13 POWDERHORN LAKE

HISTORY

Powderhorn Lake was acquired by the Minneapolis Park and Recreation Board (MPRB) in 1890 and it was so named because its original shape resembled a powderhorn. Dipper dredge operations were conducted shortly thereafter from 1894 to 1904. Later, between 1924 and 1925, the south end of the lake was deepened by hydraulic dredging with the spoils (nearly 150,000 cubic yards) used to fill the north half to create parkland. Powderhorn Lake is currently a very popular neighborhood lake (Figure 13A). It has been stocked by the Minnesota Department of Natural Resources as a Kid's Fishing Pond since 1980. Powderhorn Park hosts several large community events including the May Day Festival and Parade and the Powderhorn Art Festival.

Figure 13A. Powderhorn Lake.

Powderhorn is a shallow polymictic lake with an island and one deep hole at the southeastern end of the lake (Figure 13B). Computer modeling indicates the lake was historically eutrophic (MPRB, 1999) and restoration activities were implemented as early as 1975, when a temporary summer aerator was installed to increase oxygen content in the deeper water and prevent fish kills. In 1995, a winter aeration system was installed jointly with the MDNR, and a permanent summer aeration system was installed by early 2003. Lake water levels are occasionally augmented with groundwater and, when necessary, excess water is pumped out through a pumping station in the northeast area of the park to an adjacent watershed that drains to the Mississippi River.

The MPRB and Minneapolis Public Works (MPW) developed a major restoration plan in 1999. Work began in 2001 with the installation of five continuous deflective separation (CDS) grit chambers around the lake to remove solids from stormwater inflow. In 2002, native plantings around the lake were done to improve aesthetics, habitat and filter overland flow from the park

into the lake. The shoreline restoration also included repairing the Works Progress Administration (WPA) stone wall, removing concrete sluiceways and the installation of the summer aerator. An alum treatment was conducted in May of 2003. The combined effects of these above mentioned restoration projects have improved water quality in Powderhorn Lake, but the large watershed to lake area ratio (Table 13A) limits greater improvements seen in some other lakes.

Due to a desire to see improvements in water clarity, the MPRB has conducted barley straw treatments every spring since 2004. While it is difficult to ascertain which restoration activities have benefited the lake the most, and it likely is a combination of all the restoration work, the barley straw treatments seem to have been an important tipping point in the improvement of water clarity. For the first time, aquatic plants were noticeable in Powderhorn Lake in 2006. This is a big improvement for a lake where the algae growth limited light penetration to the extent that little or no aquatic plant growth occurred in the past.

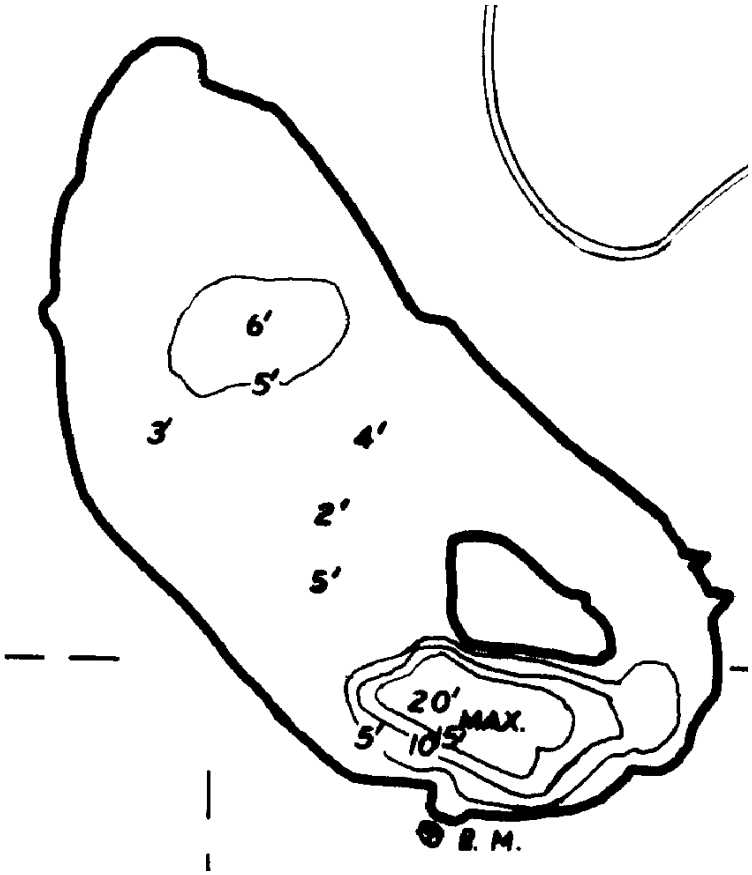

Figure 13B. Bathymetric map of Powderhorn Lake. Map courtesy of the MDNR.

Table 13A. Powderhorn Lake morphometric data. * Littoral area was defined as less than 15 feet deep.

Surface Area (acres)	Mean Depth (m)	Maximum Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
11	1.2	6.1	99%	$5.43x10^4$	286	26.0	0.2

LAKE LEVEL

Powderhorn Lake levels are recorded weekly. The historical lake levels for Powderhorn Lake are shown in Figure 13C for the entire period of record. Powderhorn Lake levels are influenced by an augmentation well that pumps groundwater into the lake periodically throughout the year to attempt to maintain a consistent level. Mean sea level elevation can be calculated by adding the city datum (710.3 feet) to the elevations shown in Figure 13C.

See Section 18 for a comparison between other MPRB lake levels.

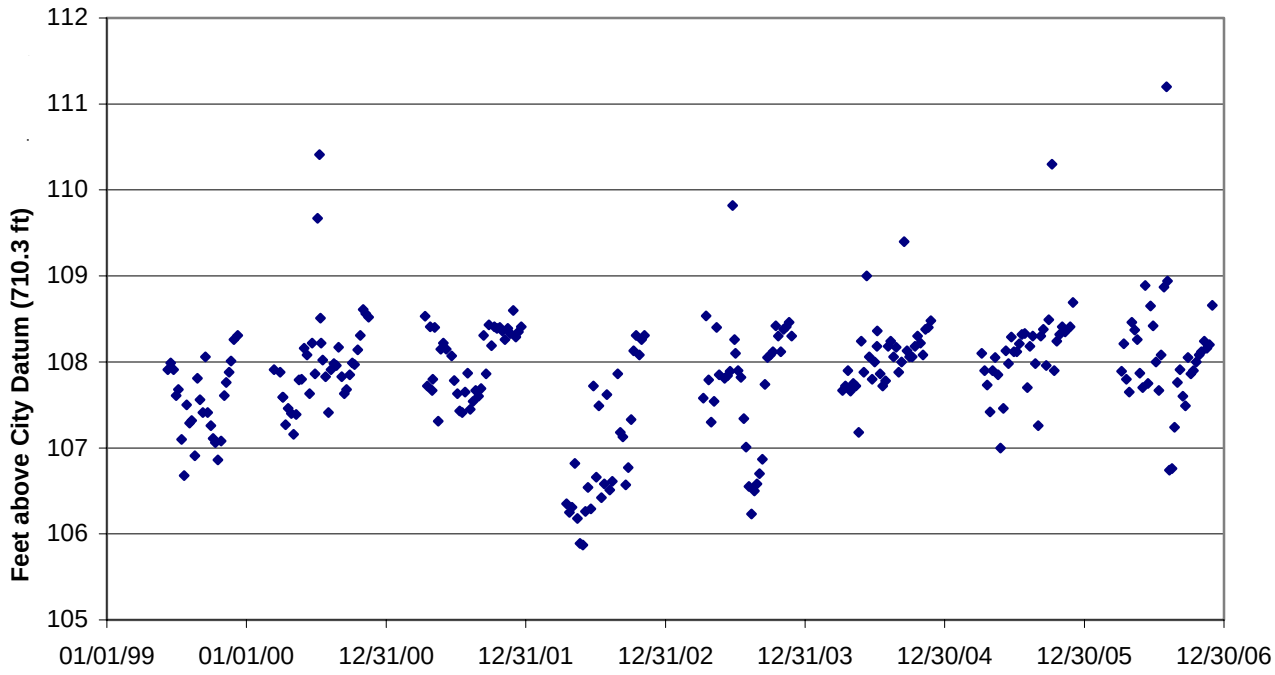

Figure 13C. Historical lake levels for Powderhorn Lake.

AUGMENTATION WELL

An augmentation well is used to maintain the water level at Powderhorn. The MDNR issues the permits and determines pumping limits for augmentation wells. The MPRB staff records groundwater levels monthly. Annual fees and reports are sent to the MDNR.

Tables 13B and 13C show the 2006 augmentation well readings and annual water usage. In 2006, all of the augmentation wells were below their MDNR allotted groundwater pumping volumes. See Section 1 for detailed information on MPRB augmentation wells.

Table 13B. 2006 monthly augmentation well volumes (gallons) at Powderhorn Lake.

Jan-April	May	June	July	August	September	October	November	December
0	163,800	271,200	2,590,800	685,800	449,400	1,152,600	3,472,800	0

Table 13C. Powderhorn Lake yearly augmentation well volumes (gallons).

Gallons Permitted	2004 Total	2005 Total	2006 Total
26,000,000	17,883,000	15,676,200	8,786,400

WATER QUALITY TRENDS (TSI)

Figure 13D shows the two regression lines for Powderhorn Lake TSI scores. Regression line A uses data from the entire period of record, and shows a stable to very slightly decreasing trend towards better TSI scores. If the regression analysis uses only the scores since the start of work on the Powderhorn Lake Restoration Plan, shown by regression line B, a strong trend towards better TSI scores is shown. A detailed explanation of TSI can be found in Section 1.

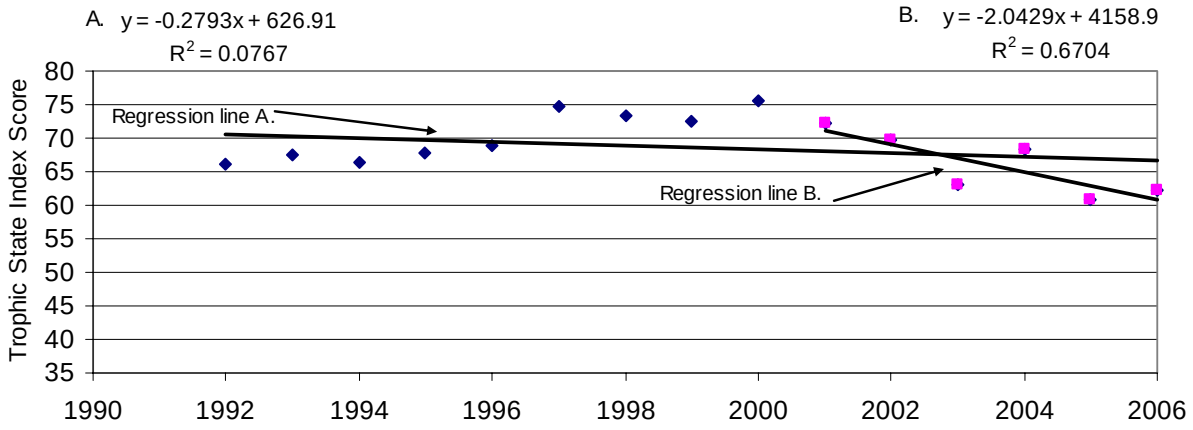

Figure 13D. Powderhorn Lake TSI scores and regression analysis. Regression line A comprises all of the data available, and shows a very weak negative trend. Regression line B only uses the data since 2001, when work began on the Powderhorn Lake Restoration Plan. Since the restoration plan was implemented the water quality trend has been towards clearer water and better TSI scores.

Powderhorn is eutrophic with considerable amounts of algae. Since restoration efforts began in 2001, TSI scores have been improving. The alum treatment in 2003 influenced the TSI score for that year. Phosphorus, solids, and sediment inputs to the lake have decreased due to the CDS units. The addition of channel catfish, in 2004, may have decreased sediment disturbance by planktivorous fish. Barley straw treatments begun in 2004 have also contributed to increased clarity. Powderhorn Lake has a TSI score that is below average for this ecoregion. It falls near the 25th percentile for lakes in this ecoregion (based on calculations from the Minnesota Pollution Control Agency, using the Minnesota Lake Water Quality Data Base Summary, 2004).

BOX AND WHISKER PLOTS

The box and whisker plots show in more detail, the scatter within the years data set, for the Secchi, chlorophyll-*a*, total phosphorus, and total nitrogen data. Long-term lake monitoring is necessary to evaluate the seasonal and year-to-year variations seen in each lake and predict trends. A further detailed explanation of box and whisker plots can be found in Section 1. Figure 13E shows the box and whisker plots for Powderhorn Lake.

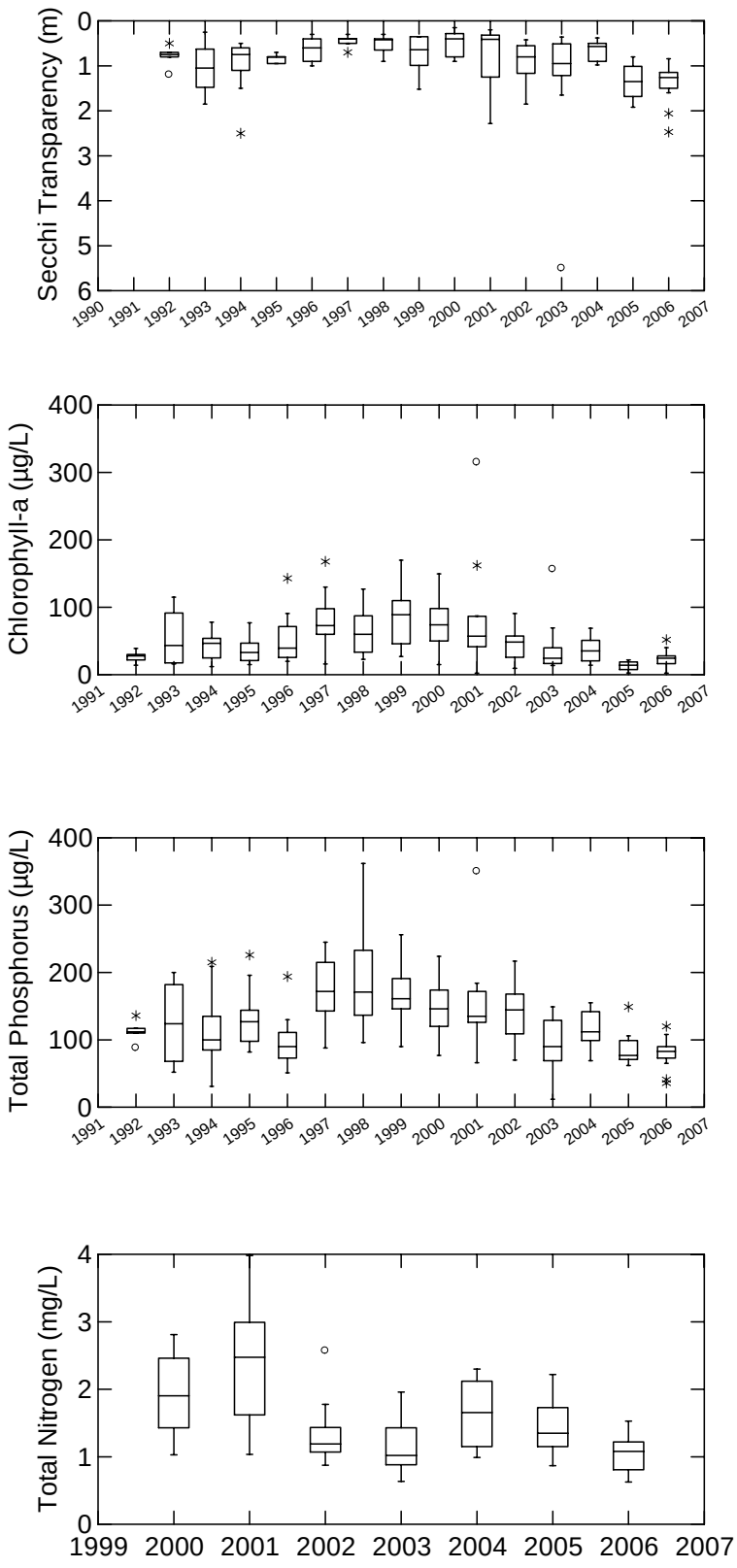

Figure 13E. Box and whisker plots of Powderhorn Lake.

Restoration efforts at Powderhorn Lake may take many years to reach a steady state. Total nitrogen, total phosphorus and chl-*a* concentrations were lower in 2006 than prior to the restoration efforts. Secchi depths also showed an improvement.

Lake Aesthetic and User Recreation Index (LAURI)

The LAURI for Powderhorn Lake is shown in Figure 13F. Powderhorn Lake scored "excellent" in aquatic plant interference and "good" in aesthetics and water clarity. It is likely that the limited water clarity leads to low aquatic plant growth in this lake. Powderhorn Lake does not have a swimming beach, therefore it was not scored for the public health category. See Section 1 for details on the LAURI.

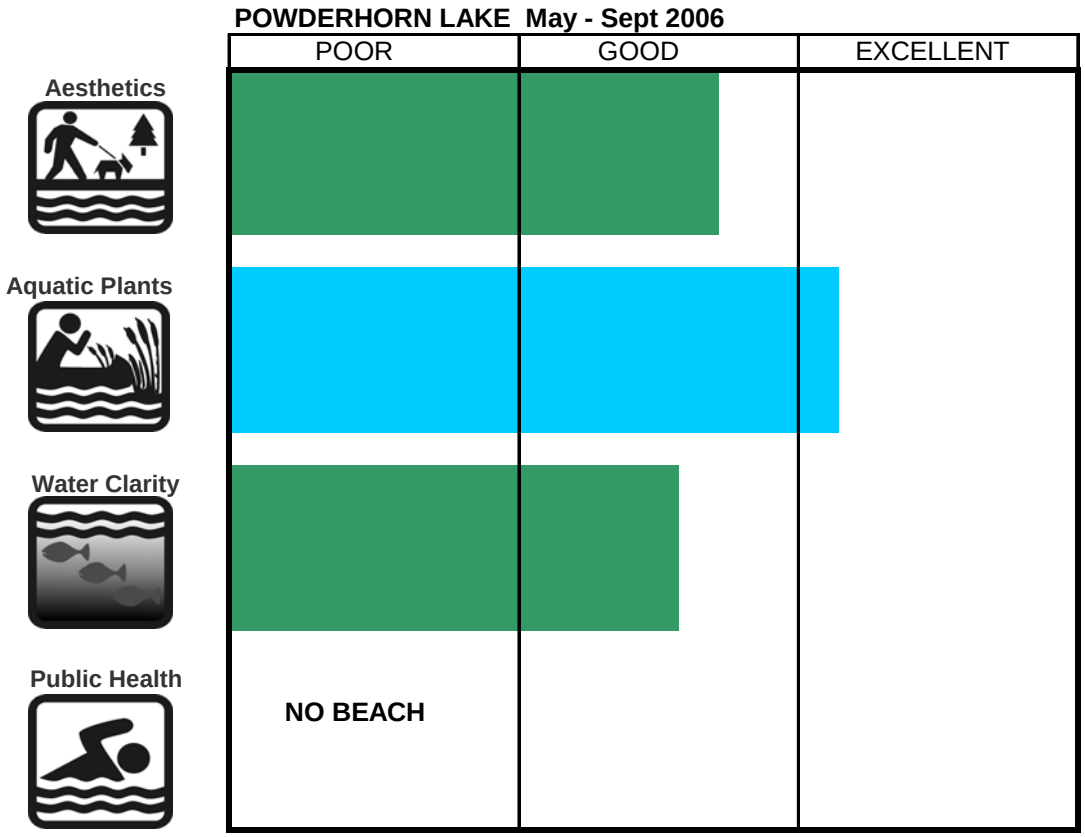

Figure 13F. The 2006 LAURI for Powderhorn Lake.

Winter Ice Cover

Ice came off Powderhorn Lake on April 5, 2006, which is average. Ice came on the lake December 1, 2006, which is a few days later than average. See Section 1 for details on winter ice cover records and Section 18 for a comparison with other lakes.

Phytoplankton and Zooplankton

Phytoplankton and zooplankton are the microscopic plant and animal life that form the basic food web of lake ecology. The greenness of a lake is measured by chlorophyll-*a* (chl-*a*) as an

expression of the phytoplankton present. Figures 13E and 13F show the phytoplankton and chlorophyll-*a* data, respectively. In 2006, the dominant species switched several times. Chlorophyta (green algae) and chrysophyta (golden algae) were most abundant in the February sample. By May, cryptophyta (cryptomonads) were 80% dominant. During the summer, pyrrhophyta (dinoflagellates) dominated, although there were significant pulses of cyanophyta (blue-green algae). Cryptomonads were again dominant in the latter part of the year, during the times of lowest chl-*a* concentrations. High chl-*a* concentrations correlated with cyanobacteria and pyrrhophyte blooms.

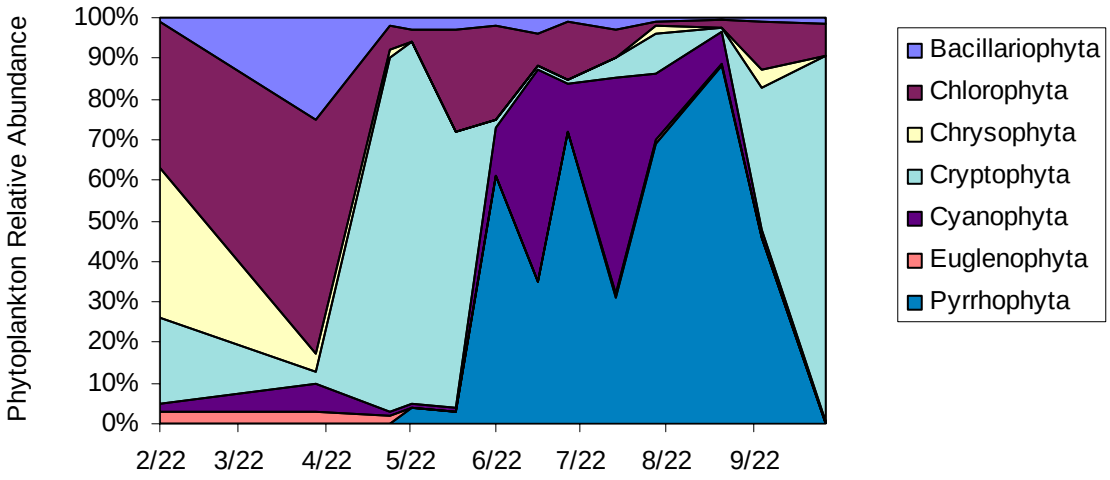

Figure 13G. Relative abundance of phytoplankton in Powderhorn Lake during the 2006 sampling season.

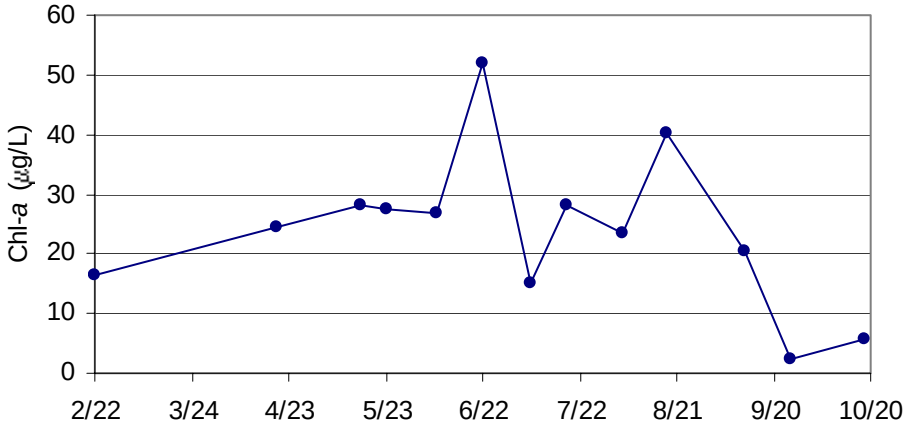

Figure 13H. Powderhorn Lake 2006 chlorophyll-*a* data.

Chlorophyll-*a* concentrations in Powderhorn Lake in 2006 were significantly lower than in most years prior to the restoration efforts. It appears that the combination of restoration efforts has lowered the amount of primary productivity in the lake.

The phytoplankton community structure in Powderhorn Lake has changed over time (Figure 13I). Between 2002 and 2004, chlorophyta and cyanobacteria were dominant during open-water season, bacillariophyta made up a significant percent of the species present in spring and fall, and cryptophyta had several spring blooms. Unusually, in 2006 pyrrhophyta made up

the majority of the individuals in the summer samples, and cryptophyta had larger blooms in spring and fall. (In comparison, several of MPRB's monitored lakes have small mid-summer pyrrhophyte blooms amounting to 5-10% of the individuals sampled.) Cyanophyta was only significantly present during June and July of 2006, and chlorophyta was also a smaller presence in 2006 than in several of the previous years.

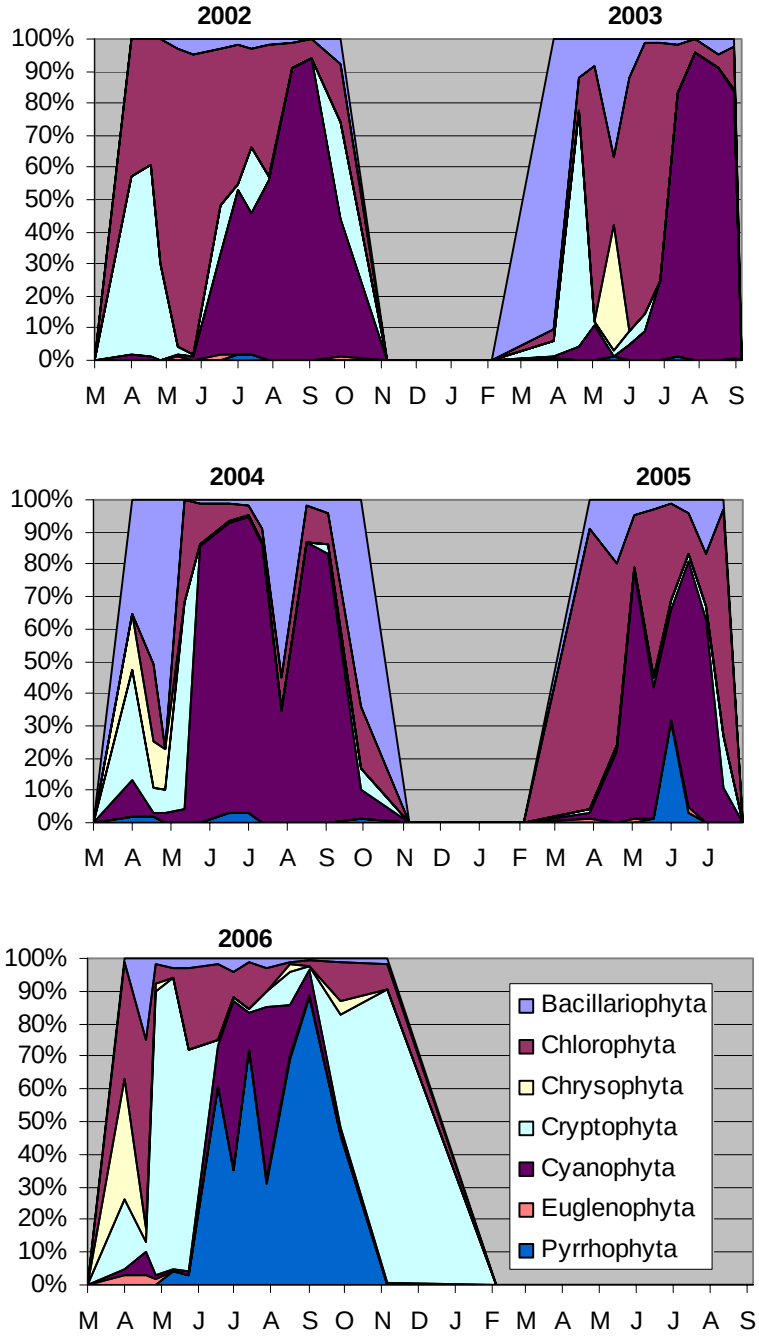

Figure 13I. Distribution of phytoplankton in Powderhorn Lake from 2002-2006.

The distribution of zooplankton in Powderhorn Lake is shown in Figure 13J. Arthropods and rotifers both peaked in spring, likely as a response to the blooms of cryptomonads, green-algae, and chrysophytes. Arthropod levels stabilized for the remainder of the season, while rotifer abundances fluctuated. Protozoans were only present in detectable numbers in August, and

represented 0.5% of the total sample.

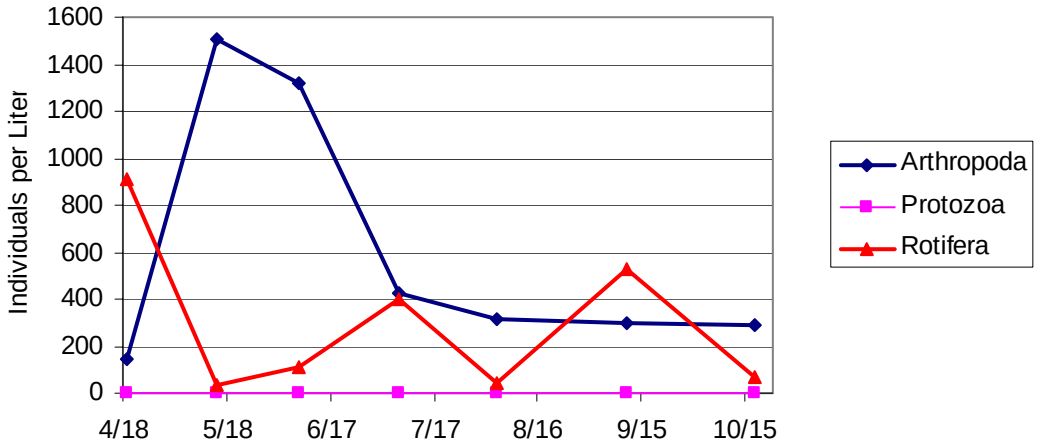

Figure 13J. Zooplankton distribution in Powderhorn Lake during the 2006 sampling season.

Fish Stocking

Additional information and a definition of fry, fingerling, yearling and adult fish can be found in Section 1.

Powderhorn Lake was stocked by the MDNR in:
1998 with 585 adult Bluegill Sunfish
1999 with 501 adult Black Crappie, 1,008 adult Bluegill Sunfish, 9 adult Largemouth Bass
2000 with 380 adult Black Crappie, 1,728 adult Bluegill Sunfish
2001 with 510 adult Black Crappie, 1,002 adult Bluegill Sunfish
2002 with 510 adult Bluegill Sunfish
2003 with 422 adult Black Crappie, 1,614 adult Bluegill Sunfish
2004 with 270 adult Black Crappie, 516 adult Bluegill Sunfish, 99 adult Channel Catfish
2005 with 500 adult Bluegill Sunfish, 120 adult Channel Catfish
2006 with 500 adult Bluegill Sunfish, 100 adult Channel Catfish

Water Quality Projects

Water quality improvement projects have been implemented to ensure the health of Powderhorn Lake. Native plantings along the shoreline will provide shoreline stabilization and wildlife habitat. Shoreline vegetation will also improve water quality by slowing and filtering rainfall runoff before it enters the lake. Stormwater grit chambers were installed as part of the stormwater drainage system. These state-of-the-art devices trap stormwater runoff before it enters the lake. Sediments in the stormwater settle to the bottom of the grit chamber and are eventually pumped out as the grit chambers fill up. Goose management, an alum treatment and a summer aerator were all components of the restoration project. For more information, on the restoration of Powderhorn Lake, see http://www.minneapolisparks.org/default.asp?PageID=708.

Figure 13K shows installation of barley straw logs in Powderhorn Lake. Barley straw was first used at Powderhorn Lake on 5/5/04 when 250 pounds/acre were added. The first treatment appeared to have little if any effect. A second application at a higher dose was applied on

5/11/05 where 360 pounds/acre were added. A third barley straw application was applied 5/11/06 where 364 pounds/acre were added. The barley straw is staked below the surface of the water where it slowly decomposes over the year. The Secchi transparencies from Powderhorn Lake in 2005 and 2006 did reflect improvements in surface water clarity. The dramatic 2005-06 Powderhorn TSI improvements are likely the combined result of the multitude of restoration efforts (CDS units, alum, summer aeration, fish manipulation, barley straw, etc). An encouraging sign was the observation of aquatic plant growth in 2006.

Figure 13K. Barley straw treatment at Powderhorn Lake.