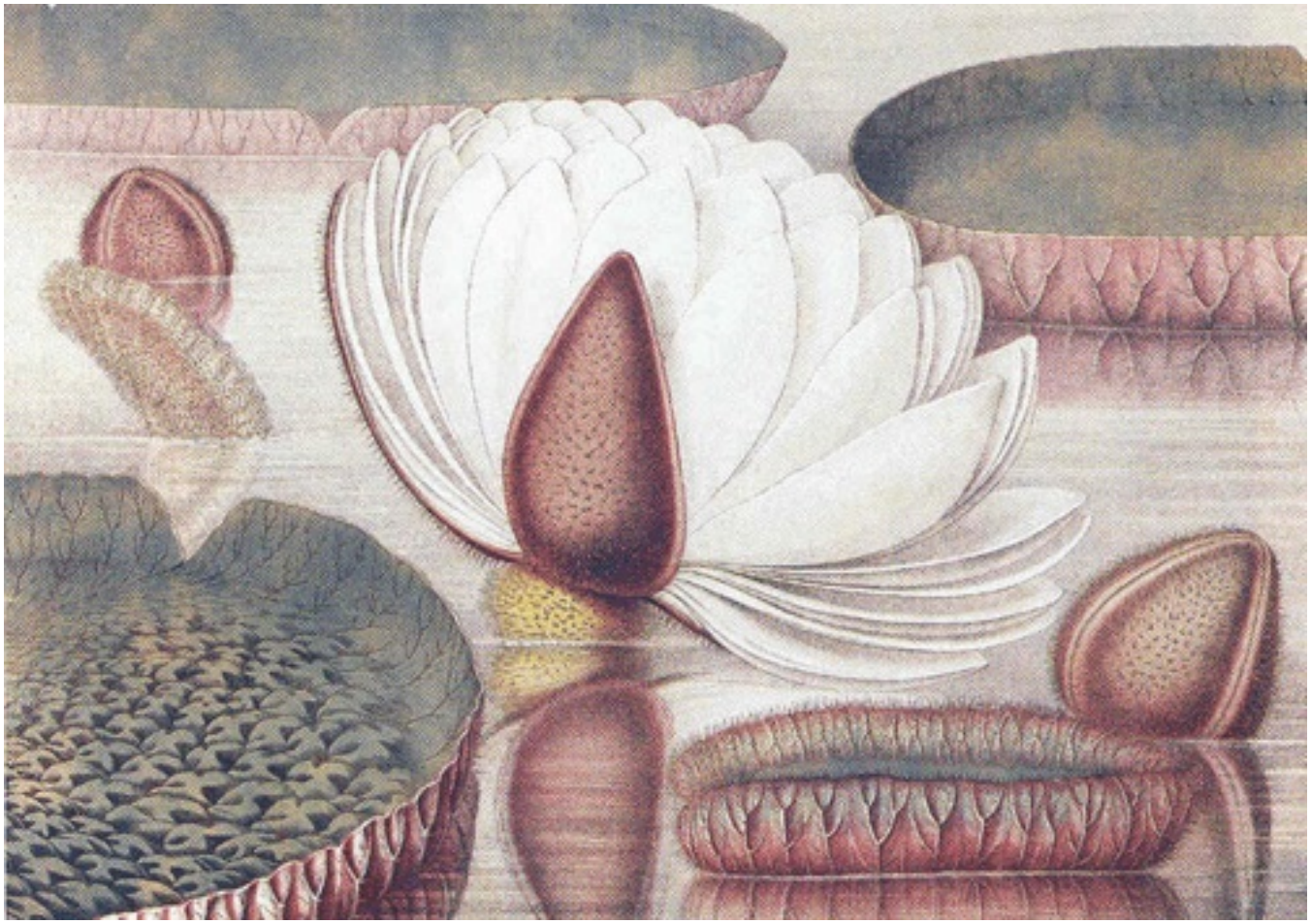

John Fisk Allen, *Victoria Regia; or the Great Water Lily of American*, **1854**

Aquatic Plant Assessment for Green and Little Green Lakes, Chisago County, Minnesota

Early Summer Aquatic Plant Survey: May 24, 2005
Second Summer (Post Herbicide) Aquatic Plant Survey: June 15, 2005

June 2005

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Aquatic Plant Assessment for Green and Little Green Lakes, Chisago County, Minnesota

Table of Contents

page number

Summary I

1. Introduction 1

2. Watershed Conditions 2
   2.1. Watershed size 2

3. Green Lake Conditions 3
   3.1. Physical features 3
   3.2. Lake water quality data summary 4
      3.2.1. Secchi disc data 5
      3.2.2. Total phosphorus data 6
   3.3. Fish status 7

4. Aquatic Plant Status 10
   4.1. Aquatic plant surveys in 2005 10
      4.1.1. First summer survey of Green Lake 11
      4.1.2. First summer survey of Little Green Lake 13
      4.1.3. Second summer survey of Green Lake 16
      4.1.4. Second summer survey of Little Green Lake 18
   4.2. Summary of native and non-native aquatic plant species for 2005 21
   4.3. Comparison of previous surveys to 2005 aquatic plant surveys 22
   4.4. Potential for nuisance growth of non-native invasion plants based on lake sediment characteristics 23
      4.4.1. Lake areas that could support nuisance curlyleaf growth based on lake sediment characteristics 25
      4.4.2. Lake areas that could support nuisance Eurasian watermilfoil growth based on lake sediment characteristics 27
   4.5. Aquatic plant architecture 29
   4.6. Aquatic plant assessment summary 31

Appendix
A. Aquatic Plant Survey Methods
B. Lake Sediment Survey Methods
C. Green and Little Green Lakes Water Quality Data
D. Minnesota Department of Natural Resources Fishery Data

Aquatic Plant Assessment for Green and Little Green Lakes, Chisago County, Minnesota

Summary

Green and Little Green Lakes are located in Chisago County, Minnesota and have a MnDNR ID number 13-0041. Green Lake is 1,714 acres in size and includes the area of Little Green Lake which is 226 acres in size (from the MnDNR fish survey, at the MnDNR Lake Finder website).

Lake Areas

	Lake Area (ac)	Littoral Area (ac)
Green Lake	1,488	1,018
Little Green Lake	226	210
Total	1,714	1,228

Table 1. Comparison of aquatic plant percent occurrences for the two summer plant surveys in 2005.

	Green Lake		Little Green Lake	
	May 24	June 15	May 24	June 15
Bulrush (*Scirpus sp*)	2	--	--	--
White waterlily (*Nymphaea sp*)	2	5	--	--
Coontail (*Ceratophyllum demersum*)	24	25	5	19
Chara (*Chara sp*)	10	21	5	5
Elodea (*Elodea canadensis*)	--	13	--	--
Northern watermilfoil (*Myriophyllum sibiricum*)	6	13	10	19
Eurasian watermilfoil (*Myriophyllum spicatum*)	24	23	14	5
Naiads (*Najas flexilis*)			--	5
Cabbage (*Potamogeton amplifolius*)	2	3	5	--
Curlyleaf pondweed (*Potamogeton crispus*)	84	77	100	10
Illinois pondweed (*P. illinoensis*)	2	--	--	--
Stringy pondweed (*P. pusillus*)	--	3	--	10
Claspingleaf pondweed (*P. Richardsonii*)	--	3	--	--
Flatstem pondweed (*P. zosteriformis*)	--	16	--	--
Water celery (*Vallisneria americana*)	--	2	--	--
Filamentous algae	6	2	5	5
Acres Covered by Plants (acres)	986	912	210	73
Percent Area Covered (%)	66	61	93	32

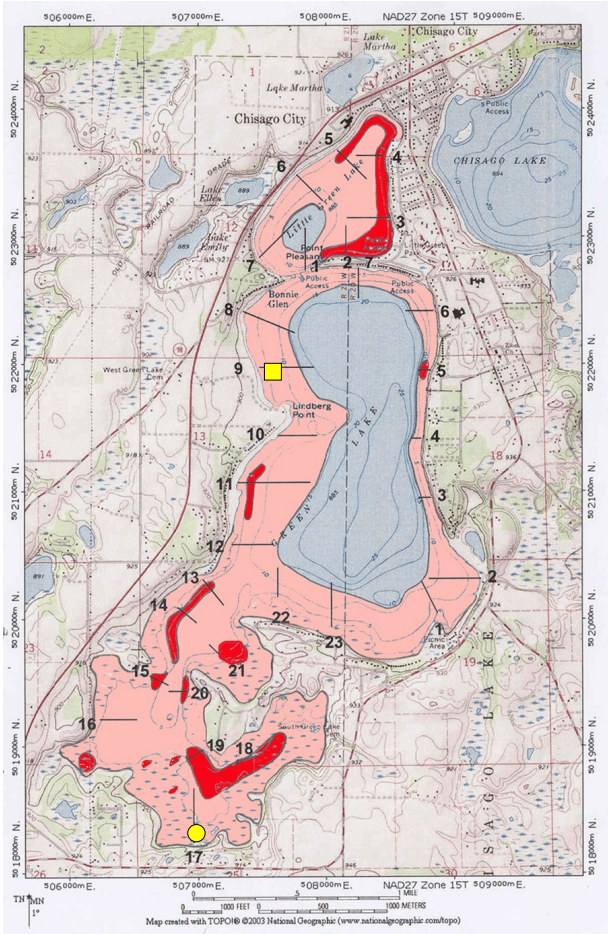


Figure 1a. Aquatic plant coverage for Green and Little Green Lakes on May 24, 2004. Plants covered a total of approximately 1,196 acres, or about 70% of the lake bottom, and grew out to a depth of 15 feet (pink shading). Nuisance growth of curlyleaf pondweed is shown in red. A bulrush patch is shown on Transect 9 and white lilies were found on Transect 17.

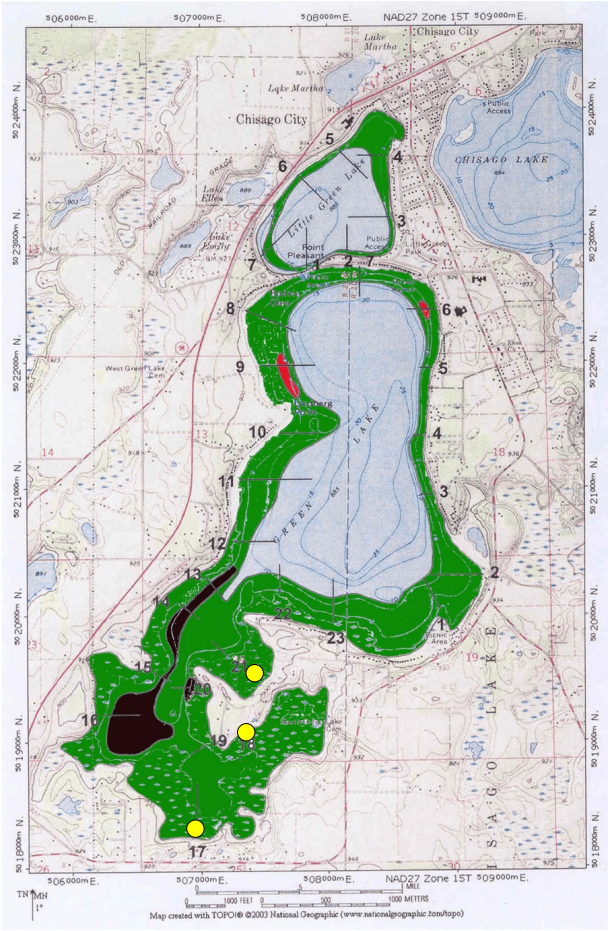


Figure 1b. Aquatic plant coverage in Green Lake on June 15, 2005. Plants covered approximately 985 acres, or about 57% of the lake bottom, and grew out to a depth of 15 feet. The black shading represents nuisance growth of Eurasian watermilfoil and the red shading represents nuisance curlyleaf pondweed growth. White lilies were found on Transects 17, 18, and 21.

1. Introduction

Aquatic plants play a vital role in the water quality dynamics of moderately fertile lakes in the North Central Hardwood Forest Ecoregion. Because Green and Little Green Lakes are in this ecoregion managing aquatic plants is a challenge that is multifold. The first challenge is to maintain a diverse native aquatic plant community. In the case of Green Lake where native aquatic plants are present, a major emphasis will be on maintaining diversity of the native aquatic plant community. Another challenge is to maintain adequate active recreational opportunities which means managing excessive aquatic plant growth so it doesn't significantly hinder navigation. Lastly, the challenge is to manage exotic plants so they have a low impact on adversely effecting water quality or recreational lake use.

This report summarizes existing water quality conditions and assesses existing aquatic plant conditions. This report can then serve as a reference for formulating aquatic plant management approaches in the future.

Figure 1. Green Lake nearshore conditions on June 15, 2005 in the south end of the lake.

2. Watershed Conditions

2.1. Watershed Size

Green Lake is listed by the MnDNR as 1,714 acres in size and includes the area of Little Green which is 226 acres in size (based on an MPCA report from 1980). However, since the lake size was determined in 1964, water level changes have, at various times increased or decreased its size. The watershed area draining to Green totals 2,092 acres (does not include the lakes area)(from a 1980 MPCA report). Watershed areas are listed in Table 1 and a subwatershed map is shown in Figure 2.

Table 1. Watershed area in the Green Lakes subwatershed.

Subwatershed	(acres)
Green / Little Green	2,092

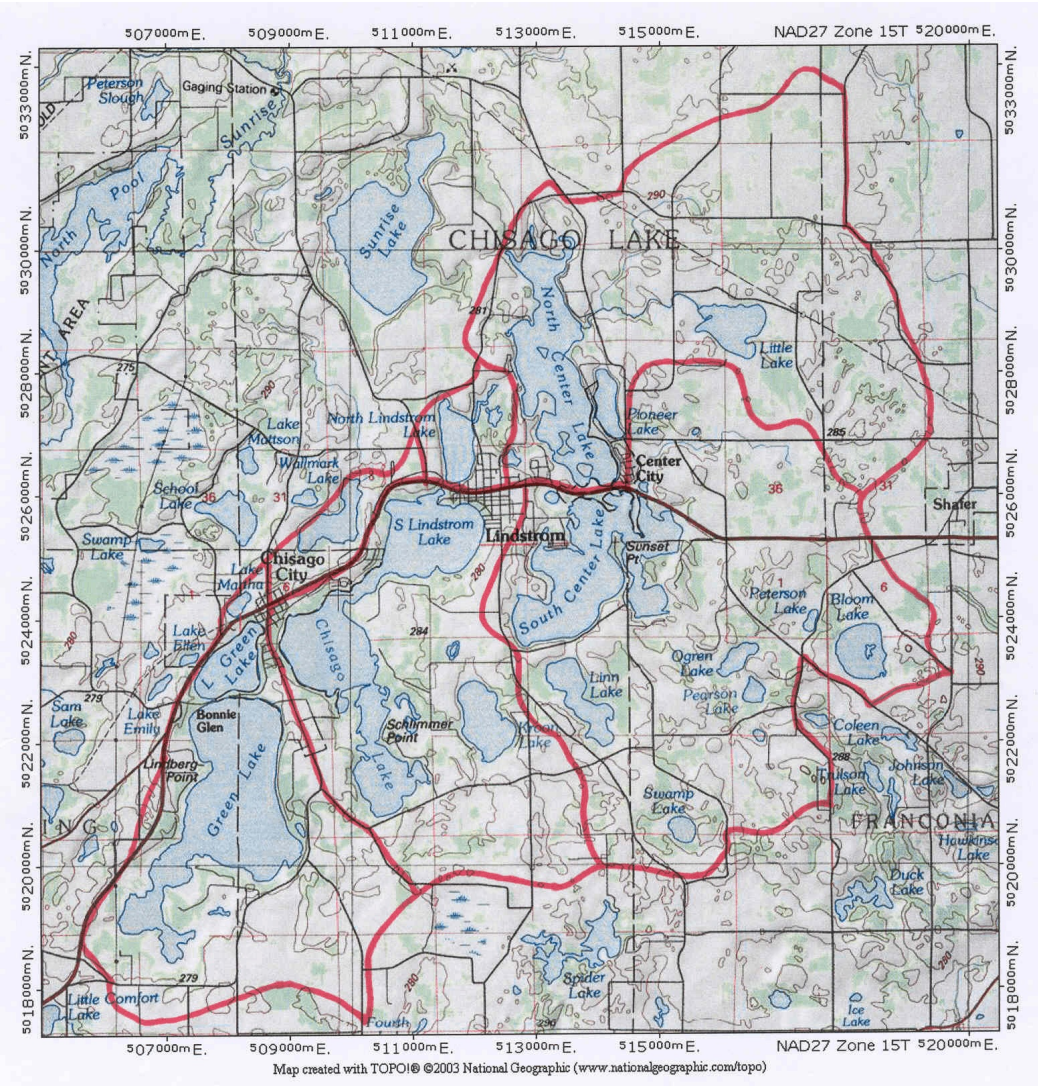


Figure 2. Subwatersheds in the Green and Little Green Lake watershed.

3. Green Lake Conditions

3.1. Physical Features

Green and Little Green Lakes are located in Chisago County, Minnesota and have a MnDNR ID number 13-0041 (Figure 3). Green Lake is 1,714 acres in size and includes the area of Little Green Lake which is 226 acres in size (from the MnDNR fish survey, at the MnDNR Lake Finder website).

Green Lake has a maximum depth of 33 feet (source: MnDNR) and a mean depth of about 19 feet. Little Green Lake has a maximum depth of 18 feet (source: MPCA). The littoral area of both lakes combined (0-15 feet deep) consists of 1,228 acres (source: MnDNR).

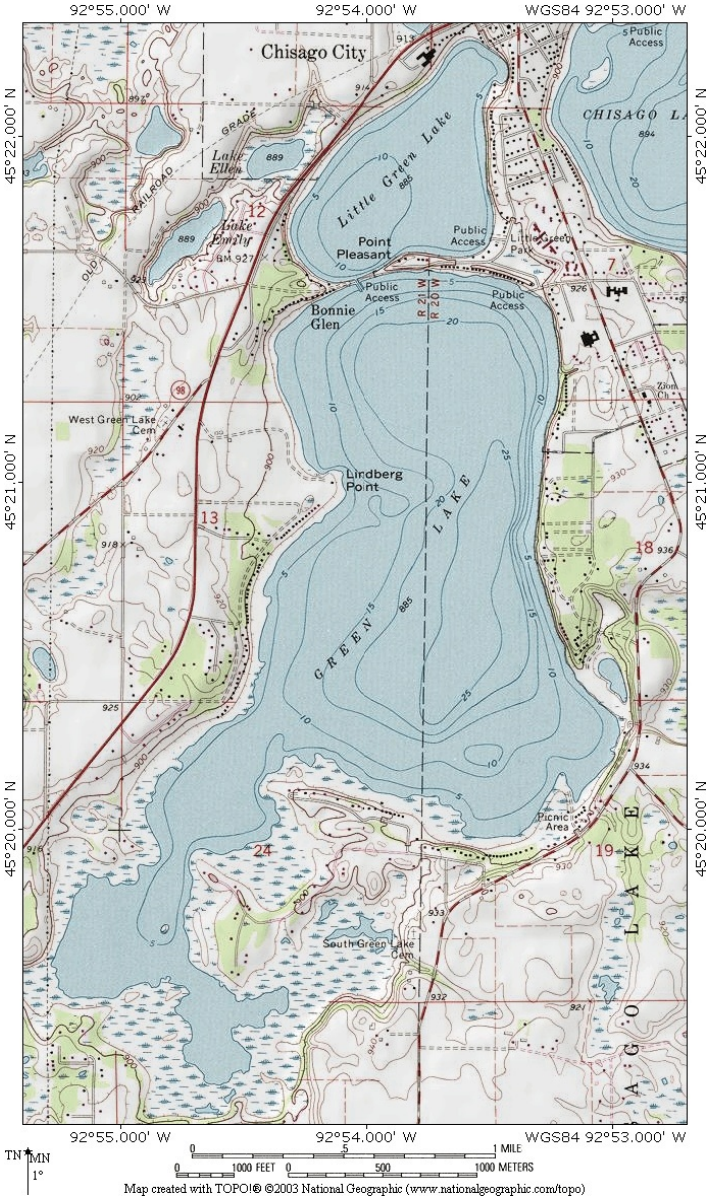


Figure 3. Contour map of Green and Little Green Lake.

3.2. Lake Water Quality Data Summary

Green Lake is moderately fertile and is classified as eutrophic based on lake phosphorus concentrations. Green Lake has a long term average summer phosphorus concentration of under 40 µg-P/l (Table 2). Transparency has been in the 4 to 6-foot range in July and August. The transparency in Little Green Lake is slightly less.

Table 2. Water quality data summer averages for June - September (source: Chisago Lakes Improvement District and MPCA).

Year	GREEN LAKE		LITTLE GREEN LAKE	
	Secchi Disc (ft)	Total Phosphorus (top) (µg/l)	Secchi Disc (ft)	Total Phosphorus (top) (µg/l)
1986		32		38
1987				
1988	3.7			
1989	5.2		2.5	
1990	3.9		3.5	
1991	7.0		5.1	
1992	6.5			
1993	5.9		4.0	
1994	4.0	41	3.0	46
1995	6.5	38	6.0	34
1996	5.3	39	4.7	50
1997	5.9	21	5.1	24
1998	6.4	27	4.8	42
1999	5.9	20	4.1	30
2000	6.7	17	3.9	28
2001	5.9	47	4.4	51
2002	5.3	10	4.2	15
2003	4.3	22	3.4	32
2004	5.6	14	4.9	19

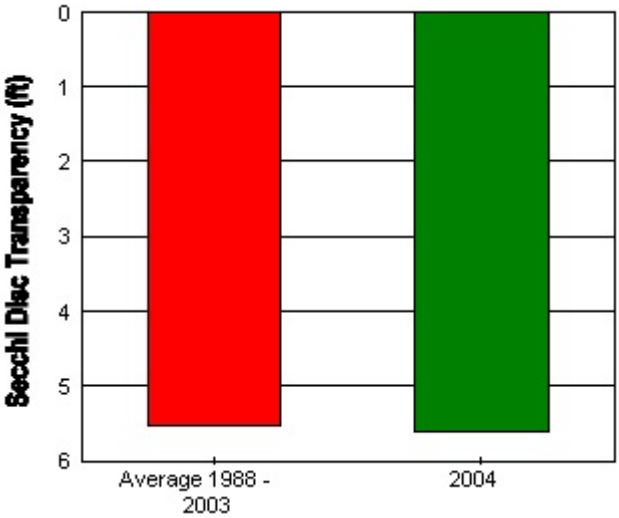


Figure 4. Water clarity was about average in Green Lake in 2004 compared to water clarity from 1988-2003.

3.2.1. Secchi Disc Data: Summer growing season water clarity going back to 1988 for Green and 1989 for Little Green is shown in Figure 5. No increasing or decreasing water clarity trends are observable for the lakes. Annual averages fluctuate from year to year within normal ranges.

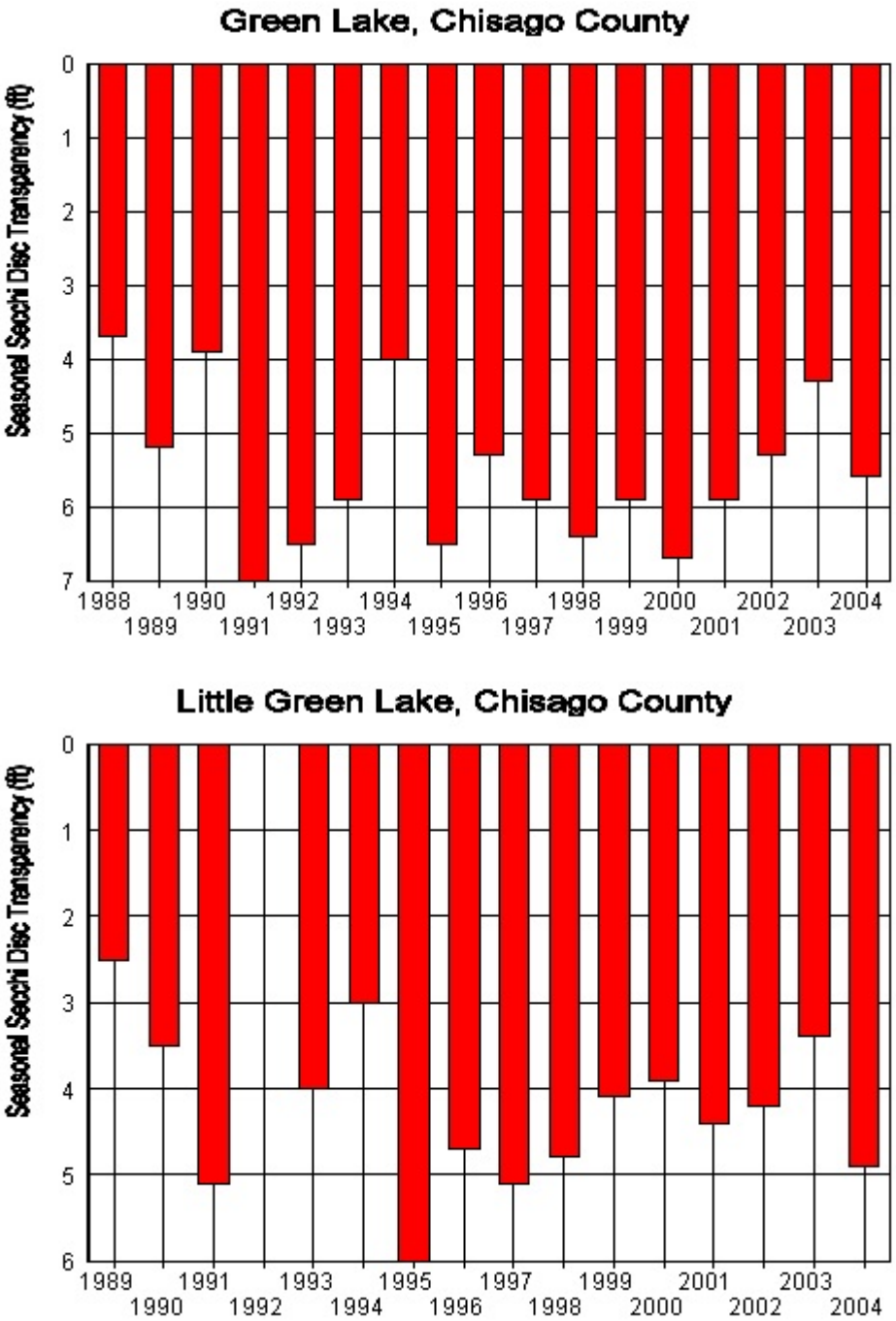


Figure 5. Summer average (June-September) Secchi disc data for Green and Little Green Lake from 1988-2004.

3.2.2. Total Phosphorus data: Lake phosphorus samples have been collected occasionally from 1986-2004 for Green and Little Green Lakes and results are shown in Table 4. The average lake phosphorus concentrations from June through August appear to be slightly lower since 2002 compared to the mid 1990s.

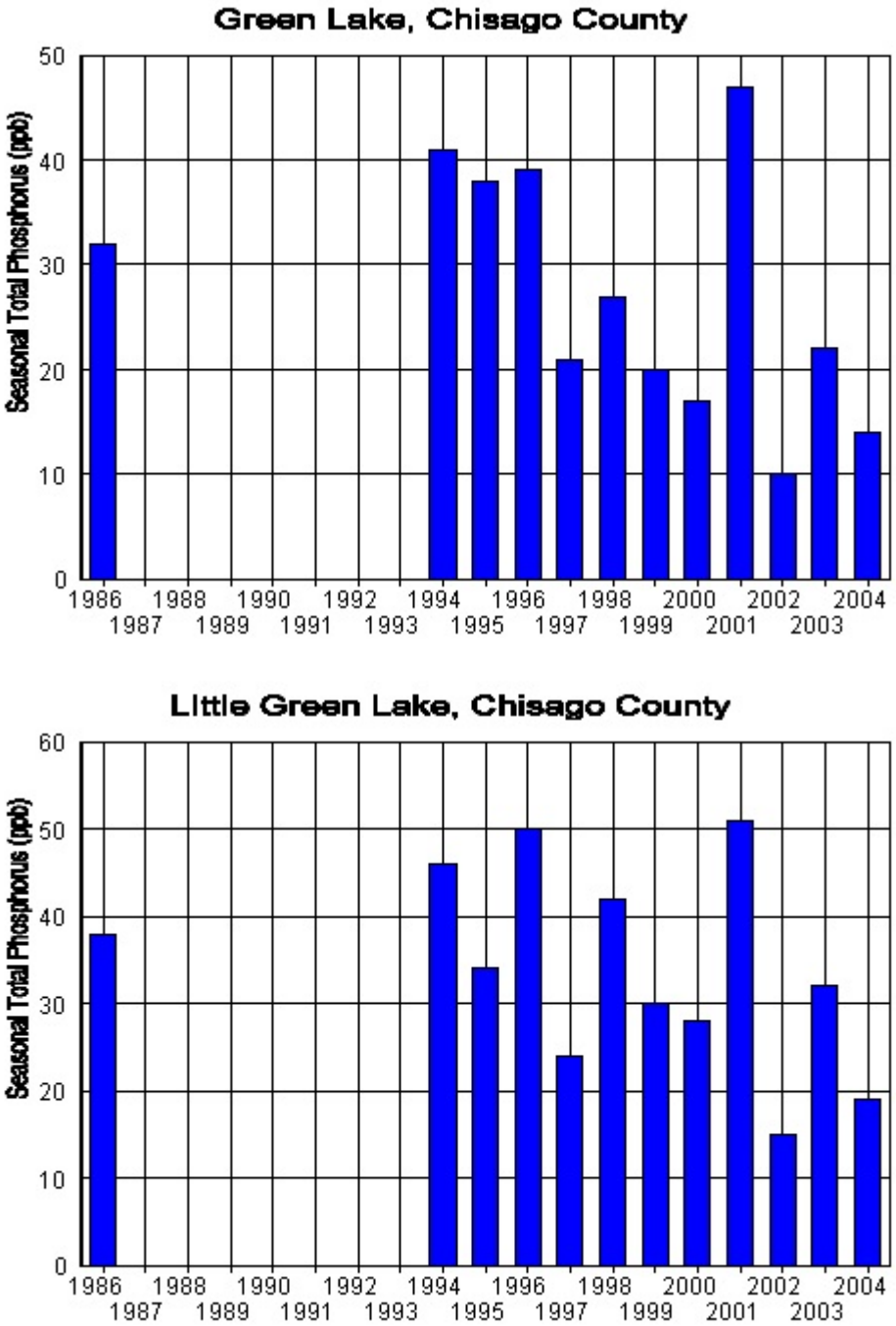


Figure 6. Summer average (June - August) phosphorus concentrations for Green and Little Green Lakes from 1986 - 2004.

3.3. Fish Status

Information of the Green Lake fish community comes from the MnDNR fish survey summary report. The last MnDNR fish survey was July 23, 2001.

Lake information report

Name: GREEN

Nearest Town: CHISAGO CITY
Primary County: Chisago

Survey Date: 07/23/2001
Inventory Number: 13-0041-00

Public Access Information

Ownership	Type	Description
City	Concrete	Access on the SE shore of Little Green Lake. Parking for about 15 vehicles with overflow parking across Green Lake Ave.
Minnesota DNR	Concrete	Access on the SE shore of Green Lake. Parking for 25 vehicles.
City	Gravel	Winter drive-on access off of 284th St. on the NE end of Green Lake. Closed during open water season.

Lake Characteristics

Lake Area (acres): 1,714.00
Littoral Area (acres): 1,228.00
Maximum Depth (ft): 32.00
Water Clarity (ft): 7.00

Dominant Bottom Substrate : N/A
Abundance of Aquatic Plants : N/A
Maximum Depth of Plant Growth (ft): N/A

Fish Sampled up to the 2001 Survey Year

Species	Gear Used	Number of fish per net	
		Caught	Average Fish Weight (lbs)
Black Bullhead	Gill net	1.1	0.60
	Trap net	0.1	0.68
Black Crappie	Gill net	11.3	0.20
	Trap net	6.9	0.23
Bluegill	Gill net	19.5	0.13
	Trap net	42.7	0.11
Bowfin (Dogfish)	Trap net	0.1	4.13
Brown Bullhead	Gill net	0.3	1.01
	Trap net	1.4	0.90
Common Carp	Gill net	0.3	ND
	Trap net	0.1	12.90
Green Sunfish	Trap net	trace	0.03
Hybrid Sunfish	Gill net	0.2	0.19
	Trap net	0.8	0.14
Largemouth Bass	Gill net	0.5	0.72
	Trap net	0.2	1.79
Northern Pike	Gill net	1.5	3.17
	Trap net	0.9	3.54
Pumpkinseed Sunfish	Gill net	0.4	0.14
	Trap net	2.3	0.17
Painted Turtle	Trap net	0.7	ND
Snapping Turtle	Trap net	0.4	ND
Softshell Turtle	Trap net	0.3	ND
Walleye	Gill net	4.1	1.88
	Trap net	0.6	1.43
White Sucker	Gill net	trace	2.35
Yellow Bullhead	Gill net	0.5	0.97
	Trap net	0.9	1.03
Yellow Perch	Gill net	0.2	0.10
	Trap net	trace	0.09

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

Status of the Fishery (as of 07/23/2001)

Comprised of three distinct basins (the north end commonly called Little Green, the central main basin, and a series of bays on the south end) Green lake, at 1,714 acres is the largest lake in Chisago county. Summer algae blooms limit water clarity between 4 and 5 feet. Minnesota lakes managed for fishing are grouped into classes based on physical, chemical, and biological similarities. Green lake is assigned to lake class 24. In order to compare the present fish population to others in the lake class and to evaluate management goals, Green lake was netted and electro fished during the summer of 2001.

Green lake is managed primarily for walleye, northern pike, and black crappie. The lake management plan calls for walleye fingerling stocking (1,228 pounds) on alternate years and northern pike stocking (31,000 fingerlings) when net catches fall below 1.5 per gillnet. A 9 inch minimum size limit for black crappie was implemented in 1997 as part of a state wide experimental regulation study. Long range management goals for Green lake include maintaining the walleye gillnet catch near 5 per set with a 1.5 pound average and the northern pike catch between 2 and 4 per net with a 2.5 pound average.

The gillnet catches for northern pike, walleye, and black crappie were within the normal range when compared to lakes in Green's lake class. The yellow perch catch was very low with only 3 being taken. The 1996 catch rate was identical but as recently as 1991 the catch rate was above the 50 percentile for the lake class.

The northern pike catch met the management goal for size with a 3.2 pound mean. The catch rate of 1.5 per net fell below the management goal. However both indices were normal compared to other catches in the lake class. Northerns ranged in length from 19.4 to 28.9 inches with a 24.0 inch average. The 1996 catch was noticeably higher at 6.7/set but in both 1991 and 1986 the catch was a mere 0.2/set. The 1997 year class was dominate, accounting for 46% of the catch. These four year old fish averaged 24 inches and should provide quality angling.

Walleye met management goals for size but fell short in numbers. Both catch rate (4.1 per net) and average weight (1.9 pounds) compared favorably to other lakes in the class. The 2001 netting marks the first time in 20 years the walleye catch rate has fallen below 5.0/net. Sampled walleye ranged from 9.3 to 29.0 inches with a 16.9 inch mean. Walleye ages ranged from 1 to 12 years with strong year classes from 1996 to 1998. The 1998 year class provided 34% of the catch and averaged 13.4 inches. Walleye growth was normal compared to the statewide average.

Both the trapnets and the gillnets sampled black crappie above the lake class 50 percentile in numbers and at the 50 percentile in weight. The combined catch ranged from 3.8 to 9.5 inches with a 7.4 inch mean. There were no crappie over 10 inches sampled during the netting; therefore the management goal for crappie was not met. Three year old crappies from the 1998 year class represented 58% of the catch and averaged 7 inches. Based on scale aging, crappie growth slowed significantly at age three.

The yellow perch gillnet catch was very low with only 3 fish being sampled. The catch was identical in 1996 but as recently as 1991 the catch rate was 17.3 per set. The current low perch abundance may be limiting walleye and northern pike production.

Bluegill were sampled at normal levels compared to other lake class catches. The trapnet catch rate (42.7/set) was quite an increase from the 1996 catch of 17.2 per net. Sampled bluegill were small compared to other lakes in the class, falling below the normal range for size for the first time in 15 years. Sampled bluegill ranged from 3.0 to 6.9 inches with a 5.2 inch mean.

Night electrofishing on May 10, 2001 sampled 43.6 bass per hour, very similar to the 1996 catch. The 71 bass ranged from 6.1 to 18.2 inches with a 10.9 inch and 0.8 pound average. Sampled bass were nearly an inch smaller on average compared to the 1996 catch. Bass ranged in age from two to eight years with the strong year classes from 1996 to 1998. The 1998 class accounted for 34% of the catch and while only 3 years old averaged 9.1 inches. Bass growth was similar to the statewide norm.

The 2001 catch indicated that while the management goals for walleye and northern pike were met based on size, both species fell short of their goal numbers. The northern pike catch rate was very near the stocking threshold. The black crappie goal was not met since no fish over 10 inches were sampled, however the mean length of sampled crappie did increase a full inch since 1996. The largemouth bass catch increased slightly in numbers and decreased slightly in size but appears healthy overall. Other species present included black bullhead, bowfin (dogfish), brown bullhead, common carp, green sunfish, hybrid sunfish, pumpkinseed sunfish, white sucker, and yellow bullhead.

4. Aquatic Plant Status

4.1. Aquatic Plant Surveys in 2005

Aquatic plant surveys were conducted on Green and Little Green Lakes on May 24 and June 15, 2005. The objectives of the surveys were to evaluate the distribution of curlyleaf pondweed and Eurasian watermilfoil as well as other native plant species in the lakes.

Several techniques were used to conduct the aquatic plant surveys. For Green Lake, 23 transects and up to three depths per transect were sampled. For Little Green Lake, 7 transects and three depths per transect were used (Figure 7). A recording sonar (Lowrance X-16) was used to delineate the depths of plant colonization. Additional information on survey methods is given in Appendix A.

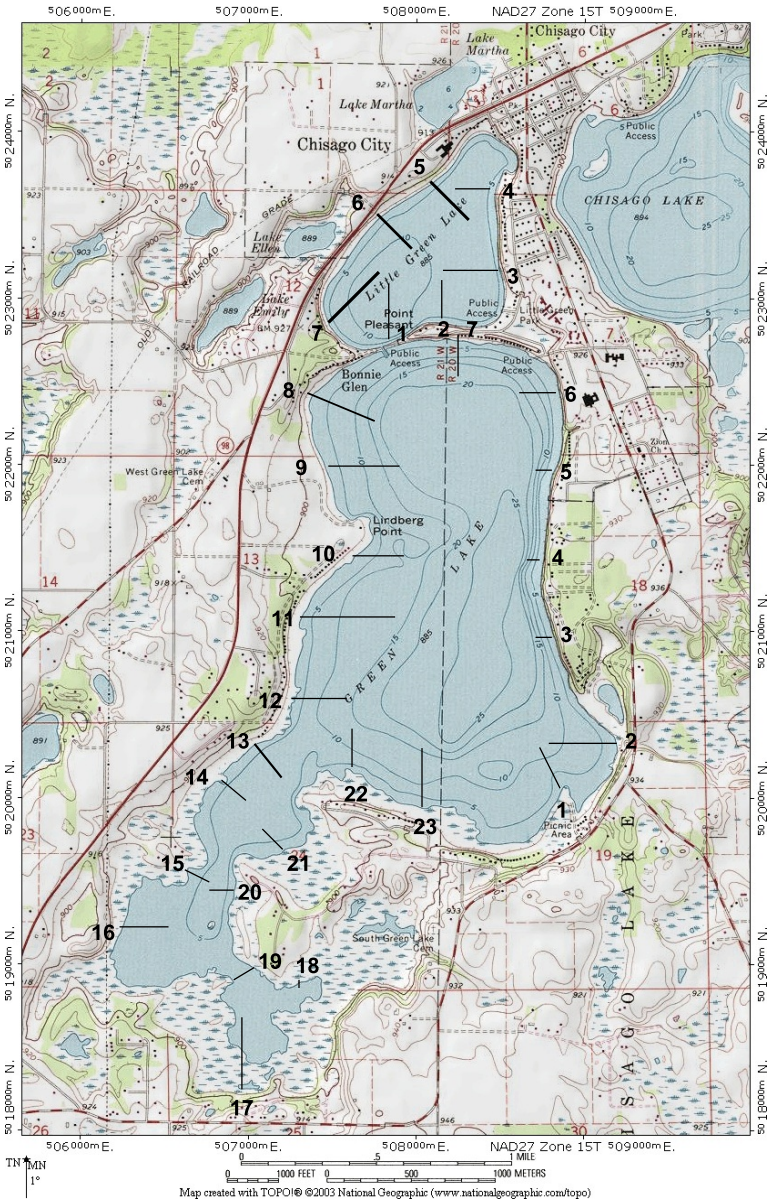


Figure 7. Transect locations for 2005 plant surveys on Little Green and Green Lakes. The lake area in the southern end of Green Lake has more open water in 2004 than shown in this USGS topographical map.

4.1.1. First Summer Survey of Green Lake: Green Lake was dominated by curlyleaf pondweed in the early summer of 2005 (Table 3). Eurasian watermilfoil was present, but its density was relatively low. Both these plants are exotics. Coontail was the most abundant native plant, showing up in 15 of 61 sites (Table 3). Plants did not grow past 15 feet of water depth in May. Plant data for individual plant transects is shown in Table 4.

Table 3. Summary of results from 23 transects for Green Lake. Green Lake aquatic plant occurrences and densities for the May 24, 2005 survey are based on 23 transects and up to 3 depths per transect, for a total of 61 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0 - 5 feet (n=23)			Depth 6 - 10 feet (n=23)			Depth 11 - 15 feet (n=15)			All Stations (n=61)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bulrush (*Scirpus sp*)	1	4	0.3	--	--	--	--	--	--	1	2	0.3
White waterlily (*Nymphaea sp*)	1	4	1.0	--	--	--	--	--	--	1	2	1.0
Coontail (*Ceratophyllum demersum*)	8	35	2.1	7	30	1.4	--	--	--	15	25	1.8
Chara (*Chara sp*)	5	22	1.1	1	4	0.2	--	--	--	6	10	0.9
Northern watermilfoil (*Myriophyllum sibiricum*)	3	13	0.8	1	4	0.3	--	--	--	4	7	0.7
Eurasian watermilfoil (*M. spicatum*)	8	35	1.4	7	30	1.2	--	--	--	15	25	1.3
Cabbage (*Potamogeton amplifolius*)	1	4	0.3	--	--	--	--	--	--	1	2	0.3
Curlyleaf pondweed (*P. crispus*)	17	74	1.8	23	100	2.6	12	80	1.2	52	85	2.0
Illinois pondweed (*P. Illinoensis*)	1	4	1.0	--	--	--	--	--	--	1	2	1.0
Filamentous algae	3	13	1.2	1	4	2.0	--	--	--	4	7	1.4

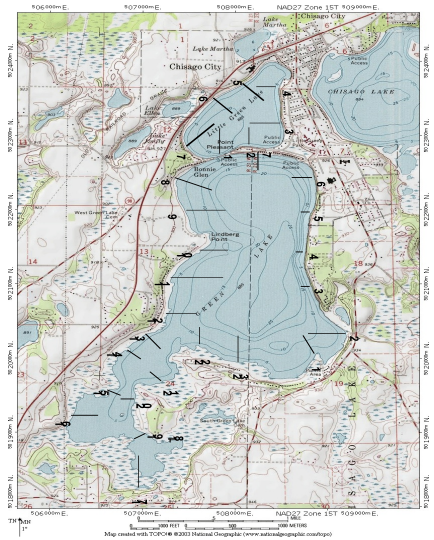
Figure 8. Aquatic plants were sampled with a rake. The density of curlyleaf pondweed shown here is estimated to be a "2", a non-nuisance condition.

Table 4. Individual transect data for Green Lake for May 24, 2005.

	T1			T2			T3			T4			T5			T6			T7			T8		
	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15
Bulrush																								
White waterlily																								
Coontail																								
Chara																			2	0.2		1		
Northern watermilfoil													0.5											
Eurasian watermilfoil																								
Cabbage																						0.3		
Curlyleaf pondweed		2.3		0.5	1.5	1		0.5		0.3	0.7		2	3.5	1	1	2.5	2		1.8	1	0.3	2.3	1
Illinois pondweed																								
Filamentous algae																								

	T9			T10			T11			T12			T13			T14		T15		T16	
	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	0 - 5	6 - 10	0 - 5	6 - 10
Bulrush	0.3																				
White waterlily																					
Coontail													1				0.3			3	3
Chara				1			0.5			0.8											
Northern watermilfoil					0.3																
Eurasian watermilfoil													1	0.5		0.3	0.3	1	0.7	2	2
Cabbage																					
Curlyleaf pondweed	0.8	1.8	1		1.7	1	2.5	4	0.8		2	1	3.5	4.2	1	0.8	3.8	4	4	2	2
Illinois pondweed																					
Filamentous algae																1					

	T17		T18		T19		T20		T21		T22			T23		
	0 - 5	6 - 10	0 - 5	6 - 10	0 - 5	6 - 10	0 - 5	6 - 10	0 - 5	6 - 10	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15
Bulrush																
White waterlily	1															
Coontail	3.5	2	2	0.5	3		2	1	1.5	2	1	1				
Chara																
Northern watermilfoil							1				1					
Eurasian watermilfoil			1	0.5	1		3	1.5	2	3						
Cabbage																
Curlyleaf pondweed	0.8	2	2	5	3	5	2	3	4.8	3	1	3	2		0.5	1
Illinois pondweed											1					
Filamentous algae							2		0.5	2						



4.1.2. First Summer Survey of Little Green Lake: Little Green Lake was dominated by curlyleaf pondweed on the May 24, 2005. Curlyleaf pondweed grew out to a depth of 15 feet. Other plants were sparse in Little Green Lake (Table 5). Plant data for individual plant transects is shown in Table 6.

Table 5. Little Green Lake aquatic plant occurrences and densities for the May 24, 2005 survey based on 7 transects and 3 depths, for a total of 21 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

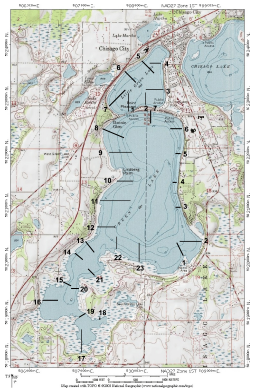
	Depth 0 - 5 feet (n=7)			Depth 6 - 10 feet (n=7)			Depth 11 - 15 feet (n=7)			All Stations (n=21)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Coontail (*Ceratophyllum demersum*)	1	14	1.0	--	--	--	--	--	--	1	5	1.0
Chara (*Chara sp*)	1	14	1.0	--	--	--	--	--	--	1	5	1.0
Northern watermilfoil (*Myriophyllum sibiricum*)	1	14	0.5	1	14	0.3	--	--	--	2	10	0.4
Eurasian watermilfoil (*M. spictatum*)	2	29	2.0	1	14	0.5	--	--	--	3	14	1.5
Cabbage (*Potamogeton amplifolius*)	1	14	0.5	--	--	--	--	--	--	1	5	0.5
Curlyleaf pondweed (*P. crispus*)	7	100	1.5	7	100	3.2	7	100	1.8	21	100	2.1
Filamentous algae	1	14	1.0	--	--	--	--	--	--	1	5	1.0

Figure 9. The density of curlyleaf pondweed shown here is estimated to be a "4". Curlyleaf is dense and growing up to the surface. This is a nuisance condition.

Table 6. Individual transect data for Little Green Lake for May 24, 2005.

	T1			T2			T3			T4		
	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15
Coontail							1					
Chara												
Northern watermilfoil	0.5											
Eurasian watermilfoil							1			3	0.5	
Cabbage	0.5											
Curlyleaf pondweed	0.5	2.5	0.5	0.8	3.6	1.3	2	2.7	4	2	4	2
Filamentous algae										1		

	T5			T6			T7		
	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15
Coontail									
Chara	1								
Northern watermilfoil					0.3				
Eurasian watermilfoil									
Cabbage									
Curlyleaf pondweed	2.5	3.6	2	1.5	3	2.5	1	2.8	0.3
Filamentous algae									



Aquatic Plant Distribution on May 24, 2005: Aquatic plant coverage in Green and Little Green Lakes is shown in Figure 10. Submerged and floatingleaf plant species covered a total of 1,196 acres or about 70% of the lake bottom. Nuisance plant growth was dominated by curlyleaf pondweed. A summary of aquatic plant coverage, in acres, is shown in Table 7.

Table 7. Areas of plant coverage for Green and Little Green Lakes on May 24, 2005.

	Green Lake	Little Green Lake	Total
Lake area	1,488	226	1,714
Littoral area	1,018	210	1,228
Area of curlyleaf pondweed plus other plants	986	210	1,196
Area of nuisance curlyleaf pondweed	85	65	150
Area of nuisance EWM	0	0	0

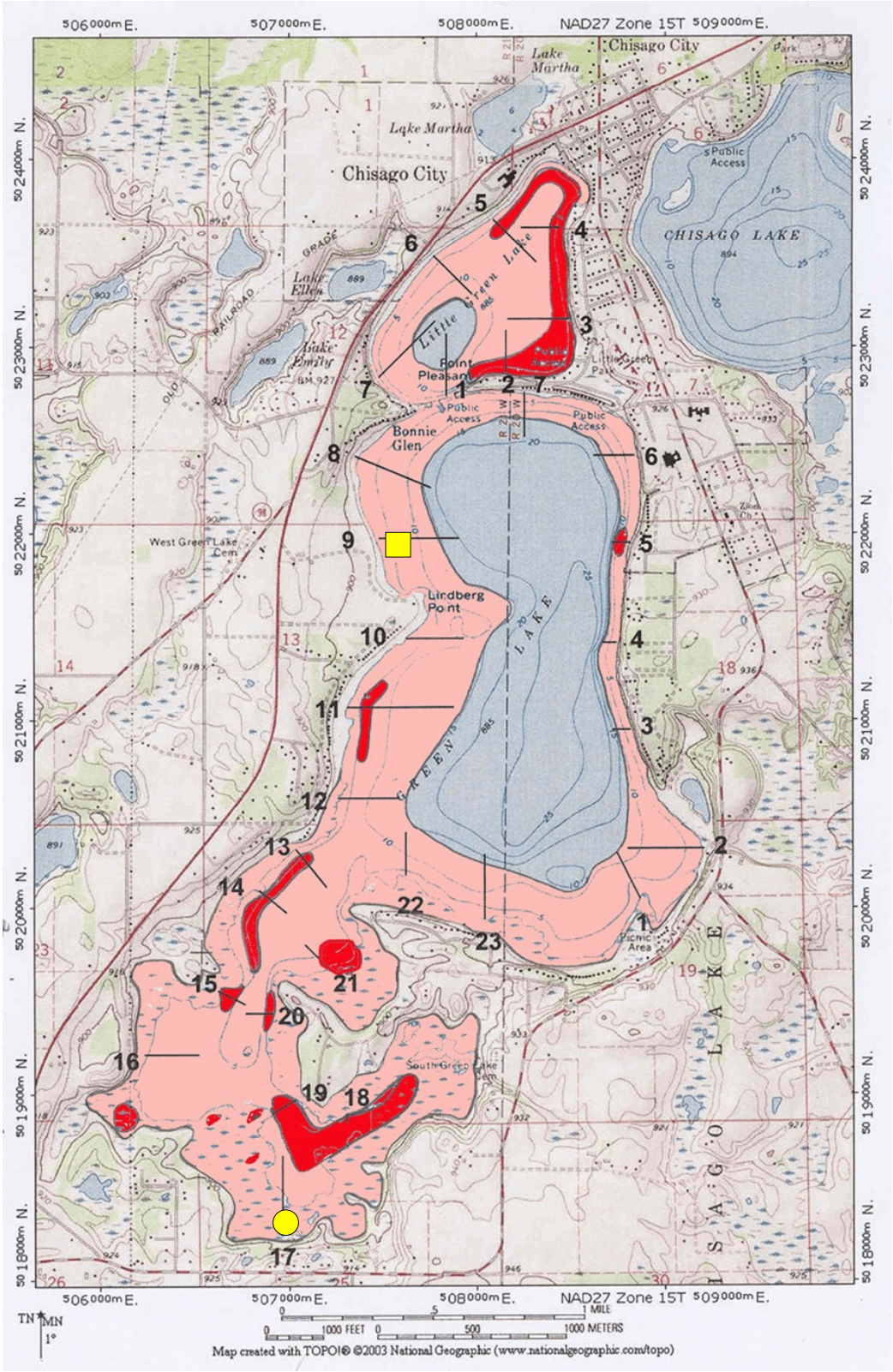


Figure 10. Aquatic plant coverage for Green and Little Green Lakes on May 24, 2004. Plants covered a total of approximately 1,196 acres, or about 70% of the lake bottom, and grew out to a depth of 15 feet (pink shading). Nuisance growth of curlyleaf pondweed is shown in red. A bulrush patch is shown on Transect 9 and white lilies were found on Transect 17.

4.1.3. Second Summer Survey of Green Lake: In the second summer plant survey on June 15, 2005, conditions changed slightly compared to the May 24, 2005 survey. Eurasian watermilfoil increased in distribution, and was found in high densities in several locations. Where curlyleaf pondweed was treated, it had died back and had not resprouted. Curlyleaf pondweed grew out to a water depth of 15 feet on several transects. In the deeper water, curlyleaf was the dominant plant. In shallower water, curlyleaf was the dominant plant but chara and coontail were common as well (Table 8). Plant data for individual plant transects is shown in Table 9.

Table 8. Summary of results from 23 transects on Green Lake. Green Lake aquatic plant occurrences and densities for the June 15, 2005 survey based on 23 transects and up to 3 depths, for a total of 62 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0 - 5 feet (n=23)			Depth 6 - 10 feet (n=23)			Depth 11 - 15 feet (n=16)			All Stations (n=62)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
White waterlily (*Nymphaea sp*)	3	13	2.7	--	--	--	--	--	--	3	5	2.7
Coontail (*Ceratophyllum demersum*)	8	35	1.9	7	30	2.3	--	--	--	15	25	2.1
Chara (*Chara sp*)	8	35	1.4	5	22	0.7	--	--	--	13	21	1.1
Elodea (*Elodea canadensis*)	4	17	1.8	4	17	1.9	--	--	--	8	13	1.8
Northern watermilfoil (*Myriophyllum sibiricum*)	2	9	1.0	5	22	0.7	1	7	1.0	8	13	0.8
Eurasian watermilfoil (*M. spicatum*)	7	30	3.3	6	26	2.2	1	7	1.0	14	23	2.7
Cabbage (*Potamogeton amplifolius*)	1	4	1.0	1	4	1.0	--	--	--	2	3	1.0
Curlyleaf pondweed (*P. crispus*)	13	57	1.8	20	87	2.1	14	93	1.6	47	77	1.9
Stringy pondweed (*P. pusillus*)	1	4	1.0	1	4	0.5	--	--	--	2	3	0.8
Claspingleaf pondweed (*P. Richardsonii*)	2	9	1.5	--	--	--	--	--	--	2	3	1.5
Flatstem pondweed (*P. zosteriformis*)	7	30	0.9	3	13	0.8	--	--	--	10	16	0.9
Water celery (*Vallisneria americana*)	1	4	0.5	--	--	--	--	--	--	1	2	0.5
Filamentous algae	--	--	--	1	4	1.0	--	--	--	1	2	1.0

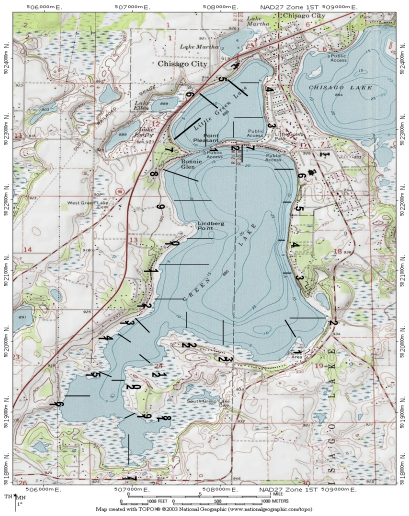
Table 9. Individual transect data for Green Lake for June 15, 2005.

	T1			T2			T3			T4			T5			T6			T7			T8		
	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15
White waterlily																								
Coontail																							2	
Chara				0.5			2				0.5					1	0.3		1	0.5		0.5		
Elodea																								
Northern watermilfoil																	0.3							
Eurasian watermilfoil			1																	0.5				
Cabbage																								
Curlyleaf pondweed		2	2		2	2	1	1.5	1		0.8	1	0.5	1.5	1.5		2.5	1		1	1.5		3	3
Stringy pondweed							1	0.5																
Claspingleaf pondweed																								
Flatstem pondweed																								
Water celery				0.5																				
Filamentous algae																								

	T9			T10			T11			T12			T13			T14		T15		T16	
	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 -10	0 - 5	6 -10	0 - 5	6 -10
White waterlily																					
Coontail																1		1		3	4
Chara										1	1		3								
Elodea																			1	1	1
Northern watermilfoil			1		0.5			0.5					1								
Eurasian watermilfoil													2	3.3		4.5	2.8	4		4.5	1
Cabbage																		1			1
Curlyleaf pondweed	4.5	4.5	2	3	2	1	1	2	2.8	0.5				2.5	1	4.5	3.3	0.5	2	1	0.5
Stringy pondweed																					
Claspingleaf pondweed										2								1			
Flatstem pondweed																		1	1	1	1
Water celery																					
Filamentous algae																					

	T17		T18		T19		T20		T21		T22			T23		
	0 - 5	6 -10	0 - 5	6 -10	0 - 5	6 -10	0 - 5	6 -10	0 - 5	6 -10	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15
White waterlily	3		3						2							
Coontail	2	3	2	2	2	3	2	1	2						1	
Chara											2				1	
Elodea	3	2	1	3.5	2											
Northern watermilfoil			1	1		1										
Eurasian watermilfoil			1				4	2.5/1*	3	3						
Cabbage																
Curlyleaf pondweed	1	1	1	2*	2/2*	2/2*	3	3		3		2.5	1			1
Stringy pondweed																
Claspingleaf pondweed																
Flatstem pondweed	1		0.5		1		1	0.5	1							
Water celery																
Filamentous algae		1														

* plants were dead and not used in statistics.



4.1.4. Second Summer Survey of Little Green Lake: On June 15, 2005, curlyleaf was nearly absent and other plants increased only slightly in occurrence compared to the May 24, 2005 survey. Northern watermilfoil and coontail were the co-dominant plants in Little Green Lake (Table 10). Individual transect data are shown in Table 11.

Table 10. Little Green Lake aquatic plant occurrences and densities for the June 15, 2005 survey based on 7 transects and 3 depths, for a total of 21 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0 - 5 feet (n=7)			Depth 6 - 10 feet (n=7)			Depth 11 - 15 feet (n=7)			All Stations (n=21)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Coontail (*Ceratophyllum demersum*)	2	29	0.5	2	29	0.8	--	--	--	4	19	0.6
Chara (*Chara sp*)	1	14	0.5	--	--	--	--	--	--	1	5	0.5
Northern watermilfoil (*Myriophyllum sibiricum*)	4	57	0.6	--	--	--	--	--	--	4	19	0.6
Eurasian watermilfoil (*M. spicatum*)	--	--	--	1	14	1.0	--	--	--	1	5	1.0
Naiads (*Najas flexilis*)	1	14	0.5	--	--	--	--	--	--	1	5	0.5
Curlyleaf pondweed (*Potamogeton crispus*)	1	14	0.5	1	14	0.3	--	--	--	2	10	0.4
Stringy pondweed (*P. pusillus*)	2	29	0.8	--	--	--	--	--	--	2	10	0.8
Filamentous algae	1	14	1.0	--	--	--	--	--	--	1	5	1.0

Figure 11. On June 15, 2005, there were no curlyleaf nuisance areas in Little Green Lake.

Table 11. Individual transect data for Little Green Lake for June 15, 2005.

	T1			T2			T3			T4		
	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15
Coontail							0.5				1	
Chara										0.5		
Northern watermilfoil	0.5											
Eurasian watermilfoil											1	
Naiads				0.5								
Curlyleaf pondweed	0.5	0.5*		1*	1*	3*		1*	2*			
Stringy pondweed										1		
Filamentous algae							1					

	T4a			T5			T6			T7		
	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15	0 - 5	6 - 10	11 -15
Coontail	0.5	0.5										
Chara												
Northern watermilfoil	0.5			1			0.5					
Eurasian watermilfoil												
Naiads												
Curlyleaf pondweed					1*			2*	2*		0.3	
Stringy pondweed				0.5								
Filamentous algae												

* plants were dead and not used in statistics.

Aquatic Plant Distribution on June 15, 2004: Aquatic plant coverage in Green and Little Green Lakes is shown in Figure 12. Submerged and floatingleaf aquatic plants covered a total of 902 acres or about 53% of the lake bottom. Nuisance plant growth was dominated by Eurasian watermilfoil in the southern end of Green Lake. A summary of aquatic plant coverage, in acres, is shown in Table 12.

Table 12. Areas of plant coverage for Green and Little Green Lakes on June 15, 2005.

	Green Lake	Little Green Lake	Total
Lake area	1,488	226	1,714
Littoral area	1,018	210	1,228
Area of curlyleaf pondweed plus other plants	829	73	902
Area of nuisance curlyleaf pondweed	12	0	12
Area of nuisance EWM	71	0	71

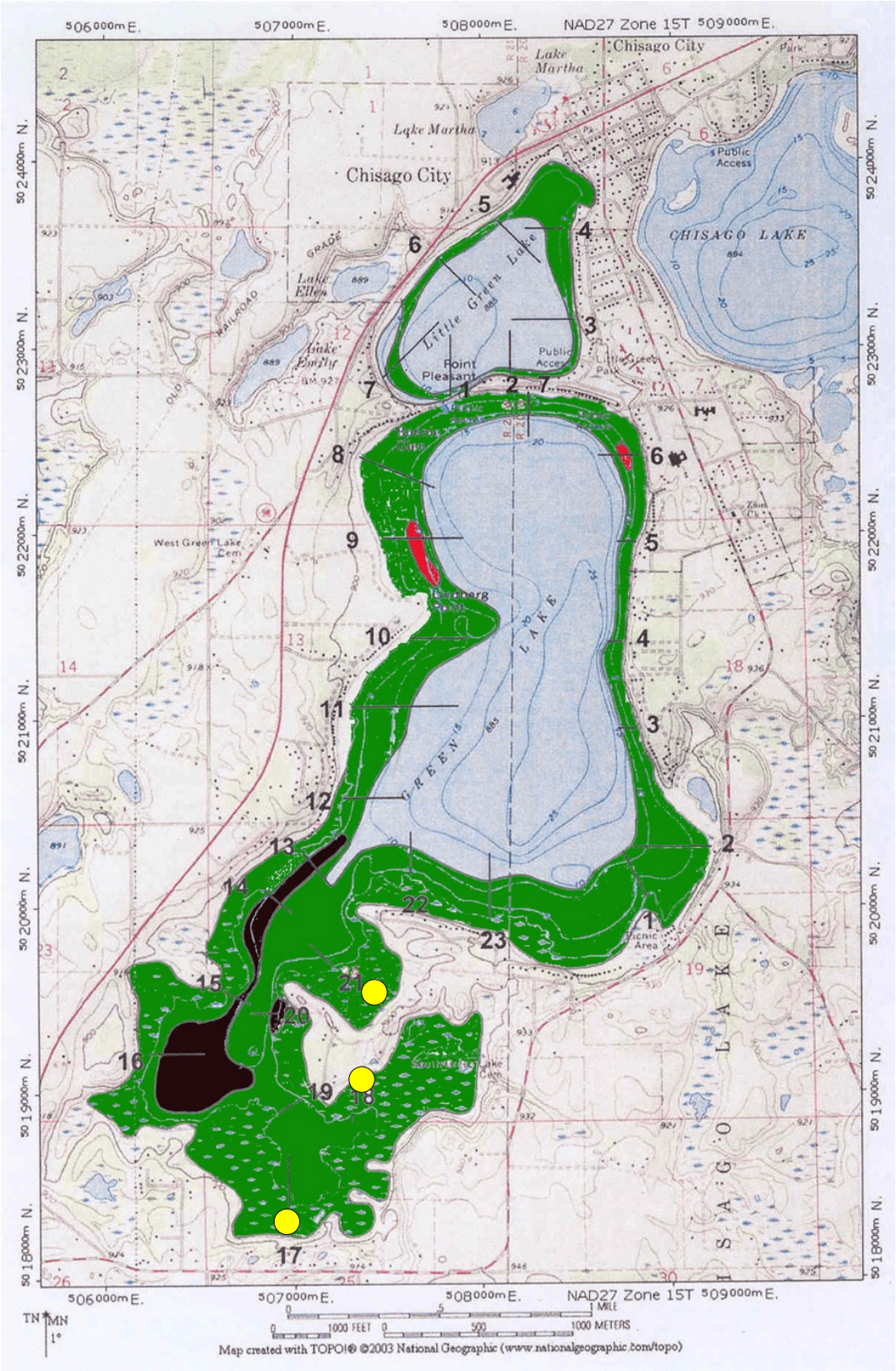


Figure 12. Aquatic plant coverage in Green Lake on June 15, 2005. Plants covered approximately 985 acres, or about 57% of the lake bottom, and grew out to a depth of 15 feet. The black shading represents nuisance growth of Eurasian watermilfoil and the red shading represents nuisance curlyleaf pondweed growth. White lilies were found on Transects 17, 18, and 21.

4.2. Summary of Native and Non-Native Aquatic Plant Species for 2005

The early summer plant diversity was fair in Green and Little Green Lakes in 2005 (Table 13. The plant community was dominated by curlyleaf pondweed in both early summer surveys in both lakes. Eurasian watermilfoil was first reported in 1990 (based on MnDNR records). Eurasian watermilfoil was common in the second survey.

Plants grew out to a water depth of 15 feet in both the first and second summer surveys.

Table 13. Comparison of aquatic plant percent occurrences for the two summer plant surveys in 2005.

	Green Lake		Little Green Lake	
	May 24	June 15	May 24	June 15
Bulrush (*Scirpus sp*)	2	--	--	--
White waterlily (*Nymphaea sp*)	2	5	--	--
Coontail (*Ceratophyllum demersum*)	24	25	5	19
Chara (*Chara sp*)	10	21	5	5
Elodea (*Elodea canadensis*)	--	13	--	--
Northern watermilfoil (*Myriophyllum sibiricum*)	6	13	10	19
Eurasian watermilfoil (*Myriophyllum spicatum*)	24	23	14	5
Naiads (*Najas flexilis*)			--	5
Cabbage (*Potamogeton amplifolius*)	2	3	5	--
Curlyleaf pondweed (*Potamogeton crispus*)	84	77	100	10
Illinois pondweed (*P. illinoensis*)	2	--	--	--
Stringy pondweed (*P. pusillus*)	--	3	--	10
Claspingleaf pondweed (*P. Richardsonii*)	--	3	--	--
Flatstem pondweed (*P. zosteriformis*)	--	16	--	--
Water celery (*Vallisneria americana*)	--	2	--	--
Filamentous algae	6	2	5	5
Acres Covered by Plants (acres)	986	912	210	73
Percent Area Covered (%)	66	61	93	32

4.3. Comparison of Previous Surveys to 2005 Aquatic Plant Surveys

It appears there have been changes in the aquatic plant community in Green Lake from 1956 to 2004. Several species have increased in Green Lake since 1956 and include flatstem pondweed, elodea, and Eurasian watermilfoil. It also appears several species have declined and include whitestem pondweed, floatingleaf pondweed, and sago pondweed.

Table 12. Comparison of aquatic plant occurrence between 1956, 1969, 1976, and 2005 data.

Species	Percent Occurrence				
	1956	1969	1976	May 24, 2005 (%)	June 15, 2005 (%)
Water smartweed			P		
Common cattail	C	A	A		
Bulrush	C	A	C	2	
Arrowhead			P		
Pickerelweed			P		
Waterlily			O		
White waterlily		C		2	5
Spatterdock		O			
Claspingleaf pondweed		C	O		3
Curlyleaf pondweed			O	84	77
Whitestem pondweed		C	A		
Largeleaf pondweed		C	O		
Floatingleaf pondweed		C	C		
Sago pondweed			C		
Coontail	A	A	A	24	25
Wild celery			P		2
Cabbage				2	3
Illinois pondweed				2	
Flatstem pondweed					16
Watermilfoil			C		
Northern watermilfoil				6	13
Eurasian watermilfoil				24	23
Stringy pondweed					3
Elodea					13
Waterweed (Anacharis)	A	O			
Pondweeds	A				
Muskgrass (Chara)	A	C		10	21
Filamentous algae				6	2
Number of species	4	7	9	8	12

4.4. Potential for Nuisance Growth of Non-native Invasive Plants Based on Lake Sediment Characteristics

For managing exotic plants it is helpful to know where the plants have the potential to grow to nuisance conditions. A technique developed by Blue Water Science shows where nuisance growth of curlyleaf pondweed and Eurasian watermilfoil can occur in a lake based on lake sediment characteristics. This technique was applied to Green Lake. A total of 17 sediment sites were sampled around Green Lake. Sediment sites and locations are shown in Table 15 and Figure 13.

Table 15. Plant densities (1-5 scale, with 5 the most dense) at individual sediment sample locations at time of sediment collection on October 28, 2000.

Sample Location	Water Depth (feet)	EWM	NWM	Chara	Coontail	Curlyleaf	Total # of species
1	5	0			1		1
2	6	4					1
3	6	4					1
4	6	0					0
5	6	0		3			1
6	6	0		1		1	2
7	6	2				2	2
8	6	2		3			2
9	6	0					0
10	6	2					1
11	6.5	0				2	1
12	6	2					1
13	6	0					0
14	6.5	1	1		3		3
15	6.5	2			2		2
16	6.5	4			2		2
17	6.5	0	1				1

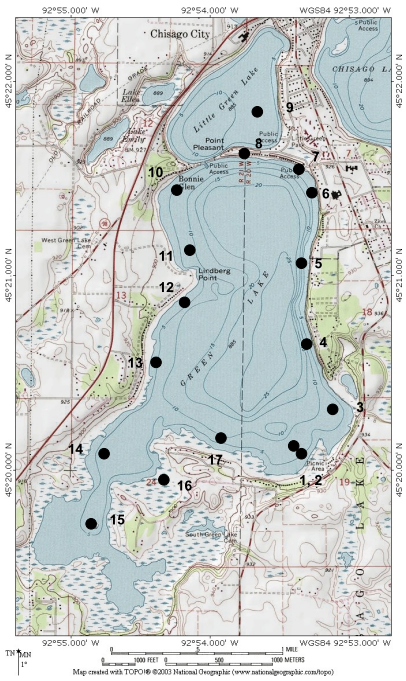


Figure 13. Lake sediment sample locations.

Green Lake sediment results are shown in Table 16. A total of 16 parameters were analyzed for each sediment sample. The high bulk density indicates lake sediments are firm and sandy except for stations 11, 14, 15, and 16, which are soft and mucky. The high organic matter content is associated with the soft sediment stations sample sites. Lake sediment phosphorus concentrations are moderate.

Table 16 Lake soil data. Sample were collected on October 28, 2000. Soil chemistry results are reported as µg/cm^3-dry which is equivalent to ppm except for organic matter (%) and pH (standard units). EWM density is given on a scale from 1 to 5 with 5 representing nuisance growth.

sample	Depth (ft)	EWM Density	Bulk Density	NH_4 ppm (corr)	Bray P ppm (corr)	Olsen P ppm (corr)	Potassi ppm (corr)	Zinc ppm (corr)	Sulfur ppm (corr)	Iron ppm (corr)	Copper ppm (corr)	Mang ppm	Boron ppm	% OM	pH unit	Calc. ppm	Magn. ppm	Sodium ppm
1	5	0	1.53	5.1	5		28	0.32	13	20.7	0.34	4.3	0.1	0.23	7.8	560	58	76
2	6	4	1.09	9.1	5		114	0.34	14	63.2	0.8	4.5	0.1	0.11	7.6	1320	215	84
3	6	4	1.38	5.1	3		22	0.54	26	22.9	0.24	3	0.1	0.51	7.7	760	33	58
4	6	0	1.34	4.2	3	5	34	0.38	39	28.9	0.38	2.9	0.16	0.18	7.4	440	48	4
5	6	0	1.43	4.8	4	6	56	0.44	35	14.4	0.22	3.3	0.1	0.01	7.8	520	20	48
6	6	0	1.42	4.5	5	6	22	0.68	30	18.3	0.26	4.8	0.11	0.01	7.8	360	25	58
7	6	2	1.41	4.2	5	6	18	0.5	25	16.7	0.16	4.7	0.13	0.01	7.8	280	20	56
8	6	2	1.38	5.4	5	8	24	0.48	22	23.1	0.36	5.3	0.15	0.43	7.7	320	28	66
9	6	0	1.37	3.8	4	6	14	0.64	49	13.1	0.2	1.4	0.15	0.01	7.5	160	35	4
10	6	2	1.28	2.9	6	7	22	1	38	19.1	0.32	3.6	0.21	0.83	7.6	720	30	66
11	6.5	0	0.60	12.9	5	9	97	2.4	53	81.6	1.34	8	0.51	11.02	7.5	2880	185	54
12	6	2	1.37	3.6	4	6	17	0.44	19	15.9	0.28	3.7	0.19	0.09	7.8	280	18	60
13	6	0	1.37	10.6	7	7	23	0.74	24	17.2	0.26	5.7	0.1	0.17	7.8	400	30	54
14	6.5	1	0.36	10.4	5	7	136	2.16	76	122.7	1.36	12.1	0.87	39.70	7.3	2360	210	106
15	6.5	2	0.35	10.6	5	5	97	3.64	93	170.1	1.48	11.6	1.33	51.33	6.3	2080	273	60
16	6.5	4	0.35	15.9	7	7	83	2.68	79	172.7	1.08	15.4	1.22	34.93	6.2	2120	263	24
17	6.5	0	1.35	8.3	8	9	23	0.74	47	23.5	0.32	6.6	0.24	0.96	7	360	43	88

4.4.1. Lake Areas that Could Support Nuisance Curlyleaf Growth Based on Lake Sediment Characteristics: Lake sediment sampling results from 2000 have been used to predict lake bottom areas that have the potential to support nuisance curlyleaf pondweed plant growth. Based on the key sediment parameters of sediment bulk density, organic matter, pH, and the Fe:Mn ratio (McComas, unpublished), the growth pattern of curlyleaf pondweed growth that could be expected is shown in Table 17 and Figure 14.

Curlyleaf pondweed growth is predicted to produce nuisance growth (where plants top out in a solid canopy) at several locations. Only one sediment sample was collected in Little Green and nuisance coverage predictions for Little Green are limited.

Table 17. Green Lake sediment data and ratings for potential nuisance curlyleaf pondweed growth.

Site	Bulk Density (g/cm^3 dry)	Organic Matter (%)	pH (su)	Fe:Mn Ratio	Potential for Nuisance Curlyleaf Pondweed Growth
Non-Nuisance	1.04	5	6.8	4.6	Low (green)
Light Nuisance	0.94	11	6.2	5.9	Medium (yellow)
Heavy Nuisance	<0.51	>20	>7.7	<1.6	High (red)
1	1.53	0.23	7.8	4.8	High
2	1.09	0.11	7.6	14.0	Medium
3	1.38	0.51	7.7	7.6	Medium
4	1.34	0.18	7.4	10.0	Medium
5	1.43	0.01	7.8	4.4	High
6	1.42	0.01	7.8	3.8	High
7	1.41	0.01	7.8	3.6	High
8	1.38	0.43	7.7	4.4	Medium
9	1.37	0.01	7.5	9.4	Medium
10	1.28	0.83	7.6	5.3	Medium
11	0.60	11.02	7.5	10.2	Medium
12	1.37	0.09	7.8	4.3	High
13	1.37	0.17	7.8	3.0	High
14	0.36	39.70	7.3	10.1	High
15	0.35	51.33	6.3	14.7	High
16	0.35	34.93	6.2	11.2	High
17	1.35	0.96	7.0	3.6	Medium

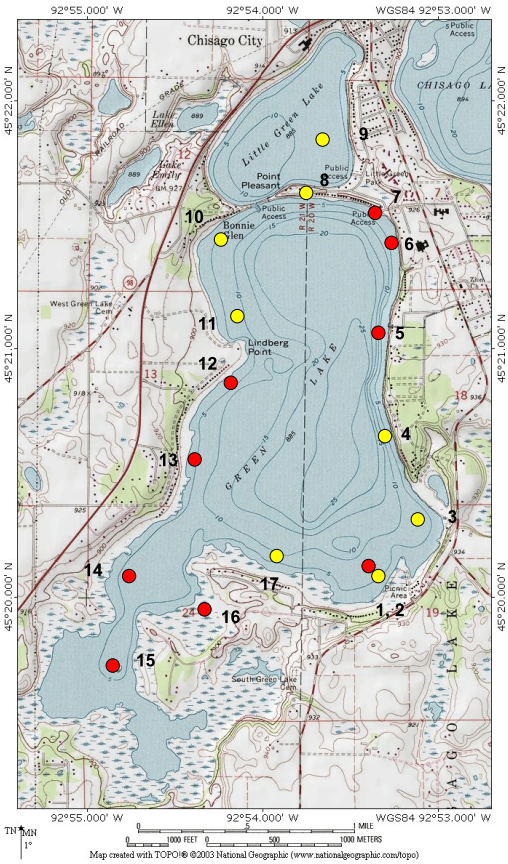


Figure 14. Sediment sample locations are shown with dots. The dot color indicates the potential for nuisance curlyleaf pondweed to occur at that site. Key: green dot = low; yellow dot = medium; red dot = high potential.

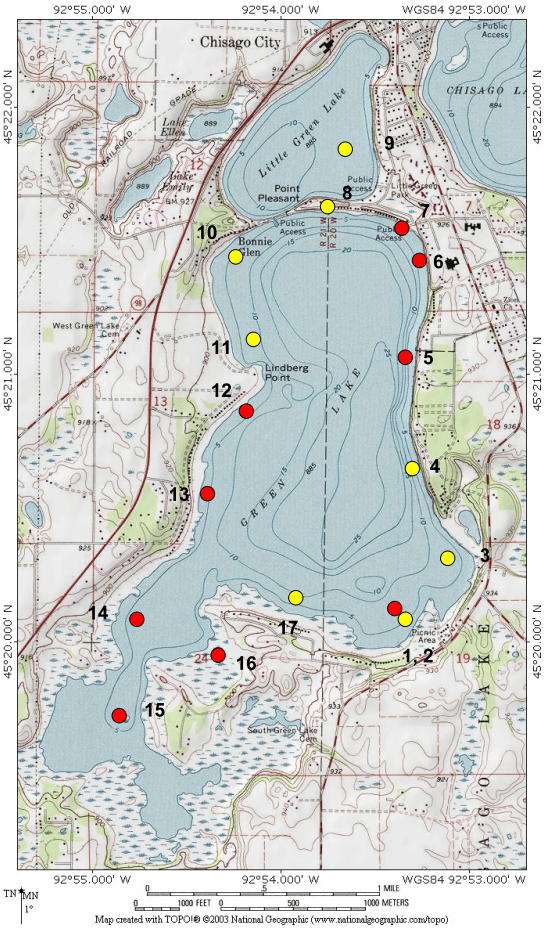


Figure 15a. Predicted curlyleaf nuisance based on sediment characteristics. Key: yellow dot = low potential; red dot = high potential for nuisance growth of curlyleaf pondweed.

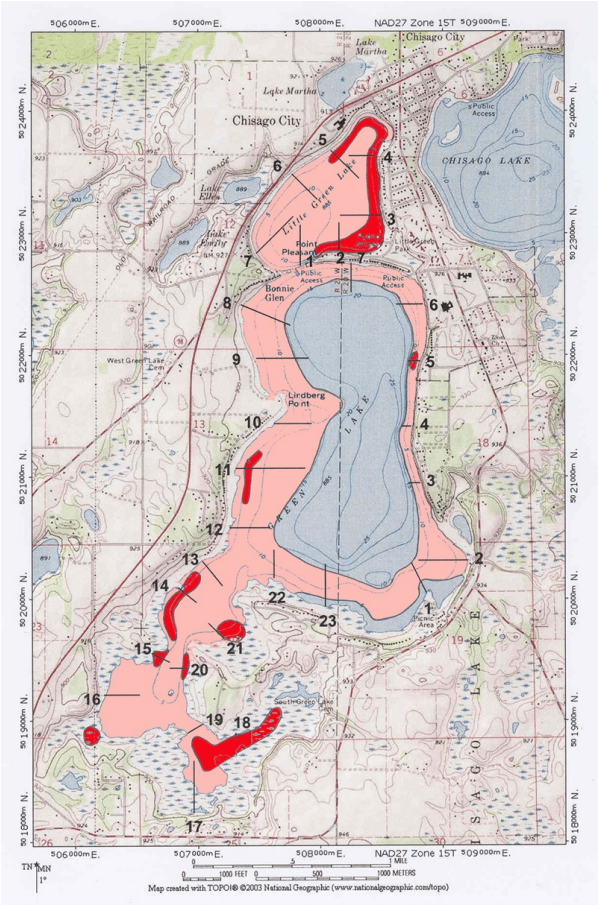


Figure 15b. Actual curlyleaf nuisance growth on May 24, 2005 is shown in red.

4.4.2. Lake Areas that Could Support Nuisance Eurasian Watermilfoil Growth Based on Lake Sediment Characteristics: Lake sediment sampling results from 2000 have been used to predict lake bottom areas that have the potential to support nuisance EWM growth. Based on the key sediment parameters of NH_4 and organic matter (McComas, unpublished), a table and map were prepared to indicate what type of growth could be expected in the future (Table 18 and Figure 16).

The sediment nitrogen conditions in Green Lake are moderate to high. Eurasian watermilfoil will grow widely through Green Lake, but it is predicted that it will produce perennial nuisance matting conditions (which are defined as heavy nuisance condition) in areas along the western shoreline. Although there are high nitrogen concentrations at stations 14, 15, and 16, there also high organic matter concentrations which can limit nuisance EWM growth.

Table 18 Green Lake sediment data and ratings for potential nuisance EWM growth.

Site	NH_4 Conc (ppm)	Organic Matter (%)	Potential for Nuisance EWM Growth
Non-Nuisance or Light Nuisance	<10	>20	Low (green) to Medium (yellow)
Heavy Nuisance	>10	<20	High (red)
1	5.1	0.23	Medium
2	9.1	0.11	Medium
3	5.1	0.51	Medium
4	4.2	0.18	Low
5	4.8	0.01	Low
6	4.5	0.01	Low
7	4.2	0.01	Low
8	5.4	0.43	Medium
9	3.8	0.01	Low
10	2.9	0.83	Low
11	12.9	11.02	High
12	3.6	0.09	Medium
13	10.6	0.17	High
14	10.4	39.70	Medium
15	10.6	51.33	Medium
16	15.9	34.93	Medium
17	8.3	0.96	Medium

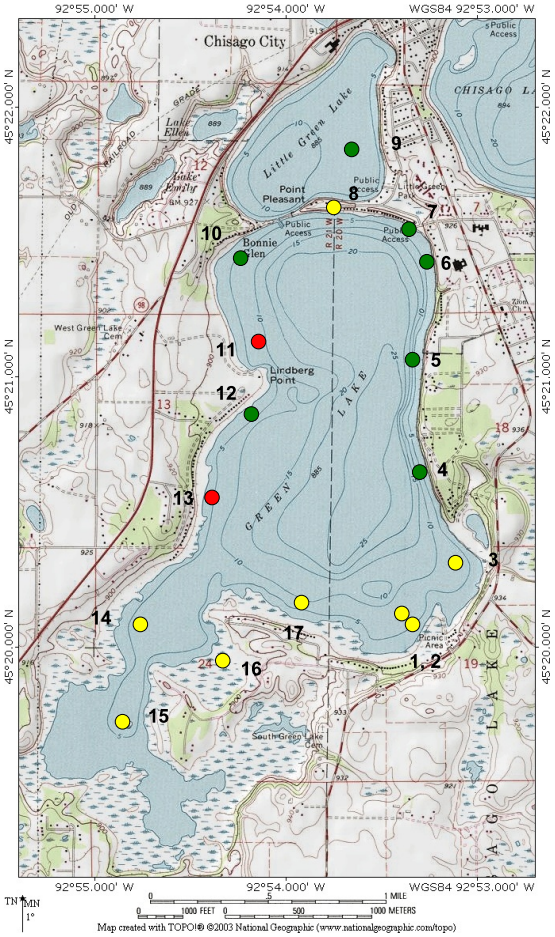


Figure 16. Sediment sample locations are shown with dots. The dot color indicates the potential for nuisance Eurasian watermilfoil to occur at that site. Key: green dot = low; yellow dot = medium; red dot = high potential.

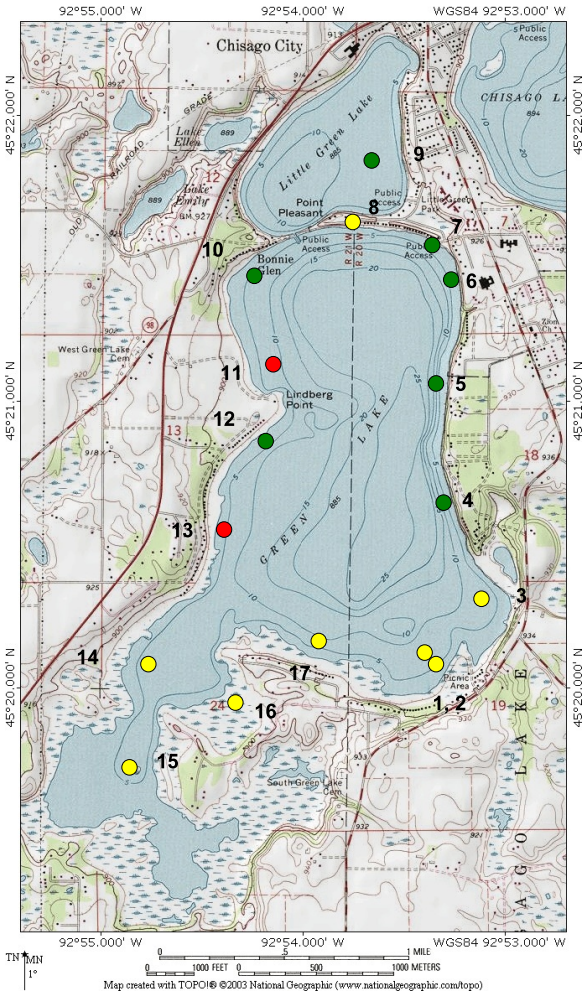


Figure 17a. Potential Eurasian watermilfoil nuisance. Key: green dot = low; yellow dot = medium; red dot = high potential.

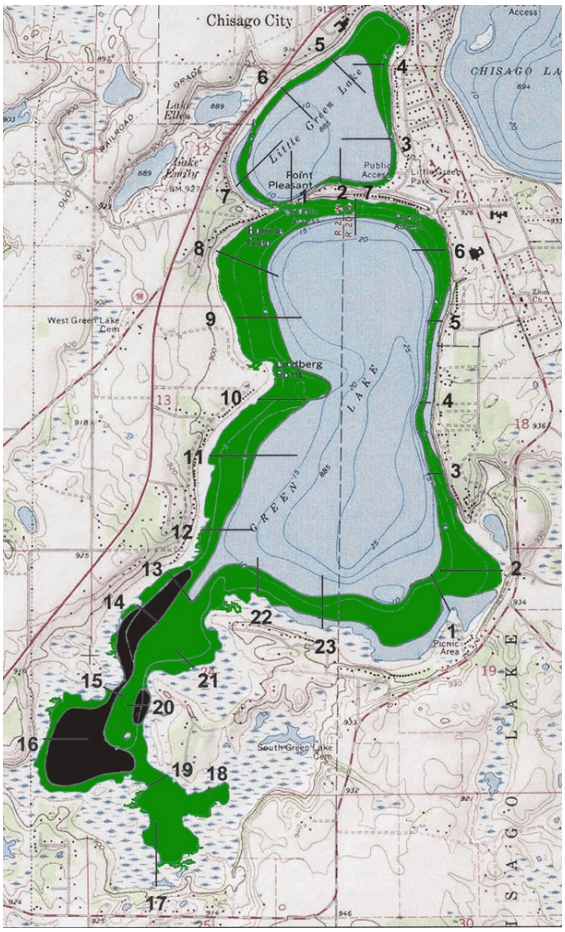


Figure 17b. Actual plant growth on June 15, 2004.

4.5. Aquatic Plant Architecture

Aquatic plants in Green and Little Green Lakes are widespread in early summer, but the dominant plant is curlyleaf pondweed, a non-native. Curlyleaf to the water surface, but for most areas, it remains below the water surface and does not hinder boating.

Examples of curlyleaf pondweed canopy structure for Green and Little Green Lakes on May 24 and June 15, 2005 are shown in Figure 18. In the examples, curlyleaf exhibited some matting growth on May 24, but was not a nuisance on the same transects on June 15.

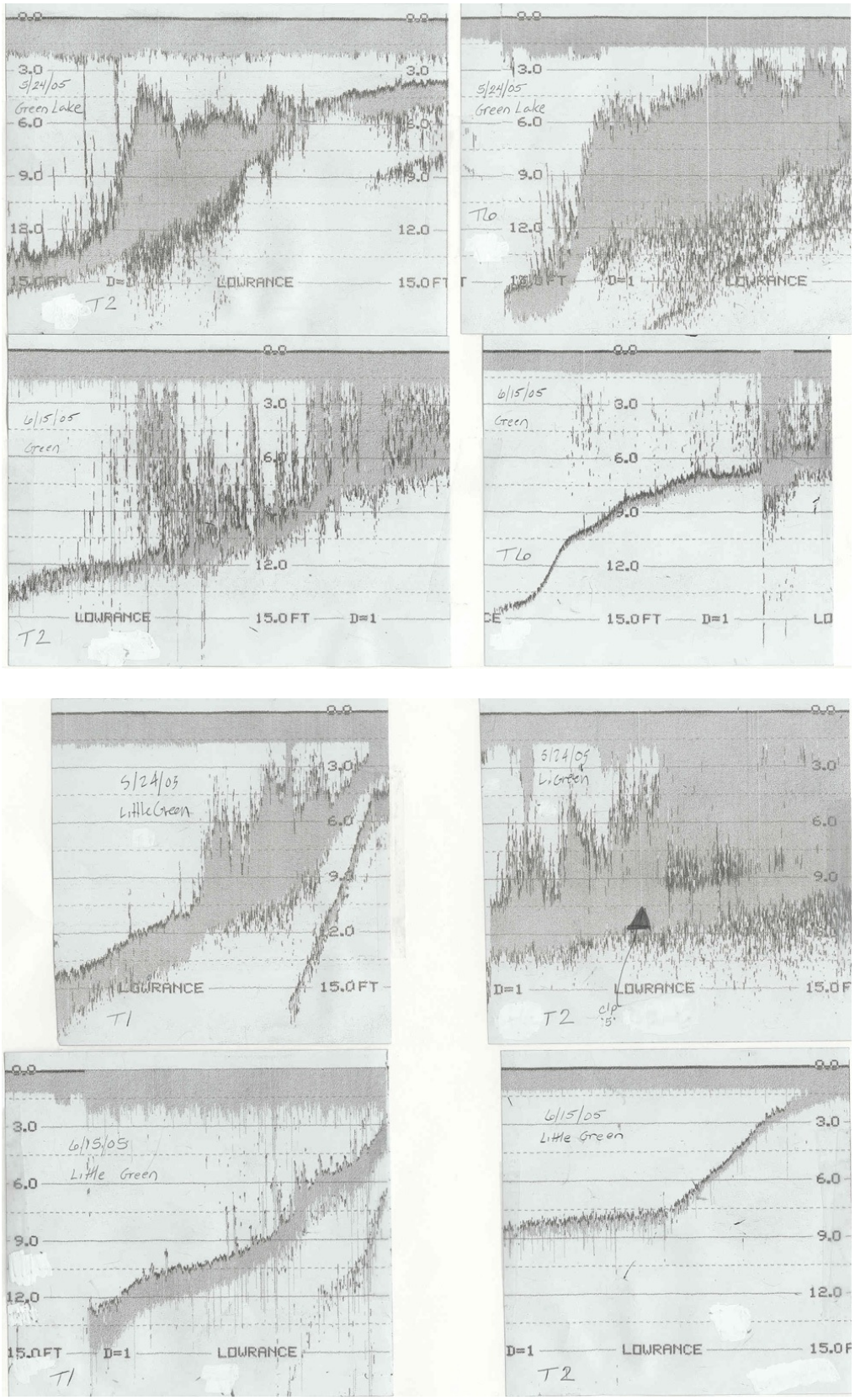


Figure 18. Sonar graphs of curlyleaf pondweed from Transects 2 and 6 for Green Lake (top) and for Transects 1 and 2 for Little Green Lake (bottom).

4.6. Aquatic Plant Assessment Summary

Two non-native invasive aquatic plant species are found in Green and Little Green Lakes. Curlyleaf pondweed was first recorded in Green Lake in a MnDNR plant survey in 1976. Eurasian watermilfoil was first identified in Green Lake in 1990 (Source: MnDNR).

Curlyleaf pondweed has a wide distribution in both Green and Little Green Lakes. It produces nuisance conditions in both lakes. Nuisance conditions are defined as areas where the plant reaches the surface producing matting conditions. Curlyleaf grows to nuisance conditions covering 85 acres in 5 to 8 feet of water in Green Lake and produces 65 acres of nuisance conditions in 6 to 10 feet of water in Little Green Lake. Curlyleaf pondweed was treated with Aquathol K in late May. On the June 15, 2005 survey, no nuisance growth conditions were observed in Little Green Lake. In Green Lake, only two areas of nuisance growth were observed.

Eurasian watermilfoil is also present in both lakes, but nuisance growth conditions were only observed in Green Lake. Eurasian watermilfoil grows to nuisance conditions in mid-June in Green Lake covering approximately 71 acres in 5 to 7 feet of water.

In the southern end of Green Lake (Transects 13 and 14) both curlyleaf pondweed and Eurasian watermilfoil reach the surface producing nuisance conditions. Otherwise, nuisance growth of curlyleaf and Eurasian watermilfoil is segregated.

Background Information on the Green Lake Aquatic Plant Assessment

MnDNR cost of this assessment: $6,500
Project coordinator: Julie Butler, Green Lake Association
Participants:
Coordination meetings: Julie Butler and John Gose, Green Lake Association
Aquatic plant surveys: Steve McComas, Blue Water Science

Duration of plant surveys:
May 24, 2005: Green Lake: 3.5 hours
Little Green Lake: 1.8 hours
Travel time: 2.5 hours
Download data from plant surveys: 4.5 hours
June 15, 2005: Green Lake: 3.5 hours
Little Green Lake: 1.8 hours
Travel time: 2.5 hours
Download data from plant surveys: 4.5 hours

Appendix

A. Aquatic Plant Survey Methods
B. Lake Sediment Survey Methods
C. Green and Little Green Lakes Water Quality Data
D. Minnesota Department of Natural Resources Fishery Data

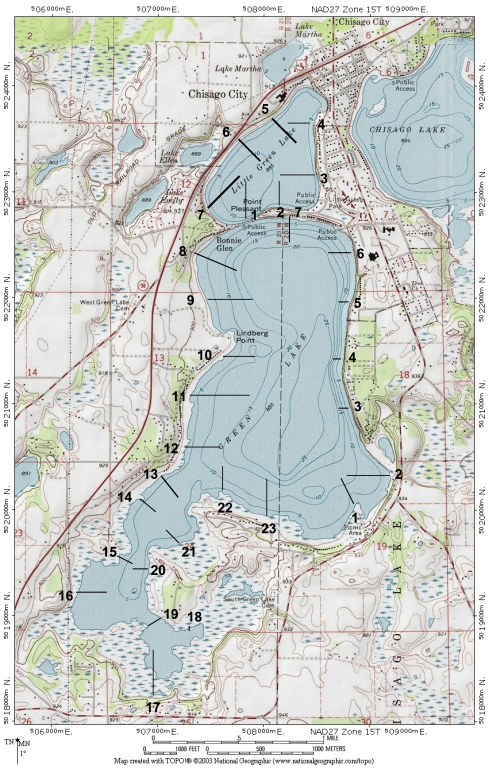
Appendix A. Aquatic Plant Survey Methods

Several techniques were used to characterize aquatic plants in Green Lake. We used 15 line transects with several passing through previously known milfoil areas (Figure 1). A recording sonar (Lowrance X-16) was used to delineate the depths of weed colonization. Three depths (0-4 feet, 5-8 feet, and 9-12 feet) on a transect were sampled with a rake to characterize species presence and density.

Aquatic plant density was estimated based on a scale from 1-5 with 1 being the less dense and 5 representing plants matting at the surface. Plant density ratings were based on the amount of plants collected on a rake head. A single stem or a trace of an identifiable plant was rated at a density of "1". If plants were collected up to at least one half of the rake head (7 out of 14 tines) it was rated at a density of "2". If plants covered all of the rake tines, the density was a "3". If plants covered all 14 tines and was dense on all tines (even obscuring them) the density was a "4". A density of "5" was only assigned to plants matting at the surface.

Two to four rake samples were collected at each depth interval. A density for each plant species was determined for each rake sample and the species density was averaged based on the number of rake samples for a depth interval.

For plant surveys of this type, depth intervals are determined based on the maximum depth of plants found in the lake. Two depth intervals are used if plant growth is 10 feet or less and three depth intervals are used if plant growth is 12 feet or greater. Aquatic plants colonized out to 12 feet in Green Lake, so the three depth zones were used and they were: 0-4 feet, 5-8 feet, and 9-12 feet.



Green Lake Transect Descriptions

	East	North	Description
T1	05 08 679	50 20 120	First house right of landing
T2	05 08 923	50 20 400	Coming in on dead trees
T3	05 08 748	50 20 860	Natural shoreline - use gps coord
T4	05 08 624	50 21 450	Right of small marina
T5	05 08 714	50 21 900	Wooden stairs in-between a wood retaining and large stone wall
T6	05 08 739	50 22 416	Right of multi tier wood retaining wall
T7	05 08 233	50 22 676	Sand beach next to rock riprap
T8	05 07 532	50 22 410	Heading into cabin with porch on stilts
T9	05 07 608	50 21 988	Heading into some bulrushes
T10	05 07 665	50 21 429	Two light blue cabins close together
T11	05 07 408	50 21 061	Two light blue cabins side by side
T12	05 07 327	50 20 621	Left of wood retaining wall
T13	05 07 144	50 20 242	Tan house with a walk out deck
T14	05 06 944	50 20 024	Right of cattails, large attached garage on gray house
T15	05 06 660	50 19 505	Second house, left of point
T16	05 06 248	50 19 128	Left of motel, power pole
T17	05 06 987	50 18 541	Most southern part, left of gravel landing
T18	05 07 664	50 19 262	Left of tan house with 2nd story deck and keystone wall
T19	05 06 961	50 18 989	Left of a big red house
T20	05 06 757	50 19 433	Right of point
T21	05 07 124	50 19 726	Left of willows
T22	05 07 611	50 20 188	Right of keystone wall
T23	05 08 083	50 19 984	Left of yellow house, on swamp

Little Green Lake Transect Descriptions

	East	North	Description
T1	05 07 875	50 22 906	Right of point
T2	05 08 178	50 22 965	Left of green house, on stumps
T3	05 08 340	50 23 260	Two tier keystone wall
T4	05 08 348	50 23 621	Left shoreline, wood deck
T4a	05 08 451	50 23 980	
T5	05 08 052	50 23 690	Undeveloped shoreline to right of a lawn with a keystone wall
T6	05 07 577	50 23 296	Right of yellow highway sign
T7	05 07 480	50 22 950	In-between two stairways with a wood retaining wall

Figure A-1. Transect map for the aquatic plant surveys conducted on Green Lake.

Appendix B. Lake Sediment Survey Methods

Lake Soil Collection: A total of 17 lake sediment samples were collected from depths ranging from 5 to 6.5 feet on October 28, 2000 by Steve McComas, Blue Water Science. Samples were collected using a modified soil auger, 5.2 inches in diameter (Figure B-1). Soils were sampled to a depth of 6 inches. The lake soil from the sampler was transferred to 1-gallon zip-lock bags and delivered to a soil testing laboratory.

Lake sediment samples were collected in the littoral zone. At each sample location, within about a 5-foot radius we noted all aquatic plant species and rated their density on a scale from 1 to 5 with one representing a low density.

Lake Soil Analysis: At the lab, sediment samples were air dried at room temperature, crushed and sieved through a 2 mm mesh sieve. Sediment samples were analyzed using standard agricultural soil testing methods. Sixteen parameters were tested for each soil sample. A summary of extractants and procedures is shown in Table B-1. Routine soil test results are given on a weight per volume basis.

Table B-1. Soil testing extractants used by University of Minnesota Crop Research Laboratory. These are standard extractants used for routine soil tests by most Midwestern soil testing laboratories (reference: Western States Laboratory Proficiency Testing Program: Soil and Plant Analytical Methods, 1996-Version 3).

Parameter	Extractant
P-Bray	0.025M HCL in 0.03M NH_4F
P-Olsen	0.5M $NaHCO_3$
NH_4-N	2N KCL
K, Ca, Mg	1N NH_4OA_c (ammonium acetate)
Fe, Mn, Zn, Cu	DTPA (diethylenetriamine pentaacetic acid)
B	Hot water
SO_4-S	$Ca(H_2PO_4)_2$
pH	water
Organic matter	Loss on ignition at 360°C

Figure B-2. Soil auger used to collect lake sediments.

Reporting Lake Soil Analysis Results: Lake soils and terrestrial soils are similar from the standpoint that both provide a medium for rooting and supply nutrients to the plant.

However, lake soils are also different from terrestrial soils. Lake soils (or sediments) are water logged, generally anaerobic and their bulk density ranges from being very light to very dense compared to terrestrial soils.

There has been discussion for a long time on how to express analytical results from soil sampling. Lake sediment research results are often expressed as grams of a substance per kilogram of lake sediment, commonly referred to as a weight basis (mg/kg). However, in the terrestrial sector, to relate plant production and potential fertilizer applications to better crop yields, soil results typically are expressed as grams of a substance per cubic foot of soil, commonly referred to as a weight per volume basis. Because plants grow in a volume of soil and not a weight of soil, farmers and producers typically work with results on a weight per volume basis.

That is the approach used here for lake sediment results: they are reported on a weight per volume basis or $\mu g/cm^3$.

A bulk density adjustment was applied to lake sediment results as well. For agricultural purposes, in order to standardize soil test results throughout the Midwest, a standard scoop volume of soil has been used. The standard scoop is approximately a 10-gram soil sample. Assuming an average bulk density for an agricultural soil, a standard volume of a scoop has been a quick way to prepare soils for analysis, which is convenient when a farmer is waiting for results to prepare for a fertilizer program. It is assumed a typical silt loam and clay texture soil has a bulk density of 1.18 grams per cm^3. Therefore a scoop size of 8.51 cm^3 has been used to generate a 10-gram sample. It is assumed a sandy soil has a bulk density of 1.25 grams per cm^3 and therefore a 8.00 cm^3 scoop has been used to generate a 10-gram sample. Using this type of standard weight-volume measurement, the lab can use standard volumes of extractants and results are reported in ppm which is close to $\mu g/cm^3$. For all sediment results reported here a scoop volume of 8.51 cm^3 was used.

However lake sediment bulk density has wide variations but only a single scoop volume of 8.51 cm^3 was used for all lake sediment samples. This would not necessarily produce a consistent 10-gram sample. Therefore, for our reporting, we have used corrected weight volume measurements and results have been adjusted based on the actual lake sediment bulk density. We used a standard scoop volume of 8.51 cm^3, but sediment samples were weighed. Because test results are based on the premise of a 10 gram sample, if our sediment sample was less than 10 grams, then the reported concentrations were adjusted down to account for the less dense bulk density. If a scoop volume weighed greater than 10.0 grams than the reported concentrations were adjusted up. For example, if a 10-gram scoop of lake sediment weighed 4.0 grams, then the correction factor is 4.00 g/ 10.00 g = 0.40. If the analytical result was 10 ppm based on 10 grams, then it should be 0.40 x 10 ppm = 4 ppm based on 4 grams. The results could be written as 4 ppm or 4 $\mu g/cm^3$. Likewise, if a 10-gram scoop of lake sediment weighed 12 grams, then the correction factor is 12.00 g / 10.00 g = 1.20. If the analytical result was 10 ppm based on a 10 gram scoop, then it should be 1.20 x 10 ppm = 12 ppm based on 12 grams. The result could be written as 12 ppm or 12 $\mu g/cm^3$. These are all dry weight determinations.

Delineating Areas of Potential Nuisance Curlyleaf and Milfoil Growth: Delineating an area of potential nuisance plant growth is based on conventional soil survey methods. When a sediment sample analysis has a nitrogen reading over 10 ppm and has an organic matter content of less than 20%, it has a high potential for nuisance milfoil growth. For sediment results with a high growth potential collected in a cove, typically, the water depths in the cove from 5 to 7 feet would be designated as having a potential for nuisance growth. If high potential samples are found along a stretch of shoreline, a designated high potential area would be delineated until there was a shoreline break or change in sediment texture. In other cases, if the next site down the shoreline records a low potential reading, then the designated nuisance area would extend midway between a high and low potential sample sites.

Appendix C-1. Green Lake Secchi disc data

Compilation of previously collected Secchi disk data for Green Lake. Data are shown in feet. Data are from the MPCA water quality web site and from Met Council CAMP data. When May Secchi disc transparencies are included in the summer average, the averages increase slightly.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Number of years with better clarity than 2004
May																		
1	8.0																	
2		8.5		8.0							14.0							
3		7.0		15.0	10.0		22.0 /20.0											
4	4.5 /4.5	6.5	6.5	16.5 /15.0	14.0 /11.5				12.0									
Average	**6.3**	**7.3**	**6.5**	**12.9**	**11.4**		**21.0**		**12.0**		**14.0**							**--**
June																		
1				15.0 /14.0	13.0	14.0 /12.0	11.0 /11.0	12.0 /13.0	9.0	19.0	7.0	11.5				8.0		
2	4.0		4.5	8.0 /9.0	12.0		8.0 /7.5	8.0	12.0	19.0	7.0	10.0	14.0 /14.0	11.0	9.5		10.5	
3		7.0		8.0 /8.0	10.0	8.0 /8.0	8.5	10.0 /10.0	12.0			8.5	9.5	9.5			9.0	
4		6.5	4.5 /4.0	6.0 /6.5 /7.0	5.5 /6.0	8.0	9.0 /10.0	8.0	10.0		6.0	8.5	9.5		6.5	3.5	6.5	
Average	**4.0**	**6.8**	**4.3**	**9.4**	**10.2**	**9.7**	**9.2**	**9.6**	**10.8**	**19.0**	**6.7**	**9.6**	**11.0**	**10.3**	**8.0**	**5.8**	**8.7**	**10.0**
July																		
1	3.0	6.5		6.0 /6.5	5.0	7.0	6.0	5.0	8.0	7.5	6.0	6.0	8.5			4.0	6.5	
2	3.5	5.5	3.0	6.0 /6.0	4.5 /5.0	5.5 /7.0	6.0	6.0		7.0		5.5		8.0	4.0	3.5	4.0	
3			2.5	4.0 /4.5	4.0 /5.0	6.0 /5.5	5.0				4.5	3.5 /3.5	8.0					
4		5.0		4.0	4.0	5.0 /5.0		4.0 /5.0 /4.0	5.0		3.0	3.5	6.0 /5.0 /6.0 /5.0	6.0 /5.0	3.5	2.5	4.0	
Average	**3.3**	**5.7**	**2.8**	**5.2**	**4.6**	**6.0**	**5.7**	**5.1**	**6.5**	**7.3**	**4.5**	**4.6**	**7.3**	**6.8**	**3.8**	**3.3**	**4.8**	**9.0**
August																		
1	1.5	3.5		3.0	4.0	5.0	3.5		4.5	6.5		3.0		5.0	4.0			
2		3.0	2.0	3.0	4.0	5.0 /4.5	4.5	4.0			3.5	3.5	5.0				3.0	
3	2.0	3.0		3.5 /3.0	3.0	5.0	3.0 /4.0	4.0		5.5		4.0		3.0	4.0		3.5	
4		3.0		3.0 /4.0 /3.0	3.0	3.5 /3.5			4.0		3.0	4.0	3.5 /4.0	2.5				
Average	**1.8**	**3.1**	**2.0**	**3.2**	**3.5**	**4.6**	**3.8**	**4.0**	**4.3**	**6.0**	**3.3**	**3.6**	**4.4**	**3.7**	**4.0**		**3.3**	**11.0**
September																		
1		3.0		3.0	3.0 /3.0	3.5	3.0 /3.0	3.0	3.5	5.0	3.5	4.5	4.0	3.5				
2				3.5	3.0													
3		3.5		3.0									4.5					
4				3.0	6.0 /7.0													
Average		**3.3**		**3.2**	**4.2**	**3.5**	**3.0**	**3.0**	**3.5**	**5.0**	**3.5**	**4.5**	**4.3**	**3.5**				**--**
Average Jun-Sep	**3.7**	**5.2**	**3.9**	**7.0**	**6.5**	**5.9**	**4**	**6.5**	**5.3**	**5.9**	**6.4**	**5.9**	**6.7**	**5.9**	**5.3**	**4.3**	**5.6**	**9**
number samples	8	17	9	31	23	19	2	13	7	7	10	14	15	9	6	5	8	

Appendix C-2. Little Green Lake Secchi disc data.

Compilation of previously collected Secchi disk data for Little Green Lake. Data are shown in feet. Data are from the MPCA water quality web site and from Met Council CAMP data.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Number of years with better clarity than 2004
May																	
1																	
2			9.0							10.0							
3						11.0											
4		6.5	9.5	7.5				8.0									
Average		**6.5**	**9.3**	**7.5**		**11.0**		**8.0**		**10.0**							
June																	
1			11.0		8.0	7.5	12.0	6.0	10.0 /10.5 /12.0	5.0			7.0				
2			6.0			5.5		5.5 /6.0 /11.5	11.0 /10.0 /10.0	5.0	9.0	6.0 /6.5	7.5	8.0		9.0	
3		4.5	5.0		5.0		11.0	9.5	10.0 /8.5 /8.0 /6.5		7.5		7.0			8.0	
4		4.0 /3.5	4.0	3.5		6.0	9.5	6.5 /5.5 /6.0 /4.5 /4.5	7.5 /6.5	4.0		6.0 /6.0	6.0 /6.0 /6.0	6.0		6.5	
Average		**3.9**	**6.5**	**3.5**	**6.5**	**6.3**	**10.8**	**6.9**	**9.1**	**4.7**	**8.3**	**6.2**	**6.9**	**7.0**		**7.8**	**3**
July																	
1			3.5				5.0	5.0 /4.5 /4.5	5.0 /6.5 /6.5	4.0	5.5	5.5	5.0		6.5	6.0	
2		2.0	2.5	3.0	4.0	4.5		4.0 /4.0	6.0 /6.0 /5.0		3.5 /3.0	6.0		3.5		4.0	
3		1.7	2.0	3.0	4.0			3.5 /3.5	4.5 /5.0	3.5		5.5	4.0				
4					3.5		3.5	4.0 /4.0 /4.0	4.5 /4.5	2.5	3.0 /3.0	3.0	3.5 /2.5	2.5	2.5	3.5	
Average		**1.9**	**2.7**	**3.0**	**3.8**	**4.5**	**4.3**	**4.0**	**5.2**	**3.3**	**3.9**	**5.0**	**4.0**	**3.0**	**4.5**	**4.5**	**2**
August																	
1	2.5					2.5		3.0 /3.0 /3.5	5.0 /4.5 /4.5		2.5 /2.5		3.0	2.5	3.3		
2	2.5	1.5		2.5	3.5			3.0 /3.0	3.5 /4.0	2.5	2.0	2.0			2.5	2.5	
3			2.0			2.0	2.5		3.0 /3.5 /3.5		1.5		2.5	2.5		2.5	
4			2.0		2.5			3.0	2.5 /3.0 /3.5 /3.0	2.5	1.5	2.3 /2.0			2.0		
Average	**2.5**	**1.5**	**2.0**	**2.5**	**3.0**	**2.3**	**2.5**	**3.1**	**3.7**	**2.5**	**1.9**	**2.1**	**2.8**	**2.5**	**2.6**	**2.5**	**5**
September																	
1					2.5	2.0	2.0	2.5 /2.5 /2.5	3.0 /3.0 /3.0 /3.0	3.5	2.0	2.0					
2																	
3											2.5	2.5					
4								4.0 /4.0									
Average					**2.5**	**2.0**	**2.0**	**3.3**	**3.0**	**3.5**	**2.3**	**2.3**					
Average Jun-Sep	**2.5**	**3.5**	**5.1**		**4.0**	**3.0**	**6.0**	**4.7**	**5.1**	**4.8**	**4.1**	**3.9**	**4.4**	**4.2**	**3.4**	**4.9**	**6**
# samples	2	7	11		8	2	10	7	7	10	14	13	13	6	5	8	

Appendix C-3. Phosphorus data for Green and Little Green Lake.

Total phosphorus data (µg/l) for Green Lake.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Number of years with lower phosphorus than 2004
June						**15**	**12**	**23**	**5**		**12**	**2**
July					**38**	**35**	**28**	**51**	**10**	**34**	**22**	**5**
August					**16**		**10**	**66**	**16**	**10**	**9**	**5**
Average Jun-Sep	**41**	**38**	**39**	**21**	**27**	**20**	**17**	**47**	**10**	**22**	**14**	**9**
number of samples	3	4	2	2	2	3	3	3	3	2	3	

Total phosphorus data (µg/l) for Little Green Lake.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Number of years with lower phosphorus than 2004
June						**15**	**14**	**17**	**13**		**11**	
July					**59**	**38**	**57**	**61**	**16**	**48**	**26**	
August					**24**		**12**	**76**	**16**	**15**	**20**	
Average Jun-Sep	**46**	**34**	**50**	**24**	**42**	**27**	**28**	**51**	**15**	**32**	**19**	
number of samples	2	4	3	2	2	2	3	3	3	2	3	

Appendix D. Minnesota Department of Natural Resources Fishery Data

Length of Selected Species Sampled for All Gear for the 2001 Survey Year

	Number of fish caught in each category (inches)								
Species	***0-5***	***6-8***	***9-11***	***12-14***	***15-19***	***20-24***	***25-29***	***>29***	***Total***
Black Bullhead	0	5	9	4	0	0	0	0	18
Black Crappie	17	207	4	0	0	0	0	0	228
Bluegill	250	111	0	0	0	0	0	0	361
Brown Bullhead	0	0	9	13	0	0	0	0	22
Green Sunfish	1	0	0	0	0	0	0	0	1
Hybrid Sunfish	7	6	0	0	0	0	0	0	13
Largemouth Bass	1	1	3	1	2	0	0	0	8
Northern Pike	0	0	0	0	4	15	11	2	32
Pumpkinseed Sunfish	21	7	0	0	0	0	0	0	28
Walleye	0	0	10	11	35	8	3	0	67
Yellow Bullhead	0	0	9	5	0	0	0	0	14
Yellow Perch	0	4	0	0	0	0	0	0	4

Fish Stocked by Species for the Last Five Years

Year	Species	Age	Number
1998	*Walleye*	Fingerling	22,599
	Walleye	Yearling	2,150
	Walleye	Fingerling	46
2000	*Walleye*	Yearling	16
	Walleye	Fingerling	1,770
	Walleye	Adult	57
2001	*Walleye*	Fingerling	1,170
	Walleye	Fingerling	6,048
2002	*Walleye*	Yearling	104
	Walleye	Fingerling	93
	Walleye	Yearling	598
2003	*Walleye*	Fingerling	12,684

Fish Consumption Advisory

Meal Advice for Pregnant Women, Women who may become pregnant and Children under age 15

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Black Crappie	◔	■	■	■	■
Carp	■	■	◔	■	■
Walleye	◔	◔	◔	■	■
White Sucker	■	■	◔	■	■

Meal Advice for the General Population

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Black Crappie	○	■	■	■	■
Carp	■	■	○	■	■
Walleye	○	○	◔	■	■
White Sucker	■	■	○	■	■

Symbol Key	unlimited	1 meal per week	1 meal per month	1 meal every 2 months	do not eat
Mercury	○	◔	◑	■	●
PCBs	□	◧	◪	⬓	■

Figure 9. Curlyleaf pondweed was the dominant plant in early summer in Green and Little Green Lakes.