2006 Lake Water Quality Study

Medicine Lake

Prepared by
Bassett Creek Watershed Management Commission

February 15, 2007

Bassett Creek Watershed Management Commission

www.bassettcreekwmo.org

2006 Lake Water Quality Study

Medicine Lake

Prepared by
Bassett Creek Watershed Management Commission

February 15, 2007

Bassett Creek Watershed Management Commission

www.bassettcreekwmo.org

2006 Lake Water Quality Study

Table of Contents

P:\23\27\051\2006\2006 Medicine Lake Report\Report\2006 Lake Wtr Quality Study Medicine Lake_Final_2-15-07.doc

List of Tables

List of Figures

List of Appendices

1.0 Executive Summary

Since 1970, when the Bassett Creek Watershed Management Commission (Commission) and its predecessor, the Bassett Creek Flood Control Commission, were formed, water quality conditions in the ten major lakes have been periodically monitored. The objective of the lake monitoring program is to detect changes or trends in water quality over time, thereby determining the effect of changing land use patterns in the watershed and the effectiveness of the Commission's efforts to prevent water quality degradation in the lakes. Also, monitoring serves another function as Medicine Lake has been listed as "impaired" (i.e., not meeting water quality standards and not supporting assigned beneficial uses) for mercury and excess nutrients by the MPCA.

This report evaluates the historic and current water quality of Medicine Lake. In 2006, the lake was monitored for water quality (Appendix A) and biota, specifically zooplankton (Appendix B). Monitoring results for 2006 and past monitoring seasons were analyzed as summer averages (June through August) and are summarized in this report. The Commission's Medicine Lake goals for Total phosphorus (TP), chlorophyll *a*, and Secchi disc depth are 38 µg/L, 10 µg/L, and 2.2 meters, respectively.

The conclusions that can be reached from the water quality monitoring data are as follows:

- The water quality in Medicine Lake appears to have improved over the previous decade (1997 through 2006) but has been variable, making clear trends difficult to ascertain. Average summer (TP) levels peaked in 1998 at 69.7 µg/L and reached a low level of 40.3 µg/L in 2001.
- Average summer chlorophyll *a* was lowest in 2001 at 17.0 µg/L and reached a peak of 36.0 µg/L in 2003. In 2006, total phosphorus and chlorophyll *a* were 42.3 µg/L and 23.7 µg/L (June through August average), respectively. Both TP and chlorophyll *a* did not meet targets set for these parameters (38 µg/L for TP and 10 µg/L for chlorophyll *a*).
- Average summer Secchi disc levels have not noticeably improved in recent years, ranging from 1.0 meters in 1998 to 2.0 meters in 2002. The summer average in 2006 was 1.4 meters at both sampling locations (Main Basin and Medicine Bay) and did not meet the target of 2.2 meters.
- Total phosphorus concentrations increased substantially in the bottom waters of Medicine Lake during the summer of 2006, indicating the presence of internal phosphorus loading in the lake. From April through August 2006, TP increased from 37.5 µg/L to 1,151 µg/L at the Main Basin sampling station. From April through September 2006, TP increased from 425.5 µg/L to 2,248.1 µg/L at the Medicine Bay monitoring station.

- Total phosphorus, chlorophyll *a*, and Secchi depth measurement all indicate that Medicine Lake is eutrophic.

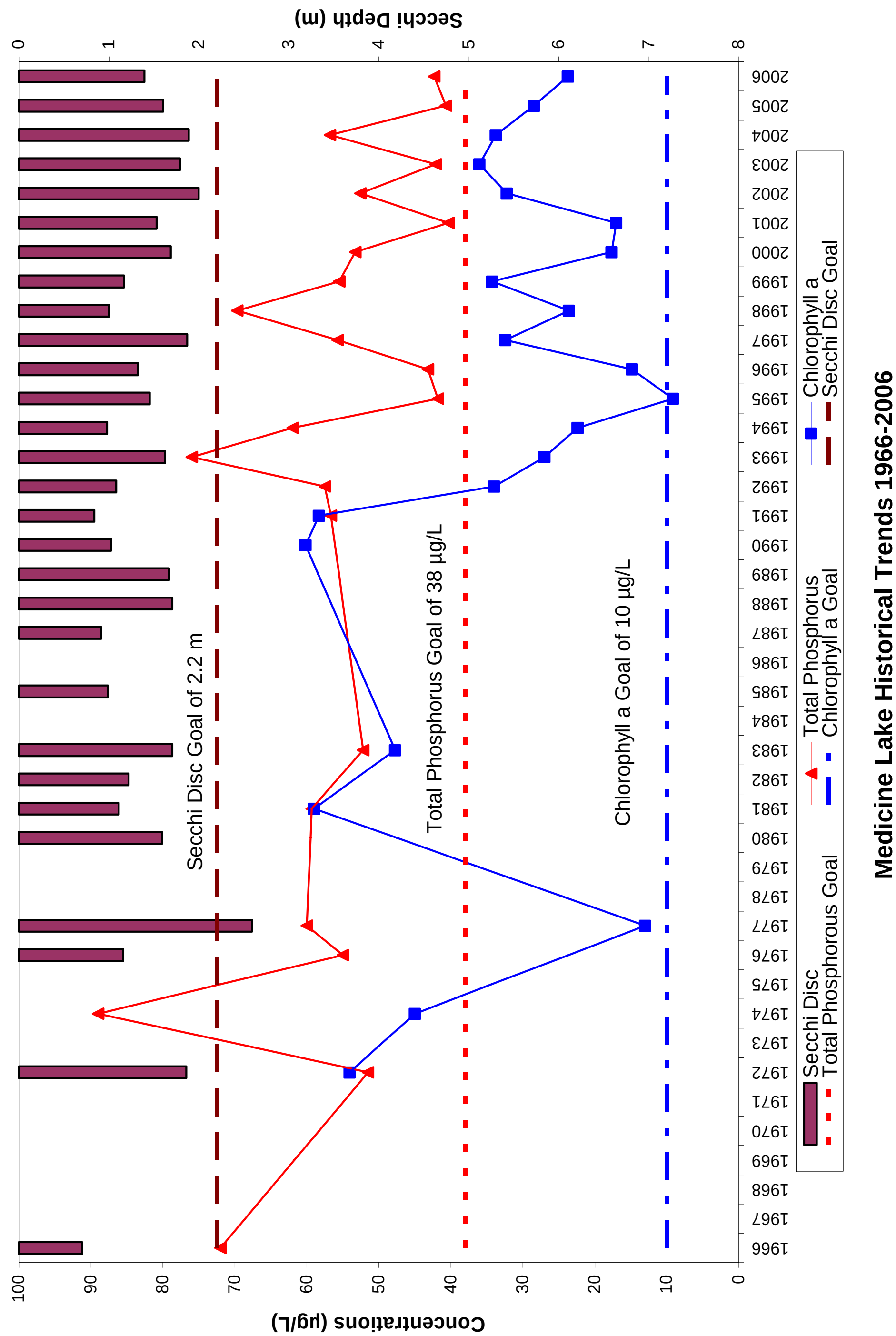


Figure 1

2.0 Introduction

Since 1970, when the Bassett Creek Water Management Commission (Commission) and its predecessor, the Bassett Creek Flood Control Commission, were formed, water quality conditions in the ten major lakes have been periodically monitored. The Commission's policy is to preserve water quality conditions, and to improve them where possible. Nonpoint source pollution (pollutants transported by stormwater runoff) is the predominant cause of lake water quality degradation. The objective of the lake monitoring program is to detect changes or trends in water quality over time, thereby determining the effect of changing land use patterns in the watershed and the effectiveness of the Commission's efforts to prevent water quality degradation in the lakes.

In 1991, the Commission established an annual lake water quality monitoring program that generally followed the recommendations of the Metropolitan Council (Osgood, 1989a) for a "Level 1, Survey and Surveillance" data collection effort. The lake sampling program generally involves monitoring of ten lakes on a 4-year rotating basis, three or four lakes per year. However, some of the lakes, including Lost Lake and Sunset Hill (Cavanaugh) Lake have been eliminated from the program. Major lakes include the following water bodies, with prior monitoring years indicated parenthetically:

Table 1 Lakes Monitored in the Basset Creek Watershed Commission Area (Years with sampling data are in parenthesis)

• Crane (1977, 1982, 1993, 1997, 2001)	• Sunset Hill (Cavanaugh) (1977, 1982, 1994, 1998)
• Lost (1977, 1982, 1993, 1997)	• Sweeney (1977, 1982, 1985, 1992, 1996, 2000, 2005)
• Medicine (1977, 1982, 1983, 1984, 1988, 1994[1], 1999[1], 2006[1])	• Twin (1977, 1982, 1992, 1996, 2000, 2005)
• Northwood (1972, 1977, 1982, 1992, 1996, 2000, 2005)	• Westwood (1977, 1982, 1993, 1997, 2001)
• Parker's (1977, 1982, 1992, 1996, 2000)	• Wirth (1977, 1982, 2001)

Wirth Lake is currently monitored annually by the Minneapolis Park and Recreation Board. Hence, Wirth Lake is not included in the Commission's lake monitoring program. Medicine Lake is currently monitored annually by the Three Rivers Park District (Three Rivers). The Commission

[1] Monitoring performed jointly with Three Rivers Park District (formerly Suburban Hennepin Regional Park District).

periodically participates with Three Rivers to monitor at a second site at Medicine Lake. The Commission partnered with the Three Rivers to perform the lake sampling for this study.

The lake sampling program occasionally includes limited monitoring for other water bodies, which has included the following ponds and the year sampled in parenthesis:

- Courtland, East Ring, and West Ring Ponds (1993)
- Grimes Pond (1996)
- North Rice and South Rice Ponds (1994, 1998)

This report presents the results of water quality monitoring in 2006 of Medicine Lake. The lake was monitored for water quality (Appendix A) and biota, specifically zooplankton (Appendix B). Monitoring results are summarized in the following pages including a narrative description of the results as well as a graphical summary. More detailed data can be found in the appendices of the report.

The discussion of water quality conditions focuses on the three principal nutrient-related water quality indicators: TP, chlorophyll *a* concentrations, and Secchi disc transparency. Phosphorus is a nutrient that usually limits the growth of algae. Chlorophyll *a* is the primary photosynthetic pigment in lake algae; therefore, the concentration in a lake water sample indicates the amount of algae present in the sampled area of the lake. Secchi disc transparency is a measure of water clarity, and is inversely related to algal abundance.

The water quality conditions were classified as to trophic state, based on the TP concentration, chlorophyll *a* concentration, and Secchi disc transparency (Table 2).

Table 2 Trophic State Classifications for Total Phosphorus, Chlorophyll *a*, and Secchi Disc Transparency

Trophic State	Total Phosphorus	Chlorophyll *a*	Secchi Disc Transparency
Oligotrophic (nutrient poor)	less than 10 µg/L	less than 2 µg/L	greater than 15 ft (4.6 m)
Mesotrophic (moderate nutrient levels)	10 µg/L – 24 µg/L	2 µg/L - 7.5 µg/L	15 ft - 6.6 ft (4.6 m - 2.0 m)
Eutrophic (nutrient rich)	24 µg/L – 57 µg/L	7.5 µg/L - 26 µg/L	6.6 ft – 2.8 ft (2.0 m - 0.85 m)
Hypereutrophic (extremely nutrient rich)	greater than 57 µg/L	greater than 26 µg/L	less than 2.8 ft (0.85 m)

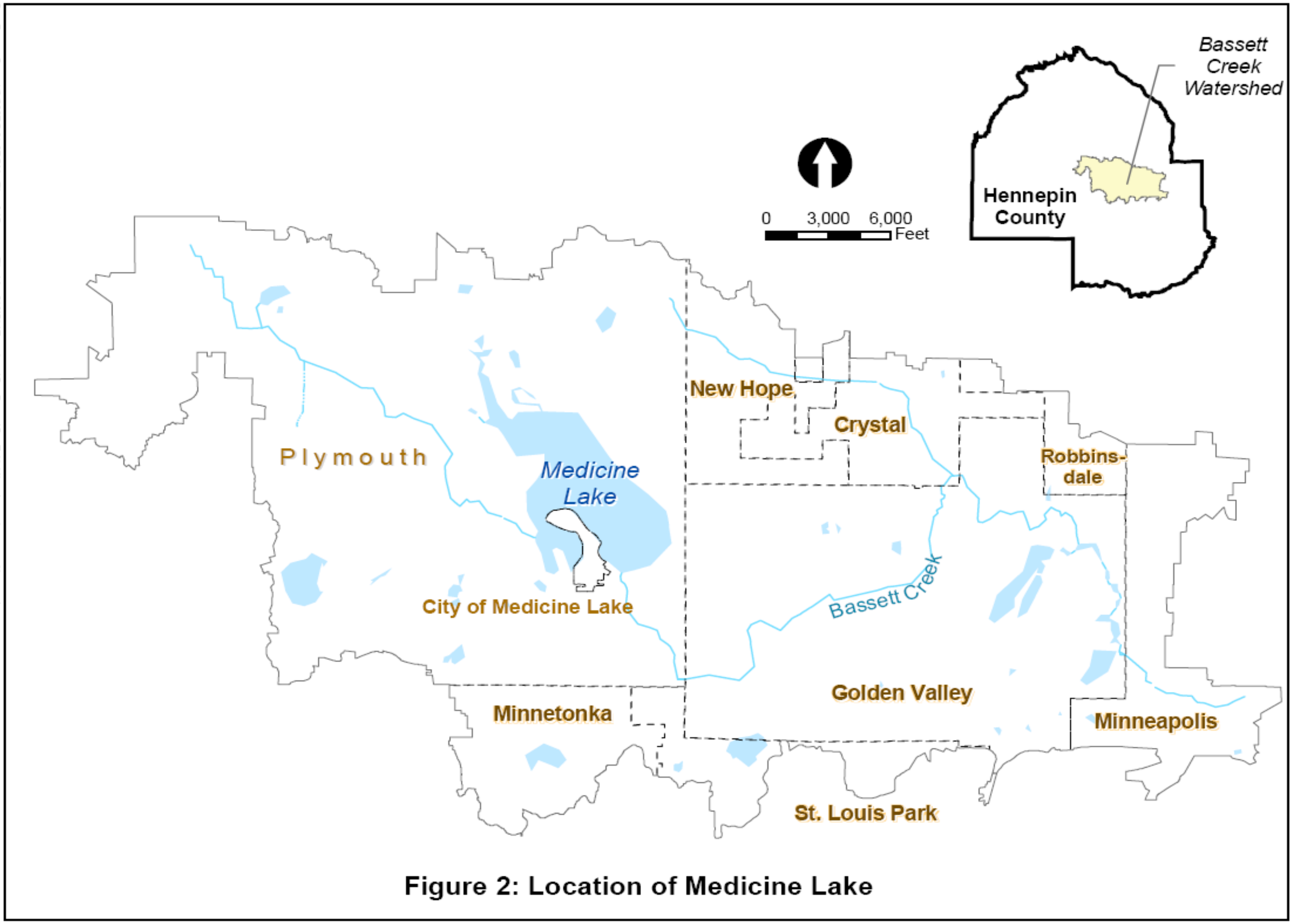


Figure 2 Location of Medicine Lake

Biological data were compiled and evaluated in this study as well (Appendix B). Zooplankton data provide insight into the health of the aquatic ecosystem associated with each water body. Aquatic communities interact with each other and influence both short- and long-term variations in observed water quality.

Zooplankton (microscopic crustaceans)—are vital to the health of a lake ecosystem because they feed upon the phytoplankton and are food themselves for many fish species. Protection of the lake's zooplankton community through proper water quality management practices protects the lake's fishery. Zooplankton are also important to lake water quality. The zooplankton community is generally comprised of three groups: Cladocera, Copepoda, and Rotifera. If present in abundance, large Cladocera can decrease the number of algae and improve water transparency within a lake.

Some of the lake and streams in the Bassett Creek Watershed have been listed as "impaired" (not meeting water quality standards and not supporting assigned beneficial uses) by the MPCA. The federal Clean Water Act requires that the MPCA assess the quality of streams and lakes in Minnesota, determine if they are impaired and list and report the impaired waters to the EPA. Water bodies on the 303(d) list (Section of the Clean Water Act) are required to have an assessment completed that addresses the causes and sources of the impairment. This process is called a total maximum daily load (TMDL) analysis and its purpose is to bring the water body back into compliance with water quality standards. The State of Minnesota's Water Quality Standards, Minnesota Rules Chapter 7050, are the numeric and narrative conditions that are used to determine if the waters are impaired.

There are currently five lakes and Bassett Creek in the Bassett Creek watershed that are included on the MPCA's 2006 Final List of Impaired Waters [303(d) list approved by U.S. EPA on June 1, 2006].

- Parkers Lake (listed for mercury)
- Medicine Lake (listed for mercury and excess nutrients)
- Sweeney Lake (listed for excess nutrients)
- Wirth Lake (listed for mercury and excess nutrients)
- Northwood Lake (listed for excess nutrients)
- Bassett Creek (listed for biota/fish)

Medicine Lake is listed for mercury with a target start and completion schedule of 1999/2011 and for excess nutrients with a target start and completion schedule of 2005/2008.

3.0 Site Description

Medicine Lake, the second largest lake in Hennepin County, is located in the cities of Plymouth and Medicine Lake, northwest of the Highway 169 and Highway 55 interchange (Figure 2). The lake has an approximate water surface area of 886 acres and a maximum depth of 49 feet. The Medicine Lake watershed consists of 11,613 acres and includes the Plymouth Creek and Ridgedale watersheds. Both watersheds discharge into Medicine Lake in the southwestern-most bay. Medicine Lake serves as the headwaters for Bassett Creek, which eventually drains into the Mississippi River in downtown Minneapolis.

Medicine Lake is designated as a Level I water body, appropriate for all recreational uses including swimming. Level I goals are: (1) TP concentration of 30 µg/L, (2) maximum chlorophyll *a* concentration of 10 µg/L, and (3) Secchi disc transparency of 2.2 meters (7.2 feet). However, due to implementation costs, the Commission's TP goal for Medicine Lake is 38 µg/L. Medicine Lake is used for a variety of recreational activities including fishing, waterskiing, and swimming. There is one public boat access point located in the Three Rivers Park District's French Regional Park. The park contains much of the shoreline for the northwest portion of the lake and the remainder of Medicine Lake's shoreline is comprised primarily of residential neighborhoods. In 2004, 2005, and 2006, the City of Plymouth treated Medicine Lake with Endothall in order to limit Curlyleaf pondweed (*Potamogeton crispus*) growth.

The BCWMC, the city of Plymouth, Three Rivers Park District, and the city of Medicine Lake have been partners in working to improve the water quality of Medicine Lake for many years. In March 2000 the Commission completed the draft *Medicine Lake Watershed and Lake Management Plan* with specific recommendations to improve the overall health of the Lake. The city of Plymouth adopted a *Medicine Lake Watershed Implementation and Management Plan* in 2001. The recommendations in the respective plans included steps to manage macrophyte growth in order to enhance recreational uses of the lake. Several methods were detailed and recommended to reduce phosphorus and sediment entering the lake as well. Many these recommendations have been completed by the City of Plymouth or jointly implemented by the Commission and the City of Plymouth. Following are some of these completed projects:

- Water quality ponds ML-4 (Medicine Lake East Beach) and ML-5 were constructed at the southeast corner of Medicine Lake during 2004.

- In-lake herbicide application was performed for three years, during 2004, 2005 and 2006 to manage macrophyte growth and reduce Curlyleaf pondweed.
- Timber Creek erosion control project located east of Medicine Lake was completed by Plymouth during 2005.
- Goose management and pavement sweeping programs and the phosphorus fertilizer ordinance have been implemented by Plymouth.
- Shoreland restoration was completed at 12 sites during 2004 and 11 sites during 2005 by Plymouth to reduce erosion along Medicine Lake.
- The Commission and Plymouth have adopted development requirements requiring water quality improvement features (ponds, rain gardens, etc.) for new and redevelopment projects.

In addition, following are several other projects proposed during the next five years:

- The Wood Creek erosion control project located east of Medicine Lake is proposed by Plymouth for 2007/2008.
- The County Road 9 and County Road 61 erosion control project located north of Medicine Lake is proposed for 2007/2008.
- The West Medicine Lake Park water quality pond and Plymouth Creek restoration project is proposed 2007-2009.
- Shoreline restoration is proposed by Plymouth at 6-10 sites during 2007.

4.0 Water Quality

4.1 Monitoring Overview

Medicine Lake was sampled at two locations during the 2006 season. One location was the Main Basin and the second and deeper location was in Medicine Bay. In 2006, Medicine Bay and the Main Basin were sampled 15 and 16 times, respectively, between April 18 and October 10 at approximately 2-week intervals.

4.2 Temperature and Dissolved Oxygen

Temperature and dissolved oxygen (DO) measurements indicate that Medicine Lake is stratified throughout much of the summer season. Temperature (Figure 3) and DO (Figure 4) measurements indicate the thermocline is located at a depth of approximately 6 to 8 meters from the lake surface and the hypolimnion is stable at depths below 10 meters. DO measurements also show the hypolimnetic layer (greater than 8 meters depth) is nearly depleted of oxygen from mid-April through late September. The anoxic zone reaches to approximately 6 meters from the bottom as more oxygen is depleted during the summer months.

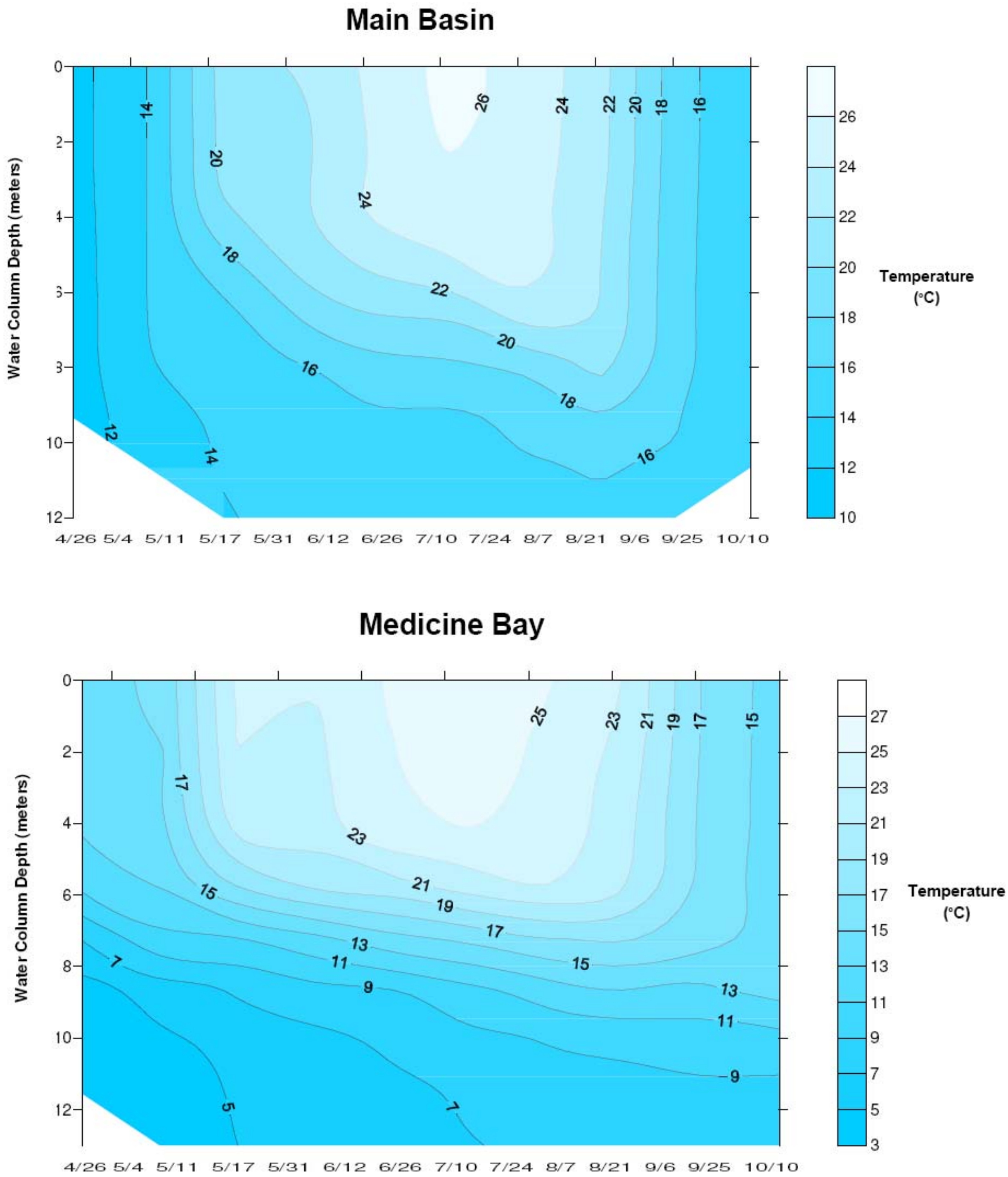
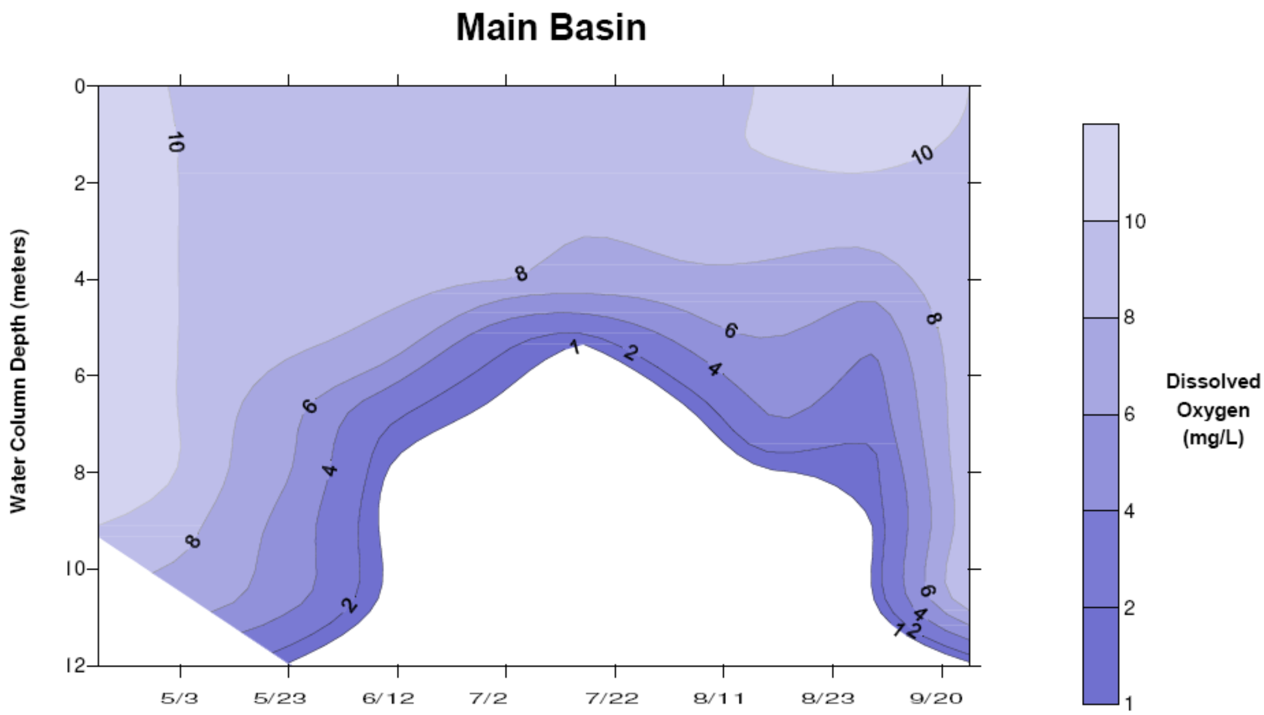


Figure 3 Temperature Profiles from April through October, 2006 in Medicine Lake



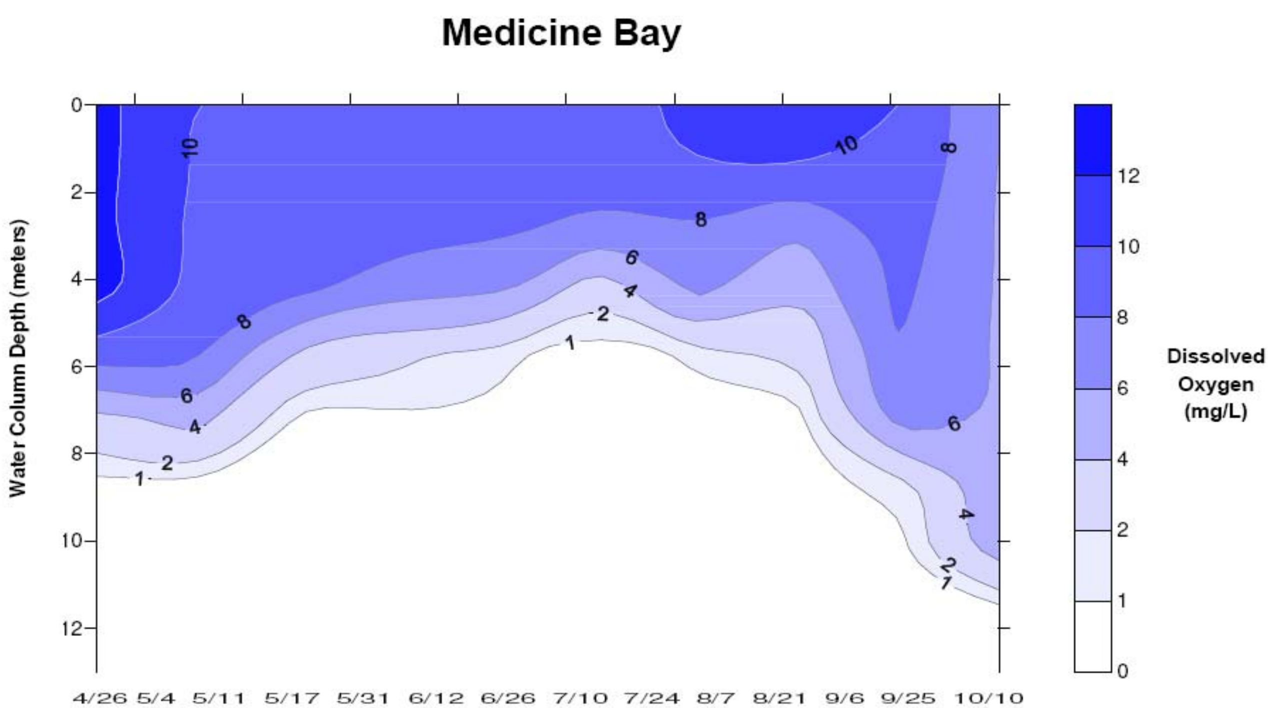


Figure 4 Dissolved Oxygen (DO) Profiles from April through October, 2006 in Medicine Lake

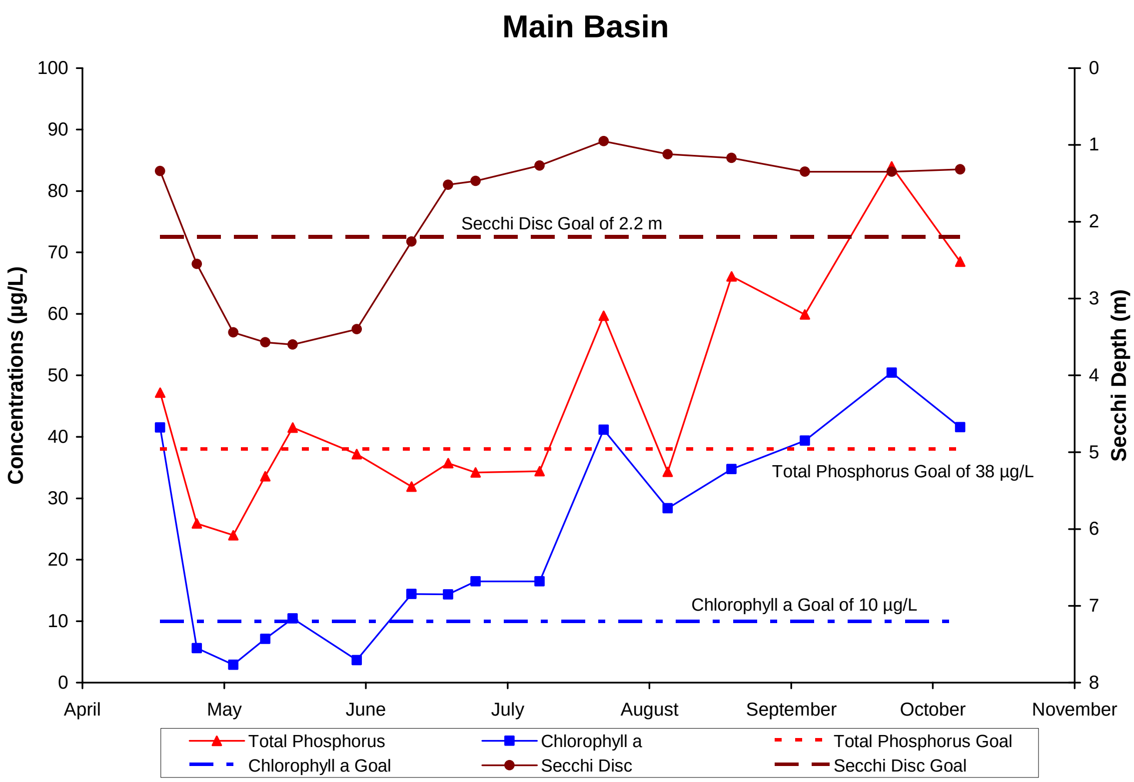
4.3 Surface Total Phosphorus, Chlorophyll *a* and Secchi Depth

While water quality in Medicine Lake appears to have improved somewhat over the previous decade (see long-term trends in Appendix D), however, TP levels are still above the water quality goals for the lake (Figure 1). Figure 1 shows TP levels have generally declined from a summer average (June through August) of 69.7 µg/L (1998) to 42.3 µg/L (2006). The recent measurements of TP in the lake water are among the lowest recorded for Medicine Lake in the past 40 years of reporting, however, the Commission goal of 38 µg/L has not yet been met. Current TP levels indicate that trophic status of the lake has improved from the hypereutrophic range to the eutrophic range since monitoring of the lake began.

Chlorophyll *a*, an indicator of algal biomass, has steadily dropped as well and has fallen by almost 35 percent since the recent peak in 2003 (June through August average) from 36.0 µg/L to 23.7 µg/L in 2006 (Figure 1). However, this is still well above the Commission's desired concentration of 10 µg/L and is just slightly below average when compared to the previous 10 years of monitoring data (average = 27 µg/L).

Summer average Secchi disc transparency was 4.6 feet (1.4 meters) and represents diminished water quality when compared to data from recent years. In 2002, the summer average Secchi disc depth was 6.7 feet (2.0 meters) and in 1999 it reached a 10-year low of 3.3 feet (1 meter). The 2006 observations (Figure 5) indicate that the Secchi disc transparency for Medicine Lake (June through August average) peaked in the month of May with readings close to 12 feet (3.6 meters), but transparency diminished greatly as the summer growing season began and never recovered above 4.4 feet (1.35 meters).

Seasonal patterns were apparent for the 2006 monitoring period (Figure 5). Both TP and chlorophyll *a* were elevated in early spring and then decreased in late spring. Both TP and chlorophyll *a* increased throughout the summer and peaked in September. Secchi disc depth was low in the early spring and increased later in the spring. During the summer it decreased to less than 1 meter (3.1 feet in July) and remained low through the end of the monitoring period (October).



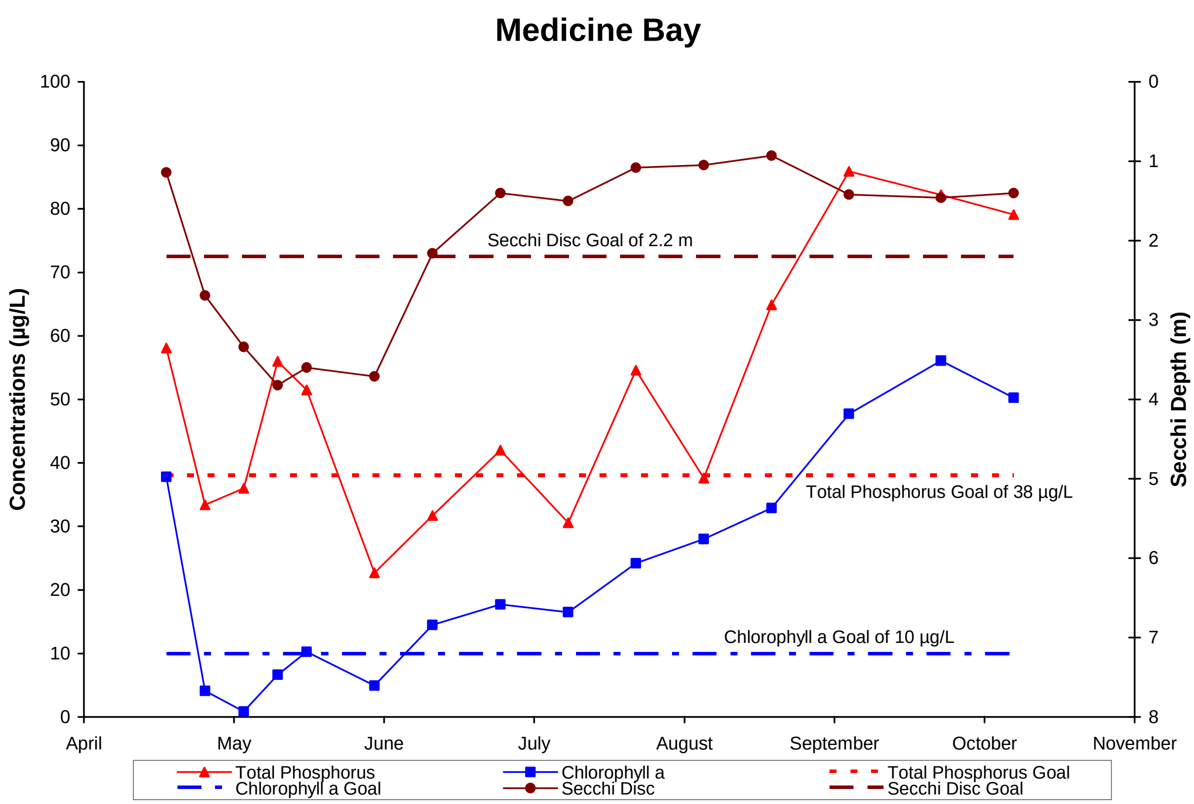
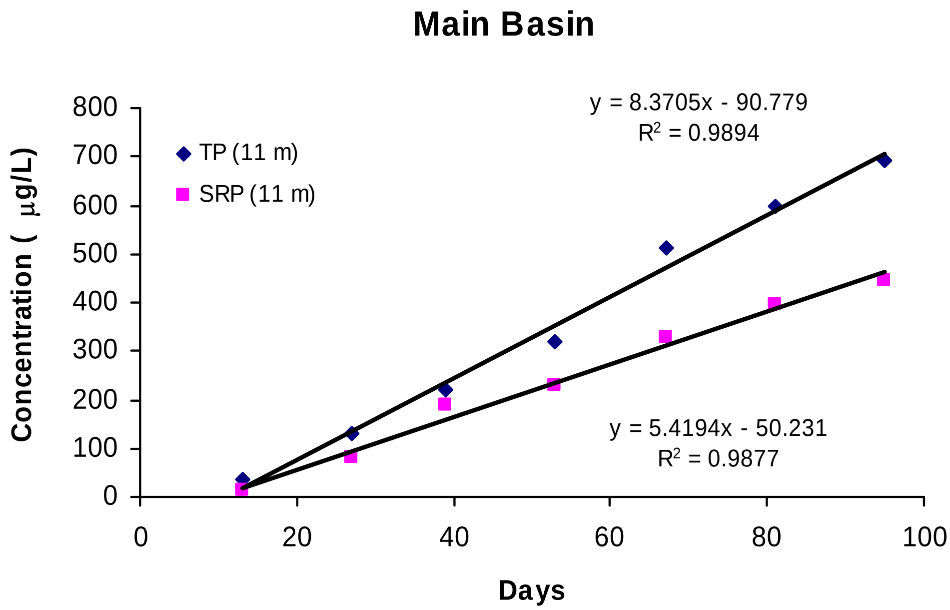


Figure 5 Medicine Lake Water Quality Data Collected in 2006

4.4 Hypolimnetic Phosphorus

Substantial increases in phosphorus concentration during the summer months are evident in both the Main Basin and Medicine Bay areas of the lake (Figure 6). According to the 2000 Draft Report, 43 percent of the TP load to Medicine Lake is due to internal release by the bottom sediments. Sediments play an important role in the cycling of phosphorus in lakes and can be either a source or a sink depending on several conditions such as season. Lake sediment can become saturated with phosphorus over time through excessive inputs (i.e., agricultural input or stormwater input associated with urban development) and contribute to poor water quality. Phosphorus release from the sediment accelerates when oxygen concentrations drop below 2 mg/L because iron, a natural binder of phosphorus in sediment, becomes reduced and releases phosphorus. As shown in Figure 4, a large area of Medicine Lake's bottom is exposed to low oxygen conditions (anoxia) during the summer months.

The 2006 water column data show a steep gradient of phosphorus between the surface and bottom waters in Medicine Lake that appears to affect surface water concentrations later in the season (Figure 7). The buildup of phosphorus in the bottom waters of Medicine Lake can be transported to the surface through direct transfer (diffusion) or mixing during storms and lake turnover events.



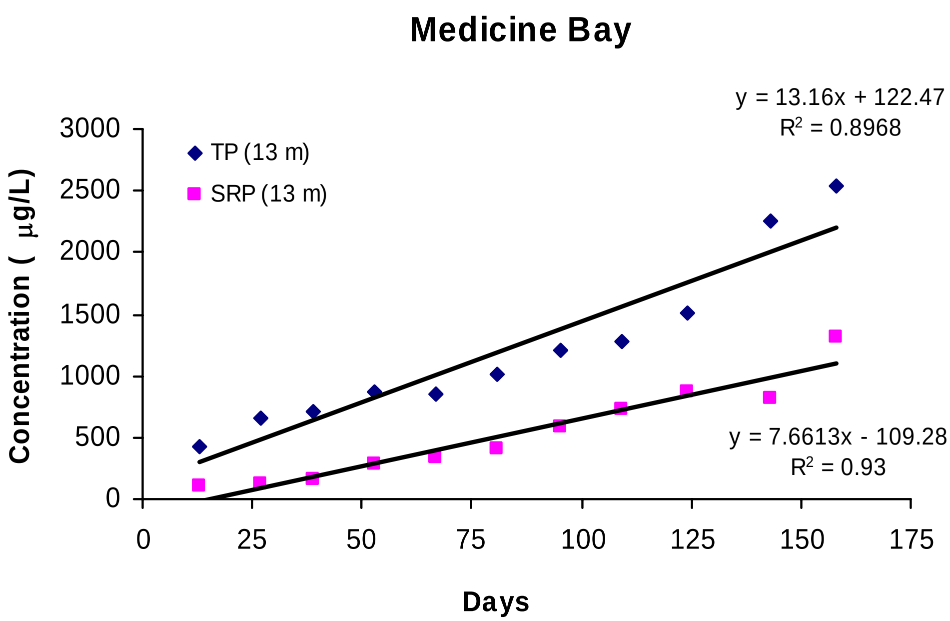
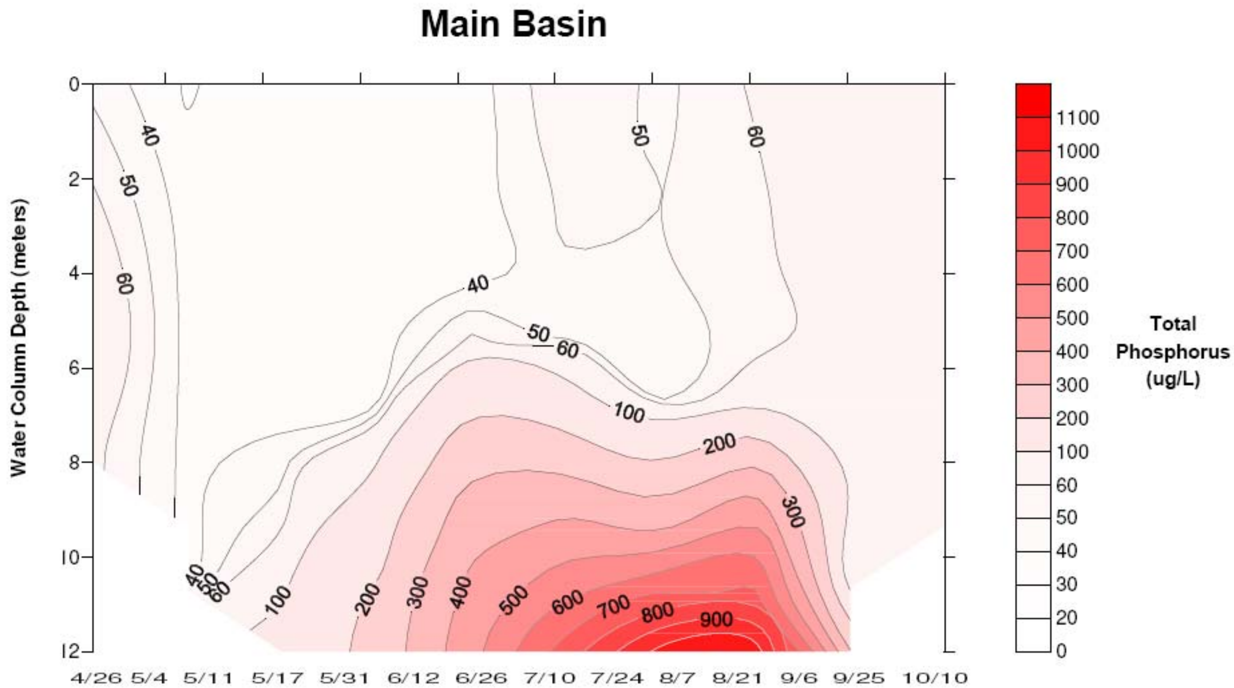


Figure 6 Increase in Hypolimnetic Concentrations of Total and Soluble Reactive Phosphorus in Medicine Lake in 2006



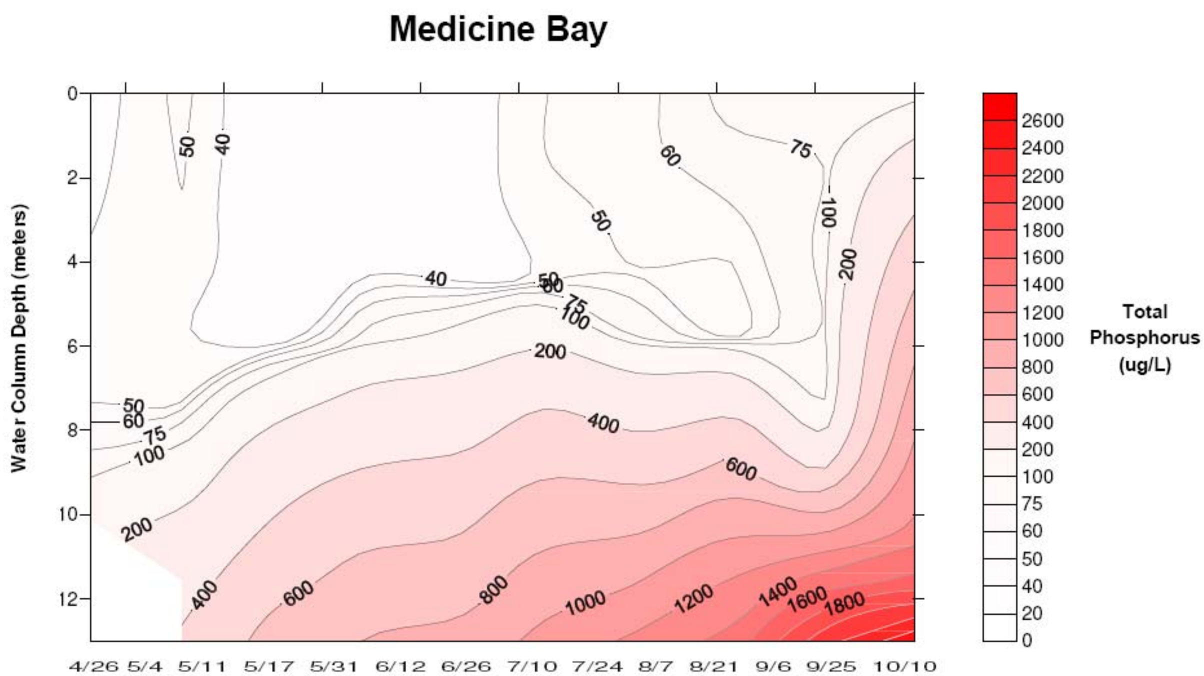


Figure 7 Water Column Total Phosphorus Concentrations During 2006 in Medicine Lake Main Basin and Medicine Bay Areas

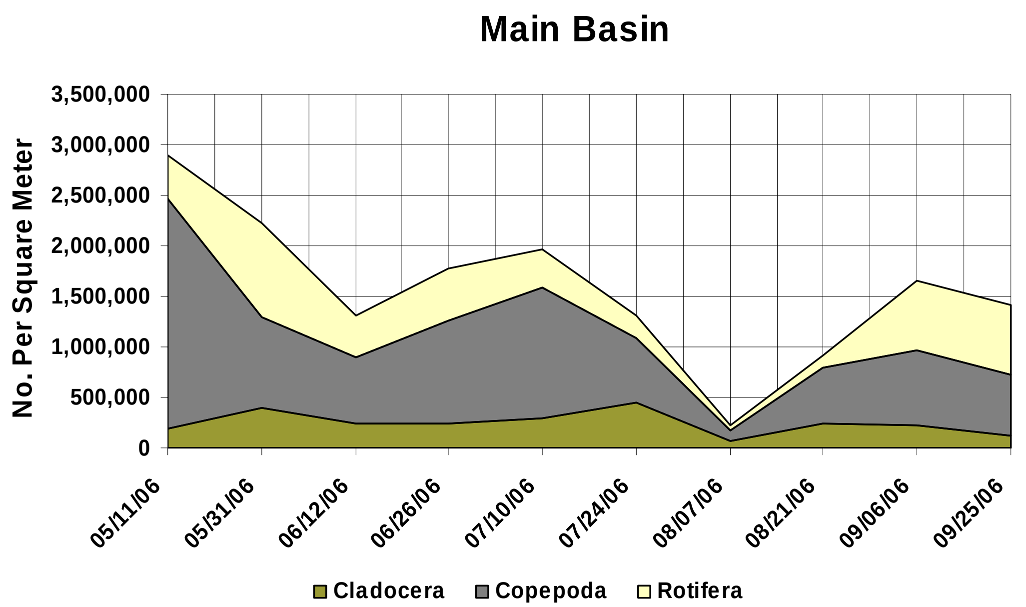
5.0 Recreational Suitability

The Metropolitan Council published a report card for many metro lakes (2005) that did not include Medicine Lake. By extrapolating Medicine Lake water quality to the standards used for lakes in the Metropolitan Council report however, Medicine Lake would have earned a grade of C. Based on 2006 Secchi disc observations, Medicine Lake can be classified as a moderately impaired water body for swimming. A moderately impaired water body occurs at Secchi disc transparencies of 1 to 2 meters; Medicine Lake's mean Secchi depth for June through August 2006 was 1.4 meters.

6.0 Biota

Zooplankton samples were collected from May through September 2006 at two locations; one located in the Main Basin and the other in Medicine Bay (Figure 8). In the Main Basin, total zooplankton population density peaked at nearly 3 million per square meter in the first sample in May. The total population decreased throughout the summer, reaching a low of around 200,000 per square meter in August 2006, before recovering and reaching around 1.4 million per square meter by the end of September. The initial decline in zooplankton is expected when a large population of planktivorous fish is present. High quality algae are food for the zooplankton in the spring and populations of zooplankton increase greatly. Zooplankton are then fed upon by young fish and then the zooplankton populations typically decrease.

The dominant taxa in 2006 were Copepoda and Rotifers, which accounted for between 66 and 93 percent of all zooplankton collected. These are smaller zooplankton that feed primarily on algae and phytoplankton. The large-bodied Cladocera were much less abundant. The lower levels of Cladocera and the decline of the total population of zooplankton throughout the summer indicate that fish are present in large numbers and exert pressure on zooplankton through grazing. Indeed, in 2004 a DNR fish population survey showed that yellow perch, black crappies, and particularly bluegills, are found in large numbers in Medicine Lake.



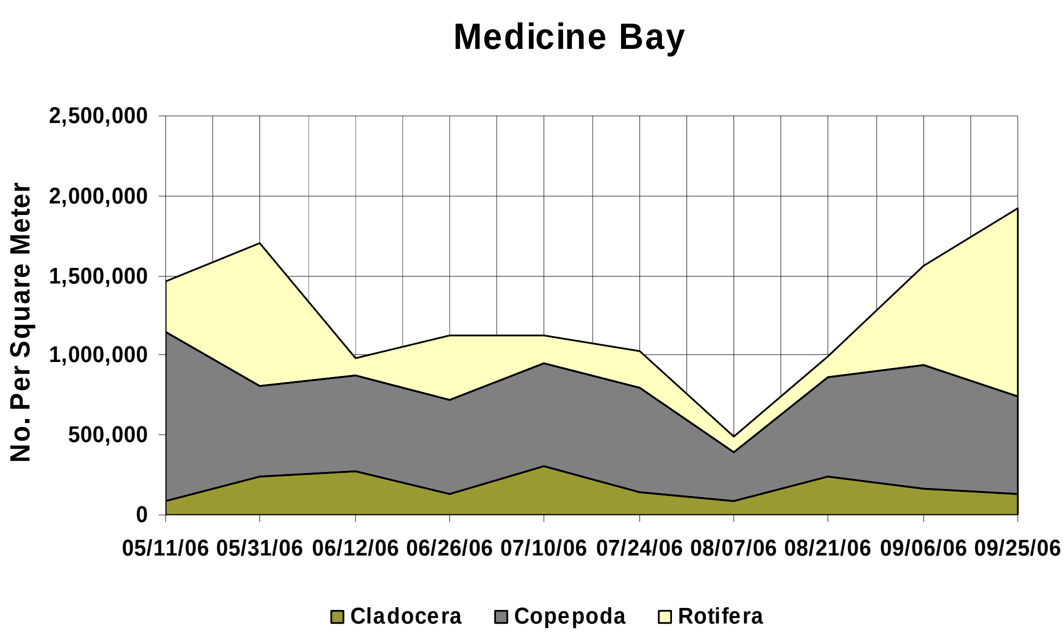


Figure 8 Medicine Lake Zooplankton Populations in 2006

7.0 Conclusions

Water quality in Medicine Lake is variable but appears to have improved somewhat when compared to historical data (i.e., the 40 years of data on record) and the last decade (i.e., 1990 through 2006). However, all three nutrient-related water quality parameters (TP, chlorophyll *a* and Secchi disc depth) did not meet the Commission's goals, or the Type I goals recommended by the State for lakes in this class.

Within season trends for the 2006 monitoring season were evident. Total phosphorus and chlorophyll *a* concentrations were initially elevated in the early spring after turnover and then decreased in May. During the summer months, TP and chlorophyll *a* both increased until reaching a peak near the end of September. Secchi disc depth, which is inversely correlated to both TP and chlorophyll *a*, was low in the early spring and increased in the late spring. Clarity then decreased in the beginning of the summer and declined to less than 1 meter near the end of July and remained near the 1 meter mark (or slightly above) for the remainder of the season.

It is interesting to note that Medicine Lake did not meet water quality goals (i.e., phosphorus levels were high) after lake turnover in early April, 2006. In late April and May, however, Medicine Lake primarily met set targets. Water quality goals were then exceeded for the remainder of the summer. The high nutrient status after spring turnover and later in the summer months is typical of lakes that are affected by internal phosphorus loading. Without additional analysis it is difficult to determine the degree to which internal loading affects lake water quality. However, it may be necessary to directly address internal loading in the future to meet the lake goals.

The Commission and the City have implemented several water quality treatment options recommended in the respective Medicine Lake plans. These improvements have reduced sediment and phosphorus loading to Medicine Lake, reduced shoreline erosion and improved storm water runoff. Several additional projects are proposed during the next five years that are anticipated to be beneficial for Medicine Lake and improve its water quality.

Continued monitoring of phosphorus inputs to Medicine Lake as well as phosphorus in the water column of Medicine Lake (preferably at 1-meter increments from the bottom to the surface) along with other standard parameters (e.g., dissolved oxygen) is recommended to help assess reasons for changes in lake water quality and to develop plans for future lake management and a TMDL study.

References

Bassett Water Management Commission. 1993a. *Draft Water Quality Management Plan*.

Bassett Water Management Commission. 1993b. *Parkers Lake Watershed and Lake Management Plan*.

Bassett Water Management Commission. 1994. *Sweeney Lake Watershed and Lake Management Plan*.

Bassett Water Management Commission. 1996b. *Northwood Lake Watershed and Lake Management Plan*.

Bassett Water Management Commission. 2000. *Twin Lake Watershed and Lake Management Plan.*

Osgood, R.A. 1989a. *An Evaluation of Lake and Stream Monitoring Programs in the Twin Cities Metropolitan Area.* Metropolitan Council Publication No. 590-89-128

Osgood, R.A. 1989b. *A 1989 Study of the Water Quality of 20 Metropolitan Area Lakes.* Metropolitan Council, St. Paul, MN. Publication No. 590-89-129. 12 pp.

Osgood, R.A. 1989c. *Assessment of Lake Use-Impairment in the Twin Cities Metropolitan Area.* Metropolitan Council Publication No. 590-89-130.

Appendix A

Medicine Bay Water Quality Data for 2006

Date	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. (umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P mg/L)	Total N (mg/L)	pH (Std. Units)
4/18/2006	1.14	0	37.8	14.3	11.5	636	58	13	0.9	8.2
		1	---	15.1	11.5	631				8.3
		2	---	15.3	11.5	625				8.4
		3	---	15.3	11.5	622	45	8		8.4
		4	---	15.3	11.4	620				8.5
		5	---	15.2	11.4	617				8.5
		6	---	15.1	9.8	629	53	13		8.5
		6.7	---	0.2	8.2	634				7.9
4/26/2006	2.69	0	4.1	12.6	14.5	603	33	1	0.5	8.1
		1	---	12.7	14.4	603				8.1
		2	---	12.7	14.3	604				8.1
		3	---	12.7	14.2	603				8.1
		4	---	12.7	13.3	603				8.1
		5	---	12.3	12.5	603				8.1
		6	---	7.8	11.1	605				7.8
		7	---	4.1	7.7	664				7.6
		8	---	0.9	4.9	886	49	0	0.9	7.3
		9	---	0.6	3.7	955				7.2
		10	---	0.4	3.5	969				7.1
		11	---	0.4	3.5	979			1.5	7.1
		11.8	---	0.4	3.6	980	186	92		7.1

Medicine Bay Water Quality Data for 2006

Date	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. (umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P mg/L)	Total N (mg/L)	pH (Std. Units)
5/4/2006	3.34	0	0.9	10.2	13.5	640	36	14	0.8	7.8
		1	---	9.1	13.5	636				7.7
		2	---	9.0	13.5	635				7.7
		3	---	9.0	13.5	636				7.6
		4	---	9.0	13.5	636				7.6
		5	---	9.0	13.4	636				7.6
		6	---	8.7	12.7	636				7.6
		7	---	7.8	9.5	710				7.6
		8	---	1.2	5.7	955	52	18		7.3
		9	---	0.8	4.5	1035				7.2
		10	---	0.6	4.2	1057				7.2
		11	---	0.5	3.8	1086				7.1
		12	---	0.4	3.7	1096				7.1
		13	---	0.4	3.7	1100	426	174		7.1
		13.6	---	0.4	3.7	1104				7.0
5/11/2006	3.82	0	6.6	9.3	14.9	584	56	14	0.8	7.1
		1	---	8.9	15.0	584				7.1
		2	---	8.9	15.0	584				7.1
		3	---	8.8	15.0	585				7.2
		4	---	8.8	15.0	586				7.2
		5	---	7.9	14.0	613				7.1
		6	---	6.7	12.6	652				7.1
		7	---	4.3	10.8	694	36	15		7.0
		8	---	0.6	7.3	892	66	51		6.8
		9	---	0.3	5.1	1035				6.7
		10	---	0.2	4.3	1077				6.5
		11	---	0.2	4.2	1084				6.5
		12	---	0.2	4.1	1095				6.5
		13	---	0.2	4.0	1102				6.5
		13.7	---	0.2	3.9	1104				6.3

Medicine Bay Water Quality Data for 2006

Date	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. (umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P mg/L)	Total N (mg/L)	pH (Std. Units)
5/17/2006	3.60	0	10.2	10.6	15.5	601	52	12	0.7	7.2
		1	---	10.5	15.4	601				7.2
		2	---	10.4	15.0	603				7.2
		3	---	10.1	14.6	599				7.2
		4	---	9.8	14.0	600				7.2
		5	---	9.4	13.6	600				7.2
		6	---	8.8	13.1	599				7.2
		7	---	7.1	11.6	622	41	19		7.1
		8	---	1.0	8.0	895	72	31		7.1
		9	---	0.7	5.3	1044				7.1
		10	---	0.5	4.7	1064				7.1
		11	---	0.4	4.4	1086				7.1
		12	---	0.4	4.3	1091				7.1
		13	---	0.4	4.3	1094	428	104		7.1
		13.7	---	0.4	4.3	1115				7.1
5/31/2006	3.71	0	4.9	9.4	23.8	615	23	0	0.6	7.9
		1	---	9.5	23.6	615				7.9
		2	---	9.2	23.4	617				7.9
		3	---	8.8	23.1	616				7.9
		4	---	8.6	21.6	616				7.9
		5	---	8.0	19.8	635	24	2		7.9
		6	---	2.8	15.5	691	22	3		7.7
		7	---	0.8	11.6	897				7.7
		8	---	0.8	8.4	1014				7.8
		9	---	0.7	6.5	1045				7.8
		10	---	0.7	5.8	1068				7.8
		11	---	0.6	5.1	1071				7.8
		12	---	0.5	5.0	1078				7.8
		13	---	0.4	4.9	1080	657	131		7.7
		13.2	---	0.4	4.9	566				7.7

Medicine Bay Water Quality Data for 2006

Date	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. (umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P mg/L)	Total N (mg/L)	pH (Std. Units)
6/12/2006	2.16	0	14.5	9.8	21.5	565	32	1	0.7	8.0
		1	---	9.7	21.1	565				8.0
		2	---	9.4	21.0	566				8.0
		3	---	8.4	20.8	566				8.0
		4	---	8.0	20.7	568				7.9
		5	---	6.8	20.2	577	38	1		7.8
		6	---	1.4	18.3	659	34	2		7.6
		7	---	0.9	11.6	844				7.7
		8	---	1.0	8.5	925				7.7
		9	---	0.8	6.9	963				7.7
		10	---	0.7	5.9	973				7.6
		11	---	0.7	5.5	979				7.6
		12	---	0.6	5.4	984				7.6
		13	---	0.5	5.3	563	707	167		7.5
6/26/2006	1.40	0	17.7	9.8	24.3	563	42	2	0.9	7.9
		1	---	9.8	23.8	563				8.0
		2	---	9.7	23.7	566				8.0
		3	---	9.5	23.5	580				8.1
		4	---	8.1	23.3	601	41	2		8.0
		5	---	3.5	21.9	680	43	3		7.8
		6	---	1.0	19.1	828				7.7
		7	---	0.6	14.6	916				7.7
		8	---	0.6	10.1	985				7.7
		9	---	0.5	8.4	1002				7.6
		10	---	0.5	6.8	1006				7.6
		11	---	0.5	6.3	1010				7.6
		12	---	0.4	6.1	1012				7.5
		13	---	0.4	6.0	544	865	276		7.5
		13.5	---	0.5	5.9	544				7.4

Medicine Bay Water Quality Data for 2006

Date	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. (umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P mg/L)	Total N (mg/L)	pH (Std. Units)
7/10/2006	1.50	0	16.5	8.8	25.3	544	31	8	0.7	8.4
		1	---	8.9	25.2	544				8.5
		2	---	8.8	25.0	544				8.5
		3	---	8.2	24.9	552				8.5
		4	---	8.0	24.8	593	31	4		8.4
		5	---	1.8	23.4	661	35	8		7.9
		6	---	1.0	19.2	790				7.8
		7	---	0.7	15.3	907				7.7
		8	---	0.6	11.2	920				7.6
		9	---	0.4	7.9	955				7.4
		10	---	0.4	7.5	959				7.4
		11	---	0.3	6.6	971				7.3
		12	---	0.3	6.4	544				7.3
		13	---	0.3	6.2	544	855	344		7.1
7/24/2006	1.08	0	24.2	9.3	26.6	544	55	1	1.2	8.6
		1	---	9.8	26.2	544				8.8
		2	---	9.4	26.0	545				8.7
		3	---	6.5	25.3	549				8.5
		4	---	3.0	24.7	552	43	1		8.0
		5	---	0.4	23.9	561	51	2		7.8
		6	---	0.3	21.1	588				7.7
		7	---	0.4	15.7	684				7.6
		8	---	0.4	11.8	806				7.5
		9	---	0.4	9.1	887				7.4
		10	---	0.4	8.1	919				7.4
		11	---	0.3	7.3	947				7.3
		12	---	0.3	6.9	959				7.2
		13	---	0.2	6.7	963	1015	412		7.1

Medicine Bay Water Quality Data for 2006

Date	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. (umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P mg/L)	Total N (mg/L)	pH (Std. Units)
8/7/2006	1.05	0	28.0	9.6	26.6	600	38	1	0.9	8.1
		1	---	9.5	26.4	601				8.2
		2	---	8.7	26.2	601				8.1
		3	---	8.4	26.2	602				8.1
		4	---	7.7	26.1	603	43	1		8.0
		5	---	2.4	25.7	609	38	2		7.5
		6	---	0.7	21.7	661				7.3
		7	---	0.5	18.4	733				7.2
		8	---	0.4	14.2	854				7.1
		9	---	0.4	10.6	959				7.0
		10	---	0.3	9.2	1011				6.9
		11	---	0.3	8.3	1040				6.9
		12	---	0.3	7.8	1054				6.8
		13	---	0.2	7.3	1066	1198	589		6.6
8/21/2006	0.93	0	32.9	11.0	24.2	597	65	7	1.0	8.6
		1	---	10.4	23.8	598				8.7
		2	---	10.1	23.5	602				8.6
		3	---	7.1	23.4	602				8.4
		4	---	5.3	23.3	602				8.2
		5	---	4.9	23.3	623	53	5		8.1
		6	---	0.9	22.3	759	53	9		7.9
		7	---	0.4	17.7	885				7.8
		8	---	0.4	12.9	941				7.6
		9	---	0.3	10.9	996				7.5
		10	---	0.3	9.2	1028				7.5
		11	---	0.3	8.1	1041				7.4
		12	---	0.2	7.7	1045				7.3
		13	---	0.2	7.5	570	1281	733		7.2

Medicine Bay Water Quality Data for 2006

Date	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. (umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P mg/L)	Total N (mg/L)	pH (Std. Units)
9/6/2006	1.42	0	47.7	11.1	22.6	570	86	3	1.2	8.3
		1	---	11.2	22.5	571				8.4
		2	---	8.6	22.2	572				8.3
		3	---	5.8	21.7	567				8.0
		4	---	5.0	21.5	569				7.9
		5	---	3.1	21.0	575	44	9		7.8
		6	---	1.8	20.4	580	47	13		7.6
		7	---	0.8	18.7	639				7.5
		8	---	0.3	12.9	887				7.3
		9	---	0.3	13.0	887				7.3
		10	---	0.2	9.6	974				7.2
		11	---	0.2	8.6	1000				7.2
		12	---	0.2	8.3	1009				7.1
		13	---	0.2	8.0	1019	1509	872		7.1
		13.7	---	0.1	7.8	1056				6.7
9/25/2006	1.46	0	56.1	9.8	15.7	522	82	15	1.0	7.4
		1	---	9.7	15.6	521				7.6
		2	---	9.5	15.5	522				7.7
		3	---	9.4	15.5	522				7.8
		4	---	9.3	15.5	523				7.8
		5	---	9.1	15.5	523				7.9
		6	---	8.8	15.3	528				7.9
		7	---	8.1	15.2	529				7.9
		8	---	6.8	15.0	534	87	29		7.8
		9	---	0.9	11.9	841				7.4
		10	---	0.7	9.9	874				7.4
		11	---	0.6	9.0	895				7.3
		12	---	0.4	8.4	912				7.3
		13	---	0.4	8.2	927	2248	823		7.2
		13.6	---	0.3	7.8	975				7.0

Medicine Bay Water Quality Data for 2006

Date	Secchi Disc (M)	Sample Depth (M)	Chl a (ug/L)	D.O. (mg/L)	Temp. (C)	Specific Cond. (umho/cm @ 25 C)	Total P (mg/L)	Soluble Reactive P mg/L)	Total N (mg/L)	pH (Std. Units)
10/10/2006	1.40	0	50.3	6.2	14.0	550	79	8	1.0	7.9
		1	---	6.0	14.0	550				8.0
		2	---	5.9	14.0	550				8.0
		3	---	5.8	14.0	550				8.1
		4	---	5.8	14.0	550				8.1
		5	---	5.8	14.0	550				8.1
		6	---	5.8	14.0	550				8.1
		7	---	5.8	13.9	552				8.1
		8	---	5.7	13.9	553				8.1
		9	---	5.6	13.7	561				8.1
		10	---	5.5	10.3	911				7.9
		11	---	1.0	8.6	964	1305	1019		7.6
		12	---	0.5	8.3	973				7.4
		13	---	0.3	8.1	990	2547	1311		7.3

Data collected by the Three Rivers Park District

Appendix B

Medicine Bay Zooplankton Populations in 2006

Vertical Tow (m)	05/11/06	05/31/06	06/12/06	06/26/06	07/10/06	07/24/06	08/07/06	08/21/06	09/06/06	09/25/06
TAXON	#/m2	#/m2	#/m2	#/m2	#/m2	#/m2	#/m2	#/m2	#/m2	#/m2
Bosmina longirostris	20,425	60,479	105,042	47,746	85,413	9,726	4,067	11,141	4,863	11,495
Ceriodaphnia sp.	0	0	0	0	0	4,863	4,067	0	4,863	17,242
Chydorus sphaericus	0	20,160	42,972	28,648	103,981	9,726	0	7,427	19,452	5,747
Daphnia ambigua	0	0	0	0	0	0	0	0	0	0
Daphnia galeata mendotae	61,275	141,117	119,366	33,423	66,845	34,041	4,067	18,568	38,905	57,473
Daphnia pulex	6,808	15,120	0	4,775	0	0	0	0	0	0
Daphnia retrocurva	0	0	4,775	4,775	25,995	53,494	28,471	163,399	72,946	22,989
Diaphanosoma leuchtenbergianum	0	5,040	0	14,324	25,995	34,041	44,740	37,136	9,726	11,495
Immature Cladocera	0	0	0	0	0	0	4,067	0	9,726	0
CLADOCERA TOTAL	**88,508**	**241,916**	**272,155**	**133,690**	**308,230**	**145,892**	**89,480**	**237,671**	**160,481**	**126,440**
Cyclops sp.	279,140	65,519	62,070	133,690	85,413	48,631	52,875	118,836	82,672	97,703
Diaptomus sp.	217,865	171,357	238,732	124,141	137,404	141,029	56,942	115,122	82,672	91,956
Nauplii	558,280	327,594	305,577	329,451	415,925	461,991	195,230	389,930	607,883	431,045
Copepodid	0	0	0	4,775	0	0	0	0	0	0
COPEPODA TOTAL	**1,055,286**	**564,470**	**606,380**	**592,056**	**638,742**	**651,651**	**305,047**	**623,887**	**773,228**	**620,704**
Asplanchna priodonta	6,808	599,749	0	0	3,714	43,768		0	0	0
Brachionus sp.	0	0	0	0	0	0	4,067	0	0	0
Filinia longiseta	0	0	0	0	0	9,726	0	0	0	0
Lecane sp.	0	80,639	0	186,211	3,714	14,589	4,067	11,141	9,726	63,220
Keratella cochlearis	204,249	30,239	33,423	133,690	111,408	92,398	12,202	77,986	398,772	850,595
Keratella quadrata	81,700	65,519	19,099	14,324	3,714	0	0	0	0	0
Kellicottia bostoniensis	27,233	115,918	42,972	52,521	25,995	43,768	61,009	22,282	189,660	247,132
Polyarthra vulgaris	0	0	0	9,549	18,568	19,452	8,135	3,714	19,452	5,747
Trichocerca cylindrica	0	0	0	0	3,714	0	4,067	14,854	4,863	5,747
Trichocerca multicrinis	0	0	4,775	0	3,714	0	0	0	0	0
ROTIFERA TOTAL	**319,990**	**892,063**	**100,268**	**396,296**	**174,540**	**223,701**	**93,548**	**129,977**	**622,473**	**1,172,441**
TOTALS	**1,463,783**	**1,698,449**	**978,803**	**1,122,042**	**1,121,512**	**1,021,244**	**488,075**	**991,535**	**1,556,182**	**1,919,585**
Cladocera	88,508	241,916	272,155	133,690	308,230	145,892	89,480	237,671	160,481	126,440
Copepoda	1,055,286	564,470	606,380	592,056	638,742	651,651	305,047	623,887	773,228	620,704
Rotifera	319,990	892,063	100,268	396,296	174,540	223,701	93,548	129,977	622,473	1,172,441

Main Basin Zooplankton Populations in 2006

Vertical Tow (m) TAXON	05/11/06 #/m2	05/31/06 #/m2	06/12/06 #/m2	06/26/06 #/m2	07/10/06 #/m2	07/24/06 #/m2	08/07/06 #/m2	08/21/06 #/m2	09/06/06 #/m2	09/25/06 #/m2
Bosmina longirostris	12,909	54,643	123,080	40,673	44,563	25,995	0	12,732	20,160	36,782
Ceriodaphnia sp.	0	9,107	0	0	0	4,333	0	0	10,080	13,793
Chydorus sphaericus	0	0	20,513	65,077	55,704	34,660	0	0	10,080	0
Daphnia ambigua	0	0	0	0	0	0	0	0	0	0
Daphnia galeata mendotae	180,729	309,645	92,310	44,740	94,697	99,649	3,272	4,244	5,040	27,587
Daphnia pulex	0	0	0	0	11,141	0	0	0	0	0
Daphnia retrocurva	0	0	0	4,067	50,134	181,967	22,901	169,765	161,277	32,185
Diaphanosoma leuchtenbergianum	0	9,107	10,257	81,346	33,423	95,316	35,987	55,174	10,080	13,793
Immature Cladocera	0	18,214	0	0	0	0	0	0	0	0
CLADOCERA TOTAL	**193,639**	**400,717**	**246,160**	**235,903**	**289,662**	**441,920**	**62,159**	**241,916**	**216,716**	**124,141**
Cyclops sp.	497,006	109,286	76,925	321,316	144,831	64,988	11,450	97,615	120,958	73,565
Diaptomus sp.	477,642	236,787	107,695	162,692	167,113	134,309	34,351	123,080	85,678	87,358
Nauplii	1,290,923	546,432	461,549	524,681	991,535	446,253	68,702	335,286	544,310	432,194
Copepodid	0	0	0	8,135	0	0	1,636	0	5,040	0
COPEPODA TOTAL	**2,265,571**	**892,506**	**646,169**	**1,016,823**	**1,303,479**	**645,550**	**116,139**	**555,981**	**755,986**	**593,117**
Asplanchna priodonta	6,455	528,218	0	0	0	4,333	0	0	0	0
Brachionus sp.	0	0	0	0	0	0	0	0	0	0
Filinia longiseta	6,455	0	10,257	337,585	0	12,998	0	0	0	0
Lecane sp.	19,364	63,750	205,133	0	0	0	6,543	16,977	20,160	55,174
Keratella cochlearis	103,274	54,643	82,053	105,750	50,134	168,969	16,358	80,639	196,556	501,161
Keratella quadrata	232,366	127,501	35,898	12,202	0	0	0	0	0	0
Kellicottia bostoniensis	71,001	118,394	66,668	24,404	317,514	17,330	17,993	21,221	453,592	137,934
Polyarthra vulgaris	0	36,429	5,128	16,269	5,570	21,663	1,636	0	15,120	4,598
Trichocerca cylindrica	0	0	5,128	0	0	0	0	0	0	0
Trichocerca multicrinis	0	0	0	24,404	0	0	0	0	5,040	4,598
ROTIFERA TOTAL	**438,914**	**928,934**	**410,266**	**520,614**	**373,218**	**225,293**	**42,530**	**118,836**	**690,467**	**703,465**
TOTALS	**2,898,123**	**2,222,157**	**1,302,595**	**1,773,340**	**1,966,359**	**1,312,763**	**220,827**	**916,732**	**1,663,169**	**1,420,723**
Cladocera	193,639	400,717	246,160	235,903	289,662	441,920	62,159	241,916	216,716	124,141
Copepoda	2,265,571	892,506	646,169	1,016,823	1,303,479	645,550	116,139	555,981	755,986	593,117
Rotifera	438,914	928,934	410,266	520,614	373,218	225,293	42,530	118,836	690,467	703,465

Appendix C

Sample Collection

The epilimnetic sample at each lake's central sampling site was collected with a 0 to 2-meter integrated composite sampler. Additional samples were collected for total and soluble reactive phosphorus above and below the thermocline and at 1/2-meter above the lake bottom.

Zooplankton samples were collected with a Wisconsin-type net towed vertically from just above the lake bottom to the surface.

At every sample site, the following parameters were measured at 1-meter depth intervals:

- Water temperature
- Dissolved oxygen concentration
- Specific electrical conductivity
- pH
- Secchi disc transparencies were also measured at each site.

Samples were collected by the Three Rivers Park District in 2006.

Chemical Analyses

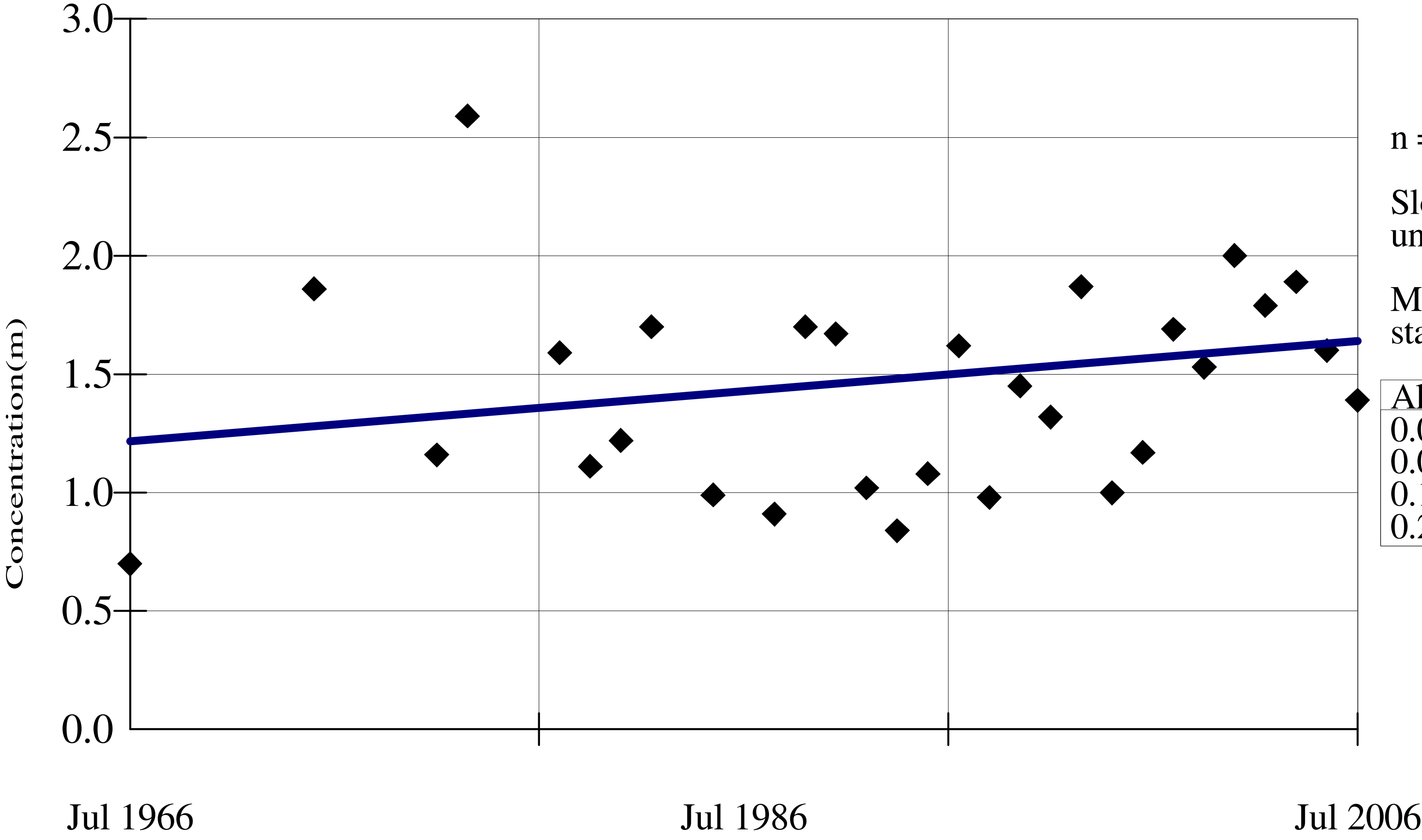
Procedures for the chemical analyses are presented in the accompanying table.

Table C-1 Procedures for Chemical Analysis Performed on Water Samples

Analysis	Procedure	Reference
Total Phosphorus	Persulfate digestion, manual ascorbic acid	Standard Methods, 16th Edition, 1985, 424 C.III, 424F, and Eisenreich, et al., Environmental Letters 9(1), 43-53 (1975)
Ortho Phosphorus	Manual ascorbic acid	Standard Methods, 16th Edition, 1985, 424F(1985) and Eisenreich, et al., Environmental Letters 9(1), 43-53 (1975)
Total Kjeldahl Nitrogen	Semi-automated	Jirka, et al., Environ. Science and Technology 10:1038-1044, (1976) and Standard Methods, 15th Edition, 1980, 424E
Chlorophyll *a*	Spectrophotometric	Standard Methods, 16th Edition, 1985, 1002G
pH	Potentiometric measurement, glass electrode	Standard Methods, 16th Edition, 1985, 423
Specific Conductance	Wheatstone bridge	Standard Methods, 16th Edition, 1985, 205
Temperature	Thermometric	Standard Methods, 16th Edition, 1985, 212
Dissolved Oxygen	Electrode	Standard Methods, 16th Edition, 1985, 421F
Zooplankton Identification and Enumeration	Sedgewick Rafter	Standard Methods, 16th Edition, 1985, 1002F (7)
Transparency	Secchi disc	

Appendix D

SEN'S SLOPE ESTIMATOR
Medicine



n = 29

Slope = 0.011
units per year.

Mann Kendall
statistic = 65

Alpha	Critical	Signif.
0.01	139	No
0.05	106	No
0.1	90	No
0.2	70	No

Constituent: SD (m)

Facility: Lake Trend Analysis

Data File: MEDICI~2

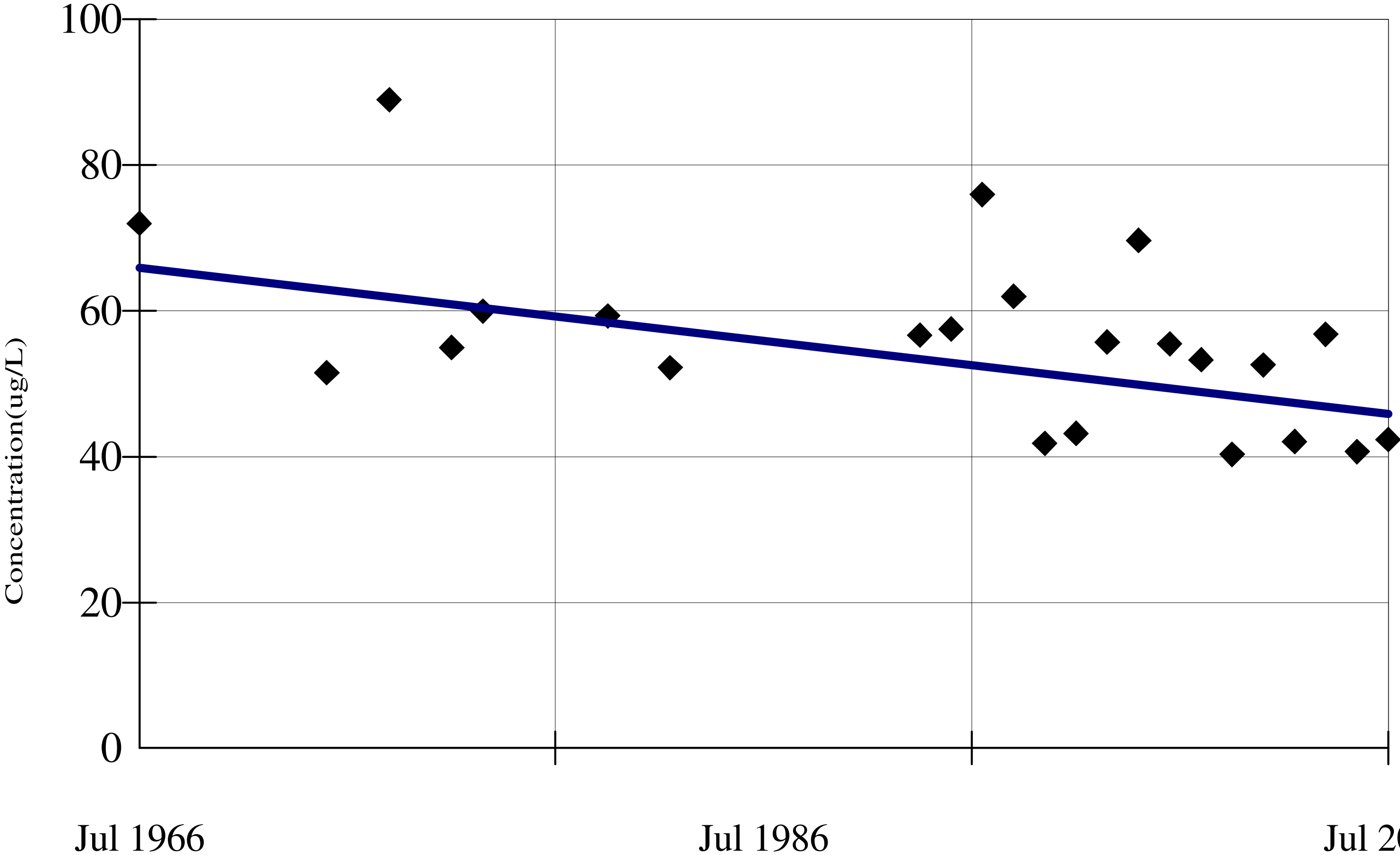
Date: 1/22/07

Time: 3:46 PM

View: Med2SD

v.1.56. CAS# n/a WQStat Plus™

SEN'S SLOPE ESTIMATOR
Medicine



n = 23

Slope = -0.5
units per year.

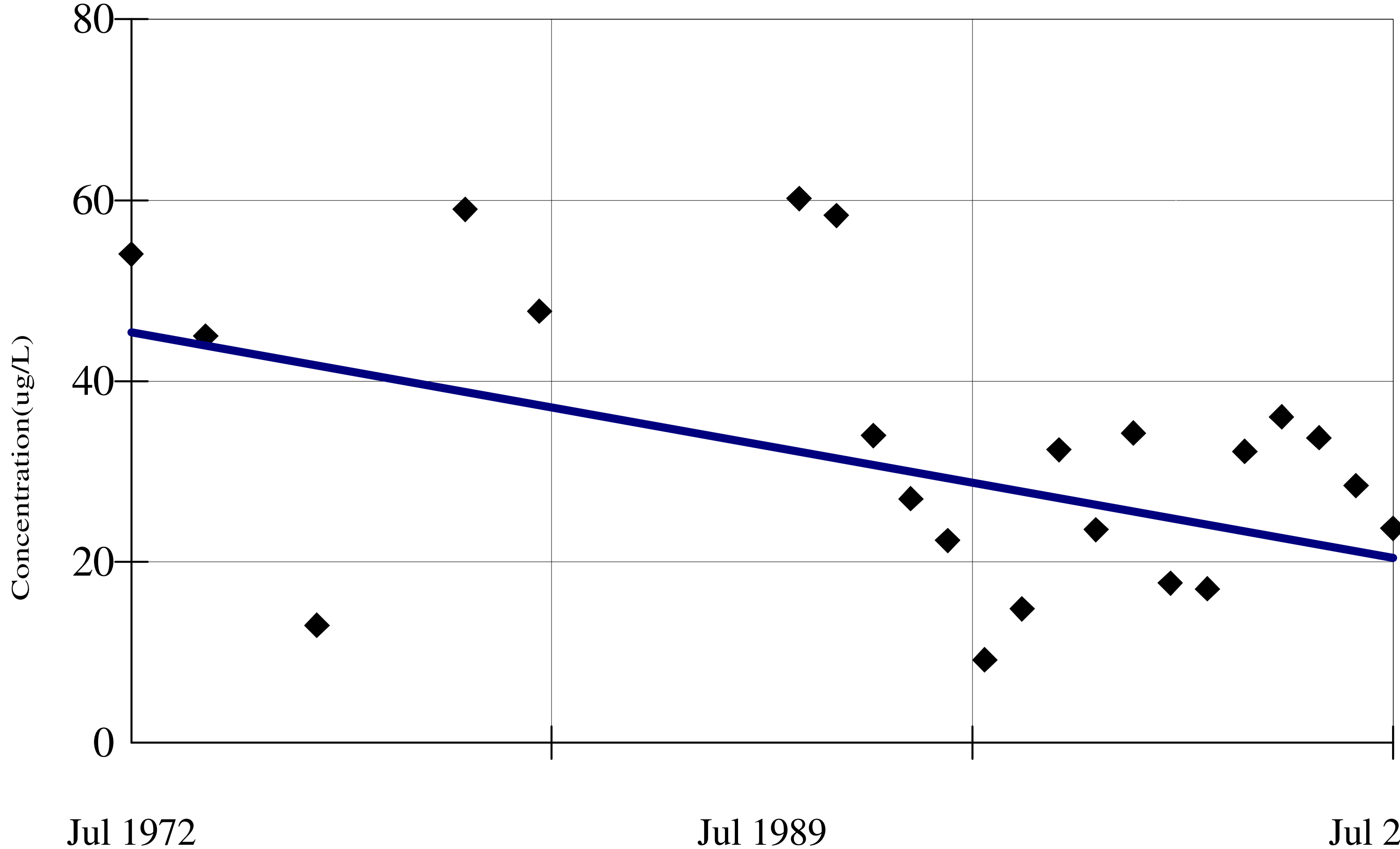
Mann Kendall
statistic = -93

Alpha	Critical	Signif.
0.01	-98	No
0.05	-76	Down
0.1	-64	Down
0.2	-50	Down

Constituent: TP (ug/L) Facility: Lake Trend Analysis Data File: MEDICI~2

Date: 1/22/07 Time: 3:56 PM View: Med2TP

SEN'S SLOPE ESTIMATOR
Medicine



n = 22

Slope = -0.733
units per year.

Mann Kendall
statistic = -57

Alpha	Critical	Signif.
0.01	-92	No
0.05	-71	No
0.1	-60	No
0.2	-47	Down

Constituent: Chl a (ug/L)

Facility: Lake Trend Analysis

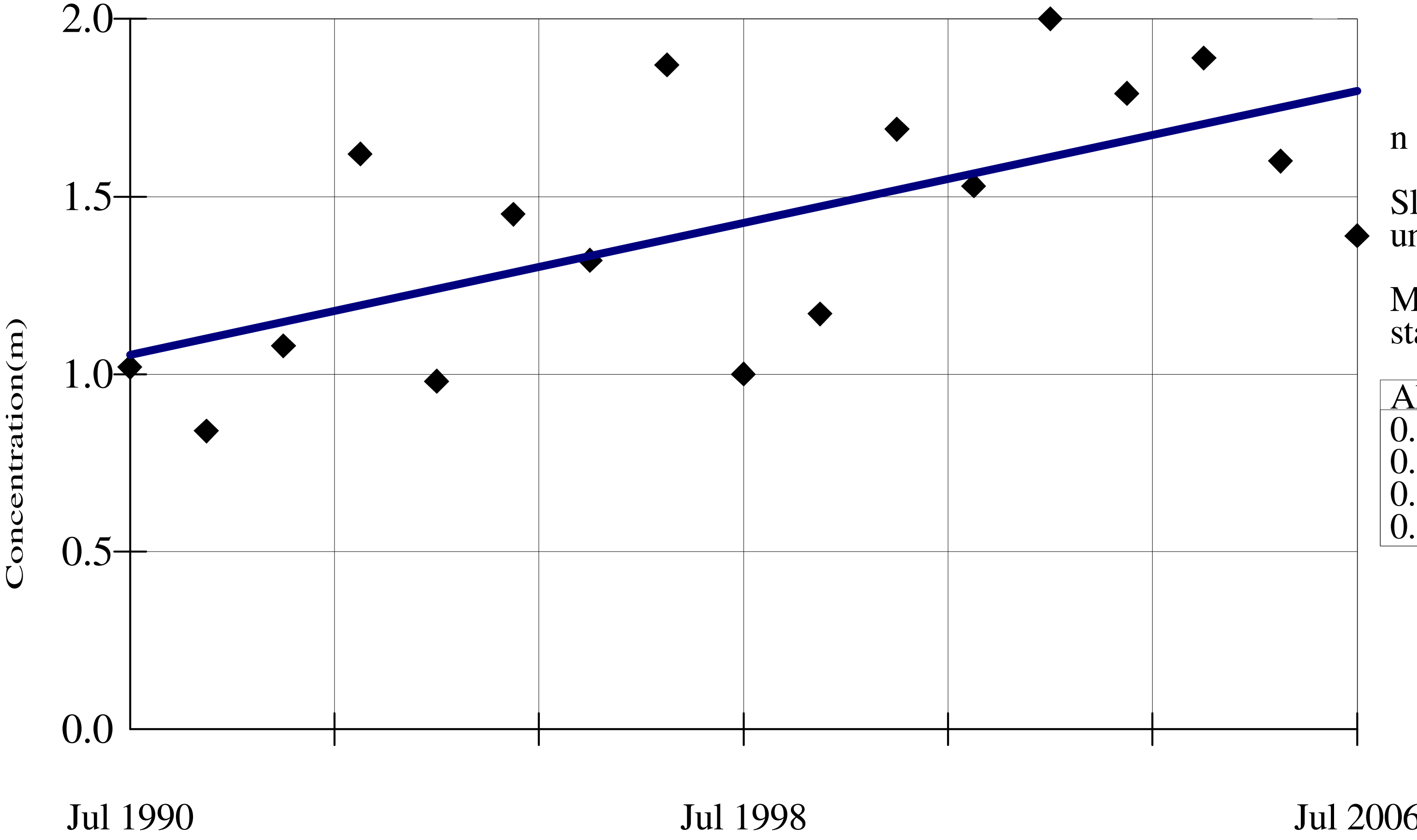
Data File: MEDICI~2

Date: 1/22/07

Time: 3:59 PM

View: Med2Chl

SEN'S SLOPE ESTIMATOR
Medicine



n = 17

Slope = 0.046 units per year.

Mann Kendall statistic = 58

Alpha	Critical	Signif.
0.01	63	No
0.05	49	Up
0.1	42	Up
0.2	33	Up

Constituent: SD (m)

Facility: Lake Trend Analysis

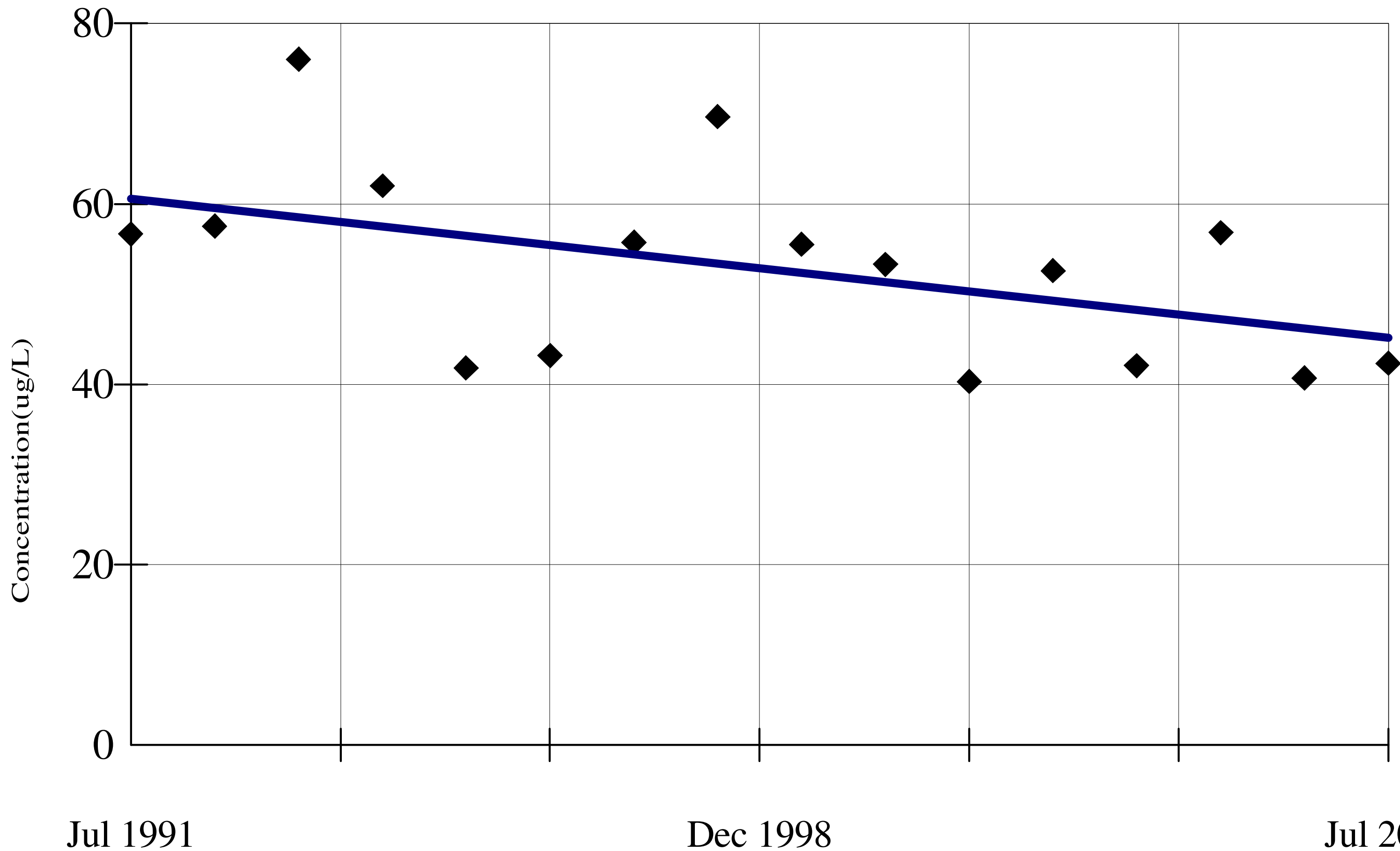
Data File: MEDICI~1

Date: 1/22/07

Time: 4:58 PM

View: Med1SD

SEN'S SLOPE ESTIMATOR
Medicine



n = 16

Slope = -1.028 units per year.

Mann Kendall statistic = -46

Alpha	Critical	Signif.
0.01	-58	No
0.05	-45	Down
0.1	-38	Down
0.2	-30	Down

Constituent: TP (ug/L)

Facility: Lake Trend Analysis

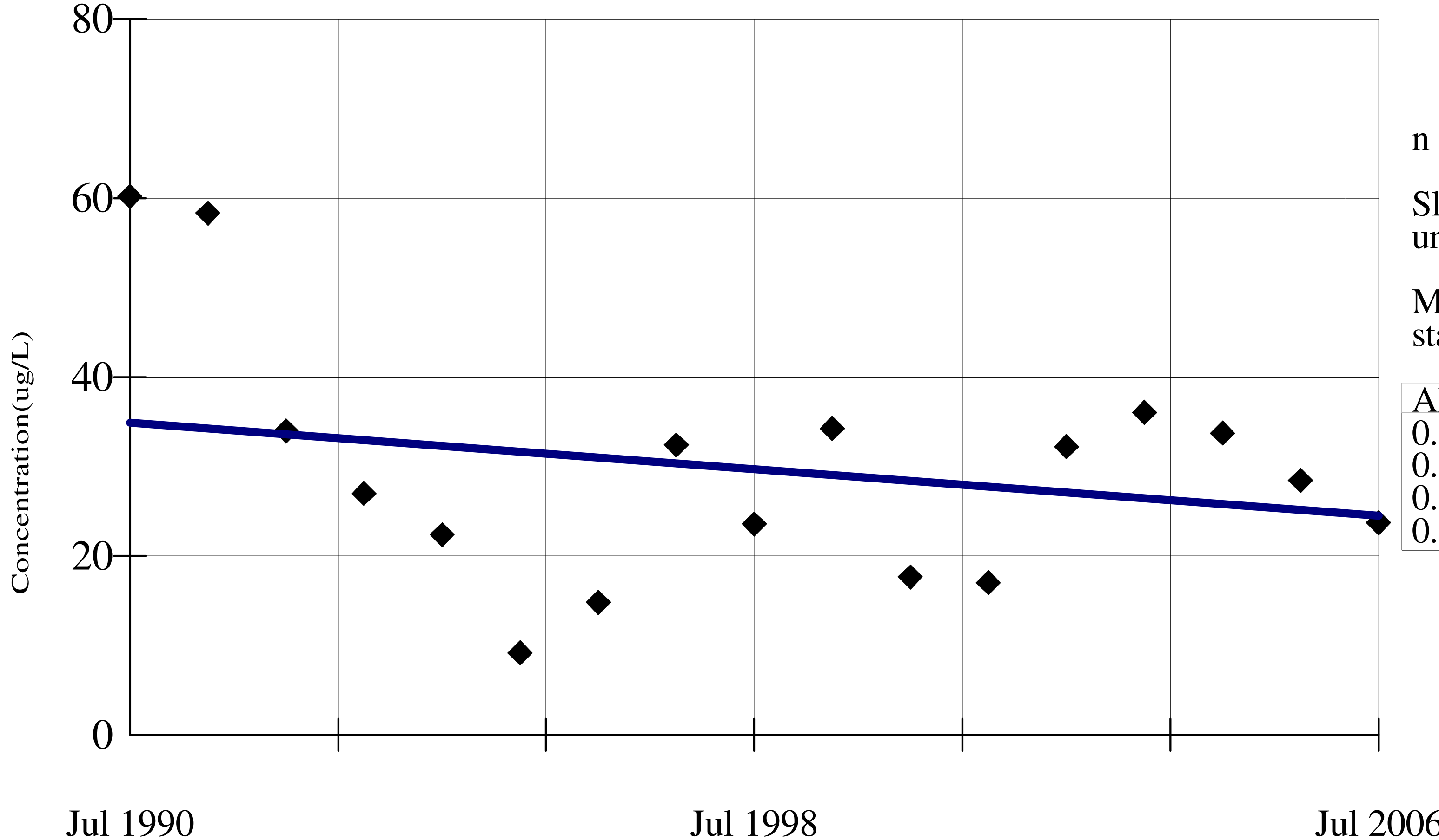
Data File: MEDICI~1

Date: 1/22/07

Time: 4:49 PM

View: Med1TP

SEN'S SLOPE ESTIMATOR
Medicine



n = 17

Slope = -0.651
units per year.

Mann Kendall
statistic = -18

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	No
0.1	-42	No
0.2	-33	No

Constituent: Chl a (ug/L) Facility: Lake Trend Analysis Data File: MEDICI~1

Date: 1/22/07 Time: 4:59 PM View: Med1Chl