A Lake Management Plan for Green Lake

Green Lake, Wisconsin

Wisconsin's Deepest Natural Inland Lake

Part 2 - Appendices

Developed in Partnership

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Appendix A

Big Green Lake 2012 Citizen Survey Results

Submitted by J. McNelly

A total of 1000 surveys were sent to 500 riparian residents who owned property around Big Green Lake and 500 residents within the Big Green Lake Watershed; 55.7% (557) of the surveys were returned. Of the surveys that were returned 535 were filled out in their entirety (no questions were skipped) for a completed survey rate of approximately 96%.

Of the surveys returned 20.5% (111) respondents who answered the question lived on or owned property on the South Shore of Big Green Lake, 19% (103) lived or owned property on the North Shore of Big Green Lake, 12.7% (69) were located in the city of Ripon, 9.6% (52) were located in the city of Green Lake, 6.3% (34) were located in the Terrace on Big Green Lake, 5.9% (32) were located in rural Ripon, 5.9% (32) were located in Silver Creek Inlet, 5.2% (28) were located in Beyer's Cove, 5.0% (27) were located in Norwegian Bay, 3.7% (20) were located on the Mill Pond, 3.7% (20) were in Rural Green Lake, and 2.6% (14) were located in County K Marsh. Sixty eight percent of all respondents lived on or around Big Green Lake and 32% lived in the watershed but not on the lake.

The length of time that survey respondents had lived, owned property, or recreated on Big Green Lake varied greatly. Responses ranged from 1 year to 100 years, with an average of 28 years.

Respondents were asked to describe their primary use of the property they owned or lived on; 53% (281) of those that answered the question indicated that their primary use was as a seasonal resident, 40.4% (214) were as a primary resident, 2.6% (14) were as a rental, 1.9% (10) was agricultural, 1.1% (6) was commercial, and 0.9% (5) was undeveloped. While these percentages are only for survey respondents, they can serve as representative of the larger population around Big Green Lake. In order to reach the more transient populations that use Big Green Lake (seasonal residents, rentals, etc.) different methods of communication and outreach may need to be considered. There are also a number of different types of properties on and around Big Green Lake that may have different uses and interests in the lake and those too, should be considered when choosing management and outreach strategies. Seventy eight percent (384) of respondents who answered the question used their property throughout the year, 24.2% (121) used their property during May through August, 8.8% (44) used their property September through December, and 1.0% (5) used their property January through April.

Survey respondents were also asked why they had chosen to live on or near Big Green Lake. Of the respondents that answered the question 62.7% (298) indicated the quality of the lake, 45.9% (218) indicated recreational opportunities, 40.4% (192) indicated family tradition, 37.9% (180) indicated the low number of people using the lake, 34.7% (165) indicated distance from primary residence, 23.8% (113) indicated good property value, 21.1% (100) indicated retirement, and 20.4% (97) indicated surrounding communities. Respondents could also write in a response to this question. The most frequent write-in answers were for work or job and because family lived here. The reasons that respondents have chosen to own or use property on or near Big Green Lake, should be considered when choosing management strategies. Some of these reasons may be a desire to protect aspects of the lake, improve others, or be considered as drivers for change in management actions.

There are a number of organizations that help guide the future and management strategies on Big Green Lake. These include the Fond du Lac County Conservation Department, Green Lake Association, Green Lake Conservancy, Green Lake County Conservation Department, Green Lake Sanitary District, and Wisconsin DNR. The survey asked respondents how familiar they were with these organizations and agencies. Survey respondents indicated that they were most familiar and had contact/communication with the Green Lake Association (49.2%, 262) and Green Lake Sanitary District (53.9%, 287). Respondents were aware of the Green Lake Conservancy (46.5%, 245), Green Lake County Conservation Department (47.5Z%, 243), and the Wisconsin DNR (49.2%, 263). The Fond du Lac County Conservation Department was the least familiar to respondents, with over half (63.7%, 323) not being aware of the agency.

To gain a better understanding of factors that may influence a respondent's familiarity with these organizations this question was broken down by lakeshore respondents versus watershed respondents. For lakeshore respondents only, most were not aware of the Fond du Lac County Conservation Department (68%, 234), but did have personal contact with the Green Lake Association (60%, 219) and with the Green Lake Sanitary District (68%, 250). Most lakeshore resident were aware of, but had no personal contact with the Green Lake Conservancy (47%, 170) and the Green Lake County Conservation Department (49%, 170). Lakeshore survey respondents were closely split between having had personal contact with the Wisconsin DNR (49%, 177) and being aware of them but having no contact (46%, 167). Looking at the same question for watershed respondents only, most were not aware of the Fond du Lac County Conservation Department (55%, 86) and were aware of but had no personal contact with the Green Lake Association (45%, 72), Green Lake Conservancy (46%, 73), Green Lake County Conservation Department (45%, 69), Green Lake Sanitary District (54%, 85) and the Wisconsin DNR (57%, 92). It is also important to note that while it appears more watershed respondents had less contact with a number of agencies then lakeshore respondents, there were also more watershed respondents that were completely unaware of these agencies then lakeshore respondents. For example the Green Lake Association had 23% (36) of watershed respondents were unaware of the organization versus 4% (14) of lakeshore respondents. There are similar numbers for the Green Lake Conservancy where 35% (55) of watershed respondents were unaware but only 11% (40) of the lakeshore respondents were unaware and the Green Lake Sanitary District where 22% (34) of watershed respondents were unaware versus 3% (11) of the lakeshore respondents. The sanitary district also had much higher personal contact rates with lakeshore respondents (68%, 250) versus watershed respondents (18%, 29). It appears that the location of the survey respondents does play a role in the amount of personal contact and awareness that they had with local organizations. For organizations more closely tied to Big Green Lake, such as the Green Lake Association, Green Lake Conservancy, and Green Sanitary District, lakeshore residents not only had more personal contact but were also more aware of these organizations. There may be an opportunity for these organizations to reach out to watershed residents to share information about their organizations, what they do, and how watershed residents can participate in them and make a difference.

A follow-up question asked survey respondents how important they felt each organization was to the protection, conservation, and preservation of Big Green Lake. The Green Lake Sanitary District (64.9%, 336), The Green Lake Association (45.3%, 234), Green Lake Conservancy (44%, 227), and the Wisconsin DNR (50%, 258) were all indicated to be very important to the future of Green Lake. Respondents were somewhat split on their belief of how important the Green Lake County Conservation Department was to the future of Green Lake. 36.6% (188) of respondents felt that the Green Lake County Conservation Department was very important and 32.9% (169) were unsure of its importance. Respondents were largely unsure about the role of the Fond du Lac County Conservation Department with 53.9% (275)

unsure of its importance. The results of these two questions can show how familiar survey respondents are with local organizations and agencies. The results can show which organizations/agencies may be able to have a greater presence in or on Big Green Lake and the watershed so citizens can better understand the roles they are able to play in the protection, conservation and preservation of the lake. Again, this question was broken down by lakeshore respondents versus watershed respondents. Most lakeshore respondents felt that the Green Lake Association (50.7%, 176), Green Lake Conservancy (49.1%, 171), Green Lake Sanitary District (71%, 248), and the Wisconsin DNR (49%, 170) were very important to the protection, conservation, and preservation of Big Green Lake. Lakeshore respondents were somewhat split on the Green Lake County Conservation Department with 39% (135) feeling that they were very important and 32.3% (111) unsure. Most lakeshore respondents were also unsure (57.6%, 197) about the importance of the Fond du Lac Conservation Department.

Most watershed respondents felt the Green Lake Sanitary District (50.3%, 80) and the Wisconsin DNR (51.3%, 81) were very important to the protection, conservation, and preservation of Big Green Lake. Watershed respondents were split on how important they felt the Green Lake Association was with 32.3% (51) responding that they were very important and 31% (49) responding that they were unsure. Respondents were also split on the Green Lake Conservancy with 34.2% (54) responding that they were unsure and 31.6% (50) responding that they were very important. Most watershed respondents were unsure how important the Fond du Lac County Conservation Department (45.6%, 72) and the Green Lake County Conservation Department (34.4%, 55) were. It is important to notice that while there is a leading percentage of importance for some of the different organizations, some of them have very close percentages.

The results of this analysis show that there is quite a bit of uncertainty among watershed respondents about local organizations and agencies. The same holds true with the lakeshore respondents as they were the least familiar with the Fond du Lac Conservation Dept. and were the most unsure about this organization. Lakeshore respondents seem to find high importance in all organizations that may have some influence over Big Green Lake, which shows that these organizations should all be included in future decisions regarding Big Green Lake.

Survey Respondents were also asked about their prior knowledge of efforts underway to protect, restore, and conserve Big Green Lake and its watershed. Respondents indicated that 8% (42) felt that they had a very high knowledge, 27.3% (144) felt they had a high knowledge, 35.6% (188) felt that they had between low and high knowledge, 19.9% (105) felt they had a low knowledge, and 9.3% (49) felt they had a very low knowledge. This question was cross-tabulated with the location of survey respondent's property they owned or lived on. The highest percentage of respondents who felt they had very high knowledge of the watershed came from North Shore (34.1%, 14). The majority of respondents who felt they had a high knowledge (27.9%, 39) and between high and low knowledge (23%, 43) were from South Shore residents. The majority of respondents who felt they had a low (21.6%, 22) or very low prior knowledge (41.7%, 20) were from the City of Ripon. These results indicate those that felt they had the highest levels of prior knowledge were located on Big Green Lake and those that had the least were located in the watershed, which is what one would expect. There may be opportunities for increased knowledge among watershed residents and how their actions potentially affect Big Green Lake.

Recreation

Respondents were asked when during the year do they use Big Green Lake. Respondents had the opportunity to choose all options that applied to them. The majority of respondents indicated they use the lake in the summer (50.4%, 264), 42% (220) use the lake year round, 24.4% (128) use the lake in the fall, 17.2% (90) use the lake in the spring, and 3.6% (19) use the lake in the winter. Another 9.2% (48) indicated no one ever uses the lake. It is important to note that Big Green Lake is used year-round for various activities and those should be taken into consideration when management strategies are being chosen. It is also important to note a rather significant portion of the respondents indicated that no one uses the lake, however that does not mean it isn't used for visual or aesthetic purposes and the quality of the lake is still important.

Respondents were also asked about the variety and frequency of activities they participated in on Big Green Lake. The five activities respondents most frequently participated in (More than 10 times in 2011) were motorized boating (57.3%, 296), scenic viewing (53.1%, 274), swimming (52.8%, 275), solitude (52.2%, 259), and Entertaining (43.7%). Activities with the lowest participation (not at all) were hunting (87.6%, 436), ice fishing (79.8%, 390), and jet skiing (69.3%, 345). It is evident that Big Green Lake is a heavily used recreational lake. It is interesting that both motorized and silent sports are among the most frequent forms of use. As recreational use continues on the lake, and may even increase in the future, care will need to be taken to ensure there is balance between all recreational uses so that conflict is kept at a minimum.

An important aspect of recreational use of Big Green Lake is the ability for users to have quality access to the lake. Respondents were asked how they felt about the quality, quantity, and location of boat landings, shore fishing sites, and handicapped accessible sites. When respondents were asked about the location of access sites to Big Green Lake, 55.6% (294) felt the locations of boat landings were adequate and 40.1% (209) felt the location of shore fishing sites were also adequate. The majority of respondents (62.2%, 324) were unsure about the location of handicapped accessible sites. When asked about the quality of access sites to Big Green Lake 53.8% (284) respondents found the quality of boat landing satisfactory. Respondents were unsure about the quality of shore fishing sites (42.3%, 220) and the quality of handicapped accessible sites (66.7%, 344). The majority of respondents (69.7%, 365) found the quantity of boat landings on Big Green Lake was adequate. Respondents were unsure about the quantity of shore fishing sites (42.8%, 220) and handicapped accessible sites (66.5%, 341). It appears that the public is satisfied with the quality, quantity, and location of boat landings on Big Green Lake. Respondents seem less sure about shore fishing sites and handicapped sites. It is unclear whether this is due to a lack of these sites or a lack of information on their location.

As shown earlier in the survey results motorized boating is one of the most popular forms of recreation on Big Green Lake. Survey respondents were asked to choose a statement that best described the boat traffic that Big Green Lake received. The statements with the highest percentage of respondents were split with 37.6% (198) answering that the traffic was not enough to bother them and 35.9% (189) answering they have had to modify their plans on occasion because of boat traffic. Only 3.8% (20) of respondents indicated they had to regularly change their plans and an additional 3.8% (20) indicated there was so much boat traffic that they didn't use the lake much anymore. From these results, there does not appear to be significant conflicts with the motorized use of the lake, which is something that will want to be continued. This may be something to watch and re-evaluate in the future if it appears that conflicts are on the rise.

Respondents were also asked to describe their experiences with other boaters. 48.6% (211) indicated that a few boaters had been discourteous and broken rules, 38% (165) indicated that boaters had been courteous and law abiding, 8.5% (37) indicated that significant numbers of boaters had been discourteous and broken rules, 3% (13) indicated that some boaters intimidate and harass other boaters, and 1.8% (8) indicated that they had generally quit boating because of the behavior of other boaters. If respondents had indicated that they had some sort of encounter with discourteous boaters they were then asked where on Big Green Lake the conflicts occurred. The majority of respondents (64.9%, 163) indicated near the shore. Mid-Lake (29.1%, 73) and Norwegian Bay (24.7%, 62) were the next two areas with the highest percentage of respondents. Since the majority of residents indicated the near shore area was where conflicts had occurred there may be opportunities to share information about proper recreational use near shores with lake users or to seek out other ways to resolve this potential issue.

Shorelines

Healthy shorelines are an important aspect of a lake's ecosystem. The questions in this section of the survey help to gather information about the perceived state of the shorelines and development on the shores of Big Green Lake. Survey respondents were asked what statement best represented their opinion of the shorelines around Big Green Lake. The majority of respondents (61.2%, 305) indicated they felt there are many structures along most of the shoreline that can be seen from the water. Thirty five percent (175) indicated some structures are visible from the water but only along parts of the shore, 3.4% (17) indicated they knew there are structures along the shore, but they are not visible from the water, and 0.2% (1) indicated there aren't any structures (walls, piers, building, etc) along the shore that are visible form the water.

Respondents were also asked how satisfied they were with the amount of development around Big Green Lake's shore. Overall, respondents were fairly satisfied with the amount of shoreline development with 53% (268) of respondents. The remaining respondents were split with 20.9% (106) being very satisfied, 17.0% (86) being not too satisfied, and 9.1% (46) being not at all satisfied. Respondents were asked how they felt about the shoreline development around Big Green Lake. The majority of respondents (60.4%, 303) felt there was just the right amount of shoreline development. Of the remaining respondents 33.3% (167) felt there was too much shoreline development and 6.4% (32) felt Big Green Lake could use more shoreline development.

Overall, most of the survey respondents seemed pleased or were okay with the current state of the shorelines and the amount of development around Big Green Lake. An area to further investigate in the future is the issue of shoreline vegetation on properties around the lake.

Aquatic Plants

Survey respondents were asked which statement best described the current amount of aquatic plant growth, including algae, in Big Green Lake for the fishery and the wildlife. The majority of respondents were unsure for both the fishery (55.5%, 283) and for wildlife (58%, 290). This may be an indication that the public has a lack of information about the aquatic plant communities in Big Green Lake, especially when it comes to how those communities affect the fisheries and wildlife.

Aquatic vegetation can potentially impact a survey respondent's use of the lake. Respondents were first asked how often aquatic plant, including algae, negatively impacted their use of Big Green Lake. Forty two percent of respondents (212) indicated they were sometimes impacted, 19.8% (100) indicated they were rarely impacted, 17.9% (90) indicated they were often impacted, 16.9% (85) indicated they were never impacted, and 3.4% (17) indicated they were always impacted.

Respondents were then asked as to what level their use of Big Green Lake was negatively impacted by aquatic plant growth, including algae. Fifty five percent (275) of respondents had a moderately negative impact, while 32.6% (163) had no impact, and 12.4% (62) had a great negative impact.
It doesn't appear that citizens have any real issues with the aquatic plant growth on Big Green Lake. However, to take a closer look, the results of the impacts of aquatic plant growth on the level of use of Big Green Lake were cross tabulated with a respondent's location on Big Green Lake. Respondents who lived on the South Shore of Big Green Lake indicated they had moderately native impacts (26.2%, 72) or great negative impacts (18.3%, 11). Respondents who lived in the City of Ripon indicated that they predominantly had no negative impact (23.2%, 37).

While aquatic plant growth may have negative impacts on the recreational uses of a lake it does play a critical role in the health of a lake's ecosystem. Respondents were asked as to what degree they believed aquatic plants, including algae, have functions that maintain the health of Big Green Lake. Forty two percent of respondents (209) indicated that they agreed aquatic plants had functions that help maintained the health, 36.5% (182) neither agreed or disagreed, 10.6% (53) strongly agreed, 8.8% (44) disagreed and 2.2% (11) strongly disagreed. Over half of all of the respondents agreed to some degree that aquatic plant communities were important to the health of Big Green Lake. This information, with the results of the above indicated that respondents are tolerant of aquatic plant communities and are aware of their benefits.

While native aquatic plants and animals are beneficial to a lake, non-native aquatic invasive species can be detrimental to a lake. Examples of aquatic invasive species include carp, white perch, zebra mussels, water milfoil, purple loosestrife and more. Respondents were asked if they had ever heard of aquatic invasive species (AIS). Ninety one percent (471) of respondents had heard of AIS while 8.5% (44) had not heard of them. While the majority of respondents had heard of AIS, there are a relatively large number of respondents that had not heard of them. This is a sign that further information needs to be shared with lake users and local citizens.

Respondents that answered they were aware of AIS, were then asked if they believed invasive species are present in Big Green Lake. Eighty eight percent (419) of those respondents indicated they did believe there were invasive species present in Big Green Lake, 10.5% (50) were unsure, and 1.5% (7) indicated they did not believe any invasive species to be present. Again, the majority of respondents were aware invasive species were present in the lake but there were respondents that were unsure and some believed there were not. Those respondents not aware of the invasive species present in the lake have a greater potential to spread invasive species either throughout the lake or to other local lakes. Respondents that answered they believed that there were AIS present in Big Green Lake were then given a list of potential invasive species and asked which they felt were the biggest threat to Big Green Lake. The five top perceived threats to Big Green Lake included zebra mussels (87.2%, 353), Common Carp (66.2%, 268), shoreland plants (purple loosestrife, spotted knapweed, garlic mustard) (39%, 158), Eurasian water milfoil (33.6%, 136), and Asian carp (32.1%, 130). These perceived threats should be compared to the actual invasive species currently present in Big Green Lake and those that pose the greatest threat. This information should be shared and promoted.

Respondents were also asked how much of the plant growth in Big Green Lake were invasive species. The majority of respondents (54.7%, 229) felt some plant growth is invasive, 36% (151) were unsure, 5.5% (23) felt some plant growth is invasive, and 3.8% (16) felt very little plant growth is invasive.

Water Quality

Often the citizens who live in or near Big Green Lake are greatly aware of the changes that take place within a lake, including changes in water quality. Respondents were asked how a number of factors had changed on Big Green Lake since they had lived on or near it. The largest number of respondents indicated a somewhat increase in the amount of algae (38.9%, 199), the amount of aquatic plants (33.2%, 167) and the amount of shoreline development (40.1%, 203). The largest number of respondents indicated no change in the number of songbirds (42.3%, 214), the quantity of shoreline wildlife (42.1%, 212), and the quantity of waterfowl (37.2%, 187).

Respondents were also asked about changes in water quality, clarity, and the quality of fishing. The greatest number of respondents indicated no change in water quality (36.9%, 189) and water clarity (35.3%, 180). The greatest number of respondents indicated that they were unsure about any changes in the quality of fishing (37.7%, 191). All of these results should be compared with actual measures of these factors to see if the perceived changes are what is actually taking place on Big Green Lake. When respondents were asked about the water quality in in Big Green Lake for a number of factors the largest number of respondents indicated the water quality is good for wildlife habitat (49.1%, 251), for swimming (52.6%, 272), for boating (48.7%, 251), for fish habitat (45.3%, 232), and excellent for scenic beauty (44.2%, 227).

Respondents were also asked about the overall water quality in Big Green Lake during the summer of 2011. Forty six percent of respondents indicated the water quality was good, 27.5% (137) said fair, 13.1% (65) were unsure, 8% (40) said excellent, and 5.4% (27) said poor.

Respondents were also offered a list of potential problems for lakes in general. They were asked how much they agreed or disagreed that each factor was a *current* issue regarding the water quality in Big Green Lake. Most respondents disagreed that the following factors were a current issue in Big Green Lake; polluted swimming areas (28.8%, 141), too little aquatic plant growth (36%, 176), and too little algae (36.3%, 174). Most respondents neither agreed nor disagreed that noise pollution (28.7%, 142), light pollution (30.9%, 152), and grass clippings and leaves from near shore and/or city storm drains (28.6%, 142) were a current issue for the lake. Most respondents agreed that too much aquatic plant growth (33%, 162), too much algae (36.3%, 179), natural runoff from shorelines and/or stream banks (31%, 152), runoff from shoreline development and clearing (30.5%, 153), fertilizers and pesticides from residential runoff (37.3%, 187), storm water runoff from city roads and feedlots (28.9%, 144), and the carp population (36.9%, 184) were all current issues for Big Green Lake. Most respondents were unsure about the loss of desirable fish species, contaminated fish, and the health risks to people and pets from algae blooms. It should be noted that a number of the factors had very close percentages and none carried a majority. The perceived issues should be taken into consideration when looking at possible management strategies. These issues should also be compared to any issues that have been identified by professionals on the lake. If there are differences between the perceived issues and the actual issues that the lake faces those should be further explored and possibly addressed.

Land Management

The way land is managed in a lake’s watershed and on its shores can have an impact on the water quality and the overall health of the lake. It can also impact a user’s enjoyment of the lake and the scenery they experience on the lake.

Respondents were asked to what extent the land purchased around or near Big Green Lake by land trusts and conservancy organizations enhance the overall quality of their lake experience. Thirty seven percent (190) of respondents felt that these purchased lands greatly enhanced their experience, 27% (137) felt they somewhat enhances their experience, 15% (76) were neutral, 10.2% (52) felt they had little to no effect, and 10.4% (53) were unsure.

Respondents were also asked how well the present land use regulations protect habitat and water quality in the lake. Forty five percent of respondents (230) felt the present regulations were fairly adequate, 31.4% (160) were unsure, 11.2% (57) felt they were very adequate, 7 .1% (36) felt they were not at all adequate, and 5.3% (27) they were not too adequate. There is a large percent of respondents who were unsure. The results do not allow us to understand if these respondents do not know what the current land use regulations are or how they protect the habitat and water quality. It appears those that know the regulations are happy with them. However, this may be a sign that the current land use regulations should be shared so citizens have a better idea of their impact on the lake.

In order to gain an idea of shoreland management practices in place on Big Green Lake, respondents were asked about the land use management practices that can improve water quality on their own properties. Natural shorelines occurred most often naturally on the landowner's properties (41.2%, 173). Most respondents would consider installing shoreline restorations (31.8%, 126), runoff diversion practices (37.2%, 149), native flowers, shrubs, and trees (29.9%, 127), shoreland stabilization (33%, 134), rain barrels (40.6%, 164), and water permeable surfaces (30.8%, 114). Most respondents would not consider installing a reduction in hard surfaces (28.3%, 116) or no mow areas (32.6%, 134).

Respondents had not heard of shoreline buffer strips (32.2%, 128) or rain gardens (39.2%, 159). Most respondents seem open to a variety of land use practices that would benefit the lake. Relatively few landowners have actually installed any of these practices and this may be an area to focus efforts that could benefit the lake. There were also practices that most respondents haven't heard of and those are areas where information can be shared.

There was interest in examining this question further to determine if the location of respondents showed any differences in land management practices that were being used. This question was broken down by lakeshore survey respondents and watershed respondents and then cross tabulated. Lakeshore respondents indicated that natural shorelines existed naturally on 49.5% (151) of the properties. Popular practices that had been installed on lakeshore respondent's properties included native flowers, shrubs, and trees (30.16%, 92) and shoreland stabilization (30.53%, 91). Practices that were popular for consideration among lakeshore respondents included runoff diversion practices (36.67%, 106), native flowers, shrubs, and trees (29.18%, 89), shoreland stabilization (32.21%, 96), rain barrels (40.6%, 119), and water permeable surfaces (32.06%, 84). Practices that most lakeshore respondents were not willing to consider included no mow areas (35.6%, 106), and reduction in hard surfaces (29.86%, 89). Most lakeshore respondents had never heard of rain gardens (37.88%, 111) or shoreline buffer strips (30.17%, 88). The two practices that had a large number of respondents that had not heard of them are two relatively simply practices that can be of great benefit to the lake. There can be some confusion regarding the name of shoreline buffer strips which may have led to the high number of respondents who were not familiar with this practice. However, they may also be the need for increased information about these practices and their potential benefits to the lake.

There is no land use management practices listed that most of the watershed respondents indicated occurred naturally or had already been installed on their properties. This in part may be due to the fact they do not own shorelines, and some of these practices are specific to shoreline properties. However, most water shed respondents indicated they would consider natural shorelines (30.84%, 33), shoreline restoration (37.37%, 37), runoff diversion practices (39.42%, 41), native flowers, shrubs, and trees

(33.63%, 37), shoreland stabilization (37.37%, 37), and rain barrels (39.80, 41). Most watershed respondents would not consider no mow areas (26, 66%). Watershed respondents were unfamiliar with shoreline buffer strips (37.11%, 36), rain gardens (42.85%, 45), no mow areas (27.61%, 29), reduction in hard surfaces (28.70%, 31), and water permeable surfaces (30.39%, 31). There is some indication that the watershed respondents are simply not aware of many of these practices, even though some of them are applicable to watershed residents. There may be opportunities to share information about these practices and their potential benefits to not only rural properties but also Big Green Lake. It is important to note no single land use practice had a majority of respondents (over 50%).

To give a better idea of what might motivate landowners to make changes in land management practices, respondents were provided a list of potential motivators and asked to identify their top choices. The top five motivators for land use change were improving water quality (65.8%, 296), increasing the natural beauty of property (59.1%, 266), provide better habitat for fish and wildlife (58.9%, 265), increasing property value (57.8%, 260), and benefiting children/grandchildren (43.8%, 197). These motivators can be used in a number of different ways. Management practices can be promoted using these motivators as reasons for implementation. For example, the management action of shoreland restorations or natural shorelines can be promoted or shared with landowner as a way to improve water quality, save landowners money and increase habitat for fish and wildlife.

Last, respondents were asked how much they agreed or disagreed with statements regarding land use and management of Big Green Lake as it relates to improving water quality in Big Green Lake. Unfortunately, most respondents neither agreed nor disagreed with any of the statements provided.

Climate Change

Climate change refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Climate change may result from natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun; natural processes within the climate system; and human activities that change the atmosphere's composition. These factors have the potential to have dramatic impacts on a lake's ecosystem. Respondents were asked how much they agreed or disagreed that climate change has the potential to affect a list of conditions of Big Green Lake. Most respondents agree climate change has the potential to affect all of the factors listed.

Demographic Information

Basic demographic information was gathered on survey respondents. Of the respondents that answered the questions 64.3% (328) were male and 35.7% (182) were female. The ages of respondents varied greatly from 22 to 100 with the average age being 62. Newspapers and websites were the most popular ways to receive information both with 40.2% (198) of respondents. Younger generations tend to find their information through electronic media while older generations tend to find their information through more traditional means of media. Because there are such varying ages in citizens within the watershed, it would be advised to employ a variety of means for communication. This also holds true because of the differences in citizen's residency (seasonal versus year round).

Appendix B

AIS Preliminary Grant Application Scope of Work

Introduction

The Green Lake Association, in partnership with the Green Lake County Land Conservation Department, is requesting a two year (January 1, 2013 – December 31, 2014) Wisconsin Department of Natural Resources (WDNR) Aquatic Invasive Species Education, Prevention, and Planning Grant to establish an Aquatic Invasive Species Program to help manage aquatic invasive species in Green Lake County. The main components of the county wide AIS program are to educate the public about AIS, prevent the spread of aquatic invasive species, and manage current AIS populations. If funded, the Green Lake Association (GLA) will work with the Green Lake County Land Conservation Department (LCD) to staff a countywide Aquatic Invasive Species Coordinator (AISC) for Green Lake County. This position will focus on AIS mapping, monitoring, early detection, rapid response, and education for Green Lake County's lakes. If funded, the AISC position will be a three quarter time position; however, to make the position more competitive, the GLA and its partner, the Green Lake County LCD, will utilize additional, personal financial resources to create a full-time position wherein the AISC will work with AIS roughly 30 hours per week and the remaining 10 hours will be spent on projects that both organizations need help completing. These projects may include activities such as youth watershed education, water quality monitoring, storm drain stenciling, and project wet activities.

Description of Project Area

There are 11 waterbodies in Green Lake County, which include: Dog Lake, Grand Lake, Big Green Lake, Heart Lake, Lake Maria, Little Green Lake, Puckaway Lake, Spring Lake, Spring Lake (Kingston), and Twin Lakes. To maximize the program's effectiveness, the Green Lake County AISC's activities will focus on lakes that have the most boat traffic and public access points, a high degree of regional importance, and chronic or critical AIS issues (See Appendix B).

Regional/State Importance

Big Green Lake is the largest in size, depth, and regional importance. Big Green Lake originated in a valley which was formed by a pre-glacial river. Glaciation deposited terminal moraines across the western end of the valley (along present-day Highway 73), which impounded the water and created the lake 12,000-23,000 years ago. With its greatest depth of 237 feet and its average depth of 100 feet, Big Green Lake is the deepest, natural inland lake in the state of Wisconsin. It is over seven miles long, its surface area is roughly 7,300 acres, and its immense watershed encompasses nearly 69,000 acres which spans both Green Lake and Fond du Lac Counties.

Big Green Lake's two tier fishery includes both warm and cold water fish species including Small and Large Mouth Bass, Bluegill, Northern, White Bass, Walleye, Lake Trout, Muskellunge, Perch, and Cisco.

Common birds such as the Loon, Horned Grebe, American White Pelican, Tundra and Trumpeter Swans, and a variety of ducks use Green Lake during migration. Bald Eagles and Ospreys also nest adjacent to the lake in a few locations, and use it in larger numbers until freeze-up. Additionally, several Conservancy Partnership Properties are located along Green Lake's shoreline and contain state documented special concern species. These species include: Great Blue Heron (*Ardea herodius*), Yellow-billed Cuckoo (*Coccyzus americanus*), Black-billed Cuckoo (*Coccyzus erythropthalmus*), Sedge Wren (*Cistotherus platensis*), Wood Thrush (*Hylocichla mustelina*) and Vesper Sparrow (*Pooecetes* *gramineus*).These properties also include several Species of Greatest Conservation Need according to the Wisconsin Wildlife Action Plan including: American Bittern (*Botaurus lentiginosis*), Willow Flycatcher (*Emipodonax trailii*), Least Flycatcher (*Empidonax minimus*) and Brown Thrasher (*Toxostoma rufum*).Yellow-bellied Flycatcher (*Empidonax flaviventris*), Purple Martin (*Progne subis*), Swainson's Thrush (*Catharus ustulatus*), Golden-winged Warbler (*Vermivorus chrysoptera*) and Nashville Warbler (*Vermivous ruficapilla*) have also been observed during the migration period, but have not subsequently been recorded as breeding species.

The sources of Big Green Lake's water, in approximate percentages, are: precipitation, 51%; surface water, 41%; ground water, 8%. Roughly 1,400 households surround Green Lake with regular lake users from Ripon, Markesan, the Town of Brooklyn, Princeton, and Berlin. Because Green Lake is one of the Midwest's premiere lakes, it is also a popular destination for visitors and is a significant economic and social resource to Green Lake County, the State of Wisconsin, and the Midwest as a whole.

While a county wide economic assessment for all county lakes has not been conducted, the total equalized value of lake homes on Big Green Lake equals $1,003,084,233 which is nearly half of the total equalized value for all of Green Lake County. Hence, maintaining the quality of Big Green Lake has important county wide economic implications. Not to be outdone by its counterpart, Little Green Lake is located just a couple of miles south of Big Green Lake, covers around 400 acres of water surface, and is considered one of the most productive Muskellunge waters in Wisconsin. Walleye, Northern, Large Mouth Bass, Blue Gills and Crappie can also be found in Little Green Lake.

Lake Puckaway is located on the border between Green Lake and Marquette counties, is a natural widening of the Fox River lying in a glacial scoured valley. Lake Puckaway is eight miles long and 1.5 miles wide, has a surface area of over 5,000 acres. Lake Puckaway receives drainage from a watershed of 805 square miles. It has 27.3 miles of shoreline, of which 60-70% is marshy and not developed. The remaining shoreline has been developed for seasonal or permanent residences. Water levels on the lake are controlled by the Princeton Dam, located 8 miles downstream from the lake. The maximum depth of five feet occurs in the west basin, while the east basin is all less than three feet. Lake Puckaway is one of the finest fishing and hunting lakes in Wisconsin. The lake contains a variety of game and rough fish and boasts the largest northern pike (*Esox lucius)* ever caught in Wisconsin (38 pounds in 1952). Lake Puckaway is also home to many birds, songbirds, migratory waterfowl (diving and puddle ducks), shorebirds, eagles, and has one of the largest colonies of the endangered Forster's Tern (*Sterna forsteri*).

Problem to Be Addressed

Several lakes within Green Lake County have identified AIS education and prevention as goals in their respective lake and/or aquatic plant management plans. However, funding to execute those goals have 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 resemble a patchwork of varying AIS efforts.

Due to the present day economic climate, there is a legitimate and real concern that Green Lake County officials may not financially support adding a new position to their county staff to work on county-wide AIS prevention and education, even if partially grant funded, and current LCD staff are maxed to their capacities with current job responsibilities. Due to the possible economic and environmental ramifications of AIS in our lakes, the Green Lake Association and the Green Lake County Land Conservation Department decided to work together to leverage its resources to create a county-wide AISC position, in spite of these economic and social challenges.

Green Lake County AIS and Threats

Zebra Mussels, Eurasian Water milfoil, Curly-leaf Pondweed, the common carp, Purple Loosestrife, and Rusty Crayfish are invasive species known to exist in Big Green Lake. Probably the most infamous and influential exotic species in Lake Puckaway is the common carp. Eurasian Water milfoil (first recorded in 1984) and Curly-leaf Pondweed have been found in this lake, as evidenced in the 2005 plant survey by Maxim. Other invasive plant species that are present in Lake Puckaway include Reed Canary Grass, Narrow-leaved Cattail, and Giant Reed (Maxim Technologies 2005). Czarapata (2005) lists Eurasian Water milfoil, Reed Canary Grass, Narrow-leaved Cattail, and Giant Reed (also known as Common Reed Grass) as "Invasive Plants of Major Concern", and Curly-leaf Pondweed as an "Invasive Plant of Lesser Concern". Both Eurasian Water milfoil and Curley-leaf pondweed can be found in Little Green Lake as well.

Big and Little Green Lakes and Lake Puckaway are statewide and regionally known throughout the Midwest for its excellent fisheries and recreational opportunities. They are also located a short distance from Lake Winnebago (an AIS "super spreader") and the Winnebago Pool Lakes system whose lakes have the heaviest inland boater use in Wisconsin. Because of its proximity to Lake Winnebago and the Winnebago Pool Lakes system and the regional and state-wide popularity of the above mentioned Green Lake County lakes, introduction of new aquatic invasive species to the county's lake are a major threat. For example, viral hemorrhagic septicemia (VHS) appeared within the Lake Winnebago Pool Lakes system in 2007. If VHS were to spread to Big Green Lake, it could devastate its unique fishery including its trout population, which plays a vital economic role for the county.

Green Lake County AISC Goals and Activities

Hiring an Aquatic Invasive Species Coordinator (AISC) is the first and most important component in establishing a holistic and comprehensive Aquatic Invasive Species program to help manage aquatic invasive species in Green Lake County. The goals for the Green Lake County AIS program are listed below.

Educational Outreach

Goal: Education is a critical step in controlling the spread of AIS. The AISC will utilize WDNR, UW-Extension, and UW Sea Grant AIS educational materials to perform consistent county-wide AIS educational outreach.

Activities: The AISC will:

1. Initiate educational opportunities. The list below is just a few of the potential opportunities that will be pursued:
    - School programs
    - Scouting programs
    - WI Boater Safety programs and WI Hunter Safety programs
    - Pre-fishing tournament meetings
    - Local special interest groups (sportsman clubs, lake associations, civic organizations, etc.) meetings
    - Gardening and aquarium retailers
    - Local hobbyist groups
2. Attend a variety of activities each year to staff AIS displays to expose the general public to AIS threats and personal responsibility that can be taken to control the spread of new AIS infestations.

3. Write and distribute periodic news articles in several local publications, including the GLA's newsletters and annual directory, which identify actions that the general public can take to help stop the spread of AIS.
4. Educate lake property owners and the public on the importance of native vegetation and ways they can promote a healthy diversity of aquatic plants in county lakes.
5. Foster working relationships with the already established partners such as the County Land Conservation Department, the Green Lake Sanitary District, additional area lake associations, sportsman groups, and civic groups (etc.) to utilize their newsletters and outreach materials as an additional source of AIS educational outreach.
6. Provide AIS education and training for Town and County road crews and Adopt-a Highway programs.
7. Place WDNR AIS links w h i c h provide information, education, and AIS news on the Green Lake Association's and County Land Conservation Department's websites.
8. Explore developing an interactive app for iPhone and android phones, which identifies AIS in each county lake and provides information and photos about each type of AIS. The app may also provide a means of taking photos and reporting new AIS.

Rapid Response

Research has found that one of the most effective methods for eradicating AIS is early detection and rapid response.

Goal: Participate and partner with the WDNR to identify, confirm, and help coordinate the early detection and rapid response of new AIS populations.

Mapping & Inventory

Goal: Gain a better understanding of how AIS has impacted Green Lake County's lakes. This information may serve as the foundation for a future countywide comprehensive strategic plan for AIS eradication and containment.

Activities: The AISC will:

1. Conduct point intercept surveys for AIS in county lakes.
2. Map and track the locations of invasive species.
3. Maintain a GIS data base for AIS in Green Lake County's lakes to include (or possibly include) such things as: sensitive shorelines, native vegetation areas, bathymetry, system wide invasive species population locations/ problem areas, major and minor AIS vector points, AIS signage locations, etc.4.
4. GIS data sharing will be coordinated between the Green Lake Association, the Green Lake County Land Conservation Department, the Green Lake Sanitary District, other lake associations, and lake protection and rehabilitation districts, as well as the WDNR.

Clean Boats, Clean Waters

Numerous lakes within Green Lake County have conducted CBCW programs over the past few years. These programs ranged from comprehensive, robust programs to very small programs. However, due to funding losses or grant cycles ending, beginning in 2013 all of Green Lake County's CBCW programs will be terminated. This grant will allow the CBCW program to continue in Green Lake County.

Goal: Conduct a two year Clean Boats, Clean Waters Program for lakes in Green Lake County.

Activities: The AISC will:

1. Manage six paid Clean Boats, Clean Water Boat Launch Inspectors from mid-May to mid-September. Each inspector will work roughly 14 hours per week for 15 weeks per year which equals 1,260 hours per year of inspecting boats at Green Lake County boat launches.
2. Focus the program on the busiest boat launches to maximize the programs effectiveness.
3. Recruit volunteers f o r t h e CBCW program for the smaller boat lunches throughout the county.
4. Enter the collected CBCW data into the WDNR's SWIMS database.
5. Provide updates to GLA's Outreach Coordinator, LCD staff, and other stakeholder groups about the CBCW program.

Citizen Lake Monitoring

Goal: Establish a county wide Citizens AIS Lake Monitoring Network (CAISLMN) that is consistent with the WDNR and UW Extension's statewide strategy.

Activities: The AISC will:
1. Work with the Green Lake County LCD, Green Lake Sanitary District and other organizations and citizens already dedicated to monitoring, educating and preventing the spread of aquatic invasive species to monitor known invasive populations and identify any new occurrences.
2. Recruit and train volunteers for the Citizen AIS Lake Monitoring Network
3. Meet with the lake monitoring volunteers to participate in lake monitoring efforts to ensure that Green Lake County lakes are consistently monitored and accurately recorded.

Policy

Goal: Serve as an advocate for sound AIS policy at state, county and local levels

Activities: The AISC will:
1. Coordinate with State, county and local officials to educate public officials (land managers, rights-of-way managers, law enforcement personnel, etc.) on Administrative Code NR 40 to assist local communities in the creation, implementation, and enforcement of local ordinances that control the spread of AIS on both public and private properties.
2. Work with the GLA's Outreach Coordinator to update her about AIS policy that can be shared with the public through her outreach efforts.

County AIS Coordination and State-Wide AIS Participation

Goal: Coordinate a countywide network of AIS partners and cooperative with Wisconsin AIS coordinators.

Activities: The AISC will:
1. Create and sustain a list of volunteers, partners and countywide stakeholders
2. Make continuous contact with this network via electronic mailing lists, websites, newsletters, personal contact and educational events.
3. Partner with Wisconsin AIS Coordinators and will actively participate in State-wide AIS programs, continued education opportunities, and meetings.

Green Lake County AISC Deliverables

The Green Lake County AIS program will provide a comprehensive system-wide approach to preventing the introduction and transfer of AIS in Green Lake County lakes. A fundamental function of the Green Lake County AISC is educational outreach. Educational programs will be tailored to public officials, public employees and local citizens to identify, monitor and control AIS that threaten the Green Lake County lakes.

The Green Lake County AIS program's outputs include:

- Implementation of the AIS portion of Big Green Lake's Lake Management Plan
- AIS network data base of stakeholders, volunteers, organizations and interested parties
- County-wide GIS mapping of AIS
- County-wide CBCW program
- County-wide Citizen AIS Lake Monitoring training, correspondence, and data collection
- County-wide AIS rapid response and early detection program
- Electronic newsletters, articles, and training opportunities related to AIS prevention
- Press releases to local media informing the reader about existing AIS and AIS threats to Green Lake County lakes
- Appearances and/or presentations at local special interest group meetings educating and promoting the AIS control program, and personal responsibilities
- Distribution of AIS materials utilizing informational booths at local events
- Increased volunteer participation regarding AIS prevention
- Increased public knowledge regarding early identification and AIS control best management practices.
- An interactive AIS app for iPhones and android smartphones.

Two Year Budget

The total project costs are expected to be $146,150 which includes the GLA's and LCD's in-kind and cash matches. Breakdowns of these costs are located in the program budget found in Appendix A.

The Green Lake Association's Project Capability

The Green Lake Association is a non-profit lake association that has been in existence for over 60 years. Throughout these years, the GLA made the transition from a 100% volunteer organization with an annual budget of roughly $60,000 to a robust non-profit with two part-time staff members working roughly 30 hours per week, a visible downtown office with daily office hours, and an annual budget of over $110,000. Additionally, the GLA has a reserve fund of roughly $50,000.

Our current staff members include an executive director who has worked for the Green Lake Association since 2007. She graduated from UW-Whitewater with a Bachelor of Science in geography with an emphasis in urban planning and a minor in environmental studies. She will be completing her Master's in Public Administration from UW-Oshkosh in spring 2013. Her professional background includes a broad spectrum of nonprofit management experience including income and membership development, event planning, volunteer management, community outreach, program evaluation and development, financial and human resource management, strategic planning, and environmental policy and administration. GLA's outreach coordinator is a 2008 University of Wisconsin-Oshkosh graduate with a Bachelor of Arts in journalism. She has a strong background in writing and communications as well as experience in marketing, graphic and website design, and nonprofit work. For the past three summers, our organization has added roughly nine additional part-time staff to implement its Clean Boats, Clean Waters program (which ends in 2012), and each school year the GLA works with Ripon College to host a semester and/or yearlong intern (s) to help carry out specific projects.

The GLA's board of directors consists of accomplished individuals from across two states whose professions include an attorney, environmental engineer, financial and banking manager, sales and marketing rep, construction and historic preservation business owner, landscape designer, UW-Madison educator, college administrator, non-profit manager, and small business owner.

Project Oversight

If funded, the AISC would be an employee of the GLA; however, this individual would be meeting weekly with Green Lake County LCD staff for additional guidance and program oversight as well as utilizing any county equipment necessary to complete activities.

Financial Management

The Green Lake County AISC position is a partnership position between the Green Lake Association (GLA) and the Green Lake County Land Conservation Department. However, the GLA is the official grant applicant and would be the financial manager of the project if the grant was awarded.

Project Partners and Stakeholders

Currently Fond du Lac County has an AISC who works in areas within the Big Green Lake watershed. The Green Lake AISC will also coordinate efforts with the Fond du Lac County's AISC to further strengthen AIS control efforts within the Big Green Lake watershed. Additionally, the AISC will also coordinate efforts with the Protection and Rehabilitation Districts for Puckaway and Little Green Lakes, the Twin Lakes Association, the Green Lake County LCD, and the Green Lake Sanitary District (GLSD) who manages a Purple Loosestrife beetle program and a weed harvesting program on Big Green Lake.

In 2011, nearly a dozen state and local partners including non-profit organizations, citizens, WDNR staff, the Green Lake Sanitary District, the cities of Ripon and Green Lake, and Green Lake and Fond du Lac County Land Conservation Departments began working together to develop a WDNR approved lake management plan for Big Green Lake. Guided by EPA's guidelines and still in its development, Big Green Lake's management plan includes AIS mapping, monitoring, early detection, rapid response, and education as important activities to meeting their goals related to AIS.

The AISC's activities are also important for additional Green Lake County lakes that have established goals for preventing and managing AIS. Page 57 of the Green Lake County Land Conservation Department Land and Water Resource Plan states that Zebra Mussels, carp, Eurasian water milfoil, Curly-leaf Pondweed, and Purple Loosestrife have been documented within the county and/or region, that new invasives are likely to appear, that all county lakes are threatened, and that Lake AIS Grants and Clean Boats Clean Water's programs should be utilized to help with remediation, prevention and education. Twin Lakes Association's Lake Management plan states on page 4 that actions to help achieve its AIS goals include conducting aquatic plant surveys to identify areas of invasive and native plant species, implementing a Clean Boats, Clean Waters education program, and developing an annual AIS monitoring program. Lake Pickaway's Comprehensive Plan's activities for achieving its AIS goals include developing and implementing an aquatic plant monitoring survey, scheduling transect surveys, and monitoring and mapping the locations and abundance of both native and invasive exotic plants. Furthermore, it's Environmental Integrity Report (2008) recommends implementing a county-wide aquatic invasive species control program which focuses on heavily on AIS education.

For more information about these plans, please visit Green Lake County's website: http://www.co.green-lake.wi.us/departments.iml?Department=13

Below is a list of all the partners and stakeholders with which the Green Lake Association is involved. It is also expected that the Green Lake Association will grow the partner list (below). The AISC will actively recruit new partners such as angling groups, civic groups, and master gardener associations to further strengthen the Coordinator’s efforts to develop a region-wide systematic approach to controlling the spread of AIS to and from Green Lake County lakes.

Partners and Stakeholders

- Green Lake School District
- Ripon School District
- Ripon College
- City of Ripon
- UW-Steven’s Point
- UW-Madison
- UW-Extension
- Green Lake County Sanitary District
- Green Lake County Board
- Green Lake County and Fond du Lac County Land Conservation Departments
- Green Lake County Land Use and Planning Department
- Green Lake Conservancy
- Green Lake Downtown Renewal
- Green Lake Chamber of Commerce
- Town Square, a non-profit that occupies the former Green Lake County Courthouse; its programming focuses on health and wellness, art and education, and the environment
- Walleyes for Tomorrow
- Wisconsin Lakes
- WDNR biologists, fish biologists, and lake specialists
- Statewide WDNR AIS Coordinators

Appendix C

Accessible Fishing Piers and Platforms

PDF Version Index

The products shown in this guide are only intended to serve as examples to illustrate the accessibility guidelines, and are not intended as endorsements of the products. Other products may be available. The Access Board does not evaluate or certify products for compliance with the accessibility guidelines. Users are advised to obtain and review product specifications for compliance with the accessibility guidelines.

Introduction

The Americans with Disabilities Act (ADA) is a comprehensive civil rights law that prohibits discrimination on the basis of disability. The ADA requires that newly constructed and altered state and local government facilities, places of public accommodation, and commercial facilities are readily accessible to, and usable by, individuals with disabilities. The ADA Accessibility Guidelines (ADAAG) is the standard applied to buildings and facilities. Recreational facilities, including fishing piers and platforms, are among the facilities required to comply with the ADA.

The Access Board issued accessibility guidelines for newly constructed and altered recreation facilities in 2002. The recreation facility guidelines are a supplement to ADAAG. As a supplement, they must be used in conjunction with ADAAG. References to ADAAG are mentioned throughout this summary. Once these guidelines are adopted by the Department of Justice (DOJ), all newly designed, constructed and altered recreation facilities covered by the ADA will be required to comply.

The recreation facility guidelines cover the following facilities and elements:

- Amusement rides
- Boating facilities
- Fishing piers and platforms
- Miniature golf courses
- Golf courses
- Exercise equipment
- Bowling lanes
- Shooting facilities
- Swimming pools, wading pools, and spas

This guide is intended to help designers and operators in using the accessibility guidelines for fishing piers and platforms. These guidelines establish minimum accessibility requirements for newly designed or newly constructed and altered fishing piers and platforms. This guide is not a collection of fishing pier designs. Rather, it provides specifications for elements on a fishing pier or platform to create a general level of usability for individuals with disabilities. Emphasis is placed on ensuring that individuals with disabilities are generally able to access the fishing pier and use a variety of elements. Designers and operators are encouraged to exceed the guidelines where possible to provide increased accessibility and opportunities. Incorporating accessibility into the design of a fishing pier should begin early in the planning process with careful consideration to accessible routes and maneuvering space.

Appendix D

PAG Notes Summation and Preliminary Issue Identification

In summarizing some of the issue sheets it became apparent understanding of the questions is blurry. This is likely due to low to moderate understandings of lake science and ecology. This is a normal condition to be expected in a Citizen Participation process involving relatively complex issues. The listings below were developed after review of PAG meeting notes. Specific comments were not tallied but the general level of understanding or support for the issues was condensed and are presented below.

<u>3/7/12 PAG Mtg</u>

OVERALL, Good support for:

- Shoreline appraisals
- BMP efficacy evals
- Watershed planning
- Plan clarity, specifics
- RSVP/Jaclum support
- Biodiversity and habitat support

<u>4/4/12 PAG Mtg</u>

OVERALL, Good support for:

- Silver Creek and CTH K Marsh management and protection
- Climate change recognized as problem but applying strategies locally not well understood
- Comprehensive planning in watershed and lake

OVERALL, Moderate support for:

- Stream habitat management
- Woody structure management
- Economic value analysis
- Prioritization of watershed pollution sources
- Enhanced I&E for shore owners
- Emergent plant restoration

Appendix E

Preliminary Issues Listing

To be finalized pending stakeholder input. The issues will be addressed within the appraisals and discussion sections.

Watershed

- **Delivery of pollutants esp. P and sediment i.e. eutrophication
- Nonpoint runoff from watershed
- Incapacity of management units to sufficiently address NPS
- Excess P delivery via tributary streams
- **Degraded tributary waters not meeting water quality or habitat standards
- Urban storm water sources unabated
- Tributary stream appraisals summary needs especially IBI/HBI indexing
- **Watershed inventory of land uses and pollution sources not up to date
- Watershed evaluation of pollutant levels unknown, i.e. did it work?
- Reduction objectives for BMP's (best management practices), timeframe, and real costs need improved definition and commitments

Aquatic Habitat

- Tributary stream habitat degraded
- **In lake large woody structure loss
- **Long range historical emergent plant habitat loss/degradation
- Existing critical habitat areas lack detailed appraisals
- **Management of Shallow water tributary areas Silver ck/Co Park Marsh critical
- Biodiversity appraisal needs
- Co Park Marsh evaluation plan not defined
- Development pressure in critical habitat areas (incl dredging)
- Filamentous algae in north shore littoral zone may be spawning obstruction

Fishery

- Comprehensive fishery appraisal on lake is needed
- **Carp population estimates and trends in Co Park Marsh lacking at a level sufficient to evaluate carp barrier efficacy
- Fish rearing facility possibly underutilized relative to potential
- Shallow water habitat degraded from carp, development
- Shallow water habitat limited due to lake morphology
- Critical habitat areas under pressure from dredging requests
- Pier and boat shading of shallow water habitat
- Forage fish shifts perceived (example Emerald Shiners) possibly from AIS (Z's)
- VHS (Viral hemorrhagic septicemia) potential to enter lake
- Spawning limitations from benthic (bottom) filamentous algae on north shore littoral zone (area of light)

I&E

- **Economic value of Green Lake unknown
- Economic value of Green Lake relative to water clarity shifts unknown
- **Educational opportunities regarding unique qualities of Green Lake
- General view visual access to Green Lake unavailable
- Photo/video opportunity for underwater qualities unavailable
- **Management conflicts on Silver Creek shallows. biodiversity Vs. recreation

Management Capacity, Planning, Integration

- Integration of Smart Growth and lake protection
- **Comprehensive Lake management plan unavailable
- **Comprehensive Watershed plan unavailable
- **Local partnership development and strengthening including maintenance of lake association membership and efficacy
- Government agency staffing levels insufficient to address issues

Water Quality

- **Lake and stream monitoring needs
- Watershed source ID and prioritization
- Shallow water marsh turbidity (Co Park)
- Shallow water marsh plant community degraded (Co Park)
- Shallow water marsh Carp disturbance
- Beyer's cove turbidity, plant community degradation, and carp

Nuisance habitat

- **Riparian expectations management
- The balance of recreation versus habitat

Natural Aesthetics

- **Characterize aesthetic values of lake, integrate with I&E
- Aesthetics loss in user experience from development
- Aesthetics loss from dense submergent aquatic plants in shallow waters
- Aesthetics loss from dense duckweed in Silver Ck
- Aesthetic objectives for view protection undefined

AIS

- **AIS prevention needs greater attention
- EWM in Silver Ck shallow water tributary
- EWM in lake; impacts not well understood
- Rusty crayfish populations not well understood
- **Carp populations not well understood
- Harvest impacts relative to EWM not well understood
- Weevil impacts relative to EWM not well understood
- **Zebra mussels changing biology of lake possibly creating shifts in forage fish base
- Lack of a regional and coordinated strategy for AIS

Use conflicts

- Shoreline development, esp. piers, associated watercraft, canopies shade out littoral biology
- **Shore land development within shallow water critical habitat areas i.e. Silver Creek channels in conflict with reasonable uses
- Expectations management for some users and property owners unrealistic relative to localized qualities of the aquatic resource

Land preservation

- **Shore land Zoning variances numerous
- Conservancy properties long range management plans are wanting
- Current or recent programs, e.g. JACLUM, RSVP status unclear
- **Visual quality of lake environs cluttered with development

Climate shifts

- **Potential Climate change impacts and response for Green Lake unknown

Shorelines and Shore land

- **Baseline conditions for shoreline/shore land quality undocumented
- RSVP program success and future commitments unknown
- Baseline flora fauna conditions on several conservancy properties unknown
- **Shoreline and shore land biodiversity and habitat loss

Citizen Participation

- **Enhanced citizen participation in lake and stream monitoring needed

Appendix F

Public Advisory Group Membership - Green Lake Planning

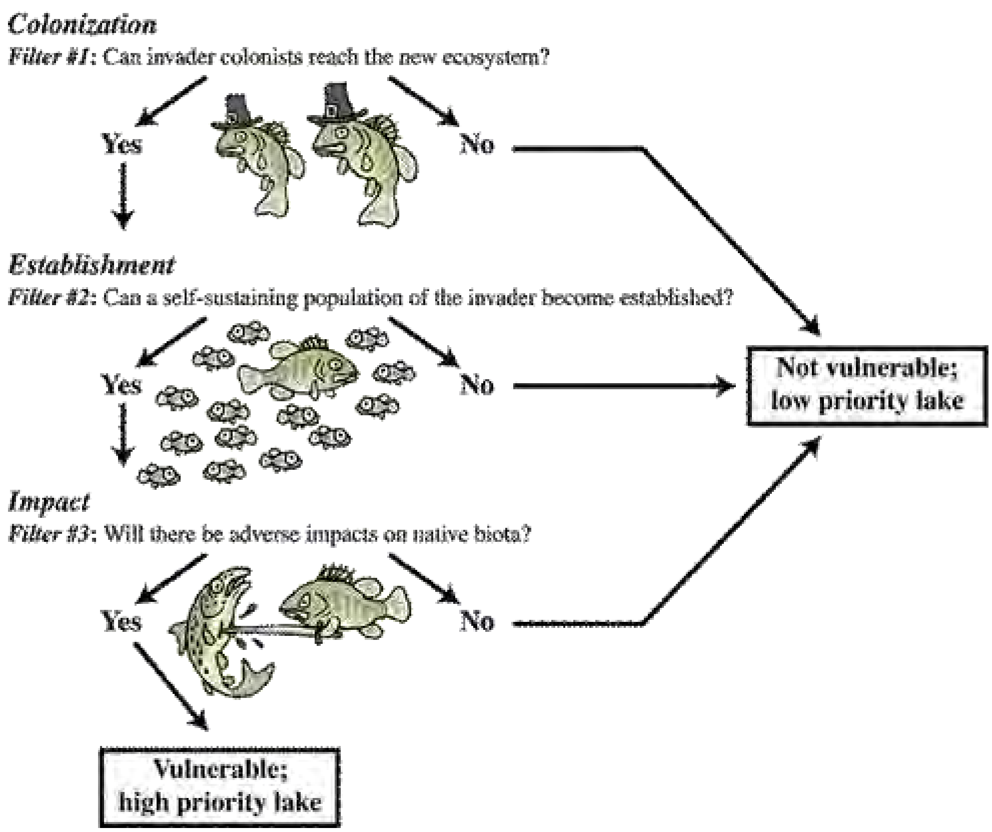
Affiliation Name Address Phone Email

- Farmer, GL, Wayne Albright W876 County K Ripon, WI (920) 748-3072 waynenalbright@centurytel.net
- Fisherman, GL, Aaron Anderson W728 Meadow Dr Green Lake, WI (414) 531-0607 aanderson@sunsrce.com
- Lake property owner (west end) Joan Blum N4404 Lakeshore Dr Princeton, WI (920) 295-4054 jblumwi@charter.net
- Lake property owner (east end) Ken Knight 580 South St. PO Box 311 Green Lake, WI (920) 807-0580 kkrnc74@gmail.com
- Recreational user and realtor, FDL Julie Mathias 224 Spaulding Ave Ripon, WI (920) 748-6683
- Business owner, GL Dave Norton W3886 Cty Rd T Princeton, WI (920) 295-3462 dave@nortonsdrydock.com
- Fisherman and business owner, GL Mike Norton W4410 Huckleberry Rd Princeton, WI (920) 295-3617 mnorton02@centurytel.net
- Farmer, FDL Larry Pollack N7160 Pollack Rd Ripon, WI (920) 748-7662 pollackvu@hotmail.com
- Lake property owner (Mill pond) Brad Ruth 369 Palmer Ave Green Lake, WI (920) 229-0524 brad@pgi-inc.com
- Business owner, GL Peter Vandervelde PO Box 21 Green Lake, WI (920) 294-3145 greenlakepiersandlifts@hotmail.com
- Farmer, GL Leonard Verch W3392 County Rd T Green Lake, WI (920) 229-7765
- Lake property owner (south side) Mark Worley 130 Blackthorn Ln Lake Forest, IL (847) 234-6937 mark@daycholahcapital.com

Appendix G

Wisconsin Aquatic Invasive Species

Smart Prevention of Aquatic Invasive Species
Wisconsin's 15,000 lakes and 45,000 miles of streams are among the state's most valuable natural resources. The abundance, diversity, and quality of Wisconsin's aquatic resources provide the cornerstone of the state's multi-billion travel and tourism industry, in addition to a wide range of recreational opportunities, and environmental and aesthetic benefits. Unfortunately, there is an ever-expanding threat to our aquatic resources. Nuisance exotic species have already taken over the Great Lakes, causing major ecological and economic damage. Increasingly, they are spreading to inland lakes and streams by hitchhiking on recreational boats, and spreading through interconnected waterways, rivers, and canals. What does the arrival of these new nuisance species mean for our inland waters? And more importantly, what can we do to stop their spread and reduce their impacts?



In response to these questions, researchers at the Center for Limnology, University of Wisconsin - Madison have been conducting studies that are relevant to understanding and managing aquatic invasive species in Wisconsin. The central theme of this work can be summarized as 'smart prevention' (Vander Zanden and Olden 2008). Because invasive species typically cannot be eliminated once they establish (Vander Zanden et al. in press), preventing their spread is generally the best management option. But with approximately 15,000 lakes in Wisconsin, how and where should prevention efforts be focused? Our research has aimed at identifying the lakes and streams that are most vulnerable to invasive species: those where invasive species are likely to be introduced, survive, and have undesired impacts (Fig. 1; Vander Zanden et al. 2004; Vander Zanden and Maxted 2008). Answering these questions has proven to be challenging. Yet with such knowledge in hand, prevention, enforcement, and monitoring efforts can be directed more effectively.

In addition to the vulnerability research described above, we have addressed a wide range of other questions relating to the spread, impact, and management of aquatic invasive species (see species accounts below). For example, recent research has found that lakes created by damming are much more likely to be invaded than their non-dammed counterparts (Havel et al. 2005; Johnson et al. 2008).

The goal of this website is to help make the results of recent research on invasive species spread, impact, and management conducted at the UW-Madison Center for Limnology available to resource managers, residents, and concerned citizens. We provide links to species accounts for the following invasive species: zebra mussel, spiny water flea, Chinese mystery snail, rusty crayfish, rainbow smelt, and round goby. In addition to the brief descriptions of our findings presented here, we also provide web links to PDFs of scientific publications and book chapters that describe our research in much greater detail. We hope that our efforts to communicate the result of this research to stakeholders are helpful in some way in the ongoing battle against invasive species in Wisconsin and elsewhere.

For support of our efforts to study and communicate the impacts of aquatic invasive species in our waters, we acknowledge the support of the Wisconsin Department of Natural Resources, the National Science Foundation (the North-Temperate Lakes Long-Term Ecological Research Site and the Bioeconomics of AIS project), and the Ira and Ineva Reilly Baldwin Wisconsin Idea Endowment.

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Appendix H

SWAT – Soil and Water Assessment Tool

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

4/15/2000, Final Draft
Prepared by Fox-Wolf Basin 2000
Paul Baumgart

Objective

The primary objective of this modeling project was to provide a predictive tool that could be used to estimate the potential for phosphorus and TSS load reductions in the Big Green Lake Watershed by assessing the impact of alternative management scenarios on total phosphorus and TSS loads to Big Green Lake. To accomplish this objective, the Soil and Water Assessment Tool (SWAT) was applied to the Big Green Lake Watershed. SWAT was developed by USDA-ARS to improve the technology used in the SWRRBWQ model (Arnold et al. 1996). SWAT is a distributed parameter, daily time step model that was developed to assess non-point source pollution from watersheds and large river basins. SWAT simulates hydrologic and related processes to predict the impact of management on water, sediment, nutrient and pesticide export from rural basins. A more detailed description of this model can be found in Appendix A.

This report describes: (1) the derivation of SWAT inputs; (2) model set up, calibration and assessment; and (3) the predicted impacts of alternative management scenarios on simulated loads of phosphorus and TSS to Big Green Lake.

Watershed description

The Big Green Lake Watershed is located primarily in Green Lake and Fond du Lac Counties, but a small portion of the watershed is located in Winnebago County (Figure 1). Big Green Lake is the deepest lake in Wisconsin, and it is the primary surface water feature in the watershed with an area of 7,325 acres (29.6 km^2). Other lakes in the watershed include Spring, Big Twin and Little Twin. As shown in Figure 1, the dominant land cover in the 244 km^2 Big Green Lake Watershed is agriculture (area without Big Green Lake).

SWAT Model Inputs

GIS layers: The following GIS data layers were used to provide inputs to the SWAT model and to prepare a various GIS-based maps and analyzes:

1. 1:24k WDNR watershed boundaries; subwatersheds were added as part of this project
2. USGS 1:24k Quadrangle Images - digital topo maps (used to delineate subwatersheds)
3. WISCLAND 1992 Land Cover from WDNR
4. NRCS certified digital soil surveys from Fond du Lac and Green Lake counties, and the Winnebago County digital soil surveys (combined into a single watershed coverage)
5. 30 meter digital elevation model (DEM), primarily used to derive overland slope
6. 1:24k surface water hydrology
7. Miscellaneous: roads, county boundaries, etc.

All the GIS coverages and images were obtained from the WDNR, except the county soil surveys. All GIS coverages were projected into WTM-NAD83/91 coordinates. The watershed was divided into 25 subwatersheds by using the DEM and USGS 1:24k digital quadrangle images to directly digitize the boundaries from the computer screen. Through this project, it was determined that subwatersheds 24 and 25 do not appear to drain to Big Green Lake. Subwatershed names and areas are provided later in the report in Table 2.

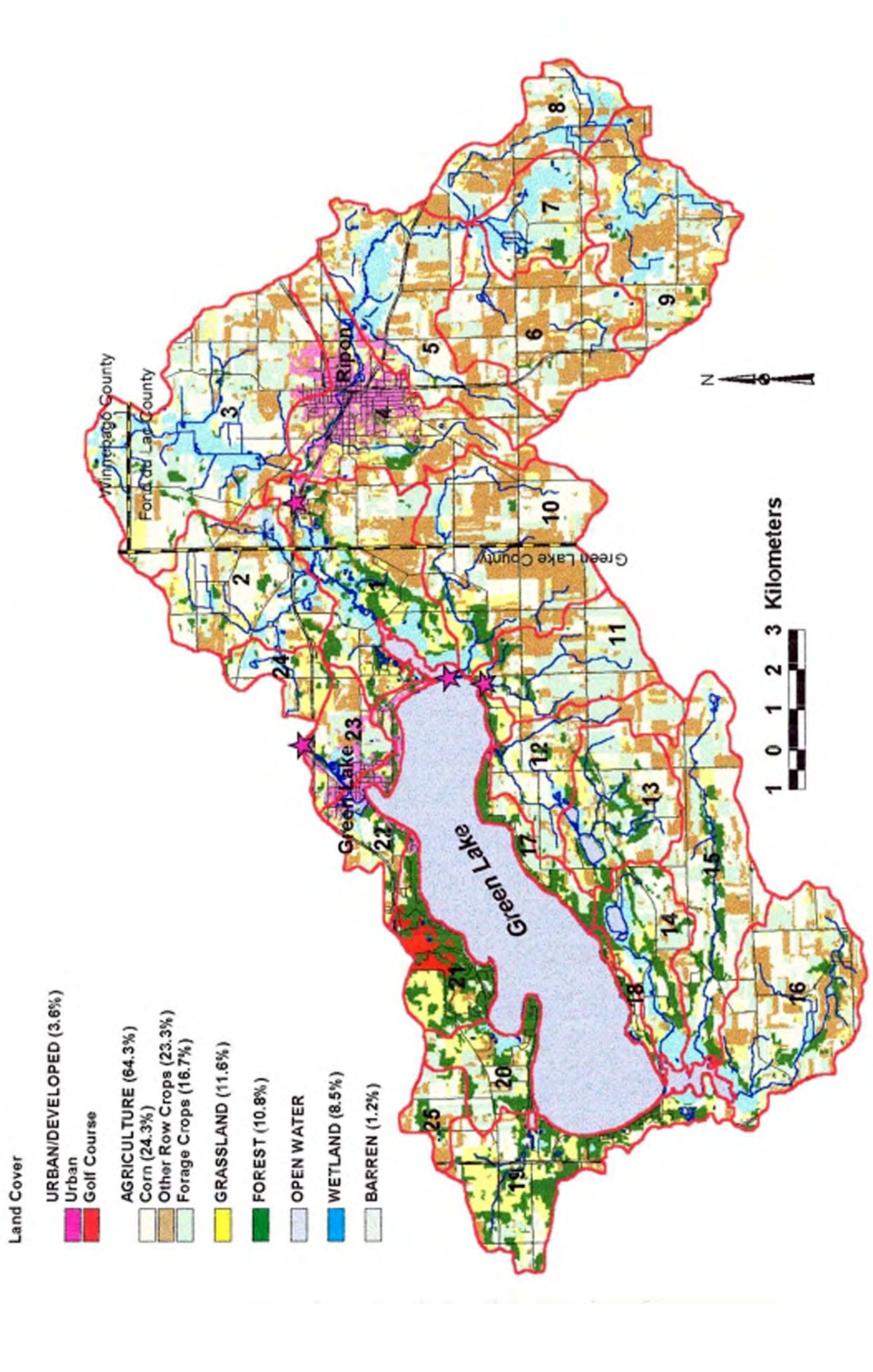


Figure 1. Big Green Lake Land Cover (based on WISCLAND 1992).

Land cover/use: Land cover within the watershed (Figure 1) was determined from the Level 3 classification of the 1992 WISCLAND land cover image, which was based on LANDSAT Thematic Mapper images. Because of the nature of interpretation and classification, forested urban areas that surround Green Lake were classified as forest in the WISCLAND coverage. The actual proportion of urban area in the entire watershed is therefore somewhat greater than that shown in Figure 1, which was based on the WISCLAND image. A GIS coverage was created to correct for this problem, and this layer was based in part on digitized USGS 1:24k quadrangle images. Another GIS coverage was later obtained from Big Green Lake county which had these types of urban areas delineated around Big Green Lake. This coverage was then used to refine the other, and the proportion of urban areas within the subwatersheds surrounding Big Green Lake were adjusted accordingly.. At this time, Figure 1 does not show these additional urban areas surrounding Big Green Lake.

The WISCLAND classified land cover image was used to assign 6 major land covers/uses which were modeled within the watershed: agriculture, urban, golf course, forest, grassland and wetland. These land covers were further divided into 11 "Hydrologic Response Units" which were directly modeled in the following fashion:

Agriculture - Dairy

1 Conventional tillage practice
2 Mulch-till
3 No-till

Agriculture - Cash crop

4 Conventional tillage practice
5 Mulch-till
6 No-till

7 Urban
8 Grassland
9 Forest
10 Wetland (or Golf Course in a subwatershed that had no significant amount of wetlands)

HRU's basically represent areas within a subwatershed that are similar in a hydrologic or management sense, but are not necessarily contiguous. No one specific farming practice could be used to model the entire watershed; therefore, various proportions of six possible agricultural practices (6 HRU's) were used to simulate what occurred in each subwatershed. For simplicity, every subwatershed was modeled as though it contained 10 HRU's in the order shown above. Since there were 25 subwatersheds, the total number of modeled HRU's was 250. A GIS overlay operation was used to derive the proportional area of the major HRU's within each of the 25 modeled subwatersheds. The next section describes how the agricultural areas were further divided in 6 agricultural HRU's. Where a subwatershed did not contain all of the landuses, the area of the non-existent landuse was assigned a negligible fraction of the total area (0.000001).

Management Practices and Hydrological Response Units (HRU)

SWAT requires detailed information regarding landuse management practices. For example, the type of crop, the date it was planted and harvested, tillage practices and dates, fertilizer applications and dates, and NRCS curve number for each period, are just some of the information that is input into SWAT's management files. The following discussion describes how these inputs were obtained.

Farm crops: The Level 3 classification of the 1992 WISCLAND classified land cover image has 3 primary crops classified within the Big Green Lake Watershed: "corn", "forage" and "other row crops". For this project, it was assumed that "other row crops" was either soybeans or another fragile crop. Unfortunately, the relatively small size of the delineated subwatersheds made it unreasonable to assume that the proportions of each crop within each subwatershed, as derived from GIS analysis of the 1992 WISCLAND image, were consistent from year to year. In some areas, the field sizes were sufficiently large that a different phase in the crop rotation would have sharply changed the proportion of the crops classified in the WISCLAND image for some of the subwatersheds. In addition, the image of the Green Lake Watershed was actually based on three separately classified scenes, which decreases the reliability of the data, particularly at the detailed Level 3 classification. Therefore, the subwatershed crop percentages derived from the WISCLAND data were not directly used as inputs. Instead, the proportion of dairy and cash cropping in each of the subwatersheds was derived by generalizing the subwatershed-specific data into two agricultural regions within the watershed: (dairy) 50% dairy and 50% cash crop; and (cash crop) 67% cash crop and 33% dairy. This task was accomplished by looking at all the sources of data including: 1) visual inspection of the WISCLAND image; 2) the proportions of each crop within each subwatershed, as indicated by the WISCLAND image; and 3) a watershed inventory conducted by Fond du Lac and Green Lake counties. The cash crop region encompassed subwatersheds 1-11 (except #3), and the remainder of the subwatersheds were assigned to the dairy regions.

Tillage practices: An inventory of farm practices within the Green Lake Watershed was gathered by the Fond du Lac and Green Lake and LCD's, in part, to support the modeling requirements of SWAT. However, the person gathering this information did not transfer this data into a database before leaving their position for different employment. Therefore, the data could only be roughly translated into a spreadsheet information system, but the accuracy of this rough translation was questionable. Therefore, management practice inputs to SWAT were based on generalizations of the collected data, as input to a spreadsheet, augmented by information obtained from the Fond du Lac and Green Lake LCD's. In addition, the Conservation Technology Information Center (CTIC) Conservation Tillage Reports from Green Lake and Fond du Lac Counties were analyzed to determine the primary tillage practice inputs to SWAT. These "Transect Survey" reports were based on statistical sampling procedures of farm fields to determine residue levels present on farm fields shortly after spring planting, as well as other information. The assumptions about current tillage practices that were utilized as data inputs for the management files in the model are summarized below. This data is based solely on the transect survey data for Green Lake County. There were probably too few data points to use the combined watershed data from both counties, particulary since data from hay/alfalfa fields were included in residue/tillage summaries for Fond du Lac County. The details of how these assumptions were derived will be described in the final report.

Summary of farm crop and management assumptions:

Crop practices

Cash crop subwatersheds: 1-11, except #3

2/3 cash crop rotation
1/3 dairy rotation

Dairy subwatersheds: (remaining subs 12-25, and #3)

50% dairy rotation (corn-grain, corn-silage, a, a, a, a)
50% cash crop rotation (corn, soybean)

Primary tillage practices

tillage	corn	soybeans
conventional practice (CT)	fall moldboard plow	fall chisel plow
mulch till (MT)	fall chisel plow	spring field cultivator, or disk
no-till (NT)	none	none

	CT	MT	NT
Dairy - present practices	61.0%	36.0%	3.0%
Cash Crop - present practices	36.0%	46.0%	18.0%
Combined Present practices	46.2%	41.7%	12.1%
Alternative A		87.9%	12.1%
Alternative B		46.2%	53.8%
Alternative C			100.0%
Alternative D		**update**	**%**

Nutrients and Nutrient Management: The following assumptions concerning commercial fertilizer and manure applications were utilized as model inputs.

Dairy rotation (cg,cs, oat/a, a,a,a) - options: moldboard plow, chisel or mulch till, no-till
1 corn grain ---- 250 lbs/acre (9-23-30 prior to planting); 30 tons manure in fall after harvest
1 corn silage ---- 250 lbs/acre (9-23-30 prior to planting)
1 oat/alfalfa
3 alfalfa ---- 2nd & 3rd year 18 lbs/acre of 0-10-60 each year; after 4th year, apply 30 t/acre manure in fall (it was assumed that only 10% of farmers apply 180 lbs/acre of 0-10-60; hence, the rate of 18 lbs/acre of fertilizer applied)

30 ton/acre/yr of dairy manure is applied for two years of this rotation (total 60 tons in 6 years)

Cash crop rotation (corn, soybeans) - options: moldboard plow, chisel mulch till, no-till
1 year corn 125 lbs/acre Anhydrous ammonia prior to planting; 280 lbs of 9-23-30 @planting

1 year soybean (soybeans serve as the legume crop or fragile crop in the cash crop rotation)
200 lbs/acre 9-23-30 @ planting (this could instead be applied during corn season; at this time the model did not show a difference; note that the nitrogen was not necessary of soybeans)

Nutrient management was not modeled at this time.

Climatological inputs: Precipitation data from Ripon, temperature data from Fond du Lac and general weather statistics from Portage were used for climatological inputs to SWAT.

Soils and overland slopes: County soil surveys were processed and combined into a single GIS coverage, and projected into WTM-NAD83 coordinates. This coverage was intersected/combined with both the WISCLAND land cover image (used to delineate HRU's), and the subwatershed delineated GIS layer, to produce soils information that was specific to each of the HRU's within each of the 25 subwatersheds. For each HRU within a subwatershed, and for each of the soil parameters required by SWAT, an area-weighted average value was assigned based on the area of each of the soil series within that HRU. A somewhat simpler procedure was conducted with the 75 meter digital elevation map to produce average slopes for each of the HRU's, within each of the 25 subwatersheds.

HRU-specific information was deemed important because slopes and soils often vary between different landuses. For example, compared to agricultural land (average slope = 3.6%), the average slope of forested land was approximately twice as steep (7.1%), and the average slope of grassland was 4.5%. This level of analysis is even more critical where there is a large proportion of wetlands, for which the average slope would substantially reduce the slope of the other HRU's in the subwatershed (unless other procedures are taken to not include the slopes from wetland areas). However, for other critical model parameters, this procedure was not as important because of the relatively homogeneous nature of the soils in the watershed. For example, the hydrologic soil group (A, B, C, D), which helps determine the NRCS curve number, did not vary much throughout the watershed, nor between the different HRU's (excluding wetlands). This was not the case when this same procedure was used in to determine subwatershed-specific soil parameters in the Lower Fox River Basin.

As previously mentioned, hydrologic soil groups varied little throughout the watershed, and therefore curve numbers also varied little. There are only four categories for hydrologic group, so this outcome is not unexpected. However, saturated conductivity did vary substantially; thereby, indicating that surface runoff and recharge proportions are unlikely to be the same throughout the watershed. Therefore, saturated conductivity was used to differentiate those subwatersheds whose soils were much more permeable than the rest. Essentially, this procedure was akin to assigning a "low B" soil hydrologic group to subwatersheds whose soils were much more permeable than others. Curve numbers for subwatersheds 18-21 were reduced by 3 units, while the curve numbers of 22-23 were reduced by 1.5 units, to reflect the reduced runoff potential expected in areas which had soils that were much more permeable than in other subwatersheds.

Stream characteristics: Geomorphic relationships between drainage area and stream channel characteristics were used to calculate both the main and routing channel depths and widths at different locations in the watershed.

Stream flows and loads: For purposes of calibrating and validating the SWAT model, stream flow, and phosphorus and total suspended solids (TSS) loads were obtained from USGS for the following locations in the watershed: Silver Creek at Koro Rd. (USGS # 040734644; 1987-96), Silver Creek at Big Green Lake inlet (USGS # 04073468; 1987-98), and White Creek at Spring Grove Road (USGS # 04030201; 1982-88; 1997-98). These monitoring sites were jointly funded by USGS, WDNR and the Green Lake Sanitary District. The monitoring locations are shown in Figure 1. Observed data from the Silver Creek-Koro Rd. station, for the 1987-92 period, was chosen to calibrate the model. Observed data from the remaining years (1993-96) at this site, and data from the Silver Creek at Big Green Lake Inlet (1987-98) were used to assess the validity of the model (validation period).

Unfortunately, the observed data from the White Creek station could not be directly utilized for calibration or validation for two reasons: (1) the annual stream flows were unusually high given the drainage area of this subwatershed; and (2) there appears to have been a substantial change in water quality between the 1982-88 period, and the 1997-98 period. Whereas the long-term stream flow on an areal basis for Silver Creek was about 250 mm (annualized over 1987-96 period), the measured flows at White Creek were much higher than could reasonably be expected (Table 1) given the amount of measured precipitation, and assumed evapotranspiration. There are at least two possible explanations for this disparity. First, the surface water drainage area of the White Creek subwatershed may be much greater than the areas delineated by either the USGS or Fox-Wolf Basin 2000. Second, the groundwater drainage area may be substantially greater than the surface water drainage areas delineated by either the USGS or Fox-Wolf Basin 2000. Further review of the 1:24,000 topological maps indicated that the eastern drainage area divide is not clearly defined, and there are also many springs in the White Creek subwatershed. In addition, road ditches may also cross the natural drainage divide at an elevation sufficiently low that large amounts of water are transferred to the White Creek subwatershed from adjacent subwatersheds. Further analysis of the White Creek data also showed that substantial changes may have occurred as result of efforts to reduce stream bank and possible gully erosion. This inference was drawn because phosphorus to TSS ratios have risen markedly, in association with what appears to be a sharp drop in TSS loads (instantaneous TSS concentrations of over 50,000 mg/L were recorded in the 1982-88 period). For example, the volumetric concentration of TSS in 1982 (calendar year) was 905 mg/L compared to a concentration of 47 mg/L in 1998 (water year), even though the total annual flows were nearly identical (1,250 cfs). In addition, the average ratio of phosphorus to TSS in the 1982-88 period was 0.93 lbs of phosphorus per ton TSS, compared to the more recent average in the 1997-98 period of 4.0 lbs of phosphorus per ton TSS.

Given the unusual water budget, and the potential temporal change in water quality over the monitoring period, it was determined that it would not be reasonable to calibrate the SWAT model with observed data from the White Creek monitoring location. This determination was particularly unfortunate because it precluded calibrating the SWAT model in two separate phases, as originally intended: (1) calibrate the subwatershed component of the model first by using a simple approach which involved modeling the White Creek subwatershed as a single subwatershed, without any routing required; and (2) then calibrating the routing component of the SWAT model by modeling the larger Silver Creek watershed, which is composed of many subwatersheds, while adjusting only those parameters that affect routing. By separating the subwatershed load-generating routines from the routing component, a more robust and predictive model may have been developed for the Big Green Lake watershed.

Table 1. Annual flows at White Creek station (areal basis) and precipitation at Ripon.

Year	Precip. mm	Flow mm	Flow % of Precip.
1982*	790	347	44%
1983	826	593	72%
1984	893	527	59%
1985	885	553	62%
1986	998	777	78%
1987	651	192	30%
1988*	574	137	24%

* all are full calendar years, except 1982 and 1988 are incomplete years

SWAT Model Setup - summary

A total of 25 subwatersheds were delineated for this project (# 24 and # 25 do not drain to Green Lake). Each of the subwatersheds contained 10 hydrologic response units (HRU's), which were based on these primary land uses: agriculture (6 HRU's), urban, grassland, forest, and wetland (or golf course). HRU's basically represent areas within a subwatershed that are similar, but are not necessarily contiguous. No one specific farming practice could be used to model the entire watershed; therefore, various proportions of six possible agricultural practices (6 HRU's) were used to simulate what occurred in each subwatershed.

The agricultural HRU's consisted of two potential farming practices:

1) Dairy-based (6 year rotation: corn-grain, corn silage, oats/alfalfa, alfalfa, alfalfa, alfalfa)

2) Cash crop (2 year rotation: corn, soybeans).

Under each of the two potential farming practices, three tillage practices were simulated: a) conventional tillage with fall moldboard plow as the primary tillage implement for corn and fall chisel plow for soybeans; b) mulch till, or chisel plow tillage in fall; and c) no-till. Hence, a total of six HRU's were used to represent agricultural areas.

SWAT98.2 was tested and modified to suit conditions in Wisconsin. Many of these code modifications were to bring in prior modifications that we made with SWAT97.2. In our testing of SWAT98.2, we have found some additional errors that required fixing. These errors have now been fixed by Fox-Wolf Basin 2000 or the model developers at USDA-ARS in Temple, Texas.

Model Calibration and Assessment

Flow Calibration: The Priestly-Taylor evapotranspiration equation was utilized for this project. The following coefficients were added to the model code which allowed adjustment of the simulated water balance to obtain a reasonable fit with the observed stream flows: Priestley-Taylor ET equation (0.77), NRCS curve number input (0.99), and available water capacity soils input (0.92).

TSS calibration: Parameters in the modified universal soil loss equation (MUSLE) were adjusted to obtain a reasonable fit between observed and simulated TSS loads. MUSLE is shown in Equation 1.

$$\text{MUSLE:}\quad Y = a\,(Q)^b\,(q_p)^c\,(DA)^d\ [(K)\,(C)\,(PE)\,(LS)] \qquad \text{(Eq. 1)}$$

where:

Y	=	sediment yield in metric tons/ha (Mg/ha)
Q	=	surface runoff volume in mm
q_p	=	peak flow rate in mm/hr
DA	=	drainage area in hectares
K	=	soil erosion factor
C	=	crop management factor
LS	=	slope-length and slope-steepness factor
PE	=	erosion control practice factor
a,b,c,d	=	constants normally set at a = 1.586, b & c = 0.56, d = 0.12 (user-specified values can be used where there are sufficient data for calibration)

The following values were utilized in the MUSLE equation for this project: a = 0.01, b = 1.6, c = 0.0 , and d = 0.0.

Annual flow and loads: Simulated and observed annual flows (mm, on an areal basis), TSS loads (metric ton) and phosphorus loads (kg) are compared in Table 2 and Figures 2a, 2b and 2c respectively, for the monitoring site located on Silver Creek at Koro Road (drainage area of 94.7 km^2). The annual totals correspond to USGS water years (October 1 to Sept 30). Annual precipitation (mm) is shown on the second y-axis in Figure 2, so precipitation and stream flow can be compared. Despite wide fluctuations in annual precipitation, observed and simulated annual values for TSS and phosphorus loads as well as annual water balance all coincide fairly well at Silver Creek during the calibration period (1987-92). However, during the validation, or assessment period (1993-96), TSS and phosphorus loads were substantially under predicted for 1993, and somewhat under predicted for 1994. Exceptionally high runoff occurred in 1993. The observed annual flow of 560 mm in 1993 represented 63% of the precipitation measured at Ripon during that year (890 mm); plus, the flow in 1993 was more than two times greater than the second highest annual flow which occurred during the 1987-96 period. Evapotranspiration must have been greatly suppressed to produce such a high flow to precipitation ratio. Spring planting was delayed during 1993, and high soil moisture levels further delayed plant emergence and growth early in the year. As a result, evapotranspiration and protective plant canopy from annual crops were lower than normal during the early growing season. Plant stress due to wet soil conditions (including reduced availability of nitrogen) is not simulated by the model, and only the average planting dates were input to the model. If these factors had been accounted for by model simulations, both of these factors would have increased simulated flows and loads, and produced a closer correspondence between observed and simulated values. Only average planting/tillage dates were input to the model to reduce the number of input files and simplify the model set up.

Silver Creek at Green Lake inlet: The model was not calibrated with data from this site, so the entire 1987-98 period could be considered a validation/assessment period; however, since this site is downstream of the primary calibration site, it may be more appropriate to consider separating the data into two periods (1987-92: calibration period; 1993-98 validatation period). Simulated and observed annual flows (mm), TSS loads (metric ton) and phosphorus loads (kg) are compared in Table 3 and Figures 3a, 3b and 3c respectively, for the monitoring site located on Silver Creek

Table 2. Observed and simulated annual flow and loads - Silver Creek at Koro Rd. Calibration period (1989-92) and Validation period (1993-96).

	Ripon Precip. (mm)	Flow (mm) Observed	Flow (mm) SWAT	TSS (MT) Observed	TSS (MT) SWAT	Total Phosphorus (kg) Observed	Total Phosphorus (kg) SWAT
1987*	640	150	160	280	380	2,640	3,480
1988	570	120	90	330	170	2,780	2,280
1989	680	200	200	1,530	1,620	9,810	10,030
1990	1,000	250	310	700	910	7,480	6,360
1991	790	240	250	780	540	3,990	4,550
1992	750	250	220	540	480	3,380	4,020
1993	890	560	440	1,530	960	10,640	6,760
1994	730	170	110	480	230	4,650	2,670
1995	840	240	220	480	630	3,910	4,810
1996*	540	250	260	510	710	3,980	4,810
Totals							
1987-92	4,440	1,210	1,220	4,150	4,110	30,070	30,710
1993-96	3,000	1,230	1,030	3,000	2,530	23,180	19,060
1987-96	7,440	2,440	2,260	7,150	6,640	53,260	49,770

* values are totals for calendar years, except 1987 (started Feb 1), and 1996 (ended Sept. 30)

Table 3. Observed and simulated annual flow and loads - Silver Cr. at Green Lake Inlet. Calibration period (1989-92) and Validation period (1993-98).

	Ripon Precip. (mm)	Flow (mm) Observed	Flow (mm) SWAT	TSS (MT) Observed	TSS (MT) SWAT	Total Phosphorus (kg) Observed	Total Phosphorus (kg) SWAT
1987*	640	160	150	520	410	2,610	3,770
1988	570	130	80	320	170	2,700	2,310
1989	680	220	200	1,790	2,170	10,570	11,200
1990	1,000	270	310	1,420	1,150	8,270	6,800
1991	790	230	250	500	610	4,160	4,980
1992	750	230	210	750	460	3,470	4,200
1993	890	560	440	3,290	1,160	12,580	7,390
1994	730	190	110	540	260	6,450	2,720
1995	840	260	210	720	640	4,370	5,150
1996	660	300	280	790	920	5,100	5,650
1997	710	240	160	740	390	4,230	3,580
1998*	620	180	150	870	610	3,230	4,240
Totals							
1987-92	4,440	1,260	1,200	5,300	4,980	31,800	33,260
1993-98	4,460	1,740	1,350	6,950	3,990	35,970	28,720
1987-98	8,900	3,000	2,550	12,260	8,970	67,760	61,990

* values are totals for calendar years, except 1987 (started Feb 1), and 1998 (ended Sept. 30)

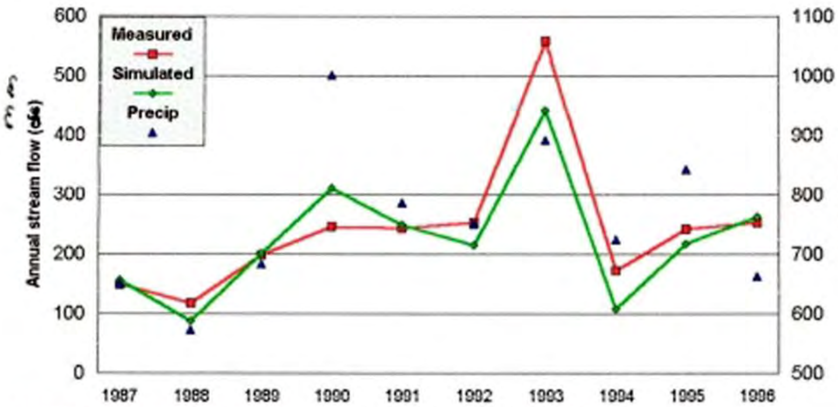


Figure 2a. Observed and simulated annual stream flow - Silver Cr. at Koro Rd.

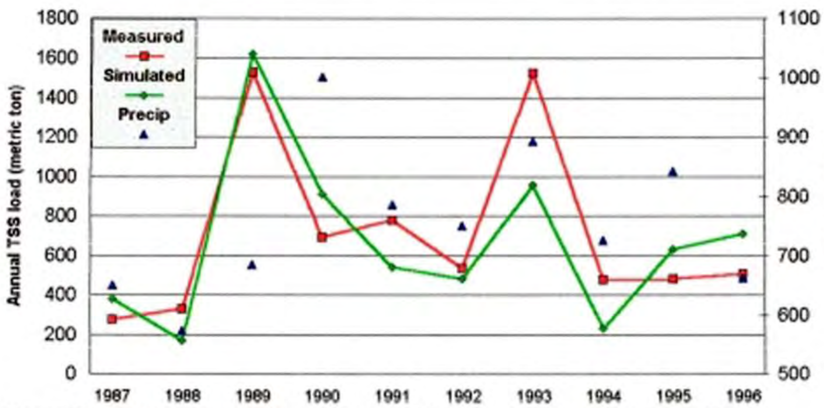


Figure 2b. Observed and simulated annual TSS load - Silver Cr. at Koro Rd.

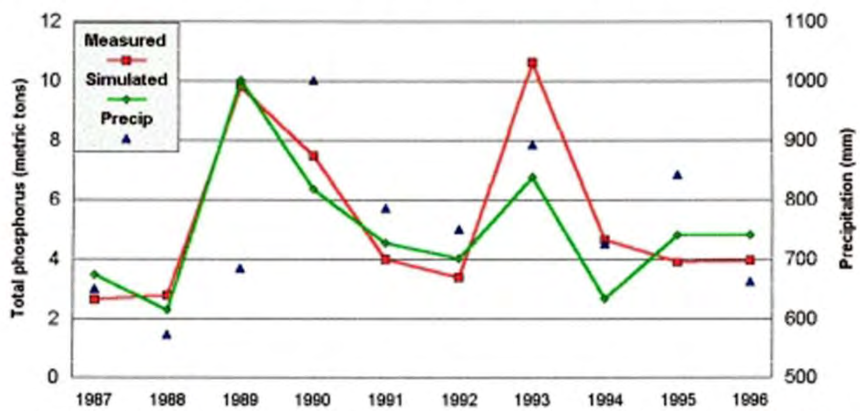


Figure 2c. Observed and simulated annual total phophorus load - Silver Cr. at Koro Rd.

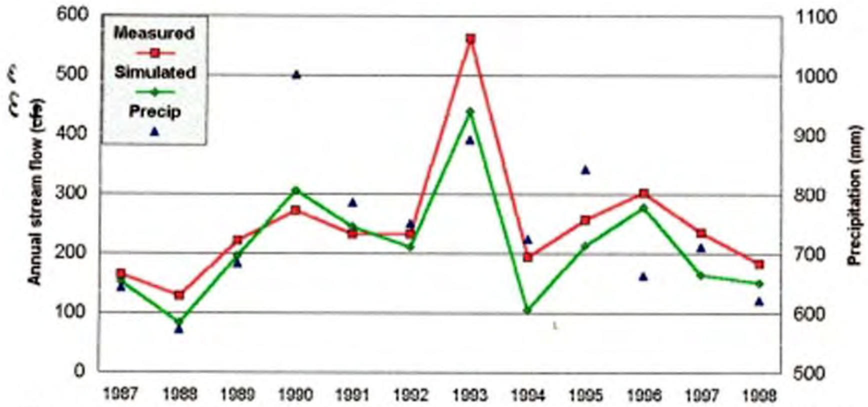


Figure 3a. Observed and simulated annual stream flow - Silver Cr. at Green Lake Inlet.

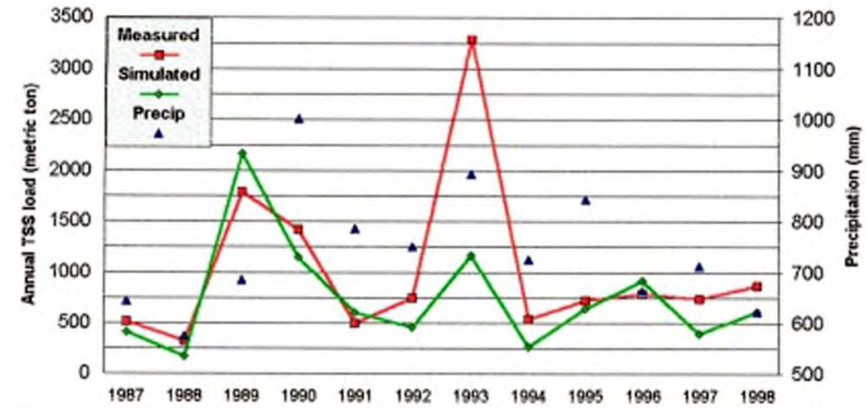


Figure 3b. Observed and simulated annual TSS load - Silver Cr. at Green Lake Inlet.

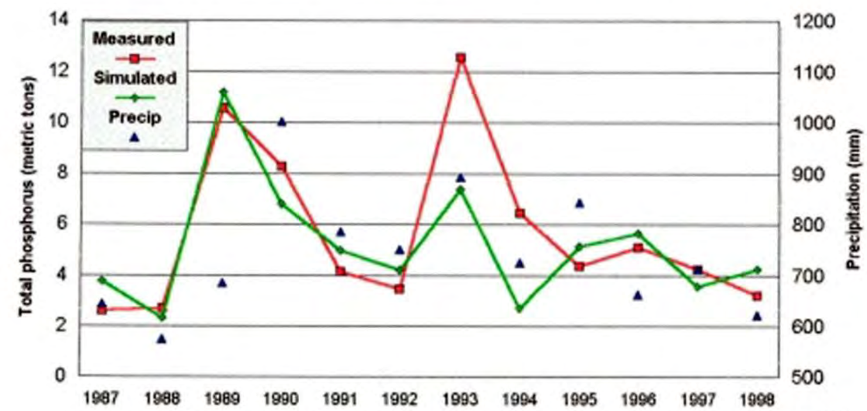


Figure 3c. Observed and simulated annual total phophorus load - Silver Cr. at Green Lake Inlet.

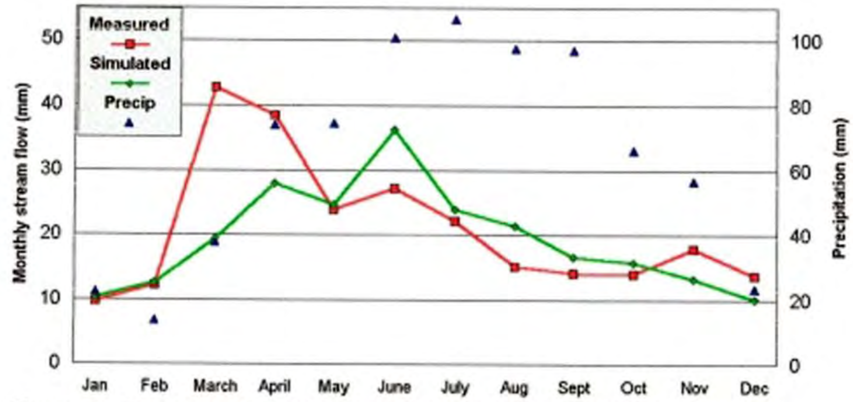


Figure 4a. Observed and simulated monthly stream flow - Silver Cr. at Koro Rd.

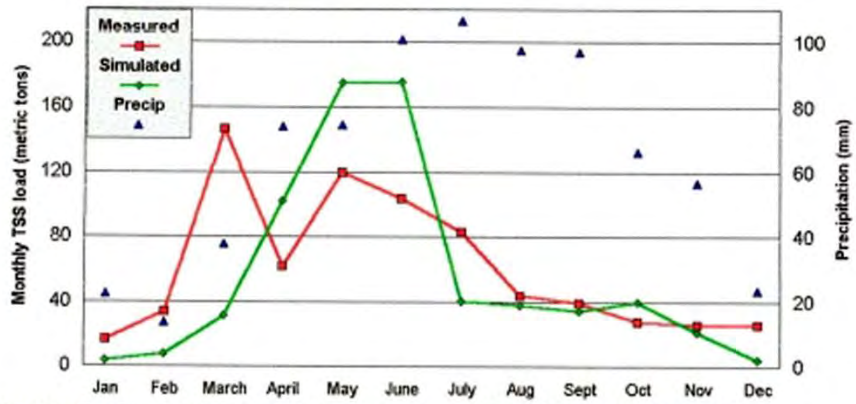


Figure 4b. Observed and simulated monthly TSS load - Silver Cr. at Koro Rd.

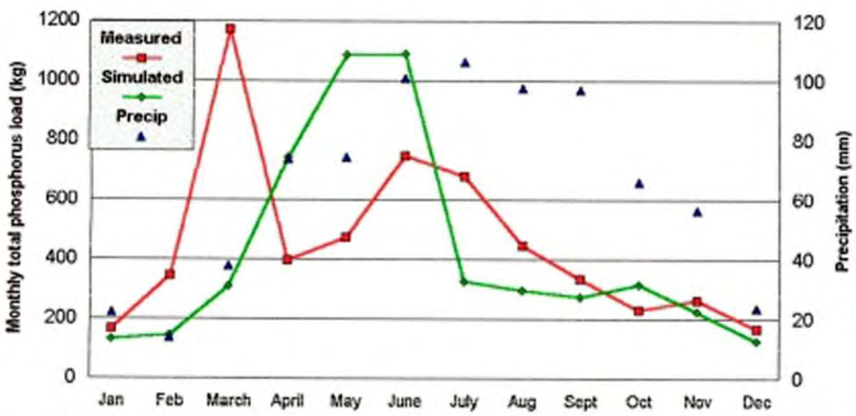


Figure 4c. Observed and simulated monthly total phophorus load - Silver Cr. at Koro Rd.

at the Green Lake inlet (drainage area of 122 km^2). Again, despite wide fluctuations in annual precipitation, observed and simulated annual values for TSS and phosphorus loads as well as annual water balance all coincide fairly well during the entire 1987-98 period, except during 1993 and 1994. Phosphorus loads were substantially under predicted in 1993 and 1994. However, TSS loads were greatly under predicted in 1993 when the simulated load was about one third of the observed load; the difference is much greater than it was for the upstream monitoring site. One potential explanation that deserves further analysis is that the model, as currently set up, is settling too much TSS within some or all of the stream reaches. Unaccounted channel degradation occurring during the high flows in 1993 could also have been responsible for the high TSS loads in 1993. It appears unlikely that delayed planting and slow early crop growth during 1993 will be sufficient to account for the discrepancy between simulated and observed TSS loads at this location. I recommend that any further refinement of the model should utilize the 1993 data for calibration purposes at this site.

Monthly flow and loads: Simulated and observed monthly average stream flow (mm), TSS loads (metric ton) and phosphorus loads (kg) are compared in Figures 4a, 4b and 4c respectively, for the monitoring site located on Silver Creek at Koro Road. The monthly values were averaged over the 1987-96 period. Monthly precipitation (mm) is shown on the second y-axis in Figure 4, so precipitation and stream flow can be compared.

In general, monthly average simulated flows were close to observed flows except during March, when the simulated average flow was less than half the observed average, while flow during April was somewhat lower than the observed average value (Figure 4a). Except for these excursions, the model was able to reliably track seasonal changes in flow despite the less than direct correspondence between observed monthly flow and preciption. It is understandable that the SWAT-estimated March flow (19.4 mm on an areal basis) did not match the observed flow because the average March precipitation at Ripon is 37.8 mm, which is lower than the observed flow of 42.7 mm (1987-96 averages). A number of conditions could contribute to the high flows observed in March including: a large groundwater storage component, high proportion of runoff due to frozen ground conditions, frozen surface water and snow storage in wetlands that thaws in spring, snow melt, and delayed groundwater flow over winter. In addition, some of the measured discharges in March may have been affected by ice conditions which would tend to overstate flow whenever the ice caused the water to backup. Therefore, while attempts may be made to refine the model and improve the fit between observed and simulated flows, it must be recognized that many of the conditions that cause the average March flow in Silver Creek to exceed the average March precipitation are likely to be difficult to model with SWAT.

Compared to stream flow, simulated TSS and phosphorus loads were much lower than the observed values during the month of March, suggesting that surface water contributions were also understated by the model simulations (Figure 4b, 4c). If only stream flow had been under-predicted by the simulations, while the loads had been closely estimated, it would have indicated that the groundwater contributions were not well predicted. Simulated TSS and phosphorus loads were substantially greater than observed loads during the months of April, May and June (Figure 4b, 4c). Phosphorus loads were particularly overstated. The precise cause of these over predications is not yet known, but further attempts may be made to refine the model and produce a better fit in the near future. Given these results, I am forced to conclude that the model as currently set up, does only a fair job of accurately representing the observed TSS and phosphorus loads during the months of April through July; while the model performs poorly in simulating loads during March. This conclusion is especially applicable to simulated phosphorus loads.

However, it is also important to note that the total simulated TSS and phosphorus loads during the March through July period were essentially identical to the observed values.

White Creek at Spring Grove Road: For reasons previously stated, TSS and phosphorus loads from the White Creek monitoring station could not be directly utilized for calibration purposes, particularly for the 1982-88 period. However, simulated and observed TSS and phosphorus loads from the 1997-98 period were compared to see how well the model could perform, given the caveat about the high observed stream flows from this drainage area. The average simulated flow for the 1997-98 calendar year period was about half of the observed average during the 1997-98 water year. The simulated average TSS load during the 1997-98 calendar year period was 102 metric tons compared to the observed average TSS load of 230 metric tons during the 1997-98 water year period. However, the simulated average phosphorus load (1997-98 calendar year) was within 10% of the observed average (1997-98 water year).

Evaluation of Alternative Management Practices

Four alternative agricultural management practices were simulated to evaluate the impact of each alternative on TSS and phosphorus loads, as routed to the outlet of each subwatershed, and routed to Big Green Lake. The four alternative management scenarios include: (A) those cropped areas practicing conventional tillage (corn - fall moldboard plow; soybeans - fall chisel plow) switched to mulch-till (corn - fall chisel plow; soybeans - field cultivator or disk in spring); (B) conventional tilled acres switched to mulch-till, plus all cropped areas practicing mulch-till switched to no-till; (C) no-till was practiced on all cropped agricultural land; and (D) no-till was practiced on all cash-crop farms, but dairy farms only switched to mulch-till, unless they were already practicing no-till. The cost to switch to mulch-till was assumed to be $30/acre for cash-crop rotations, and $15/acre for dairy rotations. The cost was lower for dairy rotations because the alfalfa acreage was only affected prior to planting or after the last harvest. To switch to no-till, the cost was assumed to be $50/acre for cash-crop rotations, and $25/acre for dairy rotations. These costs were used as examples, and different costs can be substituted in the provided spreadsheet.

Simulated subwatershed TSS and phosphorus loads for the current condition and four alternative management scenarios are shown in Tables 4 and 5, respectively (1987-98 average). The loads for subwatershed #4 do not include the discharge of the Ripon Wastewater Treatment Plant. Phosphorus loads as routed to Big Green Lake are also shown in Table 5, which includes the discharge from the Ripon Wastewater Treatment Plant. The simulated 1987-98 average annual phosphorus load from Silver Creek to Green Lake is 5,200 kg (11,500 lbs), and the total load routed to the lake is 13,700 kg (30,200 lbs).[1] The simulated 1987-98 average annual TSS load from Silver Creek to Green Lake is 750 metric tons (830 Eng. tons), and the total load routed to the lake 2,600 metric tons (2,900 Eng. tons). The simulated TSS loads are probably less reliable than phosphorus loads because of the difficulty in modeling sediment loads that are caused from stream bank erosion or severe gully erosion, which can be specific to individual subwatersheds. In addition, phosphorus is more conservative than TSS as it is routed through stream reaches, so the

[1]The total simulated load to the lake is somewhat less than this total because the upper portion of the Hill Creek watershed was not routed through the lower portion or the Twin Lakes system. Subwatershed #12 should be routed through the lake system and through subwatershed #13, but this was not done at this time to simplify the modeling process. Therefore, the actual load from sub. #12 to Green Lake should be less than indicated in this report; however, the impact of sub. #12 on the Twin Lakes system is also important.

simulated TSS loads are more sensitive to possible errors in the routing process.

The subwatersheds were also ranked and sorted on the basis of total reduced phosphorus load, as routed to Big Green Lake. Based on this ranking, the phosphorus loads, reduced loads, associated cost to reduce the load, and the unit cost to reduce the loads are shown in Table 6. These rankings show how the simulated results can be used to determine where the greatest reductions might best be targeted.

The simulated phosphorus loads for each of the four alternative scenarios, as routed to Big Green Lake, are combined with the associated cumulative cost to reduce the load in Figure 5. Each dot in the figure represents the impact of adding another subwatershed to each of the alternative management scenarios (going from left to right). Thus, if the goal is to achieve an average annual total phosphorus load to Big Green Lake of 20,000 lbs (reduce load by 33%), then Alt. C and D have nearly the same cost of $600,000/year, Alt. B will require implementation in all subwatersheds and cost $800,000/year, and Alt. A will only be able to reach a load of 24,500 lbs. The simulated data in Figure 5 suggests that the different alternative scenarios do not differ much in cost-effectiveness until the 10 least important subwatersheds undergo the management change, at which point the lines tend to diverge. The information shown in Figure 5 is summarized in Table 7.

Model limitations

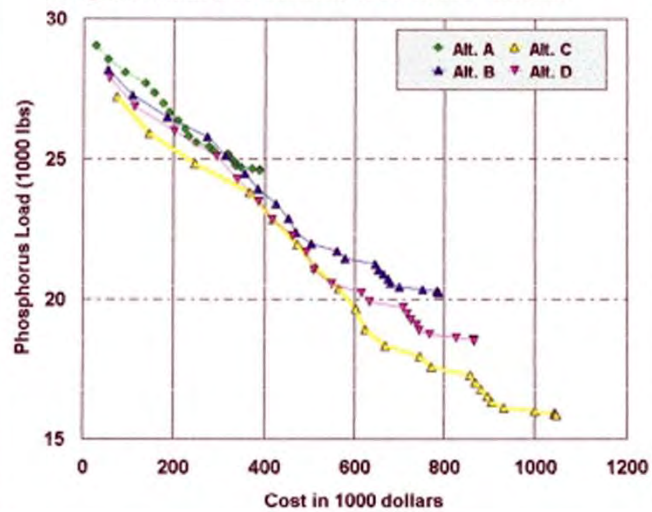
This section describes some of the limitations inherent to the simulations. These limitations should be considered when evaluating absolute and relative loads, as well as the costs to reduce these loads, within the Big Green Lake Watershed.

Until very recently, the model dealt with inorganic phosphorus fertilizer incorrectly; that is, the addition of inorganic fertilizer had no effect on the levels of phosphorus supposedly attached to sediment during erosion events. While this component of the model has been fixed, there has been insufficient time to thoroughly calibrate the response of the model to various inputs related to phosphorus. For example, the relative proportions of soluble, sediment-attached and organic phosphorus need to be adjusted to reflect results from published data for a variety of management practices. One reason the proportion of soluble phosphorus is important is that the model routes 100% of this form of phosphorus to the watershed outlets. Therefore, a pound of soluble phosphorus discharged from either an upper or a lower reach are both treated as though all of it reaches the lake.

The version of the SWAT model used in this project does not route sediment and sediment-attached phosphorus in the same manner, and this aspect of the model resulted in some undesired outcomes. In some stream reaches, sediment-attached phosphorus is settling out in the stream at a higher rate than the sediment, which is not appropriate. In addition, within every stream reach, the non-soluble portion of the phosphorus load is being trapped at a very consistent rate of about 33%. That is, on a long-term net basis, 67% of the non-soluble phosphorus that enters a stream reach passes through the reach, while 33% remains as deposited material. This is true of every reach, which seems unreasonable since there are major differences in the stream gradients. These odd results may be due to my not knowing, until recently, that the model was using a new, much more complex routine for routing phosphorus. Thus, the model results are based on the default nutrient routing parameters, without any changes to adjust these values to give better results. Without further refinement, it must be understood that the modeled results do not currently mimic the physical world in a realistic manner, but the results are still useful for comparison purposes. If the model is showing more deposition of phosphorus when routing through Silver Creek than actually occurs, then the relative load from Silver Creek is greater than indicated by the model (compared to the rest of the watershed). The same logic holds if the relative amount of soluble phosphorus is too low, because routing through the reaches of Silver Creek would have little effect on this form of phosphorus.

For a number of reasons, the predicted load reductions associated with the alternative management scenarios are probably overly optimistic. Phosphorus reductions resulting from conservation tillage may be too high because I used management inputs which distributed manure at a deeper level than actually occurs. In addition, the amount of soluble phosphorus simulated by the model with the current settings may be too low. Soluble phosphorus is more difficult to control with conservation tillage, which cannot only increase the concentration of soluble phosphorus, but actually increase the load as well. Time did not permit testing these aspects of the model thoroughly enough to be confident that the inputs that affect manure depth or the proportion of soluble P are reasonable. Another modeling assumption that may lower the reduction potential, is the proportion of land that is assumed to be under conventional tillage. These numbers were based on the county transect survey, in which an estimate was made of the residue on the fields just after planting. If it was estimated that the residue percentage directly after planting was lower than 15% for a particular field, then "conventional tillage" was assigned to that field, even though substantial protective residue may have been present between the fall harvest and spring planting period. If the prior crop was soybeans, very little residue might remain for detection after planting the next crop because of spring tillage, even if the residue was undisturbed until the soil was tilled. Yet undisturbed residue should substantially reduce TSS and phosphorus loads until spring tillage occurs. This aspect of erosion control is important because approximately 30% of the TSS load and 42% of the phosphorus load measured at the Silver Creek-Koro Road monitoring station (1987-96) occurs between the period between typical fall harvest and spring tillage.

Figure 5. Simulated Phosphorus Loads to Green Lake for Alternative Management Scenarios and Associated Cost to Reduce - 3/28/2000.



Cost Assumptions

	Dairy	Cash Crop
Alt. A	CT > MT	CT > MT
Alt. B	CT > MT MT > NT	CT > MT MT > NT
Alt. C	all NT	all NT
Alt. D	all MT	all NT
MT cost	$15/acre	$30/acre
NT cost	$25/acre	$50/acre

Table 7. Cumulative cost to reduce phosphorus loads, and associated load reduction to Big Green Lake.

Cumulative Cost to reduce Phosphorus				Cumulative total Phosphorus Reduction						
Alt. A	Alt. B	Alt. C	Alt. D	Alt. A	Alt. B	Alt. C	Alt. D		sub#	subwatershed
$28,300	$56,600	$74,500	$58,100	1,110	2,000	2,940	2,270	1	16	Wurchs Creek
$55,800	$109,400	$146,600	$114,400	1,620	2,900	4,250	3,300	2	15	Roy Creek
$92,600	$185,900	$247,700	$201,700	2,000	3,610	5,270	4,190	3	10	Dakin Creek
$137,600	$274,100	$365,800	$294,000	2,450	4,380	6,370	5,060	4	3	Silver Cr. 3 (routed, est.
$156,600	$313,400	$417,800	$338,800	2,820	5,050	7,330	5,900	5	1	Silver Cr. 1
$176,700	$355,100	$472,900	$386,400	3,170	5,690	8,230	6,680	6	2	Silver Cr. 2 (routed, est.
$191,700	$384,600	$512,400	$417,300	3,490	6,250	9,040	7,320	7	13	Hill Creek Twin Lake
$210,300	$423,100	$563,300	$461,200	3,770	6,760	9,770	7,950	8	11	White Creek
$225,200	$452,300	$602,500	$491,800	4,060	7,270	10,510	8,540	9	12	Hill Creek Lower
$233,200	$468,200	$623,700	$508,400	4,350	7,790	11,260	9,120	10	14	Spring Creek
$249,700	$502,400	$668,900	$547,400	4,580	8,190	11,840	9,620	11	4 (b)	Silver Cr. 4 (routed, est.
$277,700	$560,400	$745,600	$613,700	4,730	8,450	12,200	9,940	12	5	Silver Cr. 5 (routed, est.
$287,100	$576,800	$770,200	$632,900	4,880	8,720	12,590	10,250	13	19	Beyers Cove
$319,200	$645,300	$858,100	$708,800	4,990	8,910	12,850	10,480	14	6	Silver Cr. 6 (routed, est.
$322,900	$652,500	$867,800	$716,300	5,100	9,110	13,140	10,710	15	22	Green Lake North (f)
$328,000	$662,600	$881,300	$726,800	5,200	9,280	13,390	10,900	16	23	Green Lake North (f)
$333,400	$673,300	$895,600	$738,000	5,290	9,440	13,620	11,080	17	20	Norwegian Bay
$336,400	$679,000	$903,300	$744,000	5,380	9,600	13,860	11,270	18	17	South Shore
$346,300	$699,700	$930,600	$767,600	5,460	9,730	14,040	11,420	19	7	Silver Cr. 7 (routed, est.
$371,500	$751,800	$999,500	$827,100	5,520	9,830	14,170	11,550	20	9	Silver C. 9 (routed, est.)
$387,100	$784,200	$1,042,200	$864,000	5,540	9,880	14,230	11,600	21	8	Silver C. 8 (routed, est.)
$387,400	$784,800	$1,043,000	$864,600	5,560	9,910	14,280	11,640	22	18	SW Shore
$388,400	$786,700	$1,045,600	$866,600	5,580	9,930	14,320	11,670	23	21	Pigeon Cove/Malcolm E

Table 5. Big Green Lake watershed simulated average annual phosphorus loads and yields (1987-98) - English units.
(as simulated with modified SWAT98 model: 3/28/2000)

Sub-id	Subwatershed Name	Area (sq. mi)	Current Practices CT, MT & NT(a) Total-Phosphorus lbs	lb/acre	Alternative A CT > MT Total-Phos. lbs	lb/acre	percent reduced	Alternative B CT > MT MT > NT Total-Phos. lbs	lb/acre	percent reduced	Alternative C all NT (no-till) Total-Phos. lbs	lb/acre	percent reduced	Alternative D Dairy MT; Cash Crop (no-till) Total-Phos. lbs	lb/acre	percent reduced	% Ag area	Total Cost to reduce Alt. A CT>MT	Alt. B CT>MT MT>NT	Alt. C CT>NT MT>NT	Alt. D Dairy MT Cash crop all NT	Cost per lb total Phos. reduced Alt. A	Alt. B	Alt. C	Alt. D	
1	Silver Cr. 1	6.01	1,849	0.481	1,483	0.385	19.8%	1,176	0.306	36.4%	891	0.232	51.8%	1,016	0.264	45.0%	48.0%	$18,900	$39,200	$51,900	$44,800	$52	$58	$54	$54	1
2	Silver Cr. 2	4.49	2,302	0.800	1,801	0.626	21.7%	1,376	0.478	40.2%	976	0.339	57.6%	1,152	0.401	49.9%	68.2%	$20,100	$41,700	$55,100	$47,600	$40	$45	$42	$41	2
3	Silver Cr. 3	9.35	3,019	0.504	2,392	0.400	20.8%	1,905	0.318	36.9%	1,393	0.233	53.9%	1,746	0.292	42.2%	75.3%	$45,000	$88,300	$118,200	$92,300	$72	$79	$73	$73	3
4 (b)	Silver Cr. 4	5.39	2,476	0.717	2,165	0.627	12.6%	1,896	0.549	23.4%	1,644	0.476	33.6%	1,755	0.508	29.1%	46.6%	$16,500	$34,200	$45,200	$39,000	$53	$59	$54	$54	4
5	Silver Cr. 5	5.70	1,491	0.409	1,199	0.329	19.6%	944	0.259	36.7%	705	0.193	52.7%	806	0.221	46.0%	74.9%	$28,000	$58,000	$76,700	$66,200	$96	$106	$98	$97	5
6	Silver Cr. 6	5.33	1,522	0.446	1,215	0.356	20.2%	950	0.278	37.6%	703	0.206	53.8%	808	0.237	46.9%	91.7%	$32,100	$66,500	$87,900	$75,900	$104	$116	$107	$106	6
7	Silver Cr. 7	2.45	968	0.617	755	0.482	21.9%	568	0.362	41.3%	390	0.249	59.7%	469	0.299	51.6%	61.9%	$10,000	$20,700	$27,300	$23,600	$47	$52	$47	$47	7
8	Silver Cr. 8	3.10	378	0.190	309	0.155	18.4%	247	0.124	34.6%	191	0.096	49.5%	214	0.108	43.3%	76.7%	$15,600	$32,300	$42,800	$36,900	$225	$247	$229	$226	8
9	Silver Cr. 9	5.22	1,162	0.348	921	0.276	20.7%	718	0.215	38.2%	530	0.159	54.4%	612	0.183	47.4%	73.5%	$25,200	$52,200	$68,900	$59,500	$105	$118	$109	$108	9
10	Dakin Creek	6.84	1,889	0.432	1,509	0.345	20.1%	1,178	0.269	37.6%	870	0.199	54.0%	999	0.228	47.1%	82.3%	$36,900	$76,500	$101,100	$87,300	$97	$108	$99	$98	10
11	White Creek	3.39	1,329	0.612	1,055	0.486	20.6%	822	0.379	38.2%	605	0.279	54.5%	698	0.322	47.5%	83.5%	$18,600	$38,500	$50,900	$43,900	$68	$76	$70	$70	11
12	Hill Creek Lower	2.96	1,353	0.714	1,061	0.560	21.6%	839	0.443	38.0%	606	0.320	55.2%	767	0.405	43.3%	78.9%	$14,900	$29,200	$39,200	$30,600	$51	$57	$52	$52	12
13	Hill Creek Twin Lake	3.60	1,464	0.635	1,144	0.496	21.9%	903	0.392	38.3%	651	0.283	55.5%	825	0.358	43.7%	65.4%	$15,000	$29,500	$39,500	$30,900	$47	$53	$49	$48	13
14	Spring Creek	2.82	1,305	0.725	1,017	0.565	22.1%	794	0.441	39.2%	559	0.310	57.2%	726	0.403	44.4%	44.9%	$8,100	$15,900	$21,200	$16,600	$28	$31	$28	$29	14
15	Roy Creek	5.58	2,358	0.660	1,846	0.517	21.7%	1,458	0.408	38.2%	1,051	0.294	55.4%	1,334	0.374	43.4%	77.0%	$27,400	$53,800	$72,100	$56,300	$54	$60	$55	$55	15
16	Wurchs Creek	5.66	4,896	1.350	3,784	1.044	22.7%	2,895	0.799	40.9%	1,954	0.539	60.1%	2,621	0.723	46.5%	78.3%	$28,300	$55,600	$74,500	$58,100	$25	$28	$25	$26	16
17	South Shore	1.42	597	0.657	507	0.558	15.1%	438	0.482	26.7%	366	0.403	38.7%	416	0.457	30.4%	32.4%	$2,900	$5,700	$7,700	$6,000	$32	$36	$33	$33	17
18	SW Shore	0.46	189	0.640	172	0.584	8.8%	159	0.538	15.9%	145	0.489	23.5%	155	0.525	18.0%	10.2%	$300	$590	$790	$620	$18	$20	$18	$18	18
19	Beyers Cove	4.29	853	0.311	702	0.256	17.7%	585	0.213	31.4%	465	0.169	45.5%	549	0.200	35.6%	34.2%	$9,400	$18,400	$24,600	$19,200	$62	$69	$63	$63	19
20	Norwegian Bay	1.98	499	0.394	407	0.321	18.4%	338	0.267	32.3%	265	0.209	46.9%	317	0.250	36.5%	43.1%	$5,400	$10,600	$14,300	$11,200	$59	$66	$61	$61	20
21	Pigeon Cove/Malcolm Bay	2.40	331	0.216	315	0.206	4.8%	303	0.198	8.3%	291	0.190	12.1%	300	0.196	9.4%	6.4%	$970	$1,910	$2,560	$2,000	$62	$69	$64	$64	21
22	Green Lake North (f)	1.80	817	0.709	702	0.609	14.0%	613	0.532	24.9%	519	0.450	36.5%	587	0.509	28.2%	32.0%	$3,700	$7,200	$9,700	$7,500	$32	$35	$33	$33	22
23	Green Lake North (f)	1.74	772	0.693	676	0.607	12.4%	602	0.541	22.0%	526	0.472	31.9%	580	0.521	24.8%	46.2%	$5,100	$10,000	$13,500	$10,500	$53	$59	$55	$55	23
24 (c)	Puchyan	1.21	557	0.721	431	0.558	22.6%	336	0.434	39.7%	234	0.303	57.9%	306	0.396	45.0%	48.9%	$3,800	$7,400	$9,900	$7,700	$30	$33	$31	$31	24
25 (c)	Fox R./Berlin - UF06	0.98	379	0.601	299	0.474	21.2%	239	0.379	36.9%	178	0.282	53.1%	220	0.349	41.9%	77.4%	$4,900	$9,600	$12,800	$10,000	$61	$69	$64	$63	25
1	Silver Cr. 1	6.01	1,849	0.481	1,483	0.385	19.8%	1,176	0.306	36.4%	891	0.232	51.8%	1,016	0.264	45.0%	48.0%	$18,900	$39,200	$51,900	$44,800	$52	$58	$54	$54	1
2	Silver Cr. 2 (routed, est.)	4.49	1,582	0.550	1,226	0.426	22.6%	945	0.328	40.3%	681	0.237	57.0%	796	0.277	49.7%	68.2%	$20,100	$41,700	$55,100	$47,600	$56	$65	$61	$61	2
3	Silver Cr. 3 (routed, est.)	9.35	2,115	0.353	1,669	0.279	21.1%	1,348	0.225	36.3%	1,012	0.169	52.2%	1,240	0.207	41.3%	75.3%	$45,000	$88,300	$118,200	$92,300	$101	$115	$107	$106	3
4 (b)	Silver Cr. 4 (routed, est.)	5.39	1,753	0.508	1,521	0.441	13.2%	1,343	0.389	23.4%	1,177	0.341	32.9%	1,249	0.362	28.7%	46.6%	$16,500	$34,200	$45,200	$39,000	$71	$84	$78	$77	4
5	Silver Cr. 5 (routed, est.)	5.70	763	0.209	614	0.168	19.6%	503	0.138	34.1%	400	0.110	47.6%	440	0.121	42.3%	74.9%	$28,000	$58,000	$76,700	$66,200	$187	$223	$211	$205	5
6	Silver Cr. 6 (routed, est.)	5.33	573	0.168	462	0.135	19.4%	386	0.113	32.8%	316	0.093	44.9%	341	0.100	40.4%	91.7%	$32,100	$66,500	$87,900	$75,900	$289	$354	$342	$327	6
7	Silver Cr. 7 (routed, est.)	2.45	329	0.210	253	0.161	23.1%	199	0.127	39.5%	149	0.095	54.9%	170	0.108	48.5%	61.9%	$10,000	$20,700	$27,300	$23,600	$132	$159	$151	$148	7
8	Silver C. 8 (routed, est.)	3.10	171	0.086	146	0.074	14.7%	128	0.064	25.5%	112	0.056	34.6%	117	0.059	31.8%	76.7%	$15,600	$32,300	$42,800	$36,900	$621	$741	$721	$677	8
9	Silver C. 9 (routed, est.)	5.22	337	0.101	276	0.083	18.3%	236	0.071	30.0%	202	0.060	40.2%	214	0.064	36.5%	73.5%	$25,200	$52,200	$68,900	$59,500	$409	$515	$508	$482	9
	Silver Cr. sub-wsheds (1-9) (b,d)	47.06	15,168	0.504	12,241	2.601	19.3%	9,780	2.078	35.5%	7,424	1.578	51.1%	8,578	1.823	43.4%		$211,300	$433,100	$573,900	$485,800	$72	$80	$74	$74	
	Silver Cr. (Routed to Lake) (e)(g)	47.06	11,515	0.382	9,865	2.096	14.3%	8,613	1.830	25.2%	7,393	1.571	35.8%	8,018	1.704	30.4%		$211,300	$433,100	$573,900	$485,800	$128	$149	$139	$139	
	subwatersheds (10-23)	44.94	18,652	0.649	14,899	3.316	20.1%	11,928	2.654	36.1%	8,871	1.974	52.4%	10,874	2.420	41.7%		$177,100	$353,700	$471,700	$380,800	$47	$53	$48	$49	
	Subs (10-23) & Silver Cr. (Lake Loads)	91.99	30,167	0.512	24,764	2.692	17.9%	20,541	2.233	31.9%	16,264	1.768	46.1%	18,892	2.054	37.4%		$388,400	$786,700	$1,045,600	$866,600	$72	$82	$75	$77	
	subwatersheds 1-23 (drain to Lake) (b)	91.99	33,820	0.574	27,139	2.950	19.8%	21,708	2.360	35.8%	16,295	1.771	51.8%	19,452	2.115	42.5%		$388,400	$786,700	$1,045,600	$866,600	$58	$65	$60	$60	
	all subwatersheds (1-25)	94.19	34,756	0.577	27,869	2.959	19.8%	22,283	2.366	35.9%	16,707	1.774	51.9%	19,978	2.121	42.5%		$397,000	$803,600	$1,068,300	$884,400	$58	$64	$59	$60	

(a) Assumptions:
Cash Crop Region: 1/3 dairy, 2/3 cash crop — Dairy Region: 1/2 dairy, 1/2 cash crop
cash crop rotation: corn, soybeans — dairy rotation: corn-grain, corn-silage, 4 years alfafa

	Dairy	Cash Crop
Alt. A	CT>MT	CT>MT
Alt. B	CT>MT MT>NT	CT>MT MT>NT
Alt. C	all no-till (NT)	all no-till (NT)
Alt. D	CT>MT	all no-till (NT)

Conventional Practice (CT) — corn - fall moldboard plow; soybeans - fall chisel plow
Mulch Till (MT) — corn is chisel plowed, soybeans are field cultivated in spring
No-till (NT) — no cultivation except planting
* assumed primary tillage for alfalfa in dairy rotation is same as for corn crop

	CT	MT	NT
Dairy - present practices	61.0%	36.0%	3.0%
Cash Crop - present practices	36.0%	46.0%	18.0%
Combined Present practices	46.2%	41.7%	12.1%
Alternative A		87.9%	12.1%
Alternative B		46.2%	53.8%
Alternative C			100.0%
Alternative D			

Cost Assumptions

Cost of BMP	CT>MT	MT>NT	CT>NT
dairy: $/acre	$15	$15	$25
cash crop: $/acre	$30	$30	$50

(b) Doesn't include Ripon MTP discharge of: 1,361 kg of total phosphorus per year
(c) Drains outside Green Lake Watershed
(d) Silver Cr. subwatershed loads simply added, not routed, and without Ripon MTP discharge
(e) Silver Cr. watershed, subwatershed loads routed to Lake inlet; includes Ripon MTP & effect of Ripon Mill Pond
(f) Only a portion of the loads from subwatersheds 22 & 23 actually enter into Green Lake
(g) Reduction percentages for phosphorus from Silver Cr. are lower than elsewhere, in part because Ripon MTP load remains constant, and is a significant fraction of the total load.

Table 4. Big Green Lake watershed simulated average annual TSS loads and yields (1987-98) - English units.
(as simulated with modified SWAT98 model: 3/28/2000)

Sub-id	Subwatershed Name	Area (sq. mi)	Current Practices CT, MT & NT(a) TSS tons	t/acre	Alternative A (a) CT > MT TSS tons	t/acre	percent reduced	Alternative B (a) CT > MT MT > NT TSS tons	t/acre	percent reduced	Alternative C (a) all NT (no-till) TSS tons	t/acre	percent reduced	Alternative D (a) Dairy MT; Cash Crop (no-till) TSS tons	t/ha	percent reduced	% Ag area	Total Cost to reduce Alt. A CT>MT	Alt. B CT>MT MT>NT	Alt. C CT>NT MT>NT	Alt. D Dairy MT Cash crop all NT	Cost per ton TSS reduced Alt. A	Alt. B	Alt. C	Alt. D	
1	Silver Cr. 1	6.01	238	0.062	187	0.048	21.6%	142	0.037	40.1%	100	0.026	57.8%	120	0.031	49.4%	48.0%	$18,900	$39,200	$51,900	$44,800	$367	$410	$377	$381	1
2	Silver Cr. 2	4.49	257	0.090	198	0.069	23.2%	146	0.051	43.4%	96	0.034	62.5%	120	0.042	53.6%	68.2%	$20,100	$41,700	$55,100	$47,600	$337	$374	$342	$345	2
3	Silver Cr. 3	9.35	311	0.052	239	0.040	23.4%	180	0.030	42.1%	117	0.020	62.3%	163	0.027	47.6%	75.3%	$45,000	$88,300	$118,200	$92,300	$617	$673	$609	$623	3
4 (b)	Silver Cr. 4	5.39	265	0.077	229	0.066	13.5%	198	0.057	25.3%	168	0.049	36.8%	182	0.053	31.5%	46.6%	$16,500	$34,200	$45,200	$39,000	$459	$509	$464	$466	4
5	Silver Cr. 5	5.70	155	0.043	120	0.033	22.6%	89	0.024	42.8%	59	0.016	62.2%	73	0.020	53.1%	74.9%	$28,000	$58,000	$76,700	$66,200	$800	$873	$795	$803	5
6	Silver Cr. 6	5.33	183	0.054	141	0.041	23.1%	103	0.030	43.8%	66	0.019	63.8%	84	0.025	54.4%	91.7%	$32,100	$66,500	$87,900	$75,900	$758	$827	$751	$761	6
7	Silver Cr. 7	2.45	59	0.038	45	0.029	23.4%	33	0.021	44.2%	21	0.014	63.9%	27	0.017	55.0%	61.9%	$10,000	$20,700	$27,300	$23,600	$721	$789	$720	$723	7
8	Silver Cr. 8	3.10	28	0.014	21	0.011	23.7%	16	0.008	44.2%	10	0.005	64.7%	13	0.006	55.3%	76.7%	$15,600	$32,300	$42,800	$36,900	$2,348	$2,604	$2,357	$2,380	8
9	Silver Cr. 9	5.22	141	0.042	108	0.032	23.5%	78	0.023	44.4%	51	0.015	64.0%	64	0.019	54.9%	73.5%	$25,200	$52,200	$68,900	$59,500	$763	$834	$765	$771	9
10	Dakin Creek	6.84	210	0.048	163	0.037	22.5%	120	0.027	42.9%	79	0.018	62.3%	98	0.022	53.5%	82.3%	$36,900	$76,500	$101,100	$87,300	$782	$849	$773	$778	10
11	White Creek	3.39	159	0.073	123	0.057	22.8%	91	0.042	43.0%	61	0.028	62.0%	75	0.034	53.0%	83.5%	$18,600	$38,500	$50,900	$43,900	$512	$563	$515	$520	11
12	Hill Creek Lower	2.96	179	0.094	136	0.072	24.0%	102	0.054	43.0%	66	0.035	63.3%	92	0.049	48.5%	78.9%	$14,900	$29,200	$39,200	$30,600	$347	$380	$346	$353	12
13	Hill Creek Twin Lake	3.60	202	0.088	154	0.067	23.8%	116	0.050	42.4%	76	0.033	62.4%	105	0.046	47.7%	65.4%	$15,000	$29,500	$39,500	$30,900	$313	$345	$314	$321	13
14	Spring Creek	2.82	130	0.072	100	0.056	22.8%	77	0.043	40.6%	52	0.029	59.7%	70	0.039	45.9%	44.9%	$8,100	$15,900	$21,200	$16,600	$274	$301	$273	$279	14
15	Roy Creek	5.58	289	0.081	220	0.062	23.7%	166	0.047	42.4%	109	0.030	62.3%	151	0.042	47.7%	77.0%	$27,400	$53,800	$72,100	$56,300	$400	$440	$401	$409	15
16	Wurchs Creek	5.66	343	0.095	262	0.072	23.7%	196	0.054	42.9%	126	0.035	63.2%	177	0.049	48.4%	78.3%	$28,300	$55,600	$74,500	$58,100	$348	$378	$343	$349	16
17	South Shore	1.42	89	0.098	72	0.080	18.9%	59	0.065	34.0%	45	0.049	50.2%	55	0.061	38.4%	32.4%	$2,900	$5,700	$7,700	$6,000	$172	$188	$172	$175	17
18	SW Shore	0.46	12	0.039	10	0.035	10.3%	9	0.032	18.1%	8	0.026	26.6%	9	0.031	20.0%	10.2%	$300	$590	$790	$620	$253	$283	$257	$269	18
19	Beyers Cove	4.29	148	0.054	122	0.044	17.6%	101	0.037	31.7%	79	0.029	46.4%	95	0.035	35.7%	34.2%	$9,400	$18,400	$24,600	$19,200	$360	$392	$358	$363	19
20	Norwegian Bay	1.98	81	0.064	65	0.051	20.3%	52	0.041	36.3%	38	0.030	53.2%	48	0.038	40.5%	43.1%	$5,400	$10,600	$14,300	$11,200	$328	$358	$330	$340	20
21	Pigeon Cove/Malcolm Bay	2.40	42	0.027	39	0.025	6.5%	37	0.024	12.5%	34	0.022	18.8%	36	0.023	14.2%	6.4%	$970	$1,910	$2,560	$2,000	$365	$384	$326	$338	21
22	Green Lake North (f)	1.80	96	0.083	84	0.072	12.8%	74	0.064	23.0%	63	0.055	33.8%	71	0.062	25.8%	32.0%	$3,700	$7,200	$9,700	$7,500	$302	$327	$300	$303	22
23	Green Lake North (f)	1.74	88	0.079	73	0.065	17.7%	60	0.054	31.4%	47	0.043	46.1%	57	0.051	35.2%	46.2%	$5,100	$10,000	$13,500	$10,500	$328	$362	$332	$339	23
24 (c)	Puchyan	1.21	52	0.067	39	0.051	24.0%	30	0.039	42.2%	20	0.025	61.9%	27	0.035	47.3%	48.9%	$3,800	$7,400	$9,900	$7,700	$308	$339	$309	$315	24
25 (c)	Fox R./Berlin - UF06	0.98	70	0.111	53	0.085	23.5%	40	0.064	41.9%	27	0.043	61.4%	37	0.059	46.9%	77.4%	$4,900	$9,600	$12,800	$10,000	$269	$329	$299	$306	25
																	48.0%	$18,900	$39,200	$51,900	$44,800					
																	68.2%	$20,100	$41,700	$55,100	$47,600					
																	75.3%	$45,000	$88,300	$118,200	$92,300					
																	46.6%	$16,500	$34,200	$45,200	$39,000					
																	74.9%	$28,000	$58,000	$76,700	$66,200					
																	91.7%	$32,100	$66,500	$87,900	$75,900					
																	61.9%	$10,000	$20,700	$27,300	$23,600					
																	76.7%	$15,600	$32,300	$42,800	$36,900					
																	73.5%	$25,200	$52,200	$68,900	$59,500					
	Silver Cr. sub-wsheds (1-9) (b,d)	47.06	1,639	0.054	1,288	0.043	21.4%	985	0.033	39.9%	689	0.023	58.0%	844	0.028	48.5%		$211,300	$433,100	$573,900	$485,800	$602	$662	$604	$611	
	Silver Cr. (Routed to Lake) (e)(g)	47.06	828	0.028	724	0.024	12.6%	606	0.020	26.9%	480	0.016	42.1%	545	0.018	34.2%		$211,300	$433,100	$573,900	$485,800	$2,019	$1,944	$1,646	$1,714	
	subwatersheds (10-23)	44.94	2,068	0.072	1,623	0.056	21.5%	1,261	0.044	39.0%	884	0.031	57.3%	1,141	0.040	44.8%		$177,100	$353,700	$471,700	$380,800	$398	$438	$398	$411	
	Subs (10-23) & Silver Cr. (Lake Loads)	91.99	2,896	0.315	2,346	0.255	19.0%	1,866	0.203	35.6%	1,364	0.148	52.9%	1,686	0.183	41.8%		$388,400	$786,700	$1,045,600	$866,600	$706	$764	$682	$716	
	subwatersheds 1-23 (drain to Lake) (b)	91.99	3,707	0.063	2,911	0.049	21.5%	2,246	0.038	39.4%	1,573	0.027	57.6%	1,985	0.034	46.5%		$388,400	$786,700	$1,045,600	$866,600	$488	$538	$490	$503	
	all subwatersheds (1-25)	94.19	3,828	0.064	3,003	0.050	21.5%	2,316	0.038	39.5%	1,620	0.027	57.7%	2,049	0.034	46.5%		$397,000	$803,600	$1,068,300	$884,400	$481	$531	$484	$497	

(a) Assumptions:
Cash Crop Region: 1/3 dairy, 2/3 cash crop — Dairy Region: 1/2 dairy, 1/2 cash crop
cash crop rotation: corn, soybeans — dairy rotation: corn-grain, corn-silage, 4 years alfafa

	Dairy	Cash Crop
Alt. A	CT>MT	CT>MT
Alt. B	CT>MT MT>NT	CT>MT MT>NT
Alt. C	all no-till (NT)	all no-till (NT)
Alt. D	CT>MT	all no-till (NT)

18976840
2381970

Conventional Practice (CT) — corn - fall moldboard plow; soybeans - fall chisel plow
Mulch Till (MT) — corn is chisel plowed, soybeans are field cultivated in spring
No-till (NT) — no cultivation except planting
* assumed primary tillage for alfalfa in dairy rotation is same as for corn crop

	CT	MT	NT
Dairy - present practices	61.0%	36.0%	3.0%
Cash Crop - present practices	36.0%	46.0%	18.0%
Combined Present practices	46.2%	41.7%	12.1%
Alternative A		87.9%	12.1%
Alternative B		46.2%	53.8%
Alternative C			100.0%
Alternative D			

Cost Assumptions

Cost of BMP	CT>MT	MT>NT	CT>NT
dairy: $/acre	$15	$15	$25
cash crop: $/acre	$30	$30	$50

(b) Doesn't include Ripon MTP discharge of: 1,361 kg of total phosphorus per year
(c) Drains outside Green Lake Watershed
(d) Silver Cr. subwatershed loads simply added, not routed, and without Ripon MTP discharge
(e) Silver Cr. watershed, subwatershed loads routed to Lake inlet; includes Ripon MTP & effect of Ripon Mill Pond
(f) Only a portion of the loads from subwatersheds 22 & 23 actually enter into Green Lake
(g) Reduction percentages for phosphorus from Silver Cr. are lower than elsewhere, in part because Ripon MTP load remains constant, and is a significant fraction of the total load.

Table 6. Phosphorus Loads Routed to Big Green Lake, and Cost to Reduce Loads; Ranked by Total Reduction.

		Current Practices CT, MT and NT (a)			Cost/lb Phos. reduced				Alternative A CT > MT				Alternative B CT > MT MT > NT				Alternative C all NT (no-till)				Alternative D Dairy MT; Cash Crop (no-till)				Total Cost to reduce Phosphorus Load: Alt. A CT>MT	Alt. B CT>MT MT>NT	Alt. C CT>NT MT>NT	Alt. D Dairy MT Cash crop all NT		
		Area (sq. mi)	Total Phosphorus lbs	Total Phosphorus lb/acre	Alt. A	Alt. B	Alt. C	Alt. D	Total Phosphorus lbs	lb/acre	percent reduced	total reduced	Total Phosphorus lbs	lb/acre	percent reduced	total reduced	Total Phosphorus lbs	lb/acre	percent reduced	total reduced	Total Phosphorus lbs	lb/acre	percent reduced	total reduced	Alt. A	Alt. B	Alt. C	Alt. D	rank	
16	Wurchs Creek	5.83	4,896	1.350	$25	$28	$25	$26	3,784	1.044	22.7%	1,112	2,895	0.799	40.9%	2,001	1,954	0.539	60.1%	2,942	2,621	0.723	46.5%	2,275	$28,325	$55.585	$74,468	$58,141	1	16
15	Roy Creek	5.53	2,358	0.660	$54	$60	$55	$55	1,846	0.517	21.7%	511	1,458	0.408	38.2%	900	1,051	0.294	55.4%	1,306	1,334	0.374	43.4%	1,023	$27,426	$53.821	$72,105	$56,296	2	15
10	Dakin Creek	6.84	1,889	0.432	$97	$108	$99	$98	1,509	0.345	20.1%	381	1,178	0.269	37.6%	711	870	0.199	54.0%	1,019	999	0.228	47.1%	890	$36,898	$76.495	$101,094	$87,295	4	10
3	Silver Cr. 3 (routed, est.)	9.35	2,115	0.353	$101	$115	$107	$106	1,669	0.279	21.1%	446	1,348	0.225	36.3%	767	1,012	0.169	52.2%	1,103	1,240	0.207	41.3%	874	$44,952	$88.213	$118,181	$92,269	3	3
1	Silver Cr. 1	6.01	1,849	0.481	$52	$58	$54	$54	1,483	0.385	19.8%	366	1,176	0.306	36.4%	673	891	0.232	51.8%	958	1,016	0.264	45.0%	833	$18,949	$39.285	$51,918	$44,831	5	1
2	Silver Cr. 2 (routed, est.)	4.49	1,582	0.550	$56	$65	$61	$60	1,226	0.426	22.6%	357	945	0.328	40.3%	638	681	0.237	57.0%	902	796	0.277	49.7%	787	$20,110	$41.691	$55,098	$47,577	6	2
13	Hill Creek Twin Lake	3.60	1,464	0.635	$47	$53	$49	$48	1,144	0.496	21.9%	320	903	0.392	38.3%	560	651	0.283	55.5%	812	825	0.358	43.7%	639	$15,034	$29.505	$39,527	$30,861	7	13
11	White Creek	3.39	1,329	0.612	$68	$76	$70	$70	1,055	0.486	20.6%	274	822	0.379	38.2%	507	605	0.279	54.5%	724	698	0.322	47.5%	631	$18,568	$38.494	$50,872	$43,929	10	11
12	Hill Creek Lower	2.98	1,353	0.714	$51	$57	$52	$52	1,061	0.560	21.6%	292	839	0.443	38.0%	514	606	0.320	55.2%	747	767	0.405	43.3%	586	$14,910	$29.260	$39,199	$30,605	8	12
14	Spring Creek	2.82	1,306	0.725	$28	$31	$28	$29	1,017	0.565	22.1%	288	794	0.441	39.2%	511	559	0.310	57.2%	746	726	0.403	44.4%	579	$8,076	$15.850	$21,234	$16,579	9	14
4	Silver Cr. 4 (routed, est.)	5.39	1,763	0.508	$71	$83	$78	$77	1,521	0.441	13.2%	232	1,343	0.389	23.4%	410	1,177	0.341	32.9%	576	1,249	0.362	26.7%	504	$16,495	$34.198	$45,195	$39,026	11	4 (b)
5	Silver Cr. 5 (routed, est.)	5.70	783	0.209	$187	$223	$211	$205	614	0.168	19.6%	149	503	0.138	34.1%	260	400	0.110	47.6%	363	440	0.121	42.3%	323	$28,002	$58.052	$76,720	$66,247	13	5
19	Beyers Cove	4.29	853	0.311	$62	$69	$63	$63	702	0.256	17.7%	151	585	0.213	31.4%	268	465	0.169	45.5%	388	549	0.200	35.6%	304	$9,362	$18.371	$24,613	$19,216	12	19
6	Silver Cr. 6 (routed, est.)	5.33	573	0.168	$288	$354	$342	$327	462	0.135	19.4%	111	386	0.113	32.8%	188	316	0.093	44.9%	257	341	0.100	40.4%	232	$32,075	$66.498	$87,881	$75,885	15	6
22	Green Lake North (f)	1.80	817	0.709	$32	$35	$32	$33	702	0.609	14.0%	115	613	0.532	24.9%	204	519	0.450	36.5%	298	587	0.509	28.2%	230	$3,677	$7.215	$9,666	$7,547	14	22
23	Green Lake North (f)	1.74	772	0.693	$53	$59	$55	$55	676	0.607	12.4%	96	602	0.541	22.0%	170	526	0.472	31.9%	246	580	0.521	24.8%	192	$5,130	$10.066	$13,486	$10,529	16	23
20	Norwegian Bay	1.84	499	0.394	$59	$66	$61	$61	407	0.321	18.4%	92	338	0.267	32.3%	161	265	0.209	46.9%	234	317	0.250	36.5%	182	$5,444	$10.682	$14,311	$11,173	17	20
17	South Shore	1.47	597	0.657	$33	$36	$33	$33	507	0.558	15.1%	90	438	0.482	26.7%	159	366	0.403	38.7%	231	416	0.457	30.4%	182	$2,939	$5.769	$7,729	$6,034	18	17
7	Silver Cr. 7 (routed, est.)	2.45	329	0.210	$131	$159	$151	$147	253	0.161	23.1%	76	199	0.127	39.5%	130	149	0.095	54.9%	181	170	0.108	48.5%	160	$9,957	$20.642	$27,280	$23,556	19	7
9	Silver Cr. 9 (routed, est.)	5.22	337	0.101	$408	$515	$508	$482	276	0.083	18.3%	62	236	0.071	30.0%	101	202	0.060	40.2%	136	214	0.064	36.6%	124	$25,150	$52.141	$68,907	$59,501	20	9
8	Silver Cr. 8 (routed, est.)	3.10	171	0.086	$621	$742	$721	$677	146	0.074	14.7%	25	128	0.064	25.5%	44	112	0.056	34.6%	59	117	0.059	31.8%	55	$15,605	$32.352	$42,755	$36,919	21	8
18	SW Shore	0.46	189	0.640	$18	$20	$18	$18	172	0.584	8.8%	17	159	0.538	15.9%	30	145	0.489	23.5%	44	155	0.525	18.0%	34	$300	$589	$790	$617	22	18
21	Pigeon Cove/Malcolm Bay	2.40	331	0.216	$62	$69	$64	$64	315	0.206	4.8%	16	303	0.198	8.3%	28	291	0.190	12.1%	40	300	0.196	9.4%	31	$975	$1.913	$2,563	$2,001	23	21

Appendix I

Aquatic Plant Sensitive Area Designations for Green Lake

Aquatic Plant Sensitive Area Designations for Green Lake, Green Lake County, WI

July 25 1997

Wisconsin Department of Natural Resources
Northeast Region

CONTENTS

Questions or comments should be directed to Mark Sesing / Lake Management Specialist (920)387-7879 or e-mail "sesinm@dnr.state.wi.us"

Aquatic Plant Sensitive Areas Designation

Green Lake

The identification and protection of ecologically sensitive and unique aquatic plant communities is one objective of Wisconsin's Administrative Code NR 107. The process used to accomplish this is called Sensitive Area Designation (SAD).

The SAD process involves input from local citizens, management organizations and DNR field staff. Collectively these groups rely on observations made on the water, historical records, and their years of experience to identify critical resource areas in the lake.These areas could be on shorelines, in wetlands, or off shore. The existing plant community as well as the potential for a plant community to develop was considered when evaluating sensitive area candidates. Potentially sensitive areas were surveyed in July 1994 and August 1995 . (A listing of individuals and organizations that responded to requests for information is attached as appendix 1).

What does it mean when an area is designated? A designated area is essentially "flagged" to alert resource managers and the public to the critical resource values associated with the site when reviewing proposed water based activities. Shoreland , shoreline and water based development is often regulated by State of Wisconsin statutes. Examples of these would include dredging, chemical control of aquatic plants, shoreline rip-rap, dock development, and large landscaping projects. These proposed activities, if within a designated sensitive area, will be scrutinized as always. *This results in a proactive , rather than reactive, approach to resource protection that gives a designated sensitive area a high profile.* In effect, the critical resource value of these areas will be recognized at the front end of any proposed actions (like aquatic plant control, shoreline rip-rap or pier development). Consequently, this information may support the revision, relocation, or rejection of activities which may compromise these values.

What does it mean when an area is *not* designated? Areas that are not designated as sensitive will continue to receive the fullest protection possible under our resource laws. It is important to recognize that other areas have values which are also important to the lake ecology. Protection actions in other areas will not be discontinued in *any* way.

What about activities that do not normally require permits or are presently unregulated? With the recognition of a sensitive area, it is anticipated in most cases that some uses and actions within that area will be modified to account for the higher level of protection needed. A case in point might be the mechanical harvesting program at Green Lake. This is an unregulated activity which the designations could affect with regard to harvest locations, timing, or intensity. Cooperative decision making among interested lake management groups and AQWEED INC could improve harvest strategies to ensure sensitive area protection. County zoning decisions, development of lake use ordinances, or voluntary actions by individual property owners and lake users may be handled similarly.

Aquatic Plant Values and Trends at Green Lake

Green Lake has a large and diverse submergent aquatic plant community. Extensive areas of the lake bed are covered with lush and healthy plant beds made up of species like chara, sago pondweed, wild celery, coontail, eurasion watermilfoil, native milfoil, and yellow water buttercup (Rickett 1921, Bumby M.J., 1971). *Less extensive and more threatened* are plants with floating leaves and emerging leaves. This group includes the yellow water lily, white water lily, cattails, burreeds, sedges, arrowhead and bulrushes. Physical features of the lake basin(shore slope, infertile substrates, wave action, developed shorelines) generally restrict the emergent and floating leaf plants to backwater areas of the lake where wave action is less and depths are shallow(< 5 feet). The total area occupied by emergent and floating leaf plants is much smaller than that area inhabited by submergent plants.

Aquatic plants reduce wave forces and stabilize sediments, store nutrients, provide critical habitat for various life stages of fish and support innumerable invertebrates that serve as a food base for fish, waterfowl, shorebirds, reptiles and amphibians. Their physical structure enhances sedimentation and improves water clarity as a result (they act like filters!).

The aquatic plants at Green lake will be found most commonly in areas < 20 feet deep where the lake bottom is made up of soft sediments, usually a mix of marl/sand and organic muck. Areas without plants often have rocky shores and are influenced by wave forces. Some shallow soft bottom areas, where carp are abundant, are also without plants.

At least 2 endangered species of aquatic plants have been reported in the Green Lake area; Lake Cress, <u>Amoracia lacustris</u> and Tussock Bulrush , <u>Scirpus cespitosus</u> (WI Natural Heritage Inventory). These plants may inhabit the recommended sensitive areas, however no confirmation has been made.

The **submergent plant** community on the lake presently grows at depths less than 20 feet (Molter C. , Sesing M., 1992) and covers an estimated 500 acres of lake bottom. This area, where light penetration is sufficient to allow photosynthesis, is called the *littoral zone.* Historical accounts report plant growth down to 25 feet (Rickett, 1921)in the littoral zone at Green lake. This plant zone will generally correspond to the depth where 1% of the surface light is still available. Water clarity decreases as a result of lake fertilization (eutrophication) and may be responsible for the lower light penetration in recent times. Phosphorous, the primary nutrient, stimulates algae which then blocks out light. Large decreases in macroalgae, i.e. chara, and filamentous algae (cladophora sp) since 1921 supports the contention that clarity decreases have occurred (Bumby, M.J. , 1971)

The **emergent and floating leaf plants** grow at shallow depths usually less than 5 feet deep. This group of plants provide value that is distinct from the submergents group. Northern pike spawn in collapsed emergent stem beds during the spring. Largemouth bass utilize water lily roots as a substrate for spawning beds and use the leaves for cover. Waterfowl and shorebirds feed and nest within. Again, historical accounts report much greater areas of emergent plant growth than what exists today (Rickett, 1921). Rickett reported several species of bulrush occurring along nearly all marshy shoreline areas. The areas recommended in the SAD include many of the same areas described by Rickett as having abundant emergent growth (Dartford Bay, Silver Creek marsh, County Park marsh, Blackbird Point Channel). It is likely that stable water levels, carp, boating impacts, water pollution and shoreland development are responsible for declines of emergents.

A meadow-marsh-open water complex.
Source: Eggers and Reed, 1988.

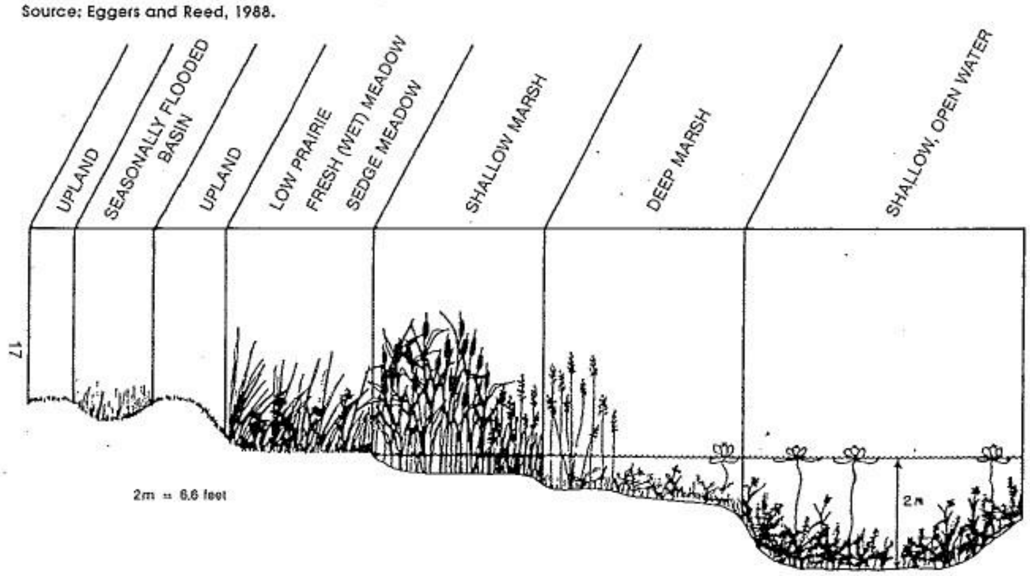


Figure 1 This cross section of aquatic plant community zones shows the emergent, floating leaf and submergent zones that are typical along natural shorelines. At Green Lake this habitat condition occurs mostly within sheltered bays and channels.

There are 2 categories of "designation" recommended. **Category 1** represents higher priority sites due mostly to the uncommon values those areas represent and their unique qualities. **Category 2** designations represent broad areas, of somewhat lesser priority due to their size and lower potential to be threatened by degrading forces.

These areas are recommended for **Category 1 Sensitive Area Designation:**

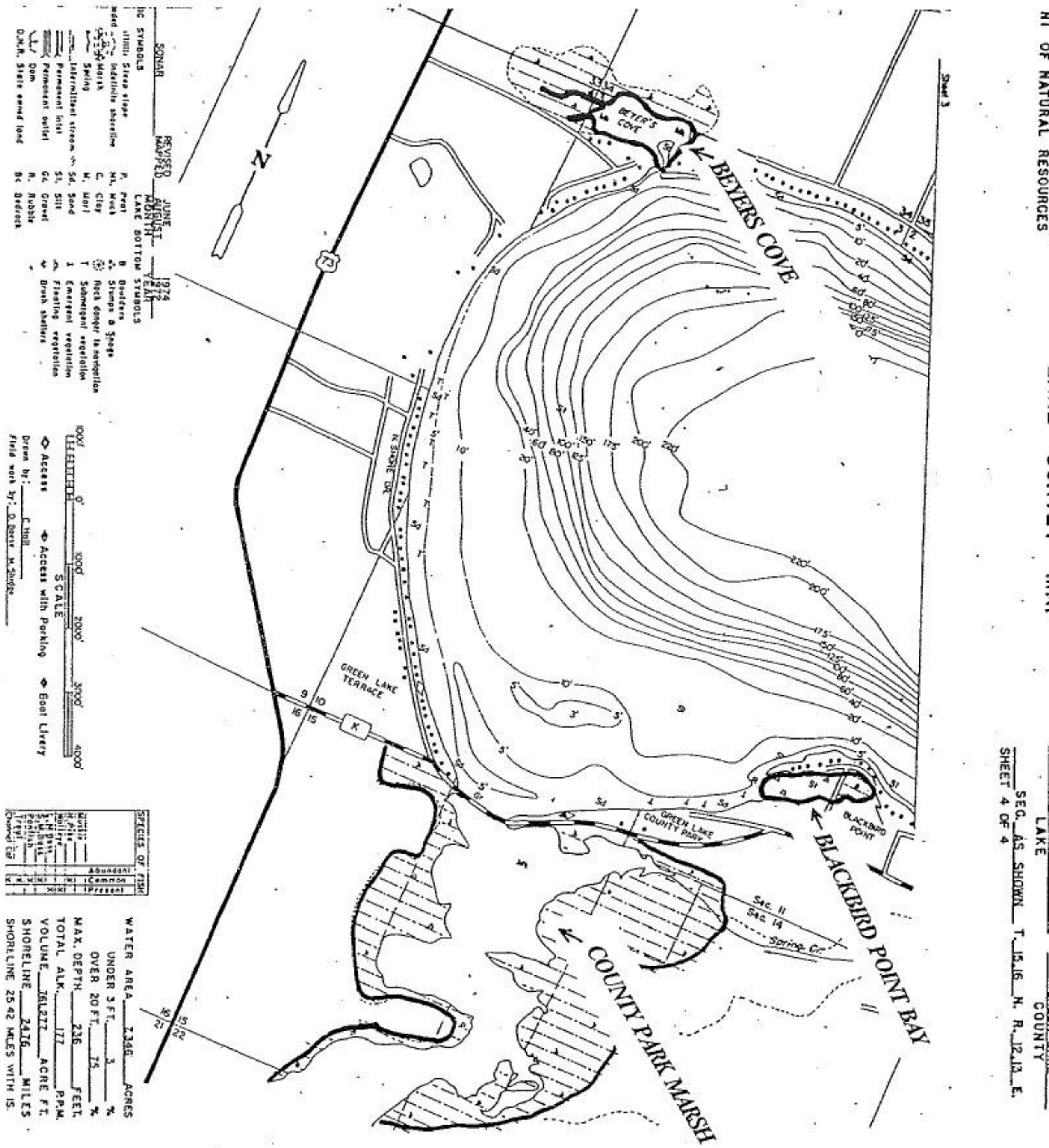
County Park Marsh (south of CTH K)
Blackbird Point Bay (all)
Beyers Cove (all)
Beyers Cove Channels (all)
West Norwegian Bay (from east edge of rush bed to shore including channel ; see map)
Dartford Bay (east shore ;see map)
Green Lake Millpond (all)
Carver Islands (Terrace Beach Islands ; sheltered zones northeast of islands)
Silver Creek Marsh (all east of CTH A including channels up to bridge)

These areas are recommended for **Category 2 Sensitive Area Designation***

Terrace Beach Bay and Heidel Bar
Sugar Loaf Point
Pigeon Cove
West Dartford Bay
Dickinson Bay (camp grow)
Southwest Corner of Lake
Sliding Rock
Sandstone Bay
Woods Bay

All the areas in the above listing were identified through citizen input and have resource values listed in Administrative Code NR 107 (Aquatic Plant Managment)

CATEGORY 1 SENSITIVE AREAS



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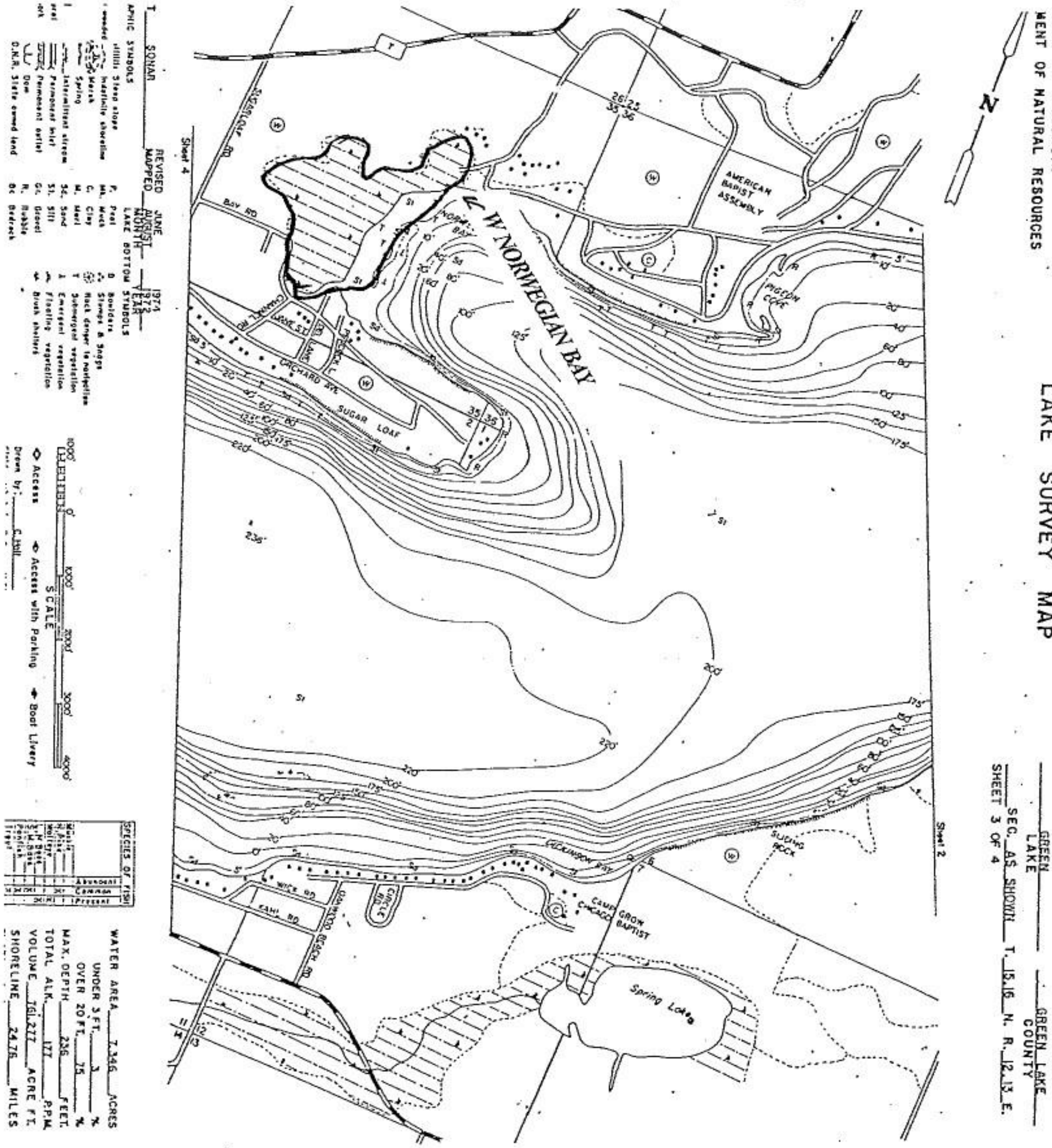
CATEGORY 1 SENSITIVE AREAS



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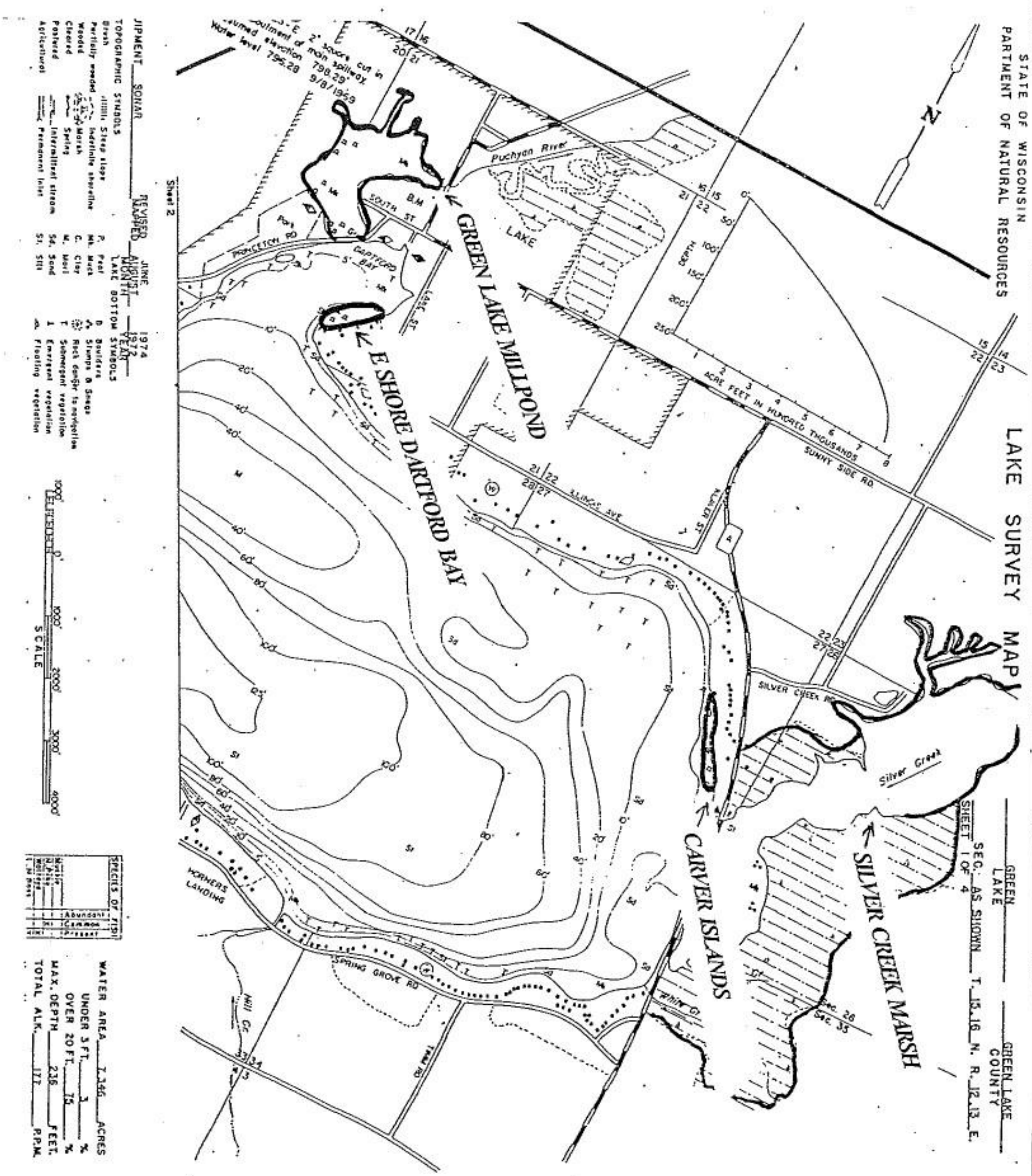
CATEGORY 1 SENSITIVE AREAS



Recommended Sensitive Areas

County Park Marsh is a unique and essential wetland area tributary to the lake. Approximately 13 sq miles of upland drain into 3 tributary streams and then through the marsh. The marsh has good potential for gamefish spawning/rearing,duck nesting/rearing, migratory bird resting,heron feeding, and furbearer uses. At present, the area is ringed with a wetland plant community dominated by cattails. Historical accounts include descriptions of a more diverse plant community. The floating leaf, emergent, and submergent aquatic plants are presently restricted by carp disturbance. Carp control is underway, and once completed, it is expected to greatly improve the fish and wildlife values within the marsh. The undeveloped nature of the surrounding uplands also enhances wildlife use and aesthetics.

The marsh is an extremely important water quality filter for the lake. Upland sources of sediment and nutrients are partially retained in the marsh system and prevented from entering the main lake basin. If the system stabilizes as a result of successful carp removal, the filtering function will improve. The aquatic plants will in turn stabilize the marsh sediments and reduce resuspension into the water, thereby helping to prevent over-fertilization of the lake.

Egrets, herons, hawks, amphibians, reptiles, and invertebrates represent only some of the wildlife utilizing the marsh area.

Blackbird Point Channel is a relatively small, shallow area well protected from the prevailing winds. The south shore of the channel is wetland and free of development. This area serves as a spawning, nursery, and feeding area for fish as well as nesting, rearing, and feeding for waterfowl. Plant species diversity , and corresponding wildlife uses, make this area important and unique. Over 12 plant species were recorded from the channel. (field notes, 1994, Sesing /Leverance/Timmel) and include emergent, submergent ,and floating leaf plants. Water lily occupy a large percentage of the area.

Beyers Cove and Beyers Cove Channels consist of a main pool with connected navigation channels. The area is a dredged wetland. Land use is residential and shoreline development has often bordered on the extreme. The Cove's value is partly due to existing uses as well as it's *potential* to become a critical backwater habitat for fish spawning and water quality filtering. If mismanaged, the area has the potential to support carp recruitment and use. It's present ecological condition appears to be unstable. Turbidity from carp, boating, land runoff, and possibly waves, is obvious (visibility of 2 feet, 7/10/95). Carp may be uprooting plants. Citizen complaints about sediment pollution from neighboring farmland have been significant. Shoreline habitat along much of the cove has been reduced to monotypical bands of gravel that provide little habitat for fish or wildlife. Plant diversity and abundance is low . However, some shorelines have excellent fish and wildlife habitat with overhanging brush and well vegetated banks. The degraded habitat condition is due to controllable factors. The cove has a high potential to become an important and unique ecological asset for the lake. With attention to management of this backwater area, the biological and water quality aspects could improve greatly. Beyer's cove would make an excellent rehabilitation project.

The large shallow open water area of the cove has the potential to support critical fish and water quality functions. Surveys during July of 1995 recorded a sparse, low diversity plant community dominated by eurasion milfoil. Other submergents present include sago pondweed, elodea, potamogeton crispus(dominant in early summer) and water stargraass. Isolated stands of water lily and burreed are present along some shores and appear to be remnants of larger historical stands. Boating , pier development, hand pulling/cutting and harvesting of water lillies may explain the lack of lillies in the cove. Bulrush and arrowhead are nearly absent and shoreland development is a likely cause for the absence of these emergent plants.

West Norwegian Bay Fish spawning, wildlife, aquatic plant diversity and water quality functions are obvious within this unique area. The area harbors the largest known stand of bulrush within the lake basin. In addition to anchoring sediments and protecting shorelines from wave erosion, emergent plants like these provide a substrate for invertebrates, a substrate for fish eggs (esp N pike) , food for waterfowl, nesting cover, brood cover, and fish nursery functions. These emergent plant communities are relatively rare at Big Green. Anecdotal and scientific evidence suggests that emergents were more common in the past but have been reduced. Factors responsible for this reduction could include boating, waves, high water levels, physical removal of plants, or natural causes including disease.

The bay provides a sheltered area which often attracts boaters and skiing. a sandbar located along the west side of the bay provides good substrate for bulrush growth as well as shallow wading opportunities for the public. In fact the area east of the stand is a popular area for mooring, wading and socializing. Unfortunately, complaints regarding the behavior of boaters in this area have been common. There is concern that frequent activity in the bulrush stands will reduce it's size. Preliminary examination of aerial photos from the mid- 50's appear to show larger areas of plants than presently exists. A "no wake" or "no motor" from the bulrush stand inward to the shore might help protect the area.

Despite these pressures, the area remains unique and ecologically significant. The shallow water marsh, deep water marsh and shallow open water area form an ecosystem that is uncommon to the lake. This area would be an excellent candidate for habitat enhancement.

Dartford Bay, like all bays on the lake, provides diversity for the aquatic ecosystem. Their shallow protected nature allows plants to survive that would not be able to otherwise exist in the deeper, wave swept areas of the lake. Shorelines in the bay that are developed often lack plant diversity but there are remnant areas of good diversity that still exist. This area is primarily along the eastern shore of Dartford Bay. It is characterized by water lily, bulrush, sedges, burreed and also a diverse submergent plant community. Typical shallow water marsh plants including cattail, bulrush, giant burreed, arrowhead and white water lily are providing wildlife and fish habitat. Submergent plants like coontail, elodea, curley leaf pondweed, yellow water buttercup and milfoil species provide important sediment stabilization and invertebrate support functions. These plants collectively provide critical uses that include water quality filtration, wildlife habitat, sediment protection, aesthetics and fish habitat functions. Sixteen species of aquatic plants have been identified within the recommended area (1995 , Horicon DNR files)

Green Lake Millpond is a large shallow area of backwater habitat near the outlet end that is popular as a panfish and bass fishing area. It is dominated by one of the largest stands of water lily on the lake. This condition helps to make it one of the more significant brood areas for waterfowl. The density of plants of all types aids in the filtration of water. The protected nature of the area supports uses by shore anglers, smaller boats and canoeists as well as providing aesthetic value. The entire shoreline area is within the City of Green Lake and adjacent land use is mostly residential but with some park shoreline.

The millpond must be cautiously managed. Disruption of the existing plant community and it's high habitat value could result in higher water turbidity and subsequently favor carp recruitment. This is true of other candidate areas as well. Carp will take advantage of changes in water quality, especially turbidity increases where sight feeding fish like pike and bluegills are at a disadvantage.

One past concern of users, especially anglers, was the mechanical harvesting of aquatic plants beyond reasonable levels for navigational needs. Conflicts between the fish spawning period and harvest timing were the focus of several complaints in 1993 and 1994. Much of the concern was alleviated with voluntary actions by Aqweed INC that addressed the timing and intensity of harvest in the millpond.

The entire area north of the road bridge is recommended for inclusion.

The Carver Islands(Terrace Beach Islands) area consists of a small grouping of islands adjacent to the north west shore. It is the area north of , or behind , the islands that is recommended for inclusion. Because of the protected backwater habitat, the area supports diverse fish spawning opportunities, waterfowl, shorebirds, and other wildlife uses. In the 1994 fishery survey (Bartz, D.) the area was found to be one of the more important largemouth bass spawning and nursery sites on the lake. Observations in 1995 (Sesing/Hoodie) and 1996 (Nelson/Bartz) showed abundant forage fish and juvenile fish use, largemouth bass(adult) use as well as documenting the presence of muskrat, ducks, turtles and frogs. Reports of occasional bald eagle sightings, kingfisher and crane use have been recorded. One citizen familiar with the area described it as "a natural nursery of perch and bass for the lake." In all, it appears to be an area of diverse aquatic plants that provides uncommon habitat, especially on this side of Big Green lake.

Silver Creek Marsh is really an impounded area of lower Silver creek that lies between CTH A and Spaulding Road. Depths are shallow, usually 1-3 feet. The bottom is generally organic and soft. This area was likely a shallow water marsh dominated by emergent plants prior to being flooded when the dam was built in the city of Green Lake.

Several channels connect with the marsh and provide boat access to the marsh and lake from residential developments.

The large open marsh area is devoid of aquatic plants because of carp and possible sedimentation. (Congdon J., Simonson D.) It is similar in many respects to County Park marsh on the southwest end of the lake. The potential for diverse and abundant plant growth is good.

The watershed area of Silver creek marsh is 53.5 sq. miles. The amount of sediment and nutrients (esp. phosphorous) from this watershed is significant. The Green Lake Sanitary District, United States Geologists Survey and WI DNR have cooperatively conducted water quality monitoring at Silver Creek for several years. Based on these results we estimate the average annual sediment and P delivery to be in the area of 1,359 tons and 15,432 pounds per year , respectively (USGS data, 1985-1995)

Silver Creek Marsh, like County Park Marsh has the potential to be an enormously important pollutant filter for Green Lake. Under present conditions it is not doing a good job of filtration. The observations and monitoring show large and visible plumes of sediment entering the east side. Self help monitoring (Bumby, Edwards /Self Help Monitoring) demonstrates lower water clarity in the east end vs the west end of the lake. More abundant aquatic plants would trap sediments and nutrients resulting in a reduction of pollutants being delivered to the lake.

The habitat potential for fish and wildlife is also great. Fish spawning, rearing, and cover habitat would increase. Waterfowl, shorebird, and raptor use would increase.

Four submergents plants were found during the 1992 plant survey; coontail, sago pondweed, eurasion watermilfoil, pondweed/unknown. (Schuman/ Sesing) Cattail are abundant and dominate the adjacent wetlands. Historical reports document arrow head, an emergent species, to be abundant. Recent observations indicate a general absence of arrowhead.

The channels along the northern shore are similar to those at Beyers Cove. They can provide good backwater habitat for fish and wildlife. When managed properly, water quality functions such as filtration and sediment stabilization should also occur.

Terrace Beach Bay ,Heidel Bar , Sugar Loaf Point , Pigeon Cove , West Dartford Bay , Dickinson Bay (Camp Grow) , southwest corner of lake , Sliding Rock , Sandstone Bay and Woods Bay are areas recommended for inclusion as category #2 sensitive areas; primary value being critical fish spawning areas. Many of these areas are listed as a result of information received from local management units (especially the green Lake Sanitary District) and individuals familiar with the lake. The plant community in the listed areas consists primarily of submergent species rather than emergent or floating leaf plants. Regulated activities in these areas will be reviewed on a case by case basis. Definite boundaries have not been established for these areas. Adjacent shorelines are largely developed but limited sections may have substantial value for wildlife, fish and water quality benefits. Non-regulated activities like mechanical harvesting of aquatic plants may be influenced through the planning process required for the grant program administered by the Wisconsin Waterways Commission.

Other Recommendations

Minimize all floating leaf or emergent plant control. Because the relative abundance of water lily, bulrush, burreed and other emergent plants is so low, the harvest or elimination of these types of plants through shoreline manipulation, mechanical harvesting, boating impacts, hand pulling or other means should be minimized.

All partners in the watershed of Big Green should consider providing suppoort for initiatives that improve or protect habitat at the lake. Beyer's Cove, County Park Marsh, Silver Creek Marsh and West Norwegian Bay are particularly good candidates for habitat restoration or protection projects.

Mechanical harvesting in all sensitive areas is reviewed by the Green Lake Sanitary District's AQWEED harvesting program. It is anticipated that, if appropriate, *harvesting operations might be modified to support the plant protection goals built into the sensitive area designation program.*

Figure 2

SUMMARY OF ECOLOGICAL VALUES IN RECOMMENDED CATEGORY 1 SENSITIVE AREAS OF GREEN LAKE

Area	Fish Spawnin Value	High Wildlife Value	High Value Plants	Water Quality Fnctn	Plant Species Diversity	Carp Potential High
County Park Marsh	+	+		+		+
Blackbrd Point Bay	+	+	+		+	
Beyers Cove	+			+		+
Beyers Cove Channel	+			+		+
W. Norweg Bay	+	+	+	+	+	
Dartfrd Bay	+		+	+	+	
Green Lake Millpnd	+	+	+	+	+	+
Carver Islands	+	+	+		+	
Silver Creek Marsh	+	+		+		+
Silver Creek Channel	+			+		+

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APPENDIX

Individuals, agencies and associations that responded to information request

Individuals
Barb Hempe
Paul Loberg
Bill La Fleur
Daren Denslow
Jack W. Lenox
Bill Wishman
Schroeder's Sport Shop
Bernard Westfahll,
John and Christine Kefer
Jim and Claire Braun
B.C. Kilbourne
Ross Dean
Charlie Nash
Joseph Novelle
Bill and Lois Myers
Ed and Harriet Dunn
Bob Henning
Norbert Blankenheim
Dennis Walker
Walter and Joan Baron
Jim Barclay
Dan Stoneberg
Patricia Martin
Michael Luller

Agencies/Associations
*Green Lake Sanitary District
(Ron Edwards, Charlie Marks
Mary Jane Bumby)

*WI Dept Nat Resources
(Dave Bartz, Jim Holzwart,
Cletus Alsteen, Jim Leverance,
Jim Congdon Andy Nelson
Dave Marshall,Barb Timmel)

*G Lake Preservation Assoc
(Marian Possin,et al)

*Green Lake Fishing Club
(Bob Hoffman)

WISCONSIN
DEPT. OF NATURAL RESOURCES
George E. Meyer
Secretary

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

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April 5, 1994

Sensitive Area Designation - Big Green Lake

The protection and preservation of critical and unique fish, wildlife and water quality values of Green Lake is important to all of us. The Administrative Code that guides Aquatic Plant Management (NR 107) includes objectives for the identification and protection of ecologically sensitive areas in our area lakes. This is where you can help.

The knowledge and experience you or your organization has accrued may help us to develop an inventory of critical aquatic plant resources in Green Lake. Once these "sensitive areas" are identified, they will receive special protective status. Examples of restricted activities could include herbicide applications, lakeshore structure placement, and shoreline construction. Aquatic plant harvesting operations, although not presently regulated by the Department, could also be influenced.

Sensitive areas are:

(1) Critical or unique fish spawning areas. For example, northern pike use bulrush and sedge stands. Their fry require this habitat for protection and growth. Yellow perch and panfish are very dependent on vegetation for protection, rearing, and food as well.

(2) Areas of high wildlife value and use. Ducks rely on aquatic vegetation for food and insects. Wild celery, sago pond weed, and other various pond weed species have been shown to be critical food sources for many ducks.

(3) Areas were plant species of high value are located. Many of the "pondweeds," wild celery, and bulrush could be included here, *especially if their distribution is very limited* in the lake. Any plant community *unique* to the lake or area should be considered. For example, in Big Green Lake, areas where floating leaf plants like water lily or water lotus grow might qualify as *unique*. Emergent species like bulrush and arrowhead are relatively uncommon and could also qualify.

(4) Areas where aquatic vegetation provides important erosion control and filtering functions that help to maintain water quality. Lake sediment stabilization should also be considered.

(5) Areas where a high relative degree of plant species diversity occurs. For example, mixed stands of pondweeds and wild celery have been reported to support 3-8 times as many invertebrates and fishes as a single species stand of eurasian milfoil (DNR, EA APM, 1989).

(6) Areas that support frogs, salamanders, snakes, turtles, birds, mink, and muskrat could also be considered for designation, especially if endangered or threatened species use the area.

This should give you a good idea of what we are looking for. I have included a map of the lake. You can indicate any areas directly on these maps and return them to the Horicon Area office. Please return these by May 1, 1994, with a short note explaining what qualities the indicated areas may have.

Your knowledge of the lake can make this resource protection effort a greater success. Call (414) 387-7879, if you have any questions or comments.

Sincerely,

Mark Sesing

Mark Sesing
Water Resource Manager

MS:lr

cc: Dave Bartz, Montello
Jim Congdon, Horicon Area
Tom Nigus, Horicon Area
Andy Nelson, Horicon Area

P.S. Please feel free to distribute this to others you feel may be helpful.

(2) If a request for a public hearing is received after the permit is issued but prior to the actual treatment allowed by the permit, the department is not required to, but may, suspend the permit because of the request for public hearing.

(3) The department may deny issuance of the requested permit if:

(a) The proposed chemical is not labeled and registered for the intended use by the United States environmental protection agency and both labeled and registered by a firm licensed as a pesticide manufacturer and labeler with the Wisconsin department of agriculture, trade and consumer protection;

(b) The proposed chemical does not have a current department aquatic chemical fact sheet;

(c) The department determines the proposed treatment will not provide nuisance relief, or will place unreasonable restrictions on existing water uses;

(d) The department determines the proposed treatment will result in a hazard to humans, animals or other nontarget organisms;

(e) The department determines the proposed treatment will result in a significant adverse effect on the body of water;

(f) The proposed chemical application is for waters beyond 150 feet from shore except where approval is given by the department to maintain navigation channels, piers or other facilities used by organizations or the public including commercial facilities;

(g) The proposed chemical applications, other than those conducted by the department pursuant to ss. 29.62 and 29.623, Stats., will significantly injure fish, fish eggs, fish larvae, essential fish food organisms or wildlife, either directly or through habitat destruction;

(h) The proposed chemical application is in a location known to have endangered or threatened species as specified pursuant to s. 29.415, Stats., and as determined by the department;

(i) The proposed chemical application is in locations identified by the department as sensitive areas, except when the applicant demonstrates to the satisfaction of the department that treatments can be conducted in a manner that will not alter the ecological character or reduce the ecological value of the area.

1. Sensitive areas are areas of aquatic vegetation identified by the department as offering critical or unique fish and wildlife habitat, including seasonal or lifestage requirements, or offering water quality or erosion control benefits to the body of water.

2. The department shall notify any affected property owners' association, inland lake district, and riparian property owner of locations identified as sensitive areas.

(4) New applications will be reviewed with consideration given to the cumulative effect of applications already approved for the body of water.

(5) The department may approve the application in whole or in part consistent with the provisions of subs. (3) (a) through (i) and (4). Denials shall be in writing stating reasons for the denial.

(6) Permits may be is

History: Cr. Register, Febr

NR 107.06 Chemical f
chemical fact sheet for
nuisance control in Wis

(1m) Chemical fact s
consin shall be develope
ceived notice of intende

(2) The applicant or p
ble chemical fact sheets
inland lake district.

(3) The department s
request.

History: Cr. Register, Febru

NR 107.07 Supervision
office 4 working days in
date, time, location, and
the department, the adv

(2) Supervision by a
any aquatic nuisance co
may include inspection
application equipment b
may result in the determ
ranted in all or part of t
control the proper dosag

History: Cr. Register, Febru

NR 107.08 Conditions
limit the application of
determines that chemic
unreasonable restriction
sary adverse side effects
partment shall state t
applicant.

(2) Chemical treatme
directions, existing pest

(3) Chemical applicat
waters along developed s
proval is given by the d

(4) Treatment of area
shall be done in a mann
permanent changes to a
tem. High value species
offer important values i
geton amplifolius, Potam
lamogeton pectinatus, Po
ocharis spp., Scirpus spp
palustris and *Brasenia s*

Appendix J

Aquatic Plant Data Tables and Graphs

BIG GREEN LAKE MACROPHYTE SURVEY 1992 TABLE #4
Quantities of each species found at each depth
Macrophyte Survey Sheet 1992.

Scientific Name	Depth>	1	3	6	9	12	15	18
Ceratophyllum demersum L.		2	8.75	18.75	16.75	23.5	24.5	3.5
Chara sp.		2	10.5	14.75	6.5	5.25	5.75	1.25
Elodea canadensis Michaux		1	6.25	6.5	1.75	0.25	0.75	0.75
Lemna spp.		1	0	0.75	0	0	0	0
Myriophyllum spicatum L.		1	1.75	3.25	1.5	1.25	0	0
Myriophyllum sibiricum (exalbescens)		1	12.5	22.5	24.25	12.5	6.25	0.25
Najus sp.		2	3	3.5	1.25	0.25	1	1.5
Nitella sp.		0	0	0	0	0	0.25	0
Potamogeton crispus		1	5	13.5	24.25	17.5	8.75	1
Potamogeton nodosus		0	0.25	0.25	0.25	0	0	0
Potamogeton pectinatus		2	6.25	6	3.75	1.25	0	0
Potamogeton pusillus		0	0	0.25	0.25	0	0	0
Potamogeton richardsonii		0	1.75	3	0.75	0	0	0
Potamogeton zosteriformis		1	4	6	4.5	3.5	3.25	0.25
Potamogeton sp. (Unknown)		0	1.5	5.25	4.75	4	4.75	2.25
Ranunculus longirostris		1	12.25	13.25	10.25	3.25	1	0
Scirpus spp.		0	0	1.5	1.25	0.25	0	0
Vallisneria americana		5	6.5	6	0.25	0.5	0	0
Zannichelia palustris L.		1	0.25	0.25	0.25	0	0	0
Zosterela dubia (Heteranthia)		1	2	4.75	1.5	0.5	2.5	0
0								
0								
Moss aquatic		0	0.75	0	0.5	0	0.25	0
Algae fillamentous		11	17.25	18.75	12.5	6.25	2	1

Friday, May 09, 1997 GENER3C Page 1

LAKENAME: Big Green Lake | YEAR: 1992

UNIQUE: 240003 | VEG. AREA (%): 70.04 | MAX OF DEPTH(m): 5.48

MWBC: 240003 | RFREQ SUB (%): 87.7 | RFREQ SENS (%): 12.97

SCINAME	FREQ(%)	AVEDEN	RFREQ(%)	RDEN(%)
Ceratophyllum demersum	45.15	1.18	12.62	15.52
Chara sp.	32.07	0.68	8.96	8.98
Elodea canadensis	12.24	0.23	3.42	2.99
Filamentous algae	41.35	0.97	11.56	12.75
Lemna sp.	0.84	0.02	0.24	0.22
Moss sp.	0.84	0.01	0.24	0.11
Myriophyllum sibiricum	8.44	0.14	2.36	1.83
Myriophyllum spicatum	46.41	1.18	12.97	15.47
Najas sp.	12.66	0.19	3.54	2.49
Nitella sp.	0.42	0.00	0.12	0.06
Potamogeton crispus	36.29	0.86	10.14	11.36
Potamogeton nodosus	1.27	0.01	0.35	0.17
Potamogeton pectinatus	16.46	0.29	4.60	3.77
Potamogeton pusillus	1.27	0.01	0.35	0.17
Potamogeton richardsonii	7.17	0.09	2.00	1.22
Potamogeton sp.	21.52	0.36	6.01	4.77
Potamogeton zosteriformis	16.88	0.35	4.72	4.66
Ranunculus longirostris	29.54	0.58	8.25	7.59
Scirpus sp.	1.69	0.03	0.47	0.44
Vallisneria americana	15.19	0.24	4.25	3.16
Zannichellia palustris	1.69	0.02	0.47	0.22
Zosterella dubia	8.44	0.16	2.36	2.05

SPECIES NO.: 22.00 | DIVERSITY: 91.50 | EXOTICS NO: 2.00

Friday, May 09, 1997 GENER3C

LAKENAME: Big Green Lake | YEAR: 1990

UNIQUE: 240003 | VEG. AREA (%): 63.33 | MAX OF DEPTH (m): 5.48

MWBC: 240003 | RFREQ SUB (%): 100.0 | RFREQ SENS (%): 8.55

SCINAME	FREQ(%)	AVEDEN	RFREQ(%)	RDEN(%)
Ceratophyllum demersum	37.14	0.83	22.22	29.34
Chara sp.	14.29	0.20	8.55	6.91
Elodea canadensis	4.29	0.05	2.56	1.69
Isoetes sp.	4.29	0.06	2.56	2.19
Myriophyllum spicatum	34.29	0.71	20.51	25.30
Najas flexilis	12.38	0.17	7.41	5.90
Nitella sp.	0.48	0.01	0.28	0.34
Potamogeton crispus	2.86	0.03	1.71	1.01
Potamogeton diversifolius	0.48	0.00	0.28	0.17
Potamogeton foliosus	1.90	0.02	1.14	0.84
Potamogeton illinoensis	0.48	0.00	0.28	0.17
Potamogeton pectinatus	3.81	0.04	2.28	1.35
Potamogeton praelongus	1.43	0.03	0.85	1.01
Potamogeton pusillus	0.95	0.01	0.57	0.34
Potamogeton richardsonii	4.76	0.08	2.85	2.87
Potamogeton zosteriformis	11.90	0.12	7.12	4.38
Ranunculus sp.	8.57	0.11	5.13	4.05
Vallisneria americana	22.86	0.34	13.68	12.14

SPECIES NO.: 18.00 | DIVERSITY 86.61 | EXOTICS NO: 2.00

BIG GREEN LAKE MACROPHYTE SURVEY 1992 TABLE #4

Quantities of each species found at each depth

Macrophyte Survey Sheet 1992.

Scientific Name	Depth>	1	3	6	9	12	15	18
Ceratophyllum demersum L.		2	8.75	18.75	16.75	23.5	24.5	3.5
Chara sp.		2	10.5	14.75	6.5	5.25	5.75	1.25
Elodea canadensis Michaux		1	6.25	6.5	1.75	0.25	0.75	0.75
Lemna spp.		1	0	0.75	0	0	0	0
Myriophyllum spicatum L.		1	1.75	3.25	1.5	1.25	0	0
Myriophyllum sibiricum (exalbescens)		1	12.5	22.5	24.25	12.5	6.25	0.25
Najus sp.		2	3	3.5	1.25	0.25	1	1.5
Nitella sp.		0	0	0	0	0	0.25	0
Potamogeton crispus		1	5	13.5	24.25	17.5	8.75	1
Potamogeton nodosus		0	0.25	0.25	0.25	0	0	0
Potamogeton pectinatus		2	6.25	6	3.75	1.25	0	0
Potamogeton pusillus		0	0	0.25	0.25	0	0	0
Potamogeton richardsonii		0	1.75	3	0.75	0	0	0
Potamogeton zosteriformis		1	4	6	4.5	3.5	3.25	0.25
Potamogeton sp. (Unknown)		0	1.5	5.25	4.75	4	4.75	2.25
Ranunculus longirostris		1	12.25	13.25	10.25	3.25	1	0
Scirpus spp.		0	0	1.5	1.25	0.25	0	0
Vallisneria americana		5	6.5	6	0.25	0.5	0	0
Zannichelia palustris L.		1	0.25	0.25	0.25	0	0	0
Zosterela dubia (Heteranthia)		1	2	4.75	1.5	0.5	2.5	0
0								
0								
Moss aquatic		0	0.75	0	0.5	0	0.25	0
Algae fillamentous		11	17.25	18.75	12.5	6.25	2	1

TABLE 1. PERCENTAGE DRY WEIGHT IN EACH SPECIES FOR ALL ZONES IN 1921 AND 1971

Species Found in 1921 & 1971	% Dry Wt. 1921	% Dry Wt. 1971
Algae		18.22
Ceratophyllum demersum	7.02	8.50
Chara sp.	15.08	20.12
Elodea canadensis	4.4	13.07
Heteranthera dubia	10.56	9.28
Myriophyllum spicatum		16.44
M. verticillatum var. *pectinatum*	9.63	
Najas flexilis	9.93	10.05
Potamogeton crispus		7.97
P. pectinatus	12.21	12.50
P. Richardsonii	14.64	19.35
P. zosteriformis	12.41	14.10
Ranunculus longirostris		13.35
R. aquatilis var. *Capillaceus*	11.69	
Vallisneria americana	7.71	6.49
Zannichellia palustris	6.96	7.10
Other		14.35
P. amplifolius	11.9	
P. foliosus	10.55	
P. gramineus	11.5	
P. natans	11.43	
Moss	19.49	
Lemna Sp.		5.71
With Algae:		15.06 ± 4.65 S. D.
Without Algae	11.19	13.58 ± 4.52 S. D.

TABLE 11. *Total weight at all depths and percentage of each species. Area: 8.573 square kilometers. From tables 8, 9, and 10.*

Species	Kilograms		Per Cent	
	Wet	Dry	Wet	Dry
Ceratophyllum	2,187,400	152,100	16.8	9.9
Chara	4,897,800	754,000	37.7	49.3
Drepanocladus	165,200	30,400	1.3	2.0
Elodea	536,500	39,900	4.1	2.6
Myriophyllum	1,557,800	152,600	12.0	10.0
Naias	116,200	11,400	0.9	0.7
Potamogeton amplifolius	199,700	22,800	1.5	1.5
Potamogeton foliosus	129,500	13,600	1.0	0.9
Potamogeton heterophyllus	198,600	23,300	1.5	1.5
Potamogeton natans	105,300	12,500	0.8	0.8
Potamogeton pectinatus	1,257,000	149,700	9.7	10.0
Potamogeton Richardsonii	137,600	16,600	1.0	1.1
Potamogeton zosterifolius	450,100	52,700	3.5	3.5
Radicula	22,500	2,200	0.2	0.1
Ranunculus	71,700	7,600	0.5	0.5
Vallisneria	437,100	30,000	3.4	2.0
Heteranthera	132,400	12,700	1.0	0.8
Carex	4,200	400	....	....
Castalia	24,000	2,000	0.2	0.1
Cladophora	800	100	....	....
Nymphaea	60,000	4,900	0.5	0.3
Scirpus	311,100	36,500	2.4	2.4
Total	13,002,500	1,527,900	100.0	100.0

CORRESPONDENCE/MEMORANDUM — **State of Wisconsin**

DATE: FILE REF: [Click **here** and type file ref.]

TO: Mark Sesing, DNR
Charlie Marks, Green Lake Sanitary District
Stan Nichols, WI Geologic and Natural History Survey

FROM: Chad Cook, DNR

SUBJECT: Norwegian Bay Bulrush

12
2.54
46
60
24
30.46

The bulrush beds of Norwegian Bay, Green Lake, were surveyed on Monday, July 8, 2002. The survey was conducted by Chad Cook, Mark Sesing, Charlie Marks, and Paul Samerdyke.

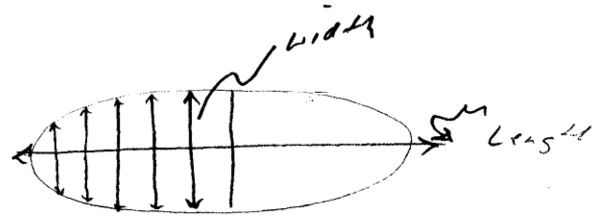
The methods used to survey the bulrush beds were the same as used in the initial 1997 survey and the follow up survey in 1998. There are three distinct beds, separated by spans of open water, generally oriented along a northeast to southwest axis on the west side of a shallow sandbar area. Surveying began with the southwest bed and moved to the center bed and then the northeast bed.

The length of each bed was measured by a marked line that was staked at the southernmost bulrush protruding from the water and strung through the bed's long axis to the northern end. The line was marked at each 2.5 meter interval. At each mark a tape measure was placed perpendicular to the line and the width of the bed measured, again defined by the maximum extent of the bulrush. A 0.4 meter wide quadrat (a 0.35 meter wide quadrat was used in 2002) was used to count the number of stems along the tape measure. The quadrat was used to give a uniform width along the tape measure for counting stems.

Visual observations by Sesing, Cook, and Marks all concluded that the stands appeared to be less dense that previously and the stems did not appear to be as robust.

The 1997, 1998, and 2002 survey data have been entered into an Excel spreadsheet. Graphs comparing stem density and stand widths have been created.

- waders
- Raingear
✓ - quadrat
- tape measures
✓ - field forms
- waders
- camera



2.5 m

3.39 ft
2.5
1695
678
8.475

Printed on Recycled Paper

. Copy Brad Johnson → Bulrush file

→ MARK SESING
DNR HORICON

CORRESPONDENCE/MEMORANDUM — State of Wisconsin

DATE: December 4, 1998 File Ref: FYI

TO: Charlie Marks - Green Lake Sanitary District

FROM: Tim Asplund - SS/RC

SUBJECT: Update on monitoring of bulrush bed in Norwegian Bay

Background

Staff at the DNR Research Center have been monitoring a hardstem bulrush (*Scirpus acutus*) stand located in the west end of Norwegian Bay on Big Green Lake, Green Lake Co. (Fig. 1) in response to concerns about motor boat activity in the bay. Large stands of bulrush used to be common in the lake. Rickett (1924) describes emergent stands along sandbars adjacent to marshy areas around the lake. He identifies 5 bulrush stands ranging in size from 3500 to 255,000 m^2. He did not specifically mention any occurring in Norwegian Bay; however, these other stands have since eroded and the Norwegian Bay stand is now the largest remaining bulrush stand in the lake (Mark Sesing, pers. comm.). As a comparison to Rickett's observations, the current stand is just over 1800 m^2. Lake residents and aerial photographs have indicated that this bulrush stand has also shrunk in recent decades.

Many factors could account for the drastic decline in bulrush stands in the lake, including shoreline development, declining water quality, higher water levels (or less variation), and motor boat activity. The latter factor is thought to be a major factor in the decline of the Norwegian Bay stand due to the popularity of the sandbar adjacent to the bed for mooring boats and wading. In the summer of 1997, an ordinance drafted by the Green Lake Sanitary District was enacted by the Towns of Brooklyn, Green Lake, and Princeton which allows placement of No-Motor buoys around the stand. We surveyed the stand in July of 1997 in order to establish baseline conditions for the stand and to begin a monitoring program to evaluate the effectiveness of the buoys at protecting the stand. We repeated the survey in 1998 and intend for this monitoring to continue for several years. The remainder of this memo describes our methods in detail and reports on our findings to date.

Methods

The bulrush stand was surveyed on July 15, 1997, and again on July 14 and 21, 1998. The stand itself consists of three distinct beds lying along the sandbar from the southwest to the northeast. We measured the length of each of the beds along the longest axis. At 2.5 m intervals, we measured the width of the bed perpendicular to the long axis. Mean width and area of each bed was calculated from these measurements. We also counted the number of stems emerging from the water along each of the width transects. We used three-sided square PVC quadrat measuring 40 by 40 cm to accurately count all the stems within 20 cm of the transect line. Dead stems were included in the count if they were still emergent. Average density per transect and per square meter were calculated for each bed. Stems per square meter were calculated by multiplying the stem count along a transect by the width of the transect and the width of the quadrat (0.4 m). In addition, distance between the three beds and GPS coordinates were taken in 1998 in order to more accurately map the beds in relation to each other.

Results

Baseline width, length, area, and stem density are listed in Table 1 for the three beds and the stand in its entirety. The southwest stand is the smallest in areal extent (114.5 m^2), length (25.5 m) and width (5.1 m). The northeast stand is slightly wider on average (7.2 m) but 3 times as long (72.5 m). The center stand is slightly shorter in length, but twice as wide and the largest bed overall (1222 m^2). Densities are similar in the center and northeast beds (24 and 21 stems/m^2 respectively), while the southwest bed is more sparse (5 stems/m^2).

Schematic drawings of the three beds indicate the irregular shape of the beds (Fig. 2). (Width measurements at each 2.5 m interval are plotted symmetrically around a common axis. These plots are not true representations of the shape of the bed, rather they give an indication of the relative size and allow direct comparisons from year to year). The center stand is the most irregular. The northeast end of the stand is much wider than the southwest end; however, the wider part is actually indented by gaps on either side that enter parallel to the long axis.

In 1998, the beds did not show much difference in extent (Fig. 2) but stem densities were higher in all three beds (Table 2). The biggest change was in the southwest bed where density increased by 57%, though still relatively sparse. Density in the center bed increased by about 17%, while in the northeast bed it increased by only 4%. It is possible that the buoys and ordinance have reduced boat and foot traffic in the bulrush beds, allowing more stems to fill into the existing bed or at least preventing stems from being pulled up or chopped off. However, other factors, such as water temperature, water clarity, or natural variability may also affect the growth and development of bulrush in any given year. Water depths were similar between the two years (about 1 m), but fluctuations in lake level earlier in the year or severity of winter ice conditions must also be considered.

Conclusions

With only two years of data, it is too early to say whether boats were indeed affecting the bulrush stand or whether the ordinance is being effective. We observed several waders in the area of the bulrush stand during the three days at the site and have heard anecdotal reports of personal watercraft and other boats traveling between the individual beds in apparent disregard of the buoys. It is encouraging that the stem densities increased between 1997 and 1998. Continued monitoring will help us determine of this is random variability, a 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.

Reference cited

Rickett, H. W. 1924. A quantitative study of the larger aquatic plants of Green Lake, Wisconsin. Transactions of the Wisconsin Academy of Science, Arts, and Letters. p. 381-414.

Table 1. Extent and density measurements made in the Norwegian Bay hardstem bulrush stand in 1997				
	Southwest Bed	**Center Bed**	**Northeast Bed**	**Entire Stand**
Area (m2)	**114.5**	**1222**	**504.5**	**1841**
Length (m)	**25.5**	**68**	**72.5**	**201.9 (inc. openings)**
Average Width (m)	**5.1**	**18.8**	**7.2**	**11.4**
Avg. Stems (stems/transect)	**9**	**148**	**69**	**90**
Avg. Density (stems/m²)	**4.9**	**20.9**	**24.3**	**19.8**
Avg.Water Depth (m)	**1.19**	**1.01**	**0.93**	**1.04**

Table 2. Extent and density measurements made in the Norwegian Bay hardstem bulrush stand in 1998				
	Southwest Bed	**Center Bed**	**Northeast Bed**	**Entire Stand**
Area (m²)	**98.3**	**1254**	**513.5**	**1866**
Length (m)	**25.0**	**70.0**	**75.0**	**206.2 (inc. openings)**
Average Width (m)	**3.6**	**17.9**	**6.9**	**10.9**
Avg. Stems (stems/transect)	**15**	**162**	**71**	**98**
Avg. Density (stems/m²)	**7.7**	**24.5**	**25.3**	**22.2**
Avg. Water Depth (m)	**1.09**	**1.06**	**0.85**	**0.96**

Figure 1. Map of Norwegian Bay, Green Lake, Green Lake Co., WI, with location of hardstem bulrush stand indicated.

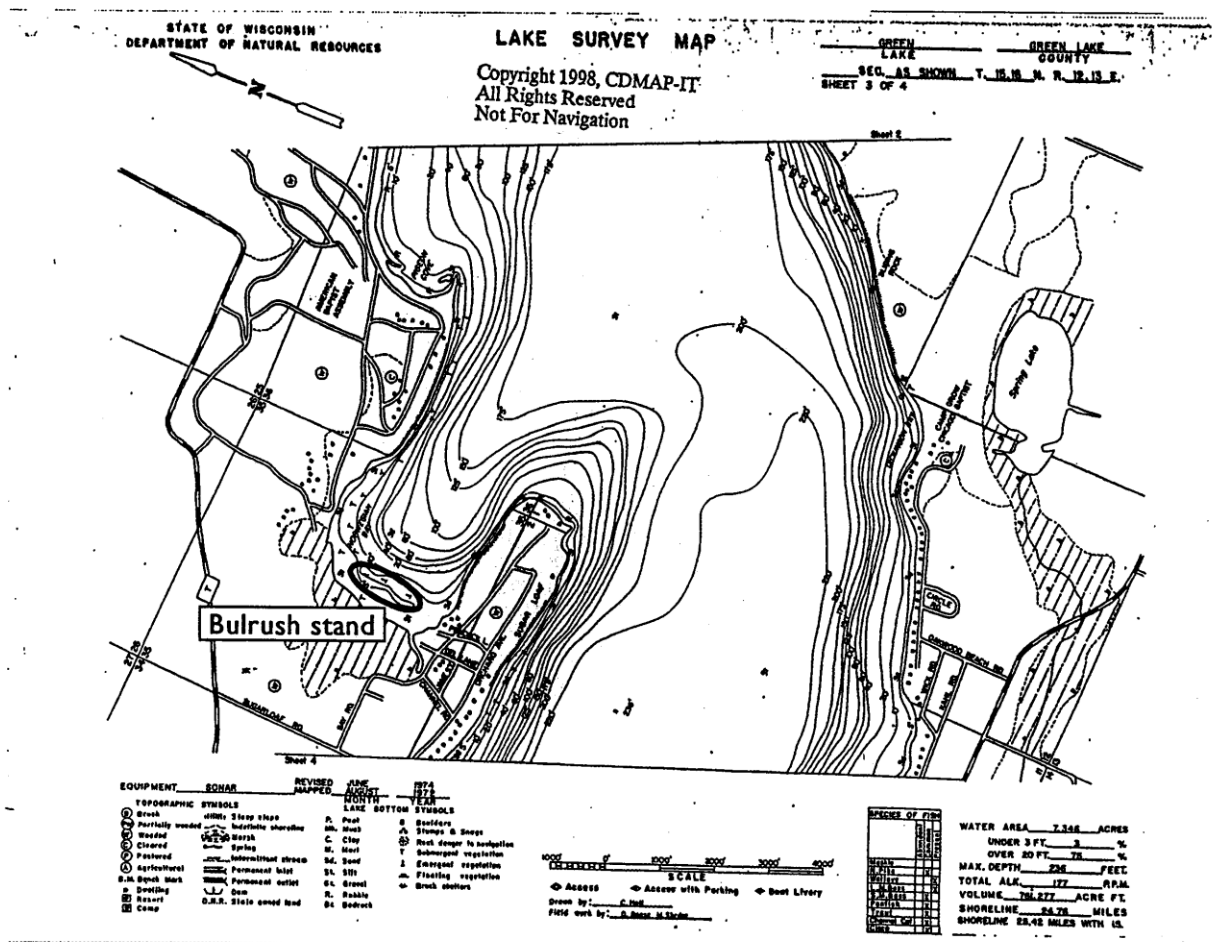
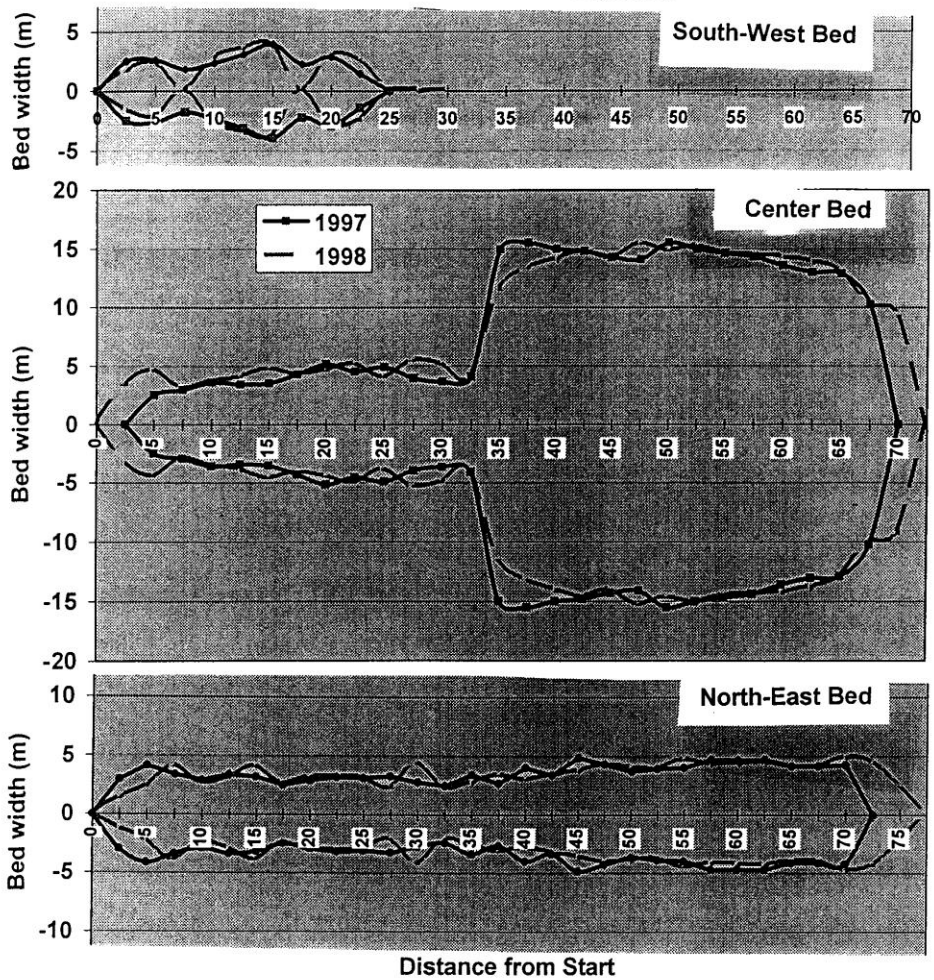
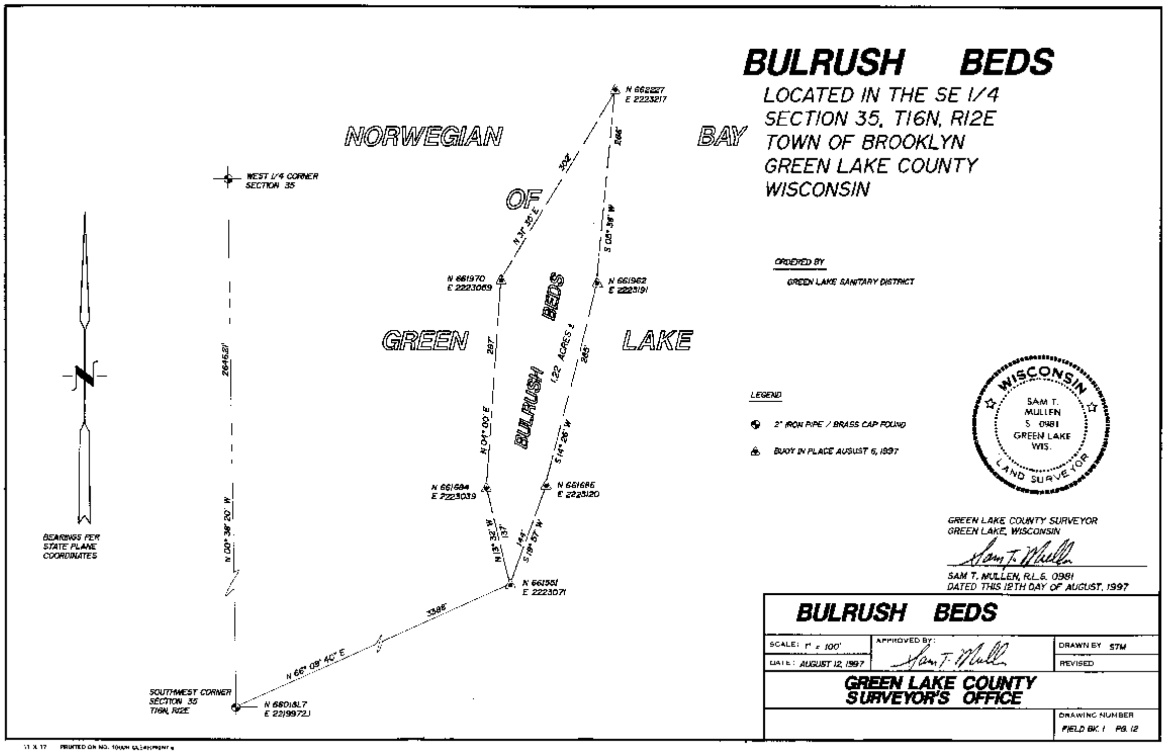


Figure 2. Schematic diagrams of three hardstem bulrush beds in Norwegian Bay




BULRUSH BEDS
LOCATED IN THE SE 1/4
SECTION 35, T16N, R12E
TOWN OF BROOKLYN
GREEN LAKE COUNTY
WISCONSIN
NORWEGIAN BAY OF GREEN LAKE
BULRUSH BEDS
1.22 ACRES ±
WEST 1/4 CORNER SECTION 35
SOUTHWEST CORNER SECTION 35 T16N, R12E
BEARINGS PER STATE PLANE COORDINATES
ORDERED BY
GREEN LAKE SANITARY DISTRICT
LEGEND
2" IRON PIPE / BRASS CAP FOUND
BUOY IN PLACE AUGUST 6, 1997
WISCONSIN
SAM T. MULLEN
S 0981
GREEN LAKE WIS.
LAND SURVEYOR
GREEN LAKE COUNTY SURVEYOR
GREEN LAKE, WISCONSIN
SAM T. MULLEN, R.L.S. 0981
DATED THIS 12TH DAY OF AUGUST, 1997
BULRUSH BEDS
SCALE: 1" = 100'
DATE: AUGUST 12, 1997
APPROVED BY:
DRAWN BY STM
REVISED
GREEN LAKE COUNTY SURVEYOR'S OFFICE
DRAWING NUMBER
FIELD BK. 1 PG. 12

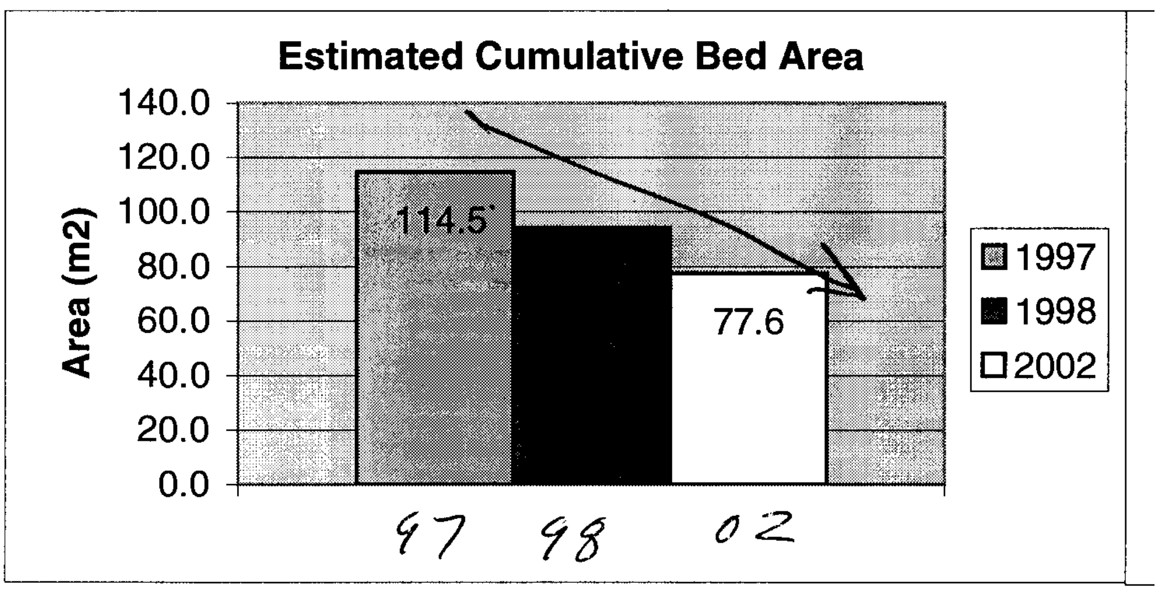

Estimated Cumulative Bed Area
Area (m2)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
114.5
77.6
1997
1998
2002
97
98
02

Figure 1 Map of 1990 and 1992 Aquatic Plant Survey Transects

Appendix K

Basin Plan recommendations 1989 WDNR

<u>BIG GREEN LAKE WATERSHED; UF-07</u>

<u>Silver Creek</u>

1. WRM staff should undertake a wasteload allocation study for Silver Creek at Ripon. The study should look at flow and possible WPDES limit modifications for conventional pollutants, nutrients, and toxics (Type D).

2. WRM, USGS, and the Green Lake Sanitary District should continue the phosphorus study for Silver Creek (Types D and E).

3. Southern District Fisheries Management and WRM staff should take measures to control carp and reestablish critical aquatic vegetation in Silver Creek (Type D).

4. Southern District Solid Waste Management and WRM staff should conduct investigations to see if pollution from the four problem abandoned landfills in the Ripon area have reached or have the potential for reaching Silver Creek (Type C).

5. The Bureau of Research along with Water Resources Management, Fisheries Management, Wildlife Management and the Green Lake Sanitary District should jointly undertake a study investigating the feasibility of a shallow marsh restoration project designed to restore a quality macrophyte and wetland community in the wetland complex at the mouth Silver Creek (Type D).

6. The City of Ripon should take measures to address urban nonpoint source pollution including the adoption and enforcement of a construction site erosion control ordinance and street sweeping (Type E).

<u>Big Green Lake</u>

7. Future monitoring of Big Green Lake by Southern District WRM staff should include aquatic vegetation surveys of shallow littoral areas (Type D).

8. Southern District WRM staff should review aquatic vegetation harvesting and other aquatic plant management projects and their potential impacts on water quality for this outstanding resource water (Type D).

9. WRM staff should continue fish monitoring for toxics, particularly chlordane levels in lake trout (Type D).

<u>City of Green Lake</u>

10. Green Lake WPDES permit reissuance and self-monitoring should evaluate the presence of the toxic substances (see page C-59) identified during toxic screening (Type A).

<u>City of Ripon</u>

11. Ripon WPDES permit reissuance and self-monitoring should require monitoring for toxic substances (Type A).

12. The Ripon WWTP should adopt a compliance schedule to address its disinfection needs by its next WPDES permit reissuance (Type B).

Appendix L

Lake Water Quality Model Study for Big Green Lake, Green Lake County, WI

LAKE WATER QUALITY MODEL STUDY FOR

BIG GREEN LAKE, GREEN LAKE COUNCTY, WISCONSIN

Completed by

John Panuska
Wisconsin Department of Natural Resources

July 15, 1999

Conclusions

Based on the results of the analysis the following conclusions can be made:

1. The surface total phosphorus concentration in Big Green Lake does not significantly different at various points across the lake.

2. Based on the spring total phosphorus concentration Big Green Lake is eutrophic.

3. Big Green Lake's chlorophyll_a response to total phosphorus is less than what regional regression equations would predict.

4. The lake's low chlorophyll_a response may be the result of food web effects (Daphnia grazing on chlorophyll_a).

5. Based on monitored flow, sediment and total phosphorus loading, 1997 was close to an average year for the lake, while 1998 was below average.

6. Silver Creek contributes the greatest annual total phosphorus loading to Big Green Lake at approximately 44% of the total and 50% of the tributary loading.

7. The Southwest Inlet is the second greatest source of total phosphorus loading at 13% of the total and 15% of the tributary input.

8. The watershed unit area total phosphorus export values for the Silver Creek watershed fall into the lower portion of the range monitored for agricultural land in Wisconsin.

9. Monitoring data indicate that no significant bypassing of Silver Creek's inflow loading is occurring.

Recommendations

Based on the above conclusions it is recommended that:

1. An in-lake total phosphorus goal be established for Big Green Lake in the near future.

2. Watershed modeling be conducted to identify total phosphorus loading source areas and BMP strategies for load reduction.

3. The BMP implementation strategy be supported by watershed modeling and be sufficient to meet the in-lake water quality goal.

5. In-lake and tributary monitoring be continued to document Big Green Lake's water quality response to land management activities.

Big Green Lake is located in Big Green Lake County of east central Wisconsin. The lake has a surface area of 7,346 acres, mean and maximum depths of 104 and 236 feet, respectively. The lake has two principal inflows, Silver Creek from the east and the Southwest Inlet. The total tributary drainage area to the lake is approximately 91.2 square miles in size of which 53.5 mi^2 and 16.3 mi^2 from Silver Creek and the Southwest Inlet area, respectively. The primary land use in the Silver Creek subwatershed is agricultural while the remaining areas are a mixture of agriculture, residential, wetland and forest. Big Green Lake is a significant resource from both a local and statewide perspective. Local interest in the management of the lake began in the early 1990's with planning grant assistance from the Department of Natural Resources (DNR). After a number of lake planning grants the Lake District received a lake protection grant from the DNR in 1998 to complete a diagnostic feasibility study. One component of the diagnostic study process is the development of a water and nutrient budget for the lake as well as a water quality model. The model will be used in the goal setting process to evaluate the impact of watershed pollutant load reduction on water quality improvement. The modeling effort is supported by in- lake monitoring data collected by self-help volunteers and DNR staff along with tributary monitoring data collected by the US Geological Survey. This report will focus on the methods, results and discussion pertaining to the modeling. Any other aspects of the monitoring or diagnostic work will be discussed only briefly and limited in context to modeling.

Analysis Methods

The analysis consisted of two parts monitoring and modeling. Monitoring was conducted both in-lake and on the majority of the tributaries flowing into the lake. The monitoring data was then used in the calibration of a model and the development of a lake loading response curve. The lake loading response curve can then be used in the watershed load reduction, lake response evaluation process.

Initially the lake was divided into three segments and monitoring was conducted at three in-lake stations corresponding to those segments as shown in Figure 1. Lake data was collected during the growing season (April-October) with an emphasis on those parameters most useful for model calibration. Monitoring parameters included surface total phosphorus (TP), chlorophyll_a and Secchi depth transparency. For the purposes of this study, all modeling was eutrophication focused. Temperature, dissolved oxygen and limited phosphorus profile data were also collected at each site as well as phyto and zooplankton data. The response curve for Big Green Lake was developed using the Wisconsin Lake Model Spreadsheet (WILMS) model version 2.00 (Panuska et al. 1996). Copies of the Big Green Lake WILMS runs for 1997 and 1998 are included in Appendix A. Within WILMS the Canfield-Bachmann, 1981 natural lake model (model No. 2) was selected for use. All known loading and flow information was input into the model. The model was then manually fit to observed conditions using an assumed load from unmonitored sources. The unmonitored sources were assumed to include internal loading, shore and bank erosion, loading from geese and any loading error. The lake's response curve was developed by plotting stepwise reductions in external loading against model predicted in-lake total phosphorus values. The loading information used for modeling was placed in pie charts. In developing the loading pie charts, the unmonitored load was combined with the estimated bypassing and placed in a category labeled "net other".

In the goal setting process it is also necessary to know what the corresponding lake water quality will be at various levels of in-lake phosphorus. The regression relationships between in-lake TP and chlorophyll_a were developed specifically for Big Green Lake. A lake specific regression was developed because the regional regression equation from Lillie et al. (1993) for TP and chlorophyll_a did not adequately describe conditions in Big Green Lake. However, the regional regression for chlorophyll_a and Secchi depth transparency was found to be adequate.
Additional discussion on the use of these equations to predict water clarity is included in the Results section of this report.

Tributary load monitoring was conducted by the US Geological Survey. Continuous gage sites with automatic samplers were established for Silver Creek at its inlet to the lake and for White Creek. Grab samples were collected after storm events from a number of the smaller tributaries and used in the load estimation calculations. Two years (1997-1998) of flow monitoring was conducted (corresponding to the lake monitoring). An analysis of historic flow, sediment and TP loading was also conducted using data from 1988-98 in order to provide a basis for comparison to long-term means. An analysis of the outflow and in-lake TP concentration data also included an estimate of the input TP load being by-passed. All monitoring years are water years defined as October through September.

Results

At the time of the initial study design, three in-lake water quality stations were established with the goal of identifying water quality responses in each segment. Review of the 1997 and 98 data indicated no significant differences between the three segments as shown in Figure 2. This implies that wind mixing eliminates any spatial water quality differences across the lake making it appropriate to model the lake as a single basin. For this reason the three individual lake station values were volume weighted and reported as single whole-lake values. Table 1 summarizes the monitored in-lake water quality data for 1997 and 1998.

Table 1: Water Column Water Quality Data
Summary

Year	Spring TP (ug/l)	Summer TP (ug/l)*	Chlorophyll_a (ug/l)	Secchi Depth (m)
1997	27	18	5	3.9
1998	22	9	3	4.5
1997 TSI	----	51	47	40
1998 TSI	----	45	43	38

* Summer equals April through October

Table 2 summarizes the results of a comparison of 10 years of monitored flows and loading with the 1997 and 1998 results.

Table 2: Comparison of 1997 - 98 Data with the 11 Yr. Medians
(Annual value / 11 year median)

Year	Flow (cfs)	Sediment (tons / day)	TP (pounds / day)
1997	32.7 / 30.6	2.2 / 2.2	26 / 26
1998	28.7 / 30.6	2.7 / 2.2	21 / 26

The lake response curve for Big Green Lake is included as Figure 3. The trophic response regression equations for total phosphorus /chlorophyll_a and chlorophyll_a/Secchi depth are as follows and as illustrated in Figures 4 and 5. Additional evaluation of the TP/chlorophyll_a predictive relationship indicated that Big Green Lake's chlorophyll_a response to TP was about
1/2 of what a regional regression equation would predict and the regional regression was therefore adjusted accordingly.

$$\textbf{Chl a} = e^{-2.63 + 1.49 \ln(TP)}$$

The above equation is modified from Lillie et al. (1993), where Chl a = chlorophyll_a in ug/l and TP = total phosphorus in ug/l.

$$\textbf{SD} = e^{2.00 - 0.58 \ln(\text{Chl a})}$$

The above equation is from Lillie et al. (1993) for central region drainage lakes, where: SD = Secchi depth (m) and Chl a = chlorophyll_a in ug/l.

The unit area loading by tributary for 1997 and 1998 is shown in Figures 6 and Figure 7, respectively. The unit area export and water yield for 1997 and the table in Appendix C summarizes the 1998 values. The total loading by tributary is shown in Figures 8 and 9 for 1997 and 98, respectively. As mentioned earlier, the "net other" category represents the sum of the unmonitored loading sources and the estimated bypassing. The estimated TP load by-passing for 1997 and 1998 were 6 and 8%, respectively when all load sources are considered.

The WILMS model outputs for 1997 and 1998 are included in Appendix A. A summary of the WILMS output is included in table 5 below.

Table 5: Summary of WILMS
Model Output

Year	Runoff Volume (AF)	Precipitation – Evaporation (In)	Water Retention Time (Yr.)	Flushing Rate (1/Yr.)	Areal TP Loading (Lb./Ac./Yr.)
1997	43,029	0.8	17.5	0.06	2.91
1998	42,785	-0.5	18.0	0.06	2.18

Discussion

Review of table 1 indicates that Big Green Lake falls into the mesotrophic range based on chlorophyll_a and Secchi depth transparency and the eutrophic range based on TP. Lakes in this range are considered to have elevated productivity relative to natural levels. One goal in managing a eutrophic lake with a predominantly agricultural watershed such as Big Green Lake should be load reduction where feasible and a strong emphasis on protection. Though the chlorophyll_a concentration is not excessively high, lakes in the eutrophic range are subject to growing season algal blooms the frequency of which is related to TP loading and water column concentration. When applying the regional regression equations for TP and chlorophyll_a it soon became apparent that Big Green Lake's algal response (as measured by chlorophyll_a) was lower than the regional regressions would predict. For example the 1997 mean TP of 27 ug/l, when input into a state wide regression equation yields a predicted chlorophyll_a of 11ug/l or approximately twice of the observed. This trend is consistent in the TSI values as well. Conditions such as these have the advantage in that the lake exhibits good (actually better than expected) water clarity. One disadvantage from a modeling perspective is that the ability to predict chlorophyll_a and water clarity is difficult. The greatest implication from a management perspective is to implement measures, which will maintain this condition in a stable state. One possible reason for depressed chlorophyll_a concentrations in Big Green Lake is the abundance of microscopic zooplankton (animals) called Daphnia. These small zooplankton can very effectively graze on algal cells resulting in a reduction in algal biomass. A strategy therefore becomes one of managing the fishery to providing conditions that favor Daphnia abundance.

As summarized in table 2, 1997 is close to an average year for flow and TP loading and was used for modeling and comparison. In reviewing the TP loading pie charts, Silver Creek contributes the greatest annual tributary loading to the lake ranging between 50 and 55% followed by the Southwest Inlet area ranging between 15 and 17%. The unit area TP loads for all tributaries range from 0.28 to 0.68 Lb./Ac./Yr. The state wide range in TP export values for agricultural land are from 0.17 to 2.6 Lb./Ac./Yr. while forested areas range from 0.04 to 0.15 Lb./Ac./Yr. (Panuska and Lillie, 1995). In the case of Silver Creek, unit area export values range from 0.22 Lb./Ac./Yr. in 1997 to 0.28 Lb./Ac./Yr. in 1998. Clearly these values fall on the lower end of the range for agricultural TP export, the principal land use in the Silver Creek watershed. These results should NOT be interpreted to mean that additional improvements can't or shouldn't be made. A better interpretation is that unless otherwise proven, the loading source area is very diffuse and the entire watershed should be considered in formulating BMP strategies. Of the individual tributary areas, White Creek has the highest unit area export at 0.68 and 0.35 Lb./Ac./Yr. in 1997 and 1998, respectively making it an area of interest for watershed management activities. These values compare to 0.64 Lb./Ac./Yr. monitored prior to watershed BMP implementation conducted in the late 1980's. Based on these data it would appear that the historically high unit area loading from White Creek has not been reduced. The results of the watershed modeling will be of significant importance in determining watershed load reductions and the targeting of BMPs.

As previously discussed, the lake monitoring program was designed to allow an estimate to be made of the fraction of Silver Creek's load that is bypassed directly to the outlet. The goal of this effort was to determine to what extent inflows from Silver Creek are currently short-circuiting directly to the outlet. The calculated values of 6 and 8% indicate that the bypassing of Silver Creek's inflows does not occur to a great extent at Big Green Lake. As previously discussed, the bypassing estimate was determined using the difference between in-lake and outflow concentrations. It is therefore not possible to accurately determine how much of the calculated bypassing is Silver Creek inflow and how much is from near-shore land areas adjacent to the outlet. However, in the case of Big Green Lake, it is most likely that the load being bypassed is from the area immediately adjacent to the outlet approach channel. Based on this data it would therefore appear that significant bypassing of Silver Creek's inflow is not occurring.

Any management plan for Big Green Lake should include a strong lake protection element. As watershed development occurs, measures must be in place to reduce a future increase in loading and prevent further degradation. Big Green Lake is a high quality resource and pollution prevention will pay dividends in the long term.

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Appendix M

What Green Lake's Sediments Tell Us About Its History

WHAT GREEN LAKE'S SEDIMENTS TELL US ABOUT ITS HISTORY

PUB-SS-966 2002 April 2002

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INTRODUCTION

Questions often arise concerning how a lake's water quality has changed through time as a result of *watershed* disturbances. In most cases there is little or no reliable long-term data. Questions often asked are if the condition of the lake has changed, when did this occur, what were the causes, and what were the historical condition of the lake? *Paleoecology* offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution. These remains include *diatom* frustules, cell walls of certain algal species, and subfossils from aquatic plants. The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. Using the fossil remains found in the sediment, we can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

Figure 1. Typical sediment core from the lake.

In 1999, sediment cores were extracted from 4 sites throughout Green Lake. The main sites were in the eastern and western basins (Figure 2). Samples from these sites were used for sediment dating, inputs of important chemical variables, and reconstruct the nutrient history of the lake during the last 150 years.

This summary sheet briefly describes the results from the sediment cores, which document changes in the water quality of Green Lake during the last 150 years.

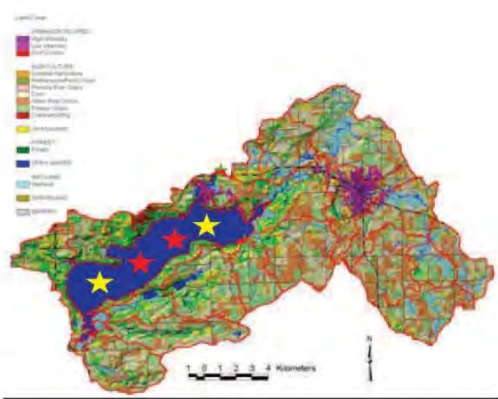

Figure 2. Green Lake and its watershed. Stars are the core sampling sites. The 2 sites are either end are the main sites.

GREEN LAKE WATERSHED HISTORY

Winnebago Indians prior to the arrival of the first European settlers in 1835 inhabited the area around Green Lake. The landscape was much different then. The land was entirely prairie with oak openings. There were few large trees. The Indians called the lake "Daycholah" while Europeans named the lake for its emerald green color. Early settlement occurred on the southern side of the lake but the town of Dartford (now Green Lake) was platted in 1847 at the lake's outlet. Through the years more settlers arrived and the area became popular for tourists. Many hotels were constructed and agricultural activity increased in the watershed. Today the village of Green Lake and the city of Ripon are located in the watershed. Landuse in most of the watershed is in agriculture but the lakeshore consists of homes.

SEDIMENTATION RATES

Sediment dating allows for the estimation of when certain things happened in the lake and its watershed. It also gives an estimation of how much sediment is accumulated over time. This is done using radionuclides that are deposited in the sediments.

The mean *sedimentation rate* over the last 150 years in the western basin was much lower at 0.017 g cm^{-2} yr^{-1} compared with 0.036 g cm^{-2} yr^{-1} in the eastern basin (Figure 3). The rate in the western basin is one of the lowest compared with other Wisconsin lakes. The higher rate in the eastern basin is because most of the tributaries enter the lake here, including the major tributary, Silver Creek. These tributaries bring in a great deal of sediment from the watershed.

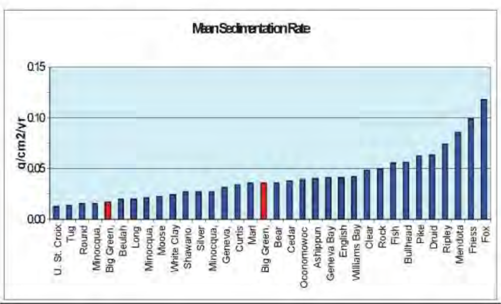

Figure 3. Mean sedimentation rates for selected Wisconsin lakes.

More important than the mean sedimentation rate is how the rate has changed during the last century. The present sedimentation rate in the eastern basin is similar to the historical rate (Table 1). In the western basin, the present rate is double the historic rate. This is increased rate is an indication that changes have occurred in the watershed during the last century.

Table 1. *Sedimentation rates in g cm^{-2} yr^{-1}*

	WESTERN	EASTERN
RECENT	0.023	0.045
HISTORICAL	0.011	0.044

SEDIMENT CHEMISTRY

By examining what chemicals have been deposited in the sediments, we can infer what changes have occurred in the watershed. For example, *titanium* is found in association with soil particles and thus is an indication of changes in soil erosional rates in the watershed. Since iron and manganese are released from the bottom sediments when the overlying waters lack dissolved oxygen, changes in their levels are an indication of changes in the oxygen content of the bottom waters. *Phosphorus* and *nitrogen* are pollutants of major concern in lakes. In high concentrations they lead to increased plant growth and algal blooms.

In both the eastern and western basins, titanium

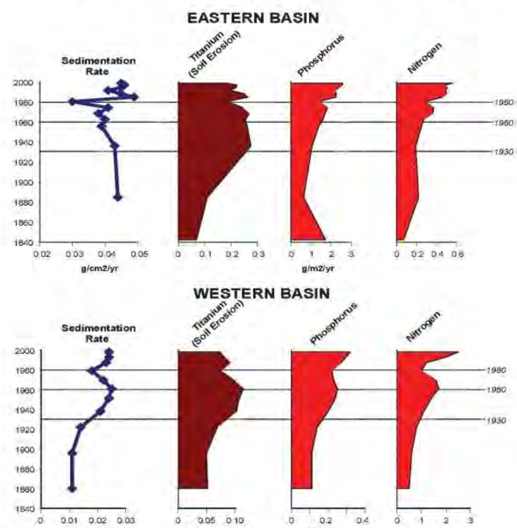

Figure 4. Profiles of important chemicals

significantly increased after 1930 (Figure 4). This is an indication of increased soil erosion in the watershed. This likely is the result of the increased mechanization of agriculture with the development of tractors and other farm equipment, which allowed more land to be cultivated. In the eastern basin during this time the sedimentation rate did not increase but it did in the western basin. In Green Lake, much of the sediment that is deposited is not from soil erosion but is *marl*. This is typical in a hard water lake like Green Lake. After 1960, titanium generally declined. This likely indicates improved cropping practices that reduced soil erosion in the watershed.

Nutrient inputs (phosphorus, nitrogen) increased after 1930 in the western basin but the increase occurred later in the eastern basin. In both basins, the greatest deposition of nutrients has occurred in the last decade. It appears that the major input of nutrients is not from soil erosion since titanium deposition has declined during this period.

Changes in the deposition of chemical variables that have occurred since European settlement are also evident in changes in sediment enrichment factors (SEF). If the present deposition rate is higher than the historical rate, the SEF will be greater than 0. The higher the factor, the greater the deposition at the present time compared with historical levels. SEFs for titanium (soil erosion) and phosphorus are higher in the eastern basin compared with the western basin (Table 2). Again, this reflects the fact that the most of the lake's tributaries enter the eastern basin. Most alarming is the increase in nutrients. There has been a doubling of phosphorus in the western basin while phosphorus deposition has increased much more in the eastern basin.

Table 2. ***Sediment enrichment factors. The higher the value the greater the increase of a chemical in recent times compared with historical levels.***

	WESTERN	EASTERN
TITANIUM	0.6	2.0
PHOSPHORUS	1.0	6.3
NITROGEN	3.9	2.9

Even though soil erosion has been decreasing in the last few decades, nutrient levels have been increasing. So what is the major source of the increase? Figure 5 shows profiles of titanium (soil erosion) and uranium. While titanium declined after 1960, uranium has steadily increased since 1950. Uranium (or cadmium) is often found as a contaminant in commercial fertilizers. This is a result of where the phosphate material is mined. Therefore increases in uranium are an indication of an increase in the use of fertilizers. In general, fertilizers have been more widely used since World War II. After the war, many factories that produced ammunition were converted to making fertilizer. It appears that in

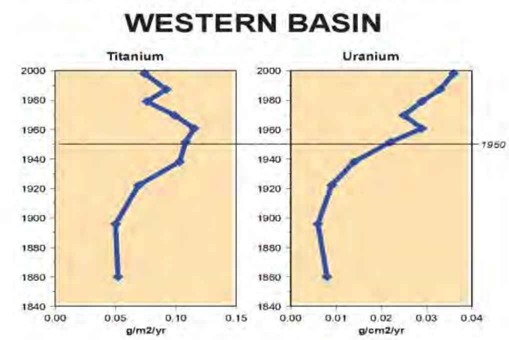

Figure 5. Profiles of titanium (soil erosion) and uranium (commercial fertilizer).

Green Lake, a significant source of nutrients during the last 50 years has been fertilizer runoff from agricultural fields and shoreline homes.

When bottom waters lose dissolved oxygen, *manganese* is released from the sediments. The decline in the ratio of iron to manganese (Fe:Mn) is an indication of declining oxygen in the deep waters

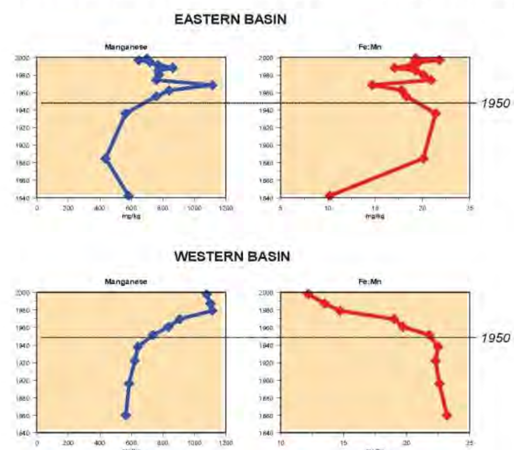

Figure 6. Profiles of manganese and Fe:Mn. A decline in the Fe:Mn indicates a loss of oxygen in the bottom waters of the lake.

of the lake. In the eastern basin there has not been a decline in the Fe:Mn ratio during the last 150 years.

In the deeper western basin, the Fe:Mn ratio has declined since 1950 (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.

INDICATOR ORGANISMS

Aquatic organisms are good indicators of a lake's water quality because they are in direct contact with the water and are strongly affected by the chemical composition of their surroundings. Most indicator groups grow rapidly and are short lived so the community composition responds rapidly to changing environmental conditions. One of the most useful organisms for paleolimnological analysis is *diatoms*. These are a type of algae which possess siliceous cell walls which enables them to be highly resistant to degradation and are usually abundant, diverse, and well-preserved in sediments. They are especially useful as they are ecologically diverse. Diatom species have unique features as shown in Figure 7, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. 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 (Figure 8). 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. In the eastern half of the lake, phosphorus levels quickly increased after 1950. This is the same time period when phosphorus deposition levels also increased in response to increased use of commercial fertilizers in the watershed. In the eastern part of the lake, phosphorus levels declined slightly from the period 1970-1990. However, in the western basin, phosphorus levels continued to increase during these two decades. Throughout the lake basin, the highest levels of phosphorus during the last 150 years occurred during the 1990's. There is some evidence that phosphorus levels have started to decline slightly during the last 5 years. However, current levels are considerably higher than they were historically.

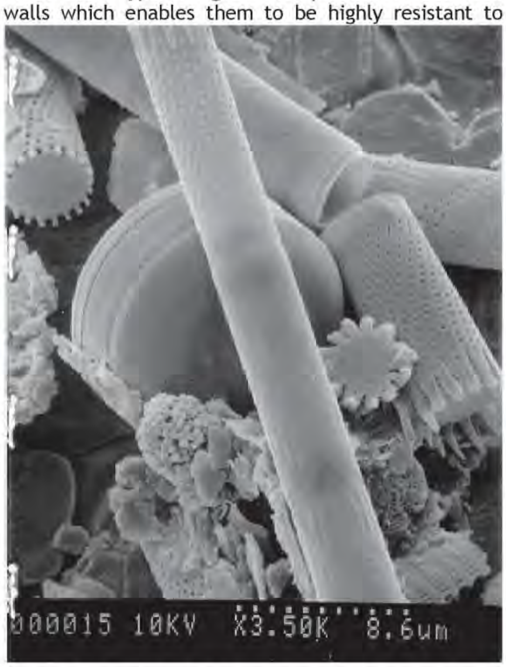

Figure 7. Picture of typical diatoms found in Green Lake.

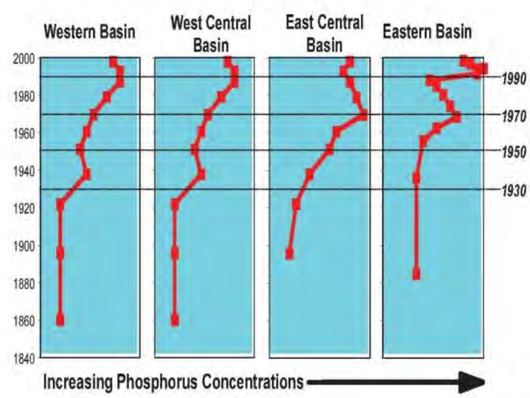

Figure 8. Profiles of diatom inferred phosphorus levels in the lake during the last 150 years.

SUMMARY

- Historically, phosphorus levels were highest in the eastern portion of the lake. This was because most of the tributaries enter the lake there.
- 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 during the 1990's.

GLOSSARY

Diatoms - Type of algae that possesses shells made of silica. This allows them to remain in the sediments for many years. Many diatoms live under unique environmental conditions including varying nutrient levels.

Manganese - A chemical that is released from the sediments when there is little dissolved oxygen in the bottom waters. Changes in its concentration indicate changes in the oxygen content of the bottom waters.

Marl - A type of sediment made of calcium carbonate that is deposited in hardwater lakes found in central and southern Wisconsin. Its color is often light gray.

Nitrogen - A major nutrient responsible for plant fertilization. While it is often not as important as phosphorus for plant growth, when present in excessive levels can help cause algal blooms.

Paleoecology - The study of a lake's history using fossils preserved in the sediments.

Phosphorus - A major nutrient responsible for plant fertilization. It is usually the nutrient that causes excessive algal growth.

Sediment dating - The use of scientific techniques to determine the age of a sediment slice.

Sedimentation rate - The rate at which sediment is deposited at the bottom of the lake.

Titanium - A chemical that is generally found only in soils. Changes in its deposition is an indication of the watershed soil erosion rate.

Funding for this project was provided by the Green Lake Sanitary District and the Wisconsin Department of Natural Resources. Chad Cook and others assisted with collection of the sediment cores. Geo- and radiochemical analyses were provided by the Wisconsin Laboratory of Hygiene and the University of Wisconsin Plant and Soils Laboratory

Appendix N

Climate Change and Wisconsin´s Great Lakes (WDNR)

Earth´s climate is changing. Human activities that increase heat–trapping ("greenhouse") gases are the main cause. Earth´s average temperature has increased 1.4 °F since 1850 and the eight warmest years on record have occurred since 1998. Increasing temperatures have led to changes in rainfall patterns and snow and ice cover. These changes could have severe effects on the Great Lakes and the plants, wildlife, and people who depend on them. While no one can predict exactly what climate change will mean for our Great Lakes, scientists agree that the following changes are likely if climate change patterns continue:

- Increased summer and winter temperatures will cause increased evaporation, lower lake water levels and warmer water, resulting in reduced habitat for cold water species and a loss of critical wetland areas.
- Decreased winter ice cover will also contribute to increased evaporation and lower lake water levels which could have severe economic consequences for our valuable shipping industry, lakeshore recreation, and coastal businesses.
- Changes in rain and snowfall patterns (including more frequent and severe storms) could change water flow in streams and rivers and increase stream bank erosion and runoff pollution.

The good news is that we can all work to slow climate change and lessen its effects. To find out more about climate change and how we can all help, please visit the following links.

Climate change is mainly the result of rising CO_2 levels in Earth´s atmosphere. Check out the most current CO_2 level and what it means: CO_2 Now [exit DNR]

General climate change information and actions we can all take to help (includes a special section for teachers and students): EPA Climate Change [exit DNR]

Climate Change and the Great Lakes:
International Assn. for Great Lakes Research Climate Change [exit DNR]
Union of Concerned Scientists [exit DNR]
Climate Change in the Great Lakes Region [exit DNR] (Sea Grant materials)
National Wildlife Federation – Great Lakes Report [PDF 1.14MB]

Wisconsin DNR Climate Change Information:
Wisconsin DNR´s new Climate Change Activity Guide for grades 7–12 teachers
Global Climate Change
Climate Change Wildlife and Wildlands Toolkit [exit DNR]