6.0 Existing Water Quality

6.1 Water Quality

6.1.1 Data Collection

To support development of this UAA, the NMCWD collected water quality data in Wing Lake and the City of Minnetonka collected water quality data in Lake Holiday and Lake Rose in 2008. The City of Minnetonka has collected water quality data from Lake Holiday, Wing Lake, and Lake Rose in 1993, 1999, 2000, 2003, and 2006 as part of their ongoing water quality monitoring program. Additionally, the Metropolitan Council's Citizen-Assisted Monitoring Program (CAMP) also collected water quality data from Wing Lake and Lake Rose in 2007 and 2008. The water quality data was typically collected between late-April and early-September. Summer-average values were calculated from the data for June through September.

The NMCWD and City of Minnetonka's monitoring in 2008 were intensive water quality sampling efforts to document conditions within Lake Holiday, Wing Lake, and Lake Rose to assist in the calibration of the water quality models used in the UAA. Several water quality indices were evaluated in the 2008 monitoring, including temperature, dissolved oxygen (DO), pH, specific conductivity (conductivity), total phosphorus (TP), chlorophyll *a* (Chl *a*), and Secchi disc transparency (transparency). Temperature, DO, and conductivity were measured at the surface and depths of 1.0 and 1.5 meters in Lake Holiday and Wing Lake. Total phosphorus was measured between zero and 2.0 meters in Lake Holiday and Wing Lake. In Lake Rose, temperature, DO, and conductivity were measured at the surface and depths of 1.0, 2.0, 3.0, and 3.5 to 3.7 meters to allow characterization of the lake's stratification profiles. Total phosphorus in Lake Rose was measured between zero and 2.0 meters, again at a depth of 3.0 meters, and again at the bottom of the lake (between 3.5 and 3.7 meters). TP and pH were measured near the water surface for each sampling event.

Water quality data collected by the CAMP program typically includes TP and Chl *a* at the water surface along with transparency. Additionally, physical observations of the lake are recorded on the sampling date.

TP, Chl *a*, and transparency are the key determinants of water quality and eutrophic state for the lakes (see Section 2.0 for further discussion). The 2008 sampling results for TP, Chl *a*, and transparency are summarized in Table 6-1, Table 6-2, and Table 6-3 for Lake Holiday, Wing Lake, and Lake Rose, respectively. The 2008 sampling results for these three water quality parameters are presented graphically on Figure 6-1 for Lake Holiday, Figure 6-2 for Wing Lake, and Figure 6-3 for Lake Rose.

Because recreational use is greatest during the summer months (June, July, August, and September), and because it is during these times that algal blooms and diminished transparency are most common, attention is usually focused on summer water quality in the upper (epilimnetic) portions of the lake. Figure 6-4, Figure 6-5, and Figure 6-6 show the historic summer-average TP concentrations, Chl *a* concentrations, and transparency data from 1993 through 2008 for Lake Holiday, Wing Lake, and Lake Rose, respectively.

In 2008, the epilimnetic summer-average concentrations for TP, Chl *a*, and transparency values in Lake Holiday were 338 µg/L, 195 µg/L, and 0.5 meters, respectively. For Wing Lake, the 2008 epilimnetic summer-averages for TP, Chl *a,* and transparency were 99 µg/L, 39 µg/L, and 1.1 meters, respectively. For Lake Rose, the 2008 epilimnetic summer-averages for TP, Chl *a,* and transparency were 88 µg/L, 59 µg/L, and 1.1 meters, respectively.

When comparing the three key water quality parameters, Lake Holiday has much poorer water quality than Wing Lake and Lake Rose with respect to all three parameters. The long-term (1993-2008) summer-average Secchi depth in Lake Holiday is 0.4 meters, compared to long-term summer-average Secchi depth of 0.8 meters for Wing Lake and Lake Rose. Similarly, the long-term summer-average total phosphorus concentration in Lake Holiday (247 µg/L) is more than double the long-term summer-average TP concentrations in Wing Lake (108 µg/L) and Lake Rose (95 µg/L). In comparing Wing Lake and Lake Rose, the water quality in Lake Rose is marginally better than Wing Lake. The 2008 summer-average TP, Chl *a,* and transparency observed in 2008 place Lake Holiday in the hypereutrophic category. This characterization means that by comparison to other lakes, Lake Holiday is rich in algal nutrients, susceptible to dense algal blooms, and exhibits poor water clarity. The 2008 summer-average TP and Chl *a* concentrations place Wing Lake and Lake Rose in the hypereutrophic category also, although the summer-average Secchi depths observed in 2008 for each lake are classified as eutrophic.

Table 6-1 Lake Holiday 2008 Water Quality Data (City of Minnetonka)

Sample Date	Epilimnetic Total Phosphorus Concentration (µg/L)	Epilimnetic Chlorophyll-*a* Concentration (µg/L)	Secchi Depth (m)	Summer-average Epilimnetic Total Phosphorus Concentration (µg/L)	Summer-average Epilimnetic Chlorophyll-*a* Concentration (µg/L)	Summer-average Secchi Depth (m)
Holiday Lake [1]						
5/1/2008	73	12	1.2	338	195	0.5
6/17/2008	320	1	1.3			
7/17/2008	150	23	0.8			
8/5/2008	430	150	0.2			
8/19/2008	420	590	0.2			
9/4/2008	370	210	0.3			

[1] Water quality data includes City of Minntonka sampling

Table 6-2 Wing Lake 2008 Water Quality Data (NMCWD and CAMP)

Sample Date	Epilimnetic Total Phosphorus Concetration (µg/L)	Epilimnetic Chlorophyll-*a* Concentration (µg/L)	Secchi Depth (m)	Summer-average Epilimnetic Total Phosphorus Concentration (µg/L)	Summer-average Epilimnetic Chlorophyll-*a* Concentration (µg/L)	Summer-average Secchi Depth (m)
Wing Lake[1]						
4/23/2008	50	8	1.4	99	39	1.1
4/30/2008	41	13	2.1			
5/17/2008	76	3	1.1			
6/1/2008	49	5	1.35			
6/15/2008	47	5	1.5			
6/16/2008 [2]	46	4	1.5			
6/29/2008	53	12	1.5			
7/13/2008	52	10	1.4			
7/17/2008 [2]	100	40	1.7			
8/5/2008 [3]	110	44	0.8			
8/11/2008	110	40	0.9			
8/19/2008 [2]	150	55	0.8			
8/26/2008	154	98	0.7			
9/5/2008 [2]	160	45	0.6			
9/10/2008	132	80	0.8			
9/26/2008	125	66	0.7			
10/12/2008	98	43	1.0			

[1] Water quality data is from NMCWD monitoring unless otherwise specified

[2] Data from CAMP monitoring

[3] NMCWD and CAMP data sampled on 8/5/08. NMCWD data presented in table above.

Table 6-3 Lake Rose 2008 Water Quality Data (City of Minnetonka and CAMP)

Sample Date	Epilimnetic Total Phosphorus Concetration (µg/L)	Epilimnetic Chlorophyll-*a* Concentration (µg/L)	Secchi Depth (m)	Summer-average Epilimnetic Total Phosphorus Concentration (µg/L)	Summer-average Epilimnetic Chlorophyll-*a* Concentration (µg/L)	Summer-average Secchi Depth (m)
Lake Rose [1]						
5/1/2008 [2]	57	8	1.6	88	59	1.1
5/4/2008	51	13	1.5			
5/16/2008	44	7	1.2			
5/31/2008	37	3	1.4			
6/15/2008	34	3	1.6			
6/17/2008 [2]	30	4	1.8			
6/27/2008	33	7	1.2			
7/10/2008	47	15	0.9			
7/17/2008 [2]	54	5	1.7			
7/25/2008	180	170	0.4			
8/5/2008 [3]	70	24	1.1			
8/19/2008 [2]	240	260	1.2			
8/23/2008	104	75	0.6			
9/4/2008	84	35	1.0			
9/6/2008 [2]	106	48	0.4			
9/20/2008	72	60	0.8			
10/4/2008	59	26	1.0			
10/16/2008	63	32	0.8			

[1] Water quality data is from City of Minnetonka monitoring unless otherwise specified

[2] Data from CAMP monitoring

[3] City of Minnetonka and CAMP data sampled on 8/5/08. City of Minnetonka data presented in table above.

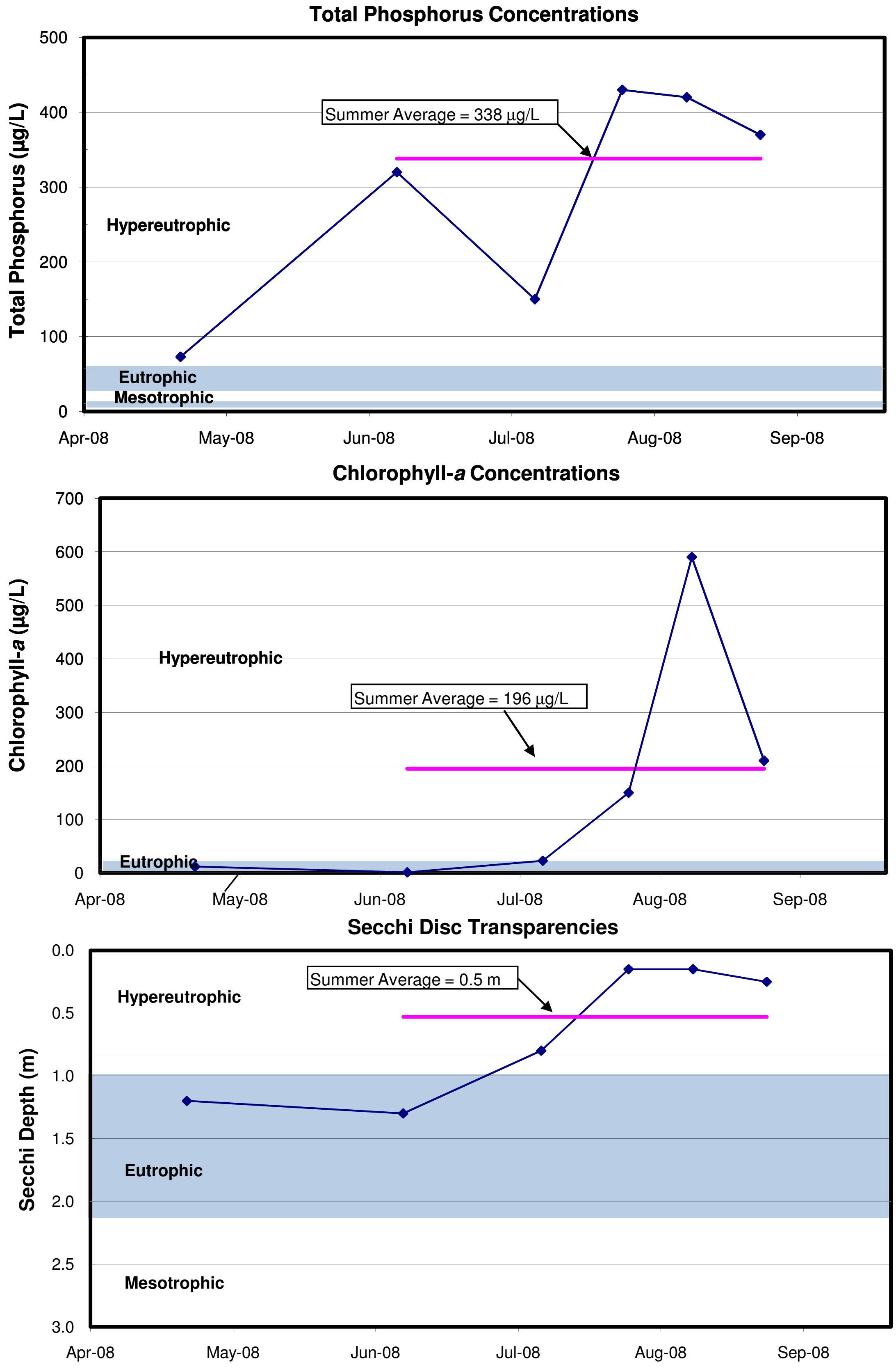
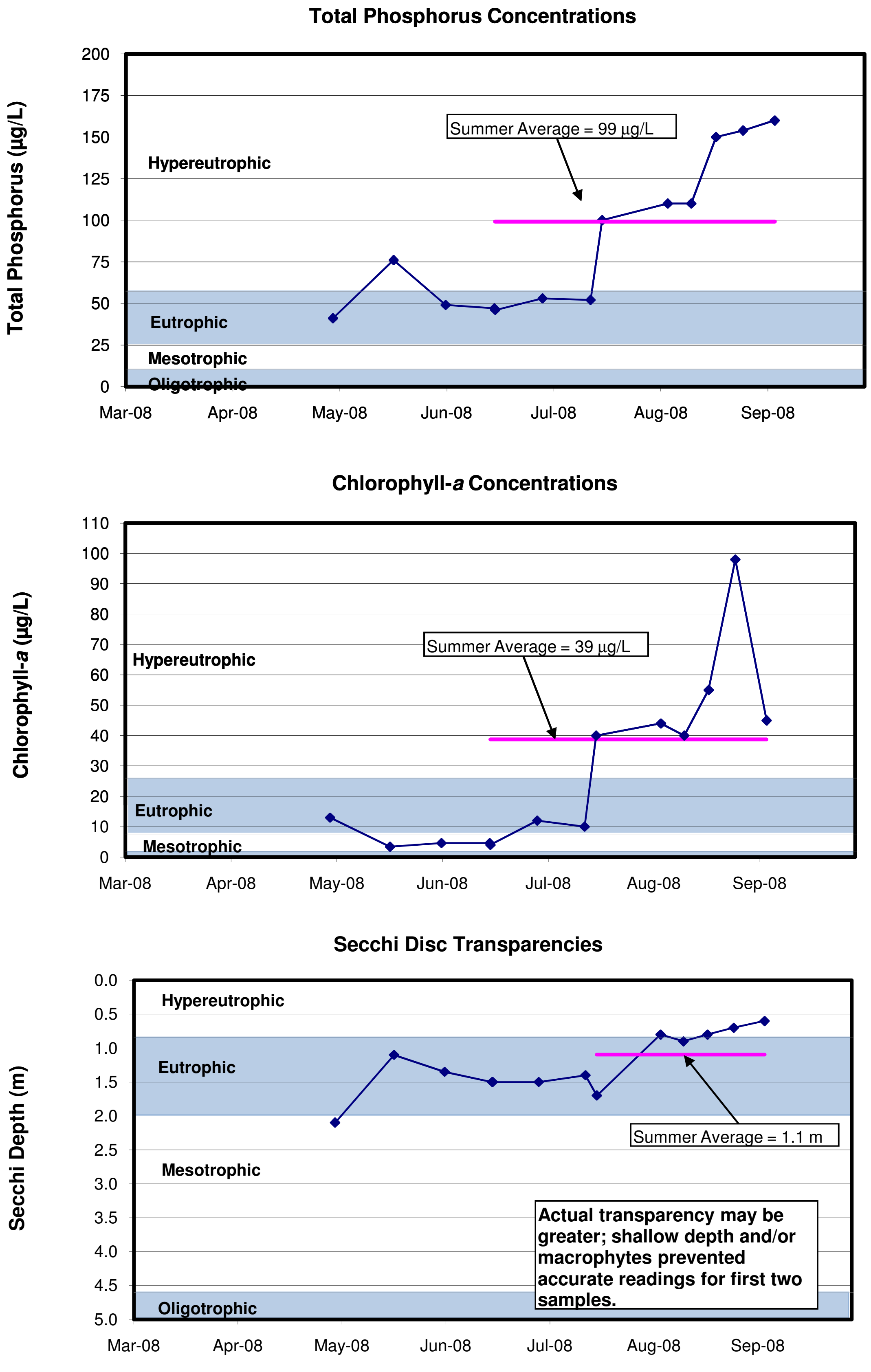


Figure 6-1
Lake Holiday 2008 Seasonal Changes in Concentrations of Total Phosphorus, Chlorophyll-*a* and Secchi Depth



Actual transparency may be greater; shallow depth and/or macrophytes prevented accurate readings for first two samples.

Figure 6-2
Wing Lake 2008 Seasonal Changes in Concentrations of Total Phosphorus, Chlorophyll-*a* and Secchi Depth

ls\23 MN\27\2327634\WorkFiles\Holiday_Wing_Rose UAA\2008 WQ Data\Wing Lake WQ08 Data from NMCWD_SGWFig 6-2 Wing WQ08

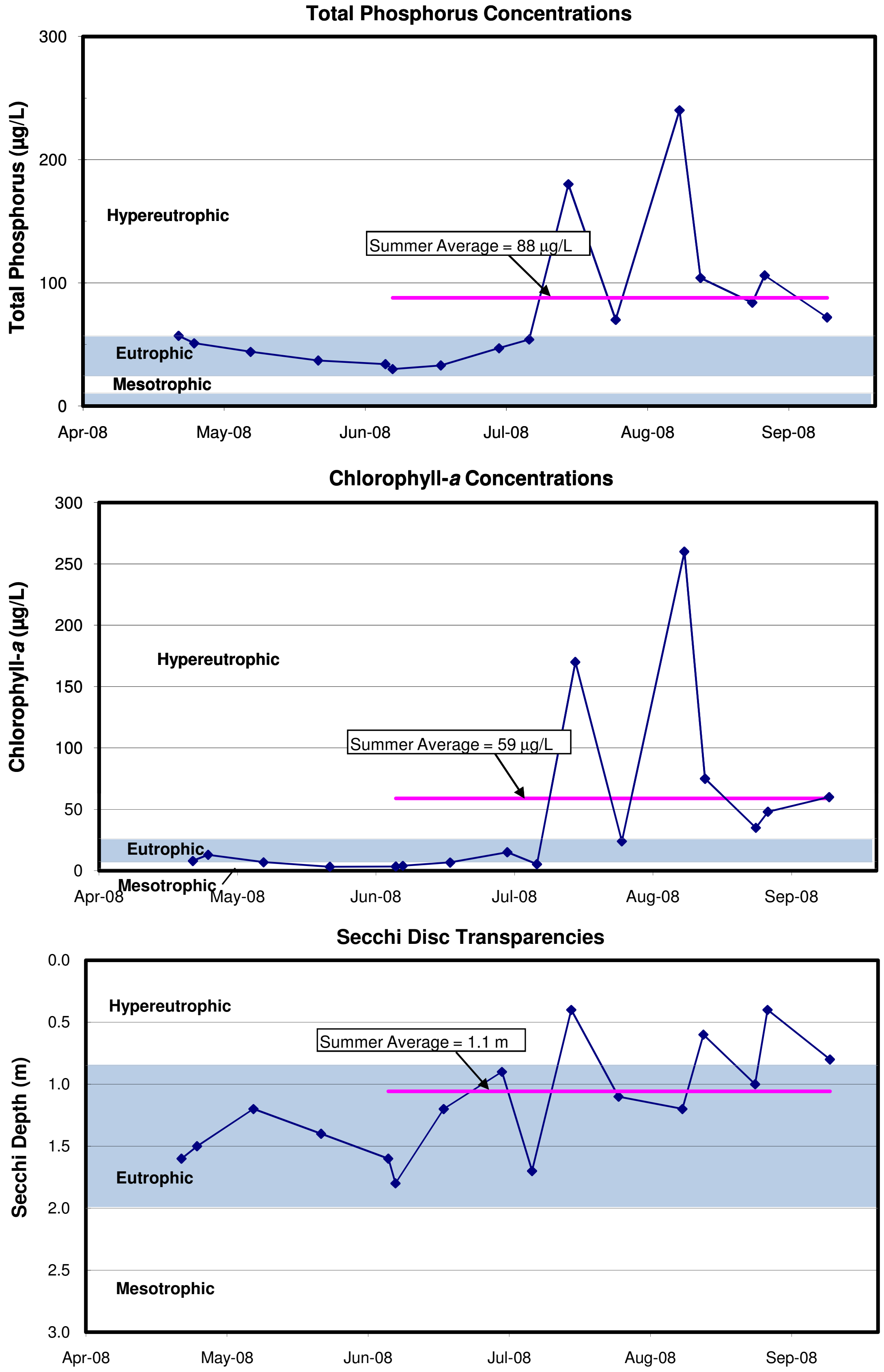
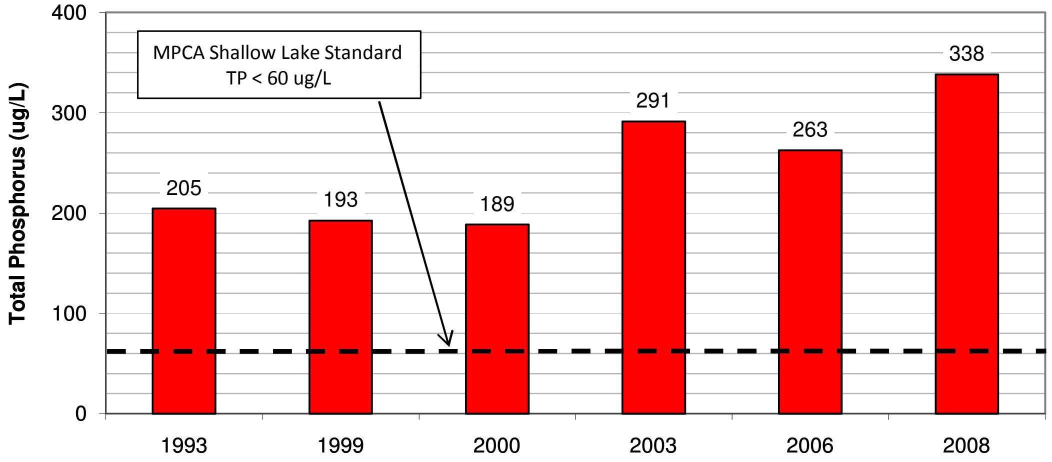
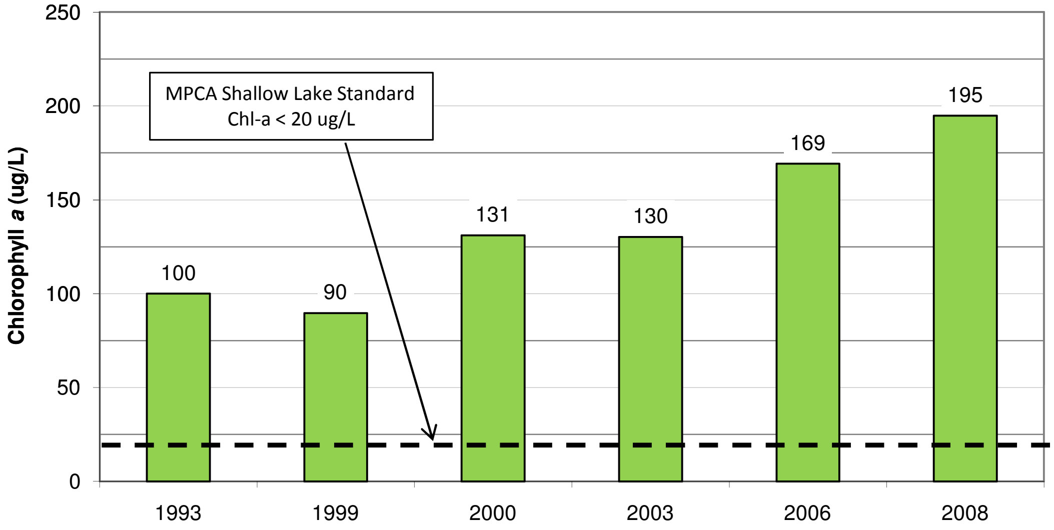


Figure 6-3
Lake Rose 2008 Seasonal Changes in
Concentrations of Total Phosphorus,
Chlorophyll-*a* and Secchi Depth

(a) Total Phosphorus Concentration (μg/L)



(b) Chlorophyll-*a* Concentration (μg/L)



(c) Secchi Disc Transparency

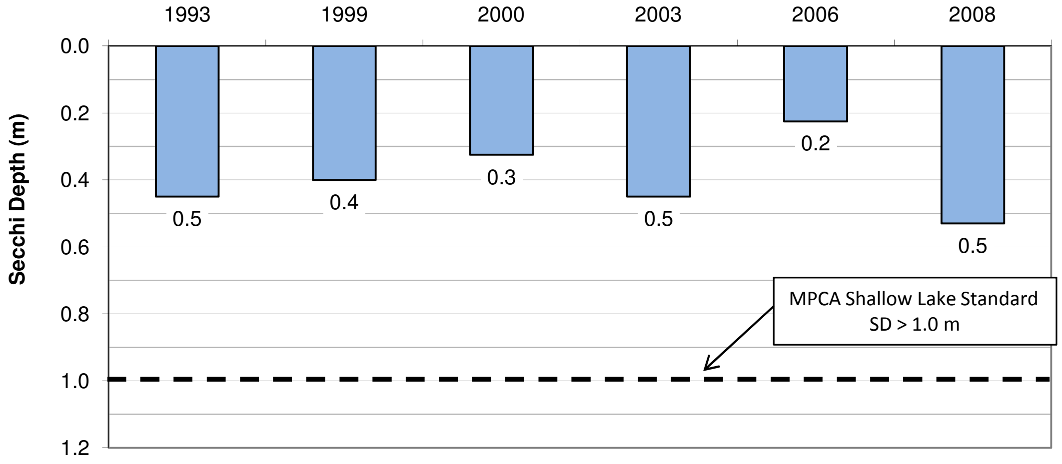
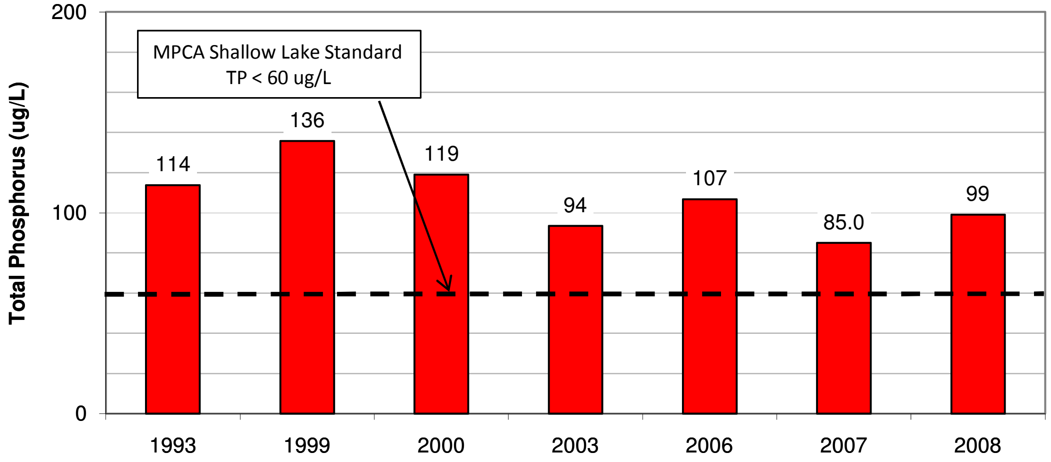
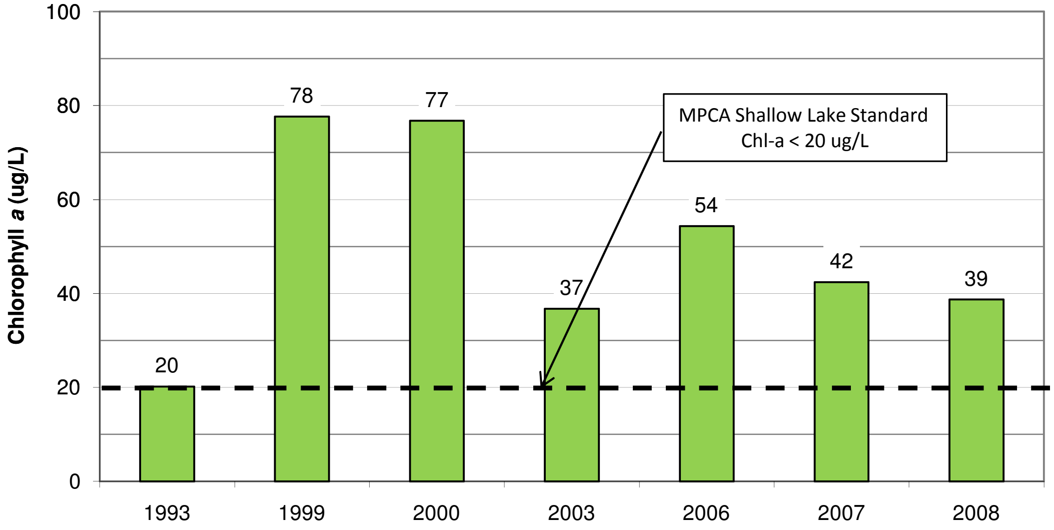


Figure 6-4
Lake Holiday Historical Summer -average Water Quality
(a) Total Phosphorus (b) Chlorophyll-*a* and
(c) Secchi Disc Transparency

(a) Total Phosphorus Concentration (µg/L)



(b) Chlorophyll-*a* Concentration (µg/L)



(c) Secchi Disc Transparency

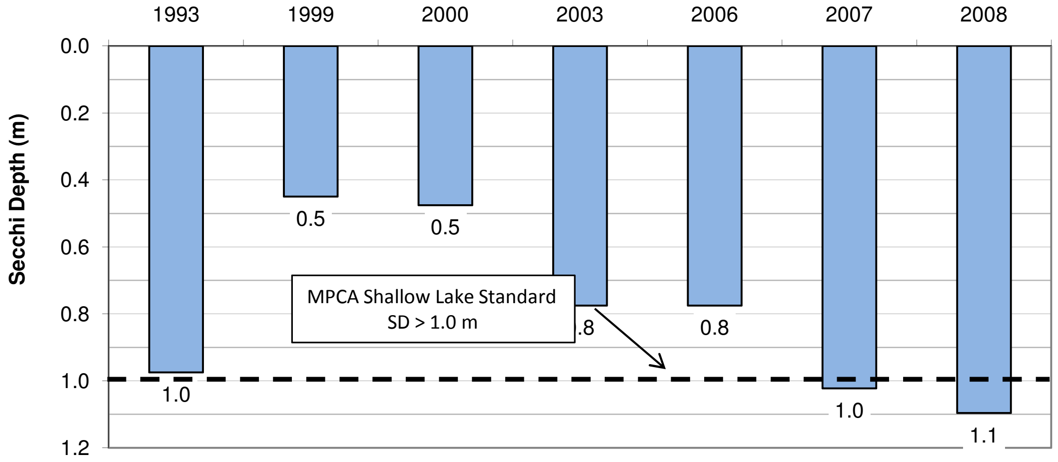
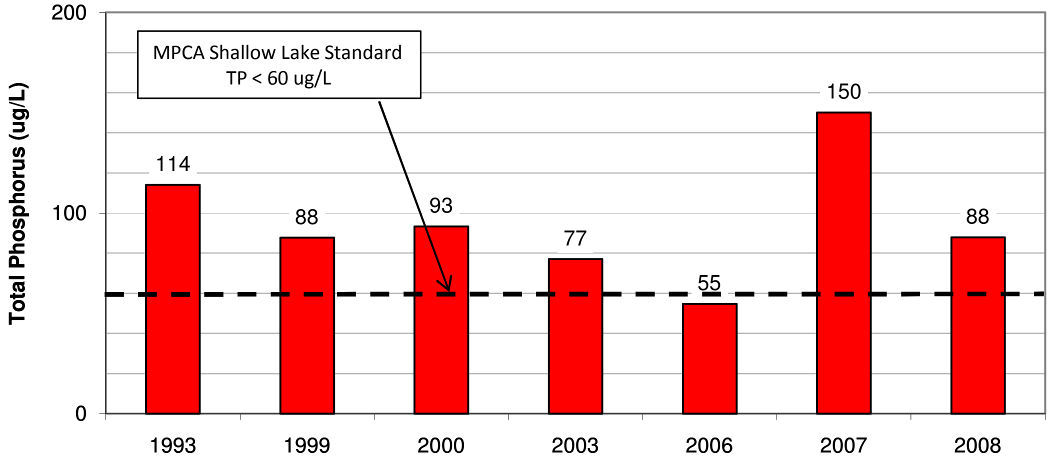
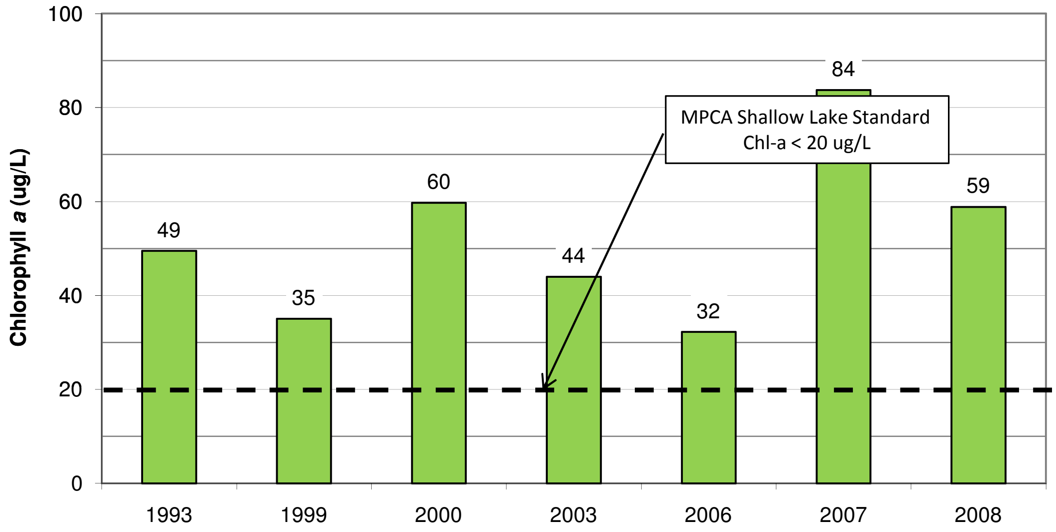


Figure 6-5
Wing Lake Historical Summer -average Water Quality
(a) Total Phosphorus (b) Chlorophyll-*a* and
(c) Secchi Disc Transparency

(a) Total Phosphorus Concentration (μg/L)



(b) Chlorophyll-*a* Concentration (μg/L)



(c) Secchi Disc Transparency

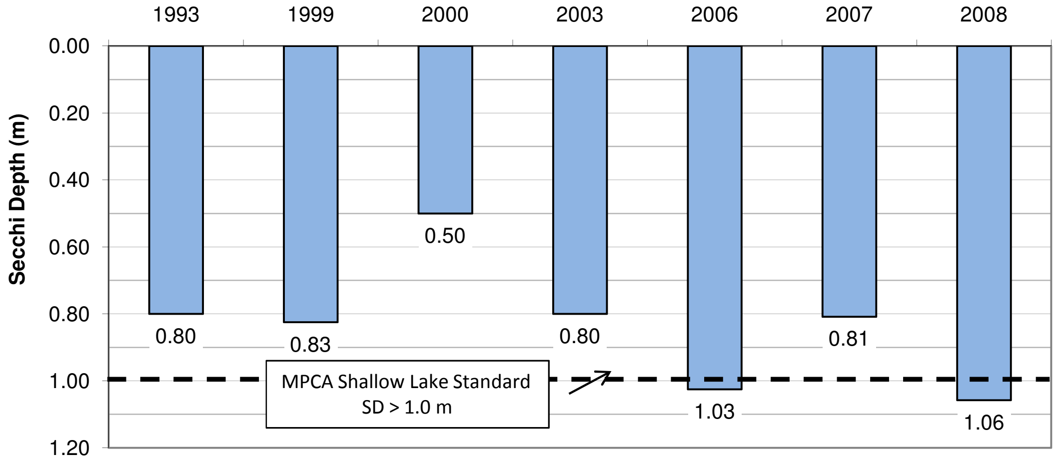


Figure 6-6
Lake Rose Historic al Summer -average Water Quality
(a) Total Phosphorus (b) Chlorophyll-*a* and
(c) Secchi Disc Transparency

6.1.2 Baseline/Current Water Quality

Current water quality data for Lake Holiday, Wing Lake, and Lake Rose were evaluated according to the trophic status categories. The trophic status categories use the lake's total phosphorus concentration, chlorophyll *a* concentration, and Secchi disc transparency measurements to assign the lake to a water quality category that best describes its water quality. Water quality categories include oligotrophic (i.e., excellent water quality), mesotrophic (i.e., good water quality), eutrophic (i.e., poor water quality), and hypereutrophic (i.e., very poor water quality). Total phosphorus, chlorophyll *a*, and Secchi disc transparency are key water quality indicators for the following reasons:

- Phosphorus generally controls the growth of algae in lake systems. Of all the substances needed for biological growth, phosphorus is typically the limiting nutrient.
- Chlorophyll *a* is the main photosynthetic pigment in algae. Therefore, the amount of chlorophyll *a* in the water indicates the abundance of algae present in the lake
- Secchi disc transparency is a measure of water clarity, and is inversely related to the abundance of algae. Water clarity determines recreational-use impairment.

6.1.2.1 Baseline Lake Water Quality Status

The Minnesota Lake Eutrophication Analysis Procedure (MnLEAP) is intended to be used as a screening tool for estimating lake conditions and for identifying "problem" lakes. MnLEAP is particularly useful for identifying lakes requiring "protection" versus those requiring "restoration" (Heiskary and Wilson, 1990). In addition, MnLEAP has been applied in the past to identify Minnesota lakes which may be in better or worse condition than they "should be" based on their location, watershed area and lake basin morphometry (Heiskary and Wilson, 1990). Results of MnLEAP completed for Lake Holiday, Wing Lake, and Lake Rose suggest that the lakes could achieve "better" water quality than is currently observed (Heiskary and Lindbloom, 1993). For the MnLEAP analysis, each lake was treated as an isolated water body (i.e. pumping from Lake Holiday to Wing Lake and overflow from Wing Lake to Lake Rose were not considered). Results of the MnLEAP analysis performed for Lake Holiday, Wing Lake, and Lake Rose are presented in Table 6-4; MnLeap predicts an estimated value as well as a standard error (presented as plus/minus in Table 6-4). Comparison of the predicted MnLEAP values and observed annual average phosphorus concentrations indicates that the water quality in each lake is worse than it "should be" based on its location, watershed area and lake basin morphometry.

Table 6-4 Estimated Ranges of Baseline/Background Water Quality

Lake	Vighi & Chiaudani	MnLEAP		
	Total Phosphorus (µg/L)	Total Phosphorus (µg/L)	Chlorophyll *a* (µg/L)	Secchi Depth (m)
Holiday	12 – 43	67 – 111	23 – 69	0.8 – 1.1
Wing	12 – 41	39 – 77	11 – 41	0.7 – 1.7
Rose	12 – 45	43 – 83	12 – 44	0.7 – 1.5

Vighi and Chiaudani (1985) developed another method to predict the phosphorus concentrations in lakes that are not affected by anthropogenic (human) inputs. As a result, the phosphorus concentration in a lake resulting from natural, background phosphorus loadings can be calculated from information about the lake's mean depth and its total alkalinity or conductivity. Alkalinity is considered more useful for this analysis because it is less influenced by development of the watershed. However, historical alkalinity data was not available for Lake Holiday, Wing Lake, or Lake Rose. Using all available specific conductivity data collected in 1993, 1999, 2000, 2003, 2006, and 2008, average specific conductivity values of 318, 273, and 357 µmho/cm were calculated for Lake Holiday, Wing Lake, and Lake Rose, respectively. These values result in predicted total phosphorus concentrations from natural, background loadings ranging between 12 and 43 µg/L for Lake Holiday, between 12 and 41 µg/L for Wing Lake, and between 12 and 45 µg/L for Lake Rose (see Table 6-4).

The range of TP concentrations predicted by the Vighi and Chiadani method (12 µg/L to 45 µg/L) is much lower than the TP concentrations predicted by the MnLEAP model. When compared to the MPCA shallow lakes standard for total phosphorus (60 µg/L), the upper end of the Vighi and Chiaudani predicted natural background TP concentration range falls below the standard, indicating that total phosphorus concentrations in these lakes were likely below the MPCA shallow lake phosphorus standard prior to development. Comparison of the TP ranges predicted by the MnLEAP model for Lake Holiday to the MPCA shallow lake standard indicates that although the lake could achieve better water quality than is currently observed, the MPCA's standard may not be attainable based on the lakes location, watershed area, and lake basin morphometry. In Wing Lake and Lake Rose, the average predicted TP concentrations are close to the MPCA standard, suggesting that the standard may be attainable.

6.1.2.2 Lake Holiday Current (2008) Water Quality

Figure 6-1 summarizes the seasonal changes in concentration of TP, Chl *a*, and Secchi disc transparencies for Lake Holiday in 2008. The data are shown compared to the trophic status categories. Throughout the sampling period the total phosphorus data collected were in the hypereutrophic (i.e., very poor water quality) category. This was likely the result of significant amounts of phosphorus added to the lake water by watershed runoff and by release of phosphorus from anoxic lake sediments.

As Figure 6-1 illustrates, the epilimnetic (surface water, i.e., 0-2 meter depth) TP concentration in Lake Holiday in 2008 generally increased throughout the spring and early summer to a maximum concentration of over 400 µg/L in July and August before decreasing in late summer. Because phosphorus has been shown to most often be the limiting nutrient for algal growth, the phosphorus-rich waters indicate the lake had the potential for abundant algal growth throughout the monitoring period. According to previous studies (Heiskary and Wilson, 1990), phosphorus concentrations of 60 µg/L typically result in the frequency of nuisance algal blooms (greater than 20 µg/L Chl *a*) to be about 70 percent of the summer. Since the summer-average TP concentration for Lake Holiday in 2008 (338 µg/L) was much higher than the 60 µg/L, Lake Holiday likely experienced nuisance algal blooms for a significant portion of the summer.

Chl *a* concentrations (0 to 2 meters) for Lake Holiday during 2008 ranged from as low as 1.3 µg/L to 590 µg/L. The 2008 summer-average concentration for Chl *a* of 195 µg/L for Lake Holiday was indicative of a hypereutrophic system. These data indicate algal blooms (greater than 20 µg/L Chl *a*) were likely prevalent in Lake Holiday in 2008.

The 2008 Lake Holiday Secchi depth measurements were in the eutrophic range (i.e. poor water quality) in the spring and early summer and in the hypereutrophic (i.e. very poor water quality) category in July, August, and September. The 2008 summer-average Secchi disc transparency was 0.5 meters for Lake Holiday. With average Secchi depths less than 0.6 meters, the TSI_{SD} for Lake Holiday places the lake within the NMCWD Management Category IV: Runoff Management (TSI_{SD}>70).

6.1.2.3 Wing Lake Current (2008) Water Quality

Figure 6-2 summarizes the seasonal changes in concentration of TP, Chl *a*, and Secchi disc transparencies for Wing Lake in 2008. The data are shown compared to the trophic status categories. Through the sampling period the total phosphorus data collected fall into the eutrophic (i.e. poor water quality) or the hypereutrophic (i.e. very poor water quality) category. The significant increase in TP concentrations towards the middle to later part of the summer suggests phosphorus was added to the lake by release of phosphorus from anoxic lake sediments.

As Figure 6-2 illustrates, the epilimnetic (surface water, i.e., 0-2 meter depth) TP concentration in Wing Lake in 2008 was relatively constant (about 50 µg/L) through June, after which TP increased through August before decreasing in September from a maximum of 160 µg/L. According to previous studies (Heiskary and Wilson, 1990), phosphorus concentrations of 60 µg/L typically result in the frequency of nuisance algal blooms (greater than 20 µg/L Chl *a*) to be about 70 percent of the summer. Since the summer-average TP concentration for Wing Lake in 2008 (99 µg/L) was higher than 60 µg/L, Wing Lake likely experienced nuisance algal blooms for a portion of the summer.

Chl *a* concentrations (0 to 2 meters) for Wing Lake during 2008 ranged from as low as 3 µg/L to 98 µg/L. The trend in 2008 Chl *a* concentrations mirrors that of TP, characterized by values in the eutrophic range in the early part of the summer and values in the hypereutrophic range in the later part of the summer. The 2008 summer-average concentration for Chl *a* of 39 µg/L for Wing Lake was indicative of a hypereutrophic system. The data indicates algal blooms (greater than 20 µg/L Chl *a*) were likely prevalent in Wing Lake in 2008.

The 2008 Wing Lake Secchi depth measurements were in the eutrophic range (i.e. poor water quality) in the spring and early summer and in the lower range of the hypereutrophic (i.e. very poor water quality) category in August, and September. The 2008 summer-average Secchi disc transparency was 1.1 meters for Wing Lake (within the eutrophic range). With a summer-average Secchi depth between 1 and 2 meters, the TSI_{SD} for Wing Lake places the lake within the NMCWD Management Category II: Partial Body Recreational Contact ($50 < TSI_{SD} < 60$). The 2008 summer-average Chl *a* concentration also falls within the range for NMCWD Management Category II, although the summer-average TP concentration is greater than the range for NMCWD Management Category II, and places the lake in NMCWD Management Category III: Fishing and Aesthetic Viewing.

6.1.2.4 Lake Rose Current (2008) Water Quality

Figure 6-3 summarizes the 2008 seasonal changes in concentration of TP, Chl *a*, and Secchi disc transparencies for Lake Rose. The data are shown compared to the trophic status categories. The total phosphorus data collected fall into the eutrophic (i.e. poor water quality) or the hypereutrophic (i.e. very poor water quality) category during the summer of 2008. The significant increase in TP concentration towards the middle to later part of the summer suggests phosphorus was added to the lake by release of phosphorus from anoxic lake sediments.

As Figure 6-3 illustrates, the epilimnetic (surface water, i.e. 0-2 meter depth) TP concentration in Lake Rose in 2008 was relatively constant (about or below 50 µg/L) through June, after which TP increased sharply in July and August, each time followed by decreases in TP. The summer-average TP concentration was 88 µg/L. The unexpected decrease is TP from late-July to early-August is corroborated in the Chl *a* data and Secchi depth data, which shows an improvement between July 25th and August 5th. It is possible that high TP in July resulted in a significant algal bloom, and the sampling on August 5th followed the die off and settlement of the algal bloom. The TP concentration on August 5th measured 270 µg/L at the bottom of Lake Rose (only epilimnetic TP was measured on July 25th), indicating that the change in TP concentrations witnessed between late-July and mid-August could be exaggerated by stratification and subsequent mixing.

Chl *a* concentrations (0 to 2 meters) for Lake Rose during 2008 ranged from as low as 3 µg/L to as high as 260 µg/L. The trend in 2008 Chl *a* concentrations mirrors that of TP, characterized by values in the eutrophic range in the early part of the summer and large fluctuations in the hypereutrophic range in the later part of the summer. The 2008 summer-average concentration for Chl *a* of 59 µg/L for Lake Rose is indicative of a hypereutrophic system. The data indicates algal blooms (greater than 20 µg/L Chl *a*) were likely prevalent in Lake Rose in 2008.

The 2008 Lake Rose Secchi depth measurements were in the eutrophic range (i.e. poor water quality) in the spring and early summer and in the hypereutrophic (i.e. very poor water quality) category periodically in July, August, and September. The 2008 summer-average Secchi disc transparency was 1.1 meters for Lake Rose (within the eutrophic range). With a summer-average Secchi depth between 1 and 2 meters, the TSI_{SD} for Lake Rose places the lake within the NMCWD Management Category II: Partial Body Recreational Contact ($50 < TSI_{SD} < 60$). The summer-average Chl *a* and TP concentrations, however, are greater than the range specified for NMCWD Management Category II, and place the lake in NMCWD Management Category III: Fishing and Aesthetic Viewing.

6.1.2.5 Lake Holiday, Wing Lake, and Lake Rose Water Quality Trend Analysis

Trend analyses were performed on the water quality data for Lake Holiday, Wing Lake, and Lake Rose collected between 1993 and 2008, as there was a sufficient amount of data for each lake to perform the analyses. The trend analyses were performed to determine if the changes in water quality over time indicate a significant improvement or degradation in water quality. Over the entire period of record (1993-2008), analysis of the historical data for TP, Chl *a*, and SD trend analyses all indicated that there was no significant improvement or degradation in water quality over the past 15 years in Lake Holiday, Wing Lake, or Lake Rose.

Although not statistically significant, the data do show that the highest observed TP concentrations in Lake Holiday have occurred in the past five years. Total phosphorus concentrations in Wing Lake and Lake Rose, however, do not demonstrate a similar trend, despite being downstream of Lake Holiday. This may be due to relatively dry conditions during the summer of 2006 and 2008 that resulted in limited pumping from Lake Holiday to Wing Lake. During 1993, a comparatively wet year, summer-average TP concentrations in Wing Lake and Lake Rose are more similar to the summer-average TP concentration observed in Lake Holiday.

6.2 Nutrient Loading

Lake Holiday, Wing Lake, and Lake Rose receive phosphorus loads from external sources, contained in the runoff from the watersheds surrounding and tributary to each lake, through atmospheric deposition, and from external discharges, such as upstream lakes. In addition, the data suggest that the lake also receives phosphorus loads from internal sources—from lake sediments via chemical and mixing processes, and through aquatic vegetation die-off. These sources of phosphorus are discussed in the following sections. Figures 6-7 and 6-8 summarize the existing annual water and phosphorus budgets for Lake Holiday for average, wet, and dry climatic conditions respectively. Figures 6-9 and 6-10 summarize the existing annual water and phosphorus budgets for Wing Lake for average, wet, and dry climatic conditions respectively. Figures 6-11 and 6-12 summarize the existing annual water and phosphorus budgets for Lake Rose for average, wet, and dry climatic conditions respectively.

6.2.1 External Loading Sources

External loading sources are those originating outside of the water body. External sources of phosphorus include direct deposition from the atmosphere, stormwater runoff from tributary watersheds, inflow from upstream lakes, and any known point sources.

6.2.1.1 Watershed Runoff

Most of the phosphorus that runs off a watershed is particulate (i.e. is associated with soil or debris particles). However, it is assumed in the P8 model that 30 percent of the phosphorus that accumulates on a watershed is soluble (i.e. not associated with particles). While BMPs that rely on particle settlement, such as detention ponds and grit chambers, are effective at removing phosphorus associated with particles in stormwater runoff, they are ineffective at removing soluble phosphorus.

6.2.1.1.1 Lake Holiday Watershed Runoff

For existing conditions in the Lake Holiday watershed, modeling simulations were performed for average climatic conditions (based on the 1999 water year), wet conditions (1993 water year), and dry conditions (2008 water year). For average climatic conditions, P8 modeling indicates an annual (water year) total phosphorus load to Lake Holiday from the watershed of 43.5 lbs and a watershed stormwater runoff volume of 158 acre-feet. The water and phosphorus loads are equivalent to 6.8 inches and 0.156 lbs TP/acre, respectively (assuming a watershed area of 278 acres, excluding the surface area of Lake Holiday). For wet climatic conditions, the annual (1993 water year) total phosphorus load from the Lake Holiday watershed was 46.3 lbs and the stormwater runoff volume was 199 acre-feet. These loads are equivalent to 8.6 inches of runoff and 0.167 lbs TP/acre. For dry climatic conditions, the annual (2008 water year) total phosphorus load from the Lake Holiday watershed was 39.9 lbs and the stormwater runoff volume was 161 acre-feet. These loads are equivalent to 6.9 inches of runoff and 0.145 lbs TP/acre. In this case, the runoff from the "dry" year is greater than the "average" year because the wet, dry, and average years are chosen based on summer precipitation. The loads listed here are based on precipitation over a complete water year.

Watershed analysis suggests that under existing conditions and all climatic scenarios, watershed loading is the largest external phosphorus loading source to Lake Holiday. The watershed contributes approximately 11 to 18 percent of the annual phosphorus load and 80 to 83 percent of the annual water load to Lake Holiday (the remainder coming from precipitation directly onto the lake). From June through September, watershed runoff contributes approximately 11 to 18 lbs of phosphorus to Lake Holiday during the summer. This load corresponds to 18 to 38 percent of the summer phosphorus load. The annual water load and summer TP load distributions for Lake Holiday are presented in Figure 6-7 and Figure 6-8, respectively.

6.2.1.1.2 Wing Lake Watershed Runoff

For existing conditions in the Wing Lake watershed, modeling simulations were performed for average climatic conditions (based on the 1999 water year), wet conditions (1993 water year), and dry conditions (2008 water year). For average climatic conditions, P8 modeling indicates an annual (water year) total phosphorus load to Wing Lake from the watershed of 34.4 lbs and a watershed stormwater runoff volume of 69 acre-feet. The water and phosphorus loads are equivalent to 7.4 inches and 0.307 lbs TP/acre, respectively (assuming a watershed area of 112 acres, excluding the surface area of Wing Lake). For wet climatic conditions, the annual (1993 water year) total phosphorus load from the Wing Lake watershed was 35.6 lbs and the stormwater runoff volume was 81 acre-feet. These loads are equivalent to 8.7 inches of runoff and 0.316 lbs TP/acre. For dry climatic conditions, the annual (2008 water year) total phosphorus load from the Lake Holiday watershed was 30.3 lbs and the stormwater runoff volume was 72 acre-feet. These loads are equivalent to 7.8 inches of runoff and 0.271 lbs TP/acre. In this case, the runoff from the "dry" year is actually greater than the "average" year because the wet, dry, and average years are chosen based on summer precipitation. The loads listed here are based on precipitation over a complete water year.

Watershed analysis suggests that under existing conditions watershed loading is not the largest external phosphorus loading source to Wing Lake. In-Lake analysis demonstrates that upstream loading from Lake Holiday accounts for between 13 and 34 percent of the summer TP loading to Wing Lake (8 to 26 lbs). Runoff from the Wing Lake watershed accounts for between 10 and 12 percent of summer TP loading (6 to 10 lbs). Similarly, the water load from Lake Holiday is greater than the water load from the watersheds tributary to Wing Lake. The Wing Lake watershed contributes approximately and 26 to 31 percent of the annual water load to Wing Lake. The annual water load and summer TP load distributions for Wing Lake are presented in Figure 6-9 and Figure 6-10, respectively.

6.2.1.1.3 Lake Rose Watershed Runoff

For existing conditions in the Lake Rose watershed, modeling simulations were performed for average climatic conditions (based on the 1999 water year), wet conditions (1993 water year), and dry conditions (2008 water year). For average climatic conditions, P8 modeling indicates an annual (water year) total phosphorus load to Lake Rose from the watershed of 39.2 lbs and a watershed stormwater runoff volume of 79 acre-feet. The water and phosphorus loads are equivalent to 4.2 inches and 0.170 lbs TP/acre, respectively (assuming a watershed area of 230 acres, excluding the surface area of Lake Rose). For wet climatic conditions, the annual (1993 water year) total phosphorus load from the Lake Rose watershed was 41.2 lbs and the stormwater runoff volume was 100 acre-feet. These loads are equivalent to 5.2 inches of runoff and 0.179 lbs TP/acre. For dry climatic conditions, the annual (2008 water year) total phosphorus load from the Lake Holiday watershed was 35.4 lbs and the stormwater runoff volume was 86 acre-feet. These loads are equivalent to 4.5 inches of runoff and 0.154 lbs TP/acre. In this case, the runoff from the "dry" year is greater than the "average" year because the wet, dry, and average years are chosen based on summer precipitation. The loads listed here are based on precipitation over a complete water year.

Watershed analysis suggests that under existing conditions watershed loading is not the largest external phosphorus loading source to Lake Rose under all climatic conditions. Runoff from the

Lake Rose watershed accounts for between 7 and 14 percent of summer TP loading to the lake (8 to 11 lbs of phosphorus). The water load from Wing Lake is greater than the water load from the watersheds tributary to Wing Lake under all climatic conditions. The Lake Rose watershed contributes approximately and 24 to 29 percent of the annual water load to Lake Rose. The annual water load and summer TP load distributions for Lake Rose are presented in Figure 6-11 and Figure 6-12, respectively.

6.2.1.2 Inflow from Upstream Lakes

Although the runoff from the watershed is a significant source of water and phosphorus loads to all three lakes, Wing Lake and Lake Rose also receive a significant water and phosphorus load from the upstream lakes. Water from Lake Holiday is pumped to Wing Lake, and water from Wing Lake flows via a gravity outlet to Lake Rose. The water quality in the upstream lake directly impacts the TP concentrations in the downstream lakes. A water balance model was developed for Lake Holiday, Wing Lake, and Lake Rose. The water balance included runoff from tributary watersheds, direct precipitation, evaporation from lake surfaces, net groundwater seepage, and inflow from upstream lakes. The water balance was calibrated to observed water surface elevations in Wing Lake and Lake Rose (observed water levels in Lake Holiday were not available). The water balance development and calibration is detailed in Section 7.2.3 of this report. The water balance estimated that the outflow from Lake Holiday to Wing Lake ranges from 55 acre-feet in a dry year to 73 acre-feet in a wet year. The inflow to Lake Rose from Wing Lake ranges from 49 acre-feet to 72 acre-feet as measured for the water year (October through September).

These discharges will contribute various TP loads to the downstream lakes depending upon the upstream water quality and volume of water discharged. It is not appropriate, however, to multiply the water load by the summer-average TP concentration to compute load, as the summer TP concentration is typically higher than the TP concentration during the remainder of the year. Summer TP loading (June – September) was computed from upstream lakes. The summer TP load from Holiday to Wing Lake ranged from 8 lbs to 26 lbs (for dry and wet years, respectively). These loads represent between 18 and 34 percent of the summer TP load to Wing Lake. The TP load from Wing Lake to Lake Rose ranged from 2 lbs to 19 lbs (for dry and wet years, respectively). These loads represent 2 to 20 percent of the summer TP load to Lake Rose. These loads are presented for Wing Lake in Figure 6-10 and for Lake Rose in Figure 6-12.

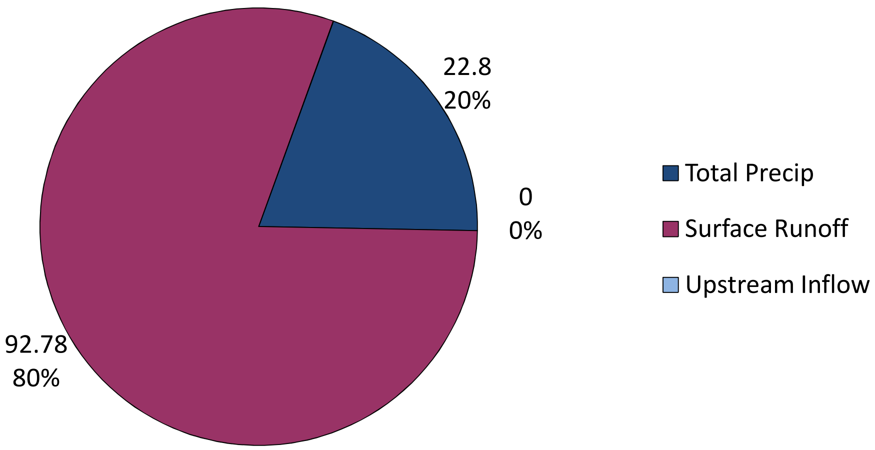
6.2.1.3 Direct Precipitation & Atmospheric Deposition

In addition to the water and phosphorus loads from the watershed and upstream inflows, atmospheric deposition and direct precipitation also contribute water and phosphorus to Lake Holiday, Wing Lake, and Lake Rose. Phosphorus can also be deposited directly onto a lake dissolved in rain, and as particles and dust (with TP associated with the surface) settle onto the water surface. An atmospheric TP deposition rate of 0.2615 kg/ha/yr (or 0.233 lb/ac/yr) was used in this UAA (Barr, 2005). This amount is applied to the surface area of each lake. This rate results in an atmospheric deposition loading of approximately 1.9 lbs per year for Lake Holiday, 3.3 lbs per year for Wing Lake, and 6.1 lbs per year for Lake Rose.

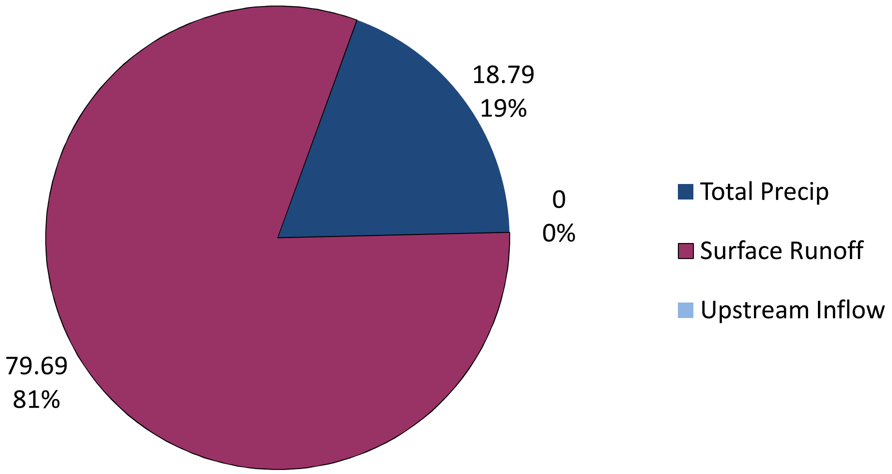
In Lake Holiday, direct precipitation account for about 18 percent of the annual water load and atmospheric deposition accounts for about 1 to 2 percent of the summer TP load (see Figures 6-7 and 6-8). In Wing Lake, direct precipitation account for about 24 percent of the annual water load, while atmospheric TP deposition accounts for about 1 to 2 percent of the annual phosphorus load (see Figures 6-9 and 6-10). Direct precipitation account for approximately 31 to 40 percent of the annual water load to Lake Rose. Atmospheric deposition is the source of 1 to 3 percent of the summer TP loading to Lake Rose (see Figures 6-11 and 6-12).

The remainder of the phosphorus loading in Lake Holiday, Wing Lake, and Lake Rose come from internal loads.

(a) Wet year water load (acre-feet)



(b) Average year water load (acre-feet)



(c) Dry year water load (acre-feet)

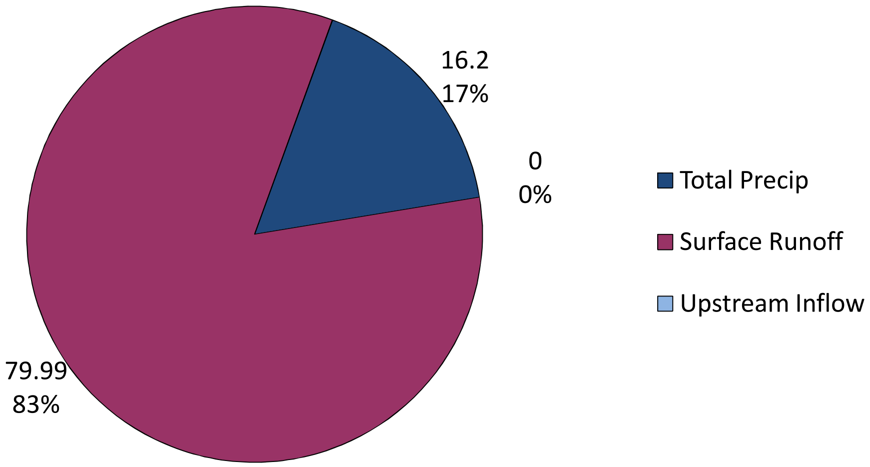
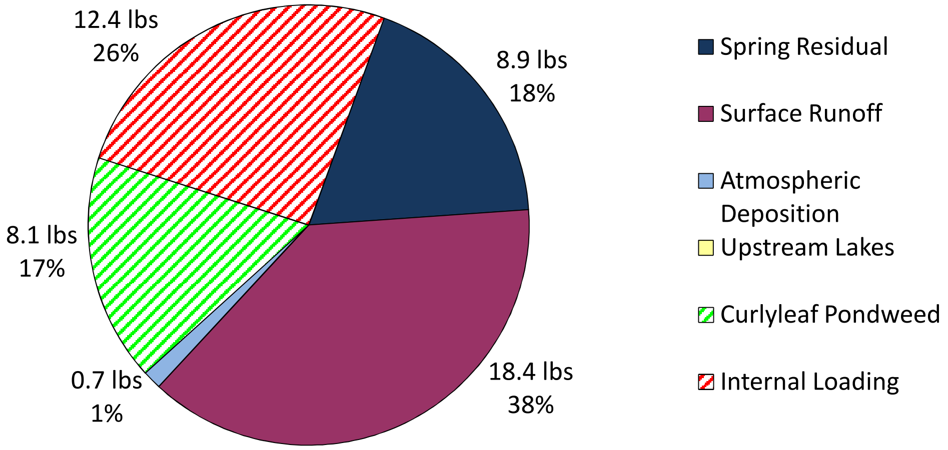


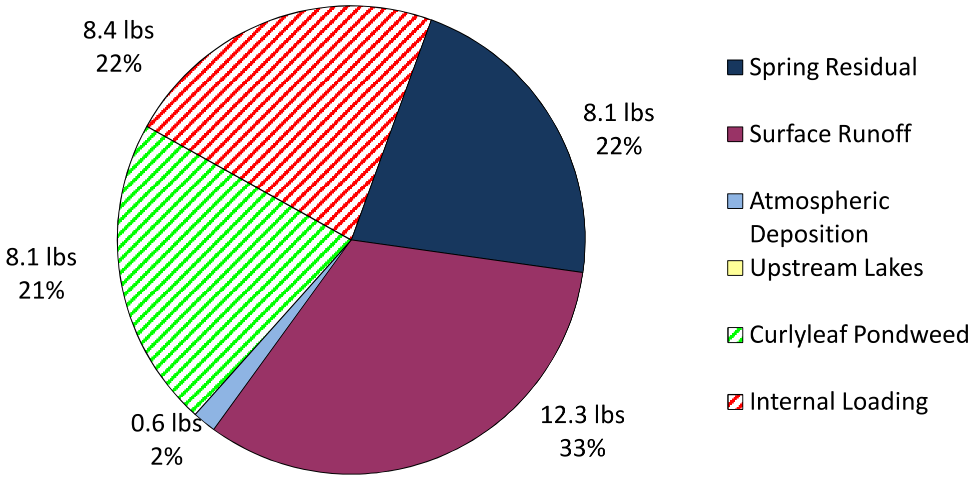
Figure 6-7

Cumulative Annual Water Loading to Lake Holiday based on Water Year (October - September)

(a) Wet year summer TP loading (lbs)



(b) Average year summer TP loading (lbs)



(c) Dry year summer TP loading (lbs)

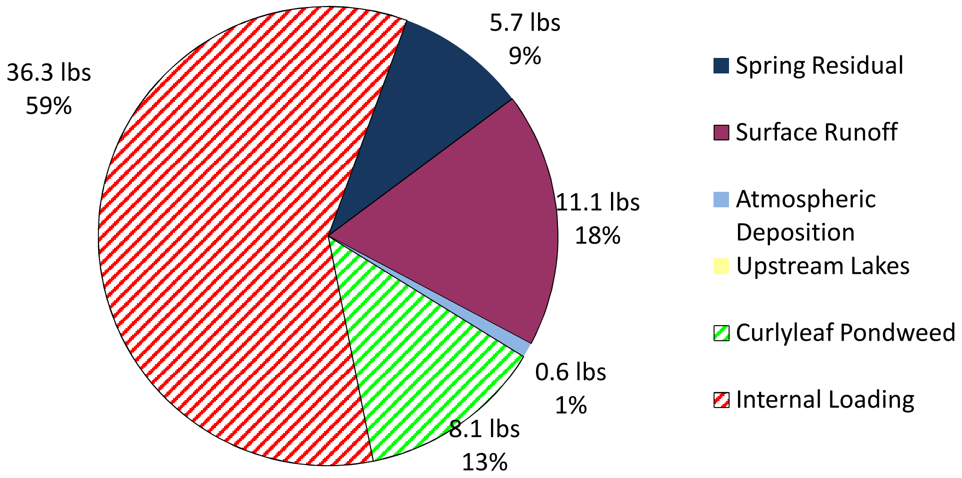
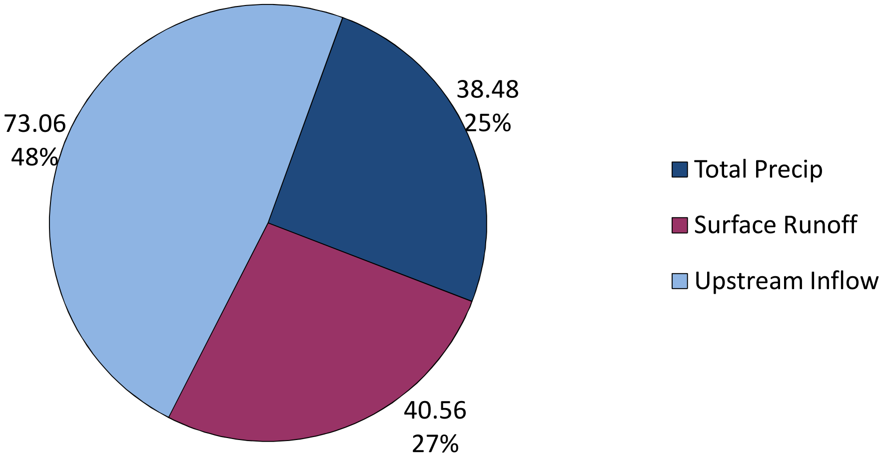


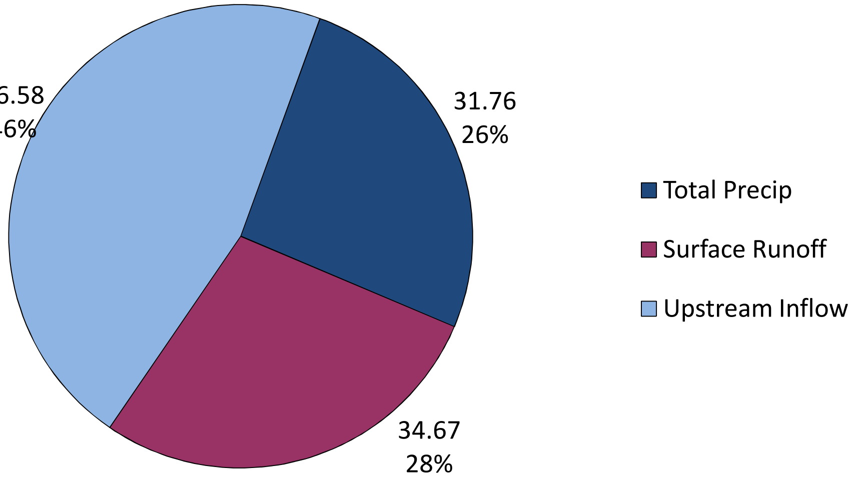
Figure 6-8

Cumulative Total Phosphorus Loading to Lake Holiday (June- September)

(a) Wet year water load (acre-feet)



(b) Average year water load (acre-feet)



(c) Dry year water load (acre-feet)

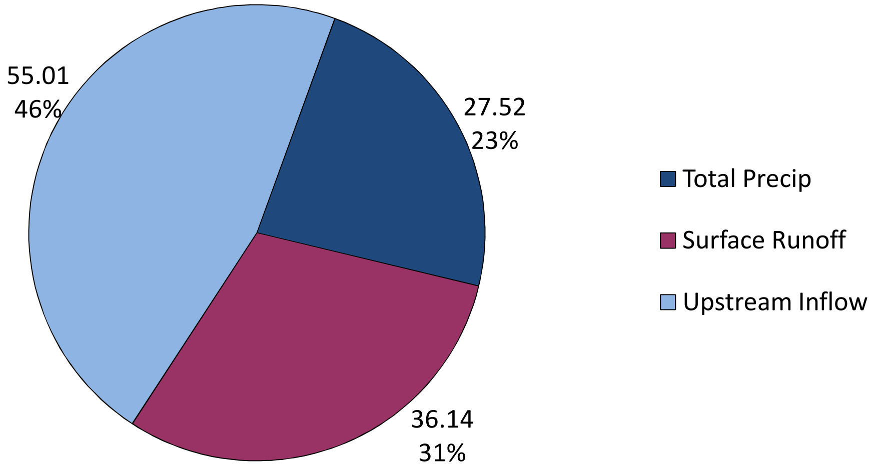
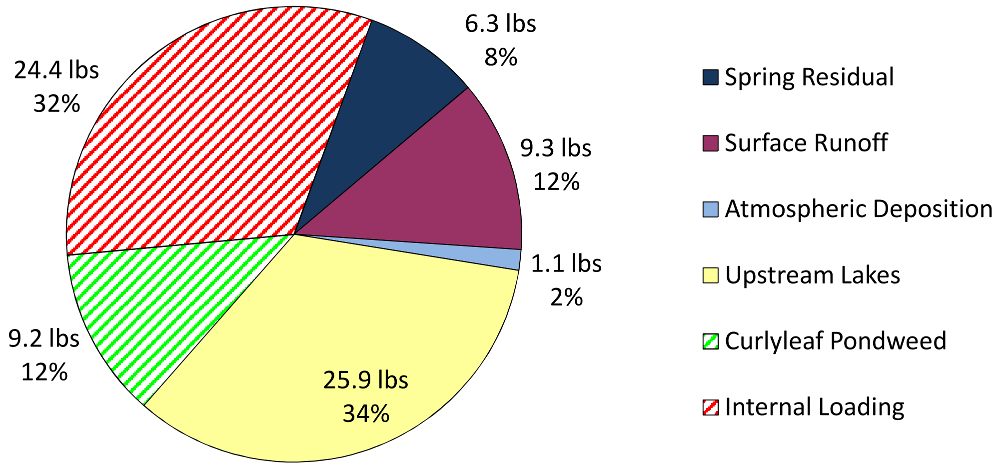


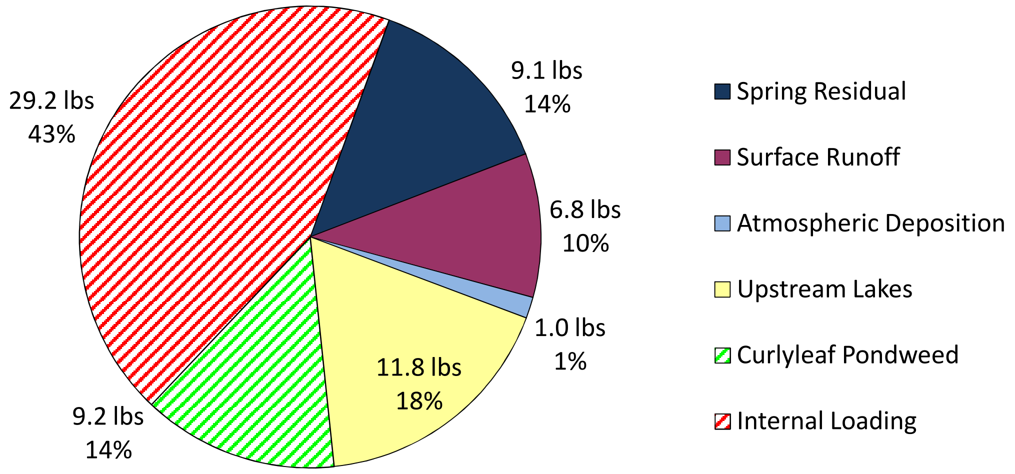
Figure 6-9

Cumulative Annual Water Loading to Wing Lake
based on Water Year (October - September)

(a) Wet year summer TP loading (lbs)



(b) Average year summer TP loading (lbs)



(c) Dry year summer TP loading (lbs)

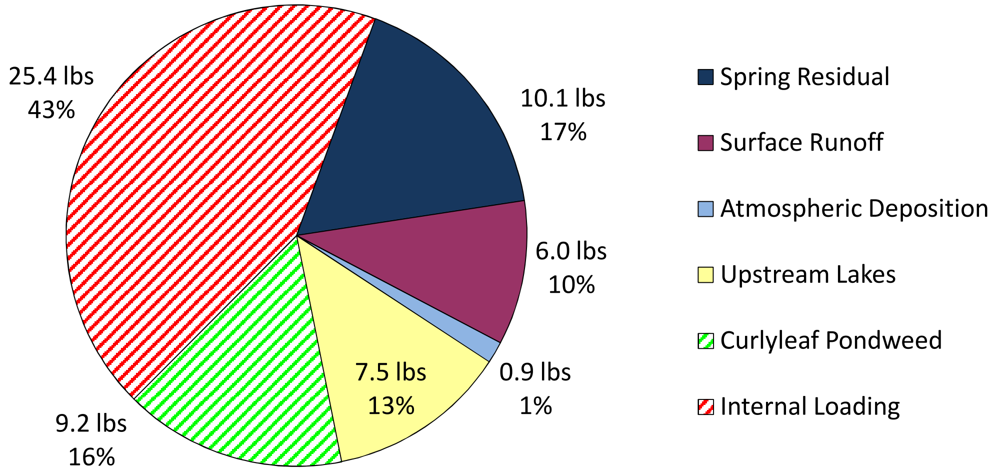
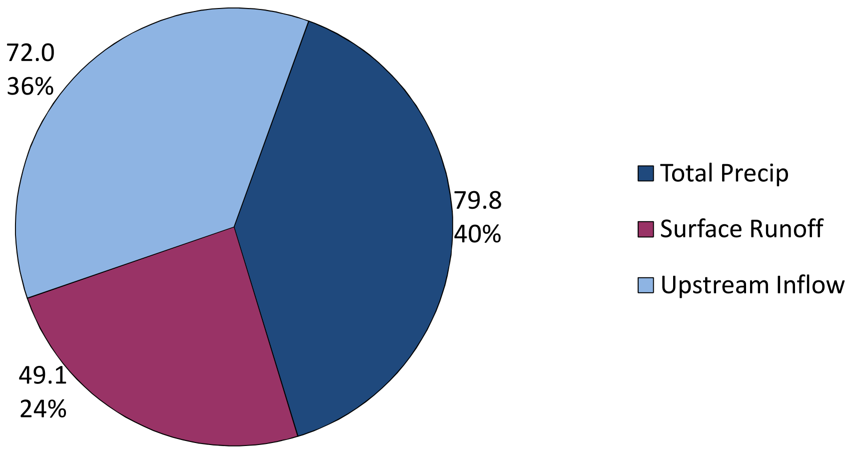


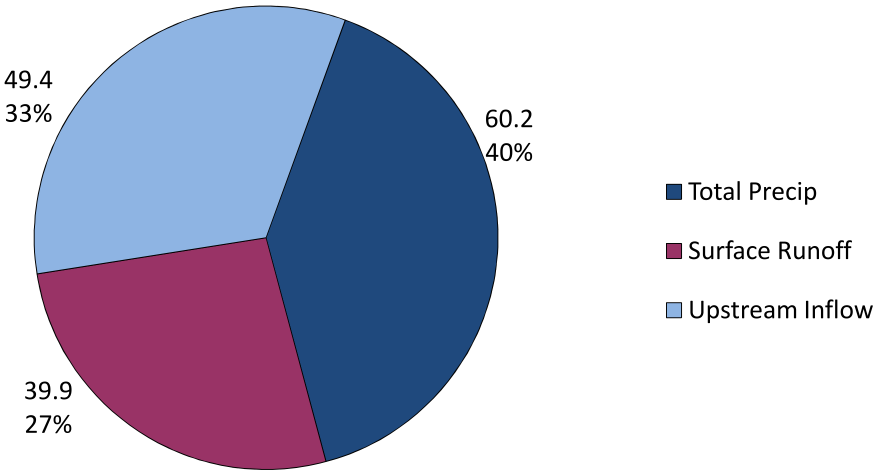
Figure 6-10

Cumulative Total Phosphorus Loading to
Wing Lake (June- September)

(a) Wet year water load (acre-ft)



(b) Average year water load (acre-ft)



(c) Dry year water load (acre-ft)

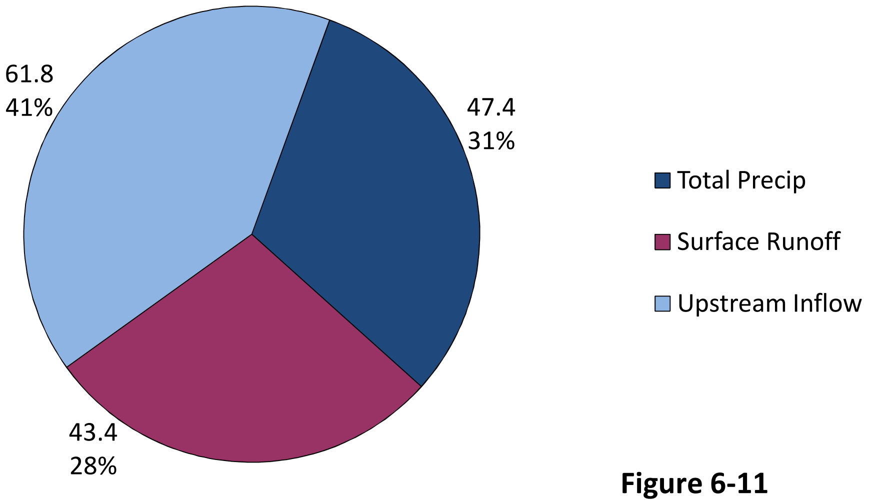
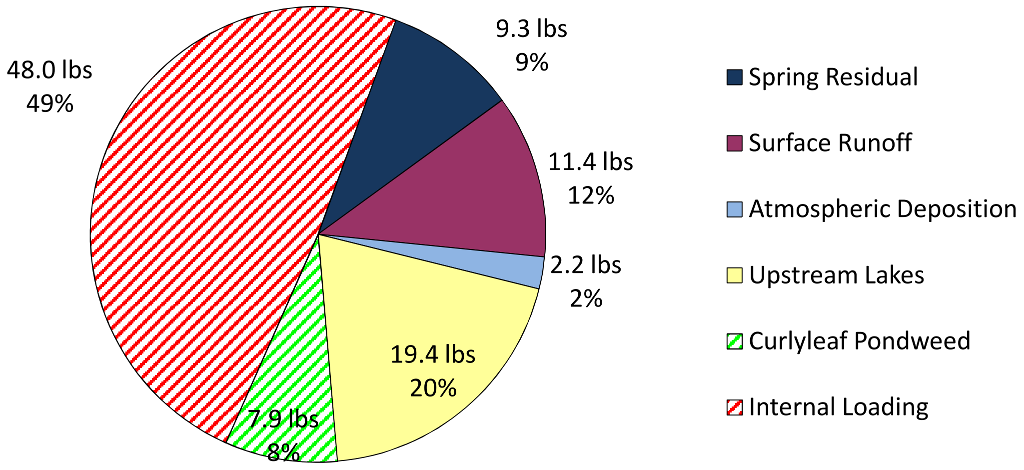


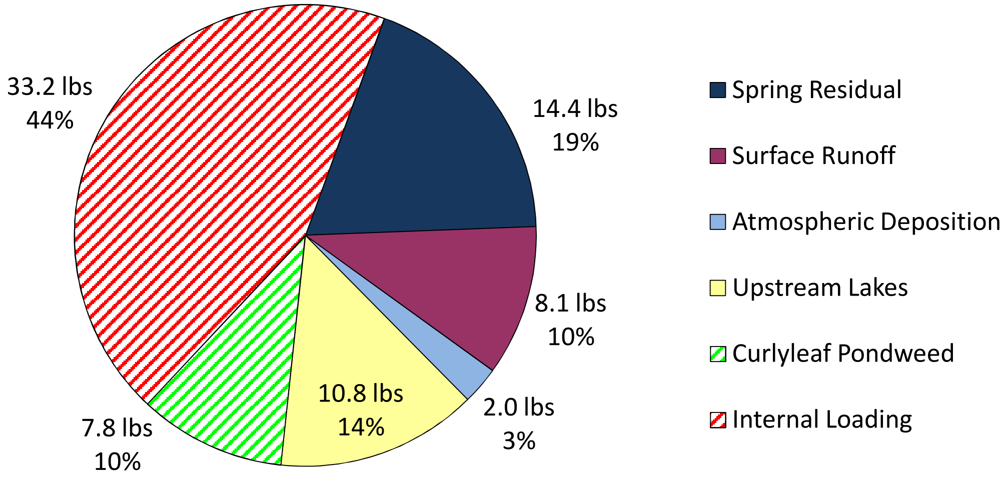
Figure 6-11

Cumulative Annual Water Loading to Lake Rose
based on Water Year (October - September)

(a) Wet year summer TP loading (lbs)



(b) Average year summer TP loading (lbs)



(c) Dry year summer TP loading (lbs)

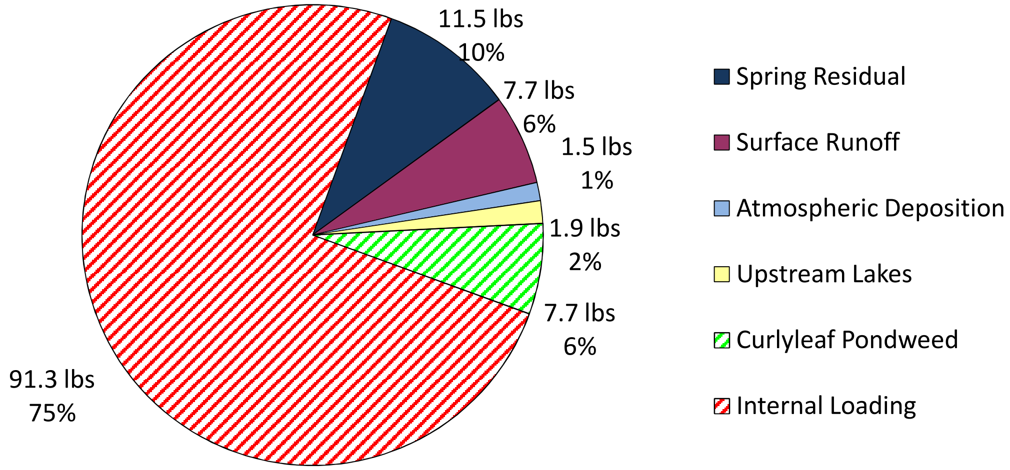


Figure 6-12

Cumulative Total Phosphorus Loading to Lake Rose (June- September)

6.2.2 Internal Loads

In addition to being affected by the runoff from the watershed, atmospheric deposition, and the discharge from any upstream lakes, the water quality of Lake Holiday, Wing Lake, and Lake Rose appears to be influenced by internal phosphorus loading. Computer simulations and observed water quality data indicate internal phosphorus loading is a component of each lake's annual phosphorus budget. Internal load may come from TP release from anoxic sediments and/or TP release from physically disturbed sediments (e.g. rough fish activity).

In-lake analyses of the three lakes (see Section 7.3) indicate that internal phosphorus loading (the release of phosphorus from lake bottom sediment) is a significant source of phosphorus in all three lakes. The summer internal phosphorus loading for Lake Holiday is estimated to range from 8 to 36 lbs (or 22 to 59 percent of the summer TP load), with the higher loading corresponding to dry conditions. In Wing Lake, summer internal loading from sediment is estimated to be 24 to 29 lbs, or 32 to 43 percent of the summer TP load. In Lake Rose, summer internal phosphorus loading is estimated to be 33 to 91 lbs, which corresponds to 44 to 75 percent of the total summer TP loading to Lake Rose. These loads are presented in Figures 6-8, 6-10, and 6-12 for Lake Holiday, Wing Lake, and Lake Rose, respectively.

The hypereutrophic condition of Lake Holiday, Wing Lake, and Lake Rose, along with the relatively shallow depths of the lakes, would be expected to provide a situation in which ephemeral thermal stratification and frequent mixing result in internal phosphorus loading from anoxic lake sediments. Internal loading will delay the lakes' response to phosphorus loading reduction efforts in the watershed. Large reductions in phosphorus loading from the watershed would eventually lead to reduced internal loading of phosphorus, although internal loading can be treated in the interim to achieve water quality goals.

In addition to sediment phosphorus release, the nonnative aquatic plant, Curlyleaf pondweed (*Potamogeton crispus)* is a significant source of internal phosphorus loading to these lakes. The aquatic plant was present in significant amounts in Lake Holiday and Wing Lake in 2008, and to a lesser degree in Lake Rose. This macrophyte grows through the winter and then dies back in early- to mid-summer, releasing phosphorus into the water column which can cause algal blooms and decreased water clarity. Curlyleaf pondweed is estimated to contribute about 8 lbs of TP to Lake Holiday, which accounts for 13 to 21 percent of the summer TP load (see Figure 6-8). In Wing Lake, Curlyleaf pondweed contributes approximately 9 lbs of TP during the summer, or 12 to 16 percent of the summer TP load (see Figure 6-10). Curlyleaf pondweed contributes about 8 lbs of TP during the summer in Lake Rose; this load accounts for 6 to 10 percent of the summer TP load in Lake Rose (see Figure 6-12). The presence of Curlyleaf pondweed will continue to be monitored in these lakes.

6.2.2.1 Sediment Core Analysis

To better understand the internal loading component from the lake sediments, sediment cores were collected from Lake Holiday, Wing Lake, and Lake Rose in the summer of 2009. The sediment cores (one each from Lake Holiday and Wing Lake, two from Lake Rose) were analyzed for mobile phosphorus (which contributes directly to internal phosphorus loading) and organic bound phosphorus. The analysis and results are presented in the report titled *Sediment Phosphorus-Internal Loading Investigation of Rose, Wing, and Lake Holidays* (Barr, 2009), which is included as Appendix H to this report. Figures 4, 5, and 6 of that report show the interpolated distribution of mobile phosphorus loading rates based on the sediment core results for Lake Rose, Lake Holiday, and Wing Lake, respectively. The internal sediment loading rates calculated for Lake Rose ranged from 2.3 $mg/m^2/day$ to 10.6 $mg/m^2/day$. In Wing Lake, the measured sediment internal loading rates were significantly less, ranging from 0.0 $mg/m^2/day$ to 2.9 $mg/m^2/day$. In Lake Holiday, the measured sediment internal loading rates ranged from 0.0 $mg/m^2/day$ to 6.0 $mg/m^2/day$. Table 6-5 shows how the maximum internal loading rates in Lake Holiday, Wing Lake, and Lake Rose compare to the rates calculated for other Metro Area lakes, using the same methodology. None of the lakes shown in Table 6-5 had alum treatments at the time of the sediment core sampling.

The average internal phosphorus loading rate calculated for all of the Metro Area lakes in Table 6-5 is 6.3 $mg/m^2/day$. It is important to note that these rates represent the maximum potential internal loading rate that the lakes could experience, given the ideal dissolved oxygen concentrations and mixing conditions. Therefore, Lake Holiday, Wing Lake, and Lake Rose likely experience an average internal loading rate that is less than these rates would indicate (as they assume perfect internal loading conditions).

Assuming that the estimated internal phosphorus loading occurs over the entire area of the lake during the 122 days in the growing season (June through September), modeling results indicate that the internal areal loading rate for Lake Holiday is estimated to be 1.0 to 4.1 $mg/m^2/day$. In Wing Lake the estimated rate is 1.6 to 1.9 $mg/m^2/day$. Applying this method to Lake Rose yields estimated internal loading rates of 1.2 to 3.2 $mg/m^2/day$. For each of these lakes, these values fall within (or below) the range developed as part of the sediment core analysis, indicating the internal phosphorus loading rates predicted by the mass balance model are reasonable.

More information about the sediment core analysis for Lake Holiday, Wing Lake, and Lake Rose can be found in Appendix H.

Table 6-5 Comparison of Lake Holiday, Wing Lake, and Lake Rose Internal Phosphorus Loading Rates to those of other Metro Area Lakes

Lake	Internal P Load (mg/m^2/d)
Kohlman[1]	17.0
Isles (pre-alum, deep hole)[2]	14.1
Harriett (pre-alum, deep hole) [2]	11.1
Calhoun (pre-alum, deep) [2]	10.8
Rose	**10.6**
Fish E[3]	10.5
Cedar (pre-alum) [2]	9.3
Fish W[3]	8.1
Como[3]	7.6
Harriet[3]	6.9
Holiday	**6.0**
Como-litoral[3]	5.7
Calhoun (pre-alum, shallow) [3]	5.6
Keller[1]	3.5
Parkers[3]	3.5
Wing	**2.9**
Phalen[3]	2.3
McCarrons[3]	2.0
Bryant[3]	1.5
Nokomis[3]	1.0
Minnewashta[3]	0.2
Christmas[3]	0.0

Sources:
[1] Barr (2005)
[2] Huser et al. (2009)
[3] Pilgrim et al. (2007)

6.3 Aquatic Communities

In addition to the physical and chemical indices of lake water quality, an evaluation of the plant and animal species that inhabit the water provides valuable information as to the health of the lake. An assessment of the current situation with respect to the aquatic communities in the lake is given in the following sections.

6.3.1 Phytoplankton

The phytoplankton communities in Lake Holiday, Wing Lake, and Lake Rose form the base of the lake's food web and affect recreational-use of the lake. Phytoplankton, also referred to as algae, are small aquatic plants naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are in turn eaten by fish. Green algae are considered beneficial in that they are edible to zooplankton and serve as a valuable food source. Blue-green algae (or cyanobacteria) are considered nuisance algae because they:

- are generally inedible for fish, waterfowl, and most zooplankton;
- float at the lake surface in expansive algal blooms;
- may be toxic to animals when occurring in large blooms; and
- can interfere with recreational uses of the lake

An inadequate phytoplankton population limits the lake's zooplankton population and can, thereby, limit the fish production in a lake. Conversely, excess phytoplankton can alter the structure of the zooplankton community and interfere with sight-based fish predation, thereby also having an adverse effect on the lake's fishery. In addition, excess phytoplankton reduces water clarity; reduced water clarity can in itself make recreational-usage of a lake less desirable.

Phytoplankton data was collected for Wing Lake and Lake Rose in 2008. Figures 6-13 and 6-14 show the overall phytoplankton levels in 2008 in Wing Lake and Lake Rose, respectively. In general, Lake Rose typically has a higher concentration of algae than in Wing Lake throughout the season. Green algae were the dominant type of phytoplankton in Wing Lake during the sampling event in June. Blue-green algae were present throughout the 2008 sampling in numbers similar to, but usually less than, green algae. The number of blue-green algae increased in August. This increase in the number of blue-green algae is typical of lakes receiving excess phosphorus loads and warm growing conditions such as in Wing Lake. It is also important to note the presence of a small number of *Microcystis aeruginosa* during most of the sampling events. This species is known to produce a hepatotoxin (toxic to the liver of animals and humans). The presence of this species indicates the need to manage lake water quality to help control the growth of these potentially hazardous species.

In Lake Rose, blue-green algae were the dominant type of phytoplankton during sampling events in June, early August, and September. Green algae were never present in greater numbers than blue-green algae. In July, euglenoids were the dominant type of algae. These types were present only in very small numbers during other sampling events. Cryptomonads were present in high numbers on the August 19th sampling date, but were not present in high quantities during other sampling events. The data shows algal blooms in August which include high numbers of blue-green algae. During these blue-green algal blooms in Lake Rose, there were *Cylindrospermopsis raciborski* present as well as *Microcystis aeruginosa*.

Figure 6-13
Wing Lake 2008 Phytoplankton Surveys
Data Summary by Division

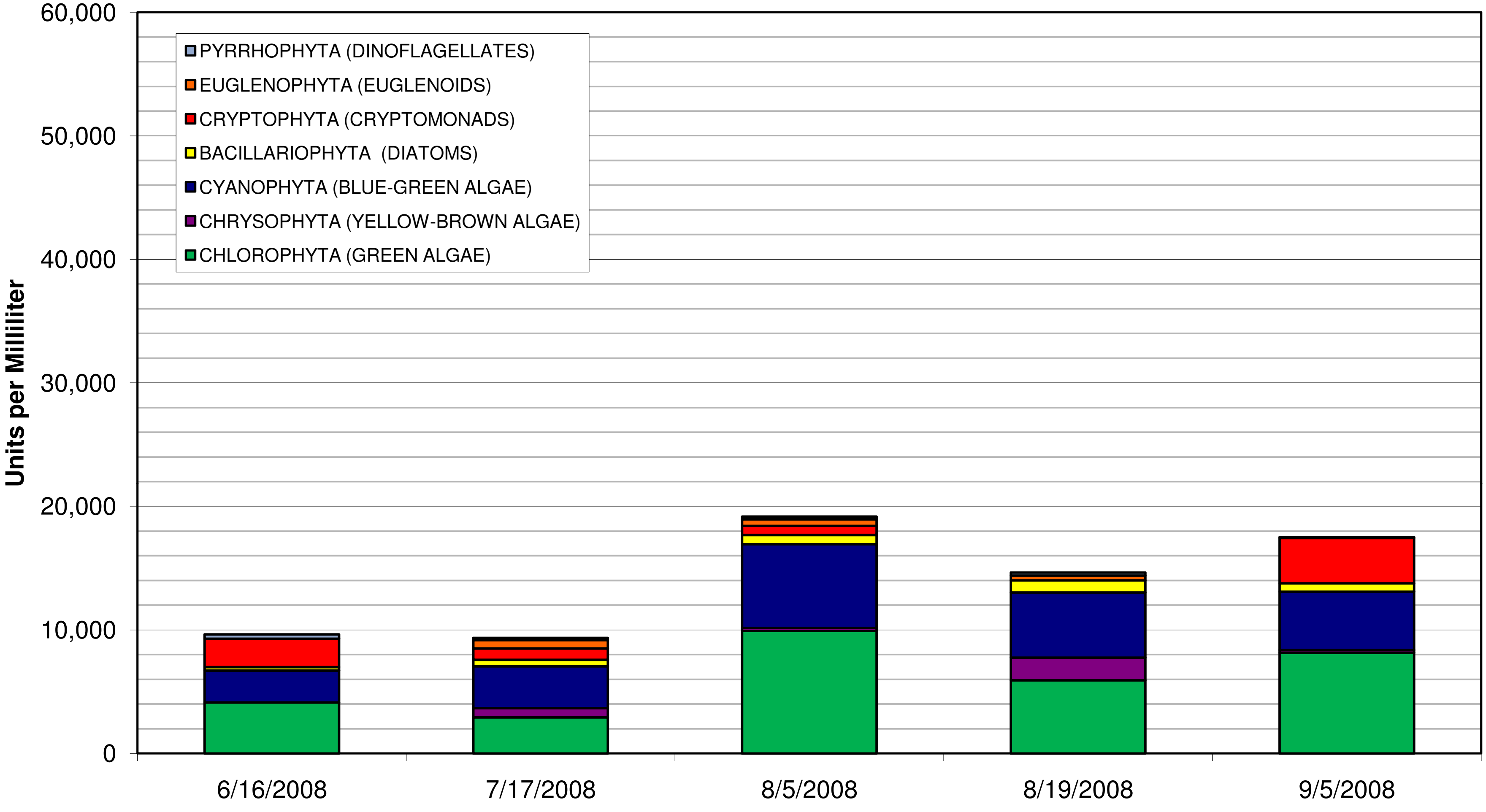


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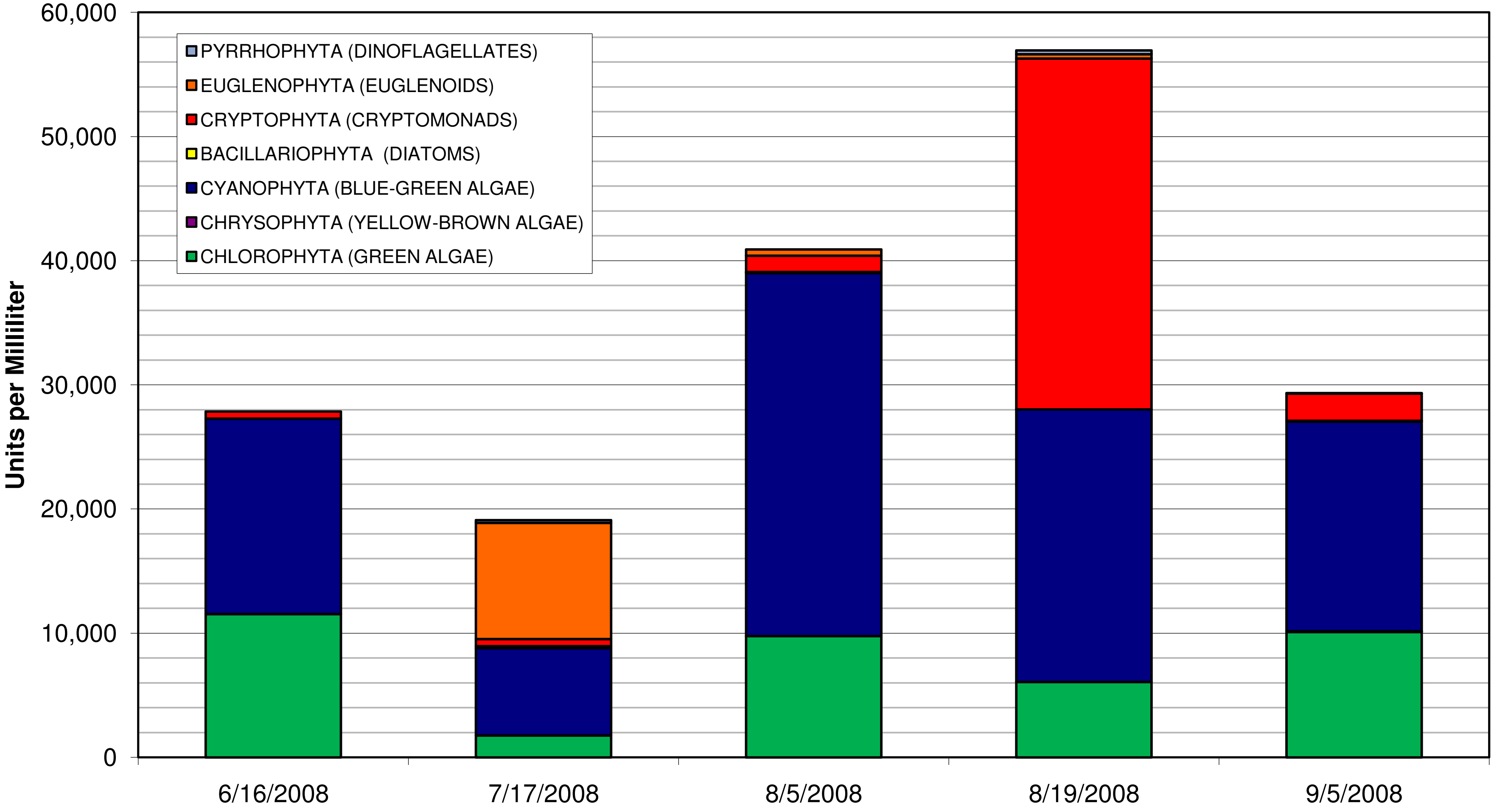
Figure 6-14
Lake Rose 2008 Phytoplankton Surveys
Data Summary by Division



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6.3.2 Zooplankton

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 is 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.

There is not a surrogate measurement of zooplankton biomass similar to Chl *a* concentration for phytoplankton biomass. Therefore, zooplankton must be identified and counted to get an estimate of zooplankton biomass. Zooplankton were sampled and counted in Wing Lake and Lake Rose in 2008. Figures 6-15 and 6-16 show the zooplankton totals (expressed as the number of organisms per square meter of lake surface) for Wing Lake and Lake Rose for several dates in 2008, respectively. The zooplankton data are provided in Appendix E. Each total shown is divided into the three main divisions of zooplankton to give an indication of their relative abundance.

The rotifers and copepods in lakes graze primarily on extremely small particles of plant matter and, therefore, do not significantly affect lake water transparency by removing algae. By contrast, cladocera graze primarily on algae and can increase transparency if they are present in abundance. *Daphnia spp*. is among the larger cladocera species and is considered especially desirable in lakes because of their ability to consume large quantities of algae.

Planktivorous fish (such as sunfish and bluegills) eat zooplankton and will preferentially select the large Daphnia. Therefore, to thrive, the *Daphnia* require either a refuge from predators (i.e., deep, well-oxygenated water) or a smaller predator population. The MDNR has not conducted fishery surveys on either Wing Lake or Lake Rose. As such, there is limited data on the dominant fish species present. It is possible that the introduction or increase in piscivorous fish such as walleye or northern pike in either lake could lead to an increase in the *Daphnia* population through the reduction of planktivorous fish (bluegills, crappies, and sunfish).

Throughout the 2008 season, rotifers were the dominant group of zooplankton in Wing Lake and Lake Rose. Because the rotifers are so small, their grazing of phytoplanktonic algae has very little impact on the clarity of the water in these lakes. A smaller number of copepods were present in each lake throughout the summer in both lakes. Very low numbers of cladocera were present in Wing Lake in July and early August. Cladocera were identified in Lake Rose on the August 19th sample date only. The highest numbers of zooplankton in Wing Lake occurred at the end of the sampling season (end of August and September). In Lake Rose, the lowest zooplankton concentrations occurred in August.

Figure 6-15
Wing Lake 2008 Zooplankton Surveys
Data Summary by Division

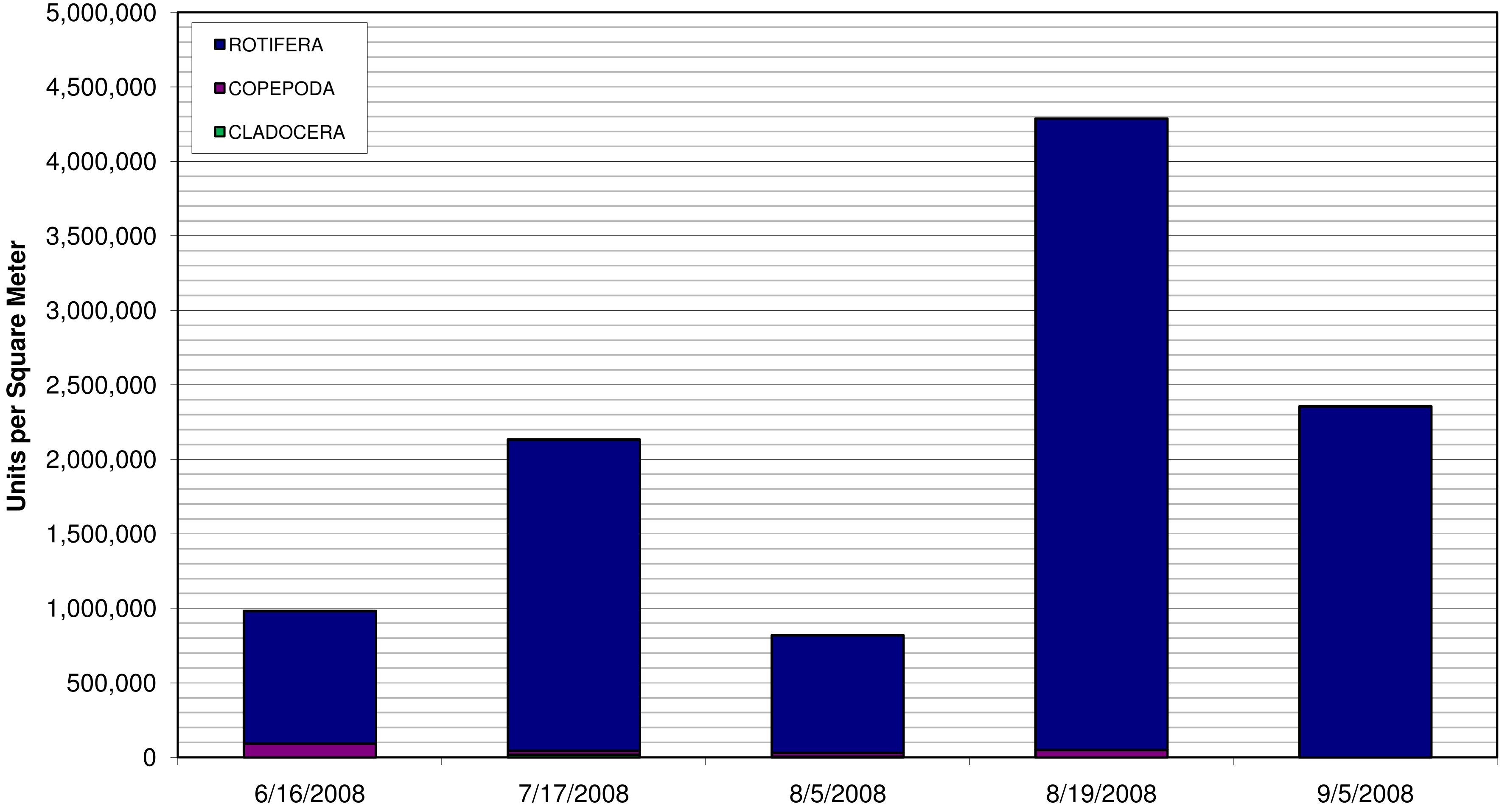

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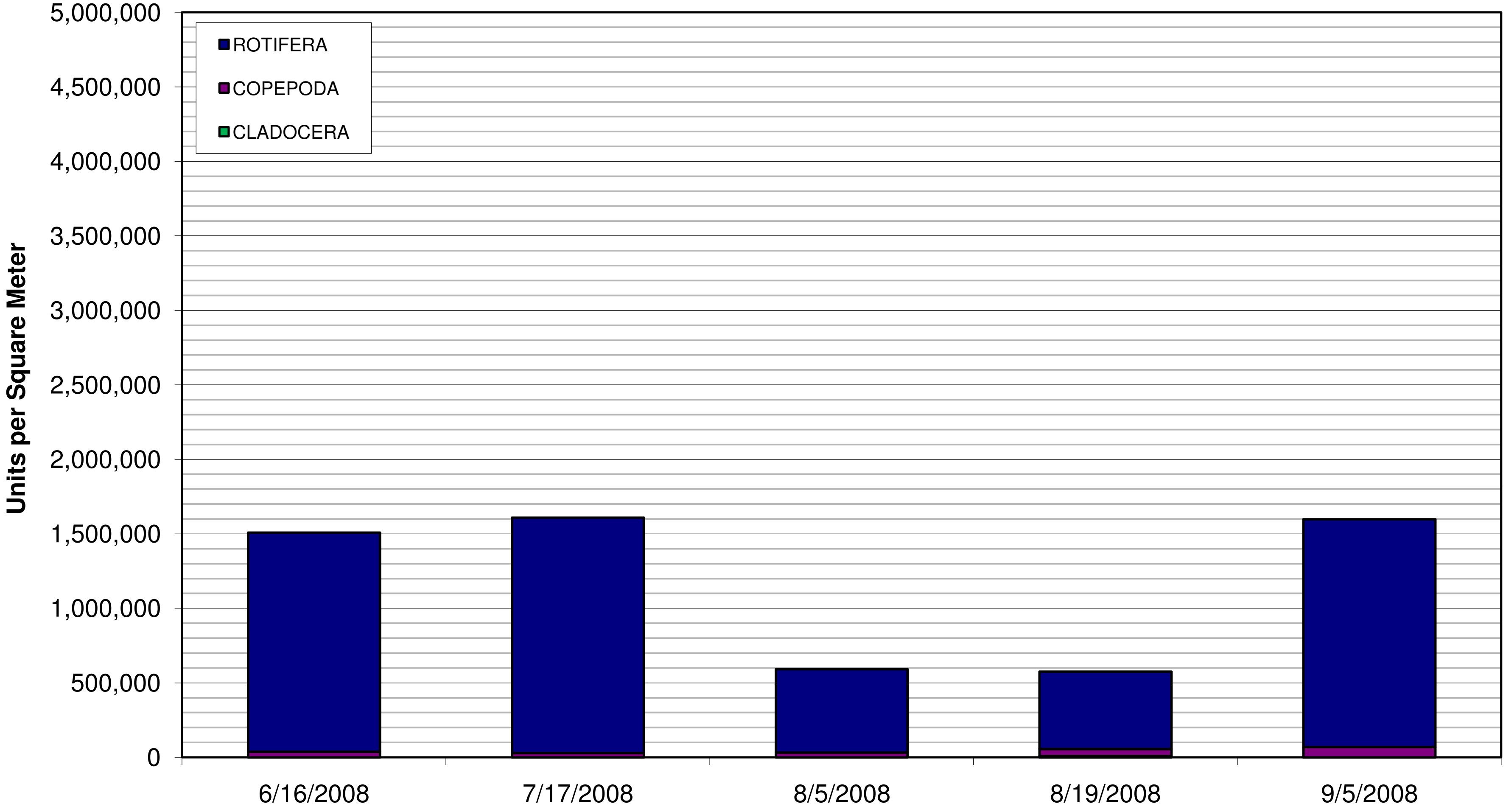
Figure 6-16
Lake Rose 2008 Zooplankton Surveys
Data Summary by Division



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6.3.3 Macrophytes

Aquatic plants—macrophytes—are a natural and integral part of most lake communities, providing valuable refuge, habitat and forage for many animal species. The lake's aquatic plants, generally located in the shallow areas near the shoreline of the lake:

- Provide habitat for fish, insects, and small invertebrates
- Provide food for waterfowl, fish, and wildlife
- Produce oxygen
- Provide spawning areas for fish in early-spring/provide cover for early-life stages of fish
- Help stabilize marshy borders and protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Surveys of the aquatic plant community in Lake Holiday, Wing Lake, and Lake Rose were completed by the NMCWD during June and August of 2008. Survey results are presented in Appendix F, and are summarized below.

6.3.3.1 Lake Holiday Macrophytes

The June 2008 macrophyte survey for Lake Holiday showed submerged aquatic plants throughout the entire lake, consisting primarily of Curlyleaf pondweed (*Potamogeton crispus*), floating leaf pondweed (*Potamogeton natans*), and narrowleaf pondweed (*Potamogeton sp.*). Additionally, other emergent plants such as the invasive purple loosestrife (*Lythrum salicaria*) are found in the shallow waters along the shores of Lake Holiday. The August 2008 survey indicated no submerged plants were present. Purple loosestrife (*Lythrum salicaria*) was still present around the entire perimeter of the lake. A dense algal bloom was observed during the August 2008 macrophyte survey.

6.3.3.2 Wing Lake Macrophytes

The June 2008 macrophyte survey for Wing Lake showed submerged aquatic plants throughout the entire lake. Several species were present, including Curlyleaf pondweed (*Potamogeton crispus*), flatstem pondweed (*Potamogeton zosteriformis*), narrowleaf pondweed (*Potamogeton sp.*), Elodea (*Elodea canadensis*), and stonewart (*Nitella sp.*). Coontail (*Ceratophyllum demersum*) was also present in high densities. Cattail (*Typha sp.*) and purple loosestrife (*Lythrum salicaria*) were identified on the south shore of the lake, near the outlet. Where lake depths were less than 3 or 4 feet, which includes most of the lake, white waterlily (*Nymphaea tuberosa*) was present in high densities.

The August 2008 macrophyte survey of Wing Lake was similar to the June survey. The die-off of submerged aquatic plants observed in Lake Holiday was not observed in Wing Lake. Although submerged species were still present in high densities, Curlyleaf pondweed (*Potamogeton crispus*) was not identified (as would be expected based on its lifecycle). Flatstem pondweed (*Potamogeton zosteriformis*), narrowleaf pondweed (*Potamogeton sp.*), coontail (*Ceratophyllum demersum*), Elodea (*Elodea canadensis*), and stonewart (*Nitella sp.*) were again present. A portion of the lake similar to that observed in June was covered with floating leaf vegetation, primarily white waterlily (*Nymphaea tuberosa*).

6.3.3.3 Lake Rose Macrophytes

The June 2008 macrophyte survey for Lake Rose showed submerged aquatic plants throughout most of the lake, with the exception of the deep hole in the east basin. Several submerged species were present, including Curlyleaf pondweed (*Potamogeton crispus*), flatstem pondweed (*Potamogeton zosteriformis*), narrowleaf pondweed (*Potamogeton sp.*), Elodea (*Elodea canadensis*), bladder wort (*Utricularia sp.*), and sago pondweed (*Potamogeton pectinatus)*. Coontail (*Ceratophyllum demersum*) was also present in high densities. Cattail (*Typha sp.*), bulrush (*Scirpus sp.*) and purple loosestrife (*Lythrum salicaria*) were identified on the shore of the west basin. In the shallower parts of the lake, which includes most of the west basin, white waterlily (*Nymphaea tuberosa*) was present.

The August 2008 macrophyte survey of Lake Rose was similar to the June survey, with the exception that Curlyleaf pondweed (*Potamogeton crispus*) was not identified. Bushy pondweed (*Najas sp.*) was identified in the August survey but not in the June survey.

6.3.3.4 Coontail, Purple Loosestrife, and Curlyleaf Pondweed

Since coontail absorbs its nutrients (including phosphorus) from the water column, its presence in Wing Lake and Lake Rose likely impacted the TP concentration observed in the lake. Another non-native emergent wetland species, purple loosestrife (*Lythrum salicaria*) appeared at various locations along the shores of Lake Holiday, Wing Lake, and Lake Rose. Purple loosestrife out-competes native plants, such as cattail, and can eventually replace the native species, thereby interfering with the wildlife-use of the lake. Animals that rely on native vegetation for food, shelter, and breeding sites cannot use purple loosestrife. The sporadic area in which purple loosestrife was found suggests the purple loosestrife growth is a more recent development.

The appearance of the nonnative Curlyleaf pondweed in Lake Rose should continue to be monitored. Once a lake becomes infested with Curlyleaf pondweed, the plant typically replaces native vegetation, increasing its coverage and density. Lake Holiday and Wing Lake already contain high densities of Curlyleaf pondweed. Curlyleaf pondweed (*Potamogeton crispus*) is one of the most widespread nuisance-forming, nonnative submerged aquatic plants in the state of Minnesota. Dense growth of Curlyleaf pondweed out-competes native aquatic vegetation, degrades lake water quality, and causes problems to navigation and recreation (Bolduan et. al, 1994). Curlyleaf pondweed begins growing in late-August and grows throughout the winter at a slow rate, grows rapidly in the spring, and dies early in the summer (Madsen et al. 2002). Native plants that grow from seed in the spring are unable to grow in the areas already occupied by the Curlyleaf pondweed, and are displaced by this plant. Curlyleaf pondweed dies off in early to mid summer, releasing phosphorus into the water column, and often resulting in increased algal growth for the remainder of the summer.

6.3.4 Fish and Wildlife

The MDNR has not performed fishery surveys for Lake Holiday, Wing Lake, or Lake Rose. There is a general lack of information regarding the fish species present in these lakes. The correlation of sediment TP release rates and estimated internal loading rates (see Section 6.2.2.1) suggest that sediment disturbance from rough fish activity is not the main cause of high internal loads.

There is no public access to Wing Lake and Lake Rose, which limits the use of the lakes for fishing or wildlife viewing.