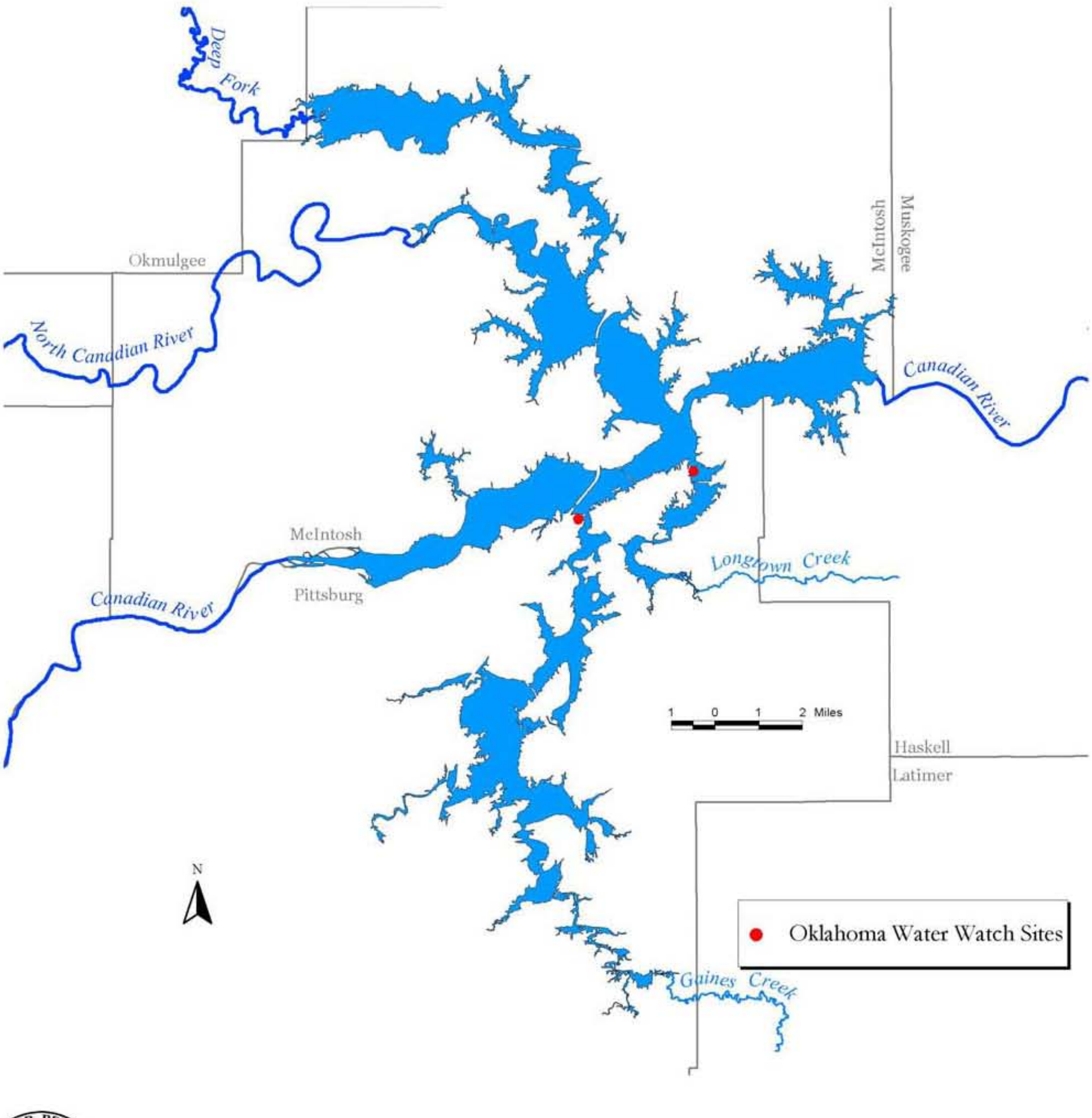
OKLAHOMA WATER WATCH

EUFAULA HIGH SCHOOL CHAPTER

DRAFT 1997 - 2002 DATA SUMMARY



STATE OF OKLAHOMA
WATER RESOURCES BOARD

Executive Summary

The Eufaula High School volunteer monitoring group was founded in 1997 by Keith Wood to monitor Lake Eufaula as a supplemental learning experience for his Biology class. Mr. Wood, and students monitor two sites once a month. Site 8 is located on a dock, on the west bank of the lake just north of Highway 9 bridge over Longtown Creek. Site 12 is located on a private dock in a cove on the west bank of the Gaines Creek arm. Approximately 54 basic parameter data sheets and 45 advanced parameter data sheets have been submitted to the Oklahoma Water Watch Program since volunteer monitoring began at Lake Eufaula in 1997. All data submitted was used in the generation of this report.

Overall, dissolved oxygen levels and pH are within Oklahoma's Water Quality Standards and appear to be of no concern to beneficial uses. There is no significant trend in Secchi disk depth at either site, however Site 8 average disk depth is twice the average depth at Site 12, thus Site 8, Longtown Creek has better water clarity than Site 12, or Gaines Creek. Over the five-year data set nutrients are relatively low. Both sites are experiencing increasing trends in ortho-phosphate and decreasing trends in ammonia nitrogen. Nitrates have remained consistent throughout the five-year sample period at both sites.

The benefit of a Volunteer Monitoring Program is that citizens who live, work, and recreate near a water resource, ie. lakes, reservoirs, streams, or wetlands, have the ability to visit a Site on a regular basis. Mr. Wood has a remarkable record of data collection. Very few months have been missed since the first data sheet was submitted in June of 1997. His efforts have created an excellent baseline data set for future studies. Lake Eufaula is a large reservoir and more volunteers like Mr. Wood could expand efforts for a holistic data set representing the entire lake. Oklahoma Water Watch Staff and the Oklahoma Water Resources Board express gratitude to Mr. Wood on his hard work, and greatly appreciate all he has done.

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Introduction

The Oklahoma Water Watch (OWW) Program was initiated in 1992 at Grand Lake, where the Grand Lake Association and a group of senior citizens became concerned with their lakes water quality. Since its inception there are currently seventeen active groups across the state from Broken Bow and Pine Creek Reservoirs in southeastern Oklahoma, to Lake Carl Etling in the far Northwest corner of the panhandle. OWW groups consist of individuals who monitor one or more lakes to teams of volunteers and school groups monitoring lakes, streams, and wetlands. This report provides basic limnology (or the study of fresh water) information for the general reader. It is important to understand what parameters are required by the OWW program and how they fit into water quality, reservoir health, and how the State of Oklahoma uses the information to manage its water resources. There is also a section in this report that explains the materials and methods the OWW program uses to collect data and ensure its quality. Other documents are available for detailed information on these subjects, however this information is provided for the general reader. For more information refer to the OWW Handbook (OWRB, 1998) and the OWW Quality Assurance Project Plan (OWRB, 1999). The final section in this report is the Data Summary. The Data Summary summarizes the data collected by the Lake Eufaula volunteers, compares to Water Quality Standards, if applicable, and provides relevant data collected by the OWRB for comparisons. For information regarding this report or the OWW program in general contact Juli Ridgway, OWW Program Coordinator at the Oklahoma Water Resources Board, 3800 N. Classen Boulevard, Oklahoma City, Oklahoma 73118, or email at jwridgway@owrb.state.ok.us.

The Eufaula High School volunteer monitoring group was founded in 1997 by Keith Wood to monitor Lake Eufaula as a supplemental learning experience for his Biology class. Mr. Wood selects student volunteers based on their interest in the program. Approximately fifteen students have passed through this group during their high school education. Mr. Wood believes in making participation in OWW a strictly voluntary activity for students. He feels this will provide truly interested students the best opportunity to benefit, along with providing OWW the highest quality data. Currently Mr. Wood's son, Christopher, assists in monthly data collections. Approximately 54 basic parameter data sheets, and 45 advanced parameter data sheets have been submitted to the Oklahoma Water Watch Program, and were used in the generation of this report. Keith Wood was nominated for the Classroom Teacher Award at the 2000 Oklahoma Environmental Educators Exposition and was also recently recognized at the OWW Anniversary Banquet, hosted by Grand Lake Association, for his five years of dedicated service to the OWW program.

Limnology 101

Data collected by volunteers consists primarily of the basic water quality parameters; air and water temperature, dissolved oxygen (D.O.), pH, color, and water clarity. Advanced parameters, add nutrients (ortho-phosphate, nitrate nitrogen, and ammonia nitrogen) to the basic parameter suite. Additional parameters volunteers can collect include water samples to perform filtration for chlorophyll-a analysis and turbidity, use of a mulitparameter sonde instrument to collect basic 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* because of the understandability for the public.

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 trap 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.

Oklahoma's Water Quality Standards and D.O.
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 the beneficial uses assigned to Lake Eufaula. 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 ≥4.0mg/l from June 16 through October 15 and ≥5.0mg/l throughout the remainder of the year. WQS for lakes is assessed slightly different. 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 Lake Eufaula.

Beneficial Use Assignments	
Lake Eufaula	Public and Private Water Supply Warm Water Aquatic Community Agriculture, Municipal and Industrial Process and Cooling Water Primary Body Contact Recreation Aesthetics

Water Temperature and Stratification
Temperature is also important in lake turnover and stratification. Deep reservoirs in Oklahoma 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, which is why ice floats.

During winter months in northern temperate lakes, the coolest lightest water (<4°C) is at the lakes surface while warmer, denser water (4°C) is at the bottom of the lake. In Oklahoma, water temperatures occasionally drop below 4°C. As the spring sun starts to warm up 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.

During the summer months, surface waters heat up more rapidly than the heat can be distributed throughout the water column therefore 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; epilimnion - surface layer, metalimnion - middle layer, and hypolimnion - bottom layer. 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 become more dense. As the heavier water begins to sink the layers begin to mix so that the circulation of cooler, heavier water produces a homothermous condition and fall turnover is underway. The problems associated with fall turnover result when nutrients trapped in the colder, deep layers of the reservoir, or hypolimnion, become available to the warmer surface waters in the photic zone, or the area where sunlight penetrates, resulting in unsightly algal blooms.

<u>pH and OWQS</u>

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 basic, or alkaline. The scale is logarithmic, thus there is a ten-fold change in acidity or alkalinity per 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 (or alkalinity), 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. Partially supported if 10–25% fall outside the screening interval, and not supported if >25% fall outside.

<u>Nutrients and Chlorophyll</u>

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 their 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.

Algae require many different nutrients to grow, of these nutrients, 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, be transported to streams and lakes. 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 do 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. However excessive amounts of algae can be detrimental to a lake or stream. Large growths of algae are know 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 low to no oxygen, or 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 monitors to test for is ammonia. Although no 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 concentrations may exceed 10mg/l (OWRB, 1998).

Secchi Disk Depth

Before discussing Trophic State Indices another factor that may affect productivity and is a measured parameter by volunteers 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 believed as his research vessel traveled around the Mediterranean Sea he discovered that 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 the lake water. Suspended materials in the lake, including both organic (algae) and inoganic (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.

Color

Color indicates the suspended solids in the water in addition to the dissolved substances that may alter the waters appearance. Oklahoma has WQS set for apparent color, however the OWW program does not measure color to this level of accuracy, therefore no WQS apply to OWW color parameter. The OWW program uses a Borger Color System booklet to match the water's surface color. 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

Again Oklahoma uses Carlson's TSI's for Chlorophyll to classify lakes in terms of trophic state or productivity. Carlson (1977) stated 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:

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

The resultant value from this equation can then be used to classify the lake as oligotrophic, mesotrophic, eutrophic, or hypereutrophic, definitions are below in Table 2. Oklahoma's WQS requires a minimum of 20 samples throughout the sample period, averaged to accurately calculate the TSI number. 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 and diving, 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 is the aging process a lake goes through when nutrients and algal growth increase over time. 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 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 to 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

[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.

dam, and typically has longer water residence time, lower concentrations of dissolved nutrients and suspended particles, and higher water transparency (deeper Secchi disk depths).

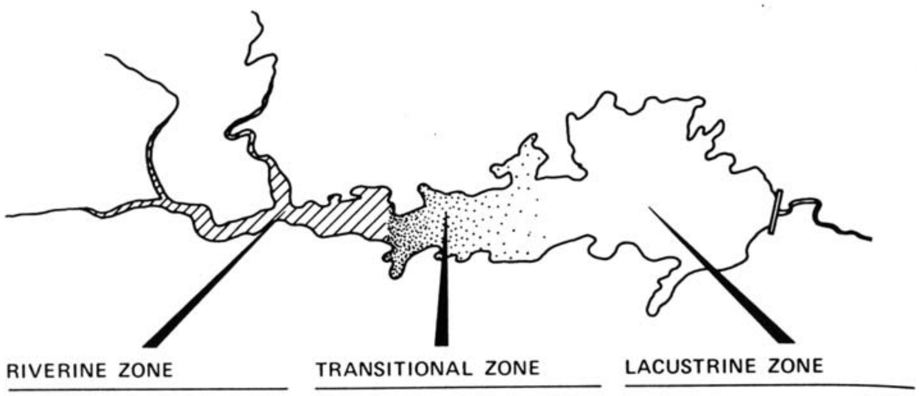


Figure 1. Longitudinal zonation that is typical in man-made lakes, or reservoirs.

Materials and Methods

<u>To Become a Monitor</u>

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 discusses the volunteer's monitoring objectives and expectations and work together to see that both the program's 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 Water Temperature	Dissolved Oxygen (mg/l) pH	Color Secchi Disk Depth
Advanced Parameters		
Ammonia Nitrogen	Nitrate Nitrogen	Ortho-phosphate
New Advanced Parameters		
Hydrolab- Vertical Profiles Turbidity		Chlorophyll-a sample collection and filtration

Water Quality Tests

The temperature, color, D.O., and pH tests are performed using LaMotte testing equipment. The Oklahoma Water Watch Handbook (1998) has detail procedures for each test. Air and water temperature is 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, which 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.

Chemical Test Limitations

Basic chemical parameters listed in Table 3 are performed using LaMotte chemical tests. For detailed information on test procedures please reference the OWW QAPP (OWRB, 1999) or the OWW Handbook (OWRB, 1999). 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 excellent screening tools to serve as an early warning system, which would 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 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, for Grand Lake Water Watch, possible ortho-phosphate contamination of the DI water used for DI blank samples were detected when DI blank values exceeded environmental samples resulting in negative orthophosphate concentrations 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

Lake Eufaula is the largest lake in Oklahoma based on surface acres. The lake is formed by an impoundment of several major river systems including the Deep Fork, North Canadian, and Canadian Rivers. From the south Gaines Creek enters the lake and is another significant contributor, although not as major as the above mentioned rivers. Due to the diverse nature of the different hydrologic systems forming Eufaula Lake the Lake has very different water quality in the different regions. For this report, OWW has one monitor that monitors two sites which represent two different arms of the reservoir; Gaines Creek and Longtown Creek. Each site was reported on independent of the other. Dissolved oxygen concentrations were plotted against water temperature and pH was plotted with WQS screening criteria. Statistical trends analysis was performed on nutrient and Secchi disk data to detect any positive or negative changes.

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.

For nutrient test results, any reported value of 0.00mg/l was used in average and median calculations and trend tests. Typically for laboratory analysis a report value of 0.00mg/l is not a “true” environmental value, and is therefore reported as “below detection limits”. However, for OWW reporting and the “gross” scale of the HACH tests, reported values of 0.00mg/l are common, and will be used in determining average concentrations.

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. A percentage of report values is provided as 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. Seasonal Kendall test for trends from WQStat Plus v. 1.5 for Windows software was used for these analyses. Only trends significant at the 95% confidence level are reported. For trend tests, sample size (n) should be greater than 40. Seasonality was not significant at either of the sites for any of the parameters. In other words, the data collected was independent of seasonal changes.

Quality Assurance/ Quality Control
The OWW program operates under an United States Environmental Protection Agency (USEPA) approved Quality Assurance Project Plan (OWRB, 1999). Each volunteer will be 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 re-certified annually before data will be accepted. Reliable volunteer collected data must be precise, accurate, complete, and comparable. The QCA's 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 and 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 monitors 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 involves that a minimum of 85% of all critical collected data to 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**.** The Eufaula High School OWW chapter was initiated in February of 1997. Since then, QCA sessions have been scheduled and attended regularly ensuring the reliability and validity of all data. 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

Variable	Range	Precision	Accuracy
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
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. DQO's are the reasons for the OWW program and intended uses of the data. Thus, the DQO's 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*

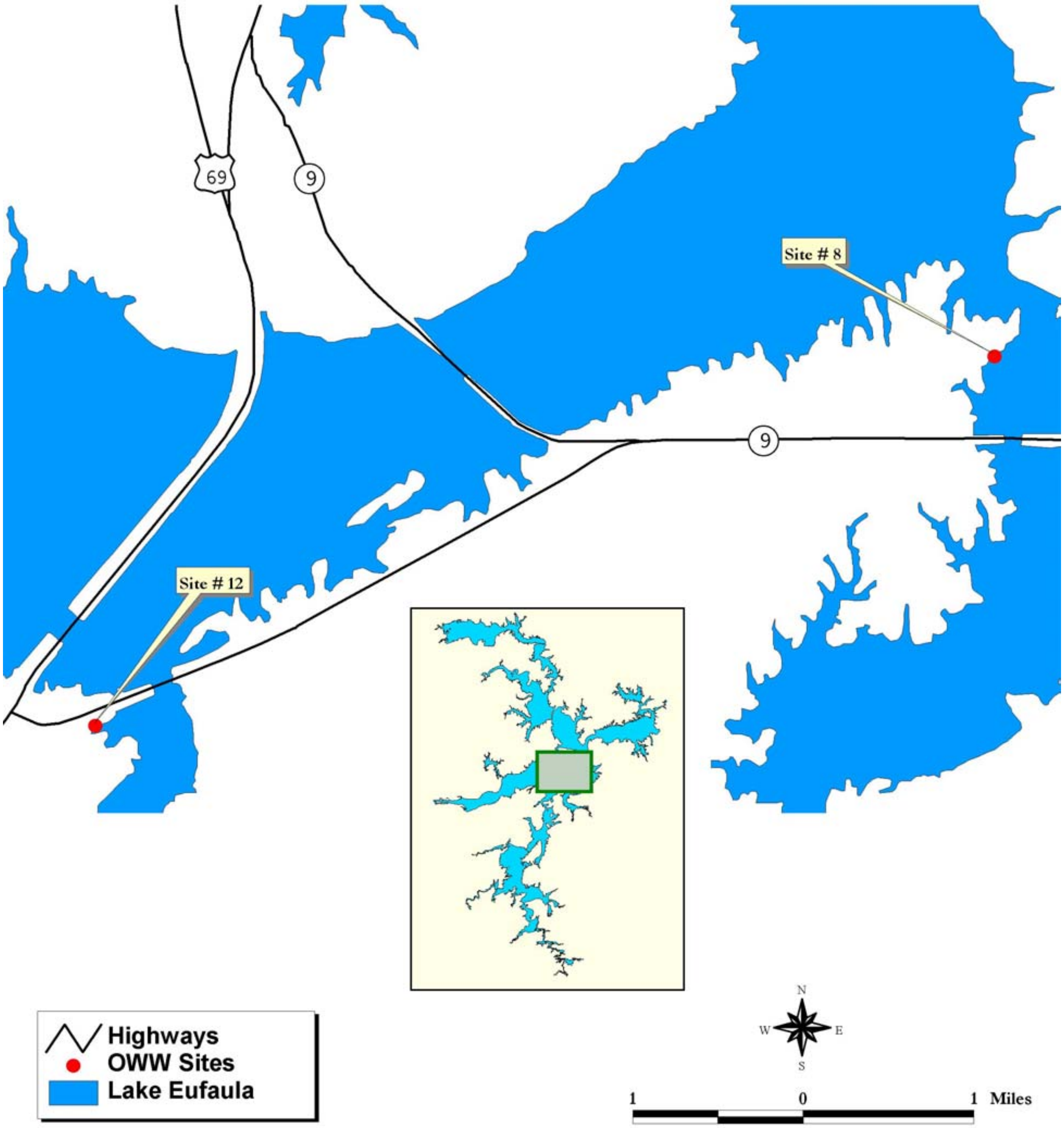
4. *Promotion of citizen participation in protecting, managing and restoring our water resources*

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

This 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 will serve 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.

Lake Eufaula

Eufaula High School Sites



Data Summary

Eufaula Lake has been sampled almost without fail on a monthly basis since June of 1997, with nearly 50 samples for all parameters (basic and advanced) at two sites, sites eight and twelve. The Figure on the previous page shows site locations. Site 8 is located on a dock, on the west bank just north of Highway 9 bridge over Longtown Creek. Site 8 corresponds with the BUMP Site 8, which is located just south of the bridge in the thalweg, or channel. Site 12 is located on a dock in a cove on the west bank of Gaines Creek, where Gaines Creek enters the main body of the reservoir. Site 12 also corresponds with the BUMP Site 12, which is located just south of the OWW Site 12, again in the thalweg, or channel. Both sites have five years of data with very few missed months. Volunteers that are able to consistently collect basic water quality data so trends may become documented and/or unusual data may be detected are the backbone of the OWW volunteer monitoring program. These volunteers' efforts are greatly appreciated.

Each site monitored is discussed individually in the following sections. Each site is representative of two distinctly different parts of the lake and should not be compared to one another under any circumstance. However, BUMP data may be used for comparison for each sites corresponding BUMP site, and has been reported for such use.

Site 8, Longtown Creek

<u>Secchi Disk Depth</u>
Secchi disk depths ranged from 29 to 117cm (n=52), with an average of 65cm and a median of 64cm. The deepest Secchi depths occurred in the summer months, particularly in July with ranges from 96 to 117cm. There was no significant trend in Secchi data. The shallowest Secchi disk depths occurred in the winter months. The annual distribution of the data is somewhat unusual because it is expected to see deeper depths in cold water with low productivity and shallower depths in the spring and summer months with increased runoff and high productivity (Wetzel. 1983). Secchi data collected near a shoreline may have several factors influencing the depths. For example, wave action may keep bottom sediments stirred up. Waves may originate from either winds or boat induced. Winter rainfall may also influence Secchi depth. Continued data will help document if Secchi readings are normal or unusual for this site. Figure 2 shows Secchi disk depth for the five-year sample period. The BUMP Secchi disk depth for this site ranged from 75-138cm (n=4), with the deepest depth of 138cm reported in July of 2000.

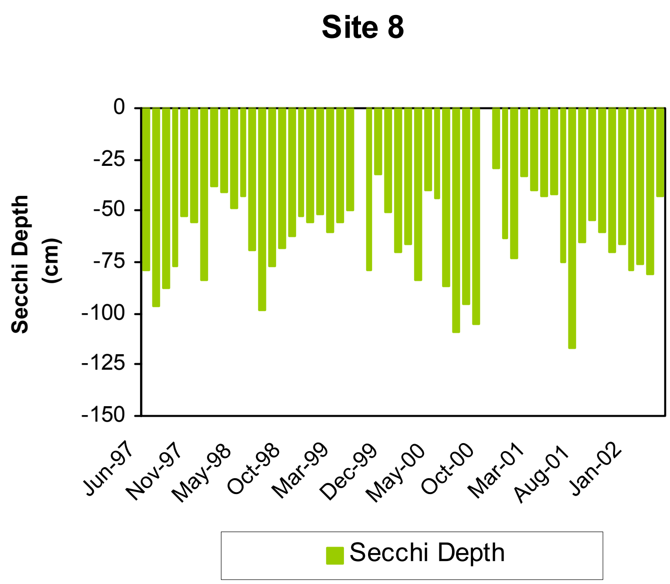


Figure 2. Secchi disk depth at Site 8.

<u>Color Analysis</u>

Overall, color reports for Site 8 were mostly light green (68%) and equal percentages of light brown and transparent and a small percent of brown. Brown's are indicative of inorganic particulate, or sediments, affecting color, while greens indicate organic particulate, or suspended algae. Of the summers sampled three out of four were 100% green, while 3 out of five fall seasons were 100% green. One of the four sampled springs had 100% green color reports. Therefore, like the overall percentage supports, the bulk of the color data show this site as light green, with possible high productivity at this site. The spring color data had the bulk of brown (light and dark browns) reports, which is indicative of sediment-laden spring runoff. The winter color data had the greatest reports of transparent, or clear water color than any other season. Figure 3 shows the percentages of color reports from the entire five-year data set.

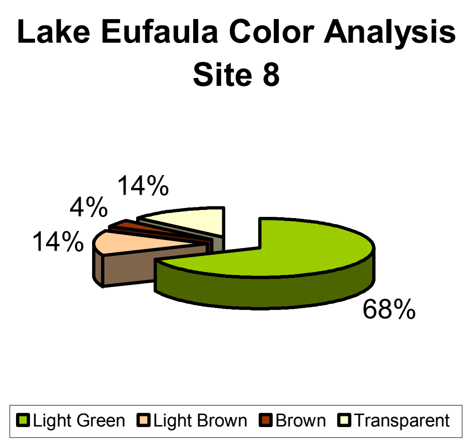


Figure 3. Overall percentages of color reports.

pH

For Site 8, pH values were all within Oklahoma's WQS's of 6.5 and 9 s.u.'s. pH ranged from 7.25- 8.75 s.u.'s (n= 54), with an average of 8.20 and a median of 8.25 s.u.'s. Figure 4 shows pH values reported at site 8 from the five-year sample period.

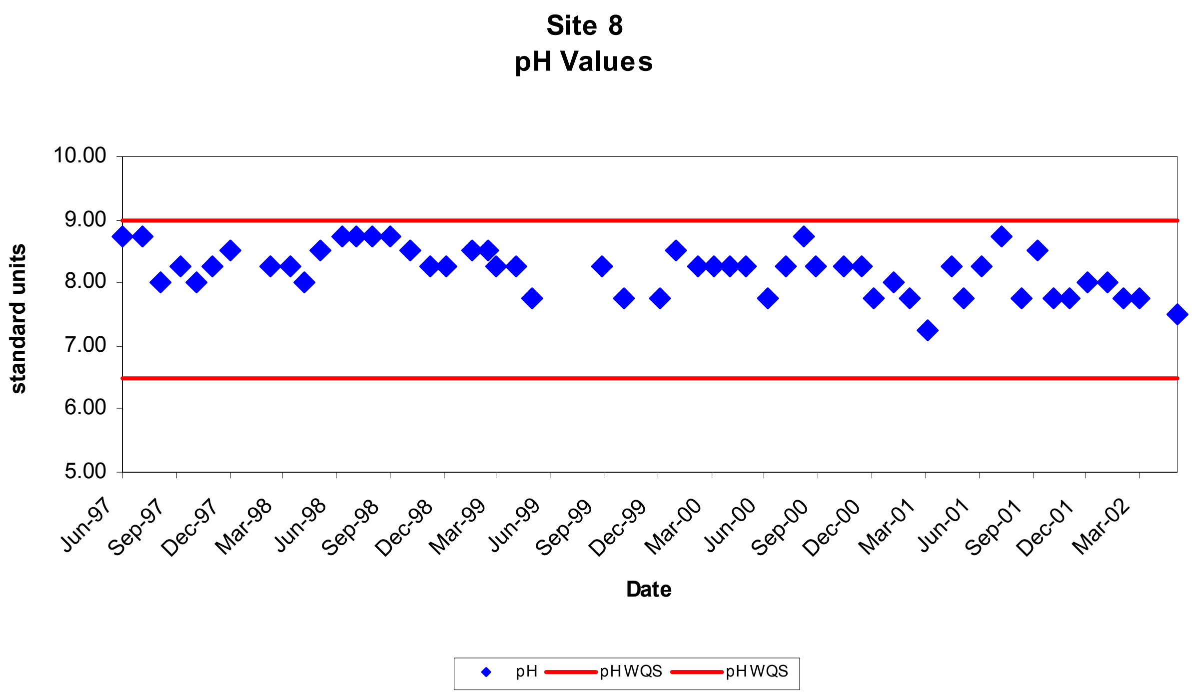


Figure 4. pH values for Site 8.

Dissolved Oxygen and Temperature Relationship

D.O. concentrations at Site 8 ranged from 5.20 – 11.60mg/l (n=54), with an average of 8.33 and a median of 8.20mg/l. None of the D.O. concentrations were below the general standard of 5mg/l for the FWP beneficial use. Low D.O. concentrations were found as expected in the late summer or warmer months, while high D.O. concentrations were found in the winter, colder months. In July of 2000 there was an unusual peak in D.O. concentrations which may likely have been a result of increased photosynthesis during that particular sample event. However, with normal concentrations of D.O. at this site no beneficial use concerns are warranted. Figure 5 shows the inverse relationship between D.O. and water temperature.

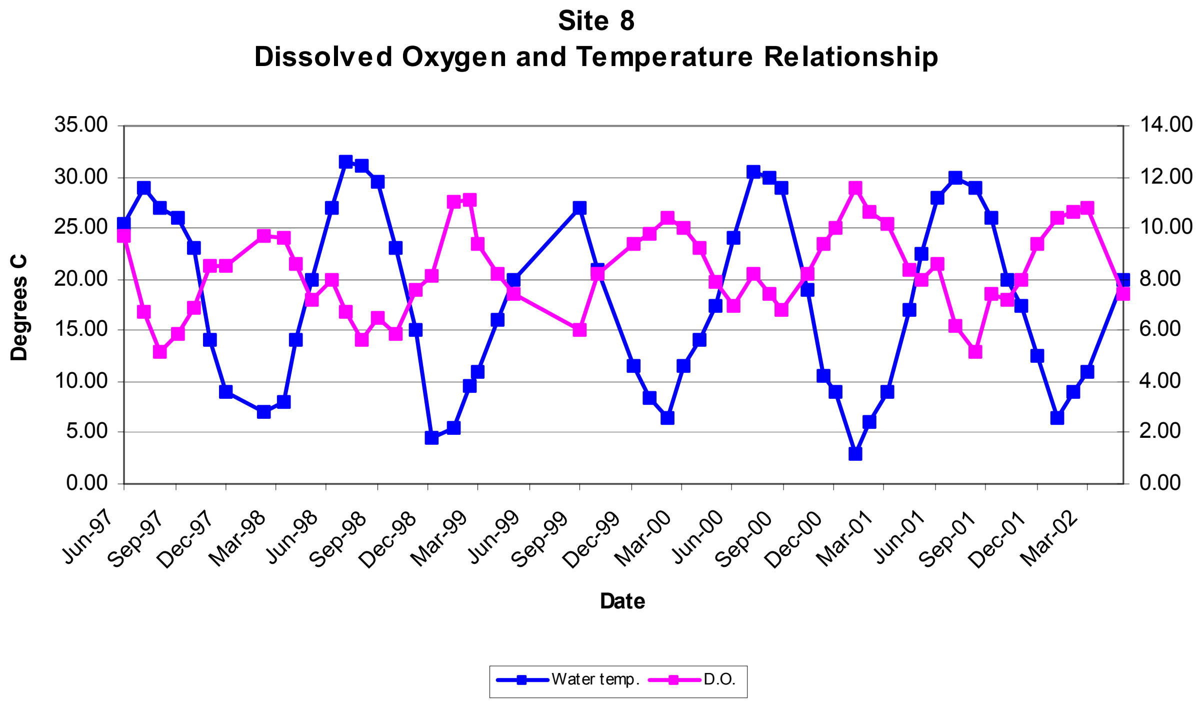


Figure 5. D.O. and Temperature for site 8.

<u>Ammonia Nitrogen</u>

Ammonia nitrogen values at Site 8 ranged from 0.00-0.35mg/l (n=43), with an average of 0.05mg/l and a median value of 0.00mg/l. Figure 6 plots ammonia concentrations for site 8. Trend analysis did show a significant decreasing trend in the five-year data set, indicated by the dotted line in Figure 6. Of the 43 samples collected 13 samples detected ammonia nitrogen. These 13 samples were detected in the beginning of the sampling period. No detection's were recorded after September 1999, likely resulting in the decreasing trend in ammonia. BUMP data collected quarterly from November 1999 through July 2000 was also below detection limits (<0.05mg/l). Therefore, recent data reflecting very low to no concentrations of ammonia is likely to be representative of the true concentration.

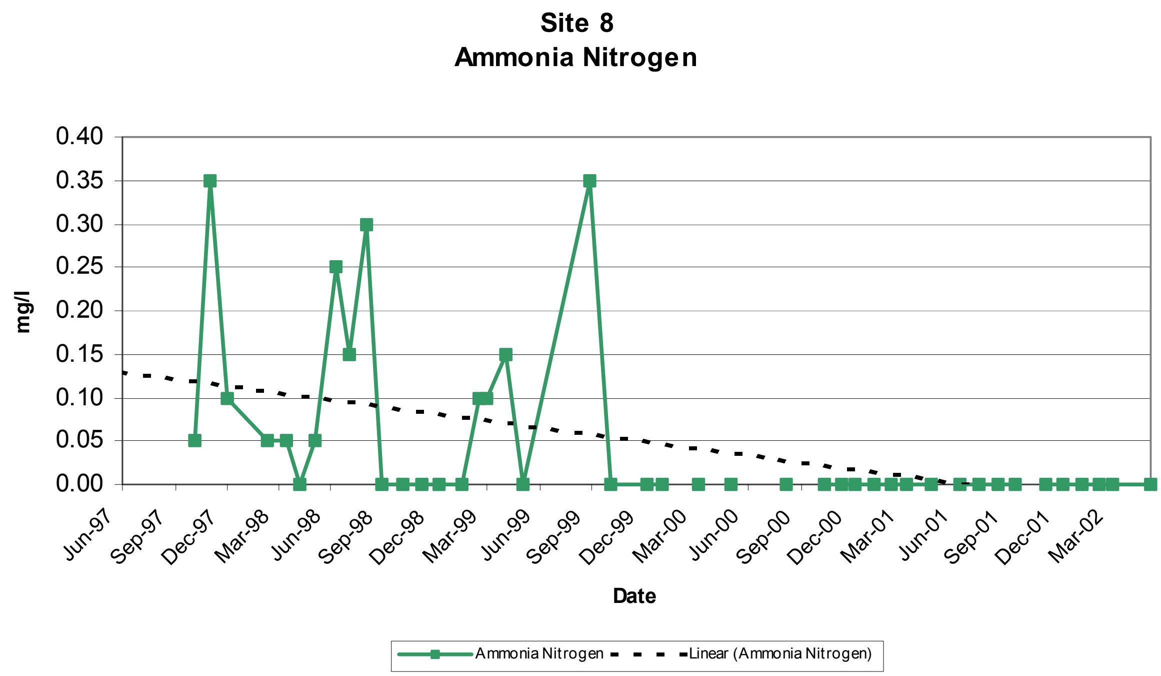


Figure 6. Ammonia nitrogen concentrations for Site 8.

Nitrate Nitrogen

Nitrate nitrogen values for Site 8 ranged from 0.00-0.25mg/l (n=44) with an average of 0.02mg/l and a median of 0.00mg/l. Figure 7 plots nitrate concentrations for site 8. There was no significant trend in nitrate data, indicated by the dotted line in Figure 7. Therefore nitrate

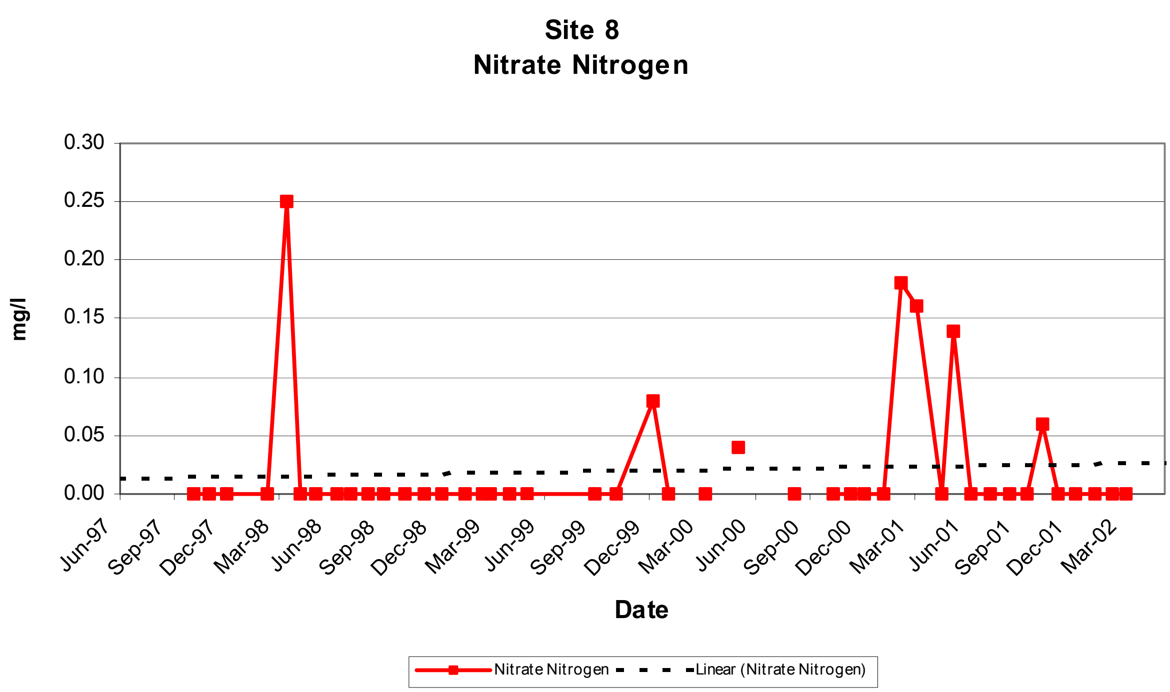


Figure 7. Nitrate Nitrogen concentrations for Site 8.

concentrations have not changed throughout the sampling period. These nitrate concentrations are relatively low (Wetzel, 1983). The drinking water standard for nitrates is 10ppm (mg/l), more than 40 times the high concentration detected at this site. Likewise, BUMP collected data also reported very low concentrations, or below detection limits (<0.05mg/l), on nitrates at this site.

<u>Ortho-phosphate</u>
Ortho-phosphate values for Site 8 ranged from 0.00-0.16mg/l (n=45) with an average of 0.02 mg/l and a median of 0.00mg/l. Trend analysis on this data set showed an increasing trend in ortho-phosphate concentrations throughout the five-year sampling period. However, of the forty-five samples collected only five detected ortho-phosphate, all after December 2000, thus producing an increasing trend in the statistic test. Average concentrations are relatively low (Wetzel, 1983), ortho-phosphate does not appear to be a concern at this site. The BUMP data detected ortho-phosphate once of the 4 sampling events with a concentration of 0.011mg/l in November 1999, also a relatively low concentration. Future data collections will help document if ortho-phosphate is approaching concern levels. Figure 8 plots ortho-phosphate concentrations collected throughout the five-year sampling period. The dotted line indicates the increasing trend.

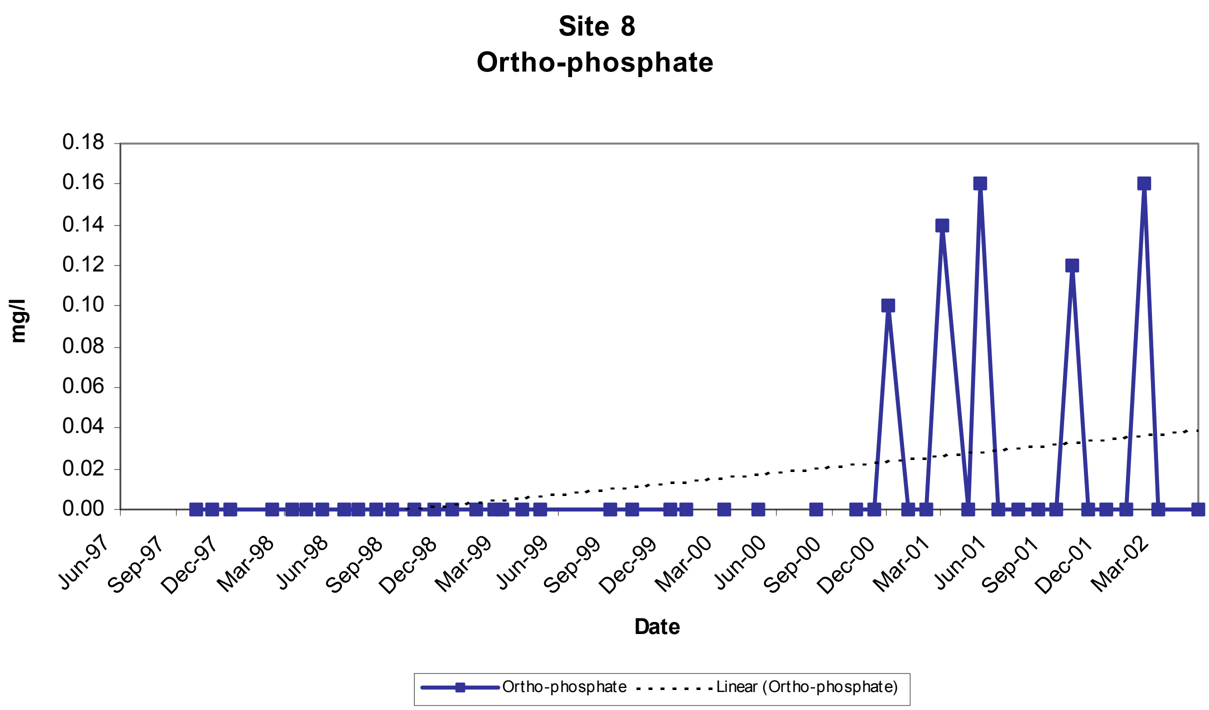


Figure 8. Ortho-phosphate concentrations for Site 8.

Site 12, Gaines Creek

Secchi Disk Depth

Secchi disk depth at Site 12 ranged from 8-72cm (n=49), with an average of 34cm and a median of 33cm. The shallowest depth was detected during the spring of 1998. Spring rains typically lower Secchi disk depth due to increased sediment in the runoff. There was no significant trend in Secchi data. The BUMP data ranged from 42-130cm (n=4), with the shallowest depths in the fall and spring and deepest in the winter and summer months. Figure 9 shows Secchi disk depth for the five-year sample period.

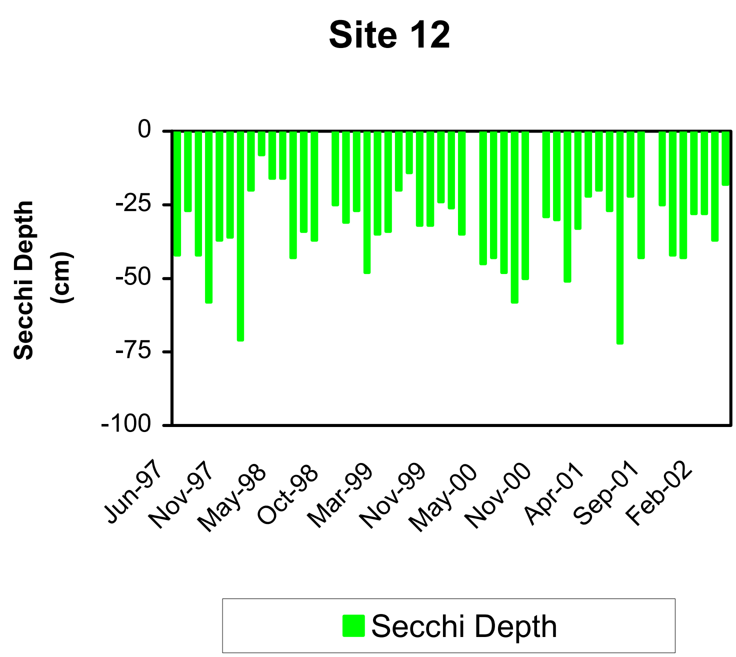


Figure 9. Secchi disk depth for Site 12.

Color Analysis

Overall, color reports for Site 12 were 54% light green and 40% browns, with 6% transparent or clear. Again, greens indicate suspended organic particulate, while browns indicate inorganic particulate. Seasonal color reports showed, like site 8, that summer and fall months mostly green (5 out of 8 seasons were 100% green), with only small percentages of browns during summer 1998, fall 2000, and summer 2001. The spring seasons were, for the most part, shades of browns, indicative of spring runoff. Winter seasons were a mixture of greens, browns, and transparent. Figure 10 shows the percentage of color reports from the five-year data set.

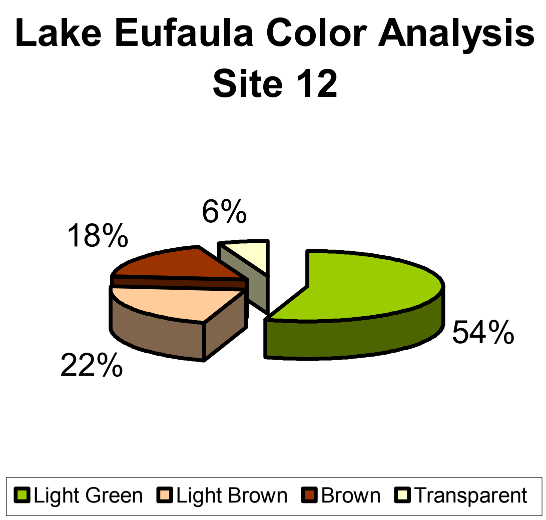


Figure 10. Overall percentages of color reports.

<u>pH</u>

For Site 12, pH values were all within Oklahoma's Water Quality Standards of 6.5 and 9.0 s.u.'s. pH ranged from 7.3-9.0 s.u.'s (n=53), with an average of 8.3 and a median of 8.1 s.u.'s. Figure 11 shows pH values reported at site 12 from the five-year sample period.

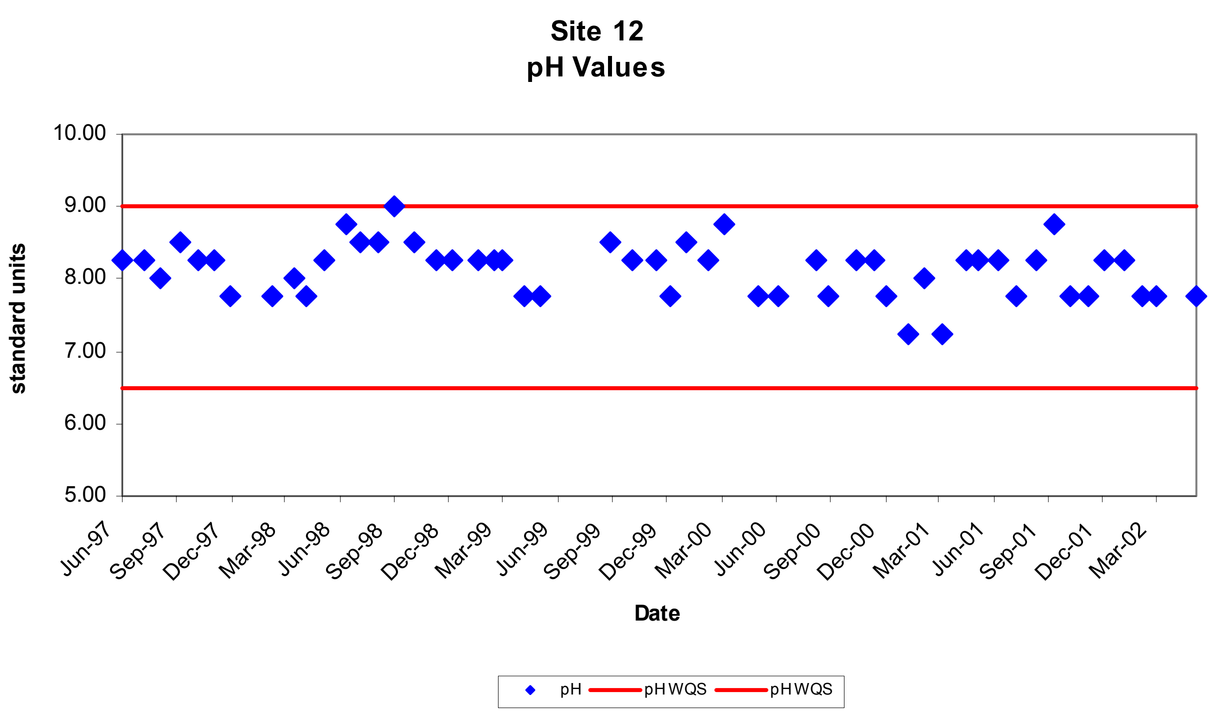


Figure 11. pH values for Site 12.

Dissolved Oxygen and Temperature Relationship

D.O. concentrations at Site 12 ranged from 5.60-11.20mg/l (n=53), with an average of 8.3mg/l and a median of 8.1mg/l. None of the D.O. concentrations were below the general standard for FWP beneficial use of 5.00mg/l. Low D.O. concentrations were detected, as expected in warm summer months, with higher D.O. concentrations in the winter months. Of the entire data set, 53 samples, only two sample events reported D.O. less than 6.00mg/l. Therefore D.O. concentrations were moderately high at this site throughout the five-year sampling period. Figure 12 shows the inverse relationship between D.O. and water temperature.

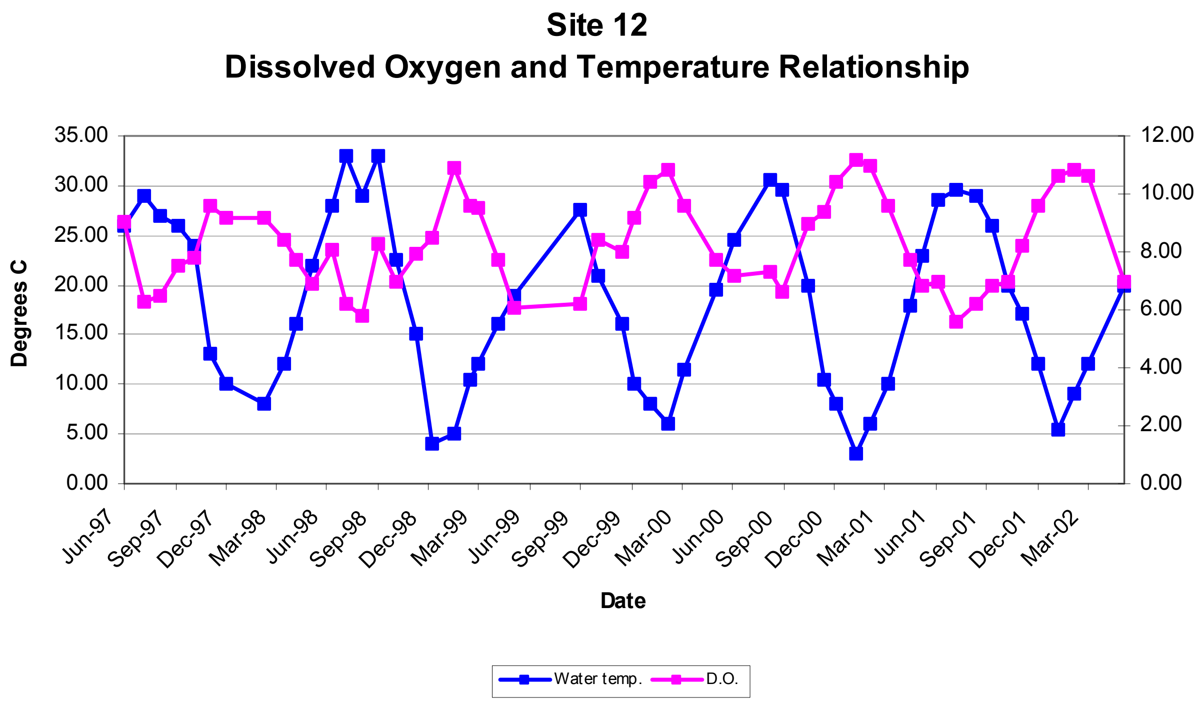


Figure 12. Dissolved Oxygen and Temperature for Site 12.

Ammonia Nitrogen

Ammonia nitrogen values at Site 12 ranged from 0.00-0.40mg/l (n=46), with an average of 0.00mg/l and a median of 0.00mg/l. Trend analysis for ammonia did show a decreasing trend from the five-year data set, however it is important to note that only 8 of the 46 samples detected any ammonia, all of which occurred before April 1999. Similarly Site 8 ammonia detection's occurred in 1999 or earlier. Figure 13 plots ammonia concentrations for Site 12. The trend is indicated by the dotted line. BUMP data for this site reported three of the four sample events below detection limits (<0.05mg/l), with one report of 0.06mg/l.

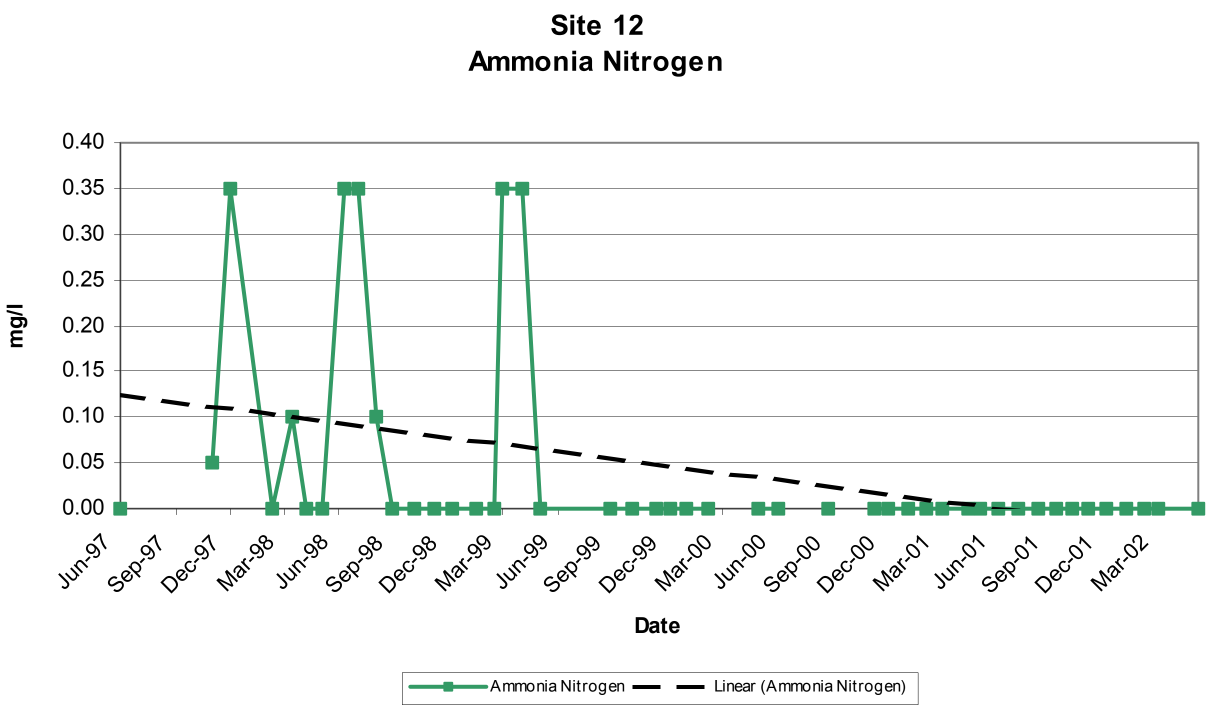


Figure 13. Ammonia Nitrogen concentrations for Site 12.

<u>Nitrate Nitrogen</u>
Nitrate nitrogen values ranged from 0.00-0.30mg/l (n=45), with an average of 0.00mg/l and a median of 0.00mg/l. Figure 14 plots nitrate concentrations for Site 12. Like Site 8, trend analysis did not show a significant trend, indicated by the dotted line in Figure 14. Also, these nitrate concentrations are relatively low (Wetzel, 1983), drinking water standards for nitrate are, again, 10ppm (mg/l), more than 30 times the high detected at this site. The BUMP data also showed this site as low in nitrates with a reported range of below detection limits (<0.05mg/l) to 0.17mg/l (n=4).

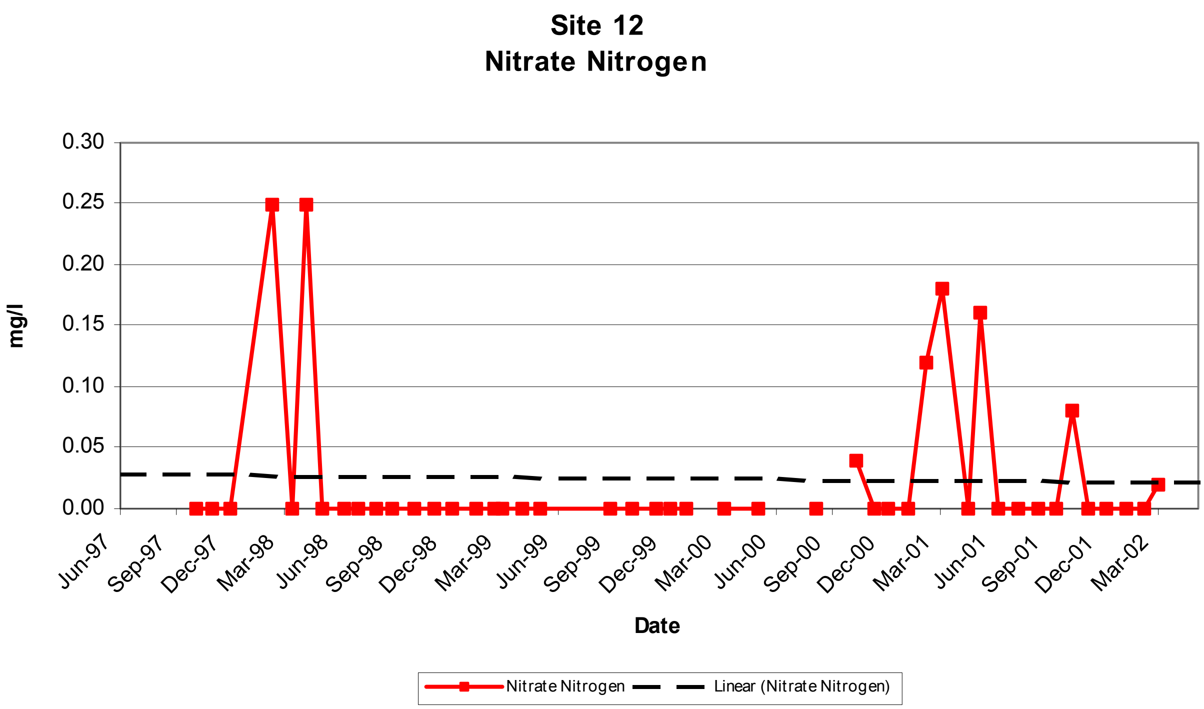


Figure 14. Nitrate nitrogen concentrations at Site 12.

<u>Ortho-phosphate</u>

Ortho-phosphate values for Site 12 ranged from 0.00-0.26mg/l (n=47), with an average of 0.00mg/l and a median of 0.00mg/l. Trend analysis for this site did show an increasing trend in data. Figure 15 Plots ortho-phosphate values for the five-year data set, the dotted line indicates the trend. Only 10 of the 47 samples detected ortho-phosphate with two detection's in March and April of 1998, and the remaining eight detection's after September 2000. BUMP data reported detection's in three of the four samples, however all were relatively low concentrations (Wetzel, 1983), ranging from <0.005-0.031mg/l. The BUMP samples were collected during November 1999 through July 2000, before high concentrations were detected in the volunteer data set. Average concentrations are relatively low (Wetzel, 1983), ortho-phosphate does not appear to be a concern at this site. Future data collections will help document if ortho-phosphate is approaching concern levels.

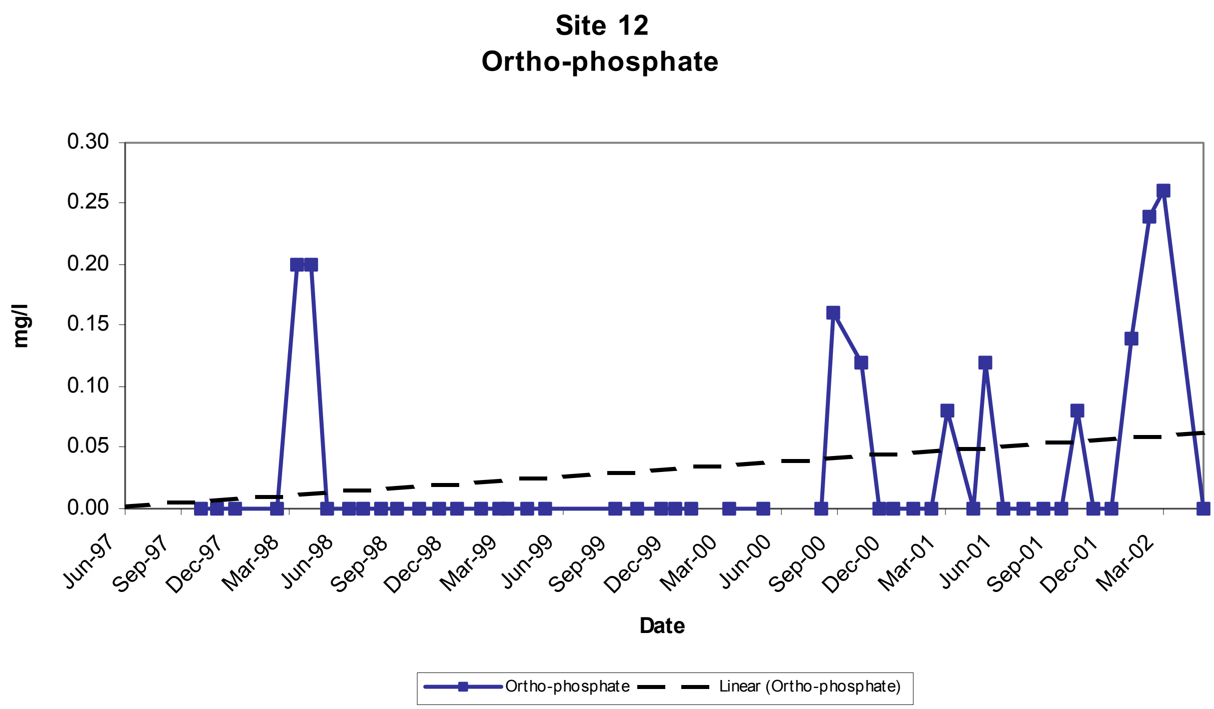


Figure 15. Ortho-phosphate concentrations at Site 12.

Conclusions

Overall, dissolved oxygen levels and pH are within WQS and appear to be of no concern related to beneficial uses. There is no significant trend in Secchi disk depth at either site, however Site 8 average disk depth is twice the average depth at Site 12, thus Site 8, Longtown Creek, has better water clarity than Site 12, or Gaines Creek. Over the five-year data set nutrients are relatively low. Several report values were 0.00mg/l for all three nutrient parameters, which resulted in low averages, however not without some scientific justification if the majority of sample concentrations were too low to record. Both sites are experiencing increasing trends in ortho-phosphate and decreasing trends in ammonia nitrogen. Nitrates have remained consistent throughout the five-year sample period at both sites. Again, the sites are independent of each other meaning, water quality is not influencing one another. However, both sites represent two different river systems contributing to Lake Eufaula.

Table 5 makes a comparison of Lake Eufaula to five other reservoirs in the state. Two of which are large, similar to Lake Eufaula in size, while the others are reputable for having clear, pristine waters. The data included in Table 5 is based on data collected in the BUMP for direct comparison between lakes. From this information, Eufaula ranks neither the high end nor the low end for all three parameters used in the Table. The chlorophyll TSI categorizes Eufaula as eutrophic, indicative of high primary productivity and nutrient rich conditions (OWRB, 2000). These summaries come from whole lake averaging of seventeen sites, with samples collected quarterly from Fall 1999 through Summer 2000 therefore, results are slightly different than individual sites.

Table 5. Water quality data collected by the BUMP for five Oklahoma Reservoirs.

	Annual TSI (chl-a)	Turbidity (NTU)	Secchi Disk Depth (cm)	Year Sampled
Lake Eufaula	51	21	65	2000
Grand Lake	58	45	62	2001
Lake Texoma	57	8	-	2000
Broken Bow Lake	40	6	204	2001
McGee Creek Reservoir	45	5	128	1999
Tenkiller Ferry Reservoir	58	6	118	2000

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