Long Lake Management Plan

May 2006

EMMONS & OLIVIER RESOURCES

Prepared for the Brown's Creek Watershed District

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History of Long Lake Management Efforts

There are a number of parties responsible for the Management of Long Lake. This section of the Long Lake Management Plan identifies these parties, explains their role in the management of Long Lake and presents the management efforts that have taken place to date.

Regulatory Authority

City of Stillwater, Minnesota

Long Lake is located in the City of Stillwater north of 62^{nd} street and south of 72^{nd} street. As a result, the operation and maintenance of Long Lake is the City of Stillwater's responsibility. The City has constructed an outlet system for the lake and is committed to maintain the structures within the system.

Minnesota Department of Natural Resources

Long Lake is identified as a Public Water by the Minnesota Department of Natural Resources (DNR) and as such is under the jurisdiction of the DNR. Public waters are all water basins and watercourses that meet the criteria set forth in Minnesota Statues, Section 103G.005, subd. 15 that are identified on Public Water Inventory maps and lists authorized by Minnesota Statutes, Section 103G.201. Public waters wetlands include all type 3, type 4, and type 5 wetlands (as defined in U.S. Fish and Wildlife Service Circular No. 39, 1971 edition) that are 10 acres or more in size in unincorporated areas or 2 ½ acres or more in size in incorporated areas (see Minnesota Statutes, Section 103G.005, subd. 17b, Wetland Type).

Minnesota Pollution Control Agency

In 2002 Long Lake was listed by the Minnesota Pollution Control Agency (MPCA) as an impaired water. It was identified as having excess nutrients which affects the aquatic recreational value of the waterbody. As the Total Maximum Daily Load (TMDL) List of Impaired Waters indicates, the target start date for a TMDL on Long Lake should be implemented by 2009. The Long Lake Management Plan is the first step in the process of developing a TMDL for this waterbody.

Brown's Creek Watershed District

According to Minnesota State Statute 103D, the purpose of a watershed district includes:

- to control or alleviate damage from flood waters;
- to improve stream channels for drainage, navigation, and any other public purpose;
- to regulate the flow of streams and conserve the streams' water;
- to divert or change all or part of watercourses;
- to provide or conserve water supply for domestic, industrial, recreational, agricultural, or other public use;
- to repair, improve, relocate, modify, consolidate, and abandon all or part of drainage systems within a watershed district; and
- to protect or enhance the water quality in watercourses or water basins.

History of Long Lake Management Efforts

In 2002, the Brown's Creek Watershed District performed an update of its Hydrologic & Hydraulic (H/H) Model of the entire watershed. During this project an evaluation of existing flooding issues on Long Lake was completed. For the last couple of years increasingly high water levels were encroaching on residential properties surrounding Long Lake and issues of freeboard were becoming a concern.

In 2002/2003, the City of Stillwater identified upgrades to the 72^{nd} street outlet structure in its Capital Improvement Program (CIP). As part of the City's CIP, a public involvement process was established to collect citizen feedback on the proposed upgrades/modifications. Since the BCWD had recently updated the H/H Model, the District was asked to serve as an advisor in this public involvement process. After a series of meetings were held with residents of the Long Lake area as well as other stakeholders, it was apparent that the group could not agree on a final recommendation to the City of Stillwater. The City of Stillwater decided to provide an outlet for which they requested the District's participation in the design. In 2003, the BCWD produced a letter report that evaluated the Long Lake outlet and made recommendations for optimizing the design of the modifications (see Appendix D). Upon presenting the letter report to the City, it was modified and re-submitted to the BCWD in the form of a permit application for the modification of the Long Lake outlet structure. The BCWD issued the permit and the City constructed the project in 2004.

In 2005, there were a series of large rainfall events that tested the modifications made to the Long Lake outlet. A number of residents involved in the previous public input process were concerned with the performance of the modifications and wanted the City of Stillwater and the BCWD to evaluate its efficacy in providing the agreed upon normal water level for the system. Since all of the modifications to the outlet structure had not been made simultaneously, the City of Stillwater performed dredging of the downstream channel in the summer/fall of 2005, the BCWD recommended monitoring the system for another year or two before deciding whether or not the outlet structure required further modifications.

A Resident's Perspective

When we moved to Long Lake in 1975 we found a watershed that was largely rural and a lake that was full of life. It served as a major stop-over for hundreds of waterfowl in the spring and again in the fall. It's abundant lake fly hatches fed the flocks of migratory warblers that arrived from Central America with the first hatch, and the fly catchers and tree swallows all summer long. River otters, eagles, and various other critters fed on the fish. Deer, turkeys, and coyotes frequented the many woods on both sides of the lake. The oak trees on the west shore produced many hatches of woodies, and great duck hunting. And it had an abundant population of frogs which kept you awake with their croaking and peeping, salamanders that made a dash through the lawns each spring to mate and lay eggs, hundreds of painted turtles, and some of the biggest snappers I have ever seen. Due to freeze-outs few game fish could survive, but the bull heads were always there for the die-hard fishing kids.

Figure 1: Long Lake - 1938

As the watershed developed, the quality of the lake and habitat diminished gradually in ways that we don't always notice immediately. In the late-70's and early 80's farm silt washed into the lake with large thunderstorms, adding to several deltas. The Croixwood holding ponds washed directly into the lake, carrying ever increasing loads of fertilizer, herbicides, and pesticides. Reconstruction of County 5 and Hwy 36, and construction of homes, apartments and industrial sites such as Cub radically increased the runoff laden with more lawn and petro chemicals. This flow washed away the ditch bank adding to the delta on the SE end of the lake. This increased runoff began to cause the lake to bounce, in spite of the DNR outlet built in 1976 to protect the Creek and our property. The lake became ever-greener, preventing the growth of weeds but bringing an odor in the heat of late July. Bull heads continued to thrive even in the face of periodic winter kills.

In the 1990's progress accelerated. Further expansion in the Stillwater Industrial sites and the new Oak Park homes and Menards site brought increased volumes to the lake. Then, in one storm during the construction of Menards and Market Place, vast quantities of mud flowed into the lake, and changed the color a red-brown for several months.. The lake bouncing grew worse and the long-time residents, fearful for their homes, asked for help. Almost a decade later a new outlet was built. Meanwhile, development continued and the lake was further silted and polluted.

Figure 2: Long Lake - 1953

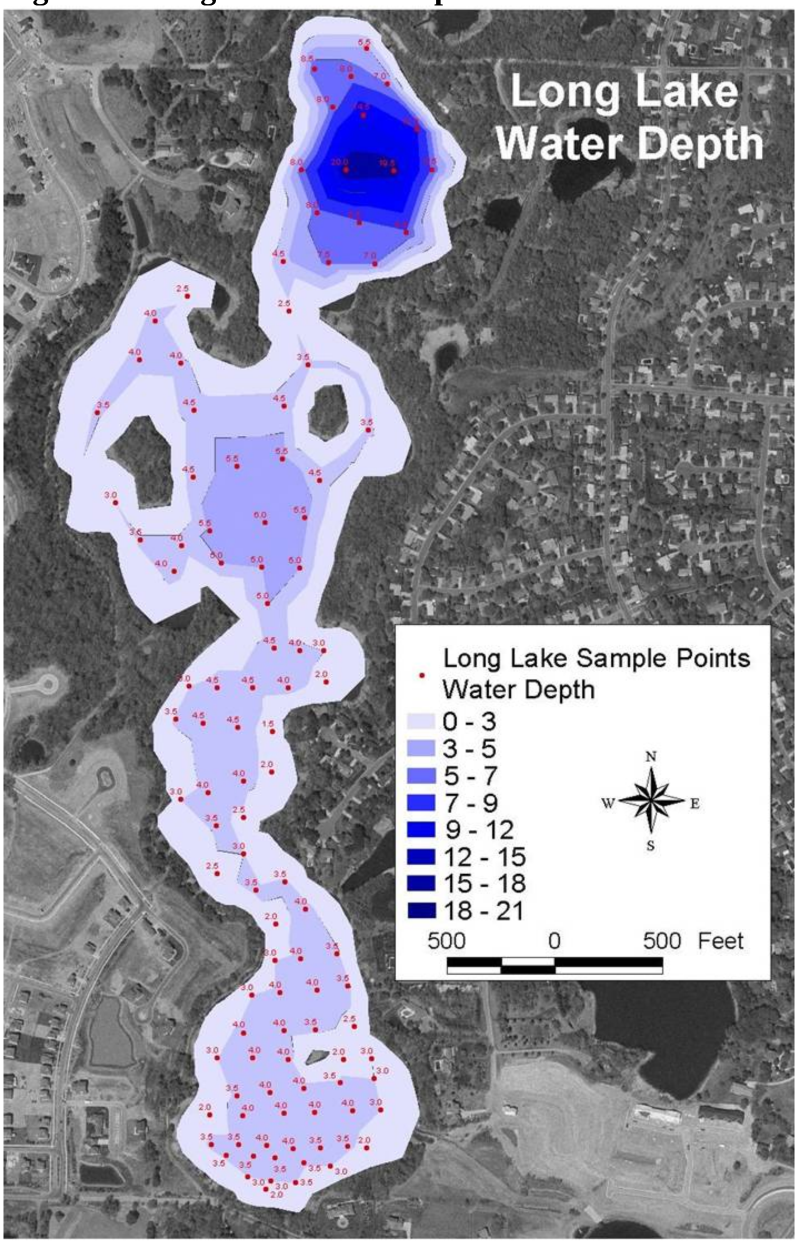
After 30 years we still have wildlife, but the migratory waterfowl have dropped significantly, the west woods no longer provide the sanctuary, frogs and salamanders are gone, and turtles are few. Water lilies have spread further around the lake helping to prevent churning of mud in the shallows, but closing some areas of the lake. In 2003-2005 we experienced the clearest water since 1975, but this caused the dormant bottom plants to grow and choke the waterways. In 2005 we had virtually no lake fly hatches, possibly due to the koi and goldfish released into the lake. As a result, the migrating warblers had no food and stayed only a few days rather than several weeks as in the past. And the flycatchers and swallows did not nest around the lake. Oh, the goldfish swimming in clear water provided a bonanza feast for several loons, three river otters, and an osprey family. But we have lost much since 1975. – Lee Miller

Long Lake Resource Data

Bathymetry

The Washington Conservation District conducted an analysis of Long Lake sediment depth. In the process they developed a bathymetric survey for the lake. The following graphic depicts the water depths within Long Lake. The WCD report can be found in Appendix B.

Figure 3: Long Lake Water Depth



Source: Washington Conservation District

Fisheries

The fish population identified in the most recent DNR survey taken in 1997 was primarily made up of black bullhead and golden shiner with some sunfish and bluegill. Current lake residents indicate that koi and bullhead are most prevalent.

Table 1: Fish Sampled up to the 1997 Survey Year

		Number of fish per net			
Species	Gear Used	Caught	Normal Range	Average Fish Weight (lbs)	Normal Range (lbs)
Black Bullhead	Trap net	118.7	2.2 - 60.5	ND	0.2 - 0.5
Bluegill	Trap net	0.3	1.9 - 29.5	0.30	0.2 - 0.3
Golden Shiner	Trap net	11.3	0.2 - 1.0	ND	0.1 - 0.1
Green Sunfish	Trap net	0.3	0.2 - 2.0	0.12	0.1 - 0.2
Hybrid Sunfish	Trap net	1.7	N/A - N/A	0.16	N/A - N/A
Snapping Turtle	Trap net	1.0	N/A - N/A	ND	N/A - N/A

Normal Ranges represent typical catches for lakes with similar physical and chemical characteristics.

Source: DNR

Table 2: Length of Selected Species Sampled for the 1997 Survey Year

	Number of fish caught in each category (inches)								
Species	*0-5*	*6-8*	*9-11*	*12-14*	*15-19*	*20-24*	*25-29*	*>29*	*Total*
Black Bullhead	23	44	6	0	0	0	0	0	73
Bluegill	0	1	0	0	0	0	0	0	1
Green Sunfish	1	0	0	0	0	0	0	0	1
Hybrid Sunfish	4	1	0	0	0	0	0	0	5

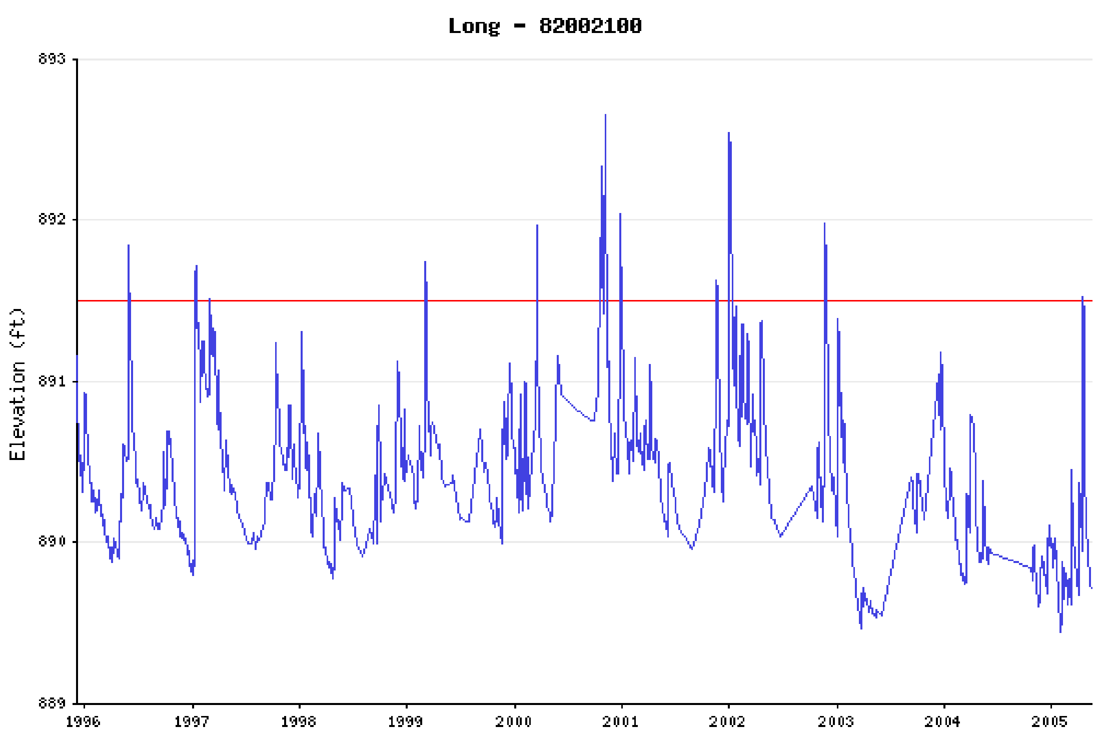
Source: DNR

Water Level

Water levels on Long Lake have been recorded since 1975. The following table describes the level data collected.

Table 3: DNR Lake Level Data
Period of record: 09/30/1975 to 10/31/2005
# of readings: 1813
Highest recorded: 892.65 ft (04/23/2001)
Highest known: 892.9 ft
Lowest recorded: 889.44 ft (07/21/2005)
Recorded range: 3.21 ft
Average water level: 890.41 ft
Last reading: 889.71 ft (10/31/2005)
OHW elevation: 891.5 ft
Datum: 1929 (ft)
Source: DNR

Figure 4: Historic Lake Levels

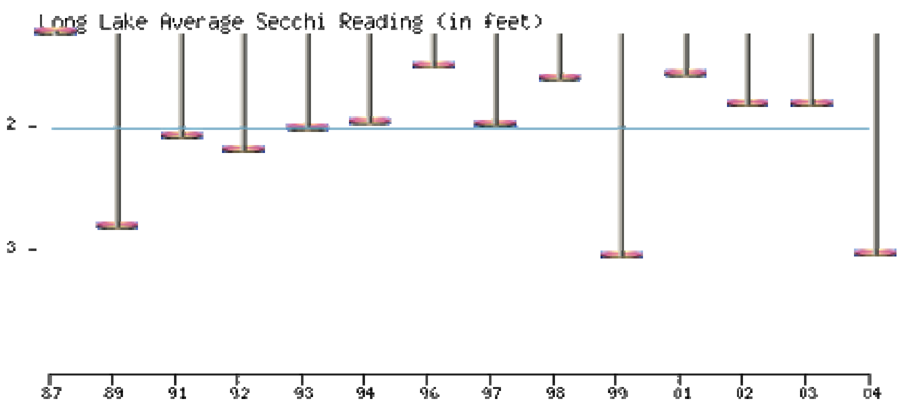


Source: DNR

Water Quality

In general, Long Lake has fairly poor water quality. The figures and table which follow describe the various water quality characteristics of the Lake. Total phosphorus is a measure of the nutrients available for growth of algae and vegetation in the lake, chlorophyll-a measures the abundance of algae, and secchi disk depth is a measure of water clarity. The first figure is a graphic representation of the secchi depth.

Figure 5: Secchi Depth



Source: MPCA

Table 4: Water Quality Readings

Total Phosphorus Mean: 115 ppb (parts per billion)
Total Phosphorus Standard Error: 5 ppb
Total Phosphorus # of Observations: 71
Total Phosphorus Minimum: 45 ppb and Maximum: 230 ppb

Chlorophyll-a Mean: 81.5 ppb
Chlorophyll-a Standard Error: 4 ppb
Chlorophyll-a # of Observations: 100
Chlorophyll-a Minimum: 5 ppb and Maximum: 248 ppb

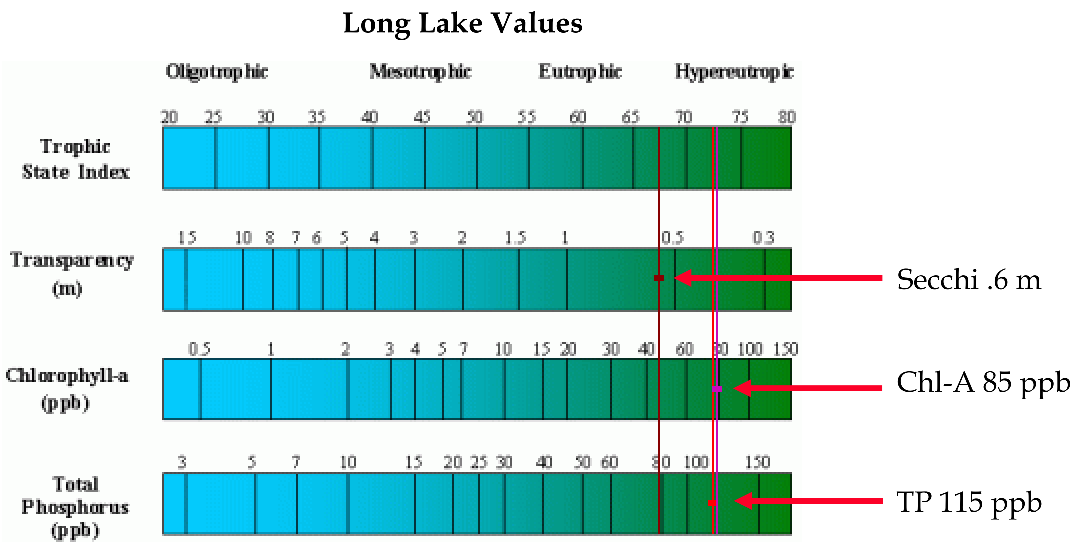
Secchi Disk Mean: 0.6 meters
Secchi Disk Standard Error: 0 meters
Secchi Disk # of Observations: 124
Secchi Disk Minimum: 0 meters and Maximum: 2 meters

Carlson Trophic Status for Total Phosphorus: 73
Carlson Trophic Status for Chlorophyll-a: 74
Carlson Trophic Status for Secchi Disk: 68
Overall Trophic Status: Hypereutrophic

Source: MPCA

The following figure shows the Carlson Trophic Status for Long Lake. The Carlson Trophic Status reflects the overall health of a lake based on the level of "productivity" of the lake. Higher productivity means that more algae and aquatic vegetation growth will occur. Lakes with low productivity are classified as oligotrophic and typically have clear water and low levels of algae growth. Lakes with very high productivity are classified as hypereutrophic and typically have water that supports abundant algae growth. Long Lake is classified as hypereutrophic.

Figure 6: Long Lake Trophic Status Summary



Source: MPCA

Issue and Goal Identification Process

A key component to any planning process is to identify the issues of concern and to develop goals for the future. In this case, two distinct groups were used to gather such input. The first group was composed of residents on the lake and in the watershed to the lake. This group, the Long Lake Citizens Task force, was responsible for identifying the issues of concern for the lake. The group met twice. At the first meeting the citizens were presented detailed information on lake ecology and watershed dynamics. This presentation included information specific to Long Lake. The group was educated on the historical characteristics of the lake. Specific information was provided which demonstrated the quality of water in Long Lake as compared to other lakes in the region as well as state standards for uses such as swimming.

The following is a list of Issues and General Goal Statements developed by the Long Lake Citizens Task Force:

- Nuisance rooted plants/open water
- Plants not just along shoreline
- Odor – rotting smell/vegetation
- Fluctuating water levels and the role they play in defining the type of shoreline vegetation present
- Sediment deltas at inlets
- More water lilies now than in past
- Resident's concerned that there is a chemical problem in the lake that is affecting the crawfish, frogs and small turtle species. There are far less of these species than in the past.
- The residents are primarily concerned with the "weedy" look of the lake. They do NOT like the lily pads and submergent plants in the lake.
- Residents desire "Pleasant Views" of the lake
- Increased fish diversity and fishing opportunities are desired
- Plants – more diverse (for water fowl food)
- More emergents
- Maintain the existing (limited) recreational use of the lake; i.e. passive recreation such as canoeing, paddle boating, etc…
- Macrophyte survey should be conducted
- Maintain wooded shoreline
- Educate homeowners through compost site education; i.e. grant through City of Stillwater
- Use "First Flush System" for nutrient removal
- Dredging options should be investigated to provide greater depths of water for recreation

Following the issue identification process, the citizen group was asked to develop a goal statement for the future management of the lake. The purpose of the goal statement was to focus and guide the implementation planning process.

Long Lake should be managed in a manner which improves the aesthetic condition and passive recreational opportunities which currently exist. The load of total phosphorus entering the lake on an average annual basis should be reduced by 35%.

In addition to the above statement, the citizen group set a specific goal related to in-lake total phosphorus (TP) concentration. The group wanted to see Long Lake reach an in-lake TP concentration of 60 ppb which is the State's standard for shallow lakes. This level of TP concentration has been determined to result in lake conditions which are generally considered to support swimming. The ramification of this goal was that existing watershed TP loading to the lake would need to be reduced by 75%. A detailed plan was developed (see subwatershed loading plan section) to reach the goal of 75% reduction. The subwatershed loading plan identifies specific projects and general BMP approaches that could be undertaken to reach the reduction goal. This information was provided to the citizen group at its second meeting. After reviewing the information, the citizen group decided that their goal for 60 ppb, while fairly aggressive, was the appropriate goal for Long Lake.

The Long Lake planning process was also guided by a second group made up of Watershed District officials and representatives from the local municipalities, the State DNR, Department of Transportation and Washington County. This group, the Stakeholders, was responsible for reviewing the technical information developed for the project and to review the goals developed by the citizen group. After a lengthy review of the magnitude of effort needed to reach the 60 ppb in-lake TP concentration the stakeholder group determined that the goal needed to be modified. **The group determined that the goal be modified to a watershed TP reduction goal of 35%.** This level was determined to be appropriate for the following reasons:

1. The St. Croix Basin team has set a 20% TP reduction goal for all areas draining to the St. Croix River.

2. A 35% reduction in watershed TP loading would result in an in-lake TP concentration at approximately 75 ppb which would put Long Lake at a level where the frequency of nuisance algal blooms would be decreased.

3. The group felt that the goal of 60 ppb was not appropriate for Long Lake given the historical use of the lake as well as the future goal for the lake as identified by the citizen group.

Watershed and Lake Modeling

P8 Watershed Modeling

The watershed draining to Long Lake was evaluated using the P8 Model (Program for Predicting Polluting Particle Passage thru Pits, Puddles & Ponds). P8 is a model for predicting the generation and transport of stormwater runoff pollutants in small urban catchments. The model performs continuous water-balance and mass-balance calculations on watersheds and treatment devices, or BMPs. The model uses five distinct particle sizes in determining mass-balances and has the ability to model up to 10 water quality constituents.

The watershed was divided into fifteen major subwatersheds and 95 distinct drainage areas. The drainage areas were built based upon previous XP-SWMM modeling that been conducted as well as a previous P8 model that was built for the Oak Park Heights / Menards Pond areas. The drainage areas that were modeled each drain to a wetland or ponding area which provides for nutrient removal. The purpose of the P8 modleing effort was to determine the amount of Total Phosphorus (TP) that is produced on the land and to determine the amount of phosphorus that is retained in the ponds and wetlands within the watershed.

The ponds within the Long Lake watershed were inventoried and assessed prior to construction of the model. The P8 model determines pollutant removal by tracking the time that runoff is retained within a particular pond or wetland. This residence time is affected by the physical characteristics of the pond and its outlet structure. Information collected in the field for each of the ponds included area and depth measurements and primary and secondary outlet elevation and geometry.

The P8 model was constructed and calibrated using flow and water quality monitoring data collected by the Washington Conservation District during 2005. The data was used to calibrate the flow predicted from the P8 Model and to choose an appropriate Particle Distribution File. The Particle Distribution File is used by the model to determine the amount of sediment and phosphorus generated from the land surface.

The model was built using current land use conditions modified to account for areas that are currently being developed. The large area to be developed in Lake Elmo adjacent to Manning Avenue was modeled as having been constructed as was the Hospital site in the Marketplace area of Stillwater.

The parameters selected for the Long Lake P8 model are discussed in the following paragraphs. P8 parameters not discussed in the following paragraphs were left at the default setting. P8 version 2.3 was used for the modeling.

- Time Steps Per Hour (Integer) - 5. Selection was based upon the number of time steps required to eliminate continuity errors greater than two percent.

- Growing Season AMC – II = 0 and AMC – III = 100. (Note that the same values were used in CRWD model) Selection of this factor was based upon the observation that the model accurately predicted runoff water volumes from monitored watersheds when the Antecedent Moisture Condition II was selected (i.e., curve numbers selected by the model are based upon antecedent moisture conditions). Modeled water volumes from pervious areas were less than observed volumes when Antecedent Moisture Condition I was selected, and modeled water volumes exceeded observed volumes when Antecedent Moisture Condition III was selected. The selected parameters tell the model to only use Antecedent Moisture Condition I when less than 0 inches of rainfall occur during the five days prior to a rainfall event and to only use Antecedent Moisture Condition III if more than 100 inches of rainfall occur within five days prior to a rainfall event.

- Particle Distribution - The particle file used for the Long Lake model was the Lincoln.par which was developed based on monitoring of a neighborhood in Madison WI.

- Precipitation - The precipitation file used is comprised of hourly precipitation measured at the Minneapolis-St. Paul International Airport for the period between 1949 and the end of September 1999. The time period from 10/01/1994 to 9/30/1995 was used in the model simulations. This time period represents an "average" precipitation year.

- Air Temperature - The temperature file was comprised of temperature data from the Minneapolis-St. Paul International Airport during the period from 1949 through 1999. As with the precipitation data, the time period from 10/01/1994 to 9/30/1995 was used in the model simulations.

- Detention Ponds - The detention pond information was from existing SWMM modeling and site plan drawings with the normal water level (and therefore dead storage volume) and the emergency overflow (and therefore the flood storage volume) verified by survey data

- Infiltration Rates - Infiltration rates for detention basins with the watershed were set at 0.0 inches/hour for the permanent pool of the pond and 0.3 inches/hour for the flood pool. In the Marketplace area the permanent pool infiltration rate was set at 0.15 in/hr

- Orifice Diameter and Weir Length - The orifice diameter or weir length was determined from field surveys or development plans of the area for each detention pond and entered here.

- Swept/Not Swept – The subwatersheds within the City of Stillwater were set with a sweeping frequency of once per year. All other areas were set as "un-swept",

- Impervious Fraction – The impervious fraction for each drainage area was determined through use of recent aerial photography and field surveys.

- Depression Storage - 0.02 for all areas within the watershed

- Impervious Runoff Coefficient – 1.0 for all watersheds.

- Passes Through Storm File - The number of passes through the storm file was determined after the model had been set up and a preliminary run completed. The selection of the number of passes through the storm file was based upon the number required to achieve model stability. Multiple passes through the storm file were required because the model assumes that dead storage waters contain no pollutants. Consequently, the first pass through the storm file results in lower pollutant loading than occurs with subsequent passes. Stability occurs when subsequent passes do not result in a change in pollutant concentration in the pond waters. To determine the number of passes to select, the model was run with three passes, five passes, and ten passes. A comparison of pollutant predictions for all devices was evaluated to determine whether changes occurred between the three scenarios. If there is no difference between three and five passes, three passes are sufficient to achieve model stability. It was determined that three passes were sufficient to achieve model stability for the Long Lake Model.

P8 Modeling Results

The following table summarizes the output from the P8 Model for the major subwatersheds to Long Lake as depicted in the figure on the following page. Detailed loading and treatment information can be found in Appendix C.

Table 5: Average Annual Pollutant Loads

Major Subwatershed	Total Phosphorus Load lbs/year	Total Suspended Solid Load lbs/year
Bruers Pond	15.32	340.93
Central Legends	7.41	554.55
Direct Drainage	29.81	15723.65
Highway 36 North	49.99	9951.52
*Highway 36 South**	*28.83*	*7039.96*
Marine Circle Pond	14.89	1695.96
*Marketplace East**	*80.23*	*22624.89*
*Marketplace North**	*154.01*	*25581.41*
Marketplace West	340.67	33109.55
*Menards Pond**	*89.74*	*10441.8*
North Croixwood	23.30	4504.23
North Legends	0.93	14.8
North Liberty	3.92	632.3
South Legends	9.14	897.92
South Liberty	1.96	342.25

* Subwatershed contributes to a downstream subwatershed. Does NOT load directly to lake.

Figure 8: Long Lake Major Subwatersheds

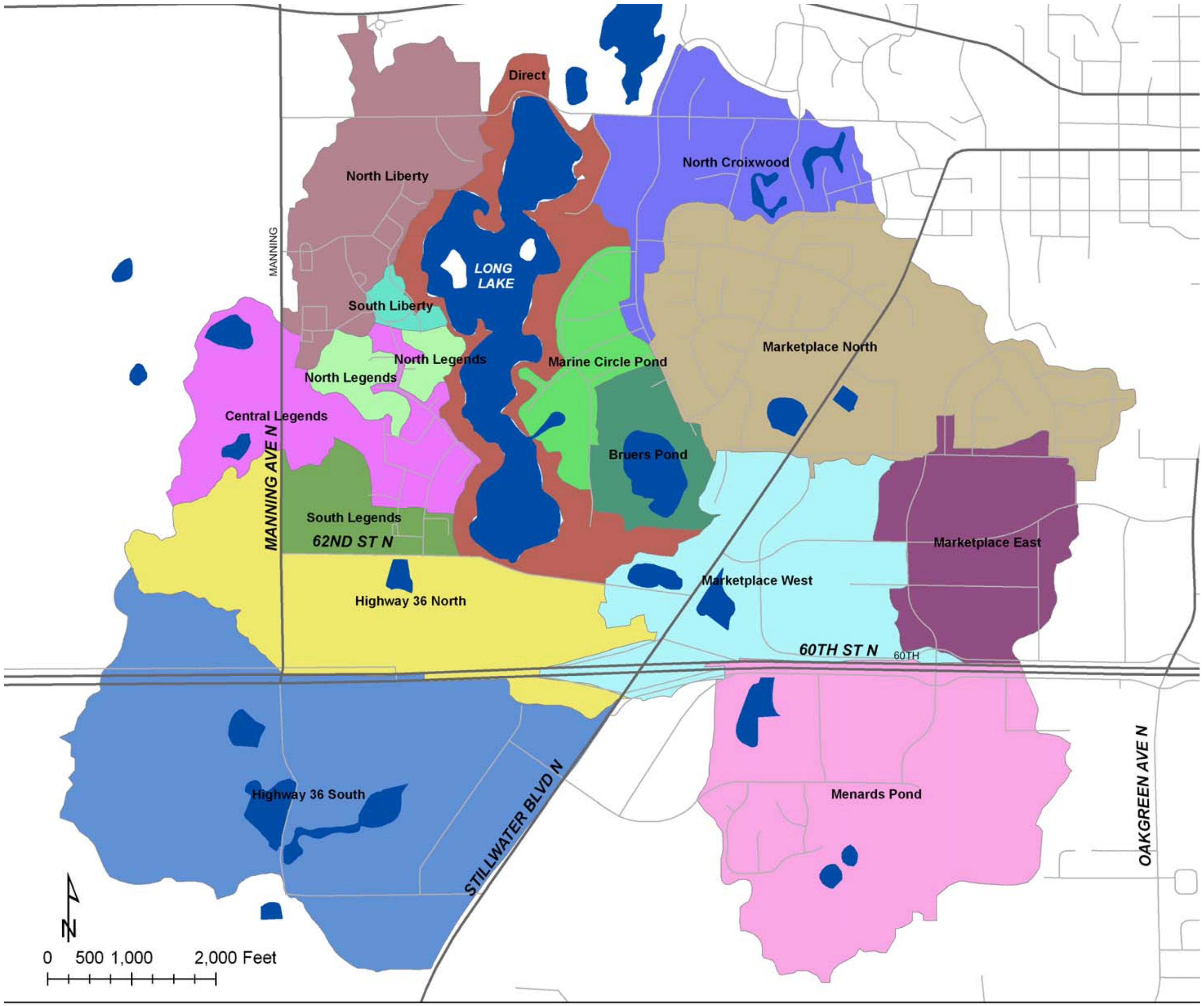


Figure 9: P8 Modeling Results Northeastern Subwatersheds

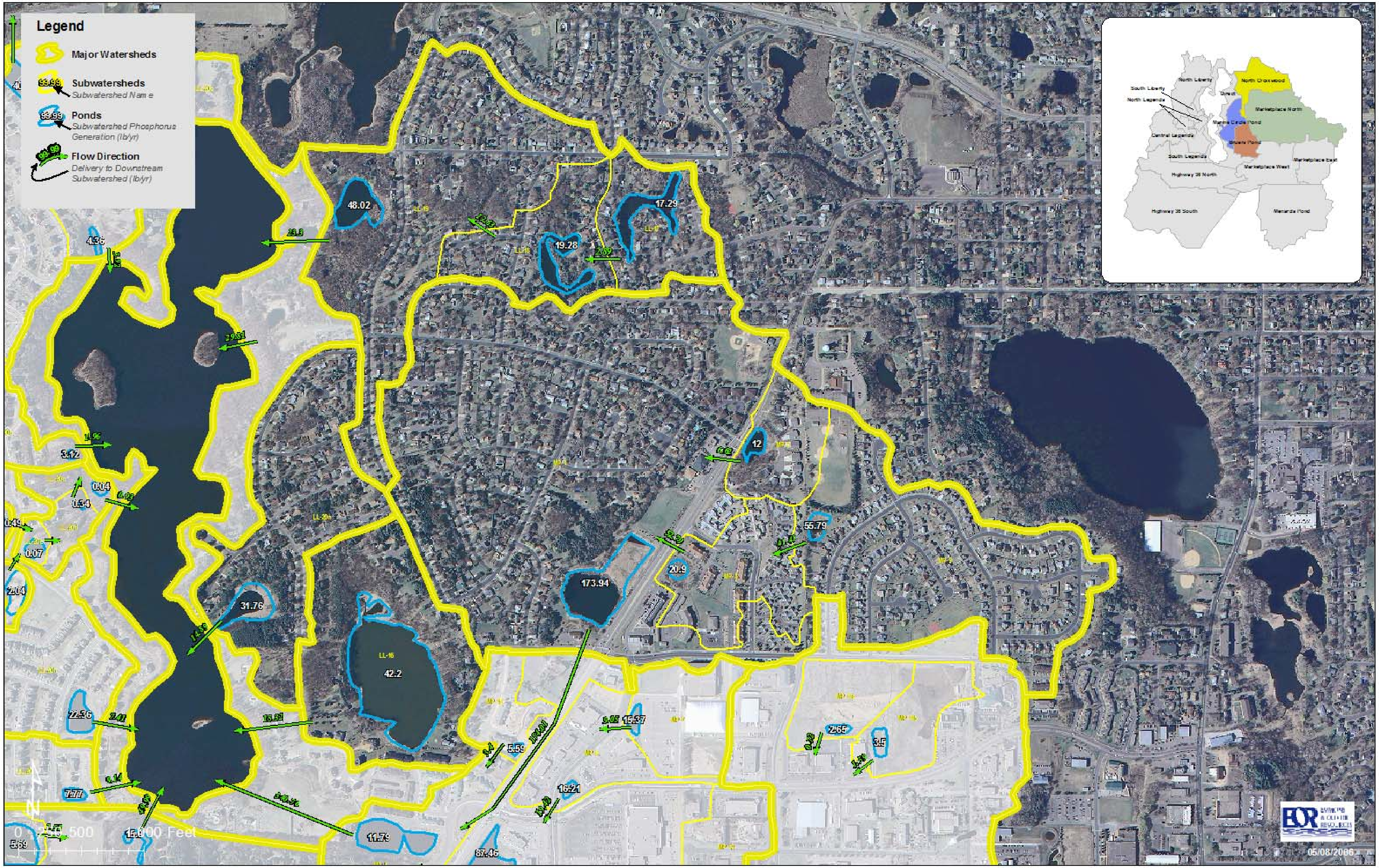


Figure 10: P8 Modeling Results Northwestern Subwatersheds

Figure 11: P8 Modeling Results Southeastern Subwatersheds

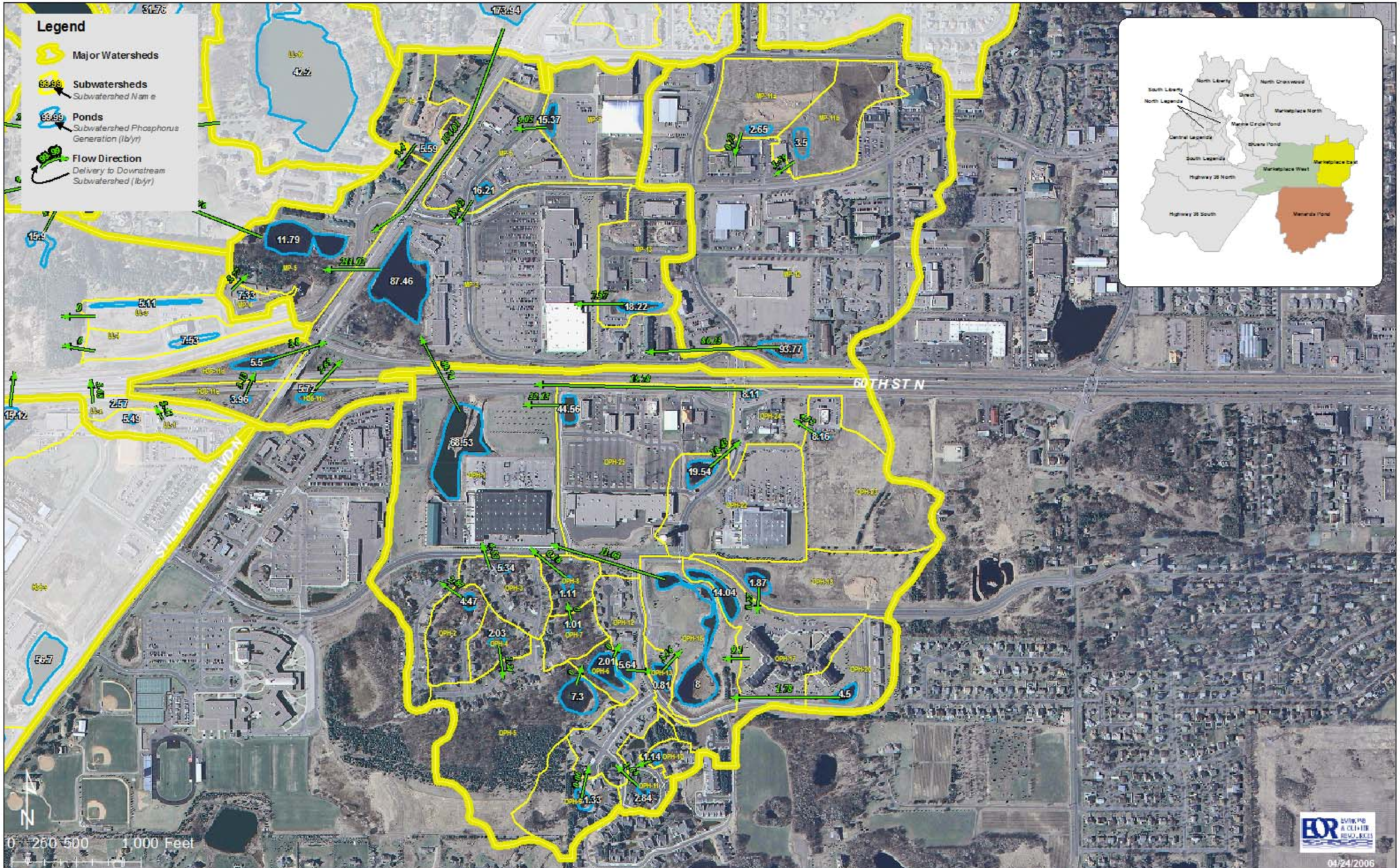
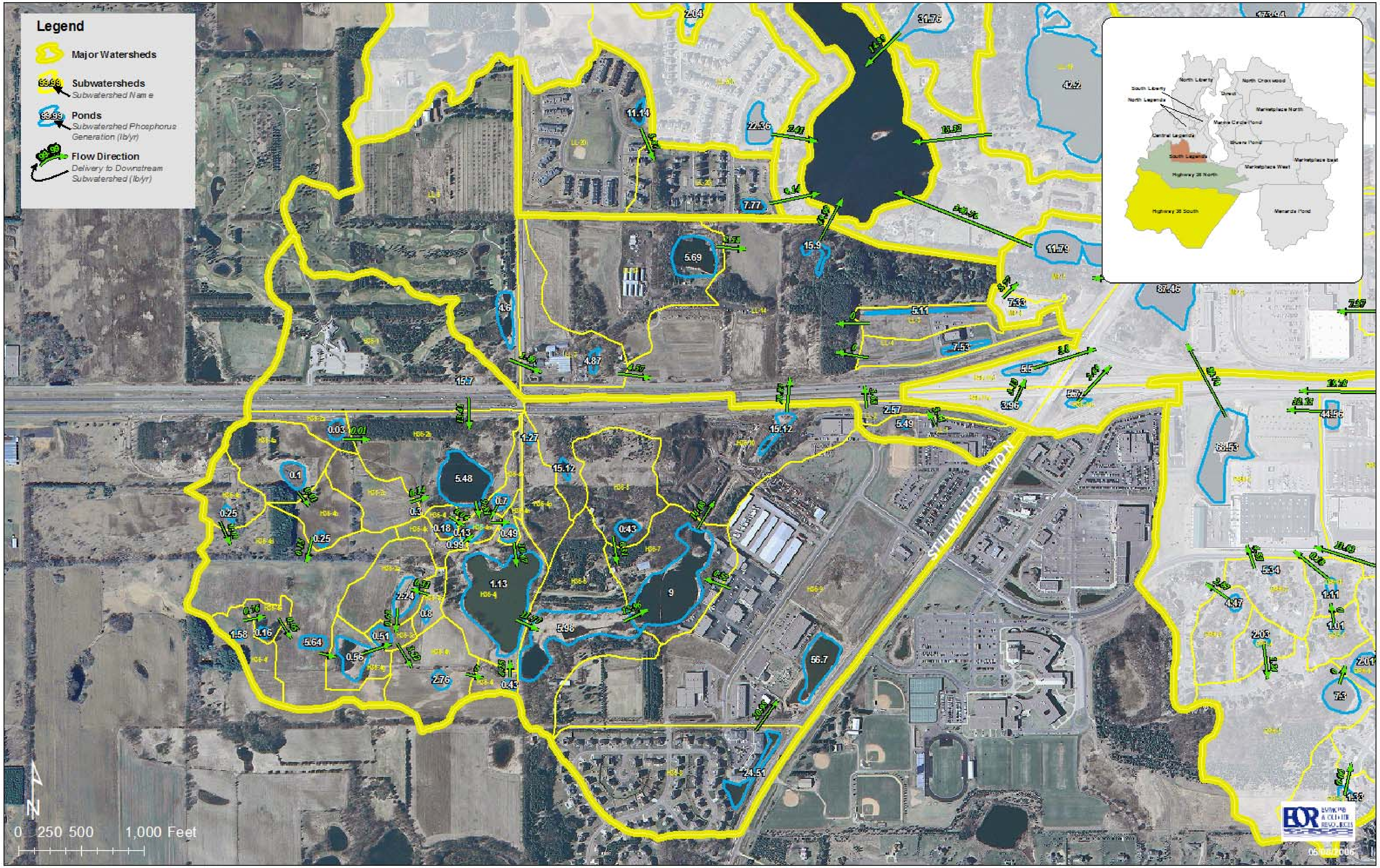


Figure 12: P8 Modeling Results Southwestern Subwatersheds



WILMS In-Lake Modeling

Following the P8 watershed modeling effort, an in-lake model was constructed for Long Lake. The WILMS (Wisconsin In-Lake Modeling Suite) model was used for modeling Long Lake. WILMs contains numerous in-lake modeling equations which allows the user to choice the most appropriate model based on the specific characteristics for the lake. In the case of Long Lake, the Canfield Bachmann Natural Lake modeling equations were used. The following data was entered into the model

Total Phosphorus Load from the Watershed as predicted by P8: 449 lbs
Watershed size: 2034 acres
Lake size: 105 acres
Lake Volume: 374 acre -feet

The model was run and calibrated to monitored in-lake TP concentrations from 1995. This year was chosen because the P8 model was run using precipitation from this year. The 1995 water year is generally regarded as an “average” precipitation year. The in-lake TP concentration in 1995 was 98 ppb. The Canfield Bachman Natural Lake modeling equations predicted a Most Likely in-lake concentration of 88ppb, which was determined to be an acceptable calibration.

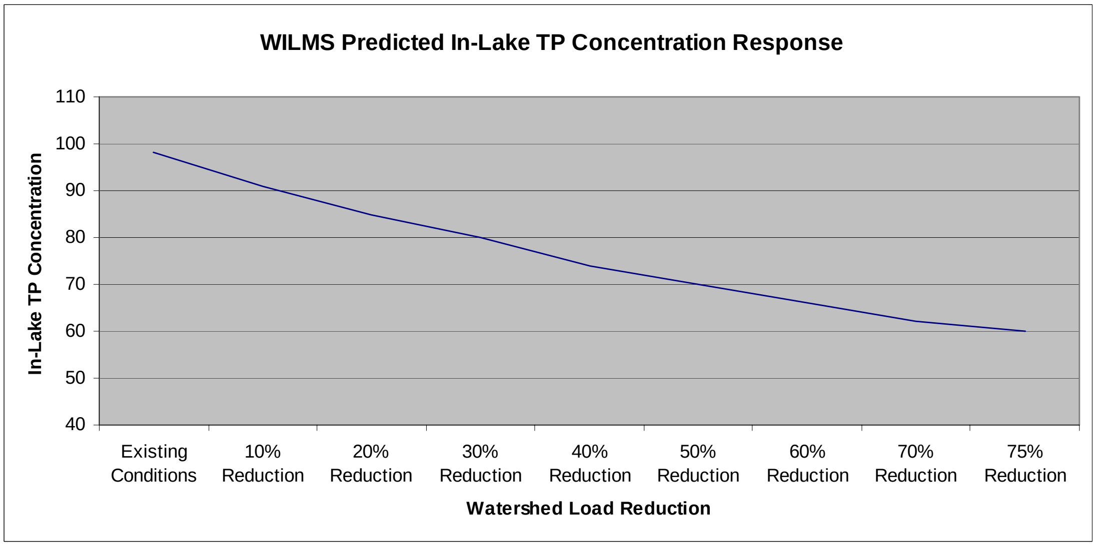
The primary purpose for constructing the in-lake model was to have a tool for predicting the response of Long Lake to decreases in TP loading from the watershed. Various reduction scenarios were run through the WILMS model. The results are summarized in the following table and graph.

Table 6: WILMS Modeling Results

Watershed TP Reduction	**Predicted In-Lake TP Concentration**
10% Reduction	91
20% Reduction	85
30% Reduction	80
40% Reduction	74
50% Reduction	70
60% Reduction	66
70% Reduction	62
75% Reduction	60

It is important to note that the model does not expressly model internal phosphorus loading. This analysis assumes that internal loading remains present at a constant rate. It may be that the internal loading would become a greater proportion of the nutrient balance and the in lake TP concentration would not decrease as noted in the table and following graph.

Figure 13: Predicted In-Lake TP Concentration Response



As the table and graph indicate, a reduction of 75% watershed loading of TP would be necessary to achieve the State standard of 60ppb for shallow lakes.

Subwatershed Loading Plan

The Subwatershed loading Plan is an attempt to allocate 35% total phosphorus reduction out across the various areas of the lakes watershed. The first step in this analysis was to look at the results of the P8 Model of the watershed to identify areas where nutrient loading could be improved. Through an iterative process, individual drainage areas were identified as follows;

1.) Prioirity was given to the Marketplace Subwatershed areas.
2.) The existing pond provided less than 60% treatment as currently configured.
3.) From a visual inspection the pond appeared to have capacity for improvement.
4.) The drainage area exported a large amount of Phosphorus.
5.) Increased nutrient removal efficiency could not be accomplished through typical maintenance of the BMP.

The above criteria were used to identify areas where improvements to existing BMPs could provide increased phosphorus removal. Many of the BMPs within the Legends and Liberty developments were eliminated because the drainage areas do not produce large amounts of phosphorus and because it was felt the efficiency of these ponds could be accomplished through maintenance of the BMP. It was felt that the appropriate strategy would be to work through the City of Stillwater and the homeowner's association to restore these ponds back to their original design configuration.

The following existing BMPs were identified as areas where greater TP removal could potential be provided;

Marketplace North Watershed
- MP-9 Pond
- MP-8 Pond
- MP-1 Pond

Highway 36 Watershed
- H36-Pond
- LL-14 Pond

Marketplace East Watershed
- MP-12 Herberger Pond

Menards Pond Watershed
- OPH-24 Applebees Pond
- OPH-25 Kohl's Pond

The figure on the following page shows the location of the existing BMPs that are proposed to be improved and the table which follows identifies the amount of TP removal that could be provided by improvements to these BMPs as well as a cost estimate for each of the potential projects.

Figure 14: Existing BMPs with Improvement Potential

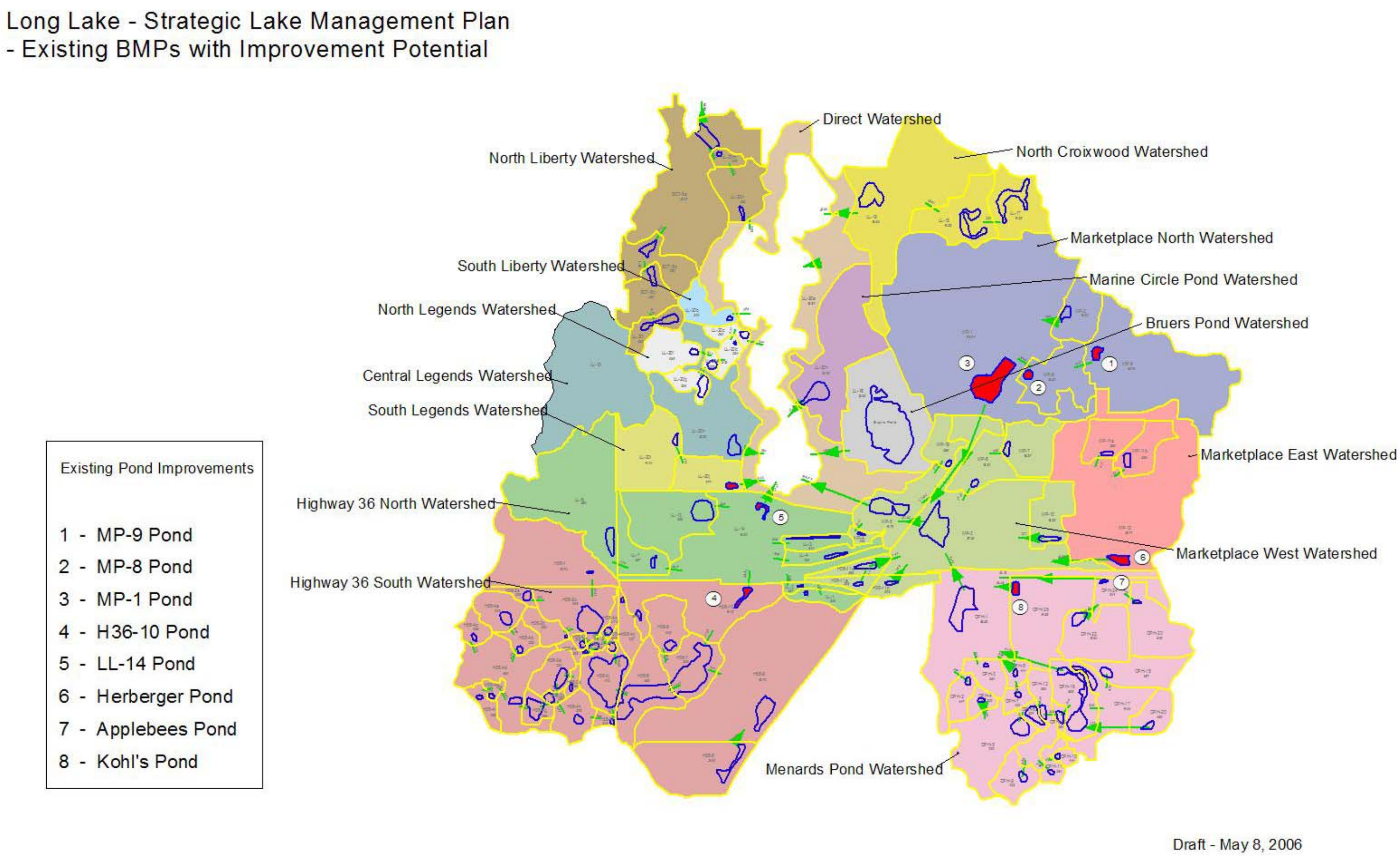


Table 7: Existing BMP Improvement Projects

Marketplace North Watershed BMP Improvements		Estimated P Removal	Estimated Design, Bidding, Permitting, Construction Observation Contingency and Construction Cost
MP-9 Pond Improvements	Pond currently receives 56 lbs and has an export of 41 lbs for a removal efficiency of 27%. Increase efficiency to 60% by increasing storage, excavation and outlet modifications. 60% removal would result in 22 lbs exported for a net reduction of 19 lbs	19 lbs/year	$ 202,500
MP-8 Pond Improvements	Pond Currently has a17% removal efficiency. Increase efficiency to 60% by increasing storage, Excavation and outlet modifications. **After MP-9 Pond Improvements** the pond will receive 43 lbs/year. 60% removal would result in 17 lbs exported for a cumulative reduction of 28 lbs.	26 lbs/year	$ 202,500
MP-1 Pond Improvements	Pond currently has 34% removal efficiency which results in 154 lbs being exported. Increase efficiency to 60% by increasing storage. **After MP-9 and MP-8 Improvements** the pond will receive 197 lbs. Improvements to MP-1 to achieve 60% removal would result in a load of 79 lbs [197-(197*.6)] and a reduction of 75 lbs (154lbs - 79 lbs)	**75 lbs/year**	$ 236,250
	Improvements are considered as an overall approach working from upstream down. Improvements to downstream BMPs without the upstream improvements in place would not be feasible. i.e. it is not realistic to expect that 60% phosphorus removal would provided by improvements to MP-8 without the improvements in MP-9.		
	Total Cost of Marketplace North Watershed Improvements		**$ 641,250**
Highway 36 South & North Watershed BMP Improvements			
H36-10 Pond Improvements	Ravine within H36-10 receives 29 lbs/year and exports 28 lbs with virtually no removal. Increase efficiency of area to 80% would result in an export of 6 lbs and a net reduction of 22 lbs	22 lbs/year	$ 67,500
LL-14 Pond Improvements	Pond currently has a 13% removal efficiency which results in 50 lbs being exported into Long Lake. After improvements to H36-10 Pond the pond will receive 37 lbs. Improvements to LL-14 to achieve 60% removal would result in a load of 15 lbs and a reduction of 35 lbs/year	**35 lbs/year**	$ 101,250
	Total Cost of Highway 36 South & North Watershed Improvements		**$ 168,750**
Marketplace East Watershed BMP Improvements			
MP-12 Pond Improvements - Herbergers Pond	Pond Currently receives 96 lbs/year and exports 80 lbs with a removal efficiency of 17%. Increase efficiency to 35% would result in an export load of 62 lbs and a reduction of 18 lbs/year.	18 lbs/year	$ 202,500
	Removal efficiency is low due to the size of the watershed. If BMPs are installed per the Subwatershed loading plan, greater efficiency could be achieved.		
	Total Cost of Marketplace East Watershed Improvements		**$ 202,500**
Menards Pond Watershed BMP Improvements			
OPH-24 Pond Improvements – Applebee's Pond	Pond currently receives 23 lbs and has an export of 20 lbs for a removal efficiency of 14%. Increased Pond efficiency to 35% would result in a load of 15 lbs and a reduction of 5 lbs	5 lbs/year	$ 67,500
OPH-25 Pond Improvements - Kohls Pond	Pond currently receives 45 lbs and exports 32 for a removal efficiency of 29%. Increasing the efficiency to 40% would result in a load of 27 lbs and a reduction of 5 lbs/year	5 lbs/year	$ 67,500
	Removal efficiencies are low due to the size of the watershed. If BMPs are installed per the Subwatershed loading plan, greater efficiency could be achieved.		
	Total Cost of Menards Pond Watershed Improvements		**$ 135,000**
	Total Cost of Improvements to Existing BMPS		**$ 1,147,500**

The improvements to existing BMPs results in 138 pounds of Total Phosphorus reduction on an average annual basis. This represents a reduction of 28% of existing TP load.

Following the analysis of improvements to existing BMPs, it was determined that additional TP reduction was needed to meet the goal of a 35% reduction of watershed TP loads. It was determined that various BMPs would be needed throughout the watersheds to reach the goal.

The first step in this analysis was to look at the potential TP removal obtained through installation of sumped catch basins in the watershed. Sumped catch basins allow for some detention of water within the structure and, therefore, some phosphorus removal. The following table indicates the design assumptions, treatment and cost estimate information for sumped catch basins.

Table 8: Sumped catch basin design and treatment assumptions

Size of Area Treated	1 acre
Sizing Assumptions	1 manhole per acre
Estimated TP Removal	15%
** TP Removal per BMP	0.08 lbs/year
BMPs per lbs TP Removed	13.3

** Based on 0.5 lbs/acre TP from average area in Long Lake Watershed. 40% Impervious Surface - from P8 Model.

The approach used in analyzing the affect of installing sumped catch basins throughout the watershed differed from the remainder of the BMPs in that they are assumed to occur in conjunction with routine road upgrading and are not a specific implementation project of their own. They are imited to older developed areas and are assumed to be a contribution by the appropriate municipality. The following table shows the potential approach for siting these practices in the watershed and summarizes the TP removal provided.

Table 9: Sumped Catch Basin Plan

Drainage Area	Acres	Number of BMPs Proposed	TP Reduction lbs/year
Bruers Pond Watershed	50	8	0.6
North Croixwood Watershed	111	17	1.4
Direct Watershed	107	16	1.3
Marine Circle Pond Watershed	49	7	0.6
Marketplace West Watershed	173	26	2.1
Marketplace East Watershed	115	17	1.4

Table 9 Continued

Drainage Area	Acres	Number of BMPs Proposed	TP Reduction lbs/year
Menards Pond Watershed	281	42	3.4
Marketplace North Watershed	275	41	3.3
	Totals	**174**	**13.92**
Catch Basin Quantity is set at 1 per 2 acres of Road (assumed at 30% of subwatershed area).			

The remaining TP reduction needed after considering improvements to existing BMPs and installation of sumped catch basins was addressed by siting BMPs throughout the watershed. The following analysis was used in calculating the removal and cost of various BMPs.

The BMP analysis is based on a typically sized practice. The assumption for the size of the various practices and the area treated by the practice is provided. Next, an estimate is made for the amount of TP to be removed per practice. Each of the practices remove TP at different efficiencies. For example, an appropriately sized and constructed small to medium scale raingarden can be expected to remove 90% of the TP from it's drainage area. In order to calculate a load of TP removed per practice, assumptions were made as to the amount of TP produced in the drainage area. For this estimate the P8 Model for the watershed was used. The average area within the Long Lake watershed was determined to be approximately 40% impervious for the purpose of this analysis. The calibrated P8 Model predicts that 0.5 pounds of TP is produced per acre of land in an average precipitation year. These assumptions were used to determine the pounds of TP removed by a particular practice. In the example of the small to medium scale raingarden which treats a 1.0 acre drainage area, the removal expected for each of these practices would be 0.45lbs/year (90% removal of 0.5 lbs/year). Each of the chosen BMPs are similarly analyzed given the size of their area treated and removal efficiency.

The following table summarizes the BMP design, performance and cost assumptions used in the subwatershed loading plan.

Table 10: BMP Sizing and Cost Assumptions

BMP	Size of Area Treated acres	Sizing Assumptions	Estimated %TP Removal	** TP Removal /BMP lbs/year	BMPs per lbs TP Removed	*** Construction Cost	Site Selection, Planning, Design, and Permitting	Total BMP Cost	Cost for 1 lbs TP Removal/year
Small to Medium scale Raingarden	1	100 sq-ft	90	0.45	2.2	$6,000	$900.00	**$6,900.00**	$15,333.33
Community-scale Raingarden	4	400 sq-ft	85	1.70	0.6	$20,000.00	$3,000.00	**$23,000.00**	$13,529.41
Community scale Infiltration Trench	3	8'W x 20'L x 15'D, filled washed gravel	95	1.43	0.7	$25,000.00	$5,000.00	**$30,000.00**	$21,052.63
Basins - Infiltration/Wet Ponds/Wetlands	15	1.2 acre-ft pond, 0.4 acre pond area, 3.0 ft ave depth	60	4.50	0.2	$75,000.00	$15,000.00	**$90,000.00**	$20,000.00
Lakeshore Buffer Creation	0.25	100 feet of Residential Lakeshore width	80	0.10	10.0	$2,000.00	$300.00	**$2,300.00**	$23,000.00

This list of BMPs is not exhaustive. The District may use other BMPs not on the list to achieve the goal of the plan as appropriate.

** Based on 0.5 lbs/acre TP from average area in Long Lake Watershed. 40% Impervious Surface - from P8 Model

*** Costs assume NO land acquisition costs

Utilizing these BMP assumptions, an approach to site various BMPs throughout the watersheds was developed. Generally, the small to medium scale raingardens were used in residential areas while the larger practices such as infiltration trenhes and detention ponds were sited in the more heavily developed retail areas. The following tables show the quantity of each BMP proposed in each of the subwatersheds.

Table 11: BMP Siting Plan

	Small to Medium Scale Raingardens		Community Scale Raingardens		Community Scale Infiltration Trenches		Basins - Infiltration/Wet Ponds/Wetlands		Lakeshore Buffer Creation	
Major Watershed	# of Proposed BMPs	TP Reduction	# of Proposed BMPs	TP Reduction	# of Proposed BMPs	TP Reduction	# of Proposed BMPs	TP Reduction	# of Proposed BMPs	TP Reduction
Bruers Pond	1	0.45	1	1.7	1	1.43			8	0.8
Central Legends	1	0.45			1	1.43				
North Croixwood			1	1.7						
North Legends			1	1.7						
North Liberty	1	0.45								
South Legends	2	0.9	1	1.7						
South Liberty	1	0.45								
Direct					1	1.43			20	2
Marine Circle Pond			1	1.7						
Menards Pond							1	4.5		
Totals	**6**	**2.7 lbs**	**5**	**8.5 lbs**	**3**	**4.28 lbs**	**1**	**4.5 lbs**	**28**	**2.8 lbs**

TP reduction is in lbs/average year

The above described approach, TP removal through improvements to existing BMPs within the watershed, installation of sumped catch basins as roads are upgraded, and construction of new BMPs, results in a 35% TP reduction. The following table shows the cost for implementing these BMPs

Table 12: BMP Estimated Costs

Major Watershed	Small to Medium Scale Raingardens		Community Scale Raingardens		Community Scale Infiltration Trenches		Basins - Infiltration/Wet Ponds/Wetlands		Lakeshore Buffer Creation	
	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Bruers Pond Watershed	1	$ 6,900.00	1	$ 23,000.00	1	$30,000.00			8	$18,400.00
Central Legends Watershed	1	$ 6,900.00			1	$30,000.00				
North Croixwood Watershed			1	$ 23,000.00						
North Legends Watershed			1	$ 23,000.00						
North Liberty Watershed	1	$ 6,900.00								
South Legends Watershed	2	$13,800.00	1	$ 23,000.00						
South Liberty Watershed	1	$ 6,900.00								
Direct Watershed					1	$30,000.00			20	$46,000.00
Marine Circle Pond Watershed			1	$ 23,000.00						
Menards Pond Watershed							1	$90,000.00		
Totals	**6**	**$41,400.00**	**5**	**$115,000.00**	**3**	**$90,000.00**	**1**	**$90,000.00**	**28**	**$64,400.00**

Implementation Plan

The following narrative describes the implementation activities for managing Long Lake. The table which follows the narrative provides a ten year approach to conducting the implementation plan as well as the costs associated with each activity.

Subwatershed Loading Plan

The subwatershed loading plan is described above. The implementation plan is aimed at providing 35% Tp reduction. The priority activities are the improvements to the existing BMPs within the Marketplace North subwatershed. These improvements are slated for the first year of the plan.

Sediment Reduction & Removal

Improved Street & Parking Lot Sweeping

Cost sharing with municipalities on improved sweeping. Rental or purchase of vacumn sweeper and contrubute to the increased cost of more frequent sweeping.

Sediment delta survey

Conduct a survey to determine the size, volume and characteristic of the sediment delta to evaluate the cost for removal

Delta Removal

Rough estimate - place holder until sediment survey is conducted. Deltas would likely be removed in conjunction with the Lake resotration project described below

Lake Restoration

Lake Restoration Feasibility Study

A feasibility study would be needed to determine the specific approach for a lake drawdown. The level to which the lake could be drawn down, the affect of the drawdown on the lake ecology and downstream resources would need to be determined. The anticipated time to refill the lake would also be determined. A specific approach for ensure a successful fish kill would be developed.

Lake Restoration Project

The lake restoration project would consist of a major lake drawdown in late fall allowing the lake level to be significantly low over the winter. The affect of the lake drawdown is anticipated to be as follows;

1. The soft substrate of the lake would become consolidated and would remain consolidated as the water levels return allowing for greater depth of water within the lake.
2. The undesirable submergent vegetation beds within the shallow portions of the lake would be exposed. This would likely kill the plants as well as their seedbed.
3. The more desirable emergent vegetation of the near lake shore would be stimulated to grow.
4. The Koi and black bullhead populations would become more vulnerable to a winter fish kill due to the lower water levels and potential for oxygen depletion.

Fisheries Management

Costs are for restocking lake and installation & maintenance of an aeration system

Monitoring
Best Management Practice Monitoring
Evaluation of BMP performance to validate sizing assumptions

In-Lake Monitoring
Monitoring of In-lake TP Concentrations

Education / Outreach
Annual Newsletter
Annual newsletter to lake and watershed residents reporting implementation activities and monitoring results.

Long Lake Management Plan Educational effort
Develop educational materials based on the chosen goal for the lake and the implementation plan to achieve the goal

Educational signage for BMP projects
Construction and installation of signs at selected, visible BMP sites.

Long Lake Management Plan - Draft Implementation Plan 5/08/06

Implementation Activity	10 Year Implementation Cost	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Subwatershed Loading Plan	$ 1,548,300.00	$ 641,250.00	$ 100,783.33	$ 100,783.33	$100,783.33	$100,783.33	$100,783.33	$100,783.33	$ 100,783.33	$100,783.33	$100,783.33
Sediment Reduction & Removal											
Improved Street & Parking Lot Sweeping	$ 100,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
Sediment delta survey	$ 5,000.00		$ 5,000.00								
Delta Removal	$ 225,000.00			$ 225,000.00							
Lake Restoration											
Lake Restoration Feasibility Study	$ 75,000.00		$ 75,000.00								
Lake Restoration Project	$ 200,000.00			$ 200,000.00							
Fisheries Management	$ 55,000.00						$ 25,000.00	$ 15,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00
Monitoring											
Best Management Practice Monitoring	$ 50,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00
In-Lake Monitoring	$ 25,000.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00
Education / Outreach											
Annual Newsletter	$ 10,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Long Lake Management Plan Educational effort	$ 10,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Educational signage for BMP projects	$ 9,000.00	$ 5,000.00		$ 1,000.00		$ 1,000.00		$ 1,000.00		$ 1,000.00	

Total 10 Year Implementation Cost	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
$ 2,312,300.00	$ 665,750.00	$ 200,283.33	$ 546,283.33	$120,283.33	$121,283.33	$145,283.33	$136,283.33	$ 125,283.33	$126,283.33	$125,283.33

Appendix A Long Lake Planning Process Participants

Long Lake Community Task Force:
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Long Lake Stakeholders
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Klayton Eckles, City of Stillwater
Shawn Sanders, City of Stillwater
Amanda Goebel, Washington County Public Health and Environment
Sharon Price, Washington County Transportation and Physical Development

Brown's Creek Watershed District
Craig Leiser, Board President
Rick Vanzwol, Board Manager
Karen Kill, Administrator
Pat Conrad, District Engineering Representative
Lisa Tilman, District Engineering Representative

Appendix B Long Lake Sediment Survey

Completed February 2004

The purpose of this project was to collect and document sediment depths and thickness in Long Lake for a possible future lake management plan. Since knowing the lake and sediment volume would be vital in the preparation of a lake management plan, the Brown's Creek Watershed District authorized the Washington Conservation District to proceed with the Long Lake Sediment Survey at their January 2004 meeting. The Long Lake Sediment Survey would be accomplished by measuring the depth of water and sediment thickness in approximately 100 sampling locations. Each sediment depth sample point was located using GPS technology. The resultant data would be compiled and plotted and displayed in isopleth maps. In addition the volumes and quantities of sediment were to be documented.

Methods

The Long Lake sediment survey work was conducted February 25, 2004. Water and sediment depth stations were set up on the ice at approximately 150-foot intervals for a total of 109 stations across the lake. Holes were drilled through the ice at each station then surveyed for water depth and depth to hard bottom. Each station location was recorded using Global Positioning System (GPS) technology (Figure 1).

Water depth was measured using an 8-inch diameter disk that was lowered into each hole until it settled on the soft sediment. Depth was measured from the water surface in each hole. The depth to hard bottom was measured using ten-foot sections of ¾ inch galvanized steel pipe. The pipe was lowered into each hole and then pushed straight down into the sediment until refusal. This was assumed to be the hard bottom. Depth was again measured from the water surface in the hole. The difference between the water depth and the depth to hard bottom was determined as the sediment thickness.

The GPS locations and the measurement data collected at each station were downloaded into the Geographic Information System (GIS). ArcView 3-D Analyst was used to create contours for water depth, depth to hard bottom, and sediment thickness. The surface areas of the polygons created by the contour lines were calculated with ArcView and the depths were then used to calculate the water and sediment volumes.

Results

Long Lake is calculated to have a water volume of 374 acre-feet (approximately 604,000 cubic yards). The greatest water depth of 20 ft was found in the northern-most lobe (Figure 2). Approximately 80% of Long Lake's surface area is less than five feet deep. Approximately 90% of the surface area is less than seven feet deep.

The depth to hard bottom survey showed that there are two distinct holes in the lake (Figure 3). The deepest depth to hard bottom, 41.0 ft, was found in the northern-most lobe of the lake, where the water is approximately twenty feet deep. The other hole was 38.0 ft and found in the central portion of the lake, where the water is approximately six feet deep.

The sediment thickness, calculated by subtracting the water depth from the depth to hard bottom, was also thickest in the northern-most lobe and the central portions of the lake. The sediment thickness was 24.0 ft and 32.0 ft, respectively (Figure 4). The majority of the lake had at least six feet of sediment.

If all "soft" sediments were removed and the lake water volume was equivalent to the depth to hard bottom, the lake would have a volume of 977 acre-feet (1,577,000 cubic yards).

The sediment found in the southern third of Long Lake was noted to be of a mineral origin; whereas, the sediment found in the northern two-thirds of Long Lake was noted to be mostly decomposed organic material.

Appendix B

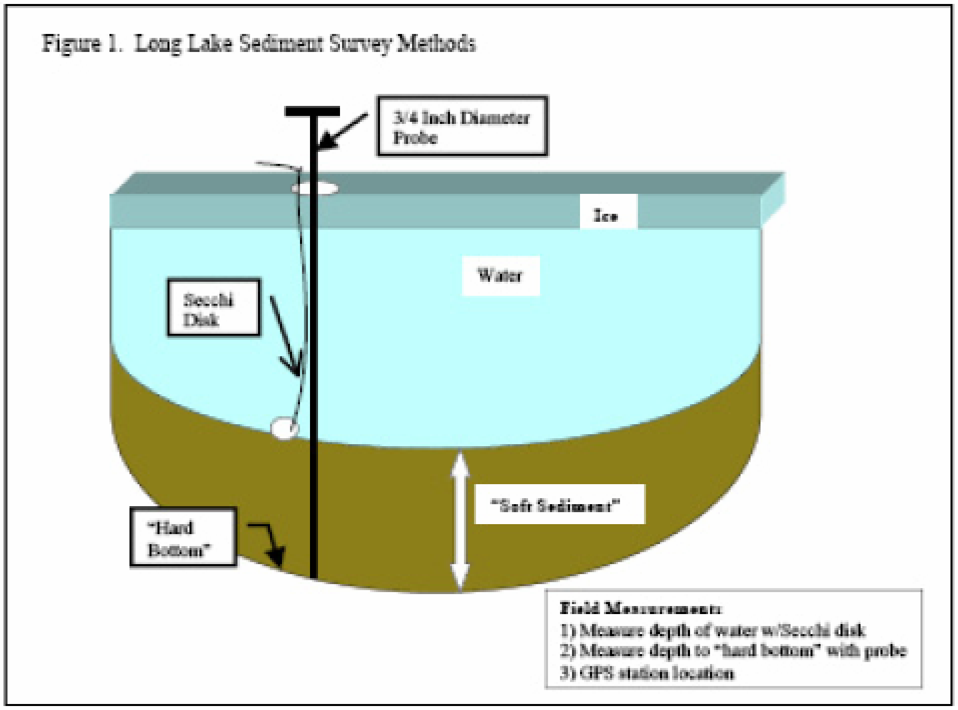
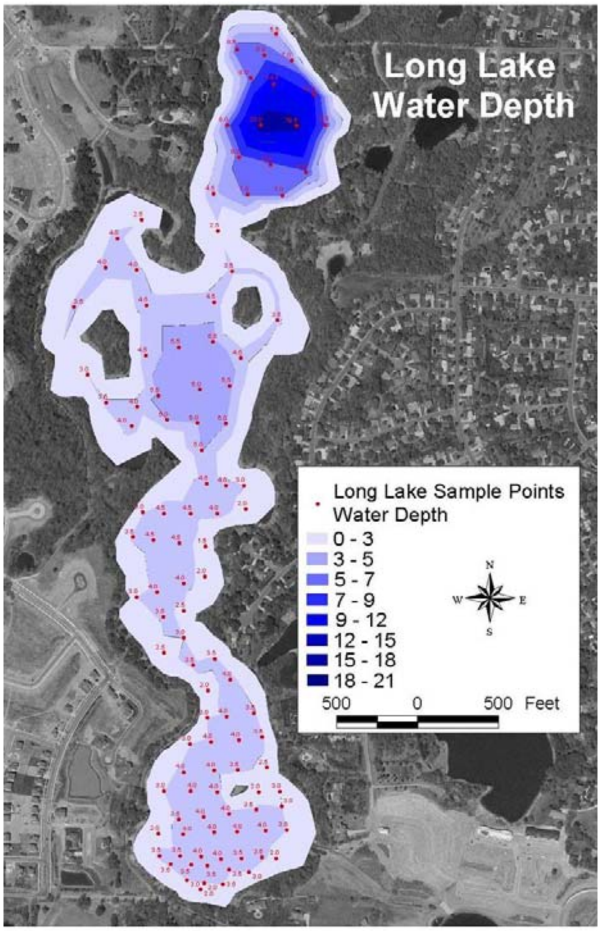


Figure 2


Long Lake
Water Depth
Long Lake Sample Points
Water Depth
0 - 3
3 - 5
5 - 7
7 - 9
9 - 12
12 - 15
15 - 18
18 - 21
500 0 500 Feet
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Appendix B

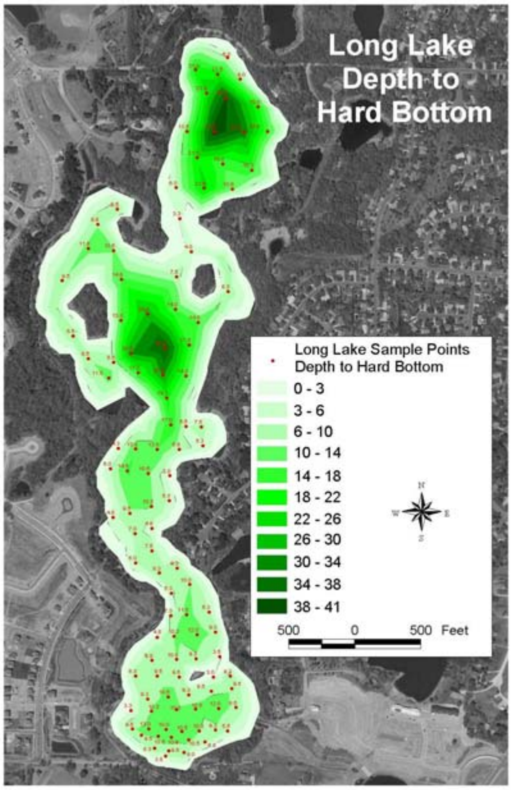

Figure 3

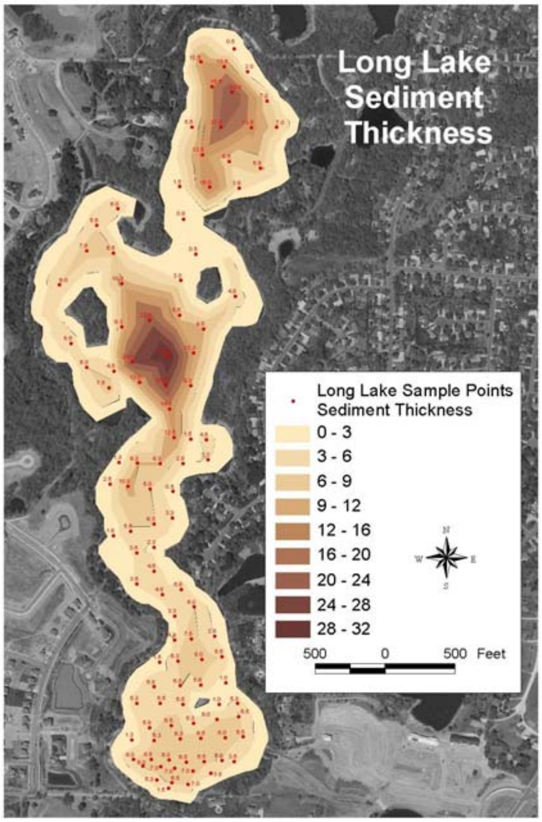
Long Lake
Sediment
Thickness
Long Lake Sample Points
Sediment Thickness
0 - 3
3 - 6
6 - 9
9 - 12
12 - 16
16 - 20
20 - 24
24 - 28
28 - 32
500
0
500 Feet

Figure 4

Appendix C: P8 Modeling Results

Bruers Pond Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-16	42.20	0.00	15.32	64%

Central Legends Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-20H	22.36	0.00	7.41	67%

Direct Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-20A	29.81	0	29.81	0%

Highway 36 North Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-6	4.60	0.00	1.89	59%
LL-7	4.87	1.89	4.57	32%
LL-13	5.69	0.00	2.58	55%
LL-1	5.49	0.00	3.41	38%
LL-2	2.57	3.41	5.68	5%
LL-3	5.11		0.00	100%
LL-4	7.53		0.00	100%
LL-14	15.90	41.65	49.99	13%

Highway 36 South Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
H36-1	15.70	0.00	13.41	15%
H36-2A	0.03	0.00	0.01	67%
H36-2B	5.48	13.55	9.81	48%
H36-2C	0.30	0.00	0.14	53%
H36-3A	2.24	0.31	0.68	73%
H36-3B	0.80	0.00	0.31	61%
H36-3C	0.51	3.28	3.22	15%
H36-4A	0.10	0.00	0.01	90%
H36-4B	0.25	0.01	0.15	42%
H36-4C	0.25	0.00	0.06	76%
H36-4D	5.64	0.86	2.96	54%
H36-4E	0.16	0.76	0.65	29%
H36-4F	1.58	0.00	0.76	52%

H36-4G	0.56	2.95	2.60	26%
H36-4H	2.76	3.22	5.00	16%
H36-4I	0.43	0.50	4.25	-357%
H36-4J	1.13	15.26	11.77	28%
H36-4K	0.99	0.00	0.50	49%
H36-4L	0.18	0.00	0.04	78%
H36-4M	0.13	10.97	10.67	4%
H36-4N	0.49	10.67	10.67	4%
H36-4O	0.70	0.00	0.61	13%
H36-4P	1.27	0.00	0.45	65%
H36-5	0.43	0.00	0.31	28%
H36-6	5.98	11.77	12.96	27%
H36-7	9.00	13.78	14.08	38%
H36-8	24.51	0.00	20.95	15%
H36-9	56.70	20.95	0.52	99%
H36-10	15.12	14.08	28.83	1%

Marine Circle Pond Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-20N	31.76	0.00	14.89	53%

Marketplace East Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
MP-11A	2.65	0.00	0.72	73%
MP-11B	3.50	0.00	1.59	55%
MP-12	93.77	23.34	80.23	31%

Marketplace North Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
MP-8	20.90	41.41	52.79	15%
MP-9	55.79	0.00	41.41	26%
MP-2	12.00	0.00	6.62	45%
MP-1	173.94	59.41	154.01	34%

Marketplace West Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
MP-3	87.46	203.26	211.02	27%
MP-13	18.22	0.00	7.37	60%
MP-6	16.21	9.05	19.42	23%
MP-7	15.37	0.00	9.05	41%
MP-19	5.59	0.00	3.40	39%
MP-4	7.33	0.00	5.77	21%
H36-11D	5.50	3.13	3.80	56%

H36-11E	3.96	0.00	3.13	21%
H36-11C	5.72	0.00	2.69	53%
MP-5	11.79	369.62	340.67	11%

Menards Pond Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
OPH-10	1.14	0.00	0.52	54%
OPH-11	2.84	0.52	1.68	50%
OPH-12	5.64	1.72	3.95	46%
OPH-13	0.81	3.95	3.46	27%
OPH-16	8.00	14.33	11.63	48%
OPH-17	14.04	0.27	9.10	36%
OPH-18	1.87		0.27	86%
OPH-2	4.47	0.00	2.87	36%
OPH-20	4.50	0.00	1.78	60%
OPH-22	19.54	0.00	10.43	47%
OPH-23	8.16	0.00	4.32	47%
OPH-24	8.11	14.75	19.78	13%
OPH-25	44.56	0.00	32.15	28%
OPH-3	5.34	0.00	4.53	15%
OPH-4	2.03	0.00	1.24	39%
OPH-5	7.30	1.24	0.00	100%
OPH-6	2.01	0.00	0.00	100%
OPH-7	1.01	0.00	0.00	100%
OPH-8	1.11	0.00	0.18	84%
OPH-9	1.33		0.06	95%
OPH-1	68.53	71.13	89.74	36%

North Croixwood Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-17	17.29	0.00	2.89	83%
LL-18	19.28	2.89	12.63	43%
LL-19	48.02	12.63	23.30	62%

North Legends Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-20G	2.04	0.00	0.64	69%
LL-20F	0.49	0.00	0.16	67%
LL-20E	0.07	0.80	0.78	10%
LL-20D	0.34	0.78	0.97	13%
LL-20C	0.04	0.97	0.93	8%

North Liberty Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-20L	0.69	0.00	0.47	32%
SCT-8A	40.97	3.11	1.02	98%
SCT-8B	5.29	1.76	3.11	56%
SCT-8C	4.60	0.47	1.76	65%
LL-20M	0.43	1.02	1.05	28%
LL-20K	4.36	1.05	3.92	28%

South Legends Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-20I	11.14	0.00	5.87	47%
LL-20J	7.77	5.87	9.14	33%

South Liberty Subwatershed

Drainage Area	TP Generated lbs/year	Upstream TP Contribution lbs/year	TP Exported Downstream lbs/year	Removal Effieciency within Drainage Area
LL-20B	3.12	0.00	1.96	37%

Appendix D Long Lake Management Study Letter Report: Outlet Evaluation and Optimization – 12/03

Background

At the November 17, 2003 BCWD Board Meeting, the Managers directed EOR to perform an evaluation of the proposed outlet structures for the Long Lake system using the most up to date version of the BCWD Hydraulic and Hydrologic Model. This evaluation was requested from the City of Stillwater following the completion of the Long Lake Management Study Report and Recommendations (October 2003). The scope to perform this evaluation was presented to the Managers by EOR at the November Board Meeting (*Scope for BCWD Participation in the Next Phase of the Long Lake Management Study, November 17, 2003)*.

The objective of this letter report is to summarize the results of this evaluation. These results may be used by the City of Stillwater in the final design phase of the Long Lake Management Study.

Long Lake Outlet Evaluation and Optimization

The improvements evaluated in this analysis were presented by the City of Stillwater in the Long Lake Management Study Report and Recommendations (October 2003). These proposed improvements include:

1. Water level controls be established at 890’ as the normal water level.

2. The controls include a weir that would allow draw-down to 889’ during the winter months for vegetation management and flood protection.

3. Improvements be completed as follows to establish these water levels:

   - The two 30-inch CMP pipes under Interlachen Road (72nd Street) will be removed and replaced with a 5’ by 10’ box culvert (or equivalent capacity pipes). The culvert will have an operational level of 890’ with an optional control at 889’.

   - The water channels between Long Lake and the Jackson WMA will be excavated to form a wider opening and continuous open water wetland corridor. The area should be restored with native wetland vegetation compatible with the existing wetland complex.

   - The existing rate control structure at County Road 12 be modified (eliminated) to operate the Jackson Wildlife Management Area at 889’.

- Grades and flows will be maintained in the channel downstream from County Road 12.

The most recent version of the BCWD Hydraulic and Hydrologic Study XP-SWMM Model was modified to include these proposed improvements. Of these proposed modifications, three remain constant for all modeling scenarios:

1. The channel downstream of County Road 12 was updated with profile information provided by the City of Stillwater.

2. The channel between Long Lake and the Jackson WMA was widened so that the system operates as one waterbody.

3. The outlet control structure at County Road 12 was removed so that the two 30-inch culverts operate alone.

During this evaluation the proposed improvements at 72nd Street were modified from what the City had originally presented. These modifications are presented below.

Proposed Outlet Configuration under 72nd Street

In an effort to determine the most suitable culvert configuration for 72nd Street the following scenarios were modeled:

- 2X30" RCP at 888'
- 2x42" RCP at 888' and 888.5'
- 2x48" RCP at 888' and 888.5'
- 5' by 10' box culvert at 888
- Two 5' by 10' box culverts at 888

The results of this analysis demonstrate that the most hydraulically effective and cost efficient culvert configuration is the two 42-inch RCP at an elevation of 888.0'.

The objective of the culvert configuration under 72nd Street is to act as an equalizer between Long Lake and the Jackson WMA. Since the restriction in the system is the two 30-inch culverts under County Road 12, there is a limit on how big the culvert configuration needs to be in order to reduce HWL's on Long Lake to the maximum extent possible. The HWL on Long Lake was the same for the 2x48" RCP, the 5' by 10' box culvert and the two 5' by 10' box culvert scenarios. In fact, the HWL on Long Lake was a bit higher for these scenarios than for the 2x42" RCP scenario. This is because the water was delivered more efficiently with the larger culvert configuration before it was restricted at the 30-inch culverts under County Road 12 resulting in a tailwater effect which produced a slightly higher HWL on Long Lake. By placing the two 42" pipes under 72nd Street, the HWL remains at 892.5 which is the allowable HWL for the 100-

year 24-hour rainfall event. In addition, this culvert configuration is a less expensive solution.

The reason for bringing down the invert elevation of the 2x42" RCP culverts to 888.0' is to provide a bigger pipe cross-sectional area (and therefore more capacity) for all flows, specifically the flows associated with the smaller rainfall events. By installing the culverts at an elevation of 888.0' they will always be subject to 10" to 12" of standing water since the elevation of the culverts under County Road 12 is 888.8'.

When the City begins drafting plans and specifications for the management of Long Lake, it should also make sure that the bottom of the channel or pool downstream of 72nd Street is at least two feet lower than the downstream elevation of the two 42-inch pipes. This will prevent the system from clogging with sediment and provide adequate capacity in the system for flood protection. It is also very important that the storage available in the Jackson WMA and the connected areas are excavated and is consistent with the volume assumed in the modeling (15.5 acres at 889.0' and 16.3 acres at 890.0').

Recommended Weir Structure Details

The following diagram shows the proposed control structure at the Long Lake outlet.

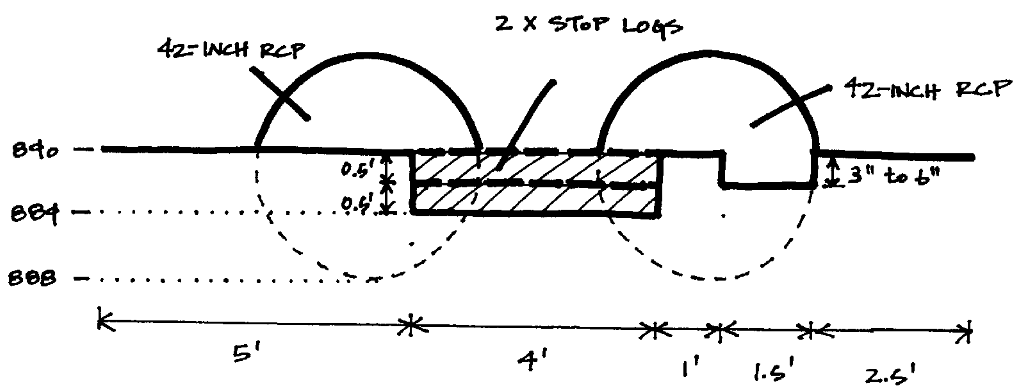

Figure 1. Cross Section of Proposed Long Lake Outlet Configuration at 72nd Street

Evaluation of Long Lake Draw-Down Time

The dimensions of the first stage of the weir (at elevation 889.0 feet) were determined by evaluating the draw-down time of Long Lake from an elevation of 890.0 feet to 889 feet. The design of the weir structure should consider the amount of time it will take to lower the elevation on Long Lake in the fall to provide additional storage capacity in the system in preparation of spring snowmelt. As Figure 2 illustrates, it will take approximately two weeks to lower the elevation from 890 feet to 889.2 feet.

As Figure 1 illustrates, the currently proposed stop logs are 4' long. This length could be potentially reduced to 3' but going below 3' would significantly increase the drawdown time above two weeks. Extended drawdown time combined with early freeze up could affect the effectiveness and operation of the log-weir.

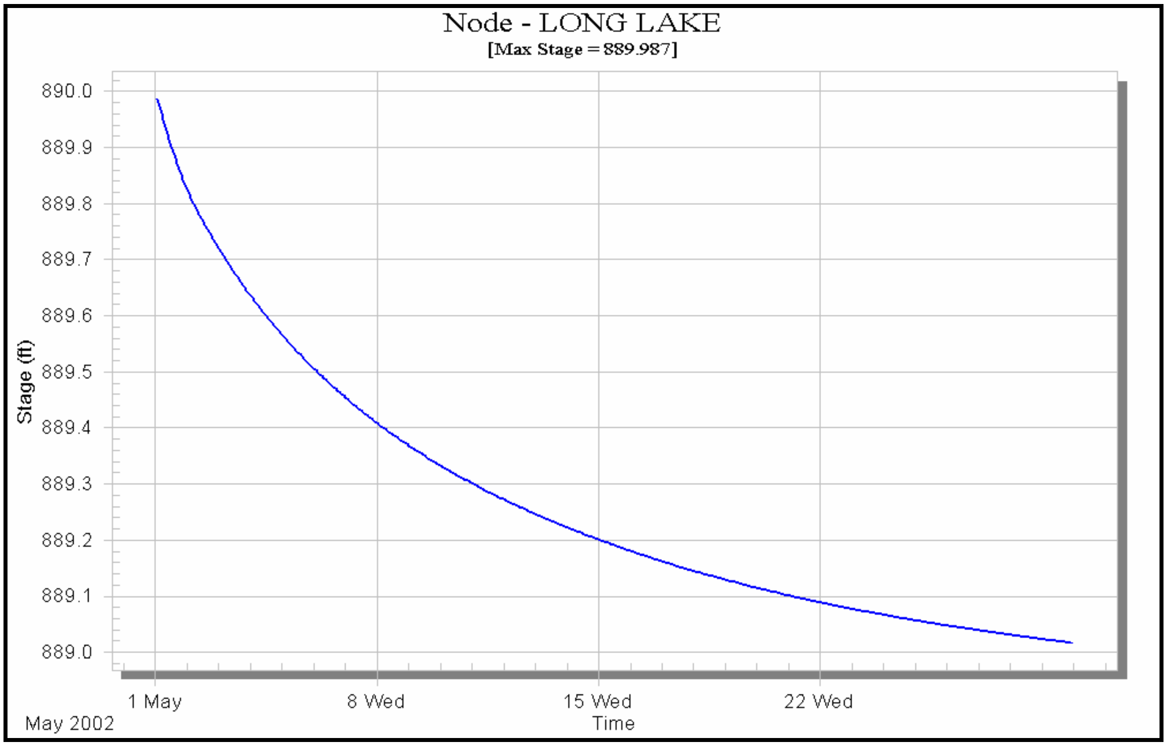

Figure 2. XP-SWMM Results for Long Lake Draw-Down Analysis

Modeling Runs and Results

Based on the scope approved at the November 17th 2003 Board Meeting, the following precipitation events were modeled with the modified and optimized outlet structure configuration:

- 100-year 24-hour rainfall event (5.9 inches)
- 7.2-inch snowmelt runoff event
- 2002 continuous rainfall event (May to October)
- 100-year 10-day precipitation event (10.8 inches)
- Wettest 1-week period on record using the Mpls-St. Paul rainfall record (14.42 inches from July 20, 1987 to July 27, 1987 with 9.2" on July 23rd)
- Side-by-side 100-year rainfall event

The following text summarizes the results for each event. Table 1 contains a summary of all of the XP-SWMM simulations and Figures 3 through 8 present the graphical results for each precipitation event.

Design 100-year event

Figure 3 displays the elevation-time series for the 100-year rainfall event (5.9-inches of rain in a 24-hour period) for Long Lake with the outlet described above in place. Initial water level at Long Lake is assumed at 889.8 feet. This rainfall event results in the lake reaching a peak elevation of 892.5 feet and remaining above 892.0 feet for a period of 1.7 days. This design event results in 1.0 foot of freeboard from the lowest house elevation.

100-year runoff event

Figure 4 displays the elevation-time series for the 7.2-inch snowmelt runoff event for Long Lake with the outlet described above in place. Applying 7.2 inches of rain over a 10-day period with frozen ground conditions simulates the 7.2-inch snowmelt event. Long Lake is assumed to start slightly above its winter drawn down elevation of 889.1 feet, or the elevation of the bottom stop log. This event results in the lake reaching a peak elevation of 893.1 feet and remaining above 893.0 feet for a period of 1.1 days. This event results in 0.4 feet of freeboard from the lowest house elevation.

2002 continuous simulation

Figure 5 displays the elevation-time series for the 2002 rain for Long Lake with the proposed outlet in place. The total amount of rain that fell during the 2002 season was 11.45 inches. Initial water level at Long Lake is assumed at 889.8 feet. This rain season results in the lake reaching a peak elevation of 891.5 feet and remaining above 891.0 feet for a period of 2.8 days. As shown in Figure 5, the lake remains at the elevation of 890.0 feet or above for most of the recreation season

Back-to-back 100-year events

Figure 8 displays the elevation-time series for back-to-back 100-year rainfall events (5.9-inches of rain in a 24-hour period) for Long Lake with the outlet described above in place. These back-to-back events were run with a dry period of 3 days between the rainfall events. The 3-day dry period was chosen in order to keep the lake level above 891.0 feet before the start of the second rainfall event. Initial water level at Long Lake is assumed at 889.8 feet. This series of events results in Long Lake reaching a peak elevation of 893.6 feet after the second rain event and remaining above 893.0 feet for a period of 1.8 days.

100-year 10-day Rainfall Event

Figure 6 displays the elevation-time series for the 100-year 10-day rainfall event (10.6-inches of rain distributed over a 10-day period) for Long Lake with the outlet described above in place. Initial water level at Long Lake is assumed at 889.8 feet. This rainfall event results in the lake reaching a peak elevation of 893.8 feet and remaining above 893.0 feet for a period of 3.6 days.

Wettest 1-week period on record for the Minneapolis - St. Paul Airport

Figure 7a displays the elevation-time series for the wettest 1-week period recorded at the Minneapolis-St. Paul International Airport since 1938. The total amount of rain that fell between July 20h and July 26th, 1987 was 14.42 inches, with the majority of it (9.15 inches) falling on July 23rd (see Figure 7b). The initial water level at Long Lake is assumed at 889.7 feet. The lake elevation begins at this level to simulate the 4 dry days prior to the rainfall events. These events result in Long Lake reaching a peak elevation of 894.9 feet and remaining above 893.0 feet for a period of 3.9 days. While this event was localized and did not generate this same amount of rainfall in Stillwater, this simulation represents how the proposed Long Lake system would react to such a rainfall on record.

Table 1. Summary of Modeling Results

Precipitation Event	Rainfall Depth [inches]	Long Lake HWL [ft]	Jackson WMA HWL [ft]	Duration Long Lake Elevation above 893.0 [days]	Duration Long Lake Elevation above 892.0 [days]	Duration Long Lake Elevation above 891.0 [days]
100-year 24-hour Event	5.9	892.5	892.2	0.0	1.7	4.3
100-year Runoff Event	7.2*	893.1	892.8	1.1	4.6	7.3
2002 Continuous Rainfall Event	11.45	891.5	891.3	0.0	0.0	2.8
100-year 10-day Precipitation Event	10.6	893.8	893.4	3.6	6.2	8.4
Wettest 1-week Period on Record using Mpls-St. Paul Airport Rainfall Record	14.42	894.9	894.4	3.9	5.4	7.4
Back-to-back 100-year Rainfall Event (includes 3 days between events)	11.8	893.6	893.2	1.8	4.8	9.3

* Total runoff generated

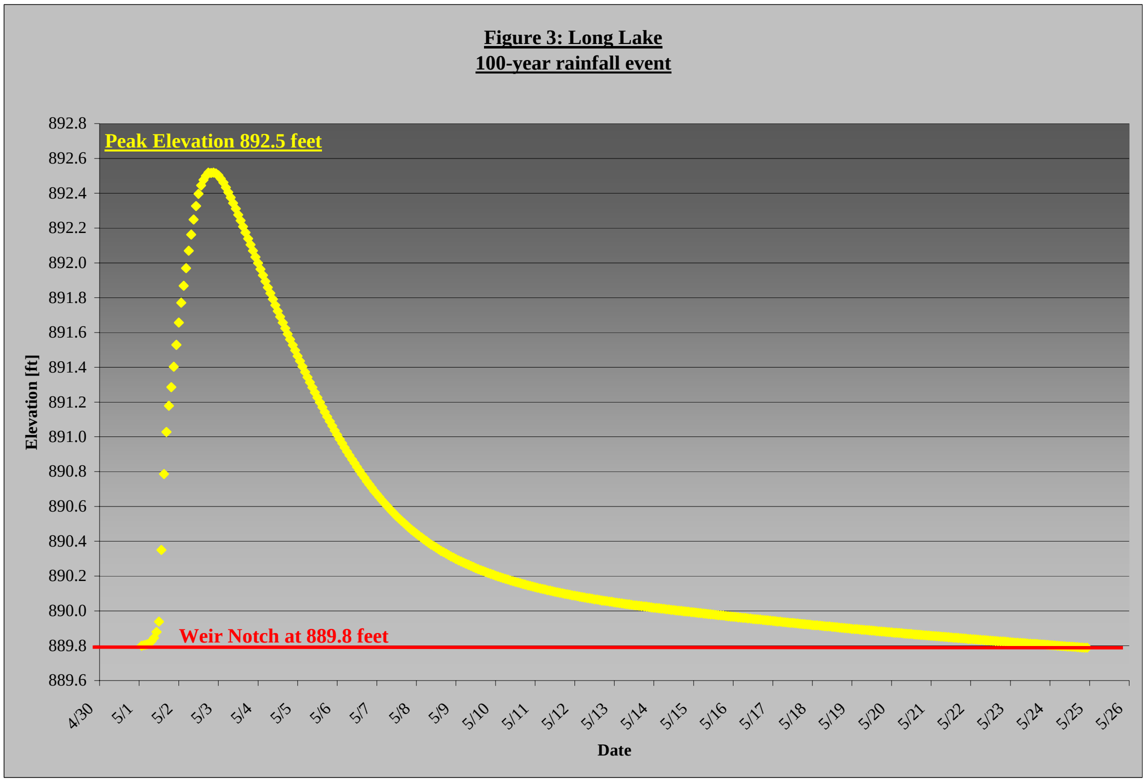

Figure 3. Long Lake 100-year 24-hour Rainfall Event

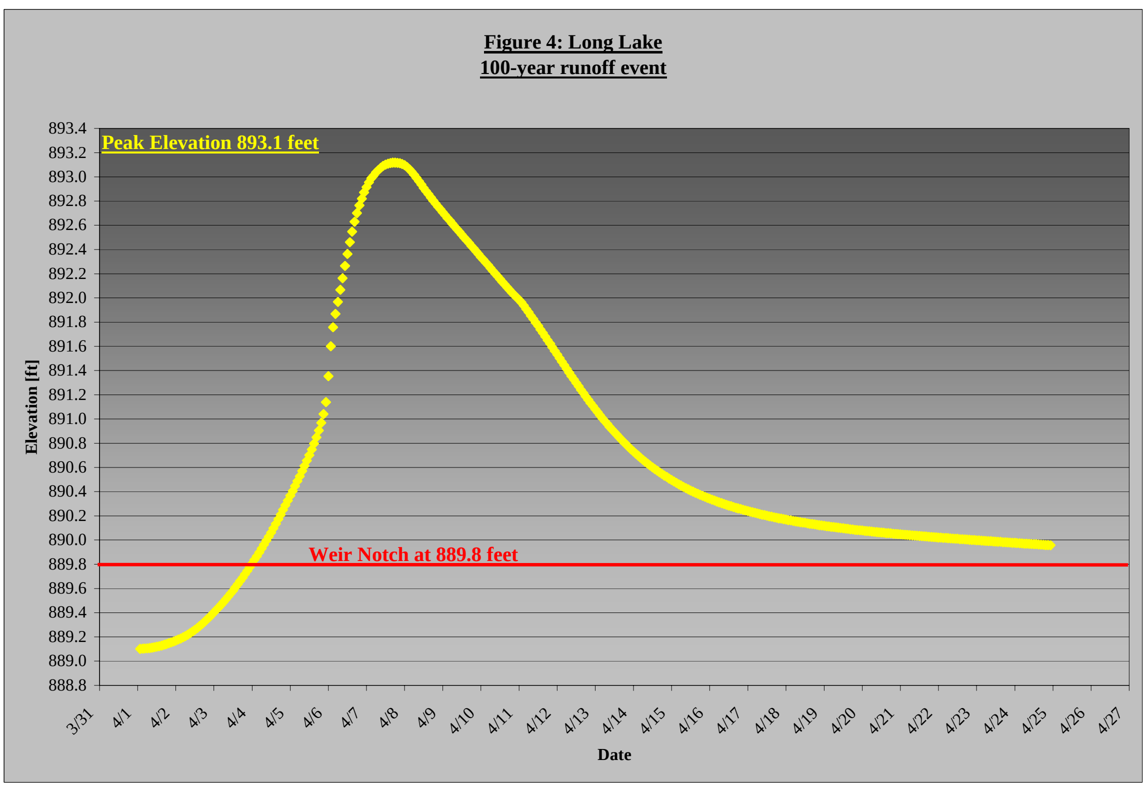

Figure 4. Long Lake 100-year Runoff Event

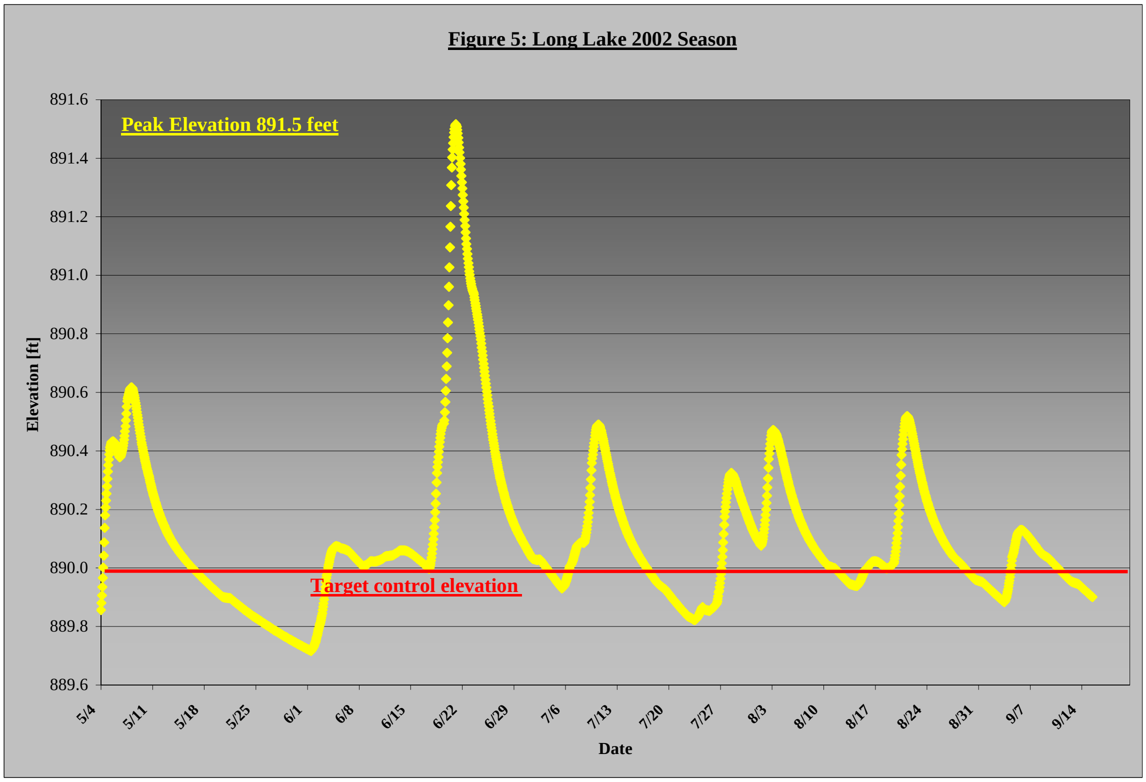

Figure 5. Long Lake 2002 Continuous Rainfall Simulation

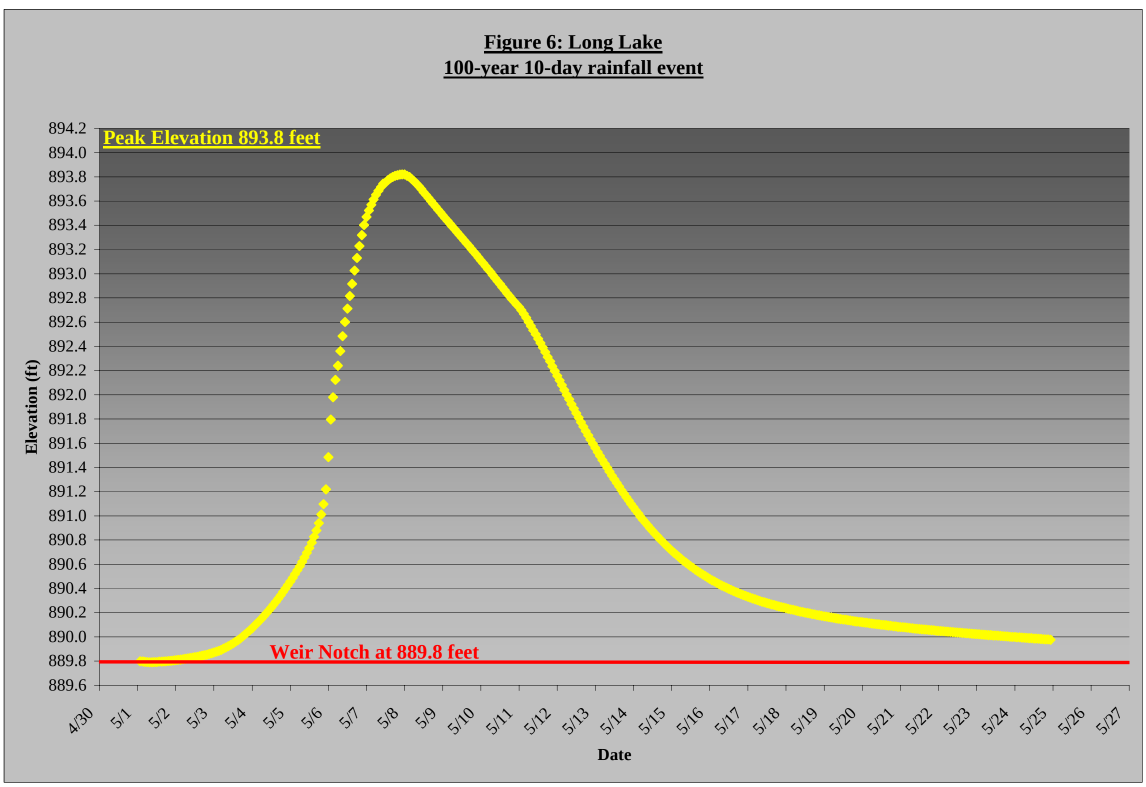

Figure 6. Long Lake 100-year 10-day Rainfall Event

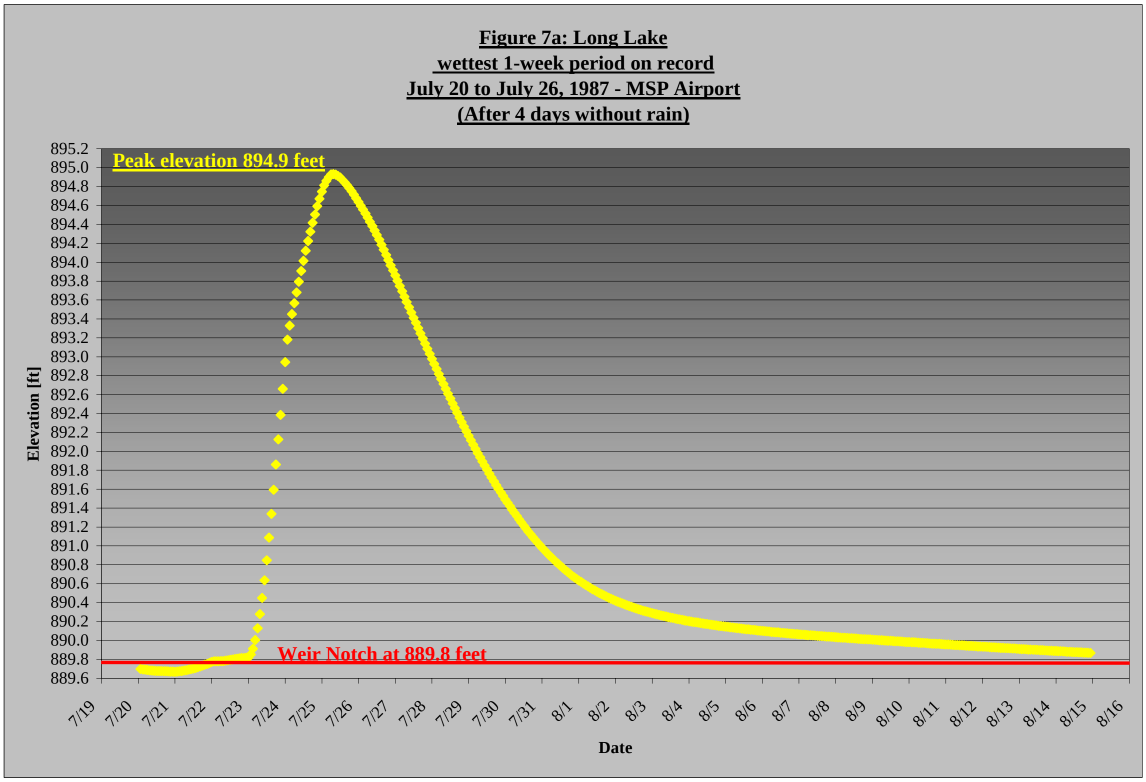

Figure 7a. Long Lake Wettest 1-week Period on Record from July 20 to July 27, 1987 – Minneapolis-St. Paul Airport

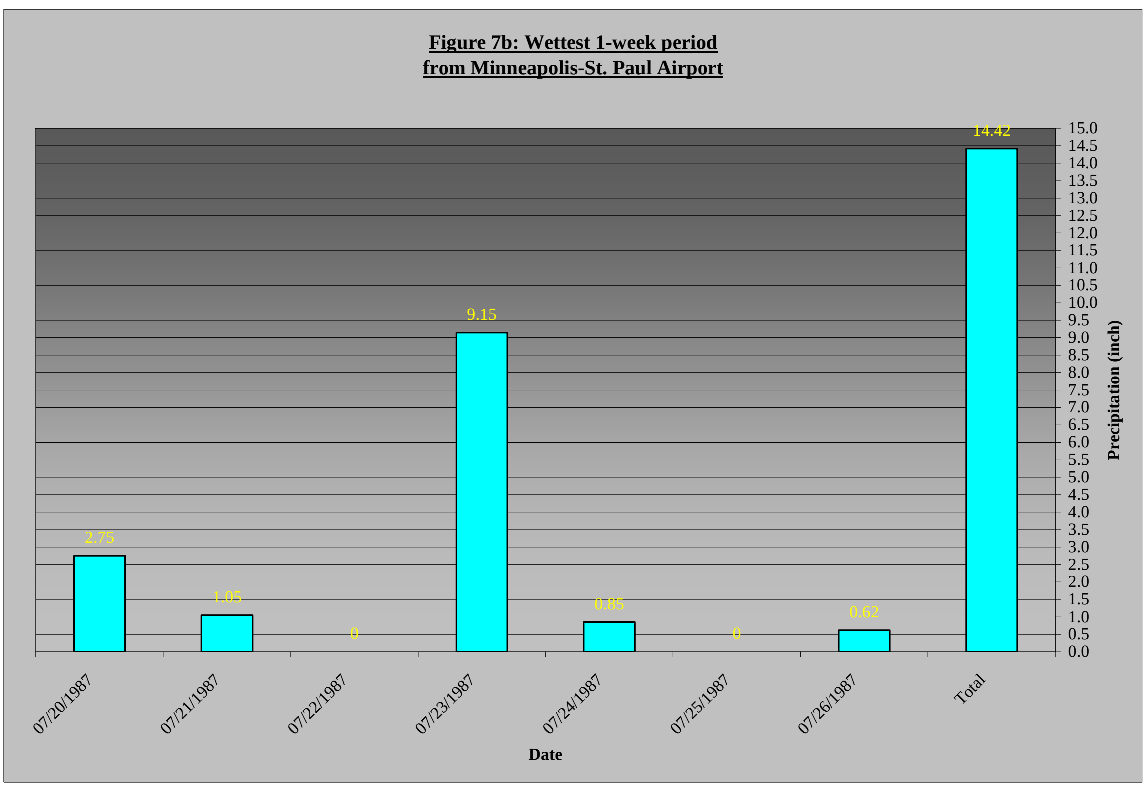

Figure 7b. Wettest 1-week Period – Minneapolis-St. Paul Airport

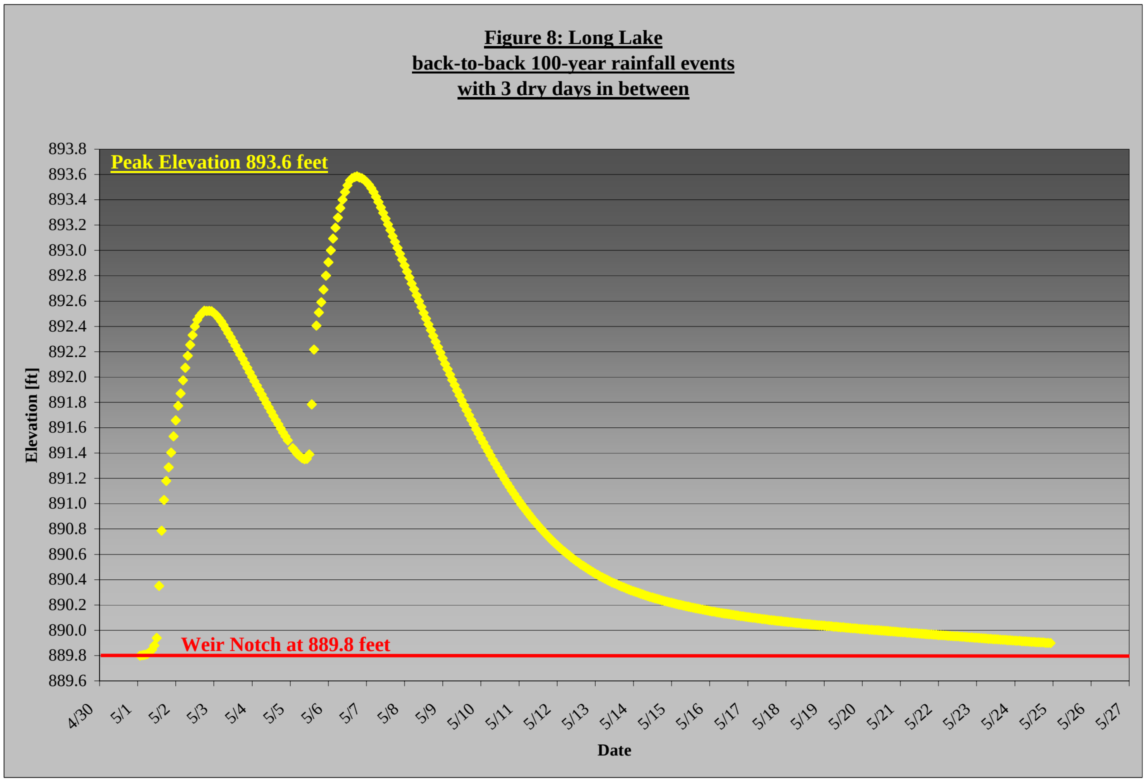

Figure 8. Long Lake Back-to-Back 100-year Rainfall Events with 3 Dry Days in Between

Conclusions and Recommendations

The following are the final conclusions and recommendations regarding the design and construction of the proposed outlet structures for the Long Lake Management Plan.

1. Implement the weir and culvert configuration under 72nd Street recommended in this report or design weir and culvert configuration with similar capacity.
2. Excavate and regularly maintain the bottom of the channel and ponds downstream of 72nd Street at or below 886.0’ to minimize the potential for sediment blockage and subsequent reduced hydraulic capacity at the Long Lake outlet.

3. Ensure that the final stage/storage available after excavation at the Jackson WMA and connected areas is consistent with the assumptions made in the model (e.g. 15.5 acres at 889.0’ and 16.3 acres at 890.0’).

4. Eliminate the existing rate control structure at County Road 12.

5. Maintain slopes, cross sections and hydraulic capacity of the channel downstream from County Road 12. The first 800 feet of the channel north of County Road 12 are particularly important due to the limited gradient.

6. Perform periodic inspection and maintenance of the system so that all elements of the proposed system will remain fully effective and operational.

The implementation and maintenance of all of the above recommendations will result in the HWL's for extreme events as shown in Table 1 and Figures 2 through 8. The standard 100-year 24-hour design storm produces a HWL of 892.5'. The implementation of these recommendations will also result in relatively stable elevations on Long Lake (see Figure 5 for 2002 Continuous Rainfall Simulation) on a normal year. Lake levels at or above 890.0' are expected to occur, on average, 67% of the time during the recreational season (May 1 to September 15).

Finally, it is also recommended that the City works with concerned Long Lake residents on reasonable and cost-effective ways to re-landscape their flood-prone backyards and provide additional freeboard protection for their houses. At the time the homes on Long Lake were constructed, the freeboard requirements were one foot above the 100-year HWL. Given the information available now and the results of the different rainfall events modeled, the District would like to see a protection level of 895.0' (2.5 feet of freeboard) if possible. As mentioned above, this would imply coordinating with willing Long Lake property owners.