LAKE SOMERSET

SOMERSET TOWNSHIP

HILLSDALE COUNTY

1992-2010 WATER QUALITY STUDIES

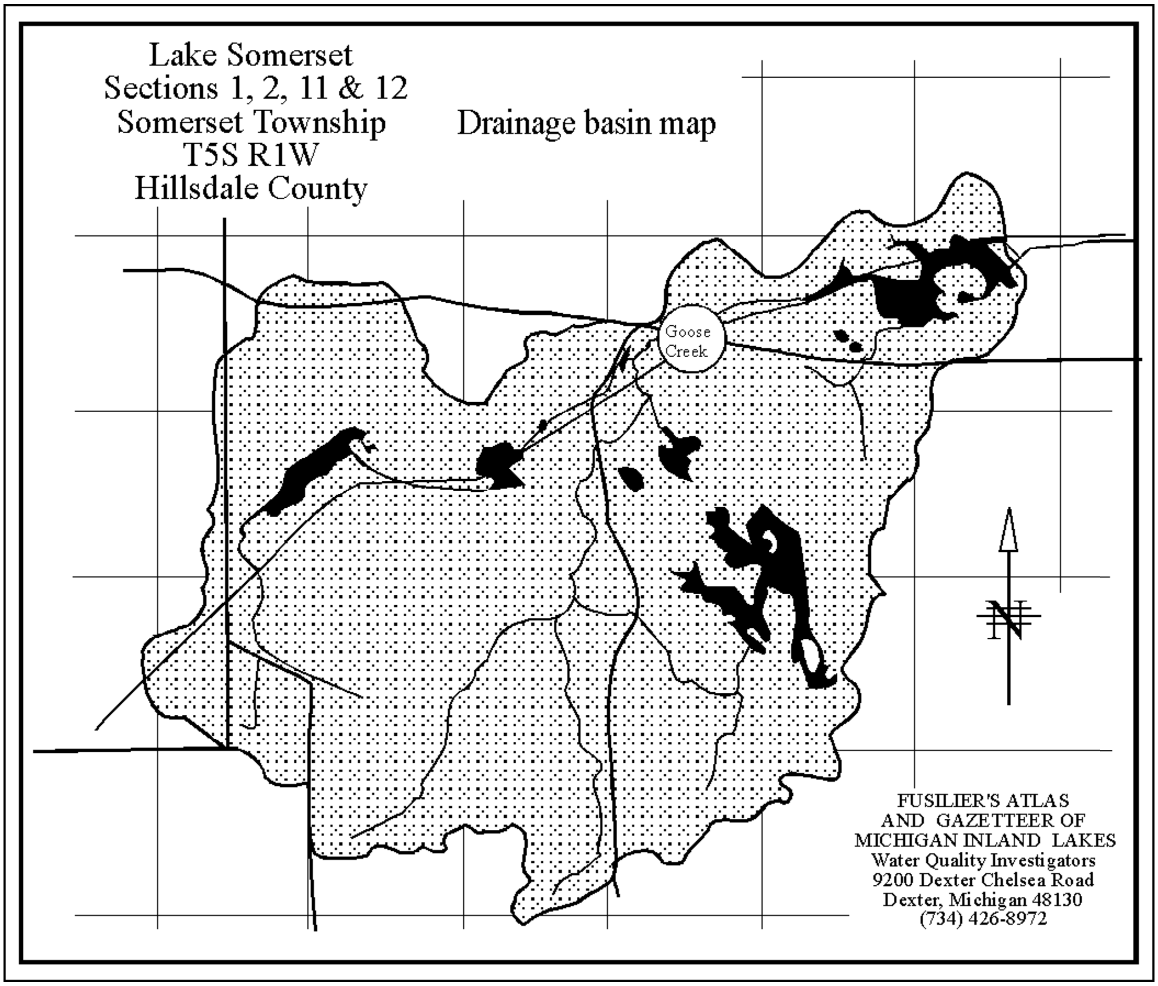
LAKE SOMERSET DATA

Lake Somerset is a 191-acre moderately hard water to hard water impoundment located in Sections 1, 2, 11 & 12, Somerset Township (T5S R1W), Hillsdale County, Michigan. It was formed in 1968 when American Central Corporation erected an earthen dam across Goose Creek. The lake has a maximum depth of 25 feet, a water volume of 2215 acre-feet, and a mean depth of 11.6 feet. There is a half-acre island in the lake. The length of the shoreline, not including the island, is 36,876 feet.

The size of the watershed, which is the land area that contributes water to the lake, but does not include the lake, is 9330 acres. The drainage area, which includes the lake and the watershed, is 9521 acres (see map below). The watershed to lake ratio is 49.9 to 1, which is large for a Michigan inland lake but normal for a lake created by damming a stream. The lake flushes rapidly, about once every 0.29 years (or every 106 days) on an average.

The elevation of the lake is 1025 feet above sea level. There are two inlets. A small stream draining 457 acres, (average flow = 0.50 CFS) flows into Lake Somerset on the south side. Goose Creek, which drains 8312 acres, (average flow = 9.03 CFS) flows into Lake Somerset on the west end. Water leaves the lake through three outlet structures on the east end. Goose Creek joins the River Raisin north of Brooklyn. The River Raisin flows into Lake Erie near Monroe, Michigan.

The longitude and latitude of the 25-foot deep hole is 84° 22.286W and 42° 03.396N.



THE SAMPLE DATES

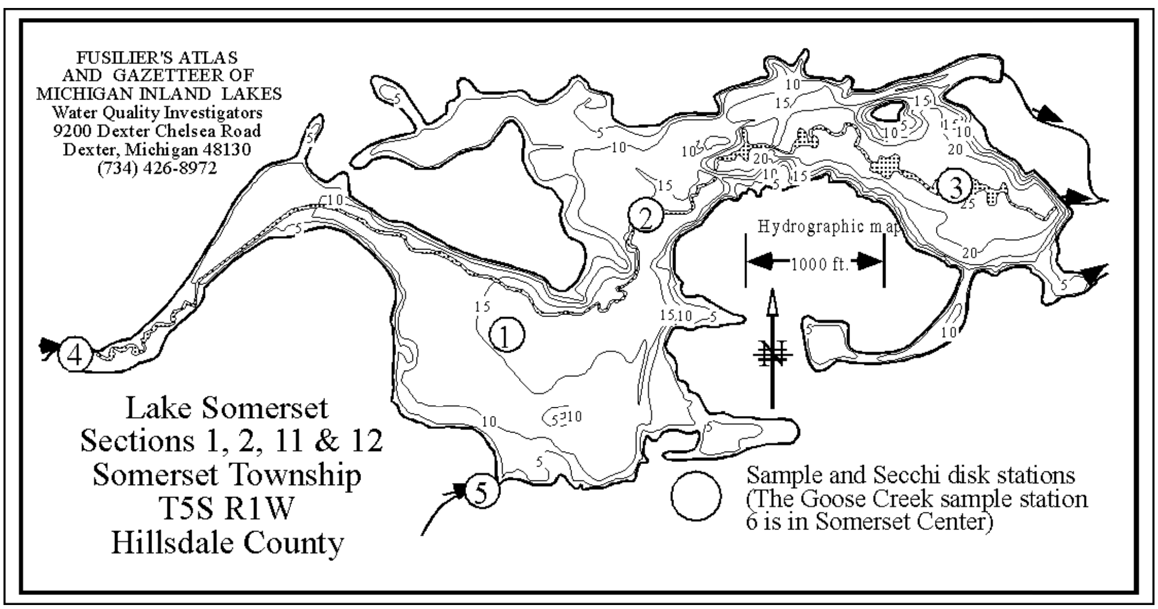
In 1992, WQI limnologists, accompanied by Dan Doyle, sampled Lake Somerset at 14 stations for water quality testing in both spring (May 10) and late summer (August 19). Top to bottom temperature and dissolved oxygen data were collected both times the lake was sampled. Bottom sediments were collected from 13 of the 14 stations in late summer. Aquatic plant populations were mapped and identified in late summer.

Dan Doyle collected three Lake Somerset spring surface samples for water quality testing May 9, 1993, and May 9, 1994. Starting in 1995, Dan or George Rausch collected the three Lake Somerset spring surface samples, plus three inlet samples for water quality testing April 20, 1995, May 25, 1996, April 29, 1997, April 22, 1998, May 7, 1999, April 23, 2000, April 27, 2001, May 3, 2002, May 14, 2003, May 15, 2004, May 4, 2005, May 3, 2006, May 4, 2007, May 5, 2008, May 12, 2009 and May 5, 2010.

WQI limnologists, accompanied by Doyle, collected three Lake Somerset late summer surface samples for water quality testing on August 2, 1993 and August 9, 1994. Since 1995, the late summer samples included the three Lake Somerset surface samples, plus three inlet samples. The sample dates were August 15, 1995, August 20, 1996, September 7, 1997, September 8, 1998, August 31, 1999, August 11, 2000, August 24, 2001, August 12, 2002, August 19, 2003, August 9, 2004, August 15, 2005, August 10, 2006, August 8, 2007, August 7, 2008, August 31, 2009 and August 4, 2010. Temperature and dissolved oxygen profile data were collected every year the lake was sampled in late summer at Station 3, the 25-foot-deep hole at the east end of the lake.

THE SAMPLE STATIONS

The locations of the sample stations are shown on the hydrographic map.



THE ANALYSES

The tests performed on the samples included total phosphorus, total nitrate nitrogen, total alkalinity, pH, conductivity, chlorophyll a, Secchi disk depth, and in summer, temperature and dissolved oxygen. Temperature, dissolved oxygen and Secchi disk depths were measured in the field. Chlorophyll a, phosphorus, nitrate nitrogen, alkalinity, pH and conductivity tests were performed at the Water Quality Investigators laboratory in Dexter, Michigan.

All test procedures followed those outlined in APHA's *Standard Methods for the Examination of Water and Wastewater* (1985).

THE TEST RESULTS

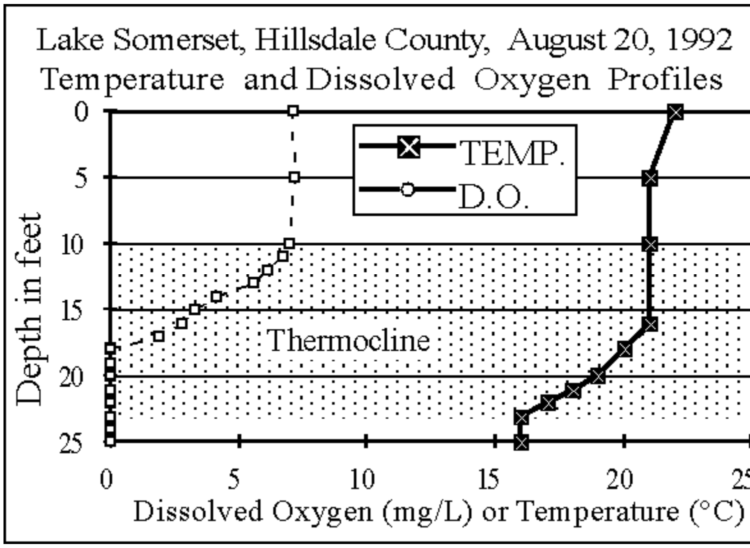
The results of the tests are found in the text on the enclosed atlas pages.

LATE SUMMER 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 gasses and biological activity.

Dissolved oxygen is the test most often selected by lake scientists as being important. Besides providing oxygen for aquatic organisms, in natural lakes oxygen is involved in the capture and release of various chemicals, such as iron and phosphorus.

Dissolved oxygen and temperature profiles were measured every time the lake was sampled in summer.

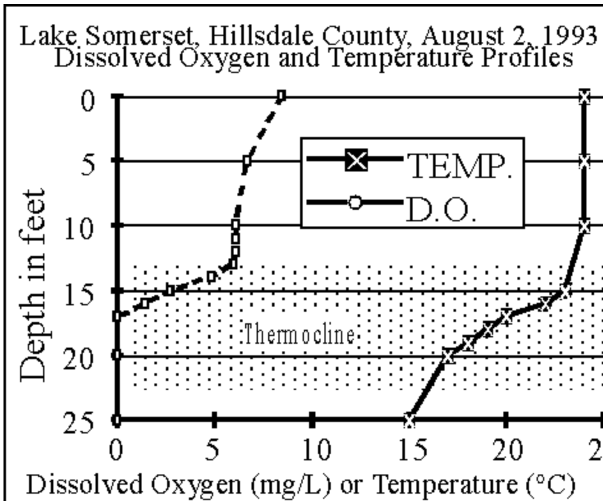


Depth	Temp.	D.O.
0	22	7.1
5	21	7.2
10	21	7.0
11	21	6.7
12	21	6.1
13	21	5.6
14	21	4.1
15	21	3.3
16	21	2.8
17	20	1.9
18	20	0
19	19	0
20	19	0
21	18	0
22	17	0
23	16	0
24	16	0
25	16	0

1992

In late summer 1992, Lake Somerset formed a 13-foot-thick thermocline from 10 to 23 feet (a thermocline is defined as a layer of water in a lake where the temperature changes more than one degree C per meter of depth, and is shown shaded on the graphs). The lake ran out of dissolved oxygen at 18 feet, and that condition remained to the bottom at 25 feet. The hypsographic (depth area) graph shows about 17 percent of the lake is deeper than 18 feet.

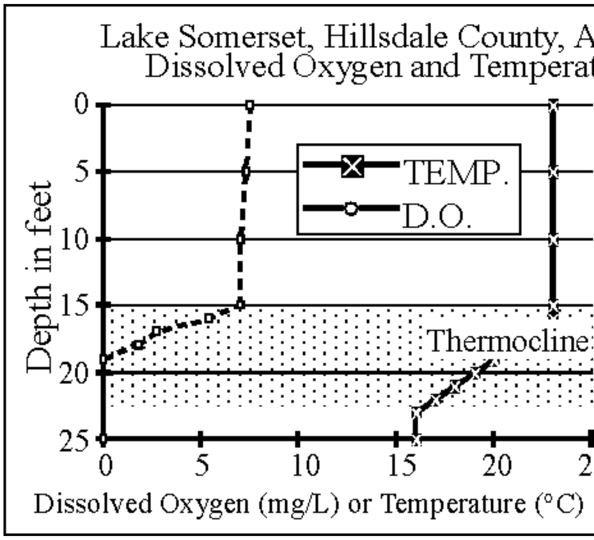
1993



Temp.	Depth	D.O.	Depth
24	0	8.4	0
24	5	6.7	5
24	10	6.1	10
23	15	6.1	11
22	16	6.1	12
20	17	6.0	13
19	18	4.8	14
18	19	2.7	15
17	20	1.4	16
15	25	0	17
		0	20
		0	25

In late summer 1993, the lake formed a 7-foot thick thermocline from 13 to 20 feet. Dissolved oxygen was plentiful in the surface water layer. The lake ran out of dissolved oxygen at 17 feet. From that depth to the bottom, Lake Somerset had no dissolved oxygen. About 22 percent of the lake is deeper than 17 feet.

1994

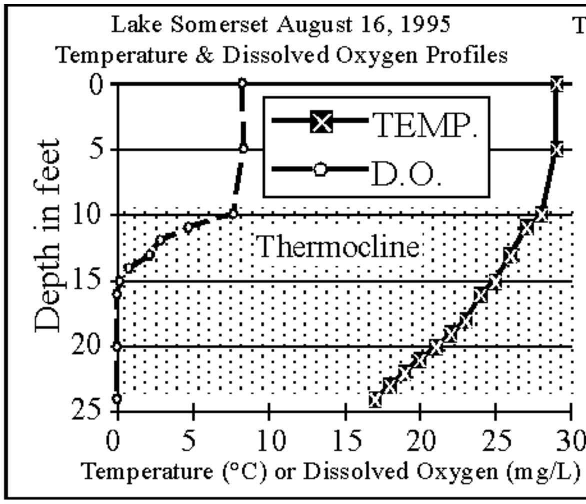


Temp.	Depth	D.O.	Depth
23	0	7.5	0
23	5	7.3	5
23	10	7.0	10
23	15	7.0	15
23	16	5.4	16
22	17	2.7	17
21	18	1.8	18
20	19	0	19
19	20	0	25
18	21		
17	22		
16	23		
16	25		

In late summer 1994, the lake formed an 8-foot-thick thermocline from 15 to 23 feet. Dissolved oxygen was plentiful in the surface water. The lake ran out of dissolved oxygen at 19 feet, and that condition remained to the bottom. About 12 percent of the lake is deeper than 19 feet.

1995

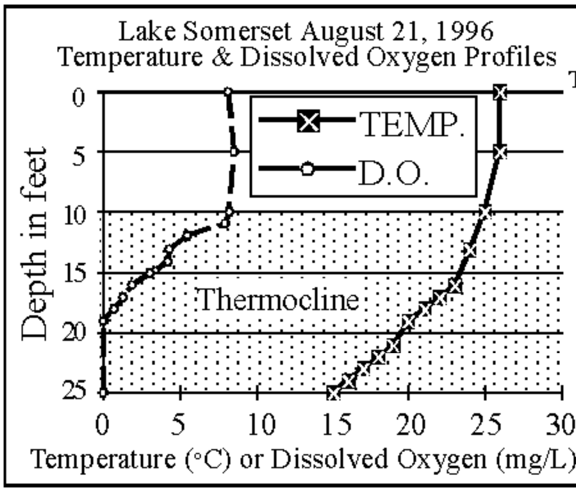
In late summer 1995, the lake formed a 14-foot-thick thermocline from 10 to 24 feet. This year the lake ran out of dissolved oxygen at 16 feet, and that condition remained to the bottom. About 27 percent of the lake is deeper than 16 feet.



Temp.	Depth	D.O.	Depth
29	0	8.3	0
29	5	8.4	5
28	10	7.7	10
27	11	4.7	11
26	13	2.9	12
25	15	2.2	13
24	16	0.8	14
23	18	0.2	15
22	19	0.0	16
21	20	0.0	20
20	21	0.0	24
19	22		
18	23		
17	24		

1996

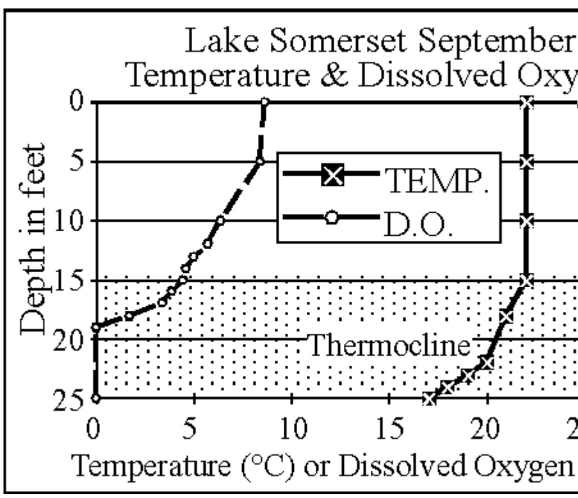
In late summer 1996, the lake formed a 15-foot-thick thermocline from 10 to 25 feet. The lake ran out of dissolved oxygen at 19 feet, and that condition remained to the bottom.



Temp.	Depth	D.O.	Depth
26	0	8.2	0
26	5	8.6	5
25	10	8.3	10
24	13	8.0	11
23	16	5.5	12
22	17	4.3	13
21	18	4.2	14
20	19	3.0	15
19	21	1.9	16
18	22	1.3	17
17	23	0.7	18
16	24	0.0	19
15	25	0.0	25

1997

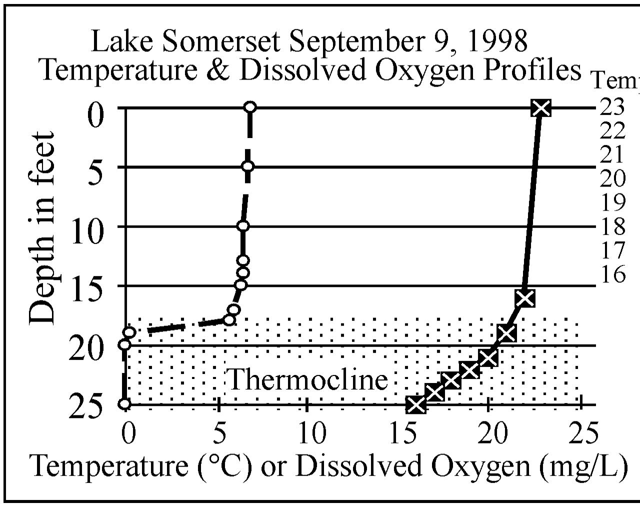
In late summer 1997, the lake formed a 10-foot-thick thermocline from 15 to 25 feet. Dissolved oxygen was plentiful in the



Temp.	Depth	D.O.	Depth
22	0	8.6	0
22	5	8.4	5
22	10	6.4	10
22	15	5.7	12
21	18	5.0	13
20	22	4.6	14
19	23	4.4	15
18	24	3.9	16
17	25	3.4	17
		1.7	18
		0.0	19
		0.0	25

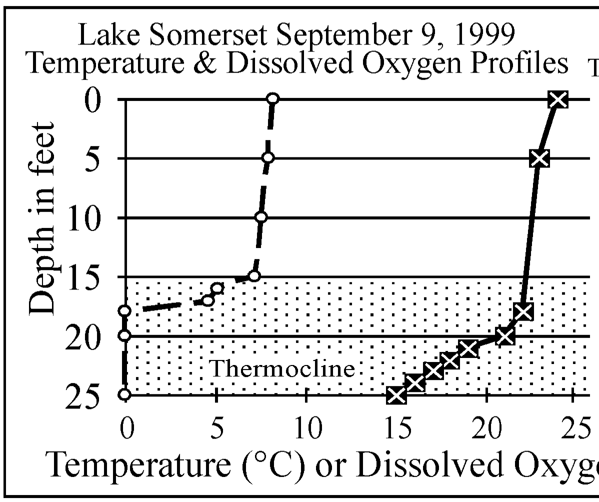
first five feet of water and started to decrease below that depth. It was zero at 19 feet. That condition remained to the bottom.

1998



Temp.	Depth	D.O.	Depth
23	0	6.9	0
22	16	6.8	5
21	19	6.5	10
20	21	6.5	13
19	22	6.5	14
18	23	6.4	15
17	24	6.0	17
16	25	5.8	18
		0.3	19
		0.0	20
		0.0	25

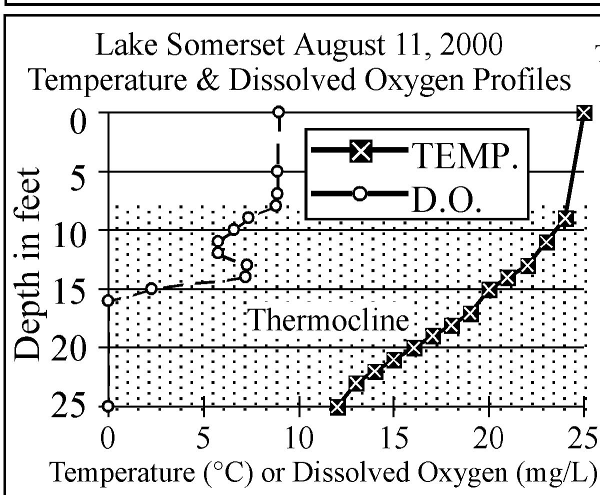
In late summer 1998, the lake formed a 7-foot-thick thermocline from 18 to 25 feet. The lake ran out of dissolved oxygen at 20 feet. About 11 percent of the lake is deeper than 20 feet.



Temp.	Depth	D.O.	Depth
24	0	8.2	0
23	5	7.9	5
22	18	7.6	10
21	20	7.2	15
19	21	5.1	16
18	22	4.6	17
17	23	0.0	18
16	24	0.0	20
15	25	0.0	25

1999

In late summer 1999, the lake formed a 10-foot-thick thermocline from 15 to 25 feet. The lake ran out of dissolved oxygen at 18 feet.

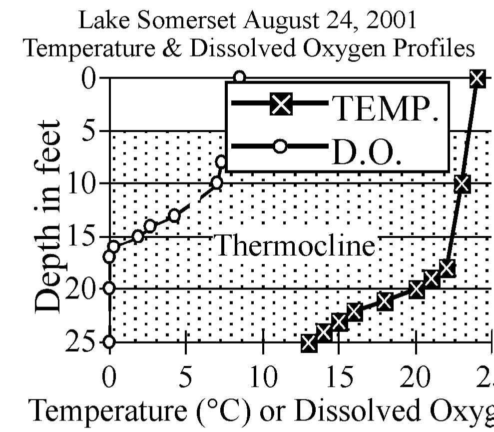


Temp.	Depth	D.O.	Depth
25	0	9.0	0
24	9	8.9	5
23	11	8.9	7
22	13	8.8	8
21	14	7.4	9
20	15	6.6	10
19	17	5.8	11
18	18	5.8	12
17	19	7.3	13
16	20	7.2	14
15	21	2.3	15
14	22	0.0	16
13	23	0.0	25
12	25		

2000

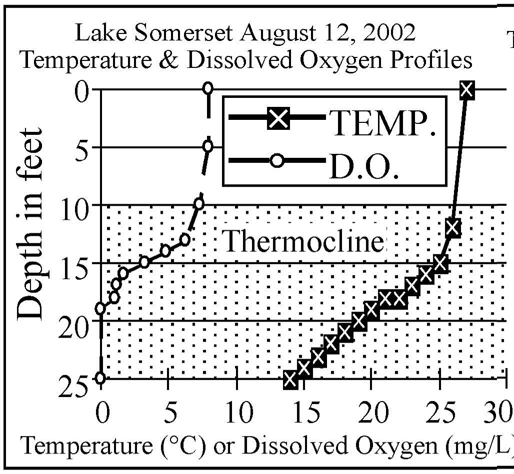
In late summer 2000, the lake formed a 17-foot-thick thermocline from 8 to 25 feet. Dissolved oxygen was plentiful in the surface water. A dissolved oxygen maximum occurred in the thermocline, probably the result of an algal bloom which settled there. The lake ran out of dissolved oxygen at 16 feet, and that condition remained to the bottom.

2001



Temp.	Depth	D.O.	Depth
24	0	8.5	0
23	10	8.5	5
22	18	7.3	8
21	19	7.0	10
20	20	4.3	13
18	21	2.7	14
16	22	1.9	15
15	23	0.3	16
14	24	0.0	17
13	25	0.0	20
		0.0	25

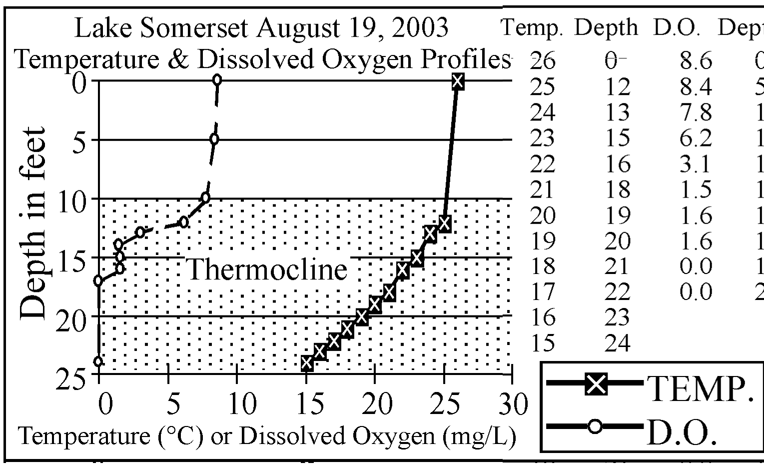
In late summer 2001, the lake formed a 20-foot-thick thermocline from five to 25 feet. Dissolved oxygen was plentiful in the first five feet (above the top of the thermocline). It started to decrease at the top of the thermocline, and was zero at 17 feet. That condition remained to the bottom.



Temp.	Depth	D.O.	Depth
27	0	8.0	0
26	12	7.9	5
25	15	7.3	10
24	16	6.3	13
23	17	4.8	14
22	18	3.2	15
21	18	1.7	16
20	19	1.2	17
19	20	1.1	18
18	21	0.0	19
17	22	0.0	25
16	23		
15	24		
14	25		

2002

In late summer 2002, the lake formed a 15-foot-thick thermocline from 10 to 25 feet.



Temp.	Depth	D.O.	Depth
26	0	8.6	0
25	12	8.4	5
24	13	7.8	10
23	15	6.2	12
22	16	3.1	13
21	18	1.5	14
20	19	1.6	15
19	20	1.6	16
18	21	0.0	17
17	22	0.0	24
16	23		
15	24		

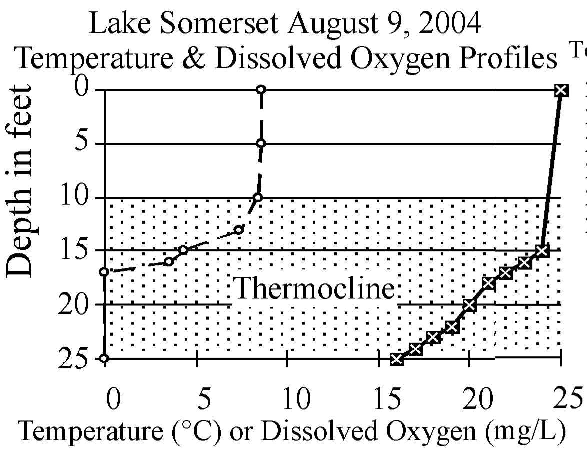
Dissolved oxygen was plentiful above the thermocline. It started to decrease at the top of the thermocline, and was zero at 19 feet. That condition remained to the bottom.

2003

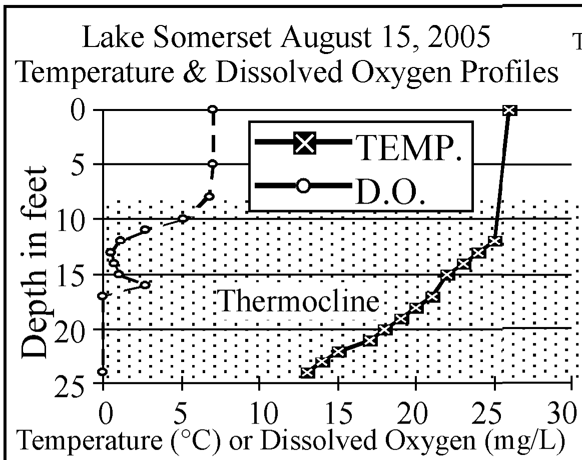
In late summer 2003, the lake formed a 15-foot-thick thermocline from 10 to 25 feet. Dissolved oxygen was plentiful above the thermocline. It started to decrease at 10 feet, the top of the thermocline, and was zero at 17 feet. That condition remained to the bottom. About 22 percent of the lake is deeper than 17 feet.

2004

In late summer 2004, the lake formed a 15-foot-thick thermocline from 10 feet to the bottom at 25 feet. Dissolved oxygen was plentiful above the thermocline. It started to decrease below 10 feet, the top of the thermocline, and was zero at 17 feet. That condition remained to the bottom.



Temp.	Depth	D.O.	Depth
25	0	8.6	0
24	15	8.6	5
23	16	8.4	10
22	17	7.4	13
21	18	4.3	15
20	20	3.6	16
19	22	0.0	17
18	23	0.0	25
17	24		
16	25		



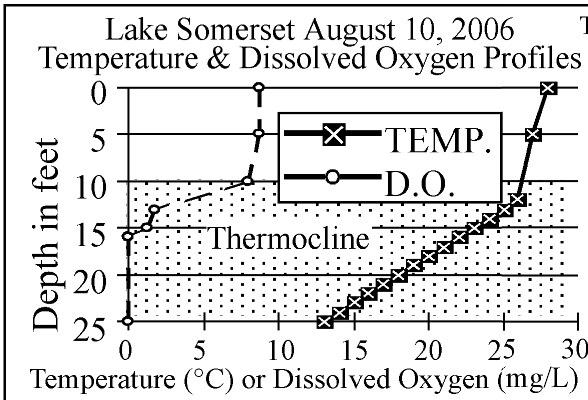
Temp.	Depth	D.O.	Depth
26	0	7.1	0
25	12	7.1	5
24	13	6.8	8
23	14	5.2	10
22	15	2.7	11
21	17	1.2	12
20	18	0.5	13
19	19	0.7	14
18	20	1.1	15
17	21	2.7	16
15	22	0.0	17
14	23	0.0	24
13	24		

2005

In late summer 2005, the lake formed a 17-foot-thick thermocline from 8 feet to the bottom at 25 feet. Dissolved oxygen was plentiful above the thermocline. It started to decrease below 8 feet, the top of the thermocline, and was zero at 17 feet. That condition remained to the bottom. A small dissolved oxygen maximum occurred in the thermocline, probably the result of an algal bloom which settled there.

2006

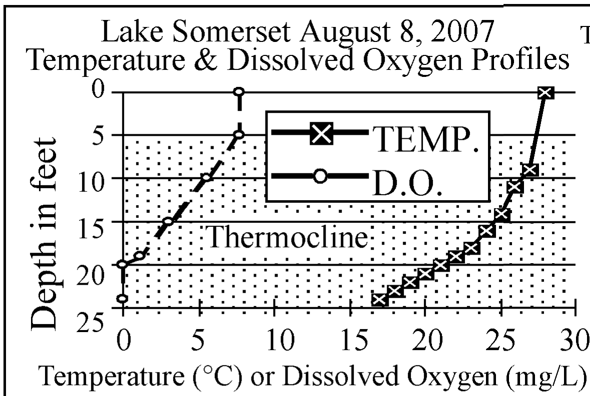
In late summer 2006, the lake formed a 15-foot-thick thermocline from 10 feet to the bottom at 25 feet. Dissolved oxygen was plentiful above the thermocline. It started to decrease at 10 feet, the top of the thermocline, and was zero at 16 feet. That condition remained to the bottom.



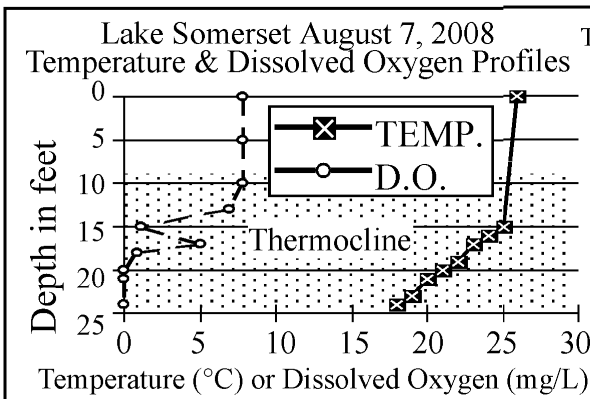
Temp.	Depth	D.O.	Depth
28	0	8.7	0
27	5	8.7	5
26	12	8.0	10
25	13	1.8	13
24	14	1.3	15
23	15	0.0	16
22	16	0.0	25
21	17		
20	18		
19	19		
18	20		
17	21		
16	22		
15	23		
14	24		
13	25		

2007

In late summer 2007 Lake Somerset formed a 20-foot thick thermocline from 5 to 25 feet, the bottom of the lake. Dissolved oxygen was low but uniform in the top five feet and started to decrease below that depth. The lake ran out of dissolved oxygen at 20 feet, and that condition remained to the bottom.



Temp.	Depth	D.O.	Depth
28	0	7.7	0
27	9	7.7	5
26	11	5.6	10
25	14	3.1	15
24	16	1.2	19
23	18	0.0	20
22	19	0.0	24
21	20		
20	21		
19	22		
18	23		
17	24		

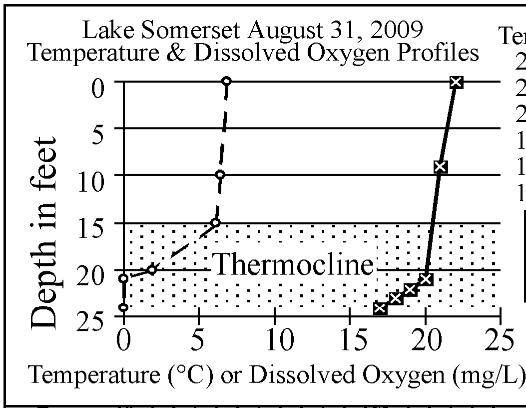


Temp.	Depth	D.O.	Depth
26	0	7.8	0
25	15	7.8	5
24	16	7.8	10
23	17	6.9	13
22	19	1.2	15
21	20	5.1	17
20	21	0.9	18
19	23	0.0	20
18	24	0.0	21
		0.0	24

2008

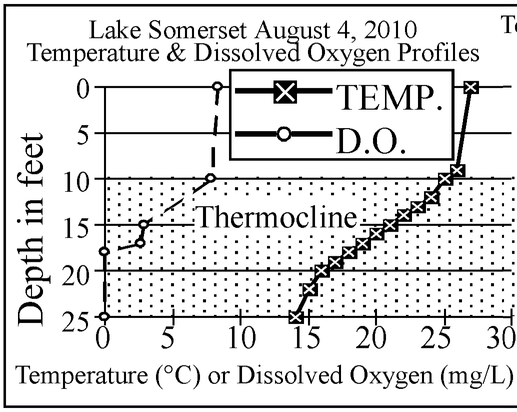
In late summer 2008 Lake Somerset formed a 14-foot thick thermocline from 10 to 24 feet, the bottom of the lake. Dissolved oxygen was low but uniform in the top ten feet and started to decrease below that depth. The lake ran out of dissolved oxygen at 20 feet, and that condition remained to the bottom.

2009



Temp.	Depth	D.O.	Depth
22	0	6.9	0
21	9	6.4	10
20	21	6.1	15
19	22	1.9	20
18	23	0.0	21
17	24	0.0	24

In late summer 2009 the lake formed a 9-foot thick thermocline from 15 to 24 feet. Dissolved oxygen supplies were low but adequate above 15 feet. The dissolved oxygen concentration started to decrease below 15 feet and at 21 feet it was zero. That condition remained to the bottom.



Temp.	Depth	D.O.	Depth
27	0	8.3	0
26	9	7.8	10
25	10	2.9	15
24	12	2.6	17
23	13	0.0	18
22	14	0.0	25
21	15		
20	16		
19	17		
18	18		
17	19		
16	20		
15	22		
14	25		

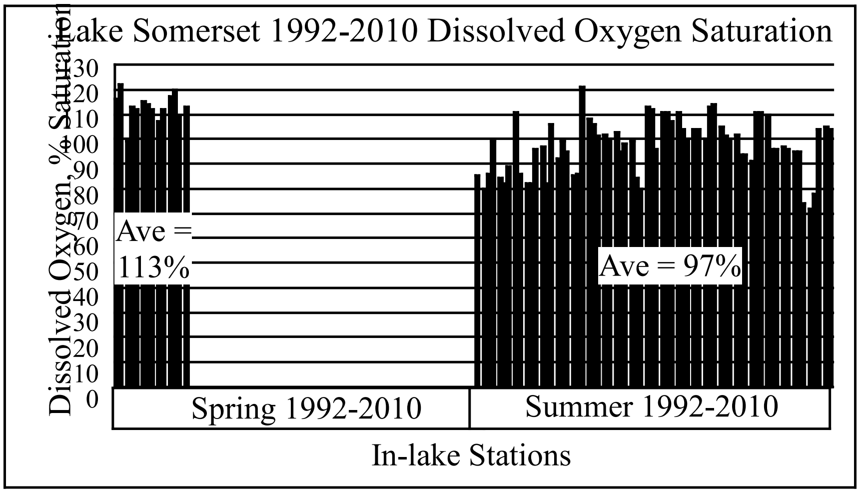
2010

In late summer 2010 the lake formed a 15-foot thick thermocline from 10 to 25 feet. Dissolved oxygen supplies were adequate above 10 feet. The dissolved oxygen concentration started to decrease below 10 feet (the top of the thermocline) and at 18 feet it was zero. That condition remained to the bottom.

DISSOLVED OXYGEN PERCENT SATURATION

Since the amount of dissolved oxygen a water can hold is temperature dependent, with cold water holding more dissolved oxygen than warm water, dissolved oxygen saturation is often a better way to determine if supplies of dissolved oxygen are adequate. Best is between 90 and 110 percent.

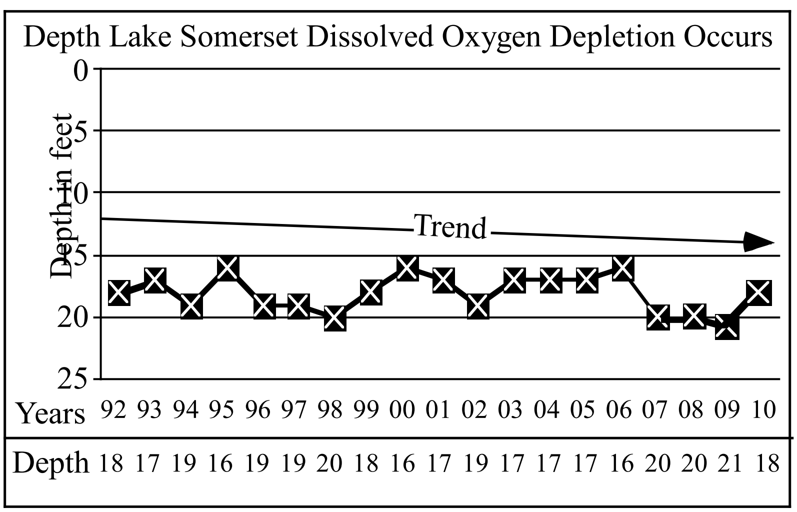
Except in 1992, spring dissolved oxygen concentrations were not measured, hence the missing spring data.



The graph shows most of the time in summer the dissolved oxygen saturation values are within the acceptable range (with a lot of variation). However in 2009, they were low at all three stations, ranging from 72 to 78 percent. The cause of these low values is unknown. 2010 values were much more acceptable.

DISCUSSION

One of the ways to follow changes in water quality is to watch the depth at which the lake runs out of dissolved oxygen. Best is when it doesn't change from year to year. Shallower losses of dissolved oxygen as the years pass is an indication of decreasing water quality. In Lake Somerset, the lake generally seems to run out of dissolved oxygen at 18 to 20 feet in late summer, although in 2000 and 2001, the depths were 16 and 17 feet, respectively. 2002 returned to 19 feet while 2003, 2004 and 2005 were 17 feet. In 2006 it was 16 feet. In 2007 and 2008 it returned to 20 feet and in 2009 it was 21 feet, which was the best so far. In 2010 it was 18 feet.



A NOTE ABOUT THE FOLLOWING GRAPHS

The Lake Somerset graphs of water quality data shown below includes all the surface data collected on the lake since 1992.

The data on the graphs below are first sorted by lake and inlet, then the lake data are sorted by spring and summer. The inlet data are not sorted by spring and summer. The purpose of doing this is to detect differences between the lake data in spring and summer, and differences between the lake and inlet data in both spring and summer. Average values for each data set are also shown on the graphs.

The data which the graphs were produced from are found in atlas pages at the end of this report and are sorted by date and then sample station.

Inlet data since 1995 are included with the surface data on the graphs where applicable (nitrates, phosphorus, conductivity, and alkalinity) while Secchi disk depth, chlorophyll a and dissolved oxygen saturation are not, since they are lake, not stream tests.

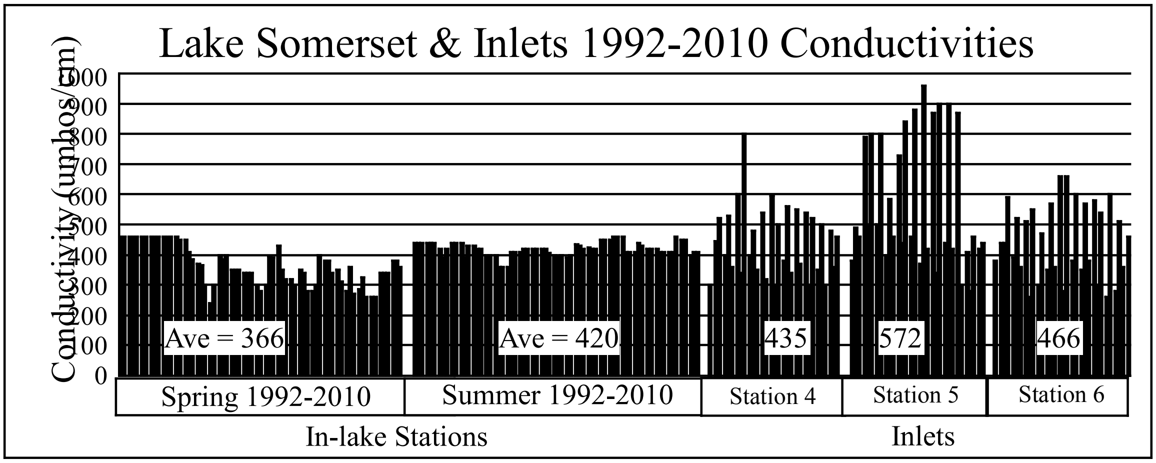
Nitrate nitrogen data are shown on two different graphs, one showing only the lake data, while another combining the lake and inlet data. The reason for this is the high nitrate concentrations of the inlet data would pretty much hide the lower lake surface nitrate nitrogen data.

CONDUCTIVITY

Conductivity, measured with a meter, detects the capacity of a water to conduct an electric current. More importantly however, it measures the amount of materials dissolved in the water (salts), 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 good quality water. I agree. Lower is usually better.

The graph shows in spring conductivities in Lake Somerset range from 240 to 460 micromhos/cm and average 366 umhos/cm. However they are usually in the 250 to 350 umhos/cm range, which is low but normal for a moderately hard water to hard water Michigan inland lake.



The graph shows in summer, conductivities are much more stable, ranging from 360 to 460 and averaging 420 umhos/cm.

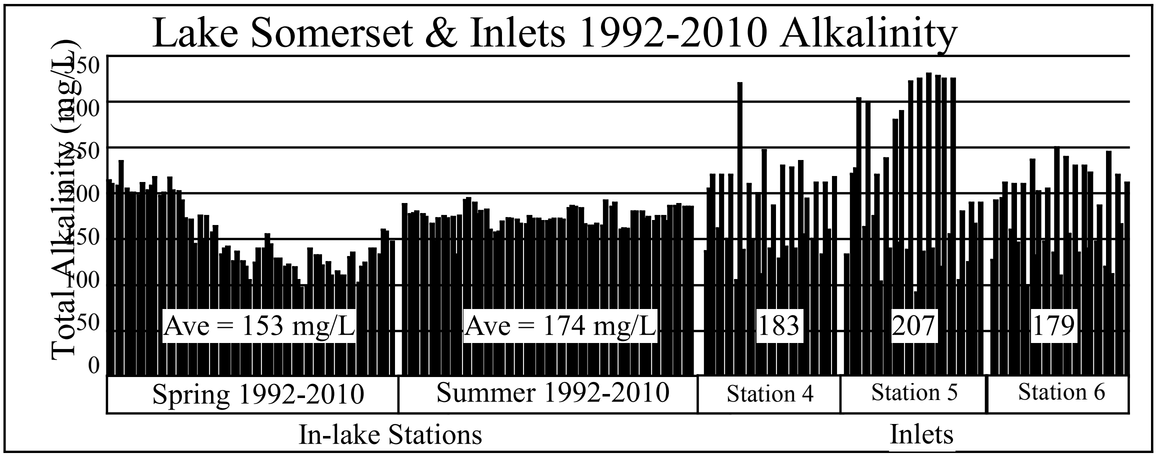
Station 4 has the lowest inlet conductivities, averaging 435 umhos/cm. Station 6 is next, with conductivities averaging 466 umhos/cm. Station 5 has the highest conductivities and the highest average conductivities, 572 umhos/cm.

These data indicate salts may be entering the lake from the inlet streams, especially Station 5. (Conductivities above 600-650 generally indicate the presence of salts in the sample.) However the lake data do not indicate salts are building up in the lake but that may be due to the high flushing rate more than anything.

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 or streams which flow into the lake. In lower Michigan, acidification of most lakes should not be a problem because of the high alkalinity concentrations.

Soft water lakes have alkalinities below 75 milligrams per liter. Moderately hard water lakes have alkalinities between 75 and 150 milligrams per liter. Hard water lakes have alkalinities above 150 milligrams per liter.



The graph shows the surface alkalinity of Lake Somerset ranges from 97 to 235 mg/L in spring and averages 153 mg/L. In summer they range from 133 to 195 mg/L and average 174 mg/L. These data indicate Lake Somerset is a moderately hard water to hard water lake. The graph shows summer alkalinities are generally higher than spring alkalinities. This is unusual because carbonates and bicarbonates, which are what the alkalinity test measures, precipitate to the bottom sediments when the water warms.
The graph shows spring alkalinities in Lake Somerset are decreasing while the summer alkalinities are stable. The cause for this decrease is unknown, although it does not signify a problem. This is a good example of why separating spring and summer data is useful.

Hard water lakes are tougher than soft water lakes because they have the ability to precipitate some phosphorus to the bottom sediments as calcium phosphate. Phosphorus thus tied up is not normally released into the water column when the lake mixes in spring or fall.

The graph shows inlet alkalinites are sometimes higher than lake alkalinities, especially those from Station 5. This is not unusual for carbonates and bicarbonates to be higher in streams than they are in lakes because they enter the stream with the ground water and are carried to the lake where they precipitate to the sediments when the water warms.

NITRATE NITROGEN

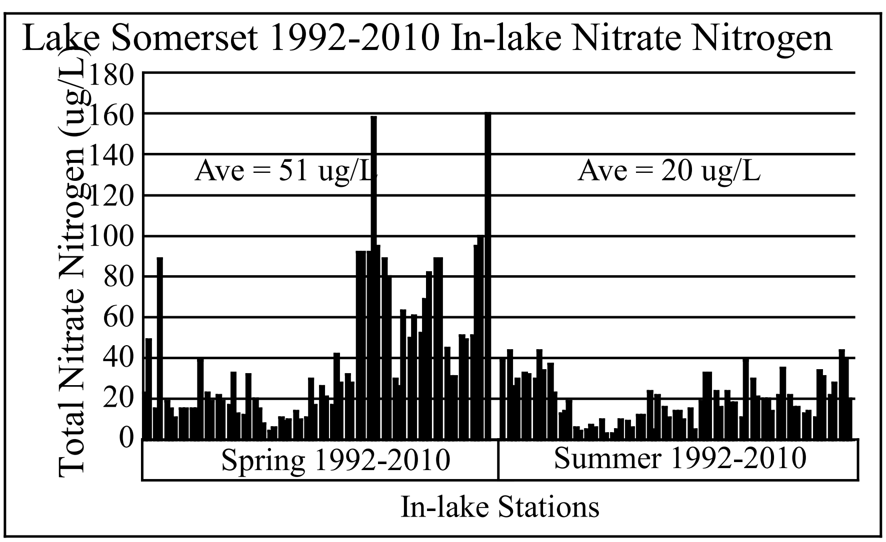
Nitrate, also measured in the parts per billion range, has traditionally been considered by lake scientists to be a limiting nutrient. The experts felt any concentration below 200 parts per billion was excellent in terms of lake water quality. The highest value found by this author was 48,000 parts per billion in a river which flowed into an Ottawa County lake.

On the other hand, we've studied hundreds of Michigan inland lakes, and many times we find them nitrate limited (very low nitrate nitrogen concentrations), especially in summer.

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 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 10-20 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 plant proteins, while phosphorus is used in the transfer of energy, but is not used to create plant material. If the nitrate concentration is less than 10-20 times the phosphorus concentration, the lake is considered nitrogen limited. If the nitrate concentration is higher than 10-20 times the phosphorus concentration, the lake is considered phosphorus limited.

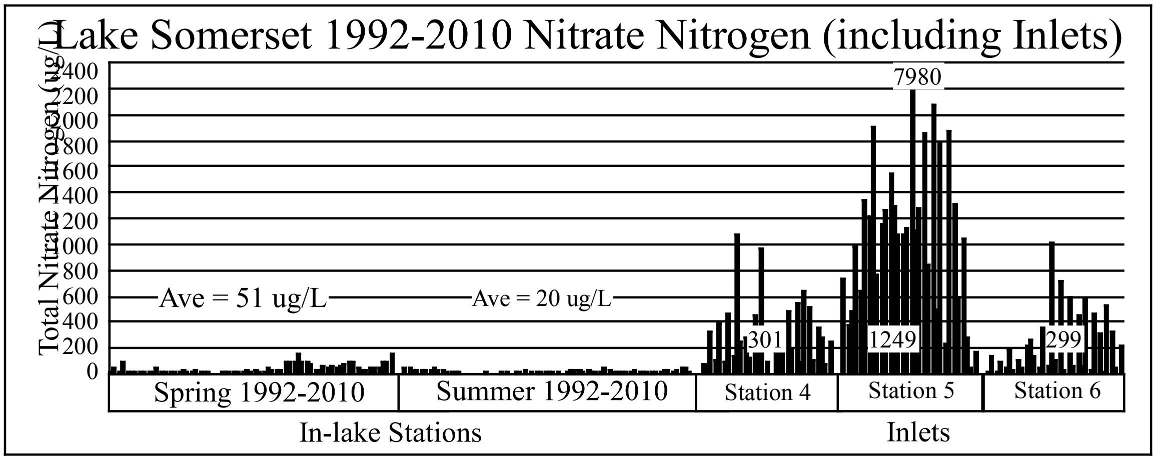
Normal spring nitrate nitrogen concentrations in Michigan inland lakes are usually around 200 micrograms per liter. Summer concentrations are usually much lower, around 20 micrograms per liter or less.



Two graphs of Lake Somerset nitrate nitrogen data are included in this report. The first shows the in-lake surface nitrate nitrogen concentrations since 1992.

This graph shows Lake Somerset nitrate nitrogen concentrations are generally low in both spring and summer although the spring values are higher, which is something we expect.

The low nitrate nitrogen data show Lake Somerset is probably nitrate rather than phosphorus limited in both spring and summer. It also means no fertilizers should be used on near-lake areas.



The second nitrate nitrogen graph shows both the in-lake data and the inlet data. The purpose of this graph is to show how much higher the inlet nitrate nitrogen concentrations are compared to the lake.

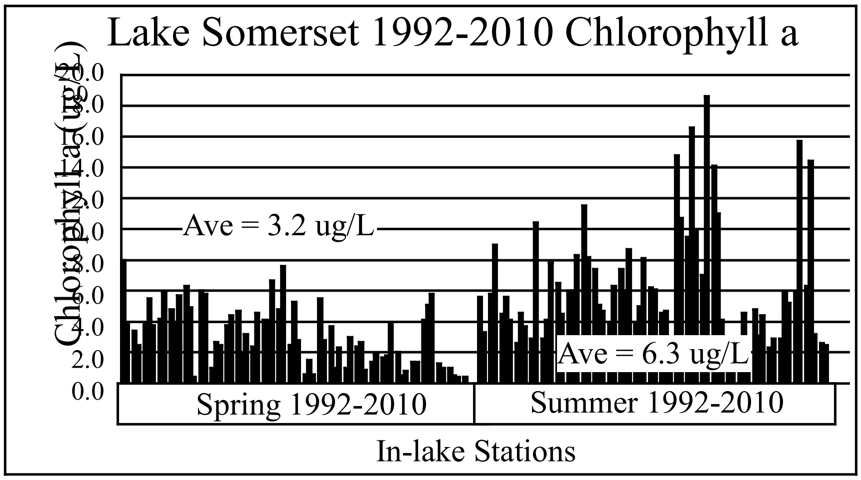
Inlet nitrate nitrogen concentrations, shown by sample station, indicate Station 5 delivers a higher concentration of nitrate nitrogen to Lake Somerset than Stations 4 or 6 (which are both Goose Creek stations). The average nitrate nitrogen concentration from Station 5 is 1249 micrograms per liter. The 7980 micrograms per liter data was truncated on the graph, and identified with the concentration. This is because if the graph had been created with that concentration shown, the rest of the data would have appeared insignificant, if at all.

The average nitrate nitrogen concentration of Station 4 is 301 ug/L, while the average nitrate concentration of Station 6 is 299 ug/L. The average nitrate nitrogen concentration of Lake Somerset is 51 ug/L in spring and 20 ug/L in summer.

The graph also seems to show nitrate nitrogen from Station 5 may be increasing, (although 2010 values were low). Fortunately the flow from this creek is small (around 0.5 cfs) so even though nitrate nitrogen concentrations are high, the amount added to Lake Somerset is not great. On the other hand, this is an ideal situation for governmental agencies such as the DEQ/DNR and the Michigan Department of Agriculture to address. If they can solve a small-source problem like this one, they might be able to solve larger problems. So far, that hasn't happened. And it isn't because they haven't been notified.

CHLOROPHYLL A

Chlorophyll a generally gives an estimate of algal densities. Best is below 1 microgram per liter.



Lake Somerset surface chlorophyll a concentrations ranged from 0.4 to 8.0 micrograms per liter, and average 3.2 ug/L in spring. In summer they ranged from 1.7 to 18.6 ug/L and averaged 6.3 ug/L. In spring 2010 they were low, 0.4 to 0.5 ug/L while in summer they were higher, ranging from 2.5 to 3.2 ug/L.

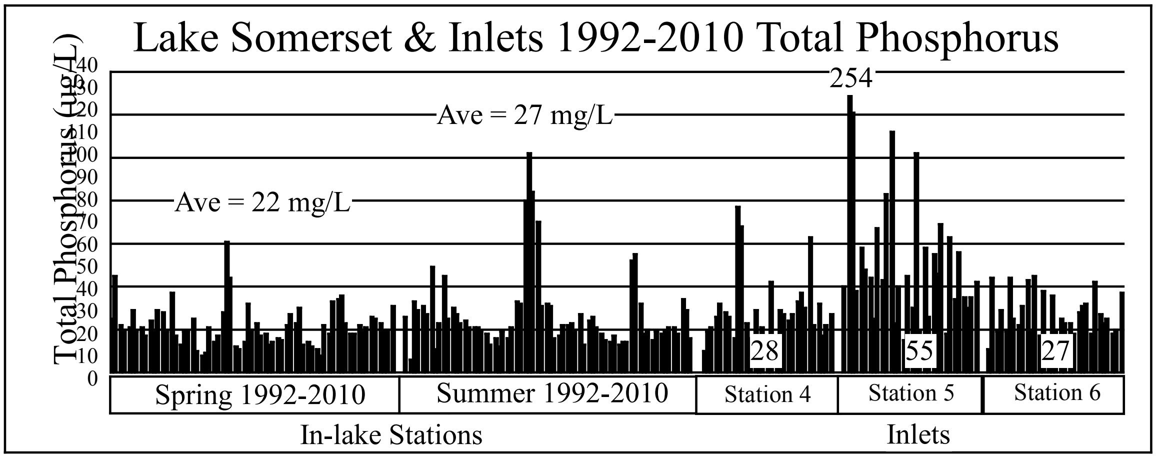
The graph shows summer chlorophylls are higher than spring chlorophylls, probably due to increased algal growth caused by warmer water.

TOTAL PHOSPHORUS

Although there are several forms of phosphorus found in lakes, the experts selected total phosphorus as being most important. This is probably because all forms of phosphorus can be converted to the other forms. Currently, most lake scientists feel phosphorus, which is measured in parts per billion (1 part per billion is one second in 31 years) or micrograms per liter (ug/L), is the one nutrient which might be controlled. If its addition to lake water could be limited, the lake might not become covered with the algal communities so often found in eutrophic lakes.

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 is considered a low concentration of phosphorus in a lake and 50 parts per billion is considered a high value in a lake by many limnologists. Best is below 10 micrograms per liter.



The graph shows spring lake phosphorus concentrations range from 8 to 61 micrograms per liter and average 22 ug/L while summer lake values range from 6 to 102 ug/L and average 27 ug/L. Inlet 4 averages 28 ug/L and inlet 6 averages 27 ug/L, which are essentially the same. That's good because they are different sample sites on the same stream.

Station 5 averaged 55 ug/L. These are high phosphorus values. Fortunately the flow from this inlet is small so the effect on the lake is minimal. However, both the DNR and the Michigan Department of Agriculture have been notified of this problem, yet it still exists. They are the ones responsible for addressing it, since they have the statutory authority.

The lake contains 6.02 billion pounds of water. Multiplying that number by the average in-lake phosphorus concentration (22 ug/L in spring and 27 ug/L in summer) indicates the lake has about 132 pounds of phosphorus in it in spring and about 163 pounds of phosphorus in it in summer. As you can see this is not a lot of phosphorus. If the amount of phosphorus in the lake would double, you would have real problems.

pH (HYDROGEN ION CONCENTRATION) (no graph)

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 southern Michigan which are being affected by acid rain. Most lakes have pH values between 7.5 and 9.0.

Lake Somerset pH values were normal for a Michigan inland lake, ranging from 7.1 to 8.8.

Normal summer pH values for Michigan inland lakes are below 9. Higher pH values, (greater than 9) can be caused by excessive plant and algal communities which use carbonates as a carbon source, removing them from the system. This allows the pH to rise.

SECCHI DISK TRANSPARENCY (originally Secchi's disk)

In 1865, Angelo Secchi, the Pope's astronomer in Rome, Italy devised a 20 centimeter (8 inch) white disk for studying the transparency of the water in the Mediterranean Sea. Later an American limnologist (lake scientist) named Whipple divided the disk into black and white quadrants which many are familiar with today.

The Secchi disk transparency is a lake test widely used and accepted by limnologists. The experts generally felt the greater the Secchi disk depth, the better quality the water. However, one Canadian scientist pointed out acid lakes have very deep Secchi disk readings. Most lakes in southeast Michigan have Secchi disk transparencies of less than ten feet. On the other hand, Elizabeth Lake in Oakland County had 34 foot Secchi disk readings in summer 1996, evidently caused by a zebra mussel invasion a couple of years earlier.

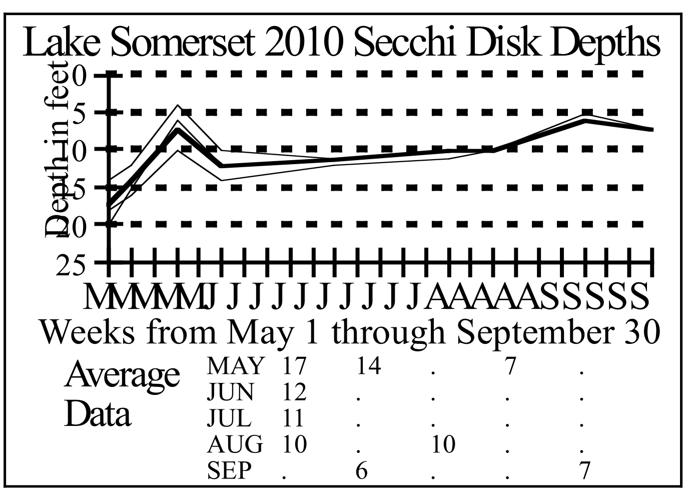
Most limnology texts recommend the following: to take a Secchi disk transparency reading, lower the disk into the water on the shaded side of an anchored boat to a point where it disappears. Then raise it to a point where it's visible. The average of these two readings is the Secchi disk transparency 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 grandchildren see it disappear 3-4 feet deeper than grandparents.

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 deeper site. Since the sampling procedure is designed to obtain "representative samples" 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 the disk is visible on the lake bottom.

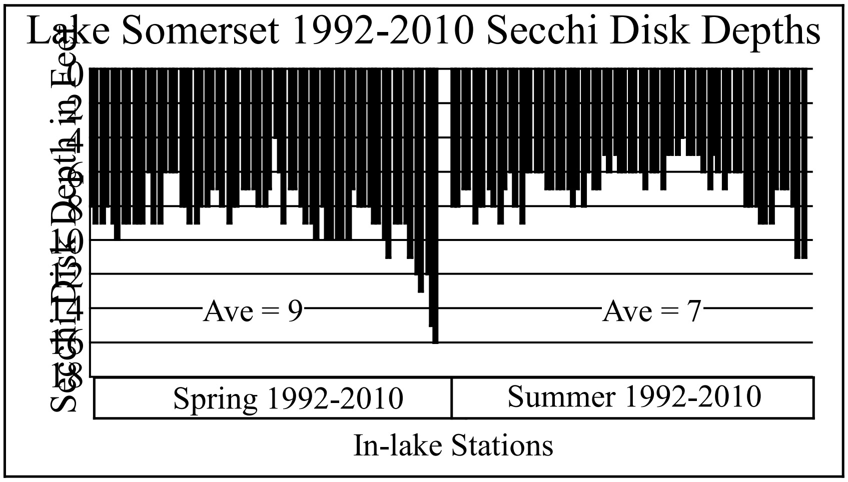
LAKE SOMERSET 2010 SECCHI DISK DATA



George Rausch did a good job taking Secchi disk readings at the three in-lake stations during the warm months in 2010. The graph shows his data. The data for each station are shown on the graph. The dark line is the average of the three data sets.

Early May average water clarity was 17 feet. Late May average readings were 7 feet. After that they increased to 10 to 12 feet through August. In September they decreased to 6 and 7 feet.

SECCHI DISK DATA COLLECTED WITH THE SAMPLES



The graph shows the Secchi disk data collected when the water samples were collected from 1992 through 2010 in spring and summer. It shows Secchi disk were getting shallower from 1992 through about 1999. Since then the clarity of the lake appears to be getting better in both spring and summer. Spring 2010 readings were 12 to 16 feet and summer readings were 8 to 11 feet. These are the best spring and summer readings since we started collecting data. Let's hope that trend continues.

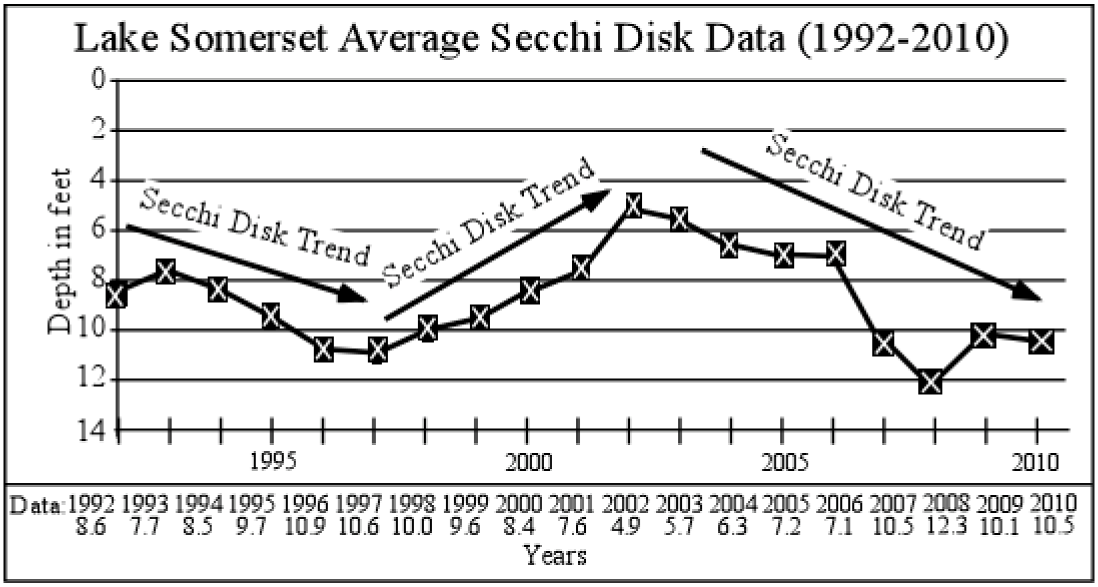
As George Rausch noted when he submitted his 2008 Secchi disk data, the increase in clarity is probably due to a zebra mussel infestation.

It is important that Lake Somerset residents continue to take Secchi disk readings on a regular basis through the warm months, especially on this lake because they provide meaningful data. And the readings should continue to be taken at all three stations.

SECCHI DISK TREND

Since Dan Doyle and now George Rausch have been taking Secchi disk readings on a regular basis since 1992, it is possible to develop a Secchi disk trend graph.

The graph shows some ups and downs to the clarity of Lake Somerset. From 1992 through 1996 the clarity was increasing, then from 1997 through 2002 the clarity decreased dramatically. Since then the clarity was getting better. 2008 was remarkably better. In 2009 and 2010 the clarity was about the same as in 2007, which was better than most years.



THE LAKE WATER QUALITY INDEX

The Lake Water Quality Index used in this study to define the water quality of Lake Somerset 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 lakes, and second, there was no agreement among lake scientists regarding what the results of various tests meant in terms of lake water quality.

Development of the index invoked the use of two questionnaires sent to a panel of 555 lake 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 panel became the index parameters (or tests). They were:

Dissolved oxygen (percent saturation)
Total phosphorus
Chlorophyll a
Secchi disk depth
Total nitrate nitrogen
Total alkalinity
Temperature
Conductivity
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 and rates lakes about the same way professors rate students: 90-100=A, 80-90=B, 70-80=C, 60-70=D, and below 60 = E. The lake with the highest LWQI was Long Lake in Grand Traverse County, with a spring LQWI of 100. The lowest LWQI seen by this author was 16 at an Ottawa County lake.

THE LAKE WATER QUALITY INDEX CALCULATION SHEETS

The Lake Water Quality Index calculation sheets which follow were developed to show graphically what the results of the nine different lake water quality tests mean 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 results of the tests are entered into the square boxes immediately under the names of the tests.

The figures which look like thermometers are actually graphs which convert the test results (the numbers found outside the thermometer) to a uniform 1-100 lake water quality rating (found inside the thermometer).

The calculation sheet permits calculation of the Lake Water Quality Index, using the results of all nine lake water quality tests.

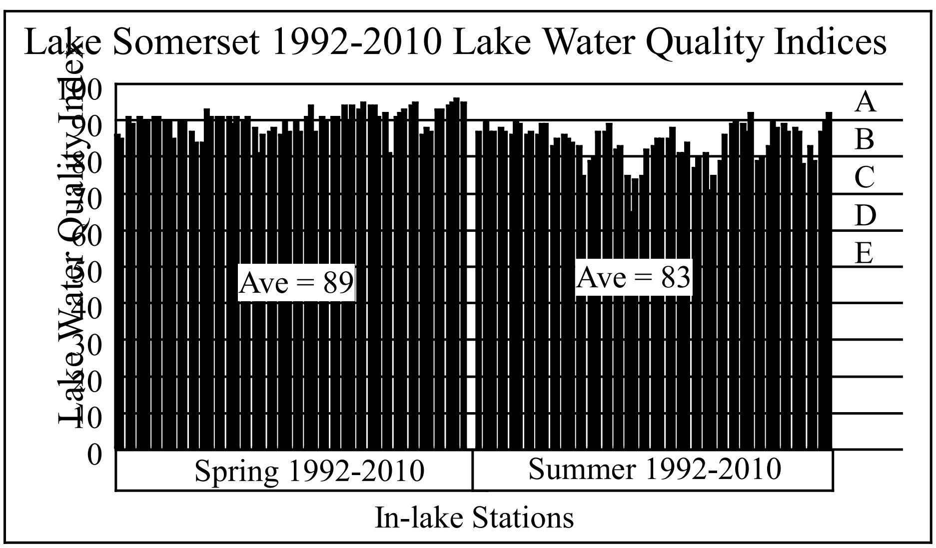
The position of the red lines across the thermometer indicates how the results of each test compare in terms of lake water quality. Test results indicating excellent water quality are indicated by red lines near the top of the thermometer. Test results indicating poor water quality are indicated by red lines lower on the thermometer. And the lower the red line on the thermometer, the greater the water quality problem. A glance at the top of the calculation sheet indicates the test and the actual test results.

The thermometer rating scales also allow you to determine what test results would be considered excellent in terms of lake water quality. They are the numbers found outside the thermometer near the top.

The index is shown three different ways, as a number 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 test sites within a lake, and determine how the water quality of the various lakes, or test sites within a lake compare.

THE 1992-2010 SPRING & SUMMER LAKE WATER QUALITY INDICES FOR LAKE SOMERSET

The graph shows the spring and summer Lake Water Quality Indices for Lake Somerset from 1992 through 2010. It shows in spring, LWQIs ranged from 80 to 95 (B to A) and averaged 89. In summer LWQIs ranged from 64 to 91 (D to A) and averaged 83.



In spring 2010, the Lake Water Quality Indices for Lake Somerset were 94 or 95 indicating the 2010 spring water quality was in the A range. In late summer 2010, the LWQIs ranged from 86 to 91 or in the A to B range.

The graph shows spring LWQIs are generally higher than summer LWQIs, and in spring it looks like the water quality is getting better.

In summer the graph shows much more variation, but overall it does not show the water quality is changing in summer.

THE LAKE WATER QUALITY INDEX CALCULATION SHEETS

Because the 2010 spring lake water quality indices were about the same, (94 95 94) and the 2010 summer lake water quality indices were relatively uniform, (86 89 91) only two Lake Water Quality Index calculation sheets are included in this report, one for the three spring 2010 surface samples, using averaged data, and a second for the three summer 2010 surface samples, again using averaged data.

In the report marked MASTER, all six of the 2010 LWQI calculation sheets are included. That is the only difference between the MASTER and the rest of the reports. The Lake Water Quality Index was designed to look at lake, not inlet water. Thus no LWQIs were calculated for the inlet samples.

BOTTOM SEDIMENTS

Many times bottom sediments tell us more about what is happening in a lake than the water quality tests do. That's because bottom sediments provide sort of a history of what's been happening in a lake, while water testing just provides a snapshot.

Bottom sediments are collected with a Pederson dredge, transferred to pint freezer containers and allowed to air dry. Once they are dry, the (usually) shrunken block of material is measured to determine volume, then ground, placed in porcelain dishes, dried at 100 degrees C, weighed, burned at 550 degrees C, and weighed again. Color after air-drying and after burning is also noted.

Bottom sediments almost always come up from the lake bottom black, and many people consider these black sediments "muck". However, that's not usually the case.

The bottom sediments are black because no oxygen penetrates them, so the decomposition processes which occur use sulfur rather than oxygen, and in this process, produce iron sulfides, which are black. However once the sediments are exposed to air, they usually turn some other color.

If the sediments remain black after air drying it usually means they are less than about 65 percent mineral (or more than 35% organic material). Sediments also remain black if they are from soft water lakes, but there's a reason for that.

If the sediments turn gray after air drying it usually means they are made up primarily of carbonates. This is what we usually see in moderately hard water and hard water lakes.

If the sediments turn tan, it usually means they are made up primarily of clays. Further evidence of this occurs when we burn the sediments at 550 degrees C.

If the gray bottom sediments remain gray after burning, they are considered carbonates, and the loss of material during this process is considered organic material. The results are expressed in the percentage of minerals in the bottom sediments.

If the tan bottom sediments turn red after burning, it means the lake is filling with clay. Clay enters the lake from near-lake activities such as road building, home building or farming. Usually clay is not a material that makes up the bottom sediments of most Michigan inland lakes.

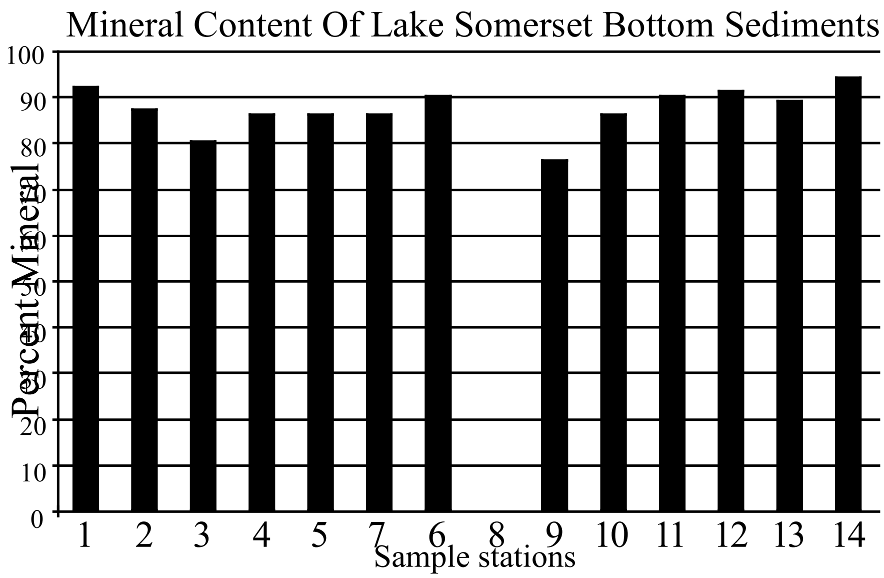
Highly organic sediments that remained black after air drying usually turn tan after burning, but the mineral content is usually quite low.

I consider high quality bottom sediments from natural hard water lakes to be above 85 percent mineral. And I consider bottom sediments of hard water lakes that are less than 50 percent mineral to be muck. Soft water lakes are a different story.

LAKE SOMERSET BOTTOM SEDIMENTS

Bottom sediments were collected from 13 of the 14 stations in Lake Somerset in late summer 1992. The graph shows the data. The color of the sediments was black when recovered from the lake bottom, but all turned gray after air-drying, indicating Lake Somerset is filling with carbonates and bicarbonates, which is normal for a southern Michigan inland lake.

The mineral content of the bottom sediments ranged from 76 to 94 percent



Characteristics of Lake Somerset Bottom Sediments (1992)

Sample I.D.	Percent Mineral	Dried at 100°C Color & Description	Color after burning at 550°C	Depth of water (feet)
1	92	Gray smooth	Brick red	8
2	87	Gray smooth	Brick red	6
3	80	Gray smooth	Bright brick red	13
4	86	Gray smooth	Brick red	6
5	86	Gray smooth	Brick red	19
6	86	Gray smooth	Brick red	11
7	90	Gray smooth	Red gray	6
8		No sample, weeds too dense		
9	76	Gray smooth	Bright brick red	12
10	86	Gray smooth	Brick red	25
11	90	Gray smooth	Gray	7
12	91	Gray smooth	Brick red	6
13	89	Gray smooth	Brick red	8
14	94	Gray smooth	Dark gray	7
87 percent = average mineral content of bottom sediments				

after burning at 550°C, and averaged 87 percent. Eleven of the thirteen samples turned red after burning, indicating either clay was being washed into the lake from near-shore activities such as road building or home building, or the lake bottom was lined with clay to prevent loss of water due to the head created by construction of the dam.

In most inland lakes, these would be considered excellent bottom sediments, but most lakes in Michigan are 7,000-10,000 years old. Lake Somerset is only about 24 years old when these samples were collected, having been constructed in 1968. It appears organic material is starting to build up in the sediments. This is generally not desirable.

Wallace E. Fusilier, Ph.D.
Consulting Limnologist
Water Quality Investigators
Dexter, Michigan
January 2011

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
5/10/92	1	17	11.3	116	8.0	8	23	214	8.3	460	25	85	B
5/10/92	2	18	11.6	122	3.9	9	49	210	8.1	460	45	84	B
5/10/92	3	17	11.0	99	3.4	9	15	208	8.1	460	22	90	A
5/10/92	4	21	10.2	113	2.5	8	89	235	8.0	460	20	88	B
5/10/92	5	18	10.6	112	4.0	9	19	205	8.2	460	21	90	A
5/10/92	6	18	10.9	115	5.5	10	15	201	8.2	460	29	89	B
5/10/92	7	21	10.3	114	3.8	9	11	201	8.2	460	19	89	B
5/10/92	8	20	10.3	112	4.2	9	15	198	8.2	460	21	90	A
5/10/92	9	19	11.1	107	5.9	9	15	211	8.2	460	17	90	B
5/10/92	10	18	10.6	112	4.8	9	15	203	8.2	460	24	89	B
5/10/92	11	19	11.0	117	3.9	9	15	208	8.2	460	20	89	B
5/10/92	12	22	10.6	120	5.7	6	39	218	8.1	460	29	84	B
5/10/92	13	20	10.0	109	6.3	9	23	197	8.1	460	28	89	B
5/10/92	14	18	10.7	113	4.9	9	19	201	8.2	460	19	89	B
8/19/92	1	23	7.4	85	5.6	8	39	188	8.4	440	26	86	B
8/19/92	2	23	7.0	80	3.3	8	44	177	8.3	440	6	89	B
8/19/92	3	22	7.6	86	5.8	7	26	178	8.3	440	33	86	B
8/19/92	4	23	8.7	99	9.0	7	30	180	8.4	440	29	86	B
8/19/92	5	23	7.3	84	4.5	9	33	177	8.3	440	31	87	B
8/19/92	6	22	7.2	82	5.6	8	32	174	8.3	440	27	86	B
8/19/92	7	22	7.8	89	4.1	8	30	167	8.3	420	49	85	B
8/19/92	8	22	9.8	111	2.6	7	44	148	8.4	390	11	89	B
8/19/92	9	22	7.6	86	4.6	8	34	173	8.3	420	23	88	B
8/19/92	10	22	7.1	82	3.7	9	37	175	8.2	440	45	85	B
8/19/92	11	23	7.1	82	2.9	7	23	173	8.3	440	25	86	B
8/19/92	12	24	8.2	96	10.4	6	13	174	8.4	440	30	85	B
8/19/92	13	23	8.5	97	2.9	8	14	133	8.3	390	27	88	B
8/19/92	14	23	7.1	82	4.1	9	19	176	8.2	430	23	88	B
5/9/93	1	---	---	---	0.4	6	22	217	8.1	450	37	86	B
5/9/93	2	---	---	---	6.0	6	19	203	8.3	450	17	83	B
5/9/93	3	---	---	---	5.8	6	17	202	8.4	410	13	83	B
8/2/93	1	24	9.0	106	7.8	6	6	193	8.1	430	24	82	B
8/2/93	2	24	7.8	92	6.5	6	4	195	8.0	420	21	84	B
8/2/93	3	24	8.4	99	4.5	6	5	190	8.2	420	21	85	B
5/9/94	1	---	---	---	1.0	8	33	192	7.9	385	19	92	A
5/9/94	2	---	---	---	2.7	8	13	173	7.9	370	19	90	A
5/9/94	3	---	---	---	2.5	9	12	171	7.9	365	25	90	A
8/9/94	1	23	8.3	95	6.0	6	7	177	8.2	400	21	84	B
8/9/94	2	23	7.4	85	6.0	7	6	181	8.3	400	19	83	B
8/9/94	3	23	7.5	86	8.3	7	10	182	8.3	400	18	82	B
4/20/95	1	---	---	---	3.8	9	32	145	8.3	300	10	90	A
4/20/95	2	---	---	---	4.4	8	20	176	7.9	240	8	90	A
4/20/95	3	---	---	---	4.7	8	15	149	8.4	300	9	88	B
4/20/95	4	---	---	---	3.2	8	78	137	7.6	300	10	88	B
4/20/95	5	---	---	---	---	---	736	133	7.8	380	40	---	---
4/20/95	6	---	---	---	---	---	20	127	7.9	380	11	---	---
8/15/95	1	29	9.4	121	11.5	7	3	160	8.8	360	13	74	C
8/15/95	2	29	8.4	108	8.2	7	3	157	8.7	360	16	78	C
8/15/95	3	29	8.3	106	7.4	7	5	158	8.7	360	12	79	C
8/15/95	5	---	---	---	---	---	381	221	8.0	490	254	---	---
8/15/95	6	---	---	---	---	---	133	192	8.0	440	44	---	---
5/25/96	1	---	---	---	2.0	7	8	175	8.3	400	21	90	A
5/25/96	2	---	---	---	3.2	7	4	157	7.9	385	14	89	B
5/25/96	3	---	---	---	2.4	8	6	164	8.3	400	17	90	A
5/25/96	4	---	---	---	---	---	68	205	8.4	445	19	---	---
5/25/96	5	---	---	---	---	---	476	227	8.3	460	121	---	---
5/25/96	6	---	---	---	---	---	9	195	8.4	440	19	---	---
8/20/96	1	26	8.3	101	5.1	8	10	169	8.2	410	19	86	B
8/20/96	2	26	8.4	102	4.7	7	9	173	8.2	410	16	86	B
8/20/96	3	26	8.2	100	3.9	8	6	172	8.3	410	21	88	B
8/20/96	4	---	---	---	---	---	324	220	8.0	520	21	---	---
8/20/96	5	---	---	---	---	---	982	304	7.4	790	38	---	---
8/20/96	6	---	---	---	---	---	92	212	7.8	590	29	---	---
4/29/97	1	---	---	---	4.6	9	11	133	8.2	350	28	87	B
4/29/97	2	---	---	---	4.1	8	9	140	8.7	350	61	80	B
4/29/97	3	---	---	---	4.1	8	10	142	8.3	350	44	85	B
4/29/97	4	---	---	---	---	---	110	162	8.0	400	26	---	---
4/29/97	5	---	---	---	---	---	644	163	8.2	500	58	---	---
4/29/97	6	---	---	---	---	---	46	160	7.3	390	19	---	---

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
9/7/97	1	23	9.0	103	6.3	6	12	171	8.7	420	33	81	B
9/7/97	2	22	8.4	95	7.4	7	12	167	8.5	420	32	82	B
9/7/97	3	22	8.6	98	6.0	7	24	166	8.6	420	80	74	C
9/7/97	4	---	---	---	---	---	392	220	8.1	530	32	---	---
9/7/97	5	---	---	---	---	---	1340	300	7.7	800	48	---	---
9/7/97	6	---	---	---	---	---	180	210	8.0	520	44	---	---
4/22/98	1	---	---	---	6.7	7	14	126	7.4	340	12	86	B
4/22/98	2	---	---	---	4.8	7	10	136	7.5	340	11	87	B
4/22/98	3	---	---	---	7.6	7	11	126	7.4	340	14	85	B
4/22/98	4	---	---	---	---	---	93	150	7.4	360	28	---	---
4/22/98	5	---	---	---	---	---	1213	175	7.4	500	44	---	---
4/22/98	6	---	---	---	---	---	28	146	7.3	360	25	---	---
9/8/98	1	23	8.6	99	8.7	5	5	175	8.5	420	102	64	D
9/8/98	2	23	7.3	84	3.9	6	22	172	8.3	420	84	73	C
9/8/98	3	23	6.9	80	5.0	5	16	172	8.3	420	70	74	C
9/8/98	4	---	---	---	---	---	467	220	8.3	600	26	---	---
9/8/98	5	---	---	---	---	---	1900	220	7.8	800	25	---	---
9/8/98	6	---	---	---	---	---	114	210	8.1	510	22	---	---
5/7/99	1	---	---	---	2.5	8	30	120	7.5	300	32	89	B
5/7/99	2	---	---	---	5.3	8	17	105	7.7	280	20	86	B
5/7/99	3	---	---	---	2.8	7	26	124	7.5	300	23	89	B
5/7/99	4	---	---	---	---	---	141	105	7.9	340	16	---	---
5/7/99	5	---	---	---	---	---	767	104	7.6	400	67	---	---
5/7/99	6	---	---	---	---	---	43	100	7.4	260	31	---	---
8/31/99	1	24	96.0	113	8.1	6	11	170	8.4	405	31	81	B
8/31/99	2	24	9.5	112	6.2	6	14	170	8.4	400	32	82	B
8/31/99	3	24	8.2	96	6.1	6	14	171	8.3	395	31	84	B
8/31/99	4	---	---	---	---	---	1080	320	7.5	800	77	81	B
8/31/99	5	---	---	---	---	---	1148	238	8.1	585	43	82	B
8/31/99	6	---	---	---	---	---	218	237	8.0	550	43	89	B
4/23/00	1	---	---	---	0.6	4	21	140	8.4	395	17	86	B
4/23/00	2	---	---	---	1.5	6	17	140	8.1	390	18	90	A
4/23/00	3	---	---	---	0.6	9	42	155	8.2	430	13	93	A
4/23/00	4	---	---	---	---	---	246	138	8.2	400	68	---	---
4/23/00	5	---	---	---	---	---	1260	140	8.1	460	83	---	---
4/23/00	6	---	---	---	---	---	258	132	8.2	300	20	---	---
8/11/00	1	25	9.3	111	4.6	6	10	172	8.7	400	16	84	B
8/11/00	2	25	9.3	111	4.7	6	15	172	8.7	390	17	84	B
8/11/00	3	25	9.0	107	2.7	7	5	171	8.7	400	22	87	B
8/11/00	4	---	---	---	---	---	286	210	8.3	480	23	---	---
8/11/00	5	---	---	---	---	---	1550	280	7.9	730	112	---	---
8/11/00	6	---	---	---	---	---	133	202	8.0	470	45	---	---
4/27/01	1	---	---	---	5.5	7	28	144	8.2	350	14	86	B
4/27/01	2	---	---	---	2.8	7	32	129	8.2	320	16	90	A
4/27/01	3	---	---	---	3.7	8	28	129	8.2	320	15	89	B
4/27/01	4	---	---	---	---	---	128	149	8.7	350	16	---	---
4/27/01	5	---	---	---	---	---	1300	146	8.9	440	23	---	---
4/27/01	6	---	---	---	---	---	40	147	8.4	350	17	---	---
8/24/01	1	24	9.5	111	14.8	6	19	184	8.5	435	22	80	B
8/24/01	2	24	8.8	104	10.7	6	33	186	8.4	430	23	80	B
8/24/01	3	24	8.5	100	9.5	7	33	185	8.4	420	20	83	B
8/24/01	4	---	---	---	---	---	457	200	8.1	540	29	---	---
8/24/01	5	---	---	---	---	---	1083	290	7.9	840	40	---	---
8/24/01	6	---	---	---	---	---	360	205	8.1	570	38	---	---
5/3/02	1	---	---	---	1.0	9	92	120	7.4	300	22	90	A
5/3/02	2	---	---	---	2.3	9	92	122	7.3	350	27	90	A
5/3/02	3	---	---	---	1.0	10	92	119	7.4	340	23	93	A
5/3/02	4	---	---	---	---	---	164	112	8.7	320	11	---	---
5/3/02	5	---	---	---	---	---	1080	138	8.4	460	15	---	---
5/3/02	6	---	---	---	---	---	68	135	7.6	360	12	---	---
8/12/02	1	27	8.3	104	16.6	5	24	184	8.3	425	27	76	C
8/12/02	2	27	8.3	104	10.0	5	16	166	8.1	420	13	79	C
8/12/02	3	27	8.0	100	7.0	5	24	165	8.2	420	24	80	B
8/12/02	4	---	---	---	---	---	960	247	8.0	595	21	---	---
8/12/02	5	---	---	---	---	---	1120	322	7.5	880	45	---	---
8/12/02	6	---	---	---	---	---	1012	250	7.9	660	36	---	---
5/14/03	1	---	---	---	3.0	8	158	105	8.2	280	30	89	B
5/14/03	2	---	---	---	2.4	10	95	97	8.3	280	13	93	A
5/14/03	3	---	---	---	2.7	10	89	98	8.1	300	14	92	A

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
5/14/03	4	---	---	---	---	---	100	140	8.6	300	11	---	---
5/14/03	5	---	---	---	---	---	7980	92	8.7	370	30	---	---
5/14/03	6	---	---	---	---	---	110	110	8.2	280	20	---	---
8/19/03	1	27	9.0	113	18.6	4	18	165	8.8	450	26	70	C
8/19/03	2	27	9.1	114	14.1	5	18	167	8.8	450	21	74	C
8/19/03	3	26	8.6	105	11.0	5	11	165	8.7	450	18	78	C
8/19/03	4	26	9.1	112	---	3	7	187	8.7	500	42	---	---
8/19/03	5	---	---	---	---	---	1104	325	7.7	960	102	---	---
8/19/03	6	---	---	---	---	---	722	240	8.2	660	25	---	---
5/15/04	1	---	---	---	0.9	10	80	140	7.7	400	12	94	A
5/15/04	2	---	---	---	1.4	10	30	132	7.9	380	11	93	A
5/15/04	3	---	---	---	1.9	10	26	132	7.7	380	8	93	A
5/15/04	4	---	---	---	---	---	166	129	7.6	380	9	---	---
5/15/04	5	---	---	---	---	---	1280	136	7.6	420	19	---	---
5/15/04	6	---	---	---	---	---	36	156	8.0	380	23	---	---
8/9/04	1	25	8.5	101	4.1	5	39	192	8.4	460	15	85	B
8/9/04	2	25	8.4	100	2.9	6	30	185	8.4	460	14	88	B
8/9/04	3	25	8.6	102	2.4	7	21	190	8.4	460	17	89	B
8/9/04	4	---	---	---	---	---	348	230	8.1	560	29	---	---
8/9/04	5	---	---	---	---	---	1860	330	7.7	870	58	---	---
8/9/04	6	---	---	---	---	---	600	230	8.0	600	23	---	---
5/4/05	1	---	---	---	1.7	7	63	121	8.2	340	22	90	A
5/4/05	2	---	---	---	1.8	8	50	125	7.9	350	18	91	A
5/4/05	4	---	---	---	---	---	170	142	7.7	340	27	---	---
5/4/05	5	---	---	---	---	---	848	140	7.9	340	26	---	---
5/4/05	6	---	---	---	---	---	66	135	8.5	350	18	---	---
8/15/05	1	26	7.7	94	2.3	5	20	160	8.2	410	13	88	B
8/15/05	2	26	7.7	94	4.6	6	20	162	8.3	410	14	86	B
8/15/05	3	26	7.1	91	1.7	7	14	161	8.2	410	14	91	A
8/15/05	4	---	---	---	---	---	476	228	8.1	550	24	---	---
8/15/05	5	---	---	---	---	---	2077	328	7.8	900	55	---	---
8/15/05	6	---	---	---	---	---	446	230	8.0	570	28	---	---
5/3/06	1	---	---	---	4.0	8	61	110	8.2	310	33	80	B
5/3/06	2	---	---	---	2.0	8	52	115	8.1	280	34	90	A
5/3/06	3	---	---	---	0.5	9	69	110	7.9	360	36	91	A
5/3/06	4	---	---	---	---	---	182	140	8.1	370	27	---	---
5/3/06	5	---	---	---	---	---	498	120	8.4	440	46	---	---
5/3/06	6	---	---	---	---	---	69	140	8.4	380	31	---	---
8/10/06	1	28	8.8	111	4.8	6	22	180	8.6	440	52	78	C
8/10/06	2	28	8.8	111	3.1	6	35	180	8.6	430	55	79	C
8/10/06	3	28	8.7	110	4.4	6	22	180	8.6	420	32	82	B
8/10/06	4	---	---	---	---	---	546	235	8.3	540	33	---	---
8/10/06	5	---	---	---	---	---	1777	325	7.8	900	69	---	---
8/10/06	6	---	---	---	---	---	581	223	8.3	580	32	---	---
5/4/07	1	---	---	---	0.8	9	82	110	7.6	270	23	92	A
5/4/07	2	---	---	---	1.4	10	89	130	7.4	285	18	93	A
5/4/07	3	---	---	---	1.4	11	89	135	7.4	325	18	94	A
5/4/07	4	---	---	---	---	---	96	155	7.9	300	37	---	---
5/4/07	5	---	---	---	---	---	230	155	7.7	420	18	---	---
5/4/07	6	---	---	---	---	---	32	147	7.7	300	18	---	---
8/8/07	1	27	7.7	96	2.3	8	16	172	8.4	420	18	89	B
8/8/07	2	27	7.7	96	2.9	8	16	174	8.4	420	20	87	B
8/8/07	3	28	7.7	97	2.9	8	13	170	8.4	410	15	88	B
8/8/07	4	---	---	---	---	---	637	194	8.0	520	30	---	---
8/8/07	5	---	---	---	---	---	1871	325	7.6	870	63	---	---
8/8/07	6	---	---	---	---	---	468	187	8.0	540	42	---	---

Surface Lake Water Quality Data

Date	Sample Station Number	Temper-ature °C	Dissolved Oxygen (mg/L)	Dissolved Oxygen Percent Satu-ration	Chloro-phyll a ug/L	Secchi Disk Depth (feet)	Total Nitrate Nitrogen ug/L	Alka-linity mg/L	pH	Conduc-tivity umhos per cm at 25°C	Total Phos-phorus ug/L	Lake Water Quality Index	Grade
5/5/08	1	---	---	---	4.1	9	45	102	7.1	260	22	85	B
5/5/08	2	---	---	---	5.1	9	31	120	7.1	260	20	87	B
5/5/08	3	---	---	---	5.8	9	31	124	7.2	260	21	86	B
5/5/08	4	---	---	---	---	---	519	150	7.0	350	63	---	---
5/5/08	5	---	---	---	---	---	1311	105	7.1	300	34	---	---
5/5/08	6	---	---	---	---	---	309	120	7.1	260	27	---	---
8/7/08	1	26	7.9	96	5.9	9	14	175	8.3	410	19	86	B
8/7/08	2	26	7.8	95	5.2	9	11	175	8.3	410	18	87	B
8/7/08	3	26	7.8	95	5.9	9	34	170	8.3	410	19	86	B
8/7/08	4	---	---	---	---	---	116	212	8.5	500	22	---	---
8/7/08	5	---	---	---	---	---	593	180	8.2	410	56	---	---
8/7/08	6	---	---	---	---	---	20	245	8.1	600	23	---	---
5/12/09	1	---	---	---	1.3	11	255	140	8.3	340	26	92	A
5/12/09	2	---	---	---	1.0	12	245	140	8.2	340	25	92	A
5/12/09	3	---	---	---	1.0	13	255	133	8.3	340	23	93	A
5/12/09	4	---	---	---	---	---	365	133	7.9	300	32	---	---
5/12/09	5	---	---	---	---	---	1040	125	7.4	280	35	---	---
5/12/09	6	---	---	---	---	---	530	112	7.3	280	25	---	---
8/31/09	1	22	6.5	74	15.7	7	31	186	8.3	460	21	77	C
8/31/09	2	22	6.3	72	6.3	7	22	186	8.2	450	21	82	B
8/31/09	3	22	6.9	78	14.4	7	28	188	8.2	450	18	78	C
8/31/09	4	---	---	---	---	---	284	212	8.2	480	17	---	---
8/31/09	5	---	---	---	---	---	288	190	8.4	460	30	---	---
8/31/09	6	---	---	---	---	---	322	220	8.0	510	18	---	---
5/6/10	1	---	---	---	0.5	12	95	160	7.8	380	19	94	A
5/6/10	2	---	---	---	0.4	15	100	158	7.8	380	20	95	A
5/6/10	3	---	---	---	0.4	16	160	147	7.9	360	31	94	A
5/6/10	4	---	---	---	---	---	80	160	8.0	360	22	---	---
5/6/10	5	---	---	---	---	---	50	167	7.8	420	35	---	---
5/6/10	6	---	---	---	---	---	50	166	7.8	360	20	---	---
8/4/10	1	27	8.3	104	3.2	8	44	185	8.5	400	34	86	B
8/4/10	2	27	8.4	105	2.6	11	40	185	8.5	410	29	89	B
8/4/10	3	27	8.3	104	2.5	11	20	185	8.4	410	16	91	B
8/4/10	4	24	8.2	96	---	---	246	218	8.0	460	27	---	---
8/4/10	5	---	---	---	---	---	167	190	8.4	440	42	---	---
8/4/10	6	---	---	---	---	---	214	212	7.9	460	37	---	---