll a are indicative of an algal bloom in the lake, an indication of poor lake water quality. The highest surface chlorophyll a found by this writer in a Michigan lake was 416 micrograms per liter.

Summer surface chlorophyll a concentrations at the six surface stations were low, less than one microgram per liter. I like to see these low chlorophyll a concentrations in late summer when the water is warm.

These are low chlorophyll a concentrations and indicate Higgins Lake does not have significant algal blooms, at least in summer.

THE LAKE WATER QUALITY INDEX (LWQI) CALCULATION SHEETS

The Lake Water Quality Index calculation sheets were developed to show graphically what the results of the nine different lake water quality tests meant in terms of lake water quality.

HOW TO READ THE LAKE WATER QUALITY INDEX CALCULATION SHEETS

Listed across the top of the calculation sheets are the tests selected by the panel of experts as being good indicators of lake water quality.

The figures which look like thermometers are graphs which convert the test results (the values found on the outside of the thermometer) to a uniform 0-100 lake water quality rating (found on the inside of the thermometer).

The calculation sheet combines all nine of the individual quality ratings into a single Lake Water Quality Index. The index ranges from 1 (very poor lake water quality) to 100 (excellent lake water quality).

The index is portrayed in three different ways: as a number ranging between 1 and 100 in the circle marked LWQI, and by a color and position on the sheet edge scale. The purpose of the sheet-edge scale is to review quickly large numbers of lakes or sample sites within a lake and determine how the quality of the various lakes or sites compare.

The position of the red line on the thermometer-type rating scales permits determination of the parameter (or parameters) which cause the index to be depressed. The lower the red line, the greater the problem. A glance at the top of the problem rating scale identifies the test and the test results. The rating scales also permit determination of what test results would be considered excellent in terms of lake water quality by the panel of experts surveyed. They are the numbers on the outside the thermometer, near the top.

Since there was little difference in water quality at the various stations, the Lake Water Quality Index calculation sheet below is based on averaged summer water quality data. The report marked MASTER COPY has all 6 LWQI calculation sheets.

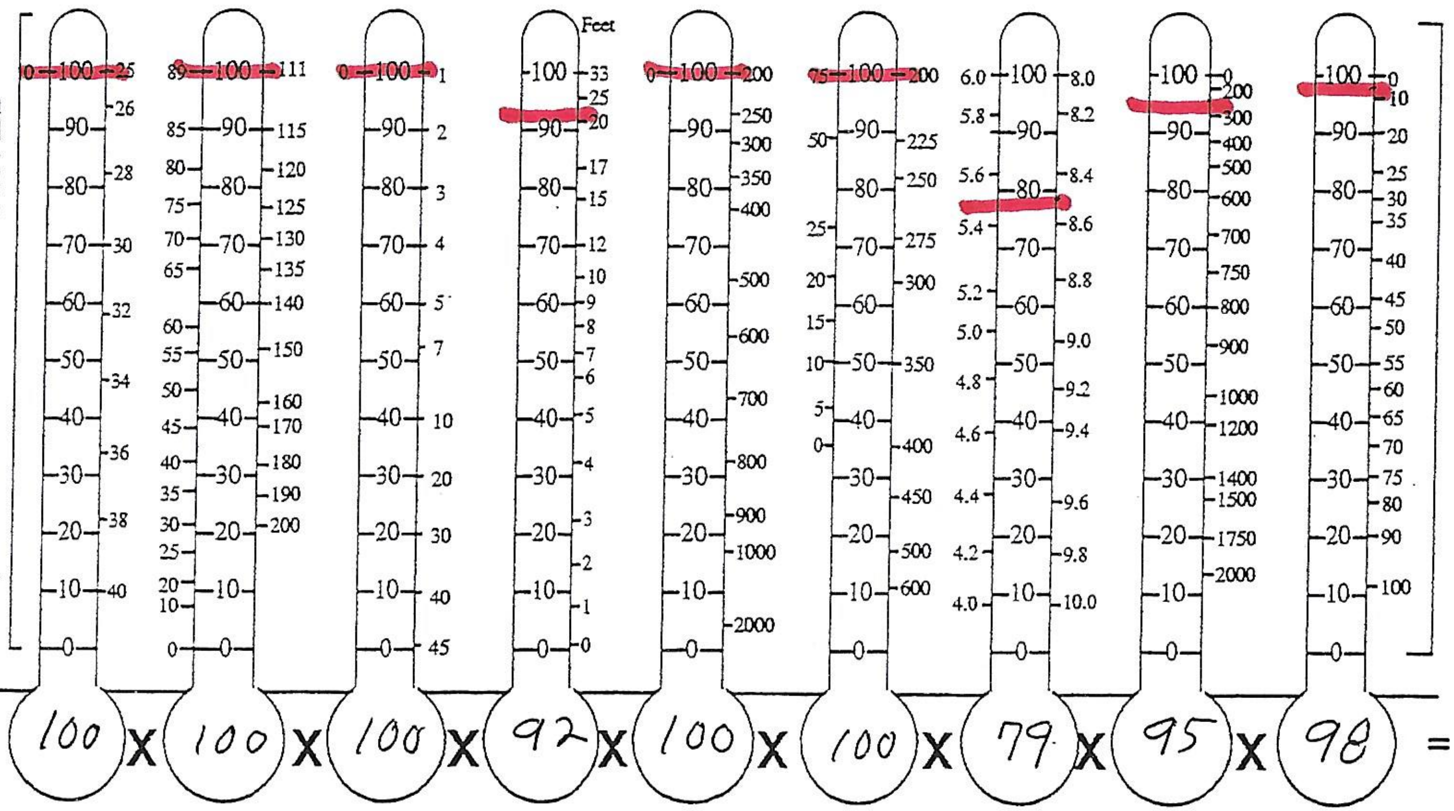
CALCULATION SHEET FOR THE UNWEIGHTED MULTIPLICATIVE LAKE WATER QUALITY INDEX

W. Fusilier, Ph.D.

QUALITY RATING CURVES

(Individual Quality Ratings never exceed 100)

Temperature in degrees C	Dissolved Oxygen, % Saturation	Chlorophyll a ug/L	Secchi Disk Depth in feet	Nitrate-N ug/L	Alkalinity mg/L	pH S. U.	Specific Conductivity umhos/cm@ 25C	Total Phosphorus ug/L
20	/ 100	<1	21	15	104	8.5	245	6



$\sqrt[9]{100 \times 100 \times 100 \times 92 \times 100 \times 100 \times 79 \times 95 \times 98} = 96$

LWQI 96

1:2.27
Lake to watershed ratio
21.5 YEARS
Flushing rate
MUSKEGON R.
Drainage Basin
32486 Ac.
Drainage Area
571577 Ac.Ft.
Lake Volume
ROSCOMMON
County
Gerrish+Lyon
Township
WQI
Analyst
135
Lake Depth
10480
Lake Area

SET THE PARAMETER QUALITY RATING AT 1 IF THE EXTERNAL EXTREME VALUE RANGE IS EXCEEDED

LAKE WATER QUALITY INDEX

0–15	15–25	25–35	35–45	45–55	55–65	65–75	75–85	85–100
Red	Red Orange	Orange	Orange Yellow	Yellow	Yellow green	Green	Blue Green	Blue

DATE 9-10-99

STATION AVEG-G)

LAKE HIGGINS

BOTTOM SEDIMENTS

Many times the bottom sediments of lakes give a better picture of what's been happening in a lake over the years than the water quality testing does. This is because the bottom sediments accumulate material over the years, while water samples just give a snapshot of the lake at the time it was tested.

We started studying bottom sediments of lakes after many riparians complained about the buildup of "muck" in the lake bottom. Since most limnology textbooks don't even mention the word "muck" it appeared more needed to be known about the bottom sediments of lakes.

We generally sample bottom sediments with a Pederson clamshell dredge in the deep portions of the lake, avoiding near shore samples to eliminate the effects of shoreline activities.

Almost all bottom sediments we collect are black, but just because they're black doesn't mean they're muck. The reason they're black is little oxygen penetrates them, so the decomposition processes occurring there use sulfur rather than oxygen, and in the process produces iron sulfide, which is black. And this seems to occur at almost all depths.

After the bottom sediments are collected, they are placed in a pint freezer container, and then allowed to air dry for several weeks. As they air dry, they may remain black, or they may turn gray or tan. And they generally shrink about 80 percent, indicating they were at least 80 percent water.

If the bottom sediments remain black after air drying, it generally indicates they are less than about 65% mineral. If they remain gray, they are generally more than 65% mineral, and probably made up of calcium carbonate (or marl).

If they turn tan, they could be sand, or they could be clay. More on this later.

The amount of shrinkage also indicates something. Sand and gravel hardly shrink at all, usually less than 5%. Clay may shrink only about 10%. The samples that remain black after air drying usually shrink the most, usually more than 95%. This means sediments that filled a four-inch-square, two-inch-deep container may shrink to smaller than an Oreo cookie.

After air drying, the amount of shrinkage is determined (by measuring the dimensions of the dried block), then the sediment samples are ground up. Portions are placed into pre-weighed porcelain dishes, and dried overnight at 100°C.

then burned in a muffle furnace at 550°C for two hours. The dish and sample are again weighed.

The loss of material after ignition (or burning) is considered to be organic material. That remaining in the dish represents the mineral content of the sample.

After burning at 550°C:

If the bottom sediments remain gray, they are generally marl, or calcium carbonate. This is generally the material the deeper portions of many Michigan inland lakes are filling with.

If the bottom sediments turn red, it indicates the presence of clay. (Red bricks are made by heating clay. As an added note, yellow bricks are made by heating the clay to a higher temperature). Clay usually enters the lake from near-shore activities, such as home building, road building or farming.

Most of the time the sediments that remained black after air drying turn a tan color after burning.

Generally I like to see bottom sediments of lakes above 85% mineral, I consider those to be excellent quality bottom sediments because it indicates organic material is not building up to any great extent in the deep-water bottom sediments.

Man (or woman) made lakes less than 50-100 years old may have bottom sediments with mineral contents in the 95% range, but that's to be expected, given the young age of those water bodies. But even some of these have lower mineral contents.

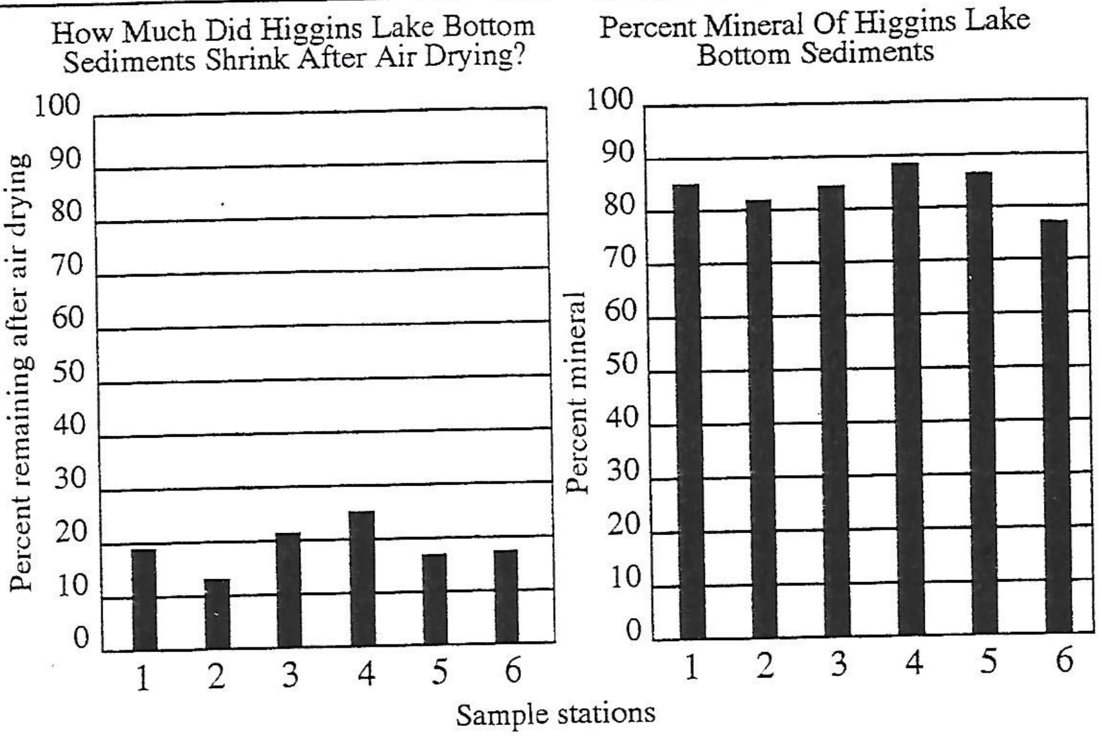
In soft water lakes filling with peat, the mineral content is in the 30-50% range.

In lakes with bottom sediments that remain black after air drying, the mineral content is usually in the 40-50% range, but this is based on the dried sediments, which when collected contained 95%+ water.

Higgins Lake bottom sediment samples were collected at the six in-lake stations in September 1998. The following graph shows the information on those sediment samples.

The bottom sediments shrunk 79 to 87 percent. This is normal for high quality inland lakes.

All the bottom sediments turn gray after air drying, and remained gray after burning at 550°C. This indicates the deep-water bottom sediments of Higgins Lake are generally made up of calcium carbonate, or marl. This is what we normally see in high quality inland lakes in Michigan.



Sample I.D.	Percent Shrinkage	Percent Mineral	Dried at 100°C Color & Description	Color after burning at 550°C	Depth of water (feet)
1	81	85	Gray	Gray	90
2	87	82	Gray	Gray	101
3	79	84	Gray	Gray	87
4	75	89	Gray	Gray	93
5	83	86	Gray	Gray	105
6	82	77	Gray	Gray	135

Characteristics of Higgins Lake Bottom Sediments (1998)

83 percent = average mineral content of bottom sediments

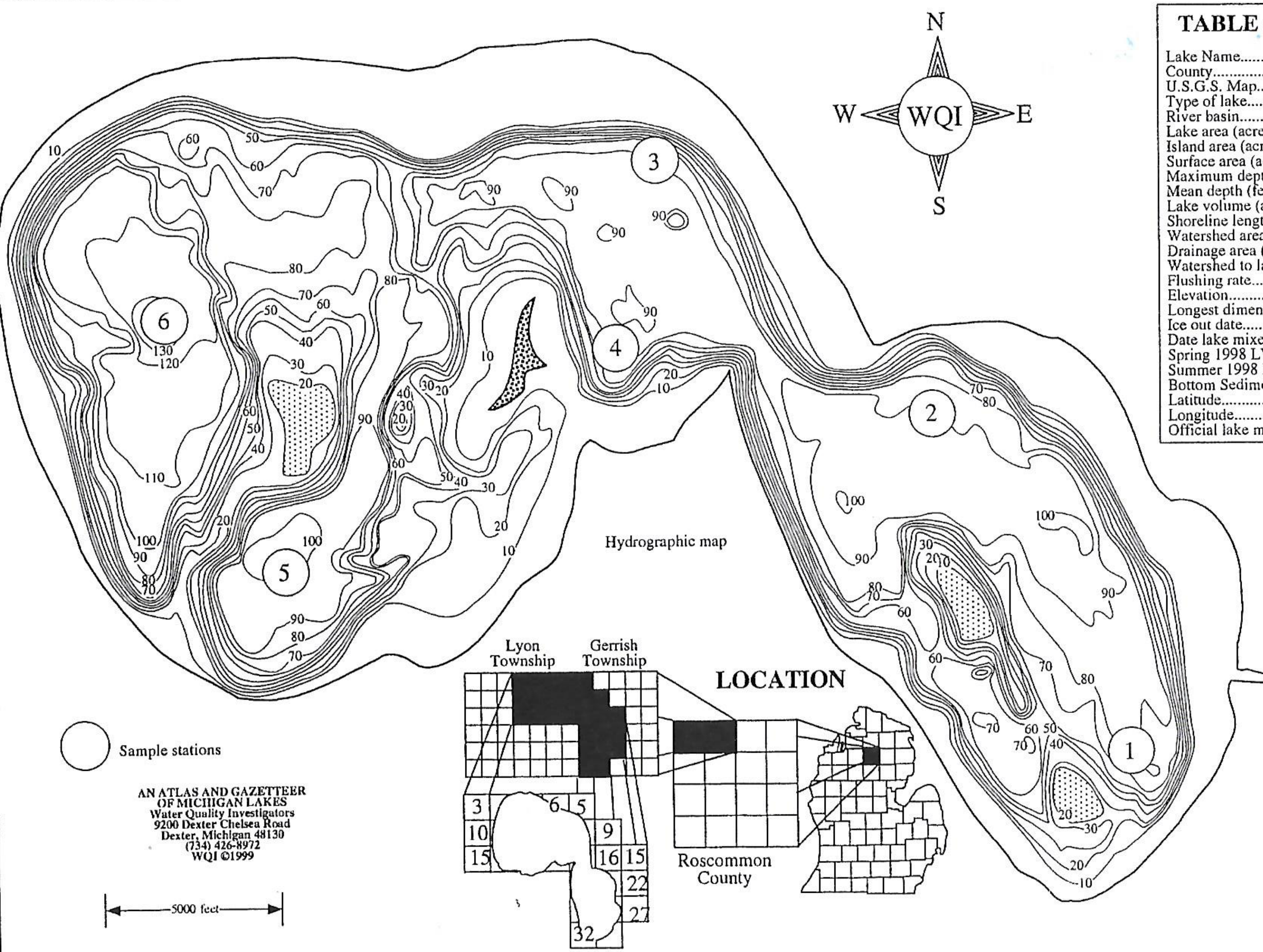
The mineral content of the sediments ranged for 77% (in the 135-foot deep hole) to 89 percent (at station 4 in 93 feet of water). The average mineral content of the six bottom sediment samples was 83 percent. This indicates Higgins Lake is just starting to accumulate organic material in the bottom sediments.

Given the long flushing time (19.5 years) nutrients which enter the lake on any given year take almost 20 years (on average) to be flushed from the lake. This long flushing rate also means the lake captures about 95% of the nutrients which enter it each year.

Wallace E. Fusilier, Ph.D.
Consulting Limnologist
Dexter, Michigan
May 1999

TABLE OF LAKE DATA

Lake Name	Higgins Lake
County	Roscommon
U.S.G.S. Map	Lyon Manor
Type of lake	Natural
River basin	Muskegon
Lake area (acres)	10480
Island area (acres)	30
Surface area (acres)	10450
Maximum depth (feet)	135
Mean depth (feet)	54.6
Lake volume (acre feet)	571577
Shoreline length (feet)	111981
Watershed area (acres)	23806
Drainage area (acres)	32486
Watershed to lake ratio	2.27
Flushing rate	21.5 years
Elevation	1154
Longest dimension (feet)	37926
Ice out date	Unknown
Date lake mixed	Unknown
Spring 1998 LWQI	No samples
Summer 1998 LWQI	95 96 96 95 96 96
Bottom Sediments, % mineral	85 82 84 89 86 77
Latitude	44° 29.845N
Longitude	84° 45.836W
Official lake monitor	Jeff Tomak



Higgins Lake
Many Sections
Gerrish Township
T24N R3W &
Lyon Township
T24 R4W
Roscommon County

Higgins Lake
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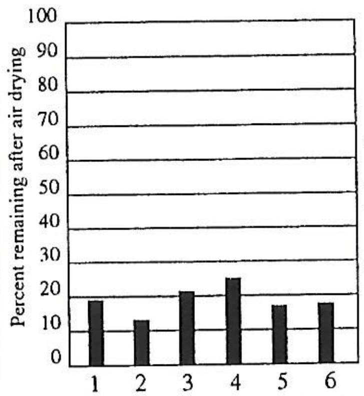
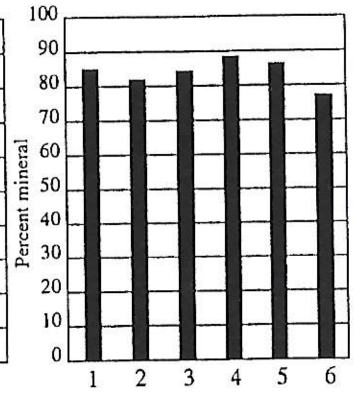
How Much Did Higgins Lake Bottom Sediments Shrink After Air Drying?



Percent Mineral Of Higgins Lake Bottom Sediments



Sample stations

Characteristics of Higgins Lake Bottom Sediments (1998)

Sample I.D.	Percent Shrinkage	Percent Mineral	Dried at 100°C Color & Description	Color after burning at 550°C	Depth of water (feet)
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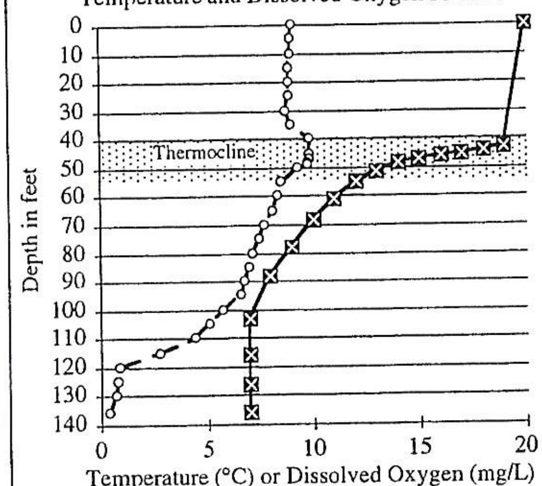
5	83	86	Gray	Gray	105
6	82	77	Gray	Gray	135

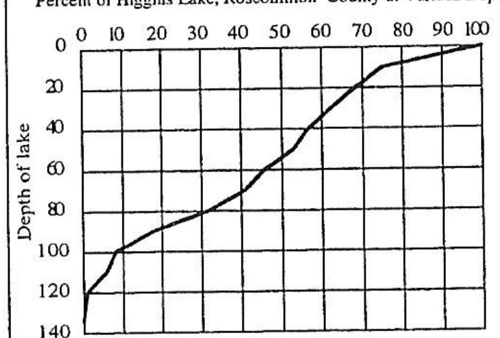
83 percent = average mineral content of bottom sediments

Higgins Lake, Roscommon County September 10, 1998
Temperature and Dissolved Oxygen Profiles



Temp.	Depth	D.O.	Depth	D.O.	Depth
20	0	9.1	0	7.7	70
19	43	9.0	5	7.5	75
18	44	9.0	10	7.2	80
17	45	8.9	15	7.0	85
16	46	8.9	20	6.8	90
15	47	8.9	25	6.6	95
14	48	8.8	30	5.7	100
13	51	9.0	35	5.1	105
12	55	9.9	40	4.4	110
11	61	9.9	45	2.7	115
10	68	9.9	47	0.9	120
9	78	9.8	48	0.8	125
8	88	9.8	49	0.7	130
7	103	9.3	50	0.4	135
7	116	8.5	55		
7	126	8.4	60		
7	135	8.1	65		

Percent of Higgins Lake, Roscommon County at Various Depths



Lake area = 10450 acres

FUSILIER'S ATLAS
AND GAZETTEER
OF MICHIGAN LAKES
Water Quality Investigators
9200 Dexter Chelsea Road
Dexter, Michigan 48130
(734) 426-8972
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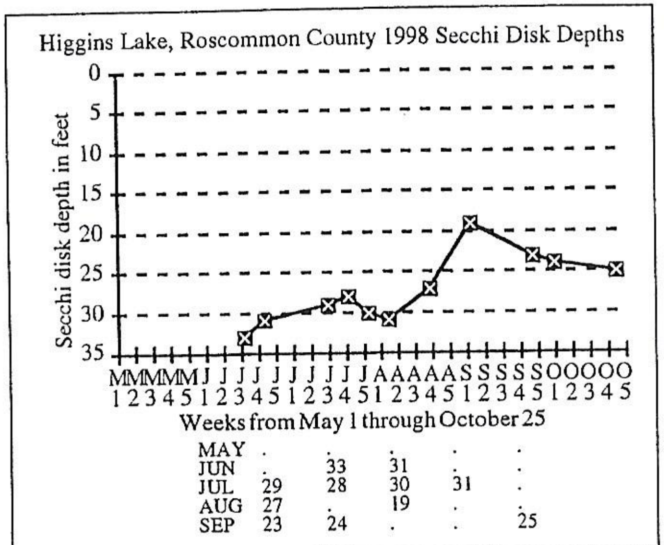
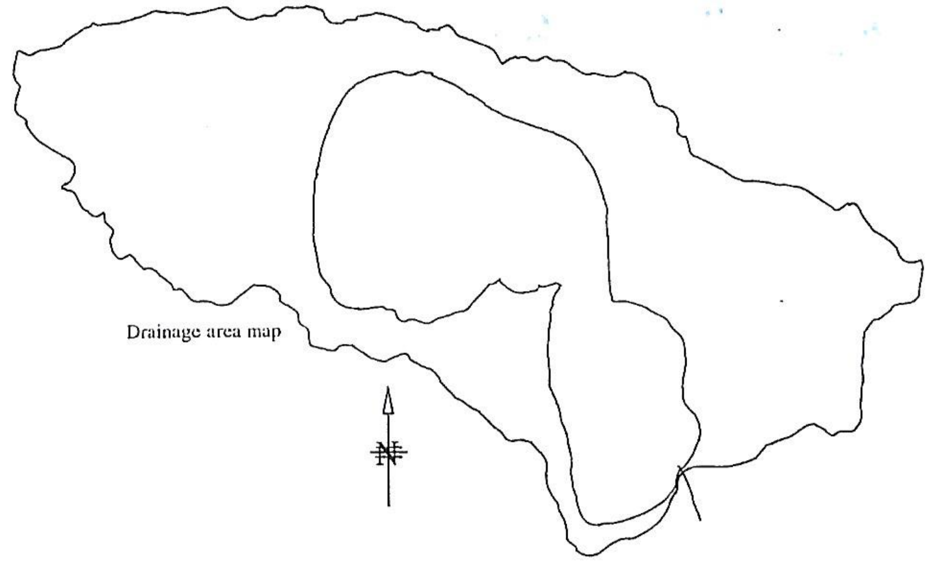
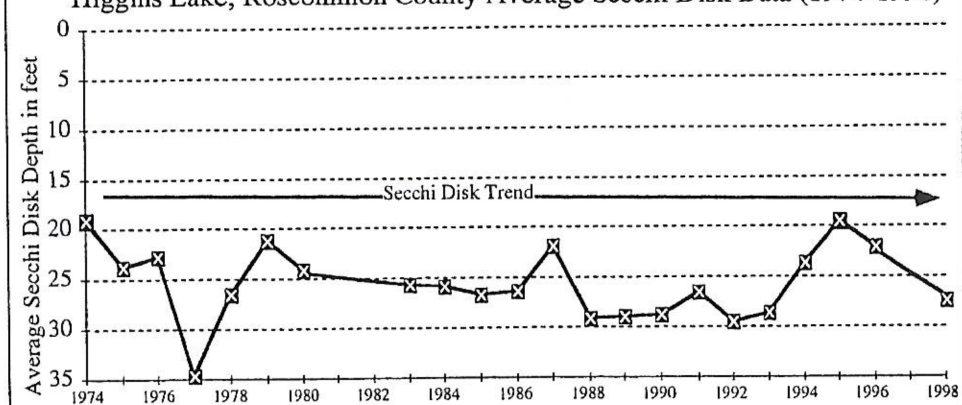
Surface Lake Water Quality Data

Date	Sample Station Number	Temperature °C	Dissolved Oxygen (mg/L)	Dissolved Oxygen Percent Saturation	Chlorophyll a ug/L	Secchi Disk Depth (feet)	Total Nitrate Nitrogen ug/L	Alkalinity mg/L	pH	Conductivity umhos per cm at 25°C	Total Phosphorus ug/L	Lake Water Quality Index	Grade
9/10/98	1	19	9.4	100	<0.1	20	6	102	8.6	245	6	95	A
9/10/98	2	20	9.3	101	<0.1	22	10	104	8.5	245	6	96	A
9/10/98	3	20	9.1	99	<0.1	22	12	103	8.5	245	6	96	A
9/10/98	4	20	9.3	101	<0.1	20	14	105	8.6	245	6	95	A
9/10/98	5	20	9.1	99	<0.1	21	16	105	8.5	245	5	96	A
9/10/98	6	20	9.1	99	<0.1	23	32	103	8.5	245	6	96	A







Data:

1974	1975	1976	1977	1978	1979	1980	1983	1984	1985	1986
19.1	23.7	22.7	34.7	26.5	21.1	24.1	25.6	25.9	26.6	26.4

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1998
21.9	29.1	29.0	28.7	26.5	29.4	28.6	23.5	19.4	22	27.3

Higgins Lake Contour Areas And Volumes

Area of various contours	Volume in Acre Feet
Surface area = 10450 acres	91491
10 feet = 7848.25 acres	74890
20 feet = 7129.71 acres	68570
30 feet = 6584.22 acres	62790
40 feet = 5973.73 acres	57820
50 feet = 5590.29 acres	51797
60 feet = 4769.09 acres	45477
70 feet = 4326.25 acres	38333
80 feet = 3340.41 acres	52655
90 feet =1925.14 acres	14003
100 feet = 875.42 acres	7344
110 feet = 593.30 acres	4047
120 feet = 216.09 acres	1267
130-135 feet = 37.23 acres	93
Lake volume = 571577 acre feet	

AN ATLAS AND GAZETTEER
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