Report

Phase I Lake Study Report

Scope ID: 00L008

Long Lake Advancement Association

May 2003

Executive Summary

Foth & Van Dyke was retained by the Long Lake Advancement Association (Association) to conduct a water quality evaluation of Long Lake. The Association received a Lake Management Planning Grant from the Wisconsin Department of Natural Resources (WDNR) which provided funding up to $10,000 for this project with in-kind services and matching funds of 25% provided by the District.

This evaluation and report focuses on the evaluation of the current trophic status of the lake. This report includes an analysis of collected water quality data, an analysis of alternatives available for dam modifications to raise and lower water levels, and an assessment of the relationship between land use practices in the Long Lake watershed and water quality of the lake.

Water Quality

A water quality sampling program was implemented to determine the lake's water quality and trophic status. Long Lake can be described as a eutrophic lake based on the high nutrient concentrations of phosphorus and nitrogen The high levels of phosphorus and nitrogen have led to algae blooms in the lake. Other parameters such as Secchi depth and chlorophyll *a* were also typical of eutrophic lakes. Dissolved oxygen was found to be adequate except for the deepest portions of the lake in summer.

Dam Evaluation

A dam was installed on the discharge of Long Lake in the late 1970's. The dam regulates the water level and reduces downstream flood damage. However, the northern pike fishery has suffered because the lack of spawning habitat. Northern pike prefer flooded marshes associated with a rise in spring water levels.

Modifications to the dam to allow varying water levels was evaluated. An earthen dam crossed with a pipe or a trench to allow water to flow through the dam at a lower level is feasible. A gate or valve would be installed at the downstream end of the dam to control the water level. The water level would be raised during the winter and spring. When the pike spawning season was done, the water level would be lowered to expose the shallow lake bed to grow grasses during the summer.

Watershed Analysis

The phosphorus loading to the lake from the watershed is estimated at 9.6 pounds per year. The existing lake contains about 324 pounds of phosphorus. The goal for long term management should strive to limit phosphorus coming into the lake to an amount lower than that removed each year. At Long Lake, phosphorus is removed through deposition on the lake bottom and the outlet stream. The phosphorus deposited on the lake bottom acts as a nutrient source for rooted plants, promoting excess growth. The sediment can also release phosphorus back into the surface water under certain conditions.

Agricultural land use is the largest category in the watershed and makes up 66% of the total land use. Residential land use makes up about 10%. The agricultural category provides about 47% of the phosphorus to Long Lake while the residential category provides about 35% of the phosphorus. Any work done to reduce phosphorus loading should begin on the agricultural and residential areas in the watershed.

Recommendations

It is recommended that the Long Lake Advancement Association proceed with the following:

- Complete a Lake Management Plan directed toward maintaining and protecting the water quality of Long Lake.
- Evaluate methods of reducing phosphorus loading to the lake.
- Evaluate chemical phosphorus removal.
- Make modifications to the dam to allow lake level variations and improve northern pike spawning habitat.
- Apply for grant funds under the Lake Management Planning Grant Program (NR 190 in Wisconsin Administrative Code) for completing a lake management plan.
- Apply for grant funds under the Lake Protection Grant Program (NR 191 in Wisconsin Administrative Code) for eligible portions of the Lake Management Plan recommendations.

Long Lake Association
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1 Introduction

Long Lake is located in eastern Manitowoc County approximately three miles southeast of the City of Brillion. The lake covers an area of approximately 119 acres, has approximately 2.2 miles of shoreline, and a maximum depth of about 38 feet. Development has occurred on approximately 90 developable lots around the lake, and these areas currently are not serviced by public sanitary sewer. All developments adjacent Long Lake have private, on-site septic systems.

In May 2001 the Long Lake Advancement Association (Association) was awarded a Lake Management Planning Grant from the Wisconsin Department of Natural Resources (WDNR) to conduct a study of the water quality of Long Lake. This study was completed in the spring of 2003.

1.1 Authorization

The Association authorized Foth & Van Dyke to complete Phase I of the lake study for Long Lake, and to prepare a report identifying the results. The study was completed through a collaborative effort between Foth & Van Dyke, the Association, and WDNR personnel.

1.2 Purpose

The purpose of the Phase I lake study was to address the following areas.

- Obtain water quality data to establish the existing water quality of Long Lake,
- Evaluate the impact of the existing dam on water levels and the lake fishery
- Develop alternatives to allow the dam to provide varying water levels, and
- To complete an analysis of the land use and associated phosphorus runoff in the lake's immediate watershed.

The results of this study will be used to provide the District with a sound understanding of the water quality of Long Lake and some potential sources of pollution to the lake. This report will also provide the District with alternatives to protect and preserve the water quality of Long Lake based on the findings of the studies.

1.3 Project Study Area

Figure 1-1 illustrates the project study area, including the two water quality sampling locations.

Figure 1-1 Project Study Area

2 Water Quality

The water quality of a lake is dependent upon a number of factors and lake characteristics. Every lake possesses a unique set of physical and chemical characteristics that may change over time. The chemical changes occur on a daily basis, while physical changes (such as plant and algae growth) occur on a seasonal basis. Seasonal changes in the physical characteristics of a lake are common because factors such as surface runoff, groundwater inflow, precipitation, temperature and sunlight are variable. A lake’s water quality will vary with the seasonal changes, therefore data must be gathered over a period of time to accurately determine if a lake is experiencing significant changes in water quality and to distinguish between natural variability and human activity impacts.

To determine the water quality and trophic status of Long Lake, a sampling program was devised which included testing numerous characteristics of the lake. The following section explains the sampling program and its components, presents the results and analysis of the sampling conducted, and provides conclusions about the water quality of Long Lake. First however, it is important to identify the natural aging process experienced by lakes (eutrophication), and the source of the lake's water supply as this contributes to the factors which effect the quality of its water supply. In addition, identification of the water source allows for sound management practices to be selected which reflect the specific characteristics of the lake.

Eutrophication - The Aging Process

The process of eutrophication is a natural aging process which occurs in all lakes whereby a lake progresses from a more oligotrophic (young lake) to a more eutrophic (old age) state. When nutrients such as phosphorus and nitrogen wash into a lake with stormwater or by soil erosion, they fertilize the lake and encourage algae and larger plants to grow. As plants and the animals that feed on them die and decompose, they accumulate on the lake bottom as organic sediments. After hundreds or thousands of years of plant growth and decomposition, the character of a lake may more closely resemble a marsh or a bog.

However, lakes also obtain nutrients from various human activities which can literally make a lake old before its time. This accelerated transition is commonly termed "cultural eutrophication", whereby changes that would normally take centuries may occur over/within one person's lifetime. Nutrients from agriculture, stormwater runoff, urban development, lawn and garden fertilizers, failing septic systems, land clearing, construction site runoff, municipal and industrial wastewater, and recreational activities contribute to the accelerated eutrophication or enrichment of lakes.

Trophic Status Indicators

The trophic state of a water body is an indicator of the nutrient levels and water clarity in a lake. Lakes can be divided into three categories based on their trophic state which include oligotrophic, mesotrophic, and eutrophic. The following provides a description of each trophic state:

Oligotrophic: Young lakes with low productivity which are generally clear, cold, deep, and free of weeds or large algae blooms. Oligotrophic lakes are low in nutrients and therefore do not support plant growth or large fish populations. However oligotrophic lakes are capable of sustaining a desirable fishery of large game fish.

Mesotrophic: These lakes are in an intermediate stage between the oligotrophic and eutrophic stages. They are moderately productive, supporting a diverse community of native aquatic plants. The bottoms of mesotrophic lakes lack oxygen in late summer months or winter periods which limits cold water fish and causes phosphorus cycling from sediments. Overall however, mesotrophic lakes support good fisheries.

Eutrophic: Lakes which are high in nutrients and support a large biomass are categorized as eutrophic. These old age lakes are usually weedy and/or experience large algae blooms. Most often they support large fish populations, however are also susceptible to oxygen depletion which limits fishery diversity. Rough fish are common in eutrophic lakes.

The trophic state of a lake can be determined by observing three lake characteristics including total phosphorus concentration (Total-P) which indicates the amount of nutrients present which are necessary for algae growth, Chlorophyll *a* concentration which is a measure of the amount of algae actually present, and Secchi disc readings which is an indicator of water clarity. As expected, low levels of Total P are related to low levels of Chlorophyll *a*, which are related to high Secchi disc readings.

To determine the trophic state of the lake, the Wisconsin Trophic State Index (WTSI) can be applied to each of the above noted factors. The WTSI converts the actual measurement into a value which is representative of one of the trophic states. Values less than or equal to 39 indicate oligotrophic conditions, values from 40-49 indicate mesotrophic conditions, and values equal to or greater than 50 represent eutrophic conditions.

General Characteristics of Long Lake

Long Lake is classified as a drainage lake. An intermittent creek enters the lake on the north end and flows over a dam on the south end of the lake. The water level in the lake is maintained by the dam and the groundwater level around the lake. Groundwater and direct precipitation are the major water sources with a small amount of flow attributed to the intermittent stream. Water quality is most impacted by the watershed around the lake.

Long Lake has a surface area of approximately 119 acres with a maximum depth of approximately 38 feet. It is a long, narrow lake with a shoreline of about 2.2 miles. There is a county park and boat landing on north end of the lake. The watershed associated with Long Lake covers 684 acres, a relatively small watershed.

2.1 Sampling Program

The sampling program used to determine the water quality of Long Lake was conducted over approximately a one year time period, beginning in August of 2001, and concluding in June, 2002. This sampling program provided information to evaluate the current water quality of the lake. Sampling was conducted on six separate occasions including:

- August, 2001
- October, 2001 (fall turnover)
- February, 2002 (ice on)
- April, 2002 (ice off - spring turnover)
- May, 2002
- June, 2002

Long Lake Association members and Foth & Van Dyke personnel performed the water sampling, while laboratory analysis of the samples was completed by the State Laboratory of Hygiene. It was important to obtain samples with ice on, ice off, and in summer months to obtain data representative of the seasonal changes which affect water quality.

Numerous parameters were included in the sampling program, including:

Dissolved Oxygen (D.O.)	Temperature	Chlorophyll *a*
Total Phosphorus	Orthophosphate	pH
Ammonia Nitrogen	Nitrate plus Nitrite Nitrogen	
Total Kjeldahl Nitrogen	Secchi Disc readings	

These parameters were measured at two sample locations. At each sample point, one sample was collected near the surface (1A and 2A) and one sample was collected near the lake bottom (1B and 2B). Temperature and D.O. were measured at various depths in the lake ranging from the lake surface to the lake bottom. Samples for the nitrogen compounds were taken on the August and May sample dates at the lake surface and lake bottom, however all factors were not sampled on the four other dates. As the primary objective of this study was to determine the trophic status of Long Lake, the parameters which contribute to making this determination were sampled more frequently than most other factors. These parameters include total phosphorus (Total P), Chlorophyll *a*, and Secchi Disc readings. For the purposes of this study, orthophosphate, dissolved oxygen, pH, and temperature were measured during each sampling event.

The following section provides the results of the sampling program, highlighting the temperature profile, dissolved oxygen levels, those factors which contribute to the determination of the lake's trophic state,

2.2 Results and Analysis

The complete results of the sampling program conducted on Long Lake are displayed in Appendix A. The following section provides a more detailed discussion of the sampling results of temperature, dissolved oxygen levels, trophic status indicators including total phosphorous concentrations, Chlorophyll *a* concentrations, and Secchi disc readings.

Temperature

Temperature exerts a major influence on biological activity and growth. To a point, the higher the water temperature, the greater the biological activity. Temperature also governs the kinds of organisms that can live in a lake. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. As temperatures get too far above or below this preferred range, the survival of individual species may be limited or eliminated.

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it is more difficult to maintain enough oxygen in warm water for survival of aquatic life.

Stratification: Layers of a Lake

Stratification is a layering effect produced by the warming of the surface waters in many lakes during summer, during which time lake water separates into layers of distinctly different temperature. Upper waters are progressively warmed by the sun and the deeper waters remain cold. Because the layers don't mix, they develop different physical and chemical characteristics, often resembling two different lakes. As a result, oxygen in the bottom waters may become depleted. In autumn, as the upper waters cool to about the same temperature as the lower water, stratification is lost and the whole lake mixes again. This process is called fall turnover. Many lakes experience stratification in winter because ice covers the lake surface. In spring, as ice melts, the water temperatures once again equalize and mixing occurs, a process called spring turnover. As summer progresses, the temperature difference (and density difference) between surface and bottom water becomes more distinct, as mentioned previously, and most lakes form three layers. The upper layer, the epilimnion, is characterized by warmer (less dense) water and is the zone of light penetration, where the bulk of productivity or biological growth occurs. The next layer, the metalimnion or thermocline, is a narrow band where the transition from warmer surface waters goes to the cooler bottom layer. This transition zone helps to prevent mixing between the upper and lower layers. The bottom layer, the hypolimnion, has much colder water. Plant material either decays or sinks to the bottom and accumulates in this isolated layer. During fall turnover, surface waters cool until the waters from top to bottom have an equal temperature and density. Wind action then mixes the lake waters, balancing the lake's chemistry.

A shallow lake or an impoundment lake, however, is more likely to be homogeneous from top to bottom. The water is well-mixed by the wind and current, and physical characteristics such as temperature (and oxygen) vary little with depth. Because sunlight reaches all the way to the bottom, photosynthesis and growth occur throughout the water column. As in a deep lake, decomposition in a shallow lake is higher near the bottom than the top simply due to the fact that when plants and animals die they sink. It is also likely that a larger portion of the water in a shallow lake is influenced by sunlight, and that photosynthesis and plant growth are proportionately higher.

Temperature Profile of Long Lake

Temperature profiles of Long Lake were taken from each sample point at different depths. The data collected shows that the lake experienced slight stratification during the summer months from June through August with a 12.7° C variation at sample point 1 and a 4.4° C variation at sample point 2. The water remained relatively "mixed", or at approximately the same temperature from top to bottom, throughout the remaining months. Overall, the water Long Lake remains mixed almost year-round, therefore distributing oxygen throughout the lake.

Dissolved Oxygen (D.O.) Concentration

The presence of oxygen in lake water determines where organisms such as fish and zooplankton are found. When water is well-mixed, such as in spring, oxygen is usually present at all depths, thus organisms may be distributed throughout the lake. However, under stratified conditions, little or no oxygen is produced in the hypolimnion. Available oxygen is consumed through decomposition of plant and animal material, and oxygen levels become too low for fish which then must move to the top layer, or epilimnion. If these conditions are prolonged and the upper waters become too warm, cold-water fish such as trout may become stressed and eventually die. In the fall, the lake layers break down and turnover replenishes oxygen to the bottom waters. The formation of ice in water reduces the supply of oxygen to the lake from the overlying air. If oxygen levels fall too low, fish and other aquatic life may die.

The concentration of dissolved oxygen (D.O.) present in a lake is important as it supports aquatic life. The solubility of oxygen depends on the temperature of the water - colder water holds more oxygen than warmer water. The amount of D.O. present in lakes at different times of the day, and at different depths, is largely determined by the processes of photosynthesis and respiration. Oxygen is produced when green plants grow (photosynthesis), and is consumed through respiration. Therefore, D.O. levels tend to be higher during daylight hours (when photosynthesis occurs), and lower at night/early morning. In addition, lake depths which are below the reach of sunlight may experience oxygen depletion. Oxygen depletion is especially apparent in winter months where snow cover prevents sunlight from penetrating the water, stopping photosynthesis and causing plants and fish to die; this is termed "winter kill" and occurs in many eutrophic lakes.

In warm water, the water quality standard for D.O. is 5 mg/l, which represents the minimum amount needed for the survival and growth of warm water fish species. D.O. concentrations between 8 mg/l and 10 mg/l indicate saturation.

The D.O. levels in Long Lake remained fairly consistent among the varying sample dates and depths ranging from approximately 5 mg/l to 11 mg/l, with the exception of depletion at the lower depths in June and August. Fish will likely move out of the lower lake levels in summer to avoid the low oxygen concentrations. The remainder of the year, oxygen levels were adequate for fish growth and survival in all parts of the lake.

Trophic Status Indicators

Total Phosphorus Concentration (Total P)

Phosphorus is the key nutrient which influences plant growth in over 80% of the lakes throughout Wisconsin. Excess phosphorus promotes excessive aquatic plant growth. In most lakes, phosphorus is the least available nutrient, so it's abundance, or scarcity, controls the extent of algae growth. For that reason, phosphorus is typically referred to as the limiting nutrient. If more phosphorus is added to the lake from septic tanks, urban or farmland runoff, lawn or garden fertilizers, sewage treatment plants, or other sources, or even if it is released from phosphorus-rich lake bottom sediments, that limitation is taken away and more weeds and algae will grow. Under certain conditions, especially when oxygen is absent from bottom waters, phosphorus is released from bottom sediments into the overlying water. In turn, algae clouds water clarity and decreases the depth of light penetration.

Algae and weeds are a source of food and energy for fish and other lake organisms, and are a vital part of all lakes. However, excessive amounts or nuisance types of algae or weeds can interfere with lake uses by inhibiting the growth of other plants by clouding the water so that it shades them, contributing - as they decay - to oxygen depletion and fish kills, and causing taste and odor problems in water and fish. In addition, it can interfere with the aesthetic environment of the lake causing unsightly algal blooms which float on the lake surface forming scums. The regular occurrence of visible algal blooms often indicates that nutrient levels, especially phosphorus, are too high.

Aquatic plants may also limit many lake uses. Although aquatic plants (macrophytes) serve a vital function for the lake by providing cover, habitat, and even food for fish and other wildlife, an overabundance of rooted and floating plants can limit swimming, fishing, skiing, sailing, and boating activities, and aesthetic appreciation. Excessive plant growth can also physically prevent mixing of oxygen through the water.

Two types of phosphorus analyses can be conducted which include soluble reactive phosphorus (orthophosphate) and total phosphorus; total phosphorus is a better indicator of the nutrient status of a lake because its levels remain more stable. The concentrations of Total P detected at the sample points and the corresponding WTSI values are presented in Table 2-1.

Table 2-1
Total Phosphorus Levels
Long Lake

Sample Point	1	1B	2	2B

Average Total P ug/l	108	148	101	117
Range Total P ug/l	58 - 186	101-193	61 - 169	100 - 172
Average WTSI	64	67	64	65

The total phosphorus data indicates that Long Lake is in a eutrophic category for lakes. The phosphorus concentrations at the two sample points are similar to each other. Phosphorus concentrations were greater at the bottom of the lake than they were at the surface. Samples collected in October during turnover were the highest. This is consistent with the mixing that takes place then when phosphorus that may have settled with plant or animal life becomes suspended.

The WDNR guide Understanding Lake Data shows that an average total phosphorus concentration for natural lakes is about 30 ug/l. This guide also states that total phosphorus should be maintained below 20 ug/l for natural lakes in order to prevent nuisance algae blooms. As indicated in Table 2-1, the total P concentrations in Long Lake exceeded 50 ug/l for all samples points at some time of the year with the average concentration over 100 ug/l. The total phosphorus concentrations in Long Lake are significantly higher than the average natural lake.

Chlorophyll a Concentration

Chlorophyll *a* is a green pigment which is present in all plant life and is necessary for photosynthesis. The amount of chlorophyll *a* present in a lake is dependent upon the amount of algae present, and is therefore used as a common indicator of water quality. It is also one of three characteristics used to determine the trophic state of a lake. Table 2-2 identifies the concentration of Chlorophyll *a* detected in Long Lake and the corresponding WTSI status.

Table 2-2
Chlorophyll *a* Levels
Long Lake

Sample Point	1	2
Average Chl. a - ug/l	41	26
Range Chl. a - ug/l	6.0 - 89	3.0 - 73
Average WTSI	59	56

Based on the results of the Chlorophyll *a* samples, the trophic status of Long Lake was identified as being eutrophic on average.

Secchi Disc Reading

A Secchi disc reading is a measure of water clarity; it is not a direct measure of water quality related to chemical and physical properties. However, water clarity is often indicative of a lake's overall water quality, especially the amount of algae present. Secchi disc readings are taken by lowering an 8 inch disc into the water, and taking the average of the depth where the disc disappears from sight and where it becomes visible again when raised. The Secchi disc reading can be used to determine the trophic state of a lake. Table 2-3 shows the average Secchi disc readings in Long Lake and the corresponding WTSI status.

Table 2-3
Secchi Depth
Long Lake

Sample Point	1	2
Average Secchi Depth - Ft.	4.25	4.23
Range Secchi Depth - Ft.	1.5 - 7	1.5 - 7.5
Average WTSI	58	58

Table 2-3 shows water clarity was similar at both sample points. The water clarity was greatest in winter and least in August (which corresponds with the highest chlorophyll a readings). These readings indicate the lake's water quality is in the eutrophic range.

Non-Trophic Status Indicators

Orthophosphate
This chemical parameter is a measurement of the soluble phosphorus available for algae and weed growth. The concentration of ortho-phosphate will vary during the season in response to algae growth. When algae growth is at its peak, ortho-phosphate concentrations will be at a minimum.

Orthophosphate was measured in samples collected in all samples. The concentrations varied considerably from sampling times. In August, during the highest algae bloom, the concentrations of orthophosphate were relatively low indicating that most soluble phosphorus was taken up in the algae. The highest orthophosphate concentrations occurred in February and May when algae levels were low.

Nitrogen (Ammonia, NO2+NO3, and TKN)
Nitrogen is an important plant nutrient. While phosphorus is typically the limiting nutrient for algae growth, nitrogen can be limiting under some circumstances. Nitrogen compounds are present in lakes as inorganic or organic. The inorganic forms are ammonia and nitrite/nitrate ($NO_2 + NO_3$) and these forms are available to plants for growth. The organic form is included in Total Kjeldahl Nitrogen. This form is found in plant and animal tissues.

The data shows total nitrogen was 2.3 mg/l or higher. The nitrogen/phosphorus ratio is greater than 20 which indicates that Long Lake is phosphorus limited in regard to algae growth (a nitrogen/phosphorus ratio of 15:1 or greater indicates a phosphorus limited condition). The inorganic forms of nitrogen totaled approximately 0.5 mg/l in May. Concentrations above 0.3 mg/l are adequate to support summer algae blooms.

2.3 Conclusions

Temperature

Long Lake does show moderate stratification characteristics during the summer and has demonstrated a somewhat mixed condition for the remaining portion of the year, meaning that the temperature of the water remains relatively stable from the top to the bottom of the lake. During times of stratification, oxygen depletion can occur.

Dissolved Oxygen

Typical of eutrophic lakes, DO concentrations were lower at the bottom of the lake in summer. At no time was the DO completed depleted even at the lowest depth. The DO concentrations were adequate for fish and other aquatic organism survival although fish likely moved out of the deepest areas when the DO was low. The lake association has a lake aerator that is used if DO levels drop over the winter. The DO levels were adequate for fish survival during the winter of 2002 and the aerator was not used.

Total Phosphorus

Concentrations of Total P were consistently in the eutrophic range. The phosphorus levels can lead to excessive algae weed growth.

Chlorophyll *a*

Measurements of chlorophyll *a* were in the eutrophic range and varied significantly throughout the year. The chlorophyll *a* directly corresponded to water clarity. Algae blooms occurred in August and April during the sampling season.

Secchi Disc

The Secchi disc measurements were also in the eutrophic range. Water clarity improves with a decrease in algae growth which is inhibited by the excessive weed growth.

Orthophosphate

Concentrations of orthophosphate were relatively low during algae blooms but were high at other times of the year.

Nitrogen

Inorganic and organic nitrogen compounds are relatively high in Long Lake. There is adequate nitrogen for algae blooms to occur and Long Lake is phosphorus limited in regards to algae growth.

Summary

The water quality parameters showed Long Lake to be a eutrophic lake for all trophic status indicators. Algae blooms do occur several times each year. The phosphorus and nitrogen concentrations are both high enough to encourage the excessive algae and weed growth currently occurring in the lake. Adequate D.O. for fish and other aquatic life is available all year except for a short period in summer in the deepest part of the lake.

3 Lake Level and Dam Evaluation

3.1 Existing Conditions

A dam was installed on the discharge at the south end of Long Lake in the late 1970's. The purpose of this dam is to regulate water levels and provide reduced downstream flood damage. The dam is an earthen dam with steel sheet pile reinforcement at the downstream end where water flows over the pile and drops about three feet to the downstream channel. Photo 1 in Appendix B shows the steel sheet pile. Figure 3-1 shows the existing dam. A result of the dam is the water levels in Long Lake are much more stable than historic levels.

Lake residents have observed a decline in northern pike populations since the dam has been installed. One theory for the decline is the spawning habitat has been damaged as a result of the dam. Northern pike spawn in April and prefer to lay eggs in flooded grass or marshes. Ideally, the marsh would be flooded for 30 to 40 days after spawning to provide protection to newly hatched northern pike. The flooded marsh areas should be at a depth of 6 to 12 inches to provide adequate water level to protect the adult pike and the newly hatched fry. The dam has minimized the water level fluctuations and eliminated some important northern pike spawning habitat. The lake level is more stable now and there is no significant fluctuation in water level in spring.

3.2 Improvement Alternatives

The process to improve northern pike spawning habitat would be to adjust the lake level to be lower during the summer and fall. This would allow the shallow areas of the lake to develop grass and weeds on the lake bottom. The water level could be raised in winter and spring to flood the grassy areas and provide optimum northern pike spawning habitat.

There are two alternatives to adjusting the lake water level. One alternative is to leave the existing water level as the low level and seasonally raise the water level. Visual observations in April 2002 noted the first floor of several homes were one to two feet above lake level. Raising the water level could potentially flood these homes. Photo 2 in Appendix B shows the flooding potential. This alternative is not feasible.

The second alternative is to use the existing water level as the high water level and seasonally lower the water level. One of the concerns over this approach is the potential navigation hazard some shallow areas of the lake may pose if the water level were lowered.

Both alternatives will improve northern pike spawning by having higher water levels in the spring during the spawning season. Each alternative also has potential negative impacts. Raising the water level and potentially flooding houses is not acceptable. Therefore, the recommended approach to lake level adjustment would be to use the existing dam elevation for the seasonal high water level and lower the lake level in summer and fall. This will allow vegetation to grow in the exposed lake bed thus providing good spawning habitat in spring when these areas are flooded.

Figure 3-1 Existing Dam

3.3 Dam Evaluation

Modifications to the dam will be required to provide the capability to adjust the water level of the lake. The earthen dam type of construction will require some excavation through the earthen dam to allow a lower water level to flow over the dam. There are two options available to allow water to pass through the earthen dam. The first option is to excavate a channel through the earthen dam that would function when the lake was to be lowered. At the end of the earthen dam, a concrete structure with a slide gate would be installed to allow the water to overflow the concrete structure if the water level is to be lowered. The gate would be closed when the lake is filling or when the lake level is over the dam. The gate would open when the lake level is to be drawn down. A schematic diagram for this type of dam structure is shown in Figure 3-2.

The second option is to install a pipe through the earthen dam and through the steel sheet pile. A valve or gate would be installed at the downstream end of the pipe to allow water through the pipe when the water is to be lowered. The upstream end of the pipe would be located in the lake bed upstream of the earthen dam. The water level in the lake would be controlled by the elevation of the pipe and the position of the valve at the end of the pipe. The valve would be closed when the lake is filling or flowing over the dam. The valve would be open when the water level is being lowered. A schematic diagram for this type of dam structure is shown in Figure 3-3.

3.4 Cost of Dam Modifications

The cost for each alternative includes constructing a trench or installing a pipe to span the 40 foot distance from the steel sheet piling to the end of the earthen dam. The costs are similar for each alternative with total costs approximately $35,000.

3.5 Operation

The valve or gate controlling the lake water level would be operated manually. The water level would be the highest in the spring to allow northern pike the optimum conditions for spawning. Immediately after spawning is complete (late May or early June) the water level should be lowered to expose 6 to 12 inches of lake bed. The rate of discharge from the control structure will need to be restricted to avoid erosion or flooding of the downstream channel and downstream lake. The lake holds 38 million gallons for every foot of depth. It is estimated that a reasonable time period for draw down of the lake will be 30 days.

When the lake is drawn down by 12 inches, the gate or valve should be closed. Weekly observation of lake levels should be done throughout the summer and adjustments made to the control structure to keep the water level at the proper elevation. The control structure should be shut in fall to allow the water to rise in preparation for the spring spawning season.

Figure 3-2 Proposed Flow Control Gate

Figure 3-3 Proposed Flow Control Valve

3.6 Implementation of Dam Modifications

The dam at Long Lake is regulated by the Wisconsin Department of Natural Resources. The dam is classified as a small dam. Modifications to the dam must be approved by WDNR under the following procedure:

- Submit a permit application including plans and a $500 application fee.
- WDNR will issue a public notice of the dam modification.
- After 30 days, WDNR will review the public comments and resolve outstanding issues. The permit will be approved when no significant issues remain.
- The approval may contain conditions on operation to avoid damage to downstream channels or lakes.

4 Watershed Analysis

A watershed is an area of land in which water drains to a common point, such as a stream, lake or wetland. A lake reflects its watershed because the watershed contributes both the water required to maintain a lake, and the majority of pollutants which enter the lake. Therefore, effective lake management programs must include watershed management practices, as lake problems generally cannot be solved without managing the water sources in the watershed. Managing the watershed to control nonpoint pollutants such as nutrients, soil, and other substances which originate over a relatively broad area is essential to protecting water quality. Water running over the land picks up these materials and transports them to the lake, either directly in runoff or through a tributary stream, drainage system, or groundwater. Water running off a lawn or driveway during a heavy rain is an example of nonpoint source runoff. Land uses such as agriculture, construction, and roadways contribute higher nonpoint pollutant loads than other land uses such as forests. Controlling nonpoint pollution sources can usually be achieved by implementing best management practices. However, it must be noted that nonpoint pollution sources are harder to identify, isolate, and control than point sources (distinct sources such as a wastewater treatment plant or an industrial facility). Controlling the water that runs from the land's surface into the lake is important as lakes receive water directly from drainage of the surrounding land (watershed) and precipitation.

The watershed, or land area, which drains ***into*** Long Lake was delineated by the Wisconsin Department of Natural Resources (WDNR) and Foth & Van Dyke, and is illustrated on Figure 4-1. The figure was prepared using LandSat imagery which is made available by the WDNR.

The watershed of Long Lake is relatively small, and is situated within Calumet and Manitowoc counties. The lake is fed by an unnamed creek which enters the lake from the north. Overall, the watershed of Long Lake comprises a land area of 684.5 acres, while the lake itself comprises approximately 119 acres of surface water. Therefore, the watershed to lake area ratio is about 6:1. The larger the ratio, the more the watershed will have an impact on the lake through nutrient, pesticide, and soil runoff. In this case, the watershed to lake area ratio is small meaning that the watershed has a small impact on the lake.

According to the generalized land cover map of the watershed (See Figure 4-1), agricultural land uses comprise the greatest amount of acreage, totaling about 47% of the watershed. Wetlands comprise 15% and rural residential areas comprise about 35% of the watershed. A county park and boat landing provide public access on the north shore.

Figure 4-1 Long Lake Watershed and Land Cover

Not all areas of the watershed are equal pollutant contributors. By identifying those critical areas that contribute excessive amounts of soil and nutrients to the lake, the most effective controls can be developed. For example, agricultural runoff carrying animal wastes, soil, and nutrients can be a critical pollutant contributor. Urban runoff from lawns, gardens, streets, and rooftops may be significant sources of sediment, oils and greases, nutrients, and heavy metals to lakes. Construction and forestry activities can provide significant quantities of sediments, especially during rainstorms. In small watersheds, lakeside residential activities may be more critical pollutant contributors. However, in large watersheds, the contributions from urban, forestry, and agricultural areas are generally more significant than those from lakeshore homes.

An estimation of phosphorus loading to Long Lake was calculated based on the existing land uses illustrated in Figure 4-1. Unit area loads by land use type in lbs/acre/year for phosphorus were provided by the WDNR. The unit area load by land use type was then multiplied by the total acreage The results of the calculation are identified in Table 4-1.

Table 4-1
Existing Phosphorus Loading (in lbs/yr)
Long Lake Watershed

Land Use Class	Acreage	Phosphorus (lbs/yr)	% of Total
Residential/Built-Up	67.7	3.4	35.4%
Agriculture	451.4	4.5	46.9%
Open Space	14.2	0.1	1.6%
Woodlands	10.7	0.1	1.5%
Wetlands	140.5	1.4	14.6%
Total	**684.5**	**9.6**	**100.0%**

The table identifies the estimated existing phosphorus loadings for the Long Lake watershed. Agricultural land use has the greatest impact on the lake's water quality based on the amount of phosphorus it contributes to the lake. As identified in the table, agricultural uses contribute approximately 47% of the phosphorus which enters the lake on an annual basis. There are some common "Best Management Practices" (BMP's) which can be used to help protect the lake's water quality from pollutants/nutrients. These BMP's are available from WDNR or local county extension offices.

In addition, residential land uses also impact the lake’s water quality, contributing roughly 35% of the phosphorus load to the lake annually. There are some common "Best Management Practices" (BMP's) which can be used to help protect the lake's water quality from pollutants/nutrients contributed from residential sources. These BMP's are available from WDNR or local county

extension offices. Some BMP's may include "zero phosphorus" lawn fertilizers and shoreline plantings to reduce runoff.
Another significant phosphorus source is from domestic wastewater. The potential phosphorus from this source can be estimated based on the following:

- 100 lakeshore homes (source: 2000 Long Lake Association Directory)
- 2.5 people per home
- ½ full-time occupancy average per home
- 0.006 lbs phosphorus/person/day

Total phosphorus from onsite wastewater treatment systems is estimated at 274 lbs/year. Of this amount, about 15% is removed in the septic tanks. The remaining 233 pounds is discharged to the soil for treatment and disposal. Phosphorus is generally removed efficiently by soil through the process of adsorption on soil particles. All soils have a finite capacity for retaining and adsorbing phosphorus. When that capacity is reached, phosphorus will pass through the soil to the groundwater and potentially discharge into the lake. Providing good wastewater treatment and keeping this source of phosphorus out of the lake should be part of a long term lake management plan. Future studies should consider evaluating the existing onsite wastewater treatment systems.

Long Lake contains about 388 million gallons of water. With an average total phosphorus concentration of 100 ug/l, the average amount of phosphorus in the water is 324 pounds. The watershed evaluation identified an annual phosphorus load of 9.6 pounds with a potential additional load from septic systems. Each year phosphorus is removed by plant uptake, sedimentation, and discharge from the outlet stream. The watershed evaluation is a rough model of phosphorus input to the lake. A more detailed phosphorus model would include the mass of phosphorus leaving the lake through the outlet stream and the mass of phosphorus entering the lake from the inlet stream.

The limited data suggest that the lake has a retention time of about 10 years based on assumed flow over the dam. Any changes to the phosphorus loading will be slow to be observed in the lake phosphorus concentration. Reductions to the phosphorus loading should be pursued but the benefits from those reductions may not be seen for many years.

5 Alternatives for Water Quality Improvements

The following presents some alternatives which may be implemented to improve the water quality of Long Lake, to slow the process of eutrophication and improve the fishery in the lake. Alternatives include educating Association property owners on ways they can contribute to improving the lake's water quality, chemical phosphorus removal, agricultural runoff reduction, and improvements to the dam to aid northern pike spawning.

5.1 Education

There are numerous ways individual landowners can contribute to maintaining or improving the water quality of Long Lake through various land practices. Land owners should be provided with educational material explaining proper land practices and the benefits of them.

A number of human activities add nutrients to the water which promote excessive plant growth. The best long-term solution to control/prevent excessive plant and algae growth and improve water quality then is to prevent surplus nutrients and sediments from entering the water. Surface water runoff is a major source of nutrients and sediments in lakes. It should be noted, however, that variations in the natural environment (i.e., temperature, weather conditions, etc.) can also cause excessive plant growth.

This section identifies the ways in which private landowners can help to improve the lake's water quality by reducing surface water runoff and controlling soil erosion:

Landscaping Along the Waterfront

Landscaping along the shoreline is best kept in its natural state and provides several benefits which include:

- ♦ Protecting the water quality of the lake by filtering nutrients and pollutants from runoff before reaching the lake.
- ♦ Preserving the beauty of the shoreline by preserving the natural appearance and screening development from view.
- ♦ Providing wildlife habitat.
- ♦ Protecting the shoreline from erosion.
- ♦ Shading lakeshore water minimizing aquatic plant growth near shore.
- ♦ Low-maintenance care.

These benefits can be achieved by doing the following:

- ♦ Preserve Natural Shoreline Buffers: Leave the shoreline in a natural state if it has not yet been altered. In areas where the land slopes to the water, construct a berm back from the shore to detain runoff, allowing time for infiltration and evaporation of water (local zoning regulations restrict shoreline vegetation removal).

- Restore Shoreline Buffer Areas: Leave a strip of unmowed grass, preferably 20 feet wide or more, along the shoreline; native flowers, shrubs and grasses will naturally grow in this area. Native species, including trees, may also be planted in these areas to add variety and provide more immediate results without requiring the use of fertilizers. The wider the buffer area, the greater the benefits.

- Shoreline Paths: Create pathways to the shoreline which follow natural contours rather than descend straight downslope to minimize erosion. Use wood chips or gravel for paving so runoff is not directed into the lake.

- Limit paved or impermeable areas. Dominating the landscape with driveways, patios, decks, and roofs increases the amount and velocity of runoff, carrying sediments and nutrients which in turn cause nuisance plant growth, damage aquatic habitat, hinder recreational activities, and speed the eutrophication of the lake. Reduce the amount of runoff from driveways and patios by constructing them with porous paving bricks, and diverting water to areas where it can evaporate or soak into the soil.

- Minimize land slopes. Keeping the land as flat as possible reduces erosion. Terracing should be used to flatten areas of steep slope.

Lawn/Garden Care

It was observed during the field study that some of the lake has extensive areas of well-kept lawns. The fertilizers and pesticides frequently used to maintain these laws and gardens can reach the water and negatively affect the water quality of the lake. A minimal amount of lawn area is recommended to maintain good water quality; ideally, native, low-maintenance groundcovers should be planted in place of lawn. There are ways however, to care for lawns and gardens which will preserve the water quality of the lake, including:

- Proper use of fertilizers and pesticides, including the use of no- or low-phosphorus containing fertilizers. Use fertilizer only if there is a nutrient deficiency present as shown by a soil test. For pesticides, avoid application 1) if rain is likely, 2) near the shoreline, and 3) near a well, do not dispose of them down a toilet or drain, do not mix different pesticides, and carefully follow the directions on the label.

- Choose a grass type or groundcover that is appropriate for your site and soils which requires minimal maintenance, fertilizer and pesticide application.

- Leave grass clippings on the lawn. This will provide up to one-half of the nitrogen the lawn needs. Do not burn grass clippings and leaves near the shore or rake them into the water.

- Do not mow more than _ of the height of grass blades. Set the mower blade to 2-2½".

- Locate gardens away from the shoreline.

- Control garden pests by using natural controls and pest predators rather than pesticides.
- Add nutrients to gardens by composting aquatic weeds.

- Divert runoff from waterways. Downspouts should be directed to areas where infiltration can occur and not to areas of steep slope. Planting beds are a good location to direct downspout runoff.

- During construction, minimize soil disturbance and revegetate bare areas as soon as possible.

Sanitary System Improvements

Properly functioning sanitary systems are designed to remove the majority of disease-causing organisms and some nutrients and chemicals from household water and wastewater, keeping them from entering surface water and groundwater. However, these systems are not designed to treat many water-soluble pollutants. It is necessary, therefore, to take extra care in the maintenance of private sanitary systems, especially those located near surface waters or where groundwater is close to the surface. Malfunctioning, unmaintained, or improperly installed sanitary systems can result in the release of nutrients such as phosphorus which encourage nuisance weed and algae growth in the lake.

The following provides improvements that can be made to upgrade malfunctioning or improperly installed/located sanitary systems, and also identifies ways in which property owners can reduce the risk of a malfunctioning sanitary system through proper maintenance and waste reduction practices.

- Relocate drainage fields on sites away from the lake, especially in areas of steep slope (i.e. uphill/across street from property if possible).

- Construct a cluster system with a number of other residents whereby one sanitary system has the capacity to be shared by multiple households. This is especially encouraged in areas where many small lots are grouped together and sufficient room is not available for individual systems.

- Change from conventional septic systems to holding tanks in areas of steep slope, where small lots are grouped together, and in low areas. Holding tanks can be successful if properly maintained.

- The Association could encourage the Town to develop ordinances allowing them to keep records of septic, mound and holding tank pumping frequencies for all systems in the Association. This would encourage proper system maintenance.

In addition to sanitary system improvements, several recommendations are identified for properly maintaining private sanitary systems, whereby increasing the life of the system, reducing the chances of system malfunction, and more importantly reducing the incidence of allowing pollutants and nutrients to enter the lake (and groundwater):

- Decrease the amount of water used. There are several ways this can be achieved including using water-efficient appliances and flow restrictors, not letting faucets run unnecessarily, do dishes/laundry only when needed (full loads), etc.

- Use no- or low-phosphate laundry detergents and minimize the use of fabric softeners and water additives which contain phosphates. Detergents with less than 0.5% phosphate are considered low phosphate; usually liquid detergents are free of phosphates. Do not use detergents which contain fillers.

- Do not dump/pour products which contain contaminants, including pesticides, household chemicals, and solvents, or oil or grease down drains, on the ground, or down the driveway. Try to use products that are non-hazardous or less-hazardous.

- Divert discharge from wash water and water softeners from the lake; direct this water to the sanitary system.

- Avoid the use of garbage disposals.

- Don't drain sump pump water into the sanitary system, as this could increase the chance of a system overload.

- Have conventional and mound system tanks pumped at least once every year or every other year. Have holding tanks pumped upon alarm.

Malfunctioning sanitary systems can be detected by the following:

- Backup of sewage in drains or basement.
- Wet areas or ponded water over the drain field.
- Grass over the drain field is bright green (indicates effluent at the surface).
- An increase in aquatic plant growth along property's shoreline.
- Drains or toilets drain slowly.
- Sewage odors.
- Bacteria or nitrates detected in a nearby well water test.
- Biodegradable dye flushed through the system is detectable in the lake.

5.2 Chemical Phosphorus Removal

Long Lake is a unique lake in that the phosphorus concentrations are high but the watershed is small and the retention time is long. Lakes with small watersheds and high retention times are typically low in phosphorus concentration.

These characteristics make Long Lake a potential candidate for chemical phosphorus removal. This technique has been tried in other lakes in Wisconsin with some success. The key to a successful application is to minimize the phosphorus loading to the lake and preventing phosphorus concentrations from increasing to the pre-application levels.

Chemical treatment is typically done with a liquid aluminum sulfate solution. The aluminum reacts with the soluble phosphorus and forms a precipitate which settles to the lake bottom. The phosphorus is tied up with the aluminum and does not become available to plants.

If the chemical treatment is done and the lake has a limited phosphorus loading from the watershed, the process will be successful in reducing phosphorus concentrations for many years.

Before proceeding with this treatment, a better understanding of the phosphorus budget for the lake should be obtained through studies of water draining into the lake and water leaving the lake. Any significant sources of phosphorus inputs to the lake should be corrected before proceeding with a chemical treatment step.

5.3 Agricultural Runoff Reduction

There are several areas within the watershed where agricultural runoff could contribute pollutants to the lake. Changes in agricultural practices, buffer strips or other management techniques may reduce runoff potential to the lake. This effort must involve state and local agencies. County land conservation agents and WDNR staff should be contacted to develop a strategy for runoff reduction.

5.4 Water Level Variation - Dam Modifications

Water level variation could be a benefit to northern pike spawning and improve the fishery. To accomplish water level variation, modifications to the dam will be required. The best alternative is to lower the water level in summer to expose the shoreline and raise the water level over winter and spring.

5.5 Spawning Habitat Improvement

Northern pike prefer to spawn in flooded long grass. Much of shoreline has a relatively steep slope and may not provide extensive spawning areas if the dam modifications and water level fluctuations were implemented. There is a larger flat area on the north end of the lake that could be modified to improve the spawning habitat. This would require grading the lake bottom or bringing some material into the lake to obtain the proper depth.

6 Recommendations

This section provides recommendations which the Association should implement to maintain and protect the water quality of Long Lake.

6.1 Evaluate Methods of Reducing Phosphorus Loading to the Lake

Phosphorus concentrations are high in Long Lake and can potentially cause excessive weed and algae growth. Methods of reducing phosphorus loading to the lake, or removing phosphorus from the lake, should be considered and included in the Lake Management Plan. Some methods include:

- Implement a public outreach program to inform residents on ways to reduce phosphorus at home.
- Consider controlling/managing boating practices that may cause erosion or sediment disturbance
- Land use planning to minimize land use impacts on the lake.
- Cooperative efforts with agricultural land owners in the watershed reduce agricultural runoff and phosphorus loading to the lake.
- Evaluate septic systems to determine if they have a significant impact on the lake.
- Continued phosphorus monitoring in the lake and extend phosphorus monitoring to the lake inlet and outlet.

6.2 Water Level Management - Dam Modifications

Water levels in the lake cannot be adjusted with the existing dam. Modifications to the dam which allow an adjustment to the lake level are recommended. The adjustment ability will allow the lake levels to be raised and lowered to improve the northern pike fishery in Long Lake. The recommended approach is to construct a channel through the earthen dam and install a gate in a concrete structure at the end of the dam. The gate will be used to control flow through the channel and adjust the water level.

6.3 Lake Management Plan

It is recommended that the Association prepare a Lake Management Plan. A Lake Management Plan identifies the plan of action to be taken towards maintaining and protecting the water quality of a lake, including determining needs, setting goals, gathering and analyzing information, and developing alternative courses of action. Activities which could be included in the plan are:

- Water Testing
- Educational Programs for Lake Residents
- Develop Management and Implementation Plans for Lake Protection
- Evaluating and Developing Ordinances Related to Sanitation, Zoning, or Pollution Control
- Chemical phosphorus removal
- Habitat improvement

Further studies will be required to complete the lake management plan. It is recommended that onsite wastewater treatment systems be evaluated for their impact on the lake. Further study regarding phosphorus loadings to support chemical phosphorus removal should also be completed for the lake management plan.

7 Implementation

The Long Lake Association can begin the process of implementing the recommendations provided in Section 6 by applying for grants to assist with costs, sending out educational flyers to the property owners throughout the Association, and proceeding with development of a lake management plan.

Lake Management Planning Grants are available from the Wisconsin Department of Natural Resources which provide cost sharing for the development of lake management plans and related activities. There are two application cycles to apply for these grants which include February 1 and August 1 of each year.

In addition, Lake Protection Grants are also available to assist in with the costs of implementing the recommendations of a lake management plan. The habitat improvement and chemical phosphorus removal alternatives are examples of eligible projects. Applications are accepted on May 1 of every year.

Modifications to the dam are not eligible for grants under the Lake Protection Grant program. Alternative financing must be obtained to fund the dam modification project. Options to consider include local and county fishing and sportsmen clubs that may be able to assist in financing the project.

Educational flyers should be distributed to all property owners within the Long Lake Association, identifying ways they can contribute to the protection of Long Lake's water quality.