Lake Owasso Use Attainability Analysis

Diagnostic-Feasibility Study:
Water Quality Issues and Potential Restorative Measures

Prepared for

Grass Lake Watershed Management Organization

April 2009

BARR

Prepared by
Barr Engineering Company

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Executive Summary

Overview

This report describes the results of the Use Attainability Analysis (UAA) for Lake Owasso on the border of Roseville and Shoreview, MN. This study provides the scientific foundation for a lake-specific management plan that assesses the water body's physical, chemical, and biological condition and provides recommendations that would help improve the water quality of Lake Owasso. This study includes both a water quality assessment and prescription of protective and/or remedial measures for Lake Owasso and the tributary watershed. The conclusions and recommendations are based on the compilation of intensive lake water quality monitoring data for the summers of 2007 and 2008. This data was coupled with computer models, which were calibrated to the 2007 and 2008 datasets, to simulate the impact of the various phosphorus sources on the water quality in Lake Owasso.

A key result of these analyses and computations was the development of annual water and phosphorus budgets for Lake Owasso, identifying the relative percent contribution of each of the various sources to the annual water and phosphorus loads. In addition, best management practices (BMPs) were evaluated to compare their relative effect on the total phosphorus concentrations and Secchi disc transparencies (i.e., water clarity) in Lake Owasso. Management options were then assessed to determine attainment or non-attainment for the lake's water quality goals and recreational uses.

Water Quality Goals for Lake Owasso

The Grass Lake Watershed Management Organization (GLWMO) has established water quality goals for Lake Owasso as part of its 2001 *Watershed Management Plan*, based on the desired use of the lake and public perception.

Table EX-1 Lake Owasso Summary of Historical Water Quality Data, Goals, and Standards

Water Quality Parameter	Mean Summer-Average for Period of Record (1973-2008)	2008Summer Average	GLWMO Existing Goal	GLWMO Action Level	MPCA's Deep Lake Standard
Total Phosphorus	54 µg/L	32 µg/L	45 µg/L	--	40 µg/L
Secchi Disc	6.2 ft (1.9 m)	6.9 ft (2.1 m)	5.2 ft (1.6 m)	8.0 ft (2.45 m)	4.6 ft (1.4 m)
Chlorophyll *a*	15.7 µg/L	13 µg/L	20 µg/L	--	14 µg/L

The results of a lake user survey (conducted in the spring of 2007) as well as discussions at public meetings indicate that residents have concerns about macrophyte interference with recreational uses of the lake as well as decreasing lake clarity.

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, therefore higher phosphorus concentrations typically result in more algae and related problems.
- 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 typically determines recreational-use impairment.

All three of these water quality indicators, either alone or in combination, can be used to determine a Trophic State Index (TSI). However, water transparency alone is typically used to develop the TSI_{SD} (Trophic State Index based on Secchi disc transparency) because people's perceptions of recreational-use impairment are often directly related to water clarity.. Water quality trophic status 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). Water quality characteristics of lakes in the various trophic status categories are listed below with their respective TSI ranges:

1. **Oligotrophic –** [$20 \leq TSI_{SD} \leq 38$] clear, low productive lakes, with total phosphorus concentrations less than or equal to 10 μg/L, chlorophyll *a* concentrations of less than or equal to 2 μg/L, and Secchi disc transparencies greater than or equal to 4.6 meters (15 feet).

2. **Mesotrophic –** [$38 \leq TSI_{SD} \leq 50$] intermediately productive lakes, with total phosphorus concentrations between 10 and 25 μg/L, chlorophyll *a* concentrations between 2 and 8 μg/L, and Secchi disc transparencies between 2 and 4.6 meters (6 to 15 feet).

3. **Eutrophic –** [$50 \leq TSI_{SD} \leq 62$] high productive lakes relative to a neutral level, with 25 to 57 μg/L total phosphorus, chlorophyll *a* concentrations between 8 and 26 μg/L, and Secchi disc measurements between 0.85 and 2 meters (2.7 to 6 feet).

4. **Hypereutrophic –** [$62 \leq TSI_{SD} \leq 80$] extremely productive lakes which are highly eutrophic and unstable (i.e., their water quality can fluctuate on daily and seasonal basis, experience periodic anoxia and fish kills, possibly produce toxic substances, etc.) with total phosphorus

concentrations greater than 57 µg/L, chlorophyll *a* concentrations of greater than 26 µg/L, and Secchi disc transparencies less than 0.85 meters (2.7 feet).

Lake Owasso Characteristics

Lake Basin Characteristics

Lake Owasso is a lake located on the border between the cities of Roseville and Shoreview. The normal water surface elevation is 886.6 feet MSL. At this elevation, the lake volume is approximately 4099 acre-feet. At the normal water surface elevation, the lake has a water surface area of approximately 375 acres and a mean depth of 10.9 feet. The maximum depth is 37 feet.

The outlet from Lake Owasso is located on the northwest side of the lake and flows under North Owasso Boulevard, discharging into a wetland area on the southwest side of Lake Wabasso. The outlet structure of Lake Owasso consists of a concrete box with three 8-foot plate weirs, followed by two reinforced concrete arched pipes. Discharge from Lake Owasso occurs when water levels are above 886.6 feet MSL; however, there is indication that ice build-up does limit the discharge from Lake Owasso during the winter months (Shoreview Public Works Director, personal communication, 1/18/2008).

Watershed Characteristics

Lake Owasso's 3060-acre watershed, including the surface area of the lake, is within the cities of Roseville and Shoreview. Runoff from the immediate watershed enters Lake Owasso through overland flow and at several sewer outfalls to the lake.

For this study, the Lake Owasso watershed was divided into five major "drainage districts" comprised of numerous smaller subwatershed area. Figure EX-1 shows the Lake Owasso drainage districts, subwatersheds, drainage patterns, and monitoring (in-lake water quality, sediment cores, watershed runoff monitoring stations, and pond discharge) locations. Each drainage district is briefly described below:

- **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.

Current and future land uses for the watershed are shown in Figure EX-2. Low density residential land use has been identified as the major land use within the Lake Owasso watershed (55 percent) followed by open water and wetland (mostly Lake Owasso. Figure EX-3 summarizes the breakdown of land use categories in the Lake Owasso watershed, for both existing (2006) and future conditions. There are no significant changes expected in the Lake Owasso watershed land use.

The infiltration capacity of soils affects the amount of direct runoff resulting from rainfall. Soils with a higher infiltration rate have a lower runoff potential. Conversely, soils with low infiltration rates produce high runoff volumes and high peak runoff rates. According to the Ramsey County Digital Soils map, the underlying soils in the Lake Owasso watersheds are predominantly classified as hydrologic soil group (HSG) B, with moderate infiltration rates. The soils along the eastern side of the lake are classified as HSG A, characterized by high infiltration rates. Soils around wetland areas within the watershed typically have low to very low infiltration capacity. Figure EX-4 shows the distribution of the HSGs throughout the Lake Owasso watershed.

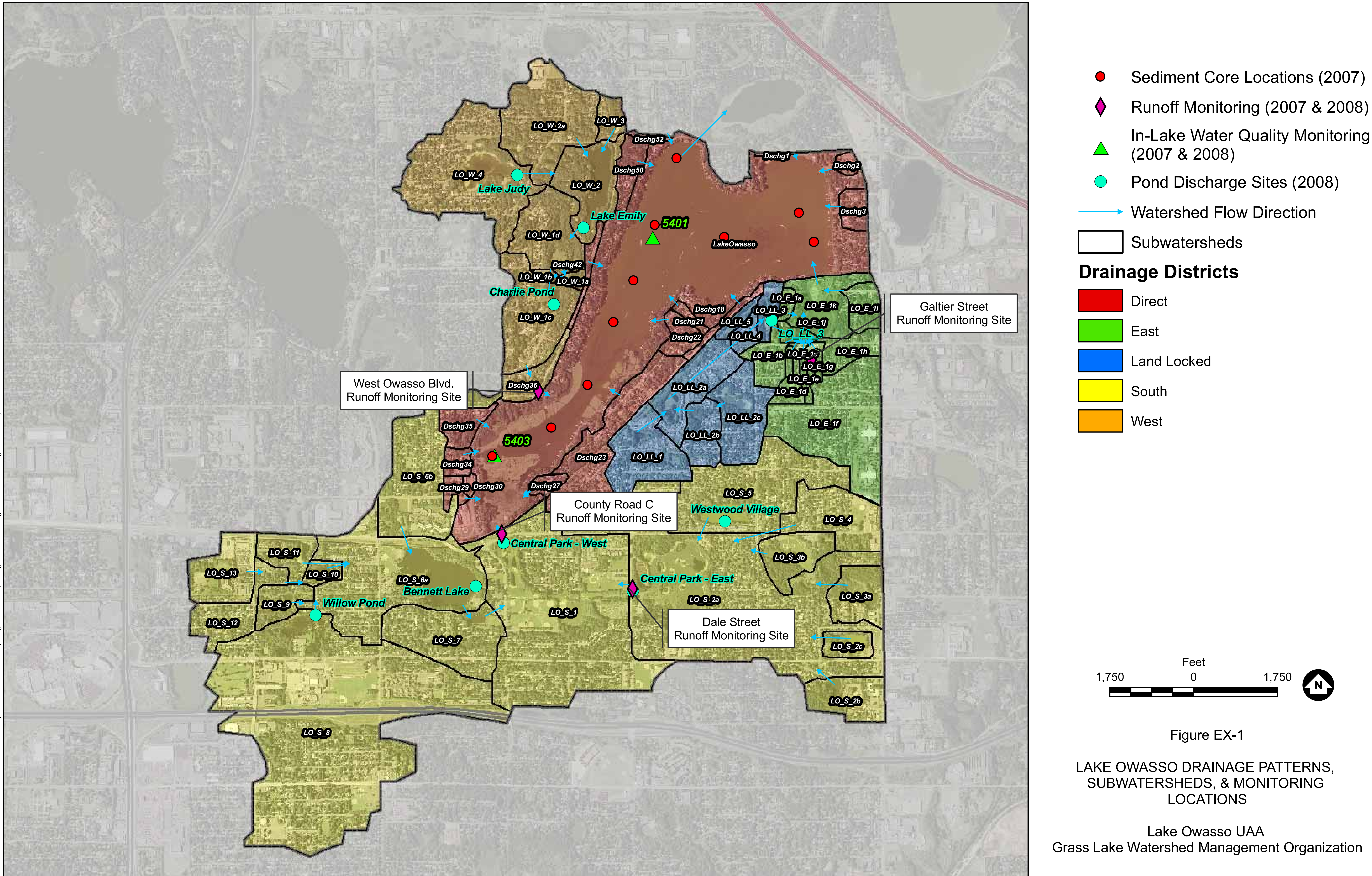
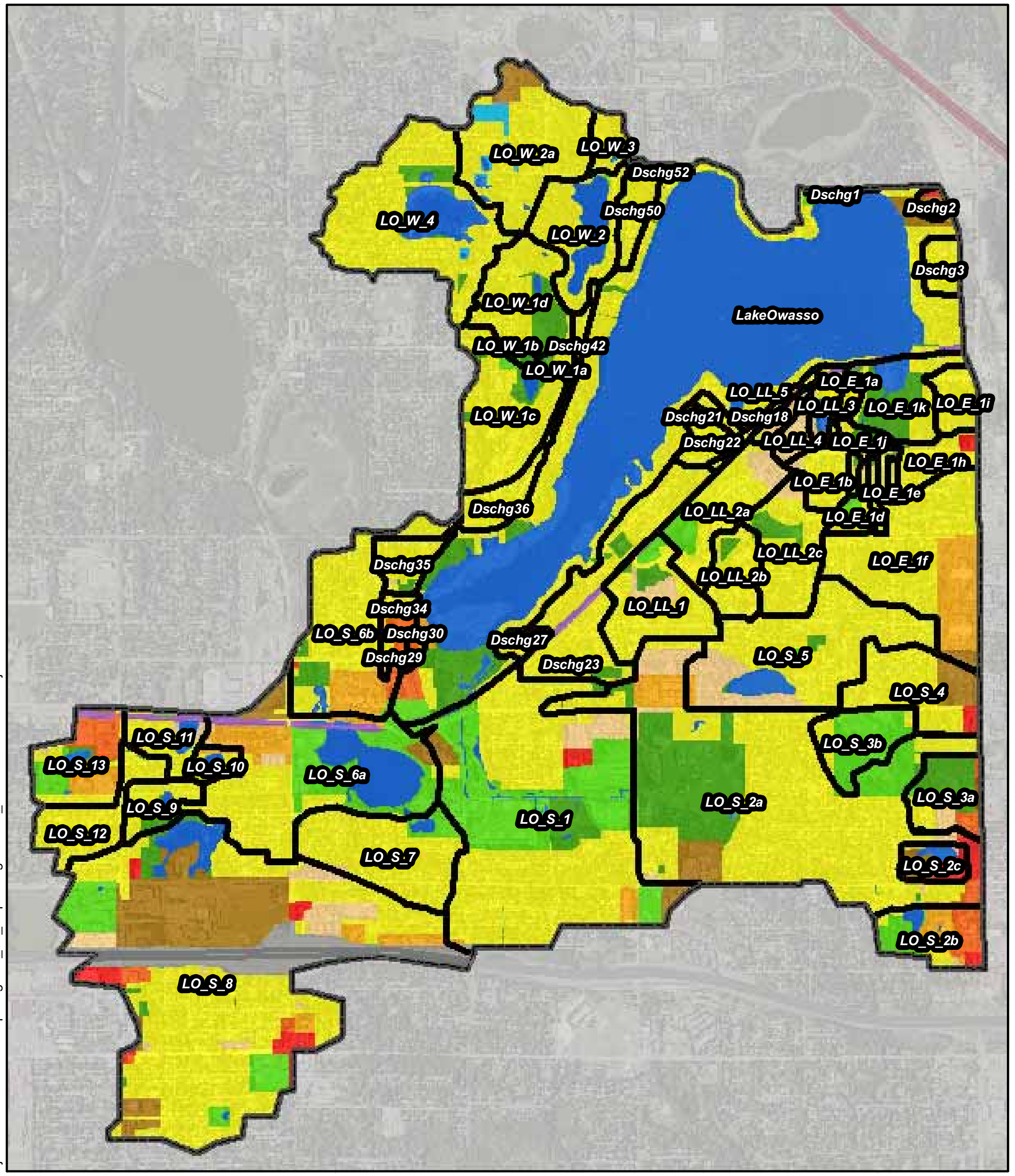


Figure EX-1

LAKE OWASSO DRAINAGE PATTERNS, SUBWATERSHEDS, & MONITORING LOCATIONS

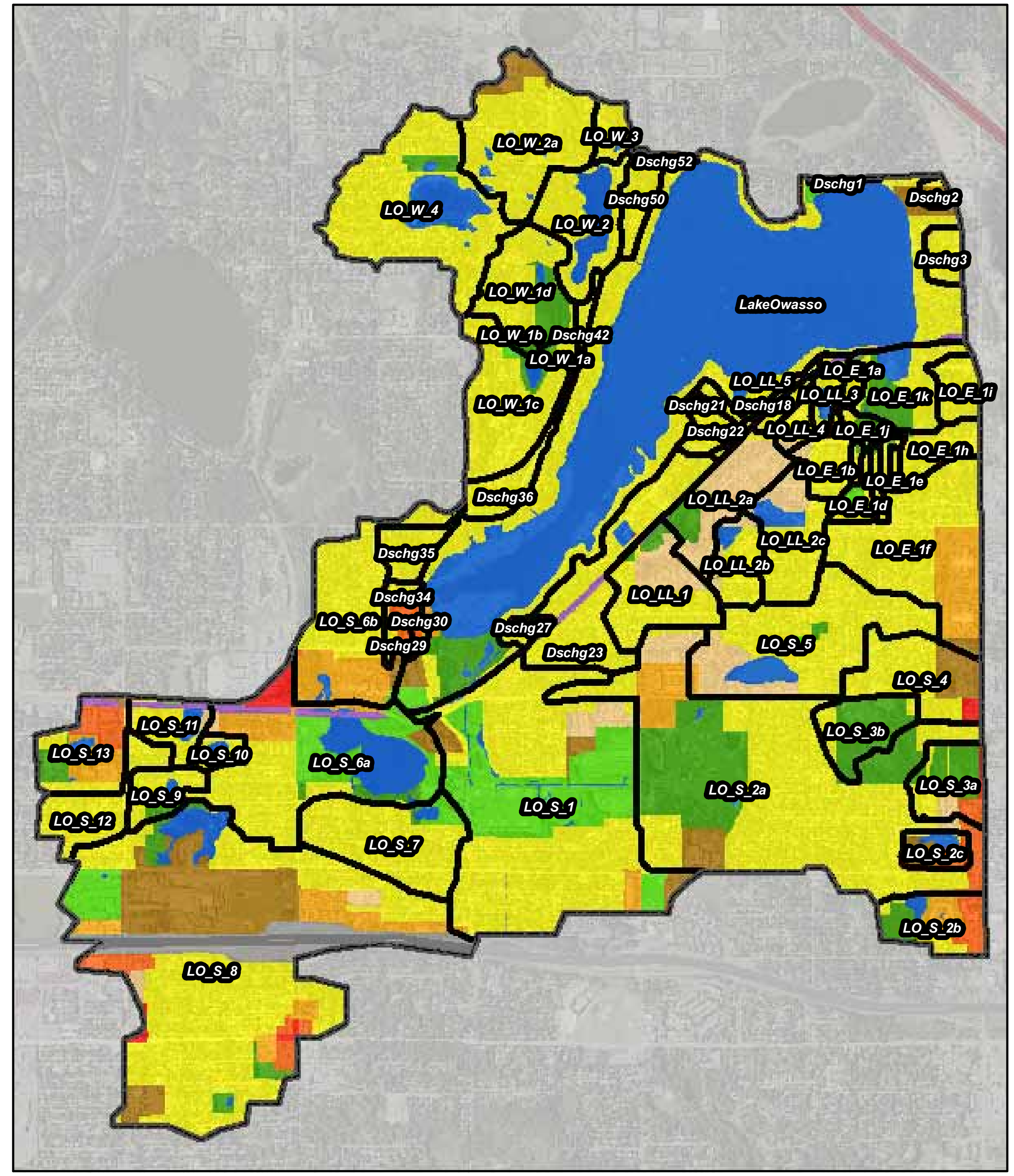
Lake Owasso UAA
Grass Lake Watershed Management Organization

Existing (2006) Land Use



Source: 2001 GLWMO Watershed Management Plan, Modified to 2006 aerial photography

Full Development (Future) Land Use



Source: 2001 GLWMO Watershed Management Plan

Subwatershed

Land Use

- Commercial
- Developed Park
- Highway
- High-Density Residential
- Institutional
- Office/Industrial
- Low-Density Residential
- Medium-Density Residential
- Natural/Open Space
- Water
- Wetland
- Railroad

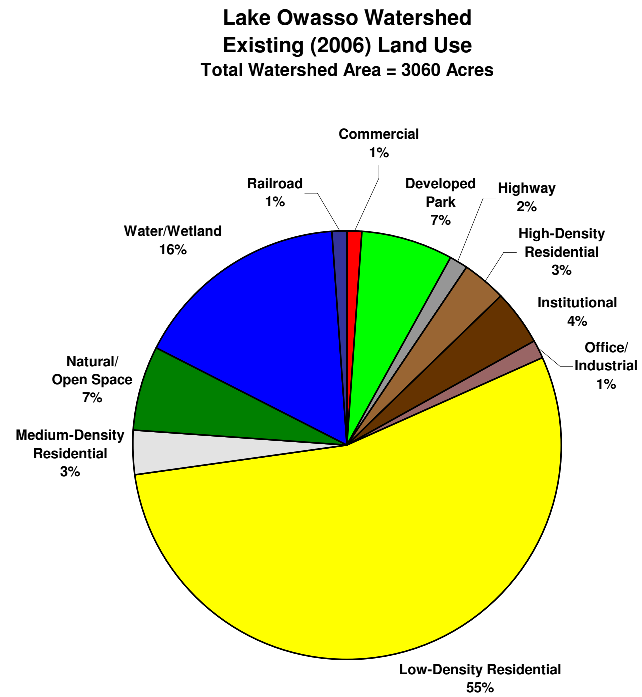
Feet

2,500 0 2,500

Figure EX-2

LAKE OWASSO WATERSHED
EXISTING AND FULL DEVELOPMENT
LAND USE

Lake Owasso UAA
Grass Lake Watershed Management Organization



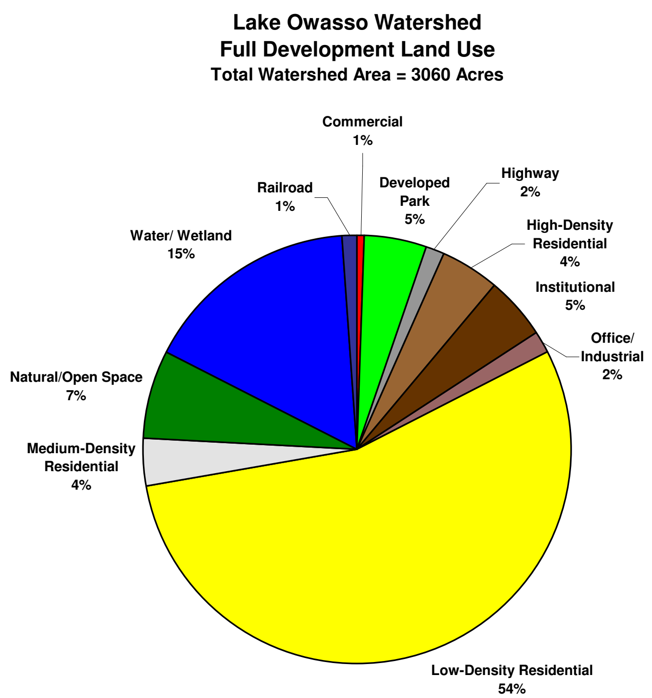
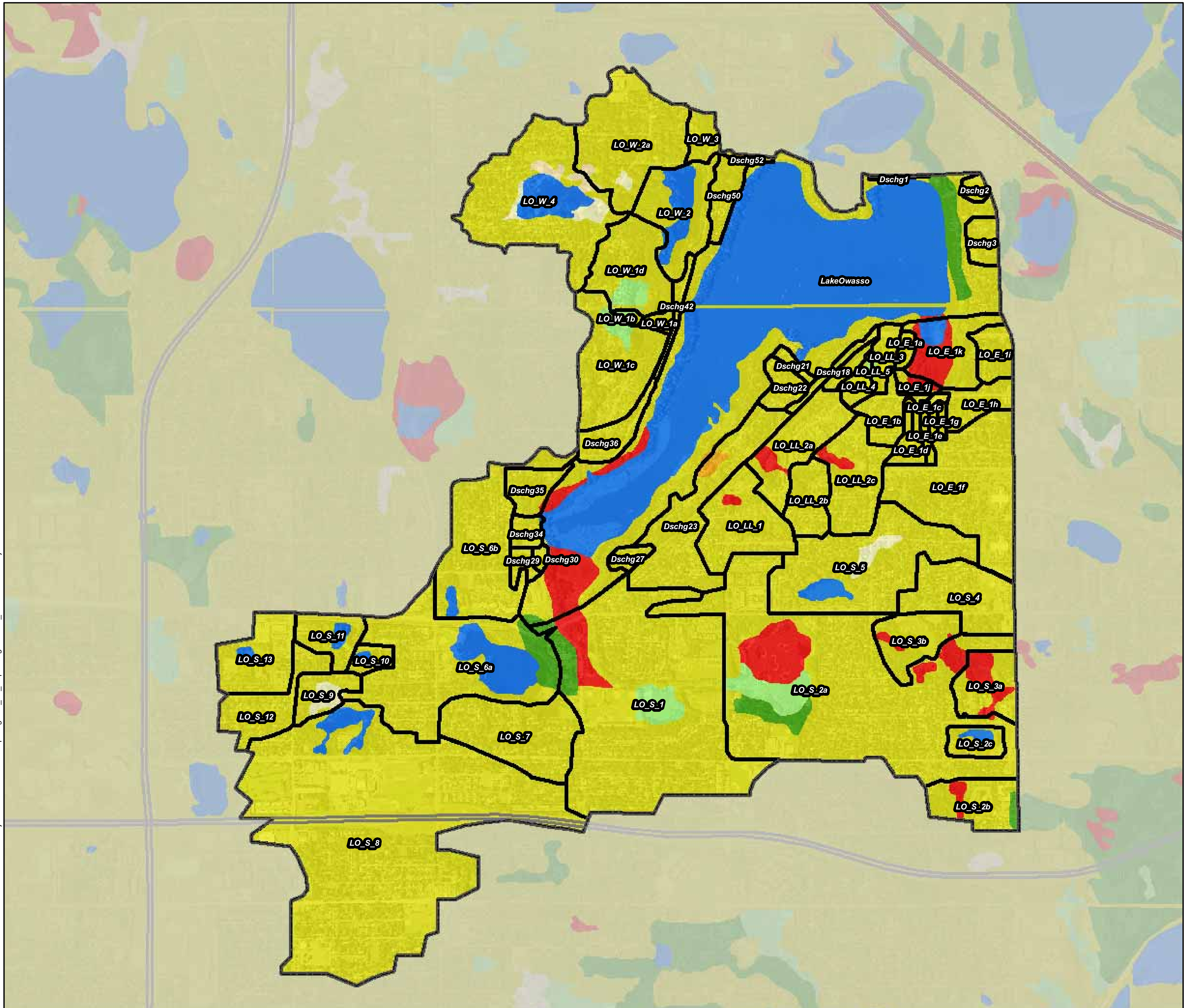


Figure EX-3
Lake Owasso Watershed
Existing (2006) and Full Development
Land Use Summary



Subwatershed

Hydrologic Soil Group (HSG)

- A - High Infiltration Potential
- A/D - Very Low Infiltration Potential
- B - Moderate Infilatration Potential
- B/D - Very Low Infiltration Potential
- C - Low Infiltration Potential
- C/D - Very Low Infiltration Potential
- D - Very Low Infiltration Potential
- Water

Feet

1,750 0 1,750

N

Figure EX-4

LAKE OWASSO WATERSHED
SOIL INFILTRATION CAPACITY

Lake Owasso UAA
Grass Lake Watershed Management Organization

Water Quality Problem Assessment

Lake Owasso Water Quality

Figure EX-5a shows the total phosphorus, Secchi disc, and chlorophyll *a* monitoring results for monitoring site 5401 in Lake Owasso for 2007 and 2008. Figure EX-5b shows the total phosphorus, Secchi disc, and chlorophyll *a* monitoring results for monitoring site 5403 in Lake Owasso for 2007 and 2008. Figure EX-6 shows the historical summer averages for the same three parameters.

Phosphorus

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.

Chlorophyll *a*

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 does 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 summer-average Secchi disc transparency for both sites 5401 and 5403 (1.6 meters and 1.8 meters) just meet the GLWMO water quality goal (1.6 meters) and fall below the GLWMO established action level (2.45 meters), thereby causing this study to be conducted. The 2008 summer average transparency for sites 5401 and 5403 (2.1 meters and 2.0 meters) also met 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.

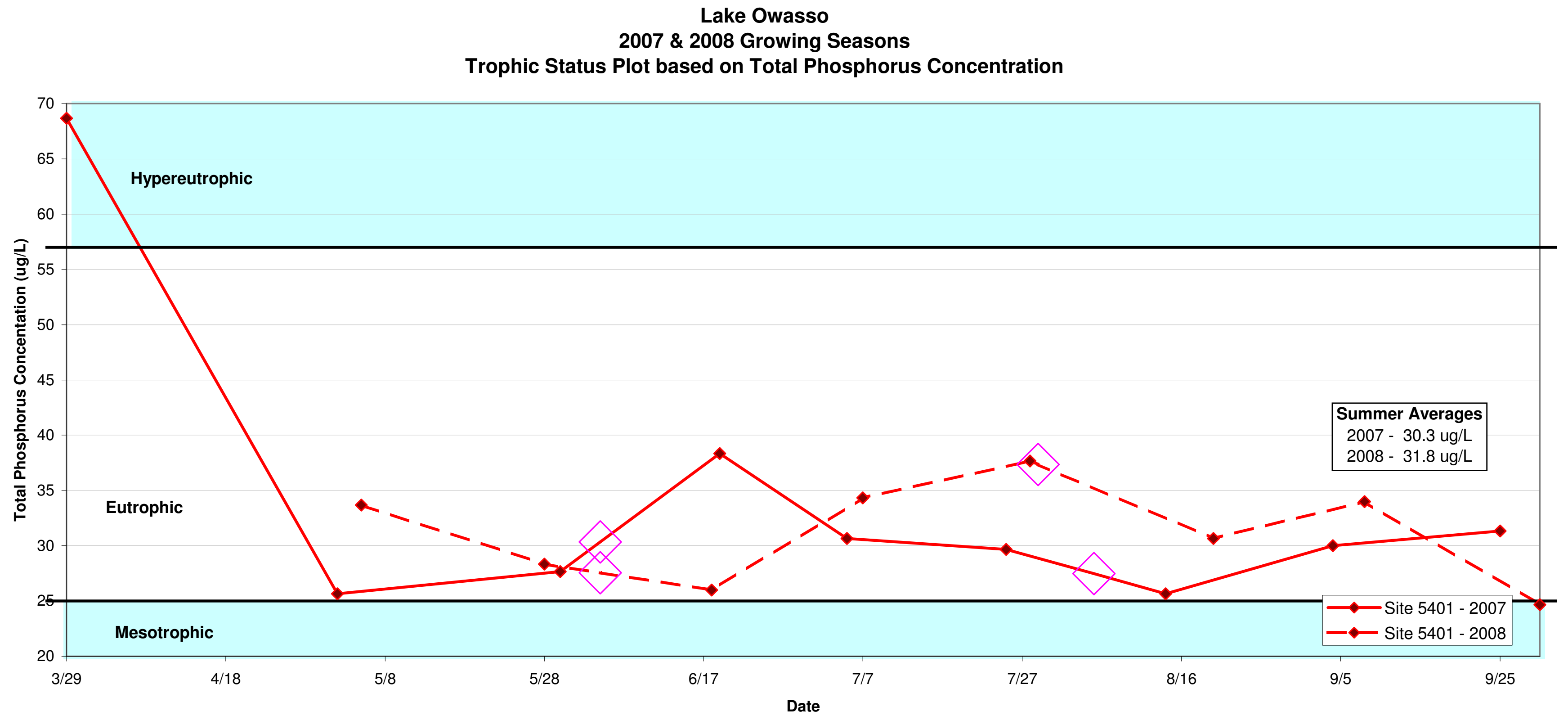
Temperature and Oxygen

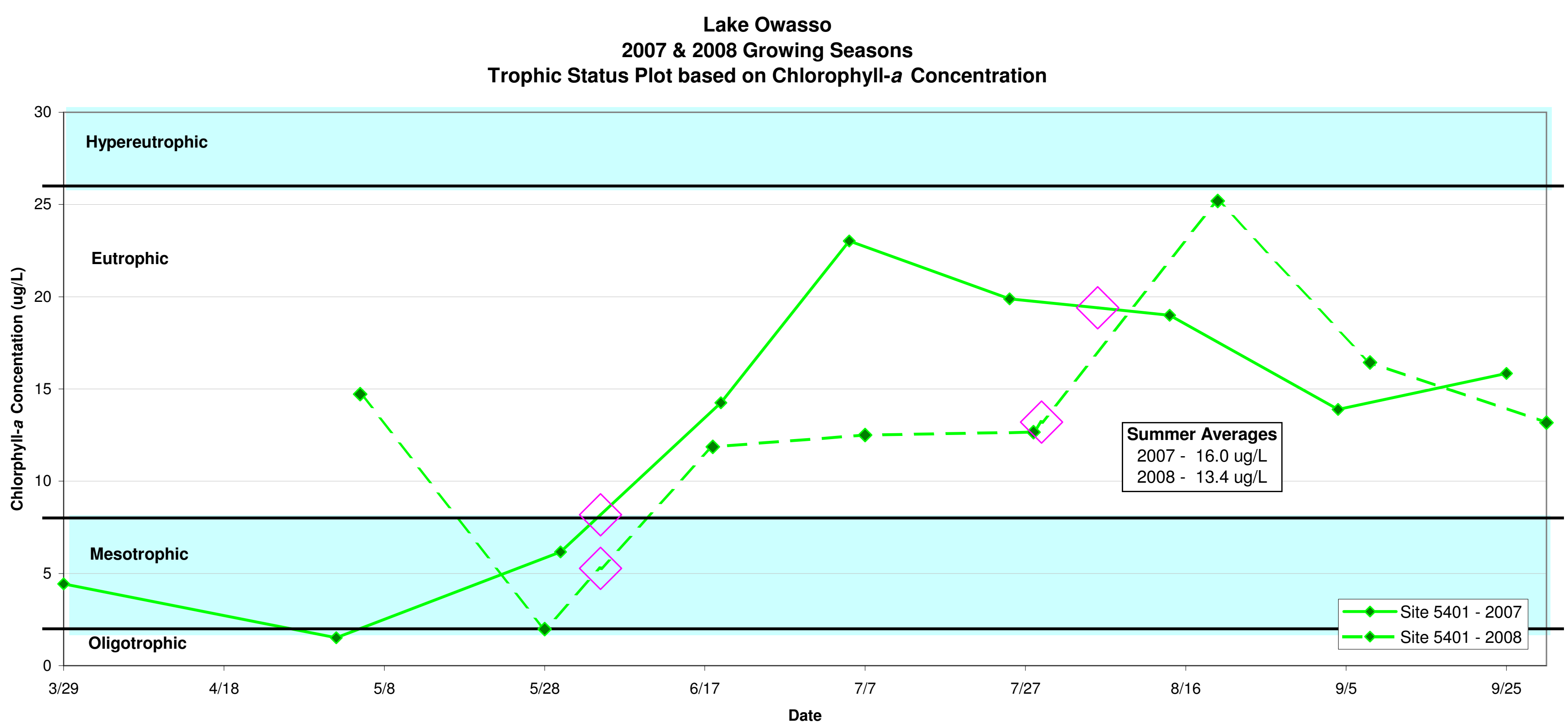
Temperature and dissolved oxygen measurements throughout the water column at both monitoring sites in Lake Owasso indicate that the entire lake does thermally stratify from May through early September, for both 2007 and 2008. At Site 5401, the depth to the thermocline was approximately 5 to 6 meters. At site 5403, the thermocline depth is about 2 to 3 meters. Because the thermocline persists throughout the summer, it can be inferred that Lake Owasso is a dimictic lake (completely mixes twice-annually).

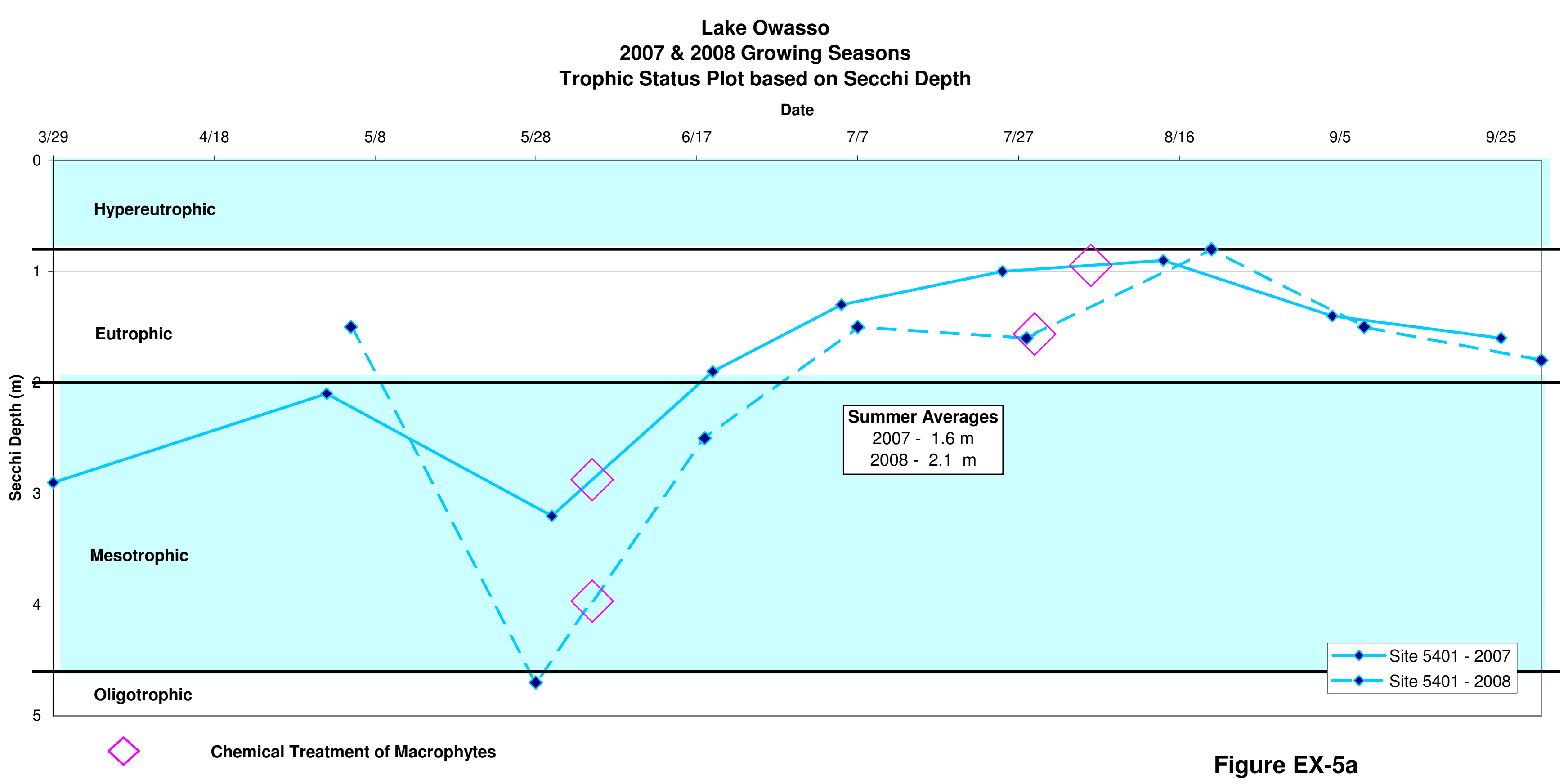
During both 2007 and 2008 in the summer months, dissolved oxygen levels varied greatly throughout the depth of the water column. Typically, dissolved oxygen levels ranged from 8 to 12 mg/L in the surface waters above the thermocline. However along and below the thermocline, dissolved oxygen levels continued to decline with concentrations less than 1 mg/L along the bottom of the lake. This indicates that Lake Owasso likely experiences sediment anoxia during the summer, resulting in internal phosphorus loading from the bottom sediments.

Chloride

Chloride measurements in Lake Owasso were relatively constant throughout the summer of 2007 with the average chloride concentration for the entire monitoring period measured at site 5401 being 55 mg/L, and at site 5403, 69 mg/L. In 2008, 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.

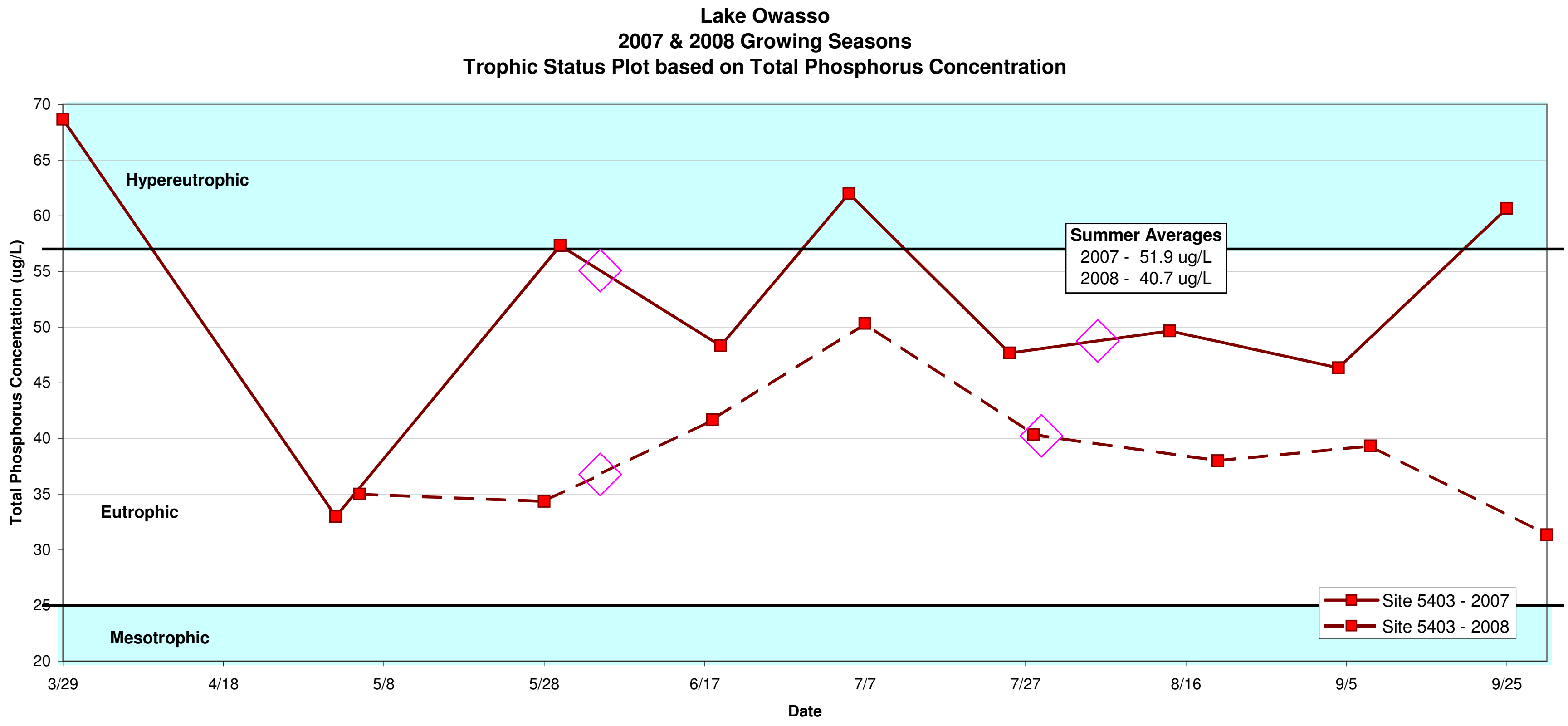


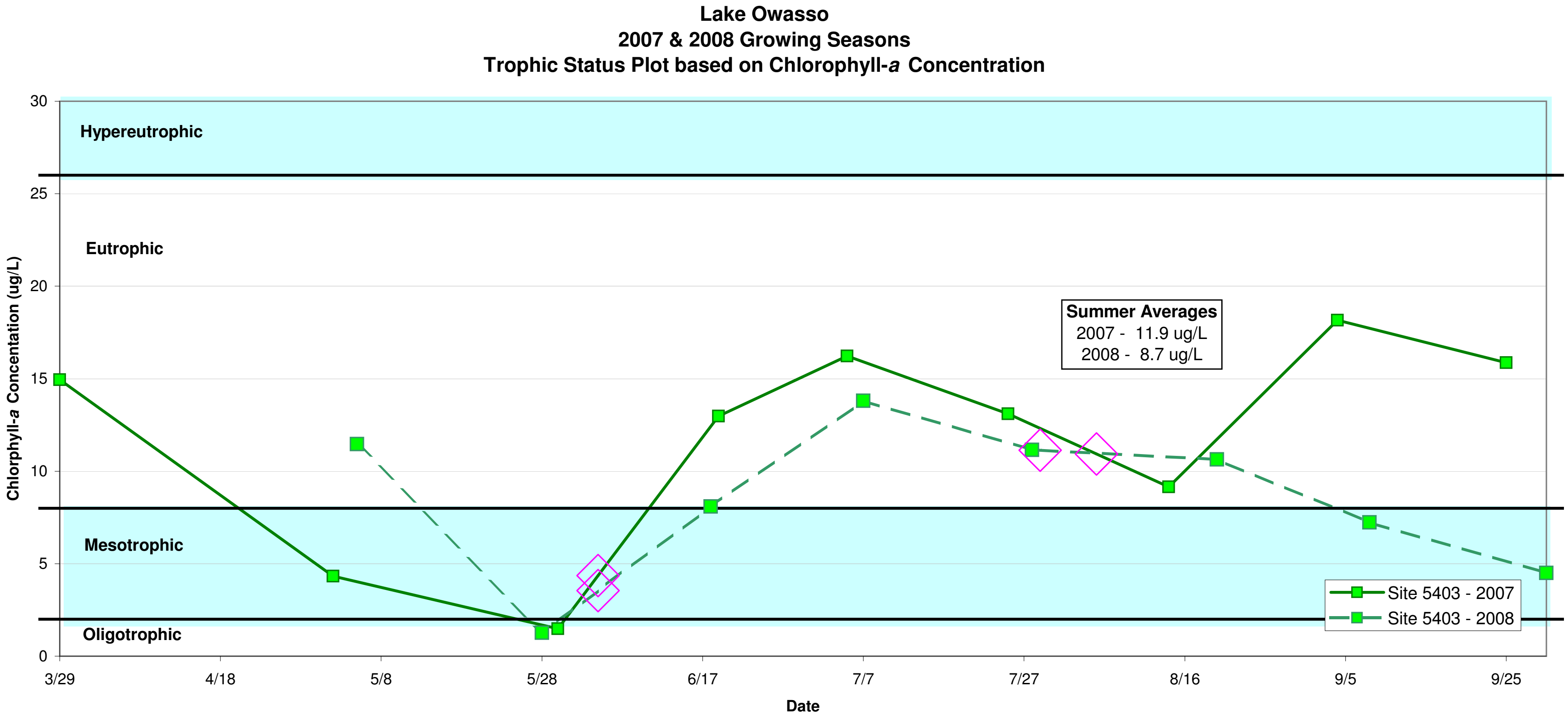


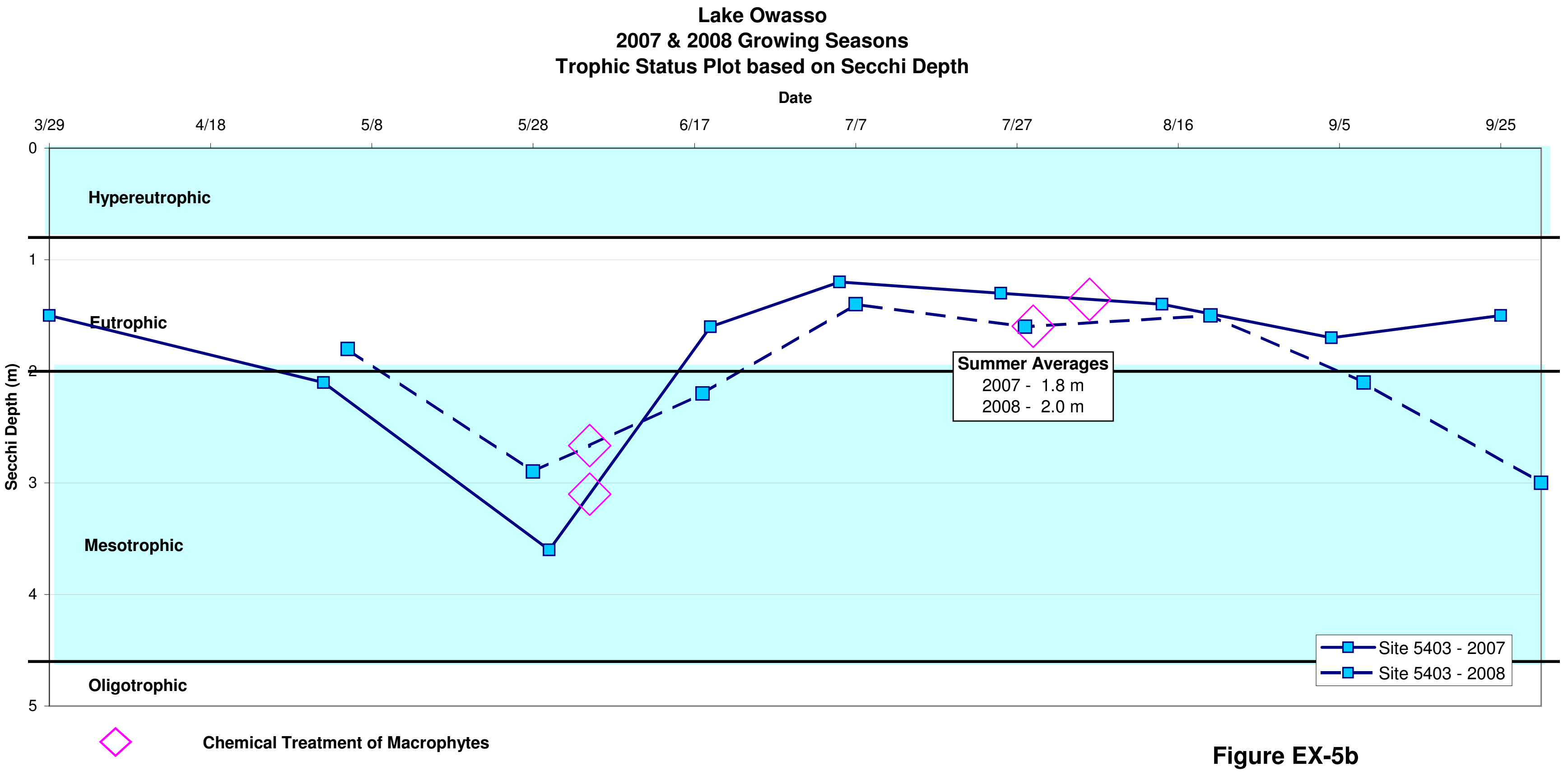


Note: Summer Averages calculated based on data from the late May through early September

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







Chemical Treatment of Macrophytes

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

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

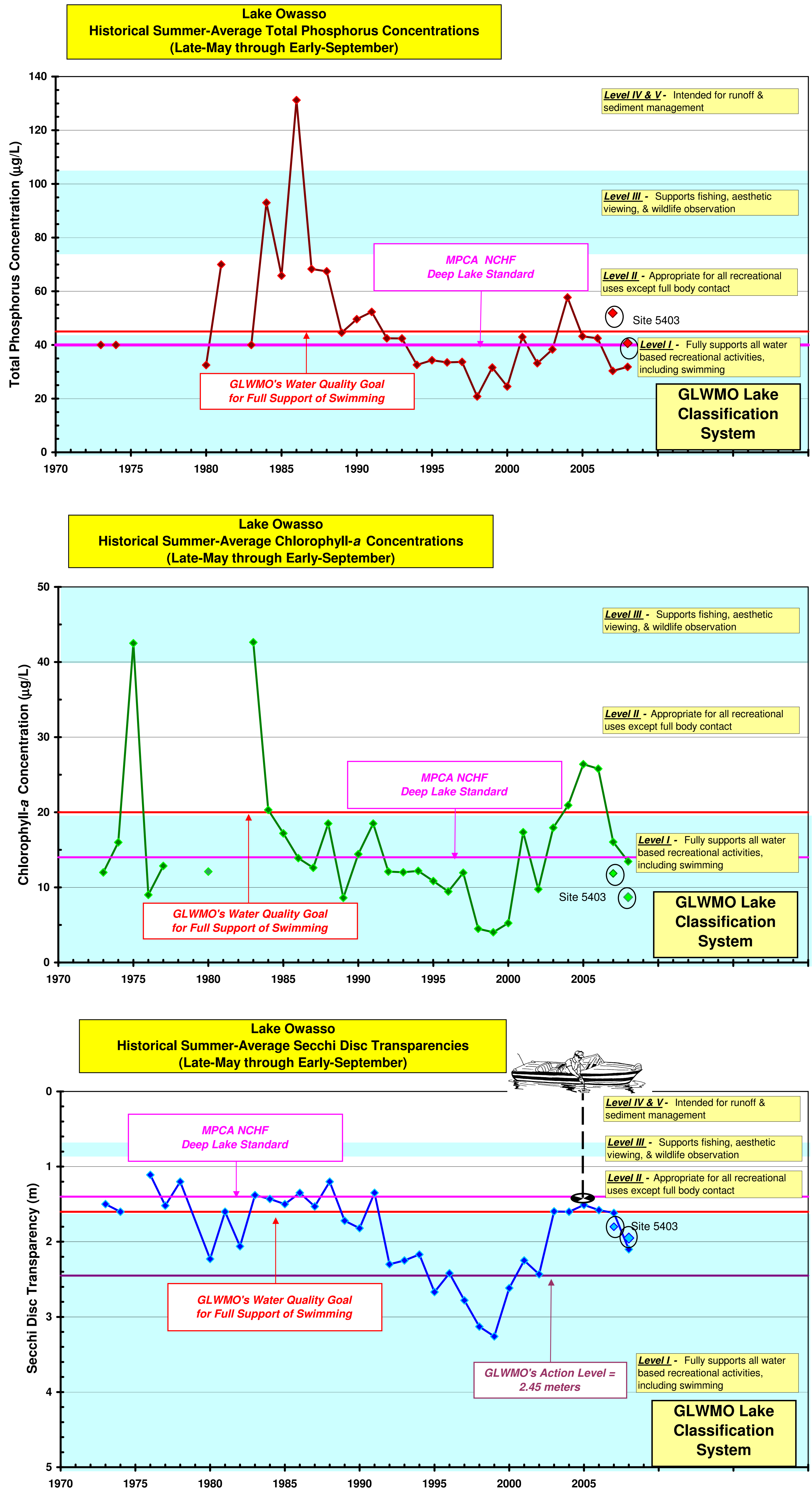


Figure EX-6
Lake Owasso Historical Summer Average (late May through early September) Total Phosphorus and Chlorphyll-*a* Concentrations and Secchi Depths

Trend Analysis

A trend analysis is often performed for lake studies when sufficient data is available. The analysis helps identifies if changes in measured water quality indices are statistically significant; it is a way to determine whether apparent trends constitute a real decline or improvement in lake water quality.

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..

Aquatic Communities

Phytoplankton

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

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. During 2006, the phytoplankton levels in Lake Owasso varied throughout the summer, 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.

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 square meter) of the three major groups: cladocera, copepoda, and rotifera. Cladocera have the largest impact on lake water clarity as they graze primarily on algae and can increase transparency if they are present in abundance. *Daphnia spp*. are among the larger cladocera species and are considered especially desirable in lakes because of their ability to consume large quantities of algae.

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.

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 and 1969). Data through the summer of 2007 was obtained from Ramsey County, processed to estimate zooplankton feeding rates, and the results have been preliminarily reviewed by Dr. Joseph Shapiro, University of Minnesota Emeritus Professor of Limnology. 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. The combination of these factors could likely contribute to the low Daphnia populations and decreased water clarity due to low phytoplankton filtering rates.

Macrophytes

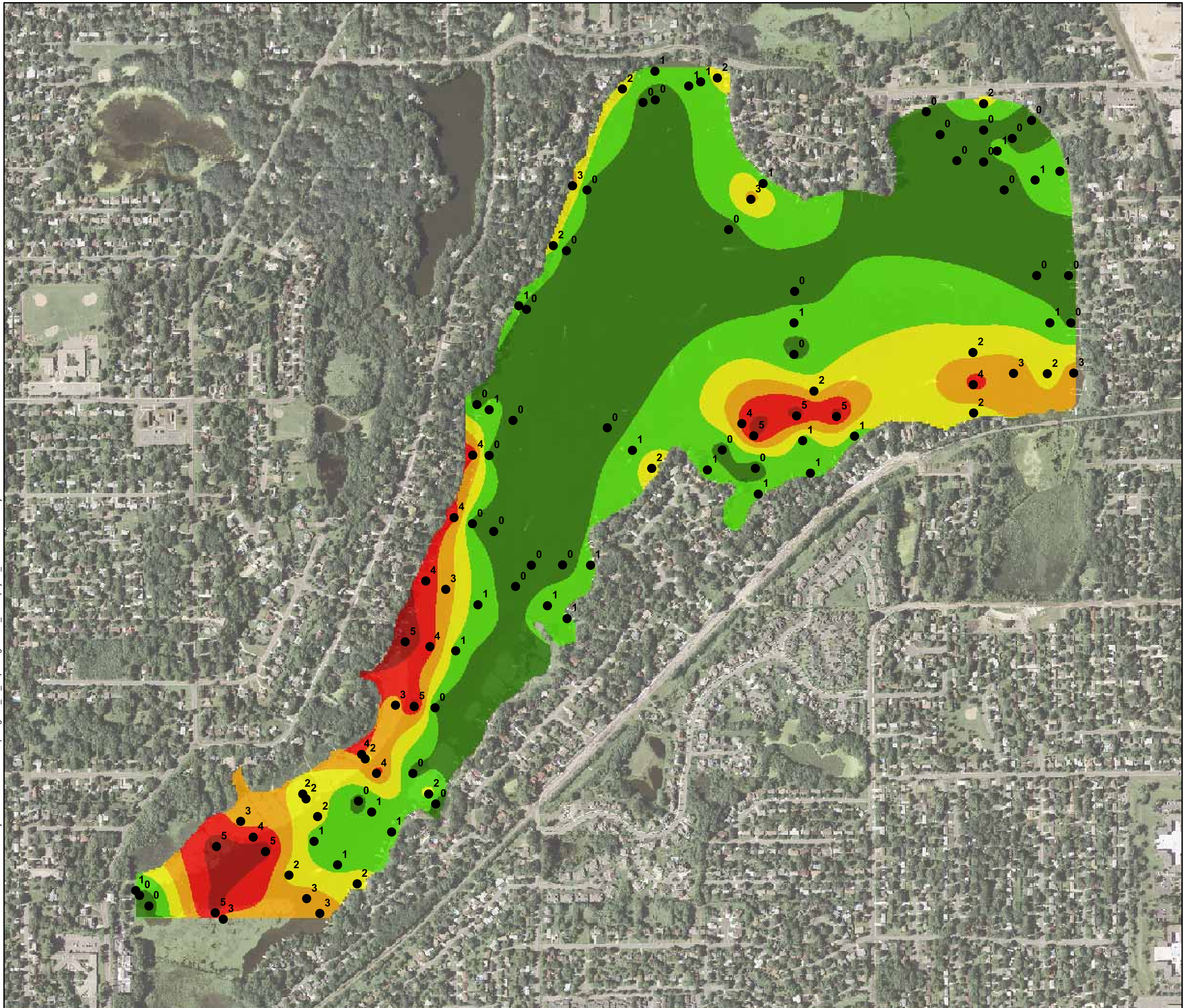
Aquatic plants (i.e., macrophytes and phytoplankton) are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. They are among the primary producers in the aquatic food chain, providing food for other aquatic life.

Although macrophytes (i.e., lake weeds) play an important role in the lake ecosystem, the introduction of exotic (nonnative) aquatic plants into a lake may cause undesirable changes to the plant community and to the lake ecosystem. Two common non-native plants include Curlyleaf pondweed and Eurasian watermilfoil. Curlyleaf pondweed dies-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 can interfere with fishing and boating.

The most recent aquatic plant survey of Lake Owasso was conducted by Ramsey County in late May, 2007. Both Curlyleaf pondweed and Eurasian watermilfoil were present in the lake. The estimated coverage and density of Curlyleaf pondweed is summarized in Figure EX-7.

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. 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 controlled and mechanically harvested for several decades, although chemical treatment is the predominant control method. Although the MNDR currently limits chemical 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 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 EX-7

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

Lake Owasso UAA
Grass Lake Watershed Management Organization

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).

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.made available for use 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.

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).

Sediment Core Analysis

Ten sediment cores were collected from Lake Owasso in May, 2007 and were analyzed for mobile phosphorus (which may potentially be recycled back into the overlying water through a process termed internal phosphorus loading) and organic bound phosphorus. Figure EX-8 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 EX-2 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. .

Table EX-2 Comparison of Lake Owasso Internal Phosphorus Loading Rates to Those of Other Metro Area Lakes

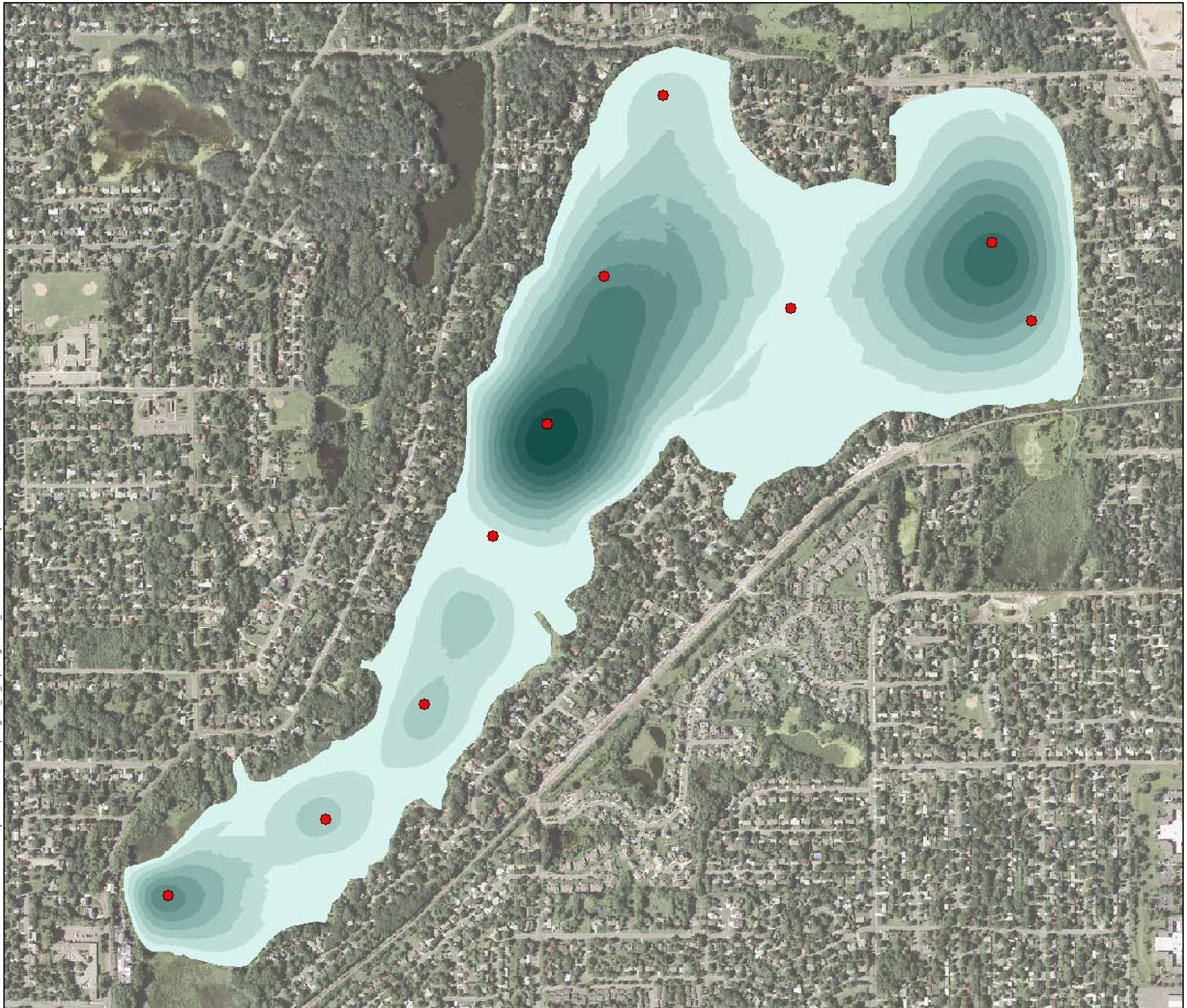
Lake	Internal P Load ($mg/m^2/d$)
Isles (pre-alum, deep hole)*	14.1
Harriett (pre-alum, deep hole)*	11.1
Calhoun (pre-alum, deep)*	10.8
Fish E**	10.5
Cedar (pre-alum)*	9.3
Fish W**	8.1
Como**	7.6
Harriet**	6.9
Como-littoral**	5.7
Calhoun (pre-alum, shallow)**	5.6
Parkers**	3.5
Lake Owasso (deep hole)	**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 EX-2 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 persistent thermal stratification of the water column and near-sediment dissolved oxygen depletion . Most of the time, the lakes experience less internal phosphorus loading 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 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 evidence indicates that motorboat activity results in the resuspension of bottom sediments in shallow areas of the lake.



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 EX-8

LAKE OWASSO SEDIMENT
MOBILE PHOSPHORUS ESTIMATES

Lake Owasso UAA
Grass Lake Watershed Management Organization

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.

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. The 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.

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) based on specific conductivity. 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 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.

Minnesota Lake Eutrophication Analysis Program (MINLEAP)

MINLEAP is intended to be used as a screening tool for estimating lake conditions and identifying "problem" lakes and has also been used 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 monitoring data falls within the range of a minimally-impacted lake with similar characteristics to Lake Owasso.

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 indicate that, prior to European settlement, its water quality would have been categorized as mesotrophic (total phosphorus concentrations between 10 and 25 μg/L), with significant increases in total phosphorus and chloride occurring 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.

Lake Owasso Water and Pollutant Loads

Watershed Pollutant Load Modeling

Stormwater Volume Calibration

The stormwater runoff modeling calibration process involved two phases. First was the calibration of the predicted P8 runoff volume to actual stormwater monitoring data. The second phase included developing a water balance model calibrated to lake level data to verify runoff volumes and estimate the expected groundwater exchange.

Stormwater Monitoring Sites (2007 and 2008)

The P8 model runoff volumes were originally calibrated to the 2007 flow monitoring data at the Galtier Street, County Road C, and West Owasso Boulevard monitoring sites. The calibrated watershed runoff parameters were based on the Galtier Street monitoring station data, as this watershed did not contain any ponds or other water quality treatment devices. The watershed parameters were applied to all subwatersheds in the Lake Owasso watershed. For both the County Road C and West Owasso Blvd. sites, the initial 2007 P8 model runs over-predicted the runoff volumes at each site. To calibrate model predictions to the actual 2007 monitoring data, an "infiltration" rate was applied to the major natural ponds and wetlands located throughout the watersheds. . This "infiltration" rate is not solely a loss to infiltration but represents losses to infiltration as well as excessive evaporation. A limitation of the P8 pollutant loading model is that this rate is a constant loss that cannot vary throughout the year.

The calibration of the runoff predicted by the P8 model was further refined with the additional monitoring data collected in 2008. This included modifications to the estimated pond and wetland "infiltration" rates as well as developing modified discharge rating curves for both the Central Park Pond—East (Dale Street) and the Central Park Pond—West (County Road C) wetlands based on the 2008 flow monitoring data. Additionally, a baseflow parameter was incorporated into the West Owasso Boulevard system to account for continuous flows observed during 2008. Table EX-3 summarizes the results of the runoff volume calibration.

Table EX-3 Summary of Lake Owasso P8 Runoff Calibration

Parameter	Site 1: Galtier Street (LO_E_1f)	Site 2: County Road C (LO_S_1)	Site 3: West Owasso Blvd. (Dschg36)	Site 4: Dale Street (LO_S_2a)
2007 Individual Site Predicted/Observed Volume Ratios[1]	1.03	0.97	1.87[2]	N/A
2008 Individual Site Predicted/Observed Volume Ratios[1]	N/A	0.97	1.03	1.04

1. Based on Cumulative Runoff Volume over the monitoring period.
2. This discrepancy is due to variation of a single storm event across the Lake Owasso watershed, as reviewed on the Minnesota Climatology Working Group website (http://climate.umn.edu/hidradius/HIDENmapFile.asp)

Water Balance Model (2006 to 2008)

Daily precipitation, the total estimated daily watershed runoff to Lake Owasso from the calibrated P8 model, along with daily evaporation values (estimated by the Meyer Model for years prior to 2008 and daily values estimated from the St. Paul Campus Climatological Observatory for 2008) and the Lake Owasso discharge rating curve were used to develop a daily water balance model. WATBUD (developed by the MDNR) was used to estimate the groundwater exchange for Lake Owasso and to verify the watershed runoff volumes predicted by the P8 model for 2008 (the calibration period). The predicted lake levels were then compared to observed lake levels, and adjustments were made to the model input parameters to obtain an optimal match between predicted and observed conditions. The groundwater exchange values from the 2008 calibration were then applied to 2006 and 2007 for verification. The results of the water balance are shown on Figure EX-9.

Several key observations were made during the runoff calibration of the P8 model and development of the Lake Owasso water balance, including the following:

- Surveys of the inverts of the outlets of the Central Park wetlands (at Dale Street and at County Road C) and review of the flow monitoring data indicates that the water levels and discharges from these water bodies are, at times, significantly impacted by the water levels in Lake Owasso. This results in rating curves for the Central Park wetlands that vary with time, depending on the water levels of Lake Owasso.

- During both the summers of 2007 and 2008, there were several ponds and wetlands with water levels below their normal outlets during portions of the summer. This included the crossing at County Road C, whose contributing area is approximately half of the Lake Owasso watershed.

- Lake Owasso is a groundwater lake that experiences periods of seepage and recharge, throughout the year. The extent of groundwater exchange varies throughout the year (seasonally). Additionally, there is variability between years as well. This was confirmed by the use of winter lake level data to estimate groundwater exchange during periods of no discharge from the Lake.

- During the winter months, discharge from Lake Owasso is reduced due to the accumulation of ice around the outlet structure, as confirmed by the City of Shoreview (Maloney, personal communication, 1/18/2008). Therefore, the Lake Owasso rating curve is variable during the winter months and is dependent on the timing of the ice-on and ice-off conditions.

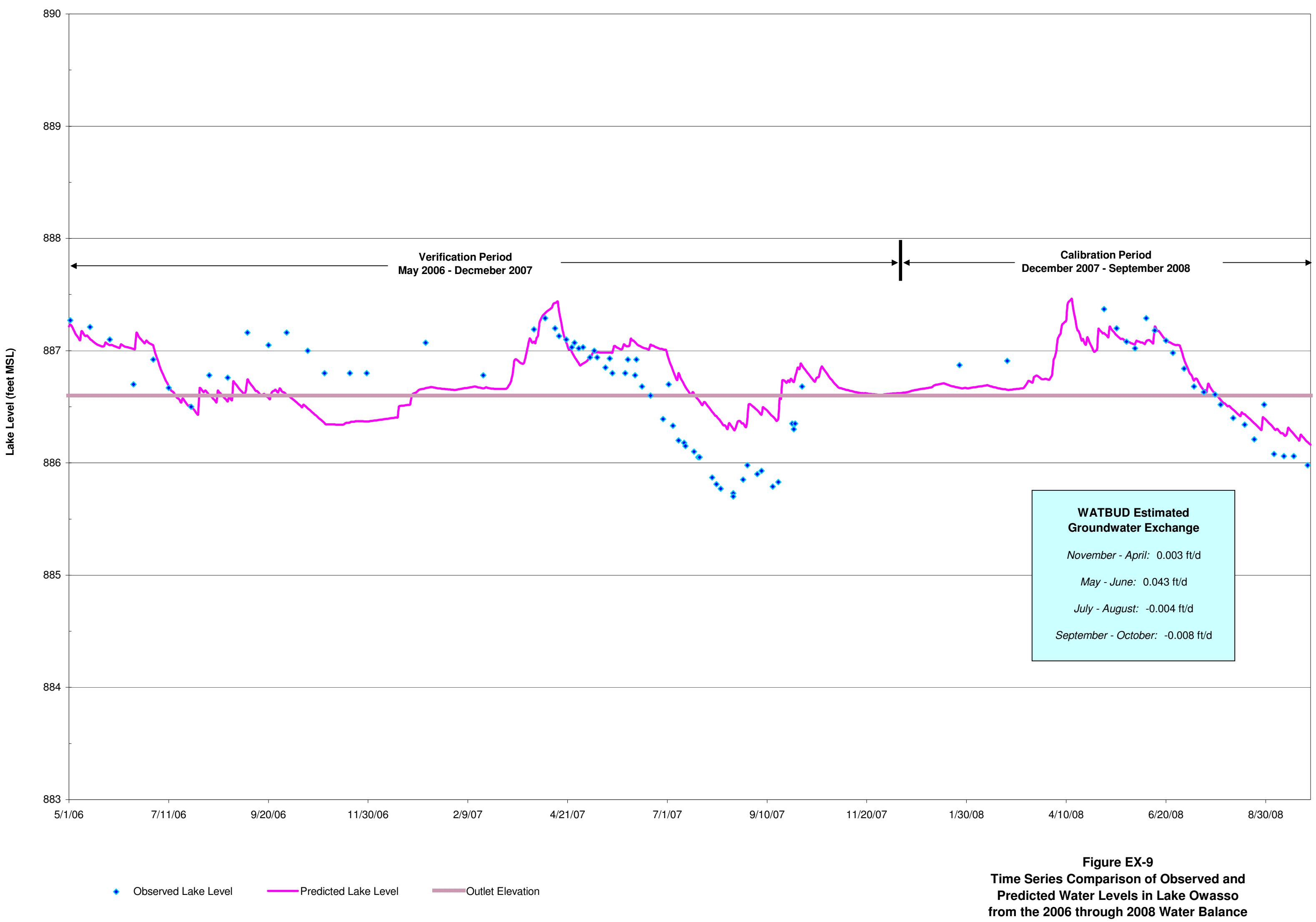


Figure EX-9
Time Series Comparison of Observed and Predicted Water Levels in Lake Owasso from the 2006 through 2008 Water Balance

Watershed Pollutant Loading Calibration

Because actual monitoring data related to the quantity and quality (total suspended solids (TSS) and total phosphorus (TP)) of stormwater runoff was available at monitoring locations around Lake Owasso in 2007, a detailed calibration of the particle and pollutant relationship in P8 was able to be performed so that model results would closely mimic the actual monitoring data from each of the sites. However, because total dissolved phosphorus was not measured, the model was not calibrated to the dissolved fraction.

Calibration was originally focused on data collected at the Galtier Street monitoring station, as this station reflected only watershed runoff (there was no treatment in the watershed upstream of the monitoring station). This would allow for the calibration of the P8 watershed pollutant loading parameters. Calibration at this site was for both TSS and TP event flow-weighted concentration, event loads, and cumulative loads. These watershed pollutant loading parameters were applied to all subwatersheds in the Lake Owasso watershed.

Similar to the runoff volume calibration method, the monitoring site at Galtier Street was used first to calibrate the pollutant parameters related to watershed build-up, wash-off, decay, and impervious and pervious runoff concentrations, as there are no treatment devices such as ponds or wetlands in the contributing watershed.

After the TSS parameter was calibrated, the TP parameters were calibrated. The 2007 water quality data was limited to total phosphorus data; therefore, it was not possible to calibrate the dissolved fraction of phosphorus (TP associated with P0). It was assumed that the P0 particle composition was equal to that used in the NURP50 particle file (99,000 mg/kg). The remaining TP particle compositions for the other particle fractions (P10% to P80%) were also maintained from the NURP50 particle file. However, the TP scale factor was adjusted to best match the Galtier Street monitoring data. Table EX-4 summarizes the results of the TSS and TP calibration procedure.

Table EX-4 TSS and TP Calibration Results (LkOwasso.par)

Parameter Adjusted	Calibrated Value
Accumulation Rate (lb/ac/day) (P10%-P50%/P80%)	1.6 / 2.8
Accumulation Decay Rate (1/day)	0.35
Impervious Runoff Coefficient	5
Impervious Runoff Exponent	3
Pervious Runoff Concentration (mg/L) (P10%-P50%/P80%)	50
Pervious Runoff Exponent	1
TP P0% Particle Composition (mg TP/kg TSS)	99000
TP P10%-P80% Particle Composition (mg TP/kg TSS)	3850
TSS Scale Factor	1
TP Scale Factor	0.7

Grab samples collected in between storm events at County Road C (Central Park – West wetland) during the summer of 2008 indicated that the concentration of the wetland was significantly higher between storm events than the concentrations observed during actual storm events, indicating the potential “internal” loading of TP within the wetland. This internal loading may be the result of a variety of factors, such as the resuspension of sediments due to activity of carp (observed in the wetland during the summer of 2008), phosphorus release from sediments, and other biological activity in the wetland.

One of the limitations of the P8 model is that it does not account for particle resuspension or loading as the result of other chemical or biological activity. As a result, the FLUX model was used to help to estimate the rate of internal TP loading for each waterbody located immediately upstream of the County Road C (Central Park – West wetland), Dale Street (Central Park – East), and West Owasso Boulevard (Charlie Ponds) monitoring stations using both 2007 and 2008 data where applicable. The FLUX model (Walker 1986) uses continuous flow records and parameter concentrations from sampled events to develop flow weighted mean concentrations and loading (in kg/yr) for sites where both flow and sample analysis data are available.

The combination of the P8 predicted watershed loads and the estimated internal loading from watershed water bodies were used as inputs into the in-lake water quality models developed for Lake Owasso for the various climatic conditions.

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 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 approximately 64 percent. The predicted annual total phosphorus removal efficiencies for each pond, wetland or BMP modeled in P8 are shown in Figure EX-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. Waterbodies that may act as a source of phosphorus to the system are shown with the pink cross-hair symbol.

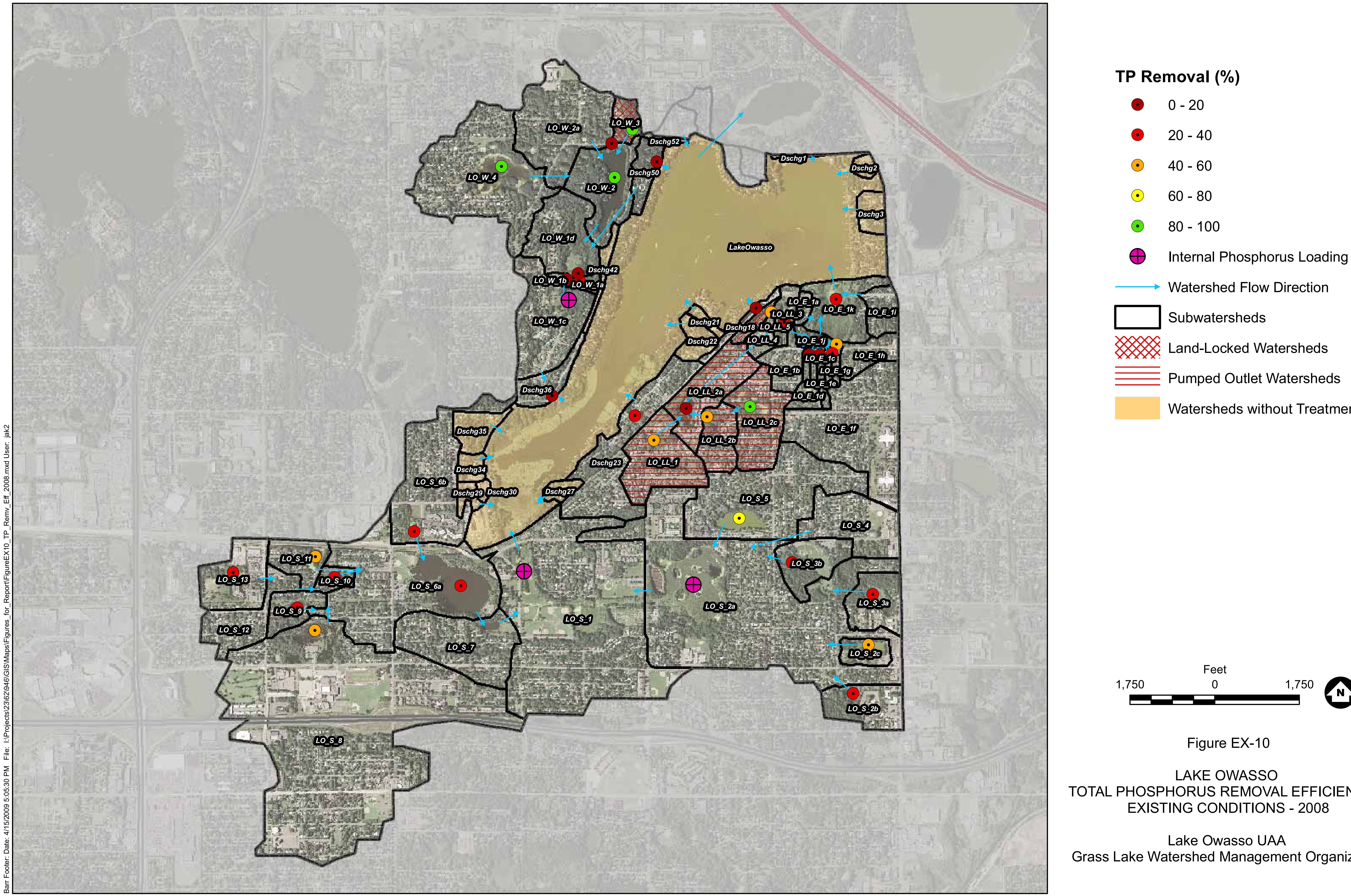


Figure EX-10

LAKE OWASSO
TOTAL PHOSPHORUS REMOVAL EFFICIENCIES
EXISTING CONDITIONS - 2008

Lake Owasso UAA
Grass Lake Watershed Management Organization

In-Lake Water Quality Modeling

To evaluate the lake's response to watershed and internal loads of phosphorus under a range of precipitation conditions, in-lake water quality models were created to route the P8 generated watershed loads, along with the estimated internal load from the major waterbodies in the watershed, through the lake for the following time periods:

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

Because the detailed in-lake water quality monitoring data in 2007 and 2008 was collected at two different locations within Lake Owasso (Site 5401 in the north and Site 5403 in the south), the in-lake water quality model was developed as a two-basin model. For the initial calibration of the Lake Owasso in-lake water quality model, the 2007 and 2008 water quality and the 2007 macrophyte survey data were used. However, because there was a significant amount of historic water quality data available at depth for Lake Owasso, in-lake modeling was performed for each climatic condition year to estimate the internal loading (from sediments and macrophyte senescence) within Lake Owasso. Parameters calibrated to the 2007 and 2008, such as the macrophyte coverage and estimated growth and die-back dates, were applied to all climatic condition models. Watershed runoff loads as predicted by P8, as well as the estimated watershed wetland "internal" loads, were developed specifically for each climatic condition.

The 2008 calibration year was selected to be representative of the dry climatic conditions for Lake Owasso, and was modeled as a two-basin in-lake model. For the wet (2002) and average (2005) climatic conditions, water quality data was only available at the northern sampling site (site 5401) and the in-lake water quality model was developed as a single basin.

The in-lake modeling methodology used for the Lake Owasso UAA is two-fold: First, the spring concentration is estimated with a steady-state, annual empirical lake model. Second, a spreadsheet mass balance model based on Dillon and Rigler (1974) is used that starts with the estimated spring concentration (from the empirical model) and routes external and internal phosphorous loads through the lake over many time steps throughout the summer season (May through September).

The method was used for existing land use conditions under a variety of climatic conditions. Once the internal loading rates have been calculated, the model could be used predictively, to evaluate lake phosphorus concentrations under a variety of BMP scenarios for each hydrologic condition. Impacts as the result of futures changes in land use were not evaluated as the Lake Owasso watershed is already fully-developed, the expected changes are minimal. As a result, future land use conditions were not evaluated.

Lake Owasso Water and Phosphorus Budgets

The main phosphorus sources to Lake Owasso include watershed runoff and internal loads from water bodies within the watershed, atmospheric deposition, groundwater inflows, as well as the estimated internal loads (due to things such as the die-back of Curlyleaf pondweed and release from sediments).

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 EX-5, along with the sources of water loads to the lake as well as the external sources of phosphorus.

Figures EX-11, EX-12, and EX-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.

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

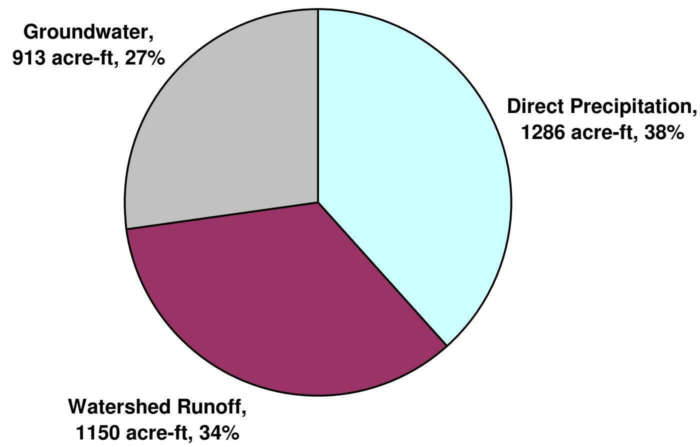
Climatic Condition		Wet	Dry[3]	Average
Water Year		2002	2008	2005
Water Budget				
Source		Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)
Direct Precipitation		1286	644	987
Watershed Runoff		1150	509	401
Groundwater[1]		913	913	913
TOTAL WATER LOAD		***3348***	***2066***	***2300***
Phosphorus Budget				
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

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

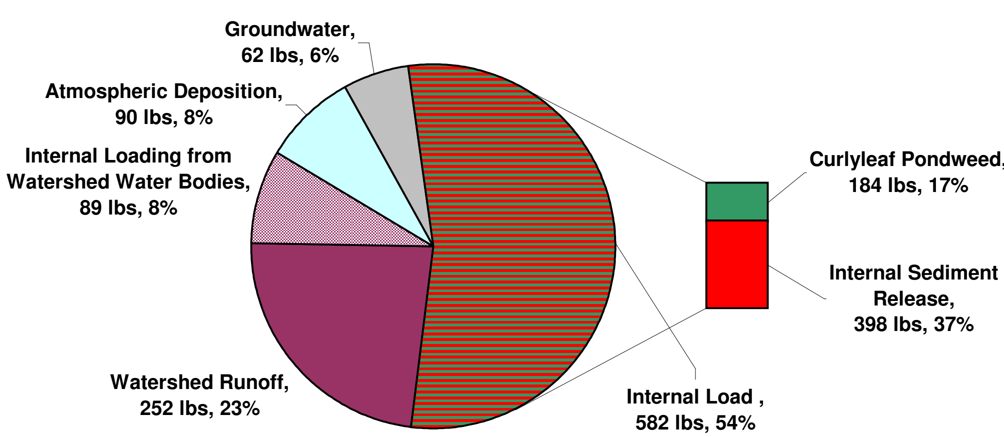


Figure EX-11
Lake Owasso
Water and Total Phosphorus Budget
Wet Climatic Conditions

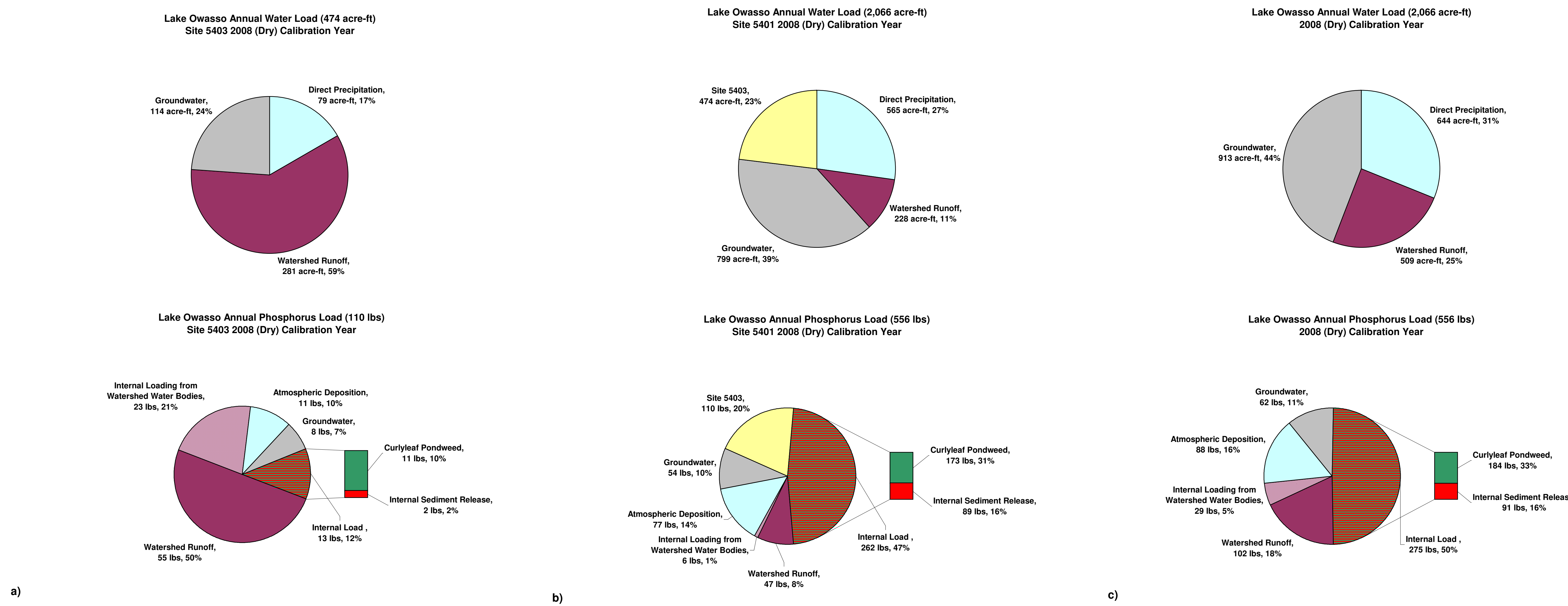
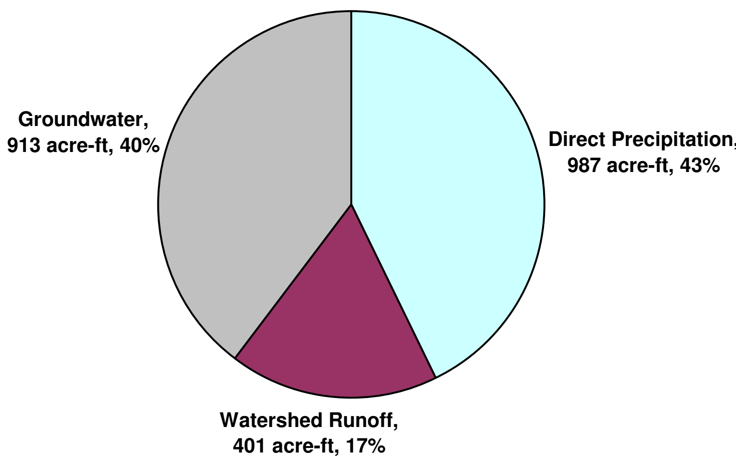


Figure EX-12
Lake Owasso
Water and Total Phosphorus Budget
Dry Climatic Conditions
a) Site 5403 (South Basin)
b) Site 5401 (North Basin)
c) Lake Owasso - Entire Basin

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



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

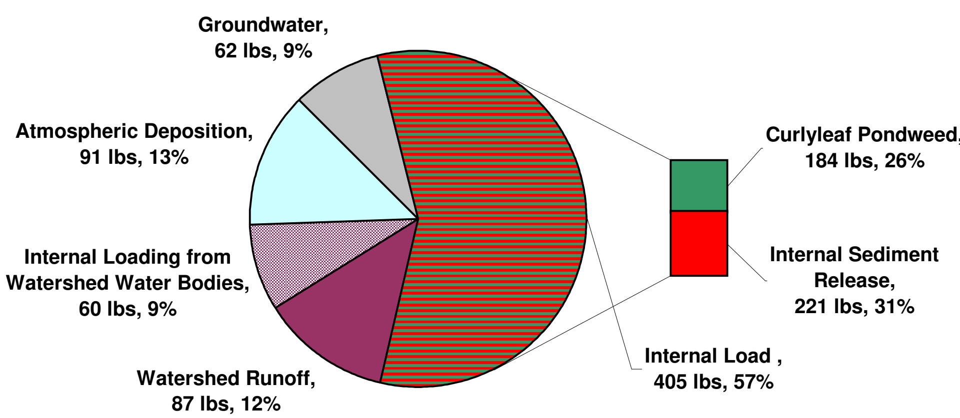


Figure EX-13
Lake Owasso
Water and Total Phosphorus Budget
Average Climatic Conditions

Feasibility Study

To maintain or improve the water quality in Lake Owasso, it will be necessary to implement BMPs in the lake as well as within the watershed. .A variety of treatment BMPs have been implemented in the Lake Owasso watershed in recent years as opportunities arose from road reconstruction or redevelopment. Additionally, several other types of BMPs were evaluated to estimate their potential impact on the overall water quality in Lake Owasso.

Three types of BMPs were considered for recommendation in this plan (structural, in-lake, and nonstructural), with each type being defined and discussed in Section 6.1 of this UAA. For watershed and in-lake water quality modeling, only structural and in-lake BMPs were evaluated for their potential impact on Lake Owasso's water quality, using the P8 and in-lake water quality models.

Specific BMP alternatives that were considered for Lake Owasso and its watershed are discussed in detail in Section 6.3 of the UAA. Selection of the BMP scenarios was primarily based upon the Lake Owasso phosphorus budgets developed for the various climatic conditions to target the major sources of phosphorus to the lake, and include: management of Curlyleaf pondweed, reductions in the estimated internal loading from water bodies within the watershed, treatment of all currently untreated watershed to NURP standards, development of extended detention in the bay in Ladyslipper Park, infiltration scenarios within the watersheds, alum treatment of sediments within the lake, as well as combinations of these BMP scenarios. Figure EX-14 shows the locations of the BMPs evaluated as part of the feasibility analysis and Table EX-6 summarizes the results of the various BMP scenarios evaluated as part of this UAA. Included in this summary table are the predicted in-lake water quality (TP and SD) for each climatic conditions as well as a planning level cost estimate for the BMPs evaluated. Figure EX-15 shows the estimated summer average total phosphorus concentration and Secchi depth in comparison with the MPCA and GLWMO goals for Lake Owasso. It is important to note that not all of the BMP alternatives evaluated are recommended for implementation.

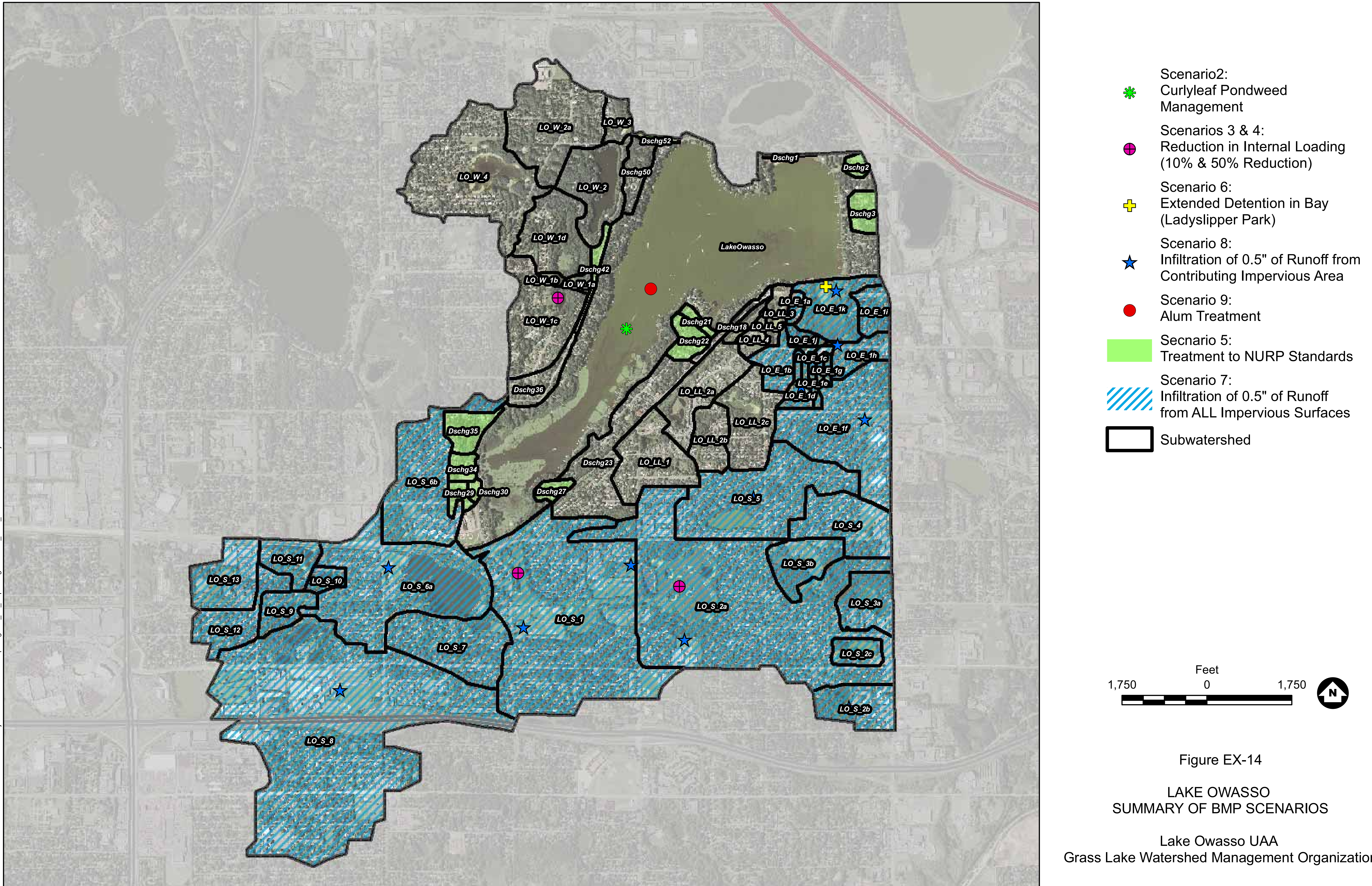


Figure EX-14

LAKE OWASSO
SUMMARY OF BMP SCENARIOS

Lake Owasso UAA
Grass Lake Watershed Management Organization

Table EX-6 Lake Owasso Summary of BMP Scenarios

Scenario		Summer Average Water Quality: Wet 2001-2002 TP (µg/L)	Wet 2001-2002 SD (m)[10]	Dry 2007-2008 Site[1]	Dry 2007-2008 TP (µg/L)	Dry 2007-2008 SD (m)[10]	Average 2004-2005 TP (µg/L)	Average 2004-2005 SD (m)[10]	Reduction in TP (%)	Estimated BMP Cost ($)
1	Existing Conditions[2]	32	2.4	5403	41	2.0	45	1.5	--	--
				5401	32	2.1				
2	80% Reduction in Curlyleaf Pondweed[6]	21	3.7	5403	29	2.6	33	2.3	27 - 39%	$649,000
				5401	19	4.2				
3	10% Reduction in the Internal Loading from Watershed Waterbodies	31	2.4	5403	38	2.0	44	1.8	2 - 4%	N/A[12]
				5401	31	2.4				
4	50% Reduction in the Internal Loading from Watershed Waterbodies	28	2.6	5403	29	2.5	42	1.9	7 - 13%	N/A[12]
				5401	30	2.5				
5	Treatment of All "Untreated" Discharges to NURP Standards[5]	32	2.3	5403	40	2.0	45	1.8	0 - 3%	$350,000
				5401	31	2.4				
6	Extended Detention in Ladyslipper Park Pond (Replace outlet under the Railroad)[7]	32	2.3	5403	41	1.9	45	1.8	0 - 3%	$55,000
				5401	31	2.4				
7	Infiltration of 0.5 inches of Runoff from ALL Impervious Surfaces in the South and East Drainage Districts[3,8,11]	26	2.9	5403	32	2.3	37	2.1	4 - 20%	$4,770,000
				5401	30	2.4				
8	Infiltration of 0.5 inches of Runoff from Select Impervious Surfaces in the South and East Drainage Districts[3,9,11]	31	2.4	5403	37	2.1	44	1.8	2 - 3%	$389,000
				5401	31	2.4				
9	Alum Treatment (80% Reduction in Internal Load from Sediments)	28	2.6	5403	40	2.0	43	1.9	6 - 11%	$198,000
				5401	30	2.5				
10 (2 + 3)	80% Reduction in Curlyleaf Pondweed & 10% Reduction in the Internal Loading from Watershed Waterbodies[6]	20	3.9	5403	26	2.8	32	2.3	29 - 39%	N/A[12]
				5401	19	4.2				
11 (2 + 4)	80% Reduction in Curlyleaf Pondweed & 50% Reduction in the Internal Loading from Watershed Waterbodies[6]	17	5.4	5403	17	5.1	29	2.5	35 - 47%	N/A[12]
				5401	18	4.6				
12 (2 + 8)	80% Reduction in Curlyleaf Pondweed & Infiltration of 0.5 inches of Runoff from Select Impervious Surfaces in the South and East Drainage Districts[6,3,9]	20	3.9	5403	25	3.0	31	2.4	31 - 38%	$1,038,000
				5401	20	4.1				
13 (2 + 9)	80% Reduction in Curlyleaf Pondweed & Alum Treatment (80% Reduction in Internal Load from Sediments)[6]	17	5.1	5403	28	2.6	30	2.4	33 - 46%	$847,000
				5401	18	4.6				

TP: Total Phosphorus Chl*a*: Chlorophyll *a* SD: Secchi Depth

1 - For 2008 (Dry Climatic Conditions), Lake Owasso was modeled as 2 separate basins (5403 - Southern Basin, and 5401 - Northern Basin) as there was water quality data available for both areas of the lake. For 2002 (Wet Climatic Conditions) and 2005 (Average Climatic Conditions), the water quality data was only collected at basin 5401 and the lake was modeled as a single basin.

2 - Existing land use and 2008 watershed/BMP conditions. Very few changes are expected in land use as the Lake Owasso watershed is fully-developed. Therefore, it was assumed that existing land use is also reflective of future land use conditions.

3 - Internal loading from the watershed was modified for the infiltration scenario based on the reduction in water load to the wetlands.

4 - It is not feasible to treat all currently untreated direct discharges to Lake Owasso using a single NURP pond. This analysis was performed to demonstrate the impact that treating each discharge to NURP standards would have on overall lake water quality

5 - This scenario is not physically feasible as the currently "untreated" direct discharges are distributed around the entire shoreline of Lake Owasso. Additionally, there is not sufficient space to incorporate NURP ponds in each of the direct discharge watersheds. This scenario was evaluated to demonstrate the impact of treating all direct discharges on the overall water quality in Lake Owasso. This cost estimate is based on the construction of a single, hypothetical NURP pond sized to treat all "untreated" discharges to Lake Owasso.

6 - The estimated cost of the Curlyleaf Pondweed Treatment includes the MDNR variance to treat the entire littoral area of Lake Owasso, 4-years of herbicide application to the Lake, as well as 4-years of detailed macrophyte monitoring to track the herbicide treatment on the Curlyleaf pondweed coverage

7 - Development of an extended detention basin in Lady Slipper Park (in subwatershed LO_E_1k) along with the replacement of the outlet under the railroad embankment with a weir structure were evaluated as part of the 1991 *Report on the Diagnostic-Feasibility Study of Lake Owasso, Lake Wabasso, and Snail Lake.* Since 1991, the City of Roseville developed infiltration and sedimentation ponds in this area as part of the South Owasso Boulevard road reconstruction project in 2006. This study evaluates replacing the outlet under the railroad embankment only.

8 - Infiltration of 0.5" from all impervious surfaces in the South and East Drainage Districts is not feasible. This scenario was evaluated to estimate the maximum impact infiltration could potentially have on Lake Owasso's water quality.

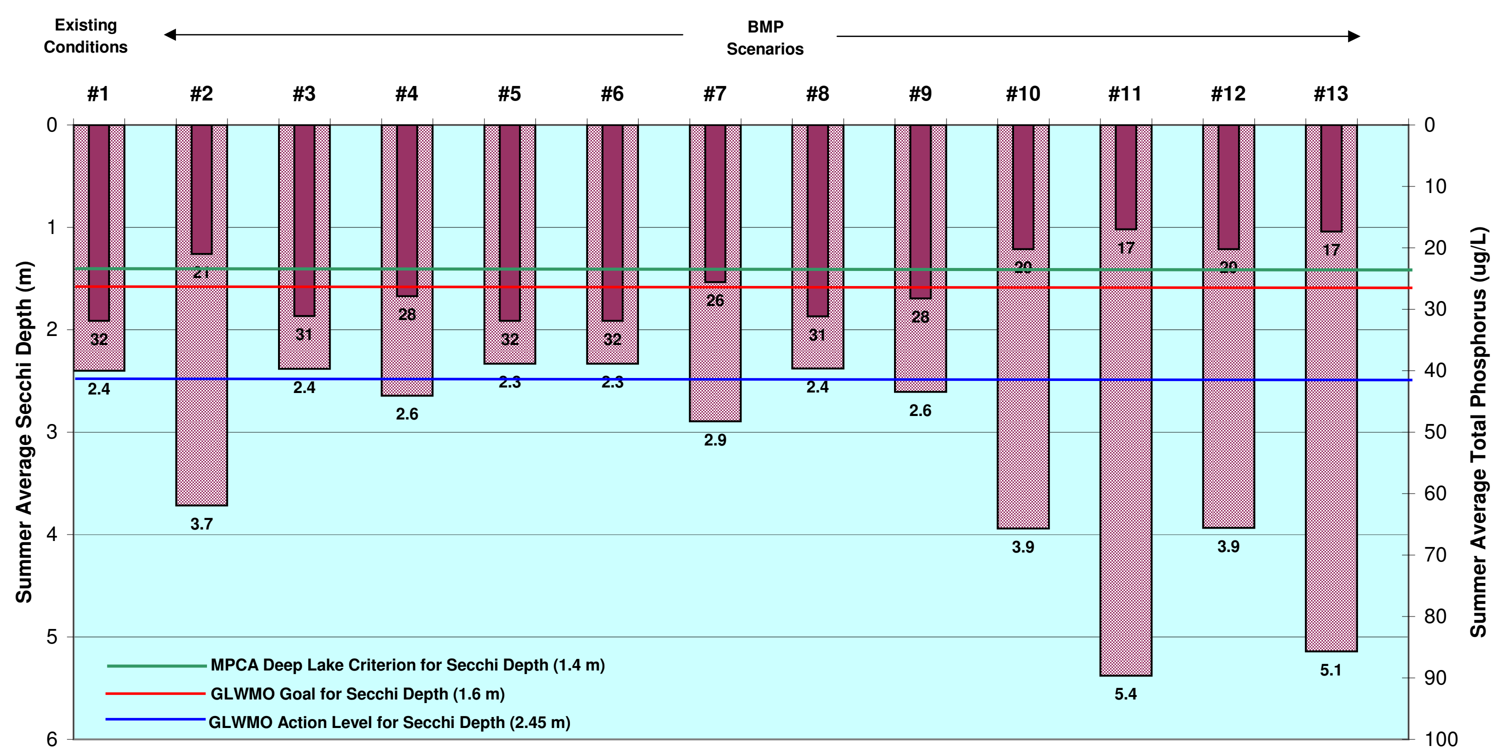
9 - Selected potential infiltration sites include 11 preliminary locations within the South and East Drainage Districts. Sites were selected based on the presence of open space, proximity to existing storm sewer (potential to reroute or divert flows), and topography. Available soils data were condsidered although much of the Lake Owasso is classified as undefined hydrologic soils group. These are planning level cost estimates and each site would require a more complete feasibility study before final design.

10 - Existing Condition summer average Secchi depth based on 2008 monitoring data; For all BMP scenarios, estimated based on the Secchi Depth versus Total Phosphorus Regression Relationship for Lake Owasso (See Figure

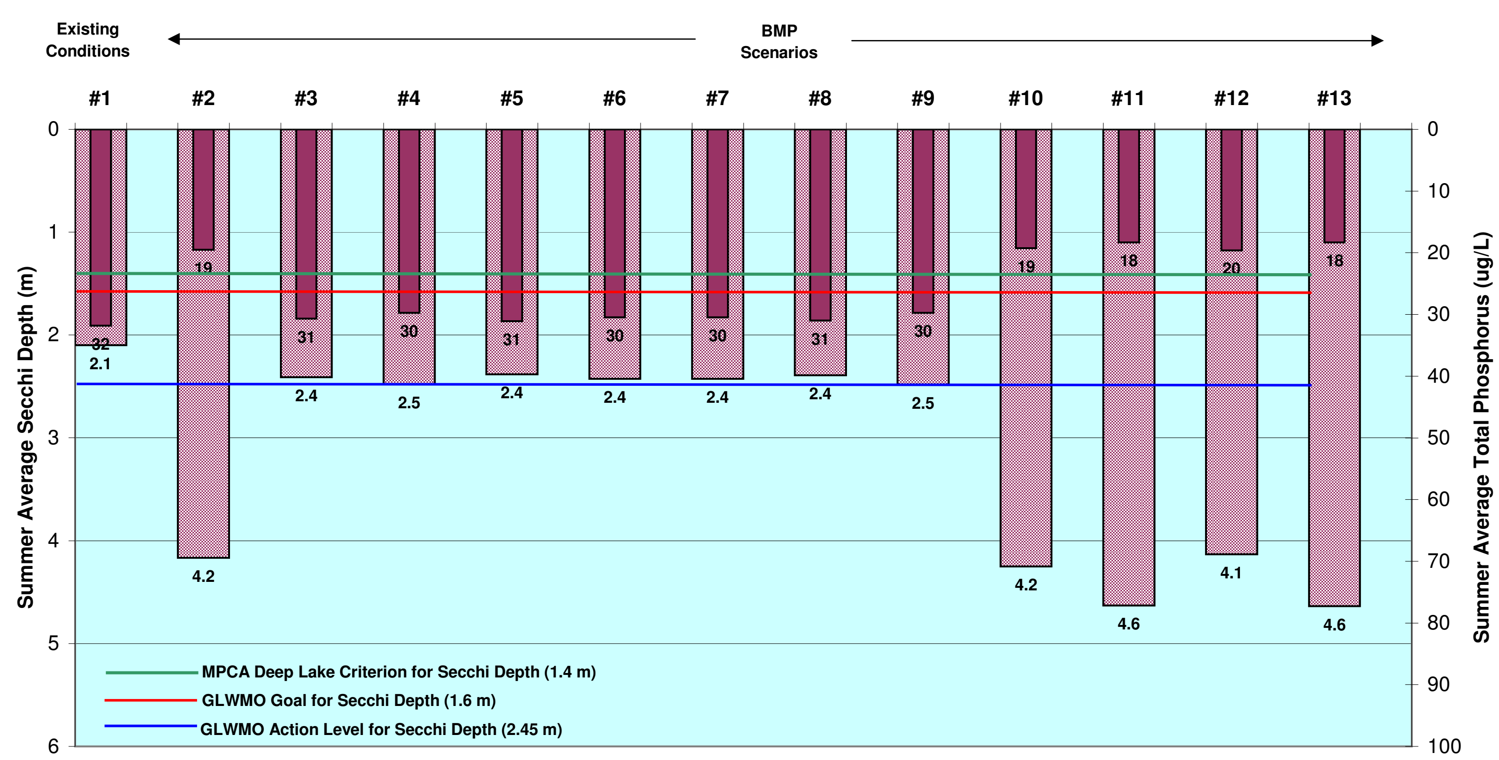
11 - The estimated cost of infiltration BMPs is based on typical unit costs ($13/sq.ft.) estimated for the construction of rain gardens plus 30 percent for engineering and design. Depression storage was assumed to be 18 inches. This cost does not include any potentially significant changes to the storm sewer system/additional piping that may be needed.

12 - Because specific BMPs to address the internal loading in the waterbodies within the watershed are not recommended until further studies of the internal loading can be completed, no costs have been estimated for these scenarios.

Lake Owasso Water Quality
Wet Year (2002) Climatic Conditions



Lake Owasso Water Quality
Dry Year (2008) Climatic Conditions*



*Site 5401

Lake Owasso Water Quality
Average Year (2005) Climatic Conditions

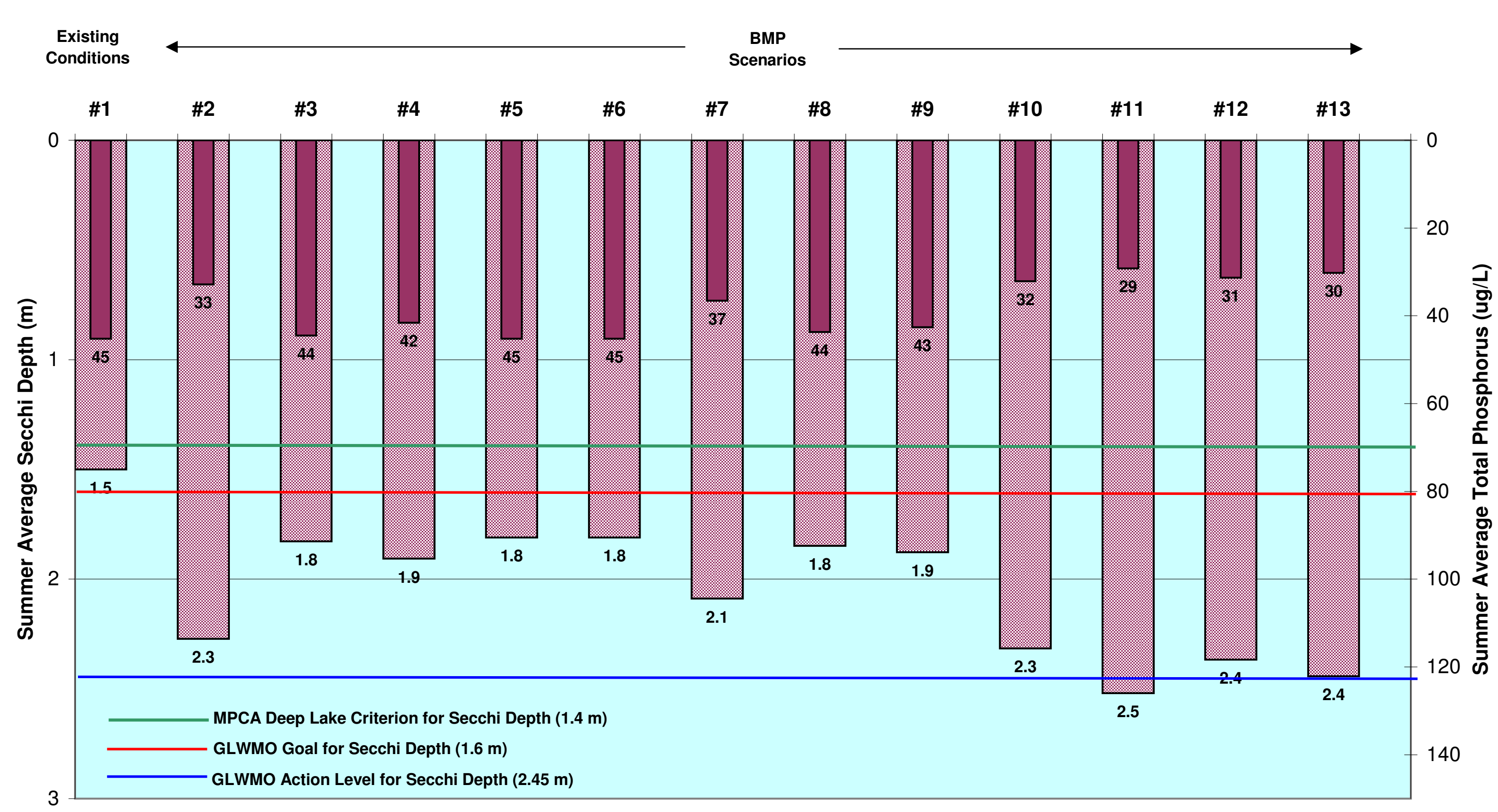


Figure EX-15
Lake Owasso Summary of BMP Scenario Results and Comparison with MPCA and GLWMO Goals

Conclusions

The following summary describes the main conclusions of this UAA that allowed for a diagnosis of the water quality issues in Lake Owasso and identification of the activities and projects that would help the lake continue to meet or improve its water quality goals in the future.

1. Water quality data collected in Lake Owasso for 2007 and 2008 would classify Lake Owasso as a eutrophic lake. Because data was collected in 2 sampling locations within the lake, the spatial variability of water quality in Lake Owasso was observed and water quality does vary through out the lake. The trend analysis for Lake Owasso 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.

2. The MNLEAP model estimated the total phosphorus concentration in a minimally-impacted lake similar to Lake Owasso to be 40 μg/L (±15 μg/L), similar to the range of water quality observed in the lake. For the Vighi and Chiaudani model and the MPCA's diatom analysis, which are predictors of natural background phosphorus concentrations (no impact from anthropogenic sources), suggested that Lake Owasso's natural background phosphorus concentration would fall within the range of 18 to 22 μg/L. Comparison of these predicted values to observed water quality in the lake indicates that Lake Owasso's water quality falls within the expected range for a minimally-impacted lake with similar characteristic, but the background levels indicate that there is potential for water quality improvement.

3. Sediment cores collected and analyzed in 2007 indicated that the average intenal loading rate from sediment release for the whole lake was 0.5 mg/m^2/day with a maximum expected loading rate of 2.9 mg/m^2/d in the deepest sediment core collected. Although some internal loading from the sediments is likely, when compared to internal loading rates for lakes across the Twin Cities metro area, the maximum expected loading rate in Lake Owasso is significantly less than the average observed across the metro (6.3 mg/m^2/day).

4. A macrophyte survey completed in late-May 2007 quantified the distribution and density of Curlyleaf pondweed throughout Lake Owasso. This macrophyte, which dies-back in early summer, can act as a significant source of phosphorus in a lake system, as is the case with

Lake Owasso. In 2007, approximately 52% of the lake was covered by Curlyleaf pondweed. Review of historic macrophyte surveys and other reports about Lake Owasso indicate that Curlyleaf pondweed has been present in the lake as far back as 1981.

5. Relationships between the three key water quality parameters (total phosphorus, chlorophyll *a,* and Secchi depth) were evaluated. There is not a strong relationship observed between cholorphyll *a* and total phosphorus concentrations, showing a similar relationship to what was observed during earlier studies. The relationship in Lake Owasso suggests that the algae concentrations in Lake Owasso are not directly controlled by total phosphorus and are impacted by zooplankton grazing, to some extent. A direct relationship between Secchi depth and total phosphorus was developed to be used predictively. The variability in the data used to develop this relationship suggest that the Secchi depths predicted by this relationship should not be taken as absolute values but rather general indicators of the clarity that can be expected.

6. Review of temperature depth profiles in Lake Owasso at both monitoring sites (site 5401 in the north and site 5403 in the south), indicate that both basins thermally stratify during the summer months, with mixing occurring during spring and fall turnover (dimictic lake). Additionally, total phosphorus and dissolved oxygen data at depth, shows that along the bottom of the lake goes anoxic (devoid of oxygen) and phosphorus accumulates within the hypolimnion, being contained below the thermocline. Because water quality data was not collected in the third deep basin located on the east side of the lake, the Osgood Index was used to estimate the probability of mixing events to occur during summer stratification. This index indicated that this third basin would also be strongly stratified during the summer (dimictic).

   Although the deep areas of the lake strongly stratify, much of the lake is relatively shallow, with an average lake depth of less than 11-feet. It is possible for mixing to occur in these shallow areas of the lake as the result of wind and motor boat activity, although it is unclear what role mixing and resuspension in the shallow areas of the lake have on the overall water quality in Lake Owasso. Anecdotal information suggests that turbidity in the lake increases as the result of motor boats in shallow areas of the lake.

7. The 2001 MDNR fishery survey indicates that small numbers of carp are present in Lake Owasso. The activity of carp, and other benthivorous fish, can result in phosphorus loading

to the lake. Additionally, carp were observed in the Central Park – West (County Road C) wetland in the spring of 2008. In late summer, there was a fish-kill in the wetlands and dead carp were observed in the area.

8. The water and phosphorus budgets developed for Lake Owasso for the various climatic conditions indicates that the sources of the water and phosphorus loads to the lake are variable. Watershed runoff plays a variable role in total phosphorus loads to the lake depending on the climatic conditions, ranging from 12 to 23 percent of the total load. However, during dry conditions, there are periods where significant portions of the watershed do not discharge during storm events, as was observed in the summers of 2007 and 2008. There also appears to be internal loading from waterbodies and wetlands within the Lake Owasso watershed that contribute to the total phosphorus load to the lake (5 to 9 percent). These loads can possibly be attributed to carp activity or release of total phosphorus from sediments. Internal phosphorus loads from within Lake Owasso (the result of Curlyleaf pondweed die-back,release from lake sediments, wind mixing, roughfish activity) were estimated to range from 50 to 57 percent of the load to the lake. Other sources of total phosphorus to the lake include atmospheric deposition and groundwater.

9. Review of the 2008 runoff water quality monitoring data at the Dale Street monitoring station, just downstream from the City of Roseville Leaf Recycling Center, suggests that the compost area is not a significant source of phosphorus to Lake Owasso. Total phosphorus concentrations observed during storm events are similar to typical urban stormwater runoff concentrations. Good housekeeping practices at the Leaf Recycling Center site should continue to be promoted, including the maintenance of the vegetated buffers around the perimeter of the site as well as maintenance of a flat grade on the site to minimize stormwater runoff. Additionally, a small sedimentation pond site could be constructed on the site to collect and treat all surface runoff from the site, before discharging to the downstream wetland.

10. In-lake modeling indicates that the control of Curlyleaf pondweed will have the most significant impact on the total phosphorus concentrations and water clarity in Lake Owasso during the summer months, for all climatic conditions. The implementation of a Curlyleaf management plans is recommended to control the growth of this non-native, invasive species in order to limit its contribution to the internal total phosphorus load, and to allow native

macrophyte species to reestablish in Lake Owasso. See Section 8.3.1 for more details about the Curlyleaf management plan proposed for Lake Owasso.

11. Runoff from the majority of the Lake Owasso watershed is routed through stormwater pond or natural wetlands prior to discharging to the lake. Therefore the watershed runoff was identified being less important than other sourcse of phosphorus to Lake Owasso. As a result, a variety of structural BMPs in the watershed were shown to have limited impacts on the water clarity of Lake Owasso. However, watershed and in-lake water quality modeling was done evaluating the implementation of infiltration practices throughout the watershed, demonstrating that the BMPs can result in the improvement of water quality in Lake Owasso. Though no one specific project is currently recommended, it is recommended that the GLWMO and the Cities of Roseville and Shoreview continue to promote the implementation of infiltration BMPs throughout the Lake Owasso watershed as opportunities arise as the result of redevelopment and infrastructure improvement projects.

12. Evaluation of the runoff monitoring data, along with the water quality modeling results, indicate that internal loading occurs in several water bodies (Central Park-West wetland (County Road C), Central Park – East wetland (Dale Street), Charlie Ponds (West Owasso)) within the Lake Owasso watershed and contributes a significant portion of the annual phosphorus load to Lake Owasso (5 to 9 percent). Because the specific sources of these "internal" loads are not fully understood at this time, additional monitoring and studies are recommended for several of these water bodies to more completely understand the systems. The focus of these studies will be additional water quality monitoring, quantifying the potential impacts of the sediments on the phosphorus load, and the observations of carp activity in some of these water bodies. See Section 8.1 for more detailed discussion of the recommended monitoring and studies.

Recommendations

Many in-lake improvement options and site-specific structural BMPs were evaluated as to their feasibility and cost-effectiveness in the course of this UAA. Ultimately, the recommended approach for improving the Lake Owasso water quality involves adaptive management, or a management approach that involves monitoring the outcomes of implemented projects, and based on the results, modifies or improves on the way the system is managed. The following summarizes the recommended monitoring and studies for Lake Owasso and its watersheds, as well as the structural, in-lake, and nonstructural BMPs recommended for Lake Owasso.

Additional Monitoring & Study Recommendations

Water Quality Monitoring in Central Park – East and West Wetlands and Charlie Pond System

To better understand the water quality and potential internal phosphorus loading in the ponds and wetlands through the summer, water quality monitoring for an additional summer (early May through late September) is recommended in the deepest portions of the Central Park – East wetland, the Central Park – West wetland, and the Charlie Pond system. More details about this study can be found in Section 8.1.1 of this UAA.

The estimated cost for this additional monitoring is expected to range from $7,000 to $9,500 including field work, laboratory analysis, and a brief technical memorandum discussing the laboratory results.

Fisheries Impact Study on Water Quality

Carp, along with other benthivorous (bottom-feeding) fish, can have a direct influence on the phosphorus concentration in a lake or water body (LaMarra, 1975). They can also cause resuspension of sediments in shallow ponds and lakes, causing reduced water clarity and poor aquatic plant growth, as well as high phosphorus concentrations (Cooke et al., 1993).

MDNR fisheries surveys for Lake Owasso (2001) and Bennett Lake (2006) indicate that carp are present in low numbers in both lakes. A 2006 MDNR population assessment also supports that carp are present in Lake Owasso. From the 2007 Lake Owasso user survey, 42 percent of respondents indicated that the fishery in Lake Owasso includes a large rough fish population, including carp. Additionally, carp were observed in the Central Park – West (County Road C) wetland in both the spring and summer of 2008.

The results of this study should provide a better understanding of carp populations in the system, including Lake Owasso, Bennett Lake, and the Central Park – West (County Road C) and Central Park – East wetlands, as well as their impact on the phosphorus loads to Lake Owasso. Because these water bodies in this system are directly-connected to each other with very little change in elevation, carp populations likely move between the water bodies. Therefore, potential items to be considered when scoping this study should include:

- Quantifying carp population in all four water bodies
- Tracking carp movement between the water bodies in the system, throughout the course of a year)

- Identification of the key carp spawning locations within the system
- Collection of water quality grab samples in the Central Park – West wetland during the study period to estimate potential impacts of carp activity on water quality (total phosphorus and total suspended solids)

Because of the need for more detailed investigation into the scope of this project as well as the potential variability in the scope, estimated costs for this study have not been developed. However, potential partnerships with the University of Minnesota and the MDNR may be possible as there is significant interest in carp management in lakes, and there is currently research being conducted to better understand this invasive fish. More details about this study can be found in Section 8.1.2 of this UAA.

Sediment Core Collection and Analysis

Release of phosphorus from sediments within water bodies within the Lake Owasso watershed may contribute to the estimated internal phosphorus load from the watershed (Central Park – East wetland, Central Park – West wetland, Bennett Lake, and Charlie Ponds). Collection and analysis of sediment cores will help better understand the mobile phosphorus associated with the sediments in these waterbodies and their potential contribution to the phosphorus loads to Lake Owasso. Along with mobile phosphorus, the sediment cores will be analyzed for organic phosphorus and total iron. More details about this study can be found in Section 8.1.3 of this UAA.

The estimated cost for the sediment cores collection and analysis is $7,900.

Water Quality Monitoring in Lake Owasso – Shallow Area

Although the deep areas of the lake strongly stratify, mixing and sediment resuspension are likely occurring in the shallow areas as the result of wind and motorboat activity. It is unclear what the potential mixing in the shallow areas of the lake has on the overall water quality observed in Lake Owasso. Therefore, additional water quality monitoring in the shallow area of the lake is recommended to help understand the water quality and mixing dynamics in the shallow areas of Lake Owasso. Sampling should begin in May and continue through the end of September, and should include the collection of samples at 1 meter depth increments, from the surface to the sediments. More details about this study can be found in Section 8.1.4 of this UAA.

This recommendation assumes that Ramsey County will collect the water quality samples at the shallow monitoring site, and that monitoring at Site 5401 (the north, deep basin) will be performed as part of Ramsey County's regular lake monitoring program. The estimated cost for water quality monitoring at a second site in Lake Owasso for one year, including field collection, laboratory analysis, and a brief technical memorandum discussing the laboratory results is expected to range from $1,800 to $2,800.

Structural BMP Recommendations

Incorporation of Infiltration BMPs throughout the Watershed

The watershed and in-lake water quality modeling of Lake Owasso has demonstrated that infiltration of stormwater runoff throughout the watershed can reduce the total phosphorus load to the lake and improve the overall water quality in Lake Owasso. Several potential sites for more regional infiltration BMPs were evaluated as part of the feasibility study. Though no single project would result in a dramatic improvement in water quality in Lake Owasso, the cumulative impact of infiltration BMPs distributed throughout the watershed can improve the overall lake water quality.

No specific infiltration projects are recommended at this time; however, we recommend that the GLWMO and the Cities of Roseville and Shoreview continue to promote the use of infiltration BMPs as opportunities associated with redevelopment and road reconstruction arise and where site conditions are conducive to infiltration.

In-Lake BMP Recommendations

Several in-lake BMPs were evaluated as part of the feasibility study including the management of Curlyleaf pondweed in Lake Owasso as well as a whole-lake alum treatment to minimize release of phosphorus from the lake's bottom sediments. Because the treatment of Curlyleaf pondweed is estimated to have the most significant impact on Lake Owasso's water quality, it is the primary recommended in-lake water quality BMP.

Curlyleaf Pondweed Management

- Curlyleaf pondweed can be managed by treatment with herbicide. Because Curlyleaf pondweed is such a significant portion of the phosphorus budget, it is the recommended in-lake management approach for Lake Owasso. This management plan would include several treatment and monitoring activities over the course of the recommended four year management plan. Activities would include:

- Herbicide (Endothall) treatment of Curlyleaf pondweed in spring (requiring an aquatic plant management permit and letter of variance from the MDNR, as well as permission from lake homeowners)

- Aquatic plant monitoring (surveys required by the MDNR both pre-treatment and post-treatment).

- Biomass monitoring (required by the MDNR to determine treatment effectiveness and effect on native plant communities)

- Turion monitoring (required by the MDNR to determine the potential for Curlyleaf growth in following years)

- Herbicide residue monitoring (to determine herbicide concentration in the water column during the 21-day period after treatment)

- Analysis and annual reporting (to the MDNR to summarize the impact of Curlyleaf pondweed treatment on Lake Owasso and to confirm compliance with permit requirements).

The estimated total cost of the four-year Curlyleaf pondweed management plan including all treatment, monitoring, and reporting is $649,000.

Nonstructural BMP Recommendations

It is quite difficult to effectively model the effects of nonstructural BMPs on lake water quality, but studies have shown that they are effective at reducing phosphorus loads. Examples of effective nonstructural BMPs that would be appropriate for the Lake Owasso watersheds include:

1. An evaluation of road salting practices in the Lake Owasso watershed is recommended. Also, storage of road salt in this area should be evaluated to determine whether unintended runoff from storage areas is occurring.
2. Continue the existing street sweeping program, including an early spring sweeping, a late fall sweeping, and additional sweepings as needed.
3. Continue public education programs to inform the residents of the Lake Owasso watershed of ways to reduce phosphorus loading through proper handling of yard fertilizers and wastes, pet wastes, soaps and detergents.
4. Encourage industrial/commercial areas to institute good housekeeping practices, including appropriate disposal of yard wastes, appropriate disposal of trash and debris, appropriate storage and handling of soil and gravel stockpiles.
5. Discourage the feeding of waterfowl at shoreline areas around Lake Owasso and upstream ponding areas.
6. Encourage vegetated buffers between yards and the shore of Lake Owasso and upstream ponding areas.

Lake Owasso Use Attainability Analyses

Diagnostic-Feasibility Study: Water Quality Issues and Potential Restorative Measures

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