The Small Lakes of Sammamish

A Report on Water Quality Monitoring Results
for Water Year 2013 at Pine and Beaver Lakes

Beaver Lake 1 – 2003

February 2014

King County

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The City of Sammamish

Submitted by:

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Department of Natural Resources and Parks

Acknowledgements

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OVERVIEW

The King County Lakes and Streams Monitoring group and its predecessor the Lake Stewardship Program have worked with volunteer monitors within the City of Sammamish for more than 20 years on both Pine Lake and the two basins of Beaver Lake. The water quality data collected to-date indicate that in general, Pine Lake and Beaver 2 are low to moderate in primary productivity with good water quality. Beaver 1 has been and continues to be highly productive, indicative of the input from the nearby wetland to the north that constitutes its major surface water source.

Both Beaver Lake and Pine Lake have public access boat launches and parks with beach frontage, where members of the public are able to access the lakes for recreation. At present, no invasive noxious aquatic weeds have been reported for either lake aside from fragrant water lily. However, residents should keep a watch on aquatic plants growing submersed or near shore to catch early infestations of Eurasian milfoil, Brazilian elodea, or other noxious weeds.

The discussion in this report focuses on the 2013 water year. The specific data used to generate the charts in this report can be downloaded from the King County Lakes and Streams Monitoring data website at:

http://your.kingcounty.gov/dnrp/wlr/water-resources/small-lakes/data/default.aspx

Data can also be provided in the form of excel files upon request.

Further introduction and a discussion of the philosophy of the volunteer lake monitoring program and the parameters measured can be found on-line at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/waterres/smlakes/2006_Intro.pdf

WHAT WE MEASURE AND WHY

Measurements that were taken at all of the lakes in the small lakes monitoring program are discussed in this section to introduce the parameters and give context to the discussions of the data that follow.

Lake level is a relative measure of the water level that is measured daily using a staff plate installed on either a pole or a fixed height dock . These data can be used to look at the annual fluctuation of water levels in the lake, as well as response to increased water coming in due to storm events and the rate at which it drains. While most of the installed staff plates at lakes around the county are not surveyed to tie the data in with sea level, this could be done in the future to give actual elevations.

Daily **precipitation** is measured at the same time as lake water level in order to relate the lake level to inputs from the watershed. These data are collected either through a plastic rain gage provided by King County that can be emptied after reading each day or by a recording weather station if the volunteer chooses to purchase a reliable unit.

Level I volunteers measure Secchi depth and water temperature at a station in the middle of the lake weekly throughout the year. Level II volunteers measure 12 times between May and October when they collect water samples for laboratory analysis.

Secchi transparency is a common method used to assess and compare water clarity. It is a measure of the water depth at which a black and white disk disappears from view when lowered from the water surface. Factors in the water that affect Secchi readings include the number and size of particles present, such as algae and silt, as well as water color from dissolved organic molecules. Other factors that affect the readings are the amount of glare, choppiness of the water, shade from tall trees or the boat, and variation in the vision of the observers.

Water temperature is usually measured using an alcohol-based thermometer that holds a specific temperature long enough to allow the observer to read the value after retrieving the thermometer from the water.

Phosphorus and nitrogen are naturally occurring elements necessary for growth and reproduction in both plants and animals. However, many activities associated with residential development can increase these nutrients in water beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is often the nutrient in least supply, meaning that biological productivity is most often limited by the amount of available phosphorus. Increases in phosphorus can lead to more frequent and dense algae blooms – a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by cyanobacteria (bluegreen algae) that can produce toxins.

Total phosphorus (TP) and **total nitrogen (TN)** are both measured every time the level II volunteers collect water at the 1m depth. More specific forms of nitrogen and phosphorus are measured twice during the sampling period, when water is collected from 3 depths at the station: 1 m, the middle depth of the water column, and 1 m from the lake bottom. These include nitrate-nitrite, ammonia, and soluble reactive phosphorus, and the data can be used to infer the amount of oxygen present in deep water, as well as the presence of internal loading of nutrients from the sediments back into the lake water.

The **ratio of total nitrogen to total phosphorus (N:P)** can be used to determine if nutrient conditions are favorable for the growth of cyanobacteria (bluegreen algae), which can negatively impact uses of the lake and potentially produce toxins. When N:P ratios are near or below 25, nitrogen is as likely to be the limiting nutrient as phosphorus. Cyanobacteria may then be able to dominate the algal community due to their ability to take up nitrogen from air.

Chlorophyll-*a* concentrations indicate the abundance of phytoplankton in the lake. Although different species of algae contain varying amounts of chlorophyll, all algae use it in order to complete the photosynthetic pathway by which they store energy. For example, some cyanobacteria have other light-catching pigments and thus have relatively little chlorophyll compared to their biovolume.

Pheophytin is a product of chlorophyll decomposition and is generally measured along with chlorophyll as an indicator of how fresh or viable the phytoplankton in the sample area. Bottom sediments will contain a large amounts of pheophytin compared to chlorophyll, while actively-growing algae from surface waters will have very little pheophytin present.

A common method of tracking water quality trends in lakes is by calculating the **Trophic State Index (TSI)**, developed and first presented by Robert Carlson in a scientific paper dated 1977. TSI values predict the biological productivity of the lake based on three parameters that are easily measured: water clarity (Secchi), total phosphorus, and chlorophyll-*a.* The values are scaled from 0 to 100, which allow them to be used for comparisons of water quality over time and between lakes. If all of the operating assumptions about a lake ecosystem are met, the 3 TSI values should be very close together for a particular lake. When they are far apart in value, lake conditions and measurements should be examined to understand what special conditions exist at the lake or to evaluate the data for errors.

The Index relates to three commonly used categories of productivity:

- *oligotrophic* (low productivity, below 40 on the TSI scale - low in nutrient concentrations, small amount of algae growth);
- *mesotrophic* (moderate productivity, between 40 and 50 on TSI scale – moderate nutrient concentrations, moderate growth of algae growth); and
- *eutrophic* (high productivity, above 50 – high nutrient concentrations, high level of algae growth).

A lake may fall into any of these categories naturally, depending on the conditions in the watershed, climate characteristics, vegetation, and rock and soil types, as well as the shape and volume characteristics of the lake basin. Activities of people, such as land development, sanitary waste systems, and agricultural practices, can also increase productivity, which is known as "cultural eutrophication."

1.0 BEAVER LAKE

In the mid-nineties, residents at both basins of Beaver Lake (Figure 1: smaller north basin referred to as Beaver-1 and large main basin referred to as Beaver-2) began monitoring water quality through participation in the King County Lake Stewardship Program (KCLSP). Volunteer monitoring efforts have continued through 2012. Physical and chemical data collected through the years of monitoring indicate that this lake in the City of Sammamish over time has remained moderate (Beaver-2) to high (Beaver-1) in primary algal productivity (mesotrophic and eutrophic, respectively), with fair to very good water quality.

Figure 1. Aerial photo of Beaver Lake showing both major lake basins. A third small basin with the lake outlet is located in the bottom left of the figure.

1.1 Physical Parameters

1.1.1 Water levels and precipitation

Excellent precipitation and water level records were kept for the main basin (Beaver-2) from mid-October 2012 through September 2013 by volunteer monitors.

Water levels in Beaver-2 increased regularly in response to storm events (Figure 2). The lake showed a pattern characteristic of the regional pattern of early autumn lows, followed by lake level increase with the onset of winter rain, similar to previous years. The record supports the relationship between rain events and a short-lived positive response in lake level. Typically, the highest lake levels do not usually persist longer than a few days to a week when the outlet is flowing freely, but there have been instances in the past when the outlet weir has been clogged with debris and when beaver activity has plugged the outlet channel, leaving lake levels high for longer periods. The winter high water levels decrease slowly through the summer months, leading to the minimum water level at the end of water year 2013.

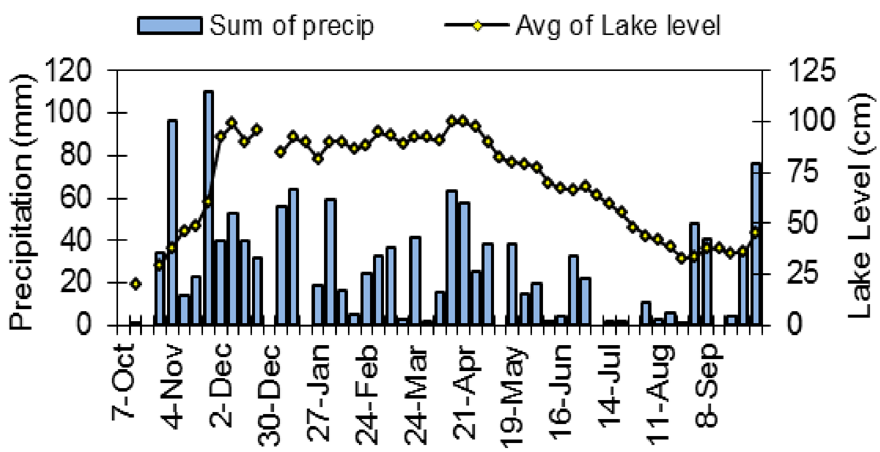

Figure 2. Water Year 2013 Beaver-2 lake level and precipitation.

Residents on Beaver-1 did not collect daily precipitation or lake level information, but the channel between the two lakes rarely shows perceptible flow between the water bodies, suggesting water levels are approximately the same or equalize quickly. Continuous lake level measurements made by the King County hydrology group for the Beaver Lake Management District showed that water levels are generally equivalent between the two basins (unpublished data).

1.1.2 Water clarity and temperature

Beaver-2 Level I volunteers collected weekly temperature and Secchi transparency data throughout the year, while Level II volunteers made temperature and Secchi measurements from late May through October as they collected water samples. Secchi transparency measured by the Level I volunteer from October through September ranged between 2.0 m and 4.0 m, with an average of 3.0 m (Figure 3). The Secchi data from the Level II volunteer, measuring from May through October only, ranged from 1.8 to 2.6 m, with a summer average of 2.3 m.

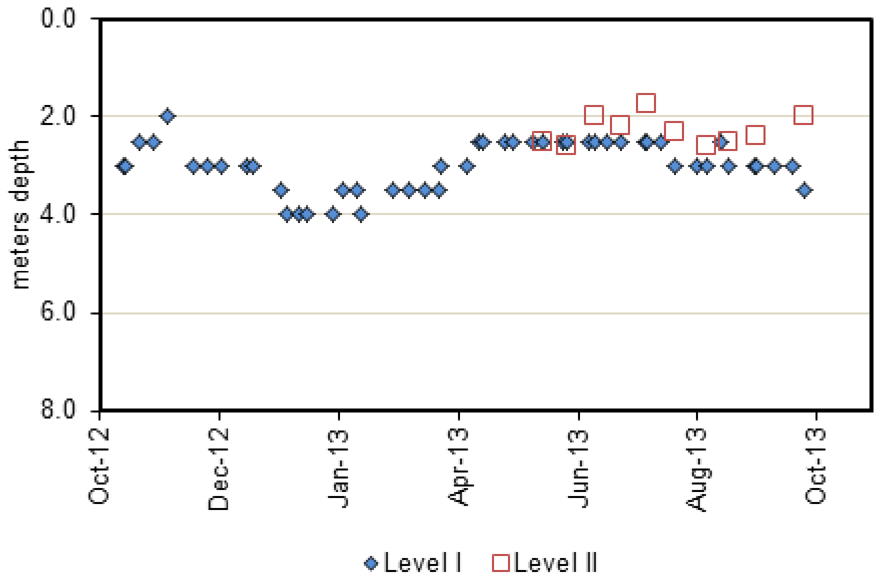

Figure 3. Water year 2013 Beaver-2 Secchi transparency (note inverted Y-axis).

Over all, the data show that water transparency fluctuated about 2m in range over 2013, with fairly good agreement between the two different observers, who may vary in how they read the endpoint of the Secchi measurement depending on their visual acuity and reaction to glare off the water surface, the type of boat they are using, and how close to the water surface they can safely view the disk. The level II observer tended to read the Secchi depth at lower values than the level I observer.

The north basin (Beaver-1) was monitored for Secchi transparency and water temperature by the Level II monitor from early May to the end of October 2013. Transparency remained remarkably steady, ranging from 1.1 m to 2.4 m with an average of 1.5 m (Figure 4). Beaver-1 was at the lower end of clarity for the lakes monitored by the KCLSP in 2013, most likely due to the tea-colored water coming from wetland ELS 21, which drains directly into the lake.

Surface water temperatures in Beaver-2 ranged between 4.0 to 26.0 degrees Celsius between October and September of water year 2013 with an annual average of 14.1 (Figure 5). The May – October average of 21.7 degrees Celsius was measured by the weekly volunteer and 20.9 degrees Celsius average was measured by the water quality monitor. An extended period without cloudiness or rain in summer 2013 is reflected by the high shallow water temperatures achieved in the lake in July and August.

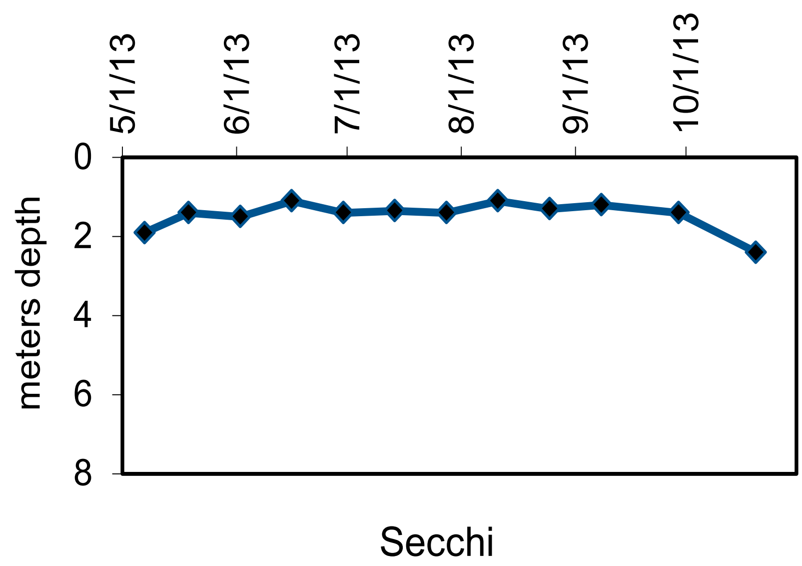

Figure 4. Water year 2013 Beaver-1 Secchi transparency (note inverted Y-axis)

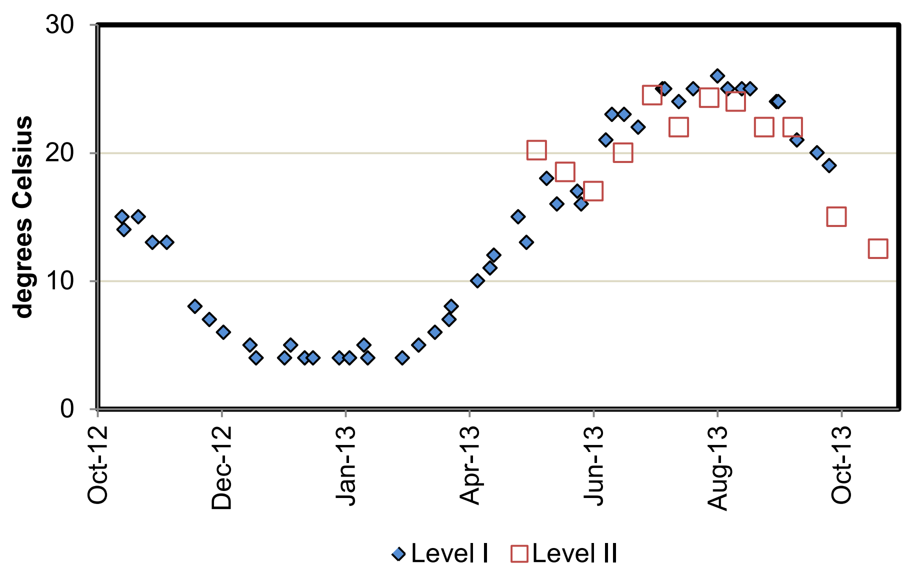

Figure 5. Water year 2103 Beaver-2 temperature at 1m depth.

Temperatures for Beaver-1 from May through October ranged from 11.5 degrees Celsius to 25.0 degrees Celsius with an average of 19.9 degrees (Figure 6) that places the north basin of Beaver Lake among the cooler lakes measured during the 2013 water quality sampling season.

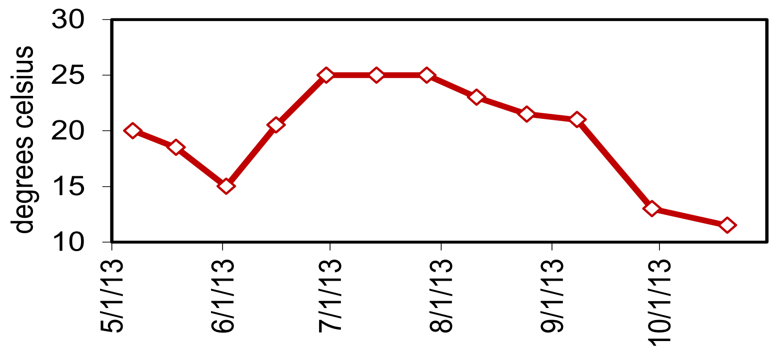

Figure 6. Water year 2013 Beaver-1 temperature at 1m depth.

Comparison for Secchi transparency and 1m temperatures can be made between the two basins for the May–October monitoring program (Level II). Beaver-2 has consistently greater water clarity than Beaver-1 throughout the entire sampling season (Figure 7). However, neither lake showed a great deal of variation in 2013 until fall, when both lakes became significantly more clear, consistent with a decrease in phytoplankton in the shallow water due to thermal mixing and the change in season.

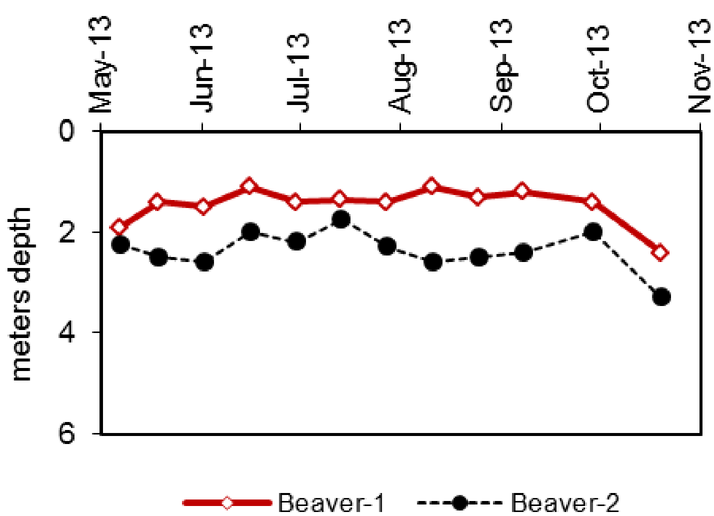

Figure 7. Secchi measurements for Beaver-1 and Beaver-2.

Water temperatures were closely correlated between the two basins (Figure 8), with both lakes cooling down in early June and then warming quickly as the weather improved in late June–July.

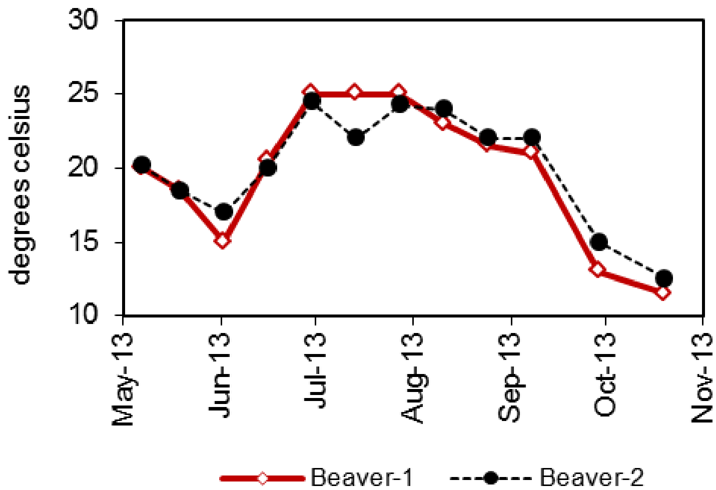

Figure 8. Water temperatures at 1m in Beaver-1 and Beaver-2.

Mean summer water temperatures for both lake basins during the monitoring period have varied from year to year, but show no overall trend toward change (Figure 9). The two basins do not track each precisely, but in most years are fairly close in value. Regressions run through the data over time show no significant directional trends to-date.

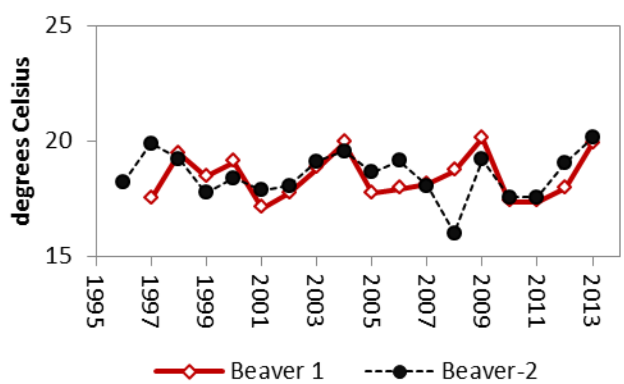

Figure 9. Mean May – October 1m water temperatures in Beaver-1 and Beaver-2.

1.2 Nutrient and chlorophyll analysis

1.2.1 Nutrients and N:P ratio

During the monitoring period, in Beaver-2 both TN and TP values remained relatively steady throughout the season, with no seasonal changes in concentrations found during the monitoring period (Figure 10). These variations are small enough that they may be within the accuracy of the sampling and analytical methods.

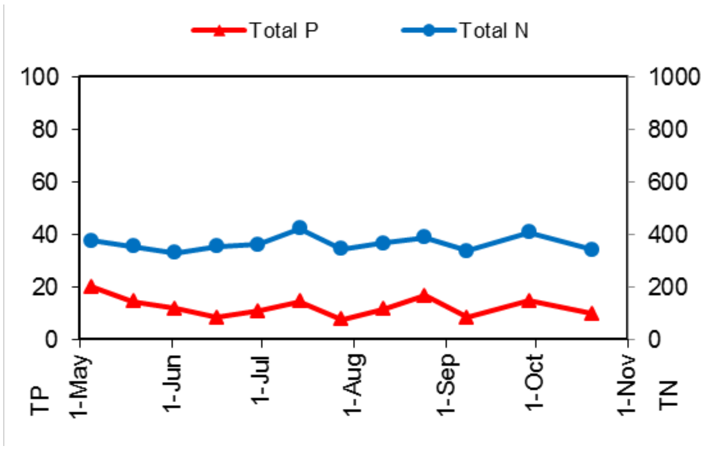

Figure 10. 2013 Beaver-2 total phosphorus (TP) and total nitrogen (TN) values in ug/L Note that the right Y-axis for TN is 10x the magnitude of the left Y-axis for TP.

Beaver-1 had higher levels of both total phosphorus and nitrogen than Beaver-2 (Figure 11), but much less than in 2011 when the nitrogen-fixing bloom of *Anabaena* caused TN levels in Beaver-1 to skyrocket (see 2011 annual report for discussion). TN was highest in May–June and then stabilized over the rest of the sampling period. Phosphorus was also highest in May, but declined earlier than nitrogen.

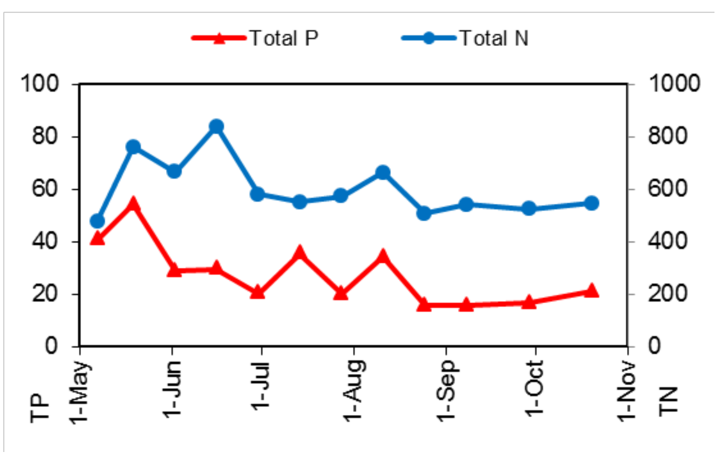

Figure 11. 2013 Beaver-1 total phosphorus (TP) and total nitrogen (TN) values in ug/L Note that the right Y-axis for TN is 10x the magnitude of the left Y-axis for TP.

The ratio of nitrogen to phosphorus (N:P) can be used to determine if nutrient conditions are favorable for the growth of cyanobacteria (bluegreen algae) that can impact beneficial uses of the lake (see "What We Measure and Why" at the beginning of this report).

In Beaver-2, the N:P ratio ranged from 18.8 to 44.8 (Figure 12), with values below 25 on 3 dates and an average of 31.5, which suggests that nutrient conditions in the larger basin were sometimes favorable for nuisance bluegreen growth in 2013, but generally not conducive to a major bloom during the period. Late in Fall 2013, a bloom of *Aphanizomenon flos-aquae* was tested for toxicity, but was found to be benign.

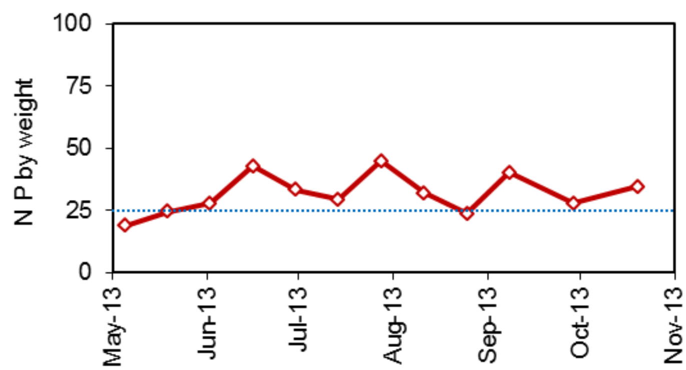

Figure 12. 2013 Beaver-2 N:P ratios in 1m water. A ratio below 25 may indicate good conditions for cyanobacterial success.

The N:P ratio in Beaver-1 ranged from 11.7 to 34.5 with an average of 24.4 (Figure 13). The ratios from 5 individual dates were below 25, mostly in the late spring, which suggested that nutrient conditions that were most favorable for nuisance bluegreen algae growth at that time, but no major blooms were reported in 2013.

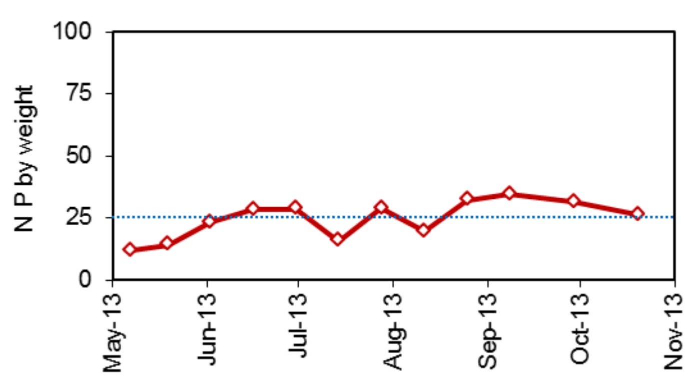

Figure 13. 2013 Beaver-1 N:P ratios in 1m water. A ratio below 25 may indicate good conditions for cyanobacterial success.

Changes in average N:P ratios over time can be analyzed to look for long term shifts in nutrient conditions in lakes that may favor cyanobacterial blooms, which are known to produce substances on occasion that are toxic to mammals. Both Beaver-1 and Beaver-2 are shown in Figure 14. Neither lake has produced data to-date suggesting a trend over time towards lower N:P ratios. While there is a much larger range of average values found in Beaver-2 than in Beaver-1, the distribution of values appears to be due to inter-annual variability and not driven in a particular direction over time.

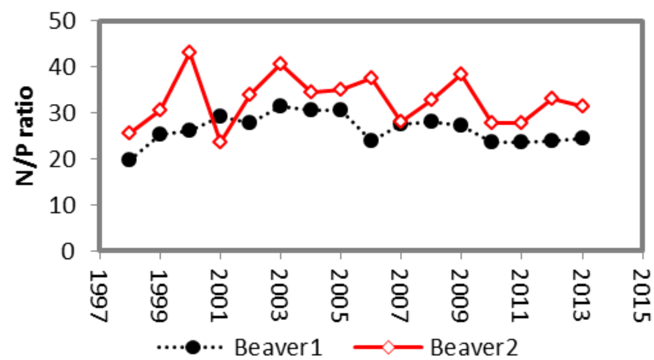

Figure 14. Average annual N:P ratios for both basins in 1m water. A ratio below 25 may indicate good conditions for cyanobacterial success.

1.2.2 Chlorophyll and pheophytin

Chlorophyll a concentrations in Beaver 2varied between 2 to 6 ug/L through most of the season, climbing to a peak of approximately 10 ug/L peak in early October, which was very similar to 2012. Pheophytin (degraded chlorophyll) levels were at or slightly above detection levels, but remained low with the exception of values in October near the end of the phytoplankton season, when temperatures were dropping and lake water began to mix from top to bottom (Figure 15).

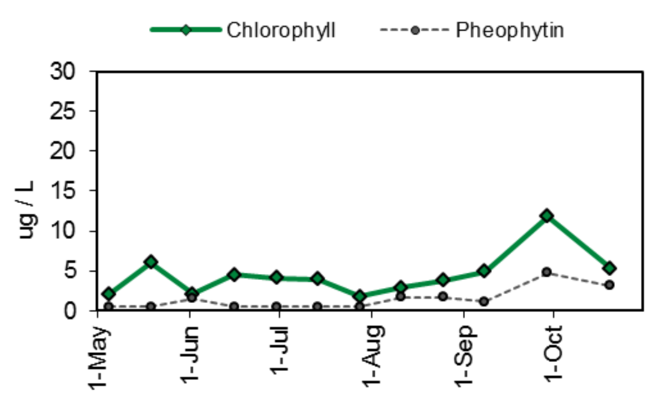

Figure 15. Water year 2013 Beaver-2 Chlorophyll a and Pheophytin concentrations.

In Beaver 1, chlorophyll a concentrations were higher and more variable through the season than in Beaver-2 (note Y-axis scale change) starting at a high level in May, dropping to a low in mid-summer and climbing again in the fall (Figure 16). This is consistent with nutrient limitation, when nutrients are exhausted in shallow water during spring by quickly growing algae and then are not replenished until water mixing in the fall brings nutrients from the deep water back up to shallow water where light is available for phytoplankton growth. Pheophytin levels were higher in the spring, particularly during the period when the temperature showed overall cooling, but were close to minimum detection levels by the end of the season.

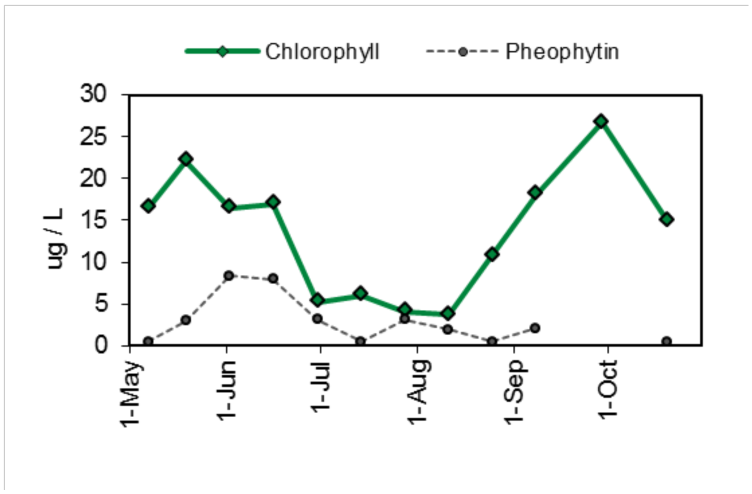

Figure 16. Water year 2013 Beaver-1 Chlorophyll a and Pheophytin concentrations.

1.2.3 Water column profiles

Samples through the water column were taken on two dates during the monitoring season to characterize temperature and nutrient differences by water depth. The first was in May at the beginning of the warm period to look at conditions near the onset of thermal stratification, and the second was in late August, when thermal stratification had been established for some time, but mixing due to seasonal changes had not yet begun.

Profile data on Beaver-2 indicates that thermal stratification was present from early summer and persisted through late summer (Table 1). Similar concentrations of total phosphorus were found at all depths in May, but the deep water was much higher by August, suggesting that anoxic conditions released phosphorus from the sediments through summer. The values for orthophosphate (OPO4) in deep water in August are consistent with this idea. Ammonia (NH3), which is another indicator of low oxygen conditions in the deep water, also was not very high in May but elevated greatly by August, indicating that anoxia in the deep water contributed to increased concentrations through the summer.

Chlorophyll *a* profile data indicated that higher concentrations of phytoplankton were in the shallow water in both May and August. However, both dates have moderately low chlorophyll concentrations overall, suggesting the lake did not support an abundance of phytoplankton and had only moderate primary productivity.

Table 1. Beaver-2 Profile Sample Analysis Results. Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg/L. UV254 is in absorption units. Sample values below minimum detection level are marked in bold, red with the MDL value.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Beaver-2	5/19/13	2.5	1	18.5	6.0	0.5	0.354	**0.005**	0.0146	**0.0020**	0.236	13.3
Beaver-2			7	8.5	0.5	4.66	0.412		0.0111			
Beaver-2			14	8.0			0.473	0.016	0.0164	0.0022		
Beaver-2	8/25/13	2.5	1	22.0	3.8	**1.7**	0.390	0.007	0.0166	**0.0010**	0.200	14.0
Beaver-2			7	8.0	0.8	1.5	0.370		0.0153			
Beaver-2			14	6.0			0.928	0.528	0.1800	0.0391		

The UV254 value shows that some tea coloration is present in the water of Beaver-2 and represents a moderate level of dissolved organic carbon, while the total alkalinity indicates soft water that is not well buffered against pH change.

Profiles from Beaver-1 (Table 2) showed that thermal stratification also set up in the lake by early spring and lasted through late summer. TP and TN levels were already elevated in the deep sample in May and were accompanied by significant ammonia (NH3) and orthophosphate (OPO4) concentrations, indicating that oxygen was already depleted in the deepest part of the lake. That was confirmed in the August profile with the same parameters showing an even greater difference than in May.

Chlorophyll *a* data suggest the most algae were found in the surface water. The chlorophyll levels were particularly high in August in the 1 m sample, but were lower overall than in 2011 when there was a large *Anabaena* bloom.

Table 2. Beaver-1 Profile Sample Analysis Results. Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg/L. UV254 is in absorption units. Sample values below minimum detection level are marked in bold, red with the MDL value.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Beaver-1	5/19/13	1.4	1	18.5	22.1	3	0.763	**0.015**	0.0542	**0.0021**	0.424	9.95
Beaver-1			7	7.0	**6.7**	7.12	0.456		0.0232			
Beaver-1			14	5.0			0.595	0.069	0.0720	0.0342		
Beaver-1	8/25/13	1.3	1	21.5	10.8	**0.5**	0.509	**0.003**	0.0158	**0.0008**	0.386	9.9
Beaver-1			7	6.5	0.5	4.39	0.460		0.0182			
Beaver-1			14	5.0			0.812	0.348	0.1670	0.0833		

The high UV254 values are indicative of the marked tea color of the water produced by dissolved organic carbon molecules leached from the upstream wetland, and are approximately double that of Beaver-2. The low alkalinity value shows that the lake water is very soft and quite poorly buffered against pH change.

1.3 TSI Ratings

The 2013 Beaver-2 TSI indicators were approximately equidistant through the mesotrophic range, with Secchi the highest and TP the lowest on the threshold between mesotrophic and oligotrophic (Figure 17), down from the values in 2009 when there was an *Anabaena* bloom. Over time, the chlorophyll and Secchi transparency TSI values have been closer together than the value for phosphorus. Conditions since 1999 appear to be stable, and Beaver-2 remains in the mid mesotrophic range.

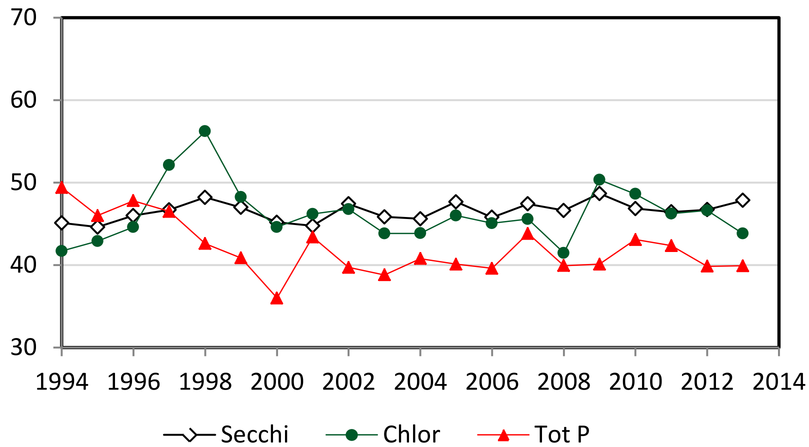

Figure 17. Beaver-2 Trophic State Indicators through 2013.

In 2013, all three TSI indicators for Beaver-1 were close to each other in the low to mid-range of eutrophic conditions (Figure 18). The high chlorophyll and Secchi TSI in 2011 was not repeated in 2013.

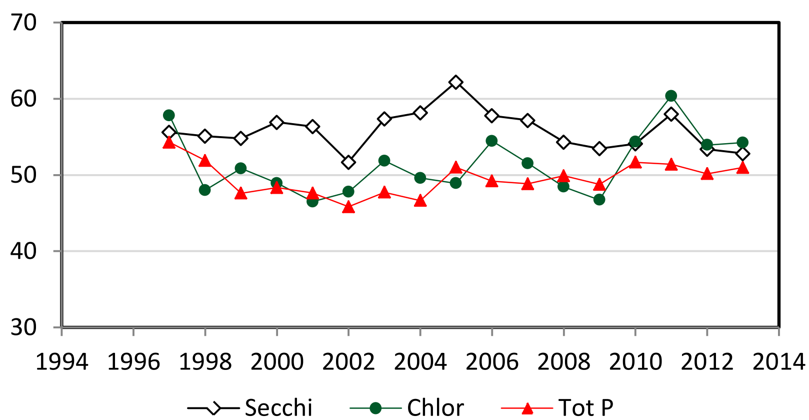

Figure 18. Beaver-1 Trophic State Indicators through 2013.

If a trend line is drawn through the average of the 3 indicators, there is no significant change over time. However, a trend line run through the TSI-TP indicator values since 1998 shows a significant increasing trend over time (Figure 19). The correlation coefficient of 0.5687 indicates that 57% of the variability over time can be explained by the upward trend. This suggests that increased nutrients may be entering the lake over time, perhaps from changes occurring in the high quality wetland feeding into the lake or from the stormwater ponds that sometimes drain to the main inlet.

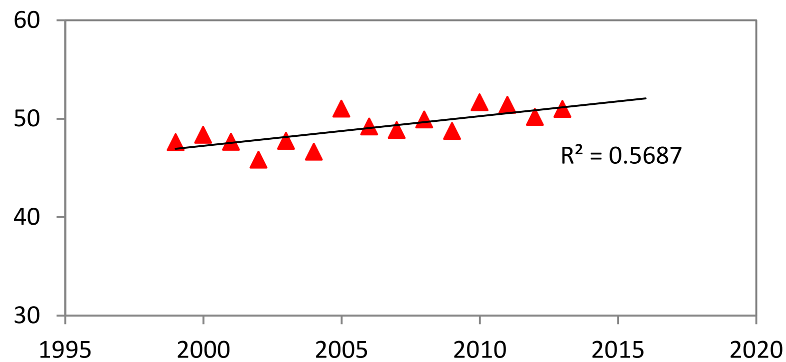

Figure 19. Annual average Beaver-1 TSI-TP. R2 is the correlation coefficient of the regression line drawn through the points.

1.4 Conclusions and Recommendations

Based on monitoring data, water quality in Beaver 2 has remained stable over recent years, and in general N:P ratios do not promote bluegreen algae blooms, although the Anabaena bloom in 2009 shows that cyanobacterial blooms can still occur on occasion.

In Beaver 1, there is a slight, but steadily increasing trend in phosphorus TSI values since 1998. The cyanobacterial summer bloom of 2011 has not been repeated since then. A close eye should be kept on the lake over the next few years to see if the increase in the phosphorus indicator continues. Continued monitoring of both nutrient and chlorophyll concentrations should be done to insure recreational safety and to assess water quality conditions into the future as development of the remaining in the watershed proceeds.

2.0 PINE LAKE

Volunteer monitoring began at Pine Lake in the 1980s and has continued, with some gaps, through 2013. The data indicate this lake is very lightly colored and currently low in primary productivity (oligotrophic) with very good water quality. A deteriorating wetland that delivered large amounts of nutrients to Pine Lake was diverted in the 1990s, an action which was effective in curbing phosphorus inputs to the lake and resulted in an increase in lake water quality. Productivity decreased between 1994—1998 and is currently steady.

2.1 Physical Parameters

2.1.1 Water level and precipitation

Excellent precipitation and water level records for Pine Lake were compiled by the volunteer monitor for the 2013 water year. Water levels in the lake responded to winter storm events and increased through mid-December, but then remained relatively steady until late April when the water level began to slowly decrease through September at the end of the water year. Precipitation and lake level data collected since 1995 suggest the lake rises with the onset of autumn rains and remains elevated through the winter and into spring. However, the highest lake levels do not usually persist longer than a week or two (Figure 20).

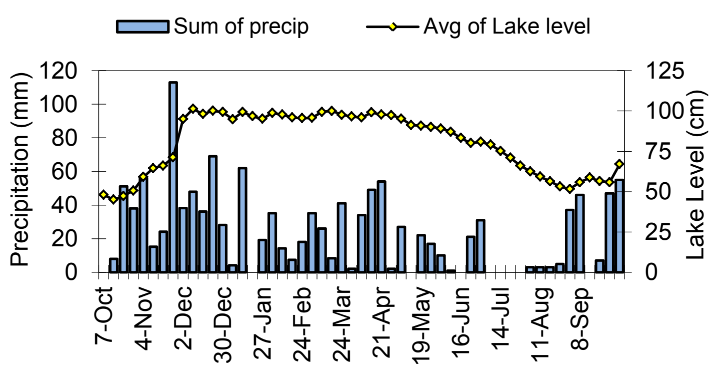

Figure 20. Water year 2013 Pine Lake levels and local precipitation.

2.1.2 Water clarity and temperature

Weekly temperature and Secchi transparency data were also collected throughout the 2013 water year. Because the same person collected data for both level I and level II monitoring efforts, the values coincide for those dates when water was also collected.

Secchi transparency ranged through the year between 2.8 and 5.8 m (Figure 21). The annual average was 4.5 m, while the summer average was 4.6 m, which placed it in the higher range of clarity for monitored small lakes in 2013. The lowest transparency values were recorded in January, possibly from a winter algae bloom as the low levels of precipitation during that period suggest that there may have been a period of sunshine to stimulate algae growth. There is a past history of winter blooms in Pine Lake that adds weight to this possibility.

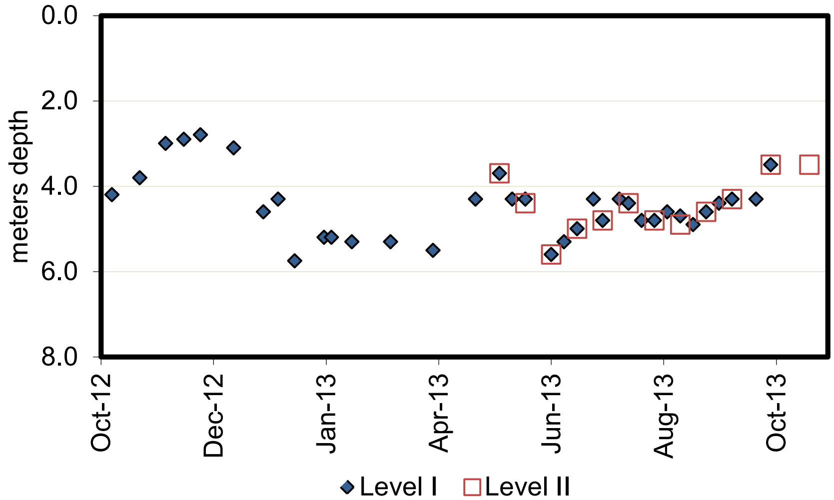

Figure 21. 2013 Pine Lake Secchi transparency (note inverted Y-axis).

Surface water temperatures ranged between 5.0 to 26.0 degrees Celsius in 2012, with an annual average of 17.1 and a summer average of 22.6 degrees, which was warmer than in 2012 (Figure 22).

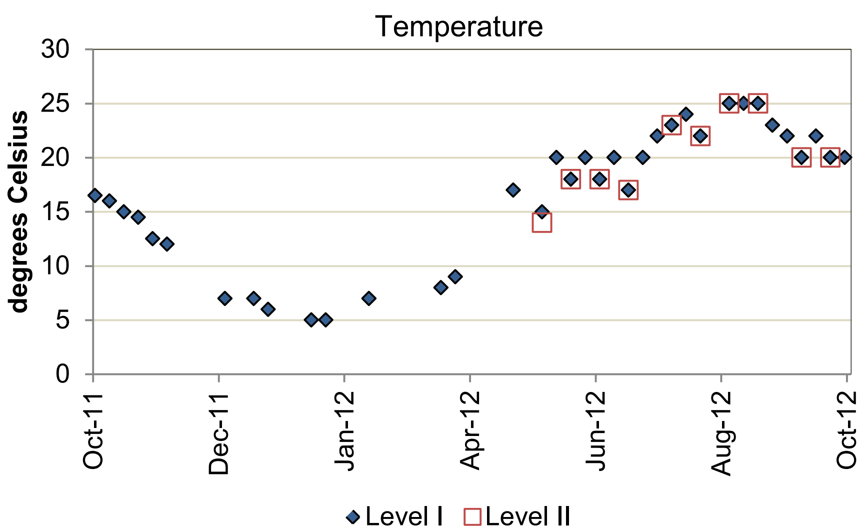

Figure 22. 2013 Pine Lake water temperatures at 1m.

Mean summer water temperatures during the time period that Pine Lake has been monitored have varied from year to year, but show no overall trend of directional change over time, although the 2013 average is the highest to-date for the years with data (Figure 23).

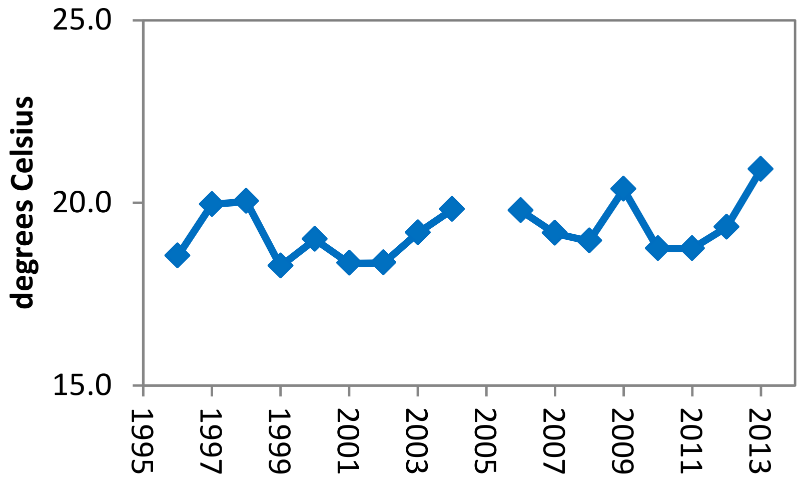

Figure 23. Mean May - October 1m water temperatures for Pine Lake over time.

2.2 Nutrient and Chlorophyll Analysis

2.2.1 Nutrients and N:P ratio

Samples collected by volunteers are analyzed for total phosphorus (TP) and total nitrogen (TN) concentrations at one meter depth.

Over the monitoring period for Pine Lake, both TN and TP values remained relatively constant, with little variation over time (Figure 24). There was a slight decrease in TN from the initial values in spring, followed by a minor increase in TN in October. TP increased over the first 3 dates and then dropped to a minimum, which was maintained until the first of October.

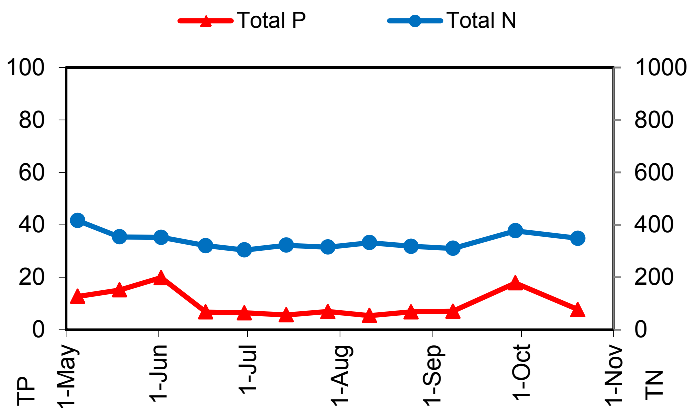

Figure 24. 2013 Pine Lake total phosphphrus (TP) and total nitrogen (TN) concentrations in µg/L. Note that the right Y-axis for TN is 10x the magnitude of the left Y-axis for TP.

The N:P varied from 19 to 45 with an average of 32 (Figure 25). Three dates produced N:P ratios below 25 and two of these were in the spring, concurrent with the increase in phosphorus, suggesting good conditions for cyanobacteria could have occurred during that time. However, the subsequent increase in N:P which suggests that nutrient conditions in the lake were generally not favorable for nuisance bluegreen blooms during most of the monitoring season.

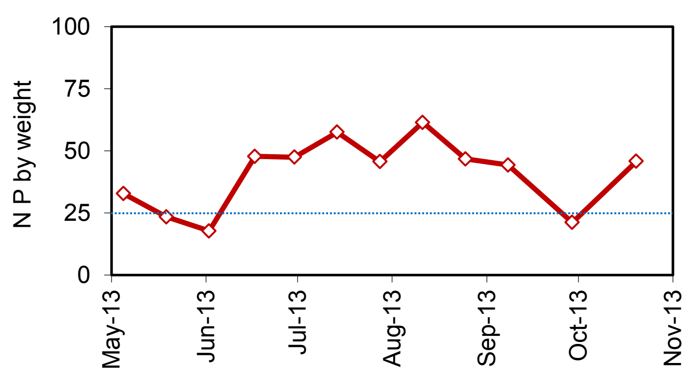

Figure 25. 2013 N/P ratios by weight.

2.2.2 Chlorophyll and pheophytin

Chlorophyll *a* concentrations in Pine Lake remained low throughout most of the sampling season, with a small peak on the second sample in late May that was not sustained increasing again in October on the last two sample dates (Figure 26). Pheophytin (degraded chlorophyll) levels remained near or below detection levels throughout the entire season, indicating that no old chlorophyll from the sediment was included in the water samples.

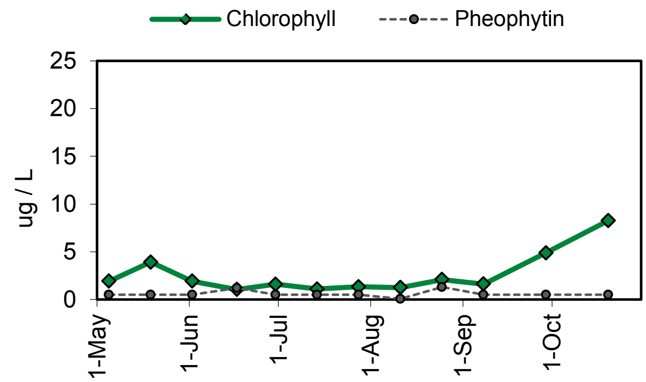

Figure 26. 2013 Pine Lake Chlorophyll a and Pheophytin concentrations.

2.2.3 Profile samples

Samples through the water column were taken on two dates during the monitoring season to characterize temperature and nutrient differences by water depth. The first was in May at the beginning of the warm period to look at conditions near the onset of thermal stratification, and the second was in late August, when thermal stratification had been established for some time, but mixing due to seasonal changes had not yet begun.

Temperature data from the profile sampling indicates that thermal stratification was present in early summer and persisted through late summer (Table 3). Higher concentrations of phosphorus were found in deep water in May and had increased by August, suggesting that some phosphorus was released from bottom sediments to deep water. However, deep water ammonia (NH3) remained low on both dates, indicating that oxygen depletion may have been minimal. Orthophosphate (OPO4) values also remained low, as did chlorophyll values, suggesting that phosphorus recycling from the sediments was minor and did not have a significant effect on phytoplankton abundance.

Table 3. Pine Lake Profile Sample Analysis Results. Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 is in absorption units. Sample values below minimum detection level are marked in bold, red with the MDL value.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Pine	5/19/13	4.4	1	18.0	3.9	**0.5**	0.354	**0.005**	0.0151	**0.0020**	0.0725	22.4
Pine			5	13.0	6.8	**0.5**	0.309		0.0125			
Pine			10	9.0			0.335	0.013	0.0159	0.0020		
Pine	8/25/13	4.6	1	24.0	2.1	**1.3**	0.318	**0.002**	0.0068	**0.0010**	0.062	21.4
Pine			5	24.0	2.1	**0.5**	0.311		0.0082			
Pine			10	11.0			0.490	**0.005**	0.0411	**0.0021**		

Both profile dates have similar chlorophyll concentrations at both shallow and mid-depths, showing that phytoplankton in the lake had limited resources in the zone that sunlight penetrates, resulting in generally low biological productivity.

The UV254 values were indicative of clear water containing little dissolved organic carbon, unlike the tea color of the water in Beaver Lake that impacts water clarity. The alkalinity value, while still low, is higher than found in neighboring Beaver Lake. This most likely relates to the higher degree of development and soil disturbance in the Pine Lake watershed. However, Pine Lake water still contains fairly soft water that is not well buffered against pH change.

2.3 TSI Ratings

The 2013 Pine Lake TSI indicators were all fairly close to each other across the threshold between oligotrophy and mesotrophy, with TSI-Secchi just above in the low mesotrophic range, while chlorophyll and phosphorus were just below in high (Figure 27). The average of all three TSI indicators has been fairly constant since 2003, suggesting that conditions in Pine Lake have stabilized in the upper ranges of oligotrophy.

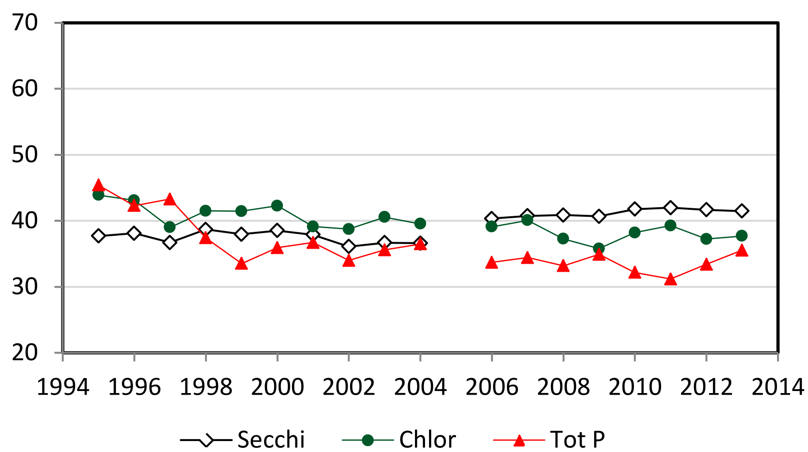

Figure 27. Pine Lake Trophic State Indicators through 2013.

A trend line run through the TSI-TP indicator values since 1998 shows a decreasing trend over time (Figure 28), although the last two years have increased from the overall low in 2011. A correlation coefficient (R^2) value of 0.313 indicates that 31% of the variability over time can be explained by a declining trend. This is less robust than the same line drawn in 2012, which had an R2 of 0.48. This change between years illustrates the impact of variability on statistical correlations and the need for long term data sets to validate trends.

The declining trend in phosphorus over time supports the effectiveness of the 1990s diversion of the inlet coming into Pine Lake from a degraded wetland in controlling nutrient inputs to the lake, as well as the more stringent stormwater controls connected to new residential development.

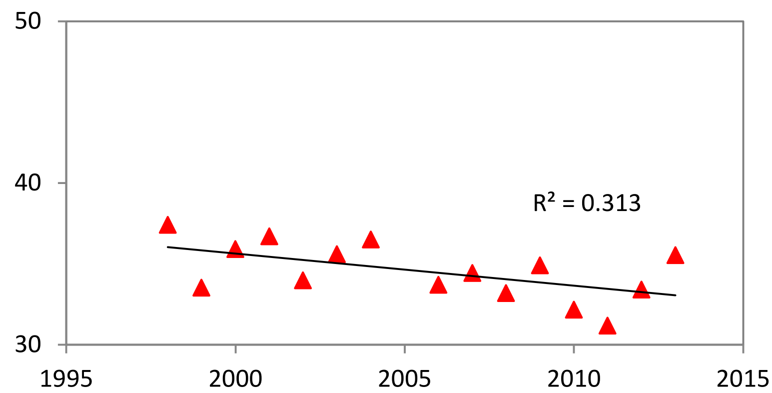

Figure 28. Annual mean TSI-TP since 1998. R2 is the correlation coefficient of the regression line drawn through the points.

2.4 Conclusions and Recommendations

Based on monitoring data, overall water quality in Pine Lake appears to have stabilized during the period measured, with a low rate of productivity during summer months. High average N:P ratios could indicate nutrient conditions are usually not favorable for nuisance bluegreen algae blooms during the recreational season. Continued monitoring of nutrient and chlorophyll concentrations will assess future conditions and track changes, as well as providing additional data to assess the statistical significance of the apparent decline in TP over time.