Report

Long Lake Hydrologic and Water Quality Study

Scope ID: 96L008

LPL-410

Long Lake Landowners Association

January 1998

Foth & Van Dyke
consultants · engineers · scientists

Long Lake Hydrologic and Water Quality Study

Scope ID: 96L008

Prepared for

Long Lake Property Owners Association

Prepared by

Foth & Van Dyke and Associates Inc.

January 1998

WISCONSIN
MICHAEL D.
LIEBMAN
E-20952
GREEN BAY,
WIS.
PROFESSIONAL ENGINEER

1-20-98

2737 S. Ridge Road, P.O. Box 19012, Green Bay, Wisconsin 54304, 920/497-2500, FAX: 920/497-8516

Executive Summary

The concerns of the Long Lake Landowners Association over the undesirable water level fluctuations and water quality deterioration of the lake were studied. Inflow rates for various storm events were compared with the hydraulic performance of the lake's outlet to gain an understanding of the water level fluctuation problem. Similarly, water samples from various points along the lake were tested at different times and this data was compared with base data generated previously, generalized water quality standards, and each other to gain a knowledge of the lake's water quality status. With that knowledge and understanding, possible solutions to these problems were formulated and recommendations for subsequent actions made.

For the water level fluctuation evaluation, it was found that the lake inlet/outlet system (channel and overbank area) is capable of discharging large runoff flows downstream while causing reasonable lake level fluctuations. The undesirable lake level rises are caused by the restricted conveyance capabilities of the bridge culvert at Lake Cloverleaf Road. Enlarging the size of this structure would improve the Long Lake outlet and allow it to handle even major storms before excessive water level fluctuations would occur in the lake. It is recommended that improvement to this bridge structure be explored and considered for implementation.

The water quality within the lake was found to be fairly consistent over the time period that data is available. This conclusion is based on past and present study results. The inflow of pollutants carried into the lake through stream runoff appears to be negligible under normal stream flow conditions because the lake inlet and outlet are both at the eastern tip of the lake. The present location of the lake inlet and outlet allows for little flow containing pollutant contamination to enter and be stored within the lake. This lack of stream flow through the lake also has a negative side, because any pollutants within the lake cannot be flushed out by stream related flows. With the recent completion of the sanitary sewer around the lake, the potential for lake pollution has been greatly reduced. Continued monitoring of the lake water quality is recommended to document any improvement and to support subsequent actions regarding water quality in the lake.

Long Lake Hydrologic and Water Quality Study

Contents

Tables

Figures

Appendices

1 Background

Long Lake is situated in the Wolf River watershed in south-central Shawano County (Figure 1). The 86-acre lake is aligned in a general northeast to southwest position. It is approximately 4,300 feet long with a width of approximately 1,000 feet. The lake is fed by a small unnamed stream which enters the lake on the far eastern tip. Immediately adjacent to the lake inlet is the lake outlet which leaves the eastern tip of the lake heading in an easterly direction. After it passes under the Lake Cloverleaf Road bridge, it meanders southeast to its ultimate confluence with the Wolf River approximately three miles downstream. Figure 2 illustrates the general layout of Long Lake, its watershed, and its relationship with the Wolf River.

The Long Lake Property Owners Association contracted with Foth & Van Dyke and Associates, their engineering consultant, to look at some aspects of Long Lake that have been causing increasing concern. In early 1996, Foth & Van Dyke applied for funding under the Wisconsin's Lake Planning Grant Program to complete a hydrologic and watershed pollution sources study. This $13,000 study was approved in October of 1996, when $9,750 (75% funding) of state aid was allocated for this project.

The primary items of concern to the Lake Association had to do with water quantity and water quality. From a water quantity standpoint, the lake's water levels were reacting too dramatically to major rainfall events. It had been reported by local residents that the lake rises as much as three to four feet during a significant runoff event. Furthermore, it had been reported that the lake level remains at these high levels for a significant period of time before it finally recedes. These large fluctuations have created problems for many residences along the Long Lake shoreline. In order to relieve this problem, an evaluation of the water level fluctuation situation in Long Lake was called for. The goal of this evaluation was to determine the cause of the problem and identify any possible solutions that could be implemented to relieve the situation.

The second area of concern to the Long Lake residents was the apparent degradation of water quality within the lake. The local residents are concerned that the previously high quality water in the lake has become more and more polluted, causing clarity, algae, weed, and general water quality problems. It is clear that further study is warranted to determine the level of water quality degradation in the lake, to identify potential pollution sources, and to develop recommendations for further study or actions which would lead to the improvement of water quality within the lake.

2 Project Description

In order to gain understanding of the water quantity and quality issues at Long Lake, a number of tasks were developed to be completed as part of the project. These tasks were completed primarily in the summers of 1996 and 1997, as described herein.

2.1 Data Acquisition/Coordination

All known past studies, information, and data were gathered and reviewed for use in the study. Of particular use for completing this study were the available USGS quadrangle maps and the 1993 study report by IPS entitled, "Phase I - Lake Management Plan, Long Lake." The IPS report detailed water quality quantifying efforts recently completed for Long Lake. This study was most useful in terms of having a data base with which new water samples could be compared. The study's sampling locations were chosen to match those of the earlier study to ensure, as much as possible, a valid comparison between the sets of data.

2.2 Field Survey

The major effort completed as part of this task entailed obtaining survey information about the pertinent hydraulic features in and around the lake. Lake water surface elevations, bridge and culvert details, top of road elevations, and other shots were surveyed to insure adequate information and detailed accuracy. Fortunately, the detailed survey of the downstream cross-sections along the outlet stream were found to be unnecessary after field investigation provided adequate knowledge of these areas.

2.3 Flow Metering/Reconnaissance

During a rainfall event, flow metering was performed in the Long Lake watershed to obtain flow values at different locations within the watershed. This information provided the background knowledge of the runoff characteristics of the watershed, showing the areas within the watershed which have the greatest impact on generating runoff flows. This understanding is important for not only the water quantity aspect of the study, but for the water quality aspect as well. This task helped identify not only peak runoff flow areas, but potential sites for water pollution generation.

The flow metering was completed using an electromagnetic probe-type meter. Using the various culverts and bridges within the watershed as control structures, the depth of flow was measured. Velocity was also measured across the section using the velocity meter. Using the geometry of the various "control sections," the conveyance area was calculated. Flows at each site were then calculated based on the basic hydraulic formula,

$$\mathbf{Q = V \times A}$$

where, **Q** = **flow** in cfs (cubic feet per second)
V = **velocity** in fps (feet per second)
A = **area** in sq. ft. (square feet)

In this way, flow rates were determined in the field at various locations within the Long Lake watershed.

Additional field investigation was completed on May 30, 1997. The hydraulics at the inlet and outlet of the lake at the eastern tip of the lake were examined, along with the stream system downstream from the lake. A small canoe was utilized to gain access to the lake outlet and downstream stream system. Channel and overbank hydraulics were studied and potential flow conveyance bottlenecks were explored.

2.4 Hydrology Modeling/Evaluation

The entire watershed draining into Long Lake was modeled with the hydrologic forecasting model TR-55. This modeling procedure was developed by the USGS's Natural Resources Conservation Service (NRCS) and is generally thought to be the premiere hydrologic modeling tool throughout the United States. This methodology uses drainage basin characteristics such as basin area, soil types, land uses, general ground slopes, and other site specific data to determine runoff flows at specific points caused by specific rainfall events.

For this evaluation, three different storm events were examined - the 5-year, 10-year, and the 25-year rainfall event. These events correspond to the rainfall and subsequent runoff which might be expected to occur once every five years, ten years, or 25 years, respectively. As such, the 25-year recurrence interval storm generates large amounts of runoff which may overtop streams and ditches and approach "flood" status, while the 5-year event is less severe and is generally handled within ditch and stream banks without significant problems.

The various rainfall events were evaluated at two different locations. Obviously, the runoff passing into the lake is of great concern, so that location was evaluated in the hydrologic modeling effort. In addition to that, however, it became apparent that the total runoff passing through the Lake Cloverleaf Road bridge was also of importance. With the layout of the drainage basin such that a significant tributary enters the lake's outlet above the bridge, the hydrologic evaluation generated flow values at the bridge as well. This data was used to ascertain the nature of the runoff flows at that point also.

2.5 Hydraulics Modeling/Evaluation

Hydraulics pertains to the effect on flowing water from a specific site. For this study, the hydraulics of concern is that related to the inlet and outlet runoff flows generated in the watershed, and how those flows are handled at Long Lake. Where the hydrologic investigation tells us how large the flow rates might be at a given site, the hydraulics tell us how high that water will back up or how deep that water will flow at a given site based on flow restrictions, obstructions, or other hydraulic characteristics. For this study, the hydraulics at the inlet to Long Lake were evaluated along with the hydraulics of the outlet, the culvert at Cloverleaf Lakes Road, and the stream system below (downstream from) the culvert.

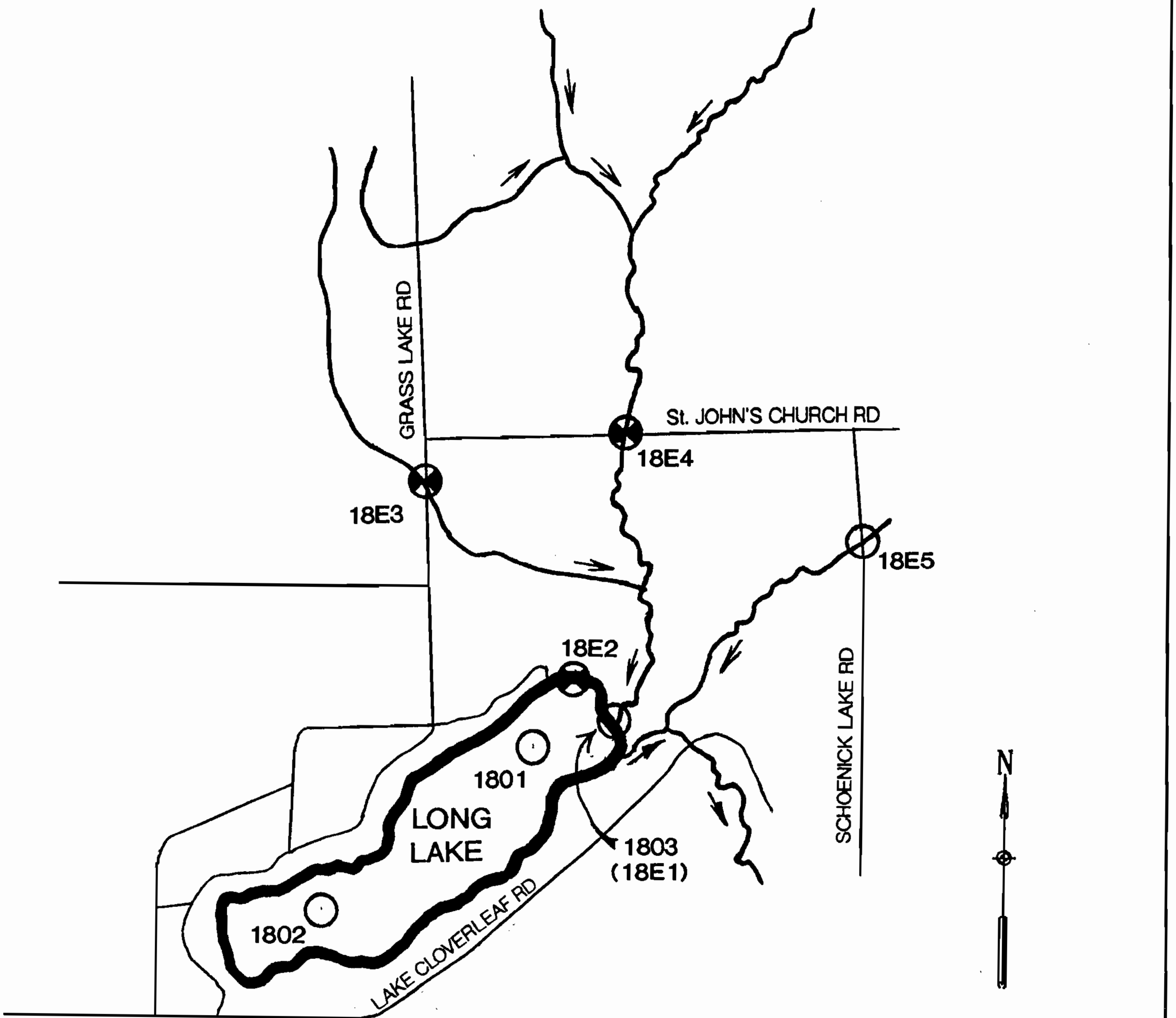
For the various locations, different hydraulic methods were evaluated. For the channel and overbank areas, the Mannings Equation was utilized to estimate hydraulic performance. For the Cloverleaf Lakes Road bridge, culvert nomographs from the federal Bureau of Public Roads were used (assuming inlet control) to develop a stage / discharge relationship for the structure. The various flow rates were then compared to the hydraulic performance to gain the needed understanding of the lake level fluctuation problem and its potential solution.

2.6 Water Quality Sampling/Evaluation

In order to track changing water quality conditions and determine the status of various water quality parameters in the lake, an extensive water sampling effort was conducted in and around the lake. Water quality data was obtained at key points in the watershed and the lake through two series of sampling events. These two water sampling events were conducted in the spring and fall of 1997. The spring sampling event was conducted first, after the lake developed a temperature stratification or formation of temperature "layers.". The fall sampling event was performed after the fall lake overturn event (when the warmer water near the surface is cooled and is replaced with the rising water from the bottom) had occurred. The samples were collected using designated sample collection methodologies and sent to the WDNR laboratory in Madison to test for the various water quality parameters. Samples were taken at the same locations as previous studies to assure consistency in result interpretation. Figure 3 shows the locations of the points along the lake where water samples were taken.

2.7 Presentation of Summary Findings

A presentation of preliminary findings was made to the Long Lake Property Owner's Association on August 31, 1997. Although final water quality sampling data was not yet available from the laboratory, the general results were presented at this meeting. This report summarizes those results as well as making final conclusions and recommendations.



LEGEND

1801 LAKE SAMPLE POINT AND ID NUMBER

18E2 TRIBUTARY SAMPLE POINT AND ID NUMBER

SAMPLE POINT NO.	LOCATION
1801	DEEPEST POINT IN LAKE
1802	WEST END OF LAKE
1803(18E1	MOUTH OF UNNAMED INLET TO LAKE
18E2	AREA OF POSSIBLE SPRING INPUT TO LAKE
18E3	UNNAMED CREEK AT GRASS LAKE RD
18E4	UNNAMED CREEK AT St. JOHN'S CHURCH RD
18E5	UNNAMED CREEK AT SCHOENICK LAKE RD

LONG LAKE

FIGURE 3

1997 WATER QUALITY SAMPLING

Foth & Van Dyke
engineers - architects - scientists

Scale: NONE
Date: 12/97
By: GJB

3 Study Findings

The findings of the 1997 Long Lake Hydrologic and Water Quality Study are summarized as follows.

3.1 Data Acquisition/Coordination

The review of past investigations gave some history of the water quality of Long Lake, but gave little input into the lake level fluctuation problem. From a water quality standpoint, the past studies had established that local residents viewed the water quality of Long Lake as being poor. The data collected during these studies indicated that the lake was in a highly eutrophic condition. Water clarity was commonly impacted by algal blooms throughout the warm weather periods. Plant growth is typically limited by the amount of inorganic nitrogen and soluble phosphorus available in the water. The previous studies indicated that phosphorus levels were impacted by three inflow sources:

1. Agricultural runoff entering Long Lake from the large, agricultural areas in the watershed through which the lake inlet stream and its tributaries flow.

2. Septic system discharges and lawn fertilizer runoff from residential property surrounding the lake.

3. Recycle of nutrients during lake overturn events from large amounts of dead and decaying organic matter on the lake bottom.

The previous study also stated that these conditions were not uncommon for a body of water located within this region. Due to the limited quantity of the data contained in the previous studies, it was recommended that additional water quality studies be conducted in the future.

3.2 Field Survey

The primary results of the survey effort are the exact elevations at critical locations associated with the lake outlet. The following table lists the critical elevations shot during the survey of June 18, 1996:

Location	Elevation
Long Lake Water Surface	794.6
Lake Cloverleaf Road Culvert Invert	791.7
Schoenick Lake Water Surface	792.4

This data shows the positive grade between Long Lake and Schoenick Lake, dropping 2.2 feet in the roughly 3000 feet distance. The flatness of that slope, however, suggests the possibility of large-spread water backup if conveyance bottlenecks exist.

3.3 Flow Metering/Reconnaissance

Contrary to the stream configuration on the USGS quadrangle mapping, it was found that the major stream draining the Long Lake drainage basin does enter directly into Long Lake. This inlet stream meanders through some very low wetland areas and has very little slope for quite some distance upstream of the lake. The stream has a well-defined bed and bank with a top width of approximately eight to ten feet. A flow velocity of perhaps one foot per second was observed in the channel during the May 30, 1997 reconnaissance. The approximate depth of the water ranged from ½ foot to 2 feet deep.

Located immediately to the south of the inlet stream is the outlet from Long Lake. This small stream is similar in size and configuration to the inlet stream entering Long Lake. A small "sand bar" with a maximum depth of only ½ foot is located across the mouth of the stream as it leaves the lake proper. The outlet stream meanders through the same lowland areas as the inlet, at some points passing within 10 yards of the inlet stream. Again, during the reconnaissance, there was noticeable velocity within the stream once into the stream proper.

Upon moving downstream, the stream maintained its original characteristics. Many overhanging trees, logs and other obstacles made progress through the stream corridor very difficult. No significant hydraulic restrictions to flow which might cause the large increase in water level fluctuations at Long Lake were observed until the roadway and arch culvert at Lake Cloverleaf Road was encountered.

The stream below Lake Cloverleaf Road maintained its characteristics in depth, slope, roughness, meandering, and surrounding lowland all the way to Schoenick Lake downstream. Any hydraulic bottlenecks downstream of Schoenick Lake would not have an effect on Long Lake, so further observation downstream was thought to be unnecessary.

The other result of the field reconnaissance effort dealt with the search for potential sources of pollution within the drainage basin. The general layout of the drainage basin suggests that any pollution from the upper reaches of the watershed would be insignificant. No large pollution sources could be found in these areas, and any pollutant laden waters from these areas would have significant chance for "treatment" as the runoff waters would pass through the many wetland areas as it moved downstream. These wetlands are shown on Figure 2 to be prevalent in township sections 13, 14, 18, and 22.

Some potential pollution sources were identified in the lower areas of the drainage basin. The farm and barnyard on Grass Lake Road just south of St. Johns Church Road showed particular potential for pollution through runoff contamination. Any stormwater runoff coming off this area would pass directly into a tributary stream which enters the inlet stream just ⅓ mile above its confluence with Long Lake. The soil erosion, farm fertilizers, and barnyard wastes which have the potential to 'wash' into the stream and possibly into the lake should be an area of concern.

The other potential pollution sources include the general farming practices immediately north of St. Johns Church Road (low level erosion and fertilizer/pesticide/herbicide runoff), and the residential areas immediately adjacent to the lake. With the inlet and outlet of the lake both at the extreme eastern tip of the lake, no flushing or flow-through of runoff will take place. This can be an advantage in that any pollution carried in from the inlet stream may pass "harmlessly" back out of the lake without doing much water quality damage to the lake itself. On the other hand, however, any pollution entering the lake from surrounding septic fields, lawn wastes, or other residential sources remains in the lake with little opportunity for the degraded water to be flushed through and out of the lake.

3.4 Hydrology Modeling / Evaluation

In order to gain an understanding of the runoff generating potential of the watershed draining to Long Lake, hydrologic calculations were completed at critical points at and near the lake outlet. NRCS TR-55 methodology was used. This computer generates peak flows at specific locations within a watershed caused by various rainfall events. Hydrologic characteristics of the drainage basin were input into the TR-55 model. These characteristics for the lake inlet are summarized in the following table:

Watershed Characteristic	Value
Tributary area	10.1 sq. miles
Runoff Curve Number (CN)	67
Time of Concentration (T_c)	7.39 hours
Wetland (storage) areas	323 acres

Based on this information, peak flow values were estimated using the NRCS methodology. The following results were obtained for the stream going into the lake, and at the Lake Cloverleaf Road bridge downstream:

Design Storm	Rainfall	Flow at Long Lake	At Bridge
5 - year	3.1 "	312 cfs	356 cfs
10 - year	3.74"	505 cfs	578 cfs
25 - year	4.3 "	700 cfs	800 cfs

These flows can be used with the lake inlet/outlet hydraulics to determine the potential and magnitude of flooding and lake level increases associated with the various rainfall events. Summary printout of the TR-55 modeling inputs and results are included in Appendix 1.

3.5 Hydraulics Modeling/Evaluation

Site specific hydraulic conditions called for different hydraulic calculations for the different critical points along the lake's inlet/outlet stream. Based on 'normal depth' calculations for the stream proper (bank to bank hydraulics), the general capacity of the stream is estimated to be between 20 and 30 cfs. This assumes general channel slope, roughness, and other characteristics detailed in the hydraulics results in Appendix 2. Obviously, when comparing this capacity value with the flows generated from the watershed, it is clear that the stream banks will be overtopped at a fairly frequent interval. This is not unusual in that the overbank areas of all stream 'systems' generally wind up conveying the majority of flows related to any significant rainfall events. Although often considered as "flooding," this overbank flow relief is normal and in this case, responsible for only a small measure of the lake fluctuations experienced along the lake.

The overbank flow capability is extensive, being dependent on the depth of flow over the overbank area. The low-lying wetland areas adjacent to the inlet and outlet streams are wide and flat, offering ample conveyance area to pass large flood flows. For example, the flow capacity of the overbank area was estimated assuming a flow depth of one foot, again using a 'normal depth' analysis. Based on that one foot depth, an assumed slope (relatively flat), an estimated roughness, and a width of flow of 300 feet, the flow capacity of the overbank was found to be 190 cfs. This would adequately convey very large runoff events, but would require additional depth and/or flow width to convey the larger 5- or 10-year event runoff flows. For comparison purposes, the conveyance capabilities of the overbank area with a two foot depth and the same flow width is estimated to be over 600 cfs and that of a three foot depth well over 1,200 cfs. So, although the lowlands surrounding the streams do not allow particularly efficient flow of floodwaters with small depths, those areas do have significant water carrying capacities with just minor increases in depth. Again, the details of the flow estimates are included in Appendix 2.

One aspect of this overbank conveyance is that during these major flood flows, the influent stream has a potential to widen out significantly and enter the lake along its entire eastern shoreline. This provides ample opportunity for large flows to enter the lake and the lake water level to subsequently rise.

It should also be noted that it is unlikely that the inlet lowland/stream conveyance would be much greater than the outlet lowland/stream conveyance. Those two conveyances being basically equal, stream flow-through would be expected which would cause little increase in the lake water levels unless some other bottleneck was present. The only potential hydraulic bottleneck capable of causing the major water backup on the lake would be the bridge structure and roadway downstream. This hydraulic structure was therefore examined, as well.

Because of the large capacity of the downstream overbank and stream system, the bridge hydraulics were evaluated using culvert nomographs with inlet control. Like the stream / overbank system, the available capacity of the bridge culvert is related to the depth of flow. Based on the culvert hydraulics, the following stage (depth)/flow relationship was developed for the Lake Cloverleaf Road bridge:

Depth of Flow	Capacity
2'	80 cfs
4'	170 cfs
6'	380 cfs
8'	520 cfs
10'	700 cfs
12'	800 cfs

Clearly, this culvert has large capacity when the depth is large, but is incapable of passing significant flows without backing up water to significant depths. Even when flowing full (after becoming submerged at depth = 7½ ') the culvert will pass less than the 10-year flow. With the large head (depth) available before road overtop, the culvert may pass as much as the 25-year flood before the roadway will overtop, which may be considered adequate if it wasn't for the other ramifications of backing up water more than 12 feet deep. That backwater extends into the lake and is responsible, in large part, with the undesirable water level increases experienced along the lake.

An example of the effect of this conveyance "bottleneck" is illustrated in the following scenario. Assume a 5-year rainfall event occurs upon the Long Lake watershed. The drainage basin will generate an estimated 578 cfs at the Lake Cloverleaf Road bridge. In order to pass that flow, the combination of channel and overbank will cause a depth of flow of perhaps $3^1/_2$ feet. The hydraulics at the bridge structure, however, will cause a backwater of more than five feet at the bridge. With that type of backwater, the overbank areas along the inlet stream at the eastern tip of the lake will become inundated and will convey huge volumes of water into Long Lake. The lake level rise of five feet will become a nuisance to adjacent homeowners and will allow as much as 18.7 million cubic feet of water to enter the lake. If the downstream outlet/culvert discharge system releases that excess volume at an average rate of 80 cfs (an assumption based on typical downstream conveyance capabilities), the time it takes to restore the lake to normal water levels will be about 65 hours. That time frame assumes no additional water will enter the lake in the interim. In actuality, significant amounts of water will be released from the wetland areas, extending the duration of the excess water discharge.

It should be noted that these calculations do not take the storage affect of the lake into account when estimating peak flow rates. This effect will tend to lower the peak flows from a given rainfall event which would tend to make the hydraulic performance somewhat better than stated herein. That effect would be fairly insignificant, though, in light of the magnitude of water level increases and the other factors affecting these results.

3.6 Water Sampling / Evaluation

The water quality sampling and evaluation portion of this project was designed to be able to collect one set of samples from each of the previous lake study's designated sample points for two separate time periods during 1997. The time periods selected were the spring and fall of 1997, near the semiannual lake overturn events. The amount of testing which each set of samples would be subjected to was determined by previous studies conducted on Long Lake. It was planned to composite both the surface and benthic (bottom) water samples from each of the deep water sample points (1801 and 1802) to get an average condition at these sample points. Figure 3 identifies the sample points used in this evaluation. Each of the two sets of samples included four sample points within or near the shoreline of Long Lake (18E3, 1801, 1802, 1803/18E1) and three sample points from tributaries flowing into Long Lake (18E2, 18E4, 18E5).

Each set of samples was planned to be collected during the early spring and late fall prior to and after temperature stratification in the deep water sample points (1801 & 1802) had been established. However, the spring sampling event was actually undertaken after temperature stratification had developed. To obtain a representative sample from the deep water sample points during the spring sampling event, a sample was collected from both the upper warm water epilimnion (layer of lake water above where temperature drops rapidly) and the cold water hypolimnion (layer of lake water below where temperature drops rapidly) below the thermocline (layer of lake where temperature drops rapidly). These two samples were then composited to obtain one sample representative of these sample points. The tributary samples consisted of one representative grab sample at each site. It was noted during the study that sample point 18E3 was located in the northernmost corner of the lake. It had been previously designated during an earlier study as a possible spring inlet. There was no evidence of spring inflow noted at this sample point during this study.

The fall sampling event occurred as planned after the fall overturn event had occurred.

A third set of tributary samples was collected during a rainfall event in early July. The purpose of this set of samples was to identify the amount of BOD_5 (biological oxygen demand) being carried into the lake during rainfall events. Elevated levels of BOD_5 would indicate that runoff in the drainage basin contained significant amounts of organic contamination. This added pollution load could produce further detrimental effects on the water quality within Long Lake after high precipitation events occur.

All samples were placed in the appropriately prepared bottles and packed on ice. The samples were then shipped overnight to the State Laboratory of Hygiene in Madison for analysis. Table 3-1 is a list of water quality characteristics for which each set of samples collected during this study were analyzed.

Table 3-1
Water Quality Testing Program

Parameter	Field	State Lab	Sample Sets Tested
Seechi Depth	Yes	No	Spring, Fall
pH	Yes	Yes	Spring, Fall
D.O.	Yes	No	Spring, Fall
Temperature	Yes	No	Spring, Fall
Conductivity	Yes	Yes	Spring, Fall
Total Alkalinity	No	Yes	Spring, Fall
TKN	No	Yes	Spring, Fall
Ammonia Alkalinity	No	Yes	Spring, Fall
$NO_2 + NO_3$ Nitrogen	No	Yes	Spring, Fall
Total Phosphorus	No	Yes	Spring, Fall
Dissolved Phosphorus	No	Yes	Spring
Chlorophyl a	No	Yes	Fall
BOD_5	No	Yes	Summer

Table 3-2 below, is a representation of the field data collected from the deep water sampling points during the May sampling period. This data indicates the development of thermal stratification in the lake. During the spring sampling event, when this set of samples was collected, a fish locator was operated on board the sampling vessel. It was noted that a large majority of the signals representing fish activity were recorded between the depths of 8 ft to 15 ft., in the thermocline above the hypolimnion. Both the temperature and the dissolved oxygen (D.O.) level dropped dramatically throughout the thermocline and very low D.O. levels were recorded in the hypolimnion near the bottom. It should be noted that D.O. levels above 5.0 are standard for sportfish waters. The seechi depth at both of these deep water sampling points during this sampling event was 7.0 feet.

Table 3-2
Spring Sampling Event
Deep Water Sampling Points

Depth (ft)	Site 1801		Site 1802	
	Temp °C	D.O. (mg/l)	Temp °C	D.O. (mg/l)
1	13.0	10.4	13.1	13.0
2	13.0	11.1	13.0	12.4
3	12.5	12.0	12.8	11.7
4	12.5	11.2	12.8	11.0
5	12.5	10.9	12.6	11.7
6	12.6	10.4	12.3	13.4
7	12.5	10.4	12.3	15.0
8	12.5	9.5	12.3	14.8
9	12.2	9.0	12.2	14.5
10	12.1	8.8	12.1	14.7
11	12.1	8.5	12.1	14.6
12	12.0	8.9	12.1	13.9
13	12.0	8.6	12.0	11.3
14	11.7	8.0	11.4	10.8
15	10.0	6.9	10.0	8.4

Depth (ft)	Site 1801		Site 1802	
	Temp °C	D.O. (mg/l)	Temp °C	D.O. (mg/l)
16	9.0	5.9	9.0	7.4
17	8.5	5.0	8.4	6.8
18	8.0	4.5	8.0	5.5
19	7.8	4.2	7.8	4.1
20	7.5	4.1	7.5	3.9
21	7.2	3.6	7.3	3.7
22	7.1	3.5	7.1	3.6
23	7.1	3.4	7.1	3.4
24	7.1	3.1	6.8	2.9
25	7.0	3.0	6.6	2.2
26	7.0	3.0	6.8	2.2
27	6.8	2.7	7.0	2.2
28	6.8	2.1	7.0	2.0
29	6.8	1.8		
30	6.7	1.7		
31	6.7	1.4		
32	6.7	1.8		
33	6.5	1.4		
34	6.5	1.4		
35	6.5	1.4		
36	6.5	1.1		

Table 3-3 is a representation of the field data collected during the fall sampling period from the two deep water sampling points in Long Lake. This data shows that at the time of this sampling, the thermal stratification within the lake had disappeared and dissolved oxygen levels had equalized throughout the depth of the lake. The equalization of oxygen levels below 5.0 mg/l during this sampling event is an indication of poor water quality. Again, the sportfish water dissolved oxygen standard of 5.0 mg/l or higher is referenced. This data indicates that the fall turnover event had occurred prior to sample collection. The seechi depths observed at these deep water sample points during this sampling event were 4.5 and 5.0 feet.

Table 3-3
Fall Sampling Event
Deep Water Sampling Points

Depth (ft)	Site 1801		Site 1802	
	Temp °C	D.O. (mg/l)	Temp °C	D.O. (mg/l)
2	8.5	3.2	8.3	3.4
4	8.4	3.2	8.3	3.4
6	8.4	3.2	8.3	3.2
8	8.4	3.1	8.2	3.0
10	8.4	3.1	8.1	2.8
12	8.4	3.1	8.1	2.7
14	8.4	3.1	8.1	2.7
16	8.4	3.1	8.1	2.8
18	8.4	3.1	8.1	2.9
20	8.4	3.1	8.0	2.8
22	8.4	3.1	8.0	2.8
24	8.4	3.1	8.0	2.8
26	8.3	3.0		
28	8.3	2.9		
30	8.3	2.7		

Table 3-4 is a representation of the analytical results which were obtained from the lake and tributary samples that were collected during this study. This table has been organized by sample point and date of sample collection. The data generated was compared to the data collected during the 1983 and 1992 sampling events. These sets of data were published in the April 1993 Lake Management Plan for Long Lake which was prepared by IPS. Although there is not enough data to establish accurate historical trends, the apparent condition is that the water quality within the lake and it's tributaries has changed little during the time span within which the data was generated.

The following are brief discussions concerning the water quality parameters for the data presented in Table 3-4 generated. These discussions are further segregated into comments pertaining to the time of year the samples were collected and to whether the samples were lake samples or tributary samples.

Sample Collection Temperature - The spring sampling event had occurred after thermal stratification had been established, therefore, lake sample temperatures during this time were comparatively high. The fall sampling event was conducted after thermal stratification had disappeared and the fall turnover event had taken place. Tributary sample temperatures were comparable for both spring and fall conditions.

pH - The pH (acidity level - 7.0 being neutral) from lake samples collected from the surface of the lake during the spring sampling event were elevated to near 9.0. The tributary sample pH and the lake inlet sample pH during this time remained near 8.0. This indicates that the thermal stratification encountered during this sampling period had an effect on lake pH within the epilimnion. This effect could be due to the establishment of an algae population in this zone. The fall lake sample pH after the turnover showed lower pH values near 7.5. This is the result of mixing the higher pH water from the epilimnion with the low pH water contained in the hypolimnion where anaerobic decomposition of organic matter on the lake bottom occurs. Anaerobic decomposition tends to lower pH values.

The tributary sample pH values collected from the spring and fall sampling events were comparably the same. From a historical perspective, sample pH values collected during the 1997 sampling events were generally higher than those reported in previous studies.

Conductivity - The conductivity data gathered during the 1997 sampling events were similar to the conductivity data reported in previous studies. Lake samples generally had lower conductivity values than tributary samples. This is probably due to the higher amount of dissolved solids and other contaminants in the tributary drainage than in the lake. This type of differential between lake contents and stream contents also shows that there is very little tributary flow entering and flushing through Long Lake under normal weather conditions.

Alkalinity - The alkalinity values obtained during this study were also similar to values reported previously. The lake samples showed alkalinity levels that were lower than those reported in the tributary samples for both sample periods of this study.

Ammonia and Nitrate Nitrogen - Ammonia nitrogen levels found during the 1997 sampling events were generally lower than those found in previous studies. The lower levels found in the deep water samples may be due to the methodology of compositing a surface and hypolimnion sample together for these sample points. The results indicate that ammonia nitrogen levels in the lake samples collected in the spring after thermal stratification were much lower than those collected during the fall after the turnover event occurred. Possibly, the warmer spring sampling event occurred after biological nitrification (ammonia converted to nitrate by bacteria) had taken place within the lake. The colder water temperatures in the fall would prevent nitrification of the ammonia which was distributed throughout the lake after the fall turnover event occurred. The nitrate data collected supports this hypothesis. Nitrate levels are lowest in the fall when nitrification is not occurring and highest during the spring after the ammonia has been nitrified to nitrate.

The tributary samples show low levels of ammonia but considerably high levels of nitrate in the water. The high nitrate levels are consistent with the fact that these tributaries traverse through an area that has significant agricultural development. Again, the fact that there is considerable difference between the tributary sample nitrate results and the lake sample nitrate results for ammonia and nitrate indicates that under normal weather conditions, Long Lake is not affected by tributary flow and little flushing occurs.

TKN and Total Nitrogen - The general observation is that the TKN values and Total Nitrogen values reported from the 1997 samples are, overall, lower than those values reported in the previous studies. Sampling methodology may again play a part in this differential. There was no significant differential observed in the TKN and Total Nitrogen values reported for lake samples and tributary samples. The highest total nitrogen values recorded came from tributary sample 18E5, which consistently contained significant nitrate levels.

Total and Dissolved Phosphorus - Total and dissolved phosphorus levels were generally found to be lower than those levels reported in previous studies. The phosphorus results from the lake indicated that the highest levels occurred in the fall after the lake overturn has occurred and lowest in the spring when thermal stratification and algae growth has begun. The tributary sample with the highest level of phosphorus was 18E5. Overall, the tributary samples contained higher levels of phosphorus than samples obtained within the lake's boundaries.

BOD_5 - A set of the tributary samples was collected during a significant rainfall event during July of 1997. All samples showed a positive level of BOD_5 caused by runoff from land within the drainage basin. Because the location of the inlet and outlet of Long Lake is in close proximity to each other, only a small portion of the lake would actually be affected by this runoff unless the precipitation and runoff quantities are very significant.

Chlorophyl a - Chlorophyl a levels are a measure of the amount of algae found in the water. During 1997, only the fall sample event was tested for chlorophyl a. The highest levels were found in the lake samples and the highest value was recorded from the far western sample point furthest from the inlet/outlet for the tributaries. The only tributary sample to contain significant levels of chlorophyl a was from sample point 18E5.

4 Conclusions and Recommendations

4.1 Lake Water Level Fluctuations

Based on the hydrology and hydraulics of the drainage basin and stream system affecting Long Lake, the following conclusions may be made concerning the dynamic water level fluctuations which occur from time to time along Long Lake:

- The inlet and outlet stream channel proper has relatively limited capacity within the banks and will overtop at fairly frequent intervals. This will cause some minor level fluctuations within the lake which may be considered insignificant.

- The overbank conveyance capabilities of the inlet / outlet stream system are large and with even minor depth increases, capable of discharging large runoff flows downstream while causing reasonable lake water level increases. Some improved efficiency may be possible by short circuiting the inlet stream which could be accomplished by cutting down the bank between the meanders to the outlet stream. This would somewhat increase the efficiency of the floodwaters and perhaps minimize the lake level fluctuations associated with those floodwaters. Such improvement, however, would be limited by the downstream bridge structure hydraulics which cause significant backwater during flood flows.

- The capacity of the Lake Cloverleaf Road bridge is adequate if large backwater depths are acceptable. The backwater caused by the bridge culvert becomes a problem, however, as the effect backs into Long Lake and results in undesirable water level fluctuations within the lake.

- Although improvements to the channel and the overbank areas of the inlet / outlet stream system could cause some reductions in the water level fluctuations in Long Lake, the more critical conveyance "bottleneck" is at the downstream culvert. It is recommended that efforts be made to improve the hydraulic capacity of that structure. By providing more capacity at that structure, the peak flows may be better passed downstream and lessor backwater levels may be generated. In addition, the duration of high water levels in the lake could be significantly reduced by adding culvert capacity to the Lake Cloverleaf Road crossing. It should be noted that the additional conveyance through Lake Cloverleaf Road may pass larger peak flows downstream, thereby increasing the floodplain areas downstream. A detailed flood storage study should be completed to determine the potential effect on the downstream floodplain.

4.2 Water Quality

The following conclusion are presented based on the analysis of data collected from the 1997 sampling events and consideration of data collected during previous sampling events in 1983 and 1992.

- The water quality of Long Lake as measured in 1997 has not changed significantly since data was first collected in 1983. Moderately lower levels of nitrogen and phosphorus were noted but may be the result of differences in sampling methodology of the three studies.

- The data suggest that there is very little flush that occurs through Long Lake. Since the inlet and outlet of the tributaries are in close proximity to one another on the same end of the lake, most of the tributary flows bypass the lake. Only when stream flow is very high and water backs up in the drainage basin, will water flow into and be stored within the lake basin. Only as the water recedes after these significant events will a modified flush of the lake take place.

- Because Long Lake frontage property is heavily populated, nutrients from the septic systems and lawn runoff have accumulated in the lake. The data indicates that these nutrients are continuously recycled and are not flushed out of the lake because there is no forward flow through the lake basin. This recycle and accumulation of nutrients within the lake would occur in this manner.

    - Phosphorus and nitrogen are discharged into the lake from septic systems and lawn fertilizer runoff.

    - Algae and weeds use the nutrients and reproduce more algae and weeds.

    - The algae and weeds eventually die and sink to the bottom of the lake. Chemical addition to kill off excessive weed growth adds to this organic debris.

    - Anaerobic (without oxygen) decomposition of the settled organic matter releases the nutrients as dissolved phosphorus and ammonia nitrogen.

    - The released nutrients accumulate in hypolimnion below the thermocline.

    - During the fall turnover event, the accumulated nutrients are again dispersed throughout the water layers within the lake and are ready to be used to produce new algae blooms in the spring.

- The nitrate and phosphorus content of the tributaries which feed the inlet of the lake do not have a great effect on the water quality within the lake under normal conditions because the lake outlet is located in the same area as the inlet on the northeast corner of the basin. The lake literally acts as a reservoir providing capacity only when tributary flows are high during rain and snowmelt events.

- Agricultural runoff significantly impacts the nutrient content of the water within the tributaries but only impacts water quality within Long Lake when flow conditions require storage of water within the lake basin.

Based on the previous water quality discussions within this report, four general recommendations can be made.

1. The water quality data collected in the 1983, 1992 and 1997 studies should be organized and compiled in one data base that can be added to when future data becomes available. This data base can then be used to statistically determine water quality trends within Long Lake and it's tributaries.

2. A detailed evaluation of inlet and outlet tributary flows should be conducted to determine whether or not Long Lake has a flow-through which produces a flushing effect. This study would accurately determine when and under what conditions flushing will occur and identify any unknown sources of inlet flow, such as springs, which may exist.

3. The Long Lake Property Owner's Association may wish to consider harvesting excessive weed growth rather than using chemicals to kill off weeds. Harvesting programs remove weeds and the nutrients they contain from the lake. Chemical kills only temporarily solve the problem, but as the nutrients are again released into the lake by anaerobic decomposition, the problem will return. The possibility for federal or state funding of a weed harvesting program should be explored.

4. The residents of Long Lake are presently replacing their septic systems with a collection system which will transport wastewater to a local community for treatment and disposal. It is recommended that once this transition is complete, an ongoing water quality sampling program be conducted to determine the effect of this improvement on the lake's water quality. It is recommended that a study be implemented 2 years after completion of the wastewater collection system.

5 Summary

The concerns of undesirable water level fluctuations and water quality deterioration were studied. From the study effort, it was found that the Lake Cloverleaf Road bridge system was in need of improvement if the water level fluctuations are to be reduced. Discussion with the appropriate town or county representatives concerning the improvement at this crossing should be considered as the next step in improving the situation.

From a water quality standpoint, it would be appropriate to continue to monitor the lake's water quality through continued sampling in the future. This is particularly important in light of the recent construction of sanitary sewer along the lake and the subsequent hookup of sewer laterals. This may have a significant effect on the improvement of the quality of water in the lake. Further study can show this improvement or find that other actions may be needed. A detailed study of the inlet and outlet flows to this lake to determine the natural flushing capacity is also suggested.

Additionally, the reduction of pollutant potential from the various agricultural and residential pollution sources noted in this study should be pursued. Additional grant funding should be explored to assist in the possible cleanup of barnyard wastes, stream erosion, residential stormwater runoff, fertilizer use or other pollution sources.