5.0 Results

5.1 Compiled Data

Water quality and limnological data acquired during the preparation of this management plan are compiled in the Appendices. Appendix A summarizes the results of the survey sent to the lakeshore owners/residents that live along, have deeded access to, or live nearby Lake Owasso. Appendix B includes the drawing of the outlet of Lake Owasso. Appendix C summarizes the results of the discharge surveys conducted by the Cities of Roseville and Shoreview during the summer of 2007. Appendix D summarizes the pond discharge surveys as conducted in late May through late July 2008. Appendix E summarizes the P8 parameter selection process during calibration and pond data used for development of the P8 model. The pond data is based on pond field surveys, data taken from development plans or using ArcView and estimated average depths. Appendix F is the tabulated 2007 and 2008 in-lake water quality data for Lake Owasso collected as a part of this UAA. Selected water quality parameters from Appendix F are analyzed and summarized in the discussion below. Appendix G contains the results of a trend analysis performed on the historical water quality data available for Lake Owasso. Appendix H summarizes the historic zooplankton and phytoplankton data for Lake Owasso as collected by Ramsey County. Appendix H also includes the preliminary memo related to the zooplankton filtering rates from Dr. Joseph Shapiro, University of Minnesota Emeritus Professor of Limnology.

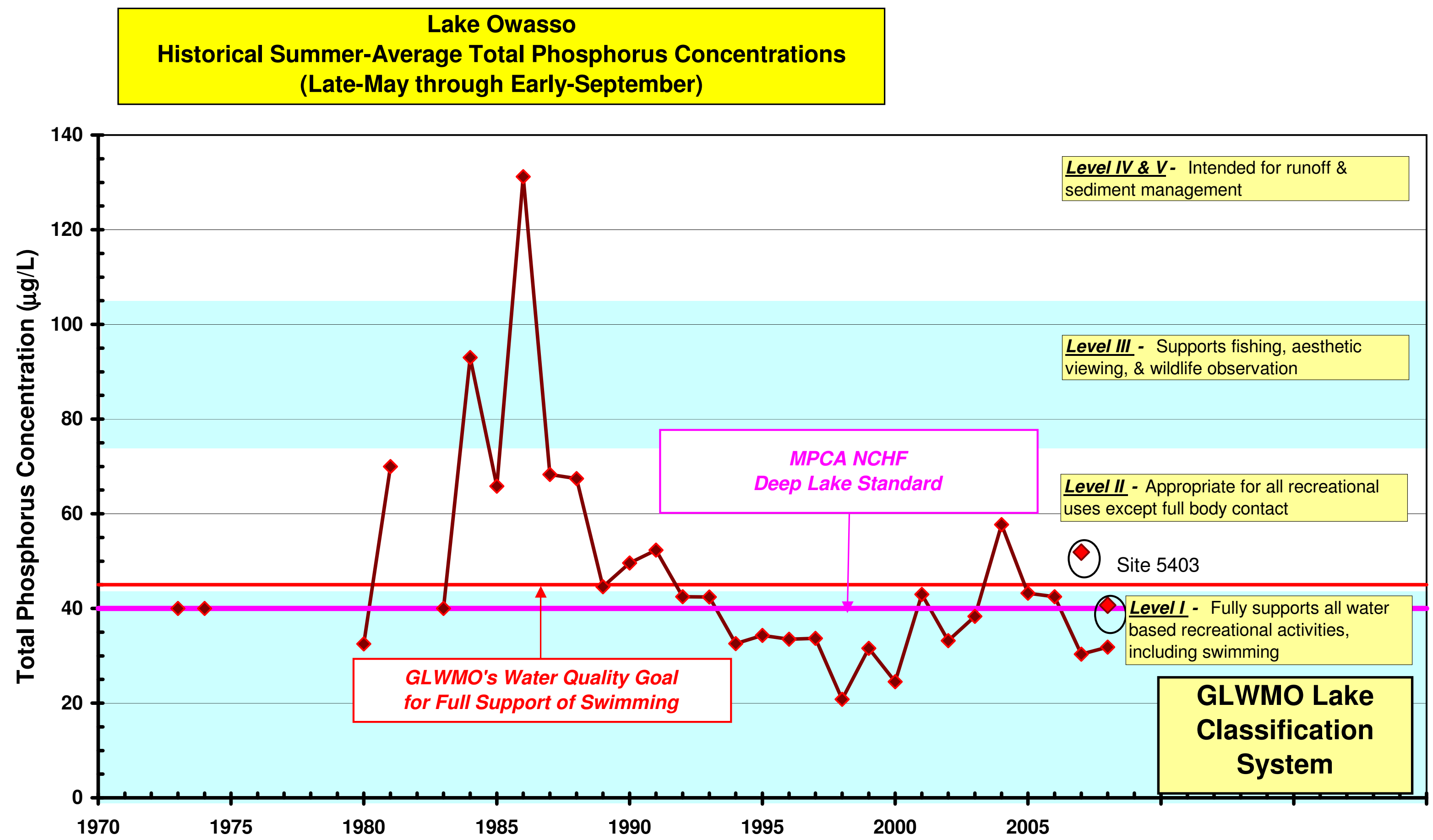
Appendix I summarizes any fishery and stocking data for the Lake as obtained from the MDNR. Appendix J includes macrophyte survey data. Appendix K includes the Lake Owasso Shoreline Survey results, as conducted by RWMWD staff. Appendix L includes the results of the in-lake water quality modeling for each of the climatic conditions. Appendix M contains the results of the 2007 sediment core analysis. Appendix N shows the detailed cost estimates for the BMPs analyzed in this study. The significance of all of these data and how they were used in this study are described below.

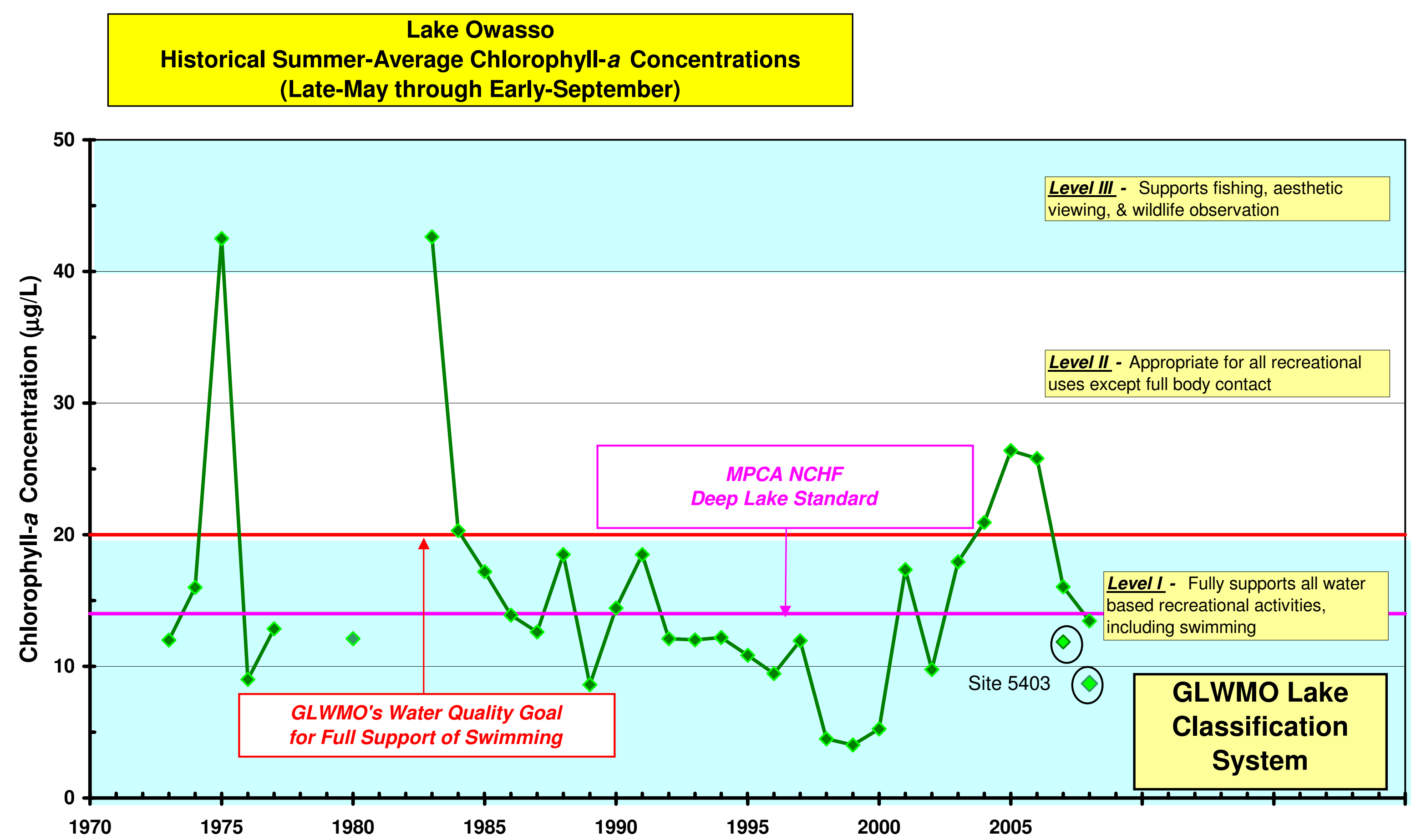
5.2 Trend Analyses of Total Phosphorus, Secchi Disc Transparency, and Chlorophyll *a* Data

5.2.1 Historical Water Quality-Lake Owasso

Historical water quality data, in terms of summer-average total phosphorus, Secchi disc and chlorophyll *a*, for Lake Owasso are presented in Figure 5-1. To define a "summer-average" for each water quality parameter, the typical averaging period was the end of May through early September to be consistent with the MPCA's method for evaluating lake water quality. For some years, the averaging period was June through early September if data for late May was not available.

In addition to the average over the period of record, two other values are noted on each chart: the GLWMO water quality goal as stated in the GLWMO *Watershed Management Plan* (Barr, 2001) and the MPCA's deep lake standard for each water quality parameter. The plot of the historical Secchi depths includes a third value, the GLWMO action level (as defined by the GLWMO *Watershed Management Plan* (Barr, 2001)).





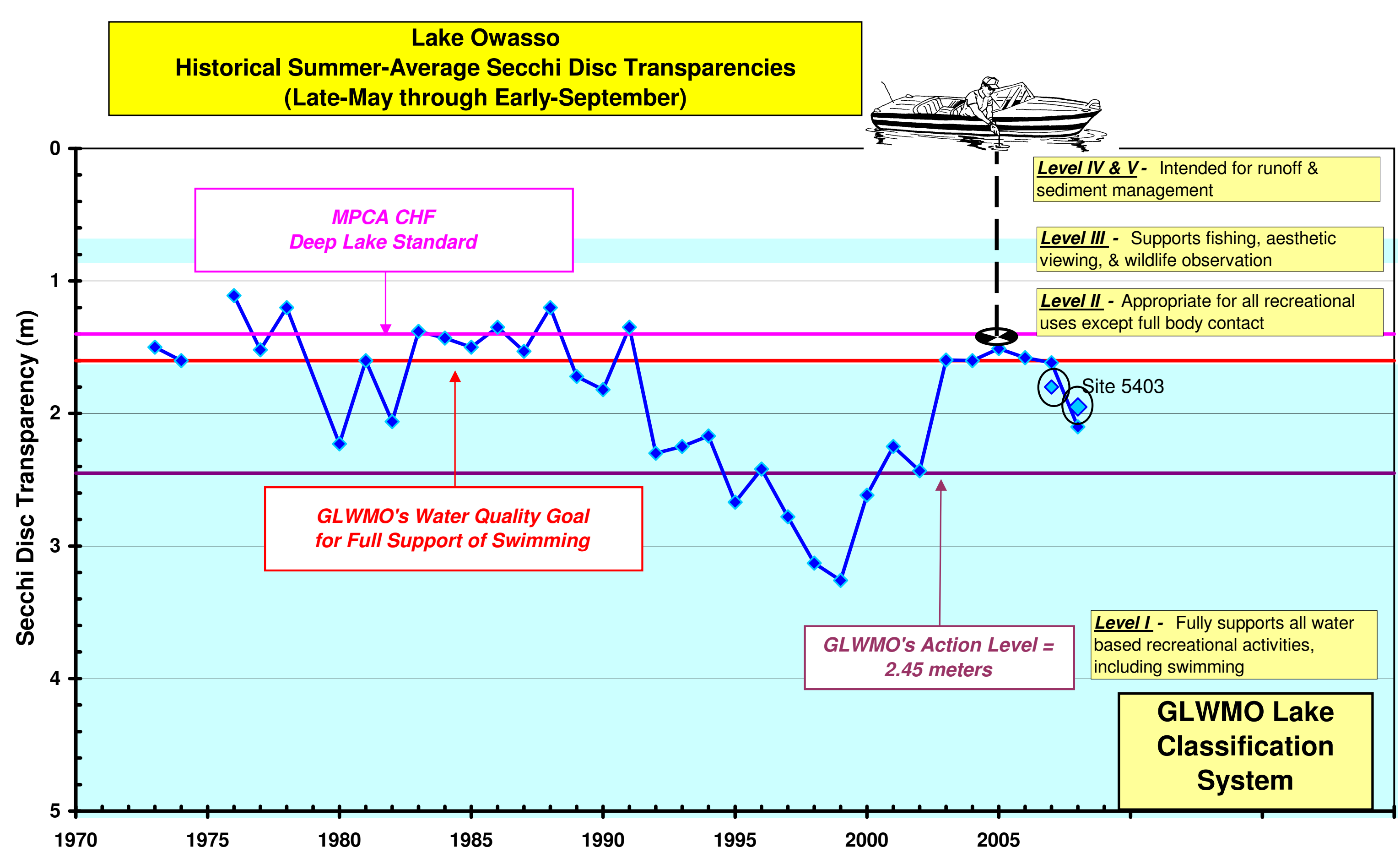


Figure 5-1
Lake Owasso Historical Summer Average
(late May through early September) Total Phosphorus
and Chlorphyll-*a* Concentrations and Secchi Depths

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The compiled data for summer-average water quality variables from Lake Owasso were analyzed to develop relationships between the water quality parameters: total phosphorus, chlorophyll *a*, and Secchi depth.

It was shown in the *Water Quality Management Alternatives* study (Barr, 1991) that the changes in chlorophyll *a* concentrations are unrelated to changes in phosphorus levels in Lake Owasso. Although phosphorus concentrations in lakes place limits on the overall abundance of algae, other features of lakes frequently modify the actual amounts of algae that are present. This can be especially true when zooplankton, which feed upon algae are of sufficient abundance and size allow, reduce the amount of algae to well below the limit allowed by the phosphorus levels.

Lake Owasso continues to show a similar relationship between total phosphorus and chlorophyll *a* concentrations through the present, as shown in Figure 5-2. Also plotted in Figure 5-2, is the total phosphorus and chlorophyll *a* regression equation developed by the MPCA based on a statewide lake database (MPCA, 2005). The slope of the relationship for Lake Owasso is much lower than the slope of the MPCA relationship, suggesting that the algae concentrations in Lake Owasso are likely more impacted by zooplankton grazing than in the lakes used by the MPCA to develop the statewide total phosphorus and chlorophyll *a* regression equations.

Because of the poor correlation (r^2=0.18) between the total phosphorus and chlorophyll *a* concentrations in Lake Owasso and because total phosphorus and Secchi depth are the major management parameters, a direct relationship between total phosphorus and Secchi depth was developed for Lake Owasso. Figure 5-3 shows the relationship between total phosphorus concentrations and Secchi depths in the lake. The regression equation relating total phosphorus to Secchi depth is:

$$[SD] = 4.0 - [\ 3.03 * (\ ([TP] - 20) / (\ ([TP] - 20) + 9.67\ )\ );\ (r^2=0.60)$$

Where:

[TP]	=	measured or estimated epilimnetic (mixed surface layer) mean summer total phosphorus concentration (µg/L)
SD	=	estimated mean summer Secchi disc transparency (m)

This equation was used to relate predicted in-lake total phosphorus concentrations to Secchi disc transparency, allowing for the comparison to the GLWMO's water quality goals as well as the MPCA's Deep Lake water quality standards (Table 1-1).

It is important to note there is a significant amount of scatter in the total phosphorus and Secchi depth data used to develop this predictive equation. Variance bands around this regression equation were developed to demonstrate that when interpreting the results of this equation, it should be understood that there is some variance associated with the predicted value, and it cannot be considered as absolute.

To develop these variance bands, the dataset was divided into two groups based on the variance observed in the Secchi depth data. In the lower total phosphorus concentrations (concentration less than 60 μg/L), the variance in the Secchi depth data was about 3 times greater than it was for the higher total phosphorus concentrations (greater than 60 μg/L). It was assumed that the data in the two groups were normally distributed. Using the calculated variance for each data group, the upper and lower 95^{th} percentiles around the regression equation were estimated.

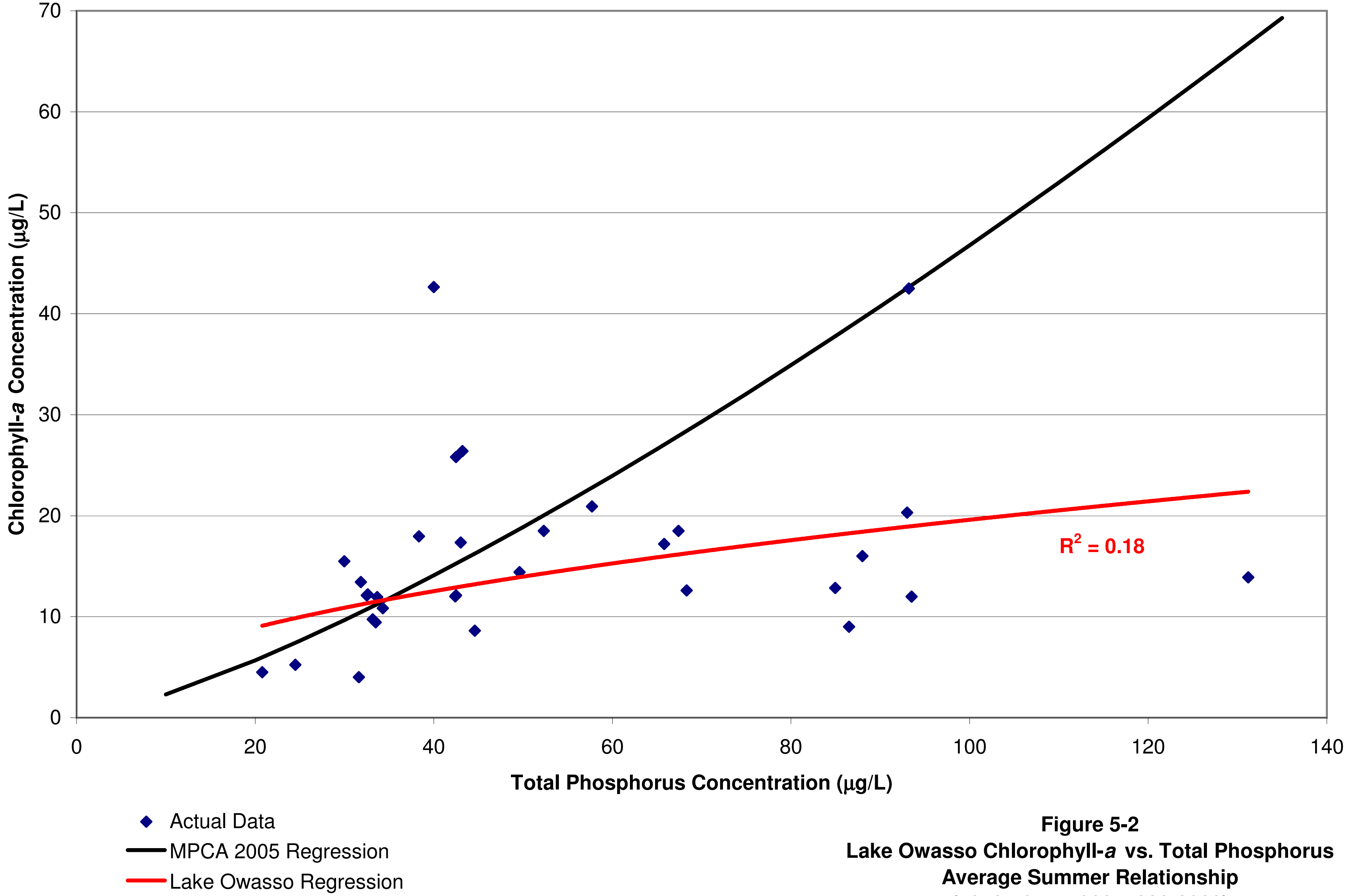

Figure 5-2
Lake Owasso Chlorophyll-*a* vs. Total Phosphorus
Average Summer Relationship
(1973-1977, 1980, 1983-2008)

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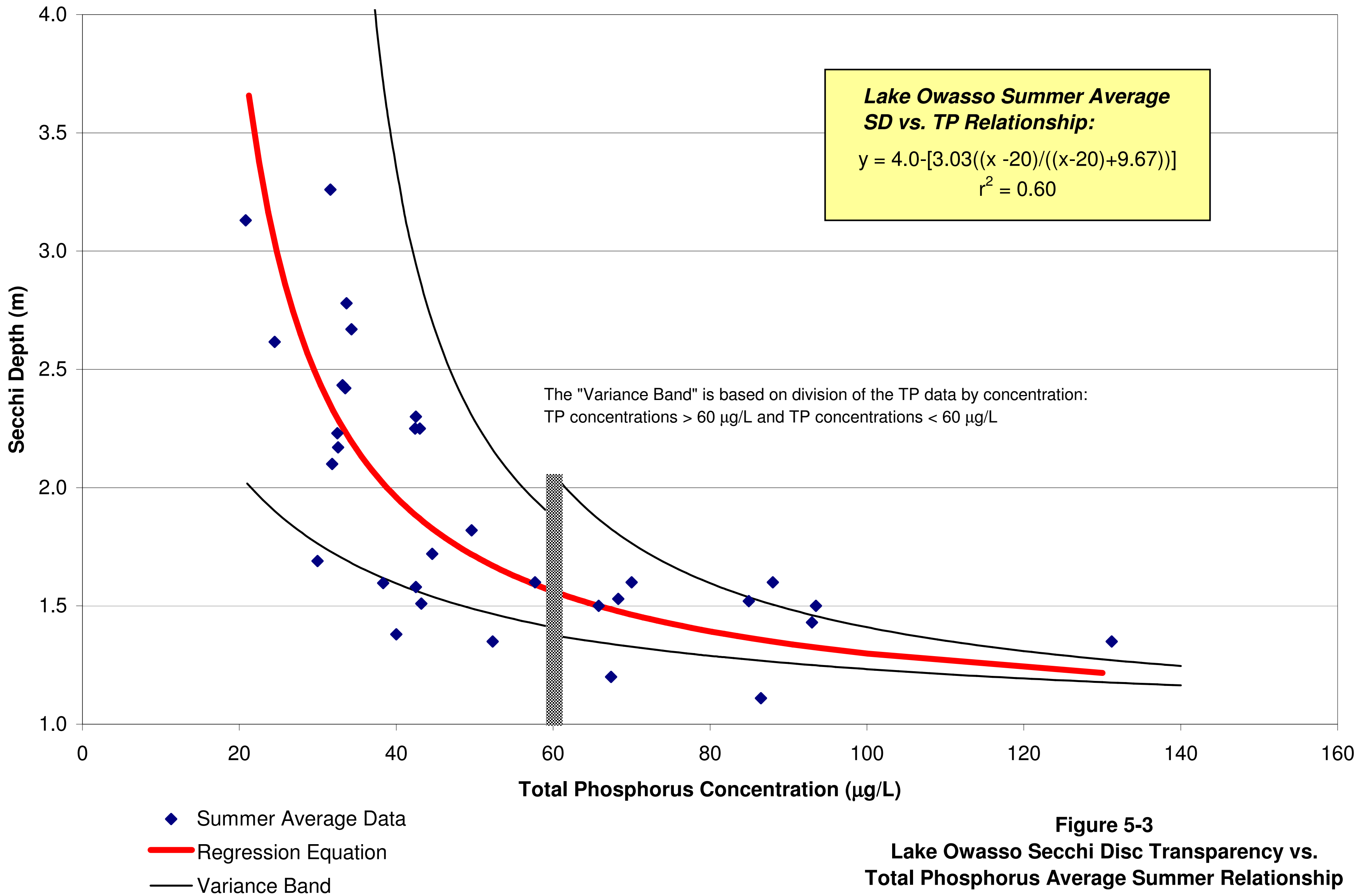


Figure 5-3
Lake Owasso Secchi Disc Transparency vs.
Total Phosphorus Average Summer Relationship
(1973-1974, 1976-1977, 1980-1981, 1983-2008)

5.2.2 Lake Owasso Water Quality Trend Analysis

A trend analysis of Lake Owasso's historical water quality data was completed to determine if the lake had experienced significant degradation or improvement during all (or a portion of) the years for which water quality data are available. Summer-average values (the typical averaging period was late-May through early-September to be consistent with the MPCA's method for evaluating lake water quality) were calculated and analyzed were used to determine water quality trends. Long-term trends are typically determined using standard statistical methods (i.e., linear regression and analysis of variance). Trend analyses were run for two different time periods. The first period was for the most recent 10 years of water quality data, evaluating the same time period that the MPCA typically considers when looking at listing surface waters for water quality impairment on the 303(d) Impaired Waters List. The second considered a period with complete water quality data for all three water quality parameters (from 1983 through 2008).

For this report, the Mann-Kendall/Sen's Slope Trend Test was used to determine water quality trends and their significance. To complete the trend test, the calculated summer average must be based on at least 4 measured values during the sampling season and at least 5 years of data are required. The trend was considered significant if the slope of the regression was statistically significant at the 95 percent confidence interval. Also, to conclude an improvement requires concurrent decreases in TP and Chlorophyll *a* concentrations, as well as increases in Secchi disc transparences; a conclusion of degradation requires the inverse of the relationship above.

The trend analysis for Lake Owasso run using the past 10 years of water quality data (1998 through 2008) found that there has not been a significant change in total phosphorus concentrations over the past 10 years while there was a statistically significant increase in the Chlorophyll *a* concentration over the same time period. Additionally, there was a significant decrease in Secchi depth. Because all three parameters do not show a similar trend, no conclusions can be made about the significance of the changes in water quality over the past 10 years. However, both Chlorophyll *a* and Secchi depth indicate that there has been some degradation in Lake Owasso water quality.

The trend analysis for Lake Owasso for the period from 1983 through 2008 found that there has been a significant decrease in total phosphorus concentrations over the past several decades. There has not been a statistically significant change in the Chlorophyll *a* concentration over the same time period. Additionally, there was a significant increase in Secchi depth. Because all three parameters do not show a similar trend, no conclusions can be made about the significance of the changes in water quality over the past 3 decades. However, both total phosphorus and Secchi depth indicate that there has been some improvement in Lake Owasso water quality since the early 1980's. This is likely due to the implementation of water quality BMPs throughout the watershed..

Results of the trend analysis can be found in Appendix G.

5.3 Seasonal Patterns in 2007 & 2008 Water Quality Conditions

Total phosphorus, Secchi disc, and chlorophyll *a* were measured for Lake Owasso in 2007 and 2008 by Ramsey County.

Phosphorus is the plant nutrient that most often limits the growth of algae. Phosphorus-rich lake water indicates a lake has the potential for abundant algal growth, which can lead to lower water transparency and a decline in hypolimnetic oxygen levels in a lake. According to previous studies (Heiskary and Wilson, 1990) summer-average phosphorus concentrations of 40 μg/L typically result in algal scums being evident (greater than 10 μg/L chlorophyll *a*) for about 65 percent of the summer and nuisance algal bloom conditions (greater than 20 μg/L chlorophyll *a*) for approximately 25 percent of the summer.

Chlorophyll *a* is a measure of algal abundance within a lake. High chlorophyll concentrations indicate excessive algal abundance (i.e., algal blooms), which can lead to recreational use impairment. As stated above, chlorophyll *a* measurements greater than 20 μg/L indicate "nuisance conditions."

Secchi disc transparency is a measure of water clarity. Perceptions and expectations of people using a lake are generally correlated with water clarity. Results of a survey completed by the Metropolitan Council (Osgood, 1989) revealed the following relationship between a lake's recreational use impairment and Secchi disc transparencies:

- Moderate to severe use-impairment occurs at Secchi disc transparencies less than 1 meter (3.3 feet).
- Moderate impairment occurs at Secchi disc transparencies of 1 to 2 meters.
- Minimal impairment occurs at Secchi disc transparencies of 2 to 4 meters.
- No impairment occurs at Secchi disc transparencies greater than 4 meters

Other notable water quality parameters that were measured in 2007 and 2008 in the lakes are temperature and dissolved oxygen, (which indicate the level of stratification in the lakes as well as measure the habitat environment for aquatic species) and chloride (which indicates the degree to which road salts have run off into the lakes from surrounding streets and parking lots, potentially adversely affecting lake biota).

Based on protection of the aquatic community from adverse toxic effects, the standard for chloride in Class 2B waters is as follows (Minnesota Rules 7050):

Chronic standard = 230 mg/L
Acute standard = 860 mg/L (MS), 1720 mg/L (FAV)

Where:

FAV = stands for "Final acute value" and means an estimate of the concentration of a pollutant corresponding to the cumulative probability of 0.05 in the distribution of all the acute toxicity values for the genera or species from the acceptable acute toxicity tests conducted on a pollutant.

MS = stands for "Maximum Standard" and means the highest concentration of a toxicant in water to which aquatic organisms can be exposed for a brief time with zero to slight mortality. The MS equals the FAV divided by two.

This section provides a brief discussion of these parameters as they were measured in Lake Owasso during 2007 and 2008 monitoring seasons.

5.3.1 Water Quality Parameters

Figure 5-4a shows the total phosphorus, Secchi disc, and chlorophyll *a* monitoring results for monitoring site 5401 in Lake Owasso for 2007 and 2008. Figure 5-4b shows the total phosphorus, Secchi disc, and chlorophyll *a* monitoring results for monitoring site 5403 in Lake Owasso for 2007 and 2008. Temperature, oxygen, and chloride data are tabulated in Appendix F.

Phosphorus

The 2007 spring total phosphorus concentration was 26 µg/L at monitoring site 5401 while in the southwest corner of the lake, at site 5403, the total phosphorus concentration was 33 µg/L. This places the lake at the low end of the eutrophic status category. The 2007 peak phosphorus concentration at site 5401 during the summer was 38 µg/L by mid-June. The peak summer phosphorus concentration at site 5403 was 62 µg/L by the beginning of July.

The 2008 spring total phosphorus concentration was 34 µg/L at monitoring site 5401 while in the southwest corner of the lake, at site 5403, the total phosphorus concentration was 35 µg/L. This places the lake at the low to mid range of the eutrophic status category. The peak phosphorus concentration at site 5401 during the summer was 38 µg/L at the end of July. The peak summer phosphorus concentration at site 5403 was 50 µg/L by the beginning of July.

The summer average phosphorus concentrations at site 5401 for 2007 and 2008 were 30 µg/L and 32 µg/L, respectively. These values meet the GLWMO water quality goal of 45 µg/L as well as the MPCA deep lake criterion (40 µg/L). At site 5403, the summer-average total phosphorus concentrations for 2007 and 2008 (52 µg/L and 41 µg/L, respectively) do not meet the MPCA criterion, but the 2008 water quality meets the GLWMO water quality goal. The total phosphorus data collected from Lake Owasso during 2007 and 2008 were generally within the eutrophic (i.e., nutrient-rich) category during the summer.

Isopleths of total phosphorus concentrations at depth through the summers of 2007 and 2008 for both Sites 5401 and 5403 in Lake Owasso can be found in Appendix F.

Chlorophyll *a*

The 2007 and 2008 spring chlorophyll *a* concentrations at monitoring site 5401 were 2 µg/L and 15 µg/L, respectively, while site 5403, chlorophyll *a* concentrations were 4 µg/L and 12 µg/L. These concentrations classify Lake Owasso as mesotrophic in 2007 and eutrophic in 2008. In 2007, as phosphorus concentrations increase over the course of the summer, chlorophyll *a* concentrations rose sharply in June to peak in the beginning of July for both sites 5401 and 5403 (peak concentrations of 23 µg/L and 16 µg/L, respectively), placing Lake Owasso in the eutropic category. There was a second peak in chlorophyll *a* concentration (18 µg/L) at monitoring site 5403 in the beginning of September that was higher than the peak in early July. In 2008, the peak chlorophyll *a* concentration at site 5401 (25 µg/L) occurred in mid-August, after the total phosphorus peak that occurred in the end of July. At site 5403, the 2008 peak chlorophyll *a* concentration (14 µg/L) occurred in early July, similar to the pattern seen in total phosphorus.

The 2007 and 2008 summer-average chlorophyll *a* concentrations at both sites 5401 (16 µg/L and 13 µg/L, respectively) and 5403 (12 µg/L and 9 µg/L) meet the GLWMO goal of 20 µg/L. However, the chlorophyll *a* concentration at site 5401 did not meet the MPCA deep lake criterion (14 µg/L) in 2007. The chlorophyll *a* data collected from Lake Owasso during 2007 and 2008 were generally within the eutrophic category throughout the summer, indicating that Lake Owasso may have experienced nuisance conditions of algal growth.

Secchi Disc

The 2007 spring Secchi disc transparency was 2.1 meters for the both monitoring sites on Lake Owasso, placing lake on the border of the mesotrophic-eutrophic status category. In 2008, the spring Secchi disc transparency at site 5401 was 1.5 meters and at site 5403 was 1.8 meters. For both years, as summer progressed, Secchi disc transparency gradually decreased. At site 5401, transparency reached a minimums of 0.9 meters in early August 2007 and 0.8 meters in early August 2008 . At site 5403, transparency was at its minimum in early July 2007 with a Secchi depth of 1.2 meters. In early July 2008, the minimum transparency at site 5403 was 1.4 meters.

The 2007 summer-average Secchi depth for both sites 5401 and 5403 (1.6 meters and 1.8 meters) just meet the GLWMO water quality goal (1.6 meters) but both are less than the GLWMO established action level (2.45 meters) for Lake Owasso. The 2008 summer average transparency for sites 5401 and 5403 (2.1 meters and 2.0 meters) also meet the GLWMO water quality goal. The summer averages at both monitoring sites meet the MPCA deep lake criterion (1.4 meters). The Secchi disc data collected from Lake Owasso during 2007 and 2008 were within the eutrophic category throughout the summer months.

Temperature and Oxygen

Temperature and oxygen measurements throughout the water column at both monitoring sites in Lake Owasso indicate that the entire lake does thermally stratify from May through early September, for both 2007 and 2008. At Site 5401, the depth to the thermocline was approximately 5 to 6 meters. At site 5403, the thermocline depth is about 2 to 3 meters.

By late Sept, temperature profiles indicate that the lake mixed at both monitoring locations, with the higher temperatures extending into the bottom waters of the lake. This is consistent with the presumption that Lake Owasso is a dimictic lake (completely mixes twice-annually).

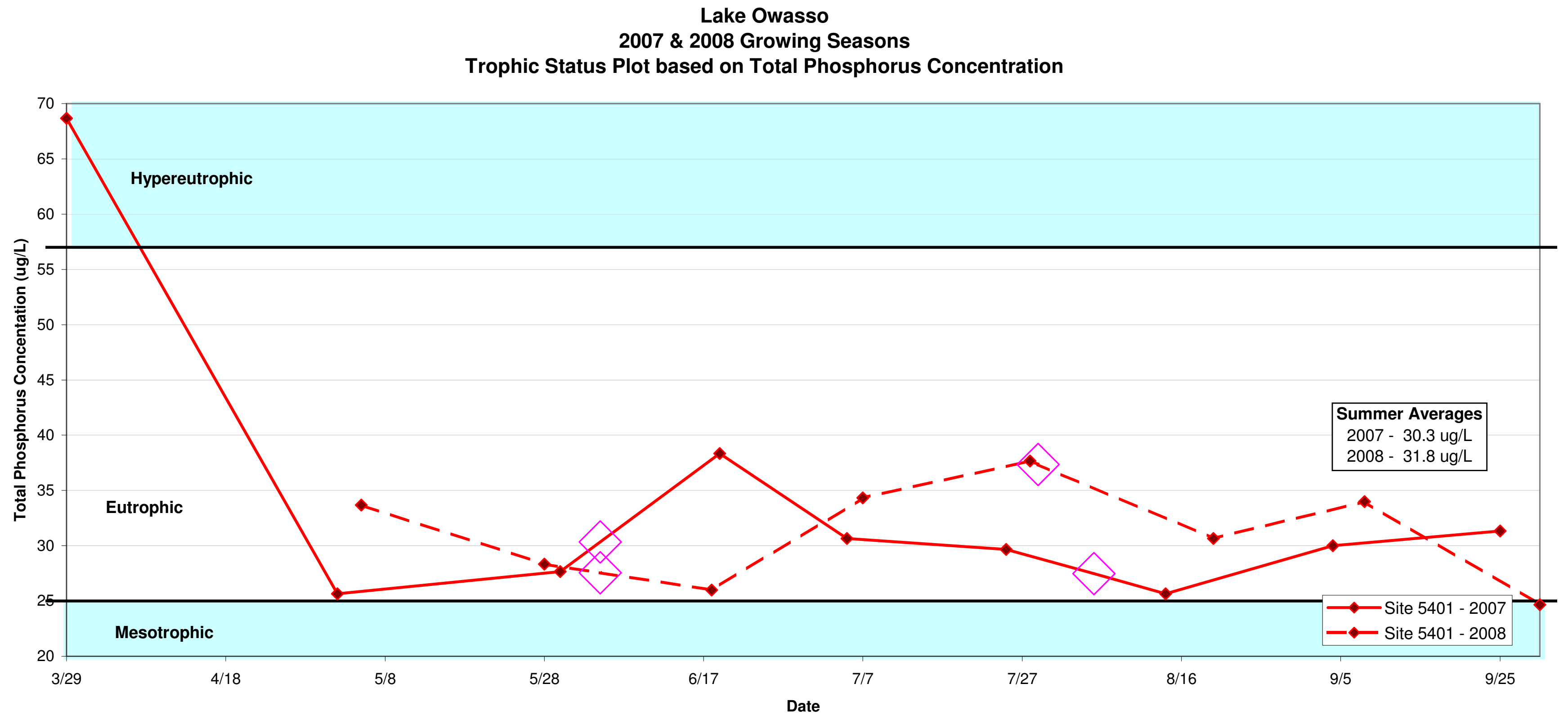
During the summer months, dissolved oxygen levels varied greatly throughout the depth of the water column. Typically, dissolved oxygen levels ranged from 8 to 12 mg/L in the surface waters above the thermocline. However along and below the thermocline, dissolved oxygen levels continued to decline with concentrations less than 1 mg/L along the bottom of the lake. This trend is seen at both monitoring sites in 2007 and 2008. This indicates that Lake Owasso likely experiences sediment anoxia during the summer, resulting in internal phosphorus loading. Phosphorus released from the sediments during these periods of oxygen depletion, accumulated in the hypolimnion, and eventually making its way to the surface waters, increasing the lake's surface phosphorus concentration.

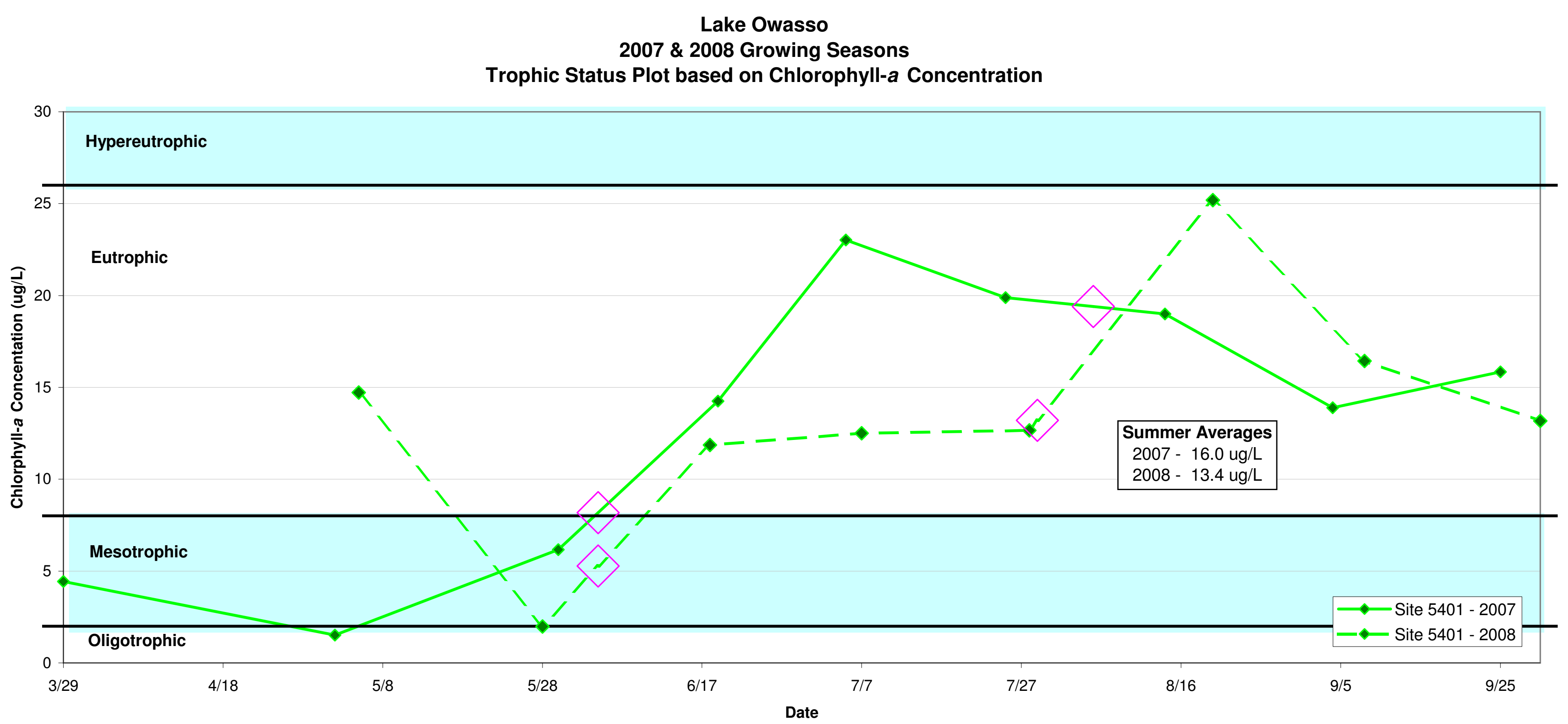
Chloride

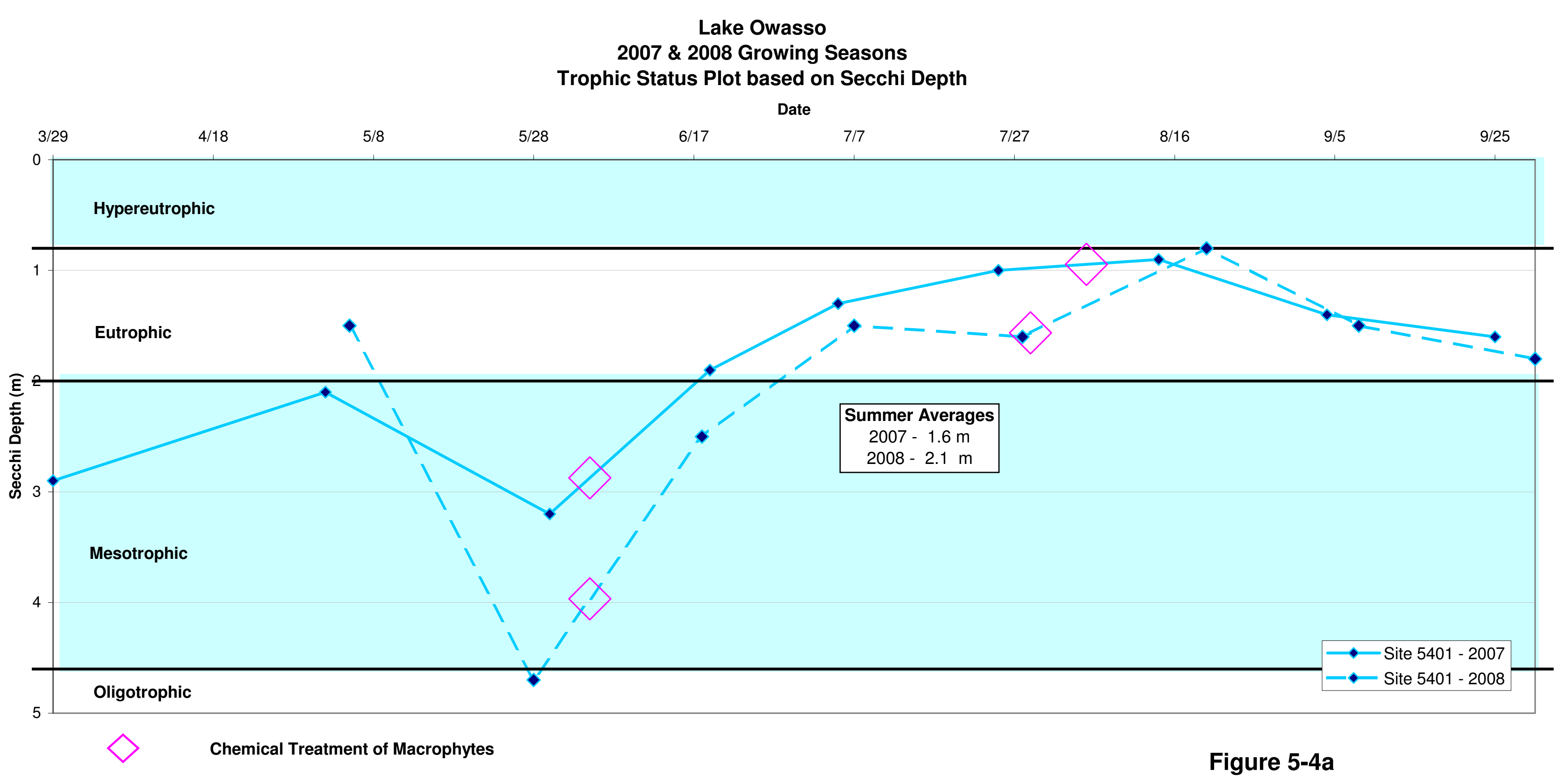
Chloride measurements in Lake Owasso were relatively constant throughout the summer of 2007 at both monitoring locations, ranging from 50 to 60 mg/L. The exception was on June 19 at site 5403 when chloride concentrations at the surface were 200 mg/L. The average chloride concentration for the entire monitoring period measured at site 5401 was 55 mg/L, and at site 5403, it was 69 mg/L.

In 2008, the surface chloride levels at both sites 5401 and 5403 typically ranged from 50 to 70 mg/L. The average chloride level for the entire monitoring period at site 5401 was 57 mg/L and at site 5403, the concentration was 69 mg/L.

The chloride concentrations for both years should not pose a threat to the biota of Lake Owasso.

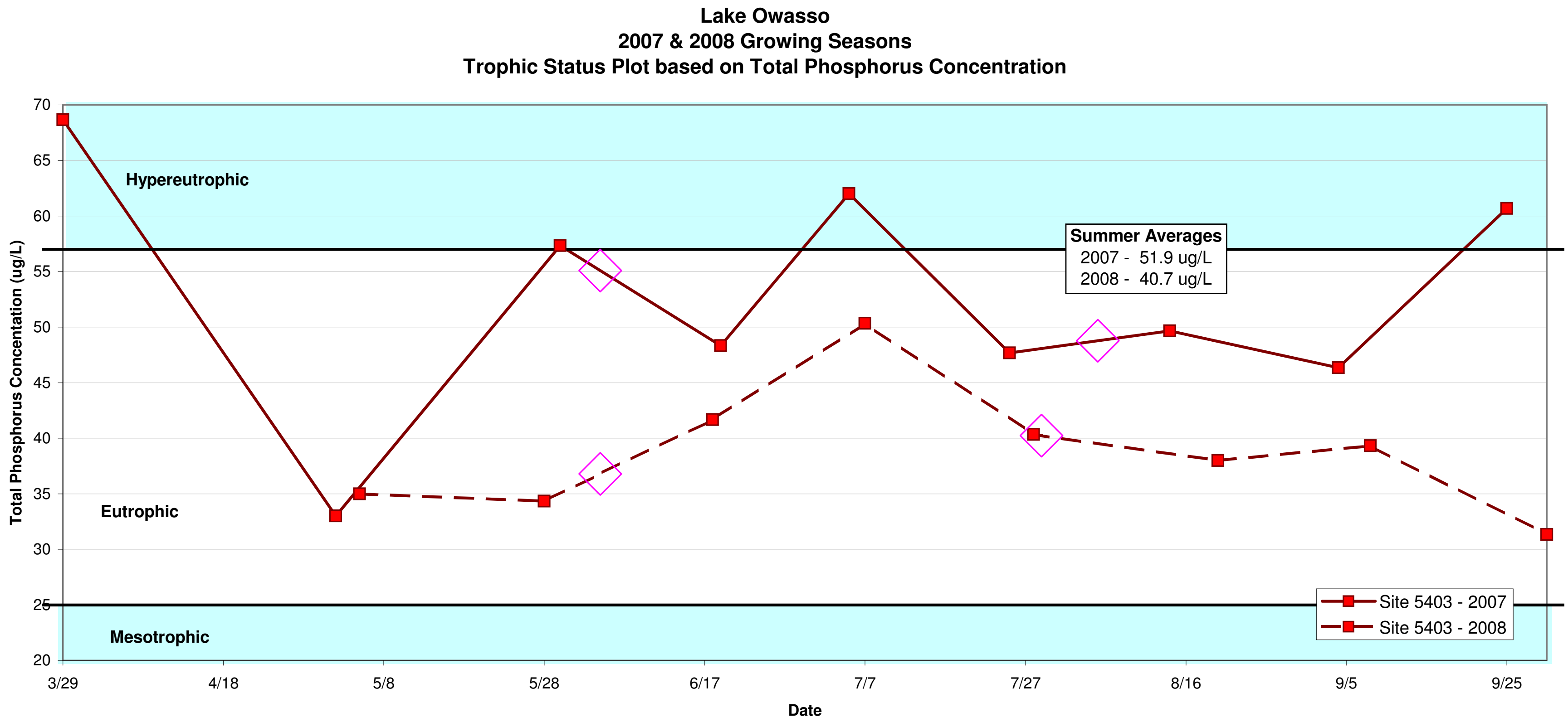


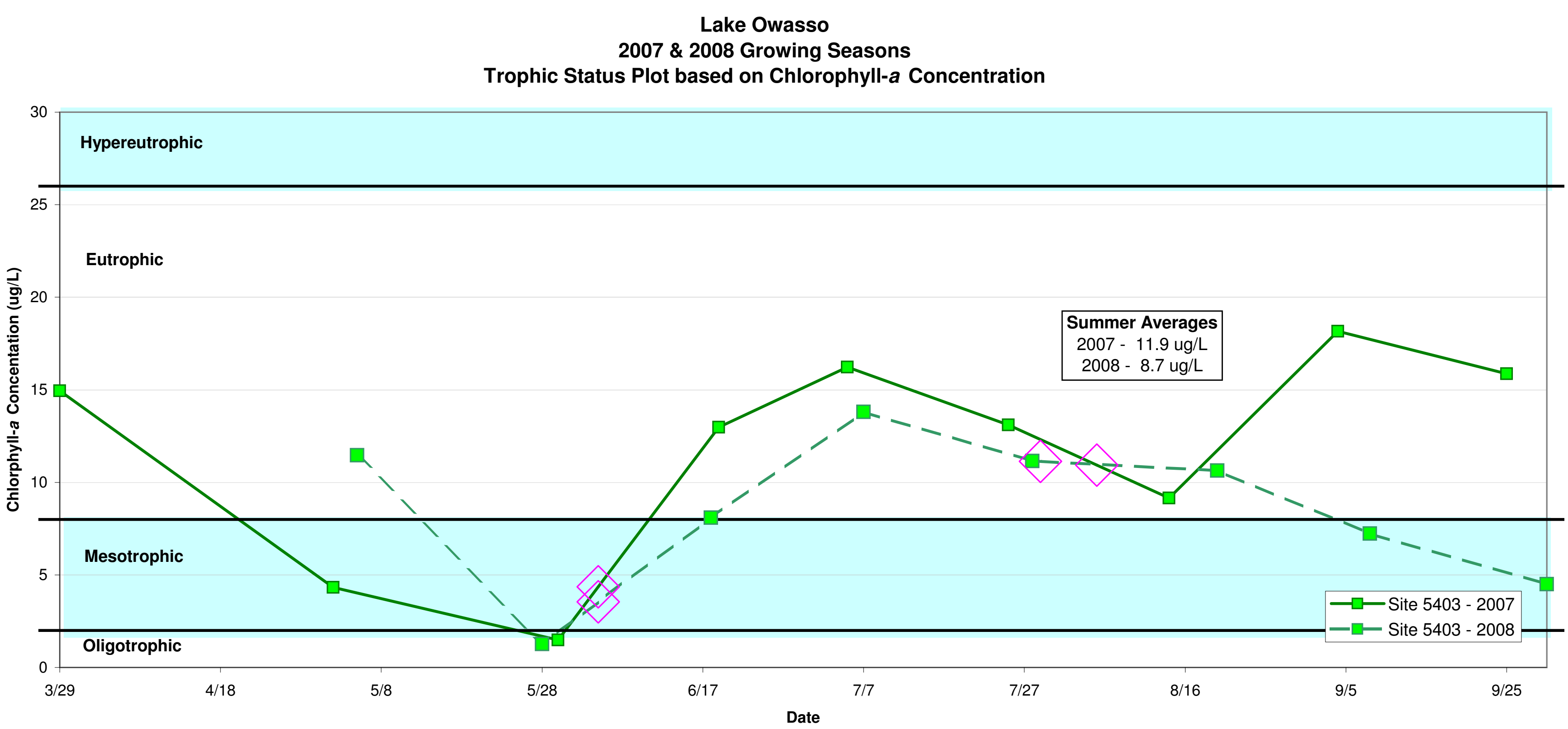


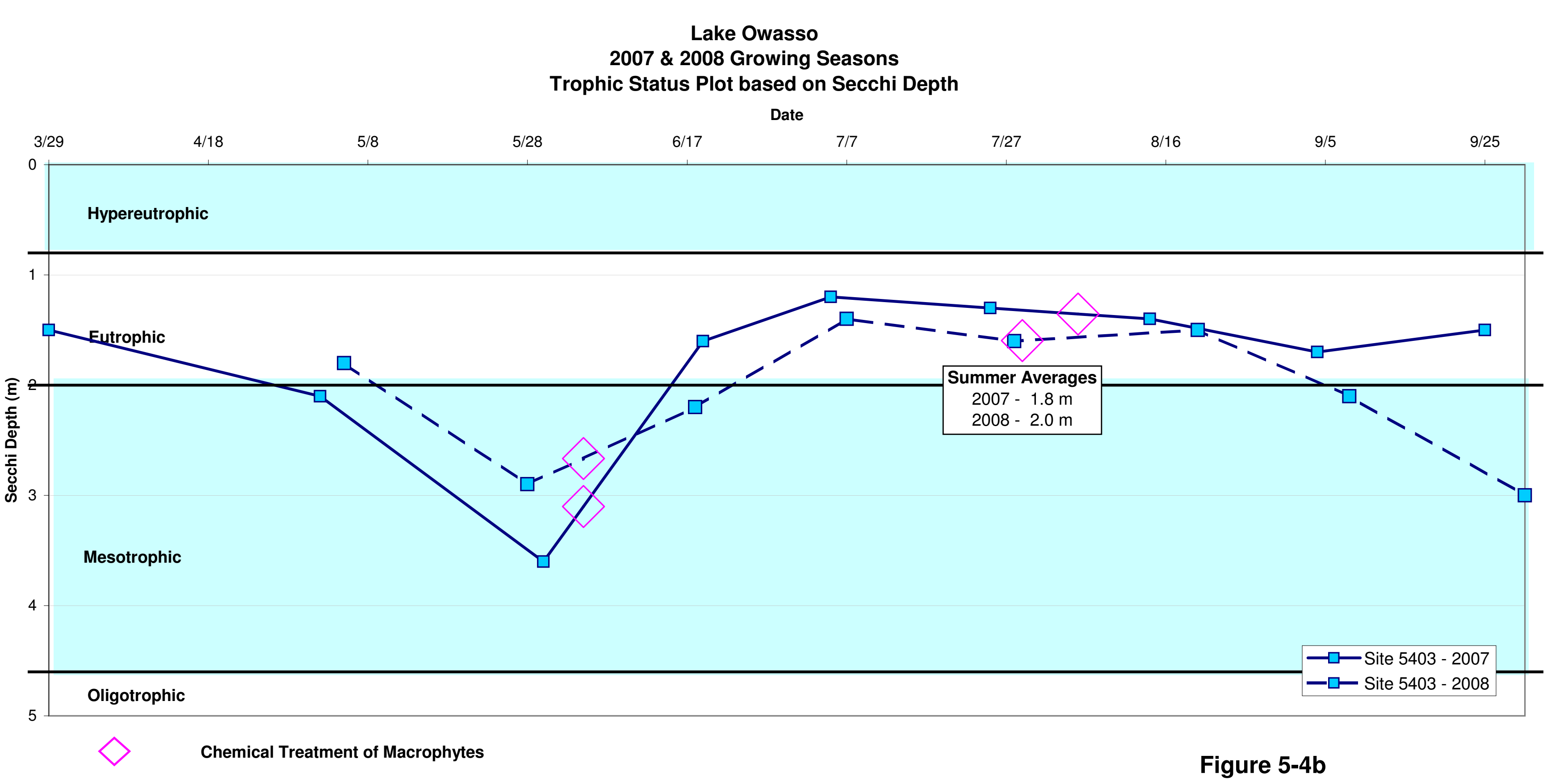


Note: Summer Averages calculated based on data from the late May through early September

Figure 5-4a
Lake Owasso - Site 5401
2007 & 2008 Water Quality







Note: Summer Averages calculated based on data from the late May through early September

Figure 5-4b
Lake Owasso - Site 5403
2007 & 2008 Water Quality

5.3.2 Sediment Core Results

Ten sediment cores were collected from Lake Owasso in May, 2007 and were analyzed for mobile phosphorus (which contributes directly to internal phosphorus loading) and organic bound phosphorus. Figure 5-5 shows the Lake Owasso sediment core locations and the interpolated distribution of mobile phosphorus loading rates based on the sediment core results. The average whole-lake internal loading rates calculated for these ranges of mobile phosphorus concentrations were 0.5 mg/m^2/day for Lake Owasso, with the highest expected loading rate being 2.9 mg/m^2/d in the deepest portion of the lake. Table 5-1 shows how the internal loading rate (deep hole) in Lake Owasso compares to the rates calculated for other Metro Area lakes, using the same methodology. None of the lakes shown in Table 5-1 had alum treatments at the time of the sediment core sampling.

Table 5-1 Comparison of Lake Owasso Internal Phosphorus Loading Rates to Those of Other Metro Area Lakes

Lake	Internal P Load ($mg/m^2/d$)
Isles (pre-alum, deep hole)*	14.1
Harriett (pre-alum, deep hole)*	11.1
Calhoun (pre-alum, deep)*	10.8
Fish E**	10.5
Cedar (pre-alum)*	9.3
Fish W**	8.1
Como**	7.6
Harriet**	6.9
Como-litoral**	5.7
Calhoun (pre-alum, shallow)**	5.6
Parkers**	3.5
Lake Owasso (deep hole)	**2.9**
Phalen**	2.3
McCarrons**	2.0
Bryant**	1.5
Nokomis**	1.0
Minnewashta**	0.2
Christmas**	0.0

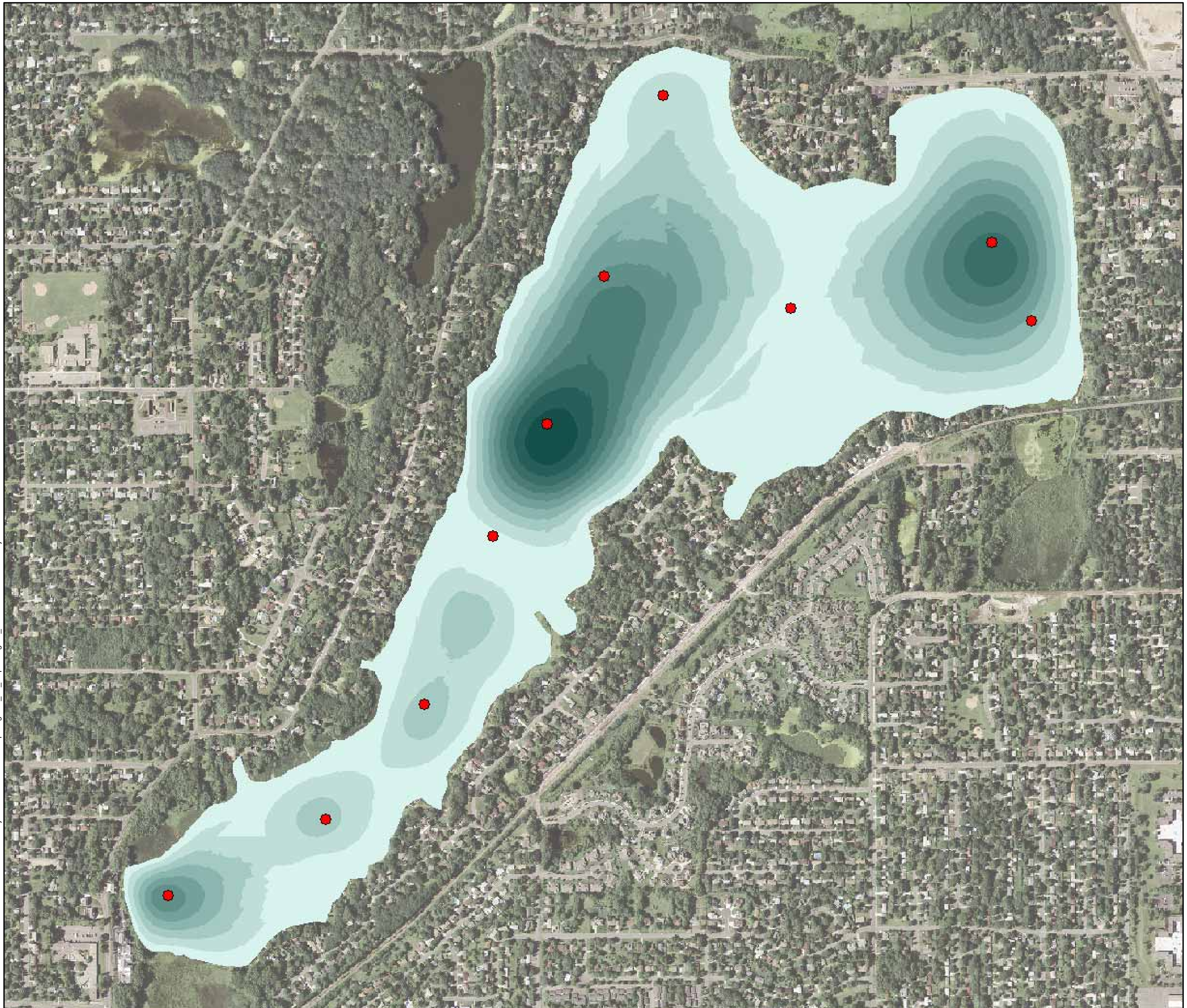
Sources:
*Huser et al. (2009)
**Pilgrim et al. (2007)

The average internal phosphorus loading rate calculated for all of the Metro Area Lakes in Table 5-1 is 6.3 mg/m^2/day. The internal phosphorus loading rate from the sediments calculated for Lake Owasso is below this average. 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 Owasso will likely experience less internal phosphorus loadings than these rates would indicate (as they assume perfect internal loading conditions).

Additionally, the amount of organic bound phosphorus was consistently higher than the mobile phosphorus measured in the sediments, indicating that available mobile phosphorus exported from the sediments during anoxic periods is quickly used by algae or plants, especially in the shallower areas of the lake.

Review of the temperature and dissolved oxygen data for Lake Owasso indicates that the lake thermally stratifies during the summer and that dissolved oxygen levels are depleted along the sediments, suggesting that internal loading from the sediments is likely. Although Lake Owasso is considered a deep lake that does thermally stratify (dimictic), with minimal mixing due to wind action, the average depth of the lake is 10.9 feet. There are several deep holes in the lake but the majority of the lake is relatively shallow. The alignment of the lake is from the southwest to the northeast and because the predominant winds during the summer months are from the south and southeast, some mixing of the shallow areas of the lake may be possible, potentially bringing phosphorus released from the sediments to the surface waters of the lake. Additionally, anecdotal information from Lake Owasso residents suggests that mixing in the shallow areas of the lake does occur as the result of motorboat activity, especially in the southern end of the lake.

More information about the sediment core testing from Lake Owasso can be found in Appendix M.



Sediment Core Locations

Estimated Internal Loading (mg/m2/d)

0.0 - 0.2
0.3 - 0.4
0.5 - 0.6
0.7 - 0.8
0.9 - 1.1
1.2 - 1.4
1.5 - 1.6
1.7 - 2
2.1 - 2.4
2.5 - 2.9

Feet
750 0 750

N

Figure 5-5

LAKE OWASSO SEDIMENT
MOBILE PHOSPHORUS ESTIMATES

Lake Owasso UAA
Grass Lake Watershed Management Organization

5.3.3 Aquatic Communities

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

5.3.3.1 Phytoplankton

The phytoplankton communities in lakes form the base of the food web and affect recreational-use of the lake. Phytoplankton, also called algae, is 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.

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.

Green algae are considered beneficial as they are edible to zooplankton and serve as a valuable food source.

Blue-green algae 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

Ramsey County has been monitoring the various types and concentrations of phytoplankton communities in Lake Owasso throughout the summers for the past two decades. This data (through 2006) provides a look at historic trends in the phytoplankton levels throughout the summer as well as over the years. Figure 5-6 shows that the overall phytoplankton levels in Lake Owasso varies during throughout the summer of 2006, with the peak phytoplankton concentration occurring in mid-August. Blue-green algae, which are typically nuisance species, were the dominant type of phytoplankton present in Lake Owasso for the entire season.

Historic phytoplankton data can be found in Appendix H.

5.3.3.2 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. Healthy zooplankton communities are characterized by balanced densities (numbers per meter squared) of the three major groups: cladocera, copepoda, and rotifera.

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. Fish predation, however, may alter the community structure by reducing the numbers of larger-bodied zooplankton (i.e., cladocerans and copepods).

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.

Ramsey County has been monitoring the various types and concentrations of zooplankton communities in Lake Owasso throughout the summers for the past two decades. In addition, the size distribution of *Daphnia spp.* were also monitored. These data provide a look at historic trends in the zooplankton levels throughout the summer as well as over the years.

Figure 5-7 shows the zooplankton concentrations (expressed as the number of organisms per cubic meter of lake) for Lake Owasso on each of the sampling dates throughout the summer of 2007. The historic zooplankton data are present in Appendix H.

The overall amount and distribution of the type of zooplankton in Lake Owasso varied throughout the 2007 season. Zooplankton concentrations were highest in early May. During June and July, the zooplankton concentrations declined and then increased again in September. The dominant groups in Lake Owasso in the early part of the season and throughout much of the summer were the copepods and rotifers. Later in the season, the numbers of the copepods declined while more cladocera species were present. In Lake Owasso, a very low numbers of the *Daphnia spp.* were observed in 2007, and those that were observed were relatively small.

Studies have been done that have analyzed zooplankton (cladocera) feeding patterns, relating body size to the maximum size of the particles ingested as well as establishing a relationship between the filtering rate of *Daphnia spp.*, temperature, and body size (Burns, 1968 & 1969). Data through the summer of 2007 was obtained from Ramsey County, processed to estimate zooplankton feeding rates, and the results have been reviewed by Dr. Joseph Shapiro, University of Minnesota Emeritus Professor of Limnology. A memo summarizing the preliminary results can be found in Appendix H. The general conclusion is that the *Daphinia spp* are present in low numbers and are small in size. As a result, filtering rates are relatively low and the impact on the reduction of phytoplankton is limited.

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 fishery data shows that both smaller than average bluegills and other small panfish are present in Lake Owasso (see Section 5.3.4.4). The combination of these factors could likely contribute to the low Daphnia populations and decreased water clarity due to low phytoplankton filtering rates.

5.3.3.3 Macrophytes

Aquatic plants (i.e., macrophytes and phytoplankton) are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. They are among the primary producers in the aquatic food chain, providing food for other aquatic life. Macrophytes (aquatic plants growing in the shallow, or littoral, area of the lake) perform a number of valuable functions in Lake Owasso. Specifically, macrophyte communities:

- Provide habitat for fish, insects, small aquatic invertebrates, and zooplankton
- Provide food for waterfowl, fish, and wildlife
- Oxygen production
- Provide spawning areas for fish in early spring
- Help stabilize marshy borders of the lake; which help protect shorelines from wave erosion
- Provide nesting sites for waterfowl and marsh birds

Macrophytes are an important component of the lake ecosystem (Ozimek, Gulati, and Van Donk 1990). However, the introduction of exotic (nonnative) aquatic plants into a lake may cause undesirable changes to the plant community and to the lake ecosystem. Dense stands of some mat-forming plant species reduce oxygen exchange, deplete available dissolved oxygen, increase water temperatures, and increase internal loading rates of nutrients (Frodge, Thomas, and Pauley 1991; Frodge et al. 1995; Seki, Takahashi, and Ichimura 1979). Dense canopies formed by some nonnative species (e.g., Curlyleaf pondweed and Eurasian watermilfoil) reduce native plant diversity and abundance, thereby reducing habitat complexity. This reduction in habitat complexity results in reduced macroinvertebrate diversity and abundance (Krull 1970, Keast 1984) and also reduces growth of fishes (Lillie and Budd 1992). The introduction of a nonnative plant species to a lake is not only deleterious to human use of aquatic systems, but is also detrimental to the native ecosystem.

Once a lake becomes infested with Curlyleaf pondweed, this plant typically replaces native vegetation, thereby increasing its coverage and density. Curlyleaf pondweed begins growing in late August, grows throughout the winter at a slow rate, grows rapidly in the spring, and dies in early summer (Madsen et al. 2002). Native plants that grow from seed in the spring are unable to grow in areas already occupied by Curlyleaf pondweed, and are displaced by this plant. Curlyleaf pondweed die-off in early summer releases phosphorus to the lake, causing increased algal growth for the remainder of the summer.

Eurasian watermilfoil is a nuisance, non-native species that typically replaces native vegetation. It has a canopy style growth pattern that causes heavy growth near the surface, making it more visible and a greater nuisance for boating and fishing.

An aquatic plant survey of Lake Owasso was conducted by Ramsey County in late May, 2007. Table 5-2 summarizes the macrophyte species observed in Lake Owasso.

Table 5-2 Lake Owasso Summary of Observed Macrophyte Species (May 2007)

Potomogeton crispus	Curlyleaf pondweed
Potomogeton amplifolius	Large-leaf pondweed
Potomogeton pectinatus	Fine-leaf (Sago) pondweed
Potomogeton natans	Floating-leaf pondweed
Myriophyllum exalbescens	Northern watermilfoil
Myriophyllum spicatum	Eurasian watermilfoil
Ceratophyllum demersum	Coontail
Nuphar Variegata	Yellow water lily
Nymphaea odorata	White water lily
Chara vulgaris	Muskgrass
Zanichellia palustris	Horned pondweed
Najas flexilis	Bushy pondweed
--	Unidentified filamentous algae

As mentioned above, the die-off of Curlyleaf pondweed (*Potomogeton crispus*) can significantly contribute to the phosphorus load within a lake. Curlyleaf pondweed was present in Lake Owasso during the spring of 2007. The estimated coverage and density of Curlyleaf pondweed is summarized in Figure 5-8. The non-native species Eurasian watermilfoil (*Myriophyllum spicatum*) is also present in Lake Owasso. According to the MDNR, Eurasian watermilfoil was first identified in Lake Owasso in 2000.

The Ramsey-Washington Metro Watershed District (RWMWD) also conducted a macrophyte survey of Lake Owasso in September 2005. During this survey, coontail was the most abundant macrophyte species, found in approximately 25% of the sites sampled in the littoral zone. Eurasian watermilfoil was the second most common macrophyte. Other common sampled species were Nitella and white and yellow waterlilies. Many of the macrophyte species observed in the May 2007 survey were also observed in the September 2005 survey.

According to the *Lake Owasso Management Plan* (Osgood, 2000) and information provided by Ramsey County, the MDNR and Ramsey County have conducted other aquatic plant surveys in Lake Owasso. The MDNR conducted surveys in 1948, 1955, 1981, and 1991. The other macrophyte surveys were conducted by Ramsey County in 1984, 1985, 1986, and again in 1990. The surveys indicate that Curlyleaf pondweed was present in Lake Owasso as far back as 1981.

Macrophytes in Lake Owasso have been both chemically and mechanically controlled for several decades, although chemical treatment is the predominant control method. Treatments typically occur in late May or early June and treat all macrophyte species, not just specific non-native species such as Curlyleaf pondweed or Eurasian watermilfoil. Although the MNDR currently limits treatment to 15 percent of a lake's littoral (shallow) area, the aquatic plant control permit for Lake Owasso has existed longer than this restriction, and allows for the treatment of up to 21 percent of its littoral area, or about 62 acres.

In recent years, the Lake Owasso Association has spent approximately $50,000 to $60,000 annually for macrophyte treatment. In both 2007 and 2008, the lake was chemically treated in June and July.

Macrophyte survey data can be found in Appendix J.

5.3.3.4 Fish and Wildlife

According to the *Lake Owasso Management Plan* (Osgood, 2000), fishery surveys have been conducted for Lake Owasso in 1948, 1956-1959, 1961, 1971, 1976, 1981, 1991, 1992, 1994, and 1996. The most recent fishery survey was conducted by the MDNR in 2001 and a population assessment was conducted in 2006.

According to MDNR's most recent (2001) Lake Survey Report for Lake Owasso, bluegill is the most abundant species present in the Lake. Small pumpkinseed sunfish were also captured in record levels of abundance. Additionally, black crappie and yellow perch were sampled. Growth rates for the bluegill, pumpkinseed sunfish, and black crappie were found to be slow and yellow perch exhibited average growth rates. Muskellunge and walleye are the primary management species in Lake Owasso. These fish are stocked by the MDNR biennially. Northern pike were sampled above median levels for abundance. Growth rates for all the major predator species were found to be good. Other species sampled in Lake Owasso include black, brown, and yellow bullhead, green and hybrid sunfish, and largemouth bass.

A 2006 population assessment indicated that bluegill is still the most abundant fish species in the lake followed by black crappie. Northern pike and walleye were also sampled, as well as large mouth bass and muskellunge.

The Lake Owasso fishery has been stocked almost annually with a variety of species since 1971 (Osgood, 2000). See Appendix I for more detailed information about the Lake Owasso fishery and stocking programs.

Additionally, there have been several periods of low winter oxygen conditions in Lake Owasso that could have resulted in potential winterkill situations. There periods were noted in the winters of

1978/79, 1988/89, 1991/92, 1992/93, and 1996/97. The Lake Owasso Management Plan (Osgood, 2000) indicated that an aeration system would be installed in Lake Owasso in 2000 and used during these low oxygen conditions to help prevent the potential winterkill. This aeration system is operated by Ramsey County. Discussion with Ramsey County indicated that the system was most recently operated during the winter of 2007/2008 (Ramsey County Staff, personal communication, January 8, 2009).

In addition to supporting its fish populations, Lake Owasso provides habitat for seasonal waterfowl, such as ducks and geese, which find refuge and forage in the lake's diverse macrophyte communities in the lake's large littoral area.

Information related to the Lake Owasso fishery and stocking information can be found in Appendix I.

5.3.3.5 Shoreland Habitat and Restoration Potential

Over the last decade, greater attention has been given to shoreland management and ecological restoration. Lake shore restoration programs encourage the establishment of natural buffer using native plants that are less prone to erosion and provide quality fish and wildlife habitat. In September 2005, the RWMWD conducted a visual survey (by boat) of the Lake Owasso shoreline. Various parameters, such as the shoreline material, shoreline slope, restoration potential, and ownership, were recorded. Restoration potential was a subjective assessment that considered the other three parameters as well as evidence of shoreland use.

Lake Owasso has approximately 5 miles of shoreland, with 2 miles having good restoration potential, just less than a mile having moderate restoration potential, and another 2 miles identified as having poor restoration potential. The northwest and west sides of the lake have 2 large sections that have poor restoration potential as the result of steep slopes and riprap (northwest side) and a large cattail fringe (west side).

More detailed information about this shoreland assessment can be found in Appendix K, including a summary of the various parameters for Lake Owasso and a figure showing the restoration potential of each of the lakeshore parcels.

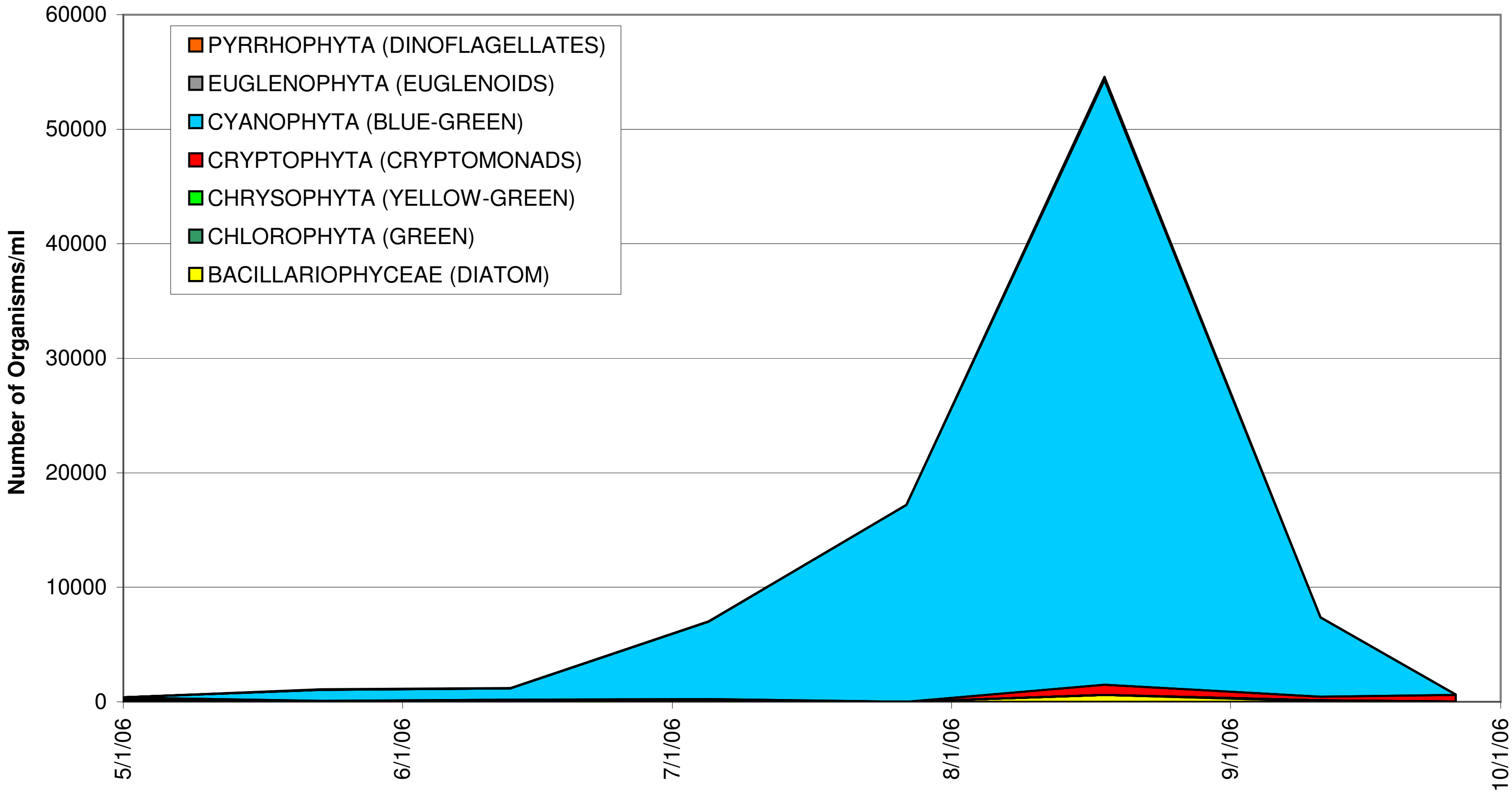
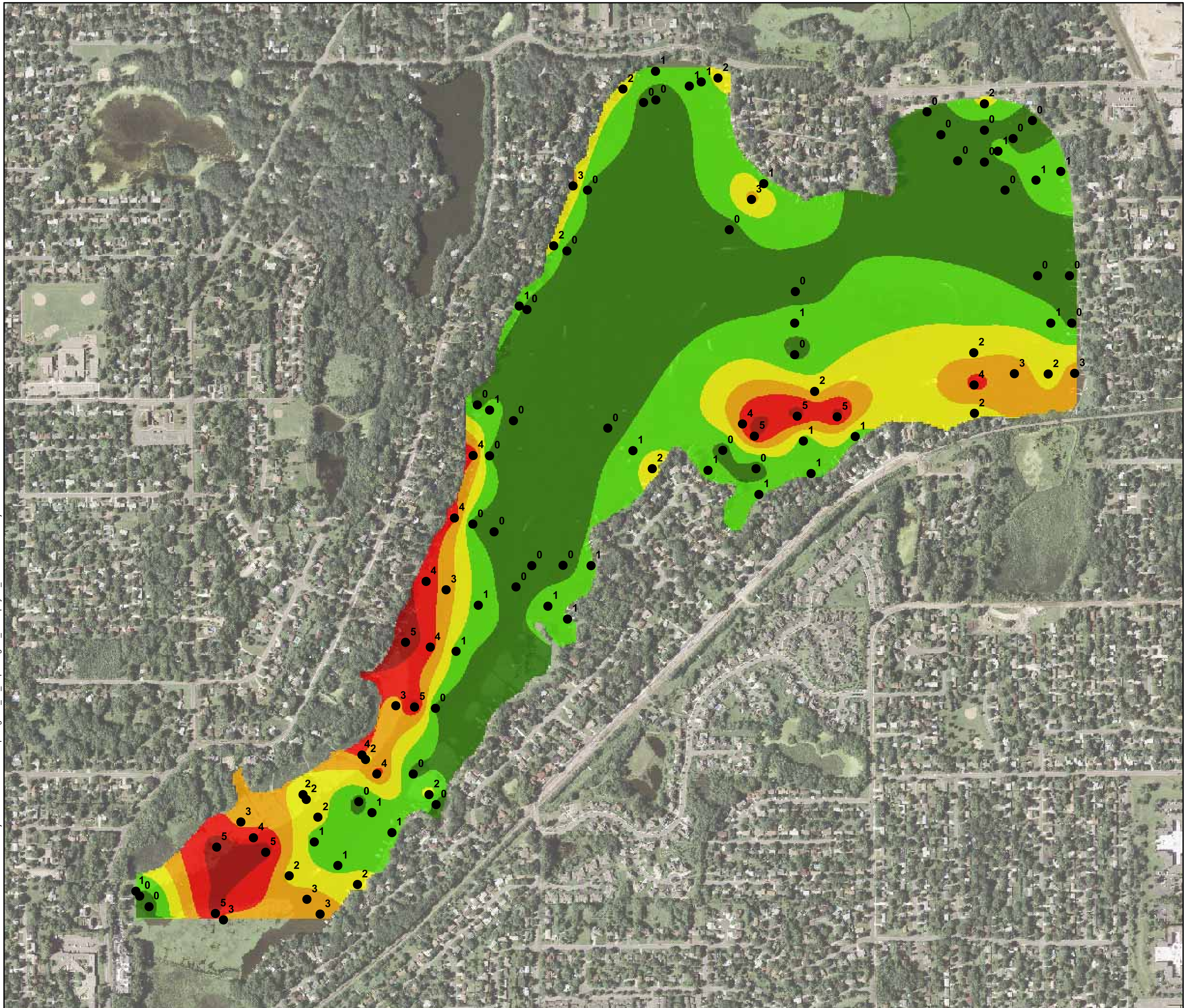


Figure 5-6
2006 Phytoplankton Concentrations



● Macrophyte Survey Points

Curlyleaf Pondweed

- Not Observed/Surveyed (0.0 - 0.5)
- Very Low Density (0.5 - 1.5)
- Low Density (1.5 - 2.5)
- Moderate Density (2.5 - 3.5)
- High Density (3.5 - 4.5)
- Very High Density (4.5 - 5+)

Area-Weighted Average for Lake Owasso = 1.1

Feet

750 0 750

N

Figure 5-8

LAKE OWASSO MACROPHYTE SURVEY
CURLYLEAF PONDWEED
May 22-30, 2007

Lake Owasso UAA
Grass Lake Watershed Management Organization

5.4 Water Quality Modeling Results

5.4.1 Baseline Lake Water Quality Status

There are several tools that can be used to evaluate the expected water quality in a lake. This study utilizes two different tools to estimate the expected water quality in Lake Owasso, including the relationship develop by Vighi and Chiaudani (1985) and the Minnesota Lake Eutrophication Analysis Program (MINLEAP) as developed by Heiskary and Wilson (1990) and programmed as part of the Wisconsin Department of Natural Resources Wisconsin Lake Modeling Suite (WiLMS, 2005). Additionally, Lake Owasso was part of a diatom reconstruction projects performed by the MPCA (Heiskary and Swain, 2002) that estimated historical phosphorus concentrations.

5.4.1.1 Vighi and Chiaudani

Vighi and Chiaudani (1985) developed a method to determine the phosphorus concentration in lakes that are not affected by anthropogenic (human) inputs. Using their method and information about the lake’s mean depth and alkalinity or conductivity, the phosphorus concentration in a lake resulting from natural, background phosphorus loadings can be predicted. Alkalinity is considered more useful for this analysis because it is less influenced by the modifying effect of anthropogenic inputs. Alkalinity was measured in Lake Owasso in 2007 along with conductivity measurements, so the expected phosphorus concentration was calculated using both parameters.

Vighi and Chiaudani relationship was used to estimate the expected total phosphorus concentrations at each of the monitoring sites as well as across the lake as a whole. Specific conductivity was relatively constant at both monitoring sites throughout the summer, and the estimated ranges were very similar. Therefore, the following is a discussion of the results using the average conductivity values from Lake Owasso. The Vighi and Chiaudani relationship predicted phosphorus concentration from natural, background loadings to be 18.8 µg/L (ranging from 18.3 µg/L to 19.2 µg/L).

Alkalinity was also used to estimate the expected total phosphorus concentration in Lake Owasso. Like specific conductivity, the alkalinity was fairly constant throughout the lake and as a result, the following only discusses the results of the Vighi and Chiaudani equation based on the average alkalinity for Lake Owasso for the entire 2007 monitoring period. The expected total phosphorus concentration in Lake Owasso based upon the average alkalinity over the period of record was 22.4 µg/L

The predicted total phosphorus concentrations based upon the lake's specific conductivity and alkalinity are lower than the 2007/2008 total phosphorus concentrations for monitoring sites 5401 and 5403 (30.3 µg/L and 51.9 µg/L, respectively), indicating that some improvement in lake water quality may be attainable.

5.4.1.2 Minnesota Lake Eutrophication Analysis Program (MINLEAP)

MINLEAP is intended to be used as a screening tool for estimating lake conditions and identifying "problem" lakes. MINLEAP is particularly useful for identifying lakes requiring "protection" versus those requiring "restoration" (Heiskary and Wilson, 1990). In addition, MINLEAP modeling has been done in the past to identify Minnesota lakes which may be in better or worse condition that they "should be" based upon their location, watershed area, and lake basin morphometry (Heiskary and Wilson, 1990).

Using the long-term summer average total phosphorus, chlorophyll *a*, and Secchi depth, MINLEAP estimated the expected concentration or depth of each of the above parameters as well as the standard error associated with the average values. For total phosphorus, the expected concentration was estimated to be 40 µg/L (with a range of 25 µg/L to 55 µg/L). The estimated chlorophyll *a* concentration was estimated to be 14.3 µg/L (with a range of 5 µg/L to 23.6 µg/L). The estimated Secchi depth for Lake Owasso was 1.6 meters (with a range of 0.9 meters to 2.3 meters). For all water quality parameters, the actual water quality data falls within the range of a minimally-impacted lake with similar characteristics to Lake Owasso.

5.4.1.3 Water Quality Reconstruction from Fossil Diatoms

Diatom reconstructions of historical phosphorus concentrations can provide a opportunity to examine temporal and spatial trends in eutrophication, helping identify the timing and extent of cultural disturbances as well as identifying predisturbance conditions (Reavie et al., 1995). In 2002, the MPCA completed a study of diatoms in 55 lakes within Minnesota, including Lake Owasso.

The results of the diatom analysis for Lake Owasso (Table 5 3) indicates that Pre-European settlement, the lake's total phosphorus and chloride levels suggested mesotrophic conditions. The analysis indicated that significant increases in total phosphorus and chloride occurred in the 1970s and 1990s, likely the result of development in the watershed and surrounding road network. Data from the mid- to late 1990s indicated declining total phosphorus levels, likely reflecting a period of less development and increased efforts to improve stormwater retention and treatment upstream of the lake.

The sediment and diatom analysis also indicated that sediment accumulation rates increased steadily from 1900, with peaks in 1960 and 1980; some reductions in accumulation rates is evident since that time, again likely linked to decreasing development and use of stormwater treatment practices.

Table 5-3 Diatom-Inferred Total Phosphorus and Chloride Concentrations in Lake Owasso

Lake	Parameter	Units	1750	1800	1970	1990
Lake Owasso	TP	µg/L	22	21	38	32
	Chloride	mg/L	2	1	27	27

5.4.2 Watershed Load Modeling Results

Using the calibration discussed in Section 4.2.2, the P8 model was used to simulate the flow and treatment of stormwater throughout the Lake Owasso watersheds for each of the modeled climatic conditions. Additionally, comparison of monitoring data to the P8 modeling results indicated that some of the wetlands and water bodies within the watershed can actually act as sources of phosphorus to Lake Owasso during certain times of the year. As a result, the P8 loads were augmented with estimated "internal" loads from select watershed waterbodies (based on FLUX and mass balance model). See Section 4.2 for a more detailed discussion of the watershed and in-lake water quality modeling methodology.

The following general scenarios were modeled:

- Existing Watershed Conditions for 2007 & 2008
- Wet, Dry, and Average Climatic Conditions for Existing Watershed Conditions

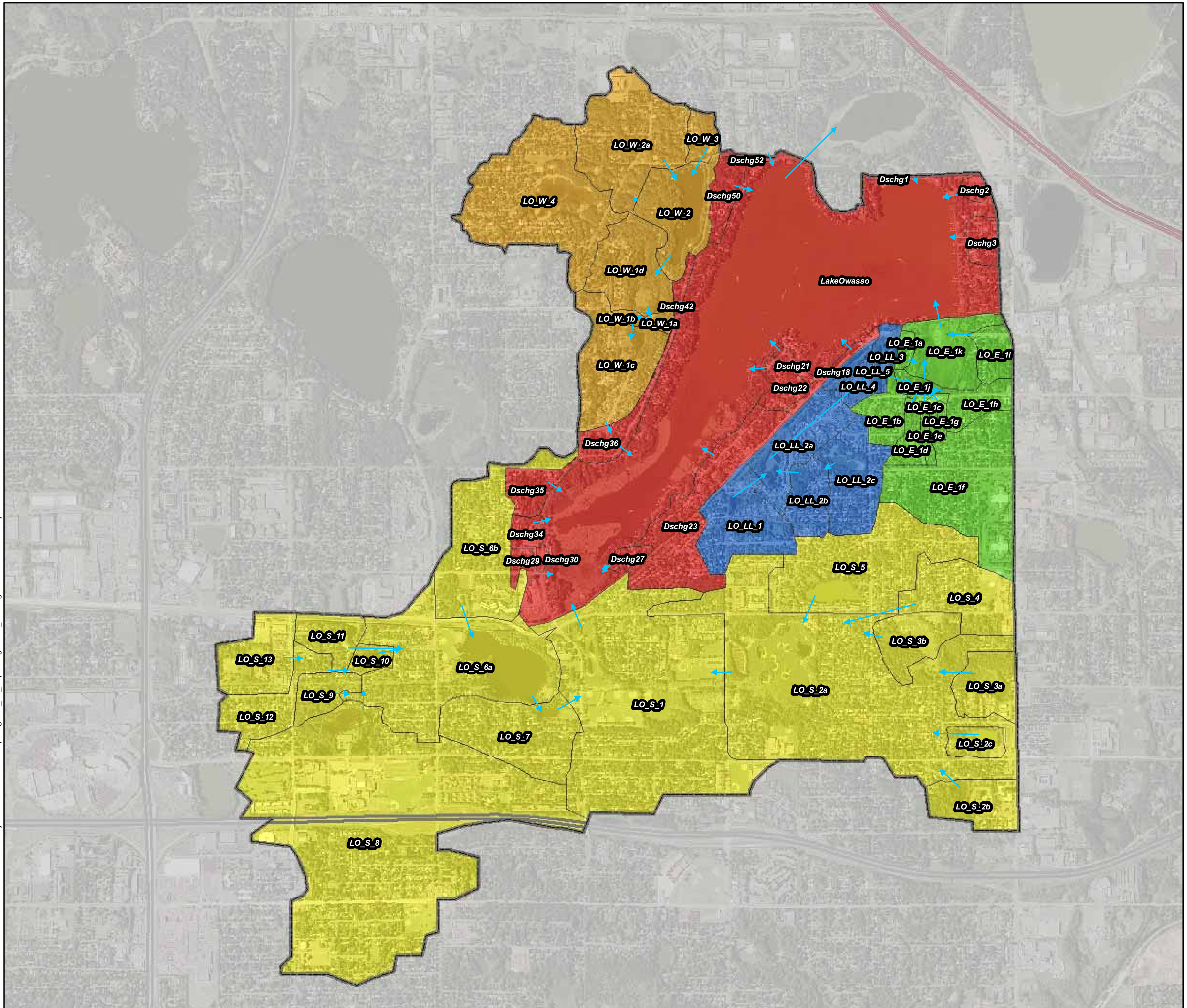
For each scenario, the stormwater runoff volume and phosphorus mass load to each of the lakes was predicted using the P8 model along with the results of the FLUX and mass balance modeling to estimate the watershed "internal" loading. The predicted runoff and loadings were then used as input into the in-lake model to predict in-lake phosphorus concentrations.

5.4.2.1 Watershed Loading for Existing Conditions for 2007 & 2008

The Lake Owasso watershed (3062 acres including the surface of Lake Owasso) was divided into five "drainage districts" comprised of numerous smaller subwatershed areas to facilitate the pollutant load modeling. Existing conditions for 2007 and 2008 were based on current land use data along with in-place watershed BMPs. Because the Lake Owasso watershed is fully developed and no significant changes in land use are expected, it is assumed that the evaluation of the existing land use data will also be reflective of future land use conditions. Two BMPs were implemented in the City of Shoreview between the summer of 2007 to the summer of 2008, and as a result, separate existing conditions watershed models were developed for each year to account for the change in the in-place watershed BMPs. Figure 5-9 shows the drainage districts. Each district is described below including a discussion of the watershed changes implemented in the watershed between 2007 and 2008:

- **Direct Drainage District—** This drainage district is approximately 729.3 acres (including the surface area of Lake Owasso), which represents 23.8 percent of the Lake Owasso watershed. The drainage district consists primarily of low density residential land use. Work was started in the summer of 2007 to collect flows from subwatershed Dschg50 in an underground storage vault. Under normal conditions, these flows will be pumped to the West Drainage District and pass through the Charlie Pond system. Flood flows will be allowed to discharge from the existing outlet. For calibration, it was assumed that subwatershed Dschg50 discharged directly to Lake Owasso, as the new system was not functioning during the summer of 2007. Modeling of future conditions will reflect this change.
- **South Drainage District—**This 1581.3 acre drainage area represents approximately 51.6 percent of the Lake Owasso watershed. Runoff from this district is conveyed to the Central Park Ponds and discharges to Lake Owasso through the west Central Park Pond via a structure under County Road C. Other larger water bodies in the district include Willow Pond, Frog Pond, Bennett Lake, and Westwood Village Pond. Much of the drainage district consists of low-density residential and open space land uses as well as institutional, highway right-of-way, and several smaller areas of high- and medium-density residential and commercial land uses.
- **West Drainage District—**This drainage area covers approximately 360.1 acres, or 11.8 percent, of the Lake Owasso watershed. There is one land locked watershed (LO_W_3) in this district. Flows from this district pass through Charlie Pond before discharging to Lake Owasso. Other larger water bodies in this district include Lake Judy and Lake Emily. In the end of 2007, a CDS structure was installed on the northwest side of Lake Emily, treating discharges from watershed LO_S_2a before discharging into Lake Emily. The predominant land uses in this drainage district are low-density residential and open space.
- **East Drainage District—**This 213.3-acre drainage district represents about 7.0 percent of the Lake Owasso watershed. Runoff from this district is discharged to the bay south of Lake Owasso before discharging to the lake. This district is primarily composed of low density residential land use with some high density land use in the upper portions of the watershed.
- **Land Locked Drainage District—** This drainage district covers approximately 178 acres which represents about 5.8 percent of the Lake Owasso watershed. The drainage area was historically land locked although a pump has been installed in subwatershed LO_LL_2a that

pumps high waters to subwatershed LO_LL_3, where it is discharged into the bay south of Lake Owasso. Subwatershed LO_LL_5 is still currently land locked and was assumed to contribute no flows to Lake Owasso. This drainage district consists primarily of low density residential land use, with wetland areas interspersed.



Watershed Flow Direction

Drainage Districts

- Direct
- East
- Land Locked
- South
- West

Feet

1,750 0 1,750

N

Figure 5-9

LAKE OWASSO DRAINAGE DISTRICTS

Lake Owasso UAA
Grass Lake Watershed Management Organization

Annual stormwater and phosphorus contributions to Lake Owasso were estimated for each drainage district using the P8 and FLUX models. These loadings were used to determine the total Lake Owasso external stormwater and phosphorus budgets under existing land use and the 2007 and 2008 hydrologic conditions. Table 5-4 summarizes the 2007 and 2008 total watershed runoff volumes and total phosphorus loads as predicted by the calibrated P8 model (for both the 2007 and 2008 watershed BMP scenarios). Additionally, the estimated "internal" phosphorus load from watershed water bodies is also summarized.

Table 5-4 2007 and 2008 Watershed Runoff and Total Phosphorus Loads to Lake Owasso

Parameter	2007 Water Year (10/1/2006 – 9/30/2007)	2008 Water Year (10/1/2007 – 9/30/2008)
Watershed Runoff Water Load (acre-ft)	563	509
Watershed Runoff Total Phosphorus Load (lbs)	124	102
Estimated Internal Phosphorus Load from Watershed Water Bodies (lbs)	45	29

The 1991 *Water Quality Management Alternatives* study estimated the hydrologic and phosphorus budgets for Lake Owasso for 1985 to 1987. This study predicted annual watershed water loads to Lake Owasso ranging from 1,598 acre-feet to 2,814 acre-feet. This is approximately 3 to 5 times more volume than the annual water loads predicted for both 2007 and 2008. Both 2007 and 2008 were relatively dry summers as were the summers of 1985, 1986, ad 1987, which were the years used for the 1991 study. The difference in the estimated water loads is that the results of the SWMM model developed for the Lake Owasso watershed for the 1991 study were not calibrated to actual monitoring data. Runoff estimates from the P8 model for this UAA were calibrated to actual runoff monitoring data. It was also observed during both the summer of 2007 as well as the summer of 2008 that there were significant periods of time where water levels in many of the major water bodies within the watershed were below their normal outlet and were not discharging downstream. In both the summer of 2007 as well as 2008, there were periods where more than half of the watershed did not contribute watershed runoff to Lake Owasso during several consecutive storm events.

5.4.2.1.1 Existing Conditions BMP Performance

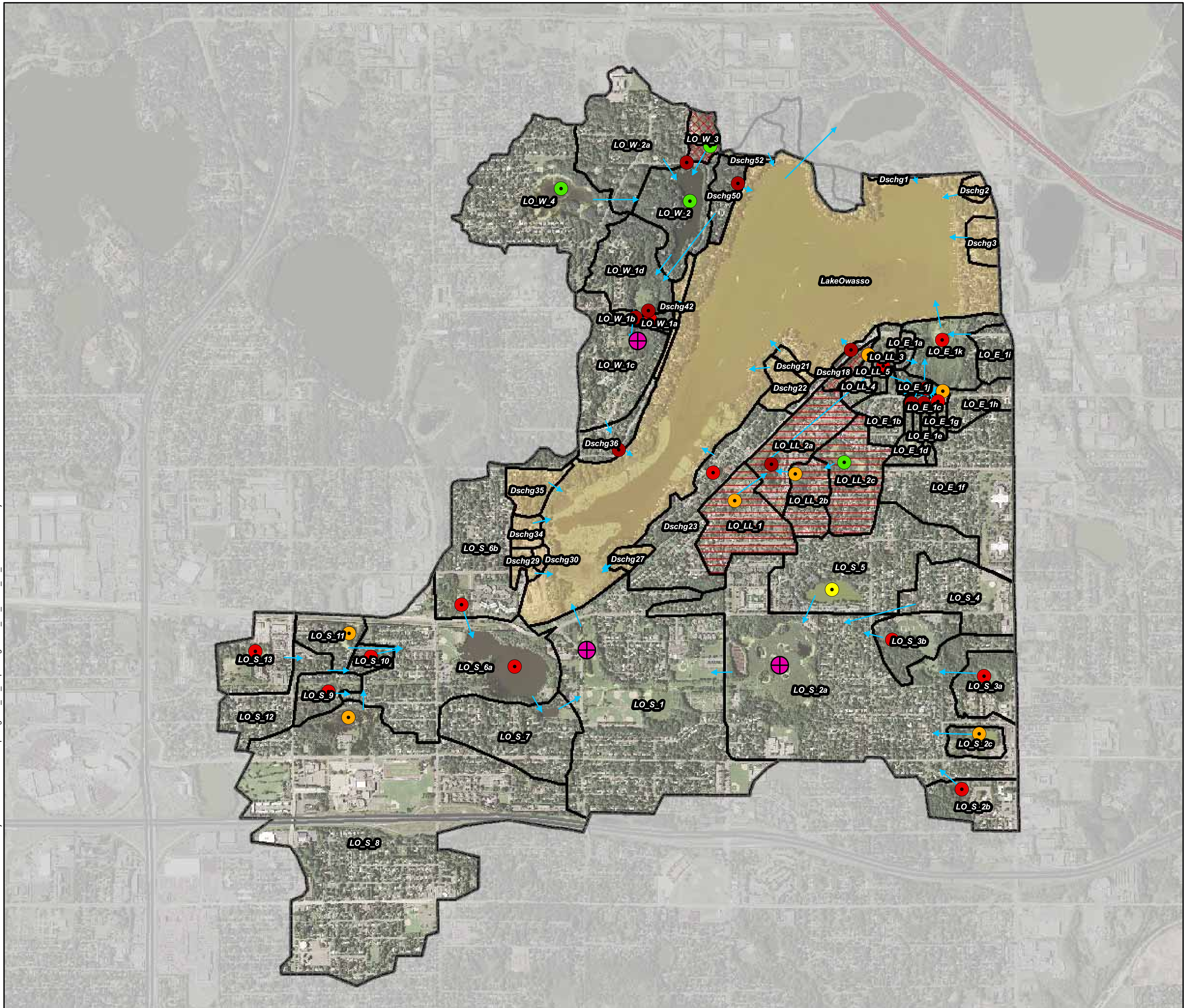
Throughout the Lake Owasso watershed, stormwater runoff flows sequentially through a number of ponds or infiltration basins before discharging to the lakes. The sediment and phosphorus removal efficiencies of the stormwater BMPs varies based on numerous factors, including the size of the pond or basin, the amount of stormwater treated, and design details such as the pond shape or outlet configuration. The existing stormwater BMPs throughout the Lake Owasso watershed were modeled in P8 based on information obtained from as-built construction plans, previous modeling, topographic data, and field survey. The P8 model developed for the 2008 watershed conditions was used to evaluate the performance of the BMPs within the Lake Owasso watershed.

The overall total phosphorus removal efficiency within the Lake Owasso watershed during the 2008 calibration year was about 64 percent. The predicted annual total phosphorus removal efficiencies for each pond, wetland or BMP modeled in P8 are shown in Figure 5 10, with the color of each treatment device representing the estimated annual total phosphorus removal as a percent. The BMP locations shown in orange, yellow, or green achieved predicted total phosphorus removal efficiencies greater than 40 percent (comply with NURP water quality standards). The BMP locations that shown in shades of red achieved predicted removal efficiencies less than 40 percent.

Review of water quality monitoring data collected in 2008 along with calibration of the P8 model suggests that the Central Park – East and West wetlands and the ponds in the Charlie Pond system can act as sources of phosphorus to Lake Owasso. For that reason, these locations are shown on Figure 5-10 as a pink, cross-haired symbol. Also shown are the subwatersheds that currently do not have any water quality treatment before discharging into Lake Owasso.

The range of phosphorus removal efficiencies is the result of a variety of factors. Some of the modeled ponds are natural ponds and wetlands that were not designed as NURP water quality treatment ponds and do not have sufficient dead storage volume to increase phosphorus removals. Some of the BMPs were constructed prior to the onset of the water quality treatment requirements, and were designed only primarily for rate control purposes. Other BMPs with predicted removal efficiencies below NURP standards may not be sized adequately for the amount of runoff and pollutant loading received under existing conditions.

The phosphorus removal efficiency of a pond or other BMP can also depend upon the sediment particle distribution of the inflowing stormwater. Stormwater that has been treated in upstream water quality ponds tends to have a higher fraction of soluble phosphorus, as much of the particulate phosphorus has already been settled out. Soluble phosphorus can be extremely difficult to remove through conventional BMPs, and therefore in some cases, the predicted removal efficiency of a pond can be negatively impacted by inflows from upstream BMPs with high fractions of soluble phosphorus. This effect can be especially pronounced with water quality treatment ponds located at the downstream end of a series of treatment ponds.



TP Removal (%)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- Internal Phosphorus Loading
- Watershed Flow Direction
- Subwatersheds
- Land-Locked Watersheds
- Pumped Outlet Watersheds
- Watersheds without Treatment

Feet

1,750 0 1,750

N

Figure 5-10

LAKE OWASSO
TOTAL PHOSPHORUS REMOVAL EFFICIENCIES
EXISTING CONDITIONS - 2008

Lake Owasso UAA
Grass Lake Watershed Management Organization

5.4.2.2 Watershed Loading for Wet, Dry, and Average Climatic Conditions

The amount of stormwater runoff and associated pollutant loading from a watershed is dependent upon hydrologic conditions such as precipitation patterns and soil saturation conditions. To evaluate the watershed loading under differing hydrologic conditions, the P8 model was run for three time periods that represent average, wet, and dry climatic conditions. Additionally, the watershed "internal" loads, based upon the FLUX modeling and the phosphorus mass balance model for Central Park – West wetland, were updated for each climatic conditions.

- "Average" climatic conditions: May 2004- September 2005
- "Wet" climatic conditions: May 2001- September 2002
- "Dry" climatic conditions: May 2007 - September 2008

Table 5-5 summarizes the precipitation depths associated with the water years (October 1 through September 30) as well as the growing season (May through September) for each of the specific climatic periods.

Table 5-5 Water Year and Growing Season Precipitation Depths for Wet, Dry and Average Climatic Conditions

Climatic Condition	Year	Precipitation Depth (in)[1]	
		Water Year	Growing Season
Wet	2002	41.2	28.4
Dry	2008	24.5	13.0
Average	2005	31.6	20.2

1 – Precipitation depths based on hourly data from the Downtown St. Paul Airport and the Minneapolis-St. Paul International Airport adjusted using the daily High Density Network data near Lake Owasso (see Section 4.2.1)

Table 5-6 summarizes the estimated external water loads, including the modeled watershed runoff volume, and external phosphorus loads to Lake Owasso for the three climatic conditions. This table also summarizes the estimated internal phosphorus loads to the lake, as will be discussed in Section 5.4.3.

Table 5-6 Lake Owasso Water Loads and Phosphorus Loads for Wet, Dry, and Average Climatic Conditions

Climatic Condition		Wet	Dry[3]	Average
Water Year		2002	2008	2005
Water Budget				
Source		Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)
Direct Precipitation		1286	644	987
Watershed Runoff		1150	509	401
Groundwater[1]		913	913	913
TOTAL WATER LOAD		***3348***	***2066***	***2300***
Phosphorus Budget				
Source		TP Load (lbs)	TP Load (lbs)	TP Load (lbs)
External Load Sources	Watershed Runoff	252	102	87
	Internal Loading from Watershed Water Bodies	89	29	60
	Atmospheric Deposition	90	88	91
	Groundwater	62	62	62
	TOTAL EXTERNAL LOAD	*493*	*281*	*300*
Internal Load Sources	Curlyleaf Pondweed[2]	184	184	184
	Internal Sediment Release	398	91	221
	TOTAL INTERNAL LOAD	*582*	*275*	*405*
TOTAL PHOSPHORUS LOAD		***1076***	***556***	***705***

1 - Groundwater exchange was estimated based on the 2008 Lake Owasso water balance modeling. It was assumed that the calibrated groundwater exchange would apply to all climatic conditions.

2 - Coverage & Density of Curlyleaf Pondweed assumed to be the same as estimated from the 2007 macrophyte survey conducted by Ramsey County Public Works for all climatic conditions.

3 - 2008 Calibration Year

5.4.3 Internal Phosphorus Load Estimates

Phosphorus enters Lake Owasso from watershed runoff, atmospheric deposition, groundwater inflow, macrophyte senescence, and sediment release. The last two sources of phosphorus in the list are often referred to as the "internal load."

Curlyleaf pondweed is an invasive macrophyte that can be an important source of phosphorus in a lake system. This macrophyte begins its lifecycle in the fall of the year and its senescense (die-off) begins in early summer. Once the plants die, the biomass begins to decompose and releasing soluble phosphorus to the water column. In this form, the phosphorus can quickly be utilized by algae, leading to intense algal blooms for the remainder of the summer. Additionally, the decay of the organic material can also result in oxygen depletion which in turn can cause the release of phosphorus for the lake bottom sediments.

Loading from the lake bottom sediments can also be a significant source of phosphorus in lakes that have a history of high phosphorus loads from their watershed. Like with Curlyleaf pondweed, phosphorus released from the sediments, either as the result of anoxic (void of oxygen) or high pH conditions, is typically in a dissolved form, causing algal blooms and decreases in water quality. Internal loading from the sediments is influenced by the lake's mixing and stratification patterns.

The monitoring data for Lake Owasso supports that it is a dimictic lake, meaning the lake thermally stratifies during the summer months and completely mixes only twice per year, during the spring and fall turnover events. Temperature and water quality monitoring data at depth shows that Lake Owasso experienced strong thermal stratification in both the northern and southern basins in the lake. Dissolved oxygen data indicates that the bottom waters become anoxic (devoid of oxygen) during the summer months. Elevated phosphorus measurements below the depth of the thermocline also show that phosphorus accumulates in the hypolimnion along the sediments as well. However, in the deep areas of the lake where strong thermal stratification occurs, the phosphorus from anoxic sediment release will likely remain in the hypoliminion until the lake complete mixes during a turnover event.

Although Lake Owasso is considered a deep lake with three basins that thermally stratify during the summer months, much of the lake is relatively shallow with the average depth of 10.9 feet for the entire lake. Because there are shallow areas of the lake, mixing and sediment resuspension as the result of wind, motorboating, and carpactivity, may also be a source of phosphorus to the lake. Observations of carp activity in the Central Park – West wetland (which is directly connected to Lake Owasso) suggest that carp are likely active in Lake Owasso as well. Additionally, observations by lake residents indicated that motor boating activity results in increased turbidity in the south end of the lake. However, there have been no data collected in these shallow areas of the lake to quantify the associated phosphorus loads with these sources, and they have not been incorporated into the in-lake water quality modeling.

5.4.3.1 In-Lake Modeling Results

The phosphorus mass balance for Lake Owasso, as described in Section 4.3, was calculated based on existing land use conditions for each of the climatic scenarios. Measured in-lake water quality data collected from May to September for 2002 (Wet), 2005 (Average), and 2008 (Dry) were also used in the in-lake models. Using the mass balance equation, the net internal loading for each climatic condition was calculated. The internal loading sources of phosphorus quantified for Lake Owasso included both the release of phosphorus from the die-back of Curlyleaf pondweed as well as from anoxic sediment release. It is important to remember that the internal load is delivered over a concentrated period of time- the growing season- during which time it can efficiently contribute to nuisance algal growth in the lake. The annual phosphorus loads to Lake Owasso from the internal sources are summarized in Table 5-6, along with the sources of water loads to the lake as well as the external sources of phosphorus.

Figures 5-11, 5-12, and 5-13 show the annual water and phosphorus budgets for Lake Owasso for the wet, dry, and average climatic conditions, respectively. Because the dry climatic year (2008; also the calibration year) was modeled as a two-basin system, the water and phosphorus budgets are shown for both the south and north basins, as well as for the overall lake system. These water and phosphorus budget figures put the estimated internal phosphorus loads in perspective with the external watershed loads that Lake Owasso receives on an annual basis. Actual results of the 2008 (dry) in-lake water quality model calibration are shown in Figure 5-14a and Figure 5-14b. In-lake modeling calibration results for all other years (2007, 2002 (wet), and 2005 (average)) can be found in Appendix L of this UAA.

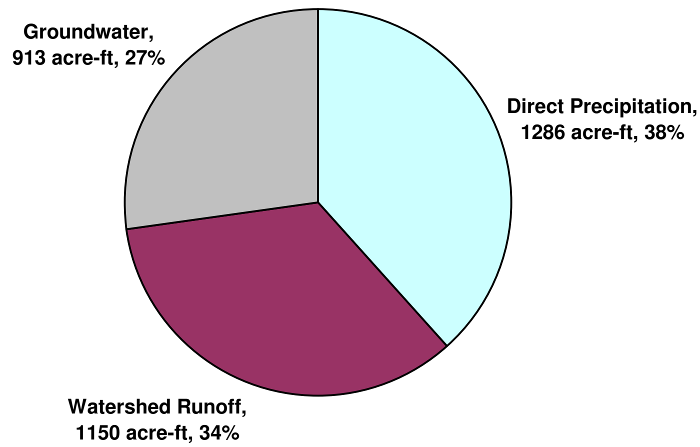
Figure 5-11 shows the breakdown of the Lake Owasso water load as well as the relative contribution of the external (watershed) and internal phosphorus loads for wet climatic conditions (water year 2002). During wet climatic conditions, direct precipitation on the lake was the most significant source of water to Lake Owasso (38 percent), closely followed by watershed runoff (34 percent). With regards to phosphorus loading to the lake, internal loads contribute ~54 percent of the total annual load of phosphorus (13 percent from Curlyleaf pondweed and 37 percent from release from sediments).

Figure 5-12 (a), 5-12 (b), and 5-12 (c) shows the breakdown of the Lake Owasso water load as well as the relative contribution of the external (watershed) and internal phosphorus loads for dry climatic conditions (water year 2008). During dry climatic conditions, groundwater inflow was the most significant source of water to Lake Owasso (44 percent), followed by direct precipitation to the lake (31 percent). With regards to phosphorus loading to the lake as a whole (Figure 5-12 (c)), internal loads contribute ~49 percent of the total annual load of phosphorus to the lake (33 percent from Curlyleaf pondweed and 16 percent from release from sediments).

Because water quality monitoring data for 2008 (the dry/calibration year) is available in both the north and south basins of Lake Owasso and the in-lake model was developed as a two basin model, the variations in phosphorus loading across the lake area could be evaluated. More than half of the watershed runoff passes through the south end of Lake Owasso (site 5403) before flows move north to the outlet on the northeast side of the lake. Figure 5-12 (a) shows the water and phosphorus budgets for the south basin of Lake Owasso. Watershed runoff has the most significant impact on this basin in the lake, accounting for 59 percent of the water load and nearly 71 percent of the phosphorus load. Internal phosphorus loading accounts for 12 percent of the phosphorus load in the south basin, the majority of it associated with the die-back of Curlyleaf pondweed. Figure 5-12 (b) shows the water and phosphorus budget for the north basin of Lake Owasso. In the north basin, groundwater was the most significant source of water (39 percent). Internal phosphorus loading is the most significant contributor to the phosphorus load in the north basin, accounting for 47 percent of the total phosphorus budget.

Figure 5-13 shows the breakdown of the Lake Owasso water load as well as the relative contribution of the external (watershed) and internal phosphorus loads for average climatic conditions (water year 2005). During average climatic conditions, direct precipitation on the lake was the most significant source of water to Lake Owasso (43 percent), closely followed by groundwater (40 percent). With regards to phosphorus loading to the lake, internal loads contribute ~57 percent of the total annual load of phosphorus (26 percent from Curlyleaf pondweed and 31 percent from release from sediments).

Lake Owasso Annual Water Load (3,348 acre-ft)
2002 (Wet) Calibration Year



Lake Owasso Annual Phosphorus Load (1,076 lbs)
2002 (Wet) Calibration Year

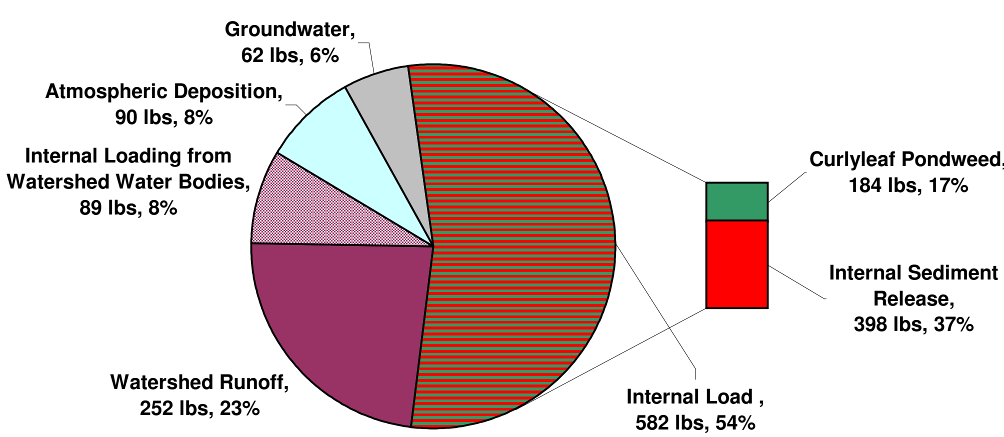


Figure 5-11
Lake Owasso
Water and Total Phosphorus Budget
Wet Climatic Conditions

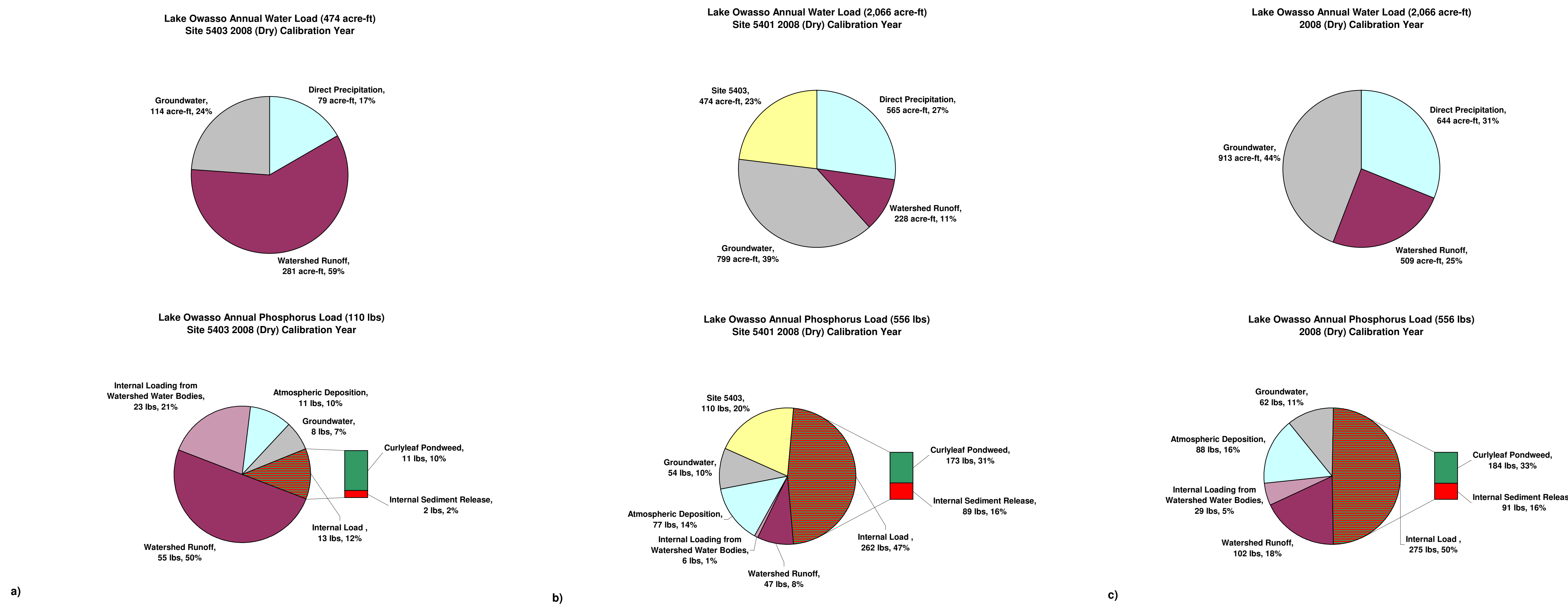
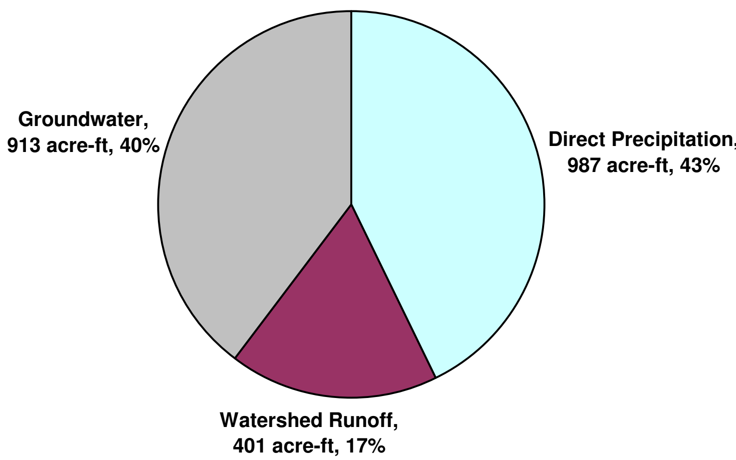


Figure 5-12
Lake Owasso
Water and Total Phosphorus Budget
Dry Climatic Conditions
a) Site 5403 (South Basin)
b) Site 5401 (North Basin)
c) Lake Owasso - Entire Basin

Lake Owasso Annual Water Load (2,300 acre-ft)
2005 (Avg) Calibration Year



Lake Owasso Annual Phosphorus Load (705 lbs)
2005 (Avg) Calibration Year

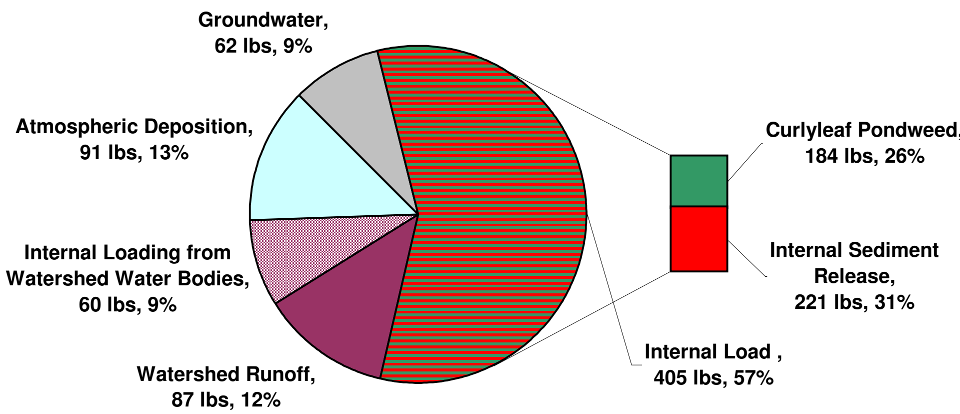


Figure 5-13
Lake Owasso
Water and Total Phosphorus Budget
Average Climatic Conditions

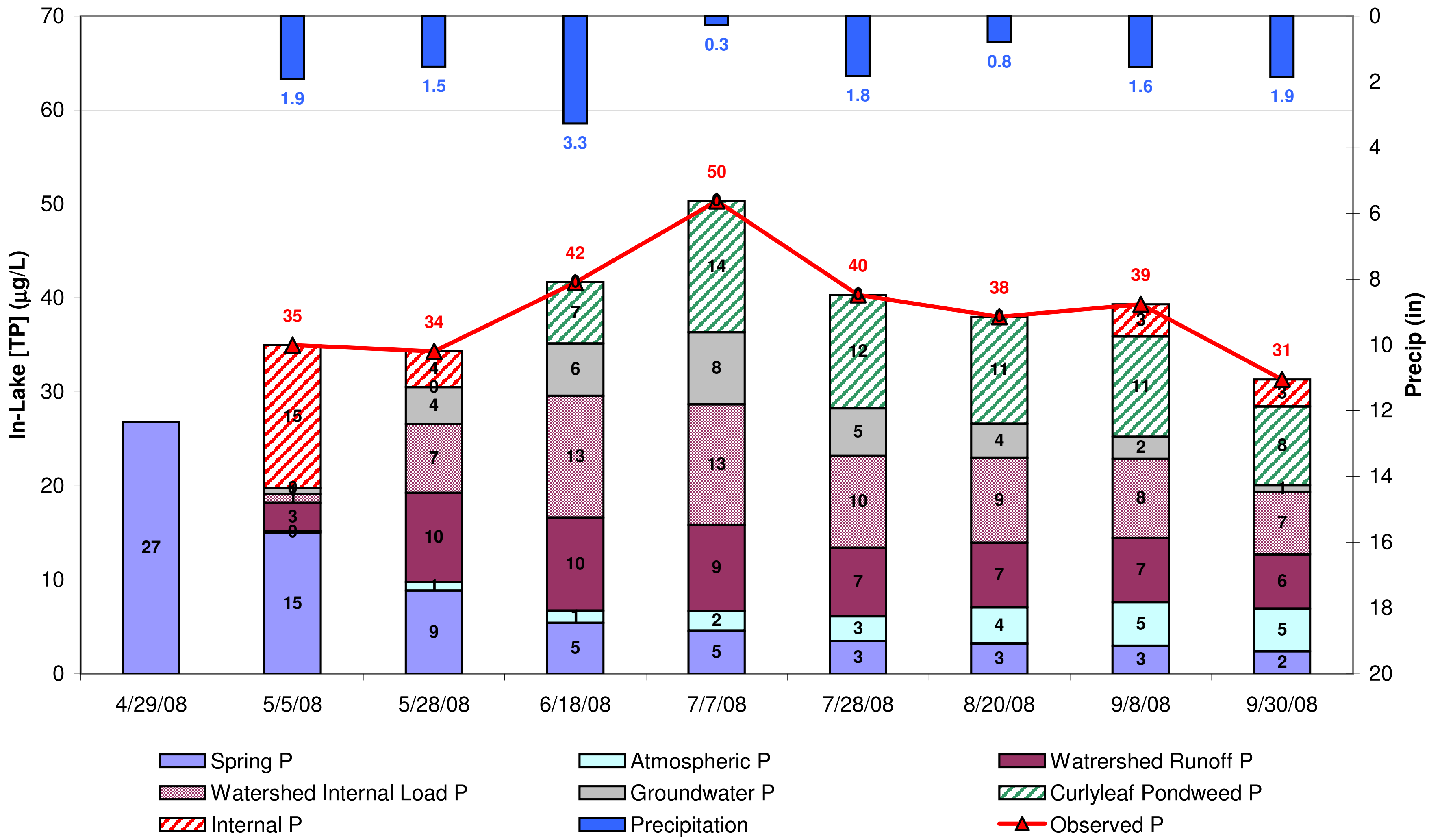


Figure 5-14a
Lake Owasso Site 5403
2008 (Dry) In-Lake Water Quality Model Calibration

P:\Mpls\23 MN\62\2362946\WorkFiles\Modeling\InLake\Calibration20072008\LakeOwasso_2008_5403_Loads4_Test3.xls: Figure5-14a