Annual Report for the Year 2002

Consent Agreement Regarding the Operation of the Platte River Hatchery

Report Prepared by

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Summary for the Year 2002

Overview

The goal of the Consent Agreement is to develop a long-term strategy to restore and preserve the water quality of Big Platte Lake (see Figure 1). This goal will be advanced by minimizing the flow and phosphorus discharge from the Hatchery and by implementing strategies to reduce non-point phosphorus loads from the watershed. The Hatchery is currently undergoing a major renovation that includes the addition of state-of-the-art effluent control systems, new outside raceways with reuse capabilities, headbox upgrades, and new flow monitoring equipment. Studies have been performed to determine the significance of Hatchery operations and environmental factors with regard to their influence on the effectiveness of the effluent ponds. Finally, data have been analyzed to evaluate the reliability of the new automated sampling equipment.

The Hatchery staff has taken over the job of sampling the Hatchery, the tributary streams, and the Lake. Laboratory analyses are now being conducted by CMU, replacing GLEC in an effort to reduce costs and expand research and special project opportunities. The sampling program accommodates the requirements of the Consent Agreement and supports the development of watershed and lake water quality models. Extensive efforts have been made to evaluate and improve the accuracy and precision of the field and laboratory procedures associated with measurement of total phosphorus and other parameters. Several other aspects of the Hatchery, tributary, and Lake sampling program are currently under comprehensive review. Recommendations are given below.

A Microsoft ACCESS database is being designed to maintain the Hatchery, tributary, and Lake data. This database will accommodate all historical and future data. It is important that the data be screened for accuracy and consistency. The database will have improved retrieval capabilities that will facilitate a much-needed comprehensive analysis of the data.

Table 1 shows the annual total phosphorus load from the Hatchery and the flow of the Platte River at the USGS gage station on US-31 since 1990. This table also shows the corresponding volume-weighted total phosphorus of Big Platte Lake and the percent of the time the concentration exceeds the water quality standard of 8.0 mg/m^3 in a given year.

The net Hatchery total phosphorus load for the year 2002 was 206 lbs based on the jug & needle sampling technique. This is in compliance with the interim standards of 210 lbs. The maximum loading for any three-month period was 81 lbs. This is not in compliance with the interim standard of 75 lbs. as defined in the Consent Agreement. However, the Hatchery is currently involved in a major construction and renovation program that is expected to reduce the Hatchery total phosphorus loading when completed.

The average 2002 Platte River flow at the USGS station was 132 cfs. This flow is higher than any other since 1994, and is slightly higher than the average flow since 1990 of 126 cfs. Thus, 2002 can be characterized as a moderately wet year.

The annual-average volume-weighted total phosphorus concentration of Big Platte Lake was 8.35 mg/m^3 in 2002. The water quality standard of 8.0 mg/m^3 was exceeded 46% of the time. This is not in compliance with the goal of 95% attainment. These violations were primarily the result of unusually high Lake total phosphorus concentrations that were measured early in the year. These high concentrations may be the result of sampling and laboratory problems or the input of unmeasured phosphorus from domestic and fruit processing wastes that impacted the Lake during the winter and spring of 2002, or other undetermined sources. This is discussed at length in later sections of this report.

A total of 19,524 adult Coho passed the Lower Weir in 2002. This is in compliance with the Consent Agreement limit of 20,000. A total of 37 adult Chinook salmon passed the Lower Weir in 2002. This is also in compliance with the Consent Agreement limit of 1,000. Excess salmon that accumulate below the lower weir were harvested, counted, and removed from the watershed. A total of 20,360 adult Coho salmon were harvested for egg collection at the Upper Weir. This slightly exceeds the number of the Coho that were counted passing through the Lower Weir. A total of 162 adult Chinook salmon were harvested at the Upper Weir. This significantly exceeds the number that were counted passing through the Lower Weir. It is not clear why more fish were collected at the upper weir than were counted when passing at the lower weir and steps will be taken to improve counts in the coming year.

LimnoTech has completed the development of an uncalibrated BASINS watershed model. In addition, several useful maps have been prepared that show sub-drainage areas, land use, soil type, topographic slope, and the proposed sampling stations for 2003. Preliminary model runs with the BASINS have demonstrated the format of the model output and the types of management options that will be possible when the model is fully calibrated. Historical and new wet weather tributary flow, turbidity, and total phosphorus data will be used to calibrate the model.

A preliminary three -layer water and sediment dynamic mass-balance model for lake total phosphorus has been developed. The model has been used to simulate the annual variation of temperature, dissolved oxygen, soluble and particulate phosphorus, chlorophyll, and Secchi

Depth. The model output agrees reasonably well with the 2000 data except for Secchi Depth. This discrepancy is being addressed by new measurements of light attenuation and extinction coefficient using the LICOR meter. The model reliability is also being enhanced by conducting special studies to directly measure some of the model coefficients such as the sediment phosphorus release and oxygen uptake rates and the influence of macrophytes on the rate of nutrient recycle.

Acknowledgements

The Implementation Coordinator would like to take this opportunity to thank Gary Whelan and Wil Swiecki for their contributions to this project. Gary has made an extraordinary effort to keep this whole project focused and moving forward. Many of the accomplishments we have made to date simply would not have been possible without his leadership and management skills. 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. They have participated in bi-weekly meetings, they always seem able to sweep away obstacles that threaten our progress, and are willing to personally tackle behind-the-scenes tasks. As a result of this constructive approach, an excellent spirit of coordination, cooperation, and communication has been maintained within our group as well as with many outside organizations and individuals.

Significant and beneficial coordination continues with the Benzie Conservation District regarding wet weather sampling and development and application of the BASINS watershed model. The authors would like to acknowledge and thank Ron Harrison for his contributions in this regard. It is expected that the District will continue to have a major role in further funding of the modeling effort and will eventually use the model to assist with the implementation of remedial activities. Penelope Moskus and Troy Naperla from LTI have done an excellent job developing the un-calibrated BASINS model in coordination with the District and the Implementation coordinator.

The authors would also like to thank and acknowledge the valuable contribution of many individuals from CMU. Jenny Estabrook and Scott McNaught have left no stone unturned in their efforts to evaluate and improve their laboratory methods for total phosphorus. Scott McNaught reviewed the historical plankton data and recommended much improved methods for sample collection. Michael Holmes and Scott McNaught are working on a project to study the sediments. Erica Francis measured the indicator bacteria late on a Saturday and Sunday night to support the shoreline study.

Several individuals on the Hatchery staff have been helpful with the transition from GLEC and the turnover in staffing assignments. Ed Eisch and Bob Humphrey have made this project one of

their top priorities and have provided valuable guidance and stability and have performed backup sampling tasks. The tough job of sample day to day collection through hot and cold, and sometimes on the ice, has been handled by Bob Kerry, Brian Haffner, and most recently Aaron Switzer. The reliability of the data would suffer without their careful and conscientious efforts. James Baker has been working on fixing the new Sigma samplers along with designing and testing a centrifuge head to remove particles from stream samples. Bob Haas from the Mt. Clemens Research Station and Jim Breck from the Institute of Fishery Research in Ann Arbor are working on macrophyte sampling techniques. Doyle Brunsen from the MDEQ helped procure, install, and provided training for the automated stream sampling equipment. Janice Heuer has providing data on the wastewater facility located in Honor.

Several individuals associated with the PLIA have made significant contributions to this project. Jerry Heiman has worked on a Watershed Planning Grant and related water sampling. Tom Inman has coordinated closely with the Hatchery staff on counting the 2002 Fall Salmon Run. Sally Casey has been making weekly Secchi Depth measurements for many years. Joe Francis and Al Amstutz have been measuring stream flow and pH of the North Branch of the Platte River and the Platte River at US-31and M-22. They also measure precipitation and pH of the Lake. Al has also help maintain the North Branch of the Platte River flow spreadsheet. Mike Pattison has updated and reviewed the EXCEL database.

Matt Heiman and Meg Woller from the Leelanau conservancy are conducting the shoreline and macrophyte studies.

The parties appreciate the efforts of the staff from Great Lakes Environmental Consulting who conducted the field and laboratory analyses through April 2002.

Russell Minnerick and his staff at the U.S. Geological Survey – Grayling Office have been involved in measuring flows at the hatchery, calibrating equipment, and providing guidance and training to hatchery staff on how to properly collect stream flow measurements.

FishPro staff (particularly Bill Jensen and Gary Wilken), Department of Management and Budget staff (particularly Ken Dao and Joel Gordon), and Three Rivers Construction staff have been instrumental in upgrading and renovating the hatchery which will soon have some of the most advanced effluent management equipment in the country at a production facility.

Recommendations and Action Items

1. The following is a summary of recommendations. More detailed discussion and justification for these are found throughout the report.

2. SOP documents for all procedures and equipment should be reviewed and missing ones should be compiled. Aaron should complete these tasks coordinating with Ray, Gary, and Wil.

3. The database should be completed. New data tracking sheets should be designed as soon as possible that contain bottle numbers, field data, and laboratory results. The new format should minimize the hand transfer of numbers and avoid replication. This tracking sheet should be compatible with the new database. Gary should complete these tasks coordinating with Aaron, Jenny, Ray, and Wil.

4. Both Sigma Sampler and jug & needle bottles should be placed and sampled for total phosphorus and turbidity until detailed evaluations are completed. Aaron should begin this immediately.

5. Triplicate measurements of turbidity and total phosphorus should be made on all Sigma Sampler and jug & needle sample bottles following vigorous shaking. Aaron should begin this immediately.

6. Hatchery loading calculations should be performed exclusively with the jug & needle samples until detailed evaluations are completed on the automated Sigma samplers. Wil and Ed should note this for future calculations.

7. The pond dip sample for turbidity should be discontinued.

8. The lower weir should be secured with a new lock and seal system. In addition, the proposal to open the Platte River to fishing below the lower weir is enthusiastically endorsed. Ed and Gary should pursue these tasks.

9. The turbidity meter should be calibrated and experiments conducted to correlate turbidity measurements with suspended solids concentrations. Ray and Aaron will work together to get this accomplished.

10. Triplicate turbidity measurements should be taken for all regular and automated tributary samples. The measurement of pH and temperature from tributary and outlet samples should be discontinued immediately to minimize wear and tear on the YSI meter. – We should consider having continuous recording thermometers installed in all of the tributaries and the main river. They are cheap and very accurate. Additionally, they can also help us with future fisheries management on the river.

11. The YSI meter should be calibrated for dissolved oxygen using saturated water at both refrigerator and room temperature. The YSI meter should also be calibrated for pH using 3 standard buffer solutions. This should be done before going out each lake sampling day. The meter should be checked again upon returning from the lake to confirm the stability of the calibration. Aaron should begin this immediately coordinating with Ray.

12. The method for sampling zooplankton should be changed immediately. Instead of the current method, zooplankton should be counted from each of three separate top to bottom vertical net hauls. The nets should have a mesh size of 64 microns.

13. The method for sampling phytoplankton should be changed. Instead of the current method, phytoplankton should be counted from each of three separate 30 foot tube composites.

14. Triplicate analyses should be performed for chlorophyll, total phosphorus, total dissolved solids, calcium, alkalinity, and turbidity on each of the three composite tube phytoplankton samples. The measurement of TDS and calcium at 4 separate depths should be immediately discontinued upon the availability of the equipment from CMU.

15. Triplicate measurements of total phosphorus, alkalinity, and turbidity should be measured at 8 separate depths. Aaron should begin this immediately.

16. Chlorophyll samples should be filtered both at the Hatchery and by CMU until detailed evaluations are complete. This should begin this immediately.

17. The concentrations of TKN, TKN-F, and nitrate should be measured from each composite sampler in triplicate on two occasions in both July and August. TKN and TKN-F analyses can be conducted at the DNR laboratory. This should begin this immediately.

18. All samples shipped to CMU or DNR for analyses should be packed in ice with a thermometer. Jenny should record the temperature upon opening shipment and report the result. This should begin this immediately.

19. CMU should immediately purchase calcium and TDS standards and perform experiments to ensure the accuracy of their methods.

20. CMU should purchase 5 and 10 mg/m^3 total phosphorus standards and use them to perform routine and regular checks on the accuracy of their methods for total phosphorus. Jenny should begin this immediately.

21. CMU should perform tests with the new centrifuge head. The tests should determine the optimum duration and speed of the centrifuge to remove interfering particles and yet not alter results when no particles are present. Jenny should begin when equipment is received from Jim.

22. CMU should immediately perform tests to determine the stability of alkalinity measurements for storage periods up to 4 days. They should make suggestions regarding modification of the alkalinity SOP if warranted.

23. A new approach should be employed to calculate the lake volume-weighted average total phosphorus concentration that uses all 8 total phosphorus measurements. In addition it is recommended that median of the three measurements be used for each depth rather than the average. This should be done for all future calculations.

24. A rain sampler should be installed to collect samples for the measurement of pH and total phosphorus concentration in rain water as well as the amount and intensity. Ray will coordinate this effort along with Wil and Ron.

Hatchery Performance

Plant Renovations

The Platte River State Fish Hatchery is undergoing a major renovation at this time that includes the addition of state-of-the-art effluent control systems, new outside raceways with reuse capabilities, headbox upgrades, and new flow monitoring equipment. Planning for this renovation project began in earnest in 2001 and by February 2002 plans were complete for the water monitoring segment of the project. This was bid out and construction for this segment was completed in September 2002. Construction on the rest of the project began in October 2002 and will be substantially complete in November 2003 with final completion in January 2004.

The effluent system will have disc filters at each raceway pass and will have no quiet settling zone so that solids will be taken out of the water column as soon as possible. Indoor raceway water will also go through one of the disc filters to remove any residual solids that escape the indoor vacuum system. All filter wastes will go to a new clarifier where the solids will be separated from the water and sent to a new sludge storage tank. There will also be an effluent pond bypass to allow for the widest range of options for effluent pond management. Other improvements may be made to the effluent pond to increase its effectiveness.

The new outdoor raceways will be reoriented and have multiple uses of the water instead of the current one pass. This, in addition to the ability to reuse water within the outdoor raceway complex, will significantly reduce the amount of water use and will allow Brundage Creek and Brundage Spring to be used as the major water sources. This has many advantages to effluent management, disease and temperature control. The outdoor raceways will be completely covered to control avian and mammalian predators and will reduce stress to the fish that should reduce effluent nutrient content.

A completely new water flow monitoring system was installed at the hatchery in September 2002. This system allows for the monitoring of all inflow and outflow water flows. It also allows for easy collection of water samples for chemical analysis. The system is operational at this time with the final system bugs being corrected at this time. A backup system (needle and jug method) is also being used to ensure sample collection is done in a timely and consistent fashion.

Flow Rate

The Consent Agreement commits the Hatchery to minimize its flow and to maintain accurate flow rate measurements. Currently the Hatchery staff estimates the flow rate by measuring the weir height at the effluent location and allocates the total effluent flow among Brundage Creek, Brundage Spring, and the Platte River. Figure 2 shows the long-term changes in the Hatchery effluent flow between 1990 and 2002. The long-term average flow is 4008 million gallons per year. The maximum and minimum flows over this period are 4666 and 2748 million gallons per year. The average flow for 2002 is 4383 million gallons per year which is somewhat higher than the long-term average. The Hatchery outflow is about 14% of the total flow of the Platte River at the USGS gage station and roughly the same magnitude as the flow from the North Branch of the Platte River. The flow and recycle operations of the Hatchery are under comprehensive review and are being modified as part of the ongoing renovation project. These modifications will likely significantly reduce the Hatchery effluent flow because the use of Platte River water will be minimized or eliminated.

Total Phosphorus Loads

The Consent Agreement states that the interim Hatchery net load will be limited to a maximum of 210 lbs. for the construction period including the year 2002. The net load is defined as the difference between the measured effluent load and the phosphorus load of the incoming water sources. In addition, the maximum allowable phosphorus net load should not exceed 75 lbs for any consecutive three month periods. The net Hatchery loading for 2002 was 206 lbs using the jug & needle samples. This load is consistent with the Consent Agreement. The maximum net load for a single three-month period was 81 lbs. This exceeds the limit by 6 lbs. Appendix 1 contains the data and describes the method used to calculate the net loads. Note that linear interpolation was used in the spreadsheet to determine net loads for the end or beginning of each month.

Figure 3 and Table 1 show the long-term pattern of decreasing Hatchery net total phosphorus. Note from Figure 3 that the net total phosphorus loads during recent years are less than 10% of the net loads that occurred during 1981. The Hatchery net total phosphorus loads have declined steadily and have been remarkably consistent for the past six years. The water quality model for the Lake currently being developed will be capable of accurately simulating the positive water quality impacts of this long-term trend of decreasing Hatchery net loads.

Figure 4 shows a bar graph of the Hatchery net loading for each month for 1998 through 2002. Note that the net loads are usually higher in the spring and fall when the Hatchery accommodates the highest biomass of actively growing fish. The maximum net loads occurred during March, August, and October in 2002. It is important to have a quantitative understanding of the relationship between the magnitude of the Hatchery net loads and other operations within the Hatchery and Lake total phosphorus concentrations. This understanding will be facilitated by the water quality model of the Lake under development.

Weir Operations

The 2002 weir operations have remained similar for the past few years. The Lower Weir was closed between August 15 and November 14, except for brief periods to allow for passage of boats and canoes and to permit salmon to migrate upstream for egg collection activities at the Upper Weir. Salmon were released upstream by raising the boat gate a small amount and manually counting the salmon as they passed. Two Hatchery employees and one PLIA observer performed independent counts that were usually within 5%. A total of 19,524 adult Coho and 37 adult Chinook salmon passed the Lower Weir in 2002. The number of salmon harvested was estimated by periodically counting the number of salmon in a tote and multiplying the average of these numbers by the number of totes harvested. All harvested salmon were removed from the watershed.

The Upper Weir stops further upstream migration of salmon after August 15. All salmon were collected and individually counted during the harvest and egg collection operations at the Upper Weir. A total of 20,360 adult Coho salmon were harvested at the Upper Weir in 2002. This is greater than the number of salmon passed through the Lower Weir. A total of 162 adult Chinook salmon were harvested at the Upper Weir this is also greater than the number passed at the Lower Weir. It is unclear why the numbers for fish harvested at the upper weir are greater than the number released at the lower weir. It is recommended that new locks and seals to installed at the lower weir to prevent tampering. In addition it is recommended that fishing be allowed below the lower weir to reduce the overall run size to the Platte River system. Appendix 2 contains a detailed report that describes the operation of the Lower and Upper Weirs in more detail.

Figure 5 shows the amount of phosphorus associated with all fish that are not captured at the Upper Weir. The phosphorus content of the fish was estimated by multiplying the number of fish by the average weight of an individual fish and converting to phosphorus assuming that the wet tissue contains 0.4465 % phosphorus. In 2002 about 365 lbs. of fish phosphorus were allowed to move upstream from the Lower Weir into the Platte River watershed. A total of approximately 56 lbs or 25 kg of this phosphorus was lost and not harvested at the Upper Weir. This lost phosphorus either remains in the lake and thereby representing a load to the system, or it could be removed by fishermen. An accurate creel census may help establish the amount of phosphorus removed from the system by fishermen. The planned water quality model of the Lake will be capable of estimating the impact of phosphorus contributed as decomposing fish tissue on the water quality of the Lake during the fall.

Note from Figure 5 that the largest difference between fish passed into the Lake and fish harvested at the Upper Weir occurred in 1999. However, also note from Table 1 that the some of the highest water quality conditions in the Lake were measured in 1999. This apparent weak link between to the amount of fish lost and water quality suggests that other factors may play a more dominate role. However, this issue is still open to careful analysis and must await completion of the water quality model.

Antibiotics and Disinfectants

The Consent Agreement commits the Hatchery to monitor and evaluate its use of antibiotics and disinfectants. Antibiotic use at the Hatchery involves supplying oxytetracyctine (OTC) to Chinook salmon delivered in the fish feed. The OTC (TM100) was mixed in the feed at a rate of 25.11 pounds per ton of feed in 2002. A total of 8,025 pounds of medicated food was delivered during the period April 12 through April 30, 2002. The total amount of OTC in the feed in 2002 was 100.7 pounds. No monitoring was conducted during 2002 because of the results of previous years. During 2002 approximately 422.37 pounds of medicated feed containing 5.3 pounds of OTC was fed on a daily basis. Flow through the hatchery during the treatment period was 19.24 mgd.

Parasite-S (formalin) is used as a disinfectant to control fungus growth on fish eggs. This product consists of 37% formaldehyde by weight in water. The standard treatment uses a 15-minute flow through with formalin at a concentration of 1 to 600 (1,667 ppm). In 2002 a total of 788 gallons of Parasite-S were used to control fungus on salmon eggs during the period October 3 to January 6, 2003. Maximum daily treatments were 12 gallons per day (per 15 minutes). Hatchery flows during the period ranged from 14.57 mgd to 17.06 mgd. No monitoring for formaldehyde in the discharge was done in 2002 because of monitoring results that were obtained in 1999.

Chloramine-T was used on May 9 and 10, 2002 to control bacterial gill disease (BGD) that affects Chinook salmon. The treatment consisted of supplying approximately 13.2 kilograms Chloramine-T to the raceways during a period when the Hatchery flows were about 9.5 mgd. Grab samples were collected at various locations to determine resultant concentrations of Chloramine-T. However, it has been that determined that Chloramine-T degrades rapidly in water, and that samples must be analyzed within 2 hours of collection to obtain valid results. The 2002 samples were not processed within this time interval and were therefore not analyzed. It is planned to test for free-chlorine in future sampling efforts. This is a residual of Chloramine-T that can be easily measured using a Hach free-chlorine test kit. A Hach free-chlorine test kit has been ordered and will be used during the next testing period.

Appendix 3 contains the complete Fisheries Division report and a more detailed discussion of antibiotic and disinfectant use at Platte River Hatchery during 2002.

<u>Production Operations</u>

The purpose of this section is to examine the hatchery production data for the purpose of gaining a better understanding of how these processes affect the net total phosphorus loading and ultimately the water quality of the Lake. Appendix 4 contains hatchery data for 2002 for the production of fish, the amount of food fed, and the number and biomass of fish lost through mortality and shipment away from the system. The following preliminary analysis is based on the assumption that

Biomass at end of month = Biomass at beginning of month + growth – mortality – export (1)

Note that monthly hatchery data are available for all the terms in Equation (1) except for growth. Thus the growth can be calculated for each month. The monthly growth summed for the whole year is the accumulative biomass of fish produced in the system. This amount, as shown in the top panel of Figure 6, represents the growth of biomass that would occur in the Hatchery assuming no mortality or export. Also shown are the losses of biomass due to mortality and export and the biomass of fish actually present in the system as a function of time throughout the year. Note that the rate of growth is nearly constant throughout the year except for December. It is also seen that mortality is a minor term. The lower panel shows the monthly amount of food fed to the fish. Note that this closely follows the biomass of fish present in the system.

The specific growth rate of the fish is defined as

Specific Growth Rate = Growth for month / Average Biomass Present during the month (2)

Note that because the growth for each month is roughly constant while the fish present in the system is time variable, the specific growth rate must also be time variable. Figure 7 shows the calculated monthly the specific growth rate of the fish as well as the temperature of Brundage

Creek. Note that the specific growth rate appears to be related to temperature as expected. The maximum specific growth rate is about 0.53 per month. This represents about a 70% potential increase in biomass for the month.

The above calculations can be used to estimate the amount of phosphorus utilized for annual fish production. This is the difference between the fish present in the system at the end and beginning of the year (as shown in Figure 6) multiplied by the amount of phosphorus in the fish tissue. The amount of phosphorus that is consumed and retained for fish production is 566 pounds. This assumes that fish biomass is 0.4465 % phosphorus by wet weight. Table 2 shows a summary of additional Hatchery operations data for the year 2002. All terms are expressed as the phosphorus equivalent to facilitate comparison. The total amount of phosphorus contained in the fish food is 3481 pounds in 2002 as calculated directly from the data in Appendix 4. Note that some of this fish tissue phosphorus is exported from the system, some is lost through mortality, and some is incorporated into new fish growth that remains in the Hatchery. The phosphorus consumed by fish for growth is about 16% of the phosphorus contained in the feed. The net phosphorus discharged from the Hatchery in 2002 was 206 pounds as calculated in a previous section. This is about 6% of the phosphorus in the feed used by the Hatchery. The monitoring data were used to estimate that about 257 pounds of phosphorus entered the pond in 2002. This means that 51 pounds were lost in the pond by sedimentation. Thus the pond removes about 20% of the phosphorus that enters the pond and about 1.5 % of the phosphorus that enters the Hatchery in the feed. The remaining phosphorus of 2658 pounds apparently leaves the Hatchery through the solids disposal. Note that solids disposal removes about 50 times more phosphorus than the amount removed by the pond. This suggests that improvements in the solids handling and removal system have the potential to produce profound benefits. On the other hand, improving the efficiency of the pond will produce less benefit.

Pond Efficiency Studies

It has been observed that the final settling ponds sometimes act to increase the Hatchery phosphorus load rather than decrease it. This negative efficiency of the Hatchery pond may be associated with increases in either soluble or particulate phosphorus. Increases in the concentration of soluble phosphorus may be caused by increases in soluble phosphorus loading to the pond or increases in the rate of hydrolysis of particulate phosphorus. In addition, decreases in the rate of algal or macrophyte uptake or increases in the rate of algal or macrophyte excretion will alter the balance between soluble and particulate forms. Finally, soluble phosphorus may be released from the pond sediments. Increases in the concentration of particulate phosphorus may be related to increases in particulate phosphorus loading to the pond or to increases in the rate of macrophyte sloughing or die-off. High winds can decrease the rate of settling of particulate phosphorus to the sediments and increase the rate of sediment scour or re-suspension. The interactions among the processes that effect removal efficiency in the pond are illustrated in Figure 8. Obviously the task of quantifying each of these mechanisms is not trivial. Therefore an extensive effort has been made to monitor the pond influent and effluent total phosphorus and turbidity, measure wind speed, and count the number of waterfowl that occupy the pond.

Figure 9 shows the variation of various pond performance parameters as a function of time. These plots show that outlet turbidity and phosphorus are highest during March and April, and again in September. This is roughly the same time when the waterfowl numbers peak, and also as seen in Figure 7, the time when the fish in the system and the amount of food fed are also near their maximum. This shows that pond performance is roughly related to the waterfowl present and the amount of food being input to the Hatchery. Performance does not seem related to wind speed.

Figures 10 and 11 examine these possibilities in more detail. Figure 10 shows a plot of the outlet turbidity as a function of the inlet turbidity. It is seen that the outlet turbidity is usually less than the inlet turbidity and that the pond is effective in reducing extremely high inlet turbidity. Figure 10 shows a similar relation for phosphorus. However, Figure 10 shows no significant relationship between outlet phosphorus and outlet turbidity (R^2 = 0.0125). Finally, Figure 10 shows that the fraction of phosphorus removed is low or negative when the inlet concentration is low. Figure 11 shows that neither the outlet turbidity nor phosphorus (R^2 = 0.0013 and R^2 = 0.0059) is significantly related to wind speed and that the outlet phosphorus has little correlation with the number of waterfowl (R^2 = 0.0001). On the other hand, some weak correlation exists between the outlet turbidity and waterfowl (R^2 = 0.289).

Thus, it is concluded that the pond outlet turbidity and phosphorus generally follow the same time pattern as the amount fish food being supplied and the number of waterfowl. However, the statistical basis of these relationships is weak. Management schemes to reduce the phosphorus loading based on these relationships are not warranted. However, the ponds serve a useful role in attenuating occasional high turbidity levels and phosphorus concentrations. Furthermore, most of the phosphorus that enters the Hatchery is removed through solids disposal processes and not pond sedimentation. The ongoing plant renovations are well directed based on this analysis and any future efforts to further reduce the Hatchery phosphorus loading should focus on improvements in the solids handling processes.

Evaluation of Automated Sampling Equipment

The concentrations of total phosphorus of the inlet and outlet flows from the Hatchery are currently sampled using two methods. For several years a 24 hour composite sample has been taken using a jug equipped with a fine gage needle that slowly allows water to enter the jug. Last year, five automated Sigma Samplers were installed in association with the renovation program. These samplers obtain a composite sample by pumping a sub-sample on an hourly basis.

Figure 12 shows a comparison between the measured total phosphorus concentrations of similar samples collected using both methods. Table 3 shows the individual data along with the collection date. Figure 12 and Table 3 show that when the Sigma Samplers were first installed the total phosphorus was well correlated with the total phosphorus from the jug & needle bottles. However, note that this correlation has been deteriorating with time. Significant differences now occur. The obvious deviations between the jug and needle and the Sigma Samplers are shown in yellow in Figure 12. Table 3 shows that four of the deviations were from the Brundage Spring sampler, two were from the Platte River, two were from the pond outlet, and one was from the Brundage Creek sampler. Therefore, it appears all the Sigma Samplers can deviate from the jug & needle bottles.

Note that recent jug & needle data appear to be higher than the Sigma Sampler data by a ratio of about 2 to 1. The Hatchery staff has visually observed that the jug and needle method generally collects less sediment material than the Sigma Sampler. This observation is reinforced by the fact that the inlet to the jug & needle bottle (that is, the needle) is smaller than the inlet tube from the Sigma Sampler. Therefore it is expected that the jug & needle bottles would have less total phosphorus than the Sigma Sampler rather than more. It is difficult to explain these surprising results. However, it is noted that the jug & needle bottles are cleaned with acid prior to each use, whereas cleaning procedures have not been employed for the Sigma Samplers. Perhaps filamentous bacteria have formed wall growth on the Sigma sampler collection tubes that absorb phosphorus on the way to the collection bottles. This would also explain why there was little deviation between the methods when the Sigma Samplers were first installed.

It is recommended that samples be taken using both methods and sent to CMU for analysis of total phosphorus. The Sigma Sampler inlet tubes should be cleaned regularly. Turbidity should be measured from both types of samplers each time a sample is taken for total phosphorus. Hatchery loading should be calculated from jug & needle total phosphorus measurements until sample values from both techniques are found to not be significantly different.

Big Platte Lake Water Quality

Total Phosphorus

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. Table 1 and Figure 13 show the volume-weighted average total phosphorus concentrations based on CMU measurements and the percent of the time that the concentrations exceed the 8 mg/m^3 standard. The average annual volume-weighted total phosphorus concentration of Big Platte Lake declined from about 9.1 mg/m^3 in 1990 to minimum of about 6.3 mg/m^3 in 1998 and 1999 and then increased to about 8.3 mg/m^3 in 2002. There were 167 days in 2002 when the total phosphorus concentration exceeded the 8.0 mg/m^3 standard. This corresponds to about 54% attainment as compared to the 95% requirement. Appendix 5 contains an Excel spreadsheet that contains the appropriate data and demonstrates the calculation of the Big Platte Lake volume-weighted total phosphorus concentrations for 2002.

Note from Table 1 that the USGS flow of the Platte River is higher in 2002 compared to the past few years. The higher total phosphorus levels and more violations of the 8 mg/m^3 goal may be related to the higher than average flow of the River in 2002. Furthermore, there was an accidental release of raw domestic sewage into Platte River during the winter of 2002 that may have contributed to increases in the lake total phosphorus concentration. Finally, an unauthorized landfill containing domestic sewage sludge and fruit processing wastes have been recently discovered that may have contaminated groundwater and a small tributary that enters the Lake below the USGS gage station. Neither of these sources of total phosphorus, or others such as dead alewife, have been accurately measured, therefore it is impossible to quantify their impact on the total phosphorus concentration of the Lake.

Figure 14 shows the seasonal variation of the volume-weighted total phosphorus concentration in Big Platte Lake for 1998 to 2002. Note that CMU values are about 2 mg/m^3 higher than GLEC values for the two occasions where measurements from both laboratories are available.
In addition, the concentration measured by CMU on May 28, 2002 (day = 148) was 13.25 mg/m^3. This is the highest recorded value in the past 5 years. Also note that the measured concentrations immediately before and after day 148 were about 3 mg/m^3 lower. For these reasons it is likely (although not certain) the samples collected on May 28, 2002 were contaminated in some manner and are not true representatives of the actual Lake concentrations

or of overall water quality. However suspect this value, it was retained in the calculations summarized in Table 1 because the Lake has unmeasured sources of total phosphorus as discussed above.

Note that for most years the GLEC concentrations are usually low during the summer and at or near maximum levels in the spring and fall. So far, this pattern has not been replicated by CMU data. This difference is analyzed in detail in the Quality Assurance and Control section later in this report.

Dissolved Oxygen

Figure 15 shows the changes of bottom water dissolved oxygen concentrations for 1998 to 2002. Note that the concentration of dissolved oxygen drops below 2 mg/L for about 100 days each year. This is an important period because this is when it is expected that dissolved phosphorus will be released from the sediments. Note that the period of low dissolved oxygen was much shorter in 2002 compared to other years. This further emphasizes the need to address the issue of the comparability of the total phosphorus measurements between GLEC and CMU.

Figure 16 isolates the dissolved oxygen concentrations and the temperatures of the bottom water of Big Platte Lake for 1998 and 2002 to facilitate comparison. Note that in 1998 temperature stratification begins about day 110 and that the dissolved oxygen of the bottom water declines significantly between days 110 and 180. On the other hand, in 2002 the lake remains completely mixed up to day 148. On day 148, the bottom water dissolved oxygen was over 10 mg/L in 2002 and less than 5 mg/L in 1998. After day 148, stratification occurs in 2002 resulting in about the same rate of oxygen decline as 1998. Stratification ends on about day 300 in 1998 and on day 289 in 2002. Oxygen responds accordingly with recovery occurring sooner in 2002. Also note that on about day 333 the bottom water dissolved oxygen in 1998 was about 11.5 mg/L, whereas in 2002 the concentration was 13.6 mg/L. Some of this 2.1 mg/L difference can be explained by the difference in lake temperature for the two years. In 1998, the uniform lake temperature was about 45 degree F. The saturated dissolved concentration in equilibrium with this temperature is 12.1 mg/L. In 2002, the uniform lake temperature was about 39.1 degree F. The saturated dissolved concentration in equilibrium with this temperature is 13.1 mg/L. Thus water on day 333 in 2002 has the potential to absorb about 1 mg/L more dissolved oxygen at equilibrium compared to 1998. This explains about one half of the difference between the two years. These types of analyses are implicit in the three-layer water quality model described in a later section of this report.

Secchi Depth

Figure 17 shows the maximum, average, and minimum Secchi Depth for 1998 to 2002 as measured by PLIA. Note that the data are very similar for most years and almost identical for 2001 and 2002. These Secchi Depth data suggest that the total phosphorus in Big Platte Lake should be similar for 2001 and 2002. However, as seen in Figure 14, the average total phosphorus in early 2002 was much higher than in 2001. This further emphasizes the need to address the issue of the comparability of the total phosphorus measurements between GLEC and CMU.

Volume-Weighted Lake Total Phosphorus Calculation

The current method of calculating the volume-weighted Lake total phosphorus concentration does not use the total the phosphorus measurement taken at the surface. This is because in 1991 there were a few very high total phosphorus measurements taken under the ice that were contaminated by debris. This occurred again for a few samples in 1996. Otherwise the surface measurements (1990-2002) are generally consistent with the samples taken at the 7.5-foot depth.

It is suggested that a new approach be employed that uses all 8 total phosphorus measurements -- surface, 7.5, 15, 30, 45, 60, 75, and 90 feet. In addition it is suggested that the median of the three measurements at each depth be used rather than the average. This eliminates the need to arbitrarily disregard any valid measurement and at the same time avoids over emphasis on a single outlier value. The algorithm multiplies the surface median phosphorus concentration by the volume of water between the surface and 3.5 feet. Next the 7.5 foot median phosphorus concentration is multiplied by the volume of water between the 3.5 feet and 11.5 feet. This process is continued for each layer culminating with the 90 foot median phosphorus concentration being multiplied by the volume of water between the 82.5 feet and 95 feet. The layers are illustrated in blue in Table 4. The product of the concentration and volume for each layer gives the total mass of phosphorus in that layer. The total mass of phosphorus in the Lake is the sum of the masses of phosphorus from each layer. The total mass of phosphorus in the Lake divided by the total lake volume gives the volume-weighted concentration. Note that this method uses the surface and bottom areas once and the middle areas twice during the calculation. The overall computation scheme is shown in Table 4. This procedure is consistent with formal and rigorous numerical algorithms such as the Trapezoidal Rule (Chapra and Canale, 1998).

The surface median concentration should be considered contaminated if it is more than double the 7.5-foot median concentration. In this case the computation is performed exactly as above, expect the contaminated surface median concentration is replaced by the 7.5 foot median concentration.

The algorithm was tested for two dates in 2002 as shown in Table 4. One time the new algorithm gave a slightly higher value compared to the old method, one time it was lower. It is recommended that the overall significance of this preferred method of calculation be tested using all the measurements when the ACCESS database is completed.

Tributary Flows and Water Quality

USGS Station at US 31

Figure 18 and Table 1 show the long-term trend of annual average flow of the Platte River measured at the USGS station at US 31. The average Platte River flow at the USGS station was 132 cfs in 2002. This flow is significantly higher than the last few years and greater than the average flow of 123 cfs since 1990. Thus, 2002 can be characterized as a moderately wet year. Figure 19 shows daily and monthly hydrographs for the Platte River at the USGS gage station for 1998 to 2002. Note that the monthly hydrograph is quite uniform with up to 25 % higher flows in the spring and fall. The actual sampling dates are shown on the daily hydrograph for 2002. Note that the sampling dates miss most of the wet weather spikes. However the average of the flows on sampling days and the average of the daily flows were almost identical. The measured non-point load may underestimate the actual non-point load because many spikes are missed. The proposed wet weather sampling and the BASINS model will permit a more accurate assessment of non-point total phosphorus loads.

Figure 20 shows total phosphorus concentrations in the Platte River at the USGS station for 1998 to 2002. Note that higher flows and concentrations generally occur during the spring. Fall total phosphorus concentrations are generally about half spring values. However note that isolated high concentrations have been observed in 2000 and 2002.

Figure 21 shows the correlation between total phosphorus and flow at the USGS station for 2002. Note that generally reasonable results were obtained except for one isolated point. This point may be a contaminated sample. Note that the linear correlation approach presented here uses instantaneous values of flow and total phosphorus and does not account for the history of flow during proceeding days. The proposed BASINS model incorporates mechanisms to simulate such phenomena and will thus permit a more accurate assessment the relationships between flow and total phosphorus concentration.

North Branch of the Platte River

Flows for 1998 to 2002 for the North Branch of the Platte River (also known as Deadstream) are shown in Figure 22. Note that values are about 15 to 20 % of the USGS flow at US 31. In addition flows are generally higher in spring and fall with intermittent spikes during wet weather. This pattern is generally consistent with the seasonal variations of the Platte River. Measured total phosphorus concentrations in the North Branch of the Platte River for 1998 to 2002 were in the same range as the Platte River with occasional higher values (Figure 23). Figure 24 shows some correlation (R^2 = 0.19) between the North Branch of the Platte River flow and USGS flow at US 31. The correlation between the North Branch of the Platte River flow and total phosphorus is poor (R^2 = 0.097). The proposed BASINS model incorporates a detailed characterization of the North Branch of the Platte River and the main River watersheds. Thus, it is expected that this approach will permit a more accurate assessment the relationships between flow and total phosphorus concentration for the system.

M-22 Outlet

Figure 25 shows the relationship between the total phosphorus concentration at the M-22 outlet and the average surface and 7.5 foot depth lake concentration. Highly significant relationships exist for both 1993 and 1994 (R^2 = 0.8408) and for 2002 (R^2 = 0.8028). One suspicious outlier value was eliminated from the 2002 data set. Also note that the range of concentrations in 1993 and 1994 was between about 4.5 mg/m^3 and 9.5 mg/m^3. The range of values was shifted about 1.5 mg/m^3 higher in 2003. This further emphasizes the need to address the issue of the comparability of the total phosphorus measurements between GLEC and CMU.

Monitoring Program

Overview

In 2001, it was decided to completely review the sampling and water chemistry testing program for the Platte River State Fish Hatchery Consent Agreement. After examining the existing program, it became evident that there may advantages to having the DNR staff conduct the field sampling with the oversight of the Implementation Coordinator, and to have the laboratory chemical analysis sent out for competitive bidding. Both of these steps have been completed and have provided cost savings that have been used on other implementation items such as supporting the watershed phosphorus modeling and allowing for some additional new laboratory research that will help the modeling and implementation process.

In October 2001, four labs were contacted requesting bids on the laboratory analysis. The lowest cost bid that had the appropriate accuracy was Central Michigan University's Water Research Center and their bid included opportunities to conduct additional special investigations. They were awarded the work in March 2002 and started water chemistry analysis in the first week of April. Great Lakes Ecological Center (GLEC) continued water chemistry analysis until April 19th to allow for side by side comparisons of the data.

In October 2001, the DNR hired a new water quality technician to handle the water sampling aspects of the Consent Agreement. Robert Kerry took the position in early December 2001 and started at Platte River State Fish Hatchery in late December 2001. Robert Kerry and Bob Eggleston (Platte River State Fish Hatchery Technician) handled all aspects of water sampling using approved Standard Operating Procedures (SOPs). DNR water quality sampling was started in early March 2002. Side by side sampling with GLEC was conducted from April 1 to 19 to allow for side by side training and comparison of sampling. The parties are appreciative of the efforts of GLEC and hope that they will bid on future work associated with this facility.

An early retirement process and subsequent hiring/promotion process caused significant changes during the period from July 2002 through May 2003 in all parts of Fisheries Division. Robert Kerry moved over to take a vacant Fisheries Technician position at Platte River State Fish Hatchery. Brian Haffner came down to the Platte River State Fish Hatchery in December 2002 to take the Water Quality Technician position and in May 2003 moved over to take the other vacant Fisheries Technician position. Aaron Switzer moved down from Oden State Fish Hatchery in June 2003 to permanently take the Water Quality Technician position. This personnel shuffling is coming to an end and the system is expected to stabilize for some time to come. The good news from this experience is that the DNR will have 3 fully trained staff to handle the water quality sampling program and this will give us sufficient redundancy to cover any situation.

To support water quality effort, the DNR has purchased a number of pieces of equipment including a flow meter, turbidity meter, YSI multi-function sampler for lake sampling, a Licor light meter, and other laboratory equipment. All of the necessary equipment has been purchased or obtained from other facilities to conduct the required sampling.

Additional efforts by the parties have resulted in the acquisition of the necessary equipment to bring the existing weather station at Platte River State Fish Hatchery up to operational standards to provide key weather data for the watershed modeling efforts. In April 2003, 4 mobile automatic samplers were obtained from DEQ and installed with the assistance of Benzie County

Conservation District. This equipment will allow for storm event sampling in the Platte River Watershed which fills a significant data gap in our understanding of phosphorus processing in the watershed.

Objectives

The sampling program has the following specific objectives.

1. To quantify the total phosphorus loading from the Hatchery as required by the NPDES permit for the facility and the Consent Agreement.

2. To determine the volume-weighted total phosphorus concentration of Big Platte Lake to insure compliance with water quality standards.

3. To collect data to support trend analyses of the water quality of Big Platte Lake and its tributary streams.

4. To collect data to construct mass balances for water and total phosphorus for the system.

5. To collect data to support the development, calibration, and validation of the BASINS model for watershed total phosphorus loading as a function of land-use, soil type, and weather conditions.

6. To collect data to support the development, calibration, and validation of a water quality model of Big Platte Lake.

7. To determine total phosphorus and suspended solids loads from sub-watershed basins during storm events.

8. To document changes in water quality following possible future remedial activities within the watershed.

9. To provide a GIS-based assessment tool for local planning and zoning officials.

These extensive data collection efforts will near completion when the BASINS and lake water quality models have been verified using regular and wet-weather monitoring data. At this point, available resources may be shifted toward the special sampling program described below. These efforts will directly measure some of the model coefficients thereby further enhancing the reliability of the models. When these models are completed, it may be possible to divert sampling resources to other uses. For example, additional lake nutrient models should be developed for upper watershed lakes (Ann Lake and Bronson Lake), and the existing model for Long Lake model (Canale, 2000) should be validated. This work will help to improve water resource management in these rapidly developing lake watersheds, support the efforts of local lake associations; and most importantly, promote more complete understanding of the nature of nutrient and sediment delivery processes in the Platte River system.

Sampling Plan

Several water quality sampling studies have been conducted in the past to define the magnitude of various sources of total phosphorus within the watershed and the Hatchery loading and to estimate their impact on the water quality of Big Platte Lake. The most significant of these studies were those performed by Grant in 1979 and by Kenega and Evans in 1982. In addition, the MDNR and PLIA have conducted an extensive sampling program in the watershed since about 1990.

A major effort will be made during the next two years to repeat the Kenega and Evans study and to obtain tributary data during wet weather events. Figures 26 and 27 and Table 5 describe historical, current, and proposed sampling locations for the system. The Kenega and Evans study sampled nine tributary and one lake location on a monthly basis in 1980. The data were used to perform hydrologic and total phosphorus balances for the system. The data provide a good historical baseline and can be used to evaluate changes in water quality in the tributaries and lake over time. The current sampling plan proposes to conduct regular sampling at these same stations in 2003 and 2004. This will allow a detailed evaluation of water quality for various hydrologic conditions and will be supplemented by wet weather event sampling. Note that only two of the nine Kenega and Evans tributary stations are currently being sampled. It is planned to sample twelve tributary locations in the system during three wet weather storm events. Six samples are taken to define transient conditions during each event at each location. The flow as well as the concentration of total phosphorus and turbidity will be measured for each sample. This program is difficult to conduct and depends on suitable weather conditions. Therefore completion of this part of the program may require 2 or more years. Automatic sampling equipment has been installed to facilitate this task as a cooperative project with the Benzie County Conservation District.

The net Hatchery total phosphorus load to the system is evaluated by subtracting the inlet load from the total outlet loading. Measurements of flow and total phosphorus concentration are currently taken at five locations two times per week using both the jug & needle and Sigma samplers. It is proposed to maintain this regular schedule in 2002. In addition, it is recommended that turbidity be measured in triplicate on both the jug & needle and Sigma samples each time total phosphorus samples are collected.

It is proposed to sample the lake at 8 depths every two weeks during both the non-stratified and stratified periods of the year. The lake samples at 8 depths should be analyzed for total phosphorus, turbidity, and alkalinity. Phytoplankton, total phosphorus, alkalinity, turbidity, chlorophyll, total dissolved solids, and calcium should be measured from three separate top 30 foot composite tube samples. Three top to bottom vertical net hauls should be used to measure zooplankton. Light penetration, Secchi Depth, dissolved oxygen, temperature, pH, and ORP should be measured with field instruments. The YSI meter dissolved oxygen readings should be calibrated using both air and water techniques before and after each use. The YSI pH meter should be calibrated using 3 buffer solutions before and after each use. It is recommended that the chlorophyll samples be filtered at the Hatchery laboratory immediately following lake sampling. It is recommended that all samples shipped to CMU be packed in ice.

Quality Assurance and Control

The transition from the GLEC to the CMU laboratory was made in the spring of 2002 in order to save money and take advantage of research capabilities of CMU. Replicate lake, tributary, and Hatchery samples were taken in April through July of 2002 and analyzed at both laboratories to compare CMU and GLEC results. Figure 28 shows that the total phosphorus data taken by both laboratories correlate reasonably well ($R^2 = 0.7707$). However, this relationship deviates from the 45 degree perfect correlation line. Note that when the total phosphorus concentrations are below about 12.5 mg/m^3 CMU values are usually higher than GLEC values. When concentrations are between about 12.5 mg/m^3 and 20 mg/m^3 CMU values are approximately the same as GLEC values, above 20 mg/m^3 CMU values are lower than GLEC values but this is based on only four scatted measurements. For a GLEC total phosphorus value of 6 mg/m^3, the regression line gives a CMU value of about 8.4 mg/m^3. For a GLEC value of 8 mg/m^3, the regression line gives a CMU value of about 9.6 mg/m^3. Thus if GLEC and CMU were to measure the same lake water with a true concentration of around 8 mg/m^3, the CMU lab would detect higher % violation compared to GLEC. In other words, the CMU laboratory procedures suggest more lake water quality violations compared to GLEC.

The question becomes which laboratory procedure is more reliable in terms of accuracy (or bias) and precision. Historically comparatively little information is available concerning the accuracy of either the GLEC or CMU procedures. Thus, a comprehensive effort was conducted to evaluate the accuracy and precision of the laboratory procedures for total phosphorus.

Accuracy and Precision of Total Phosphorus Laboratory Procedure

Note that although the above data compare laboratory results using essentially the same water samples, the true concentration of these samples is not known. Therefore, additional comparisons were made between the CMU and GLEC laboratories by purchasing standards with a known concentration and accuracy. These tests were performed on October 24, 2002 and November 8, 2002 with the results reported in Table 6. Note that October CMU values were generally higher than the 4 mg/m^3 standard, about the same as the 8 mg/m^3 standard and lower than the 12 mg/m^3 standard. On the other hand, October GLEC values are usually lower for the 4 and 8 mg/m^3 standards and higher than the 12 mg/m^3 standard. This is generally consistent with patterns shown in Figure 28 and indicates that CMU values are usually higher than the GLEC for the low range of concentrations. A second set of samples was analyzed by CMU after being stored in the refrigerator for 2 weeks. The results shown in Table 6 are much closer to the standards than the first CMU tests. The reason for the improvement is not clear. However, the results for both laboratories with this test are inconclusive.

Because the initial round of results were inconclusive, additional tests were performed. This involved diluting field samples 50% with distilled water and comparing the values with the non-diluted results. The data shown in Table 7 are averages of triplicate analyses. The results for 25 dates show that the CMU average of the diluted samples was 53% of the non-diluted samples. This is an excellent result given that some small amount of phosphorus may be contributed by the distilled water itself. On the other hand, one triplicate diluted GLEC set was only 36% of the undiluted samples.

Both laboratories use a similar method where reagents combine with dissolved inorganic phosphorus to produce a blue color whose intensity is proportional to the concentration of phosphorus. Very marginal amounts of color are produced at low concentrations that are difficult to detect. The lower the concentration of total phosphorus in the sample, the more difficult this task becomes. GLEC uses a spectrophotometer equipped with a cell that has a light path length of 1 cm. CMU uses a 10 cm path cell to detect color during their total phosphorus analyses. It is possible that the marginal amounts of color produced at low total phosphorus concentrations cannot be accurately detected with the 1 cm path length. This could be an inherent limitation of 1 cm path technology.

This hypothesis was tested by developing calibration curves using both 1 cm and 10 cm procedures using the same standard solutions. These curves are shown in Figure 29. Although the regression coefficients for both calibration curves are very close to 1.0, the regression coefficient for 10 cm path length curve is slightly higher and there is less scatter in the data. Also note that absorbance values for the 10 cm path are about one order of magnitude higher than the 1 cm path. Next several lake, tributary, and hatchery samples were analyzed using both curves. The results are shown in Figure 30. Note the similarity between Figures 28 and 30. The concentrations measured using 10 cm technology were generally about 2.5 mg/m^3 higher than the 1 cm method for concentrations around 5 mg/m^3. As the concentrations approach about 12 to 15 mg/m^3, the methods give results that converge to about the same values. Thus it appears that 1 cm technology may be biased low for low concentrations even when a highly significant 1 cm standard curve can be developed and used in conjunction with an analysis of lake samples. This result can be understood through an analysis presented by de la Camp and Seely. They have demonstrated that the errors associated with laboratory methods that depend on detecting color become large when the absorbance values are small. They recommend a lower limit of absorption of 0.1 which corresponds to a total phosphorus concentration of about 10 mg/m^3 using 10 cm path techniques. The largest absorbance using the 1 cm technique was less than 0.05, a value well below the recommended range.

Several modifications were made in an attempt to improve the accuracy and precision of the CMU procedures. Errors introduced through the pipettes and flasks were evaluated using manufacturer specifications. These pipettes and flasks are only used for preparation of standards. The combined effect of these errors has a maximum value of about 4% as a worse case. In addition, a new 15 mg/m^3 standard was added to the standard curve increasing the number of points on the calibration curve. Following these improvements, two additional sets of standards with total phosphorus concentrations of 5 and 10 mg/m^3 were purchased from the same laboratory that supplies the CMU primary standard solution. Sixteen replicates of each concentration were measured by CMU. Results are shown in Table 8. The accuracy and precision (R^2 = 0.202 and 0.237) of these results are excellent for concentrations in this low range.

The overall conclusion from the above analyses is that the CMU laboratory procedures for total phosphorus are both highly accurate and precise and adequately serve the needs of this project. It is recommended that we continue to engage the services of CMU for future total phosphorus measurements.

<u>Container Issues</u>

The hatchery staff uses a high density polyethylene bottle manufactured by Eagle-Picher for collection of samples for analysis of total phosphorus. They have full EPA quality assurance treatment. The bottles have wide mouths and polyethylene-lined screw caps. They contain no acid preservative. The bottles are acid washed by CMU before they are used to collect samples. On the other hand, GLEC used glass bottles containing a few drops of sulfuric acid to collect samples. Figure 28 indicates that CMU measurements of lake concentrations are often higher than GLEC when the total phosphorus concentrations are below about 10 mg/m^3. Thus, it is important to conduct experiments to determine if the sample collection container influences the measured total phosphorus concentration. Glass, new acid washed polyethylene containers, and polyethylene containers that have been used several times (also called here either old or conditioned poly bottles) were tested.

The first tests were performed on March 28, 2003 using 10 mg/m^3 standard stored in a refrigerator for three days in both conditioned polyethylene and glass bottles. The results shown in Table 9 are virtually identical. These suggests that the observed differences between the measured total phosphorus concentrations by CMU and GLEC are not likely due to their use of different types of containers.

Further tests were performed on April 23, 2003 to determine if new polyethylene bottles either adsorbed or add total phosphorus to the sample bottles. Distilled water was stored in a refrigerator for four days in both new and conditioned polyethylene bottles. The results are shown in Table 10. The results suggest that new polyethylene bottles release about 1.5 mg/m^3 total phosphorus. On the other hand conditioned polyethylene bottles do not release phosphorus. The negative reported values are caused by small variations in the calibration curves and within the tolerance of the test. Thus, it can be concluded that new polyethylene bottles used by CMU early in 2002 may have increased the actual concentration of total phosphorus by about 1.5 mg/m^3. Furthermore, after three or four uses these new bottles become conditioned and are expected to give results comparable to glass bottles. It is recommended that only conditioned plastic bottles be used for future water analyses.

Storage and Stability Issues

Tests were performed to determine the stability of phosphorus stored in conditioned polyethylene bottles over an extended period. CMU prepared a series of working standards and a calibration curve on September 19, 2002 using normal procedures. These standard solutions were then stored in conditioned polyethylene bottles for 14 days in the refrigerator. After 14 days a completely new set of standards was prepared and a new calibration curve developed. The stored samples were then analyzed and concentrations calculated using both the original and new calibration curves. The results for the original standard curve are shown in the upper panel of Table 11, while the results using the new calibration curve are shown in the lower panel. The values are virtually identical over a range of 0 to 50 mg/m^3. These data confirm that total phosphorus samples are stable in refrigerated conditioned polyethylene bottles for up to 14 days. Furthermore, the calibration curves that are used to analyze such samples are remarkably stable as well. Despite this stability, CMU develops a new calibration curve each time a new batch of samples is analyzed.

We also determined if there was any difference between samples being stored frozen or refrigerated. Freezing samples could be appropriate during the summer. The test was conducted by preparing and storing 10 mg/m^3 standard either frozen or refrigerated for 6 days in conditioned polyethylene bottles and then measuring total phosphorus in the normal manner. The results shown in Table 12 suggest that both methods of storage are acceptable and do not affect the concentration of total phosphorus. Thus, it can be concluded that the CMU standard solutions are stable and do not change their concentrations when stored either refrigerated or frozen for several days in either glass or poly bottles. It is recommended that all samples be refrigerated as soon as possible after collection. They should be packed with block ice and a thermometer prior to shipment to CMU. The temperature should be recorded when the shipment container is open by CMU.

<u>Suspended Solids Interference with Total Phosphorus Analyses</u>

Future sampling will include examining several tributaries in the future for total phosphorus during wet weather events. It is expected that these samples will have high turbidity and concentrations of suspended organic and inorganic particles. Such particles are suspected of interfering with the test for total phosphorus because the test involves passing a light source through the sample to detect color. This theory was tested by kicking up sediments in the Platte River and sampling the disturbed water and sediment mixture. First the samples were analyzed in triplicate in the normal manner. Next the samples were digested in the normal manner then spun in a centrifuge for several minutes before reading in a spectrophotometer. The results shown in Table 13 demonstrate that centrifugation reduces the concentration from over 100 mg/m^3 to about 30 mg/m^3. The difference is attributed to particle interference rather than a true difference in actual concentration because the centrifugation occurred after strong acid digestion at a high temperature.

Thus, it can be concluded that suspended particles will cause interference in the test for total phosphorus and it is recommended that we centrifuge all storm event samples. Plans are underway to construct and test a special custom-made centrifuge head that will accommodate a full rack of 40 digestion tubes. This will enable us to remove particles quickly and efficiently without transferring the samples to separate containers avoiding cross-contamination and handling errors.

Other Comparisons

Table 14 shows several comparisons between CMU and GLEC for pH, total dissolved solids, calcium, alkalinity, and chlorophyll. The obvious differences are quite significant for all parameters. Particularly noteworthy are the pH variations because it is used to calculate the Saturation Index. This index is used to evaluate the potential for calcium precipitation and it is quite sensitive to pH. It is recommended that the YSI pH meter be calibrated both before and after each use using 3 buffer solutions. It is also recommended that standards for total dissolved solids and calcium be purchased by CMU to verify the accuracy of the CMU procedures. Finally it is recommended that tests be performed to determine the significance of storage time on alkalinity samples. If holding time proves significant, it may be necessary to measure the alkalinity of the samples at the hatchery immediately after sampling.

Table 15 shows the difference between chlorophyll measured after being filtered at the hatchery shortly after the lake sampling compared to chlorophyll measured from samples shipped in liquid form to CMU for filtration. Twice the samples filtered at the hatchery were lower than those filtered at CMU, once it was lower. There differences were as large as 47%. Because these results are not consistent it is recommended that both procedures be continued until consistent patterns emerge.

Phytoplankton and Zooplankton Sampling

The abundance and diversity of zooplankton and phytoplankton can provide insight and a more thorough understanding of nutrient dynamics and long-term changes in the productivity of Big Platte Lake. Dr Scott McNaught from CMU conducted a review of the techniques used currently to collect plankton in Platte Lake and performed a brief evaluation of data collected in 2002. At a gross taxonomic level (division, phylum, class, and order), the zooplankton and phytoplankton of Platte Lake are typical of many other Michigan lakes. Cyclopoid copepods, nauplii, and the cladoceran *Bosmina* dominate the crustacean zooplankton. Most of the zooplankton species are grazers that feed on diatoms and green algae. *Polyarthra* and *Keratella* are the dominant rotifers. Diatom species and small green algae dominate the phytoplankton. The most common diatom species were *Fragilaria* and *Melosira*. The most common green algae were *Scenedesmus* and an unidentified picoplankter. *Dinobryon* was the most common chrysophyte. Diatoms are usually dominant in the spring and fall, whereas green algae prevail during the summer.

Currently, both the phytoplankton and zooplankton are measured by collecting a single water sample at 8 discrete depths. This sampling regime is labor intensive and expensive. Worse, it is inadequate because a single set of samples does not permit replicates that are necessary to make estimates of average abundance. In addition many plankton move up and down the water column and may be missed entirely. Most monitoring programs focus on seasonal or annual trends of vertically integrated samples. It is recommended that the zooplankton be collected with a 30-cm diameter 64 micron mesh net. Rotifers will also be accurately sampled with this net. It is recommended that a 64 micron mesh be used because some newly hatched rotifers can be smaller than 80 microns. If a mesh size smaller than 64 microns is used, sampling efficiency will decrease. Three vertical net tows from 0.5 m above the bottom sediments to the surface are sufficient to accurately assess abundance of all taxonomic groups. The net should be hauled from the bottom to the surface in approximately 60 seconds. The contents of each net tow should be stored in separate, labeled bottles (125-250 mL) and preserved with formalin solution (final concentration = 4 % formaldehyde). A 2-week sampling interval is sufficient for routine monitoring.

Phytoplankton should be sampled with a 2-cm diameter rubber/silicone tube dropped vertically through the epilimnion (where algae are most abundant). The tube sampler should be outfitted with a one-way foot valve on the lower end to facilitate sample collection. As the tube is withdrawn from the water, the contents should be released into a clean acid-washed container. A 250-mL sub-sample should be taken from this clean container and preserved with Lugol's solution. Three tube samples should be collected from separate locations off the boat. These composite tube samples should be used to measure chlorophyll and other water quality parameters. A 2-week sampling interval is sufficient for routine monitoring.

Special Studies

Overview

The development, calibration, and final validation of the BASINS watershed loading model and the water quality model for Big Platte Lake will be based on the Hatchery, tributary, and lake monitoring data described above. However, it is also desirable to enhance the model reliability by conducting a few special studies that will provide direct estimates of some of the model coefficients that are independent of the regular monitoring data. Several special studies are described below. These research studies will be designed and coordinated jointly by CMU and the Implementation Coordinator. Although these studies may require the occasional help and assistance of the hatchery staff, they will not require routine commitments.

The magnitude of the internal sources of phosphorus from the sediments of Big Platte Lake is directly related to the area of the bottom that experiences anoxic conditions. Therefore, it is important to measure the area of bottom sediments that are in contact with overlying water that has low dissolved oxygen concentrations (< 2 mg/L). Phosphorus release and oxygen uptake rates are dependent on the sediment physical and chemical properties. Measurement of these parameters will be used to develop correlation relationships between sediment flux rates and various sediment properties.

A macrophyte survey should be conducted to determine type, density, area, and phosphorus content of the plants. These data can be used to make first-cut approximation of the amount of phosphorus absorbed from the sediments during the growing season and subsequently released during the fall die-off period. This information can be used to determine the significance of macrophyte activity on phosphorus dynamics in Big Platte Lake. Measurements should be conducted to determine the fate and transport of decaying macrophytes both in the lake and in the major tributaries.

Laboratory tests should be performed to determine the bio-availability of different point and non-point sources of phosphorus. These include the hatchery effluent, the upper Platte River, major tributaries within the watershed, and small local drainage that discharge directly to the lake. The tests should measure the growth rate of a test algal species to determine the growth potential of various sources of phosphorus.

Water clarity, as characterized by measurements of Secchi Depth, is an important indicator of water quality conditions in Big Platte Lake. However, this measurement of light attenuation is often inconsistent and inaccurate. Therefore a LICOR meter has been purchased to measure the light attenuation as a function of depth. These measurements should enhance our understanding of the relationships among Secchi Depth, chlorophyll concentrations (or phytoplankton and zooplankton counts), calcium carbonate precipitation, pH, and color. The pH is a function of the lake chemistry, algal activities, and perhaps input of acid rain. It is important to determine if there are relationships between lake clearing events and rainfall.

The filter-feeding activities of zebra mussels can reduce phytoplankton concentrations and consequently increase Secchi Depth (Canale and Chapra, 2002). The respiration of zebra mussels can also be a significant oxygen demand. Lake residents have observed numerous small zebra mussels during the summer of 2002. A survey should be conducted to estimate the area, density, and size-distribution of resident mussels.

The major loss mechanism of phosphorus in Big Platte Lake is the settling of particulate matter to the sediments. The settling velocity of these particles is also an important model coefficient. The value of the settling coefficient can be estimated through model calibration by fitting the model output to measured data. However, it is preferable to measure the settling velocity directly. This is accomplished by placing collection chambers in the lake and measuring the accumulated solids as a function of time. The settling velocity can be then calculated from these data.

It would be appropriate to confirm earlier MDNR findings that the growth of phytoplankton in Big Platte Lake is limited by phosphorus. This can be accomplished by measuring the concentration of TKN, TKN-F, and nitrate or total nitrogen in the Lake. It is recommended that these parameters be measured in triplicate in the surface water and at 7.5 and 15 feet on two occasions in July and August when algal growth is most active.

Finally, it is recommended that a shoreline study be performed for the purpose of identifying pollution sources not captured by the regular monitoring program. This can be accomplished by measuring total phosphorus, indicator bacteria, and the density of *Cladophora* at several locations along the shoreline approximately three times during the year. Samples taken in late spring will identify pollution sources not associated with summer residents. Samples collected during mid-summer and then again in late-summer will evaluate the changes that result from increased summer population.

Light Study Progress

Figure 31 shows changes in measured Secchi Depth in 2001 as well as a preliminary model calculation that involves the chlorophyll concentration and Saturation Index. The model is reasonably consistent with the data for some parts of the year, but it does not predict the mid-summer minimum which is the most important value in terms of water quality impacts. Therefore it is important to better understand the relationships among Secchi Depth, chlorophyll, turbidity, particulate fractions, and other limnological parameters. Secchi Depth is difficult to accurately measure. It was therefore decided to purchase a LICOR submersible light meter. This allows the direct quantitative measurement of light attenuation as a function of depth. These data can be used to calculate the extinction coefficient using regression analysis. The relationships are defined by Equation (3).

$$\text{Light} = \text{Exp} (- K_e * \text{Depth}) \qquad (3)$$

where K_e is the extinction coefficient that describes light attenuation with depth according to Beer's Law (feet^{-1}). Depth is the water depth measured from the surface downward (ft) and Light is the light intensity measured with the LICOR meter ($\mu E/m^2/sec$). Measured light data for August 20, 2002 are shown in Figure 32. The EXCEL curve fitting routine results in an excellent fit of the data and a best-fit value for K_e = 0.1495 $feet^{-1}$.

Similar calculations have been conducted for several other dates. Calculated extinction coefficient values and correlations with corresponding measured values of chlorophyll, turbidity, and Secchi Depth are shown in Figure 33. As yet no clear patters have emerged. Thus, additional data are needed to fully define the relationships. The correlations with chlorophyll are particularly poor. They should improve with implementation of the recommended enhancements in the field and laboratory techniques for chlorophyll.

However, some useful insights are emerging. For example, a simple formula has been proposed to relate the extinction coefficient to the Secchi Depth in Chapra (1997).

$$K_e = C1/\text{Secchi Depth} \qquad (4)$$

The value of the constant (C1) is given by Chapra as between 1.7 and 1.9. The average value calculated from our measurements is 2.0. This is good agreement with measurements from other lakes.

Also many researchers have determined that K_e is linearly related to the chlorophyll concentration and turbidity according to the following:

$$K_e = C2 + C3 * \text{Chlorophyll} + C4 * \text{Turbidity} \qquad (5)$$

where C2, C3, and C4 are empirical constants. Eventually, it may be possible to evaluate these constants using chlorophyll and turbidity data as shown in Figure 33.

Proposed Shoreline Studies

Meg Woller and Matt Heiman from the Leelanau Conservancy will shortly conduct a shoreline study of Big Platte Lake. The major funding for the study is being provided by PLIA with assistance from the MDNR and guidance from the Implementation Coordinator. A comprehensive shoreline survey will be conducted on June 14 and 15, 2003. Additional surveys may be proposed for the late summer of 2003 to determine the impact of summer activity on water quality. The purpose will be to identify possible sources of pollution not measured by the regular monitoring program. Approximately 75 samples will be collected along the shoreline in at a depth of about 1.0 foot. Several samples will focus on the impact of a fruit waste contaminated stream entering Big Platte Lake.

Total phosphorus, *E. coli*, *Cladophora*, and temperature will be measured to identify possible nutrient inputs from septic tank drain fields, fertilized lawns, footing drain tiles, groundwater springs, and small tributaries. *Cladophora* growth will be characterized by measuring the location, area, density, and tissue phosphorus content. GPS data and photographs will be taken at each site to verify the sample location and identify possible sources of pollutant inputs.

Proposed Macrophyte Studies

Meg Woller and Matt Heiman from the Leelanau Conservancy are working on a project to study macrophytes in Big Platte Lake. The major funding for the study is being provided by PLIA with assistance from the MDNR and guidance from the Implementation Coordinator. Robert Haas from the MDNR - Fisheries Division – Research Section has agreed to measure the spatial distribution and density of the macrophytes using side scan sonar techniques throughout the lake on one occasion in either late July or early August. The purpose is to determine the total biomass of the macrophytes as well as the species and tissue phosphorus content. The data will be used to quantify the contribution of decaying macrophytes to the observed fall increases in Big Platte Lake phosphorus concentrations and support the development of the water quality model.

The sonar readings will be calibrated using harvesting techniques to measure macrophyte density. Species will be identified and tissue phosphorus will be measured at several locations throughout the lake. An associated ground effort will identify three density (gm DW/ m^2) classifications by harvesting macrophytes from light, medium, and heavy growth sites. The plant material from these sites will be dried, weighed, and analyzed for tissue phosphorus content in the laboratory. Three replicate samples will be collected from each density category.

GIS maps of the macrophyte distributions will be produced that show the bed size and light, medium, and heavy areas. A list of the major species present in the lake will be generated. Graphical and tabular data will be collected that will describe the changes in the seasonal production of macrophytes.

Macrophytes will also be measured at one location every two weeks throughout the growing season. The purpose is to determine the macrophyte growth rate as a function of light, temperature, and tissue nutrient content. The data will be used to identify the time of the year when the macrophytes start to decay in the fall. Several coefficients will be measured that will be inputs to the water quality model.

Growth rate will be determined directly by measuring the change in plant density over time and indirectly using the Light/Dark Bottle technique. Active plant tissue will be placed in BOD bottles and incubated in the lake under both dark and light conditions. The changes in dissolved oxygen concentration in the BOD bottles can be used to calculate the production and respiration rates of the plants.

Phosphorus will be measured in the macrophyte tissue, the surrounding water, and the pore water of the sediments. The light attenuation of both the water and the macrophytes will be measured using the LICOR meter. Temperature, pH, and alkalinity will be measured from a composite sample created from three locations in the surrounding water column. Underwater photographs will be taken to define the vertical distribution of the macrophyte biomass.

GIS maps of the macrophyte distributions will be produced that show the bed size and light, medium, and heavy growth areas. A list of the major species present in the lake will be generated. Graphical and tabular data will be collected that will describe the changes in the seasonal production of macrophytes. The results from these studies will be used to support the water quality model for the lake and will include evaluating the significance of macrophyte decay and nutrient recycle.

Proposed Sediment Studies

Michael Holmes and Scott McNaught from CMU are working on a project to study sediment phosphorus release dynamics of Big Platte Lake with the Implementation Coordinator. Total sediment phosphorus concentrations and oxygen depletion in the water overlying the sediment are two of the primary factors that regulate phosphorus release. Much of the oxygen in the overlying water is consumed by sediment during chemical and biological processes. Previous experiments have shown that a relationship exists between hypolimnetic oxygen depletion and sediment phosphorus release (Freedman and Canale 1977; Nurnberg 1988; Penn et al. 2000).

Sediment oxygen uptake will be measured along with other sediment parameters to better characterize dissolved oxygen depletion. The overall objective is to measure and characterize phosphorus release and oxygen uptake in the sediment from different locations and determine the influence of different sediment types. The sediment parameters measured will include chemical oxygen demand (COD), total organic carbon (TOC), volatile solids (VS), grain size (GS), and total sediment phosphorus (total phosphorus). The first objective is to determine the range of specific sediment parameters that are present in different locations in Platte Lake. After the range of sediment characteristics has been determined, sites will be chosen and monitored for oxygen uptake and phosphorus release. The final goal is to determine if a relationship exists between phosphorus release and total sediment phosphorus and between sediment oxygen uptake and COD, TOC, VS, or grain size.

A general sediment survey will be conducted to determine the variability in sediment characteristics at different locations in Platte Lake. Initially, 10-20 sites will be chosen along three transects from deep-water zones to shallow-water zones. Each site will be sampled with a Ponar grab sampler and COD, TOC, VS, GS, and total phosphorus will be measured. Subsequent sampling will be based on the observed variability in COD, TOC, VS, GS, and total phosphorus between locations.

Four sites will be chosen based on the survey data and monitored for phosphorus release and oxygen uptake. Grab samples will again be collected along with sediment cores for phosphorus release and oxygen uptake experiments. Sediment cores will be taken with a Kajak corer. Sampling will begin mid-summer of 2003 and proceed for a minimum of one year. All sediment cores will be incubated in the dark at temperatures similar to the current hypolimnion.

The phosphorus release experiments will be handled similarly to studies done by Kamp-Nielson (1974) and Penn et al. (2000) in which phosphorus release was monitored under both oxic and anoxic conditions. For an incubation period of approximately 10 days, phosphorus release will be measured on alternate days in 4 undisturbed sediment cores. Two of the cores will be monitored under oxic conditions, and the other two cores will be monitored under anoxic conditions.

The oxygen uptake experiments will be modeled after Gardiner's (1984) oxygen demand experiments. Water overlying the sediment will be saturated with O2, and the decrease in dissolved oxygen over time will be recorded. Oxygen uptake will be monitored in sealed cores that will be handled identically to the cores used for the phosphorus release experiments.

The total phosphorus content of the upper layers of sediment is expected to be the most significant parameter regulating phosphorus release from Platte Lake. Phosphorus release into the overlying water is expected to show a positive correlation with total phosphorus. Locations with high total phosphorus are expected to have higher release rates. Nurnberg (1988) performed a similar study and showed that a significant correlation existed between phosphorus release and total phosphorus. However, this has been shown to be dependent upon the different chemical fractions of bound phosphorus (Nurnberg 1988). Seasonal variation in release rates is also expected due to changing hypolimnetic oxygen concentrations throughout the year. Summer and winter months with the lowest oxygen concentrations are expected to have the greatest release rates. This would most likely be due to previously bound phosphate being released from reduced metals during anoxia. Moreover, the deepest areas of the lake are expected to have the greatest phosphorus release rates due to longer periods of anoxia and to less scour/resuspension.

Sediment oxygen uptake is expected to show a positive correlation with COD. Locations with a high COD are expected to have the highest uptake rates. COD data should quantify the portion of oxygen used for chemical oxidation and may serve as a surrogate parameter for estimation of sediment oxygen uptake (Gardiner 1984). The oxygen uptake rate is expected to remain relatively constant when the oxygen concentration in the overlying water is above 2 mg O2/L (Gardiner 1984). Dependent upon the organic composition of the sediment, TOC could be expected to show a positive correlation with oxygen uptake. If there is little variability in the types organic compounds present at different locations, a direct relationship between TOC and oxygen uptake may exist. Sediments consisting of large amounts of easily oxidized organic matter would be expected to consume the most oxygen.

Data Management

Mr. Wil Swiecki and Dr. Michael Pattison have performed the huge task of constructing and maintaining Excel spreadsheets that contains the hatchery loading, lake and tributary data and calculations. The existing database is based upon a series of EXCEL spreadsheets. The current spreadsheets are primarily intended to provide for storage of the measured data. As a result it is often awkward to use them to retrieve data and to produce plots, tables, and, reports. Furthermore, the structure of the EXCEL spreadsheets makes it very difficult to perform mass balance calculations for the Lake, watershed, or the Hatchery.

Therefore, it was decided to develop a new relational ACCESS database that will capture all of the existing data, allow easy linking to a Geographic Information System (GIS) database under development, and provide new data entry forms to allow easy data input. The Department of Natural Resources – Fisheries Division started this task in 2001 using the existing spreadsheets as templates. The initial process attempted to directly use the spreadsheets as databases but this proved to be unsuccessful and an entirely new database model was developed. The new data framework is complete and data is being transferred to it. The new database is expected to be operational in summer 2003.

Modeling

Overview of BASINS Model

The overall goal of the modeling program is to develop a watershed loading model (BASINS) and a lake water quality model. These models can be used as predictive tools to guide and optimize the planning process and as teaching aids to facilitate our understanding of the important physical, chemical, and biological processes that impact the water quality of Big Platte Lake.

The BASINS model predicts the magnitude of non-point total phosphorus and suspended solids loads as a function of land-use, soil type, and rainfall conditions in the watershed. The BASINS model is being developed in phases by LimnoTech, Inc. of Ann Arbor, Michigan (LTI). This model is well known and is supported by USEPA. This model will provide loading input information to a water quality model for the lake that can be used to predict the impact of non-point total phosphorus loads from the watershed and the hatchery total phosphorus loads. This model will be used to estimate the effectiveness of various remedial control measures designed to promote compliance with the water quality goals of the lake. The goal of phase 1 of this effort is to develop the BASINS model for the Big Platte Lake watershed using existing data. This task will involve not only obtaining data necessary to drive the model, but also data analysis and formatting for application within the model. The goal of phase 2 of the project is two-fold. The first part is to refine the model calibration using new climatic and tributary data to be collected during several storm events at several locations within the watershed. These data will be used to further refine the model calibration, focusing on storm events and several additional locations within the watershed that drain predominantly one land-use. The second part is to test the effectiveness of several management scenarios using the model. This phase of the project will involve the definition of several management scenarios jointly with the Benzie Conservation District. Because of limitations in BASINS, it may be necessary to simulate the impacts of some scenarios (e.g. buffer strips) outside of the BASINS framework. Estimated costs for completing the tasks associated with Phase 1 (initial development) are $50,000 and approximately $30,000 for Phase 2 (final calibration and management applications). These funds are being provided by the Benzie County Conservation District.

Progress on Calibration of BASINS Model

BASINS has been developed using daily climate data and available land-use and soils data. The Big Platte Lake watershed has been subdivided into twenty three sub-watersheds with outlets that coincide with existing monitoring stations and the outlet of Long Lake (see Figure

34.) Figure 35 shows the land use data. This is a primary input of the watershed model. Various model parameters are related to characteristics of the land. Using several distinct land use types allows model parameters to be varied spatially throughout the watershed. Model parameters that are related to land use characteristics include percent imperviousness, pollutant build-up rates, vegetation types, and management practices. The model is currently uses 9 distinct land use types that occur within the watershed. The land uses names and percent of the watershed are:

- Barren (0.2%);
- Commercial/Industrial (1.0%);
- Low Density Residential (5.1%);
- Forest (67.9%);
- Orchard (1.3%);
- Cropland (9.5%);
- Permanent Pasture/Open Space (13.2%);
- Wetland (1.9%); and
- Combined Animal Feeding Operations (1 site, 0.0%).

Soil characteristics are shown in Figure 36. Soil type is related to many model parameters affecting the hydrologic calibration such as the infiltration rate and soil storage. The slopes of the land surface and stream reaches are important input parameters to BASINS. The GIS capabilities allow these slopes to be estimated from digital elevation maps as shown in Figure 37.

Model calibration will include a comparison between model-predicted flows and measured flows. Although the watershed model has not yet been calibrated, a preliminary comparison of model predictions to measured flows at USGS gage at US 31 is shown in Figure 38. The current, un-calibrated model predicts a similar average flow as is observed at the USGS gage, but shows differences seasonally and during individual storms. The process of model calibration will reduce these differences, and may highlight the need for additional site-specific data, such as rainfall.

The BASINS model will also predict total phosphorus at each sampling station in the watershed. The model includes both soluble and particulate phosphorus. However, model calibration and validation will only include total phosphorus assuming that the model results for each component are reasonable. Predicted values will be compared to observed data to calibrate the water quality prediction. The predicted loads from the watershed model will then be used by the Platte Lake water quality model underdevelopment and described in the next section of this report. Figure 39 shows plot of daily total phosphorus concentrations that suggest rain events influence in stream concentrations. The un-calibrated daily total phosphorus concentrations range from 1 to 85 mg/m^3. These values will change during the calibration process. They are shown here only to provide an example of what the model is capable of predicting.

The model, when fully calibrated, will be used to test the impact that different management practices, or expected land use changes in the watershed will have on water quality. Figure 40 shows a hypothetical example where current predicted phosphorus concentrations are compared to future concentrations, assuming that much of the forested land in the watershed has been converted to residential land in the future. The model shows that under increased development, phosphorus concentrations may increase. These values will change during the calibration process. They are shown here only to provide an example of what the model is capable of predicting.

Overview of Lake Water Quality Model

A comprehensive water quality model for the lake will eventually be needed that can predict the impact of the non-point total phosphorus loads from the watershed (as determined by BASINS) and the hatchery total phosphorus loads on the water quality of Big Platte Lake. It is also important that the model accurately simulate light attenuation (extinction coefficient or Secchi Depth) and the internal loading of phosphorus from the sediments associated with low bottom water dissolved oxygen concentrations. This model will be used to estimate the effectiveness of various remedial control measures designed to promote compliance with the water quality goals of the lake.

Water quality models for Big Platte Lake have been developed by in the past by Canale et al. (1991), Chapra (1996), Lung (2000), and Walker (1998). Unfortunately, these models do not adequately address exchange processes between the water and the sediments and do not include dissolved oxygen or Secchi Depth as model variables. Thus, these models must be improved before they can be used to accurately forecast changes in the water quality of Big Platte Lake.

Progress on Calibration of Lake Water Quality Model

The development of a new water quality model for the lake is proceeding in stages. It started with a simple approach they drew upon existing monitoring data and the findings of other modeling efforts. The simplest form of the model produced a useful tool that can be used to analyze and understand water quality measurements in the lake. It has also been used to refine the design of the lake and tributary sampling program.

Figure 41 shows the mechanisms for one layer dynamic total phosphorus model for Big Platte Lake develop last year. These include tributary flow and loading, overflow, settling, sediment release, and any extra loads not measured. Although this model has proven useful for the analysis of the measured data and provided useful insights, it cannot yet be used directly for management applications because it does not predict algal levels, Secchi Depth, or dissolved oxygen. Thus multiple water and sediment layers have been added to the model. This will allow simulations of the history of the water quality of the lake and permit predictions of long-term recovery and response to remedial activities.

Figure 42 shows the proposed three layer model with shallow, medium, and deep water and sediment components. Such a spatial segmentation is simple yet it allows for the capture of the major limnological processes and features of the measured data. Figure 43 shows the model kinetic components. The model mechanism were chosen to allow accurate modeling of phosphorus, water clarity, and dissolved with minimum model complexity. This model requires the solution of 30 linked time-variable non-linear differential equations.

Figure 44 shows the calibration of temperature in the lower layers. This calibration uses the measured temperature for 2000 in surface layer as a forcing function. The vertical exchange coefficients are determined in this manner and held the same for simulation of other model parameters. Figure 45 shows the 2000 model and data for dissolved oxygen. Note that the model does an excellent job of simulating winter and summer turnover and stratification. Figure 46 shows model calculations and measured 2000 concentrations of total phosphorus and chlorophyll and Secchi Depth. The model fits the spring and fall increases in phosphorus as well as the minimum in the summer. The model also simulates a long spring phytoplankton bloom as well a shorter fall increase with summer clearing in between. The model does not replicate the secchi death very well, especially during the important summer minimum period.

It is planned to make additional improvements to this model framework as more monitoring data become available and the special studies are completed.

Coordination

An excellent spirit of coordination, cooperation and communication has been maintained between the Implementation Coordinator and the parties. Telephone conference calls are held on a regular basis. Appendix 6 documents the agenda and minutes from 22 coordination meetings conducted during 2002.

PLIA representatives have participated in the effort to count and record the salmon that pass the Lower Weir. A good working relationship exists between the hatchery staff and the PLIA.

Significant coordination continues with the Benzie Conservation District regarding wet weather sampling and development and application of watershed model.   The District has funded the development of the BASINS model and will eventually use the model to assist with the implementation of remedial activity. The District is also working cooperatively with the hatchery staff to procure and install automatic sampling equipment to facilitate data collection during wet weather.

The District has developed a Partnership Agreement with the MDNR and the PLIA. This Partnership will facilitate the efforts of the District to secure additional funds to support the objective of preserving the water quality of Big Platte Lake. The National Park Service has also been asked to join the Partnership. Their participation is encouraged because it would strengthen the Partnership and adds momentum to efforts to protect the water quality of Big Platte Lake. In addition, lines of communication have been established with nearby lake-protection associations from Crystal and Long Lakes and other conservation agencies.

References

Canale, R. P. (2000). *Long Lake Water Quality Model.* Report prepared for GLEC, 4 pages.

Canale R. P., Whelan, G., and Swiecki W. (2001). *Annual Report for the Year 2000.* Report prepared for MDNR and PLIA.

Canale, R. P. and Chapra S. C. (2002). "Modeling Zebra Mussel Impacts on Water Quality of the Seneca River, NY". To appear in the *Journal of the Environmental Engineering Division*, ASEC.

Canale, R. P., Swiecki, W. J. and Chapra, S. C. (1991). *Fish Hatchery Impacts on High Water Quality Lakes*. Report Prepared for PLIA, 25 pages.

Chapra, S. C. (1997). *Surface Water-Quality Modeling*. McGraw-Hill, New York.

Chapra, S. C., (1996). *Data Analysis and Preliminary Modeling of Platte Lake, Michigan*. Report prepared for MDNR and PLIA.

Chapra, S.C. and Canale, R. P. (1998). *Numerical Methods for Engineers*. 3rd Edition. McGraw-Hill, New York

Clerk, Saloni. (2001). *Fossil Chironomids as Indicators of Water Quality: Impacts from Aquaculture Activities*. Master's Thesis, Queen's University, Kingston, Ontario Canada.

de la Camp, U and Seely, O. *Accuracy of Spectrophotometer Readings*. Class Notes from the California State University at Dominguez Hills.

Durbin, A. G., Nixon, S. W. and Oviatt, C. A. (1979). "Effects of the Spawning Migration of the Alewife, *Alosa Pseudoharengus*, on Freshwater Ecosystems". *Ecology,* Vol. 60, No. 1, 8-17.

Freedman, P.L. and Canale, R.P. 1977. Nutrient release from anaerobic sediments. *Journal of the Environmental Engineering Division. Proceedings of the American Society of Civil Engineers.* Vol. 103, No. EE2: 233-244.

Gardiner, R.D. 1984. *Sediment oxygen demand and related surficial sediment characteristics in Green Bay (Lake Michigan)*. Master's Thesis, Department of Civil Engineering, Michigan Technological University, Houghton, Michigan.

Kamp-Nielson, L. 1974. Mud-water exchange of phosphate and other ions in undisturbed sediment cores and factors affecting the exchange rates. *Arch. Hydrobiol.* 73: 218-237.

LinmoTech, Inc. (2001). Report Prepared for Benzie Conservation District

Lung, W., (2000). *Modeling Total Phosphorus and Dissolved Oxygen in Platte Lake.* Report prepared for 30th Circuit Court, state of Michigan.

Nurnberg, G.K., (1986). Prediction of Phosphorus Release Rates from Total and Reductant-Soluble Phosphorus in Anoxic Lake Sediments, *Can. J. Fish. Aquat. Sci.*, Vol 45, pages 453-462.

Penn, M.R., Auer, M.T., Doerr, S.M., Driscoll, C.T., Brooks, C.M., and Effler, S.W. 2000. Seasonality in phosphorus release rates from the sediments of a hypereutrophic lake under a matrix of pH and redox conditions. *Can. J. Fish. Aquat. Sci*. 57: 1033-1041.

Walker, W. W., (1998). *Analysis of Monitoring Data from Platte Lake, Michigan.* Report prepared for Michigan Department of Natural Resources.

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