A Review of Pickerel Lake Water Quality

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Introduction

The SDSU Water Resources Institute (WRI) began water quality monitoring at Pickerel Lake in 1991 as part of the Non-Point Source Task Force's Lake protection strategy. A surface composite and a bottom composite was collected (formed from 3 locations on the lake) in mid June, July and August each year from 1991 through 1995. Data collection using the same methods resumed in 2002 by WRI in cooperation with Day Conservation District (DCD) and the Pickerel Lake Sanitary District (PLSD). The Greater Pickerel Lake Association (GPLA) contributed funding to continue in-lake monitoring and initiate tributary monitoring in 2008 after the PLSD declined further participation in studies to assess the health of Pickerel Lake. Other water quality data collected by the SD Department of Water and Natural Resources is available for 1979 and 1989.

This data set is unusual in its length and consistent collection procedures. It provides a basis for assessing long-term and year-to-year variations in algal productivity (i.e., trophic status) of Pickerel Lake. We hope to continue monitoring in-lake sites and look for trends to determine if the observed changes are short-term (e.g. weather related or related to a disturbance) or are of a longer term nature (e.g., long-term increase in TP loading). We will also be able to quantify the amount of nutrients entering the lake through tributary runoff during 2008 and 2009 due to a new tributary monitoring program. Land use in the watershed is also being updated for 2009. This information will allow us to make a better connection between watershed runoff and lake water quality.

Pickerel Lake has been assigned the following beneficial uses according to the South Dakota Board of Water and Natural Resources. Reference to these standards will be made where applicable.

* Warm water permanent fish life propagation

* Immersion recreation

* Limited contact recreation

* Wildlife propagation and stock watering

Trophic State

Trophic state is an indicator of water quality. Lakes can be divided into categories based on nutrient concentrations, algae populations and water clarity. Common characteristics or parameters used to make the determination are:

Total phosphorus concentration (an important nutrient that often limits algal growth)
Chlorophyll a concentration (a measure of the amount of algae present)
Secchi disc transparency (a measure of water clarity)

Total phosphorus tells us the amount of this nutrient that is available to grow algae, chlorophyll a tells us how much algal biomass has accumulated and transparency tells us how much the algae have clouded the water. Calculating a Trophic State Index (TSI) puts these three parameters in comparable units and is used as a way to describe how productive or enriched a lake may be compared to other lakes. Lakes range from nutrient poor (oligotrophic), to moderately rich (mesotrophic), to highly enriched (eutrophic), to excessively enriched (hyper-eutrophic). The word eutrophic comes from the Greek words eu (well) and trophe (nourishment) and literally means well nourished. Cultural eutrophication is the enrichment or over-nourishment of lakes with nutrients caused by human activity.

Oligotrophic lakes are generally deep and have very transparent water with out algae blooms. Low nutrient concentration result in little weed growth and fewer fish but oligotrophic lakes often provide a deep, cold, well oxygenated habitat that can support desirable sport fish such as Lake Trout

Mesotrophic lakes are more productive than oligotrophic lakes but less than eutrophic lakes stages. They usually have a diverse and stable fishery. Deeper mesotrophic lakes can lose most of their of oxygen in the deeper waters by late summer and which limits habitat for cold water fish and may cause release of phosphorus from sediments.

Eutrophic lakes are high in nutrients and support a large biomass (all the plants and animals living in a lake). They are usually either weedy or subject to algae blooms in late summer, or both. Eutrophic lakes often support large fish populations, but can be subject to low oxygen concentrations especially during winters with abundant snowfall.

Hyper-eutrophic lakes often exhibit severe algae blooms that begin in June and last all summer. Small, shallow, hyper-eutrophic lakes are especially vulnerable to winterkill which can reduce the number and variety of fish. Rough fish are commonly found in eutrophic lakes.

Water quality in lakes is a reflection of the watersheds that discharge water to them. The activities and practices of people living in the watershed and along the lakeshore can have a significant impact on the water quality of a lake. Weather and other factors can also affect water quality in any given year. We see year to year variations in water quality of Pickerel Lake that may be due to weather patterns, changes in phosphorus loads from the watershed or in-lake sources of phosphorus. Mesotrophic lakes typically respond to relatively small increases or decreases in phosphorus loadings. Pickerel Lake is sensitive to changes in trophic status due to the nutrient loading from watershed or in-lake sources.

A time line of events with a potential to affect water quality are presented in table 1. These events may help explain some of the year to year variations in water quality that we observe in Pickerel Lake.

Table 1. Events That May Affect Lake Water Quality

1987	Majority of 1985 CRP fields have grass cover established
1989	Heavy spring runoff, 14 inches of snow in March, 3.2 inches rain in April
1993	Heavy summer rainstorms in July, total precipitation for year @ 26.75 inches
1995	Three animal waste systems completed within 1 to 2 miles of lakeshore
1997	1985 CRP contracts expire, most acres resigned however producers required to replant 50% of renewed contracts to native grass
1998	Record setting precipitation @ 29.59 inches for year.
2001	Final phase of sanitary sewer system completed, 90% of lake homes on enclosed system, majority of CRP fields w/mature stands of grass
2004	Large developments begin on northern shores of lake at the old YMCA Camp and north of Bass Beach and yellow clay erodes into the lake
2005	Separation ridge between old fish rearing ponds and main lake removed Fall 05 800+ cattle in feedlot located on north east tributary of the lake during winter 05-06
2006	Approximately 7,000 cubic yards of phosphorus rich sediment released into the lake beginning in spring 06 from the old rearing ponds

Limnologists often calculate a trophic state index (TSI) value to quantify the enrichment level of lakes. The TSIs calculated each year can be used to detect water quality changes that have occurred in a lake over the years. Annual mean TSIs for Pickerel Lake based on total phosphorus is shown in Figure 1 and TSIs based on Secchi disc transparency are shown in Figure 2.

What do these graphs tell us about Pickerel Lake? In the period from 1979 to 2008 Pickerel Lake could be described as eutrophic most of the time based on phosphorus but is mesotrophic to moderately eutrophic based on Secchi disc transparency. This tells us that Pickerel Lake is more transparent than the amount of phosphorus available would indicate. This is also true for Clear Lake in Marshall County.

Water quality in Pickerel Lake improved somewhat in the period from 1989 to 1995. No monitoring was conducted from 1996 to 2001 but Pickerel Lake had drifted to more eutrophic conditions by 2002. Apparently weather events or watershed activity had increased phosphorus loadings to the lake. A large rain event which occurred in 1993 may have increased loadings and caused an increase in TSI in 1994. Large snowfalls in 1996-1997 probably increased phosphorus loadings to the lake but no data is available.

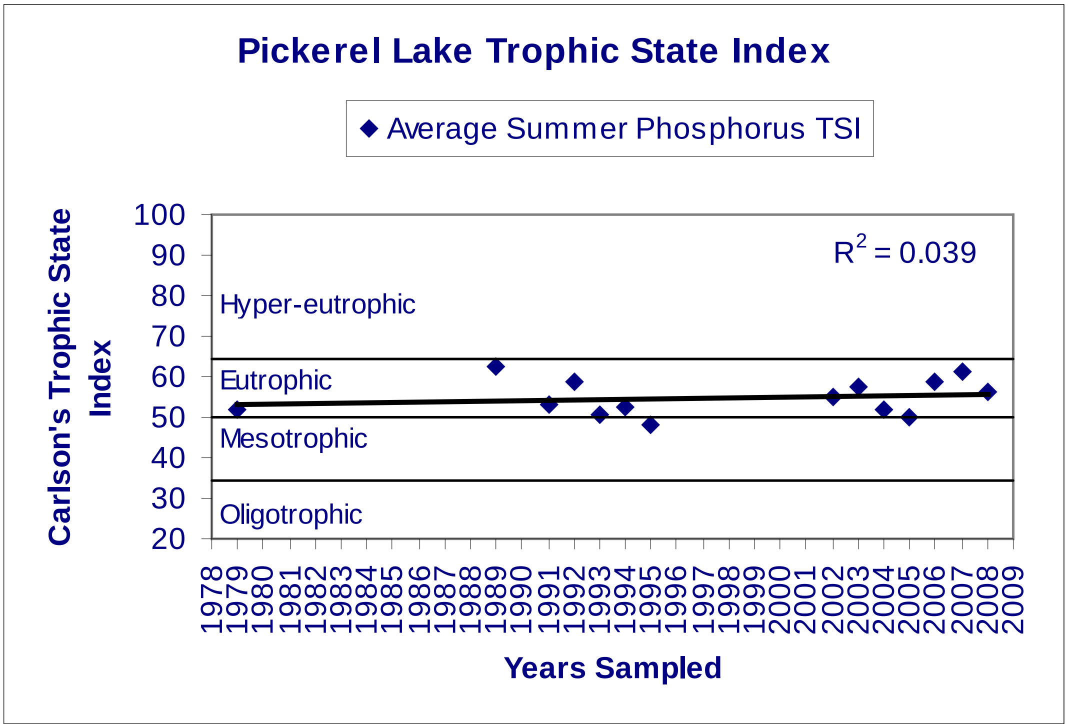

Figure 1. TSIs based on total phosphorus.

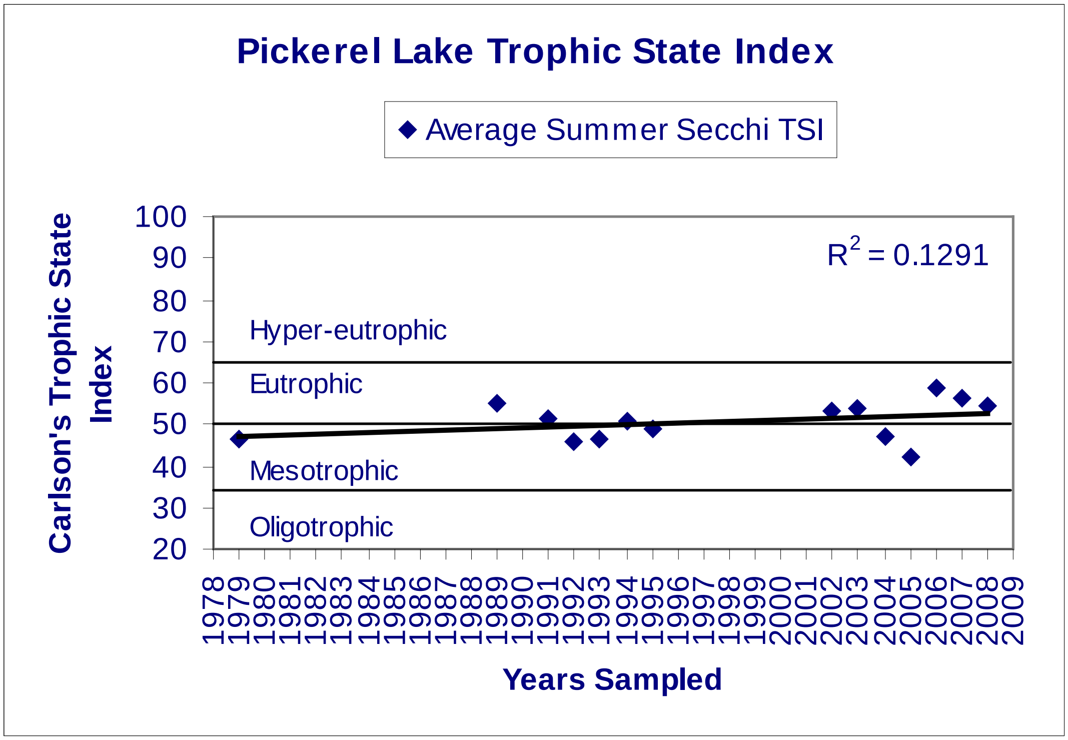

Figure 2. TSIs based on Secchi disc transparency.

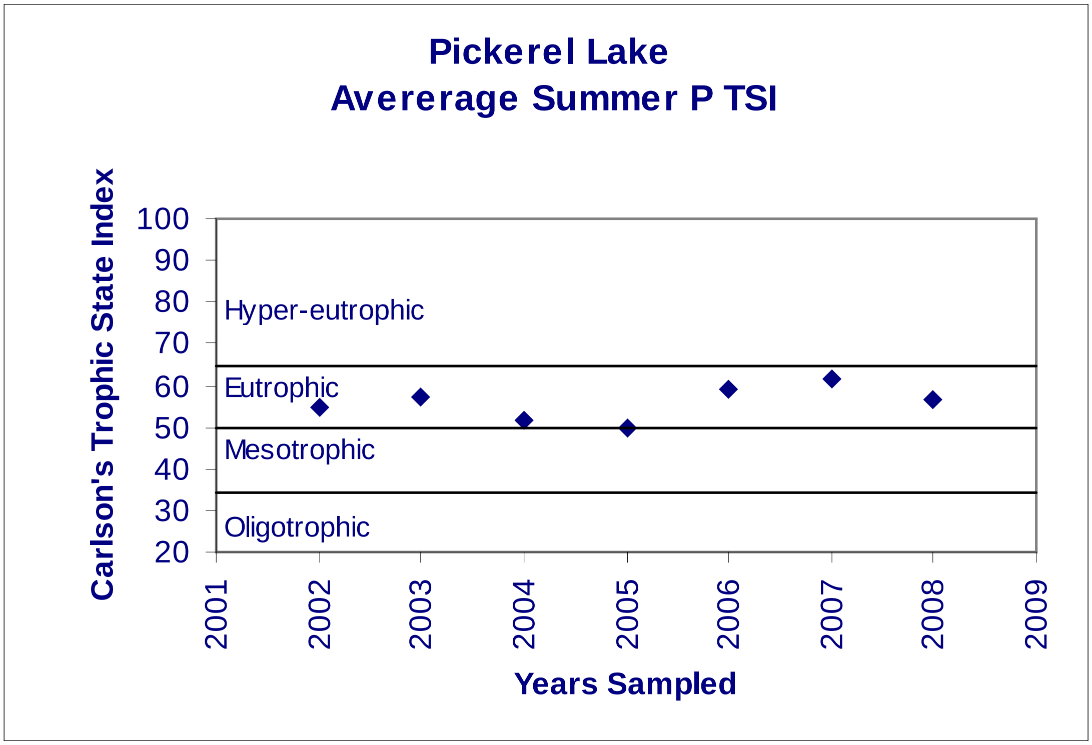

Figure 3. TSIs based on Phosphorus since 2002.

If we look at the most recent 7 years of data for both phosphorus TSIs and Secchi disc TSIs we see improving water quality from 2003 through 2005. Several factors could account for these improvements. Relatively normal runoff has occurred during this period so watershed loadings have probably been moderate. Also a large portion of cropland in the watershed was enrolled in the Conservation Reserve Program (CRP) which has probably reduced phosphorus loadings to the lake. Construction of the sanitary sewer has also reduced phosphorus loadings since it was completed in 2000.

A sudden decline in water clarity occurred in 2006 (Figure 2). It was the largest decline in average transparency we have observed since we started collecting data in 1991. The lake also exhibited increased phosphorus concentrations in 2006 compared to 2005 (Figure 3). The lake changed borderline mesotrophic to eutrophic. Several events may be related to the decline in water quality. In the fall of 2005 rich organic sediment was exposed to the main lake due to construction activities on the west side of the lake. A bay was created when the narrow ridge that separated the old rearing ponds from the lake was removed. In the spring of 2006 during periods of strong south winds a plume of turbid waters could be seen extending from the old rearing ponds to the northeast end of the lake.

A second factor may have been the large number of cattle that were wintered along a tributary on the north end of the lake during the winter of 2005-2006. The effect was made worse when heavy runoff occurred during 2007 due to above average rains (Figure 4). The lake responded by being more productive (more eutrophic) in 2006 and 2007.

During 2008 the lake began to improve and moved back toward the less productive mesotrophic condition. Without an annual data set we would not be able to detect these subtle changes in lake productivity. We are anxious to see how the large snowmelt in 2009 affects productivity of the lake this summer.

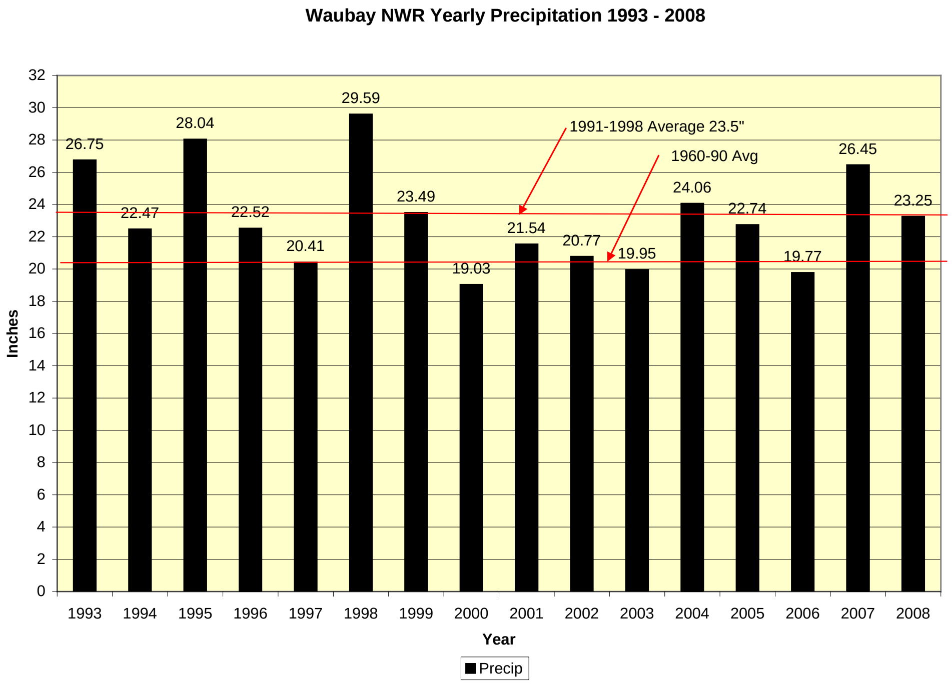

Figure 4. Waubay NWR Precipitation 1993 to 2008.

Shoreline development tends to increase phosphorus loadings of lakes and can result in declining water quality. Large development projects in 2004 (Table 1) at the north end of the lake increased erosion of sediment into the lake but may not have increased phosphorus loadings significantly since the weathered till (yellow clay) that was exposed during construction is relatively low in phosphorus. The sediment in the old rearing ponds on the west end of the lake may be different. Sediment samples were collected on 9-16-2007 at two locations from the bay that was created when the narrow ridge that separated the old rearing ponds from the lake was removed. The sediments samples were analyzed for phosphorus by the SDSU Soil Testing Lab. Olsen soil test P ranged from 10 to 14 ppm in the two samples collected (Figure 5). These samples are considered to be high in phosphorus.

The samples were also incubated without oxygen to determine the potential for phosphorus release under anoxic conditions. The samples exhibited a strong oxygen demand when incubated in a closed container. Sample 2 released nearly 2 ppm to the overlying water during incubation which is about 50 times higher than total P concentrations typically found in Pickerel Lake Figure 5. Sample 1 did not sealed properly, oxygen was present and less phosphorus was released from the sediment.

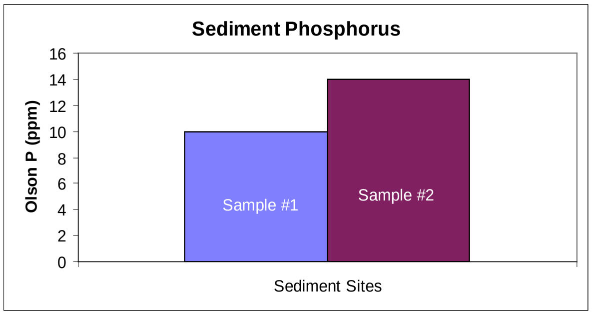

Figure 5. Olsen soil test of sediment.

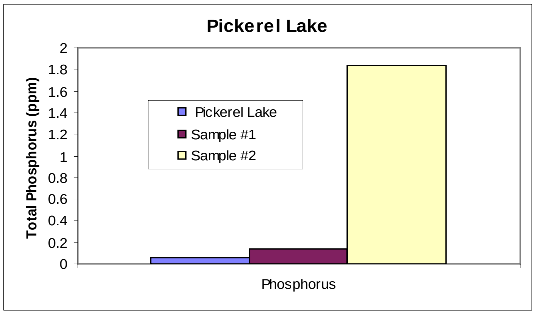

Figure 6. Total P in overlying water.

Summary of In-lake Chemical Data Collected During 2008

Parameters used to calculate TSIs to determine productivity of lakes but we also collect other parameters help determine whether a lake is providing suitable habitat and meeting its beneficial uses as assigned by the state of South Dakota. Results of chemical analysis of in-lake samples collected from Pickerel Lake during 2008 are presented in Table 2.

Table 2. Pickerel Lake Water Quality 2008

Parameters	Unit	May		June		July		August		September	
		5/14/2008		6/12/2008		7/15/2008		8/13/2008		9/16/2008	
Transparency	ft	4.1,4.2,3.9		5.2,6.0.7.8		4.7,5.8,NA		5.1,5.2,5.4		3.1,3.3,3.6	
		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Water Temperature	°C	10.6	9.1	16.1	14.93	23.5	21.6	24.7	23.2	18	16.5
Dissolved Oxygen	ppm	11.2	10.9	8.9	8.1	9.2	4.9	8.6	4.4	10.1	8
pH	--	8.64	8.59	8.59	8.52	8.22	8.47	8.63	8.38	8.75	8.5
Suspended Solids	ppm	9.25	16.5	6.12	11.2	5.67	8.00	6.75	9.25	11.5	15.2
TKN	ppm	0.77	0.83	0.65	0.726	0.81	0.89	1.17	0.93	0.94	0.94
Nitrate	ppm	0.01	N.D.	N.D.	0.05	0.01	0.02	N.D.	0.04	0.02	0.01
Ammonia	ppm	0.106	0.113	0.062	0.064	0.065	0.198	0.137	0.178	0.112	0.032
Total P	ppm	0.041	0.06	0.031	0.044	0.035	0.045	0.038	0.032	0.045	0.055
Total Dissolved P	ppm	N.D.	0.012	0.014	0.013	0.016	0.011	0.02	0.002	0.012	0.019

Dissolved Oxygen

During the summer, lakes more than 20 feet deep usually experience a layering called stratification. Depending on their shape, small lakes can stratify even if they are less than 20 feet deep. In larger lakes, the wind may continuously mix the water to a depth of 30 feet or more. Pickerel Lake usually forms a weak stratification if cool windy weather dominates during early summer and a more stable stratification is established if warmer calm weather predominates. To maintain a permanent warm water fishery a standard of not less than 5.0 mg/l has been established. Oxygen concentrations below 5 mg/l were not observed in waters near the surface of Pickerel Lake during any of the sampling dates since 1991.

Thermal stratification and depression of oxygen concentrations near the bottom is common in Pickerel Lake. Oxygen concentrations less than 5 mg/l were observed on 10 of 15 sampling dates in water near the bottom between 1991 and 1995. Oxygen concentrations were near zero at the bottom in July and August 1991, August of 1993, and July of 1994 and 1995. Near zero oxygen concentrations in bottom waters have become less common in recent years. During 2008 the lake was weakly stratified with the most pronounced stratification on 7-15-2008. Oxygen and temperature profiles for site 2 (the deepest) on 7-15-2008 are presented in Figure 7. Oxygen near the bottom at site 2 on 7-15-2008 was 3.4 ppm.

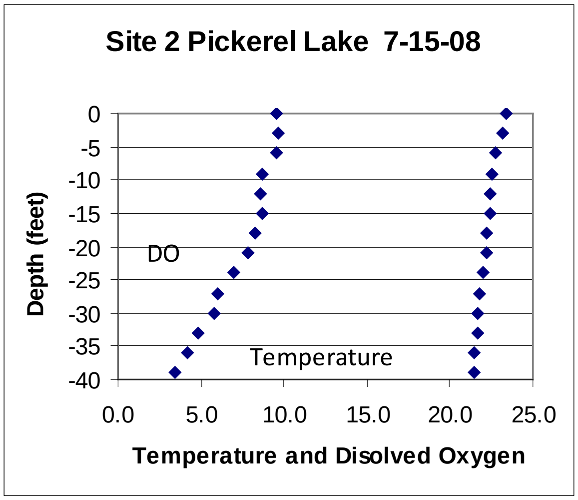

Figure 7. Site 1 Temp & DO profile on 7-15-08

An unusual pattern of depressed oxygen concentrations was observed on 7-17-2006. Normally stations one and two exhibit a similar pattern of stratification. Oxygen and temperature profiles for sites 1 and 2 on 7-17-2006 are presented in Figures 8 and 9 respectively. Station 1 located at the north end of the lake exhibited much lower oxygen concentrations (1.9 ppm) at depth compared to station 2 (6.2 ppm) which is located in the middle of the lake. This data indicates a larger oxygen demand at the north end of the lake during 2006. The increased demand for oxygen may have been caused by the erosion of organic sediments into the lake from the old rearing ponds that were opened to the lake in the fall of 2005.

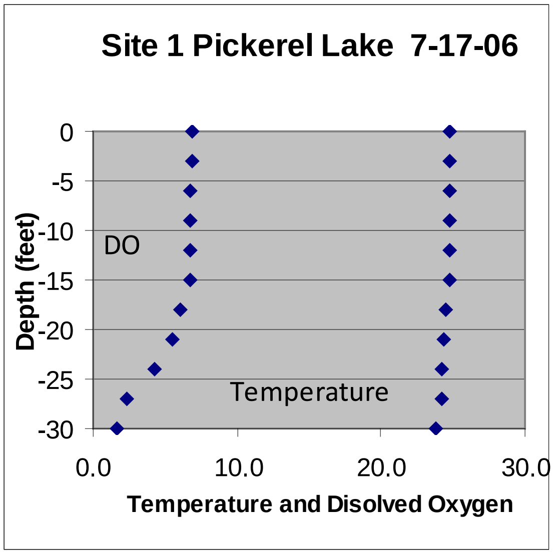

Figure 8. Site 1 Temp & DO profile.

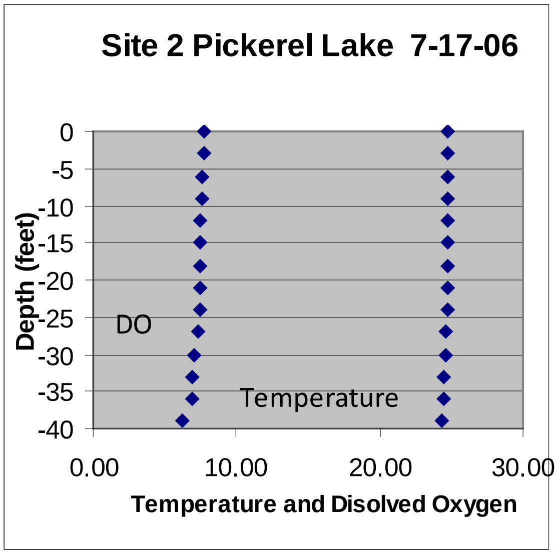

Figure 9. Site 2 Temp & DO profile.

pH

Permanent warm water fish propagation has the most restrictive criteria for pH (between 6.5 and 9.0 units). Observed pH in Pickerel Lake did not exceed the criteria in any samples collected during 2008 (Table 2). Higher pH in surface samples reflect the use of carbon dioxide by algae as they are actively growing. As carbon dioxide is consumed during photosynthesis, pH rises. Peak accumulated algal biomass usually occurs in August or September. High pH can have an impact on other chemical parameters such as ammonia as discussed below.

Transparency

Transparency as measured by secchi disk for three sites is presented in Table 2. The values used for TSIs represent the mean of the three measurements taken at different sites on the lake for sampling dates in June, July and August. The highest transparency (7.8 ft) was observed in June at site 3. By September transparency had been reduced to just over 3 feet. Transparencies in this range are common in eutrophic lakes (Table 2).

Nitrogen

Nitrogen is present in lakes in several forms, both inorganic and organic. The inorganic forms (ammonia, nitrite and nitrate) are important indicators of nutrients available for plant growth. Organic nitrogen represents nitrogen incorporated into living (or once living) material. The atmosphere is 78% nitrogen gas which enters the lake at the surface. Nitrogen gas (N_2) is not available to plants and algae (except blue-greens) so it needs to be converted to nitrate or ammonia before it is available for plant growth. This can occur by lightning in the atmosphere, alfalfa and other nitrogen-fixing plants on land or by fertilizer production. Cyanobacteria or “blue-green” algae begin fixing nitrogen gas in lakes when nitrogen becomes scarce. This gives them a major competitive advantage over other algae when phosphorus is abundant and nitrogen is scarce. For this reason we focus on reducing phosphorus loadings to prevent eutrophication.

Total Kjelldahl Nitrogen

Total Kjeldahl Nitrogen or TKN is the sum of organic nitrogen; ammonia (NH_3) and ammonium (NH_4+) in the chemical analysis of water. Most of the TKN present in Pickerel Lake represents organic nitrogen. Organic nitrogen is an indirect measure how fertile lakes are. TKN concentrations observed in Pickerel Lake are typical of those found in mesotrophic to eutrophic lakes (Wetzel, 1983). Bottom samples exhibited slightly higher concentration than surface samples except for August 2008 (Table 2).

Ammonia as Nitrogen

Ammonia is generated as an end product of bacterial decomposition of organic matter (dead things). It is also a major excretory product of aquatic animals, but this is a minor source compared to bacterial decomposition. Ammonia is directly available for plant growth and is the most easily used form of nitrogen. It can support the rapid development of algal blooms if other nutrients are present. Total ammonia as measured in the lab includes both ammonia (NH_3) and ammonium (NH_4+). The balance between the two forms depends on the pH and temperature. As pH and temperature rises ammonium (NH_4+) is converted to ammonia (NH_3). It is the unionized (NH_3) form that is toxic to aquatic organisms.

In the upper areas of lakes where light is available, ammonia is rapidly assimilated by algae and is usually low in lakes with low algal productivity. Ammonia concentrations in Pickerel lake surface samples were somewhat elevated but not above the criteria for permanent warm water fish propagation as determined by a complex formula. Un-ionized ammonia is calculated based on total ammonia concentrations, pH and temperature.

Ammonia concentrations were usually higher in the bottom composite than in the surface composite except for those collected in September. Ammonia is released from sediments under anoxic conditions and can accumulate in the deeper areas of the lake where algae cannot make use of it. This probably accounts for the higher concentrations of ammonia in bottom samples. Elevated concentrations of ammonia in surface waters during August and September was probably due to senescence of algae blooms and the commencement of decay and decomposition.

Nitrate

Nitrate is also directly available for algal growth. Low concentrations were observed on most sampling dates in both surface and bottom waters (Table 2). The highest concentrations were observed in August bottom samples at .04 ppm. There appears to be strong competition for nitrate in Pickerel Lake most of the time.

Total Phosphorus and Total Dissolved Phosphorus

As discussed earlier, trophic state is commonly described by concentrations of total phosphorus. Total phosphorus concentrations remained fairly stable throughout the summer of 2008. Total dissolved phosphorus concentrations can indicate the amount of phosphorus available for use by algae and other plants. Dissolved phosphorus is rapidly consumed by algae and seldom reaches high concentrations unless other factors are limiting algal growth. Dissolved phosphorus is an important plant nutrient that often limits algal growth if concentrations are very low.

Dissolved phosphorus can accumulate in the deeper waters of eutrophic stratified lakes where it is unavailable to the algae. Dissolved phosphorus concentrations were relatively low during 2008 including in bottom waters (Table 2). The lack of a pronounced stratification and the presence of oxygen near the bottom probably prevented a release of phosphorus from the sediments. There was no significant difference in dissolved P between surface and bottom samples during 2008.

Phosphorus is released from sediments and becomes dissolved in the water under anoxic conditions. In previous years when oxygen near the sediment surface was low, dissolved phosphorus and ammonia accumulated in Pickerel Lake's bottom waters in the summer. When these nutrients became available at the surface after fall turnover they encourage the fall algal blooms that are sometimes observed in the lake. Reduced internal loadings of phosphorus during 2008 probably contributed to the improvement in water quality that was observed in 2008.

Suspended Solids

Low suspended solids concentrations are desirable in lakes for aesthetic reasons and for maintenance of a healthy fishery. Fish populations can be affected by high suspended solids in several ways. Fish can be killed directly or their growth, resistance to disease and reproduction success may be reduced. Migrations can also be affected (EPA, 1976). High suspended solids concentrations result in reduced aesthetic value of a lake which can limit recreational use.

The state standard for maintaining a warm water permanent fishery is 90 mg/l. This standard was not exceeded on any of the sampling dates reported (Table 2). Suspended solids concentrations in surface samples were below 12 mg/l on all of the sampling dates.

Bottom samples were slightly higher. In Pickerel Lake suspended solids is primarily a reflection of the small plants and animals that live in the open water (plankton) rather than the suspended sediment that is often present in shallower lakes. Pickerel Lake's depth prevents the wind from stirring bottom sediment to any large degree. Recreational use of the lake and ability to support a healthy fishery are apparently not limited by high suspended solid at this time.

Tributary Runoff Data Collected during 2008

We will be able to quantify the amount of nutrients entering the lake through tributary runoff during 2008 and 2009 due to a new tributary monitoring program supported by the GPLA and an education grant from the Discovery Center in Pierre. This information will allow us to make a better connection between watershed runoff and lake water quality. The tributary monitoring program also allows us to identify problem areas in the watershed. We now know that Chekapa Creek for example carries a higher concentration of nutrients into the lake than North Creek that drains the northern 1/3 of the Pickerel Lake watershed. We also see higher sediment loads and more fecal Coliform bacteria below areas where cattle have access to the stream. The Day Conservation District has identified some of these problem areas and is working with area land owners including the Sisseton Whapeton Oyate to change land use and protect sensitive areas. Having actual water quality data is important evidence to encourage needed changes. Tributary monitoring sites are shown in Figure 10.

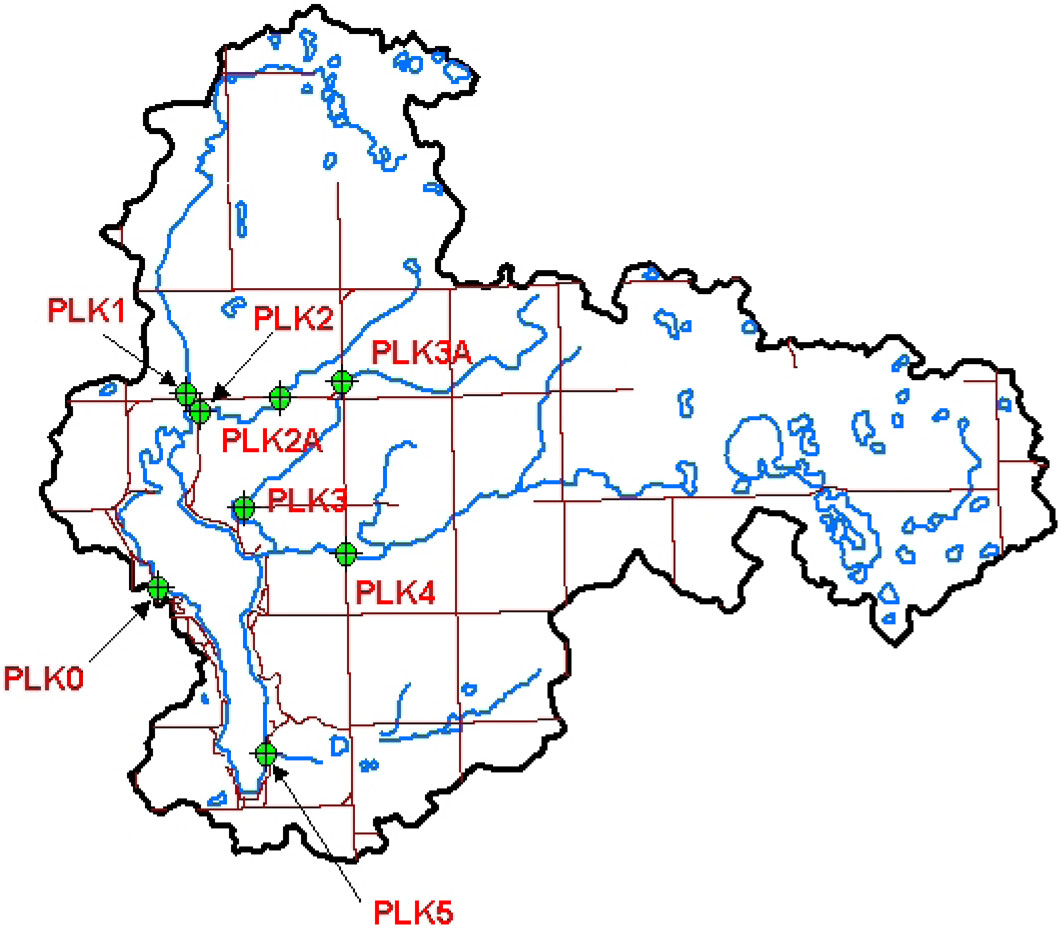

Figure 10. Tributary monitoring Sites in the Pickerel Lake Watershed.

Tributary water quality data collected during 2008 is presented in Tables 3 and 4. Data from tributaries with a single monitoring site are shown in Table 3. Sample sites include PLK-O at the outlet, PLK-1 on North Creek, PLK-4 on Chekapa Creek and PLK-5 on Hatchery Creek. One sample (south-lake) was collected on the drainage at the very south end of the lake.

Table 3. Pickerel Lake Tributary Field Parameters (single station)

Date Sampled	Sample Location	Discharge (CFS)	Stage (Feet)	Fecal Coliform	DO (mg/L)	pH (su)	Ammonia Nitrogen	Nitrate Nitrogen	Total Dissolved Phosphorus	Total Phosphorus	Total Kjeldahl Nitrogen (TKN)	Total Suspended Solids
3/20/08	PLK0	32.95	0.65		9.8	7.24	0.076	0.19	0.011	0.022	0.648	2.40
5/9/08	PLK0	34.75	0.6		11.9	8.23	0.101		0.014	0.037	0.716	7.75
6/6/08	PLK0	20.17			8.2	8.63	0.082	0.01	0.019	0.042	0.907	11.5
7/7/08	PLK0	8.99	0.3		7.3	8.46	0.074	0.25	0.017	0.032	0.772	4.25
3/14/08	PLK1				2.5	6.23	0.426	0.00	0.305	0.328	1.76	3.33
4/16/08	PLK1	10.69	6.3		5.7	7.72	0.080	1.94	0.060	0.061	0.478	28.5
5/9/08	PLK1	2.84	7.19		5.8	7.74	0.081		0.022	0.023	0.504	0.250
6/6/08	PLK1	4.58	7.15		2.5	7.63	0.060	0.03	0.063	0.061	0.700	0.750
6/11/08	PLK1						0.057	0.3	0.042	0.052	0.674	0.333
7/7/08	PLK1	0.11	7.65		2.03	7.5	0.156	0.17	0.134	0.136	0.872	4.00
8/12/08	PLK1	0.33	7.53	30/100	1.5	7.51	0.162	N.D.	0.068	0.089	1.02	3.00
9/2/08	PLK1	5.6	ND	430/100	1.39	7.45	0.134	0.06	0.123	0.133	1.27	2.12
10/7/08	PLK1	2.5	7.3	10/100	3.8	7.6	0.060	0	0.059	0.056	0.800	1.50
10/13/08	PLK1	4.19	7.13		5.5	7.6	0.098	0.116	0.046	0.049	0.586	54.2
3/14/08	PLK4	ND	1.8		11.3	6.85	0.428	0.24	0.325	0.416	2.65	32.8
3/30/08	PLK4	21.68	2		12.2	6.86	0.238	N.D.	0.281	0.350	2.21	28.7
3/31/08	PLK4			20/100								
4/3/08	PLK4	23.68	1.8		11.5	7.97	0.265	N.D.	0.444	0.671	2.45	104.
4/15/08	PLK4	34.29	2.7		12	8.05	0.130	N.D.	0.260	0.334	0.911	49.0
4/15/08	PLK4	82.2	3		10.5	8.13	0.164	N.D.	0.172	0.243	1.05	56.0
5/9/08	PLK4	9.97	1.25		11.6	8.2	0.082		0.018	0.036	0.736	3.00
6/6/08	PLK4	15.64	1.45		6.3	7.92	0.658		0.223	0.365	3.46	9.00
6/11/08	PLK4	ND	ND		7.1	7.9	0.187	0.89	0.133	0.217	1.32	46.0
7/7/08	PLK4	4.2	0.8		4.5	7.74	0.145		0.063	0.085	0.984	12.0
8/12/08	PLK4	4.54	0.85	160/100	4.1	7.7	0.174	N.D.	0.069	0.094	0.839	11.0
9/2/08	PLK4	11.76	1.2	210/100	2.83	7.7	0.066	0.12	0.154	0.176	1.03	5.00
10/7/08	PLK4	6.19	0.9	10/100	6.1	7.79	0.078	N.D.	0.054	0.059	0.685	8.00
10/13/05	PLK4	4.49	0.8		7.8	7.84	0.091	0.172	0.068	0.074	0.640	60.3
4/15/08	PLK4A				12.8	7.82	0.152	N.D.	0.571	0.590	1.32	52.0
4/15/08	PLK5	3.78	0.9		10	7.61	0.107	N.D.	0.025	0.091	0.886	43.0
5/9/08	PLK5	4.52			8.8	7.91	0.090		0.020	0.028	0.466	3.25
6/6/08	PLK5	2.18	1.1		6.4	7.85	0.114		0.032	0.046	0.918	6.00
7/7/08	PLK5	0.69	1.45		6	7.76	0.100		0.046	0.050	0.723	3.00
9/2/08	PLK5				6.9	7.73	0.134	0.12	0.057	0.069	1.06	2.00
10/13/08	PLK5						0.138	0	0.037	0.055	0.892	46.3

Tributaries with upstream and downstream sites to evaluate the effects of animal feeding areas are designated PLK2 and PLK2A on Kulesa Creek and PLK3 and PLK3A on Gruby Creek are shown in Table 4.

Table 4 Pickerel Lake Tributary Field Parameters Upstream vs Downstream

Date Sampled	Sample Location	Discharge (CFS)	Stage (Feet)	Fecal Coliform	DO (mg/L)	pH (su)	Ammonia Nitrogen	Nitrate Nitrogen	Total Dissolved Phosphorus	Total Phosphorus	Total Kjeldahl Nitrogen (TKN)	Total Suspended Solids
3/30/08	PLK2	ND	1.8	ND	12.4	6.54	0.342	N.D.	0.262	0.331	1.83	7.67
3/31/08	PLK2			20/100								
4/15/08	PLK2	15.08	2.7		11.3	7.93	0.124	N.D.	0.132	0.204	1.29	80.5
5/9/08	PLK2	0.71	1.9		11	8.23	0.051		0.035	0.044	0.524	3.75
6/6/08	PLK2	7.14	2.1		6.9	8.08	0.127	0.14	0.164	0.311	2.27	58.5
6/11/08	PLK2	12.86	2.6		7.5	8.01	0.108	0.14	0.155	0.284	1.61	61.0
7/7/08	PLK2	0.11	0.9		9.4	8.3	0.028	0.36	0.040	0.044	0.536	3.00
9/2/08	PLK2	1.4	1.68	1500/100	6	7.69	0.182	0.23	0.428	0.458	2.03	9.50
10/7/08	PLK2	1.6	1.7	60/100	3.9	7.94	0.108	0.38	0.198	0.223	1.20	12.7
10/13/08	PLK2	0.64	1.7		9.8	8.1	0.102	0.114	0.117	0.139	0.788	72.3
3/14/08	PLK2A				12.9	7.06	0.258	0.08	0.337	0.362	1.70	3.00
3/30/08	PLK2A				12.8	7.01	0.158	N.D.	0.102	0.109	1.32	1.25
3/31/08	PLK2A			<10/100								
4/15/08	PLK2A				11.1	8.03	0.106	N.D.	0.090	0.092	0.770	24.5
5/9/08	PLK2A				11	8.07	0.082		0.032	0.037	0.456	0.750
6/6/08	PLK2A				6.2	8.06	0.075	0.19	0.069	0.109	1.03	3.67
6/11/08	PLK2A				7	8.01	0.084	0.45	0.047	0.071	0.891	3.75
9/2/08	PLK2A				5.69	7.8	0.226	0.14	0.352	0.377	1.83	2.75
10/7/08	PLK2A			20/100	8.8	8.02	0.094	N.D.	0.107	0.113	0.855	1.00
10/13/08	PLK2A				10.3	8.13	0.114	0	0.089	0.094	0.679	71.0
3/30/08	PLK3	3.73	0.9		12.5	6.86	0.198	0.2	0.326	0.342	1.56	2.00
3/31/08	PLK3			<10/100								
4/3/08	PLK3	6.6	1.1		12.2	7.87	0.228	0.14	0.303	0.360	1.58	25.4
4/15/08	PLK3	7.35	0.9		11.8	8.05	0.108	N.D.	0.109	0.251	0.962	95.0
5/9/08	PLK3	1.14	0.65		10.1	8.3	0.028		0.038	0.047	0.425	7.52
6/6/08	PLK3	1.5	1.1		7.8	8.29	0.056	0	0.114	0.155	0.822	14.3
6/11/08	PLK3						0.117	0.18	0.212	0.288	0.92	6.25
9/2/08	PLK3	0.43	0.65	1200/100	8.04	7.84	0.268	0.09	0.137	0.892	6.43	540.
10/7/08	PLK3	0.31	0.6	30/100	9.6	8.17	0.244	0.33	0.242	0.442	2.50	24.8
10/13/08	PLK3	0.85	0.9		11.7	8.29	0.099	0	0.110	0.127	0.560	82.8
4/15/08	PLK3A				10.2	7.8	0.074	N.D.	0.033	0.046	0.474	42.0
5/9/08	PLK3A				7.3	7.8	0.030		0.021	0.019	0.266	0.500
6/6/08	PLK3A				4.6	7.83	0.034	0.01	0.054	0.054	0.605	0.750
6/11/08	PLK3A				4.7	7.78	0.073	0.08	0.046	0.050	0.428	0.750
9/2/08	PLK3A				2.28	7.72	0.086	0.15	0.141	0.170	1.04	1.25
10/7/08	PLK3A			<10/100	4.8	7.86	0.112	N.D.	0.073	0.073	0.560	0.750
10/13/08	PLK3A				7.5	7.88	0.144	0.01	0.059	0.061	0.445	46.2

A comparison of upstream and downstream samples from Gruby Creek indicate increases in both total phosphorus (Figure 11) and dissolved phosphorus (Figure 12) on most sampling dates. An animal waste system was installed at a dairy located between the sample sites during the 1990s which has improved water quality in Gruby Creek but the system is apparently not able to remove all impacts from the stream. Large increases in suspended solids, TKN and ammonia in downstream samples (PLK3) on 9/2/08, 10/7/08 and 10/13/08 (Table 4) may indicate that animals have direct access to the Creek. The large spike in fecal Coliform bacteria on 9/2/08 is probably also due to animal access to the creek. Providing alternative water sources and limiting animal access to the creek and improved manure management may improve water quality at this site.

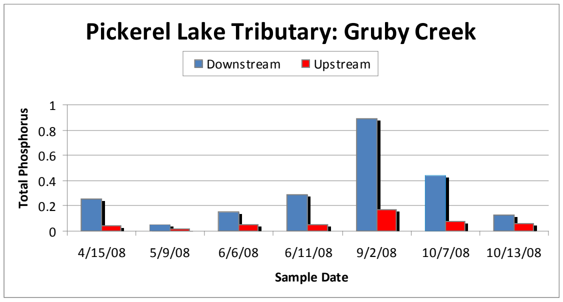

Figure 11. Total Phosphorus at site PLK3.

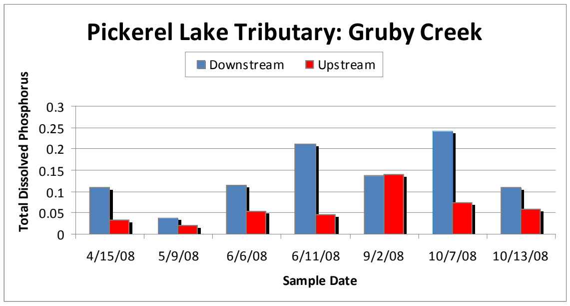

Figure 12. Total Dissolved P at site PLK3.

A comparison of upstream and downstream samples from Kulesa Creek indicate increases in both total phosphorus (Figure 13) and dissolved phosphorus (Figure 14) on most sampling dates. On most dates the difference is small however. The large number of animals fed at the site during the winter of 2005 and 2006 are no longer present but animals in the pasture still have access to the creek. A large spike in fecal coliforms on 9/2/08 and spikes in suspended solids at PLK2 were probably also due to animal access to the creek. Animal waste in the old feeding area may also be contributing nutrients. Removing old stockpiles of manure and limiting animal access to the stream could improve water quality at the site. Phosphorus concentrations over 0.3 ppm composed mostly of the dissolved form at site PLK 2A on 3/14/08 and 9/2/08 indicate potential sources of phosphorus in the upper part of the watershed. Additional work needs to be completed to identify these sources.

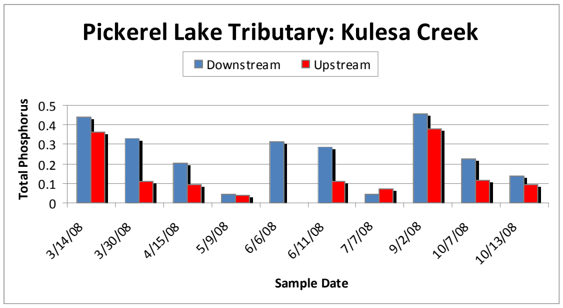

Figure 13. Total Phosphorus at site PLK2.

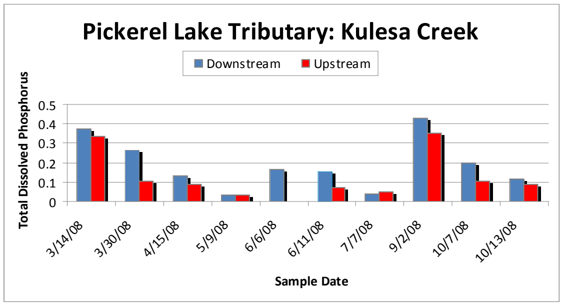

Figure 14. Total Dissolved P at site PLK2.

Other tributaries carry significant nutrient loads especially during spring snowmelt and rain events (Table 3). Chekapa Creek exhibited high phosphorus, ammonia, and suspended solids concentrations on several sampling dates in 2008 (Table 3). A record of water depth in Chekapa Creek at sample site PLK-4 is shown in Figure 15. The continuous record of stage depth began in June 2008 when stage recorders were installed on the major tributaries. The continuous stage record allows use to calculate more accurate flows and loadings. We can also relate flow events to water quality samples. For example higher flows due to rainfall increased total phosphorus concentrations on 6-6-08 and 6-11-08 in Chekapa Creek. When sufficient flow measurements at a range of stage heights have been collected the stage data will be converted to flow rates for each creek. Flow rates (discharge) combined with water quality data allows us to calculate loadings of nutrients and sediment to the lake. Additional work is needed to complete this analysis.

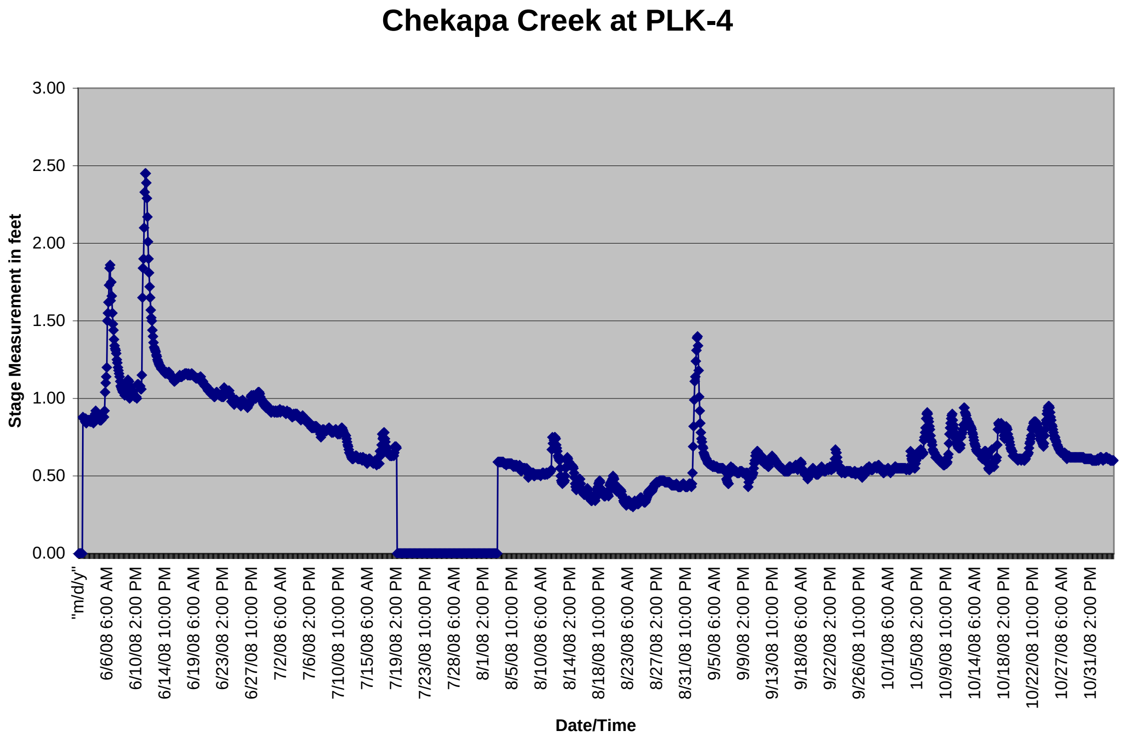

Figure 15. Stage records for Chekapa Creek at sample site PLK-4

North Creek and Hatchery Creek exhibited better water quality compared to Chekapa Creek but North Creek carried significant loads of mostly dissolved phosphorus during snowmelt in March 2008. Elevated concentrations of sediments and nutrients were observed in hatchery creek during runoff events in both April and October 2008 (Table 3).

Land Use

Some of the variations in water quality we observe between tributaries may be affected by land use in the watershed and more importantly subwatersheds.

The Chekapa Creek Subwatershed (Figure 16) is the main perennial tributary supplying the lake with surface runoff and groundwater from springs year-round. An intermittent tributary of Chekapa Creek drains the northern portion of this subwatershed. The majority of the extant cropland and expiring CRP contracts are located along this tributary. The Northeast Glacial Lake Watershed Protection and Improvement Project is working with landowners to buffer a majority of this streams reach, already the lower third of this intermittent stream is protected by a riparian buffer zone.

One Road Lake when full discharges to Chekapa Creek. As shown in Figure 17, the majority of this watershed is currently pasture and rangeland. A majority of this lake's shorelines is owned by the Sisseton Wahpeton Oyate, US Fish and Wildlife Service, or the SD Dept. of Game, Fish and Parks, therefore shoreline development along One Road Lake is highly unlikely.

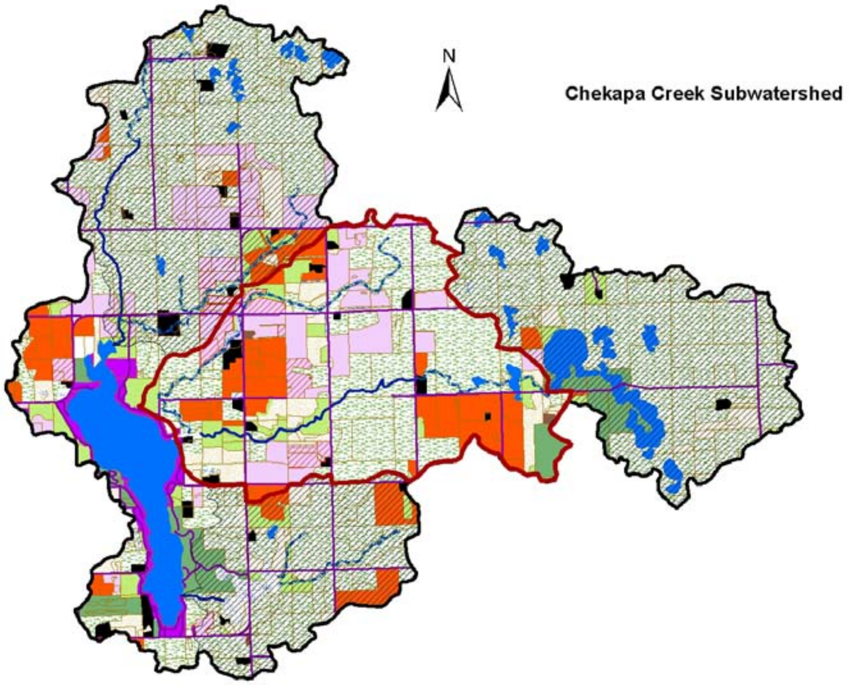

Figure 16. Chekapa Creek Subwatershed

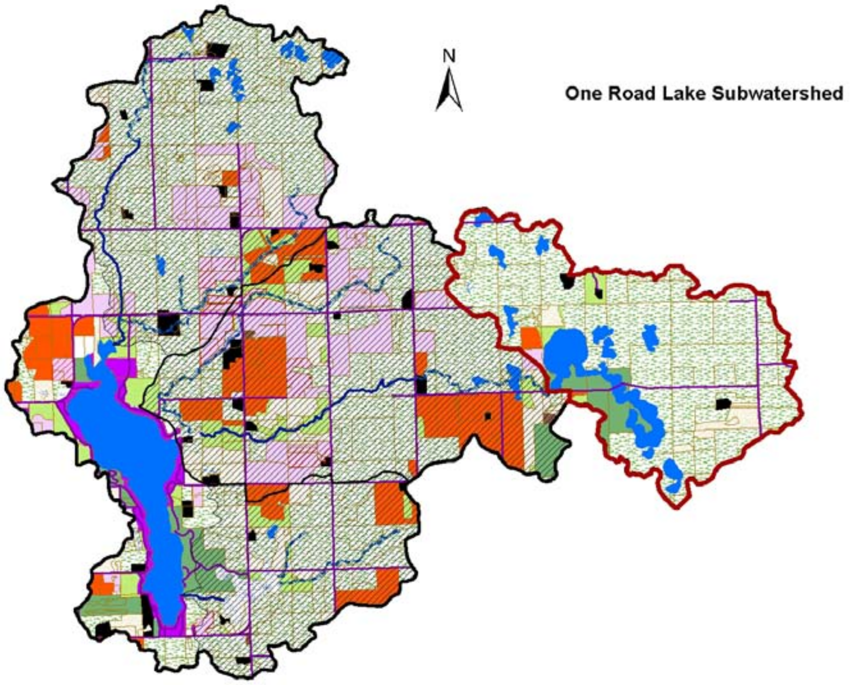

Figure 17. One Road Lake Watershed

The North Creek subwatershed's main tributary flows from the north beginning in Marshall County. The majority of water in this perennial tributary is groundwater from several upstream springs and fens. The main tributary is well buffered by pasture and rangeland as seen in Figure 18. An intermittent flowing tributary of North Creek begins just north of Zoar Lutheran Church and flows through the majority of the cropland located in this subwatershed. Water quality data given above shows the impact this intermittent stream has on Pickerel Lake. The Northeast Glacial Lake Watershed Protection and Improvement Project is working with landowners to buffer a majority of this streams reach.

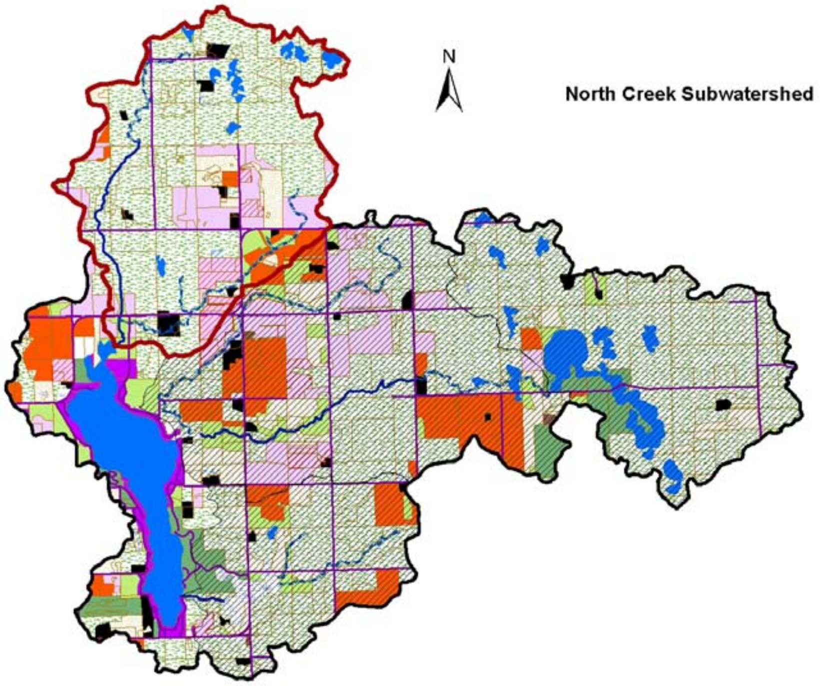

Figure 18. North Creek Subwatershed.

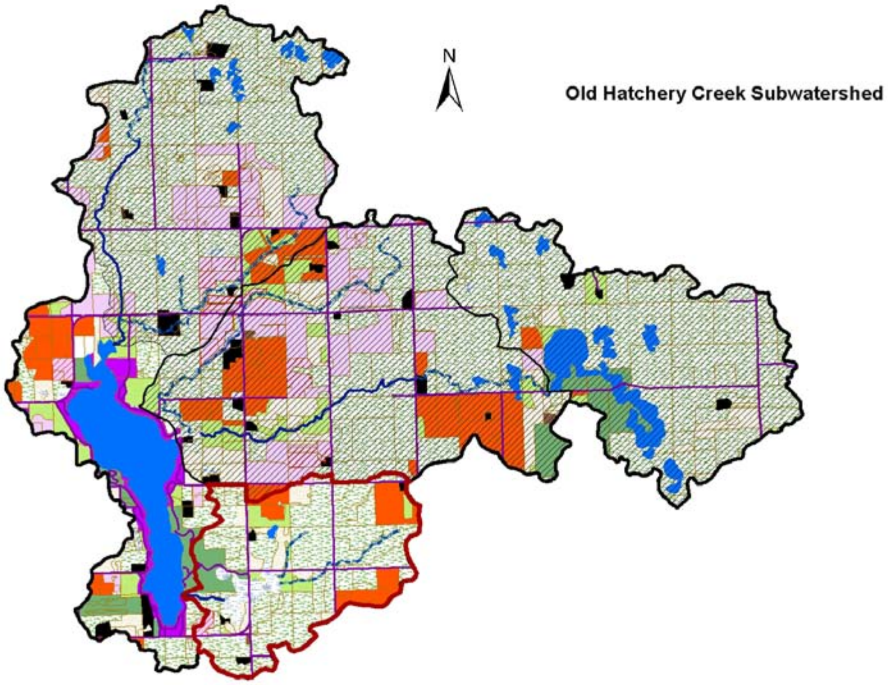

Figure 19. Old Hatchery Creek Subwatershed

The Old Hatchery Creek subwatershed (Figure 19) has little effect on Pickerel Lakes water quality. The majority of this streams flow comes from an artesian well used to provide water to the former Pickerel Lake State Fish Hatchery located near the creeks entrance to Pickerel Lake. Land use in this subwatershed is mainly pasture and rangeland. This subwatershed is buffered by a very large wetland complex located just south of the entrance to the Pickerel Lake State Recreation Area's east unit that traps and utilizes any sediment and nutrients coming from upstream.

Land Use Changes

There was little change in land usage in Pickerel Lake's watershed between 1996 and 2007 (Figures 20 and 21).

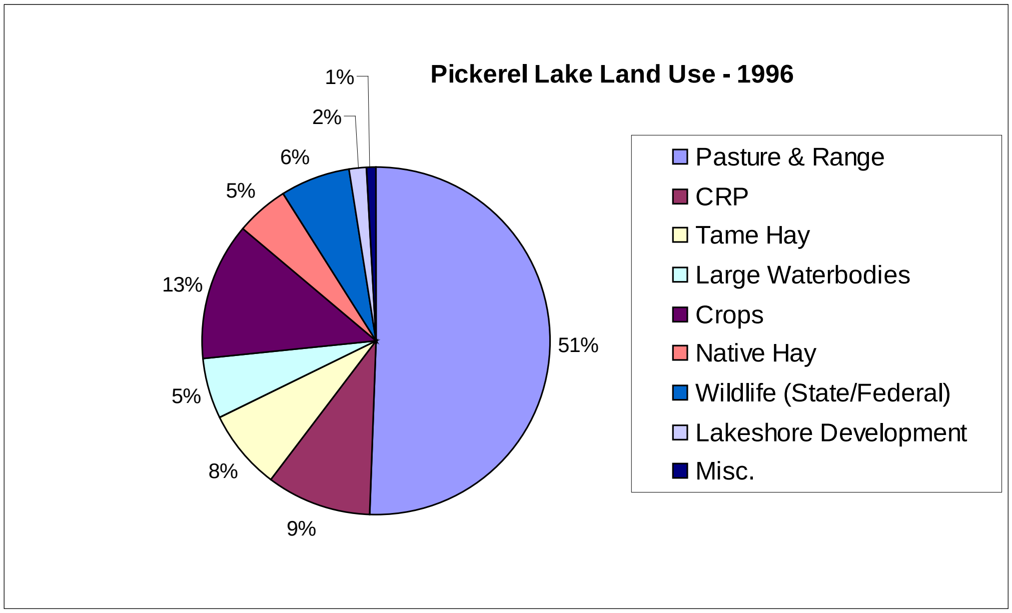

Figure 20. Watershed Land Use 1996

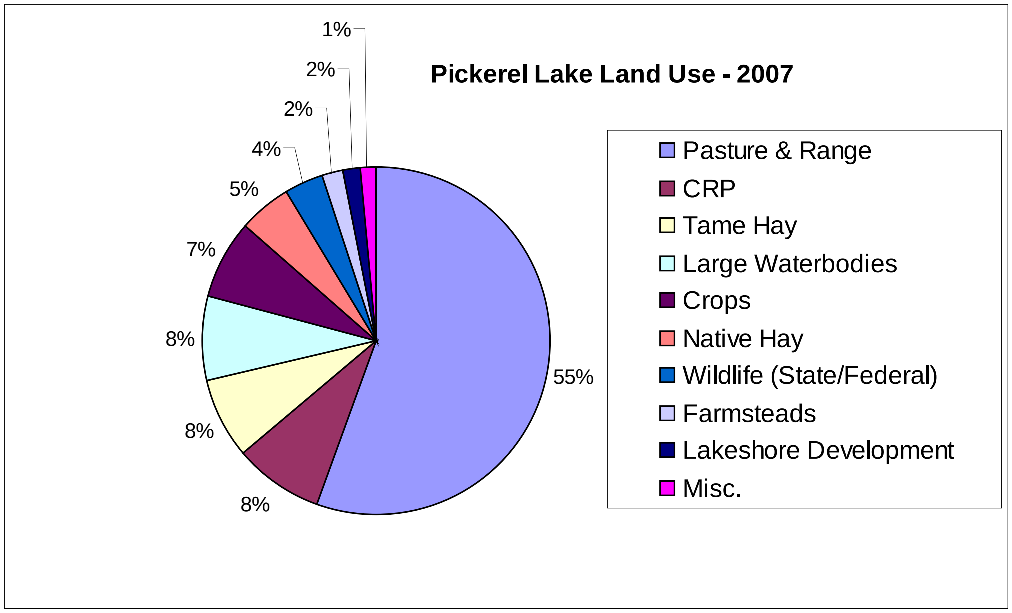

Figure 21. Watershed Land Use 2007

However, beginning the fall of 2008 many Conservation Reserve Program (CRP) contracts began to expire. Due to high corn prices, most producers chose to revert these CRP acres back to cropland. Figure 22 denotes the location of former CRP contracted acres now reverted back to row crops. Many more contracts will expire the fall of 2009 and 2010, and dependant on commodity prices or the possibility of new CRP programs will be the determining factor in how these acres are utilized in the near future.

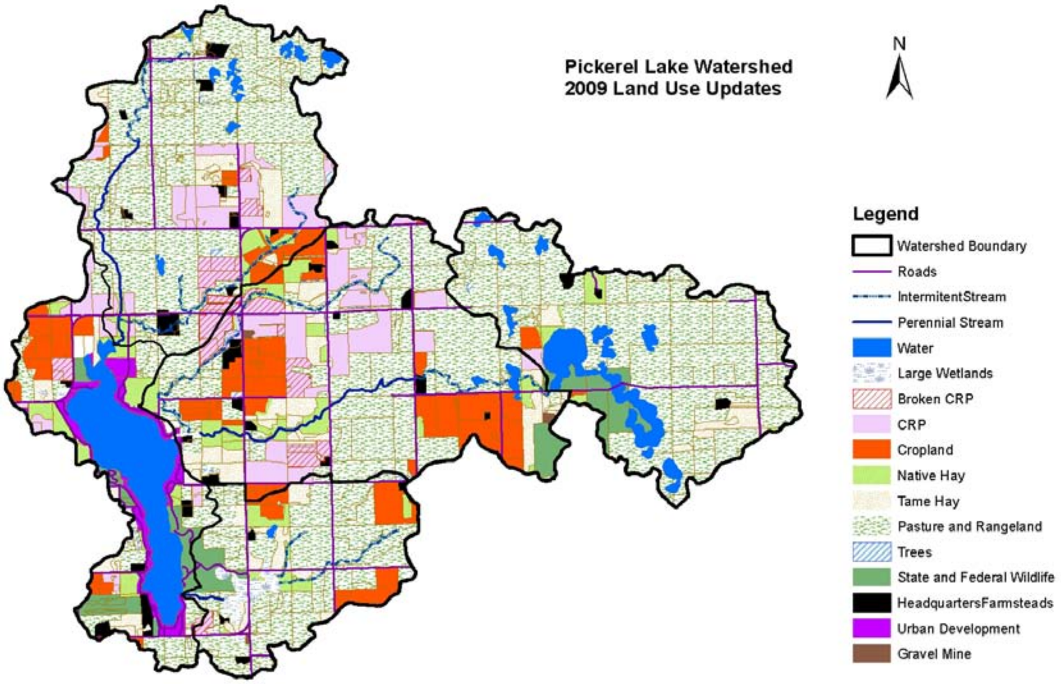

Figure 22. Pickerel Lake Watershed 2009 Land Use Updates

Summary and Recommendations

The data we have collected so far indicates that Pickerel Lake currently supports beneficial uses but it is sensitive to changes in phosphorus loadings. It is likely that if conditions in the watershed change and phosphorus loadings increase, it may drift to a more eutrophic condition. When the CRP land in the watershed is returned to production the combined increases in phosphorus loadings from cropland and shoreline development will probably result in declining water quality in Pickerel Lake if phosphorus loadings from other sources are not reduced. It is essential; therefore, that GPLA work with all local governments, the PLSD and other lake protection groups and land use/zoning authorities for Day County to control nutrient and sediment sources in the watershed if the quality of Pickerel Lake is to be maintained.

The GPLA should develop a Lake Action Plan for protecting the water quality of the lake. This plan should convey a series of prioritized activities for the long-term protection and improvement of the lake water quality. The plan should be developed cooperatively by a committee of representatives from state agencies and local units of government, and association members. Activities that could be included in the plan include:

Form Local Partnerships: The GPLA should seek representation on boards or commissions that address land management activities to insure that impacts to the lake are considered. Develop and use local ordinances to protect the condition of the lake.

Continued in-lake monitoring: Data collected by the same methods each year provides an excellent basis for assessing long-term and year-to-year variations in algal productivity (i.e., trophic status) of the lake. Other sources of funding should be sought to allow GPLA resources to be targeted on education of lake residents on the plan and the action needed.

Monitor Development: Shoreline development and land use changes in the watershed should be monitored and practices should be encouraged that minimize water quality impacts on Pickerel Lake. The GPLA should maintain formal contacts with the SD DENR to insure that storm water regulations are followed during and following any major construction/development activities in the watershed. The GPLA should seek representation on boards or commissions that address land management activities to insure that impacts to the lake are considered.

Continue Educational Efforts: Most lawns do not need additional phosphorus. The GPLA should continue to encourage the use of P-free fertilizers on lawns in the watershed. There are other Best Management Practices (BMP’s) that may reduce nutrient loading from other sources in the watershed. The GPLA should continue to work with the Day Conservation District to identify and promote BMPs that protect water quality.

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