Annual Report for the Year 2003

Consent Agreement Regarding the Operation of the Platte River Hatchery

Report Prepared by

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Summary for the Year 2003

Overview

The goal of the Consent Agreement is to implement a long-term strategy to restore and preserve the water quality of Big Platte Lake. This goal is being advanced by minimizing the flow and phosphorus discharge from the Hatchery and by developing strategies to reduce non-point phosphorus loads from the watershed. Table 1 summarizes the compliance with the Consent Agreement and the major accomplishments for 2003.

Compliance with Consent Agreement

The Consent Agreement mandates that the Hatchery net load will be limited to a maximum of 225 lbs. for the construction period including the year 2003. 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 period. The net Hatchery loading for 2003 was 170.1 lbs using the jug & needle samples. This includes both the loads from the upper outfall and the bypass loads for three months during construction periods. This calculation uses linear interpolation to determine loads on days where no measurements were taken. Negative net loads are set equal to zero for calculation purposes. This load is well within the Consent Agreement limit. The maximum net load for a single three-month period was 93 lbs. This exceeded the limit by 18 lbs. and was caused by construction related problem.

The average volume-weighted total phosphorus concentration of Big Platte Lake was 8.12 mg/m^3 in 2003. The water quality goal of 8.0 mg/m^3 was exceeded 50% of the time. This is not in compliance with the goal of 95% attainment as stipulated in the Consent Agreement.

A total of 16,255 adult Coho passed the Lower Weir in 2003. This is in compliance with the Consent Agreement limit of 20,000. A total of 422 adult Chinook salmon passed the Lower Weir in 2003. This is also in compliance with the Consent Agreement limit of 1,000. Excess salmon that accumulated below the lower weir were harvested, counted, and removed from the watershed. A total of 13,000 adult Coho salmon were harvested for egg collection at the Upper Weir. This is 80% of the number of the Coho that were counted passing through the Lower Weir. A total of 154 adult Chinook salmon were harvested at the Upper Weir. This is 36.5% of the number that were counted passing through the Lower Weir.

Major Accomplishments for 2003

- The Hatchery has nearly completed the major renovation program that included the addition of state-of-the-art effluent control systems, new outside raceways with reuse capabilities, headbox upgrades, and new flow monitoring equipment.

- A Microsoft ACCESS database has been developed to maintain Hatchery, tributary, Lake, and other data. The database has extensive report retrieval capabilities that facilitate comprehensive data analysis.

- 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. Calibration procedures for the YSI meter have been established for dissolved oxygen and pH. SOP documents for field procedures and laboratory analyses have been updated.

- Correlations between turbidity and suspended solids were developed for both the laboratory and field turbidity meters. These calibrations can be used to estimate suspended solids concentration from turbidity measurements.

- Wet weather flow, phosphorus, and turbidity data were collected for several storm events at selected Platte River and Brundage Creek locations. These data will be used to further calibrate the BASINS watershed model.

- An annual phosphorus mass balance model has been completed for the Hatchery.

- LimnoTech has completed the development and baseline calibration of the BASINS watershed model using historical water quality and quantity data.

- Special studies were completed for macrophytes and shoreline water quality. Studies of sediments and light attenuation in the lake are underway.

- Water flow and phosphorus mass balances were developed for the watershed and lake.

- A peer-reviewed technical article was accepted for presentation at the Water Environment Federation meeting in Detroit in July 2004. The article has been published in the conference proceedings (Appendix A).

Recommendations and Action Items for 2004

- Hatchery water sources and discharges should be continued to be sampled using both the Jug & Needle and Sigma sampler methods. Analyses comparing the techniques should continue until all parties are satisfied that the Sigma sampler can replace the Jug & Needle sampler.

- The Hatchery production report should separate fish planted into the Platte River from those shipped away from the system. It should also include the weight of coho and Chinook salmon eggs processed at the Hatchery.

- The stored liquid and sludge volumes and phosphorus concentrations of the Hatchery storage tank should be estimated at the beginning of January, the end of December, and at intermediate monthly intervals. All trucked liquid and sludge should have volumes recorded and have phosphorus concentrations measured on them.

- The concentrations of TKN and TKN-F should be measured in the lake from the tube composite sampler in triplicate on two occasions in July and August.

- The concentration of reactive silica, total dissolved phosphorus, and nitrate should be measured in the lake from the 0 to 30 foot tube sampler and the 45, 60, 75, and 90 foot depths.

- PLIA and Hatchery staff should compare methods for Secchi depth measurement. These measurements should also be compared to light extinction measurements.

- SOP documentation should be written for the collection of flow data for the North Branch of the Platte River at the Little Platte Dam.

- Flow, phosphorus, and turbidity should be measured at tributary locations until the end of the year. Emphasis should be placed on collecting samples during wet weather. Automatic continuous samplers should be used when available, otherwise grab samples should be used.

- The BASINS model should be calibrated using wet weather stream data.

- The sediment and light special studies should be completed as soon as possible.

- Development and calibration of the water quality model for the lake should continue as additional data become available.

- A survey should be conducted to estimate the area, density, and size-distribution of resident zebra mussels.

Acknowledgements

The Implementation Coordinator would like to take this opportunity to thank Gary Whelan and Wil Swiecki for their continuing contributions to this project. Gary has extraordinary leadership and management skills and has kept this project focused and moving forward. Wil has been tireless in his efforts to ensure the reliability of the data and has displayed incredible perseverance working toward the PLIA goal of preserving the water quality of the Lake. As a result, excellent coordination and communication has been maintained within our group as well as with many outside organizations and individuals. The minutes of 20 coordination meetings in 2003 are contained in the Appendix B.

Jim Berridge deserves a special medal for outstanding service to Platte Lake. He has contributed his talents and endless hours of his time to create an Access database for the laboratory and field data collected on this project. This daunting task is nearing completion. All those interested in preserving the water of Big Platte Lake owe him their gratitude.

Aaron Switzer has taken over full responsibility of collecting the field data and has done an absolutely outstanding job with this task. He has contributed not only through his perseverance and consistency but also through thoughtful analysis of procedures and data. He always stands ready to get “just a few more samples” to satisfy the needs of Ray, Gary, and Wil. Ed Eisch and Bob Humphrey have also made this project one of their top priorities and have provided valuable guidance and stability, and performed backup sampling tasks. The reliability of the data would suffer without their careful and conscientious efforts.

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. Scott McNaught has reviewed the historical plankton data, recommended much improved methods for sample collection, and added biomass measurements. Michael Holmes and Scott McNaught are working on a project to study phosphorus release dynamics from Big Platte Lake sediments.

Bob Haas from the Mt. Clemens Research Station and Jim Breck from the Institute of Fishery Research in Ann Arbor conducted a very useful study of distribution and density of macrophytes in Big Platte Lake.

Beneficial coordination continues with the Benzie Conservation District (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.

Penelope Moskus and Troy Naperla from LTI have done an excellent job developing and calibrating the BASINS model in coordination with the District and the Implementation coordinator.

Meg Woller and Matt Heiman from the Leelanau Conservancy did a great job conducting the shoreline study of the lake to identify nutrient sources.

Mark Mitchell has been measuring the flow rates of several tributaries and collecting samples for measurement of water quality parameters.

Finally, 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. Mike Pattison has updated and reviewed the EXCEL spreadsheets and is involved in the maintenance of the Access database.

Monitoring Program

Objectives

The overall purpose of the monitoring program is to facilitate and support the goals of the Consent Agreement. The sampling program has the following specific objectives.

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

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

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

- To collect data to construct mass balances for water and total phosphorus for the Hatchery, lake, and watershed.

- 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.

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

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

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

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

Sampling Plan

The sampling plan for 2003 involves collecting data from the Hatchery, watershed streams (see Figure 1) and Big Platte Lake. The sampling stations are shown in Figures 2 and 3. The sampling frequency of each station and the list of measured parameters is given in Figure 4.

The net Hatchery total phosphorus load to the system is evaluated by subtracting the inlet load from the total outlet loading. Measurements of flow, total phosphorus concentration, and turbidity 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 2004.

The tributary sampling program is designed to calculate the non-point phosphorus loading into Big Platte Lake. Measurements of flow, phosphorus, and turbidity are taken every two weeks and during wet weather flow events. These data will allow a detailed evaluation of water quality for various hydrologic conditions, provide sub-watershed loading estimates, and will support the calibration and validation of the BASINS watershed model.

The lake is sampled at 8 depths every two weeks during the year. The YSI meter is used to measure dissolved oxygen, temperature, pH, conductivity, and ORP. Discrete depth and tube samples are analyzed for total phosphorus, turbidity, phytoplankton, alkalinity, chlorophyll, total dissolved solids, and calcium. Zooplankton is sampled using a vertical net haul. Light penetration is measured with a Licor Light Meter. Secchi depths are measured with a standard Secchi disk.

Quality Assurance and Control

There is an ongoing effort to insure the accuracy of all of the various field and laboratory procedures. The following is a list and brief description of activities conducted in 2003.

- Procedures were developed to calibrate the YSI meter dissolved oxygen meter before every use. This is accomplished using air saturated refrigerated and room temperature distilled water to simulate conditions on the bottom and surface of the lake. The dissolved oxygen concentration of these waters is measured with the air-calibrated YSI meter. The measured concentrations are compared to known values to verify the accuracy of the meter readings.

- Procedures were developed to calibrate the pH readings from the YSI meter. This is done with purchased pH 7.0 and 8.3 standard solutions.

- Samples for measurement of chlorophyll are filtered both immediately after returning form the field and at the CMU laboratory. Both measurements are retained for comparison.

- Measurements of phosphorus and turbidity from the 0 to 30 composite tube sampler are compared with the average of discrete depth measurements taken a 0, 7.5, 15, and 30 foot depth. The data are retained to facilitate evaluation of the sampling methods.

- Experiments were performed on various pieces of sampling equipment, containers, and other materials that come in contact with samples for the purpose of evaluating the potential for leaching phosphorus and contaminating samples. It was determined that the horizontal plastic Kemmerer sampler cannot be used because it leaches significant quantities of phosphorus. Other material are still under investigation.

- The CMU laboratory has implemented procedures to insure the accuracy of their phosphorus measurements. Calibration curves for phosphorus are created using standard solutions before actual samples are analyzed. The 10 mg/m^3 standard is rerun at the end of the day to determine any drift in the baseline calibration. In addition, CMU purchases 5 and 10 mg/m^3 standards and measures these solutions using laboratory standards curves to insure accuracy.

- CMU has performed tests with purchased standard solutions to verify the accuracy of their measurements of calcium, total dissolved solids, and chlorophyll. Tests were performed to insure that storage time did not significantly affect alkalinity test results.

- SOP documentation for various field measurements has been updated.

These efforts help insure that Hatchery and CMU field and laboratory procedures are as consistent and accurate as possible. It is recommended that efforts during 2004.

Data Management

An ACCESS database has been developed that accommodates the current sampling at the Hatchery, in tributary streams, and the lake. The new database contains all the 2003 data and is current with data being collected in 2004. The Platte Lake Watershed Sampling Database consists of three components: Field, Data Manager, and Data Viewer as shown in Figure 5.

The Field component is used to enter various measurements taken in the field or conducted in the Hatchery laboratory on the computer keyboard. Typical Field measurements are the YSI probe data, turbidity, flow rates, weather conditions, and light attenuation with depth. The Field component also records bottle numbers associated with samples and measurement instructions. The field measurements, bottle numbers, and measurement instructions are sent to the Data Manager component as small text files through email. The bottle numbers and the measurements instructions are sent to CMU. This information is sent to CMU in the form of text files using email and as hard copy sheets packed in the shipping coolers.

Laboratory results for various bottle numbers are sent to the Data Manager in the form of EXCEL spreadsheets using email. The Data Manager program imports the laboratory results and matches this information with the bottle numbers obtained from the Field component. At this point conflicts such as inconsistent bottle numbers and missing data must be resolved. Following the resolution of all conflicts the Data Manager updates and distributes the data files to the Data Viewer through email.

The main function of the Data Viewer component is to produce and analyze various reports that summarize the data in convenient forms. The Data Viewer component cannot change data entries in the database. However, the Viewer can suspend use of suspicious data temporarily or make other adjustments to facilitate interpretation of the data. The reports examined through the Data Viewer are also used to produce graph and tables for the Annual Report.

Note that despite the computer programs developed to accommodate these tasks, significant communication and coordination is required among the four components to insure that all data are correctly entered and displayed. With time, these coordination tasks may diminish.

Hatchery Operations

Renovations

At this time, nearly all of the renovation work is complete at the Platte River State Fish Hatchery with only minor punch list items remaining to be completed. The following is an update for each component of the renovation:

- Flow meters were installed in 2002 and have been in service since that time without any substantial down time. A calibration procedure has been developed for some of the flow meters and will be implemented in the summer 2004.

- Problems with Sigma samplers have been resolved and the reliability of the samplers greatly improved. Comparison testing with jug and needle is ongoing and it is expected that this testing will be completed in the summer of 2004.

- The new head-tank was completed in October 2003 and has been in operation since that time.

- The new covered outdoor raceways have been in use since October 2003 and the operation has been satisfactory during most of that period. The final large component to be installed will be the new automated fish feeders that will be fully operational in October 2004. In March 2004, a recirculation pump and alarm system failure caused the mortality of 457,000 yearling coho salmon. The cause of this incident was a failure of a Variable Frequency Drive Controller Board on the main reuse pumps that resulted in the loss of water to the Raceway B complex. Additionally, the alarm system failed to pick up the failure of the pump. Remedies have been put into place and additional analysis continues on the failure. Dead fish were buried above the Brundage Creek intake on hatchery property after receiving DEQ and Platte Lake Improvement Association concurrence.

- The new effluent treatment system has been in operation since October 2003. The initial results are very promising. The total phosphorus loads were less then 12 lbs. per month during the period from October 2003 to March 2004. There are still operational problems to be worked on with respect to cleaning/backwashing the disc filters, clarifier operation, system maintenance, and removal of sludge from the storage tank. Some punch list items remain with this system and should be complete by fall 2004.

- The alarm and monitoring system has worked well since October 2003 when it became operational. Some there are some ongoing issues with the alarm computer server and initially some alarm points were not set correctly.

The hatchery is expected to be substantially completed by October 2004 when all of the final punch list items should be completed. The hatchery will move from the current construction effluent limits to the testing phase effluent limits on June 1, 2004.

Antibiotic and Disinfectant Use

Antibiotic use at the Platte River State Fish Hatchery involved feeding oxytetracycline (OTC) to Chinook salmon to produce a readable mark on the vertebra of hatchery produced fish. The antibiotic was delivered to the fish in the form of medicated feed which was produced by Bio Oregon of Warrenton, Oregon. The OTC (TM100) was mixed in the feed at a rate of 25.11 pounds per ton of feed in 2003. A total of 7,568 pounds of medicated food was delivered and used during the marking process that occurred during the period April 25 through May 25, 2003. This compares to a total of 8,025 pounds fed during 2002. The total amount of OTC in the feed in 2003 was 95.0 pounds which compares to 100.7 pounds in 2002. The marking protocol for 2003 called for the fish to be fed the OTC food for 4 days with one day off followed by 4 additional days of the OTC feed. No monitoring was planned during the Chinook salmon marking of 2003 because of the results of previous years. The maximum amount fed on a given day during the treatment period was 715 lbs (9.0 lbs of TM100). Flow through the hatchery during the treatment period was 10.42 mgd. In 2002, the flow during the treatment period was 19.24 mgd.

Parasite-S (formalin) is used to control fungus on fish eggs. Parasite-S is a trade name for formalin that consists of 37% formaldehyde by weight in water. The standard treatment used is a 15-minute flow through with formalin at a concentration of 1 to 600 (1,667 mg/L). In 2003, six hundred eighty-eight gallons of Parasite-S were used to control fungus on salmon eggs during the period October 7, 2003, to January 5, 2004. Total formalin usage was down nearly 13 percent when compared to 788 gallons of formalin used during the 2002 incubation season. Maximum daily treatments were 10.2 gallons per day (per 15 minutes). Hatchery flows during the period ranged from 11.83 mgd to 14.80 mgd as compared to a range of 14.57 to 17.06 mgd during the 2002 incubation season. No monitoring for formaldehyde in the discharge was done in 2003 because of monitoring results that were obtained in 1999.

Fish Production

The MDNR has operated a fish culture facility on the Platte River since 1928. The facility began as a trout rearing station and was expanded during the period from 1966 to 1972 to support the Department's Great Lakes salmon program. Figure 6 shows the history of the use of food at the hatchery. Approximately 35,000 lbs of fish feed was used annually prior to facility expansion program. A maximum of about 550,000 lbs of feed was needed in 1974 during the peak production period. Food use at the hatchery has gradually declined and is currently about 15% of the maximum mid-1970 levels and three times the baseline amount used prior to 1966.

The history of fish production at the Hatchery in Honor is shown in Figure 7. The annual production of fish at the original rearing station was approximately 23,000 lbs. This fish production is about two-thirds of the amount of food fed. Currently about 100,000 lbs of fish are produced using about 100,000 lbs of feed. This demonstrates that the efficiency of fish production has increased over time along with significant improvements in fish foods.

Net Total Phosphorus Load

The process water used to culture the fish becomes enriched with phosphorus from fish fecal pellets and unconsumed feed. The net phosphorus loading from the Hatchery is defined as the increase in the phosphorus concentration in the process water above background levels times the flow rate from the facility. During the period from 1928 to 1964 the phosphorus loading was relatively constant at about 163 lbs/yr. This loading increased to a maximum of about 4,300 lbs/yr in 1974. The increase in loading was associated with increased food usage and fish production and accelerated by the fact that the phosphorus content of the feed increased because the composition changed from 66% waste slaughter house parts (0.24% P) and 33% fish meal (1.5% P) prior to the salmon program, to a nearly 100% diet of Oregon moist pellets that ranged from 2.0 to 3.5% P. The history of changes in the phosphorus loading from the facility is shown in Figures 8 and 9. Note that the current phosphorus loading of about 170 lbs/yr is about 4% of the maximum mid-1970 values and essentially equal to the early historical load before the expansion program.

Figure 10 shows the long-term changes in the Hatchery effluent flow between 1990 and 2003. The long-term average flow is about 4.1 billion gallons per year. The maximum and minimum flows over this period are 4.75 and 2.75 billion gallons per year. The average flow or water use for 2003 is 4.75 billion gallons per year which is the highest amount for the long-term period and about 16% higher than the average water use. The Hatchery outflow is about 16% of the total

flow of the Platte River at the USGS gage station for 2003 and about 2/3 of the flow from the North Branch of the Platte River.

Figure 11 shows a bar graph of the Hatchery net loading for each month that separates the normal outfall from the construction bypass in July, August, and September. Higher net loads occur in the spring and fall when the Hatchery accommodates the highest biomass of actively growing fish. Note that the net load exceeded the 75 lb limit for the months of August and September which is attributed to an effluent pond construction problem.

Figure 12 shows the calculated cumulative net Hatchery phosphorus loading for 2003. Note that the daily load increased significantly around mid-July during the construction bypass. This resulted in a large increase in the net load. However, with the ongoing construction the net load for the year was 170.1 lbs, an amount that is only about 3% higher than the load when the Hatchery was only a rearing station. The low loading in 2003 is the result of improved facilities and efficient management.

Figure 13 shows the flow, turbidity, and phosphorus of various Hatchery sources and discharges. Note that most of the water used by the Hatchery came from the Platte River in 2003 and that the least used source was Brundage Spring. Brundage Spring had the highest phosphorus concentration, and the Platte River had the lowest average value. Brundage Creek had the highest and Brundage Creek the lowest average turbidity. These considerations suggest that the Platte River may be a better water source than Brundage Creek with respect to turbidity and phosphorus but is considered poorer water source for fish production because of the higher pathogen loads and greater temperature fluctuation. Both of these factors will greatly increase stress on the hatchery fish and ultimately, will reduce food efficiency at the hatchery.

Figures 14 and 15 show the measured values of phosphorus and turbidity of the Brundage Creek input water using the Jug & Needle and Sigma methods. Note that high spikes in phosphorus concentration are almost always associated with spikes in turbidity for both methods. Figures 16 and 17 compare the phosphorus concentrations and turbidity of the Brundage Creek intake water sampled with the Jug & Needle and Sigma methods. Note that although long-term average values of the two methods are similar, the phosphorus and turbidity spikes do not always occur on the same days for the two methods. This suggests that on a given day different water samples are being taken. It is also noted that the location of the influent stream samplers are not exactly the same. Note that similar analyses can be conveniently performed on the other water sources with Data Viewer component of the database. Figures for these cases are not presented here for the sake of brevity, but can be viewed using the Data Viewer.

Evaluation of Automated Sampling Equipment

The concentrations of total phosphorus and turbidity of the inlet and outlet flows from the Hatchery are currently sampled using two methods. For several years a composite sample has been taken using a jug equipped with a fine gage needle that slowly allows water to enter the jug. Sigma Samplers were recently installed in association with the renovation program. These samplers obtain a 24 hour composite sample by pumping sub-samples at regular intervals.

Appendix C shows that the Jug & Needle collection containers are often completely fully in less than 24 hours. As a result, the phosphorus and turbidity concentrations for the two methods are not the same, particularity for cases when the concentrations may be varying rapidly as a function of time.

It is recommended that samples be taken using both methods and analyzed for phosphorus and turbidity. The Sigma Sampler inlet tubes should be cleaned regularly. The official Hatchery loading should be calculated from Jug & Needle total phosphorus measurements until sample values from both techniques are found to not be significantly different or all parties agree that the Sigma sampler is providing superior data.

Pond Efficiency

Figure 18 shows the ratio of the pond output to input for phosphorus and turbidity. Values less than 1.0 indicate that the pond has removed phosphorus or turbidity on that day. On the other hand, values greater than 1.0 show days when the pond was exporting rather than removing phosphorus and turbidity. Note that removal or discharge of phosphorus and turbidity are not necessarily highly correlated as shown from analyses contained in the 2002 Annual Report. Figure 19 shows the accumulative phosphorus input and discharge for the pond. The difference between the curves is the accumulation or retention in the pond. Note that despite daily variations, the pond consistently removes phosphorus after about day 75, and eventually removes 70.7 lbs for the year 2003. Note that improvements including closing off short circuits and improving pond flow patterns were made to the pond in 2003. The effects of these pond improvements will be analyzed in 2004.

Hatchery Phosphorus Mass Balance

The purpose of this section is to examine all of the major sources and sinks of phosphorus in the hatchery 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.

The following are the major sources of phosphorus to the Hatchery:

- Brundage Spring
- Brundage Creek
- Platte River
- Fish food
- Fish eggs

Note that fish present in the system at the start of the year is also a source of phosphorus.

The following are the sinks or losses from the system:

- Waste liquid and sludge
- Upper discharge
- Construction bypass
- Losses from the pond
- Fish planted into the Platte River
- Fish shipped from the Hatchery
- Fish mortality (morts)
- Fish in the hatchery

Note that fish present in the system at the end of the year must also be accounted for as a sink of phosphorus.

Figure 20 shows the calculations associated fish production and this contribution to the Hatchery mass balance for phosphorus. These calculations assume that fish biomass is 0.4465 % phosphorus by wet weight and that fish eggs are 1.3 % phosphorus by wet weight. Note that the ratio of the weight of fish produced to the weight of fish food used is 1.37. This means that 1.37 pounds of fish were produced for every pound of fish feed used in 2003. This is likely the result of cannibalism, use of excess production to feed fish, and water uptake.

Figure 21 shows calculations for the amount of phosphorus that is trucked away from the Hatchery or that accumulates in the Storage Tank. Note these preliminary data indicate that a

relatively small amount of phosphorus is disposed of in this manner. It is recommended that stored and trucked liquid and sludge volumes and phosphorus concentration measurements be collected at the beginning of January and the end of December and for monthly intervals. These data will allow a more accurate calculation of the amount of phosphorus stored or trucked from the storage tank.

Figures 22 and 23 illustrate a summary of all the Hatchery phosphorus sources and sinks for the year 2003. All terms are expressed as the phosphorus equivalent to facilitate comparison. The phosphorus from the three input streams is calculated using measured flow and phosphorus concentrations. Note that about 88 more pounds of phosphorus are calculated to enter the system than leaves. This is only about 5% of the overall amount of phosphorus that is processed by the Hatchery. This close agreement suggests that the overall process is well understood and that accurate measurement techniques are being employed. Better estimates of the storage tank phosphorus volumes and phosphorus concentrations might allow even more accurate estimations in 2004.

Tributary Flows and Water Quality

USGS Station at US 31

Figure 24 shows 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 124.7 cfs in 2003. This flow is close to the long-term average flow of 124.98 cfs since 1990. Thus, 2003 can be characterized as an average year. Figure 25 shows daily hydrographs for the Platte River at the USGS gage station for 2003. Note that the hydrograph is relatively uniform with the spring high flows being about 50% greater than the summer low flows. Several spikes in flow correspond to significant rainfall events as shown in Figure 26. Note that the sampling dates correspond closely to some of these wet weather spikes. The average of the flows on the actual sampling days was 6% higher than the average of all the daily flows.

Figures 27 and 28 show examples of data collected with automatic sampling equipment during storm events in 2003. Note that order of magnitude increases of phosphorus and turbidity are associated with relatively small increases in flow gauge levels. The duration of such events is several hours. Thus, non-point loads based on routine measurements alone may underestimate the actual non-point load because many spikes are missed. Furthermore, the magnitude of the phosphorus loads associated with these events is expected to exceed the annual phosphorus

load from the Hatchery. Thus, it is important that the tributary monitoring program and the BASINS modeling effort accurately evaluate the non-point total phosphorus loads in the system.

Figures 29 and 30 contain laboratory measurements of turbidity and suspended solids concentrations. These data show that these two measurements are highly correlated. The linear regression formulations can be used to estimate suspended solids concentration from field measurements of turbidity. This is convenient because direct laboratory measurement of suspended solids is relatively expensive, time-consuming, and imprecise. Information concerning suspended solids concentrations during storm events is expected to be helpful for calibrating the BASINS model.

Figure 31 shows measured total phosphorus concentrations in the Platte River at the USGS station for 2003. Measurements taken with a new plastic horizontal Kemmerer sampler were significantly higher than measurements taken using the traditional dip sampling method. Investigations have shown that the plastic horizontal Kemmerer equipment leaches dissolved phosphorus at a significant rate. Thus, the data obtained with this equipment is considered erroneous and will not be used in calculations of phosphorus loading. The average phosphorus concentration using the dip method was 14.8 mg/m^3 which are similar to the values measured in 2002.

North Branch of the Platte River

Measured total phosphorus concentrations in the North Branch of the Platte River for 2003 are shown in Figure 32. Fortunately, the plastic horizontal Kemmerer sampler was not used to sample the North Branch of the Platte River. The average phosphorus concentrations using the dip method was 14.95 mg/m^3 which is similar to the values measured in 2002. Studies are underway to calibrate gauge reading at the North Branch station and measured flows.

M-22 Outlet

Figure 33 shows measured total phosphorus concentrations at the M-22 outlet station for 2003. Again, measurements taken with the new plastic horizontal Kemmerer sampler were significantly higher than measurements taken using the traditional dip sampling method. Investigations have shown that the plastic horizontal Kemmerer sampler leaches dissolved phosphorus at a significant rate. Thus the data obtained with this equipment is considered erroneous and will not

be used in calculations of phosphorus loading. The average phosphorus concentration using the dip method was 7.65 mg/m^3 which is similar to the values measured in 2002.

Figures 34 and 35 compare the measured the total phosphorus concentration at the M-22 outlet and the average surface and 7.5 foot depth lake concentration. The plastic horizontal Kemmerer sampler values were significantly higher than the lake surface values. The average M-22 outlet phosphorus concentration was 7.65 mg/m^3 when measured using the dip method. This value is nearly the same as the average of the lake surface concentration 7.94 mg/m^3.

Figure 36 shows M-22 turbidity measurements taken with the plastic horizontal Kemmerer sampler compared to the lake surface. Note that the turbidity measurements of the M-22 samples are generally less than the lake surface water. This indicates that algae and other suspended particles present in the lake are lost by settling or dissolution by the time the water reaches the M-22 outlet. This phenomenon will be further investigated using 2004 data.

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. Figures 37 and 38 and show the long-term trend of the annual average volume-weighted average total phosphorus concentrations and the percent of the time that the concentrations exceed the 8 mg/m^3 standard. The volume average concentration was calculated using all 8 discrete depth total phosphorus measurements -- surface, 7.5, 15, 30, 45, 60, 75, and 90 feet. The median of the three measurements at each depth were used to eliminate the need to arbitrarily disregard any valid measurement and over-emphasize any single value. The algorithm is described in detail in the 2002 Annual Report. It multiplies the surface median phosphorus concentration by the volume of water between the surface and 3.5 feet to obtain the mass of phosphorus in the first layer. The mass of phosphorus in the second layer is determined by multiplying the 7.5 foot median phosphorus concentration 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 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 values twice during the calculation. This procedure is consistent with formal and rigorous numerical algorithms such as the Trapezoidal Rule (Chapra and Canale, 1998). The annual variation of volume weighted total phosphorus in Big Platte Lake in 2003 is shown in Figure 39 and the annual variation of each layer is detailed in Figure 40. The average annual volume-weighted total phosphorus concentration was 8.12 mg/m^3. There were 183 days in 2003 when the total phosphorus concentration exceeded the 8.0 mg/m^3 goal. This corresponds to about 50% attainment as compared to the 95% requirement.

Note that the lake phosphorus concentrations are high in the spring and fall and lower in the summer and winter. The spring and fall peaks could be associated with increased runoff from tributaries and less settling in the lake due to more mixing caused by less thermal stratification. During the summer and winter settling of particulate phosphorus is expected during periods of low vertical mixing. The lake water quality model under development should be able to quantify these observations.

Figure 41 compares the average of the surface, 7.5, 15, and 30 foot phosphorus and turbidity measurements with the 0 to 30 foot tube composite samples. Note that there is good the correspondence between sampling methods. This is an important validation of the sampling and laboratory procedures. It also suggests that the tube sampler could be used to reduce the field and laboratory costs if necessary.

Dissolved Oxygen Depletion

Figures 42 and 43 show that the annual variation of temperature and dissolved oxygen at eight lake depths. As expected, dissolved oxygen depletion in the hypolimnion of Big Platte Lake is closely related to temperature stratification. Figure 42 shows maximum winter stratification on day 70, spring overturn on day 120, and fall turnover on day 280. Thus, the lake was stratified for about 160 days during 2003. Figure 43 illustrates that the bottom water dissolved oxygen concentration decreases rapidly with the onset of spring stratification. Figure 44 shows the oxidation potential of the lake waters. Negative ORP values suggest anaerobic conditions that promote the release of phosphorus from the sediments.

The concentration of dissolved oxygen drops below 2 mg/L in waters deeper than 90 feet for 91 days in 2003. This is an important period because this is when it is expected that dissolved phosphorus will be released from the sediments. Shallower water experience shorter periods low dissolved oxygen conditions as shown. These data will be used to calculate the phosphorus

release from the sediments in another section of this report. This internal loading of phosphorus will be compared to both non-point and point sources and used by the lake water quality model to simulate the annual dynamics of phosphorus in the lake. Ultimately, the magnitude of the internal source of phosphorus will be used to determine how quickly the lake will respond to changes in input phosphorus loadings.

Light Attenuation

Secchi depth is a common and simple method used to measure water clarity and light attenuation. Figure 45 shows the maximum, average, and minimum Secchi Depth for 1980 to 2003. Note the upward trend of the average Secchi depth over time. Figure 46 shows the annual variation of Secchi depth as measured by both the Hatchery staff and PLIA. The average values for the two organizations are nearly identical (13.791 vs. 13.775 feet). There are two periods of relatively low Secchi depth. One period is around day 160 and the other occurs between day 220 and 260, with high values in the middle of this interval. These variations will be discussed further in subsequent sections below.

Turbidity is another way to characterize light attenuation. The annual variation of turbidity at each depth in 2003 is shown in Figures 47 and 48. A minor peak in turbidity is seen around day 120 and a major peak around day 230. This is similar to the variation of Secchi depth. Figure 48 shows average turbidity for top, middle, and bottom layers. This view shows that maximum turbidity values around day 225 can be attributed to the surface layer, whereas on other days, the bottom water turbidity generally exceeds top water turbidity. This suggests that the measure high turbidity values and low Secchi depth are related to some surface phenomenon such as algal blooms and elevated chlorophyll levels.

Water clarity, as characterized by measurements of Secchi Depth and turbidity, are important indicators of water quality conditions in Big Platte Lake. However, these measurements of light attenuation are often inconsistent and inaccurate. Therefore, a quantitative LICOR light meter is used to measure the light attenuation as a function of depth. These data will help us better understand the relationships among Secchi Depth, turbidity, chlorophyll concentrations, 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 LICOR submersible light meter makes direct measurements 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 (1).

$$\text{Light} = \text{Exp}\ (\ -K_e * \text{Depth}\ ) \qquad (1)$$

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 ($\mu E/m^2/sec$). Example measured light data for July 30, 2003 are shown in Figure 49. Curve fitting algorithms result in an excellent fit of the data and a best-fit value for K_e = 0.110883 $feet^{-1}$.

Similar calculations have been conducted for several other dates. Calculated extinction coefficient values and correlations with corresponding measured values of Secchi Depth are shown in Figure 50. This shows that peaks in extinction coefficient occur during periods when the Secchi depth is low. Note that both methods identify a clearing event of short duration around day 200. Correlation analysis of Secchi depth and light extinction were performed in 2002.

The marl lakes such as Big Platte Lake may precipitate calcium carbonate causing high turbidity and low Secchi depth. Such events are usually associated with high pH conditions that occur during periods of intense algal activity. The Saturation Index is used to evaluate the potential for calcium precipitation. It is a function of temperature, pH, alkalinity, calcium, and total dissolved solids. Positive values of the Saturation Index characterize conditions that favor the precipitation of calcium carbonate, whereas negative values indicate dissolution of calcium carbonate. Figures 51 through 54 show the measured variations of parameters used to calculate the Saturation Index for 2003. The calculated Saturation Index is compared with various measures of water clarity in Figure 55. Positive Saturation Index values clearly correspond to relatively high extinction coefficients, high turbidity values, and low Secchi depth.

Although casual relationships among these variables are observable, plans are in place to enhance this effort by using mathematical model based on a theoretical framework.

Plankton Abundance

The abundance and diversity of zooplankton and phytoplankton can provide insight and a more thorough understanding of nutrient and water clarity dynamics and long-term changes in the productivity of Big Platte Lake. The easiest way to estimate the quantity of phytoplankton in the

lake is through measurements of chlorophyll a. Figure 56 shows the seasonal variation of chlorophyll in the top 30 feet of water in Big Platte Lake. High chlorophyll values were documented near day 120 and 240. Also observe that samples filtered at the Hatchery are similar to those filtered at the CMU laboratory.

A better way to measure plankton abundance is through direct measurements of numbers and biomass. Currently, phytoplankton is sampled every two weeks with a 2-cm diameter rubber/silicone tube dropped vertically through the epilimnion (where algae are most abundant). The tube sampler is 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 are released into a clean acid-washed container. A 250-mL sub-sample is 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 are also used to measure chlorophyll and other water quality parameters. Algal numbers are determined by direct counts using a microscope. Algal biomass is determined by multiplying algal counts by the size of an individual and the appropriate weight for the individual species at that size. Additional details are provided in Appendix D.

Zooplankton is collected every two weeks with a 30-cm diameter 64 micron mesh net. Rotifers are accurately sampled with this net. 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 is hauled from the bottom to the surface in approximately 60 seconds. The contents of each net tow are stored in separate, labeled bottles (125-250 mL) and preserved with formalin solution (final concentration = 4 % formaldehyde). Zooplankton numbers are determined by direct counts using a microscope. Biomass is determined by multiplying zooplankton counts by the size of an individual. Additional details are provided in Appendix D.

Figure 57 shows phytoplankton numbers and biomass. Diatom species and small green algae dominate the phytoplankton. The most common diatom species are *Fragilaria* and *Melosira*. The most common green algae were *Scenedesmus* and an unidentified picoplankter. *Dinobryon* was the most common golden algae (chrysophyte). Diatoms are dominant in the spring and fall, whereas green and blue green algae prevail during the summer. The golden algae were common throughout the year. The algal biomass has a major peak around day 130 and minor peaks around day 220 and 280.

Figure 58 shows zooplankton numbers and biomass. At a gross taxonomic level (division, phylum, class, and order), the zooplankton 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. Zooplankton numbers and biomass peak between days 130 and 170 in Big Platte Lake.

Figure 59 shows chlorophyll, turbidity, and phytoplankton biomass. It is seen that the overall patterns are similar except that algae around day 230 caused relatively more turbidity (and smaller Secchi depths) that the smaller peak around day 130. This could be because different algal types were present.

Figure 60 shows a food web for Big Platte Lake. Figure 61 shows total zooplankton except the copepods and total phytoplankton except the glue greens. It is seen that spring diatom bloom is followed by an increase in zooplankton. Lower zooplankton biomasses are associated with smaller blooms in the summer and fall. Note also that the composition of the zooplankton community is affected by the presence of fish that crop off the larger zooplankton.

The interactions between phytoplankton and zooplankton species is discussed in more detail in Appendix D.

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 important to enhance the model reliability by conducting special studies that will provide direct estimates of some of the model coefficients that are independent of the regular monitoring data. These special studies are described below.

Macrophyte Abundance

Robert Haas from the MDNR - Fisheries Division – Research Section measured the spatial distribution and density of the macrophytes during the summer of 2003 using side scan sonar techniques. Plants were also harvested directly for measurement of density and tissue phosphorus content. Figure 62 shows hydro-acoustic transects where data were obtained. The dark # indicates pings where submerged plants were detected. Figure 63 shows the distribution and estimated density of macrophytes as determined from the hydro-acoustic data. The data are

integrated over the entire lake to obtain an estimate of 2,014 lbs dry weight of macrophytes in the lake as shown in Figure 64. The average density with the growth areas was 237 gmDW/m^2. Measured densities using harvesting techniques from three locations are generally consistent with hydro-acoustic density estimates.

These data can be used to estimate the amount of phosphorus absorbed from the sediments during the growing season and subsequently released during the fall die-off period. This information will be used to help construct a detailed phosphorus mass balance for the lake and determine the significance of macrophyte activity on phosphorus dynamics in Big Platte Lake.

Note that the above measurements do not include *Chara*, which appears to be very abundant in the lake. Measurements taken in 2004 will help make estimates of the impact of this species on phosphorus mass balance and dynamics.

Sediment Studies

Michael Holmes and Scott McNaught from CMU are working on a project to study sediment oxygen demand and phosphorus release dynamics of Big Platte Lake (see Appendix E). 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 have been measured at several sites as shown in Figure 65. Measured parameters will include chemical oxygen demand (COD), total organic carbon (TOC), volatile solids (VS), grain size (GS), and total sediment phosphorus (total phosphorus). Figure 66 shows that sediment total phosphorus and COD increase as a function of depth in the lake. The study is designed 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.

Sediment cores were taken at several sites and stored on ice prior to conducting phosphorus release and oxygen uptake experiments. All sediment cores were 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 experimental apparatus is shown in Figure 67. 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.

Figure 68 shows preliminary results for SOD and phosphorus release rates in Big Platte Lake. The SOD ranges between 0.5 and 2.0 $gmO_2/m^2/day$. These are values that would be expected for a lake like Big Platte Lake. Preliminary phosphorus release rates measured in Platte Lake are lower than might be expected compared to data published by Nurnberg (1986). This might be caused by the high marl content of the sediment. It is planned to measure the phosphorus concentration of the sediment pore waters and ammonia release rates to test these hypotheses.

Shoreline Studies

Meg Woller and Matt Heiman from the Leelanau Conservancy conducted a shoreline study of Big Platte Lake (see Appendix F). The purpose was to identify possible sources of pollution not measured by the regular monitoring program. Approximately 100 samples were collected along the shoreline in at a depth of about 1.0 foot during June and September of 2003. Total phosphorus, *E. coli*, and *Cladophora* were measured to identify possible nutrient inputs from septic tank drain fields, fertilized lawns, footing drain tiles, groundwater springs, and small tributaries. *Cladophora* growth was characterized by measuring the location and area. GPS data and photographs were taken at each site to verify the sample location and identify possible sources of pollutant inputs.

Figure 69 shows the stations sampled in September. The June stations were similar but not all exactly matched the September locations. Stations were selected at several shoreline types to determine possible sources of pollution. No consistent pattern or statistically significant relationship was observed between shoreline type and elevated phosphorus concentrations, *E. coli* levels, or *Cladophora* growth. However, some stations had higher than backgrounds levels of contamination (hot spots). Phosphorus, *E. coli* levels, and *Cladophora* hot spots are shown in Figures 70, 71, and 72. The location of the hot spot stations for both June and September are shown in Figure 73. No one station or location is consistently higher for all parameters and no trends were found with respect to possible sources of contamination. Furthermore, although concentrations at hot spots are higher than natural background levels, the elevated levels are moderate and are not strong indicators of pollution. Stations that had high *E. coli* in June were generally low in September. No single station had elevated phosphorus or *Cladophora* both June and September.

It is concluded from this study that no single shoreline land-use or type or individual station stands out as a source of contamination. It is recommended that this study be repeated in every five years and that emphasis be placed on the hot spots.

Others

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, both native and zebra mussels.

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, Platte River water at the inflow to Big Platte Lake, 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.

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 and recommended 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.

Watershed Modeling

Overview

Non-point phosphorus loads from Platte River watershed are being analyzed using the Better Assessment Science Integrating Point and Non-point Sources (BASINS) approach. This is an integrated multipurpose environmental analysis tool developed by the U.S. Environmental Protection Agency's (EPA's) Office of Water. It comprises of a suite of interrelated components that perform various watershed analyses (USEPA, 2001). A powerful element of BASINS is the Hydrological Simulation Program – FORTRAN (HSPF). HSPF is a lumped parameter watershed and stream model that is well suited for modeling non-point phosphorus loads from the Platte

River drainage basin. The modeling effort is being conducted by LimnoTech and is described in detail in Appendix G.

BASINS can be used to simulate non-point pollutants coming off the land. It can also predict the consequences of future land use management scenarios by simulating the generation and movement of pollutants such as sediment and phosphorus from multiple sources in the watershed. These results can be used as inputs to a water quality model for the Big Platte Lake. In this way the BASINS and lake models can be used to help assess the impacts of both point sources from the hatchery and non-point sources such as agricultural operations, forests, and land developments. Figure 74 illustrates the overall approach.

Input Data

The BASINS model requires detailed data that describe various characteristics of the Platte River watershed. Geographic Information Systems (GIS) is being used to provide a convenient automated method to access, analyze and use these data. Data layers describing features such as land-use, stream networks, lakes, and soil characteristics are available in the appropriate GIS format. Other site-specific data, such as that collected from stream gauging sites and weather stations are also required to accurately simulate watershed response. These data are combined with stream discharges, watershed water quality data and hatchery monitoring data to fully model the watershed in a map-based analysis system.

The Platte River watershed boundary was obtained from the MDEQ Land and Water Management Division, Hydrologic Studies Unit. This watershed boundary was published in 1998 and was created from USGS 7.5 minute Topographic Quadrangles, using MIRIS digital base maps as a control reference. The watershed boundary defines the study area and includes portions of three counties (see Figure 1). The stream network for the Platte River and its tributaries was obtained in GIS format from the State of Michigan CGI website. This information was supplemented with measurements of cross-section profiles of the Platte River and many of its tributaries. Continuous flow data were obtained from the USGS gage located on the Platte River near Honor, MI (USGS Gage No. 04126740).

Land-use data were available in the appropriate GIS format from the Benzie County Conservation District (Benzie County 1996 data and Grand Traverse County 2000 data) and from the Land Information Access Association (Leelanau County, 2000 data). Some manipulation of the data and reclassifications of land-use designations were needed to produce a coherent and consistent map of land-use within the watershed. The final land-use categories employed in the model are

shown in Figure 75. The largest land-uses are forest (56.5%), pasture (16.1%), and cropland (8.6%). Currently, about two-thirds of the watershed remains undeveloped.

Soils data are used to estimate model parameters related to infiltration, water storage, and susceptibility to erosion. The USDA STATSGO soil data for the watershed were used for the Platte River watershed. Figures 76 and 77 show soil types and land elevations.

Climatological data are used as forcing functions to simulate the hydrologic cycle. Precipitation and evaporation data, along with soil properties, are used to predict the relationships between rainfall and runoff in the model. Runoff generated by precipitation or snowmelt may cause erosion and transport pollutants to Big Platte Lake. Air temperature, dew-point temperature, evaporation, and solar radiation data are used to predict snowmelt, stream water temperature, and evaporation. The climatological data required by the model were obtained from the National Climatic Data Center (NCDC), Michigan Department of Natural Resources Weather Station at the Platte River State Fish Hatchery, and the International Atmospheric Data Network.

Calibration

Calibration of the BASINS watershed model is proceeding using a phased approach. The first phase consists of a baseline calibration for flow and total phosphorus. The flow calibration starts in March 1990 to coincide with the installation of the USGS flow gauge. The calibration ends in September 2000 because at the time this work was initiated, the meteorological data used to estimate evaporation were only available through 2000. This effort will be expanded as more data are collected on the project.

The baseline total phosphorus calibration begins in November 1989 and ends in September 2002. This period corresponds to the available data record. The total phosphorus calibration is considered preliminary because sufficient suspended sediment and wet weather event data are not available for the baseline calibration period. Suspended sediment data will improve the phosphorus calibration because phosphorus binds to sediment. Therefore, watershed erosion and scoured sediment are potential sources of in-stream phosphorus. Concurrent in-stream suspended sediment and phosphorus data will be collected in 2004 to facilitate the calibration of the model. Local rain and snowfall data will also be collected along with wet-weather event stream data that will better define site-specific event mean concentrations (EMC) and other in-stream responses to non-point source loadings.

The flow calibration focused on comparisons between model results and observed flows at the USGS gauge. Figure 78 compares the model predicted cumulative volumetric flow at the USGS gauge with observed values. This result indicates that over the ten-year calibration period the model does not exhibit significant bias for prediction of flow. Further analyses and discussion of the accuracy of the model are presented in Appendix G. Figure 79 compares observed and predicted average monthly flows at the USGS gauge for the ten-year calibration period. This figure shows that the model reproduces the seasonal hydrologic response of the watershed. Figure 80 shows favorable comparisons between the simulated and observed annual volume at the USGS gauge. This indicates that the model is adequately simulating the long-term hydrologic response within the watershed and the variations in flow volume between dry and wet years. It also indicates that the available meteorological data are adequate for long term-simulations, although more site-specific meteorological information is required for future event calibration efforts. Figure 81 presents both modeled and observed percent of average daily flows that exceed a given flow at the USGS gauge. The similarity between the two curves indicates that the flows predicted by the model are within a similar range and occur with similar frequency as those observed at the gauge. The shape of the frequency of exceedance curve confirms geological evidence that flow in the Platte River is supplemented by groundwater sources (Seelbach, 1997). Overall, it is concluded that the annual and seasonal flow trends and patterns observed at the USGS are well represented by the model.

The preliminary phosphorus model calibration focused on comparisons with measured concentrations and loads at five stations using data collected between March 1990 and September 2000. The total phosphorus calibration proceeded in a two-step iterative process. The event mean concentrations for each land-use were estimated using the HSPF model and compared with literature values (see Table 2). Next, the diffuse loadings generated by the model were adjusted (within the range cited in the literature) to match observed measurements at the USGS gauge (see Figure 82). This preliminary total phosphorus calibration will be expanded when data become available for in-stream sediment and storm event concentrations of sediment and phosphorus.

Application

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 83 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.

Lake Water Quality Model

Overview

A comprehensive water quality model for the lake is 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 (see Figure 74). It is important that the model accurately simulate light attenuation (extinction coefficient or Secchi Depth), algal production, dissolved oxygen concentrations, and the internal loading of phosphorus from the sediments. 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.

Mass Balances

The first step in the modeling process is to develop annual average balances for water and phosphorus. Figure 84 shows a preliminary water balance for 2003 in terms of average flow rate from various sources in units of cfs. Table 3 shows associated assumptions and measurements. The non-point and tributary flows are based on 1997 BASINS calculations. This was used because the total annual rainfall in 1997 and 2003 were similar, and model runs for 2003 have not been made. Other values such as the flows to and from the Hatchery are based on direct measurements. Historical data from the Kenaga and Evans (1982) and a few tributary measurements are included for comparison.

Figure 85 shows a preliminary watershed mass balance for phosphorus in terms of lbs/yr for 2003. The non-point loads are based on the 1997 BASINS model (stated above). Hatchery loads are based on 2003 measurements (stated above). Table 4 shows calculations for estimating the phosphorus associated with fish lost between the lower and upper weirs. The

phosphorus lost is the difference between the fish passing the lower weir and that collected at the upper weir (26,875 lbs) times the percent phosphorus in the fish flesh (0.4465%). Table 5 shows calculations for planted fish the using measured mass of planted fish and assuming 10% are lost in the lake. Table 5 also shows the estimated atmospheric phosphorus loading calculated by multiplying the annual rainfall for 2003 times the surface area of the lake times the average of measured rainfall phosphorus concentrations. The macrophyte load consists of fall senesce plus continuous sloughing and excretion. Senesce is calculated as the product of the macrophyte biomass times the measured percent phosphorus of 1.3%. The biomass is the measure value developed by Haas using hydro-acoustic techniques (stated above). A rough approximation of the sloughing and excretion component is the measured biomass divided by two, times a 90 day growing period, times an excretion rate of 0.05 per day as obtained from the literature. Finally, the lake outlet was determined by multiplying the outlet flow times the measured lake surface concentration. Table 6 shows calculations of phosphorus release from the sediments. The release rate is taken directly from the measurements (as stated above) and the duration of the period when the dissolved oxygen is less than 2 mg/L as observed from direct measurements for various lake depths.

Figure 7 shows calculation of phosphorus retention in the lake and an effective settling velocity. Retention is based on subtracting the lake outlet phosphorus from the total inputs. The retention of 61% is consistent with other oligotrophic lakes (Chapra, 1997). The settling velocity is based on a settling area below 30 feet in depth and the average lake phosphorus concentration. The calculated settling velocity is consistent with other values determined in similar modeling studies.

Calibration

Figure 86 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 (Chapra, 1997). Figure 87 shows the model kinetic components. The model mechanism were chosen to allow accurate modeling of phosphorus, water clarity, and dissolved with minimum model complexity.

Figure 88 shows the calibration of temperature in the lower layers. This calibration uses the measured temperature for 2000 in surface layer and time-variable exchange coefficients to model the temperature of the lower two layers. The vertical exchange coefficients are determined in this manner and held the same for simulation of other model parameters.

Figure 89 shows the 2000 model output and data for dissolved oxygen. The model output pattern generally follows a similar pattern as the measured data. For example, the model simulates the timing and duration of winter and summer turnover and stratification. Figure 90 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 depth very well, especially during the important summer minimum period. It is recommended that additional improvements to this model framework be implemented as more monitoring data become available and the special studies are completed.

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Appendices