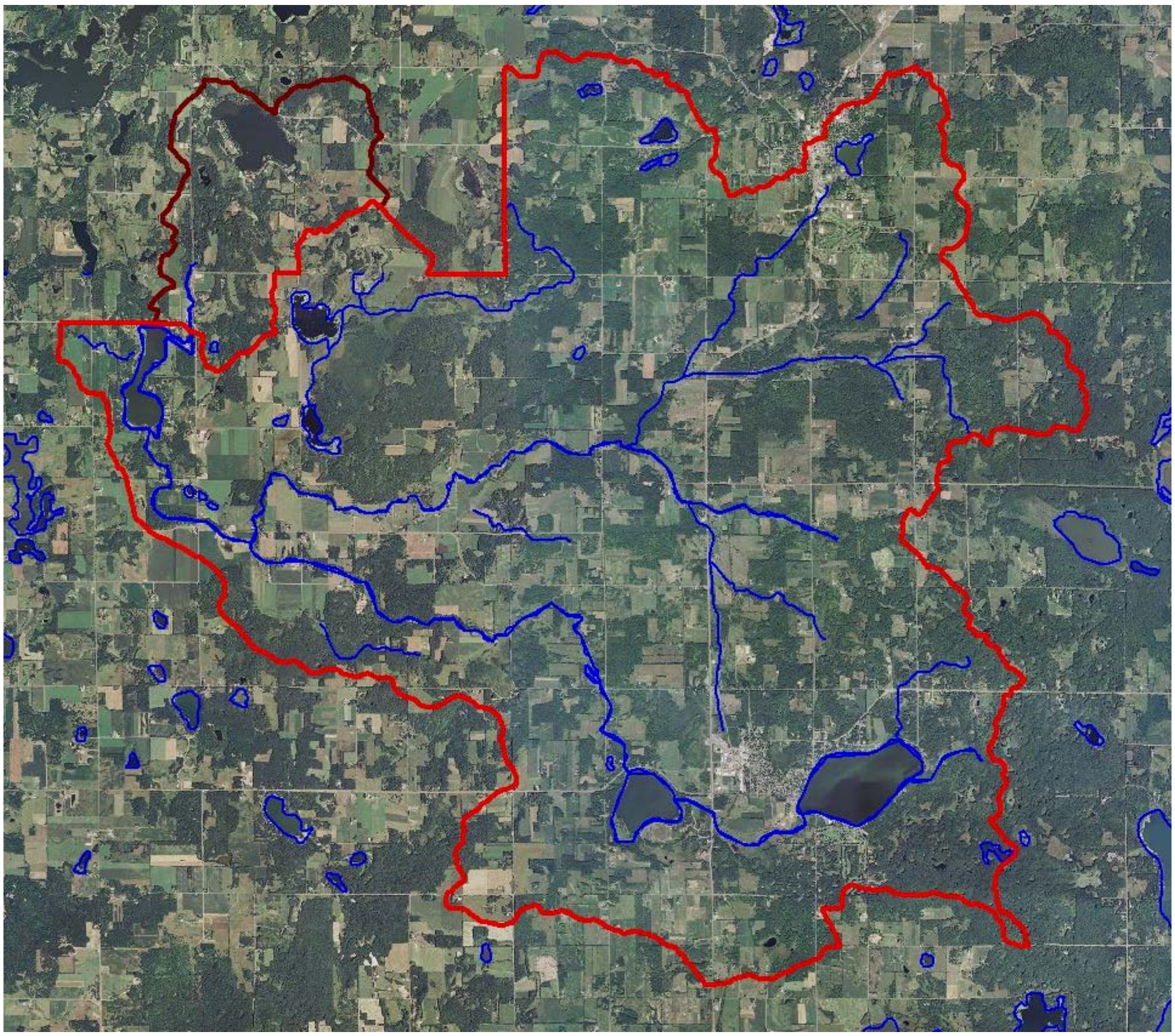
Round and Long Trade Lakes Water Quality and Watershed Assessment Report
LPL-1174-07
LPL-1173-07
December 16, 2008



The Trade River system begins in Polk County near of the Villages of Luck and Frederic, flows west into Long Trade Lake, then into Round Lake (Burnett County) and the rest of the Trade River lakes, eventually returning to Polk County and emptying into the St. Croix River. The watershed of Long Trade Lake encompasses 32,572 acres. The residents on Round Lake perceived a decline in water clarity in 2002 which prompted an evaluation of the chemistry of the lake and upstream influences. The land use within the watershed affects the chemistry and quality of the water in Long Trade Lake and Round

Lake. The Polk County Land and Water Resources Department sampled both lakes as well as 9 sites along the Long Trade River to survey nutrient concentrations throughout the watershed. Flow of the river system was also measured to determine loading of phosphorus at these 9 sites.

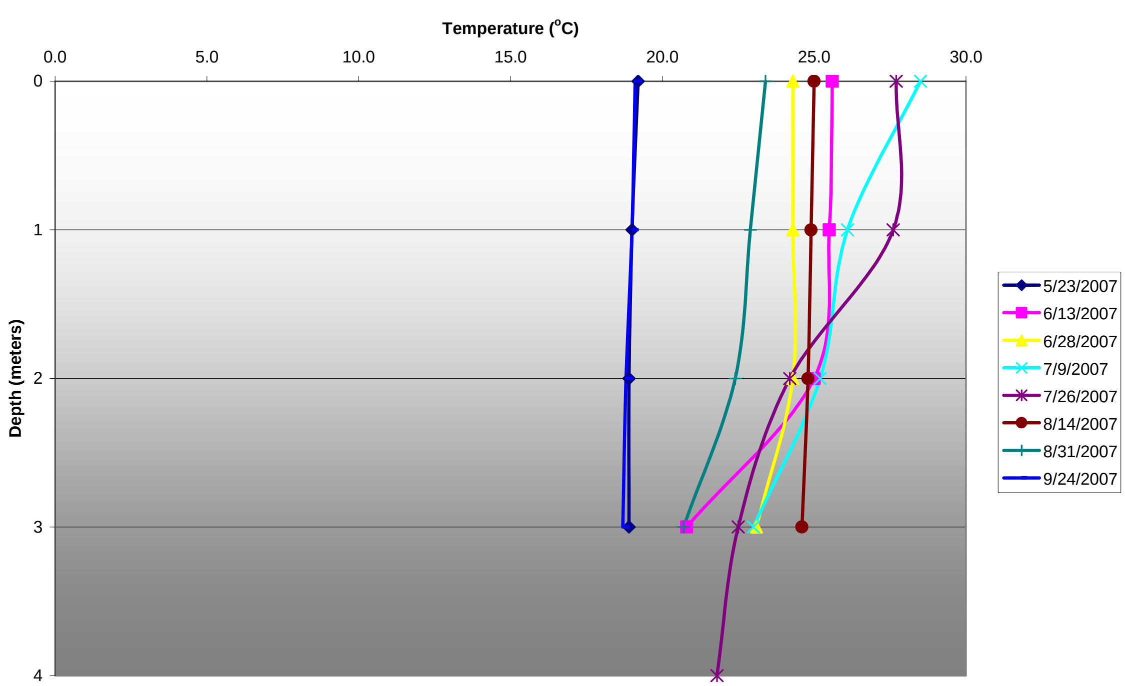
LONG TRADE LAKE LIMNOLOGICAL CHARACTERISTICS

Physical Properties

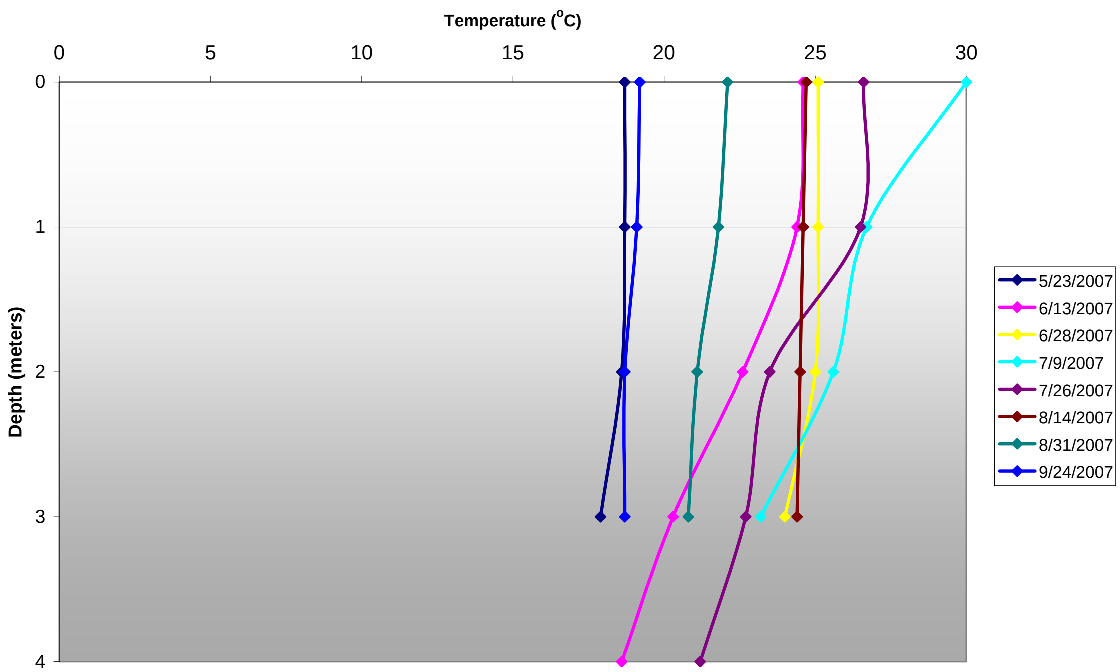
Long Trade Lake is a drainage lake with the river flowing in and out of the lake. Long Trade is also a very shallow (mean depth 8 feet), mixed lake of 153 acres; the temperature of the water column stays uniform throughout the growing season. The upper surface of the lake in the month of July was slightly warmer because of the heating from the sun and atmosphere. The uniform water temperature means the water is mixing and able to circulate throughout the column (because of a lack of density differences). This also means that nutrients that may fall to the bottom of a deeper lake are in constant flux and supply nutrients to the water column.

The TEMPERATURE of Long Trade Lake ranged from 19^{o}C in the spring and fall to a maximum of 30^{o}C in July. The color of the lake may absorb more heat from the sun than clear water.

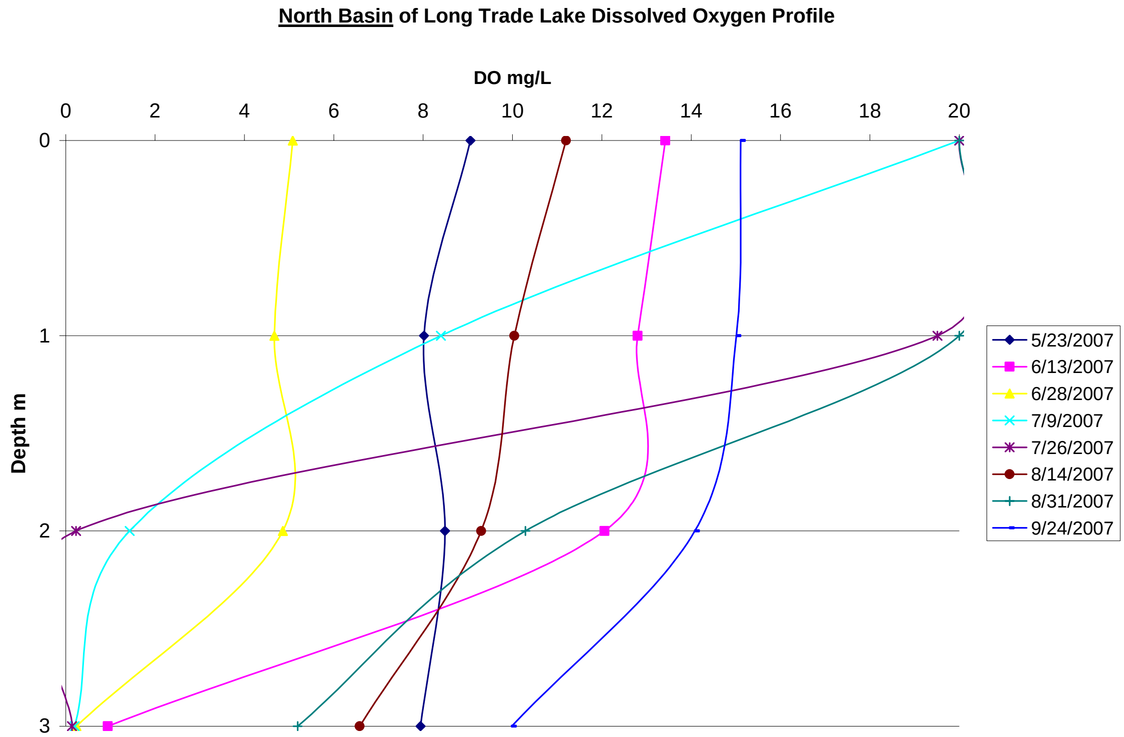
North Basin of Long Trade Lake Temperature Profile

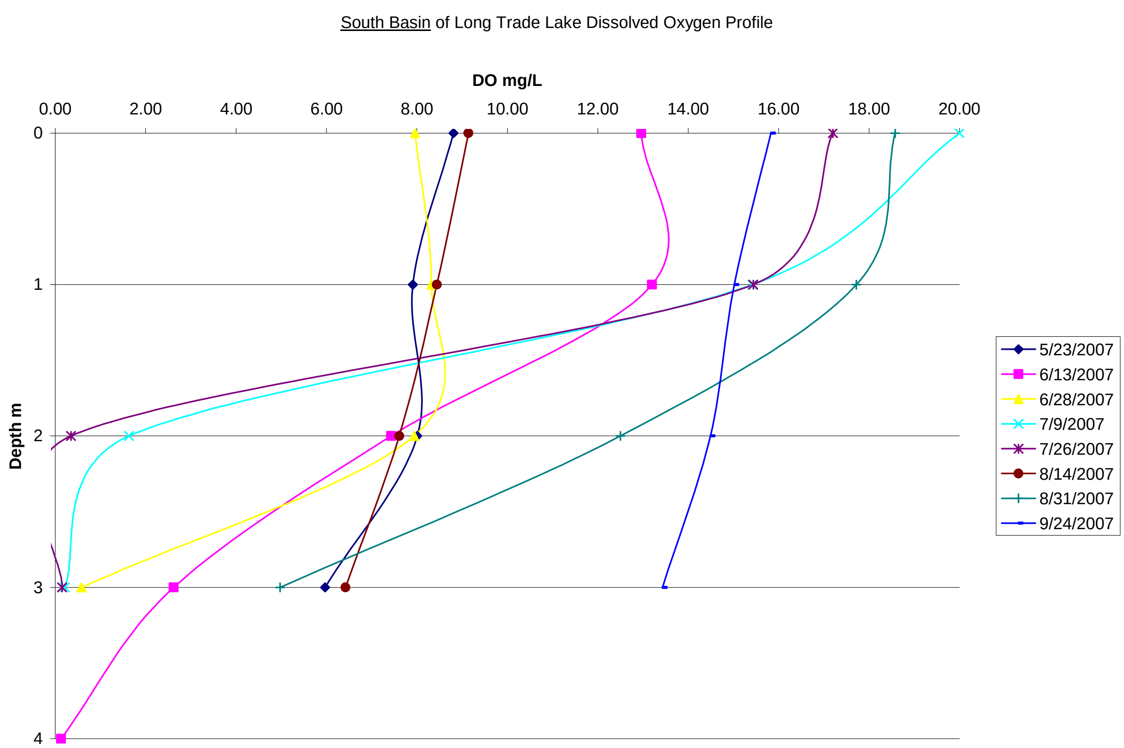


South Basin of Long Trade Lake Temperature Profile

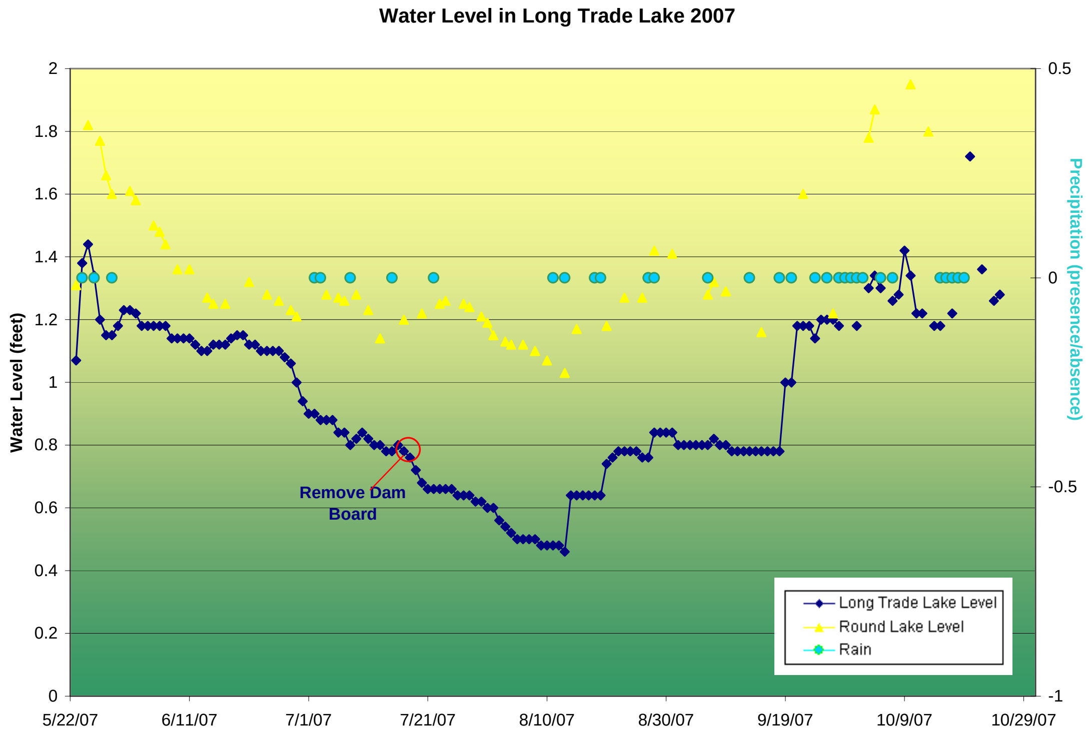


The DISSOLVED OXYGEN concentration in Long Trade Lake varied throughout the season. Dissolved oxygen is important for the biota that lives in the lake. Fish need a minimum of 5 mg/L of dissolved oxygen to survive and grow. Oxygen solubility is a function of the temperature of the water, decreasing with warmer water. (Think of a can of pop, the carbonation fizzes out as the pop warms because the solubility of gas in a warm solution is less.) However, many other factors influence dissolved oxygen concentration -- rates of decomposition of organic matter, byproducts of photosynthesis by plants and algae, night respiration, inputs from the atmosphere, and incoming oxygen concentrations from a flowing river and groundwater. The sum of these effects on Long Trade Lake is graphed below.





Despite cooler water temperatures in the spring and early summer, dissolved oxygen concentrations in Long Trade Lake were highest in mid to late summer when temperatures were higher. This is likely due to algae growth. The higher temperatures increase biological action, and as algae near the surface in the water column convert sunlight and carbon dioxide to carbohydrates, the process gives off oxygen. Meanwhile on the bottom of the lake, increased bacterial processes and decomposition of organic matter consume oxygen and nearly deplete the dissolved oxygen at the bottom. Fish would not be able to survive in Long Trade Lake below 2 meters. The Long Trade River may have kept dissolved oxygen concentrations more constant (around 9 mg/L) in the south basin of the lake with continue inflow of water.

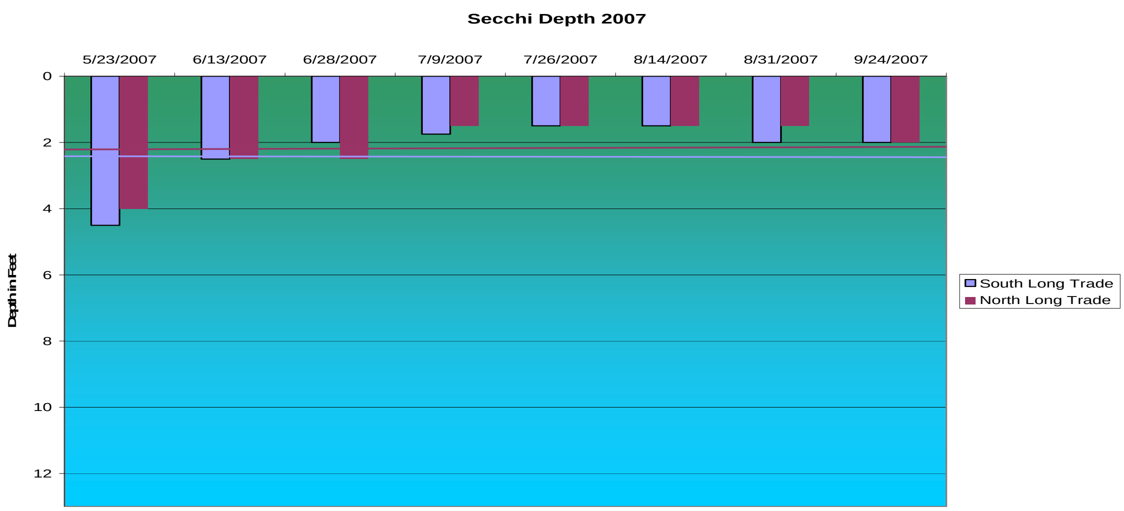


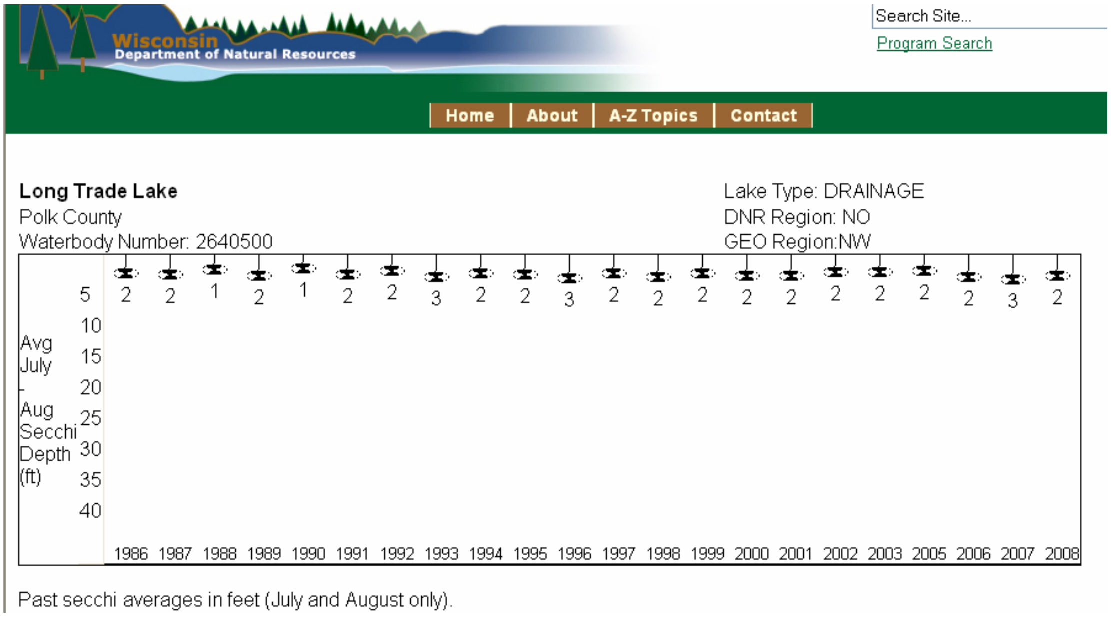
The daily WATER LEVEL of Long Trade Lake was recorded over the summer months at the Atlas General Store. The water level of a lake is an important aspect of lake management. Graphs show how a lake responds to precipitation events and if a lake receives much surface water runoff. Many times water clarity or nutrient concentrations also correspond to rain events as the storm water carries in sediments that pollute the lake. A delay in lake level rise following a precipitation event may mean that groundwater is a more influential component to lake quality.

Because Long Trade Lake is connected to the river system, an immediate rise in lake level is seen following a rain event. Unfortunately, precipitation amounts were not recorded, only the event itself. Another factor affecting lake level is the height of the dam boards at the outlet at Atlas Park. A record log was not kept of the change in board height, but we coincidentally met the technicians at Atlas Park on July18 as they were removing a dam board. For the majority of the season, it is not known if the change in lake level is due to evaporation, rain events, or changes in dam height on Long Trade Lake. Changing water levels can affect the plant community in the lake. This disturbance to the native community may allow Eurasian Water Milfoil to expand (Sheffer, 1998.)

SECCHI DEPTH is a measure of the clarity of the water. The Secchi depth of a lake is affected by minerals *dissolved* in the water column as well as algae and sediment *suspended* in the water. A deeper Secchi depths means more light penetrates the water column allowing aquatic macrophytes to grow. The average Secchi depth for the south basin of Long Trade Lake was 2.2 feet and 2.1 feet for the north basin. This correlates to very poor water clarity.

As reflected by the Secchi depth measurements, the amount of suspended particles in the lake increased during the growing season (May – September). This was most likely the growth of algae due to warmer temperatures, increased hours of daylight, and continuous contributions of nutrients either through runoff, surface water inputs, or internal recycling from the sediments. While this decrease in clarity over the summer months is a normal phenomenon, the amount on Long Trade Lake can be considered nuisance and limit recreation on the lake as well as wildlife value.





Lake Chemistry

WATER SAMPLES from Long Trade Lake were collected five times over the summer of 2007 in both the south and north basin at the deepest location to assess if there was a difference in in-lake processing of nutrients. Phosphorus concentration in lake water is the main nutrient that drives algae blooms. Other indicators of water quality were also tested.

Growing Season Average	SRP (mg/L)	TP (mg/L)	TN (mg/L)	Chloro A (ug/L)	TSS (ppm)	Cl (mg/L)
South Long Trade	0.071	0.164	1.91	80	13.4	10.4
North Long Trade	0.098	0.172	2.12	57	11.8	10.5

The soluble reactive phosphorus is the dissolved portion of phosphorus that is in the water column and biologically available to plants for consumption. Ideally, SRP should be 0.010 mg/L or less in early spring to prevent summer algae blooms. Long Trade Lake averaged 0.071 and 0.098 mg/L SRP in the south and north basin, respectively.

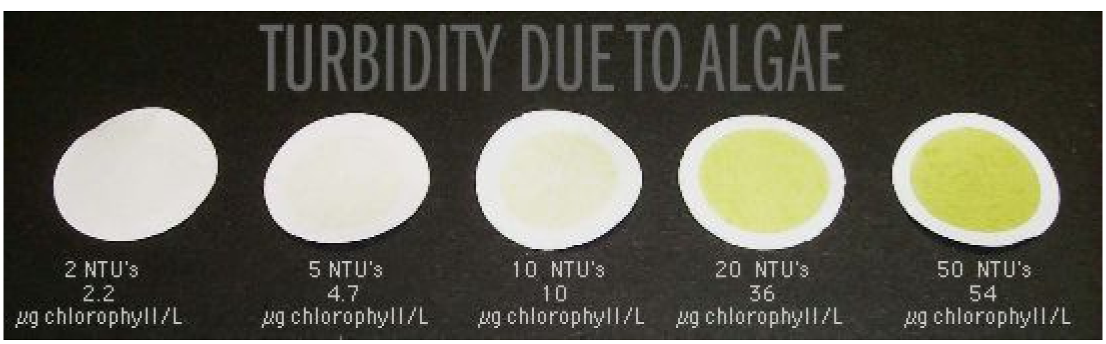
Total phosphorus is a measure of dissolved and particulate phosphorus in organic (plant matter) and inorganic (sediment) matter. Total phosphorus is considered a better indicator of a lake's nutrient status because its levels remain more stable than SRP. The average total phosphorus concentration was 0.164 mg/L and 0.172 mg/L in the south and north basin, respectively. These concentrations provide enough phosphorus to fuel spring algae blooms.

Chlorophyll *a* is a pigment in all plants, including algae, that helps plants photosynthesize. The higher the concentration of chlorophyll *a* theoretically the more algal biomass in the lake. The south basin had 80 ug/L of chlorophyll *a* while the north basin had 57 ug/L. Both of these concentrations indicate Long Trade is very eutrophic. Algal concentrations at these high levels tend to shift in the composition towards a blue-green dominated community rather than green algae or diatom composition, which serve as a better food source for the lake fauna.

Total nitrogen is also important for plant and algae growth. Nitrogen exists in lakes in several forms. All inorganic forms of nitrogen can be used by aquatic plants and algae (nitrate, nitrite, and ammonium), while excessive amounts of ammonium can be harmful to fish and other biota. When nitrogen supplies have run out, the algal community can shift to species that are able to obtain nitrogen from the atmosphere, called nitrogen-fixation.

It appears that nitrate-nitrite is being converted to organic forms of nitrogen (TKN). The incoming nitrate-nitrite concentration is much higher in the tributaries (0.14 – 0.76 mg/L) than found in the lake (0.03 and 0.04 mg/L); the organic nitrogen is higher in the lake than the tributaries (1.84 and 1.99 mg//L in lake versus 0.52 – 0.97 mg/L in the tributaries.) The abundance of nutrients (both nitrogen and phosphorus) is being utilized by plants and algae and converted to organic material.

Total suspended solids are a measure of the particulate matter in a water sample. The greater the amount of total suspended solids (TSS) in the water, the murkier it appears and the higher the measured turbidity. Turbidity refers to how clear the water is. On Long Trade Lake the TSS concentration was 11.8 and 13.4 mg/L, south and north basin respectively. The major source of turbidity in Long Trade Lake is most likely due to phytoplankton. Long exposure to even low levels of turbidity can begin to stress fish.



Taken from Water on the Web www.waterontheweb.org

The differences in nutrients between the north and the south basin of Long Trade Lake may be contributed to two factors. The south end of Long Trade Lake is closer to a wetland complex which may increase biological activity and tie up nutrients. The north basin of Long Trade Lake may be affected by road sediments, which could increase the phosphorus concentration without increasing the biological activity (chlorophyll concentration).

Investigation into the extent of macrophytes may also explain some difference between the distribution of nutrients within the lake as well as additional years of sampling.

Using the data collected, lakes can be categorized into three states – oligotrophic, mesotrophic, and eutrophic (Shaw et al., 2000.) This category is meant to serve as an overall interpretation of the lake's productivity level. Trophic status is commonly measured by Secchi depth (water clarity), total phosphorus, and chlorophyll *a* concentrations (measure of algae). Although many factors influence these relationships, the link between Secchi depth, phosphorus, and chlorophyll *a* is the basis of comparison for the Trophic State Index (TSI) (Lillie and Mason, 1983). Three equations for the TSI were examined for Long Trade Lake:

TSI (P) = 14.42 * Ln [TP] + 4.15 (where TP is in ug/L)
TSI (C) = 30.6 + 9.81 Ln [Chlor-a] (where the chlorophyll *a* is in ug/L)
TSI (S) = 60-14.41 * Ln [Secchi] (where the Secchi depth is in meters)

South Long Trade	Value for Equation	**TSI**
Total Phosphorus	164	**77.7**
Chlorophyll *a*	80	**73.6**
Secchi Depth	0.68	**65.5**

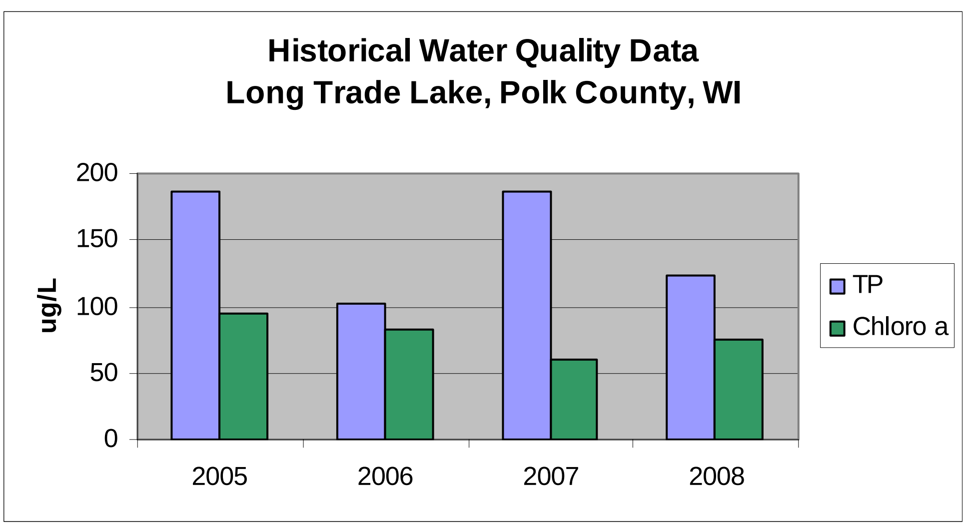
North Long Trade	Value for Equation	**TSI**
Total Phosphorus	172	**78.4**
Chlorophyll *a*	57	**70.3**
Secchi Depth	0.65	**66.2**

TSI	General Description
<30	Oligotrophic; clear water, high dissolved oxygen throughout the year throughout the lake
30-40	Oligotrophic; clear water, possible periods of oxygen depletion in the lower depths of the lake
40-50	Mesotrophic; moderately clear water, increasing change of anoxia near the bottom of the lake in summer, fully acceptable for all recreation/aesthetic uses
50-60	Mildly eutrophic; decreased water clarity, anoxic near the bottom, may have macrophyte problem; warm-water fisheries only.
60-70	Eutrophic; blue-green algae dominance, scums possible, prolific aquatic plant growth. Full body recreation may be decreased
70-80	Hypereutrophic; heavy algal blooms possible throughout the summer, dense algae and macrophytes
>80	Algal scums, summer fish kills, few aquatic plants due to algal shading, rough fish dominate.

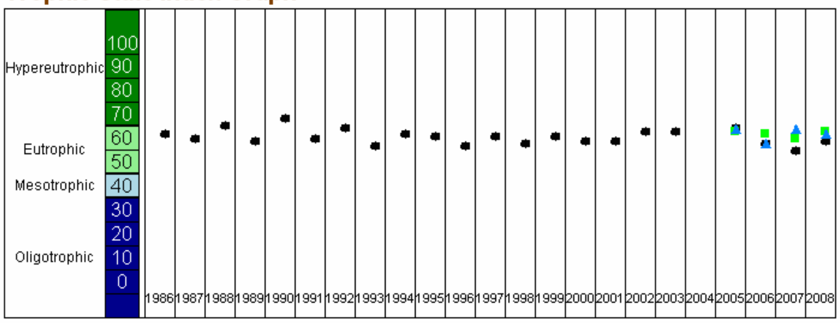
Long Trade TSI Ratings

Although the concentrations and TSI numbers between the north and south basins of Long Trade Lake differ, the range and relative values of the TSI are the same. The trophic state index for total phosphorus is higher than the TSI for chlorophyll *a* which is higher than the TSI for Secchi depth. This indicates that the lake is algae dominated (rather than macrophyte), but the algal biomass is limited by zooplankton grazing or possibly other factors.

Water chemistry data has been collected on Long Trade Lake since 2005 by volunteers. Seasonal total phosphorus has ranged from 102 – 187 ug/L, and chlorophyll *a* has ranged from 60 – 94 ug/L. Secchi depth information has been collected since 1986 and has measured between 1 and 3 feet.



Trophic State Index Graph

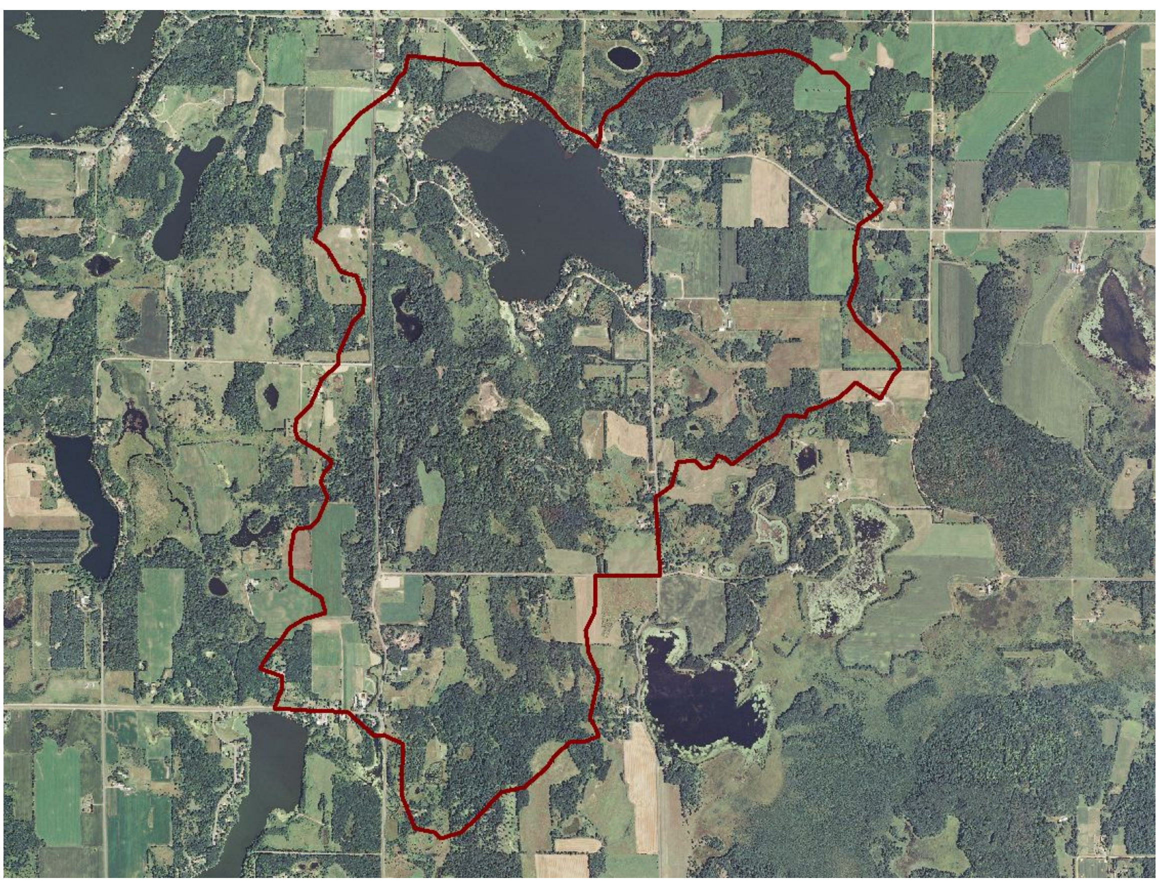


Monitoring Station: Long Trade Lake - Deep Hole-South Basin, Polk County
Past Summer (July-August) Trophic State Index (TSI) averages.

• = Secchi ■ = Chlorophyll ▲ = Total Phosphorus

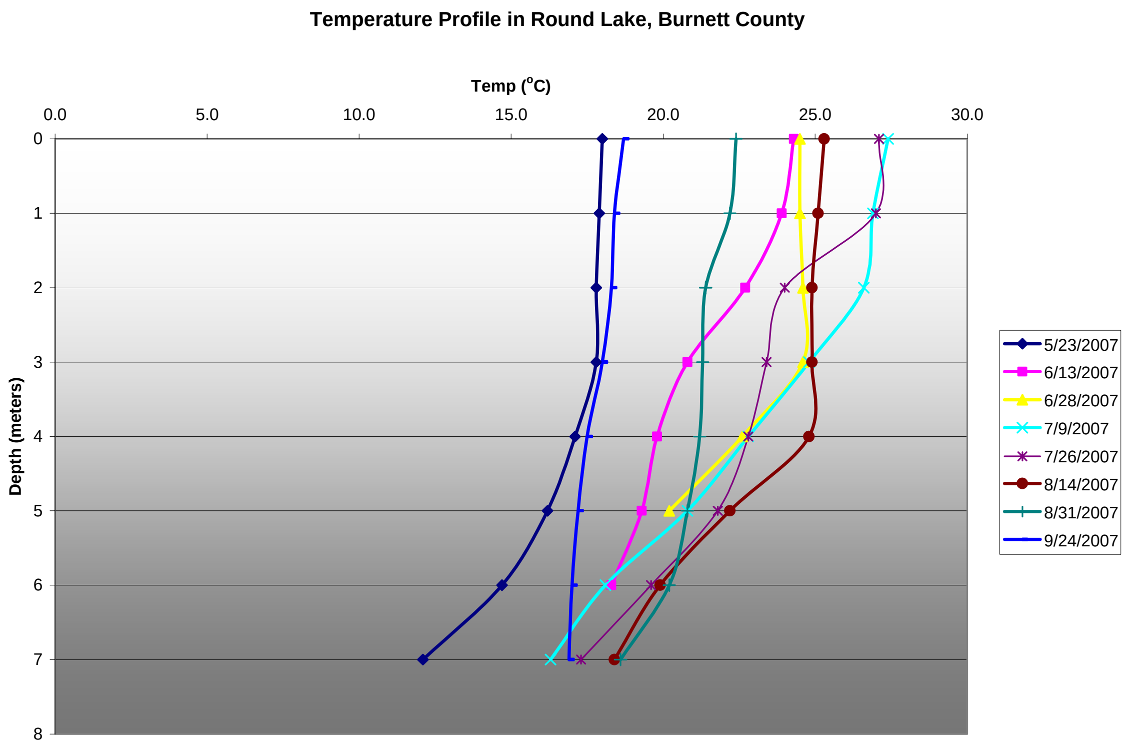
TSI(Chl) = TSI(TP) = TSI(Sec)	It is likely that algae dominate light attenuation.
TSI(Chl) > TSI(Sec)	Large particulates, such as Aphanizomenon flakes dominate
TSI(TP) = TSI(Sec) > TSI(Chl)	Non-algal particulate or color dominate light attenuation
TSI(Sec) = TSI(Chl) >= TSI(TP)	The algae biomass in your lake is limited by phosphorus
TSI(TP) > TSI(Chl) = TSI(Sec)	Zooplankton grazing, nitrogen, or some factor other than phosphorus is limiting algae biomass

Round Lake Physical Properties and Water Chemistry

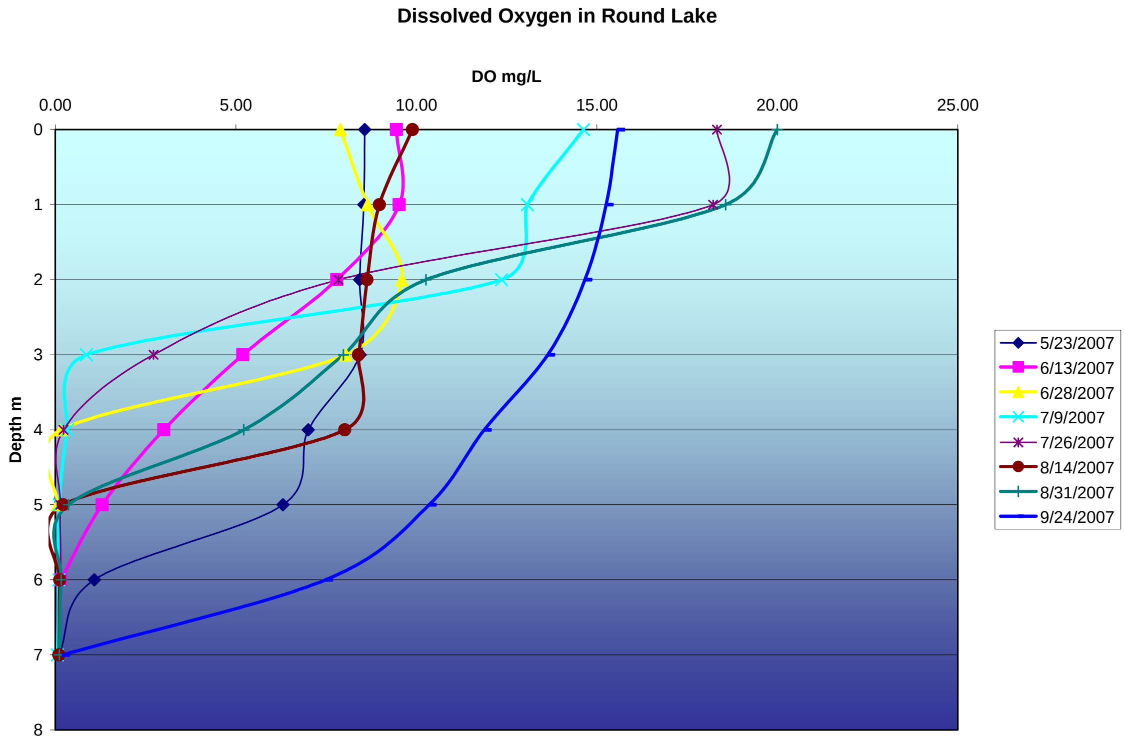


Round Lake is approximately 26 feet deep. The temperature profiles indicate that Round Lake does stratify, but does not develop a strong gradient. The samples and profiles were taken at the deep hole in the eastern bay, the most likely place for stratification to occur. Either the shallow nature of the greater part of the lake (mean depth is 15 feet), the flow of the river through the lake, or recreational impact limit the degree of stratification. Again, this may have an effect on nutrient cycling in the water column.

The maximum temperature of Round Lake was 27.4 degrees Celsius which occurred on July 9, 2007. The minimum temperature was 18.0 degrees Celsius (12.1 ^{o}C on the bottom) measured on May 23, 2007. The maximum temperature difference measured on any one sampling date was 11.1 degrees of July 9, 2007. Dissolved oxygen profiles since 2005 show Round Lake to be a dimictic lake with two seasonal turnovers.

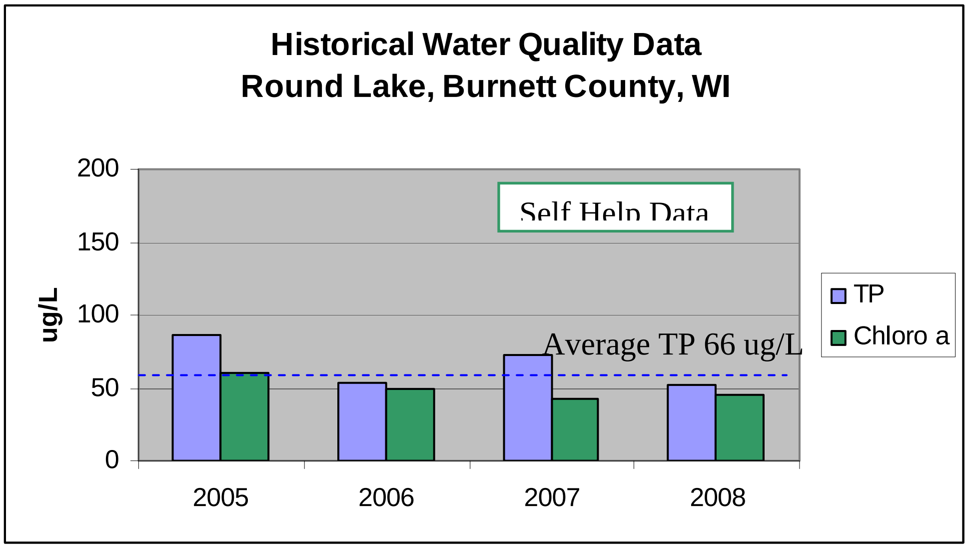


Round Lake is well oxygenated throughout the top three meters of water (see graphic below). Below three meters, dissolved oxygen concentration begins to decline throughout the bottom depths of the lake. During the middle of the summer, algal blooms photosynthesize causing an increase in dissolved oxygen. Typically Round Lake is without oxygen below five meters.



The comments from the volunteer data base give a relative value to the perception of water quality on Round Lake. Citizens are asked to rank the water from 1 to 5. A value of 1 indicates the water is beautiful and could not be nicer. A value of 5 indicates enjoyment is substantially impaired due to algae. One must take into consideration the natural summer succession of lake biota and chemistry, but here is a summary of data reported from volunteers.

Sampling Year	Perception	Comments
1986	2 → 5	
1987	4	
1988	2 – 3	Breezy, water level up
1989	2 → 3	7200# carp taken, normal water level
1990	2 → 4	Early crappie kill, mid summer bloom
1991	2 – 3	
1993	2 – 3	Lake level dropping, monitoring ends by June
1999	2 – 3	Limited monitoring
2000		Limited monitoring
2001		Limited monitoring
2002		Limited monitoring
2003		Lake murky as summer progresses
2004	3 → 4	
2005	2 → 4	*DO profile and chemical data available*
2006	2 → 4	*DO profile and chemical data available*
2007	3	*DO profile and chemical data available*
2008	1 - 3	*DO profile and chemical data available*

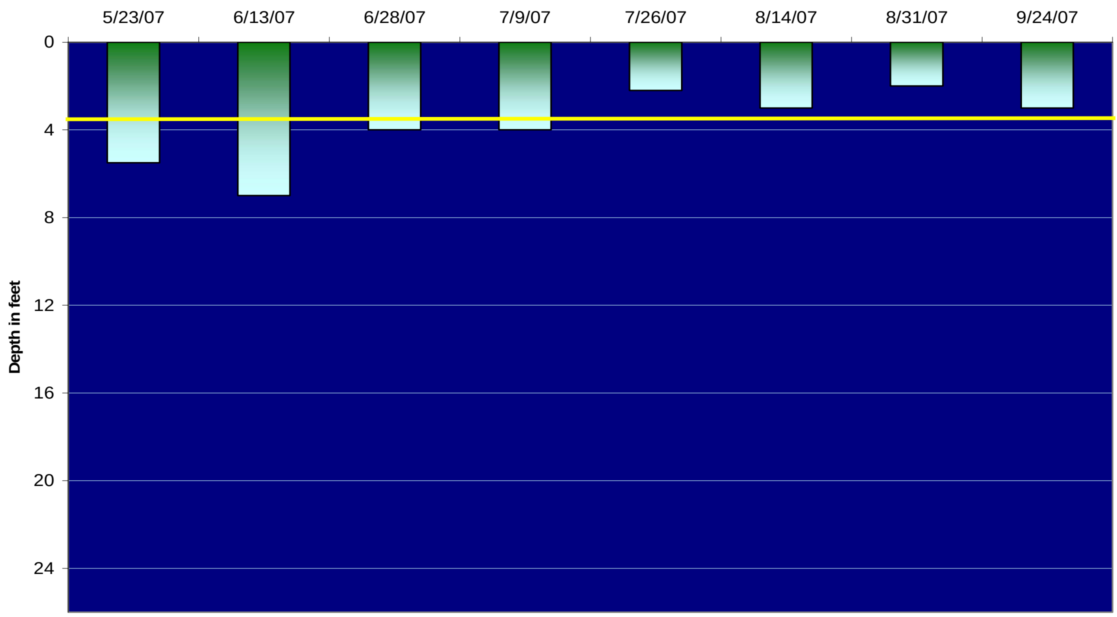


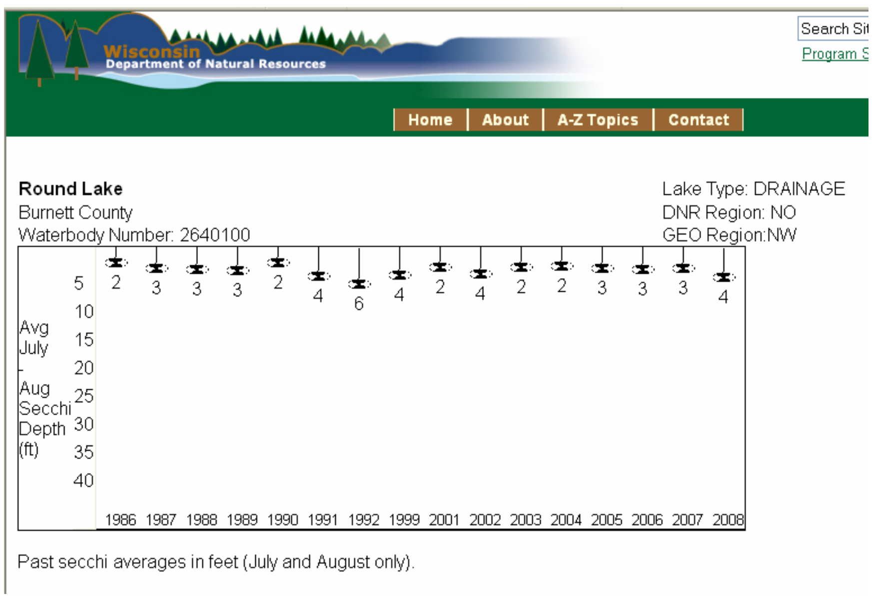
Round Lake had an average total phosphorus concentration of 0.054 mg/L. While this concentration of phosphorus is less than that of Long Trade Lake, there is still enough phosphorus to cause nuisance algal blooms throughout the summer. The average Secchi depth, measuring water clarity, of Round Lake was 3.8 feet. The chlorophyll *a* concentration was 38 ug/L.

All units in **mg/L** unless indicated	**SRP**	**TP**	**TKN**	**NO_{2+3}**	**NH_4**	**Chloro a (ug/L)**	**TSS**	**Cl**
Average	0.025	0.054	1.16	0.10	0.11	38	5	9.4

Nitrogen also appears to be utilized by plants and algae in Round Lake, with inorganic forms of nitrogen having very low concentrations and the organic form (TKN) averaging 1.16 mg/L. The total suspended solids (TSS) in Round Lake averaged 5 mg/L (compared to 11.8 and 13.4 mg/L on Long Trade Lake) which indicates there is less suspended algae and sediment material in the water column.

Round Lake Secchi Depth 2007

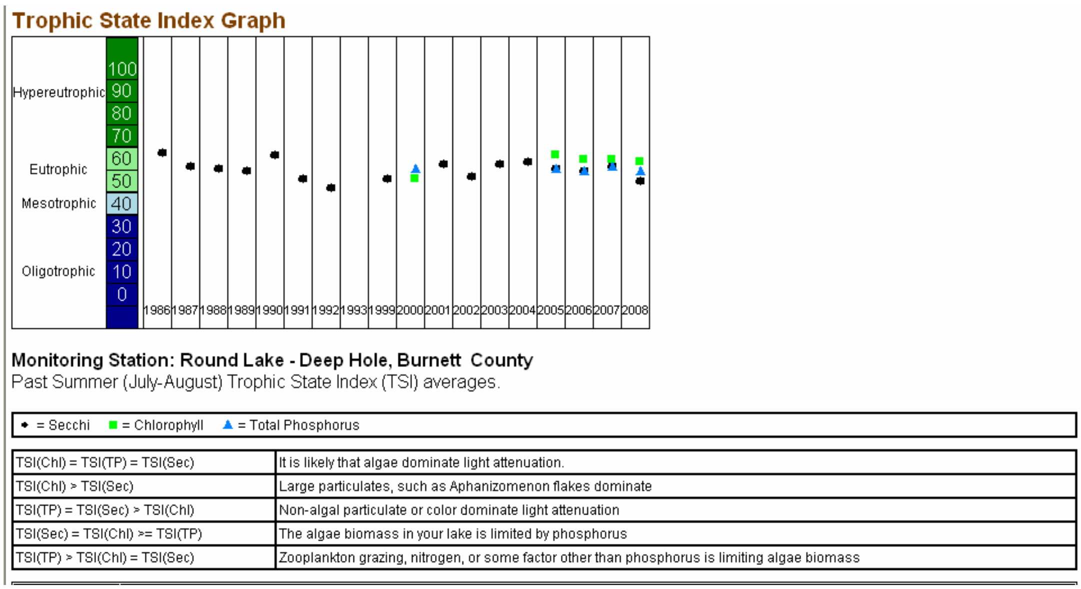




Using the nutrient concentrations and water clarity measurements in the Trophic State Index as before, Round Lake fares as a mildly eutrophic lake. The relationship between TSI variables indicate that non-algal particulates or color dominate light attenuation. White, milky lake water and marl was observed on the macrophytes in Round Lake, which is a precipitation of calcium carbonate. The particles affecting water clarity are most likely calcium in Round Lake, but could also be sediments or tannins (derived from organic matter staining the water). The groundwater data, discussed in a later section, also supports this conclusion. The three groundwater sites sampled closest to Round Lake had total hardness concentrations significantly higher than those samples in the rest of the Trade River watershed. (Total hardness is a measure of calcium, magnesium, sulfates, sodium, and other negatively charged metals.) The geology of the near-watershed for Round Lake contains a different composition (either deeper in the ground or different materials) that can act as a sink for phosphorus in the lake that lowers the phosphorus concentration (compared to Long Trade Lake) and keeps the algae concentration lower.   Oxidized metals can cause co-precipitation of phosphorus.

Round Lake	**Value for Equation**	**TSI**
Total Phosphorus	54	**61.7**
Chlorophyll *a*	38	**41.4**
Secchi Depth	1.17	**57.7**

(See Trophic Chart on Page 11 for description.)

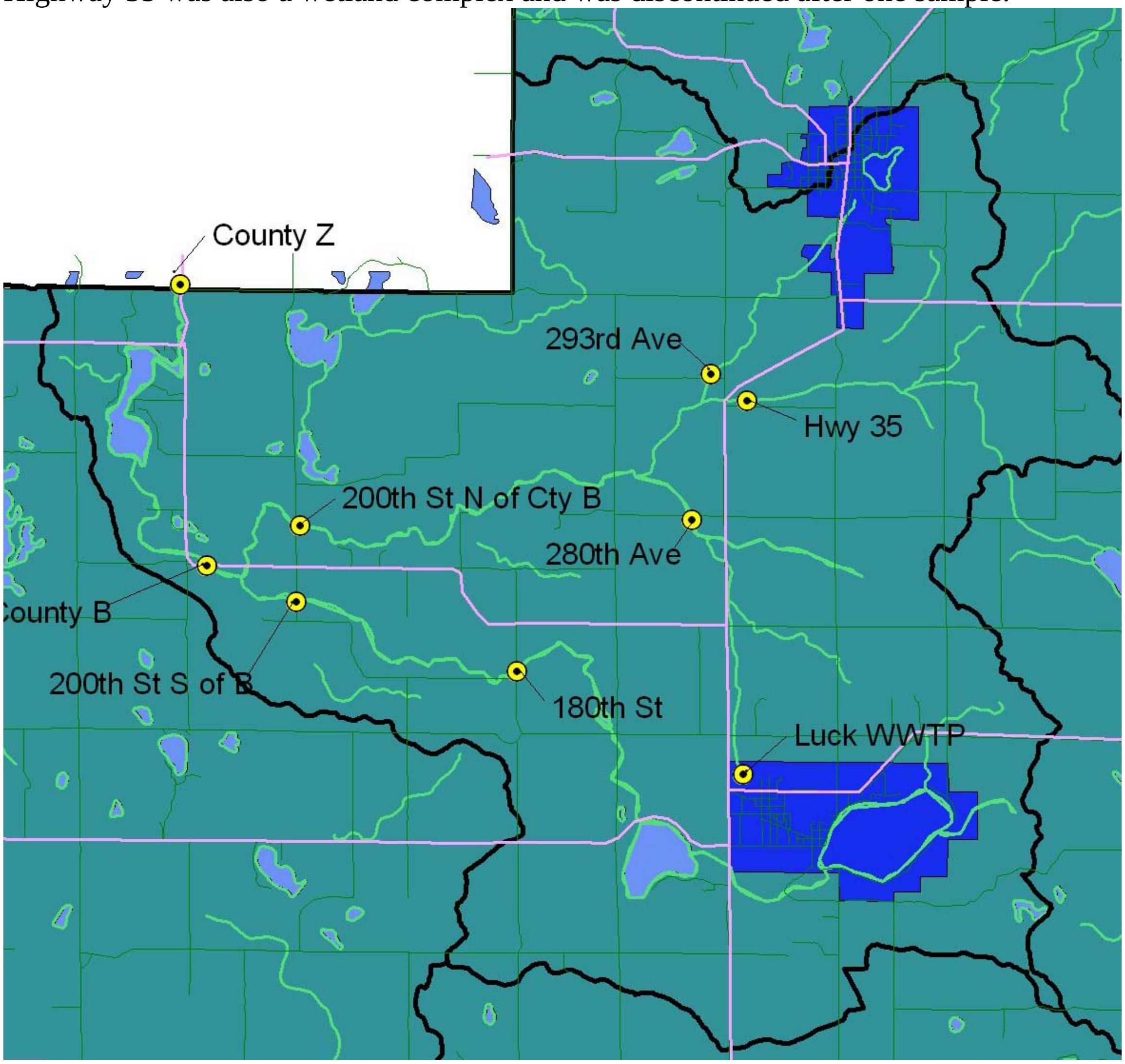


Long Trade River and Its Tributaries

The headwaters of the Long Trade River originate near Luck and Frederic. Big Butternut Lake is connected to Little Butternut Lake via Butternut Creek, which joins the Trade River near County Highway B and Long Trade Lake. Several branches of the Trade River begin east of Highway 35 and flow west toward Long Trade Lake. North Star Creek receives discharge from the Luck Wastewater Treatment Plant (WWTP) and flows north meeting the South Branch of the Trade River near Highway 35. Brown Creek begins near Frederic, downstream of its WWTP seepage cells, and flows through a wetland complex before entering the main branch of the Trade River.

The Trade River tributaries were monitored to develop a phosphorus gradient and calculate loading to the lakes. Once a hot spot is identified, it can be investigated to identify if land use or geology is a contributor and possibly managed.

The tributaries were systematically monitored to see the influence at inflow of the lakes, at the outflow of the lakes, and on the major branches of the Trade River. The sites were accessible from the roadway. A grab sample was collected once a month if the tributary was flowing, and a Marsh McBirney Flo-Mate™ velocity flowmeter was used to calculate the flow of the stream twice a month. Two of the sites were dry late in the summer (200th Street South of County Road B and 180th Street) and one site had water in a wetland complex, but did not flow when we visited the site (293rd Avenue). The site at Highway 35 was also a wetland complex and was discontinued after one sample.



Below are the results of the summer 2007 sampling. The total phosphorus concentration of a water sample was determined at the Water and Environmental Analysis Laboratory. This concentration is specific to a date and location. The phosphorus concentration was multiplied by the volume of water that moves at that location (discharge in cubic feet per second). This theoretically tells us how much phosphorus was entering the lakes. The average instantaneous load of phosphorus is calculated by multiplying the *average* TP concentration by the *average* season discharge. Note that the results are given in pounds of phosphorus delivered by the river system per year. Also note that the Luck Waste

Water Treatment Plan only discharges waste water 6 months of the year, so their calculated annual TP load was divided by two.

Site	Average TP Concentration (ug/L)	Average Discharge (cfs)	Average Instantaneous Load (lb of TP/year)	Number of Samples
Round Outlet	50	77.7	7601	5
County Z	130	72.9	18,558	5
200th St. N of Cty B	155	18.4	5587	4
County B	166	16.2	5275	5
Hwy 35	140	15.1	4159	1
200th St. S of Cty B	86	10.3	1739	1
Spirit Creek	89	10.2	1780	5
280th Ave	271	4.6	2443	5
180th St	126	2.5	626	3
Luck WWTP (2002 data)	4443	0.34 mgd	2295 (1043 kg/yr)	
Luck WWTP (2007 data)	3800 (into wetland discharge)	0.154 mgd	563 (256 kg/yr)	4
293rd Ave	1041	0	0	2

The above table is arranged by descending order of discharge with the exception of Luck Wastewater Treatment Plant data. The Luck WWTP data was not collected by LWRD, but was submitted to the DNR and shared for this report.

The smaller discharge streams (those with lower water flow) are lower in the table, but further up in the landscape closer to the headwaters. We would expect to see these headwater streams to have low phosphorus concentrations and loads. Phosphorus tends to bind with solids and move as a solid (sediment and organic material) rather than as dissolved in the water, so upstream water that has less interaction with the watershed tends to be cleaner.

The lowest phosphorus concentration found at any site in the watershed was on June 13, 2007 at the 200th Street site south of County B. The TP concentration was 0.086 mg/L. The highest TP concentration was 1.119 mg/L found at 293rd Avenue on July 9, 2007. However this site was not discharging to Brown Creek at the time.

A loading calculation shows the total amount of phosphorus that flows downstream from a site, taking into account both how much water passes through a site and the phosphorus concentration. Headwater sites had phosphorus loads ranging from 626 to 4159 lb TP/year. Butternut Creek headwaters had a loading of 626 lb/yr. The next site along Butternut Creek, 200th Street south of County B, had a loading of 1739 lb/yr, which entered the main branch of the Trade River.

North Star Creek receives discharge from the Luck WWTP; the first measured loading was 2443 lb/yr at 280th Avenue. The creek meets with Brown Creek, and the Trade River had a loading of 5587 lb/yr at 200th Street north of County B. The two branches come together (Butternut Creek and the Trade River Branch) at County B site and have an average loading of 5275 lb/yr of phosphorus, which enters Long Trade Lake. Downstream of Long Trade Lake, the phosphorus load was calculated to be 18,558 lb/yr at County Z, which enters Round Lake. This phosphorus seems to be retained in Round Lake and the phosphorus loading leaving Round Lake was 7601 lb/yr.

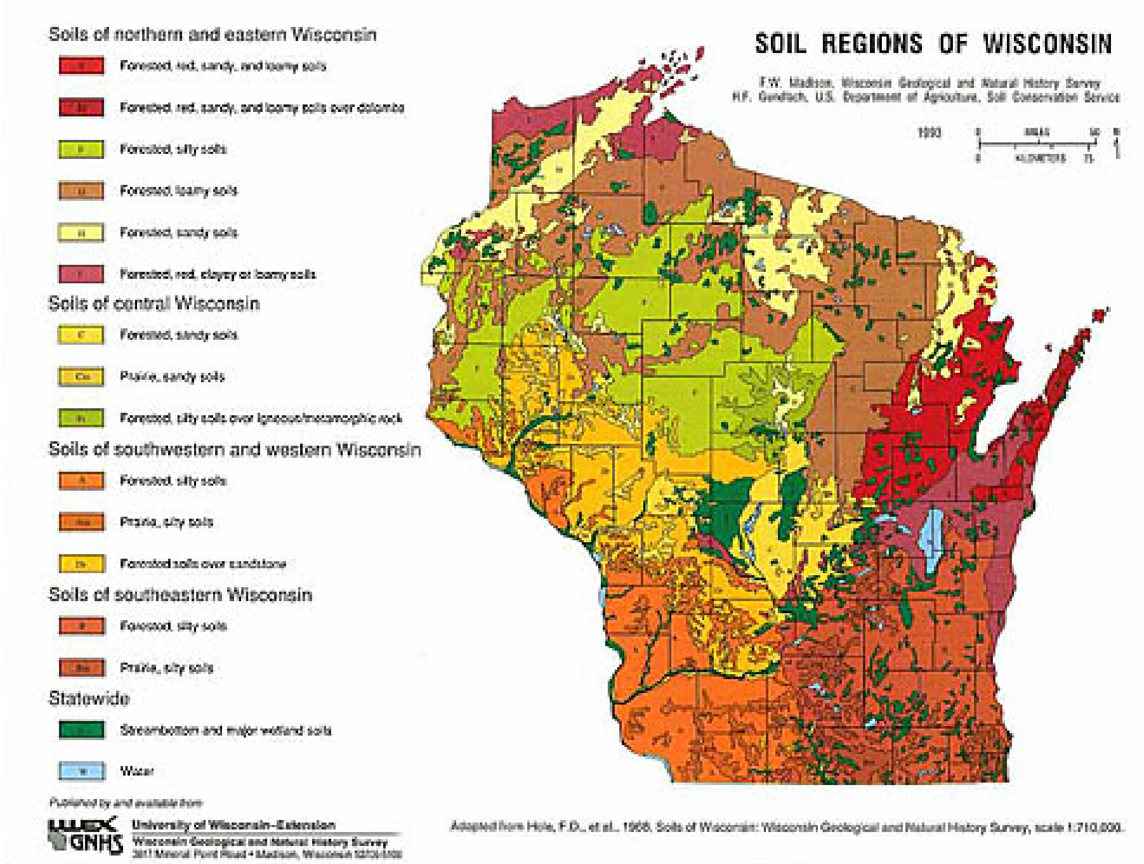
The sample collected at County Road Z had both a high phosphorus concentration and phosphorus loading. The loading into Round Lake from this site is extremely high. Investigation into this location should be conducted to see if there is a specific cause for the elevated phosphorus (manure pit, erosion gullies formed, or other land practices.) If there is not a specific source of phosphorus, further investigation should be conducted to see if Long Trade Lake and the land up to County Z are adding 13,000 pounds of phosphorus to the river system.

280th Avenue also seems to have high loading, but is filtered well throughout the river corridor reducing the phosphorus *concentration* downstream. It is hypothesized that although Luck WWTP does not discharge all year, the build up and release of nutrients and chemicals in the water is slowly released downstream throughout the year. The basis of this theory is that chloride is elevated at 280th Avenue in all samples, not just samples following the release of waste water. Background concentrations of chloride are typically under 2 mg/L; the 280th Avenue site had a chloride concentration range of 19.8 - 38.6 mg/L.

The 293rd Avenue site on Brown Creek also exhibited high chloride and phosphorus concentrations, indicating human influences on the water quality. The Frederic Waste Water Treatment Plant is located near the headwaters of Brown Creek. The Frederic plant uses 3 seepage cells and discharges to groundwater. However, the cells are 20 feet deep, located in sand which drains quickly, and the site is approximately 20 feet from bedrock. The waste water may seep through the sand until it reaches the bedrock, and then flow along the top of the bedrock to the nearest surface water site. According to the waste water plant operator, Frederic has not discharged effluent to surface water since 1980. The plant did collect total phosphorus data in 2006. The effluent was sampled before it reached the seepage cells; they do not have discharge P data, so the information is higher than what would be sampled at discharge. The 2006 average TP in the effluent from Frederic was 5.2 mg/L.

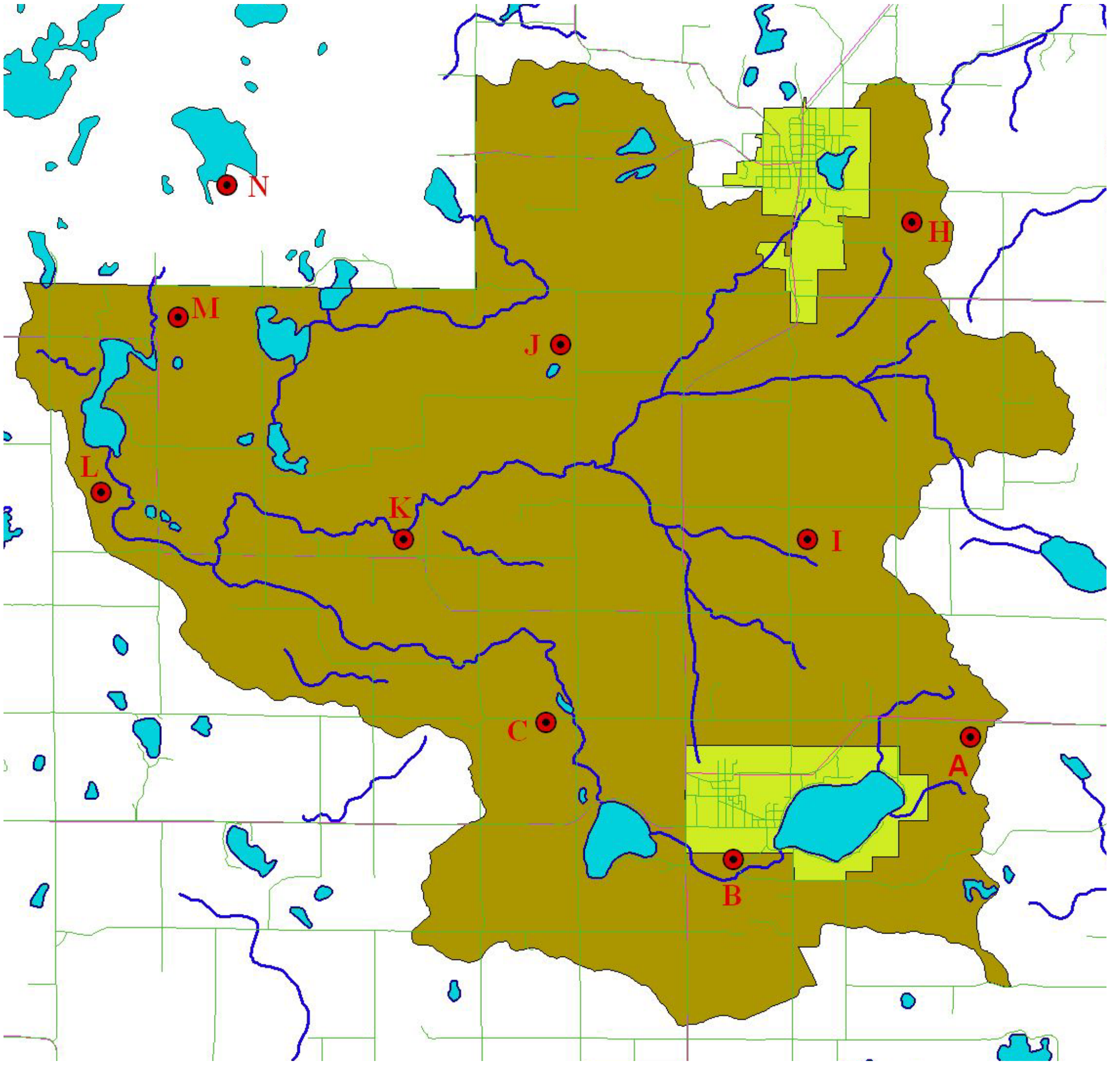
The subwatershed on Brown Creek includes a lot of agriculture, which may contribute nutrients and chloride to the creek. A test for caffeine may indicate whether effluent or agriculture is the main culprit. A review of nutrient management plans for the farms in the subwatershed would also be prudent for the protection of Brown Creek and the Trade River.

The Groundwater of Long Trade River Watershed in Upper Polk County



The chemical composition of groundwater is influenced by glacial deposits, bedrock, anything applied to the land surface that permeates the soil, and the amount of time that water is in contact with these materials. The Polk, St. Croix, and Barron County area in northwestern Wisconsin was identified by Lillie and Mason (1983) as encompassing a disproportionately high percentage (44%) of the State's phosphorus-enriched lakes. Muldoon et al (1990) indicated portions of Polk County have soils that are naturally high in phosphorus. The eutrophic condition of headwater lakes prompted an assessment of the groundwater quality throughout the watershed and entering Long Trade and Round Lakes.

Ten groundwater samples were collected in August 2007 in the Trade River upper watershed (upstream of Round Lake) to classify the water quality characteristics of the watershed, determine if there were any trends or threats to groundwater quality, and establish baseline data for future management. Samples were obtained from constructed homeowner wells under 100 feet deep in strategic locations. This shallow aquifer will be the groundwater that is in closest connection with the lake. Samples were sent to the Water and Environmental Analysis Lab (WEAL) at UWSP and tested for 7 parameters.



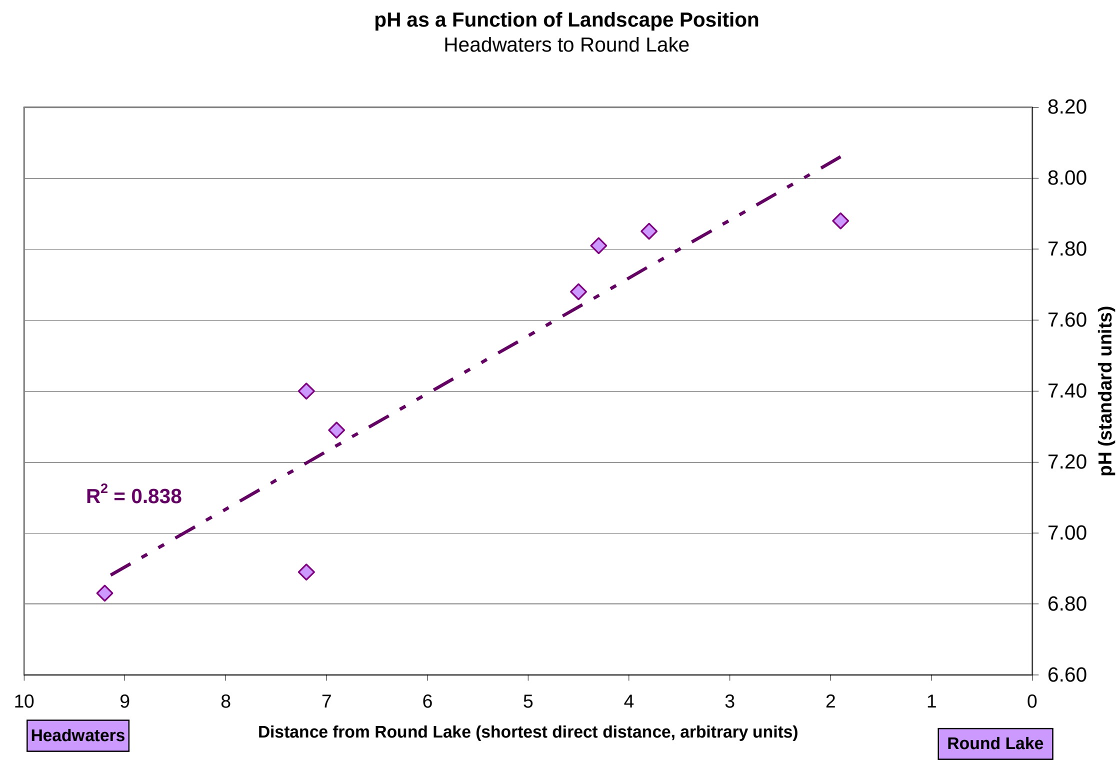
Location of Groundwater Sampling Sites (A-C and H-N)

Site A had a water treatment system in place (water softener) which altered the pH, increased the conductivity, and decreased the hardness and alkalinity. Another well, Site N, was 106 feet deep, but a sample was collected because of its location near Round Lake. The phosphorus data collected at these sites was useful, but the other characteristics are not representative of the shallow aquifer. These sites are excluded from many analyses.

The source of drinking water in Polk and Burnett County is groundwater. Overall, there were no water quality problems found in the groundwater samples collected. Nitrate concentrations ranged from less than 0.1 mg/L to 8.2 mg/L. Nitrate concentrations above 2 mg/L represent human influence on groundwater. However, the EPA drinking water standard is 10 mg/L. All samples had nitrate concentrations within safe drinking water standards.

pH values in the groundwater ranged from 6.83 (slightly acidic) at the headwaters to 8.05 (slightly basic) in the tail waters. The pH is affected by the amount of contact time the water has had with bedrock and ground materials. A longer residence time in the ground allows more materials to be dissolved in the water and be transported. A shorter residence time allows gases to exist in the ground which tend to be acidic. These parameters are all a reflection of landscape position and travel time of the groundwater. Since water enters the ground in the headwaters, fewer materials are dissolved early in the landscape.

The following figure graphs the pH values for each sample against its distance from Round Lake. The shortest distance between the site and Round Lake was measured, not the actual path taken by Trade River. The landscape position explains 84% of the pH variability in the samples.

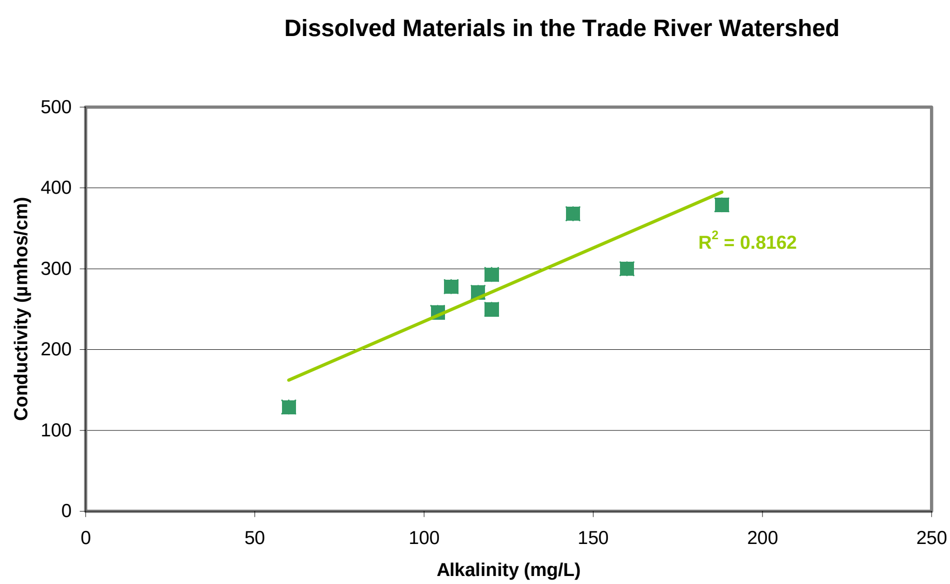


Alkalinity follows the same increasing trend as groundwater moves out into the landscape. Alkalinity increases further out into the watershed, indicating bedrock and glacial materials are dissolving with the groundwater. Alkalinity is a measure of water's ability to neutralize acids, and is therefore related to pH. It results primarily from dissolving limestone or dolomite minerals in the aquifer. Alkalinity and total hardness are usually nearly equal in concentration (when they are both reported as calcium carbonate in mg/L $CaCO_3$) because they form from the same minerals. The alkalinity in the watershed ranged from 60 – 188 mg/L, which generally means the watershed (and lakes in the watershed) is not sensitive to acid rain.

Water is a good solvent and picks up impurities easily. Pure water -- tasteless, colorless, and odorless -- is often called the universal solvent. When water is combined with carbon dioxide, it forms very weak carbonic acid, an even better solvent. As water moves through soil and rock, it dissolves very small amounts of minerals and holds them in solution.

Calcium and magnesium are two common minerals dissolved and give water its "hardness." Total hardness is a measure of calcium, magnesium, sulfates, sodium, and other negatively charged metals in water. As the concentration rises above 120 mg/L $CaCO_3$, the water is said to be "hard." The increase in hardness is affected by the amount of time groundwater is in contact with the soil and rock (distance from the original source), the depth (less oxygen creates more carbonic acid which dissolves more calcium and magnesium), as well as any abrupt change in the geology that the water flows through. This increase in total hardness along the Trade River watershed is visible as the site moves down gradient (see the chart on Page 26). The total hardness of the samples range from soft water at Site B, to very hard water found at Sites L and M. Most of the sites sampled in the watershed were classified as having hard water.

Conductivity is a measure of the ability of water to conduct an electrical current. It is related to the amount of dissolved substances (or ions) in water, but it does not give an indication of which minerals are present. Conductivity (measured in μmhos/cm) is about twice the hardness in most uncontaminated waters in Wisconsin. If it is much greater than two times the hardness, it may indicate the presence of other ions such as sodium, chloride, nitrate, or sulfate, which may be human-influenced or naturally occurring. Changes in conductivity over time may indicate changing water quality. The water samples collected from the Trade River watershed ranged from 129-379 μmhos/cm in conductivity. Alkalinity explains 82% of the variability in conductivity in the samples.



The other test constituents analyzed on the groundwater samples were soluble reactive phosphorus (SRP) and chloride. Chloride does not occur naturally in the environment above concentrations of 2 mg/L (Shaw 2000). Chloride will not affect water taste until it reaches 250 mg/L, but its presence indicates anthropogenic manipulation of the environment. Chloride found above this level is due to human influences such as road salts, fertilizers, pesticides, septic systems, or other salt additives. Chloride is not utilized in biological activity and can kill beneficial diatoms and microscopic organisms in surface water.

A few sites showed elevated concentrations of chloride, but not at any cause for concern. The occurrence of chloride was also not correlated with any specific region in the watershed, but seems most likely to occur in wells of depths between 46-65 feet. Being that the watershed of the Trade River is largely agriculture, land use should not be ruled out as a potential impact. Chloride has a strong correlation with nitrite + nitrate concentration (R^2 = 69%).

Site	NO_2+ NO_3(N)	pH	Cond umol/cm	Alkalinity as $CaCO_3$	Total Hard as $CaCO_3$	Cl	SRP	Well Depth feet
units in mg/L unless specified								
A*	<0.1	8.07	502	240	<4	18.7	0.120	70
B	1.2	6.83	129	60	56	1.2	0.118	22
C	2.2	7.29	271	116	128	5.4	0.087	29
H	3.1	6.89	246	104	124	10.2	0.039	46
I	3.0	7.40	278	108	136	11.4	0.077	58
J	2.8	7.81	293	120	140	14.3	0.059	
K	2.1	7.68	250	120	140	3.6	0.060	
L	8.2	7.85	368	144	200	17.3	0.023	65
M	2.1	7.88	379	188	200	6.4	0.059	65
N	<0.1	8.05	300	160	156	2.0	0.148	106

* THIS SITE HAD A WATER SOFTNER.

SRP is the soluble form of phosphorus that is biological available to plants and algae. Because this study was focused on the quality of water that reaches the lake through the ground, we were interested in SRP, not the total phosphorus in groundwater. Additions of phosphorus to lakes can lead to increased biological productivity to the point of pollution. Phosphorus as an element is covalent and readily binds to other elements. Phosphorus is usually found connected to soil particles, calcium, magnesium, aluminum, iron, or organic matter. It tends to be found as a solid and only low concentrations of dissolved phosphorus are normally found in Wisconsin. However, when soil particles become saturated with phosphorus and have no more binding sites, phosphorus will remain in solution and leach with groundwater.

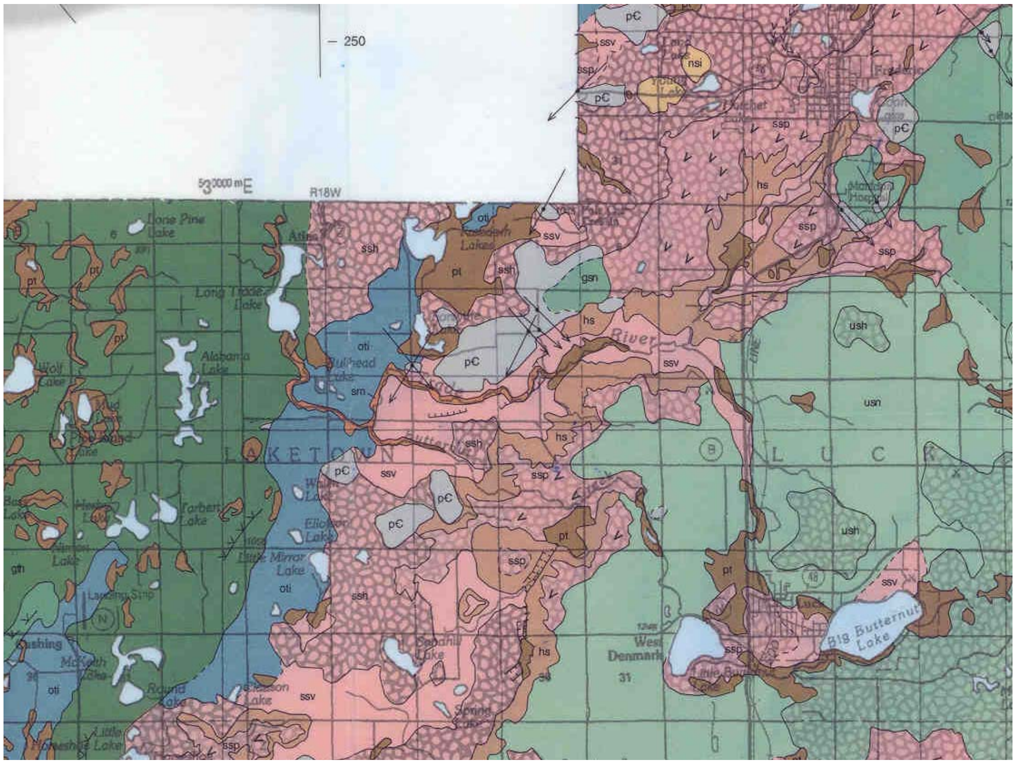
Phosphorus in soils originates from the weathering of minerals (Sturgul 2002). The geology of the Trade River Watershed is comprised of Trade River Formations and Copper Falls Formations. The Copper Falls Formation was deposited earlier than 11,500 years ago. The Copper Falls Formation consists of sandy till and sandy outwash deposited by glacial meltwater. Trade River Formation till is silt-rock and calcareous; Trade River Formation till exhibits a low degree of weathering and erosional modifications (Johnson, 2000). *The Pleistocene Geology of Polk County, Wisconsin, Bulletin 92* does not give information about nutrient content in the soils, but many of the deposits of the Trade River Watershed are from former lakes or rivers. When the rivers ran out or the lakes dried, the accumulated sediment and organic debris from the lake or river bed were deposited and now make up the Trade River watershed soils. These lake or river deposits may have higher phosphorus concentrations.

The soluble reactive phosphorus ranged in the groundwater samples from a low of 0.023 mg/L to 0.148 mg/L. The average SRP concentration of all of the samples was 0.079 mg/L. Results show that Long Trade Watershed is comparatively high in groundwater phosphorus which enters the river and lake system. Groundwater phosphorus concentrations found in other studies have used a slightly different collection method, but the following table gives some regional SRP values.

Watershed	Study Agency	Year	Ave SRP (mg/L)
Balsam Lake, Polk County	USGS	1988	0.016
Ward Lake, Polk County	LWRD	1999	0.028
Bear Lake, Waupaca County	UWSP	2001	0.031
Little St. Germain, Vilas County	USGS	2001	0.019
Lotus Lake Watershed, Polk County	LWRD	2007	0.061
Long Trade Watershed	**LWRD**	**2007**	**0.079**

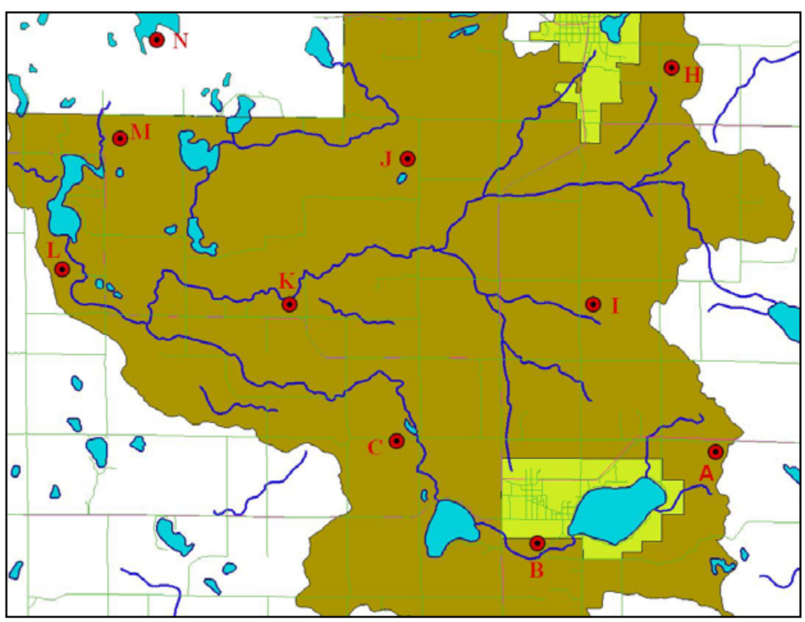
There are some differences in groundwater quality that can be explained by the geology. Twenty units of soil parent material are described in *The Pleistocene Geology of Polk County*. All five hummocky or mucky units of Polk County are present within the Trade River watershed. The soil material in the southeast where the watershed begins is described as “low-relief hummocky landscape with a thick stream sediment underlayer”, which may be a source of phosphorus. These sites, A and B, had high phosphorus concentrations.

Two units of soil parent material contain calcareous sediments and are present in the west end of the watershed near Long Trade Lake. This diagonal deposit of till runs east of Long Trade Lake from Freedom Lake to McKeith Lake. It is a distinct feature in the Trade River watershed of differentiating till (shown as the blue member on the following map). As mentioned previously, calcium and other metals have a tendency to bind with phosphorus to become a stable molecule. When this happens, phosphorus becomes a solid and is taken out of the groundwater. Site L shows evidence of this. Site L sits in the band of calcareous till and had a phosphorus concentration of 0.023 mg/L. It is the lowest SRP concentration of any samples and one of the highest total hardness concentrations (200 mg/L as $CaCO_3$). (The next lowest phosphorus sample was 0.039 ug/L at Site H. Site H was the only acidic sample with a pH of 6.83.) This parent material is the only area in the watershed that is described as having calcareous till. Sites M and N, downstream of this calcareous till, had a marked increase of total hardness concentration presumably due to groundwater which flowed through the calcium or magnesium present in the geologic deposits.

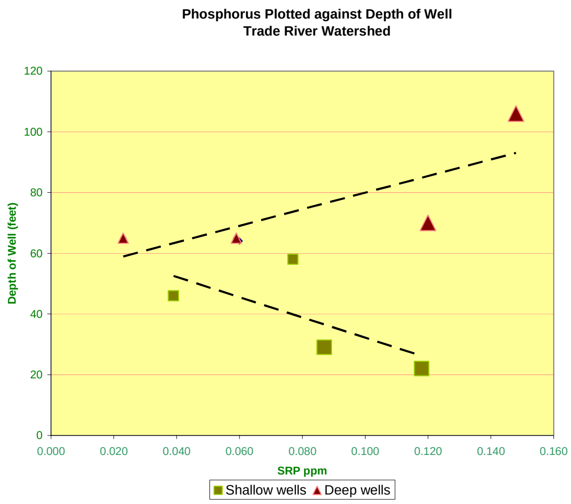


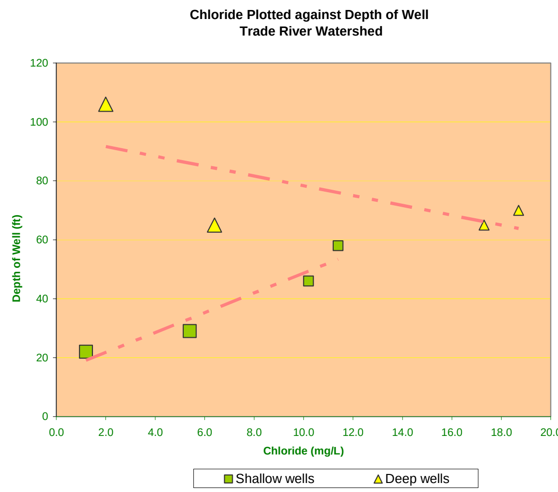
The formation that Long Trade is in describes that the hummocky till plain is <u>underlain</u> by calcareous till, not necessarily connected to the lake.

Following the formation of calcareous till, it was noted that phosphorus levels in the groundwater (and Round Lake water) were slightly lower than sites just up gradient of them (from 0.060 down to 0.023 and 0.059 ug/L).



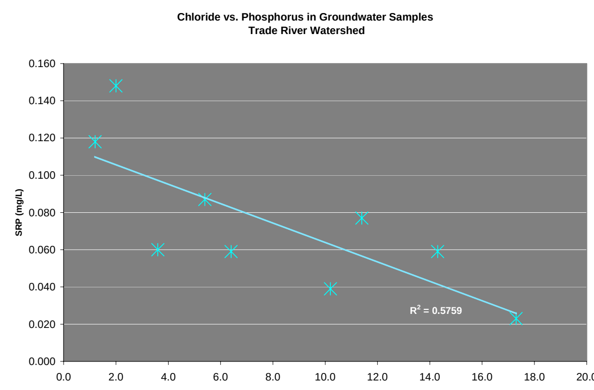
Overall, there were some interesting trends found throughout the watershed. A trend was noted between the depth of the well and the amount of phosphorus at a site. The shallowest wells AND the deepest wells had the highest phosphorus concentrations while the mid-depth wells had less phosphorus.





The chloride concentrations seemed to follow the reverse pattern. The shallowest wells and the deepest wells had the lowest chloride concentration while the highest concentration of chloride was found at wells of middle-range depth.

When graphed together, phosphorus showed an inverse relationship with chloride, meaning that increased concentrations of phosphorus do not correlate with increases in chloride (an indicator of human influence). The more chloride that was found, less SRP was present. This trend indicates that the excess phosphorus is due largely to something other than human impact.



The data set is small with only 10 samples; however, the contrast is stark between chloride and phosphorus. The majority of phosphorus in the groundwater is most likely due to natural incidence. While geology certainly has an influence in this region, it <u>does not rule out</u> human impact on groundwater quality.

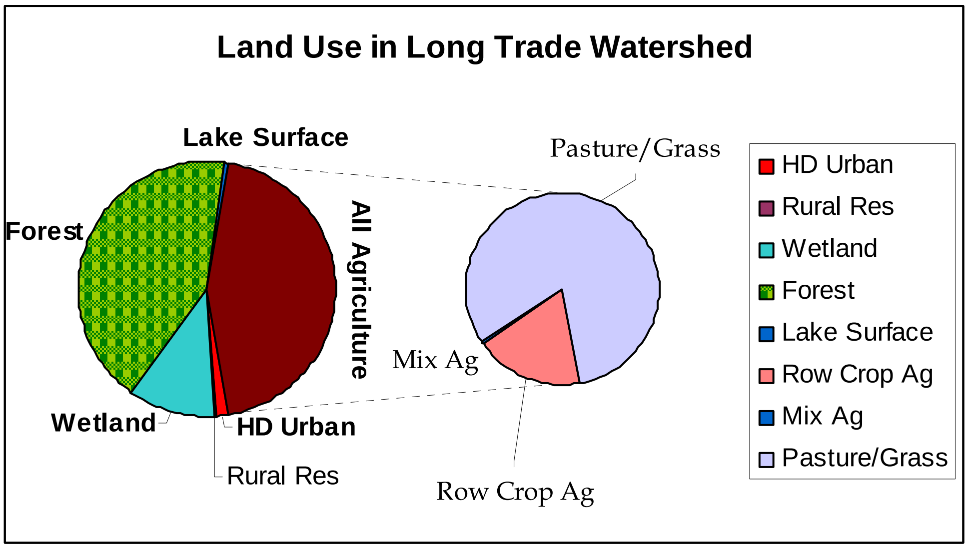
The groundwater of the Trade River system showed low nitrates but high phosphorus that may be affecting the water quality of Long Trade and Round Lakes. A baseflow survey of groundwater during the water year in the Trade River will be more indicative of how the quality is affecting the lake if determined that groundwater is a large source of water.

In retrospect, groundwater samples should be collected downstream of the two waste water treatment plants seepage cells to see if phosphorus is leaching into the groundwater system. This sampling should be done in collaboration with the Villages and DNR to assess the nutrient retention of the cells and tertiary treatment.

Phosphorus Modeling on Round and Long Trade Lakes

It is difficult to determine what proportion of phosphorus originates from groundwater and what is caused by human impact on the landscape. Computer modeling based on the land use types in the watershed can give an indication of phosphorus runoff. However, with a watershed as large as the Trade River system, these coefficients may be intercepted by other mechanisms.

The land use in the watershed is 44% agriculture, 42% forest, 11% wetland, 2% high density (HD) urban, 0.5% rural residential, and 0.5% lake surface. The agricultural land use can be broken further into pasture land or grassland (36% of total watershed), row crops (8% of total watershed), and mixed agriculture (including farmsteads, 0.25% of total watershed).



Using WiLMS (Wisconsin Lakes Modeling Suite) developed by the Wisconsin Department of Natural Resources, observed phosphorus data and land uses were entered into the model to try to predict the input of phosphorus and internal processes of the lakes. www.dnr.state.wi.us/org/water/fhp/**lake**s/**WiLMS**Documentation.pdf

On Long Trade Lake, it is calculated that the lake receives 12,403 lb TP/year from the drainage area. This input to the lake can be broken down into 4599 lb/yr from point sources (stream phosphorus input), 7757 lb/yr from non-point sources (watershed influence), and 81 lb/ac-yr from atmospheric loading.

The internal cycle of nutrient processing of a lake is termed internal loading, that is, phosphorus contributions to the water column from sources within the lake itself. These internal sources encompass all biological activities in the lake including processing of terrestrial vegetation by bacteria, consumption of the bacteria by zooplankton, the life cycle of benthic and pelagic algae, interaction of macroinvertebrates, decomposition of aquatic macrophytes, and the predation pressure of fish on the biological and physical community. Internal loading also includes the chemical processes that contribute nutrients from the sediment water interface to the water column under continuous changing conditions of pH and oxygen concentrations. It is difficult to understand all of these mechanisms as well as measure them. The movement of the lake water by recreation, wind, and seiche also affects the amount of internal loading in a lake, but is not accounted for with the WiLMS modeling. The WiLMS model uses number of days of anoxic conditions, lake bathymetry, and lake bottom area to determine the internal loading of the lake.

Using both the point source and non-point sources loading scenario, the Wisconsin Internal Load Estimator predicted the lake is cycling 707 lb of phosphorus, which affects the lake water quality. The modeled most-likely in-lake phosphorus concentration should be 181 ug/L according to the Rechow 1977, Anoxic model, with a 70% confidence range of 111-251 ug/L.

When modeling Long Trade Lake again without the point source of phosphorus (ie. without the incoming stream phosphorus), the lake received 51 lb/acre-year from areal loading and 7757 lb/yr of non-point sources of phosphorus (from the watershed). The Wisconsin Internal Load Estimator calculated 4044 pounds of phosphorus to be cycling in the lake from the bottom sediments to result in the phosphorus value that was observed in the lake. The Rechow Anoxic model predicted the phosphorus concentration of the lake water (without the point source loading) should be 116 ug/L with a 70% confidence range of 68-202 ug/L.

In assessing the internal load of Long Trade Lake, if we look at the actual monitored inflow of phosphorus and the outflow of phosphorus, we see that there is a contribution from the lake to the river system. Because the hypolimnion (the bottom layer of lake water near the sediment) samples were not collected, it is not possible to predict the internal load of Long Trade Lake at this time; we are just able to calculate an estimate from the modeling scenarios. Again, the actual observed phosphorus load upstream of Long Trade Lake was 5275 lb/year, and the load downstream of Long Trade Lake was 18,558 lb/year measured at County Road Z bridge. The difference between these two sample sites is 13,283 lb/year. Seemingly the source of phosphorus to Long Trade Lake is a combination of the point source loading and the internal loading from sediments as well as watershed influence. Carp may be a factor of internal loading in Long Trade Lake.

Round Lake was also modeled using WiLMS. A direct drainage area was entered at 2382 acres, and the Trade River was modeled as a point source of phosphorus. The phosphorus contribution from the drainage area was calculated at 493 lb/year. (This is in contrast to the 7,757 pounds from Long Trade's watershed; however, the entire 32,573-acre watershed was used for Long Trade Lake.)

The modeled internal load (Method 1) on Round Lake was -8175 lb/year. That is to say that Round Lake is retaining phosphorus and acting as a sink rather than a source of nutrients. This was the model that most fits the observed data. Using Method 3, the in situ phosphorus increase from internal load was calculated to be 1252 lb/year.

The Rechow Anoxic (1977) model predicts that the most likely in-lake phosphorus concentration is 112 ug/L with a 70% confidence range of 38-185 ug/L. This does not closely fit with the observed data. The Vollenweider 1982 Shallow Lake or Reservoir model predicts the most likely in-lake phosphorus concentration at 60 ug/L with a range of 16-111 ug/L.

Recommendations for Future Management

In deciding what is practical and feasible for Long Trade and Round Lake, it is essential to know the water quality conditions of the lakes before the anthropogenic changes took place. As a lake ages, the sediments that accumulate on the lake bottom document the lake processes. The tier of sediments and organic matter accumulated each year from the watershed can be compared to other years. A full paleolimnological sediment core would document the nutrient change over the last 150 years in the lake, graphing the time period where large inputs were added and a shift in the lake community occurred. This information gives an indication of the land use in the watershed and how the lake reacted to these changes (increasing algae levels, for example, or from green algae to the less desirable blue-green algae community) and approximately when this happened. This historical record also tells us what the original condition was before any changes took place. The historical condition is important to establish to set of achievable management goals. A full sediment core could be analyzed with a minimum price tag of $10,000, or just a top and bottom sediment core could be analyzed to determine historic conditions for approximately $1,000.

The lake association may wish to pursue additional upstream sampling to determine tributary loading. It is prudent to have five years of data to establish a baseline of information. Variations in rainfall, snowmelt patterns, and storm patterns can be great from year to year. Five years of data can rule out any anomalies and determine true trends. The Round/Trade Lake Improvement Association may also wish to take samples during baseflow of the river system to separate human influence from ambient water quality.

The lake association may choose to participate in discussions on the efficacy of waste water treatment plants. The WPDES permit that the waste water treatment plants hold will be up for renewal. The Village of Frederic’s WPDES permit expires on December 31, 2009, and the Village of Luck expires on March 31, 2009. The Round/Trade Lake Improvement Association should contact the Villages of Luck and Frederic for the opportunity to work with the communities to develop their plans. Through the Wisconsin Pollutant Discharge Elimination System (WPDES) permit program, the DNR regulates municipal, industrial, and animal waste operations discharging water to surface or groundwater. "Point source" dischargers, facilities discharging wastewater to surface water from a specific point such as from the end of a pipe, must meet either the federal minimum requirements for secondary treatment in the case of a municipality, and technology-based categorical (base level) limits for industries, or the discharges must meet levels necessary to achieve water quality standards, whichever is more stringent. Since passage of the 1972 Federal Clean Water Act, Wisconsin communities invested a tremendous amount of time, labor, and money to upgrade and construct wastewater treatment facilities for water quality improvements.

As of 2005, approximately 690 municipalities held WPDES permits to discharge to surface and/or groundwater in Wisconsin. As communities upgrade treatment facilities, some find combining systems into a joint regional treatment facility more economical. Other municipalities upgrade the existing facility or construct a new one at or near the existing site. http://www.dnr.state.wi.us/org/water/wm/ww/permproc.htm

The biology of a lake ecosystem can also greatly affect the chemistry of lake water. The natural vegetation (native trees, shrubs, forbs and understory) should be enhanced surrounding the lakeshore to intercept as much runoff as possible from the near shore area. The macrophyte community in the lake should be enhanced by limiting disturbance as well as controlling aquatic invasive species.

Within the watershed, it was noted that cattle were in dry streambeds. LWRD and NRCS will work with landowners to fence out cattle and provide alternate watering systems. A major gully has formed in another location of Butternut Creek. Slope stabilization and erosion control can be designed to protect the streambank and limit nutrients from entering the waterbodies.

Additional monitoring of phosphorus "hotspots" in the watershed is warranted. Flow and nutrient concentration data will strengthen the understanding of the loading from certain areas within the watershed.

An analysis of in-lake loading, nutrient budget, and water budget would be prudent. This information would discern groundwater influence from watershed influence from lake-processing influence on the nutrient concentration and could help identify what management practices are possible. A "baseflow" concentration from the river can be determined to estimate how geologic phosphorus is entering the lakes. An in-lake monitoring strategy taking both top and bottom water samples will calculate the phosphorus flux from internal sources. USGS may be able to perform a two-year study in the Trade River system.

The restoration of a native plant community can only better the water clarity of both lakes. Non-native species can change the nutrient dynamics of a lake not only by affecting the timing of growth and senesce, but also by affecting the biological web and food processing of a lake. The Round/Trade Lake Improvement Association should pursue an Aquatic Invasive Species (AIS) Control Grant to oppress the current population of Eurasian Water Milfoil (EWM) and purple loosestrife. The spread of EWM to other locations within the lake as well as to other lakes could adversely affect the economic factions of the lake.

As with any lake, there are a number of recommendations for good lake living. Maintain septic systems to be sure they do not leach to the ground or lake water, maintain a minimum of 35 feet of native vegetation at the shoreline, observe the slow-no-wake speed limit within 100 feet of shorelines when boating, use phosphorus-free fertilizers (if any), use phosphorus free detergents and eco-friendly cleaning supplies (http://dnr.wi.gov/org/water/dwg/gw/pubs/bhgw.pdf), limit impervious areas, keep fire pit ashes and pet waste from entering the lake, be active in lake improvement activities, and help educate others on lake ecology, land use decisions, and aquatic invasive species.

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Future Direction

1. Address EWM infestation on Long Trade and Round Lakes and survey lakes downstream to determine if EWM is present.
    a. Apply for AIS control grants to map beds, develop APM Plans, and treat EWM.
    b. Monitor to assess results.

2. Decide where additional monitoring is warranted.
    a. In-lake loading
    b. Historical loading – top –bottom sediment sample $1,000 each (small scale lake planning grant)
    c. Total Nutrient Budget – USGS $180,000 (Lake Protection Grant)
    d. Additional tributary sampling to assess source loading – along County Road Z and others
    e. Hotspots along river –293rd Avenue, possibility for infiltration basins or enhanced wetlands to reduce nutrient loading from Brown Brook tributary.

3. Work with communities in watershed to alleviate stormwater and waste water impact
    a. WWTP – contact Villages and DNR
    b. Additional tributary sampling

4. Shoreline work around lakes
    a. Lake restoration
    b. SIP
    c. Education campaign

Appendix A – WiLMS Modeling Assumptions – Long Trade Lake with Point Source

Lake Id: Long Trade
Watershed Id: 49

Hydrologic and Morphometric Data

Tributary Drainage Area: 32572.8 acre
Total Unit Runoff: 8.00 in.
Annual Runoff Volume: 21715.2 acre-ft
Lake Surface Area <As>: 153.0 acre
Lake Volume <V>: 1264.0 acre-ft
Lake Mean Depth <z>: 8.3 ft
Precipitation - Evaporation: 3.3 in.
Hydraulic Loading: 22138.5 acre-ft/year
Areal Water Load <qs>: 144.7 ft/year
Lake Flushing Rate <p>: 17.51 1/year
Water Residence Time: 0.06 year
Observed spring overturn total phosphorus (SPO): 0.0 mg/m^3
Observed growing season mean phosphorus (GSM): 168.0 mg/m^3
% NPS Change: 0%
% PS Change: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High
		|---- Loading (kg/ha-year) ----|				|----- Loading (kg/year) ----|		
Row Crop AG	2545.8	0.50	1.00	3.00	18.3	515	1030	3091
Mixed AG	84.2	0.30	0.80	1.40	0.5	10	27	48
Pasture/Grass	11539.7	0.10	0.30	0.50	24.9	467	1401	2335
HD Urban (1/8 Ac)	534.3	1.00	1.50	2.00	5.8	216	324	432
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	64.3	0.05	0.10	0.25	0.0	1	3	7
Wetlands	3518.9	0.10	0.10	0.10	2.5	142	142	142
Forest	13459.8	0.05	0.09	0.18	8.7	272	490	980
Lake Surface	153.0	0.10	0.30	1.00	0.3	6	19	62

POINT SOURCE DATA

Point Sources	Water Load (m^3/year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %

SEPTIC TANK DATA

Description		Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)		0.30	0.50	0.80	
# capita-years	54.0				
% Phosphorus Retained by Soil		98.0	90.0	80.0	
Septic Tank Loading (kg/year)		0.32	2.70	8.64	0.0

TOTALS DATA

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	6557.8	12402.5	16402.8	100.0
Total Loading (kg)	2974.6	5625.7	7440.3	100.0
Areal Loading (lb/ac-year)	42.86	81.06	107.21	
Areal Loading (mg/m^2-year)	4804.21	9085.93	12016.52	
Total PS Loading (lb)	2888.0	4598.8	0.0	37.1
Total PS Loading (kg)	1310.0	2086.0	0.0	37.1
Total NPS Loading (lb)	3655.4	7756.8	16247.2	62.9
Total NPS Loading (kg)	1658.1	3518.4	7369.7	62.9

Wisconsin Internal Load Estimator

Method 1 - A Complete Total Phosphorus Mass Budget

Method 1 - A Complete Total Phosphorus Mass Budget 168 mg/m^3
Phosphorus Inflow Concentration: 206.0 mg/m^3
Areal External Loading: 9085.9 mg/m^2-year
Predicted Phosphorus Retention Coefficient: 0.24
Observed Phosphorus Retention Coefficient: 0.18
Internal Load: 707 Lb 321 kg

Method 2 - From Growing Season In Situ Phosphorus Increases

Start of Anoxia

Average Hypolimnetic Phosphorus Concentration: mg/m^3
Hypolimnetic Volume: 0.0 acre-ft
Anoxia Sediment Area: 0.0 acres

Just Prior To The End of Stratification

Average Hypolimnetic Phosphorus Concentration: 0 mg/m^3
Hypolimnetic Volume: 0.0 acre-ft
Anoxia Sediment Area: 0.0 acres
Time Period of Stratification: 1 days
Sediment Phosphorus Release Rate: 0 mg/m^2-day 0 lb/acre-day
Internal Load: 0 Lb 0 kg

Method 3 - From In Situ Phosphorus Increases In The Fall

Start of Anoxia

Average Hypolimnetic Phosphorus Concentration: 168 mg/m^3
Hypolimnetic Volume: 0.0 acre-ft
Anoxia Sediment Area: 0.0 acres

Just Prior To The End of Stratification

Average Water Column Phosphorus Concentration: 168 mg/m^3
Lake Volume: 1264.0 acre-ft
Anoxia Sediment Area Just Before Turnover: 0.0 acres
Time Period Between Observations: 30 days
Sediment Phosphorus Release Rate: 0 mg/m^2-day   0 lb/acre-day
Internal Load: 577 Lb   262 kg

Method 4 - From Phosphorus Release Rate and Anoxic Area
Start of Anoxia Anoxic Sediment Area: 0.0 acre
End of Anoxia Anoxic Sediment Area: 0.0 acre
Phosphorus Release Rate As Calculated In Method 2: 0 mg/m^2-day
Phosphorus Release Rate As Calculated In Method 3: 0 mg/m^2-day
Average of Methods 2 and 3 Release Rates: 0.0 mg/m^2-day
Period of Anoxia: 30 days
Default Areal Sediment Phosphorus Release Rates:

	Low	Most Likely	High
	6	14	24
Internal Load: (Lb)	0	0	0
Internal Load: (kg)	0	0	0

Internal Load Comparison (Percentages are of the Total Estimate Load)
Total External Load: 12403 Lb   5626 kg

	Lb	kg	%
From A Complete Mass Budget:	707	321	5.4
From Growing Season In Situ Phosphorus Increases:	0	0	0.0
From In Situ Phosphorus Increases In The Fall:	577	262	4.4
From Phosphorus Release Rate and Anoxic Area:	0	0	0.0

Predicted Water Column Total Phosphorus Concentration (ug/l)

	Low	Most Likely	High
Nurnberg+ 1984 Total Phosphorus Model:	0	0	0

Osgood, 1988 Lake Mixing Index: 0
Phosphorus Loading Summary:

	Low	Most Likely	High
Internal Load (Lb):	0	0	0
Internal Load (kg):	0	0	0
External Load (Lb):	0	0	0
External Load (kg):	0	0	0
Total Load (Lb):	0	0	0
Total Load (kg):	0	0	0

Phosphorus Prediction and Uncertainty Analysis Module
Date: 9/12/2008   Scenario: 9
Observed spring overturn total phosphorus (SPO): 0.0 mg/m^3
Observed growing season mean phosphorus (GSM): 168.0 mg/m^3
Back calculation for SPO total phosphorus: 0.0 mg/m^3
Back calculation GSM phosphorus: 207.41 mg/m^3
% Confidence Range: 70%
Nurenberg Model Input - Est. Gross Int. Loading: 207 kg

Lake Phosphorus Model	Low	Most Likely	High

Model	Total P (mg/m^3)	Total P (mg/m^3)	Total P Predicted (mg/m^3)	P -Observed (mg/m^3)	% Dif. (mg/m^3)
Walker, 1987 Reservoir	59	112	148	-56	-33
Canfield-Bachmann, 1981 Natural Lake	84	148	188	-20	-12
Canfield-Bachmann, 1981 Artificial Lake	70	114	139	-54	-32
Rechow, 1979 General	74	141	186	-27	-16
Rechow, 1977 Anoxic	96	181	239	13	8
Rechow, 1977 water load<50m/year	58	110	146	-58	-35
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	61	103	129	19	23
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	52	92	117	8	10
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxic	90	164	214	-4	-2

Lake Phosphorus Model	Confidence Lower Bound	Confidence Upper Bound	Fit?	Parameter Back Calculation (kg/year)	Model Type
Walker, 1987 Reservoir	67	158	Tw	10402	GSM
Canfield-Bachmann, 1981 Natural Lake	46	426	L	8289	GSM
Canfield-Bachmann, 1981 Artificial Lake	35	328	FIT	13181	GSM
Rechow, 1979 General	81	206	P	8286	GSM
Rechow, 1977 Anoxic	111	251	FIT	6455	GSM
Rechow, 1977 water load<50m/year	64	159	P	10561	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	51	174	FIT	13294	ANN
Dillon-Rigler-Kirchner	N/A	N/A	N/A		

N/A N/A
Vollenweider, 1982 Shallow Lake/Res. 46 153 FIT
14478 ANN
Larsen-Mercier, 1976 N/A N/A N/A
N/A N/A
Nurnberg, 1984 Oxic 89 255 P L
7195 ANN

Water and Nutrient Outflow Module

Average Annual Surface Total Phosphorus: 168mg/m^3
Annual Discharge: 2.21E+004 AF => 2.73E+007 m^3
Annual Outflow Loading: 9666.3 LB => 4384.6 kg

Expanded Trophic Response Module

Total Phosphorus: 168 mg/m^3
Growing Season
Chorophyll a: 10.5 mg/m^3
Secchi Disk Depth: .65 m
Cholorphyll a Nuisance Frequency
Chla Mean Min: 5
Chla Mean Max: 100
Chla Mean Increment: 5
Chla Temporal CV: 0.62
Chla Nuisance Criterion: 20

Mean	Freq %
5	0.5
10	7.7
15	21.9
20	37.8
25	52.0
30	63.5
35	72.3
40	79.0
45	84.1
50	87.9
55	90.7
60	92.8
65	94.4
70	95.6
75	96.6
80	97.3
85	97.8
90	98.3
95	98.6
100	98.9

Long Trade Lake – WiLMS Modeling Assumptions – No Point Source

Lake Id: Long Trade
Watershed Id: 49

Hydrologic and Morphometric Data

Tributary Drainage Area: 32572.8 acre
Total Unit Runoff: 8.00 in.
Annual Runoff Volume: 21715.2 acre-ft
Lake Surface Area <As>: 153.0 acre
Lake Volume <V>: 1264.0 acre-ft
Lake Mean Depth <z>: 8.3 ft
Precipitation - Evaporation: 3.3 in.
Hydraulic Loading: 21757.3 acre-ft/year
Areal Water Load <qs>: 142.2 ft/year
Lake Flushing Rate <p>: 17.21 1/year
Water Residence Time: 0.06 year
Observed spring overturn total phosphorus (SPO): 0.0 mg/m^3
Observed growing season mean phosphorus (GSM): 168.0 mg/m^3
% NPS Change: 0%
% PS Change: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High
		|---- Loading (kg/ha-year) ----|				|----- Loading (kg/year) ----|		
Row Crop AG	2545.8	0.50	1.00	3.00	29.1	515	1030	3091
Mixed AG	84.2	0.30	0.80	1.40	0.8	10	27	48
Pasture/Grass	11539.7	0.10	0.30	0.50	39.6	467	1401	2335
HD Urban (1/8 Ac)	534.3	1.00	1.50	2.00	9.2	216	324	432
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	64.3	0.05	0.10	0.25	0.1	1	3	7
Wetlands	3518.9	0.10	0.10	0.10	4.0	142	142	142
Forest	13459.8	0.05	0.09	0.18	13.8	272	490	980
Lake Surface	153.0	0.10	0.30	1.00	0.5	6	19	62

POINT SOURCE DATA

Point Sources	Water Load (m^3/year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %

=

SEPTIC TANK DATA

Description	Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)	0.30	0.50	0.80	

capita-years 54.0
% Phosphorus Retained by Soil 98.0 90.0
80.0
Septic Tank Loading (kg/year) 0.32 2.70
8.64 0.1

TOTALS DATA

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	3669.8	7803.7	16402.8	100.0
Total Loading (kg)	1664.6	3539.7	7440.3	100.0
Areal Loading (lb/ac-year)	23.99	51.00	107.21	
Areal Loading (mg/m^2-year)	2688.47	5716.89	12016.52	
Total PS Loading (lb)	0.0	0.0	0.0	0.0
Total PS Loading (kg)	0.0	0.0	0.0	0.0
Total NPS Loading (lb)	3655.4	7756.8	16247.2	99.9
Total NPS Loading (kg)	1658.1	3518.4	7369.7	99.9

Wisconsin Internal Load Estimator

Method 1 - A Complete Total Phosphorus Mass Budget

Method 1 - A Complete Total Phosphorus Mass Budget 168 mg/m^3
Phosphorus Inflow Concentration: 131.9 mg/m^3
Areal External Loading: 5716.9 mg/m^2-year
Predicted Phosphorus Retention Coefficient: 0.24
Observed Phosphorus Retention Coefficient: -0.27
Internal Load: 4044 Lb 1834 kg

Method 2 - From Growing Season In Situ Phosphorus Increases

Start of Anoxia

Average Hypolimnetic Phosphorus Concentration: 0 mg/m^3
Hypolimnetic Volume: 0.0 acre-ft
Anoxia Sediment Area: 0.0 acres

Just Prior To The End of Stratification

Average Hypolimnetic Phosphorus Concentration: 0 mg/m^3
Hypolimnetic Volume: 0.0 acre-ft
Anoxia Sediment Area: 0.0 acres
Time Period of Stratification: 1 days
Sediment Phosphorus Release Rate: 0 mg/m^2-day 0 lb/acre-day
Internal Load: 0 Lb 0 kg

Method 3 - From In Situ Phosphorus Increases In The Fall

Start of Anoxia

Average Hypolimnetic Phosphorus Concentration: 0 mg/m^3
Hypolimnetic Volume: 0 acre-ft
Anoxia Sediment Area: 0 acres

Just Prior To The End of Stratification

Average Water Column Phosphorus Concentration: 168 mg/m^3
Lake Volume: 1264.0 acre-ft
Anoxia Sediment Area Just Before Turnover: 0 acres
Time Period Between Observations: 30 days
Sediment Phosphorus Release Rate: 0 mg/m^2-day 0 lb/acre-day
Internal Load: 577 Lb 262 kg

Method 4 - From Phosphorus Release Rate and Anoxic Area

Start of Anoxia Anoxic Sediment Area: 0 acre
End of Anoxia Anoxic Sediment Area: 0 acre
Phosphorus Release Rate As Calculated In Method 2: 0 mg/m^2-day

Phosphorus Release Rate As Calculated In Method 3: 0 mg/m^2-day
Average of Methods 2 and 3 Release Rates: 0.0 mg/m^2-day
Period of Anoxia: 0 days
Default Areal Sediment Phosphorus Release Rates:

	Low	Most Likely	High
	6	14	24
Internal Load: (Lb)	0	0	0
Internal Load: (kg)	0	0	0

Internal Load Comparison (Percentages are of the Total Estimate Load)

Total External Load: 7804 Lb 3540 kg

	Lb	kg	%
From A Complete Mass Budget:	4044	1834	34.1
From Growing Season In Situ Phosphorus Increases:	0	0	0
From In Situ Phosphorus Increases In The Fall:	577	262	6.9
From Phosphorus Release Rate and Anoxic Area:	0	0	0

Predicted Water Column Total Phosphorus Concentration (ug/l)

	Low	Most Likely	High
Nurnberg+ 1984 Total Phosphorus Model:	0	0	0

Osgood, 1988 Lake Mixing Index: 0

Phosphorus Loading Summary:

	Low	Most Likely	High
Internal Load (Lb):	0	0	0
Internal Load (kg):	0	0	0
External Load (Lb):	0	0	0
External Load (kg):	0	0	0
Total Load (Lb):	0	0	0
Total Load (kg):	0	0	0

Phosphorus Prediction and Uncertainty Analysis Module

Observed spring overturn total phosphorus (SPO): 0.0 mg/m^3
Observed growing season mean phosphorus (GSM): 168.0 mg/m^3
Back calculation for SPO total phosphorus: 0.0 mg/m^3
Back calculation GSM phosphorus: 207.41 mg/m^3
% Confidence Range: 70%
Nurenberg Model Input - Est. Gross Int. Loading: 207 kg

Lake Phosphorus Model	**Low** Total P (mg/m^3)	**Most Likely** Total P (mg/m^3)	**High** Total P (mg/m^3)	**Predicted % Dif.** -Observed (mg/m^3)
Walker, 1987 Reservoir	38	82	171	-86 -51
Canfield-Bachmann, 1981 Natural Lake	50	100	190	-68 -40
Canfield-Bachmann, 1981 Artificial Lake	44	81	141	-87 -52
Rechow, 1979 General	42	90	189	-78 -46

Rechow, 1977 Anoxic	54	116	243	-52	-31
Rechow, 1977 water load<50m/year	34	71	150	-97	-58
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	38	71	131	-13	-15
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	32	62	119	-22	-26
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxic	55	107	217	-61	-36

Lake Phosphorus Model	**Confidence** Lower Bound	**Confidence** Upper Bound	Fit?	**Parameter** Calculation (kg/year)	**Back Model** Type
Walker, 1987 Reservoir	47	144	Tw	8998	GSM
Canfield-Bachmann, 1981 Natural Lake	31	288	FIT	8175	GSM
Canfield-Bachmann, 1981 Artificial Lake	25	233	FIT	13034	GSM
Rechow, 1979 General	50	161	FIT	8169	GSM
Rechow, 1977 Anoxic	68	202	FIT	6345	GSM
Rechow, 1977 water load<50m/year	40	127	P	10297	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	34	131	FIT	13087	ANN
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	30	115	FIT	14253	ANN
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxic	57	194	P L	7094	ANN

Round Lake WiLMS Assumptions

Lake Id: Round Lake
Watershed Id: 013

Hydrologic and Morphometric Data

Tributary Drainage Area: 2381.8 acre
Total Unit Runoff: 10.80 in.
Annual Runoff Volume: 2143.6 acre-ft
Lake Surface Area <As>: 204.0 acre
Lake Volume <V>: 3050.0 acre-ft
Lake Mean Depth <z>: 15.0 ft
Precipitation - Evaporation: 4.1 in.
Hydraulic Loading: 54982.6 acre-ft/year
Areal Water Load <qs>: 269.5 ft/year
Lake Flushing Rate <p>: 18.03 1/year
Water Residence Time: 0.06 year
Observed spring overturn total phosphorus (SPO): 0.0 mg/m^3
Observed growing season mean phosphorus (GSM): 54 mg/m^3
% NPS Change: 0%
% PS Change: 0%

NON-POINT SOURCE DATA

Land Use	Acre (ac)	Low	Most Likely	High	Loading %	Low	Most Likely	High
		|---- Loading (kg/ha-year) ----|				|----- Loading (kg/year) ----|		
Row Crop AG	202.1	0.50	1.00	3.00	0.9	41	82	245
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0
Pasture/Grass	720.5	0.10	0.30	0.50	1.0	29	87	146
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	51.0	0.05	0.10	0.25	0.0	1	2	5
Wetlands	134.8	0.10	0.10	0.10	0.1	5	5	5
Forest	1268.5	0.05	0.09	0.18	0.5	26	46	92
Open Water	4.8	0.10	0.30	1.00	0.0	0	1	2
Lake Surface	204.0	0.10	0.30	1.00	0.3	8	25	83

POINT SOURCE DATA

Point Sources	Water Load (m^3/year)	Low (kg/year)	Most Likely (kg/year)	High (kg/year)	Loading %

SEPTIC TANK DATA

Description	Low	Most Likely	High	Loading %
Septic Tank Output (kg/capita-year)	0.30	0.50		

0.80
capita-years 44.0
% Phosphorus Retained by Soil 98.0 90.0
80.0
Septic Tank Loading (kg/year) 0.26 2.20
7.04 0.0

Description	Low	Most Likely	High	Loading %
Total Loading (lb)	244.6	19110.7	1291.4	100.0
Total Loading (kg)	110.9	8668.6	585.8	100.0
Areal Loading (lb/ac-year)	1.20	93.68	6.33	
Areal Loading (mg/m^2-year)	134.37	10500.23	709.55	
Total PS Loading (lb)	0.0	18558.3	0.0	97.1
Total PS Loading (kg)	0.0	8418.0	0.0	97.1
Total NPS Loading (lb)	225.8	492.9	1093.9	2.9
Total NPS Loading (kg)	102.4	223.6	496.2	2.9

Wisconsin Internal Load Estimator

Method 1 - A Complete Total Phosphorus Mass Budget

Method 1 - A Complete Total Phosphorus Mass Budget 54 mg/m^3
Phosphorus Inflow Concentration: 127.8 mg/m^3
Areal External Loading: 10500.2 mg/m^2-year
Predicted Phosphorus Retention Coefficient: 0.15
Observed Phosphorus Retention Coefficient: 0.58
Internal Load: -8175 Lb -3708 kg

Method 2 - From Growing Season In Situ Phosphorus Increases

Start of Anoxia
Average Hypolimnetic Phosphorus Concentration: 0 mg/m^3
Hypolimnetic Volume: 0.0 acre-ft
Anoxia Sediment Area: 0.0 acres
Just Prior To The End of Stratification
Average Hypolimnetic Phosphorus Concentration: 151 mg/m^3
Hypolimnetic Volume: 0.0 acre-ft
Anoxia Sediment Area: 0.0 acres
Time Period of Stratification: 1 days
Sediment Phosphorus Release Rate: 0 mg/m^2-day 0 lb/acre-day
Internal Load: 0 Lb 0 kg

Method 3 - From In Situ Phosphorus Increases In The Fall

Start of Anoxia
Average Hypolimnetic Phosphorus Concentration: 0 mg/m^3
Hypolimnetic Volume: 0.0 acre-ft
Anoxia Sediment Area: 0.0 acres
Just Prior To The End of Stratification
Average Water Column Phosphorus Concentration: 151 mg/m^3
Lake Volume: 3050.0 acre-ft
Anoxia Sediment Area Just Before Turnover: 0.0 acres
Time Period Between Observations: 30 days
Sediment Phosphorus Release Rate: 0 mg/m^2-day 0 lb/acre-day
Internal Load: 1252 Lb 568 kg

Method 4 - From Phosphorus Release Rate and Anoxic Area

Start of Anoxia Anoxic Sediment Area: 0.0 acre
End of Anoxia Anoxic Sediment Area: 0.0 acre
Phosphorus Release Rate As Calculated In Method 2: 0 mg/m^2-day

Phosphorus Release Rate As Calculated In Method 3: 0 mg/m^2-day
Average of Methods 2 and 3 Release Rates: 0.0 mg/m^2-day
Period of Anoxia: 0 days
Default Areal Sediment Phosphorus Release Rates:

	Low	Most Likely	High
	6	14	24
Internal Load: (Lb)	0	0	0
Internal Load: (kg)	0	0	0

Internal Load Comparison (Percentages are of the Total Estimate Load)

Total External Load: 19111 Lb 8669 kg

	Lb	kg	%
From A Complete Mass Budget:	-8175	-3708	-74.7
From Growing Season In Situ Phosphorus Increases:	0	0	0.0
From In Situ Phosphorus Increases In The Fall:	1252	568	6.2
From Phosphorus Release Rate and Anoxic Area:	0	0	0

Predicted Water Column Total Phosphorus Concentration (ug/l)

	Low	Most Likely	High
Nurnberg+ 1984 Total Phosphorus Model:	-53	113	7

Osgood, 1988 Lake Mixing Index: 5.0

Phosphorus Loading Summary:

	Low	Most Likely	High
Internal Load (Lb):	-8175	626.2	0
Internal Load (kg):	-3708	284.0	0
External Load (Lb):	245	19111	1291
External Load (kg):	111	8669	586
Total Load (Lb):	-7930	19737	1291
Total Load (kg):	-3597	8953	586

Phosphorus Prediction and Uncertainty Analysis Module

Observed spring overturn total phosphorus (SPO): 0.0 mg/m^3
Observed growing season mean phosphorus (GSM): 54.0 mg/m^3
Back calculation for SPO total phosphorus: 0.0 mg/m^3
Back calculation GSM phosphorus: 67.5 mg/m^3
% Confidence Range: 70%
Nurenberg Model Input - Est. Gross Int. Loading: 7 kg

Lake Phosphorus Model	**Low** Total P (mg/m^3)	**Most Likely** Total P (mg/m^3)	**High** Total P (mg/m^3)	**Predicted % Dif.** -Observed (mg/m^3)
Walker, 1987 Reservoir	1	78	5 24	44
Canfield-Bachmann, 1981 Natural Lake	2	97	8 43	80
Canfield-Bachmann, 1981 Artificial Lake	2	80	8 26	48
Rechow, 1979 General	1	95	6 41	76

Rechow, 1977 Anoxic	1	112	8	58	107
Rechow, 1977 water load<50m/year	N/A	N/A	N/A	N/A	N/A
Rechow, 1977 water load>50m/year	1	98	7	44	81
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	2	70	8	43	159
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	1	60	6	33	122
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxic	1	109	7	55	102

Lake Phosphorus Model Parameter	**Confidence** Lower Bound	**Confidence** Upper Bound	Fit?	**Back** Calculation (kg/year)	**Model** Type
Walker, 1987 Reservoir	26	131	Tw	7483	GSM
Canfield-Bachmann, 1981 Natural Lake	30	279	L	5668	GSM
Canfield-Bachmann, 1981 Artificial Lake	25	230	FIT	6894	GSM
Rechow, 1979 General	31	162	FIT	6140	GSM
Rechow, 1977 Anoxic	38	185	FIT	5216	GSM
Rechow, 1977 water load<50m/year	N/A	N/A	N/A	N/A	N/A
Rechow, 1977 water load>50m/year	39	153	FIT	5965	GSM
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	19	131	FIT	8371	ANN
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	16	111	FIT	9973	ANN
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxic	32	193	P L	5376	ANN

Water and Nutrient Outflow Module

Average Annual Surface Total Phosphorus: 54mg/m^3
Annual Discharge: 5.50E+004 AF => 6.78E+007 m^3
Annual Outflow Loading: 7716.3 LB =>   3500.1 kg