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A Lake Management Plan for Green Lake

Green Lake, Wisconsin

Wisconsin's Deepest Natural Inland Lake

Part 1 – Main Contents

Developed in Partnership

January 2013

Partners

Green Lake Sanitary District
Green Lake Association
Green Lake County Land Conservation Department
Fond du lac County Land and Water Conservation Department
Green Lake Conservancy
Wisconsin Department of Natural Resources
United States Geological Survey
City of Green Lake
City of Ripon
Citizens of Wisconsin

Acknowledgements

The principal consultant and author of this lake management plan is Mark F. Sesing, retired WDNR Water Resource Management Specialist. For their contributions, thanks to the following and their respective boards and agencies: Charlie Marks, Jen Kaiser, Derek Kavanaugh, Ted Johnson, Tom Eddy, Lynn Mathias, Paul Tollard, Glen McCarty, Jim Hebbe, David Bartz, and Phil Hoopman. We offer special thanks to the Public Advisory Group members and the citizens of Wisconsin for their guidance in developing this document.

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Introduction and Background

There are few lakes in the state that can compare to Green. Named for the reflective green emerald hue of its water, all who visit Green Lake's shores are taken in by its beauty. Sandstone bluffs, clear viewing vistas, and sheltered bays balance the sharply descending drop-offs and darkening depths of Wisconsin's deepest natural lake.

Understanding Green Lake requires an exploration of the creative forces responsible for its unique character. The lake is nestled within a valley scoured out by an ancient river prior to the start of Wisconsin's last glacial period, the Wisconsin glaciation. Beginning about 110,000 years ago and ended just over 10,000 years ago this period of massive continental ice is characterized by four sub-stages of alternating advances and retreats. These sub-stages, from the oldest to the youngest, are the Iowan, Tazewell, Cary and Mankato. It was during the Cary sub-stage that Green Lake was impounded within a deep valley that had been formed before the glacial period began. The Cary sub stage formed a large recessional moraine on the west end of the lake basin, impounding water in what we now recognize as Green Lake.

With a surface area of 7,346 acres and a maximum depth of 236 feet, Green Lake contains a vast volume of water, nearly 762,000 acre feet. Put into perspective, Lake Winnebago has a volume of 1,370,000 acre feet. Green Lake holds the second largest volume of water of any lake in the State; Lake Geneva (Walworth County) can fit into Green Lake twice over. Given normal stream flow, it would take 20 years to fill the basin. This long residence time represents a very low flushing rate, with implications for lake fertility, and ultimately, algae growth, bloom intensity and frequency. Essentially, with such a low flushing rate, it would take many years before fertility would "reverse." On other lakes, such as Lake Puckaway, it would take less than a month to fill the lake.

Green Lake has over 25 miles of shoreline. This is a critical area for the lake's biological diversity as it represents a transitional edge—an ecotone—that supports aquatic life unique to the shore zone. Green Laker is also relatively unique in the region for supporting both warm- and coldwater fish. This feature also means lake management requires more complex strategies.

Green Lake stratifies in the summer period: that is, thermal layers form at varied depths dependent upon wind, air temperature, and ice cover during the previous winter. This layering, termed thermal stratification, forms in late spring and ends in the late fall. During most of the open water recreational season, the upper thermal layer (epilimnion) is characterized by warmer water, an obvious presence of algae, warm water fish, and aquatic plants. These grow only at depths of less than 25 feet. There are three thermal strata that typically form in lakes like Green: the epilimnion, the metalimnion, and the hypolimnion.

Today's Threats

Green Lake presents a special challenge. As Wisconsin's deepest lake, it represents the embodiment of our state's lake partnership (Eddy 2011) and is a reflection of our relationship with all 15,000 lakes in Wisconsin. Despite serious threats and significant degradation, the lake presently meets most of the community's expectations for a fishery, recreation, and esthetic beauty. These are the ecosystem services that we garner from its waters, but the lake cannot be taken for granted.

As history is our guidepost, complacency will be Green Lake's loss, and thus ours. Green Lake is subject to becoming degraded in many ways. Excessive sediment and nutrient loading has affected oxygen levels and there is the threat of further oxygen depletion in the deepest parts of the lake, thus threatening the trout fishery. Habitat, water clarity and natural features have also been degraded over the past century creating a less resilient lake that is now more susceptible to breakdown. At the risk of being an alarmist, we must do what needs to be done soon or suffer the consequences. The concept here is that of the ecological tipping point. All seems well and the lake at a stable state, with only minor changes, until a point is reached where the lakes quickly slides into an alternate stable state with a loss of its fishery, its recreational valve and its esthetic beauty.

Our historical experience with Wisconsin lakes, including Green, has been directed at managing water fertility, shore development, the fishery and aquatic plant habitat. In the face of recent threats, new to our doorstep, the relatively familiar period of traditional lake management schema is quickly becoming less viable. Our management tasks now include addressing invasive plant and animal species, increasing urbanization in the entire watershed, changing agricultural practices, as well as climate change.

Aquatic invasive species (AIS) have been on the move. Less than a decade ago zebra mussels remained the problem of other lakes, now this mollusk is an important member of the Green Lake community. *Myriophyllum* (water milfoil) has been a nuisance in the lake for much longer. It is easy to see how the success of these newly arriving species has affected lake dynamics. A defensive strategy is needed to mitigate the effects of these invaders and to prevent additional invasions.

For some people climate change is of small concern for Wisconsin lakes, yet the ice-on/ice-off data for lakes in Madison argues otherwise. In the decade of 1900 to 1910 the average ice-on period for Lake Mendota was 98 days; from 2000-2006 the ice-on period was 70 days (Wisconsin State Climatology Office). Flooding events also are predicted to increase in frequency and these may result in increased runoff from the watershed into the lake.

Watershed use remains an important concern. The evidence shows a long-term delivery of phosphorous and sediment that began soon after area settlement and continues to be a problem. Oxygen trends within the lake are pointing to problems. While individual pollution sources can be identified and then addressed, non-point sources remain a serious issue.

The Green Lake community represents a powerful group of stakeholders, which in partnership with state, federal and local resources are capable of formulating a successful management plan for the region. It is through this spirit of commitment that the next era for Green Lake will be defined.

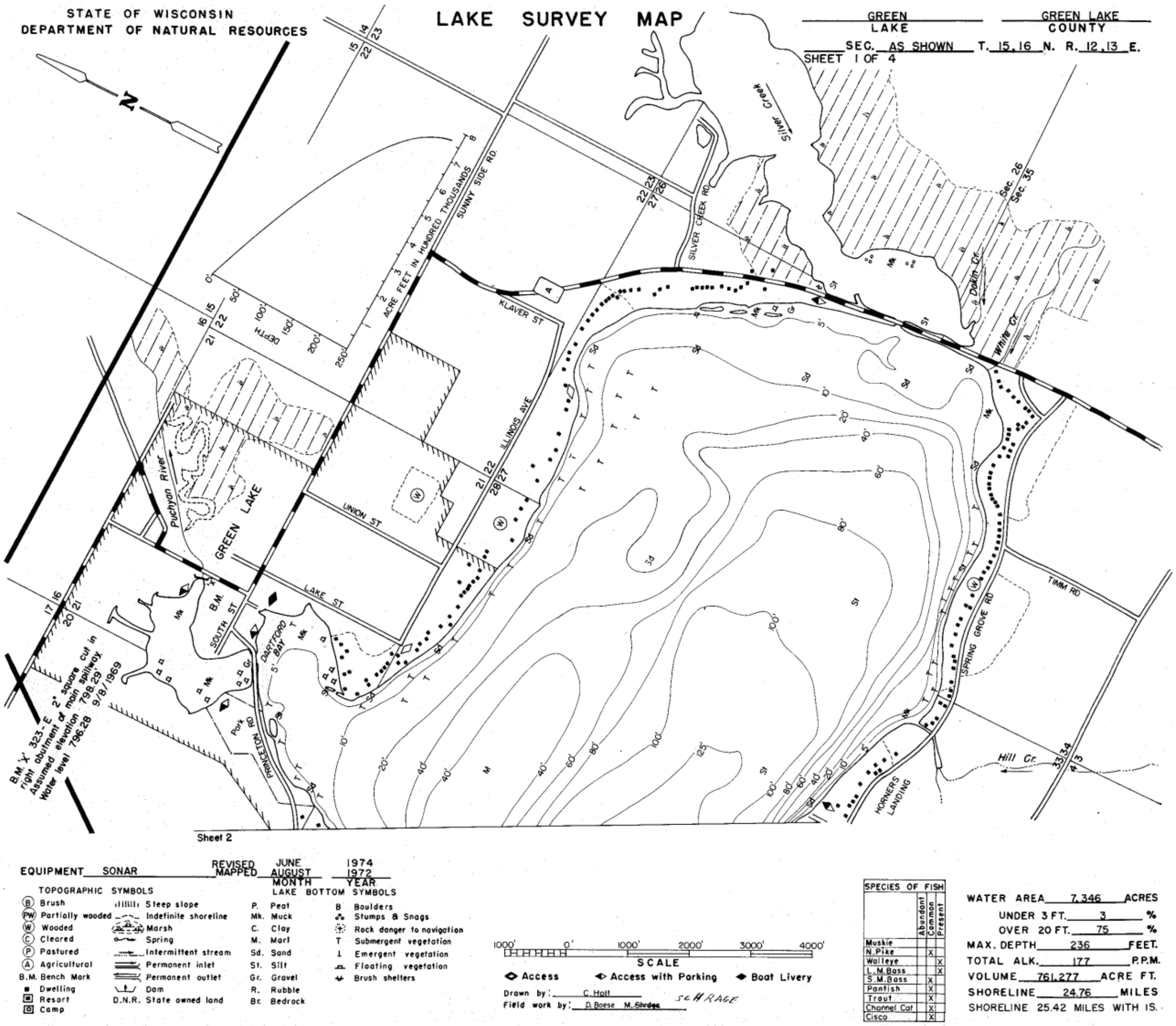

Figure 1 The map above shows the eastern end of Green Lake, including the largest tributary to the lake, Silver Creek inlet and the lake's outlet, which is the beginning of the Puchyan River. The Puchyan enters the Upper Fox River, which then flows through Lake Butte des Mort, Winnebago, and ultimately to the waters of Green Bay. There are 2 shallow water areas that currently support diverse habitat and water quality filtration, Silver Creek Inlet and Green Lake Millpond.

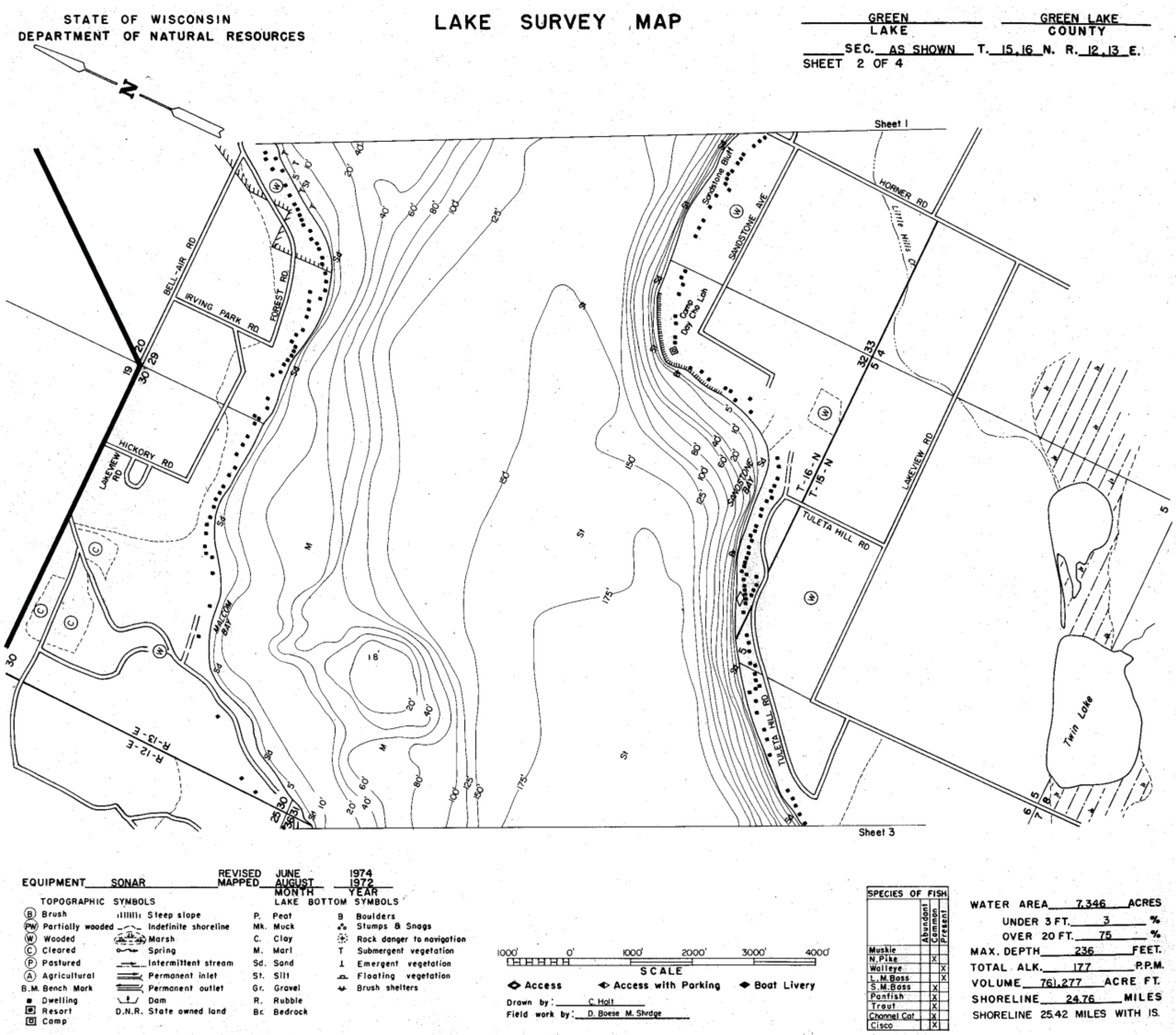

Figure 2 Green Lake shores are diverse, not only in levels of residential development, but also in geological features like sandstone bluffs, indicated here on the south shore of the lake in the area of Sandstone Bay.

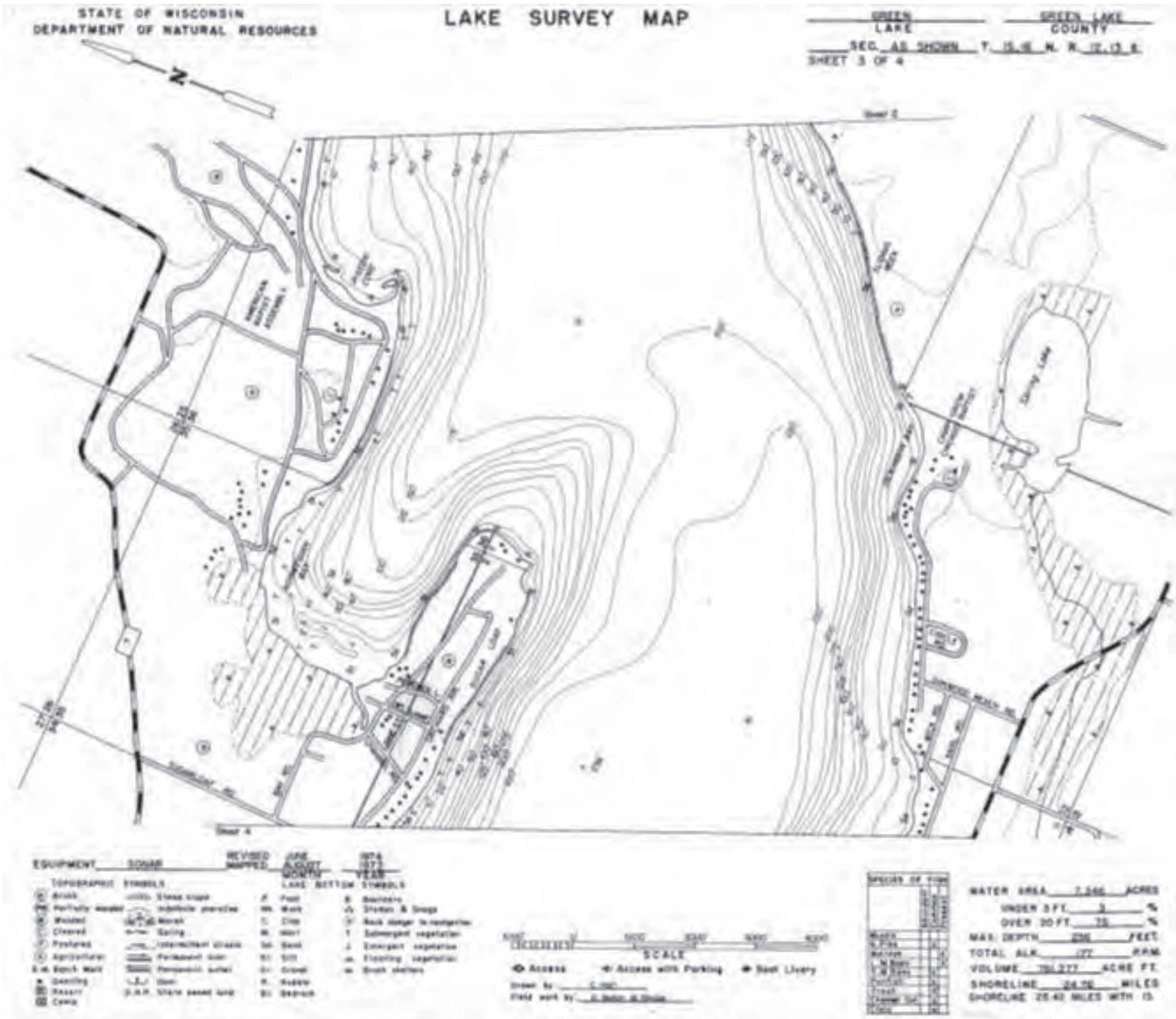

Figure 3 The deepest point in the lake is shown above, located just south of Sugarloaf peninsula. At 236 feet, it is officially the state of Wisconsin's deepest natural lake. Only one lake in Wisconsin is deeper, Wazoo Lake, an abandoned man-made quarry lake. Also shown is Norwegian Bay, a popular recreational area for boating, wading, angling, and wildlife watching. This bay also supports remnant bulrush stands important for fish and wildlife support.

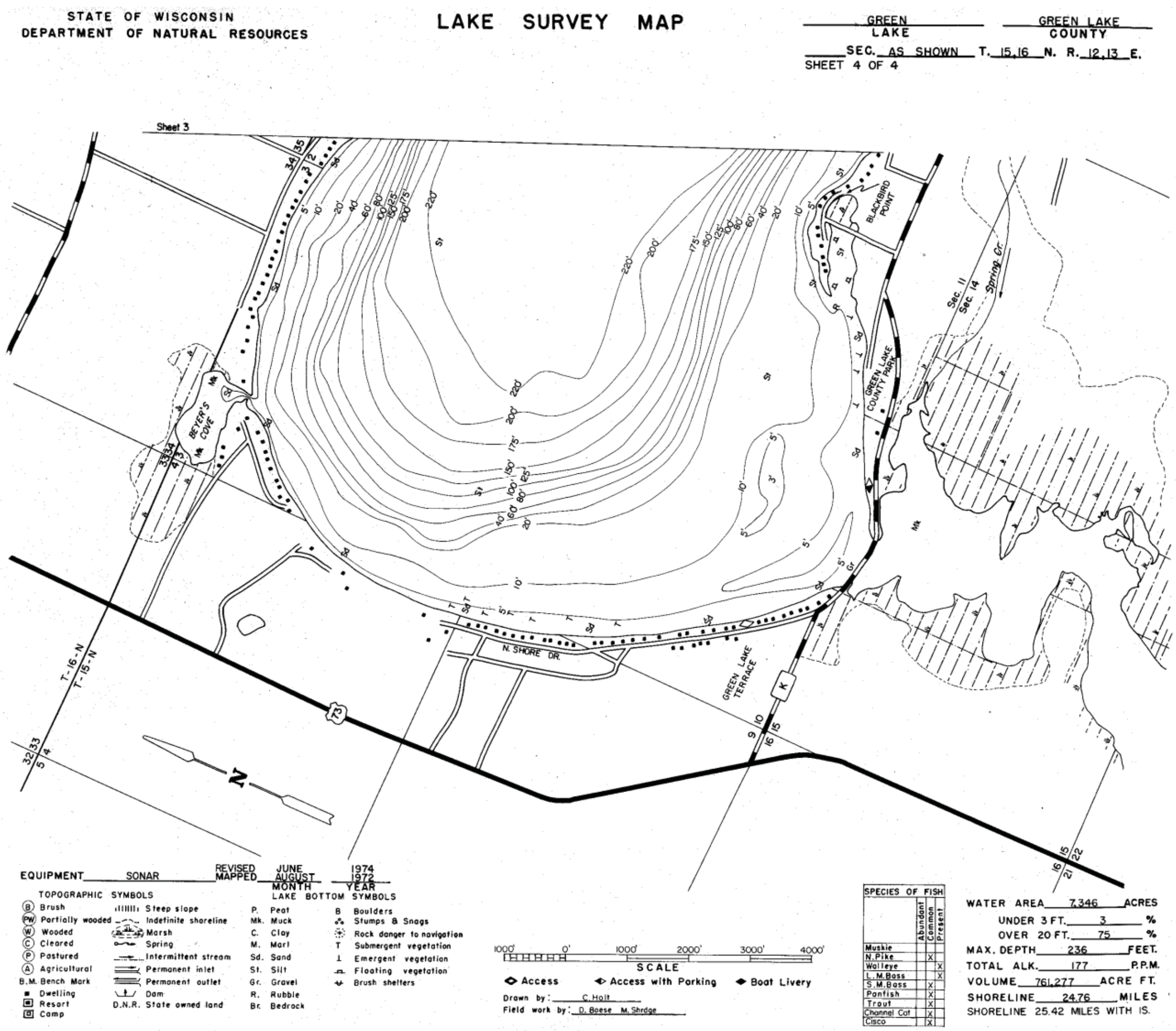

Figure 4 The west end of the lake includes two backwater areas with potential to support critical habitat and water quality functions, County Park Marsh and Beyer's Cove. These shallow water areas have problems with carp, habitat loss, and water quality functions, County Park Marsh and Beyer's Cove. These shallow water areas have problems with carp, habitat loss, and water quality filtering. This is the area where huge glacial deposits essentially acted like a dam, backing up water in the original deep glacial valley.

Stakeholders and Public Participation

From the beginning of the planning process the free participation and integration of all stakeholders was a priority. These are some of the avenues opened for public participation:

- Multiple forums
- Newsletter announcements
- Interagency participation in core planning team
- Consultation with leadership interests from user groups and associations
- Public Opinions and Issues survey

- Green Lake Public Advisory Group (PAG)

Several public forums were completed. The content of these forums informed and interviewed stakeholders. Issues on Green Lake and within the watershed were identified and prioritized via consultation with all stakeholders. Data from prior studies, agency files, community experience, lake scientists, individual interviews, and the representatives from GLA, GLSD, GLLWCD, and WDNR were all used in developing this document.

A public mailing survey was conducted and compiled through the UW-Steven's Point Center for Watershed Science and Education. The survey was designed for three purposes: 1. To better understand people's perceptions about lake issues; 2. To illuminate future educational opportunities; 3. To better understand people's values and visions for the lake. Strategies were not part of the survey, although survey results were used to develop strategies in the plan. The credibility of the results is supported by statistical analysis of the data. The survey approach compliments other avenues for individual and community sentiment to ensure credible strategies for the lake. Many of the strategies in the plan reflect the citizen survey sentiments. The complete survey is included as Appendix A.

The PAG is represented by a diverse group of lake users including farmers, anglers, lake property owners, recreational users, and business owners. PAG membership contact information is in Appendix A.

Public informational meetings were held to establish citizen awareness of the plan, its implications, and receive public feedback. Significant public feedback will be considered for plan amendments via the core team's consensus. We consider this plan to be an evolving document subject to amendments as new issues emerge and we develop appropriate strategies in response.

Project Guidance

Green Lake Association — The GLA is a non-profit membership organization created in 1951. It works to promote the conservation of Big Green Lake and its watershed. GLA envisions a community that actively cares for its watershed and a healthy, clean lake for living, playing, working, and building family legacies. 920-294-6480 www.greenlakeassociation.com

Green Lake Conservancy—The GLC is a community based 501(c)3 non-profit land trust that helps to identify environmentally sensitive areas and works with landowners to protect and conserve their land. 920-294-3592 www.greenlakeconservancy.org

Green Lake County Land Conservation Department — The "LCD" is a conservation management unit critical in the management of water and lands in Green Lake County, specializing in agricultural stewardship and shore land restoration. 920-294-4051 www.co.green-lake.wi.us

Green Lake Sanitary District — The GLSD was formed as a means to protect Big Green Lake and its associated resources with respect to sanitation and related land, air and water quality matters. The GLSD has administrative responsibility for leading lake management at Green Lake. 920.295.4488 www.GLAKESD.com

City of Green Lake — The City of Green Lake is a working partner and has implemented many control measures. The city continues to investigate future best management practices. 920-294-6912 http://www.cityofgreenlake.com/citygl

City of Ripon — The city is a strong partner in Green Lake management and has employed several management approaches for preserving Greens water quality. 920-748-4916 www.cityofripon.com

Fond du Lac County Land and Water Conservation Department — FCLWCD helps provide agricultural and natural resource management within the upper reaches of the Green Lake watershed, roughly 1/3 of the land area draining to the lake. 920-929-3033, ext 3 www.fdlco.wi.gov

WI Department of Natural Resources — The WDNR has a mandate to protect the waters of Wisconsin and works with the Wisconsin Lakes Partnership to accomplish thi**s.** 920-787-3048 www.dnr.wi.gov

Plan Development Process

Step 1. Appraisal

Data collection. Identify what is known about the lake, what problems are perceived and what people desire. Complete a comprehensive assessment that characterizes the resource and determines the lake's ecological potential and sets general management strategy. This will lay the groundwork for future activities.

Step 2. Appraisal Approval

DNR approves the appraisal where partners agree and set a "charter" for general lake management directions. This assures a foundation for future management and avoids unnecessary planning. Department/partners determine level of assistance and commitment of resources i.e. "charter"
Check that data fulfills all basic lake data needs.

Step. 3. Management Plan

This step creates a management plan with specific management objectives.
And may proceed on single issue i.e. APM, water quality, lake use, habitat or be comprehensive.
Green Lakes planning will be comprehensive.

Step 4. Plan Approval

The local community or sponsor with DNR approves improvement or enhancement recommendations.
Public hearings, EA and permits (local, state and fed) must be approved if required.

Step 5. Plan Implementation

Development of projects/recommendations approved for implementation (Source: WDNR)

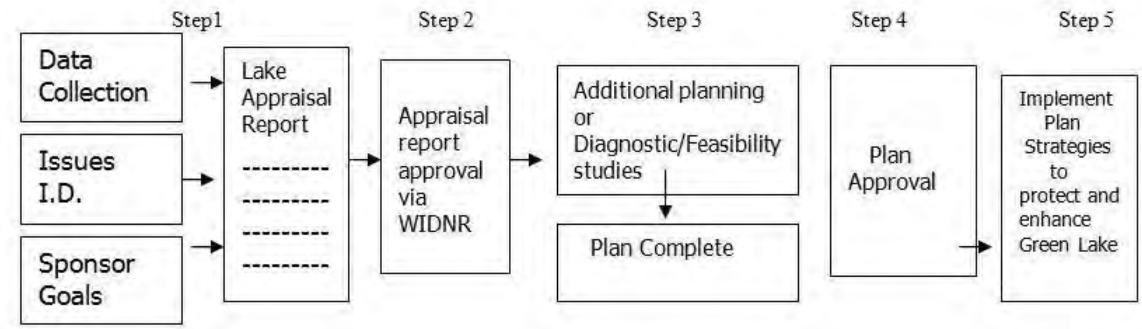

Figure 5 Plan development process

A good deal of appraisal data for Green Lake already exists and additional work is ongoing. Water quality, watershed, fishery, aquatic invasive species (AIS) and land preservation conditions are well represented within existing informational materials. This allows for accelerated plan development. In those areas where further appraisal may be needed, the plan directs appropriate action.

Natural Resource Appraisals, Objectives and Strategy

Water Quality of the Lake

Prior to European settlement, Green Lake was an oligotrophic lake. However, as a result of nutrient loading from its watershed the lake's water quality has degraded. Over the past five years, the lake would generally be classified as a mesotrophic lake, with an average-summer near-surface phosphorus concentration of 21 ug/L. This general condition assessment indicates and warrants further evaluations that may support a 303d listing under the Clean Water Act. If listed, the State of Wisconsin would formally recognize Green Lake as an "impaired" two story fishery lake, with an average summer near-surface phosphorus concentration exceeding 15 ug/L.

USGS reports - The United States geological Survey (USGS) has been active at Green Lake for many years. Data collected over the last decade has included lake water quality, inflows from Silver Creek and White Creek, outflows at the Puchyan River, as well as estimates of watershed sediment delivery. This data is available from USGS at: http://wdr.water.usgs.gov/adrgmap/index.html.

Long term Trend Monitoring – The WDNR initiated water quality monitoring in 1987. Parameters include the following: temperature, Secchi clarity, and concentrations of dissolved oxygen, total phosphorous, nitrogen, and chlorophyll-a. The parameters were also completed at lower frequency.

Table 1. LTT Lake Water Quality Monitoring Protocol

Parameter		Protocol details
Secchi	Method Equipment Frequency QA/QC	• Standard, to nearest 0.1 m or ¼ ft • 8 inch B&W disk • Spring turnover + 3X during summer index period (15 July – 15 Sept) • Paired observers when possible
Total P	Method Equipment Frequency QA/QC	• Field fixed, persulfate digestion • 2m integrated sampler • Spring turnover + 3X during summer index period (15 July – 15 Sept) • Field reps on 10% of lakes; Field blanks on 10% of samples or once per week
Chl a	Method Equipment Frequency QA/QC	• Field filtered, fluorometric • 2m integrated sampler • 3X during summer index period (15 July – 15 Sept) • Field reps on 10% of lakes
DO and Temp profile	Method Equipment Frequency QA/QC	• Profile at 1 m intervals • DO meter or multi-parameter sonde • 3X during summer index period (15 July – 15 Sept) • Calibration record
Conductance & pH profile (field) - optional	Method Equipment Frequency QA/QC	• Profile at 1 m intervals • Multi-parameter sonde • 3X during summer index period (15 July – 15 Sept) • Calibration record
Conductivity, pH, and alkalinity (lab)	Method Equipment Frequency QA/QC	• Field collected, standard lab methods • 2m integrated sampler • 1X during summer index period (15 July – 15 Sept) • Field reps on 10% of lakes; Field blanks on 10% of samples or once per week
Color	Method Equipment Frequency QA/QC	• Field collected • 2m integrated sampler • 1X during summer index period (15 July – 15 Sept) • Field reps on 10% of lakes; Field blanks on 10% of samples or once per week
Nitrogen series (NO2-NO3, TKN)	Method Equipment Frequency QA/QC	• Field fixed (sulfuric) • 2m integrated sampler • 1X during summer index period (15 July – 15 Sept) on selected lakes • Field reps on 10% of lakes; Field blanks on 10% of samples or once per week
Ca, Mg	Method Equipment Frequency QA/QC	• Field fixed (nitric) • 2m integrated sampler • One time per lake • Field reps on 10% of lakes; Field blanks on 10% of samples or once per week

Figure 6 Recommended Lake Water Quality Monitoring Protocol*

* Note: actual protocol might diverge from above depending on mutual agreement with USGS and GLSD

There are 3 basic productivity levels, called trophic states recognized in the classification of lakes.

- Oligotrophic (*low* nourishment and productivity) — Oligotrophic lakes tend to be very clear with low phosphorous levels and low production of biological material.

- Mesotrophic (*moderate* nourishment and productivity) — Mesotrophic lakes are more fertile with higher phosphorous levels, and moderately clear water. Biological productivity is elevated including fish production.

- Eutrophic (*high* nourishment and productivity) — Eutrophic lakes are very fertile, supporting high production of algae and or aquatic plants. The lake condition reflects abundant quantities of fish, frequent algae blooms, and user conflicts with boating and swimming.

Green Lake is classified as mesotrophic, meaning moderate productivity when compared with other lakes in Wisconsin. Prior to settlement, Green Lake was oligotrophic (Paul Garrison, WDNR, Personal Communication). TSI or trophic state indices are used to establish this productivity level or trophic state. At Green Lake (as in most WI lakes), there is a strong relationship between algal concentration, phosphorous, and water clarity. This exists because the primary nutrient, phosphorous, regulates algae growth. More phosphorous means more algae, which in turn means less water clarity. This relationship is common in Wisconsin lakes but can vary due to other environmental factors. At Green the relationship between the concentration of phosphorous and algae is affected by zooplankton grazing. Algal grazing by zooplankton is quite intense, and the level of algae as a function of the phosphorous concentration is less than expected. Overall, the result is better clarity. In many other WI lakes, the level of algae would be higher, and as a result more turbid. This relationship is seen more clearly upon examination of the trophic state indices graphs. This relationship is relevant to setting water quality objectives for the lake i.e. target levels to achieve.

All natural lakes in Wisconsin were created during the post-glacial period 12-15,000 years ago. After initial creation, the lakes began to accumulate sediments and nutrients via natural physical and biological process. This process of nourishment (called eutrophication) is variable and depends on many factors including watershed soil types and size, riparian wetlands, lake volume, human influence, and tributary inputs from rivers and streams. Lakes in the northern regions of Wisconsin tend to be less nourished (oligotrophic to mesotrophic) while southern lakes trend towards high productivity and the issues associated with greater fertility.

To date, we have been gifted much while we ride a learning curve in our stewardship of the lake. Averaging over 100 feet, and with a maximum depth of 236 feet, Green Lake has an enormous capacity for absorbing pollutants while maintaining a relatively stable condition for water quality. The volume of Green is large, nearly 750,000 acre feet. If Green Lake had less volume, its capacity to absorb sediment and nutrients, without visible degradation, would be greatly diminished. We have been fortunate to have a lake capable of keeping a stable trophic state. That's good news, but the lake has a threshold in its capacity to absorb nutrients. Once crossed, the lake will slide toward an alternate stable state that will reduce the ecosystem services discussed above. At this point it will be extremely difficult to reverse the processes. Thus, an aggressive protection strategy is needed.

With great certainty, Green Lake has been degraded. We know this through coring of lake sediments and inference through review of long-range aquatic plant conditions.

Green Lake Water Clarity (feet)
Citizen Lakes Monitoring Network 1986-2010- West Basin

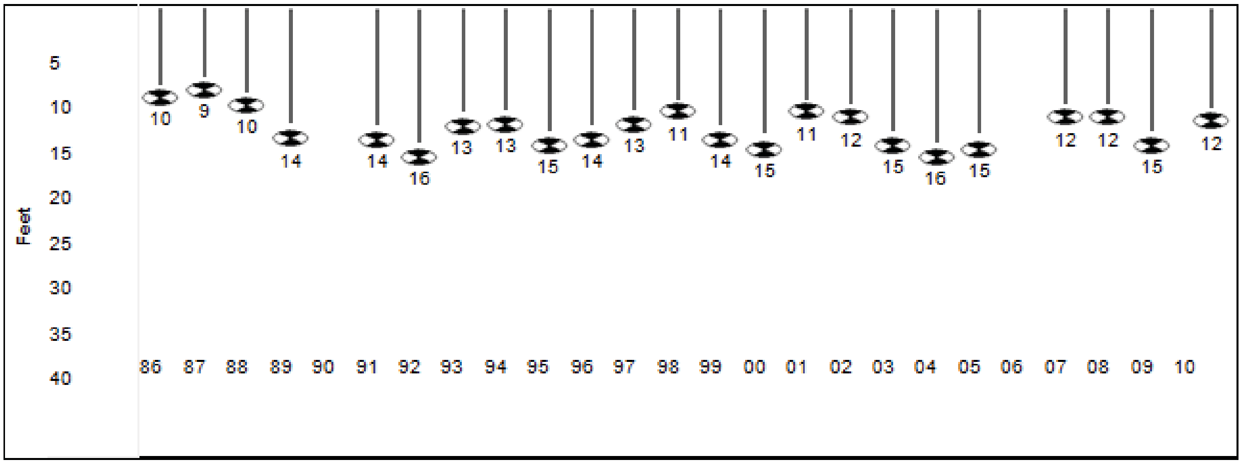

Figure 7 The above graph shows the annual average summer water clarity of Green Lake as measured by Secchi disc, over the past 25 years. The water clarity of the lake, despite the apparent annual variability, appears to be predictable, in the 10 to 16 foot range for average summer clarity (SWIMS data, WDNR). The average value does not indicate the maximum or minimum readings which could exceed 16 feet or be less than 10 feet on a particular day.

Sediment deposited over several hundred years (Garrison P. WDNR) is a direct result of past conditions within the lakes watershed. Green Lake's watershed is 100+ square miles and events over the long haul have "had their say". Agricultural runoff, urban development, post-World War 2 technology, and deforestation events all resulted in the evolution of the lake from oligotrophic to mesotrophic, all of which is recoded in the lake's sediments (Appendix 9). The information obtained through the core analysis is a history of the lakes evolution. Long-term changes in the aquatic plant community also point to anthropogenic eutrophication of the lake. This can be seen in the reduction of light penetration in the littoral zone of the lake. This has been indicated through comparison of aquatic plant survey data gathered since 1921 (Rickett et al). Measured depths for plant colonization in 1921, 1977, 1990-92, and 2007 have decreased, indicating water clarity reductions over the last century (Bumby, M.J. and WDNR).

A State of Wisconsin biologist in 1952 recorded Secchi depths of 40 feet. In 1977 a consulting firm measured the maximum secchi depth of 25 feet In a review of more recent records a mid-June Secchi depth of 48 feet was reported by the Green Lake Sanitary District in 1999 (Marks, C.). The variability of water clarity from one year to another can be wide ranging so long term averages and trends are considered more conclusive than any one point in time.

One method to measure long-range condition involves paleolimnological coring of lake sediments. Paleolimnological coring results have shown negative changes in Greens water quality. Sediment cores obtained in year 2000 were analyzed for chemical properties, rates of deposition, and relic diatom species. The outcome of this analysis is presented here:

http://www.greenlakeassociation.com/gla/Assets/Watershed/Green%20Lake%20SIS.pdf

A summary of the findings follows.

- In the deeper western basin, the Fe: Mn ratio has declined since 1950 (Garrison, P., Figure 6). This corresponds with increase in phosphorus deposition. This implies that the increased phosphorus has resulted in increased productivity in the lake and the increased decaying organic matter is depleting oxygen at a faster rate than happened prior to 1950. This does not mean that the bottom waters of the western basin are completely devoid of oxygen, just that the level of oxygen is lower at the present time compared to pre-1950

- Throughout the lake basin, the highest levels of phosphorus occurred during the last 20 years. However, current levels are considerably higher than they were historically (Garrison, P.)

- The diatom community indicates that the lake's water quality during the 1800's was very good. Phosphorus levels were somewhat lower in the western basin compared with the eastern basin. Phosphorus levels remained low until about 1930 when they began to slightly increase in the western basin until the levels were similar throughout the entire lake basin (Garrison ,P.)

- Historically, phosphorus levels were highest in the eastern portion of the lake. This was because most of the tributaries enter the lake there (i.e., the most flow from tributaries)
- Soil erosion in the watershed increased significantly beginning around 1930. This was the result of increased mechanization of agriculture.
- Following World War II, the use of commercial fertilizers increased resulting in increased delivery of phosphorus to the lake. This increased phosphorus happened despite a reduction in soil erosion in the watershed. The lake soon responded to increased phosphorus loading by experiencing an increase in algal levels. This was most apparent in the eastern part of the lake.
- The highest phosphorus levels during the last 150 years occurred within the last 20 years (Note: the project concluded in the year 2001, so the previous decade, 2000 - 2012 was not analyzed.)

The coring data supports a strategy of reducing pollutants before it is too late. That is, before the lake shifts from its current state to an alternate stage that is unacceptable to lake stakeholders. This is clearly evidenced by the sediment cores, which indicate that the oxygen levels in the west basin have been declining for many years, "Hypolimnetic DO will potentially go lower or become absent as streams are delivering high amounts of N and P to the system....... these consequences will likely be impossible to reverse even if the source of P is completely shut off" (Johnson, T., WDNR).

Secchi depths have been monitored for many years by various agencies, volunteers and associations, with the most of the data having been collected under the volunteer program, Citizens Lakes Monitoring (Bumby, M.J. et al). The east and west sides of the lake have been monitored since the 1980's under this program. This water clarity data shows the east basin has greater turbidity than the west basin of the lake. This difference is due to a number of factors. The east basin is shallow compared to the west and receives major tributary flow (Silver Creek) from a 58 sq. mile drainage area. As a result, elevated levels of phosphorous (when compared to the west basin) and sediment are seen. Additionally, prevailing west winds can resuspend lake sediments in the shallow depths. Lake sediment core analysis also indicates higher phosphorous levels have historically occurred in the east end of the lake.

Water clarity is driven by both dissolved and suspended material in the water column. Phytoplankton and zooplankton, along with suspended inert (non-volatile) solids disperse the light penetrating through the lakes surface. Elevated levels of suspended material increase light dispersion resulting in reduced clarity. Aquatic plants will only grow at depths where sufficient light is available. If water clarity decreases, plants will grow in shallow water only. In contrast, as water clarity improves, plants are capable of growing in deeper water and their overall abundance increases. Because aquatic plants influence fish, algae, wildlife, water quality, and stability in lakes, clarity is a critical factor in lake management.

Another indirect measure of water clarity is the maximum depth at which aquatic plants can root. As can be seen in the section on aquatic plant survey results, early studies recorded plants growing deeper than at present. This, in essence, is because the water was more clear back then.

Phosphorus is a fertilizer for algae, thus the amount of phosphorus is a critical driver in controlling lake fertility. Simply put, the more phosphorus entering the lake, the more plant growth, both vascular plants and algae. This plant growth usually leads to problems. Many of the strategies in this plan are for controlling phosphorus. It is not the only problem factor at Green Lake, however, it is the most important for protecting the lake as we know it.

A confounding issue is that the phosphorus in the sediments will continue to be released into the water column for decades to come.

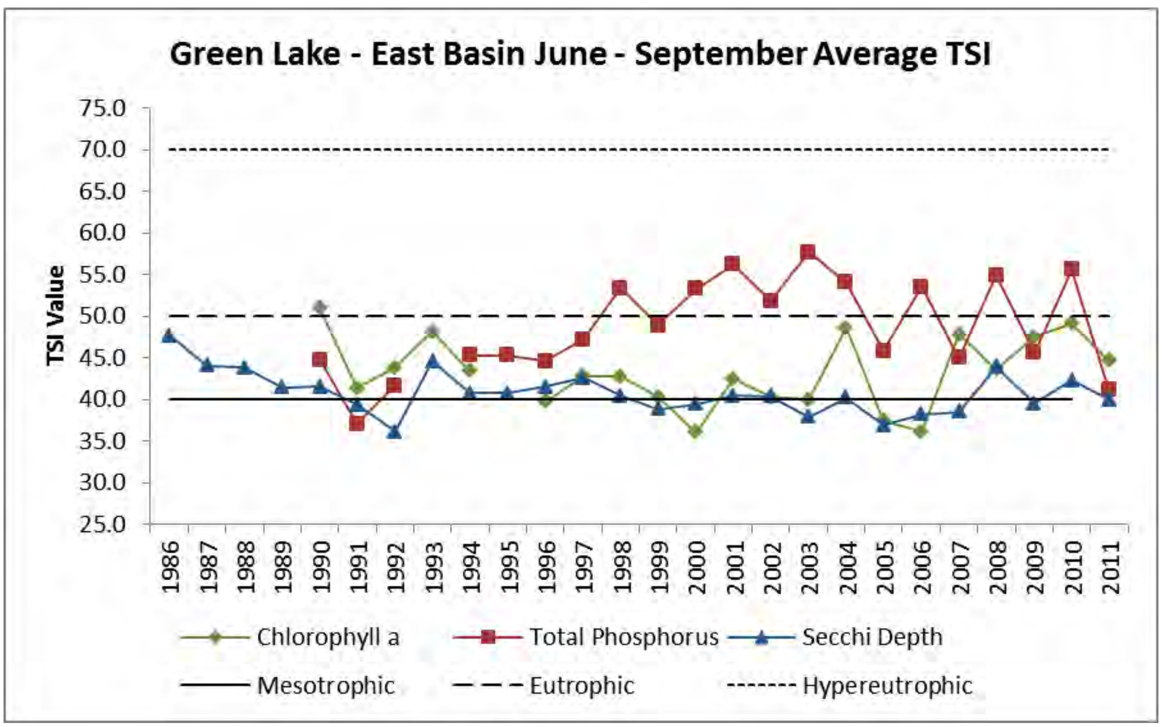

Figure 8 TSI (trophic state index) is a numerical value reflecting the nourishment level of a lake. The index values are on a 0 - 100 scale and reflect the levels of algae, phosphorous, and clarity in a lake. At Green Lake the TSI is generally in the 40 – 50 range, and considered mesotrophic, or mid-level of nourishment.

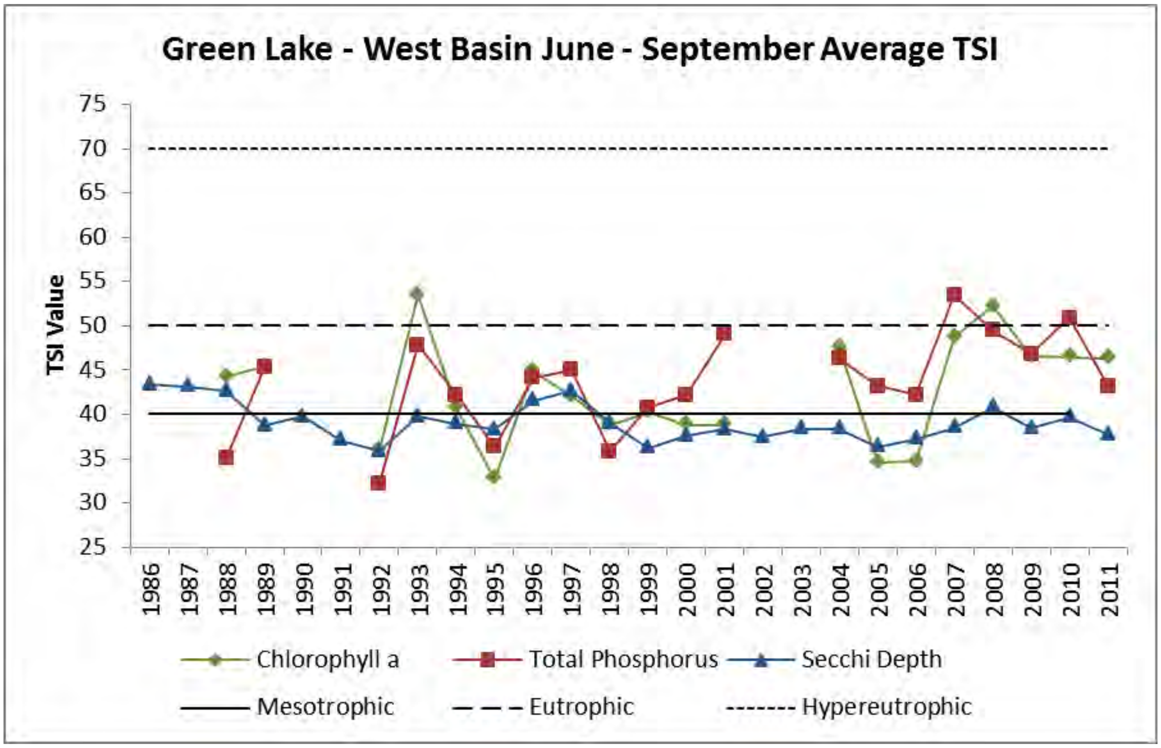

Figure 9 TSI (trophic state index) is a numerical value reflecting the nourishment level of a lake. The index values are on a 0 - 100 scale and reflect the levels of algae, phosphorous, and clarity in a lake. At Green Lake the TSI is generally in the 40 – 50 range, and considered mesotrophic, or mid-level of nourishment.

WisCALM (Wisconsin Consolidated Assessment and Listing Methodology)

WisCALM (Wisconsin Consolidated Assessment and Listing Methodology) is an assessment protocol for gauging the quality of a lake. Based on known relationships between historical lake quality and present day water quality, it is possible to assess lakes (and streams) as having poor, fair, good, or excellent water quality. This assessment is based on the Trophic State Index (TSI) of the lake. Furthermore, as required by the Clean Water Act, WisCALM enables biologists to determine if a lake is truly impaired due to cultural influence. This involves completion of a more specific assessment using multi-parameter numerical criteria and is illustrated in Figure 10, cited from WisCALM guidance.

All assessments are based on the natural community classification of a particular lake. Green Lake is classified as a *deep lowland drainage lake supporting a two-story fishery* (cold and warmwater fish species). The general condition criteria for two-story lakes is defined in WisCALM and indicated in Figure 10, taken from the guidance. Because of the two-story fishery, the threshold criteria are more conservative than for any other natural community classification.

Table 2. Trophic Status Index (TSI) Thresholds – General Assessment of Lake Natural Communities

Condition Level	Shallow			Deep			
	Headwater	Lowland	Seepage	Headwater	Lowland	Seepage	Two-Story
Excellent	< 53	< 53	< 45	< 48	< 47	< 43	< 43
Good	53 – 61	53 – 61	45 – 57	48 – 55	47 – 54	43 – 52	43 – 47
Fair	62 – 70	62 – 70	58 – 70	56 – 62	55 – 62	53 – 62	48 – 52
Poor	≥ 71	≥ 71	≥ 71	≥ 63	≥ 63	≥ 63	≥ 53

Figure 10 Trophic status index (TSI) thresholds for general assessment of lake natural communities

Chlorophyll a is the preferred trophic state parameter to be used. The TSI based on Chl a must be averaged over the last five years (2007-2011) per guidance. It can be seen the TSI values at Green Lake are borderline "fair to good" based on the above table, with the five year average for the east end (or basin) at 46.6 and the west end at 48. As a result it appears the lake's general condition level would be considered "fair' to "good" (based on the last five years of data). Because the general condition assessment is borderline, further specific assessments for examination of phosphorus, Chl a concentrations and other threshold criteria included in Table 4A (Figure 13) are warranted.

Although Chl a TSI is the preferred parameter specified in WisCALM guidance, it is also possible to use Secchi clarity TSI. When the Secchi TSI is looked at, the criteria in Table 2 (Figure 10) above clearly indicates an "excellent" condition for Green Lake , with the five year average for the east end (or basin) at 41 and the west end at 39 with both Secchi TSI values below the 43 threshold for two-story lakes. Because WisCALM guidance uses Chl a as the preferred parameter, we would continue to recommend further specific assessments. It is noteworthy however to point out the discrepancy. It has been suggested this difference may be due to zooplankton dynamics and heavy grazing of algae by cladocerans like *Daphnia* (Panuska 1999).

Green Lake TSI Values
Chlorophyll A, Phosphorus, and Secchi Depth – 1986-2011

	East Basin TSI				West Basin TSI		
	Chlorophyll A	**Total Phosphorus**	**Secchi Depth**		**Chlorophyll A**	**Total Phosphorus**	
1986			47.7				43.3
1987			44.1				43.1
1988			43.8		44.2	35.0	42.6
1989			41.4		45.4	45.3	38.8
1990	51.0	44.8	41.5				39.7
1991	41.4	37.1	39.4				37.1
1992	43.8	41.7	36.2		36.0	32.2	35.8
1993	48.2		44.6		53.5	47.8	39.7
1994	43.5	45.3	40.8		40.7	42.2	39.0
1995		45.3	40.7		32.7	36.4	38.3
1996	39.7	44.6	41.5		44.9	44.1	41.5
1997	42.9	47.2	42.6		42.1	45.0	42.6
1998	42.8	53.4	40.4		38.8	35.8	39.0

1999	40.3	48.9	38.9		40.2	40.8	36.2
2000	36.1	53.3	39.5		38.8	42.2	37.6
2001	42.5	56.2	40.5		38.8	49.0	38.3
2002	40.3	51.9	40.4				37.4
2003	40.0	57.7	37.9				38.4
2004	48.6	54.1	40.2		47.6	46.3	38.4
2005	37.4	45.8	36.9		34.5	43.2	36.3
2006	36.2	53.5	38.2		34.7	42.2	37.2
2007	47.9	45.0	38.6		48.7	53.5	38.5
2008	43.6	54.9	43.9		52.2	49.5	40.8
2009	47.6	45.6	39.5		46.5	46.8	38.4
2010	49.2	55.6	42.3		46.5	50.9	39.7
2011	44.7	41.1	40.0		46.3	43.2	37.7

Figure 11 Green Lake TSI values

The excerpt below is from "Working Paper # 2", Max Anderson and Associates for the Green Lake Property Owners Association 1972. The data referenced indicates similar conditions in 1970's when compared to today. This does not suggest an absence of degradation, but does indicate conditions in the early 1970's demonstrated TP levels of potential concern.

> Phosphorus. Green Lake is a phosphorus limited body of water. In other words it is the presence of specific levels of the nutrient phosphorus which determines if there will be nuisance levels of weeds and algae. An average mean total phosphorus level of .03 mg/liter is considered by some to be the level below which there will be no aquatic growth problems, while lakes exhibiting levels of .03 to .05 mg/liter may experience periodic problems. Above .1 mg/liter is considered the level at which a lake can expect frequent algal blooms and excessive weed growth (Lueschow 1970). Measurements by Lueschow, et.al., reveal levels of .051 mg/liter in the upper levels of the lake. Higher concentrations were found in the lower levels due to the natural process of phosphorus settling to the bottom of the lake. Observations by EPA in the summer of 1972 manifest this settling phenomenon with readings of total phosphorus ranging from a low of .011 mg/liter near the surface to .249 mg/liter at the depth of 205 feet. Data collected by DNR, July 1968 to November 1970, indicated average total concentrations of phosphorus of .04 mg/liter at the surface and .10 mg/liter at depths greater than 200 feet. Again measurements vary with respect to time of the year and location. Based on Lueschow's standards the level of phosphorus in Green Lake could be expected to cause periodic plant growth problems.

The phosphorus graph below was developed from recent data (SWIMS). The epilimnetic TP concentrations (mg/L) range from less than 10 ug/L to nearly 50 ug/L. The higher values seen during the last decade (commonly >30 ug/L) could be a trend but this cannot be substantiated without further analysis. In any case, these values appear likely to exceed the Recreational *and* Fish and Aquatic Life impairment threshold of 15ug/L, meaning the lake is more likely to be considered "impaired" and listed as such under Section 303d of the Clean Water Act.

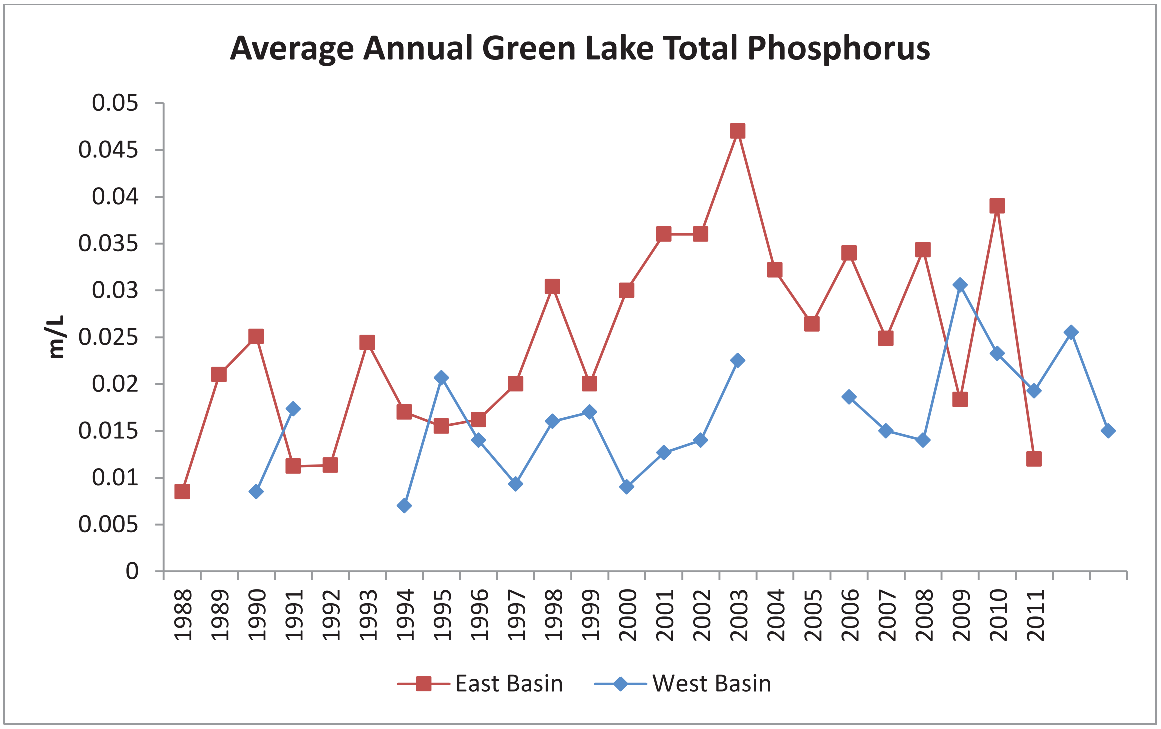

Figure 12 Green Lake total phosphorus (Sabai, A., SWIMS)

Table 4A below is from the WisCALM guidance (May 2012) and indicates the threshold criteria for various parameters including phosphorus (TP). The 15 ug/L threshold for TP appears likely to be exceeded based on the existing data from Green Lake. Other parameters could also exceed threshold criteria. Criteria are also subject to further modification based on administrative review.

Table 4A. Fish & Aquatic Life Impairment Thresholds for Lake Natural Communities

Note: Data are evaluated from within the most recent 10 year period for all parameters. For TP and chl *a*, data from within the most recent 5 year period are used for impairment assessments.

Indicators	Min. Data Requirement (see text for details)	Exceedance Frequency (see text for details)	Impairment Threshold - LAKES - Fish & Aquatic Life Use						
			Shallow			Deep			
			Headwater Drainage Lake	Lowland Drainage Lake	Seepage Lake	Headwater Drainage Lake	Lowland Drainage Lake	Seepage Lake	Two-story fishery lake
Biological Indicators									
chl a	6 values (3 values/2 yrs, or 2 values/3 yrs) from July 15 - Sept. 15	Annual Average exceeds for at least 2 years (or majority of yrs of data)	≥60 ug/L (≥71 TSI)	≥60 ug/L (≥71 TSI)	≥60 ug/L (≥71 TSI)	≥27 ug/L (≥63 TSI)	≥27 ug/L (≥63 TSI)	≥27 ug/L (≥63 TSI)	≥10 ug/L (≥53 TSI)
Maximum Rooting Depth	*Baseline aquatic plant survey*	*NA (1 survey)*	*(reserved until sufficient guidance available)*						
Floating Leaf Plant Community	*Baseline aquatic plant survey*	*NA (1 survey)*	*(reserved until sufficient guidance available)*						
Conventional physico-chemical indicators									
TP	3 monthly values for 2 years (June 1-Sept. 15)	Annual Average exceeds for at least 2 years (or majority of yrs of data)	≥100 ug/L	≥100 ug/L	≥100 ug/L	≥60 ug/L	≥60 ug/L	≥60 ug/L	≥15 ug/L
DO	10 discrete[1] epilimnetic values (ice free period, epilimnetic samples)	10% or more of all values	< 5 mg/L						
Temperature	20 discrete[1] values	Vary (see thresholds)	Daily (mean) and seasonal T° fluctuations (min. & max. daily mean) [2] not maintained; and Maximum T° increase exceeding 3°F above natural temperature[2]						
pH	10 discrete[1] values	Vary (see thresholds)	- Outside the range of 6.0-9.0 - Change >0.5 units outside natural seasonal maximum (mean) & minimum (mean)[2]						
Turbidity	10 discrete[1] values	*(to be determined)*	*(reserved until sufficient data available)*						
TSS	10 discrete[1] values	*(to be determined)*	*(reserved until sufficient data available)*						
Aquatic Toxicity-based indicators									
Acute aquatic toxicity	2 values within a 3-year period	Maximum daily concentration not exceeded more than once every 3 years	≥ values provided in Tables A & B below						
Chronic aquatic toxicity		Maximum 4-day concentration not exceeded more than once every 3 years	≥ values provided in Tables A & B below						

(1) Discrete values refer to samples collected on separate calendar days. DO, temperature and pH criteria are taken from s. NR 102.04, Wis. Adm. Code, Water Quality Standards for Wisconsin Surface Waters.
(2) Based on historical data or reference site.

Figure 13 Table 4A, Fish & Aquatic Life Impairment Thresholds for Lake Natural Communities

Summary

The general condition assessment indicates and warrants further evaluations that may support a 303d listing under the Clean Water Act. If listed the State of WI would formally recognizes the lake as "impaired." Furthermore, the TP threshold of 15ug/L will be exceeded, considering the existing numerical value (subject to modification). It is recommended the WDNR complete refinements to the WisCALM guidance and complete specific assessments for parameters as indicated in Table 4A above.

Objectives for Lake Water Quality

1. Adopt a 10-year P reduction goal of 15% or 1.5% per year. This reduction would necessitate a 10% total P load decrease in the same time period.
2. Adopt an intermediate-range 20-year P reduction goal. "Reduce the average summer near-surface total phosphorus concentration by 3 ug/L over the next 20 years. This reduction would require that the total phosphorus loading to the lake would need to be reduced by about 30 %; however, the specific reduction in phosphorus loading may be modified based on future refined lake response models.

3. Adopt a long-range 50-year P reduction goal. Reduce the phosphorus concentration in Green Lake, such that the lake would be removed from the 303d list (P concentration less than 15 ug/L) and returned to being classified as an oligotrophic lake (P concentration less than 12 ug/L).
4. Maintain water quality functions of all riparian wetlands/marshes/inlets. Navigation, aesthetic perceptions, and nuisance aquatic plant management also will be supported by the lakes partnership. However, the protection of the lake water quality, through the maintenance of wetland/marshes/inlet areas will take priority in situations where conflicts occur.

Strategy for Lake Water Quality

1. Re-evaluate changes that have occurred in the water quality of the lake including historical data collected by the University of Wisconsin over the past 100 years. This analysis would include evaluating the quality of the data currently included in the WDNR database.
2. Given that extensive lake water quality data and tributary data have been collected by the U.S. Geological Survey, and lake watershed modeling has been conducted by the University of Green Bay since previous lake response modeling that was conducted by the WDNR almost 15 years ago, use these data to refine the phosphorus loading to the lake and refine the lake response models. This information will enable the specific load reductions needed for Green Lake to reach its water quality goals.
3. Identify priority sites (worst sources of sediment and nutrients) using SWAT (or other appropriate model) - Plan to complete watershed modeling with SWAT the “Soil and Water Assessment Tool” (and/or other models) if possible in 2014. Watershed BMP’s will continue to be addressed utilizing 2001 SWAT pending the 2014 effort.
    a. Maintain or restore riparian wetlands/marsh/inlet areas.
    b. Pursue the restoration of County Park (CTH K) Marsh utilizing carp control methods including rotenone, barriers, bio-manipulation, or other acceptable tools. Maintain County Park Marsh for primary and secondary uses.
    c. Maintain Silver Creek Marsh for natural functions while maintaining navigation and reasonable recreational uses.
4. Appraise conditions in Beyer’s Cove, evaluate alternative actions.
5. Conduct a preliminary feasibility analysis on artificial water level fluctuation (WLF) in the County Park Marsh area. This could involve analysis of pumping systems, flow volumes, water control structures and permitting constraints. This action would target the County Park Marsh only and not to be directed at lake wide WLF.
6. Promote watershed management actions improving resilience of the lake ecosystem as it relates to the frequency and magnitude of flood or drought events. Resilience of the ecosystem will come from wetland preservation, restoration and possible construction of new wetlands, as well as enhancement of BMPs in rural and urban areas. These enhancements could include BMP (retention basins, artificial wetlands, storm water systems, rain gardens, buffers) construction, reconstruction, or modifications to accommodate more flooding events.
7. Project Implementation Review and State of the Lake Reporting – An annual meeting will be held (with all partners in attendance) to assess the status of the lake and in the implemention

of all strategic initiatives. As appropriate changes to the plans will be discussed and a one-page summation will be written describing the year's relevant events and decisions.

8. Continue to monitor the lakes water quality through USGS, Volunteer forces, CLMN, GLA, GLSD, WDNR, and LWCD. The lead agency for lake water quality monitoring is GLSD, partnering with USGS. Protocol is indicated in Figure 2. Volunteer monitoring as completed through the CLMN program is recommended. Special project monitoring is also possible and should be coordinated with GLSD, the principle management unit for lake protection. Example; Determine trends in hypolimnetic oxygen levels within the west basin.
9. Integrate with CLMN network to enhance volunteer participation at Green Lake and its tributaries. The GLA, County LCD, and GLSD should agree on a coordinator role and what priorities will be. Unilateral implementation should be discouraged.
10. Estimate load reductions from riparian properties due to "zero P" implementation and use results in I&E programs and Phosphorus loading management. This would be an estimate and made under presumptions of compliance with zero P fertilizer law. Another option would be to complete the exercise as a sub-task under a lake or watershed modeling effort.
11. Require riparian buffers of 35 feet to reduce P-loading and sediment loading via runoff and bank erosion.

Water Quality of Tributary Streams

There are eight tributary streams to Green Lake.

Silver Creek: Silver is the largest tributary, draining a watershed area of 58 square miles including the City of Ripon and portions of Fond du Lac Co. Water quality and quantity of the creek has been monitored by USGS over several years. Data is available through the USGS site: http://wdr.water.usgs.gov/adrgmap/index.html

White Creek: another USGS monitored stream was once known to have Wisconsin's highest sediment loadings (prior to 1998) when measured on a per acre basis (unit area load of suspended solids was 338 tons/sq. mile). The good news is the White Creek watershed is relatively small (3.1 sq. mi) and although the local impacts were significant, its watershed size helped to constrain impacts to the lake. The median loads for the Eco region was 130 tons/sq. mile (USGS, Gartner et al). In response to the findings of USGS, the Green Lake County staff, and GLSD partnered to employ best management practices in the watershed to abate the high sediment loads. Presently, the condition of the White Creek watershed area is excellent (USGS).

Tributary creeks: Dakin, Hill, Wurches, Spring, Roy and Assembly make up the remaining streams entering Green Lake. Variable levels of sediment and nutrients continue to enter Green Lake from these sources. Much of the source is related to agriculture and stream bank erosion in the watershed areas. WDNR has listed several of these streams as degraded under the 303d impaired waters program meaning they are declared as impaired based on nutrients, sediments, and habitat problems. Presently, in-stream habitat, stream banks and pollutant loads entering the lake are of concern and requiring abatement. The following graph (Figure 5) shows the phosphorus concentrations during base flow conditions.

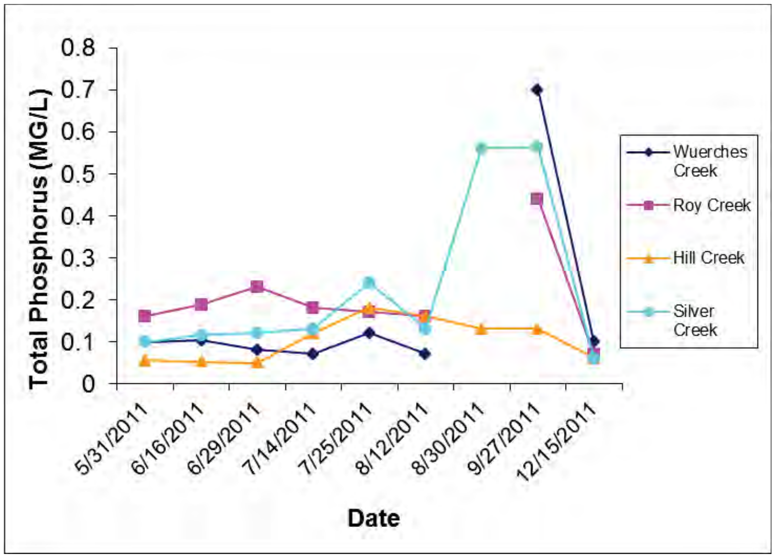

Figure 14 Total P concentrations of streams entering Green Lake. Most of the sampling was conducted under base flow conditions. The high concentrations from the 9/27 event reflect runoff from rains.

County K Marsh data - Two sampling dates

8/2/07 - Mid- TP = 0.57 mg/l; TSS = 122 mg/l; Chl A = 91 Ug/l; no reported secchi
8/2/07 - North- TP = 0.40 mg/l; TSS = 61 mg/l; Chl A = 68.6 Ug/l; no reported secchi
6/18/08 - Mid- TP = 0.24 mg/l; TSS =21 mg/l; Chl A = 5.7 Ug/l; 0.2m secchi
6/18/08 - North TP = 0.23 mg / l; TSS = 31 mg/l; Chl a = 10.3; 0.2m secchi
6/18/08 - South TP = 0.24 mg/l; TSS = 22 mg/l; Chl a = 5.2 Ug/ l; 0.3m secchi

Figure 15 This data above reflects the highly degraded condition of the Co Park Marsh as a result of several factors, including 303d tributary inputs, carp, and lack of aquatic plants. Total phosphorus concentrations in the marsh water are often 10x higher than the levels typical for Green Lake.

Lake modeling completed in 2001 (Baumgart,P. Fox Wolf 2000) estimates the major portion of incoming nutrient (44% of the total P loads) and sediments entering the lake are from the Silver Creek watershed. Another major source (13% to 15% of the Total P loads) comes from the 3 tributaries located within the County Park Marsh complex. Despite these large loadings, it has been seen that the unit area loads coming from the Silver Creek watershed fall into the lower range for agricultural land in Wisconsin (Panuska, J.).

Another important parameter used as an indicator of water quality is bacteria levels. Fecal coliform and fecal streptococcus bacteria have been monitored at several locations to indicate pollution from warm-blooded animal sources in the watershed. These bacteria are typically associated with animal waste from livestock, pets, birds, and humans. Urban runoff, farm-land, feed lots, storm sewers, and even roof top drains are all sources.

Bacteria levels at two stations in the watershed are problematic. Bacteria levels in Silver Creek at K-Mart in Ripon are higher on average, and frequency of occurrence, when compared to Spaulding Rd levels. Bacteria levels appear to drop as the water from the subwatershed enters Green Lake, at least when compared to the levels at Ripon K-Mart station. Bacteria concentrations decrease at Green Lake in most events, but not always. Results from samples obtained via GLSD show, out of a possible 36 bacteria monitoring events, 27 were poorer in quality (i.e. high in bacteria levels) when compared to Silver Creek samples. These results demonstrate that a reduction of bacteria concentration occurs between Ripon and the mouth of Silver Creek. This improvement might be due to hydrology, stream process, or other biological conditions involving multiple sources of bacteria. Urban runoff, agriculture runoff, and wastewater discharges are candidates, and typically are precipitation/rain driven non-point sources.

Objectives for Stream Water Quality

1. Improve understanding of condition and trends in tributary pollutants and habitat
2. Restore stream habitat and water quality within degraded tributary reaches

Strategy for Stream Water Quality

1. Implement the installation of a USGS gauging and water quality stations at CTK K and Roy Creek. Retire the Deacon Mills (Puchyan River) outlet station and White Creek station. Maintain all other monitoring not modified here. Adjust annual GLSD budget to accommodate monitoring enhancements via USGS. This monitoring approach will track 70% of the lake phosphorous and suspended solids loadings.
2. Work with partners to establish stations and protocol for baseline stream appraisals in upper watershed areas to include Fond du lac County.
3. Silver Creek data report - Compile, review, and interpret historical Silver Creek data and references. Ripon College, Green Lake Co, and UW-Oshkosh are partners capable of long range and short term commitments.
4. Silver Creek Diagnostics Study – Pending outcomes from #3 above, contract with suitable agency for a water quality study to identify significant contributing tributary areas in the Silver Creek subwatershed. This may include an upstream/downstream appraisal focusing on the City of Ripon.
5. Employ USGS for annual report on the state of the “Lake”. This review and report presentation should capture significant events requiring management decisions as related to data collected in lake and watershed. A summary of data collected in that year should be available. This is a conditional appraisal action, not an evaluation (did it work?): i.e. a “state of the union” summary.
6. Evaluation of BMPs- Employ USGS or similar to evaluate efficacy of implementation. To meet current criteria for receiving grants from federal or State programs, evaluation of objectives achieved, successes and failures, are required. This will be completed on 2 levels;
    a. Level 1 – Longer range general lake or stream condition appraisals that will show macro trends. Seasonal lake and Silver Creek monitoring by CLMN, GLSD, and USGS are examples. Watershed modeling would also fall into this category
    b. Level 2 – Focused evaluations specific to the site where BMP employed. Can involve upstream vs. downstream studies, biotic indexing, physical surveys, or other appropriate methods characterizing the before and after conditions, and how it might affect the lake. This approach is recommended for Roy Creek and County Park Marsh evaluations, both prime candidates. Other evaluations could involve buffers, stream bank repairs, modeled loadings, anecdotal evidence, images, and other acceptable modifications.
7. Maintain existing BMPs where needed. Examples; sediment basins, validate BMP construction

8. Conduct a feasibility review for the potential adoption of "perpetual" or "lifetime" BMP commitments.
9. Project Implementation Review and State of the Lake Reporting – Annual meeting to assess where we are at, make changes, improvements, or further actions. A one-page summation should describe the year's relevant events and decisions, with all partners in attendance.
10. SWAT- further SWAT application and input refinements should be completed. This action will run in parallel with on-going actions driven by earlier modeling results we believe applicable (SWAT, Baumgardt, P., 2001) Upon SWAT (or other model) completion in years 2013 or 2014, the results will be subsequently applied. In lieu of this completion, BMP priorities will follow the earlier modeling guidance from 2001.
11. Evaluate the efficacy of BMP's on Roy Creek and Co Park marsh – The two stations specified will help to evaluate if the BMPs worked. Along with the flow, TP, suspended solids, temp, DO and other potential parameters, these actions are recommended.
    a) Complete carp population estimate. Method must be useable as post treatment comparison. If possible or practical, complete fishery evaluation including all species abundance. Pre Vs. post best.
    b) Complete PI or utilize 2007 PI in restorable area of marsh to serve as baseline for habitat (plants) restoration efficacy review.
    c) Complete Aerial photos during May, July, and Sept intervals. Photo set of 3 aerials. Also complete aerial imaging for Silver Creek estuary. Conduct on annual frequency.
    d) Model subwatershed area. This is an alternative to modeling the entire watershed. This could include a focused subwatershed area, e.g. Roy creek. Outcome; develop a specific numerical target for plan objectives.
    e) Monitor relevant parameters of water quality including Secchi disk clarity, Chlorophyll A concentrations, Total P, T.S.S., T.V.S.S., temperature, oxygen, pH, fishery evaluation, PI, carp population estimate. The frequency of monitoring these parameters will be variable, but within standard norms for the limnological assessment of lake health. The carp evaluation water quality tests will be modified to include volatile suspended solids *and* total suspended solids. This will allow for improved data review respective of cause-and-effect conclusions.
12. The City of Green Lake Department of Public Works recommends that the city complete a desktop study on its storm water collection system, develop a plan and implement best management practices when and where it is cost effective. In the future the city will consider effluent trading with regard to its phosphorus limit in the WPDES permit for the wastewater utility.

Lake Habitat and Plants

Aquatic plants form the foundation of healthy and flourishing freshwater ecosystems. They not only protect water quality, but they also produce life-giving oxygen. Aquatic plants are a lake's own filtering system, helping to clarify the water by absorbing nutrients like phosphorus and nitrogen that could stimulate algal blooms. Plant beds stabilize soft lake and river bottoms and reduce shoreline erosion by reducing the effect of waves and current. Healthy native aquatic plant communities help prevent the establishment of invasive non-native plants, e.g. Eurasian water-milfoil and purple loosestrife (WDNR).

At Green Lake aquatic plant conditions have a history of appraisals with the first significant work completed by Rickett in 1921. The most recent work was completed in 2007 by WDNR, and included over 1000 sample stations or "PI" points (point intercept). The surveys listed below were completed using various sponsors, methods, and objectives. Because of these differences, interpretation of results must take into account the many variables. Determining species trends is difficult but broader long range trends can be concluded from the knowledge gathered over the years.

This listing includes all survey work considered relevant to management of Green Lake plants:

Chronology of Aquatic Plant Surveys on Green Lake *

1. **1921 Rickett (Lake)**
2. **1971 Bumby (Lake)**
3. **1990 WDNR (Lake and Marsh)**
4. **1992 WDNR (Lake and Marsh)**
5. **1997, 1998, 2002 Norwegian Bay bulrush**
6. **1999 and 2006 Silver Creek Marsh (Carp Control Evaluation)**
7. **2007 WDNR (Lake and Marsh)**

*** Surveys in WDNR files**

Sensitive Area Designations (aka Critical Habitat Designations)

In 1997 WDNR completed, with the help of citizens, the identification of ecologically sensitive areas on Green Lake. The full report is included in the appendices. The areas designated included County Park Marsh (CTH K), Silver Creek inlet, Blackbird Point, Beyer's Cove, West Norwegian Bay, Dartford Bay (SE shore), Green Lake Millpond, and Carver Islands channel. All the areas designated either support or have the potential to support fish and wildlife due to habitat features.

When an area of the lake is designated as "sensitive", that designation empowers lake managers and regulatory staff to enact protective and restorative measures ensuring the full value of all ecological functions are realized. In essence the designation "flags" an area as critical relative to the health of the lake. Subsequent management actions become more defensible. These actions could include permits, fishery management, grant support, water quality projects, boating ordinance develop.

Ultimately it is important to recognize these areas as special and treat them as such. Many of the strategies include within this plan will integrate with the sensitive areas listed above.

Aquatic Plant Survey records

Survey #1, 1921 - H.W.Rickett- A Quantitative Study of the Larger Aquatic Plants on Green Lake, WI.

This is the earliest comprehensive aquatic plant survey on record. Rickett was a graduate student at UW-Madison, and was guided in his lake project by E.A. Birge. The plant study he completed looked at wet and dry biomass of the aquatic plants at Green Lake. The methodology used is comparable in some ways to those methods presently used but with limitations. He identified various plant species (i.e. qualitative) and their typical depths of colonization and much of this information is comparable to more recent surveys. However, the quantitative aspects differ in that plant abundance was determined by direct measurement of plant mass (dry and wet weight) within specific plots set up on transect lines. In contrast, more recent survey work is based on grid sampling at numerous locations covering the entire lake, rather than a linear transect line. While Rickett used divers to collect plants, more recent survey work involves sampling with raking devices attached to ropes and /or poles.

One of the more significant observations made by Rickett was a determination of the maximum depth of aquatic plant colonization in Green lake. Plants were observed as deep as 10 meters (32.6 feet) "In one such station (station 25) plants were found at a depth of 10 meters, though small and stunted in growth". However, Rickett found that colonization by *mature healthy plants* typically occurred at a maximum depth of 8 meters (26.1 feet). E.A. Birge of the University of Wisconsin, also estimated the colonization depth maximum at Green Lake of 8 meters based on water quality measurements, affirming Rickett's determination. Contrasting with this is Birge's estimation of the maximum rooting depth on Lake Mendota at 4 meters. Mendota and Green Lake served as relative indicators for nutrient enrichment with Mendota being notably more fertile than Green (as is the case today).

Rickett identified 22 species of plants at Green. This qualitative identification is mostly comparable with species identification used in recent surveys. Some official plant species names have changed, yet there remains a large body of useful comparative information regarding species present in 1921 vs. later survey work completed by M.J.Bumby and WDNR and or/GLSD.

The following table represents Rickett's findings. Note the listing is alphabetical and not in order of abundance. Looking at the table it can be seen that *Chara*, Coontail (*Ceratopyllum demersum*), milfoil (*Myriophyllum verticillum*) and Sago pondweed (*Potamogeton pectinatus*) were most abundant as measured by weight in 1921. At the time of Ricketts survey, Eurasian water milfoil (*Myriophyllum spicatum*) and Curley leaf pondweed (*Potamogeton crispus*) were not yet present in the region. All later survey work, starting in 1971, included the invasives CLP and EWM as well as those native plants found by Rickett.

Ceratopyllum, *Myriopyllum*, sago pondweed, and *Chara* were dominant plants as measured by dry weight. *Chara* was by far the most abundant plant, representing nearly 50 % of the plant biomass in the lake. The other 3 species collectively made up nearly 30 % of plant biomass (Rickett)

Survey #2, 1971 - Bumby, M.J.

In 1971, a study meant to partially replicate Rickett's methodology was conducted. In addition to species found in 1921, *M. spicatum*, *P. crispus*, and *Cladophora* were found in larger quantities vs. the 1921 survey. Also of significance, the maximum rooting depth for the macrophyte community was noted by Bumby at approximately 5 meters (16.3 feet), much less than the 1921 findings of Rickett at 8 meters (26.1 feet). This suggests decreasing water clarity long term. Essentially, macrophytes in the deepest littoral zones of the lake have decreased. Also noteworthy is Bumby's suggestion that, Eurasian water milfoil was likely responsible for the large decrease in the native milfoil species *M. verticillum* that Rickett had recorded.

In his 1924 report Rickett noted a low occurrence of *Cladophora* in Green Lake, and went so far as to contrast the filamentous algae's relative scarcity in Green Lake, although it was abundant in Lake

Mendota in Madison. However, much *Cladophora* was noted by Bumby in 1971 growing in depths less than 1.5 meters (5 feet). *Cladophora*, notably along the north shore, has also been reported reaching nuisance level conditions (verbal communication, Bartz, D.), and suggesting possible fish spawning impediments in areas where it is abundant.

Survey # 3 & 4) 1990, 1992 - WI Department of Natural Resources

This survey was completed in 1990 and repeated in 1992, due to species identification concerns. However, despite the identification issues, the survey provided insight into maximum rooting depths (15 to 18 feet) and documented dominance by two of Green Lake's most abundant species, *Ceratophyllum demersum* and *Myriophyllum spicatum* also known as coontail and Eurasian water milfoil. Approximately 18 species were noted in the 1990 survey and 22 in the 1992 survey.

This statement below was from the introduction for the 1990, WDNR survey report;

"The photic zone was estimated before the survey to be between 18 and 21 feet. This zone's edge was confirmed by occasionally trying to sample at 21 feet where either dead plant debris or no plants were found at all. This is documented in Table #5, which shows macrophyte growth tapering off sharply after 15 feet. "

The maximum depth of plant growth was estimated to be between 18 and 21 feet. The maximum depth at which plants grew in the 1990 and 1992 surveys was certainly less than 21 feet, however, as frequent attempts were made to collect plants at this depth with no success. However, due to the protocol for the transect survey, the depths sampled were incremental (3 feet intervals) and essentially representing a depth range rather than at a distinct depth as specified in PI (point intercept) survey protocol used for recent studies (2007). Upon examination of the data in a table below it is clear plant life drops off dramatically at the 18 foot interval.

The 1990 and 1992 surveys found two invasive species in each survey, *Myriophyllum spicatum* and *Potamogeton crispus*.

Inlet marsh areas — There are 2 major marsh/inlet areas around the lake having the potential to function as water quality filters and nurseries for fish and wildlife: Silver Creek inlet and CTH K inlet (i.e., Co Park Marsh); both showed very low plant densities in 1990 and 1992. Although Silver Creek inlet has since been restored, CTH K inlet remains severely degraded due to carp and sediment from the watershed.

The significance of the marsh degradation is critical to the health of the lake. Healthy marsh environments typically have dense aquatic plant growth. The 1921 Rickett study indicates areas of emerging plants like bulrush were much larger than today. Many functions are supported by healthy shallow water marshes, including water filtration, fish spawning, and wildlife feed. The access to marsh areas for pike, panfish, forage minnows, and waterfowl, for example, is critical to support of these species.

Survey # 5, 1997, 1998, and 2002 - Norwegian Bay

This work was performed in response to perceived losses of bulrush habitat occurring as a result of boat and wading activity within and around the stand of hard stem bulrush, *Scirpus acutus*. Reports of lake residents along with aerial photographs support the assertion that bulrush stands have been lost (Bumby, M.J.). Bulrush plays an important role for spawning of *Esox luscius*, the Northern Pike. In the spring this species uses a bed of collapsed bulrush stems to brood its spawn. However, because bulrush beds provide good cover, waterfowl also use bulrush beds to rear their broods. Moreover, these beds stabilize sediment, protect shores from erosion forces, and help maintain water clarity.

Five major bulrush stands were identified by Rickett in 1924 ranging in size from 3500 to 255,000 sq. meters. Today, with the exception of a stand in Norwegian Bay these communities have disappeared. The stands noted by Rickett occurred in areas of sandbars adjacent to marshy areas. The stand in Norwegian Bay is roughly 1800 sq. meters and located in shallow (1 to 1.5 Meter) water with a sand-muck substrate (Cook,C. , WDNR)

Three separate surveys were completed starting in 1997. The 1997 survey established baseline conditions for the hard stem bulrush stand in Norwegian Bay. Stem counts were completed in several established transects and total area of the stand determined. Subsequent surveys were completed in 1998 and in 2002 with the objective to measure improvements as a result of a "no motor" ordinance implemented in 1997 (Marks, C. GLSD).

In 1998, subsequent to the 1997 survey WDNR researcher Tim Asplund reported; "With only two years of data, (to compare with the baseline survey) it is too early to say whether boats were indeed affecting the bulrush stand or whether the ordinance is being effective … . It is encouraging that the stem densities increased between 1997 and 1998. Continued monitoring will help us determine if this is random variability, short term effect, or a long term trend. In addition, while increased density is a positive outcome, expansion of the beds is the ultimate sign of success. A more current survey is needed to establish changes…"

Unfortunately the 2002 survey data showed a decline in stem density for the Norwegian Bay stands when compared to 1998. Several factors could be responsible; these include changes in water levels, deeper winter snow cover, continued boat related impacts and insect damage from larval stages that eat bulrush. Motorboat activity within the stands appears to have decreased (Sesing, M. Marks, C. pers. obs.) likely due to ordinance postings (Appendix H).

There was a limited 2005 survey conducted by students under the guidance of Tom Eddy, Green Lake School educator. These results are not included in this analysis due to variable methodology. However, the integration of the schools with the bulrush initiative links youth with the lake, its habitat, and real life issues.

Survey #6, 1999 and 2006 Silver Creek Marsh Carp Evaluation

The objective for this effort was to determine whether submerged plants would respond favorably when carp were excluded from access to a small area of the Silver Creek marsh. After prior survey work in 1990 and 1992 confirmed the absence of plant life typical for a shallow water marsh, management focus shifted to identification of factors responsible for the poor conditions in the marshy area.

In 1999 two appraisal actions were employed in an effort to confirm the degradation by carp. The evaluation included the construction of a fenced area designed to prevent carp entry. The 2nd action was to establish baseline aquatic plant condition.

- A fenced exclosure (10'x10' fencing) was designed to exclude carp from the test area. Plant sampling within and outside the exclosure was completed 4 months after initial installation. Due to poor plant growth in the general area it was impossible to come to meaningful conclusions. Although more plants were found within the exclosure, the number of plants did not allow for analysis. Because the inlet area water had low clarity (less than 0.5 feet) turbidity was likely a factor in the poor plant growth. (Water clarity averaged ½ feet (Marks, C.) Phosphorous levels excessive (3 samples obtained, all, greater than 110 mg/L))
- Three transects were set up within the marsh area east of CTH A and appraised by taking 60 rake drags. No plants were recovered at any of the 3 transect stations, indicating very poor habitat conditions. Under normal circumstances, submerged or floating leaf plants would colonize a majority of the tested area.

Coontail, EWM, sago pondweed and water lily were observed *visually* within the general area. These four species of plants are turbidity tolerant and do well in cloudy water. All submergent plants were laden with silt.

In 2006, Silver Creek inlet was surveyed after a carp barrier was installed. Density of plants was high with a 97% frequency of occurrence. Seven species were present and dominated by coontail, EWM, and Water Lilly. Prior conditions, before the carp barrier installation, included diminished plant coverage, loss of filtering capacity, turbid conditions, and poor fish/wildlife nursery/spawning (Sesing, Marks, and Provost).

Aesthetic and navigation issues were noted within the marsh. The re-vegetated condition created a use conflict in the inlet zone with homeowners and boaters. Strategies directed at alleviation of the conflict are included in the strategy section.

Survey #7, 2006-2007, WDNR, GLSD-Point Intercept Method

The 2006-07 survey methodology provided complete areal coverage of aquatic plants at Green Lake. The method used can be described as a grid approach, similar to a checker board, laid out onto the lake. Once the grid is determined, all points in the grid are essentially monitored. This method provides good coverage of the littoral zone i.e. the area of lake bed with sufficient sunlight penetration to allow plant growth and improves on the transect methods used previously. The survey included shallow water marsh areas of Silver Creek and the area known as CTH K (County Park) Marsh.

The history of management has been directed at re-vegetation of the marsh. Carp control actions by the GLSD go back close to 20 years. To date, the vegetation condition of the marsh remains relatively poor. The construction of the most recent carp gate at CTH K should have a positive impact. Some anecdotal evidence suggests the marsh appears to be building an improved plant base (via Charlie Marks). Plant survey work, as it relates to 303 d reviews and the 2007 WDNR point intercept (PI) plant survey, are available to define baseline vegetation condition. There is also a small data set of nutrient and sediment samples taken within the marsh (not the tributaries) prior to 2007. These samples were obtained on two occasions under the 303 d (impaired waters) review for the marsh and results are available in SWIMS, the DNR's database.

In a comprehensive 2007 plant survey of the lake 38 species of plants were identified. This demonstrates a rich plant community in the lake. The dominant aquatic plants were EWM, coontail, and *Chara*. A maximum rooting depth of 21 feet and 36 species were documented.

Aquatic Plant Summary Statistics - Green Lake 2007

Total number of points sampled	1041
Total number of sites with vegetation	691
Total number of sites shallower than maximum depth of plants	919
Frequency of occurrence at sites shallower than maximum depth of plants	75.19
Simpson Diversity Index	0.88
Maximum depth of plants (feet)	21.00
Number of sites sampled using rake on Rope (R)	239
Number of sites sampled using rake on Pole (P)	668
Average number of all species per site (shallower than max depth)	2.32
Average number of all species per site (veg. sites only)	3.08
Average number of native species per site (shallower than max depth)	1.79
Average number of native species per site (veg. sites only)	2.42
Species Richness	36
Species Richness (including visuals)	38

Figure 16 Green Lake Aquatic Plants - Statistics on 2007 Survey (SOURCE: WDNR Integrated Science Services)

The maximum rooting depth of the plants of 21 feet, which agrees with survey observations in 1992, also occurs at 21 feet. Sunlight penetration into the water column allows for plants to grow this deep. Rickett, in 1921, recorded maximum rooting depths up to 10 meters (32.6 feet). These observations suggest the clarity of the lake has decreased due to eutrophication (i.e. nourishment) over the last 90 years. In contrast, the 1971 survey indicated max rooting depths at less than 21 feet or approximately 16.3 feet. Although the difference seems considerable, some of the discrepancy might be explained by different methodology for determination of max rooting depth, annual variability in light conditions, or other ecological variable. Analyzing plant rooting depths in the 1921 and 1971 sampling years might be a better comparison as the methods used in those years were comparable.

Simpson's diversity index (SDI) is a routine index that is used to measure biodiversity in ecosystems. The SDI takes into account the number of species present and the abundance of each species. The SDI represents the probability that two randomly selected individuals in the habitat will not belong to the same species. This index varies between 0 to 1 scale, with 1 indicating infinite diversity and 0 indicating a lack of diversity. The SDI at Green was 0.88, and in a relative sense represents a relatively high and stable plant community, despite indications of long term water quality changes in the lake. Of course this level of plant biodiversity does not a guarantee that the community will remain healthy, but it does argue that the community will have greater resilience to stress. Yet too much stress (e.g., pollution, invasives, mismanagement) will destabilize even a healthy system.

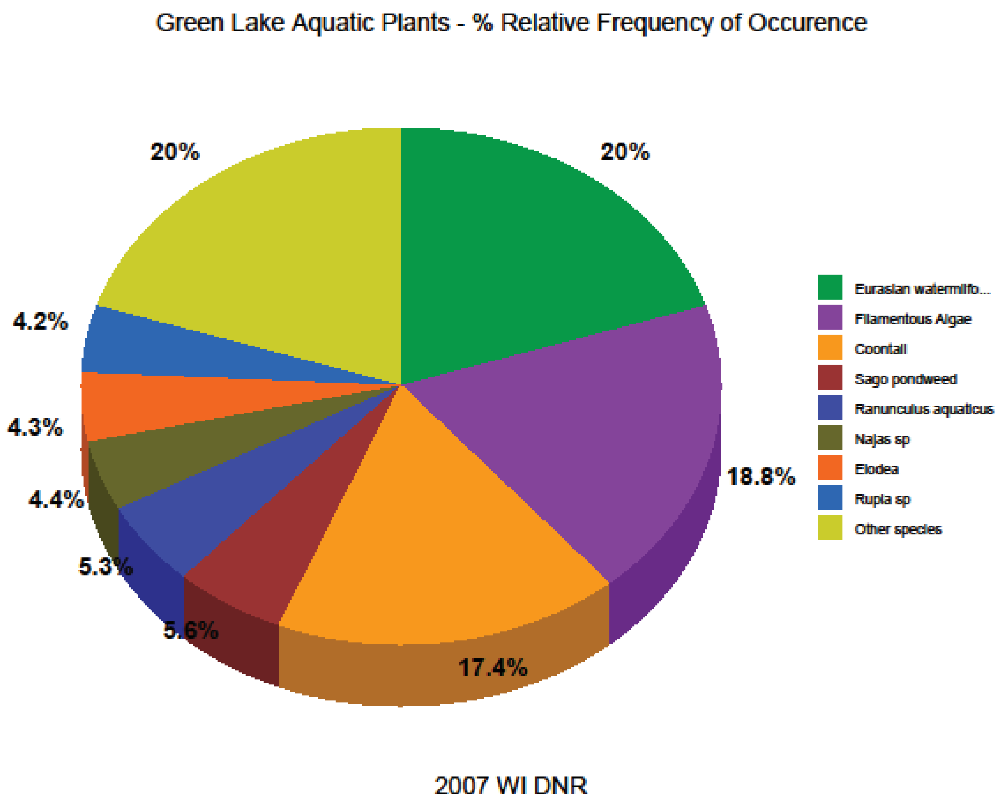

Figure 17 Green Lake Aquatic Plants – Frequency of occurrence

This figure reflects the number of times a species was detected during the 2007 survey. Eurasian water milfoil, filamentous algae, and coontail were found most often. Filamentous algae are a growing concern at the lake, and it appears to be increasing in its frequency of occurrence. Although additional data is needed, observations by lake management experts indicate a growing problem (WDNR) and thus, represent a significant threat to the fishery.

The outlet dam and Green Lake water levels – Water levels on the lake, in backwater areas, bays, and on shorelines are controlled in part by the outlet dam. Water levels can be an extremely powerful tool for managing aquatic plant conditions. Depending on timing, water level management can increase, decrease, or maintain plants in the lake. In the case of Eurasian watermilfoil, a winter level drop can freeze the plant roots, thus reducing growth the following summer. In contrast to this, a summer drop can enhance the growth of many plants, e.g. bulrush. Significant use conflicts will occur if a water level change is made (even a temporary one). This fact often prevents the water level tool from being employed. It does, however, remain an optional tool for plant management, albeit a very difficult one due to public acceptance. The Lake Level Permit has been court tested and remains very controversial especially during naturally occurring high and low level conditions.

Ceratophyllum demersum ☺

Also known as "coontail" this submergent plant is very common in Green. Coontail is a native aquatic plant to Wisconsin and provides major benefits to fish, wildlife and water quality. It is often confused with EWM due to its prolific growth. It is a dominant plant in Green.

Myriophyllum spicatum ☹

The notorious EWM or Eurasian water milfoil provides habitat and water quality functions. Unfortunately, it is a very aggressive non-native invasive plant to Wisconsin and effectively outcompetes more desirable native species. It is also a dominant plant in Green.

Cladophora spp. ☹

Of growing concern, this filamentous alga covers much of Green Lake benthos. When abundant it will suppress fish spawning, create odorous mats, and impact bottom dwelling lake life. Although the causes at this time are not understood, suspects include groundwater nutrients, zebra mussel feces, and watershed loads of phosphorus and nitrogen.

Objectives for Aquatic Plants and Habitat

1. Reduce the user conflicts via integrated strategy including mechanical harvest, herbicide applications, I&E, and defining/employing riparian development guidance
2. Protect integrity of the native aquatic plants and woody habitat

3. Restore shallow water habitat of tributary areas
4. Control expansion of non-native invasive plants
5. Evaluate the aquatic plant population trends
6. Restore woody habitat on lake shores

Strategy for Aquatic Plants and Habitat

1. Review I&E needs and subsequently enhance I&E for the lake environs, including the watershed
2. Develop homebuyers guide (with intent to reduce conflicts) with overview of lake programs and special qualities. Silver Creek preservation, CO Park Marsh restoration, shore land zoning, near shore habitat and Revitalization of Shoreland Vegetation Program (RSVP) are typical program areas to illustrate, as well as restrictions for APM (Aquatic Plant management)
3. Complete Point Intercept plant surveys at a minimum frequency of once every 5 years for the entire lake. This appraisal will identify trends in the plant community.
4. Appraise feasibility for EWM control on lake
5. Appraise the filamentous algae *Cladophora* condition on the north shore. Appraise potential factors leading to a perceived increase in the abundance of filamentous algae (*Cladophora*).

Strategy – Woody Structure and Critical habitat Areas

1. Review and inventory areas designated as sensitive in the report "Sensitive Area Designations, Green Lake, WI". Conduct Critical Habitat Designation Survey following established DNR protocols.
2. Appropriate I&E materials for all critical habitat sites should be prepared, distributed and illustrated for lake boaters and property owners.
3. Conduct a lakeside survey for course woody structure and develop a strategy for restoration and enhancement if appropriate. Strategy development will consider benefits to specific fish species, waterfowl, aesthetics, safety, maintenance and riparian interests.
4. County Park (CTH K) Marsh:
   a. Conduct a mark-recapture population estimate for carp density
   b. Determine feasibility of winter rotenone treatments, commercial harvest, and bio manipulation (ex: stocking pike, bowfin, and catfish to improve predator fish populations.)
   c. Conduct annual aerial photo appraisals of the marsh during the growing season.
   d. Complete P load estimate pre and post carp removal to determine % reduction
   e. Determine feasibility of aquatic plant introductions vs. natural re-colonization
   f. Prioritize the plant restoration as a critical management action

Aquatic Invasive Species (AIS)

Eurasian water milfoil (EWM) was first verified in 1969 within the main body of green Lake (Bumby M.J.). All subsequent plant surveys have confirmed EWM as one of the dominant plant species at Green. Along with chara and coontail, EWM is widely distributed throughout the lake. Nuisance conditions have been documented in mostly shallow littoral zones of the lake and inlets. Silver Creek, Dartford Bay and the Millpond are notable areas with dense growth of EWM along with other species.

Despite EWM presence in the main body of the lake, it grows at depths deep enough for the terminal growth to remain submersed and as a result has less of a nuisance presence in the main lake.

Curleyleaf pondweed, *Potamogeton crispus*, is well established in Green Lake and its tributary areas. Early senescence allows for subsequent recreational use. However, it has been noted as an early summer nuisance in Silver Creek and Beyer's Cove.

CLP continues to be investigated on other WI lakes as a source of concern re: phosphorus delivery/loadings due to fast release of decaying cell material and nutrients (nitrogen & phosphorus) in CLP breakdown. Algae blooms and other trophic phenomena can be driven by the elevated phosphorus concentrations. Sudden nutrient pulses stimulate the algae growth, leading to algae blooms of health concern to users.

The German carp or common carp (*Cyprinus carpio*) has been a degrading force in the shallow water areas of the lake and its tributaries. Silver Creek and County Park Marsh have been hit hard by the effects of abundant carp; sediment re-suspension, nutrient solubility, aquatic plant habitat loss leading to loss of spawning habitat and fish recruitment, turbid water, loss of waterfowl production, and elevated nutrient loadings to the lake. Carp management has been attempted for nearly 3 decades with minimal success. In the 1980's carp exclosures were installed in Silver creek to determine the impacts of carp on aquatic plants (Simonson, D. GLSD). Further efforts have included commercial netting, barrier construction, innovative barrier design and implementation (Marks, C. and Randall, R.), carp trapping, and aquatic plant surveys and carp exclosures (Marks, C. and Sesing, M.).

Various barriers have been installed at the County A bridge and the County K bridge to prevent carp from reaching spawning areas. The barriers have had varying levels of success, as well as public acceptance. The CTH K physical barrier has had no obvious positive impact to date but was complimented with an adaptive effort to harvest carp inhabiting the shallow back-water areas. The CTH K barrier has been modified in 2011 and results of the modification are pending. The barrier at CTH A bridge is a bubble barrier operated seasonally, and has been in place since 2007. Prior, a mechanical physical barrier was in place from 2003 to 2006 with a substantial response in aquatic plants and water quality. More focus on the carp eradication is planned, with an objective to restore habitat. WI lake Partnership Grants helped fund the projects, along with the GLSD. Several partners support or integrate with the carp management program.

Carp control success in the Silver Creek inlet, a 270-acre tributary area, has seen good results in the re-establishment of aquatic plants. The formerly depauperate plant community in the shallow water tributary area is now heavily vegetated. While this success has brought about enhanced fishery and wildlife conditions, improved water quality and filtering, it has also become a user conflict regarding navigation and aesthetic conditions. The Silver Creek property owners group is especially affected being riparian to the restored shallow water areas. While these conflicts are inevitable in restoration initiatives, the use conflicts for some shoreline owners are real and management actions are being employed. These include plant harvesting and herbicidal treatments. Overall, the benefits of improved water quality and fish/wildlife habitat are seen by lake managers to outweigh the negative use issues. This does not mean the user conflicts can be ignored.

The SW area of the lake known as County Park Marsh has seen less success in its objectives for carp control and habitat restoration. Despite several years of carp trapping and harvest, the shallow water area remains a turbid, plant depauperate condition. Exploration of various management alternatives is already underway with implementation in 2013. Rotenone, a plant root derived fish toxicant, is one of the alternatives being considered. Netting is another possible action. A major objective will be reducing sediment and nutrients, especially phosphorus, to the west basin of the lake. Watershed modeling in

1999 (Panuska, J.) estimated 13-15% of total P loading to Green Lake was coming through this marsh area. A successful restoration here would likely reduce the loadings to the west lake basin to a significant degree (Johnson,T. WDNR, memorandum).

First reported by Eddy (personal communication) in 2001 (Zebra Mussel Watch), the Zebra Mussel, *Dreisenia polymorpha* has increased in abundance and coverage. Pier supports and other hard surfaces within the littoral zone of the lake are often colonized by the mussels (Specht, J. personal communication/photo). To date, obvious trophic impacts are subtle, but suspect in recent lake phenomena. A green filamentous alga, very likely *Cladophora* sp., has been noted growing densely along large expanses of the north shoreline. It is believed this coverage is increasing and is now excessive and possibly affecting walleye spawning (Bartz, D. WDNR, personal communication). Although a cause/effect relationship has not been established, the phenomenon has been noted in other lakes regionally, after ZM colonization. This might be due to compartmentalization and/or solubilization of nutrients near the lakebed where the mussels are actively feeding and excreting. Other stimulus is possible from groundwater and/or and climate change (i.e. warming waters). Several effects are probable but remain less obvious, including shifting plankton populations, fishery quality, and aquatic plant condition. It may be many years before the impacts of a growing zebra mussel population are seen.

Purple Loosestrife, a vibrant purple flowering invasive, appears to be suppressed in several areas in the watershed near Green Lake. The plant is an aggressive perennial that pushes out the more desirable native wetland species resulting in a loss of biodiversity. A beetle raising program, volunteers, and the GLSD have teamed up to slow the spread of purple loosestrife advance into area wetlands. Suppression efforts will need to continue into the foreseeable future to maintain success.
Potential invasive species at Green Lake include Spiny Water Fleas, Rainbow Smelt, Round Goby, VHS, Quagga Mussels and others, e.g. the notorious Asian carp.

Several lakes within Green Lake County, including Green Lake and its tributaries, have identified AIS education and prevention as goals in their respective lake and/or aquatic plant management plans. However, funding to execute those goals has ceased and/or will be terminated in the near future. Additionally, there are several lakes wherein no and/or limited AIS prevention activities are being implemented. As a result, Green Lake County's AIS prevention and education activities remain a patchwork of varying AIS efforts represents a scope of work to be included in an AIS educational grant for 2013 (Appendix B). The outcome of this action, if funded, will address the concerns expressed here.

In recent years AIS prevention actions have been initiated among partners;

- Green Lake Co – Green Lake County Land Conservation Department – Staff expertise includes invasive aquatic plant management, grants assistance and partnerships. Green Lake County employed an AIS Coordinator during the summer months from 2007-2011. Due to budget cuts the position was terminated in 2012. Services are available to most of Green Lake County lakes.
- The GLA – conducts a clean boats clean water program (CBCW) during the summer with a part-time staff including 1 coordinator and several landing inspectors. They provide AIS education around the Green Lake Area.
- GLSD raises beetles for purple loosestrife control, as well as employing seasonal staff to operate a weed harvester during the summer months to provide nuisance relief in shallow areas. Associated with wet areas, the control of buckthorn, garlic mustard, and other invasive plants is

supported on all conservancy properties, some of which are in ecological sensitive areas (Critical Habitat) biologically linked to the lake environs.

- WDNR has provided grants and technical assistance for AIS work including Clean Boats Clean Waters program support, monitoring of new infestations, and access point postings at Green and regionally.
- Green Lake Schools – Students active in early tracking of Zebra mussels, stream biotic indexing, and land ecology, much of this on riparian property.

Aquatic Invasive Species (AIS) Objectives

1. Prevent AIS spread (i.e., import and export)
2. Control AIS populations as reasonable in the lake and tributaries
3. Appraise conditions and trends in AIS populations
4. Educate and inform the public and
5. Establish responsibility for AIS coordination

Aquatic Invasive Species (AIS) Strategy

1. Form an Aquatic Invasive Species (AIS) steering team for Green Lake
2. Conduct quarterly review of AIS activity under AIS team for Green Lake
3. Integrate all Green Lake partners with Green Lake AIS actions
4. Integrate Green Lake strategy implementation with regional coordination efforts
5. Complete scope of work with AIS steering team and apply for Aquatic Invasive Species Education, Prevention and Planning grant (See Appendix B)
6. Complete "smart control" review of AIS threats. The intensity of this action can vary, but, adopt an approach incorporating species tolerance, symbiosis, movement potential, water quality requirements, and major boating travel lanes
7. Review, adopt, and support Clean Boats Clean Waters, or CBCW
8. Review feasibility for boat wash stations lake wide. Estimate costs and efficacy
9. Explore potential design improvements for Green Lake landings considering
    a. Submersion depths
    b. Substrate quality (muck, sand, plants)
    c. Use frequency, boat type/size
10. Encourage education partners Green Lake School, Princeton, Markesan and Ripon Schools to be part of AIS program execution
11. Track existing AIS populations. Determine methods and Employ AIS monitoring for EWM, CLP, Zebra mussels and carp. Incorporate hands on scuba teams with partners when appropriate as I&E, or Control action
12. Prioritize Silver Creek inlet, Beyer's Cove, Dartford Bay, Norwegian Bay, for AIS control implementation. In Green Lake proper, conduct a review of feasible control alternatives
13. Conduct preliminary feasibility analysis for lake wide EWM control

Watershed

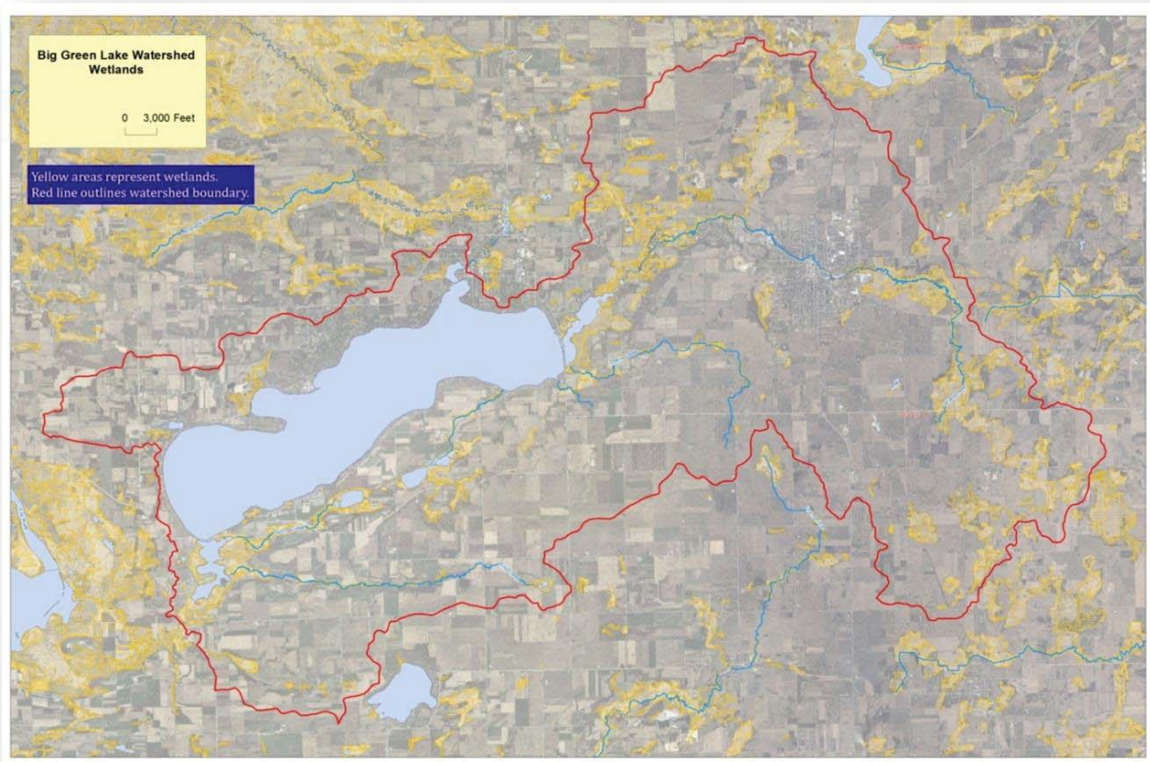

Figure 18 The Green Lake watershed encompasses 110 square miles of land area including farmland, streets, wetlands, rooftops, lawns, and parking lots Green Lake is part of the Big Green Lake Watershed, which is primarily located in Green Lake County. East and West Twin Lakes and Spring Lake are included in the watershed.

Watershed Statistics

Watershed Area	68,676 acres
Streams and Rivers	141 miles
Lakes	655 acres
Wetlands	5,102 acres

Green Lake

Greatest Depth	237 feet
Average Depth	100 feet

Surface Area	7,346 acres
Length	7.3 miles
Width	2 miles
Shoreline	27.3 miles

Water Source

Rainfall	51%
Runoff	41%
Springs	8%

More lake and watershed information available at:
http://www.greenlakeassociation.com/gla/watershed.html

In 2001 an Upper Fox basin study was completed by UW-Green Bay that identified environmental stress factors for the basin (Green Lake is a sub watershed in the Upper Fox basin).

Three priorities rose to the top when compared to all of the other stressors affecting the natural resources of the basin and the uses of those resources by the public. (State of Basin Report, WDNR)

1. Nutrient loading and nonpoint source pollution
2. Habitat loss and habitat fragmentation
3. Wetland filling and Wetland loss

A decade later, the state of the basin remains problematic. Although many positive actions and best management practices have successfully been completed, some old problems remain and new problems have come to the forefront.

What we know about the watershed – In year 2001, SWAT, the Soil and Water Assessment Tool was completed on the Green Lake watershed area. This is an analytical model that indicates problem areas in the watershed. The model utilizes general land cover (agricultural, urban, residential, etc.) and land slope to predict sediment delivery. The management value of SWAT is in its predictive ability for evaluating management actions. Sediment and phosphorus sources in the watershed were characterized, and then tributary streams ranked relative to these loadings (Appendix I).

One major urban area drains to Green Lake, the city of Ripon. Conditions in Ripon, as on agricultural land, will influence conditions on Green Lake.

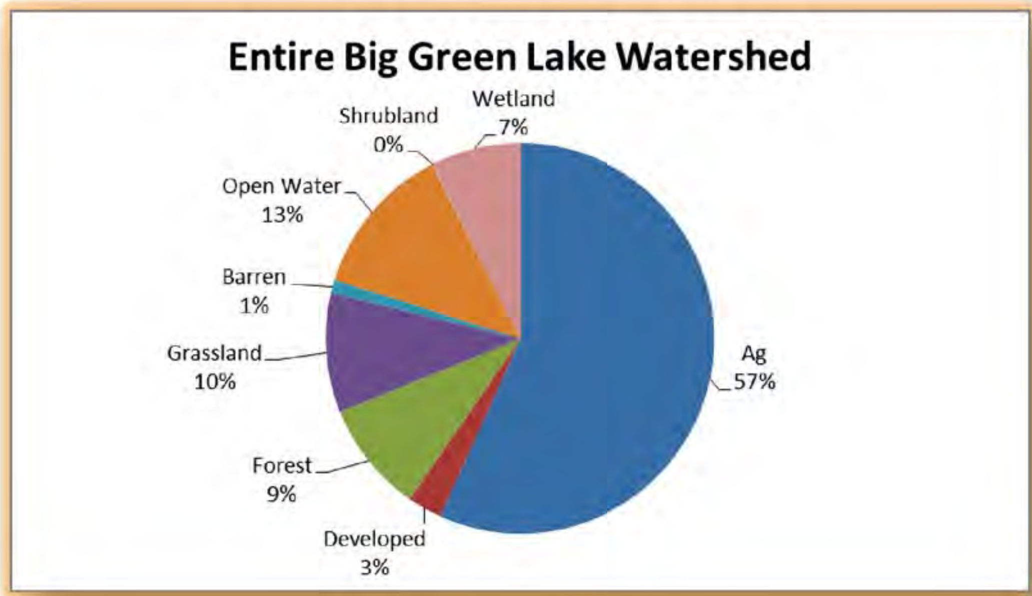

Figure 19 The watershed urban area is approximately 3 % of the area draining to Green Lake. The majority area is made up of agricultural lands (Hebbe, J.)

The application of lake models has provided insight into future conditions on the lake while assuming varied levels of pollution inputs, mostly from the watershed (Panuska, J., 2001). This model, known as WILMS (Wisconsin Lakes Management Suite) has been developed through the study and characterization of lake responses to volume of flow, residence time, nutrient levels, algae density, water clarity, lake morphometry, and watershed conditions. It is possible to predict the trophic state of the lake and the changes occurring in the trophic state as a result of simulated or real changes in the condition of the lakes environment.

This approach was taken in 2001 and involved estimation of the nutrient pollution reductions needed for the water quality of the lake to shift either higher or lower. In an example scenario, the model can predict changes in the lake as a result of increasing the size of the city of Ripon. In another example, we can predict the improvements to the lake water quality as a result of improved agricultural practices. This tool allows for the adoption of realistic target levels for watershed pollutant reduction. The “X” in the following graph represents the target objective for phosphorus reductions, based on the WILMS modeling (Figure 12).

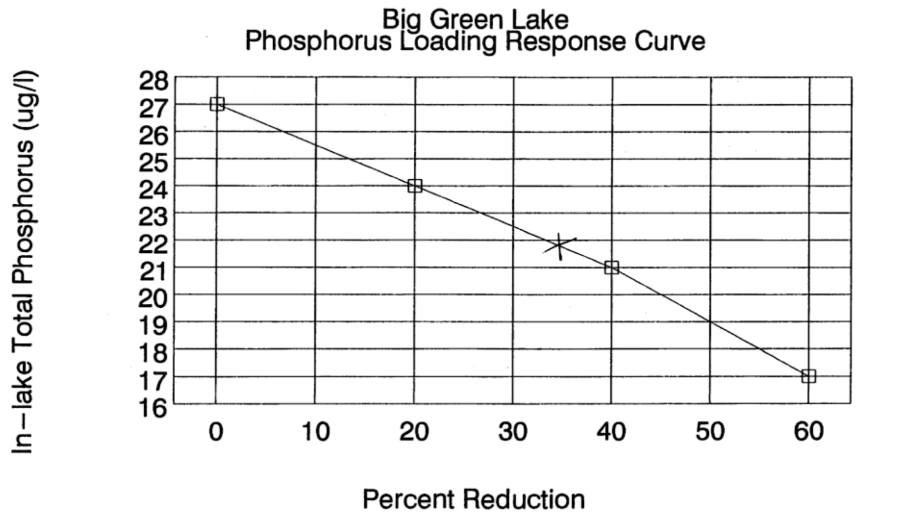

Figure 20 The regression curve above predicts Phosphorous response (in spring TP concentration) based on anticipated (target) reductions in total P loading to the lake (Panuska, J. 2001). The "X" approximates a 33% reduction in total P load to the lake. This target reduction, adopted by the GLSD in 2001, sets an objective for achieving a spring In-Lake Total P concentration of 22ug/L. Further evaluation monitoring is needed to determine how successful this previous effort has been. This plan includes objectives for improving evaluations of past and future efforts.

Watershed and lake model strategies included in this plan will be used to re-examine the loadings and lake responses to anticipated reductions. Because the last modeling effort is over 10 yrs. old, and improved tools are available for characterizing watershed and lake conditions, new modeling should improve understanding.

The strategy for watershed actions includes recommendations to enact a buffer ordinance in all watershed counties. Considerations for enacting buffer ordinances are many. Buffers must be defined relative to width and vegetation types (standards based on slope, vegetation type, to be grass, forbs, shrubs, trees). However, not all buffers are equal. A significant portion of sediment may be coming from within the buffers themselves. Following is a case in point. Consider steep or wet wooded buffers with little to no ground cover. Upland runoff runs through these often creating gullies. Stream bank erosion must be considered as well. Regarding jurisdiction, both Fond du Lac and Green Lake County will need to enact buffer ordinances for an effective approach. Inspecting and measuring buffers will be needed to ensure they meet standards. Responsibility for enforcement will most likely fall on county's corporation counsel. Corporation counsels in either county must pursue legal action for enforcement or the ordinance has no teeth.

Large dairy farms — The public has evolving concerns about Concentrated Animal Feeding Operations (CAFO) and possible issues regarding permit compliance, manure application and runoff impacts. Road surface quality and frequent truck use on roads is also generating concern regarding public roadway safety and maintenance costs. These questions are to be expected, and, to date there is no evidence of wrongdoing. CAFO's are large obvious operations and their activity is easily noted in neighborhoods, on highways, and sometimes in the air. However, from the perspective of lake management, some of these concerns may require further appraisal.

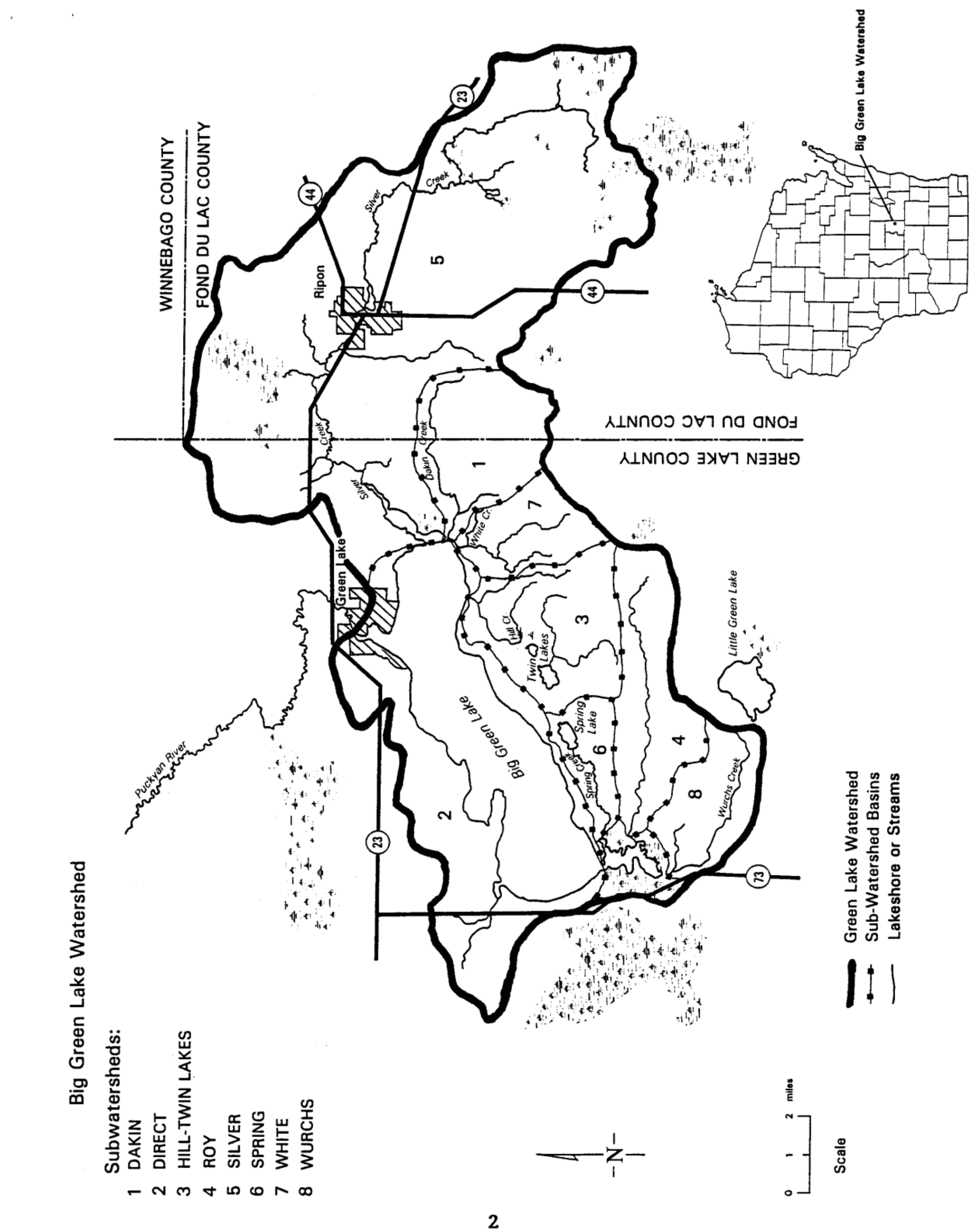

Figure 21 The map outlines the eight subwatershed areas tributary to the lake (Big Green Lake PL-566 Study, Hebbe, J. et al, and Green lake LWCD)

SWAT – Soil and Water Assessment Tool

SWAT was completed in year 2000 (Baumgart, P) and identified subwatershed loadings of phosphorus and sediment within the Green lake watershed (Table 6, Appendix H). The full report "Predicting Phosphorus and TSS Export with the Soil and Water Assessment Tool (SWAT) to Evaluate Alternative Agricultural Management Practices in the Big Green Lake Watershed, Wisconsin" is included as Appendix H.

Four alternative agricultural management scenarios were evaluated and phosphorus and sediment load reductions estimated for each subwatershed (Figure 5 and Table 7, Appendix H). Land cover from 1992 WISCLAND mapping was used to characterize land use within 23 sub watersheds. Hydrologic Response Units (HRU) were defined in each subwatershed including no-till, mulch-till, conventional till, grassland , urban, forest, and wetland.

The outcome from the SWAT effort supports ongoing BMP implementation as well as proposed actions within this plan. The subwatershed areas known as Wurches Creek and Roy Creek (Table 5, Appendix H) are targeted for intensive BMP applications in 2013 and 2014. Wurches Creek and Roy Creek were identified for high P loadings at 4,896lbs/yr. and 2,358lbs/yr. respectively. Although the SWAT effort is from year 2000, these subwatershed areas continue to deliver obvious and significant loadings of P and sediment. In 2012 USGS deployed a monitoring station at the outlet carrying the flows from these 3 subwatersheds. This monitoring will provide evaluation data for determination of efficacy for the anticipated BMP treatments within the upstream areas.

The Silver Creek watershed encompasses nine subwatersheds defined in the 2000 SWAT effort. The loadings of P and sediment are problematic in at least 3 of these areas (Table 5, Appendix H). Ongoing actions within the Silver Creek watershed include Silver Creek Marsh restoration, Silver Creek APM/AIS initiatives, watershed BMP treatments and proposed actions that include the Silver Creek Diagnostic/Feasibility study (See P load reduction strategy.) In 2012 USGS deployed a monitoring station at the inlet of Silver creek marsh. This monitoring will provide evaluation data for determination of efficacy for the anticipated BMP treatments within the upstream areas.

Overall, the 2000 effort was deemed satisfactory relative to observed vs. modeled conditions. The 2000 effort also helped to identify some weaker aspects of the modeling. One of these was under prediction of loading in the Silver Creek subwatershed, possibly due to channel degradation and bank erosion factors (Baumgart, P). These are anticipated to be improved in the next modeling effort we hope to employ in 2013.

The complete 2000 SWAT report is included as Appendix H.

Phosphorus Reduction Goals

How do we plan to reduce .phosphorus from entering Green Lake?

1. **Strategically (through sub-watersheds with impaired 303d tributaries) placed BMPs** – In Green Lake County install corrective BMPs. Projected funding would be through a Lake Protection Grant (75% State, 25% Local Partners).

2. **Conduct Watershed Study of the Silver Creek System** – Utilize the results of this study to identify sub-basins contributing disproportionately high amounts of P. Then, as a follow-up to the identified "problem sub-basins", write a FDL County Lake Protection Grant to address the problem sub-basins by installing corrective BMPs designed to greatly reduce or eliminate the P runoff. Projected funding would be through a Lake Protection Grant (75% State, 25% Local Partners).

3. **Restore the County K Estuary** – Track the progress made by opening the carp gate, etc. Continue aggressive carp removal efforts and move to chemical treatments in short term (1 year) if gate operation and carp removal efforts don't produce the desired results (re-vegetation, restoration of biodiversity). Flow and tributary evaluation monitoring will continue at the outlet mouth (CTH K bridge). Lake modeling identified the CTH K marsh and its three tributaries as a significant total P load (around 15% of total lake load) in its present unrestored and ecologically dysfunctional condition (see plan description of marsh). References indicate Total P retention, as a result of marsh wetland restoration, range widely. Presently, in the case of Cth K marsh, the efficiency of P retention (pre-restoration) is likely to be low due to absence of plants and the presence of carp. Restoration of the marsh is expected to improve P retention efficiency but predicting this retention improvement is difficult (K. R. Reddy et al., 1999). Funding to be provided by GLSD.

4. **Silver Creek Estuary AIS Treatment Plan** – Begin with the spring of 2013 for first treatment, and then, proceed with an AIS control grant application during the summer of 2013 to acquire the necessary funding to cover the entire estuary over the next three to five years. Prevention of anaerobic conditions favoring P release from sediments will also be considered. This source of P release can potentially be managed with strategically designed mechanical harvest in conjunction with selective chemical control of EWM. Funded by GLSD along with an AIS Control Grant.

5. **Buffer Work** – Implement changes as discussed with LMP team, give new buffer approach (as outlined by Lynn Mathias) the chance to effect changes needed, if unsuccessful, pursue agricultural shore land management ordinance (first in GL then FDL). Funded through a Lake Planning Grant along with additional assistance by local partners (i.e. GL Co., etc).

6. **Evaluate feasibility of Urban Opportunities** – These opportunities include three high level strategies identified so far: first, look at alternatives for redirecting the Ripon WWTP discharge pipe to bypass Big Green Lake (i.e. Puchyan,). Second, to look at water treatment options for storm water end of pipe discharges in both Green Lake and Ripon. And third, to offer to have our engineers work with the cities of Green Lake and Ripon operations people to identify other urban nutrient reduction opportunities in addition to storm water. Funding to be provided by the GLSD.

How do we plan to measure the success of reaching our P reduction goals?

1. **Rerun SWAT at predetermined time** – initiate 2013 and after 10 year interval (2023) GLSD funded
2. **Rerun Lake Model** – initiate 2013 , and at 5 year interval (2018) GLSD funded
3. **Continue lake and stream tributaries monitoring with USGS and track USGS data and information on tributaries and Lake to validate improvements** GLSD funded

4. **Continue CLMN volunteer monitoring on lake** No funding required
5. **Annual Inventory of LMP Implemented Strategies & Solutions** No funding required (staff work)
6. **Site specific evaluation monitoring of County K estuary (to include aquatic plants, carp population, clarity, suspended solids, and total P loads)** No funding required (staff work)
7. **Keep our LMP Updated and Dynamic –** inventory completed lake and watershed improvement/protection activities and continue to investigate/add new initiatives

Watershed Objectives

1. Reduce nonpoint pollution sources by 10% over the next 10 years
2. Adopt a 10-year P reduction goal of 15% or 1.5% per year
3. Integrate and support objectives within the Green Lake County and Fond du Lac County Land and Water Resource Conservation plans
4. Protect surface waters from flooding and riparian zones from heavy erosion
5. Improve agricultural operations compliance with NR151 standards
6. Determine % of sediment and phosphorus loads from urban sources
7. Inventory shoreline conditions (integrates with Objectives in shore land strategy section)
8. Improve awareness within municipal and citizen base regarding watershed influence on water quality (integrates with objectives in I&E strategy section)

Watershed Strategy

1. Enhance watershed I&E in Green Lake and Fond du lac counties
    a. Conduct inlet stenciling and storm drain awareness campaign,
    b. Include-Shore owners, home owners, agriculture community, urban residents,
    c. Urban storm water management- Work with cities of Green lake and Ripon regarding storm water management, ordinance opportunities, street sweeping, and
    d. Erect road signs at all watershed boundary points especially main roadways.
2. Integrate watershed objectives with all water quality strategies, stream and lake related.
3. Ensure wetlands function for optimum water quality filtrations i.e. ensure plants abundance.
4. Review Nutrient Management Planning efficacy and compliance.
5. Review capacity of watershed regarding flood capacity and subsequently, possible actions.
6. Review the potential impact and permit compliance of CAFO (Concentrated Animal Feeding Operation) operators within the watershed.
7. With Grant Funding, contract with one individual to carry out the following:
    - Identify critical areas - *The project person needs to make an initial visit to those they think need buffers to simply introduce themselves and the goals/needs of the project. The relationship is critical to future success.*
    - Prepare a site specific financial incentive package utilizing existing Federal and State programs as well as partner funds. *Leverage key progressive farmers in the watershed that are well-respected in the watershed.*
    - Present the financial incentive package to the landowner during “one on one” meetings.
    - Assist the landowner with any and all program signup paperwork, and permit requirements.
    - Assist the landowner with securing resources for the installation of the appropriate BMPs. *Harvested buffers are recommended (they function well, do not grow up in brushy vegetation, and the harvesting actually removes some phosphorus).*
    - Submit bills for payment from the appropriate entities.
    - Track accomplishments through GIS.

- Utilize NR-151, FPP and other enforcement tools as necessary for non-cooperating landowners with critical sites

8. Grants
    a. Planning grants – study the watershed where we do not have sufficient P loading data (esp. Silver Creek) to make watershed improvement decisions. Modeling along with load appraisal studies, will be employed. Consecutive, staged grant projects would likely be required.
    b. Protection Grants – Pursue monies for BMP's to address the high priority sites. Prioritize the worst areas and work down the list while consulting with a committee to prioritize watershed work.
    c. TRIM Grants – Grants will be pursued based on availability, applicability, need, and workload capacity
9. Review agricultural operations within the watershed for compliance with NR151 agricultural standards.
    a. Identify operations that are not meeting current standards
    b. Prioritize operations based on sediment loading and distance
    c. Utilize programs to bring operations into compliance (EQIP, TRM, SWRM, etc.)
    d. Review efficacy of BMPs utilizing pre/post sampling for TSS and TP
10. Model urban areas and estimate urban loadings for sediment and phosphorus. Some limited monitoring could be involved.

The criteria listed below are used as guidance for the State of Wisconsin grants application review. Recommendations included within this plan, especially those directed at best management practice (BMP) installation and funding, may not address the 9 criteria below, but they acknowledge the need for these criteria to be satisfied when specific BMP actions are initiated.

EPA's- 9 Criteria for Watershed Projects

The nine elements of a comprehensive watershed plan per FY03 EPA Guidance are:

a. An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan.

b. An estimate of the load reductions expected for the management measures described under paragraph (c) below.

c. A description of the NPS management measures that will need to be implemented to achieve the load reductions estimated under paragraph (b) above and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

d. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan.

e. An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

f. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.

g. A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

h. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a NPS TMDL has been established, whether the NPS TMDL needs to be revised.

i. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

Fishery

Introduction

Big Green Lake is still capable of supporting a cold water Lake Trout fishery that is maintained by stocking. It is one of only a handful of inland lakes, in the state, that has a Lake Trout fishery. Because of the uniqueness of the Coldwater fishery, this aspect of the lakes management has received most of the attention. However the predominate fish in the lake are cool and warmwater species. Self-sustaining populations of northern pike, walleye, smallmouth and largemouth bass, bluegill, crappie, white bass, yellow perch, rock bass and channel catfish provide a high quality, heavily utilized fishery. The majority of anglers seek these species. Conflicting viewpoints over management priorities have resulted in considerable controversy.

Warmwater Fishery

The predominant fishery in Green Lake is a warmwater fishery. Past surveys have shown excellent, naturally reproducing populations of small and largemouth bass, walleye, northern pike, white bass, channel catfish, along with pan fish species such as bluegill, black and white crappie, yellow perch and rock bass. Green Lake also contains a low-density population of muskellunge that is sustained through stocking.

Northern Pike are a highly prized game fish in Big Green Lake. Pike rely on shallow, marshy habitat to spawn and create successful year classes. Development, heavy boat traffic, and carp have degraded much of this habitat. Attempts have been made to improve the marshy inlet areas of Green Lake to improve conditions for northern pike spawning. The 26” size limit and bag of two was also implemented to help improve the pike population. Although the population appears to be stable, angler harvest may still be having the greatest impact on the pike population. Habitat improvement measures may help to assure that northern pike continue to thrive.

The **Walleye** population in Green Lake is considered to be a self-sustaining low-density population. Because of fluctuating year classes, the population has not been able to reach its maximum potential, but it is one that is heavily targeted by anglers. The lake also contains little littoral (shallow) habitat that is key to walleye success. The great depth of Green Lake along with slow warming in the spring reduces the success for spawning walleye in the main lake. Slow warming temperatures in combination with heavy algae blooms may be contributing to low hatching success of eggs. Predation on eggs, fry, and small fingerlings also may affect the success of walleye year classes. In years of good spring runoff and sufficient flows in Silver Creek, walleye have been known to migrate up the creek to spawn. Historically, good year classes were documented in those years. Requests from the public to stock walleye into Green Lake have been denied by the DNR because of genetic concerns. The Green Lake Chapter of Walleyes for Tomorrow has operated a portable hatchery for many years in an attempt to improve the walleye population. Contributions to the population, up to this point, have not been documented.

Smallmouth and Largemouth Bass are popular with many anglers. Green Lake, with its steep rocky shorelines and numerous bars, is ideal habitat for smallmouth bass. Populations appear to be stable with year classes being produced in most years and good growth rates. Largemouth bass, which rely more on shallow vegetated areas, are more susceptible to the habitat losses and lack of littoral areas. Efforts need to be taken to protect these critical habitats and restore areas that have been degraded. Like smallmouth, the largemouth does appear to be producing year classes in most years and do exhibit good growth rates. However, there exists potential to improve critical habitat and increase these populations.

Interest in a low density **Musky** fishery has been evident for many years. Private clubs along with the WDNR have been stocking musky, in low numbers, for a number of years. Musky have been showing up in the angler's creel and in recent surveys. The current plan is to manage the musky as a low-density trophy fishery. Some 2500 fingerlings are stocked each fall to maintain this fishery. In recent years there has been some concern from local fishermen, that the musky may be having negative impacts on other species.

Pan fish species including Bluegill, Black and White Crappie, Yellow Perch and Rock Bass are highly targeted by anglers. All pan fish species rely on healthy littoral zones to thrive. Intensive development has put pressure on these areas including the loss of near shore vegetation and coarse woody debris. Although healthy populations of pan fish do exist, habitat protection and restoration are key to help improve population numbers to reach their full potential.

Control of **carp** has been an issue since shortly after they were introduced into waters of Wisconsin. Although the numbers of carp in Green Lake do not appear to be of nuisance numbers, they can be very destructive of shallow habitat when they concentrate in these areas to spawn. Because of the shortage of shallow littoral habitat, it is more critical to protect these areas from damage. Attempts have been made over the years to reduce carp numbers and the impact that they have on fragile habitat. Use of carp barriers, and removal by commercial fishermen are two methods that are currently being used to help restore native vegetation in the inlet bays of Green Lake. The two barriers in place on the Cty A and Cty K bridges are fairly new and hopefully will do a good job at preventing carp from entering these sensitive areas. The Cty A marsh has had a functioning barrier in place for a number of years and the benefits of the reduction in carp are reflected in the resurgence of aquatic plants. The Cty K barrier is fairly new and we are hopeful that if the Commercial Fishermen can remove some substantial numbers of carp from behind the trap, a similar response will occur. If Carp numbers cannot be reduced, a potential project to chemically treat the marsh may be considered.

Green filamentous algae (*Cladophora*) dominate large parts of the lake-bed of the north shore shallows zone early in spring and into the summer. This condition is suspected of limiting fish reproduction, particularly walleye spawning success. We know watershed runoff nutrients could be a factor. Nutrient influx at the lake bed as a result of other sources, including lawn fertilizer, zebra mussel feces, and groundwater contaminants could also be factors. This phenomena, although not directly linked, is also occurring along Lake Michigan shorelines. It is also possible that lake warming due to climate change influences algae mass.

"Does the drought make Cladophora worse?" http://dnr.wi.gov/lakes/commonquestions/

> "Cladophora, which grows in Lake Michigan, is a little bit different than blue-green algae. Since it grows on the lake-bed, it needs clear water, but growth (cell division) is still a function of water temperature. High water temperatures increase biological activity and potentially (and likely) increase the growth rate of *Cladophora*. And while greater growth of *Cladophora* doesn't mean more toxins, what it does mean is that more ends up on the beach, causing much higher bacterial counts, which is a problem."

Coldwater Fishery

The primary emphasis for the Coldwater fishery has been a stocked lake trout fishery and a native cisco population. Although other species of cold-water fish including splake, brook, brown and rainbow trout have been stocked, lake trout have a long history and tradition in Big Green Lake. They were first stocked in 1886 and have provided a prized and popular fishery for many years. The Department of Natural Resources feels that **Lake Trout** are the best suited cold-water species for Green Lake and has set an annual stocking quota of 25,000 yearlings. Size, quality and survival of these fish have greatly improved since the establishment of the Green Lake Cooperative fish rearing facility. The Green Lake Sanitary District owns this facility and the fish are raised in Cooperation with the WDNR. Fish are brought to the facility, as small fingerlings, around August, held over winter and stocked out as spring yearlings in April. This stocking strategy has resulted in a lake trout population that remains fairly stable.

Reports of adult lake trout scarring (from predation?) also have been received. It is reported to occur among trout in the length class of 20 to 26 inches. The cause is not confirmed, but it is suggested musky are responsible. Because the lake supports both a cold- and warm-water fishery, some conflicts might be occurring.

Cisco are native to Big Green Lake and have provided a unique addition to the fishery for many years. Although the population has fluctuated over the years it continues to provide a heavily utilized fishery. Populations of cisco are on the decline in many inland lakes possibly due to eutrophication and concomitant changes in the lake ecology. Recent gill net surveys show a slight decline in cisco abundance. The population up till now has remained robust, but changes in the bag limit of this fragile species may be considered.

A recent study was conducted by the University of Wisconsin-Madison and the Wisconsin Department of Natural Resources to gauge how warm lakes in the state were becoming and the rise in the population of invasive aquatic species. According to Sapna Sharma, a researcher at the UW-Madison Center for Limnology and the lead author of the study, 2100, 30 to 70 percent of cisco populations could be extirpated in Wisconsin due to climate change (Sharma 2011). The study concludes that cisco are much more at risk due to climate change rather than interactions with exotic species.

Oxygen levels in the west basin appear to be threatened as indicated by sediment analysis. The analysis looked at ratios of iron: manganese over a long-term period. The results indicate decreasing oxygen levels in the west basin of the lake. This suspected long-term trend is due to increasing productivity over time. The implications could be severe for the fishery if the trend continues downward. Further examination of the O_2 issue is warranted. Although not an eminent short-term threat, the condition should be appraised for long-range implications to the fishery and water quality of the lake.

Objectives for the Fishery

1. Improve public I&E opportunities to integrate with fish management activity
2. Protect the balance within the two-tier fishery
3. Create cold water fishery advisory committee
4. Investigate predation of lake trout
5. Protect spawning beds and nursery areas (i.e., in shallow waters)
6. Restore degraded fish spawning and nursery areas
7. Monitor Carp activity and continue commercial harvest
8. Conduct routine sampling to assure the health of the fishery

Strategy for the Fishery

1. Grow educational opportunities re: fish farming, management in fish raising, biological, financial aspects
2. Ensure the protection and maintenance of sensitive areas for nursery, feeding, shelter through support of cross strategies for aquatic plants and water quality
3. Conduct an analysis of problem areas of filamentous algae growth
    a. Determine areal coverage and evaluate growth trends of filamentous algae
    b. Conduct appraisal of causal factors (nutrients in groundwater, zebra mussels, land runoff and climate change)
4. Explore possible link; musky vs. lake trout management conflict. Assure that current stocking and adult population remains at levels that will not negatively affect the predator/prey relationship. Determine degree of significance and alternative management actions if appropriate

Natural Aesthetics and Land Conservancy

Steep bluffs and woodlands are natural features of some Green Lake shores. In many areas bluffs allow for pier development yet restrict properties from being constructed near shore. Likewise, many of the parcels are wooded for the same reason. The bluffs of dolomite and sandstone create a vertical relief feature uncommon for regional lakes. Green lake features deep and relatively clear water, with the green hue originating with the lakes plankton community. The more than 7,300 acres of open water space enhance the on-water experience and provides an uncluttered open surface for boating.

Several areas around the lake stand out: Sugarloaf, Green Lake Conference Center grounds, County Park Marsh (CTH K), Silver Creek estuary, Blackbird Point, Sugar Island, Sandstone Bluff, Sliding Rock, the Millpond, Norwegian Bay Wetlands (Eddy 2001), and Mitchell Glen (Eddy 1999) feature their own special aesthetic qualities. Some of these properties are completely protected through the Green Lake Conservancy (Eddy 2012). The view vistas are diverse and also include farmland and residential views. Many of the homes are distinctive in their history, construction and placement.

The Green Lake Conservancy has made tremendous progress through its land preservation actions. Several properties (see Land Preservation section) with special values are preserved.

There are 14 properties now under conservancy protection. Each property has its own unique aesthetic features and value. Management employs multiple tools in order to preserve and maximize upon the intrinsic values. These include trails, invasive species control, flora and fauna appraisals, public access, education integration, view vista preservation, elevated boardwalks and hard work.

The following map and listing provide a good overview of the Green Lake landscape.

Figure 22 Map of Conservancy properties. Each marked dot represents a Conservancy property that is protected in perpetuity.

Green Lake Conservancy Partnership Properties

Assembly Creek and Springs

This beautiful 20+ acre property was purchased from the Green Lake Conference Center in 2008. Hammer's Trail (a walking loop of about 2/3 mile) was established in 2009, and included the construction of five bridges over several creeks and springs, which merge into Assembly Creek flowing into Norwegian Bay. The trailhead and parking area is just west of the GLCC's historic Tea House, near the Green Lake Sanitary District lift station. It can also be reached by boat from Green Lake.

Blackbird Point Wetlands

Acquired in 1998, this property consists of 5+ acres of cattail marsh and forest on the east side of Blackbird Point Road, north of McAfee Road. These wetlands help provide a buffer for the waters of Green Lake, as well as a home for native plants and wildlife.

Folsom Nature Preserve (private conservation easement – no public access)

This 551-acre working farm is the first conservation easement undertaken by the Green Lake Conservancy Foundation, with the property title retained by the landowner. It includes a diverse portion of lowland marshes and sedge meadows that border Silver Creek, with many springs and seepages that feed into this waterway and eventually into Green Lake. This legal designation will help to ensure that the native plant communities and their associated animals will remain protected for future generations.

Forest Avenue Oak Savanna

With a conveyance and donations from the Green Lake neighbors, the GLCF restored a previous commercial property to native oak savanna, the dominant vegetation community of the Green Lake region prior to European settlement.

Guskey & Miller Prairies

These two adjacent properties include 38.8 acres of restored tall grass prairie and forest that borders Silver Creek. The native grassland buffer filters and absorbs surface water runoff before it enters Green Lake's main tributary.

Mitchell Glen Conservancy (restricted access)

Formerly owned by S. D. Mitchell, this magnificent glen contains 12.2 acres of maple-basswood climax forest. It includes unique geological formations, outstanding biodiversity, and the spring-fed waters of Glen Creek, which drains into Green Lake. Public access is limited to guided tours that are offered once or twice annually by the Green Lake Sanitary District.

Norwegian Bay Wetlands

Contains 20.5 acres of wetlands and Green Lake shoreline on Norwegian Bay. The marshy vegetation and adjacent bay provide a vital spawn area for fish and habitat for a variety of wildlife, including songbirds and amphibians. Accessible via the trail and boardwalk from Bay Road, or by boat via Norwegian Bay.

Pools Hill Nature Preserve

Consists of nearly three acres of wetland vegetation and upland trees and grassland bordering the Silver Creek Inlet. This property is only accessible by boat (or across the ice in winter) from the Inlet.

Silver Point Wetlands

Property consists of a narrow strip of wetland vegetation extending along County Road A at the Silver Creek Inlet. It protects about two acres of shoreline, and is directly across the Inlet from the Sugar Island conservancy.

Sugar Island Wetlands

Protected in 2004, this conservancy includes about 30 acres of critical shoreland habitat on Silver Creek, Green Lake's main tributary. The property includes cattail marsh, lowland forest and Sugar Island, a site where the Ho-Chunk Native Americans made maple sugar. Accessible via boat during warmer months, or across the frozen Inlet in the winter.

Sunnyside Conservancy

Located along Silver Creek Inlet, the 44+ acre property contains a mixture of woods, shrubs, grasslands and wetlands along several man-made channels. The total shoreline in this conservancy is over a mile. Walking trails extend from the parking area off Lakeview Road, or it may be accessed by boat via Silver Creek Inlet. Over time, we hope to restore the upland fields to native prairie and oak savanna.

Tuleta Hill Prairie

This conservancy contains 7.5 acres along Tuleta Hill Road. Previously farmland, this area is being restored over time to prairie and oak savanna with walking paths.

Wick Nature Preserve

This conservancy protects 3.2 acres of mature oak forest and wetlands that store and filter surface water runoff before it drains into Green Lake. Considerable work has been undertaken to remove invasive buckthorn shrubs, and establish plantings of native woodland vegetation.

Winnebago Trail Conservancy

Originally part of the Green Lake Conference Center, this property consists of 7+ acres of sloping forest and a bit of relict prairie along the north shore of Green Lake. It contains a former Indian trail that follows along the elevated shoreline, and is accessible from the trailhead near the historic Lawson water tower on Hillside Road. The eastern access trail extends under the large stone arch and up to the GLCC's missionary trail – and one can take a quick right to return to Hillside Road, and then follow it west back to the parking area.

Objectives for Lands Conservancy and Aesthetic Preservation

1. Maintain the organizational partnership and success
2. Maintain the lands under protection while seeking new opportunities
3. Promote regional handicap and broad community integration

Strategy for Land Conservancy and Aesthetic Preservation

1. Support and maintain the Green Lake Conservancy and partners through grants, donations, financial incentives and community actions
2. Work actively with realtors and property owners regarding conservancy opportunities
3. Identify a vision for the next level of objectives in the conservancy partnership
4. Survey existing property uses (could incorporate into an economic impact study)
5. Promote the success of the program
6. Promote access to appropriate recreational opportunities at properties including handicap access
7. Protect sensitive features on properties with unique qualities, and restore, to the degree reasonable, all properties to their natural state, thereby ensuring habitat, water quality functions and historical significance
8. Develop guidelines for specific and variable uses of existing Conservancy properties. Rules need to be clear, and maintaining of property character

Shorelines and Shoreland

Home of RSVP (revitalization of shoreland vegetation project), an award-winning innovative restoration program, Green Lake has been a leader in Wisconsin shore protection and restoration. Local leadership from the GLA/GLSD partnership was strong and key to the program's success (Hill. N. and Marks, C.). The RSVP partnership integrates private business, municipal properties, private shorelines, technical applications assistance and cost share.

Shore development, access clearing, rip-rap installations, boat houses, pier expansion, removal of trees and logs, and navigational demands have collectively peeled away important shore structure that would otherwise support habitat for fish and wildlife, increase biodiversity, and improve water quality and general aesthetics (i.e., a sense of wildness). Bulrush beds, that are critical to pike spawning success, have experienced large losses (estimate 90%) with the only exception being protected bays and backwater shallows. Continued pressure on the lake shoreline illustrates the conflict of best practices for lake management vs. individual preference. Original shoreline features are unlikely to be fully restored, but much can be done to improve the situation.

The following text is an excerpt from a conservancy property site conservation plan and illustrates the issues.

Green Lake Conference Center and Norwegian Bay Property

Biodiversity is another conservation target. Healthy shore habitat and the associated native plant and animal communities are declining. This reality is occurring at Green Lake and all over the state. Healthy natural and native submergent, emergent and floating leaf plant communities are under increasing threats and require cautious management via protective and restorative actions. Stands of hard stem bulrush located adjacent to the site are mere remnants of a former emergent plant community. Floating leaf communities of white, yellow, and spatterdock lily have declined. Aquatic invasive species, especially Eurasian water milfoil and curly-leaf pondweed promote monotypic conditions and biodiversity loss.

Woody structure, another contributor to biodiversity in Green Lake, is increasingly rare. The physical structural diversity of fallen trees and overhanging branches near the water's edge creates micro- and macrohabitats and diverse niches for amphibians, reptiles, shore birds, raptors, forage fish and invertebrates. The resilience of a biodiverse shoreline and upland is critical for sustaining a native natural condition.

Objectives for Shorelines and Shore Land

1. Preserve natural views
2. Preserve and restore biodiversity of shorelines

Strategy for Shorelines and Shore Land

1. Renew the RSVP program. Enhance the program for the restoration of woody habitat on shorelines considering:
    a. Safety / Durability / Efficacy / Habitat priorities / Cost- Benefit
    b. Inventory significant woody habitat
    c. Identify potential restoration sites
    d. Complete "pilot" restoration

2. Encourage "no motor, no wake" behavior for sensitive shallow water habitat. Silver Creek estuaries, Norwegian Bay bulrush, County Park Marsh are included. Habitat protection ordinances and I&E tools should be employed where appropriate.
3. Identify principle view sites and approaches for preservation
4. Employ zoning when possible to preserve natural lake values

Information and Education

The principle I&E outlets on Green Lake are (1) the Green Lake Association (GLA), (2) the Green Lake Sanitary District (GLSD), and (3) the Green Lake County Land Conservation Department (GLCLCD). These groups have provided consistent leadership while integrating with the lake community. Newsletters, community events and educational forums are focused on the fishery, recreation opportunities, ecology, aquatic invasive species, natural history, land stewardship, partnering and more. Partners in Fond du Lac County are also active in the watershed, although less directly involved on the lake itself.

Objectives for I & E

1. Improve the public's understanding of lakes, streams, watersheds, and how these resources impact community and quality of life
2. Improve communications between partners to leverage and expand our outreach efforts

Strategy for I & E

1. Construct a virtual watershed tour. This "tour" would be an interactive web based program that allows the user to experience the issues and solutions of lake, stream, and land within the Green Lake watershed. It is recommended that the virtual tour project be initiated in 2013.

2. Construct a website linking all of the individual environmental lake organizations, aka a portal site for directing and enabling communications and information sharing
3. Summarize lake and watershed trends in media.(newsletters, web sites, newspapers) Examples: Oxygen depletion trends in west basin of lake / possible cold water fishery impacts due to climate change / total phosphorous trends in the lake water / Aquatic Invasive Species trends and invasions / algal trends in growth / user conflicts.
4. Continue the Green Team actions; an example, the fish hatchery education initiative (GLSD) and Youth Angler program (GLA).
5. Complete an economic analysis of the "natural capital" of the lake resource as it relates to the local business community and incorporate findings into the broader I&E program
6. Continue GLA's outreach initiatives and integrate the Priority Action Plan objectives
7. Develop and Implement "Watershed Outreach Campaign" with guidance via EPA
8. Work with partners to provide watershed education opportunities to the public.

Management Capacity, Objectives and Strategies

Management at Green Lake has been exemplary. Local leadership has been strong, and the results are obvious to those associated with the critical aspects of lake management. A challenge for the lake community and its leadership is maintenance of management capacity. Proper attention to management capacity involves all partners, including the general public.

One issue rising to the top relates to the public's understanding of "who does what" in the lake and watershed. Because multiple interests are involved clarity of responsibility is blurred. Aside from principle management units GLSD, GLA, GL LWCD, and WDNR, there are many stakeholders. The challenge for the partnership will be to act on, and promote, continued integration, while improving the public's understanding about management structure.

Evaluation of BMP's and restorations — Although it might seem unrelated, the evaluation of BMP's (Best Management Practices) and restorations (County Park marsh, potentially) is closely associated with management capacity. An improved understanding of BMP/restoration outcomes (their success or failure) will ensure long-range support for our lake management actions. Sufficient evaluation monitoring or modeling will make it possible to sustain partnerships with stakeholders. This issue (evaluation of actions) was identified in the public participation process. Questions arise, such as "are we getting our money's worth" and "how well did the BMP (or other management actions) perform" are reflecting real concern from partners and citizens whom we expect to support the overall lake management mission.

The principle management units continue to evolve and this evolution demands acknowledgement of respective responsibilities. All units have grown in recent decades thereby creating a more complex management structure around the lake. As responsibilities grow, so does the need for disseminating information.

All individuals on a team must be equipped with working skills in order to effectively represent themselves and their respective management unit. Working on cooperative projects and being on a team with common objectives requires knowledge of human nature, consensus building, and team process. Building these skills is not an easy task. Advanced learning for maintaining a long range strong partnership is necessary.

Objectives for Management Capacity

1. Improve public understanding of management organization in the watershed and lake
2. Maintain and enhance the partnerships among principle and secondary management units
3. Improve understanding of cost/benefits, and efficacy of BMPs
4. Enhance the capacity of individuals on the team to be effective partners

Strategy for Management Capacity

1. Provide a clear description of management unit responsibilities and interaction with partners. This can be partially completed via existing I&E vehicles including partner's newsletters and annual meetings. Develop professional publications which list all the organizations, what they do, how they do it, and how they work together
2. Evaluate priorities on annual basis and make adjustments
3. On an annual basis evaluate and report on efficacy of a significant restoration or BMP installation (to include cost/benefit analysis). Examine and adopt a "model" review process for these evaluations.
4. Create a timeline chart with management accomplishments. This should include significant milestones for all local partner organizations.
5. Complete training in team and consensus process to all team members

Climate Change

Climate change is a controversial topic. Politics can impede or support carbon trading, energy efficiency regulation, conservation, research, and education in our schools. In the planning of management for Green Lake a conservative approach is taken. Rather than ignore the issue, or relegate it as a "hopeless" cause, we are acknowledging the scientific basis and climate theory accepted by the majority of climate experts. We believe this is *the safest* route to take. Climate trends indicate increasing average temperatures, greater flooding, and longer droughts. Some considerations for Green Lake and the region are outlined below.

- Flooding events are destabilizing. Storm water filtering in wetlands decreases while elevated water levels suffocate plant communities during extended or repeated flooding events. All the while, sediment loads to the lake and tributaries increase.
- Greater pollutant delivery to the lake as a result of failing designs, based on design standards adopted in earlier decades. As rainfall intensity increases in the watershed, stream capacity as well as the capacity of standard pollution control installations, can be overwhelmed
- Intensive rains and increased runoff rates prevent the recharge of aquifers leading to groundwater depletion
- Changing thermal properties affect plankton, fish, wildlife, leading to biological instability

Floods will increase in magnitude and frequency. Flooding will stress emergent and submergent aquatic plants especially in tributary areas like Silver Creek and County Park marsh. Well maintained stable wetlands and riverine systems will have greater resilience to stress. Resilience ensures these areas will serve as biological nurseries for fish and other species, and provide water quality filtering functions. Protecting and restoring these areas is an investment in long-range lake health. Resilient shallow water areas and riparian wetlands support aquatic plants, which lead to increased water clarity. With limited assumptions and applied science, anticipated climatic trends and their impact on the area lakes can be managed to a reasonable degree. The cause will be difficult to manage at the local level however. The lakes sensitivity to the longer-range threats must be acknowledged so we can react with appropriate management steps to minimize the negative impacts.

As average temperatures increase, the atmosphere is able to hold more water as vapor, resulting in more frequent and intensive rainfall. Increased intensity of rainfall results in a great percentage and total volume of runoff and associated suspended loads. The standards used to construct much of the storm water infrastructure throughout the watershed were not designed for anticipated runoff quantities that we can expect in the future. The majority of storm water infrastructure is based on anticipated storm volumes that occur once every 10 to 25 years (4.0 to 4.6 inches of rainfall in a 24 hour period). This resulted in the structures being overtopped or bypassed once per decade or less. As storm intensities increase, these storm water controls are providing fewer efficacies, and designs will need to be modified in the future to manage these changes. These numbers might sound distant and unrelated to recreation, but recreational uses will be affected. More use conflicts with plants are likely, fish species can shift, and invading organisms thrive. A flood series (repeating events over a small time period) can wipe out entire wetland plant communities. The cascading effects are mostly negative. Water quality filtering is reduced, wildlife, fish recruitment, is lost for long periods or decades in many cases.

New BMP's (best management practices) will be considered to counter the effects. Some of the phenomena we anticipated under climate change scenarios are now starting to play out. Not always obvious, the effects are predictable when averaged data is examined. It is the average that must be focused on. Single, outside the norm events, do not illustrate the average condition, but only a single isolated short-term condition. *Averages* are key to understanding the climatic changes.

As the average seasonal temperature increases, duration of lake ice cover will be reduced. Fewer days of ice on the lake will allow for greater light penetration into the water. Thus, light, instead of reflecting off the ice, will be absorbed by the water, which will increase the heat that the lake absorbs. As a result temperature increases within the lake will affect the coldwater and warmwater fishery. Intensity and duration of light penetration for plant growth will affect timing, quantity and quality of the lake plants. Unfortunately, filamentous algae (e.g *Cladophora*) are among the plants affected.

Actions also need to be taken by upstream stakeholders within the watershed. Ripon for example is a major stakeholder in the health of Green Lake. The value of the lake for the Ripon area is critical to Ripon's economy. The economy of Ripon and region is dependent on high quality recreation. It is within the city's interests to remain a strong partner in lake protection. Possible actions include constructing sediment basins in critical hydrologic units around and within the city. Buffers, yard care, street cleaning practices, rain gardens, diversions, and artificial wetlands are some of the actions possible.

The following graph is an illustration of the climate trends being recorded in Wisconsin. The duration of ice cover on many Wisconsin lakes is decreasing and the graph shows the ice cover period for Green Lake has decreased by over 25 days since 1940. At the rate indicated, Green Lake will lose one full day of ice every three years for the foreseeable future. This may be perceived as a minor loss but, at the rate of ice loss indicated, Green Lake will have zero ice cover by year 2087. Predictive models, based on CO_2 trends, are indicating accelerated warming. This means a faster warming trend than the trend indicated in the graph. Models predict ice will be gone sooner than 2087, possibly much sooner. A UW-Oshkosh Climatologist (Peterson) predicted in 2008 that ice on Lake Winnebago would be gone by 2050 (Sesing, M. personal communication).

The trend is "warmer" globally and within the Green Lake community. July of 2012 was the warmest month recorded since records from the late 1800's.

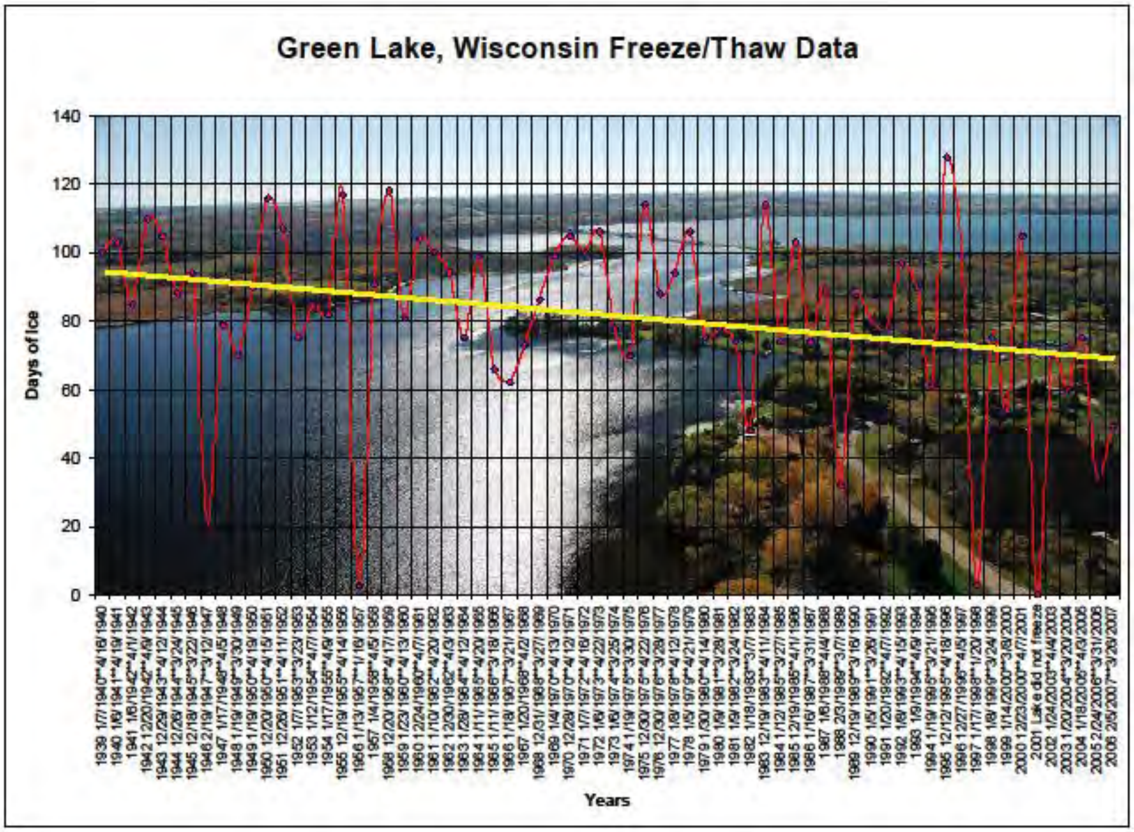

Figure 23 The duration of ice cover on Green Lake is decreasing as seen in the trend line above. The graph covers a period from 1940 through 2007 or 66 years of record. Similar trends are occurring on Lake Mendota and other Wisconsin lakes (Eddy, T).

For further information on climate change in Wisconsin refer to the website "Wisconsin Initiative on Climate Change Impacts (UW WI, 2010): http://www.wicci.wisc.edu/

Objectives for Climate Change

1. Manage Green Lake to counterbalance negatives from climate change
2. Promote understanding of the issue locally
3. Integrate anticipated climate issues into lake planning

Strategy for Climate Change

1. Promote innovation in existing and future BMP construction
2. Enhance the I&E program at Green to include objectives re: local understanding climate change effects
3. Encourage robust, native and diverse wetland, riparian, and aquatic plant communities within the entire watershed area including Silver Creek and County Park Marsh shallow water areas.
4. Complete a feasibility analysis for creating a long-range wild shore zones in the Silver creek and Co Park Marsh estuaries. Acquisitions and zoning are specific actions that could be considered.

The outcome of this approach could also serve to manage user conflicts as related to dense aquatic plant growth.

5. Ensure future watershed development meets existing design standards *or better*, in anticipation of climate change induced flooding in the watershed. This would pertain to storm water structures, agriculture, new development, municipal storm water control. Define a process for lake partnership review, support, and implementation.
6. Appraise Ripon Dam and Millpond conditions, review potential flooding issues and feasibility of dam removal at Ripon Millpond. Economic, biological effects to consider, safety issues to consider.
7. Identify operational contingencies/limitations for Green lake outlet dam as it relates to flooding and dam protection. Partnerships with Green Lake County Emergency Management division required.
8. Identify and report on opportunities for reducing impervious areas around the lake and in city of Ripon. Work with the City of Ripon on storm water control, rain gardens, or other appropriate storm or pollutant attenuation actions.

Use Conflicts

Use conflicts are largely driven by a few issues on the lake. The predominant one is arguably nuisance aquatic plants in shallow waters of the lake system. This conflict is difficult to resolve, because it is inherent that dense aquatic plants and navigational expectations (or aesthetic “look”) are in opposition to one another. Ultimately one or the other must give way, or both can compromise. Complete resolution is unrealistic as long as the opposing conditions exist so one must look toward management that lessens the conflict if it is desired to maintain the desired uses.

In the case of shallow water area around the lake, the conflict is apparent; too many plants in an area of user demands. Navigation, fishing, swimming, and overall appearance are in conflict and these uses are reduced. On the other hand, a well-established and stable plant population on the shoreline of the lake builds resilience to extreme nutrient loads, invading species, flooding, and shore erosion.

In some cases the multiple use of an area might be unsustainable: i.e. the uses, or one of the uses, should not be maintained. Take the example of Norwegian Bay; lake safety is a necessary condition for the lake using public. Safety and boating can be conflicted as in the case of Norwegian Bay shallow water zones where high speed recreational boating is in conflict with the safety of children and adults wading within close proximity of the boating behavior. This is a case where boating behavior can be modified through local ordinance adoption: i.e. no wake zoning. Boating can continue, but at a reduced speed. In this case the existing use, speed boating/water skiing, would not be maintained and considered non-sustainable.

Objectives for Use Conflict

1. Ensure the safety of all lake users
2. Protect and enhance multiple uses on the lake while considering sustainability of the natural lake features
3. Determine and maintain the optimal balance of aquatic plant density (conditions) in multiple use recreation zones. These zones occur primarily within areas of critical (sensitive) habitat where residential uses are significant or navigation demands are high.

Strategy for Use Conflict

1. Maintain nuisance plant harvesting (presuming natural characteristics are protected). This could involve enhancing the harvesting approaches through additional equipment, schedule changes, staffing changes, or other means to manage use conflicts or its causes. Exploration of acquiring a 2nd harvester is recommended.
2. Provide I&E for shore areas where resource condition value is high and use conflicts occur.
3. Where practical reduce the conflict through easement or leasing of lands where the conflict happens. Consider purchase of "use rights".
4. Commit to maintaining complete aquatic plant community functions in critical habitat areas.
5. Investigate alternative approaches to cutting and harvesting. Bio control, research plots, I&E, regulation, and boating behavior change.
6. Define and employ optimum balance of management in multiple use recreation areas.
7. Establish a "no wake" zone in the west end of Norwegian Bay from the existing bulrush stand westward to the shore of the conservancy wetland.

Glossary of Lake Terms

Aerobic: Requiring oxygen to live or occurring in the presence of oxygen.

Anaerobic: The absence of oxygen (also anoxic).

Algae: Simple single-celled (phytoplankton), colonial, or multi-celled, mostly aquatic plants, containing Chlorophyll And lacking roots, stems and leaves. Aquatic algae are microscopic plants that grow in sunlit water that contains phosphates, nitrates, and other nutrients. Algae, like all aquatic plants, add oxygen to the water and are important in the fish food chain. Algae is either suspended in water or attached to rocks and other substrates. Algae are an essential part of the lake ecosystem and provide the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short. (Refer to Phytoplankton and Periphyton)

Algal Bloom: A heavy growth of algae in and on a body of water. This usually is a result of high nitrates and phosphate concentrations entering water bodies.

Alkalinity or Acid Neutralizing Capacity (ANC): Describes the ability of the water to buffer any acidic inputs. This is typically low in NH lakes due to the lack of calcium in our soils and bedrock, which underlies our lakes.

Bedrock: The solid rock beneath the soil or loose sediments.

Benthic: Located on the bottom of a body of water or in the bottom sediments.

Bioaccumulation: The process by which the concentration of a substance is increased through successive links in a food chain, which may result in toxic concentrations at the top of the chain.

Best Management Practices (BMPs): An engineered structure or management activity that eliminates or reduces adverse environmental effects of pollutants.

Biological Production: Total amount or weight of living plants and animals that an ecosystem yields.

Buffer Strip: Grass or other vegetation planted between a waterway and an area of intensive land use in order to reduce erosion.

Chlorophyll-a: The green pigment found in plants and is essential for photosynthesis. It is sometimes used to measure the amount of algae in the lake.

Chlorides: Sodium chloride (table salt) is often used in Wisconsin to de-ice roadways during winter months. The salt (chloride) may then be washed into nearby lakes and streams resulting in elevated chloride levels in the water body. Elevated chloride levels can have an adverse effect on aquatic plants and animals. In public water supplies the EPA has set a standard that requires chloride levels not to exceed 250 mg/L due to possible health concerns.

Conductivity: A measure of the electrolytes in the water, which may be elevated by the presence of salts resulting from soil composition, faulty septic systems, or road salts.

Cultural Eutrophication: When human activities lead to the premature aging of a lake or pond.

Cyanobacteria (Blue-Green Algae): Bacteria that photosynthesize (use sunlight to produce food) and are blue-green in color. While cyanobacteria occur naturally in all lakes and ponds, elevated nutrient levels may cause cyanobacteria to "bloom" or grow out of control and cover the lake surface. The concern associated with cyanobacteria is that some species produce toxins that may affect domestic animals or humans through skin contact or ingestion. These toxins may cause a variety of symptoms, including nausea, vomiting, diarrhea, fever, skin rashes, eye and nose irritations, and general malaise. If you see a cyanobacteria bloom do not go in the water, do not drink the water, and do not let pets or livestock go in or drink the water.

Dimitic: A lake that mixes freely twice a year (once in the spring and once in the fall), is thermally stratified in the summer, and has a stable temperature in the winter.

Dissolved Oxygen: The amount of oxygen in the water. Dissolved oxygen may be produced by algae and aquatic plants or mixed into the water from the air. It is used by fish, aquatic insects, crayfish and other aquatic animals. Dissolved oxygen is usually measured in milligrams per liter.

Dredging: Removing solid matter from the bottom of a water body to make a deeper channel.

E. coli: A common bacteria that is specific to the intestines of warm blooded animals. It is often used as an indicator of the possible presence of other, more harmful (pathogenic) bacteria.

Ecology: The study of the interactions between organisms and their environments.

Epilimnion: The upper, well-circulated, warm layer of a thermally stratified lake. (Refer to Hypolimnion and Metalimnion)

Erosion: The gradual wearing a way of land surface materials, especially rocks, sediments, and soils, by the action of water, wind, or a glacier. Usually erosion also involves the transport of eroded material from one place to another.

Eutrophic: Nutrient rich waters, generally characterized by high levels of biological production. (Refer to Mesotrophic and Oligotrophic)

Exotic Species: A plant or animal species introduced to an area from another country or state that is not native to the area.

Food Chain: A succession of organisms in an ecological community that constitutes a continuation of food energy from one organism to another as each consumes a lower member and in turn is preyed upon by a higher member.

Groundwater: (1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturated zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

Headwater: The source and upper reaches of a stream; also the upper reaches of a reservoir.

Hypolimnion: The deep, cold, relatively undisturbed bottom waters of a thermally stratified lake. (Refer to Epilimnion and Metalimnion)

Internal Loading: The release of phosphorus from the lake bottom sediments into the bottom layer of the water; enhanced by oxygen levels on the bottom of the lake which are less than 0.5 milligrams per liter.

Kemmerer Bottle: A piece of equipment used to collect water samples from a specific depth in a lake or pond.

Lake Association: A voluntary organization made up of people who own land on or near a lake. The organization usually works towards preventing or solving any water quality concerns of the lake. A formal lake association should understand legal and tax issues, as well as keep financial records, and determine where funding will come from.

Leaching: The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

Lentic: Referring to standing waters such as ponds and lakes.

Limiting Nutrient: An essential nutrient for plant growth, which has the least abundance in the environment relative to the needs of the plant. Phosphorous is usually the limiting nutrient in freshwater lakes and rivers.

Limnology: The study of the biology, chemistry, and physics of freshwater lakes and ponds.

Littoral: The shoreline zone of a lake where sunlight penetrates to the bottom and is sufficient to support rooted plant growth.

Lotic: Refers to running waters such as streams and rivers.

Low-Impact Development: A type of site development and design in which runoff water is allowed to infiltrate into the soil rather than flowing directly into a lake or stream. Low-impact development allows the lake or stream to function in a more natural way, with less human impact. (Refer to Runoff)

Mercury: A naturally occurring metal that may be found in rocks, soils, sediments, and the atmosphere. Human activities, such as coal burning and industrial uses, have increased the amount of mercury emitted to the environment. Mercury may enter lakes by atmospheric deposition. The mercury then enters the food chain and bio accumulates in aquatic animals. Mercury data collection has occurred primarily in fish species. Please refer to the Fish Consumption Advisory for Freshwater Fish (Fact Sheet

ARD-EHP-25) for information on fish consumption guidelines, and mercury and other contaminants in fish.

Mesotrophic: Waters containing an intermediate level of nutrients and biological production. (Refer to Eutrophic and Oligotrophic)

Metalimnion: The middle layer of water in a thermally stratified lake, between the epilimnion and hypolimnion, where the decrease in temperature with depth is at its greatest. (Refer to Epilimnion and Hypolimnion)

Monomictic (Cold Lakes): Lakes with water temperatures never greater than 4° C and with only one period of circulation in the summer. These lakes are typically found in the Arctic or mountains and although they may be ice-free for brief periods in the summer, they are in frequent contact with glaciers or permafrost.

Monomictic (Warm Lakes): Lakes with water temperatures that do not drop below 4° C and circulate freely in the winter. These lakes stratify directly in the summer. Warm monomictic lakes are common to warm regions of the temperate zones, in particular in areas influenced by ocean climates and in mountainous areas of subtropical latitudes.

Non-Point Pollution: Pollution originating from a diffuse area (not a single point) in the watershed, often entering the water body via surface runoff or groundwater.

Nutrients: Inorganic substances required by plants to manufacture food by photosynthesis. Phosphorus is the nutrient that usually limits the amount of aquatic plant growth in New Hampshire lakes.

Oligotrophic: Nutrient poor waters, generally characterized by low biological production. (Refer to Eutrophic and Mesotrophic)

Oxbow Lake: A crescent-shaped lake formed when a meander of a river or stream is cut off from the main channel.

Paleolimnology: The science that studies ancient lakes from their sediments and fossils.

Periphyton: An assemblage of microorganisms (plants and animals) firmly attached to and growing upon solid surfaces, such as the bottom of a stream, rocks, logs, pilings, and other structures.

pH: The measure of how acidic the water is, on a scale of 1-14; 1 is very acidic, and 14 is very basic. New Hampshire lakes tend to be acidic due to acid rain and snow.

Phosphorus: The nutrient most necessary for plant and algal growth in New Hampshire lakes, which comes from many sources including faulty septic systems, lawn fertilizers, and decaying plant matter.

Phytoplankton: Microscopic plants that float within or on top of lake water. (Refer to Algae)

Plankton Net: A fine mesh net used to collect microscopic plants and animals.

Point Source Pollution: Pollution into a water body from a specific and identifiable source, such as industrial waste or municipal sewers.

Polymictic: A term used to describe shallow lakes that mix more than twice a year. These lakes may mix on a daily basis or every few days.

Riprap: Large rocks placed along the bank of a waterway to prevent erosion.

Runoff: Precipitation that enters surface waters from overland flow and from groundwater.

Sanitary Survey: A sanitary survey is used to identify existing or potential contaminants to a water body. Normally the contaminants of concern are pathogenic (harmful) organisms known to cause a variety of human diseases. A sanitary survey is usually conducted when high levels of contamination are suspected and the source is unknown. Some common sources of contamination include: sewage spills, faulty septic systems, and agriculture.

Secchi Disk: A simple device used for measuring the transparency of lakes. Usually it is a 20-cm diameter disk with black and white quadrants; in marine systems is can be 1 m in diameter.

Sedimentation: The transport and deposition of sediment particles by flowing water.

Silt Screen: A sheet of fabric placed around a construction site to trap sediments and prevent them from entering a water body.

Thermal Stratification: A process by which a deep lake becomes layered by temperature in the summer months. The layers will separate because colder water sinks to the bottom, leaving warmer water at the surface. Because these layers form chemical and biological barriers, limnologists sample at each layer of the lake. During the winter months, when ice forms on the lake, Inverse Thermal Stratification occurs under the ice, in which colder, less dense water overlies warmer, denser water near the maximum density of four degrees Celsius.

Thermocline: The point of maximum temperature decrease with depth in a thermally stratified lake.

Transparency: A measure of water clarity often determined by the depth at which a Secchi disk can be seen below the surface of the water. Transparency may be reduced by the presence of algae and suspended materials such as silt and pollen.

Tributary: A stream that flows to a larger stream or other body of water.

Trophic Classification: Biologically ranking the quality of lakes using a model that incorporates several parameters. In New Hampshire these parameters are: chlorophyll-a, Secchi disk transparency, aquatic plant abundance, and dissolved oxygen.

Trophic State: The trophic state of a lake is a general concept with no precise definition and no well-defined units of measure. In general, trophic state refers to the biological production, both plant and animal life, that occurs in a lake. The level of production that occurs is defined by several factors, but primarily by the phosphorus supply to the lake and the volume and residence time of the water in the lake. (Refer to Oligotrophic, Mesotrophic, Eutrophic)

Turbidity: A measure of the particles suspended in the water column which affect the clarity and transparency of the water. These particles may include silt, clay, and algae.

Vernal Pool: A contained basin lacking a permanent visual outlet. It may not contain water throughout the entire year and does not support fish.

Water Residence Time: The number of years required to completely replace the water volume of a lake by incoming water, assuming complete mixing.

Watershed: The land area draining to a particular water body. A watershed is often described as a funnel, where the lake or river is the bottom of the basin, collecting all the water that falls inside the funnel.

Watershed Districts and Ordinances: Methods of zoning that recognize watershed boundaries instead of political boundaries as a means of regulating land uses that may affect surface water quality. A watershed district or ordinance may implement regulations in the watershed in order to protect surface waters such as streams and lakes. Some of the regulations include: land use restrictions, buffer strip requirements, low-impact development, and best management practices. (Refer to Best Management Practices, Buffer Strips, and Low-Impact Development)

Watershed Management: Implementing practices within a watershed designed to protect or restore the water quality of the receiving water body. Such practices may include the implementation of Best Management Practices.

Zooplankton: Microscopic animals that live in lakes.

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