Consent Agreement Annual Report
2012

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Summary - 2012

Overview

The goal of the Consent Agreement is to restore and preserve the water quality of Big Platte Lake (Lake) and its watershed. This goal is being advanced by minimizing the flow and phosphorus discharge from the Platte River State Fish Hatchery (Hatchery, PRSFH) and by developing strategies to reduce other DEQ permitted and non-point phosphorus loads from the watershed.

Compliance with Consent Agreement

Figure 1 summarizes the level of compliance with the Consent Agreement. The Consent Agreement mandates that the Hatchery net annual load should be limited to a maximum of 175 lbs. of phosphorus per year. The corresponding maximum load for any consecutive three month period is 55 lbs of phosphorus, as calculated using a running average. The actual net Hatchery annual loading for 2012 was 30.05 lbs of phosphorus and the maximum 3 month loading was 23.49 lbs of phosphorus. These amounts are 17.2% of the annual loading limit and 42.7% of the 3 month loading, respectively, and do not exceed either of the maximum allowable phosphorus loads. The average water use at the Hatchery was 7.0 million gallons per day (mgd) which is 65% less than the Consent Agreement limit of 20 mgd.

The average volume-weighted total phosphorus concentration of Big Platte Lake was 7.77 mg/m^3 in 2012. The water quality goal of 8.0 mg/m^3 of phosphorus was achieved 64% of the time. This is not consistent with the goal of 95% attainment as stipulated in the Consent Agreement.

A total of 18,942 adult coho and 628 adult Chinook salmon passed the Lower Weir in 2012. These numbers are in compliance with the Consent Agreement limits of 20,000 adult coho and 1,000 adult Chinook salmon.

Major Accomplishments for 2012

1 All requirements of the Settlement Agreement have been met by all parties for 2012.

2 PRSFH staff has completed the task of working out the laboratory procedures regarding the measurement of total phosphorus. An acceptable SOP has been completed (Appendix A).

3 A series of laboratory tests have been completed that have identified iron interference issues associated with the measurement of total phosphorus concentrations in water samples. The digestion time has been increased to 2.5 hours to insure complete phosphorus recovery (Appendix A).

4 The calculation of the net phosphorus loadings from the hatchery has been refined to include the flow from the Hot Pond.

5 The Sigma and ISCO automatic sampling equipment are programmed to obtain 72 hour composite samples. This schedule is working well and provides for essentially continuous sampling of the phosphorus concentration of various inlet and output Hatchery flows. Recent data collected using this strategy has improved the accuracy of phosphorus mass balance calculations for the Hatchery.

6 Two bioenergetics papers have been peer reviewed and published in Aquaculture. One paper has been submitted and is waiting for review, and two are in preparation.

7 The parties have been directly involved in the update of the Platte River Watershed Plan that is nearing completion.

8 A study in progress at the Hatchery that indicates that adding alum to toilet flushes reduces the phosphorus concentration in the septic tank overflow by about 60%. The final results of this experiment could have significant implications across the watershed for phosphorus loadings.

9 The database is being improved on an ongoing basis and a refined version is in development.

Recommendations for 2012

1 It is recommended that a portable tablet device be used to record daily flow and other operational data to reduce errors and data processing time. These data should be sent via email to database for conversion into flow rate and calculation of the phosphorus monthly load.

2 The Implementation Coordinator should continue efforts to calibrate and validate the fish bioenergetic and Hatchery process models and publish the results in peer reviewed journals, whenever possible and appropriate.

3 Efforts should continue to improve the accuracy of the phosphorus mass balance calculations for the Hatchery. A project should be conducted to improve existing estimates of the fish tissue phosphorus content.

4 Efforts should be made to refine the minimum number of samples needed to characterize the annual average phosphorus concentration of Big Platte Lake and to determine compliance with the Consent Agreement water quality standard.

5 It is recommended that work continue on the watershed plan and that it be expanded into the Upper Platte River Watershed. In addition it is recommended that the current BASINS model be re-calibrated for the Lower Platte River Watershed using data collected during recent years. Following re-calibration, it is recommended that the BASINS model be expanded to the upper watershed. This will require additional data in the Upper Platte River Watershed to support the development of the BASINS model and models for total phosphorus for Long Lake and Lake Ann.

6 It is recommended that a shoreline E. coli and *Cladophora* survey be conducted around Big Platte Lake every 5 years. The survey should consist of two sampling periods. The first sampling should be conducted in the early summer and should measure phosphorus and fecal coliform bacteria and map the growth of *Cladophora* as an indicator of sources of phosphorus. The second survey should be conducted in late summer to determine if summer residents increase local concentrations of phosphorus or the number of indicator bacteria.

7 It is recommended that the septic tank demonstration project be continued through 2013.

8 Efforts should be made to quantify the effect of the Honor WWTP on the water quality of Big Platte Lake. This effort should include resumption of sampling of Collision Creek, the Platte River at Pioneer Road and the Henry Bridge, and an upstream location on the North Branch to be determined.

9 All SOP documents and equipment maintenance schedules should be reviewed and updated annually. Certification letters regarding the accuracy of the net phosphorus loading, fish production, and weir numbers in the database should be sent to the Implementation Coordinator for inclusion in the Annual Report.

10 The Implementation Coordinator should continue efforts to calibrate and validate the water quality models for the lake.

11 It is recommended that sampling of Little Platte Lake and secondary tributaries be resumed when funding is available. The cycling of various forms of nitrogen is of particular interest because it appears that nitrogen limits algal growth during the summer in Little Platte Lake. An annual mass balance budget for various forms of nitrogen should be constructed.

12 The functionality and reliability of the database requires significant maintenance, it is recommended that these efforts continue. It is recommended that a refined smaller version of the database developed and documented.

Acknowledgements

The Implementation Coordinator would like to take this opportunity to again thank Gary Whelan (MDNR Fisheries Division) and Wil Swiecki (PLIA) for their continuing contributions to this project. Gary has extraordinary leadership and management skills and has kept this project focused and moving forward. Wil has been tireless in his efforts to ensure the reliability of the data and has displayed incredible perseverance working toward the PLIA goal of preserving the water quality of the Lake. As a result, excellent coordination and communication has been maintained within our group as well as with many outside organizations and individuals. The minutes of our coordination meetings in 2012 are contained in the Appendix B.

In addition we wish to commend the following individuals from the MDNR Fisheries Division: Edward Eisch for his support of the Consent Agreement requirements and the overall management of the facility; Aaron Switzer for work on fish production and his broad water quality sampling expertise that helps to guide other staff; Paul Stowe for his efforts on sample collection of Hatchery, Lake, and tributaries; and Nikki Sherretz for her work on laboratory measurement of total phosphorus.

We also acknowledge and appreciate the support and assistance of several individuals from the Platte Lake Improvement Association (PLIA): Jim Berridge for his work on the database; Mike Pattison for his regular participation in the coordination meetings and his work on the web site; Steve Peterson for his marketing and public relations efforts; and Maris Ziemelis for taking over the PLIA task of independent measurement of the Secchi depth in Big Platte Lake.

Finally, we appreciate the efforts of Scott McNaught from Central Michigan University who has reviewed the historical plankton data, recommended improved methods for sample collection, added biomass measurements, and contributed annual reports.

Hatchery Operations

Net Total Phosphorus Load

The water used to culture fish becomes enriched with phosphorus as it passes through the Hatchery from fish excretion, egestion, and from unconsumed feed. A summaries of Hatchery and fish production activities in contained in Appendices C and D. The net phosphorus daily loading from the Hatchery for 2012 is defined as the difference between the daily phosphorus loading that leaves the system (usually from the Upper Discharge or other discharge point) and the daily phosphorus entering the system from three major surface water sources (Brundage Spring, Brundage Creek, and the Platte River) and two minor mostly groundwater sources (Filter Backwash and Hot Pond waste pump). Negative net loads on any day are set equal to zero for calculation purposes as specified in the Consent Agreement. Linear interpolation is used to determine the net load on days when no measurements are taken. This may require the use of the last measurement of the proceeding year and the first measurement of the following year to complete the calculation. The summation of daily net loads for the year gives the annual net phosphorus loading. Figure 2 shows the history of total annual net phosphorus loads from the Hatchery from 2005 through 2012. The net phosphorus load from the hatchery to the Platte River was 32.05 lbs. for 2012, a value that is about 16% of the 2005 load and 4% of the 2000 load.

The concentrations of total phosphorus and turbidity of the Hatchery inlet and outlet flows were measured using 72-hour composite samples during 2012. Figure 3 shows the concentration of total phosphorus in the Upper Discharge during 2012. Note that there are three distinct periods. High concentrations were typical during the first 75 days of 2012, followed by low values during the summer, then a general rise for the remainder of the year. Figure 4 shows the corresponding 3-month net phosphorus loads for 2012. These values generally follow the fish biomass in the system with the loads for the first 4 months corresponding to a period when water temperatures at the Hatchery are increasing and the Chinook salmon from the current year and the coho salmon from the proceeding year class are reaching maximum size just before being planted. The lower loading during the summer occurs during a period where the sizes of the current year class coho salmon are still relatively small and biomass is low at the Hatchery. Normally, rapid growth and increased feeding of the current year class coho salmon results in a higher loading during late summer and fall. These increases are offset by the addition of ferric chloride in excess amounts during 2012 as shown in Figure 5.

Phosphorus Mass Balance

Mass Balance can be used to help understand and develop a model for changes in the net load from the Hatchery as a function of production activities and facilities operation. The mass balance equation requires that the accumulation of phosphorus in the Hatchery is equal to the difference between the amount of phosphorus that enters the system (Inputs) and the amount leaving the system (Outputs).

Accumulation of P in the Hatchery = Sum on Inputs – Sum of Outputs (1)

The input terms refer to any phosphorus that enters the Hatchery, these terms include:

1. Food P. This term is the amount of phosphorus associated with the food that is fed to the fish in the Hatchery starter building and raceways. This term is calculated by multiplying the weight of the food fed times the phosphorus content of the feed.

2. Source Water P. This is the amount of phosphorus contained in all of the Hatchery source water. The sources are Brundage Spring and Creek, the Platte River (only used rarely), and Service water. The phosphorus value of the input amount is determined by multiplying the flow rate times the phosphorus concentration.

3. Fry Tissue P. This term refers to the phosphorus introduced to the system when fry are added into the fish inventory. It is calculated by multiplying the wet weight biomass of the fry times the percent phosphorus in the fry tissue. Note that this approach avoids the need to count or weigh the egg harvest and egg morts.

The output terms refer to phosphorus that leaves the Hatchery, these terms include:

1. Shipped, Planted, and Mort Fish Tissue P. This term refers to all the phosphorus that leaves the Hatchery in the form of fish tissue. It is not relevant to the mass balance equation if the fish are shipped to another watershed, planted in the Platte River, or disposed as mortalities. The phosphorus value of this term is calculated by multiplying the whole wet weight biomass of the fish times the percent phosphorus in the fish tissue.

2. Discharge P. This term refers to the gross loading of phosphorus that leaves the system as effluents from the Hatchery. These flows include the Upper and Lower Discharges and any other discharge points. Currently, the Upper Discharge is only outlet flow. Note that the phosphorus value of this term is calculated by multiplying the discharge flow rate times the phosphorus concentration. The Net Discharge is the difference between the phosphorus measured Gross Discharge and the sum of the measured phosphorus inputs, and is used for NPDES and Settlement Agreement purposes.

3. Trucked P. This term refers to the amount phosphorus that is trucked away from the Hatchery, predominately the result of emptying and cleaning the solids storage tank. The phosphorus value of this term is calculated by multiplying the measured number of gallons of liquid trucked away times the average measured phosphorus concentration of the liquid.

The accumulation terms are calculated by subtracting the outlets from the inputs. Accumulation can be positive or negative. The three major accumulation terms are:

1. Fish Tissue P. This term refers to the phosphorus present in fish in the Hatchery Building and raceways. The phosphorus value of this term is calculated by multiplying the whole wet weight biomass of the fish times the percent phosphorus in the fish tissue. If the fish tissue phosphorus is greater at the end of the year than the start of the year, the accumulation term is positive. If the fish tissue phosphorus is less at the end of the year than the start of the year, this term is negative. Additions, transfers, or removals of fish from the system are not considered in the calculation because such factors are accommodated by other terms in the mass balance equation.

2. Tank P. This term refers to the amount of phosphorus in the solids storage tank. The phosphorus value of this term is the average phosphorus concentration of the solids in the tank multiplied by the tank volume. This term can also have a positive or negative

value depending on the amount of phosphorus in the tank at the start and end of the year. Phosphorus removed by truck is included in separate terms in the mass balance equation.

3. Pond P. This term refers to the amount phosphorus that settles and is stored in the bottom of the pond. Phosphorus that settles to the bottom is prevented from leaving the pond by a clay liner and remains in the bottom sediments until the system is drained and dredged. The phosphorus value of this term cannot be easily measured directly, but is usually calculated by subtracting all the inputs of phosphorus to the pond from the outlets. Normally, the inputs are greater than the outlets. Other terms in the mass balance would need to be added to cover the case where the pond is drained and bottom materials removed.

Hatchery Mass Balance for 2012

Figure 6 shows Hatchery mass balance terms for 2012. The phosphorus associated with the source water and discharge was measured using the Sigma 72 hour sampling method. The fish production terms were calculated using a fish tissue phosphorus content of 0.42% of the gross wet weight. This value is a rough estimate based on the upper range of several but inconsistent measurements (see Figure 8). There was a net increase of 6 lbs. of phosphorus associated with fish resident in the system at the end of the year when compared to values at the start of the year. The calculations suggest that the filters removed about 45% of the phosphorus that leaves the Hatchery Building and Raceways. Approximately 98% of the phosphorus removed by the filters is retained in the sludge storage tank with about 8.1lbs of phosphorus flowing to the pond as clarifier overflow. Approximately 61.4 lbs (19%) are removed by the pond resulting in a net discharge of 17.1 lbs based on mass balance that gives credit for negative discharge days. The net Hatchery loading increases to approximately 32 lbs. when no credit is given for negative days. The sludge storage tank was emptied and cleaned at the end of August 2012. The measured removal was 342.5 lbs of phosphorus. Linear extrapolation can be used to estimate that an additional accumulation of approximately 114 lbs of phosphorus would be in the tank at the end of the year. This amount is offset by 114 lbs that were present in the tank at the beginning of 2012. Mass balance calculations suggest that 351 lbs of phosphorus would be accumulated in the tank in 2012. The mass balance calculated amount expected in the tank is only about 21 lbs greater than the measured amount. A total of 103 lbs. of phosphorus enter the filters based on an assumed fish phosphorus content of 0.42% compared to the amount measured in the backwash and filter overflow streams.

Shearer (1997) measured the tissue phosphorus content of rainbow trout. The average phosphorus concentration of the trout for sizes between 1 and 30 grams was 0.0495%. Figure 7 shows a phosphorus mass balance for the Hatchery similar to Figure 6 but assumes that the fish tissue phosphorus is 0.495%. This value exactly balances the in and out phosphorus loading for the filters. This demonstrates that the fish tissue phosphorus is a critical driving factor that affects the mass balance calculations.

Figure 8 shows scattered measurements of tissue phosphorus for PRSFH coho and Chinook salmon performed by Lake Superior State University and Great Lakes Scientific compared to correlations developed by Shearer (1997). Given that significant efforts have been made to accurately measure the all of the other components of the mass balance calculation, it is recommended that additional efforts be made to measure the tissue phosphorus content of the PRSFH coho and Chinook salmon. In addition, it is imperative that significant efforts be continued to accurately measure all the inputs and outputs of phosphorus from the system so that mass balance calculations can be verified each year. Understanding of the operation of the Hatchery and the ability to track movement of various phosphorus pathways comes under significant question without such mass balance closure.

Lake Water Quality of Big Platte Lake

Total Phosphorus: The annual variation of the volume-weighted total phosphorus concentration in Big Platte Lake for 2012 is shown in Figure 9. The average value for the year was 7.77 mg/m^3. There were 125 days when the total phosphorus concentration exceeded the 8.0 mg/m^3 goal. The Consent Agreement mandates that the volume-weighted total phosphorus concentration of Big Platte Lake be maintained below 8.0 mg/m^3 95% of the time. The actual attainment was 66%, significantly higher than the 95% requirement.

Secchi Depth: Secchi disk depth is a visual method used to measure water clarity and is an important indicator of water quality. Measurements of Secchi depth have made in Big Platte Lake since 1982. The 2012 seasonal variation of Secchi depth in Big Platte Lake is shown in Figure 10 and the minimum measured Secchi depth was about 9 feet. Secchi depth dynamics are a complex function of calcite precipitation and the concentrations of plankton and phosphorus in the Lake. These relationships have been recently described by mathematical models developed by Homa and Chapra (2012) for nearby Torch Lake. Such models can be used to calculate increases in water clarity as a function of decreases in Hatchery and watershed phosphorus loading. Readers should note that as phosphorus concentrations in the Lake decrease, corresponding increases in water clarity may be less than expected due to the precipitation of calcite (marl). It is recommended that a model similar to the Torch Lake model be developed for Big Platte Lake.

Dissolved Oxygen: The 2012 annual variation of dissolved oxygen concentrations in Big Platte Lake is shown in Figure 11. Dissolved oxygen depletion in the hypolimnion of Big Platte Lake is closely related to temperature gradients and the onset of spring stratification (Figure 12). The concentration of dissolved oxygen dropped below 2 mg/L in waters deeper than 90 feet for 91 days in 2012. This is a critical period for phosphorus dynamics in the Lake because dissolved phosphorus will be released from the sediments during this anoxic/chemically reducing period. Shallower water depths at 75, 60, and 45 feet experience shorter periods of low dissolved oxygen conditions as shown at the top of Figure 11. Another key period of phosphorus release from sediments is during the winter ice cover when there is significant potential for oxygen depletion. These data are used to calculate the estimated phosphorus release from the sediments. The internal loading and cycling of phosphorus can be compared to both non-point and point sources and can be used to estimate an annual phosphorus budget for the lake as shown in Figure 19. Ultimately, the magnitude of the internal cycling of phosphorus determines how quickly the lake will respond to changes in input phosphorus loadings.

Plankton: Appendix E contains a report on the abundance and dynamics of phytoplankton and zooplankton in Big Platte Lake during 2012. The plankton community structure measured during 2012 is similar to that measured and reported in previous years.

Watershed Flow and Phosphorus Balances

Watershed Flow and Phosphorus Balance

Figure 13 shows the long-term trend of mean annual flow of the Platte River as measured by the U.S. Geological Survey (USGS) (Station ID 04126740). The mean annual Platte River flow was 113.6 cfs in 2012. This flow is lower than the long-term average flow of 122.8 cfs since 1990. Thus, 2012 can be characterized as a drier than the average year.

Figure 14 shows the daily hydrograph of the Platte River as well as the days sampled for water quality. Note that only one sample was taken during the peak of a high flow event, while the remaining samples characterize baseline flow conditions. Inspection of the hydrograph suggests that there were about 20 storm events when higher than baseline flow and total phosphorus concentrations are expected. Figures 15 and 16 show measurements of total phosphorus and turbidity at the USGS site on the Platte River and at the North Branch of the Platte River at

Deadstream Road. The high concentrations of phosphorus that occurred on February 29, 2012 were associated with high turbidity during a high runoff event.

Figures 17 and 18 show the annual average flow and total phosphorus concentrations at various sites in the Lower Platte River Watershed. Figure 19 shows the phosphorus load balances for the lower watershed starting at Fewins Road and extending to the outlet of Big Platte Lake. The flow balance includes the tributary flows into the Platte River and discharge by the Hatchery. Tributary and non-point flows and flows at intermediate locations on the Platte River are based on linear relationships with the USGS measured flows at US-31. These linear relationships were developed over a three-year period using flow measurements at intermediate locations in the watershed. The flow at the USGS location is about 2.2 times the flow at Fewins Road, and the Lake outlet is about 2.7 times that of the flow at Fewins Road. Figure 14 shows about 20 storm events in 2012 where flows rapidly increased and then receded over a one or two day period. The storm flows during peak events accounted for about 7.5% of the total flow during 2012 (see Figure 17). Baseflows are generally associated groundwater inputs and accounted for 92.5% of the hydrologic inputs.

The development of an accurate annual phosphorus balance for the watershed is not a simple task because the Platte River and tributary loadings are significantly affected by high flow events that occur during several storm events throughout the year. The Platte River was sampled for total phosphorus concentration during only one of these storm events in 2012 from a total of about 20 (Figure 14). Thus, estimates of the total phosphorus loading into Big Platte Lake based on the 25 baseflow measurements are not expected to accurately estimate the loading because of the inaccurate and under representation of storm events. Unfortunately, it is impractical to measure flow and phosphorus concentration during every storm event at all key locations in the watershed every year.

Extensive storm event measurements were taken from 2004 to 2006 at the Old Residence location on Brundage Creek and at the Stone Bridge and USGS Gauging Station at Honor, MI sites on the Platte River using continuous water sampling equipment. The average event total phosphorus concentrations at these locations were 67.95, 45.35, and 51.07 mg/m^3, respectfully. The storm event concentrations at the Fewins site and North Branch sites were assumed to be identical to those measured at the Stone Bridge site. The measured storm event total phosphorus concentrations measured at the Old Residence site on Brundage Creek were used to characterize storm events for the Stanley, Carter, and Collision Creek sites. The total phosphorus concentrations during baseflow conditions were averaged for all years for Stanley, Carter, and Collision Creeks because limited measurements are available for these sites and they are no longer included in the regular monitoring program. These data, along with the regular monitoring data for 2012, were used to determine the total phosphorus loads into Big Platte Lake as shown in Figure 19.

The annual phosphorus load at the USGS Gauging Station site was 3,060.5 pounds in 2012. Storm events contributed 16.3% of total phosphorus load compared to only 7.5% of the flows. The total phosphorus concentration at the USGS Gauging Station at Honor, MI site was measured 25 times during 2012. The average total phosphorus concentration was 11.5 mg/m^3 and the annual average flow was 117.7 cfs. This is equivalent to an annual phosphorus load of 2,665 lbs., an amount that is about 13% lower than the annual load that accounts for increases during storm events. The difference is the result of storm event flows with their higher total phosphorus concentrations being disproportionately greater than corresponding phosphorus loads from dry weather or baseflow conditions.

The above calculations are considered adequate representations of the hydrologic and phosphorus watershed balances despite the assumptions and approximations used in the analyses. Practical alternatives to this approach are problematic. The monitoring program needed to compile a more accurate phosphorus balance for the total watershed is monumental and outside of the current budget for this program. Given these difficulties and limitations, the above approach is considered a good alternative and a reliable screening tool that can be used for planning applications. However, it is recommended that the full dry and wet weather monitoring program be resumed and the BASINS model be re-calibrated if watershed planning issues arise in the future that involve large expenditures or significantly influence watershed land use.

Monitoring Program

Hatchery

The net Hatchery total phosphorus load is evaluated by subtracting the inlet load from the total outlet load. It is recommended that measurements of flow, total phosphorus concentration, and turbidity be taken at six locations using automatic samplers. The equipment should collect 72 hour composite samples twice each week. In addition, all flow rates should be calibrated annually. The flow rate of the clarifier and waste pumps should be calculated daily based on the capacity and the running times of the pumps. The flow rates of the backwash pumps are added to the flows from Brundage Creek and Brundage Spring to calculate the total flow of the Upper Discharge.

Watershed

The sampling plan for 2012 involves collecting data from watershed streams and Big Platte Lake. The proposed lake and watershed sampling program for 2013 does not include sampling of Little Platte Lake or analyses for nitrogen or total dissolved phosphorus. Only three samples are taken for phytoplankton and zooplankton in Big Platte Lake.

The tributary sampling program is designed to approximate the phosphorus loading into Big Platte Lake. Measurements of flow, phosphorus, and turbidity are taken on a regular basis independent of flow conditions. These data allow evaluation of water quality for various hydrologic conditions; provide sub-watershed loading estimates; and assist in defining high priority remediation areas. The recommended monitoring program for 2012 should include three sites on the Platte River – one just upstream of the Hatchery, another at the USGS Station on US31, and the last below Big Platte Lake on M-22. One sample should be taken in the North Branch of the Platte River at Deadstream Road.

It is recommended that Big Platte Lake be sampled at two locations every two weeks during the year, whenever it is safe to do so. A calibrated Yellow Springs Instruments (YSI) meter should continue to be used to measure dissolved oxygen, temperature, pH, conductivity, and ORP. Eight discrete depths (0, 7.5, 15, 30, 45, 60, 75, and 90 feet) and composite tube (0 to 30 feet) samples should be analyzed for total phosphorus, turbidity, and chlorophyll. Phytoplankton and zooplankton should be sampled during the spring, summer, and fall. Secchi depths should be measured with a standard Secchi disk and collected during each lake sampling. Additional Secchi depths should be collected whenever possible by PLIA members to supplement the standard sampling program. It is recommended that four more upstream tributary sites be added and samples be taken for nitrate and TN when funds are available.

References

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