Hubbard County

COLA

Coalition of Lake Associations

2006

Lake Water Quality Monitoring Report

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Summary and Recommendations

Summary

Last summer was the tenth year of Hubbard County COLA's lake water monitoring program. Volunteers recorded Secchi disk readings and collected water samples on numerous lakes in Hubbard County. The water samples were sent to RMB Environmental Laboratories, Inc. in Detroit Lakes, MN, for phosphorus and chlorophyll-a tests.

Hubbard County COLA's lake monitoring program has been successful over the past 10 years in gathering valuable data for determining lake water quality. Forty-four lakes participate in the program, and over 80% of the lakes are within the average water quality of the ecoregion or better. Four lakes showed significant improvement in water quality over the past 5-10 years, while 12 lakes showed a significant decline in water quality over the past 3-10 years. The remaining lakes that did not show trends are still important to monitor in case future trends develop.

This report contains a summary of the current state of Hubbard County COLA lakes and recommendations for future monitoring.

General Recommendations

- Continue monthly monitoring of all Hubbard County COLA lakes (Total Phosphorus, Chlorophyll a and Secchi depth).

- Because the monitoring program is so reasonably priced, try not to miss years of monitoring leading to gaps in data. For example, 4th Crow Wing had a significant decline in water quality, but due to a gap in their data we do know when the impact occurred.

- Continue to follow BMP (Best Management Practices) in the watershed:
  - Plant natural vegetation along the shoreline
  - Take good care of septic systems and their drainfields
  - Don't use phosphorus fertilizer on your lawn

- Complete a ground truthing study of the watersheds of the 12 lakes showing significant declines in water quality over the past 10 years:
  - Visually inspect the shoreline of each parcel and look for erosion, lack of a vegetation buffer and other harmful management practices
  - Visually inspect stream inlets to the lake to look for sources of phosphorus and erosion

- Begin stream inlet monitoring and storm event monitoring for the 12 lakes showing significant declines in water quality over the past 10 years to determine where the phosphorus is coming from.

Hubbard County COLA Purpose

Hubbard County COLA was organized in 1988 to facilitate cooperation among member lake associations and to assist in fostering appropriate and legal use of lakes and watersheds by:

- Identifying and analyzing environmental impact problems and disseminating information thereof to member associations and the general public.

- Developing guidelines concerning the development, and preservation of the rivers, lakes, shorelands and other lands within the county.

- Presenting such guidelines and association positions to agencies of the government, business and private individuals in order to bring about appropriate action for the effective use of these valuable natural resources.

- Communicating information about the above goals to members through meetings, written communications, and phone contacts with representatives of members.

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Water Quality Introduction

In order to get a true picture of lake water quality, it is important to take numerous measurements in a year and continue this practice over many years. Water quality can vary seasonally as well as year to year depending on temperature, rainfall and adjacent land use practices. Secchi depth, phosphorus and chlorophyll-a measurements are very good assessments of water quality, and are fairly easy to implement.

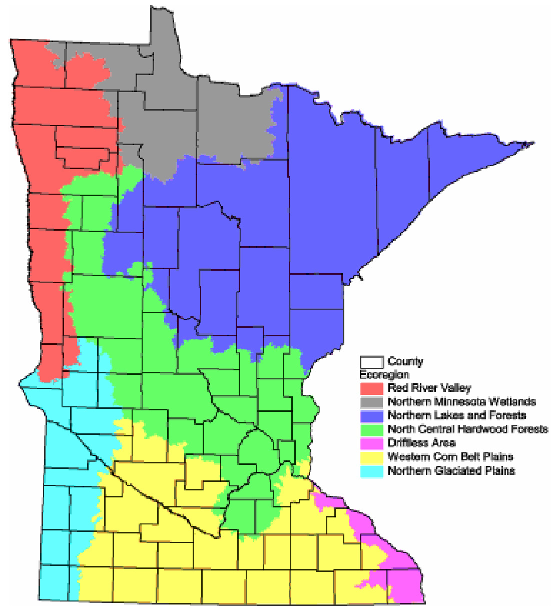


Figure 1. Minnesota Ecoregions. The Northern Lakes and Forest Ecoregion is highlighted in Blue.

Bear in mind, when comparing lakes to each other there are many factors that affect how a lake functions. Lake depth, size, and shape can all affect how a lake cycles phosphorus and supports algal growth. Small, shallow lakes are more affected by increased phosphorus loading, which can result in large algal blooms. Large, deep lakes are able to handle occasional surges in phosphorus input without changing water quality; however, continuous heavy input of phosphorus will still decrease water quality.

Minnesota is divided into 7 ecoregions (Fig. 1). Lakes in each ecoregion can be compared to each other because they have similar geology, vegetation and climate. The Minnesota Pollution Control Agency (MPCA) has tested numerous lakes in each ecoregion to evaluate average water quality values within the ecoregion. These values can be used as references for comparing water quality.

Water Quality in Hubbard County COLA Lakes

Overview

Hubbard County is located in the Northern Lakes and Forests Ecoregion, and 44 lakes participate in the lakes monitoring program. Overall, Hubbard County COLA lakes are within the average water quality for the ecoregion, which is very good.

Table 1. Summer average water quality characteristics for lakes by ecoregion based on interquartile range (25^{th}-75^{th} percentile) for ecoregion reference lakes (MPCA).

Parameter	Northern Lakes and Forests Ecoregion
Total Phosphorus (ug/l)	14-27
Chlorophyll-a mean	<10
Chlorophyll-a maximum	<15
Secchi Depth (feet)	8-15

Trophic State

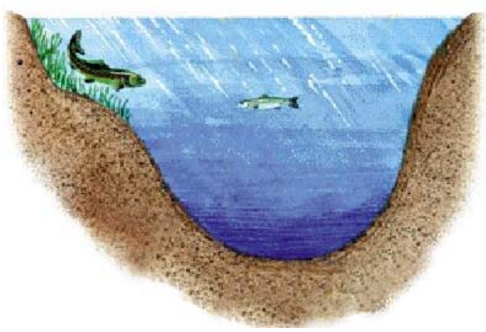
Trophic State Index (TSI) is a measurement of overall lake productivity (nutrient enrichment). The overall TSI of a lake is the average of the TSI for phosphorus, chlorophyll-a and secchi depth; therefore, it can be thought of as the water quality of a lake taking into account phosphorus, chlorophyll-a and secchi depth.

Trophic states are defined divisions of a continuum in water quality. The continuum is Total Phosphorus concentration, Chlorophyll a concentration and Secchi depth. Scientists define certain ranges in the above lake measures as different trophic states so they can be easily referred to. Many other factors play into trophic state such as lake depth, size and shape. Lake eutrophication is a natural process; however humans can speed that process by adding large amounts of phosphorus to the watershed and ultimately, the lake. Oligotrophic and mesotrophic lakes are considered the best lakes for recreation and fishing.

Oligotrophic

Crystal clear water, oxygen throughout the year in the hypolimnion, trout fisheries, cool water temperature, low densities of plants and algae

TSI: 0-40



Mesotrophic

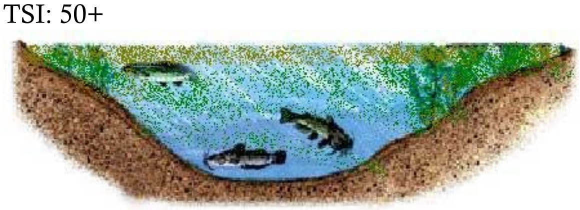
Water moderately clear, increasing probability of no oxygen in the hypolimnion during summer, walleye fisheries, moderate densities of plants and algae

TSI: 40-50

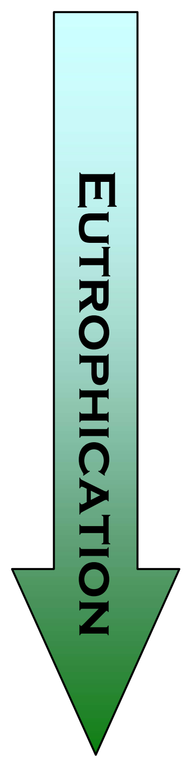
Eutrophic

Greenish cloudy water, oxygen gone in the hypolimnion, warm water, bass and carp, high densities of plants and algae

TSI: 50+



Low Phosphorus
Low Chlorophyll a
High Secchi depth



High Phosphorus
High Chlorophyll a
Low Secchi depth

There are 8 oligotrophic lakes, 29 mesotrophic and 7 eutrophic lakes in Hubbard County COLA (Table 2).

Table 2. Trophic state rankings for Hubbard County COLA lakes. Bear in mind that ranking is unscientific, especially when the amount of data for each lake differs. Over 5 years of data is more accurate for predicting trophic state and trends.

Lake	Rank	Years of data	Average TSI	Trophic State
Little Sand	1	10	35.3	Oligotrophic
Belle Taine	2	10	36.3	Oligotrophic
Big Sand	3	9	36.4	Oligotrophic
Spider	4	10	36.9	Oligotrophic
Lower Bottle	5	9	38.0	Oligotrophic
Blue Lake	6	5	39.0	Oligotrophic
Little Mantrap	7	2	39.0	Oligotrophic
Gilmore	8	10	39.1	Oligotrophic
Kabekona	9	10	40.4	Mesotrophic
Palmer	10	10	40.8	Mesotrophic
11th Crow Wing	11	1	41.0	Mesotrophic
Upper Bottle	12	8	41.1	Mesotrophic
Peysenke	13	6	41.6	Mesotrophic
Waboose	14	2	41.6	Mesotrophic
Boulder	15	3	42.1	Mesotrophic
Lord	16	2	42.3	Mesotrophic
Shallow	17	2	42.4	Mesotrophic
Ham	18	1	42.6	Mesotrophic
Middle Crooked	19	1	42.6	Mesotrophic
Moran	20	2	42.7	Mesotrophic
Hinds	21	2	43.0	Mesotrophic
Emma	22	8	43.2	Mesotrophic
Potato	23	10	43.3	Mesotrophic
Ojibway	24	1	43.4	Mesotrophic
Big Mantrap	25	10	43.6	Mesotrophic
Fishhook	26	8	43.6	Mesotrophic
Long Lake	27	10	44.2	Mesotrophic
Stony	28	7	44.8	Mesotrophic
Duck	29	2	45.5	Mesotrophic
Bad Axe	30	1	45.8	Mesotrophic
Eagle	31	10	45.8	Mesotrophic
6th Crow Wing	32	9	47.9	Mesotrophic
5th Crow Wing	33	9	48.5	Mesotrophic
Plantagenet	34	7	48.6	Mesotrophic
4th Crow Wing	35	7	48.8	Mesotrophic
Stocking	36	10	49.2	Mesotrophic
Island South	37	9	49.3	Mesotrophic
Upper Twin	38	4	50.0	Eutrophic
2nd Crow Wing	39	6	50.5	Eutrophic
8th Crow Wing	40	5	50.8	Eutrophic
7th Crow Wing	41	5	51.0	Eutrophic
3rd Crow Wing	42	10	51.4	Eutrophic
1st Crow Wing	43	9	53.3	Eutrophic
Portage	44	10	59.0	Eutrophic

Phosphorus
Generally the more phosphorus is in the lake, the lower the water quality. Increased phosphorus is food for plants and algae and can cause algal blooms and decreased water clarity. Phosphorus can enter the lake through runoff from agriculture, fertilized lawns, manure and improperly maintained septic systems. Most of the lakes in the Hubbard County COLA (84%) are within the average Total Phosphorus for the ecoregion or better. Only 15% of the lakes fall below the ecoregion average for Total Phosphorus (Table 3). Lakes do have the ability to rebound in water quality if phosphorus inputs are reduced or eliminated.

Secchi Depth
Secchi depth is a measure of water clarity. Six lakes (14%) are above the ecoregion average for water clarity. Thirty lakes (68%) are within the ecosystem average for water clarity, and only eight lakes (18%) are below average (Table 4).

Secchi depth can vary throughout the summer, and it is important to get readings at least every month. After large storms and above average rainfall events, the water clarity can temporarily decline due to all the particles that wash into the lake.

Chlorophyll-a
Chlorophyll-a is the pigment that makes plants and algae green. Chlorophyll-a is measured in lakes to determine algal concentration. Most of the Hubbard County COLA lakes (81%) are within the average Chlorophyll a concentrations for the ecoregion. Only 18% of the Hubbard County COLA lakes are above average for Chlorophyll a concentrations (Table 5).

Table 3. Historical average total phosphorus for each Hubbard County COLA lake compared to ecoregion averages. Bear in mind that ranking is unscientific, especially when the amount of data for each lake differs. Over 5 years of data is more accurate for predicting trophic state and trends.

Lake	Rank	Years of data	Average TP (ug/l)	Relation to ecoregion
Big Sand	1	9	10.5	Below average total phosphorus for the ecoregion
Spider	2	10	10.9	
Little Sand	3	10	11.0	
Gilmore	4	10	11.4	
Shallow	5	2	12.0	
Belle Taine	6	10	12.1	
11th Crow Wing	7	1	12.2	
Palmer	8	10	12.3	
Blue Lake	9	5	12.6	
Little Mantrap	10	2	12.8	
Lower Bottle	11	9	12.8	
Kabekona	12	10	13.5	
Ham	13	1	14.0	Average total phosphorus for the ecoregion
Peysenke	14	6	14.0	
Boulder	15	3	14.4	
Lord	16	2	14.5	
Moran	17	2	14.7	
Waboose	18	2	15.1	
Potato	19	10	15.3	
Upper Bottle	20	8	15.3	
Hinds	21	2	15.6	
Long Lake	22	10	15.7	
Stony	23	7	15.9	
Middle Crooked	24	1	16.0	
Island South	25	9	16.5	
Fishhook	26	8	17.4	
Duck	27	2	17.5	
Emma	28	8	18.2	
Big Mantrap	29	10	18.5	
Ojibway	30	1	18.6	
Eagle	31	10	19.0	
Bad Axe	32	1	21.4	
2nd Crow Wing	33	6	21.9	
6th Crow Wing	34	9	23.0	
Plantagenet	35	7	23.0	
5th Crow Wing	36	9	24.7	
4th Crow Wing	37	7	25.0	
3rd Crow Wing	38	10	28.0	Above average total phosphorus for the ecoregion
7th Crow Wing	39	5	28.0	
Stocking	40	10	30.2	
8th Crow Wing	41	5	35.0	
Upper Twin	42	4	37.6	
1st Crow Wing	43	9	51.4	
Portage	44	10	52.0	

Table 4. Secchi Depth rankings for Hubbard County COLA lakes. Bear in mind that ranking is unscientific, especially when the amount of data for each lake differs. Over 5 years of data is more accurate for predicting trophic state and trends.

Lake	Rank	Years of data	Average Secchi Depth (ft)	Relation to ecoregion
Belle Taine	1	10	22.4	Above average Secchi depth for the ecoregion
Little Sand	2	10	21.6	
Big Sand	3	9	20.1	
Spider	4	10	19.3	
Lower Bottle	5	9	17.6	
Little Mantrap	6	2	17.0	
Upper Bottle	7	8	15.4	Average Secchi depth for the ecoregion
Blue Lake	8	5	15.3	
Waboose	9	2	15.1	
Gilmore	10	10	14.9	
Hinds	11	2	14.0	
Ojibway	12	1	13.9	
Middle Crooked	13	1	13.6	
Boulder	14	3	13.3	
Big Mantrap	15	10	13.2	
Palmer	16	2	13.1	
Lord	17	10	13.1	
11th Crow Wing	18	1	13.0	
Island South	19	9	12.5	
Kabekona	20	10	12.3	
Potato	21	10	11.6	
Ham	22	1	11.4	
Moran	23	8	11.3	
Fishhook	24	2	11.3	
Bad Axe	25	1	10.8	
Long Lake	26	9	10.3	
5th Crow Wing	27	10	10.3	
Stocking	28	10	10.2	
Eagle	29	10	10.2	
Peysenke	30	6	10.0	
Plantagenet	31	5	9.5	
Emma	32	8	9.5	
8th Crow Wing	33	7	9.5	
Stony	34	7	9.4	
Duck	35	2	9.2	
6th Crow Wing	36	9	8.4	
Upper Twin	37	2	7.4	Below average Secchi Depth for the region
Shallow	38	4	7.4	
4th Crow Wing	39	7	7.3	
7th Crow Wing	40	5	7.1	
3rd Crow Wing	41	10	6.9	
2nd Crow Wing	42	6	6.4	
1st Crow Wing	43	9	4.3	
Portage	44	10	4.2	

Table 5. Chlorophyll a rankings for Hubbard County COLA lakes. Bear in mind that ranking is unscientific, especially when the amount of data for each lake differs. Over 5 years of data is more accurate for predicting trophic state and trends.

Lake	Rank	Years of data	Average Chlorophyl-a (ug/l)	Relation to ecoregion
Little Sand	1	10	1.9	Average Chlorophyll a for the ecoregion
Big Sand	2	9	2.5	
Belle Taine	3	10	2.7	
Peysenke	4	6	2.8	
Shallow	5	2	2.8	
Little Mantrap	6	2	2.9	
Lower Bottle	7	9	2.9	
Kabekona	8	10	3.2	
Gilmore	9	10	3.4	
Spider	10	10	3.4	
Palmer	11	10	3.8	
Blue Lake	12	5	3.9	
Emma	13	8	4.0	
Ham	14	1	4.0	
Ojibway	15	1	4.2	
Moran	16	2	4.5	
Middle Crooked	17	1	4.6	
Waboose	18	2	4.8	
Fishhook	19	8	4.9	
11th Crow Wing	20	1	5.0	
Upper Bottle	21	8	5.0	
Lord	22	2	5.1	
Duck	23	2	5.2	
Long Lake	24	10	5.4	
Stony	25	7	5.4	
Hinds	26	2	5.5	
Big Mantrap	27	10	5.6	
Island South	28	9	5.6	
Potato	29	10	5.6	
Boulder	30	3	5.9	
Upper Twin	31	4	6.3	
Bad Axe	32	1	6.6	
Eagle	33	10	7.0	
4th Crow Wing	34	7	7.7	
6th Crow Wing	35	9	8.7	
5th Crow Wing	36	9	9.2	
3rd Crow Wing	37	10	10.6	Above average Chlorophyll a for the ecoregion
2nd Crow Wing	38	6	10.9	
Stocking	39	10	10.9	
Plantagenet	40	7	12.0	
8th Crow Wing	41	5	13.2	
7th Crow Wing	42	5	13.3	
Portage	43	10	21.7	
1st Crow Wing	44	9	23.9	

Trends in Hubbard County COLA Lakes

Overview

Tracking trends in data over several years can indicate improving or declining water quality. Generally, it is best to have more than 5 years of data with more than 5 measurements per year to really be confident in an emerging trend. Statistically, the probability that a trend is truly describing the water quality and not just a random trend is important. A probability over 90% is required by the MPCA to really be confident in the observed trend.

Improving Water Quality

Four Hubbard County COLA lakes showed improving water quality trends over the past 5-10 years (Table 6). Water quality can be improved by locating the sources of phosphorus to the lake and limiting them. Phosphorus could be entering a lake through stream inlets, large agricultural areas, animal feedlots and leaking septic systems and holding tanks near the lake.

Big Sand Lake has shown the greatest improvement across the board. It has gone from mesotrophic (average TSI of 40) to oligotrophic (average TSI of 32) (Figure 2, Table 6). It has decreased phosphorus concentrations (95% probability) (Figure 3), decreased chlorophyll a concentrations (95% probability) (Figure 4) and greatly increased Secchi depth (99% probability) (Figure 5). In fact, the Secchi depth on average over the past 9 years has increased by 12 feet! Management practices on Big Sand Lake should be commended.

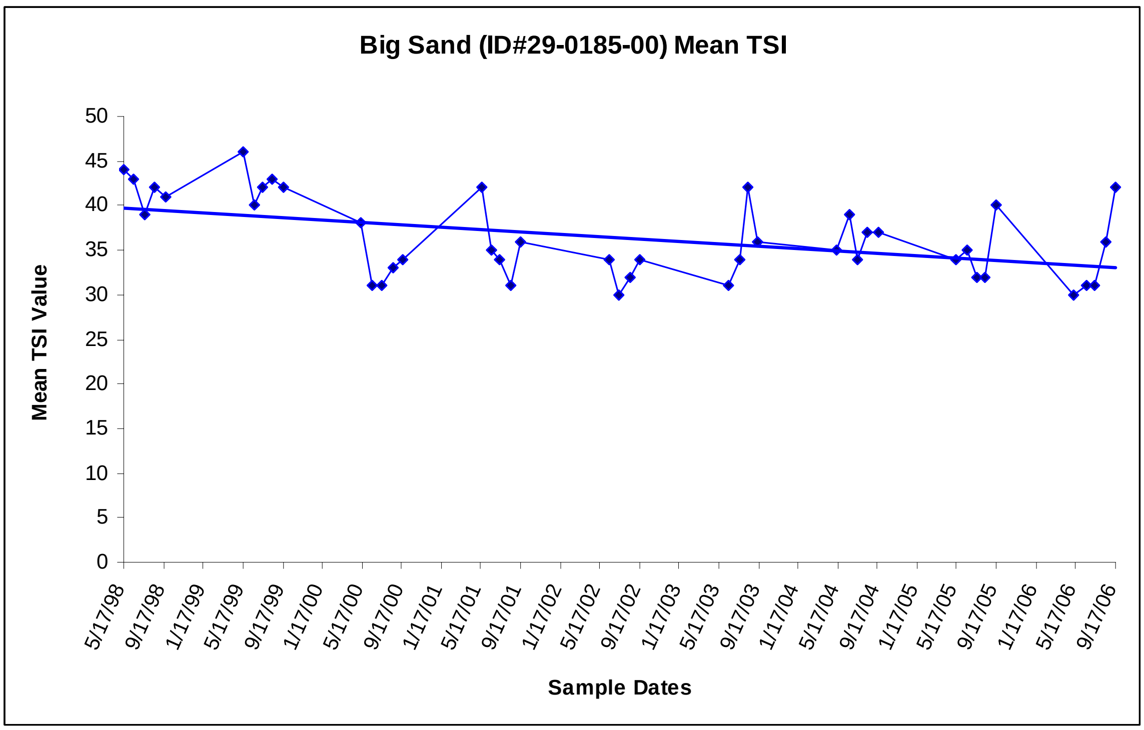


Figure 2. Mean Trophic State Index values for **Big Sand Lake**, 1998-2006. The probability that a true significant trend exists is 99%.

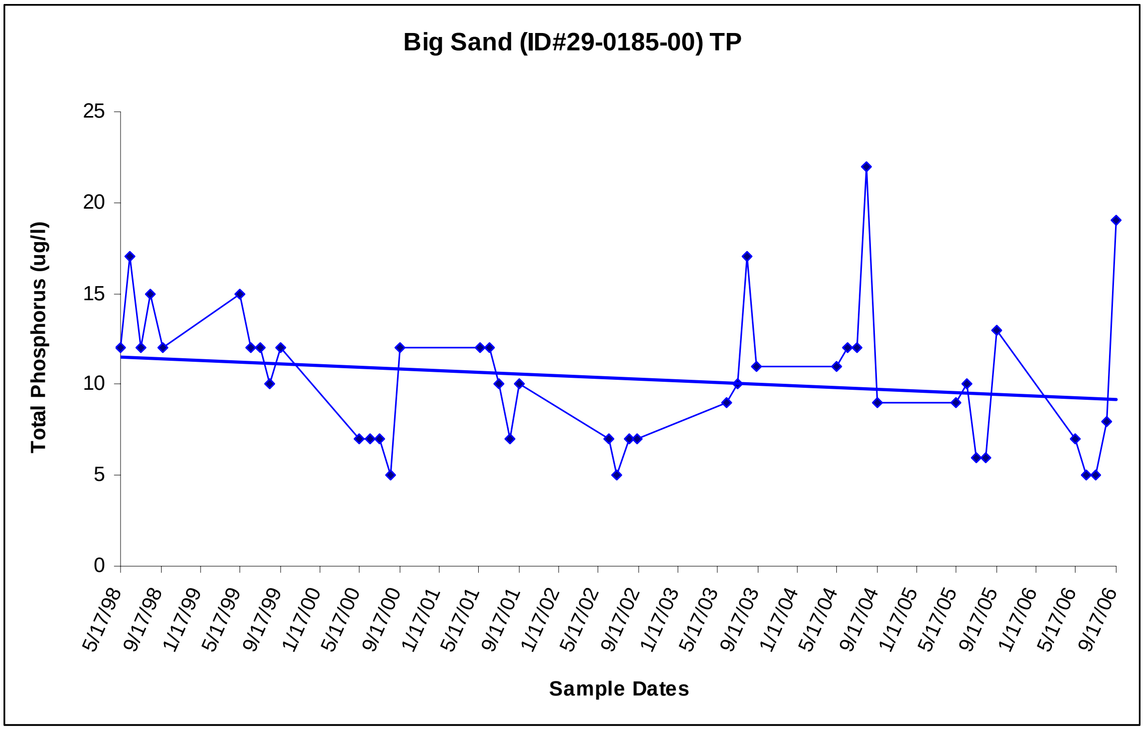


Figure 3. Total Phosphorous concentrations for **Big Sand Lake**, 1998-2006. The probability that a true significant trend exists is 95%.

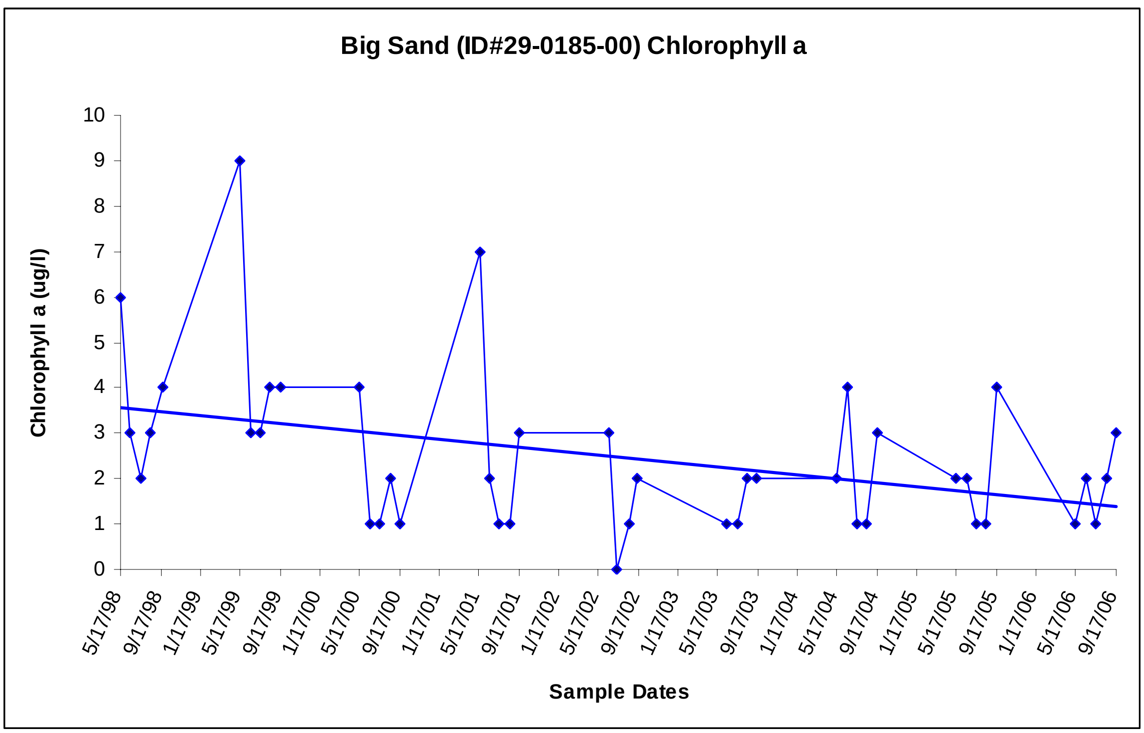


Figure 4. Chlorophyll a concentrations for **Big Sand Lake**, 1998-2006. The probability that a true significant trend exists is 95%.

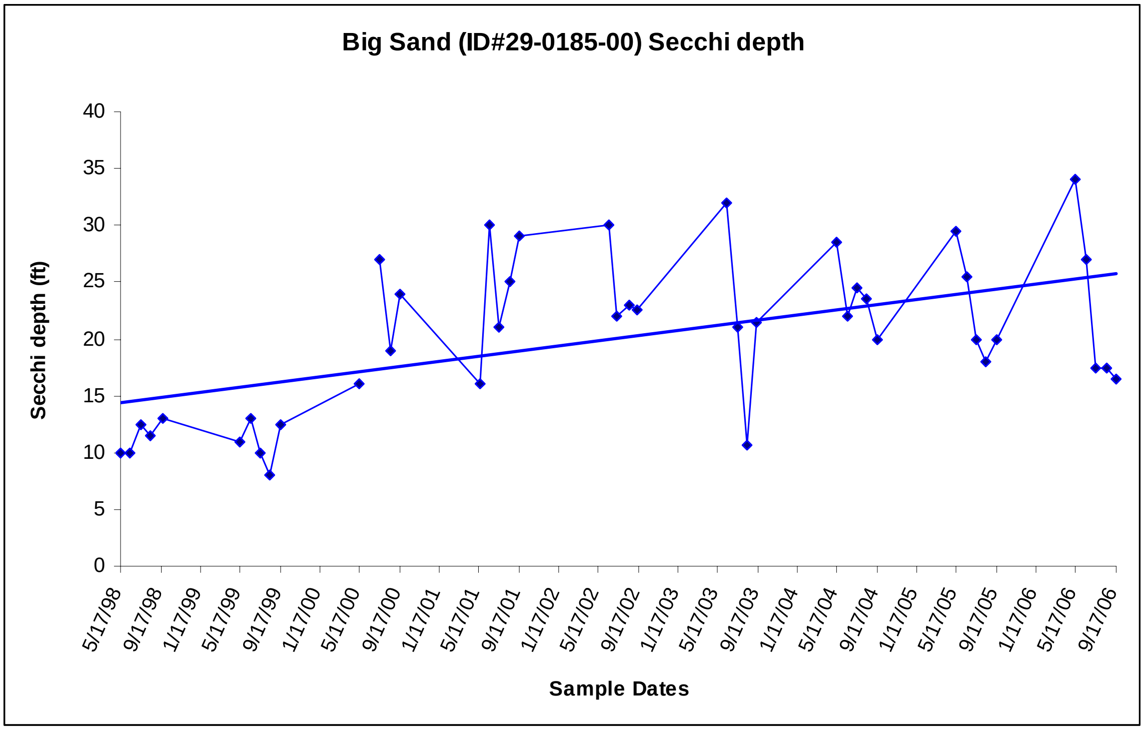


Figure 5. Secchi depth for **Big Sand Lake**, 1998-2006. The probability that a true significant trend exists is 99%.

Stocking Lake has an average increased Secchi depth of 4 feet (90% probability) over the past 10 years. There was no significant decrease in phosphorus or chlorophyll a (Table 6). These results suggest that less particles are washing into the lake and that erosion has been stopped or water levels have dropped.

Over the past 5 years, Blue Lake has gone from mesotrophic (TSI=42) to oligotrophic (TSI=36) (Figure4), shown a decrease in phosphorus concentration (95% probability), and an increase in Secchi depth of 5 feet (90% probability) (Table 6). These Blue Lake trends are promising; however, they must be taken with caution since there are only 5 years of data. In the next couple years, we will be able to be more confident about Blue Lake's improving water quality.

Island South Lake has shown a decrease in TSI, a decrease in phosphorus concentration (90% probability) and a decrease in chlorophyll a concentration (90% probability) over 9 years; however, there has been no significant change in Secchi depth (Table 6). These data indicate that phosphorus inputs to Island South have decreased and management practices around the lake have improved. If phosphorus inputs continue to stay at very low levels or decrease over time, the Secchi depth should catch up and reflect increased water clarity.

Table 6. Hubbard County COLA lakes that have improved in water quality. The number in parentheses is the probability that the trend is true versus just happening by random chance.

Lake	Years of data	Average TSI Trend	TP Trend	CHL-A Trend	Secchi Trend	Comments
Big Sand	9	Improve (99%)	Improve (95%)	Improve (95%)	Improve (99%)	Secchi average increase of 12 feet
Stocking	10	no	no	no	Improve (90%)	Secchi average increase of 4 feet
Blue Lake	5*	Improve (95%)	Improve (95%)	no	Improve (90%)	Secchi average increase of 5 feet, *only 5 years data
Island South	9	Improve (95%)	Improve (90%)	Improve (95%)	no	Phosphorus inputs declined

No trend
The majority of the Hubbard County COLA lakes (64%) have no significant improving or declining trend in water quality (Table 7). These lakes should still continue their monitoring programs to detect any future changes in water quality.

Table 7. Hubbard County COLA lakes that show no significant improving or declining trends in water quality.

Lake	Years of data
Little Sand	10
Long Lake	10
Palmer	10
Belle Taine	10
3rd Crow Wing	10
Eagle	10
Spider	10
Lower Bottle	9
5th Crow Wing	9
Emma	8
Fishhook	8
Upper Bottle	8
Peysenke	6
2nd Crow Wing	6
8th Crow Wing	5
7th Crow Wing	5
Duck	2
Hinds	2
Little Mantrap	2
Lord	2
Moran	2
Shallow	2
Waboose	2
11th Crow Wing	1
Bad Axe	1
Ham	1
Middle Crooked	1
Ojibway	1

Declining Water Quality

Twelve Hubbard County COLA lakes have shown declining water quality; however, two of them have four or less years of data so their results should be taken cautiously (Tables 8-9). Declining water quality can occur when phosphorus inputs to the lake increase, or the water level of the lake increases significantly, taking top soil and other nutrients and debris into the lake.

The lake of highest concern and most severe decline in water quality is 4th Crow Wing Lake. The mean TSI went from Mesotrophic (TSI=45) to Eutrophic (TSI=54) with 99.9% confidence over 7 years (Figure 6).

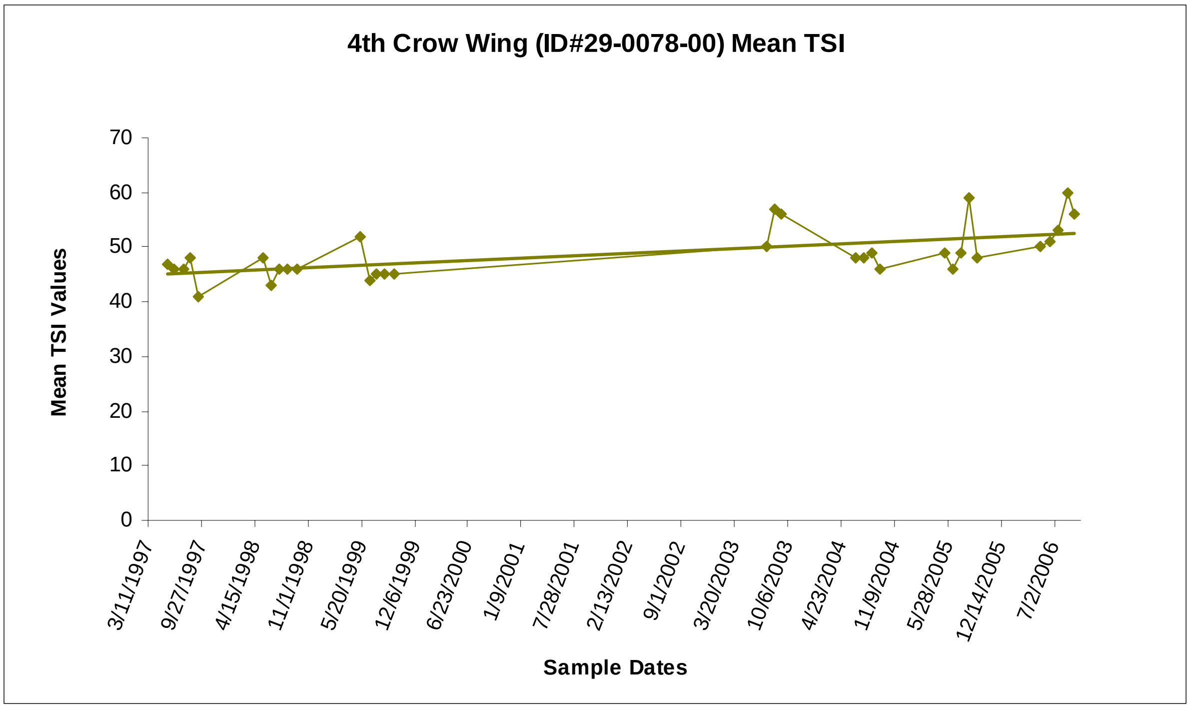


Figure 6. Long-term trend of Mean Trophic State Index for **4th Crow Wing Lake**, 1997-2006. The probability that a true significant trend exists is 99.9%.

There is a gap in data for 4th Crow Wing Lake between 2000-2002. The Mean TSI looks stable around 45 (Mesotrophic) for 1997-1999 (Figure 7). After the gap in data, the Mean TSI increased from 50-54 (Eutrophic) for 2003-2006 (Figure 7). Something must have happened between 2000-2002 that impacted the water quality of 4th Crow Wing Lake. Since there is no data for this period, we suggest looking at changes in land use around the lake during that time.

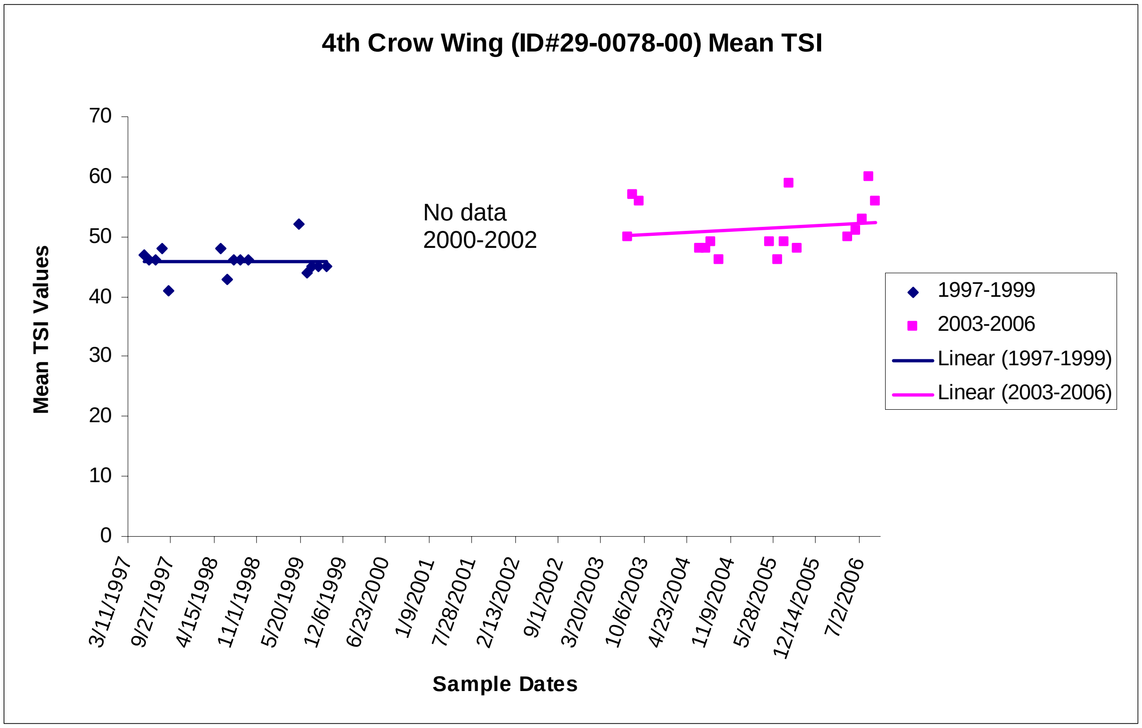


Figure 7. Increasing Mean Trophic State Index for **4th Crow Wing Lake**, 1997-1999 and 2003-2006. Notice the line, which represents the average, is lower 1997-1999 and higher 2003-2006.

4th Crow Wing Lake also increased significantly in phosphorus concentration over 7 years (Figure 8). The average Total Phosphorus over 7 years is 25 ug/l; however, the average Total Phosphorus for 1997-1999 is 20 ug/l, while the average for 2003-2006 is 29 ug/l (Figure 9). These results indicate that phosphorus input into the lake has increased since 2000. Land use practices such as animal feedlots, fertilizing lawns and leaking septic systems and holding tanks can be responsible for increasing phosphorus in a lake. We recommend monitoring the inlets to the lake to see if they are responsible for carrying increased phosphorus to the lake. In addition, we recommend visually inspecting the perimeter of the lake to look for harmful land use practices. The spikes in phosphorus have occurred in August over the past few years (Figure 8), which indicates that some land practice occurring in August is contributing large amounts of phosphorus to the lake. Annual monitoring without a gap is necessary to follow patterns in water quality. Due to the 3 year gap in data for 4th Crow Wing Lake, we are unable to determine which year the significant change/impact in water quality occurred.

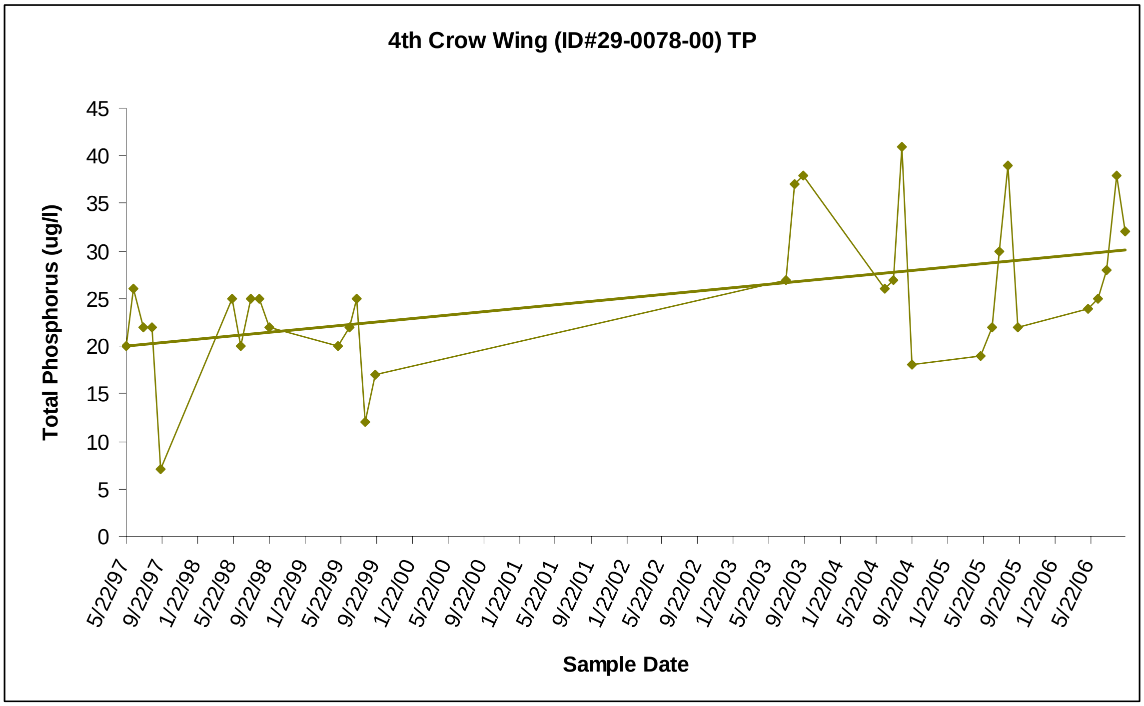


Figure 8. Increasing Total Phosphorus for **4th Crow Wing Lake**, 1997-2006. The probability that a true significant trend exists is 95%.

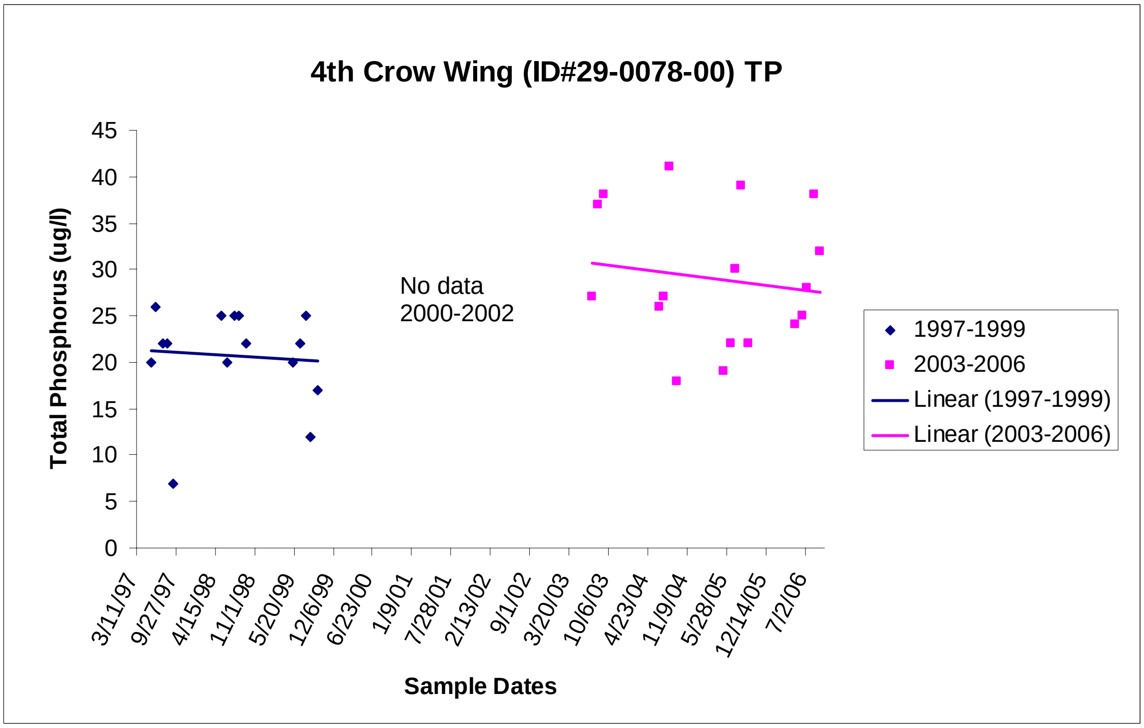


Figure 9. Increasing Total Phosphorus for **4th Crow Wing Lake**, 1997-1999 and 2003-2006. Notice the line, which represents the average, is lower 1997-1999 and higher 2003-2006.

In addition to an increase in Trophic State Index and Total Phosphorus, there has been an increase in chlorophyll a concentration (Figure 10), and a decrease averaging 3 feet in Secchi depth (Figure 11).

If the decline of water quality in 4th Crow Wing Lake is to be stopped, an evaluation of the watershed and its phosphorus inputs must be completed. This project could begin with monitoring all the inlets and outlets of the lake for their phosphorus contribution to the lake and visually inspecting the watershed and shoreline for areas not following Best Management Practices (see page 25 for descriptions).

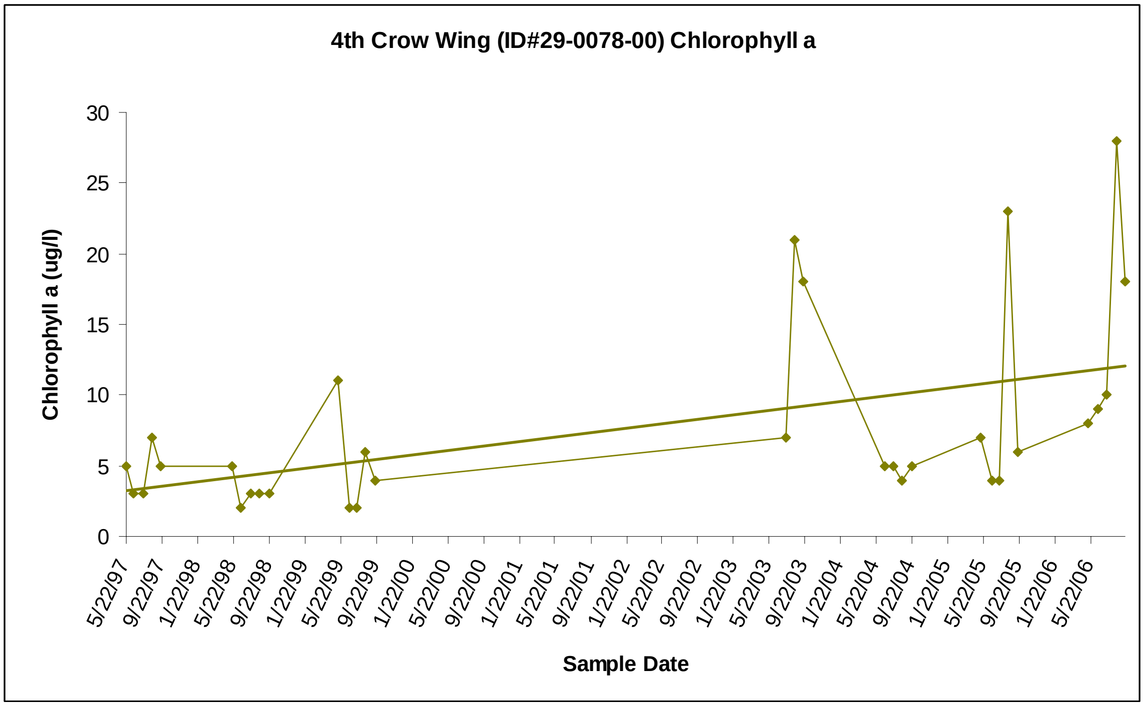


Figure 10. Increasing Chlorophyll-a long-term trend for **4th Crow Wing Lake**, 1997-2006. The probability that a true significant trend exists is 99%.

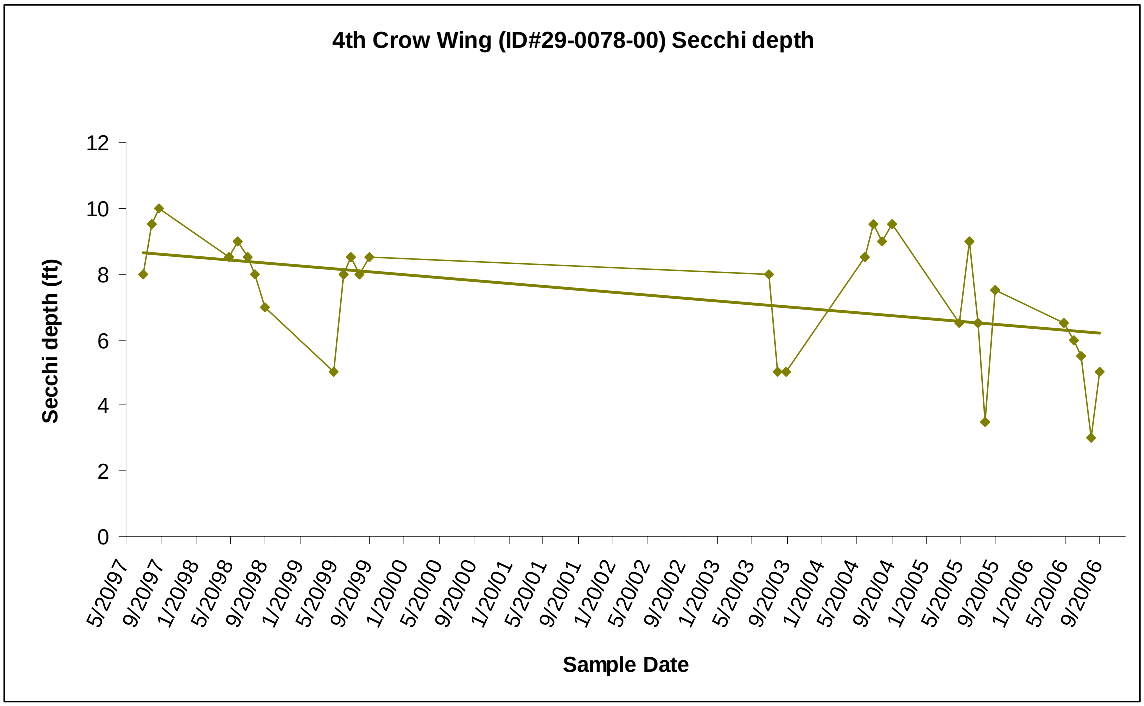


Figure 11. Decreasing Secchi depth long-term trend for **4th Crow Wing Lake**, 1997-2006. The probability that a true significant trend exists is 99%.

The lakes with the next level of concern are 1st Crow Wing and Portage. These two lakes had a significant decline in TSI and Secchi depth (90% probability) and a significant increase in phosphorus concentration (90% probability). There was no change in chlorophyll a, which means that the increase in phosphorus has not been reflected in an increase in algal concentrations yet. If current phosphorus inputs continue, we would expect the chlorophyll a concentrations to increase as well.

Big Mantrap, Plantagenet and Potato lakes show an increase in phosphorus concentration (95% probability), but no change in chlorophyll a and Secchi depth. These results show that phosphorus inputs to the lake have increased, but have not translated to an increase in chlorophyll a and a decrease in Secchi depth yet. If current phosphorus inputs continue, we would expect the chlorophyll a concentrations to significantly increase and the Secchi depth to significantly decrease. Monitoring the inlets to these lakes would be a useful way of locating where the phosphorus in entering the lake and how to control it.

6th Crow Wing, Gilmore, Kabekona and Stony lakes show a significant decrease in Secchi depth (90-99%), but no change in TSI, phosphorus or chlorophyll-a. A decrease in water clarity could mean that the lake water levels are high, causing more particles to be washed into the lake and suspended in the water column. The edge of the lake and the stream banks of the inlets to the lake should be inspected for signs of erosion. If erosion is occurring, the stream banks and lake shore can be stabilized by rip rap or dense riparian vegetation.

Boulder Lake and Upper Twin lake show declining water quality over the past 3-4 years (Table 9). More data needs to be collected from these lakes to be confident in the observed trends. Boulder Lake only shows a significant decrease in Secchi depth (90% probability). Upper Twin Lake shows an increase in average TSI (90% probability) (Figure 7) and an increase in phosphorus concentration (90% probability) (Figure 8). Upper Twin data collection stops at the end of 2002; we recommend that data collection resume on Upper Twin Lake to see if it is still showing a decrease in water quality.

Table 8. Hubbard County COLA lakes that have declined in water quality over 7 or more years of data. The number in parentheses is the probability that the trend is true versus just happening by random chance.

Lake	Years of data	TSI Trend	TP Trend	CHL-A Trend	Secchi Trend	Comments
1st Crow Wing	9	Decline (90%)	Decline (90%)	no	Decline (90%)	
4th Crow Wing	7	Decline (99.9%)	Decline (95%)	Decline (99%)	Decline (99%)	Declines across the board with very high probability
6th Crow Wing	9	no	no	no	Decline (90%)	Secchi average decline of 2 ft
Big Mantrap	10	no	Decline (95%)	no	no	Gradual P loading
Gilmore	10	no	no	no	Decline (99%)	Secchi average decline of 6 feet
Kabekona	10	no	no	no	Decline (99%)	Secchi average decline of 3 feet
Plantagenet	7	Decline (95%)	Decline (99%)	no	no	P loading
Portage	10	Decline (90%)	Decline (95%)	no	Decline (90%)	Secchi trend: 1997-2001 no trend; 2002-2006 95% trend
Potato	10	Decline (90%)	Decline (95%)	no	no	2000-2006 no trend (Z=0.4)
Stony	7	no	no	no	Decline (99.9%)	Secchi average decline of 3 feet

Table 9. Hubbard County COLA lakes that have declined in water quality over 4 or less years of data. With less than 5 years of data, the trend calculation is less reliable. The number in parentheses is the probability that the trend is true versus just happening by random chance.

Lake	Years of data	TSI Trend	TP Trend	CHL-A Trend	Secchi Trend	Comments
Boulder	3	no	no	no	Decline (90%)	Secchi average decrease of 3 feet
Upper Twin	4	Decline (90%)	Decline (90%)	no	no	P loading

Reference Material

Trophic States

Explanation of trophic state and a list of possible changes that might be expected in a north temperate lake along the trophic state gradient.

TSI	Chl (ug/L)	SD (ft)	TP (ug/L)	Attributes	Fisheries & Recreation
<30	<0.95	>26.2	<6	**Oligotrophy:** Clear water, oxygen throughout the year in the hypolimnion	Trout fisheries dominate
30-40	0.95-2.6	13.1-26.2	6-12	Hypolimnia of shallower lakes may become anoxic	Trout fisheries in deep lakes only
40-50	2.6-7.3	6.6-13.1	12-24	**Mesotrophy:** Water moderately clear; increasing probability of hypolimnetic anoxia during summer	Hypolimnetic anoxia results in loss of trout. Walleye may predominate.
50-60	7.3-20	3.3-6.6	24-48	**Eutrophy:** Anoxic hypolimnia, macrophyte problems possible	Warm-water fisheries only. Bass may dominate.
60-70	20-56	1.6-3.3	48-96	Blue-green algae dominate, algal scums and macrophyte problems	Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating.
70-80	56-155	0.8-1.6	96-192	**Hypereutrophy:** (light limited productivity). Dense algae and macrophytes	
>80	>155	<0.8	192-384	Algal scums, few macrophytes	Rough fish dominate; summer fish kills possible

<u>Source:</u> Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography*. 22:361-369.

Best Management Practices

Best management practices (BMP) are ways to manage your lake property causing as little impact as possible to the lake water quality.

Lawns
Plant natural vegetation along the shoreline instead of turf lawn directly to the lakeshore. The natural vegetation acts as a buffer to the lake and can absorb runoff before it enters the lake. Don’t use phosphorus fertilizer on your lawn, as it can be washed off the lawn into the lake, causing algal blooms.

Septic Systems and Holding Tanks
Take good care of septic systems and holding tanks and make sure you pump them when needed. Improperly maintained septic systems and holding tanks can leak sewage into the lake, which can add phosphorus and cause algal blooms. In addition, leaking sewage can cause harmful bacteria to enter the lake. If you have a septic system, make sure you take care of the drainfield as well. The drainfield is where microbes in the soil treat the sewage. If you water your drainfield or drive on your drainfield, you can clog the filtering ability of the soil.

Organic Matter
"Organic material" or "organic matter" is informally used to denote a material that originated as a living organism; most such materials contain carbon and are capable of decay. While composting is an effective and beneficial way to recycle organic waste, runoff from compost can add nutrients into the lake. Large amounts of organic waste such as leaf and grass clipping should be transported to a compost site away from the lakes and streams. Even though raking leafs and grass into the lake is convenient, the appearance and smell of aquatic composting will inhibit aesthetics.

Chemicals
Chemicals can include everything from house hold cleaners to industrial herbicides and are generally bad and illegal to introduce into water bodies. Some chemicals such as pesticides and exotic species treatments can increase livability with minimal impacts, and control exotic species. This use of chemicals is closely monitored by the DNR and requires permits. Most chemical however damage the ecosystem because they destroy wildlife. Chemicals are synthetic and as a result do not degrade. Once they are introduced into the environment they never go away. If chemicals are continually induced they will eventually build up to sufficient quantity to destroy wildlife. Even small amounts of chemicals damage microscopic wildlife. This in turn affects wildlife down the food chain. The following are some examples of common chemicals that should be kept out of the water: bleaches and ammonias, pesticides, paint and dyes, fuels, lubricants, petroleum products, herbicides.

Glossary

Anoxic: without oxygen. Organisms cannot survive in prolonged periods of anoxia.

Chlorophyll-a: the pigment that makes plants and algae green. Chlorophyll-a is measured in lakes to determine algal concentration.

Dissolved oxygen: oxygen that is dissolved in the water column. Aquatic organisms (zooplankton, aquatic invertebrates and fish) need this oxygen to survive.

Epilimnion: The top layer of a lake where the sunlight penetrates and provides energy for plants and algae to grow.

Fall turnover: when the summer stratification layers of a lake mix due to the cooling epilimnion (upper layer of the lake). This mixing distributes all the nutrients evenly through the water column.

Fertility: the amount of plant and animal life that can be produced within a lake. Fertility is directly related to the amount of nutrients present in the lake to "feed" plants and animals (phosphorus, nitrogen).

Hypolimnion: The deep part of a lake that is cold and dark due to no sunlight penetration. This area of a lake can be anoxic in the summer due to stratification and decomposition.

Littoral area: the area around a lake that is shallow enough to support plant growth (usually less than 15 feet). This part of the lake also provides the essential spawning habitat for most warm water fishes (e.g. bass, walleye, and panfish).

Nitrogen: a nutrient important for plant growth. Nitrogen can enter a lake through groundwater, surface runoff and manure.

OP (Ortho Phosphate): the amount of inorganic phosphorus within a lake. Inorganic phosphorus is readily usable by algae and plants for growth.

Phosphorus: a nutrient needed for plant growth. Phosphorus can enter a lake through runoff from manure and fertilizer or through seepage from leaking septic and holding tanks.

Productivity: the amount of plant and animal life that can be produced within a lake. Productivity is directly related to the amount of nutrients present in the lake to "feed" plants and animals (phosphorus, nitrogen).

Secchi Depth: a measure of water clarity that can indicate the overall health of a lake. A black and white metal disc is lowered into the water on a rope until it can't be seen anymore and raised to the point it can be seen. The depth of the disk to the surface of the water is the Secchi Depth.

Spring turnover: when the ice melts off the lake in the spring and cold water on the top of the lake sinks. This mixing distributes all the nutrients evenly through the water column.

Stratification: The process in which most Minnesota lakes separate into three layers during the summer. The upper layer (epilimnion) becomes warm and is penetrated by sunlight, the lower layer (hypolimnion) is cold and dark and the middle area (thermocline) separates the top and bottom layers. Warm water is less dense than cold water, which is why the upper layer floats on top of the bottom layer and does not mix in the summer. Minnesota lakes mix in the spring and the fall, when the top layer of the lake cools off.

Thermocline: The area between the warm top layer of a lake and the cold bottom part of the lake. The thermocline is characterized by a sharp drop in temperature.

TP (Total Phosphorus): the total amount of organic and inorganic phosphorus within a lake. Organic phosphorus includes detritus, feces, dead leaves and other organic matter.

TMDL (Total Maximum Daily Load): the amount of a particular pollutant that a body of water can handle without violating state water quality standards.

Trend Analysis (Mann Kendall statistic): a way to test the probability of a trend being real versus just happening by chance. A trend probability of 90% (minimum probability used by MPCA) means that there is a 90% probability that the observed trend is real and a 10% probability that the observed trend is just from random chance.

Turbidity: refers to how clear the water is. Cloudiness (turbidity) in the water can be due to suspended matter such as silt, clay, plankton and other organic matter. The more turbid the water is, the less sunlight can pass through.

Watershed: the area of land that drains into a lake directly or by way of a stream that flows into the lake. The land use practices of an entire watershed can affect the water quality of a lake.

TSI: Trophic State Index is a measurement of overall lake productivity (nutrient enrichment). The overall TSI of a lake is the average of the TSI for phosphorus, chlorophyll-a and secchi depth.

Oligotrophic: A lake that has very clear water and very low productivity (phosphorus and chlorophyll-a). Oligotrophic lakes have a Trophic State Index under 30, the hypolimnion contains oxygen throughout the year and can support trout.

Mesotrophic: A lake that has moderate water clarity and productivity (phosphorus and chlorophyll-a). Mesotrophic lakes have a Trophic State Index between 30 and 50, and the hypolimnion can become anoxic during the summer.

Eutrophic: A lake that has low water clarity and high productivity (phosphorus and chlorophyll-1). Eutrophic lakes have a Trophic State Index between 50 and 70, an anoxic hypolimnion in the summer, algal and aquatic plants are prevalent, and can only support warm water fish.

Hypereutrophic: A lake that has very low water clarity and very high productivity (phosphorus and chlorophyll-a). Hypereutrophic lakes have a Trophic State Index over 70, and usually have heavy algal blooms and very dense aquatic plants.