Lakes Probabilistic Monitoring Network for the State of Oklahoma

2011-2015

Final Report

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

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Executive Summary

Protecting Oklahoma's valuable water resources is essential to maintaining quality of life for all Oklahomans and economic benefits for the state. Oklahoma has over 200 manmade lakes with beneficial uses including *Public and Private Water Supply*, *Fish and Wildlife Propagation*, *Recreation, Hydropower,* and *Irrigation.* Oklahoma lakes provide water supply for millions of Oklahomans and generate millions of dollars every year for the state's economy. It is important to provide the public, scientists, and decision makers with information on the condition of the state's lakes. A statistical survey, or probabilistic approach to water quality monitoring, provides the opportunity to gain understanding about a large population based on unbiased samples from a smaller population. The statistical survey design has allowed Oklahoma lake managers to sample a subset of lakes and make inferences about the entire target population of Oklahoma's lakes.

A statewide lake probabilistic monitoring study was conducted by the Oklahoma Water Resources Board (OWRB) Beneficial Use Monitoring Program (BUMP) providing a statewide perspective on the condition of Oklahoma lakes. The bullets below highlight key findings from the study.

- 69% of Oklahoma's lake acres are classified as eutrophic and hypereutrophic
- 60% of Oklahoma's lake acres are classified as most disturbed for total nitrogen, indicating that nitrogen is a prevailing stressor on Oklahoma lakes.
- Reducing total nitrogen concentrations to the range of moderate to least disturbed values could potentially improve summer chlorophyll *a* condition by about 28%
- 43% of Oklahoma's lake acres are classified as most disturbed for total phosphorus
- During the summer critical season, zero lakes satisfy the chlorophyll threshold for the least disturbed condition
- 50% of Oklahoma's lake acres were found to be classified as moderately to most disturbed condition for turbidity

Introduction

Protecting and improving the water quality of Oklahoma's lakes is vital to quality of life for Oklahoman's and provides economic benefits for the state. Quality of life benefits and economic benefits are both directly connected to maintaining healthy lake ecosystems. Oklahoma has over 200 manmade lakes ranging in size from 50 to over 100,000 surface acres. The designated beneficial uses of Oklahoma's lakes include, *Public and Private Water Supply*, *Fish and Wildlife Propagation*, *Recreation, Hydropower,* and *Irrigation* (OAC 785:45). Oklahoma's lakes provide 54 percent of the public water supply across the state and U.S. Army Corps of Engineers (USACE) water supply lakes provided a $689.4 million (in 2017 dollars) economic benefit (USACE, 2017).

Lakes in Oklahoma also generate millions of dollars for state and local economies each year through recreation activities. Information from the U.S. Army Corps of Engineers provides a snapshot of the recreational and economic benefits of Oklahoma's lakes. In fiscal year 2016 there were over 11 million visitors to USACE recreational resources in Oklahoma and of these there were 3.7 million anglers, 3.5

million boaters, 1.7 million swimmers, and .5 million skiers (USACE 2016a). 2016 economic data reported that there was $377 million in visitor spending and 3,379 jobs within 30 miles of a USACE lake (USACE 2016a). At Eufaula Lake alone (Oklahoma's largest lake at 105,500 surface acres) there were a total of 2.2 million visitors with 1 million boaters, 0.8 million anglers, 0.6 million swimmers, and 0.1 million water skiers (USACE 2016b). The economic benefit of Eufaula is reported as $93 million in visitor spending and 778 jobs within 30 miles of the lake (USACE 2016b). Likewise, Canton Lake (7,900 surface acres), a much smaller lake located in western Oklahoma, had about 250,000 visitors with 101,000 sightseers, 56,000 anglers, 39,000 swimmers, and 19,000 water skiers (USACE 2016c). This recreation activity at the lake resulted in $5.7 million in visitor spending and 58 jobs within 30 miles of the lake (USACE 2016c). It is clear that lakes in Oklahoma are cherished recreational resources, and important contributors to the local and state economy. The significance of Oklahoma's lakes has regularly been recognized by the Office of the Governor, and since 2014 each July has been proclaimed Oklahoma Lakes Appreciation Month.

The Oklahoma Water Resources Board (OWRB) in service to all Oklahomans has had a long standing commitment to monitor lake water quality and guide actions to better manage Oklahoma lake ecosystems. The Beneficial Use Monitoring Program (BUMP) was initiated in 1998 with three key objectives 1) detect and quantify water quality trends, 2) document and quantify water quality impairments, 3) identify pollution problems before they become a pollution crisis. This 2011 statewide lake probabilistic monitoring initiative conducted by BUMP provides a statewide perspective on the condition of Oklahoma lakes allowing scientists, lake managers, and other decision makers to work together to protect valuable lake ecosystems.

Methods

Design of Oklahoma Lake Statistical Survey

A statistical survey or probabilistic approach to water quality monitoring provides the opportunity to gain understanding, and make statements about a large population based on unbiased samples from a smaller population. A key strength of statistical surveys is the power to characterize the overall population with documented statistical confidence (NWQMC, 2017). Using an unbiased sample, statistical surveys are designed to estimate waterbody condition on a broader scale, such as basin wide or statewide scale. The statistical survey design has allowed Oklahoma lake managers to sample a subset of lakes and make inferences about the entire target population of Oklahoma's lakes.

Statistical based survey designs assist Oklahoma's water quality managers in several ways:

- Allow estimation of the extent of impacted waters across a state
- Support analysis of whether the impacted waterbodies have common attributes that could inform management priorities

- Provide data that enable the state to make a statistically valid assessment of the condition of all Oklahoma lakes and reservoirs, as required under Section 305(b) of the Clean Water Act (CWA)
- Greatly assist resource managers in long and short-term program planning and resource allocation
- Infer relationships of stressors (e.g., nitrogen or phosphorus) to indicators of condition (e.g., chlorophyll *a*).

In 2010, Oklahoma worked closely with EPA's National Health and Environmental Effects Research Laboratory (NHEERL) in Corvallis, Oregon to ensure that the statistical survey design met Oklahoma's objectives. For this project, a Generalized Random Tessellation Stratified (GRTS) survey design (Appendix A) for a finite resource was used to select lakes across the state. The sample design was weighted to ensure various sized waterbodies were adequately represented. Because lakes are not equally weighted and are not of equal size, the population that was sampled was actually number of lake acres in the state as opposed to the population of all individual lakes. As such, when condition results are discussed, they represent a population of lake acres in Oklahoma. The design also included an "oversample" list. This list provides alternate sites when sites from the original sample populations do not meet criteria for the target population, or where the request for access is denied by private landowners.

The survey designed included 68 lakes greater than 500 surface acres and these lakes were monitored quarterly for one year. Additionally, ten randomly drawn lakes greater than 50, yet less than 500 surface acres, were also monitored quarterly for one year. The monitoring took place over a 5 year period with approximately one-fifth of the lakes being monitored each year based on a randomized draw. Many of these smaller lakes would not be sampled through the current BUMP trend monitoring rotation. Some of these lakes are small municipal water supplies and of particular interest since little is known about this population of lakes.

This study was spatially limited to lakes above 50 surface acres and specifically to sites that were randomly generated by the staff of the EPA's NHEERL for Oklahoma's draw. Extreme hydrologic circumstances may have caused sites to be inaccessible such as, low water level caused by drought or alternatively, waterbodies that are inaccessible due to flood as a result of unseasonably heavy rainfall. In 2012, there were instances where target waterbodies had to be dropped from the list due to impact from drought conditions. In each case a new waterbody was selected from the oversample list of alternative sites. The replacement of a dropped site with an alternative site from the oversample list was essential to maintaining the integrity of the random design and to sample sites consistent with the original number planned. **Figure 1** presents a map of the lakes sampled during the study period of 2011-2015. Additionally, the list of all lakes included for this project and their status as a target, non-target, oversample, or rejected lake is provided in **Appendix C**.

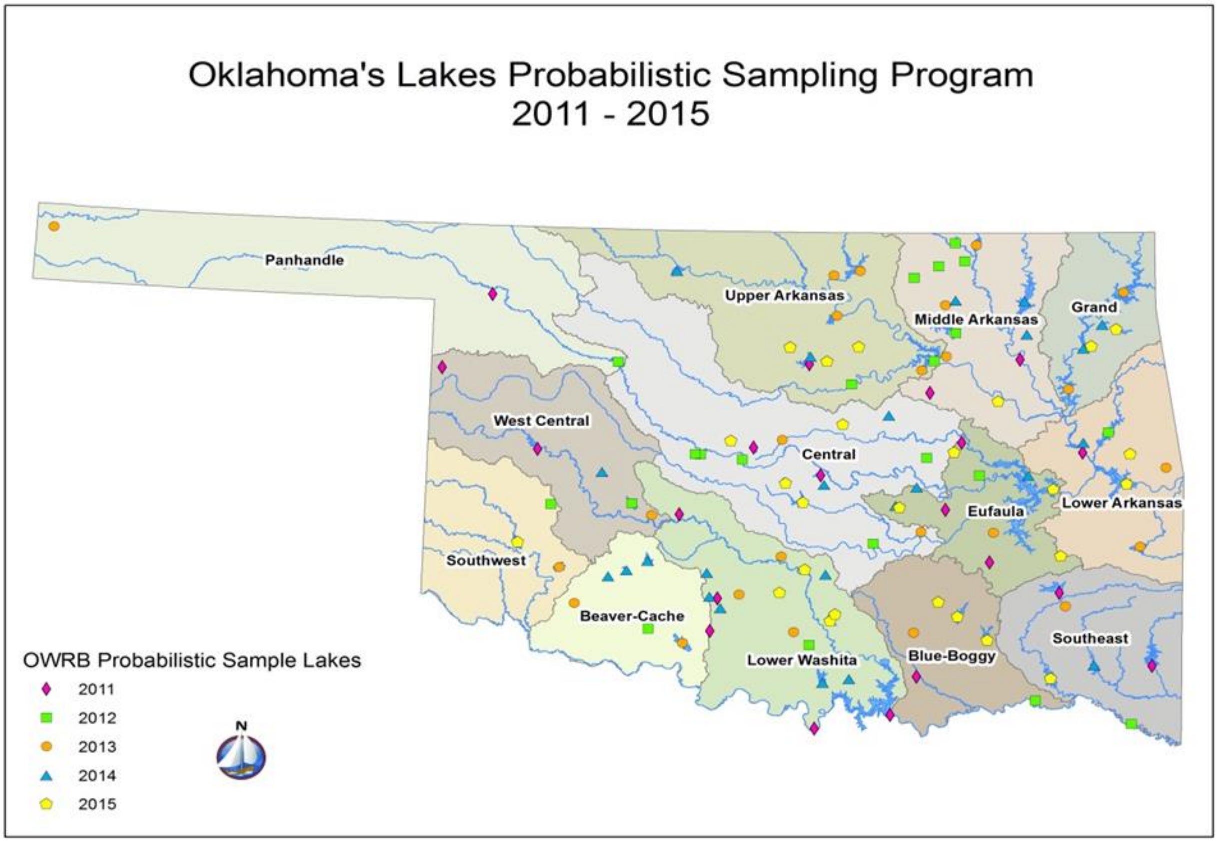


Figure 1. Map of Lakes Sampled, 2011-2015

Site Reconnaissance

Limited accessibility to the waterbody of interest is the most common problem with any probabilistic study. Some waterbodies may not be accessible by public roads and private landowners may or may not provide permission to access a site on their property. Additionally, probabilistic sites are selected from data frames that are not 100% accurate and may include non-candidate sites. Fortunately, proper planning and having available oversample sites can alleviate these issues. OWRB staff implemented lessons learned from previous statewide probabilistic stream/river surveys and the 2007 National Lakes Assessment by utilizing a three-stage site reconnaissance approach.

The first stage of planning was a "desk top" reconnaissance to determine if the proposed site was a candidate lake site. In order to be considered a candidate lake site certain criteria must be met, including: 1) lake depth of at least 1 meter deep, 2) greater than 50 surface acres in size, 3) not a sewage treatment pond/lagoon, 4) not a private aquaculture pond, and 5) landowner permission granted. Initially, each site was located using a variety of resources including topographic maps, and other GIS mapping tools. A site reconnaissance and tracking form was created for each site documenting the ultimate determination to "accept" or "reject" a site. An example of the tracking form can be found in **Appendix B**. Required hydrological characteristics were verified at the beginning and if not met the site was rejected without further consideration. A site map containing at least two geographical scales was included with the site tracking form. Any necessary information to determine landownership was collected, including coordinates, legal description of site, and county. The county assessor's offices were the main source of landowner information. However, in some instances staff used a variety of other resources including relationships with local conservation districts. Finally, a landowner permission packet was sent to each landowner. The permission packet included a standardized permission letter (example letter presented in **Appendix B**), maps, study brochure, and self-addressed stamped envelope for them to review and mail back the permission letter to the OWRB either approving or disallowing access to their property. Based on landowner response, the sites were 1) accepted, 2) accepted with restrictions/further instructions, or 3) rejected. However, even when accurate landowner information was available, response to permission requests were occasionally slow and therefore, a two stage process was developed to deal with slow responses. If a response was not received within two to three weeks, staff attempted contact by phone and if unsuccessful would send a reminder postcard. If still unsuccessful, in-person contact was attempted. If each of these attempts failed, the site was rejected.

Once site accessibility was verified (i.e., accepted) and a lake was labeled as a study candidate site, a second planning stage was initiated. The second planning stage objective was simply to collect thorough well-documented information to assist field crews in locating and accessing the sampling site. Utilizing available color aerial satellite imagery, considerable information was gathered with desktop analysis. Notes were made and included in the tracking form for special considerations including hazards, best route of entry, time of travel, etc. In addition to this, some sites still required an on-site initial visit to complete the planning phase. Concerns did arise about the cost versus benefit of an extra site visit. However, based on past experience, crews discovered that much of the information collected during an initial on-site planning visit was of great benefit on sampling visits.

The third planning stage involved all activities up to the first sampling visit. This included compiling a complete site visit packet. The packet incorporated all information gathered in stages one and two, containing a completed tracking form, landowner permission letter, and pertinent pictures and maps. In addition, all necessary field forms and labels were compiled as well as a checklist of equipment needed. This complete site packet provided sampling teams all the essential information necessary when sampling was conducted.

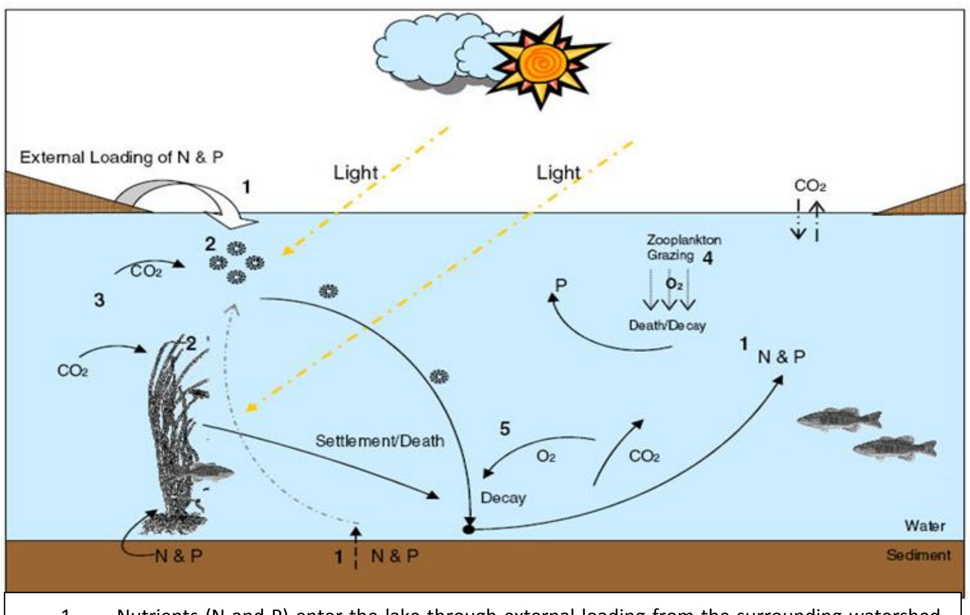
Water Quality Indicators

In order to characterize the physical, chemical, and biological condition of Oklahoma lakes a group of water quality indicators were selected. The water quality indicators were sampled at each candidate site. This section describes each water quality indicator and their associated thresholds. Thresholds for each indicator are needed as they provide the point of reference from which to evaluate indicator results and differentiate waterbody condition.

Nutrients (Phosphorus & Nitrogen)

Phosphorus and nitrogen are two essential nutrients necessary for all aquatic life. It is a fundamental ecological process in lakes that nutrients support algal growth and algae provide the foundation for the overall lake food web. Phosphorus and nitrogen are present within waterbodies, in various organic and inorganic forms as well as dissolved and particulate forms. Phosphorus and nitrogen can come from natural sources through physical, chemical, and biological processes; but they also come from anthropogenic sources including agriculture activities (synthetic fertilizer and animal manure application), wastewater discharges (municipal wastewater treatment plants and septic systems), industrial discharges (nitrogen fertilizer production, paper mills, and petroleum refining), and stormwater runoff.

There are many biological responses to nutrients in lakes and the conceptual model (**Figure 2**) below outlines the basics of nutrient cycling in lakes. The biologically available nutrients and light stimulate phytoplankton (algae) and or macrophyte growth. As these plants grow they provide food and habitat for other organisms such as, zooplankton and fish. When these aquatic plants die they will release nutrients back into the water through decomposition. The decomposition of plant material consumes oxygen from the water column and recycled nutrients are available to stimulate additional plant growth. Physical properties including light, temperature, residence time, and wind mixing also play integral roles throughout the pathways described.



1. Nutrients (N and P) enter the lake through external loading from the surrounding watershed and internal recycling processes
2. Nutrients and light stimulate the growth of phytoplankton and macrophytes (aquatic plants)
3. Aquatic plants consume carbon dioxide and the increase the pH of the lake
4. Zooplankton (aquatic invertebrates) graze on the phytoplankton population
5. Aquatic plants break down and or die, consume oxygen as part of decomposition, and recycle ammonia, phosphorus, and carbon dioxide into the water and the sediments

Figure 2. Nutrient Cycling in Lakes

These normal biological and chemical processes can become over stimulated by excess amounts of nutrients leading to an overabundance of plant and algal growth known as eutrophication. Eutrophication can result in a number of detrimental impacts to aquatic life and human health (Dorgham, 2014). For example, as the overabundance of algal growth decomposes it consumes available oxygen, which can cause oxygen concentrations to decline below the concentrations needed to sustain many aquatic organisms. Persistent low dissolved oxygen concentrations in lakes can lead to the loss of habitat for fish and their food. In extreme situations this can lead to hypoxic or anoxic conditions causing fish kills (Horne and Goldman, 1994). Likewise, excess nutrients can lead to noxious algal scums causing drinking water taste and odor issues, as well as harmful algal blooms (HABs) (NOAA, 2018). HABs may produce toxins that can sicken people and pets recreating at lakes and contaminate drinking water sources (USEPA, 2019a, USEPA, 2019b CDC, 2017). Excessive nutrients can also lead to phytoplankton community shifts, which have cascading impacts on the overall lake food web (Havens, 2014). These impacts have considerable consequences for lake beneficial uses such as: water supply, recreational opportunities, and fisheries. Nitrogen and phosphorus pollution are among the most serious and widespread water quality challenges throughout the country, including Oklahoma (EPA, 2013).

Chlorophyll a

Chlorophyll *a* is the green pigment that is responsible for a plants ability to convert light energy into chemical energy. The concentration of chlorophyll *a* is used to estimate the amount of phytoplankton biomass present in the lake. Phytoplankton serve a foundational role in the lake food web as primary producers. Primary producer is a term for organisms that can utilize light to convert inorganic chemicals such as, nitrogen, phosphorus, carbon dioxide, and other minerals into living biomass (Water on the Web, 2004). Therefore, measurements of chlorophyll *a* are a useful way to estimate lake productivity. The biologic productivity of a lake, measured as chlorophyll *a*, also influences the trophic state and dissolved oxygen water quality indicators described below.

Increased lake algal productivity, measured as elevated chlorophyll *a* concentrations, can have a myriad of impacts on public water supplies including: operational problems (e.g. clogged filters), taste and odor complaints, and increased disinfection by-product formation (Jüttner & Watson, 2007, Rashash et al., 1997, Young et al., 1996, Cooke & Kennedy, 2001, Wardlaw et al., 1991). Particular algal species are known to produce musty/earthy odors that lead to taste and odor problems at drinking water treatment facilities. Additionally, drinking water facilities that use a chlorination process are at risk of forming disinfection by-products such as, carcinogenic trihalomethane (THM) when chlorophyll concentrations are high (Callinan et al.,2013, Cooke & Kennedy, 2001, Wardlaw et al., 1991). Excessive algal growth in a lake increases the levels of organic matter which is a precursor to THM formation. Many of Oklahoma's public water supply lakes are subject to nutrient pollution and elevated chlorophyll *a* concentrations; consequently, it is valuable to use chlorophyll *a* as an indicator to evaluate the condition of these lakes in the context of water supply.

Cyanobacteria are a particular group of phytoplankton that under certain conditions (e.g. excessive nutrients, warm water temperatures, and slow-moving/calm water) can rapidly multiple and produce a HAB with toxins (USEPA, 2019). The toxins produced have the potential to harm people, pets, wildlife, and livestock. Often children and dogs are most likely to be affected by HABs due to their smaller body size, increased risk of ingesting water, and tendency to stay in the water for longer periods of time (CDC, 2017). Exposure to HAB toxins in recreational waters can cause eye irritation, skin rashes, diarrhea, and cold or flu-like symptoms (CDC, 2017a). Harmful algal blooms are capable of producing toxins, which can also pose health risk to humans through drinking water. Conventional water treatment can generally remove low levels of toxins; however treatment facility efficacy may be tested during a severe bloom event when the toxin concentration in the lake is high (USEPA, 2019). People consuming water with HAB toxins are at risk for health affects including, vomiting and diarrhea, as well as liver and kidney damage (USEPA). The occurrence(s) of a HAB in an Oklahoma lake presents a considerable risk to recreation and drinking water beneficial uses.

As chlorophyll concentration (a measure of phytoplankton biomass) increases there is greater and greater likelihood that the phytoplankton biomass in the lake is dominated by cyanobacteria (Tetra Tech, 2018, Havens, 2014). When cyanobacteria are dominating the phytoplankton community there is a greater prospect for a HAB event if /when the advantageous conditions occur within the lake. Thus, chlorophyll concentrations can be used as a proxy for the potential presence of HAB toxins.

Trophic Status

A method of classifying lakes based on biological response to nutrients is trophic state, which indicates the amount of biological activity sustained in a waterbody at a particular time. Lakes that have high nutrient concentrations and productive plant growth are described as eutrophic; whereas, low nutrient concentrations and low plant growth lakes are characterized oligotrophic (Water on the Web, 2004). Lakes that exhibit moderate levels of nutrients and plant growth are termed mesotrophic. Carlson (1977) developed the most commonly used biomass based trophic status index (TSI) to classify and describe lakes. The Carlson chlorophyll TSI metric has long been used by OWRB to determine lake trophic status. **Table 1** below presents the various trophic states and associated descriptions.

Table 1. Carlson's Trophic State Categories.

Trophic State	Carlson TSI Value	Trophic Description
Oligotrophic	≤ 40	Low primary productivity and/or low nutrient levels
Mesotrophic	41-50	Moderate primary productivity with moderate nutrient levels
Eutrophic	51-60	High primary productivity and nutrient rich
Hypereutrophic	≥ 60	Excessive primary productivity and excessive nutrients

The process of cultural eutrophication in lakes, as described in the previous section, advances lakes toward a eutrophic or hypereutrophic condition. This is often accelerated by anthropogenic activities that introduce excess nitrogen and phosphorus into lakes. Dissolved Oxygen

Dissolved oxygen (DO) is fundamental to the lake ecosystem and is essential to all aquatic organisms. Thus, the dynamics and distribution of oxygen within lakes is extremely important. Oxygen is supplied to the lake from the atmosphere and photosynthesis and distributed throughout the lake via diffusion and physical mixing. Respiration and decomposition processes are the key drivers of oxygen consumption within the lake. Photosynthesis is a light reaction and therefore only occurs during the daylight hours whereas, respiration and decomposition occur at all times. This difference produces daily (diurnal) variations in dissolved oxygen concentrations. At night dissolved oxygen concentrations steadily decline due to ongoing respiration and decomposition without photosynthesis to replenish the oxygen.

Eutrophication aggravates typical lake DO dynamics; for example, abundant algal biomass can actually increase oxygen concentrations via photosynthesis such that the oxygen concentration becomes saturated. Yet, conversely the additional biomass accelerates the rate of oxygen depletion due to decomposition in the deeper areas of the lake, especially when the lake is stratified in the summer season (Water on Web, 2004). This feedback loop increases the opportunity for summer fish kills in eutrophic and hypereutrophic lakes. Fish kills are most apt to occur at times when daytime photosynthesis is diminished due to clouds and calm winds minimize the entrainment of oxygen from the atmosphere thus, oxygen production at the lake surface is reduced. At the same time, the generous amounts of organic material hasten respiration and decomposition processes, which deplete the lake's oxygen. Through the combination of these events oxygen in the lake can be consumed causing the lake to become hypoxic (2 mg/L DO) and or anoxic (0 mg/L DO) causing a direct impact of the lake's fish community (Water on Web, 2004).

Turbidity

Turbidity is a measure of lake water clarity and relates to erosion and sedimentation. The greater the amount of total suspended solids in the water, the less clear the water will be, and the higher measured turbidity. Suspended solids that contribute to lake turbidity include silt, clay, algae, plankton, and organic matter. Increased turbidity affects lakes in a myriad of ways. For example, the suspended particles absorb more heat, which can raise water temperature and reduce the dissolved oxygen concentration. This happens as a result of the water's oxygen saturation threshold being lower when water is warmer (Water on Web, 2004). Turbidity also influences lake algal growth by limiting the amount of light penetration into the water column. Aquatic life are impacted by increased turbidity, as particles of silt, clay, and or organic material settle to the lake bottom they can suffocate larvae and fill in areas around rocks that serve as benthic habitat (Water on Web, 2004). Fine suspended material can also damage gill structure of fish (Water on Web, 2004, MPCA, 2008). Moreover, as the suspended solids settle to the lake bottom, the lake becomes shallower and its capacity is reduced limiting water supply availability. Finally, high turbidity can also negatively impact the aesthetic and recreational qualities of lakes.

Phytoplankton

Phytoplankton are free-floating, microscopic algae that live in open water, taking up nutrients from the water and energy from sunlight (Water on the Web, 2004). They inhabit the sunlit uppermost layers of the water column in order to photosynthesize (USEPA, Great Lakes Monitoring). The ability of phytoplankton to photosynthesize makes them a primary producer of food and energy within the lake ecosystem; for example, phytoplankton are the food source for other organisms such as zooplankton. Phytoplankton are uniquely adapted to specific depths, habitats, and nutrients conditions. The composition and diversity of the phytoplankton community are affected by a myriad of environmental conditions and can be used as an indicator of the biological condition of a waterbody (USEPA, 2016).

There have been various scientific attempts to develop phytoplankton biotic condition indices for lakes and the EPA NLA team endeavored create one; however, the analysis was not successful and a phytoplankton multi-metric index was not created (Mitchell, 2018). Therefore, the information related to the phytoplankton indicator will not be presented in this report.

Zooplankton

Zooplankton are small, free-floating aquatic microorganisms in lakes. They live near the surface and can migrate vertically within the water column to be near food sources. The zooplankton community is composed of both primary consumers, which eat free-floating algae, and secondary consumers, which feed on other zooplankton (USEPA, 2016). Zooplankton are an important part of the food web in lakes, transferring energy between primary producers and other levels in the food chain. As a result of their central position in lake food webs, zooplankton can strongly affect water quality, algal densities, fish production, and nutrient cycling (International Institute for Sustainable Development, 2016). Through grazing zooplankton help maintain the balance of algae population within the lake. Zooplankton have close links with the surrounding environment throughout their life cycles and they demonstrate rapid changes in their populations when disturbances such as eutrophication occurs. As such, changes in zooplankton community structure and composition can indicate water quality changes in lakes making them a good indicator of biological condition in lake systems.

The 2012 NLA developed a zooplankton multi-metric index to assess the biological condition of lakes. The index included various measures of zooplankton community structure such as, abundance, taxonomic richness, trophic guild, and three taxonomic groups (cladoceran, copepod, rotifer). The specific metrics selected to characterize each of these measures varied for ecoregion. Detailed information on the NLA zooplankton index can be found in the NLA 2012 Technical Report (USEPA, 2016). Oklahoma collected zooplankton information as part of this project, but it has not been analyzed and will not be addressed in this report. The analysis of zooplankton will be provided in an addendum to this report in the future.

Physical Habitat

Near-shore physical habitat structure in lakes is complex and crucial for supporting biota and ecological processes in lakes (Kauffmann et al., 2014) Habitat includes all the physical, chemical and biological attributes that affect or sustain organisms within the lake ecosystem. Aquatic and riparian biota are concentrated near lakeshores, making near-shore physical habitat ecologically valuable to the lake ecosystem. These valuable areas are vulnerable to anthropogenic perturbation, as human activity and its resulting impact, are concentrated along the lakeshore (Strayer and Findlay, 2010).

As transitions zones from terrestrial ecosystems, they are areas of highly diverse biological communities (Strayer and Findlay, 2010, Merrell et al., 2009). This complexity promotes interchange of water, nutrients, and biota between the aquatic and terrestrial zones of lake ecosystems. Structural complexity and variety of cover elements in littoral areas provide diverse opportunities for supporting assemblages of aquatic organisms (Strayer and Finlay, 2010). In addition to serving as habitat for biota, shorelines provide other valuable ecosystem services including: recreation, harvestable resources, production and processing of organic matter, dissipation of wave energy, flood protection, and maintenance of water quality. Intact riparian vegetation along the water's edge absorbs wave energy thereby reducing erosion and acts as a buffer, slowing inputs from upland activities during storm events and reducing nutrient loading (Strayer and Finlay, 2010, Habitat Network, 2016).

As part of this project OWRB field staff collected physical habitat data from each lake, this data has yet to be reviewed and analyzed. It is expected that lake physical habitat information will be an addendum to this report in the future.

Water Quality Indicator Thresholds

The data collected for each indicator was independently reviewed and assessed against various thresholds. The thresholds were used to place a lake into one of three disturbance classes.

1. Most disturbed, signifying that reported values are out of balance or poor condition
2. Moderately disturbed, signifying that reported values are somewhat out of balance or possibly in poor condition
3. Least disturbed, signifying that reported values are in balance or good condition

The thresholds for classifying lakes were either set equivalent to EPA National Lakes Assessment (NLA) derived thresholds, OWRB water quality criteria, and/or OWRB water quality assessment benchmarks. The NLA thresholds for nutrients, *chlorophyll aa*, and turbidity are based on the distribution of indicator values from ecoregion reference lakes. As determined by NLA, a reference lake is a lake, either natural or man-made, with water quality conditions that come as close as practical to those expected in a natural state. Ecoregions are geographic areas where ecosystems are generally similar. Ecoregions are categorized by analyzing the patterns and composition of biotic and abiotic factors that differentiate ecosystems. On the national scale EPA used nine aggregate ecoregions for reference lake classification. Four of these ecoregions 1) southern plains, 2) coastal plains, 3) southern Appalachians, and 4) temperate plains occur within Oklahoma (**Figure 3**) and were used for the distribution of indicator values in Oklahoma.

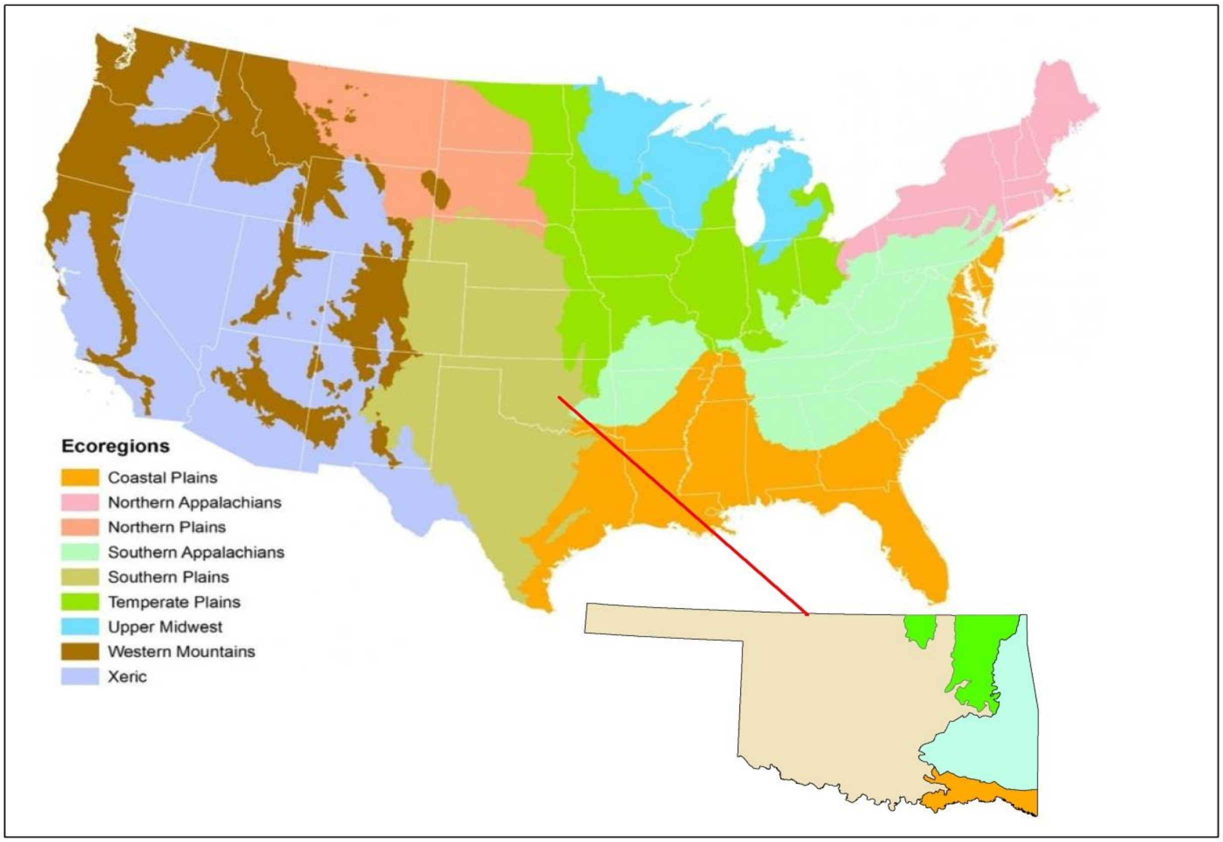


Figure 3. EPA's Aggregated Ecoregions utilized for National Aquatic Resource Surveys

The NLA team identified reference lakes in each ecoregion and identified the distribution of indicator concentrations to separate between least, moderately, and most disturbed classes. The 75th percentile served as the cutoff between least disturbed and moderately disturbed lakes and the 95th percentile was the cutoff between moderately disturbed and most disturbed lakes (USEPA, 2017). The EPA thresholds for trophic status were set based on accepted nationwide values. Details on the development of NLA Assessment thresholds can be found in the NLA 2012 Technical Report (USEPA, 2016). The tables below present the thresholds for nutrients, chlorophyll *a*, and turbidity by ecoregion and trophic status.

Table 2. Total Phosphorus Thresholds by Aggregated Ecoregions in Oklahoma

	Disturbance Class		
Ecoregion	**Least Disturbed**	**Moderately Disturbed**	**Most Disturbed**
Southern Plain	≤ 34.0 µg/L	34.0 – 56.0 µg/L	≥ 56.0 µg/L
Coastal Plain	≤ 37.0 µg/L	37.0 – 51.0 µg/L	≥ 51.0 µg/L
Southern Appalachians	≤ 19.0 µg/L	19.0 – 33.0 µg/L	≥ 33.0 µg/L
Temperate Plains	≤ 49.0 µg/L	49.0 – 82.0 µg/L	≥ 82.0 µg/L

Table 3. Total Nitrogen Thresholds by Aggregated Ecoregions in Oklahoma

	Disturbance Class		
Ecoregion	**Least Disturbed**	**Moderately Disturbed**	**Most Disturbed**
Southern Plain	≤ 657 µg/L	657 – 830 µg/L	≥ 830 µg/L
Coastal Plain	≤ 510 µg/L	510 – 801 µg/L	≥ 801 µg/L
Southern Appalachians	≤ 309 µg/L	309 – 407 µg/L	≥ 407 µg/L
Temperate Plains	≤ 1,105 µg/L	1,105 – 1,699 µg/L	≥ 1,699 µg/L

Table 4. Chlorophyll *a* Thresholds by Aggregated Ecoregions in Oklahoma

	Disturbance Class		
Ecoregion	**Least Disturbed**	**Moderately Disturbed**	**Most Disturbed**
Southern Plain	≤ 6.85 µg/L	6.85– 13.8 µg/L	≥ 13.8 µg/L
Coastal Plain	≤ 11.5 µg/L	11.5– 28 µg/L	≥ 28 µg/L
Southern Appalachians	≤ 5.23 µg/L	5.23 – 11.5 µg/L	≥ 11.5 µg/L
Temperate Plains	≤ 13.9 µg/L	13.9 – 22.7 µg/L	≥ 22.7 µg/L

Table 5. Turbidity Thresholds by Aggregated Ecoregions in Oklahoma

	Disturbance Class		
Ecoregion	**Least Disturbed**	**Moderately Disturbed**	**Most Disturbed**
Southern Plain	≤ 3.32 NTU	3.32– 4.67 NTU	≥ 4.67 NTU
Coastal Plain	≤ 3.38 NTU	3.38 – 4.05 NTU	≥ 4.05 NTU
Southern Appalachians	≤ 2.83 NTU	2.83 – 3.94 NTU	≥ 3.94 NTU
Temperate Plains	≤ 3.70 NTU	3.70 – 5.38 NTU	≥ 5.38 NTU

Additionally, a combination of OWRB water quality criteria and assessment benchmarks were used to set indicator thresholds specific to Oklahoma. The dissolved oxygen least disturbed threshold was based upon the OWRB criteria of 5 mg/L and the most disturbed threshold was set at less than 3 mg/L as the lower limit of oxic conditions (Table 6).

Two different groups of thresholds were used for the chlorophyll indicators (Table 6). The threshold values for one group is related to the evaluation of public water supplies and the second group of chlorophyll indicator values is a surrogate for signifying when there is increased likelihood to exceed a human health target design to protect against HAB exposure.

The Oklahoma Water Quality Standards include a *chlorophyll a* criterion of 10 ug/L for the protection of the *Public and Private Water Supply* beneficial use in lakes classified as Sensitive Water Supply. This criterion was used as the least disturbed threshold for the chlorophyll indicator related to the water supply. Twice the criterion value (20 ug/L) was used as the threshold for the most disturbed class. Moreover, in Oklahoma lakes a chlorophyll concentration of 15 ug/L is related to human health targets designed to provide protection from cyanobacteria HABs (WHO, 2003 Australian Government National Health and Medical Research Council, 2008, Tetra Tech, 2018). When the chlorophyll concentration is less than 15 ug/L the probability of exceeding a cyanobacteria human health target is sufficiently low and as chlorophyll *a* concentrations increase the probability of exceeding the human health target also increases (Tetra Tech, 2018). Table 6 also presents the turbidity thresholds. The Oklahoma Water Quality Standards include a criterion of 25 NTU applicable to lakes and this value is set at the most disturbed threshold; the moderately disturbed and least disturbed values were established based on the expertise of OWRB staff and consistent with BUMP water clarity rating.

Table 6. Oklahoma Specific Water Quality Thresholds

	Disturbance Class		
Indicator	**Least Disturbed**	**Moderately Disturbed**	**Most Disturbed**
Dissolved Oxygen	≥ 5 mg/L	> 3 and < 5 mg/L	≤ 3 mg/L
Chlorophyll: Water Supply	≤ 10 µg/L	> 10 and < 20 µg/L	≥ 20 µg/L
Chlorophyll: Potential Human Health Risk	≤ 15 µg/L	> 15 and < 30 µg/L	≥30 µg/L
Turbidity	≤10 NTU	≥ 10 and ≤ 25 NTU	≥25 NTU

The OWRB lakes monitoring program has long employed the Carlson chlorophyll TSI to determine lake trophic status and reported these values in the annual Oklahoma Lakes Report. Carlson's TSI has four key categories that are used to describe tropic status. These TSI values were used as thresholds to categorize lake trophic state in this report (**Table 7**).

Table 7. Carlson's Trophic State Categories

Trophic State	Carlson TSI Value	Trophic Description
Oligotrophic	≤ 40	Low primary productivity and/or low nutrient levels
Mesotrophic	41-50	Moderate primary productivity with moderate nutrient levels
Eutrophic	51-60	High primary productivity and nutrient rich
Hypereutrophic	≥ 60	Excessive primary productivity and excessive nutrients

Data Collection (Field Sampling)

All lake sites were visited four times during the respective sample year to ensure seasonality was represented. The number of sampling stations per lake varied depending on lake size and morphology. In general, 3-5 stations were chosen per lake in order to represent the riverine, transitional and lacustrine zones of the waterbody.

Data for water quality indicators was collected following OWRB standard operating procedures (SOPs) for the water quality samples (OWRB, 2013a). Several variables (pH, dissolved oxygen, water temperature, and specific conductance) were monitored *in-situ* utilizing a Hydrolab® Minisonde or YSI® multi-probe instrument. Regardless of instrumentation and in accordance with manufacturer's specifications and/or published SOP's, all instruments (except water temperature) were calibrated weekly and verified daily with appropriate standards. Measurements were recorded at each sampling station on the lake. Vertical profiles were recorded in 1-meter increments from the lake surface to the lake bottom, with a final reading at 0.5 m above the lake bottom. Vertical profiles of dissolved oxygen were recorded at each sampling site during each visit; however, dissolved oxygen levels at the surface of the dam site during the critical period (summer) were used to determine condition for this report. Following NLA procedures, the surface DO was calculated by taking the mean of recorded values between 0 and 2 meters in depth.

Data for all other indicators (**Table 8**) were amassed from water quality samples collected at the lake. Water quality samples were collected via surface grab with water collected from 0.5 m below the lake surface. The sample was collected by completely submerging the bottle, allowing it to fill to the top, and capping the bottle underwater. Each sample included three bottles for general chemistry analyses (one ice preserved and one sulfuric acid preserved), and one bottle each for field chemistry analysis and sestonic chlorophyll *a* (ice preserved and kept dark). The Oklahoma Department of Environmental Quality State Environmental Laboratory (ODEQ-SEL) analyzed samples for most parameters listed in Table 8 in accordance with the ODEQ's Quality Assurance Plan (ODEQ, 2019) and Data Quality Manual (ODEQ, 2018). OWRB personnel measured hardness and alkalinity using Hach® titration protocols, and nephelometric turbidity using a Hach® Portable turbidometer.

Table 8. Water Quality Parameters Included in Study

Sample Parameters		
	***In-situ* Parameters**	
Dissolved Oxygen (DO)	% DO Saturation	pH
Water Temperature	Specific Conductance	Salinity
Oxidation-Reduction Potential (ORP)	Total Dissolved Solids	
	Field Parameters	
Nephelometric Turbidity	Total Alkalinity	Total Hardness
Secchi Disk Depth	Habitat	
	General Chemistry Parameters	
Total Kjeldahl Nitrogen	Total Phosphorus	Chlorides
Nitrate Nitrogen	Nitrite Nitrogen	Sulfates
	Biological Parameters	
Chlorophyll*a*	Zooplankton	Phytoplankton

Samples for algal biomass (chlorophyll *a*) were collected at all sample sites and processed in accordance with standard procedures outlined (OWRB, 2011b). All chlorophyll *a* samples were analyzed by the ODEQ-SEL under the previously mentioned QMP (ODEQ, 2007). Additionally, phytoplankton and zooplankton samples were also collected on a quarterly basis for taxonomic identification. Samples were collected at the dam site. Phytoplankton samples were collected as a surface grab sample while zooplankton were collected as a tow using a Wisconsin-style plankton net. The length of the tow varied, representing the entire depth of the water column. All samples were collected and processed in accordance with standard procedures (OWRB 2011c).

Habitat information was collected from ten equidistant stations along the perimeter of each lake. Protocols from the NLA field operations manual were adopted by the OWRB and followed for the collection this information. Each plot measured 15 meters wide, including a littoral plot extending 10 meters towards the lake, a drawdown zone plot, a 1 meter shoreline zone, and a riparian plot (**Figure 4**). Indicators of physical habitat condition included, drawdown, measures of human disturbance, water's edge, and near shore vegetation and condition (USEPA, 2017)

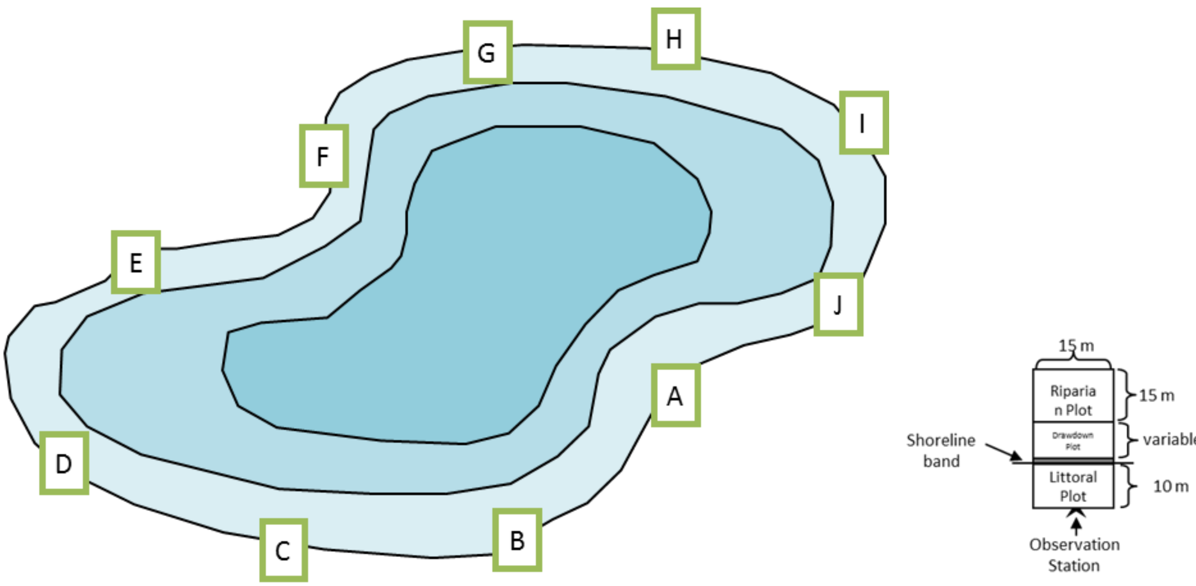


Figure 4. Physical Habitat Station Layout and Placement

Statistical Methods

In order to express chemical and biological lake condition estimates as percent of lake acres, the site weights from the probability design must be combined with the data from individually sampled lakes. As part of a statistical survey design, each lake has a known probability of being sampled and the sample weight is the inverse of the probability for each lake (USEPA, 2017). The indicator thresholds are used to evaluate the data from each lake and place that lake into one of the three disturbance classes (least, moderately, or most disturbed). Then the site weights from the probability design are summed across the disturbance class to estimate the percent of lake acres in each class (USEPA, 2017). Please note that throughout the discussion of this report the term "*percent of lakes*" may be used, but the analysis most accurately represents percent of lake *acres*. The processing of data for condition extent, relative risk, and attributable risk values were accomplished with R-statistical Software (R Foundation, 2013) using methodologies and R-scripts developed for the NARS program (Van Sickle, 2012). Adjusted site weights were calculated and provided by the USEPA (Kincaid, 2018). Other analyses were performed using Minitab statistical software (Minitab, 2013).

Results

Due to of the statistical design of the survey, the sampled lake information was used to make inferences about the total population of lakes greater than 50 surface acres. This project was not designed to report on individual lakes, but to report on the statewide scale. Thus, results are expressed as percent of lake acres in a particular disturbance class for the entire state. The three disturbance classes are:

1. Most disturbed, signifying that reported values are out of balance or poor condition
2. Moderately disturbed, signifying that reported values are somewhat out of balance or possibly poor condition
3. Least disturbed, signifying that reported values are in balance or good condition

Because Oklahoma lake morphology can be highly dendritic, the analysis was conducted to present results for both the whole lake area and lacustrine (open water area) area only. Viewing results from these two perspectives serves to guard against the possibility that poor or good water quality conditions occurring in only one area of the lake would skew the evaluation of overall lake water quality. However, it is important to note that the lacustrine results are based on a single sampling location generally near the lake's dam. Finally, the analysis provides both a point estimate of condition and the 95th percentile confidence intervals around that estimate.

Nutrients (Phosphorus & Nitrogen)

The total phosphorus whole lake results reported that 43% of Oklahoma lake acres are in the most disturbed class; while 27% and almost 30% of lake acres are in the moderately and least disturbed classes, respectively (**Figure 5**). The results for the lacustrine lake area indicate that 46% of lake acres fall in the least disturbed condition, 21% are in the moderately disturbed and 33 % are in the most disturbed condition for total phosphorus (**Figure 6**).

Results for whole lake area indicate that 29% of Oklahoma lake acres fall in the least disturbed class, 8% are in the moderately disturbed and 64% are in the most disturbed class as it relates to total nitrogen (**Figure 7**). The results for the lacustrine region of the lake are very similar to those seen when considering the whole lake. Results indicate that 30% of the lake acres fall in the least disturbed condition, 12% are in the moderately disturbed and 58% are in the most disturbed class for total nitrogen (**Figure 8**).

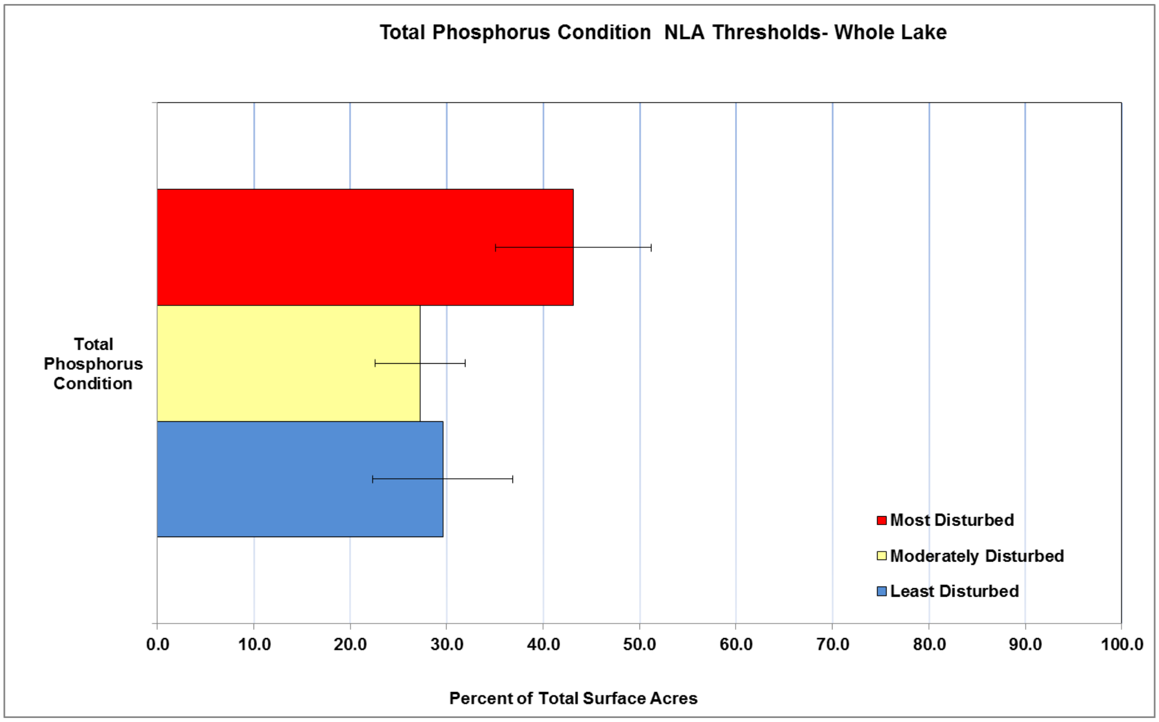


Figure 5. Total Phosphorus Condition, Whole Lake

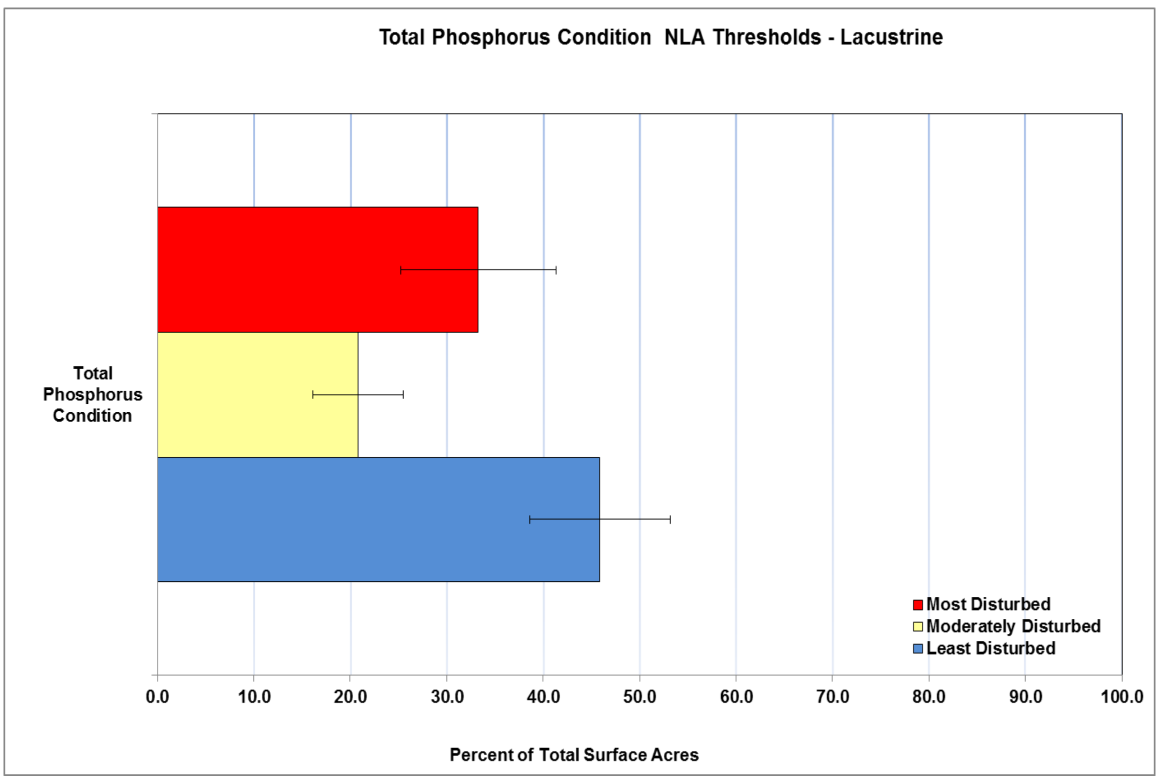


Figure 6. Total Phosphorus Condition, Lacustrine Zone

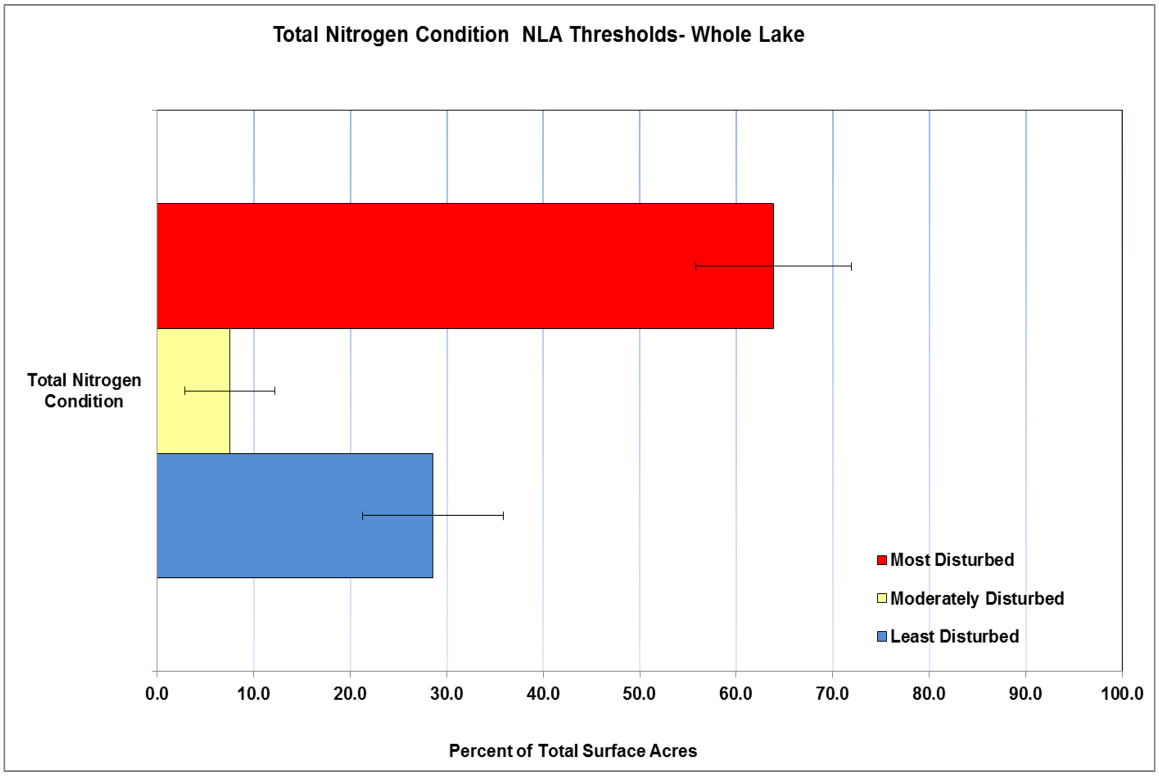


Figure 7. Total Nitrogen Condition, Whole Lake

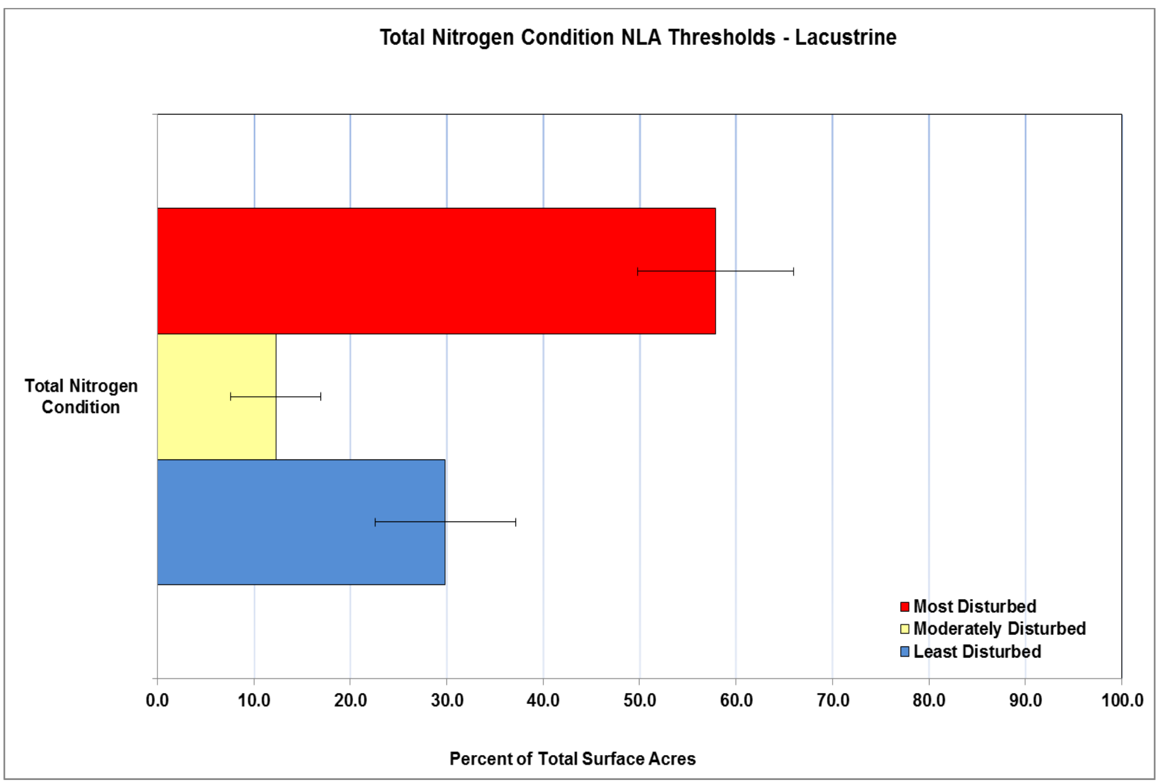


Figure 8. Total Nitrogen Condition, Lacustrine Zone

Chlorophyll

As discussed in the threshold section, there are various thresholds for chlorophyll and consequently there are various chlorophyll results. Table 9 presents the results for the NLA chlorophyll *a* threshold, the OK water supply criterion threshold, and the OK chlorophyll potential human health risk threshold for both whole lake and lacustrine areas. The NLA chlorophyll *a* threshold produced fairly consistent results with generally about 20% of lake acres in the least disturbed class, approximately 40% of lake acres in the moderately disturbed class, and approximately 40% in the most disturbed class. This generalized pattern was consistent across the summer and annual seasons and between the whole lake and lacustrine spatial scales. When evaluating the results based on the Oklahoma water supply threshold the greatest distinctions were between the summer and annual time periods and there was little distinction between the whole lake and lacustrine area results. In the summer critical season none of Oklahoma's lake acres were classified as least disturbed for the water supply threshold and an overwhelming 87% were moderately disturbed (Table 9). This contrasted with the annual results where about 50% of lake acres become classified as least disturbed and the remaining 50% are split between moderately and most disturbed.

The results based on the OK potential human health threshold were fairly consistent between summer and annual time periods and there was very little difference between the whole lake versus lacustrine area. Generally, 60% of lake acres were classified as least disturbed and 24-34% are moderately disturbed, which leaves roughly 10% of lake acres in the most disturbed category. Graphical representation of these same results is provided in Appendix G.

Table 9. Chlorophyll condition results for both whole lake and lacustrine zone.

		Summer			**Annual**		
		Disturbance Class			**Disturbance Class**		
	Chlorophyll Threshold	**Least Disturbed**	**Moderately Disturbed**	**Most Disturbed**	**Least Disturbed**	**Moderately Disturbed**	**Most Disturbed**
Whole Lake	NLA Chlorophyll Condition	15%	41%	44%	22%	39%	39%
	OK Water Supply Criterion	0%	87%	13%	45%	32%	23%
	OK Potential Human Health Risk	59%	27%	14%	59%	34%	7%
Lacustrine Area	NLA Chlorophyll Condition	20%	42%	38%	26%	45%	29%
	OK Water Supply Criterion	0%	87%	13%	50%	29%	21%
	OK Potential Human Health Risk	66%	24%	10%	68%	24%	8%

Trophic State

A sizable majority of Oklahoma's lake acres are classified as eutrophic to hypereutrophic regardless of the TSI threshold applied (Figures 9 – 12). When the Carlson TSI, routinely used by the OWRB lake monitoring program was applied the breakdown between eutrophic and hypereutrophic was typically about 40% versus 20% with slight variation between the summer or annual time periods and whole lake or lacustrine areas (Figures 9 –12). By comparison, the NLA trophic status threshold expands the eutrophic class to 58% and reduces the hypereutrophic and mesotrophic classes to 14% and 24%, respectively (Figure 13).

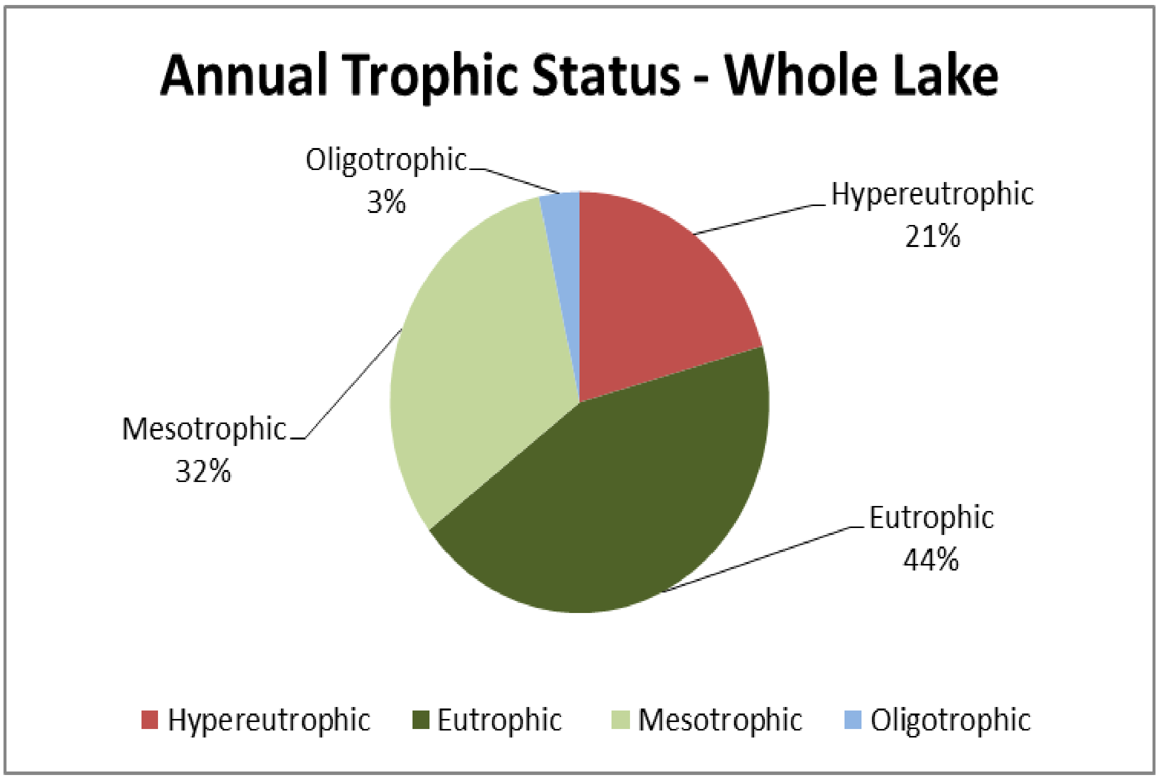


Figure 9. Carlson's Annual TSI, Whole Lake

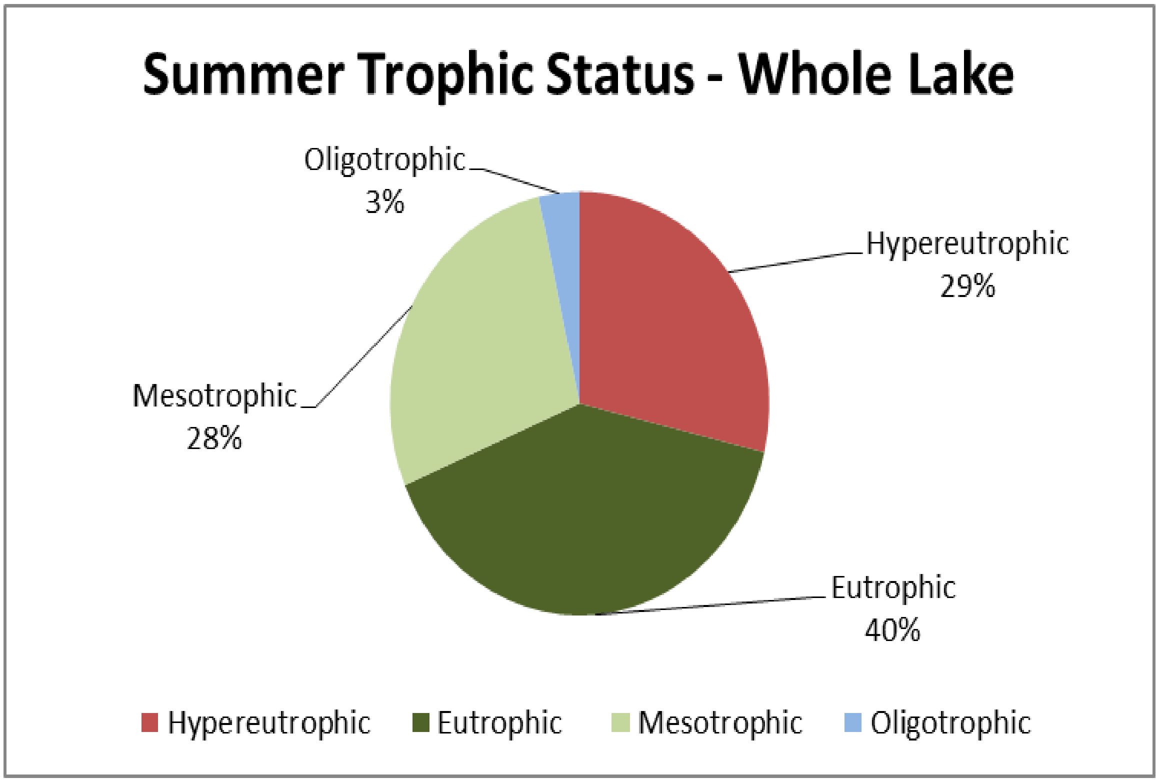


Figure 10. Carlson's TSI, Summer Only for Whole Lake

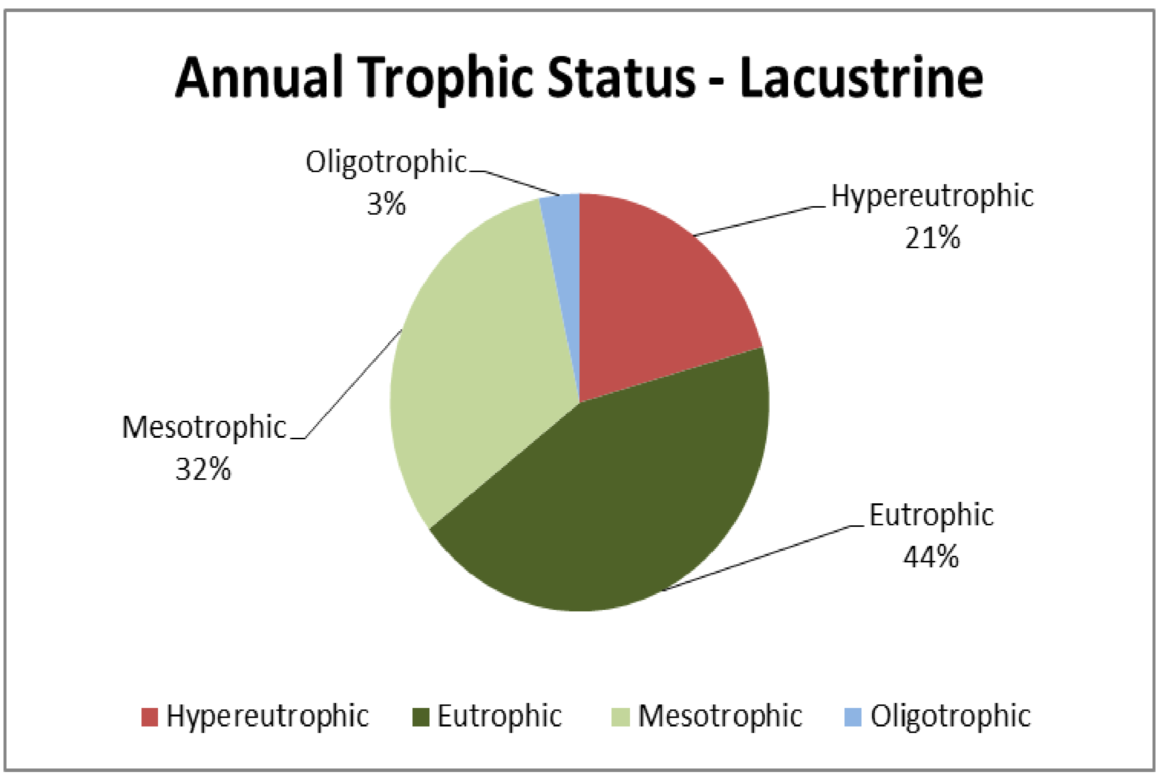


Figure 11. Carlson's Annual TSI, Lacustrine Zone

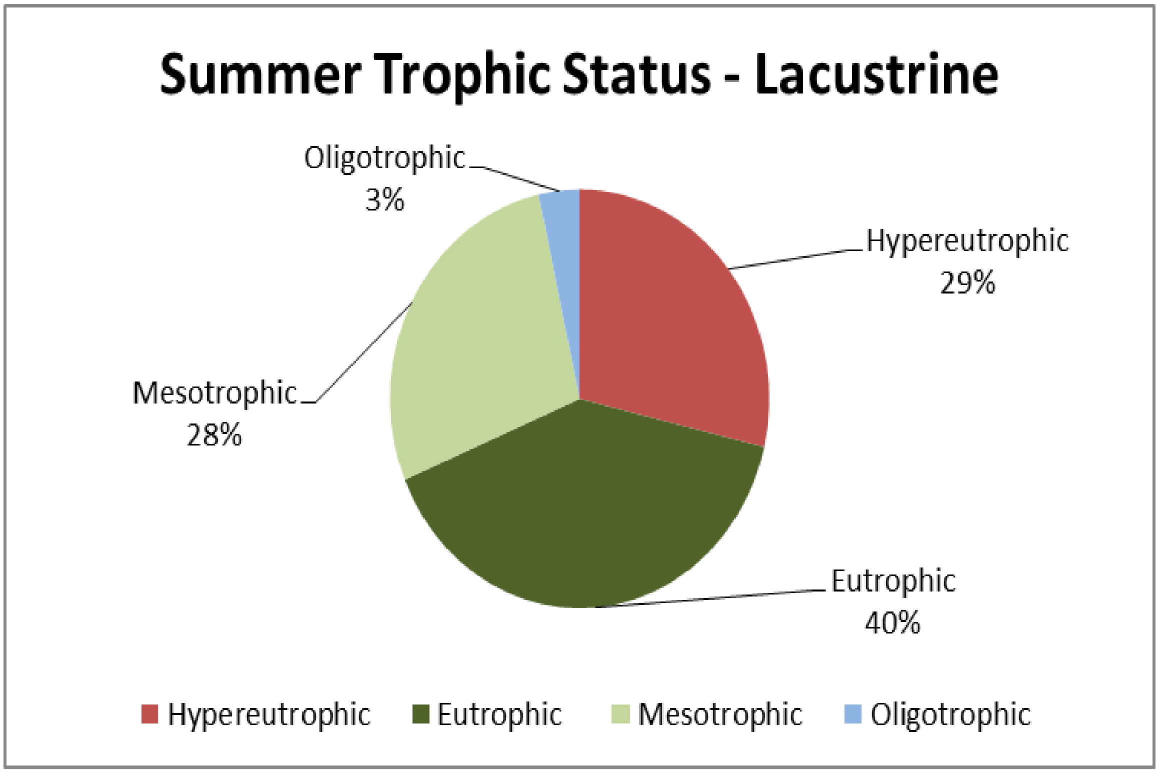


Figure 12. Carlson's TSI, Summer Only for Lacustrine Zone

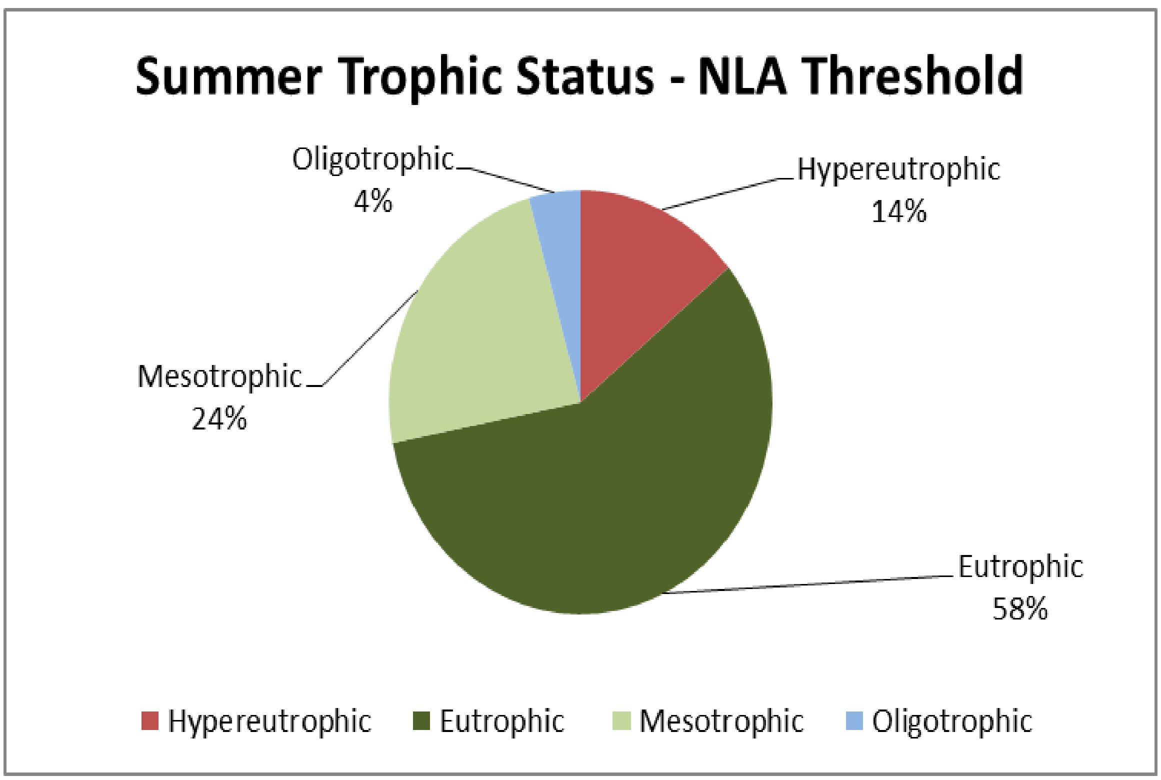


Figure 13. Summer TSI, using NLA Thresholds

Dissolved Oxygen

The surface layer (0-2 meters) of Oklahoma's lakes have sufficient dissolved oxygen; ninety-two percent of lake acres are in the least disturbed class with DO concentrations greater than or equal to 5 mg/L (**Figure 14**). Five percent of the state's lake acres are considered moderately disturbed and 1% was in the most disturbed class. Two percent of lake acres were not assessed because DO measures from the summer period were not available.

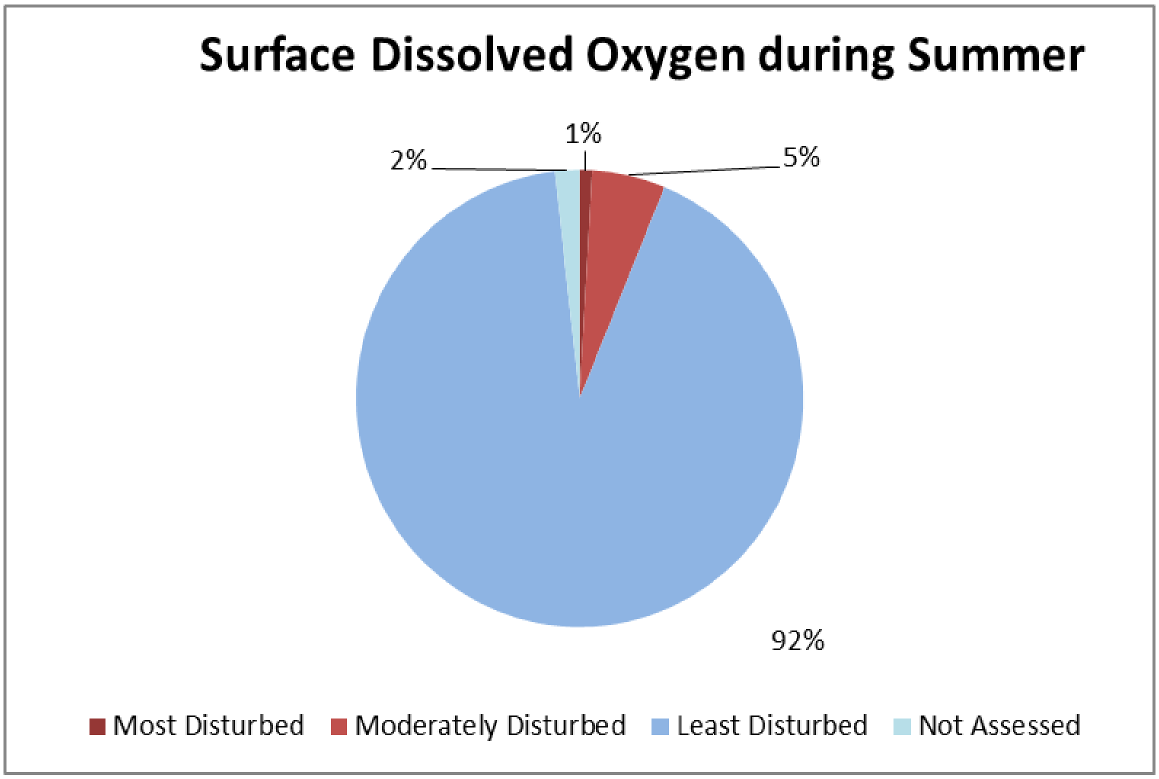


Figure 14. Surface Dissolved Oxygen during the Critical Period

Turbidity

The NLA threshold, derived from ecoregional reference lakes, is considerably lower than Oklahoma's threshold and as a result more than 90% of lake acres are classified as most disturbed (**Figure 15**). Comparing the whole lake area to Oklahoma's criterion threshold of 25 NTU for turbidity, the lake acres are fairly evenly distributed across each disturbance class (**Figure 16**). However, the application of the NLA turbidity thresholds reveals strikingly different results.

Figures 17 and 18 present turbidity in the lacustrine portion of the lake. When comparing to the Oklahoma water quality criterion threshold 50% of the lake acres are least disturbed while 24% and 26% of lake acres fall in the moderately and most disturbed categories. Based on the NLA threshold values the distribution of lake acres in each of the categories was similar to that of the whole lake.

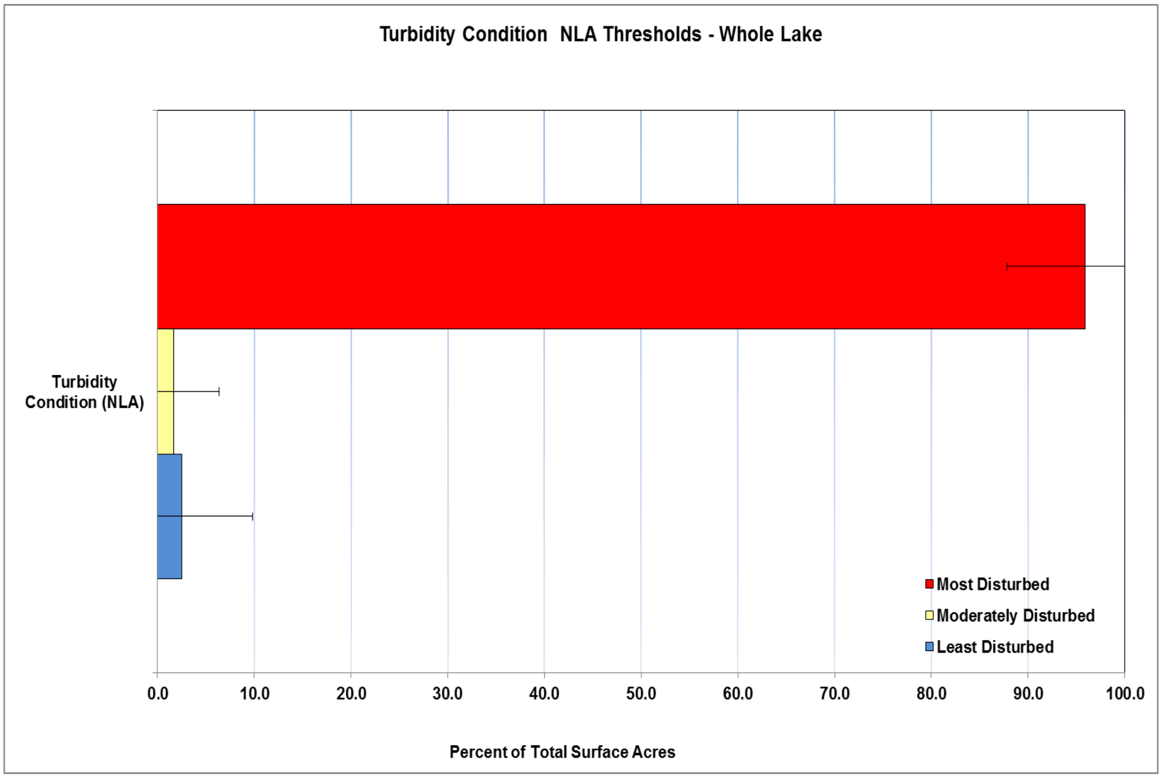


Figure 15. Turbidity Condition using NLA Thresholds, Whole Lake

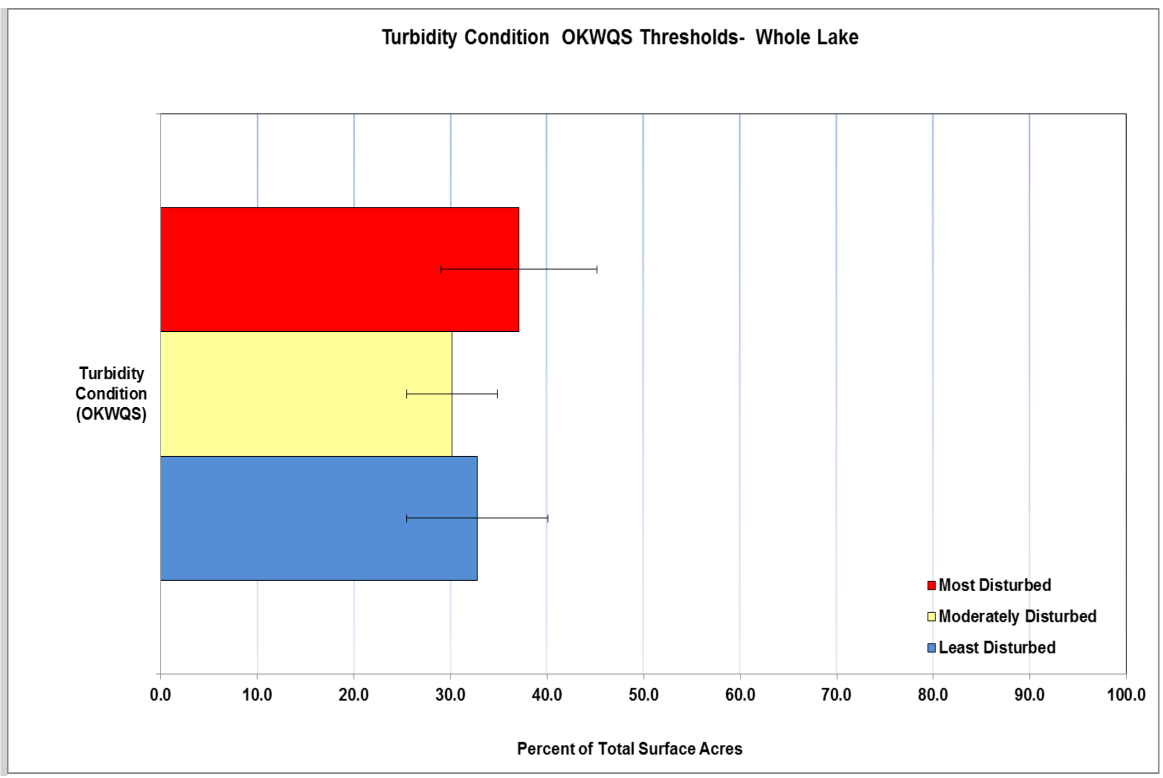


Figure 16. Turbidity Condition using OKWQS Thresholds, Whole Lake

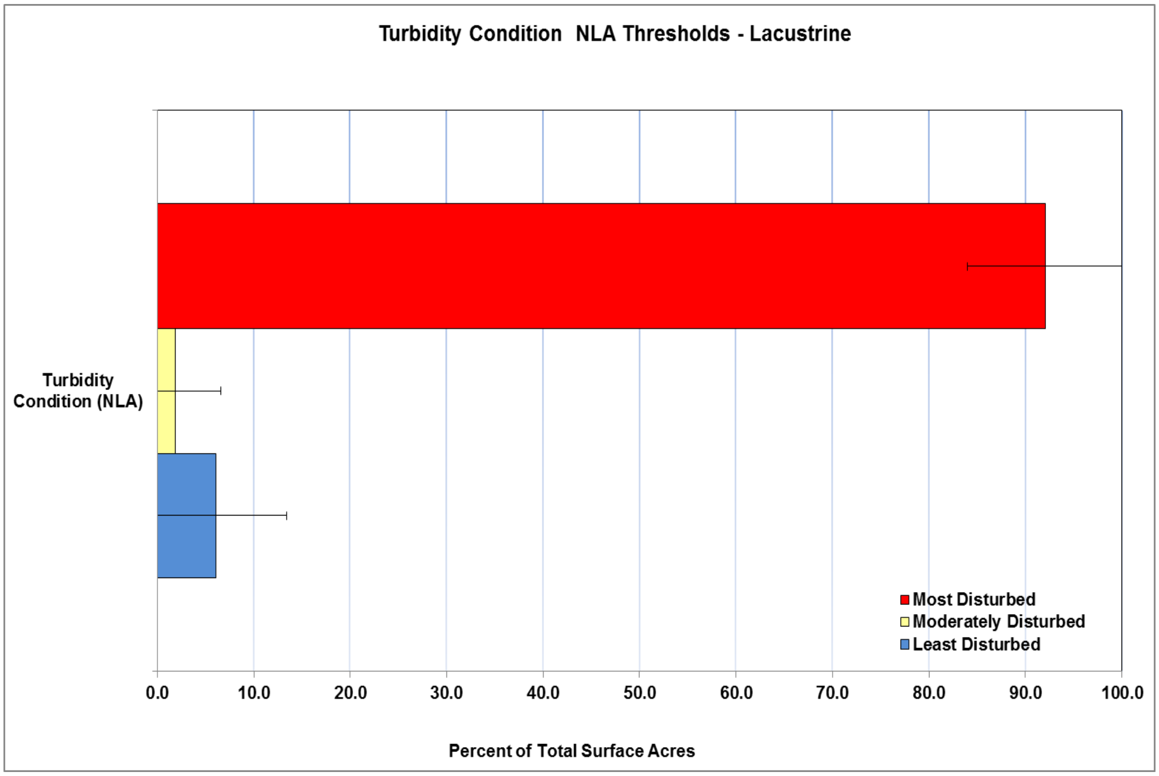


Figure 17. Turbidity Condition using NLA Thresholds, Lacustrine Zone

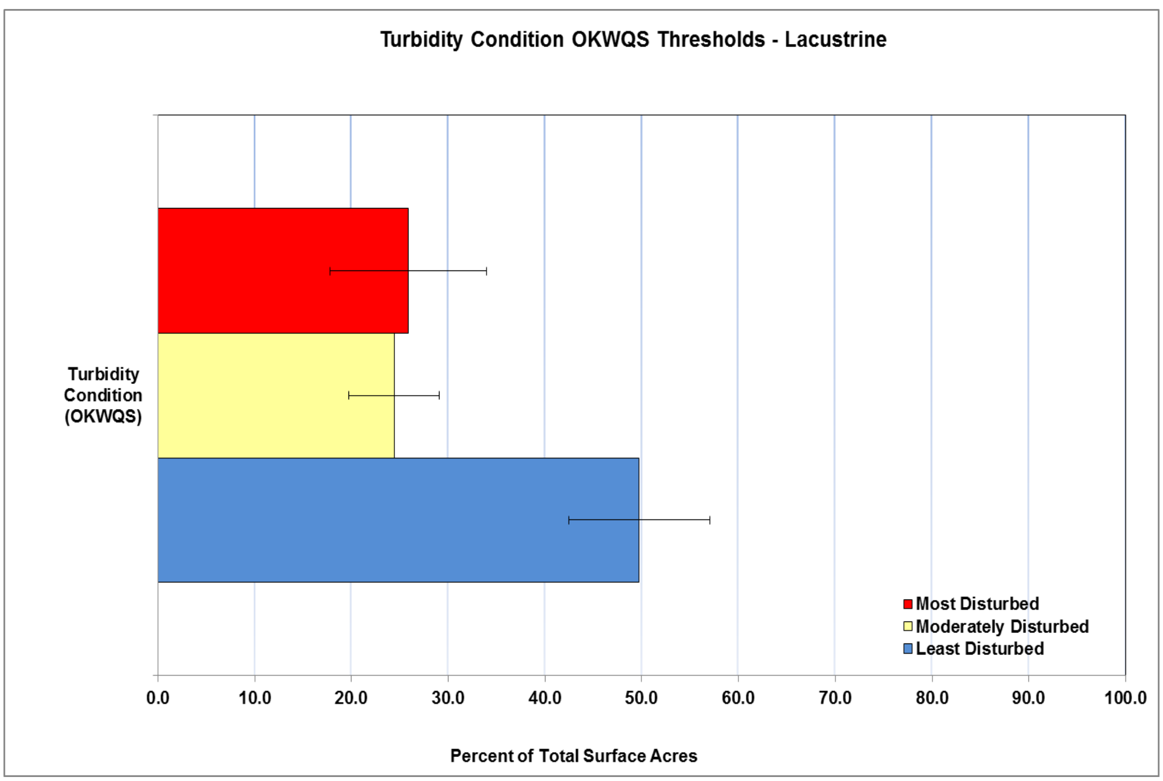


Figure 18. Turbidity Condition using OKWQS, Lacustrine Zone

Relationship between Stressors and Biological Condition in Lakes

An important benefit of conducting a statewide statistical survey of lakes is the ability to assess the relative importance of key stressors on lake biological response. As discussed in the Water Quality Indicator section, chlorophyll is a key biological response metric and several stressors (phosphorus, nitrogen, turbidity) influence how the chlorophyll response is expressed in a lake. In this section the analysis evaluated which stressors are most associated with poor biological conditions (i.e. high chlorophyll concentrations) in the lake.

Relative Risk

The first analysis was relative risk. Relative risk characterizes the influence of a stressor as a measure of the likelihood (or "*risk*") of finding a *most disturbed* biological condition in the lake when a particular stressor is also in the *most disturbed* condition (USEPA, 2017). Relative Risk is a ratio of the probability of an outcome occurring in a stressed group versus the probability of the outcome occurring in a non-stressed group. In this study, the *most disturbed* condition is considered the stressed group and the *least disturbed* and *moderately disturbed* results are combined to create the non-stressed group. The 2012 NLA Technical guidance document provides formulas and details for calculating relative risk (USEPA, 2016). Because relative risk is calculated as a ratio a result value of 1 indicates that there is no association between the stressor and biological response, if relative risk is less than 1 it indicates that the *most disturbed* biological condition is actually less like to occur whether or not the stressor is also in a *most disturbed* condition. Finally, if the relative risk value is greater than 1 it indicates that the stressor is in fact influencing the biological response being in the *most disturbed* condition (**Table 10**). As the relative risk value increases above a value of 1, the relative risk of the stressor also increases. Confidence intervals were calculated according to Van Sickle and Paulsen, 2008.

Table 10. Relative Risk Evaluation.

Relative Risk Result	Interpretation
<1	Most disturbed biological condition not effected by stressor
1	No association between stressors & biological response
>1	Stressor likely has effect on most disturbed biological condition

It is important to note that the relative risk analysis does not evaluate joint effects of correlated stressors. Meaning that each stressor is presented individually, when in reality stressors may interact with one another and potentially increase or decrease impact on biological condition (USEPA, 2017).

The relative risk analyses compared phosphorus, nitrogen, and turbidity stressors to biological condition for chlorophyll and for each stressor relative risk was determined for the lacustrine zone and whole lake. In the graphs the red bars indicate stressors that have significant relative risk and the blue bars indicate stressor for which the relative risk was not significant. When evaluating the lacustrine zone only, total phosphorus shows no significant relative risk for summer and annual chlorophyll *a* based on the NLA condition threshold. The picture was somewhat different when considering the lake as a whole versus the lacustrine zone in regards to nutrients. Chlorophyll *a* condition was likely to be most disturbed when both total phosphorus and total nitrogen are in the most disturbed condition. For both summer and annual average chlorophyll *a* condition was 1.7 times more likely to be most disturbed when total phosphorus condition was also most disturbed (**Figure 19**).

Regarding nitrogen, the risk analysis indicates that summer chlorophyll *a* in the lacustrine zone was 3.8 times more likely to be *most disturbed* and annual chlorophyll *a* was 2.9 time more likely to be *most disturbed* when total nitrogen was also in *most disturbed* condition (**Figures 20 and 21**). When evaluating the whole lake for nitrogen risk there was 3.6 and 3.2 times greater likelihood that chlorophyll *a* will be *most disturbed* for summer and annual chlorophyll, respectively. *a*

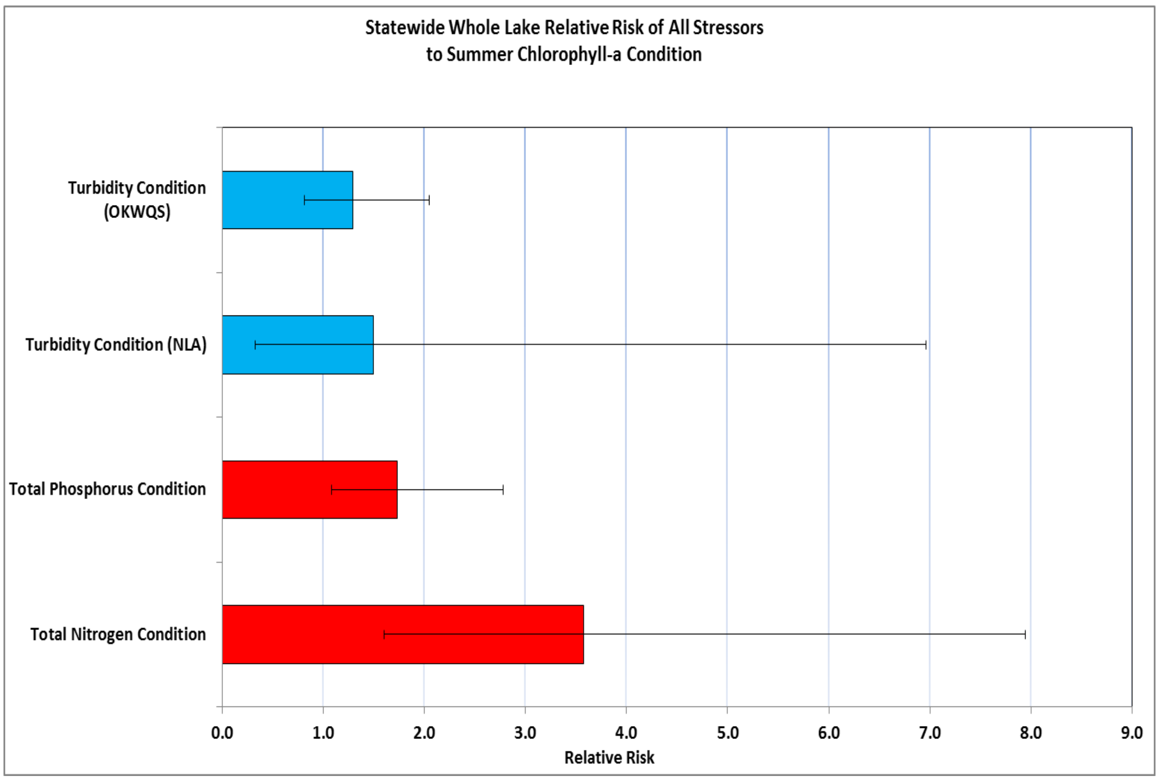


Figure 19. Relative risk of stressors affecting summer chlorophyll *a* condition, whole lake.

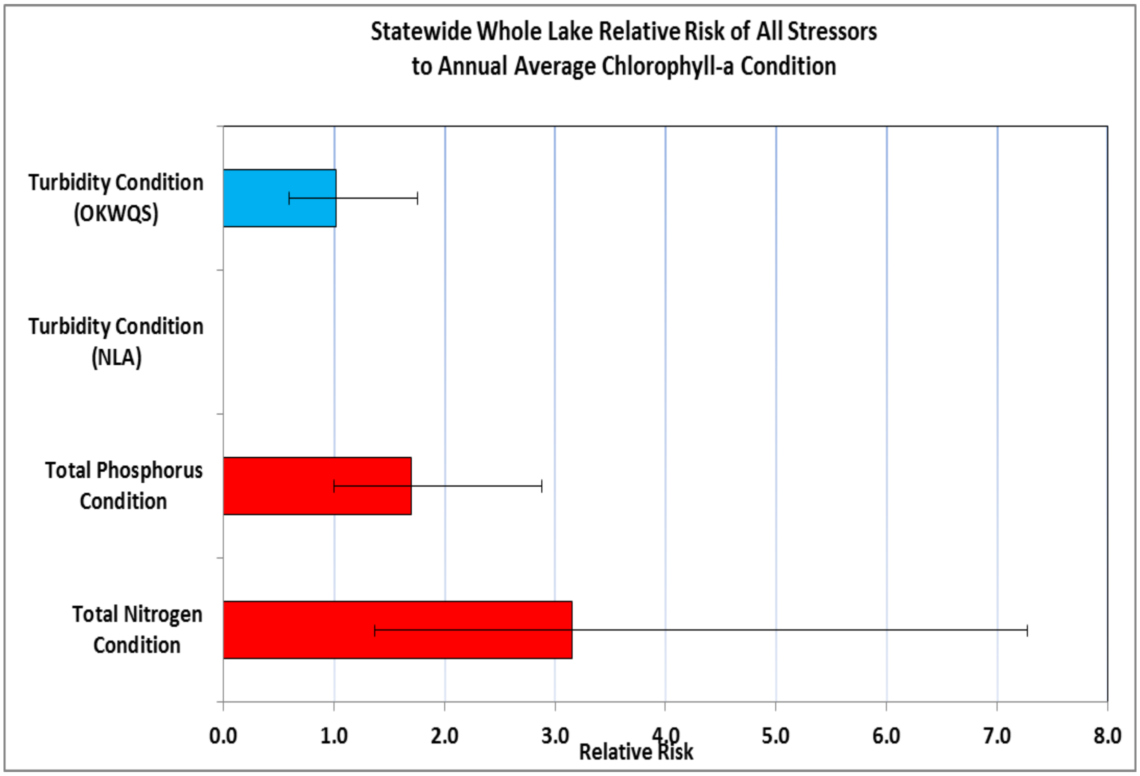


Figure 20. Relative risk of stressors affecting annual average chlorophyll *a* condition, whole lake,

Turbidity indicates no significant relative risk regardless of comparing to the Oklahoma water quality criterion of 25 NTU or the NLA threshold (**Figures 21 and 22**). Nutrients and turbidity demonstrate no significant risk to summer or annual chlorophyll *a* condition based on the Oklahoma criterion of 10µg/l regardless of whether the whole lake or lacustrine area only was considered (**Figures 23 - 26)**.

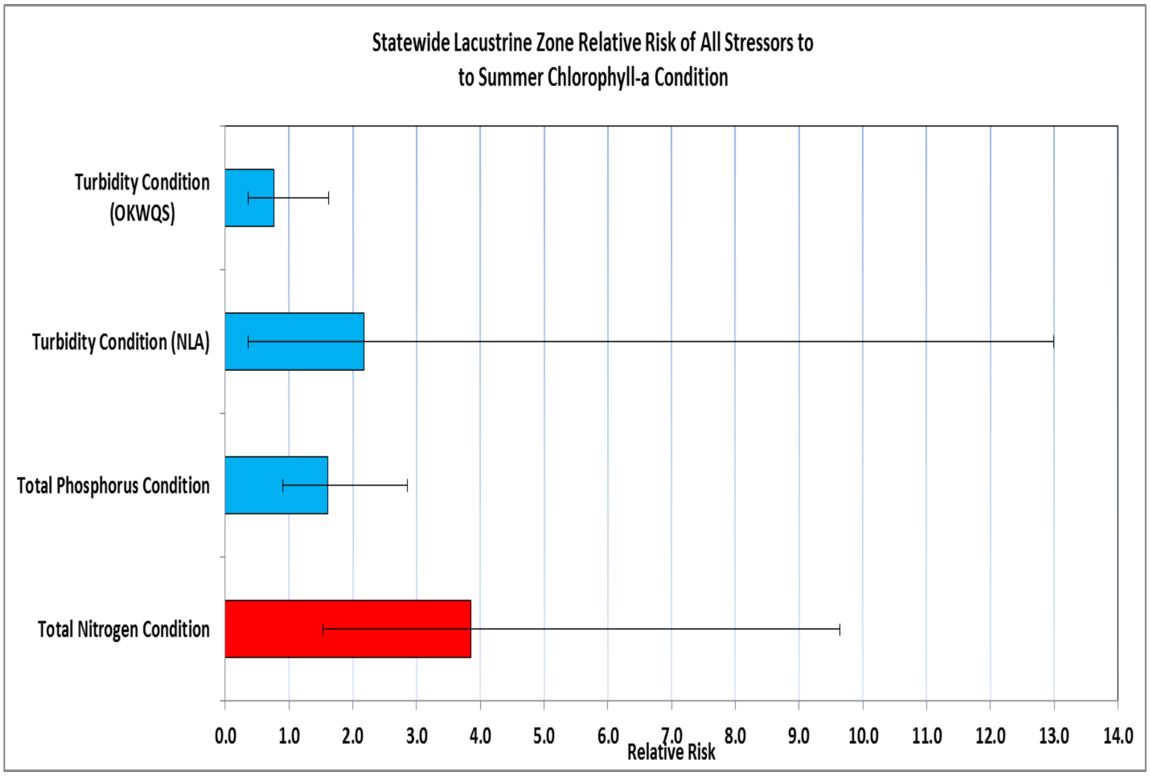


Figure 21. Relative risk of stressors affecting summer chlorophyll *a* condition, lacustrine zone.

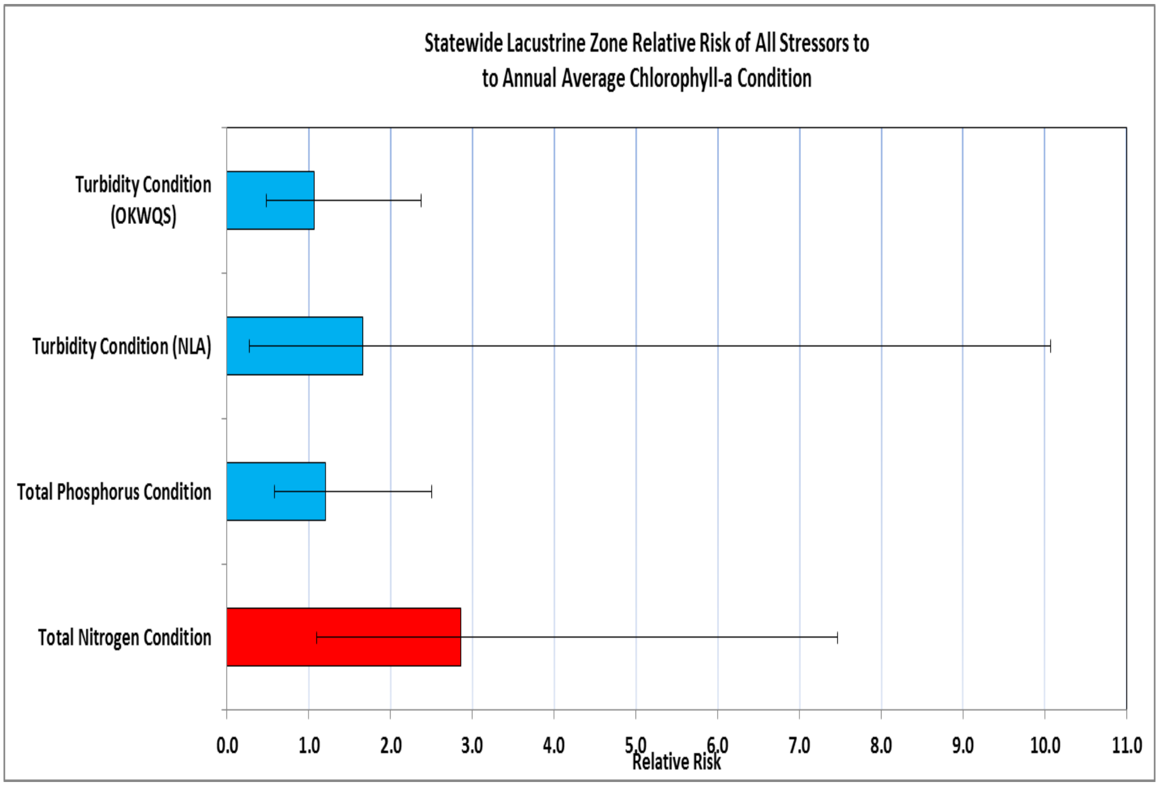


Figure 22. Relative risk of stressors affecting annual average chlorophyll *a* condition, lacustrine zone.

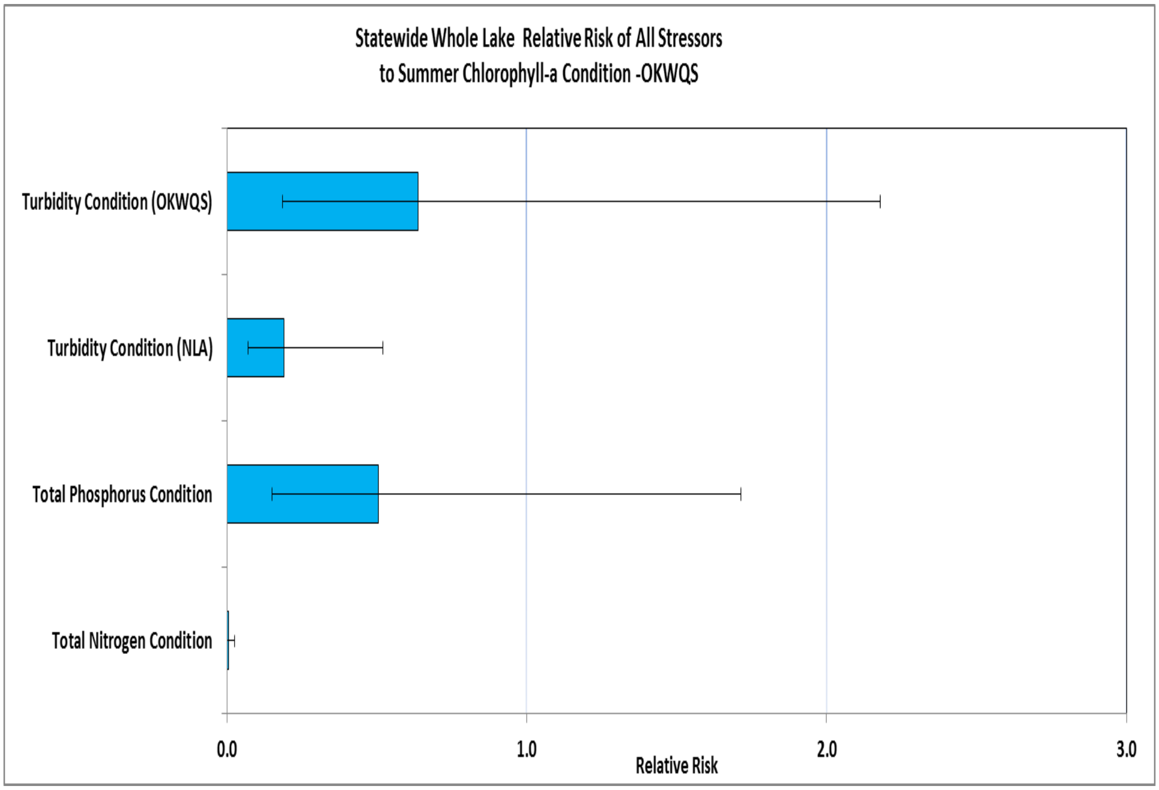


Figure 23. Relative risk of stressors affecting summer chlorophyll *a* condition comparison to OKWQS, whole lake.

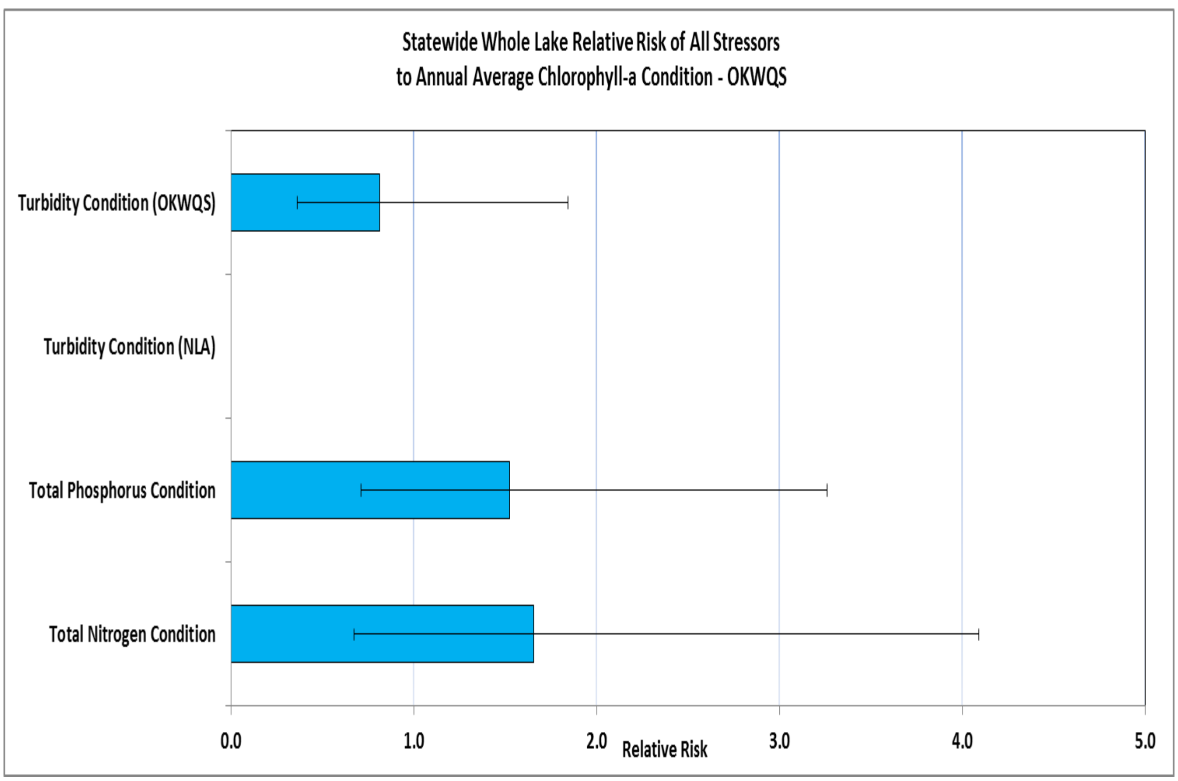


Figure 24. Relative risk of stressors affecting annual average chlorophyll *a* condition comparison to OKWQS, whole lake.

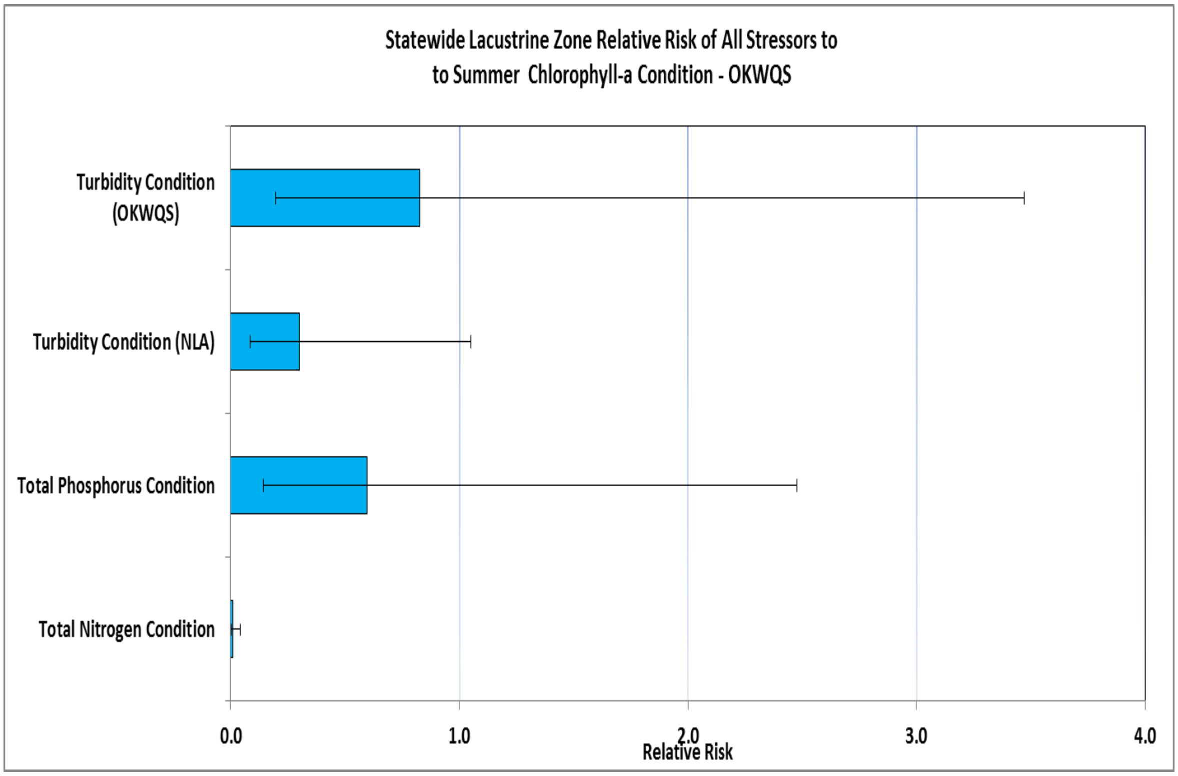


Figure 25. Relative risk of stressors affecting summer chlorophyll *a* condition comparison to OKWQS, lacustrine zone.

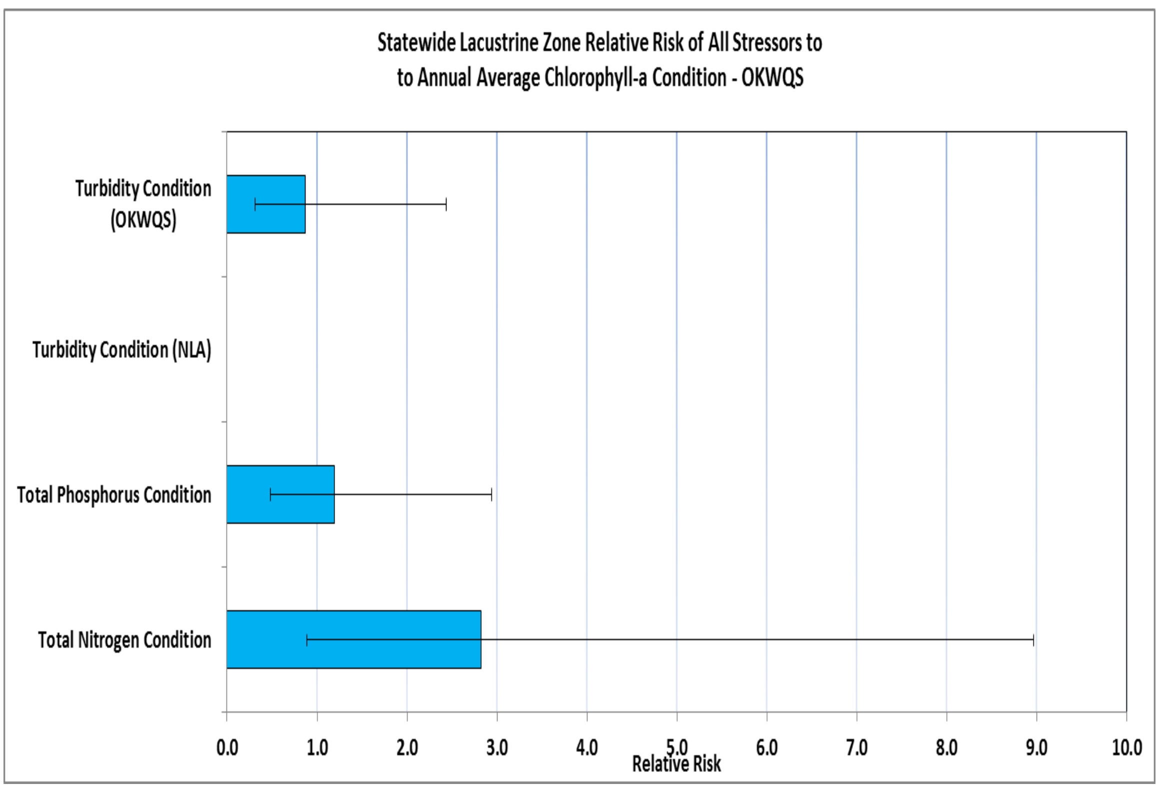


Figure 26. Relative of stressors affecting annual average *a* condition comparison to OKWQS, lacustrine zone.

Attributable Risk

Attributable risk characterizes a scenario in which a given stressor is mitigated to achieve the non-stressed (least and moderately disturbed) condition and estimates the expected decreased extent of most disturbed biological condition. Attributable risk is derived by combining relative extent and relative risk into a single estimate of the expected improvement in biological condition if a particular stressor is eliminated from the most disturbed condition. Attributable risk involves the following assumptions (USEPA, 2016, USEPA, 2017):

1) supports a causal relationship between stressor and biological condition response
2) effects would be reversed if the stressor were removed
3) each stressor is independent, so individual stressor effects can be estimated in isolation from other stressors

Attributable risk can emphasize which stressors might be higher priorities, and provide direction to policymakers and managers when making decisions related to lake management and protection.

The results of attributable risk for this study are provided in **Figures 27 and 28**. Due to the manner in which attributable risk is calculated, a stressor has no attributable risk if it has zero extent or no association with the biological response condition, that is a relative risk equal to 1 (Table 10) (Van Sickle and Paulsen, 2008). Therefore, in order to provide a meaningful analysis, pollutant elimination analyses were only performed when stressor relative risk was significant. Confidence intervals were also calculated for each risk analysis. Potential reduction of the most disturbed condition is only significant when the upper confidence bound is not equal to or greater than the original percent in poor condition. For example, in **Figure 27** an elimination of total phosphorus concentrations greater than the most disturbed threshold could reduce the percentage of lake acres most disturbed for NLA summer chlorophyll condition by about 4%. However, because the upper confidence limit was not lower than the original percentage of lakes in most disturbed condition the potential reduction may not be effectively different from zero and therefore was not significant.

Attributable risk analysis for chlorophyll *a* condition for the lacustrine zone and whole lake with the stressors total nitrogen and total phosphors were completed. Various response conditions were characterized for each stressor. The response conditions were 1) NLA threshold summer chlorophyll condition (Table 4), 2) NLA threshold annual chlorophyll condition, 3) Oklahoma chlorophyll benchmark (Table 6). The summer chlorophyll condition, based on the Oklahoma criterion of 10µg/l, was not included as part of attributable risk analysis because it estimated a negative rate of change due to the zero extent in the least disturbed class.

The most significant elimination analyses were for total nitrogen. An elimination of total nitrogen from the most disturbed class could reduce poor chlorophyll *a* condition (based on NLA thresholds) by approximately 28% when considering summer and by 23% when considering annual average chlorophyll

(**Figure 27**). Whereas, the elimination of total phosphorus generally predicts a 4 - 10% reduction of poor chlorophyll conditions; however, notably this potential reduction of lake acres in the most disturbed class was not statistically significant **Figure 27**). The attributable risk results from the lacustrine zone only showed similar results in that the elimination of nitrogen values within the most disturbed class has the potential to reduce the percentage of lake acres within the summer chlorophyll most disturbed class by 24% (**Figure 28**). The remaining attributable risk results for the lacustrine zone are interesting however none of them are statistically significant.

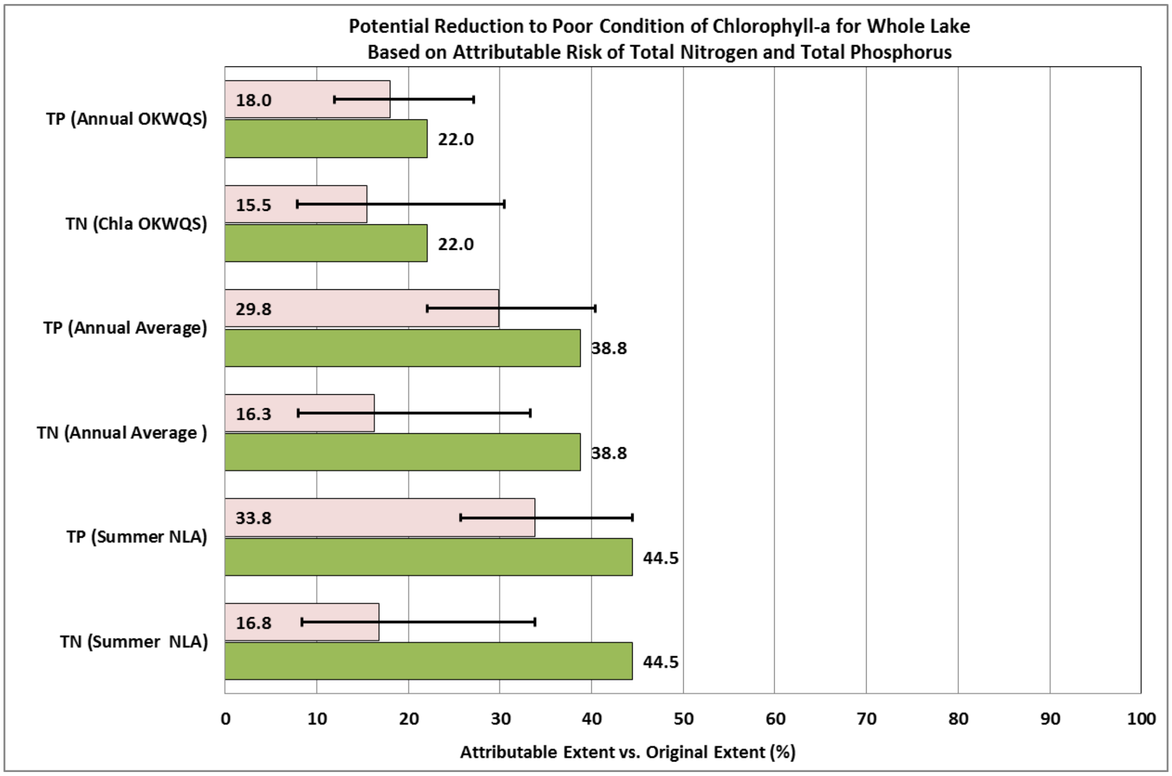


Figure 27. Potential reduction to poor condition of *a* for whole lake based on attributable risk of total nitrogen and total phosphorus.

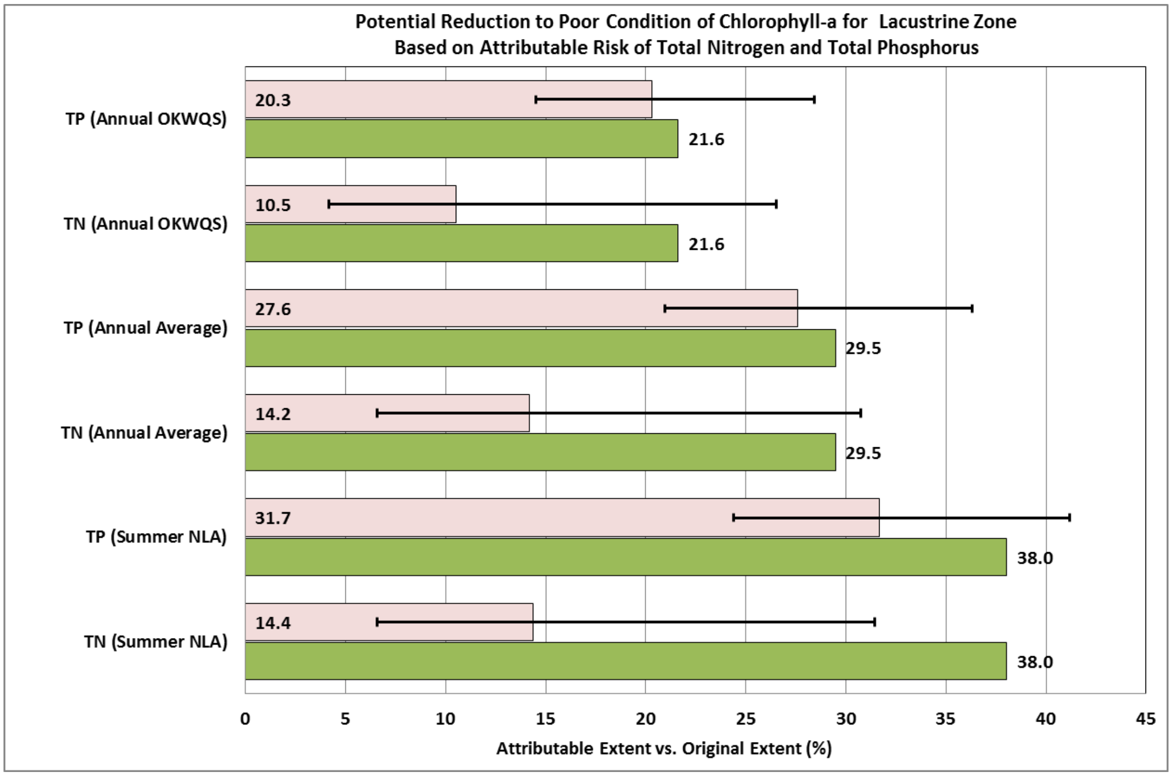


Figure 28. Potential reduction to poor condition of chlorophyll *a* for lacustrine zone based on attributable risk of total nitrogen and total phosphorus.

Discussion and Conclusions

As presented in the water quality indicator section nutrients are essential for lake ecology; however, there are severe consequences to lake conditions when nutrient concentrations become too high. The condition extent results found that more than 60% of Oklahoma lake acres are classified as most disturbed for total nitrogen. This represents in lake total nitrogen concentrations greater than 407 – 1,699 ug/L depending on the ecoregion. Forty-three (43%) percent of lake acres are classified as most disturbed for total phosphorus, which was characterized by total phosphorus concentrations greater than 33-82 ug/L depending on ecoregion. These high nutrient concentrations combined with the TSI results showing that 69% of lake acres are either eutrophic or hypereutrophic, reveal that many of Oklahoma's lakes experience negative water quality conditions on a regular basis.

The nutrient thresholds for this study were set by the NLA on an ecoregion basis, so it was possible to view the Oklahoma nutrient results in comparison to the rest of the country. On the national scale 40% of lake acres are classified as most disturbed for total phosphorus. Oklahoma lakes are similar to lakes in the rest of the country in terms of elevated phosphorus concentrations. Although, Oklahoma only has 30% of lake acres classified as least disturbed for total phosphorus and nationwide 45% are least disturbed. The total nitrogen however, exhibits different result. At the national level only 35% of lake acres are most disturbed for total nitrogen and in Oklahoma it was more than 60%, indicating that nitrogen is a prevailing stressor on Oklahoma lakes. This was further demonstrated by the risk analysis results where total nitrogen has the greatest relative risk related to both summer and annual chlorophyll concentrations. Moreover, the summer total nitrogen attributable risk results were most significant for nitrogen. The attributable risk results highlight that if lake total nitrogen concentrations were reduced to concentrations satisfying the thresholds for least and or moderately disturbed then the percentage of lake acres in the most disturbed class could be improved from 45% to 17%. These results provide strong evidence for the need to reduce and manage nitrogen pollution across Oklahoma.

The reason that total phosphorus results show fairly low relative risk to both summer and annual chlorophyll concentrations has more to do with how relative risk was calculated than a definitive result on phosphorus as a stressor. Recall that in the relative risk calculation the categories of least disturbed and moderately disturbed are combined into a single “non-stressed” category; the percentage breakdown of the original categories can mute the sensitivity or explanatory ability of the relative risk calculation. Upon review of the original total phosphorus condition extent results, it appears to have happened in this case. Oklahoma only has 30% of lake acres classified as least disturbed for total phosphorus, this means that 70% of lake acres are subject to out of balance or degraded phosphorus conditions. So, even though the results of this study don’t strongly emphasize phosphorus risk for Oklahoma lakes clearly phosphorus concentrations are elevated. This interconnects with other results such as, 69% of lake acres identified as eutrophic or hypereutrophic. Additionally, it has been shown that there is a strong relationship between total phosphorus and chlorophyll *a* concentration in Oklahoma lakes (Tetra Tech, 2018). Taken together the nitrogen and phosphorus results from this study confirm that nutrients are a ubiquitous stressor on Oklahoma lakes and addressing nutrient pollution is a vital interest for state water quality management.

A striking result from the summer chlorophyll analysis was that zero lake acres were in the least disturbed class; meaning that at the time of this study no lake acres in Oklahoma were attaining the chlorophyll value established to protect drinking water supply. One hundred and twenty four lakes in OK are designated with the *Public and Private Water Supply* beneficial use and 73 are also classified as *Sensitive Water Supply.* It is a serious water quality management concern that none of these lakes are classified as least disturbed, especially during the summer season when difficulties and dangers associated with high chlorophyll concentrations are greatest. Conversely, the annual average chlorophyll results show that 45% of lake acres met the threshold for least disturbed. This substantial divergence between summer and annual average results demonstrates the influence of averaging periods on data analysis. Outside of the growing season (generally May-October) Oklahoma lakes typically have lower chlorophyll concentrations due to cold temperatures and decreased light. In a separate analyses, OWRB staff analyzed the seasonal distribution of mean and median chlorophyll concentrations in public water supply lakes and this seasonal pattern was evident (**Figures 29 and 30**) (Porter, 2020).

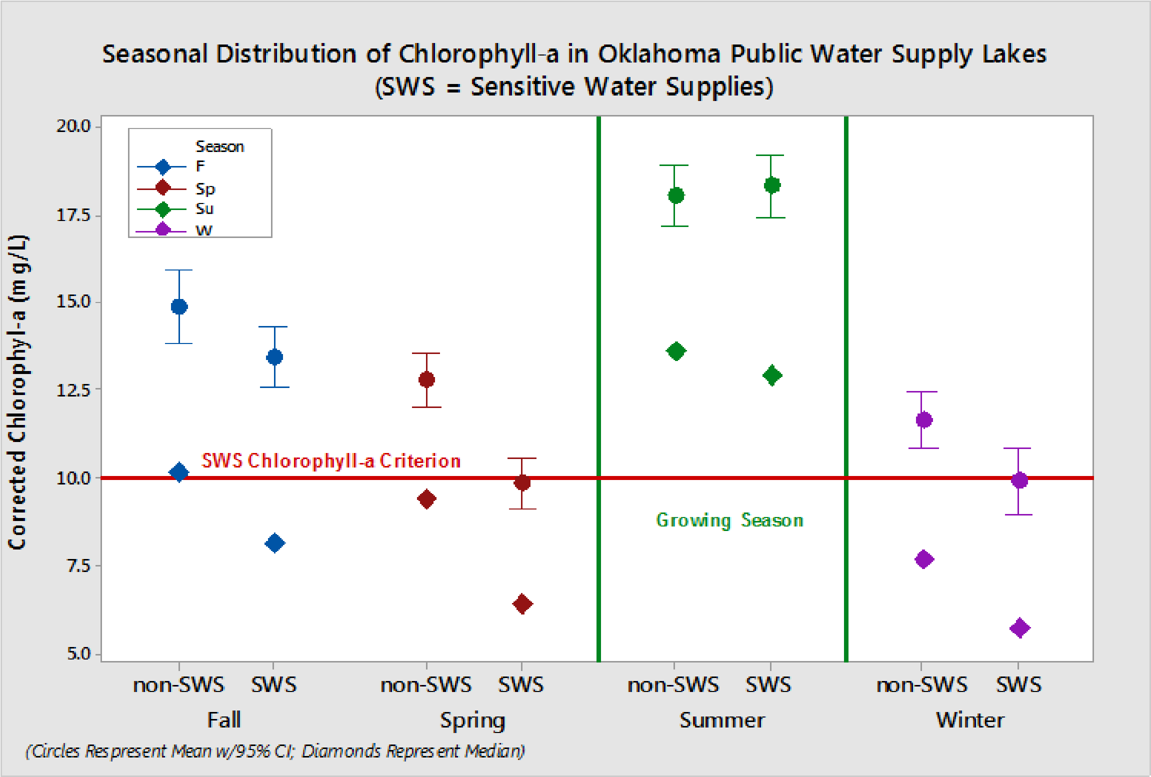


Figure 29. Seasonal distribution of *a* in Oklahoma public water supply lakes.

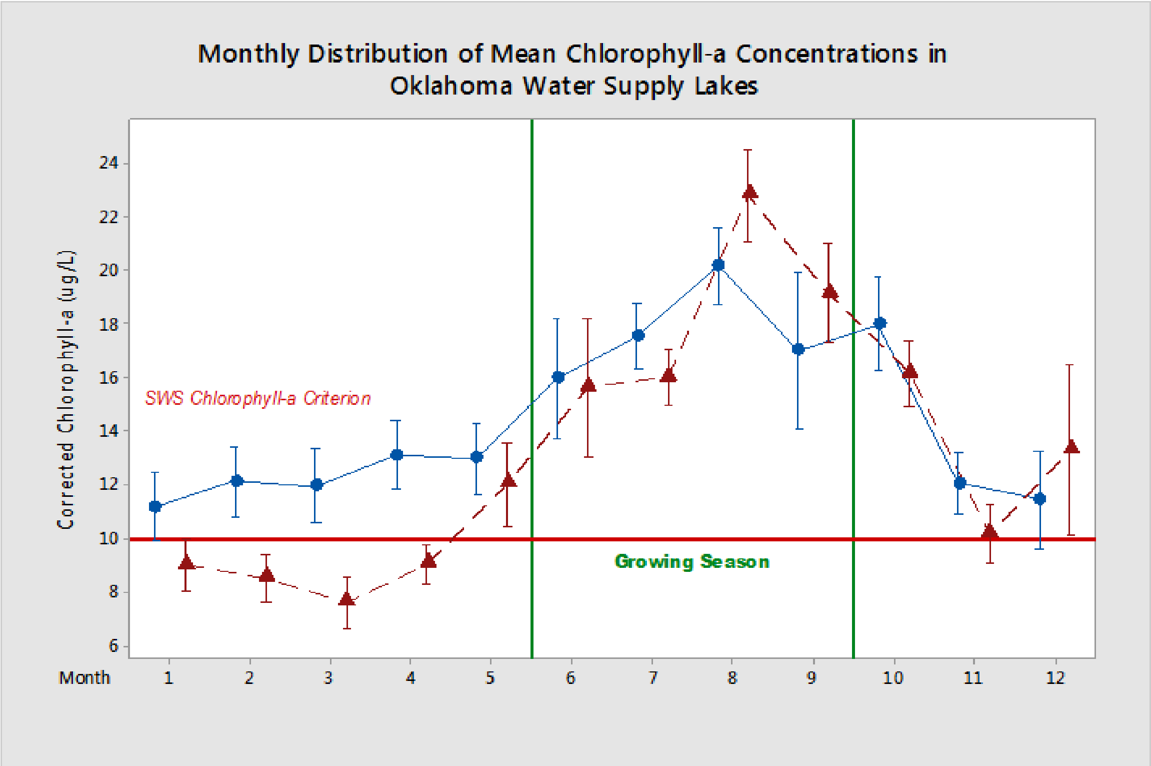


Figure 30. Monthly distribution of mean chlorophyll *a* concentrations in Oklahoma water supply lakes.

When data is averaged on an annual basis, low chlorophyll values measured in the winter months disguise the high concentrations measured during the summer critical season and is misleading regarding water quality condition and beneficial use protection. In the Oklahoma lake monitoring program it has long been the practice to report and evaluate annually averaged or multi-year averaged chlorophyll data; for example, when conducting assessments for the Oklahoma Integrated Report (ODEQ, 2016) chlorophyll values are averaged for a 10 year period. This approach is likely misrepresenting whether a waterbody's beneficial use is attained or impaired and does not align with the water quality standards principle to ensure that beneficial uses are protected during critical periods. The analysis in this report provides strong evidence that the OWRB lake monitoring program should revise practices regarding the averaging period for chlorophyll data.

Dissolved oxygen criteria thresholds are designed to protect the diverse aquatic communities found in lake ecosystems. Comparisons made to the NLA DO thresholds (Table 6) indicate a very large portion of Oklahoma waterbodies are in the least disturbed condition, with 92% having DO greater than 5mg/L at the surface (0-2m). However, only taking surface values into consideration may lead to overestimating the amount of oxygen in the system and not accurately depict conditions in Oklahoma waterbodies. In warm, highly productive systems, the normal production of oxygen through photosynthesis can be greatly accelerated through high concentrations of phytoplankton at the surface. This can lead to the supersaturation of dissolved oxygen. During the night when photosynthesis is no longer occurring, the high concentrations of phytoplankton and other biotic communities consume oxygen at a rapid rate through cellular respiration processes. This along with decomposition of any existing organic matter loads can drive dissolved oxygen down to very low levels. Since most dissolved oxygen data obtained through routine monitoring programs was collected during the daytime this situation was difficult to capture and not truly reflected in the condition assessment.

Additionally, in deeper waters there are additional oxygen sinks including respiration of watershed loads of dissolved and particulate organic matter, respiration of organic matter from cellular debris from in-lake biological communities, and oxidation of reduced chemical species from sedimentary diagenesis. All of these processes consume oxygen and in many lake systems this can occur at a faster rate than oxygen is replenished by diffusion. In well mixed systems oxygen can be replaced by downward moving and mixing of oxygen rich surface waters. In stratified systems this movement is hindered and very low oxygen conditions can rapidly develop and be maintained through stratified periods. Since only the surface, usually non-stratified, portion of the water column was included in the NLA condition assessment methodology, it is likely that the level of dissolved oxygen was overestimated in many of Oklahoma's lakes.

In a separate stressor-response study the relationship between hypolimnetic dissolved oxygen and chlorophyll *a* concentrations was explicitly evaluated for Oklahoma lakes. Results demonstrated that at 10 ug/L chlorophyll, the proportion of the hypolimnion with less than 2 mg/L DO exceeded 70% and this proportion nears 90% when chlorophyll *a* concentration was above 30 ug/L (Tetra Tech, 2018). Furthermore, also at chlorophyll *a* concentration of 10 ug/L there was a near 80% probability that there was less than 1 meter of hypolimnetic depth to provide sufficient cool water refuge for fish with 4 mg/L dissolved oxygen (Tetra Tech, 2018). These results strongly advocate for including both surface and water column DO in future condition assessments to more accurately represent in conditions in Oklahoma waterbodies. The Oklahoma lakes monitoring programs does utilizes two assessment methodologies to protect the *Fish and Wildlife Propagation* beneficial use, a surface assessment based on data at 0.5 m depth and a water-column or volumetric assessment that utilizes data across the entire depth of the lake (OAC 785:46-15-5). However, to be comparable with national condition assessment methods only the NLA methodology was used in this report. The Oklahoma method of evaluating both surface and water column dissolved oxygen provides a more accurate evaluation of lake condition and robustly protects beneficial uses.

Many lakes in Oklahoma experience elevated turbidity and this was seen in the condition estimates comparing observed values to both NLA and Oklahoma specific thresholds. The NLA ecoregion thresholds are considerably lower than Oklahoma's criterion threshold and as a result more than 90% of the lake acres fall into the most disturbed condition class. It seems that the ecoregional turbidity values were not discriminating for Oklahoma lakes and because the analysis was so sensitive to the most disturbed threshold it was difficult to decipher the results.

In contrast, when comparing to Oklahoma's criterion threshold of 25 NTU, waterbodies are distributed more equally with 30-37% of waterbodies across each of the condition classes for the whole lake zone. The distribution of lacustrine zone only values was quite different with 50% of the lake acres in the least disturbed condition; while this appears to be positive, we must keep in mind that the remaining 50% are in the moderately to most disturbed condition indicating that turbidity was a considerable impairment in Oklahoma. Lakes are generally broken into three zones, lacustrine, transitional and riverine. Sediment typically has more time to settle out as it moves across the waterbody towards the lacustrine (open water) portion of the lake. In most waterbodies this was the area of the lake where turbidity values are the lowest. This was observed in Oklahoma lakes with the greatest percentage of lake acres identified as least disturbed when only lacustrine data was considered.

Another observation to be taken from these results was the importance of collecting multiple samples across a waterbody, as water quality condition can vary greatly between the zones. If only the lacustrine zone was used to characterize lake condition it will potentially over or under estimate results, depending on indicator, as compared to the whole lake. For example, during storm events lakes receive additional sediment loading due to runoff from the surrounding landscape, which can greatly increase in-lake turbidity; however, much of this sediment load will settle out in riverine and transitional zones of the lake and would not be observed in measurements only collected in the lacustrine zone. Moreover, the delivery of material from the watershed to the lake is a driver of lake ecology and it is important to capture this by monitoring all lake zones. Oklahoma is a state dominated by manmade lakes that are often dendritic, run of the river systems and as such all lake zones must be taken into account. The OWRB lakes monitoring program has multiple sampling locations on each lake and results in this report demonstrate that this has been a wise scientific investment and should be maintained as essential to the program.

The findings in this report provide scientific information and point towards various lake management priorities, but this report also satisfies a regulatory requirement for the state of Oklahoma. The OWRB is the agency responsible for conducting water quality monitoring and assessment of lakes on behalf of the state. Assessments are made on data for a wide variety of biological, chemical, and physical water quality indicators. One purpose of these data collections was to meet federal Clean Water Act requirements to compile a list of impaired waterbodies and determine the condition of all of these waters. These reports are compiled to the biannual Oklahoma Water Quality Assessment Integrated Report (ODEQ, 2018). This report benefits the Integrated Report in two key ways. First, this report marks Oklahoma's first statistically based assessment of the condition of Oklahoma's lakes. The OWRB recommends that this report be adopted into the 305(b) section of a future Integrated Report. Included graphics can be used to show overall statewide and regional condition. Second, individual waterbodies not yet included in Oklahoma's Integrated Report now have some level of assessment. The OWRB regularly submits waters for inclusion on Oklahoma's 303(d) and 305(b) lists, and will do so again in October 2021. As a part of OWRB's submission, consistent with Use Support Assessment Protocols (OAC 785:46-15), waterbodies assessed as part of this study will be included for consideration in the 2022 Integrated Report.

Assessing the ecological health of Oklahoma's lakes required an evaluation of both the biota and the environmental stressors that have a direct and or indirect effect on the biota. It is effective to assess both the biota and stressors together because then the analysis will simultaneously uncover both the current ecological condition and the relative importance of various stressors. The results of this study highlight the extent of Oklahoma lake acres that express poor ecological health and the stressors that predominantly contribute to this problem. The findings of this report provide an opportunity to, initiate conversations, deepen discussions, and plan strategies for protection and restoration of lakes in Oklahoma.

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Appendix A –Oklahoma Lakes Survey Design 2011-2015

Description of Sample Design

Target population: All lakes and reservoirs within the state of Oklahoma that are >50 acres and have public access.

Sample Frame: GIS polygon shapefile received from Oklahoma includes all lakes of interest. Lakes were categorized as lakes from 50 acres to 500 acres and lakes > 500 acres

Survey Design: A Generalized Random Tessellation Stratified (GRTS) survey design for a finite resource was used. The GRTS design includes reverse hierarchical ordering of the selected sites.

Stratification: Two strata: LakesLT500 (lakes from 50 acres to 500 acres) and LakesGT500 (lakes lakes > 500 acres)

Multi-density categories: None.

Panels: For LakesGT500 five panels based on year are defined so that 14 lakes in each panel are sampled in year designated. For LakesLT500, ten panels based on year are defined so that 10 lakes in each panel are sampled in year designated.

Expected sample size: See above. Expected sample size is 24 lakes to be sampled each year.

Over sample: No over sample required.

Site Use: Assume the base design has 50 sites. Sites are listed in siteID order and must be used in that order within each stratum. All sites that occur prior to the last site used must have been evaluated for use and then either sampled or reason documented why that site was not used. As an example, if 50 sites are to be sampled and it required that 61 sites be evaluated in order to locate 50 sampleable stream sites, then the first 61 sites in siteID order would be used.

Sample Frame Summary

stratum

LakesLT500	LakesGT500	Total
143	68	211

Site Selection Summary

Number of lakes

	Stratum		
panel	LakesGT500	LakesLT500	Sum
Year_2011	14	10	24
Year_2012	14	10	24
Year_2013	14	10	24
Year_2014	13	10	23
Year_2015	13	10	23

Year_2016	0	10	10
Year_2017	0	10	10
Year_2018	0	10	10
Year_2019	0	10	10
Year_2020	0	10	10
Sum	68	100	168

Description of Sample Design Output

The output is provided as a point shapefile for the lakes selected.

Design related variables have the following variable definitions:

Variable Name	Description
SiteID	Unique site identification (character)
x	x-coordinate from map projection (see below)
y	y-coordinate from map projection (see below)
mdcaty	Multi-density categories used for unequal probability selection
weight	Weight (in square km), inverse of inclusion probability, to be used in statistical analyses
stratum	Strata used in the survey design
panel	Identifies base sample by panel name and Oversample by OverSamp
EvalStatus	Site evaluation decision for site: TS: target and sampled, LD: landowner denied access, etc (see below)
EvalReason	Site evaluation text commment
auxiliary variables	Remaining columns are from the sample frame provided

Projection Information

PROJCS[“USA_Contiguous_Albers_Equal_Area_Conic_USGS_version”,
GEOGCS[“GCS_North_American_1983”,
DATUM[“D_North_American_1983”,
SPHEROID[“GRS_1980”,6378137.0,298.257222101]],
PRIMEM[“Greenwich”,0.0],
UNIT[“Degree”,0.0174532925199433]],
PROJECTION[“Albers”],
PARAMETER[“False_Easting”,0.0],
PARAMETER[“False_Northing”,0.0],
PARAMETER[“Central_Meridian”,-96.0],
PARAMETER[“Standard_Parallel_1”,29.5],
PARAMETER[“Standard_Parallel_2”,45.5],
PARAMETER[“Latitude_Of_Origin”,23.0],
UNIT[“Meter”,1.0]]

Evaluation Process

The survey design weights that are given in the design file assume that the survey design is implemented as designed. Typically, users prefer to replace sites that cannot be sampled with other sites to achieve the sample size planned. The site replacement process is described above. When sites are replaced, the survey design weights are no longer correct and must be adjusted. The weight adjustment requires knowing what happened to each site in the base design and the over sample sites. EvalStatus is initially set to “NotEval” to indicate that the site has yet to be evaluated for sampling. When a site is evaluated for sampling, then the EvalStatus for the site must be changed. Recommended codes are:

EvalStatus Code	Name	Meaning
TS	Target Sampled	site is a member of the target population and was sampled
LD	Landowner Denial	landowner denied access to the site
PB	Physical Barrier	physical barrier prevented access to the site
NT	Non-Target	site is not a member of the target population
NN	Not Needed	site is a member of the over sample and was not evaluated for sampling
Other codes		Many times useful to have other codes. For example, rather than use NT, may use specific codes indicating why the site was non-target.

Statistical Analysis

Any statistical analysis of data must incorporate information about the monitoring survey design. In particular, when estimates of characteristics for the entire target population are computed, the statistical analysis must account for any stratification or unequal probability selection in the design. Procedures for doing this are available from the Aquatic Resource Monitoring web page given in the bibliography. A statistical analysis library of functions is available from the web page to do common population estimates in the statistical software environment R.

Contact for additional information

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Appendix B – Land Owner Packet

Date

John Doe Trust
C/O Jane Doe
Rt. 1 Box 1
Anywhere, OK 74534

Dear Sir/Madam:

The Oklahoma Water Resources Board (OWRB) is beginning a probabilistic survey project to perform water quality assessments on randomly selected lakes across Oklahoma. This effort involves on-site visits by OWRB personnel to a lake on or adjacent to your property to sample for both water chemistry and biological parameters. Information about lake conditions such as depth and physical characteristics, as well as observations of vegetation characteristics, will also be recorded. The findings of the study are not intended for enforcement or regulatory purposes.

One of the sites that we would like to assess the lake is located on your property in Section 32, Township 20 N, Range 16 EI, in Rogers County, Oklahoma. We are writing to ask for your permission to come onto your property to visit the site and conduct sampling activities. We realize that working on your property is a privilege and we will respect your landowner rights at all times. If you grant us permission, we will make four visits to your land over the course of the year. Each site will be visited once a quarter during the 2010-2011 sample period. A crew of two people will use your land to access the site. The crew will bring a boat in order to conduct in-lake sampling.

Once a sampling date is set, OWRB staff will contact you, either by telephone or in person, if you wish, before accessing your property to sample the lake. After OWRB staff contact you, they will access the lake by boat and collect the necessary samples and data. Other than launching a boat at your lake, the staff will diligently try to not leave any trace of their activity on your property. Staff will honor any special instructions you have, such as accessing land only with an escort or opening and closing gates responsibly.

If you are agreeable to the activities described above, please complete and sign the "Landowner Permission" page and mail it back to us in the enclosed, stamped return envelope by November 08, 2010. We have enclosed a duplicate of this letter, which you may keep for your records.
Please include contact information so that we may contact you by phone. Thank you for your consideration. If you have any questions about this request, please contact Darrin Martin (Probabilistic Monitoring Coordinator) or myself at 405-530-8800.

Sincerely,

Julie Chambers
Lakes Monitoring Coordinator

Enclosures: Map
Duplicate of original letter
Return envelope

LANDOWNER PERMISSION

I grant permission to the employees of the Oklahoma Water Resources Board to come onto my property and conduct lake sampling activities as described in this letter.

_________ Permission granted

_________ Permission granted, subject to the following restrictions or instructions:

____

____

____

_________ Permission not granted

Landowner's Name (please print): ____________________________________

Landowner's Signature: ____________________________________

Landowner's Daytime Phone No. _______________

Probabilistic Monitoring – Site Reconnaissance & Tracking Form

Lake Name: Clark Lake

Site ID: OKL11-075

Lat/Long: 35.637256, -96.732935

Legal Description:

County: Lincoln

WB ID: 520700040240

HUC(11):

Site Type: **target** or oversample

Sample Status: Accepted or **Rejected**

If Rejected, what is the reason:

[ ] Landowner Denied Permission
[X] Site is dry
[ ] Site is a sewage treatment pond/lagoon
[ ] Site is less than 1 meter (3 feet) in depth
[ ] Site is a private aquaculture waterbody
[ ] Other, please explain:

If rejected, what site replaces this one: Langston Lake

Landowner Requests:

Directions/Access to Site:

Appendix C – List of Sites by Sample Year

Site_ID	GNIS_NAME	County	Stratum	Evaluation Status	Evaluation Reason
OKL11-001	Lake Chickasha	Caddo	GT500	Target	Public Access
OKL11-002	Lake Texoma	Bryan	GT500	Target	Public Access
OKL11-003	Brown Lake		GT500	Target	Public Access
OKL11-004	Heyburn Lake	Creek	GT500	Target	Public Access
OKL11-005	Lake Hefner	Oklahoma	GT500	Target	Public Access
OKL11-006	Clear Creek Lake	Stephens	GT500	Target	Public Access
OKL11-007	Webbers Falls Reservoir	Muskogee	GT500	Target	Public Access
OKL11-008	Lake Carl Blackwell	Payne	GT500	Target	Public Access
OKL11-009	Okmulgee Lake	Okmulgee	GT500	Target	Public Access
OKL11-010	Foss Reservoir	Custer	GT500	Target	Public Access
OKL11-011	Broken Bow Lake		GT500	Target	Public Access
OKL11-012	Fort Supply Lake	Woodward	GT500	Target	Public Access
OKL11-013	Wes Watkins Reservoir	Pottowatomie	GT500	Target	Public Access
OKL11-014	Sardis Lake	Pushmataha	GT500	Target	Public Access
OKL11-069	Leeper Lake	Love	LT500	Target	Access Granted
OKL11-070	Horseshoe Lake	Oklahoma	LT500	Rejected	Access not granted
OKL11-071	Lake Sahoma	Creek	LT500	Rejected	Lake Drained
OKL11-072	Fin & Feather Lake		LT500	Target	Access Granted
OKL11-073	Brooks Lake	Hughes	LT500	Target	Access Granted
OKL11-074	Lake Lloyd Vincent	Ellis	LT500	Target	Access Granted
OKL11-075	Clark Lake	Lincoln	LT500	Rejected	Lake Dry
OKL11-076	Little Cedar Creek	Pushmataha	LT500	Rejected	Access not granted
OKL11-077	Comanche Lake	Stephens	LT500	Target	Med
OKL11-078	Lake George	Comanche	LT500	Rejected	Access not granted
OKL11-079	Langston Lake	Logan	LT500	Oversample	Public Access
OKL11-080	Talawanda Lake No. 2	Pittsburg	LT500	Oversample	Public Access
OKL11-081	Durant Lake	Bryan	LT500	Oversample	Public Access
OKL11-082	Fairfax Lake	Osage	LT500	Oversample	Public Access
OK11-083	Lake Frances		LT500	Rejected	Dam Breached
OKL11-084	Cedar Lake	LeFlore	LT500	Oversample	Public Access

List of sites evaluated for inclusion in 2011 Study Year.

Site_ID	GNIS_NAME	County	Stratum	Evaluation Status	Evaluation Reason
NLA12_OK-109	Bluestem Lake	Osage	GT500	Target	Public Access
NLA12_OK-106	Canton Lake	Blaine	GT500	Target	Public Access
NLA12_OK-103	Fort Cobb Reservoir	Caddo	GT500	Target	Public Access
NLA12_OK-134	Hulah Lake	Osage	GT500	Target	Public Access
NLA12_OK-103	Keystone Reservoir	Tulsa	GT500	Target	Public Access
NLA12_OK-135	Lake Henryetta	Okmulgee	GT500	Target	Public Access
NLA12_OK-101	Lake Konawa	Seminole	GT500	Target	Public Access
NLA12_OK-105	Lake Overholser	Oklahoma	GT500	Target	Public Access
NLA12_OK-108	Okemah Lake	Okfuskee	GT500	Target	Public Access
NLA12_OK-104	Skiatook Lake	Osage	GT500	Target	Public Access
NLA12_OK-107	Tenkiller Ferry Lake	Sequoyah	GT500	Target	Public Access
NLA12_OK-116	Newt Graham Lake	Rogers	LT500	Rejected	Part of Lock & dam
NLA12_OK-117	Lake Rolla	Canadian	LT500	Target	Access granted
NLA12_OK-118	Rocky (Hobart) Lake	Washita	LT500	Target	Public Access
NLA12_OK-119	Jean Neustadt Lake	Carter	LT500	Target	Public Access
NLA12_OK-120	Hudson Lake	Osage	LT500	Target	Public Access
NLA12_OK-121	Cushing Lake	Payne	LT500	Target	Public Access
NLA12_OK-122	Walters (Dave Boyer) Lake	Cotton	LT500	Target	Public Access
NLA12_OK-245	Lake El Reno	Canadian	LT500	Oversample	Public Access
NLA12_OK-247	Sunset Lake	Osage	LT500	Oversample	Access granted
NLA12_OK-248	Roebuck Lake	Choctaw	LT500	Oversample	Access granted
NLA12_OK-246	Lake Charles	McCurtain	LT500	Oversample	Access granted
NLA12_OK-244	Ward Lake	McCurtain	LT500	Rejected	Dry

List of sites evaluated for inclusion in 2012 Study Year.

Site_ID	GNIS_NAME	County	Stratum	Evaluation Status	Evaluation Reason
NLA12_OK-114	Birch	Osage	GT500	Target	Public Access
NLA12_OK-111	Copan	Washington	GT500	Target	Public Access
NLA12_OK-142	Fort Gibson Reservoir	Cherokee	GT500	Target	Public Access
NLA12_OK-138	Grand Lake	Mayes	GT500	Target	Public Access
NLA12_OK-113	Kaw Lake	Osage	GT500	Target	Public Access
NLA12_OK-137	Lake Arcadia	Oklahoma	GT500	Target	Public Access
NLA12_OK-110	Lake Frederick	Tillman	GT500	Target	Public Access
NLA12_OK-112	Lake Fuqua	Stephens	GT500	Target	Public Access
NLA12_OK-139	Lake McAlester	Pittsburg	GT500	Target	Public Access
NLA12_OK-140	Lake Ponca	Kay	GT500	Target	Public Access
NLA12_OK-136	Tom Steed Reservoir	Kiowa	GT500	Target	Public Access
NLA12_OK-143	Waurika Lake	Jefferson	GT500	Target	Public Access
NLA12_OK-136	Wister Lake	Le Flore	GT500	Target	Public Access
NLA12_OK-141	Sooner Lake	Pawnee	GT500	Target	Public Access
NLA12_OK-123	Mountain Lake	Carter	LT500	Target	Access granted
NLA12_OK-124	Lake Carl Etling	Cimarron	LT500	Target	Public Access
NLA12_OK-125	Mannford Reservoir	Tulsa	LT500	Target	Public Access
NLA12_OK-174	Shell Lake	Osage	LT500	Target	Public Access
NLA12_OK-175	Holdenville Lake	Hughes	LT500	Target	Public Access
NLA12_OK-176	Muldrow Lake	Sequoyah	LT500	Target	Public Access
NLA12_OK-179	Delaware Creek St. 3 Res.	Johnson	LT500	Target	Public Access
NLA12_OK-250	Maysville Lake	McClain	LT500	Oversample	Public Access
NLA12_OK-255	Clayton Lake	Pushmataha	LT500	Oversample	Public Access
NLA12_OK-259	Public Svc. Reservoir # 3	Caddo	LT500	Oversample	Access granted
NLA12_OK-177	Gate Lake	Beaver	LT500	Rejected	Dry
NLA12_OK-178	Tecumseh Lake	Pottawatomie	LT500	Rejected	Dry
NLA12_OK-173	White Lake	Tillman	LT500	Rejected	Dry

List of sites evaluated for inclusion in 2013 Study Year.

Site_ID	GNIS_NAME	County	Stratum	Evaluation Status	Evaluation Reason
NLA12_OK-151	Great Salt Plains Reservoir	ALFALFA	GT500	Target	Public Access
NLA12_OK-150	Greenleaf Lake	MUSKOGEE	GT500	Target	Public Access
NLA12_OK-148	Lake Ellsworth	COMANCHE	GT500	Target	Public Access
NLA12_OK-146	Lake Hudson	MAYES	GT500	Target	Public Access
NLA12_OK-156	Lake Humphreys	STEPHENS	GT500	Target	Public Access
NLA12_OK-157	Lake Lawtonka	COMANCHE	GT500	Target	Public Access
NLA12_OK-154	Lake McMurtry	NOBLE	GT500	Target	Public Access
NLA12_OK-147	Lake Murray	LOVE	GT500	Target	Public Access
NLA12_OK-152	Oologah Lake	ROGERS	GT500	Target	Public Access
NLA12_OK-149	Pine Creek Lake	MCCURTAIN	GT500	Target	Public Access
NLA12_OK-144	RC Longmire Lake	GARVIN	GT500	Target	Public Access
NLA12_OK-153	Shawnee Reservoir	POTTAWATOMIE	GT500	Target	Public Access
NLA12_OK-136	Spavinaw Lake	MAYES	GT500	Target	Public Access
NLA12_OK-155	Stroud Lake	CREEK	GT500	Target	Public Access
NLA12_OK-126	Sportsman Lake	SEMINOLE	LT500	Target	Access granted
NLA12_OK-127	Lake Duncan	STEPHENS	LT500	Target	Public Access
NLA12_OK-128	Crowder Lake	WASHITA	LT500	Target	Public Access
NLA12_OK-181	Lake Waxhoma	OSAGE	LT500	Target	Public Access
NLA12_OK-182	Quanah Parker Lake	COMANCHE	LT500	Target	Public Access
NLA12_OK-183	Lake Claremore	OSAGE	LT500	Target	Public Access
NLA12_OK-185	Cohee Lake	OKFUSKEE	LT500	Target	Access granted
NLA12_OK-186	Hauani Lake	MARSHAL	LT500	Target	Access granted
NLA12_OK-261	Taylor Lake	GRADY	LT500	Oversample	Public Access
NLA12_OK-262	Onappa (Checotah Mun. Lake)	MCINTOSH	LT500	Oversample	Access granted
NLA12_OK-180	Colbert Lake	MCCURTAIN	LT500	Rejected	Dry
NLA12_OK-184			LT500	Rejected	Not a lake

List of sites evaluated for inclusion in 2014 Study Year.

Site_ID	GNIS_NAME	County	Stratum	Evaluation Status	Evaluation Reason
NLA12_OK-158	Atoka Reservoir	ATOKA	GT500	Target	Public Access
NLA12_OK-170	Bell Cow Lake	LINCOLN	GT500	Target	Public Access
NLA12_OK-163	Chimney Rock Lake (W.R. Holway)	MAYES	GT500	Target	Public Access
NLA12_OK-166	Dripping Springs Lake	OKMULGEE	GT500	Target	Public Access
NLA12_OK-169	Eufaula Lake	HASKELL	GT500	Target	Public Access
NLA12_OK-165	Hugo Lake	CHOCTAW	GT500	Target	Public Access
NLA12_OK-159	Lake Eucha	DELAWARE	GT500	Target	Public Access
NLA12_OK-167	Lake Lugert-Altus	GREER	GT500	Target	Public Access
NLA12_OK-171	Lake of the Arbuckles	MURRAY	GT500	Target	Public Access
NLA12_OK-162	Lake Thunderbird	CLEVELAND	GT500	Target	Public Access
NLA12_OK-160	Lone Chimney Lake	PAWNEE	GT500	Target	Public Access
NLA12_OK-172	McGee Creek Reservoir	ATOKA	GT500	Target	Public Access
NLA12_OK-164	Pauls Valley Lake	GARVIN	GT500	Target	Public Access
NLA12_OK-161	Robert S Kerr Reservoir	SEQUOYAH	GT500	Target	Public Access
NLA12_OK-168	Stanley Draper Lake	CLEVELAND	GT500	Target	Public Access
NLA12_OK-129	Lake Perry		LT500	Target	Public Access
NLA12_OK-130	Veterans Lake	MURRAY	LT500	Target	Public Access
NLA12_OK-131	Coalgate Reservoir	COAL	LT500	Target	Public Access
NLA12_OK-263	Elmore City	GARVIN	LT500	Oversample	Public Access
NLA12_OK-188	Fourche Maline Creek Site 7 Reservoir (Lloyd Church Lake)	LATIMER	LT500	Target	Public Access
NLA12_OK-266	Bixhoma			Oversample	Public Access
NLA12_OK-190	Boomer Lake	PAYNE	LT500	Target	Public Access
NLA12_OK-191	Wewoka Lake	SEMINOLE	LT500	Target	Public Access
NLA12_OK-192	Sallisaw Creek Site 29 Reservoir (Brushy Creek Res.)	SEQUOYAH	LT500	Target	Public Access
NLA12_OK-193	Northwood Lake	CANADIAN	LT500	Target	Access granted
NLA12_OK-189	Doc Hollis Lake	GREER	LT500	Rejected	No permission
NLA12_OK-187	Flag Lake	OKMULGEE	LT500	Rejected	Dry

List of sites evaluated for inclusion in 2015 Study Year.

Appendix D – Stressor Indicator Condition Classes

Station ID	Station Description	AG_ECO9	Segment	TN_NLA_Cond	TP_NLA_Cond	Turbidity_NLA_Cond	Turbidity OKWQS
OKL11-008	Carl Blackwell	SPL	Whole Lake	poor	fair	poor	poor
OKL11-008	Carl Blackwell	SPL	Lacustrine	poor	good	poor	fair
OKL11-001	Chickasha	SPL	Whole Lake	poor	fair	poor	fair
OKL11-001	Chickasha	SPL	Lacustrine	poor	fair	poor	fair
NLA12_OK-245	El Reno	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-245	El Reno	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-148	Ellsworth	SPL	Lacustrine	poor	poor	poor	fair
NLA12_OK-148	Ellsworth	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-124	Etling	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-124	Etling	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-110	Frederick	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-110	Frederick	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-135	Henryetta	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-135	Henryetta	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-119	Jean Neustadt	SPL	Lacustrine	poor	good	poor	fair
NLA12_OK-119	Jean Neustadt	SPL	Whole Lake	poor	good	poor	fair
NLA12_OK-101	Konawa	SPL	Lacustrine	poor	good	poor	good
NLA12_OK-101	Konawa	SPL	Whole Lake	poor	good	poor	good
NLA12_OK-157	Lawtonka	SPL	Lacustrine	fair	good	poor	good
NLA12_OK-157	Lawtonka	SPL	Whole Lake	fair	fair	poor	good
NLA12_OK-139	McAlester	SAP	Lacustrine	poor	poor	poor	poor
NLA12_OK-139	McAlester	SAP	Whole Lake	poor	poor	poor	poor
NLA12_OK-154	McMurtry	SPL	Lacustrine	fair	good	poor	fair
NLA12_OK-154	McMurtry	SPL	Whole Lake	fair	good	poor	fair
NLA12_OK-147	Murray	SPL	Lacustrine	good	good	good	good
NLA12_OK-147	Murray	SPL	Whole Lake	good	good	poor	good

NLA12_OK-105	Overholser	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-105	Overholser	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-140	Ponca	SPL	Lacustrine	poor	good	poor	good
NLA12_OK-140	Ponca	SPL	Whole Lake	poor	good	poor	fair
NLA12_OK-168	Stanley Draper	SPL	Lacustrine	good	good	poor	poor
NLA12_OK-168	Stanley Draper	SPL	Whole Lake	good	good	poor	poor
NLA12_OK-162	Thunderbird	SPL	Lacustrine	poor	fair	poor	good
NLA12_OK-162	Thunderbird	SPL	Whole Lake	poor	fair	poor	fair
OKL11-074	Vincent	SPL	Lacustrine	good	good	poor	fair
OKL11-074	Vincent	SPL	Whole Lake	good	good	poor	fair
NLA12_OK-249	Wayne Wallace	SAP	Lacustrine	poor	good	poor	good
NLA12_OK-249	Wayne Wallace	SAP	Whole Lake	poor	good	poor	good
NLA12_OK-167	Altus	SPL	Lacustrine	poor	poor	poor	good
NLA12_OK-167	Altus	SPL	Whole Lake	poor	poor	poor	good
NLA12_OK-171	Arbuckle	SPL	Lacustrine	good	good	fair	good
NLA12_OK-171	Arbuckle	SPL	Whole Lake	good	good	poor	good
NLA12_OK-137	Arcadia	SPL	Lacustrine	poor	good	poor	fair
NLA12_OK-137	Arcadia	SPL	Whole Lake	poor	good	poor	fair
NLA12_OK-158	Atoka	SAP	Lacustrine	poor	poor	poor	poor
NLA12_OK-158	Atoka	SAP	Whole Lake	poor	poor	poor	poor
NLA12_OK-170	Bellcow	SPL	Lacustrine	poor	good	poor	good
NLA12_OK-170	Bellcow	SPL	Whole Lake	poor	good	poor	fair
NLA12_OK-114	Birch	SPL	Lacustrine	poor	good	poor	good
NLA12_OK-114	Birch	SPL	Whole Lake	poor	good	poor	fair
NLA12_OK-266	Bixhoma	SPL	Lacustrine	good	good	fair	good
NLA12_OK-266	Bixhoma	SPL	Whole Lake	good	good	fair	good
NLA12_OK-109	Bluestem	TPL	Lacustrine	good	good	poor	fair
NLA12_OK-109	Bluestem	TPL	Whole Lake	good	good	poor	poor
NLA12_OK-190	Boomer	SPL	Lacustrine	poor	fair	poor	fair

NLA12_OK-190	Boomer	SPL	Whole Lake	poor	poor	poor	fair
OKL11-011	Broken Bow	CPL	Lacustrine	good	good	good	good
OKL11-011	Broken Bow	CPL	Whole Lake	good	good	good	good
OKL11-073	Brooks	SPL	Lacustrine	poor	poor	poor	poor
OKL11-073	Brooks	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-192	Brushy Creek	SAP	Lacustrine	poor	fair	poor	good
NLA12_OK-192	Brushy Creek	SAP	Whole Lake	poor	fair	poor	good
NLA12_OK-106	Canton	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-106	Canton	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-246	Charles	CPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-246	Charles	CPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-183	Claremore	TPL	Lacustrine	fair	good	poor	good
NLA12_OK-183	Claremore	TPL	Whole Lake	fair	fair	poor	good
NLA12_OK-255	Clayton	SAP	Lacustrine	poor	good	poor	good
NLA12_OK-255	Clayton	SAP	Whole Lake	poor	good	poor	good
OKL11-006	Clear Creek	SPL	Lacustrine	fair	FALSE	poor	good
OKL11-006	Clear Creek	SPL	Whole Lake	fair	fair	poor	fair
NLA12_OK-131	Coalgate City	SAP	Lacustrine	poor	poor	poor	poor
NLA12_OK-131	Coalgate City	SAP	Whole Lake	poor	poor	poor	poor
NLA12_OK-185	Cohee	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-185	Cohee	SPL	Whole Lake	poor	poor	poor	poor
OKL11-077	Comanche	SPL	Lacustrine	good	good	poor	fair
OKL11-077	Comanche	SPL	Whole Lake	good	good	poor	fair
NLA12_OK-111	Copan	TPL	Lacustrine	good	fair	poor	poor
NLA12_OK-111	Copan	TPL	Whole Lake	good	fair	poor	poor
NLA12_OK-128	Crowder	SPL	Lacustrine	poor	fair	poor	good
NLA12_OK-128	Crowder	SPL	Whole Lake	poor	poor	poor	fair
NLA12_OK-121	Cushing Municipal	SPL	Lacustrine	fair	poor	poor	poor

NLA12_OK-121	Cushing Municipal	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-179	Delaware Creek Site Three	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-179	Delaware Creek Site Three	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-166	Dripping Springs	SPL	Lacustrine	good	good	poor	good
NLA12_OK-166	Dripping Springs	SPL	Whole Lake	good	good	poor	good
NLA12_OK-127	Duncan	SPL	Lacustrine	poor	fair	poor	fair
NLA12_OK-127	Duncan	SPL	Whole Lake	poor	fair	poor	fair
NLA12_OK-263	Elmore City	SPL	Lacustrine	poor	fair	poor	fair
NLA12_OK-263	Elmore City	SPL	Whole Lake	poor	fair	poor	fair
NLA12_OK-159	Eucha	SAP	Lacustrine	poor	fair	poor	good
NLA12_OK-159	Eucha	SAP	Whole Lake	poor	fair	poor	good
NLA12_OK-169	Eufaula	SAP	Lacustrine	poor	poor	poor	fair
NLA12_OK-169	Eufaula Canadian River DF	SAP	Segment	poor	poor	poor	poor
NLA12_OK-169	Eufaula Gaines Creek	SAP	Segment	poor	poor	poor	poor
NLA12_OK-169	Eufaula North Canadian	SAP	Segment	poor	poor	poor	poor
NLA12_OK-169	Eufaula	SAP	Segment	poor	poor	poor	fair
NLA12_OK-169	Eufaula Longtown Creek	SAP	Segment	poor	fair	poor	fair
NLA12_OK-169	Eufaula Canadian River	SAP	Segment	poor	poor	poor	poor
OKL11-072	Fin & Feather	SPL	Lacustrine	good	good	poor	good
OKL11-072	Fin & Feather	SPL	Whole Lake	good	good	fair	good
NLA12_OK-102	Fort Cobb	SPL	Lacustrine	poor	poor	poor	good

NLA12_OK-102	Fort Cobb	SPL	Whole Lake	poor	poor	poor	fair
NLA12_OK-142	Fort Gibson	TPL	Lacustrine	good	fair	poor	good
NLA12_OK-142	Fort Gibson Lower	TPL	Segment	good	fair	poor	good
NLA12_OK-142	Fort Gibson Upper	TPL	Segment	good	poor	poor	good
OKL11-012	Fort Supply	SPL	Lacustrine	fair	poor	poor	poor
OKL11-012	Fort Supply	SPL	Whole Lake	poor	poor	poor	poor
OKL11-010	Foss	SPL	Lacustrine	good	good	poor	good
OKL11-010	Foss	SPL	Whole Lake	good	good	poor	fair
NLA12_OK-112	Fuqua	SPL	Lacustrine	poor	good	poor	good
NLA12_OK-112	Fuqua	SPL	Whole Lake	poor	good	poor	fair
NLA12_OK-138	Grand	SAP	Lacustrine	poor	poor	poor	good
NLA12_OK-138	Grand Upper	SAP	Segment	poor	poor	poor	poor
NLA12_OK-138	Grand Lower	SAP	Segment	poor	poor	poor	good
NLA12_OK-138	Grand Middle	SAP	Segment	poor	poor	poor	fair
NLA12_OK-151	Great Salt Plains	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-151	Great Salt Plains	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-150	Greenleaf	TPL	Lacustrine	good	good	good	good
NLA12_OK-150	Greenleaf	TPL	Whole Lake	good	good	fair	good
NLA12_OK-186	Hauani	SPL	Lacustrine	fair	good	fair	good
NLA12_OK-186	Hauani	SPL	Whole Lake	fair	good	fair	good
OKL11-005	Hefner	SPL	Lacustrine	poor	poor	poor	good
OKL11-005	Hefner	SPL	Whole Lake	poor	poor	poor	good
OKL11-004	Heyburn	SPL	Lacustrine	good	fair	poor	poor
OKL11-004	Heyburn	SPL	Whole Lake	fair	fair	poor	poor
NLA12_OK-175	Holdenville	SPL	Lacustrine	poor	good	poor	fair
NLA12_OK-175	Holdenville	SPL	Whole Lake	poor	good	poor	fair
NLA12_OK-120	Hudson	SPL	Lacustrine	fair	good	poor	fair

NLA12_OK-120	Hudson	SPL	Whole Lake	fair	good	poor	fair
NLA12_OK-146	Lake Hudson	TPL	Lacustrine	good	fair	poor	good
NLA12_OK-146	Lake Hudson Lower	TPL	Segment	good	fair	poor	good
NLA12_OK-146	Lake Hudson Upper	TPL	Segment	good	fair	poor	fair
NLA12_OK-165	Hugo	CPL	Lacustrine	fair	poor	poor	poor
NLA12_OK-165	Hugo	CPL	Whole Lake	fair	poor	poor	poor
NLA12_OK-134	Hulah	SPL	Lacustrine	fair	fair	poor	poor
NLA12_OK-134	Hulah	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-156	Humphreys	SPL	Lacustrine	poor	fair	poor	good
NLA12_OK-156	Humphreys	SPL	Whole Lake	poor	fair	poor	good
NLA12_OK-113	Kaw	SPL	Lacustrine	poor	poor	poor	good
NLA12_OK-113	Kaw Lower	SPL	Segment	poor	poor	poor	good
NLA12_OK-113	Kaw Upper	SPL	Segment	poor	poor	poor	poor
NLA12_OK-103	Keystone	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-103	Keystone	SPL	Segment	poor	poor	poor	poor
NLA12_OK-103	Keystone Cimmaron River Upper	SPL	Segment	poor	poor	poor	poor
NLA12_OK-103	Keystone Arkansas River Arm	SPL	Segment	poor	poor	poor	poor
NLA12_OK-103	Keystone Cimmaron River Lower	SPL	Segment	poor	poor	poor	poor
OKL11-079	Langston	SPL	Whole Lake	good	good	poor	fair
OKL11-079	Langston	SPL	Lacustrine	good	good	poor	fair
OKL11-069	Leeper	SPL	Whole Lake	poor	poor	poor	poor

OKL11-069	Leeper	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-188	Lloyd Church	SAP	Whole Lake	poor	fair	poor	fair
NLA12_OK-188	Lloyd Church	SAP	Lacustrine	poor	fair	poor	fair
NLA12_OK-160	Lone Chimney	SPL	Whole Lake	poor	fair	poor	fair
NLA12_OK-160	Lone Chimney	SPL	Lacustrine	poor	good	poor	fair
NLA12_OK-125	Mannford	SPL	Whole Lake	fair	good	poor	good
NLA12_OK-125	Mannford	SPL	Lacustrine	fair	good	poor	good
NLA12_OK-172	McGee Creek	SAP	Whole Lake	poor	good	poor	good
NLA12_OK-172	McGee Creek	SAP	Lacustrine	poor	good	poor	good
NLA12_OK-123	Mountain	SPL	Whole Lake	fair	good	poor	good
NLA12_OK-123	Mountain	SPL	Lacustrine	poor	good	poor	good
NLA12_OK-176	Muldrow	SAP	Whole Lake	poor	good	poor	good
NLA12_OK-176	Muldrow	SAP	Lacustrine	poor	good	poor	good
NLA12_OK-193	Northwood	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-193	Northwood	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-108	Okemah	SPL	Whole Lake	good	good	poor	fair
NLA12_OK-108	Okemah	SPL	Lacustrine	good	good	poor	FALSE
OKL11-009	Okmulgee	SPL	Whole Lake	good	good	poor	good
OKL11-009	Okmulgee	SPL	Lacustrine	good	good	poor	good
NLA12_OK-262	Onapa	TPL	Whole Lake	good	good	good	good
NLA12_OK-262	Onapa	TPL	Lacustrine	good	good	good	good
NLA12_OK-152	Oolagah	TPL	Whole Lake	good	fair	poor	fair
NLA12_OK-152	Oolagah	TPL	Lacustrine	good	good	poor	fair
NLA12_OK-164	Pauls Valley	SPL	Whole Lake	fair	fair	poor	poor
NLA12_OK-164	Pauls Valley	SPL	Lacustrine	fair	good	poor	poor
NLA12_OK-129	Perry	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-129	Perry	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-149	Pine Creek	SAP	Whole Lake	poor	fair	poor	good
NLA12_OK-149	Pine Creek	SAP	Lacustrine	poor	fair	poor	good

NLA12_OK-259	Public Service Reservoir Three	SPL	Whole Lake	poor	good	poor	good
NLA12_OK-259	Public Service Reservoir Three	SPL	Lacustrine	poor	good	poor	good
NLA12_OK-182	Quanah Parker	SPL	Whole Lake	poor	good	good	good
NLA12_OK-182	Quanah Parker	SPL	Lacustrine	poor	good	good	good
NLA12_OK-144	RC Longmire	SPL	Whole Lake	poor	fair	poor	fair
NLA12_OK-144	RC Longmire	SPL	Lacustrine	poor	good	poor	fair
NLA12_OK-161	Robert S Kerr	SAP	Whole Lake	poor	poor	poor	poor
NLA12_OK-161	Robert S Kerr	SAP	Lacustrine	poor	poor	poor	poor
NLA12_OK-118	Rocky	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-118	Rocky	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-248	Roebuck	CPL	Whole Lake	poor	poor	poor	fair
NLA12_OK-248	Roebuck	CPL	Lacustrine	poor	poor	poor	fair
NLA12_OK-117	Rolla	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-117	Rolla	SPL	Lacustrine	poor	poor	poor	poor
OKL11-014	Sardis	SAP	Whole Lake	good	fair	poor	fair
OKL11-014	Sardis	SAP	Lacustrine	fair	good	poor	fair
NLA12_OK-153	Shawnee Twin One	SPL	Whole Lake	good	good	poor	fair
NLA12_OK-153	Shawnee Twin One	SPL	Lacustrine	good	good	poor	fair
NLA12_OK-257	Shawnee Twin Two	SPL	Whole Lake	fair	good	poor	fair
NLA12_OK-257	Shawnee Twin Two	SPL	Lacustrine	fair	good	poor	fair
NLA12_OK-174	Shell	SPL	Whole Lake	poor	good	poor	good
NLA12_OK-174	Shell	SPL	Lacustrine	poor	good	poor	good
NLA12_OK-104	Skiatook	SPL	Whole Lake	good	good	poor	fair

NLA12_OK-104	Skiatook	SPL	Lacustrine	good	good	poor	good
NLA12_OK-141	Sooner	SPL	Lacustrine	fair	good	good	good
NLA12_OK-141	Sooner	SPL	Whole Lake	fair	good	fair	good
NLA12_OK-155	Spavinaw	SAP	Lacustrine	poor	fair	poor	good
NLA12_OK-155	Spavinaw	SAP	Whole Lake	poor	fair	poor	good
NLA12_OK-126	Sportsman	SPL	Lacustrine	fair	good	poor	good
NLA12_OK-126	Sportsman	SPL	Whole Lake	fair	good	poor	good
NLA12_OK-145	Stroud	SPL	Lacustrine	good	good	poor	good
NLA12_OK-145	Stroud	SPL	Whole Lake	good	good	poor	good
NLA12_OK-247	Sunset	SPL	Lacustrine	poor	good	poor	fair
NLA12_OK-247	Sunset	SPL	Whole Lake	poor	fair	poor	fair
NLA12_OK-281	Talawanda One	SAP	Lacustrine	poor	good	fair	good
NLA12_OK-281	Talawanda One	SAP	Whole Lake	poor	good	fair	good
OKL11-080	Talawanda Two	SAP	Lacustrine	good	good	poor	good
OKL11-080	Talawanda Two	SAP	Whole Lake	good	good	poor	good
NLA12_OK-261	Taylor	SPL	Lacustrine	poor	poor	poor	fair
NLA12_OK-261	Taylor	SPL	Whole Lake	poor	poor	poor	fair
NLA12_OK-107	Tenkiller Ferry	SAP	Lacustrine	poor	good	poor	good
NLA12_OK-107	Tenkiller Ferry	SAP	Segment	poor	good	poor	good
NLA12_OK-107	Tenkiller Ferry Illinois River Arm	SAP	Segment	poor	poor	poor	fair
OKL11-002	Texoma	SPL	Lacustrine	good	good	poor	good
OKL11-002	Texoma	SPL	Segment	good	good	poor	good
OKL11-002	Texoma Lake Red River Arm Upper	SPL	Segment	poor	poor	poor	poor
OKL11-002	Texoma Lake Washita River Arm Lower	SPL	Segment	good	good	poor	good

OKL11-002	Texoma Lake Red River Arm Lower	SPL	Segment	good	fair	poor	good
NLA12_OK-136	Tom Steed	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-136	Tom Steed	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-130	Veterans	SPL	Whole Lake	good	good	fair	good
NLA12_OK-130	Veterans	SPL	Lacustrine	good	good	fair	good
NLA12_OK-143	Waurika	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-143	Waurika	SPL	Lacustrine	poor	poor	poor	fair
NLA12_OK-181	Waxhoma	SPL	Whole Lake	good	good	fair	good
NLA12_OK-181	Waxhoma	SPL	Lacustrine	good	good	fair	good
OKL11-007	Webbers Falls	TPL	Whole Lake	good	poor	poor	fair
OKL11-007	Webbers Falls	TPL	Lacustrine	good	poor	poor	fair
OKL11-013	Wes Watkins	SPL	Whole Lake	poor	fair	poor	fair
OKL11-013	Wes Watkins	SPL	Lacustrine	poor	fair	poor	fair
NLA12_OK-191	Wewoka	SPL	Whole Lake	fair	fair	poor	fair
NLA12_OK-191	Wewoka	SPL	Lacustrine	fair	good	poor	fair
NLA12_OK-250	Wiley Post Memorial	SPL	Whole Lake	poor	poor	poor	poor
NLA12_OK-250	Wiley Post Memorial	SPL	Lacustrine	poor	poor	poor	poor
NLA12_OK-115	Wister	SAP	Whole Lake	poor	fair	poor	fair
NLA12_OK-115	Wister	SAP	Lacustrine	poor	fair	poor	fair
NLA12_OK-163	WR Holoway	SAP	Whole Lake	poor	poor	good	good
NLA12_OK-163	WR Holoway	SAP	Lacustrine	poor	poor	good	good

Appendix E – Biological Indicator Condition Classes

Station ID	Station Description	AG_ECO9	Segment	Summer Chl-a NLA COND	Annual Avg. Chl*a* NLA COND	Summer Chl*a* OKWQS	Annual Avg. Chl*a* OKWQS
OKL11-008	Carl Blackwell	SPL	Whole Lake	Poor	Fair	Fair	Good
OKL11-008	Carl Blackwell	SPL	Lacustrine	Poor	Fair	Fair	Good
OKL11-001	Chickasha	SPL	Whole Lake	Fair	Poor	Fair	Poor
OKL11-001	Chickasha	SPL	Lacustrine	Poor	Poor	Fair	Poor
NLA12_OK-245	El Reno	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-245	El Reno	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-148	Ellsworth	SPL	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-148	Ellsworth	SPL	Whole Lake	Poor	Fair	Fair	Fair
NLA12_OK-124	Etling	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-124	Etling	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-110	Frederick	SPL	Lacustrine	Good	Fair	Good	Good
NLA12_OK-110	Frederick	SPL	Whole Lake	Fair	Fair	Fair	Fair
NLA12_OK-135	Henryetta	SPL	Lacustrine	Fair	Good	Good	Good
NLA12_OK-135	Henryetta	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-119	Jean Neustadt	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-119	Jean Neustadt	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-101	Konawa	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-101	Konawa	SPL	Whole Lake	Poor	Poor	Fair	Poor
NLA12_OK-146	Lake Hudson	TPL	Lacustrine	Fair	Fair	Fair	Poor
NLA12_OK-157	Lawtonka	SPL	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-157	Lawtonka	SPL	Whole Lake	Fair	Fair	Good	Good
NLA12_OK-139	McAlester	SAP	Lacustrine	Fair	Good	Good	Good
NLA12_OK-139	McAlester	SAP	Whole Lake	Fair	Fair	Good	Good
NLA12_OK-154	McMurtry	SPL	Lacustrine	Fair	Good	Good	Good
NLA12_OK-154	McMurtry	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-147	Murray	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-147	Murray	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-105	Overholser	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-105	Overholser	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-140	Ponca	SPL	Lacustrine	Fair	Fair	Fair	Fair
NLA12_OK-140	Ponca	SPL	Whole Lake	Fair	Poor	Good	Fair

NLA12_OK-168	Stanley Draper	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-168	Stanley Draper	SPL	Whole Lake	Good	Good	Good	Good
OKL11-002	Texoma	SPL	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-162	Thunderbird	SPL	Lacustrine	Poor	Poor	Poor	Fair
NLA12_OK-162	Thunderbird	SPL	Whole Lake	Poor	Poor	Poor	Poor
OKL11-074	Vincent	SPL	Lacustrine	Good	Fair	Good	Good
OKL11-074	Vincent	SPL	Whole Lake	Fair	Fair	Good	Good
NLA12_OK-249	Wayne Wallace	SAP	Lacustrine	Fair	Poor	Good	Poor
NLA12_OK-249	Wayne Wallace	SAP	Whole Lake	Fair	Poor	Good	Poor
NLA12_OK-167	Altus	SPL	Lacustrine	Fair	Fair	Fair	Fair
NLA12_OK-167	Altus	SPL	Whole Lake	Fair	Fair	Good	Good
NLA12_OK-171	Arbuckle	SPL	Lacustrine	Fair	Poor	Good	Fair
NLA12_OK-171	Arbuckle	SPL	Whole Lake	Fair	Poor	Fair	Fair
NLA12_OK-137	Arcadia	SPL	Lacustrine	Poor	Fair	Poor	Fair
NLA12_OK-137	Arcadia	SPL	Whole Lake	Poor	Poor	Poor	Fair
NLA12_OK-158	Atoka	SAP	Lacustrine	Fair	Fair	Fair	Good
NLA12_OK-158	Atoka	SAP	Whole Lake	Poor	Fair	Fair	Good
NLA12_OK-170	Bellcow	SPL	Lacustrine	Fair	Poor	Fair	Poor
NLA12_OK-170	Bellcow	SPL	Whole Lake	Fair	Poor	Fair	Poor
NLA12_OK-114	Birch	SPL	Lacustrine	Fair	Fair	Fair	Good
NLA12_OK-114	Birch	SPL	Whole Lake	Fair	Good	Good	Good
NLA12_OK-266	Bixhoma	SPL	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-266	Bixhoma	SPL	Whole Lake	Fair	Fair	Good	Good
NLA12_OK-109	Bluestem	TPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-109	Bluestem	TPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-190	Boomer	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-190	Boomer	SPL	Whole Lake	Poor	Poor	Poor	Poor
OKL11-011	Broken Bow	CPL	Lacustrine	Good	Good	Good	Good
OKL11-011	Broken Bow	CPL	Whole Lake	Good	Good	Good	Good

OKL11-073	Brooks	SPL	Lacustrine	Poor	Fair	Fair	Fair
OKL11-073	Brooks	SPL	Whole Lake	Fair	Fair	Fair	Fair
NLA12_OK-192	Brushy Creek	SAP	Lacustrine	Poor	Poor	Poor	Fair
NLA12_OK-192	Brushy Creek	SAP	Whole Lake	Poor	Poor	Poor	Fair
NLA12_OK-106	Canton	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-106	Canton	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-246	Charles	CPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-246	Charles	CPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-183	Claremore	TPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-183	Claremore	TPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-255	Clayton	SAP	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-255	Clayton	SAP	Whole Lake	Fair	Fair	Fair	Good
OKL11-006	Clear Creek	SPL	Lacustrine	Poor	Poor	Poor	Poor
OKL11-006	Clear Creek	SPL	Whole Lake	Poor	Poor	Poor	Fair
NLA12_OK-131	Coalgate City	SAP	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-131	Coalgate City	SAP	Whole Lake	Fair	Fair	Fair	Fair
NLA12_OK-185	Cohee	SPL	Lacustrine	Good	Fair	Good	Good
NLA12_OK-185	Cohee	SPL	Whole Lake	Good	Good	Good	Good
OKL11-077	Comanche	SPL	Lacustrine	Fair	Fair	Fair	Good
OKL11-077	Comanche	SPL	Whole Lake	Fair	Fair	Fair	Good
NLA12_OK-111	Copan	TPL	Lacustrine	Good	Good	Good	Fair
NLA12_OK-111	Copan	TPL	Whole Lake	Fair	Fair	Fair	Fair
NLA12_OK-128	Crowder	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-128	Crowder	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-121	Cushing Municipal	SPL	Lacustrine	Good	Fair	Good	Good
NLA12_OK-121	Cushing Municipal	SPL	Whole Lake	Good	Fair	Good	Good
NLA12_OK-179	Delaware Creek Site Three	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-179	Delaware Creek Site	SPL	Lacustrine	Poor	Poor	Poor	Poor

	Three						
NLA12_OK-166	Dripping Springs	SPL	Lacustrine	Fair	Fair	Fair	Good
NLA12_OK-166	Dripping Springs	SPL	Whole Lake	Fair	Fair	Fair	Good
NLA12_OK-127	Duncan	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-127	Duncan	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-263	Elmore City	SPL	Lacustrine	Fair	Fair	Fair	Fair
NLA12_OK-263	Elmore City	SPL	Whole Lake	Fair	Fair	Fair	Fair
NLA12_OK-159	Eucha	SAP	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-159	Eucha	SAP	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-169	Eufaula	SAP	Segment	Fair	Fair	Good	Good
NLA12_OK-169	Eufaula	SAP	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-169	Eufaula Canadian River	SAP	Segment	Fair	Fair	Good	Good
NLA12_OK-169	Eufaula Canadian River DF	SAP	Segment	Poor	Fair	Fair	Good
NLA12_OK-169	Eufaula Gaines Creek	SAP	Segment	Fair	Fair	Good	Good
NLA12_OK-169	Eufaula Longtown Creek	SAP	Segment	Fair	Fair	Good	Good
NLA12_OK-169	Eufaula North Canadian	SAP	Segment	Fair	Fair	Good	Fair
OKL11-072	Fin & Feather	SPL	Lacustrine	Poor	Poor	Poor	Fair
OKL11-072	Fin & Feather	SPL	Whole Lake	Poor	Fair	Poor	Fair
NLA12_OK-102	Fort Cobb	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-102	Fort Cobb	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-142	Fort Gibson	TPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-142	Fort Gibson Lower	TPL	Segment	Poor	Fair	Poor	Poor

NLA12_OK-142	Fort Gibson Upper	TPL	Segment	Fair	Poor	Poor	Poor
OKL11-012	Fort Supply	SPL	Lacustrine	Poor	Poor	Fair	Fair
OKL11-012	Fort Supply	SPL	Whole Lake	Poor	Poor	Fair	Fair
OKL11-010	Foss	SPL	Lacustrine	Fair	Good	Good	Good
OKL11-010	Foss	SPL	Whole Lake	Fair	Good	Fair	Good
NLA12_OK-112	Fuqua	SPL	Lacustrine	Poor	Fair	Fair	Good
NLA12_OK-112	Fuqua	SPL	Whole Lake	Poor	Fair	Fair	Good
NLA12_OK-138	Grand	SAP	Lacustrine	Poor	Fair	Poor	Fair
NLA12_OK-138	Grand Lower	SAP	Segment	Poor	Poor	Poor	Fair
NLA12_OK-138	Grand Middle	SAP	Segment	Good	Good	Good	Good
NLA12_OK-138	Grand Upper	SAP	Segment	Fair	Poor	Fair	Fair
NLA12_OK-151	Great Salt Plains	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-151	Great Salt Plains	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-150	Greenleaf	TPL	Lacustrine	Fair	Fair	Fair	Fair
NLA12_OK-150	Greenleaf	TPL	Whole Lake	Good	Fair	Fair	Fair
NLA12_OK-186	Hauani	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-186	Hauani	SPL	Whole Lake	Good	Good	Good	Good
OKL11-005	Hefner	SPL	Lacustrine	Poor	Poor	Fair	Poor
OKL11-005	Hefner	SPL	Whole Lake	Poor	Poor	Poor	Poor
OKL11-004	Heyburn	SPL	Lacustrine	Fair	Good	Good	Good
OKL11-004	Heyburn	SPL	Whole Lake	Fair	Good	Good	Good
NLA12_OK-175	Holdenville	SPL	Lacustrine	Good	Poor	Good	Fair
NLA12_OK-175	Holdenville	SPL	Whole Lake	Fair	Poor	Good	Fair
NLA12_OK-120	Hudson	SPL	Lacustrine	Fair	Fair	Fair	Good
NLA12_OK-120	Hudson	SPL	Whole Lake	Fair	Fair	Fair	Good
NLA12_OK-165	Hugo	CPL	Lacustrine	Good	Fair	Good	Fair
NLA12_OK-165	Hugo	CPL	Whole Lake	Fair	Fair	Fair	Poor
NLA12_OK-134	Hulah	SPL	Lacustrine	Good	Fair	Good	Good
NLA12_OK-134	Hulah	SPL	Whole Lake	Fair	Fair	Good	Good
NLA12_OK-156	Humphreys	SPL	Lacustrine	Poor	Poor	Poor	Poor

NLA12_OK-156	Humphreys	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-113	Kaw	SPL	Lacustrine	Poor	Fair	Poor	Fair
NLA12_OK-113	Kaw Lower	SPL	Segment	Poor	Fair	Fair	Good
NLA12_OK-113	Kaw Upper	SPL	Segment	Poor	Poor	Fair	Fair
NLA12_OK-103	Keystone	SPL	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-103	Keystone	SPL	Segment	Fair	Good	Good	Good
NLA12_OK-103	Keystone Arkansas River Arm	SPL	Segment	Poor	Poor	Fair	Fair
NLA12_OK-103	Keystone Cimmaron River Lower	SPL	Segment	Fair	Fair	Fair	Fair
NLA12_OK-103	Keystone Cimmaron River Upper	SPL	Segment	Poor	Poor	Poor	Poor
NLA12_OK-146	Lake Hudson Lower	TPL	Segment	Fair	Good	Fair	Fair
NLA12_OK-146	Lake Hudson Upper	TPL	Segment	Poor	Poor	Poor	Poor
OKL11-079	Langston	SPL	Whole Lake	Good	Good	Good	Good
OKL11-079	Langston	SPL	Lacustrine	Good	Good	Good	Good
OKL11-069	Leeper	SPL	Whole Lake	Poor	Poor	Poor	Poor
OKL11-069	Leeper	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-188	Lloyd Church	SAP	Whole Lake	Fair	Good	Good	Good
NLA12_OK-188	Lloyd Church	SAP	Lacustrine	Fair	Good	Good	Good
NLA12_OK-160	Lone Chimney	SPL	Whole Lake	Fair	Fair	Fair	Good
NLA12_OK-160	Lone Chimney	SPL	Lacustrine	Fair	Fair	Fair	Good
NLA12_OK-125	Mannford	SPL	Whole Lake	Fair	Good	Good	Good
NLA12_OK-125	Mannford	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-172	McGee Creek	SAP	Whole Lake	Fair	Fair	Good	Good
NLA12_OK-172	McGee Creek	SAP	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-123	Mountain	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-123	Mountain	SPL	Lacustrine	Good	Good	Good	Good

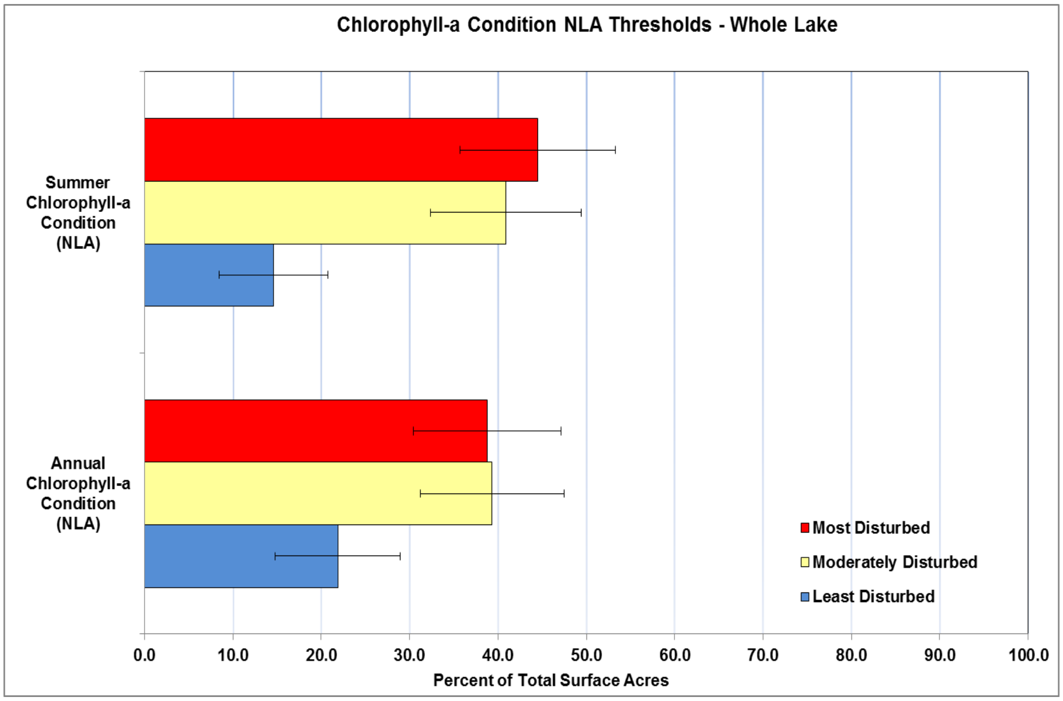
NLA12_OK-176	Muldrow	SAP	Whole Lake	Fair	Poor	Fair	Fair
NLA12_OK-176	Muldrow	SAP	Lacustrine	Fair	Poor	Fair	Fair
NLA12_OK-193	Northwood	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-193	Northwood	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-108	Okemah	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-108	Okemah	SPL	Lacustrine	Good	Good	Good	Good
OKL11-009	Okmulgee	SPL	Whole Lake	Fair	Good	Good	Good
OKL11-009	Okmulgee	SPL	Lacustrine	Fair	Good	Good	Good
NLA12_OK-262	Onapa	TPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-262	Onapa	TPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-152	Oolagah	TPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-152	Oolagah	TPL	Lacustrine	Good	Good	Good	Fair
NLA12_OK-164	Pauls Valley	SPL	Whole Lake	Poor	Fair	Fair	Fair
NLA12_OK-164	Pauls Valley	SPL	Lacustrine	Good	Fair	Good	Good
NLA12_OK-129	Perry	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-129	Perry	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-149	Pine Creek	SAP	Whole Lake	Poor	Poor	Fair	Fair
NLA12_OK-149	Pine Creek	SAP	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-259	Public Service Reservoir Three	SPL	Whole Lake	Poor	Poor	Poor	Fair
NLA12_OK-259	Public Service Reservoir Three	SPL	Lacustrine	Poor	Poor	Poor	Fair
NLA12_OK-182	Quanah Parker	SPL	Whole Lake	Fair	Good	Good	Good
NLA12_OK-182	Quanah Parker	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-144	RC Longmire	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-144	RC Longmire	SPL	Lacustrine	Poor	Poor	Poor	Fair
NLA12_OK-161	Robert S Kerr	SAP	Whole Lake	Poor	Poor	Fair	Fair
NLA12_OK-161	Robert S Kerr	SAP	Lacustrine	Fair	Fair	Good	Fair
NLA12_OK-118	Rocky	SPL	Whole Lake	Poor	Poor	Poor	Poor

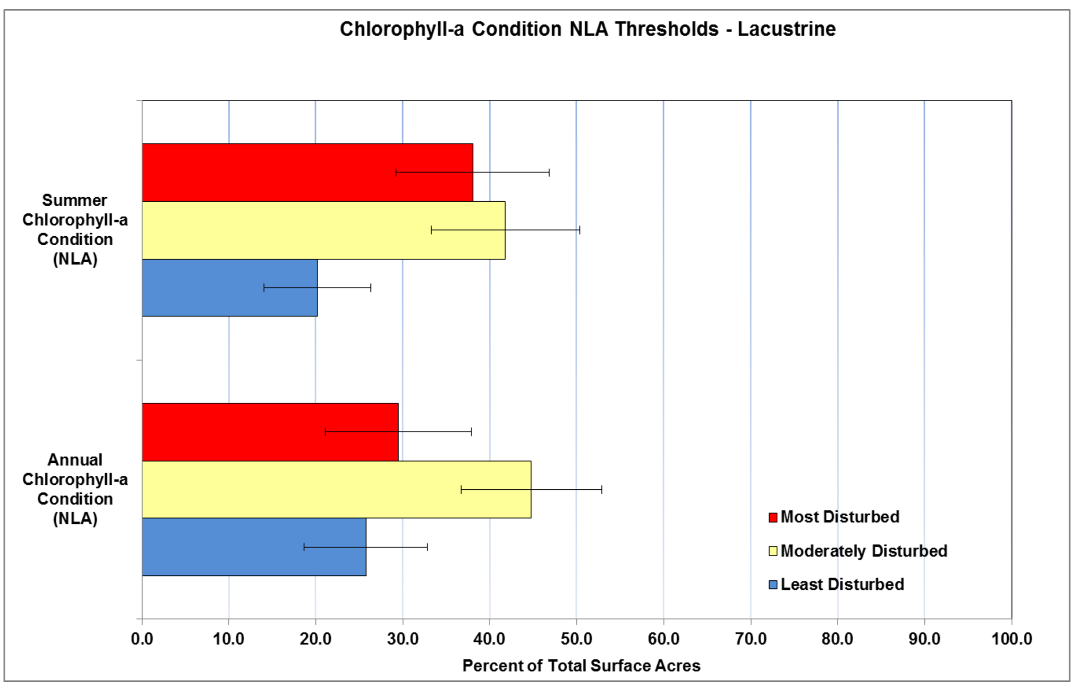
NLA12_OK-118	Rocky	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-248	Roebuck	CPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-248	Roebuck	CPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-117	Rolla	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-117	Rolla	SPL	Lacustrine	Poor	Poor	Poor	Poor
OKL11-014	Sardis	SAP	Whole Lake	Fair	Fair	Fair	Good
OKL11-014	Sardis	SAP	Lacustrine	Fair	Fair	Fair	Good
NLA12_OK-153	Shawnee Twin One	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-153	Shawnee Twin One	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-257	Shawnee Twin Two	SPL	Whole Lake	Good	Fair	Good	Fair
NLA12_OK-257	Shawnee Twin Two	SPL	Lacustrine	Good	Fair	Good	Fair
NLA12_OK-174	Shell	SPL	Whole Lake	Poor	Fair	Poor	Fair
NLA12_OK-174	Shell	SPL	Lacustrine	Poor	Fair	Fair	Good
NLA12_OK-104	Skiatook	SPL	Whole Lake	Fair	Good	Good	Good
NLA12_OK-104	Skiatook	SPL	Lacustrine	Fair	Good	Fair	Good
NLA12_OK-141	Sooner	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-141	Sooner	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-155	Spavinaw	SAP	Lacustrine	Fair	Poor	Fair	Fair
NLA12_OK-155	Spavinaw	SAP	Whole Lake	Fair	Poor	Fair	Fair
NLA12_OK-126	Sportsman	SPL	Lacustrine	Fair	Good	Fair	Good
NLA12_OK-126	Sportsman	SPL	Whole Lake	Poor	Good	Fair	Good
NLA12_OK-145	Stroud	SPL	Lacustrine	Good	Good	Good	Good
NLA12_OK-145	Stroud	SPL	Whole Lake	Good	Good	Good	Good
NLA12_OK-247	Sunset	SPL	Lacustrine	Poor	Poor	Fair	Fair
NLA12_OK-247	Sunset	SPL	Whole Lake	Poor	Poor	Poor	Fair
NLA12_OK-281	Talawanda One	SAP	Lacustrine	Fair	Good	Good	Good
NLA12_OK-281	Talawanda One	SAP	Whole Lake	Fair	Good	Good	Good

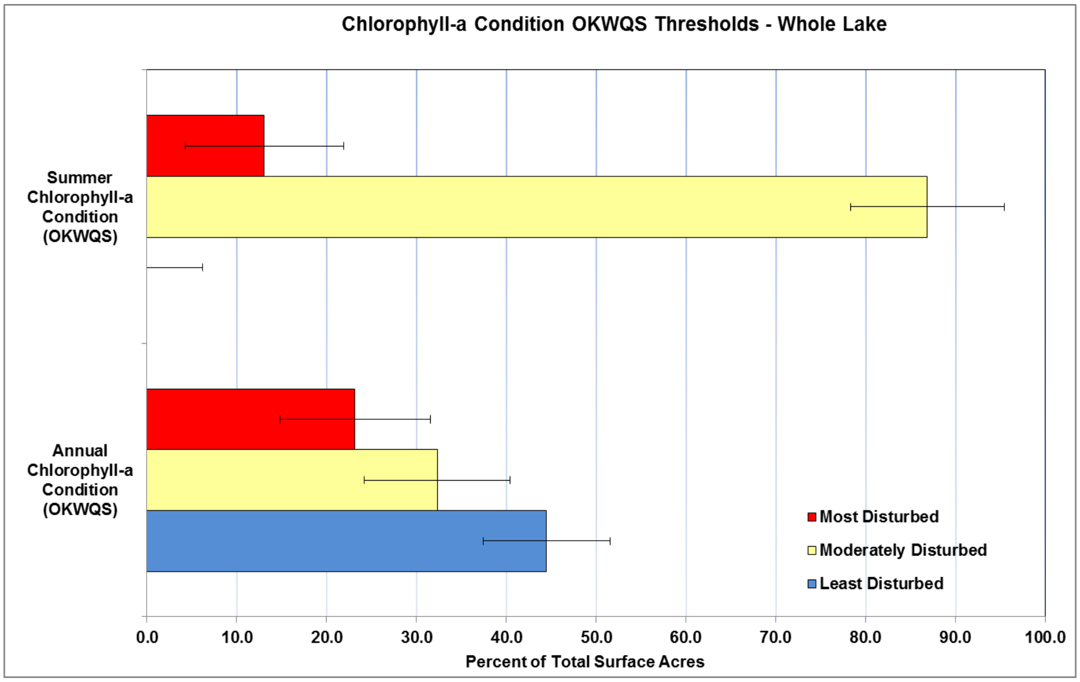
OKL11-080	Talawanda Two	SAP	Lacustrine	Good	Good	Good	Good
OKL11-080	Talawanda Two	SAP	Whole Lake	Good	Good	Good	Good
NLA12_OK-261	Taylor	SPL	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-261	Taylor	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-107	Tenkiller Ferry	SAP	Lacustrine	Fair	Fair	Good	Good
NLA12_OK-107	Tenkiller Ferry	SAP	Segment	Fair	Fair	Good	Good
NLA12_OK-107	Tenkiller Ferry Illinois River Arm	SAP	Segment	Poor	Poor	Poor	Fair
OKL11-002	Texoma	SPL	Segment	Fair	Fair	Good	Good
OKL11-002	Texoma Lake Red River Arm Lower	SPL	Segment	Fair	Fair	Fair	Fair
OKL11-002	Texoma Lake Red River Arm Upper	SPL	Segment	Poor	Poor	Fair	Fair
OKL11-002	Texoma Lake Washita River Arm Lower	SPL	Segment	Fair	Fair	Good	Good
NLA12_OK-136	Tom Steed	SPL	Whole Lake	Poor	Poor	Fair	Fair
NLA12_OK-136	Tom Steed	SPL	Lacustrine	Poor	Poor	Poor	Fair
NLA12_OK-130	Veterans	SPL	Whole Lake	Fair	Fair	Good	Good
NLA12_OK-130	Veterans	SPL	Lacustrine	Good	Fair	Good	Good
NLA12_OK-143	Waurika	SPL	Whole Lake	Poor	Poor	Poor	Poor
NLA12_OK-143	Waurika	SPL	Lacustrine	Fair	Fair	Good	Fair
NLA12_OK-181	Waxhoma	SPL	Whole Lake	Fair	Good	Fair	Good
NLA12_OK-181	Waxhoma	SPL	Lacustrine	Good	Good	Good	Good
OKL11-007	Webbers Falls	TPL	Whole Lake	Poor	Poor	Poor	Poor
OKL11-007	Webbers Falls	TPL	Lacustrine	Poor	Good	Poor	Fair
OKL11-013	Wes Watkins	SPL	Whole Lake	Poor	Fair	Poor	Fair
OKL11-013	Wes Watkins	SPL	Lacustrine	Poor	Fair	Poor	Fair

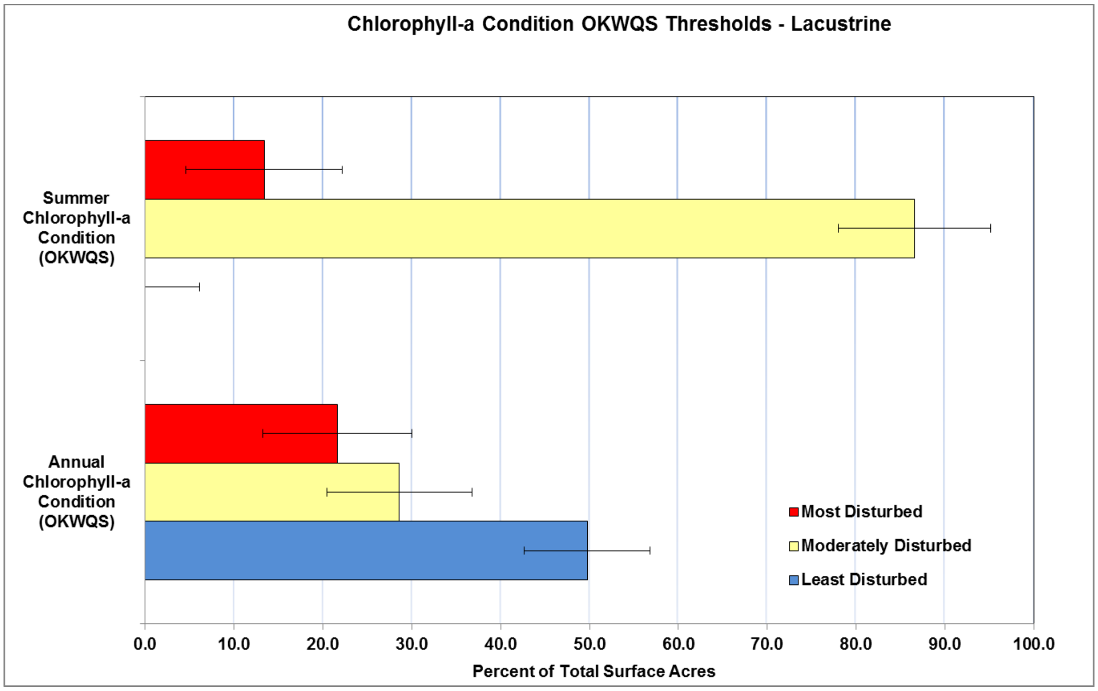
NLA12_OK-191	Wewoka	SPL	Whole Lake	Poor	Fair	Fair	Fair
NLA12_OK-191	Wewoka	SPL	Lacustrine	Poor	Fair	Fair	Fair
NLA12_OK-250	Wiley Post Memorial	SPL	Whole Lake	Fair	Poor	Good	Fair
NLA12_OK-250	Wiley Post Memorial	SPL	Lacustrine	Fair	Poor	Fair	Fair
NLA12_OK-115	Wister	SAP	Whole Lake	Poor	Poor	Fair	Fair
NLA12_OK-115	Wister	SAP	Lacustrine	Poor	Poor	Poor	Poor
NLA12_OK-163	WR Holoway	SAP	Whole Lake	Poor	Fair	Fair	Fair
NLA12_OK-163	WR Holoway	SAP	Lacustrine	Poor	Fair	Fair	Fair

Appendix F – Chlorophyll *a* Condition Figures






Chlorophyll-a Condition OKWQS Thresholds - Whole Lake
Summer Chlorophyll-a Condition (OKWQS)
Annual Chlorophyll-a Condition (OKWQS)
Most Disturbed
Moderately Disturbed
Least Disturbed
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Percent of Total Surface Acres


Chlorophyll-a Condition OKWQS Thresholds - Lacustrine
Summer Chlorophyll-a Condition (OKWQS)
Annual Chlorophyll-a Condition (OKWQS)
Most Disturbed
Moderately Disturbed
Least Disturbed
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Percent of Total Surface Acres

Appendix G – Recreation Condition Figures