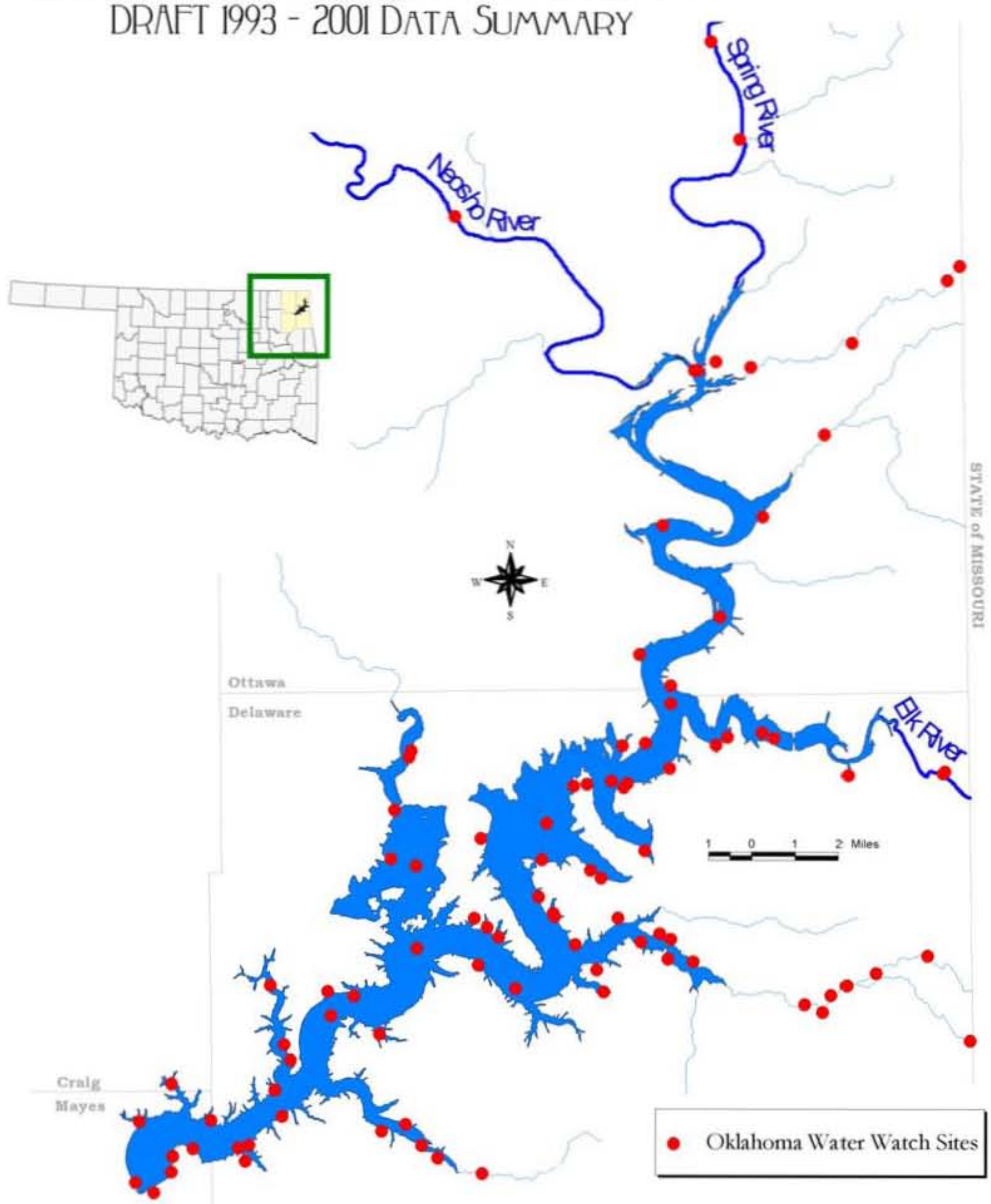
OKLAHOMA WATER WATCH
GRAND LAKE ASSOCIATION CHAPTER
DRAFT 1993 - 2001 DATA SUMMARY



STATE OF OKLAHOMA
WATER RESOURCES BOARD

OKLAHOMA WATER WATCH

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Executive Summary

From 1993-2001 Volunteers collected over 10,000 data points in Grand Lake and the Grand Lake basin. Basic surface water quality for Grand Lake follows typical reservoir behavior. During winter months with cooler temperatures, the lake holds more dissolved oxygen than in the summer months. Lake profile data revealed the deeper areas of the lake were thermally stratified during the summer months. Also, during the summer months, the lake experienced low oxygen, or became anoxic, in the hypolimnion. Only on a few August sample events did surface dissolved oxygen (D.O.) concentrations drop below 5 mg/l, the water quality standard for the Fish and Wildlife Propagation (FWP) beneficial use support. Three of the in-lake sample events documented D.O. in the water column that was partially supporting the FWP beneficial use with between 50% and 70% of the water column having concentrations less than 2mg/l.

Surface data for pH, averaged from all sites, was within Oklahoma Water Quality Standards. However, in-lake sampling using a Hydrolab® field-monitoring instrument showed that eight of the thirty-three vertical profile sampling events had pH levels in excess of water quality standards affecting greater than 25% of the water column. Elevated pH's were found at all sites in the lake during the summer months when temperatures were extreme, and was likely due to increased photosynthesis. Overall, this data is not a concern for meeting beneficial uses. The discrepancies between data results of the chemical test versus the Hydrolab® may be a result of test sensitivity, time of day sampling occurred, or the averaging of data points performed for the surface water quality data analyses. More investigation for validation or discrepancy explanation will follow.

Secchi disk depth increased moving from Twin Bridges towards the dam. The deepest Secchi disk depths were recorded at the dam and Drowning Creek. However, Secchi disk depth was found to be significantly less from historical values based on the ten-year data set trends analysis for the upper part of the Grand Lake. This unfortunately coincides with reported increased algal blooms in this area of the lake.

The upper lake area of Grand Lake is nutrient enriched. Ortho-phosphate concentrations are relatively high in the upper end of the lake. Average ammonia concentrations increase moving down the lake towards the dam. Nitrate and ortho-phosphate concentrations decrease towards the dam. However for ammonia and nitrate, a significant decreasing trend was documented within each individual region of the lake. Ortho-phosphates are significantly decreasing in the upper area of the lake, increasing above Honey Creek and in Honey Creek Cove and decreasing below Horse Creek Confluence. Overall, average nutrient concentrations are highest in the upper end and lowest in Honey Creek Cove.

Color data showed the lake shaded from brown to green moving down the reservoir, towards the dam. Horse Creek Cove had the greatest percentage of browns, with the lower lake having the greatest percentage of greens. This is typical due to suspended sediments in the headwater or riverine area of the lake contributing higher inorganic turbidity, with particles settling out and increasing productivity with increased residence time in the transition and lacustrine zones. Honey Creek Cove had the greatest reported percentage of transparent water color, or clear water.

Data from the river was intended to be used to determine contribution of nutrients from the sub-watersheds. Historical Volunteer data collections have been somewhat inconsistent, therefore it was difficult to make any determinations at this time. However, it was found that Spring River is higher in nitrates than Neosho River. Higher concentrations of nutrients were found in lower Lost Creek than at the State Line. Honey Creek data sets were too sporadic and inconsistent to perform statistical analyses with any degree of confidence.

Introduction

The Grand Lake Association (GLA) Oklahoma Water Watch Chapter was initiated in 1992, with consistent data collections beginning in 1993, and was the pilot group for the Oklahoma Water Resources Board Volunteer Monitoring Program. Since then, more than 90 volunteers have invested approximately 10,000 person hours (almost 5 years of full time work) testing water quality throughout the Grand Lake basin. Over the years, the program has added new parameters and new testing procedures, increasing each volunteer's responsibility. These dedicated individuals have willingly taken on these new duties and responsibilities.

Volunteers are vital to the success of Oklahoma Water Watch, and the Grand Lake Association has been instrumental in obtaining and maintaining these volunteers. At the time of this report, the GLA OWW chapter has 48 active sites, six of which are in-lake where vertical profiling is performed using Hydrolab® instruments. Basic parameters are tested at all monitoring sites, while advanced parameters (nutrients) have been tested at 75% of the sites. Data collected by volunteers supplement agency data to fill gaps where resources and staff are otherwise not available. The information generated in reports such as this, provides state water quality officials with long-term, consistent water quality information to document changes or unusual events that otherwise may go unnoticed. The longevity of these types of programs is what makes these programs successful. The Oklahoma Water Resources Board truly appreciates the efforts of the individuals who have contributed to the information in this report.

Pat Wilson determines color changes for a nutrient sample during a Quality Control Assessment Session.

John Gillette proceeds with the shaking step during his water testing.

In addition to water quality testing, Grand Lake volunteers have been very effective at advertising their efforts in the area through press releases and attendance at public events. Through the years, volunteers have managed a booth at the Grand Lake Boat Show to recruit new volunteers and promote program awareness. At these types of events, volunteers spend time speaking to the public and answering questions about the Grand Lake Association Oklahoma Water Watch Chapter's activities at Grand Lake. Several new volunteers have joined the program as a result of these booths. Volunteers coordinate fund-raising events such as an annual golf tournament held at Patricia Island Golf Course, which provides additional funds for the Chapter. Group Coordinator Cliff Younger secured grant assistance to purchase a mascot costume, "Samplin' Sam", to be used at local and statewide events for program promotion.

Lonnie Stover and John Gillette discuss OWW at the Boat Show.

Included in this report to provide general information to the reader is a section covering basic Limnology, or the study of lakes and reservoirs. This section was written to educate volunteers on the parameters they monitor, how they fit into Oklahoma Water Quality Standards, and how the OWRB uses the information to interpret data results. The Materials and Methods section of the report was written not only for the volunteers but for individuals outside of the program so they can learn more about and understand how OWW operates.

Samplin' Sam says "Happy Sampling!"

Limnology 101

Basic data collected by volunteers consists primarily of the basic parameters; air and water temperature, dissolved oxygen (D.O.), pH, color, and water clarity. Advanced parameters, measured by some volunteers, add nutrients (ortho-phosphate, nitrate nitrogen, and ammonia nitrogen) to the basic parameter suite. Some monitors additionally collect water to perform filtration for chlorophyll-a analysis, use a Hydrolab® mulitparameter sonde instrument to collect data at one meter intervals through out the water column, and collect bottom samples for nutrient analysis. This section briefly describes the parameters measured by volunteers and how they fit into reservoir limnology. Some of the language for this section was borrowed from the *Lakes of Missouri Volunteer Monitoring Program*.

Dissolved Oxygen (D.O.)

Oxygen is produced during photosynthesis of plants and consumed during respiration and decomposition. Because it requires light, photosynthesis occurs only during daylight hours. Respiration and decomposition, on the other hand, occur 24 hours a day. This difference can account for large daily variations in D.O. concentrations. D.O. concentrations steadily decline during the night and are the lowest just before dawn, when photosynthesis resumes. This is why it is important to always measure D.O. at the same time of day. Other sources of oxygen come from the air and mixing with flowing, turbulent water. More oxygen dissolves into water when wind mixing occurs. Therefore, rivers and streams may deliver oxygen to a lake or reservoir, especially if they are turbulent (http://www.fish.washington.edu).

For most organisms, oxygen in the environment is a requisite for life (Cole, 1983). Dissolved oxygen in surface water, under normal conditions, has an inverse relationship with water temperature. Colder waters have the capability to hold more D.O. Therefore in the winter months when air and water temperatures are low it is likely to see higher D.O. concentrations in surface waters. In the summer months, as temperatures rise the capacity of the water to retain high concentrations of D.O. will decline.

Beneficial use designations for streams and lakes may be found in Appendix A of Oklahoma Administrative Code (OAC) 785:45 (Chapter 45 of the Oklahoma Water Resources Board rules). Appendix A of Chapter 45 has a list of waterbodies in Oklahoma and their beneficial uses. Table 1 provides those beneficial uses assigned to Grand Lake and its major tributaries. The Use Support Assessment Protocols (USAP) for Oklahoma's Water Quality Standards (WQS) requires that D.O. concentrations in streams for warm water aquatic communities (WWAC) shall be ≥5.0mg/l from June 16 through October 15 and ≥6.0mg/l throughout the remainder of the year. Use attainment in USAP for lakes is assessed differently. Lakes' dissolved oxygen criteria are based on water column concentrations. For example, the Fish and Wildlife Propagation (FWP) beneficial use is deemed to be not supported if greater than 70% of the water column dissolved oxygen concentrations are less than 2mg/l, hence the importance of D.O. data collected in vertical profiles performed by some volunteers. USAP goes on to state that lakes are partially supporting the FWP beneficial use if only 50% (but not more than 70%) of the water column is less than 2mg/l, and fully supporting if less than 50% may fall below 2mg/l.

Table 1. Beneficial use assignments for Grand Lake.

Beneficial Use Assignments	
Grand Lake	Public and Private Water Supply, Fish and Wildlife Propagation - Warm Water Aquatic Community, Agriculture class 1, Hydropower, Municipal and Industrial Process and Cooling Water, Primary Body Contact Recreation, Aesthetics
Elk River	Public and Private Water Supply, Fish and Wildlife Propagation - Cool Water Aquatic Community, Agriculture class 1, Municipal and Industrial Process and Cooling Water, Primary Body Contact Recreation, Aesthetics
Horse Creek	Emergency Water Supply, Fish and Wildlife Propagation - Warm Water Aquatic Community, Agriculture, Municipal and Industrial Process and Cooling Water, Primary Body Contact Recreation, Aesthetics
Honey Creek	Public and Private Water Supply, Fish and Wildlife Propagation - Cool Water Aquatic Community, Agriculture, Primary Body Contact Recreation, Aesthetics, High Quality Water (anti-degradation designation)

Water Temperature and Stratification

Temperature is an important component in lake turnover and stratification processes. Deep reservoirs in Oklahoma, including Grand Lake tend to see some type of thermal stratification in the summer months, specifically Grand Lake will stratify. Stratification is dependent on the density of water. The density of water changes as the temperature of water changes. An important concept to understand is that water's maximum density occurs at approximately 4°C. As it cools below 4°C to become ice, it actually gets lighter or less dense due to the way water forms ice crystals. This is why ice floats.

During winter months, as lakes approach a frozen state, the coldest, lightest water (<4°C) is at the lakes surface while denser waters, nearer 4°C is at the bottom of the lake. As the spring sun starts to warm the surface waters the upper layer of the lake begins to sink. This continues until the entire water column is 4°C from surface to bottom. At this point the lake is mixing and spring turnover is occurring. As the surface water continues to warm, springtime winds and rains further the mixing process until the whole lake gradually warms up from surface to bottom. Spring turnover is less common in Oklahoma lakes due to lack of subzero temperatures, however it has been documented in some years.

During the summer months, surface waters heat up more rapidly than the heat can be distributed throughout the water column. These warmer, less dense waters tend to remain at the surface as summer progresses. Since the density of water depends on temperature, the depth of this layer varies from lake to lake, and year to year. The lighter/ warmer upper layers do not mix with the deeper, cooler layers. Summer stratification is complete when three main layers are formed. These layers are called the epilimnion (surface), metalimnion (middle), and hypolimnion (bottom). During summer stratification the hypolimnion may become anoxic due to lack of photosynthesis and/or oxygen introduced by wind mixing.

As fall approaches and cooler air is present the surface water temperatures begin to decrease and surface waters become denser. As the heavier water begins to sink the layers begin to mix so that the circulation of cooler, heavier water produces a homothermous (same temperature) condition and fall turnover is underway. The problems associated with fall turnover result when nutrients trapped in the colder, deep layers of the reservoir become available to the warmer surface waters in the photic zone, or area of light penetration, resulting in unsightly algal blooms.

pH

In addition to temperature and dissolved oxygen, pH is a basic parameter measured by all volunteers. The pH test measures the hydrogen ion concentration of water. It provides a gauge of the relative acid/base nature of a water sample. A pH of 7 is considered to be neutral. Substances with pH less than 7 are acidic; substances with pH greater than 7 are alkaline (or basic). The scale is logarithmic, thus there is a ten-fold change in acidity or alkalinity per pH unit change. For example, water with a pH of 5 is ten times more acidic than water with a pH of 6.

The buffering capacity of water affects its pH. Photosynthesis may alter the equilibrium of carbon dioxide (CO_2), which results in a rise of pH values (more alkaline), whereas in respiration the reaction moves in the other direction lowering pH (Cole, 1983). Low pH values (or acidic waters) are usually found in natural water rich in dissolved organic matter, ie. swamps, bogs, or marshes typically seen in southeastern Oklahoma. Acidic precipitation, or acid rain, can also lower the pH of surface waters. OWQS for pH for both lakes and streams falls within the same criteria. The acceptable range or screening interval for pH is between 6.5 and 9 standard units (s.u.). The USAP states that the FWP beneficial use will be deemed fully supported if no more than 10% of sample concentrations fall outside the screening interval, partial supported if 10–25% fall outside the screening interval, and not supported if >25% fall outside.

Nutrients and Chlorophyll

New Oklahoma law has recently implemented a total phosphorus criteria for scenic rivers of 0.037 mg/l, otherwise, Oklahoma's WQS and USAP have not yet developed criteria for nutrients. Strides are being made towards nutrient assessment and how it relates to health of a stream or lake. In Oklahoma, for lakes, trophic state indices (TSI) are used to relate productivity of lakes to beneficial use support. Calculations for determining TSI's which use total phosphorus, total nitrogen, and chlorophyll-a concentrations, are a useful reference for Oklahoma but in actuality are more relative to northern temperate lakes where they were developed by Dr. Robert Carlson (1977).

Algae require many different nutrients to grow. Of these, nitrogen and phosphorus are the most important because they occur in the smallest supply relative to algae's needs. Generally as nitrogen and phosphorus increase in a lake, so does the amount of algae. Nitrogen and phosphorus may be found in soils, and associated with soil runoff, and be transported to streams and lakes during rain events. Often the nutrient levels of a lake reflect that of the soils surrounding the lake. For the most part natural levels of nitrogen and phosphorus are not enough to cause severe algal blooms or water quality concerns. Typically levels that cause concern are human induced. The following is a list of some of the most common human activities that can increase nutrient levels in lakes (OCC, 2000).

- Excessive fertilizer applications to lawns, golf courses, and fields
- Runoff from feedlots and pastures
- Releases from sewage treatment plants
- Drainage from improperly working septic systems
- Increased soil erosion from farm fields and construction sites

Numerical ranges for nitrogen and phosphorus may vary dramatically in Oklahoma lakes, and without existing WQS criteria it is even more difficult to assess what is within an acceptable range for Oklahoma. Lakes may have high nutrients and not have high productivity due to high suspended solids and light limitation. On the other hand, clearer lakes with low suspended solids may only have minimal levels of these nutrients yet experience productivity problems. Therefore in Oklahoma, the OWRB has implemented through USAP the use of Carlson's Trophic State Indices (Carlson, 1973) using chlorophyll- a concentrations to determine the "health" of a reservoir based on its trophic state.

Chlorophyll is the green pigment used by plants, or algae, for photosynthesis. Algae, like other plants, require sunlight, nutrients and carbon dioxide to live. When animals such as zooplankton or small fish eat the algae they acquire the energy stored in the algal cells. When bigger fish eat these organisms the energy moves up the food chain to the next level. Thus algae are the origin of much of the energy passed through the food web and are an important part of a lake's ecosystem. Additionally, during photosynthesis oxygen is produced as a by-product, which is a major source of D.O. in our lakes. Excessive amounts of algae can be detrimental to a lake or stream. Large growths of algae are known as algal blooms and can result in poor aesthetics and taste and odor problems with drinking water treatment plants. Algal blooms may also affect the recreational value of a lake by hindering swimming, boating, and fishing. When algae populations exceed the forage demand then those algae that don't get eaten tend to die and sink to the bottom of the lake. Decomposition or bacterial breakdown of these dead algae uses up the D.O. in the lake water resulting in anoxic conditions. When large amounts of algae die off, oxygen levels can dramatically decrease and may result in a fish kill.

The OWRB and other state agencies use chlorophyll concentrations as a biological indicator for the amount of algae in the water. Because all algae contain chlorophyll this is typically a reliable method for estimating biomass, or productivity.

The last nutrient OWW trains volunteers to test for is ammonia. Although no numerical WQS exist for this nutrient either, under aerobic conditions it is found in very low concentrations because in the presence of oxygen it is quickly converted to nitrite (NO_2) and nitrate (NO_3). Typical concentrations, in unpolluted waters, are 0-5mg/l ammonia (NH_4), whereas in anaerobic conditions, found in hypolimnetic waters, concentrations may exceed 10mg/ (OWRB, 1998).

<u>Secchi Disk Depth</u>

Another factor measured by volunteers that may indirectly reflect productivity is Secchi disk depth. The Secchi disk is an 8-inch diameter disk with contrasting black and white quadrants. The disk was developed in 1865 by Fr. Pietro Secchi, a scientific observer to the Pope (NALMS, 1996). It is generally believed that as his research vessel traveled around the Mediterranean Sea, he discovered the dirty dishes the cook threw out the windows were visible at different depths in different areas of the sea. From this discovery, an easy to use measurement for water clarity was born. The disk is lowered into the water and the difference between the depths in which it disappears and reappears is recorded.

The disk measures water clarity by estimating the depth of light penetration into lake water. Suspended materials in the lake, including both organic (algae) and inorganic (sediments, silt, etc) inhibit sunlight penetration and thus affect the depth of visibility. Similarly, the depth of sunlight penetration directly affects photosynthesis, and algal growth. Therefore by measuring Secchi disk depth we can better understand light penetration conditions that may affect productivity. Secchi disk depth does not however differentiate between organic and inorganic turbidity, nor is it a measure of turbidity.

Color
Color indicates the suspended solids in water in addition to dissolved substances that may alter the water's appearance. Oklahoma has a WQS for apparent color, but the OWW program does not measure color to this level of accuracy, therefore no WQS apply to the OWW color parameter. The OWW program uses a Borger Color System booklet to match the water's surface color to a color chip. This information is strictly used to detect differences in colors – green versus brown versus transparent. This information is useful in determining what may or may not be in the water at the time of sampling. For example, shades of greens may indicate suspended algal cells, whereas shades of browns may indicate suspended sediments, or dirt. This information, combined with Secchi disk depth, may help identify influences affecting transparency.

Trophic State Indices
Oklahoma uses Carlson's TSIs to classify lakes in terms of trophic state or productivity. Carlson (1977) stated that chlorophyll-a seems to be the most acceptable parameter to use in calculating TSI and estimating algal biomass. In accordance with historical OWRB calculations and Carlson's suggestion to use chlorophyll-a concentration, it is the variable used for TSI calculations by the OWRB. Carlson's TSI equation using chlorophyll-a (in µg/l) as the trophic state indicator is as follows:

$$TSI = 9.81 \times \ln(\text{chlorophyll-}\underline{a}) + 30.6.$$

The resultant value from this equation can then be used to classify the lake as oligotrophic, mesotrophic, eutrophic, or hypereutrophic. Oklahoma's USAP requires a minimum of 20 samples throughout the sample period averaged to accurately calculate the TSI. Table 2 shows the range of TSI values and defines the trophic state class.

Table 2. Carlson's Trophic State Indices definitions.

Carlson TSI No.	Trophic State	Definition[1]
< 40	Oligotrophic	Low primary productivity, tends to be clear; great for swimming, boating, and diving.
41 – 50	Mesotrophic	Moderate primary productivity, slight greeenish in color; okay for swimming, boating, good fishery
51 – 60	Eutrophic	High primary productivity, not so clear, greenish to brown in color; recreation may be impaired during algal blooms, and anoxic conditions may be present during the summer
> 61	Hypereutrophic	Excessive primary productivity; recreation is likely impaired

Eutrophication
In relation to trophic state, an additional term useful to know is eutrophication. Eutrophication means the process whereby the condition of low biological productivity andclear water to one of high productivity and water made turbid by the accelerated growth of algae (OWRB, 2001). In a classical sense a lake begins as oligotrophic and moves through mesotrophy and eutrophy. In natural lakes this process of increasing productivity is natural and occurs over thousands of years. In man-made lakes, or reservoirs the process occurs much faster from inputs of nutrients

[1] These definitions are borrowed from the *Lakes of Missouri Volunteer Program*. In Oklahoma, lakes may be classified as oligotrohpic or mesotrophic with low productivity due to excessive suspended solids and light limitation inhibiting productivity. Therefore, a lake classified in one of these categories may not be clear or slightly greenish in color, but very turbid with brown to red coloration.

and soil erosion that naturally occurred in the river that is now impounded. The problem most Oklahoma reservoirs face is anthropogenic eutrophication, which describes the accelerated increase of nutrient levels and soil erosion due to human influences. A gradual increase in productivity is acceptable but rapid changes due to human activity are usually not desirable.

Lake Zones

Longitudinal zonation plays a vital role in light and nutrient availability for productivity and trophic status in reservoirs. Longitudinal gradients are important in terms of basin morphology, flow velocity, water residence time, suspended solids, light and nutrient availability (Thornton, 1990). Figure 1 shows the three typical zones present in reservoirs; riverine zone, transition zone, and lacustrine zone. The following definitions are borrowed from *Reservoir Limnology, Ecological Perspectives (Thornton, 1990)*, and provide a good understanding of the impacts zones play on reservoir water quality. The riverine zone, located in the headwaters of the reservoir, is characterized by higher flow, shorter water residence time, and higher levels of suspended solids, nutrients, and limited light availability as a result of increased suspended solids. The transition zone is characterized by higher productivity in conjunction with increasing reservoir width, decreasing flow velocity, increased water residence time, sedimentation of suspended solids and increased light availability. The lacustrine zone occurs down reservoir, nearest the dam, and typically has longer water residence time, lower concentrations of dissolved nutrients and suspended particles, and higher water transparency (deeper Secchi disk depths).

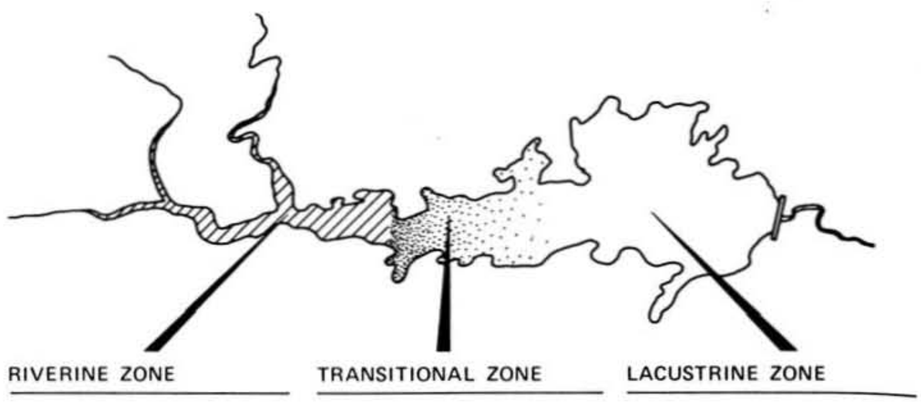


Figure 1. Longitudinal zonation that is typical in man-made lakes, or reservoirs.

Materials and Methods

To Become a Monitor

To obtain certification, each volunteer must undergo the three phases of Water Watch training. Phase I consists of an introduction to the program. The Training Coordinator covers the program's goals, brief history and future objectives. The Volunteer and Training Coordinator discuss the volunteer's monitoring objectives and expectations and work together to see that both the program and volunteer's needs are met. Phase I also covers safety, water quality concepts, kit maintenance, site selection and testing procedures. The second phase of training allows the volunteer to gain hands on practice with the monitoring kits. Phase II is conducted with minimal assistance from the Training Coordinator, where the volunteer actually conducts all tests as if in the field. During Phase III, the newly trained volunteer is observed and should be able to complete the testing procedures competently without assistance from the Training Coordinator. If all of the testing procedures are completed correctly, the volunteer monitor is ready for certification.

Once certified, the volunteer monitor spends an average of three and a half-hours a month performing water quality sampling. Each volunteer or group of volunteers are issued a water quality monitoring kit. Volunteers test basic parameters, pH, water and air temperature, water color, dissolved oxygen, Secchi disk depth, and physical site characteristics (Table 3). Some volunteers become further certified to perform testing for Advanced Parameters. These include ammonia nitrogen, nitrate nitrogen, and ortho-phosphate. Further involvement includes performing in-lake profiling, using a Hydrolab® multi-probe water monitoring instrument, chlorophyll-a sample collection and filtering, and turbidity. These new advanced parameters are ideally collected from a boat, in-lake away from shoreline interference.

Table 3. Oklahoma Water Watch water quality parameters.

Basic Water Quality Parameters		
Air Temperature	Dissolved Oxygen (mg/l)	Color
Water Temperature	pH	Secchi Disk Depth
Advanced Parameters		
Ammonia Nitrogen	Nitrate Nitrogen	Ortho-phosphate
New Advanced Parameters		
Hydrolab®- Vertical Profiles		Chlorophyll-a sample collection and filtration
Turbidity		

Water Quality Tests

The temperature, color, D.O., and pH tests are performed using LaMotte testing equipment. The Oklahoma Water Watch Handbook (1999) has detailed procedures for each test. Air and water temperature are recorded using a LaMotte armored thermometer. Color is determined by matching the water color to a color chip in the Borger Color System booklet. D.O. is measured by a modified Winkler titration/azide method. The pH test is a basic colorimetric test using a pH wide range indicator reagent resulting in a measurable color change.

Nutrient tests are performed using HACH colormetric tests for nitrate nitrogen, ammonia nitrogen and ortho-phosphate. All tests are performed on blank samples of deionized water (DI) before each test is performed on sample water. This process accounts for background color changes and may detect equipment contamination. Color changes are matched to a color wheel from which a “value” is obtained. The volunteer records both the DI blank value and the value from the environmental sample. The DI blank value is then subtracted from the environmental sample to give a true value.

Nitrate nitrogen generally occurs in natural waters at low concentrations, therefore some detectable concentrations of nitrates should be expected. Phosphorus may be found in natural waters in several forms. The most common form measured by water quality laboratories is total phosphorus. This is the concentration used for TSI calculations and in reference to water quality standards. Ortho-phosphate is the dissolved form readily available for algae assimilation. Oklahoma Water Watch measures ortho-phosphate primarily due to test capabilities. Total phosphorus analysis requires a digestion process, which involves a boiling step, and is not suitable for volunteer monitoring. Ammonia is quickly used by algae and broken down in the presence of oxygen. Therefore it is common to not see detectable quantities of ammonia under normal conditions.

<u>Chemical Test Limitations</u>
Basic chemical parameter tests listed in Table 3 are performed using LaMotte chemical tests. For detailed information on test procedures please reference the Quality Assurance Project Plan (QAPP) or the OWW Handbook. These basic tests have proven highly effective for volunteers to achieve accurate results, and are the basis of the program. For the nutrient tests, also listed in Table 3, HACH chemical tests are used. Again, these HACH tests are colormetric tests that are read using a color wheel and matching colors. Due to individual differences in deciphering colors between volunteers, these tests should be considered with limited utility. They are however, an excellent screening tool to serve as an early warning system to identify problems which may not be documented by routine monitoring by state agencies.

The HACH nitrate nitrogen test may have interference when nitrite is present. Since volunteers do not test for presence of nitrite, the nitrate result is likely combined nitrate and nitrite concentrations. Additional problems exist with the nitrate test when it was discovered in 2001 that some volunteers were using reagents designed for salt water analysis. Although the result from the analysis only altered the reading +1mg/l, again caution should be used when reviewing the data.

Problems with the orthophosphate test include discrepancies between “chemical lots” of reagents ordered from HACH. This potential error was brought to OWW staff attention late in 2001, steps have been made towards its resolution, however historical data collections are again questionable. Also, possible phosphate contamination of the DI water used for DI blank samples was detected when DI blank values exceeded environmental samples resulting in negative orthophosphate concentrations being recorded in the database. Other problems with the orthophosphate test are in reading the color wheel. The blue color can be influenced dramatically by background light and eyesight limitation. A small difference in color determination may result in a significant difference in data result.

No problems have been encountered with the ammonia test at this time. Ammonia is rarely detected in environmental samples. Again steps are being taken to resolve all of these concerns, however, they are noted in this section of the report to document the limitations of the nutrient tests.

Reported Data

Grand Lake is the third largest lake in the State of Oklahoma. It is riverine with several major arms that contribute runoff from distinct portions of the watershed. Grand Lake Water Watch is the largest, longest running volunteer monitoring group in the state. Likewise, monitors have come and gone with monitoring sites continuously coming and going too. With that in mind, the lake was divided into sections based on number of sites, number of data points (which may differ to number of sites by longevity of particular sites), and hydrologic influences so that meaningful data analyses could be performed. Sections include Upper Lake- Twin Bridges down lake below Elk River confluence, Mid-Lake- from below Elk River confluence to below Horse Creek Cove, and Lower Lake- Below Horse Creek Cove to the Dam. Mid-Lake was further broken into smaller sections including above Honey Creek Cove, Honey Creek Cove, and below Honey Creek Cove, while the Lower Lake was broken into lower lake to the Delaware County line, Drowning Creek Cove, and the Dam area. Area maps of each section are included as a preface to that sections' data summary. Sites outside of the lake proper, located in the rivers of the watershed, were treated differently in the analysis.

Surface data analysis was performed for each section by averaging all data points collected each month to obtain one value for that month for that section of the lake, ending in December 2001. Other than dissolved oxygen and temperature data, monthly averages were calculated for each section and subsection. D.O. and temperature were averaged monthly for the three main sections to create D.O. and temperature relationship graphs. Statistical trends analysis was performed on nutrient and Secchi disk data to detect any positive or negative changes. Hydrolab® data collected from the in-lake sites at one meter intervals will be used in comparison with OWQS for DO and pH. Hydrolab® collected D.O. and temperature is also displayed in vertical profile plots depicting stratification or lack thereof.

Units of measure used for this report for D.O., nitrate nitrogen, ortho-phosphate, and ammonia nitrogen are reported in milligrams per liter which is abbreviated as mg/l, and is equivalent to parts per million or ppm. Chlorophyll is reported in milligrams per cubic meter or mg/m^3, which is equivalent to micrograms per liter or µg/l. The difference between mg/l and µg/l is a factor of 1000 (1 mg/l = 1000 µg/l). Secchi disk depth is reported in centimeters, and temperature is reported in degrees Celsius.

Color was analyzed by assigning a color (i.e. green, brown, transparent, etc.) to each of the Borger Color System numbers. All reported numbers were then categorized according to color, for each section of the lake. The number of times a color was reported, or percentage, is provided for the analysis for color. It is important to note that the determination of color for this report is in no way related to the apparent color parameter listed in Oklahoma WQS which is analyzed by a certified water quality laboratory. The color analysis in this report is a generalization of reported BCS numbers related to an assigned color.

Statistical Methods

An analysis of central tendency was made for mean, or average, median, minimum, and maximum for all averaged surface water quality data. Trend analyses were performed on Secchi and nutrient parameters to determine if concentrations were decreasing or increasing. Trends were determined using the Seasonal Kendall test for trends from WQStat Plus v. 1.5 for Windows software. Only trends significant at the 95% confidence level are reported. For trend tests, sample size (n) should be greater than 40 to really perform any significant trend analyses. Occasionally, this criteria was not met with too small sample sizes, therefore analysis of trends are questionable for these particular data sets, and should be viewed as such. For the river data, a non-parametric analysis of variance (ANOVA) was used to determine significant differences between data at upstream versus downstream sites. If differences were found to be significant, box and whisker plots were then used to determine which site was higher or lower in concentration. Again, significance was determined at the 95% confidence level. Seasonality was not significant at any of the sites for any of the parameters. The bulk of data used in this report was collected during summer months, which may be why, statistically, it is independent of seasonal changes.

Quality Assurance/ Quality Control

The OWW program operates under a United States Environmental Protection Agency (USEPA) approved Quality Assurance Project Plan (QAPP) (OWRB, 1999). Each volunteer is subjected to minimum of one (1) Quality Control Assessment (QCA) annually to maintain certification as an OWW monitor. All volunteers must maintain certification, be certified or attend a QCA annually before data will be accepted. Reliable volunteer collected data must be precise, accurate, complete, and comparable. The QCAs have been developed to ensure these conditions are met.

Precision and accuracy analyses are performed using pH and nutrient spike samples with known values. Precision is a measure of reproducibility hence 4 repetitions are performed during a QCA session on an individual sample. These repetitions help to determine if any problems with data precision are due to testing protocols, kit contamination, or human error. Long-term precision estimates are also measured and established through the repetitive QCA session's volunteers attend. Accuracy is the degree of correlation between the value a monitor obtains and the "true" or "known" value of a sample. After the volunteer has recorded his or her test results, OWW staff compares the obtained result to the "true" value of the spike sample. Completeness of data collection requires that a minimum of 85% of all critical collected data be acceptable. For quality assurance, the data or information collected must be comparable from one sampling period to the next. The data must also be comparable to other water quality studies using similar collection and Quality Control methods. Since the program inception in 1992, QCA sessions have been scheduled and attended regularly by volunteers, with over 90% of volunteers successfully passing. Table 4 lists the ranges for the tests and the acceptable levels for precision and accuracy.

Table 4 . Summary table of volunteer measured water quality variables and their associated range of values, precision and accuracy.

Variable	Range	Precision	Accuracy
Dissolved Oxygen	0 to 20 mg/l	0.30 mg/l	± 0.60mg/l
pH	3.0 - 10.5	0.25	± 0.50
Temperature (air & water)	-5 -50°C	0.25°C	± .50°C
Secchi disc	0 - 3.0 m	2 cm	± 5 cm
Nitrate	0 - 1.0 mg/l (low-range)	0.04 mg/l	± 0.10 mg/l
	0 - 10.0 mg/l (high-range)	0.4 mg/l	± 1.0 mg/l

Variable	Range	Precision	Accuracy
Ortho-phosphate	0 - 1.0 mg/l (low-range)	0.04 mg/l	± 0.1 mg/l
	0 - 5.0 mg/l (mid-range)	0.2 mg/l	±0.5 mg/l
	0 - 50.0 mg/l (high-range)	2.0 mg/l	±5.0 mg/l
Ammonia	0 - 2.5 mg/l	0.10 mg/l	± 0.20 mg/l

OWW Data Quality Objectives
QCA sessions are vital to determine if data quality objectives (DQOs) listed in the QAPP are being met and to refresh volunteer monitors on proper collection, analysis protocols, kit maintenance and proper data sheet completion. Monitors must successfully "pass" the QCA events to retain certification. DQOs are the reasons for the OWW program and intended uses of the data. Thus, the DQOs for OWW are as follows:

1. *Collection of environmental data, indicating baseline water quality for Oklahoma's water resources*

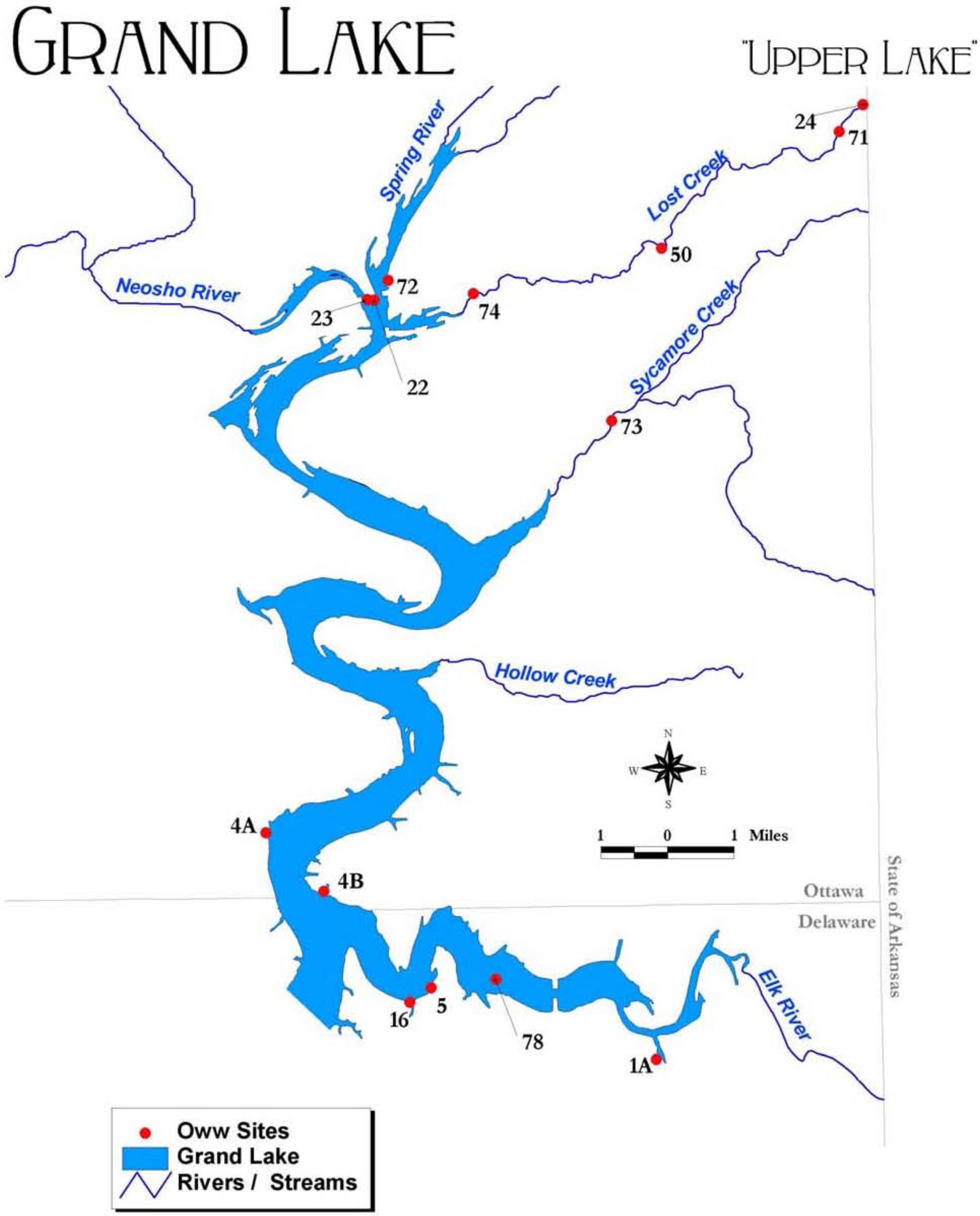
2. *Identification of water quality threats or concerns*

3. *Determination of water quality trends*

4. *Promotion of citizen participation in protecting, managing and restoring our water resources*

5. *Education of the public regarding basic ecological concepts related to our water resources.*

The program is not designed to be used as, nor is it intended for, any type of permitting or enforcement purposes. It is intended to motivate citizens to take an active role in managing the state's water resources and to supplement state monitoring efforts. The program serves as an early warning system for many of our state's water resources to identify problems or concerns, which would not be documented by routine monitoring by state agencies. Local citizens familiar with the water resources in their "backyard" are far more likely to notice a deviation from the norm than state or federal personnel who visit a lake or stream sporadically and who could quite likely miss a short-term water quality insult altogether.


GRAND LAKE
"UPPER LAKE"
Spring River
Lost Creek
Neosho River
Sycamore Creek
Hollow Creek
Elk River
24
71
50
72
74
23
22
73
4A
4B
16
5
78
1A
N
W
E
S
1
0
1 Miles
Ottawa
Delaware
State of Arkansas
Oww Sites
Grand Lake
Rivers / Streams

Upper Lake

Surface water quality for the upper part of Grand Lake includes from Twin Bridges to below the confluence of Elk River (sites 23, 22, 4A, 4B, 5, 16, and 1A). The figure on the previous page shows site locations. Nearly 200 data points for basic data points and just over 100 advanced data points have been collected in this region of the lake. The first data point was collected in July 1992 with data collection somewhat consistent through October 2001. Data points from all sites collected within a particular month were averaged to obtain one value per month for analysis. This compensates for retired, inconsistent, and newly added sites and returns a value closer to the true environmental value.

Basic Parameters

<u>Secchi Disk Depth</u>
Secchi disk depth recordings ranged from 3-100 cm with an average of 38 cm and a median value of 36 cm (n=81). Low Secchi disk depths indicate poor visibility in the water column. It does not differentiate between organic (algae) and inorganic (sediment) types of suspended particulate. Low values are often found in shallow, riverine waters, typical of the upper part of Grand Lake. Trend analysis showed a decreasing trend, in the ten-year data set. A decreasing trend for Secchi depth indicates the depth of visibility is becoming shallower. Figure 2 shows average Secchi disk depths plotted over time.

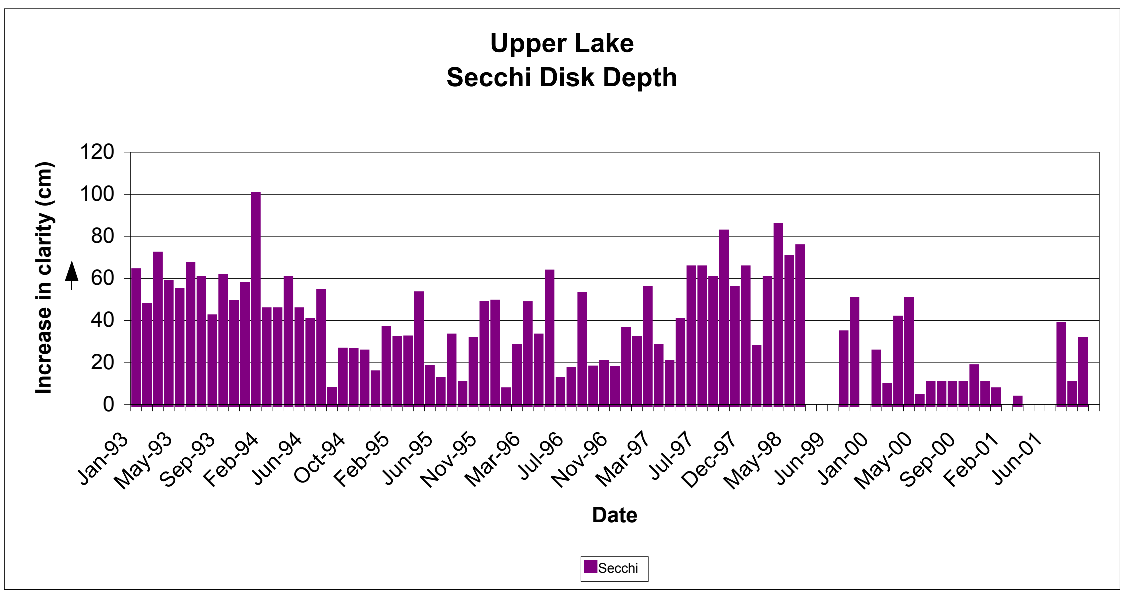


Figure 2. Secchi Disk Depth for Upper Grand Lake.

Color Analysis

Figure 3 depicts color reported for upper portion of the lake. Ninety-nine percent of the data reported were shades of green and brown. Like Secchi data, it is typical to see more suspended particulates in the shallow, riverine areas of lakes, thus resulting in murky, greenish brown waters. Brown coloration is likely due to suspended sediments, or dirt, while green colors may be attributed to suspended algal cells.

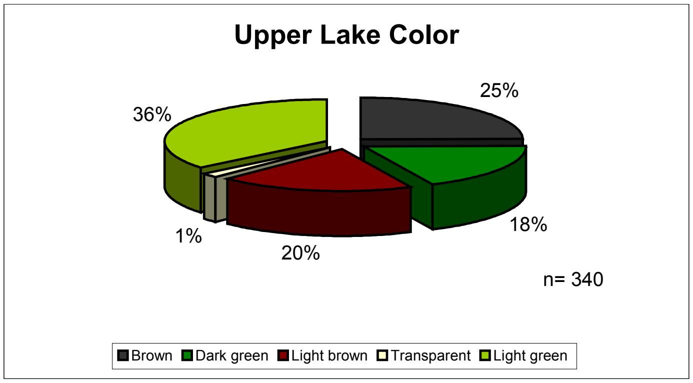


Figure 3. Percent color for Upper Grand Lake.

pH Values

Surface pH values ranged from 7.00-8.80 s.u. with an average and median value of 7.80 s.u. (n=88). Oklahoma's WQS for pH ranges from 6.50 to 9.00 s.u., therefore none of the values were in violation of WQS. Figure 4 shows average pH values plotted over time.

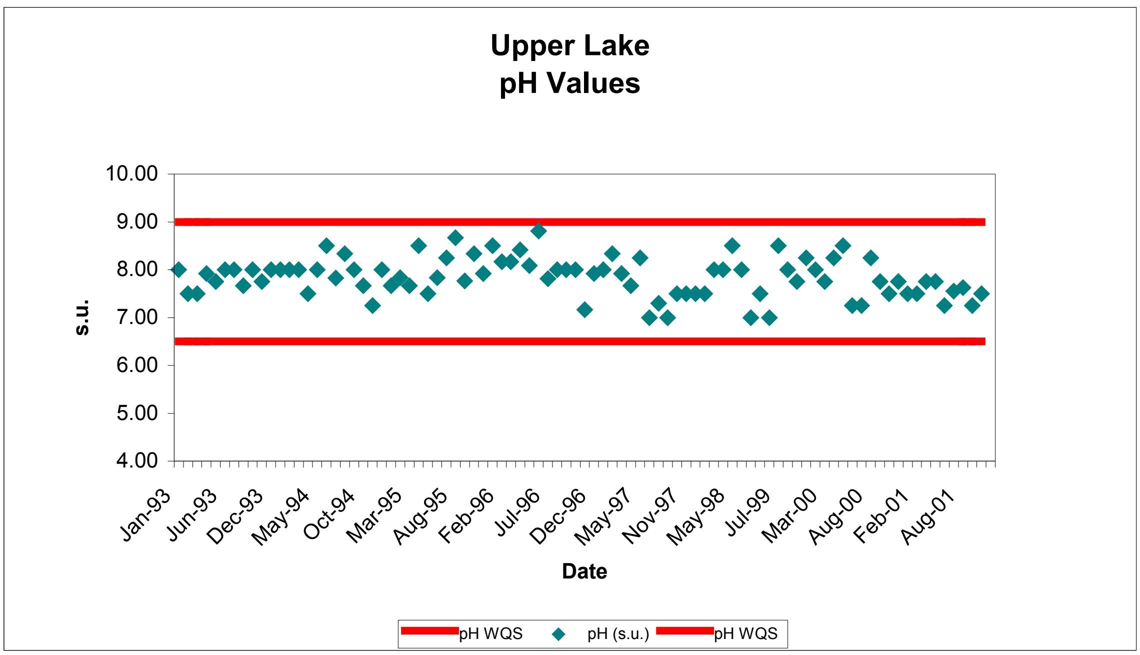


Figure 4. pH values for Upper Grand Lake.

Dissolved Oxygen and Temperature Relationship

Dissolved oxygen (D.O.) values ranged from 2.80-12.00 mg/l with an average of 8.03 mg/l and a median value of 8.10 mg/l (n=88). Only 7 of the 88 report values (or 8%) were below 5 mg/l. The low value of 2.80 mg/l was detected in August of 1997. Oklahoma WQS for D.O. on lakes incorporates percent water column, therefore no comparisons to WQS can be accurately made with surface D.O. data only. However, with less than 10% of values below the general standard of 5 mg/l for FWP beneficial use, reported D.O. concentrations do not suggest a concern. D.O. concentrations and temperature represented a typical inverse relationship as cooler waters hold more oxygen than warmer waters. Figure 5 plots averaged D.O. concentrations versus temperature throughout the monitoring period. The relationship plot identifies five of the eight summers (indicated in green in the plot) monitored have peak D.O. concentrations during maximum temperatures. These unusual D.O. peaks are likely due to high algal growth, and thus photosynthetic activity during daylight hours.

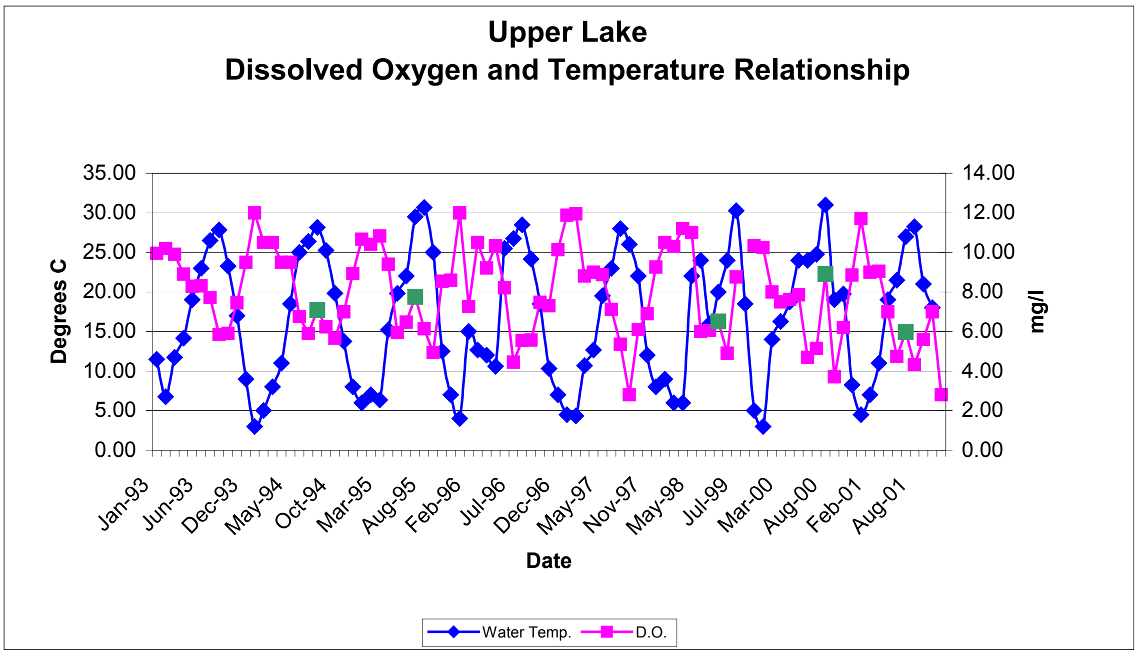


Figure 5. D.O. and Temperature for Upper Grand Lake.

Advanced Parameters

Ammonia Nitrogen

Ammonia nitrogen values ranged from 0.00-1.00 mg/l with an average of 0.24 mg/l and a median value of 0.20 mg/l (n=60). Ammonia data collection began in July 1994 and continued through October 2001. Trend analysis for the seven-year data set showed a decreasing trend in ammonia concentrations. Figure 6 shows ammonia concentrations plotted against time.

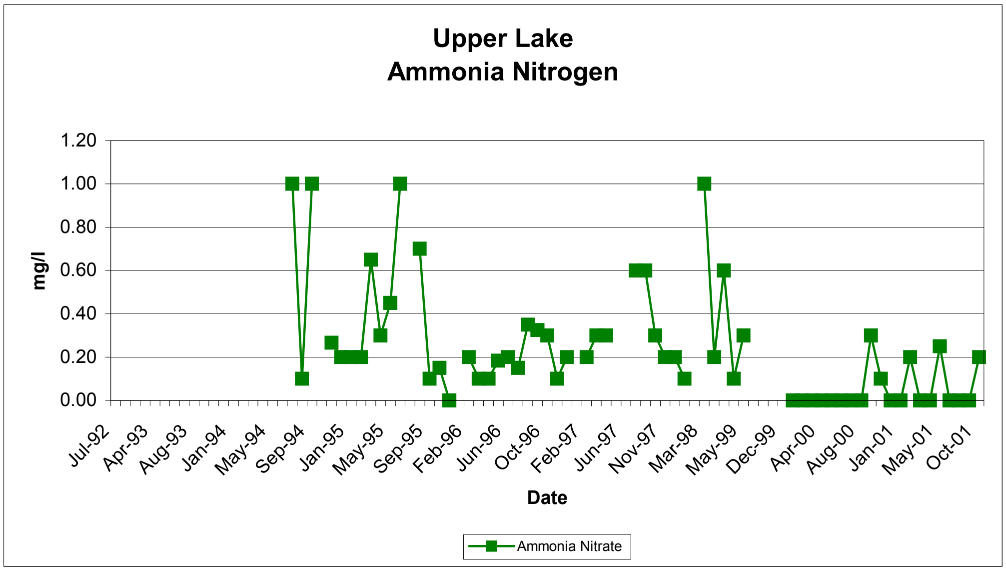


Figure 6. Ammonia Nitrogen concentrations for Upper Grand Lake.

Nitrate Nitrogen

Nitrate nitrogen values ranged from 0.00-2.50 mg/l with an average of 0.74 mg/l and a median value of 0.50 mg/l (n=56). Nitrate data collections also began in July 1994 through October 2001. Nitrates showed no significant trend in data at the 95% confidence level. Figure 7 shows average nitrate concentrations plotted against time.

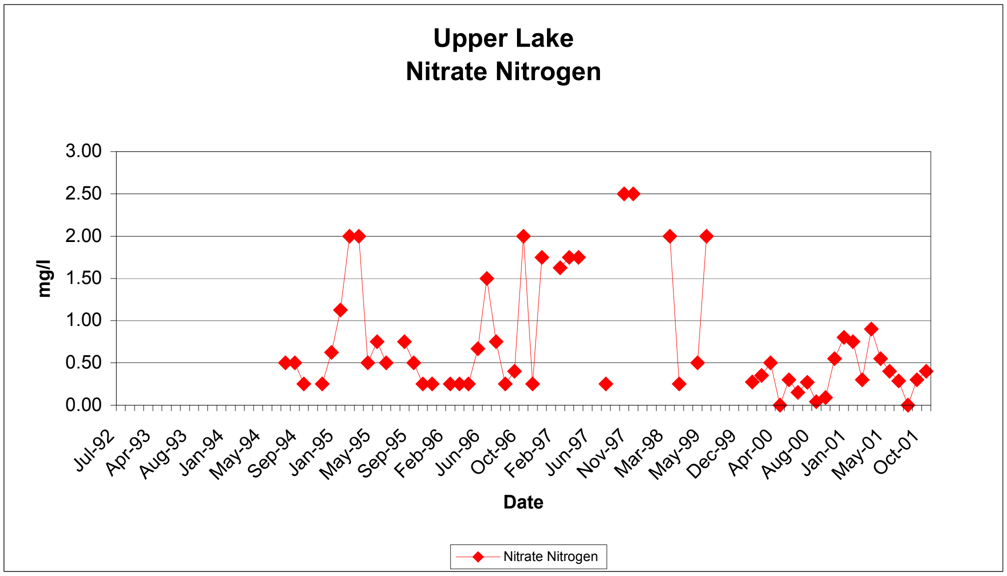


Figure 7. Nitrate Nitrogen concentrations for Upper Grand Lake.

<u>Ortho-Phosphate</u>

Ortho-Phosphate values ranged from 0.00-1.25 mg/l with an average of 0.25 mg/l and a median value of 0.23 mg/l (n=60). Data collections for ortho-phosphate were consistent from July 1994 through October 2001. There is no significant trend in ortho-phosphate data. Figure 8 shows ortho-phosphate concentrations plotted against time.

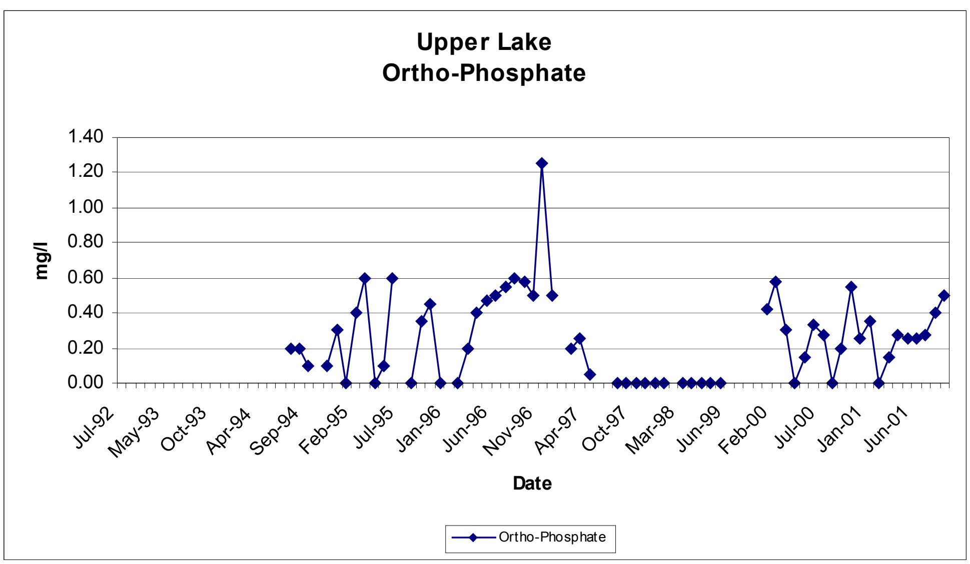
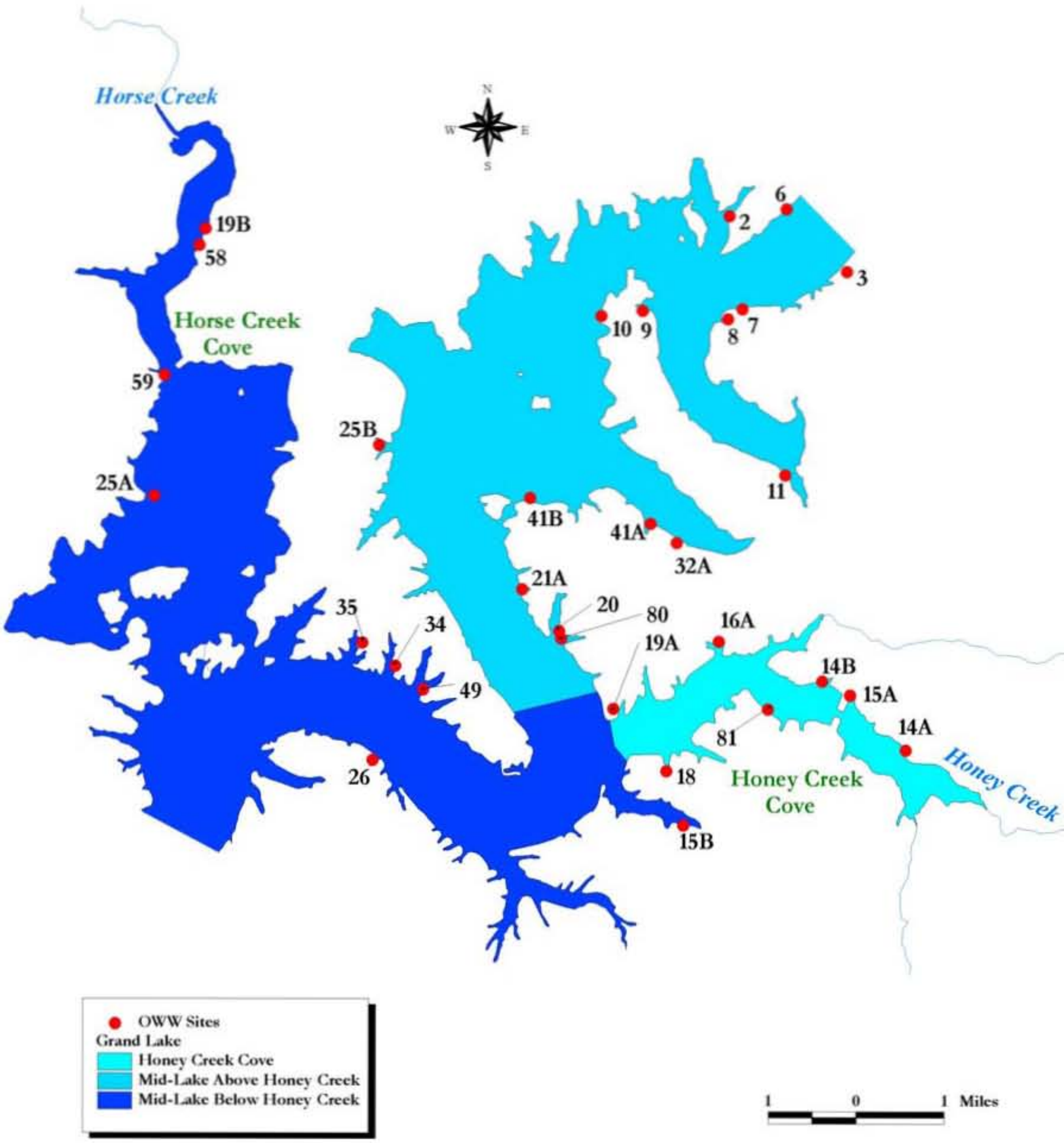


Figure 8. Ortho-Phosphate concentrations for Upper Grand Lake.

GRAND LAKE

"MID-LAKE"



Mid-lake

Surface water quality summary for the Mid-Lake section of Grand Lake includes sites from below the confluence of Elk River to below the confluence of Horse Creek Cove. Over 720 basic data points and 340 advanced data points have been collected in this section from January of 1993 through December of 2001. This section of Grand Lake is more developed than the upper lake section and includes the City of Grove, private residents and several major resorts and golf courses. The Mid-Lake section was further broken into three sections to segregate Honey Creek and its influence to Grand Lake. The figure on the previous page shows site locations. The sections include Mid-Lake above Honey Creek (includes sites 6, 3, 2, 7, 8, 11, 9, 10, 32A, 41A, 41B, 21A, 20, and 80), Honey Creek Cove (includes sites 14A, 15A, 14B, 81, 16A, 18, and 19A), and Mid-Lake below Honey Creek (includes sites 15B, 49, 34, 35, 26, 25A, 19B, 58, and 59). Like the Upper Lake section, all data points from all sites collected within a particular month were averaged to obtain one representative data point for each month, for each of the three sections. Again, this compensates for retired, inconsistent, and newly added sites and returns a value closer to the true environmental value.

Basic Parameters

<u>Secchi Disk Depth</u>
Mid-Lake above Honey Creek Secchi disk depth recordings ranged from 13-134 cm with an average of 50 cm and a median value of 52 cm (n=104). Trend analysis showed an increasing trend in Secchi disk depth from January 1993 through December 2001. Secchi disk depth in Honey Creek Cove ranged from 20-155 cm with an average of 79 cm and a median value of 76 cm (n=84). Trend analysis also showed an increasing trend in Secchi disk depth from January 1993 through September 2001. Secchi disk depth in Mid-Lake below Honey Creek ranged from 25-140 cm with an average of 74 cm and a median value of 70 cm (n=61), and there was no significant trend in data. The increasing trends in Secchi disk depth show that water clarity is getting better in the upper two sections of Mid-Lake, whereas no significant trend in the lower section means there is no real change in clarity or data is insufficient to detect a trend. Figure 9 shows average Secchi disk depths for the three sections of Mid-Lake.

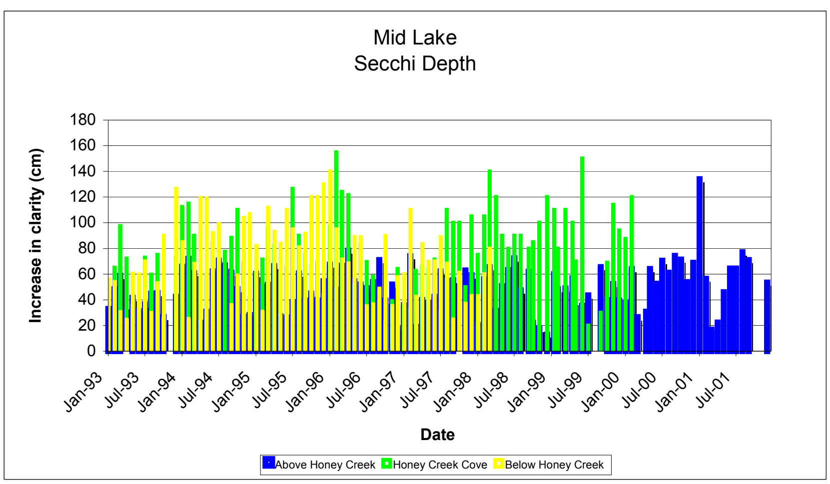


Figure 9. Secchi Disk Depth for the Mid-Lake section of Grand Lake.

Color Analysis

Color analysis for Mid-Lake was sectioned slightly different than the other water quality parameters based on river influences. The main body of the reservoir was compiled, while Honey Creek Cove and Horse Creek Cove were separated out. The Mid-Lake color chart (Figure 10) shows that almost 98% of the color reports were shades of green and brown (50% green and 48% brown). In Honey Creek Cove, 30% of the color reports were brown, while 38% were green (Figure 12). Honey Creek Cove also had the highest percentage (32%) of transparent waters than any other section of the lake. In Horse Creek Cove, 73% of color reports were brown, while 19% were green (Figure 11). From this data, it can be assumed that the largest percentage of sediment-laden waters are coming from Horse Creek, while the other sections are equally green and brown, and Honey Creek being the clearest.

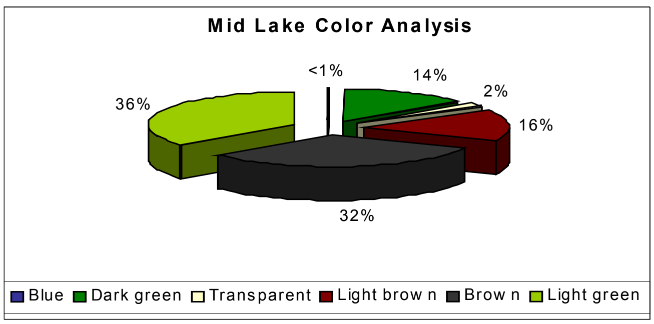


Figure 10. Mid-Lake color analysis.

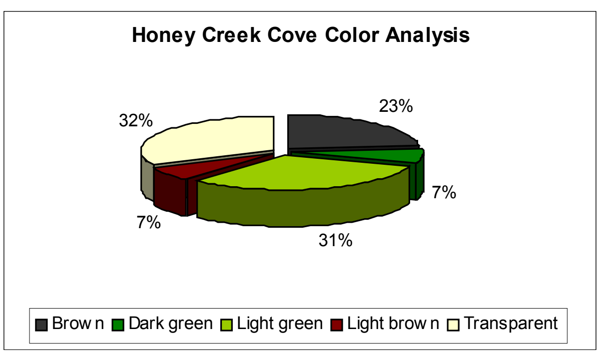


Figure 12. Honey Creek Cove color analysis.

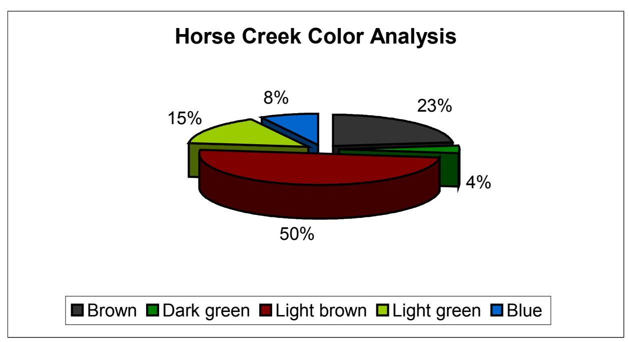


Figure 11. Horse Creek color analysis.

pH

Most all of the pH values for Mid-Lake fell within Oklahoma WQS. For Mid-Lake above Honey Creek pH values ranged from 7.14-8.50 s.u. with an average of 7.84 s.u. and a median value of 7.88 s.u. (n=104). The pH values in Honey Creek Cove ranged from 6.38-8.50 s.u. with an average of 7.73 s.u. and a median value of 7.75 s.u. (n=84), and the pH values below Honey Creek Cove ranged from 7.00-9.00 s.u. with an average of 7.92 s.u. and a median value of 7.97 s.u. (n=61). Figure 13 depicts average pH values for Mid-Lake plotted over time. A high pH was detected in winter of 1996 below Honey Creek Cove confluence, and one low value was reported in Honey Creek Cove in the summer of 1997. The low value falls outside of WQS, however it is less than 1% of the data therefore is not a concern.

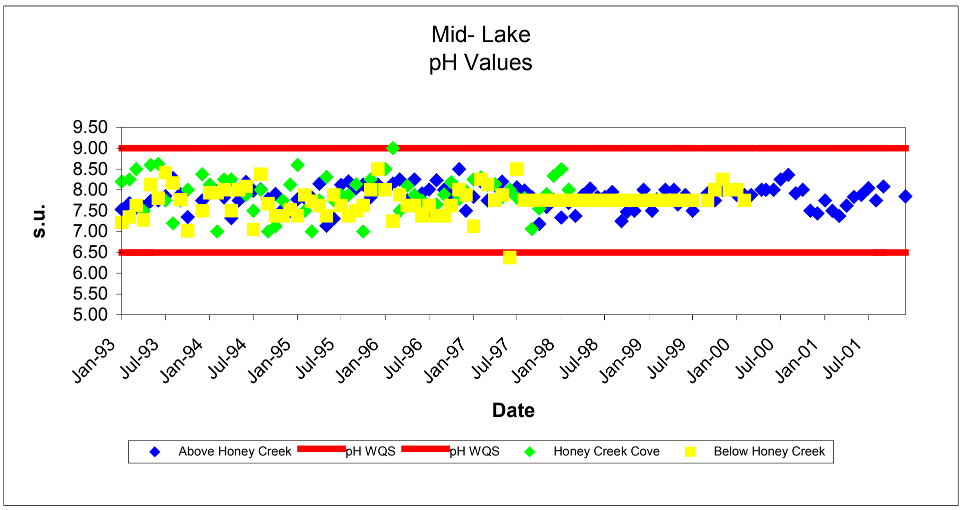


Figure 13. pH values for Mid-Lake.

Dissolved Oxygen and Temperature Relationship

Mid-Lake D.O. concentrations ranged from 5.3- 12.90 mg/l, with an average of 8.59 mg/l and a median of 8.38 mg/l (n=104). None of the D.O. concentrations fell below the general standard of 5 mg/l for FWP beneficial use in the summer months (June 16 – October 15). Figure 14 shows the inverse relationship between D.O. and temperature. Nine years were sampled, of which five winters experienced drops in D.O. (indicated in green on the plot), most of which occurred in the fall. Respiration is the most likely cause for drops in D.O. Two of these unusual declines in D.O. corresponded with increased temperature. Unseasonal warm temperatures might have stimulated an algal bloom, resulting in excessive overnight respiration. In the summer months, two D.O. peaks (indicated in red on the plot) occurred in the summer of 1995 and summer of 2001. Unusual peaks in the summer, or height of the growing season, is likely the result of excessive photosynthetic activity. The benefits of volunteer monitoring allow for this consistent measuring of parameters so unusual increases or decreases may be detected.

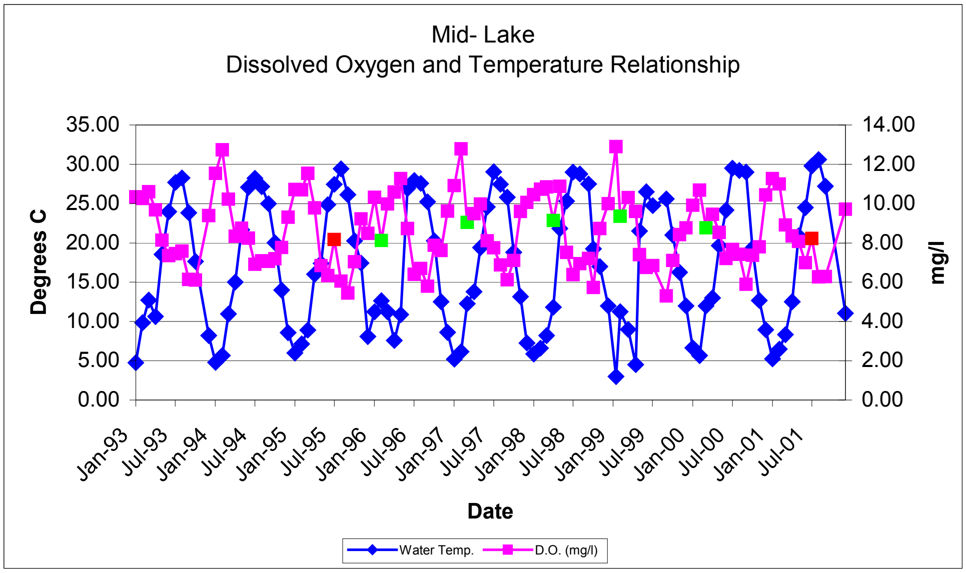


Figure 14. D.O. and Temperature for Mid-Lake.

Advanced Parameters

Ammonia Nitrogen

Ammonia nitrogen values in Mid-Lake above Honey Creek Cove ranged from 0.00-2.88 mg/l with an average of 0.36 mg/l and a median value of 0.29 mg/l (n=88). Ammonia data collection began in December of 1993 through December 2001. Trend analysis showed a decreasing trend in ammonia above Honey Creek Cove. Ammonia values in Honey Creek Cove ranged from 0.00-1.00 mg/l with an average of 0.13 mg/l and a median value of 0.00 mg/l (n=63). Trend analysis also showed a decreasing trend in data from December 1993 through September 2001, however there was a large data gap between June 1998 and September 1999. Likewise, ammonia values in Mid-Lake below Honey Creek Cove ranged from 0.00-5.50 mg/l with an average of 0.62 mg/l and a median value of 0.30 mg/l (n=25). Data collection for this section began in January of 1994 through February of 1995, then ceased until March 1997 through June of 1998, thus only two complete years of nutrient data was collected for this section. Trend analysis at the 95% confidence level showed no significant trend. This particular data set was smaller than the recommended data set of greater than 40 (n ≥ 40), therefore no real conclusions may be drawn from this data. Again it is important to stress the value of volunteer data and its consistency and quantity of data points. Figure 15 shows average ammonia concentrations collected for Mid-Lake.

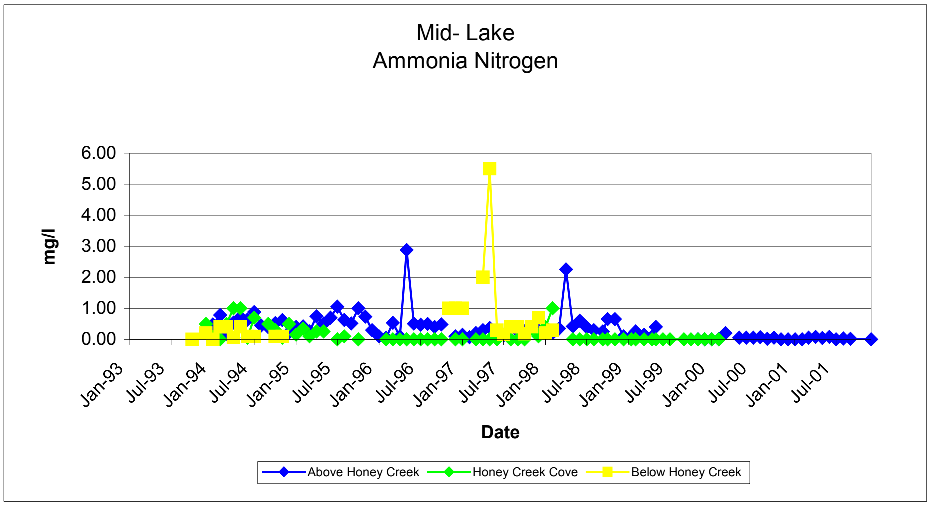


Figure 15. Ammonia Nitrogen concentrations for Mid-Lake.

<u>Nitrate Nitrogen</u>

Nitrate nitrogen values for Mid-Lake above Honey Creek Cove ranged from 0.00-5.13 mg/l with an average of 0.58 mg/l and a median value of 0.25 mg/l (n=87). Trend analysis from December 1993 through December 2001 showed a significant decreasing trend. Nitrate nitrogen values in Honey Creek Cove ranged from 0.00-3.00 mg/l with an average of 0.29 mg/l and a median value of 0.03 mg/l (n=63). Trend analysis showed no significant trend. Mid-Lake below Honey Creek Cove nitrate nitrogen values ranged from 0.00-2.00 mg/l with an average of 0.55 mg/l and a median value of 0.29 mg/l (n=26). Again this data set is too small to accurately detect trends, however no significant trend could be detected at any of the confidence levels. Figure 16 shows average nitrate nitrogen concentrations for Mid-Lake.

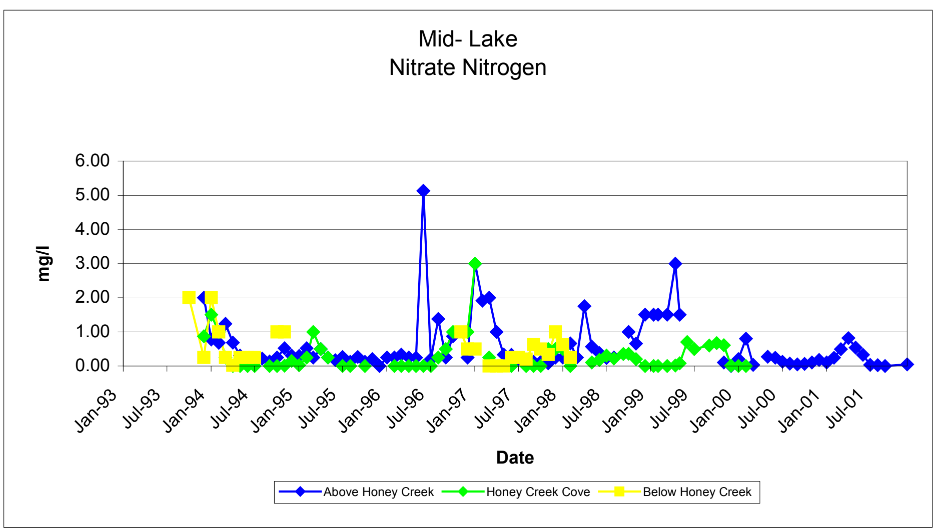


Figure 16. Nitrate Nitrogen concentrations for Mid-Lake.

Ortho-Phosphate

Ortho-phosphorus values for Mid-Lake above Honey Creek Cove ranged from 0.00-0.50 mg/l with an average of 0.11 mg/l and a median value of 0.10 (n=85). Trend analysis showed an increasing trend. Honey Creek Cove ortho-phosphate values ranged from 0.00-0.80 mg/l with an average of 0.06 mg/l and a median value of 0.00 mg/l (n=63). Trend analysis for this section of the lake showed an increasing trend. There was no detection (or 0.00 mg/l) in the first two-thirds of the data set and some relatively high values detected in recent years, which may have influenced the statistical test. For the Mid-Lake below Honey Creek Cove section, ortho-phosphate ranged from 0.00-0.60 mg/l with an average of 0.12 mg/l and a median value of 0.00 (n=26). Again, this data set is too small to determine accurate trends however, with available data the trend decreases. The newest data (March 1997 through June 1998) shows no detects, or 0.00 mg/l, with relatively high values reported in earlier years again likely influencing the statistical test. Figure 17 shows average ortho-phosphate concentrations for Mid-Lake.

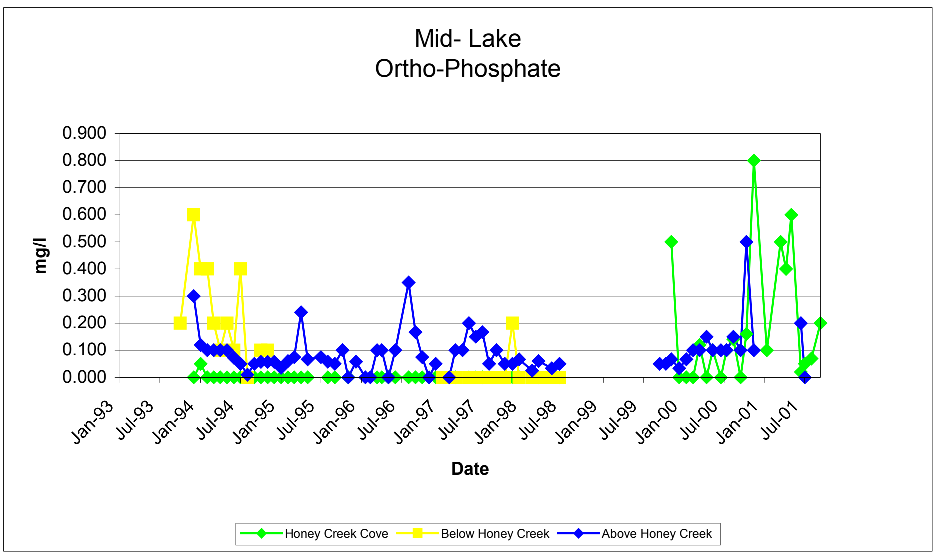
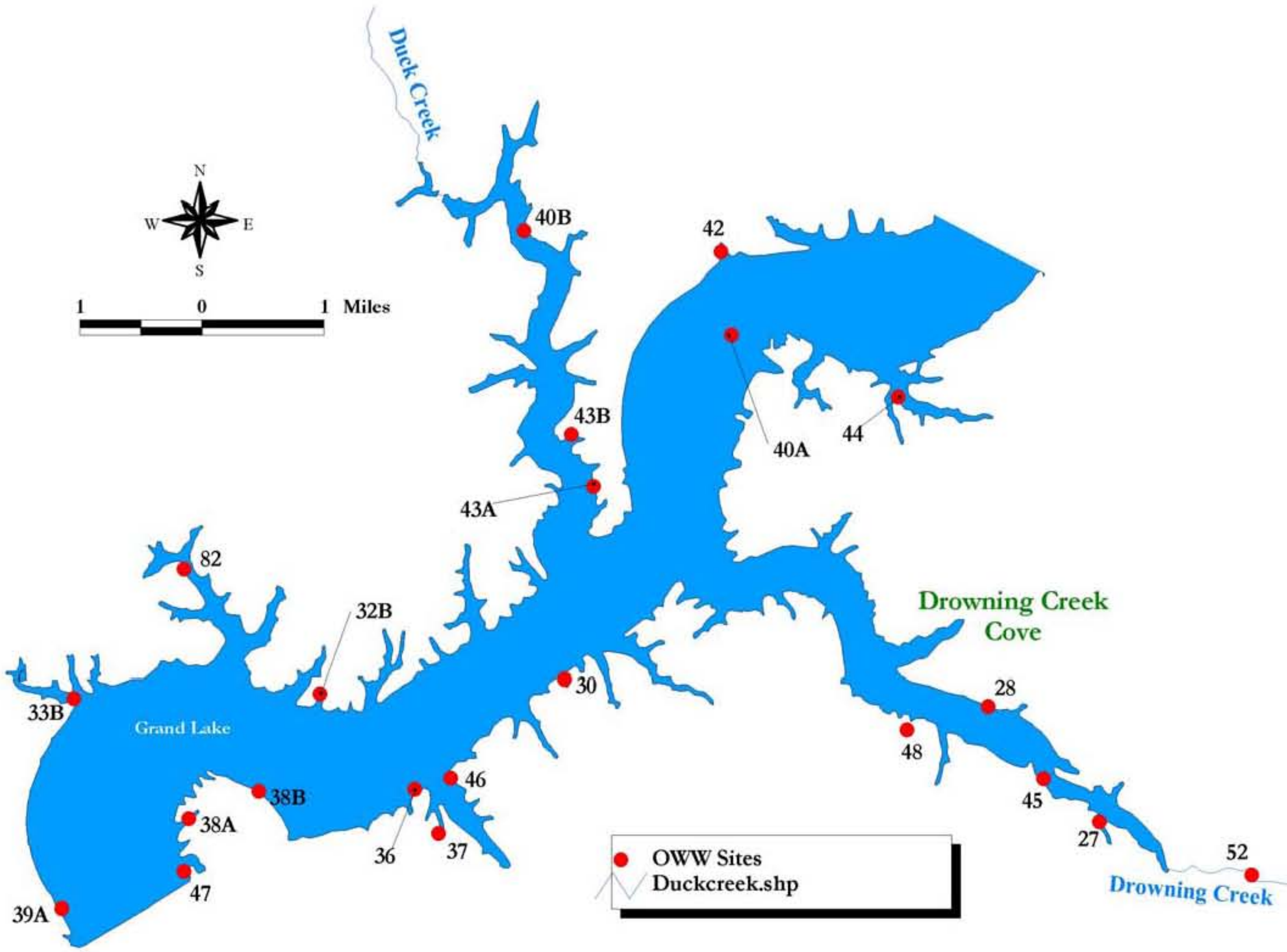


Figure 17. Ortho-Phosphate concentrations for Mid-Lake.

Grand Lake "Lower Lake"



Lower-lake

Surface water quality summary for the lower-lake section of Grand Lake includes from below the confluence of Horse Creek Cove to the dam. Over 510 basic data points and 130 advanced data points have been collected since January of 1993 through September of 2001. Like the Mid-Lake section, this section of the lake was broken into different sections for certain parameters. The figure on the previous page shows site locations. Sufficient data points existed for Secchi disk and pH data to be further broken into sections. These sections are from below Horse Creek Cove to the Delaware County line (includes sites 42, 44, 40A, 43A, 43B, 40B, 30, 46, 37, and 36), Drowning Creek Cove (includes sites 27, 45, 28, and 48), and the dam area (included sites 32B, 82, 33B, 38B, 38A, 47, and 39A). The dam area lacks recent surface water quality data, particularly Secchi disk depth, due to the implementation of in-lake sampling in 2000, thus this data is addressed in the In-Lake Sampling section of the report. D.O. and nutrient data were averaged for the whole lower lake section. Again, averaging all data points from a given month to return one value for that month compensates for retired, inconsistent, and newly added sites.

Basic Parameters

<u>Secchi Disk Depth</u>
Secchi disk depth for the Lower Lake ranged from 6– 175 cm with an average of 75 cm, and a median value of 80 cm (n=90). There was no significant trend in Secchi disk depth for this upper section of Lower Lake to the Delaware County line. The broad range of disk depths likely attributed to the lack of significant trend. Secchi disk depth in Drowning Creek Cove ranged from 31-140 cm with an average of 93 cm and a median value of 98 cm (n=74). Trend analysis for this cove showed a very dramatic positive increasing trend. Therefore, based on Secchi disk depth, Drowning Creek Cove water clarity is improving. Secchi disk depth from the dam area ranged from 41-211 cm with an average of 129 cm and a median value of 132 cm (n=39). Trend analysis for the dam area also showed an increasing trend, and thus reflects improving water clarity. Figure 18 shows average Secchi disk depths for lower Grand Lake.

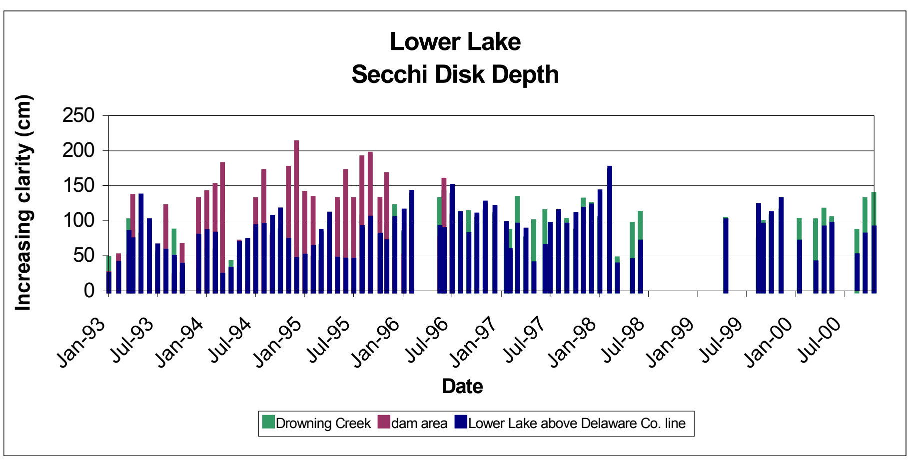


Figure 18. Secchi Disk Depth for Lower Grand Lake.

Color Analysis

Percent color for Lower Lake was determined from all reported values. Figure 19 depicts percentages of colors reported. Again, shades of greens and browns represent the majority of the reported values, 67% green and 31% brown. Greens most likely represent algal growth while browns likely represent suspended sediments.

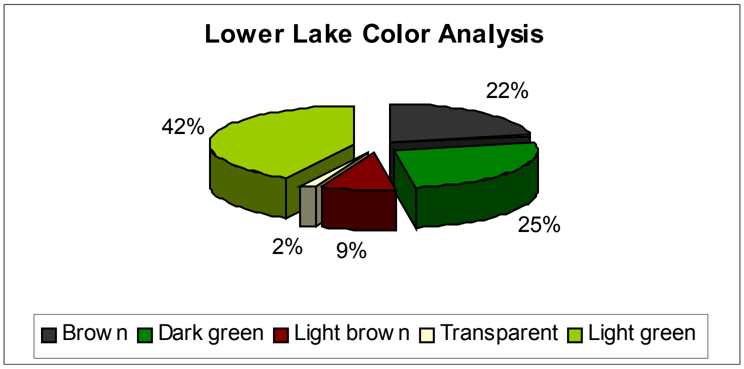


Figure 19. Percent colors reported for Lower Grand Lake.

pH

Most all of the pH values for Lower Lake are within Oklahoma's WQS. The upper part of Lower Lake pH values ranged from 5.67- 8.5 s.u. with an average of 7.69 s.u. and a median of 7.77 s.u. (n=90). Drowning Creek Cove pH values ranged from 7.00- 8.50 s.u. with an average of 7.86 s.u. and a median value of 7.87 s.u. (n=74), and the dam area pH values ranged from 7.25- 9.00 s.u. with an average of 8.00 s.u and a median value of 7.75 s.u. (n=39). Figure 20 depicts pH values for Lower Lake plotted over time. One low pH value of 5.67 s..u., detected in February of 1995, falls below OWQS of 6.5 s.u., however one data point is not a concern considering the majority of the data.

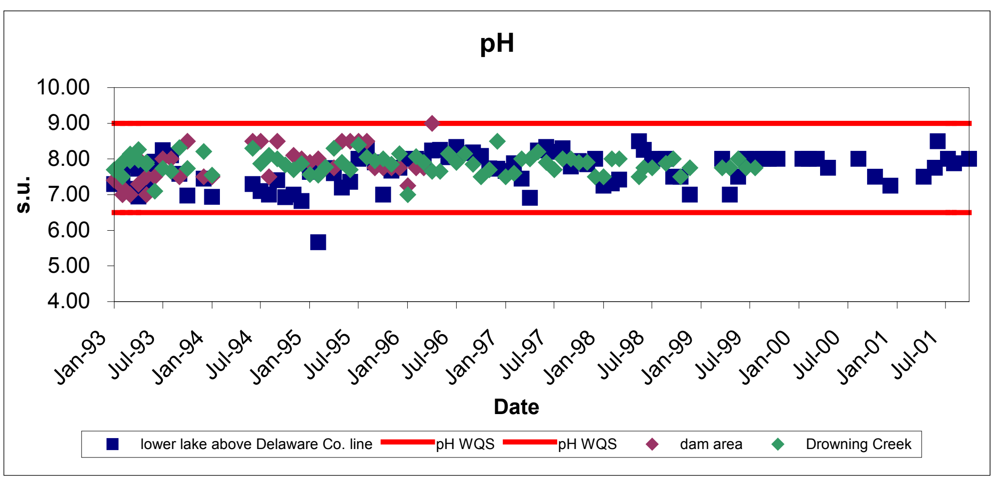


Figure 20. pH values for Lower Grand Lake.

Dissolved Oxygen and Temperature Relationship

Lower lake D.O. concentrations ranged from 4.93- 11.66 mg/l with an average of 8.32 mg/l and a median of 8.07 mg/l (n=93). None of the D.O. concentrations fell below the FWP beneficial use WQS of 5 mg/l. Figure 21 shows the inverse relationship between D.O. concentrations and temperature. Two of the summers sampled experienced peaks in D.O. Again this unusual phenomena may be the result of photosynthetic activity.

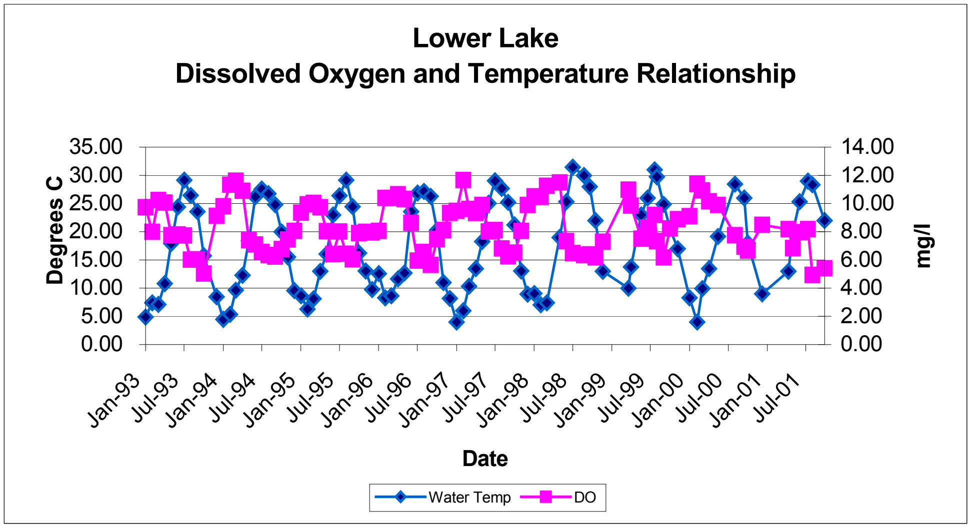


Figure 21. D.O. and Temperature for Lower Grand Lake.

Advanced Parameters

Ammonia Nitrogen

Ammonia nitrogen values ranged from 0.00- 6.50 mg/l with an average of 0.76 mg/l and a median of 0.47 mg/l (n= 59). Trend analysis from September 1993 through June 2001 showed a significant decrease in ammonia. However there is no data between April of 1999 and May of 2001 with only two data points in 2001, therefore trends likely represent data through 1999. Figure 22 shows average ammonia concentrations plotted over time. There were three “high” data points in the data set, however they are insignificant to the data set.

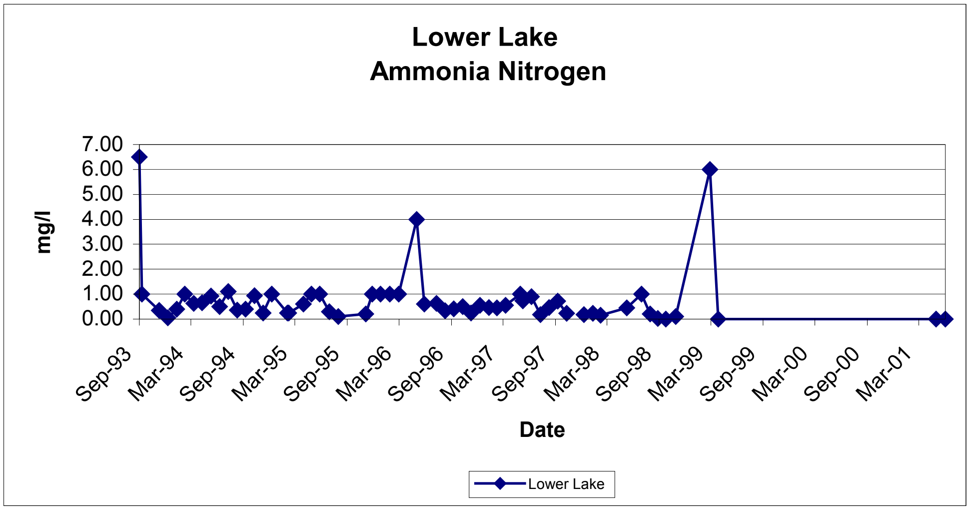


Figure 22. Ammonia Nitrogen concentrations for Lower Grand Lake.

<u>Nitrate Nitrogen</u>
Nitrate nitrogen values ranged from 0.00- 1.50 mg/l with an average of 0.39 mg/l and a median of 0.25 mg/l (n= 60). Trend analysis for the eight-year data set showed a significant trend, however slope equaled zero. Therefore the data set was broken in half for trend detection. The first half of data from September of 1993 through December of 1997 (n= 47) trends were decreasing. There was no significant trend from January 1997 through June 2001 (n=25), and sample size was less than recommended for accurate trend results to be determined. Therefore, decreasing trends likely occurred in the first half of the data set, with no information on current trends. Figure 23 shows average nitrate concentrations plotted over time.

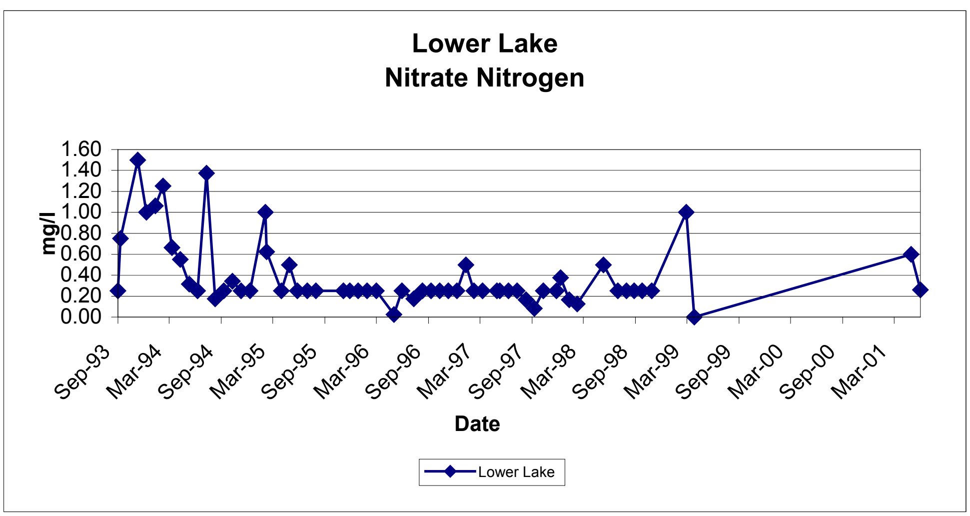


Figure 23. Nitrate Nitrogen concentrations for Lower Grand Lake.

<u>Ortho-phosphate</u>
Ortho-Phosphate values ranged from 0.00- 1.40 mg/l with an average of 0.09 mg/l and a median of 0.00 mg/l (n=60). Trend analysis for ortho-phosphate showed no significant trend, however by splitting the data set in half, data from September 1993 through December of 1996 had a significant decreasing trend. Again, lack of data for recent years likely resulted in lack of significance for the eight-year data set. Figure 24 shows average ortho-phosphate concentrations plotted over time. There is one outlier of the complete dataset, the last point collected. Future data will help identify if this should be a concern, or just an unusual point.

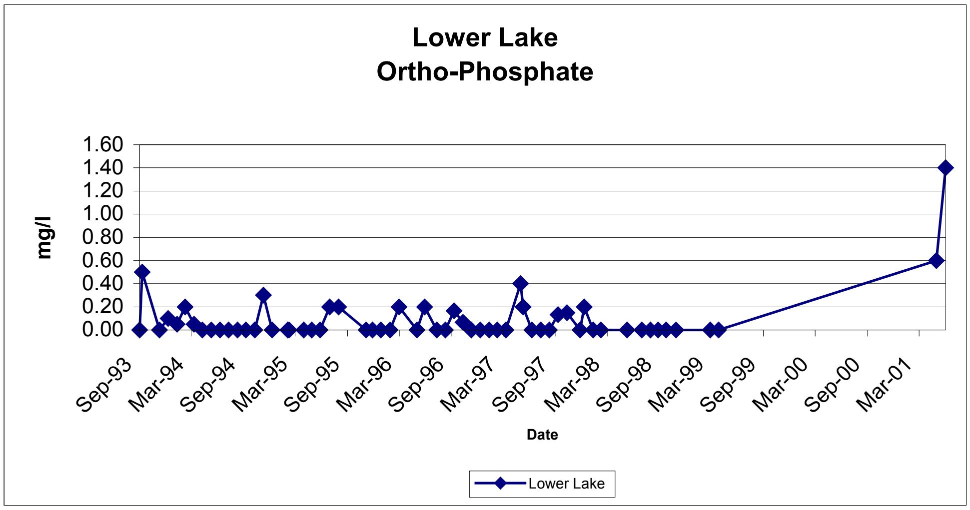
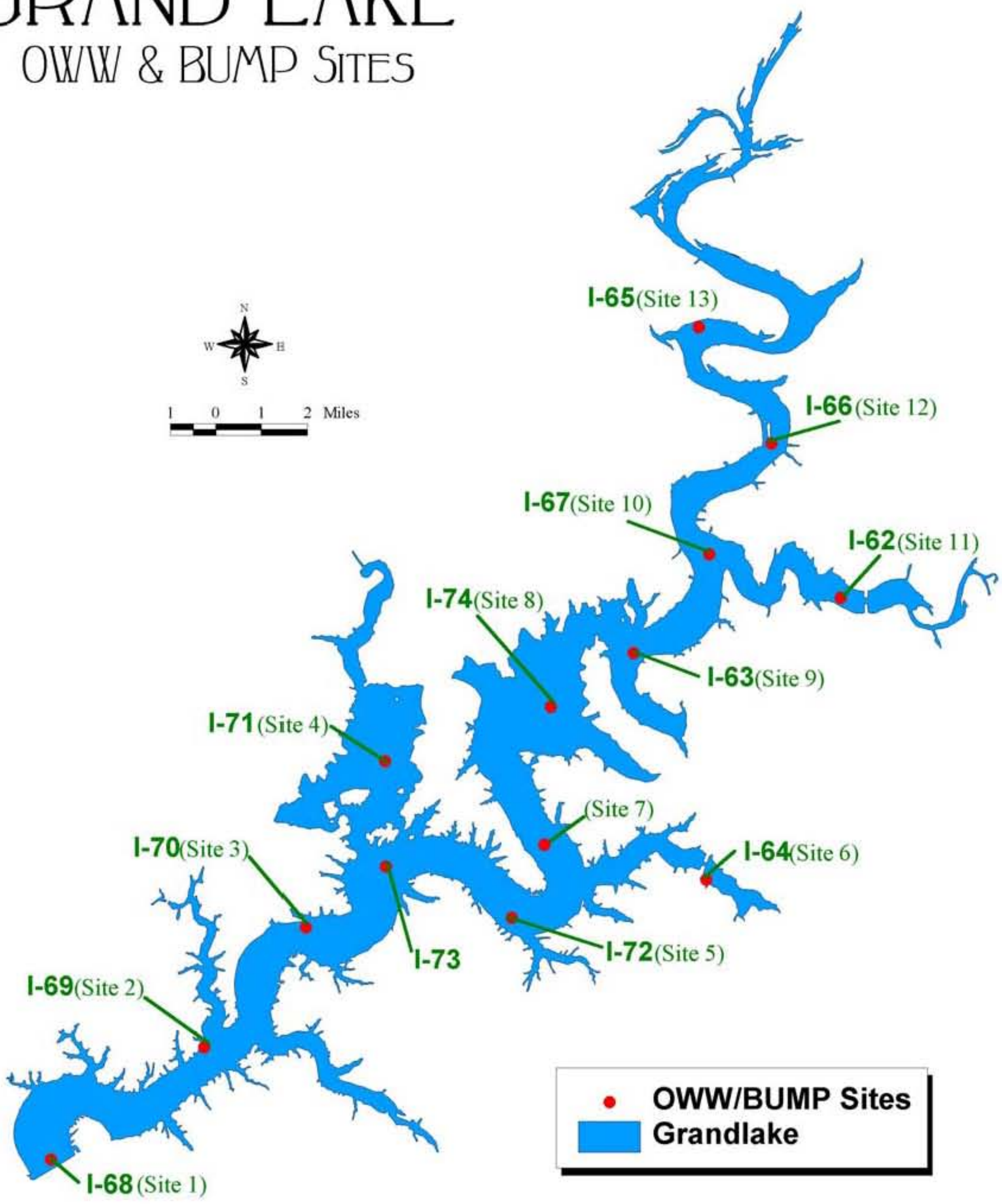


Figure 24. Ortho-Phosphate concentrations for Lower Grand Lake.

GRAND LAKE
OWW & BUMP SITES



In-Lake Sampling

Several monitors sample in the main channel of the reservoir at the same (or close to) sites the OWRB samples in the Beneficial Use Monitoring Program (BUMP). The figure on the previous page shows the location of the In-Lake sites monitored by both OWW monitors and the OWRB. In-lake sampling began in the spring/ summer of 2000. Again, one of the benefits of volunteer monitoring allows for data collection to occur consistently, and to fill data gaps in the absence of water quality professionals. At the time of this report, about half of the BUMP sites are being monitored by volunteers, and since 2001, more of these BUMP sites have been added to the In-Lake sampling regime.

In-lake sampling differs from shoreline sampling due to the use of special instrumentation and equipment. Volunteers use a Hydrolab® Multiparameter Sonde unit, a VanDorn (bottom sampler), Hach nutrient tests, and a Secchi disk. The Hach nutrient tests are performed identically to shoreline testing procedures however in addition to the surface sample they also test a sample collected, using the VanDorn, one-half meter off the bottom of the lake. The Hydrolab® electronically reads temperature, pH, dissolved oxygen, specific conductance, and ORP, or oxidation-reduction potential. To use the Hydrolab®, the monitor begins at the water surface (or 0 meters) then lowers the unit down the water column, recording data every one meter, until they reach the bottom. This information allows the OWRB to document thermal stratification, changes in pH, anoxic conditions, conductivity, and if reducing conditions are present. For purposes of this report each site will be discussed individually. WQS applies only when sample sizes of 20 or more are present. However inferences will made to what the standard is and how the data compares.

<u>Site I-68</u>
Site I-68, located at the dam is the deepest part of the lake. This site typically was 29 to 31 meters in depth depending on lake levels. This site was monitored nine times beginning in July of 2000 through June 2001. The first sample event in July of 2000 the Hydrolab® cable was not long enough to reach the bottom, therefore some assumptions were made for data under 14 meters. Subsequent sampling events however, had adequate cable length.

At this site thermal stratification was present in September of 2000, two sample events occurred during this month, at the beginning and at the end, both were stratified between 14-15 meters and 23-24 meters, respectively. It is common to see the stratified layer drop in the water column throughout the summer as warmer surface temperatures penetrate. The next summer in June (2001), data showed that thermal stratification was beginning to set up with a three degree temperature drop between 20 and 21 meters. This was the last sample event used in this report, however it can be assumed stratification was present throughout the summer. The lake was anoxic in the bottom during the summer months, however, anoxic conditions did not reflect thermal stratification. In other words, the lake became anoxic when stratification may or may not have been present. In July and September of 2000, 60% of the water column was anoxic with less than 2 mg/l of D.O. In WQS, if 50 – 70% of the water column is less than 2 mg/l then the FWP beneficial use is partially supported ($n \geq 20$). Figure 25 graphically shows D.O., temperature and depth relationships. The lake was still anoxic in November 2000 in 17% of the water column, although not a concern to WQS, it is unusual for D.O. to be so low when temperatures are cooling and the lake was completely mixed. Anoxic conditions were not present during late winter and the spring of 2001.

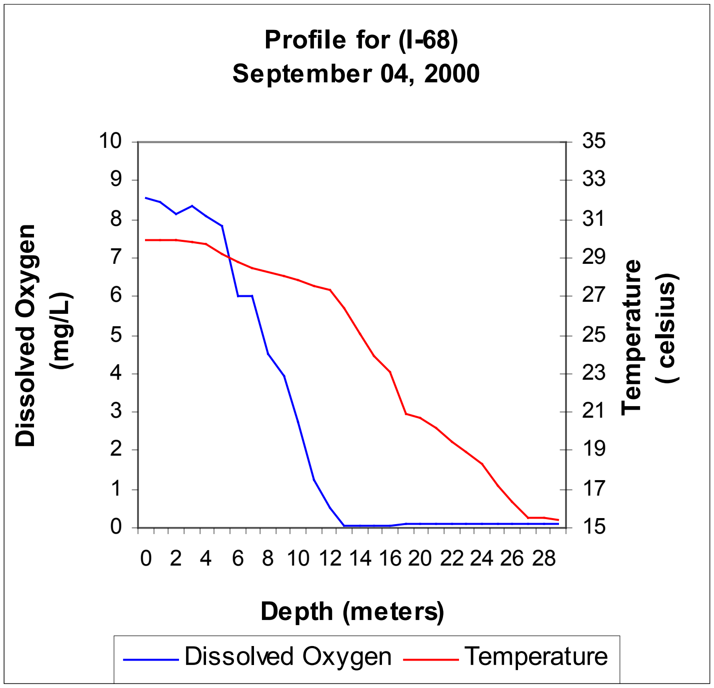


Figure 25. Dissolved oxygen and temperature vertical profile at the dam.

During July of 2000, pH values were higher than WQS screening criteria of 6.5 – 9 s.u. Thirty-three percent of the water column was above 9 s.u. Again, there is insufficient sample numbers to compare to WQS, but for this site at this time pH could be a concern. Elevated pH are likely the result of photosynthetic activity in the surface waters removing carbon dioxide (CO_2) and converting it to carbonate ($CO_3^{=}$) (Cole, 1983).

Nutrients were collected eight of the nine sample events. Surface ortho-phosphates ranged from 0.0- 0.8mg/l, (n=8), nitrates ranged from 0.0 – 0.94mg/l (n=8), and ammonia was not detected. Chlorophyll-a ranged from 5.5- 6.9 mg/m^3, (n= 2) and would classify the lake as mesotrophic (Wetzel, 1983) during this sample event. During two of the three stratified events, nutrient concentrations were higher in the hypolimnion. Not only does stratification assist in keeping the constituents in the specific layers of the reservoir, but anoxia in the bottom strata results in releases of phosphates from the bottom sediments. The consequence of excessive ortho-phosphates in the hypolimnion is that during fall turnover they become available to the upper layer of the lake (epilimnion) and productivity at the lake surface can increase.

<u>Site I-73</u>
Site I-73, located in the main channel just below Horse Creek Cove, was sampled twice in August and September 2001. This site is approximately 14-15 meters in depth. Nutrients and chlorophyll were monitored at both sampling events. For the August sample, the Hydrolab® data poses a concern because after review of calibration records it appeart the D.O. probe was out of calibration. Therefore there will be no discussion on D.O. at this site. The same results appeared at Site 1-64, same instrument and same sample day.

Thermal stratification was present in both August (between11 and 12 meters) and September (between 13, 14, and 15 meters). D.O. levels in September were relatively normal with anoxia beginning at 9 meters, with 56% of the water column anoxic. Figure 26 shows the D.O., temperature and depth relationship for the September sample event. In August 87% of the water column pH values exceeded WQS criteria. Usually this is representative of increased photosynthesis, which should be reflected in high D.O. concentrations, however this is the site where the D.O. readings are extremely low. pH values were also elevated in September in the top 5 meters, or 31% of the water column. Again, although WQS were not directly applied to these samples, these samples would cause a concern for pH.

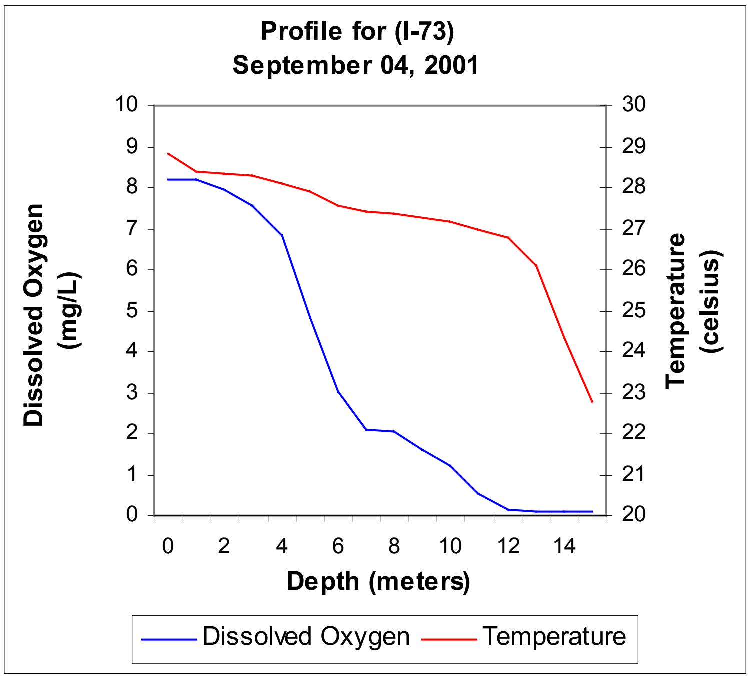


Figure 26. Dissolved oxygen and temperature vertical profiles below Horse Creek Cove.

Ortho-phosphate was detected at the surface in August of 0.02 mg/l. No other surface nutrients were detected. Ortho-phosphate and ammonia were detected in the hypolimnion, again not uncommon in stratified, anoxic reservoirs. The one chlorophyll-a concentration, collected in September was 15.76 mg/m^3 which classifies this site as eutrophic (Wetzels, 1983).

<u>Site I-64</u>

Site I-64, located in Honey Creek Cove was sampled twice, August and September of 2001. Like Site I-73, the same Hydrolab® instrument was used in August (same day), thus the D.O. results for that sample event will not be discussed. The approximate depth for this site is between 5 and 6 meters. Thermal stratification did not occur during either sample event. This is common in shallow riverine zones of reservoirs. Anoxic conditions were present below 4 meters, or 33% of the water column in September. Figure 27 shows D.O., temperature and depth relationship for the sample event. In August, pH values exceeded WQS of 9 s.u. in 100% of the water column. pH values in September were within WQS's. Again, August data is in question for its quality and more investigation should be made to accurately reflect if D.O. was depleted at this time, and if pH might have been altered too.

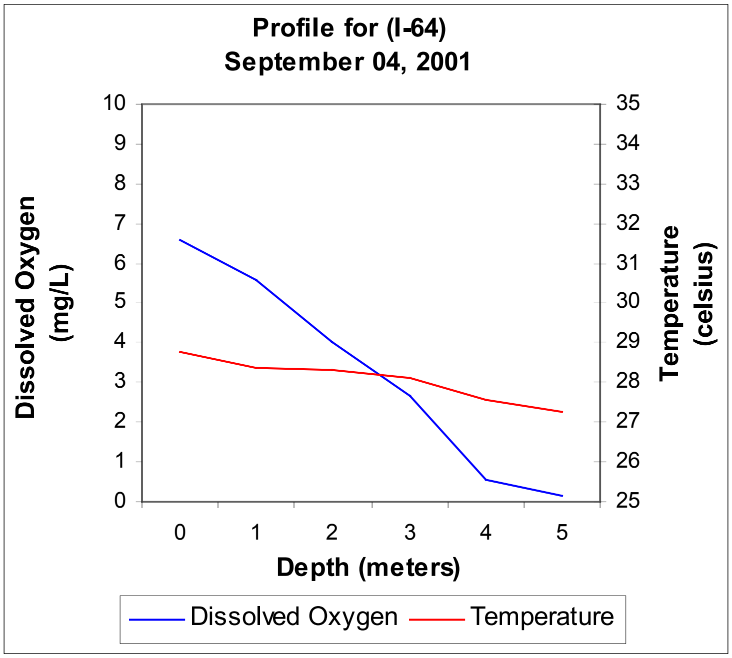


Figure 27. Dissolved oxygen and temperature vertical profile in Honey Creek Cove.

No nutrient data was available however chlorophyll-a samples were collected. The chlorophyll-a concentration was 28.79 mg/m^3, which is relatively high according to Wetzel (1983), classifying the lake as hypereutrophic for that one sample event.

<u>Site I-63</u>

Site I-63 is located in the main channel east of Sailboat bridge and was sampled seven times beginning in August 2000. This site is approximately 15 to 16 meters in depth. Thermal stratification was present in October of 2000 at the surface (0-1 meter), June and July of 2001, between 4 and 5 meters, and 5 and 6 meters, respectively. The lake was anoxic below 9 meters, or 44% of the water column during August of 2000, below 9 meters, or 18% in June 2001, and below 6 meters, or 45% in July 2001. The low D.O. in July also coincided with thermal stratification. Figure 28 shows D.O., temperature and depth relationship for July of 2001. Elevated pH did occur in both August of 2000 (12% of water column) and June 2001 (37%).

Nutrient data was collected four times. Three of the four samples for ortho-phosphate were no detects. For the one sample collected in June of 2001, the epilimnion ortho-phosphate concentration was 0.1 mg/l, and the hypolimnion concentration was higher at 0.17 mg/l. The lake was stratified and anoxic at this time. Nitrates ranged from 0- 0.3 mg/l (n=4) at the surface, and hypolimnetic samples exceeded surface concentrations. Ammonia was only detected once in October of 2000, and homogenous throughout the water column. Chlorophyll-a was collected four times, and ranged from 7.3- 28.1 mg/m^3 (n=4). Three of the four chlorophyll samples would classify the lake as hypereutrophic (Wetzel, 1983). These three samples were collected during the late summer during peak growing conditions when it is not uncommon to find elevated levels of chlorophyll-a.

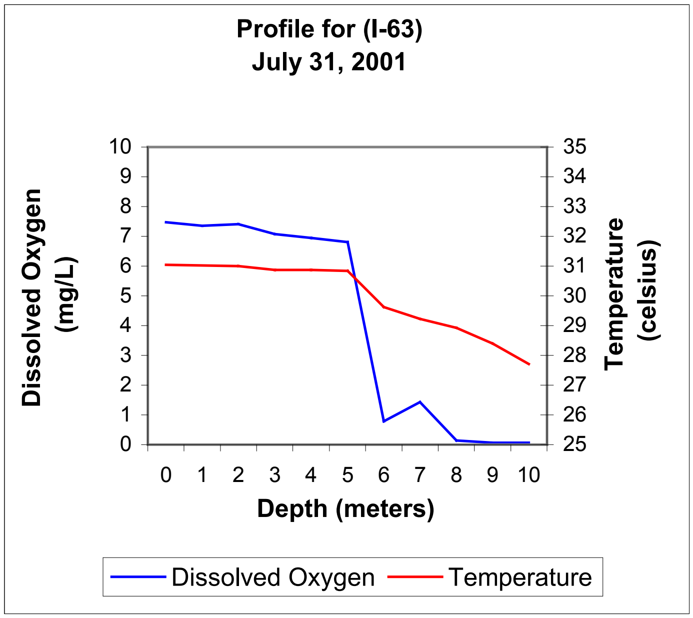


Figure 28. Dissolved oxygen and temperature vertical profile for the main channel east of Sailboat Bridge.

<u>Site I-62</u>

Site I-62 is located in Elk River Cove, and was sampled six times beginning in July of 2000 through July of 2001. This site was typically 5 to 8 meters deep, depending on lake levels. Thermal stratification was present only once in June of 2001 between 5 and 6 meters; again in shallow, riverine areas of a reservoir the water column tends to remain mixed. Anoxic conditions were present the summer months of August 2000 below 4 meters, or 50% of the water column, June of 2001 below 6 meters, or 14%, and July of 2001, below 7 meters, or 25%. The June 2001 sample event was both anoxic and stratified. Figure 29 shows D.O., temperature and depth relationships for this site. July of 2000 and August of 2000 sampling events both experienced high pH levels, or greater than 9 s.u. in the epilimnion, 67% and 50%, respectively.

Nutrients were collected at all six sampling events. Surface ortho-phosphates ranged from 0.03- 0.60 mg/l (n=6), nitrates ranged from 0- 0.2 mg/l (n=6) and all surface ammonia concentrations were 0 mg/l however bottom ammonia concentrations were detected in the summer months ranging from 0- 0.4 mg/l (n=6). For ortho-phosphates and nitrates, all sample events detected higher concentrations in the hypolimnion, again, which is not uncommon for anoxic reservoirs. One chlorophyll-a sample was collected in July of 2001 and was 0.9 mg/m^3 . This value is unusually low considering surface nutrients and summer growing season. According to Wetzel (1983) this value indicates low productivity, or oligotrophy. In this case, turbidity data would be helpful to determine if productivity was being limited by light attenuation.

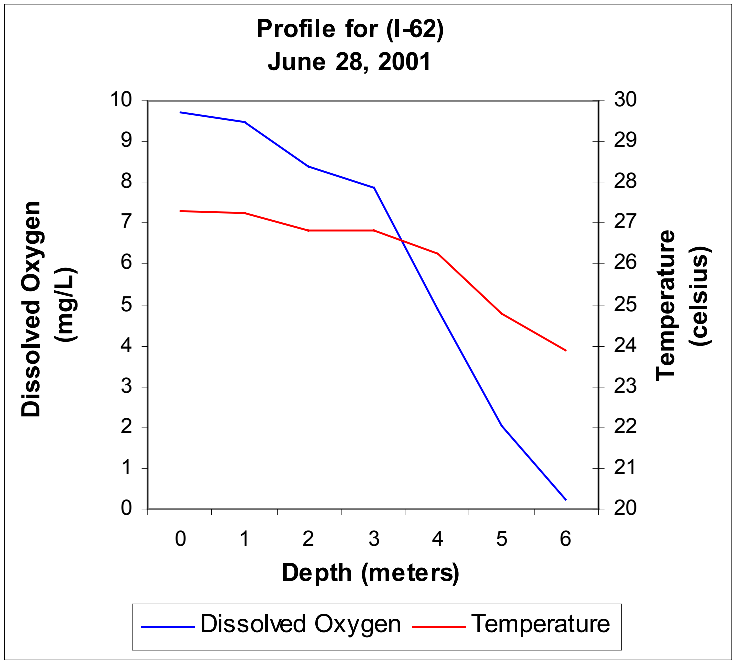


Figure 29. Dissolved oxygen and temperature vertical profile for Elk River Cove.

I-67
Site I-67 is located in the main channel of the reservoir just above the confluence of Elk River. This site has been sampled seven times, beginning in August of 2000 through September of 2001. This site is approximately 8 to 10 meters deep. Thermal stratification did occur in the summer months of May 2001, June 2001 and September 2001. Stratification occurred between 7 and 8 meters, 4 and 5 meters, then at the surface (0 to 1 meter) for each month, respectively. Anoxic conditions occurred during the summer months of August 2000, at 7 meters (or 22% of the water column), May of 2001 at 9 meters (or 22%), June 2001 at 5 meters (or 45%) and July 2001 at 7 meters (or 30%). Figure 30 shows D.O., temperature and depth relationships for this site. Elevated pH levels were detected in both the August of 2000 and June of 2001 sample events. In August 22% of the water column was above the WQS of 9 s.u and the June 2001 sample, 36% were above WQS. Also, D.O. levels were high at the surface when elevated pH’s were present. This may be an indicator of excessive photosynthesis adding oxygen and elevating pH.

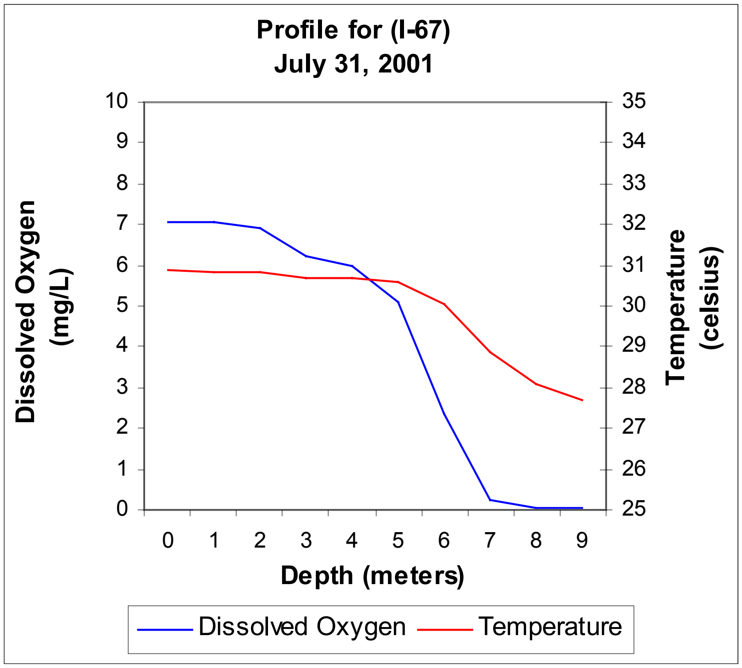


Figure 30. Dissolved oxygen and temperature vertical profile for upper end of Grand Lake.

Nutrients were collected five times at this site. Surface ortho-phosphate concentrations ranged from 0.02- 0.5 mg/l (n=4), nitrates ranged from 0- 0.18 mg/l (n= 5), and ammonia was only detected once at 0.05 mg/l in October of 2000. Hypolimnetic samples for ortho-phosphate were higher during anoxic conditions, however for nitrates only August of 2000 bottom sample exceeded the surface. Chlorophyll-a concentrations ranged from 12.6- 34.3 mg/m^3 (n=3). Based on Wetzel's (1983) two samples were high and would classify this site as hypereutrophic.

<u>Summary</u>

For In-lake sampling using the Hydrolab®, thirty-three sample events took place on six sites throughout the lake. Thermal stratification occurred during the late summer months at all sites except in Honey Creek Cove and Elk River Cove. These two sites are shallow and riverine, where flow and wind mixing assist in keeping the water column mixed, preventing stratification. All sites experienced anoxic conditions in the hypolimnion, with five samples only partially support the FWP beneficial use, with 50 – 70% of the water column less than 2 mg/l D.O. The FWP beneficial use was deemed partially supported for pH with 11% of the sample concentrations greater the 9.00 s.u. The BUMP 2001 data report also found Grand Lake as partially supporting the FWP beneficial use with D.O., however this report did not detect elevated pH.

For nutrient data, hypolimnetic sample concentrations exceeded surface samples during anoxic conditions. Anoxia commonly causes releases of phosphates from bottom sediments, therefore potential phosphate sources may be associated with sediment (phosphorus bound sediments) runoff entering the lake and settling to the bottom. Higher bottom concentrations pose a threat for algal blooms during fall turnonver when these nutrients become readily available for productivity. Sixteen chlorophyll-a samples were collected. For chlorophyll-a analysis the OWRB uses annual averages all concentrations to calculate a TSI value to determine the status of the reservoir. For the volunteer data set, the calculated TSI is 58, or eutrophic. USAP states a minimum of 20 samples must be used to determine that average. Additionally the majority of the data was collected during the peak growing season or summer months. To get an accurate representation the data needs to be evenly distributed throughout the year. However, the TSI reported in the 2001 BUMP report for Grand Lake was 59, also eutrophic. The similiarity between these two values lends credit to the OWW program, and indicates Grand Lake is somewhat consistently eutrophic.

River Data

Volunteers have collected data from the rivers and streams that flow into Grand Lake since 1993. Like the lake sites, river sites have been retired, moved, and newly added. For analysis purposes sites, located on the same river, were compared statistically to one another to see if one site is significantly different. If differences were detected then plotted to see which site had the higher or lower concentration. Although this information is interesting, some statistical tests may give false positives or false negatives based on differences in sample sizes and years sampled. For example, high (or low) concentrations may have a tendency to "stand out" in a data set of five samples versus a data set of thirty. So again, analysis for significance may be questionable, and one should take note of sample size when making assumptions.

<u>Neosho River</u>
Figure 31 shows the OWW sites along the Neosho River. Site 60 was monitored five times for nutrients from January of 2000 through October of 2000. Site 23, located in-lake where the Neosho River joins Grand Lake has been monitored thirty times since July of 1994 through October of 2001.

There was no significant difference in ortho-phosphates between the two sites, however there was a significant difference between nitrate and ammonia concentrations, where site 23 was higher. Again, comparing data with a large difference in sample size may produce questionable results.

<u>Spring River</u>
Figure 31 also shows the OWW sites along the Spring River. These sites include site 61, located near the town of Quapaw. This site was monitored from August of 1999 through March 2000. No nutrients were collected at this site; therefore no nutrient discussion will occur. Site 1B was monitored from February of 1995 through August of 1997, and also lacked nutrient data. Site 72 is located just north of Twin Bridges on Spring River. This site was monitored beginning in January of 2000 through August of 2001. Nutrients have been collected at this site consistently throughout the sampling period. Lastly, site 22 is located in Grand Lake where Spring River enters the lake. This site has been monitored since July of 1994 through present. Over 40 data points have been collected from this one site alone, therefore trends analysis was also performed to determine if nutrients have increased or decreased since sampling began. Another benefit of volunteer monitoring is the quantity of data that can be collected so these types of analyses can be performed.

Site 22 was significantly higher in nitrates and ammonia than site 72. Sample sizes are dramatically different and may play a role in these differences. There was no difference in ortho-phosphate concentrations, however ortho-phosphates were very high with averages over 0.25 mg/l at both sites. Trend analysis for nutrients at site 22 showed decreasing trends for both nitrates and ammonia, and no trend for ortho-phosphate.

GRAND LAKE "NEOSHO & SPRING RIVERS"

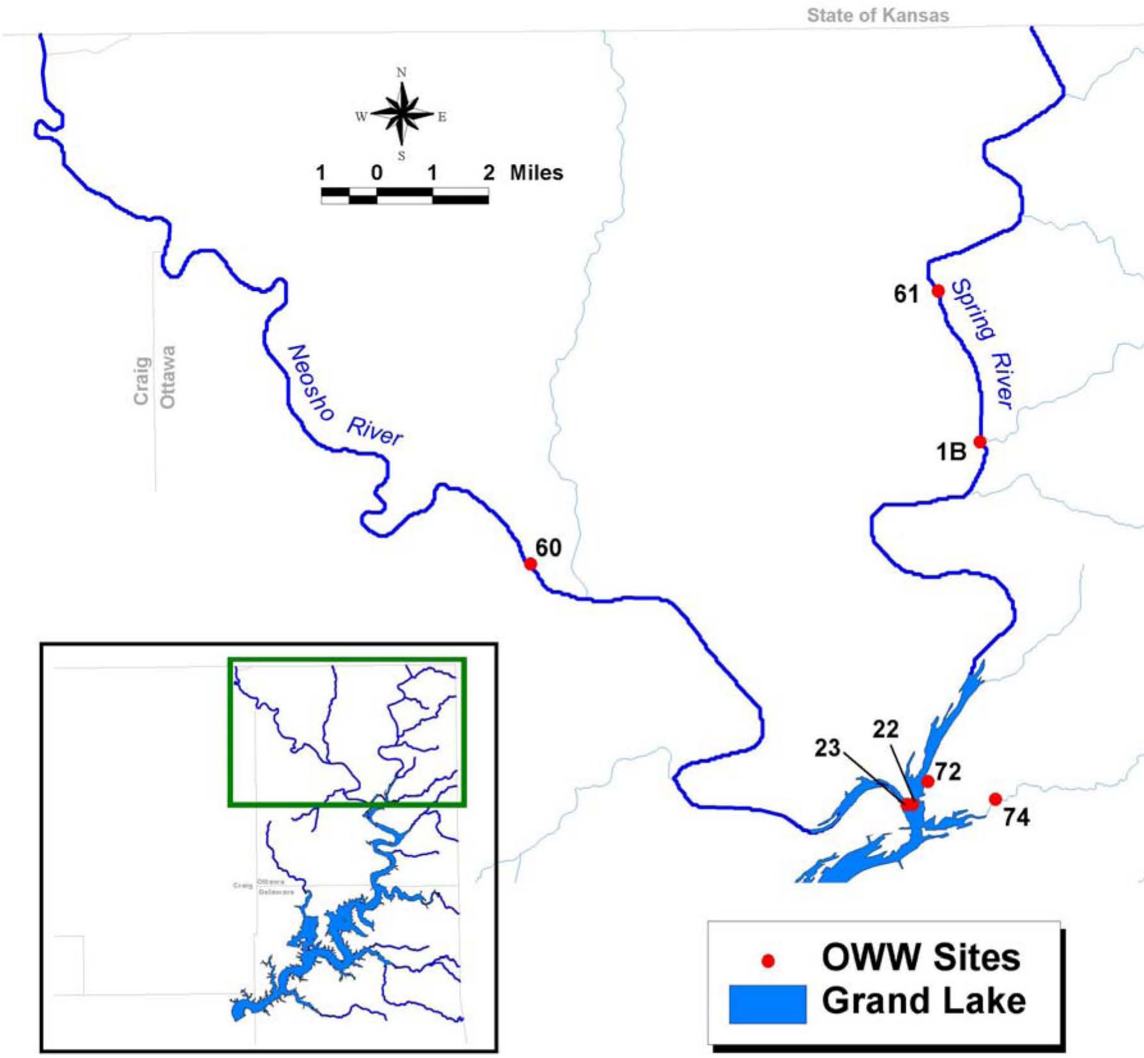


Figure 31. OWW sites on Neosho and Spring Rivers.

Lost Creek

There are four sites along Lost Creek. Site 24 is at the Missouri state line, and was added to the program in January of 1996, with nutrient testing beginning in December of 1996 through December of 2001. Site 71 was sampled from October of 1999 through April of 2001. Site 50 was sampled from July of 1997 through September of 1999, and site 74 was sampled from October of 1999 through September of 2001. Sites 24 and 50 had similar sample sizes of n= 31 and n= 24, respectively, while sites 71 and 74 were similar with n=6 and n=12, respectively. Figure 32 shows these site locations along the creek.

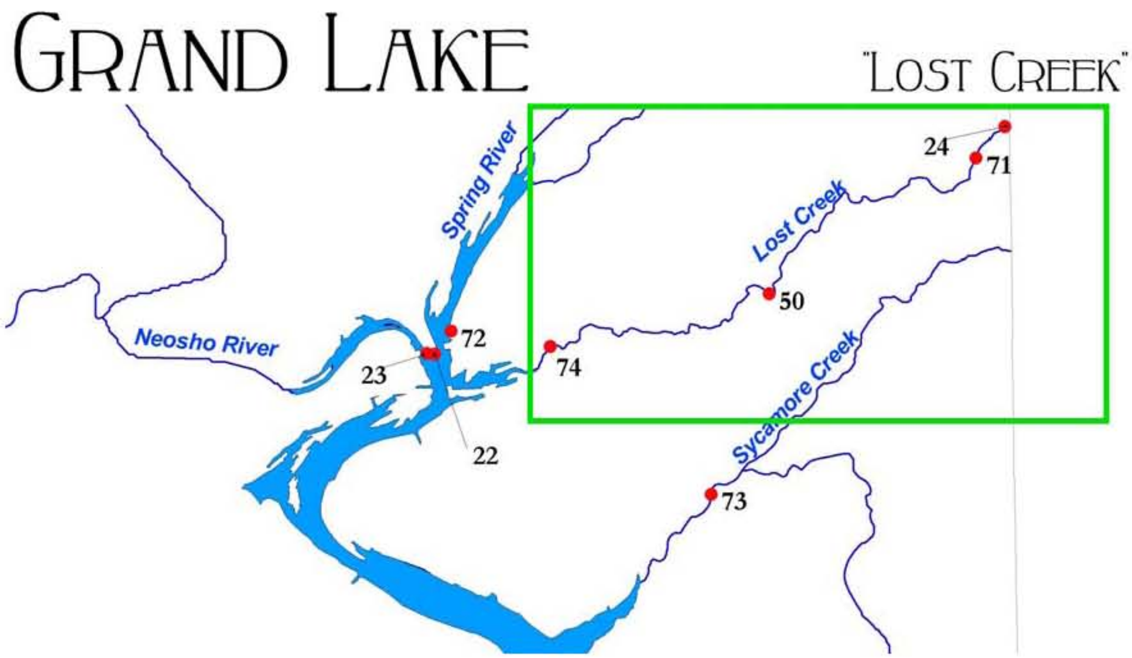


Figure 32. OWW sites along Lost Creek.

There were no significant differences between sites 71 and 74 for any of the nutrients. There were also no significant differences for nitrates or ammonia at sites 24 and 50, however, ortho-phosphates were significantly higher at site 50 than 24. The following Box and Whisker plots graphically show nitrate and ortho-phosphate data sets for Lost Creek (Figure 33 and Figure 34). The box represents the middle 50% of the data and the whiskers represent the upper and lower 25%. The “+” is the average, while the horizontal bar is the median. These plots are provided for comparison of the data sets to one another along Lost Creek.

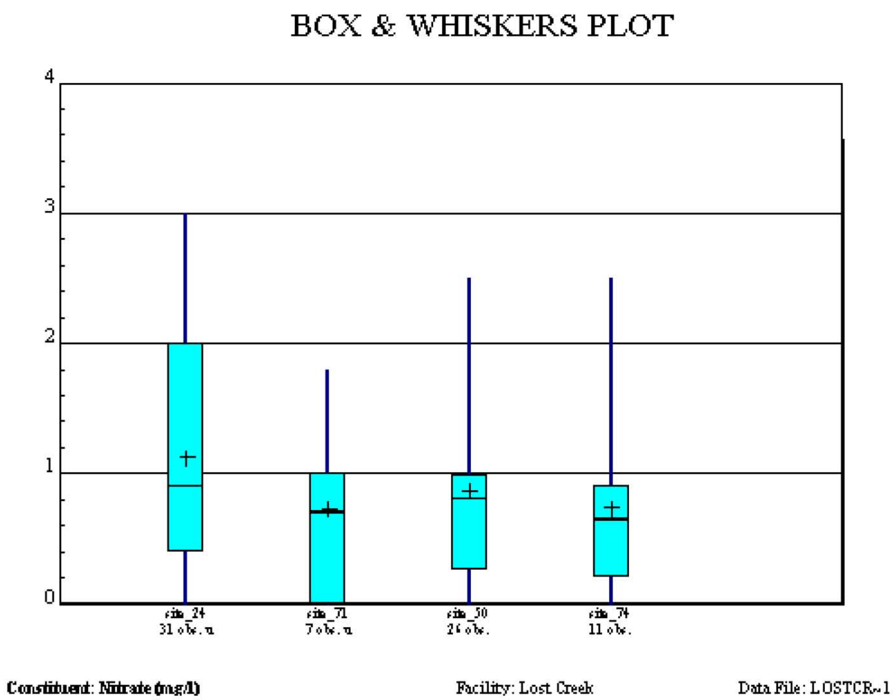


Figure 33. Nitrate concentrations for Lost Creek.

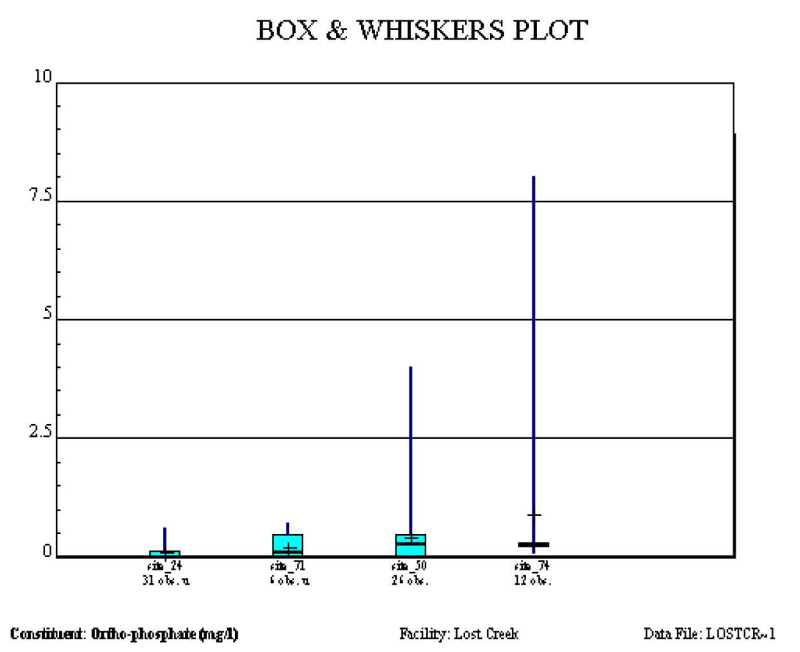


Figure 34. Ortho-phosphate concentrations for Lost Creek.

Honey Creek

There are six sites along Honey Creek, however data collection from these sites has been sporadic and inconsistent through the years. No data has been collected since August of 1999. Figure 35 shows OWW sites along Honey Creek. Site 31, on the Missouri State line was sampled from November 1996 through August 1997, and no nutrient data was collected. Site 29, just below the confluence of Cave Springs Branch was sampled for nutrients from August of 1997 through September of 1999 (n=12). Site 53 is downstream of 29 and was sampled from April of 1997 through August 1999 (n=10). Site 17 is on a small tributary and feeds into Honey Creek at Site 53. This site was sampled for nutrients from December of 1993 through June of 1996 (n=9). Site 54 is downstream of 53, and was sampled for nutrients from July of 1997 through April of 1999 (n= 9). Farthest downstream and nearest the lake, site 55 was sampled from June of 1997 through June of 1999 (n=16). There was insufficient data for analysis at site 13B on Cave Springs Branch.

All of these sample sizes are relatively small for statistical analyses to be performed. However, for discussion purposes, analysis of variance did show site 29 to be higher in nitrates and ortho-phosphates than downstream at site 53. Site 53 was higher in nitrates than just upstream in the tributary at site 17. Site 53 was also higher in nitrates than just downstream at site 54. On the other hand, site 55, downstream of 54, was higher in nitrates and ortho-phosphates than upstream sites 53 and 54. It may be important to note that there was questionable data quality at sites 55 and 29, and these two sites were significantly higher for all nutrients than other sites in the creek. The following Box and Whisker plots graphically represent nitrate and ortho-phosphate data (Figure 36 and Figure 37). These plots identify the higher concentrations detected at sites 29 and 55.

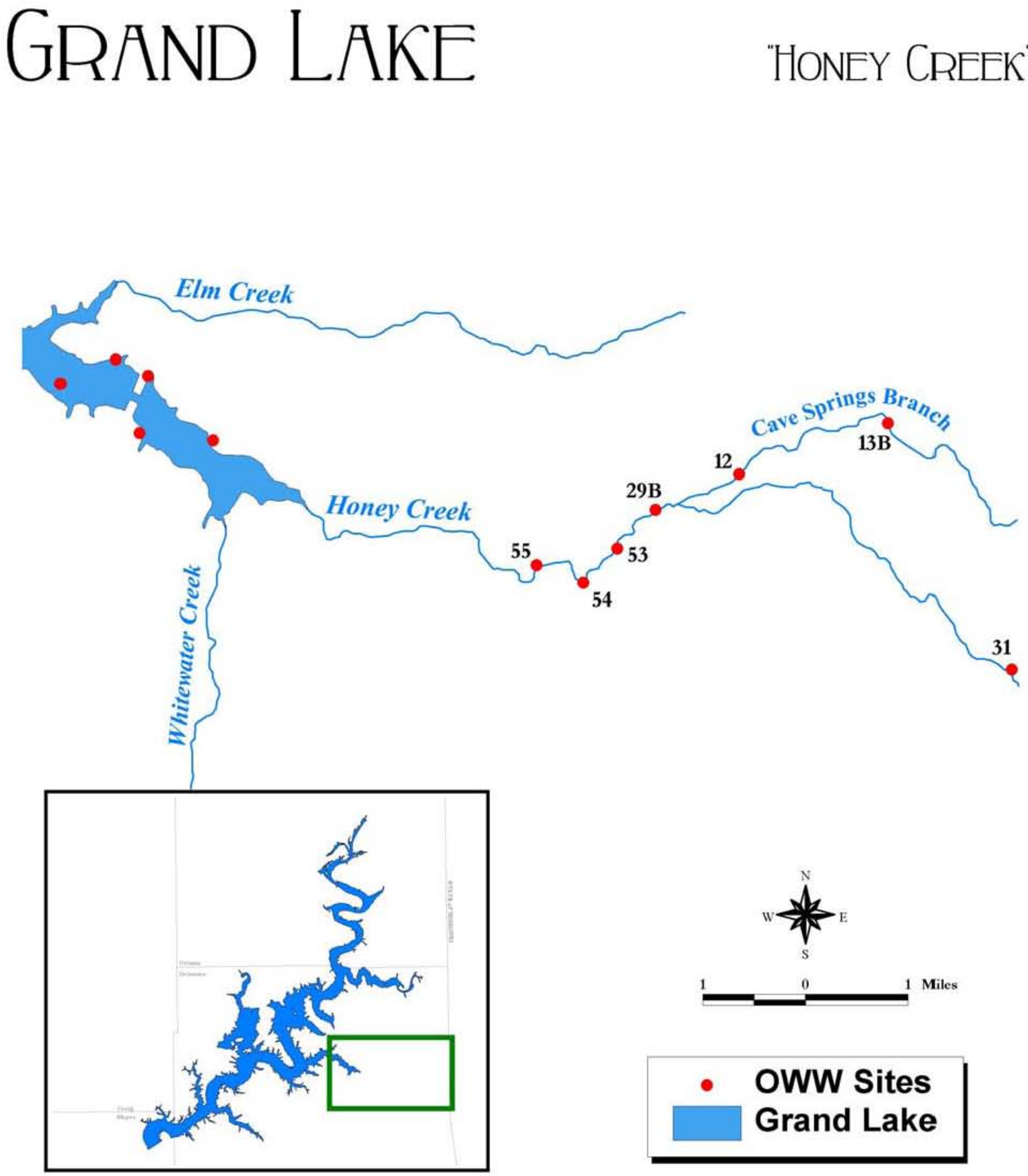


Figure 35. OWW sites along Honey Creek.

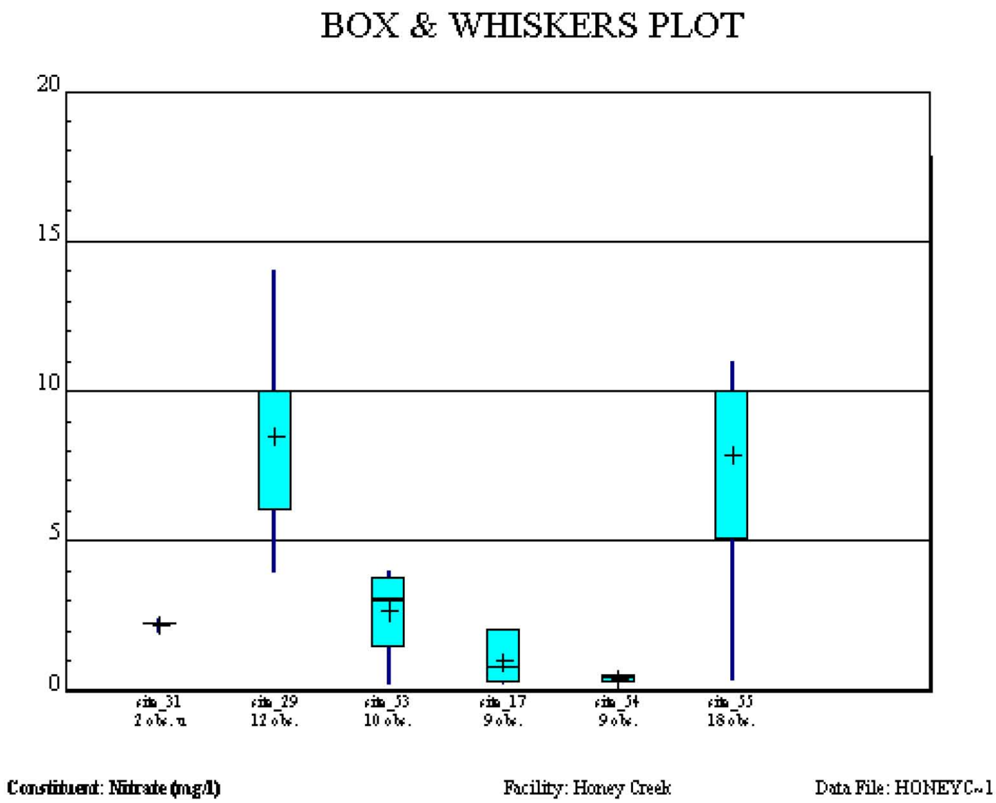


Figure 36. Nitrate concentrations in Honey Creek.

Figure 37. Ortho-phosphate concentrations in Honey Creek.

Summary

The Neosho River has insufficient data to make assumptions of nutrients entering the lake from this source. Spring River, at the point it enters the lake, is carrying high concentrations of ortho-phosphates. Also, this site is richer in nitrates and ammonia than just upstream. This may be the result of reduced flow, therefore accumulation of these nutrients as the river widens and enters the lake may be occurring. For Lost Creek, sites 71 and 74 data sets may be too small to determine any significant differences. However for sites 24 and 50, it appears that ortho-phosphates are increasing as the creek flows towards the lake. Nitrates and ammonia are not changing downstream. Honey Creek data is difficult to assess, although statistics show that sites 29 and 55 are higher in concentration that other sites, this is not representative of accumulation of nutrients related to downstream flow. Additionally, there is reason to question the data generated at these sites. Also, sample sizes were relatively small and inconsistent. Professional data should be referenced before conclusions on Honey Creek water quality can be made.

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