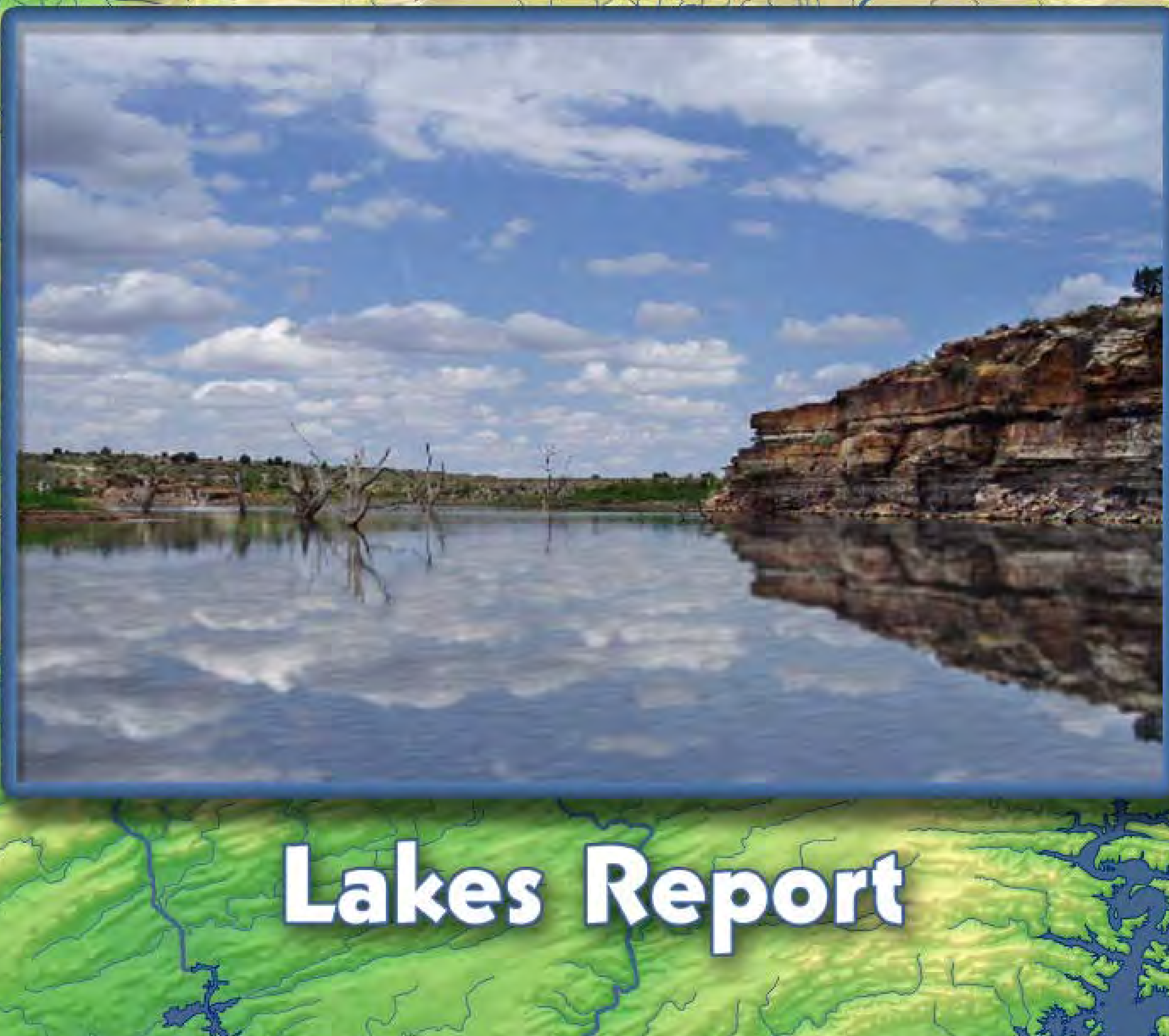
2004 Report of the Oklahoma

# Beneficial Use Monitoring Program (BUMP)



# Lakes Report

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the water agency

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# EXECUTIVE SUMMARY

***Beneficial Use Monitoring Program Goal:***

**The goal of the Beneficial Use Monitoring Program is to document beneficial use impairments, identify impairment sources (if possible), detect water quality trends, provide needed information for the OWQS, and facilitate the prioritization of pollution control activities.**

The Beneficial Use Monitoring Program exists as a result of the vital economic and social importance of Oklahoma's lakes, streams, wetlands, and aquifers and the associated need for their protection and management. The data contained in this report is scientifically defensible and has been collected and analyzed following procedures outlined in Use Support Assessment Protocols (USAP), developed by Oklahoma's environmental agencies. Specifically, USAPs establish a consistent method to determine if beneficial uses assigned for individual waters through Oklahoma Water Quality Standards (OWQS) are being supported. (Legitimacy of data analyzed following protocols other than those outlined in the USAP must be defended.) If the BUMP report indicates that a designated beneficial use is impaired, threatened, or otherwise compromised, measures must be taken to mitigate or restore the water quality.

The Oklahoma Water Resources Board (OWRB) has worked diligently to follow the guidelines outlined in the USAP. Recommendations in this report should be consistent with recommendations for the state's 303(d) list. Although certain inconsistencies do exist, every effort has been taken to assure compatibility between the BUMP Report and the 303(d) list. Issues regarding stream/lake segmenting additional data from non-BUMP sources and unique non-representative conditions all affect the impairment decision-making process

Traditionally, the State of Oklahoma has utilized numerous water monitoring programs conducted by individual state and federal agencies. In general, each environmental agency designs and implements its own program with only limited participation from with other state, municipal, or federal entities. These programs collect information for a specific purpose or project (e.g., development of Total Maximum Daily Loads, OWQS process, lake trophic status determination, water quality impact assessments from nonpoint and point source pollution, stream flow measurement, assessment of best management practices, etc.). Therefore, the information is specific to each project's data quality objectives (DQOs) and is often limited to a very small geographic area.

To synchronize Oklahoma's monitoring efforts related to water quality, the State Legislature appropriated funds in 1998 to create the Beneficial Use Monitoring Program under the direction of the Oklahoma Water Resources Board, who maintains Oklahoma's Water Quality Standards. The BUMP brings the OWRB's overall water quality management program full circle. From the promulgation of OWQS, to permitting and enforcement of permits stemming from OWQS-established criteria, to non-point source controls, all agency water quality management activities are intended to work in concert to restore, protect, and maintain designated beneficial uses.

The specific objectives of the BUMP are to detect and quantify water quality trends, document and quantify impairments of assigned beneficial uses, and identify pollution problems before they become a pollution crisis. This report interprets current Oklahoma Lake data collected as part of the comprehensive, long-term program. As the program has matured, the BUMP report has become one of the most important annually published documents in Oklahoma.

## BENEFICIAL USE MONITORING PROGRAM COMPONENTS

- **Monitoring Rivers & Streams** - The OWRB is currently monitoring approximately 180 stations on a monthly basis. These sites are segregated into two discrete types of monitoring activities. The first monitoring activity is focusing on fixed station monitoring on rivers and streams and the second monitoring activity focuses on a number of sample stations with locations that rotate on an annual basis. The two monitoring components are explained below.

    - **Fixed Station Monitoring on Rivers & Streams** - Fixed station monitoring is based largely upon the 67 United States Geological Survey (USGS) 8-digit hydrologic unit code (HUC) basins present in Oklahoma. In general, at least 1 sample station was located in all of the HUC watersheds with the exception of some of the smaller HUC watersheds adjacent to the state line or in a HUC that does not contain a free flowing stream at some point during the year. After consultation with the other state environmental agencies and over time the OWRB has identified 119 fixed stations of which 99 are currently being monitored.

    - **Rotating Station Monitoring on Rivers & Streams** - Over the life of the BUMP, rotational sampling has occurred on 200 stream segments. Sample stations and variables monitored are based upon Oklahoma's 303(d) list and input from other state environmental agencies on their monitoring needs. Variables monitored as part of this program component are specific for each stream segment monitored

- **Fixed Station Load Monitoring** –The OWRB is currently working jointly with the USGS to conduct flow monitoring on all of our fixed station sites that do not have an automated flow monitoring USGS gage. This cooperative effort allows for loadings to be calculated and provides much needed data for the Use Support Assessment process.

- **Fixed Station Lakes Monitoring** - Quarterly sampling (approximately once every 90 days) of approximately 55-60 lakes annually is currently occurring. This represents approximately a 40% increase in effort over historical BUMP Lake sampling efforts. In general, a minimum of three stations per reservoir, representing the lacustrine zone, transitional zone, and riverine zone, are designated for sampling at each lake, with additional sites sampled as needed. Additional water quality parameters and lake sites were added to the lake sampling program in 2001 to aid in making use support determinations.

- **Fixed Station Groundwater Monitoring** - Limited monitoring as part of this task has occurred in the program. Results of monitoring are presented in this report. OWRB staff has made recommendations in this report related to the scope and magnitude of groundwater monitoring activities that the state should pursue in the future. Any proposed groundwater monitoring efforts will be coordinated with the Oklahoma Department of Environmental Quality (ODEQ).

- **Intensive Investigation Sampling** - Although no funding was made available for this element of ther program, it is important that waters identified as impaired be restored. If routine monitoring identifies impairment, then an intensive study will be undertaken to document the source of the impairment and recommend restorative actions if possible. This task will not be conducted in year one or year two of the program, but thereafter, intensive investigations will be conducted as warranted. If water bodies are not identified for intensive study as part of this task, then monies will be reallocated to Tasks **1** and **3**. Other entities (i.e., tribal or governmental units outside of Oklahoma) are involved as circumstances dictate or allow.

## PROGRAM HISTORY/OVERVIEW

Sampling of the numerous lakes, streams, and rivers across this state was initiated in the summer and fall of 1998. Lake sampling in connection with the Beneficial Use Monitoring Program began in July of 1998. Sampling on numerous streams and rivers began in earnest in November of the same year. The two sampling programs, one for lakes and one for streams, had separate starting dates for a number of reasons. First, the OWRB has been conducting a lake-sampling program during the warmer summer months since 1990 as part of the Federal Clean Lakes Program. This historical lake sampling program was funded through federal dollars with the express purpose of determining lake trophic status. The trophic status of a reservoir can range from oligotrophic (low biological productivity) to hypereutrophic (excessive biological productivity). In general, the more productive a reservoir, the more water quality problems it is likely to experience. Federal dollars to fund this trophic state assessment of our state's lakes were discontinued in 1994. At that time, the OWRB searched for other funding sources, and through working with the Secretary of the Environment and the Oklahoma Conservation Commission, the Water Board was able to obtain a one time federal 319 nonpoint source grant to continue the lake trophic state assessment program. The OWRB subsequently initiated a quarterly lake sampling program in the spring of 1998 and was able to roll the existing lake program into the BUMP. Since 1998, both the number of lakes sampled annually and monitored water quality constituents for have increased as the program has continued to adapt to meet the data quality needs for Oklahoma. It is hoped that the program can be further enhanced in the future to increase its usefulness to the environmental decision making process in Oklahoma.

The OWRB has developed Use Support Assessment Protocols (USAP) for lakes and streams, which are essential if the state is to be consistent in identifying waters that are not meeting their assigned beneficial uses or are threatened. The Water Resources Board has incorporated the USAP into Oklahoma Administrative Code (OAC) 785:46 to ensure that consistent determinations for impairments are made by the all of the monitoring agencies.

**The state must follow consistent procedures for listing waters as impaired. Using the OWRB Use Support Assessment Protocols, it has been possible for OWRB staff to assess whether threats or impairments are present in our waterways. With continued funding, identification of impaired waters will be accomplished on additional waters.**

### Results of Lakes Sampling Efforts

Data collected by OWRB on a quarterly basis for 65 lakes in 2003-2004 and 54 lakes in 2002-2003 was used for this report. For the current sample year, data was collected from the September of 2003 through September of 2004. The results of the sampling efforts are summarized below. As shown in Figure 1, a relatively small percentage (8%) of lakes sampled were determined to have serious water quality nutrient concerns based upon their classification as hypereutrophic reservoirs. Lakes classified as hypereutrophic have the potential for beneficial use impairments due to low dissolved oxygen concentrations, taste and odor problems, nutrient inputs, excessive productivity, and general lake aesthetics. Hypereutrophic waters are adversely impacted primarily by excessive nutrients and primary productivity and should be monitored intensively in the future to document the presence or absence of "beneficial use impairments." Fifty-one percent of the lakes sampled were classified as eutrophic, characterized by high primary productivity and nutrient rich conditions. A eutrophic lake also has the potential for beneficial use impairments, though the potential is less than for hypereutrophic waters. Mesotrophic waters have a small potential for beneficial use impairments and overall are representative of good water quality, low to moderate levels of nutrients, and productivity. Of the lakes sampled, 28% were classified as mesotrophic. Oligotrophic waters have very low levels of primary productivity and usually low concentrations of nutrient constituents. In Oklahoma, oligotrophic waters are either very clear waters with little nutrient inputs and genuinely good water quality conditions, or the waters are very turbid with poor water clarity with the absence of sufficient ambient light inhibiting lake productivity. Only six of the 65 lakes sampled were classified as oligotrophic. Based on the results for trophic state index calculations, 63% of the waters sampled were exhibiting high to excessive levels of primary productivity and nutrient rich conditions characteristic of eutrophic and hypereutrophic waterbodies.

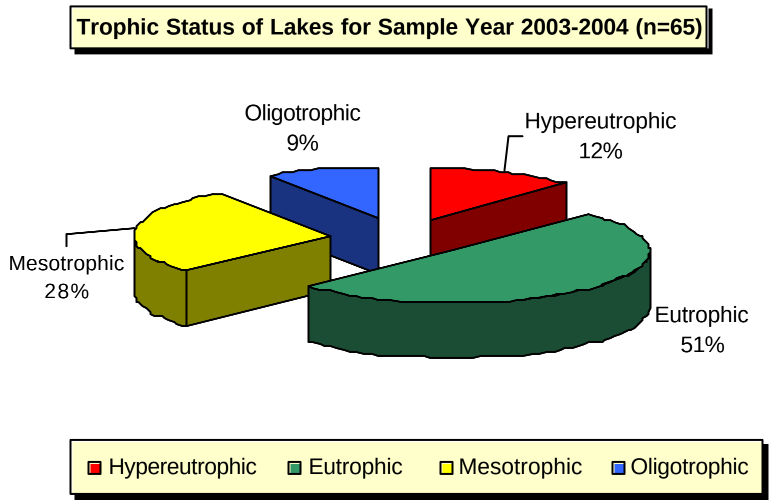



**Figure 1.** Trophic Status of Lakes Sampled in 2003-2004

The distribution changes somewhat when the lake surface acres for each reservoir are classified into the corresponding trophic status. Results in Figure 2 are different than Figure 1, indicating the lakes classified as eutrophic were larger in surface acres than the lakes classified as mesotrophic and hypereutrophic. When you look at lake trophic status broken out by the number of lake surface acres in each trophic state category, 72% of all surface acres sampled were eutrophic, 6% were mesotrophic, 8% were hypereutrophic, and 14% were oligotrophic. The two largest reservoirs sampled in 2003-2004

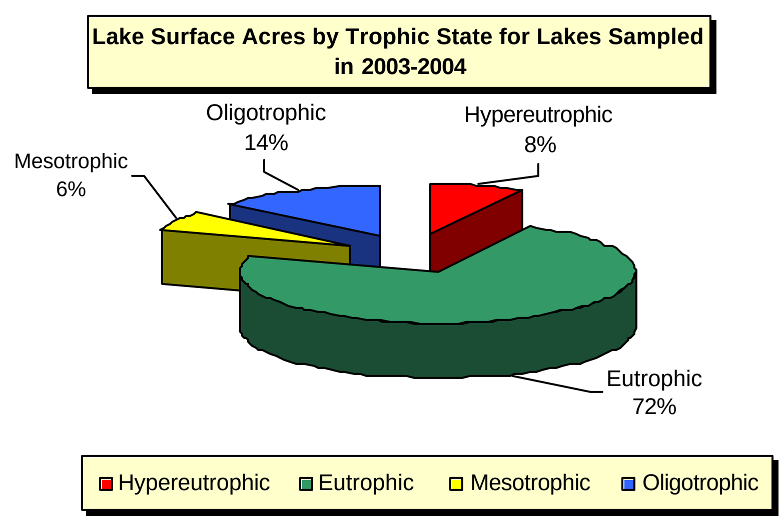



**Figure 2.** Lakes surface acres segregated by trophic state.

were classified as eutrophic (Grand and Keystone), which skewed the surface acres percentages heavily towards the eutrophic category. In general, the larger reservoirs in the state have more extensive watersheds and are generally deeper than smaller lakes, which increase the likelihood of beneficial use impairments being present since a larger surface area is available. During stratification, the larger/deeper reservoirs have a greater portion of the water column that becomes anoxic for long periods of time, which also increases the potential for nutrient release from sediments. It is obvious that many reservoirs in Oklahoma are experiencing adverse environmental impacts. However, with the available data it is not possible to adequately assess if lakes are meeting their assigned beneficial uses as they relate to nutrients. At this time, 14 lakes have been identified by the OWRB as “Nutrient-Limited Watersheds” (NLW) in the OWQS and efforts should be taken to definitively determine if NLW waters are meeting their uses through initiation of a Nutrient Impairment Study to definitively determine the presence or absence of nutrient impairments in our NLW lakes. NLW are lakes with a TSI = 62, based on Carlson’s trophic state classification system and using chlorophyll-a as the trophic state indicator. Lakes sampled as part of the BUMP, their trophic status, and potential threats or impairments are listed in Table 1.

**Table 1.** Lakes Sampled by the BUMP with Associated Use Attainment Status.

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| American Horse | Blaine | | 2003 | D.O. | | | | |
| Arbuckle | Murray | 310800 | 2003 | D.O. | | | | |
| Arcadia | Oklahoma | 520710 | 2003 | D.O.<br>Turbidity | | | | |
| Ardmore City | Carter | 310800 | 2003 | D.O. | | | | |
| Atoka | Atoka | 410400 | 2004 | Turbidity<br>D.O. | | | | True Color |
| Bellcow | Lincoln | 520700 | 2004 | D.O. | | | | |
| Birch | Osage | 121300 | 2003 | D.O.<br>Turbidity | | | | True Color |
| Bixhoma | Wagoner | | 2004 | D.O. | | | | |
| Bluestem | Osage | 121300 | 2004 | D.O. | | | | |
| Boomer | Payne | 620900 | 2002 | Turbidity | | | | |
| Broken Bow | McCurtain | 410210 | 2004 | pH<br>D.O. | | | | |
| Brushy Creek | Sequoyah | 220200 | 2004 | pH | | Entero | | |
| Burtschi ‡ | Grady | | 2004 | | | Entero. | | |
| Canton | Blaine | 720500 | 2004 | Turbidity | | | | |
| Carl Albert | Latimer | 410310 | 2004 | | | | | |
| Carl Blackwell | Payne | 620900 | 2002 | D.O. | | | | |
| Carter | Marshall | 310800 | 2004 | | | | | |
| Cedar (Mena) | LeFlore | 410210, 410300 | 2004 | D.O.<br>pH | | | | |
| Chandler | Lincoln | 520700 | 2003 | D.O. | | | | |
| Chickasha ‡ | Caddo | 310830 | 2003 | | | | | |

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| Claremore | Rogers | 121500 | 2004 | | | | | NLW |
| Clear Creek | Stephens | 310810 | 2003 | D.O. | | Entero. | | |
| Cleveland City | Pawnee | | 2004 | D.O. | | | | |
| Clinton ? | Washita | 310830 | 2004 | Turbidity | | Entero. | | True Color |
| Coalgate City | Coal | 410400 | 2004 | D.O. Turbidity | | | | True Color |
| Comanche | Stephens | 311300 | 2003 | D.O. | | | | |
| Copan | Washington | 121400 | 2003 | Turbidity D.O. | | | | |
| Crowder | Washita | 310830 | 2004 | | | | | NLW |
| Cushing Municipal | Payne | 620900 | 2004 | Turbidity | | | | True Color |
| Dave Boyer (Walters) | Cotton | 311300 | 2004 | Turbidity | | | | True Color |
| Dripping Springs | Okmulgee | 520700 | 2002 | D.O. | | | | |
| Duncan | Stephens | 310810 | 2003 | D.O. | | | | |
| El Reno | Canadian | | 2003 | Turbidity | | | | |
| Elk City | Beckham | 311500 | 2004 | | | Entero. | | NLW |
| Ellsworth | Comanche | 311300 | 2004 | Turbidity D.O. | | | | |
| Elmer Thomas | Comanche | 311300 | 2003 | D.O. | | | | |
| Etling, Carl | Cimarron | 720900 | 2004 | Turbidity pH | | | | |
| Eucha ? | Delaware | 121600 | 2003 | D.O. | | | | NLW |
| Eufaula | Haskell | 220600 | 2003 | D.O. Turbidity | | | | True Color |
| Fairfax City | Osage | 621200 | 2004 | D.O. | | | | |
| Fort Cobb ‡ | Caddo | 310830 | 2004 | Turbidity | | Entero. | | NLW |
| Fort Gibson ? | Cherokee | 121600 | 2004 | | | | | NLW |
| Fort Supply † | Woodward | 720500 | 2002 | Turbidity | | | | NLW True Color |
| Foss | Custer | 310800, 310810 310820, 310830 310840 | 2003 | D.O. Turbidity | | | | |
| Frederick | Tillman | 311310 | 2003 | Turbidity | | | | |
| Fuqua | Stephens | 310810 | 2003 | D.O. | | Entero. | | True Color |
| Grand Lake | Mayes | 121600 | 2004 | D.O. Turbidity | | | | |
| Great Salt Plains | Alfalfa | 621010 | 2004 | Turbidity | | Entero. | Sulfates & Chlorides | NLW |
| Greenleaf | Muskogee | 120400 | 2004 | | | Entero. | | |
| Guthrie | Logan | 620910 | 2004 | Turbidity | | Entero. | | NLW |
| Healdton City | Carter | 311100 | 2004 | Turbidity | | | | True Color |
| Hefner | Oklahoma | 520520, 520530 | 2004 | Turbidity | | | | |

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| Henryetta ? | Okmulgee | 520700 | 2003 | D.O. | | | | |
| Heyburn | Creek | 120420 | 2003 | D.O.<br>Turbidity | | Entero. | | |
| Holdenville | Hughes | 520800 | 2002 | D.O. | | Entero. | | |
| Hominy Municipal | Osage | 121300 | 2004 | D.O. | | | | |
| Hudson | Osage | | 2004 | D.O. | | | | |
| Hudson | Mayes | 121600 | 2003 | D.O. | | | | |
| Hugo | Choctaw | 410300 | 2003 | Turbidity<br>D.O. | | | | True Color |
| Hulah | Osage | 121400 | 2003 | Turbidity | | | | NLW |
| Humphreys | Stephens | 310810 | 2003 | D.O. | | | | |
| Jean Neustadt | Carter | 310800 | 2003 | D.O. | | | | |
| John Wells | Haskell | 220200 | 2004 | | | | | |
| Kaw | Osage | 621210 | 2003 | Turbidity<br>D.O. | | | | True Color |
| Keystone | Tulsa | 621200 | 2004 | Turbidity | | Entero. | | |
| Konawa | Seminole | | 2002 | | | | | |
| Langston | Logan | 620900 | 2004 | | | | | |
| Lawtonka | Comanche | 311300 | 2004 | | | | | |
| Liberty | Logan | 620910 | 2004 | Turbidity | | Entero. | | |
| Lloyd Church | Latimer | 220100 | 2004 | D.O. | | | | |
| Lone Chimney | Pawnee | 621200 | 2004 | | | | | |
| Lugert-Altus ? | Greer | 311500, 311510 | 2003 | pH | | | | NLW |
| Maysville/Wiley Post | McClain | | 2002 | D.O.<br>Turbidity | | | | |
| Mc Alester | Pittsburg | 220600 | 2003 | Turbidity<br>D.O. | | | | |
| McGee Creek | Atoka | 410400 | 2004 | D.O.<br>pH | | | | |
| Mc Murtry | Noble | 620900 | 2002 | D.O. | | | | |
| Meeker | Lincoln | 520700 | 2004 | Turbidity | | | | True Color |
| Murray | Love | 311100 | 2004 | D.O. | | | | |
| Nanih Waiya | Pushmataha | | 2003 | D.O. | | | | |
| New Spiro ? | LeFlore | 220100 | 2004 | D.O. | | | | |
| Okemah | Okfuskee | 520700 | 2002 | D.O. | | | | |
| Okmulgee | Okmulgee | 520700 | 2002 | D.O. | | | | |
| Oologah | Rogers | 121510 | 2003 | Turbidity<br>D.O. | | | | |
| Overholser ? | Oklahoma | 520520, 520530 | 2004 | Turbidity | | | | NLW<br>True Color |
| Ozzie Cobb | Pushmataha | 410300 | 2003 | D.O.<br>pH | | | | NLW |

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| Pauls Valley City | Garvin | 310810 | 2003 | D.O. | | | | |
| Pawhuska | Osage | 121600 | 2003 | D.O. | | | | |
| Pawnee | Pawnee | 621200 | 2004 | | | | | |
| Perry | Noble | 621200 | 2003 | Turbidity | | | | |
| Pine Creek | McCurtain | 410210 | 2004 | D.O.<br>Turbidity<br>pH | | | | |
| Ponca | Kay | 621200 | 2003 | D.O. | | | | |
| Prague City | Lincoln | 520510 | 2003 | D.O. | | | | |
| Purcell | McClain | 520610 | 2002 | D.O. | | | | |
| Raymond Gary | Choctaw | 410300 | 2000 | D.O.<br>pH | | | | |
| R.C. Longmire | Garvin | 310810 | 2003 | D.O. | | | | |
| Robert S. Kerr | Sequoyah | 220200 | 2003 | Turbidity | | | | True Color |
| Rock Creek | Carter | 310800 | 2003 | D.O. | | | | |
| Rocky (Hobart) ‡ | Washita | 311500 | 2004 | Turbidity | | Entero. | | |
| Sahoma | Creek | 120420 | 2004 | D.O.<br>Turbidity | | | | True Color |
| Sardis | Pushmataha | 410310 | 2003 | D.O. | | | | |
| Shawnee Twin # 1 | Pottawatomie | 520510 | 2004 | | | | | |
| Shawnee Twin # 2 | Pottawatomie | 520510 | 2004 | | | | | |
| Shell | Osage | 120420 | 2004 | D.O. | | | | |
| Skiatook | Osage | 121300 | 2003 | D.O. | | | | |
| Sooner | Pawnee | | 2003 | D.O. | | | | |
| Spavinaw ? | Mayes | 121600 | 2003 | D.O. | | | | NLW |
| Sportsman | Seminole | 520500 | 2002 | | | | | |
| Stanley Draper | Cleveland | | 2004 | | | | | |
| Stilwell City | Adair | 220200 | 2001 | D.O. | | | | |
| Stroud | Creek | 520700 | 2004 | | | | | |
| Talawanda # 1 | Pittsburg | 220600 | 2003 | D.O.<br>pH | | | | |
| Talawanda # 2 | Pittsburg | 220600 | 2003 | D.O. | | | | |
| Taylor (Marlow) ? | Grady | 310840 | 2003 | Turbidity<br>D.O. | | | | NLW |
| Tecumseh | Pottawatomie | 520510 | 2004 | | | | | |
| Tenkiller Ferry | Sequoyah | 121700 | 2004 | D.O. | | | | |
| Texoma | Bryan | 311100, 310800 | 2003 | D.O.<br>Turbidity | | | | |
| Thunderbird | Cleveland | 520810 | 2004 | Turbidity | | | | |

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| Tom Steed | Kiowa | 311500 | 2003 | Turbidity<br>pH | | | | |
| Vanderwork | Washita | 310830 | 2004 | | | | | NLW |
| Vincent, Loyd | Ellis | 720500 | 2000 | | | | | |
| W.R. Holway | Mayes | | 2003 | D.O. | | | | |
| Waurika | Jefferson | 311210 | 2003 | D.O.<br>Turbidity | | | | |
| Waxhoma | Osage | | 2004 | D.O. | | Entero. | | |
| Wayne Wallace | Latimer | 220100 | 2003 | D.O.<br>pH | | | | |
| Webbers Falls | Muskogee | 121400 | 2004 | | | Entero. | | |
| Wes Watkins | Pottawatomie | 520510 | 2002 | | | | | |
| Wetumka | Hughes | | 2001 | D.O. | | | | |
| Wewoka | Seminole | 520500 | 2002 | | | | | |
| Wister ? | LeFlore | 220100 | 2003 | pH<br>Turbidity | | | | NLW<br>True Color |
| Yahola ? | Tulsa | 121300 | 1999 | | | | | |

† Lake Listed Based Upon 1995 U.S. Army Corps. Of Engineers Intensive Study

‡ These Lakes will not be recommended for listing as part of the next WQS revision due to insufficient data

? Lake Listed Based Upon OWRB Phase I Clean Lakes Study

? Lake does not fit the classic definition of oligotrophy, as inorganic particulates are the controlling factor in limiting biological productivity

? Lake was not assessed through the BUMP, but through another OWRB project

? These Lakes will be recommended for NLW listing as part of the next WQS revision process

| Impairment Codes | | |
|---|---|---|
| NS = Not Supporting | PS = Partially Supporting | PL = Provisionally Listed |

| Acronyms | |
|---|---|
| NLW = Nutrient Limited Water | D.O. = Dissolved Oxygen |
| Entero. = Enterococci | |

| Assigned OWQS Beneficial Uses | |
|---|---|
| FWP = Fish & Wildlife Propagation | AES = Aesthetics |
| PPWS = Public & Private Water Supply | AG = Agriculture |
| PBCR = Primary Body Contact Recreation | |

# INTRODUCTION

Protecting Oklahoma's valuable water resources is essential to maintaining the quality of life for all Oklahomans. Used for a myriad of purposes, such as irrigation, hydropower, public/private water supply, navigation, and a variety of recreational activities, the state's surface and groundwaters provide enormous benefits to Oklahoma from both an economic and recreational standpoint.

The National Recreation Lakes Study Commission (NRLSC) estimates that 32,100 people in Oklahoma are employed in support of activities related to our numerous man-made lakes. Also according to the NRLSC, 18,718,000 visitor days are spent on Oklahoma lakes each year and recreation in and around these lakes contributes approximately $2.2 billion each year to Oklahoma's economy. Of additional value are the recreational benefits associated with our smaller municipal/watershed projects, Oklahoma Department of Wildlife lakes, and rivers and streams throughout the state, which infuse millions into state coffers through fishing, hunting, camping, and related activities. (In 1987, the Oklahoma Comprehensive Outdoor Recreation Plan estimated that approximately $10.7 million was realized through camping and $15.2 million through hunting/fishing.[1]) According to a 2001 federal study, fishing activities alone contribute $476,019 dollars to Oklahoma's economy, not including the substantial ancillary costs associated with that extremely popular sport.[2]

In addition to surface waters, abundant groundwaters also fuel the state's economy, serving as supply for thousands of municipalities, rural water districts, industrial facilities, and agricultural operations. According to the 1995 update of the *Oklahoma Comprehensive Water Plan*, groundwater represents the primary water supply for approximately 300 cities and towns and comprises 60 percent of the total water used in the state each year.[3] Groundwater resources also supply approximately 90 percent of the state's irrigation needs.

Oklahoma works to protect and manage its water resources through a number of initiatives, with the Oklahoma Water Quality Standards (OWQS) serving as the cornerstone of the state's water quality management programs. The Oklahoma Water Resources Board (OWRB) is designated by state statute as the agency responsible for promulgating water quality standards and developing or assisting the other environmental agencies with implementation framework. State agencies are responsible for implementing the OWQS as outlined by the OWRB through development of Implementation plans. Protecting our waters is a cooperative effort between many state agencies, and because the OWQS are utilized by all agencies and represent a melding of both science and policy, they are an ideal mechanism to assess the effectiveness of our diverse water quality management activities.

The OWQS are housed in OAC 785:45 and consist of three main components: beneficial uses, criteria to protect beneficial uses, and an antidegradation policy. An additional component, which is not directly part of the OWQS but necessary to water resource protection, is a monitoring program. A monitoring program is required in order to ensure that beneficial uses are

[1] Oklahoma Statewide Comprehensive Outdoor Recreation Plan (SCORP), 1987.
[2] U.S. Department of Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.*
[3] Oklahoma Water Resources Board, *Update of the Oklahoma Comprehensive Water Plan, 1995*.

maintained and protected. If uses are not being maintained, the cause of that impairment must be identified and restoration activities should be implemented to improve water quality such that it can meet its assigned beneficial uses.

All state agencies are currently required to implement Oklahoma's Water Quality Standards within the scope of their jurisdiction through the development of an Implementation Plan specific for their agency. This process, called OWQS Implementation, allows the OWQS to be utilized by other state agencies in the performance of their regulatory (statutory) responsibilities to manage water quality or to facilitate best management practice initiatives.

Recently, the need for a protocol to determine beneficial use impairment was identified, which would facilitate state agencies in directing their time and money to the areas in most need of protection or remediation. The OWRB, working in close concert with other state environmental agencies and concerned parties, developed Use Support Assessment Protocols (USAP) to be used by all parties for assessing if waters were meeting their assigned beneficial uses. In addition, protocols were developed that could be coupled with a trend monitoring system to detect threatened waters before they become seriously impaired. Data collection efforts connected with protocol development and/or implementation also serves a vital purpose in refining numerical criteria currently included in the OWQS and in developing appropriate numerical and narrative criteria for future OWQS documents. It is essential that our waters meet their assigned uses and that OWQS implementation protocols are appropriate. Please see Appendix A for the applicable Oklahoma Administrative Code (OAC) 785:46 related to the USAP. Final approval of the USAP occurred in 2000, and the OWRB has constantly worked every year since then to refine the existing protocols and pursue the addition or modification of USAP protocols to further enhance its utility and effectiveness.

Work to be performed towards development and implementation of the critical fourth component of the OWQS program, monitoring, is the subject of this report. All sampling activities described and conducted as part of this program were consistent with the Oklahoma USAP. It is also important to note that they are consistent with Environmental Protection Agency (EPA) reporting requirements for the "*Integrated Water Quality Monitoring and Assessment Report" [305(b) Report and 303(d) list]*, §319 Nonpoint Source (NPS) Assessment, and §314 Lake Water Quality Assessment (LWQA).

## BACKGROUND & PROBLEM DEFINITION

The State of Oklahoma has historically had numerous monitoring programs conducted by several state and federal agencies. In general, each environmental agency conducts their monitoring programs with some degree of integration and coordination with other state, municipal, or federal programs. Most water quality monitoring programs in Oklahoma are designed and implemented by each agency to collect information for one specific purpose or project (i.e., development of Total Maximum Daily Loads, the OWQS process, lake trophic status determination, determining water quality impacts from point source dischargers, stream flow measurements, documenting success of best management practices, etc.). Information of this type is very specific to each individual project's data quality objectives (DQOs) and is often limited to a very small geographic area. This document describes sampling activities the OWRB has historically conducted for lakes and efforts that are currently ongoing for lakes and streams across Oklahoma as part of a comprehensive, long-term, statewide Beneficial Use Monitoring Program (BUMP). The goal of the BUMP is to detect and quantify water quality trends, document and quantify impairments of assigned beneficial uses, and identify pollution problems before they become a pollution crisis.

## BENEFICIAL USE MONITORING PROGRAM (BUMP) OVERVIEW

The overall goal of the Beneficial Use Monitoring Program is to document beneficial use impairments, identify impairment sources (if possible), detect water quality trends, provide needed information for the OWQS, and facilitate the prioritization of pollution control activities.

## BENEFICIAL USE MONITORING PROGRAM COMPONENTS

- **Monitoring Rivers & Streams** - The OWRB is currently monitoring approximately 180 stations on a monthly basis. These sites are segregated into two discrete types of monitoring activities. The first monitoring activity focuses on fixed station monitoring on rivers and streams, and the second monitoring activity focuses on a number of sample stations whose locations rotate on an annual basis. The two monitoring components are explained below.

    - **Fixed Station Monitoring on Rivers & Streams** - Fixed station monitoring is based largely upon the 67 United States Geological Survey (USGS) 8-digit hydrologic unit code (HUC) basins present in Oklahoma. In general, at least one sample station was located in all of the HUC watersheds with the exception of some of the smaller HUC watersheds adjacent to the state line or in a HUC that does not contain a free flowing stream at some point during the year. After consultation with the other state environmental agencies and over time the OWRB has identified 119 fixed stations of which 99 are currently being monitored.

    - **Rotating Station Monitoring on Rivers & Streams** - Over the life of the BUMP, rotational sampling has occurred on 200 stream segments. Sample stations and variables monitored are based upon Oklahoma's 303(d) list and input from other state environmental agencies on their monitoring needs. Variables monitored as part of this program component are specific for each stream segment monitored.

- **Fixed Station Load Monitoring** - The OWRB is currently engaged in a cooperative effort with the USGS to conduct flow monitoring at fixed station BUMP sites that do not currently have an existing USGS flow gage. This effort focuses on collecting both water quality and quantity information in order to calculate pollutant loads, which will provide OWRB staff with the data necessary to make a use support determination. This initiative is facilitated through the OWRB's Cooperative Agreement with USGS and various Compact Commission activities. The USGS cost share program, Oklahoma's 319 program, Oklahoma's 314 program and the 303(d)-process will drive sample site locations associated with this task.

- **Fixed Station Lakes Monitoring** - Fixed station lakes monitoring goal is designed to facilitate sampling on the 130 largest lakes in Oklahoma every other year. To accomplish this task, the OWRB is currently sampling approximately 55 to 60 lakes on a quarterly basis. Under this scenario, repeat sampling on a lake will occur approximately every other year, with the inclusion of lakes data collected by other sources, like the Corps of Engineers, to meet the goal of 130 lakes every two years. Data collected consists primarily of water chemistry, nutrients, and chlorophyll-a information. In general, three stations per reservoir, representing the lacustrine zone, transitional zone, and riverine zone are sampled. On many reservoirs, additional sites are monitored, including major arms of the reservoir as appropriate. Water quality parameters have been added to the lakes sampling effort over the years to enhance our ability to make use support determinations.

- **Fixed Station Groundwater Monitoring** - Limited monitoring as part of this task has occurred in the program. Results of monitoring are presented in this report. OWRB staff has made recommendations in this report related to the scope and magnitude of groundwater monitoring activities that the state should pursue in the future. Any proposed groundwater monitoring efforts will be coordinated with the Oklahoma Department of Environmental Quality (ODEQ).

**Intensive Investigations** - If beneficial use impairment is identified or suspected, then all appropriate state agencies will be alerted and an investigation will be initiated to confirm if beneficial use impairment is occurring. If routine monitoring cannot definitively identify impairments, then an intensive study will be undertaken, and if impairment is present, the source of the impairment will be identified if possible. One potential use for the intensive studies envisioned was identified during the data analysis phase of this reporting process. For example, monies could be spent to identify if high turbidity readings in rivers and streams are due to natural processes or due to human activities in the watershed of concern. Some potential causes of beneficial use impairment are improper beneficial use or criteria (Oklahoma Water Resources Board jurisdiction), point source problems (Oklahoma Department of Environmental Quality or Oklahoma Department of Agriculture, Food & Forestry), non-point source problems (Oklahoma Conservation Commission, Oklahoma Department of Agriculture, Oklahoma Corporation Commission, or Oklahoma Department of Environmental Quality), oil and gas contamination (Oklahoma Corporation Commission), agricultural activities (Oklahoma Department of Agriculture, Food & Forestry), or mining activities (Oklahoma Department of Mines). All monitoring activities will be cooperative in nature with the agency with statutory authority assuming the lead role for intensive monitoring. If water bodies are not identified for intensive study as part of this task, then monies will be reallocated for routine monitoring of beneficial use attainment. Other entities (e.g., tribal or governmental units outside of Oklahoma) will be involved as appropriate. All intensive-monitoring activities will be consistent with the OWQS and the USAP. If no protocols exist, then best professional judgment or State/Environmental Protection Agency guidance will be used as appropriate.

# LAKES MONITORING PROGRAM

Lake trophic status is important from a water quality perspective because it is an indicator of potential nutrient impacts to a lake. In general, the higher the trophic state index (TSI) of a lake, the more nutrient loading into the system is occurring and the more productive the lake. One outcome of historical trophic assessment activity on Oklahoma's lakes was the prioritization of lakes most in need of remediation. Outcomes have included in-lake restoration activities or implementation of best management practices in the lake watershed. Results from the BUMP sampling effort should be viewed as a means to make relative comparisons between lakes and to determine beneficial use impairments based on USAP, detailed in Oklahoma Administrative Code (OAC) 785:46-15-5. Lakes with relatively poor water quality are identified, but that does not necessarily mean that these lakes have beneficial use impairments. Some lakes, due to the nature of their watershed and basin morphometry, may never attain the water quality of some of the state's more pristine waters. For example, an expectation that Broken Bow Lake and Great Salt Plains Reservoir can attain the same level of water quality would be unrealistic, because these two reservoirs exhibit great differences in basin morphometry and substrate material and are located in totally different parts of the state. Soil types such as clays have a very small particle size such that the clay particulates are constantly resuspended in the lake water column and never settle out, which is evident in some lakes across the state. In addition, the shallow nature of many of our lakes contributes to lake bottom sediments being resuspended in the water column due to wind action. Because so many factors affect the water quality of a reservoir, comparing lakes from various parts of the state should only be viewed as a relative comparison.

For each lake assessed, a general analysis of water quality was made and a water quality condition map generated. The maps presented are a representation of the water quality throughout the year based on the average of the data collected. Turbidity, measured in nephelometric turbidity units (NTU), and chlorophyll-a values were averaged to obtain an annual value for each site in the lake, and then the maps were generated accordingly. Graphics for seasonal TSI values at each site were also created, as well as seasonal turbidity and true color graphics for each site. A brief narrative summary is included for each lake that presents water quality issues related to the reservoir and assessment of beneficial use support for that lake. Dissolved oxygen/temperature vertical profiles recorded at site 1 (the dam) for each quarter are also included on a graphics page following the lake summary. Hydrolab® profile information is discussed in the narrative section for each lake. The brief synopsis of information presented for each lake should be beneficial in providing a relative comparison of water quality for lakes across the state.

For 2003-2004, the BUMP identified lakes that had beneficial use impairments or threats. However, a data set to truly determine which lakes are not supporting their beneficial uses due to excess nutrients does not currently exist, nor have nutrient criteria for lakes been promulgated into the OWQS. The OWRB has previously identified 14 lakes that are listed in the OWQS as Nutrient Limited Watersheds (NLW). More intensive work on the twelve lakes is required before a definitive assessment of nutrient impairment or non-support can be made. The OWRB recommends a Nutrient Impairment Study (NIS) be performed on identified NLW lakes. An NLW is defined in the OWQS as "a watershed of a waterbody with a designated beneficial use which is adversely affected by excess nutrients as determined by Carlson's TSI (chlorophyll-a) of 62 or greater." If a lake is identified as having a TSI =62 based on chlorophyll-a, and the minimum data requirements are met (n=10 on lakes with <250 surface acres; n=20 on lakes with >250 surface acres), it is recommended for listing as an NLW through the OWQS setting process. Currently, the parameters that are analyzed to determine whether or not there is beneficial use impairment or threat include turbidity, true color, dissolved oxygen, metals, chloride, sulfates, biological collections, total dissolved solids, and pH values. A brief discussion on lake monitoring procedures and methods is provided below with data results following.

## MATERIALS & METHODS FOR LAKE SAMPLING

Data was collected quarterly on 65 lakes across the state from the fall of 2003 through the summer of 2004. Vertical water quality profiles were recorded at one meter intervals from the lake surface to the lake bottom for the following parameters; temperature, pH, dissolved oxygen, salinity, dissolved oxygen % saturation, oxidation-reduction potential (redox), specific conductance, and total dissolved solids (TDS). A vertical profile was recorded for at least three sites per reservoir: in the central pool area near the dam (lacustrine zone), in the upper portion of the lake and in the major arms of the water body (riverine zone), and in the area between the lacustrine zone and the riverine zone (transitional zone). Turbidity values for each surface site were measured using a HACH portable turbidimeter. For lakes greater than 250 acres in size with only three routine chemical monitoring stations, additional sample sites were established solely for the purpose of determining turbidity and chlorophyll-a concentrations at the lake surface. Thus, at least five sites were monitored at all lakes for turbidity and chlorophyll-a. Secchi disk depths (in centimeters) were determined at all routine water chemistry sample sites. Water quality samples were collected at each site at the surface and one meter from the lake bottom at site 1, the dam, and preserved for analysis of nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, kjeldahl nitrogen, ortho-phosphorus, total phosphorus, true color, chloride, sulfate, and total alkalinity. OWRB staff calculated total nitrogen based on laboratory-derived values. In addition, metals samples were collected in the spring quarter for analysis. A Van Dorn sampler was used to collect samples near the lake bottom and grab samples were collected at the lake surface. At the dam site, a churn-splitter was used to split the surface sample for Quality Assurance (QA) purposes. Surface samples were also collected at all sites and analyzed for chlorophyll-a and pheophytin concentrations. Additional chlorophyll-a samples were collected for QA purposes. Filtration and grinding (extraction of the chlorophyll-a collected in a filter with acetone) of the samples was performed immediately upon return to the OWRB lab. All chlorophyll-a samples were filtered, as stated in Standard Methods (APHA 1995), within 24 hours and stored for no more than 30 days in the freezer.

## SAMPLE LAKE LOCATIONS

Lakes sampled by the BUMP Lakes staff in 2003-2004 are shown in Figure 3. Lake locations are identified on the map and are shaded in different colors based on their calculated TSI values.

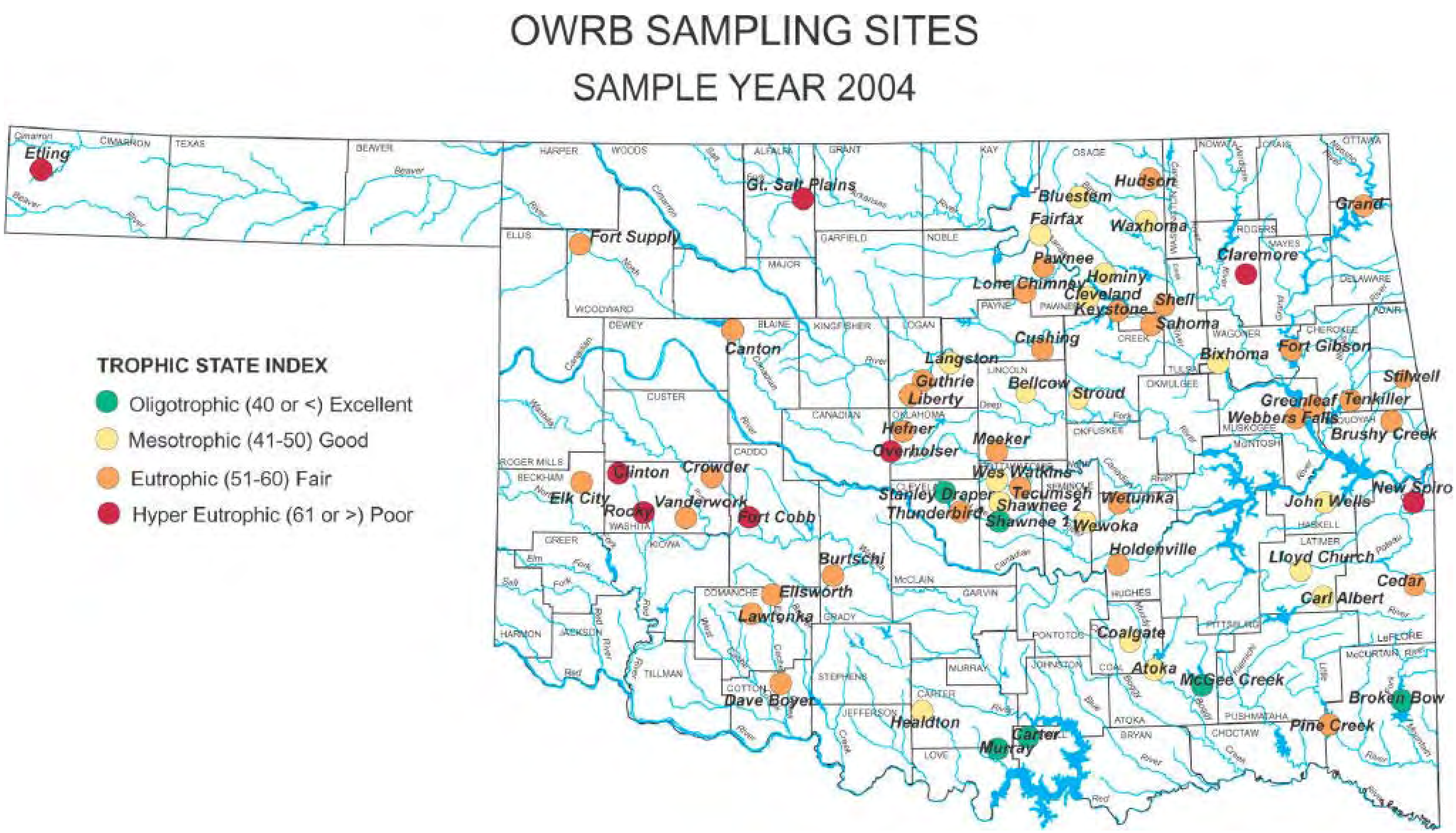



**Figure 3.** Lakes Sampled by the Beneficial Use Monitoring Program.

## LAKE DATA ANALYSIS PROTOCOLS

There are numerous methods available for determining the trophic status of lakes. The majority of the trophic state models rely on a mathematical calculation to generate a single numerical value that is then categorized in an assessment hierarchy. Numerous chemical, and in some cases biological data are utilized in the various trophic indices, which characterize the "trophic status" of a water body. Some of the commonly used water quality parameters utilized in trophic state indices include chlorophyll-a, secchi disc depth, total phosphorus, total nitrogen, aquatic macrophytes, organic nitrogen, turbidity, lake user surveys, and hypolimnetic oxygen depletion rates, etc. Most indices use one or more variables in the determination of trophic status with varying degrees of applicability to reservoir systems. The OWRB has traditionally used Carlson's Trophic State Index (TSI) (Carlson, 1977) for reporting purposes, utilizing chlorophyll-a concentrations in calculating the lake trophic status. Carlson's TSI equation using chlorophyll-a (in µg/L) as the trophic status indicator is as follows:

**TSI = 9.81 x ln(chlorophyll-a) + 30.6**.

In 1998, 1999, and 2000, the TSI was calculated using chlorophyll-a concentrations from the growing season (spring and summer only). Beginning in sample year 2001, an annualized trophic assessment was made as this was determined to be a more accurate reflection of trophic conditions for each reservoir. In order to make beneficial use determinations, minimum data requirements must be met as listed in OAC 785:46-15-3. A minimum of 20 samples is required on lakes greater than 250 surface acres, and a minimum of 10 samples on lakes 250 surface acres and less. In 2001-2002, sites were added for chlorophyll-a and turbidity collections on lakes greater than 250 surface acres, in order to meet the minimum data requirements annually. Although data can be aggregated and historical values used, there was a concern in using data that was collected in the summer only as this would bias the data. An analysis of the limnological data collected on lakes is performed to determine the trophic state of each lake monitored. Chlorophyll-a concentrations for each lake sample site are determined and all values are averaged for each lake for all four sampling quarters. This annual chlorophyll-a value is then used in Carlson's TSI equation to determine trophic status of the lake. Through use of this technique the presence of localized trophic conditions are minimized (i.e. the effects of a single elevated chlorophyll-a value is minimized in the calculation of the TSI). The derived TSI represents an accurate assessment of the water quality of the reservoir as a whole and individual isolated areas that may be impacted due to eutrophication will be minimized in the reported TSI. A list of lake trophic state categories and corresponding TSI numerical values are displayed in Table 2. There are other descriptive terms and subset categories for trophic status, like dystrophic; however, Carlson's TSI has four major categories and these will be used to describe lake trophic status. Further discussion is included in each of the lake summaries as necessary. As stated earlier, prior to 2001, the TSI was based on growing season (spring and summer) chlorophyll-a concentrations. However, beginning in 2001, all TSI evaluations were based on an annualized chlorophyll-a value for each lake and comparisons to previous TSI calculations will be specified as annual, growing season, or summer only evaluations. Prior to the onset of BUMP collections, lakes were sampled only in the summer and therefore the TSI was typically much higher than the annual assessments that are being done currently.

**Table 2.** Lake Trophic State Categories.

| Carlson TSI No. | Trophic State | Definition |
|---|---|---|
| = 40 | Oligotrophic | Low primary productivity and/or low nutrient levels |
| 41 - 50 | Mesotrophic | Moderate primary productivity with moderate nutrient levels |
| 51 – 60 | Eutrophic | High primary productivity and nutrient rich |
| = 61 | Hypereutrophic | Excessive primary productivity and excessive nutrients |

The beneficial use support determinations for the reservoirs sampled were determined following guidelines outline in the Use Support Assessment Protocols (USAP) promulgated into Oklahoma Administrative Code (OAC) 785-46: Subchapter 15. In general the USAP states that environmental data must be collected to take seasonal conditions into consideration. A minimum of 20 samples is required on lakes more than 250 surface acres to assess beneficial use support for water quality parameters such as dissolved oxygen, pH and temperature. In addition, data more than ten years old should not be used for use support purposes unless more recent data is not available. A minimum of 10 samples is required on lakes or lake-arms of 250 surface acres of less. Samples may be aggregated to meet the minimum data requirements. For some parameters such as metals, organic compounds, or toxics, fewer samples are required. Toxicants (metals and organics) require a minimum of 5 samples to determine use support, but less than 5 samples can be used to determine if a use is partially supported or not supported. Furthermore, if at least 2 sample concentrations of a toxicant exceed the criteria prescribed in the OWQS by two or more orders of magnitude, then the use is determined to be “not supporting”.

The USAP also addresses the issue of how the data should be used spatially for lake monitoring. In general, when determining what size area the data is representative of best professional judgment is used. Such things as major tributaries and major lake arms are considered when deciding the extent of the area that the data was applied to. Arms or portions of lake may be treated separately from the main body of a lake, however in most instances Water Resources Board staff chose to deal with the lake as a single unit. Unless it was demonstrated to the contrary, a single site was not considered representative of an entire lake or an arm of the lake that was greater than two hundred and fifty surface acres in size.

**Default Protocols.** USAP outlines the procedures for determining whether a set of data points for a particular variable support, partially support, or do not support a particular beneficial use. These protocols are constructed around two distinct types of numerical variables — short-term averages and long-term averages. In each case, samples collected for the range of water quality parameters are analyzed and aggregated in different ways.

Short-term average numerical variables measure variables with exposure periods of less than seven days (e.g., turbidity or a sample standard for chlorides). In other words, the set of samples that is being analyzed considers each sample as a separate entity. For example, turbidity samples collected monthly from January through December are considered unique samples, and consequently, are not aggregated into a single sample for analysis but are considered a fraction of the whole. Use support determination for short-term numerical variables requires a three-step process:

1. Each sample exceeding the prescribed criterion or screening level for a particular variable is identified,

**2.** The number of samples exceeding the prescribed criterion or screening level is divided by the total number of samples collected to obtain a percent exceedance, and
**3.** The percent exceedance is compared to a range of prescribed percent exceedances to determine use support. The prescribed percent exceedances are:
   **i)** supporting — less than or equal to 10%,
   **ii)** partially supporting — greater than 10% but less than 25%,
   **iii)** not supporting — greater than or equal to 25%.

Long-term average numerical variables measure variables with exposure periods of greater than or equal to seven days (e.g., yearly mean standard for chlorides). In other words, the set of samples that is being analyzed is considered a unique entity. For example, chloride samples collected monthly from January through December are aggregated through the calculation of a geometric mean. Use support determination for long-term numerical variables requires a three-step process:

**1.** Samples for a particular variable are aggregated into a geometric mean,
**2.** The geometric mean is compared to the prescribed criterion or screening level, and
**3.** Use support is determined to be supporting if the mean is less than the prescribed criterion or screening level or not supporting if the mean is greater than the prescribed criterion or screening level.

Because the long-term average compares only one value (the geometric mean) to the prescribed criterion or screening level, it cannot be considered partially supporting. In most instances, at least 10 samples are required to calculate a geometric mean.

**Assessment of Fish & Wildlife Propagation Beneficial Use Support.** The FWP beneficial use utilizes five different water quality variables to assess use support: dissolved oxygen (D.O.) concentration, toxicants, hydrogen ion activity (pH), and turbidity. For purposes of this report, only D.O., metals concentrations in the water column, pH, and turbidity will be used in the assessment. The USAP for dissolved oxygen beneficial use support for lakes reads as follows:

**(A)** If greater than 70% of the volume of water in a lake or an arm of a lake is less than 2 mg/L, the Fish and Wildlife Propagation beneficial use shall be deemed to be not supported.
**(B)** If 50% or more, but not greater than 70%, of the water volume in a lake or arm of a lake is less than 2 mg/L, the Fish and Wildlife Propagation beneficial use shall be deemed to be partially supported.
**(C)** The screening level for surface D.O. in a lake or arm of a lake shall be 4 mg/L from June 16 through October 15 each year and 5.0 mg/L for the remainder of the year.

Use support for dissolved oxygen concentrations was determined following the above criteria. Estimations of lake volume were made based on the depth at each site sampled and USAP criteria were applied accordingly. Water column information at each site is likely representative of lake volume conditions and is currently considered adequate for reporting purposes. A proposal to modify the USAP for assessment of dissolved oxygen during the last OWQS revision process was made to more accurately reflect the decision criteria being followed. As of July 1, 2002, the word "volume" was changed to "column" to more accurately reflect the decision criteria utilized. It is possible that in the future a bathymetric map will be constructed for each of the BUMP lakes and a better assessment of dissolved oxygen conditions for the lake volume can be made. For assessing Fish & Wildlife propagation use support related to turbidity concentrations, the criterion outlined in the OWQS was used as the screening level. If an average lake-wide turbidity concentration of >25 nephelometric turbidity units was detected, then the lake was listed as not supporting its Fish & Wildlife propagation beneficial use for turbidity. Rain and storm events were considered when making this determination as conditions dictated. The protocol for short-term average numerical parameters is used to assess the level of support.

For assessing the beneficial use support from pH concentrations, the following criteria were used:

1) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to pH occurring other than by natural causes if no more than 10% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(g)(3).
2) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be partially supported with respect to pH occurring other than by natural causes if greater than 10% but less than 25% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(g)(3).
3) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to pH occurring other than by natural causes if at least 25% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(g)(3).

Each lake was profiled using a Hydrolab, and pH concentrations were recorded at all sites for all four quarters. Based on all the data collected per sample year, the percentage of pH values above or below the acceptable range of 6.5 to 9 units was assessed for each site and this percentage determined whether or not the lake was supporting the Fish & Wildlife Propagation beneficial use. All lakes that exceeded the pH criteria have been only provisionally listed at this point in time as further examination is necessary to determine “natural causes”.

Numerical criteria is prescribed for toxicants in OWQS 785:45-5-12(g)(6)(G) in a table entitled “Numerical Criteria for Toxic Substances”. To determine use support, the protocol for short-term average numerical parameters is used. Sample values must be compared to both acute and chronic criterion. Both criterions need not be exceeded for the variable to be partially supported or not supported.

**Assessment of Agriculture Beneficial Use Support.** The AG beneficial use utilizes three variables to assess use support: total dissolved solids, chlorides, and sulfates. Numerical criteria for both yearly mean standards and sample standards are located in Appendix F of OAC 785:45. The yearly mean standard for each variable is compared to the geometric mean of the samples using a long-term average numerical protocol. The sample standard for each variable is also compared to each sample using a short-term average numerical protocol. Use support assessment for each variable requires a three-step process:

1) The sample standard and yearly mean standard for the six digit management segment which encompasses the monitoring must be located in Appendix F of OAC 785:45;
2) The geometric mean of the samples is compared to the yearly mean standard (if the geometric mean exceeds the yearly mean standard, the use is not supported and no further analysis is necessary);
3) If the geometric mean meets the yearly mean standard, the sample standard is compared to each sample and percent exceedance is calculated (depending on

the percent exceedance, the variable is supporting, partially supporting, or not supporting). Regardless of the criteria in Appendix F of OAC 785:45, if all TDS samples are less than 750 mg/L and all chloride and sulfate samples are less than 250 mg/L, the AG beneficial use is supported. Only one variable needs to violate the assessment protocol for the beneficial use to be partially supported or not supported.

**Assessment of Aesthetics Beneficial Use Support.** The Aesthetics beneficial use is assessed using a couple of water quality parameters--true color and nutrients. The sample standard for each variable is compared to the each sample using a short-term average numerical protocol. Criteria are located in OAC 785:45-5-19 and read as follows.

1) **Color.** Surface waters of the state shall be virtually free from all coloring materials that produce an aesthetically unpleasant appearance. Color producing substances, from other than natural sources, shall be limited to concentrations equivalent to 70 Platinum-cobalt true color units.

2) **Nutrients.** Nutrients from point source discharges or other sources shall not cause excessive growth of periphyton, phytoplankton, or aquatic macrophyte communities, which impairs any existing or designated beneficial use.

For assessing the Aesthetics beneficial use support status for color, data collected was compared to the numerical standard of 70 units for true color. Assessment of use support for this water quality parameter was simple and straightforward.

For assessing the Aesthetics beneficial use support status for nutrients, Carlson's TSI was applied. As stated in Table 2 a TSI value = 61 is considered to be characteristic of a hypereutrophic lake (excessive primary productivity). Guidelines for determining if a lake is a Nutrient Limited Watershed (NLW) are outlined in the OWQS that states a Carlson's TSI value of > 62 is to be the criterion to be used to classify a lake as an NLW. Classification as an NLW in Appendix A of the OWQS means that a lake has been determined to be threatened due to nutrients. A TSI value of 62 was chosen as the "break-point" because it is a conservative number. As noted in Table 5, several lakes had a TSI value greater than 62 and have not yet been listed as an NLW, and likewise, there are lakes listed as NLW that have a TSI less than 62. This will be addressed during the next standards revision process. If it can be demonstrated that nutrient loading to a lake may be adversely impacting a beneficial use designated for that lake, then the OWRB may determine that the lake and its watershed is an NLW and the lake and watershed will be identified as NLW in Appendix A of OAC 785:45. Once a lake is identified as an NLW, it is assumed to be threatened until an NLW Impairment Study has been conducted to definitively assess if the water body is partially supporting or not supporting. If an NLW Impairment Study demonstrates that beneficial uses are not threatened, then the Board will remove the NLW identification in the OWQS.

**Assessment of Primary Body Contact Recreation (PBCR) Support.** The PBCR beneficial use utilizes two different bacteriological classes and one bacteriological species to assess use support: fecal coliform (FC), *Escherichia coli* (*E. coli*), and enterococci (Ent.). The assessment is performed by using the long-term average numerical protocol to compare to a prescribed geometric mean and by using a modified version of the short-term average numerical protocol to compare each sample to a prescribed screening level. The prescribed geometric means (GM) and screening levels (SL) are: FC—GM of 400 colony forming units/mL (cfu/mL) and SL of 400 cfu/mL; *E. coli*—GM of 126 cfu/mL and SL of 235 cfu/mL in scenic rivers and 406 cfu/mL in all other waters; and Ent.—GM of 33 cfu/mL and SL of 61 cfu/mL in scenic rivers and 406 cfu/mL in all other waters. For *E. coli* and Ent., both the SL (only one sample exceedance is necessary) and the GM must be exceeded for the use to not be supported. If all of the samples meet the SL or the GM is met, the use is supported. In the case of FC, the use may only be supported if the GM is met and no greater than 25% of the sample concentrations exceed the SL. If either the GM is exceeded or greater than 25% of the sample concentrations exceed the SL, the use is not supported for FC. In no instance is the PBCR beneficial use partially supported. Furthermore, PBCR support is only determined from samples collected during the recreational season from May 1 through September 30 of each year. Only one variable needs to violate the assessment protocol for the beneficial use to be not supported.

## LAKE MONITORING RESULTS & DISCUSSION

A lake-wide annual average of the chlorophyll-a values was calculated for each lake and used in the final calculation of the TSI. A summary table is included (Table 3) to present the number of lakes and appropriate surface acre size for each of the four trophic categories in 2002-2003 as well as the percentages of the total. As shown in Table 3, eight lakes were hypereutrophic, thirty-three were eutrophic, eighteen were mesotrophic, and six were oligotrophic. Of the total 203,093 surface acres sampled, 15,855 were classified hypereutrophic, 146,6054 were classified as eutrophic, 12,551 were classified as mesotrophic and 28,082 acres were classified as eutrophic. TSI results, county, surface area, and volume for lakes sampled in 2003-2004 are listed in Table 4.

Although TSI based on the chlorophyll-a concentration is used for the BUMP, a comparison of TSI values calculated with total phosphorus and secchi disk depth was generated and is displayed as Table 5. Data displayed is for the growing season using the various water quality parameters that can be used in calculating Carlson's TSI. The chlorophyll and phosphorus TSI calculations were derived through results of regression analysis relating secchi disk depth to the other two variables.

**Table 3.** Summary of Lake Trophic Status Results

| Trophic Status | Number of Lakes | % of Total Lakes | Surface Area (Acres) | % of Total Surface Acres |
|---|---|---|---|---|
| **Hyper-Eutrophic** | **8** | **12%** | **15,855** | **8%** |
| **Eutrophic** | **33** | **51%** | **146,605** | **72%** |
| **Mesotrophic** | **18** | **53%** | **12,551** | **6%** |
| **Oligotrophic** | **6** | **9%** | **28,082** | **14%** |
| **Totals =** | **65** | **100%** | **203,093** | **100%** |

**Table 4.** List of Lakes Sampled in Sample Year 2003-2004.

| | Lake Name | County | Surface Area (Acres) | Volume (Acre/Ft.) | TSI | Carlson's Trophic State |
|---|---|---|---|---|---|---|
| 1 | ATOKA | ATOKA | 5,700 | 125,000 | 50 | MESOTROPHIC |
| 2 | BELL COW | LINCOLN | 1,153 | | 49 | MESOTROPHIC |
| 3 | BIXHOMA | WAGONER | 110 | 3,130 | 48 | MESOTROPHIC |
| 4 | BLUESTEM | OSAGE | 762 | 17,000 | 43 | MESOTROPHIC |
| 5 | BROKEN BOW | MCCURTAIN | 14,200 | 918,070 | 37 | OLIGOTROPHIC |
| 6 | BRUSHY CREEK | SEQUOYAH | 358 | 3,258 | 51 | EUTROPHIC |
| 7 | BURTSCHI, LOUIS | GRADY | 180 | 2,140 | 56 | EUTROPHIC |
| 8 | CANTON | BLAINE | 7,910 | 111,310 | 55 | EUTROPHIC |
| 9 | CARL ALBERT | LATIMER | 183 | 2,739 | 41 | MESOTROPHIC |
| 10 | CARTER | MARSHALL | 108 | 990 | 40 | OLIGOTROPHIC |
| 11 | CEDAR (MENA) | LEFLORE | 78 | 1,000 | 55 | EUTROPHIC |
| 12 | CLAREMORE | ROGERS | 470 | 7,900 | 61 | HYPEREUTROPHIC |
| 13 | CLEVELAND | PAWNEE | 159 | 2,200 | 50 | EUTROPHIC |
| 14 | CLINTON | WASHITA | 335 | 3,980 | 66 | HYPEREUTROPHIC |
| 15 | COALGATE | COAL | 352 | 3,437 | 46 | MESOTROPHIC |
| 16 | CROWDER | WASHITA | 158 | 2,094 | 57 | EUTROPHIC |
| 17 | CUSHING | PAYNE | 591 | 3,304 | 51 | EUTROPHIC |
| 18 | ELK CITY | BECKHAM | 240 | 2,583 | 56 | EUTROPHIC |
| 19 | ELLSWORTH | COMANCHE | 5,600 | 95,200 | 54 | EUTROPHIC |
| 20 | ETLING, CARL | CIMARRON | 159 | 1,717 | 72 | HYPEREUTROPHIC |
| 21 | FAIRFAX | OSAGE | 111 | 1,795 | 47 | MESOTROPHIC |
| 22 | FORT COBB | CADDO | 4,100 | 80,010 | 64 | HYPEREUTROPHIC |
| 23 | FORT GIBSON | CHEROKEE | 14,900 | 355,200 | 58 | EUTROPHIC |
| 24 | FORT SUPPLY† | WOODWARD | 1,820 | 13,900 | 57 | EUTROPHIC |
| 25 | GRAND LAKE | MAYES | 46,500 | 1,672,000 | 57 | EUTROPHIC |
| 26 | GREAT SALT PLAINS | ALFALFA | 8,690 | 31,240 | 70 | HYPEREUTROPHIC |
| 27 | GREENLEAF | MUSKOGEE | 920 | 14,720 | 54 | EUTROPHIC |

| | Lake Name | County | Surface Area (Acres) | Volume (Acre/Ft.) | TSI | Carlson's Trophic State |
|---|---|---|---|---|---|---|
| 28 | GUTHRIE | LOGAN | 274 | 3,875 | 60 | EUTROPHIC |
| 29 | HEALDTON | CARTER | 370 | 3,766 | 45 | MESOTROPHIC |
| 30 | HEFNER | OKLAHOMA | 2,500 | 75,000 | 55 | EUTROPHIC |
| 31 | HOLDENVILLE | HUGHES | 550 | 11,000 | 50 | MESOTROPHIC |
| 32 | HOMINY | OSAGE | 165 | 5,000 | 49 | MESOTROPHIC |
| 33 | HUDSON | OSAGE | 250 | 4,000 | 54 | EUTROPHIC |
| 34 | JOHN WELLS | HASKELL | 194 | 1,352 | 43 | MESOTROPHIC |
| 35 | KEYSTONE | TULSA | 23,610 | 557,600 | 56 | EUTROPHIC |
| 36 | LANGSTON | LOGAN | 304 | 5,792 | 47 | MESOTROPHIC |
| 37 | LAWTONKA | COMANCHE | 2,398 | 56,574 | 58 | EUTROPHIC |
| 38 | LIBERTY | LOGAN | 167 | 2,740 | 56 | EUTROPHIC |
| 39 | LLOYD CHURCH | LATIMER | 160 | 3,060 | 44 | MESOTROPHIC |
| 40 | LONE CHIMNEY | PAWNEE | 550 | 6,200 | 53 | EUTROPHIC |
| 41 | MCGEE CREEK | ATOKA | 3,810 | 113,930 | 39 | OLIGOTROPHIC |
| 42 | MEEKER | LINCOLN | 250 | 1,818 | 51 | EUTROPHIC |
| 43 | MURRAY | LOVE | 5,728 | 153,250 | 34 | OLIGOTROPHIC |
| 44 | OVERHOLSER | OKLAHOMA | 1,500 | 15,000 | 64 | HYPEREUTROPHIC |
| 45 | PAWNEE | PAWNEE | 257 | 3,855 | 51 | EUTROPHIC |
| 46 | PINE CREEK | MCCURTAIN | 3,750 | 53,750 | 51 | EUTROPHIC |
| 47 | ROCKY (HOBART) | WASHITA | 347 | 4,210 | 68 | HYPEREUTROPHIC |
| 48 | SAHOMA | CREEK | 312 | 4,850 | 51 | EUTROPHIC |
| 49 | SHAWNEE TWIN NO. 1 | POTTAWATOMIE | 1,336 | 22,600 | 40 | OLIGOTROPHIC |
| 50 | SHAWNEE TWIN NO. 2 | POTTAWATOMIE | 1,100 | 11,400 | 42 | MESOTROPHIC |
| 51 | SHELL CREEK | OSAGE | 573 | 9,500 | 52 | EUTROPHIC |
| 52 | SPIRO, NEW | LEFLORE | 254 | 2,160 | 67 | HYPEREUTROPHIC |
| 53 | STANLEY DRAPER | CLEVELAND | 2,900 | 100,000 | 39 | OLIGOTROPHIC |
| 54 | STILWELL | ADAIR | 188 | 3,110 | 55 | EUTROPHIC |
| 55 | STROUD | CREEK | 600 | 8,800 | 47 | MESOTROPHIC |

| | Lake Name | County | Surface Area (Acres) | Volume (Acre/Ft.) | TSI | Carlson's Trophic State |
|---|---|---|---|---|---|---|
| 56 | TECUMSEH | POTTAWATOMIE | 127 | 1,118 | 56 | EUTROPHIC |
| 57 | TENKILLER | SEQUOYAH | 12,900 | 654,100 | 56 | EUTROPHIC |
| 58 | THUNDERBIRD | CLEVELAND | 6,070 | 119,600 | 58 | EUTROPHIC |
| 59 | VANDERWORK | WASHITA | 135 | 1,578 | 60 | EUTROPHIC |
| 60 | WALTERS | COTTON | 148 | 861 | 52 | EUTROPHIC |
| 61 | WAXHOMA | OSAGE | 197 | 2,100 | 43 | MESOTROPHIC |
| 62 | WEBBERS FALLS | MUSKOGEE | 11,600 | 170,100 | 59 | EUTROPHIC |
| 63 | WES WATKINS | POTTAWATOMIE | 1,132 | | 50 | EUTROPHIC |
| 64 | WETUMKA | HUGHES | 169 | 1,839 | 50 | MESOTROPHIC |
| 65 | WEWOKA | SEMINOLE | 371 | 3,301 | 49 | MESOTROPHIC |

The TSI calculation using total phosphorus (in $mg/m^3$) as the variable is:

**TSI = 14.42 x ln(total phosphorus) + 4.15.**

The TSI calculation using secchi disk depth (in meters) as the variable is:

**TSI = 60 – (14.41 x ln(secchi depth)).**

Calculations using secchi disk depth could be erroneous, because this is not a good parameter to use in highly turbid reservoirs where turbidity is inorganic in nature or colored lakes, both fairly common occurrences in Oklahoma. Phosphorus may not be an accurate variable to use in calculating the TSI in lakes that are not phosphorus-limited or lakes that are highly turbid due to clay particulates. Carlson (1977) stated chlorophyll-a seems to be the most acceptable parameter to use in calculating TSI, especially during the growing season and for estimating algal biomass. In accordance with historical calculations at OWRB, and Carlson's suggestion to use chlorophyll-a concentration in the growing season, rather than secchi disk depth or total phosphorus, it is the utilized variable for TSI calculations for BUMP. Values displayed in Table 5 were calculated using lake-wide annual averages for all three parameters.

Using chlorophyll-a, eight lakes were hypereutrophic, thirty-one lakes were eutrophic, twenty lakes were mesotrophic, and six were oligotrophic. Using total phosphorus and secchi disk depth in the TSI calculation produced a much different result, although classification using these two variables is somewhat comparable to each other. Twenty-seven lakes were hypereutrophic, twenty-one lakes were eutrophic, fourteen lakes were mesotrophic and three were oligotrophic using the total phosphorus variable for TSI. For the secchi disk depth trophic evaluation, forety-nine lakes were identified as hypereutrophic, fifteen lakes were eutrophic and one lake was mesotrophic. The TSI values calculated using secchi depth were the highest of the three variables. For example, Shawnee Twin Lake #2 was classified as oligotrophic using chlorophyll-a concentration, mesotrophic using total phosphorus as the trophic state indicator, and hypereutrophic using secchi disk depth as the trophic state indicator. Most of the TSI values were lowest using the chlorophyll-a concentration; therefore, it seems reasonable to say that this parameter is the most conservative variable to use.

**Table 5.** Comparison of Methods Used to Calculate Carlson's Trophic State Index for 2003-2004.

| Lake Name | Chl-a | Trophic State | Total P. | Trophic State | Secchi | Trophic State |
|---|---|---|---|---|---|---|
| Atoka Lake | 50 | Mesotrophic | 68 | Hypereutrophic | 82 | Hypereutrophic |
| Bell Cow Lake | 49 | Mesotrophic | 52 | Eutrophic | 66 | Hypereutrophic |
| Bixhoma Lake | 48 | Mesotrophic | 46 | Mesotrophic | 55 | Eutrophic |
| Bluestem Lake | 43 | Mesotrophic | 56 | Eutrophic | 68 | Hypereutrophic |
| Broken Bow Lake | 37 | Oligotrophic | 39 | Oligotrophic | 42 | Mesotrophic |
| Brushy Creek Reservoir | 51 | Eutrophic | 49 | Mesotrophic | 58 | Eutrophic |
| Burtschi Lake | 56 | Eutrophic | 56 | Eutrophic | 60 | Eutrophic |
| Canton Lake | 55 | Eutrophic | 65 | Hypereutrophic | 72 | Hypereutrophic |
| Carl Albert Lake | 41 | Mesotrophic | 45 | Mesotrophic | 57 | Eutrophic |
| Carter Lake | 40 | Oligotrophic | 43 | Mesotrophic | 59 | Eutrophic |
| Cedar (Mena) Lake | 55 | Eutrophic | 50 | Mesotrophic | 55 | Eutrophic |
| Claremore Lake | 61 | Hypereutrophic | 64 | Hypereutrophic | 71 | Hypereutrophic |
| Cleveland City Lake | 50 | Mesotrophic | 61 | Hypereutrophic | 70 | Hypereutrophic |
| Clinton Lake | 66 | Hypereutrophic | 77 | Hypereutrophic | 81 | Hypereutrophic |
| Coalgate City Lake | 46 | Mesotrophic | 67 | Hypereutrophic | 82 | Hypereutrophic |
| Crowder Lake | 57 | Eutrophic | 67 | Hypereutrophic | 69 | Hypereutrophic |
| Cushing Municipal Lake | 51 | Eutrophic | 68 | Hypereutrophic | 76 | Hypereutrophic |
| Elk City Lake | 56 | Eutrophic | 61 | Hypereutrophic | 69 | Hypereutrophic |
| Ellsworth Lake | 54 | Eutrophic | 65 | Hypereutrophic | 72 | Hypereutrophic |
| Lake Etling | 72 | Hypereutrophic | 81 | Hypereutrophic | 82 | Hypereutrophic |
| Fairfax City Lake | 47 | Mesotrophic | 53 | Eutrophic | 61 | Hypereutrophic |
| Fort Cobb Reservoir | 64 | HyperEutrophic | 67 | Hypereutrophic | 64 | Hypereutrophic |
| Fort Gibson Lake | 58 | Eutrophic | 71 | Hypereutrophic | 62 | Hypereutrophic |
| Fort Supply Lake | 57 | Eutrophic | 65 | Hypereutrophic | 75 | Hypereutrophic |
| Grand Lake | 57 | Eutrophic | 70 | Hypereutrophic | 62 | Hypereutrophic |
| Great Salt Plains Lake | 70 | Hypereutrophic | 84 | Hypereutrophic | 95 | Hypereutrophic |
| Greenleaf Lake | 54 | Eutrophic | 56 | Eutrophic | 61 | Hypereutrophic |
| Guthrie Lake | 60 | Eutrophic | 61 | Hypereutrophic | 68 | Hypereutrophic |
| Healdton City Lake | 45 | Mesotrophic | 58 | Eutrophic | 75 | Hypereutrophic |
| Lake Hefner | 55 | Eutrophic | 67 | Hypereutrophic | 63 | Hypereutrophic |
| Holdenville Lake | 50 | Mesotrophic | 54 | Eutrophic | 67 | Hypereutrophic |
| Hominy Municipal Lake | 49 | Mesotrophic | 47 | Mesotrophic | 58 | Eutrophic |
| Hudson Lake | 54 | Eutrophic | 55 | Eutrophic | 65 | Hypereutrophic |
| John Wells Lake | 43 | Mesotrophic | 41 | Mesotrophic | 55 | Eutrophic |
| Lake Keystone | 56 | Eutrophic | 81 | Hypereutrophic | 74 | Hypereutrophic |

| LAKE NAME | CHL-A | TROPHIC STATE | TOTAL P. | TROPHIC STATE | SECCHI | TROPHIC STATE |
|---|---|---|---|---|---|---|
| LANGSTON LAKE | 47 | MESOTROPHIC | 43 | MESOTROPHIC | 60 | EUTROPHIC |
| LAKE LAWTONKA | 58 | EUTROPHIC | 52 | EUTROPHIC | 60 | EUTROPHIC |
| LIBERTY LAKE | 56 | EUTROPHIC | 57 | EUTROPHIC | 69 | HYPEREUTROPHIC |
| LLOYD CHURCH LAKE | 44 | MESOTROPHIC | 47 | MESOTROPHIC | 64 | HYPEREUTROPHIC |
| LONE CHIMNEY LAKE | 53 | EUTROPHIC | 58 | EUTROPHIC | 67 | HYPEREUTROPHIC |
| MCGEE CREEK RESERVOIR | 39 | OLIGOTROPHIC | 40 | OLIGOTROPHIC | 52 | EUTROPHIC |
| MEEKER LAKE | 51 | EUTROPHIC | 58 | EUTROPHIC | 77 | HYPEREUTROPHIC |
| LAKE MURRAY | 34 | OLIGOTROPHIC | 39 | OLIGOTROPHIC | 51 | EUTROPHIC |
| LAKE OVERHOLSER | 50 | MESOTROPHIC | 59 | EUTROPHIC | 62 | HYPEREUTROPHIC |
| PAWNEE LAKE | 64 | HYPEREUTROPHIC | 84 | HYPEREUTROPHIC | 84 | HYPEREUTROPHIC |
| PINE CREEK LAKE | 51 | EUTROPHIC | 57 | EUTROPHIC | 65 | HYPEREUTROPHIC |
| ROCKY (HOBART) LAKE | 51 | EUTROPHIC | 50 | MESOTROPHIC | 62 | HYPEREUTROPHIC |
| LAKE SAHOMA | 68 | HYPEREUTROPHIC | 74 | HYPEREUTROPHIC | 77 | HYPEREUTROPHIC |
| SHAWNEE TWIN LAKE #1 | 51 | EUTROPHIC | 61 | HYPEREUTROPHIC | 74 | HYPEREUTROPHIC |
| SHAWNEE TWIN LAKE #2 | 40 | OLIGOTROPHIC | 49 | MESOTROPHIC | 66 | HYPEREUTROPHIC |
| SHELL LAKE | 42 | MESOTROPHIC | 51 | EUTROPHIC | 71 | HYPEREUTROPHIC |
| SPIRO (NEW) LAKE | 52 | EUTROPHIC | 49 | MESOTROPHIC | 64 | HYPEREUTROPHIC |
| LAKE STANLEY DRAPER | 67 | HYPEREUTROPHIC | 70 | HYPEREUTROPHIC | 72 | HYPEREUTROPHIC |
| STILWELL LAKE | 39 | OLIGOTROPHIC | 45 | MESOTROPHIC | 63 | HYPEREUTROPHIC |
| STROUD LAKE | 55 | EUTROPHIC | 69 | HYPEREUTROPHIC | 59 | EUTROPHIC |
| TECUMSEH LAKE | 47 | MESOTROPHIC | 47 | MESOTROPHIC | 56 | EUTROPHIC |
| TENKILLER FERRY LAKE | 56 | EUTROPHIC | 76 | HYPEREUTROPHIC | 85 | HYPEREUTROPHIC |
| THUNDERBIRD LAKE | 56 | EUTROPHIC | 58 | EUTROPHIC | 57 | EUTROPHIC |
| LAKE VANDERWORK | 58 | EUTROPHIC | 56 | EUTROPHIC | 69 | HYPEREUTROPHIC |
| WALTERS (DAVE BOYER) LAKE | 60 | EUTROPHIC | 59 | EUTROPHIC | 65 | HYPEREUTROPHIC |
| LAKE WAXHOMA | 52 | EUTROPHIC | 68 | HYPEREUTROPHIC | 87 | HYPEREUTROPHIC |
| WEBBERS FALLS RESERVOIR | 43 | MESOTROPHIC | 51 | EUTROPHIC | 63 | HYPEREUTROPHIC |
| WES WATKINS RESERVOIR | 59 | EUTROPHIC | 74 | HYPEREUTROPHIC | 74 | HYPEREUTROPHIC |
| WETUMKA LAKE | 50 | MESOTROPHIC | 53 | EUTROPHIC | 64 | HYPEREUTROPHIC |
| WEWOKA LAKE | 49 | MESOTROPHIC | 52 | EUTROPHIC | 68 | HYPEREUTROPHIC |

Results for each of the 130 BUMP lakes from the most recent sampling are listed in Table 6. As stated previously, the OWRB is currently monitoring 65 lakes with repeat sampling on each reservoir scheduled to occur every two to three years. Prior to 1998, data was only collected once for each lake during the summer months. In 1998, the OWRB began collecting data on lakes on a quarterly basis resulting in a great improvement to the data set available to make management decisions on our lake resources. Lakes that are identified as hypereutrophic should be sampled more often than quarterly, especially during the warmer months. Lakes identified as "Nutrient-Limited Watersheds" (NLW) should also be sampled more intensively to confirm if a water quality threat or impairment is present. Minimum data requirements as listed in USAP were closely followed to make beneficial use determinations. All impairments are listed in Table 6. Toxicity concerns, if present, are listed as provided by the ODEQ as part of their Rotating Lakes Toxics Program and/or through sampling conducted by the OWRB.

**Table 6.** Lakes Sampled by the BUMP with Their Associated Use Attainment Status.

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| American Horse | Blaine | | 2003 | D.O. | | | | |
| Arbuckle | Murray | 310800 | 2003 | D.O. | | | | |
| Arcadia | Oklahoma | 520710 | 2003 | D.O.<br>Turbidity | | | | |
| Ardmore City | Carter | 310800 | 2003 | D.O. | | | | |
| Atoka | Atoka | 410400 | 2004 | Turbidity<br>D.O. | | | | True Color |
| Bellcow | Lincoln | 520700 | 2004 | D.O. | | | | |
| Birch | Osage | 121300 | 2003 | D.O.<br>Turbidity | | | | True Color |
| Bixhoma | Wagoner | | 2004 | D.O. | | | | |
| Bluestem | Osage | 121300 | 2004 | D.O. | | | | |
| Boomer | Payne | 620900 | 2002 | Turbidity | | | | |
| Broken Bow | McCurtain | 410210 | 2004 | pH<br>D.O. | | | | |
| Brushy Creek | Sequoyah | 220200 | 2004 | pH | | Entero | | |
| Burtschi ‡ | Grady | | 2004 | | | Entero. | | |
| Canton | Blaine | 720500 | 2004 | Turbidity | | | | |
| Carl Albert | Latimer | 410310 | 2004 | | | | | |
| Carl Blackwell | Payne | 620900 | 2002 | D.O. | | | | |
| Carter | Marshall | 310800 | 2004 | | | | | |
| Cedar (Mena) | LeFlore | 410210, 410300 | 2004 | D.O.<br>pH | | | | |
| Chandler | Lincoln | 520700 | 2003 | D.O. | | | | |
| Chickasha ‡ | Caddo | 310830 | 2003 | | | | | |
| Claremore | Rogers | 121500 | 2004 | | | | | NLW |
| Clear Creek | Stephens | 310810 | 2003 | D.O. | | Entero. | | |
| Cleveland City | Pawnee | | 2004 | D.O. | | | | |
| Clinton ? | Washita | 310830 | 2004 | Turbidity | | Entero. | | True Color |
| Coalgate City | Coal | 410400 | 2004 | D.O.<br>Turbidity | | | | True Color |
| Comanche | Stephens | 311300 | 2003 | D.O. | | | | |
| Copan | Washington | 121400 | 2003 | Turbidity<br>D.O. | | | | |
| Crowder | Washita | 310830 | 2004 | | | | | NLW |
| Cushing Municipal | Payne | 620900 | 2004 | Turbidity | | | | True Color |
| Dave Boyer (Walters) | Cotton | 311300 | 2004 | Turbidity | | | | True Color |
| Dripping Springs | Okmulgee | 520700 | 2002 | D.O. | | | | |
| Duncan | Stephens | 310810 | 2003 | D.O. | | | | |
| El Reno | Canadian | | 2003 | Turbidity | | | | |
| Elk City | Beckham | 311500 | 2004 | | | Entero. | | NLW |
| Ellsworth | Comanche | 311300 | 2004 | Turbidity | | | | |

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| | | | | D.O. | | | | |
| Elmer Thomas | Comanche | 311300 | 2003 | D.O. | | | | |
| Etling, Carl | Cimarron | 720900 | 2004 | Turbidity pH | | | | |
| Eucha ? | Delaware | 121600 | 2003 | D.O. | | | | NLW |
| Eufaula | Haskell | 220600 | 2003 | D.O. Turbidity | | | | True Color |
| Fairfax City | Osage | 621200 | 2004 | D.O. | | | | |
| Fort Cobb ‡ | Caddo | 310830 | 2004 | Turbidity | | Entero. | | NLW |
| Fort Gibson ? | Cherokee | 121600 | 2004 | | | | | NLW |
| Fort Supply † | Woodward | 720500 | 2002 | Turbidity | | | | NLW True Color |
| Foss | Custer | 310800, 310810 310820, 310830 310840 | 2003 | D.O. Turbidity | | | | |
| Frederick | Tillman | 311310 | 2003 | Turbidity | | | | |
| Fuqua | Stephens | 310810 | 2003 | D.O. | | Entero. | | True Color |
| Grand Lake | Mayes | 121600 | 2004 | D.O. Turbidity | | | | |
| Great Salt Plains | Alfalfa | 621010 | 2004 | Turbidity | | Entero. | Sulfates & Chlorides | NLW |
| Greenleaf | Muskogee | 120400 | 2004 | | | Entero. | | |
| Guthrie | Logan | 620910 | 2004 | Turbidity | | Entero. | | NLW |
| Healdton City | Carter | 311100 | 2004 | Turbidity | | | | True Color |
| Hefner | Oklahoma | 520520, 520530 | 2004 | Turbidity | | | | |
| Henryetta ? | Okmulgee | 520700 | 2003 | D.O. | | | | |
| Heyburn | Creek | 120420 | 2003 | D.O. Turbidity | | Entero. | | |
| Holdenville | Hughes | 520800 | 2002 | D.O. | | Entero. | | |
| Hominy Municipal | Osage | 121300 | 2004 | D.O. | | | | |
| Hudson | Osage | | 2004 | D.O. | | | | |
| Hudson | Mayes | 121600 | 2003 | D.O. | | | | |
| Hugo | Choctaw | 410300 | 2003 | Turbidity D.O. | | | | True Color |
| Hulah | Osage | 121400 | 2003 | Turbidity | | | | NLW |
| Humphreys | Stephens | 310810 | 2003 | D.O. | | | | |
| Jean Neustadt | Carter | 310800 | 2003 | D.O. | | | | |
| John Wells | Haskell | 220200 | 2004 | | | | | |
| Kaw | Osage | 621210 | 2003 | Turbidity D.O. | | | | True Color |
| Keystone | Tulsa | 621200 | 2004 | Turbidity | | Entero. | | |
| Konawa | Seminole | | 2002 | | | | | |
| Langston | Logan | 620900 | 2004 | | | | | |
| Lawtonka | Comanche | 311300 | 2004 | | | | | |
| Liberty | Logan | 620910 | 2004 | Turbidity | | Entero. | | |
| Lloyd Church | Latimer | 220100 | 2004 | D.O. | | | | |

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| Lone Chimney | Pawnee | 621200 | 2004 | | | | | |
| Lugert-Altus ? | Greer | 311500, 311510 | 2003 | pH | | | | NLW |
| Maysville/Wiley Post | McClain | | 2002 | D.O.<br>Turbidity | | | | |
| Mc Alester | Pittsburg | 220600 | 2003 | Turbidity<br>D.O. | | | | |
| McGee Creek | Atoka | 410400 | 2004 | D.O.<br>pH | | | | |
| Mc Murtry | Noble | 620900 | 2002 | D.O. | | | | |
| Meeker | Lincoln | 520700 | 2004 | Turbidity | | | | True Color |
| Murray | Love | 311100 | 2004 | D.O. | | | | |
| Nanih Waiya | Pushmataha | | 2003 | D.O. | | | | |
| New Spiro ? | LeFlore | 220100 | 2004 | D.O. | | | | |
| Okemah | Okfuskee | 520700 | 2002 | D.O. | | | | |
| Okmulgee | Okmulgee | 520700 | 2002 | D.O. | | | | |
| Oologah | Rogers | 121510 | 2003 | Turbidity<br>D.O. | | | | |
| Overholser ? | Oklahoma | 520520, 520530 | 2004 | Turbidity | | | | NLW<br>True Color |
| Ozzie Cobb | Pushmataha | 410300 | 2003 | D.O.<br>pH | | | | NLW |
| Pauls Valley City | Garvin | 310810 | 2003 | D.O. | | | | |
| Pawhuska | Osage | 121600 | 2003 | D.O. | | | | |
| Pawnee | Pawnee | 621200 | 2004 | | | | | |
| Perry | Noble | 621200 | 2003 | Turbidity | | | | |
| Pine Creek | McCurtain | 410210 | 2004 | D.O.<br>Turbidity<br>pH | | | | |
| Ponca | Kay | 621200 | 2003 | D.O. | | | | |
| Prague City | Lincoln | 520510 | 2003 | D.O. | | | | |
| Purcell | McClain | 520610 | 2002 | D.O. | | | | |
| Raymond Gary | Choctaw | 410300 | 2000 | D.O.<br>pH | | | | |
| R.C. Longmire | Garvin | 310810 | 2003 | D.O. | | | | |
| Robert S. Kerr | Sequoyah | 220200 | 2003 | Turbidity | | | | True Color |
| Rock Creek | Carter | 310800 | 2003 | D.O. | | | | |
| Rocky (Hobart) ‡ | Washita | 311500 | 2004 | Turbidity | | Entero. | | |
| Sahoma | Creek | 120420 | 2004 | D.O.<br>Turbidity | | | | True Color |
| Sardis | Pushmataha | 410310 | 2003 | D.O. | | | | |
| Shawnee Twin # 1 | Pottawatomie | 520510 | 2004 | | | | | |
| Shawnee Twin # 2 | Pottawatomie | 520510 | 2004 | | | | | |
| Shell | Osage | 120420 | 2004 | D.O. | | | | |
| Skiatook | Osage | 121300 | 2003 | D.O. | | | | |
| Sooner | Pawnee | | 2003 | D.O. | | | | |
| Spavinaw ? | Mayes | 121600 | 2003 | D.O. | | | | NLW |
| Sportsman | Seminole | 520500 | 2002 | | | | | |

| Lake Name | County | W.Q. Segment # | Year Sampled | FWP | PPWS | PBCR | AG | AES |
|---|---|---|---|---|---|---|---|---|
| Stanley Draper | Cleveland | | 2004 | | | | | |
| Stilwell City | Adair | 220200 | 2001 | D.O. | | | | |
| Stroud | Creek | 520700 | 2004 | | | | | |
| Talawanda # 1 | Pittsburg | 220600 | 2003 | D.O.<br>pH | | | | |
| Talawanda # 2 | Pittsburg | 220600 | 2003 | D.O. | | | | |
| Taylor (Marlow) ? | Grady | 310840 | 2003 | Turbidity<br>D.O. | | | | NLW |
| Tecumseh | Pottawatomie | 520510 | 2004 | | | | | |
| Tenkiller Ferry | Sequoyah | 121700 | 2004 | D.O. | | | | |
| Texoma | Bryan | 311100, 310800 | 2003 | D.O.<br>Turbidity | | | | |
| Thunderbird | Cleveland | 520810 | 2004 | Turbidity | | | | |
| Tom Steed | Kiowa | 311500 | 2003 | Turbidity<br>pH | | | | |
| Vanderwork | Washita | 310830 | 2004 | | | | | NLW |
| Vincent, Loyd | Ellis | 720500 | 2000 | | | | | |
| W.R. Holway | Mayes | | 2003 | D.O. | | | | |
| Waurika | Jefferson | 311210 | 2003 | D.O.<br>Turbidity | | | | |
| Waxhoma | Osage | | 2004 | D.O. | | Entero. | | |
| Wayne Wallace | Latimer | 220100 | 2003 | D.O.<br>pH | | | | |
| Webbers Falls | Muskogee | 121400 | 2004 | | | Entero. | | |
| Wes Watkins | Pottawatomie | 520510 | 2002 | | | | | |
| Wetumka | Hughes | | 2001 | D.O. | | | | |
| Wewoka | Seminole | 520500 | 2002 | | | | | |
| Wister ? | LeFlore | 220100 | 2003 | pH<br>Turbidity | | | | NLW<br>True Color |
| Yahola ? | Tulsa | 121300 | 1999 | | | | | |

† Lake Listed Based Upon 1995 U.S. Army Corps. of Engineers Intensive Study

‡ These Lakes will not be recommended for listing as part of the next WQS revision due to ins ufficient data

? Lake Listed Based Upon OWRB Phase I Clean Lakes Study

? Lake does not fit the classic definition of oligotrophy, as inorganic particulates are the controlling factor in limiting biological productivity

? Lake was not assessed through the BUMP, but through another OWRB project

? These Lakes will be recommended for NLW listing as part of the next WQS revision process

| Impairment Codes | | |
|---|---|---|
| NS = Not Supporting | PS = Partially Supporting | PL = Provisionally Listed |

| Acronyms | |
|---|---|
| NLW = Nutrient Limited Water | D.O. = Dissolved Oxygen |
| Entero. = Enterococci | |

| Assigned OWQS Beneficial Uses | |
|---|---|
| FWP = Fish & Wildlife Propagation | AES = Aesthetics |
| PPWS = Public & Private Water Supply | AG = Agriculture |
| PBCR = Primary Body Contact Recreation | |

The pH was examined and compared to the OWQS for pH, 6.5 to 9 units, listed in 785:45-5. Five of the 65 lakes sampled in 2003-2004 were provisionally listed as partially supporting the FWP beneficial use based on pH values and six lakes were provisionally listed as not supporting (see Figure 4). Turbidity, in Nephelometric turbidity units (NTU), was measured via a HACH turbidimeter for all sites on each lake sampled to identify lakes that exceeded the OWQS of 25 NTU. Seasonal turbidity values at each site are displayed for each lake as well as the lake-wide annual turbidity value. Of the 65 lakes sampled in 2003-2004, thirty-three lakes were not supporting their Fish & Wildlife Propagation (FWP) beneficial use, fourteen were partially supporting the and 82 were fully supporting their FWP beneficial use based on turbidity values (see Figure 6). True color units were also averaged for the year to compare to the OWQS of 70 units. Seasonal true color values per site are displayed graphically for each lake (see Figure 5). In 2002-2003, 14 lakes were not supporting the Aesthetics beneficial use based on high true color values. Vertical profiles recorded with a Hydrolab® were examined to determine if anoxic conditions were present and whether or not the lake was meeting the FWP beneficial use. The USAP lists dissolved oxygen violations as values below 2.0 mg/L for 70% of the entire water column and partially supporting if between 50% and 70% of the lake. Of the 54 lakes sampled in 2002-2003, seven were not supporting the FWP beneficial use based on anoxic conditions, primarily in the summer season (see Figure 7). Metals were sampled beginning in 2001-2002 to look at toxicant levels in our lake resources. This is a new initiative added to the lakes monitoring

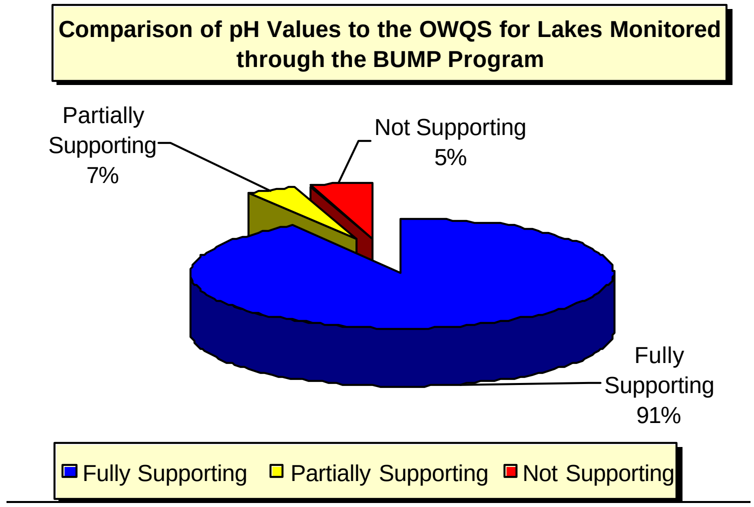



**Figure 4.** Percent of lakes assessed that exceeds or meets the OWQS for pH

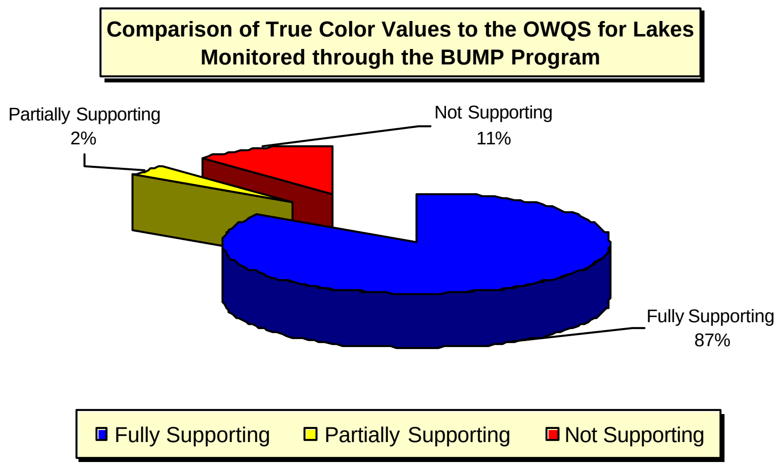



**Figure 5.** Percent of lakes assessed that exceeds or meets the OWQS for true color.

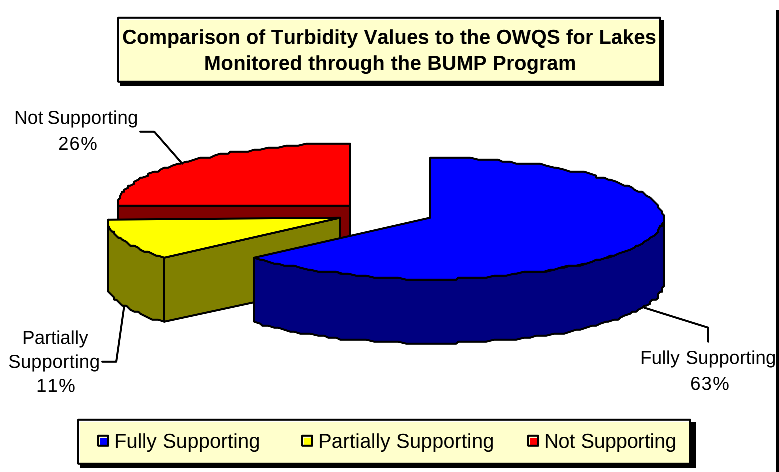



**Figure 6.** Percent of lakes assessed that exceeds or meets the OWQS for turbidity.

program and it is hoped that it can be continued in the future. Results from metals sampling indicated that metals concentrations in the water column were not a problem in any of the lakes sampled in 2003-2003 or 2003-2004. To more fully address the toxics issues in our reservoirs it is hoped that the OWRB and ODEQ can work cooperatively in the future to increase the number of lake fish communities sampled for toxics in fish tissue. Chloride and sulfate water quality parameters were also added to the lake sampling program in year 2003-2004. These additions allow for an assessment of the agriculture beneficial use of our reservoirs and much like metals sampling is a sampling effort that we plan on continuing into the future. Analysis of the chloride and sulfate data revealed that only one sampled lake was not supporting its agriculture beneficial use (See Figure 8). The lake not supporting was Great Salt Plains Reservoir. This was not an unexpected result. Analysis of the bacteria data indicated that three lakes were not supporting their Primary Body Contact Recreation beneficial use (See Figure 9).

It is the intent of the OWRB monitoring program to pursue adding additional monitoring parameters to the lake sampling initiative to allow all beneficial uses to be assessed. It is also the OWRB intent to accomplish this without having to reduce the number of lakes sampled annually.

A brief synopsis of the results from OWRB field sampling for each of the 65 lakes sampled in 2003-2004 as well as the 54 lakes sampled in 2002-2003 is discussed in alphabetical order on the following pages.

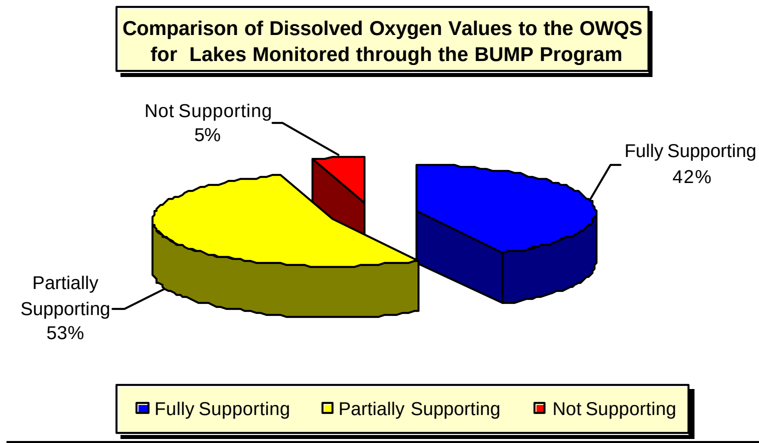



**Figure 7.** Percent of lakes assessed and their support status of the OWQS for dissolved oxygen

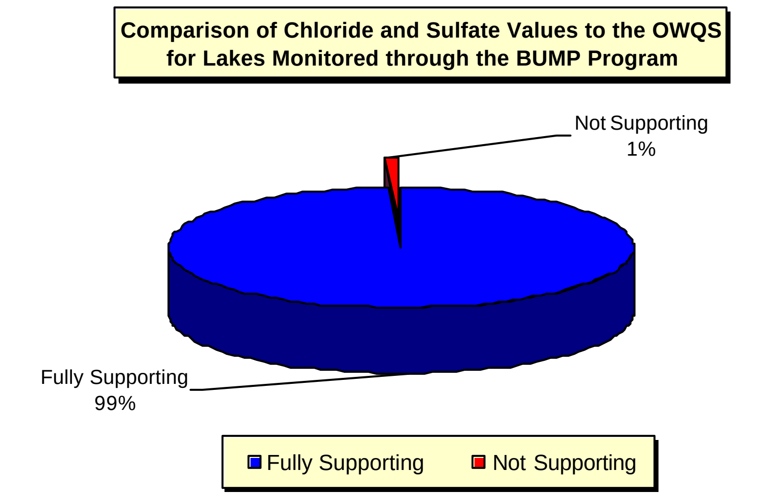



**Figure 8.** Percent of lakes assessed and their support status of the OWQS for chlorides & sulfates

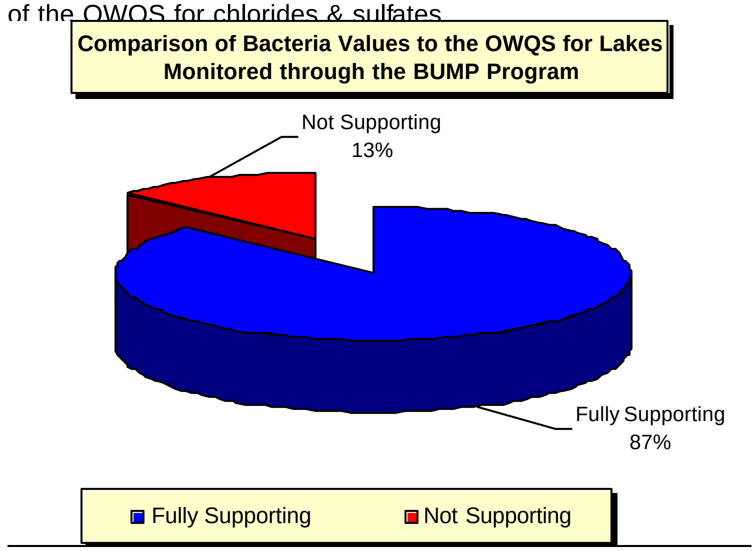



**Figure 9.** Percent of lakes assessed and their support status of the OWQS for bacteria.

# American Horse Lake

American Horse Lake was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at three (3) sites to represent the riverine, transition and lacustrine zones of the lake. Samples were collected from the lake surface at all sites and at 0.5 meters from the bottom at site 1, the dam. The lake-wide annual average turbidity was 3 NTU (Plate 1), true color was 13 units and secchi disk depth was 228 centimeters in sample year 2003. Based on these three parameters, American Horse Lake had excellent water clarity. The trophic state index, using Carlson's TSI (chlorophyll-a) was calculated using values collected at all three sites for four quarters (n=12). The result was a TSI of 55 (Plate 1), classifying the lake as eutrophic, indicative of high primary productivity and nutrient rich conditions. Although this is slightly higher than the value calculated in 2000 (TSI=52), the lake remains in the same trophic category. The TSI values varied seasonally at American Horse Lake throughout 2003 from upper eutrophic in the fall to hypereutrophic in the winter and mesotrophic in both spring/summer quarters (Figure 10). Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU meeting the beneficial use of Fish and Wildlife Propagation. Seasonal true color values are displayed in (Figure 11b). All color values were well below the aesthetics OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.16 parts per thousand (ppt) to 0.18 ppt for this sample year. Specific conductance ranged from 321 mS/cm to 370 mS/cm, which falls within the range of values commonly reported for Oklahoma lakes. These values indicate a moderate level of current conducting ions (salts) were present in the system. The pH values at American Horse Lake ranged from 7.15 to 8.49, representing a neutral to slightly alkaline system. Oxidation-reduction potentials ranged from 245 mV in the spring to 470 mV in the fall. Reducing conditions were not present in this reservoir during the 2002-2003-sample year. During the fall and winter quarters stratification was not present (Figure 11c-10d). Thermal stratification was evident in both spring and summer quarters. In the spring stratification occurred at several 1-meter intervals throughout the water column and dissolved oxygen ranged from 8.62 mg/L at the surface to 0.28 mg/l at the lake bottom. During the summer quarter the lake exhibited strong thermal stratification between 6 and 7 meters at which point the dissolved oxygen dropped below 2 mg/L for the remainder of the water column (Figure 11f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for

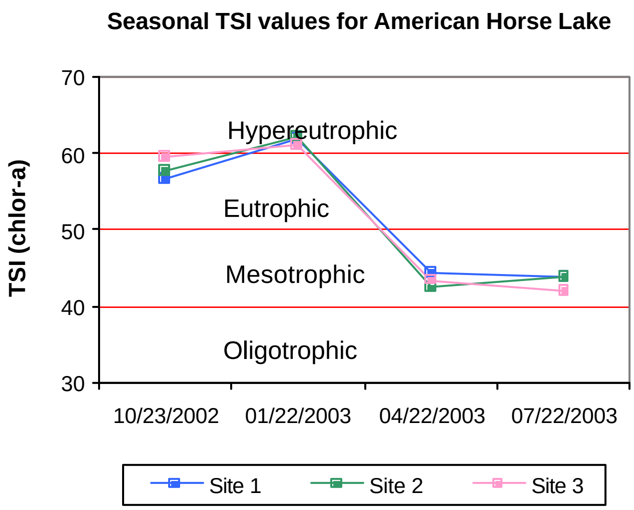



**Figure 10.** TSI values for American Horse Lake

50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 30% of the water column in the spring and 65% percent of the water column in the summer falling below 2.0 mg/L the FWP Benicia use is partially supported at American Horse Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.51mg/L at the surface and 1.08 mg/L at the lake bottom. The TN at the surface ranged from 0.45 mg/L to 0.72 mg/L. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the surface and 0.104 at the lake bottom. The total phosphorus at the surfaced ranged from 0.016 mg/L to 0.029 mg/L with lower values occurring in the spring quarter. The nitrogen to phosphorus ration (TN:TP) was 24:1 for sample year 2003. This value is much higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, American Horse Lake was eutrophic, indicative of high primary productivity and nutrient conditions consistent with the results from the 2000 data collection efforts. Water clarity was excellent based on true color, turbidity and secchi disk depth. The lake is supporting the FWP beneficial use based on pH, and turbidity. Anoxic conditions present in both spring and summer months constitute a listing of partial support for the FWP beneficial use based on dissolved oxygen concentrations at American Horse Lake. With an annual average for true color of 3 units and a TSI of 55 the Aesthetics beneficial use is supported. This reservoir is located in Blaine County and is managed by the Oklahoma Department of Wildlife Conservation for the purpose of recreation.

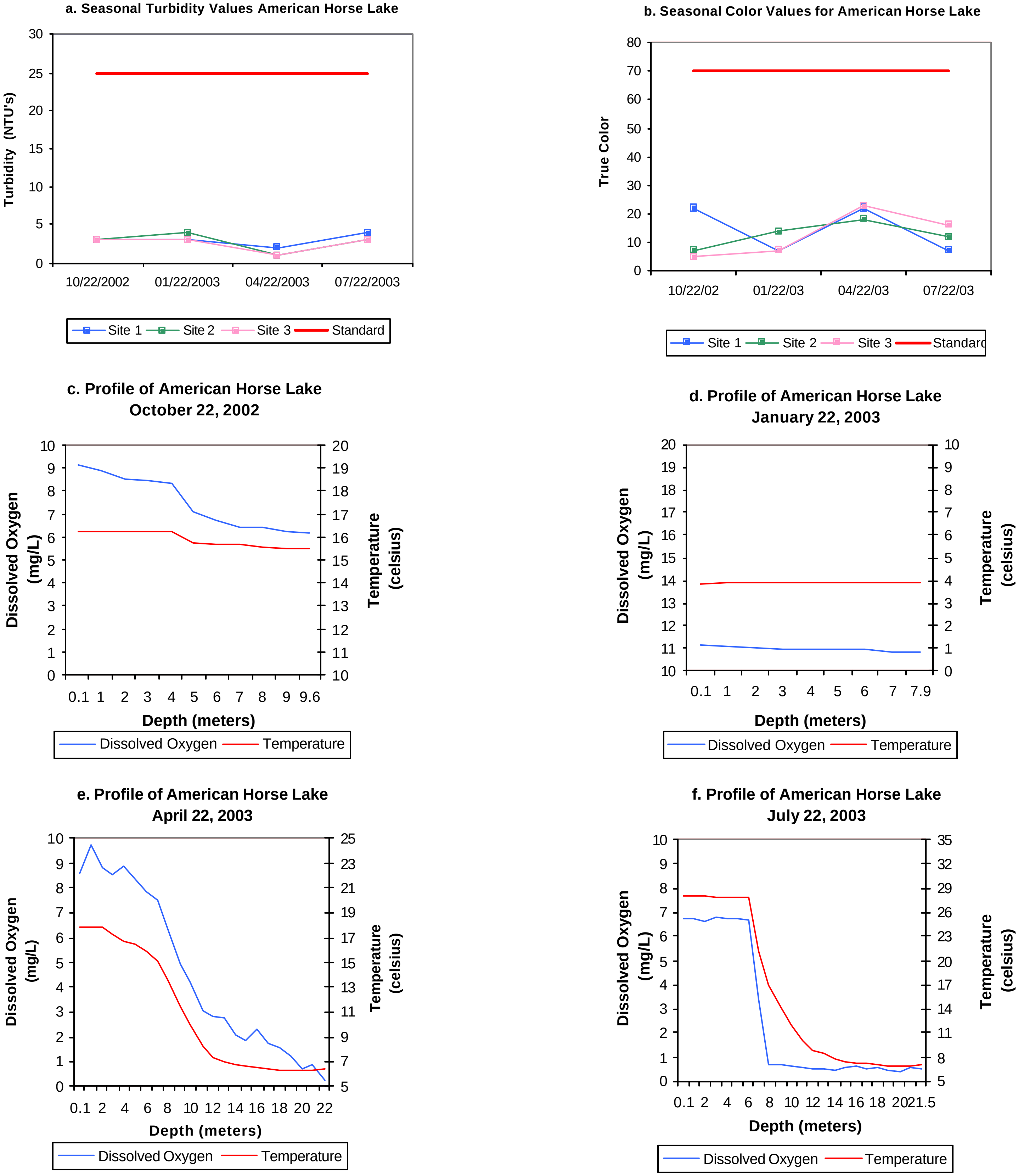
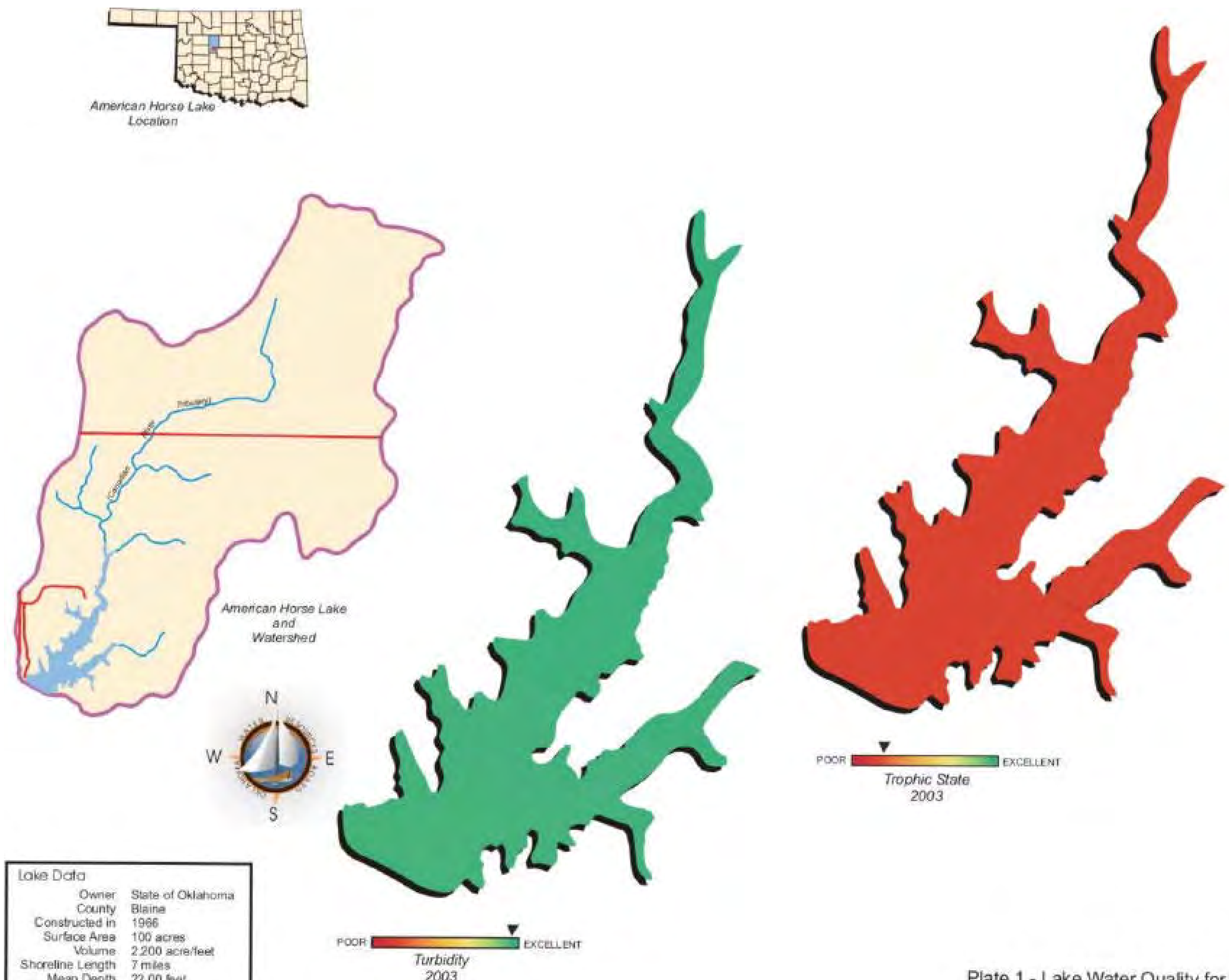



**Figure 11a-11f.** Graphical representation of data results for American Horse Lake.




Lake Data

| | |
|---|---|
| Owner | State of Oklahoma |
| County | Blaine |
| Constructed in | 1966 |
| Surface Area | 100 acres |
| Volume | 2,200 acre/feet |
| Shoreline Length | 7 miles |
| Mean Depth | 22.00 feet |
| Watershed Area | 3,124 acres |

Plate 1 - Lake Water Quality for
American Horse Lake

# Arbuckle Reservoir

Arbuckle Reservoir was sampled for four quarters from October 2002 through July 2003. Water quality samples were collected at five (5) sites to represent the riverine, transition and lacustrine zones of the lake. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 5 NTU, (Plate 2), true color was 16 units and average secchi disk depth was 127 centimeters. Based on these parameters water clarity at Arbuckle Reservoir was excellent in sample year 2003. The trophic state index using Carlson's TSI (chlorophyll-a) was calculated using values collected at all sites for four quarters (n=20). The result was a TSI of 48 (Plate 2), indicating the lake was mesotrophic in sample year 2003. The TSI values were fairly consistent and ranged from mesotrophic in the fall, spring and summer quarters to during the winter (Figure 12). Based on spring and summer values only the calculated TSI in 2000 was eutrophic (TSI=55). The lower trophic value in 2003 is probably a more accurate depiction since it is based on data collected year round as opposed to the growing season only. Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. Due to an accident in the lab the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met and an assessment of the Fish and Wildlife propagation (FWP) beneficial use for turbidity cannot be made at this time; however upon reviewing current and historical data it is likely that the beneficial use would be fully supported. Seasonal true color values are displayed in Figure. All color values were well below the aesthetics OWQS of 70 units (Figure 13b).

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential and salinity were recorded at all sample sites. Salinity ranged from 0.16 ppt to 0.19 ppt. This value is within the average range recorded for Oklahoma lakes. Specific conductivity ranged from 327.7 mS/cm to 394.5 mS/cm, indicating moderate levels of current conducting ions were present in the lake system. The pH values at Arbuckle Reservoir ranged from 6.98 in the fall quarter to 8.27 in the spring representing a neutral to slightly alkaline system. Oxidation-reduction potentials (ORP) ranged from –31 mV at the lake bottom in the fall to 660 mV in the winter. Reducing conditions were present in the fall quarter when anoxic conditions were present for much of the water column. Dissolved oxygen (D.O) levels remained above 7.0 mg/L during the winter and spring sampling quarters (Figure 13d-13e) when the water column was evenly mixed. Thermal

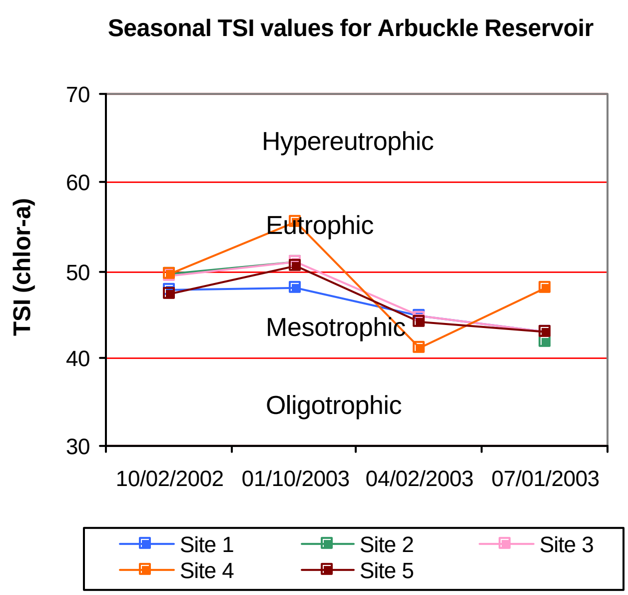



**Figure 12.** TSI values for Arbuckle Reservoir

stratification was evident and anoxic conditions were present in both the fall and summer quarters (Figure 13c and 13f). In the fall stratification occurred between 10 and 11 meters with dissolved oxygen levels falling below 2.0 mg/L to the lake bottom of 23.8 meters accounting for 60% of the water column at site 1, to be experiencing anoxic conditions. During the summer sampling interval, stratification occurred between 6 and 7 meters at site 1 accounting for 70% of the water column being anoxic. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions present for 60% of the water column in the fall and 70% of the water column in the summer Arbuckle Reservoir is considered to be partially supporting the FWP beneficial use. These conditions could however pose a serious concern, threatening the FWP beneficial use and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Arbuckle Reservoir was also sampled for bacteria to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five (5) sites during the recreation season of May through September. All sample results were at or below the detection limit therefore the PBCR beneficial use is considered to be supporting.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the surface and 0.97 mg/L at the lake bottom. Surface TN ranged from 0.33mg/L to 0.53 mg/L, with the highest values seen in the fall and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.015 mg/L at the surface and 0.073 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.008 mg/L to 0.019 mg/L. Similar to nitrogen, surface TP was highest in the fall quarter but the low values varied seasonally for both parameters. The nitrogen to phosphorus ratio (TN:TP) was 13:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Arbuckle Reservoir was classified as mesotrophic indicative of moderate productivity and nutrient levels in 2002-2003. This classification differs from that in 2000 when the TSI was 55, indicative of eutrophic conditions; however the current classification is based on a larger data set and is likely a more accurate depiction of productivity within the lake. Water clarity was excellent based on true color, turbidity, and high secchi disk depth readings. The lake is fully supporting the FWP beneficial use based on pH and partially supporting based on dissolved oxygen levels. Turbidity values were all well below the OWQS of 25 NTU however minimum data requirements were not met and an assessment of the FWP beneficial use cannot be made at this time. Reviewing both current and historical data it is likely that the beneficial use would be fully supported. The Aesthetics beneficial use is also supported based on its trophic status and extremely low true color readings. Arbuckle Reservoir, located in Murray County, was constructed by the Bureau of Reclamation and is utilized as a municipal water supply, flood control, and fish and wildlife recreation lake.

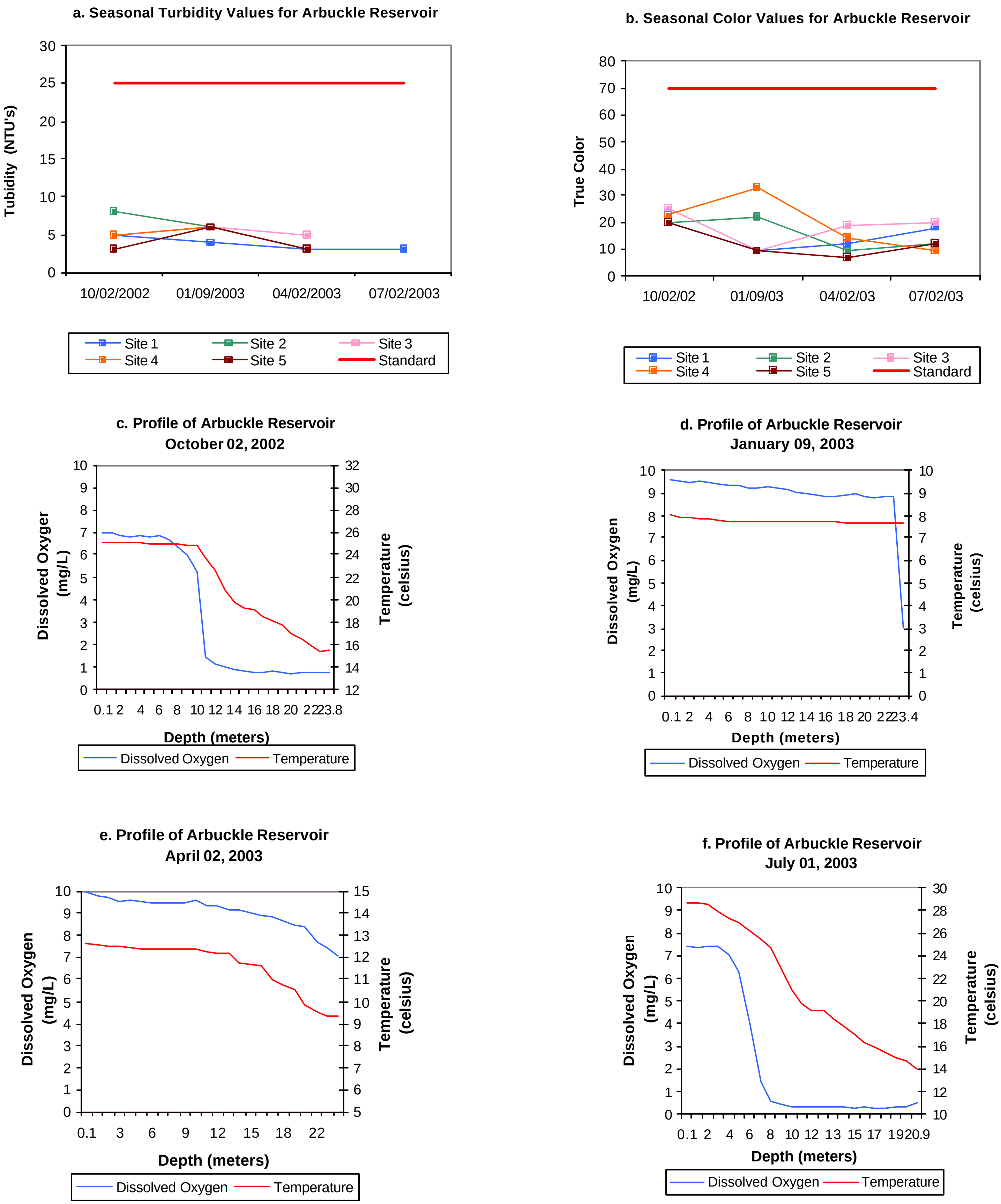
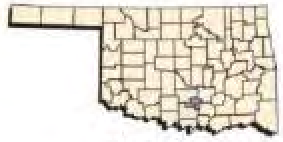



**Figure 13a13-f.** Graphical representation of data results for Arbuckle Reservoir.

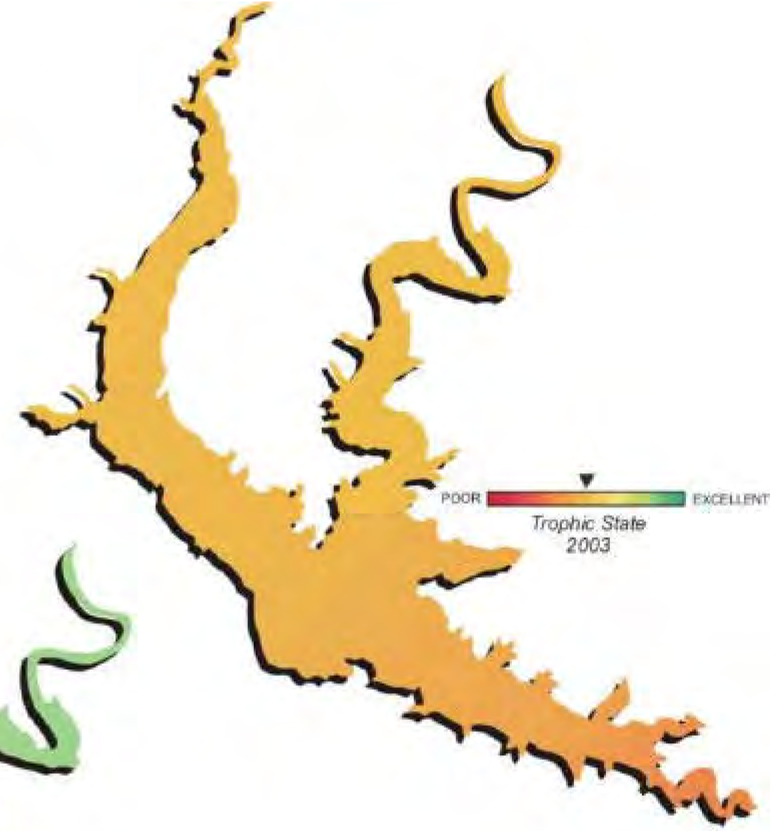

Arbuckle Reservoir and Watershed



Arbuckle Reservoir Location


Lake Data

| | |
|---|---|
| Constructed by | Bureau of Reclamation |
| County | Murray |
| Constructed in | 1967 |
| Surface Area | 2,350 acres |
| Volume | 72,400 acre/feet |
| Shoreline Length | 36 miles |
| Mean Depth | 30.8 feet |
| Watershed Area | 126 square miles |



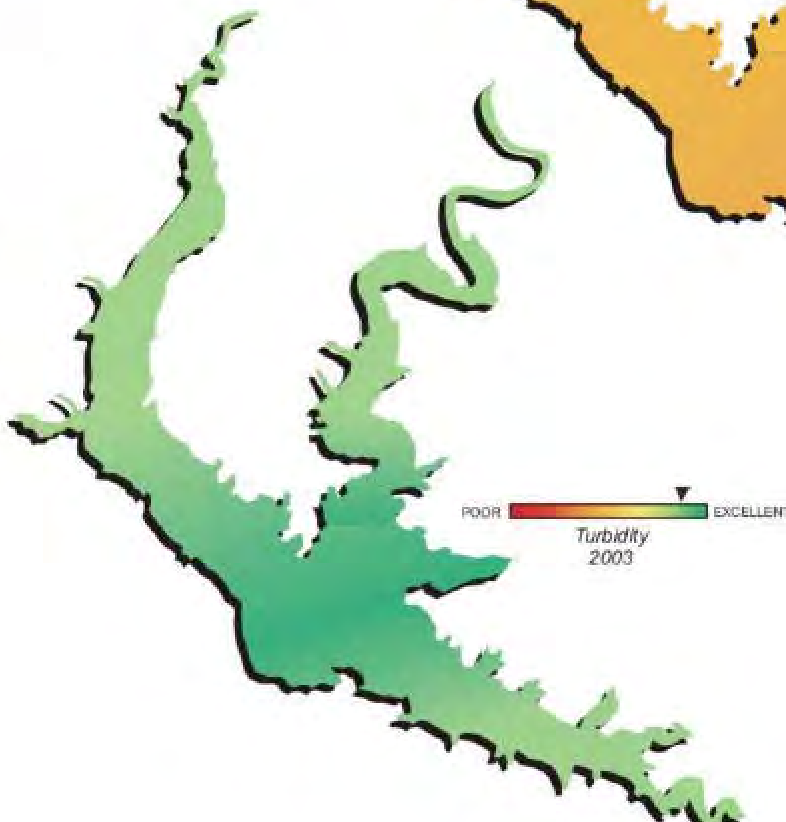




Plate 2 - Lake Water Quality for
## Arbuckle Reservoir

# Arcadia Lake

Arcadia Lake was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at five (5) sites to represent the riverine, transition and lacustrine zones and major arms of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 20 NTU (Plate 3), true color was 27 units, and average secchi disk depth was 58 centimeters in sample year 2002-2003. Water clarity was average at Arcadia Lake based on these three parameters. Results for turbidity, true color, and secchi disk depth are similar to those recorded in 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 59 (Plate 3), indicating the lake was eutrophic, with high levels of productivity and nutrient conditions for sample year 2003. This value is similar to that calculated in 2000 (TSI=58) indicating no significant change in productivity has occurred. The TSI for all sites varied seasonally and ranged from mesotrophic in the spring to meso-eutrophic in the winter and hypereutrophic in both summer and fall (Figure 14). Seasonal turbidity values by site are displayed in Figure. Although the lake-wide average for turbidity was 20 NTU, below the OWQS of 25 NTU, there are instances when some values were near or above the standard. These spikes in turbidity occurred at sites 4 and 5 in the upper portions of the lake during the fall and spring quarters (Figure 15a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The FWP beneficial use is partially supported at Arcadia Lake with 15% of the values above the turbidity standard of 25 NTU. Seasonal true color values are displayed in Figure 15b. All color values are well below the aesthetics OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.19 parts per thousand (ppt) to 0.25 ppt. This is within the average range of values seen in Oklahoma reservoirs. Specific conductance ranged from 333.6 mS/cm to 497.3 mS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 7.07

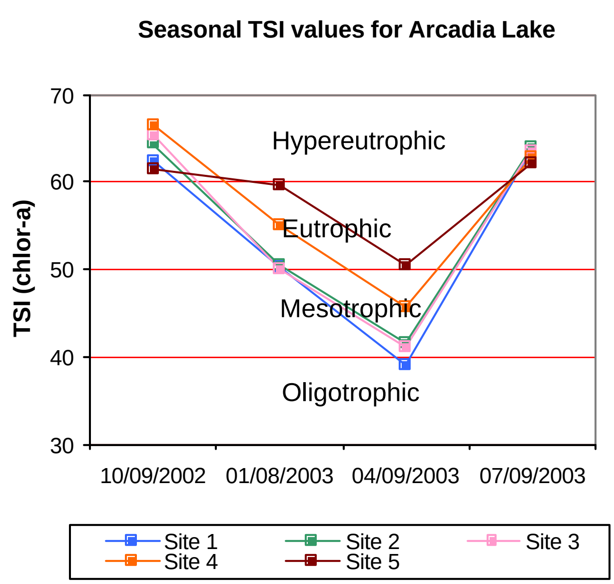



**Figure 14.** TSI values for Arcadia Lake

in the summer to 8.15 in the fall representing a neutral to slightly alkaline lake system. Oxidation-reduction potentials (ORP) ranged from 215mV in the hypolimnion in the summer to 660 mV in the winter. Reducing conditions were not present at this reservoir during the 2002-2003-sample year. Arcadia Lake was not thermally stratified the in first three sampling quarters (Figure 15c-15e). The lake was stratified and anoxic conditions were present in the hypolimnion during the summer. Stratification occurred at two 1-meter intervals, the first at the 7 to 8 meter depth and again between 8 and 9 meters at which point dissolved oxygen (D.O.) levels dropped below 2 mg/L for the rest of the water column (Figure 15f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. levels are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is considered partially supported. With approximately 35% of the water column experiencing anoxic conditions in the summer months Arcadia Lake is listed as partially supporting the Fish and Wildlife Propagation beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.73 mg/L at the surface and 0.83 mg/L at the lake bottom. Surface TN ranged from 0.41 mg/L to 0.96 mg/L with the highest values recorded in the spring quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.049 mg/L at the surface and 0.122 mg/L at the lake bottom. Surface TP ranged from 0.016 mg/L to 0.110 mg/L was highest in the fall months, and like total nitrogen the low values occurred during the winter sampling quarter. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Arcadia Lake was classified as eutrophic indicative of high primary productivity and nutrient rich conditions. These results are similar to those seen is 2000 indicating no significant increase or decrease in productivity has occurred. Water clarity was average with values for turbidity, true color and secchi disk depth being similar to those recorded in sample year 2000. The lake is currently supporting the FWP beneficial use based on pH, and turbidity, but is partially supporting the beneficial use based on low dissolved oxygen levels in the summer months. The Aesthetics beneficial use is supported based on trophic state and true color values. The Oklahoma Department of Environmental Quality (ODEQ) sampled the fish community in 2002 and none of the fish tissue samples exceeded the screening level or low consumption advisory for metals toxicity. Arcadia Lake is located in Oklahoma County and was constructed by the United States Army Corps of Engineers (USACE) to serve as the water supply for the City of Edmond as well as flood control and recreation purposes. The OWRB completed a Phase I Diagnostic and Feasibility Study of Arcadia Lake in March 2000 and can be referenced for further information.

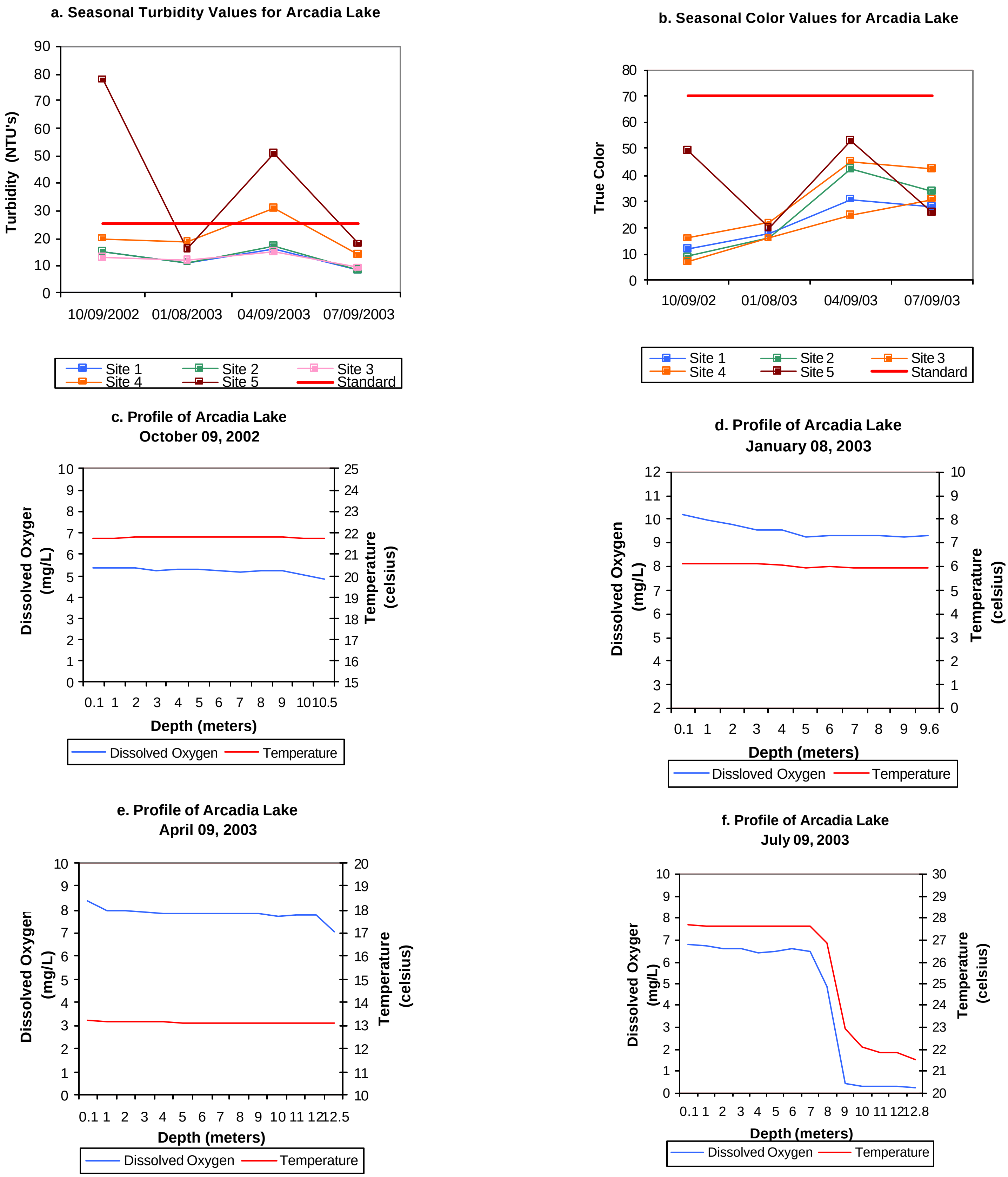
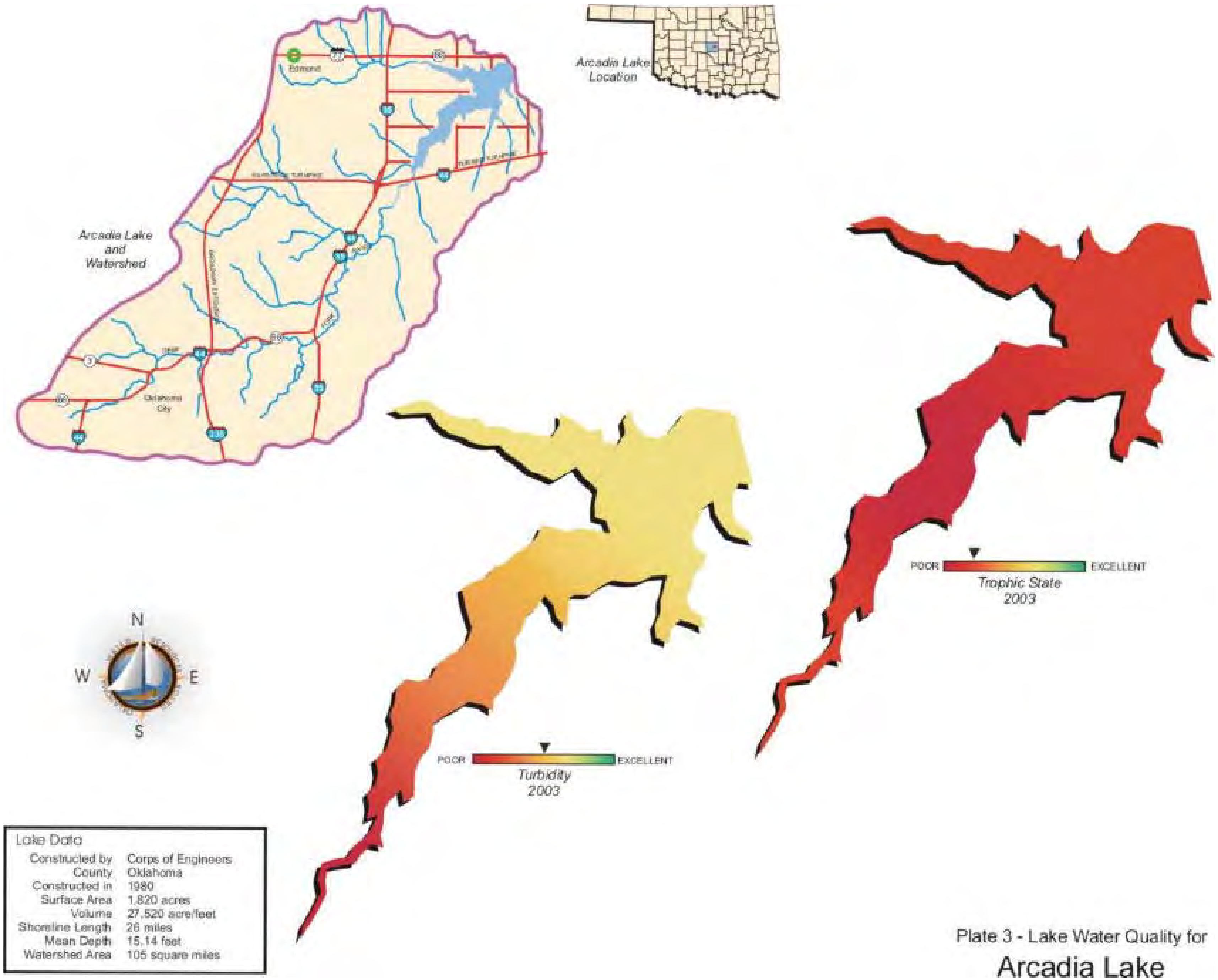



**Figure 15a-15f.** Graphical representation of data results designed for Arcadia Lake.




Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Oklahoma |
| Constructed in | 1980 |
| Surface Area | 1,820 acres |
| Volume | 27,520 acre/feet |
| Shoreline Length | 26 miles |
| Mean Depth | 15.14 feet |
| Watershed Area | 105 square miles |

Plate 3 - Lake Water Quality for
## Arcadia Lake

# Ardmore City Lake

Ardmore City Lake was sampled for three quarters, from March 2003 through August of 2003. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 5 NTU (Plate 4), true color was 19 units, and average secchi disk depth was 128 centimeters in sample year 2001. Water clarity was excellent at Ardmore City Lake based on the high secchi disk depth and low turbidity values and is similar to results from the 2001 evaluation. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=9). The TSI was 45 (Plate 4), indicating the lake was mesotrophic in sample year 2003. The TSI values for all sites throughout the sample year varied seasonally ranging from oligotrophic to upper mesotrophic to lower eutrophic (Figure 16). In 2001, the calculated TSI value was also mesotrophic (TSI=49) indicating no significant change in productivity has occurred. All turbidity values were well below the turbidity standard of 25 NTU (Figure 17a) and all color values were well below the aesthetics OWQS for color (70 units). The minimum data requirements were not met for these parameters and attainment of the beneficial uses cannot be assessed at this time, however upon reviewing current and historical data it is likely that the applicable beneficial uses would be fully supported.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.12 parts per thousand (ppt) to 0.19 ppt, which is within the average range of values seen in Oklahoma reservoirs. Specific conductance ranged from 261.2 mS/cm to 372.8 mS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.97 to 8.29 representing a neutral to slightly alkaline lake system. Oxidation-reduction potentials (ORP) ranged from 363mV in the hypolimnion in the spring to 497 mV in the summer. In general, reducing conditions were not present at this reservoir during the 2002-2003-sample year. Thermal stratification was evident and anoxic condition present in both spring and summer sampling quarters. In the spring stratification occurred at several 1-meter intervals with dissolved oxygen concentrations (D.O.) falling below 2.0 mg/L from 6 meters in depth to the lake bottom of 9.8 meters accounting for approximately 45 % of the water column to be experiencing anoxic conditions (Figure 17d). In the summer quarter similar conditions were found, with dissolved oxygen levels less than 2.0 mg/L for greater than 50% of the water column at sites 1 and 2 (Figure 17e). If D.O. values are less than 2.0

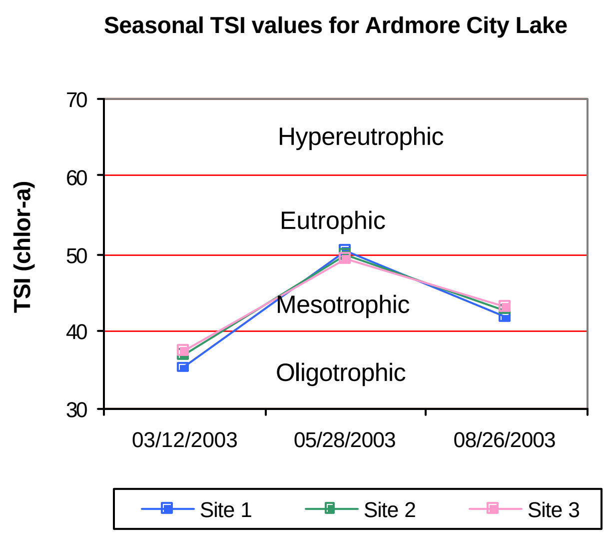



**Figure 16.** TSI values for Ardmore City Lake

mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. levels are less than 2.0 mg/L for 50 to 70% of the water column the FWP beneficial use is considered partially supported. At this time Ardmore City Lake is partially supporting the FWP beneficial use based on low dissolved oxygen concentrations in the spring and summer.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.44 mg/L at the surface and 1.13 mg/L at the lake bottom. Surface TN ranged from 0.37 mg/L to 0.51 mg/L with the highest values recorded in the summer quarter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.016 mg/L at the surface and 0.0.046 mg/L at the lake bottom. Surface TP ranged from 0.014 mg/L to 0.022 mg/L was highest in the fall months and the lowest during the summer sampling quarter. The nitrogen to phosphorus ratio (TN:TP) was 27:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Ardmore City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels in sample year 2003. These results are similar to those seen in 2001 indicating no significant increase or decrease in productivity has occurred. Water clarity was excellent based on turbidity, true color, and secchi disk depth readings. The lake is currently supporting the Fish and Wildlife Propagation (FWP) beneficial use based on pH and partially supporting based on dissolved oxygen. An assessment of the FWP beneficial use could not be made in regards to turbidity due to the minimum data requirements not being met. All true color values were well below the OWQS of 70 units however the minimum data requirements were also not met for this parameter. Ardmore City Lake constructed in 1910 is located in Carter County for the purpose of recreation.

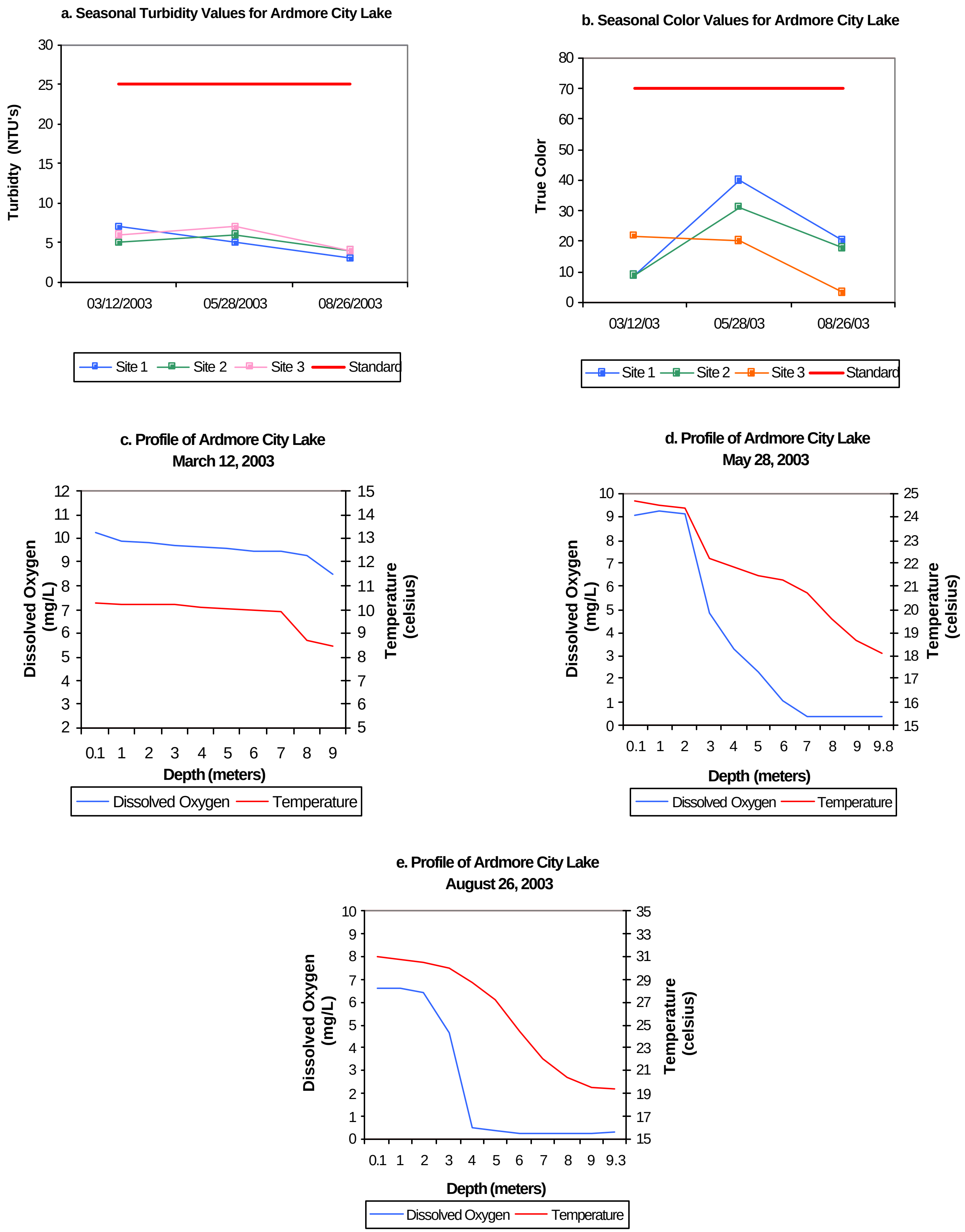



**Figure 17a-17e.** Graphical representation of data results designed for Ardmore City Lake.


| Lake Data | |
|---|---|
| Owner | City of Ardmore |
| County | Carter |
| Constructed in | 1910 |
| Surface Area | 142 acres |
| Volume | 600 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 4.23 feet |
| Watershed Area | 2,046 acres |




Plate 4 - Lake Water Quality for
Ardmore City Lake

# Atoka Lake

Atoka Lake was sampled for four quarters, from October 2003 through July of 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and an additional sample was collected at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 94 NTU (Plate 5), true color was 156 units, and average secchi disk depth was 21 centimeters in sample year 2003-2004. Water clarity was poor at Atoka Lake based on the low secchi disk depth and high turbidity values. Atoka Lake has always had high levels of clay particulates suspended in the water column, which results in low water clarity. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 50 (Plate 5), indicating the lake was mesotrophic bordering eutrophic in sample year 2003-2004. The TSI values for all sites throughout the sample year were fairly consistent with all values in the mesotrophic and eutrophic categories (Figure 19). The only exception to this was site 3 during the month of April, which was oligotrophic. Seasonal turbidity values per site for this sample year are displayed in Figure 20a. All turbidity values were well above the turbidity standard of 25 NTU with the lowest recorded value of 47 NTU and the maximum value of 302 NTU. With 100% of the values exceeding the numerical criteria the lake is considered not supporting its Fish & Wildlife Propagation (FWP) beneficial use. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. However, in the case of Atoka Lake, evidence suggests that the high turbidity readings are natural based on the local soil conditions. Seasonal true color values are also displayed in Figure 20b. The average lake-wide color was calculated at 156 units, which greatly exceeded the Aesthetics OWQS for color (70 units). The minimum value recorded was 44 units and the maximum value recorded was 282 units. Applying the same default protocol, Atoka Lake is not meeting the aesthetics beneficial use based on true color.

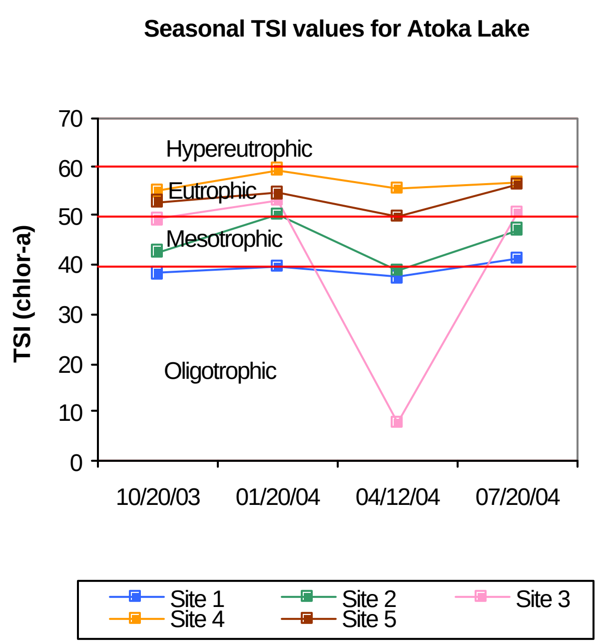



**Figure 19.** TSI values for Atoka Lake.

In 2003-2004, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. The salinity values for Atoka Lake ranged from 0.02 parts per thousand (ppt) to 0.10 ppt for this sample year. Specific conductivity ranged from 57 to 211.1 mS/cm, which falls within the range of values commonly reported for Oklahoma reservoirs. These values indicate relatively low levels of ions were present in the system. The pH values at Atoka Lake ranged from 6.21 units at the lake bottom in the summer to 8.02 at the lake surface in the fall quarter, representing a neutral to slightly acidic system. Oxidation-reduction potentials ranged from 346mV in the hypolimnion in the summer to 582mV in the winter. Reducing conditions were not present at this reservoir in the 2003-2004-sample year. During the fall, winter and spring quarters stratification was not present, the lake was well mixed, and dissolved oxygen values were generally above 7 mg/L (see Figure 20a-20f). Thermal stratification was evident in the summer quarter and anoxic conditions were present. In the summer the lake was stratified between 11 and 12 meters at which point dissolved oxygen dropped to <2mg/L for the rest of the water column at site 1 (see Figure 20c). Sites 4 and 5 also exhibited stratification with approximately 57% and 33% respectively below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 33 to 57% of the water column less than 2.0 mg/L the lake is considered to be partially supporting its FWP beneficial use. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.65 mg/L. The TN at the surface ranged from 0.30 mg/L in the spring to 1.21mg/L in the winter months. Surface TN was highest in the winter and summer quarters and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.083 mg/L. The TP at the surface ranged from 0.043 mg/L to 0.198mg/L. The surface TP was highest in the spring quarter and lowest in the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003-2004. This value is close to the 7:1 ratio generally used to determine the limiting nutrient, characterizing the lake as potentially phosphorus-limited to co-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is considered to be fully supporting its Fish Consumption beneficial use.

In summary, Atoka Lake was classified as mesotrophic with moderate productivity and nutrient levels in 2003-2004, indicating no significant increase or decrease in lake productivity or nutrient levels has occurred since the 2001-2002 evaluation. Water clarity was poor based on secchi disk depth, high turbidity and true color values and is likely to always be poor based on the soil composition of the area. The lake is not supporting its FWP beneficial use based on turbidity, partially supporting based on D.O. and supporting based on pH values. The lake is supporting its Aesthetics beneficial use based on its trophic status, but is not supporting the use due to extremely high true color concentrations. Atoka Lake is a recreational reservoir managed by the City of Oklahoma City. The lake also serves as a water supply for the city with water from Atoka

Lake transported via pipeline to Lake Stanley Draper. It is then treated and transported to Oklahoma City water customers. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 21) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

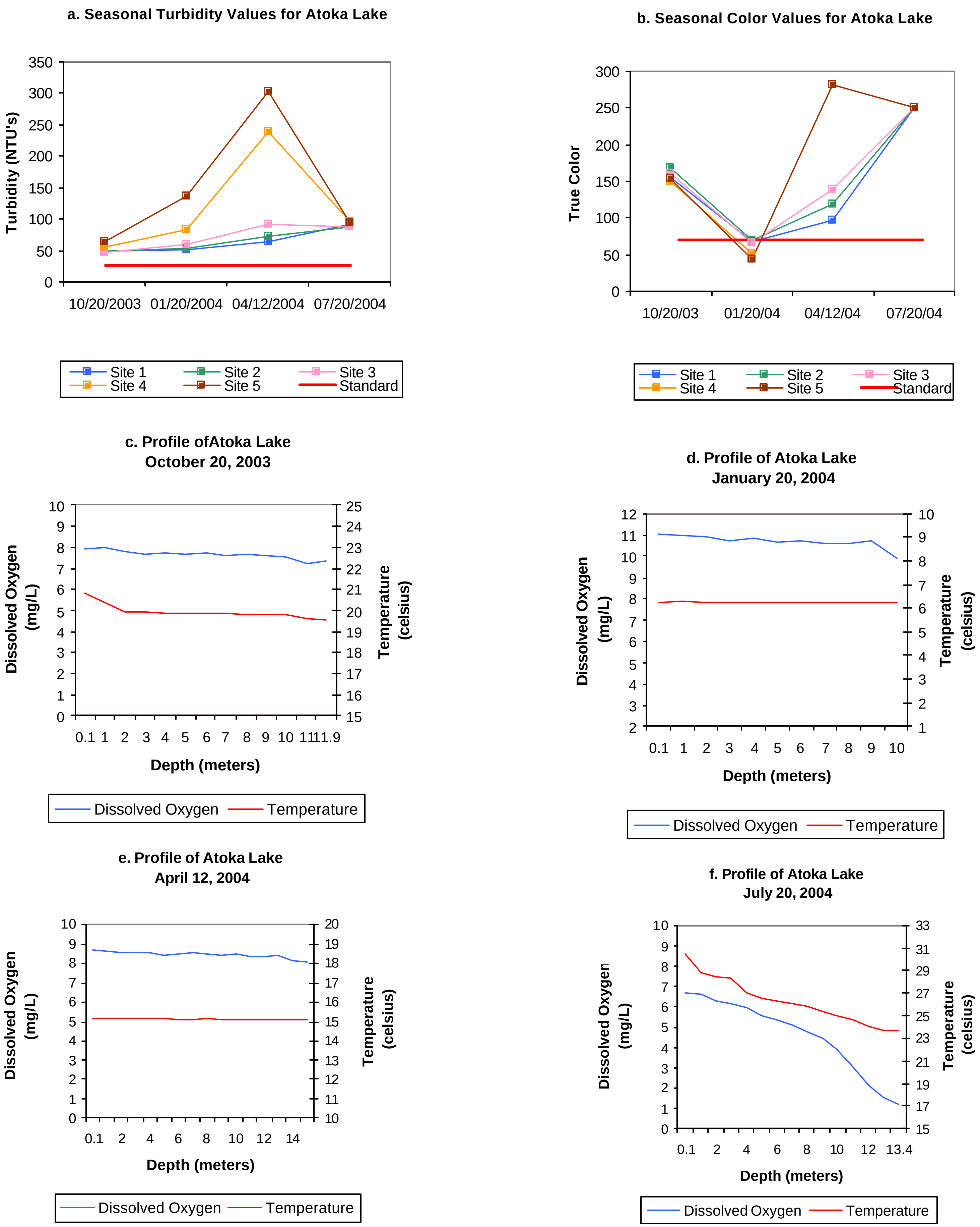
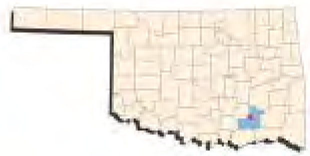



**Figure 20a-20f.** Graphical representation of data results for Atoka Lake.


Atoka Lake and Watershed



Atoka Lake Location

| Lake Data | |
| --- | --- |
| Owner | City of Oklahoma City |
| County | Atoka |
| Constructed in | 1964 |
| Surface Area | 5,537 acres |
| Volume | 105,195 acre/feet |
| Shoreline Length | 70.02 miles |
| Mean Depth | 18.32 feet |
| Watershed Area | 172 square miles |


Turbidity 2004


Trophic State 2004

Plate 5 - Lake Water Quality for
Atoka Lake

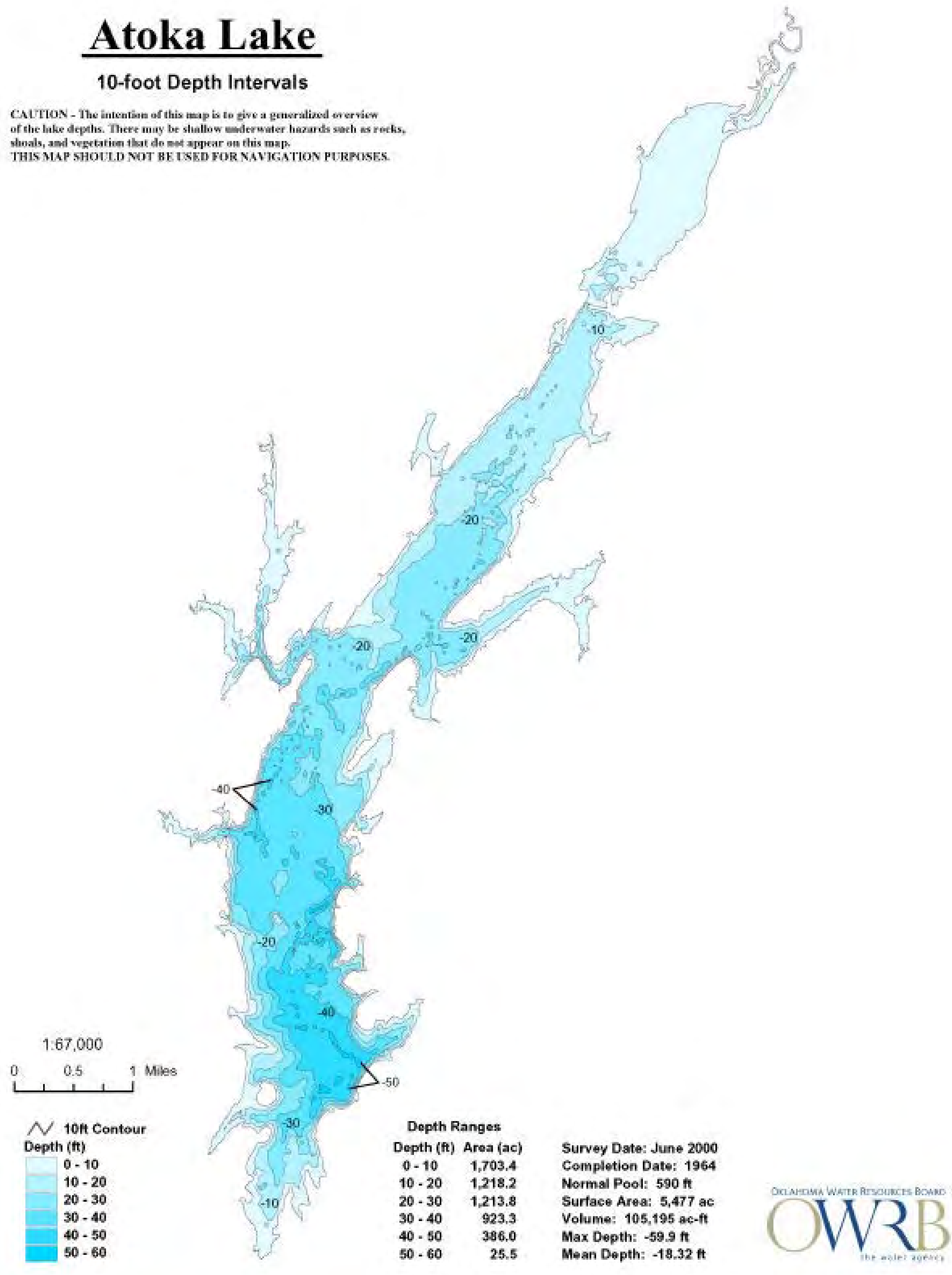



**Figure 21.** Bathymetric Map of Atoka Lake.

# Bellcow Lake

Bellcow Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and an additional sample was collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 18 NTU (Plate 6), true color was 19 units, and average secchi disk depth was 66 centimeters. Water clarity was average based on the secchi disk depth, and turbidity values, similar to the previous sampling in 2001. True color values were excellent throughout the reservoir. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites (n=20). The TSI was 49 (Plate 6), indicating the lake was mesotrophic, indicative of moderate primary productivity and nutrient conditions in sample year 2003-2004. The TSI values for all sites throughout the sample year varied from lower mesotrophy to upper eutrophy (Figure 22). According to seasonal observations, Bellcow Lake is typically mesotrophic in the fall and winter to upper mesotrophic spring and is at the high end of eutrophy during the warmer summer months. Turbidity values for the sample year are displayed in Figure 23a. Turbidity values collected throughout all four sampling intervals were below the Oklahoma Water Quality Standards (OWQS) of 25 NTU, with the exception of the site 3 located in the upper end of the lake, which exceeded the OWQS in the spring. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity with 5% of the collected values exceeding 25 NTU. Seasonal true color values are displayed in Figure 23b. All true color values were well below the Aesthetics OWQS of 70 units; therefore the beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity readings ranged from 0.15 parts per thousand (ppt) to 0.20 ppt throughout sample year 2003-2004. Specific conductivity values were moderate in nature, ranging from 310 mS/cm at the lake surface in the winter to 396.8 mS/cm at the lake bottom in the summer. These values are comparable to levels seen in most Oklahoma reservoirs, indicating there are moderate

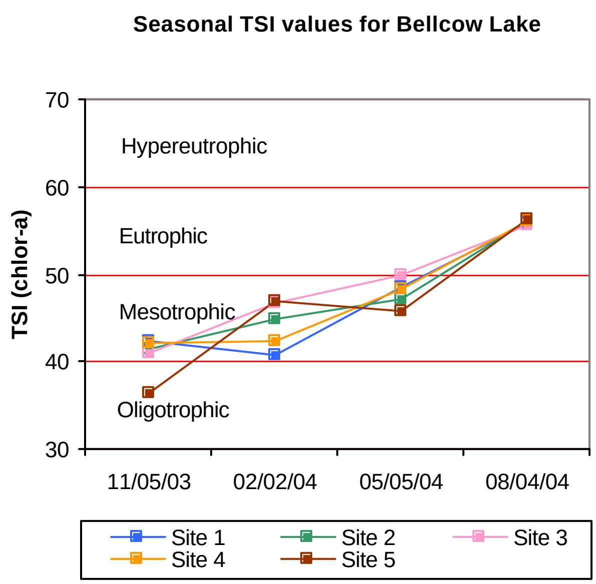



**Figure 22.** TSI values for Bellcow Lake.

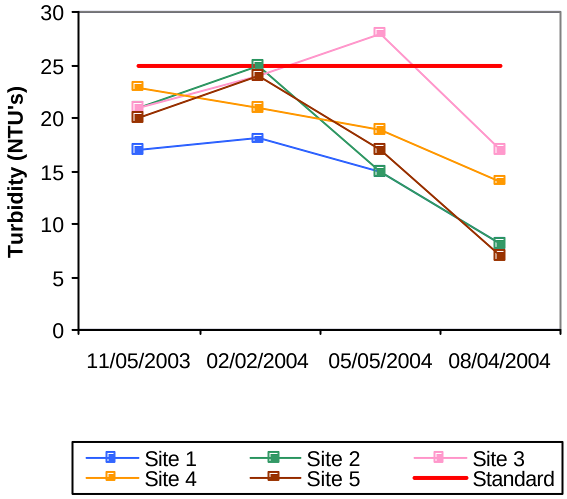
amounts of salts or ions in Bellcow Lake. Values for pH ranged from 7.51 to 8.65 units, indicating the lake was neutral to slightly alkaline in nature. Of the pH values collected, none exceeded the numerical pH criteria for FWP specified in OAC 785:45-5-12. According to Use Support Assessment Protocols (USAP) in OAC 785:46-15-5, if more than 25% of pH values fall outside the 6.5 to 9.0 numerical criteria range the FWP beneficial use is not being met. All recorded values were within the acceptable range, therefore the lake is considered fully supporting the FWP use for pH. Oxidation-reduction potentials (redox) ranged from 403 mV to 483 mV, indicating the absence of reducing conditions in the lake system. Thermal stratification was not evident in the fall, winter or spring quarters and the lake was well oxygenated with dissolved oxygen (D.O) remaining above 5.7 mg/L (Figure 23c-23e). In the summer, a thermocline was present between 3 and 4 meters, with dissolved oxygen (D.O.) values dropping below 2.0mg/L from 5-meters below the surface to the lake bottom of 10.4 meters at site 1, the dam (Figure 23f). During the summer sampling interval all sites exhibited stratification and the presence of anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 50% of the water column experiencing anoxic conditions at site 1, the dam, the lake is considered partially supporting its FWP beneficial use. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

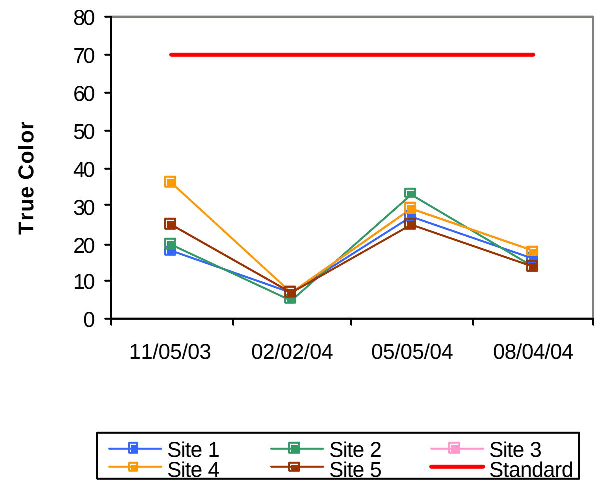
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.75 mg/L and 1.05 at the lake bottom. The surface TN ranged from 0.47 mg/L to 1.05 mg/L. TN was highest in the winter quarter and lowest in the fall quarter. The lake-wide total phosphorus (TP) average was 0.027 mg/L at the surface and 0.079 at the lake bottom. The TP ranged from 0.024 mg/L to 0.033 mg/L. TP was highest in the spring and lowest in the winter. The nitrogen to phosphorus ratio (TN:TP) was 27:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Bellcow Lake was mesotrophic, indicative of moderate to high primary productivity and nutrient levels. Results were slightly lower than previous historical data. Water clarity was average in comparison to other Oklahoma reservoirs based on turbidity, true color values and secchi disk depth. The lake was fully supporting its Aesthetics beneficial use based on true color and trophic state. The lake was fully supporting its FWP beneficial use based on turbidity and pH concentrations, but will be listed as partially supporting based on D.O. concentrations. Bellcow Lake, constructed by the Natural Resource Conservation Service (NRCS), was constructed to serve for flood control, water supply, recreation and fish and wildlife purposes.

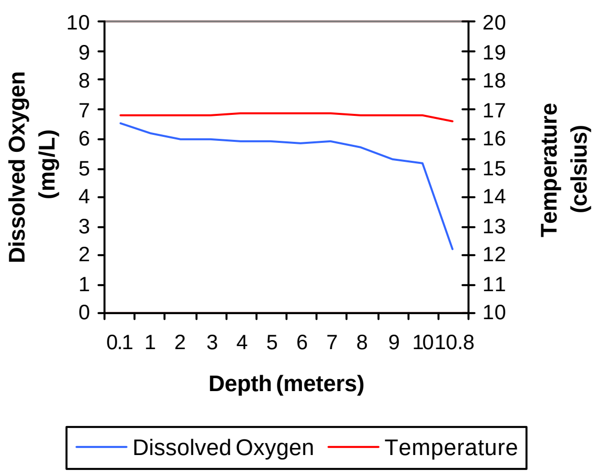
**a.Seasonal Turbidity Values for Bellcow Lake**



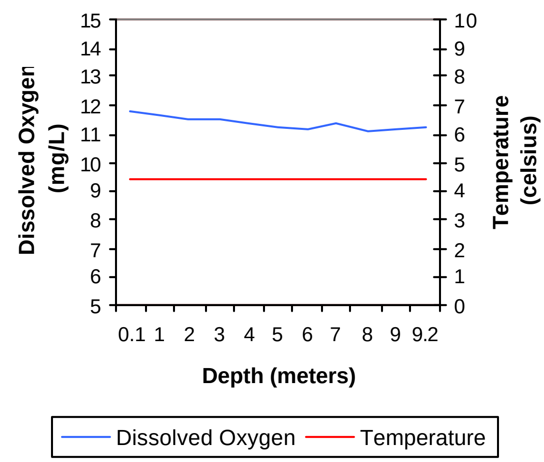

**b. Seasonal Color Values for Bellcow Lake**



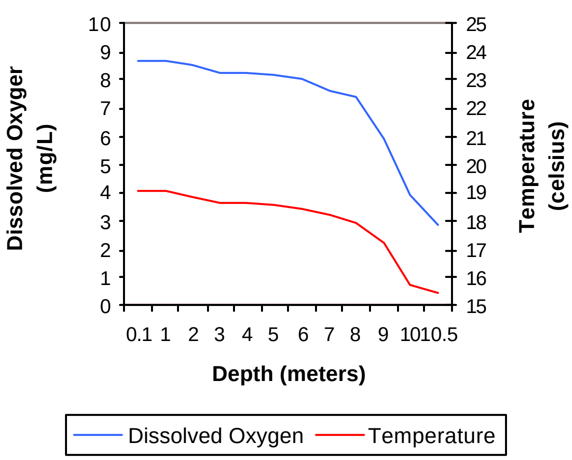

**c. Profile of Bellcow Lake**
**November 05, 2003**




**d. Profile of Bellcow Lake**
**February 02, 2004**




**e. Profile of Bellcow Lake**
**May 05, 2004**




**f. Profile of Bellcow Lake**
**August 04, 2004**

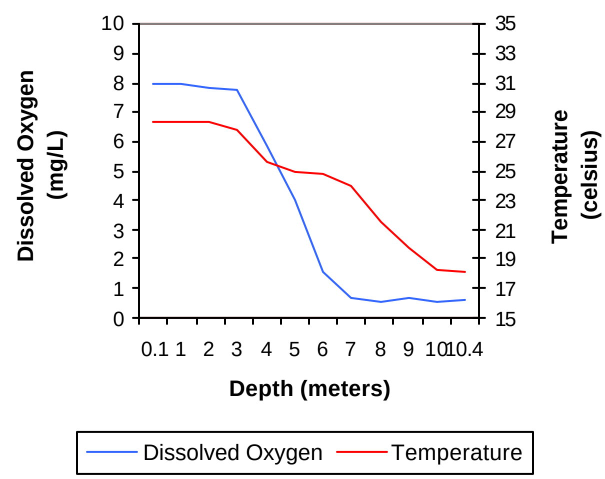
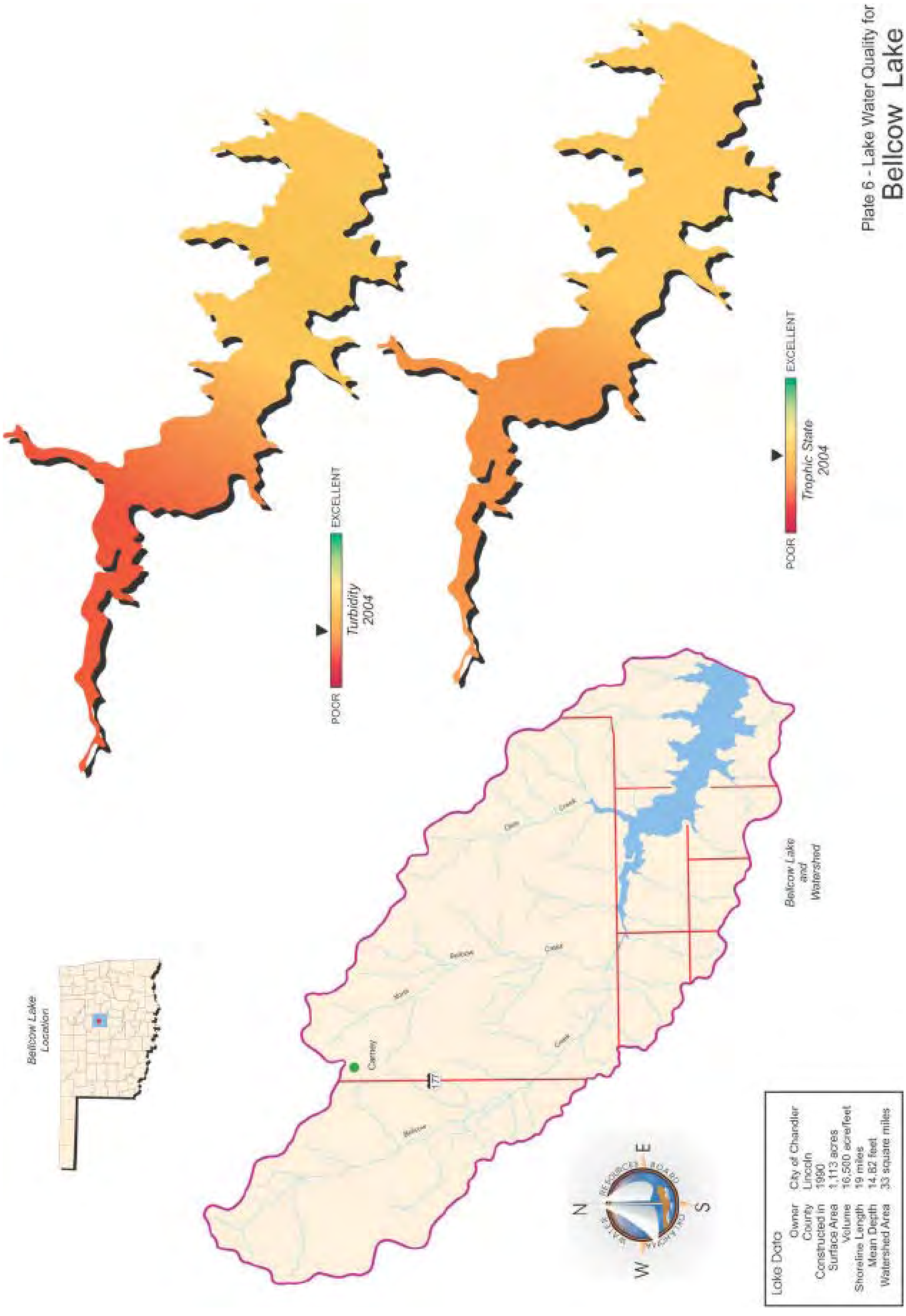



**Figure 23a-23f.** Graphical representation of data results for Bellcow Lake.




Lake Data

| | |
|---|---|
| Owner | City of Chandler |
| County | Lincoln |
| Constructed in | 1990 |
| Surface Area | 1,113 acres |
| Volume | 16,500 acre/feet |
| Shoreline Length | 19 miles |
| Mean Depth | 14.82 feet |
| Watershed Area | 33 square miles |

Plate 6 - Lake Water Quality for
Bellcow Lake

# Birch Lake

Birch Lake was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 17 NTU, true color was 56 units and average secchi disk depth was 85 centimeters in sample year 2002-2003. Based on these three parameters water clarity was average at Birch Lake. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 47 (Plate 7), indicating the lake was mesotrophic in sample year 2002-2003. The TSI values for all sites throughout the sample year were fairly consistent and ranged from upper oligotrophic to eutrophic (Figure 24). Seasonal turbidity values per site are displayed in Figure 25a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Of the samples collected, 25% of the turbidity values were above the turbidity standard of 25 NTU therefore the Fish and Wildlife Propagation (FWP) beneficial use is considered partially supported based on turbidity. Seasonal true color values are also displayed in Figure 25b. Of the 20 samples collected at Birch Lake 28% of the true color values exceeded the OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is partially supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation- reduction potential and salinity were recorded at all five sample sites during the sample year. Salinity values ranged from 0.05 parts per thousand (ppt) in the spring to 0.10 ppt in the fall. Specific conductance ranged from 125.5 mS/cm to 217.1 mS/cm, which falls within the range of values commonly observed in Oklahoma reservoirs. These values indicate low levels of current conducting compounds (salts) in the lake system. The pH values were generally neutral and ranged from 6.42 units to 7.84 units. Oxidation-reduction potentials ranged from 56 mV in the fall to 609 mV in the summer. In general, reducing conditions were not present with all recorded values above 100 mV with the exception of two values recorded at the

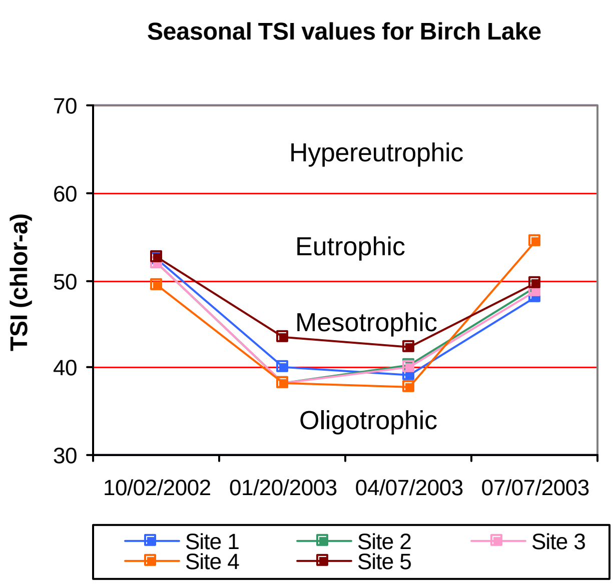



**Figure 24.** TSI values for Birch Lake.

lake bottom at the dam. Dissolved oxygen (D.O.) levels remained above 7.0 mg/L during the winter and spring sampling quarters (see Figure 25d-25e) when the water column was evenly mixed. Thermal stratification was evident and anoxic conditions were present in both the fall and summer quarters. In the fall stratification occurred several 1-meter intervals but dissolved oxygen concentrations fell below 2.0 mg/L between 10 and 11 meters in depth, accounting for 27% of the water column at site 1 to be anoxic. During the summer sampling interval stratification occurred between 4 and 5 meters at sites 1, 2, and 4. At these sites anoxic conditions were present for 45 to 55% of the water column (see Figure 25f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column the FWP beneficial use is deemed partially supported. Birch Lake is considered to be partially supporting the FWP beneficial use based on D.O for this sample year. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.55 mg/L at the surface and 0.65 mg/L at the lake bottom. Surface TN ranged from 0.29 mg/L to 0.80 mg/L with the highest values recorded in the summer quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.025 mg/L at the surface and 0.033 mg/L at the lake bottom. Surface TP ranged from 0.007 mg/L to 0.059 mg/L and was highest in the spring months. The lowest values occurred during the winter sampling quarter. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Birch Lake was classified as mesotrophic with moderate productivity and nutrient levels. Water clarity was average based on true color, turbidity, and secchi disk depth. The lake is partially supporting the Fish and Wildlife propagation (FWP) beneficial use based on turbidity and dissolved oxygen and supporting based on pH values. Birch Lake is supporting the Aesthetics beneficial use based on its trophic status, but only partially supporting the use with 28% of the true color values exceeding the OWQS of 70 color units. Birch Lake is located in Osage County and was constructed by the United States Army Corps of Engineers (USACE) to serve as a water supply, flood control and recreation reservoir.

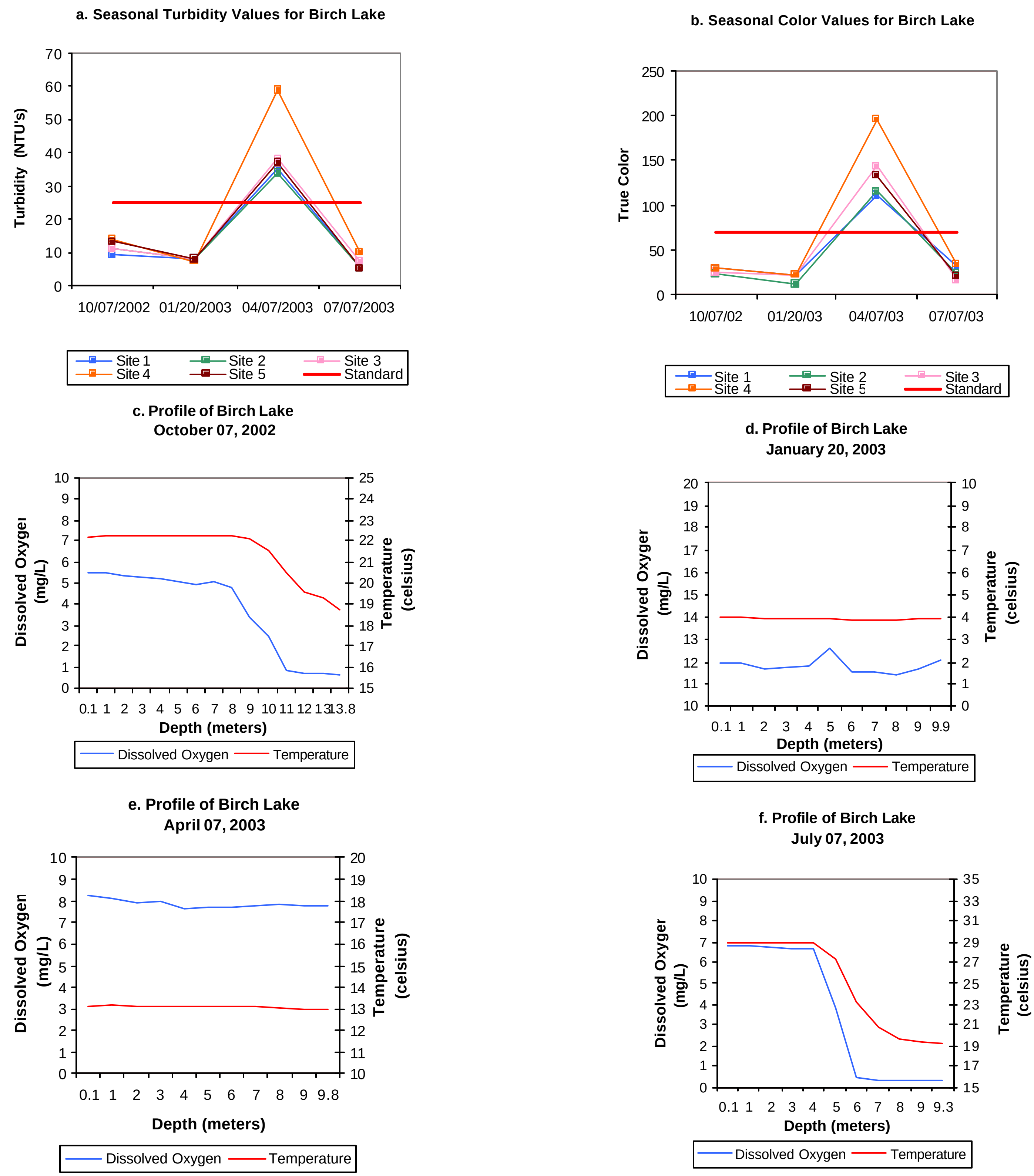
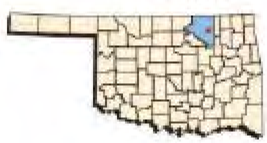



**Figure 25a-25f.** Graphical representation of data results for Birch Lake.

Birch Lake
Location


Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Osage |
| Constructed in | 1977 |
| Surface Area | 1,137 acres |
| Volume | 19,200 acre/feet |
| Shoreline Length | 27 miles |
| Mean Depth | 16.88 feet |
| Watershed Area | 66 square miles |



Plate 7 - Lake Water Quality for
## Birch Lake

# Lake Bixhoma

Lake Bixhoma was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, lacustrine zones of the lake. Samples were collected from the lake surface at all sites and an additional sample was collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 7 NTU (Plate 8), true color was 27 units, and average secchi disk depth was 143 centimeters in sample year 2004. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. Water clarity was slightly better than values in 2002. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 48 (Plate 8), indicating the lake was mesotrophic, indicative of moderate primary productivity and nutrient conditions. This is very similar to the value calculated in 2002 (TSI=47), indicating no significant increase or decrease in productivity has occurred over time. The TSI values varied seasonally throughout the year, ranging from oligotrophic in the fall to mesotrophic in the winter and summer quarters, with only one eutrophic spike occurring in the spring (see Figure 26). All turbidity values per site for the sample year were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 27a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 27b. All true color values were below the Aesthetics OWQS of 70 units and were consistent throughout all four-sample quarters. Applying the same default protocol, the lake was fully supporting its Aesthetics beneficial use for true color.

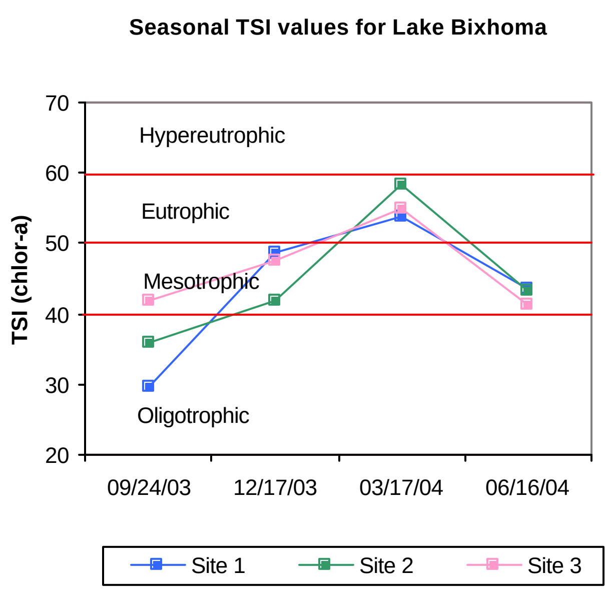



**Figure 26.** TSI values for Lake Bixhoma.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.05 ppt, well within the range of values if not lower than most values observed in Oklahoma lakes. Specific conductivity values ranged from 21.8 to 125.4 mS/cm, also indicative of negligible salt content and ion level in the lake system. Values for pH were generally neutral, ranging from 6.25 in the fall to 7.41 in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The low pH values recorded primarily in the fall at Lake Bixhoma may be due to natural conditions and with only 6% of the values recorded falling outside the acceptable range the lake is supporting the FWP beneficial use. Oxidation-reduction potentials (ORP) were positive at all sample sites and ranged from 258mV in the spring up to 644mV in the winter. In general, reducing conditions were not present in the reservoir during the study period. Thermal stratification was not evident in either the winter or spring intervals (Figure 27d-27e). In the fall, Lake Bixhoma was thermally stratified between 5 and 6 meters in depth with 63% of the water column having a dissolved oxygen (D.O.) concentration below 2.0 mg/L (see Figure 27c). In the summer stratification occurred at several 1-meter intervals, the first being between 2 and 3 meters below the lake surface with dissolved oxygen concentrations less than 2.0 mg/L between 4-6 meters in depth and then an increase in D.O. concentration was observed. Dissolved oxygen concentrations rose between 7 and 14 meters in depth and ranged from 2.6 to 5.26 mg/L. Stratification occurred again between 13 and 14 meters in depth and D.O. levels were once again less than 2.0 mg/L from 15 meters to the lake bottom at 18.7 meters. This event also occurred at site 2 as well and is possibly be due to interflow within the lake (Figure 27f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The D.O. values in the winter and spring were generally above 9 mg/L. During the fall, the D.O. values dropped below 2.0 mg/L at the 7-meter depth extending to the lake bottom at sites 1 and 2. Therefore, the FWP beneficial use is considered partially supported with 63% of the water column anoxic at site 1. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.41 mg/L. The TN at the surface ranged from 0.29 mg/L to 0.58 mg/L. The highest surface TN was in the spring quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.018 mg/L. The TP ranged from 0.012 mg/L to 0.027 mg/L. Similar to total nitrogen surface TP was highest in the spring and lowest in the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 23:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Bixhoma was classified as mesotrophic, indicative of moderate primary productivity and moderate nutrient conditions (Plate 8). Water clarity was excellent based on true color; turbidity and secchi disk depth and is consistent with observations in the previous evaluation. The FWP beneficial use was fully supported as it relates to turbidity and pH; however was only partially supporting the FWP based on D.O. values in the fall and summer months. The lake is fully supporting its Aesthetics beneficial use based on true color data and trophic status. Lake Bixhoma is owned by the City of Bixby and was constructed in 1965 to serve as a water supply and recreational outlet for the public use.

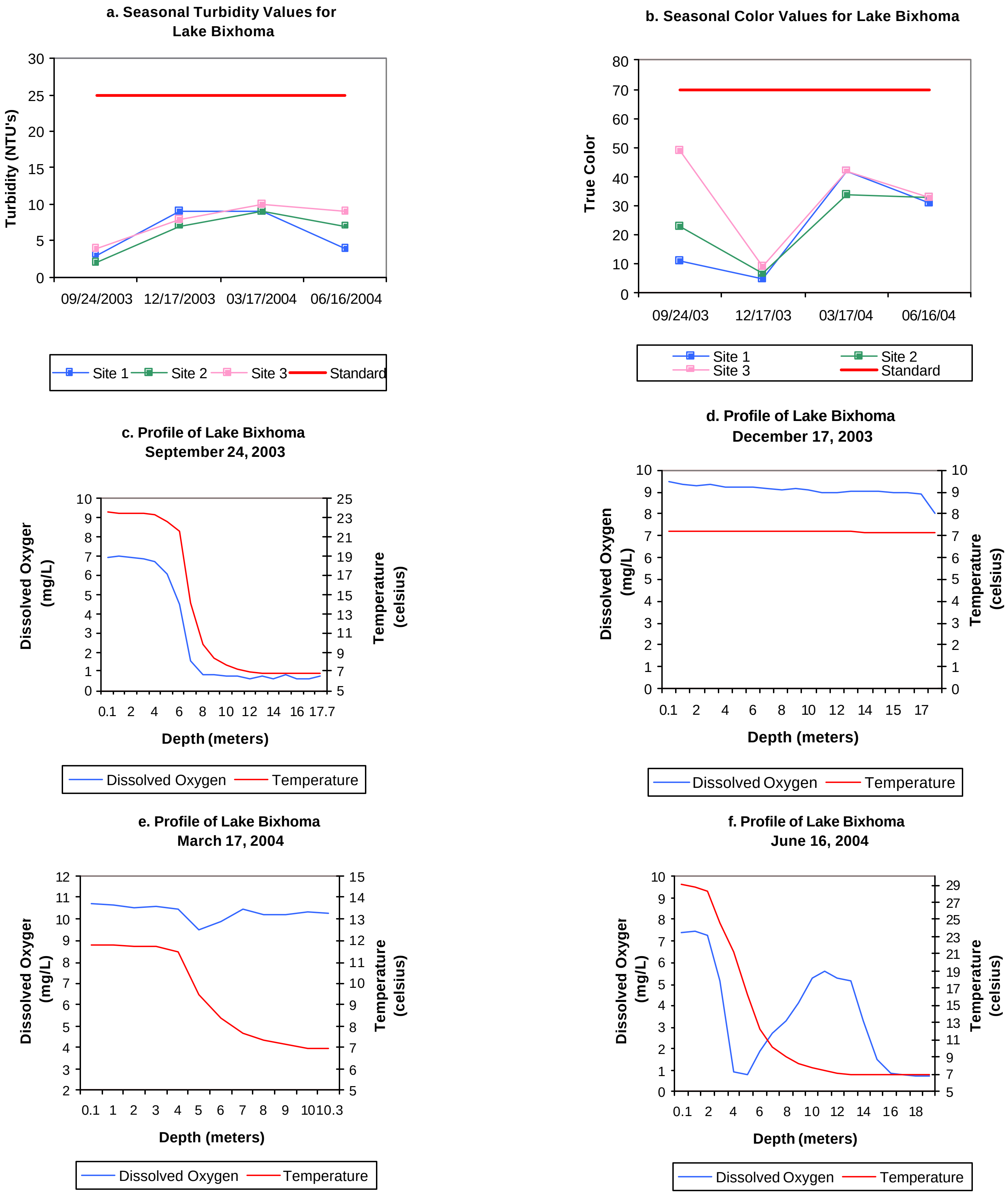



**Figure 27a-27f.** Graphical representation of data results for Lake Bixhoma.

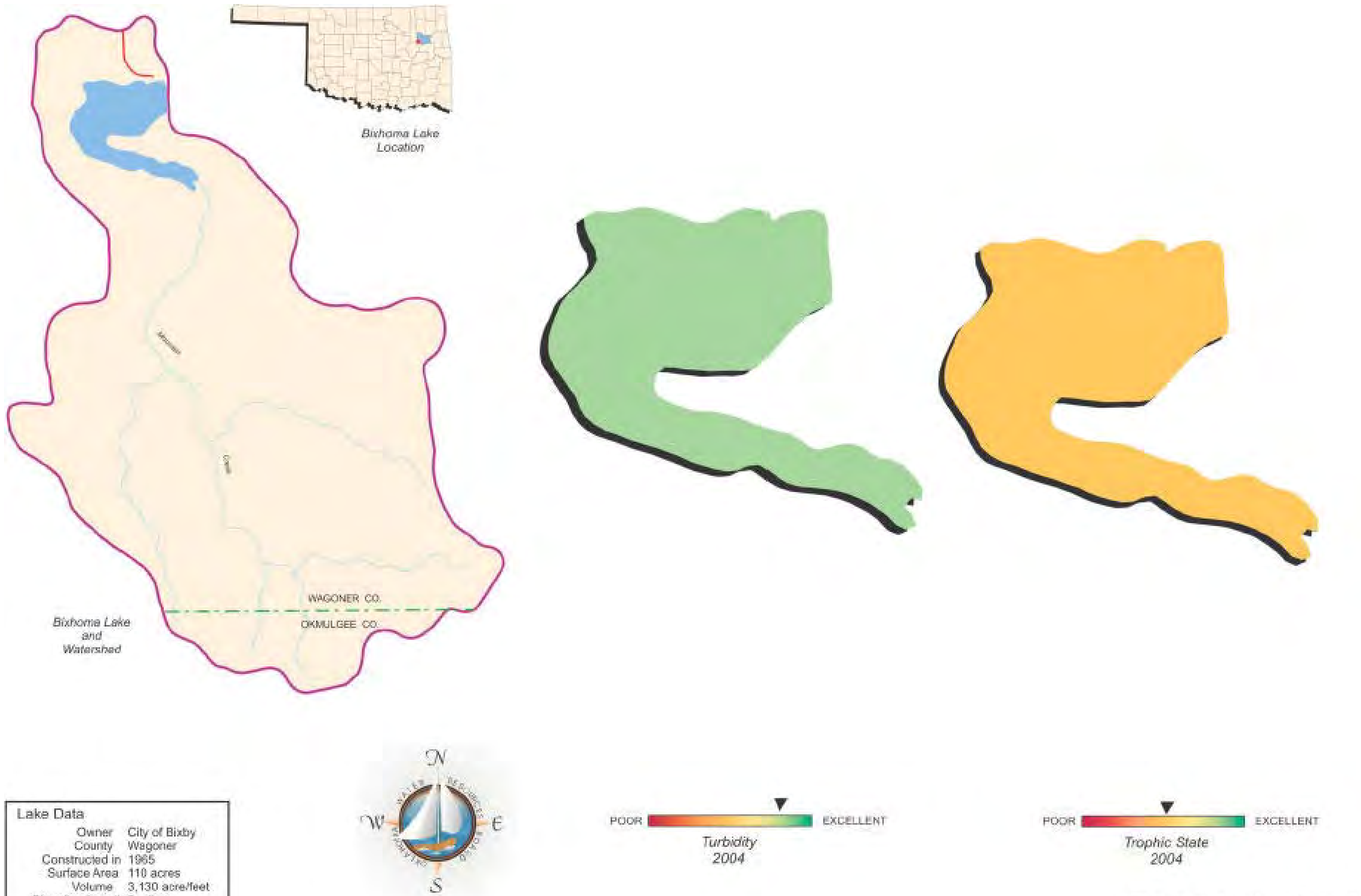



Plate 8 - Lake Water Quality for
Bixhoma Lake

# Bluestem Lake

Bluestem Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 29 NTU (Plate 9), true color was 42 units, and average secchi disk depth was 56 centimeters. Water clarity was average based on secchi disk depth, true color and turbidity. Results for these parameters were similar to historical lake sampling efforts. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 43 (Plate 9), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions. This is consistent with previous monitoring results in 2001-2002 where the calculated TSI was also mesotrophic (TSI=45). The TSI values throughout the sample year were primarily mesotrophic with oligotrophic values at all sites in the spring of 2004 (see Figure 28). Turbidity values fluctuated throughout the year with the lowest values recorded in the fall and winter quarters and the highest values recorded in both spring and summer (see Figure 29a). Approximately 55% of the turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, with 45% of the values exceeding the numerical criteria. According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity is likely due to seasonal storm events, therefore Bluestem Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 29b. All true color values were below the Aesthetics OWQS of 70 units with the exception of the spring sampling results where values exceeding the criteria were detected at all sites. Although 25% of the collected values exceeded the prescribed numeric criteria the Aesthetics use support for true color is considered supported, because the peak in true color is likely due to a storm event.

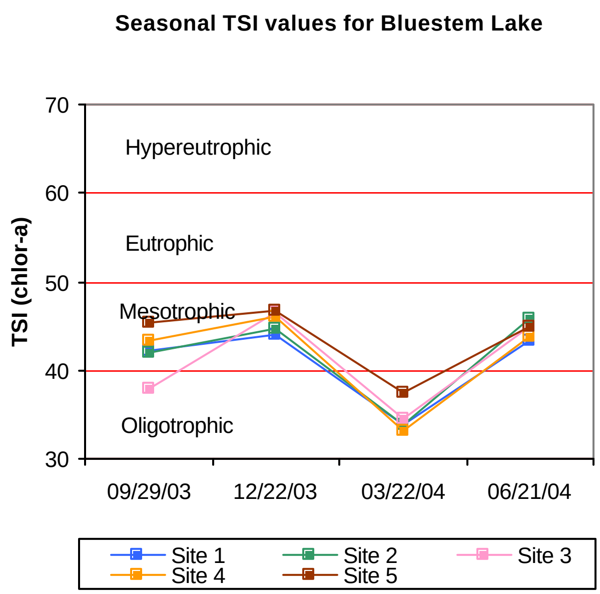



**Figure 28.** TSI values for Bluestem Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites during the study period. Salinity values were consistent throughout the water column for each quarter, ranging from 0.10 parts per thousand (ppt) to 0.16 ppt. Readings for specific conductance were relatively consistent throughout the water column for each quarter, ranging from 214.6 mS/cm (spring) to 365.2 mS/cm (winter). Both salinity and conductivity values were consistent with values seen in other Oklahoma reservoirs, indicating low to moderate levels of current conducting compounds or salts were present in the lake system. The pH was generally neutral to slightly alkaline with values ranging from 6.97 units to 8.03 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All pH values recorded were within the range therefore meeting the FWP beneficial use. The oxidation-reduction potential (redox) ranged from 360 mV to 513 mV, indicating an absence of reducing conditions during the study period. Bluestem Lake was well mixed in the winter and spring quarters with thermal stratification absent and dissolved oxygen (D.O.) concentrations above 7.5 mg/L in all instances (see Figure 29d-28e). Thermal stratification and anoxic conditions were present in both fall and summer sampling events. In the fall, the lake was stratified between 11-12 meters with D.O. concentrations falling below 2.0 mg/L from 13 meters to the lake bottom of 17.4 meters (Figure 29c). In the summer, stratification occurred between 6 and 7 meters below the surface at all sites. D.O. levels were below 2.0 mg/L from 9 meters to the lake bottom at 18.1 meters. Anoxic conditions were presenting approximately 53% of the water column at site 1, the dam (see Figure 29f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Bluestem Lake. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. The PBCR beneficial use is considered supported for 2003-2004.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.51 mg/L at the surface and 0.76 mg/L at the lake bottom. The TN at the surface ranged from 0.42 mg/L to 0.69 mg/L. Surface TN was highest in the spring and lowest in the fall quarter. The lake-wide total phosphorus (TP) average was 0.036 mg/L at the surface and 0.051 at the lake bottom. The total phosphorus ranged from 0.017 mg/L to 0.071 mg/L at the surface. Surface TP was highest in the summer and lowest in the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 14:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Bluestem Lake was classified as mesotrophic, indicative of low to moderate primary productivity and nutrient levels (Plate 9). Water clarity was average based on true color, turbidity, and secchi disk depth. Available flow and rainfall data suggest that the peak in turbidity is likely due to seasonal storm events, therefore Bluestem Lake will not be listed as not supporting its Fish & Wildlife Propagation (FWP) beneficial use due to high turbidity concentrations. The lake is fully supporting its FWP based on pH concentrations and is partially supporting based on recorded D.O. values in the water column. Bluestem is fully supporting its

Aesthetics beneficial use based on trophic status. Although 25% of the collected values were exceeding the OWQS of 70 units, it is likely this is a result of seasonal storm events therefore, the lake is still considered supporting its beneficial use for true color. Bluestem Lake is the municipal water supply reservoir for the City of Pawhuska and is also utilized for flood control and recreational purposes.

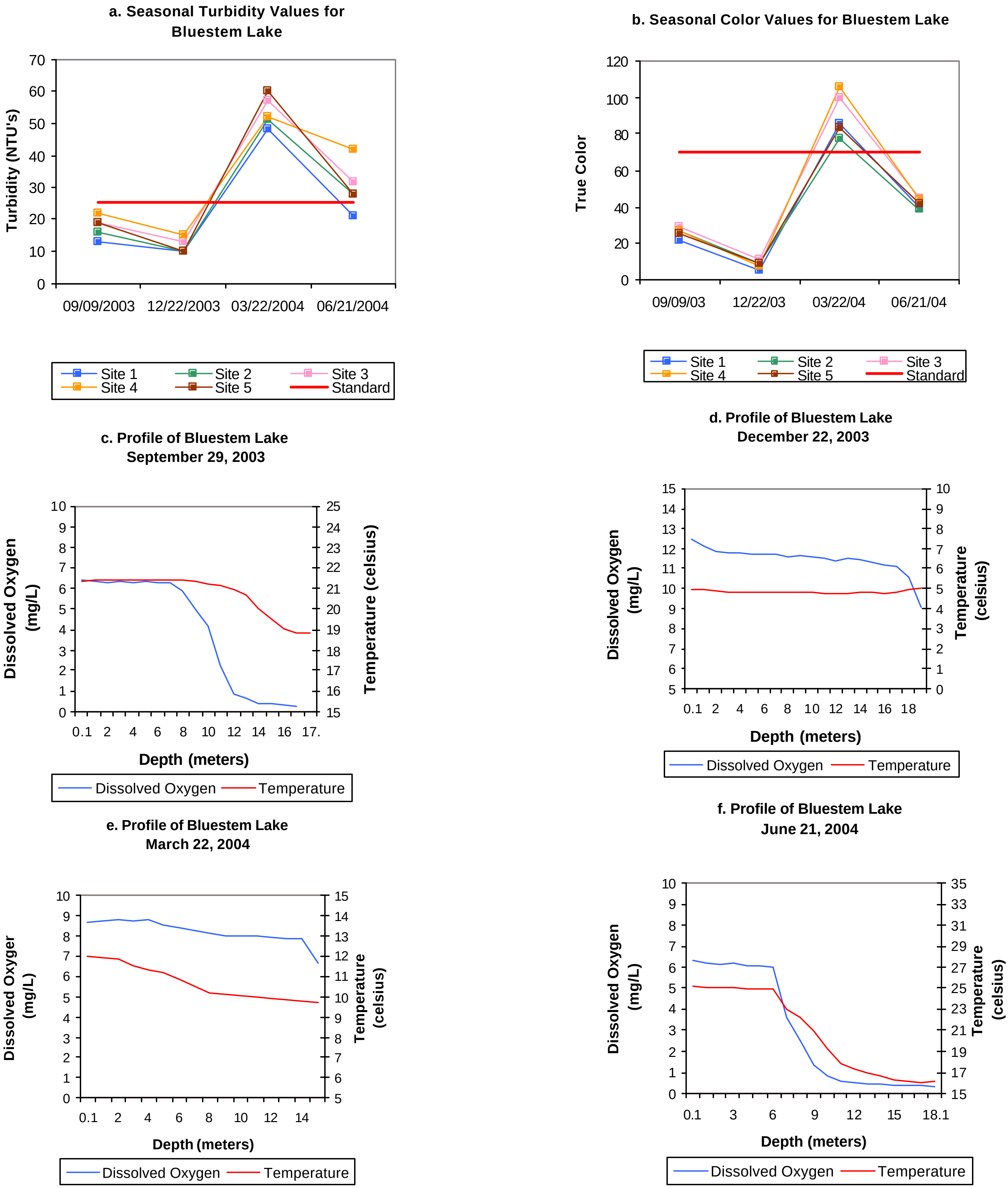



**Figure 29a-29f.** Graphical representation of data results for Bluestem Lake.

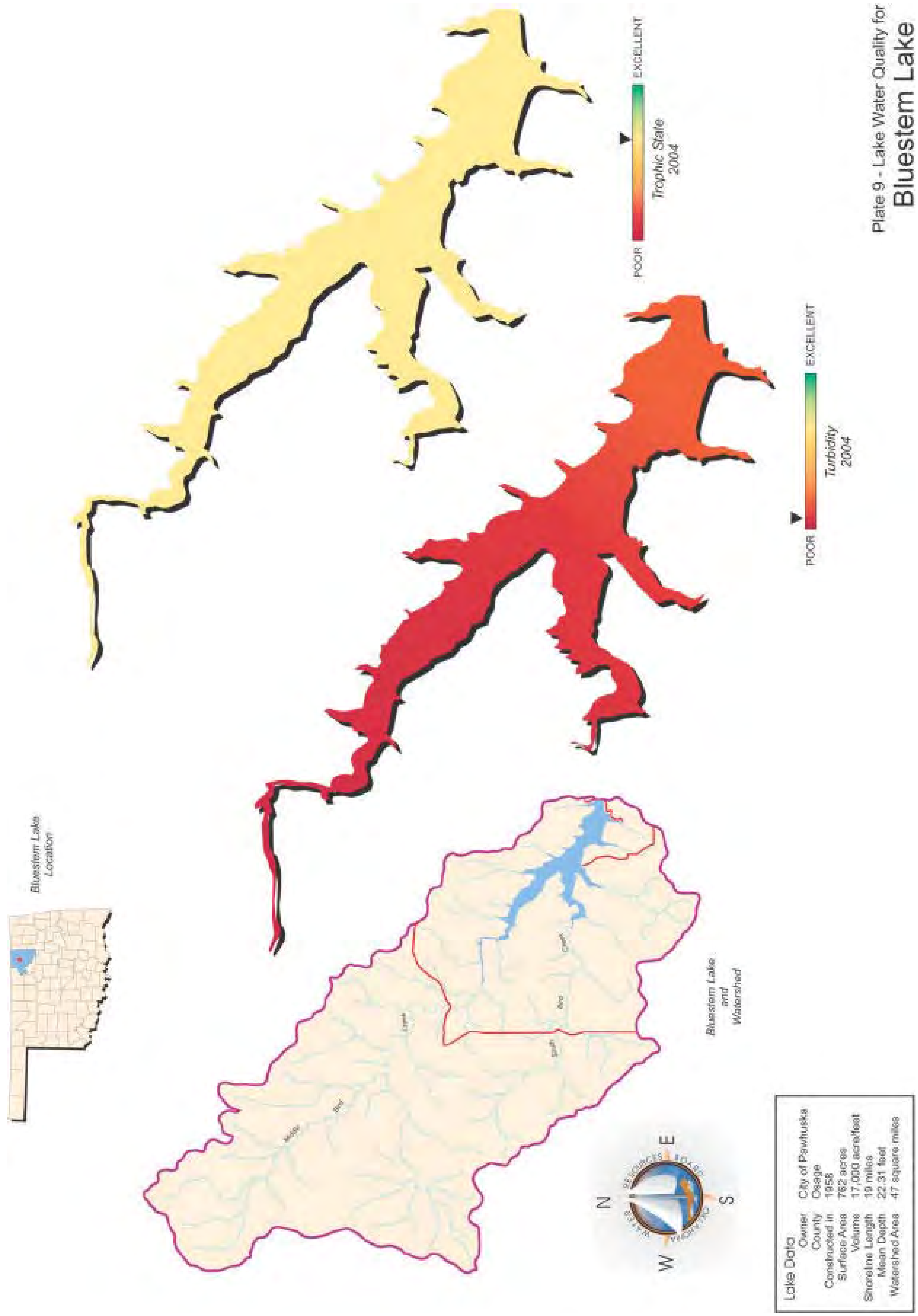



Plate 9 - Lake Water Quality for Bluestem Lake

# Boomer Lake

Boomer Lake was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 for chlorophyll-a and turbidity analysis to meet minimum data requirements. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide turbidity value was 20 NTU (Plate 10), true color was 37 units, and average secchi disk depth was 50 centimeters in 2001-2002. Water clarity was average to slightly poor based on these three parameters. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI calculated was 49 (Plate 10), indicating the lake was mesotrophic in sample year 2001-2002. The TSI values throughout the sample year varied from upper oligotrophy to lower eutrophy. Not surprisingly, during the winter months the lake was oligotrophic and during the summer months the lake was at the lower end of eutrophy (Figure 30). For sample year 2001-2002, 75% of the turbidity values collected were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and 25% were above (see Figure 31a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Boomer Lake is not supporting its Fish & Wildlife Propagation (FWP) beneficial use due to high turbidity concentrations. Seasonal true color values are also displayed in Figure 31b. All true color values, with one exception recorded at site 3 in the winter, were well below the Aesthetics OWQS of 70 units therefore the Aesthetics beneficial use is being supported based on true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.12 parts per thousand (ppt) to 0.15 ppt, which was within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Readings for specific conductivity ranged from 259.6 mS/cm in the winter to 330.6 mS/cm in the summer. Specific conductance values were also within the expected range for Oklahoma reservoirs, indicating relatively low levels of electrical current conducting compounds like salts. Oxidation-reduction potentials (redox) ranged from 59 mV to 550 mV, indicating that reducing conditions were not present in the water column during any time of the year. Low redox potentials were recorded near the lake bottom on two occasions, but not at a level indicating problems with reducing conditions in the lake. The pH values in Boomer Lake were neutral, ranging from 7.15 in the spring to 8.39 units in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting

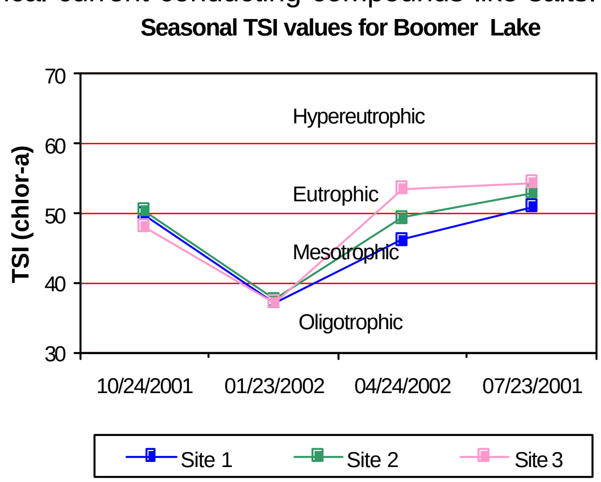



**Figure 30.** TSI values for Boomer Lake.

beneficial uses. Boomer is currently supporting its FWP beneficial use based on pH concentrations. The lake was well mixed during the fall and winter quarters with dissolved oxygen (D.O.) values above 7.25 mg/L throughout the water column (see Figure 31c-31f). In the spring, the lake was stratified between 4 and 5 meters, at which point the D.O. concentration dropped to 4.04 mg/L, still well above the criteria of 2.0 mg/L. In the summer, the lake was thermally stratified with a thermocline present between 3 and 4 meters below the lake surface at which point the D.O. fell below 1.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Approximately 40% of the water column at the dam site was anoxic, and the FWP beneficial use was fully supported. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.60 mg/L at the surface. The epilimnetic TN ranged from 0.49 mg/L to 0.76 mg/L. Surface TN was highest in the summer and fall quarters and lowest in the winter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.036 mg/L for the surface. The TP ranged from 0.038 mg/L to 0.077 mg/L at the surface. Surface TP was highest in the fall and spring quarters and lowest in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2001-2002. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Boomer Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column. The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2000 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Boomer Lake was classified as mesotrophic, indicative of moderate productivity and nutrients (Plate 10). Water clarity was average to slightly poor, however the Aesthetics beneficial use for true color was fully supported based on currently collected data. The Aesthetics use was also fully supported based upon lake trophic status. The lake is partially supporting its FWP beneficial use based on high turbidity concentrations. Boomer was fully supporting its FWP use based upon D.O. and pH values collected in the water column (OAC 785:46). Boomer Lake is owned by the City of Stillwater and was constructed for hydroelectric power and recreational uses. The lake dam has been reconstructed and a significant portion of the shoreline has been stabilized to prevent erosion from occurring.

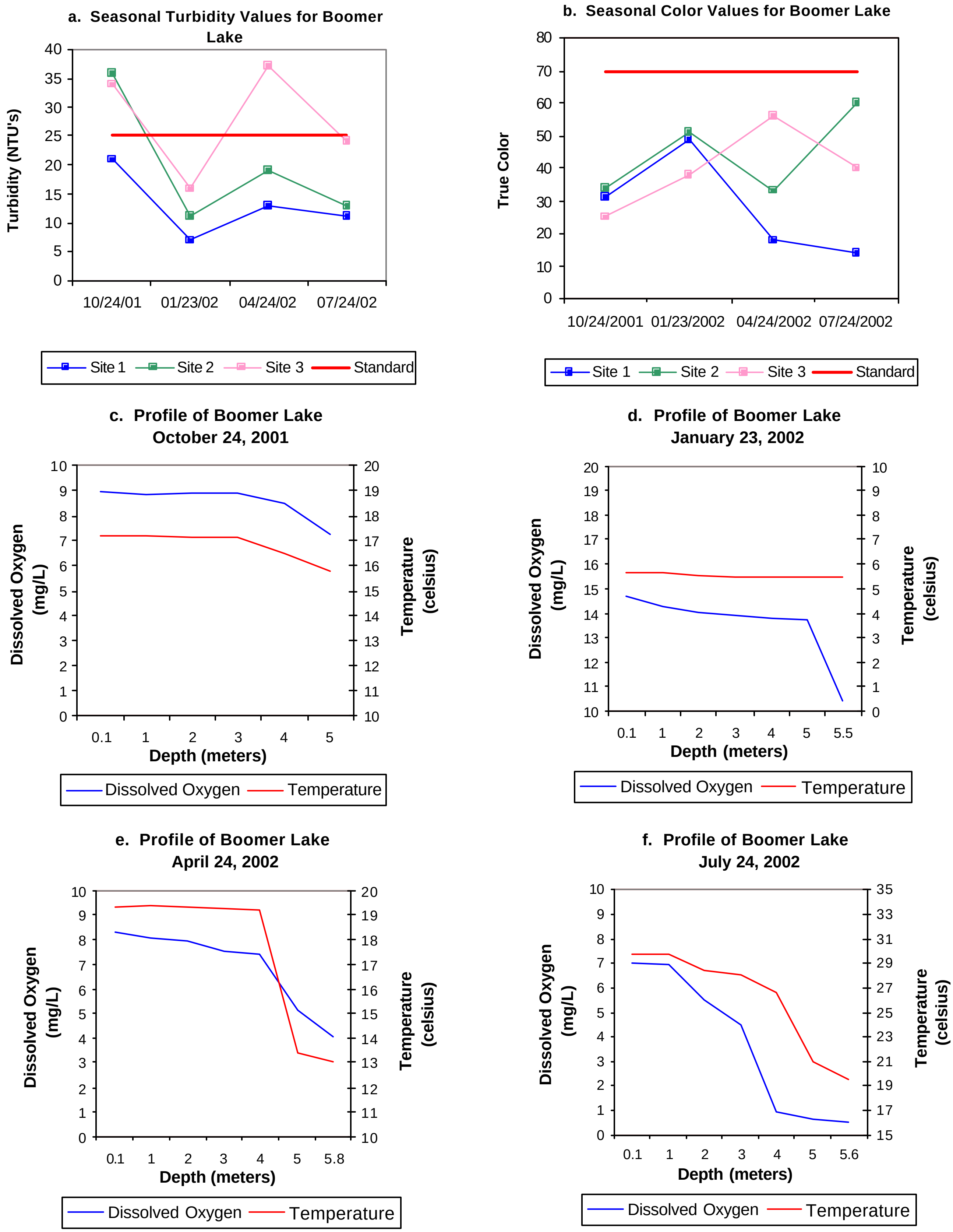



**Figure 31a-31f.** Graphical representation of data results for Boomer Lake.


| Lake Data | |
|---|---|
| Owner | City of Stillwater |
| County | Payne |
| Constructed in | 1932 |
| Surface Area | 260 acres |
| Volume | 3,200 acre/feet |
| Shoreline Length | 6 miles |
| Mean Depth | 12.31 feet |
| Watershed Area | 9 square miles |




Plate 10 - Lake Water Quality for
Boomer Lake

# Broken Bow Lake

Broken Bow Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at eight (8) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as the major arms and tributaries. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 2 nephelometric turbidity units (NTU) (Plate 11), true color was 9 units, and average secchi disk depth was 339 centimeters in sample year 2004. Water clarity was excellent based on the high secchi disk depth, low turbidity and true color values. Results for these parameters are similar to if not slightly better than that observed in 2000-2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=32). The TSI was 37, indicating the lake was oligotrophic during the study period. The TSI values for all sites throughout the sample year varied from oligotrophic to mesotrophic. According to seasonal observation, Broken Bow Lake is typically considered oligotrophic with mesotrophic conditions in the spring and summer at the upper end of the lake (sites 6,7 and 8). Seasonal turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, ranging from a low of 1 NTU to a high of 9 NTU (Figure 33a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Broken Bow Lake is considered fully supporting the Fish and Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 33b. All true color values were well below the aesthetics OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered supported.

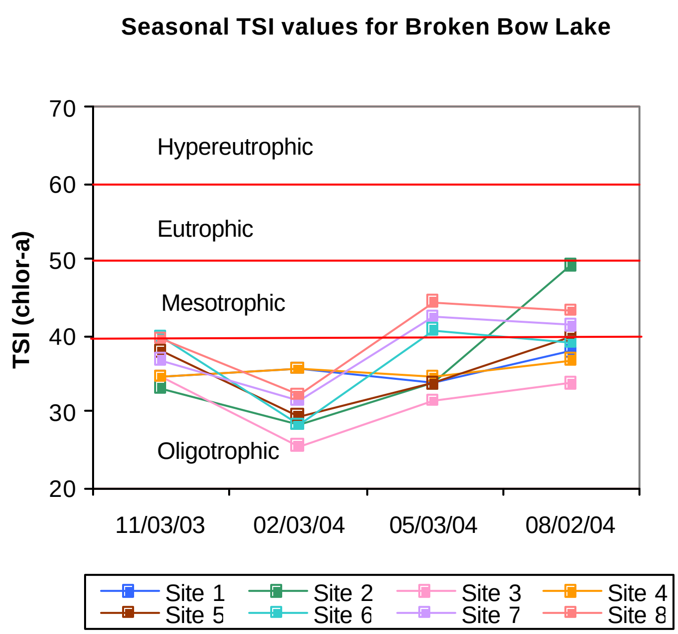



**Figure 32.** TSI values for Broken Bow Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.02 ppt. Specific conductivity values were also very low, ranging from 0 in the winter to 60.2mS/cm in the fall. The values recorded for both salinity and specific conductivity are much lower than that typically seen in Oklahoma lakes and reservoirs and are indicative of extremely low concentrations of electrical current conducting ions (salts or other chlorides) in Broken Bow Lake. Values for pH were slightly acidic to slightly alkaline, ranging from 5.84 in the hypolimnion in the spring to 8.65 near the surface in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 20% of the recorded values less than 6.5, Broken Bow Lake is partially supporting the FWP beneficial use. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (redox) ranged from 177 mV to 623 mV, indicating an absence of reducing conditions during the sample year. The lake was not thermally stratified in the winter or spring and the lake was well mixed with dissolved oxygen values at or above 6.0 mg/L throughout most of the water column (see Figure 33d-33e). In the fall quarter the lake was thermally stratified between 10 and 12 meters at various sites throughout the waterbody. Dissolved oxygen concentrations fell below 2.0 mg/L at different points among the sites and accounting for anywhere from 4 to 48% of the water column to be experiencing anoxic conditions. In the summer quarter, there was a metalimnetic oxygen deficit that occurred throughout the main body of the lake (site 1-6) between 9 and 14 meters below the surface (Figure 33f). Dissolved oxygen values were less than 2.0 mg/L with in this layer. It is not known at this time what causes this to occur and the lake should be studied further. In the upper most reaches of the lake (sites 7 and 8), thermal stratification occurred between 7 and 8 meters with D.O. falling to below 2.0 mg/L to the lake bottom of 26 and 28 meters, respectively. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered not supported at Broken Bow Lake with 73% of the water column at site 8 exhibiting anoxic conditions during the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. All collected values were at or below the detection limit, therefore the PBCR is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42mg/L at the surface. The TN at the surface ranged from 0.15 mg/L to 1.09 mg/L. Surface TN was highest in the spring, and summer quarters and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.011 mg/L at the surface. The TP ranged from 0.005 mg/L to 0.022 mg/L at the surface. Similar to total nitrogen, surface TP was highest in the spring and summer and lowest in the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 36:1 for 2003-2004. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Broken Bow Lake was classified as oligotrophic, indicative of low primary productivity and nutrient levels (Plate 11), consistent with 2001 sampling results (TSI=40). Water clarity continues to be excellent at this reservoir based on low turbidity and true color values and the high secchi disk depths. The lake is fully supporting its Aesthetics beneficial use for true color and trophic state. The lake is fully supporting its FWP beneficial use based on nephelometric turbidity and not supporting based on anoxic conditions present in the upper end of the reservoir during the summer quarter. With 20% of the recorded pH values less than 6.5, Broken Bow Lake is partially supporting the FWP beneficial use. Low pH values are commonly seen in Southeast Oklahoma and are likely due to natural causes. For this reason the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. All collected values were at or below the detection limit, therefore the PBCR is considered fully supported. Broken Bow lake was constructed by the USACE for flood control, hydroelectric power, water supply, recreation, and fish and wildlife purposes. This is truly one of the nicest lakes in the state.

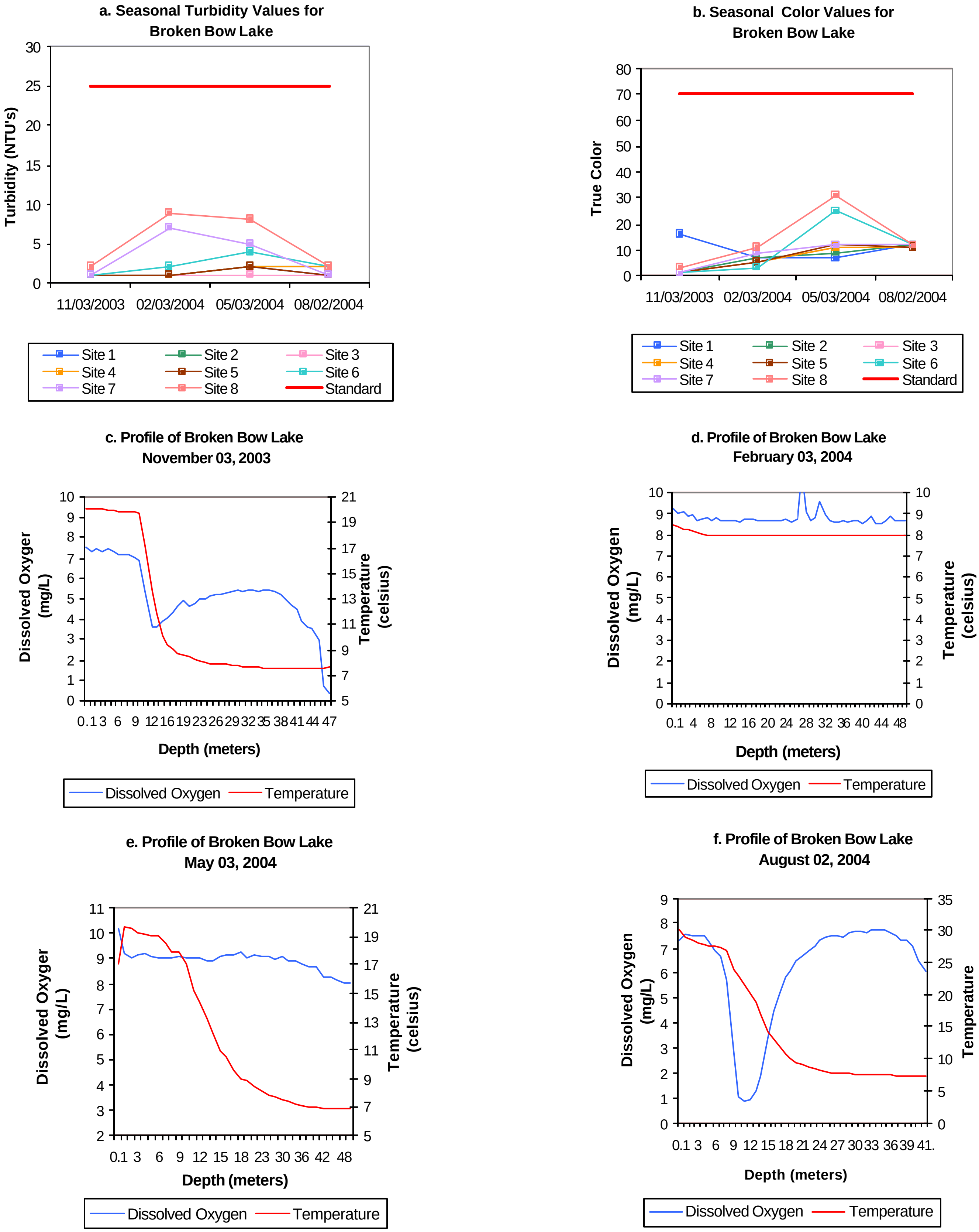



**Figure 33a-33f.** Graphical representation of data results for Broken Bow Lake.



Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | McCurtain |
| Constructed in | 1968 |
| Surface Area | 14,200 acres |
| Volume | 918,070 acre/feet |
| Shoreline Length | 180 miles |
| Mean Depth | 64.7 feet |
| Watershed Area | 754 square miles |



Plate 11 - Lake Water Quality for
Broken Bow Lake

# Brushy Creek Reservoir

Brushy Creek Reservoir was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, lacustrine zones of the lake. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 7 NTU (Plate 12), true color was 22 units, and average secchi disk depth was 112 centimeters in sample year 2004. Based on these three parameters water clarity was excellent. Results for these parameters were similar to the results found in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 51, indicating the lake was eutrophic, bordering mesotrophic, with moderate to high primary productivity and nutrient conditions. This is exactly the same classification as the 2000-2001 evaluation, indicating no significant increase or decrease in productivity has occurred over time. The TSI values throughout the sample year were primarily mesotrophic with the eutrophic values occurring in the fall and summer quarters (see Figure 34). Seasonal turbidity values are displayed in Figure 35a). Turbidity values ranged from 4-10 NTU, well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Brushy Creek Reservoir is considered fully supporting the Fish and Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 35b. All true color values were well below the aesthetics OWQS of 70 units although there was evident seasonal variability. Applying the same default protocol the Aesthetics beneficial use is considered supported.

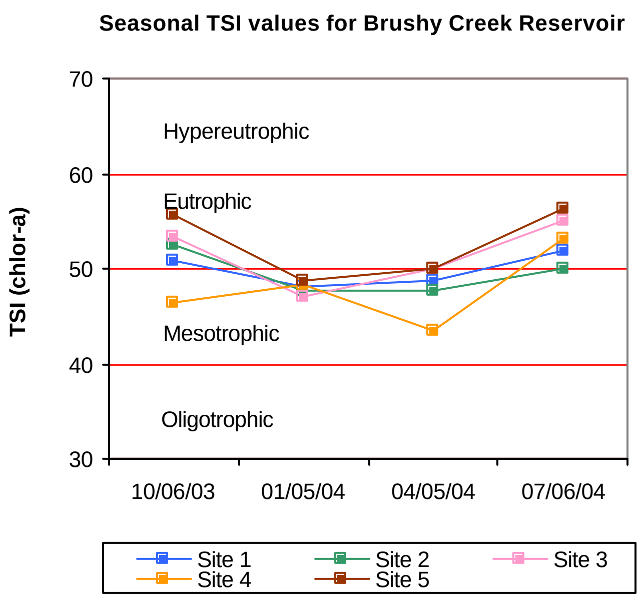



**Figure 34.** TSI values for Brushy Creek Reservoir.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.09ppt. Salinity concentrations were consistently lower than the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductance values were also lower than the expected range for Oklahoma reservoirs, indicating low levels of electrical current conducting compounds (i.e. salts) in the lake system. Values ranged from 18.7 mS/cm in the summer to 213.6 mS/cm in the fall. Lake pH values were slightly acidic to neutral, ranging from 6.11 to 7.73 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Brushy Creek Reservoir is partially supporting its FWP beneficial use as it relates to pH with 17% of the collected values falling outside the acceptable range. Oxidation-reduction potentials ranged from 332 mV to 600 mV, indicating reducing conditions were not present throughout the year. The lake was not thermally stratified in the winter and spring sampling quarters and the lake was well mixed with dissolved oxygen (D.O.) levels remaining above 5.3 mg/L (Figure 35d-35e). In both the fall and summer months thermal stratification was evident and anoxic conditions were present (see Figure 35c, 35f). In the fall, the lake was stratified between 5 and 6 meters in the depth at the three deepest sites (1,2, and 4). From 6 meters below the surface D.O. levels dipped down below 2.0 mg/L to the bottom of the lake. In the summer the lake was again stratified at the same sites; however the thermocline appeared further down, accounting for 35% of the a water column to be experiencing anoxic conditions at sites 1 and 4 (Figure 35f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is fully supported at Brushy Creek Reservoir based on D.O.. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected, 7 (70%) of the values exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (102.9) exceeds the prescribed geometric mean of 33 for enterococci. The PBCR is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.55 mg/L at the lake surface. The epilimnetic (surface) TN ranged from 0.40 mg/L to 0.69 mg/L. TN was highest in the winter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the lake surface. The TP ranged from 0.011 mg/L to 0.043 mg/L at the surface. TP was highest in the summer and lowest in the winter. The nitrogen to phosphorus ratio (TN:TP) was approximately 25:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Brushy Creek Reservoir is classified as eutrophic bordering mesotrophic, indicative of moderate to high primary productivity and nutrient conditions (Plate 12). The current TSI is exactly the same as that of previous monitoring efforts, indicating no change in productivity over time. Water clarity continues to be excellent based on the reported low turbidity and true color values. The Aesthetics beneficial use is being met based on trophic status and true color values (100%) below the numeric criteria of 70 units. The FWP beneficial use was found to be supporting for turbidity and dissolved oxygen; however was partially supporting based on pH values. Low pH values are not uncommon in this area of the state and are likely due to natural causes, therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected, 7 (70%) of the values exceeded the prescribed screening level of 61 cfu/ml and the geometric mean of 33 for enterococci. The PBCR is therefore considered not supported.

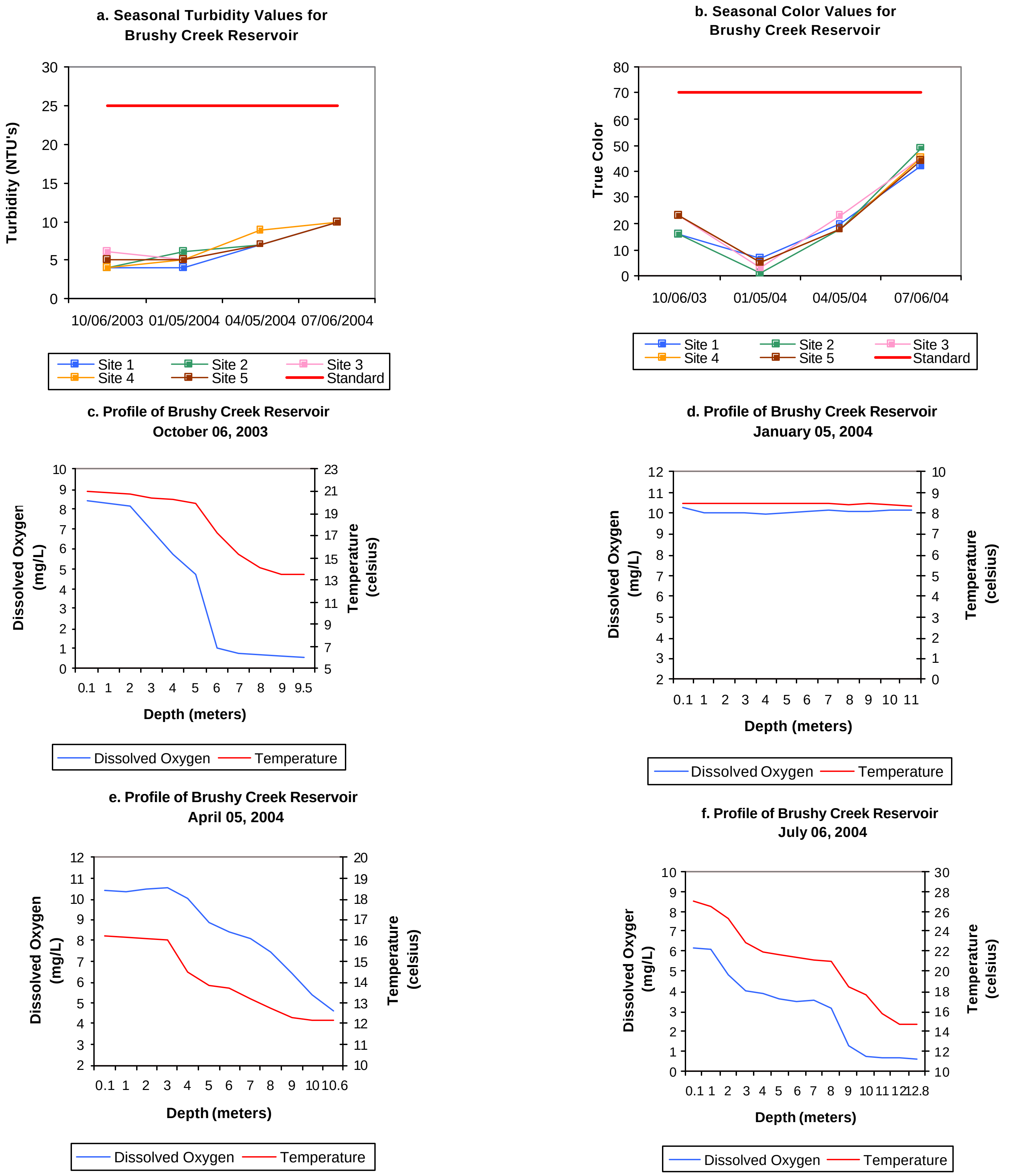
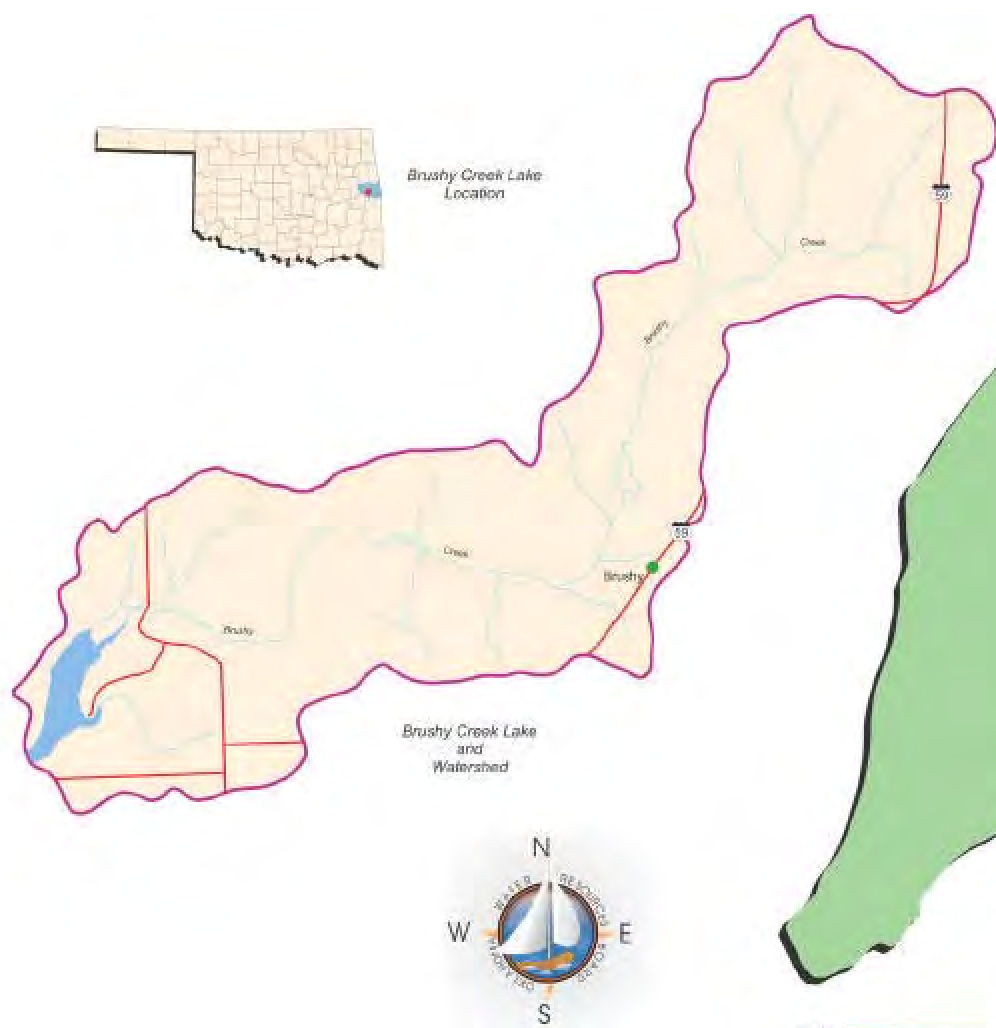
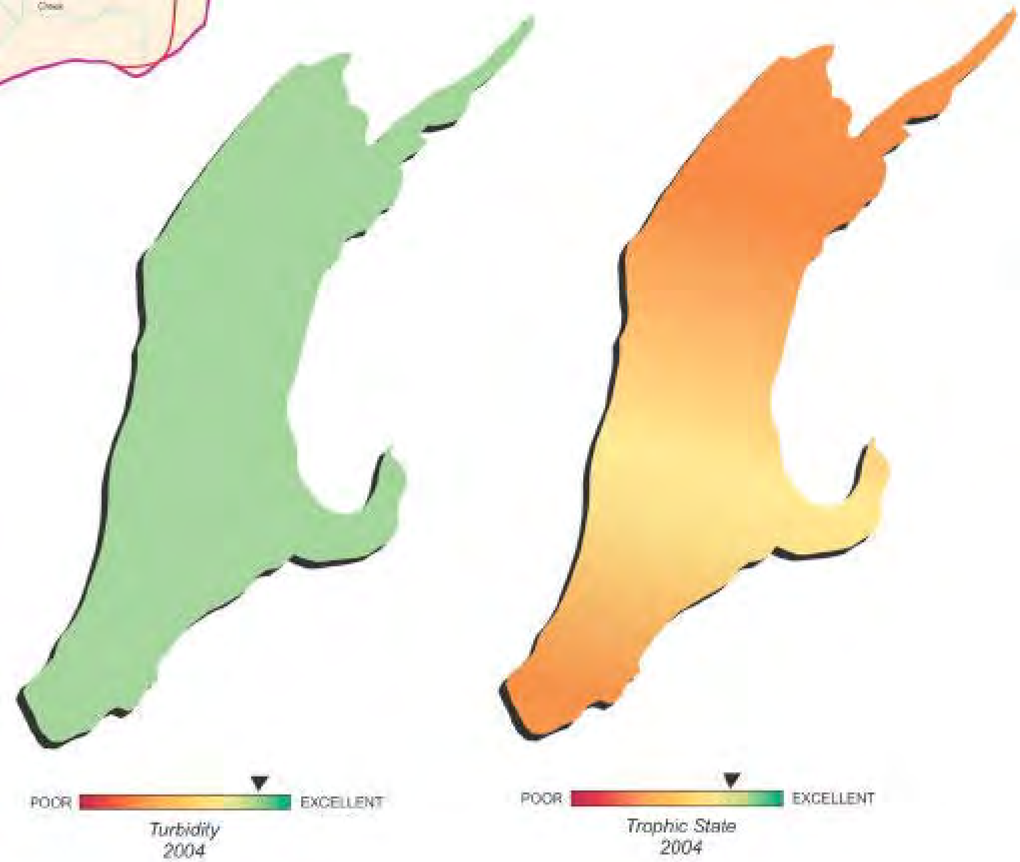



**Figure 35a-35f.** Graphical representation of data results for Brushy Creek Reservoir.




Lake Data

| | |
|---|---|
| Owner | Leased to State of Oklahoma |
| County | Sequoyah |
| Constructed in | 1964 |
| Surface Area | 358 acres |
| Volume | 3,258 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 9.10 feet |
| Watershed Area | 21 square miles |

Plate 12 - Lake Water Quality for
**Brushy Creek Lake**

# Lake Burtschi

Lake Burtschi was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and an additional sample was collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide turbidity value was 10 NTU (Plate 13), true color was 13 units, and average secchi disk depth was 101 centimeters. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. Results for these parameters were similar to historical data collection efforts in 2004. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI calculated was 56 (Plate 13), indicating the lake was eutrophic in sample year 2003-2004. The TSI values throughout the sample year varied seasonally from upper eutrophic in the fall to hypereutrophic in the winter and mesotrophic in the spring and summer sample quarters (Figure 36). Turbidity values per site were well below the OWQS of 25 NTU for all seasons with exception of site 2 in the summer (see Figure 37a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Based upon nephelometric turbidity concentrations Lake Burtschi was meeting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 37b. All true color values were below the Aesthetics Oklahoma Water Quality Standard (OWQS) of 70 units. Lake Burtschi was meeting its Aesthetics beneficial use related to true color. Although the lake water clarity is very good, the availability of light coupled with the shallow morphometry of the lake could be contributing greatly to the high primary productivity readily apparent in the lake.

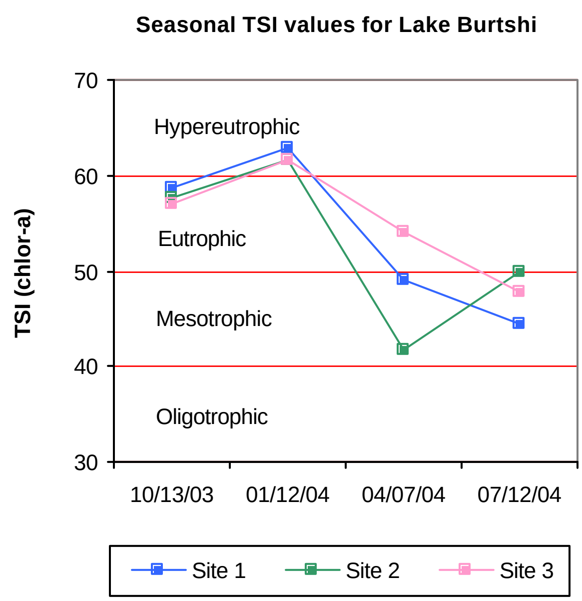



**Figure 36.** TSI values for Lake Burtschi.

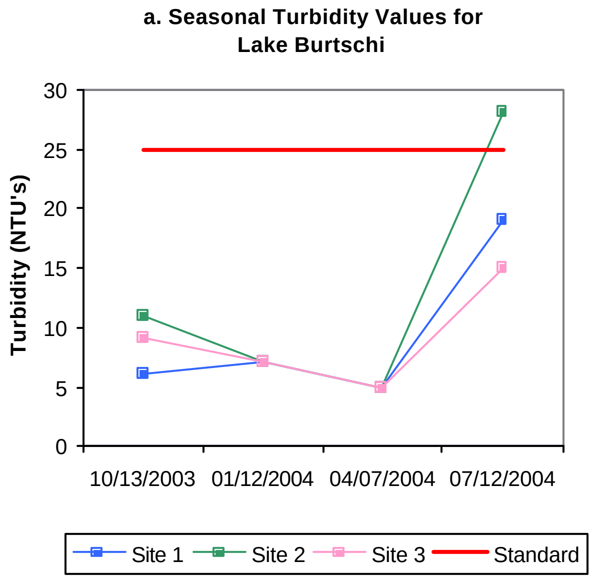
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.47 part per thousand (ppt) at all sites in the fall to 0.53 ppt recorded in the spring. Moderate salinity values in the water column indicate chlorides or salts were present in large concentrations in the lake system. Specific conductivity was also greater than most values recorded in Oklahoma reservoirs, indicating moderate to high levels of electrical current conducting compounds like salts present in the water column. Values ranged from 899 mS/cm in the fall of 2003 to 1030 mS/cm in the spring of 2004. Lake pH values were neutral to slightly alkaline, ranging from 7.15 to 8.73 units. According to the USAP outlined in (OAC) 785:46-15-5, pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for $\geq$25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With all values recorded within the acceptable range the lake is meeting the FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 25 to 512 mV recorded at site 1 in the summer. Reducing conditions were not present at the time of sampling. Low redox values in the hypolimnion are not uncommon when a lake is strongly thermally stratified and anoxic conditions are present. The lake was not thermally stratified in the winter; however stratification was evident the other three sampling intervals. (See Figure 37a-37f). In the fall and spring quarters, stratification occurred between the 5 and 6 meters below the surface with anoxic conditions only present in the hypolimnion. The lake was strongly thermally stratified in the summer between 4 and 5 meters at which point dissolved oxygen (D.O.) concentrations fell below 1.0 mg/L (see Figure 37f). Although D.O. concentrations were less than 2.0 mg/L below 5 meters to the lake bottom at 8.2 meters (about 27% of the water column), at site 1, this is not sufficient to result in listing the lake as not supporting it's FWP beneficial use. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lake Burtschi. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

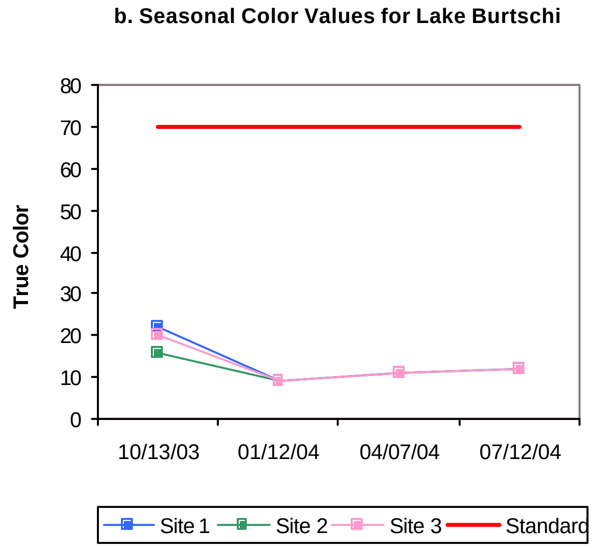
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected, four (40%) of the values exceeded the prescribed screening level of 61 cfu/ml and the geometric mean of 33 for enterococci. The PBCR is therefore considered not supported.

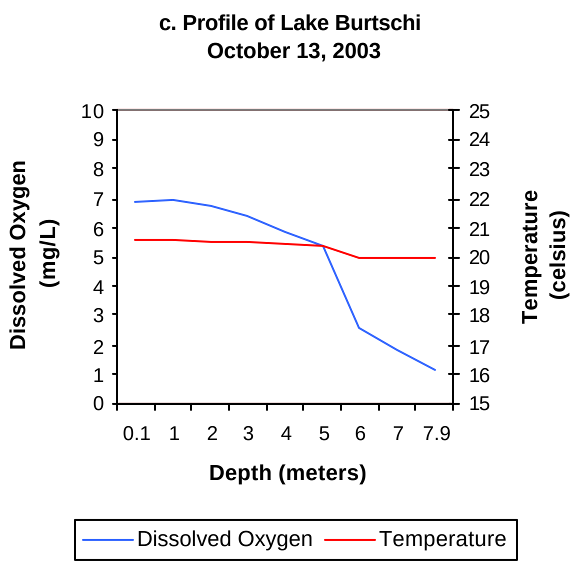
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.98 mg/L at the surface and 1.14 mg/L at the lake bottom, which is a relatively high value when compared to other lakes across the state. The TN at the surface ranged from 0.69 mg/L to 1.37 mg/L. Surface TN was highest in the fall, winter, and summer quarters and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.036 mg/L at the surface and 0.045 mg/L at the lake bottom. The TP ranged from 0.028 mg/L to 0.042 mg/L at the surface. Surface TP was highest in the winter and spring and lowest in the summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 27:1 for 2003-2004. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

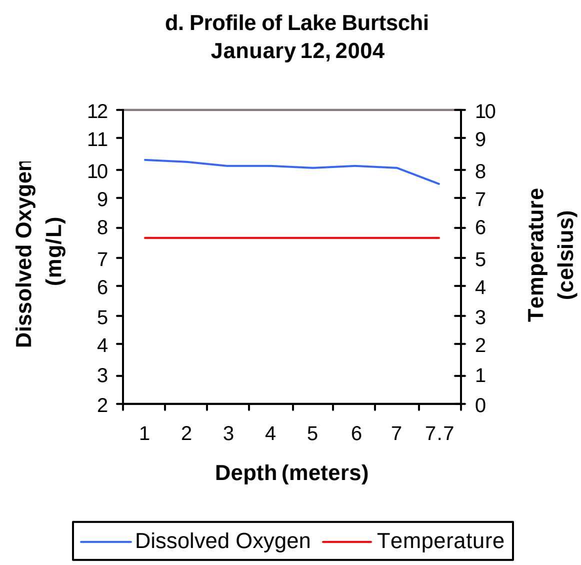
In summary, Lake Burtschi was classified as eutrophic in nature, indicative of high to excessive primary productivity and nutrient rich conditions (Plate 13). The lake is fully supporting its Aesthetics beneficial use for true color and trophic state. Lake Burtschi is fully supporting its FWP beneficial use based on D.O., pH and nephelometric turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use Of the ten samples collected, four (40%) of the values exceeded the prescribed screening level of

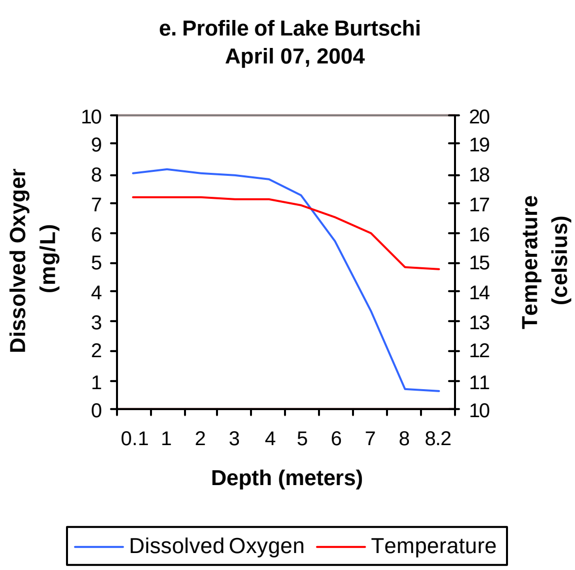
61 cfu/ml and the geometric mean of 33 for enterococci. The PBCR is therefore considered not supported. The State of Oklahoma via the Oklahoma Department of Wildlife Conservation (ODWC) constructed Lake Burtschi in 1954 for the express purpose of promoting recreational activities, primarily fishing. The lake is managed by the ODWC specifically for the purpose of promoting angling activities.



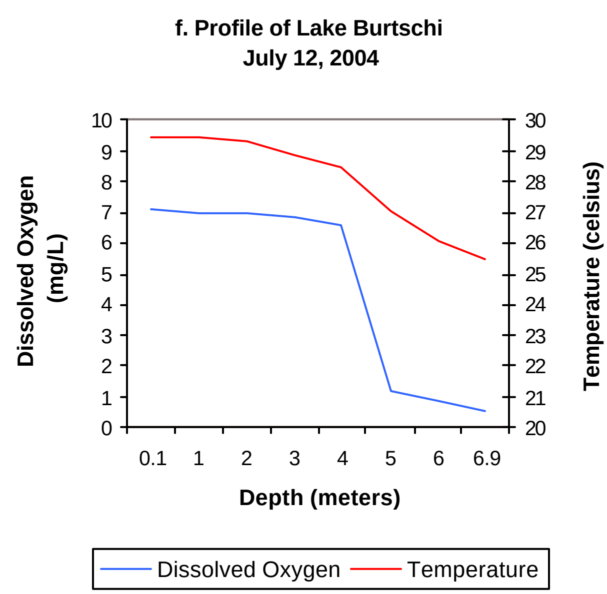
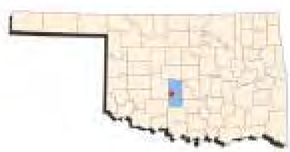
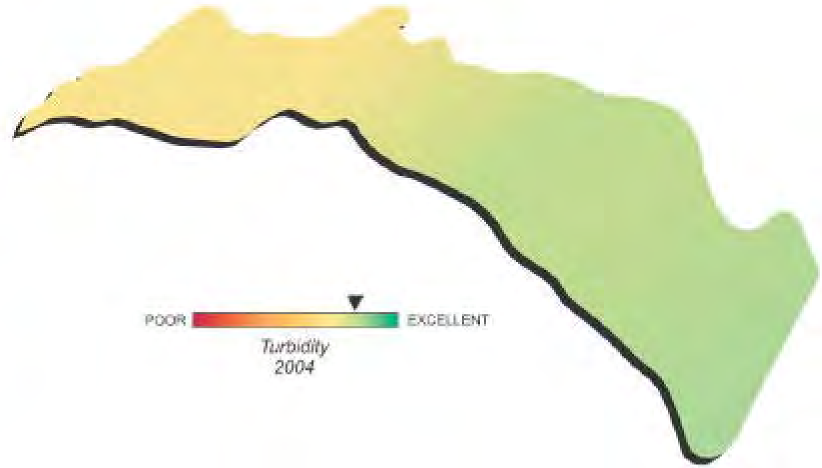




**Figure 37a-37f.** Graphical representation of data results for Lake Burtschi.

Burtschi Lake
and
Watershed


Burtschi Lake
Location

| Lake Data | |
|---|---|
| Owner | State of Oklahoma |
| County | Grady |
| Constructed in | 1954 |
| Surface Area | 180 acres |
| Volume | 2,140 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 11.89 feet |
| Watershed Area | 4,692 acres |



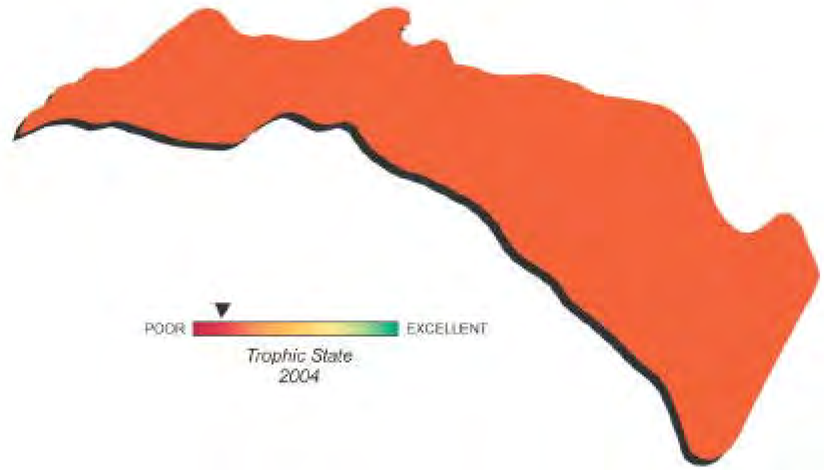




Plate 13 - Lake Water Quality for
## Burtschi Lake

# Canton Lake

Canton Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Water chemistry samples were collected from the lake surface at all sites and with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 31 NTU (Plate 14), true color was 35 units, and secchi disk depth was 30 centimeters. Water clarity was fair to poor based on secchi disk depth, turbidity, and true color values and results for these parameters were similar to that in 2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was calculated at 55 (Plate 14), indicative of high primary productivity and nutrient rich conditions. This is exactly the same result as previous data collection efforts, indicating no significant change in productivity has occurred. The TSI values throughout the sample year varied seasonally from eutrophic in the fall and winter to mesotrophic in the spring and upper eutrophy bordering hypereutrophic in the summer (Figure 38). Turbidity values varied by site and were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons except for the spring quarter with 65% of the values recorded exceeding the OWQS (see Figure 39a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Canton lake is currently not supporting is Fish & Wildlife Propagation (FWP) beneficial use based on high turbidity values recorded for the reservoir. Seasonal true color values are displayed in Figure 39b. All true color values were below the Aesthetics OWQS of 70 units, with highest values reported in the fall. Applying the same default protocol to determine the average for true color, the Aesthetics beneficial use is supported.

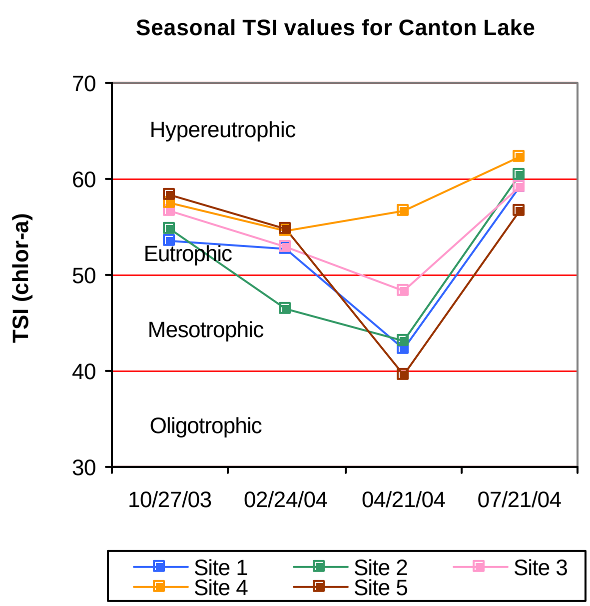



**Figure 38.** TSI values for Canton Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.74 parts per thousand (ppt) in the summer to 0.80ppt in the winter and spring. Salinity concentrations were consistently elevated above the range of expected values for Oklahoma lakes, reflecting the moderate to high presence of chlorides or other salts in the lake. Specific conductance values were also higher than the expected range for Oklahoma reservoirs, indicating a high level of electrical current conducting compounds (i.e. salts). Values ranged from 1423 mS/cm in the summer to 1514 mS/cm in the winter. Lake pH values were neutral to moderately alkaline, ranging from 7.39 to 8.36 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Canton Lake is supporting its FWP beneficial use as it relates to pH with 100% of the collected values falling within the acceptable range. Oxidation-reduction potentials ranged from 327 mV in the summer to 571 mV in the winter, indicating reducing conditions were not present throughout the year. The lake was not stratified at any point during the sample year indicating the lake was well mixed. Dissolved oxygen (D.O.) concentrations were above 5.0 mg/L throughout the water column and were generally above 6.0 mg/L for most of the sample year (see Figure 39c-39f). According to the Use Support Assessment Protocols (USAP), if D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is fully supported at Canton Lake based on D.O. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected all of the values were within the prescribed screening level and the geometric mean for each was met. The PBCR is therefore considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) was 0.85 mg/L at the lake surface and 0.77 mg/L at the lake bottom. The epilimnetic (surface) TN ranged from 0.69 mg/L to 1.39 mg/L. TN was highest at site 4 in the fall. The lake-wide total phosphorus (TP) average was 0.066 mg/L at the lake surface and 0.061 mg/L at the lake bottom. The TP ranged from 0.044 mg/L to 0.101 mg/L at the surface. TP was both highest and lowest in the spring at the surface. The nitrogen to phosphorus ratio (TN:TP) was approximately 13:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Canton Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 14). The trophic status of the reservoir fluctuated greatly depending on the quarter sampled, but was primarily eutrophic. Water clarity was poor and the lake was not supporting its FWP beneficial use based upon collected turbidity values. The lake is supporting its FWP beneficial use based on pH and D.O. concentrations. The lake was fully supporting its Aesthetics beneficial use for both trophic state and true color. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected all of the values were within the prescribed screening level and the geometric mean for each was met. The PBCR is therefore considered fully supported. The United States Army Corps of Engineers constructed Canton Lake in 1948 to serve as a flood control, water supply and irrigation reservoir. The lake also serves as a municipal water supply reservoir for the City of Oklahoma City, which pays to have water released from the lake for water supply purposes when necessary.

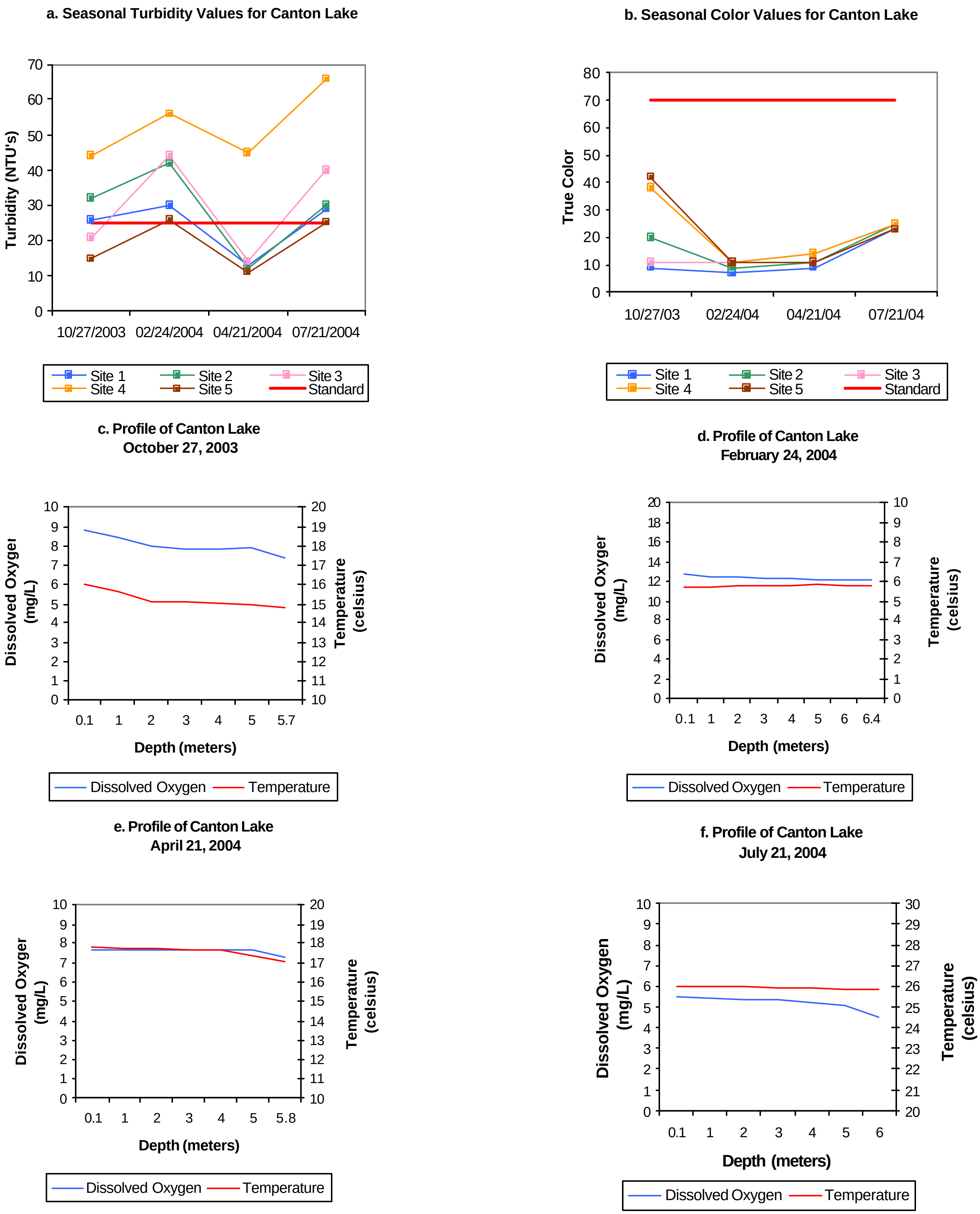
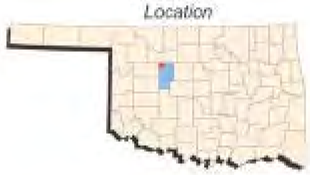


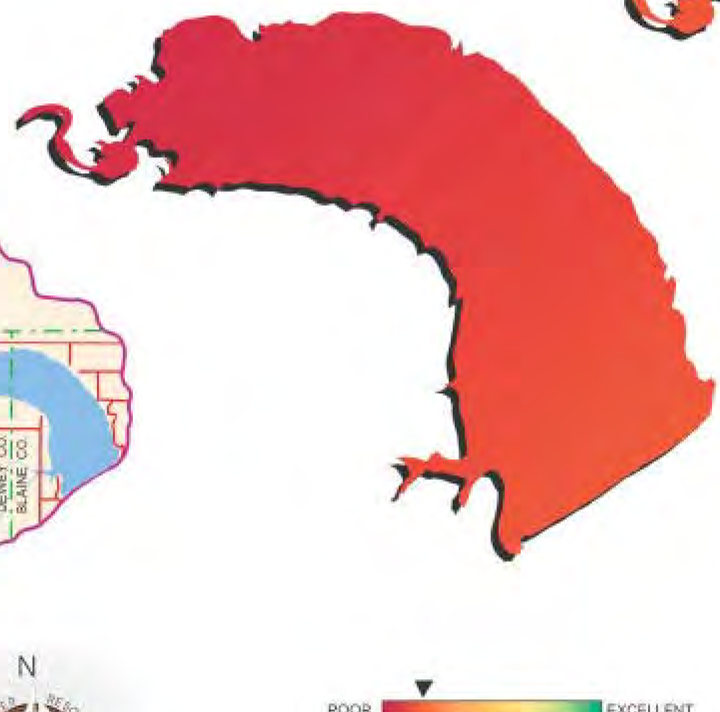

**Figure 39a-39f.** Graphical representation of data results for Canton Lake.



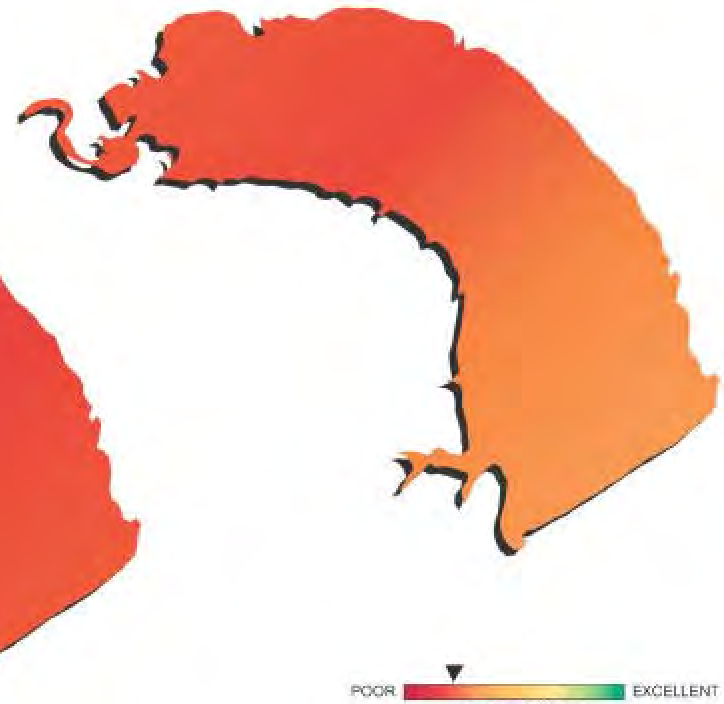
Canton Lake Location


Canton Lake and Watershed

| Lake Data | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Blaine |
| Constructed in | 1948 |
| Surface Area | 7,910 acres |
| Volume | 111,310 acre/feet |
| Shoreline Length | 45 miles |
| Mean Depth | 14.99 feet |
| Watershed Area | 12,483 square miles |




Turbidity 2004




Trophic State 2004

Plate 14 - Lake Water Quality for
## Canton Lake

# Carl Albert Lake

Carl Albert Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at three sites to represent the riverine, transitional, and lacustrine zones. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 7 NTU (Plate 15), true color was 31 units, and average secchi disk depth was 127 centimeters. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. Results for these parameters were slightly better than the results found in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 41 (Plate 15), indicating the lake was mesotrophic, bordering oligotrophic, indicative of low to moderate primary productivity and nutrient conditions in sample year 2004. The TSI in 2001 was also 41, indicating no significant increase or decrease has occurred since previous data collection efforts. The TSI values at all sites were oligotrophic in the fall and winter with mesotrophic values in the spring and summer (see Figure 40). Turbidity values were fairly consistent among sites with values ranging from 4 to 10 NTU (Figure 41a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Carl Albert Lake is currently supporting its Fish & Wildlife Propagation (FWP) beneficial use with 100% of values recorded for the reservoir well below the prescribed numeric criteria. Seasonal true color values are displayed in Figure 41b. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered supported.

In 2003-2004, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all three-sample sites during the study period. Salinity ranged from 0.0 to 0.02 parts per thousand (ppt), which is within the range, if not lower than values, recorded for most Oklahoma reservoirs. Specific conductance ranged from 20.9 mS/cm to 58.6 mS/cm, indicative of low levels of current conducting ionic compounds (or other analogous materials) in the lake. The pH values were neutral to slightly acidic ranging from 6.33 to 7.74 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting

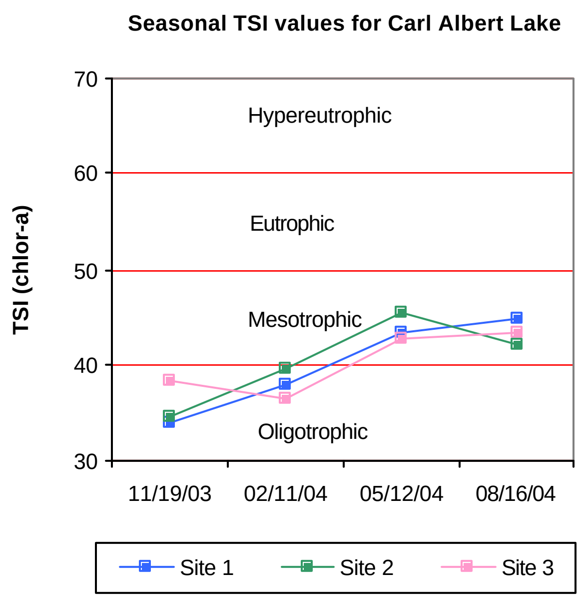



**Figure 40.** TSI values for Carl Albert Lake.

its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only 3.6% of the recorded values falling outside the acceptable range the FWP beneficial use is supporting based on pH concentrations. Low pH values are commonly seen in S.E. Oklahoma lakes and reservoirs and may be due to natural causes. Continued monitoring should be conducted to determine if impairment due to pH exists. Oxidation-reduction potentials (redox) ranged from -17mV in the summer to 523 mV in the winter. Reducing conditions were present in the summer near the bottom at site 1,which could result in the release of nutrients into the water column where they become available for biotic uptake. Low redox values in the hypolimnion are not uncommon when the lake is strongly thermally stratified and anoxic conditions are present. The lake was not thermally stratified in the fall or winter and dissolved oxygen (D.O.) concentrations were well above 6.0 mg/L throughout the water column (See Figure 41c-41d). In the spring the lake was thermally stratified between 4 and 5 meters below the surface, with the D.O. concentrations less than 2.0 mg/L for approximately 46% of the water column at site 1 (see Figure 41e). During the summer interval the lake was strongly thermally stratified between 3-4 meters with D.O. dropping below 1.0 mg/L to the lake bottom of 11.5 meters (Figure 41f). Site 2 also exhibited thermal stratification; however dissolved oxygen remained above 2.0 mg/L throughout out the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the lake is supporting its FWP beneficial use with only 46-69% of the water column in the spring and summer sampling intervals less than the proscribed 2.0-mg/L water quality standard. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected all of the values were within the prescribed screening level and the geometric mean for each was met. The PBCR is therefore considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.25 mg/L at the lake surface and 0.51mg/L at the lake bottom. The epilimnetic (surface) TN ranged from 0.08 mg/L to 0.41 mg/L. TN was highest at in the spring and lowest in the winter quarter. The lake-wide total phosphorus (TP) average was 0.017 mg/L for the lake surface and 0.057 mg/L at the lake bottom. The TP ranged from 0.014 mg/L to 0.026 mg/L at the lake surface. TP was highest in the winter and lowest in the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 15:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Carl Albert Lake was classified as mesotrophic, bordering oligotrophic, indicating low to moderate primary productivity and nutrient levels (Plate 15). The calculated TSI is exactly the same as that in 2001, indicating no change in productivity has occurred over time. Based on turbidity, true color, and high secchi disk depth, water clarity is excellent for this lake. The FWP beneficial use is currently fully supported for turbidity, pH, and dissolved oxygen values recorded during the study period. Carl Albert Lake is also supporting the Aesthetic use based on trophic status and all true color values reported below the numeric criteria of 70 units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected all of the values were within the prescribed screening level and the geometric mean for each was met. The PBCR is therefore considered fully supported. Located in Latimer County, Carl Albert Lake was constructed in 1964 for the purpose of water supply, flood control and recreation.

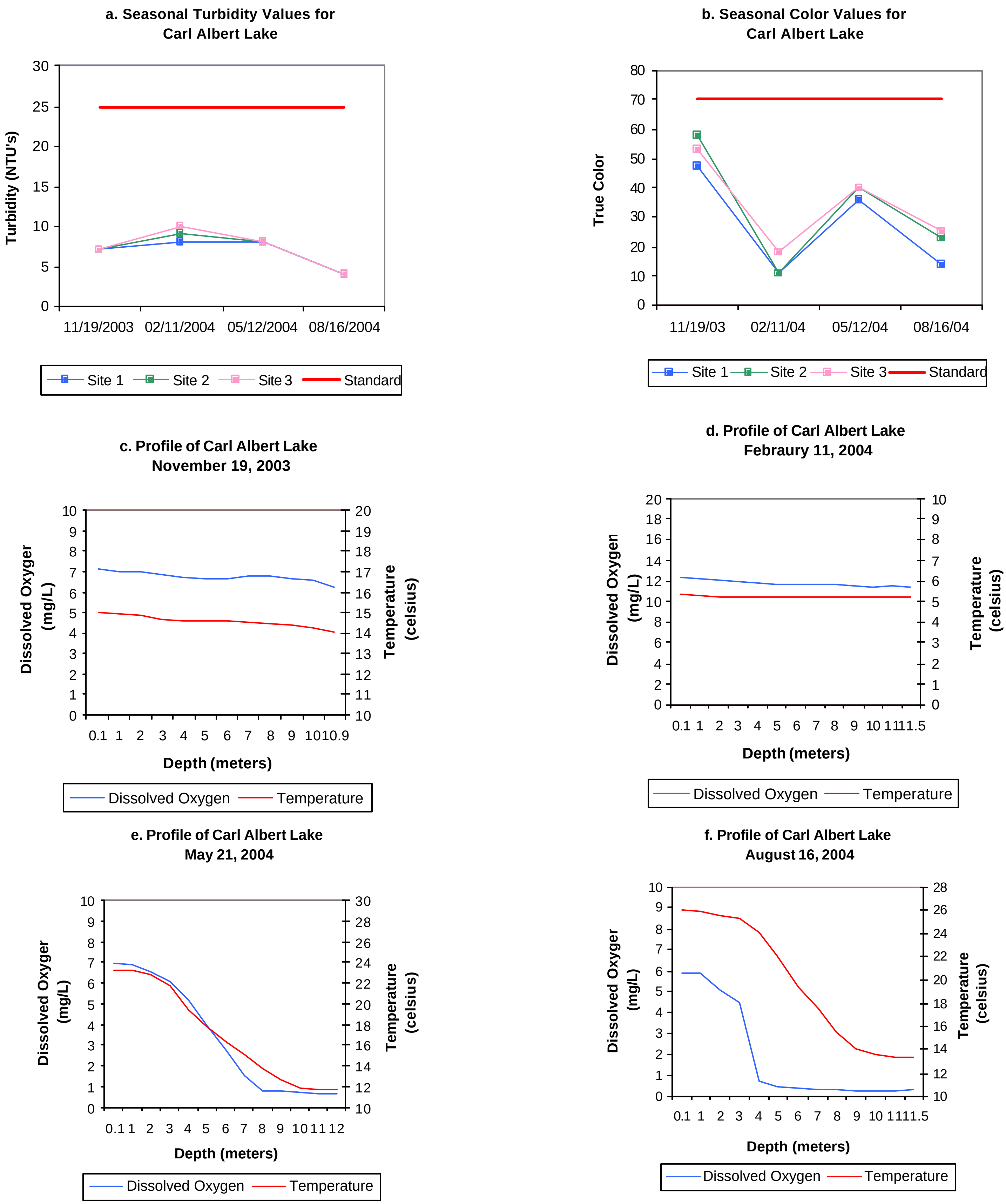
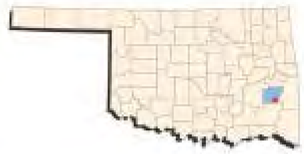
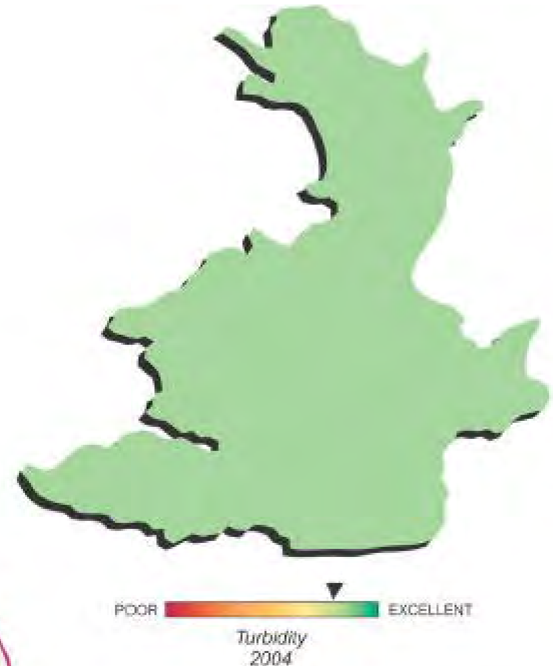



**Figure 41a-41f.** Graphical representation of data results for Carl Albert Lake.







Lake Data

| | |
|---|---|
| Owner | City of Talihina |
| County | Latimer |
| Constructed in | 1964 |
| Surface Area | 183 acres |
| Volume | 2,739 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 14.97 feet |
| Watershed Area | 3850 acres |

Plate 15 - Lake Water Quality for
## Carl Albert Lake

# Lake Carl Blackwell

Lake Carl Blackwell was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as major arms. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 20 NTU (Plate 16), true color was 29 units, and secchi disk depth was 61 centimeters in 2001-2002. Based on these three parameters, Lake Carl Blackwell had good to fair water clarity. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The calculated TSI was 55 (Plate 16), indicating the lake was eutrophic in sample year 2001-2002. The TSI values throughout the sample year didn't vary seasonally with almost all calculations in the eutrophic range with just a couple of instances where the lake was mesotrophic or at the border of hypereutrophy (Figure 42). Of the turbidity values collected, 75% were below the turbidity standard of 25 NTU and 25% exceeded the turbidity standard for lakes (see Figure 43a). According to the Use support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is considered not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on 25% of the collected turbidity data exceeding the criteria. Seasonal true color values are displayed in Figure 43b. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol to determine the average for true color the Aesthetics beneficial use is supported.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all three sample sites during the study period. Salinity ranged from 0.16 to 0.20 parts per thousand (ppt), which was consistent with values, recorded most Oklahoma reservoirs. Specific conductance ranged from 334.2 mS/cm to 413.0 mS/cm, which was also consistent with numbers seen for most Oklahoma lakes, indicative of low to moderate levels of current conducting ionic compounds (or other analogous materials) in the lake. The pH values at Lake Carl Blackwell were slightly alkaline ranging from 8.18 to 8.74 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Lake Carl Blackwell is fully supporting its FWP beneficial use based on pH concentrations recorded during the study period. Oxidation-reduction potentials (redox) ranged from –15 mV in the summer to 457 mV in the fall, which indicated an absence of reducing conditions with the exception of sites 1 and 5 in the summer quarter. The lake was not thermally stratified in the fall, winter or spring and

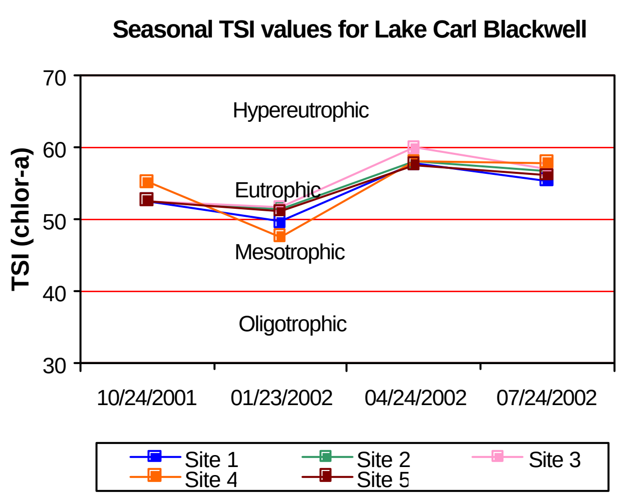



**Figure 42.** TSI values for Lake Carl Blackwell.

dissolved oxygen (D.O.) concentrations were well above 6.0 mg/L throughout the water column except at the lake bottom (see Figure 43c-43e). In the summer, the lake was strongly thermally stratified between 6 and 7 meters, where the D.O. concentration fell to 1.0 mg/L or less as you moved down the water column (see Figure 43f). Anoxic conditions were not present at sites 2, 3, or 4 during the summer probably because they were all 5 meters or less in depth. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the lake is partially supporting its FWP beneficial use with 57% of the water column in the summer less than the proscribed 2.0-mg/L water quality standard. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.60 mg/L at the lake surface. The epilimnetic (surface) TN ranged from 0.32 mg/L to 0.74 mg/L. TN was highest at site 4 in the summer and lowest in the fall at site 2. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.034 mg/L for the lake surface. The TP ranged from 0.022 mg/L to 0.069 mg/L at the lake surface. TP was highest in the fall at site 4 and lowest in the winter at site 2. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Carl Blackwell was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1997 as part of their Toxics Monitoring Program and detected no compounds at the FDA Action level, ODEQ warning level or ODEQ concern level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Carl Blackwell was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 16). Water clarity was average to fair and the Aesthetics beneficial use was fully supported based on current true color data. The lake is also supporting its Aesthetics use based on its trophic status. The FWP beneficial use is fully supported based on current turbidity and pH data. D.O. conditions in the summer were sufficient to cause the FWP beneficial use to only be partially supporting. Lake Carl Blackwell is owned and managed by Oklahoma State University and the State of Oklahoma. The lake is managed as a municipal water supply and source of recreational activities.

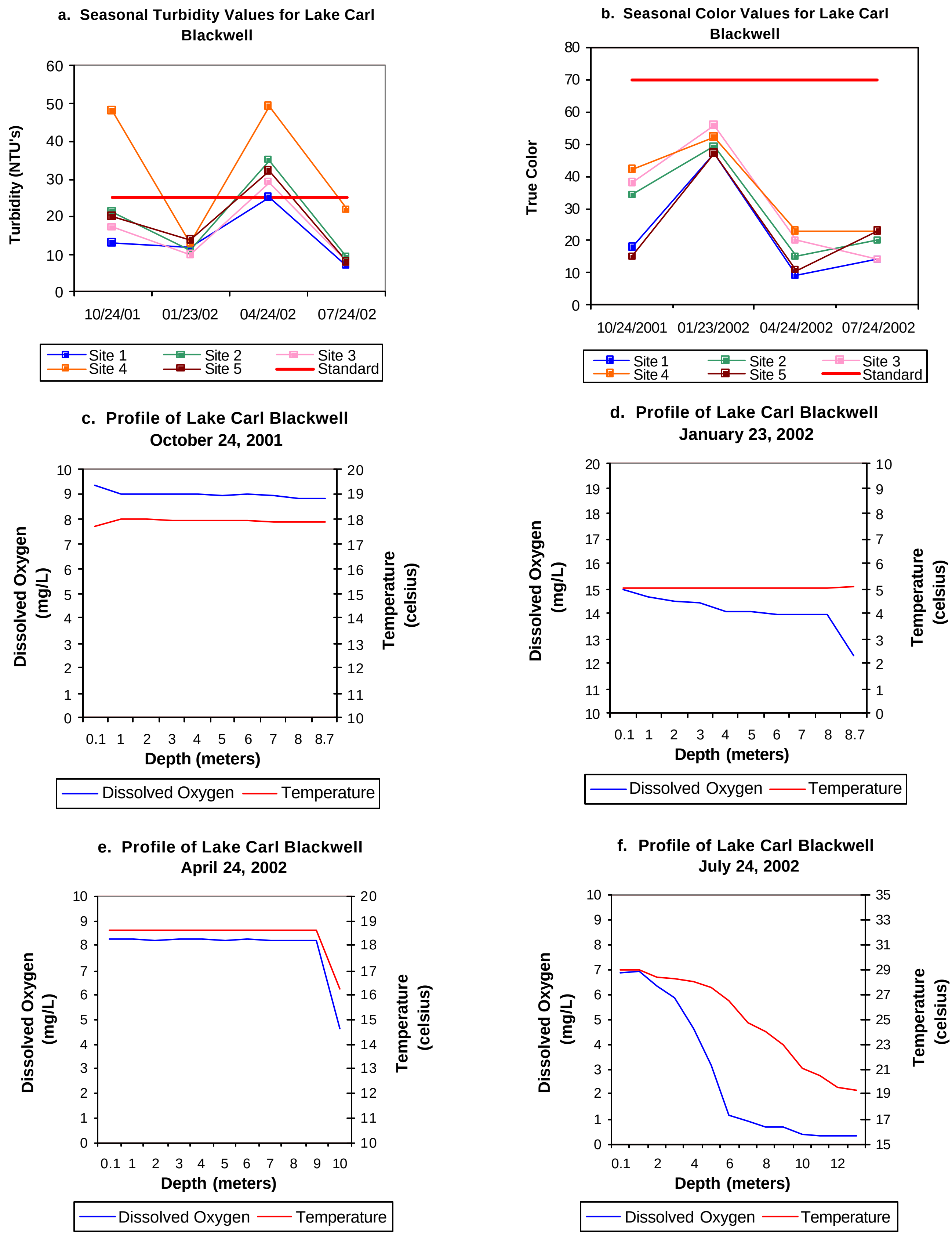
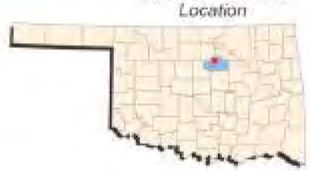
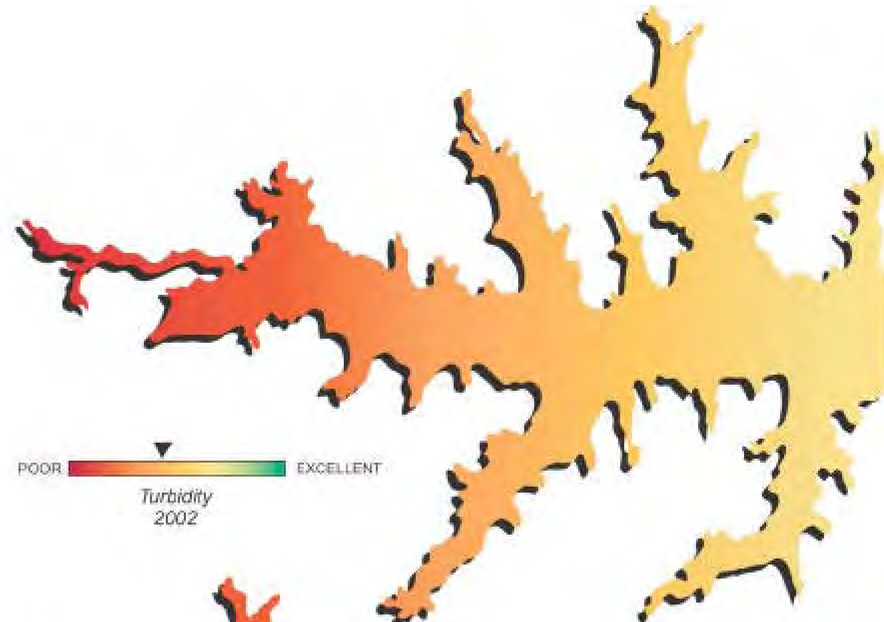
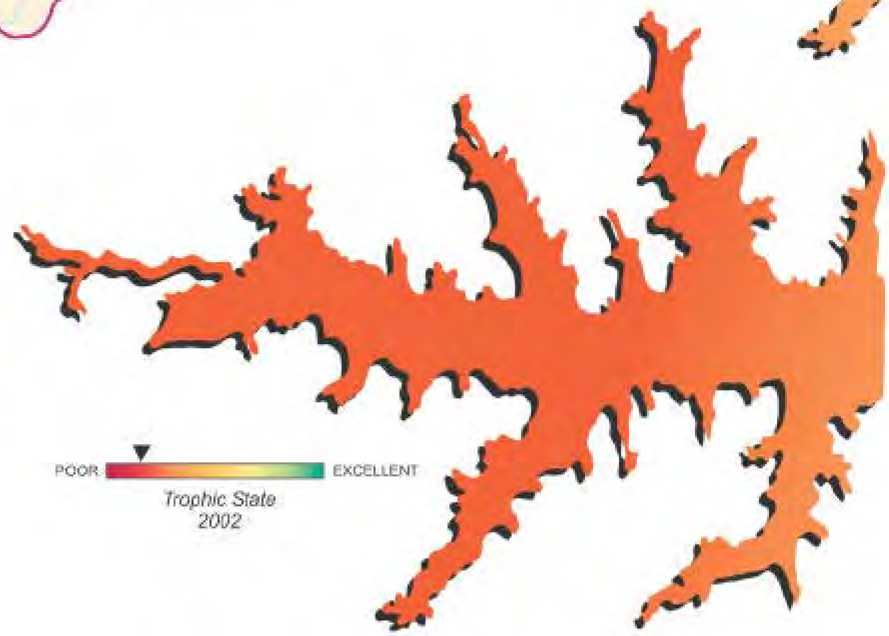



**Figure 43a-43f.** Graphical representation of data results for Lake Carl Blackwell.






Lake Data

| | |
|---|---|
| Owner | Oklahoma State University |
| County | Payne |
| Constructed in | 1937 |
| Surface Area | 3,370 acres |
| Volume | 61,500 acre/feet |
| Shoreline Length | 58 miles |
| Mean Depth | 18.25 feet |
| Watershed Area | 49,278 square miles |

Plate 16 - Lake Water Quality for
Lake Carl Blackwell

# Carter Lake

Carter Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and as well as 0.5 meters from the lake bottom at site 1, the dam. The lake-wide turbidity value was 8 NTU (Plate 17), true color was 15 units, and average secchi disk depth was 108 centimeters. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 40, indicating the lake was oligotrophic bordering mesotrophic with low primary productivity and nutrient conditions in sample year 2004. This value is less than that reported in 2001 (TSI=44); however it is likely a more accurate depiction of lake productivity as it is based on four seasons of data versus three in the previous evaluation. The TSI values throughout the sample year were primarily oligotrophic with mesotrophic values at all sites in the spring and site 3 during the summer (Figure 44). Seasonal turbidity values per site for the sample year were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons and are displayed in Figure 45a. According to the Use support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use with 100% of the collected turbidity data below the criteria. Seasonal true color values are displayed in Figure 45b. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol to determine the average for true color the Aesthetics beneficial use is supported.

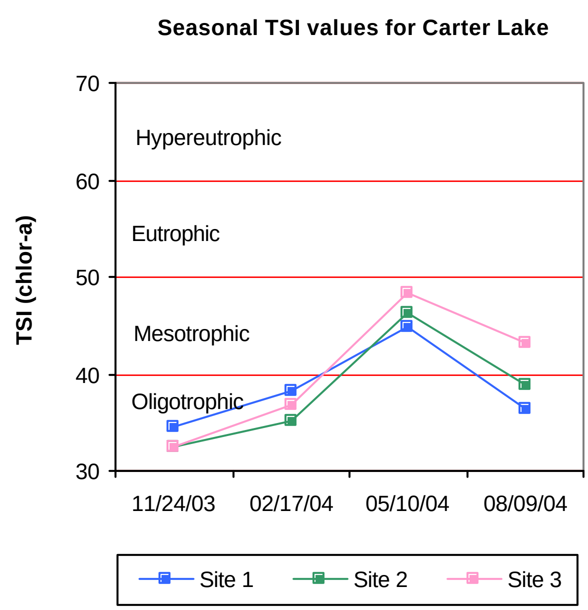



**Figure 44.** TSI values for Carter Lake.

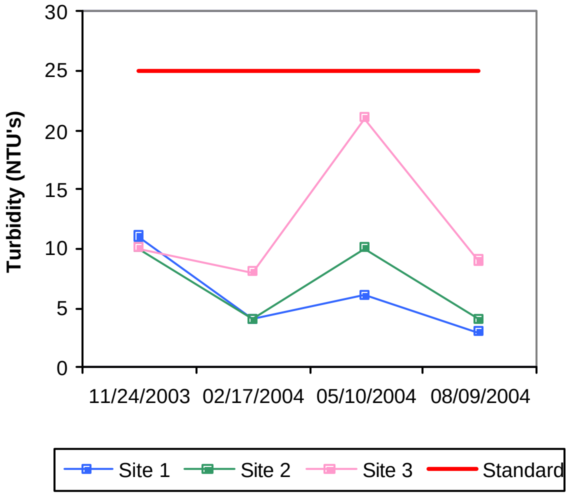
In 2003-2004, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all three-sample sites during the study period. Salinity ranged from 0.09 to 0.11 parts per thousand (ppt) well within the range of values recorded for most Oklahoma reservoirs. Specific conductance ranged from 189.1 mS/cm to 239.4 mS/cm, indicative of low levels of current conducting ionic compounds (or other analogous materials) in the lake. The pH values were neutral to slightly alkaline ranging from 7.22 to 8.28 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Carter Lake is supporting the FWP beneficial use based on pH values recorded during the study period. Oxidation-reduction potential (redox) ranged from 336 mV to 462 mV, indicating that reducing conditions were not present in the lake. Thermal stratification was not present in the fall or winter and dissolved oxygen (D.O.) concentrations were well above 7.0 mg/L throughout the water column (See Figure 45c-45d). In the both spring and summer, the lake was thermally stratified between 4 and 5 meters, with the D.O. concentrations less than 2.0 mg/L for approximately 1 meter of the water column above the lake bottom (see Figure 45-45f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the lake is supporting its FWP beneficial use with only 12-14% of the water column in the spring and summer sampling intervals less than the prescribed 2.0 mg/L water quality standard. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. The PBCR is considered supported for sample year 2003-2004.

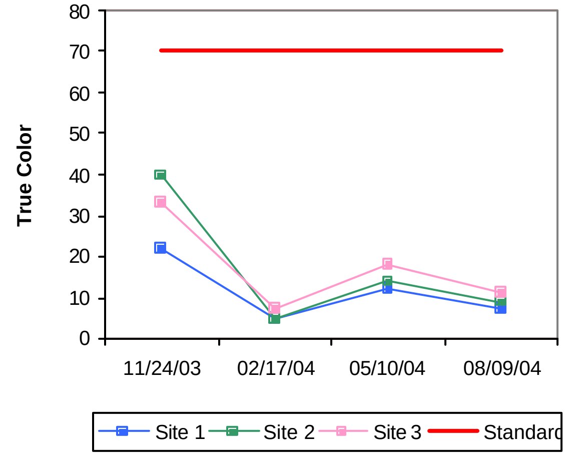
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.50 mg/L at the lake surface and 0.54 mg/L at the lake bottom. The epilimnetic (surface) TN ranged from 0.31 mg/L to 0.68 mg/L. TN was highest in the spring and lowest in the fall quarter. The lake-wide total phosphorus (TP) average was 0.015 mg/L for the lake surface and 0.014 at the lake bottom. The TP ranged from 0.011 mg/L to 0.021 mg/L at the lake surface. TP was highest and lowest values occurred in the spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 34:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Carter Lake was classified as oligotrophic bordering mesotrophic, indicative of low to moderate levels of primary productivity and nutrient conditions (Plate 17). This classification is lower than that of 2001 (TSI=44); however is likely more accurate as it is based on a full year of data versus only three sampling intervals as in the previous evaluation. Water clarity is excellent based on turbidity, true color, and secchi disk depth. The FWP beneficial use is being met as it relates to turbidity, pH and dissolved oxygen. Carter Lake is also meeting the Aesthetics beneficial use for trophic status and reported true color values. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use and the PBCR is considered supported for sample year 2003-2004. The lake was constructed in 1960 and is managed by the city of Madill for water supply and recreation purposes.

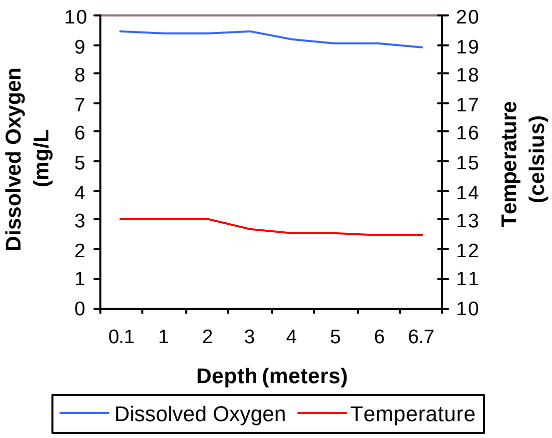
a. Seasonal Turbidity Values for Carter Lake



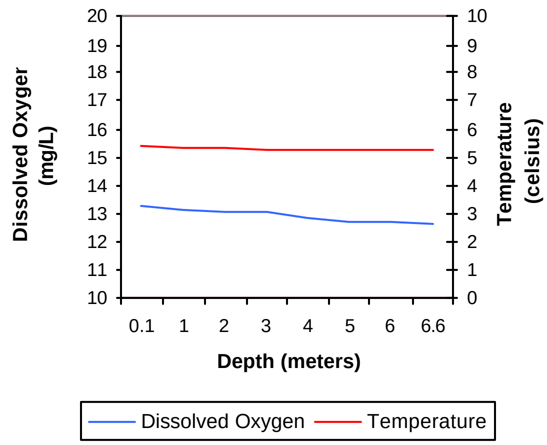

b. Seasonal Color Values for Carter Lake



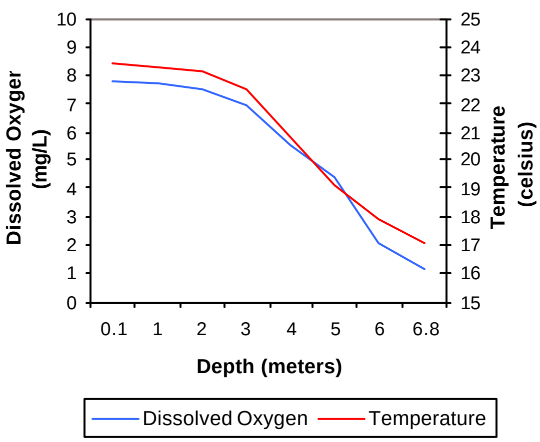

c. Profile of Carter Lake
November 24, 2003




d. Profile of Carter Lake
February 17, 2004




e. Profile of Carter Lake
May 10, 2004




f. Profile of Carter Lake
August 09, 2004

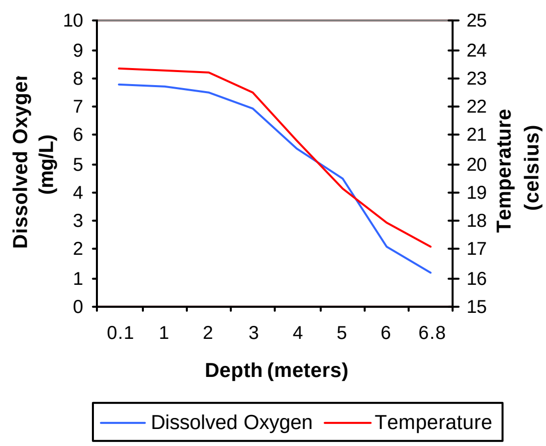
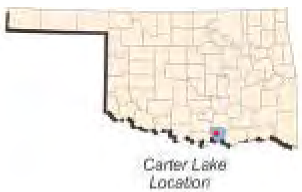
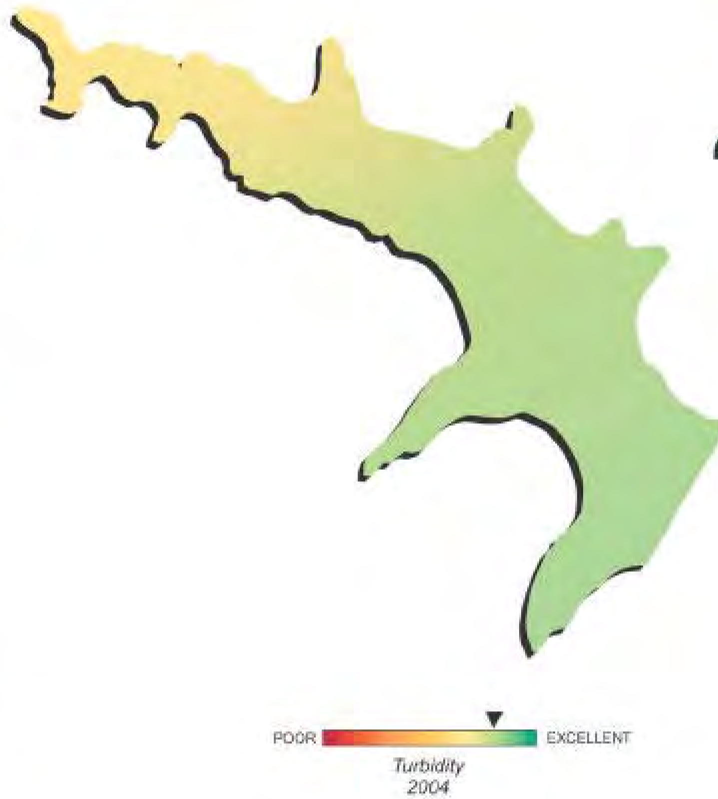
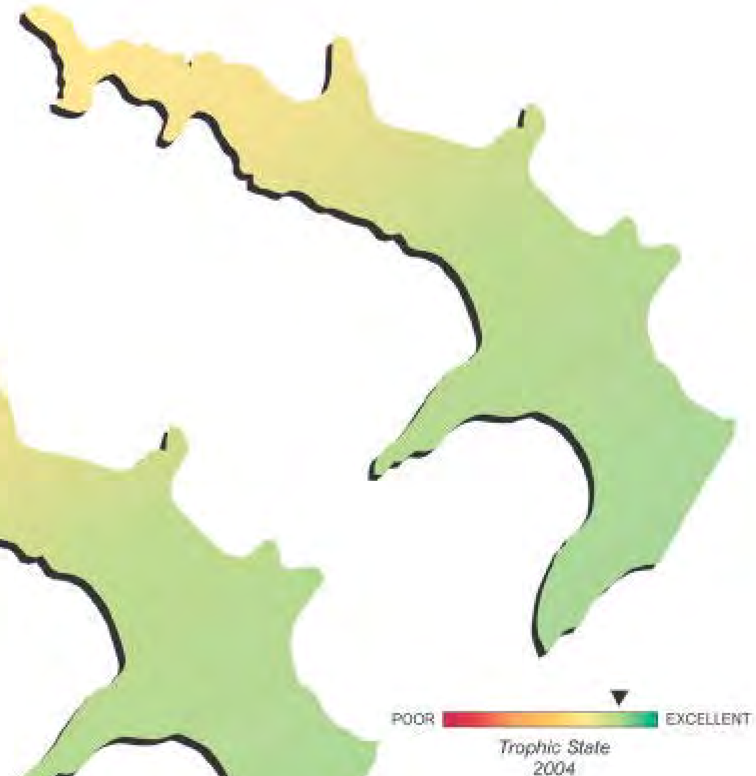



**Figure 45a-45f.** Graphical representation of data results for Carter Lake.








Lake Data

| | |
|---|---|
| Owner | City of Madill |
| County | Marshall |
| Constructed in | 1960 |
| Surface Area | 108 acres |
| Volume | 990 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 9.17 feet |
| Watershed Area | 1,134 acres |


Plate 17 - Lake Water Quality for
## Carter Lake

# Cedar Lake

Cedar Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide turbidity value was 5 NTU (Plate 18), true color was 26 units, and average secchi disk depth was 140 centimeters. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. Results for these parameters were similar to the results found in 2001 data collection efforts. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 55, indicating the lake was eutrophic in sample year 2004. This is consistent with the previous evaluation in 2001 indicating no significant change in productivity has occurred over time. The TSI values throughout the sample year varied seasonally from hypereutrophic in the fall to meso-eutrophic in the winter and spring to eutrophic during the summer (Figure 46). Turbidity values per site for sample year 2004 were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons (See Figure 47a). The lake-wide annual turbidity of 5 NTU seems to accurately represent conditions at Cedar Lake. According to the Use support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use with 100% of the collected turbidity data below the criteria. Seasonal true color values are displayed in Figure 47b. All true color values were below the Aesthetics OWQS of 70 units. Applying the same default protocol to determine the average for true color the Aesthetics beneficial use is supported.

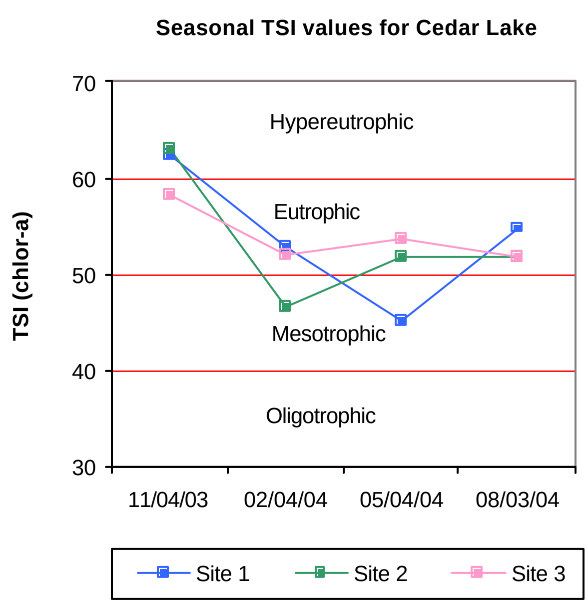



**Figure 46.** TSI values for Cedar Lake.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity ranged from 0.0 parts per thousand (ppt) to 0.18 ppt for this sample year. Specific conductance ranged from 9 mS/cm to 305 mS/cm, which falls within the range, if not lower than, of values commonly reported for Oklahoma lakes. These values indicate a minimal presence of ions (chlorides or other salts) present in the system. The pH values at Cedar Lake ranged from 5.77 to 7.6, representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 38% of the recorded values falling outside the acceptable range the FWP, beneficial use is not supporting based on pH concentrations. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 132 mV in the fall to 542 mV in the winter, however, this low value was the only value indicative of reducing conditions and most likely resulted because it was recorded at the lake bottom at the dam site. Thermal stratification was evident and anoxic conditions present in three of the four sampling intervals (Figure 47c-47f). In the fall quarter, the thermocline occurred between 4 and 5 meters at sites 1 and 2, at which point dissolved oxygen (D.O) was below 2.0 mg/L to the lake bottom 8.9 meters. The lake was stratified at several 1-meter intervals in the spring with oxygen concentrations less than 2.0 mg/L in 33-45% of the water column at the same two sites (Figure 47e). During the summer quarter the lake was strongly thermally stratified between 2 and 3 meters below the surface at which point the dissolved oxygen dropped below 1 mg/L for the remainder of the water column (Figure 47f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With approximately 73% of the water column falling below 2.0 mg/L at site 1 in the summer, the FWP beneficial use is not supported at Cedar Lake. Low dissolved oxygen concentrations in the water column throughout most of the year could pose a threat to fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled chlorides, and sulfates to assess the Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2003-2004.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.66mg/L at the surface. The TN at the surface ranged from 0.26 mg/L in the winter to 1.44 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.077 mg/L at the surface. The total phosphorus at the surface ranged from 0.021 mg/L to 0.476 mg/L with lower values occurring in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2004. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Cedar Lake is classified as eutrophic, with high levels of primary productivity and nutrient rich conditions (Plate 18). Results were similar to 2001 (TSI=51) indicating no significant increase or decrease in productivity has occurred over time. Water clarity continues to be excellent in comparison to other Oklahoma lakes based on true color, turbidity and high secchi disk depths. The FWP beneficial use is supported as it relates to turbidity with 100% of the recorded values below the OWQS of 25 NTU and is not supported for dissolved oxygen concentrations. Anoxic conditions were present in three of the four sampling intervals with approximately 73% of the water column less than 2.0 mg/L during the summer; therefore the FWP use is not supported. Low dissolved oxygen (D.O.) throughout most of the year could pose a threat to fish and wildlife propagation. Cedar Lake was also not supporting the FWP beneficial use based on low pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is fully supported based on trophic status and true color. The USDA constructed Cedar Lake, located in the Ouchita National Forest, in 1937 for recreational purposes.

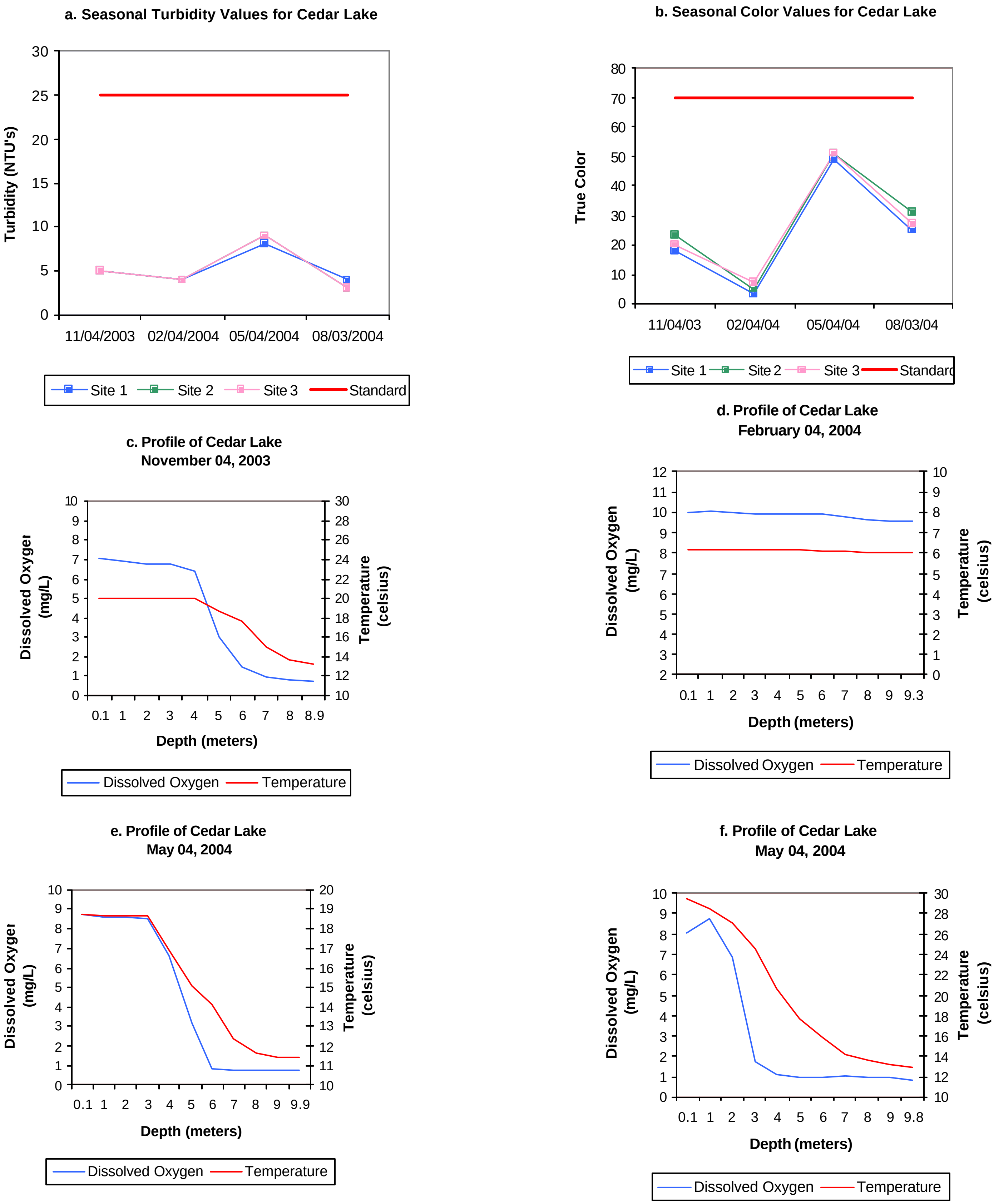



**Figure 47a-47f.** Graphical representation of data results for Cedar Lake.




| Lake Data | |
|---|---|
| Owner | U.S. Dept. of Agriculture |
| County | LeFlore |
| Constructed in | 1937 |
| Surface Area | 78 acres |
| Volume | 1,000 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 12.82 feet |
| Watershed Area | 9 square miles |



Plate 18 - Lake Water Quality for
Cedar Lake

# Chandler Lake

Chandler Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 8 NTU (Plate 19), true color was 18 units, and secchi disk depth was 115 centimeters in 2003. Water clarity was good based on secchi disk depth, turbidity, and true color values. Compared to values recorded in 2001, results for these parameters are very similar, although secchi disk depth was a little higher than previously reported. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 52 (Plate 14), indicating the lake was eutrophic with high primary productivity and nutrient conditions in sample year 2003. The TSI values throughout the sample year varied seasonally from oligotrophic in the winter to eutrophic in the summer (Figure 48). Turbidity values per site for sample year 2003 were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons (Figure 49a). The lake-wide annual turbidity of 8 NTU was representative of conditions at Chandler Lake in 2003. All true color values were below the aesthetics OWQS of 70 units, meeting the Aesthetic beneficial use.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity ranged from 0.12 parts per thousand (ppt) to 0.18 ppt for this sample year. Specific conductance ranged from 259.2 mS/cm to 373.1 mS/cm, which falls within the range of values commonly reported for Oklahoma lakes. These values indicate a minimal presence of ions (chlorides or other salts) present in the system. The pH values at Chandler Lake ranged from 6.81 to 8.42, representing a neutral to slightly alkaline system. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 95 mV in the spring to 470 mV in the fall, however, this low value was the only value indicative of reducing conditions and most likely resulted because it was recorded at the lake bottom at the dam site. In general, reducing conditions were not present in this reservoir. The lake was not stratified during the fall, winter and spring quarters (see Figure 49c-49e). During the summer quarter the lake exhibited thermal stratification between 4 and 5 meters at which point the dissolved oxygen dropped below 1 mg/L for the remainder of the water column. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP

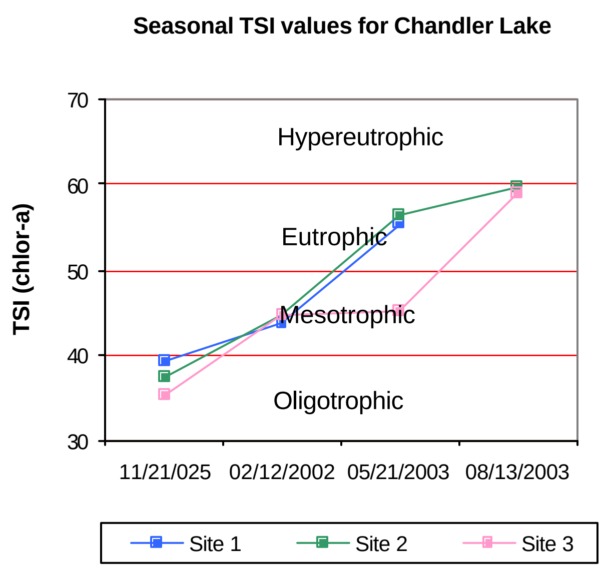



**Figure 48.** TSI values for Chandler Lake

beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 44% of the water column falling below 2.0 mg/L, the FWP Benicia use is partially supported at Chandler Lake. The lake was also sampled for total dissolved solids, chlorides, and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.63mg/L at the surface and 0.85 mg/L at the lake bottom. The TN at the surface ranged from 0.38 mg/L in the winter to 0.87 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.021 mg/L at the surface and 0.090 mg/L at the lake bottom. The total phosphorus at the surfaced ranged from 0.011 mg/L to 0.027 mg/L with lower values occurring in the fall quarter. The nitrogen to phosphorus ration (TN:TP) was 30:1 for sample year 2003. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Chandler Lake was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions. This classification differs from that in 2001 when the TSI of 48 resulted in a mesotrophic classification. The lake should be monitored closely in the future to determine if a change in productivity has actually occurred. Water clarity was good based on turbidity, true color and secchi disk depth and results were similar to those observed in 2001. The lake is supporting the FWP beneficial use based on pH and turbidity, but is listed as partially supporting based on dissolved oxygen levels. The Aesthetics beneficial use is also being met by both the trophic status and true color concentrations. Chandler Lake is located in Lincoln County and is owned by the city of Chandler. Constructed in 1954 it serves as the city's municipal water supply and is also utilized for recreation.

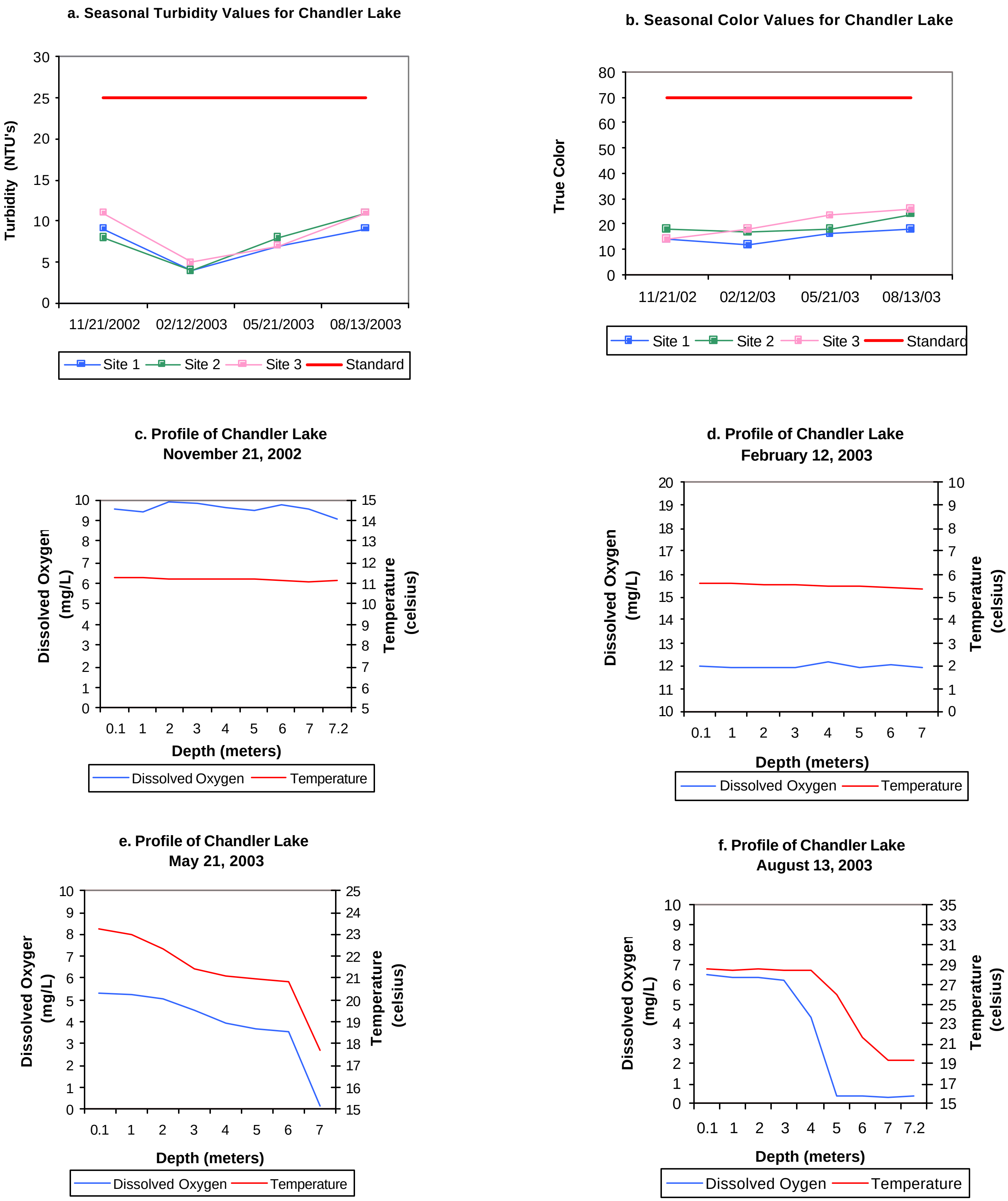
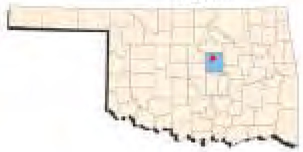



**Figure 49a-49f.** Graphical representation of data results for Chandler Lake.







Lake Data

| | |
|---|---|
| Owner | City of Chandler |
| County | Lincoln |
| Constructed in | 1954 |
| Surface Area | 129 acres |
| Volume | 2,778 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 21.53 |
| Watershed Area | 3,403 acres |

Plate 19 - Lake Water Quality for
Chandler Lake

# Lake Chickasha

Lake Chickasha was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and winter and at five (5) sites in the spring and summer sampling quarters. Additional sample sites were added to ensure that an adequate amount of data was being collected as this reservoir is greater than 250 surface acres in size. Samples were collected at the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 9 NTU (Plate 15), true color was 11 units, and annual average secchi disk depth was 69 centimeters. Based on these three parameters water clarity was good at Lake Chickasha in sample year 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=16). The result was a TSI of 59 (Plate 15), indicating the lake was eutrophic with high primary productivity and nutrient levels in sample year 2002-2003. This value is lower than that calculated in 2000 (TSI=66), however the current calculation is based on the entire dataset and not just data collected during the summer months so it is likely a more accurate depiction of productivity within the lake system. The TSI values for all sites were fairly consistent throughout the year and ranged from hypereutrophic in the fall to mesotrophic in the winter and eutrophic in both spring and summer quarters (see Figure 50). Seasonal turbidity values are displayed in Figure 51a. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and ranged from a low of 4 NTU to a maximum of 15 NTU. With 100% of the recorded values below 25 NTU the Fish and Wildlife Propagation (FWP) beneficial use is considered fully supported. Seasonal true color values were all well below the OWQS of 70 units and are displayed in Figure 51b. Due to the minimum data requirements not being met assessment of the Aesthetics beneficial use based on true color could not be made.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 1.14 parts per thousand (ppt) to 1.36 ppt for this sample year. Specific conductance ranged from 2137 mS/cm to 2530 mS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence of high levels of electrical current conducting compounds (salts) in the lake, consistent with higher salinity concentrations. The pH values at Lake Chickasha ranged from 6.92 to 8.13, representing a neutral to slightly alkaline system. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 92 mV in the spring to 470 mV in the fall, however this low value was the only value indicative of reducing conditions and most likely resulted

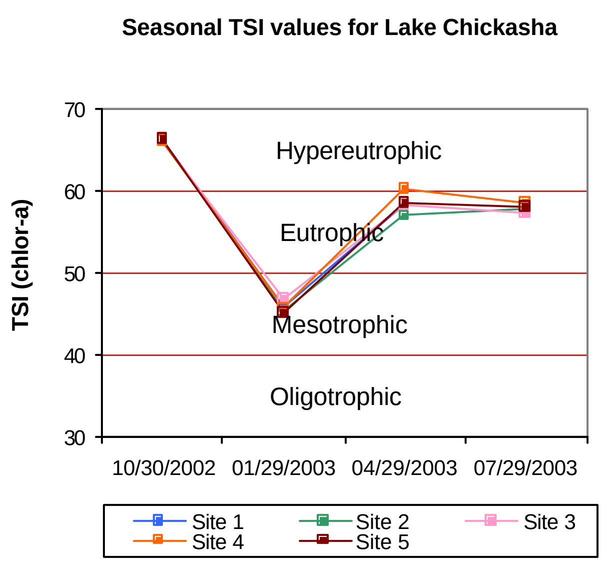



**Figure 50.** TSI values for Lake Chickasha

because it was recorded at the lake bottom at the dam site. In general, reducing conditions were not present in this reservoir. The lake was not stratified during any of the sampling quarters (see Figure 51c-51f). Dissolved oxygen (D.O.) levels were generally above 4.0 mg/L throughout the sample year. The absence of stratification may be attributed to the shallow nature of this reservoir where wind and wave action keep the lake well mixed. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 100% of the water column above 2.0 mg/L the FWP Benicia use is fully supported at Lake Chickasha. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.21mg/L at the surface and 1.21 mg/L at the lake bottom. The TN at the surface ranged from 0.68 mg/L in the fall to 1.48 mg/L in the winter. The lake-wide total phosphorus (TP) average was 0.021 mg/L at the surface and 0.090 at the lake bottom. The total phosphorus at the surfaced ranged from 0.033 mg/L to 0.035 mg/L with lower values occurring in the winter quarter. The nitrogen to phosphorus ration (TN:TP) was 37:1 for sample year 2003. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Chickasha was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions. This classification differs from that in 2000 when the TSI of 66 resulted in a hypereutrophic classification. The current calculation is based on a larger dataset and not just data collected during warmer summer months so it is likely a more accurate depiction of productivity within the lake system. The lake should be monitored closely in the future to determine if a change in productivity has actually occurred. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and turbidity, and dissolved oxygen levels. The Aesthetics beneficial use is being met by the trophic status, however the minimum data requirement of 20 samples for lakes greater than 250 surface acres was not met for true color. Lake Chickasha is located in Caddo County serves as a municipal water supply as well as a recreational reservoir.

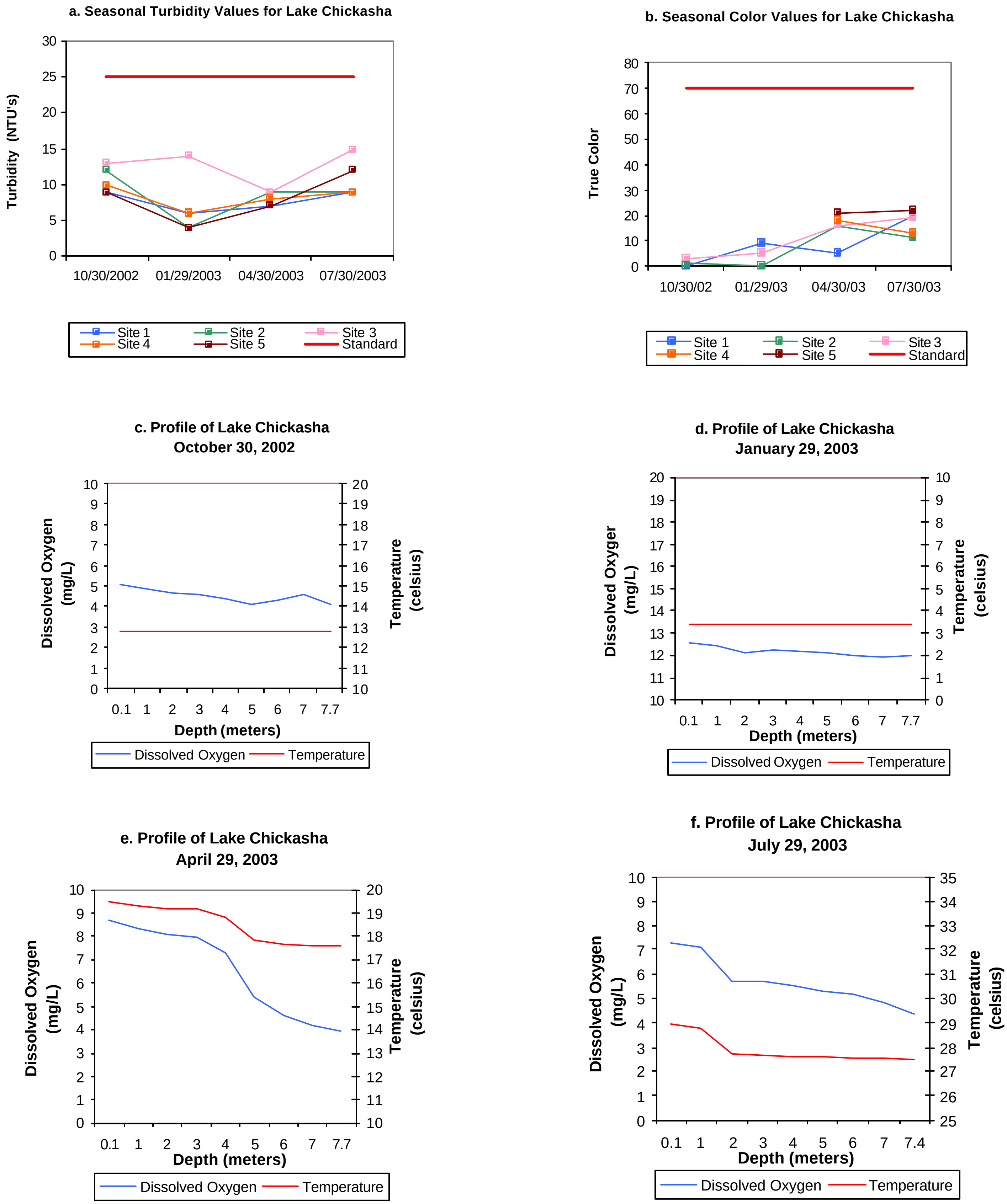
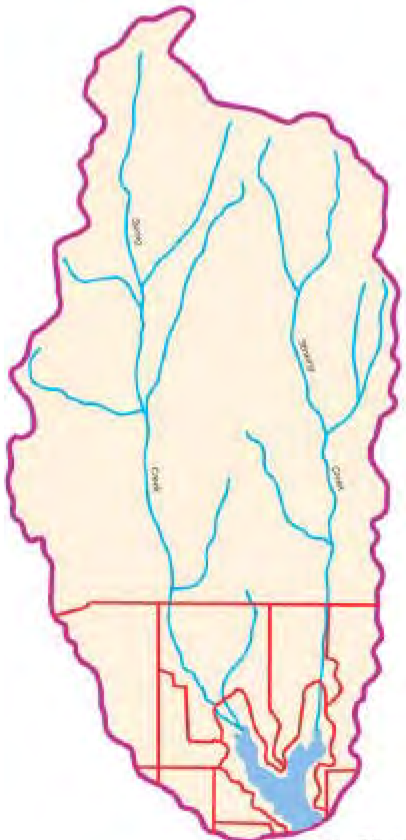



**Figure 51a-51f.** Graphical representation of data results for Lake Chickasha.



Lake Chickasha
and
Watershed

Lake Chickasha
Location


Turbidity
2003


Trophic State
2003


Lake Data

| | |
|---|---|
| Owner | City of Chickasha |
| County | Caddo |
| Constructed in | 1958 |
| Surface Area | 820 acres |
| Volume | 41,080 acre/feet |
| Shoreline Length | 10 miles |
| Mean Depth | 50.10 feet |
| Watershed Area | 74 square miles |

Plate 20 - Lake Water Quality for
**Lake Chickasha**

# Claremore Lake

Claremore Lake was sampled for four quarters from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. All water samples were collected from the lake surface at all sites as well as 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 16 NTU (Plate 21), true color was 30 units, and secchi disk depth was 47 centimeters in 2003-2004. Based on these three parameters, Claremore Lake had average to good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The calculated TSI was 61 (Plate 21), indicating the lake was hypereutrophic during the study period. The TSI values throughout the sample year varied very little from season to season with almost all values falling in the hypereutrophic range (Figure 52). These results are consistent with historical data collection efforts on the lake, which also found the lake to be hypereutrophic. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient threatened. All turbidity values, with the exception of site 3 in the fall quarter were below the turbidity water quality standard of 25 NTU (see Figure 53a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake was fully supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity with only 5% of the values exceeding the standard. Seasonal true color values are displayed in Figure 53b. None of samples collected had true color values exceeding the 70 units criteria, therefore the Aesthetics use is considered fully supported.

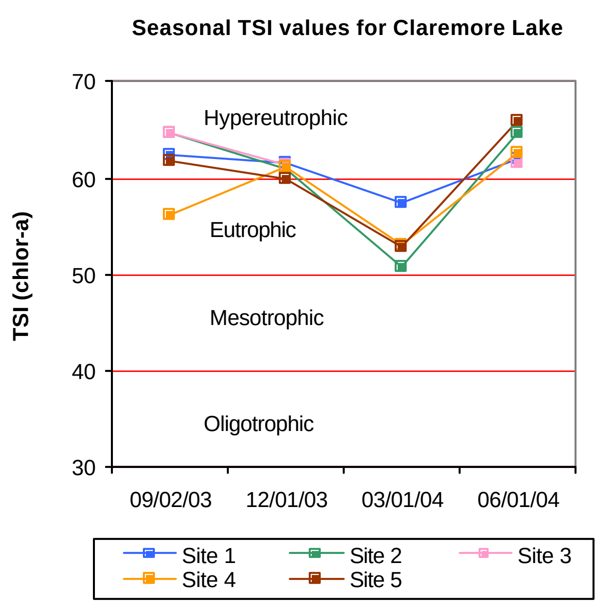


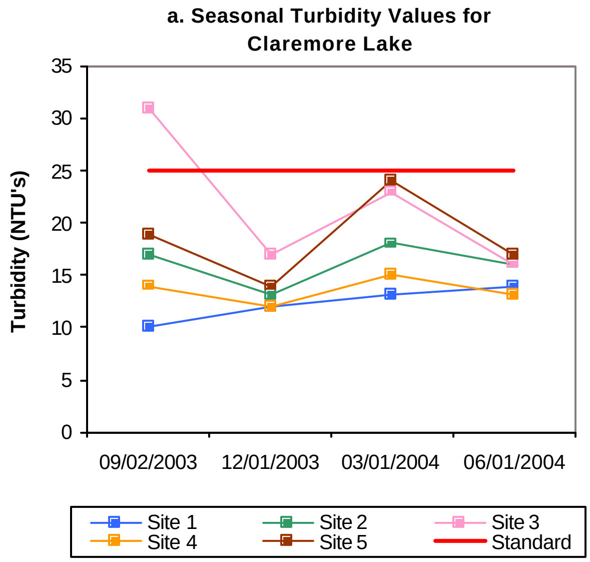

**Figure 52.** TSI values for Claremore Lake.

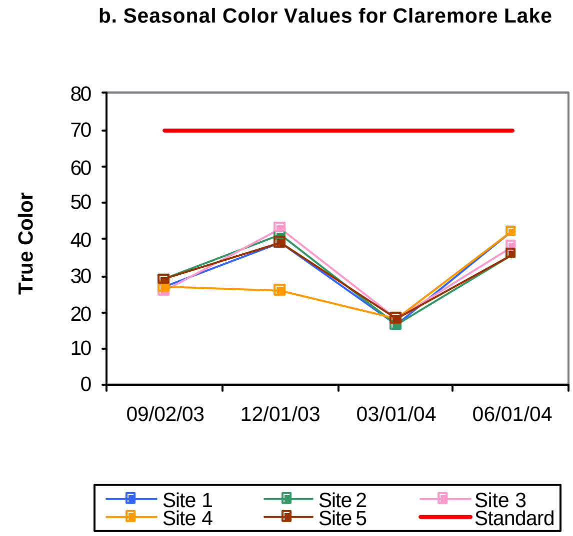
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. The salinity concentrations at Claremore Lake ranged from 0.04 parts per thousand (ppt) to 0.09 ppt. This is well within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductance values were also well within the expected range for Oklahoma reservoirs, indicating minimal presence of electrical current conducting compounds like salts. Specific conductance values ranged from 101.3 mS/cm in the fall quarter to 200.8 mS/cm recorded in the spring quarter. The pH values at Claremore Lake were neutral to slightly alkaline ranging from 6.76 to 8.36 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and the lake should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting its FWP beneficial use. With 100% of collected values within the acceptable range Claremore Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (redox) ranged from 378 mV in the winter to 567 mV recorded in the fall, which indicated an absence of reducing conditions. The lake was not thermally stratified in the fall, winter, or spring quarters. Dissolved oxygen (D.O.) concentrations were above 3.0 mg/L throughout the water column during these three seasons and were generally above 6.0 mg/L (see Figure 53c-53e). In the summer quarter, the lake showed thermal stratification between 5 and 6 meters with D.O. concentrations less than 2.0 mg/L from 7 meters to the lake bottom at 7.8 meters at site 1, the dam site (see Figure 53f). Anoxic conditions were not present at the other four sites in the summer quarter, as all sites are less than 6 meters in depth. If D.O. values are less than 2 .0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, Claremore Lake is fully supporting its FWP beneficial use with 12.5% of the water column was less than 2.0 mg/L. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

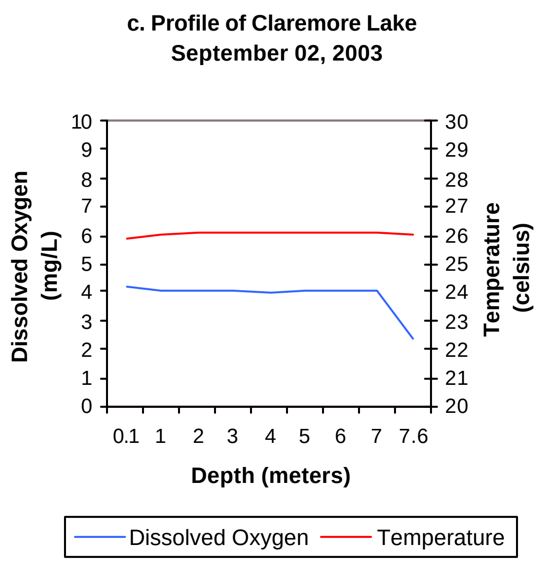
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. All samples were at or below the detection limit .The PBCR beneficial use is considered fully supported for sample year 2003-2004.

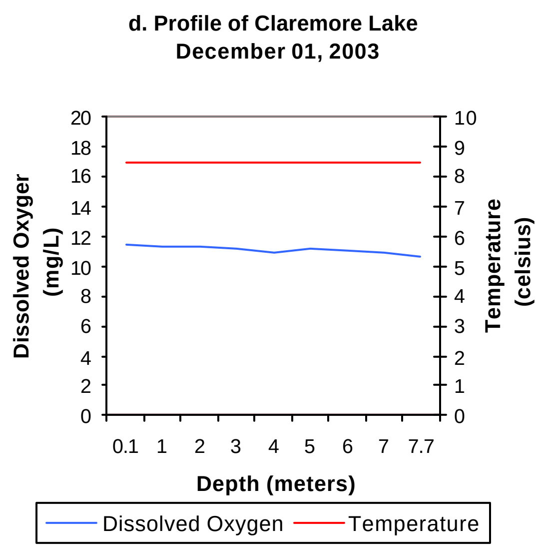
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.92 mg/L at the lake surface and 0.93 mg/L at the lake bottom. The TN at the surface ranged from 0.72 mg/L to 1.38 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.062 mg/L at the lake surface and 0.067 at the lake bottom. The TP ranged from 0.038 mg/L to 0.104 mg/L at the lake surface. The highest surface TP values were reported in the fall quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

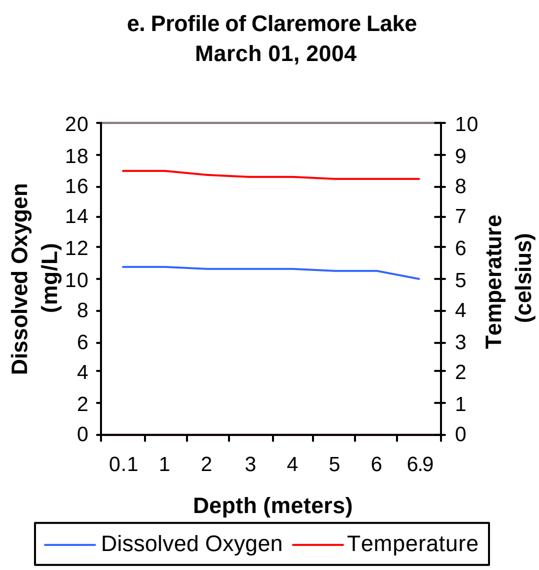
In summary, Claremore Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 21). This finding is consistent with historical data collection efforts. The Aesthetics beneficial use is considered fully supported based on true color values, however a determination cannot be made based on trophic status. Currently, the lake is listed in the OWQS as a NLW indicating that the Aesthetics beneficial use is considered threatened by nutrients. The lake should be monitored intensively to determine if the Aesthetics beneficial use is supported for nutrients. Claremore Lake was fully supporting the FWP beneficial use based on turbidity, pH, and D.O. concentrations. The PBCR beneficial use is considered fully supported for sample year 2003-2004. Claremore Lake is the municipal water supply reservoir for the City of Claremore and is owned and operated by the city. The lake was constructed in 1930 and is also utilized for recreation purposes.



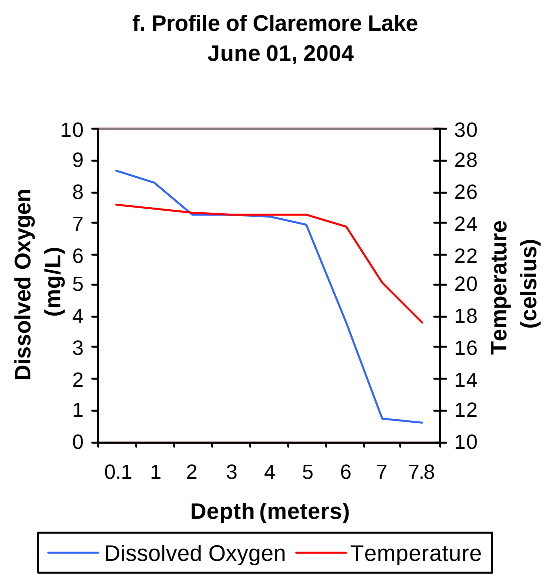
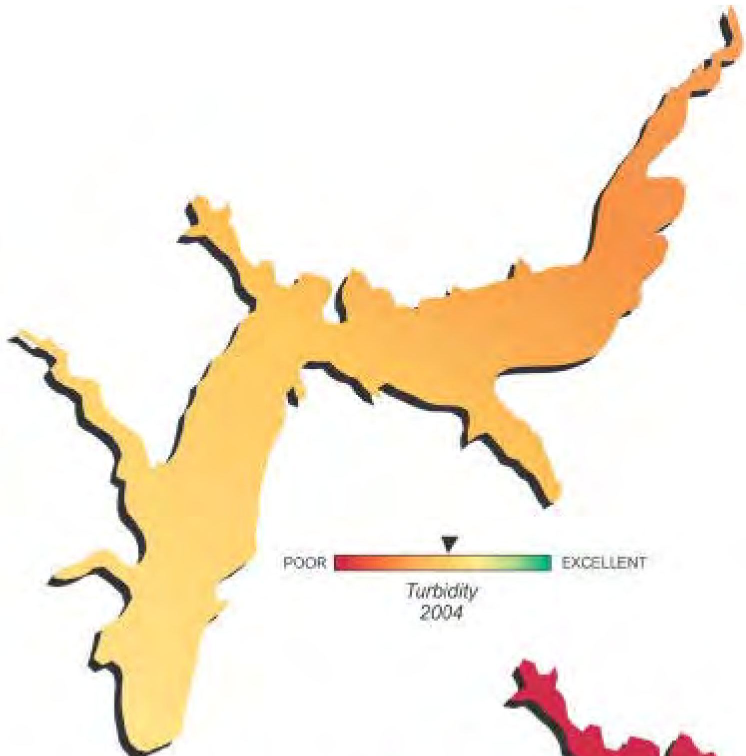
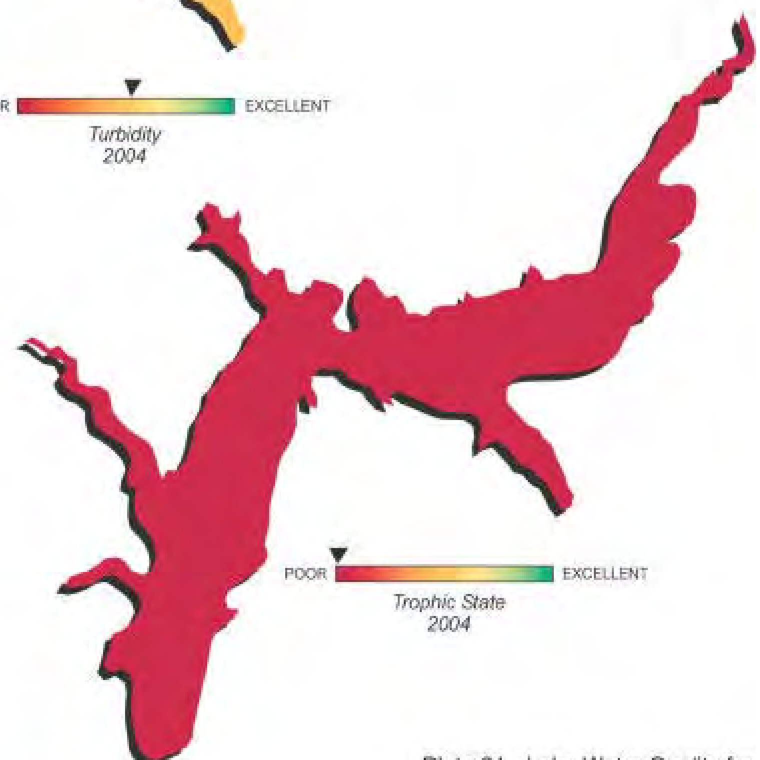




**Figure 53a-53f.** Graphical Representation of data results for Claremore Lake.




Lake Data

| | |
|---|---|
| Owner | City of Claremore |
| County | Rogers |
| Constructed in | 1930 |
| Surface Area | 470 acres |
| Volume | 7,900 acre/feet |
| Shoreline Length | 9 miles |
| Mean Depth | 16.81 feet |
| Watershed Area | 57 square miles |

Plate 21 - Lake Water Quality for
## Claremore Lake

## Clear Creek Lake

Clear Creek Lake was sampled for four quarters, from November 2002 through July 2003. Water quality samples were collected at 3 sites in the fall and winter and from five (5) sites in the spring and summer quarters to represent the riverine, transition, and lacustrine zones of the reservoir. Additional sample sites were added half way in to the sample year to ensure that an adequate amount of data was being collected, as this reservoir is greater than 250 surface acres in size. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 12 NTU (Plate 22), true color was 14 units, and secchi disk depth was 100 centimeters in 2003. Based on these three parameters, Clear Creek Lake had good water clarity. These values are very similar to those calculated in 2001, indicating no significant increase or decrease over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=16). The TSI was 48 (Plate 22), indicating the lake was mesotrophic in sample year 2003. The TSI values throughout the sample year were fairly consistent and ranged from mid-mesotrophic to eutrophic (see Figure 54). The TSI in 2001 was 52 indicative of eutrophic conditions. The lower trophic value in 2003 is probably a more accurate depiction since it was based on a larger dataset. Seasonal turbidity values are displayed in Figure 55a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the OWQS of 25 NTU. If 10 to 25% of the turbidity values exceed the numerical criteria, the lake should be listed as partially supporting beneficial uses. With only 5% of the values exceeding 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is supported based on turbidity. The lake-wide annual turbidity of 12 NTU was representative of conditions at Clear Creek Lake in 2001. Seasonal true color values were all well below the OWQS of 70 units and are displayed in Figure 55b. Due to the minimum data requirements not being met assessment of the Aesthetics beneficial use based on true color could not be made.

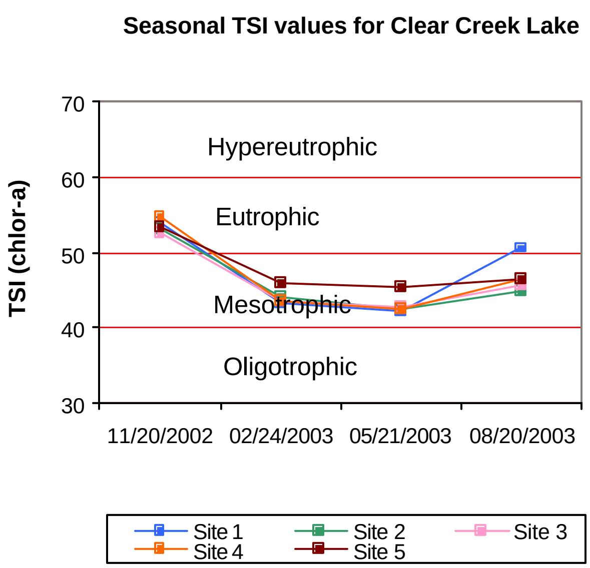


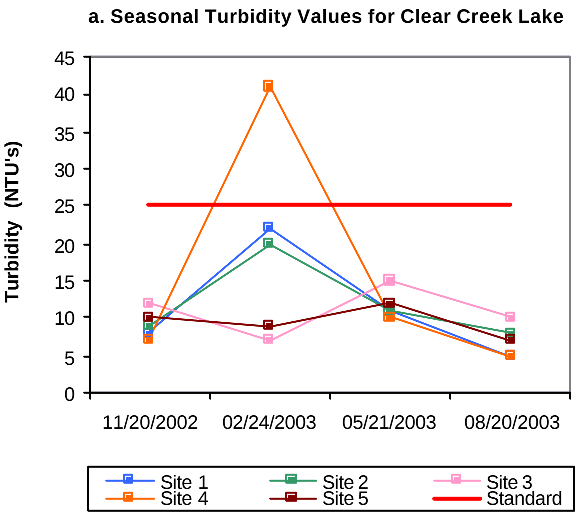

**Figure 54.** TSI values for Clear Creek Lake.

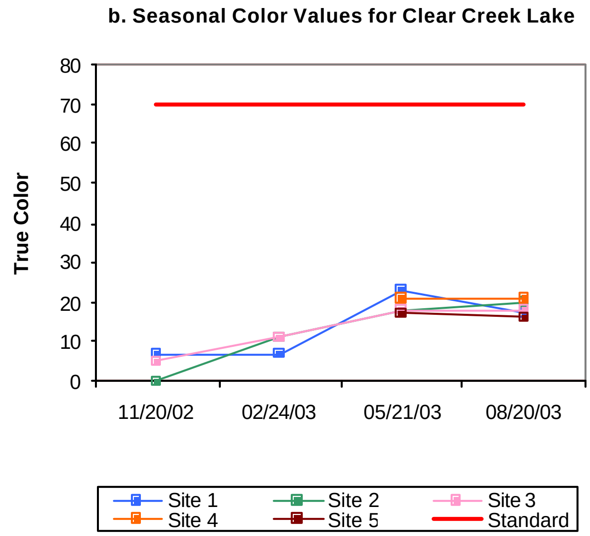
In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.27 parts per thousand (ppt) to 0.34 ppt for this sample year. Specific conductance ranged from 530.9 mS/cm to 655.9 mS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence of moderate levels of current conducting compounds (chlorides and salts) in the lake, consistent with recorded salinity concentrations. The pH values at Clear Creek Lake ranged from 7.08 to 8.16, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range Clear Creek Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 311 mV in the hypolimnion during the summer to 467 mV in the fall. In general, reducing conditions were not present in this reservoir. The lake was not stratified during the fall, winter or spring sampling quarters (see Figure 55c-55e) and dissolved oxygen (D.O.) levels were generally above 5.0 mg/L. Thermal stratification and anoxic conditions were present in the summer sampling interval with dissolved oxygen levels fall below 2.0 mg/L below the thermocline. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 40% of the water column below 2.0 mg/L the FWP beneficial use is partially supported at Clear Creek Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases on numerical criteria located in OAC 785:45 – Appendix F.

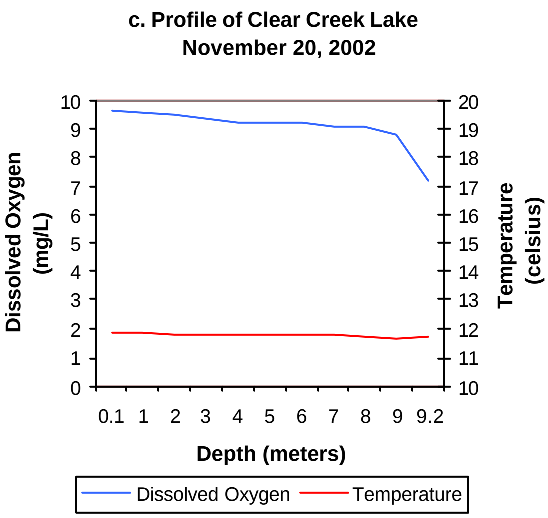
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (37.8 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

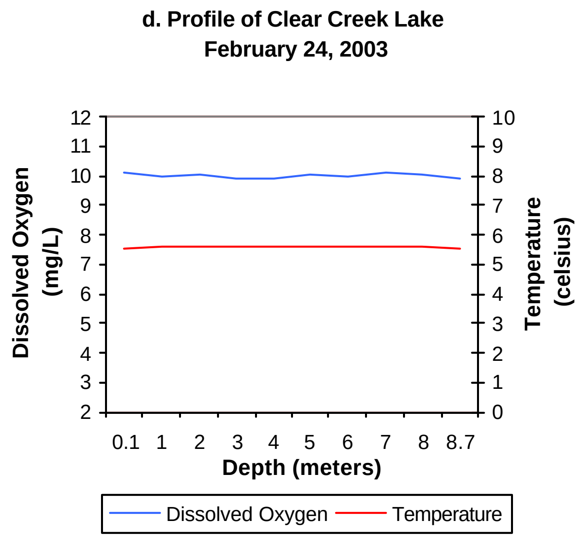
Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.69 mg/L at the surface and 0.90 mg/L at the lake bottom. The TN at the surface ranged from 0.80 mg/L in the spring to 0.98 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.021 mg/L at the surface and 0.027 at the lake bottom. The total phosphorus at the surfaced ranged from 0.012 mg/L to 0.027 mg/L with lower values occurring in the fall quarter. The nitrogen to phosphorus ration (TN:TP) was 33:1 for sample year 2003. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

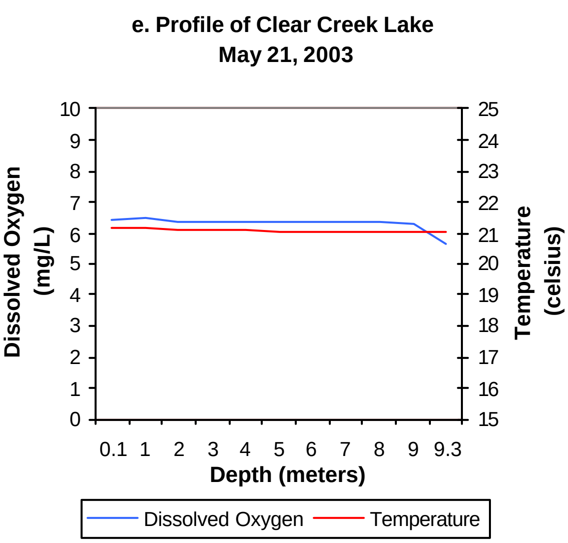
In summary, Clear Creek Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. This classification differs from that in 2001 when the TSI of 53 resulted in a eutrophic classification. The current calculation is based on a larger dataset and is likely a more accurate depiction of productivity within the lake system. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use for pH and turbidity, but partially supporting based on dissolved oxygen levels. The Aesthetics beneficial use is being met by the trophic status, however the minimum data requirement of 20 samples for lakes greater than 250 surface acres was not met for true color. Clear Creek Lake, located in Stephens County, serves as a municipal water supply as well as a recreational reservoir for the city of Duncan.



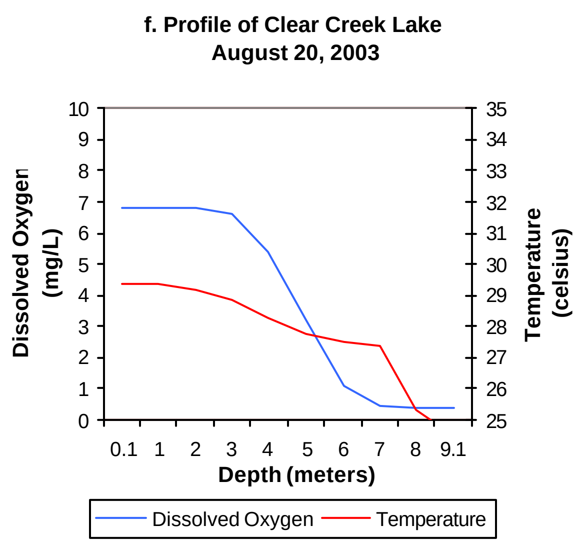
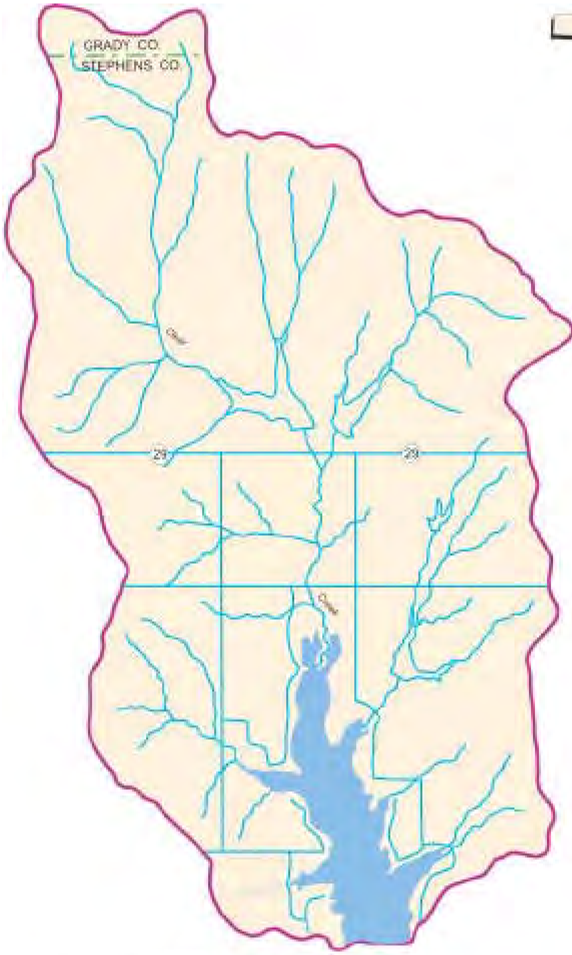
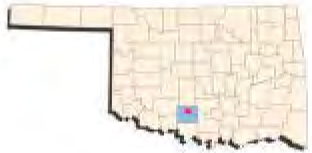




**Figure 55a-55f.** Graphical representation of data results for Clear Creek Lake.




Clear Creek Lake and Watershed



Clear Creek Lake Location


Turbidity 2003


Trophic State 2003

N W E S

Lake Data

| | |
|---|---|
| Owner | City of Duncan |
| County | Stephens |
| Constructed in | 1948 |
| Surface Area | 722 acres |
| Volume | 7,710 acre/feet |
| Shoreline Length | 11 miles |
| Mean Depth | 10.68 feet |
| Watershed Area | 20 square miles |

Plate 22 - Lake Water Quality for
## Clear Creek Lake

# Cleveland City Lake

Cleveland City Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 39 NTU (Plate 23), true color was 75 units, and secchi disk depth was 49 centimeters. Based on these three parameters, Cleveland City Lake had moderate to fair water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average calculated TSI was 50 (Plate 23), indicating the lake was mesotrophic bordering eutrophic, with moderate to high levels of primary productivity and nutrients conditions. The TSI values throughout the sample year varied seasonally from eutrophic in the fall and summer to mesotrophic during the winter. In the spring values were lower mesotrophic at site 1 and upper oligotrophic at sites 2 and 3 (Figure 56). Of the turbidity values collected, 50% were above the turbidity standard of 25 NTU, however available flow and rainfall data suggest the elevated readings are likely the result of storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity (see Figure 57a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Seasonal true color values are displayed in Figure 57b. Of the 12 samples collected at Cleveland City Lake in 2003-2004, 25% of the true color values exceeded the 70 units criteria listed in OWQS. Similar to turbidity, a peak in true color occurred in the spring quarter and is likely the result of seasonal storm events and the Aesthetics beneficial use is considered supported at Cleveland City Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.04 parts per thousand (ppt) to 0.12 ppt. This is well within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductance values were also well within the expected range for Oklahoma reservoirs, coinciding with the low salinity concentrations.

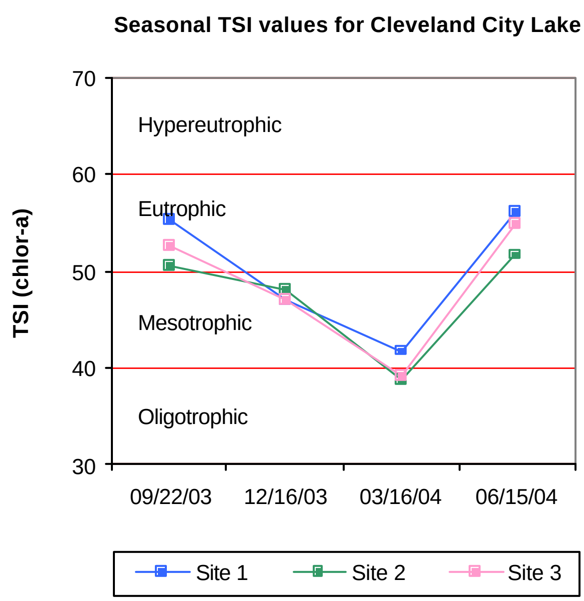



**Figure 56.** TSI values for Cleveland City Lake.

Specific Conductance values ranged from 94.5mS/cm in the spring to 260.3 mS/cm in the summer. Oxidation-reduction potentials (redox) ranged from 315 mV in the spring quarter to 520 mV in the winter season, indicating reducing conditions were not present in the lake during the study period. The pH values indicated that the lake was neutral to slightly alkaline with values ranging from 6.83 to 8.01 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and the lake should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting its FWP beneficial use. Cleveland Lake is fully supporting its FWP as it relates to pH. During the fall quarter the lake exhibited weak stratification with anoxic conditions present for 25 % of the water column (Figure 57c). The lake was not thermally stratified and the water column appeared to be well mixed during the winter and spring months (see Figure 57d-57e). In the summer, the lake was strongly thermally stratified between 2 and 3 meters from the lake surface. At which point the D.O. concentrations fell below 2.0 mg/L all the way to the lake bottom at 8.9 meters (see Figure 57f). Site 2 was also stratified between 2 and 3 meters in depth with 50% of the water column below 2.0 mg/L during the summer. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 50 to 60% of the water column of Cleveland Lake being less than 2.0 mg/L the lake is listed as "partially supporting" its FWP beneficial use. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. The PBCR beneficial use is considered supported for sample year 2003-2004.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.91 mg/L at the lake surface. The TN at the surface ranged from 0.49 mg/L to 1.23 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.053 mg/L at the lake surface. The TP ranged from 0.035 mg/l to 0.092 mg/L. Similar to the TN values, the highest surface TP values were reported in the fall quarter however the lowest were seen in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Cleveland City Lake was classified as mesotrophic bordering eutrophic, indicative of moderate to high primary productivity and nutrient rich conditions. Water clarity was moderate to fair in this reservoir when compared to other Oklahoma reservoirs. The lake is fully supporting its Aesthetics beneficial use for and trophic state (for nutrients) and true color. Cleveland City Lake is fully supporting its FWP beneficial use based on pH and partially supporting the beneficial use based on low D.O. concentrations in the water column during the summer sampling interval. Of the turbidity values collected, 50% were above the turbidity standard of 25 NTU, however available flow and rainfall data suggest the elevated readings are likely the result of storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. The PBCR beneficial is considered supported. Cleveland City Lake is owned and operated by the City of Cleveland and serves as the municipal water supply reservoir for the city and is also utilized for recreation purposes.

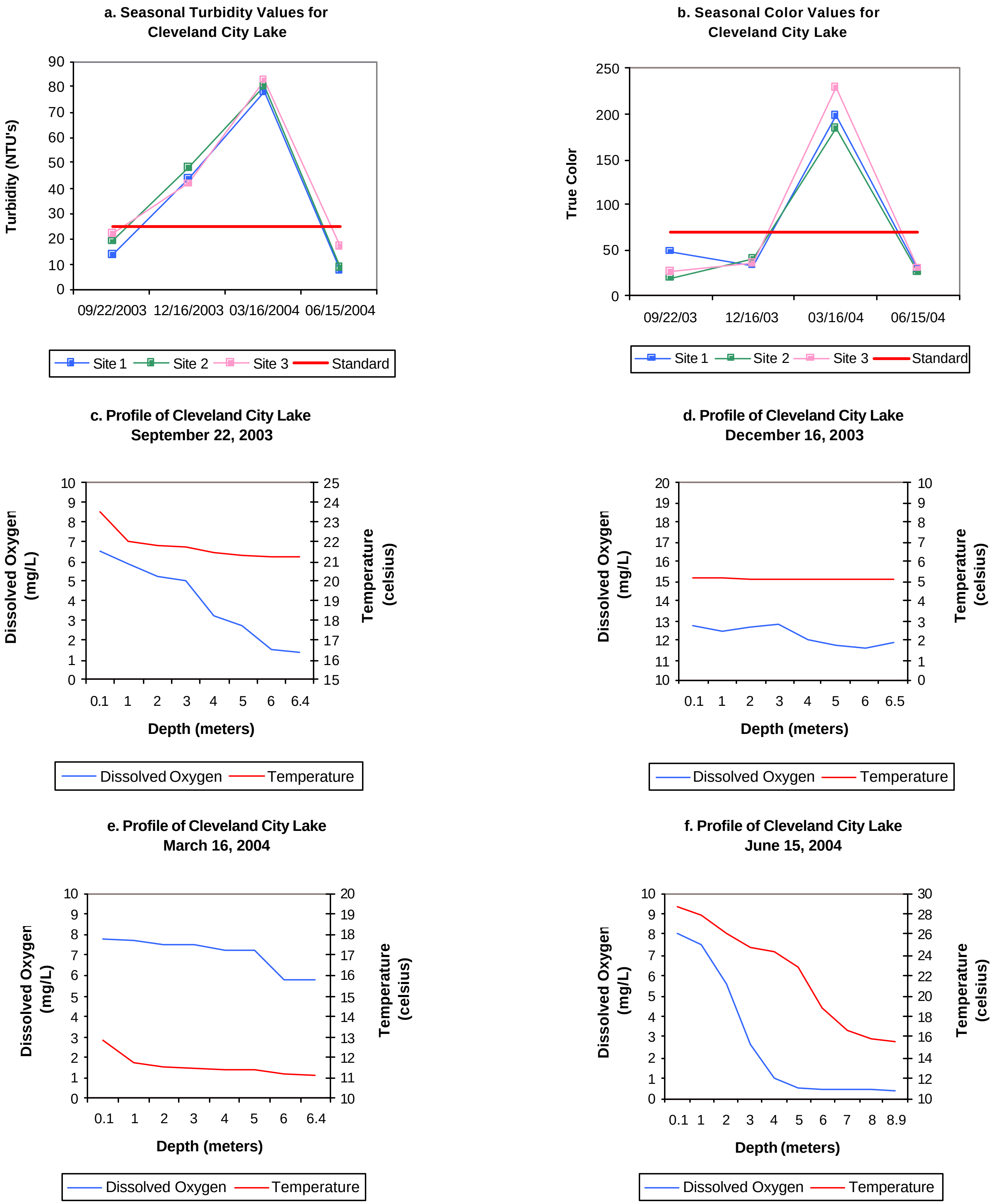
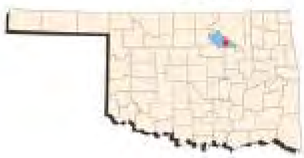
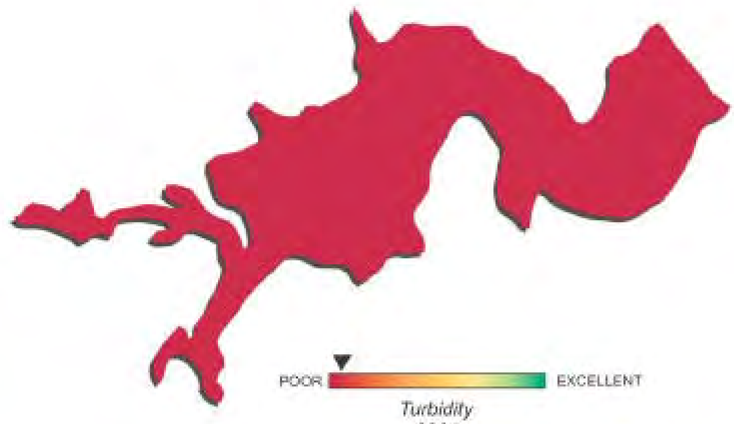


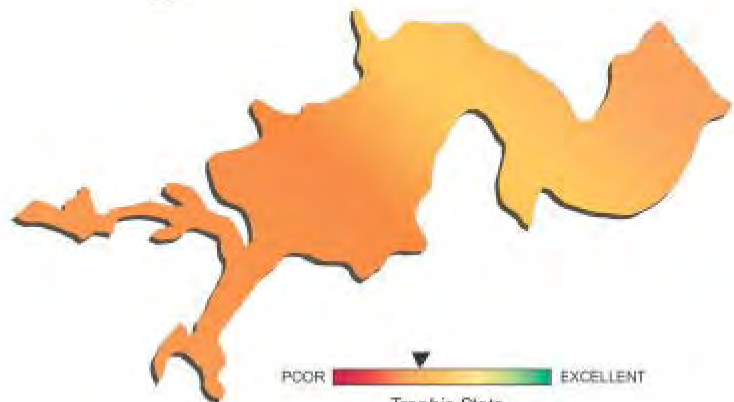

**Figure 57a-57f.** Graphical representation of data results for Cleveland City Lake.

Cleveland Lake Location



Cleveland Lake and Watershed


Lake Data

| | |
|---|---|
| Owner | City of Cleveland |
| County | Pawnee |
| Constructed in | 1936 |
| Surface Area | 159 acres |
| Volume | 2,200 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 13.84 feet |
| Watershed Area | 22 square miles |

Plate 23 - Lake Water Quality for
Cleveland Lake

# Clinton Lake

Clinton Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites and an additional sample was collected at 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 67 NTU (Plate 24), true color was 36 units, and secchi disk depth was 23 centimeters. Based on these three parameters, Clinton Lake had poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 66 (Plate 24), indicating the lake was hypereutrophic in nature, with high to excessive levels of productivity and nutrients. The TSI values fluctuated very little based on the season and sample site, never varying from upper eutrophy to hypereutrophy at all sites (see Figure 58). Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (OWQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Turbidity values per site were generally above the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons with 80% of the collected data exceeding the OWQS (see Figure 59a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting its FWP beneficial use. The lake-wide annual turbidity of 67 NTU was representative of conditions at Clinton Lake in 2003-2004 and consistent with historical findings. Clinton Lake is currently not meeting its Fish & Wildlife Propagation (FWP) beneficial use due to high turbidity values. The system should be further examined to determine if the high turbidity present is due to natural conditions. Seasonal true color values are displayed in (Figure 59b). Of the 12 values collected, three (15%) exceeded the numeric criteria of 70 units. Applying the same default protocol, the Aesthetics use is partially supported.

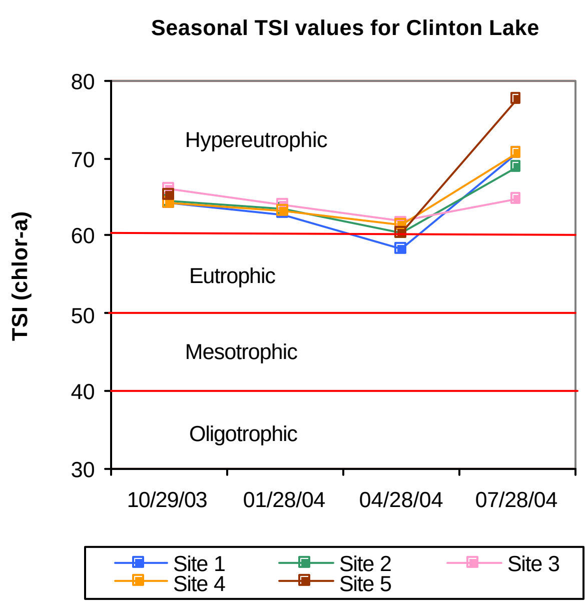



**Figure 58.** TSI values for Clinton Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.23 parts per thousand (ppt) to 0.33ppt, which slightly higher than the range of values observed in most Oklahoma lakes. Reflecting moderate levels of chlorides or other salts in the lake. Specific conductivity values were also slightly higher than most Oklahoma reservoirs, with values ranging from 460.4 mS/cm in the summer to 642.9 mS/cm in the fall. Oxidation-reduction potentials ranged from 149 mV to 534 mV, indicating reducing conditions were not present in the lake. The pH was neutral to slightly alkaline with values ranging from 8.0 to 8.74 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Based on pH values collected Clinton Lake is currently supporting its FWP beneficial use. The lake was not thermally stratified and the water column appeared to be well mixed throughout all four quarters, this can be attributed to the shallow nature of the lake and limited shoreline structure to prevent wind-mixing of the lake (see Figure 59c-59f). Dissolved oxygen (D.O.) values remained above 4.0 mg/L and the D.O. percent saturation was never less than 50% in any of the sample quarters except at the very bottom of the lake. The FWP beneficial use is fully supported based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (42.3 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.94 mg/L at the surface and 1.80mg/L at the lake bottom. The TN at the surface ranged from 1.36 mg/L to 3.06 mg/L, which is higher than generally seen in Oklahoma lakes. The highest surface TN value was reported in the summer quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.152 mg/L at the surface and 0.157 mg/L at the lake bottom. The TP ranged from 0.089 mg/L to 0.244 mg/L at the lake surface. The highest surface TP values were reported in the fall quarter and the lowest were in the spring quarter. Nitrogen values in Clinton Lake were higher than normally seen in most Oklahoma Lakes. The nitrogen to phosphorus ratio (TN:TP) was approximately 13:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Clinton Lake was classified as hypereutrophic, indicative of high to excessive primary productivity and nutrient levels (Plate 24). The lake will be recommended for listing as an NLW in the next OWQS revision process and its Aesthetics beneficial use is considered nutrient threatened. Based on reported true color values the Aesthetics use is partially supported at Clinton Lake. D.O. and pH values were fully supporting the FWP beneficial use, however the Lake was not meeting its FWP beneficial use due to high turbidity values. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (42.3 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported. Clinton Lake is one of the municipal water supply reservoirs for the City of Clinton and is utilized for recreation purposes. The lake was constructed in 1931 and is owned by the City of Clinton.

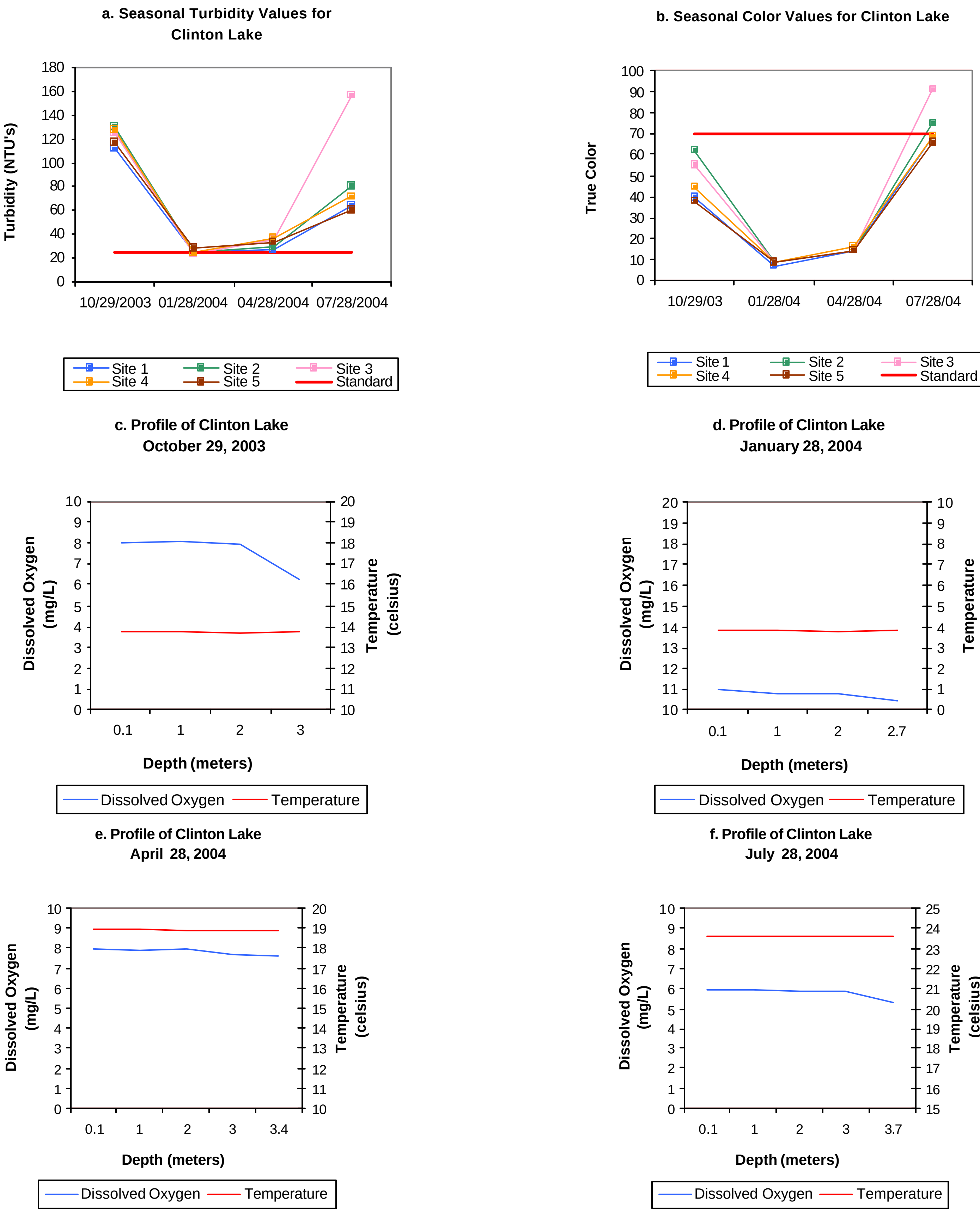
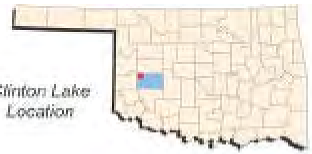



**Figure 59a-59f.** Graphical representation of data results for Clinton Lake.





| Lake Data | |
|---|---|
| Owner | City Clinton |
| County | Washita |
| Constructed | 1931 |
| Surface Area | 335 acres |
| Volume | 3,980 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 11.88 feet |
| Watershed Area | 27 square miles |



Plate 24- Lake Water Quality for
Clinton Lake

# Coalgate City Lake

Coalgate City Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. All samples were collected at the lake surface and 0.5 meters from the lake bottom at sample site 1, near the dam. The lake-wide annual turbidity value was 77 NTU (Plate 25), true color was 202 units, and secchi disk depth was 22 centimeters. Based on these three parameters, Coalgate City Lake had poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 46 (Plate 25), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. This value is consistent with historical data collection efforts, indicating no significant change in productivity has occurred over time. The TSI values varied seasonally from lower mesotrophic in the fall quarter to oligotrophic values present in the winter quarter and eutrophic conditions present in the summer season (see Figure 60). Turbidity values per site for sample year 2003-2004 were all above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 61a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake-wide annual turbidity of 77 NTU is representative of conditions at Coalgate City Lake and is consistent with historical findings for this lake. Coalgate Lake is currently not meeting its Fish & Wildlife Propagation (FWP) beneficial use based on high turbidity concentrations in the lake. Approximately 95% of the true color values were above the aesthetics OWQS of 70 units, (see Figure 61b). Applying the same default protocol for determining the short-term average for true color, the Aesthetics beneficial use is considered not supported.

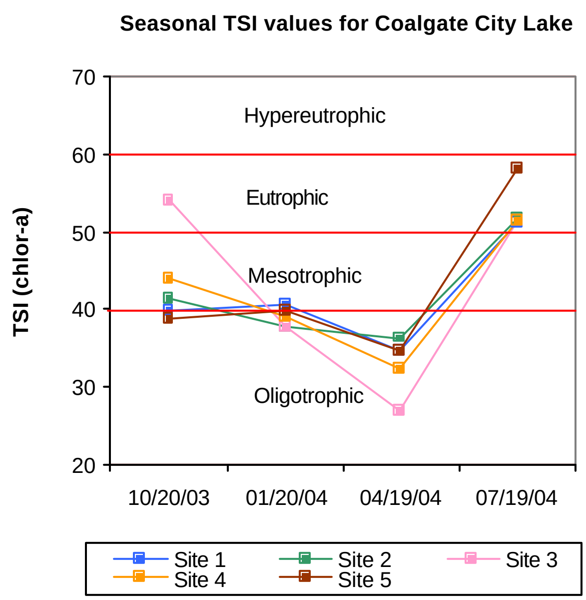



**Figure 60.** TSI values for Coalgate City Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.03 ppt, well within the expected range for most Oklahoma lakes if not less than what is normally seen. Values reflect the minimal presence of chlorides or other salts in the lake system. Specific conductance values followed a similar pattern and were much lower than most Oklahoma reservoirs, with values ranging from 52 mS/cm in the winter to 147.3 mS/cm in the summer, which indicates a very low content of electrical current conducting compounds or salts. Oxidation-reduction potentials ranged from 353 mV to 636 mV, indicating reducing conditions were not present in the reservoir at the time data collection occurred. The pH was generally neutral with values ranging from 6.8 to 7.86 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 for and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Coalgate Lake was fully supporting its FWP beneficial use as it relates to pH. The lake was not thermally stratified in the fall, winter or spring and the water column was well mixed (see Figure 61c-61e). Dissolved oxygen (D.O.) values remained above 6.0 mg/L (except at the very bottom of the lake) and the dissolved oxygen percent saturation was never less than 70% in these three sampling intervals. In the summer quarter, the lake was strongly stratified between 2 and 3 meters and the D.O. concentration dropped to less than 2.0 mg/L from 4 meters in depth to the lake bottom at 7.8 meters (see Figure 61f). Readings at sites 2 and 5 were very similar and anoxic conditions were also present in the bottom two meters of the lake. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 33 to 55% of the water column in the summer less than 2.0mg/L, Coalgate Lake is considered partially supporting its FWP. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.81 mg/L at the lake surface. The TN at the surface ranged from 0.61 mg/L to 1.25 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.079 mg/L at the lake surface. The TP ranged from 0.063 to 0.095 mg/L at the lake surface. Similar to total nitrogen, the highest surface TP values were reported in the spring quarter and the lowest were in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Coalgate City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 25). The high levels of inorganic turbidity contribute to the lack of productivity in the lake as it is limiting the amount if light available. The lake is fully supporting its Aesthetics beneficial use for trophic state but not supporting the use with 95% of the collected values exceeding the OWQS of 70 units. Values for pH were not a cause for concern in meeting the FWP beneficial use. Coalgate City Lake was found to be partially supporting its FWP beneficial use based on D.O concentrations and not supporting the FWP beneficial use based on elevated turbidity in the lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Coalgate City Lake is the municipal water supply reservoir for the City of Coalgate and is owned and operated by the city. The lake is also utilized for recreational and flood control purposes.

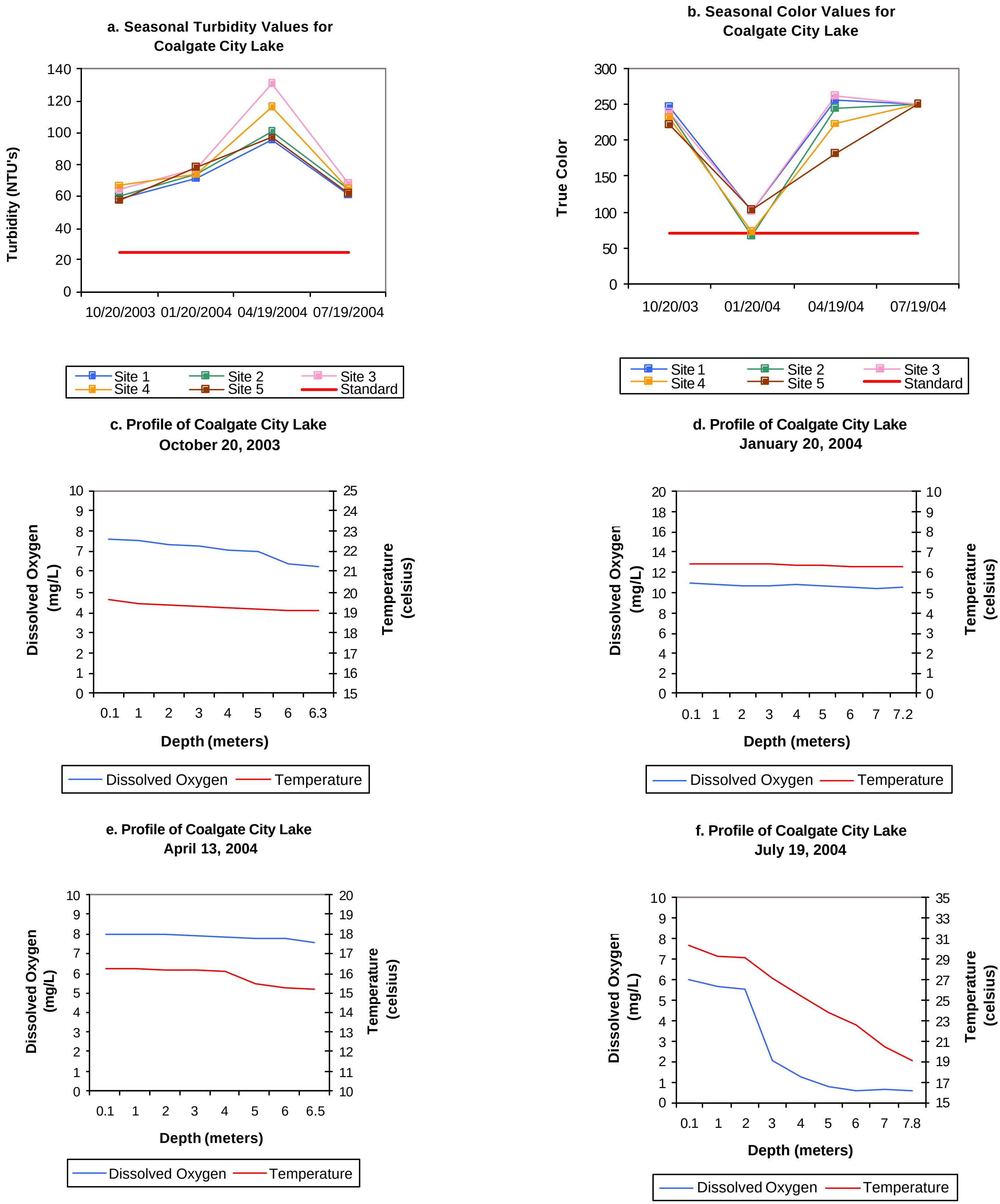
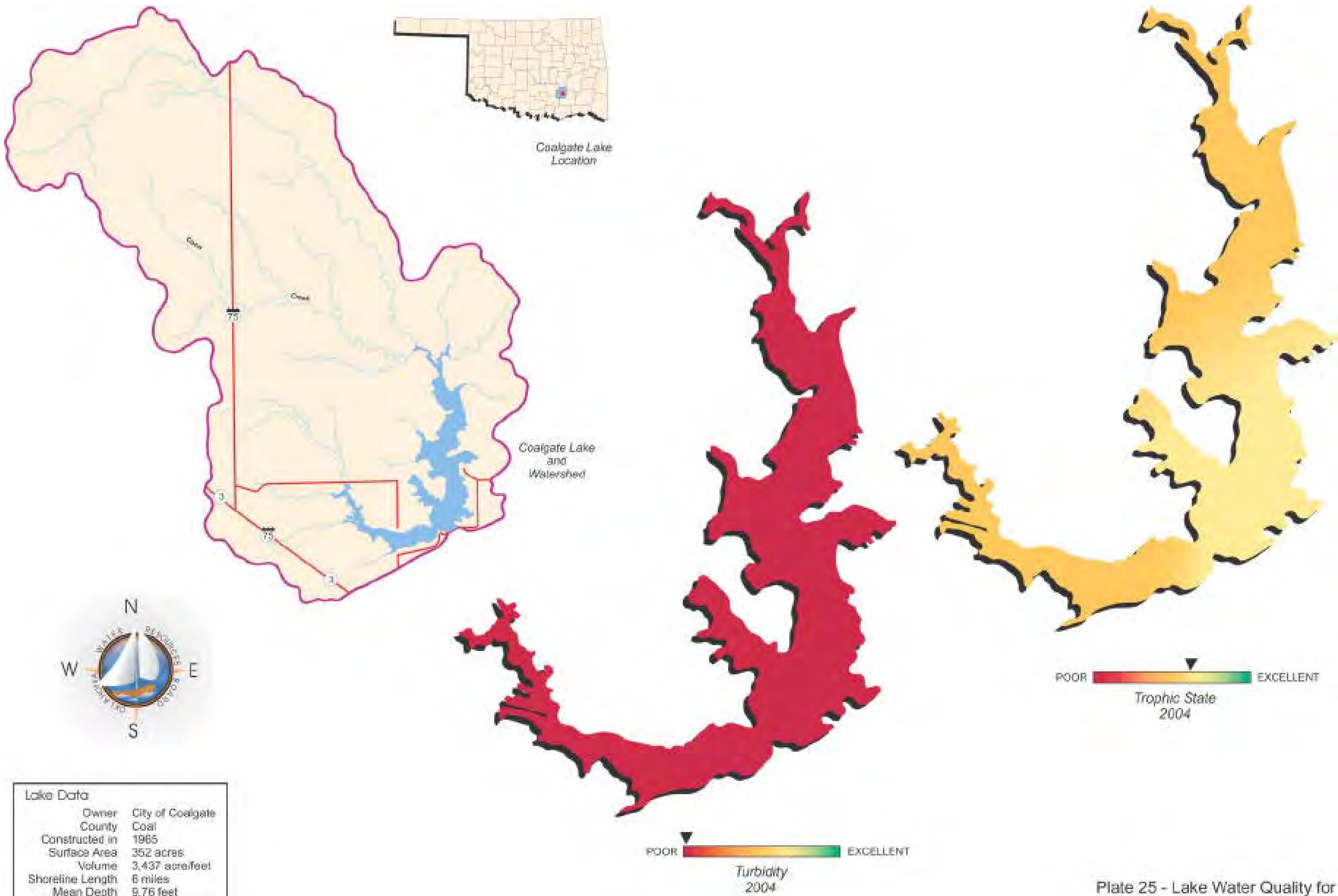



**Figure 61a-61f.** Graphical representation of data results for Coalgate City Lake.




| Lake Data | |
|---|---|
| Owner | City of Coalgate |
| County | Coal |
| Constructed in | 1965 |
| Surface Area | 352 acres |
| Volume | 3,437 acre/feet |
| Shoreline Length | 6 miles |
| Mean Depth | 9.76 feet |
| Watershed Area | 14 square miles |

Plate 25 - Lake Water Quality for
## Coalgate Lake

# Comanche Lake

Comanche Lake was sampled for four quarters from November 2002 through July 2003. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 12 NTU (Plate 26), true color was 16 units, and secchi disk depth was 86 centimeters in 2003. Based on these three parameters, Comanche Lake had good water clarity in comparison to other Oklahoma reservoirs. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 45 (Plate 26), indicating the lake was mesotrophic in sample year 2003. Although this value is slightly lower than that in 2001(TSI=50), the lake is still classified as mesotrophic, indicating little or no change in productivity has occurred. The TSI values throughout the sample year were fairly consistent and ranged from oligotrophic in the winter, to mesotrophic the remainder of the sample year (see Figure 62). The one exception to this was a spike in chlorophyll concentration at site 2 in the spring quarter. Seasonal turbidity values are displayed in Figure. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values well below the standard, the Fish and Wildlife Propagation beneficial use is fully supported based on turbidity. Of the 12 samples collected at Comanche Lake in 2003, none of the true color values exceeded the 70 units criteria listed in OWQS (Figure 63b). Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the high true color values.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.11 parts per thousand (ppt) to 0.16 ppt for this sample year. Specific conductance ranged from 216.6 mS/cm to 321.2 mS/cm, which is within the range recorded for most Oklahoma reservoirs. These values indicate the presence of moderate levels of current conducting compounds (chlorides and salts) in the lake. The pH values at Comanche Lake ranged from 6.84 to 8.56, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they

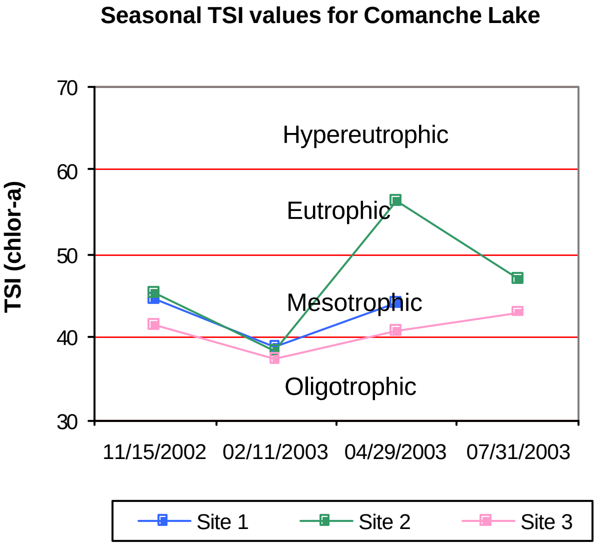



**Figure 62.** TSI values for Comanche Lake

fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range Comanche Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 229 mV in the spring to 493 mV in the winter. In general, reducing conditions were not present in this reservoir. During the fall, winter and spring quarters stratification was not present and the lake was well mixed. Thermal stratification was evident and anoxic conditions were present during the summer. Stratification occurred between 5 and 6 meters in depth at which the dissolved oxygen (D.O.) fell below 1.0 mg/L for the rest of the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 50% of the water column in the summer less than 2.0mg/L, Comanche Lake is considered partially supporting its FWP. The lake was sampled for total dissolved solids, chlorides, and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the surface and 0.78 mg/L at the lake bottom. The TN at the surface ranged from 0.21 mg/L in the winter to 0.51 mg/L in the fall. The lake-wide total phosphorus (TP) average was 0.017 mg/L at the surface and 0.104 at the lake bottom. The total phosphorus at the surfaced ranged from 0.008 mg/L to 0.023 mg/L with lower values occurring in the fall quarter. The nitrogen to phosphorus ration (TN:TP) was 24:1 for sample year 2003. This value is much higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Comanche was classified as mesotrophic with moderate primary productivity and nutrient conditions in 2002-2003, indicating no significant change has occurred since 2001. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use for pH and turbidity, but partially supporting based on dissolved oxygen levels. The Aesthetics beneficial use is also being met for both the trophic status and true color parameters. Comanche Lake is located in Stephens County and serves as a municipal water supply as well as a recreational reservoir for the city of Comanche.

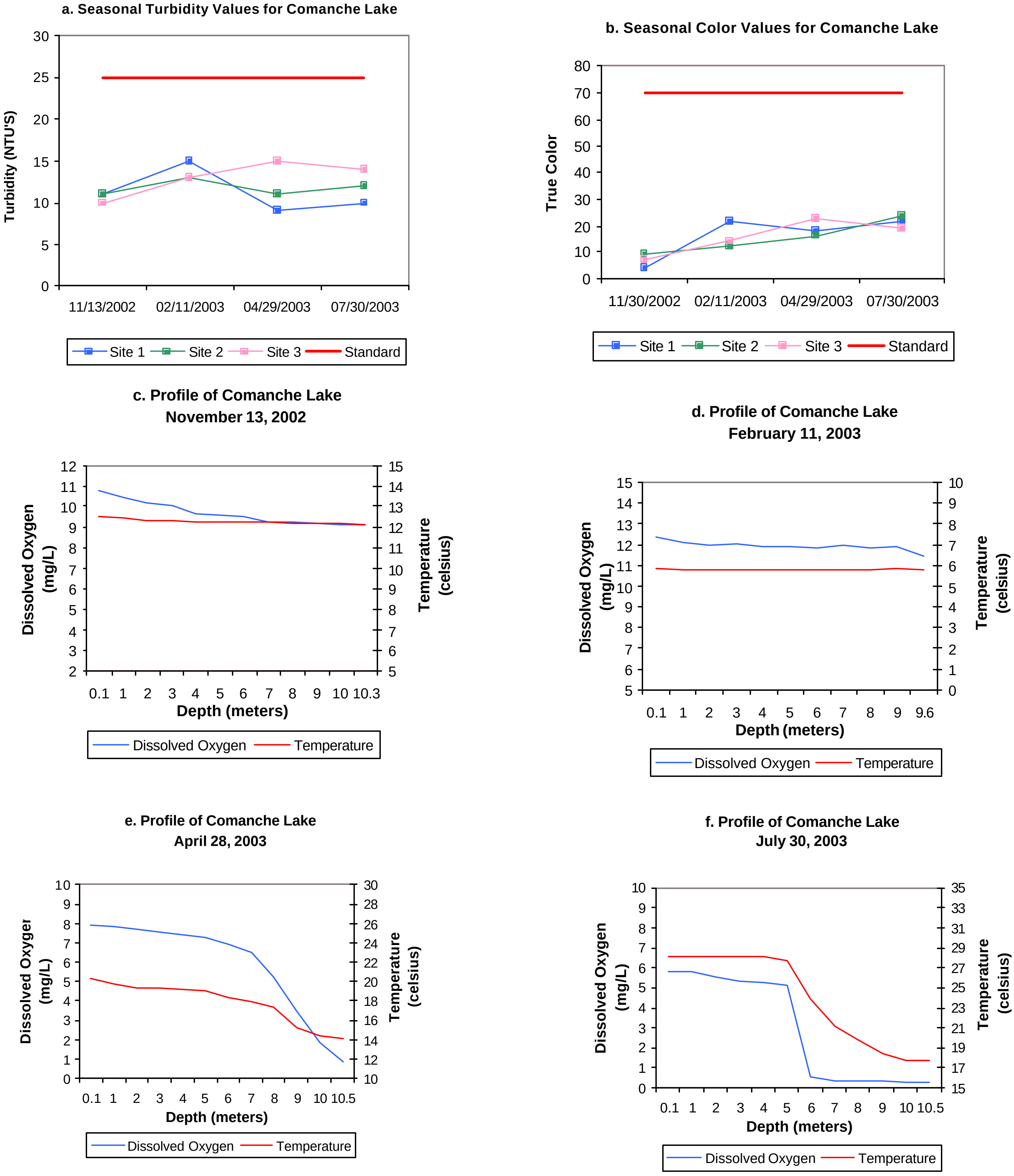
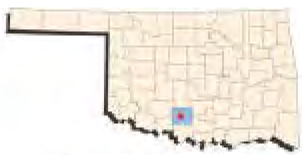



**Figure 63a-63f.** Graphical representation of data results for Comanche Lake.



Comanche Lake
Location

Comanche Lake
and
Watershed



Turbidity
2003


Trophic State
2003

Lake Data

| | |
|---|---|
| Owner | City of Comanche |
| County | Stephens |
| Constructed | 1960 |
| Surface Area | 184 acres |
| Volume | 2,500 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 13.59 |
| Watershed Area | 2,288 acres |

Plate 26 - Lake Water Quality for
## Comanche Lake

# Copan Lake

Copan Lake was sampled for four quarters, from October 2002 through July 2003. Samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites, and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 46 NTU (Plate 27), true color was 50 units, and average secchi disk depth was 36 centimeters in sample year 2002-2003. Water clarity was poor at Copan Lake based on these three parameters. Results for turbidity, true color and secchi disk depth are similar to those recorded in 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 59 (Plate 27), indicating the lake was eutrophic, with high levels of productivity and nutrient conditions for sample year 2003. This value is similar to that calculated in 2000 (TSI=57) indicating no significant change in productivity has occurred. The TSI values for all sites were fairly consistent and ranged from upper eutrophic to lower hypereutrophic (Figure 64). Seasonal turbidity values by site are displayed in Figure 65a. Although the lake-wide average for turbidity was 46 NTU, above the OWQS of 25 NTU, there are instances when some values were near or below the standard. These lower turbidity values occurred at all sites during the winter quarter (see Figure 65a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥ 25% of the samples exceed the Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is not supported at Copan Lake, as 70% of the values exceed the turbidity standard of 25 NTU. Seasonal true color values are displayed in Figure 65b. Of the 20 samples collected, 20% exceeded the OWQS of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is partially supported based on the true color values.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.14 ppt, which is within the range of values seen in Oklahoma reservoirs. Specific conductance ranged from 152.1 mS/cm to 256.3 mS/cm, indicative of minimal levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.81 in the summer to 8.18 in the spring, representing a neutral to slightly alkaline lake system. According to USAP (OAC 785:46-15-

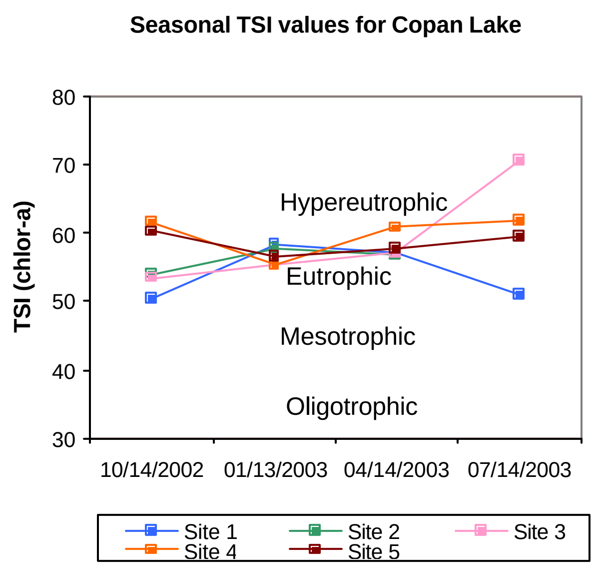



**Figure 64.** TSI values for Copan Lake

5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range, Copan Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 407mV in the hypolimnion in the spring to 594 mV in the fall. In general, reducing conditions were not present at this reservoir during the 2002-2003-sample year. Copan Lake was not thermally stratified during any of the sampling quarters (see Figure 65c-65f). Dissolved oxygen (D.O.) levels were generally above 4.0 mg/L throughout the sample year. The relatively shallow nature of the lake is likely responsible for keeping the lake well mixed. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 100% of the water column above 2.0 mg/L the FWP Benicia use is fully supported at Copan Lake. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.55mg/L at the surface and 0.36 mg/L at the lake bottom. Surface TN ranged from 0.25 mg/L to 1.38 mg/L, with the highest values recorded in the summer quarter, and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.080 mg/L at the surface and 0.057 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.023 mg/L to 0.184 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 7:1 for sample year 2003 characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Copan Lake was classified as eutrophic with high primary productivity and nutrient levels in 2002-2003. This value is similar to that calculated in 2000 (TSI=57), indicating no significant change in productivity has occurred. Water clarity was poor based on turbidity, true color and secchi disk depth. The lake is not supporting the FWP beneficial use based on turbidity, but is supporting based on pH and dissolved oxygen values. The Aesthetics beneficial use is supported based on the trophic status, and is partially supported for true color, as 20% of the collected values exceed the OWQS of 70 units. Copan Lake is located in Washington County and was constructed by the United States Army Corps of Engineers (USACE) to serve as a flood control, waters supply, and fish and wildlife reservoir.

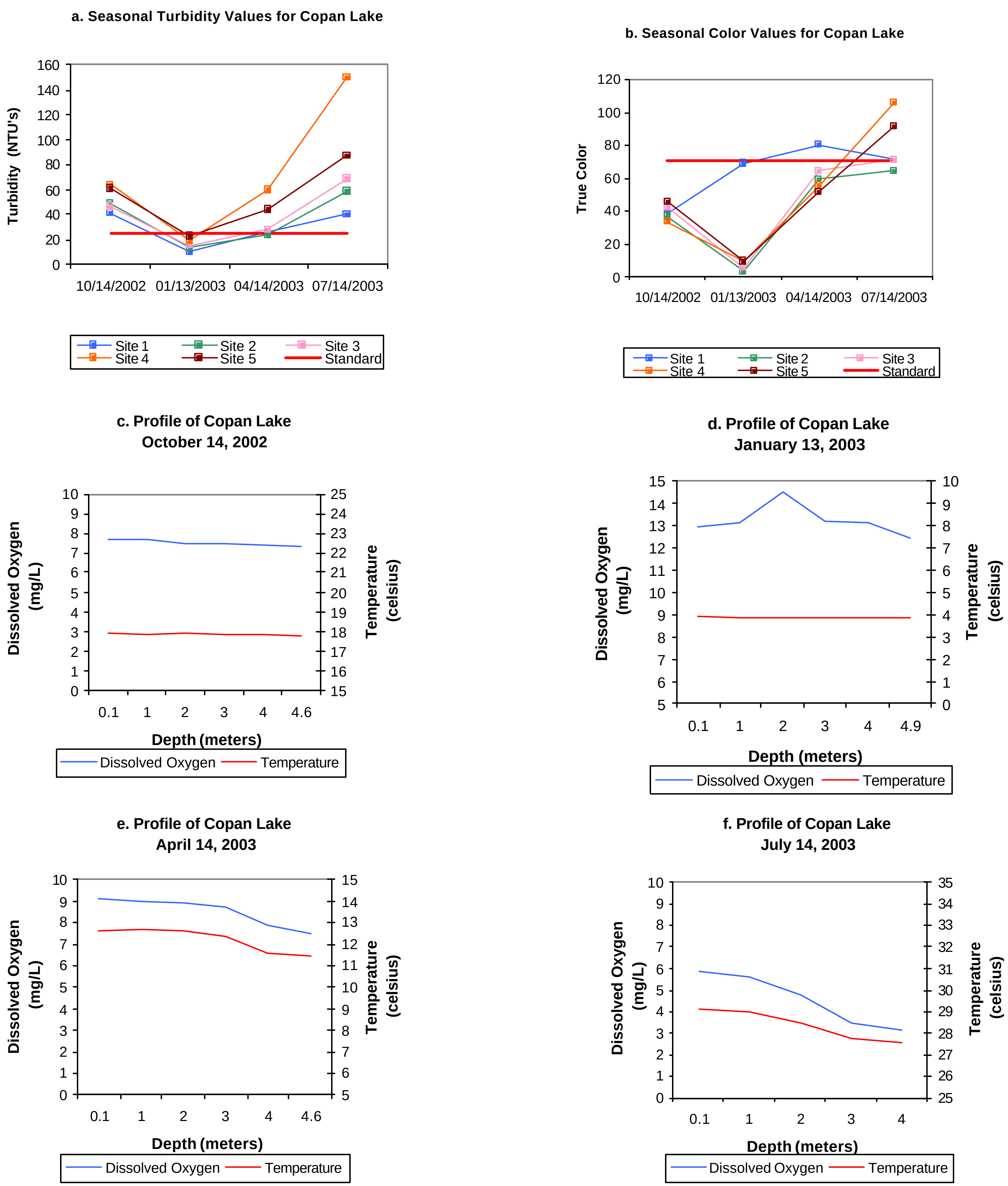
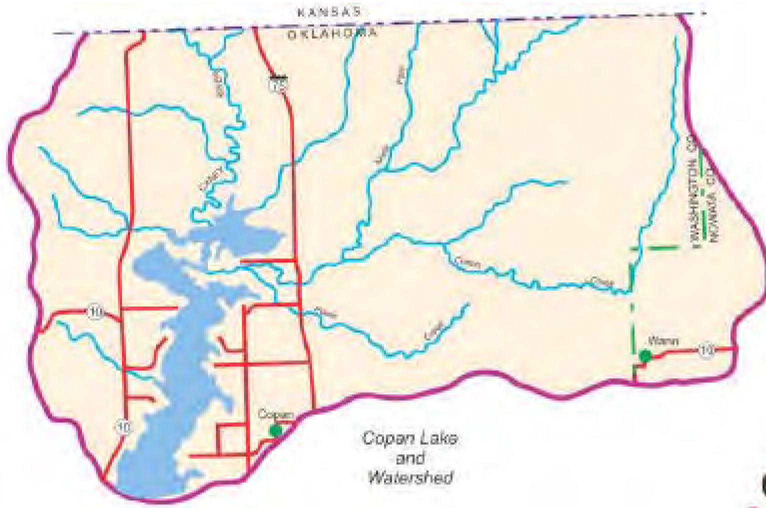
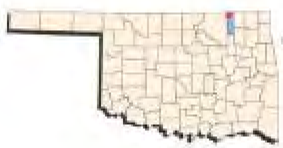



**Figure 65a-65f.** Graphical representation of data results for Copan Lake.




Copan Lake and Watershed



Copan Lake Location


| Lake Data | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Washington |
| Constructed in | 1983 |
| Surface Area | 4,850 acres |
| Volume | 43,400 acre/feet |
| Shoreline Length | 30 miles |
| Mean Depth | 8.95 feet |
| Watershed Area | 505 square miles |


Turbidity
2003


Trophic State
2003

Plate 27 - Lake Water Quality for
## Copan Lake

# Crowder Lake

Crowder Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, near the dam. The lake-wide annual turbidity value was 24 NTU (Plate 28), true color was 16 units, and secchi disk depth was 52 centimeters. Based on these three parameters, Crowder Lake had average water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 57 (Plate 28), indicating the lake was eutrophic, with high levels of productivity and nutrients. The current calculation is slightly less than that in 2001 (TSI=60) although in the same trophic category. The TSI values varied seasonally from eutrophic in the fall and winter to mesotrophic in the spring and peaking in the summer when hypereutrophic conditions were present (See Figure 66). Crowder Lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Turbidity values per site were generally below the OWQS of 25 NTU for all seasons except for one event in the spring, which exceeded the standard (see Figure 67a). Site 3 had recorded values exceeding the standard in three of the four sampling quarters. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Crowder Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. All true color values were below the Aesthetics OWQS of 70 units (see Figure 67b). Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values.

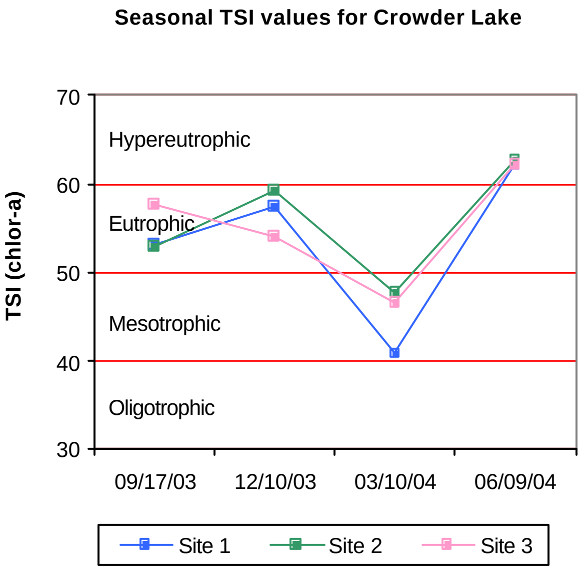



**Figure 66.** TSI values for Crowder Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.36 parts per thousand (ppt) to 0.61 ppt, which is higher than the expected range for most Oklahoma lakes. Salinity values indicate a moderate to high presence of chlorides or other salts in the lake.

Specific conductance values exhibited a similar pattern and were somewhat higher than most Oklahoma reservoirs, with values ranging from 700 mS/cm in the spring to 1161 mS/cm in the winter, which is indicative of a high content of electrical current conducting compounds or salts throughout the lake system. Oxidation-reduction potentials (redox) ranged from 370 mV to 499 mV, indicating reducing conditions were not present during the study period. The pH was neutral to slightly alkaline with values ranging from 7.3 to 8.17 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Crowder Lake is fully supporting its FWP for pH. The lake was not thermally stratified and the water column appeared to be well mixed throughout the fall, winter and spring quarters at all sites (see Figure 67c-67e). Dissolved oxygen (D.O.) values remained above 4.0 mg/L throughout the water column and were generally above 5.0 mg/L and the dissolved oxygen percent saturation was never less than 45% in the first three seasons. Due to equipment failure there is no profile data available for the summer sampling interval. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Crowder Lake with all values in the first three quarters well above 2.0 mg/L. Because the summer profile data is missing an assessment for that season cannot be made at this time. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected two (20%) exceeded the prescribed screening level of 61 cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.80 mg/L at the lake surface. The TN at the surface ranged from 0.76 mg/L to 1.79 mg/L. The highest and lowest surface TN value was reported in the spring quarter. The lake-wide total phosphorus (TP) average was 0.076 mg/L at the lake surface. The TP ranged from 0.045 mg/L to 0.169 mg/L at the lake surface. The highest surface TP values were reported in the winter quarter and the lowest were in the fall quarter. The total nitrogen phosphorus ratio (TN:TP) was 11:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Crowder Lake was classified as eutrophic bordering on hypereutrophic, indicative of high to excessive primary productivity and nutrient levels (Plate 28). Based on secchi disk depth, turbidity and true color, Crowder Lake had average water clarity in comparison to other Oklahoma reservoirs. The FWP beneficial use was fully supported based on pH and dissolved oxygen Available flow and rainfall data suggest that the peak in turbidity, which occurred in March, is likely due to seasonal storm events, therefore Crowder Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. The lake was fully supporting its Aesthetics beneficial use for true color. Crowder Lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected two (20%) exceeded the prescribed screening level of 61 cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Crowder Lake is owned and operated by the State of Oklahoma for the express purpose of providing flood control and recreational opportunities to the citizens of Oklahoma.

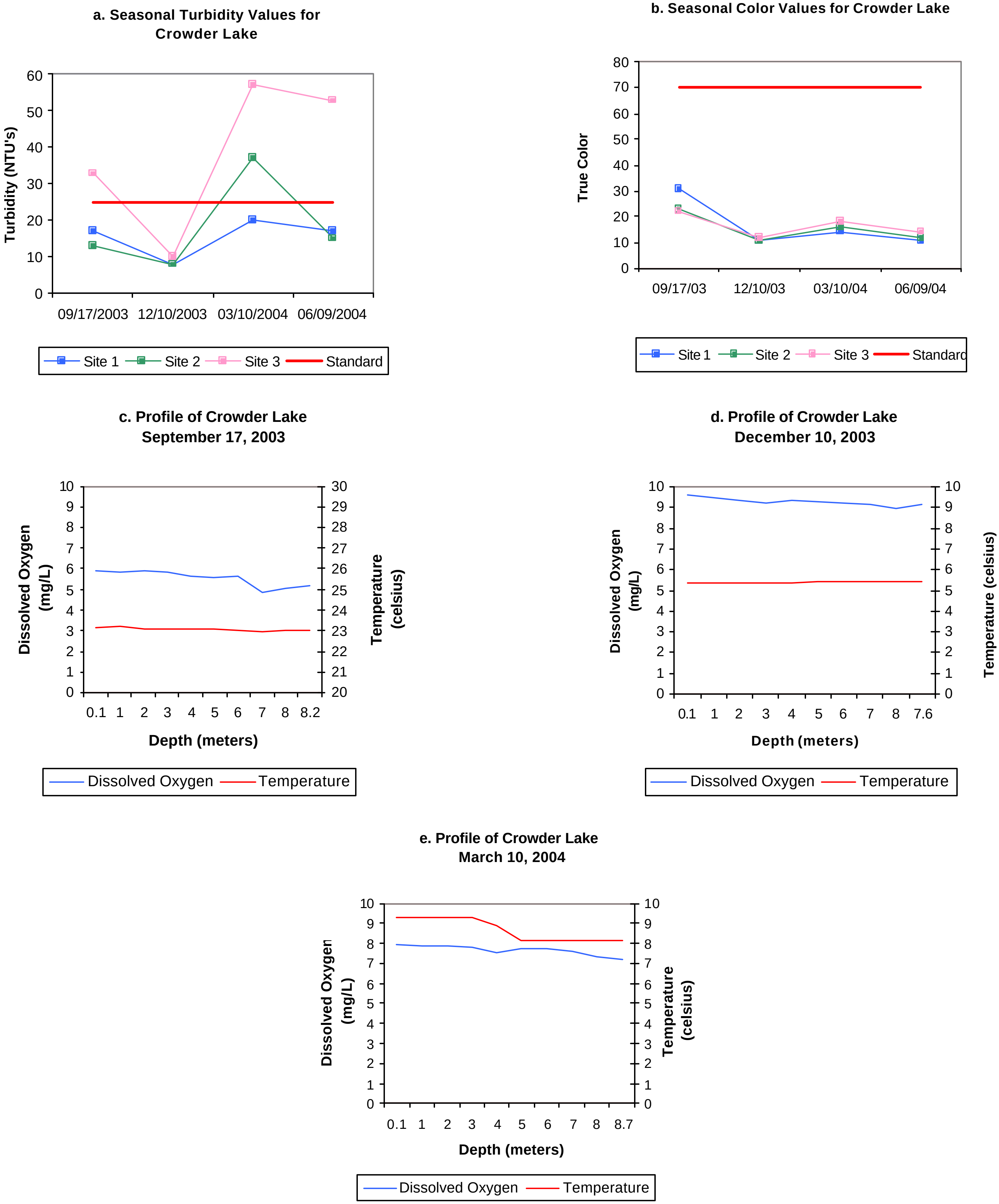



**Figure 67a-67f.** Graphical representation of data results for Crowder Lake.

Plate 28 - Lake Water Quality for
# Crowder Lake


Lake Data

| | |
|---|---|
| Operator | State of Oklahoma |
| County | Washita |
| Constructed | 1959 |
| Surface Area | 158 acres |
| Volume | 2,094 acre/feet |
| Shoreline Length | 9 miles |
| Mean Depth | 13.25 feet |
| Watershed Area | 27 square miles |


Turbidity
2004


Trophic State
2004

# Cushing Municipal Lake

Cushing Municipal Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected at the surface at all sites as well as 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 49 NTU (Plate 29), true color was 101 units, and secchi disk depth was 34 centimeters. Based on these three parameters, Cushing Municipal Lake had poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 51 (Plate 29), indicating the lake was eutrophic, with high levels of productivity and nutrients. This is similar to the findings in 2002, indicating no significant increase or decrease in productivity had occurred. The TSI values were very consistent across the seasons and were either at the extreme upper end of mesotrophy or the lower end of eutrophy (see Figure 68). Turbidity values per site for sample year were all near or above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 69a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 80% of the samples collected above the standard, Cushing Lake is not meeting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. The lake-wide annual turbidity of 49 NTU is in consistent with historical data collection results seen for the lake. Of the twenty true color values collected 40% were above the aesthetics OWQS of 70 units (see Figure 69b). Applying the same default protocol, the Aesthetics beneficial use is considered not supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.13 ppt, which was within the expected range for most Oklahoma lakes and reflecting minimal presence of chlorides or other salts in the lake system. Specific conductance values were also consistent with values that would normally be seen in Oklahoma reservoirs, with values ranging from 197.4 mS/cm in the fall to 274.6 mS/cm in the summer. Values did not indicate a high content of electrical current

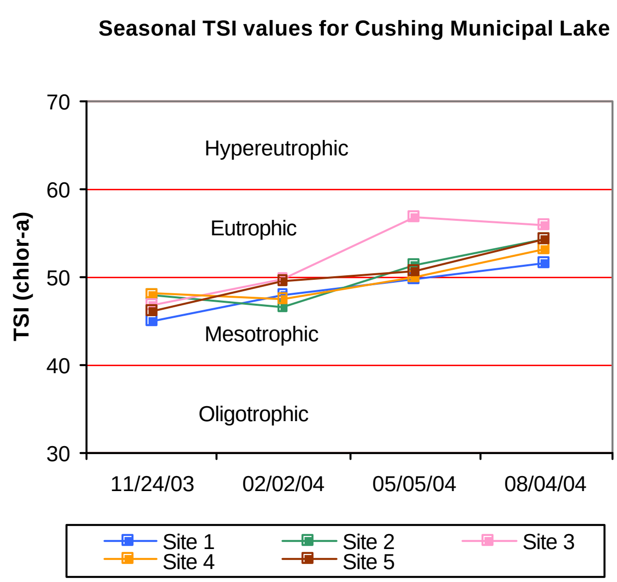



**Figure 68.** TSI values for Cushing Municipal Lake.

conducting compounds or salts in the lake. Oxidation-reduction potentials ranged from 392 mV to 583 mV, indicating reducing conditions were not present at any time during the sampling period. The pH was neutral to slightly alkaline with values ranging from 7.06 to 8.53 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The FWP beneficial use was fully supporting based on pH values collected during the study period. The lake was not thermally stratified and the water column appeared to be well mixed throughout the fall, winter and spring sampling quarters at all sites (see Figure 69c-69e). Dissolved oxygen (D.O.) values remained above 6.5 mg/L and the D.O. percent saturation was never less than 60% in the first three sampling intervals (see Figure 69c-69e). In the summer the lake was stratified at site 1 between 3 and 4 meters and the D.O. concentration dropped from 6.91 mg/L to 0.45 mg/L at the lake bottom of 6.1 meters (Figure 69f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the (FWP) beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 38% of D.O. readings collected at site 1 in the summer less than 2.0 mg/L, the lake is partially supporting its FWP beneficial use. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 samples collected all were below the prescribed screening levels. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.86 mg/L at the lake surface. The TN at the surface ranged from 0.60 mg/L to 1.28 mg/L. The highest surface TN value was reported in the spring and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.086 mg/L at the lake surface. The TP ranged from 0.039 mg/L to 0.184 mg/L at the lake surface. The highest surface TP values were reported in the spring quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Cushing Municipal Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 29). Given the level of nutrients present in the lake system, the high levels of inorganic turbidity are serving as a mitigating factor for lake productivity through light limitation. The lake is fully supporting its Aesthetics beneficial use based on trophic status and not supporting for true color with 40% of the recorded values exceeding 70 units. The FWP beneficial use was fully supported based on pH and dissolved oxygen concentrations. The lake was not meeting its FWP beneficial use due to high turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples collected all were below the prescribed screening levels. The PBCR beneficial use is therefore considered supported. Cushing Municipal Lake constructed in 1950, is the municipal water supply for the City of Cushing and is also utilized for recreational purposes.

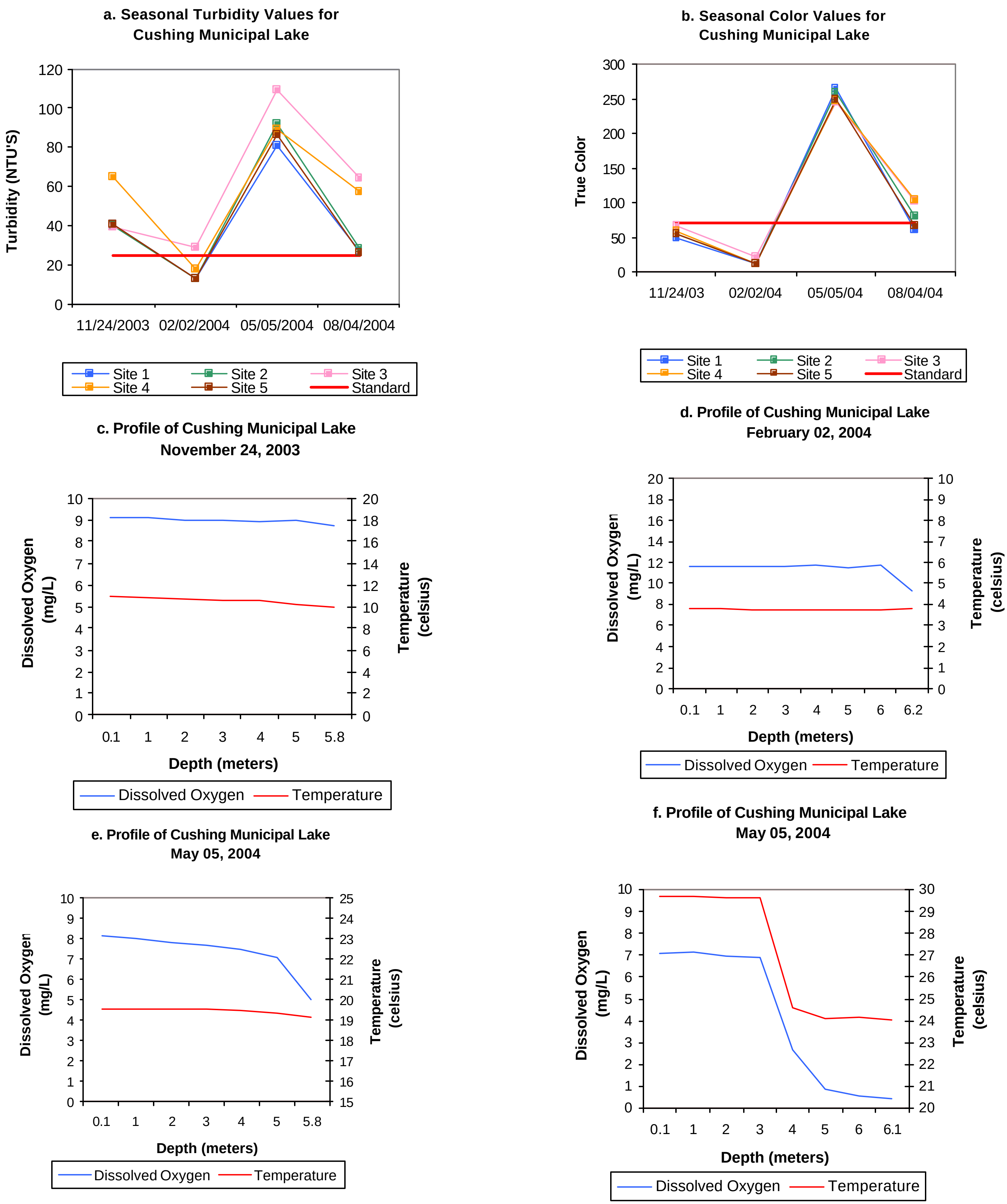



**Figure 69a-69f.** Graphical representation of data results for Cushing Municipal Lake.




Lake Data

| | |
|---|---|
| Owner | City of Cushing |
| County | Payne |
| Constructed in | 1950 |
| Surface Area | 592 acres |
| Volume | 3,304 acre/feet |
| Shoreline Length | 9 miles |
| Mean Depth | 5.58 feet |
| Watershed Area | 32 square miles |

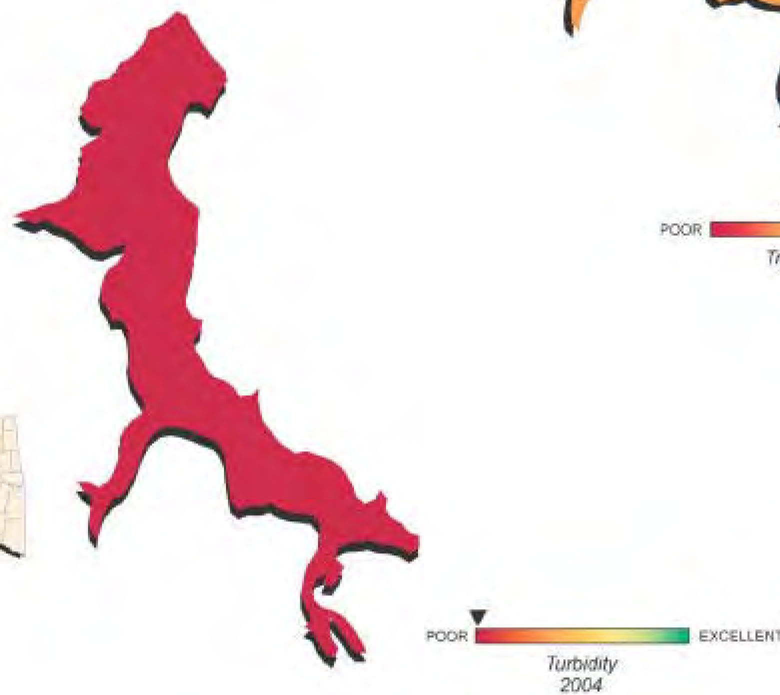




Plate 29 - Lake Water Quality for
## Cushing Lake

# Dave Boyer (Walters) Lake

Dave Boyer (Walters) Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at three sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 89 NTU (Plate 120), true color was 48 units, and secchi disk depth was 16 centimeters in 2003-2004. Based on these three parameters, Dave Boyer Lake had poor water clarity in comparison to other Oklahoma reservoirs. Water clarity was similar in the 2001, and is always poor based on the soil composition and nature of this lake. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 52 (Plate 120), indicating the lake was eutrophic with high levels of productivity and nutrients. This value is similar to the TSI in 2001 (TSI= 51), indicating no change in productivity has occurred since the last evaluation. The TSI values were generally eutrophic with the exception of the winter when two of the three sites were mesotrophic (See Figure 70). Seasonal turbidity values are displayed in (Figure 71a). Turbidity values were well above the turbidity standard of 25 NTU at all sites throughout the year. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The FWP beneficial use is considered not supported at Dave Boyer Lake with 100% of the collected values exceeding the numeric criteria of 25 NTU. Seasonal true color values are displayed in (Figure 71b). Of the 12 samples collected at Dave Boyer Lake in 2003-2004, 25% of the true color values exceeded the 70 units criteria listed in OWQS. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is considered not supported based on the high true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.20 parts per thousand (ppt) to 0.25 ppt, which was well within the expected range for most Oklahoma lakes. Specific conductance ranged from 398.1 mS/cm in the summer quarter to 494.2 mS/cm in the spring quarter, indicative of moderate levels of electrical current conducting compounds or salts in the lake system. Oxidation-reduction potentials ranged from 209 mV to 526 mV, indicating reducing conditions were not present at any point in the water column when sampling occurred. The pH was neutral to alkaline with values ranging from 7.65 to 8.43 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the

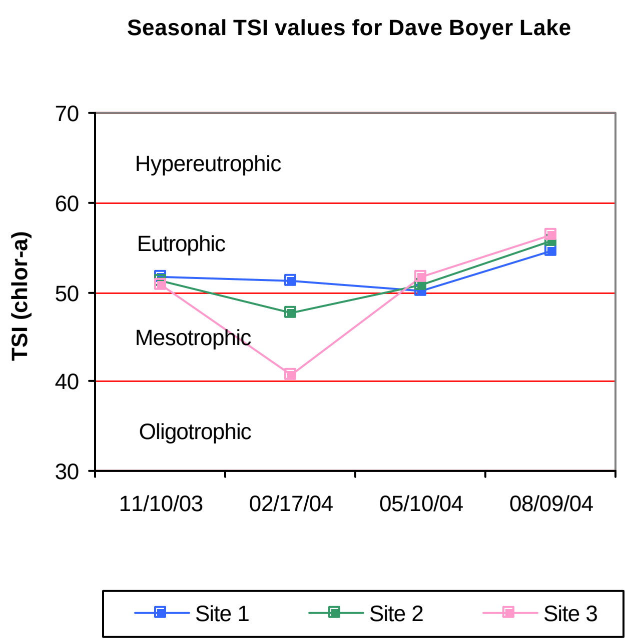



**Figure 70. TSI values for Dave Boyer Lake**

waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all values within the acceptable range Dave Boyer Lake is meeting its FWP beneficial use based on pH. The lake was not thermally stratified and the water column appeared to be well mixed in the winter, spring and summer sampling events (see Figure 71c-71e). Dissolved oxygen (D.O.) values generally remained above 5.0 mg/L. Due to equipment failure there is no profile data available for the fall sampling interval. However, it is likely that thermal stratification did not occur as this lake is very shallow in nature and stays well mixed due to wind action. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Dave Boyer Lake is supporting its FWP beneficial use based on D.O. concentrations in the water column. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E. coli,* fecal coliform, and enterococci analysis during the recreation season of May through September. The PBCR is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.74 mg/L at the lake surface. The TN at the surface ranged from 0.60 mg/L to 0.88 mg/L. The highest surface TN values occurred in the summer and the lowest was reported in the winter quarter. The lake-wide total phosphorus (TP) average was 0.084 mg/L at the lake surface. The TP ranged from 0.048 mg/L to 0.112 mg/L at the lake surface. Similar to total nitrogen the highest TP values were reported in the summer quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Dave Boyer Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 120). This is consistent with the 2001 evaluation indicating no significant increase or decrease in productivity has occurred over time. The Aesthetics beneficial use was fully supporting for trophic state and not supporting for true color with 25% of the collected values exceeding the numeric criteria of 70 units. The FWP beneficial use is considered fully supported for pH and dissolved oxygen; however is not meeting based on high turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. The PBCR is considered fully supported. Dave Boyer Lake, located in Cotton County, is owned by the city of Walters and serves as a water supply and recreation reservoir.

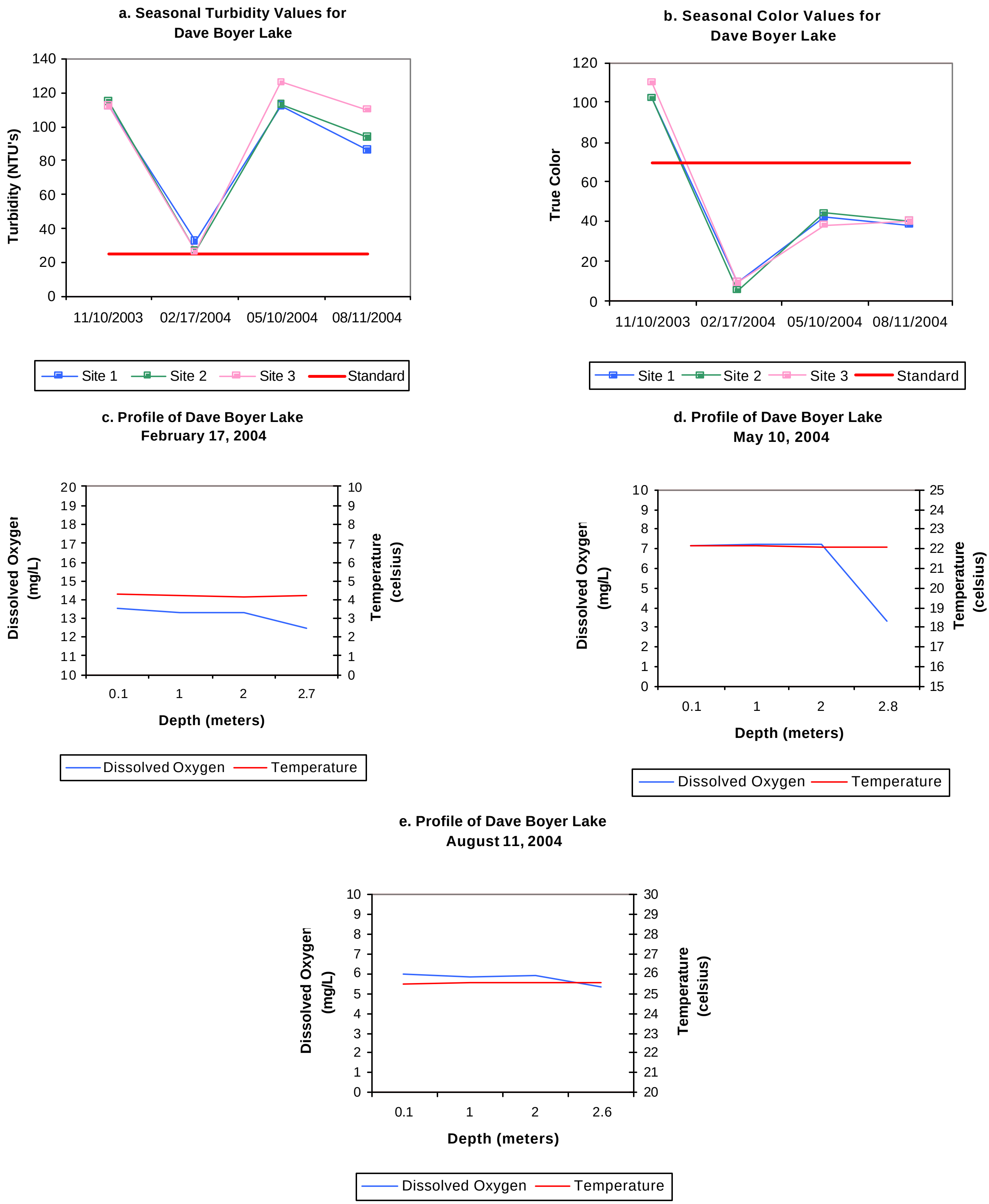
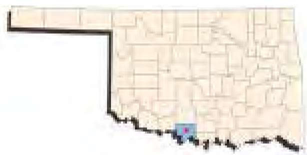
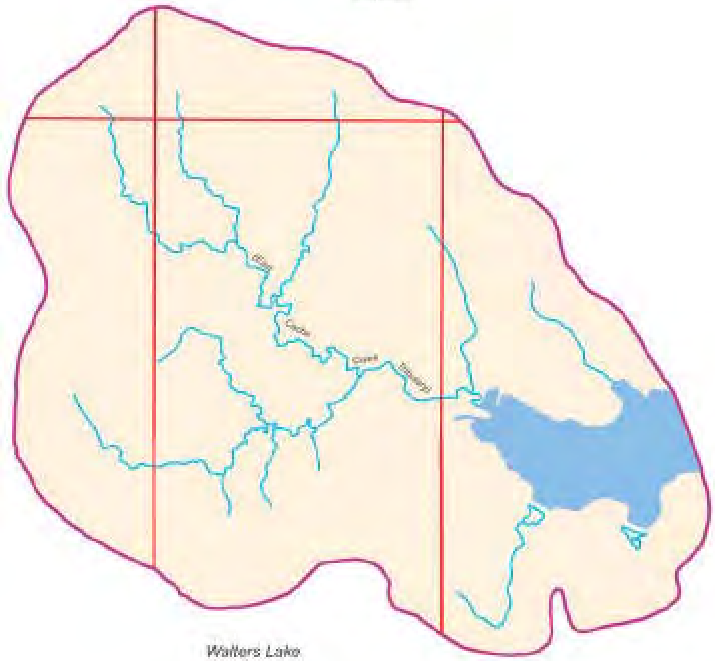


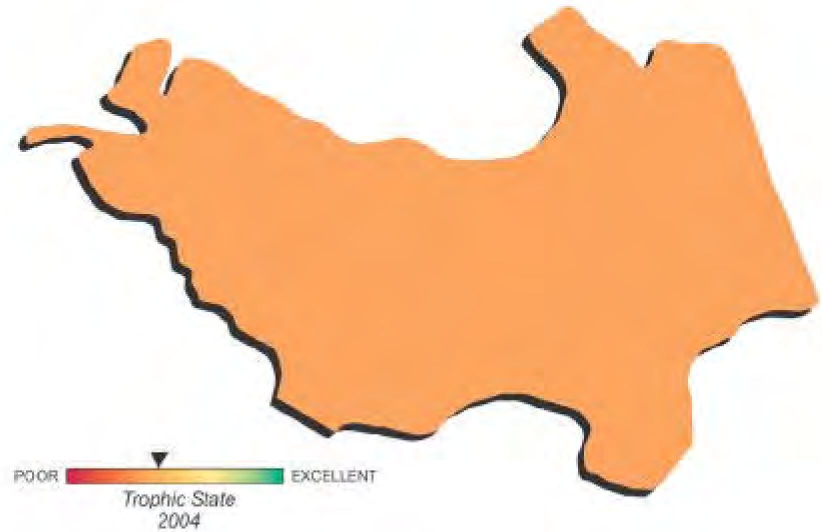

**Figure 71a-71e.** Graphical representation of data results for Dave Boyer Lake.





| Lake Data | |
|---|---|
| Owner | City of Walters |
| County | Cotton |
| Constructed | 1936 |
| Surface Area | 148 acres |
| Volume | 861 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 5.82 feet |
| Watershed Area | 2,389 acres |



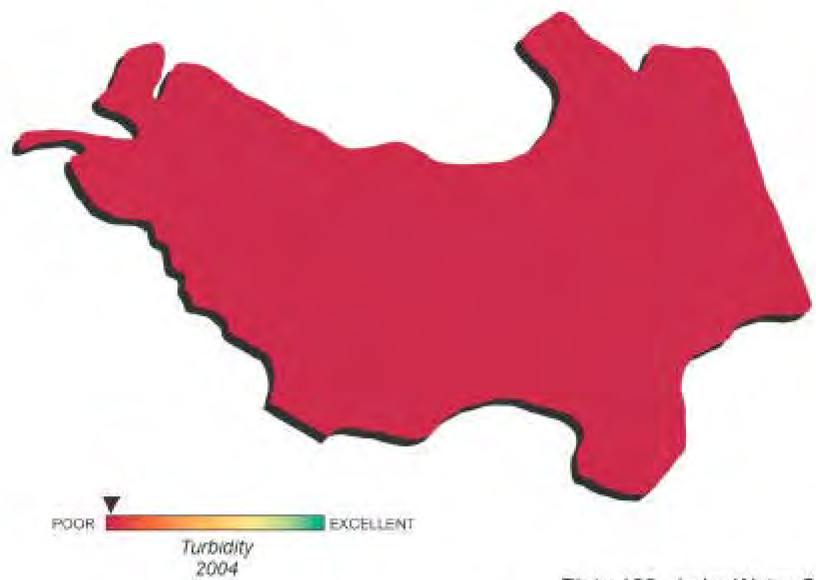




Plate 120 - Lake Water Quality for
# Dave Boyer (Walters) Lake

# Dripping Springs Lake

Dripping Springs Lake was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as major lake arms. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 11 NTU (Plate 30), true color was 27 units, and secchi disk depth was 88 centimeters in 2001-2002. Based on these three parameters, Dripping Springs Lake had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 46 (Plate 30), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. The TSI values were mesotrophic in the first three seasons, but some sites were oligotrophic during the summer season (see Figure 72). Turbidity values per site for sample year 2001-2002 were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 73a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake-wide annual turbidity of 11 NTU seemed representative of conditions at Dripping Springs Lake in 2001-2002 and the lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity concentrations. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use supported based on the true color values (see Figure 73b).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.04 ppt, which was well within the expected range for most Oklahoma lakes if not lower than the normally seen values. The low salinity concentrations recorded reflected minimal presence of chlorides or other salts in the lake. Specific conductance values were also very low when compared to most Oklahoma reservoirs, with values ranging from 53.0 mS/cm in the fall quarter to 99.0 mS/cm in the winter quarter, which indicated that a very low content of electrical current conducting compounds or salts in the water column. Oxidation-reduction potentials ranged from 130 mV to 514 mV, indicating reducing conditions were not present at any point in the water column when sampling occurred. The pH was neutral to alkaline with values ranging from 6.43 to 8.9 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially

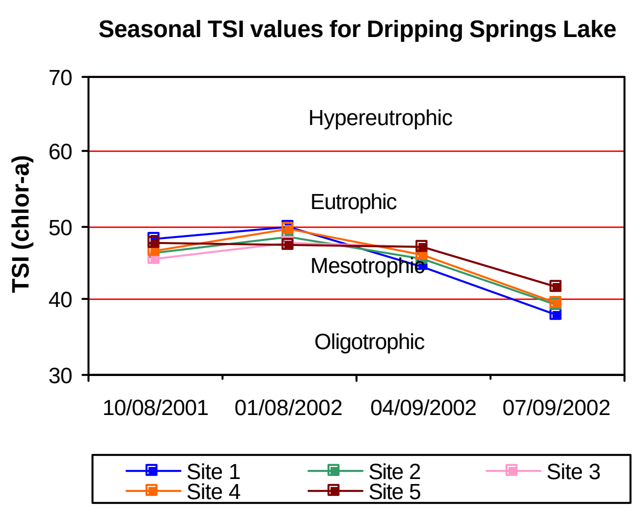



**Figure 72.** TSI values for Dripping Springs Lake.

supporting beneficial uses. Dripping Springs Lake had 4% of the pH values collected fall outside the prescribed range, which indicated that the lake was meeting its FWP beneficial use based on pH. The lake was not thermally stratified and the water column appeared to be well mixed throughout in the fall, winter and spring at all sites (see Figure 73c-73f). Dissolved oxygen (D.O.) values generally remained above 6.0 mg/L except at the very bottom of the lake and the dissolved oxygen percent saturation was never less than 50% in the first three seasons with the exception of the actual lake bottom in the fall quarter (see Figure 73c-73e). In the summer, the lake was strongly thermally stratified between 4 and 5 meters and the D.O. concentration dropped from 2.4 mg/L 4 meters from the lake surface to 0.37 mg/L at the lake bottom of 14 meters (see Figure 73f). The readings in the lake hypolimnion were anoxic at all five sites and approximately 67% of the values collected at site 1 were below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Dripping Springs Lake is partially supporting its FWP beneficial use based on D.O. concentrations in the water column. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.49 mg/L at the lake surface. The TN at the surface ranged from 0.32 mg/L to 0.70 mg/L. The highest and lowest surface TN values were both reported in fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.020 mg/L at the lake surface. The TP ranged from 0.009 mg/L to 0.032 mg/L at the lake surface. The highest surface TP values were reported in the spring quarter and the lowest were in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 24:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Dripping Springs Lake was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Dripping Springs Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 30). The Aesthetics beneficial use was fully supporting for true color and trophic state. Turbidity and pH values were not a cause for concern in meeting the FWP beneficial use and they were fully supporting. Dripping Springs is partially supporting its FWP beneficial use based on D.O. concentrations. In general, the water quality of Dripping Springs is very good. Dripping Springs Lake is owned and operated by the City of Okmulgee and is managed for water supply uses, flood control uses and for recreational purposes.

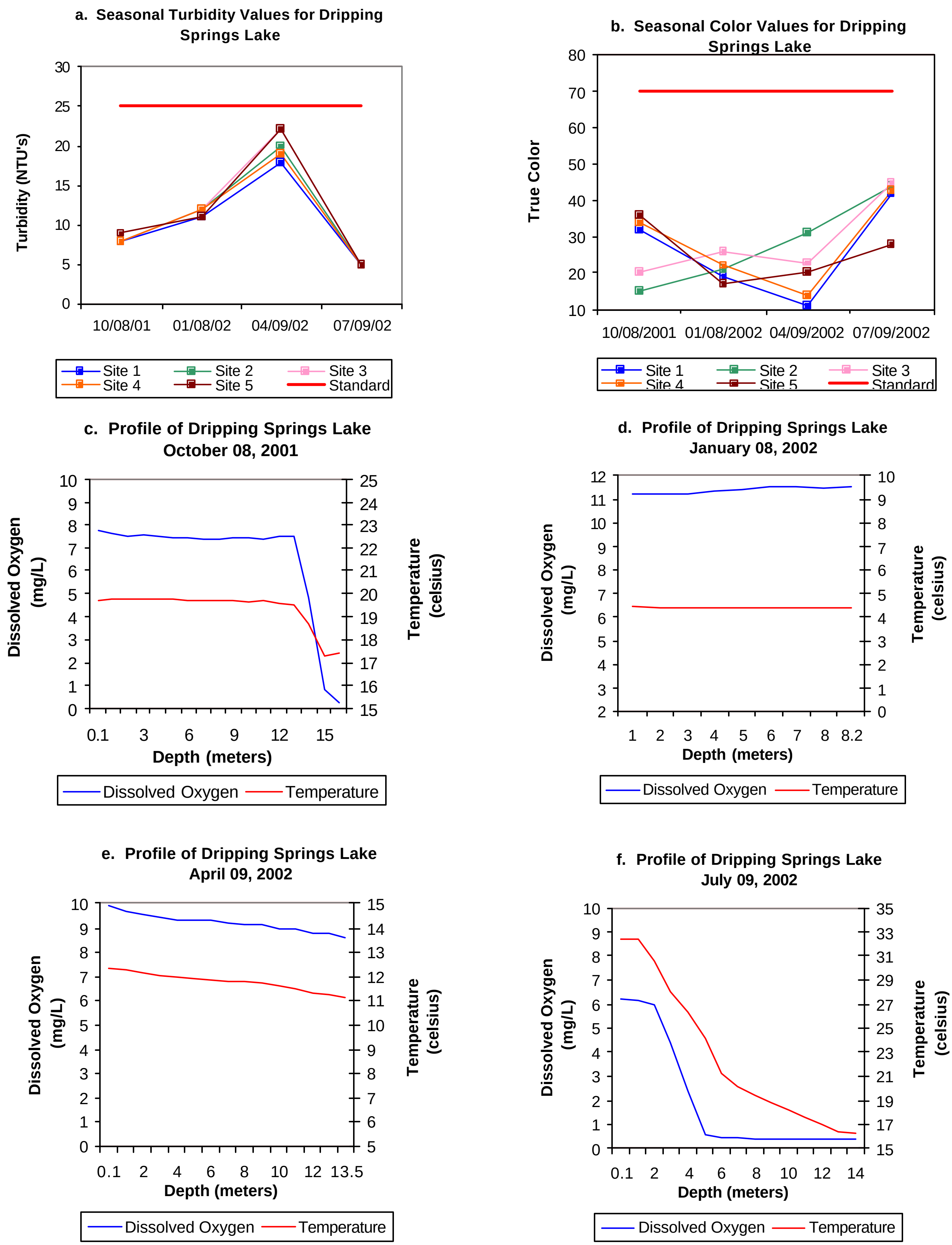
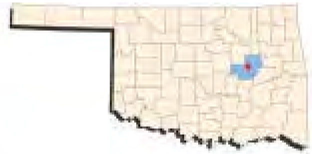



**Figure 73a-73f.** Graphical representation of data results for Dripping Springs Lake.

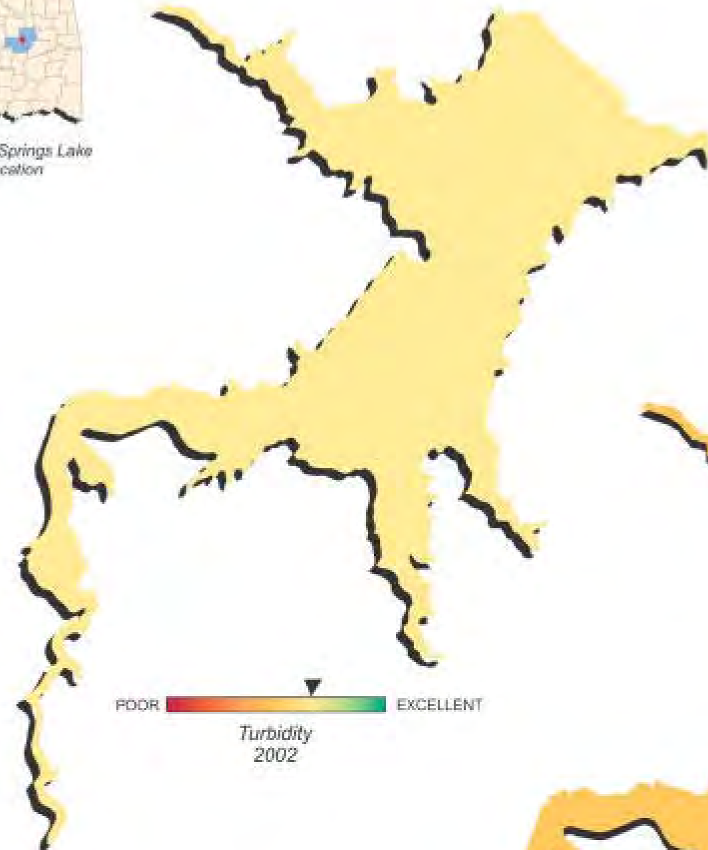
# Plate 30 - Lake Water Quality for
# Dripping Springs Lake

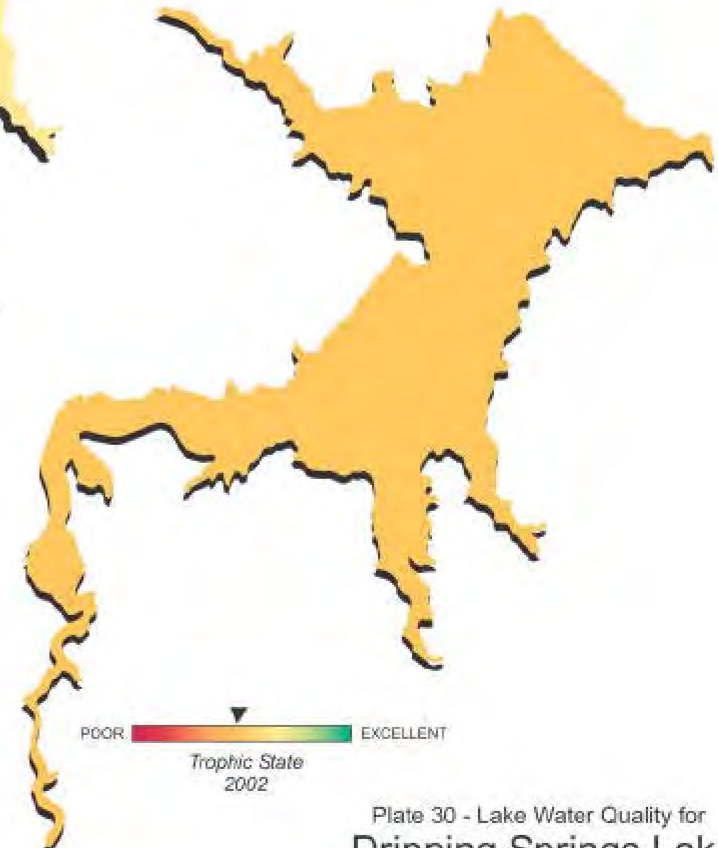

Dripping Springs Lake and Watershed



Dripping Springs Lake Location

| Lake Data | |
|---|---|
| Owner | City of Okmulgee |
| County | Okmulgee |
| Constructed in | 1976 |
| Surface Area | 1,150 acres |
| Volume | 16,200 acre/feet |
| Shoreline Length | 18 miles |
| Mean Depth | 14.09 feet |
| Watershed Area | 25 square miles |



# Duncan Lake

Duncan Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in both the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure minimum data requirements for lakes of this size were met. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 14 NTU (Plate 31), true color was 15 units, and secchi disk depth was 84 centimeters in 2003. Based on these three parameters, Duncan Lake had average water clarity comparable to other Oklahoma reservoirs. Water clarity was slightly better than in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=16). The average TSI was 47 (Plate 31), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. This value is similar to the TSI in 2001 (TSI=49), indicating no significant increase or decrease over time. The TSI values were fairly consistent with all values mesotrophic to upper mesotrophic (see Figure 74). Seasonal turbidity values are displayed in Figure 75a. Turbidity values per site for sample year 2003 were generally below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons except for the winter when values were near or above the standard. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 5% of the turbidity values above the standard, the Fish and Wildlife Propagation (FWP) beneficial use is fully supported based on turbidity. Seasonal true colors are displayed in Figure 75b. All true color values were below the Aesthetics OWQS of 70 units, however a beneficial use determination cannot be made because the minimum data requirements were not met.

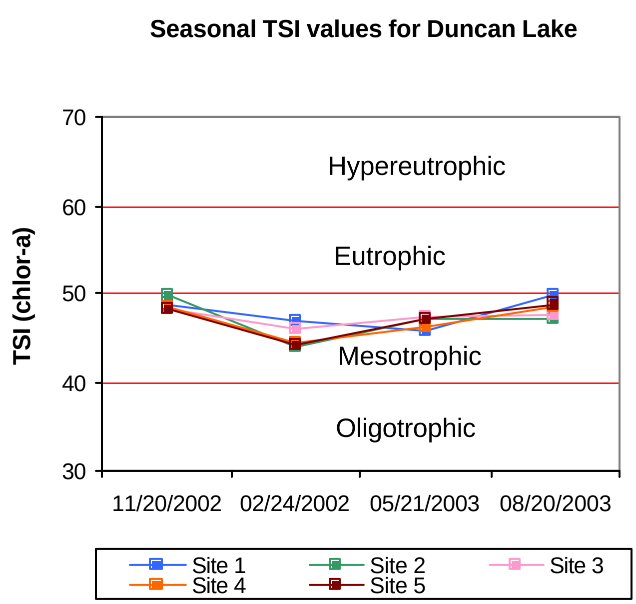



**Figure 74.** TSI values for Duncan Lake

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all five sample sites in 2002-2003. Salinity values ranged from 0.19 parts per thousand (ppt) to 0.21 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 385.3 mS/cm to

423.7 mS/cm, indicative of moderate levels of current conducting ions (chlorides and salts) in the lake system. The recorded values for pH ranged from 7.09 in the summer to 8.26 in the fall representing a neutral to slightly alkaline lake system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range Duncan Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 389mV in the spring to 627 mV in the summer. In general, reducing conditions were not present at this reservoir during the 2002-2003-sample year. Duncan Lake was not thermally stratified during the fall, winter and spring quarters (see Figure 75c-75e). Dissolved oxygen (D.O.) levels were generally above 4.0 mg/L throughout the sample year. The lake was stratified and anoxic conditions were present in the hypolimnion during the summer. Stratification occurred between 4 and 5 meters (Figure 75f) at which point dissolved oxygen (D.O.) levels dropped below 1 mg/L for the rest of the water column. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 37% of the water column below 2.0 mg/L the FWP beneficial use is partially supported at Duncan Lake. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.50mg/L at the surface and 0.50 mg/L at the lake bottom. Surface TN ranged from 0.22 mg/L to 0.72 mg/L with the highest values recorded in the spring quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the surface and 0.025 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the summer quarter and lowest in the fall with values ranging from 0.011 mg/L to 0.027 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 23:1 for sample year 2003. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Duncan Lake was classified as mesotrophic with moderate primary productivity and nutrient levels in 2002-2003. This value is similar to the TSI in 2001 (TSI=49), indicating no significant increase or decrease over time. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity and pH, but partially supporting based dissolved oxygen values. The Aesthetics beneficial use is supported based on the trophic status however a beneficial use determination cannot be made for true color because the minimum data requirements were not met. Duncan Lake is located in Stephens County serves as a water supply and recreation reservoir for the city of Duncan.

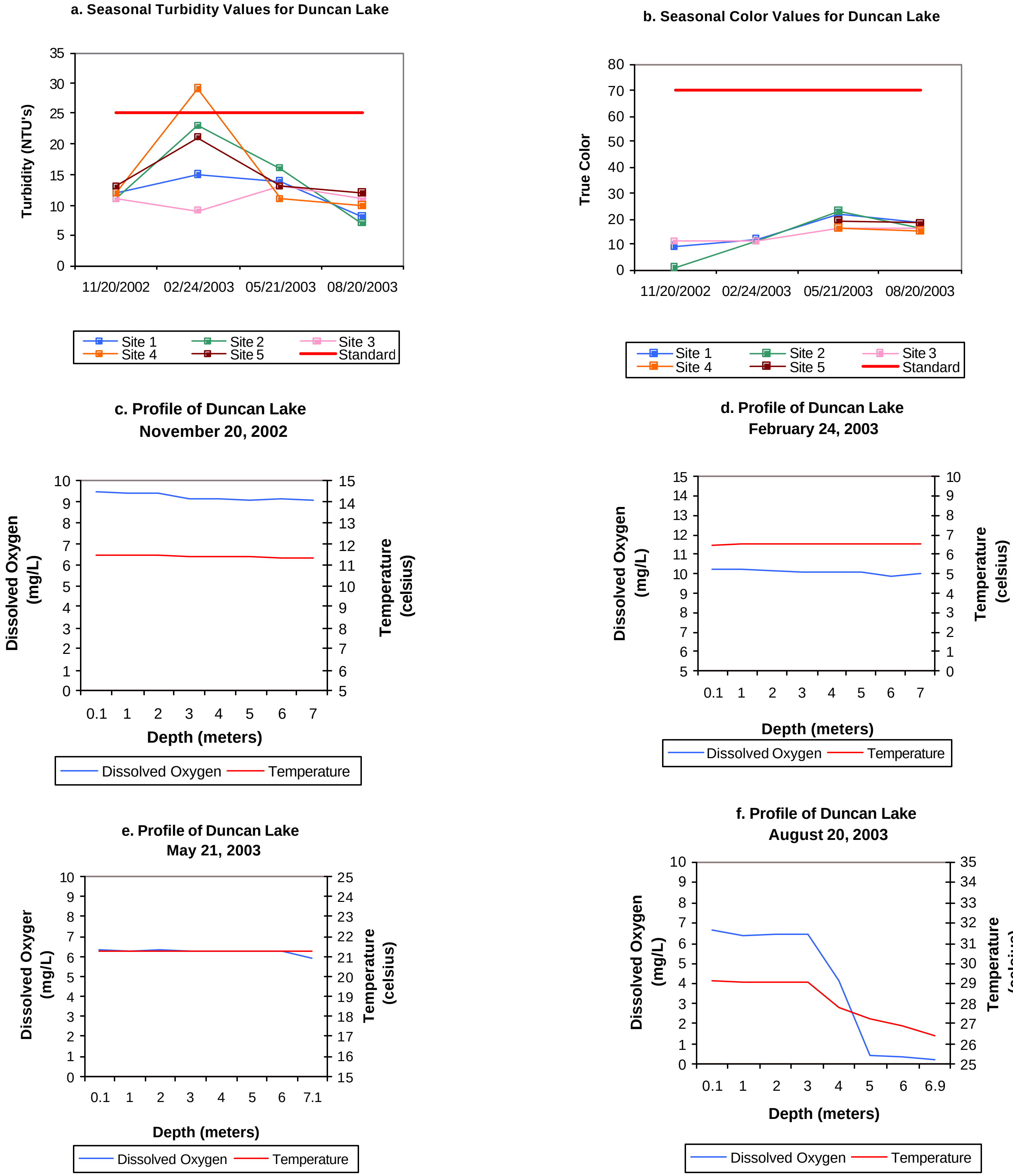
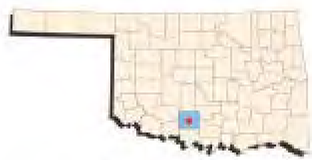
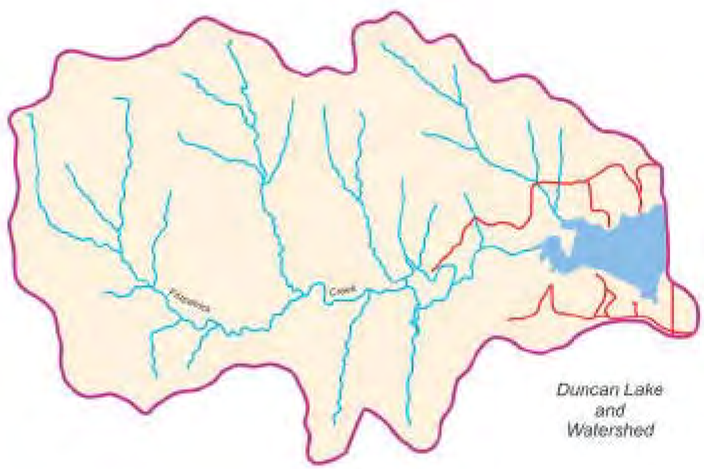



**Figure 75a-75f.** Graphical representation of data results for Duncan Lake.



Duncan Lake Location


Turbidity 2003




Duncan Lake and Watershed


Trophic State 2003

Lake Data

| | |
|---|---|
| Owner | City of Duncan |
| County | Stephens |
| Constructed | 1960 |
| Surface Area | 500 acres |
| Volume | 7,200 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 14.40 feet |
| Watershed Area | 11 square miles |

Plate 31 - Lake Water Quality for

# Duncan Lake

# Lake El Reno

Lake El Reno was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 26 NTU (Plate 32), true color was 21 units, and secchi disk depth was 45 centimeters in 2003. Based on these three parameters, Lake El Reno had fair water clarity in comparison to other Oklahoma reservoirs. Water clarity was very similar in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 59 (Plate 32), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is slightly higher than the TSI in 2001 (TSI=56), although in the same trophic category, indicating no significant increases or decreases over time. The TSI values were primarily eutrophic throughout the year, with hypereutrophic values in the fall and summer quarters (Figure 76). Seasonal turbidity values are displayed in Figure 77a. Turbidity ranged from a low of 8 NTU to a maximum of 55 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The Fish & Wildlife Propagation (FWP) beneficial use is considered partially supported at Lake El Reno with 42% values recorded exceeding the OWQS of 25 NTU. Seasonal true color values are displayed in Figure 77b. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is supported based on true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity ranged from 0.71 parts per thousand (ppt) to 0.90 ppt for this sample year. Specific conductance ranged from 1340 mS/cm to 1693 mS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence of current conducting compounds (salts) in the lake, consistent with higher recorded salinity concentrations. The pH values at Lake El Reno ranged from 7.70 to 8.32, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should

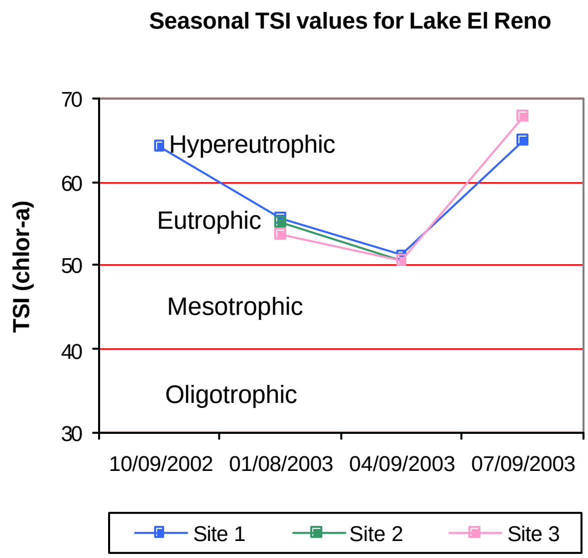



**Figure 76.** TSI values for Lake El Reno

be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range Lake El Reno is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 208 mV in the hypolimnion during the spring to 585 mV in the winter. In general, reducing conditions were not present in this reservoir. The lake was not stratified during any of the sampling quarters (see Figure 77a-77f) and dissolved oxygen (D.O.) levels were generally above 6.0 mg/L. The absence of stratification may be attributed to the shallow nature of this reservoir where wind and wave action keep the lake well mixed. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 100% of the water column above 2.0 mg/L the FWP beneficial use is supported at Lake El Reno. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.98 mg/L at the surface and 1.15 mg/L at the lake bottom. The TN at the surface ranged from 0.68 mg/L in the winter to 1.47 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.204 mg/L at the surface and 0.202 at the lake bottom. The total phosphorus at the surface ranged from 0.119 mg/L in the spring to 0.295 mg/L in the fall quarter. These values are very similar to those seen in 2001. The nitrogen to phosphorus ration (TN:TP) was 5:1 for sample year 2003. This value is much lower than 7:I, characterizing the lake as nitrogen limited (Wetzel, 1983).

In summary, Lake El Reno was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This classification is the same as 2001 indicating no change in productivity has occurred. Water clarity was fair based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use for pH and dissolved oxygen levels, but only partially supporting based on turbidity. The Aesthetics beneficial use is being met based on both trophic status and true color. Lake El Reno, located in Canadian County, is owned by the city of El Reno and serves as a flood control and recreation reservoir.

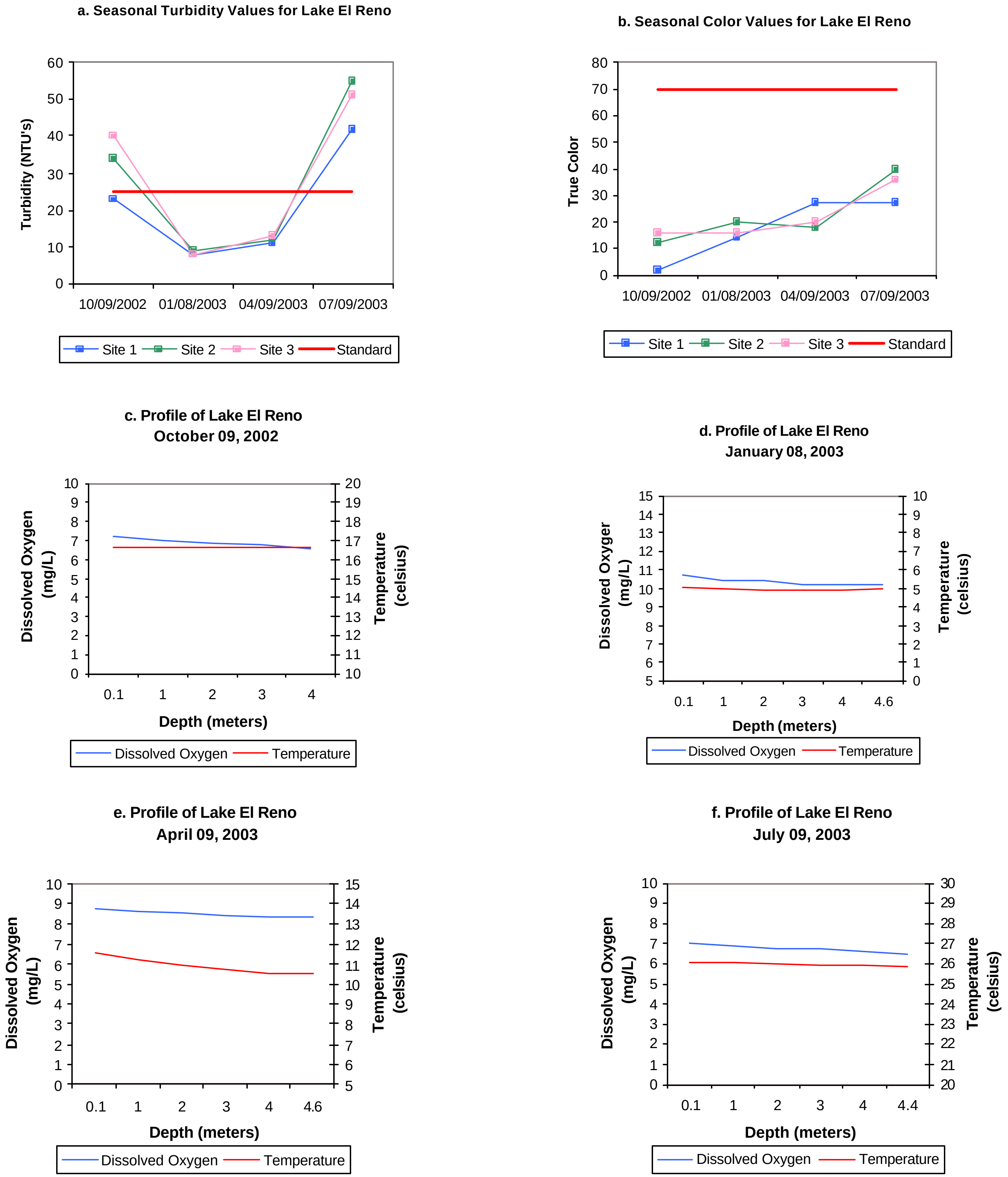



**Figure 77a-77f.** Graphical representation of data results for Lake El Reno.





Lake Data

| | |
|---|---|
| Owner | City of El Reno |
| County | Canadian |
| Constructed | 1966 |
| Surface Area | 170 acres |
| Volume | 709 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 4.17 feet |
| Watershed Area | 4,242 acres |

Plate 32 - Lake Water Quality for

## Lake El Reno

# Lake Elk City

Lake Elk City was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 18 NTU (Plate 33), true color was 16 units, and secchi disk depth was 55 centimeters. Results were slightly better than that observed during the 2001-2002 evaluation. Based on these three parameters, Lake Elk City had fair to poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 56 (Plate 33), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values were generally eutrophic throughout the sampling year, with one mesotrophic value present at site 2 in the winter quarter, and hypereutrophic conditions present in the summer quarter (see Figure 78). Lake Elk City is currently listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The lake should be further studied to understand the nutrient dynamics involved. Turbidity values were above OWQS of 25 NTU approximately 8% of the time (see Figure 79a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Elk City was supporting its Fish & Wildlife Propagation (FWP) beneficial use based on OAC 785:46. All true color values were below the Aesthetics OWQS of 70 units (See Figure 79b). Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the high true color values.

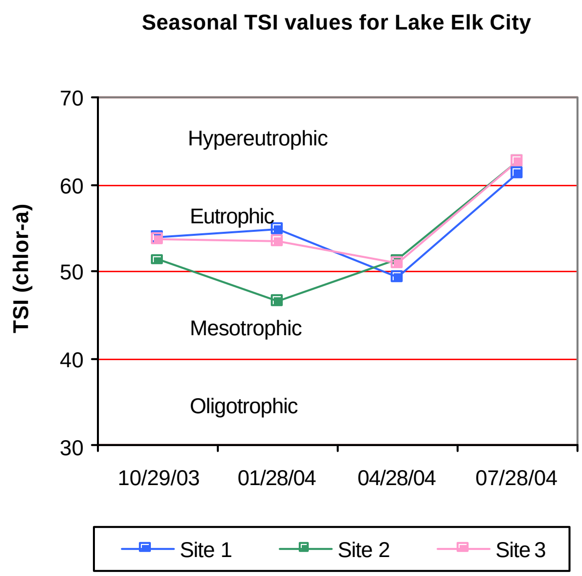



**Figure 78.** TSI values for Lake Elk City.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all sample sites and yielded the following results. Salinity readings ranged from 0.31 parts per thousand (ppt) to 0.34ppt, slightly higher than most values recorded in Oklahoma reservoirs. Readings for specific conductance were consistent with values normally seen in most Oklahoma reservoirs if perhaps only slightly higher. Specific Conductance ranged from 605.5 mS/cm in the winter quarter to 653.9 mS/cm in the summer quarter, indicating moderate to slightly elevated concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 298 mV to 649 mV, indicating reducing conditions were not present during any sampling events. Lake pH values were neutral to slightly alkaline, ranging from 7.45 to 8.59 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Elk City was fully supporting its FWP beneficial use based on pH values collected during the study period. The lake was not thermally stratified during any of the four quarters sampled (see Figure 79c-79f). The water column was evenly mixed and oxygenated during the entire study period, which may be attributed to the shallow nature of the lake (see Figure 79c-79e). Dissolved oxygen (D.O.) concentrations never fell below 4.3 mg/L at any point in the water column during the sample year. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered supported based on dissolved oxygen concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (62.6 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.00 mg/L at the lake surface and 1.04 mg/l at the lake bottom. The TN at the surface ranged from 0.84 mg/L to 1.41 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.050 mg/L at the lake surface and 0.057 mg/L at the lake bottom. The TP ranged from 0.037 mg/L to 0.062 mg/L at the lake surface. The highest surface TP values were reported in the summer quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 20:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Elk City was as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 33). This is consistent with historical data collection efforts in 2002 (TSI=57), indicating no significant increase or decrease in productivity has occurred over time. The lake is fully supporting its FWP beneficial based turbidity pH and D.O. concentrations recorded throughout the study period. Elk City Lake is fully supporting its Aesthetics beneficial use based on true color readings and based on its listing as an NLW the use is considered nutrient threatened. The lake is listed in the OWQS as an NLW and it should be more intensively studied to confirm the Aesthetics beneficial use non-support status as well as understand the nutrient dynamics at work in the system. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (62.6 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported. Lake Elk City was constructed in 1970 and is owned and operated by the City of Elk City. The lake is utilized by the city for flood control and recreational purposes.

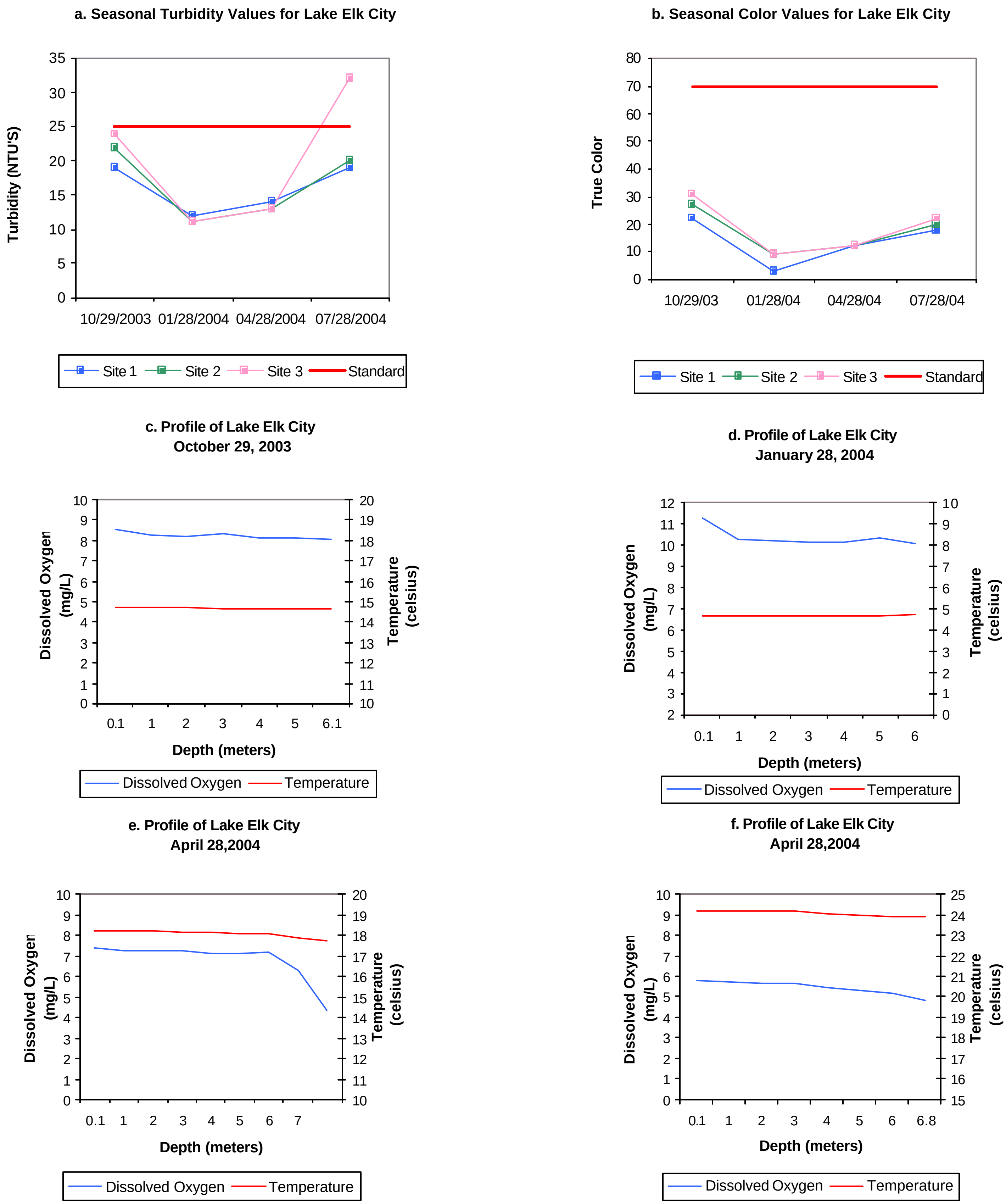



**Figure 79a-79f.** Graphical representation of data results for Lake Elk City.




Lake Data

| | |
|---|---|
| Owner | City of Elk City |
| County | Beckham |
| Constructed in | 1970 |
| Surface Area | 240 acres |
| Volume | 2,583 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 10.76 feet |
| Watershed Area | 23 square miles |

Plate 33 - Lake Water Quality for
Elk City Lake

# Lake Ellsworth

Lake Ellsworth was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites as well as 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 35 NTU (Plate 34), true color was 22 units, and secchi disk depth was 43 centimeters. Based on these three parameters, Lake Ellsworth had fair to poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 54 (Plate 34), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values varied seasonally with meso-eutrophic values present in the fall and winter and mesotrophy in the spring to upper eutrophic. Hypereutrophic values present in the summer quarter (see Figure 80). Turbidity values for site 1 were all below the Oklahoma Water Quality Standard (OWQS) of 25 NTU; however, at site 2 25% of the collected values exceeded the criteria and the vast majority of the data collected at sites 3-5 exceeded the criteria (see Figure 81a). According to Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The FWP beneficial use is considered not supported at Lake Ellsworth with 50% of the sample values exceeding the criteria. All true color values were below the aesthetics OWQS of 70 units (see Figure 81b). Applying the same default protocol, the Aesthetics beneficial use is supported based on true color values collected during the sample year.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all sample sites and yielded the following results. Salinity readings ranged from 0.27 parts per thousand (ppt) to 0.35 ppt, which is slightly higher than the expected range of values recorded for Oklahoma reservoirs. Readings for specific conductance were within the range of expected values recorded for most Oklahoma reservoirs. Specific conductance ranged from 544.3 mS/cm in the spring quarter to 671.8 mS/cm in the summer quarter. This indicates moderate to slightly elevated concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials ranged from 128 mV to 492 mV, indicating reducing conditions

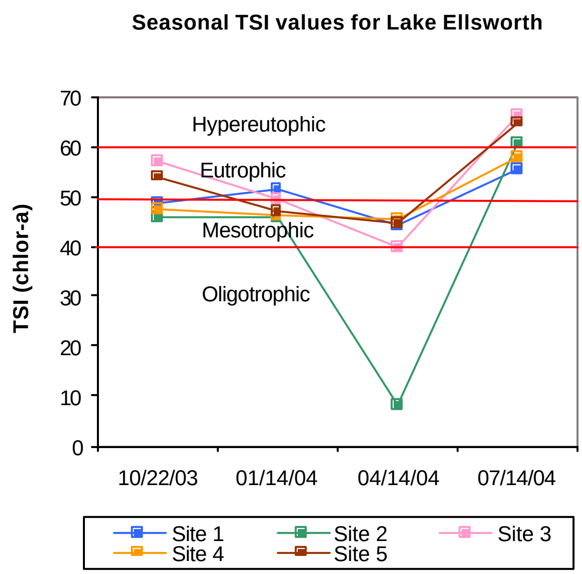



**Figure 80.** TSI values for Lake Ellsworth.

were absent present during 2003-2004 sampling. Lake pH values were neutral to slightly alkaline, ranging from 7.06 to 8.47 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The FWP beneficial use is fully supported based on pH with all values within the acceptable range. The lake was not thermally stratified during the fall or spring quarters (see Figure 81c-81d) and the water column was evenly mixed and oxygenated. After reviewing the data collected during the winter it appears that there was a probe malfunction and dissolved oxygen (D.O.) values appear to be erroneous. Due to seasonality and historical data available, it is likely that stratification was not present and the water column was well oxygenated. In the summer quarter the lake was thermally stratified first between the 3 to 4 meter depths, with dissolved oxygen (D.O.) concentrations dropping below 2.0 mg/L from 7 meters to the lake bottom at 12.2 meters (see Figure 81e). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With approximately 50% of the water column experiencing anoxic conditions, the FWP beneficial use according to USAP (OAC 785:46-15-5) is partially supported. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 samples collected none exceeded the prescribed screening level or geometric mean. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.80 mg/L at the lake surface. The TN at the surface ranged from 0.50 mg/L to 1.25 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.070 mg/L at the lake surface. The TP ranged from 0.048 mg/L to 0.115 mg/L at the lake surface. The highest surface TP values were reported in the spring quarter and the lowest were in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 12:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1997 as part of their Toxics Monitoring Program and detected no compounds at the FDA Action level, ODEQ warning level, or ODEQ concern level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Ellsworth was as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 34). The FWP beneficial use is considered not supported for turbidity at Lake Ellsworth with 50% of the sample values exceeding the criteria. The Aesthetics beneficial use is supported based on true color and trophic status values collected during the sample year. The FWP beneficial use is supported for pH and partially supported based on dissolved oxygen. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples collected none exceeded the prescribed screening level or geometric mean. The PBCR beneficial use is therefore considered supported. Lake Ellsworth is owned and operated by the City of Lawton and the lake was constructed in 1962. The lake was constructed to serve as a water supply for the city and provide recreational opportunities to the public.

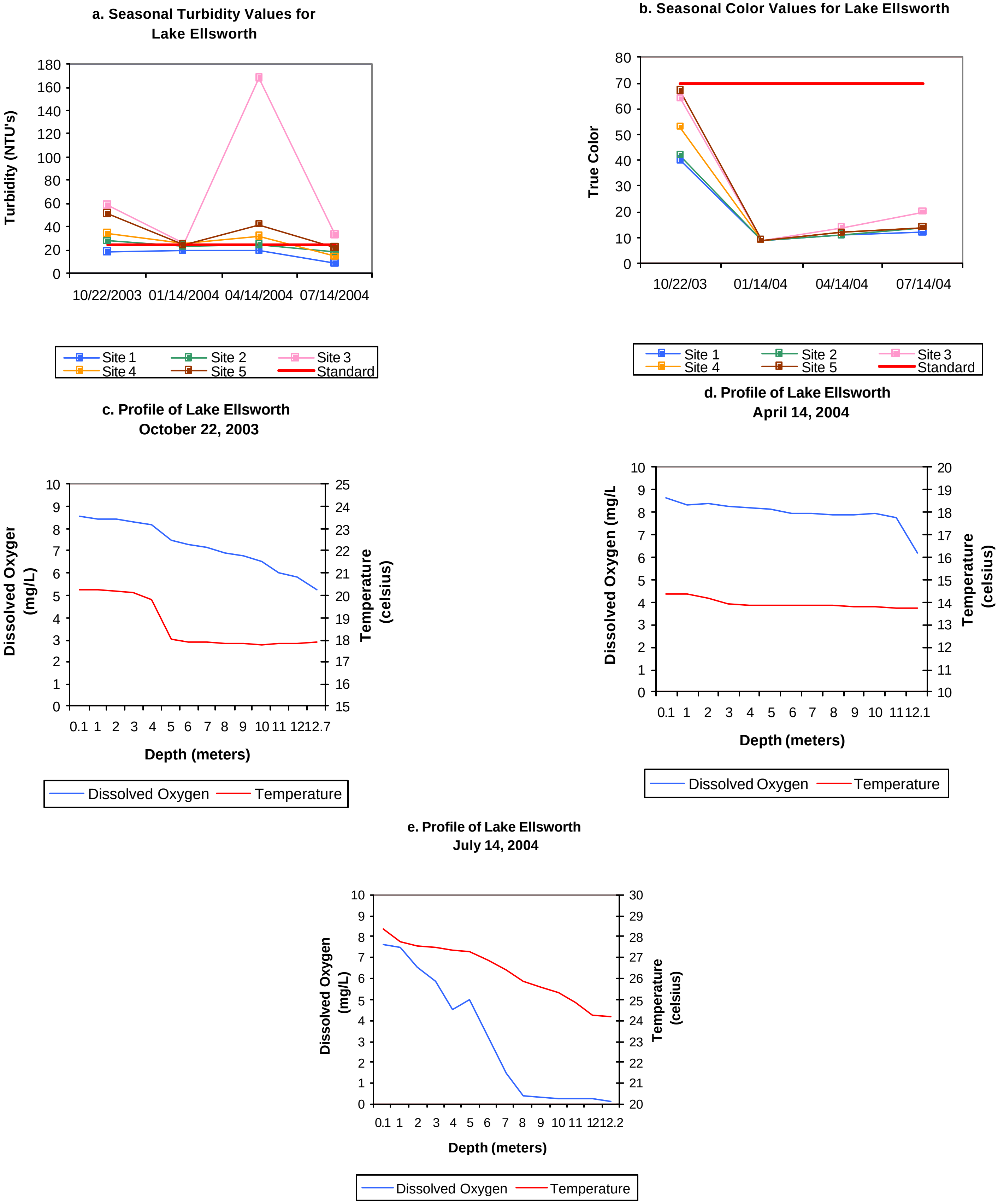
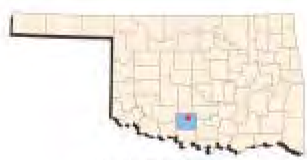



**Figure 81a-81e.** Graphical representation of data results for Lake Ellsworth.


Lake Ellsworth and Watershed



Lake Ellsworth Location


Turbidity 2004


Trophic State 2004

Lake Data

| | |
|---|---|
| Owner | City of Lawton |
| County | Comanche |
| Constructed | 1962 |
| Surface Area | 5,600 acres |
| Volume | 95,200 acre/feet |
| Shoreline Length | 43 miles |
| Mean Depth | 17.00 feet |
| Watershed Area | 247 square miles |

Plate 34 - Lake Water Quality for

# Lake Ellsworth

# Elmer Thomas Lake

Elmer Thomas Lake was sampled for three quarters from January 2003 through July 2003. Water quality samples were collected at three (3) sites in the winter and from five (5) sites in the spring and summer quarters. Additional sites were added to ensure sample size was representative for the reservoir as it is greater than 250 surface acres in size. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity was 2 NTU (Plate 35), true color was 18 units and secchi disk depth was 290 centimeters. Water clarity was excellent at Elmer Thomas Lake and is similar to results from the 2000 evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=15). The TSI was 34 (Plate 35), indicating the lake was oligotrophic, with low primary productivity and nutrient levels in sample year 2002-2003. The TSI values for all sites were consistent with all values in the oligotrophic category (Figure 82). This value is lower than that in 2000 (TSI=43), however, fewer samples were used to calculate trophic status in 2000. The current value is based on data collected for the entire year versus growing season only, and is likely a more accurate depiction of productivity within the lake system. Seasonal turbidity values are displayed in Figure 83a. Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. Due to the minimum data requirements of 20 samples for lakes greater than 250 surface acres not being met, assessment of the Fish and Wildlife Propagation (FWP) beneficial use cannot be made at this time; however upon reviewing historical data it is likely that the use would be supported. Seasonal true color values were all below the aesthetics standard of 70 units and are displayed in Figure 83b. Like turbidity, minimum data requirements were not met but it is likely that the Aesthetics beneficial use would be supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites in 2002-2003. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.06 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 36.8 mS/cm to 141.5 mS/cm, indicative of minimal levels of current conducting ions (chlorides and salts) in the lake system. The recorded values for pH ranged from 6.24 in the summer to 8.04 in the fall representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial

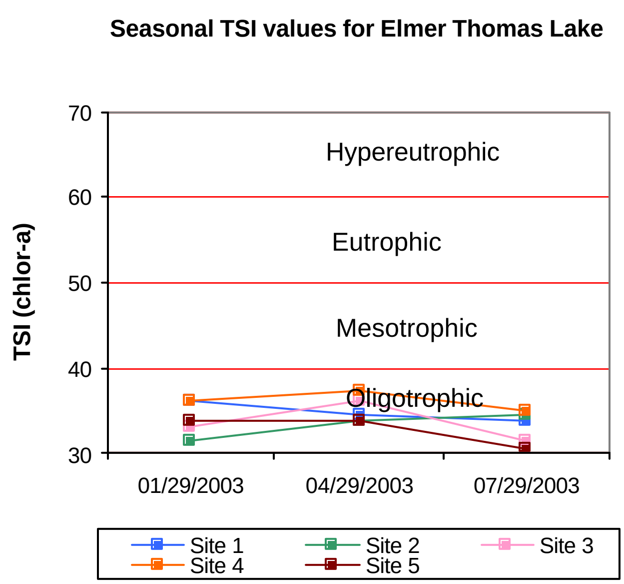



**Figure 82.** TSI values for Elmer Thomas Lake.

uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 12% of collected values out of the acceptable range Elmer Thomas Lake is partially supporting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 58mV in the spring to 650 mV in the fall. In general, reducing conditions were not present at this reservoir, with all values above 100 mV, with the exception of the one value recorded at the lake bottom at site 1, the dam. Elmer Thomas Lake was not thermally stratified during the winter and spring quarters (see Figure 83c-83d). Dissolved oxygen (D.O.) levels were generally above 4.0 mg/L throughout the sample year. The lake was stratified and anoxic conditions were present in the hypolimnion during the summer. Stratification occurred between 7 and 8 meters at which point dissolved oxygen (D.O.) levels dropped below 1 mg/L for the rest of the water column (Figure 83e). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 62% of the water column below 2.0 mg/L the FWP beneficial use is partially supported at Elmer Thomas Lake. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.41mg/L at the surface and 0.46 mg/L at the lake bottom. Surface TN ranged from 0.32 mg/L to 0.54 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.010 mg/L at the surface and 0.015 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.008 mg/L to 0.012 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 39:1 for sample year 2003. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Elmer Thomas Lake was classified as oligotrophic with low primary productivity and nutrient levels in 2002-2003. This value is lower than that in 2000 (TSI=43), however, fewer samples were used to calculate trophic status in 2000. The current value is based on data collected year round versus growing season only, and is likely a more accurate depiction of productivity within the lake system. Water clarity was excellent based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH, but partially supporting based dissolved oxygen values. The minimum data requirements (20 samples) were not met for turbidity; therefore attainment of the FWP based on turbidity cannot be made at this time. Reviewing historical data it is likely that the beneficial use would be supported. The Aesthetics beneficial use is supported based on the trophic status however a beneficial use determination cannot be made for true color because like turbidity, the minimum data requirements were not met. Elmer Thomas Lake, located in Comanche County, was constructed by the U.S. Department of Interior for the purpose of recreation.

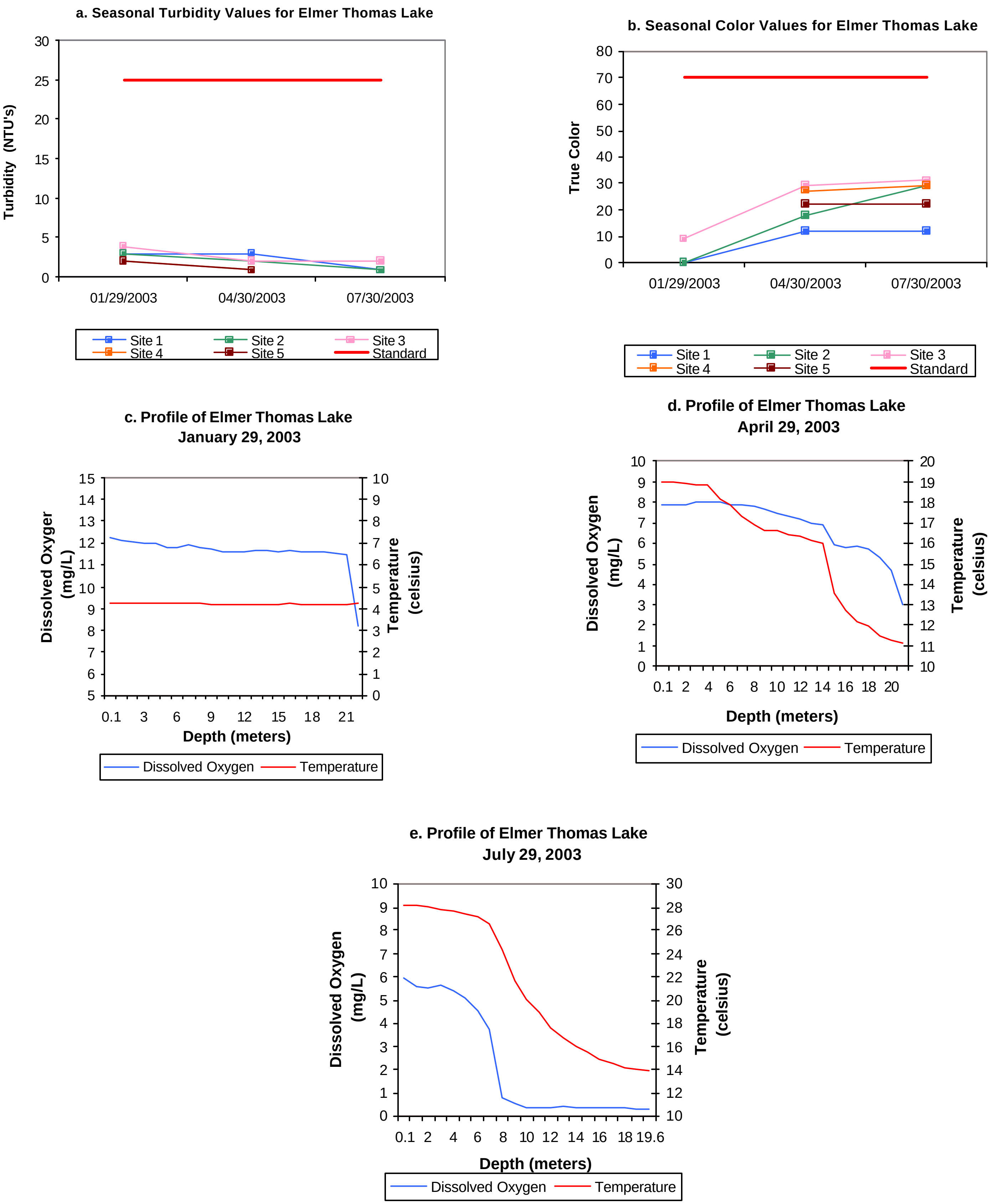
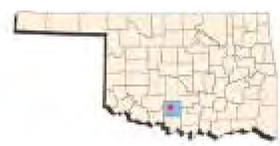
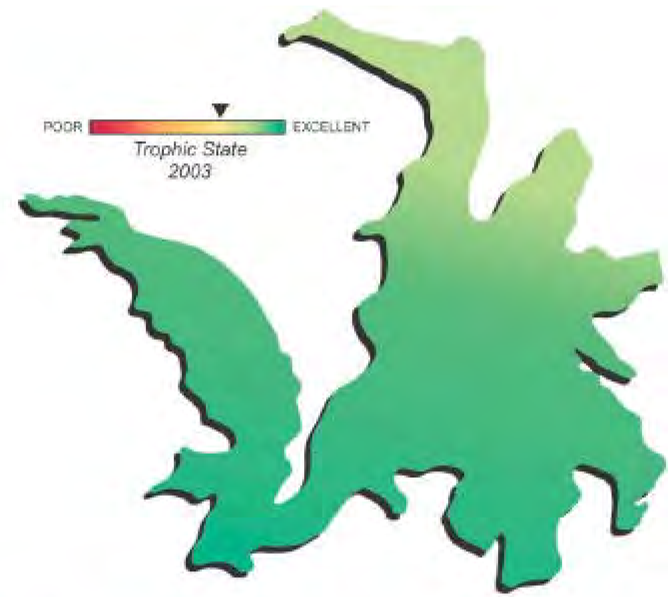


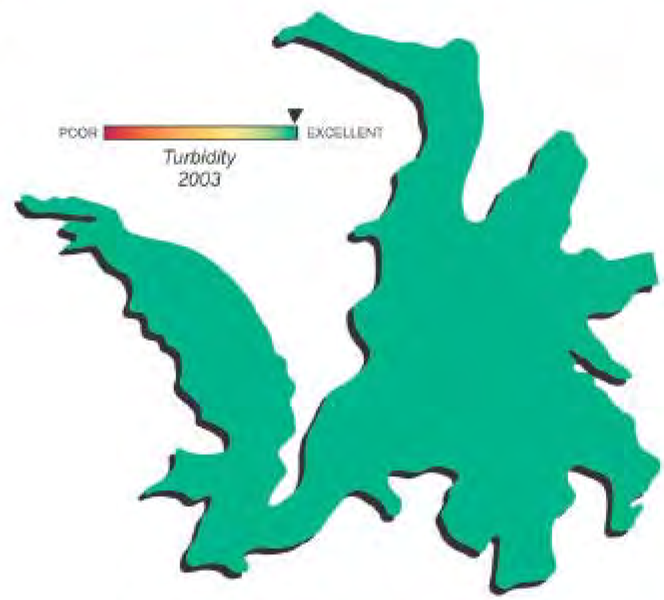

**Figure 83a-83e.** Graphical representation of data results for Elmer Thomas Lake.



Elmer Thomas Lake Location

Elmer Thomas Lake and Watershed





Lake Data

| | |
|---|---|
| Owner | U.S. Dept. of the Interior |
| County | Comanche |
| Constructed in | N/A |
| Surface Area | 334 acres |
| Volume | 12,000 acre/feet |
| Shoreline Length | 8 miles |
| Mean Depth | 35.92 feet |
| Watershed Area | 4,377 acres |

Plate 35 - Lake Water Quality for

Elmer Thomas Lake

# Lake Etling

Lake Etling was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at 3 sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites. Due to drought conditions and low lake levels a bottom sample was not taken at any point during the sample year. The lake-wide annual turbidity value was 65 NTU (Plate 36), true color was 18 units, and secchi disk depth was 22 centimeters in 2004. Based on these three parameters, Lake Etling had fair water clarity in comparison to other Oklahoma reservoirs. Water clarity differed from 2001 with both an increase in turbidity and a decline in the average secchi disk depth. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 72, indicating the lake was hypereutrophic, indicative of excessive levels of productivity and nutrient rich conditions. This value is greater than the TSI in 2001 (TSI=57), indicating a significant increase in trophic status since previous data collection efforts were conducted as is likely related to the decrease in lake levels. The TSI values were hypereutrophic at all sites throughout the study period (See Figure 84). Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (OWQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in (Figure 85a). Only three of the twelve turbidity values were below the OWQS of 25 NTU, constituting a listing as not supporting the Fish & Wildlife Propagation (FWP) beneficial use. According to USAP (Oklahoma Administrative Code 785:46-15-5), a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. All true color values were below the aesthetics OWQS of 70 units for all four seasons at all sites (Figure 85b). Applying the same default protocol for determining the short-term average for true color, the Aesthetics beneficial use is considered supported.

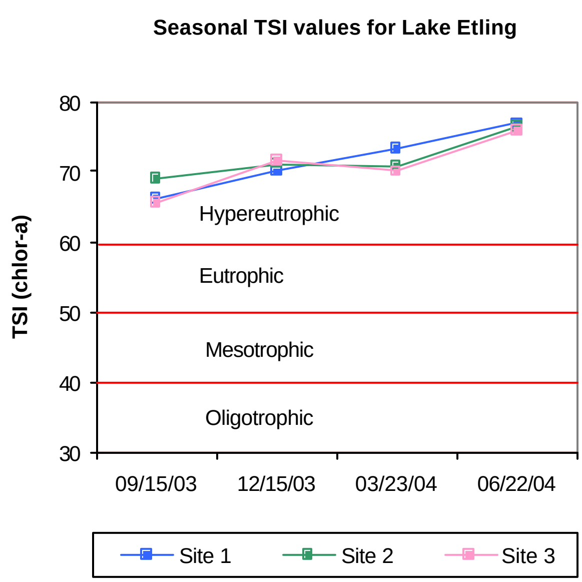



**Figure 84.** TSI values for Lake Etling.

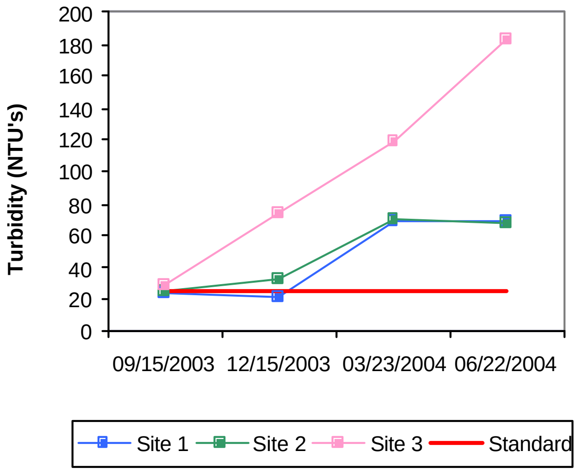
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.9 parts per thousand (ppt) to 1.4 ppt, which is higher than the expected range for most Oklahoma lakes. Salinity values indicate a moderate to high presence of chlorides or other salts in the lake. Specific conductance values exhibited a similar pattern and were somewhat higher than most Oklahoma reservoirs, with values ranging from 1688 mS/cm in the fall to 2596 mS/cm in the summer, which is indicative of a high content of electrical current conducting compounds or salts throughout the lake system. Oxidation-reduction potentials (redox) ranged from 269 mV to 499 mV, indicating reducing conditions were not present during the study period. The pH was alkaline in nature with values ranging from 8.18 to 9.42 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Etling is not supporting the FWP use, with 28% of the collected values falling outside the acceptable range. Slightly alkaline conditions seem to be common in the western part of the state and may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in this portion of the state. The lake was not thermally stratified during any of the four quarters sampled (see Figure 85c-85f). The water column was evenly mixed and oxygenated during the entire study period, which may be attributed to the shallow nature of the lake. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lake Etling based on dissolved oxygen values. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 samples none exceeded the prescribed screening level or geometric mean listed in the OWQS. The PBCR beneficial use is therefore considered supported.

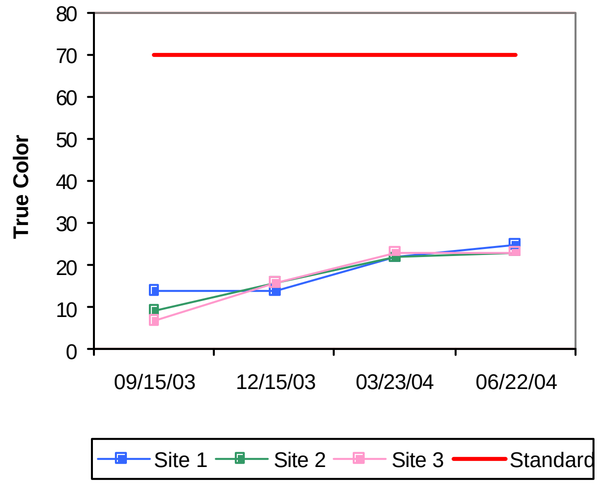
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 3.50 mg/L at the lake surface, much higher than seen in most Oklahoma lakes and reservoirs. The TN at the surface ranged from 2.31 mg/L to 4.51 mg/L. The highest was reported in the summer quarter and lowest surface TN value was reported in the fall quarter. The lake-wide total phosphorus (TP) average was 0.213 mg/L at the lake surface. The TP ranged from 0.122 mg/L to 0.293 mg/L at the lake surface. The highest surface TP values were reported in the spring quarter and the lowest were in the fall quarter. The total nitrogen phosphorus ratio (TN:TP) was 16:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Etling was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 36). Based on secchi disk depth, turbidity and true color, Lake Etling had fair water clarity in 2003-2004. The FWP beneficial use was fully supported based on dissolved oxygen; however the use is not supported as it relates to turbidity. The lake was also found to be "provisionally not supporting" the FWP use as it relates to pH with 28% of the values outside the 6.5 to 9 range listed in the OWQS. The lake was fully supporting its Aesthetics beneficial use for true color. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (OWQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples none exceeded the prescribed screening level or geometric mean listed in the OWQS. The PBCR beneficial use is therefore considered supported. Lake Etling is owned and operated by the State of Oklahoma for the purpose of providing recreational opportunities to the citizens of Oklahoma.

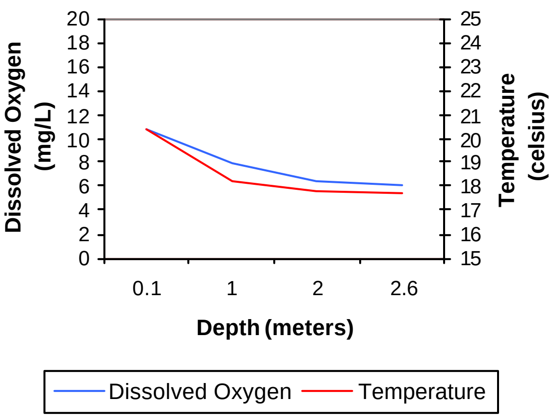
**a. Seasonal Turbidity Values for Lake Etling**



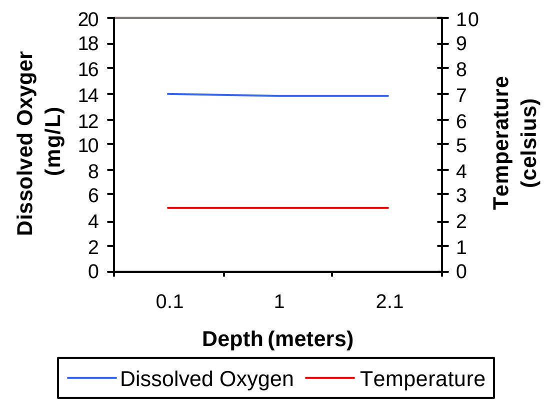

**b. Seasonal Color Values for Lake Etling**



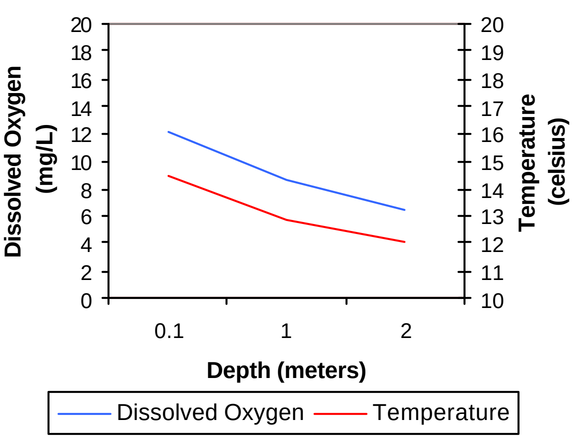

**c. Profile of Lake Etling**
**September 15, 2003**




**d. Profile of Lake Etling**
**December 15, 2003**




**e. Profile of Lake Etling**
**March 23, 2004**




**f. Profile of Lake Etling**
**June 22, 2004**

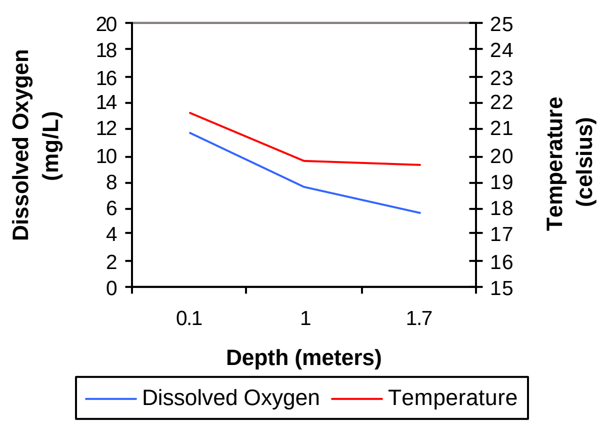
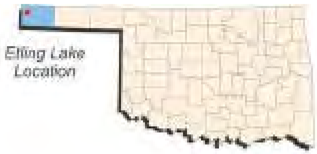


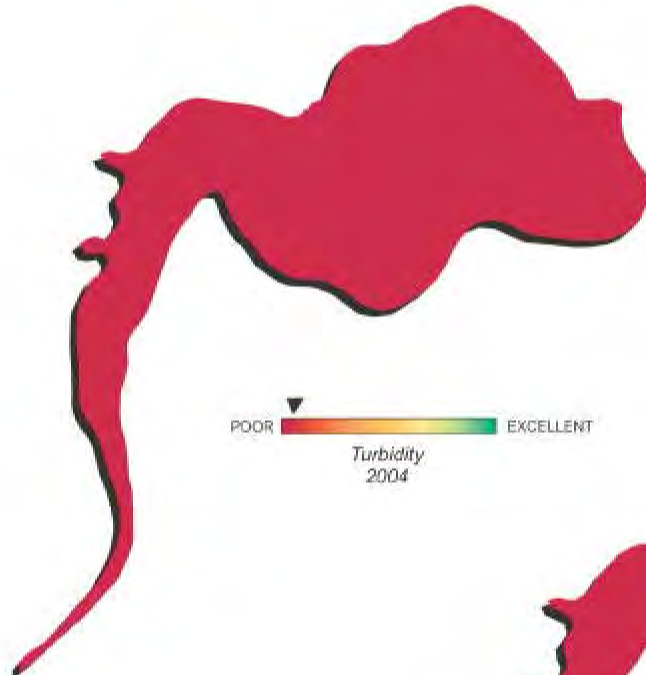

**Figure 85a-85f.** Graphical representation of data results for Lake Etling.






Lake Data

| | |
|---|---|
| Owner | State of Oklahoma |
| County | Cimarron |
| Constructed in | 1958 |
| Surface Area | 159 acres |
| Volume | 1,717 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 10.80 feet |
| Watershed Area | 37 square miles (OK only) |



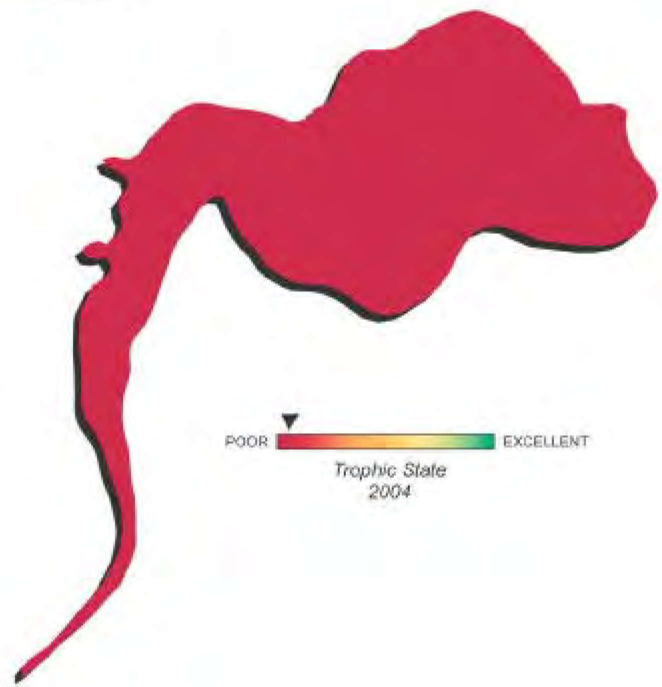




Plate 36 - Lake Water Quality for
## Lake Etling

# Eucha Lake

Eucha Lake was sampled for four quarters from October 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer, to represent the riverine, transition, and lacustrine zones of the lake. Additional sites were added to ensure the sample size was representative for lakes greater than 250 surface acres in size. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site1, the dam site. The average lake-wide turbidity was 8 NTU (Plate 37), true color was 8 units, and secchi disk depth was 118 centimeters. Based on these three parameters water clarity at Eucha Lake was good in sample year 2002-2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 50 (Plate 37), indicating the lake was mesotrophic bordering eutrophic, indicative of moderate primary productivity and nutrient levels in sample year 2002-2003. The TSI values varied seasonally and generally ranged from mesotrophic to lower eutrophic, with the exception of the spring quarter when values dipped down to oligotrophic (Figure 86). These results differ with historical data collection efforts on the lake, which found the lake to be hypereutrophic in 1999 (TSI=62). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient impaired and a nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 87a. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and ranged from a low of 3 NTU to a maximum of 24 NTU. With 100% of the recorded values below 25 NTU the Fish and Wildlife Propagation (FWP) beneficial use is considered fully supported. Seasonal true color values were all well below the OWQS of 70 units and are displayed in Figure 87b. Due to the minimum data requirements not being met assessment of the Aesthetics beneficial use based on true color could not be made.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.13 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 155 mS/cm to 266.1 mS/cm, indicative of minimal levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.88 in the summer to 8.43 in the fall representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are

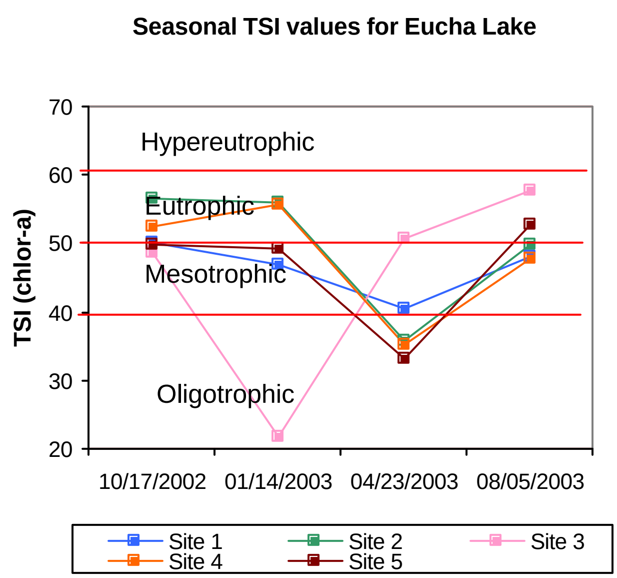



**Figure 86.** TSI values for Eucha Lake.

exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With all the collected values within the acceptable range Eucha Lake is fully supporting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 25 mV in the hypolimnion in the summer to 522 mV in the winter quarter. In general, reducing conditions were not present at this reservoir, with all values above 100 mV, with the exception of the summer quarter when anoxic conditions were present for much of the water column (see Figure 87f). The lake was stratified and anoxic conditions were present in the hypolimnion during both fall and summer sampling intervals. In the fall stratification occurred between 8 and 9 meters at which point dissolved oxygen levels dropped to 1.0 mg/L for the remainder (55%) of the water column at site 1, the dam site. During the summer sampling interval, stratification occurred between 5 and 6 meters at site 1 accounting for 70% of the water column being anoxic. Anoxic conditions were also present at sites 2,4, and 5 where D.O. was below 2.0 mg/L for 40 to 60% of the water column at these sample sites. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions present for 55% of the water column in the fall and 70% of the water column in the summer Eucha Lake is considered to be partially supporting the FWP beneficial use. These conditions could however pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.79 mg/L at the surface and 1.26 mg/L at the lake bottom. Surface TN ranged from 0.33 mg/L to 1.78 mg/L with the highest values recorded in the winter quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.027mg/L at the surface and 0.087 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the winter quarter and lowest in the fall with values ranging from 0.013 mg/L to 0.054 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 29:1 for sample year 2003. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

**In summary, Eucha Lake was classified as mesotrophic, bordering eutrophic, with moderate to high primary productivity and nutrient levels in 2002-2003. These results differ with historical data collection efforts on the lake, which found the lake to be hypereutrophic in 1999 (TSI=62). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient threatened and a nutrient impairment study should be conducted to determine if uses are impaired. Several studies have been conducted in Eucha/Spavinaw complex by the OWRB and other state agencies and can be referenced for further information. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and turbidity, but partially supporting based dissolved oxygen values. The Aesthetics beneficial use is supported based on the trophic status however a beneficial use determination cannot be made for true color because the**

**minimum data requirements were not met. Eucha Lake, located in Delaware County, is owned by the city of Tulsa utilized for a water supply and recreation. In 1999, the Tulsa Municipal Authority contracted the OWRB to conduct a bathymetric survey of Eucha Lake (**

Figure 88) to determine current lake volume, capacity and sedimentation rates. The survey information was used to support numerical modeling of proposed water quality improvements by the OWRB. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

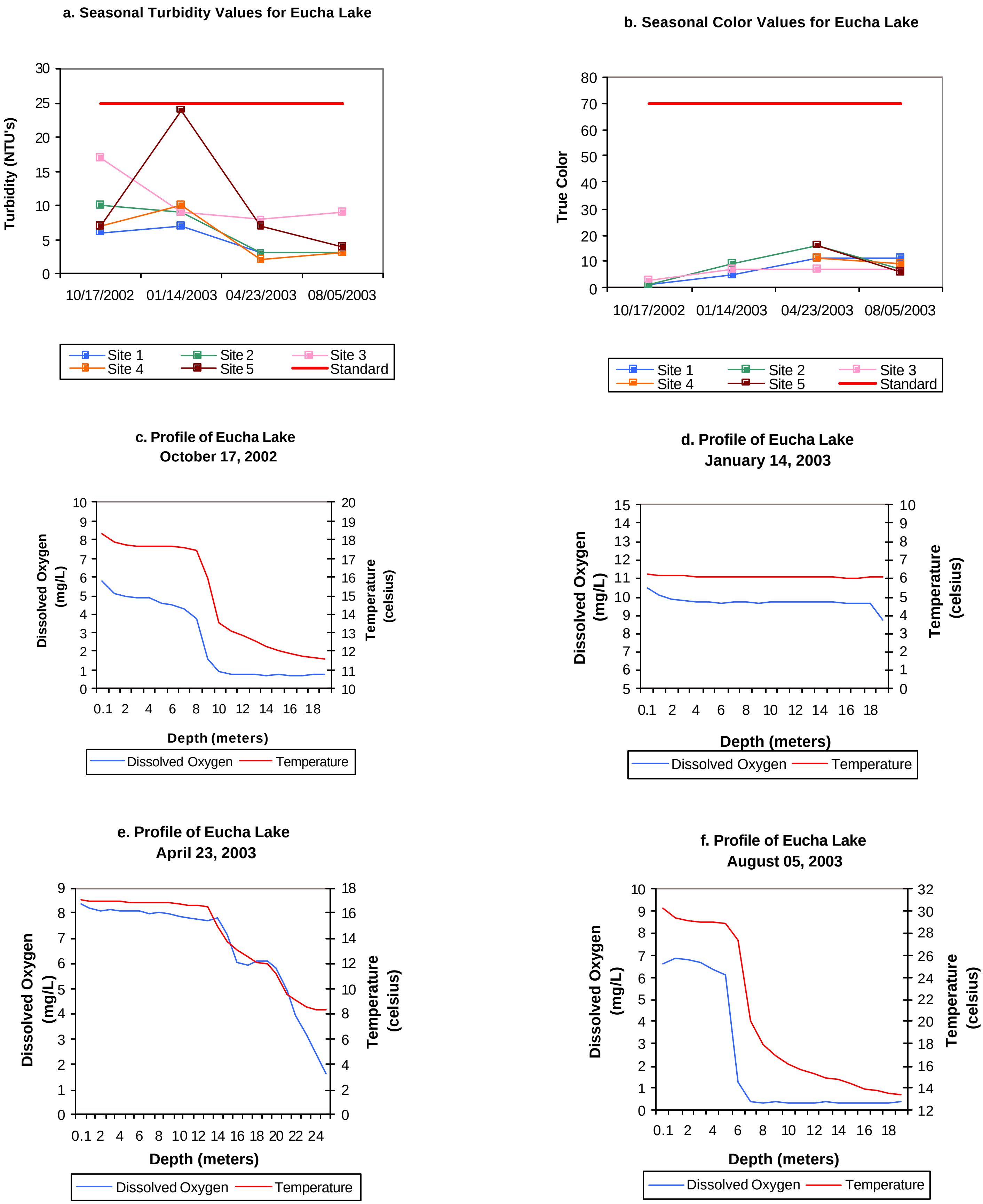
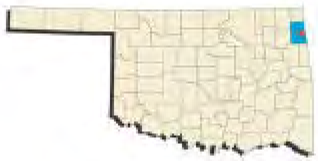
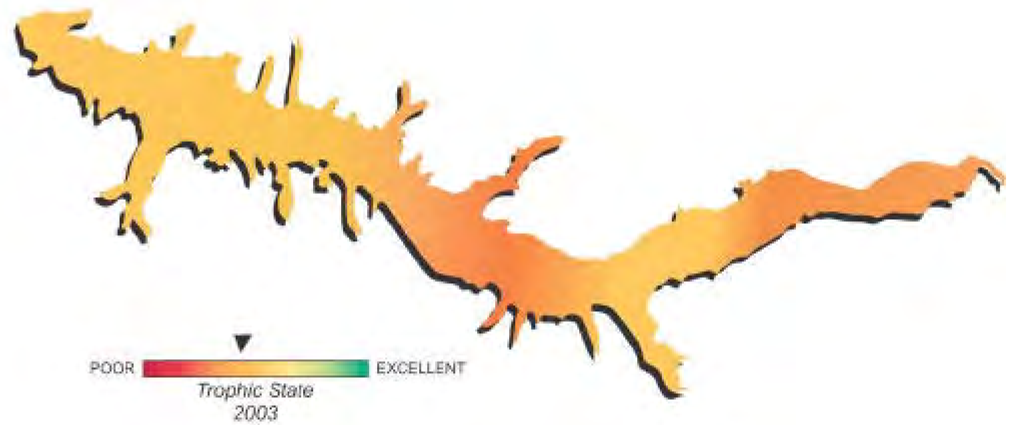



**Figure 87a-87f.** Graphical representation of data results for Eucha Lake.









Lake Data

| | |
|---|---|
| Owner | City of Tulsa |
| County | Delaware |
| Constructed | 1952 |
| Surface Area | 2,860 acres |
| Volume | 79,600 acre/feet |
| Shoreline Length | 49 miles |
| Mean Depth | 27.83 feet |
| Watershed Area | 216 square miles |

Plate 37- Lake Water Quality for

Lake Eucha

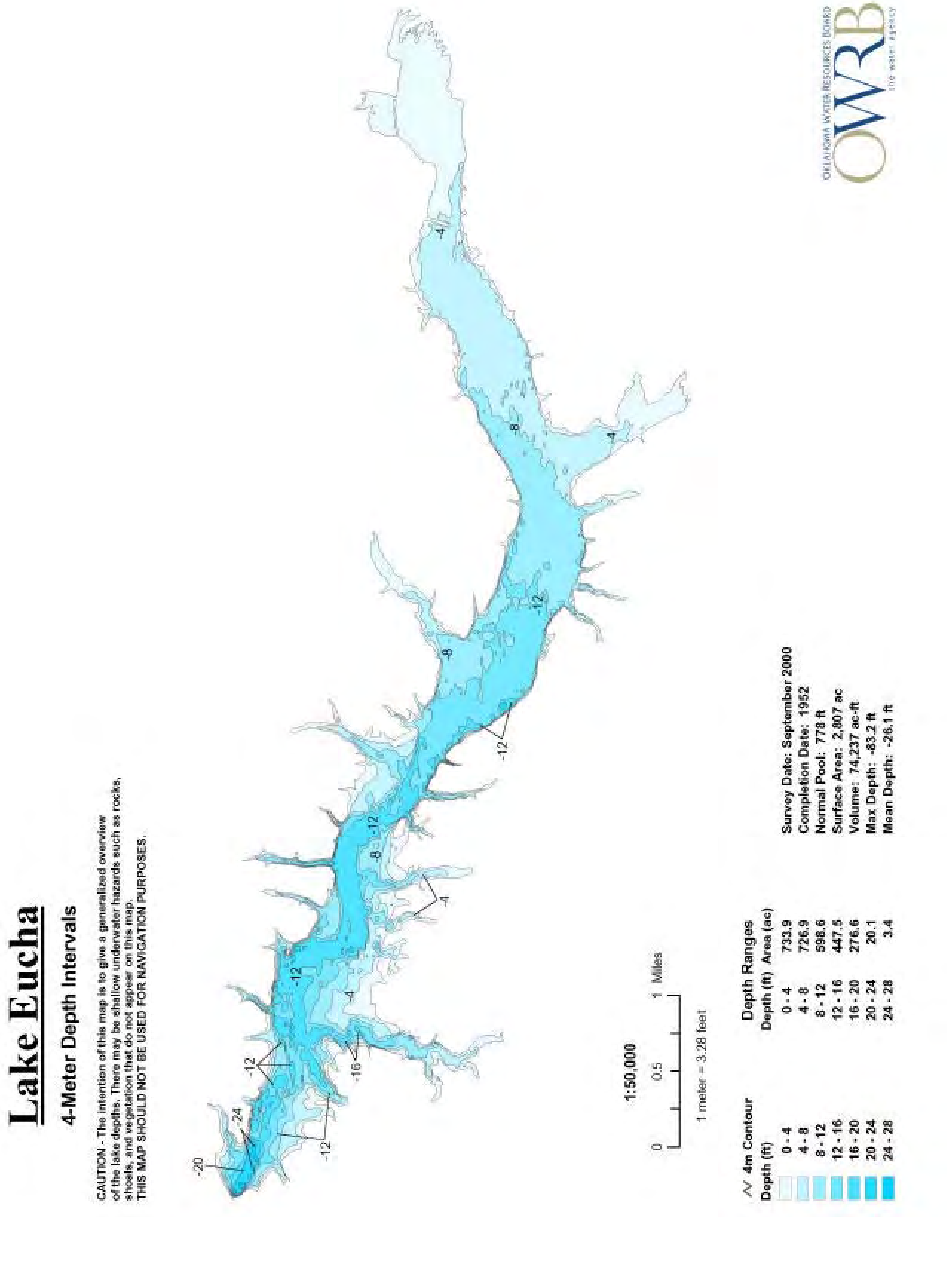



**Figure 88.** Bathymetric Map of Eucha Lake.

# Eufaula Lake

Eufaula Lake was sampled for four quarters from December 2002 through August 2003. Water quality samples were collected at seventeen (17) sites to represent the riverine, transition and lacustrine zones, and major arms of the reservoir. This is the largest lake monitored by BUMP in both surface acres and number of sites sampled. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 7, the dam. The lake-wide average turbidity was 21 NTU (Plate 38), true color was 50 units, and secchi disk depth was 85 centimeters. Water clarity was average at Eufaula Lake in comparison to other Oklahoma reservoirs based on these three parameters, and results are similar to those of the 2000 evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=68). The TSI was 52 (Plate 38), indicating the lake was eutrophic, indicative of high primary productivity and nutrient levels in sample year 2002-2003. This value is similar to that calculated in 2000, (TSI=53), indicating no significant increase or decrease in productivity has occurred. The TSI values varied seasonally and ranged from oligotrophic to hypereutrophic (Figure 89). Turbidity values varied by site and by season, but were typically above the Oklahoma Water Quality Standard (OWQS) of 25 NTU in the more riverine portions of the lake and below the standard in the lacustrine portions of the lake. The highest turbidity values throughout the year occurred at sites 14-17, the Gaines Creek arm. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 28% of the turbidity values above the standard, the Fish and Wildlife Propagation (FWP) beneficial use is not supported based on turbidity (see Figure 90a). Seasonal true color values are displayed in Figure 90b. True color values followed the same trend as turbidity, with values exceeding the OWQS of 70 units at sites 14-17 throughout the year except for the summer quarter. Of the values collected, 17.5% exceeded 70 units. Applying the same default protocol, the Aesthetic beneficial use is partially supported based on true color.

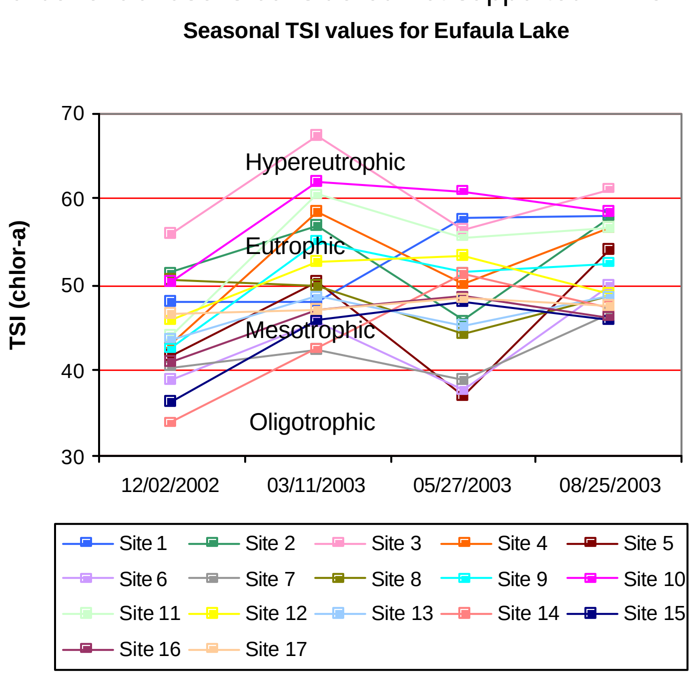



**Figure 89.** TSI values for Eufaula Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the 2002-2003-sample year. Salinity values at Eufaula Lake varied by site and season, but generally ranged from 0.04 (winter, site 16) to 0.43 parts per thousand (spring, site 10). The lowest salinity values occurred in the winter (site 16), and throughout the year were lowest in the Gaines Creek arm of the reservoir (sites 14-17). The highest values were in the spring (site 10) and were always highest in the Canadian River arm (sites 10 and 11) throughout the year. Specific conductance ranged from 105 mS/cm to 831.5 mS/cm, indicative of moderate to high levels of current conducting ions (salts) in the lake system. The trend for conductivity was similar to salinity, as the Canadian arms were always higher and the Gaines Creek arm sites had the lowest values throughout the year. The recorded values for pH ranged from 6.85 to 8.80 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range, Eufaula Lake is partially supporting its FWP beneficial use for pH. In general, the lake was not thermally stratified during the fall, winter, and spring sampling quarters and the water column was mixed (see Figure 90c-90e). Dissolved oxygen (D.O.) was above 4.0 mg/L, with the exception of site 8 (Highway 9 Landing), in the spring. This is the only site to exhibit stratification during the first three quarters. At that time approximately 26% of the water column fell below 2.0 mg/L. In the summer, the lake was stratified throughout between 4 and 6 meters depending on the site. Dissolved oxygen levels below the thermocline were less than 2.0 mg/L for the remainder of the water column (Figure 90f). Anoxic conditions were present throughout accounting for 33 to 70% of the water column having oxygen levels below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions present for 26% of the water column in the spring, and up to 70% of the water column in the summer Eufaula Lake is considered to be partially supporting the FWP beneficial use. These conditions could, however, pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.67 mg/L at the surface and 0.68 mg/L at the lake bottom. Surface TN ranged from 0.25 mg/L to 1.54 mg/L with the highest values recorded in the fall and lowest in the winter quarter. The lake-wide total phosphorus (TP) average was 0.042mg/L at the surface and 0.078 mg/L at the lake bottom. TP values at the surface ranged from 0.011 mg/L to 0.127 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2003. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Eufaula Lake was classified as eutrophic with high primary productivity and nutrient rich conditions. This is the same classification as 2000 (TSI=53), indicating no significant increase or decrease in productivity has occurred. Water clarity was average in comparison to other Oklahoma reservoirs based on turbidity, true color, and secchi disk depth. The lake is not supporting the FWP beneficial use based on turbidity, and partially supporting based on dissolved oxygen levels. Anoxic conditions present throughout the lake in the summer could pose a threat to fish and wildlife propagation and should be monitored closely in the future. The Aesthetics baneful use is supported based on trophic status, but partially supported based on true color values as 17.5% of the collected values exceed the OWQS of 70 units. Eufaula Lake, located in Haskell County, was constructed by the United State Army Corps of Engineers (USACE) for flood control, water supply, hydroelectric power and navigational purposes.

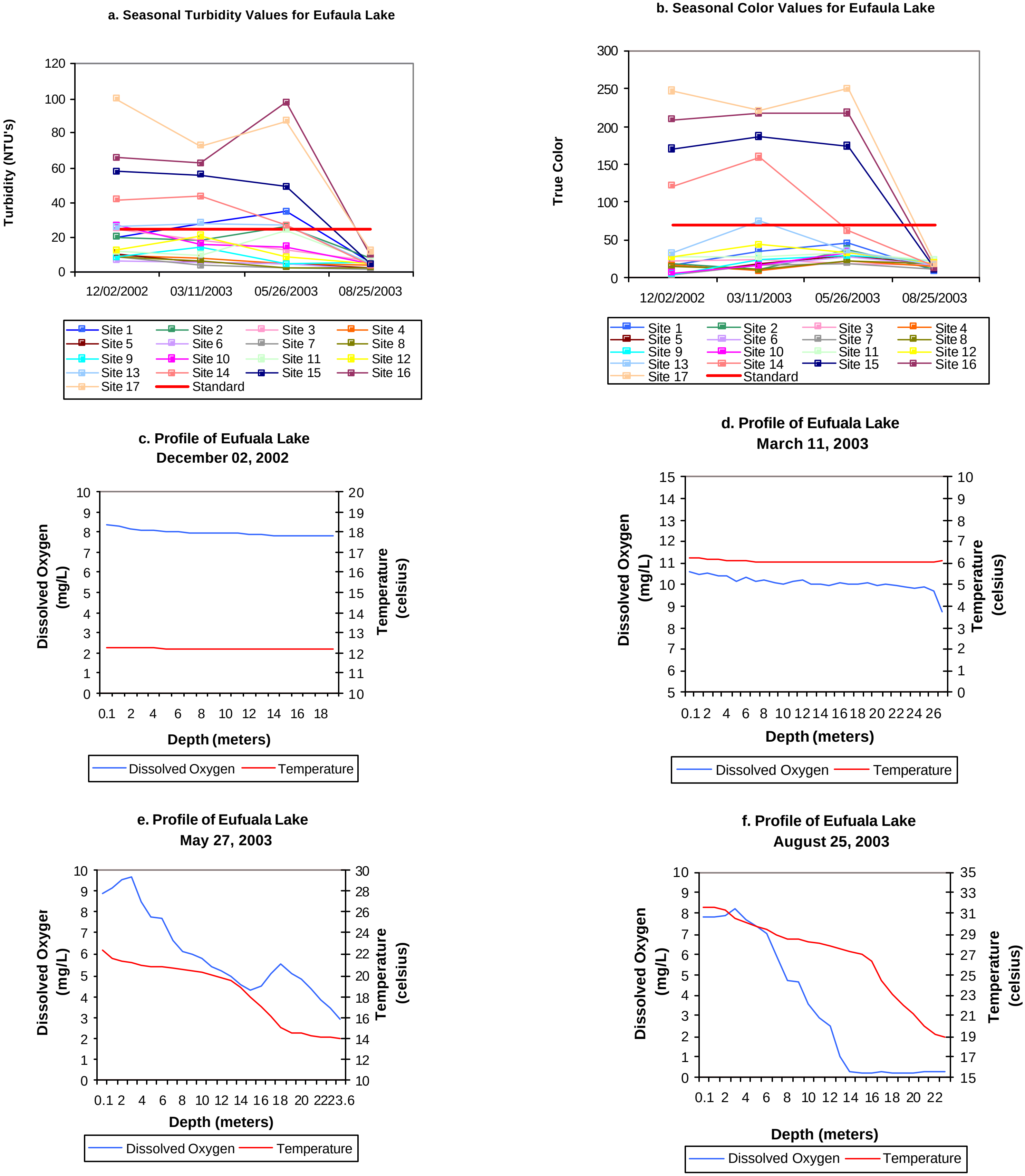
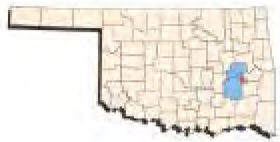
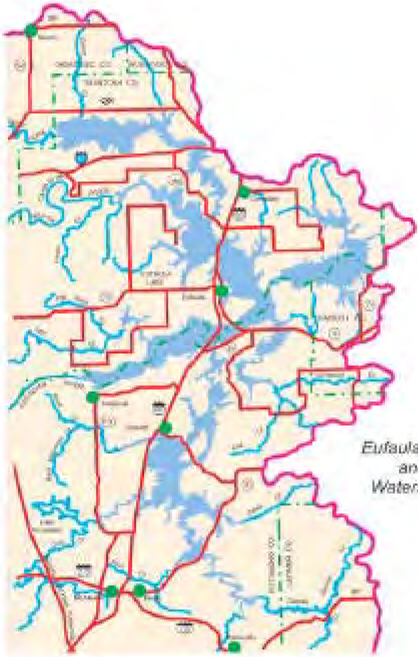
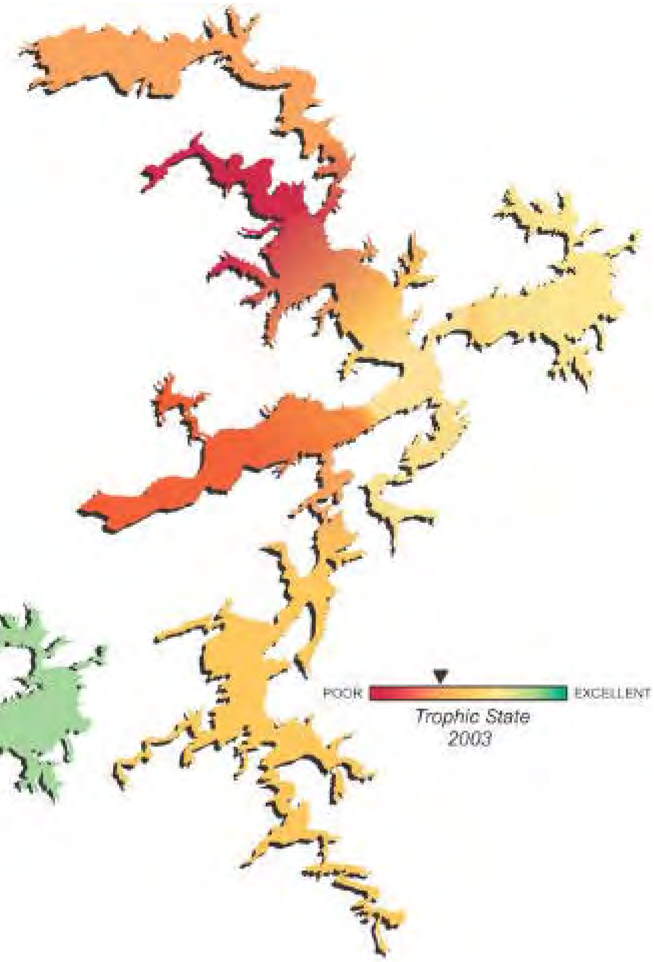


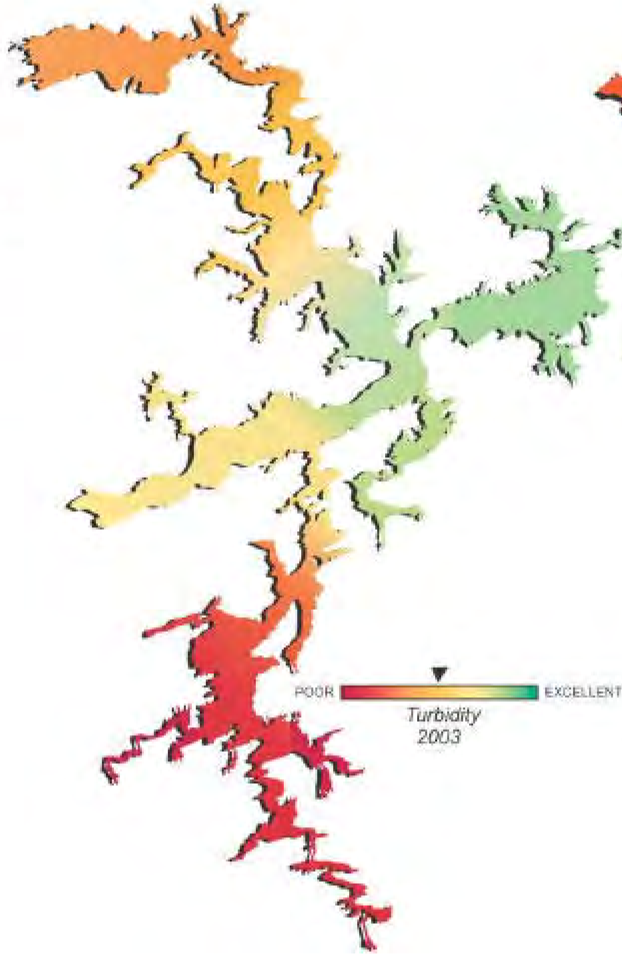

**Figure 90a-90f.** Graphical representation of data results for Eufaula Lake.








Lake Data

| | |
|---|---|
| Consrtucted by | Corps of Engineers |
| County | McIntosh (Dam) |
| Constructed | 1964 |
| Surface Area | 105,500 acres |
| Volume | 2,314,600 acre/feet |
| Shoreline Length | 600 miles |
| Mean Depth | 21.94 feet |
| Watershed Area | 47,522 square miles |

Plate 38 - Lake Water Quality for
# Eufaula Lake

# Fairfax City Lake

Fairfax City Lake was sampled for four seasons, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 12 NTU (Plate 39), true color was 25 units, and secchi disk depth was 91 centimeters. Based on these three parameters, Fairfax City Lake had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 47 (Plate 39), indicating the lake was mesotrophic, indicative of moderate levels of productivity and nutrient conditions. The TSI values were mesotrophic in the first three seasons and lower eutrophic during the summer (see Figure 91). Turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU in all seasons, with the exception of the spring quarter (See Figure 92a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 16.6% of the samples exceeded 25 NTU, the Fish & Wildlife Propagation (FWP) beneficial use is considered supported as the spike in turbidity it likely the reasult of seasonal storm events. Seasonal true color values are displayed in Figure 92b. Similar to turbidity there was a spike in recorded true color values in the spring; however only one (8%) of the twelve values exceeded 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.16 ppt, within the expected range for Oklahoma reservoirs. Readings for specific conductance were also well within the range of expected values for most Oklahoma reservoirs. Conductivity ranged from 217.2 mS/cm recorded in the spring quarter to 326.1 mS/cm recorded in the winter quarter of 2003, indicating moderate concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials

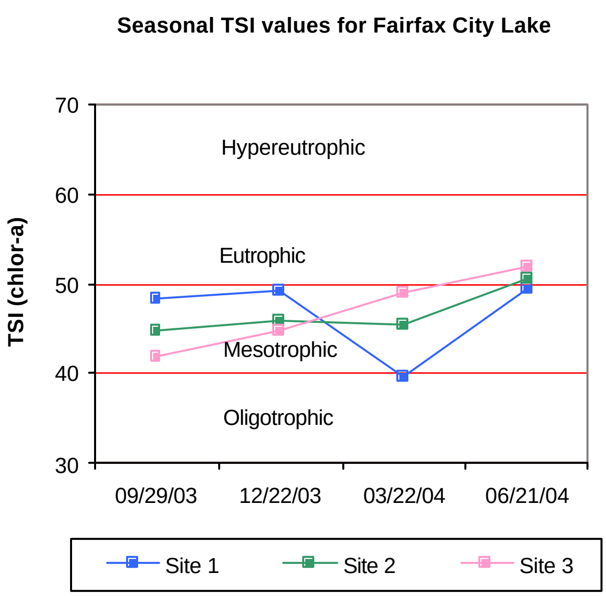



**Figure 91.** TSI values for Fairfax City Lake.

(redox) ranged from 352 mV to 501 mV, indicating reducing conditions were not a concern during 2003-2004 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 7.06 in the summer quarter to 8.07 in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The FWP beneficial use was fully supported based on pH values collected during the study period. The lake was not thermally stratified in the fall or winter quarters and the water column was well mixed (See Figure 92c-92d). The lake was weakly stratified in the spring however anoxic conditions were not present (Figure 92e). Fairfax Lake was strongly thermally stratified in the summer quarter between the 3 and 4 meters depths at which point D.O. values fell below 2.0 mg/L to the lake bottom of 10 meters (see Figure 92f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With approximately 64% of the water column less than 2.0 mg/L the lake is partially supporting its FWP beneficial use based on D.O. values. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected two or 20% exceeded the prescribed screening level for enterococci and *E. coli*, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.51 mg/L at the lake surface. The TN at the surface ranged from 0.40 mg/L to 0.62 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.030 mg/L at the lake surface. The TP ranged from 0.020 mg/L to 0.058 mg/L. The highest surface TP values were reported in the spring quarter and the lowest were in the remaining three quarters. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Fairfax City Lake was classified as mesotrophic indicative of moderate primary productivity and nutrient conditions (Plate 39). The Aesthetics beneficial use was fully supported based on true color values and the lakes trophic state. Fairfax City Lake was fully supporting the FWP beneficial use based on pH and partially supporting based and dissolved oxygen concentrations in the water column. Although 16.6% of the samples exceeded 25 NTU, the Fish & Wildlife Propagation (FWP) beneficial use is considered supported as the spike in turbidity is likely the reasult of seasonal storm events. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected two or 20% exceeded the prescribed screening level for enterococci and *E. coli* however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Fairfax City Lake is owned and operated by the City of Fairfax and is managed as a water supply reservoir and recreational outlet for the city and the public. In conclusion, the water quality of Fairfax City Lake is very good when compared to other lakes across the state and is one of the nicer smaller municipal lake resources available to the public.

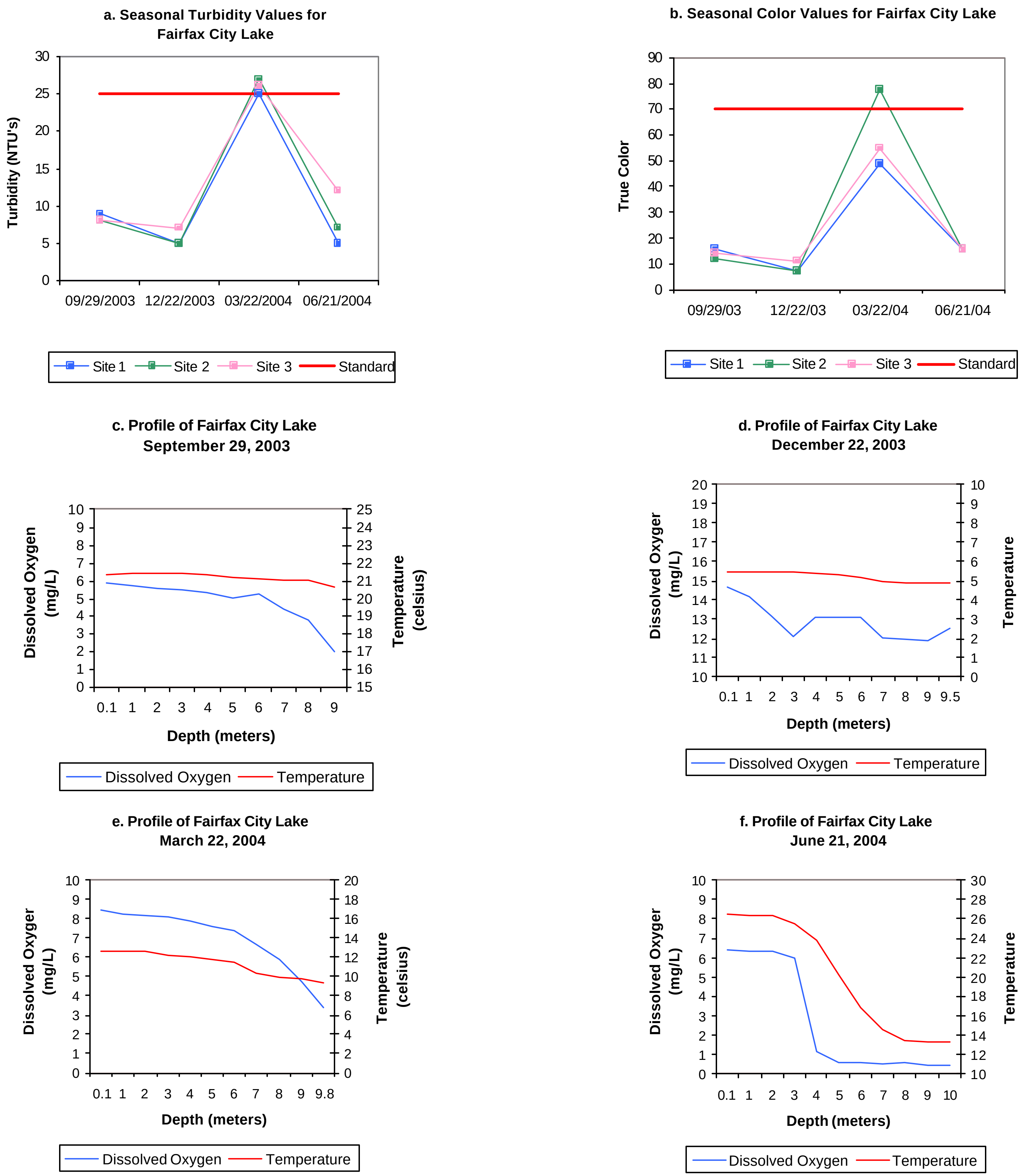
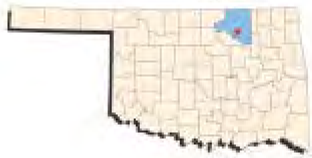
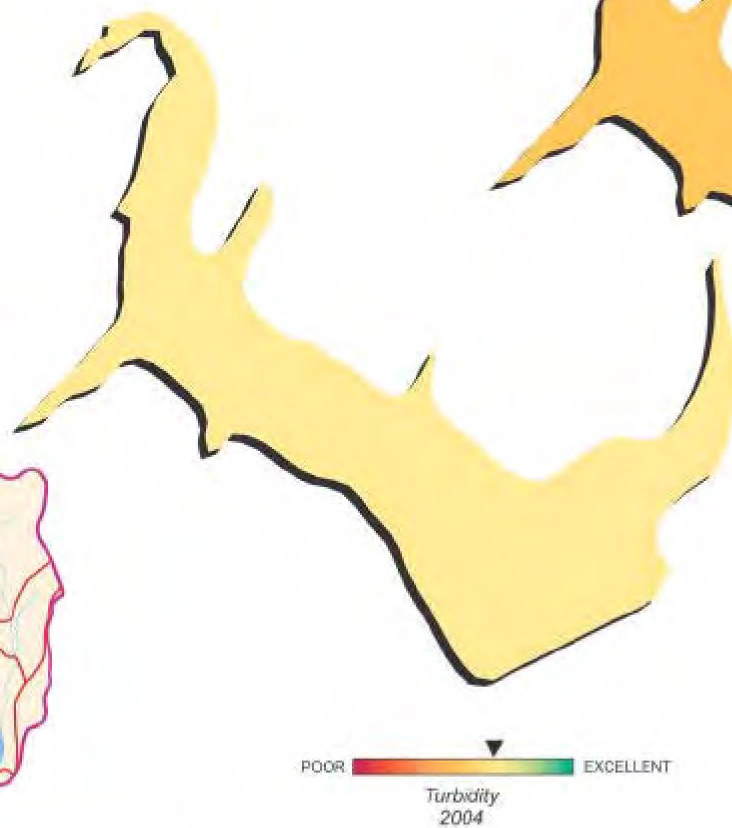



**Figure 92a-92f.** Graphical representation of data results for Fairfax City Lake.




Fairfax Lake
and
Watershed

| | |
|---|---|
| Lake Data | |
| Owner | City of Fairfax |
| County | Osage |
| Constructed | 1936 |
| Surface Area | 111 acres |
| Volume | 1,795 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 16.17 feet |
| Watershed Area | 9 square miles |



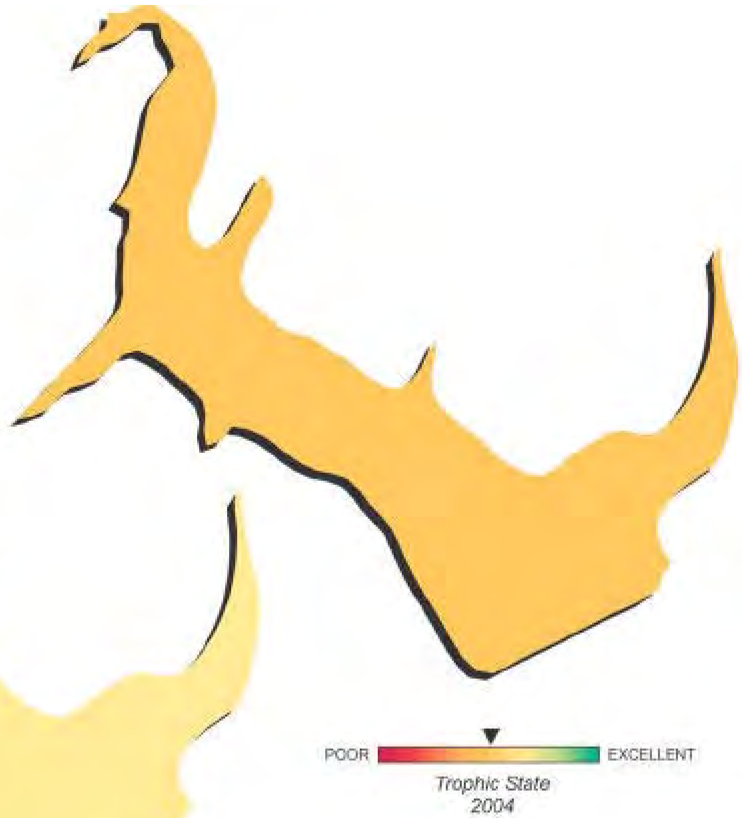
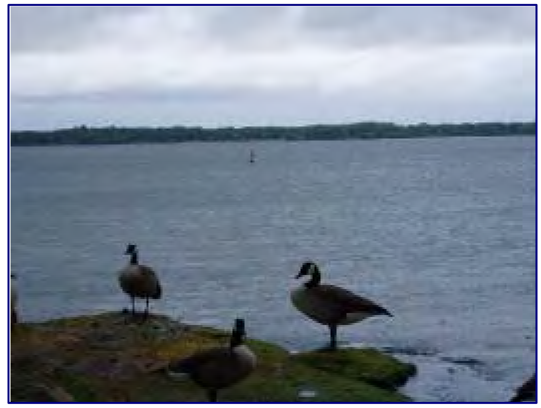




Plate 39- Lake Water Quality for
Fairfax Lake

# Fort Cobb Reservoir



Fort Cobb Reservoir was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at six (6) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as any major arms and tributaries. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 18 NTU (Plate 40), true color was 11 units, and secchi disk depth was 75 centimeters. Based on these three parameters, Fort Cobb Reservoir had fairly good water clarity in comparison to other Oklahoma reservoirs, similar to that of previous data collection efforts in 2001-2002. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=24). The average TSI was 64 (Plate 40), indicating the lake was hypereutrophic, indicative of excessive levels of productivity and nutrient rich conditions. This finding is consistent with historical data collection efforts and supports the listing of the lake as a Nutrient Limited Watershed (NLW) as listed in the Oklahoma Water Quality Standards (OWQS). At this time Fort Cobb is considered threatened due to nutrients until a non-support status can be confirmed. The TSI values varied seasonally from hypereutrophy in the fall and summer to eutrophic in the winter and spring (see Figure 93). Only three of the twenty-four turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 94a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Fort Cobb reservoir is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 94b. All true color values were below the Aesthetics OWQS of 70 units for all four quarters at all sites thus meeting the Aesthetics beneficial use for true color.

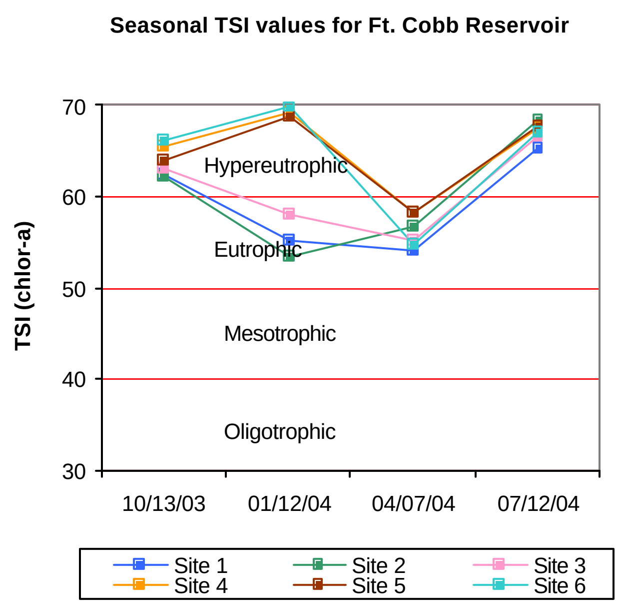



**Figure 93.** TSI values for Fort Cobb Reservoir.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.21 parts per thousand (ppt) to 0.27 ppt, slightly higher than the expected range for most Oklahoma reservoirs. Readings for specific conductance were within the expected range for Oklahoma reservoirs. Specific conductivity ranged from 426.2 mS/cm in the fall to 569.7 mS/cm in the winter quarter, indicating moderate concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 282mV near the lake bottom in the fall quarter to 544 mV in the summer quarter, indicating reducing conditions were not present in the lake system during 2003-2004 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 7.07 units to 8.87 all within the OWQS range of 6.5-9.0 units, therefore the FWP beneficial use was supported based on pH. The lake was not thermally stratified in the fall, winter or spring quarters and the lake was well mixed and oxygenated, with dissolved oxygen values above 5.0 mg/L except at the very bottom of the lake (see Figure 94c-94e). Fort Cobb Reservoir was thermally stratified during the summer quarter between 10 and 11 meters below the surface at site 2, at which point dissolved oxygen (D.O.) concentrations fell below 2.0 mg/L and remained below 1.0 mg/L all the way to the lake bottom at 12.7 meters (see Figure 94f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 21% of the water column violating the criteria the lake is considered to be fully supporting its FWP beneficial use based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected three (30%) exceeded the prescribed screening level of 61cfu/ml and the geometric mean (34) exceeds the prescribed geometric mean of 33 cfu/ml for enterococci. The PBCR beneficial use is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.41 mg/L at the lake surface and 1.55 mg/L at the lake bottom. The TN at the surface ranged from 1.03 mg/L in summer quarter to 1.84 mg/L recorded in the spring quarter. The lake-wide total phosphorus (TP) average was 0.077 mg/L at the lake surface to 0.094 mg/L at the lake bottom. The TP ranged from 0.045 mg/L to 0.137 mg/L. The highest surface TP values were reported in the summer and the lowest were in the spring. The nitrogen to phosphorus ratio (TN:TP) was 18:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Fort Cobb Reservoir was classified as hypereutrophic indicative of excessive primary productivity and nutrient rich conditions (Plate 40). This is consistent findings from previous data collection efforts and further supports the listing of the lake in the OWQS as NLW water with nutrient threats present. The lake was fully supporting its Aesthetics beneficial use based on true color. With 12.5% of the collected values above the OWQS criteria for turbidity, the lake is partially supporting its FWP beneficial use for turbidity and with only 21% of the experiencing anoxic conditions during the summer, the lake is supporting the FWP beneficial use as it relates to dissolved oxygen. There are high levels of nutrients in the water column, which coupled with the relatively good water quality, which serves to fuel primary productivity in the lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected three (30%) exceeded the prescribed screening level of 61cfu/ml and the geometric mean (34) for enterococci. The PBCR beneficial use is therefore considered not supported. Fort Cobb Reservoir is owned and operated by Bureau of Reclamation and was impounded in 1959. The lake serves multiple uses including municipal water supply, flood control, and recreational purposes. The Bureau of Reclamation and its contractors are currently studying the lake intensively to further identify the source of the nutrient problems and to recommend corrective actions in the lake and watershed.

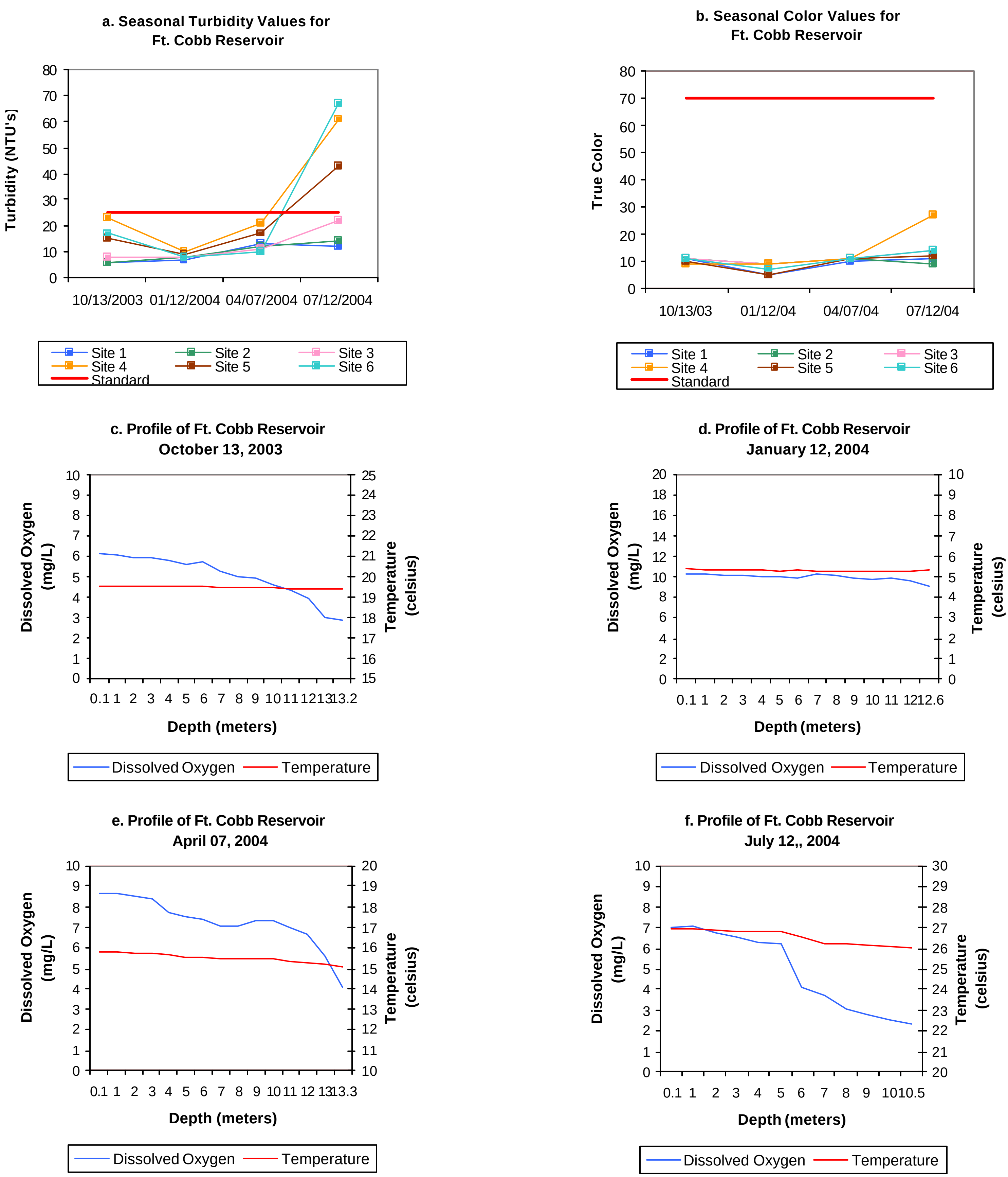
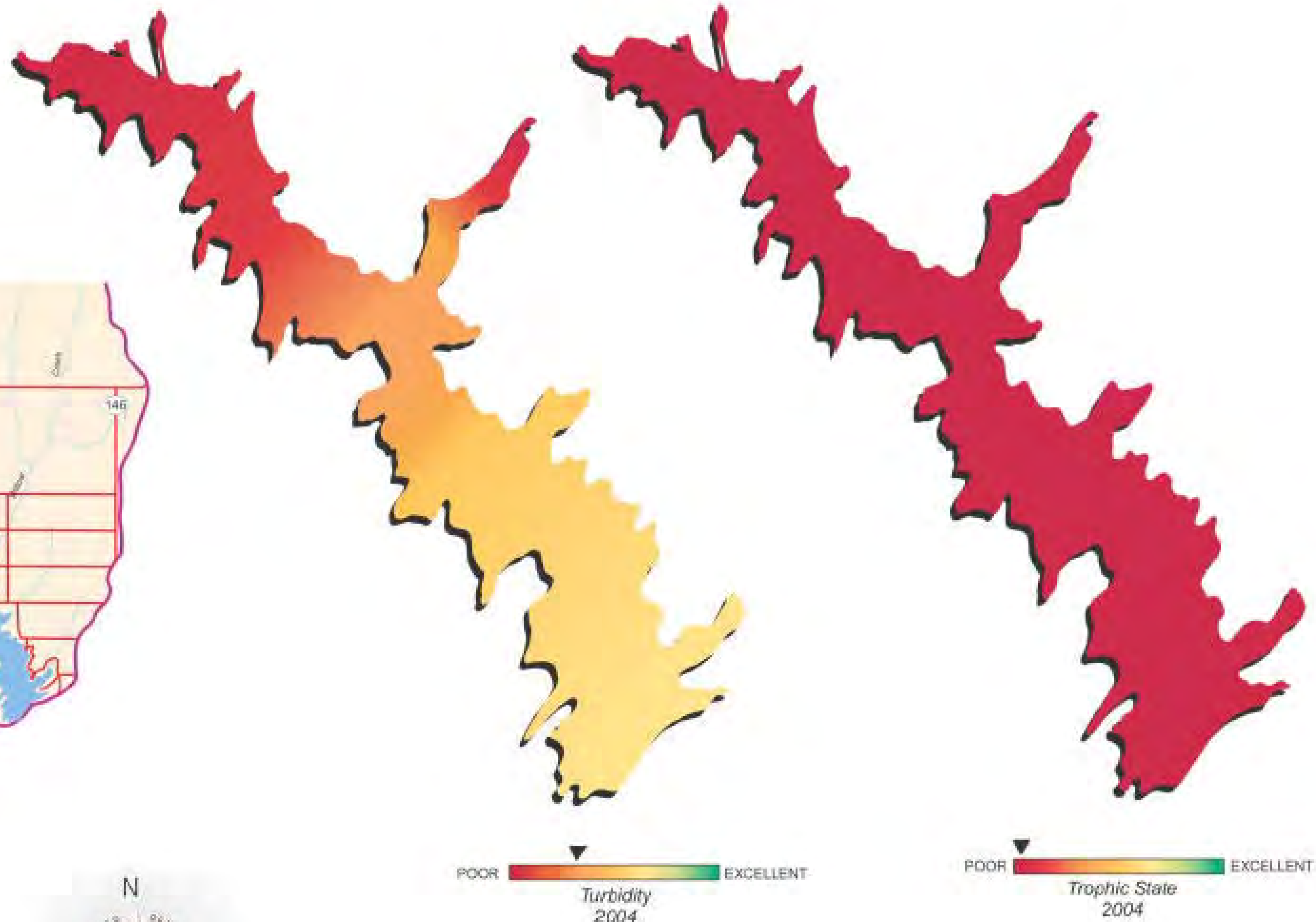



**Figure 94a-94f.** Graphical representation of data results for Fort Cobb Reservoir.






Lake Data

| | |
|---|---|
| Consrtucted by | Bureau of Recalmation |
| County | Caddo |
| Constructed | 1959 |
| Surface Area | 4,100 acres |
| Volume | 80,010 acre/feet |
| Shoreline Length | 45 miles |
| Mean Depth | 19.48 feet |
| Watershed Area | 314 square miles |

Plate 40 - Lake Water Quality for
Fort Cobb Lake

# Fort Gibson Lake

Fort Gibson Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at eight (8) sites to represent the riverine, transitional, and lacustrine zones of the lake as well as any major arms of the reservoir. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 12 NTU (Plate 41), true color was 24 units, and secchi disk depth was 85 centimeters in 2004. Based on these three parameters, Fort Gibson Lake had good water clarity in 2004. Water clarity is very similar to 2000-2001, as secchi disk depth has improved while true color and turbidity are about the same as previously reported. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=32). The average TSI was 58, classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is lower than the TSI in 2002 (TSI=64). Based on previous data collection efforts, the lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The TSI values were primarily hypereutrophic or eutrophic at all sites although the TSI at several sites in the winter were mesotrophic or oligotrophic (Figure 95). Only two of the 32 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (See Figure 96a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 6% of the reported values above the standard the FWP use is considered supported based on turbidity. All true color values were below the aesthetics OWQS of 70 units throughout the sample year (Figure 96b). Applying the same default protocol, the Aesthetics beneficial use is still considered fully supported.

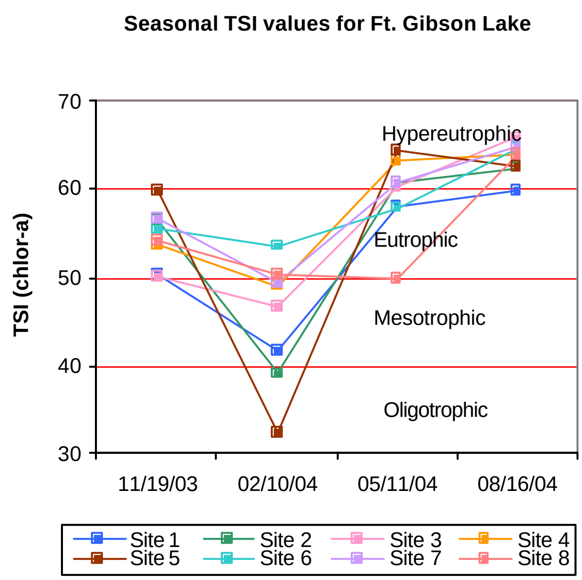



**Figure 95.** TSI values for Ft. Gibson Lake.

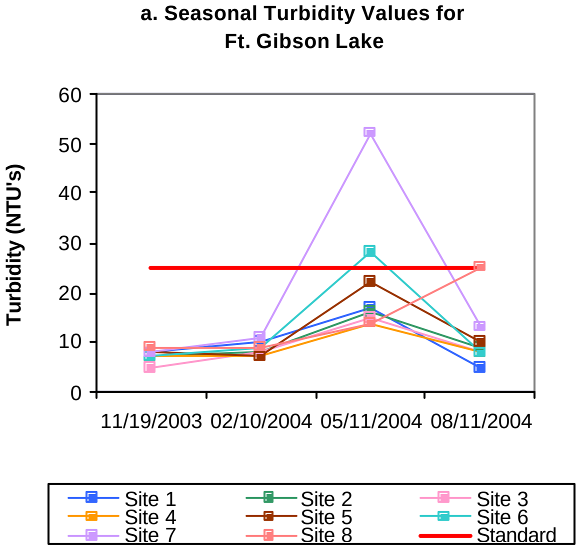
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.17 ppt, well within the expected range for most Oklahoma reservoirs. Readings for specific conductance were within the expected range for Oklahoma reservoirs. Specific conductivity ranged from 234 mS/cm in the summer quarter to 309.5 mS/cm in the fall quarter, indicating low to moderate concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 282mV near the lake bottom in the fall quarter to 544 mV in the summer quarter, indicating reducing conditions were not present in the lake system during 2003-2004 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 7.25 units to 8.65 all within the OWQS range of 6.5-9.0 units, therefore the FWP beneficial use was supported based on pH. The lake was not thermally stratified in the fall, winter or spring quarters and the lake was well mixed and oxygenated, with dissolved oxygen values above 5.0 mg/L except at the very bottom of the lake (see Figure 96c-96e). Fort Gibson Lake was thermally stratified during the summer quarter between 10 and 11 meters below the surface at site 1, at which point dissolved oxygen (D.O.) concentrations fell below 2.0 mg/L and remained below 1.0 mg/L all the way to the lake bottom at 17.3 meters (see Figure 96f). Site 1 was the only sample station to have D.O. concentrations less than 5.0 mg/L at the lake surface. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With approximately 28% of the water column violating the criteria the lake is considered to be fully supporting its FWP beneficial use based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

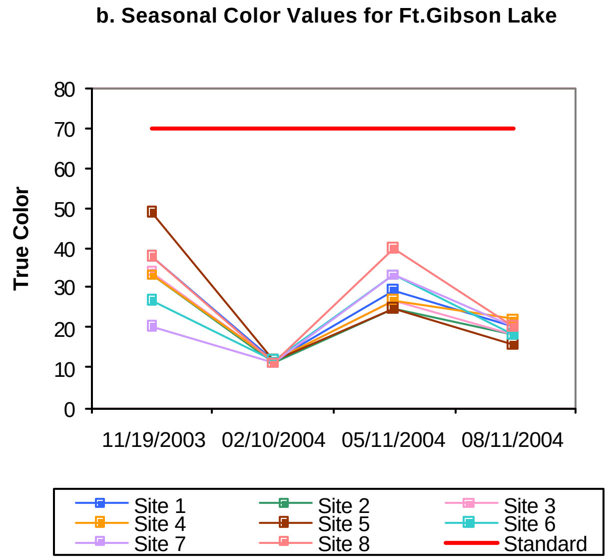
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

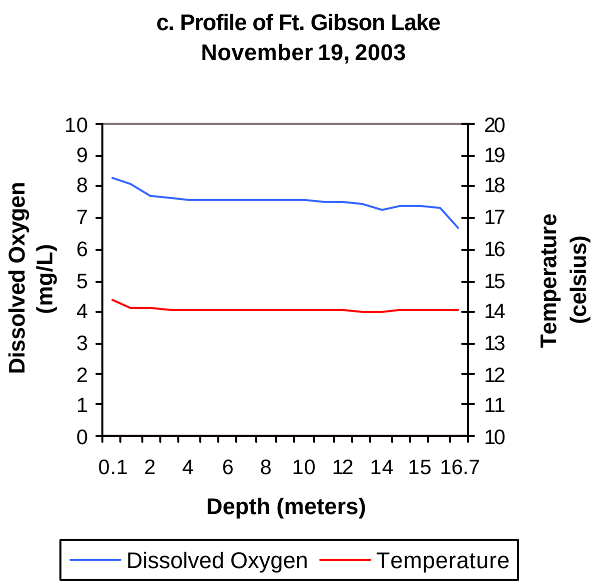
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.97 mg/L at the lake surface and 0.94 mg/L at the lake bottom. The TN at the surface ranged from 0.49 mg/L in fall quarter to 1.77 mg/L recorded in the spring quarter. The lake-wide total phosphorus (TP) average was 0.100 mg/L at the lake surface to 0.097 mg/L at the lake bottom. The TP ranged from 0.048 mg/L to 0.149 mg/L. The highest surface TP values were reported in the fall and the lowest were in the winter. The nitrogen to phosphorus ratio (TN:TP) was 10:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

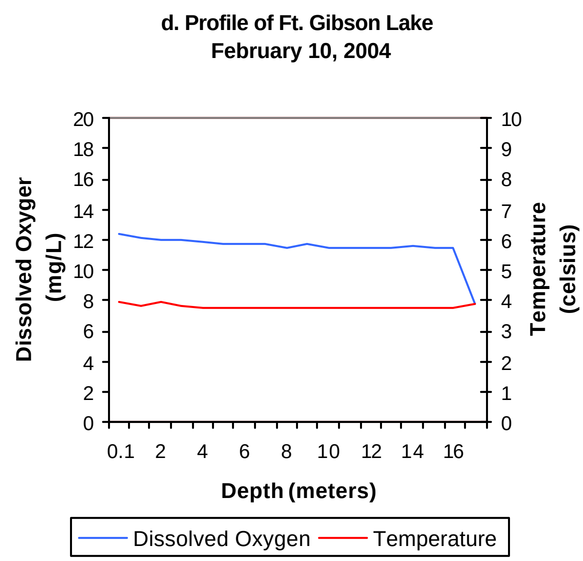
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

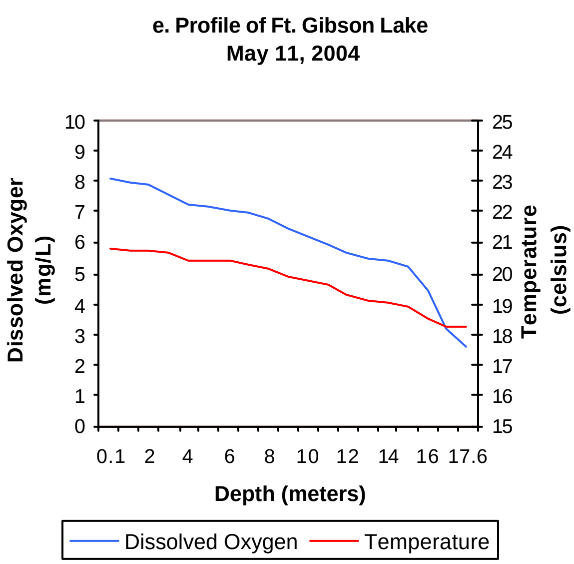
In summary, Fort Gibson Lake was classified as eutrophic indicative of high primary productivity and nutrient rich conditions (Plate 41). The lake was fully supporting its Aesthetics beneficial use based on true color. Based on previous from previous data collection efforts the lake is currently listed in the OWQS as Nutrient Limited Watershed (NLW) water. This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. With only 6.3% of the collected values above the OWQS criteria for turbidity, the lake is fully supporting its FWP beneficial use for turbidity and with 28% of the experiencing anoxic conditions at site 1 during the summer, the lake is also supporting the FWP beneficial use as it relates to dissolved oxygen. There are high levels of nutrients in the water column, which coupled with the relatively good water quality serves to fuel primary productivity in the lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Fort Gibson Lake, constructed by the USACE, was built for flood control and hydroelectric power purpose. The lake also provides many recreational opportunities for the citizens of Oklahoma to enjoy.



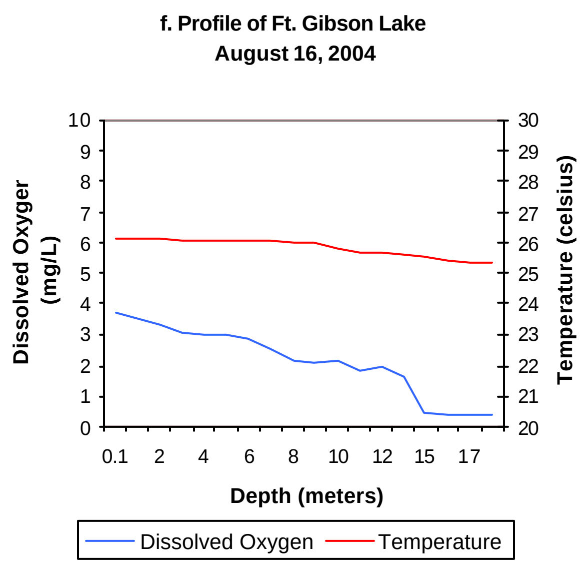
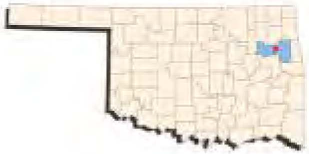




**Figure 96a-96f. Graphical representation of data results for Ft. Gibson Lake.**



Fort Gibson Lake Location


Fort Gibson Lake and Watershed

W N E S

| Lake Data | |
|---|---|
| Consrtucted by | Corps of Engineers |
| County | Cherokee (Dam) |
| Constructed | 1953 |
| Surface Area | 19,900 acres |
| Volume | 365,200 acre/feet |
| Shoreline Length | 225 miles |
| Mean Depth | 23.84 feet |
| Watershed Area | 12,492 square miles |

POOR EXCELLENT

*Turbidity 2004*

POOR EXCELLENT

*Trophic State 2004*

Plate 41 - Lake Water Quality for

Fort Gibson Lake

# Fort Supply Lake

Fort Supply Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites with an additional collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 51 NTU (Plate 42), true color was 36 units, and secchi disk depth was 37 centimeters. Based on these three parameters, Fort Supply Lake had fair to poor water clarity in 2003-2004, similar to findings in previous data collection efforts. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 57 (Plate 42), classifying the lake in the upper end of eutrophy, indicative of high levels of productivity and high nutrient conditions. Currently Fort Supply Lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The TSI values were primarily eutrophic in the fall, winter and spring quarters and low to mid-hypereutrophic in the summer quarter (see Figure 97). Turbidity values are displayed in (See Figure 98a). According to the Use Support Assessment Protocols (USAP) detailed in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The Fish & Wildlife Propagation (FWP) beneficial use is not supporting with 80% of the collected values exceeding the numeric criteria of 25 NTU. Seasonal true color values are shown in Figure 98b. Applying the same default protocol, the Aesthetics beneficial use is considered partially supporting with 10% of the true color values exceeding the OWQS of 70 units.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.49 parts per thousand (ppt) to 0.53 ppt, which is much higher than the range of expected values for Oklahoma lakes, reflecting elevated levels of chlorides or other salts in the lake. Specific conductance values were also above the expected range for Oklahoma reservoirs, coinciding with the high salinity concentrations. Values ranged from 944.1 mS/cm in the winter to 1006 mS/cm recorded in the spring. Oxidation-reduction potentials (redox) ranged

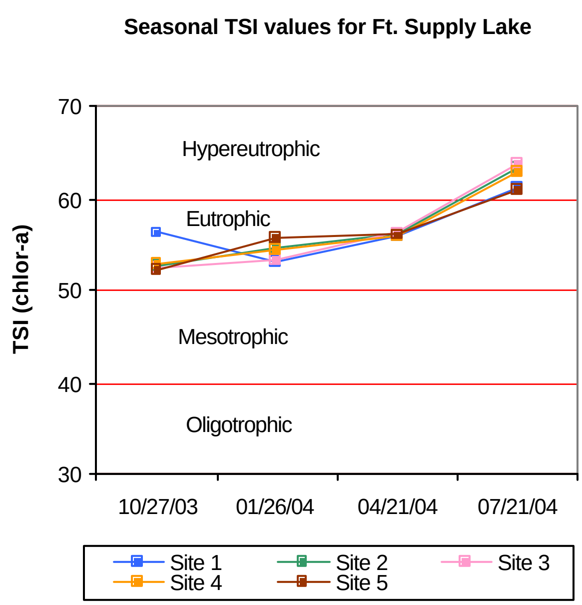



**Figure 97.** TSI values for Fort Supply Lake.

from 310 mV in the summer quarter to 633 mV in the spring, indicating reducing conditions were not present at the time of sampling. Lake pH values were neutral to slightly alkaline with values ranging from 7.5 in the fall to 8.29 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Of the pH values recorded none were outside the acceptable range, therefore the lake is supporting its FWP beneficial use based on pH. Thermal stratification was not evident in any quarterly sampling events due to the shallow nature of the reservoir and fact that wind mixing prevents a thermocline from developing (see Figure 98c-98f). Dissolved oxygen (D.O.) values were above 3.5mg/L throughout the water column at all sites during the study period, indicating the water column was well oxygenated and well mixed (see Figure 98c-98f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use was fully supported based on D.O. values. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.92 mg/L at the lake surface. The TN at the surface ranged from 0.81 mg/L to 1.35 mg/L. The highest surface TN value was reported in the fall and the lowest was in the winter. The lake-wide total phosphorus (TP) average was 0.069 mg/L at the lake surface. The TP ranged from 0.031 mg/L to 0.110 mg/L. The highest surface TP value was reported in the summer and the lowest was in the winter. The nitrogen to phosphorus ratio (TN:TP) was 13:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1997 as part of their Toxics Monitoring Program and detected no compounds at the FDA Action level, ODEQ warning level or ODEQ concern level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Fort Supply Lake was classified as eutrophic, bordering hypereutrophic, indicative of high primary productivity and high nutrients (Plate 42). Water clarity is fair to poor based on turbidity, true color and secchi disk depth, consistent with historical findings. The lake is partially supporting its Aesthetics beneficial use based on true color. Fort Supply Lake is currently listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The FWP beneficial use is not supporting based on turbidity and is supporting based on pH and dissolved oxygen concentrations in the lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected none exceeded the prescribed screening level. The PBCR beneficial use is therefore considered supported. Fort Supply Lake, constructed by the United States Army Corps of Engineers, was built in 1942 for flood control and hydroelectric power purposes.

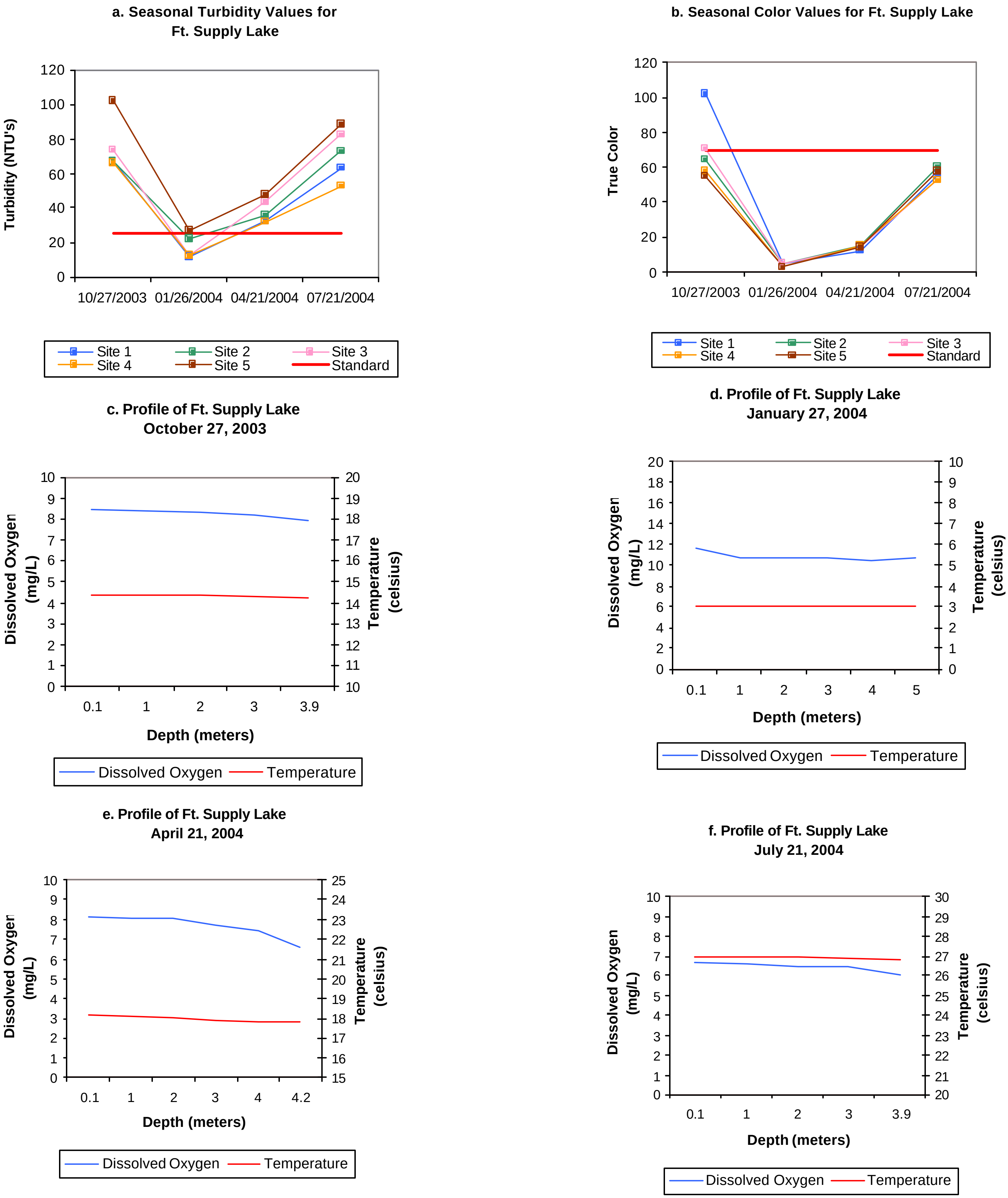



**Figure 98a-98f.** Graphical representation of data results for Fort Supply Lake.



| Lake Data | |
|---|---|
| Consrtucted by | Corps of Engineers |
| County | Woodward |
| Constructed | 1942 |
| Surface Area | 1,820 acres |
| Volume | 13,900 acre/feet |
| Shoreline Length | 26 miles |
| Mean Depth | 7.64 feet |
| Watershed Area | 1,735 square miles |


Turbidity
2004


Trophic State
2004

Plate 42 - Lake Water Quality for
# Fort Supply Lake

# Foss Reservoir

Foss Reservoir was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at five (5) sites to represent the riverine, transition and lacustrine zone of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 12 NTU (Plate 43), true color was 10 units, and average secchi disk depth was 161 centimeters in sample year 2002-2003. Water clarity was good at Foss Reservoir based on these three parameters. Results for turbidity, true color, and secchi disk depth are similar to those recorded in 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 48 (Plate 43), indicating the lake was mesotrophic, with moderate levels of productivity and nutrient conditions for sample year 2003. This value is similar to that calculated in 2000 (TSI=47) indicating no significant change in productivity has occurred. The TSI for all sites varied seasonally and ranged from oligotrophic in the spring to mesotrophic in the winter and eutrophic in both summer and fall (Figure 99). A similar pattern was seen during the 2000 evaluation. The only exception occurred at site 5, when chlorophyll concentrations spiked in the spring, which made this site hypereutrophic. Seasonal turbidity values by site are displayed in Figure. Although the lake-wide average for turbidity was 12 NTU, below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, there are instances when some values were near or above the standard. These spikes in turbidity occurred at sites 4 (summer) and 5 (fall) in the upper portions of the lake (see Figure 100a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is partially supported at Foss Reservoir with 10% of the values above the turbidity standard of 25 NTU. Seasonal true color values are displayed in Figure 100b. All color values are well below the aesthetics OWQS of 70 units.

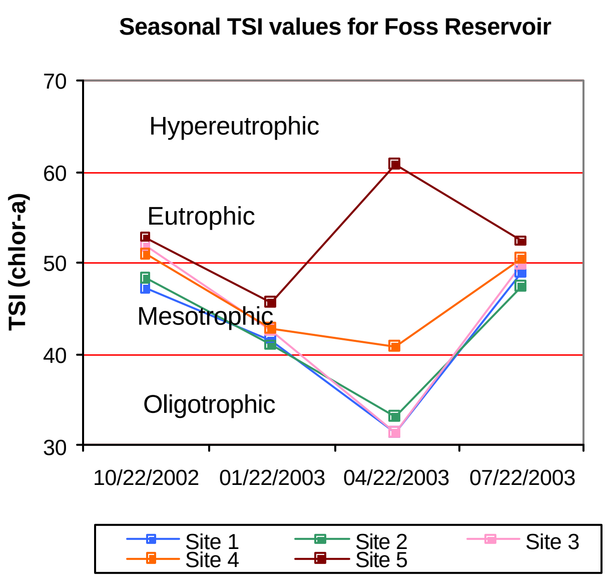


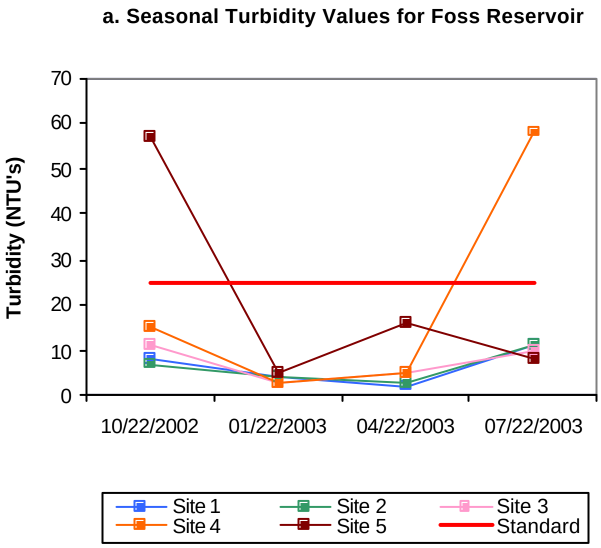

**Figure 99.** TSI values for Foss Reservoir.

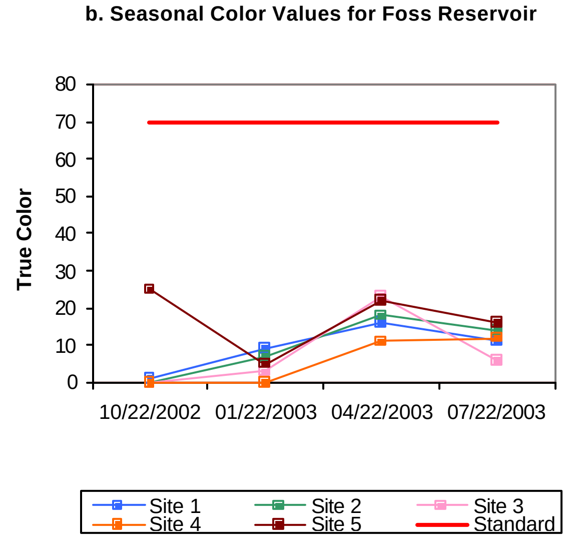
In 2002-2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Foss Reservoir ranged from 0.67 parts per thousand (ppt) to 1.29 ppt, which is higher than most Oklahoma reservoirs. Specific conductivity ranged from 1274 mS/cm to 2409 mS/cm, indicating extremely high concentrations of current conducting compounds (chlorides and salts) in the lake, consistent with higher salinity concentrations. The pH values ranged from 7.31 at the lake bottom in the summer to 8.23 at the surface in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 100% of the values recorded within the acceptable range the lake supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 329 mV in the hypolimnion in the spring to 525 mV during the fall. During the fall, winter, and spring thermal stratification was not present and the lake was well mixed with dissolved oxygen values remaining above 7.0 mg/L (see Figure 100c-100e). The lake was thermally stratified and anoxic conditions were present during the summer sampling interval. Stratification generally occurred between 8 and 10 meters with dissolved oxygen (D.O.) values falling below 2.0 mg/L for the rest of the water column (Figure 100f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions accounting for 39% of the water column in the summer, Foss Reservoir is considered partially supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

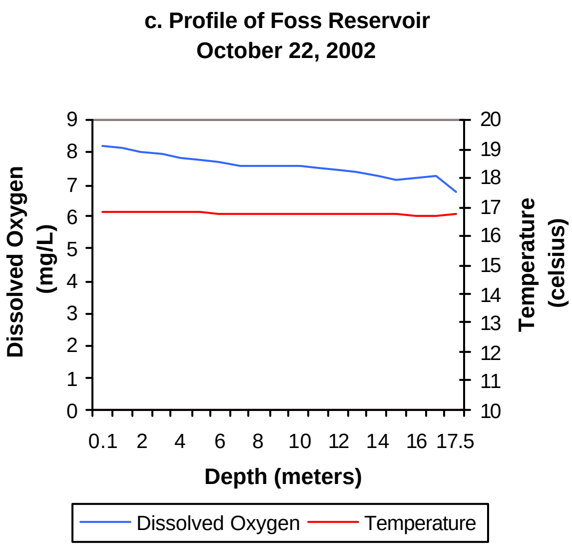
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

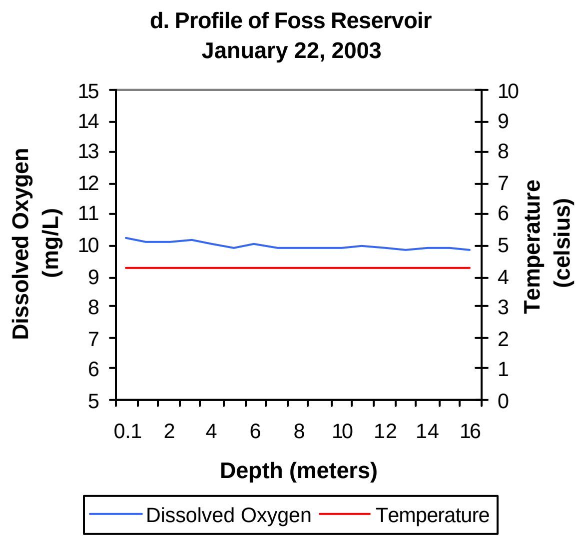
Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.52 mg/L at the surface and 0.48 mg/L at the lake bottom. Surface TN ranged from 0.29 mg/L to 0.82 mg/L with both the highest and lowest values occurring during the summer. The lake-wide total phosphorus (TP) average was 0.024mg/L at the surface and 0.020 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the summer quarter, however, the lowest value was seen in the fall. TP values ranged from 0.011 mg/L to 0.091 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2003. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

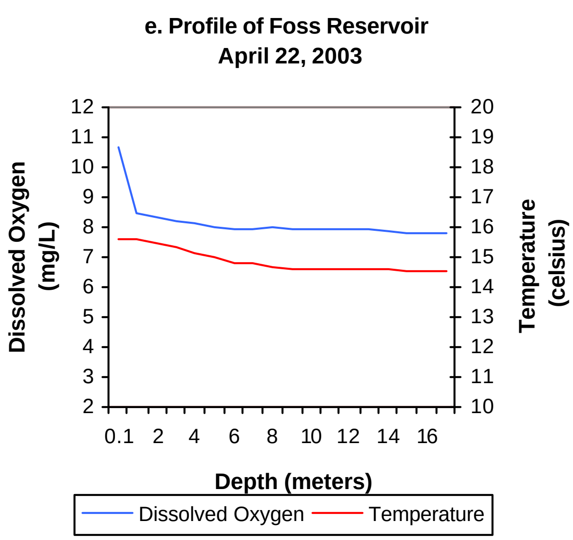
In summary, Foss Reservoir was classified as mesotrophic with moderate primary productivity and nutrient conditions. The current trophic status is similar that in 2000 (TSI=47), indicating no significant change in productivity has occurred since the last evaluation. Water clarity was good in 2002-2003 based on turbidity, true color and secchi disk depth. The FWP beneficial use is supported based on pH, but is partially supported based on both turbidity and dissolved oxygen levels. The Aesthetics beneficial use is supported at Foss Reservoir based on its trophic status and true color. Foss Reservoir was constructed by Bureau of Reclamation to serve as a flood control, water supply and a fish and wildlife recreation reservoir. Foss State Park is located in western Oklahoma in Custer County.



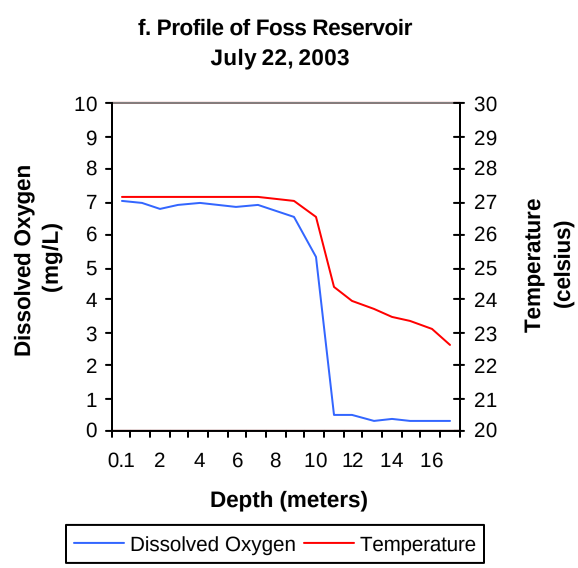
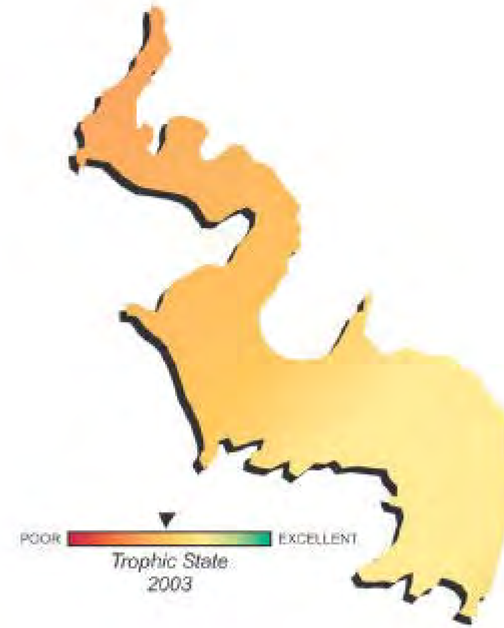



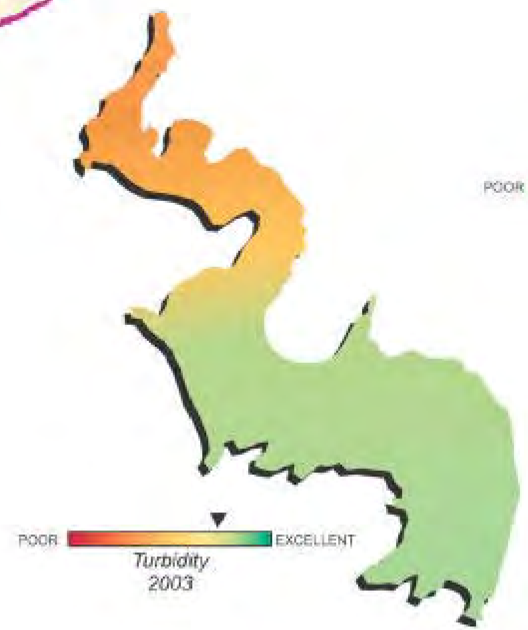

**Figure 100a-100f.** Graphical representation of data results for Foss Reservoir.

Foss Reservoir
Location


Foss Reservoir
and
Watershed


Trophic State
2003




Turbidity
2003

Lake Data

| | |
|---|---|
| Owner | U.S. Dept. of the Interior |
| County | Custer |
| Constructed in | 1961 |
| Surface Area | 8,800 acres |
| Volume | 256,220 acre/feet |
| Shoreline Length | 63 miles |
| Mean Depth | 23.15 feet |
| Watershed Area | 1,496 square miles |

Plate 43 - Lake Water Quality for
## Foss Reservoir

# Lake Frederick

Frederick Lake was sampled for four quarters from October 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for the reservoir as it is greater than 250 surface acres in size. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 93 NTU (Plate 44), true color was 57 units, and secchi disk depth was 17 centimeters. Based on these three parameters, Frederick Lake had poor water clarity in 2003. Water clarity was similar to historical data and is likely always poor based on the soil composition and nature of this lake. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 51 (Plate 44), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This value is consistent with the TSI in 2000 (TSI=50). The TSI values were eutrophic throughout the year at all sites except for sites 3 and 5 in the summer, which were mesotrophic, and therefore the lake-wide TSI of 51 seems representative of conditions at Lake Frederick (Figure 101). Seasonal turbidity values are displayed in Figure 102a. All turbidity values (100%) in 2003 exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥ 25% of the samples exceed the Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is not supported at Lake Frederick based on high turbidity. Seasonal true color values are displayed in Figure 102b. All color values are well below the aesthetics OWQS of 70 units during the first three sampling quarters, but were above the standard in the spring. It is likely that this is due to spring rains and runoff. Additional samples sites were not added until later in the sample year therefore the minimum data requirements of 20 samples for lakes greater than 250 surface acres was not met and a determination for the Aesthetics beneficial use cannot be made.

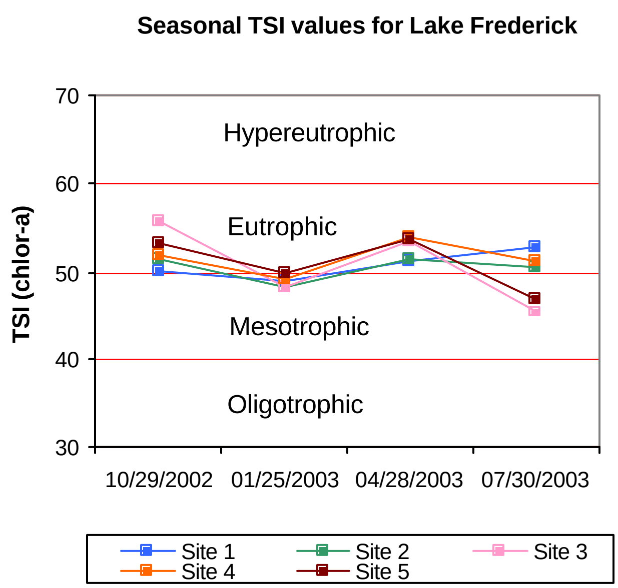



**Figure 101.** TSI values for Lake Frederick.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values at Lake Frederick ranged from

0.14 parts per thousand (ppt) to 0.26 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 286.5 mS/cm to 503.7 mS/cm, indicating minimal concentrations of current conducting compounds (chlorides and salts) in the lake system. The pH values ranged from 7.21 at the lake bottom in the summer to 8.29 at the surface in the spring. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. All values recorded within the acceptable range the lake supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 210 mV in the spring to 615 mV in the hypolimnion during the fall. All ORP values were positive and above 100 mV indicating reducing conditions were not present in the lake. Thermal stratification was not present and the lake was well mixed with dissolved oxygen (D.O) values remaining above 4.0 mg/L (see Figure 102c-102f) throughout the entire sample year. The only time the D.O. fell below 4.0 mg/L was during the summer near the lake bottom. With 100% of the dissolved oxygen values above 2.0 mg/L, Lake Frederick is considered to be supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.59 mg/L at the surface and 0.56 mg/L at the lake bottom. Surface TN ranged from 0.22 mg/L to 0.87 mg/L with the lowest values occurring during the fall and the highest in the spring. The lake-wide total phosphorus (TP) average was 0.065 mg/L at the surface and 0.062 mg/L at the lake bottom. Surface TP was also highest in the spring quarter; however, the lower value recorded in the summer. TP values ranged from 0.041 mg/L to 0.115 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2003. This value is slightly higher than 7:1, characterizing the lake phosphorus limited to co-limited (Wetzel, 1983).

In summary, Lake Frederick was classified as eutrophic (TSI=51), indicative of high primary productivity and nutrient rich conditions. This value is slightly higher than the TSI in 2001 that classified the lake as mesotrophic bordering eutrophic, however the current value is based on a larger dataset and is likely a more accurate depiction of productivity in the system. Water clarity is poor based on turbidity, true color, and secchi disk depth and is likely to always be poor based on soil composition of the area. The Fish and Wildlife Propagation beneficial use is supported based on dissolved oxygen and pH, but is not supported based on high turbidity values. The Aesthetics beneficial use is supported based on its trophic status, however a beneficial use determination cannot be made for true color due to minimum data requirements for lakes greater than 250 surface acres not being met. Due to the lake's use as a municipal water supply reservoir and past and present drought conditions, the city of Frederick was concerned with sedimentation and current lake volumes. During the summer of 2000 the city of Frederick contracted the OWRB to conduct a bathymetric survey of the lake to generate a bathymetric map (Figure 103) and determine current lake volume. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405)

530-8800. Frederick Lake was constructed in 1974 by the Soil Conservation Service and is located in Tillman County.

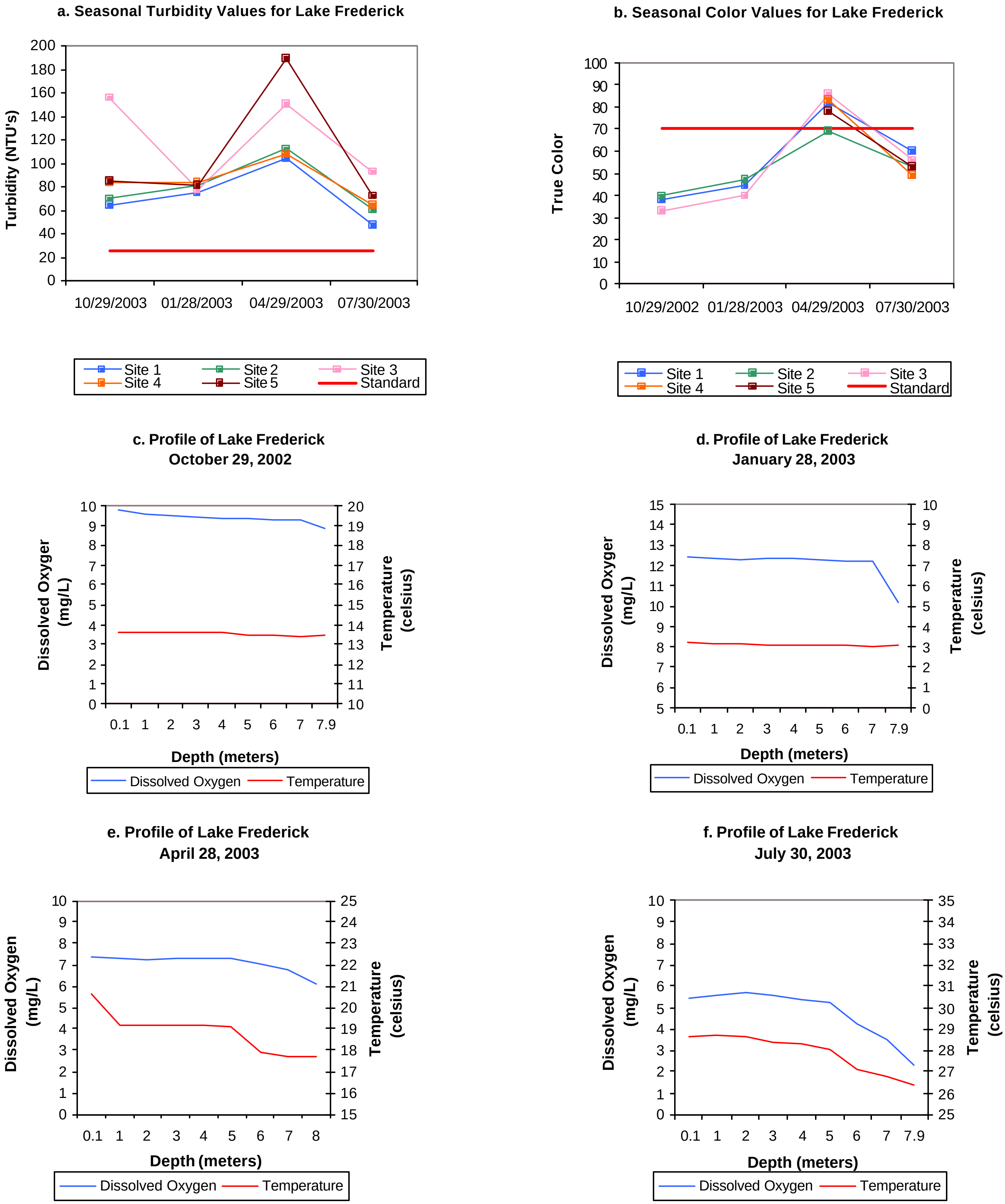
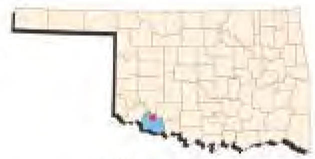



**Figure 102a-102f.** Graphical representation of data results for Lake Frederick.


*Frederick Lake and Watershed*



*Frederick Lake Location*



*Turbidity 2003*


*Trophic State 2003*

Lake Data

| | |
|---|---|
| Owner | City of Frederick |
| County | Tillman |
| Constructed in | 1974 |
| Surface Area | 876.8 acres |
| Volume | 9,715 acre/feet |
| Shoreline Length | 18.9 miles |
| Mean Depth | 10.83 feet |
| Watershed Area | 57 square miles |

Plate 44 - Lake Water Quality for

## Lake Frederick

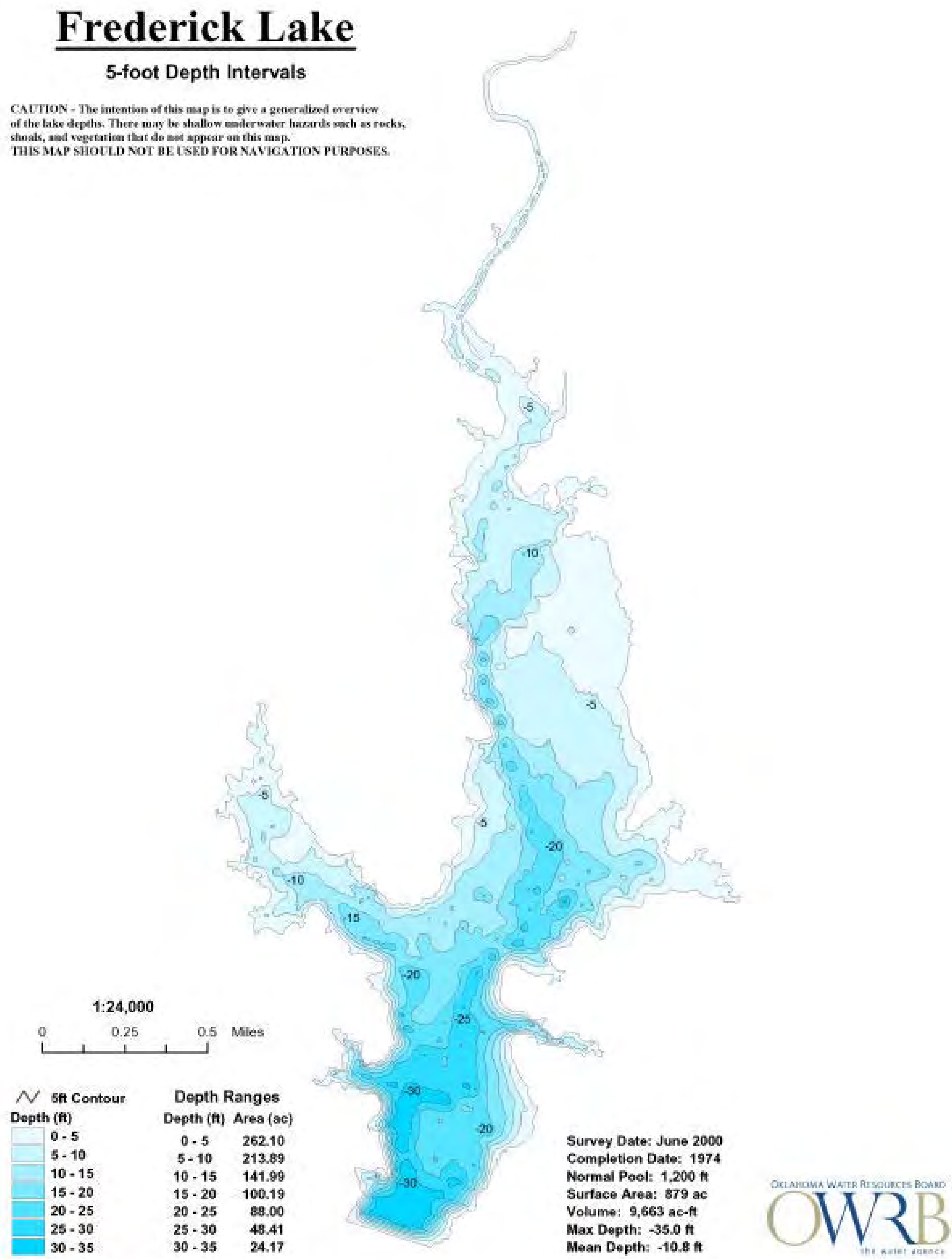



**Figure 103.** Bathymetric Map of Lake Frederick.

# Fuqua Lake

Fuqua Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones and major arms of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 17 NTU (Plate 45), true color was 12 units, and secchi disk depth was 98 centimeters. Based on these three parameters, Fuqua Lake had good water clarity in 2003, better than observed in the 2001 evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). Due to a lab accident the chlorophyll for one of the twenty samples could not be analyzed. The average TSI was 47 (Plate 45), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is similar to the one in 2001 (TSI=48), indicating no significant increase or decrease in productivity has occurred. All of the collected values were in the mesotrophic category (Figure 104). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although five of the nineteen or 26% of the turbidity values exceeded the OWQS of 25 NTU the minimum data requirements of 20 samples for lakes greater than 250 surface acres was not met and a determination cannot be made at this time. However upon reviewing historical data it is likely that the lake would be listed as partially supporting the Fish and Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 105b. All true color values were well below the OWQS of 70 units. Applying the same default protocol the Aesthetic beneficial use is fully supported based on true color.

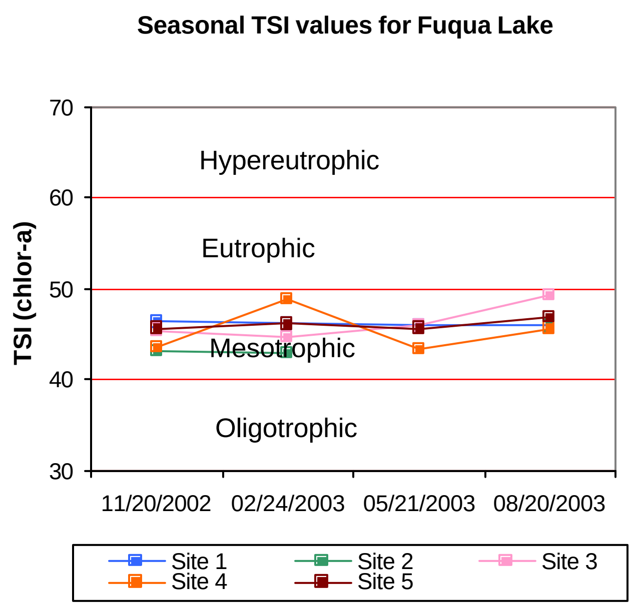



**Figure 104.** TSI values for Fuqua Lake

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Fuqua Lake ranged from 0.25 parts per thousand (ppt) to 0.29ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 490.4 mS/cm to 566.5 mS/cm, indicating moderate concentrations of current conducting compounds or other analogous material (salts) in the lake system. The pH values ranged from 7.16 to 8.29 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. All values recorded were within the acceptable range therefore the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 375 mV in the fall to 515 mV in the in the winter. Reducing conditions were not present in the lake during the study period. Thermal stratification was not present and the lake was well mixed with dissolved oxygen (D.O) values remaining above 4.0 mg/L (see Figure 105c-105e) during the first three sampling quarters. Thermal stratification was evident and anoxic conditions present in the summer. During the summer quarter the lake exhibited thermal stratification between 5 and 6 meters with dissolved oxygen dropping below 2.0 mg/L from the thermocline to the lake bottom (see Figure 105f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 33% of the water column was less than 2.0 mg/L in the summer Fuqua Lake is considered partially supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (58.8 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.36 mg/L at the surface and 0.43 mg/L at the lake bottom. Surface TN ranged from 0.16 mg/L in the winter to 0.54 mg/L in the spring. The lake-wide total phosphorus (TP) average was 0.018mg/L at the surface and 0.017 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.007 mg/L in the fall to 0.033 mg/L in the spring. The nitrogen to phosphorus ratio (TN:TP) was 20:1 for sample year 2003. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Fuqua Lake was classified as mesotrophic with moderate primary productivity and nutrient levels in 2002-2003. The TSI in 2001 was also mesotrophic, indicating no increase or decrease in productivity. Water clarity was good based on turbidity, true color, and secchi disk depth, even better than that observed in 2001. The lake is supporting its FWP beneficial use for pH, but only partially supporting based on dissolved oxygen values. Although there are only nineteen of the twenty required turbidity values, it is likely that the FWP beneficial use would be partially supported. The Aesthetics beneficial use is supported based on its trophic status and true color values. The PBCR beneficial use is not supported as five (5) or 50% enterococci samples exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (58.8 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. Fuqua Lake is owned by the city of Duncan and serves as a municipal water supply and recreational reservoir.

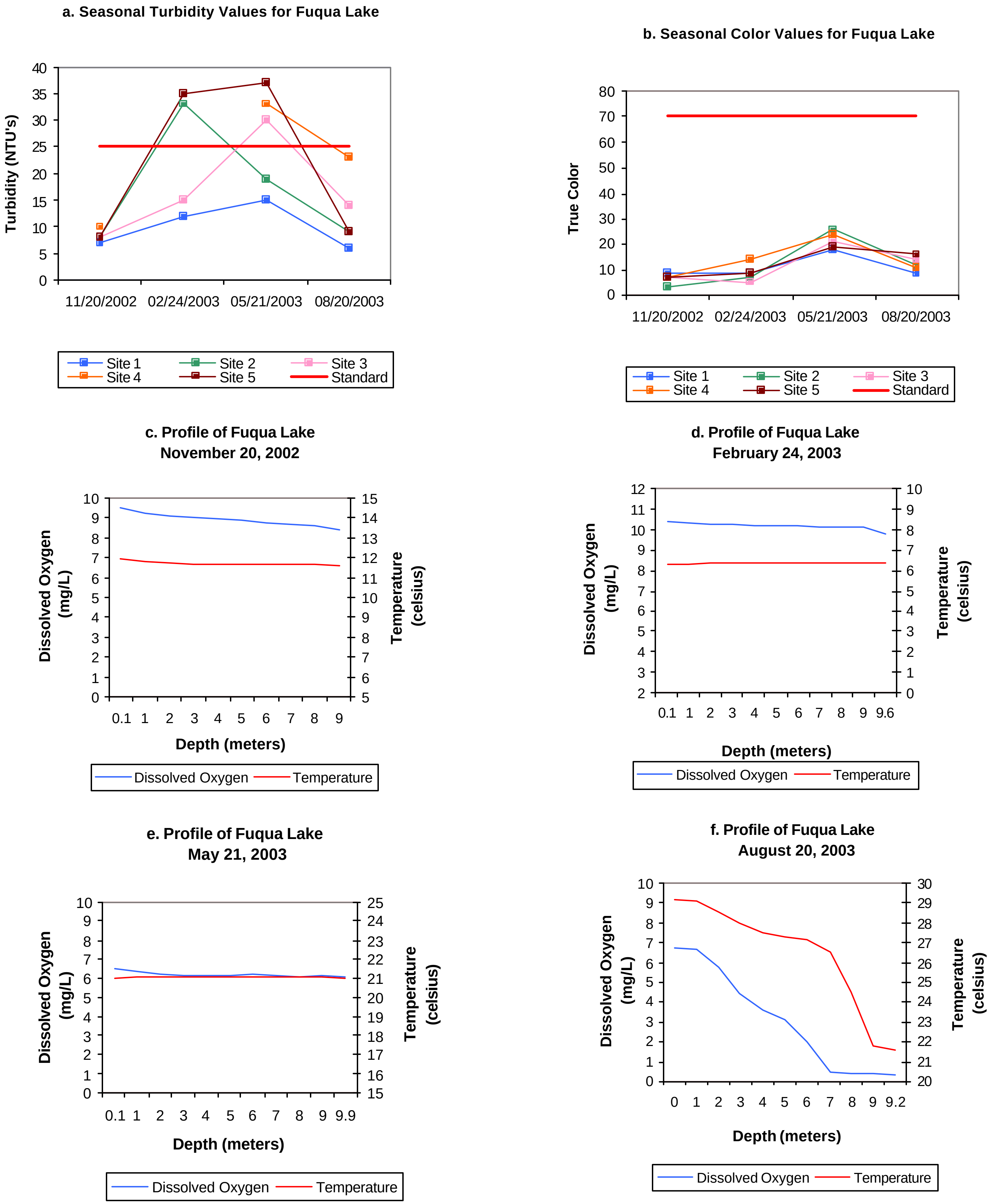
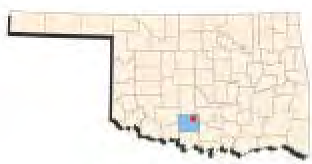



**Figure 105a-105f.** Graphical representation of data results for Fuqua Lake.


Fuqua Lake and Watershed

Fuqua Lake Location

Lake Data

| | |
|---|---|
| Owner | City of Duncan |
| County | Stephens |
| Constructed in | 1962 |
| Surface Area | 1,500 acres |
| Volume | 21,100 acre/feet |
| Shoreline Length | 18 miles |
| Mean Depth | 14.07 feet |
| Watershed Area | 38 square miles |


Turbidity 2003


Trophic State 2003

Plate 45- Lake Water Quality for
# Fuqua Lake

# Grand Lake

Grand Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at 13 sites to represent the riverine, transition, and lacustrine zones as well as major arms and tributaries of the reservoir. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 16 NTU (Plate 46), true color was 31 units, and secchi disk depth was 89 centimeters. Based on these three parameters, Grand Lake had average to good water clarity, slightly better than that observed in 2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=52). The average TSI was 57 (Plate 46), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is slightly lower than the one calculated in 2001 (TSI=59), although it is within the same trophic category. Chlorophyll-a values were varied by site and season during the study period at this reservoir (See). The TSI values ranged from oligotrophic (17%) to hypereutrophic (23%), although most values were in the mesotrophic (31%) or eutrophic category (29%). As expected, the lowest TSI average was at the lower end of the lake (sites 1) as well as sites 7 and 8 and the most productive sites were in the tributary arms, Honey Creek (site 6) and Spring/Neosho River arm (sites 13 and 12). Seasonal turbidity values are displayed in (Figure 107a). Turbidity values were also variable between sites and seasonally with lower values observed in the more lacustrine areas of the lake. Six (11.5%) of the 52 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU constituting a listing as "partially supporting" the Fish & Wildlife Propagation (FWP) beneficial use. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. In the fall and summer very few samples exceeded the criteria; however in the spring, sites 9,10,12, and 13 were above 25 NTU. Seasonal true color values are displayed in Figure 107b. Only 2 of the 52 true color values exceeded the numeric criteria of 70 units, therefore, the

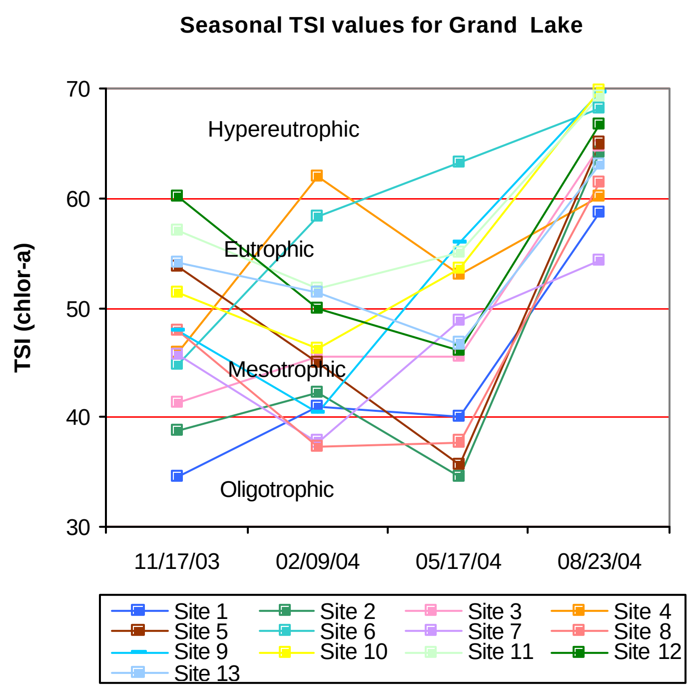



**Figure 106.** TSI values for Grand Lake.

Aesthetics beneficial use is considered fully supported. For most sites, true color was highest in the spring and lowest in the winter, which is the common pattern for most lakes.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Grand Lake ranged from 0.11 parts per thousand (ppt) to 0.18 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 216.1 mS/cm to 404.2 mS/cm, indicating low to moderate concentrations of current conducting compounds or other analogous material (salts) in the lake system. The pH values ranged from 6.65 to 9.46 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All values recorded were within the acceptable range, except at site 11 in the winter. With less than 1% of the values outside the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 60 mV to 564 mV, indicating reducing conditions were not present in the lake during the study period. Thermal stratification was not present in the fall and winter quarters and the lake was well mixed with dissolved oxygen (D.O) values generally above 4.0 mg/L (see Figure 107c-107d). In the fall, site 1 only had values less than 2.0 mg/L reported from 32 to 36.1 meters below the surface. In the spring the lake was weakly stratified at various depths among the sites, and low dissolved oxygen values were recorded in only 6 to 10% of the water column (Figure 107e). Thermal stratification was more evident and anoxic conditions present to a greater extent during the summer. During the summer quarter the lake was stratified between 13 and 14 meters at site 1 with dissolved oxygen dropping below 2.0 mg/L from the thermocline to the lake bottom of 32 meters (see Figure 107f). Sites 2 and 3 were also very stratified with approximately 38% of the water column at both sites below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 50% of the water column less than 2.0 mg/L at the dam in the summer Grand Lake is considered partially supporting the FWP beneficial use. The lake was also sampled for chlorides and sulfates, to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected three (30%) exceeded the prescribed screening level of 61 cfu/, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 1.36 mg/L at the surface and 1.26 mg/L at the lake bottom. Surface TN ranged from 0.54 mg/L in the summer to 2.88 mg/L in the winter. The lake-wide total phosphorus (TP) average was 0.095mg/L at the surface and 0.239 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.047 mg/L in the fall to 0.243 mg/L in the spring. The nitrogen to phosphorus ratio (TN:TP) was 14:1 for 2003-2004. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Grand Lake was classified as eutrophic, with high primary productivity and nutrient rich conditions (Plate 46). This is consistent with finding from the 2001(TSI=59) data collection efforts, indicating no significant increase or decrease in productivity has occurred. Water clarity is average to good based on true color, turbidity, and secchi disk depth. The Aesthetics beneficial use is considered supported based on trophic status and reported true color values. Only two (3.8%) of the recorded values exceeded the OWQS numeric criteria of 70 units for true color. The FWP beneficial use is fully supported for pH and is considered partially supported as it relates to turbidity with 11.5% values reported as greater than 25 NTU. Based on anoxic condition present in the summer, the FWP is also considered partially supported at Grand Lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected three (30%) exceeded the prescribed screening level of 61 cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. The Grand River Dam Authority (GRDA) constructed Grand Lake, the third largest reservoir in Oklahoma, for flood control and hydroelectrical power and is also utilized for various recreational purposes.

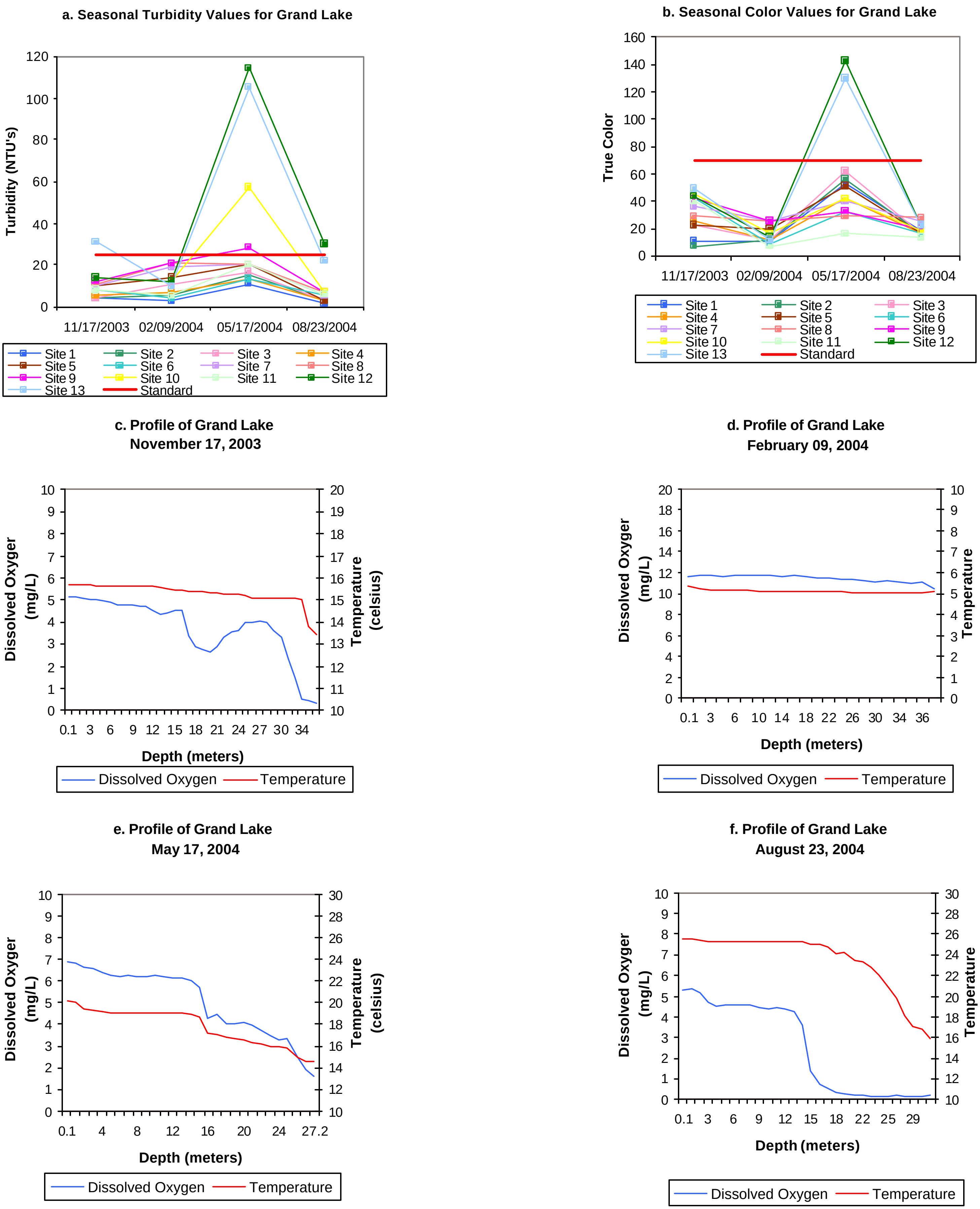



**Figure 107a-107f.** Graphical representation of data results for Grand Lake.

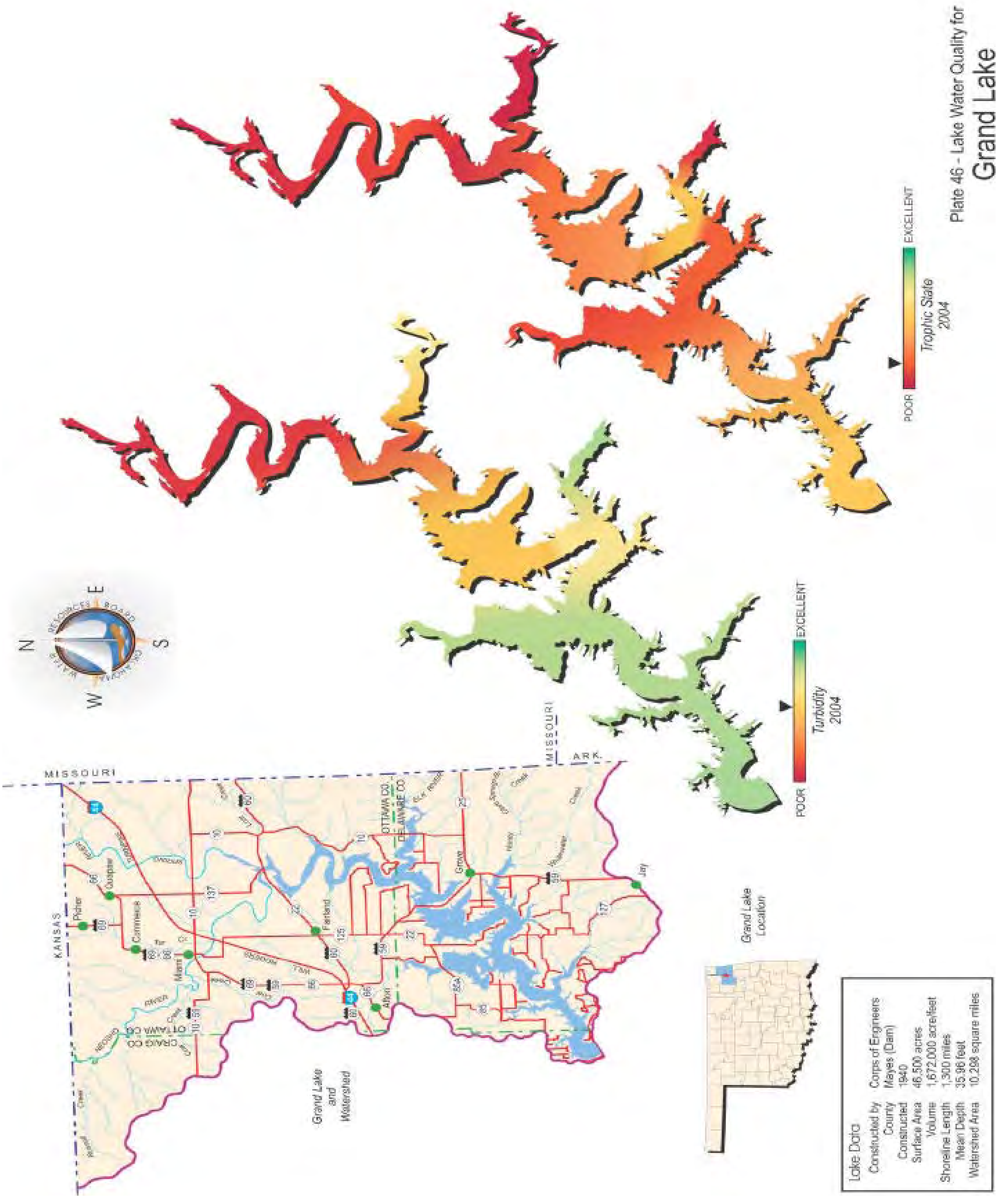



Plate 46 - Lake Water Quality for
Grand Lake

# Great Salt Plains Lake

Great Salt Plains Lake was sampled for four quarters from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water samples were collected from the lake surface at all three sites and an additional sample was taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 187 NTU (Plate 47), true color was 40 units, and secchi disk depth was 9 centimeters. Based on these three parameters, Great Salt Plains Lake had poor water clarity; which is consistent with historical data collection results on this lake. Water clarity is likely to always be poor based on the soil composition and shallow morphometry of this lake. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=17). The average TSI was 70 (Plate 47), classifying the lake as hypereutrophic, indicative of excessive levels of primary productivity and nutrients. Although three of the twenty samples were unable to be processed, the trophic status would likely be unaffected by the addition or omission of these samples. Currently the lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The TSI values for Great Salt Plains were hypereutrophic throughout the year with the exception of the fall when the value for site 4 was eutrophic, still indicating the lake had high productivity and nutrient levels (see Figure 108). All 20 turbidity values (100%) exceeded the OWQS of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Great Salt Plains Lake is currently not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on high turbidity (see Figure 109a). Seasonal true color values are displayed in Figure 109b. Site 4 was the only site that exceeded, the OWQS of 70 units in the fall quarter although the remaining sites were very near the standard. The Aesthetics beneficial use is considered supported at this time.

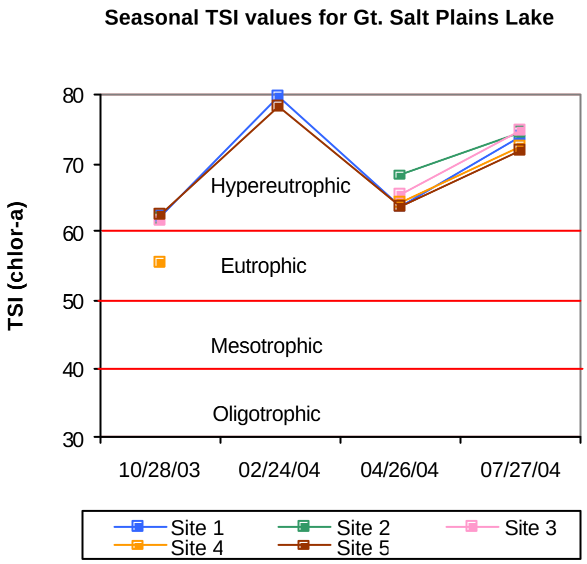



**Figure 108.** TSI values for Great Salt Plains Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity ranged from 1.84 to 3.82 parts per thousand (ppt), which is much higher than the range of expected values for Oklahoma lakes, reflecting the presence of large amounts of chlorides or other salts in the lake. Specific conductance values ranged from 3400 mS/cm to 6881 mS/cm, which also indicated extremely high levels of current conducting ionic compounds (or other analogous materials) present in the water column. Oxidation-reduction potentials (redox) ranged from 366 mV to 490 mV, indicating an absence of reducing conditions at any time in the water column during the course of lake sampling. The pH values were neutral to slightly alkaline, ranging from 7.59 in the spring quarter to 8.54 in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the collected values within the acceptable range the lake is supporting its FWP beneficial use based on pH. Thermal stratification was not present in this reservoir at any point during the sample year, due to the shallow nature of the reservoir (see Figure 109c-109f) and dissolved oxygen (D.O.) concentrations were above 2.0 mg/L at all times and were generally above 6.0 mg/L (see Figure 109c-109f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported and If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the use is deemed partially supported. The FWP beneficial use is fully supported at Great Salt Plains Lake. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be not supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected nine (90%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (277.4) exceeds the prescribed geometric mean of 33 for enterococci. The PBCR beneficial use is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.78 mg/L at the lake surface. The TN at the surface ranged from 0.083 mg/L to 2.71 mg/L, which is a lot of nitrogen to be present in the water column. The highest surface TN value was reported in the winter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.0247 mg/L at the lake surface, which was also very high value. The TP ranged from 0.163 mg/L to 0.483. The highest surface TP value was also reported in the winter and the lowest was in the spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 7:1. This value is the same 7:1, characterizing the lake as possibly co-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening or consumption advisory levels. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Great Salt Plains Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 47). The lake is currently listed in the OWQS as NLW water and should be studied intensively in the future to verify beneficial use non-support status. Until such time, the Aesthetics beneficial use is considered threatened due to nutrients and fully supported based on true color values recorded in 2003-2004. Water clarity is consistently poor at this lake and is likely to always be poor based on the soil composition and shallow optometry of this lake. The lake was not supporting its FWP beneficial use based on extremely high turbidity and is supporting its FWP beneficial use for pH concentrations. The FWP is fully supported based on D.O. concentrations. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected nine (90%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (277.4) exceeds the prescribed geometric mean of 33 for enterococci. The PBCR beneficial use is therefore considered not supported. The United States Army Corps of Engineers constructed Great Salt Plains Lake in 1941 for flood control and other conservation purposes and is a popular spot for birding related activities.

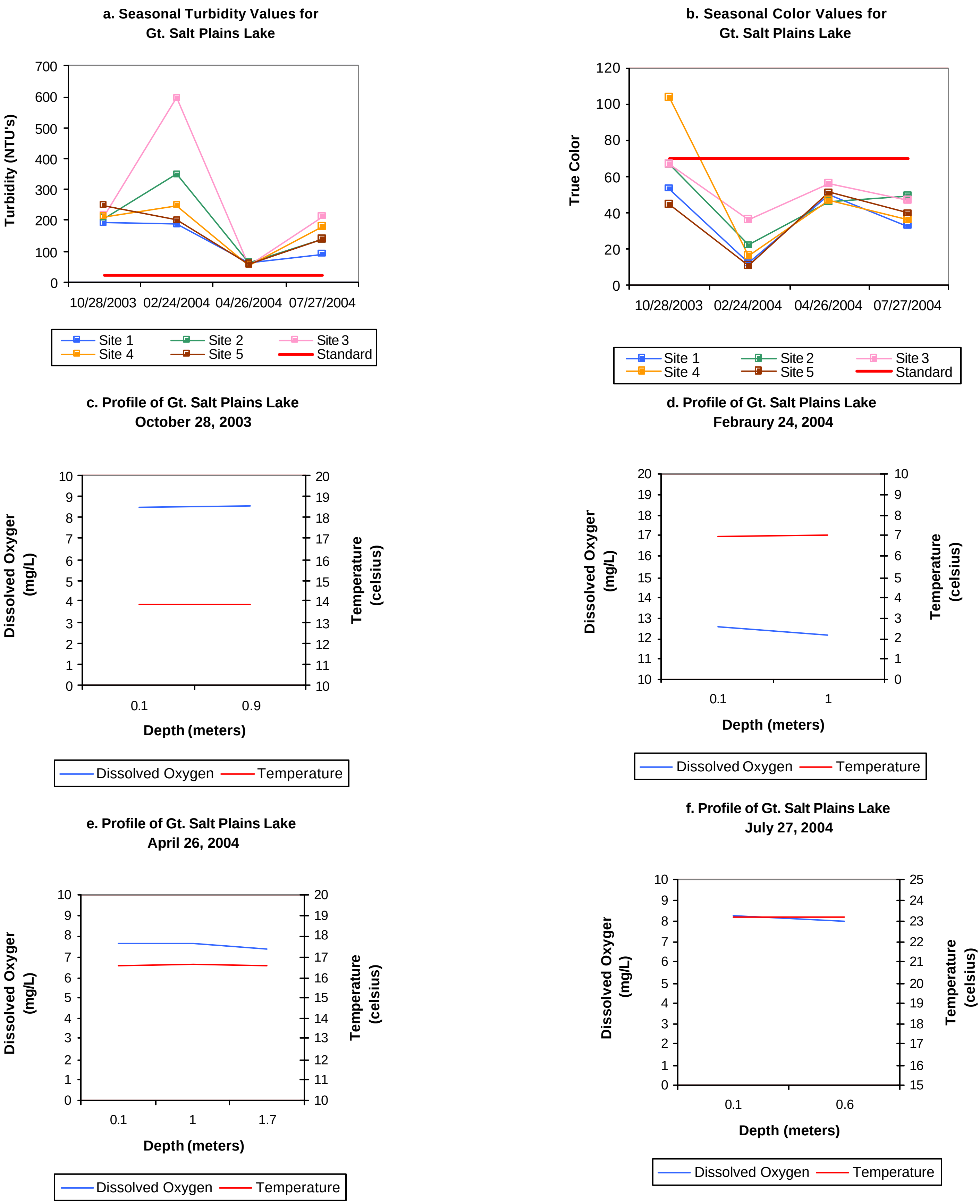
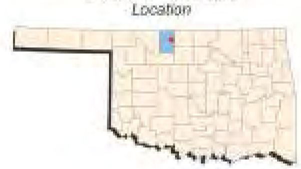


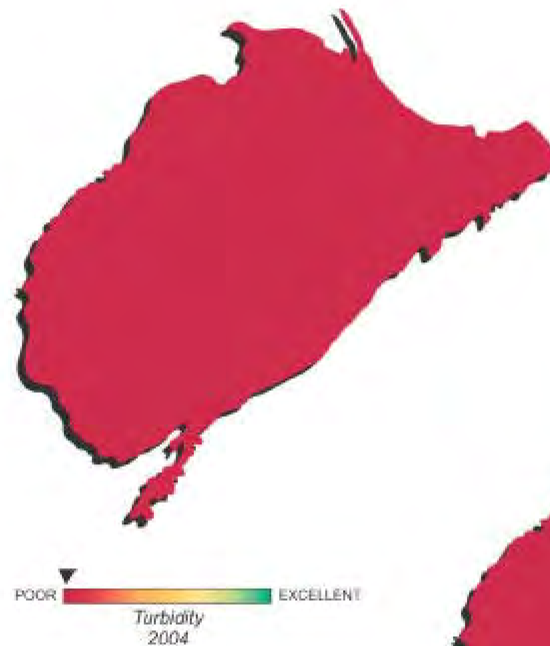

**Figure 109a-109f.** Graphical representation of data results for Great Salt Plains Lake.






Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Alfalfa |
| Constructed in | 1941 |
| Surface Area | 8,690 acres |
| Volume | 31,420 acre/feet |
| Shoreline Length | 41 miles |
| Mean Depth | 4.22 feet |
| Watershed Area | 3,200 square miles |



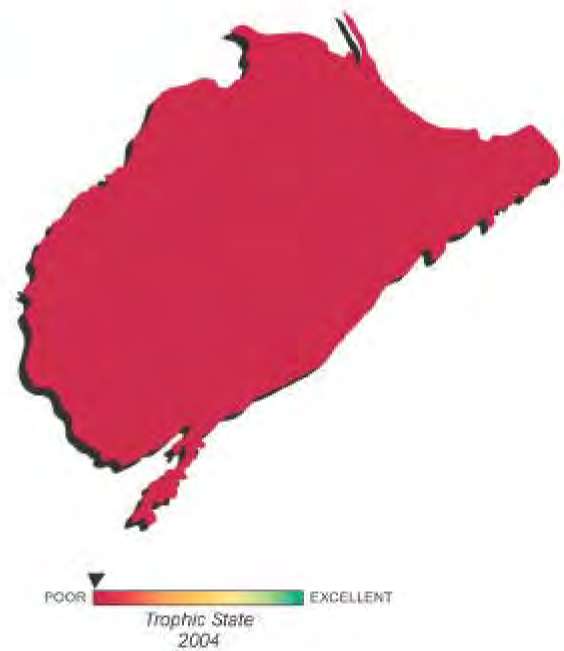




Plate 47 - Lake Water Quality for
# Great Salt Plains Lake

# Greenleaf Lake

Greenleaf Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample was collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 15 NTU (Plate 48), true color was 39 units, and secchi disk depth was 91 centimeters. Based on these three parameters, Greenleaf Lake had good water clarity in 2004. The water clarity was slightly better in 2001 although very similar. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 54 (plate 48), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is the same as the one calculated in 2001 (TSI=54), indicating no change in trophic status over time. The TSI values were all eutrophic with the exception of the spring quarter when mesotrophic conditions were present (See Figure 110). The annual TSI of 54 seems representative of conditions at Greenleaf Lake throughout 2003-2004. Turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU except during the summer when there was a dramatic spike in turbidity at all sites (Figure 111a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity, which occurred in July is likely due to seasonal storm events, therefore Greenleaf Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in (Figure 111b). Similar to turbidity, 25% of the samples collected exceeded the OWQS numeric criteria of 70 units in the month of July. This too is likely the result a storm event therefore the Aesthetics beneficial use is considered supported Greenleaf Lake.

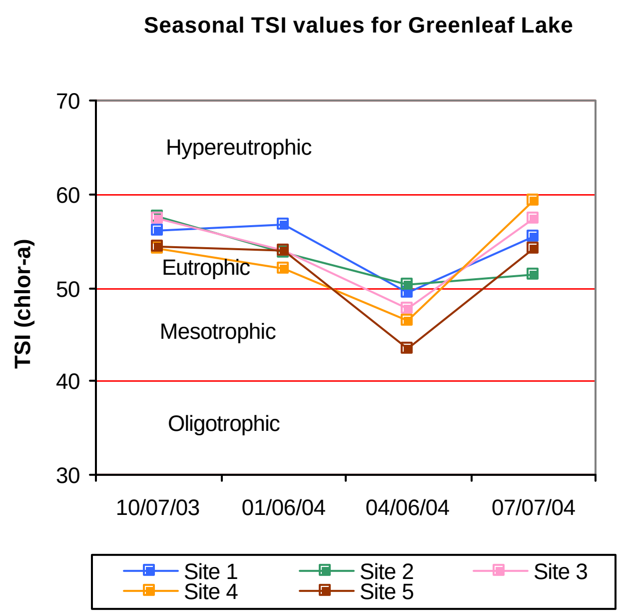



**Figure 110. TSI values for Greenleaf Lake.**

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.08 ppt, well within the expected range for most Oklahoma reservoirs if not slightly lower. Readings for specific conductance were within the expected range for Oklahoma reservoirs. Specific conductivity ranged from 39.6 mS/cm in the summer quarter to 303.8 mS/cm in the fall quarter, indicating low concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 363mV in the summer quarter to 517 mV near the lake bottom in the fall quarter, indicating reducing conditions were not present in the lake system during 2003-2004 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 6.69 units to 8.2 all within the OWQS range of 6.5-9.0 units, therefore the FWP beneficial use was supported based on pH. The lake exhibited weak thermal stratified in the fall with 30 to 35% of the water column experiencing anoxic conditions at sites 1,2 and 5, the three deepest sites (Figure 111c). In the winter and spring quarters the lake was well mixed and oxygenated, with dissolved oxygen values above 5.0 mg/L except at the very bottom of the lake (see Figure 111d-111e). During the summer the lake was thermally stratified at several 1-meter intervals throughout the water column, however dissolved oxygen (D.O.) concentrations only fell below 2.0 mg/L from 9 meters below the surface to the lake bottom at 11.5 meters at site 1 (see Figure 111 f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With approximately 35% of the water column in the fall and 23% in the summer violating the criteria the lake is considered to be fully supporting its FWP beneficial use based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected eight (80%) exceeded the prescribed screening level of 61cfu/ml and the geometric mean (131.3) exceeds the geometric mean of 33. for enterococci. The PBCR beneficial use is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.56 mg/L at the lake surface. The TN at the surface ranged from 0.26 mg/L in spring quarter to 0.78 mg/L recorded in the fall quarter. The lake-wide total phosphorus (TP) average was 0.037 mg/L at the lake surface. The TP ranged from 0.020 mg/L to 0.077 mg/L. The highest surface TP values were reported in the summer and the lowest were in the winter. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2000 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Greenleaf Lake is classified as eutrophic with high primary productivity and nutrient rich conditions (Plate 48). This classification is consistent previous data collection efforts. Water clarity is good in comparison to other Oklahoma lakes and reservoirs. Available flow and rainfall data suggest that the peak in turbidity and true color, which occurred in July is likely due to seasonal storm events, therefore Greenleaf Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) and Aesthetics beneficial use for these parameters. The Aesthetics beneficial use is supported based on trophic status. The lake is supporting the FWP use as it relates to pH and dissolved oxygen concentrations within the water column. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected eight (80%) exceeded the prescribed screening level of 61cfu/ml and the geometric mean (131.3) exceeds the geometric mean of 33. for enterococci. The PBCR beneficial use is therefore considered not supported. Greenleaf Lake is leased to the State of Oklahoma for recreational purposes and is located at Greenleaf State Park in the eastern part of the state.

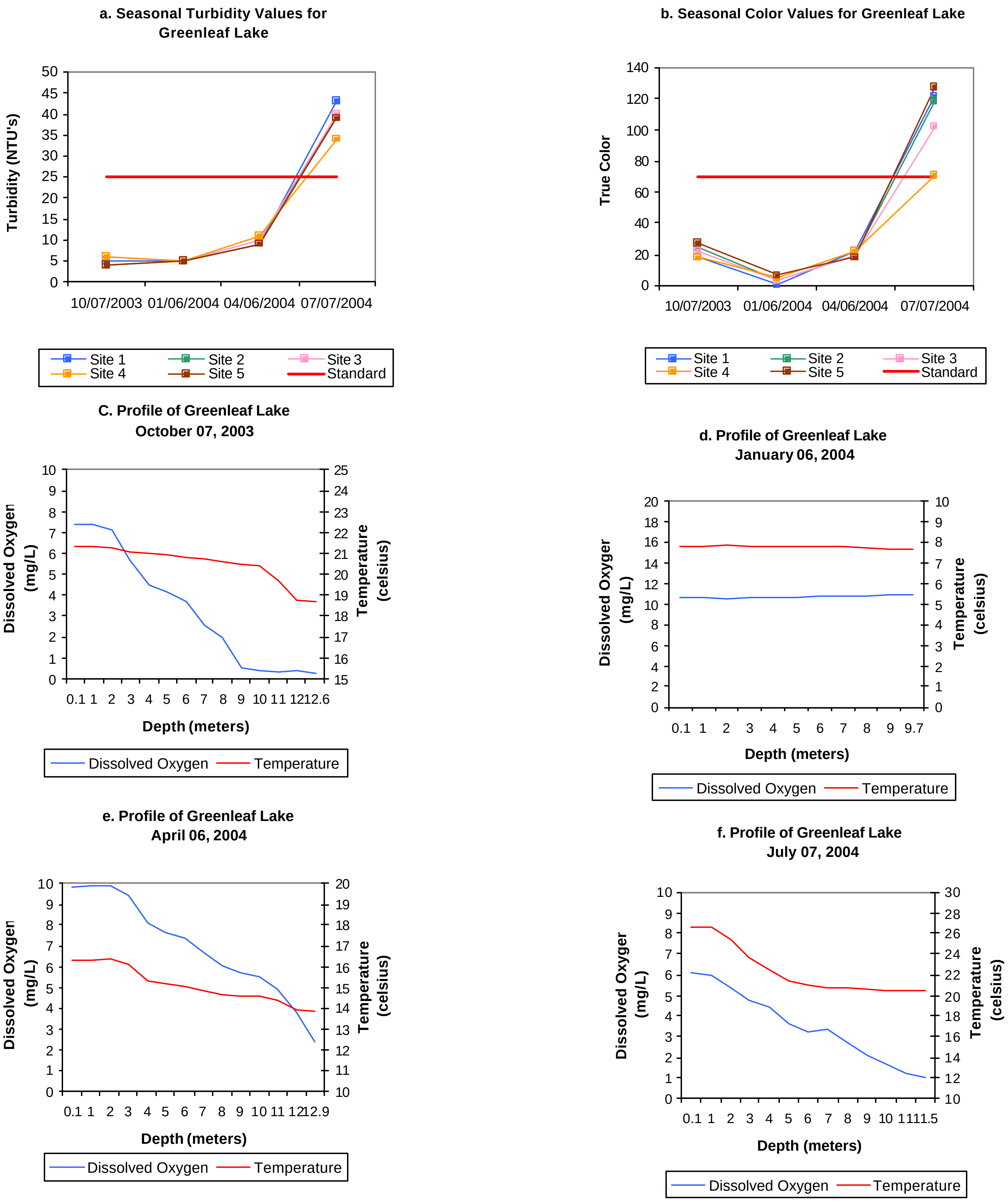
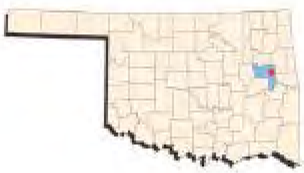



**Figure 111a-111f.** Graphical representation of data results for Greenleaf Lake.





| Lake Data | |
|---|---|
| Owner | Leased to State of Oklahoma |
| County | Muskogee |
| Constructed in | 1939 |
| Surface Area | 920 acres |
| Volume | 14,720 acre/feet |
| Shoreline Length | 18 miles |
| Mean Depth | 16.00 |
| Watershed Area | 86 square miles |



Plate 48 - Lake Water Quality for
## Greenleaf Lake

# Guthrie Lake

Guthrie Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 15 NTU (Plate 49), true color was 13 units, and secchi disk depth was 57 centimeters. Based on these three parameters, Guthrie Lake had average to fairly good water clarity in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 60 (Plate 49), classifying the lake as eutrophic bordering hypereutrophic, indicative of high primary productivity and nutrients conditions. The TSI values ranged from hypereutrophic in the fall quarter with eutrophic conditions in the winter and spring to upper eutrophic conditions in the summer quarters (see Figure 112). Only two (10%) of the twenty turbidity values exceeded the OWQS of 25 NTU (see Figure 113a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Guthrie Lake is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 113b. None of the true color values exceeded the numeric criteria of 70 units. Applying the same default protocol for determining the short-tem average for true color, the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity ranged from 0.31 to 0.41 parts per thousand (ppt), which is slightly higher than the expected range for Oklahoma lakes. Readings for specific conductance ranged from 659.3 mS/cm to 789.2 mS/cm, indicating moderate to slightly elevated concentrations of electrical current conducting compounds (salts) present in the water column throughout the year. In general, pH values were neutral to alkaline, ranging from 7.29 in the summer quarter to 8.74 units in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH

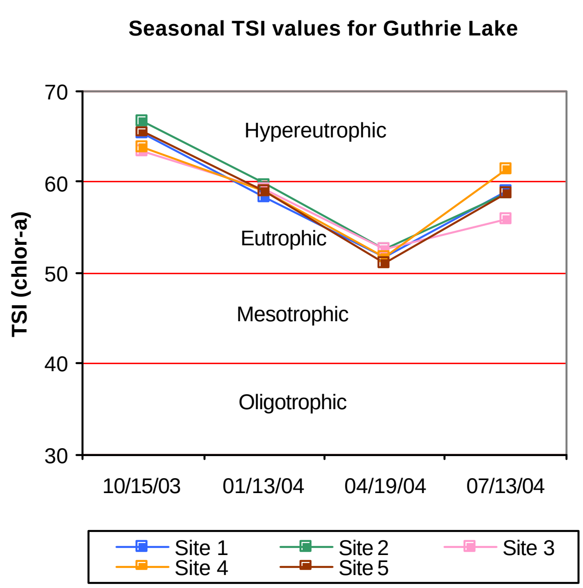



**Figure 112.** TSI values for Guthrie Lake.

values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Guthrie Lake is meeting its FWP beneficial use as it realties to pH. Oxidation-reduction potentials (redox) ranged from 63 mV at the sediment-water interface in the summer to 567 mV in the spring, indicating that reducing conditions were not present in the water column during the course of sampling. The lake was not thermally stratified in the fall, winter, or spring and dissolved oxygen (D.O.) concentrations were generally above 6.0 mg/L throughout the water column, with the exception of the sediment-water interface at the lake bottom (see Figure 113c-113e). The lake was thermally stratified in the summer and anoxic conditions were present below the thermocline at site 1, constituting about 38% of the water column (see Figure 113f). The thermocline occurred between 3 and 4 meters at the dam site with D.O. concentrations falling below 2.0 mg/L from the 5-meter depth to the lake bottom at 6.6 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Guthrie Lake. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected eight (80%) exceeded the prescribed screening level of 61cfu/ml and the geometric mean (327.3) exceeds the geometric mean of 33. for enterococci. Forty percent of the samples also exceeded the screening level of 235 cfu/mL for *E.coli*. The PBCR beneficial use is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.99 mg/L at the lake surface. The TN at the surface ranged from 0.55 mg/L to 1.61 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.053 mg/L at the lake surface. The TP ranged from 0.039 mg/L to 0.086 mg/L. Similar to total nitrogen the highest surface TP value was reported in the fall quarter and the lowest was in the spring and summer quarters. The nitrogen to phosphorus ratio (TN:TP) was approximately 19:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2001 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Guthrie Lake was classified as eutrophic bordering hypereutrophic in 2003-2004, indicating high primary productivity and nutrient levels (Plate 49). Water clarity was average to fairly good based on turbidity, true color, and secchi disk depth. The Aesthetics beneficial use is considered supported based on true color and trophic status. Guthrie Lake is meeting its FWP beneficial use based on pH and dissolved oxygen concentrations and partially supporting based with 10% of the collected values exceeding the OWQS of 25 NTU. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected eight (80%) exceeded the prescribed screening level of 61cfu/ml and the geometric mean (327.3) exceeds the geometric mean of 33. for enterococci. Forty percent of the samples also exceeded the screening level of 235 cfu/ml for *E.coli*. The PBCR beneficial use is therefore considered not supported. Guthrie Lake was constructed in 1919 and is owned and operated by the City of Guthrie and is utilized for water supply and recreational purposes.

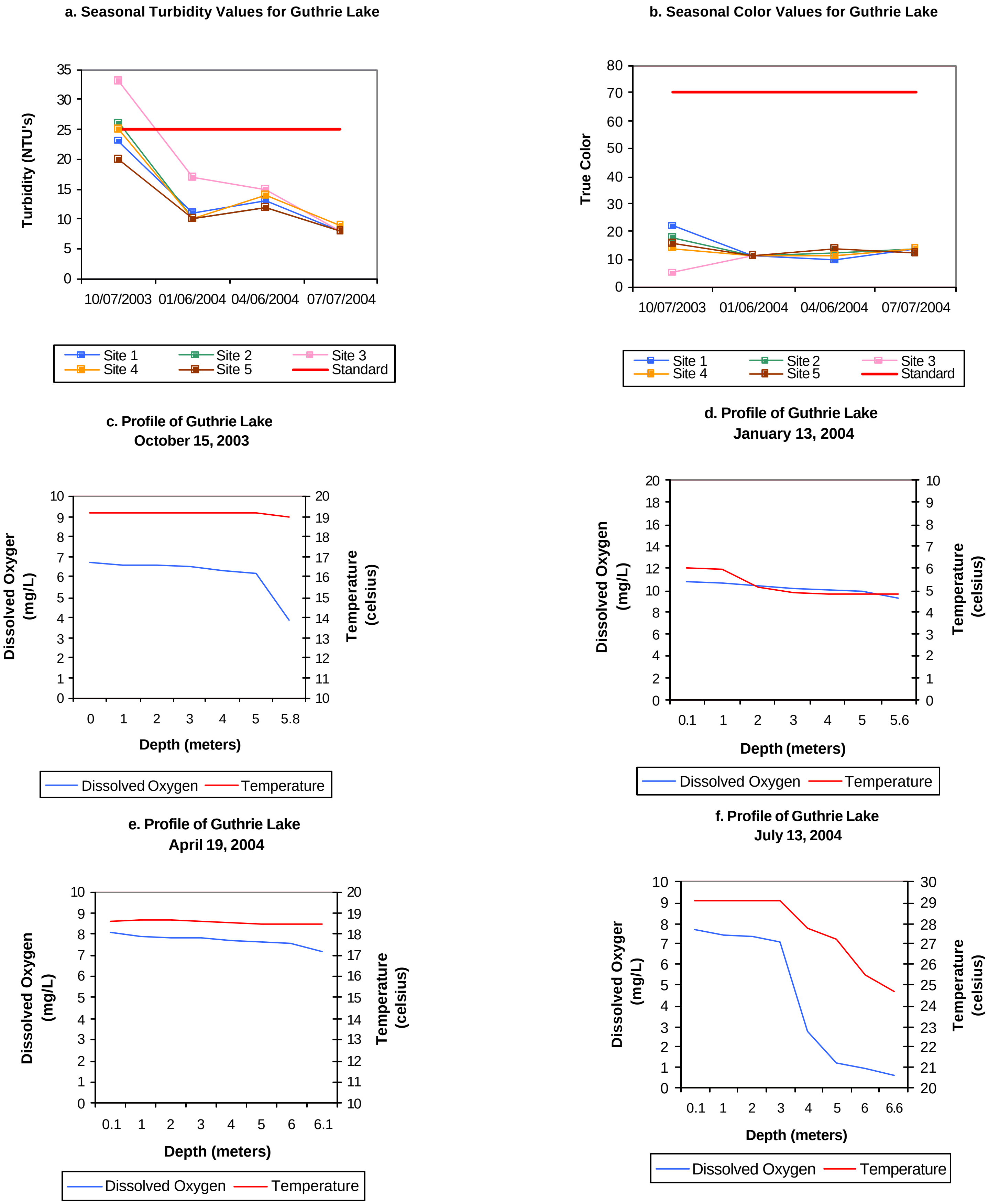
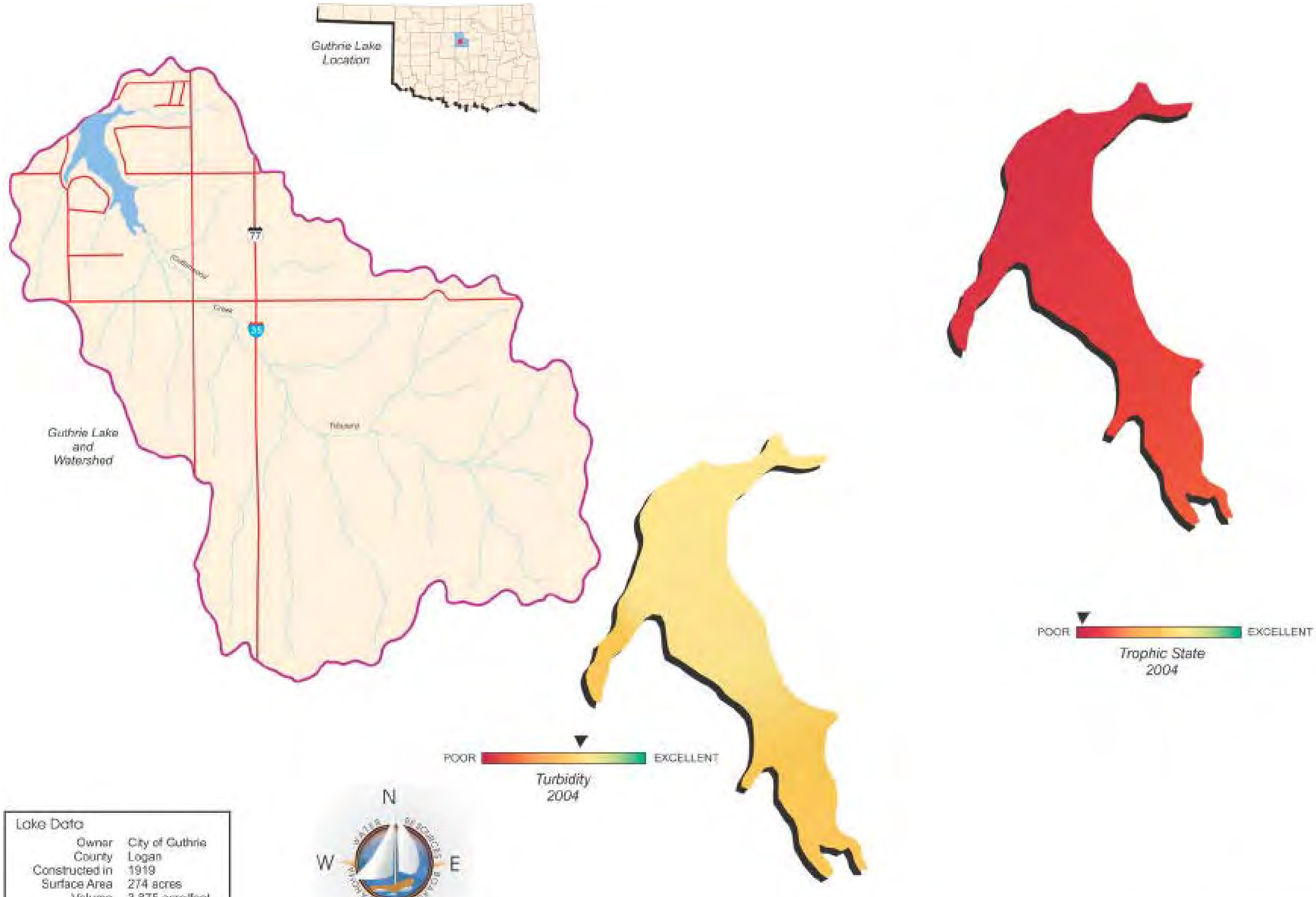



**Figure 113a-113f.** Graphical representation of data results for Guthrie Lake.




| Lake Data | |
|---|---|
| Owner | City of Guthrie |
| County | Logan |
| Constructed in | 1919 |
| Surface Area | 274 acres |
| Volume | 3,875 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 14.14 feet |
| Watershed Area | 13 square miles |

Plate 49 - Lake Water Quality for
**Guthrie Lake**

# Healdton City Lake

Healdton City Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 49 NTU (Plate 50), true color was 81 units, and secchi disk depth was 35 centimeters. Based on these three parameters, Healdton City Lake had poor water clarity in 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 45, classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is consistent with findings in 2001 (TSI=42), indicating no significant increase or decrease in productivity has occurred. The TSI values were mesotrophic throughout the sample year (Figure 114). Seasonal turbidity values are displayed in Figure 115a. All turbidity values were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU except in the winter, when all five sites were below the standard. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 75% of the samples collected above the standard the FWP use is considered not supporting at Healdton Lake. True color followed a pattern similar to turbidity (Figure 115b). True color values were above the Oklahoma Water Quality Standard (OWQS) of 70 except in the winter, when all five sites were below the standard. With 70% of the recorded true color values exceeding the standard the Aesthetics beneficial use is considered not supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity ranged from 0.12 to 0.14 parts per thousand (ppt), well within the expected range for Oklahoma lakes. Readings for specific conductance ranged from 25.34 mS/cm to 291.9 mS/cm, indicating low to moderate concentrations of electrical current conducting compounds (salts) present in the water column throughout the year. In general, pH values were neutral to slightly alkaline, ranging from 7.33 in the winter quarter to 7.97 units in the summer quarter. According to USAP (OAC

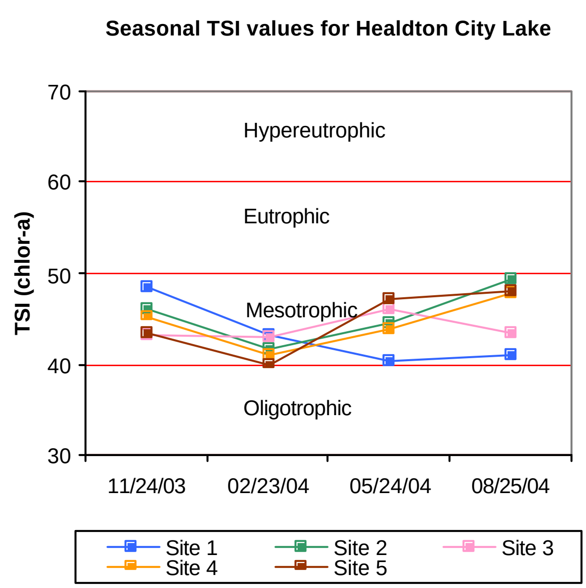



**Figure 114.** TSI values for Healdton City Lake.

785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range, Guthrie Lake is meeting its FWP beneficial use as it realties to pH. Oxidation-reduction potentials (redox) ranged from 369 mV at the sediment-water interface in the fall to 581 mV in the winter, indicating the absence of reducing conditions in the lake system. The lake was not thermally stratified in the fall or winter sampling intervals and dissolved oxygen (D.O.) concentrations were generally above 6.0 mg/L throughout the water column (see Figure 115c-115d). In the spring quarter, the lake exhibited weak thermal stratification between 4 and 5 meters below the surface with D.O. values below 2.0 mg/L from 6 meters to the lake bottom of 6.5 meters (Figure 115e). The lake was not thermally stratified in the summer and anoxic conditions were not present at any site (Figure 115f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Healdton Lake. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric mean. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.57 mg/L at the lake surface. The TN at the surface ranged from 0.37 mg/L to 0.86 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.042 mg/L at the lake surface. The TP ranged from 0.026 mg/L to 0.079 mg/L. The highest surface TP value was reported in the spring quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 14:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Healdton Lake was classified as mesotrophic, indicating moderate primary productivity and nutrient levels (Plate 50). Water clarity was poor based on turbidity, true color, and secchi disk depth. The Aesthetics beneficial use is considered supported based on trophic status however with 70% of the values exceeding the OWQS of 70 units the use is not supported for true color. Healdton Lake is meeting its FWP beneficial use based on pH and dissolved oxygen concentrations and is not supporting with 75% of the turbidity values exceeding the OWQS of 25 NTU. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric mean. The PBCR beneficial use is therefore considered supported. Healdton Lake was constructed in 1979 and is owned and operated by the City of Healdton and is utilized for water supply, flood control and recreational purposes.

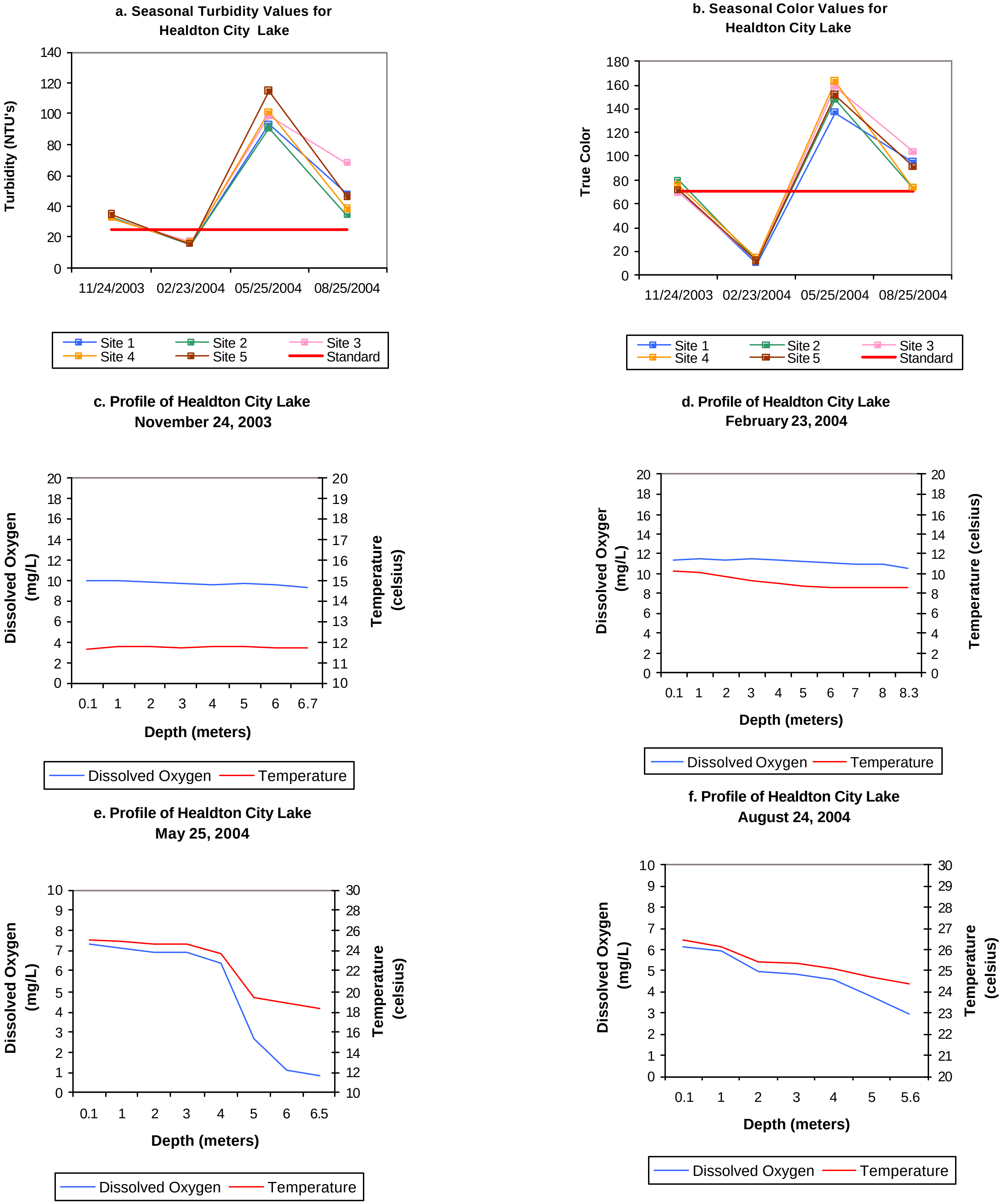
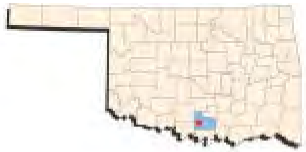



**Figure 115a-115f.** Graphical representation of data results for Healdton City Lake





| Lake Data | |
|---|---|
| Owner | City of Healdton |
| County | Carter |
| Constructed in | 1979 |
| Surface Area | 370 acres |
| Volume | 3,766 acre/feet |
| Shoreline Length | 7 miles |
| Mean Depth | 10.18 feet |
| Watershed Area | 11 square miles |



Plate 50 - Lake Water Quality for
## Healdton Lake

# Lake Hefner

Lake Hefner was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 18 NTU (Plate 51), true color was 16 units, and secchi disk depth was 82 centimeters. Based on these three parameters, Lake Hefner had good water clarity in 2003-2004. This was not unexpected as the lake is an off-channel reservoir, meaning that the lake is not located along a stream course. The lake is "filled" through runoff immediately adjacent to the lake with the bulk of the water in the lake being transported from the North Canadian River via diversion into the Bluff Creek canal, which flows into Lake Hefner. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 55 (Plate 51), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to that in 2001 (TSI=56), indicating no change in productivity has occurred over time. Chlorophyll-a values were variable with the lake being eutrophic during the fall and spring, mesotrophic during the winter quarter (see Figure 116). Eutrophic conditions were again present during the summer quarter, with exception of site 5, which was borderline mesotrophic Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU in the fall, winter and summer quarters. In the spring sites 3,4 and 5 were greater than 25 NTU (see Figure 117a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Hefner is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 117b. None of the collected true color values exceeded the numeric criteria of 70 units; therefore the Aesthetics beneficial is fully supported for true color.

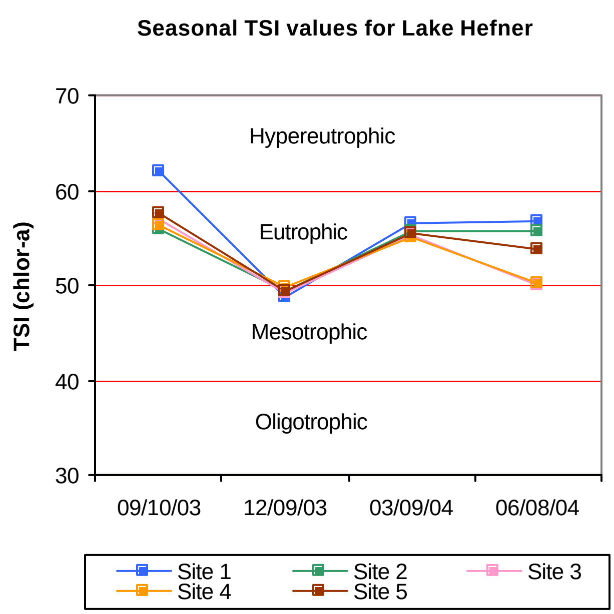



**Figure 116.** TSI values for Lake Hefner.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample during the study period. Salinity ranged from 0.50 to 0.59 parts per thousand (ppt), which was higher than the expected range of values reported for Oklahoma lakes. Specific conductivity ranged from 933.6 mS/cm in the spring quarter to 1129 mS/cm in the summer quarter, indicating moderate to elevated concentrations of electrical conducting compounds (salts) were present in the water column. In general, pH values were neutral to alkaline, ranging from 7.27 units in the fall quarter to 8.36 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Hefner is fully supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (redox) ranged from 307 mV near the sediment-water interface in the spring at site 1 to 493 mV in the summer quarter, indicating that reducing conditions were not present in the water column during the study period. The lake was not thermally stratified during any of the sampling intervals with dissolved oxygen (D.O.) concentrations well above 6.0 mg/L throughout the water column at all sites (see Figure 117c-117f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Lake Hefner based on dissolved oxygen concentrations collected during the sample year. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 samples, collected two (20%) exceeded the prescribed screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.95 mg/L at the lake surface and 1.02 mg/L at the lake bottom. The TN at the surface ranged from 0.71 mg/L to 1.31 mg/L. The highest surface TN value was in the winter quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.078 mg/L at the lake surface and 0.075 mg/L at the lake bottom. The TP ranged from 0.044 mg/L to 0.147 mg/L. The highest surface TP value was reported in the spring and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 12:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2001 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Hefner was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 51). The lake is fully supporting its Aesthetics beneficial use based on its trophic status and for true color. Lake Hefner is fully supporting its FWP beneficial use based on D.O. and pH values. With 20% of the collected turbidity values exceeding the OWQS of 25 NTU, the FWP beneficial use is only partially supported at Lake Hefner. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples, collected two (20%) exceeded the prescribed screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. The lake is owned and operated by the City of Oklahoma City and was constructed in 1947. It serves as a water supply for Oklahoma City and also offers a recreational outlet for the public. Hefner is one of the premier sailing lakes in the United States. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 118) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

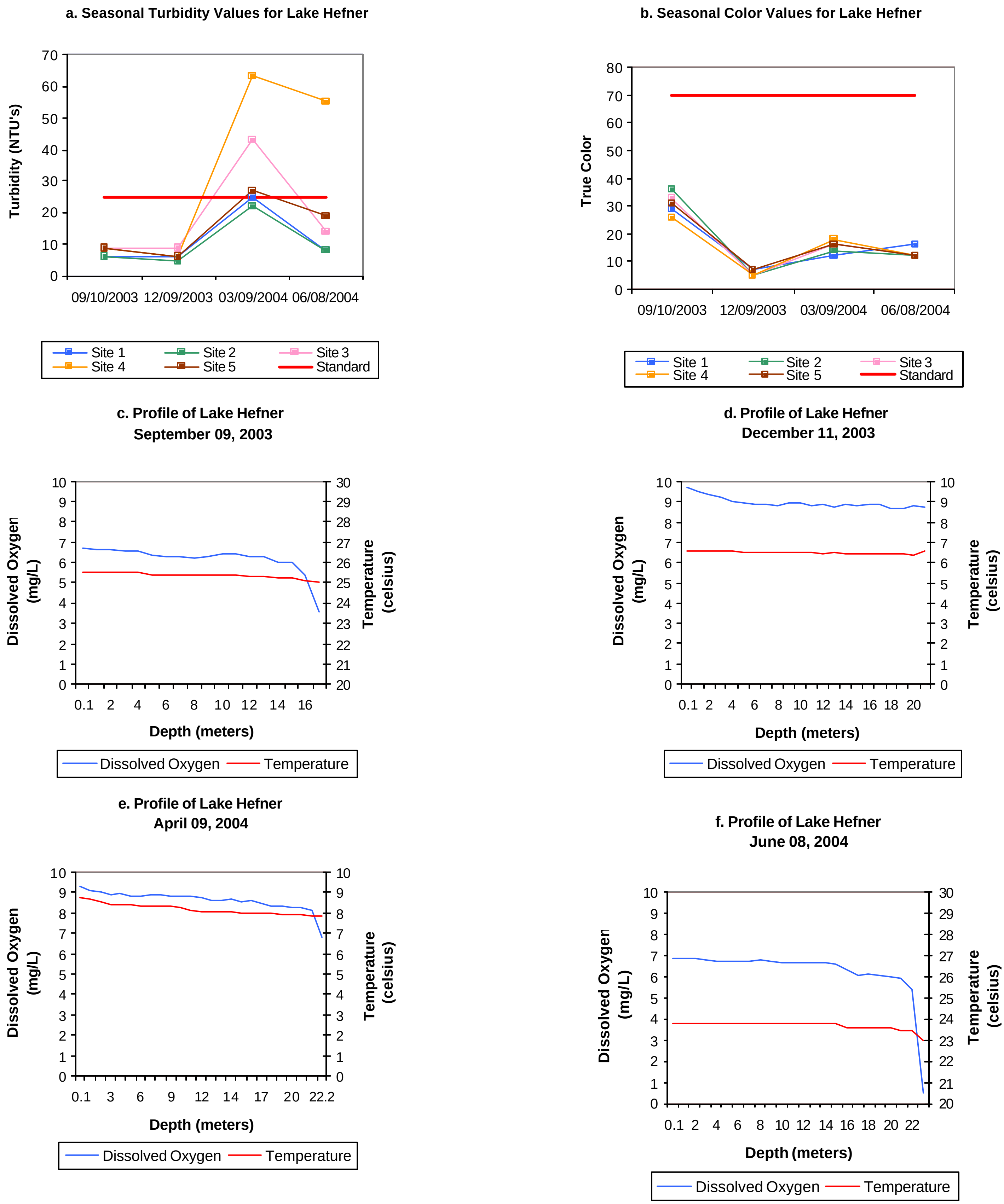
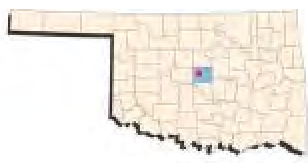



**Figure 117a-117 f.** Graphical representation of data results for Lake Hefner.



Hefner Lake Location


Hefner Lake and Watershed

Lake Data

| | |
|---|---|
| Owner | City of Oklahoma City |
| County | Oklahoma |
| Constructed in | 1947 |
| Surface Area | 2,537.9 acres |
| Volume | 68,867 acre/feet |
| Shoreline Length | 15.8 miles |
| Mean Depth | 27.13 feet |
| Watershed Area | 9 square miles |


Turbidity 2004


Trophic State 2004

Plate 51 - Lake Water Quality for

# Hefner Lake

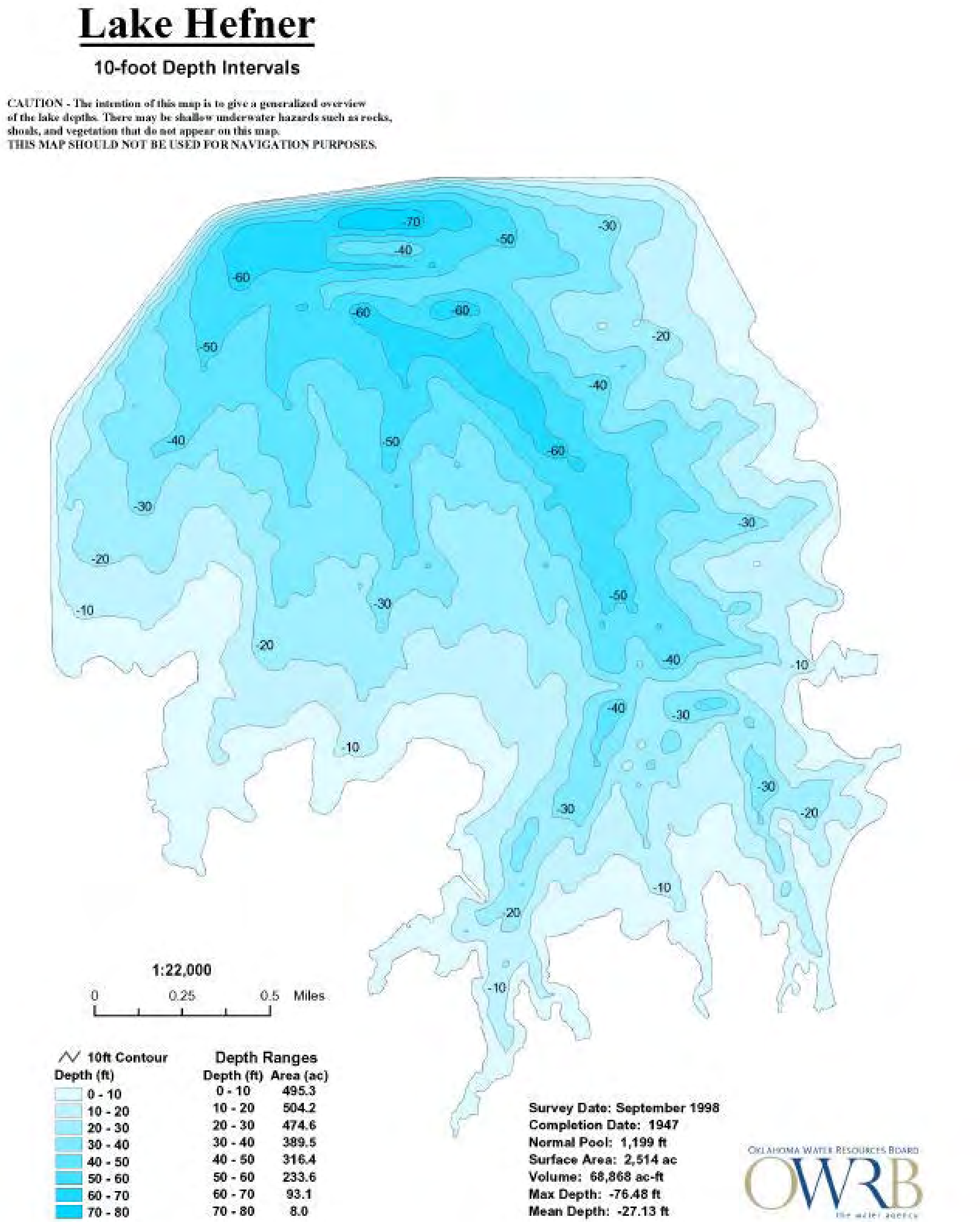



**Figure 118.** Bathymetric map of Hefner Lake.

# Lake Henryetta

Lake Henryetta was sampled for three quarters from October 2002 through July 2003. Due to low water levels we were unable to launch the boat and sample during the winter. Water quality samples were collected at three (3) sites in the fall and at five (5) sites in the spring and summer. The additional sites were added to ensure that sample size was representative for a lake greater than 250 surface acres in size. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 126 NTU (Plate 52), true color was 250 units and average secchi disk depth was 17 centimeters. Based on these parameters water clarity was poor at Lake Henryetta. These values are similar to those calculated in 2000 indicating no significant increase or decrease over time. The trophic state index (TSI) was calculated using values collected at all sites for three quarters (n=15). The result was a TSI of 43 (Plate 52), indicating the lake was mesotrophic in sample year 2002-2003. This value is higher than that in 2000 (TSI=38), however, fewer samples were used to calculate trophic status in 2000. The current value is based on data collected year round versus growing season only, and is likely a more accurate depiction of productivity within the lake system. The TSI values were fairly consistent and ranged seasonally from oligotrophic in the fall to mesotrophic in the spring and summer (Figure 119). The only exception was a spike in chlorophyll concentration that resulted in a hypereutrophic value at site 1 during the summer. Seasonal turbidity values are displayed in Figure 120a. All turbidity values were well above the turbidity standard of 25 NTU and ranged from a low of 113 NTU to a maximum of 152 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values above the standard, the Fish and Wildlife Propagation (FWP) beneficial use should be considered not supported based on turbidity; however with data from only three sampling quarters there is not enough data to make beneficial use assessment. Seasonal true color values are displayed in Figure 120b. True color values followed the same trend as turbidity, with all values exceeding the OWQS of 70 units. Reviewing historical data it is likely that both true color and turbidity would not be supporting.

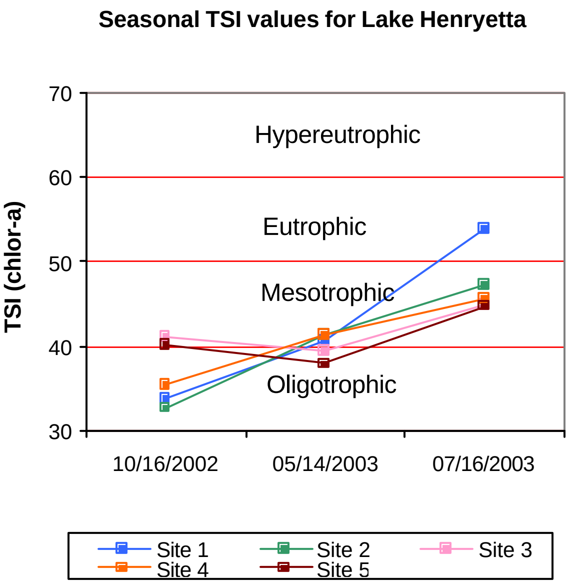



**Figure 119.** TSI values for Lake Henryetta.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at sites in 2002-2003. The salinity at Lake Henryetta ranged from 0.01 parts per thousand (ppt) to 0.02 ppt, which is lower than that seen in most Oklahoma reservoirs. Specific conductivity ranged from 52.3 mS/cm in the summer to 82 mS/cm in the spring, indicating the minimal presence of current conducting ions (salts and chlorides) in the lake system. The pH values ranged from 6.44 to 7.37 representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. Only one value recorded was less than 6.5 and is likely due to the instrument being in the sediment therefore the lake will be listed as supporting the FWP beneficial use for pH. Oxidation-reduction potential ranged from 399 mV at the surface to 519 mV in the hypolimnion in the fall. In general, reducing conditions were not present at any time during the study period. Thermal stratification was not present during the fall or spring quarters and the lake was well mixed with dissolved oxygen (D.O) levels remaining above 5.0 mg/L (Figure 120c-120d). In the summer the lake was between 5 and 6 meters at which point the dissolved oxygen dropped below 2.0 mg/L to bottom of the lake accounting for 26% of the water column to be experiencing anoxic conditions (Figure 120e). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Lake Henryetta is considered partially supporting the FWP beneficial use based on low D.O. values in the summer. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is therefore considered supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 1.05 mg/L at the surface and 0.96 mg/L at the lake bottom. Surface TN ranged from 0.50 mg/L in the fall to 1.31 mg/L in the spring. The lake-wide total phosphorus (TP) average was 0.130mg/L at the surface and 0.148 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.115 mg/L in the summer to 0.147 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) was 8:1 for sample year 2003. This value is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Lake Henryetta was classified as mesotrophic with moderate primary productivity and nutrient conditions, indicating no significant increase or decrease in productivity has occurred since 2000. Water clarity is poor based on true color; turbidity and low secchi disk depth and is consistent with findings from the 2000 data collection efforts. The FWP beneficial use is supported based on pH, but only partially supporting based on dissolved oxygen levels. The lake is supporting the Aesthetics beneficial use based on its trophic status. Due to low lake levels we were unable to sample during the winter and do not have enough data to meet the minimum data requirements of 20 samples to make a use determinations based on turbidity and true color. Lake Henryetta, located in Okmulgee County, constructed in 1928 serves as municipal water supply and recreation reservoir.

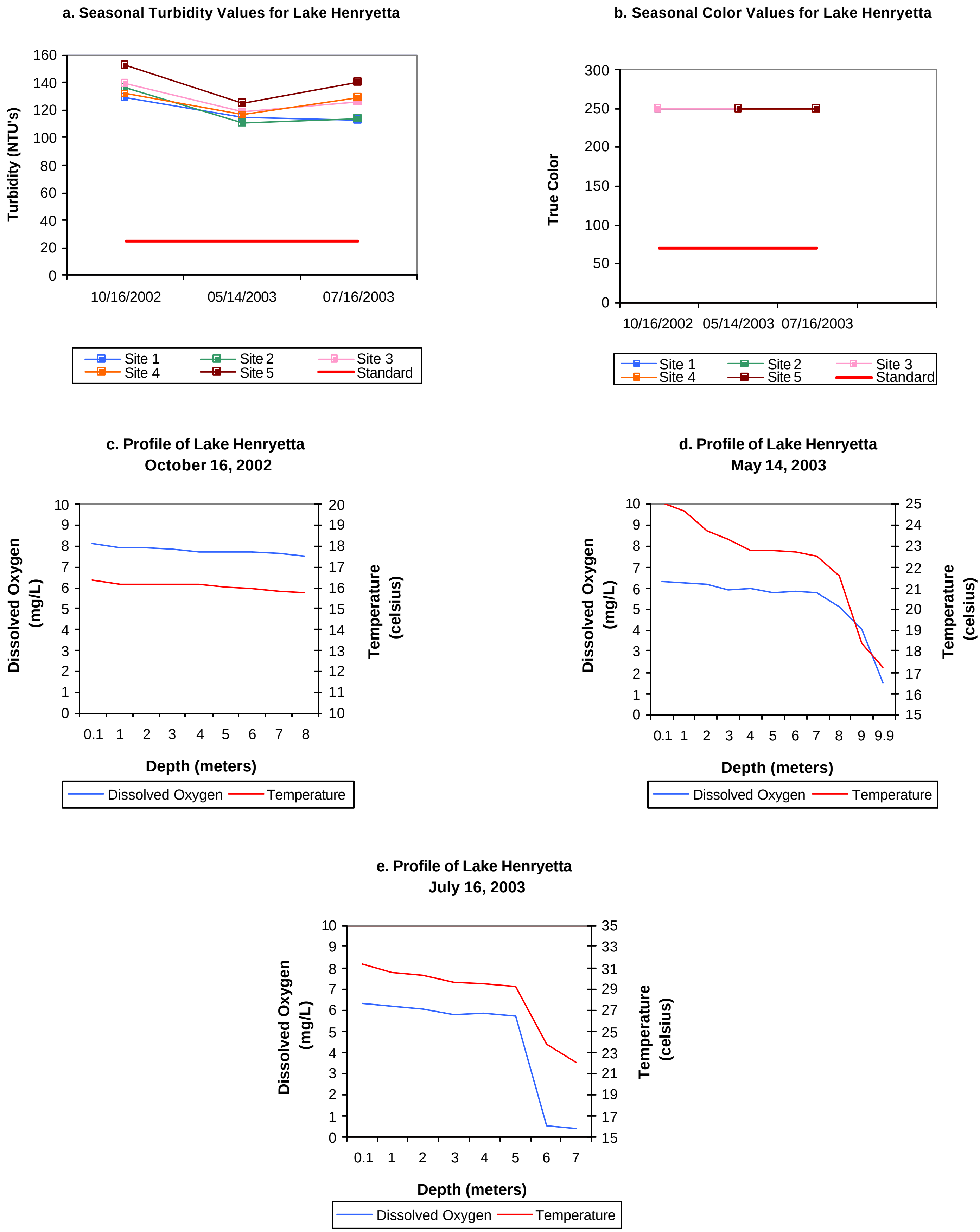
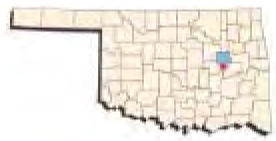



**Figure 120a-120e.** Graphical representation of data results for Lake Henryetta.






Lake Data

| | |
|---|---|
| Owner | City of Henryetta |
| County | Okmulgee |
| Constructed in | 1928 |
| Surface Area | 450 acres |
| Volume | 6,660 acre/feet |
| Shoreline Length | 11 miles |
| Mean Depth | 14.80 feet |
| Watershed Area | 21 square miles |



Plate 52 - Lake Water Quality for
## Lake Henryetta

# Heyburn Lake

Heyburn Lake was sampled for four quarters from October 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and at five (5) sites in the spring and summer. Additional sites were added to ensure that sample size was representative for a lake greater than 250 surface acres in size. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 67 NTU (Plate 53), true color was 144 units and average secchi disk depth was 32 centimeters. Based on these parameters Heyburn Lake had poor water clarity in sample year 2002-2003. These values are similar to those calculated in 2000 indicating no significant increase or decrease over time. The trophic state index (TSI) was calculated using values collected at all sites for four quarters (n=20). The result was a TSI of 46 (Plate 53), indicating the lake was mesotrophic during the study period. This value is the same as that calculated in 2000 (TSI=46), indicating that no change in productivity has occurred. The TSI values were fairly consistent and varied seasonally from oligotrophic in the winter to upper mesotrophic/eutrophic in the fall, spring, and summer quarters (Figure 121). Seasonal turbidity values are displayed in Figure 122a. Turbidity values ranged from a low of 16 NTU to a maximum of 164 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 70 % of the turbidity values above the standard, the Fish and Wildlife Propagation (FWP) beneficial use is not supported based on turbidity. Seasonal true color values are displayed in Figure 122b. Although thirteen of the sixteen (81%) values were a above the OWQS of 70 units a beneficial use determination cannot be made at this time due to the minimum data requirements of 20 samples for lakes larger than 250 surface acres not being met.

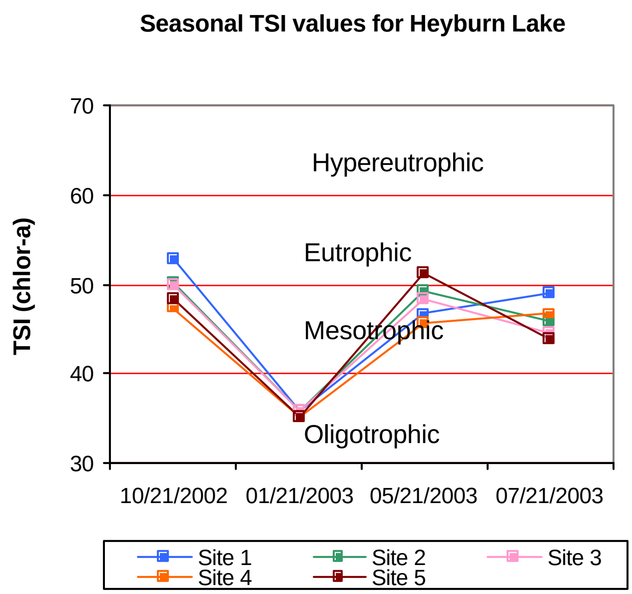



**Figure 121.** TSI values for Heyburn Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at sites in 2002-2003. The salinity at Heyburn Lake ranged from 0.03 parts per thousand (ppt) to 0.10 ppt. This is within the average recorded for most Oklahoma reservoirs. Specific conductivity ranged from 87.7 mS/cm to 214.1 mS/cm indicating the minimal presence of current conducting ions (salts and chlorides) in the lake system. The pH values ranged from 6.85 to 8.03 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all of the recorded values within the acceptable range the lake will be listed as supporting the FWP beneficial use for pH. Oxidation-reduction potential (ORP) ranged from 276 mV to 467 mV. In general, reducing conditions were not present at any time during the study period. Thermal stratification was not present during any of the first three quarters and the lake was well mixed. (Figure 122c-122e). In the summer the lake was stratified between 3 and 4 meters at which point the dissolved oxygen dropped below 2.0 mg/L to bottom of the lake accounting for 33% of the water column to be experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Heyburn Lake is considered partially supporting the FWP beneficial use based on low D.O. values in the summer. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (142.8 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.63 mg/L at the surface and 0.59 mg/L at the lake bottom. Surface TN ranged from 0.32 mg/L in the fall to 1.22 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.062 mg/L at the surface and 0.098 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.0.18 mg/L in the winter to 0.145 mg/L in the spring. The nitrogen to phosphorus ratio (TN:TP) was 10:1 for sample year 2003. This value is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Heyburn Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels in sample year 2002-2003. This value is the same as that calculated in 2000 (TSI=46), indicating that no change in productivity has occurred. Water clarity was poor based on turbidity, true color, and low secchi disk depth readings. The FWP beneficial use is supported based on pH, partially supported for dissolved oxygen and not supported based on high turbidity values. The Aesthetics beneficial use is supported based on its trophic status. Although minimum data requirements were not met for true color and a beneficial use determination cannot be made, it is likely that it would not be supported based on true color. The Oklahoma Department of Environmental Quality (ODEQ) sampled Heyburn Lake in 2002 as part of the Toxics and Reservoirs program. Mercury residue exceeding the advisory level was found in fish tissue and the ODEQ recommends continued sampling. The United States Army Corps of Engineers (USACE) constructed Heyburn Lake for flood control and other recreation purposes.

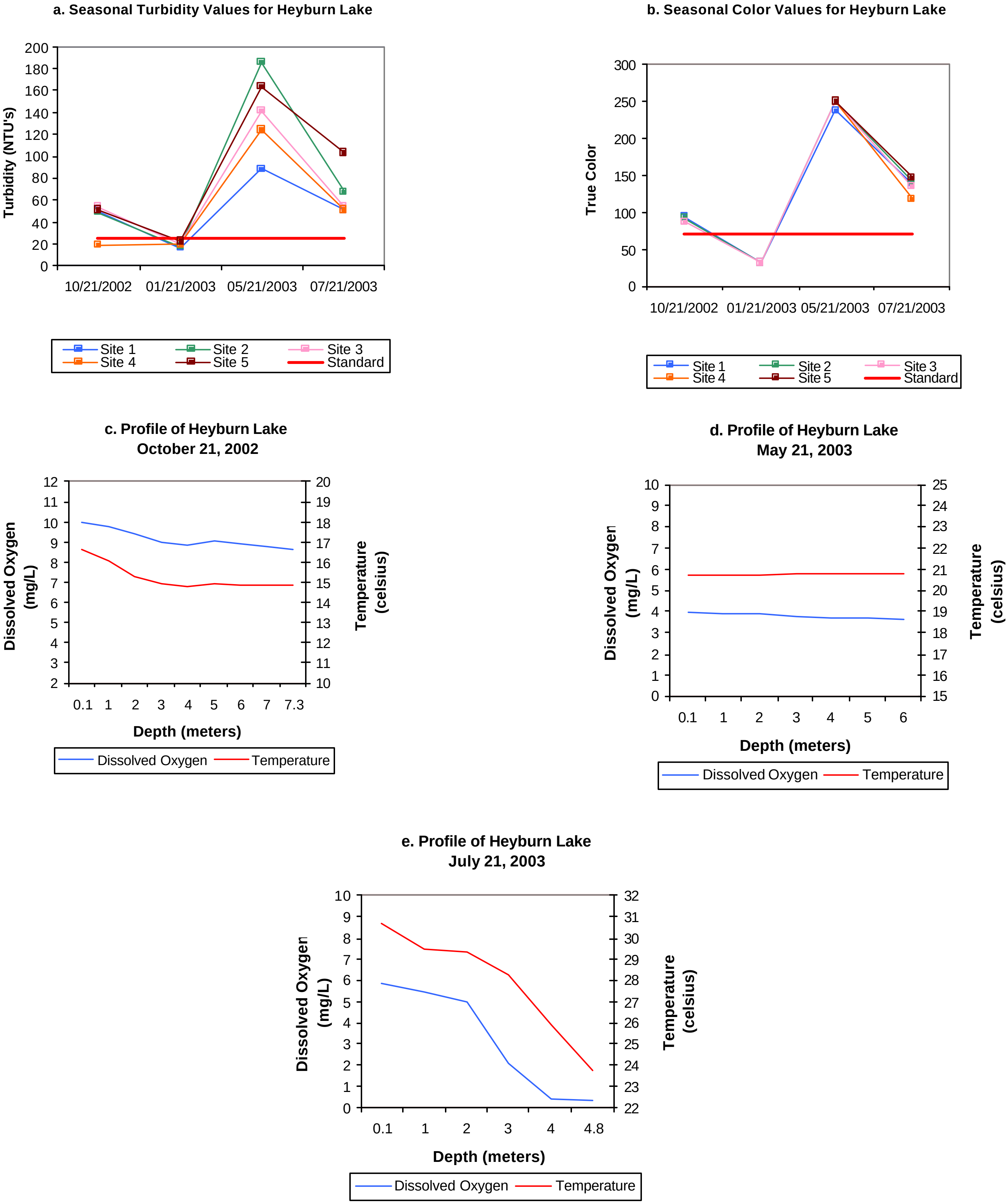
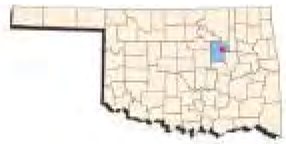
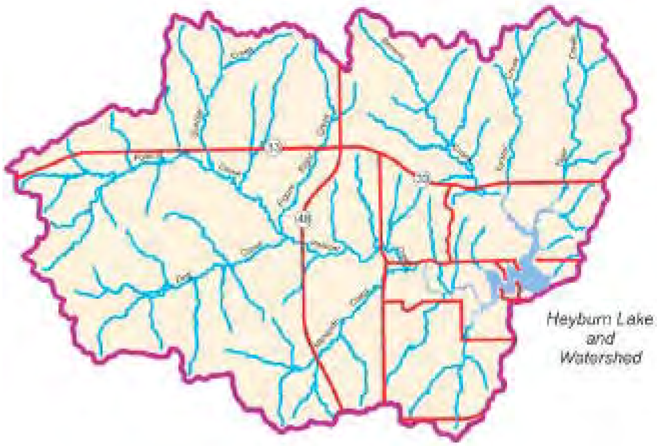
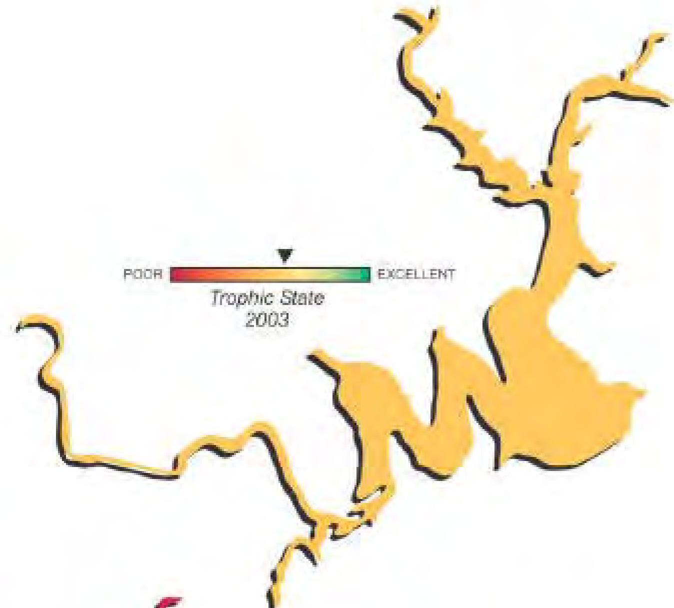
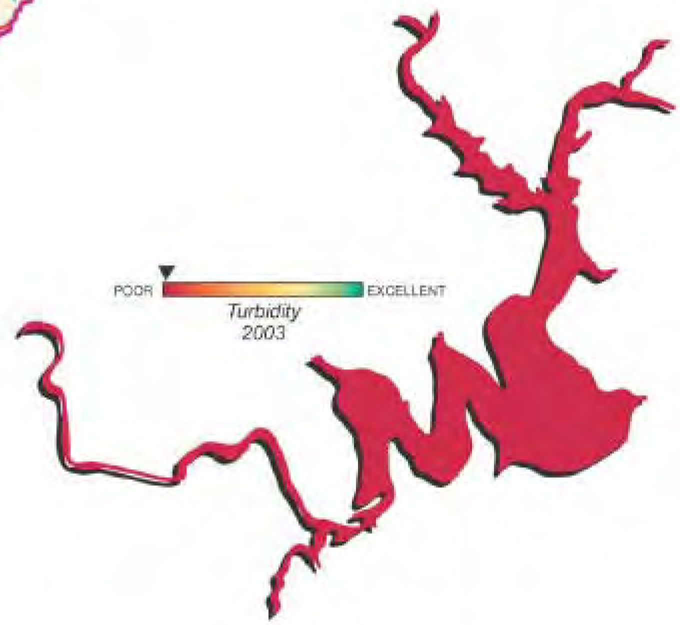



**Figure 122a-122e.** Graphical representation of data results for Heyburn Lake.




N
W
E
S

Lake Data

| | |
|---|---|
| Owner | Corps of Engineers |
| County | Creek |
| Constructed in | 1950 |
| Surface Area | 880 acres |
| Volume | 7,101 acre/feet |
| Shoreline Length | 50 miles |
| Mean Depth | 8.37 feet |
| Watershed Area | 123 square miles |

Plate 53 - Lake Water Quality for
## Heyburn Lake

# Holdenville Lake

Holdenville Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 18 NTU (Plate 54), true color was 26 units, and secchi disk depth was 61 centimeters. Based on these three parameters, Holdenville Lake had average to good water clarity in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 50 (Plate 54), classifying the lake as mesotrophic bordering eutrophic, indicative of moderate to high levels of productivity and nutrient conditions. The TSI values varied seasonally from eutrophic in the fall and mid to upper mesotrophic in the winter and spring quarters. Eutrophic conditions were again present during the summer sampling interval (see Figure 123). Six of the twenty turbidity values collected were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 124a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 30% of the samples collected in 2003-2004 were above the standard, it is likely that the peak seen in March is due to seasonal rain events. Holdenville Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial as it relates to turbidity. Seasonal true color values are displayed in Figure 124b. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol for determining the short-term average for true color the Aesthetics beneficial use is considered fully supported at Holdenville Lake.

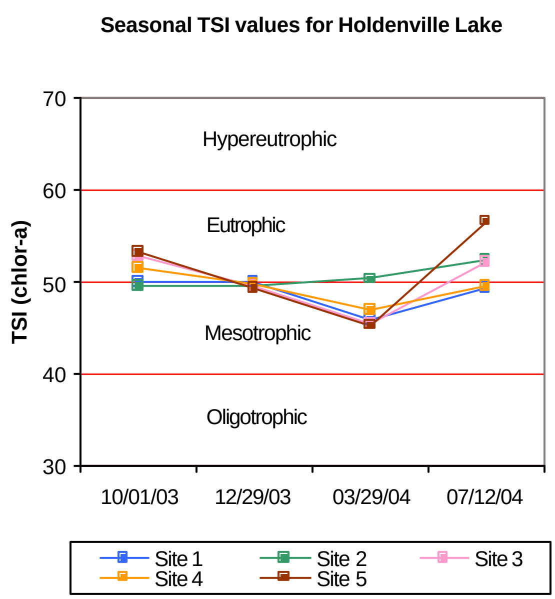



**Figure 123.** TSI values for Holdenville Lake.

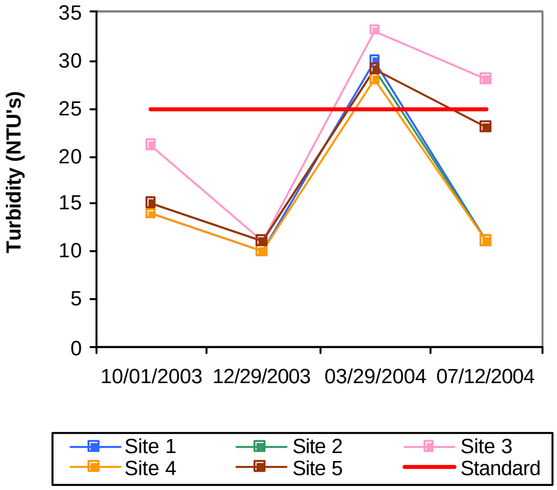
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity ranged from 0.06 parts per thousand (ppt) to 0.08, well within the range of expected values for Oklahoma lakes. Reflecting the minimal presence of chlorides or other salts in the lake. Specific conductance values were also well within the expected range for Oklahoma reservoirs, coinciding with the low salinity values seen for the lake. Values ranged from 142.7 mS/cm in the spring quarter to 183.1 mS/cm in the winter quarter. Oxidation-reduction potentials (redox) ranged from 392 mV near the sediment-water interface at the lake bottom in the summer to 577 mV in the fall in the water column. Reducing conditions were absent in all sampling intervals. Lake pH values were neutral with values ranging from 7.11 to 7.92 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Holdenville Lake is fully supporting its FWP beneficial use based on pH. Thermal stratification was not evident in the fall, winter or spring quarters and dissolved oxygen (D.O.) remained above 4.0 mg/L at all times and was generally above 7.0 mg/L (see Figure 124c-124e). In the summer, both thermal stratification was evident and anoxic conditions were present. The lake was stratified between 4 and 5 meters below the surface and D.O. concentrations were 1.0 mg/L or less from 5 meters to the lake bottom at 11.2 meters (see Figure 124f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial is considered partially supported at Holdenville Lake with approximately 62% of the water column having D.O. concentrations less than 2.0 mg/L at site 1, in the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected four (40%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (36.7 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

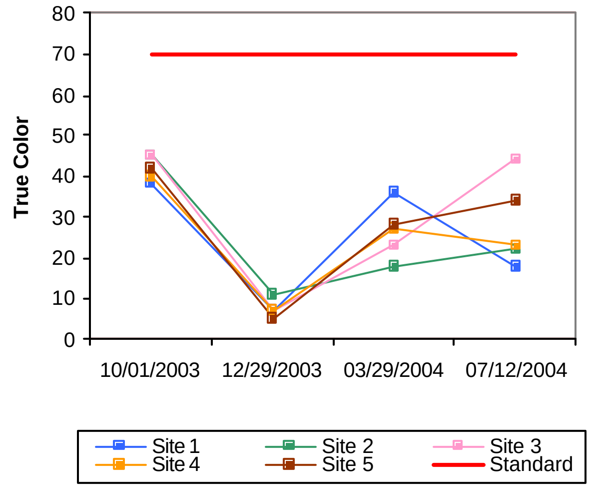
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.55 mg/L at the lake surface. The TN at the surface ranged from 0.24 mg/L to 0.72 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.031 mg/L at the lake surface. The TP ranged from 0.023 mg/L to 0.046 mg/L. The highest surface TP value was reported in the summer quarter and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Holdenville Lake is currently mesotrophic bordering eutrophic, indicative of high primary productivity and nutrient conditions (Plate 54). Holdenville Lake is fully supporting its FWP beneficial use for pH. Although 30% of the samples collected in 2003-2004 were above the standard, it is likely that the peak seen in March is due to seasonal rain events, thereforeHoldenville Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial as it relates to turbidity. Anoxic conditions were present in the summer therefore the lake is partially supporting its FWP beneficial used based on recorded D.O. values (OAC 785:46). The lake is fully supporting its Aesthetics beneficial use based on its trophic status and true color. Water clarity is average to good based on turbidity, true color and secchi disk depth. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected four (40%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (36.7 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported. Holdenville Lake was constructed in 1931 and is owned and operated by the City of Holdenville. The lake is managed to serve as the Holdenville's municipal water supply and also offers a recreational outlet for the general public to utilize.

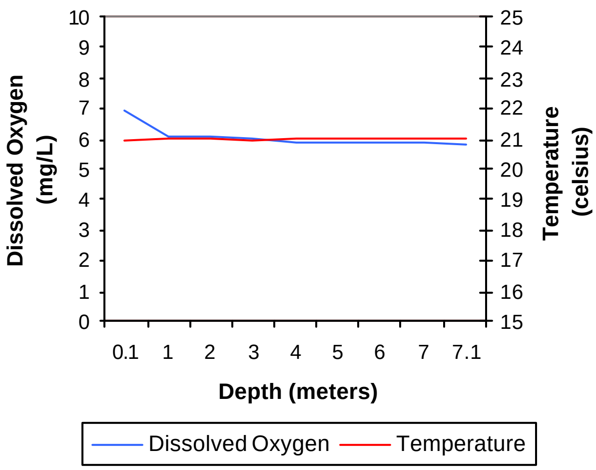
**a. Seasonal Turbidity Values for Holdenville Lake**



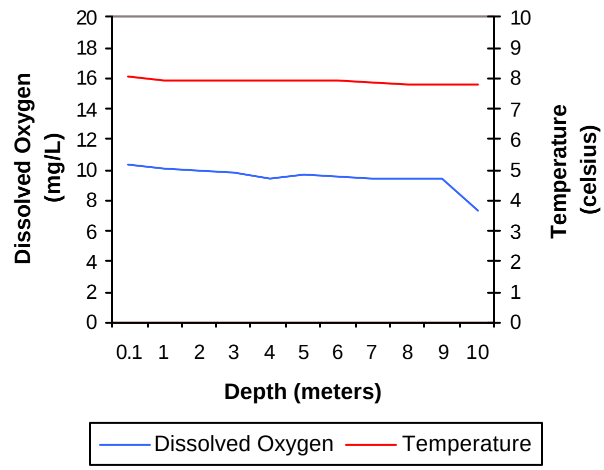

**b. Seasonal Color Values for Holdenville Lake**



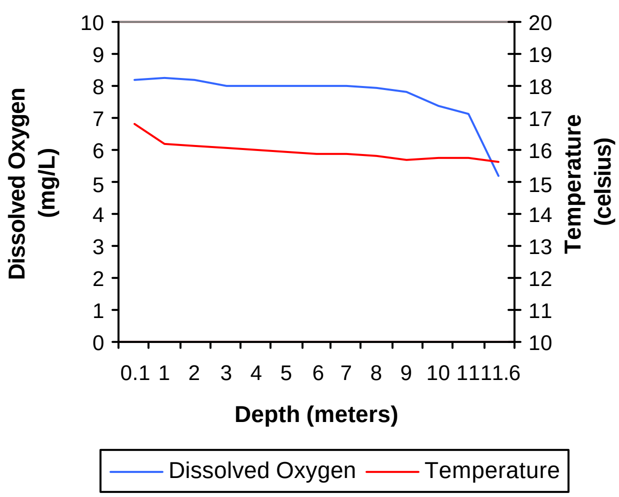

**c. Profile of Holdenville Lake October 01, 2003**




**d. Profile of Holdenville Lake December 29, 2003**




**e. Profile of Holdenville Lake March 29, 2004**




**e. Profile of Holdenville Lake July 12, 2004**

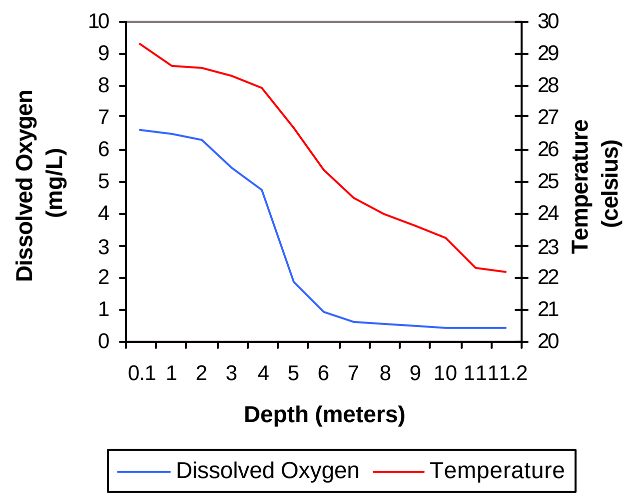
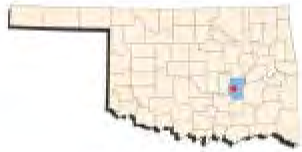



**Figure 124a-124f.** Graphical representation of data results for Holdenville Lake.

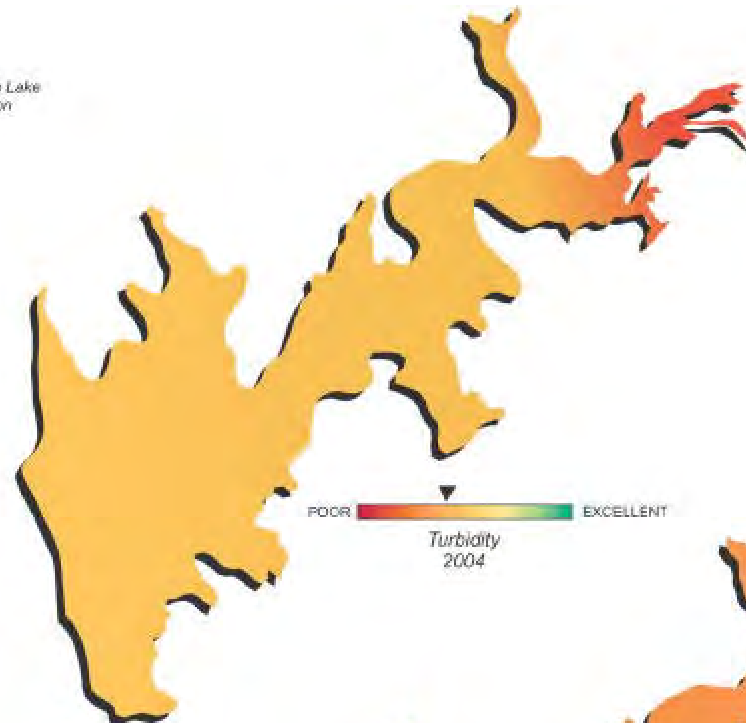
Plate 54 - Lake Water Quality for

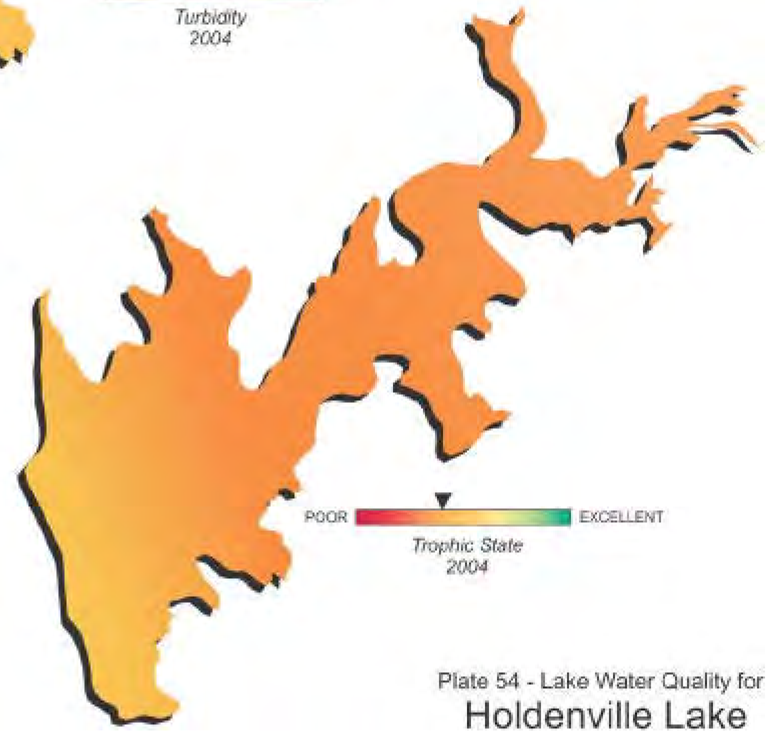
# Holdenville Lake





| Lake Data | |
|---|---|
| Owner | City of Holdenville |
| County | Hughes |
| Constructed in | 1931 |
| Surface Area | 550 acres |
| Volume | 11,000 acre/feet |
| Shoreline Length | 11 miles |
| Mean Depth | 20.00 feet |
| Watershed Area | 9 square miles |



# Hominy Municipal Lake

Hominy Municipal Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 9 NTU (Plate 55), true color was 17 units, and secchi disk depth was 114 centimeters. Based on these three parameters, Hominy Municipal Lake had excellent water clarity in 2003-2004 and is one of the nicer small municipal lakes in Oklahoma. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 49 (Plate 55), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. The TSI values were generally mesotrophic with eutrophic conditions present during the spring sampling interval (see Figure 125). All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 126a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples below the standard, the Fish & Wildlife Propagation (FWP) beneficial use is fully supported. Seasonal true color values are displayed in Figure 126b. True color values were fairly consistent between seasons and were all below the aesthetics OWQS of 70 units (see Figure 126b). Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity values ranged from 0.08 parts per thousand (ppt) to 0.15 ppt, which is within the expected range for Oklahoma reservoirs. Readings for specific conductivity were also within the normal range of values recorded in most Oklahoma lakes, ranging from 177 mS/cm in the spring to 307 mS/cm in the winter quarter. These values indicate low concentrations of electrical current conducting materials (salts) were present in the lake system, which corresponds with the low salinity values. In general, pH values were neutral to slightly alkaline, ranging from 6.81 to 8.17 units. According to USAP (OAC

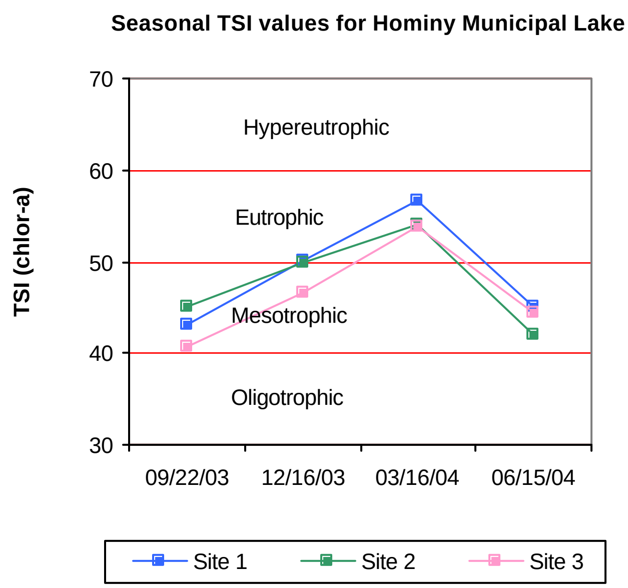



**Figure 125.** TSI values for Hominy Municipal Lake.

785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Hominy Municipal Lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 309 mV in the spring quarter to 513 mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir in during the sampling period. The lake was thermally stratified in the fall quarter between 6 and 7 meters below the surface at which point dissolved oxygen (D.O.) concentrations in the water column were below 2.0 mg/L to the lake bottom at 11 meters (Figure 126c). In both winter and spring quarters the lake was well mixed and oxygenated with D.O. values above 8.0 mg/L (Figure 126d-126e). In the summer the lake was strongly thermally stratified between 4 and 5 meters, at site 1, with D.O. values falling below 2.0 mg/L from 6 meters to the lake bottom of 13.4 meters (see Figure 126f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use could be considered partially supported at Hominy Municipal Lake because approximately 60% of the water column was anoxic at site 1 in the summer quarter. During the fall quarter, only 33% of the water column has D.O. concentrations of less than 2.0 mg/L. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 samples collected one (10%) exceeded the prescribed screening level of 235 cfu/ml for *E. coli*, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.41 mg/L at the lake surface. The TN at the surface ranged from 0.29 mg/L to 0.63 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.019 mg/L at the lake surface. The surface TP ranged from 0.012 mg/L to 0.28 mg/L. The highest surface TP value was reported in the spring and the lowest was recorded in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Hominy Municipal Lake was classified as mesotrophic, indicating moderate productivity and nutrient levels (Plate 55). The FWP beneficial use is fully supporting based on turbidity and pH values, however the use is partially supported based on the collected D.O. values in the water column. The Aesthetics beneficial use was supported based on true color values as well as the trophic status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 235 cfu/ml for *E. coli*, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. In general, the lake is one of the nicer small municipal lakes in Oklahoma and has good water quality. Hominy Municipal Lake is the municipal water supply for the City of Hominy and is owned and operated by the city. The lake was constructed in 1940 and is also utilized for recreational purposes.

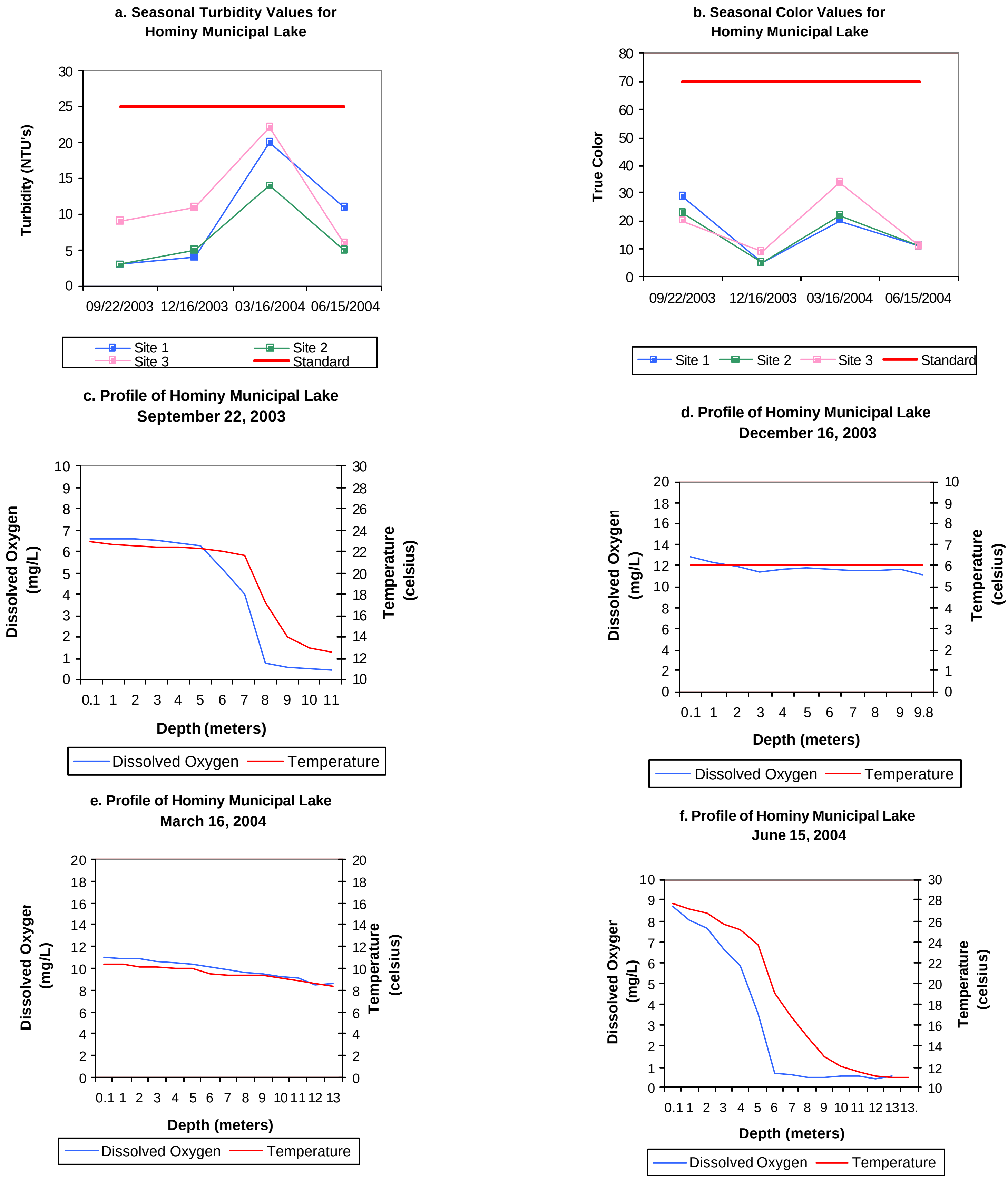
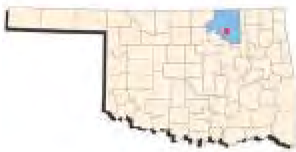
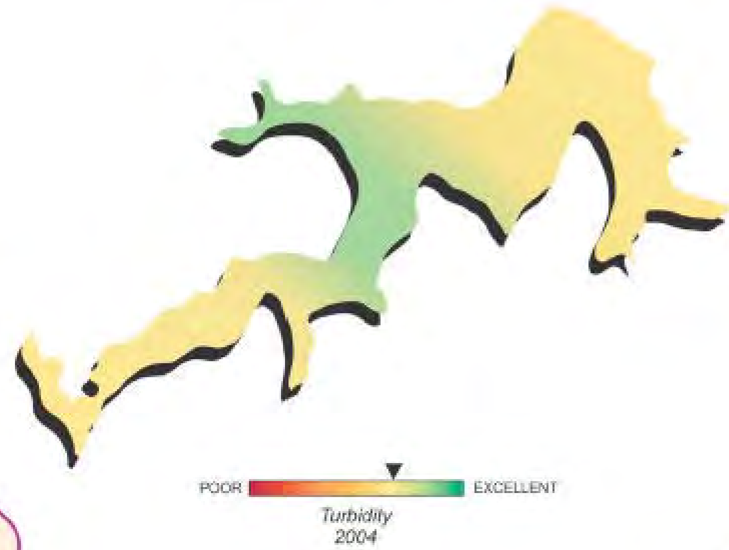



**Figure 126a-126f.** Graphical representation of data results for Hominy Municipal Lake.





| Lake Data | |
|---|---|
| Owner | City of Hominy |
| County | Osage |
| Constructed in | 1940 |
| Surface Area | 165 acres |
| Volume | 5,000 acre/feet |
| Shoreline Length | 6 miles |
| Mean Depth | 30.30 feet |
| Watershed Area | 3,282 acres |



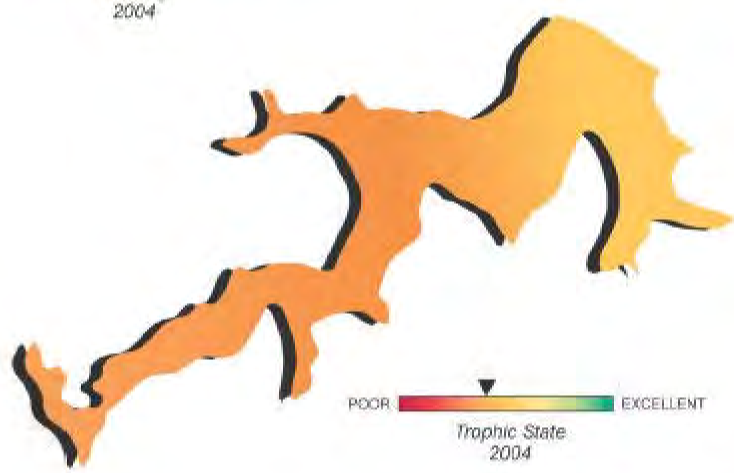




Plate 55 - Lake Water Quality for
Hominy Lake

# Hudson Lake (Osage County)

Hudson Lake (Osage County) was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 16 NTU (Plate 57), true color was 36 units, and secchi disk depth was 71 centimeters. Based on these three parameters, Hudson Lake (Osage County) had fairly good water clarity in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 54 (Plate 57), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This is very similar to the TSI in 2002 (TSI=56), indicating no significant increase or decrease in productivity has occurred over time. The TSI values varied seasonally at Hudson Lake (Osage County) from mesotrophic in the spring, to upper mesotrophic in the winter and eutrophic in both fall and summer quarters (see Figure 127). All turbidity values in with the exception of the spring quarter were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 128a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Hudson Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 128b. Three (25%) of the twelve values recorded the Aesthetics OWQS of 70 units (see Figure 128b). Similar to turbidity the peak in true color occurred in the month of March and is likely due to seasonal storm events. The Aesthetics beneficial use is therefore considered supported based on true color concentrations in the water column.

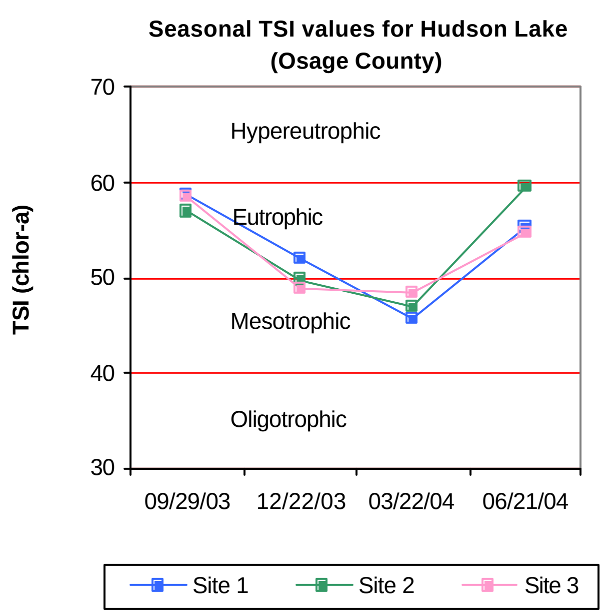


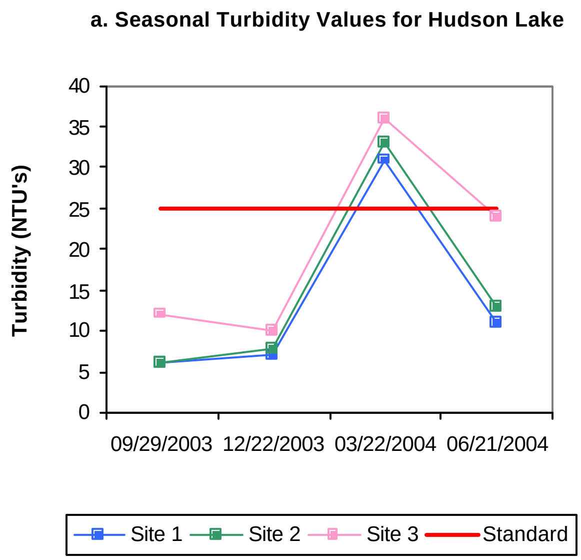

**Figure 127.** TSI values for Hudson Lake.

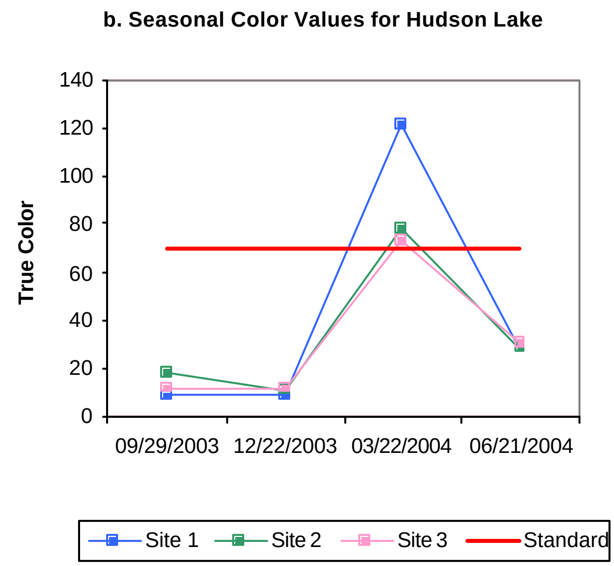
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.03 parts per thousand (ppt) to 0.12 ppt, which is within the range of values reported for Oklahoma lakes. Readings for specific conductance ranged from 77.4 mS/cm to 262.5 mS/cm, indicating low to moderate concentrations of electrical current conducting compounds (salts) were present in the water column throughout the year. These values also corresponded with the recorded salinity values. In general, pH values were neutral to very slightly alkaline, ranging from 6.78 to 8.46 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Hudson Lake is fully supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (redox) ranged from 359 mV in the summer to 604 mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir, in fact; only 4 readings were less than 200 mV in 2001-2002. In the fall quarter the lake exhibited weak thermal stratification between 6 and 7 meters with dissolved oxygen (D.O.) recorded as less than 2.0 mg/L from 8 meters to the lake bottom of 8.4 meters (Figure 128c). The lake did not exhibit thermal stratification in the winter or spring quarters (see Figure 128d-128e). In the summer the lake was stratified between 3 and 4 meters at sites 1 and the D.O. concentration was less than 2.0 mg/L below 5 meters extending to the lake bottom at 9.7 meters (see Figure 128f). Anoxic conditions were present in approximately 44% of the water column at site 2 during the summer sampling interval. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 55% of the water column at site 1 experiencing anoxic conditions in the summer, the FWP beneficial use is considered partially supported at Hudson Lake (Osage County). The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

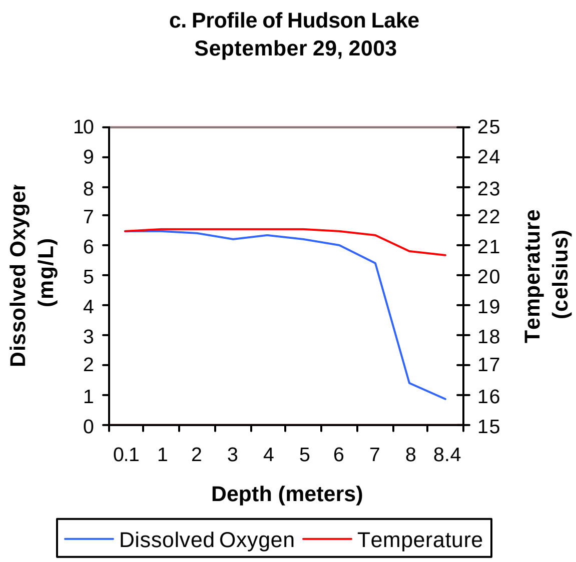
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected three (30%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

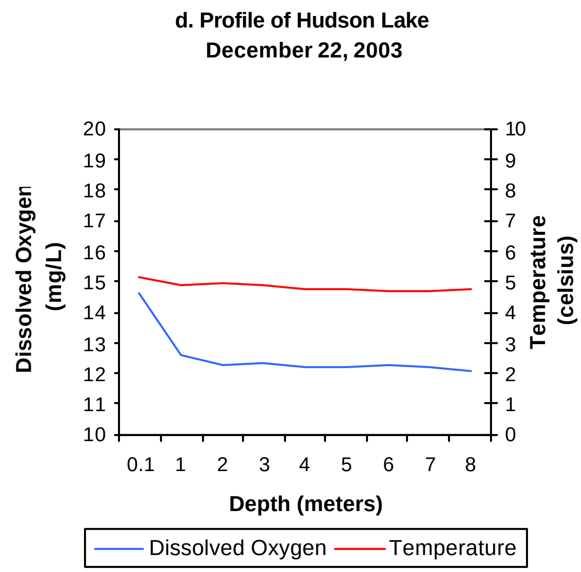
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.73 mg/L at the lake surface and ranged from 0.55 mg/L to 0.86 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.034 mg/L at the lake surface. The surface TP ranged from 0.024 mg/L to 0.049 mg/L. The highest surface TP value was reported in the spring and the lowest was in the winter. The nitrogen to phosphorus ratio (TN:TP) was approximately 21:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

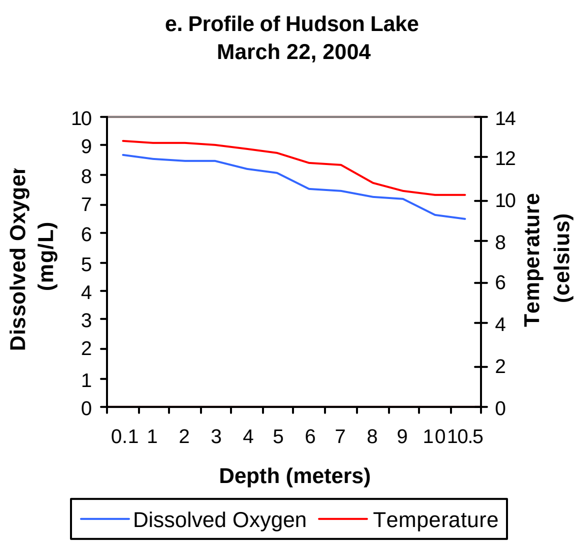
In summary, Hudson Lake (Osage County) was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 57). Water clarity was fairly good based on turbidity, true color and secchi depth. The FWP beneficial use w as fully supported based on pH and only partially supporting based on anoxic conditions during the summer quarter. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Hudson Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. The Aesthetics beneficial use was fully supported based on trophic status. Similar to turbidity the peak in true color occurred in the month of March and is likely due to seasonal storm events. The Aesthetics beneficial use is therefore considered supported based on true color concentrations in the water column. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected three (30%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Hudson Lake (Osage County), is owned and operated by the City of Bartlesville and was constructed in 1949 to serve as a municipal water supply for the city and to offer recreational opportunities for the public.



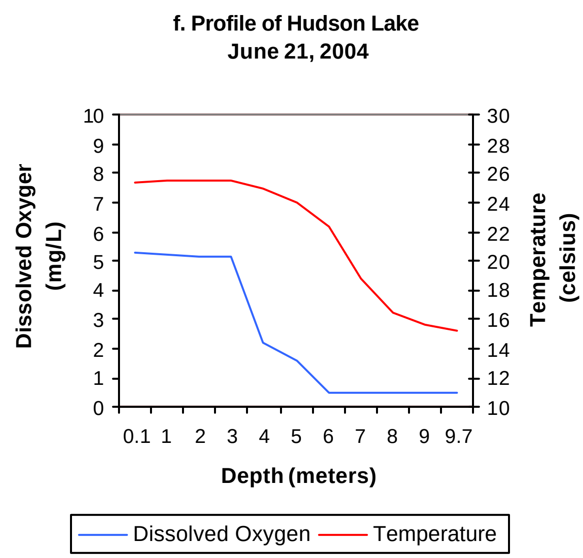
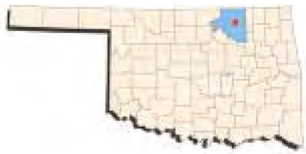
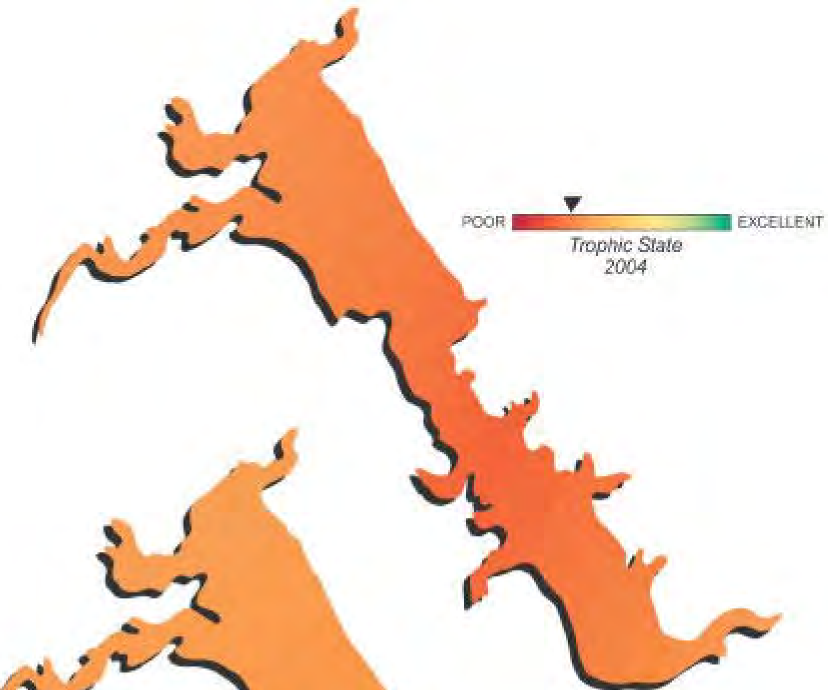




**Figure 128a-128f.** Graphical representation of data results for Hudson Lake (Osage County).






| Lake Data | |
|---|---|
| Owner | City of Bartlesville |
| County | Osage |
| Constructed in | 1949 |
| Surface Area | 250 acres |
| Volume | 4,000 acre/feet |
| Shoreline Length | 8 miles |
| Mean Depth | 16.00 feet |
| Watershed Area | 14 square miles |



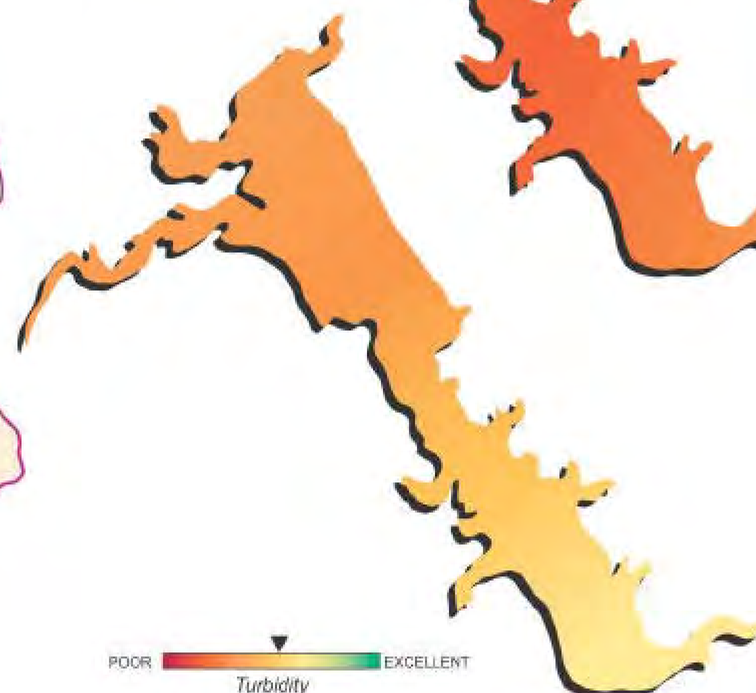




Plate 57 - Lake Water Quality for
Hudson Lake (Osage Co.)

# Lake Hudson (Mayes Co.)

Lake Hudson was sampled for four quarters from November 2002 through August 2003. Water quality samples were collected at eight (8) sites to represent the riverine, transition and lacustrine zones and arms of the reservoir. Samples were collected at the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 9 NTU (Plate 56), true color was 17 units and average secchi disk depth was 97 centimeters. Based on these three parameters Lake Hudson had good water clarity in 2003. These values are similar to the values reported in 2000 with true color and secchi disk depth showing some improvement since the last evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using values at all site for four quarters (n=32). The TSI was 55 (Plate 56), indicating the lake was eutrophic in sample year 2002-2003. Although this differs from the value reported in 2000, (TSI= 61), the current calculation is based on data collected year round as opposed to growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values for all sites were fairly consistent and ranged from mesotrophic (sites 1-4) to eutrophic/hypereutrophic in the upper lake (sites 5-8) in the fall and winter and all sites were eutrophic in the spring and summer quarters (see Figure 129). Seasonal turbidity values are displayed in Figure 130a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU although site 6 came close with a value of 23 NTU reported during the summer. With 100% of the values below the standard the Fish and Wildlife Propagation beneficial use is deemed fully supported. Seasonal true color values are displayed in Figure 130b. All true color values were well below the OWQS of 70 units for all quarters during the sample year. Applying the same default protocol the Aesthetics beneficial use is supported based on true color.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential and salinity were recorded at all three sample sites. Salinity ranged from 0.03 parts per thousand (ppt) to 0.14 ppt for this sample year. This is within the average range of values reported for Oklahoma lakes. Specific conductance ranged from 230.3 mS/cm to 287.6 mS/cm, which falls within the range of values commonly reported for Oklahoma lakes. These values indicate a moderate level of current conducting ions (salts) were present in the system. The pH values at Lake Hudson ranged from 6.77 to 8.68, representing a neutral to slightly alkaline system.

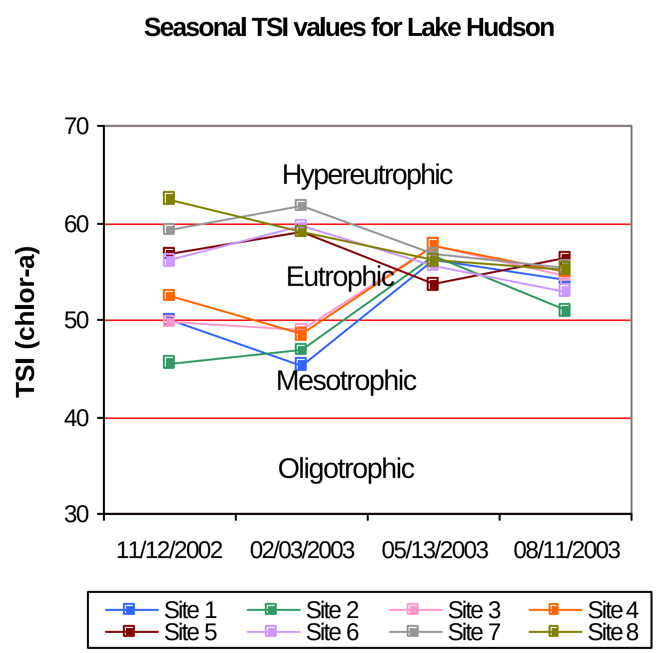



**Figure 129.** TSI values for Lake Hudson.

Oxidation-reduction potentials ranged from 379 mV in the fall to 636 mV in the summer. Reducing conditions were not present in this reservoir during the 2002-2003-sample year. During the fall, winter, and spring sampling intervals stratification was not present (Figure 130c-130e). In the summer stratification was evident occurred at several 1-meter intervals throughout the water column and dissolved oxygen ranged from 8.47 mg/L at the surface to 0.26 mg/l at the lake bottom at site 1. The lake exhibited strong thermal stratification between 6 and 7 meters at which point the dissolved oxygen dropped below 2 mg/L for the remainder of the water column (Figure 130f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 50% of the water column in the summer falling below 2.0 mg/L the FWP beneficial use is partially supported at Lake Hudson. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the surface and 0.46 mg/L at the lake bottom. Surface TN ranged from 0.18 mg/L to 0.72 mg/L, with the highest values seen in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.055 mg/L at the surface and 0.073 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.034 mg/L to 0.089 mg/L. Surface TP was highest in the fall quarter and lowest during the summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003. This is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Lake Hudson was classified as eutrophic, indicative of high primary productivity and nutrient conditions in sample year 2002-2003. Although this differs from the classification reported in 2000, (TSI= 61), the current TSI calculation is based on data collected year round as opposed to growing season only and is likely a more accurate depiction of productivity within the lake. Water clarity is good based on true color, turbidity and secchi disk depth and is consistent with finding from previous sampling efforts. The FWP beneficial use is supported based on turbidity and pH, but is partially supporting based on dissolved oxygen levels in the summer. The lake is also supporting the Aesthetics beneficial use based on its trophic status and true color. The Oklahoma Department of Environmental Quality (ODEQ) sampled Lake Hudson in 2002 as part of the Toxics and Reservoirs program and found no problems with toxic organic or metal residues in the fish tissue they analyzed. Lake Hudson was constructed by the Grand River Dam Authority (GRDA) for flood control and hydroelectric purposes and is located in Mayes County.

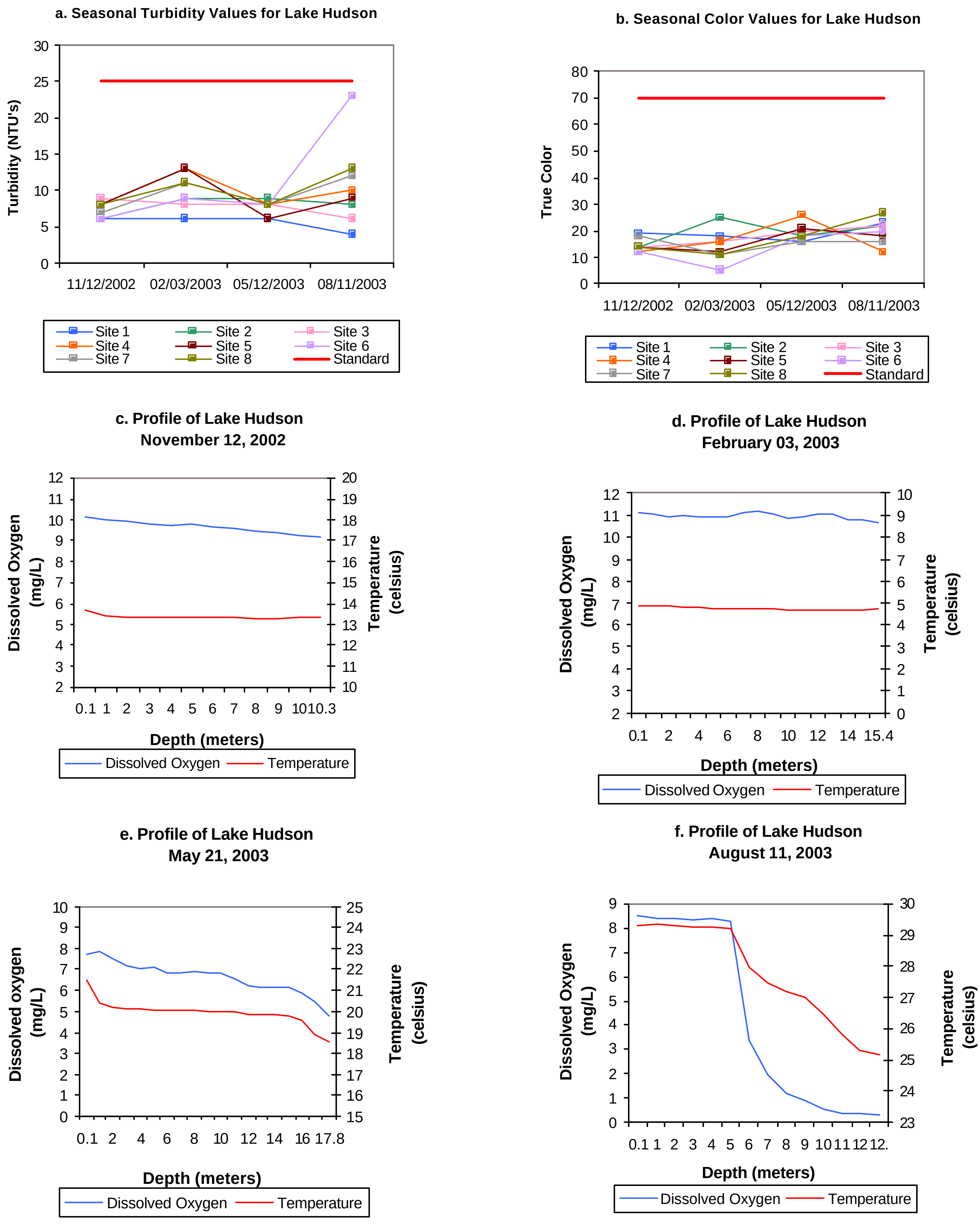
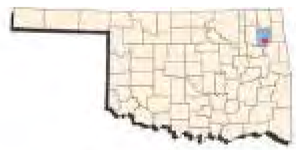



**Figure 130a-130f.** Graphical representation of data results for Lake Hudson (Mayes Co.).





| Lake Data | |
|---|---|
| Constructed by | Grand River Dam Authority |
| County | Mayes |
| Constructed in | 1964 |
| Surface Area | 10,900 acres |
| Volume | 200,300 acre/feet |
| Shoreline Length | 200 miles |
| Mean Depth | 19.38 feet |
| Watershed Area | 11,533 square miles |



Plate 56 - Lake Water Quality for
Lake Hudson (Mayes Co.)

# Hugo Lake

Hugo Lake was sampled for four quarters from November 2002 through August 2003. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 40 NTU (Plate 58), true color was 116 units, and secchi disk depth was 37 centimeters. Based on these three parameters, Hugo Lake had poor water clarity in 2003. Water clarity is similar compared to historical data and is likely always poor based on the soil composition and nature of this lake. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). The average TSI was 55 (Plate 58), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This value is the same as the TSI in 2000 (TSI=55), indicating no change in productivity has occurred since the last evaluation. The values at all sites in the fall were eutrophic; two out of five sites were hypereutrophic in the winter and spring and summer values ranged from mesotrophic to eutrophic (Figure 131). A similar pattern was observed during the 2000 sample year. Seasonal turbidity values are displayed in Figure. In general turbidity values in 2003 exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU with the exception of sites 1-3 in the fall (see Figure 132a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is not supported at Hugo Lake with 85% of the collected values exceeding the standard. Seasonal true color values are displayed in Figure 132b. True color values were at or near the aesthetics OWQS of 70 units in the fall and above the standard for the remainder of the year. With 90% of the collected values exceeding the standard the lake is not supporting the Aesthetics beneficial use.

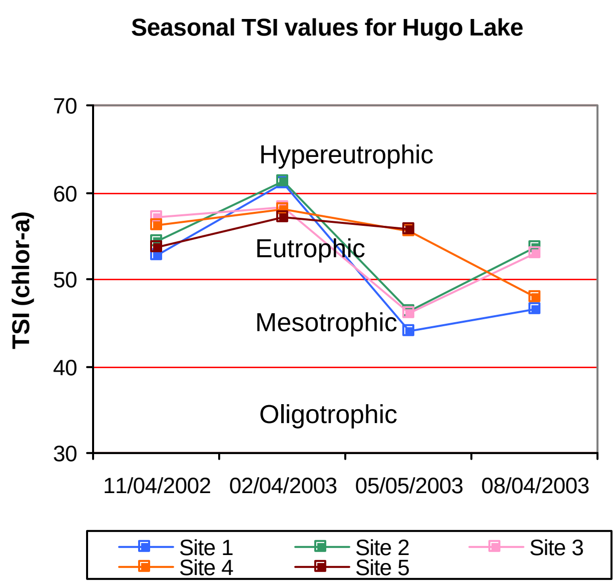



**Figure 131.** TSI values for Hugo Lake.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Hugo Lake ranged from 0.01 parts per thousand (ppt) to 0.04 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 31.1 mS/cm to 103 mS/cm, indicating minimal concentrations of current conducting compounds (chlorides and salts) in the lake system. The pH values ranged from 6.33 to 7.86 representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With only 6% of the values falling outside the acceptable range the lake is considered supporting the beneficial use based on pH. The slightly acidic conditions are also seen in other lakes in this region of the state and are like due to natural conditions. Oxidation-reduction potential (ORP) ranged from 418 mV in the spring to 591 mV in the hypolimnion during the summer. All ORP values were positive and above 100 mV indicating reducing conditions were not present in the lake. Thermal stratification was not present during the fall, winter and spring and the lake was well mixed with dissolved oxygen (D.O) values remaining above 5.0 mg/L (see Figure 132c-132e). The lake was stratified in the summer at site 1 and 4 between 8 and 9 meters in depth at which point the dissolved oxygen (D.O) fell below 2.0 mg/L to the lake bottom (see Figure 132f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 18 to 28 % of the water column less than 2.0 mg/L, therefore the FWP Benicia use is partially supported at Hugo Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the surface and 0.39 mg/L at the lake bottom. Surface TN ranged from 0.05 mg/L to 0.75 mg/L, with the highest values seen in the summer and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.064 mg/L at the surface and 0.065 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.044 mg/L to 0.091 mg/L. Surface TP was highest in the spring quarter and lowest during the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 7:1 for sample year 2003. This is consistent with the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Hugo Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions. This is consistent with the 2000 evaluation indicating little to no change in productivity has occurred. Water clarity was poor based on turbidity, true color and low secchi disk depth and is likely to always be poor based on the soil composition and nature of this lake. The lake is supporting the FWP beneficial use based on pH, partially supporting based on dissolved oxygen, but not supporting based turbidity. The Aesthetics beneficial use is supported based on its trophic status, but not supporting due to reported true color values. In 1999, a bathymetric survey was conducted at Hugo Lake (Figure 133) as part of the Kiamichi River Development Project. The purpose of the survey was to generate a 3-D simulation of water level changes within the reservoir in response to concerns local citizens had regarding the potential transfer of water to other areas of the state and /or the north Texas area. Specific concerns included fluctuating lake levels and the subsequent impacts on fish/wildlife, recreation, tourism and economic development in the area. For further information about this study or bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800. The United States Army Corps of Engineers (USACE) constructed Hugo Lake for flood control, water supply, fish and wildlife and recreational purposes. The lake is located in Choctaw County approximately 7 miles east of the city of Hugo.

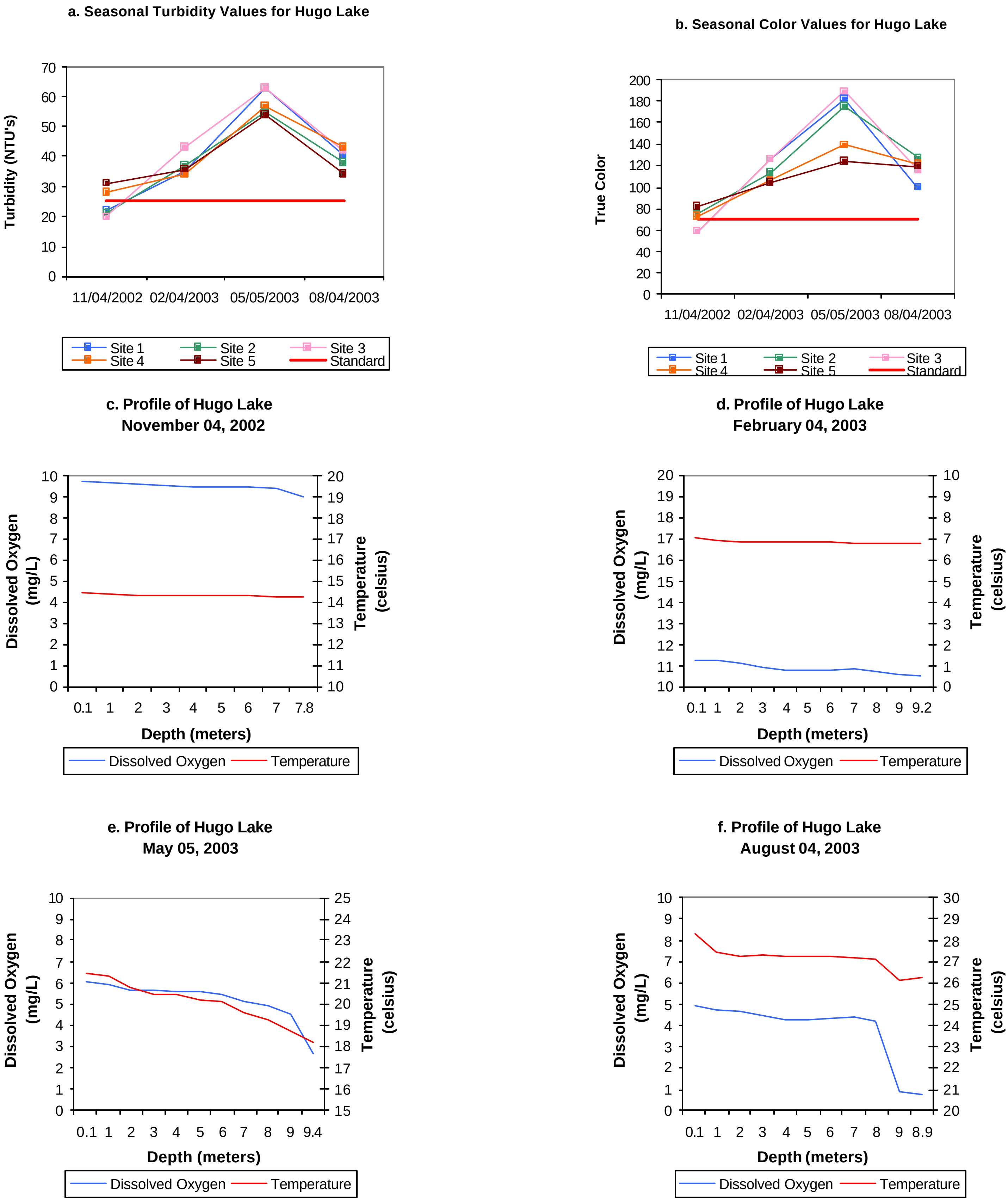
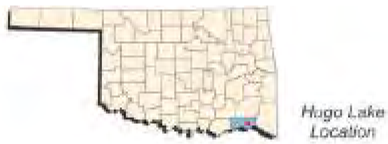



**Figure 132a-132f.** Graphical representation of data results for Hugo Lake.





| Lake Data | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Choctaw |
| Constructed in | 1974 |
| Surface Area | 11,592 acres |
| Volume | 126,740 acre/feet |
| Shoreline Length | 71.33 miles |
| Mean Depth | 10.56 feet |
| Watershed Area | 1,709 square miles |



Plate 58 - Lake Water Quality for
Hugo Lake

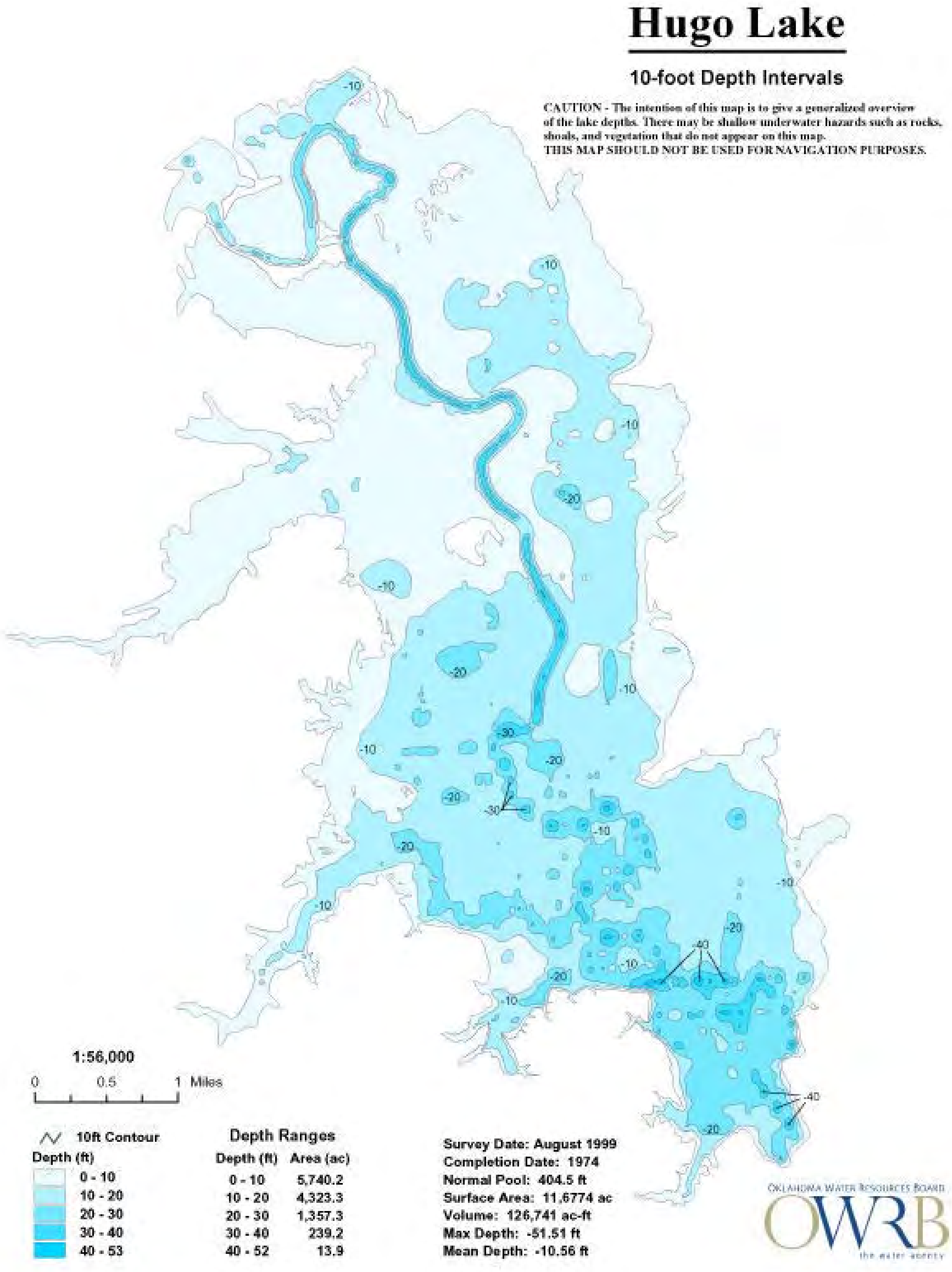



**Figure 133.** Bathymetric Map of Hugo Lake.

# Hulah Lake

Hulah Lake was sampled for four quarters from October 2002 through July 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for lakes larger than the 250 surface acres. Samples were collected at the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam site. The average lake-wide turbidity was 42 NTU (Plate 59), true color was 48 units and average secchi disk depth was 34 centimeters in sample year 2003. Based on these three parameters water clarity was poor at Hulah Lake in 2003, consistent with results from 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 55 (Plate 59), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This value is the similar to the TSI in 2000 (TSI=58), indicating no significant change in productivity has occurred. The TSI values for all sites were eutrophic except for one mesotrophic value for site 1 during the summer (Figure 134). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient impaired. A nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 135a. Only five of the twenty values collected were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥ 25% of the samples exceed the OWQS of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. With 75% of the collected values exceeding the numerical criteria the Fish and Wildlife Propagation (FWP) beneficial use is not supported. Seasonal true color values are displayed in Figure 135b. True color values ranged from 1 to 83 units with higher values occurring in the spring and summer. Applying the same default protocol the Aesthetics beneficial use should be considered partially supported; however the minimum data requirement of 20 samples for lakes larger than 250 surface acres.

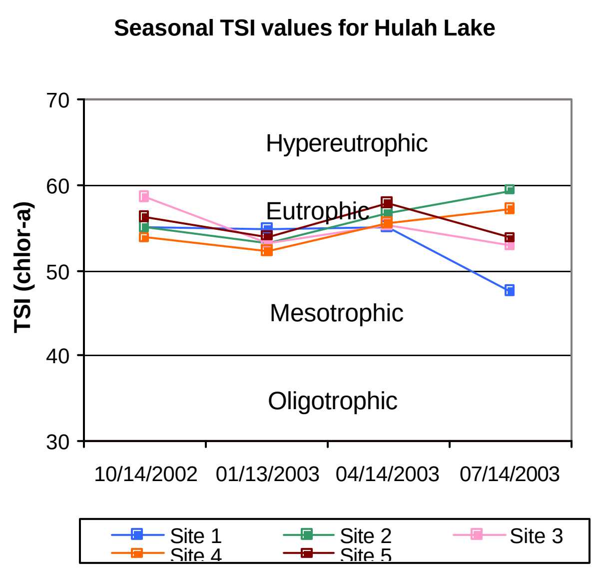



**Figure 134.** TSI values for Hulah Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values at Hulah Lake ranged from 0.11 parts per thousand (ppt) to 0.17 ppt. This is within the average range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 238.6 mS/cm to 336.6 mS/cm, indicating moderate concentrations of electrical current conducting compounds (chlorides and salts) in the lake system. The pH values ranged from 7.03 to 8.12 representing a neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all values within the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 275 mV in the spring to 493 mV during the winter. All ORP values were positive indicating reducing conditions were not present in the lake. Thermal stratification was not present during the fall, winter and spring sampling intervals and the lake was well mixed (see Figure 135c-135e). In the summer dissolved oxygen (D.O) only fell below 2.0 mg/L at the sediment-water interface (see Figure 135f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered supported at Hulah Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.50 mg/L at the surface and 0.56 mg/L at the lake bottom. Surface TN ranged from 0.10 mg/L to 0.90 mg/L, with the highest values seen in the summer and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.059 mg/L at the surface and 0.075 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.014 mg/L to 0.114 mg/L. Similar to TN surface TP was highest in the summer and lowest during the winter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003. This slightly higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Hulah Lake was eutrophic, indicative of high primary productivity and nutrient levels in 2002-2003. This is consistent with the evaluation in 2000, indicating no significant change in productivity has occurred since the lake was last sampled. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient impaired. A nutrient impairment study should be conducted to determine if uses are impaired. Water clarity was poor based on true color, turbidity and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and dissolved oxygen values, but not supporting based on high turbidity. The Aesthetics beneficial is supported based on its trophic status, however use support based on true color could not be made due to minimum data requirements of samples not being met. Hulah Lake, located in Osage County, was constructed by the United States Army Corps of Engineers (USACE) for the purpose of flood control, water supply, low-flow regulation and conservation.

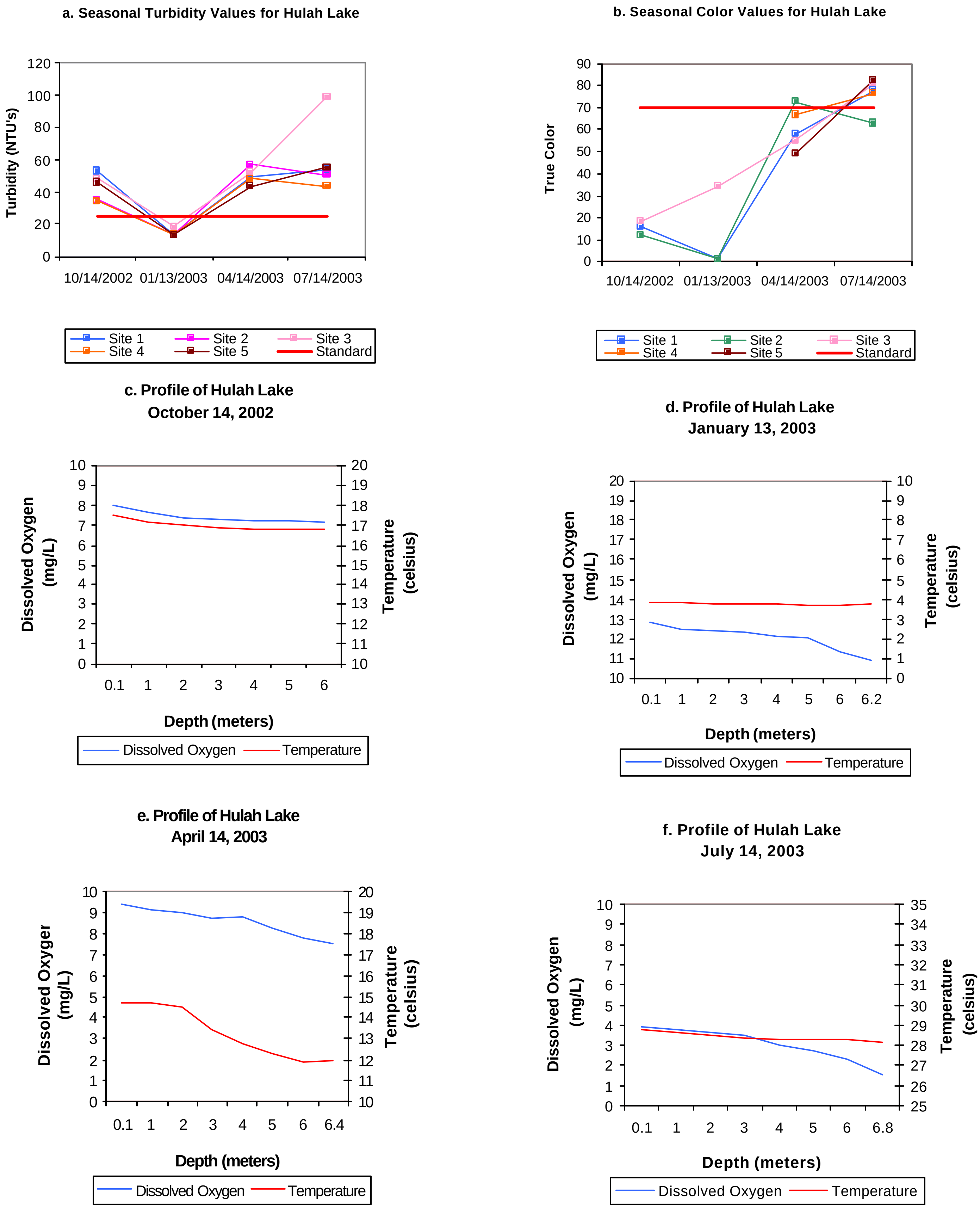
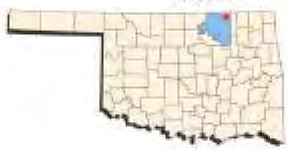
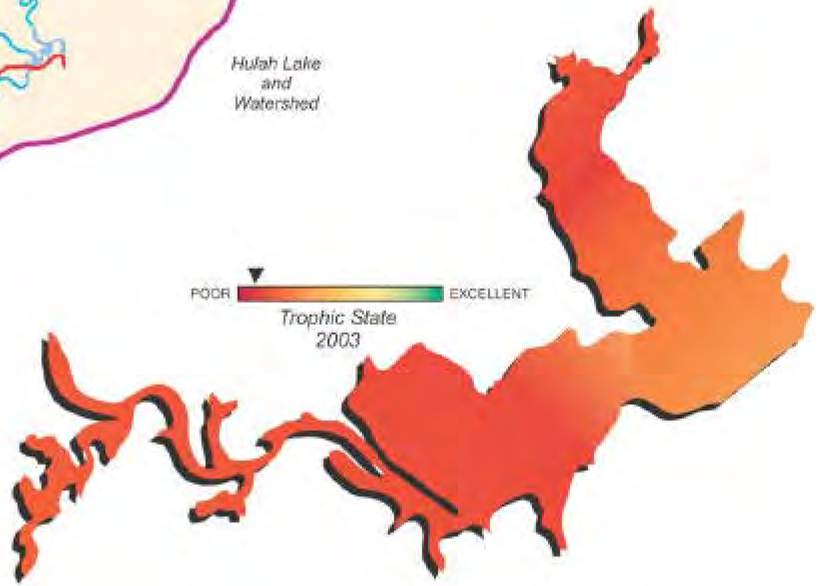
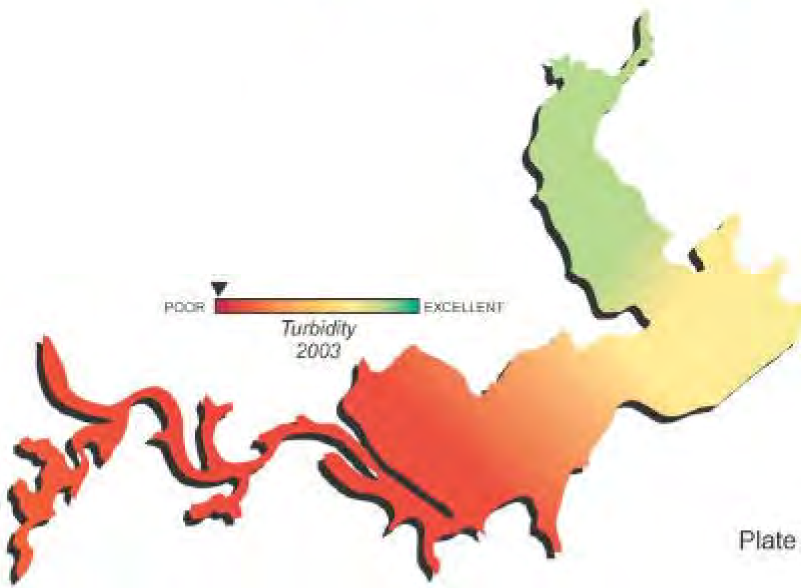



**Figure 135a-135f.** Graphical representation of data results for Hulah Lake.


N
W E
S

Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Osage |
| Constructed in | 1951 |
| Surface Area | 3,570 acres |
| Volume | 31,160 acre/feet |
| Shoreline Length | 62 miles |
| Mean Depth | 9.64 feet |
| Watershed Area | 732 square miles |

Plate 59 - Lake Water Quality for
# Hulah Lake

# Humphreys Lake

Humphreys Lake was sampled for four quarters, from November 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition, and lacustrine zones of the reservoir. Addition al sites were added to ensure sample size would be representative of lakes larger than 250 surface acres. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 15 NTU (Plate 60), true color was 17 units, and secchi disk depth was 48 centimeters in 2001. Based on these three parameters, Humphreys Lake had average water clarity in 2003. The water clarity was very similar in sample year 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 56 (Plate 60), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to the one calculated in 2001 (TSI=53) indicating no significant increase or decrease in productivity has occurred. The TSI values were eutrophic throughout the year except in the spring quarter when two of the five sites were hypereutrophic (Figure 136). Seasonal turbidity values are displayed in Figure 137a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. With all turbidity values in 2003 at or below the OWQS of 25 NTU the Fish and Wildlife Propagation beneficial use is considered supported. The annual turbidity value of 15 NTU seems representative of turbidity at Humphreys Lake. Seasonal true color values are displayed in Figure 137b. All true color values were below the OWQS of 70 units, however due to the minimum data requirements of 20 samples, for lakes 250 surface acres or greater, not being met a use support determination couldn't be made at this time.

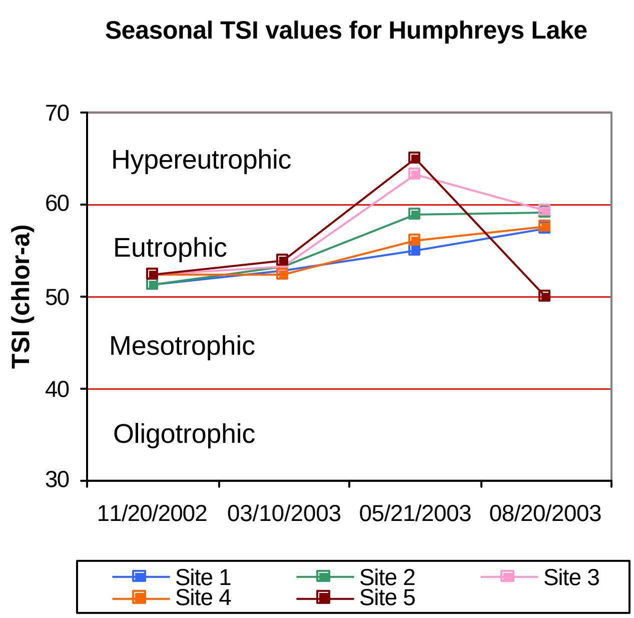



**Figure 136.** TSI values for Humphreys Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values at Humphreys Lake ranged from 0.27 parts per thousand (ppt) to 0.33 ppt. This is within the average range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 528.1 mS/cm to 636.6 mS/cm, indicating moderate concentrations of electrical current conducting compounds (chlorides and salts) in the lake system consistent with salinity readings. The pH values ranged from 7.06 to 8.25 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 100% of the collected values within the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from -2 mV to 627 mV. In general, reducing conditions were not present with all recorded values above 100 mV with the exception of two values recorded at the lake bottom at the dam in the summer quarter. Thermal stratification was not present during the fall, winter and spring sampling intervals and the lake was well mixed with dissolved oxygen levels above 5.0 mg/L (see Figure 137c-137e). In the summer stratification occurred at several 1-meter intervals with dissolved oxygen concentrations (D.O.) falling below 2.0 mg/L from 4 meters in depth to the lake bottom of 9.5 meters accounting for approximately 55 % of the water column to be experiencing anoxic conditions (see Figure 137f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered supported at Humphreys Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.1.00 mg/L at the surface and 1.59 mg/L at the lake bottom. Surface TN ranged from 0.74 mg/L to 1.57 mg/L, with both the highest and lowest values occurring in the spring. The lake-wide total phosphorus (TP) average was 0.042 mg/L at the surface and 0.103 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.026 mg/L to 0.090 mg/L. Surface TP was highest in the summer and lowest during the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 24:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Humphreys Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This is consistent with findings from the 2001 evaluation indicating that little or no change in productivity has occurred. The lake is supporting the FWP beneficial use based on turbidity and pH, but partially supporting based on dissolved oxygen levels. The Aesthetics beneficial use is supported based on its trophic status and although minimum data requirements were not met for true color it is likely that it would be supported. Humphreys Lake is owned by the City of Duncan and serves as a flood control, water supply, and recreational reservoir.

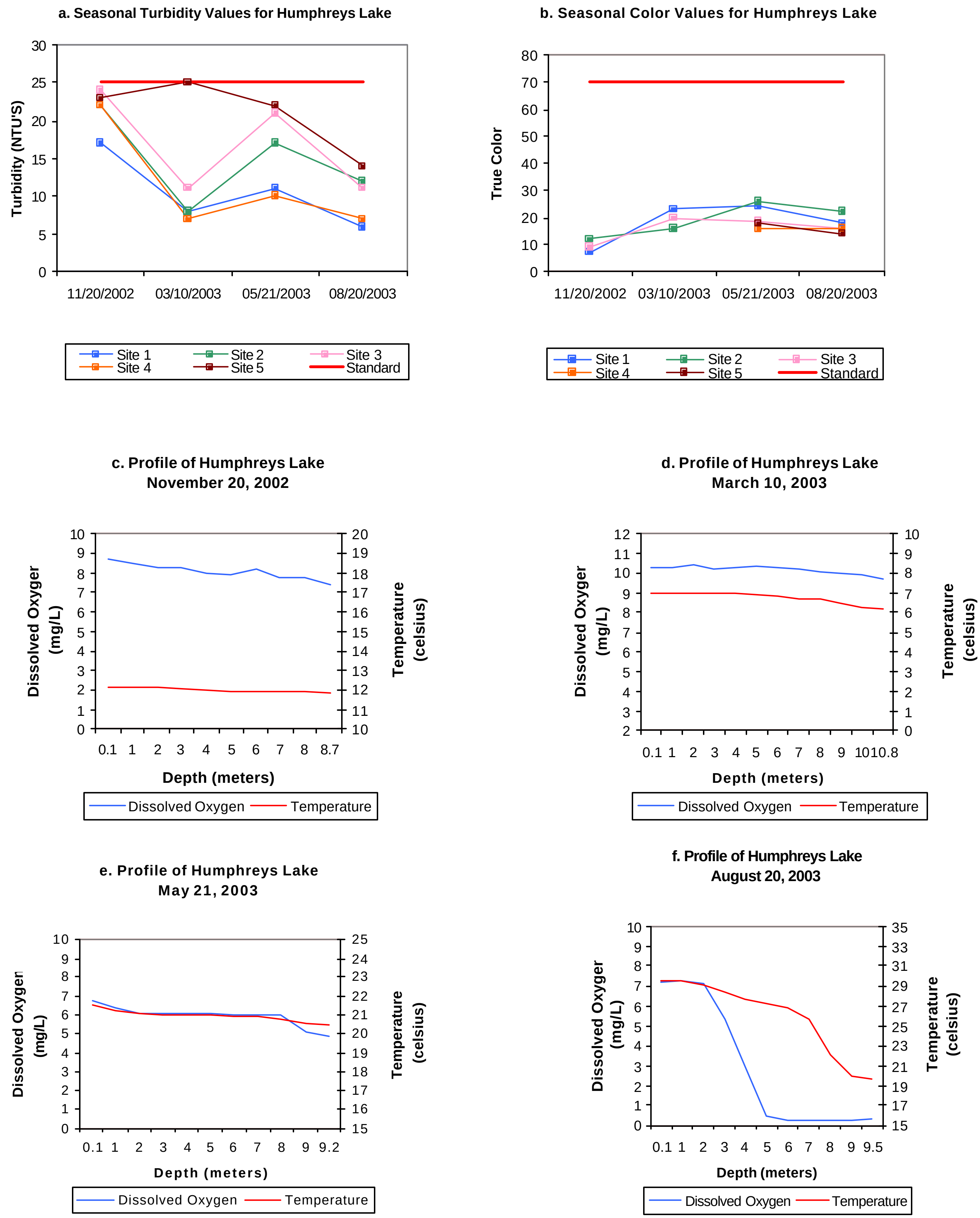
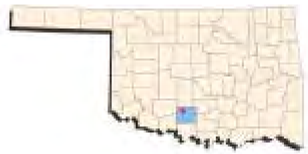



**Figure 137a-137f.** Graphical representation of data results for Humphreys Lake.


Humphreys Lake
and
Watershed



Humphreys Lake
Location



Trophic State
2003


Turbidity
2003

Lake Data

| | |
|---|---|
| Owner | City of Duncan |
| County | Stephens |
| Constructed in | 1958 |
| Surface Area | 882 acres |
| Volume | 14,041 acre/feet |
| Shoreline Length | 17 miles |
| Mean Depth | 15.92 feet |
| Watershed Area | 31 square miles |

Plate 60 - Lake Water Quality for
# Humphreys Lake

# Lake Jean Neustadt

Lake Jean Neustadt was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for lakes greater than 250 surface acres in size. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity was 10 NTU (Plate 61), true color was 15 units, and secchi disk depth was 55 centimeters. Based on these three parameters, Lake Jean Neustadt had good water clarity in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 47 (Plate 61), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. This value is lower than the one calculated in 2001 (TSI=58) but is most likely a more accurate depiction of the trophic status at Lake Jean Neustadt as the value is based on a larger dataset. The TSI values were fairly consistent with values ranging from lower mesotrophic in the summer to the upper end of mesotrophy the rest of the sample year (Figure 138). Seasonal turbidity values per site are displayed in Figure 139a. All turbidity values in 2003 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU therefore supporting the Fish and Wildlife Propagation (FWP) beneficial use. The annual turbidity value of 10 NTU accurately reflects turbidity at Lake Jean Neustadt. Seasonal true color values are displayed in Figure 139b. All true color values were below the aesthetics OWQS of 70 units at all sites. Although 100% of the samples collected in 2003 were below the standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres. However, upon reviewing current and historical data, it is likely the Aesthetics beneficial use is fully supported.

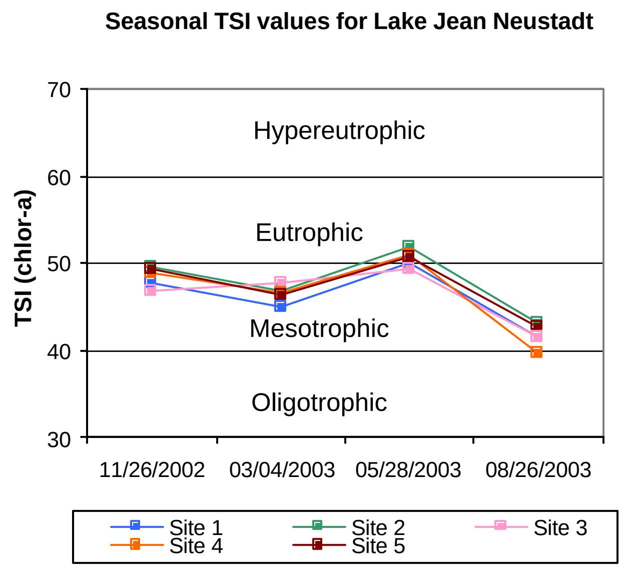



**Figure 138.** TSI values for Lake Jean Neustadt.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values at Lake Jean Neustadt ranged from 0.02 parts per thousand (ppt) to 0.17 ppt. This is within the average range of values for most Oklahoma reservoirs. Specific conductivity ranged from 232.2 mS/cm to 339.1 mS/cm, indicating minimal concentrations of electrical current conducting compounds (chlorides and salts) in the lake system consistent with salinity readings. The pH values ranged from 7.07 to 8.25 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 100% of the collected values within the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 311 mV to 490 mV. Reducing conditions were not present with all recorded values above 100 mV. The lake was not stratified during the fall and winter sampling intervals and the lake was well mixed with dissolved oxygen levels above 7.0 mg/L (see Figure 139c-139d). Thermal stratification was evident and anoxic conditions were present in the both spring and summer quarters. In the spring, stratification occurred between 5 and 7 meters with dissolved oxygen falling below 2.0 mg/L from 6 meters to the lake bottom of 9.2 meters accounting for approximately 36% of the water column to be anoxic (Figure 139e). In the summer quarter, similar conditions were found with dissolved oxygen concentrations (D.O.) falling below 2.0 mg/L for greater than 60 % of the water column at sites 1 and 4 (see Figure 139f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered partially supported at Lake Jean Neustadt based on low D.O. in the spring and summer months. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.47 mg/L at the surface and 0.94 mg/L at the lake bottom. Surface TN ranged from 0.28 mg/L to 0.69 mg/L, with the highest values reported in the winter and the lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the surface and 0.095 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.012 mg/L to 0.053 mg/L. Similar to TN, surface TP was highest in the winter and lowest during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 21:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Jean Neustadt was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. Although this is lower than the TSI calculated in 2001, (TSI=58), it is likely a more accurate depiction of productivity as it is based on a larger dataset. Water clarity was good based on true color, turbidity, and secchi disk depth in sample year 2002-2003. The FWP beneficial use is supported based on turbidity and pH, but partially supporting based on dissolved oxygen levels. The lake is supporting the Aesthetics beneficial use based on its trophic status, however no listing can be made for true color as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres. Lake Jean Neustadt, located in Carter County, serves as a recreational reservoir for the City of Ardmore.

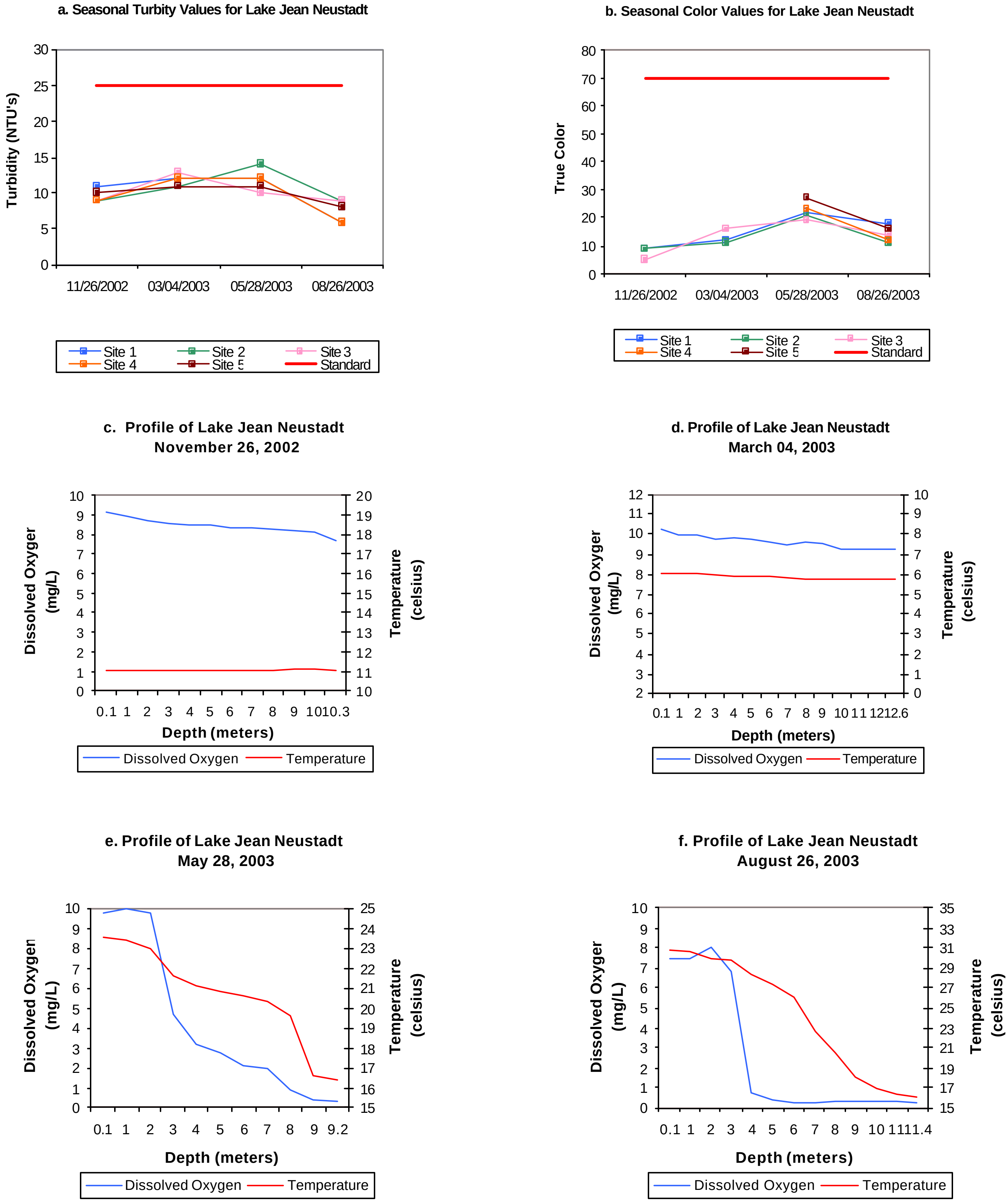
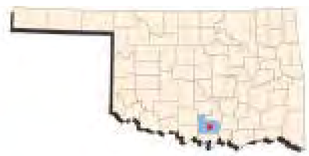



**Figure 139a-139f.** Graphical representation of data results for Lake Jean Neustadt.


Jean Neustadt Lake and Watershed



Jean Neustadt Lake Location

| Lake Data | |
|---|---|
| Owner | City of Ardmore |
| County | Carter |
| Constructed in | 1969 |
| Surface Area | 462 acres |
| Volume | 6,106 acre/feet |
| Shoreline Length | 10 miles |
| Mean Depth | 13.22 feet |
| Watershed Area | 17 square miles |




Plate 61 - Lake Water Quality for
## Lake Jean Neustadt

# John Wells Lake

John Wells Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 4 NTU (Plate 62), true color was 7 units, and secchi disk depth was 140 centimeters. Based on these three parameters, John Wells Lake had excellent water clarity in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 43 (Plate 62), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. The TSI values were generally mesotrophic throughout the sample year with oligotrophic values occurring in the fall quarter (see Figure 140). All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 141a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. John Wells Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 141b. True color values were all well below the aesthetics OWQS of 70 units at all sites. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values. In general, John Wells Lake is one of the nicer small municipal reservoirs in Oklahoma.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.06 ppt, well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance ranged from 44.3 mS/cm to 142.2 mS/cm, indicating low concentrations of electrical current conducting compounds (salts) were present in the water column. In general, pH values were neutral to slightly alkaline, ranging from 6.69 in the fall to 8.17 units in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside

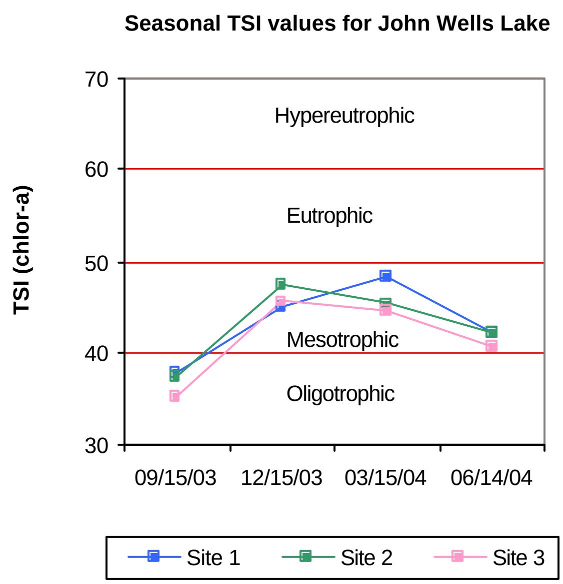



**Figure 140.** TSI values for John Wells Lake.

the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range, the FWP use is considered supported as it relates to pH. Oxidation-reduction potentials (redox) ranged from 326 mV at the sediment-water interface in the fall to 512 mV in the winter. Redox readings indicated that reducing conditions were not present in the reservoir in an appreciable way. The lake was thermally stratified in the fall between 6 and 7 meters at which point dissolved oxygen (D.O.) fell below 2.0 mg/L from 7 meters to the lake bottom of 9.3 meters. In the winter quarter thermal stratification was not evident and the lake was well mixed and oxygenated with (D.O.) values remaining above 7.0 mg/L throughout the water column at all sites with the exception of site 1 (See Figure 141d). Readings at site 1 were recorded as less than 5.0 mg/L throughout the entire water column, which seems suspect for this time of year. Due to equipment failure, profile data is not available for the spring sampling interval. The lake was strongly thermally stratified in the summer quarter between 5 and 6 meters at which point D.O. values fell below 1.0 mg/L extending all the way to the lake bottom at 9.7 meters (see Figure 141e). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at John Wells Lake with 42% of the water column being anoxic at site 1 in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected two (20%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.47 mg/L at the lake surface. The TN at the surface ranged from 0.27 mg/L to 1.05 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.013 mg/L at the lake surface and 0.022 mg/L on the lake bottom. The surface TP ranged from 0.010 mg/L to 0.017 mg/L. The highest surface TP value was reported in the summer quarter and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 36:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, John Wells Lake was classified as mesotrophic, indicative of moderate productivity and nutrient conditions (Plate 62). Water clarity was excellent based on true color, turbidity, and secchi disk depth. Both true color and trophic status were fully supporting the Aesthetics beneficial use. John Wells Lake was fully supporting the FWP beneficial use based on pH and D.O. values recorded during the study period. The lake was also fully supporting the FWP beneficial use for turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected two (20%) exceeded the prescribed screening level of 61 cfu/ml for enterococci, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. John Wells Lake is owned and operated by the City of Stigler and is used as a municipal water supply for Stigler and provides numerous recreational opportunities for the public.

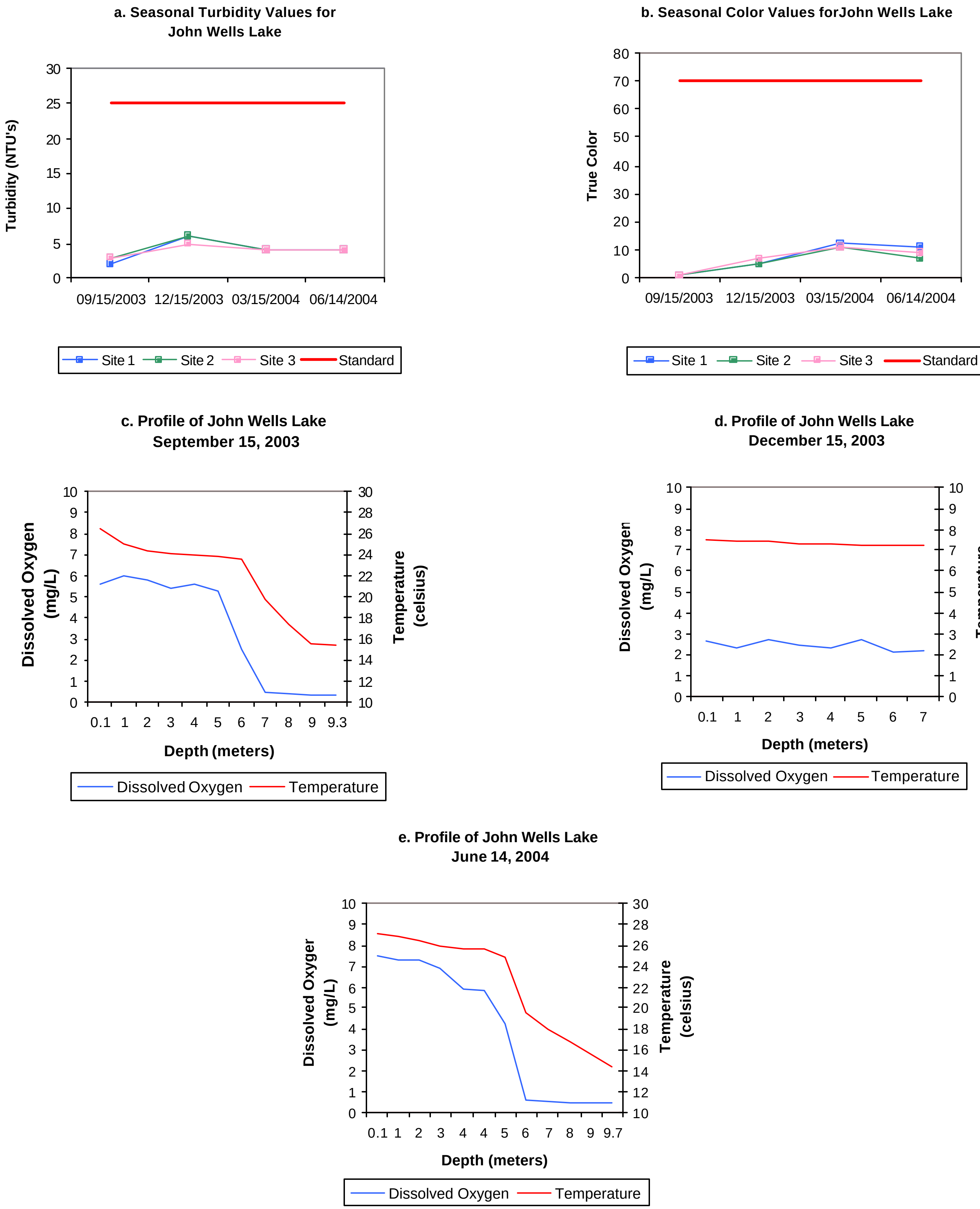
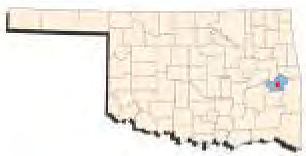
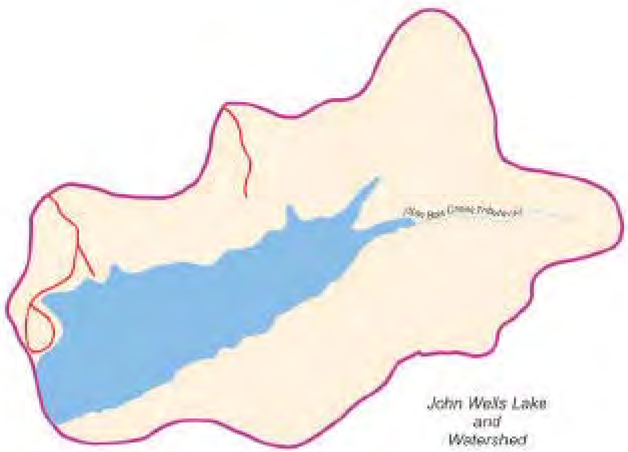
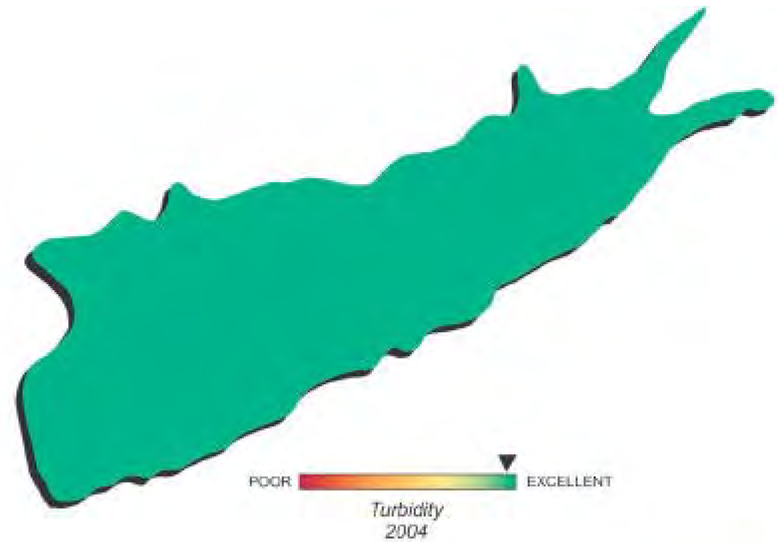


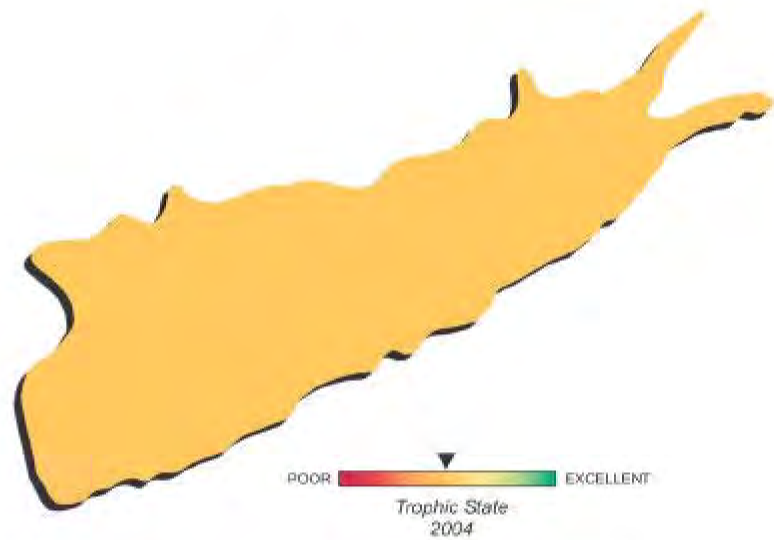

**Figure 141a-141f.** Graphical representation of data results for John Wells Lake.








Lake Data

| | |
|---|---|
| Owner | City of Stigler |
| County | Haskell |
| Constructed in | 1936 |
| Surface Area | 194 acres |
| Volume | 1,352 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 6.97 feet |
| Watershed Area | 961 acres |

Plate 62 - Lake Water Quality for
## John Wells Lake

# Kaw Lake

Kaw Lake was sampled for four quarters from October 2002 through July 2003. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones and arms of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 132 NTU (Plate 63), true color was 94 units, and average secchi disk depth was 42 centimeters. Based on these three parameters Kaw Lake had fairly poor water clarity in sample year 2002-2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 53 (Plate 63), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient conditions. This value is consistent with that from 2000 (TSI=54), therefore no significant change in productivity has occurred since the last evaluation. Seasonal TSI values varied by site and season and spanned all trophic categories in sample year 2003. In the fall, winter, and spring sampling quarters values were generally oligotrophic to mesotrophic. In the spring, values ranged from oligotrophic at sites 1 and 2, to mesotrophic at site 4, eutrophic at site 3, and hypereutrophic at site 5 (Figure 142). TSI values in the summer were all eutrophic to hypereutrophic. The highest values throughout the year occurred at site 5 in the upper end of the reservoir. Seasonal turbidity values per site are displayed in Figure 143a. Turbidity ranged from a bw of 12 NTU to a maximum of 1158 NTU in 2003. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 65% of the recorded values exceeding the OWQS of 25 NTU, Kaw Lake is not supporting its Fish and Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 143b. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is not supported with 35% of the true color values exceeding the OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.75 ppt. This is higher than most values reported for Oklahoma lakes. Specific conductivity ranged from 234.3 mS/cm to 1415 mS/cm indicating

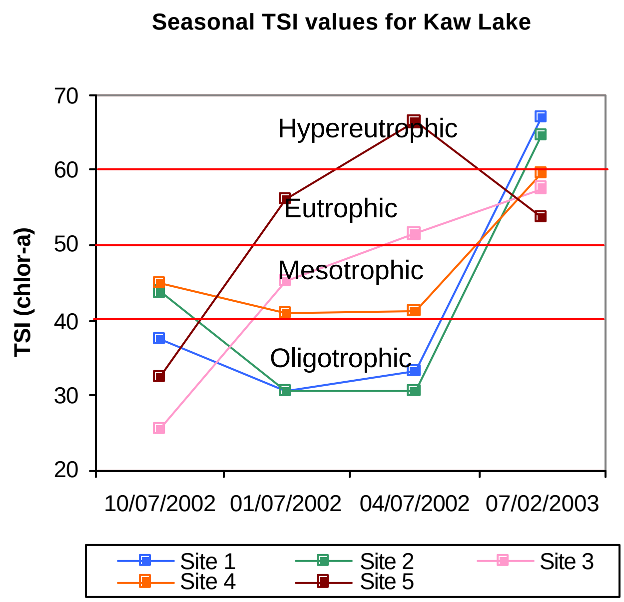



**Figure 142.** TSI values for Kaw Lake.

that very high concentrations of electrical current conducting compounds (salts) were present in the lake system, consistent with the elevated salinity readings. The lowest salinity and specific conductivity values occurred at sites 3 and 5 in the Arkansas River arm during the fall. The highest recorded values also were reported at sites 3 and 5 during the other three sampling quarters. The pH values at Kaw Lake ranged from 6.47 to 8.39, representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With only 1 (0.3%) of the collected values falling outside the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 80 mV to 537 mV. In general, reducing conditions were not present at this reservoir. During the fall, winter, and spring quarters, stratification was not present and the lake was well mixed with dissolved oxygen (D.O.) levels generally above 5.0 mg/L (Figure 143c-143e). Thermal stratification was evident in the summer and anoxic conditions were present. In the summer stratification occurred at several 1-meter intervals throughout the lake with 25 to 66% of the water column experiencing anoxic conditions (Figure 143f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Kaw Lake, with 25 to 66% of the water column below 2.0 mg/L in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.80 mg/L at the surface and 1.81 mg/L at the lake bottom. Surface TN ranged from 1.26 mg/L to 2.73 mg/L, with both the highest and lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.226 mg/L at the surface and 0.202 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.117 mg/L to 0.800 mg/L. Surface TP was highest in the winter and lowest during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Kaw Lake was classified as eutrophic, indicative of high levels of primary productivity and nutrient conditions. This value is consistent with that from the 2000 (TSI=54), therefore no significant change in productivity has occurred since the last evaluation. Water clarity was fairly poor at Kaw Lake based on true color, secchi disk depth and high turbidity readings. The lake is partially supporting the FWP beneficial use based on dissolved oxygen and pH, but not supporting based on turbidity. The Aesthetics beneficial use is supported based on its trophic status, but not supported based on true color with 35% of the collected values exceeding the OWQS of 70 units. The United States Army Corps of Engineers (USACE) constructed Kaw Lake for the purpose of flood control, water supply and quality, recreation and fish and wildlife. The lake is located in Osage County approximately 8 miles east of Ponca City.

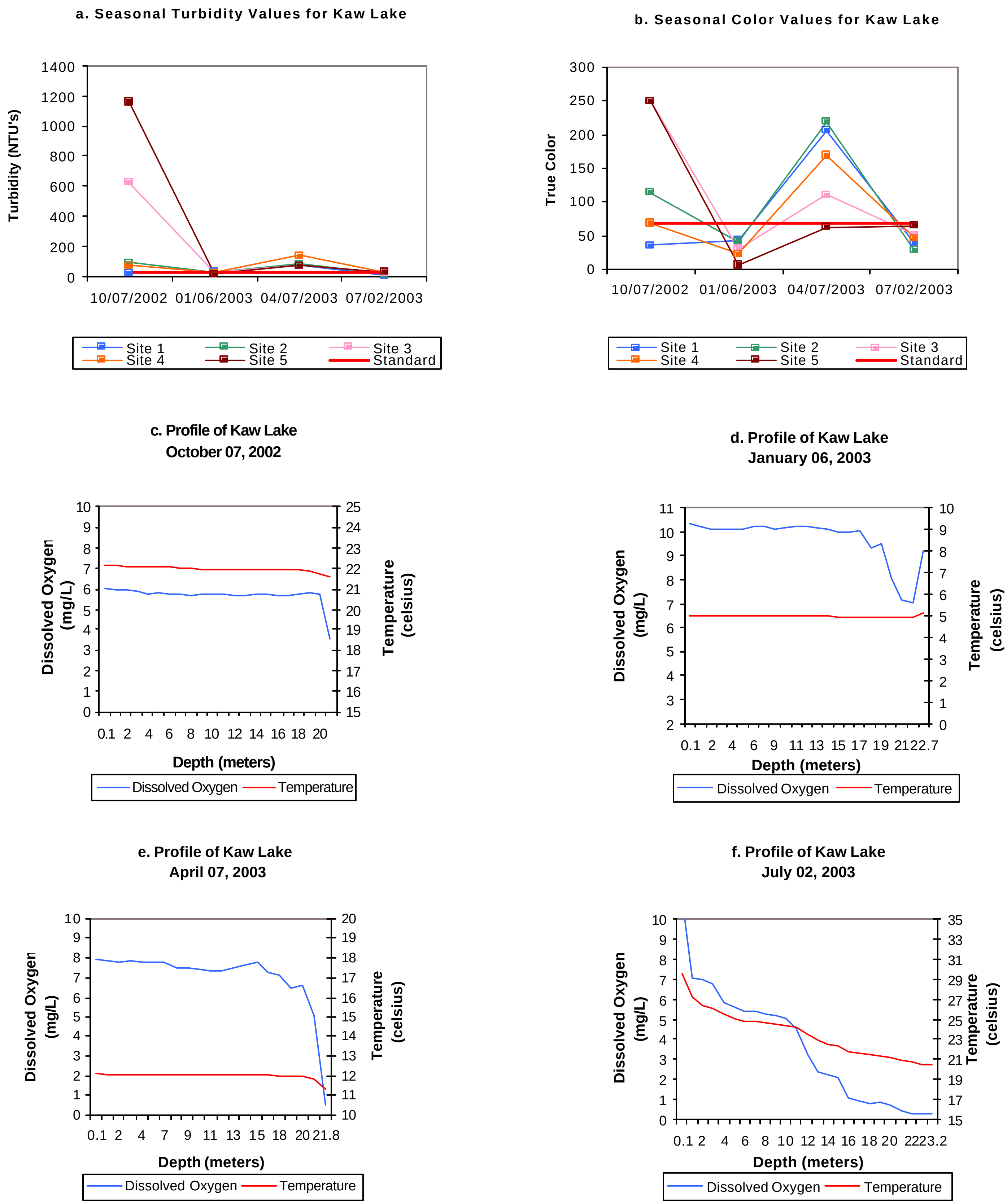
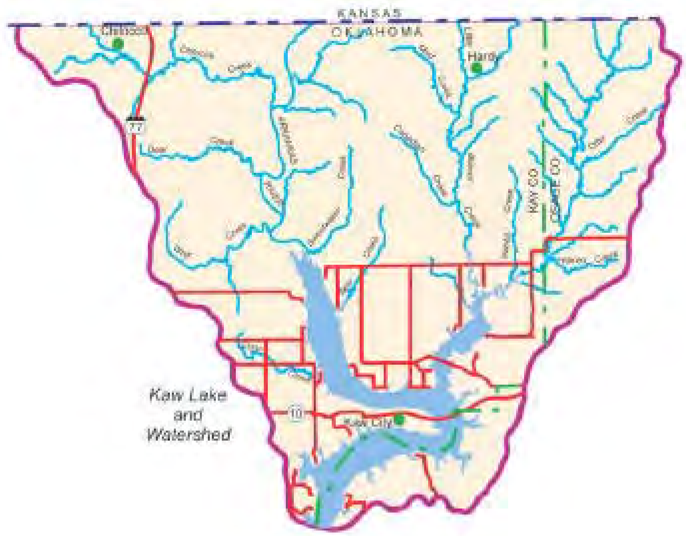
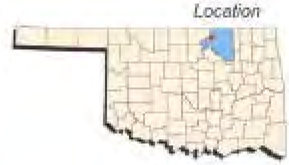


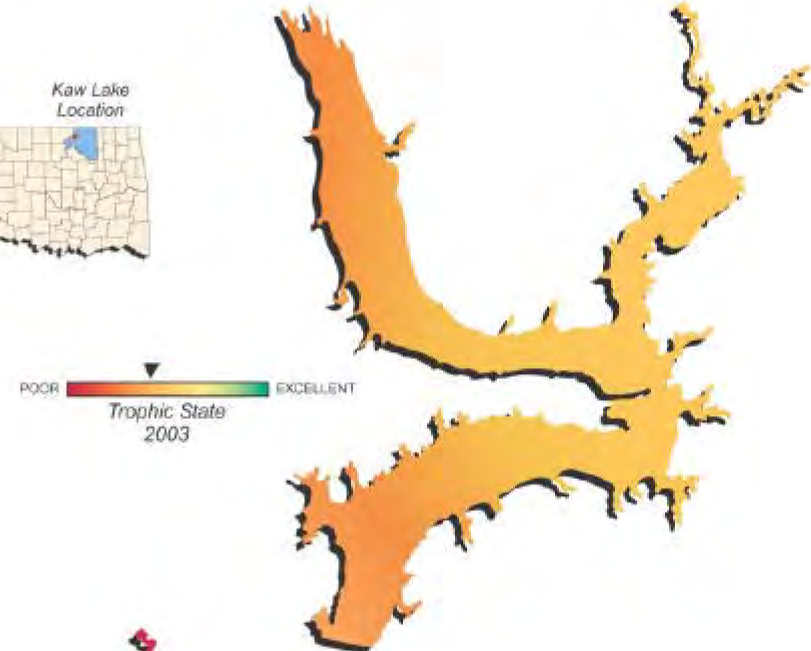

**Figure 143a-143f.** Graphical representation of data results for Kaw Lake.




Kaw Lake and Watershed



Kaw Lake Location




Trophic State 2003


Turbidity 2003


Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Osage |
| Constructed in | 1976 |
| Surface Area | 17,040 acres |
| Volume | 428,600 acre/feet |
| Shoreline Length | 168 miles |
| Mean Depth | 25.21 feet |
| Watershed Area | 46,530 square miles |

Plate 63- Lake Water Quality for
## Kaw Lake

# Keystone Lake

Keystone Lake was sampled for four seasons, from September 2003 through June 2004. Water quality samples were collected at twelve (12) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as major arms of the lake. Samples were collected from the lake surface at all 12 sites as well as 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 162 NTU (Plate 64), true color was 66 units, and secchi disk depth was 37 centimeters in 2003-2004. Based on these three parameters, Keystone Lake had fair to poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=48). The average TSI was 56 (Plate 64), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. The TSI values were oligotrophic in the fall and winter nearest the dam area (1,6) and eutrophic or hypereutrophic in the rest of the lake (see Figure 144). In the spring and summer quarters the vast majority of the lake was either eutrophic or hypereutrophic in nature. The sites in the upper most reaches of the lake (5, 11, and 12) were the most productive throughout the entire year. The turbidity values in 2004 were quite high with 58% of the total values exceeding the OWQS of 25 NTU (see Figure 145a). Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is due to seasonal storm events, however even when the spring data is excluded 50% of the remaining values (n=36) are still greater than 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered partially supported if 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Keystone is not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 145b. Similar to turbidity, a significant peak in true color was observed in the spring quarter. Exluding the spring data only 5% of the true color values were above the numeric criteria of 70 units, the Aesthetics beneficial use is considered supported.

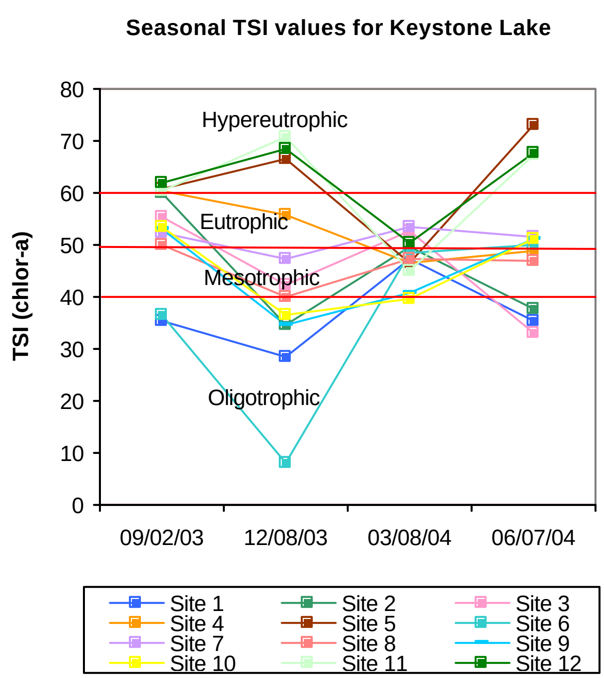



**Figure 144.** TSI values for Keystone Lake.

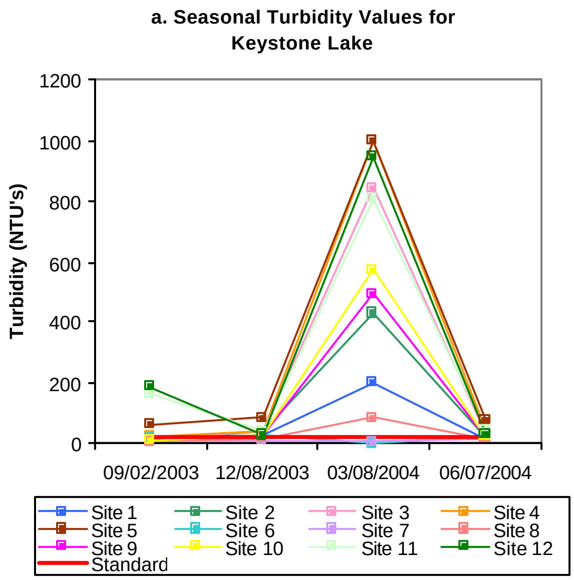
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.12 to 3.86 parts per thousand (ppt) indicating low to very high salt content within the lake depending where the sample site was located. In general, salinity values are very high in the Cimarron River arm of the reservoir, especially in the spring with rainfall runoff events occurring. Salinity readings across the entire lake were higher than the normal range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also very high, ranging from 259.1 mS/cm to 6946 mS/cm, indicating extremely high amounts of electrical current conducting compounds (salts) in the lake system throughout the year. Keystone Lake continues to live up to its historical reputation as one of the "saltiest" lakes in Oklahoma. In general, pH values were slightly neutral to alkaline, ranging from 6.75 to 8.59 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of pH values falling within the acceptable range the lake was fully supporting its FWP beneficial use as it relates to turbidity. Oxidation-reduction potentials (redox) ranged from 290 mV at the sediment-water interface in the winter to 680mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir during the study period. In the fall the lake was weakly thermally stratified and dissolved oxygen (D.O.) was 5.0 mg/L or less among all the sites. At site 1 the lake was stratified between 10 and 11 meters below the surface, at which point D.O. was less than 2.0 mg/L to the lake bottom of 18 meters (Figure 145c). The lake was not thermally stratified in winter or spring quarters and dissolved oxygen (D.O.) values remained were generally above 5.0 mg/L throughout the majority of the water column (see Figure 145d-145e). In the summer, the lake was not thermally stratified but appeared to be chemically stratified between 14 and 15 meters below the lake surface and D.O. values from the 15 meter depth to the lake bottom of 20 meters at site 1 were less than 2.0 mg/L (see Figure 145f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Keystone Lake with only 42% of the water column experiencing anoxic conditions in the fall and 32% in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

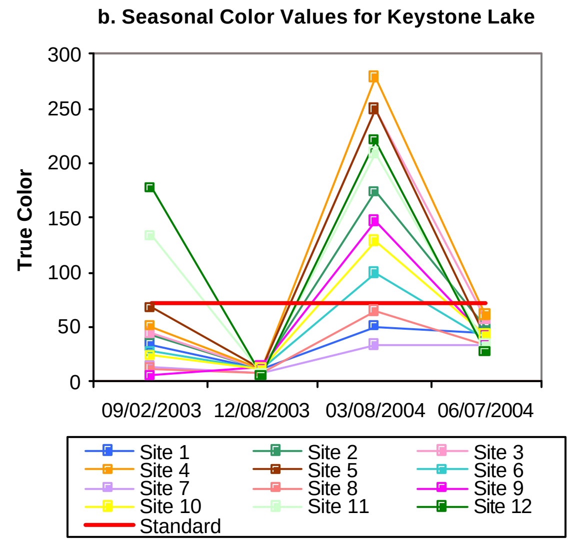
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected six (60%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (78.5) exceeds the prescribed geometric mean of 33 for enterococci. The PBCR beneficial use is therefore considered not supported.

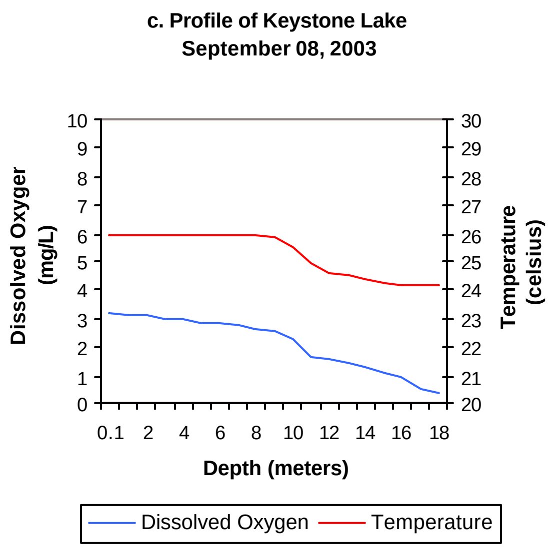
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.49 mg/L at the lake surface and 1.52 mg/L at the lake bottom. The TN at the surface ranged from 0.31 mg/L in the winter to 4.31 mg/L in the spring quarter. The lake-wide total phosphorus (TP) average was 0.206 mg/L at the lake surface and 0.174 mg/L at the lake bottom. The surface TP ranged from 0.060 mg/L in the winter quarter to 0.940 mg/L in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 7:1. This value is the same as 7:1, characterizing the lake possible co-limited (Wetzel, 1983).

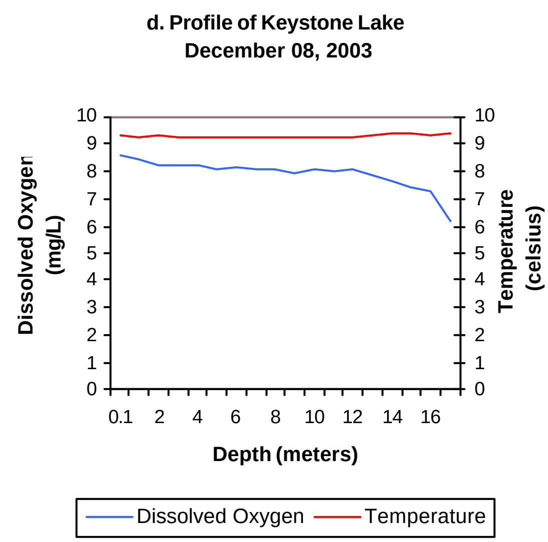
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

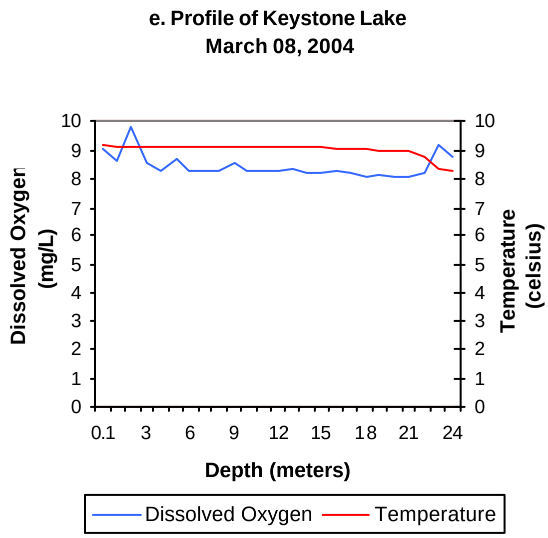
In summary, Keystone Lake was classified as eutrophic, indicative of excessive productivity and nutrient levels (Plate 64). This is lower than the TSI calculated in 2002(TSI=62) and may be the result of the increase in turbidity seen during the current study period. The lake is fully supporting its Aesthetics use based trophic status and true color. Keystone is fully supporting its FWP beneficial use based on D.O. and pH values, but is not supporting based on extremely high turbidity values. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is due to seasonal storm events, however even when the spring data is excluded 50% of the remaining values (n=36) are still greater than 25 NTU. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected six (60%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (78.5) exceeds the prescribed geometric mean of 33 for enterococci. The PBCR beneficial use is therefore considered not supported. Keystone Lake is managed by the United States Army Corps of Engineers and was constructed in 1964 to serve as a flood control, water supply, hydroelectric power, navigation, and fish and wildlife resource.



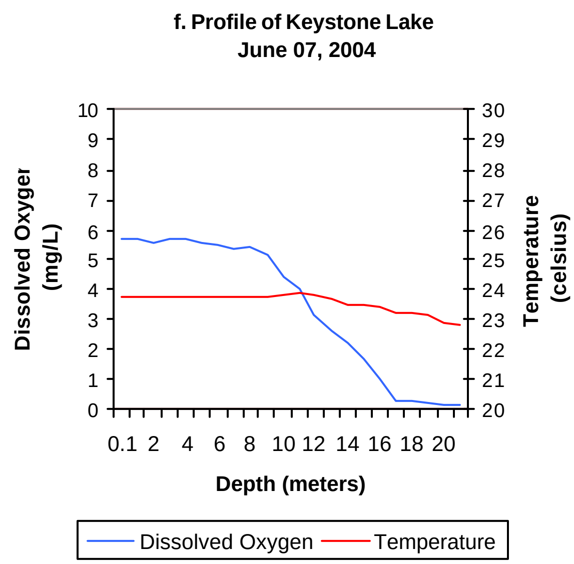
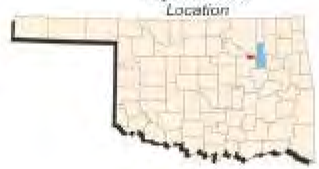




**Figure 145a-145 f.** Graphical representation of data results for Keystone Lake.

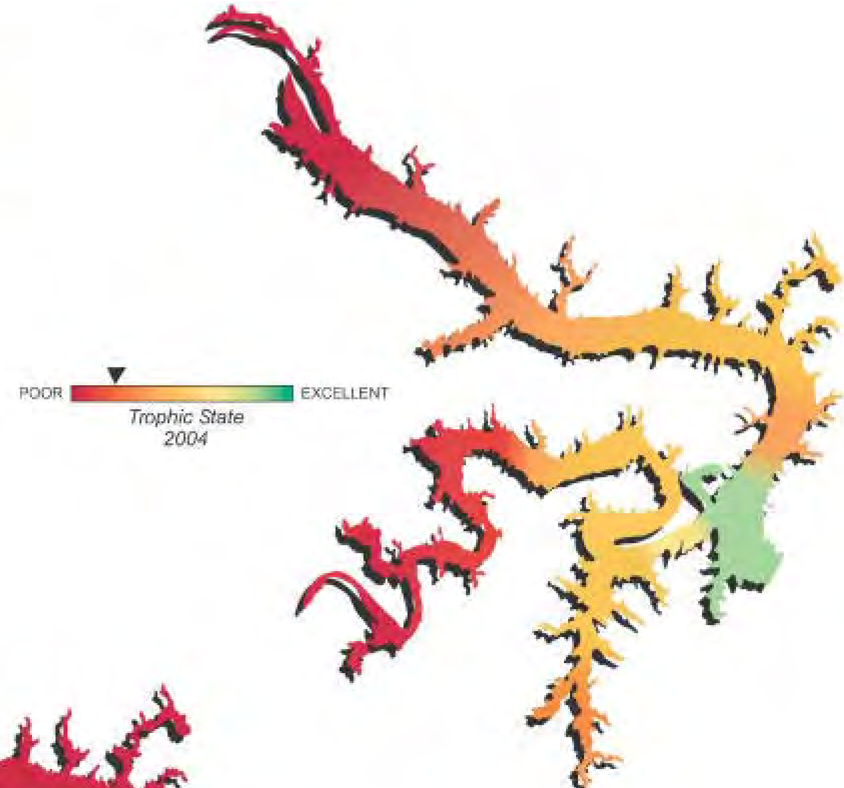
Plate 64 - Lake Water Quality for

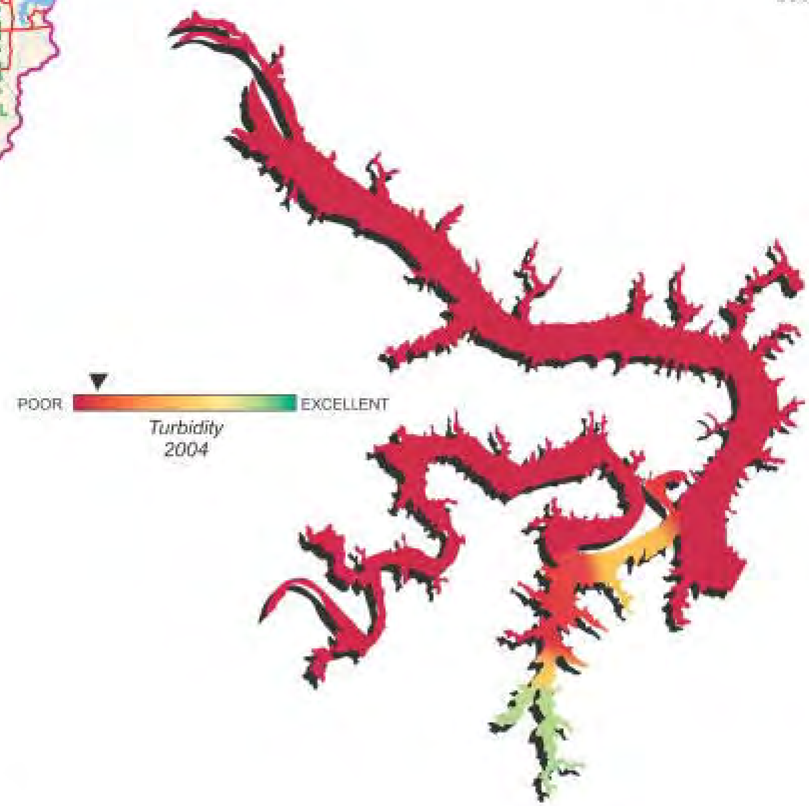
# Keystone Lake


Keystone Lake and Watershed



Keystone Lake Location




Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Tulsa |
| Constructed in | 1964 |
| Surface Area | 23,610 acres |
| Volume | 557,600 acre/feet |
| Shoreline Length | 330 miles |
| Mean Depth | 23.62 feet |
| Watershed Area | 74,506 square miles |

# Konawa Reservoir

Konawa Reservoir was sampled for three seasons, from November 2001 through May 2002. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. However, the chemistry samples collected for analysis at the contract laboratory were not run in he summer quarter due to an accident which decreased the available data set to make use support determinations. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 6 NTU (Plate 65), true color was 26 units, and secchi disk depth was 90 centimeters in 2001-2002. Based on these three parameters, Konawa Reservoir had good to excellent water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=15). The average TSI was 54 (Plate 65), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. The TSI values were constant from season to season in the eutrophic range with only a small number of instances where the lake was classified in the upper end of mesotrophy (see Figure 146). The turbidity values collected on the lake were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 147a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With no violations of the criteria detected Konawa Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it pertains to turbidity. Seasonal true color values are displayed in Figure 147b. All of the true color values were below the numeric criteria of 70 units, however, a definitive determination of the Aesthetics beneficial use cannot be made as insufficient data was available due to lack of information for the summer quarter. Collected data strongly suggests that the lake would be supporting its Aesthetics beneficial use related to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.53 parts per thousand (ppt) to 0.55 ppt much higher than the range of values normally seen for Oklahoma reservoirs. Values indicated high salt content and were much higher than the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were elevated above the expected range normally seen in most Oklahoma reservoirs with values ranging from 1015 mS/cm to 1053 mS/cm, indicating the substantial presence of electrical current conducting compounds (salts) in the water column throughout the year. These values were also paralleled by the salinity values to some extent. In general, pH values were slightly alkaline to neutral, ranging from 6.94 to 8.43

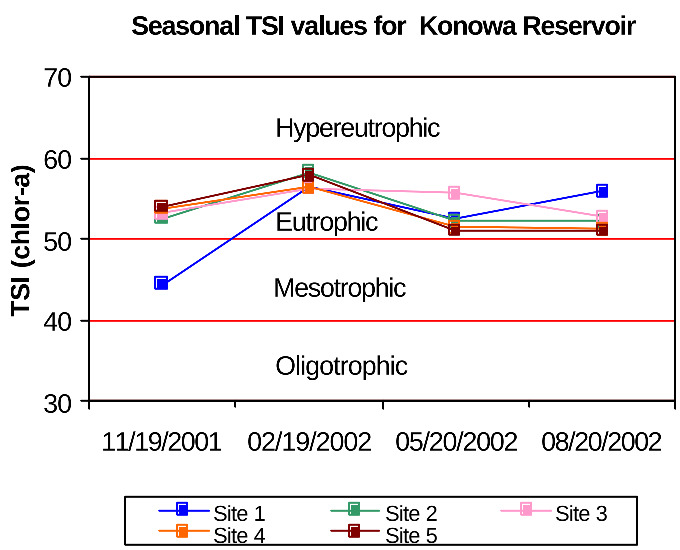



**Figure 146.** TSI values for Konawa Reservoir.

units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Konawa Reservoir is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from –66 mV at the sediment-water interface in the summer to 571 mV also recorded in the summer. Redox readings indicated that reducing conditions were not present in the reservoir to any appreciable degree. The lake was not thermally stratified in the fall, winter, or spring and dissolved oxygen (D.O.) values were above 3.0 mg/L throughout the water column at all sites and were generally above 6.0 mg/L except near the lake bottom (see Figure 147c-147e). In the summer, the lake exhibited weak thermal stratification in the bottom 2 or 3 meters of the water column with 25% of the values collected at site 1 less than 2.0 mg/L (see Figure 147f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Konawa Reservoir based on D.O. readings in the water column.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.75 mg/L at the lake surface. The TN at the surface ranged from 0.52 mg/L in the spring quarter to 1.04 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.078 mg/L at the lake surface. The surface TP ranged from 0.028 mg/L in the spring to 0.160 mg/L in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Konawa Reservoir was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column.

In summary, Konawa Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 65). Konawa Reservoir was meeting its FWP beneficial use for pH, turbidity, and D.O. Konawa Reservoir was meeting its Aesthetics beneficial use for nutrients and true color could not be assessed due to insufficient information. Konawa Reservoir was constructed in 1968 and is owned and operated by the Oklahoma Gas & Electric Company. Although it serves as a cooling reservoir it offers numerous recreational opportunities for the public.

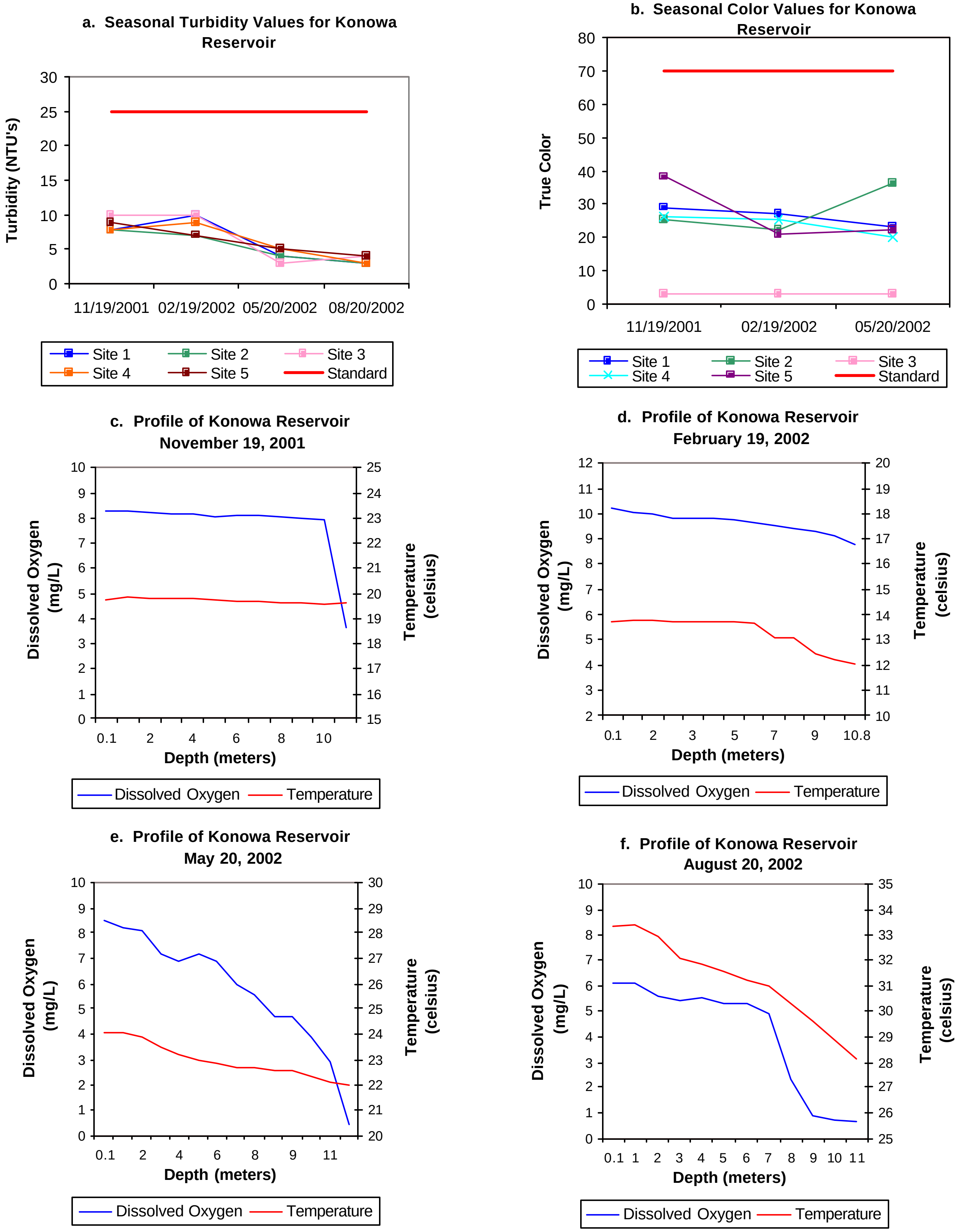
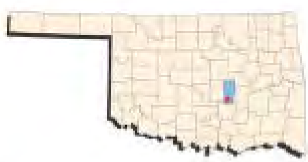



**Figure 147a-147f.** Graphical representation of data results for Konawa Reservoir.


Konawa Lake
and
Watershed



Konawa Lake
Location

N
W
E
S

| Lake Data | |
|---|---|
| Owner | Oklahoma Gas & Electric Co. |
| County | Seminole |
| Constructed in | 1968 |
| Surface Area | 1,350 acres |
| Volume | 23,000 acre/feet |
| Shoreline Length | 20 miles |
| Mean Depth | 17.04 feet |
| Watershed Area | 12 square miles |


Turbidity
2002


Trophic State
2002

Plate 65 - Lake Water Quality for
## Konawa Lake

# Langston Lake

Langston Lake was sampled for four seasons, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the lake. Samples were collected at all sites from the lake surface and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 11 NTU (Plate 66), true color was 12 units, and secchi disk depth was 103 centimeters. Based on these three parameters, Langston Lake had excellent water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 47 (Plate 66), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This finding is very similar to that of 2002 (TSI=44), indicating that no significant increase or decrease in productivity has occurred over time. The TSI values were consistently mesotrophic throughout all four quarters sampled 2003-2004 (see Figure 148). All turbidity values collected were less than the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 149a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 10% of the collected turbidity values exceeding the OWQS, Langston Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 149b. All of the true color values were below the numeric criteria of 70 units. Applying the same default protocol, the Aesthetics beneficial is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.15 parts per thousand (ppt) to 0.18 ppt, which is within the expected range of salinity values, reported for most Oklahoma lakes. Readings for specific conductivity ranged from 304.3 mS/cm to 365.9 mS/cm, indicating that low to moderate amounts of electrical current conducting compounds. (salts) were present in the water column. In general, pH values were neutral to slightly alkaline, ranging from 7.35 to 8.48 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all pH values falling within the acceptable range of values the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 47 mV at the sediment-water interface in the spring to 507 mV recorded in the winter quarter. Redox

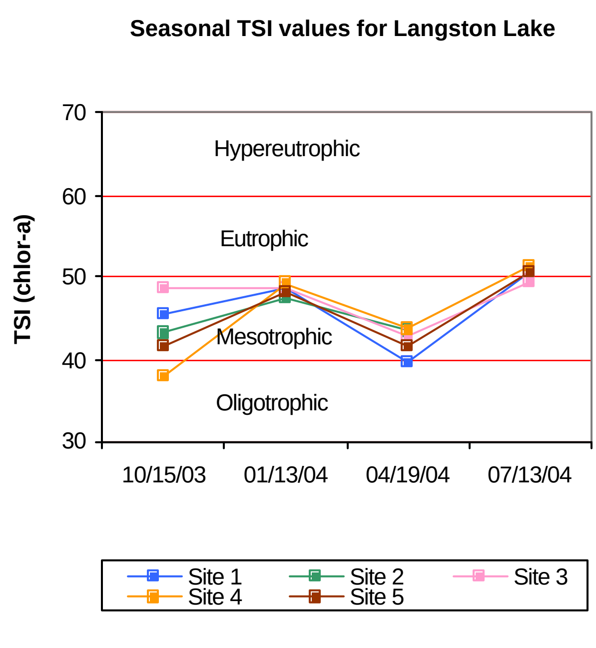



**Figure 148.** TSI values for Langston Lake.

readings indicated that reducing conditions were not present in the reservoir at any point during the sample season. The lake was not thermally stratified in either the fall , winter or spring quarters and dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column at all sites (see Figure 149c-149e). In the summer, the lake was stratified between 5 and 6 meters and below 6 meters; D.O. values were less than 1.0 mg/L to the lake bottom at 11.7 meters at site 4 (see Figure 149f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Langston Lake because 42% of the water column was anoxic at site 1 in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.40 mg/L at the lake surface. The TN at the surface ranged from 0.12 mg/L in the spring quarter to 0.75 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average was 0.014 mg/L at the lake surface. The surface TP ranged from 0.010 mg/L in the winter quarter to 0.018 mg/L in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 28:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Langston Lake was classified as mesotrophic, indicative of moderate productivity and nutrient levels (Plate 66). This is the same classification given in 2001-2002, which indicates little to no change in productivity has occurred over time. Water clarity was excellent based on true color, turbidity, and secchi disk depth. The lake was meeting its FWP beneficial use at it relates to turbidity, pH, and D.O. readings collected during the study period. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml for enterococci, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Langston Lake was constructed in 1966 and is owned and operated by the City of Langston. The lake serves as a municipal water supply for the city and also serves as a flood control structure. The lake also offers many recreational opportunities for the public.

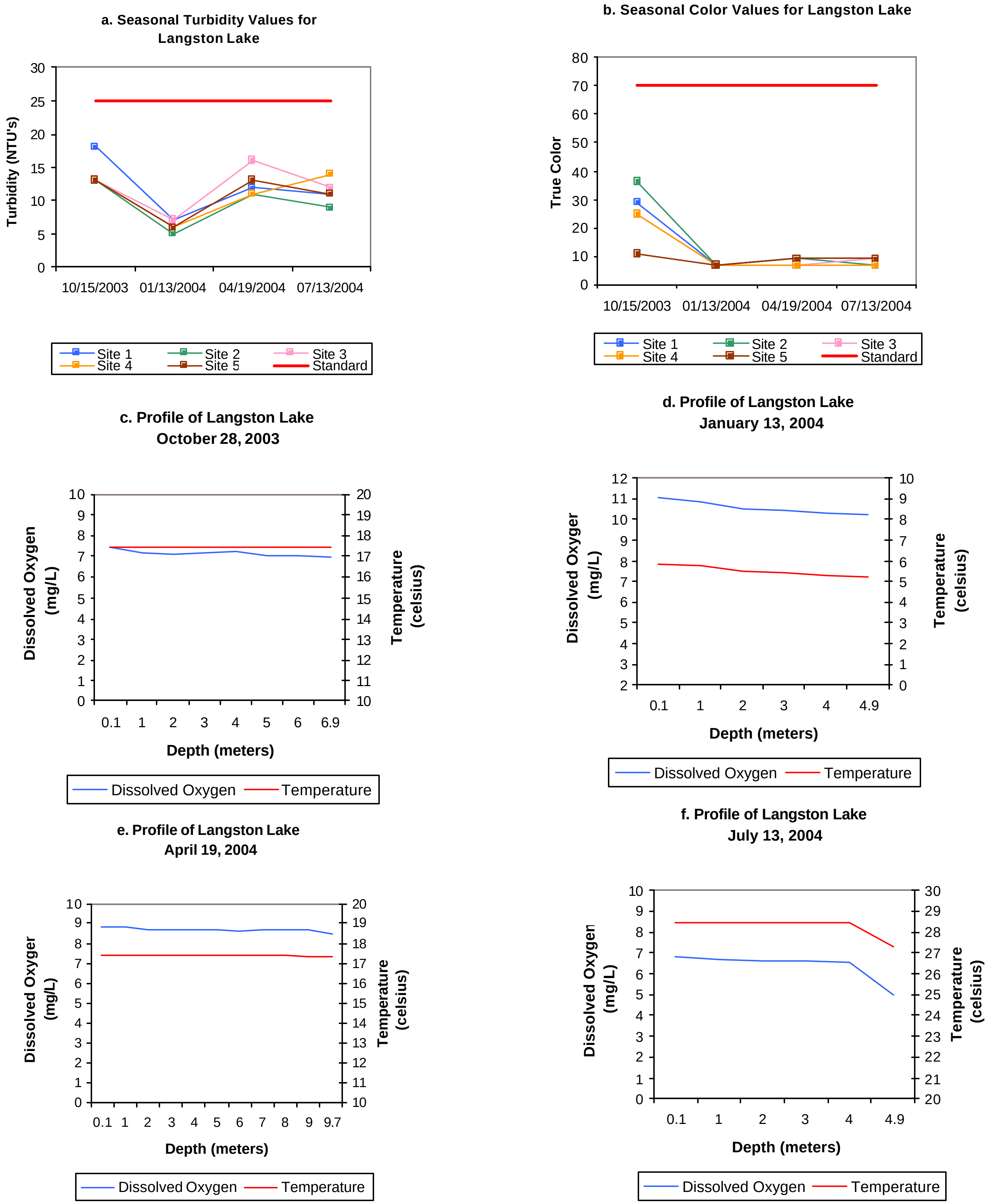
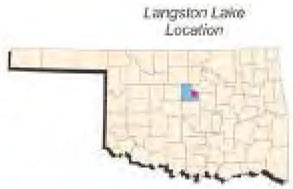



**Figure 149a-149f.** Graphical representation of data results for Langston Lake.



| Lake Data | |
|---|---|
| Owner | City of Langston |
| County | Logan |
| Constructed in | 1966 |
| Surface Area | 304 acres |
| Volume | 5,792 acre/feet |
| Shoreline Length | 8 miles |
| Mean Depth | 19.05 feet |
| Watershed Area | 3798 acres |



Plate 66 - Lake Water Quality for
Langston Lake

# Lake Lawtonka

Lake Lawtonka was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as any major arms of the lake. Samples were collected from the lake surface with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 7 NTU (Plate 67), true color was 12 units, and secchi disk depth was 102 centimeters. Based on these three parameters, Lake Lawtonka had good water clarity in comparison to other Oklahoma reservoirs. Results were similar if not slightly better than that of the previous evaluation. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 58 (Plate 67), classifying the lake as eutrophic with high primary productivity and nutrient conditions. Results in 2002 were very similar (TSI=53), indicating no significant increase or decrease in productivity has occurred. The TSI values were primarily eutrophic to the lower end of hypereutrophy (see Figure 150). Site 1 was the only site to have a mesotrophic value, which occurred in the spring quarter. The turbidity values for Lake Lawtonka were all less than the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 151a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Lawtonka is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity values. Seasonal true color values are displayed in Figure 151b. All of the true color values were well below the numeric criteria of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values.

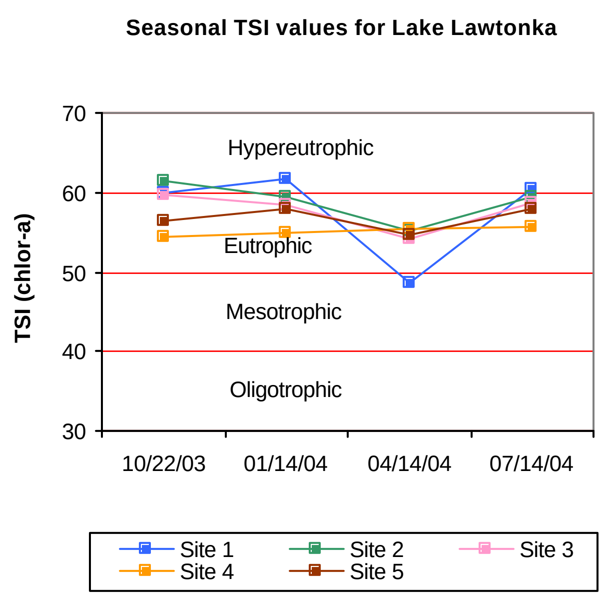



**Figure 150.** TSI values for Lake Lawtonka.

Vertical profiles for dissolved oxygen; pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five (5) sample sites. Salinity values ranged from 0.19 parts per thousand (ppt) to 0.23 ppt and were within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also within the range of expected values for Oklahoma lakes, ranging from 386.5 mS/cm to 464.1 mS/cm, indicating moderate levels of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline, ranging from 7.29 in the summer to 8.55 units in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. None of the collected pH values were outside the acceptable range. Lake Lawtonka is fully supporting its FWP beneficial use based on pH values recorded during the study period. Oxidation-reduction potentials (redox) ranged from 171 mV to 529 mV. Redox readings indicated that reducing conditions were not present in the reservoir at any time in an appreciable way. The lake was not thermally stratified in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values were generally above 5.0 mg/L throughout most of the water column. (See Figure 151c-151e). In the summer, the lake was thermally stratified between 8 and 9 meters below the lake surface. D.O. readings below 9 meters were less than 2.0 mg/L extending all the way to the lake bottom at 16 meters at site 1 (see Figure 151f). Stratification and anoxic conditions were also present at sites 2 and 3. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lake Lawtonka with 47% of the water column experiencing anoxic conditions at site 1 during the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected four (40%) exceeded the prescribed screening level of 61 cfu/ml for enterococci, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.61 mg/L at the lake surface and 0.61 mg/L at the lake bottom. The TN at the surface ranged from 0.25 mg/L in the spring quarter to 0.92 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average was 0.028 mg/L at the lake surface and 0.055 at the lake bottom. The surface TP ranged from 0.022 mg/L in the spring quarter to 0.036 mg/L in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1996 and 1997 as part of their Toxics Monitoring Program and detected no compounds at the FDA Action level, ODEQ warning level or ODEQ concern level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Lawtonka was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 67). Water clarity is good based on true color, turbidity and secchi disk depth. Lake Lawtonka was fully supporting the FWP beneficial use based on turbidity, pH and D.O. values recorded during the study period. The lake was also fully supporting its Aesthetics beneficial use based on true color values and its trophic status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected four (40%) exceeded the prescribed screening level of 61 cfu/ml for enterococci, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Lake Lawtonka is the municipal water supply for the City of Lawton and is owned and operated by the city. The lake is also provides numerous recreational activities for the citizens of Oklahoma.

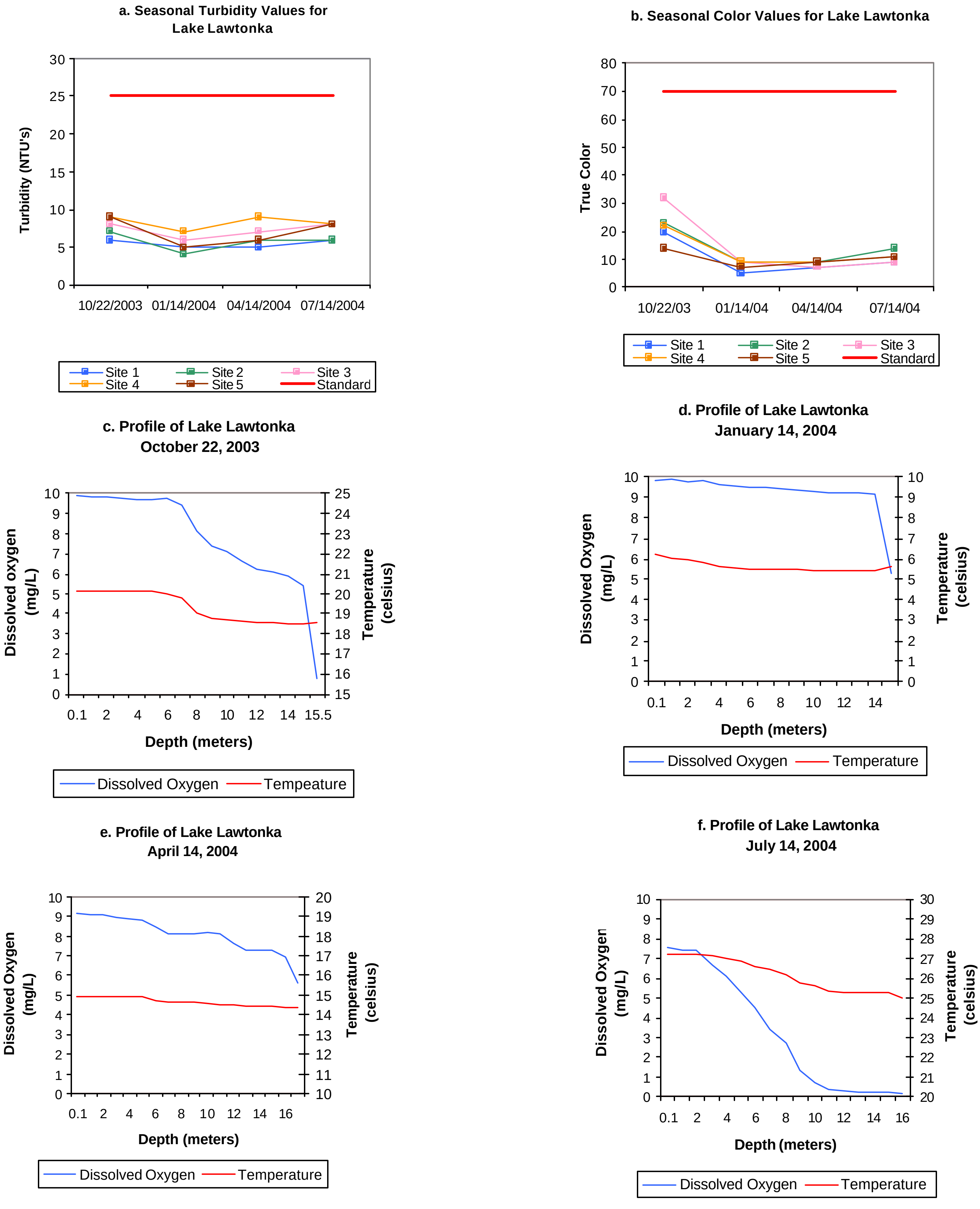
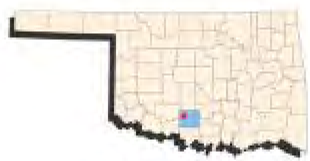



**Figure 151a-151f.** Graphical representation of data results for Lake Lawtonka.







Lake Data

| | |
|---|---|
| Owner | City of Lawton |
| County | Comanche |
| Constructed in | 1905 |
| Surface Area | 2,398 acres |
| Volume | 55,574 acre/feet |
| Shoreline Length | 21 miles |
| Mean Depth | 23.59 feet |
| Watershed Area | 92 square miles |

Plate 67 - Lake Water Quality for
Lake Lawtonka

# Liberty Lake

Liberty Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 16 NTU (Plate 68), true color was 16 units, and secchi disk depth was 55 centimeters. Results were similar to that of the 2002 evaluation. Based on these three parameters, Liberty Lake had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for all quarters (n=12). The average TSI was 56 (Plate 68), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This is consistent with the 2001-2002 evaluation (TSI=55), indicating no significant increase or decrease in productivity has occurred over time. The TSI values were consistently in the eutrophic range for every quarter sampled fluctuating between lower and upper eutrophy (see Figure 152). Site 3 was the most variable site with a hypereutrophic reading in the fall and a mesotrophic reading in the summer quarter. The turbidity values for the lake were all below the Oklahoma Water Quality Standard (OWQS) of 25 NTU except for two values recorded in fall and spring quarters for site 3 at the upper end of the lake (see Figure 153a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Liberty Lake is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity concentrations in the lake as only 16.7% of the collected values exceeded the criteria. Seasonal true color values are displayed in Figure 153b. All of the true color values recorded were below the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered fully supported as it relates to true color.

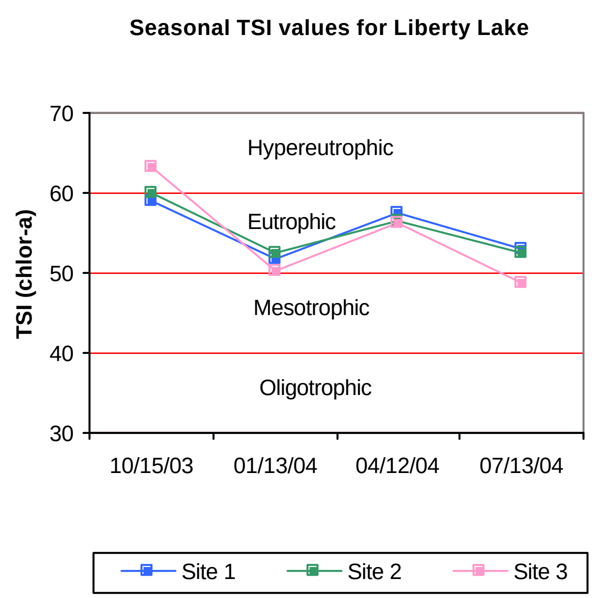



**Figure 152.** TSI values for Liberty Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.23 parts per thousand (ppt) to 0.29 ppt, which is higher than the expected range of values for Oklahoma lakes indicating above average salt content levels. Readings for specific conductance ranged from 464.2 mS/cm to 559.5 mS/cm, indicating the presence of moderate levels of electrical current conducting compounds (salts) in the water column throughout the year. These values were also paralleled by the recorded salinity values. In general, pH values were neutral to slightly alkaline in nature, ranging from 7.69 units in the spring quarter to 8.53 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All pH values collected on Liberty Lake were within the allowable range therefore the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 325 mV at the sediment-water interface in the fall to 544 mV recorded in the winter quarter. Redox readings indicated that reducing conditions were not present in the reservoir during the sample year. The lake was not thermally stratified in the fall, winter or spring quarters and the dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column at all sites and times (see Figure 153c-153e). In the summer, the lake was strongly thermally stratified between 2 and 3 meters and at 4 meters below the surface the D.O. values were less than 2.0 mg/L and remained so all the way to the lake bottom at 5 meters at site 1 (see Figure 153f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Liberty Lake with approximately 33% of the water column less than 2.0 mg/L at site 1 in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected eight (80%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (220.3) exceeds the prescribed geometric of 33 for enterococci. Twenty percent of the *E.coli* samples exceeded the screening level of 235 cfu/mL. The PBCR beneficial use is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.74 mg/L at the lake surface. The TN at the surface ranged from 0.30 mg/L recorded in the spring quarter to 1.18 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average was 0.040 mg/L at the lake surface. The surface TP ranged from 0.028 mg/L in the winter quarter to 0.062 mg/L recorded in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 19:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Liberty Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 68). This is consistent with the 2001-2002 evaluation (TSI=55), indicating no significant increase or decrease in productivity has occurred over time. Based on true color, turbidity and secchi disk depth, water clarity was good at Liberty Lake. The lake is meeting its FWP beneficial use for dissolved oxygen and pH, but partially supporting for turbidity, with

16.7% of the values exceeding the OWQS of 25 NTU. Liberty Lake was fully supporting its Aesthetics beneficial use for both true color and trophic status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected eight (80%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (220.3) exceeds the prescribed geometric of 33 for enterococci. Twenty percent of the *E.coli* samples exceeded the screening level of 235 cfu/mL. The PBCR beneficial use is therefore considered not supported. Liberty Lake was constructed in 1948 and a municipal water supply for the City of Guthrie. The lake is also used as a recreational outlet for the general public.

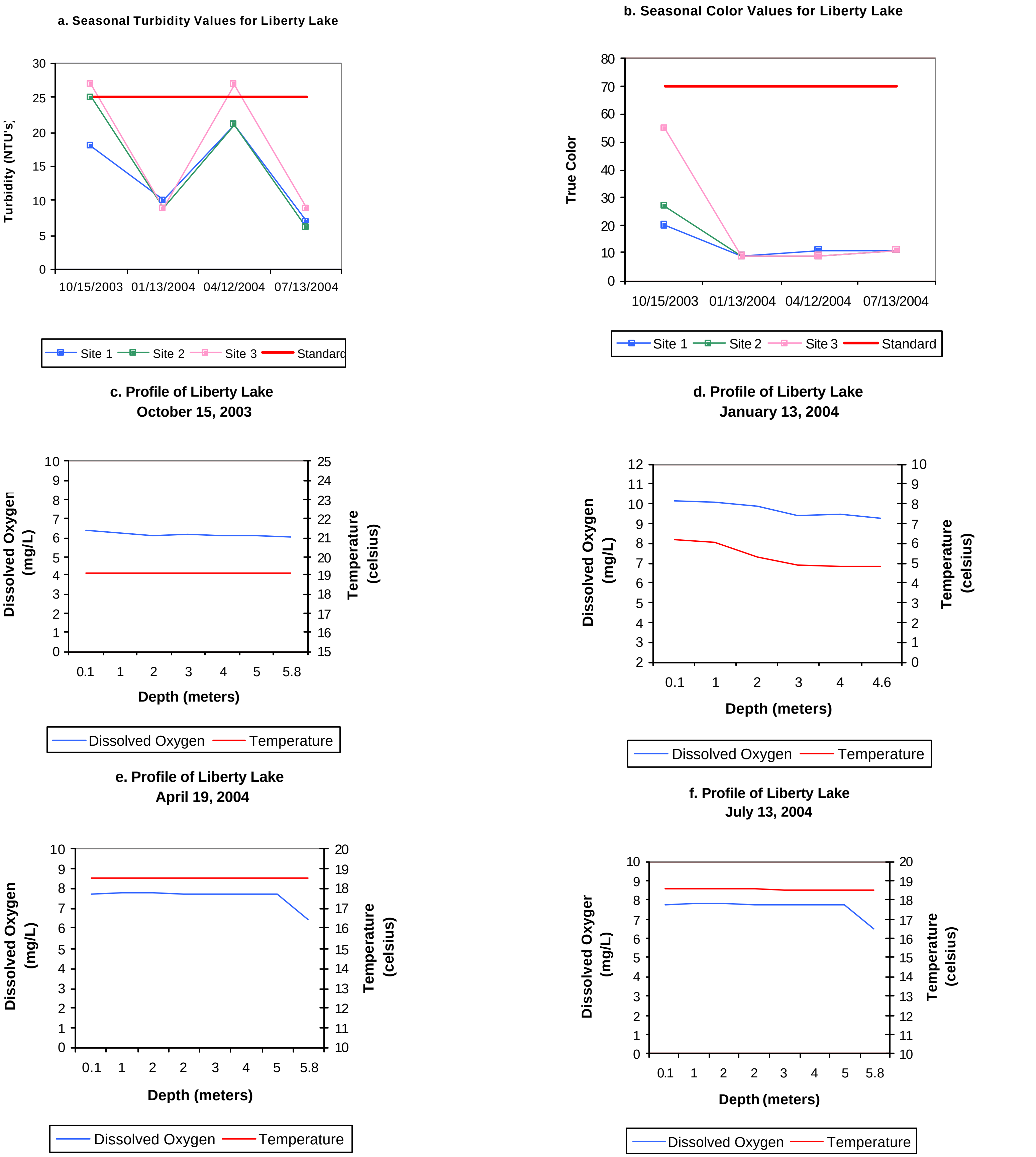



**Figure 153a-153f.** Graphical representation of data results for Liberty Lake.



Lake Data

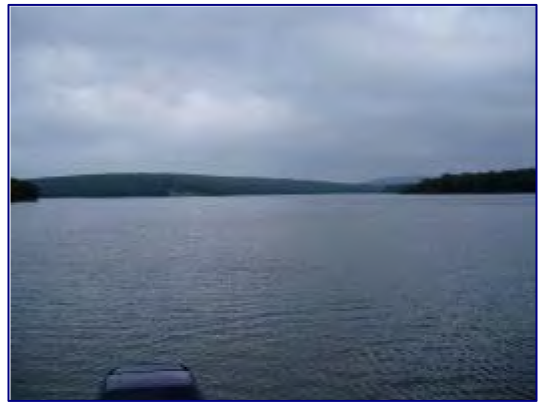
| | |
|---|---|
| Owner | City of Guthrie |
| County | Logan |
| Constructed in | 1948 |
| Surface Area | 167 acres |
| Volume | 2,740 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 16.41 feet |
| Watershed Area | 11 square miles |



Plate 68- Lake Water Quality for

# Liberty Lake

# Lloyd Church (Wilburton) Lake



Lloyd Church Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at three sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 13 NTU, true color was 35 units, and secchi disk depth was 77 centimeters. Based on these three parameters, Lloyd Church Lake had good water clarity in comparison to other Oklahoma reservoirs. Water clarity was similar if not slightly better than in 2001, which was based on only three quarters of data. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters plus the additional site in the winter (n=12). The average TSI was 44, classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is slightly lower than the one calculated in 2001 (TSI=49) but is most likely a more accurate depiction of the trophic status at Lloyd Church Lake as the current value is based on more samples collected in all four seasons. The TSI values were oligotrophic in the fall and winter quarters and mesotrophic in the spring and summer sampling intervals (Figure 154). All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU constituting a listing as fully supporting the Fish & Wildlife Propagation (FWP) beneficial use (Figure 155a). According to USAP (OAC 785:46-15-5), a beneficial use is considered not supported if =25% of the samples exceeds the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Seasonal true color values are displayed in Figure 155b. All of the true color values were below the numeric criteria of 70 units, therefore, although values recorded in the spring were very close to the standard. The Aesthetics beneficial use is considered fully supported at Lloyd Church Lake.

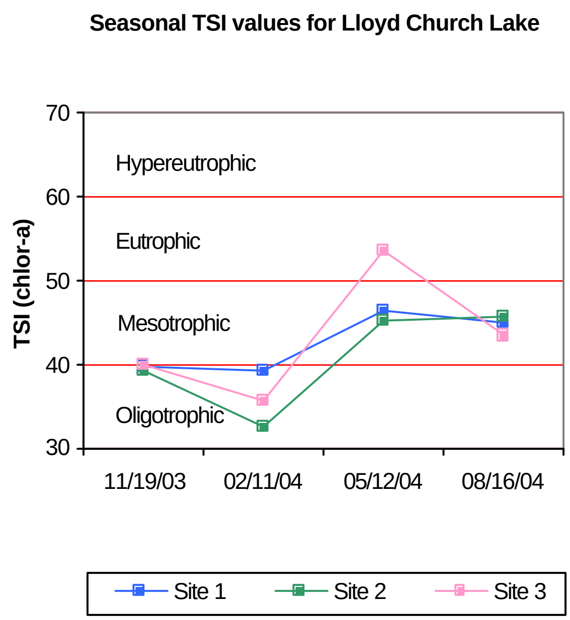



**Figure 154.** TSI values for Lloyd Church Lake.

Based on these three parameters, Lloyd Church Lake had good water clarity in comparison to other Oklahoma reservoirs.
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.01 ppt. Specific conductivity values were also very low, ranging from 10.9 mS/cm to 52.8 mS/cm. The values recorded for both salinity and specific conductivity are much lower than that typically seen in Oklahoma lakes and reservoirs and are indicative of

extremely low concentrations of electrical current conducting ions (salts or other chlorides) in the lake system. Values for pH were slightly acidic to neutral, ranging from 6.38 in the hypolimnion in the spring to 7.84 near the surface also in the spring quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only 6.6% of the recorded values falling outside the acceptable range the FWP beneficial use is considered supported based on pH concentrations. Low pH values are not unusual in S.E. Oklahoma lakes and reservoirs and may be due to natural causes. Continued monitoring should be conducted to determine if impairment due to pH exists. Oxidation-reduction potentials (redox) ranged from 26 mV to 618 mV, indicating an absence of reducing conditions during the sample year. Low redox values in the hypolimnion are not uncommon when a lake is strongly thermally stratified and anoxic conditions are present. The lake was not thermally stratified in the fall or winter quarters and the dissolved oxygen (D.O.) values were above 5.0 mg/L throughout the water column at all sites (see Figure 155 c-155d). During the spring the lake was thermally stratified between 3 and 4 meters, however dissolved oxygen (D.O.) remained above 2.0 mg/L until 12 meters below the surface at which point anoxic conditions were present to the lake bottom of 13.3 meters (Figure 155e). In the summer, the lake was strongly thermally stratified between 4 and 5 meters with anoxic conditions comprising approximately 62% of the water column at site 1 (see Figure 155f). Site 2 also exhibited stratification at the same point in the water column with D.O. values less than 2.0 mg/L from 5 meters to the lake bottom of 9.4 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Liberty Lake with approximately 62% of the water column less than 2.0 mg/L at site 1 in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric mean The PBCR beneficial use is therefore considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.30 mg/L at the lake surface. The TN at the surface ranged from 0.19 mg/L recorded in the summer quarter to 0.42 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average was 0.020 mg/L at the lake surface. The surface TP ranged from 0.015 mg/L in the fall quarter to 0.025 mg/L recorded in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 15:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary Lloyd Church Lake was classified as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is slightly lower than the one calculated in 2001 (TSI=49) but is most likely a more accurate depiction of the trophic status at Lloyd Church Lake as the current value is based on more samples collected in all four seasons. Based on turbidity, true color and secchi disk depth Lloyd Church Lake had good water clarity. The FWP beneficial use is considered fully supported for pH and turbidity, but is partially supporting with approximately 62% of the water column experiencing anoxic conditions. The Aesthetics use is also considered supported based on trophic status and true color values recorded during 2003-2004. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric mean. The PBCR beneficial use is therefore considered fully supported. Latimer County serves as the municipal water supply for the city of Wilburton.

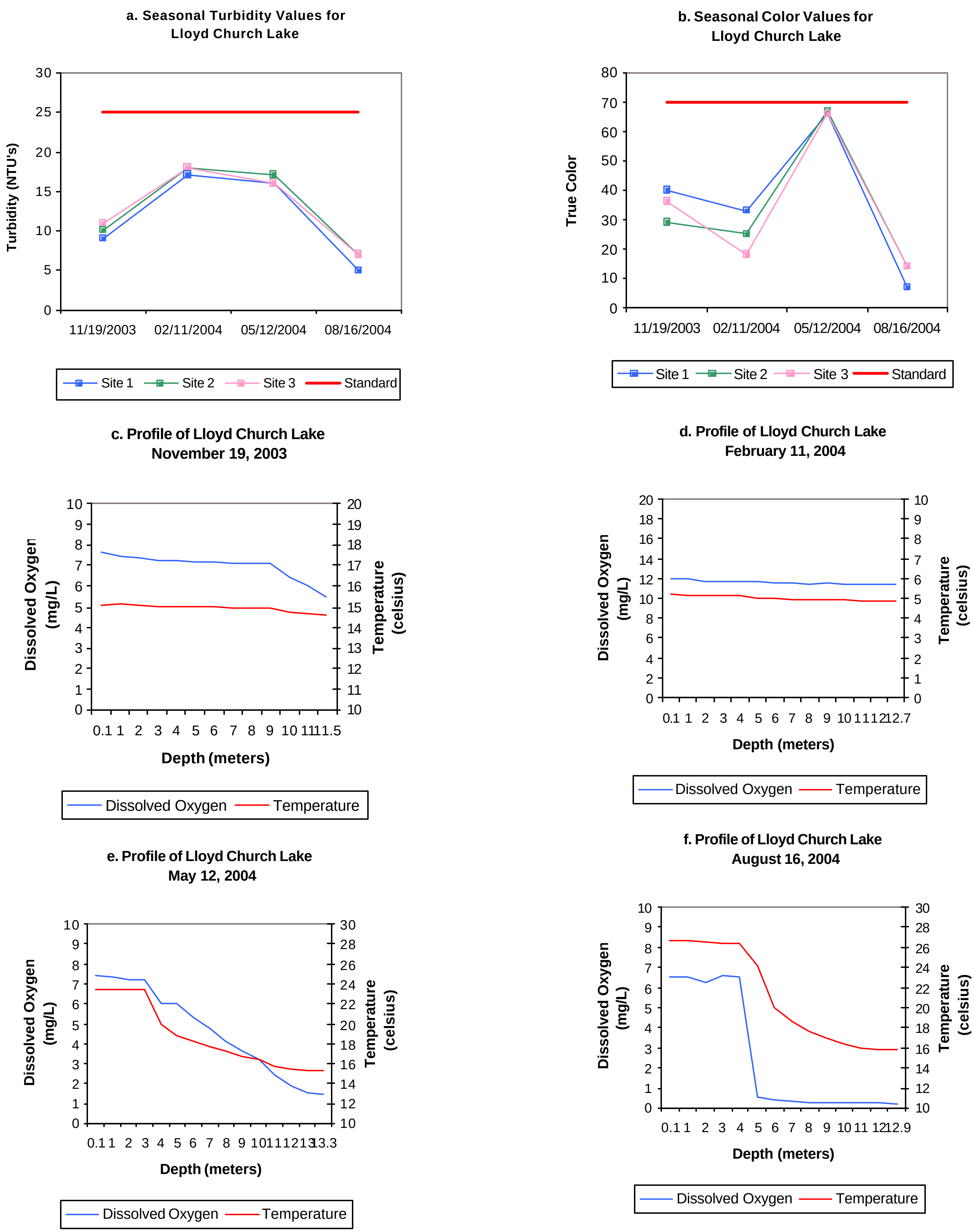
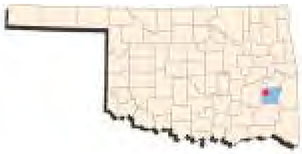
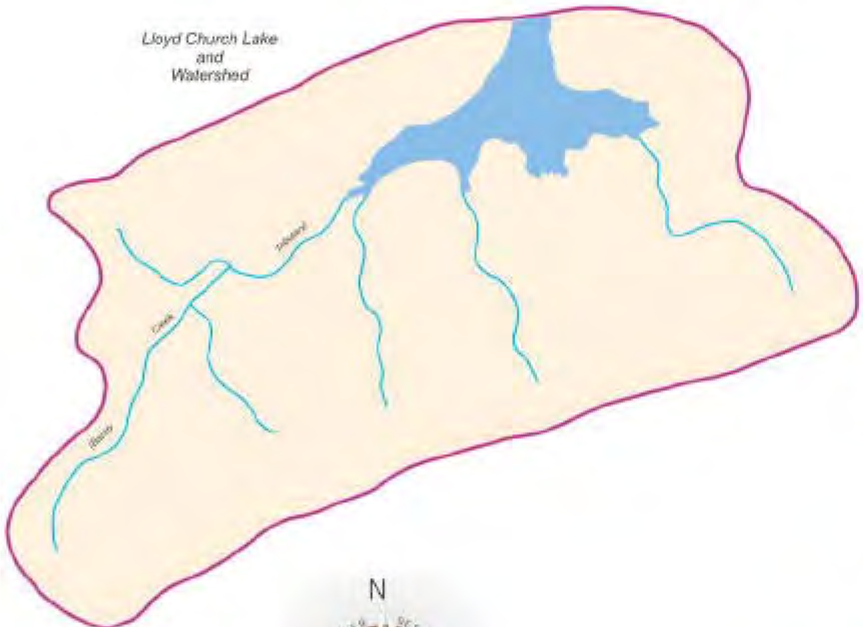
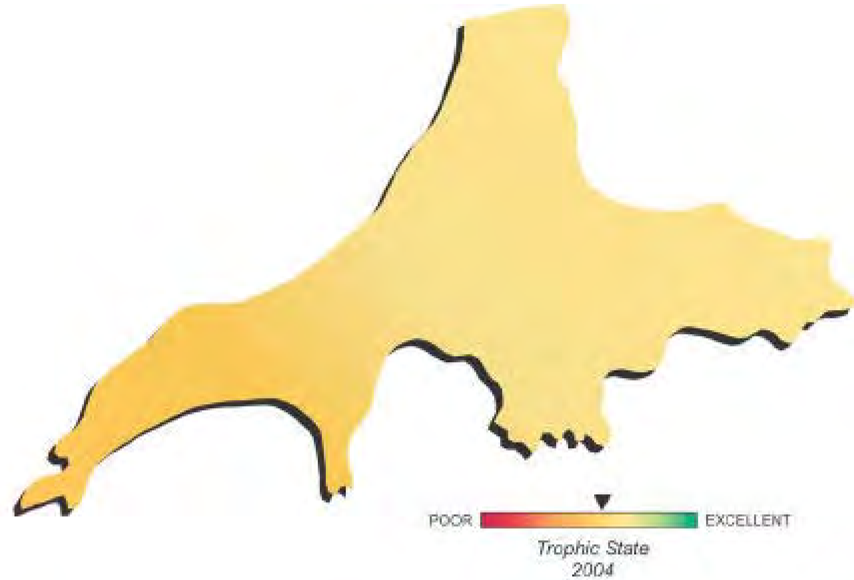
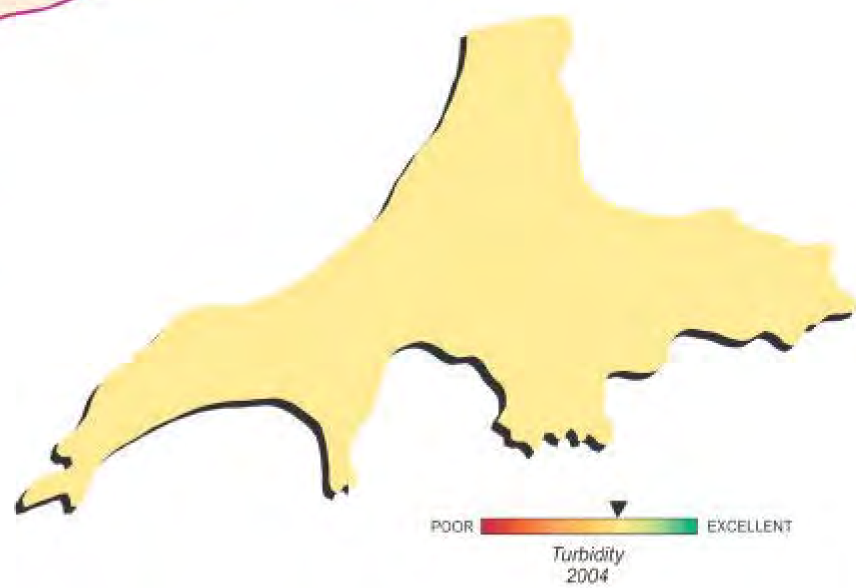



**Figure 155a-155f.** Graphical representation of data results for Lloyd Church Lake.




Lake Data

| | |
|---|---|
| Owner | City of Wilburton |
| County | Latimer |
| Constructed in | 1964 |
| Surface Area | 160 acres |
| Volume | 3,060 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 19.13 feet |
| Watershed Area | 2,627 acres |

Plate 69 - Lake Water Quality for
## Lake Lloyd Church

# Lone Chimney Lake

Lone Chimney Lake was sampled for four quarters, from October 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface with an additional sample taken at 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 18 NTU (Plate 70), true color was 41 units, and secchi disk depth was 63 centimeters. Based on these three parameters, Lone Chimney Lake had fair to good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for all quarters (n=20). The average TSI was 53 (Plate 70), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. The TSI values were consistent throughout all four quarters and ranged from the lower end of eutrophy to the upper end of eutrophy (see Figure 156). The turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU with the exception of the spring quarter when all five sites were above the standard (see Figure 157a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Lone Chimney Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 157b. Of the true color values collected 20% were above the numeric criteria of 70 units. Similar to turbidity a peak in true color occurred in the spring quarter and is likely the result of seasonal storm events and therefore the Aesthetics beneficial will be considered supported at Lone Chimney Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.06 parts per thousand (ppt) to 0.17 ppt indicating low to moderate salt content and well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were somewhat lower, ranging from 156.9 mS/cm to 312.5 mS/cm, indicating low to moderate electrical current conducting compounds (salts) in the water column

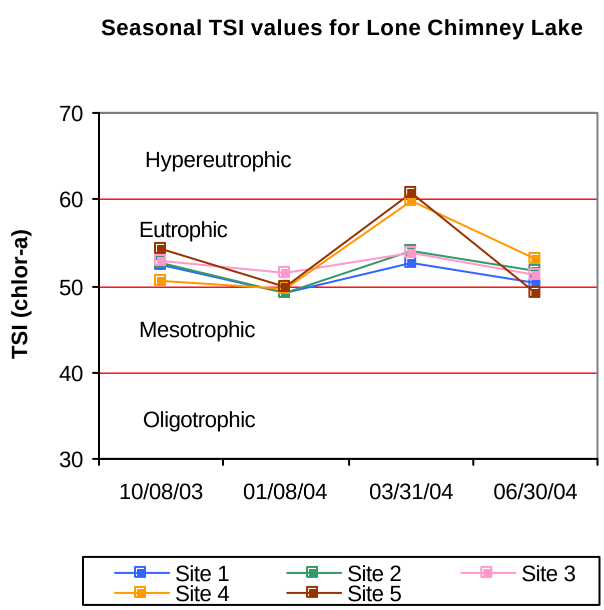



**Figure 156.** TSI values for Lone Chimney Lake.

throughout the year. In general, pH values were neutral to slightly alkaline, ranging from 7.01 units near the lake bottom in the spring quarter to 8.31 units recorded in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all collected pH values falling well within the acceptable range of pH, Lone Chimney Lake was fully supporting its FWP beneficial use. Oxidation-reduction potentials (redox) ranged from 319 mV in the summer to 552 mV near the sediment-water interface in the winter quarter. Redox readings indicated that reducing conditions were not present in the reservoir. In the fall, weak thermal stratification was evident and anoxic conditions were present in approximately 23% of the water column (Figure 157c). The lake was not thermally stratified in the winter or spring quarters and the dissolved oxygen (D.O.) values were above 5.0 mg/L throughout the water column except near the lake bottom (see Figure 157d-157e). In the summer, the lake was again strongly thermally stratified between 4 and 5 meters and below 4 meters from the surface the D.O. values were less than 1.0 mg/L to the lake bottom at sites 1 and 2 (see Figure 157f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lone Chimney Lake because 23% of the water column was anoxic in the fall quarter and 44% of the water column during the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.77 mg/L at the lake surface. The TN at the surface ranged from 0.58 mg/L in the winter quarter to 1.05 mg/L recorded in the spring. The lake-wide total phosphorus (TP) average was 0.041 mg/L at the lake surface. The surface TP ranged from 0.021 mg/L in the winter to 0.083 mg/L in the spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 19:1. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lone Chimney Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 70). The lake was fully supporting its FWP beneficial use based on pH and dissolved oxygen values recorded during the study period. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Lone Chimney Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Lone Chimney was supporting its Aesthetics beneficial used based on its assessed trophic status. Similar to turbidity a peak in true color occurred in the spring quarter and is likely the result of seasonal storm events and therefore the Aesthetics beneficial will be considered supported at Lone Chimney Lake.. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Lone Chimney Lake was constructed in 1984 and is owned and operated by the Tri-county Development Authority. The lake serves as a municipal water supply and is also used for flood control and recreational purposes.

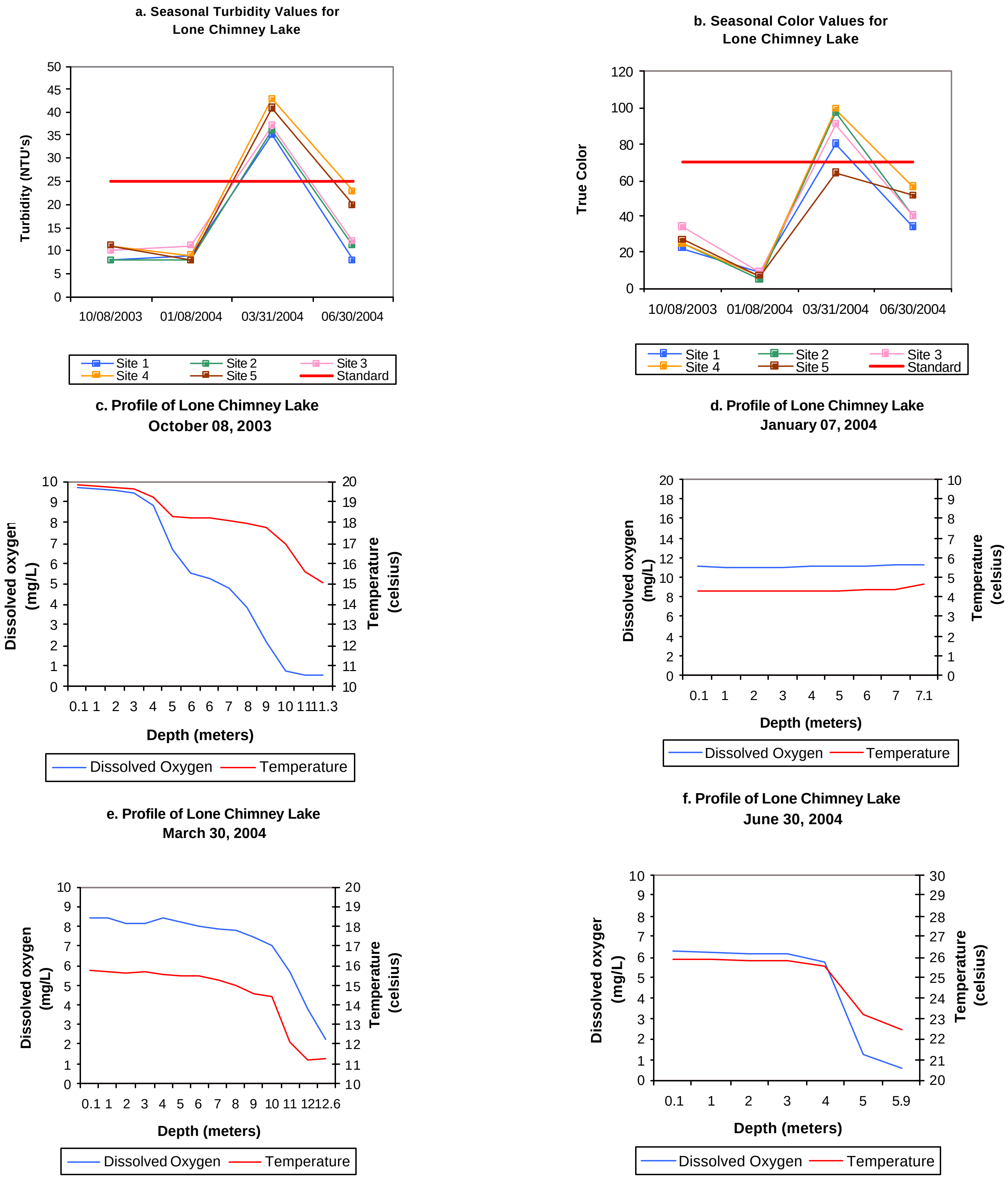
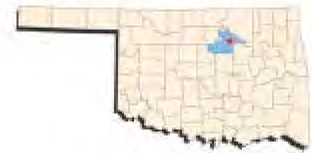
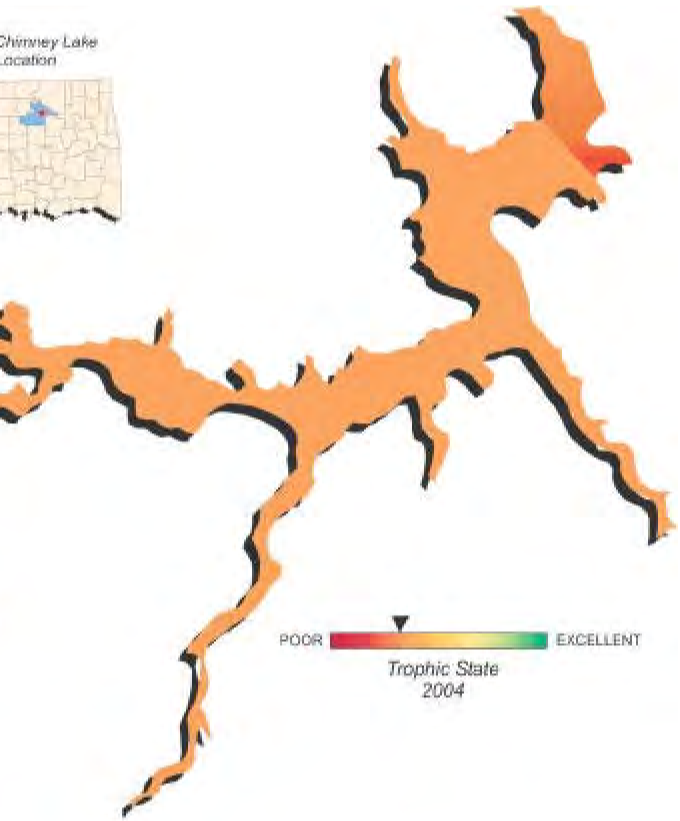


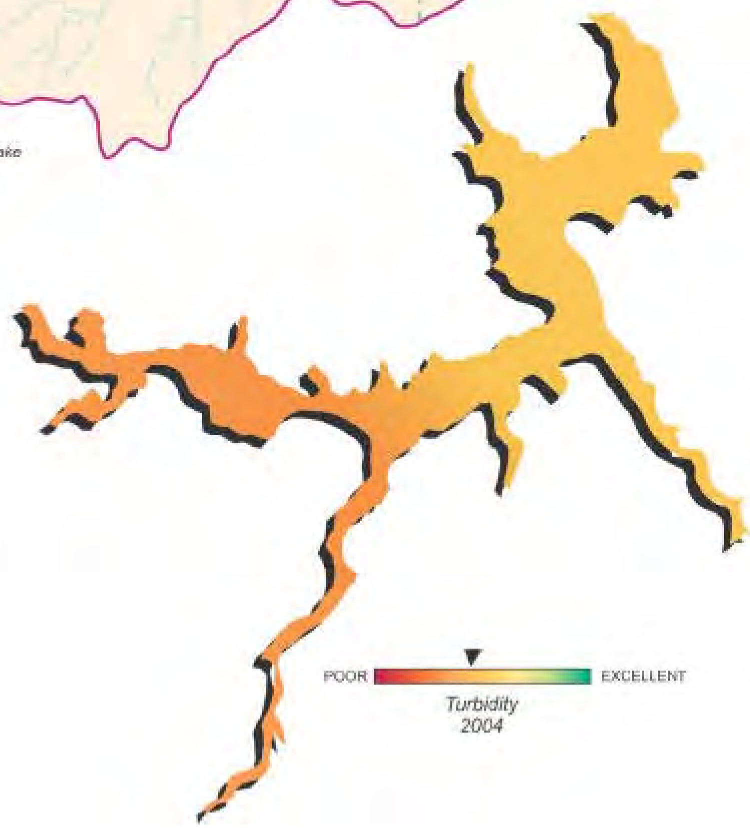

**Figure 157a-157f.** Graphical representation of data results for Lone Chimney Lake.

Lone Chimney Lake Location




Lone Chimney Lake and Watershed




Lake Data

| | |
|---|---|
| Owner | Tri-County Dev. Auth. |
| County | Pawnee |
| Constructed in | 1984 |
| Surface Area | 550 acres |
| Volume | 6,200 acre/feet |
| Shoreline Length | 17 miles |
| Mean Depth | 11.27 feet |
| Watershed Area | 28 square miles |

Plate 70 - Lake Water Quality for
# Lone Chimney Lake

# Lugert-Altus Reservoir

Lugert-Altus Reservoir was sampled for four quarters from November 2002 through June 2003. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake wide turbidity was 19 NTU (Plate 71), true color was 22 units, and average secchi disk depth was 51 centimeters in sample year 2003. Based on these three parameters, Lugert-Altus Reservoir had fair water clarity. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The result was a TSI of 63 (Plate 71), indicating the lake was hypereutrophic in sample year 2003. The TSI values for all sites throughout the sample year were fairly consistent, with values ranging from upper eutrophic to lower hypereutrophic (Figure 158). This value is slightly higher than that in 2000 (TSI=57); however, fewer samples were used to calculate trophic status in 2000. Seasonal turbidity values are displayed in Figure 159a. Turbidity values ranged from a low of 6 NTU to a maximum of 46 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. With 33% of the samples exceeding 25 NTU, the beneficial use of Fish and Wildlife propagation (FWP) should be considered not supported in regards to turbidity; however due to an accident in the lab there is not enough data to make an assessment. Seasonal true color values are displayed in Figure 159b. All color values were well below the aesthetics OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all five sample sites. The salinity values for Lugert-Altus Reservoir ranged from 1.16 parts per thousand (ppt) to 1.25 ppt for this sample year. Specific conductance ranged from 2166 to 2346 mS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence of electrical current conducting compounds (salts) in the lake, consistent with higher salinity concentrations. The pH values at Lugert-Altus Reservoir were slightly acidic, ranging from 5.07 in the winter to 8.38 in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9

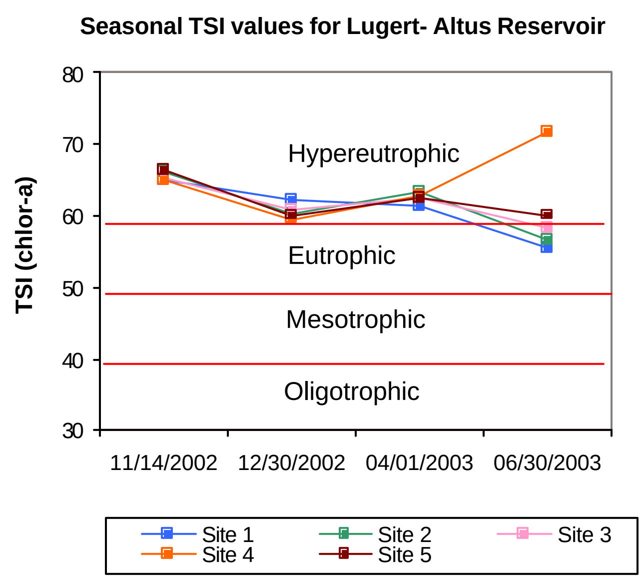



**Figure 158.** TSI values for Lugert-Altus Reservoir.

range the lake is considered partially supporting. With 22% of the values recorded being less than 6.5 the lake is partially supporting based on pH the FWP use. Oxidation-reduction potentials ranged from 401 mV in the summer to 564 mV in the fall. Reducing conditions were not present at this reservoir in the 2002-2003-sample year. During the fall, winter, and spring quarters stratification was not present and dissolved oxygen values were generally above 7 mg/L (see Figure 159c-159e). Thermal stratification was evident during the summer quarter, although, anoxic conditions were not present. Dissolved oxygen (D.O.) concentrations reached a low of 3.13 mg/L at the bottom of the lake (Figure 159f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 100% of the collected values greater than 2.0 mg/L, the lake is fully supporting its FWP beneficial use based on dissolved oxygen. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.76 mg/L. The TN at the surface ranged from 0.44 mg/L to 1.38 mg/L in the upper reaches of the lake. Surface total nitrogen was highest in the summer and lowest in the spring. The lake-wide total phosphorus (TP) was 0.043 mg/L. The TP at the surface ranged from 0.028 mg/L to 0.087 mg/L. Similar to nitrogen, surface TP was highest in the summer but the lowest values were seen during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 18:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lugert-Altus Reservoir was classified as hypereutrophic, indicative of excessive primary productivity and nutrients in 2003. This is a slight increase from 2000 where the calculated TSI resulted in a value of 57, which had placed the lake in the eutrophic category. More data was available this past sample year, resulting in a more accurate determination of trophic state and does not necessarily indicate that there was an increase in productivity. Water clarity was fair based on secchi disk depth and turbidity. The lake will be considered for addition to the OWQS as a nutrient-limited watershed (NLW). The lake is supporting its FWP beneficial use based on dissolved oxygen values and partially supporting based on pH. A determination based on turbidity could not be made at this time, as a minimum sample requirement was not met. The lake is supporting the Aesthetics beneficial use based on true color, but not supporting based on its trophic status (TSI=63). Lugert-Altus Reservoir is located in Greer county and is utilized for water supply, flood control and irrigation purposes.

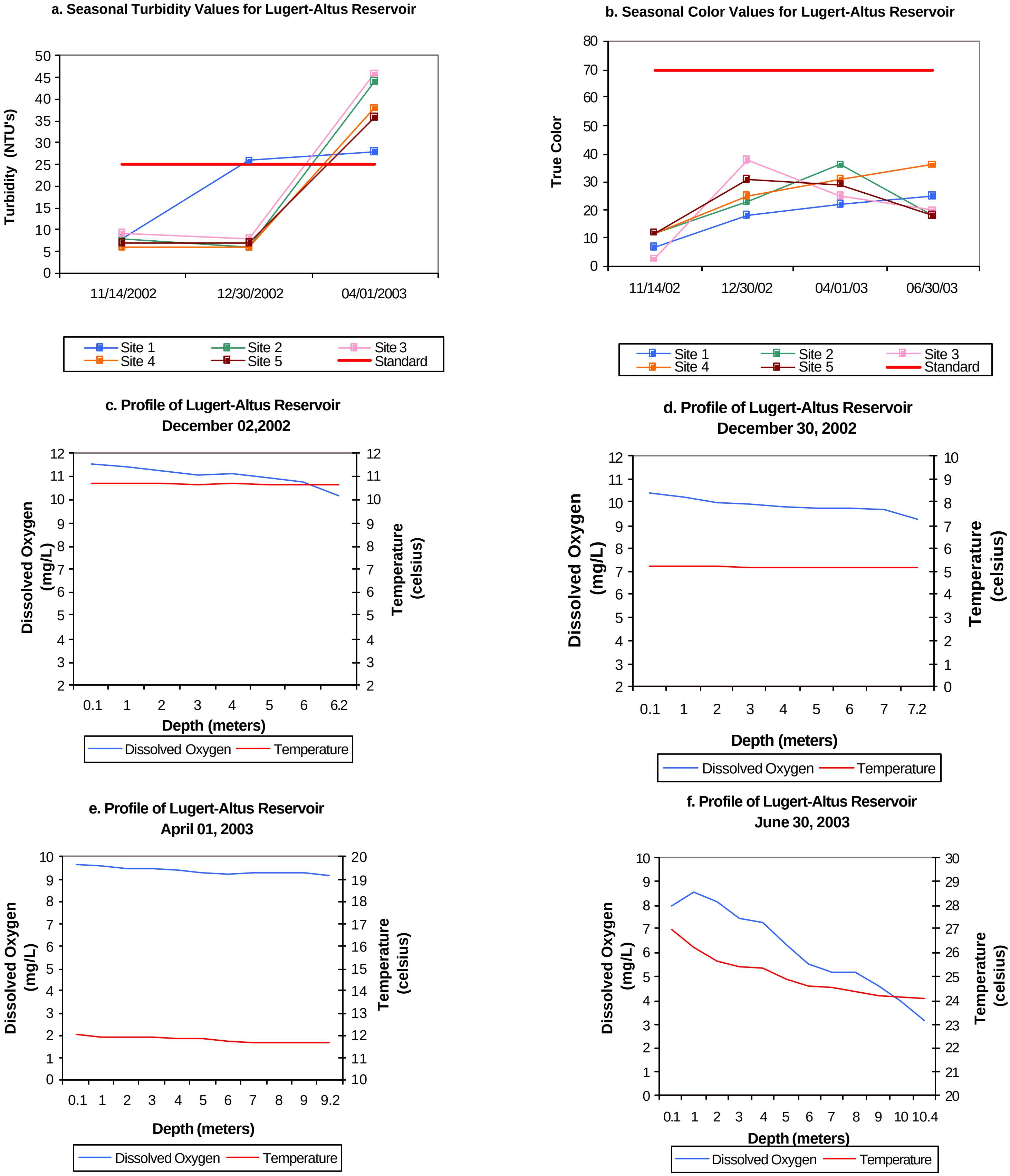



**Figure 159a-159f.** Graphical representation of data results for Lugert -Altus Reservoir.


Lake Data

| | |
|---|---|
| Constructed by | Bureau of Reclamation |
| County | Greer |
| Constructed in | 1948 |
| Surface Area | 6,260 acres |
| Volume | 132,830 acre/feet |
| Shoreline Length | 49 miles |
| Mean Depth | 21.22 feet |
| Watershed Area | 2,515 acres |

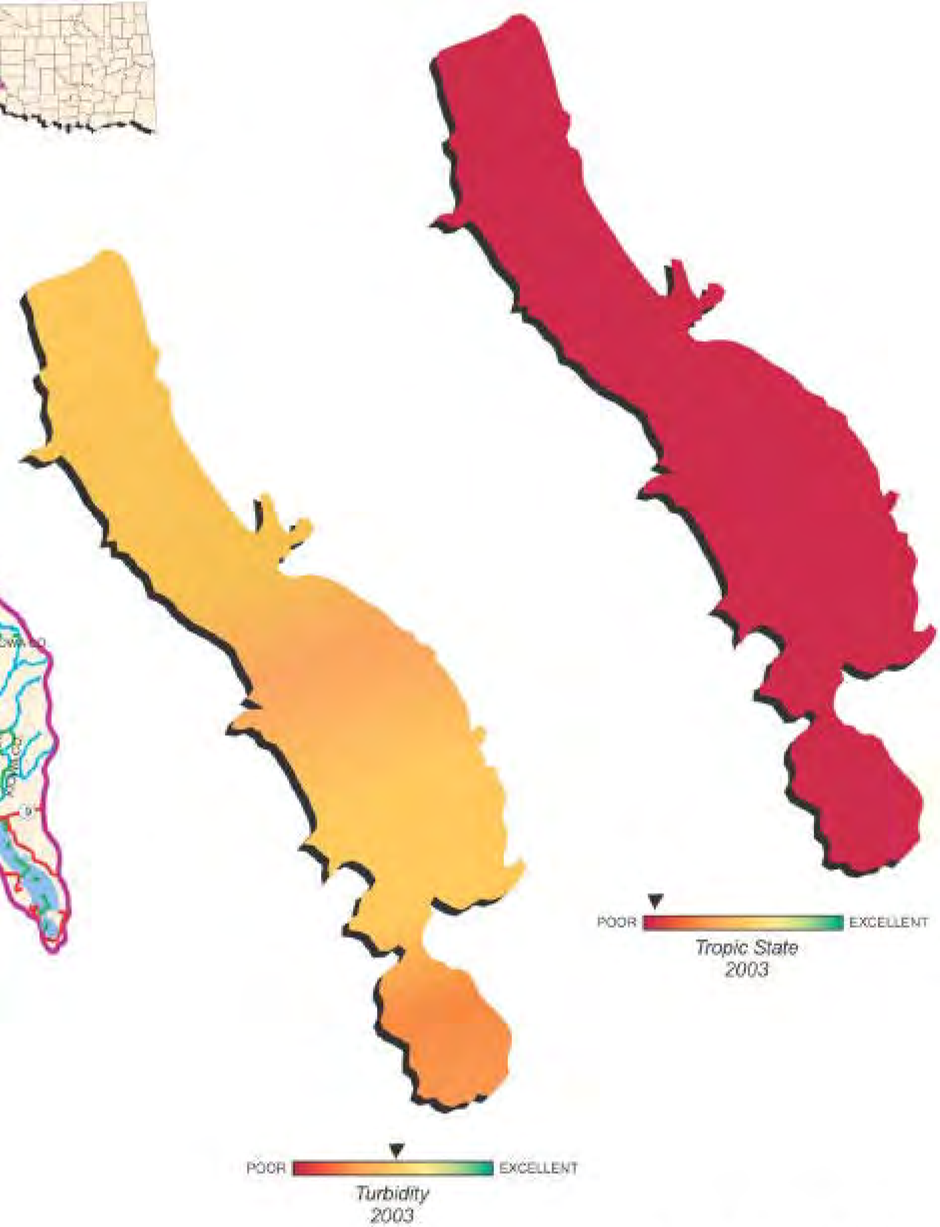



Plate 71 - Lake Water Quality for
## Lugert-Altus Lake

# Maysville (Wiley Post) Lake

Maysville Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 at the lake surface for the purpose of assessing chlorophyll-a and turbidity concentrations. Samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 44 NTU (Plate 128), true color was 64 units, and secchi disk depth was 31 centimeters in 2001-2002. Based on these three parameters, Maysville Lake had poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 57 (Plate 128), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. The TSI values varied seasonally with the lake being mesotrophic in the fall, eutrophic in the winter and spring and bordering on hypereutrophic in the summer quarter (see Figure 160). The turbidity values collected on this lake almost always exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU constituting a listing as not supporting the Fish & Wildlife Propagation (FWP) beneficial use (see Figure 161a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 75% of the samples collected exceeding the criteria, turbidity is a beneficial use problem in Maysville Lake. Seasonal true color values are displayed in Figure 161b. Of the true color values collected 42% were above the numeric criteria of 70 units, however, the Aesthetics beneficial could not be definitively assessed due to insufficient data. Available data strongly suggested that the lake would not be supporting its Aesthetics beneficial use for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.18 parts per thousand (ppt) to 0.25 ppt indicating moderate salt content and the values were well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance ranged from 357.5 mS/cm to 503.7 mS/cm, indicating the presence of moderate amounts of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline in nature, ranging from 7.48 units in the summer quarter to 8.79 units in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With none of the collected values falling outside the specified range, Maysville Lake is fully supporting its FWP beneficial use. Oxidation-reduction potentials (redox) ranged

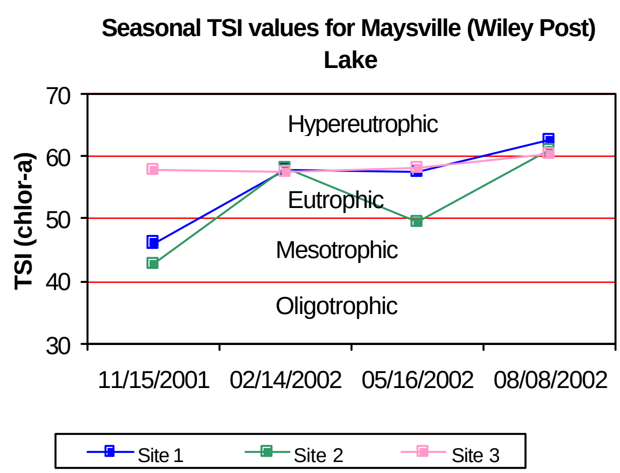



**Figure 160.** TSI values for Maysville Lake.

from 142 mV at the sediment-water interface in the summer to 380 mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir at any point when the lake was sampled. The lake was not thermally stratified in the fall, winter or spring quarters and dissolved oxygen (D.O.) values were above 5.7 mg/L throughout the entire water column at all sites and were generally above 7.3 mg/L in most of the water column (see Figure 161c-161e). In the summer, the lake was strongly thermally stratified between 2 and 3 meters and also between 3 and 4 meters. In a lake that was only 4.5 meters deep when sampled in the summer quarter this was an unexpected occurrence. The water column at site 1 had D.O. readings less than 1.0 mg/L from 3 meters to the lake bottom (see Figure 161f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Maysville Lake because approximately 50% of the water column was anoxic at site 1 in the summer. This is not a situation that is normally seen for such a shallow reservoir and can only be attributed to a long period of calm winds and/or a pattern where little rainfall occurs. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.73 mg/L at the lake surface. The TN at the surface ranged from 0.51 mg/L in the winter to 0.87 mg/L in the spring quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.087 mg/L at the lake surface. The surface TP ranged from 0.053 mg/L in the winter quarter to 0.114 mg/L in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2001-2002. This value is slightly greater than 7:1, characterizing the lake as potentially phosphorus-limited (Wetzel, 1983).

Maysville Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Maysville Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 128). Most of the turbidity values were above the OWQS of 25 NTU, constituting a non-support of the FWP beneficial use based on turbidity (OAC 785:46). The lake was fully supporting the FWP beneficial use based on pH, however, anoxic conditions present in the summer constituted a non-support of the FWP beneficial use based on D.O. values collected in the water column (OAC 785:46). Maysville is fully supporting its Aesthetics beneficial use based on the lakes trophic status but not enough information was available to assess the Aesthetics use for true color. Maysville Lake was constructed in 1971 and is owned and operated by the City of Maysville and serves as a municipal water supply. The lake is also used for flood control and recreational purposes.

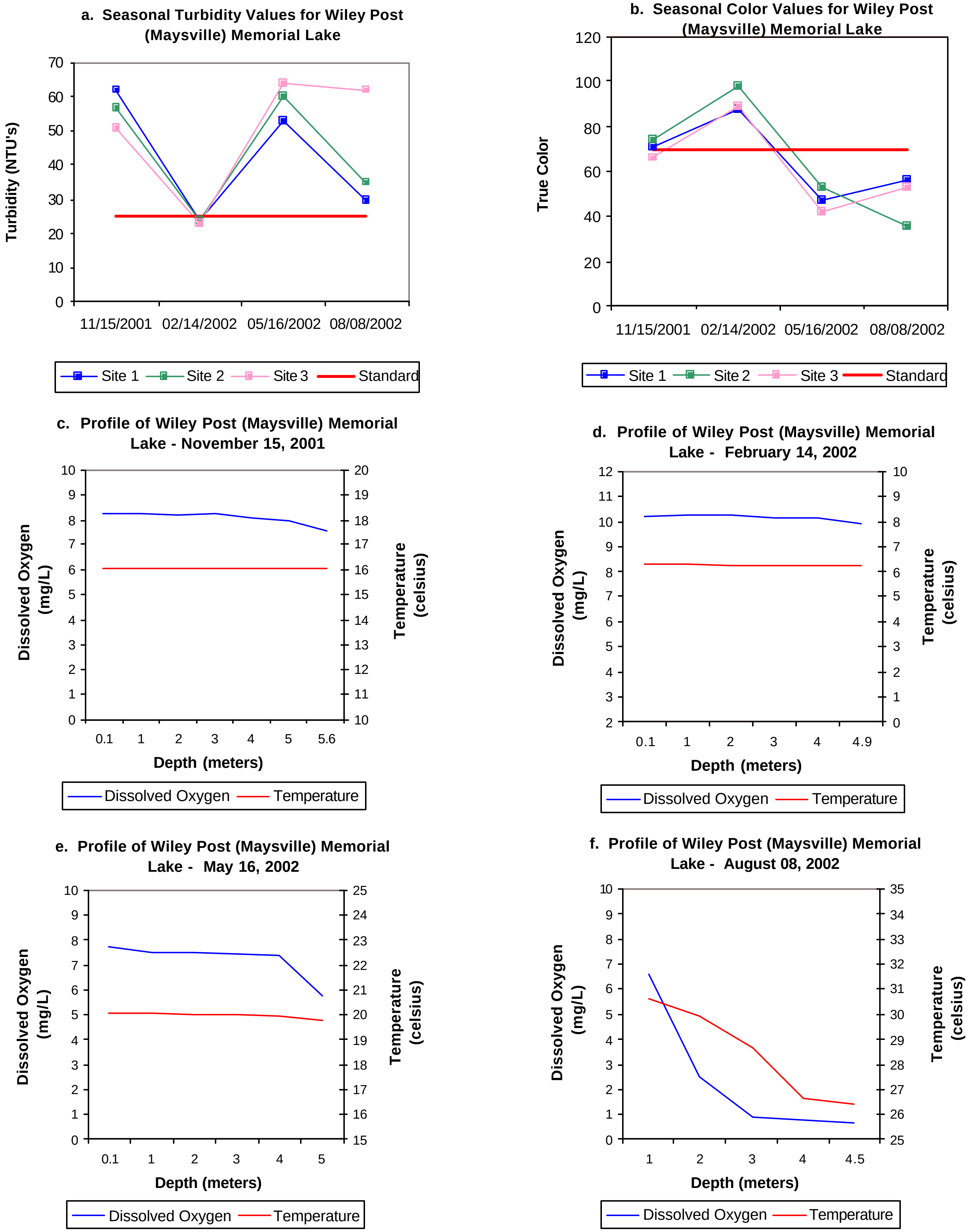
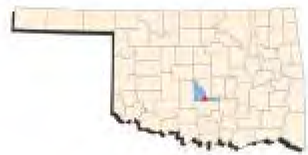



**Figure 161a161f.** Graphical representation of data results for Maysville Lake.

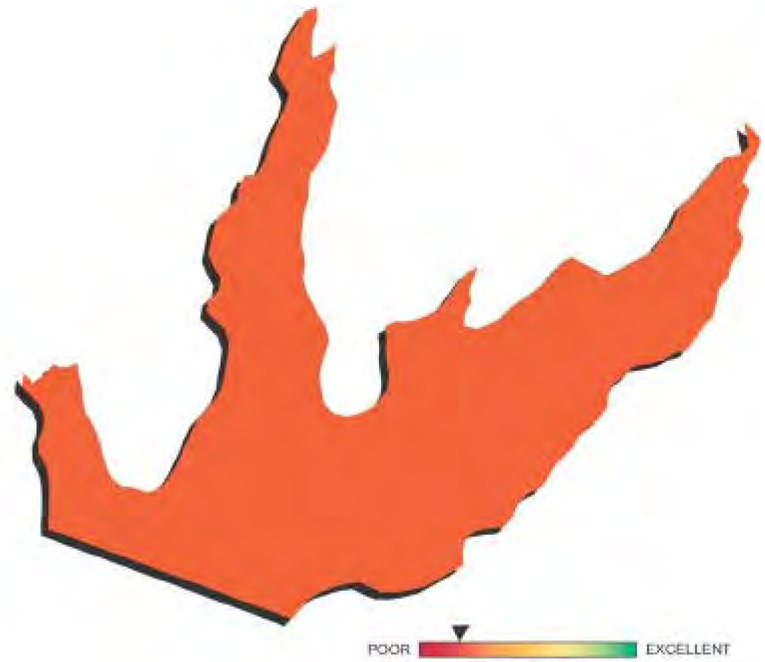

Wiley Post Lake
and
Watershed



Wiley Post Lake
Location


Lake Data

| | |
|---|---|
| Owner | City of Maysville |
| County | McClain |
| Constructed in | 1971 |
| Surface Area | 302 acres |
| Volume | 2,082 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 6.89 feet |
| Watershed Area | 13 square miles |




Trophic State
2002


Turbidity
2002

Plate 128 - Lake Water Quality for

## Wiley Post (Maysville) Lake

# Lake McAlester

Lake McAlester was sampled for four quarters, from October 2002 through July 2002. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a reservoir larger than 250 surface acres in size. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 83 NTU (Plate 72), true color was 244 units, and secchi disk depth was 20 centimeters in 2003. Based on these three parameters, Lake McAlester had poor water clarity. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 45 (Plate 72), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is similar to the one calculated in 2001 (TSI=47), and in the same trophic category, but is likely a more accurate depiction of trophic status as more samples were collected throughout the year. The high turbidity and true color values are probably the reason for the trophic state determination, as inorganic turbidity is a limiting factor in lake productivity. The TSI values in 2003 were primarily mesotrophic although values at site 1 were oligotrophic in the fall and eutrophic in the winter (Figure 162). All turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 163a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples collected in 2003 exceeding the OWQS of 25 NTU, the lake is not supporting the Fish and Wildlife Propagation (FWP) beneficial use. True color was fairly consistent and was above the aesthetics OWQS of 70 units at all sites (Figure 163b). Although 100% of the samples collected in 2003 were above the standard, a use determination cannot be made as the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met

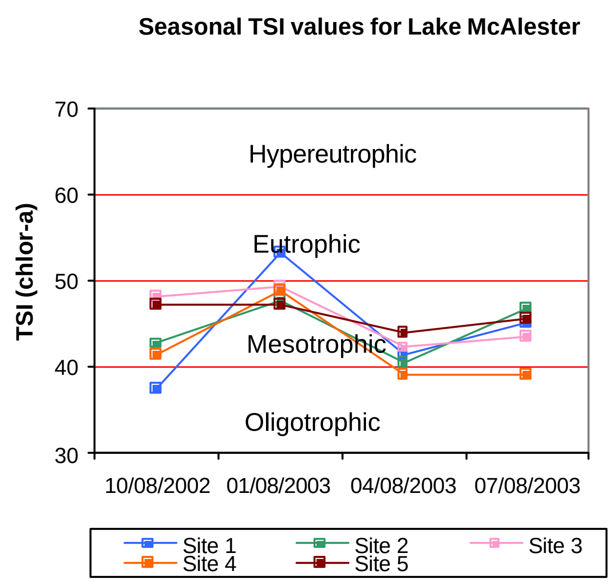



**Figure 162.** TSI values for Lake McAlester.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.03 ppt. This is within the average values reported for Oklahoma lakes. Specific conductivity ranged from 61.8 mS/cm to 91.3 mS/cm indicating that minimal concentrations of electrical current conducting compounds were present in the lake system. The pH values at Lake McAlester ranged from 6.56 to 7.79, representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all of the collected values within the acceptable range the lake is considered to be supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 400 mV in the summer to 593 mV in the fall. Reducing conditions were not present at this reservoir with all values being positive and above 100 mV through the study period. During the fall, winter, and spring quarters, stratification was not present and the lake was well mixed with dissolved oxygen (D.O.) levels generally above 5.0 mg/L (Figure 163c-163e). Thermal stratification was evident in the summer and anoxic conditions were present. In the summer, stratification occurred between 5 and 6 meters at which point the D.O. fell below 2.0 mg/L to the lake bottom of 10 meters accounting for approximately 45% of the water column, at site 1, to be anoxic (Figure 163f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Lake McAlester based on D.O. values in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.66 mg/L at the surface and 0.56 mg/L at the lake bottom. Surface TN ranged from 0.33 mg/L to 0.96 mg/L, with the highest values reported in the summer and the lowest values in the winter. The lake-wide total phosphorus (TP) average was 0.110 mg/L at the surface and 0.098 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.035 mg/L to 0.174 mg/L. Similar to TN, surface TP was highest in the summer and lowest during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 6:1 for sample year 2003. This is slightly lower than 7:1, characterizing the lake as potentially nitrogen limited to co-limited (Wetzel, 1983).

In summary, Lake McAlester was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in sample year 2002-2003. Similar conditions were found during the 2000 evaluation, indicating that no significant increase or decrease in productivity has occurred. Water clarity was poor based on true color, turbidity and secchi disk depth and is likely to always be poor based on the soil composition of the area. The lake is supporting the FWP beneficial use based on pH, partially supporting based on dissolved oxygen and not supporting based on the extremely high turbidity values. The Aesthetics beneficial use is supported based on its trophic status, however a use determination based on true color cannot be made as the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met. Lake McAlester is located in Pittsburg County and was constructed in 1930 for water supply and recreational purposes.

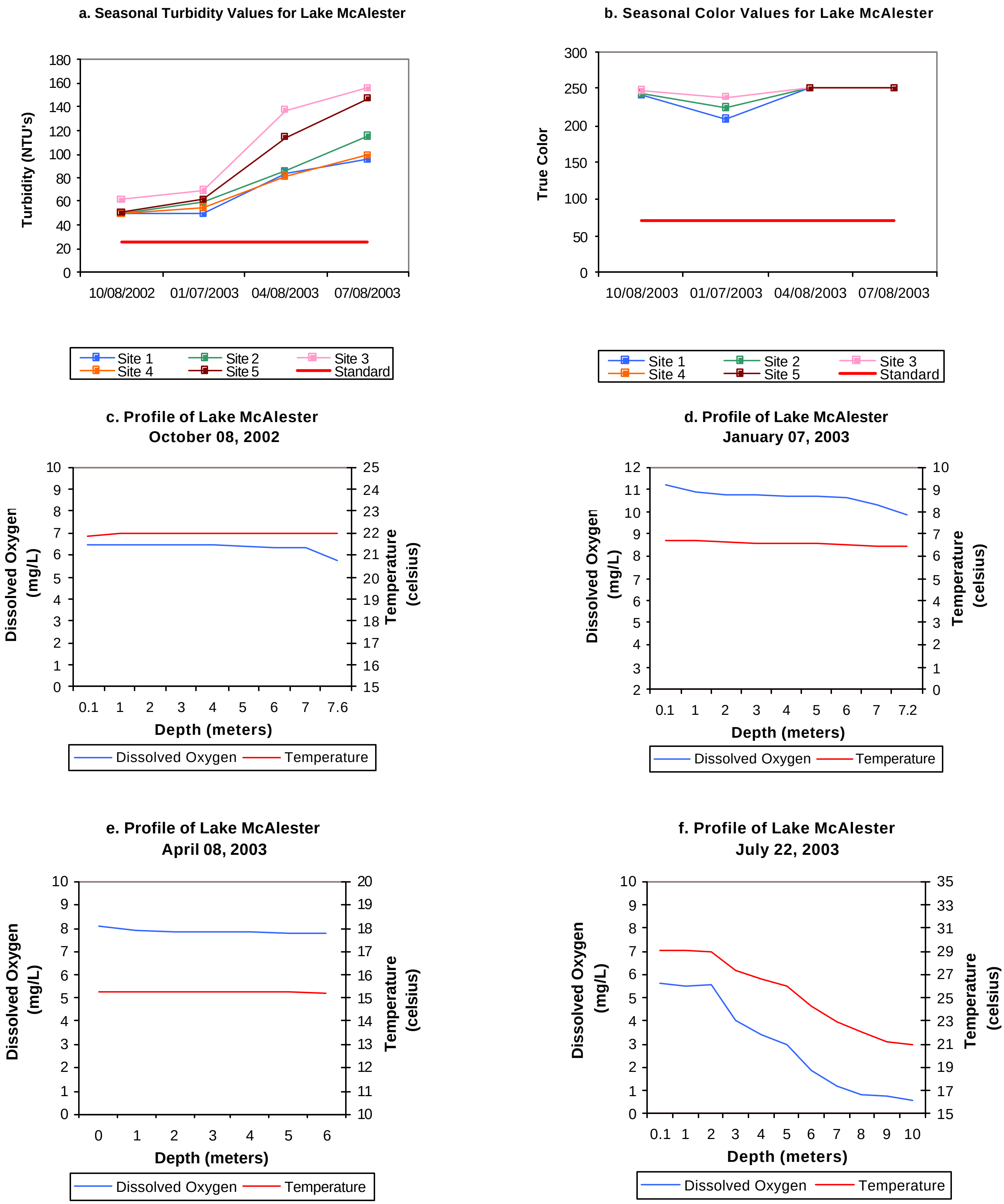
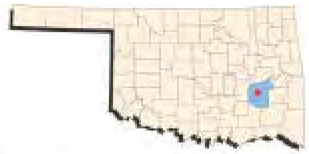



**Figure 163a-163f.** Graphical representation of data results for Lake McAlester.





| Lake Data | |
|---|---|
| Owner | City of McAlester |
| County | Pittsburg |
| Constructed in | 1930 |
| Surface Area | 1,521 acres |
| Volume | 13,398 acre/feet |
| Shoreline Length | 20 miles |
| Mean Depth | 8.81 feet |
| Watershed Area | 31 square miles |

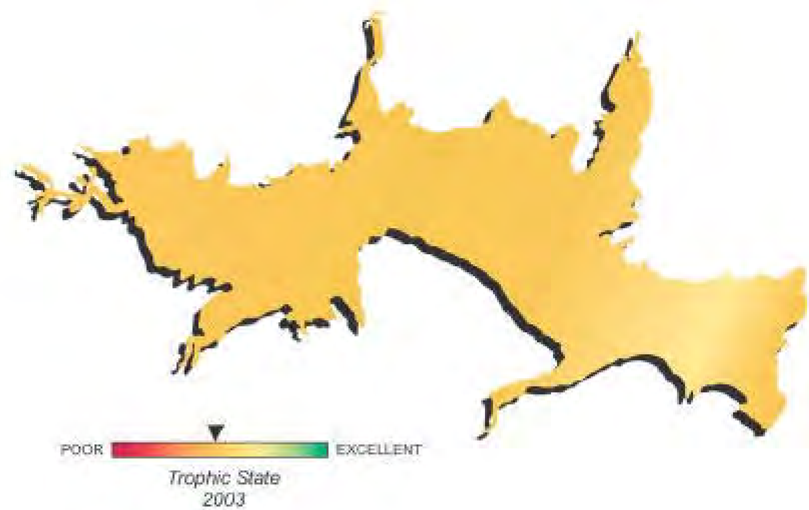




Plate 72 - Lake Water Quality for
Lake McAlester

# McGee Creek Lake

McGee Creek Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as major lake arms. Samples were collected from the lake surface at all sites with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 5 NTU (Plate 73), true color was 18 units, and secchi disk depth was 175 centimeters. Based on these three parameters, McGee Creek Lake had excellent water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for all four quarters (n=20). The average TSI was 39 (Plate 73), classifying the lake as oligotrophic bordering on mesotrophic, indicative of low to moderate levels of primary productivity and nutrients. The TSI values were consistent across all sample seasons varying from lower oligotrophic to upper oligotrophic at all sites in the winter, spring, and summer sampling intervals. The most productive quarter observed in the lake was actually in the fall, where four of the five sites were classified as mesotrophic. Site 4 was mesotrophic in nature or bordering mesotrophic conditions throughout all four quarters (see Figure 164). All of the collected turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 165a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. McGee Creek Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it related to nephelometric turbidity. Seasonal true color values are displayed in Figure 165b. All of the true color values were below the numeric criteria of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is fully supported based on the true color values.

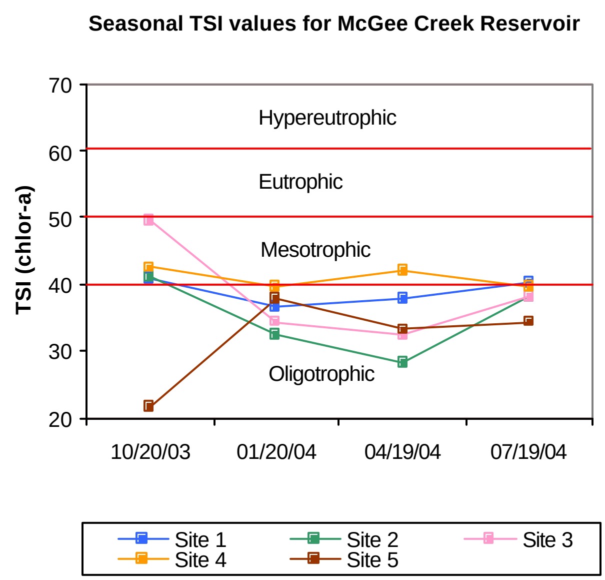



**Figure 164.** TSI values for McGee Creek Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.03ppt, well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also extremely low, ranging from 20.8 mS/cm to 83.2 mS/cm, indicating the presence of little to no electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were slightly acidic to neutral, ranging from 5.93 in the summer quarter to 7.24 units at site 3 in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 40% of the recorded values less than 6.5, McGee Creek Lake is not supporting the FWP beneficial use as it relates to turbidity. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (redox) ranged from 285 mV at the sediment-water interface in the fall quarter to 550 mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir during any of the sampling intervals. The lake was thermally stratified and anoxic conditions were present in fall quarter between 9 and 10 meters below the lake surface at sites 1,2 and 5. Approximately 59% of the water column was experiencing dissolved oxygen (D.O.) concentrations below 1.0 mg/L at site 1 near the dam (see Figure 165c). McGee Creek was not thermally stratified in the winter quarter and D.O. values were above 7.0 mg/L throughout the water column (See Figure 165d). In the spring, the lake was strongly thermally stratified between 10 and 11 meters below the lake surface; however all D.O. concentrations remained above 5.0 mg/L throughout the water column at all sites (see Figure 165e). In the summer quarter, there was a metalimnetic oxygen deficit that occurred in the main body of the lake (site 1 and 5) between 5 and 9 meters below the surface (Figure 165f). Dissolved oxygen values were less than 2.0 mg/L within this layer and from 10 meters to the lake bottom of 32 meters D.O. ranged from 2.6 to 5.08 mg/L (see Figure 165f). It is not known at this time what caused this to occur and the lake should be studied further. At sites 2,3 and 4, thermal stratification occurred between 3 and 4 meters in depth with D.O. falling to below 2.0 mg/L and anoxic conditions present in 40 to 70% of the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. In the spring quarter 59% of the water column at site 1, near the dam had dissolved oxygen readings of less than 2.0 mg/l. During the summer 40 to 70% of the water column was anoxic in the arms of the lake, McGee Creek Lake is partially supporting its FWP beneficial use based on low D.O. readings in the water column. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.37 mg/L at the lake surface and 0.47 mg/L at the lake bottom. The TN at the surface ranged from 0.17 mg/L in the fall quarter to 0.66 mg/L in the winter. The lake-wide total phosphorus (TP) average was 0.012 mg/L at the lake surface and 0.018 mg/L at the lake bottom. The surface TP ranged from 0.006 mg/L in the fall to 0.0.18 mg/L also recorded in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 32:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 and 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, McGee Creek Lake was classified as oligotrophic bordering mesotrophic, indicative of low to moderate primary productivity and nutrient levels in 2003-2004 (Plate 73). Water clarity continues to be excellent at this reservoir based on turbidity, true color and secchi disk depth. The lake was fully supporting its FWP based on turbidity readings, however is partially supported based on anoxic conditions present in both the fall and summer quarters. With 40% of the pH values recorded in the fall, spring and summer below 6.5 units the FWP beneficial is considered not supported. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is fully supported based trophic status and true color readings with 100% of the values being below the OWQS of 70 units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported. McGee Creek Lake was constructed in 1988 and is owned and operated by the Bureau of Reclamation. The lake serves as a municipal water supply source, flood control, fish & wildlife habitat, and offers many recreational opportunities for the citizens of Oklahoma. The City of Oklahoma City can transfer water from McGee Creek Lake to Lake Atoka and then pump that water to Lake Stanley Draper where is can be used by the citizens of Oklahoma City and its suburbs. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 166) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

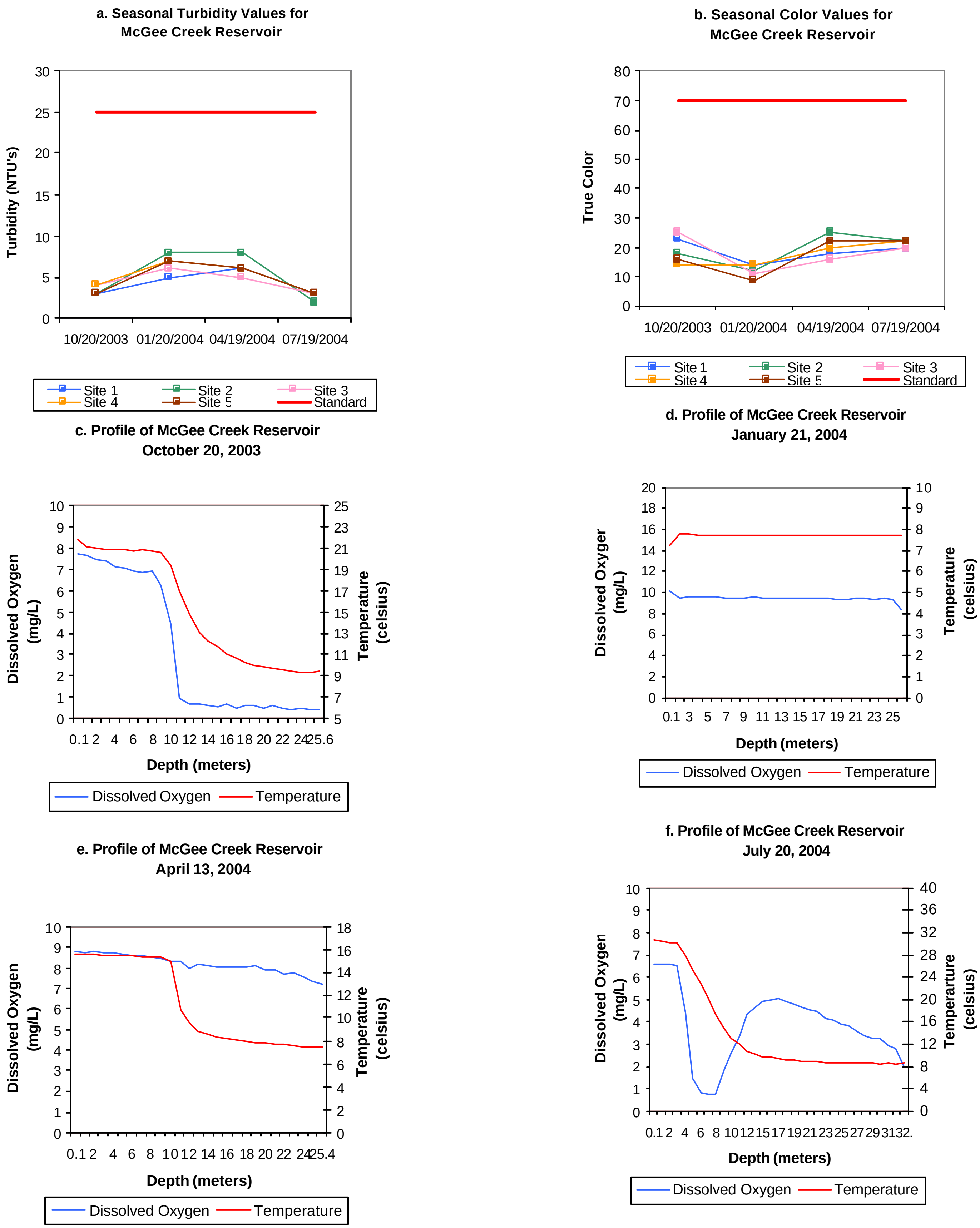
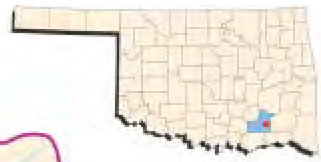



**Figure 165a-165f.** Graphical representation of data results for McGee Creek Lake.


McGee Creek Lake
and
Watershed



McGee Creek Lake
Location

Lake Data

| | |
|---|---|
| Constructed by | Bureau of Reclamation |
| County | Atoka |
| Constructed in | 1987 |
| Surface Area | 3,709 acres |
| Volume | 100,146 acre/feet |
| Shoreline Length | 80 miles |
| Mean Depth | 26.9 feet |
| Watershed Area | 178 square miles |



Plate 73 - Lake Water Quality for
McGee Creek Lake

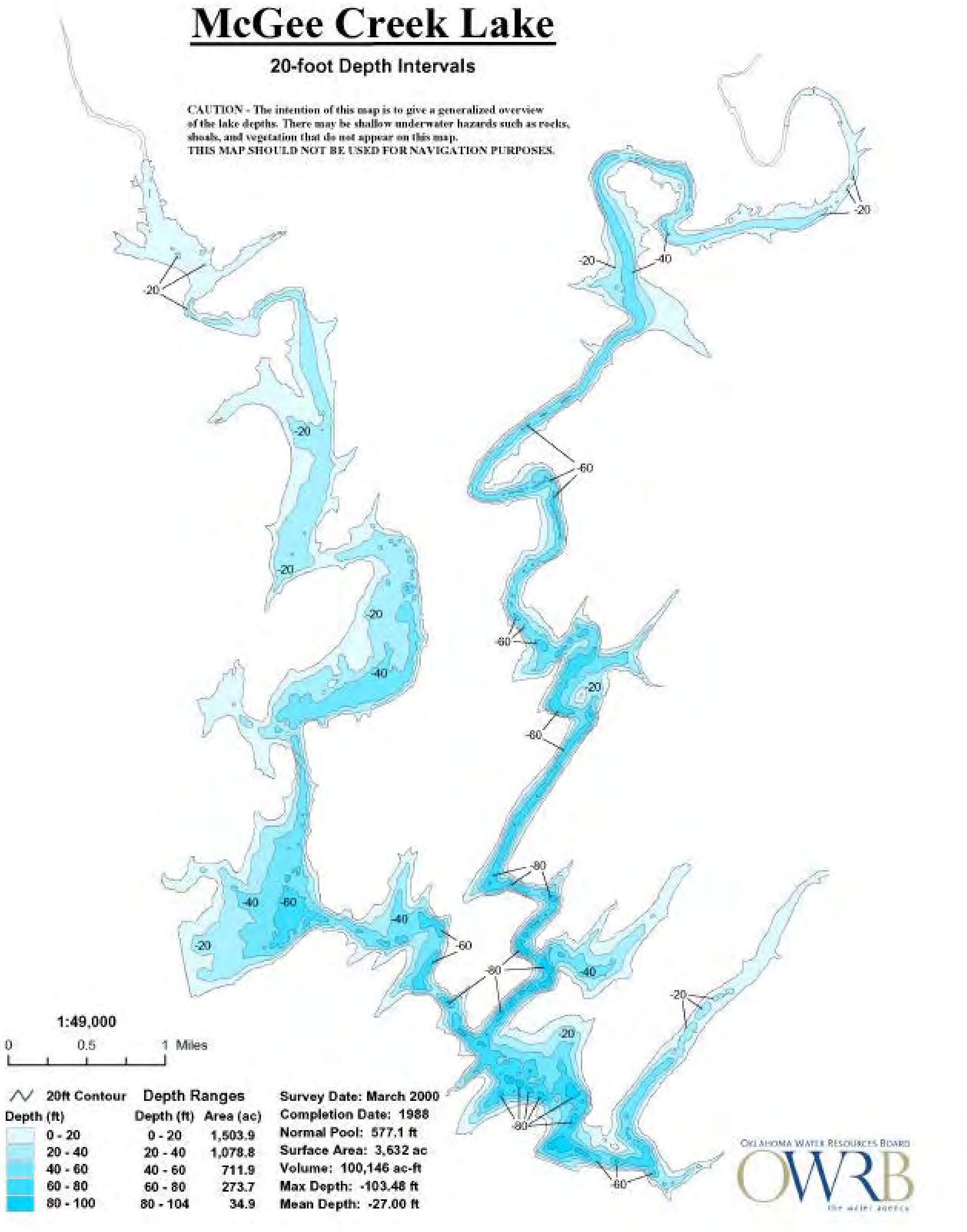



**Figure 166. Bathymetric map of McGee Creek Reservoir.**

# Lake McMurtry

Lake McMurtry was sampled for four quarters from October 2001 through July 2002. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major lake arms. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 15 NTU (Plate 74), true color was 39 units, and secchi disk depth was 69 centimeters in 2002. Based on these three parameters, Lake McMurtry had average water clarity when compared to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 50 (Plate 74), classifying the lake at the upper end of mesotrophy, indicative of moderate levels of primary productivity and nutrients. The TSI values in 2001-2002 varied seasonally with the lake at the lower end of eutrophy in the fall and in the spring. The lake was upper mesotrophic in the summer and oligotrophic during the winter quarter (see Figure 167). Almost all of the turbidity values collected were less than the Oklahoma Water Quality Standard (OWQS) of 25 NTU except for one value collected in the spring at the upper end of the lake (see Figure 168a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 5% of the samples collected above the standard the lake is fully supporting its Fish & Wildlife Propagation (FWP) based on nephelometric turbidity. Seasonal true color values are displayed in Figure 168b. Much like the turbidity data collected, almost all readings were below the OWQS of 70 units with the exception of one site in the upper end of the lake in the spring quarter (see Figure 168b). With only 5% of the collected data violating the OWQS the Aesthetics beneficial use is considered fully supported.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.21ppt, indicating low to elevated salt content. Collected values were well within the expected range of salinity values reported for most Oklahoma lakes though some readings were above the expected range. Readings for specific conductance were also within the range of normally encountered values, ranging from 0.0 mS/cm (probably due to operator error) to 426.2 mS/cm, indicating moderate presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline with values ranging from 7.32 units at the lake bottom in the spring quarter to 8.49 units recorded at the lake surface in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values

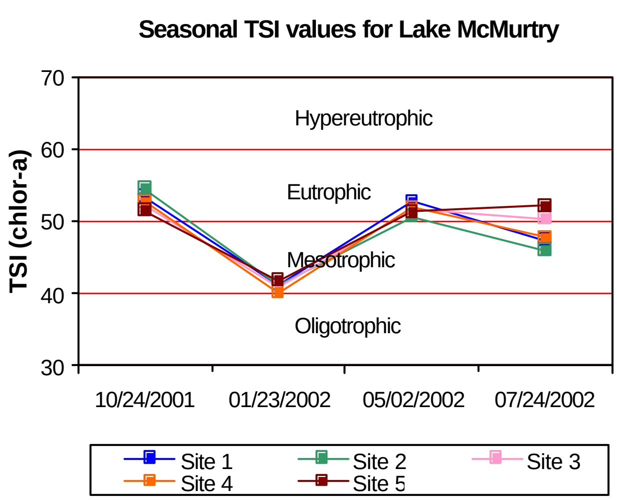



**Figure 167.** TSI values for Lake McMurtry.

fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. None of the collected values fell outside the acceptable range so the FWP beneficial use is fully supported based on pH. Oxidation-reduction potentials (redox) ranged from 39 mV in the summer to 457 mV in the fall quarter, indicating an absence of reducing conditions in the water column. Lake McMurtry was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.5 mg/L throughout the water (see Figure 168c-168d). In the spring quarter the lake was strongly thermally stratified near the lake bottom indicating the initial onset of stratification. One D.O. values below 2.0 mg/L was recorded near the sediment-water interface at site 1 near the dam (see Figure 168e). In the summer, the lake was thermally stratified near the 5 to 6 meter depth. Below a depth of 5 meters the D.O. values were less than 2.0 mg/L to the lake bottom at 12.5 meters (see Figure 168f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Lake McMurtry because 57% of the water column was anoxic at site 1 in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.56 mg/L at the lake surface. The TN at the surface ranged from 0.32 mg/L to 0.78 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.024 mg/L at the lake surface. The surface TP ranged from 0.17 mg/L to 0.34 mg/L. The highest surface TP value was reported in the spring quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 23:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake McMurtry was sampled for metals at five sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake McMurtry was classified as upper mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 74). According to USAP (OAC 785:46), the lake was fully supporting its FWP beneficial use based on turbidity and pH values and partially supporting the use based on low D.O. readings. The lake was fully supporting its Aesthetics beneficial use based on true color and lake trophic status findings. Lake McMurtry was constructed in 1971 and is owned and operated by the City of Stillwater. The lake is used as a municipal water supply and for flood control and recreational purposes.

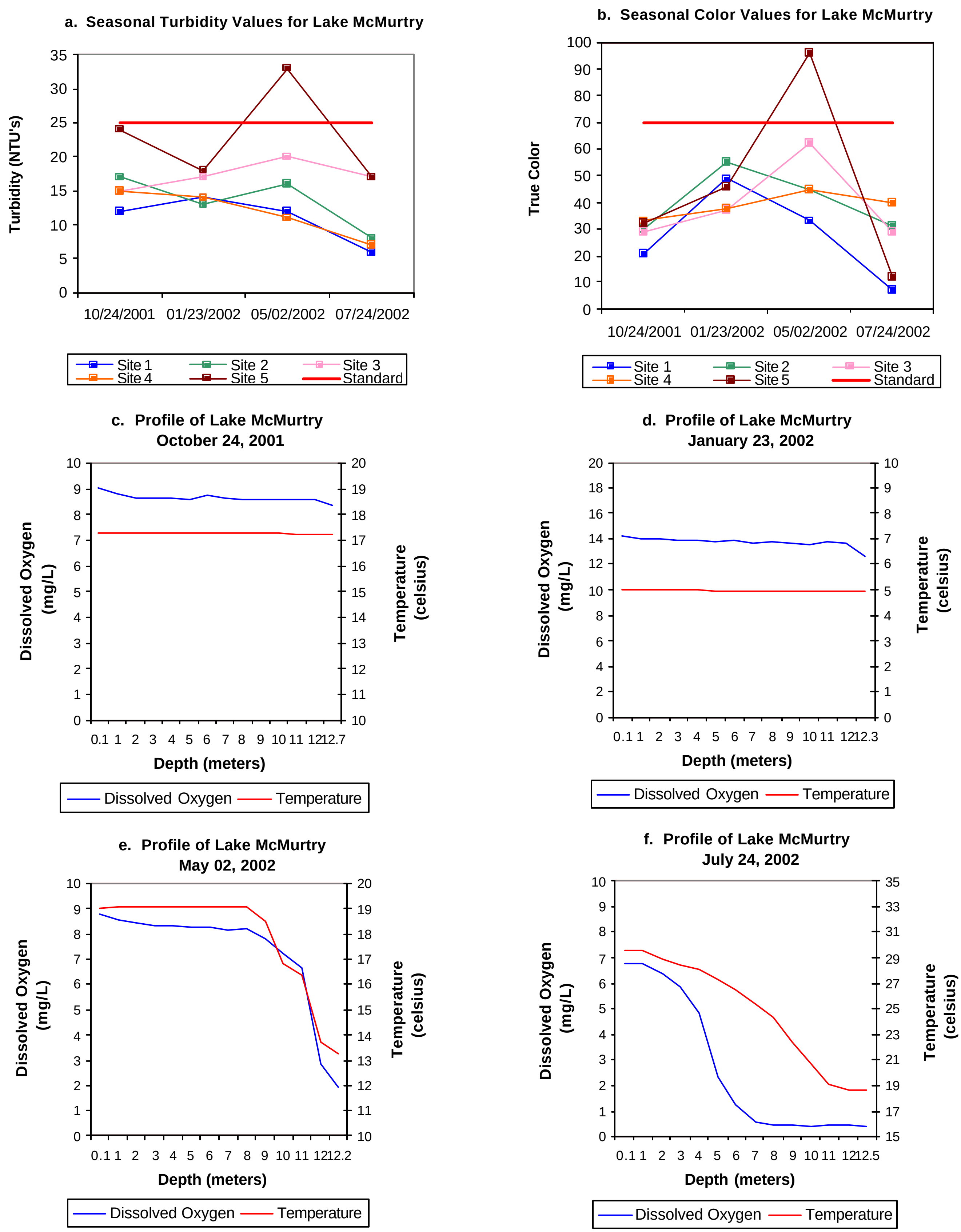
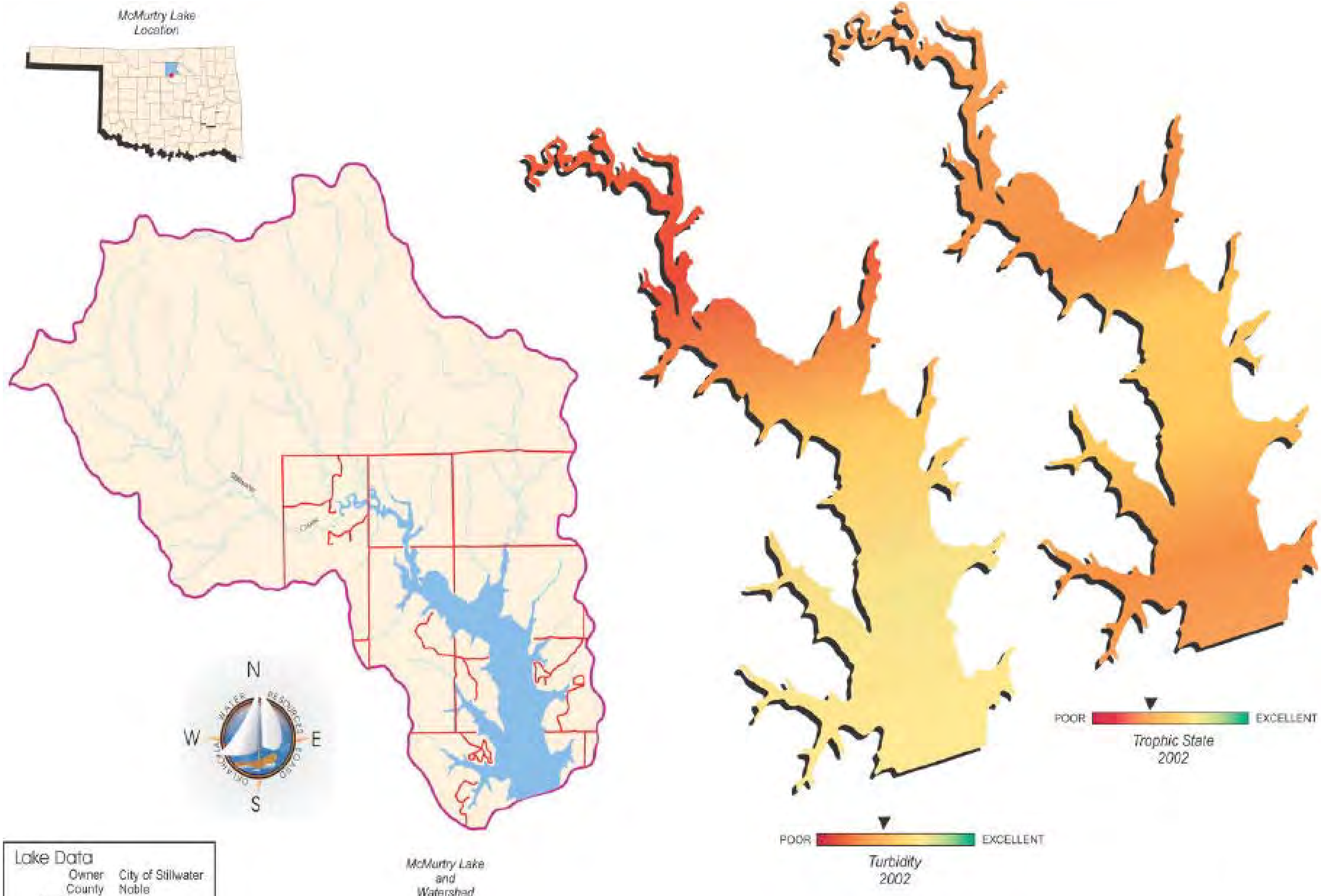



**Figure 168a-168f.** Graphical representation of data results for Lake McMurtry.




Lake Data

| | |
|---|---|
| Owner | City of Stillwater |
| County | Noble |
| Constructed | 1971 |
| Surface Area | 950 acres |
| Volume | 19,733 acre/feet |
| Shoreline Length | 28 miles |
| Mean Depth | 17.08 feet |
| Watershed Area | 25 square miles |

Plate 74 - Lake Water Quality for
Lake McMurtry

# Meeker Lake

Meeker Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 45 NTU (Plate 75), true color was 47 units, and secchi disk depth was 30 centimeters. Results were slightly better than that observed in 2002. Based on these three parameters, Meeker Lake had fair to poor water clarity when compared to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 51 (Plate 75), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. The TSI values varied seasonally from oligotrophic at site 1 in the fall quarter to upper mesotrophy in the winter and lower mesotrophy in the spring (see Figure 169). In the summer eutrophic and hypereutrophic conditions were present. All turbidity values in 2003-2004 were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 170a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the collected turbidity values exceeding the criteria the lake is not meeting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 170b. Although all sites were near the standard in the fall and summer quarters, only two (16.6%) of the twelve values recorded exceeded the OWQS of 70 units, constituting a partial support status of the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values were 0.01 parts per thousand (ppt) throughout the study period, indicating minimal salt content and within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also within the expected range of values reported for most Oklahoma lakes, ranging from 208.1 mS/cm to 224.1 mS/cm, indicating the presence of minimal concentrations of electrical current conducting compounds (salts) in the water column. In general, pH values were neutral to

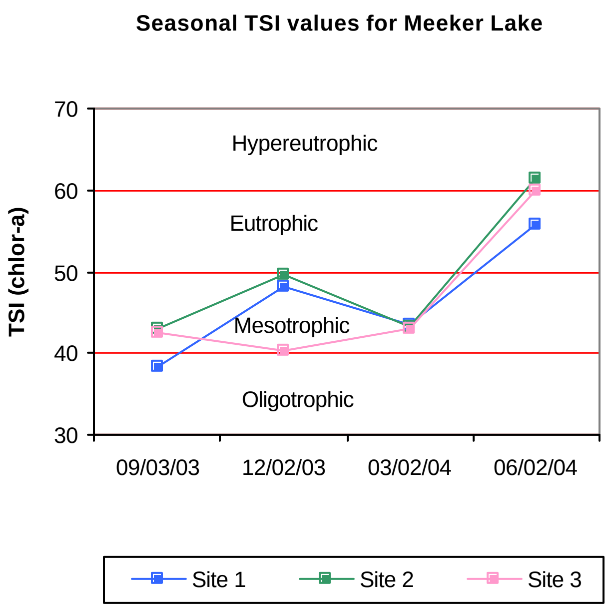



**Figure 169.** TSI values for Meeker Lake.

slightly alkaline with values ranging from 7.11 units in the fall to 8.36 in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 361 mV in the winter to 568 mV in the spring quarter, indicating an absence of reducing conditions in the water column during any of the sampling events. Meeker Lake was not thermally stratified in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values were above 4.0 mg/L throughout the water column in all three seasons (see Figure 170c-170e). In the summer the lake was weakly thermally stratified however D.O. values remained well above 2.0 mg/L , except at the lake bottom at site 1, the dam (see Figure 170f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Meeker Lake based on dissolved oxygen values collected during the sample year. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) was 0.65 mg/L at the lake surface. The TN at the surface ranged from 0.55 mg/L to 0.74 mg/L. The highest and lowest surface TN value was reported in the fall quarter. The lake-wide total phosphorus (TP) average was 0.041 mg/L at the lake surface. The surface TP ranged from 0.029 mg/L to 0.066 mg/L. The highest surface TP value was reported in the summer quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 16:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Meeker Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 65). The lake is fully supporting its Aesthetics beneficial use based on its trophic state, but is partially supporting the use based on true color values. The lake is fully supporting its FWP beneficial use based on pH and D.O. concentrations recorded in the water column, however it is not supporting the use based on high nephelometric turbidity concentrations in the lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported. Meeker Lake, located in Lincoln County, was constructed in 1970 and is owned and operated by the City of Meeker. The lake is utilized as a municipal water supply, for flood control, and for recreational purposes. Meeker Lake is one of Oklahoma's more turbid reservoirs.

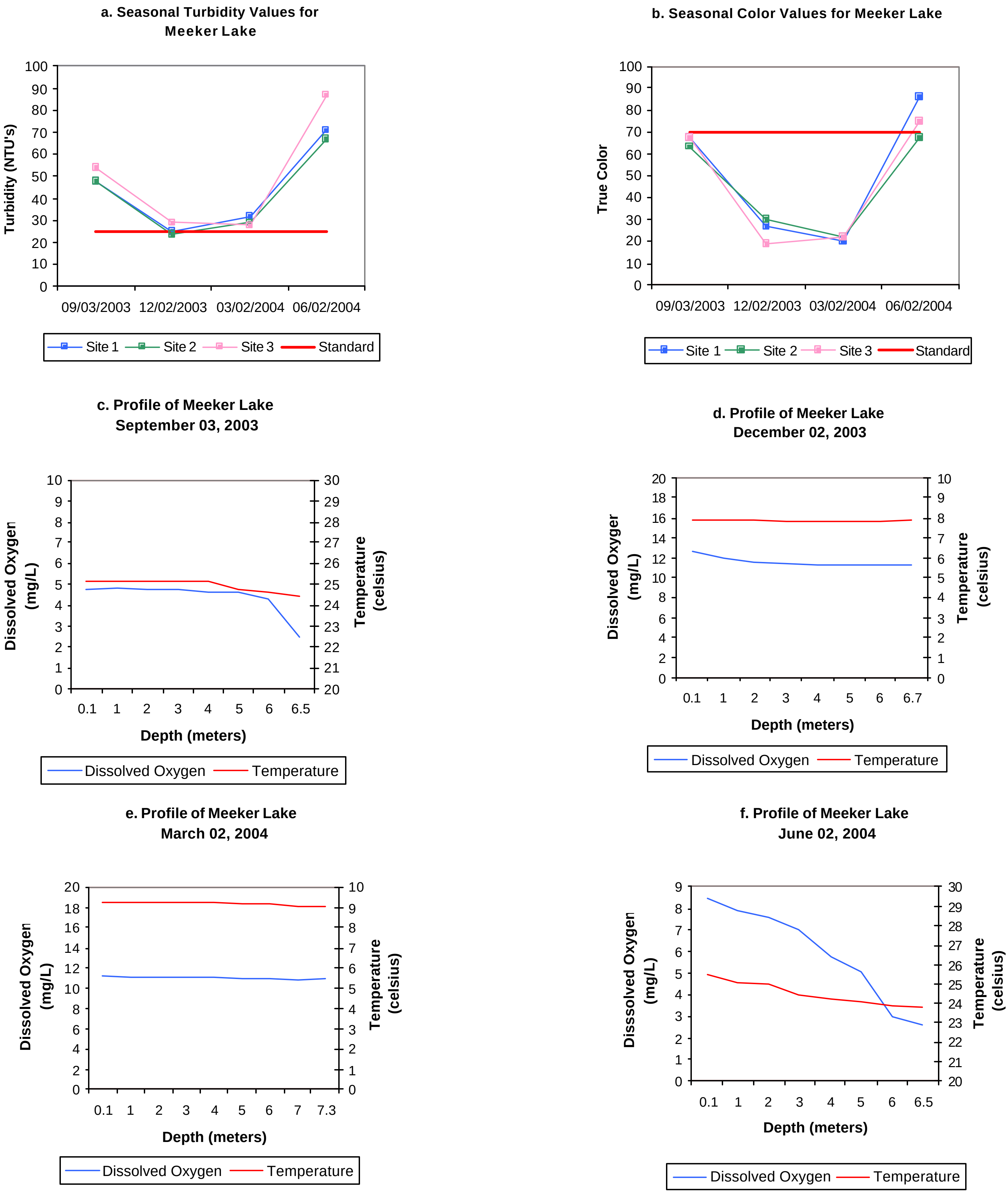
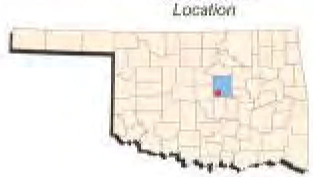
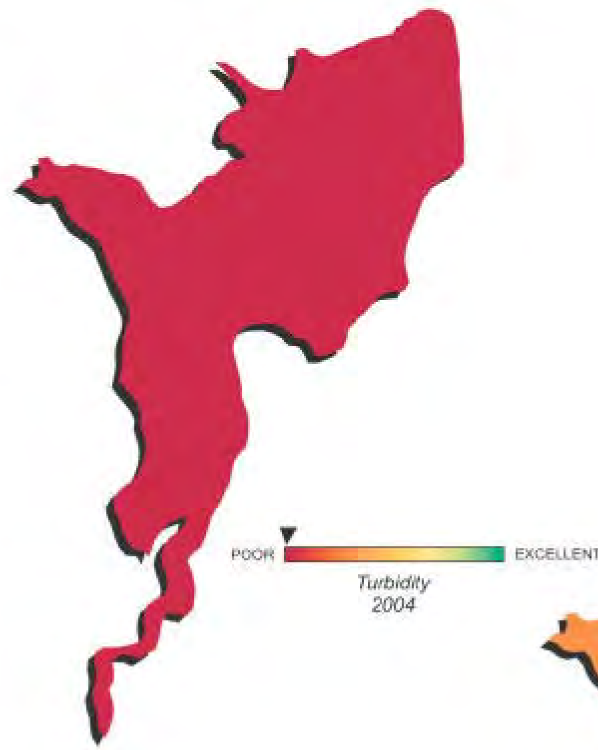



**Figure 170a-170f.** Graphical representation of data results for Meeker Lake.



| Lake Data | |
|---|---|
| Owner | City of Meeker |
| County | Lincoln |
| Constructed in | 1970 |
| Surface Area | 250 acres |
| Volume | 1,818 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 7.27 feet |
| Watershed Area | 12 square miles |



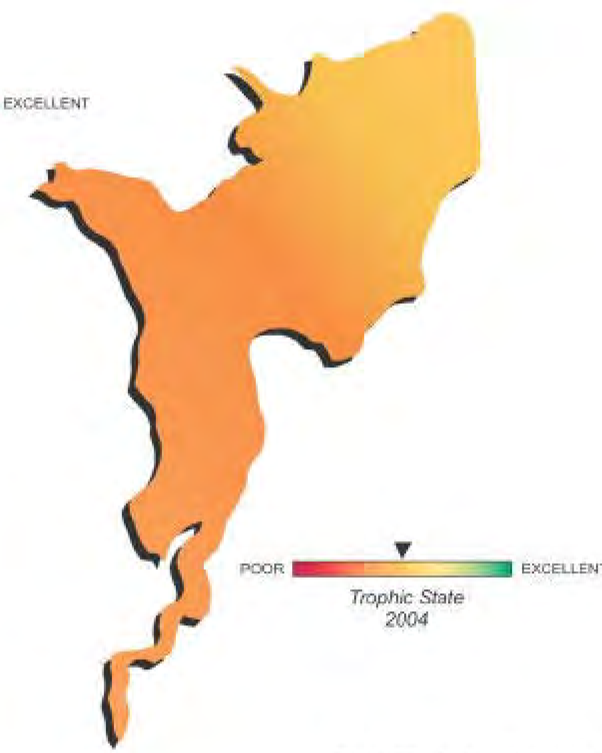




Plate 75 - Lake Water Quality for
## Meeker Lake

# Lake Murray

Lake Murray was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones and major arms of the reservoir. Samples were collected from the lake surface at all sites with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 5 NTU (Plate 76), true color was 10 units, and secchi disk depth was 182 centimeters. Based on these three parameters, Lake Murray had excellent water clarity in 2003-2004. These values are similar to those reported for sample year of 2001, indicating there has been no significant change in clarity over time. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 34 (Plate 76), classifying the lake as oligotrophic, indicative of low levels of productivity and nutrients. This value is lower than the one calculated in 2001 (TSI=42) indicating a possible decrease in productivity since the lake was previous sampled. The TSI values were consistently oligotrophic in all seasons, with the exception of site 5 in the summer, which was borderline mesotrophic (Figure 171). All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (Figure 172a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the collected turbidity values below the criteria, the lake is meeting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 172 b. With only 5% of the true color values recorded above the OWQS of 70 units the Aesthetic beneficial use is considered fully supported at Lake Murray.

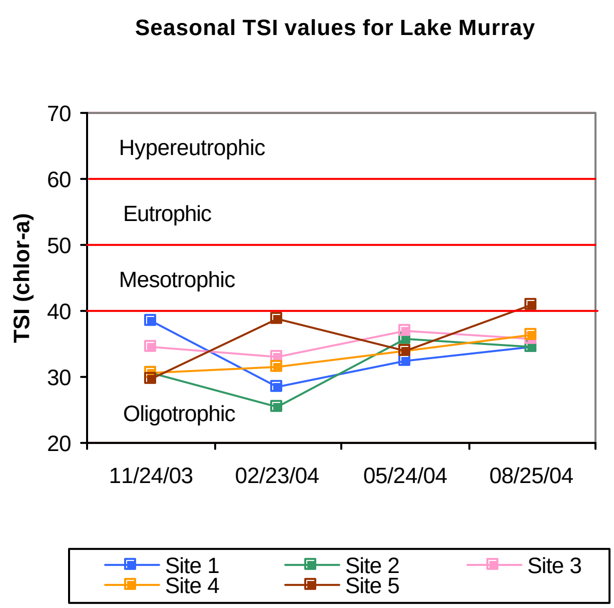



**Figure 171.** TSI values for Lake Murray.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values were 0.13 parts per thousand (ppt) to 0.15 ppt. Readings indicate low to moderate salt content and are within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also within the expected range of values reported for most Oklahoma lakes, ranging from 274.5 mS/cm to 304.9 mS/cm, indicating the presence of low to moderate concentrations of electrical current conducting compounds (salts) in the water column. In general, pH values were neutral to slightly alkaline with values ranging from 6.96 units in the spring to 8.12 in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 334 mV in the winter to 490 mV in the spring quarter, indicating an absence of reducing conditions during any of the sampling period. Lake Murray was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column (see Figure 172c-172d). Thermal stratification was evident in the spring quarter between 11 and 12 meters in depth, with D.O. remaining well above 2.0 mg/L except at the very bottom at sites 1 and 2 (Figure 172d). In the summer the lake was thermally stratified and anoxic conditions were present. Below the thermocline D.O. values were less than 2.0 mg/L, extending from 10 meters below the surface to the lake bottom of 27.4 meters at site 1, the dam (see Figure 172f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 66% of the water column experiencing anoxic conditions in the summer quarter, Lake Murray is partially supporting the FWP beneficial use based on dissolved oxygen values. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) was 0.25 mg/L at the lake surface and 0.25 mg/L at the lake bottom. The TN at the surface ranged from 0.10 mg/L to 0.44 mg/L. The highest TN value was reported in the summer quarter and lowest surface TN value was reported in the winter quarter. The lake-wide total phosphorus (TP) average was 0.011 mg/L at the lake surface and 0.011 mg/L at the lake bottom. The surface TP ranged from 0.007 mg/L to 0.023 mg/L. Both the highest and the lowest surface TP were reported in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 23:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1997 as part of their Toxics Monitoring Program and detected chlordane at the FDA Action level, ODEQ warning level and ODEQ concern level. The ODEQ sampled the lake again in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Murray was classified as oligotrophic, with low primary productivity and nutrient conditions (Plate 76). This value is lower than the one calculated in 2001 (TSI=42) indicating a possible decrease in productivity since the lake was previous sampled. Water clarity continues to be excellent at this reservoir based on turbidity, true color and secchi disk depth. The FWP beneficial use is fully supported based on turbidity and pH, however the lake is partially supporting the use based on anoxic conditions present during the summer. The Aesthetic beneficial use is fully supported based on trophic status and low true color values reported during the study period. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported. In 2001 a bathymetric survey (Figure 173) was conducted to determine current storage capacity and volume as well as create a database for future determination of sedimentation, assess shoreline exposure during lake level fluctuations. The data collected was also used to create a water usage plan for the reservoir. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800. Lake Murray, located in Love County is owned by the State of Oklahoma and is utilized for recreational purposes. Lake Murray and the state park surrounding it are one of the state's nicer recreational get aways.

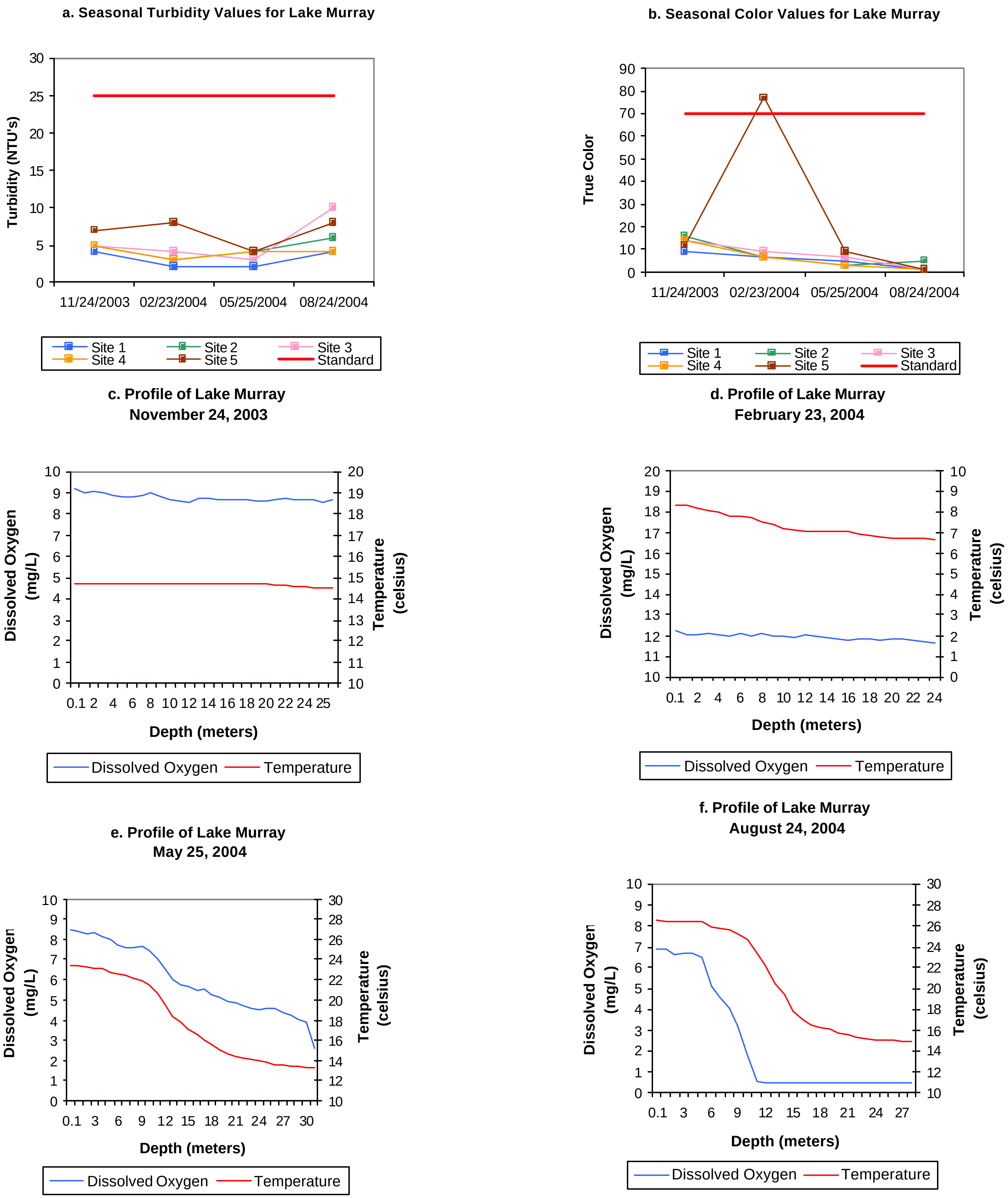
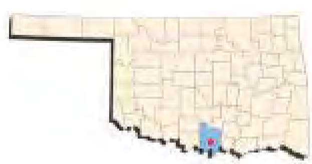



**Figure 172a-172f.** Graphical representation of data results for Lake Murray.


Lake Murray and Watershed

Lake Murray Location

| Lake Data | |
|---|---|
| Owner | State of Oklahoma |
| County | Love (Dam) |
| Constructed | 1960 |
| Surface Area | 5,728 acres |
| Volume | 153,250 acre/feet |
| Shoreline Length | 67 miles |
| Mean Depth | 26.75 feet |
| Watershed Area | 55 square miles |


Turbidity 2004


Trophic State 2004

Plate 76- Lake Water Quality for
**Lake Murray**

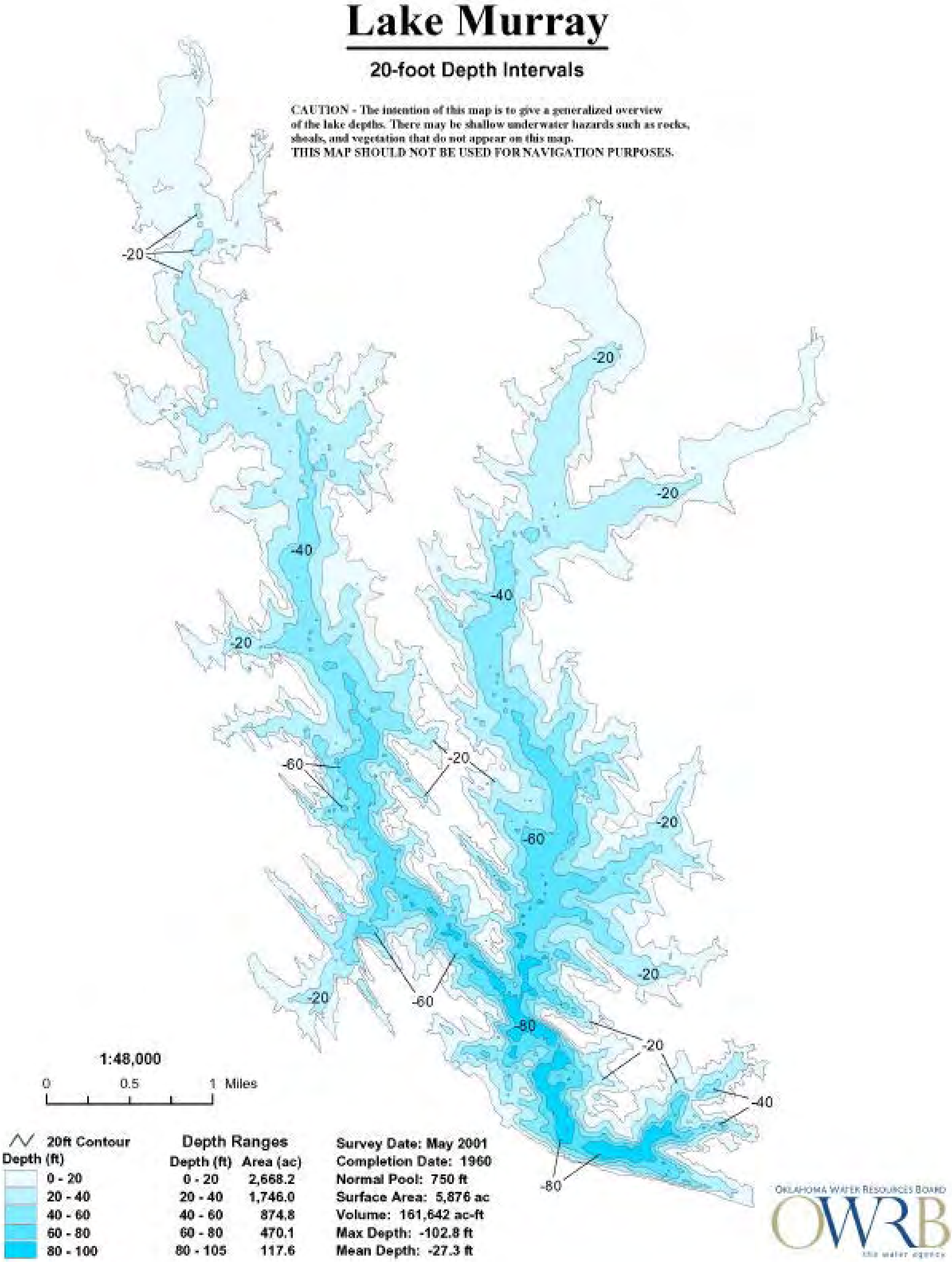



**Figure 173. Bathymetric map of Lake Murray.**

# Lake Nanih Waiya

Lake Nanih Waiya was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected from three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 7 NTU (Plate 77), true color was 13 units, and average secchi disk depth was 132 centimeters. Based on these three parameters Lake Nanih Waiya had excellent water clarity in sample year 2002-2003, similar to that observed in 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using values collected at all sites for four quarters (n=12). The TSI was 45 (Plate 77), classifying the lake as mesotrophic, indicative of moderate primary productivity and nutrient conditions. This is lower than the calculated values in 2000 (TSI=53), however the current value is based on data from the entire year as opposed to growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values were fairly consistent with all values in the mesotrophic category with the exception of site 3, in the summer, which dipped down to the oligotrophic category (see Figure 174). All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU therefore meeting the Fish and Wildlife Propagation (FWP) beneficial use (see Figure 175a. Seasonal turbidity values per site are displayed in Figure. Seasonal true color values are displayed in Figure 175b. Applying the same default protocol, the Aesthetics beneficial use is considered fully supported with 100% of the collected values below the OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.03 ppt. This is lower than the average range of values reported for Oklahoma lakes. Readings for specific conductivity ranged from 41 mS/cm to 209.8 mS/cm, indicating that low concentrations of electrical current conducting compounds (salts) were present in the lake system. The pH values at Lake Nanih Waiya ranged from 6.27 units to 8.18 units, representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With only 2 (3.3%) of the collected values falling outside the acceptable range, the lake is

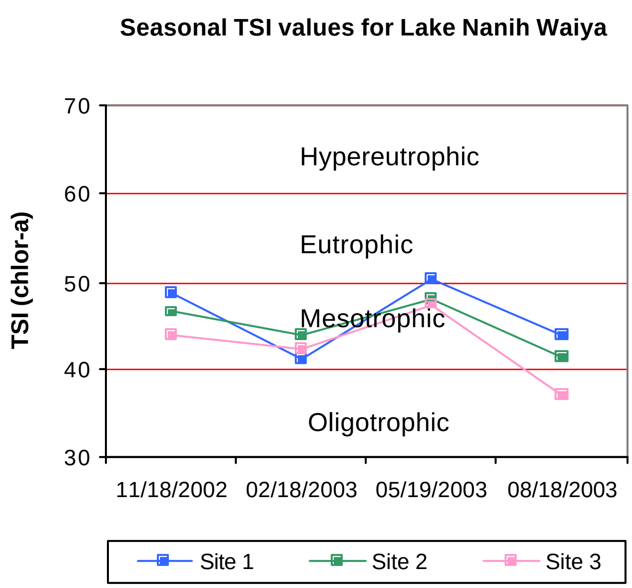



**Figure 174.** TSI values for Lake Nanih Waiya.

considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 358 mV in the summer to 643 mV in the fall. In general, reducing conditions were not present at this reservoir with all values being positive and above 100 mV throughout the study period. Stratification was not present during the fall and winter and the lake was well mixed with dissolved oxygen (D.O.) levels generally above 5.0 mg/L (see Figure 175c-175d). Thermal stratification was evident in both spring and summer and anoxic conditions were present. During the spring, the lake was stratified between 4 and 5 meters with dissolved oxygen falling below 2.0 mg/L for approximately 29% of the water column at site 1 (see Figure 175e-175f). In the summer sampling quarter, stratification occurred between 3 and 4 meters at which point the D.O. fell below 2.0 mg/L to the lake bottom of 5.3 meters accounting for approximately 43% of the water column, at site 1, to be experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Lake Nanih Waiya based on D.O. values in the spring and summer quarters. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.38 mg/L at the surface and 0.55 mg/L at the lake bottom. Surface TN ranged from 0.05 mg/L to 0.65 mg/L, with the highest values reported in the summer and lowest values in the winter. The lake-wide total phosphorus (TP) average was 0.017 mg/L at the surface and 0.030 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.008 mg/L to 0.028 mg/L. Surface TP was highest in the winter and lowest during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Nanih Waiya was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions during sample year 2002-2003. This is lower than the calculated value in 2000 (TSI=53), however the current value is based on data from the entire year as opposed to growing season only and is likely a more accurate depiction of productivity within the lake. Water clarity was excellent based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial used based on turbidity and pH values and only partially supporting based on low D.O. values in the spring and summer months. The Aesthetics beneficial use is fully supported based on its trophic status and true color values. Lake Nanih Waiya, located in Pushmataha County, is owned by the State of Oklahoma and is utilized for recreational purposes.

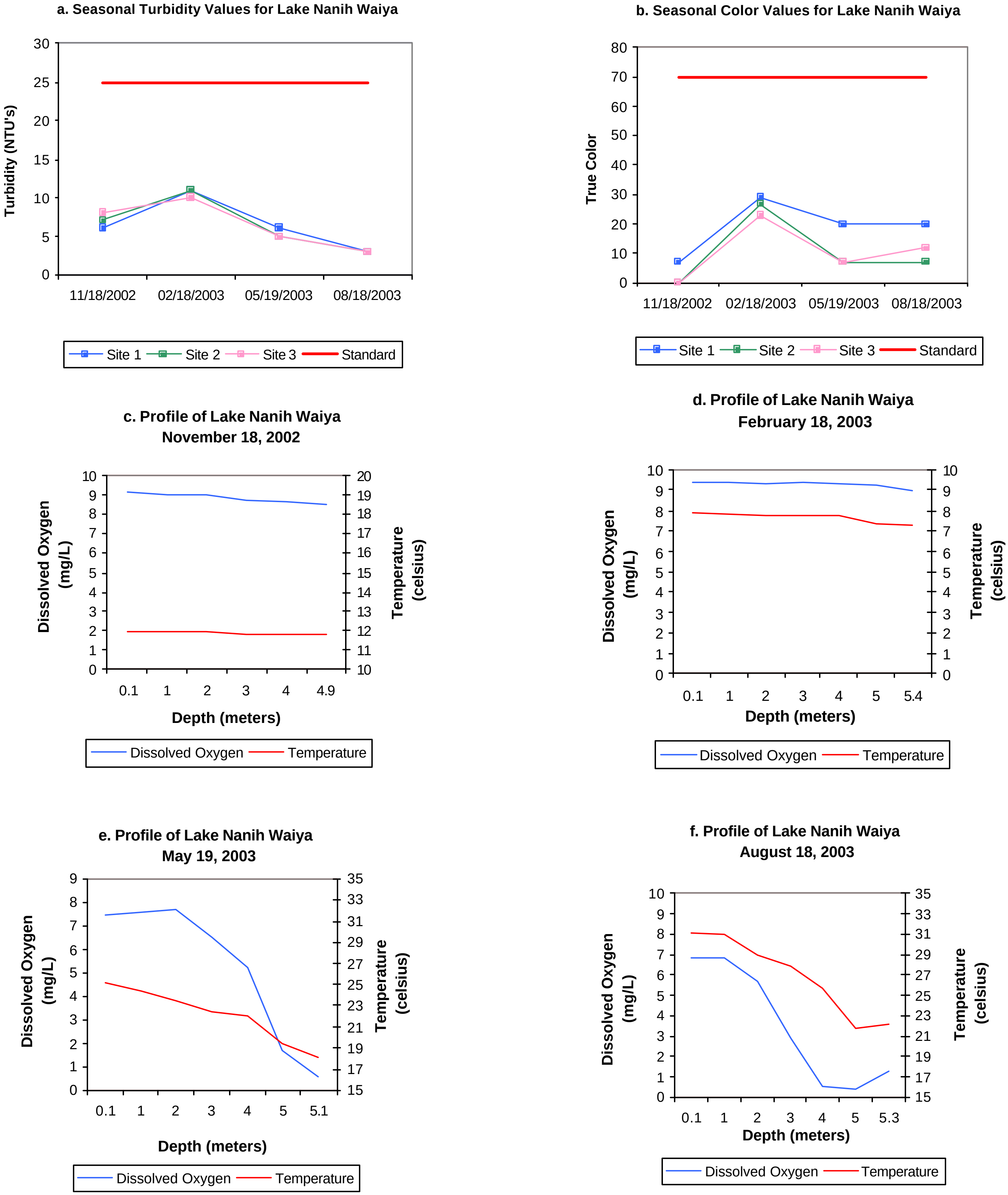
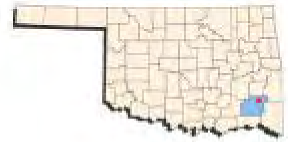



**Figure 175a-175f.** Graphical representation of data results for Lake Nanih Waiya.





Lake Data

| | |
|---|---|
| Owner | State of Oklahoma |
| County | Pushmataha |
| Constructed in | 1958 |
| Surface Area | 131 acres |
| Volume | 1,064 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 8.12 feet |
| Watershed Area | 2,848 acres |

Plate 77 - Lake Water Quality for
## Lake Nanih Waiya

# Okemah Lake

Okemah Lake (761 surface acres) was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at four (4) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. In addition, a sample was also collected at the lake surface at site 5 for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. Samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 14 NTU (Plate 78), true color was 26 units, and secchi disk depth was 98 centimeters in 2001-2002. Based on these three parameters, Okemah Lake had good to excellent water clarity in comparison to other Oklahoma reservoirs. Nephelometric turbidity readings would have been much lower for this lake if a couple of very high readings recorded in the upper end of the in the spring quarter had not occurred. In general lake turbidity readings were below 14 NTU and were often in the single digits. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 43 (Plate 78), indicating the lake was mesotrophic in sample year 2001-2002 indicative of moderate to low primary productivity and nutrients present in the lake. The TSI values throughout the sample year varied seasonally. The lake was generally mesotrophic in the fall and winter and oligotrophic in the spring and summer. This is a reversal of the normal pattern seen in Oklahoma lakes (see Figure 176). Turbidity values were all well below the turbidity standard of 25 NTU with the exception of two values in the spring discussed above (see Figure 177a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 10% of the values exceeding the OWQS the lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 177b. True color values were below the aesthetics OWQS of 70 units at all times (see Figure 177b). A definitive determination of beneficial use support for true color could not be made due to insufficient data, though collected information strongly suggests the lake would fully support its Aesthetics use.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.03 parts per thousand (ppt) to 0.09 ppt, indicating low salt content in the lake and were well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were low, ranging from 92.6 mS/cm to 191.3 mS/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to alkaline in nature with values ranging from 6.72 units in the summer quarter to 9.1 in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the

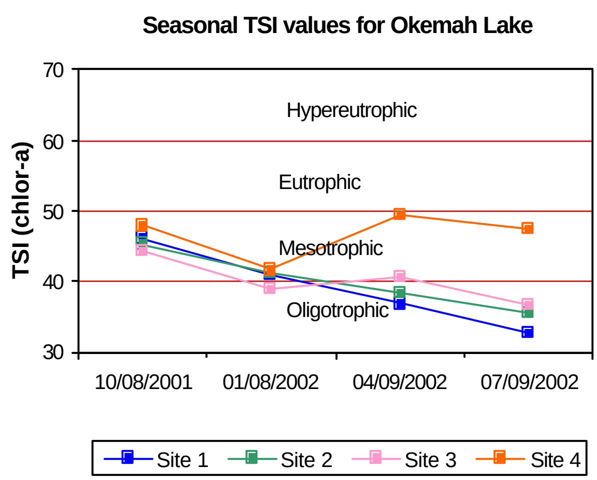



**Figure 176.** TSI values for Okemah Lake.

values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Although several values were above the 9.0 unit threshold, the lake is fully supporting its FWP beneficial use based on pH values with only 6% of the collected values falling outside the acceptable range. Oxidation-reduction potentials (redox) ranged from 88 mV in the summer to 524 mV in the fall, indicating an absence of any significant reducing conditions in the lake. Okemah Lake was not stratified in the fall, winter or spring quarters and dissolved oxygen (D.O.) values were above 5.0 mg/L throughout the water column in all three seasons and were generally above 6.0 mg/L (see Figure 177c-179e). In the summer quarter, the lake was strongly thermally stratified between 4 and 5 meters and between 5 and 6 meters at site 1 (see Figure 177f). Anoxic conditions were present below the 5-meter depth at site 1 and D.O. readings were below 1.0 mg/L from 6 meters to the lake bottom at 12 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, with 62% of the water column less than 2.0 mg/L at site 1 in the summer, the FWP beneficial use is partially supported at Okemah Lake. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.42 mg/L at the lake surface. The TN at the surface ranged from 0.25 mg/L to 0.81 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.024 mg/L at the lake surface. The surface TP ranged from 0.009 mg/L to 0.121 mg/L. The highest surface TP value was reported in the spring quarter and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Okemah Lake was sampled for metals at four sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Okemah Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 78). The lake was fully supporting its Aesthetics beneficial use based on its trophic status but a definitive determination could not be made based on true color, though collected data suggests it would be fully supporting. Okemah Lake was fully supporting its FWP beneficial use based on turbidity and pH. The FWP beneficial use was partially supported based on D.O. values. Okemah Lake is owned and operated by the City of Okemah and serves as a municipal water supply and offers numerous recreational opportunities to the public. Okemah Lake is one of the nicer small municipal reservoirs in Oklahoma and should managed and preserved to ensure that its water quality is not degraded over time.

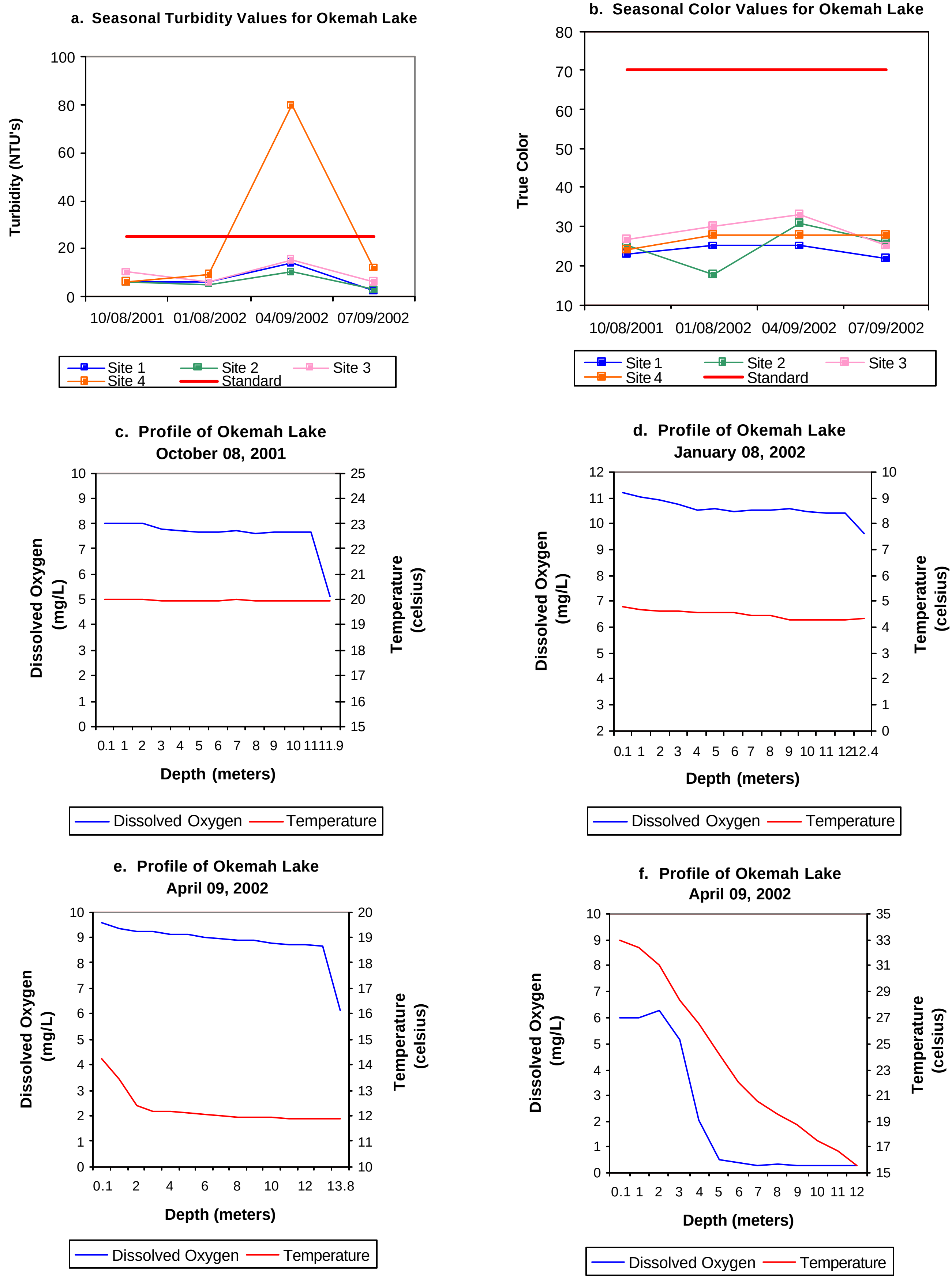
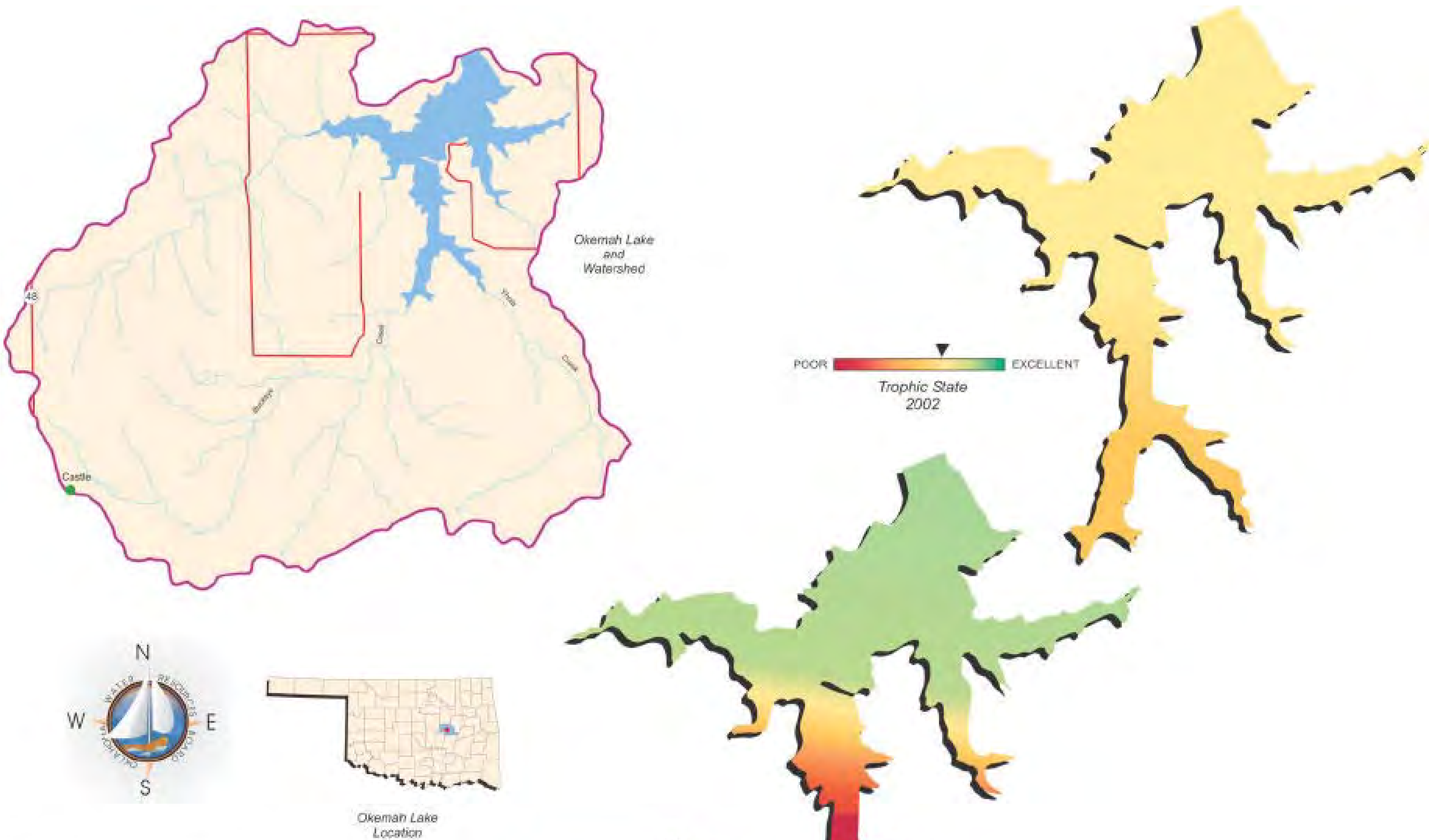



**Figure 177a-179f.** Graphical representation of data results for Okemah Lake.




Lake Data

| | |
|---|---|
| Owner | City of Okemah |
| County | Okfuskee |
| Constructed in | NA |
| Surface Area | 761 acres |
| Volume | 13,100 acre/feet |
| Shoreline Length | 16 miles |
| Mean Depth | 17.21 feet |
| Watershed Area | 20 square miles |

Plate 78 - Lake Water Quality for
## Okemah Lake

# Okmulgee Lake

Okmulgee Lake was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. In addition, samples were collected at the lake surface at sites 4 and 5 for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. Water quality samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 12 NTU (Plate 79), true color was 37 units, and secchi disk depth was 95 centimeters in 2001-2002. Based on these three parameters, Okmulgee Lake had good to excellent water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 45 (Plate 79), indicating the lake was mesotrophic in sample year 2001-2002. The TSI values throughout the sample year varied seasonally from upper mesotrophic in the fall, to the middle of the mesotrophic range in the winter and spring, to oligotrophic in the summer quarter (see Figure 178). It is not common to see lower primary productivity occurring in the warmer summer months and to have your highest productivity in the fall. High primary productivity in the fall/winter does occur, but the minimum in the summer was unexpected and cannot be easily explained. Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU with the exception of one values recorded in the spring quarter at site 3 (see Figure 179a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Only 5% of the recorded turbidity values were above the criteria, so the Fish & Wildlife Propagation (FWP) beneficial use is fully supported as it relates to turbidity. Seasonal true color values are displayed in Figure 179b. True color values were all below the OWQS of 70 units at all sites, however no definitive determination of Aesthetics use support could be made due to insufficient data. Collected data strongly supports the supposition that the lake would be fully supporting the use.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.04 ppt, indicating low salt content and all values were well within the expected range of salinity reported for most Oklahoma lakes. Readings for specific conductance were very low, ranging from 38.6 mS/cm to 98.3 mS/cm, indicating the very slight presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were slightly neutral to alkaline with values ranging from 6.49 units in the summer quarter to 9.24 in the summer at site 1 at the lake surface. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the

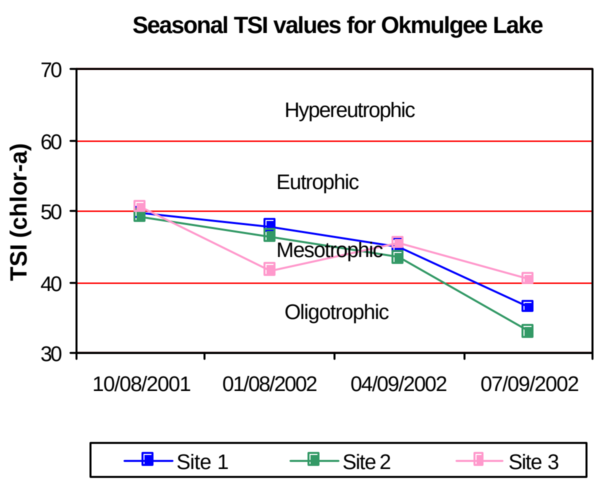



**Figure 178.** TSI values for Okmulgee Lake.

pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Okmulgee Lake had only 2% of its pH values falling outside the acceptable range and for this reason it is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 98 mV in the summer to 489 mV in the fall quarter, indicating an absence of reducing conditions. Okmulgee Lake was thermally stratified in the fall very near the lake bottom and dissolved oxygen (D.O.) concentrations in the bottom three meters of the lake were less than 1.0 mg/L (see Figure 179c). In the winter and spring quarters the lake was not thermally stratified and D.O. concentrations never fell below 8.25 mg/L at any point in the water column (see Figure 179d-181e). In the summer the lake was strongly thermally at several depths throughout the water column (see Figure 179f) and D.O. values below the 3-meter depth were all less than 2.0 mg/L and were generally less than 1.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is not supported with 73% of the water column experiencing anoxic conditions. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.52 mg/L at the lake surface. The TN at the surface ranged from 0.32 mg/L to 1.32 mg/L. The highest surface TN value was reported in the winter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.20 mg/L at the lake surface. The surface TP ranged from 0.009 mg/L to 0.042 mg/L. The highest surface TP value was reported in the spring and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 26:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Okmulgee Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Okmulgee Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 79). The lake was fully supporting its FWP beneficial use based on turbidity and pH concentrations, however the lake was not supporting based on low D.O. readings in the water column in the summer quarter. The lake was fully supporting its Aesthetics beneficial use basic on trophic state and sufficient data was not available to assess use support related to true color. True color data did strongly suggest that the lake would be meeting its Aesthetics use for color. Okmulgee Lake, located in Okmulgee County, was constructed in 1928 and is owned and operated by the City of Okmulgee. The lake is the municipal water supply for the city and is also utilized for recreational purposes.

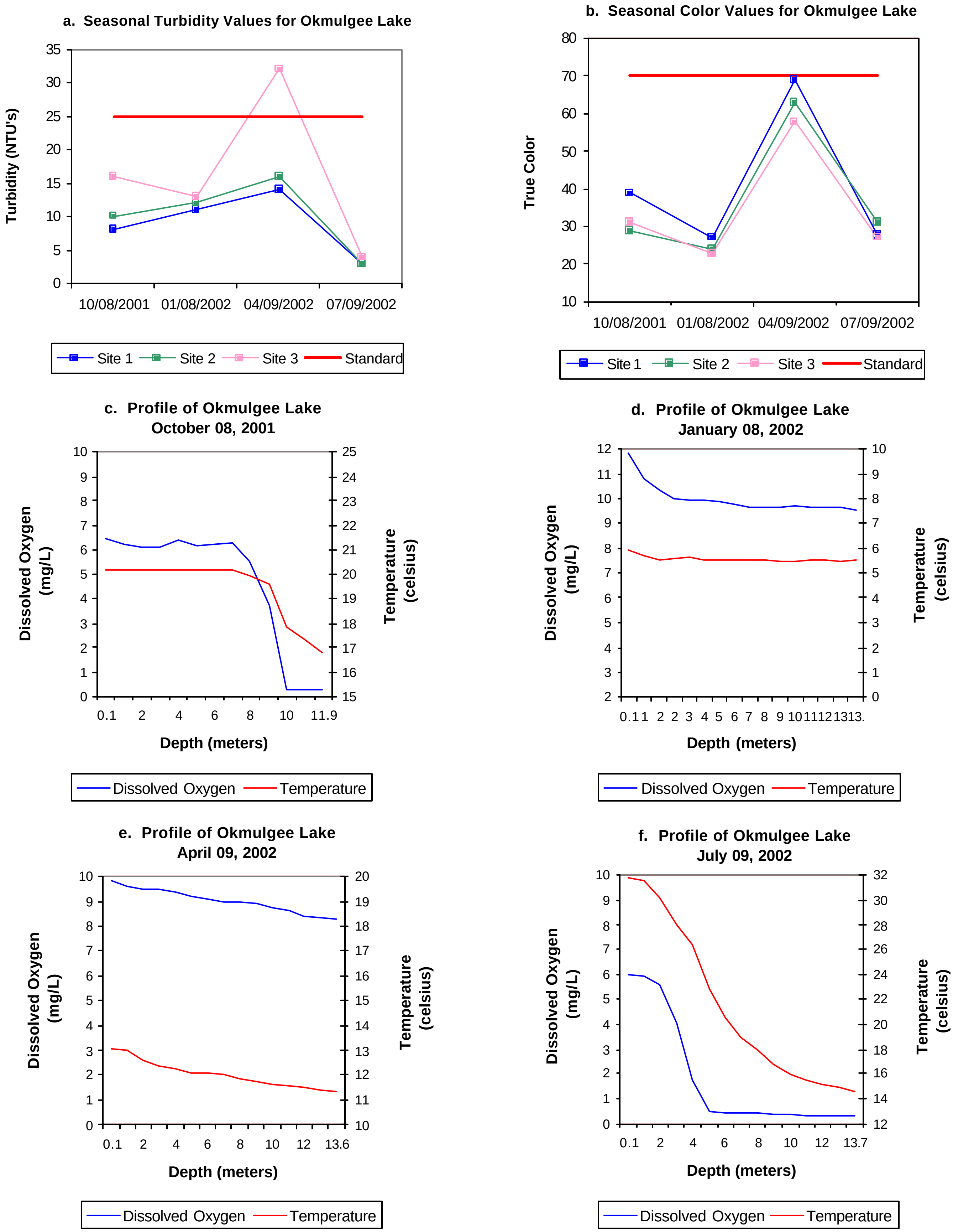
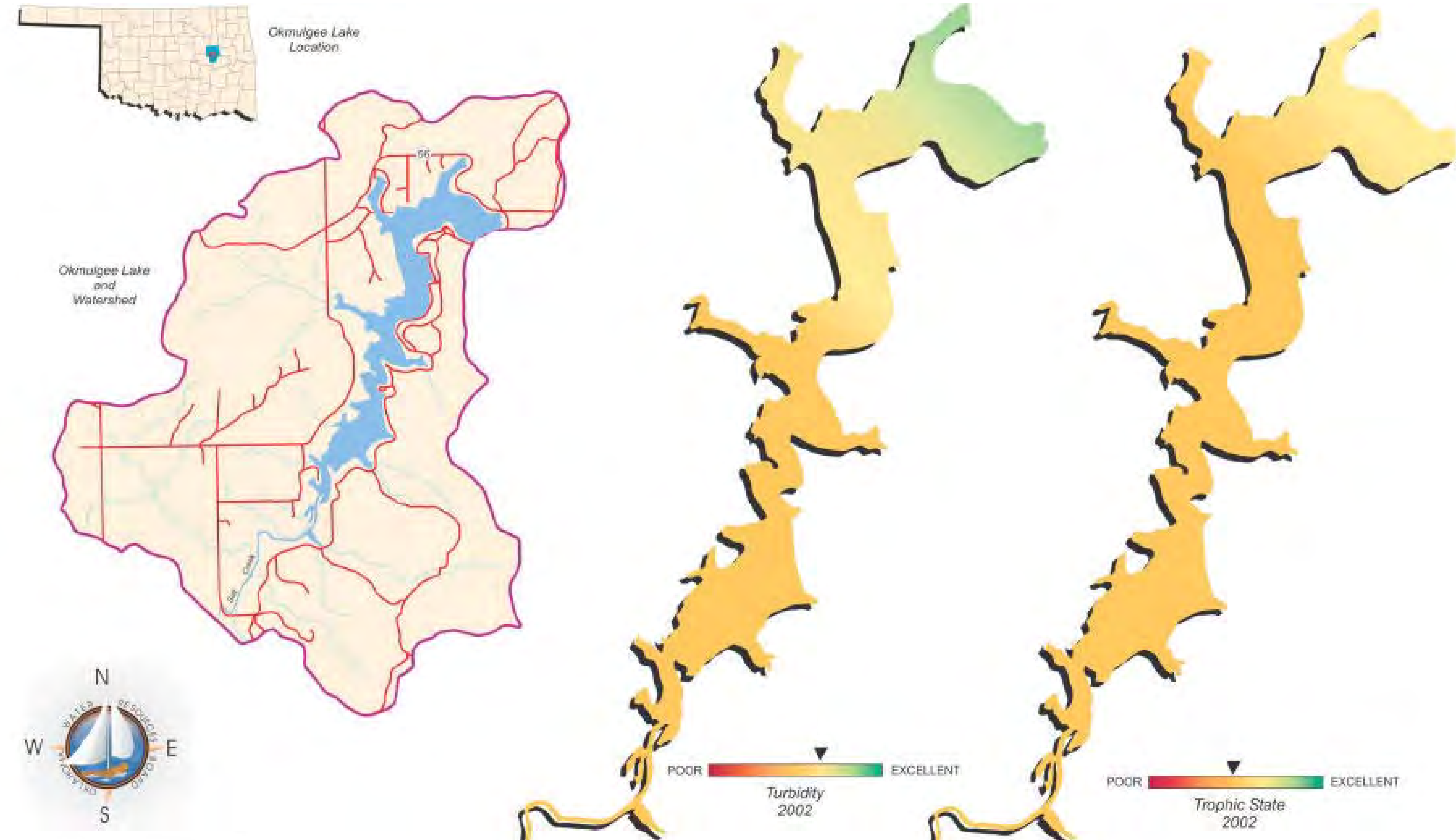



**Figure 179a-181f.** Graphical representation of data results for Okmulgee Lake.




Lake Data

| | |
|---|---|
| Owner | City of Okmulgee |
| County | Okmulgee |
| Constructed in | 1928 |
| Surface Area | 668 acres |
| Volume | 14,170 acre/feet |
| Shoreline Length | 19 miles |
| Mean Depth | 21.21 feet |
| Watershed Area | 14 square miles |

Plate 79 - Lake Water Quality for
## Okmulgee Lake

# Oologah Lake

Oologah Lake was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at seven (7) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 22 NTU (Plate 80), true color was 23 units, and secchi disk depth was 41 centimeters in 2001-2002. Based on these three parameters, Oologah Lake had fair water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=28). The TSI was 48 (Plate 80), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions in sample year 2002-2003. This is lower than the value calculated in 2000, (TSI=51), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of lake productivity. The TSI values were fairly consistent and ranged from mesotrophic to the lower end eutrophic during the study period (see Figure 180). Seasonal turbidity values are displayed in Figure. In the fall, five of the seven sites were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, but varied the other three quarters. In the winter and spring most values were near or below the standard while in the summer about half were above and half were below (see Figure 181a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 31% of the recorded turbidity values above the standard the Fish and Wildlife Propagation (FWP) beneficial use is partially supported based on turbidity. Seasonal true color values are displayed in Figure 181b. All true color values were below the OWQS of 70 units except for site 5, which had a value of 84 units recorded in the spring. Applying the same default protocol, the Aesthetics beneficial use is fully supported based on true color values (see Figure 181b).

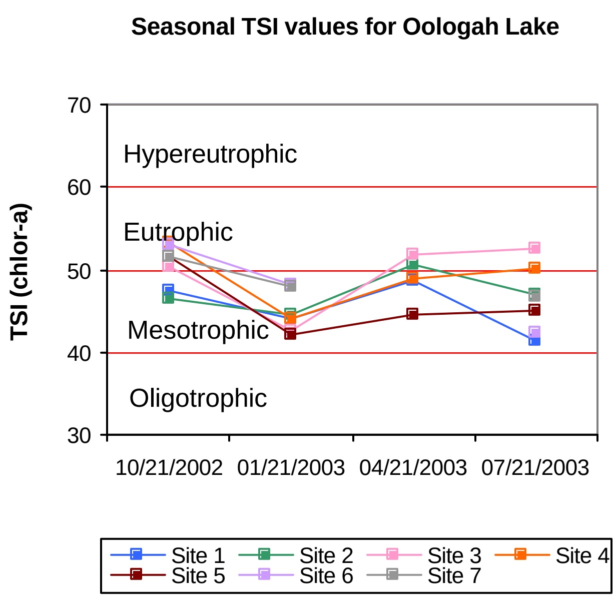



**Figure 180.** TSI values for Oologah Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sites during sample year 2002-2003. Salinity values at Oologah Lake ranged from 0.13 parts per thousand (ppt) to 0.23 ppt. This is within the average range of values reported for Oklahoma reservoirs.

Specific conductivity ranged from 263.1 mS/cm to 635 mS/cm, indicating that low to moderate concentrations of electrical current conducting materials (salts) were present in the lake system. The pH values collected at Oologah Lake ranged from 7.07 to 8.22 representing a neutral to slightly alkaline system. Oxidation-reduction potentials ranged from 317 mV in the fall to 635 mV in the summer. Reducing conditions were not present in 2003, with all recorded values positive and above 100 mV. Thermal stratification was not present during the fall, winter, or spring sampling quarters, and the lake was well mixed with dissolved oxygen (D.O) levels remaining above 6.0 mg/L (see Figure 181c-183e). In the summer, stratification was evident and anoxic conditions were present. The lake was stratified at several 1-meter intervals with dissolved oxygen generally below 2.0 mg/L from the thermocline to the bottom of the lake accounting for 10 to 56% of the water column to be experiencing anoxic conditions (see Figure 181f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, Oologah Lake is considered partially supporting the FWP beneficial based on dissolved oxygen. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.41 mg/L at the surface and 0.48 mg/L at the lake bottom. Surface TN ranged from 0.22 mg/L to 0.71 mg/L, with the highest values reported in the spring and lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.048 mg/L at the surface and 0.072 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.022 mg/L to 0.097 mg/L. Similar to TN, surface TP was highest in the spring and lowest during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003. This is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Oologah Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient condition. Although this is lower than the previous classification in 2000 (TSI=51), the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. Water clarity was fair based on turbidity, true color and secchi disk depth readings. The lake is supporting the FWP beneficial use based on pH, partially supporting based on dissolved oxygen, and not supporting the use based on turbidity. The Aesthetics beneficial use is supported based on both its trophic status and reported true color values. Oologah Lake, constructed by the United States Army Corps of Engineers (UASCE), serves a water supply for the City of Tulsa and is utilized for flood control and navigational purposes.

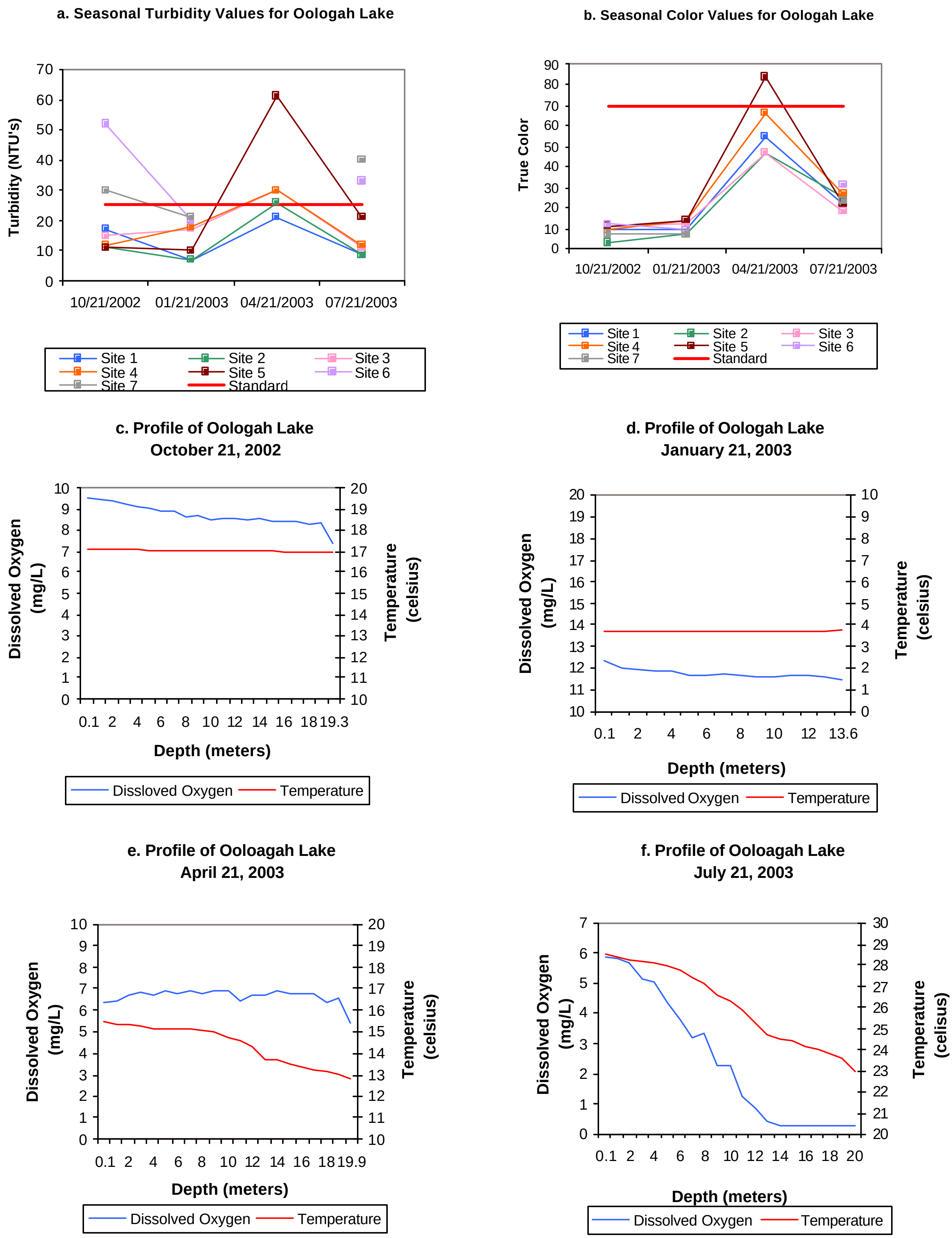
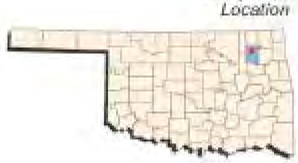



**Figure 181a-183f.** Graphical representation of data results for Oologah Lake.


Oologah Lake and Watershed

Oologah Lake Location




Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Rogers |
| Constructed in | 1974 |
| Surface Area | 29,460 acres |
| Volume | 553,400 acre/feet |
| Shoreline Length | 180 miles |
| Mean Depth | 18.7 feet |
| Watershed Area | 4,339 square miles |


Turbidity
2003


Trophic State
2003

Plate 80 - Lake Water Quality for
Oologah Lake

# Lake Overholser

Lake Overholser was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 205 nephelometric turbidity units (NTU) (Plate 81), true color was 82 units, and secchi disk depth was 19 centimeters. Based on these three parameters, Lake Overholser had fair to poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was calculated at 64 (Plate 81), indicating the lake was hypereutrophic with excessive primary productivity and nutrient levels in sample year 2003-2004. This is similar to the TSI calculated in 2002 (TSI=68), which also found the lake to be hypereutrophic. The TSI values were consistent from season to season and were only eutrophic in the spring and summer quarters and hypereutrophic for the other two quarters of the year (see Figure 182). Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (OWQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Turbidity values were also elevated in the lake with 100% of the collected data exceeding the OWQS of 25 NTU (see Figure 183a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Overholser Lake is not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on high nephelometric turbidity concentrations in the water column. Seasonal true color values are displayed in Figure 183b. True color values were below the Aesthetics OWQS of 70 units in the fall, winter and summer sampling intervals, however all sites exceeded the standard in the spring quarter. With 25% of the values greater than the standard, the Aesthetics beneficial use is considered not supporting for true color.

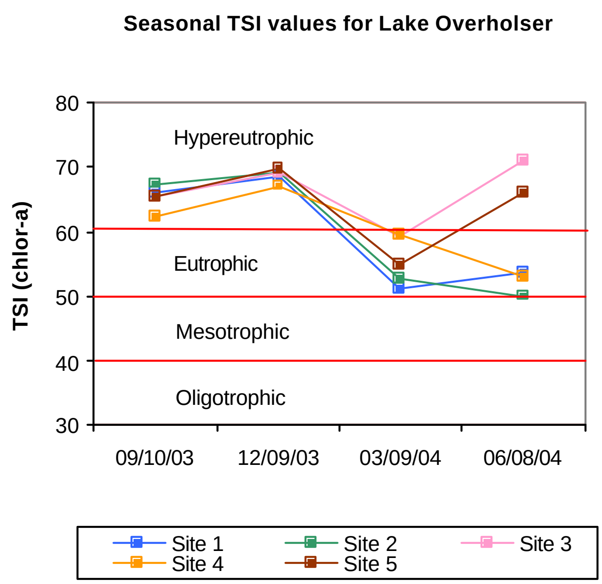



**Figure 182.** TSI values for Lake Overholser.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.1 parts per thousand (ppt) to 0.84ppt, indicating moderate to high amounts of salts in the water column when compared to most Oklahoma lakes. Readings for specific conductance were also very high, ranging from 208.3 mS/cm to 1589 mS/cm, indicating moderate to high amounts of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline with values ranging from 7.57 units in the spring quarter to 8.41 units in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All pH values were within the accepted range therefore supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 318 mV in the summer quarter to 547 mV in the winter quarter, indicating an absence of reducing conditions during the study period. Lake Overholser was not thermally stratified in any of the sampling quarters and dissolved oxygen (D.O.) values were above 7.5 mg/L throughout the water column in all four seasons (see Figure 183c-185f). This lake is very shallow (about 2.5 meters deep) and it is likely wind mixing precludes the onset of thermal stratification. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the Fish & Wildlife Propagation (FWP) beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Lake Overholser. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical Oklahoma Water Quality Standards (OWQS) for these parameters. The lake-wide total nitrogen (TN) average was 1.97 mg/L at the lake surface. The TN at the surface ranged from 1.09 mg/L to 3.25 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.262 mg/L at the lake surface. The surface TP ranged from 0.120 mg/L to 0.665 mg/L. Similar to total nitrogen, the highest surface TP value was reported in the spring quarter and the lowest was in the summer quarter. In general, nutrient concentrations in this lake were very high, probably due to its shallow nature and re-suspension of nutrient laden sediment into the water column. The nitrogen to phosphorus ratio (TN: TP) was approximately 8:1. This value is close to 7:1, characterizing the lake possibly co-limited (Wetzel, 1983).

In summary, Lake Overholser was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 81). Water clarity was fair to poor based on turbidity, true color and secchi depth. The lake will be recommended for listing as a Nutrient Limited watershed (NLW) in the next OWQS revision process and its Aesthetics beneficial use is considered nutrient threatened until studies can be conducted to confirm non-support status. The Aesthetics use is not supported with 25% of the reported values exceeding 70 units. The lake is fully supporting its FWP beneficial use based on pH and dissolved oxygen, however, the lake is not supporting the use based on high nephelometric turbidity readings. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected, none, exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported. Lake Overholser was constructed in 1919 and is owned and operated by Oklahoma City. It serves as a municipal water supply and offers recreational opportunities to the public. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 184) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

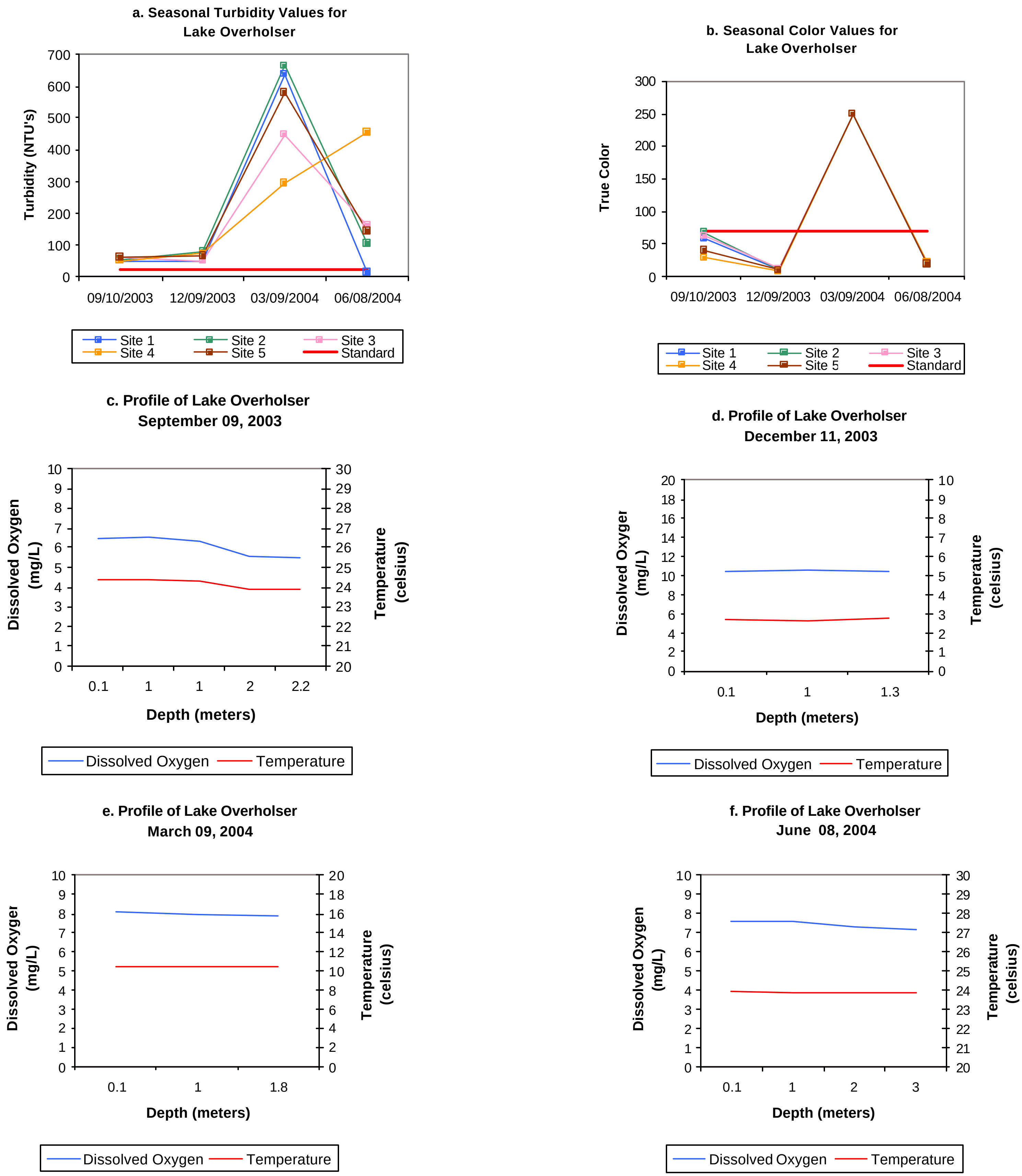
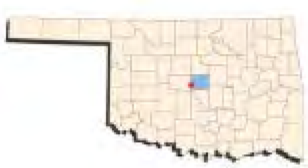



**Figure 183a-185f.** Graphical representation of data results for Lake Overholser.

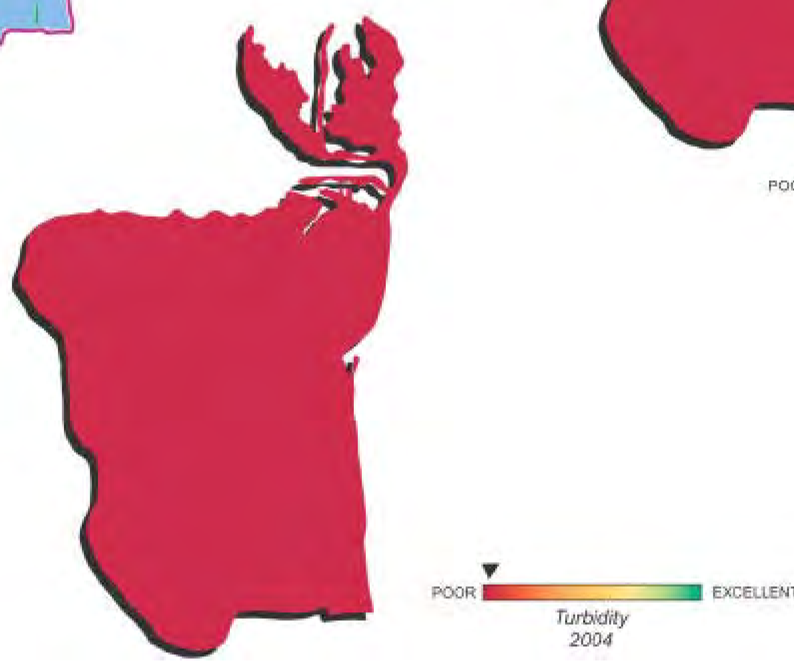

Overholser Lake
and
Watershed



Overholser Lake
Location

Lake Data

| | |
|---|---|
| Owner | City of Oklahoma City |
| County | Oklahoma |
| Constructed in | 1919 |
| Surface Area | 1,591 acres |
| Volume | 13,913 acre/feet |
| Shoreline Length | 7.4 miles |
| Mean Depth | 18.75 feet |
| Watershed Area | 13,215 square miles |




*Turbidity*
*2004*


*Trophic State*
*2004*

Plate 81 - Lake Water Quality for
## Overholser Lake

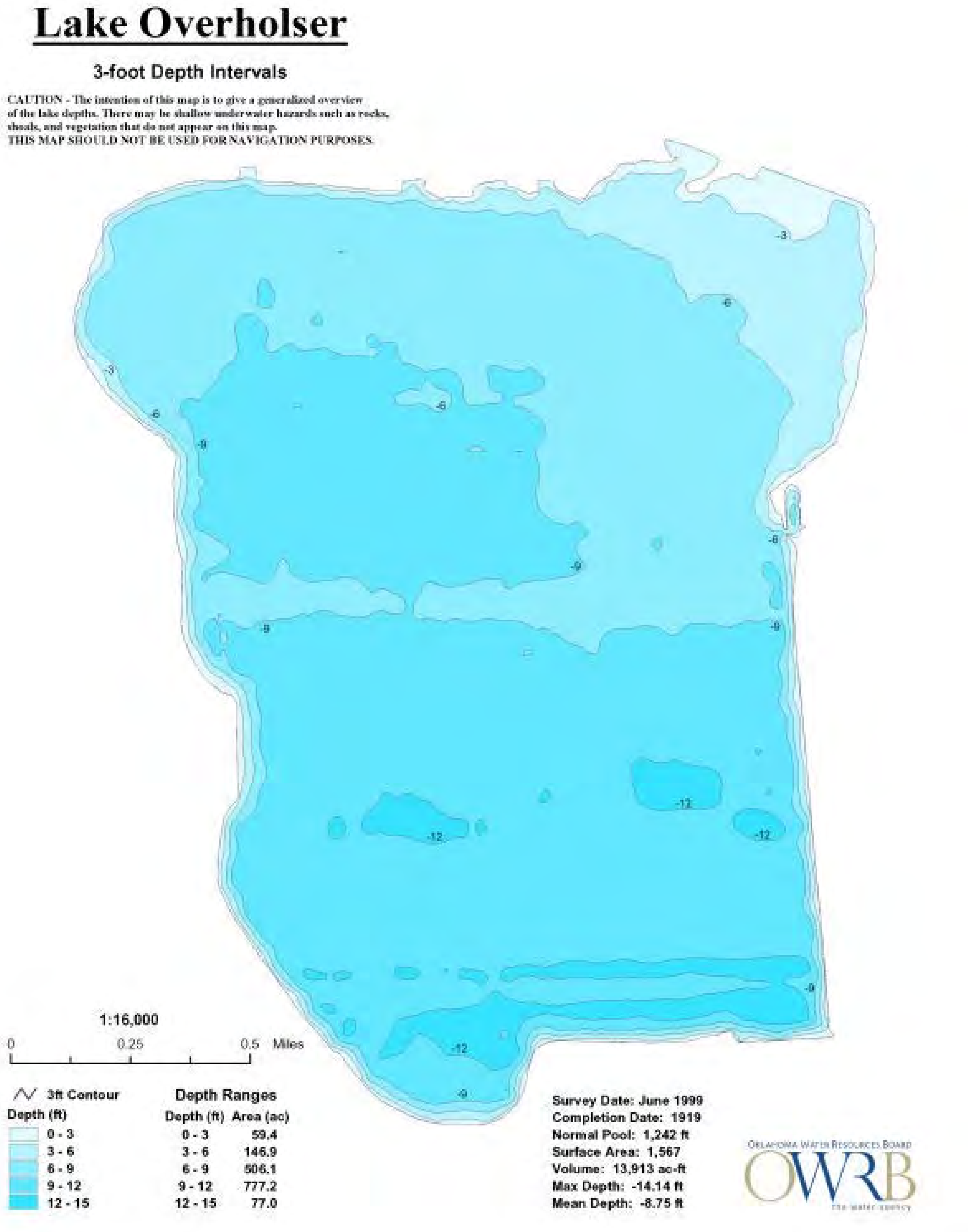



**Figure 184.** Bathymetric map of Lake Overholser.

# Lake Ozzie Cobb

Lake Ozzie Cobb was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 16 NTU (Plate 82), true color was 74 units, and secchi disk depth was 65 centimeters. Based on these three parameters, Lake Ozzie Cobb had fair to average water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was calculated at 54 (Plate 82), indicating the lake was eutrophic with high primary productivity and nutrient levels in sample year 2001-2002. This is lower than the value calculated in 2000, (TSI=65), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of lake productivity. Lake Ozzie Cobb is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW) indicating that its Aesthetics use is threatened due to nutrients (based on trophic status). A nutrient impairment study should be conducted to determine if uses are impaired. In general, the TSI values were eutrophic except during the winter, which had values ranging from oligotrophic to mesotrophic (see Figure 185). Seasonal turbidity values are displayed in Figure 186a. Turbidity values ranged from a low of 9 NTU to a maximum of 28 NTU with the highest values reported in the winter quarter. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥ 25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. With 25% of the samples exceeding 25 NTU, the beneficial use of Fish and Wildlife propagation (FWP) is considered not supporting in regards to turbidity. Seasonal true color values are displayed in Figure 186b. Applying the same default protocols, the Aesthetics beneficial use is considered not supported with 50% of the reported values exceeding the OWQS of 70 units.

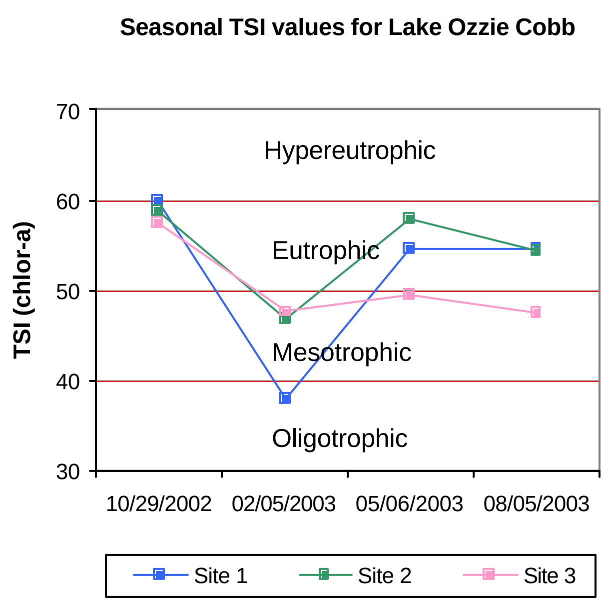



**Figure 185.** TSI values for Lake Ozzie Cobb.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites. The salinity values for Lake Ozzie Cobb ranged from 0.00 parts per thousand (ppt) to 0.07 ppt for this sample year. Specific conductivity ranged from 20.3 to 162.7 mS/cm, which is much lower than most Oklahoma reservoirs. These values indicate the minimal presence of electrical current conducting compounds (salts) in the lake, consistent with low salinity concentrations. The pH values at Lake Ozzie Cobb were slightly acidic, ranging from 5.86 to 6.84. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 56% of the values recorded being less than 6.5 the lake should be listed as not supporting the FWP beneficial use based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials ranged from 436 mV to 557 mV. Reducing conditions were not present at this reservoir in the 2002-2003-sample year. During the fall and winter quarters stratification was not present and dissolved oxygen (D.O.) values were generally above 7 mg/L (see Figure 186c-188d). Thermal stratification was evident in both spring and summer quarters, with anoxic conditions present below the thermocline. In the spring, anoxic conditions were present for 50% of the water column at sites 1 and 2 (Figure 186e). A similar pattern was observed in the summer with stratification occurring between 2 and 3 meters at which point dissolved oxygen fell below 2.0 mg/L accounting for 40% of the water column experiencing anoxic conditions (Figure 186f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The lake is partially supporting its FWP beneficial use based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dssolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.54 mg/L at the surface and 0.66 mg/L at the lake bottom. The TN at the surface ranged from 0.10 mg/L to 1.28 mg/L. Surface total nitrogen was highest in the summer and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.045 mg/L and 0.054 mg/L at the lake bottom. The TP at the surface ranged from 0.038 mg/L to 0.054 mg/L. Surface TP was highest in the spring and the lowest values were seen during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 12:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Ozzie Cobb was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This is lower than the value calculated in 2000, (TSI=65), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of lake productivity. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient threatened and a nutrient impairment study is needed to determine if uses are impaired. Water clarity was fair to average based on true color, turbidity and secchi disk depth. The lake is partially supporting the FWP beneficial use and dissolved oxygen, but not supporting based on turbidity and low pH values reported throughout the year. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is supported based on its trophic status and not supporting based on true color with 50% of the recorded values exceeding the OWQS of 70 units. Lake Ozzie Cobb is owned by the State of Oklahoma and is utilized for recreation.

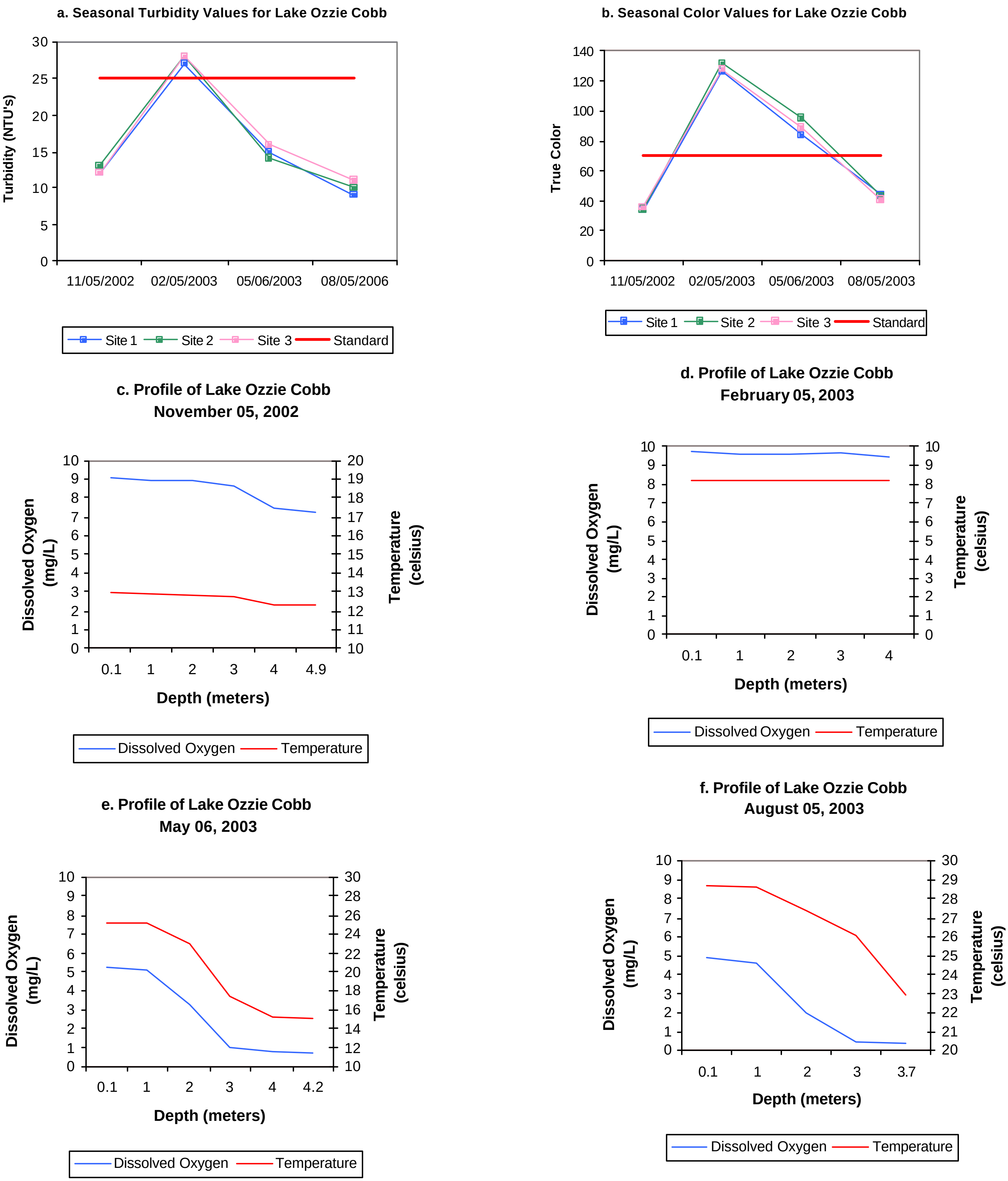



**Figure 186a-188f.** Graphical representation of data results for Lake Ozzie Cobb.




| Lake Data | |
|---|---|
| Owner | State of Oklahoma |
| County | Pushmataha |
| Constructed in | 1958 |
| Surface Area | 116 acres |
| Volume | 833 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 7.18 feet |
| Watershed Area | 4,378 acres |



Plate 82 - Lake Water Quality for
## Lake Ozzie Cobb

# Pauls Valley City Lake

Pauls Valley City Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer quarters to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were added to ensure sample size was representative for a lake greater than 250 surface acres. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 15 NTU (Plate 83), true color was 27 units, and secchi disk depth was 72 centimeters. Based on these three parameters, Pauls Valley City Lake had good water clarity in sample year 2002-2003, even better than reported in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 41 (Plate 83), indicating the lake was mesotrophic/bordering oligotrophic in sample year 2003. The TSI values throughout the sample year were fairly consistent with values ranging from mesotrophic at all sites in the fall and winter to oligotrophic in the spring and summer (Figure 187). The only exception to this was site 1, which remained in the mesotrophic category throughout the year. This TSI value was lower than calculated in 2000 (TSI=50), however the current value is based on a larger dataset and is likely a more accurate depiction of productivity within the lake. Seasonal turbidity values are displayed in Figure 188a. Turbidity values in the winter, spring and summer seasons were below the turbidity standard of 25 NTU. In the fall quarter, there was a spike in turbidity, possibly due to seasonal rain events, at which point the values were at or near the standard at all sites. The Fish and Wildlife Propagation (FWP) beneficial use is considered supported based on turbidity. Seasonal true color values are displayed in Figure 188b. True color values followed the same pattern as turbidity with higher values observed in the fall sampling quarter. Although 100% of samples in 2003 were below the 70-unit standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites. Salinity values for Pauls Valley City Lake ranged from 0.11 parts per thousand (ppt) to 0.14 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 239.5 to 283.8 mS/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations.

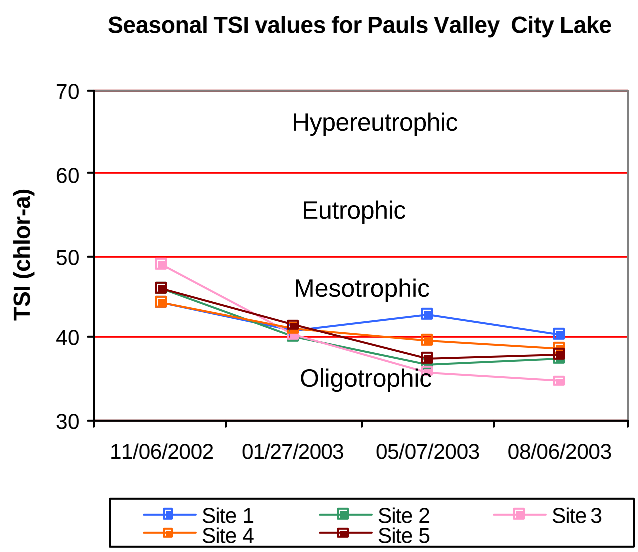



**Figure 187.** TSI values for Pauls Valley City Lake.

In general pH values were neutral to slightly alkaline with values ranging from 6.93 to 8.06 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 379 mV to 550 mV, indicating an absence of reducing conditions. During the fall and winter quarters, stratification was not present and lake was well mixed (see Figure 188c-190d). In the spring, the lake was weakly stratified between 4 and 5 meters, however dissolved oxygen (D.O.) remained above 2.0mg/L. In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline (see Figure 188f). In the summer stratification occurred at several 1-meter intervals with D.O. falling below 2.0 mg/L from 5 meters to the lake bottom of 7.5 meters, accounting for approximately 33% of the water column experiencing anoxic conditions. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Pauls Valley City Lake is partially supporting its FWP beneficial use based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.31 mg/L at the surface and 0.34 mg/L at the lake bottom. The TN at the surface ranged from 0.10 mg/L to 0.54 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.019 mg/L and 0.027 mg/L at the lake bottom. The surface TP ranged from 0.005 mg/L to 0.024 mg/L. The highest surface TP was reported in the summer and the lowest values were seen during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Pauls Valley City Lake was classified at the lower end of mesotrophic, indicative of moderate primary productivity and nutrient conditions. This differs from the 2001 evaluation, which placed the lake at the uppermost end of mesotrophic with a TSI of 50. The current TSI calculation is based on a larger dataset (n=20) and is likely a more accurate depiction of productivity with the lake system. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity and pH, but is only partially supported based on low dissolved oxygen values reported in the summer. The Aesthetic beneficial use is supported based on its trophic status, however use determination cannot be made for true color as a minimum of 20 samples are required in lakes greater than 250 surface acres. Pauls Valley City Lake is located in Garvin County and serves as a water supply and recreational reservoir for the city.

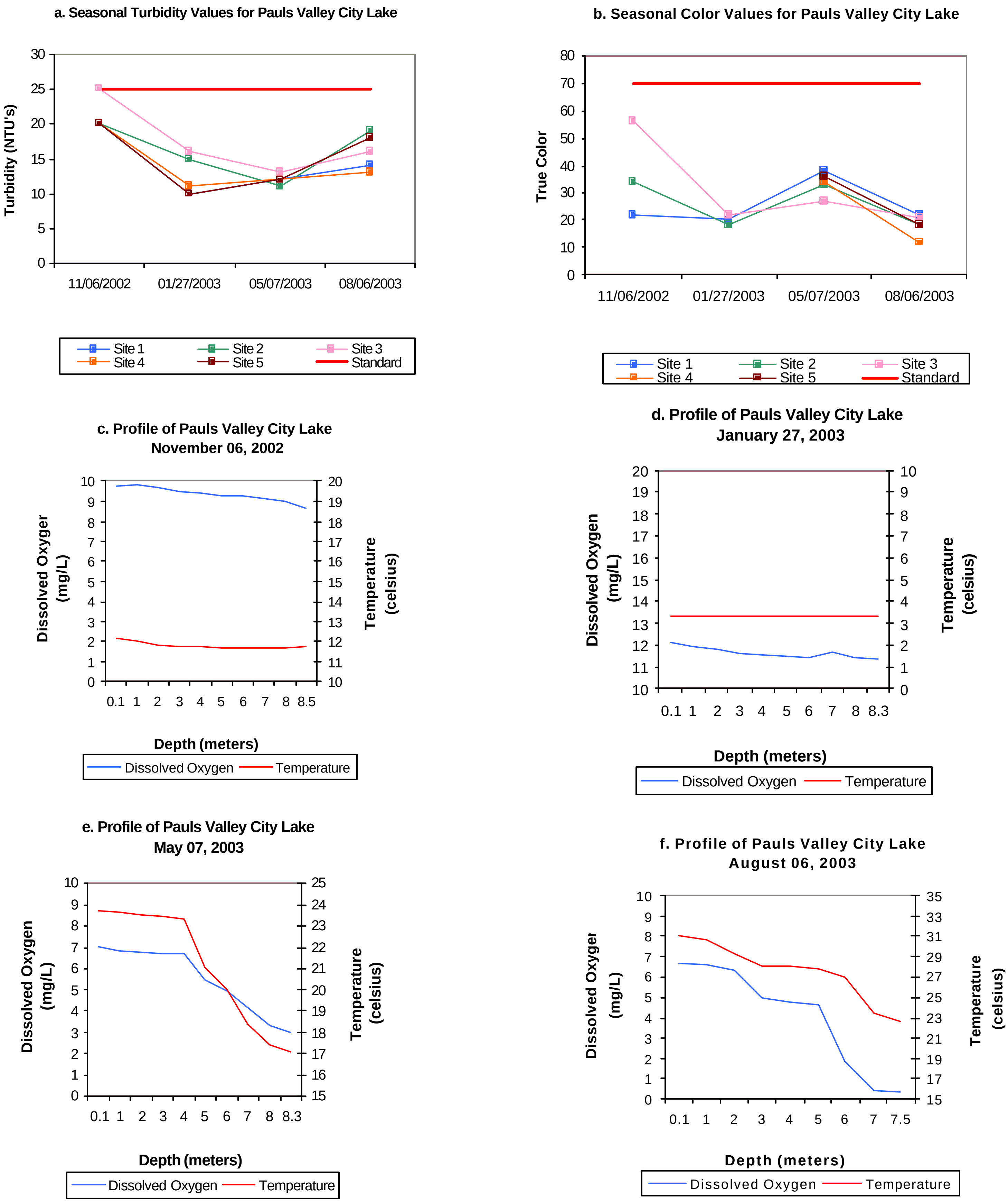
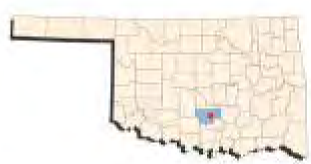



**Figure 188a-190f.** Graphical representation of data results for Pauls Valley City Lake.


Pauls Valley Lake and Watershed



Pauls Valley Lake Location

Lake Data

| | |
|---|---|
| Owner | City of Pauls Valley |
| County | Garvin |
| Constructed | 1954 |
| Surface Area | 750 acres |
| Volume | 8,730 acre/feet |
| Shoreline Length | 8 miles |
| Mean Depth | 11.84 feet |
| Watershed Area | 21 square miles |


Turbidity 2003


Trophic State 2003

Plate 83 - Lake Water Quality for
Pauls Valley Lake

# Lake Pawhuska

Lake Pawhuska was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 3 NTU (Plate 84), true color was 10 units, and secchi disk depth was 280 centimeters. Based on these three parameters, Lake Pawhuska had excellent water clarity in sample year 2002-2003, consistent with data reported in 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 43 (Plate 84), indicating the lake was mesotrophic in sample year 2003 (Plate 73). This is similar to the TSI in 2000 (TSI=41), indicating no significant increase or decrease in productivity has occurred since the last evaluation. The TSI values throughout the sample year were fairly consistent with values ranging from mesotrophic at all sites in the fall and winter to oligotrophic in the spring and summer (Figure 189). Seasonal turbidity values per site are displayed in Figure 190a. Turbidity values throughout the year were all well below the turbidity standard of 25 NTU. The Fish and Wildlife Propagation (FWP) beneficial use is considered supported based on turbidity. Seasonal true color values are displayed in Figure 190b. True color values followed the same pattern as turbidity with all reported values well below the standard of 70 units, therefore the Aesthetics beneficial use is considered fully supported based on true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.14 parts per thousand (ppt) to 0.19 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 287.4 to 375 mS/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations. The pH values were neutral to slightly alkaline with values ranging from 6.63 to 8.13 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use

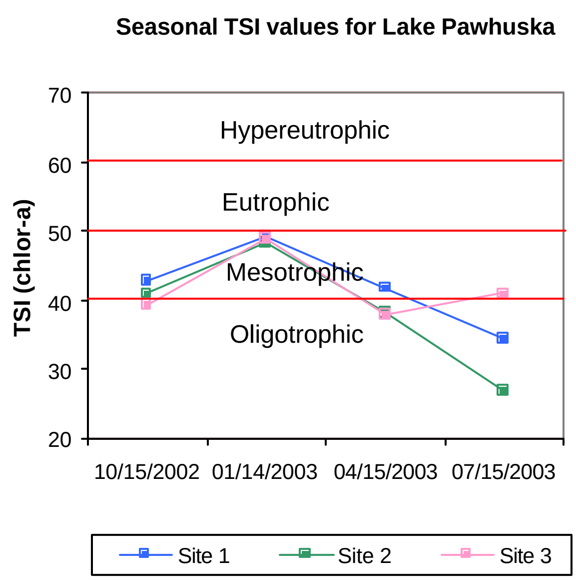



**Figure 189.** TSI values for Lake Pawhuska.

based on pH. Oxidation-reduction potentials (ORP) range d from 218 mV to 483 mV, indicating an absence of reducing conditions during the study period. During the fall and winter quarters, stratification was not present and lake was well mixed (see Figure 190c-192d). In the spring, the lake was weakly stratified, however dissolved oxygen (D.O.) remained above 7.0mg/L (Figure 190e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline. In the summer stratification occurred at several 1-meter intervals with D.O. falling below 2.0 mg/L from 5 meters to the lake bottom of 10.9 meters, accounting for approximately 50% of the water column at site 1 experiencing anoxic conditions (Figure 190f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 50% of the water column below 2.0 mg/L the FWP beneficial use is considered partially supported based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.23 mg/L at the surface and 0.32 mg/L at the lake bottom. The TN at the surface ranged from 0.06 mg/L to 0.35 mg/L. The highest surface total nitrogen was reported in the summer and the lowest in the winter. The lake-wide total phosphorus (TP) average was 0.009 mg/L and 0.012 mg/L at the lake bottom. The surface TP ranged from 0.005 mg/L to 0.017 mg/L. Similar to TN, the lowest surface TP was reported in the winter however the highest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 24:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Pawhuska was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. This is consistent with the previous evaluation, indicating no significant increase in productivity has occurred. Water clarity continues to be excellent based on true color, turbidity and the high secchi disk depths. The lake is supporting the FWP beneficial use based on turbidity and pH, but only partially supporting based on low D.O. values in the summer. The Aesthetics beneficial use is also fully supported based on its trophic status and true color. Lake Pawhuska was constructed in 1936 and for the purpose of water supply and recreation. The lake is located in Osage County and is one of the nicer small lakes in the state.

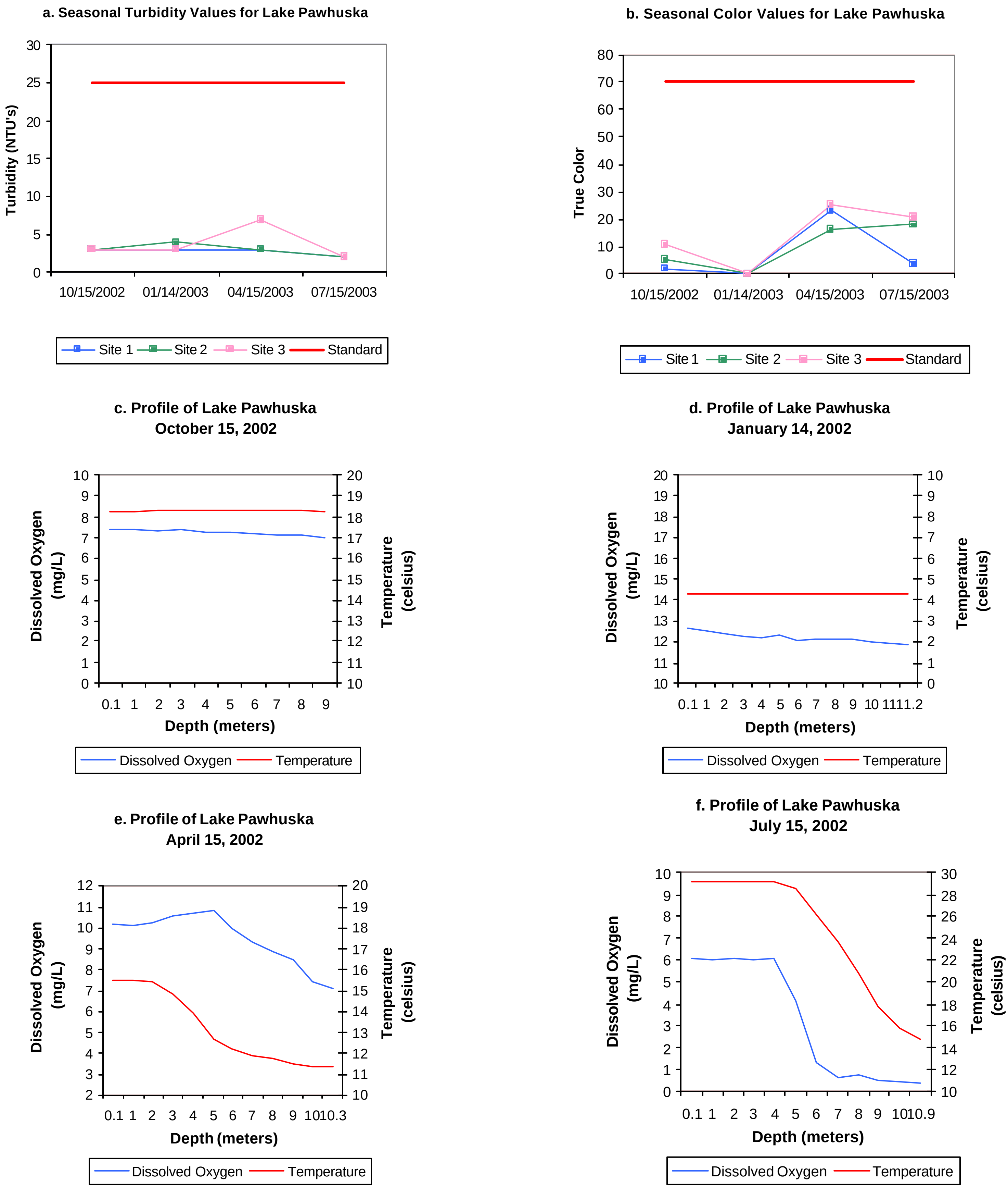
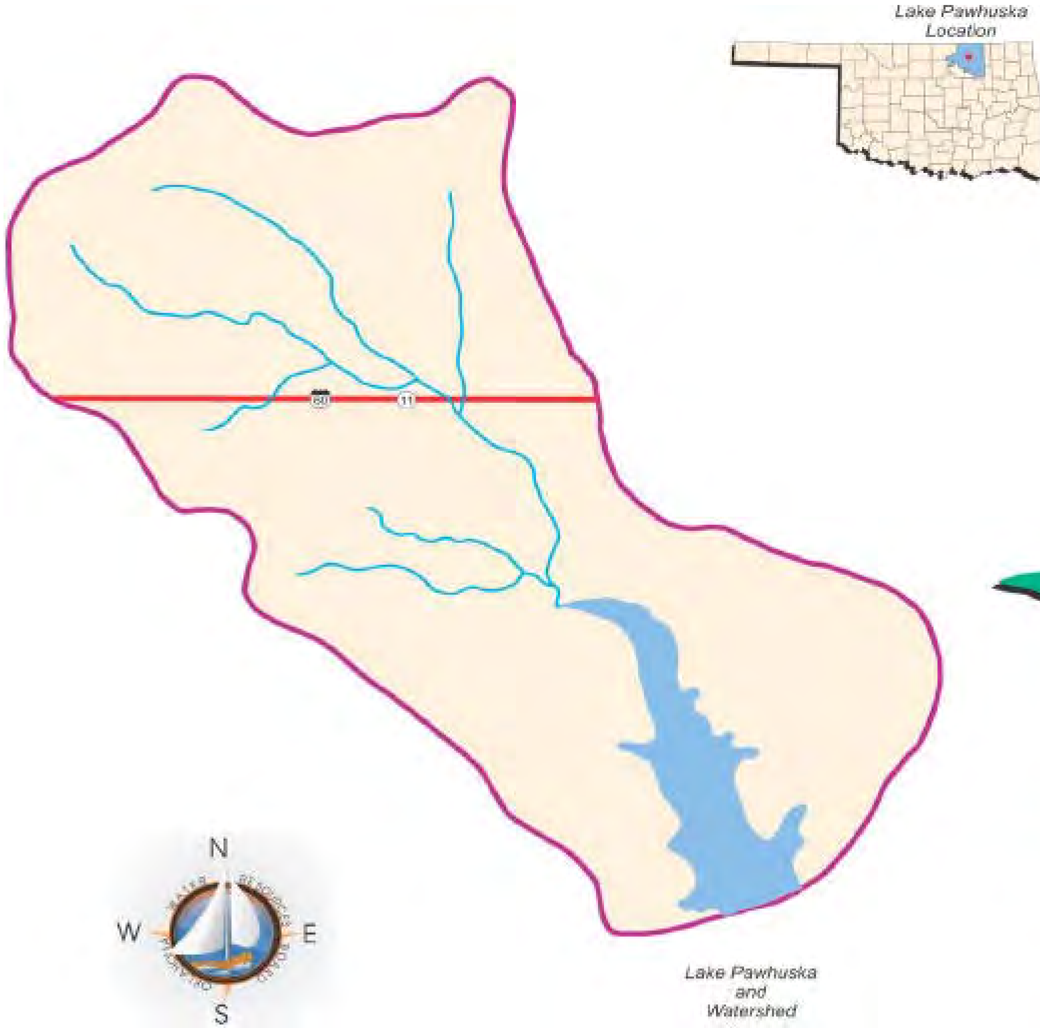



**Figure 190a-192f.** Graphical representation of data results for Lake Pawhuska.






Lake Data

| | |
|---|---|
| Owner | City of Pawhuska |
| County | Osage |
| Constructed in | 1936 |
| Surface Area | 96 acres |
| Volume | 3,600 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 37.50 feet |
| Watershed Area | 1754 acres |

Plate 84 - Lake Water Quality for
## Lake Pawhuska

# Pawnee Lake

Pawnee Lake was sampled for four quarters, from October 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 20 NTU (Plate 85), true color was 35 units, and secchi disk depth was 73 centimeters. Based on these three parameters, Pawnee Lake had average water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). The TSI was 51 (Plate 85), indicating the lake was eutrophic with high levels of primary productivity and nutrients. This is close to the value calculated in 2002 (TSI=55) indicating no significant increase or decrease in productivity occurred over time. The TSI values throughout the sample year varied seasonally from eutrophic in the fall quarter, to mesotrophic in the winter quarter and to upper eutrophy in summer quarter (see Figure 191). In the spring quarter sites 1 and 5 were mesotrophic while the other three sites were in the oligotrophic category. Turbidity readings ranged from a low of 8 NTU to a high of 56 NTU (see Figure 192a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Pawnee Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 192b. True color values were generally below the aesthetics OWQS of 70 units at all times with the exception of the spring quarter (see Figure 192b). Similar to turbidity a peak in true color occurred in the spring quarter and is likely the result of seasonal storm events and therefore the Aesthetics beneficial will be considered supported at Pawnee Lake.

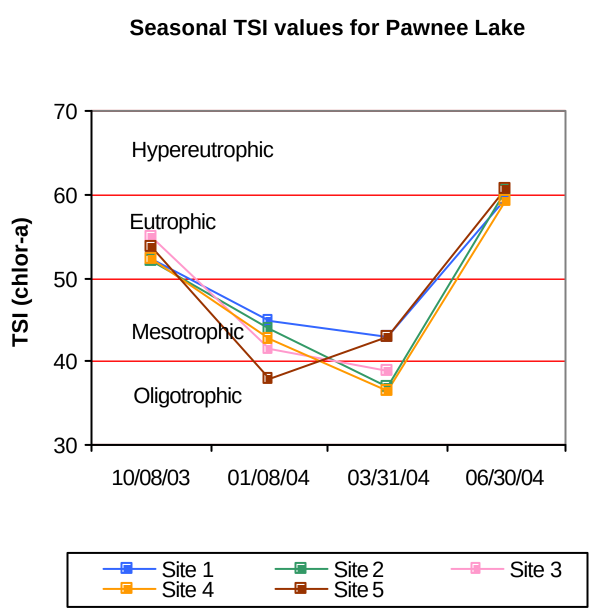



**Figure 191.** TSI values for Pawnee Lake.

In 2003-2004, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.17 ppt, indicating moderate salt content in the lake system. Values were slightly higher than the expected range of salinity readings reported for most Oklahoma lakes. Readings for specific conductance were also within the range of expected values, ranging from 212.7 mS/cm to 337.5 mS/cm, also indicative of moderate amounts of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline with values ranging from 6.97 units in the fall quarter to 8.33 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all values within the acceptable range the lake is fully supporting its FWP beneficial use as it relates to pH. Oxidation-reduction potentials (redox) ranged from 338 mV in the summer quarter to 674 mV in the fall quarter, indicating an absence of reducing conditions in the lake at the time it was sampled. Pawnee Lake was not thermally stratified in the fall or winter or spring quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L throughout the water column in all three seasons (see Figure 192c-194e). In the summer, the lake was weakly thermally stratified, and anoxic conditions were also present at site 1(see Figure 192f). Although this lake is fairly shallow (about 7 meters deep), about 44% of the water column was anoxic. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Pawnee Lake with only 44% of the water column less than 2.0 mg/L in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected two (20%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.73 mg/L at the lake surface. The TN at the surface ranged from 0.55 mg/L to 1.06 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.040 mg/L at the lake surface. The surface TP ranged from 0.020 mg/L to 0.092 mg/L. Similar to total nitrogen, the highest surface TP value was reported in the spring quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 18:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Pawnee Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 85). This is similar to the value calculated in 2002 (TSI=55) indicating no significant increase or decrease in productivity occurred over time. Water clarity is average based on true color, turbidity and secchi disk depth. The lake was fully supporting its Aesthetics beneficial use based on trophic status. Although 25% of the true color values were exceeding the OWQS of 70 units, the peak in the spring quarter is likely the result of seasonal storm events, therefore the Aesthetics beneficial will be considered supported at Pawnee Lake. Pawnee was fully supporting its FWP beneficial use based on pH, and D.O. readings recorded during the study period. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Pawnee Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected two (20%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Pawnee Lake was constructed in 1932 and is owned and operated by the City of Pawnee. The lake is managed as a municipal water supply and offers numerous recreational opportunities to the public.

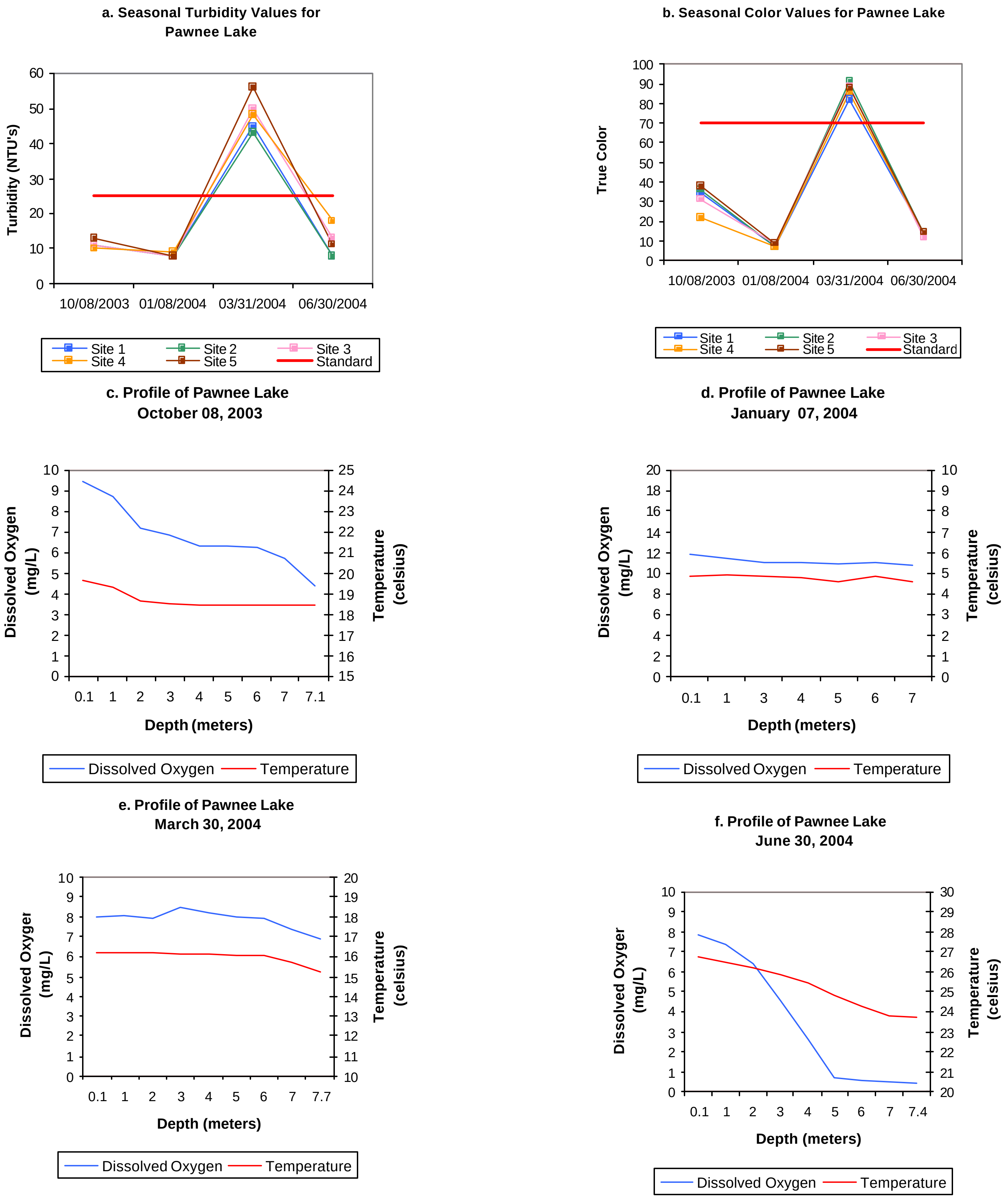



**Figure 192a-194f.** Graphical representation of data results for Pawnee Lake.




Lake Data

| | |
|---|---|
| Owner | City of Pawnee |
| County | Pawnee |
| Constructed in | 1932 |
| Surface Area | 257 acres |
| Volume | 3,855 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 15.00 feet |
| Watershed Area | 13 square miles |



Plate 85 - Lake Water Quality for

# Pawnee Lake

# Perry Lake

Perry Lake was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a lake larger than 250 surface acres in size. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 70 NTU (Plate 86), true color was 144 units, and average secchi disk depth was 22 centimeters. Based on these three parameters, Perry Lake had poor water clarity. These results are similar to those in 2000 indicating no significant change has occurred over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 42 (Plate 86) indicating the lake was mesotrophic in sample year 2002-2003 with moderate levels of primary productivity and nutrients. This value is lower than the TSI calculated in 2000 (TSI=48), although in the same trophic category, indicating no significant change in productivity has occurred since the last time sampled. The TSI values throughout the sample year were fairly consistent ranging from oligotrophic in the fall and winter to mesotrophic in the spring and summer (Figure 193). Seasonal turbidity values are displayed in Figure 194a. Turbidity ranged from a low of 45 NTU to a maximum of 88 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The average lake-wide turbidity of 70 NTU seems representative of conditions at Perry Lake and is consistent with historical findings for this lake. With 100% of the collected values exceeding the standard of 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is considered not supported. Seasonal true color values are displayed in Figure 194b. Although all true color values (n=16) were above the aesthetics standard of 70 units, the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met and use determination cannot be made.

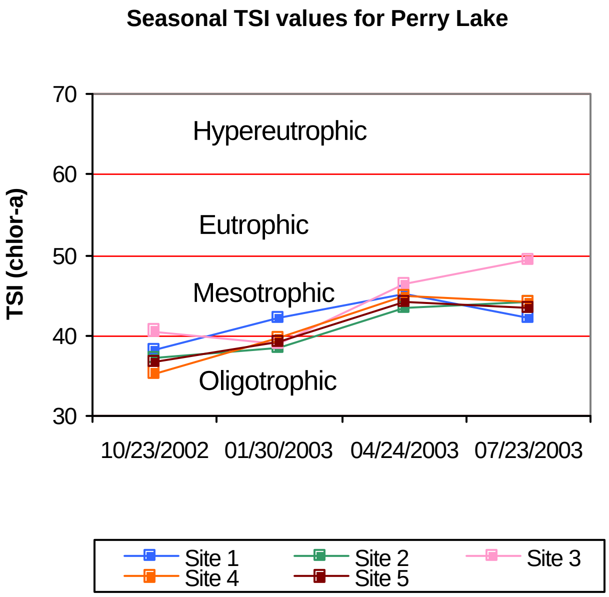



**Figure 193.** TSI values for Perry Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at sample sites during the study period. The salinity values ranged from 0.15 parts per thousand (ppt) to 0.22 ppt, which is within the average range of values for most Oklahoma reservoirs. Specific conductivity ranged from 305.7 mS/cm to 438 mS/cm indicating low to moderate concentrations of electrical current conducting materials (salts & chlorides) were present in the lake. These values are also within the range commonly seen in Oklahoma reservoirs and are consistent with recorded salinity values. The pH values were neutral and ranged from 7.42 to 7.96. Oxidation-reduction potentials (ORP) ranged from 223 mV in the spring to 586 mV in the w inter, indicating reducing conditions were not present in sample year 2002-2003. Stratification was not evident in any of the first three sampling intervals and the lake was well mixed with dissolved oxygen (D.O.) remaining above 7.0 mg/L (Figure 194c-196e). In the summer, the lake was thermally stratified and anoxic conditions were present below the thermocline. Perry Lake was stratified between 7 and 8 meters with D.O. falling below 2.0 mg/l to the lake bottom of 11.7 meters, accounting for approximately 39% of the water column experiencing anoxic conditions at site 1 (see Figure 194f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 39% of the water column below 2.0 mg/L the FWP beneficial use is considered partially supported based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.78 mg/L at the surface and 0.82 mg/L at the lake bottom. The TN at the surface ranged from 0.56 mg/L to 1.02 mg/L. The highest surface total nitrogen was reported in the spring and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.084 mg/L at the surface and 0.089 mg/L at the lake bottom. The surface TP ranged from 0.062 mg/L to 0.102 mg/L. Similar to TN, the lowest surface TP was reported in the summer however the highest values were seen during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Perry Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. The current trophic status is the same as that calculated in 2000, indicating little or no change in productivity has occurred. The FWP beneficial use is supported based on pH, only partially supporting based on dissolved oxygen and not supported based on high turbidity values. The Aesthetics beneficial use is supported based on trophic status, however a use determination based on true color cannot be made, as minimum data requirements were not met. Upon reviewing current and historical data it is likely the use would not be supported based on true color. Additional sites have been added to ensure data requirement will be met in the future. Perry Lake, located in Noble County, was constructed for the purpose of flood control, water supply, and recreation.

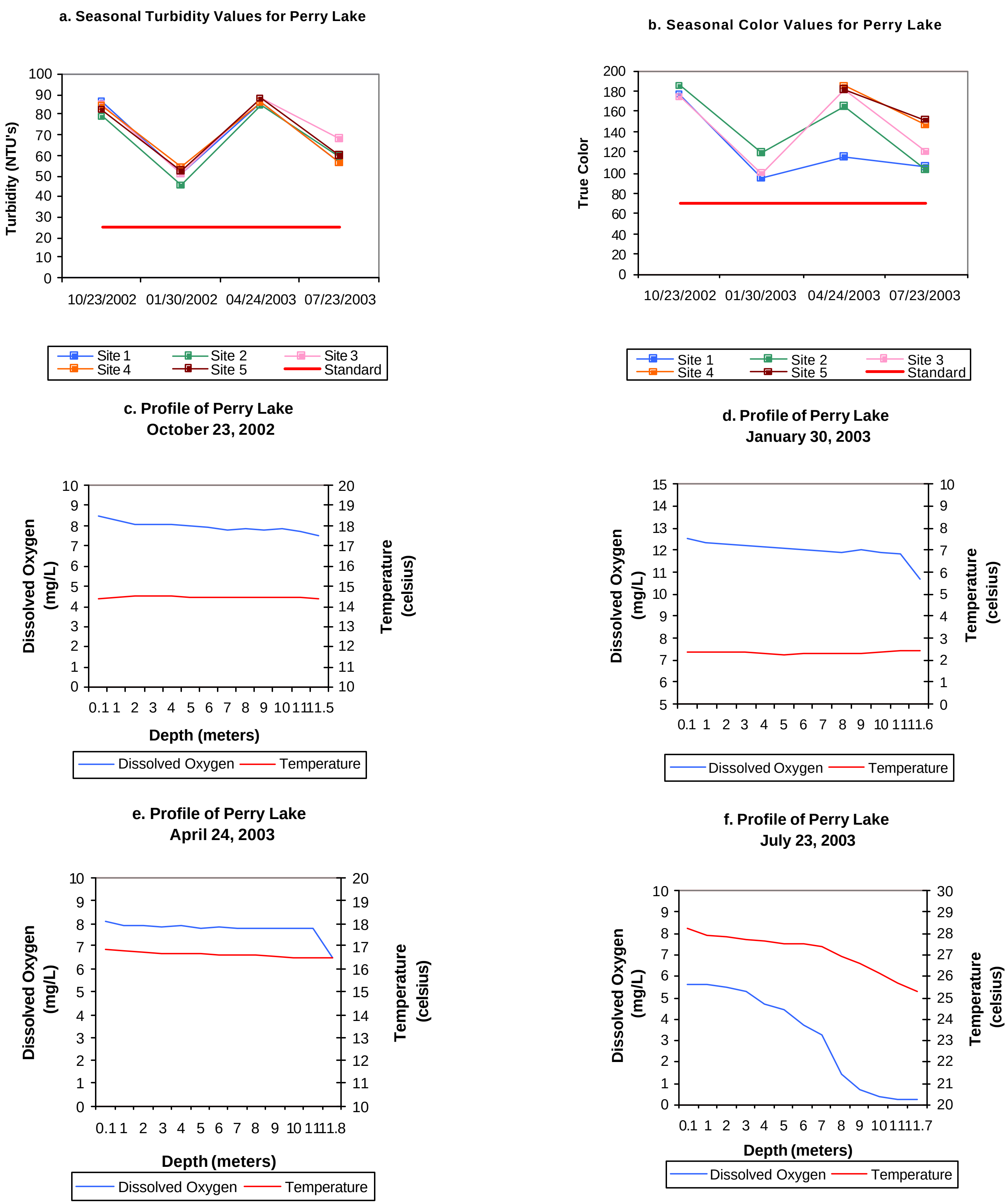



**Figure 194a-196f.** Graphical representation of data results for Perry Lake.






Lake Data

| | |
|---|---|
| Owner | City of Perry |
| County | Noble |
| Constructed in | 1937 |
| Surface Area | 614 acres |
| Volume | 6,892 acre/feet |
| Shoreline Length | 11 miles |
| Mean Depth | 11.22 feet |
| Watershed Area | 16 square miles |

Plate 86 - Lake Water Quality for
Perry Lake

# Pine Creek Lake

Pine Creek Lake was sampled for four quarters from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as major lake arms and tributaries. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at site 1,near the dam. The lake-wide annual turbidity value was 13 NTU (Plate 87), true color was 26 units, and secchi disk depth was 89 centimeters. Results for true color and secchi disk depth were better than that observed in 2001-2002. Based on these three parameters, Pine Creek Lake had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 54 (Plate 87), indicating the lake was eutrophic in nature with high levels of primary productivity and nutrients. This is identical to the value calculated in 2002 (TSI=54), indicating no significant increase or decrease in productivity has occurred. The TSI values throughout the sample year were predominantly eutrophic with only the winter quarter experiencing mesotrophic and oligotrophic conditions (see Figure 195). This same pattern occurred in the 2001-2002 evaluation. Turbidity values in the fall, spring and summer seasons were below the Oklahoma Water Quality Standard (OWQS) for turbidity of 25 NTU (see Figure 196a). There was a spike in turbidity in the winter quarter, possibly due to seasonal rain events, at which point values were at or above the standard at sites 3,4 and 5. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 10% of the collected values exceeding the criteria, the lake is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 196b. True color values varied seasonally and with 100% of the sample values below the OWQS of 70 units the lake is fully supporting its Aesthetics beneficial use for true color (see Figure 196b).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.02 ppt, well within the expected range of salinity values if not less than reported values for most Oklahoma lakes. Readings for

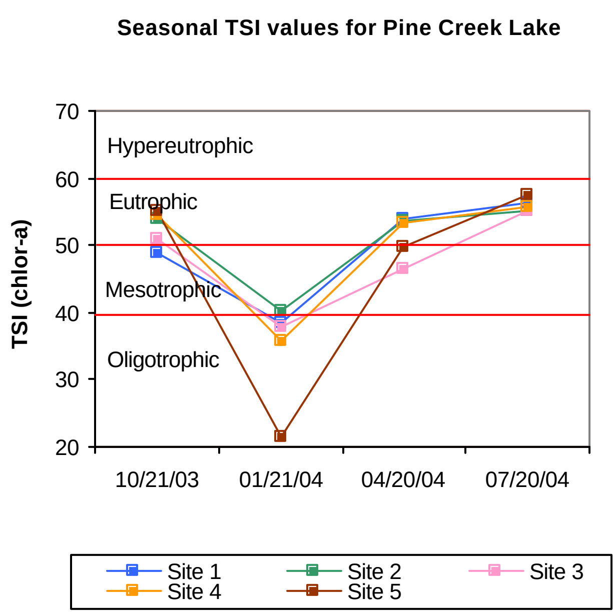



**Figure 195.** TSI values for Pine Creek Lake.

specific conductance were also lower than the expected range for most Oklahoma lakes, ranging from 0.0 mS/cm to 66.5 mS/cm, indicating the presence of little or no electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly acidic with values ranging from 5.73 units in the summer quarter to 7.56 also in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 56% of the values recorded as less than 6.5 units Pine Creek Lake is not supporting the FWP as it relates to pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (redox) ranged from 323 mV in the summer quarter to 524 mV recorded at the lake surface in the winter quarter. Reducing conditions were not present during the study period. Pine Creek Lake was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) readings were above 3.0 mg/L (see Figure 196c-198d). The lake was weakly thermally stratified in the spring quarter between 12 and 13 meters below the lake surface at site 1; however, D.O. readings remained above 2.0 mg/L until very near the lake bottom at 17.1 meters (see Figure 196e). In the summer, the lake was strongly thermally stratified at several 1-meter intervals among all five sites with the first occurring between 2 and 3 meters below the surface. Dissolved oxygen was below 2.0 mg/L from 4 meters in depth to the lake bottom at 14 meters at site 1, the dam (see Figure 196f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. In the summer quarter 73% of the water column at site 1 was experiencing anoxic conditions, which is cause for classifying the lake as not supporting its FWP beneficial use based on D.O. concentrations in the water column. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling found the Agriculture beneficial use to be fully supported based on criteria in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml for enterococci, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.61 mg/L at the lake surface. The TN at the surface ranged from 0.10 mg/L to 2.16 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.025 mg/L at the lake surface. The surface TP ranged from 0.015 mg/L to 0.38 mg/L. The highest surface TP value was reported in the winter quarter and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 25:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2000 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Pine Creek Lake was classified as eutrophic, indicating high primary productivity and nutrient levels (Plate 87). This is similar to the value calculated in 2002 (TSI=54), indicating no significant increase or decrease in productivity has occurred. Based on true color, turbidity and secchi disk depth, Pine Creek Lake had good water clarity in 2003-2004. The lake is fully supporting its Aesthetics beneficial use based on its trophic status and true color values recorded during the study period. The lake was partially supporting its FWP beneficial use based on nephelometric turbidity and not supporting for D.O. due to anoxic conditions present in 73% of the water column in the summer. With 56% of the pH values less than 6.5 the FWP beneficial use is not supported based on collected pH values. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Pine Creek Lake, was constructed in 1969 by the United States Army Corps of Engineers for multiple purposes including, flood control, municipal water supply, fish & wildlife, and general recreation.

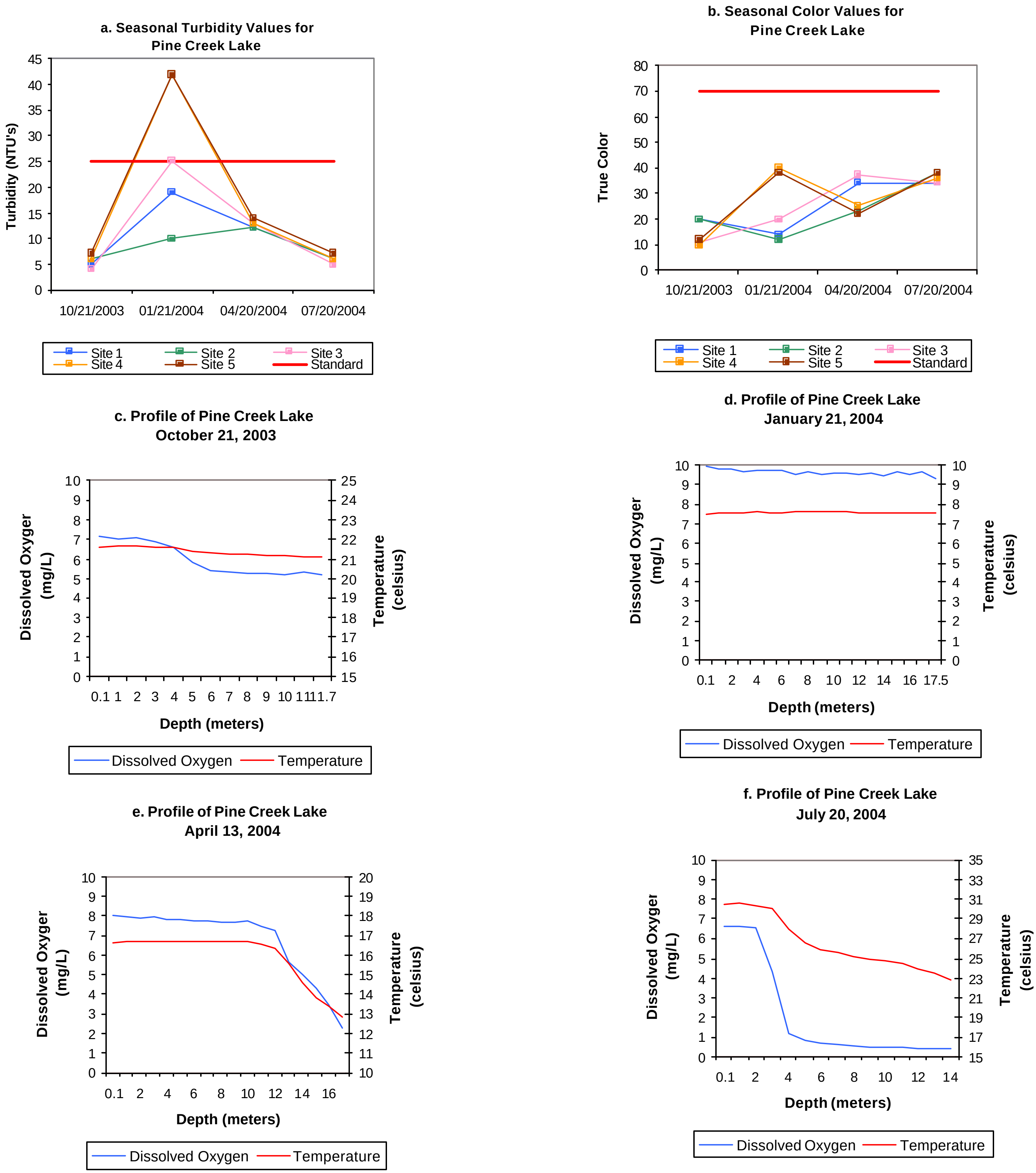
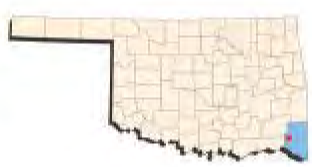



**Figure 196a-198f.** Graphical representation of data results for Pine Creek Lake.


Pine Creek Lake
and
Watershed

Pine Creek Lake
Location

| Lake Data | |
|---|---|
| Constructed by | Corps of Engineers |
| County | McCurtain |
| Constructed in | 1969 |
| Surface Area | 3,750 acres |
| Volume | 53,750 acre/feet |
| Shoreline Length | 74 miles |
| Mean Depth | 14.2 feet |
| Watershed Area | 635 square miles |



Plate 87 - Lake Water Quality for

## Pine Creek Lake

# Lake Ponca

Lake Ponca was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative of a lake greater than 250 surface acres. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 14 NTU (Plate 88), true color was 30 units and average secchi disk depth was 76 centimeters. Based on these three parameters, Lake Ponca had average water clarity. These values are similar to those in 2000, indicating no significant change in clarity has occurred over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). The TSI was 54 (Plate 88), indicating the lake was eutrophic in sample year 2002-2003 with high levels of primary productivity and nutrients. This value is similar to that from 2000 (TSI=58), indicating no significant change in productivity has occurred since the last evaluation. Seasonal TSI values varied by site and season and spanned three trophic categories in sample year 2003. In the fall, spring, and summer sampling quarters values were generally eutrophic. In the fall values ranged from eutrophic at sites 1, 2, and 4 to hypereutrophic at sites 3 and 5 (Figure 197). TSI values in the winter were all mesotrophic. Seasonal turbidity values per site are displayed in Figure 198a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, therefore meeting the Fish and Wildlife (FWP) beneficial use. Although 100% of samples in 2003 were below the 70-unit color standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres (see Figure 198b).

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.12 parts per thousand (ppt) to 0.17 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 251.9 to 339.7 mS/cm, indicating low concentrations of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations. The pH values were neutral to slightly alkaline with values ranging from 6.63 in the summer to 8.05 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH

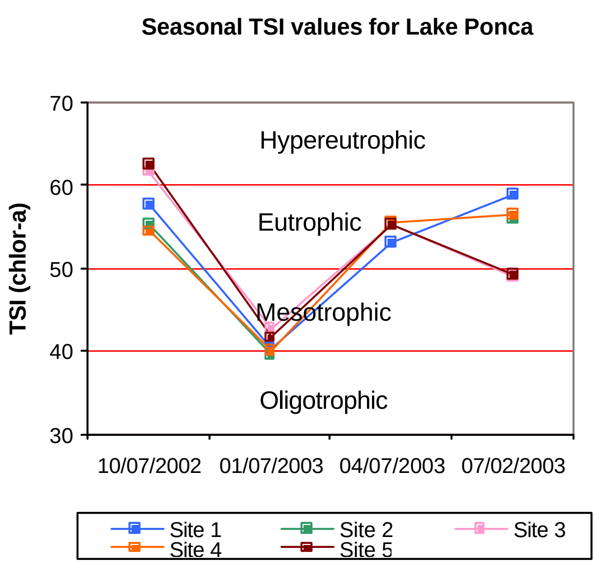



**Figure 197.** TSI values for Lake Ponca.

values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 87 mV in the hypolimnion in the fall to 467 mV in the summer. In general, reducing conditions present were not during the study period. During the fall, winter, and spring quarters stratification was not present and lake was well mixed (see Figure 198c-200e). In the fall dissolved oxygen was generally above 5.0 mg/L only falling below 2.0 mg/l at the lake bottom at the sediment-water interface (Figure 198f). In the summer stratification occurred at several 1-meter intervals with dissolved oxygen (D.O.) falling below 2.0 mg/L between 4 and 5 meters throughout the lake, accounting for 55 to 70% of the water column to be experiencing anoxic conditions. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered partially supported based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.78 mg/L at the surface and 0.65 mg/L at the lake bottom. The TN at the surface ranged from 0.56 mg/L to 1.04 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.036 mg/L and 0.059 mg/L at the lake bottom. The surface TP ranged from 0.012 mg/L to 0.055 mg/L. The lowest surface TP was reported in the winter however the highest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Ponca was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This is consistent with the 2000 evaluation indicating no significant change in productivity has occurred. Based on true color, turbidity, and secchi disk depth, Lake Ponca had average water clarity in comparison to other Oklahoma lakes. The lake is supporting the FWP beneficial use based on turbidity and pH, but only partially supporting based on low dissolved oxygen values in the summer. The Aesthetics beneficial use is supported based on its trophic status, however due to minimum data requirements not being met true color cannot be assessed. Lake Ponca is a water supply and recreational reservoir for the city of Ponca City.

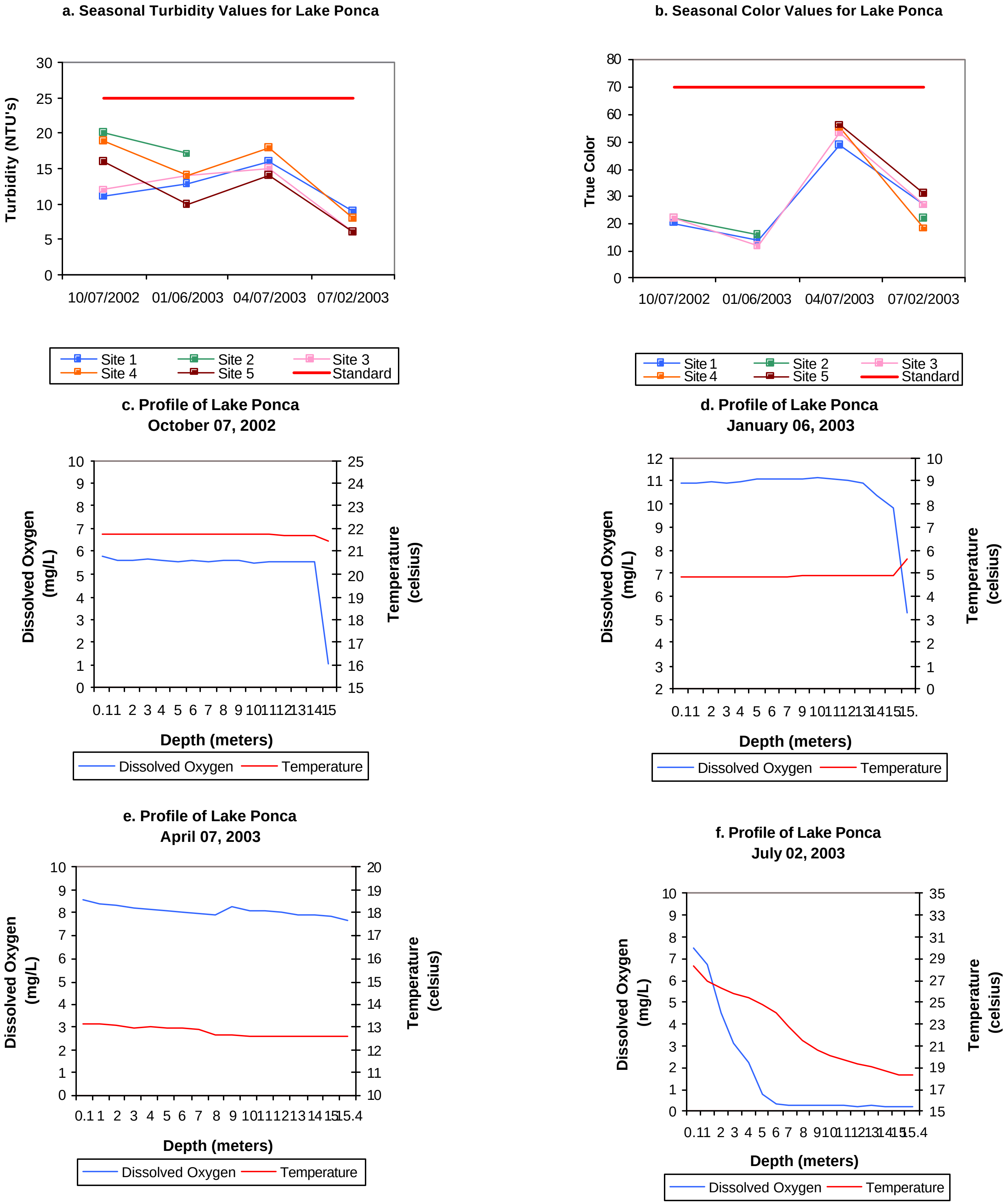



**Figure 198a-200f.** Graphical representation of data results for Lake Ponca.

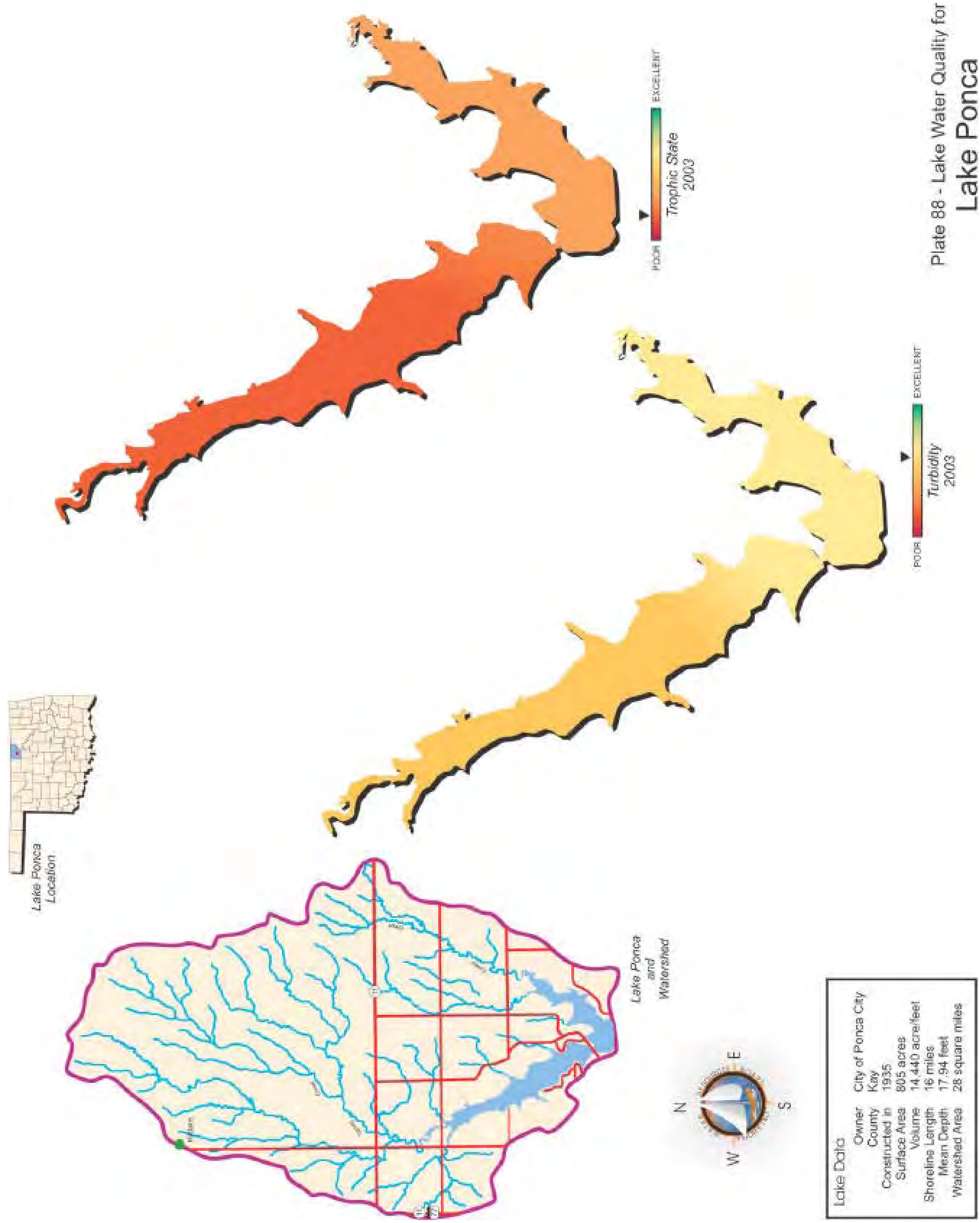



Plate 88 - Lake Water Quality for
Lake Ponca

# Prague City Lake

Prague City Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected from three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 9 NTU (Plate 89), true color was 19 units and average secchi disk depth was 92 centimeters. Based on these three parameters, Prague City Lake had good water clarity in 2003. These values are similar to those in 2000, indicating no significant change in clarity has occurred over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 43 (Plate 89), indicating the lake was mesotrophic indicative of moderate levels of primary productivity and nutrients. This value is similar to that from 2000 (TSI=45), indicating no significant change in productivity has occurred since the last evaluation. Seasonal TSI values were fairly consistent and ranged from oligotrophic in the fall and winter to mesotrophic in the spring and summer. Site 1 was the only mesotrophic site in the winter sampling quarter (see Figure 199). Seasonal turbidity values per site are displayed in Figure 200a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, therefore meeting the Fish and Wildlife (FWP) beneficial use. Seasonal true color values are displayed in Figure 200b. With 100% of the collected values well below the OWQS of 70 units the lake is supporting the Aesthetics beneficial use.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.13 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 231.8 to 273.4 mS/cm, indicating low concentrations of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations. The pH values were neutral to slightly alkaline with values ranging from 6.99 in the summer to 8.34 in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials

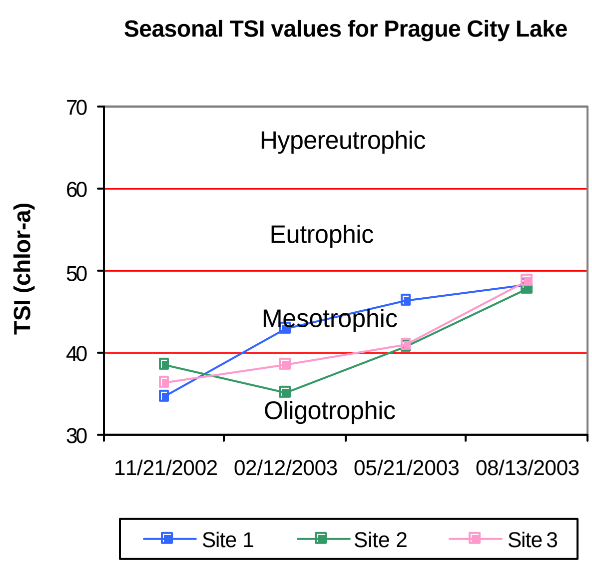



**Figure 199.** TSI values for Prague City Lake.

(ORP) ranged from 142 mV in the hypolimnion in the spring to 548 mV in the winter, indicating the absence of reducing conditions. The lake was not thermally stratified in the fall or winter quarters with dissolved oxygen (D.O) above 8.0 mg/L (Figure 200c-202d). Thermal stratification was evident and anoxic conditions present in both spring and summer quarters. In the spring, stratification occurred between 6 and 7 meters with dissolved oxygen falling below 2.0 mg/L to the lake bottom of 8.4 meters, accounting for approximately 30% of the water column at site 1 to be anoxic (Figure 200e). In the summer quarter, stratification was evident at all sites with anoxic conditions present in 28 to 40 % of the water column (Figure 200f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered partially supported at Prague City Lake based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the surface and 0.63 mg/L at the lake bottom. The TN at the surface ranged from 0.24 mg/L to 0.57 mg/L. The highest surface total nitrogen was reported in the fall and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.015 mg/L and 0.025 mg/L at the lake bottom. The surface TP ranged from 0.007 mg/L to 0.019 mg/L. The lowest surface TP was reported in the fall and the highest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 28:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Prague City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in 2002-2003. This is consistent with the 2000 evaluation (TSI=45), indicating no significant increase or decrease in productivity has occurred. Water clarity was good based on turbidity, true color, and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity, and pH, but only partially supporting due to low dissolved oxygen values in the spring and summer. The Aesthetics beneficial use is supported by both trophic status and true color. Prague City Lake was constructed in 1984 for the purpose of flood control, water supply and recreation.

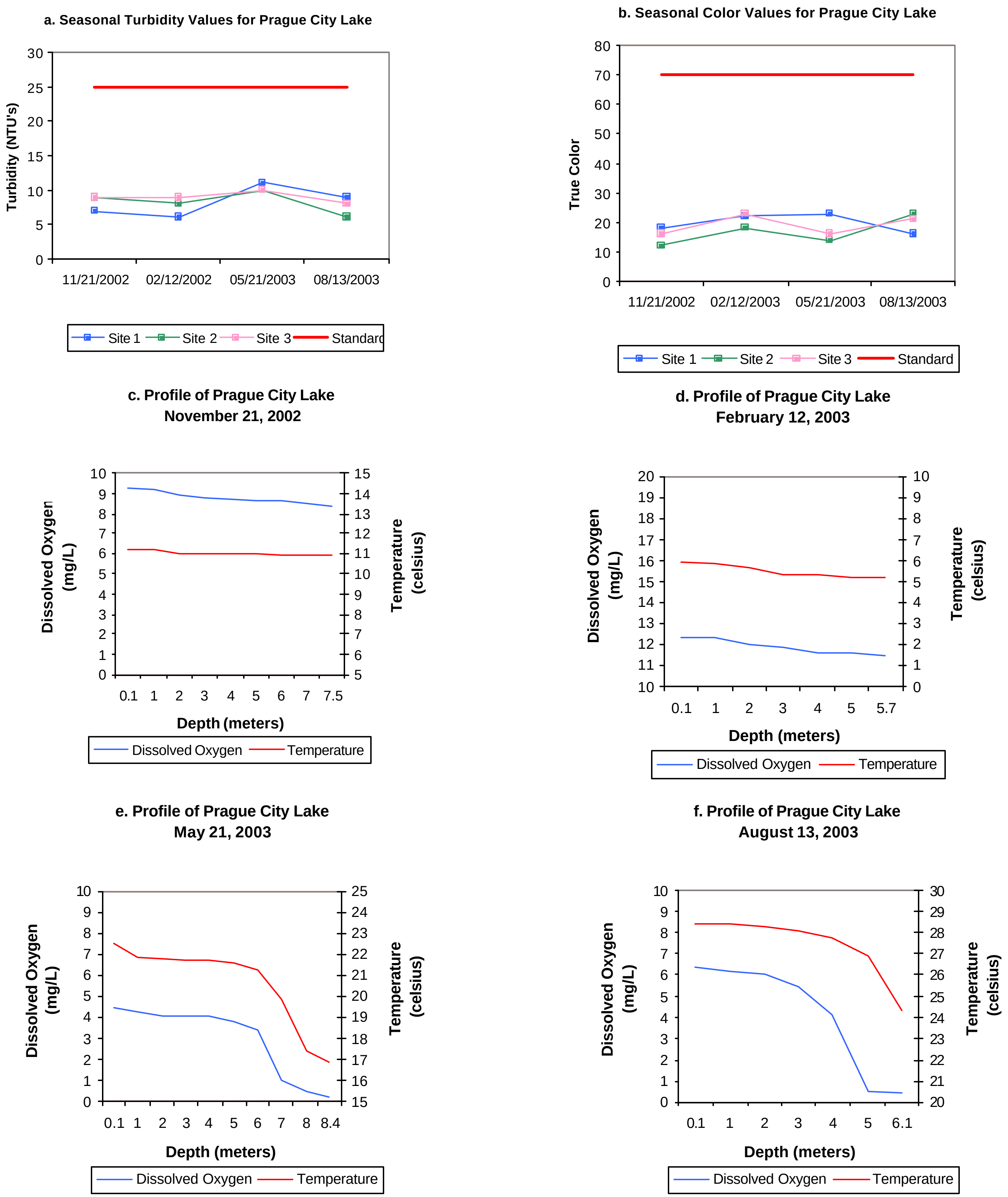
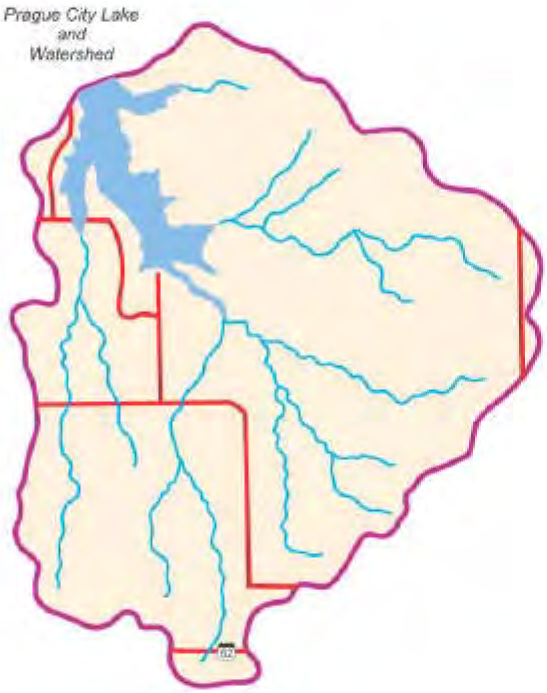



**Figure 200a-202f.** Graphical representation of data results for Prague City Lake.






Lake Data

| | |
|---|---|
| Owner | City of Prague |
| County | Lincoln |
| Constructed in | 1984 |
| Surface Area | 225 acres |
| Volume | 2,415 acre/feet |
| Shoreline Length | 6 miles |
| Mean Depth | 10.73 feet |
| Watershed Area | 4,322 acres |



Plate 89 - Lake Water Quality for
## Prague City Lake

# Purcell Lake

Purcell Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 18 NTU (Plate 90), true color was 32 units, and secchi disk depth was 49 centimeters in 2001-2002. Water clarity was average based on secchi disk depth, turbidity, and true color values. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 52 (Plate 90), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. The TSI values were eutrophic in the fall, spring and summer quarters and were mesotrophic in the winter quarter (see Figure 201). The annual trophic assessment seems representative of conditions at Purcell Lake for 2001-2002. Turbidity values per site were all below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons (see Figure 202a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Purcell Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity concentrations. Seasonal true color values are displayed in Figure 202b. All true color values were below the Aesthetics OWQS of 70 units (see Figure 202b). Purcell Lake is fully supporting its Aesthetics beneficial use as it relates to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites in 2001-2002. Salinity ranged from 0.17 parts per thousand (ppt) in the fall to 0.25 ppt in the spring, indicating moderate salt content and readings were within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 352.2 mS/cm in the fall quarter to 486.7 mS/cm in the spring quarter indicating that moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, with values ranging from 7.53 units in the spring to 8.62 units in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. All collected values were within the acceptable range; therefore the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 13 mV to 481 mV in the summer indicating reducing conditions were not present during any of the sample quarters. The lake was not thermally stratified in the fall, winter or spring quarters and was well mixed with dissolved oxygen (D.O.) concentrations above 7.0 mg/L throughout the water column with the exception of site 1

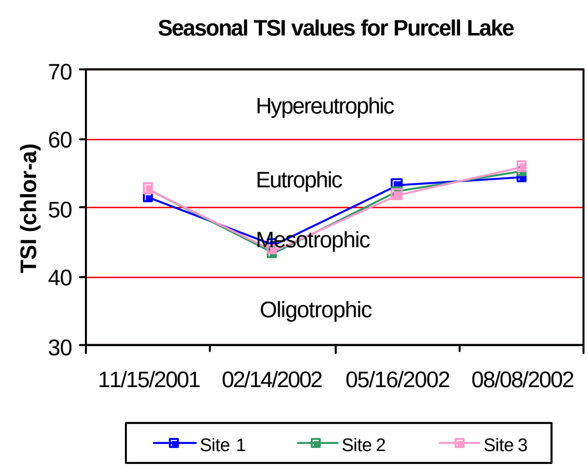



**Figure 201.** TSI values for Purcell Lake.

at the very bottom of the lake where a value less than 1.0 mg/L was recorded (see Figure 202c-204e). In the summer the lake was thermally stratified between 2 and 3 meters below the surface at the dam. Below 2 meters at site 1 to the lake bottom (5.1 meters), D.O. values were less than 2.0 mg/L, constituting about 57% of the water column (see Figure 202f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Purcell Lake. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.67 mg/L at the lake surface. The TN at the surface ranged from 0.36 mg/L to 0.89 mg/L. The highest surface TN value was reported in the spring and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.034 mg/L at the lake. The surface TP ranged from 0.027 mg/L to 0.045 mg/L. The highest surface TP value was reported in the fall quarter and the lowest was in the winter. The nitrogen to phosphorus ratio (TN: TP) was approximately 19:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Purcell Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Purcell Lake was classified as eutrophic, indicating high primary productivity and nutrient rich conditions (Plate 90). The lake was fully supporting its Aesthetics beneficial use based on trophic status (nutrients) and on true color readings. The lake was fully supporting its FWP beneficial use based on nephelometric turbidity and pH, but only partially supporting based upon water column D.O. readings. Purcell Lake was constructed in 1930 and is owned and operated by the City of Purcell. The lake is managed as a municipal water supply and is also utilized for recreational purposes.

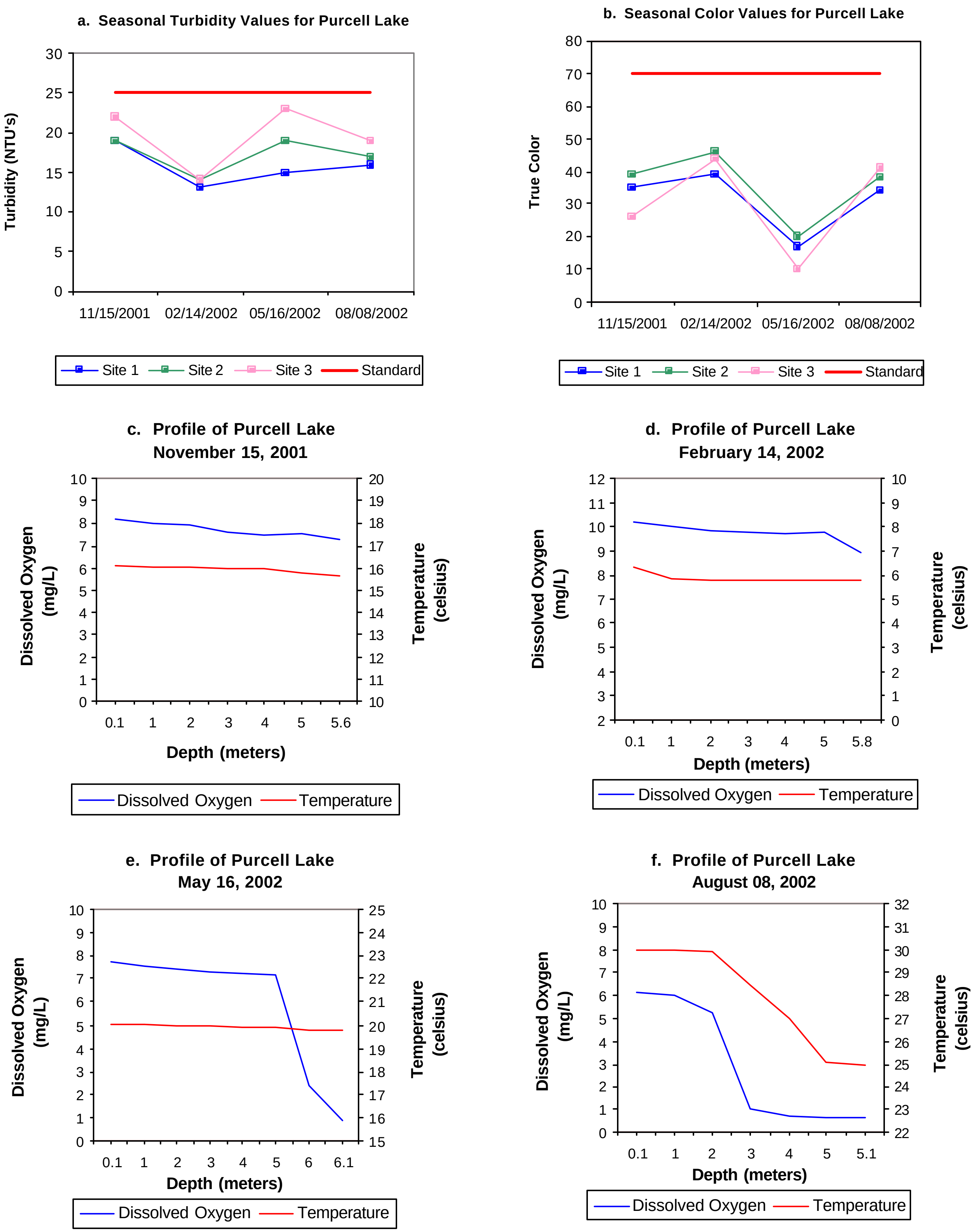
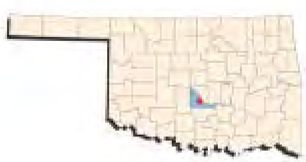


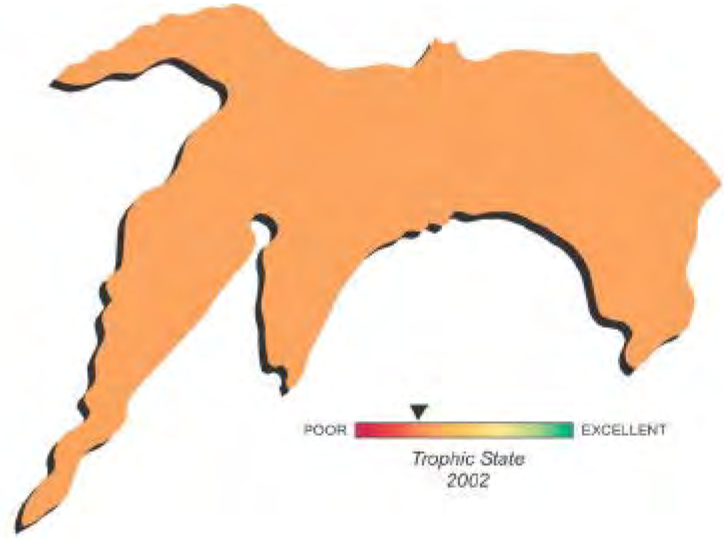

**Figure 202a-204f.** Graphical representation of data results for Purcell Lake.


Purcell Lake
and
Watershed

Purcell Lake
Location

| Lake Data | |
|---|---|
| Owner | City of Purcell |
| County | McClain |
| Constructed in | 1930 |
| Surface Area | 150 acres |
| Volume | 2,800 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 17.33 feet |
| Watershed Area | 2,432 acres |




Trophic State
2002


Turbidity
2002

Plate 90 - Lake Water Quality for
## Purcell Lake

# Lake Raymond Gary

Lake Raymond Gary was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a reservoir greater than 250 surface acres. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 10 NTU (Plate 91), true color was 36 units, and secchi disk depth was 74 centimeters. Based on these parameters water clarity was good in 2003. Results for these parameters were similar to the results found in 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 55 (Plate 91), indicating the lake was eutrophic, with high levels of productivity and nutrient conditions. This value is the same as the TSI in 2000 (TSI=55), indicating no significant increase or decrease over time. The TSI values were primarily eutrophic in 2003, except at site 5 in the fall, which was mesotrophic (see Figure 203). Seasonal turbidity values are displayed in Figure 204a. Turbidity ranged from a low of 6 NTU to a maximum of 20 NTU, with higher values reported for all sites in the fall sampling quarter. With all collected values below the Oklahoma Water Quality Standard (OWQS) of 25 NTU the Fish and Wildlife Propagation beneficial use is fully supported in regards to turbidity. Seasonal true color values are displayed in Figure 204b. True color values were below the OWQS of 70 throughout the sample year, however the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met and a use determination cannot be made.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all sample sites during the sample year. Salinity values ranged from 0.00 parts per thousand (ppt) to 0.81 ppt. Readings for specific conductance ranged from 33.5 mS/cm in the winter to 1530 mS/cm in the summer, indicating that concentrations of chlorides or salts in the lake varied seasonally from very low to the very high in the summer. The higher readings were only recorded at sites 1 and 4, both near the dam site. The heavier saline waters have settled here, as these sites are located in the deepest part of the lake. The pH values at Lake Raymond Gary were slightly acidic, ranging from 6.2 in the summer to 7.33 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they

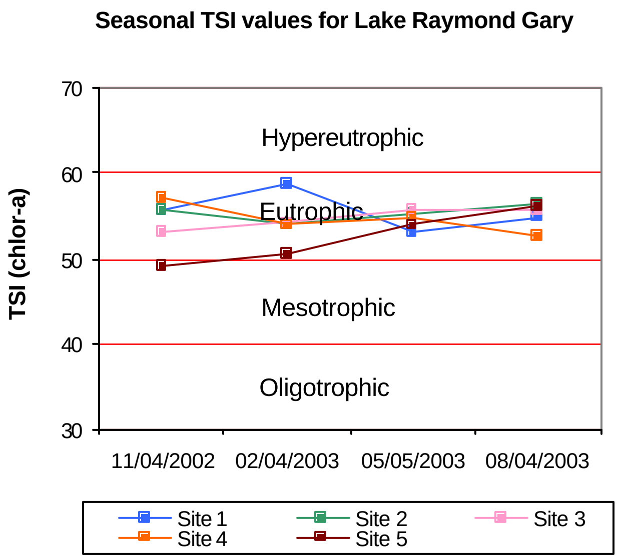


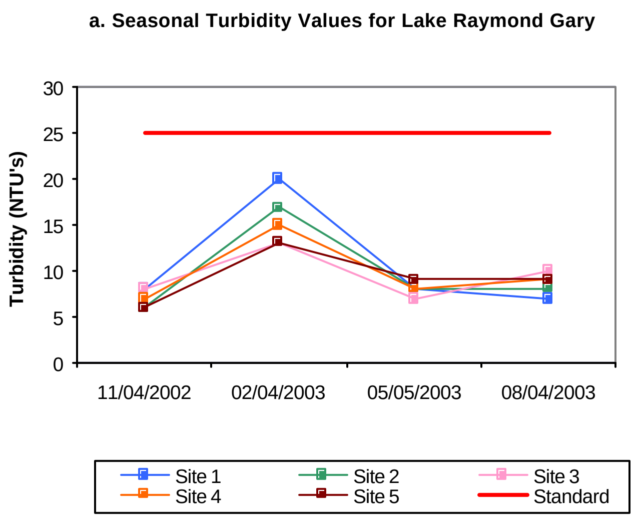

**Figure 203.** TSI values for Lake Raymond Gary.

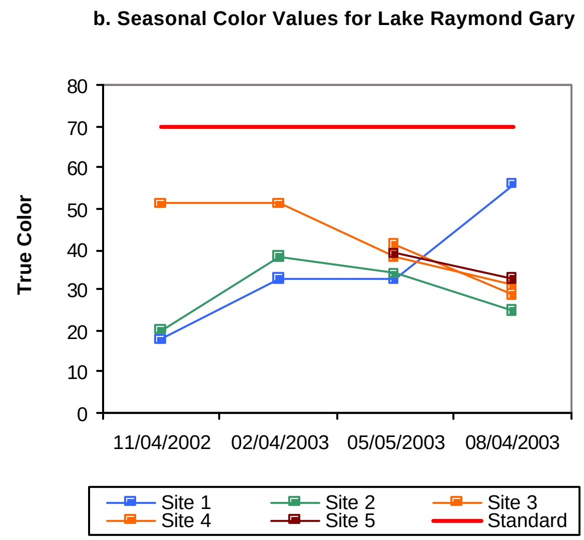
fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 22% of the values recorded being less than 6.5 the lake will be listed as partially supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials ranged from 373 mV to 534 mV, indicating the absence of reducing conditions. The lake was not thermally stratified during the fall or winter and the lake was well mixed with dissolved oxygen (D.O.) values above 7.0 mg/L throughout the water column (Figure 204c-206d). In the spring, site 1 was the only site to stratify with D.O. falling below 2.0 mg/L from 2 meters to the lake bottom of 4.3 meters (Figure 204e). Dissolved oxygen values in the summer were also below 2.0 mg/L for 25 to 50% of the water column at all sites (Figure 204f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Lake Raymond Gary is considered partially supporting the FWP beneficial use based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

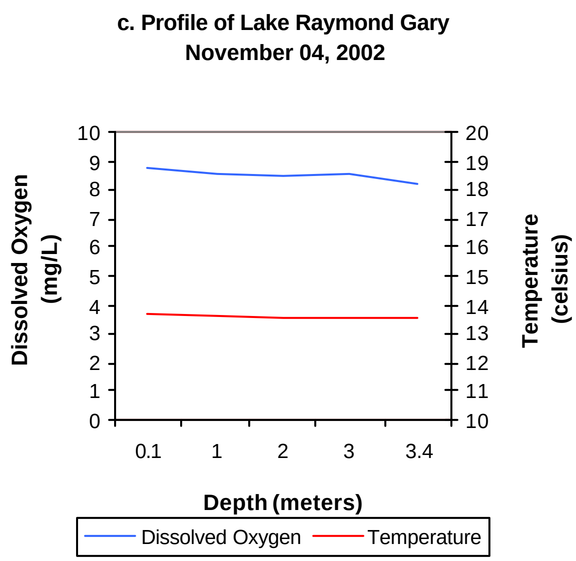
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

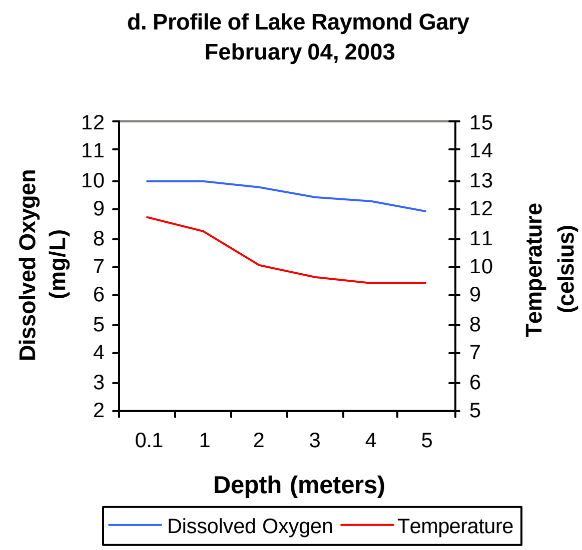
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.36 mg/L at the surface and 0.52 mg/L at the lake bottom. The TN at the surface ranged from 0.05 mg/L to 0.70 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.033 mg/L and 0.065 mg/L at the lake bottom. The surface TP ranged from 0.023 mg/L to 0.053 mg/L. The lowest surface TP was reported in the fall and the highest values were seen during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 11:1 for 2002-2003. This value is greater than 7:1, indicating the lake was phosphorus-limited (Wetzel, 1983).

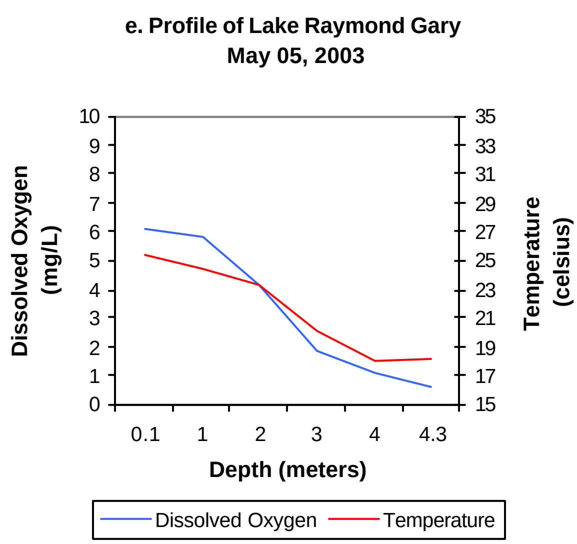
In summary, Lake Raymond Gary was classified as eutrophic, indicative of high primary productivity and nutrient conditions. This classification is consistent with data collected in 2000, indicating no change in productivity has occurred over time. Water clarity was good in sample year 2002-2003, based on turbidity, true color, and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity, but only partially supporting based on low dissolved oxygen values in both spring and summer quarters. With 22% of the recorded pH values less the 6.5 units the lake will be listed as partially supporting the FWP beneficial use. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial is supported based on its trophic status, however an assessment based on true color could not be made due to minimum data requirements not being met. Additional sites have been added to ensure sample size is representative of a lake this size. Lake Raymond Gary is a recreational reservoir owned by the State of Oklahoma.



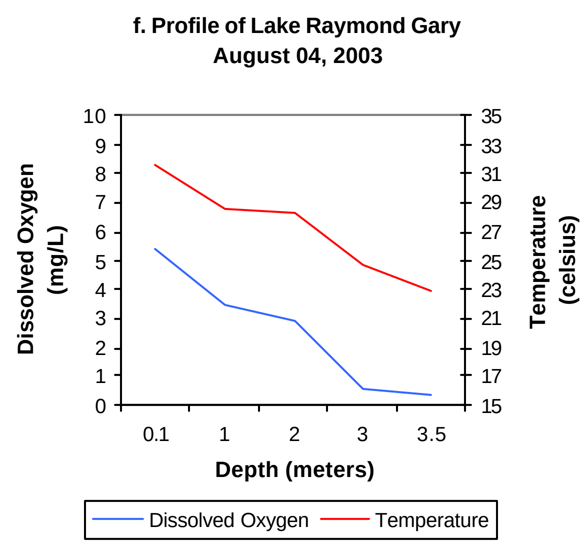
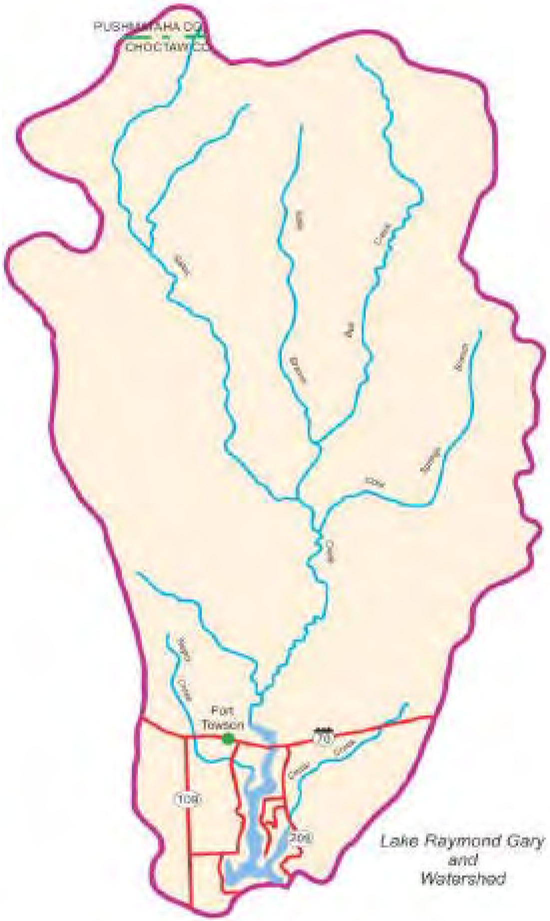
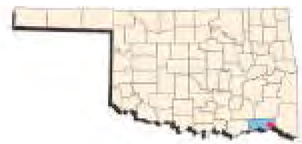




**Figure 204a-206f.** Graphical representation of data results for Lake Raymond Gary.




Lake Raymond Gary and Watershed



Lake Raymond Gary Location


Turbidity 2003


Trophic State 2003

Lake Data

| | |
|---|---|
| Owner | State of Oklahoma |
| County | Choctaw |
| Constructed in | 1956 |
| Surface Area | 263 acres |
| Volume | 1,681 acre/feet |
| Shoreline Length | 10 miles |
| Mean Depth | 6.39 feet |
| Watershed Area | 56 square miles |

Plate 91 - Lake Water Quality for
**Lake Raymond Gary**

## R.C. Longmire Lake

R.C. Longmire Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative of a reservoir greater than 250 surface acres. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity value was 12 NTU (Plate 92), true color was 19 units, and secchi disk depth was 86 centimeters. Water clarity was good based on secchi disk depth, turbidity, and true color values. Results for these parameters are slightly better than the results found in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). The average TSI was 47 (Plate 92), indicating the lake was mesotrophic, with moderate levels of productivity and conditions. This value is lower than the TSI in 2001 (TSI=55). The TSI values were all mesotrophic in 2003, except site 2 in the spring, which was eutrophic (Figure 205). The annual trophic assessment seems representative of conditions at R.C. Longmire Lake for 2003. Turbidity values per site were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons and are displayed in Figure 206a. The lake-wide annual turbidity of 12 NTU seems representative of conditions at R.C. Longmire Lake in 2003. All true color values were below the aesthetics OWQS of 70 units (Figure 206b). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (70 units for color). If 10 to 25% of the values exceed the numeric criteria, the lake should be listed as partially supporting beneficial uses. Although 100% (n=16) of samples in 2003 were below the 70-unit standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites. Salinity values for R.C. Longmire Lake ranged from 0.13 parts per thousand (ppt) to 0.16 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 269.2 to 364.5 mS/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations. In general

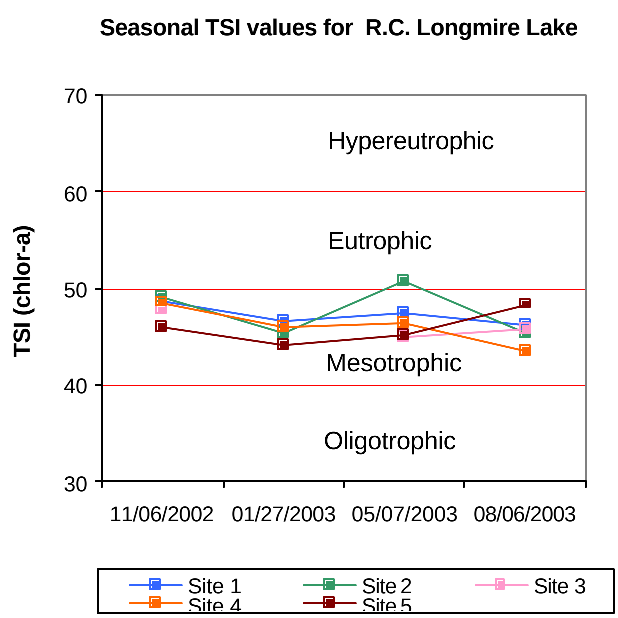



**Figure 205.** TSI values for R.C. Longmire Lake.

pH values were neutral to slightly alkaline with values ranging from 6.83 to 8.11 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the Fish and Wildlife Propagation (FWP) beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 379 mV in the summer to 644 mV in the spring, indicating the absence of reducing conditions. During the fall and winter quarters stratification was not present and lake was well mixed (see Figure 206c-208d). In the spring the lake was stratified between 9 and 10 meters, with 21% of the dissolved oxygen (D.O.) values below 2.0 mg/L (Figure 206e). In the summer the lake was stratified between 6 and 7 meters, at site 1, with D.O. falling below 2.0 mg/L to the lake bottom of 10.8 meters (Figure 206f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. R.C. Longmire Lake is partially supporting its FWP beneficial use with 21% of the D.O. values in the spring and 42% in the summer falling below 2.0 mg/L. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.77 mg/L at the surface and 1.29 mg/L at the lake bottom. The TN at the surface ranged from 0.50 mg/L to 1.04 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.024 mg/L and 0.068 mg/L at the lake bottom. The surface TP ranged from 0.018 mg/L to 0.043 mg/L. The highest surface TP was reported in the winter and the lowest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 32:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, R.C. Longmire Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in 2002-2003. Although this is lower than the TSI in 2001 (TSI=55), the current value is based on a larger dataset and is likely a more accurate depiction of productivity within the lake. Water clarity is good based on turbidity, true color and secchi disk depth, slightly better than clarity in 2001. The lake is supporting the FWP beneficial use based on turbidity and pH, but is partially supporting based on anoxic conditions present in the spring and summer. The lake is supporting the Aesthetics based on its trophic status, however assessment based on true color could not be made as the minimum data requirements of 20 samples for lakes larger than 250 surface acres were not met. R.C. Longmire Lake is located in Garvin County and is a popular fishing lake.

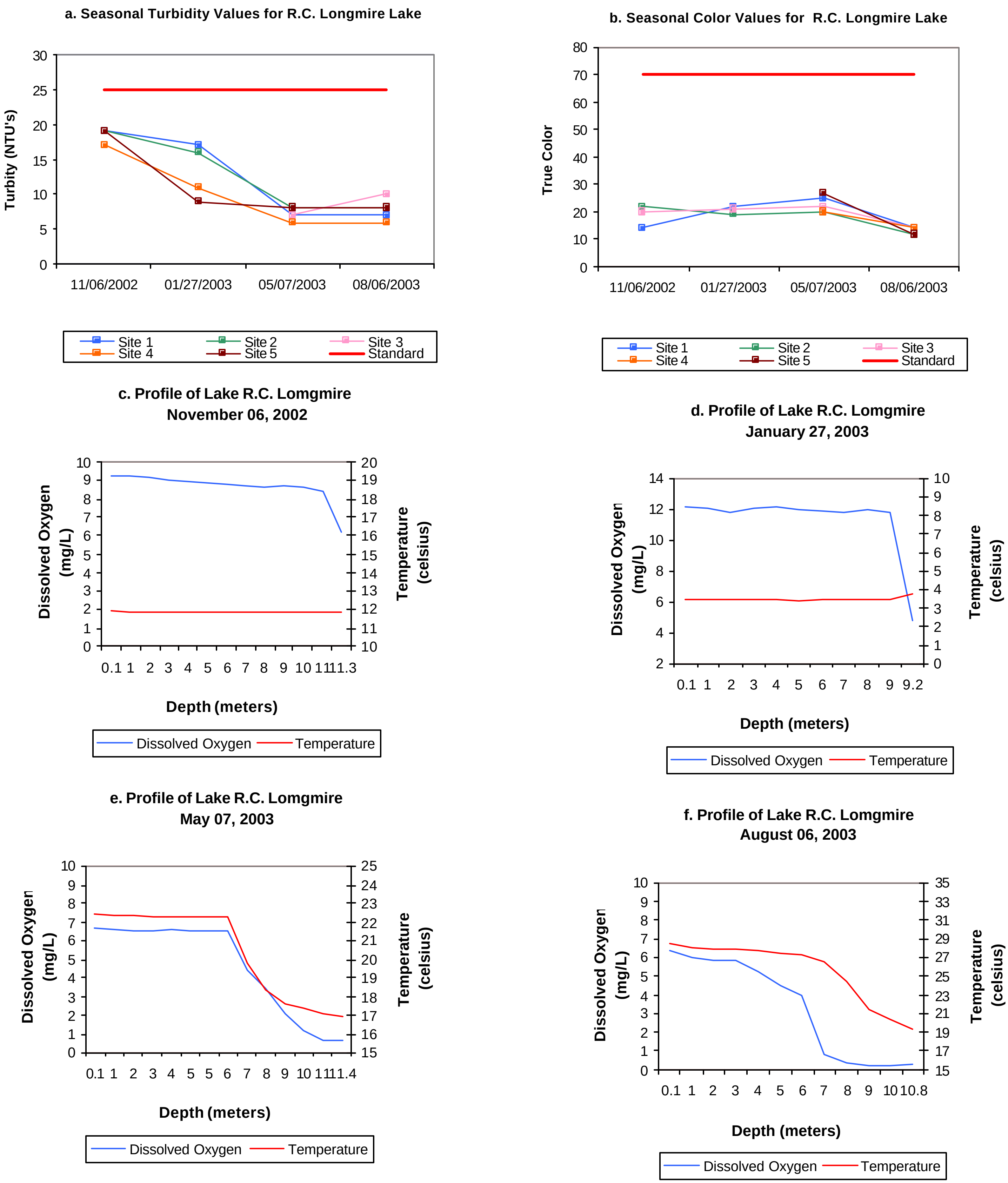



**Figure 206a-208f.** Graphical representation of data results for R.C. Longmire Lake.

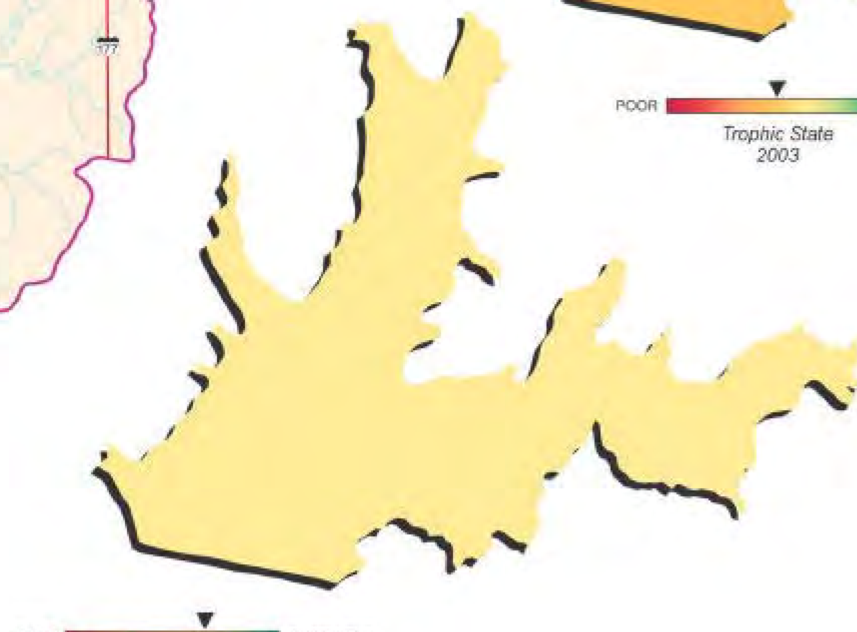

R. C. Longmire Lake
and
Watershed

R. C. Longmire Lake
Location


Lake Data

| | |
|---|---|
| Owner | City of Pauls Valley |
| County | Garvin |
| Constructed in | 1989 |
| Surface Area | 745 acres |
| Volume | 14,424 acre/feet |
| Shoreline Length | 12 miles |
| Mean Depth | 19.36 |
| Watershed Area | 29 square miles |


Trophic State
2003




Turbidity
2003

Plate 92 - Lake Water Quality for
R. C. Longmire Lake

# Robert S. Kerr Reservoir

Robert S. Kerr Reservoir was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected from six (6) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 40 NTU (Plate 95), true color was 43 units and average secchi disk depth was 48 centimeters. Based on these three parameters, water clarity at R.S. Kerr Reservoir was fairly poor. Results are similar to those reported in 2000, indicating little change has occurred over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=24). The average TSI was 55 (Plate 95), indicating the lake was eutrophic, with high levels of primary productivity and conditions. This value is similar to the one calculated in 2000 (TSI=53), indicating the no significant increase or decrease in productivity has occurred since the lake was last evaluated. The TSI values were primarily eutrophic throughout the sample year although sites 1 and 2 were mesotrophic in the spring (See Figure 207). Seasonal turbidity values are displayed in Figure 208a. Turbidity values were well above the Oklahoma Water Quality Standard (OWQS) of 25 NTU in the first three quarters, but below the standard during the summer. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 75% of the samples collected in 2003 exceeding the standard, the lake is not supporting the Fish and Wildlife Propagation (FWP) beneficial use. True color varied seasonally with the highest values reported in the fall and the lowest during the winter (Figure 208b). Applying the same default protocol, the Aesthetics beneficial use is partially supported with 12% of the values exceeding the OWQS of 70-units for true color.

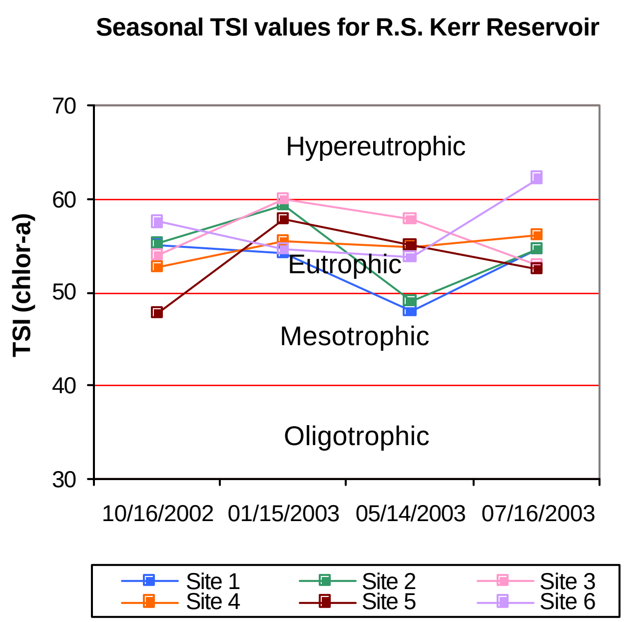



**Figure 207.** TSI values for R.S. Kerr Reservoir**.**

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values ranged from 0.32 parts per thousand (ppt) in the summer to 1.09 ppt in the winter. This is higher than the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 624.4 to 2033 mS/cm, indicating high concentrations of electrical current conducting compounds (salts) within the lake, consistent with the elevated salinity readings. In general, pH values were neutral to slightly alkaline with values ranging from 7.14 to 8.57 during the study period. According to USAP (OAC 785:46-15-5), pH v values are exceeding standards if they fall outside the 6.5 to 9 range, for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 357 mV in the summer to 651 mV in the fall, indicating reducing conditions were not present during the study period. The lake was not stratified during any of the sampling intervals and was well mixed (Figure 208c-210f). The only instance where dissolved oxygen (D.O.) fell below 2.0 mg/L occurred at site 2 in the summer quarter. R.S. Kerr Reservoir is fully supporting its FWP beneficial use based on dissolved oxygen. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.01 mg/L at the surface and 1.05 mg/L at the lake bottom. The TN at the surface ranged from 0.62 mg/L to 1.71 mg/L. The highest surface total nitrogen was reported in the fall and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.109 mg/L and 0.126 mg/L at the lake bottom. The surface TP ranged from 0.070 mg/L to 0.157 mg/L. The highest surface TP was reported in the spring and the lowest values were seen during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Robert S. Kerr Reservoir was classified as eutrophic with high primary productivity and nutrient conditions. This is similar to the value in 2000 (TSI=53), indicating no significant increase or decrease in productivity has occurred since the last evaluation. Water clarity was poor based on turbidity, true color, and secchi disk depth. The lake is supporting the FWP beneficial use based on dissolved oxygen and pH values, but not supporting based on high turbidity. The Aesthetics beneficial use is supported based on its trophic status, but partially supporting based on high true color values reported in the fall quarter. The Oklahoma Department of Environmental Quality (ODEQ) sampled the fish community in 2002 as part of the Toxics and Reservoirs program and none of the fish tissue samples exceeded the screening level or low consumption advisory for metals toxicity. The Fish Consumption beneficial use is considered supported. The United States Army Corps of Engineers (USACE) constructed Robert S. Kerr Reservoir in 1971 for navigation, hydroelectrical and recreation purposes. The lake is located in both Sequoyah and Leflore Counties approximately 8 miles south of Sallisaw.

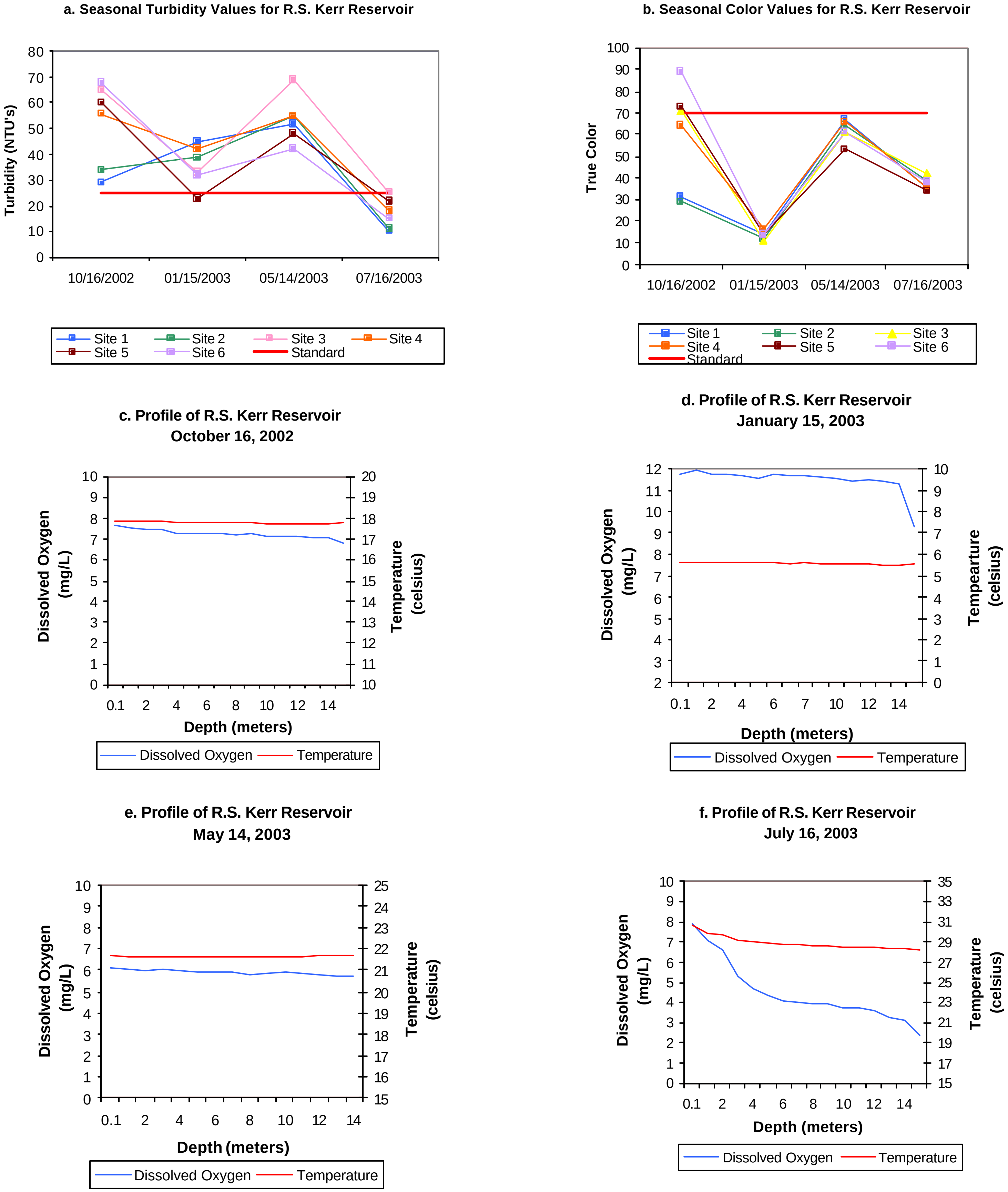
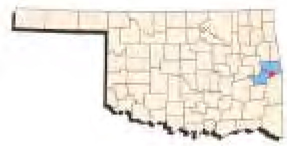
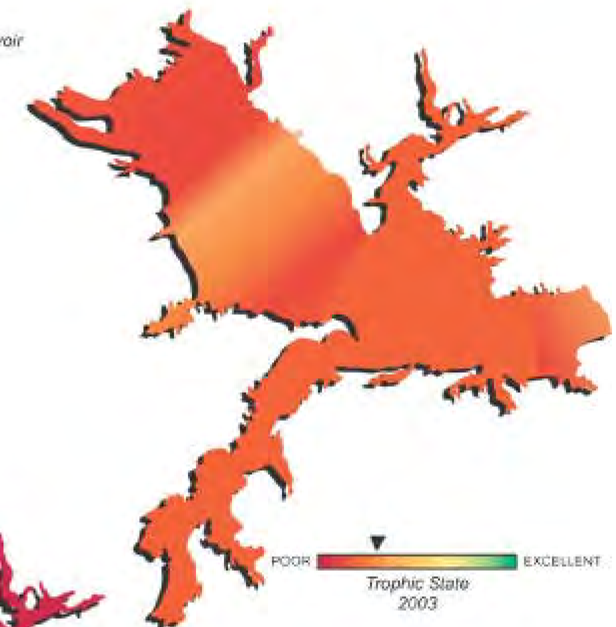


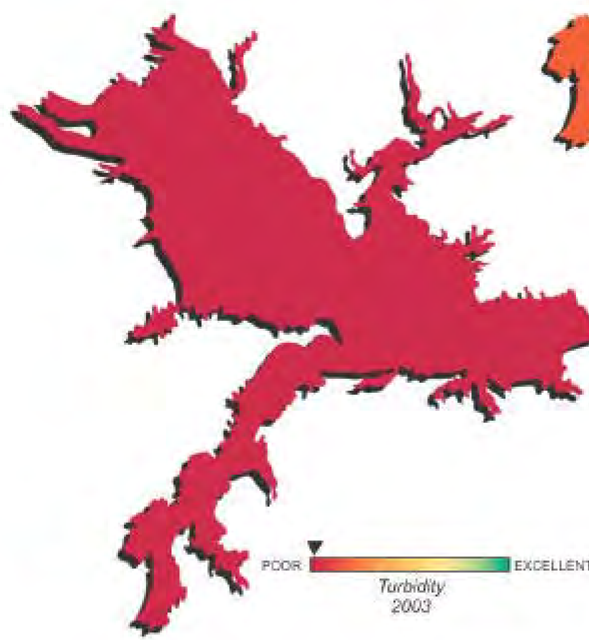

**Figure 208a-210f.** Graphical representation of data results for R.S. Kerr Reservoir.

Robert S. Kerr Reservoir and Watershed


Robert S. Kerr Reservoir Location



Trophic State 2003

Turbidity 2003

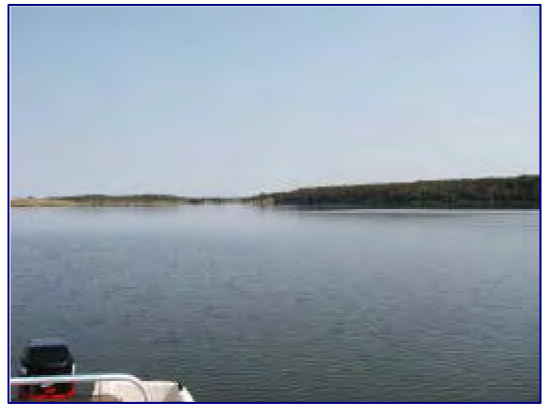
Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Sequoyah/LeFlore |
| Constructed in | 1971 |
| Surface Area | 43,800 acres |
| Volume | 525,700 acre/feet |
| Shoreline Length | 250 miles |
| Mean Depth | 11.75 feet |
| Watershed Area | 147,756 square miles |

Plate 95 - Lake Water Quality for

## Robert S. Kerr Reservoir

# Rock Creek Reservoir



Rock Creek Reservoir was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 9 NTU (Plate 93), true color was 16 units, and secchi disk depth was 90 centimeters. Based on these three parameters, Rock Creek Reservoir had good water clarity. Water clarity was even better than reported in 2000, with secchi disk depth twice as high as previously reported. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 50 (Plate 93), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. This value is similar to the TSI in 2000 (TSI=55), and in the same trophic category, indicating no significant increase or decrease over time. The TSI values varied seasonally from eutrophic in the fall and spring to mesotrophic in the winter and summer (see Figure 209). Seasonal turbidity values are displayed in Figure 210a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples below the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2003. True color values were below the aesthetics OWQS of 70 units at all sites throughout the year (Figure 210b). Applying the same default protocol, the lake is supporting the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.14 ppt. This is within the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 191.7 to 293.1 mS/cm, indicating low concentrations of electrical current conducting compounds (salts) were present in the lake, consistent with the elevated salinity readings. In general pH values were neutral to slightly alkaline with values ranging from 7.09 to 8.64 during the study period. According to

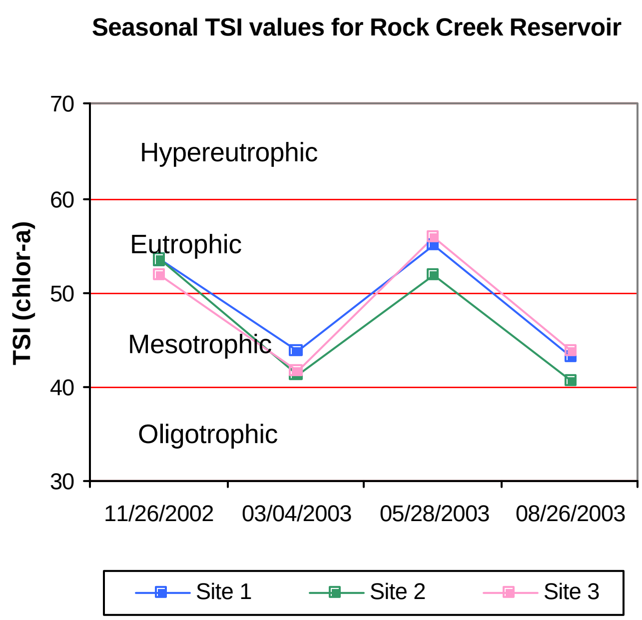



**Figure 209.** TSI values for Rock Creek Reservoir.

USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 348 mV in the winter to 527 mV in the summer, indicating reducing conditions were not present during the study period. The lake was not stratified during the fall and winter quarters and the lake was well mixed with dissolved oxygen values generally above 8.0 mg/L (Figure 210c-212d). The lake was thermally stratified and anoxic conditions were present in both spring and summer quarters. In the spring the lake was stratified between 6 and 7 meters at which point dissolved oxygen (D.O.) fell below 2.0 mg/L for 36% of the water column (Figure 210e). During the summer the thermocline occurred higher in the water column (between 2 and 3 meters), falling below 2.0 mg/L from 4 meters to the lake bottom of 9.1 meters at site 1 (Figure 210f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Rock Creek Reservoir is partially supporting its FWP beneficial use with 36% of the D.O. values in the spring and 64% in the summer falling below 2.0 mg/L. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.50 mg/L at the surface and 0.54 mg/L at the lake bottom. The TN at the surface ranged from 0.34 mg/L to 0.66 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.016 mg/L and 0.023 mg/L at the lake bottom. The surface TP ranged from 0.009 mg/L to 0.030 mg/L. Similar to TN, the lowest surface TP was reported in the fall but the highest values were reported during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 31:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Rock Creek Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This is consistent with the 2000 evaluation, indicating no significant change in productivity has occurred over time. Water clarity was good based on true color, secchi disk depth and turbidity. The lake is supporting the FWP beneficial use based on turbidity and pH, but only partially supporting the use due to anoxic conditions in the spring and summer quarters. The Aesthetic beneficial use is fully supported by both trophic status and collected true color values. Rock Creek Reservoir is located in Carter County and serves as a recreational reservoir for the City of Ardmore.

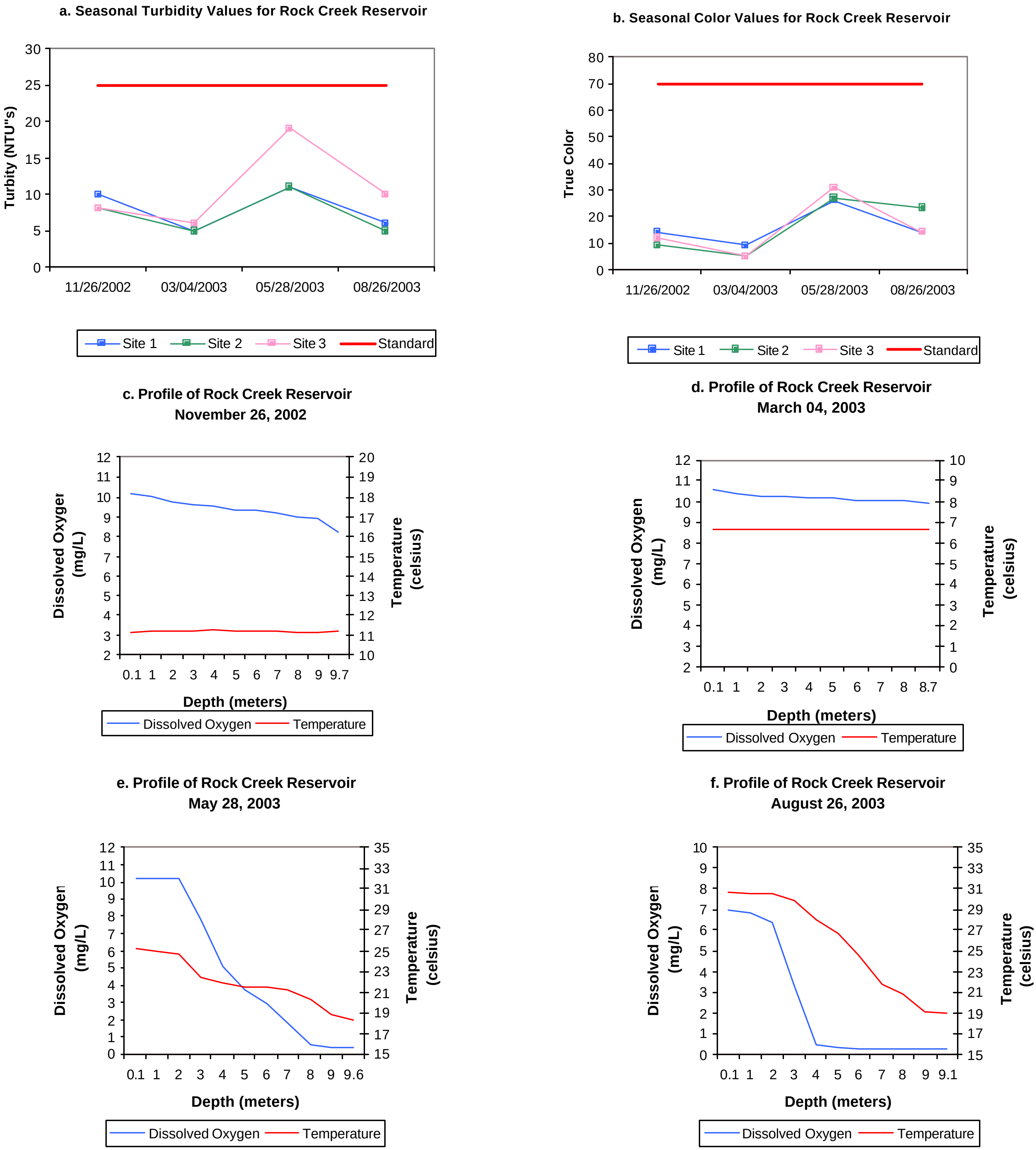
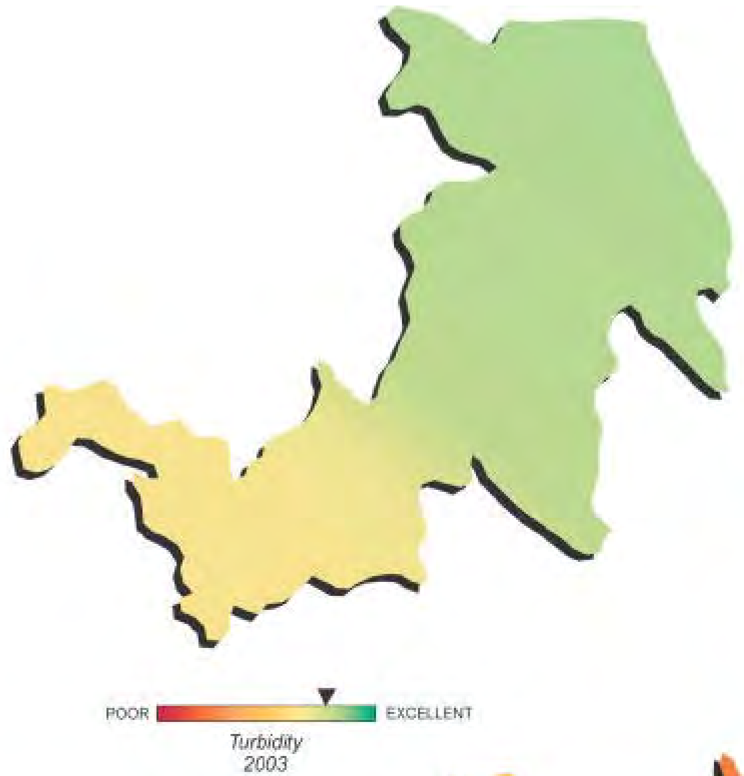



**Figure 210a-212f.** Graphical representation of data results for Rock Creek Reservoir.



Lake Data

| | |
|---|---|
| Owner | City of Ardmore |
| County | Carter |
| Constructed in | 1979 |
| Surface Area | 248 acres |
| Volume | 3,588 acre/feet |
| Shoreline Length | 6 miles |
| Mean Depth | 14.47 feet |
| Watershed Area | 3,545 acres |



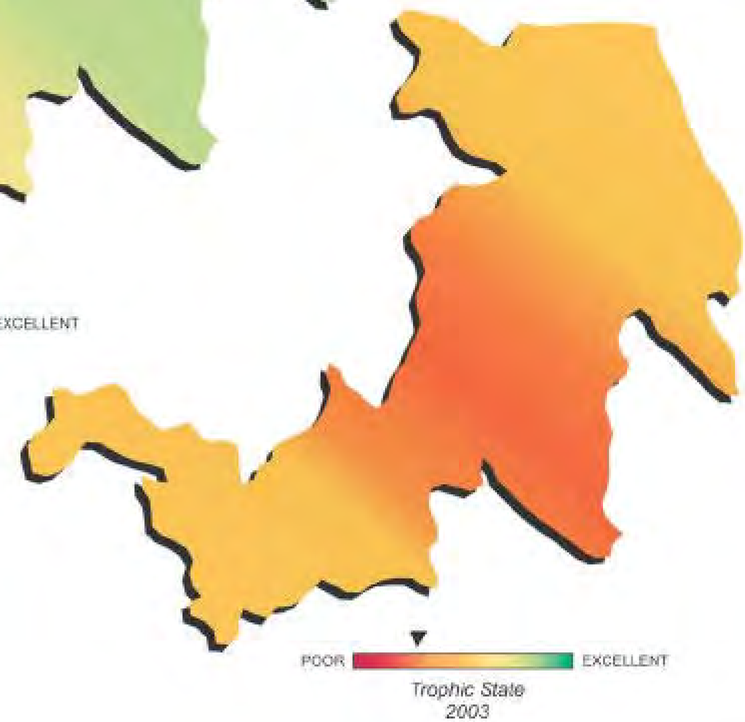




Plate 93 - Lake Water Quality for
# Rock Creek Reservoir

# Rocky (Hobart) Lake

Rocky Lake was sampled for four quarters, from November 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 40 NTU (Plate 94), true color was 29 units, and secchi disk depth was 31 centimeters. Based on these three parameters, Rocky Lake had poor water clarity in comparison to other Oklahoma reservoirs. Water clarity was similar in 2001; with true color improving slightly. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 68 (Plate 94), classifying the lake as hypereutrophic, indicative of excessive levels of productivity and nutrients. This value is very similar to the one calculated in 2001 (TSI=66) indicating little or no change in trophic status over time. The TSI values were hypereutrophic at all sites during the sample year (See Figure 211). Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (OWQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Æsthetics beneficial use non-support status. All turbidity values, except for four sites in the spring, were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (Figure 212a). According to the Use Support Assessment Protocols (USAP) outlined in OAC 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 80% of the turbidity values exceeding the OWQS of 25NTU, the Fish and Wildlife Propagation (FWP) beneficial us is considered not supported. Seasonal true color values are displayed in Figure 212b. Of the twenty true color values collected, only one (5%) was above the numeric criteria of 70 units in the fall quarter. Applying the same protocol for determining the short-term average for true color, the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all sample sites and yielded the following results. Salinity readings ranged from 0.21 parts per thousand (ppt) to 0.35ppt, slightly higher than most values recorded in Oklahoma reservoirs. Readings for specific conductance were also slightly higher than values normally seen in most Oklahoma reservoirs. Specific Conductance ranged from 420.8 mS/cm in the spring quarter to 680.4 mS/cm in the winter quarter, indicating moderate to slightly elevated concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 353 mV to 455 mV, indicating reducing conditions were not present during any sampling events. Recorded pH values were neutral to slightly

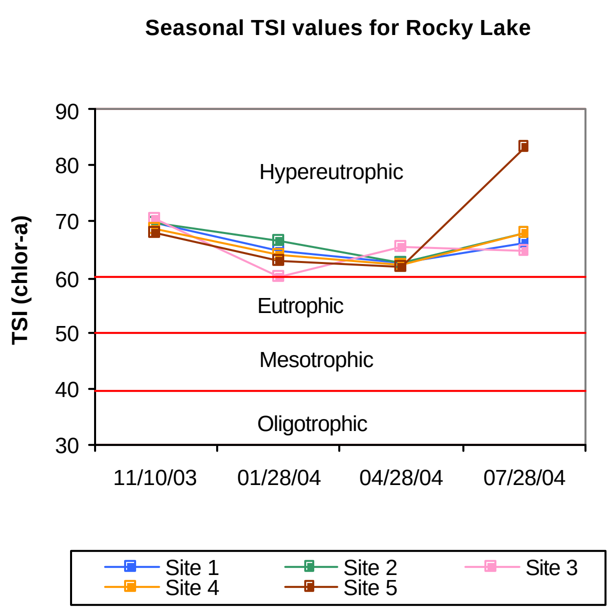



**Figure 211. TSI values for Rocky Lake.**

alkaline, ranging from 7.13 to 8.66 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Rocky Lake was fully supporting its FWP beneficial use based on pH values collected during the study period. Due to equipment failure, profile data is not available for the fall quarter, although it is likely that thermal stratification did not occur. The lake was not thermally stratified during winter, spring or summer quarters (see Figure 212c-214e). The water column was evenly mixed and oxygenated during the entire study period, which may be attributed to the shallow nature of the lake (mean depth of 2.9 meters). Dissolved oxygen (D.O.) concentrations never fell below 2.0 mg/L at any point in the water column during the sample year. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered supported based on dissolved oxygen concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

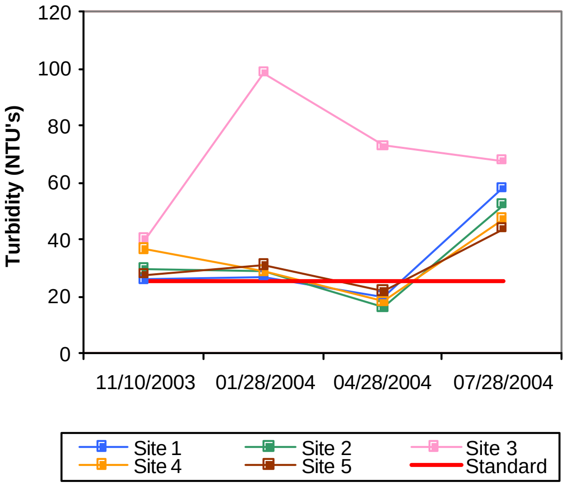
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected seven (70%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (74.3 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.39 mg/L at the lake surface. The TN at the surface ranged from 0.92 mg/L to 2.12 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.130 mg/L at the lake surface. The TP ranged from 0.092 mg/L to 0.155 mg/L at the lake surface. Both the highest and lowest surface TP values were reported in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 11:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

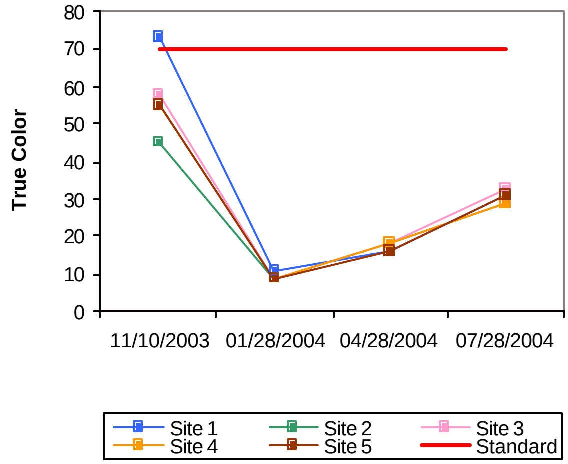
In summary, Rocky Lake was as hypereutrophic, indicative of excessive primary productivity and nutrient rich conditions (Plate 94). This is consistent with historical data collection efforts in 2001 (TSI=66), indicating no significant increase or decrease in productivity has occurred over time. Based on its trophic status the lake will be recommended for listing as a Nutrient Limited watershed (NLW) in the next OWQS revision process and its Aesthetics beneficial use is considered nutrient threatened until studies can be conducted to confirm non-support status. With only 5% of the collected values greater than the OWQS of 70 units, Rocky Lake is fully supporting its Aesthetics beneficial use based on true color readings. Water clarity continues to be poor at this lake based on true color secchi disk depth and high turbidity values. The FWP beneficial use is fully supporting based on pH and D.O. concentrations, and is not supported based on high turbidity values recorded throughout the study period. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected seven (70%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (74.3) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported. Rocky Lake was constructed in

1933 and is owned and operated by the City of Hobart. The lake is utilized by the city for water supply and recreational purposes.

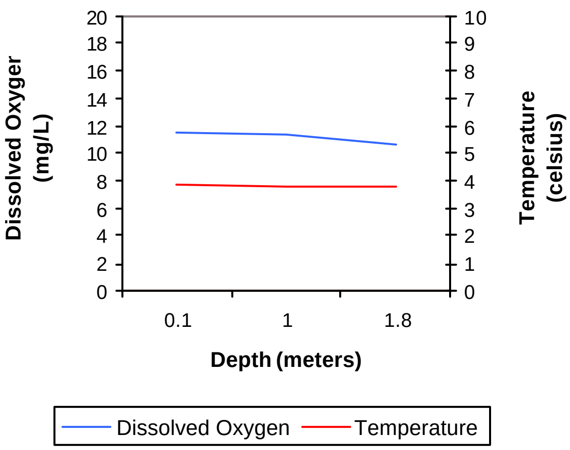
**a. Seasonal Turbidity Values for Rocky Lake**



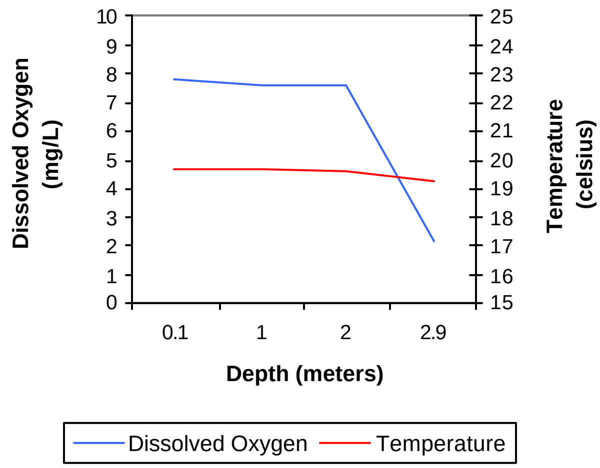

**b. Seasonal Color Values for Rocky Lake**




**c. Profile of Rocky Lake**
**January 28, 2004**




**d. Profile of Rocky Lake**
**March 28, 2004**




**e. Profile of Rocky Lake**
**July 28, 2004**

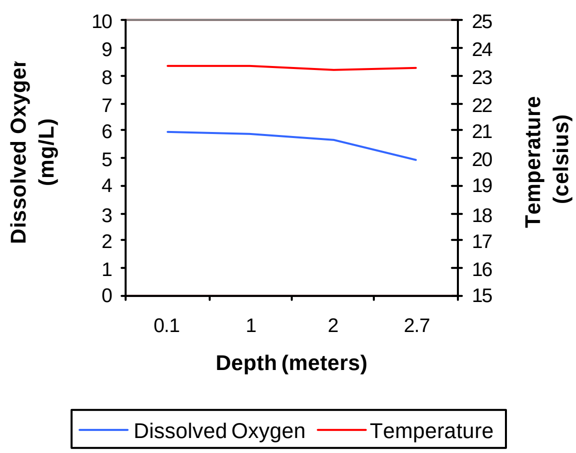



**Figure 212a-214e.** Graphical representation of data results for Rocky Lake.



Lake Data

| | |
|---|---|
| Owner | City of Hobart |
| County | Washita |
| Constructed in | 1933 |
| Surface Area | 347 acres |
| Volume | 4,210 acre/feet |
| Shoreline Length | 8 miles |
| Mean Depth | 11.64 feet |
| Watershed Area | 58 square miles |



Plate 94 - Lake Water Quality for

# Rocky (Hobart) Lake

# Lake Sahoma

Lake Sahoma was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 34 NTU (Plate 96), true color was 104 units, and secchi disk depth was 37 centimeters. Water clarity was fair to poor based on secchi disk depth, turbidity, and true color values. Results were similar in 2001-2002 indicating no significant change in water clarity has occurred. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 51 (Plate 96), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. The TSI values varied seasonally ranging from eutrophy in the fall and summer quarters to oligotrophic in the winter (site 1 and 2) and mesotrophic in the spring quarter (see Figure 213). Turbidity values consistently exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU in all season except during the fall quarter (see Figure 214a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 70% of the collected turbidity values exceeding the criteria, Lake Sahoma is not supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 214b. With 75% of the true color values above the Aesthetics OWQS of 70 units, the lake is not supporting its Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites in 2003-2004. Salinity ranged from 0.04 parts per thousand (ppt) in the fall and winter quarters to 0.08 ppt in the summer quarter, indicating low salt content and below the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 100.2 mS/cm to 169.7 mS/cm in the fall quarter, indicating that very low levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral with values ranging from 6.60 units in the fall to 8.03 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding

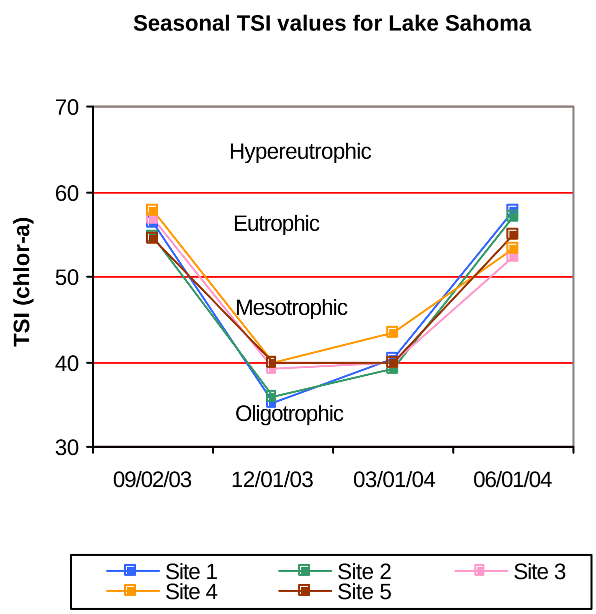


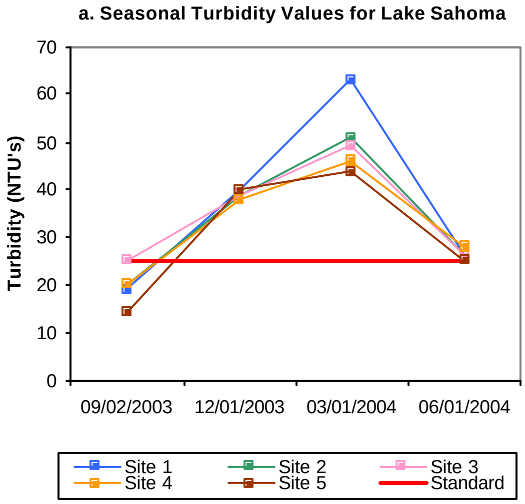

**Figure 213.** TSI values for Lake Sahoma.

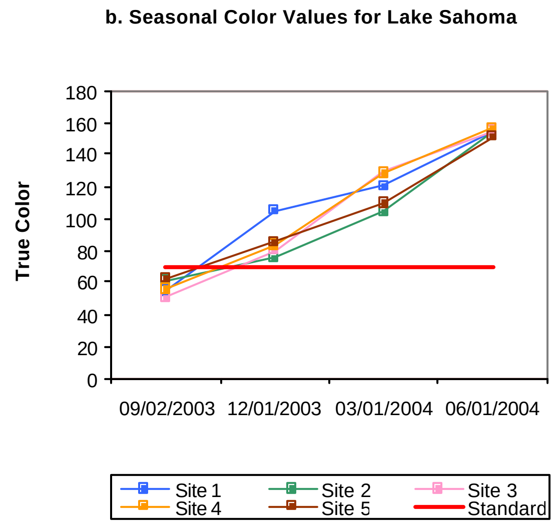
standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All collected pH values were within the acceptable range, therefore Lake Sahoma is fully supporting its FWP beneficial as it relates to pH. Oxidation-reduction potentials (redox) ranged from 351 mV to 500 mV, indicating reducing conditions were not present during the sampling events. Thermal stratification was evident and anoxic conditions present in the fall quarter. Stratification occurred between 4 and 5 meters below the surface at site 1 with anoxic conditions comprising approximately 38 % of the water column (Figure 214c). Site 2 was also stratified and dissolved oxygen (D.O.) was less than 2.0 mg/L from 3 meters to the lake bottom of 6.5 meters (63% of the water column). The lake was not thermally stratified in the winter or spring quarters and was well mixed with dissolved oxygen (D.O.) concentrations remaining above 7.0 mg/L throughout the water column and generally above 9.0 mg/L (see Figure 214d-216e). In the summer quarter, the lake was strongly thermally stratified between 1 and 2 meters, however D.O. values were less than 1.5 mg/L only from the 5-meter depth to the lake bottom at 8 meters (see Figure 214f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Lake Sahoma with approximately 63% of the water column anoxic during the fall and 55% during the summer sampling events. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

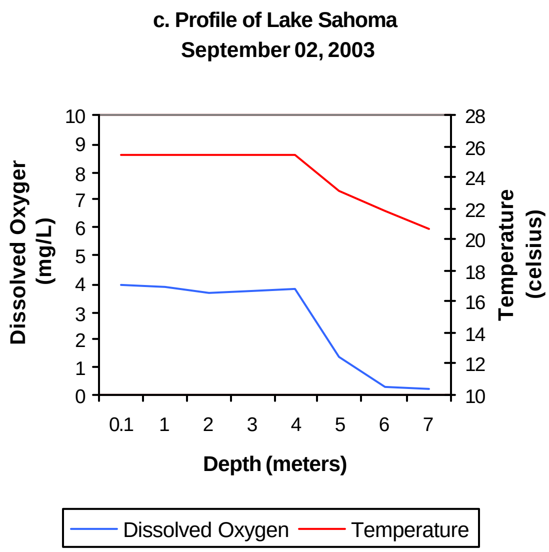
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level or the geometric mean. The PBCR beneficial use is therefore considered fully supported.

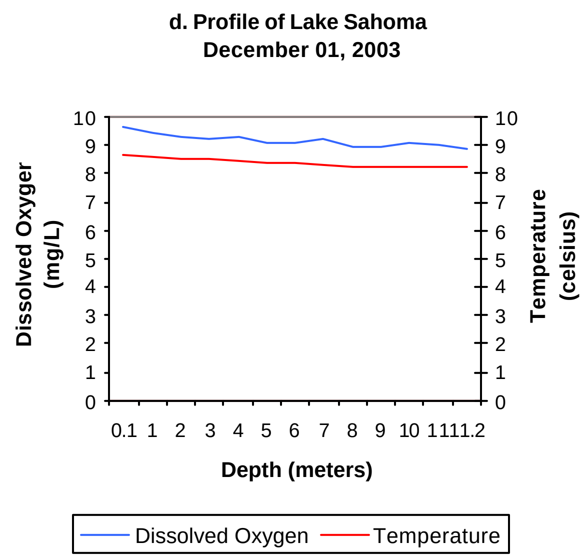
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.95 mg/L at the lake surface. The TN at the surface ranged from 0.50 mg/L to 1.44 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.053 mg/L at the lake surface. The surface TP ranged from 0.034 mg/L to 0.061 mg/L. The highest surface TP value was reported in the winter quarter and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 18:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

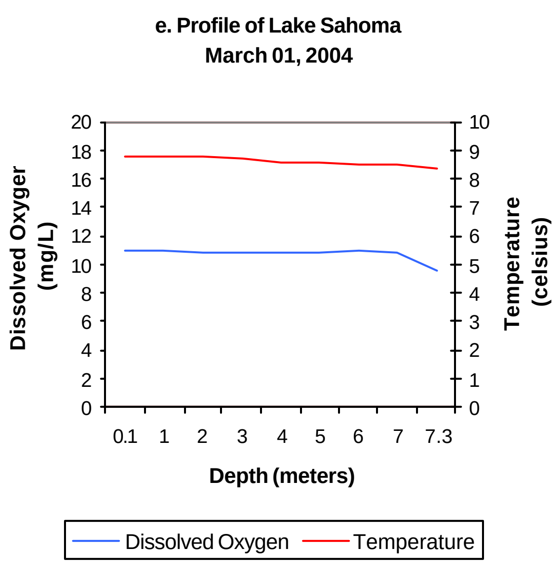
In summary, Lake Sahoma was classified as eutrophic, indicating high primary productivity and nutrient rich conditions (Plate 96). Water clarity was fair to poor based on secchi disk depth, turbidity, and true color values. The lake was fully supporting its Aesthetics beneficial use based on its trophic status (for nutrients) and not supporting for true color as 75% of the recorded values were exceeding the OWQS of 70 units. Sahoma was fully supporting its FWP beneficial use based on pH partially supporting for D.O. concentrations, and not supporting the beneficial use based on nephelometric turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected none exceeded the prescribed screening level or the geometric mean. The PBCR beneficial use is therefore considered fully supported. Lake Sahoma, was constructed in 1947 and is owned and operated by the City of Sapulpa. The lake is managed as a municipal water supply and offers numerous recreational opportunities to the public.



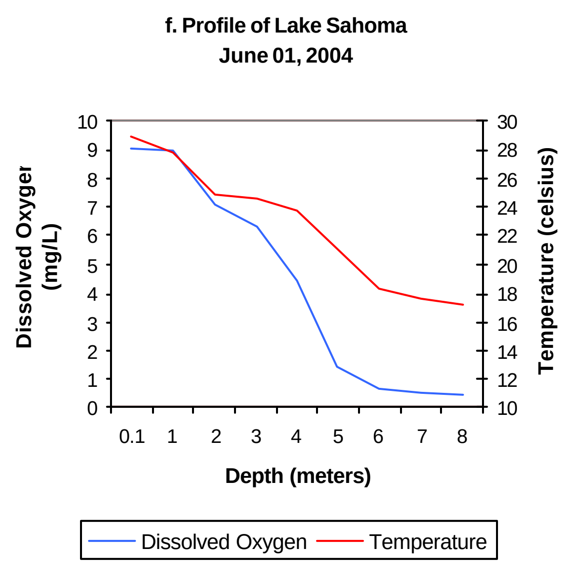
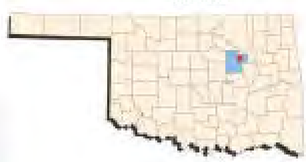
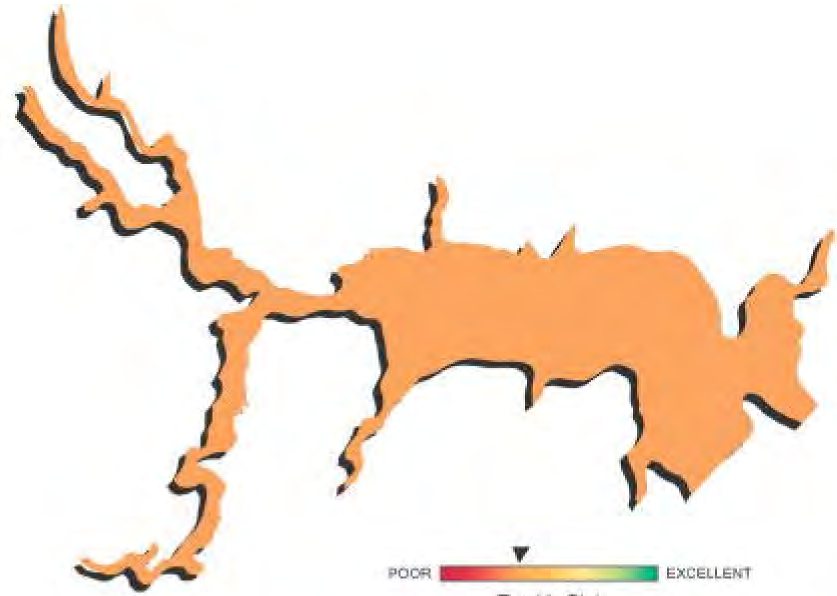
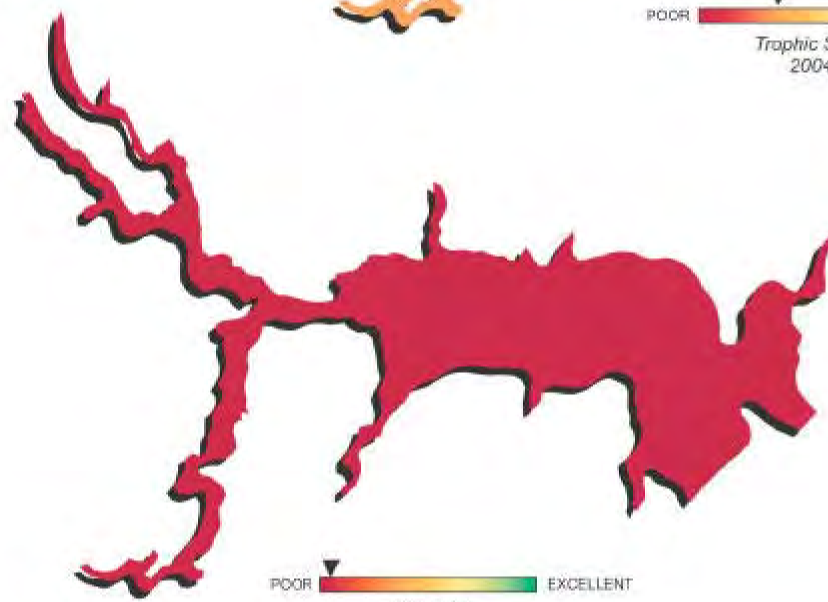




**Figure 214a-216f.** Graphical representation of data results for Lake Sahoma.


N
W E
S

Lake Data

| | |
|---|---|
| Owner | City of Sapulpa |
| County | Creek |
| Constructed in | 1947 |
| Surface Area | 312 acres |
| Volume | 4,850 acre/feet |
| Shoreline Length | 11 miles |
| Mean Depth | 15.54 feet |
| Watershed Area | 40 square miles |

Plate 96 - Lake Water Quality for
Sahoma Lake

# Sardis Lake

Sardis Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 13 NTU (Plate 97), true color was 32 units, and average secchi disk depth was 94 centimeters. Based on these three parameters, Sardis Lake had good water clarity, similar to that reported in 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using values at all sites for four quarters (n=20). The TSI was 45 (Plate 97), classifying the lake as mesotrophic, with moderate primary productivity and nutrient conditions. This is very similar to the value calculated in 2000 (TSI=47), indicating no significant change in productivity has occurred. The TSI values were primarily mesotrophic throughout the year and the TSI of 45 seems to accurately represent conditions at Sardis Lake. The only time collected values were not mesotrophic was in the summer when 4 out of the 5 sites were oligotrophic (see Figure 215). Seasonal turbidity values are displayed in Figure 216a. In general, turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, the only exception being site 2, which was recorded at 25 NTU in the winter. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples at or below the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2003. Seasonal true color values are displayed in Figure 216b. True color followed the same pattern as turbidity with all values below the OWQS of 70, except for site 2, which had a value of 80 units reported in the winter quarter. Applying the same default protocol, the Aesthetics beneficial use is fully supported.

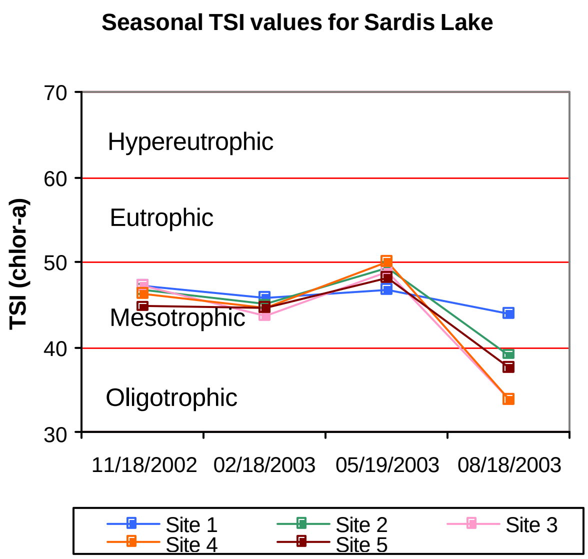



**Figure 215.** TSI values for Sardis Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values were 0.00 parts per thousand (ppt) at all sites throughout the study period. This is much lower than the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 17.7 to 37.9 mS/cm, indicating extremely low concentrations of electrical current conducting compounds (salts) were present in the lake, consistent with the salinity readings. In general pH values were neutral with values ranging from 6.23 to 7.69 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With only 6.4% of the recorded values less than 6.5 the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 440 mV to 581 mV, indicating the absence of reducing conditions during the sample year. The lake was not stratified during the first three sampling quarters and the lake was well mixed (Figure 216c-218e). The lake was thermally stratified and anoxic conditions were present during the summer. In the summer the lake was stratified between 9 and 10 meters at which point dissolved oxygen (D.O.) fell below 2.0 mg/L for 44% of the water column (Figure 216f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Sardis Lake is partially supporting its FWP beneficial use due to anoxic conditions in the summer. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.27 mg/L at the surface and 0.24 mg/L at the lake bottom. The TN at the surface ranged from 0.05 mg/L to 0.56 mg/L. The highest surface total nitrogen was reported in the summer and the lowest in the winter. The lake-wide total phosphorus (TP) average was 0.018 mg/L and 0.022 mg/L at the lake bottom. The surface TP ranged from 0.010 mg/L to 0.039 mg/L. The lowest surface TP was reported in the fall but the highest values were reported during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Sardis Lake was classified as mesotrophic with moderate primary productivity and nutrient conditions in 2003, consistent with results from the 2000 evaluation. Water clarity was good based on true color, turbidity, and secchi disk depth. The FWP beneficial use is supported by both turbidity and pH, but only partially supporting the use with anoxic conditions present for 44% of the water column during the summer. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values. In 1999, a bathymetric survey was conducted at Sardis Lake (Figure 217) as part of the Kiamichi River Development Project. The purpose of the survey was to generate a 3-D simulation of water level changes within the reservoir in response to concerns local citizens had regarding the potential transfer of water to other areas of the state and /or the north Texas area. Specific concerns included fluctuating lake levels and the subsequent impacts on fish/wildlife, recreation, tourism and economic development in the area. For further information about this study or bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800. Sardis Lake, located in Pushmataha County, was constructed by the United States Army Corps of Engineers (USACE) for flood control, water supply, and fish and wildlife purposes.

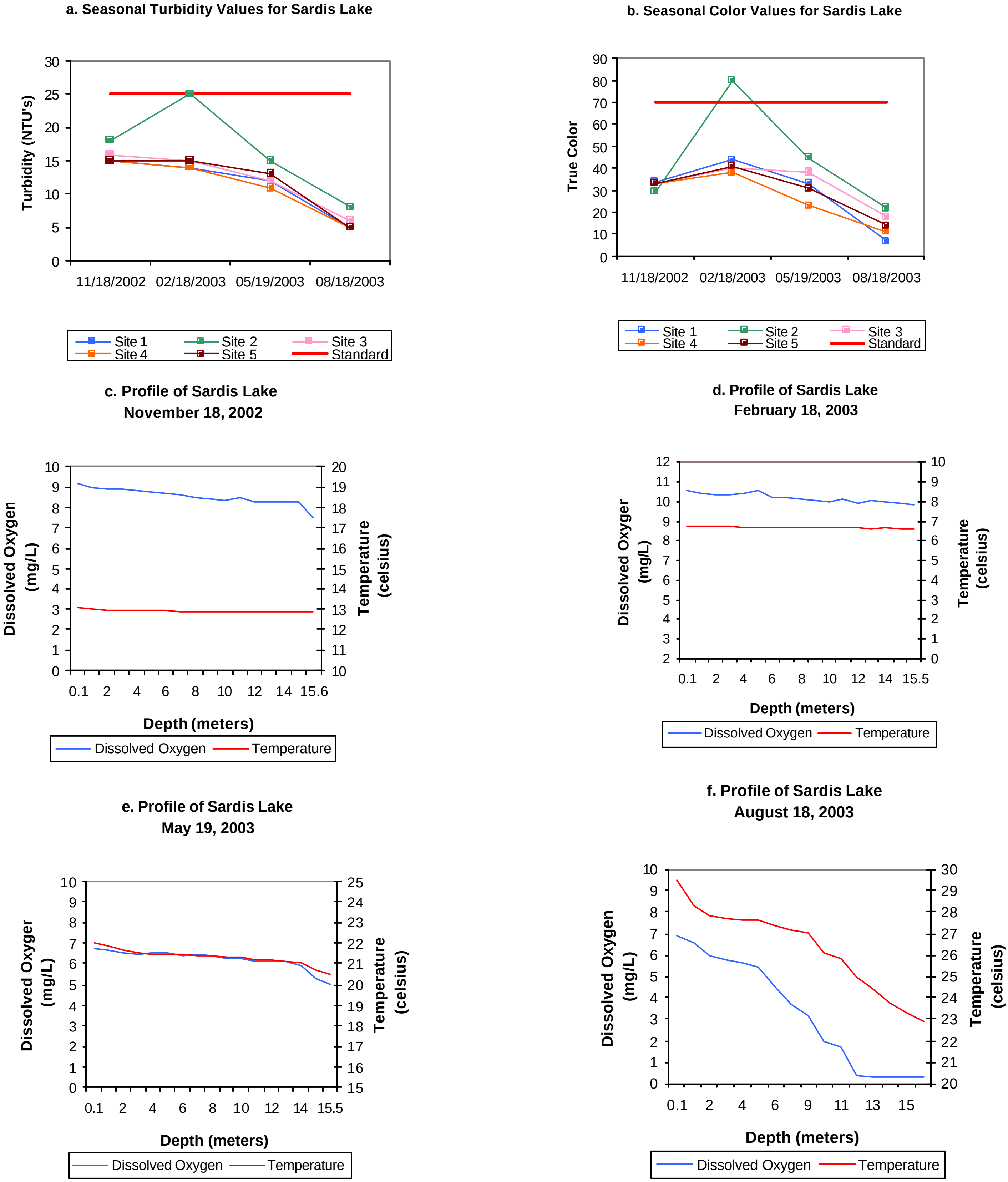
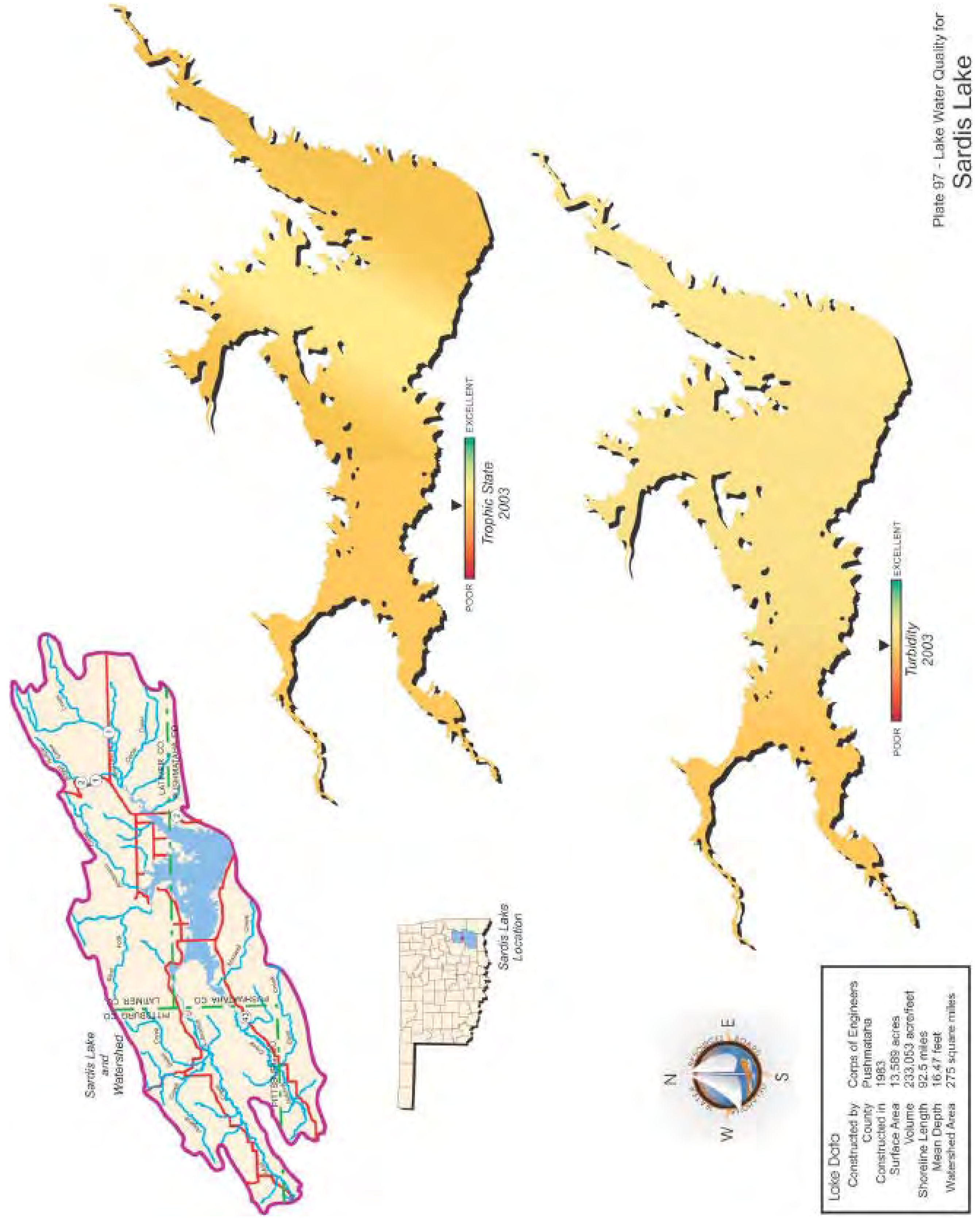



**Figure 216a-218f.** Graphical representation of data results for Sardis Lake.



Sardis Lake and Watershed
Sardis Lake Location
Trophic State 2003
POOR
EXCELLENT
Turbidity 2003
POOR
EXCELLENT
N
S
E
W
Lake Data
Constructed by Corps of Engineers
County Pushmataha
Constructed in 1983
Surface Area 13,589 acres
Volume 233,053 acre/feet
Shoreline Length 92.5 miles
Mean Depth 16.47 feet
Watershed Area 275 square miles
Plate 97 - Lake Water Quality for
Sardis Lake

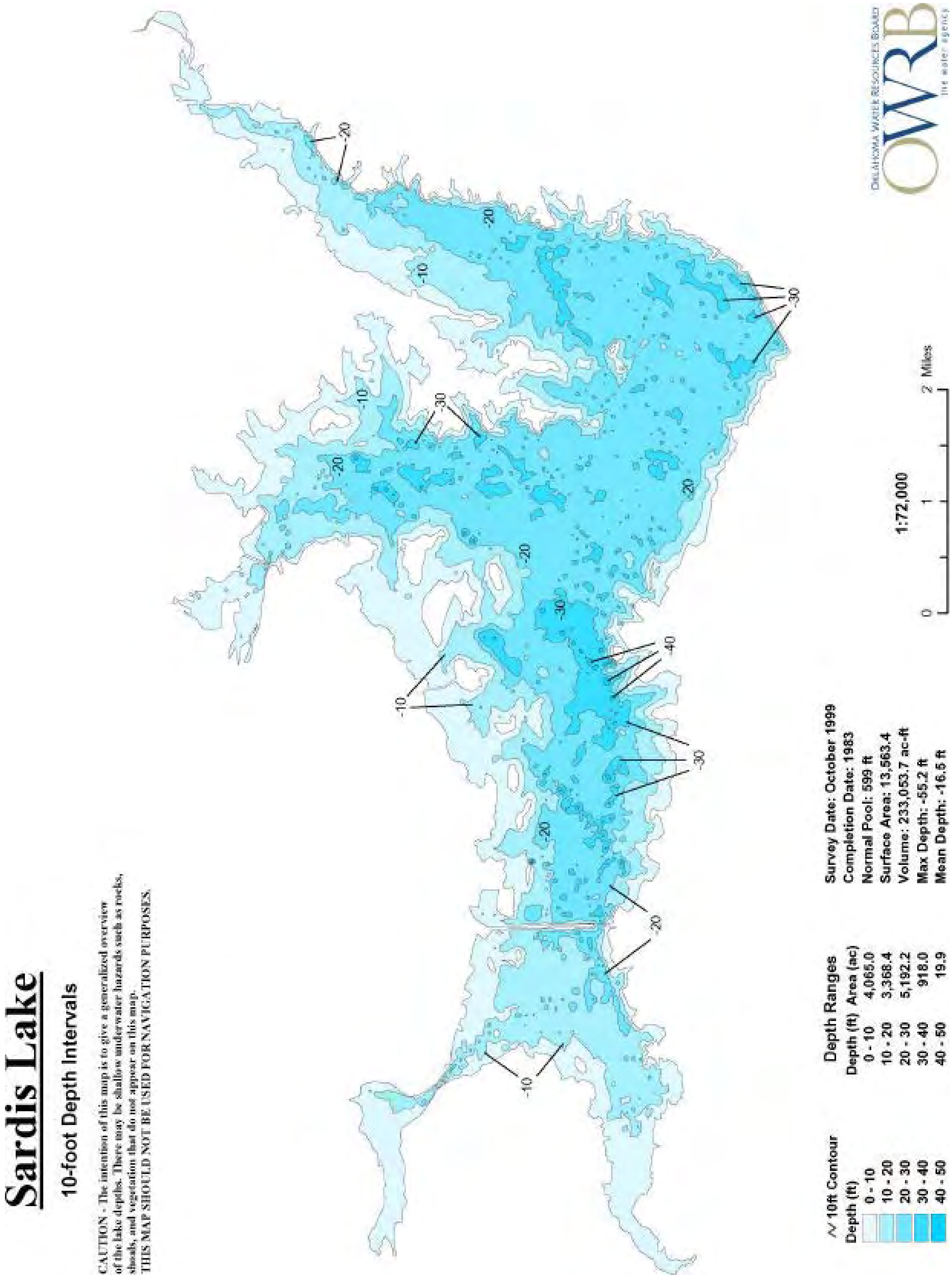



**Figure 217.** Bathymetric Map of Sardis Lake.

# Shawnee Twin Lake # 1

Shawnee Twin Lake # 1 was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major arms. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 23 NTU (Plate 98), true color was 34 units, and secchi disk depth was 66 centimeters in 2003-2004. Based on these three parameters, Shawnee Twin Lake # 1 had excellent water clarity. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 40 (Plate 98), indicating the lake was oligotrophic, bordering mesotrophic, with moderate levels of primary productivity and nutrient conditions. The TSI values varied from mesotrophic in the winter and spring quarters to oligotrophic in the winter quarter (see Figure 218). Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 219a) throughout the year with the exception of the spring quarter. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 25% of the values were above the criteria, available flow data suggests the peak in turbidity that occurred in May is likely due to seasonal storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 219b. True color values were below the aesthetics OWQS of 70 units at all sites throughout the sample period (see Figure 219b). With only 100% of the collected samples below the numerical criteria for true color, the lake is fully supporting its Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five (5) sample sites in 2003-2004. Salinity was 0.11 parts per thousand (ppt), which is well within the expected range of salinity concentrations, reported for most Oklahoma lakes. Specific conductance ranged from 227.3 mS/cm in the winter to 241.9 mS/cm in the fall quarter, indicating that low to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral with values ranging from 7.24

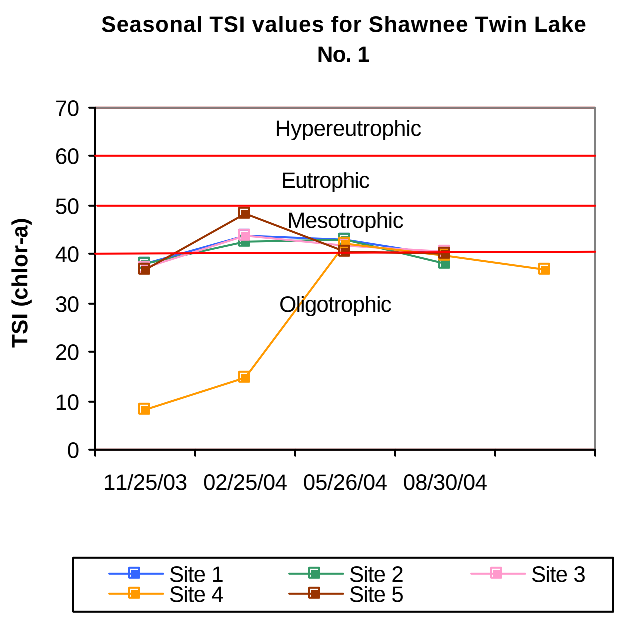



**Figure 218.** TSI values for Shawnee Twin Lake # 1.

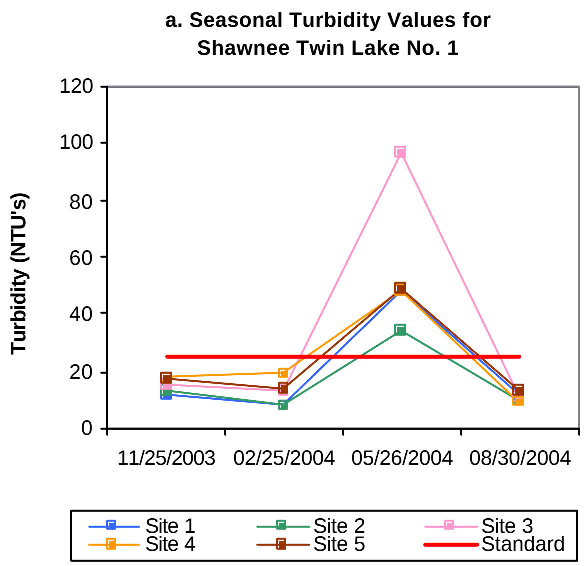
units in the fall to 8.3 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the allowable range, the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 370 mV to 521 mV indicating that reducing conditions were not present during any of the sampling events. The lake was not thermally stratified at any site during the sample period and dissolved oxygen (D.O.) concentrations were above 5.0mg/L throughout the water column (see Figure 219c-221f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Shawnee Twin Lake # 1 as all recorded values were above 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2003-2004 was 0.41 mg/L at the lake surface. The TN at the surface ranged from 0.22 mg/L to 0.74 mg/L. The highest surface TN value was reported in the spring and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average for sample year 2003-2004 was 0.022 mg/L at the lake surface. The surface TP ranged from 0.012 mg/L to 0.044 mg/L. The highest surface TP value was reported in the spring and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 18:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Shawnee Twin Lake # 1 was classified as oligotrophic bordering mesotrophic, indicating low to moderate primary productivity and nutrient conditions (Plate 98). The lake is currently fully supporting its Aesthetics beneficial use based on the trophic status (nutrients) and true color. At the time of sampling, the lake was fully supporting its FWP beneficial use for pH, and D.O. . Although 25% of the values were above the criteria of 25 NTU, available flow data suggests the peak in turbidity that occurred in May is likely due to seasonal storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported. In general, the water quality condition of the lake was excellent with no water quality concerns detected in the current sample year. Shawnee Twin Lake # 1 was constructed in 1935 and is owned and operated by the City of

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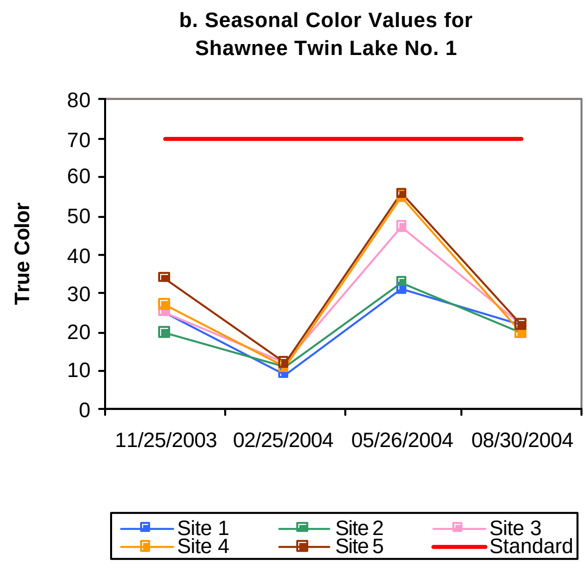
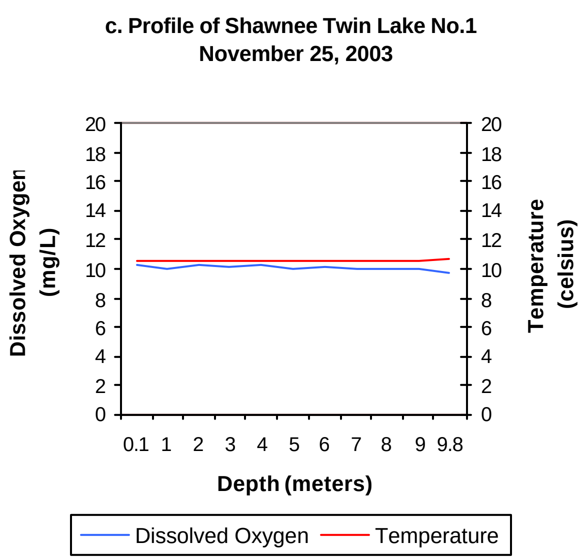
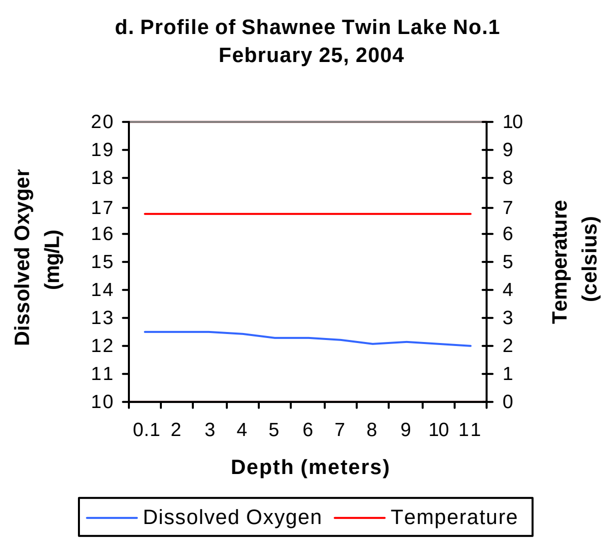
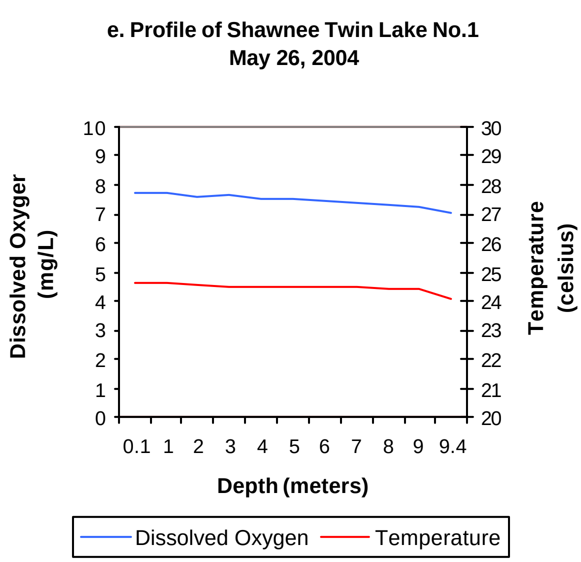


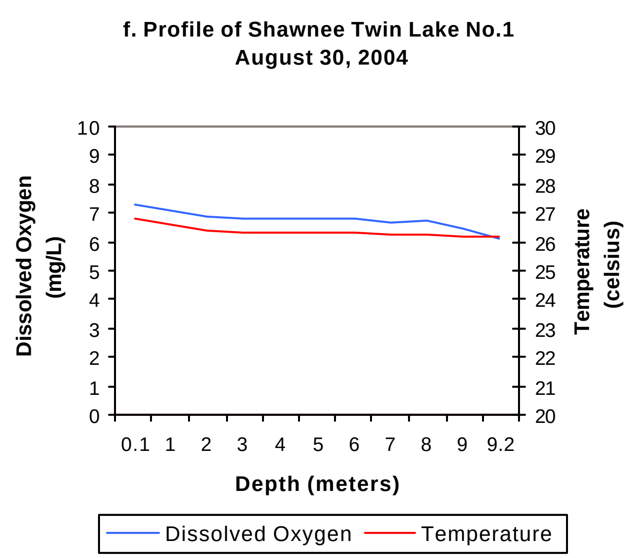




**Figure 219a-221f.** Graphical representation of data results for Shawnee Twin Lake # 1.

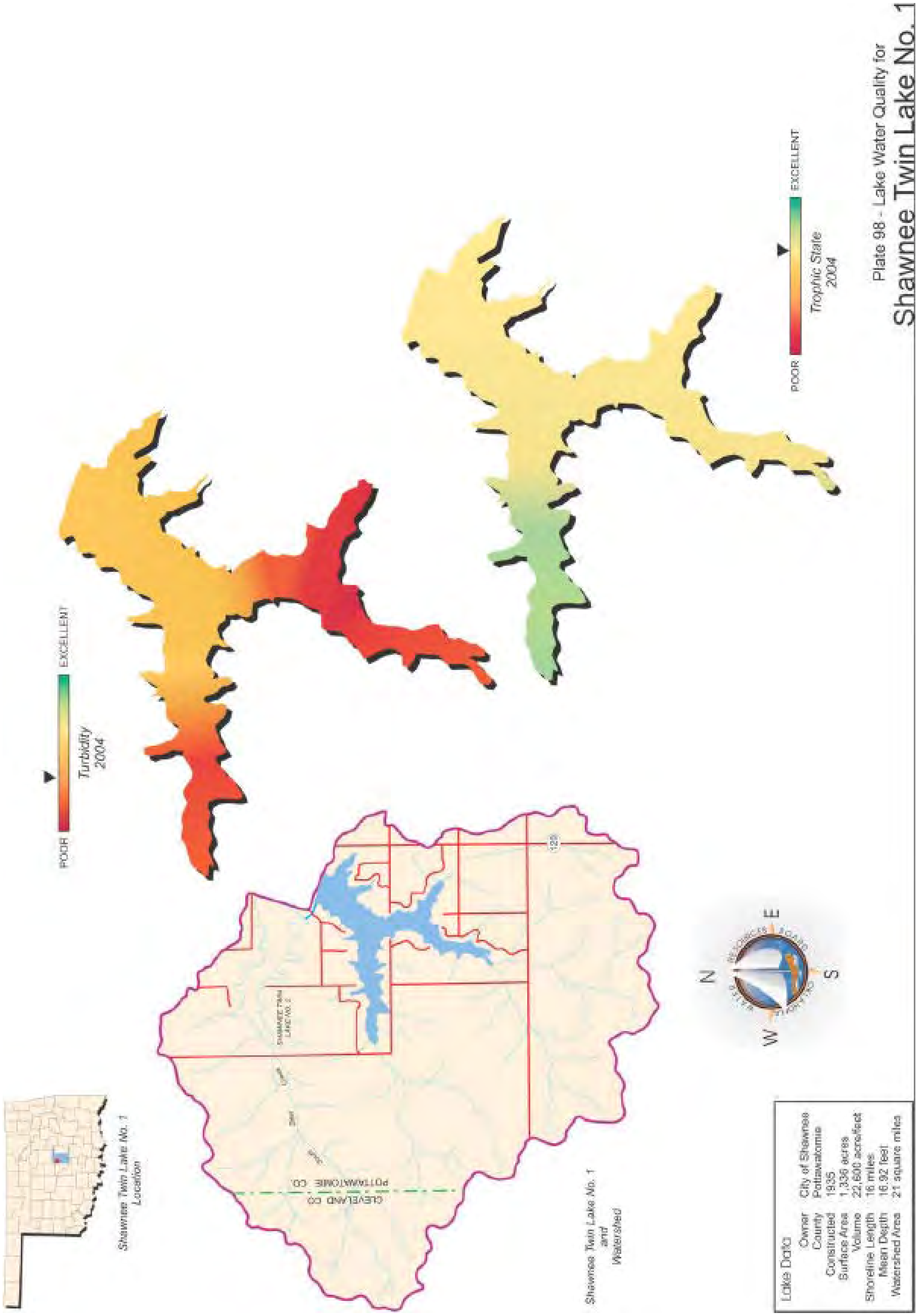


Plate 98 - Lake Water Quality for
Shawnee Twin Lake No. 1
Shawnee Twin Lake No. 1
Location
Shawnee Twin Lake No. 1
and
Watershed
POTTAWATOMIE CO.
CLEVELAND CO.
SHAWNEE TWIN LAKE NO. 2
Turbidity
2004
Trophic State
2004
POOR
EXCELLENT
N
E
S
W
Lake Data
Owner City of Shawnee
County Pottawatomie
Constructed 1935
Surface Area 1,336 acres
Volume 22,600 acre/feet
Shoreline Length 16 miles
Mean Depth 16.92 feet
Watershed Area 21 square miles

# Shawnee Twin Lake # 2

Shawnee Twin Lake # 2 was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as any major lake arms Water quality samples were collected from the lake surface at five sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 25 NTU (Plate 99), true color was 34 units, and secchi disk depth was 47 centimeters in 2003-2004. Based on these three parameters, Shawnee Twin Lake # 2 had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for all four quarters (n=20). The average TSI was 42 (Plate 99), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. This value is exactly the same as that calculated in 2002, indicating that no significant change in trophic status has occurred. Seasonal TSI values were mesotrophic throughout the year except for site 3 in the winter quarter, which dipped down into the oligotrophic category in the winter quarter (see Figure 192). Turbidity values are displayed in (see Figure 221a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 25% of the values were above the criteria, available flow data suggests the peak in turbidity that occurred in May is likely due to seasonal storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 221b. Of the twenty true color values collected, three (15%) were above the OWQS of 70 units, corresponding with the elevated turbidity readings. The Aesthetics beneficial use is considered supported as the high true color readings are likely due to seasonal rain events.

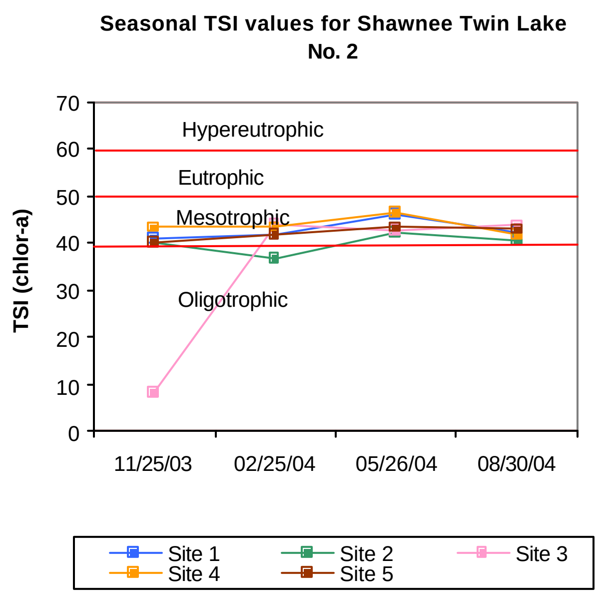



**Figure 220.** TSI values for Shawnee Twin Lake # 2.

Vertical profiles for dissolved oxygen; pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five (5) sample sites. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.11 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 216.7 mS/cm reported in the winter quarter to 242.1 mS/cm in the spring, indicating that low to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral, ranging from 7.23 to 8.62 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The lake was fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 394 mV in the winter to 546 mV recorded in the summer quarter near the sediment-water interface at site 5. Redox readings indicated that reducing conditions were not present in the reservoir during any of the sampling events. The lake was not thermally stratified in the winter, and dissolved oxygen (D.O.) readings were above 7.0 mg/L throughout the water column (see Figure 221c). In the spring and summer, the lake was thermally stratified between the 6 and 7-meter depth at site 1, the dam. Below 6 meters, D.O. values were less than 2.0 mg/L and remained so all the way to the lake bottom at 8.3 meters (see Figure 221d-223e). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Shawnee Twin Lake # 2 with only 20-22% of the water column with D.O. values less than 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2003-2004 was 0.49 mg/L at the lake surface. The TN at the surface ranged from 0.29 mg/L in the summer quarter to 1.15 mg/L in the fall. The lake-wide total phosphorus (TP) average for sample year 2003-2004 was 0.026 mg/L at the lake surface. The surface TP ranged from 0.014 mg/L in the summer to 0.065 mg/L in the spring quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 19:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Shawnee Twin Lake # 2 was classified as mesotrophic, indicative of moderate primary productivity and nutrients. This is consistent with data collection efforts in 2002 (TSI=42) The lake was fully supporting its Aesthetics beneficial use based on trophic status for nutrients (Plate 99) and supporting based on true color. The lake is supporting the FWP beneficial use based on pH, and D.O. concentrations. Although 25% of the values were above the criteria, available flow data suggests the peak in turbidity that occurred in May is likely due to seasonal storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported. Much like its sister lake

(Shawnee Twin Lake # 1) the water quality of this reservoir was good during the sample period with no water quality concerns detected. Shawnee Twin Lake # 2 was constructed in 1960 and is owned and operated by the City of Shawnee. The lake is utilized as a municipal water supply and affords numerous recreational opportunities to the public.

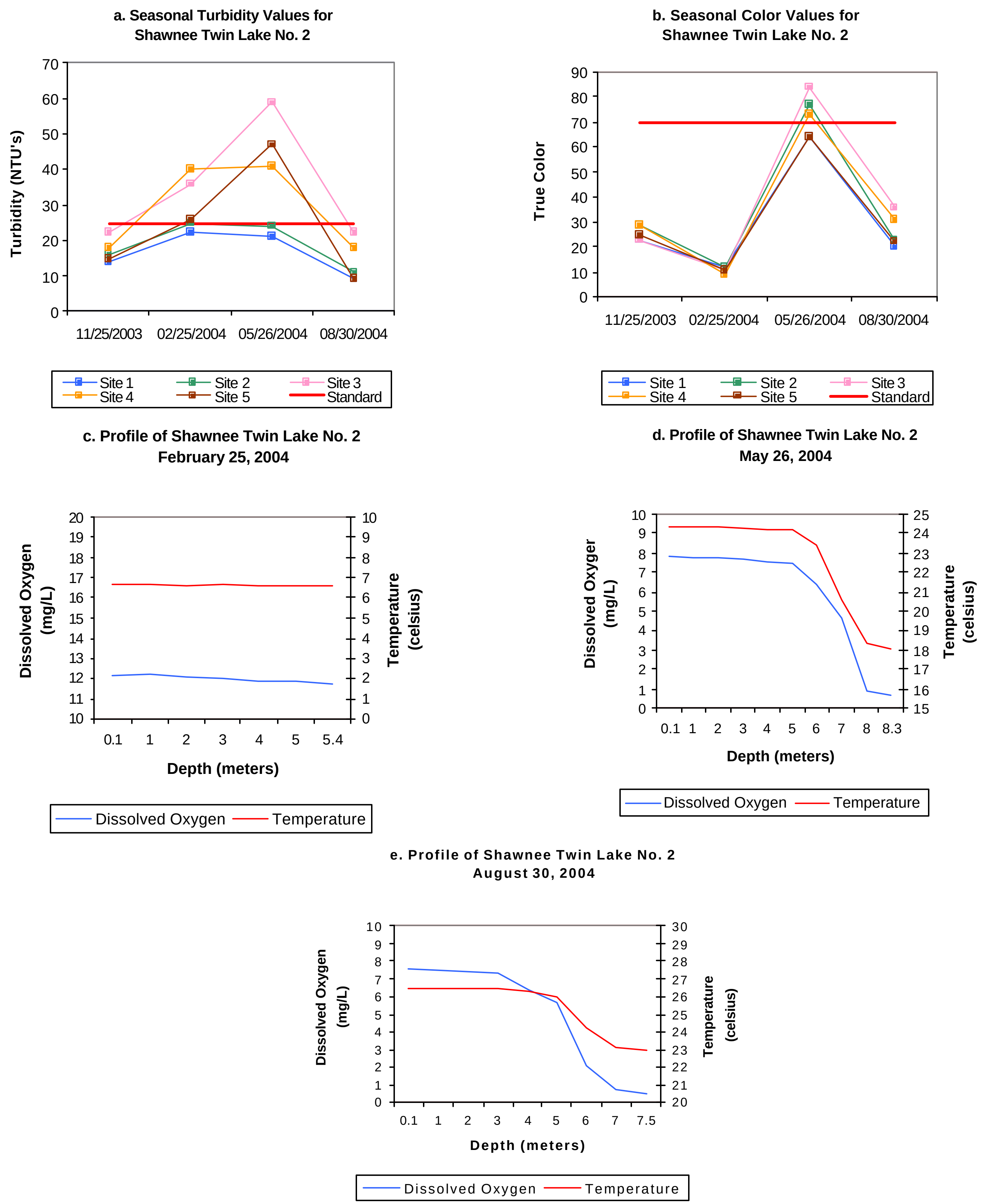
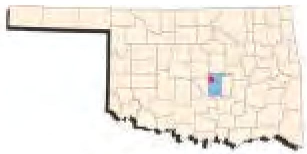
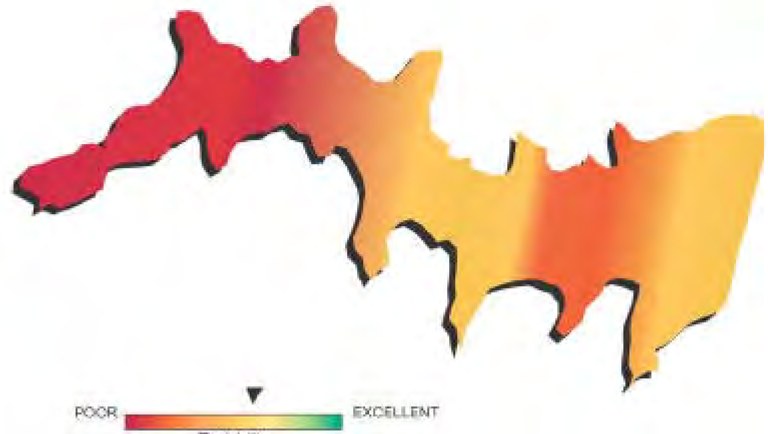



**Figure 221a-223e.** Graphical representation of data results for Shawnee Twin Lake # 2.

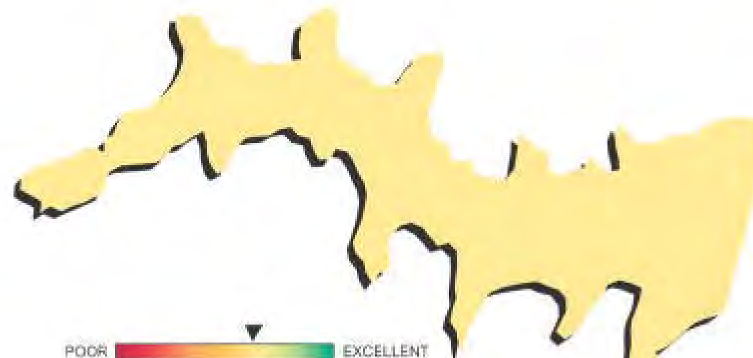


Shawnee Twin Lake No. 2
Location


Shawnee Twin Lake No. 2
and
Watershed




Turbidity
2004




Trophic State
2004

Lake Data

| | |
|---|---|
| Owner | City of Shawnee |
| County | Pottawatomie |
| Constructed | 1960 |
| Surface Area | 1,100 acres |
| Volume | 11,400 acre/feet |
| Shoreline Length | 9 miles |
| Mean Depth | 10.36 feet |
| Watershed Area | 11 square miles |

Plate 99 - Lake Water Quality for
Shawnee Twin Lake No. 2

# Shell Lake

Shell Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones as well as any major arms of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 11 NTU (Plate 100), true color was 28 units, and secchi disk depth was 77 centimeters in 2003-2004. Based on these three parameters water clarity at Shell Lake was excellent at the time of sampling. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 52 (Plate 100), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. This value is similar to that calculated in 2002 (TSI=51), indicating no significant change in productivity has occurred. The TSI values varied seasonally from mesotrophic in the spring and summer quarters, to lower eutrophy in the winter, to upper eutrophy in the fall quarter (see Figure 222). All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 223a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With a lake-wide annual turbidity average of 11 NTU Shell Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 223b. All of the true color values were below the numeric criteria of 70 units in 2003-2004, Applying the same default protocol; Shell Lake is supporting the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.05 parts per thousand (ppt) to 0.08 ppt, indicating low salt content and were well within the expected range of salinity values reported for most Oklahoma lakes and reservoirs. Specific conductance ranged from 122.9 mS/cm to 185.1 mS/cm, indicating very low levels of electrical conducting compounds (salts) were present in the lake system, corresponding with the recorded salinity values. In general, pH values were neutral to slightly alkaline, ranging from 6.78 units to 7.95 units. According to USAP (OAC 785:46-15-5), pH values are exceeding

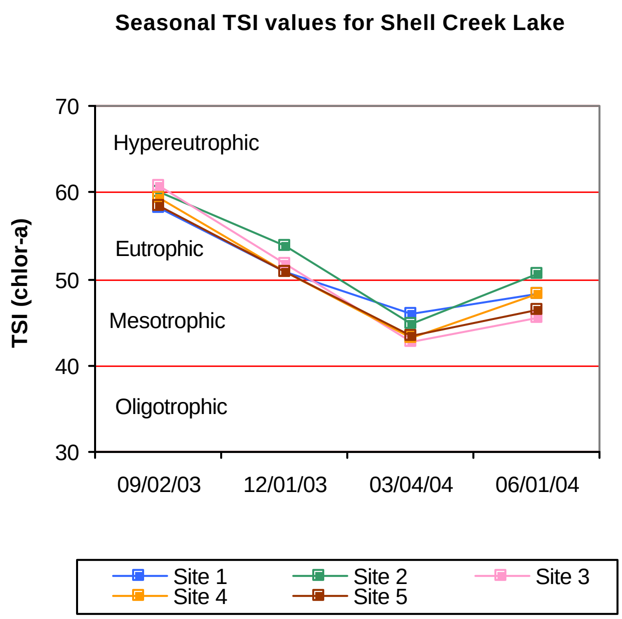



**Figure 222.** TSI values for Shell Lake.

standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All of the collected pH values fell within the acceptable range, therefore Shell Lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 341 mV at the sediment-water interface in the winter to 525 mV in the summer quarter. Redox readings indicated that reducing conditions were not present in the reservoir during the study period. The lake was not thermally stratified in the winter or spring quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L throughout the water column (see Figure 223c-225e). In the fall the lake was stratified at the two deepest sites (1 and 5) between 5 and 6 meters in depth at which point dissolved oxygen concentrations fell below 2.0 mg/L to the lake bottom. In the summer, the lake was again strongly thermally stratified between 3 and 4 meters below the surface and again at the 5-6 meter depth throughout the lake, at which point D.O. values were less than 1.0 mg/L from the 6-meter depth to the lake bottom (see Figure 223f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supporting at Shell Lake as approximately 45-63% of the water column was anoxic at site in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2003-2004 was 0.76 mg/L at the lake surface. The TN at the surface ranged from 0.56 mg/L to 1.06 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the summer. The lake-wide total phosphorus (TP) average for sample year 2003-2004 was 0.023 mg/L at the lake surface. The surface TP ranged from 0.018 mg/L to 0.027 mg/L. The highest surface TP value was reported in the spring and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 33:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Shell Lake was eutrophic in 2003-2004, indicative of high primary productivity and nutrient rich conditions (Plate). The calculated TSI was similar to that of 2002 (TSI=51) indicating that no significant change in productivity has occurred. Water clarity is very good at this lake based on true color, turbidity and secchi disk depth. Shell Lake was fully supporting its Aesthetics beneficial use based on its nutrient status and true color. True color data collected strongly supports the supposition that the lake would be supporting the Aesthetics use for true color. The FWP beneficial use was fully supported for turbidity and pH, but was partially supported for D.O. because 45-63% of the water column was anoxic. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported. Shell Lake was constructed in 1922 and is owned and operated by the City of Sand Springs. The lake is maintained as a municipal water supply offers numerous recreational opportunities to the public.

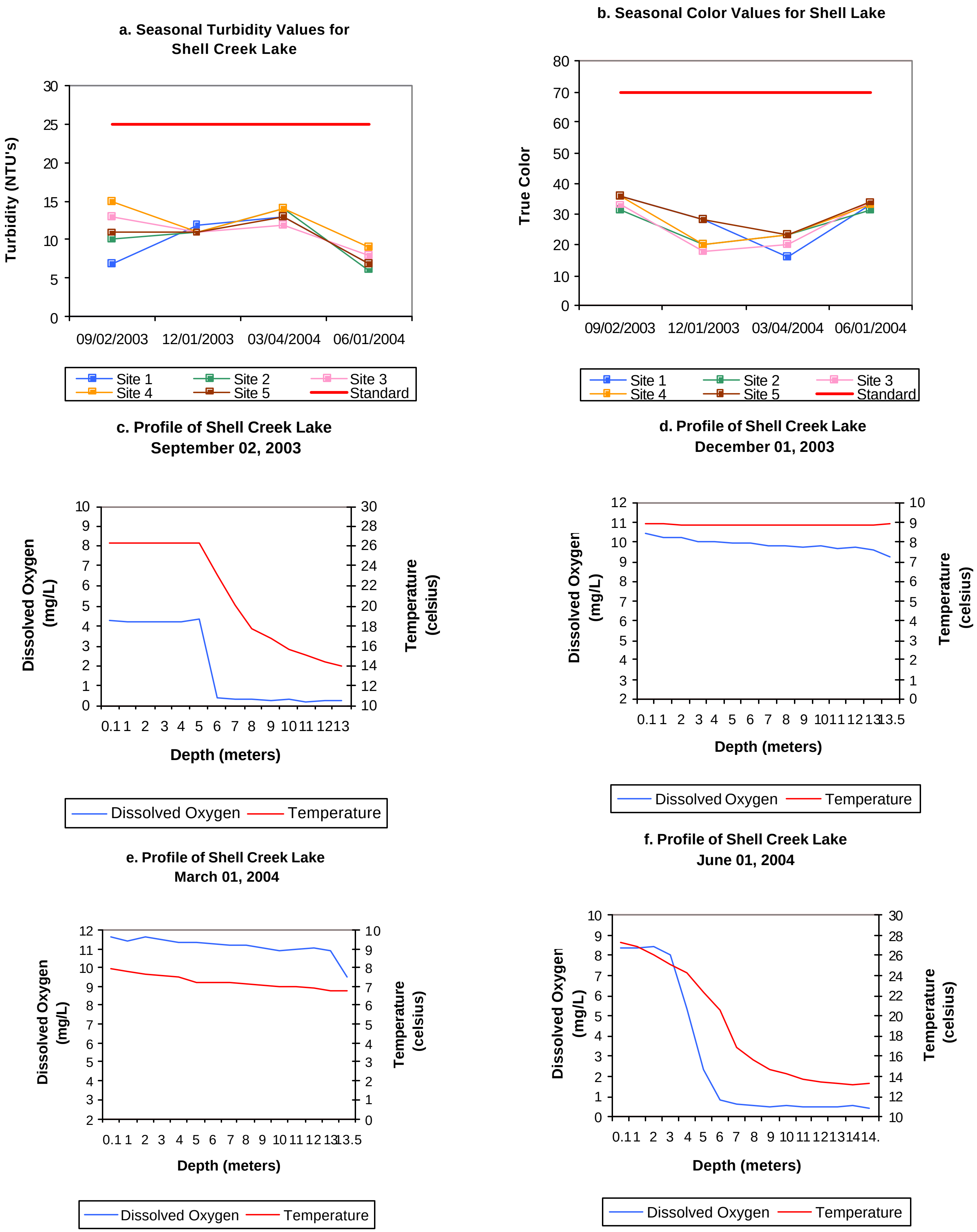
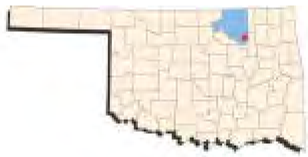
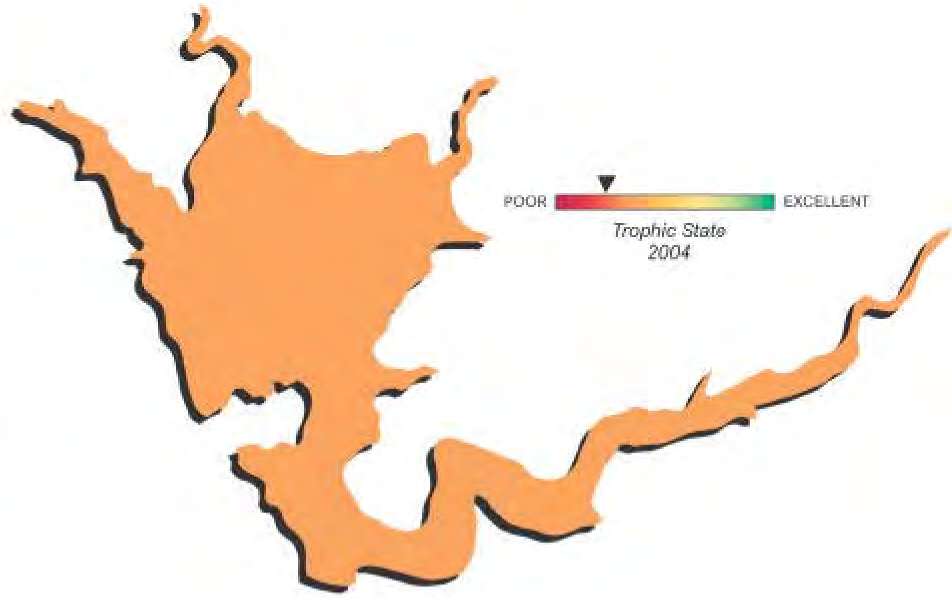
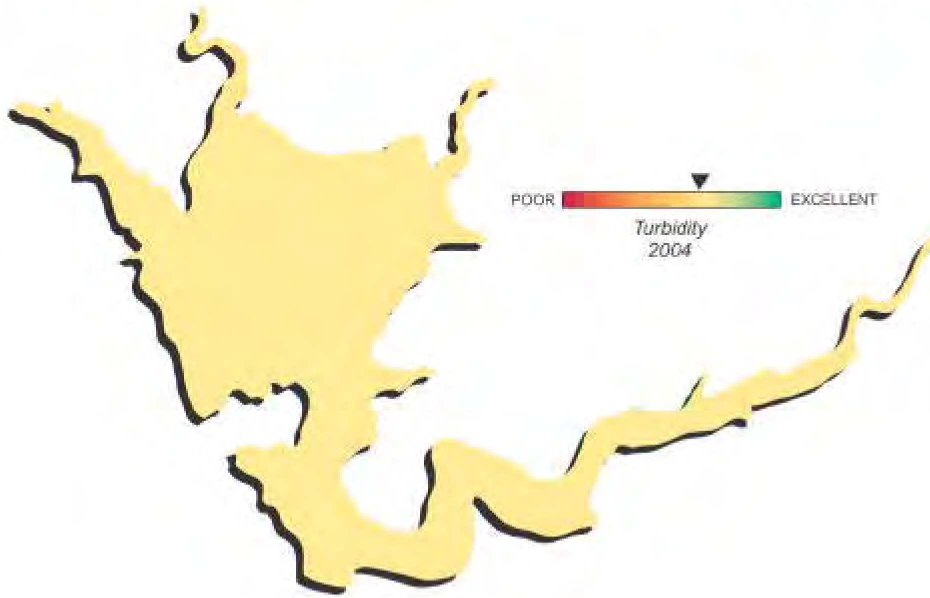



**Figure 223a-225f.** Graphical representation of data results for Shell Lake.






Lake Data

| | |
|---|---|
| Owner | City of Sand Springs |
| County | Osage |
| Constructed in | 1922 |
| Surface Area | 573 acres |
| Volume | 9,500 acre/feet |
| Shoreline Length | 13 miles |
| Mean Depth | 16.58 feet |
| Watershed Area | 15 square miles |

Plate 100 - Lake Water Quality for
## Shell Lake

# Skiatook Lake

Skiatook Lake was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at seven (7) sites to represent the riverine, transitional, and lacustrine zones and major arms of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The average lake-wide annual turbidity value was 13 NTU (Plate 101), true color was 34 units, and average secchi disk depth was 137 centimeters. Based on these three parameters Skiatook Lake had excellent water clarity in 2002-2003, even better than reported in sample year 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=28). The average TSI was 45 (Plate 101), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions. This value is slightly lower than the TSI calculated in 2000 (TSI=50), although in the same trophic category, and is likely a more accurate depiction of productivity as it is based on data collected year round versus the growing season. The TSI values varied by site and season throughout the sample year (Figure 224) with values spanning three trophic categories. In the fall and winter values were primarily mesotrophic with sites 4 and 5 falling in the eutrophic category. In the spring and summer quarters TSI values were split with half of the values being oligotrophic and the other half mesotrophic. The only exception was site 4, which was eutrophic in the summer (Figure 224). Seasonal turbidity values are displayed in Figure 225a. Turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU throughout the year, except sites 4 (Hominy Creek arm) and 5 (Bull Creek arm) in the spring. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 7% of the samples exceeding the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2003. Seasonal true color values are displayed in Figure 225b. True color followed the same pattern as turbidity with all values below the OWQS of 70, except for sites 4 and 5, which had a values of 250 and 133 units, respectively reported in the spring quarter. Applying the same default protocol, the Aesthetics beneficial use is fully supported.

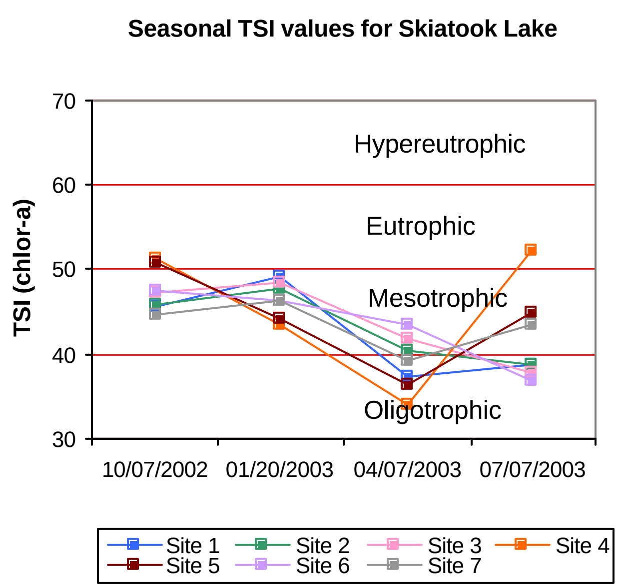



**Figure 224.** TSI values for Skiatook Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.23 ppt during the study period. This is within the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 197.6 to 282.4 mS/cm, indicating the presence of minimal concentrations of electrical current conducting compounds (salts) were present in the lake, consistent with the salinity readings. In general, pH values were neutral to slightly alkaline with values ranging from 6.59 to 8.18 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 100% of the recorded values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 71 mV in the fall to 526 mV in the spring, generally indicating the absence of reducing conditions. The lake was not stratified in the winter or spring sampling quarters and the water column was well mixed with dissolved oxygen (D.O.) concentrations generally above 7.0 mg/L (Figure 225d-227e). Thermal stratification was evident and anoxic conditions were present in both the fall and summer quarters. In the fall, the lake was stratified between 10 and 11 meters at sites 1,2, 3 and 4 at which point D.O. fell below 2.0 mg/L for the rest of the water column (Figure 225c-192f). During the summer, stratification occurred at several 1-meter intervals throughout the entire waterbody with anoxic conditions constituting 25 to 65% of the water column. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Skiatook Lake is partially supporting its FWP beneficial use due to anoxic conditions in both fall and summer sampling quarters. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.48 mg/L at the surface and 0.53 mg/L at the lake bottom. The TN at the surface ranged from 0.13 mg/L to 1.42 mg/L. The highest surface total nitrogen was reported in the spring and the lowest in the fall. The lake-wide total phosphorus (TP) average was 0.016 mg/L and 0.013 mg/L at the lake bottom. The surface TP ranged from 0.005 mg/L to 0.111 mg/L. Similar to TN, the highest surface TP was reported in the spring and the lowest values were reported during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 31:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Skiatook Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. These results are similar to those reported in 2000, indicating no significant increase or decrease in productivity has occurred. Water clarity was excellent in 2003, even better than reported in 2000 with secchi disk depth readings showing the biggest increase. The lake is supporting the FWP beneficial use based on turbidity and pH, but only partially supporting due to anoxic condition in both fall and summer quarters. With anoxic conditions present for such a large portion of the water column the lake should be monitored closely in the future. The Aesthetics beneficial use is fully supported by both its trophic status and true color values. Skiatook Lake was constructed by the United States Army Corps of Engineers (USACE) for flood control, water supply and quality control, recreation, fish and wildlife purposes. The lake is located in Osage County approximately five miles west of Skiatook.

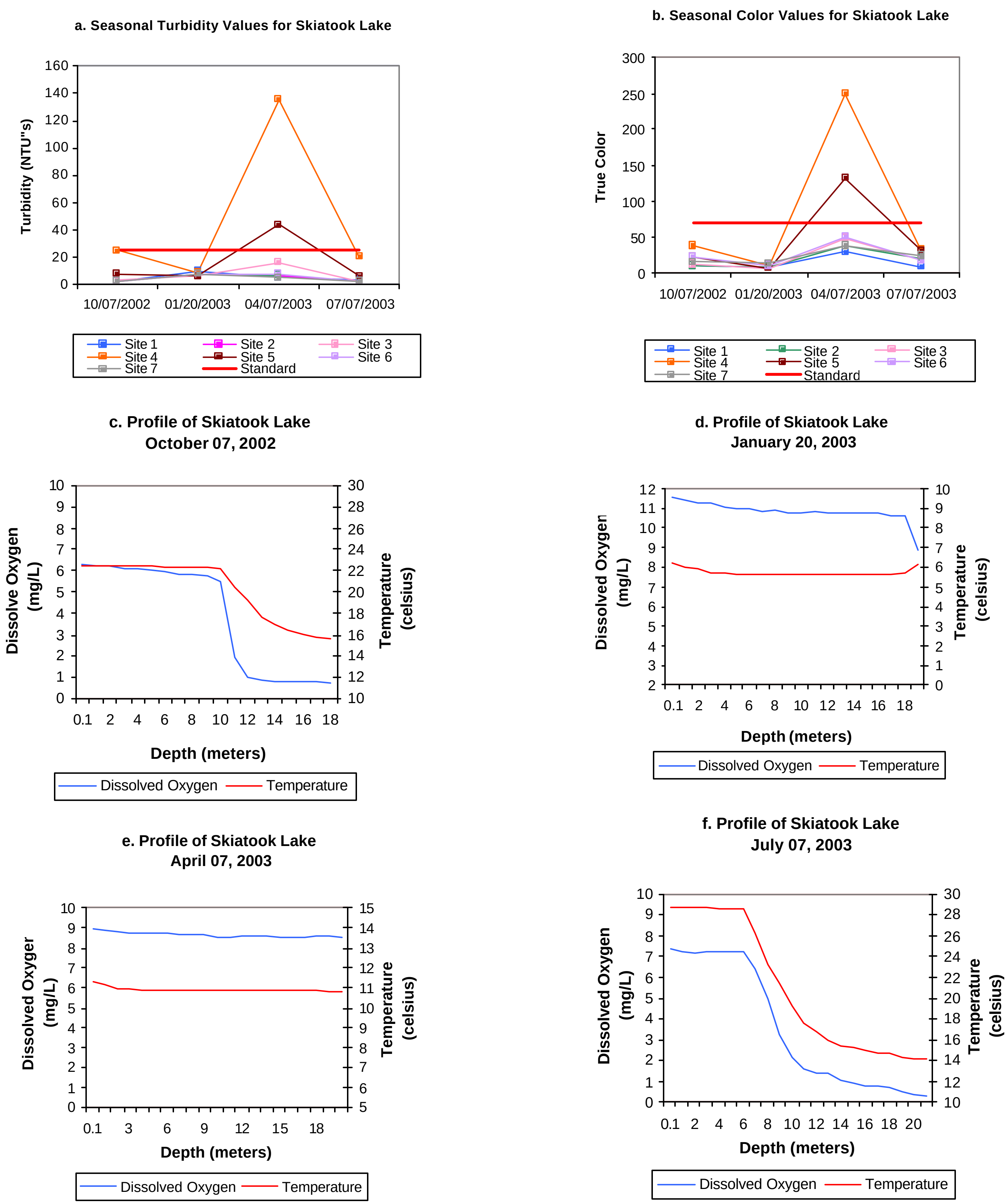



**Figure 225a-227f.** Graphical representation of data results for Skiatook Lake.

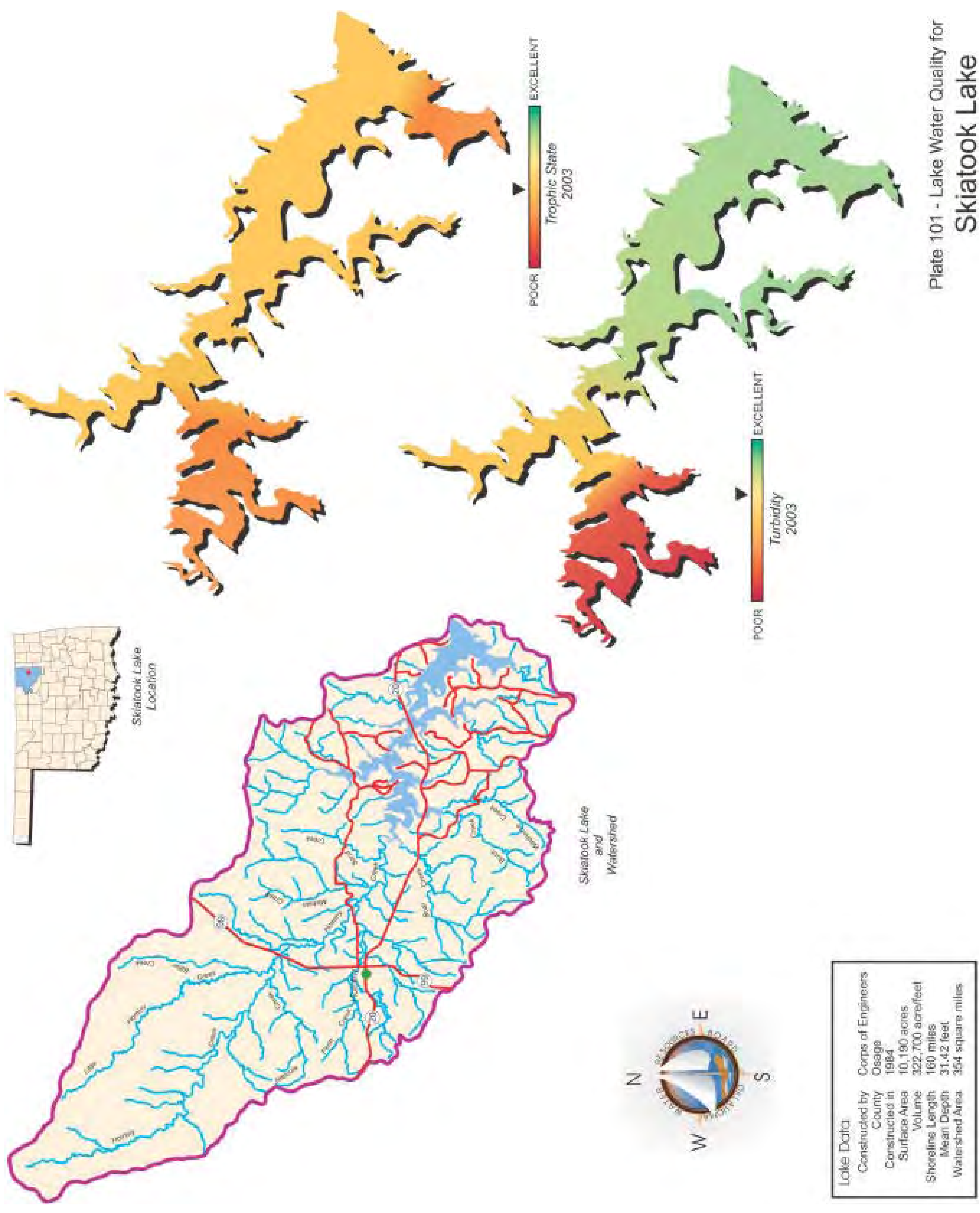



Plate 101 - Lake Water Quality for
Skiatook Lake

# Sooner Reservoir

Sooner Reservoir was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative of a lake larger than 250 surface acres. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The average lake-wide turbidity value was 9 NTU (Plate 102), true color was 12 units, and average secchi disk depth was 126 centimeters. Based on these three parameters, Skiatook Lake had excellent water clarity in 2002-2003. These results are similar to those in 2000, indicating no change has occurred in clarity over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 48 (Plate 102), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions. This value is the same as the TSI calculated in 2000 (TSI=48), indicating no change in productivity has occurred since the last evaluation. The TSI values varied seasonally ranging from eutrophic in the fall to mesotrophic in the winter and summer and oligotrophic in the spring (see Figure 226). Seasonal turbidity per site is displayed in Figure 227a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. A spike in turbidity occurred at site 3 in the spring, but it was still below the standard with a reported value of 24 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples below the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2003. Seasonal true color values are displayed in Figure 227b. All of the true color values were below the numeric criteria of 70 units, however a beneficial use assessment for Aesthetics could not be made due the minimum data requirements of 20 samples for lakes greater than 250 surface acres not being met. Available data strongly suggests that the Aesthetics use would be fully supporting if sufficient data were available.

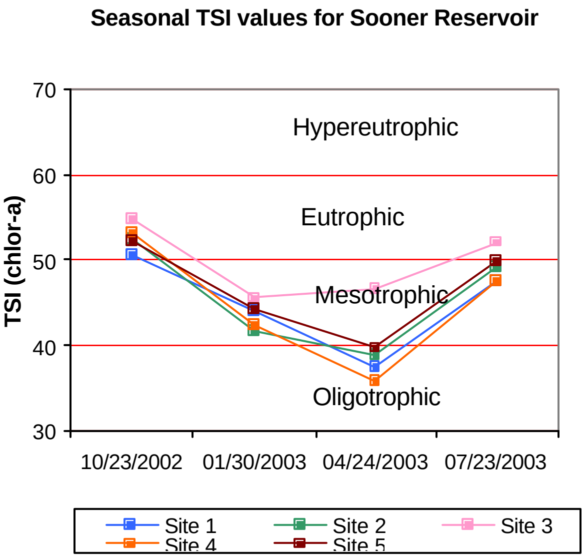



**Figure 226.** TSI values for Sooner Reservoir.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.98 parts per thousand (ppt) to 0.106 ppt during the study period. This is much higher than the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 1836 to 1969 mS/cm, indicating high concentrations of electrical current conducting compounds (salts) were present in the lake, consistent with the elevated salinity readings. In general pH values were neutral to slightly alkaline with values ranging from 7.31 to 8.38 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 100% of the recorded values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 257 mV to 674 mV, indicating the absence of reducing conditions. During the fall, winter, and spring quarters the lake was well mixed with dissolved oxygen generally above 7.0 mg/L (Figure 227c-229e). Thermal stratification was evident and anoxic conditions were present below the thermocline in the summer (Figure 227f). The lake was stratified between 10 and 11 meters with dissolved oxygen (D.O.) concentrations below 2.0 mg/L for approximately 54% of the water column. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Sooner Reservoir is considered partially supporting its FWP beneficial use with 54% of the water column experiencing anoxic conditions in the summer sampling quarter. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.41 mg/L at the surface and 0.49 mg/L at the lake bottom. The TN at the surface ranged from 0.29 mg/L to 0.59 mg/L. The highest surface total nitrogen was reported in the spring and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.020 mg/L at the surface and 0.021 mg/L at the lake bottom. The surface TP ranged from 0.014 mg/L to 0.026 mg/L. Similar to TN, the highest surface TP was reported in the spring and the lowest values were reported during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 21:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Sooner Reservoir was classified as mesotrophic with moderate primary productivity and nutrient condition. This is same as the 2000 evaluation (TSI=48), therefore no change in productivity has occurred over time. Water clarity was excellent in 2002-2003, based on true color, turbidity and secchi disk depth. The FWP beneficial use is supported based on turbidity and pH, but only partially supported due to the presence of anoxic condition in the summer. The lake is supporting the Aesthetics beneficial use based on its trophic status. Although 100% of the collected true color values were below the standard of 70 units, a use determination cannot be made due to minimum data requirements not being met. Sooner Reservoir, located in Pawnee County, is owned and operated by the Oklahoma Gas and Electric Company (OG&E) as a cooling reservoir.

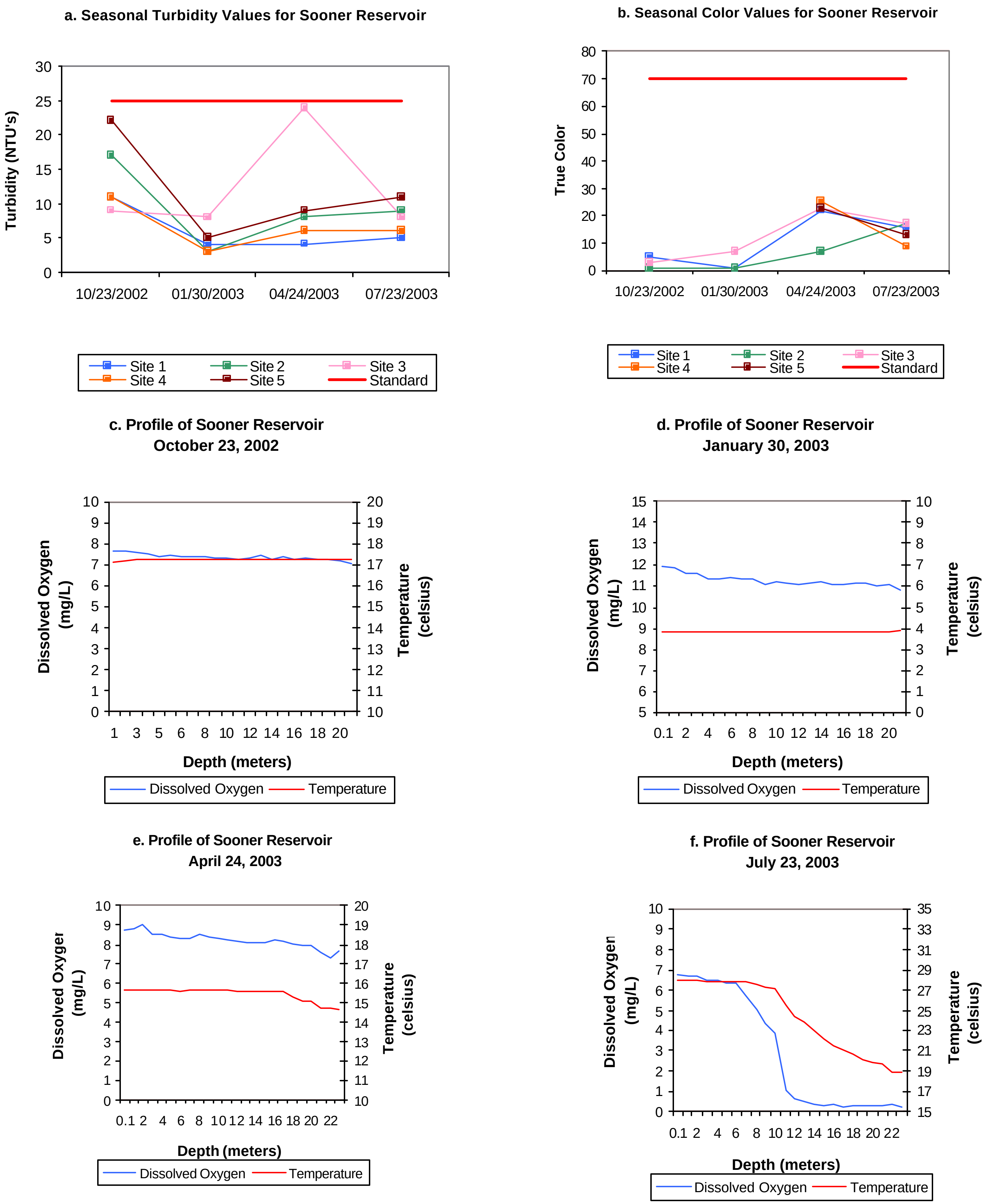
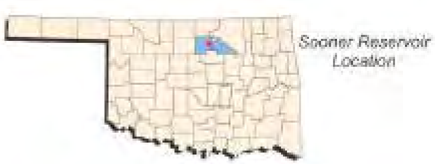
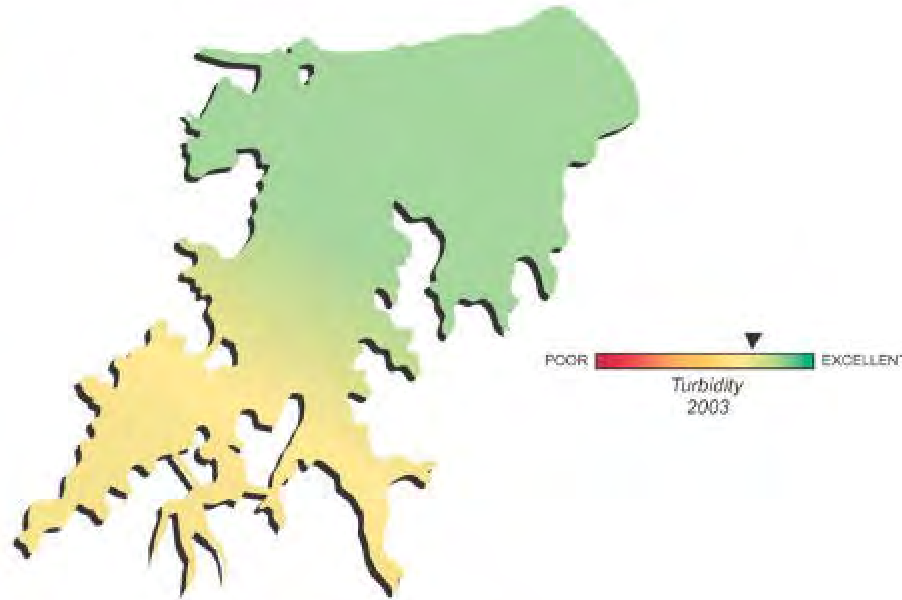
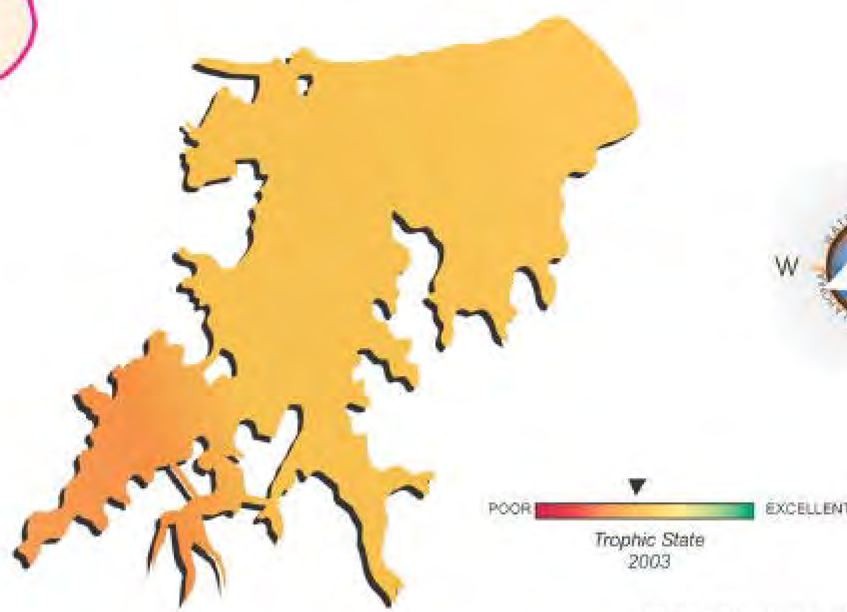



**Figure 227a-229f.** Graphical representation of data results for Sooner Reservoir.



Lake Data

| | |
|---|---|
| Owner | OG & E* |
| County | Pawnee (dam) |
| Constructed | 1972 |
| Surface Area | 5,400 acres |
| Volume | 149,000 acre/feet |
| Shoreline Length | 42 miles |
| Mean Depth | 27.59 feet |
| Watershed Area | 18,536 acres |

*Oklahoma Gas and Electric Co.

Plate 102 - Lake Water Quality for
Sooner Reservoir

# Spavinaw Lake

Spavinaw Lake was sampled for four quarters, from October 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer, to represent the riverine, transition, and lacustrine zones of the lake. Additional sites were added to ensure the sample size was representative for lakes greater than 250 surface acres in size. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam site. The average lake-wide turbidity was 7 NTU (Plate 103), true color was 9 units, and secchi disk depth was 124 centimeters. Based on these three parameters water clarity at Eucha Lake was excellent in sample year 2002-2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 52 (Plate 103), indicating the lake was eutrophic, indicative of moderate primary productivity and nutrient levels in sample year 2002-2003. The TSI values were primarily eutrophic with the exception of site 1, which was mesotrophic in both fall and winter quarters (Figure 228). These results differ from historical data collection efforts on the lake, which found the lake to be at the upper end of eutrophy in 1999 (TSI=58). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient impaired. A nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 229a. Turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and ranged from a low of 3 NTU to a maximum of 20 NTU. With 100% of the recorded values below 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is considered fully supported. Seasonal true color values were all well below the OWQS of 70 units and are displayed in Figure 229b. Due to the minimum data requirements not being met assessment of the Aesthetics beneficial use based on true color could not be made, however the available data suggests that it would be supporting.

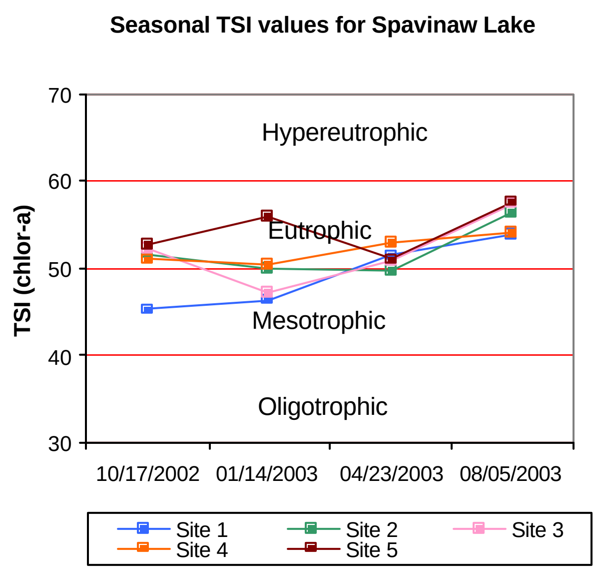



**Figure 228.** TSI values for Spavinaw Lake.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.30 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 165.1 mS/cm to 304.4 mS/cm, indicative of low to moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.96 to 8 .30, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With all the collected values within the acceptable range Spavinaw Lake is fully supporting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 87 mV in the hypolimnion in the summer to 590 mV in the fall quarter. In general, reducing conditions were not present at this reservoir, with all values above 100 mV, with the exception of the one value recorded at the lake bottom at site 1 in the summer. The lake was not stratified in the fall and winter and the water column was well mixed with dissolved oxygen (D.O.) values generally above 5.0 mg/L (see Figure 229c-231d). In the spring, the stratification was only observed at site 1, with D.O. only falling below 2.0 mg/L near the sediment-water interface (Figure 229e). Thermal stratification was evident and anoxic conditions were present throughout the lake in the summer (Figure 229f). During the summer sampling interval, stratification occurred between 6 and 7 meters at which point dissolved oxygen dropped below 2.0 mg/L to the lake bottom. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions accounting for 30 to 59% of the water column, in the summer, Spavinaw Lake is considered to be partially supporting the FWP beneficial use. These conditions could pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.37 mg/L at the surface and 1.01 mg/L at the lake bottom. Surface TN ranged from 0.18 mg/L to 0.71 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.022mg/L at the surface and 0.197 mg/L at the lake bottom. Similar to total nitrogen, surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.015 mg/L to 0.030 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Spavinaw Lake was classified as eutrophic, with high primary productivity and nutrient levels in 2002-2003. These results differ from historical data collection efforts on the lake, which found the lake to be hypereutrophic in 1999 (TSI=58). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient impaired. A nutrient impairment study should be conducted to determine if uses are impaired. Several studies have been conducted in Eucha/Spavinaw complex by the OWRB and other state agencies and can be referenced for further information. Water clarity was excellent based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and turbidity, but partially supporting based on low dissolved oxygen values occurring in the summer. The Aesthetics beneficial use is currently supported based on the trophic status however a beneficial use determination cannot be made for true color because the minimum data requirements were not met. Spavinaw Lake, located in Mayes

County, is owned by the city of Tulsa and utilized for a water supply, recreation, and wildlife reservoir. In 1999, the Tulsa Municipal Authority contracted the OWRB to conduct bathymetric survey of Spavinaw Lake (Figure 197) to determine current lake volume, capacity, and sedimentation rates. The survey information was used to support numerical modeling of proposed water quality improvements by the OWRB. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

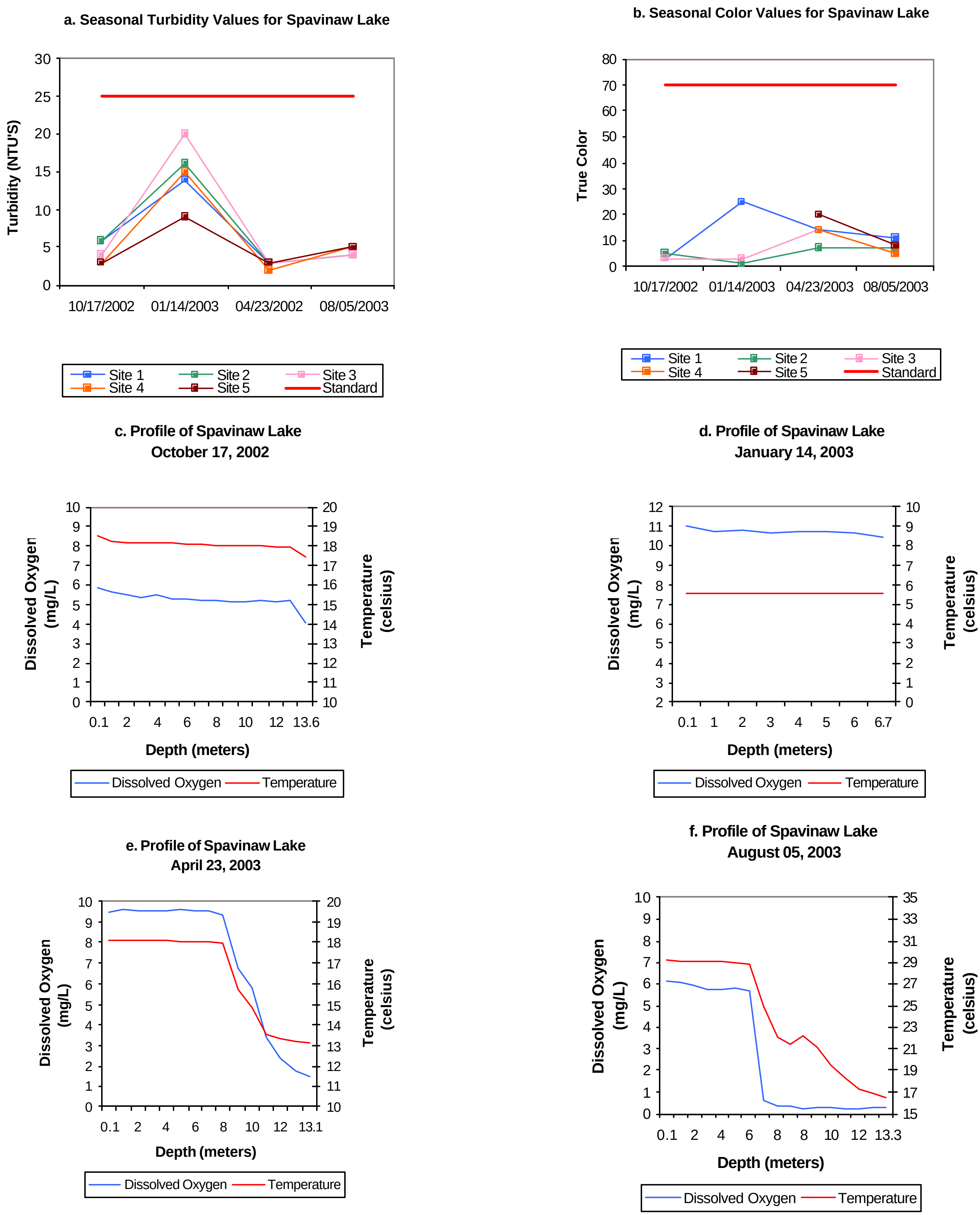
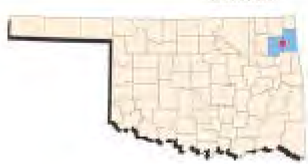
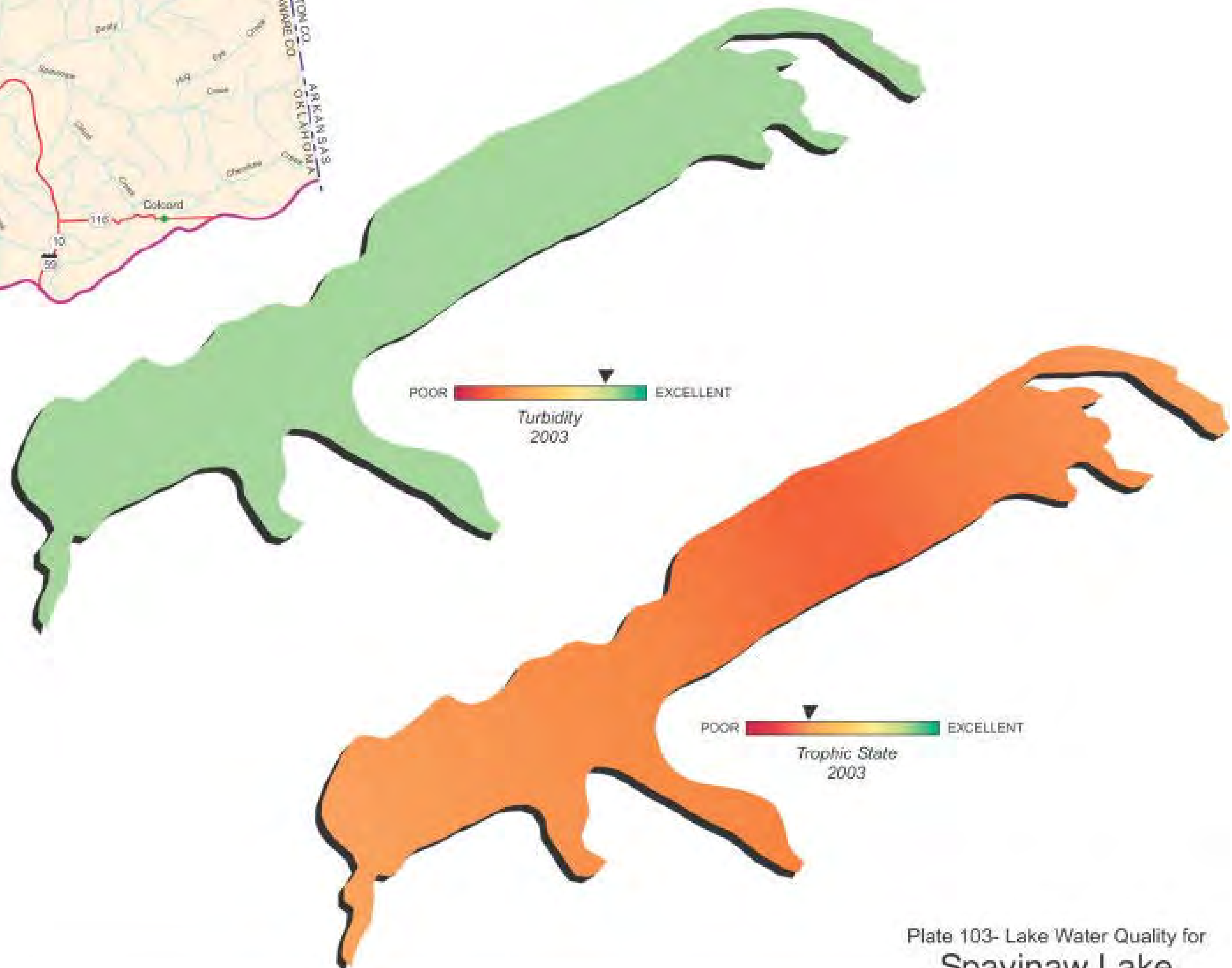



**Figure 229a-231f.** Graphical representation of data results for Spavinaw Lake.


Spavinaw Lake
and
Watershed



Spavinaw Lake
Location




| Lake Data | |
|---|---|
| Constructed by | City of Tulsa |
| County | Delaware/Mayes |
| Constructed in | 1924 |
| Surface Area | 1,578 acres |
| Volume | 25,941 acre/feet |
| Shoreline Length | 26.71 miles |
| Mean Depth | 16.10 feet |
| Watershed Area | 248 square miles |

Plate 103- Lake Water Quality for
Spavinaw Lake

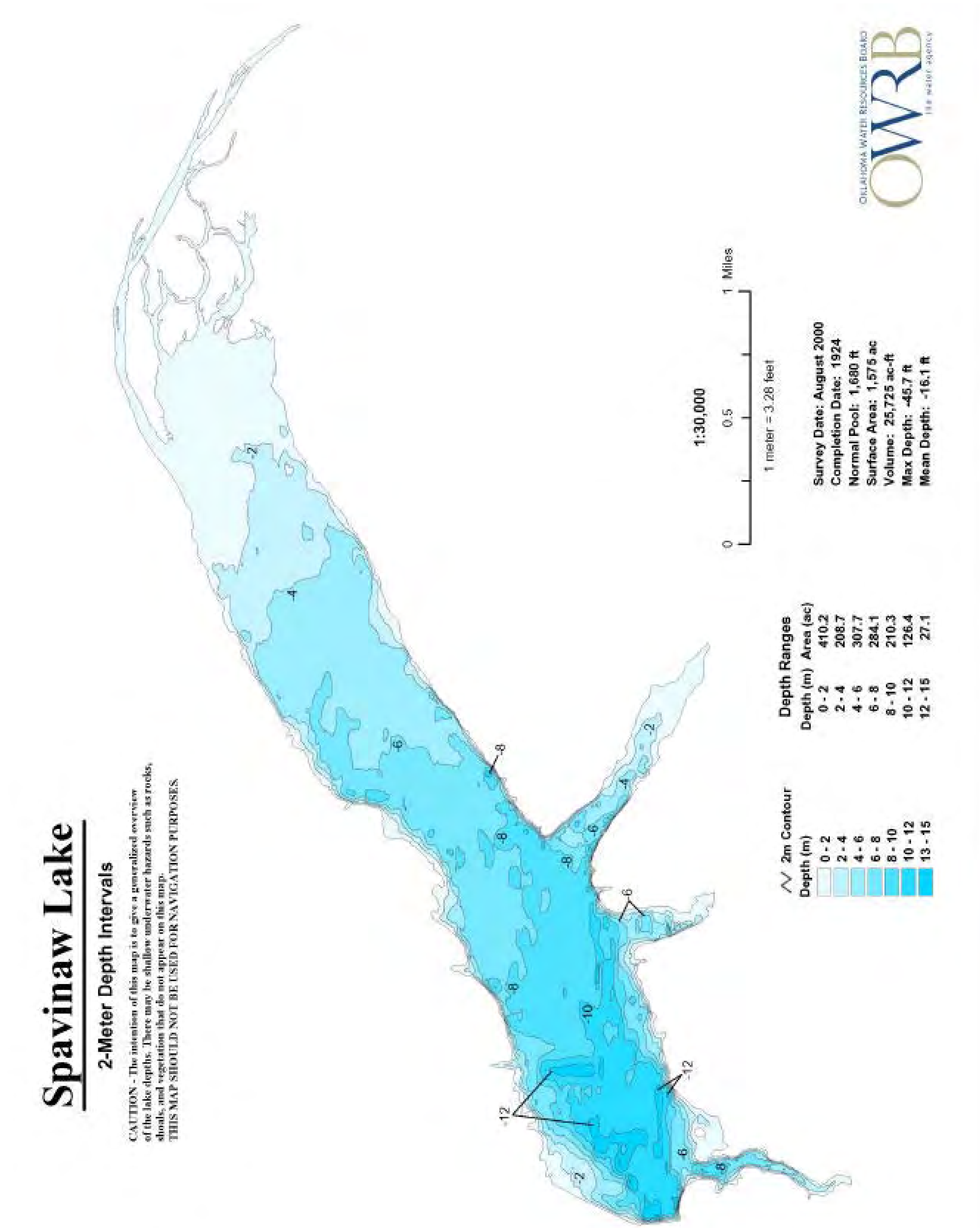



**Figure 230.** Bathymetric Map of Spavinaw Lake.

# Spiro Lake

New Spiro Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at three sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 15 NTU (Plate 104), true color was 37 units, and secchi disk depth was 43 centimeters in 2003-2004. Based on these three parameters, New Spiro Lake had good water clarity in comparison to other Oklahoma reservoirs. Water clarity is similar to previous collection efforts, with the exception of turbidity, which is lower to that seen in 2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was calculated at 67 (Plate 104), indicating the lake was hypereutrophic, with excessive primary productivity and nutrient conditions in sample year 2004. This value is higher than that in 2001 (TSI=61). The TSI values throughout the sample year varied seasonally from primarily upper eutrophic in the fall to hypereutrophic the remainder of the year (see Figure 231). Based on the trophic classification the lake will be recommended for listing in the next Oklahoma Water Quality Standards (OWQS) revision process as a Nutrient Limited watershed (NLW). This listing means the lake is considered nutrient threatened until a more intensive study can confirm the Aesthetics beneficial non-support status. Seasonal turbidity values are displayed in Figure 232a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the values below the OWQS the lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 232b. True color values were below the aesthetics OWQS of 70 units at all times (see Figure 232b). Applying the same default protocol, the Aesthetics beneficial use is considered fully supported.

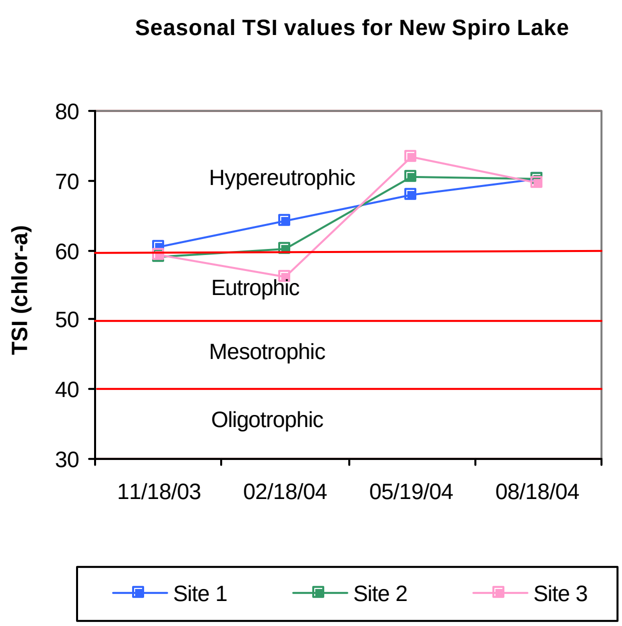



**Figure 231.** TSI values for New Spiro Lake

In 2003-2004, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.07 ppt, indicating low salt content in the lake and were well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were low, ranging from 57.2 mS/cm to 159.3 mS/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to alkaline in nature with values ranging from 6.43 units in the spring quarter to 8.98 in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only one value below 6.5 units the lake is fully supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (redox) ranged from 424 mV in the fall to 500 mV in the winter, indicating an absence of reducing conditions in the lake. New Spiro Lake was not stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column. (See Figure 232c-Figure 232d). The lake was thermally stratified and anoxic conditions were present in both spring and summer quarters. In the spring the lake was stratified between 3-4 meters at which point dissolved oxygen fell below 2.0 mg/L for 33% of the water column at site 1 (Figure 232e-Figure 232f). During the summer quarter, the lake was strongly thermally stratified between 1 and 2 meters at all sites (see Figure 232f). Anoxic conditions were present below the 2-meter depth at all three sites and D.O. readings were below 1.0 mg/L from 3 meters to the lake bottom at 4.6 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, with 66% of the water column less than 2.0 mg/L at site 1 and 50% at site 2 in the summer, the FWP beneficial use is partially supported at New Spiro Lake. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body contact Recreation (PBCR) beneficial use. Samples were collected at five sites for E. coli, fecal coliform and enterococci during the recreation season of May through September. Of the 10 samples collected one (1) or 10% of the samples exceeded the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2003-2004 was 1.30 mg/L at the lake surface and 1.81 mg/L at the lake bottom. The TN at the surface ranged from 0.84 mg/L to 1.92 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2003-2004 was 0.099 mg/L at the lake surface and 0.203 at the lake bottom. The surface TP ranged from 0.049 mg/L to 0.133 mg/L. The highest surface TP value was reported in the winter quarter and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 13:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, New Spiro Lake was classified as hypereutrophic, with excessive primary productivity and nutrient levels in sample year 2004 (Plate 104). This value is higher than that in 2001 (TSI=61) indicating an increase of productivity since previous data collection efforts. The lake will be recommended for listing as an NLW in the next OWQS revision process and its Aesthetics beneficial use is considered nutrient threatened. The lake was fully supporting its

Aesthetics beneficial use based true color. New Spiro Lake was fully supporting its FWP beneficial use based on turbidity and pH. The FWP beneficial use was partially supported based on D.O. values. Bacteriological samples were also collected to assess the Primary Body contact Recreation (PBCR) beneficial use. Of the 10 samples collected one (1) or 10% of the samples exceeded the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. New Spiro Lake was constructed in 1960 is owned and operated by the City of Spiro and serves as a municipal water supply and offers numerous recreational opportunities to the public.

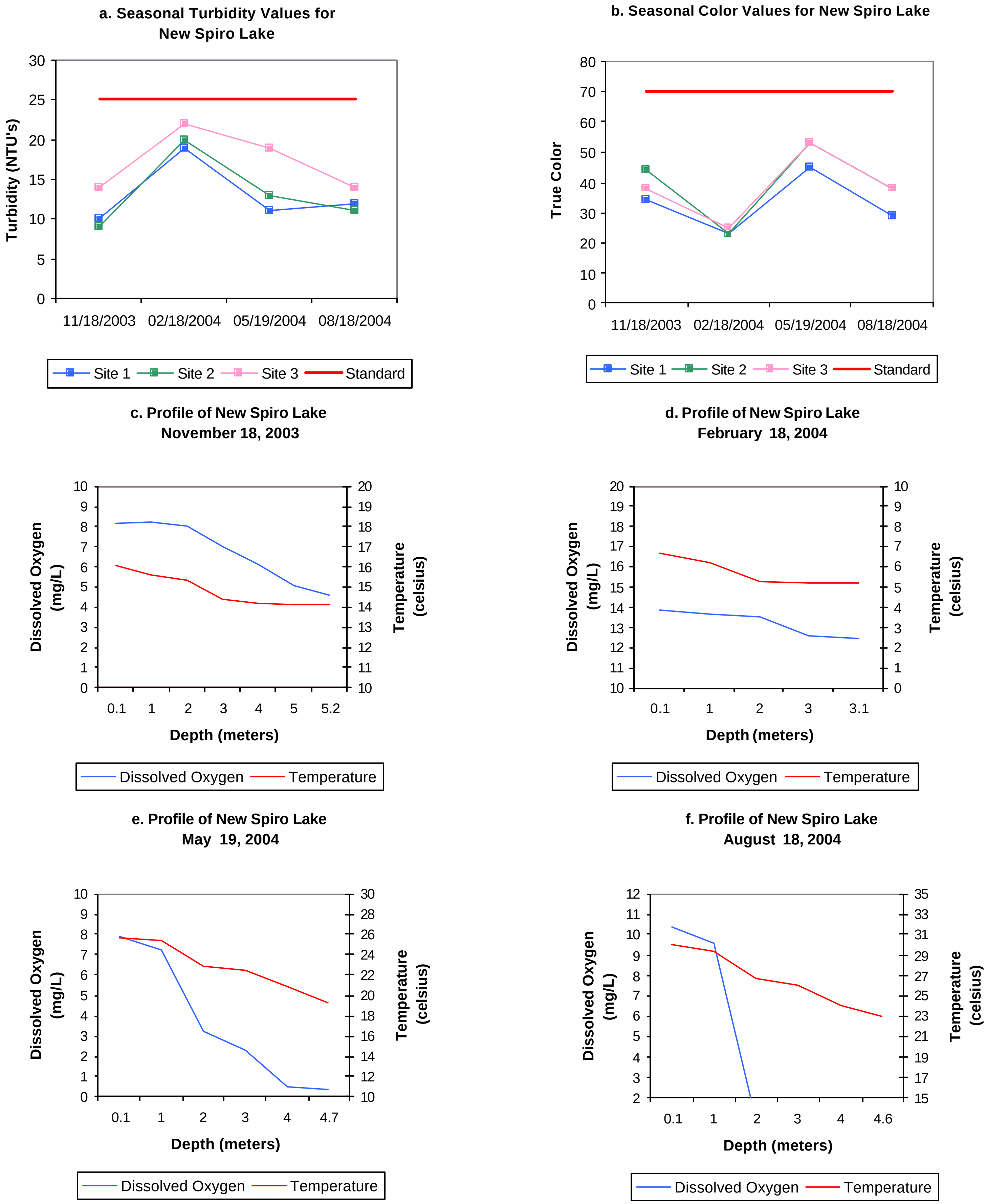
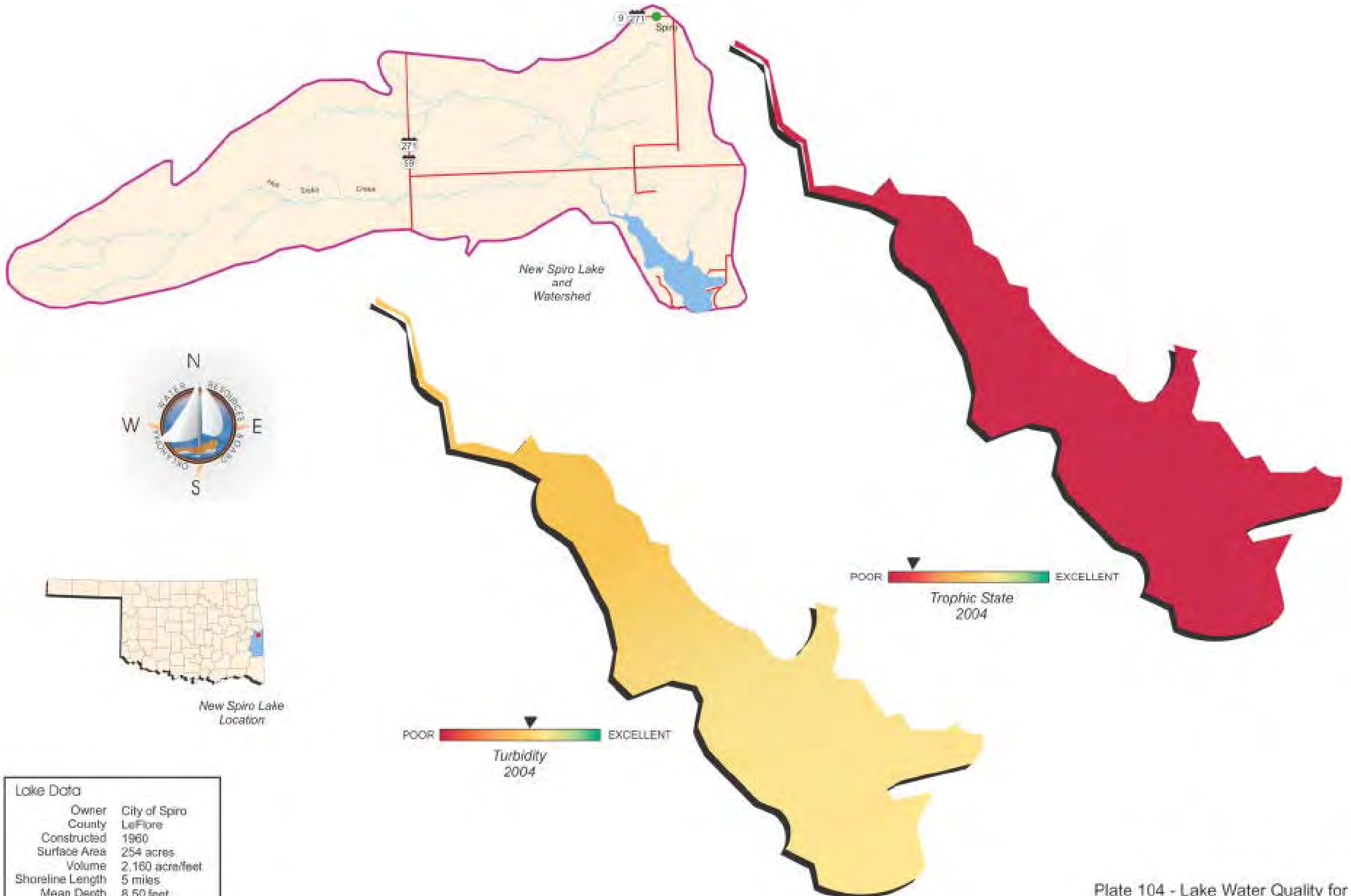



**Figure 232a-232f. Graphical representation of data results for New Spiro Lake.**




Lake Data

| | |
|---|---|
| Owner | City of Spiro |
| County | LeFlore |
| Constructed | 1960 |
| Surface Area | 254 acres |
| Volume | 2,160 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 8.50 feet |
| Watershed Area | 14 square miles |

Plate 104 - Lake Water Quality for
Spiro (New) Lake

# Sportsman Lake

Sportsman Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 at the lake surface for the determination of chlorophyll-a and nephelometric turbidity concentrations. Water quality samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 8 NTU (Plate 105), true color was 32 units, and secchi disk depth was 102 centimeters in 2001-2002. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 41 (Plate 105), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions. The TSI values varied seasonally from oligotrophic in the winter and spring quarter to lower mesotrophy in the fall and summer quarters (see Figure 233). Sportsman Lake was on the border between oligotrophy and mesotrophy. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 234a). The lake-wide annual turbidity average of 8 NTU seems to accurately represent the conditions at this lake. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Sportsman Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to nephelometric turbidity. Seasonal true color values are displayed in Figure 234b. All of the true color values were below the Aesthetics numeric criteria of 70 units in 2001-2002, however, a definitive determination of the use support could not be made due to lack of sufficient data. Recorded data does strongly support the supposition that the lake would be supporting its Aesthetics beneficial use for true color.

Vertical profiles for dissolved oxygen, pH, temperature; specific conductance, oxidation-reduction potential, and salinity were recorded at all three water chemistry sample sites. The salinity values ranged from 0.11 parts per thousand (ppt) to 0.15 ppt, indicating moderate salt content and were within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 225.7 mS/cm in the spring quarter to 317.5 mS/cm in the summer, indicating low to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral, ranging from 6.72 to 7.94 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Sportsman was fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 48 mV at the sediment-water interface in the summer to 400 mV in the fall quarter. Redox

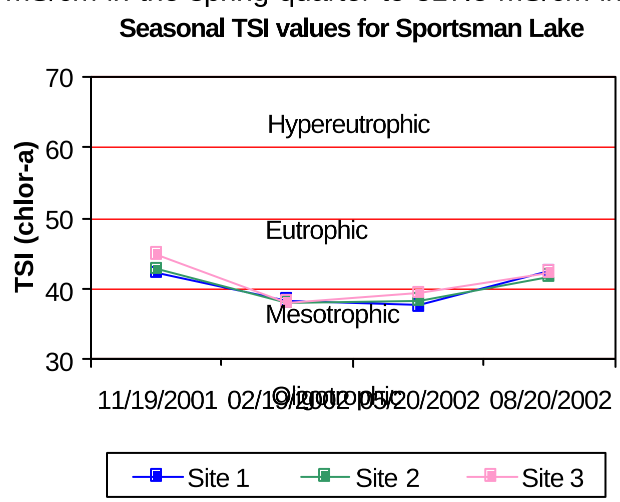



**Figure 233.** TSI values for Sportsman Lake.

readings indicated that reducing conditions were not present in the reservoir during any of the sampling events. The lake was not thermally stratified in the fall or winter quarter and dissolved oxygen (D.O.) values were above 8.8 mg/L throughout the water column (see Figure 234c-234d). In the spring, the lake was strongly thermally stratified at several 1-meter intervals, the first one between 6 and 7 meters at site 1 and again between 7 and 8 meters at site 1 (see Figure 234e). Below the 7-meter depth at sites 1 and 2, the D.O. concentrations were less than 2.0 mg/L extending to the lake bottom at 9.2 meters (see Figure 234e). In the summer, the lake was once again strongly thermally stratified between 5 and 6 meters, at which point D.O. values were less than 2.0 mg/L all the way to the lake bottom at 9.2 meters (see Figure 234f). From the 5-meter depth to the lake bottom at 9.2 meters the water temperature dropped over 10° Celsius, which is a large temperature difference in a lake this shallow. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at as in the spring only 27% of the water column was less than 2.0 mg/L and in the summer only 46% of the water column. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.52 mg/L at the lake surface. The TN at the surface ranged from 0.23 mg/L to 1.69 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the winter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.030 mg/L at the lake surface. The surface TP ranged from 0.014 mg/L to 0.063 mg/L. The highest surface TP value was reported in the fall and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 17:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Sportsman Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column.

In summary, Sportsman Lake was mesotrophic, indicative of moderate to low primary productivity and nutrient conditions (Plate 105). Water clarity was excellent at this lake. Sportsman Lake was fully supporting its Aesthetics beneficial use based on its trophic state and true color data strongly supports the supposition that it would be fully supporting for that parameter as well. The FWP beneficial use was fully supporting for nephelometric turbidity, pH and D.O. in the water column. There were no water quality concerns associated with the lake and it is one of the nicer small municipal lakes in Oklahoma. Sportsman Lake was constructed in 1958 and is owned and operated by the City of Seminole. It is utilized for flood control and offers numerous recreational opportunities to the public. This lake should be managed and maintained to protect its excellent water quality.

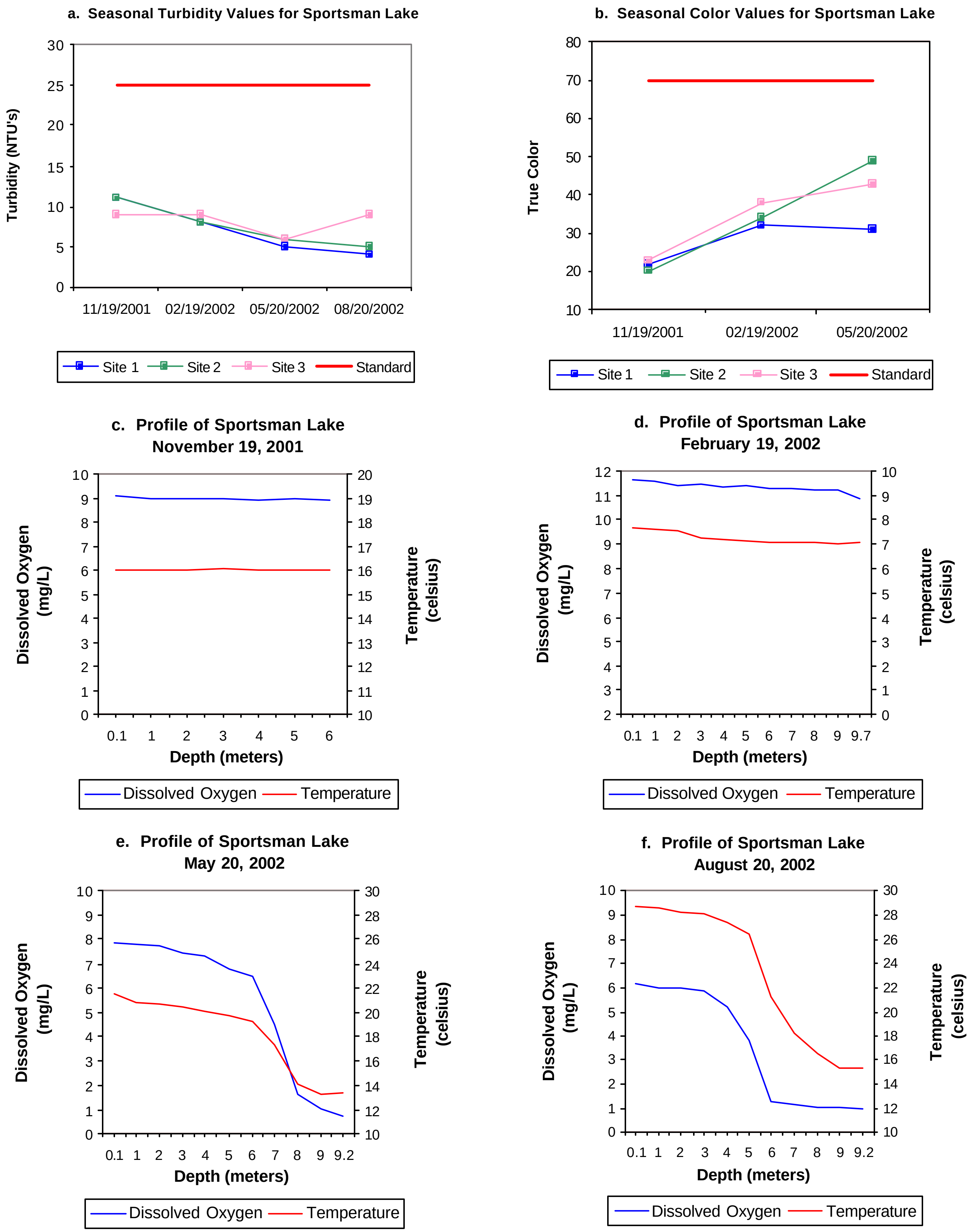
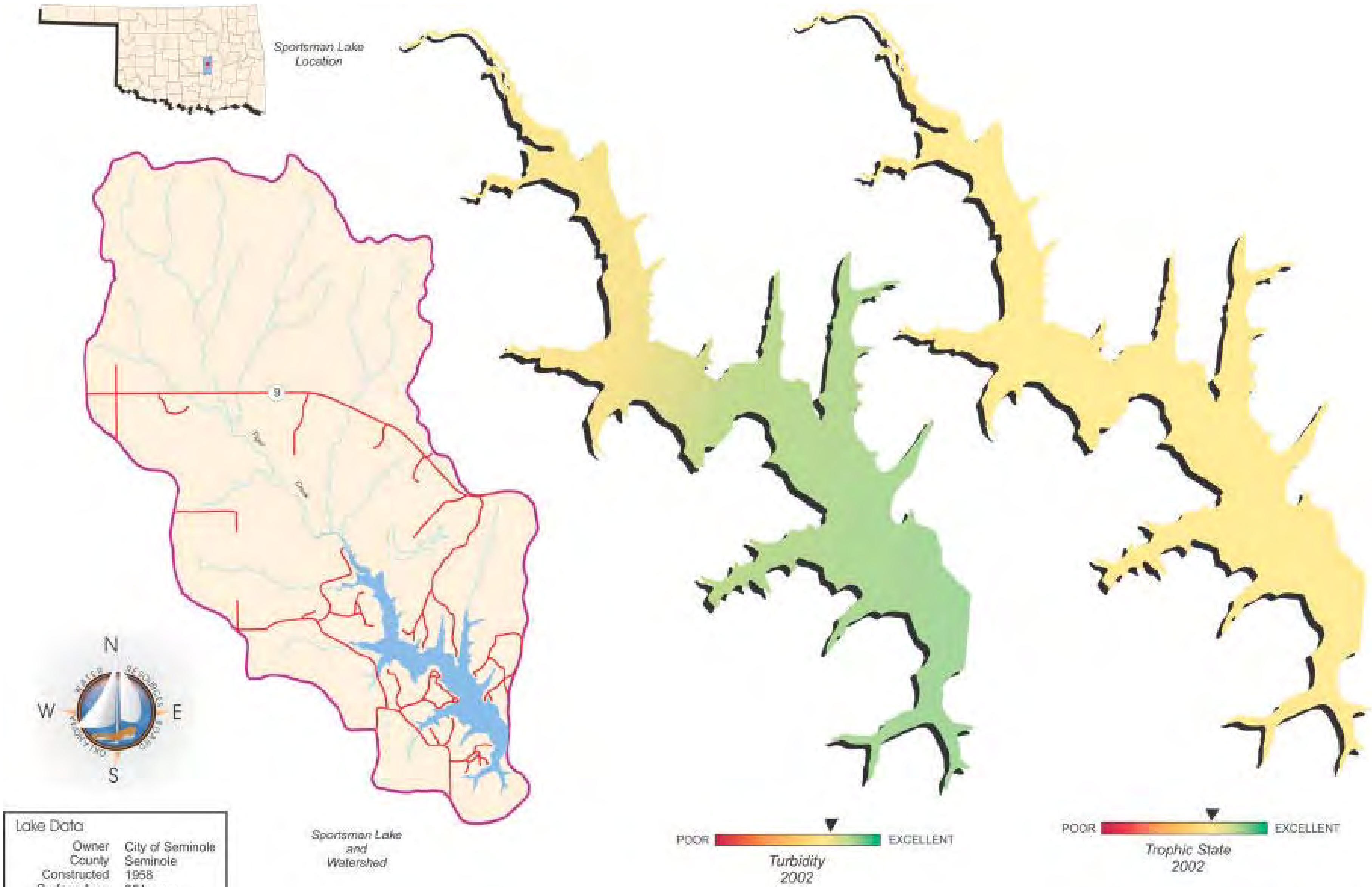



**Figure 234a-234f.** Graphical representation of data results for Sportsman Lake.




Lake Data

| | |
|---|---|
| Owner | City of Seminole |
| County | Seminole |
| Constructed | 1958 |
| Surface Area | 354 acres |
| Volume | 5,349 acre/feet |
| Shoreline Length | 15 miles |
| Mean Depth | 15.11 feet |
| Watershed Area | 13 square miles |

Plate 105 - Lake Water Quality for
Sportsman Lake

# Lake Stanley Draper

Lake Stanley Draper was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major lake arms. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 22 NTU (Plate 106), true color was 41 units, and secchi disk depth was 79 centimeters in 2003-2004. Based on these three parameters, water clarity of the reservoir was average in comparison to other reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 39 (Plate 106), classifying the lake as oligotrophic, indicative of low levels of primary productivity and nutrient. This value is no doubt due in large part to the high levels of inorganic turbidity present in the water column limiting the amount of light available for use by the biotic community. The calculated TSI for the 2002 sample year was very similar (TSI=40), indicating that no change in productivity has occurred. The TSI values varied seasonally, from oligotrophic at in the fall and winter quarters to lower mesotrophy in the spring and summer quarters (see Figure 235). Nearly half of the turbidity values were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 236a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 40% of the turbidity values exceeded the criteria of 25 NTU, available rainfall data suggets the increase in turbidity is likely the result of seasonal rain events. The lake is therefore considered supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 236b. Of the twenty true color values collected, only 1 (5%) was above the numeric criteria of 70 units therefore the lake is supporting its Aesthetics beneficial use.

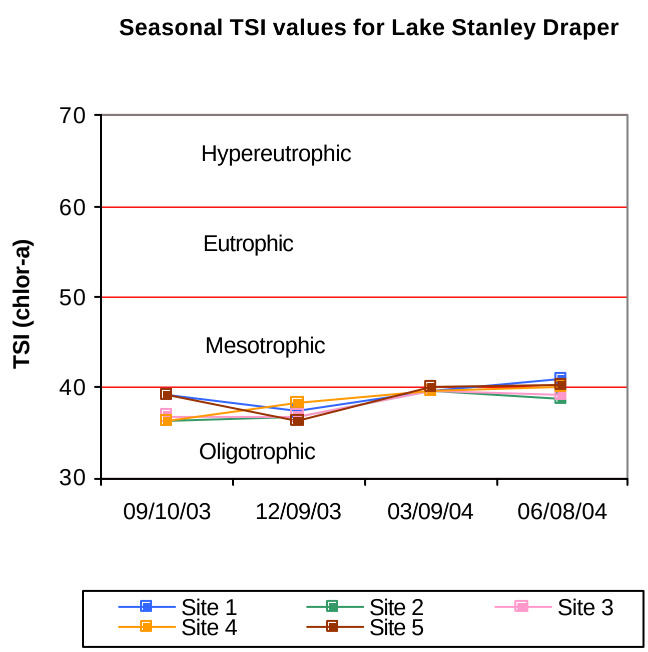



**Figure 235.** TSI values for Lake Stanley Draper.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.04 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most

Oklahoma lakes if not slightly lower. Specific conductance ranged from 66.8 mS/cm in the fall to 94.5 mS/cm in the summer quarter, indicating very low levels of electrical conducting compounds (salts) were present in the lake system, corresponding with the recorded salinity values. In general, pH values were neutral to slightly alkaline, ranging from 6.74 units to 7.92 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Stanley Draper was fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 319 mV in the summer quarter to 521 mV at the sediment-water interface in the fall. Redox readings indicate that reducing conditions were not present in the reservoir during the sample period. The lake was thermally stratified in the fall quarter and dissolved oxygen (D.O.) readings in the bottom 3 meters of the reservoir were less than 2.0 mg/L at site 1 (see Figure 236c) from 25 to 27.1 meters below the lake surface. Site 3 also exhibited stratification between 10 and 11 meters in depth with D.O. falling below 2.0 mg/L from 12 meters to the lake bottom at 14.4 meters. The lake was not thermally stratified in the winter, spring, or summer quarters and D.O. values were well above 5.0 mg/L throughout the water column (see Figure 236d-236f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered fully supported at Lake Stanley Draper as only 14% of the water column was anoxic at site 1 and 25 % was anoxic at site 3 in the fall quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2003-2004 was 0.45 mg/L at the lake surface and 0.36 mg/L at the lake bottom. The TN at the surface ranged from 0.13 mg/L to 0.45 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the spring. The lake-wide total phosphorus (TP) average for sample year 2003-2004 was 0.017 mg/L at the lake surface. The surface TP ranged from 0.013 mg/L to 0.022 mg/L. The highest surface TP value was reported in the spring and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 26:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2001 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Stanley Draper was oligotrophic, indicative of low primary productivity (Plate 106). Water clarity was average at this lake and no doubt light limitation plays a major role in mitigating the productivity of the lake. Although 40% of the turbidity values exceeded the criteria of 25 NTU, available rainfall data suggets the increase in turbidity is likely the result of seasonal rain events. The lake is supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity, pH and dissolved oxygen. The lake was fully supporting its Aesthetics use based on its trophic state and on true color. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported. Lake Stanley Draper was constructed in 1962 and is owned and operated by the City of Oklahoma City and is utilized as a municipal water supply and for recreational purposes. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 237) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

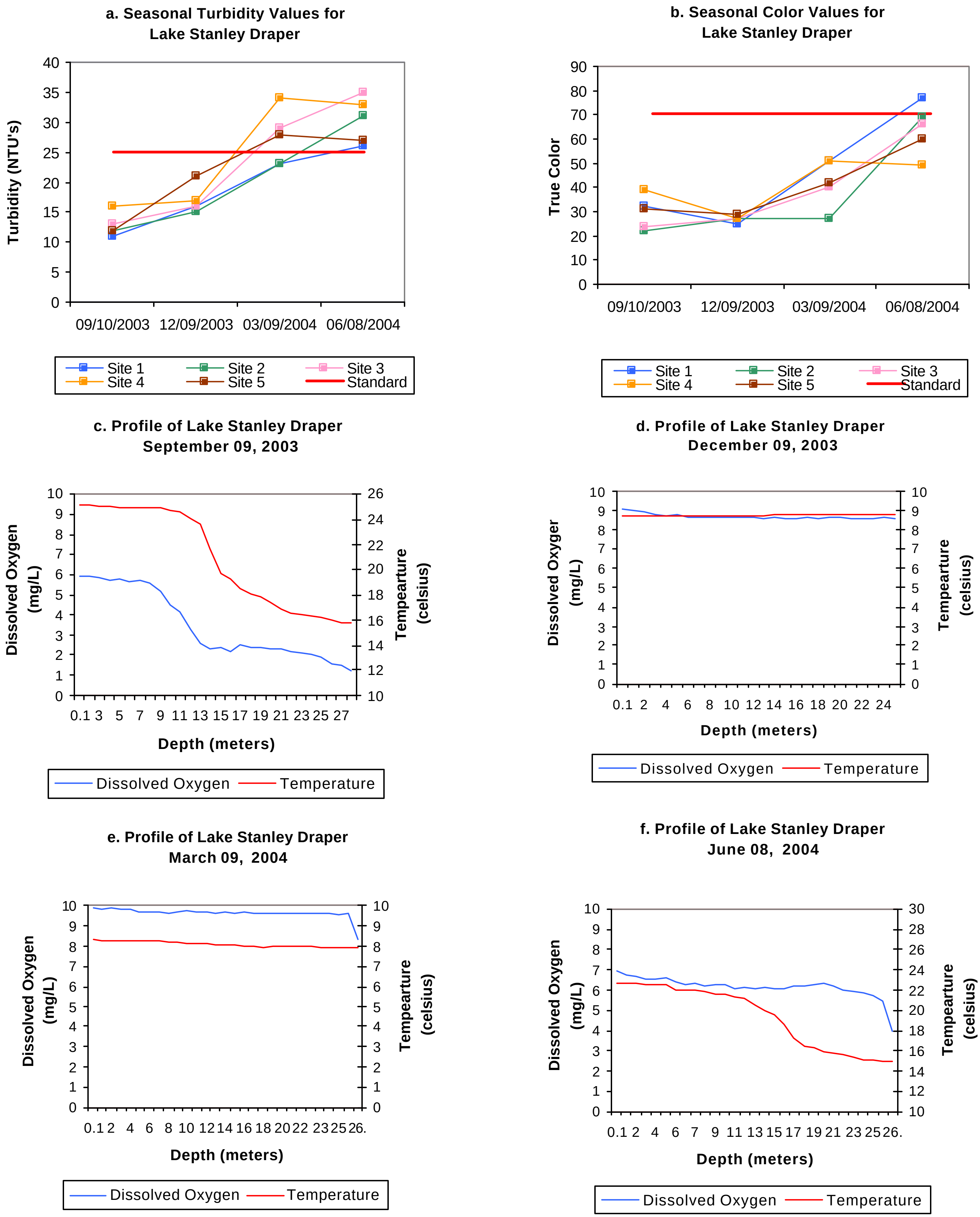


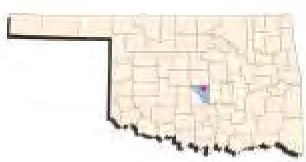

**Figure 236a-236f.** Graphical representation of data results for Lake Stanley Draper.


Stanley Draper Lake and Watershed



Lake Data

| | |
|---|---|
| Owner | City of Oklahoma City |
| County | Cleveland |
| Constructed in | 1962 |
| Surface Area | 2,519 acres |
| Volume | 87,296 acre/feet |
| Shoreline Length | 33.8 miles |
| Mean Depth | 34.6 feet |
| Watershed Area | 12 square miles |



Stanley Draper Lake Location

Plate 106 - Lake Water Quality for

## Stanley Draper Lake

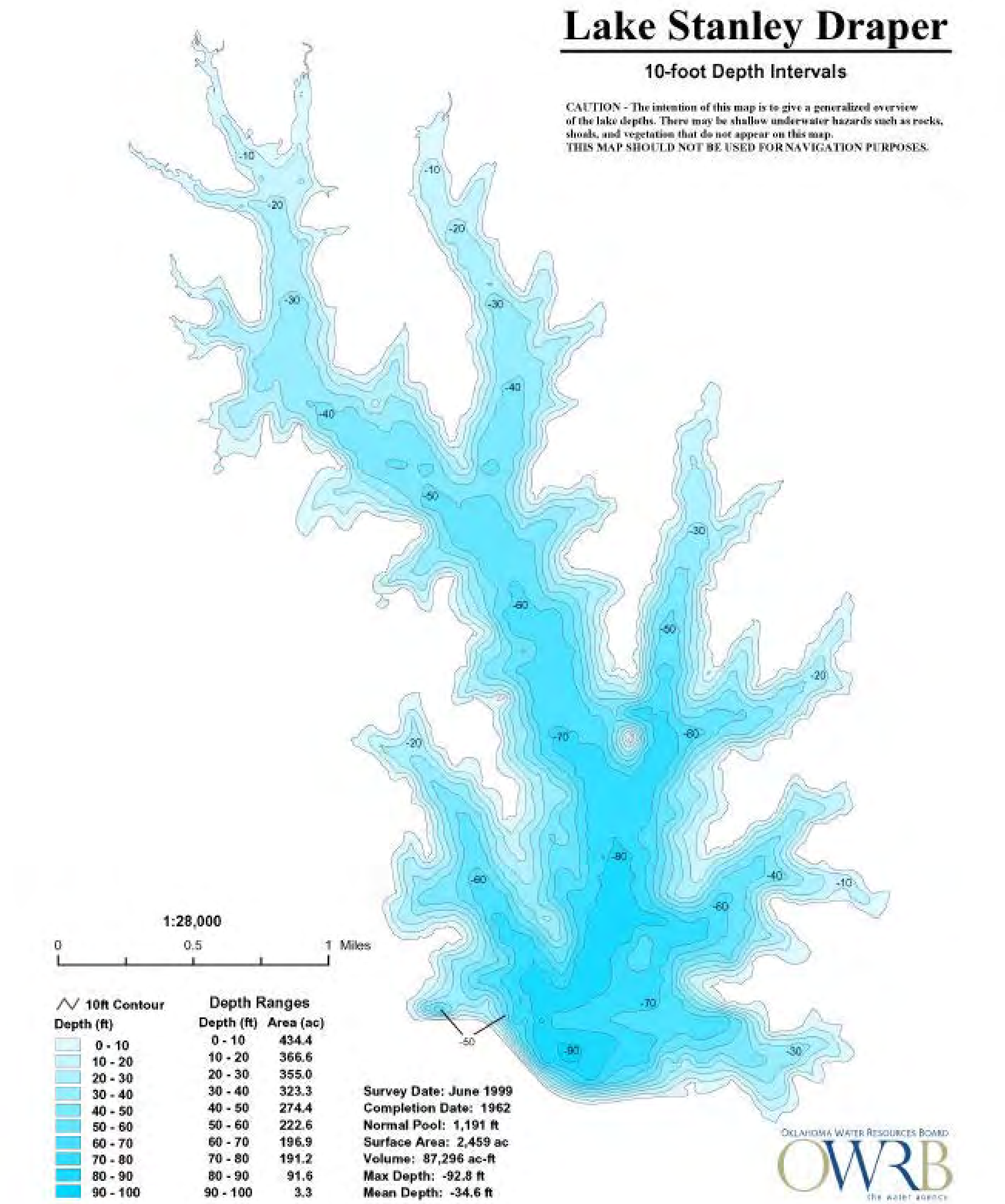



**Figure 237.** Bathymetric map of Lake Stanley Draper.

# Stilwell City Lake

Stilwell City lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 28 NTU (Plate 107), true color was 36 units, and secchi disk depth was 111 centimeters in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 55 (Plate 107), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. This value is similar to the one calculated in 2001 (TSI=58) indicating little or no change in trophic status over time. The TSI values varied seasonally, from hypereutrophic at site 1 to mesotrophic at site 2 in the fall with eutrophic values seen the remaindering three quarters (see Figure 238). Seasonal turbidity values are displayed in Figure 239a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 25% of the collected values exceeded 25 NTU, available flow and rainfall data suggest the elevated turbidity are due to seasonal storm events. Stilwell Lake is therfore considered supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 239b. Applying the same default protocol, Stilwell Lake is partially supporting the Aesthetics beneficial use with approximately 17% of the true color values above the Aesthetics numeric criteria of 70 units.

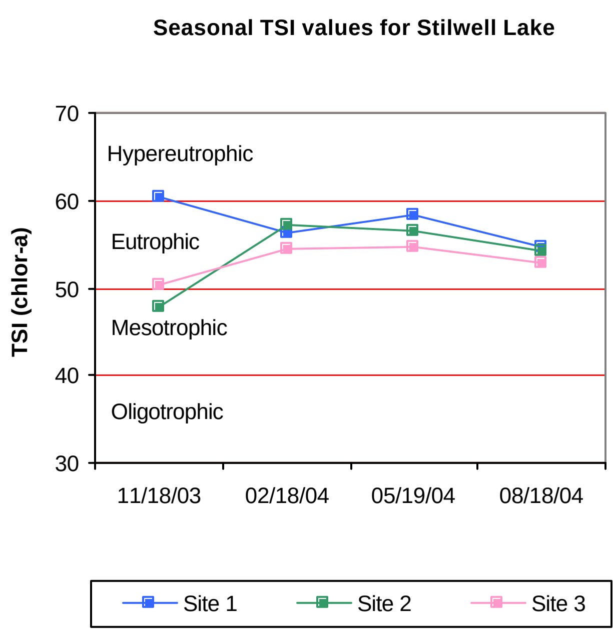



**Figure 238. TSI values for Stilwell Lake.**

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.05 parts per thousand (ppt) to 0.15 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 0.123.7 mS/cm to 299.6 mS/cm in the summer, indicating low levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, ranging from 6.66 to 8.32 units. According to

USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 326 mV at the sediment-water interface in the fall to 625 mV in the winter quarter. Redox readings indicated that reducing conditions were not present in the reservoir during sampling events in 2003-2004. The lake was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 3.0 mg/L throughout the water column in both quarters (see Figure 239c-239d). Thermal stratification was evident and anoxic conditions were present in both spring and summer quarters. In the spring, the lake was strongly thermally stratified between 3 and 4 meters below the lake surface at both sites 1 and 2. Water column D.O. values were less than 2.0 mg/L from 4 meters in depth to the lake bottom at 12.2 meters (see Figure 241e), accounting for 55 to 71% of the water column to be anoxic. The same situation was present in the summer quarter with D.O. values less than 2.0 mg/L from 2 meters below the lake surface to the lake bottom of 14.5 meters (see Figure 211f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered not supported at Stilwell Lake, as 55 to 71% of the water column was anoxic at site 1 and 2 in the spring and 63 to 81% of the water column was anoxic at both sites in the summer. These conditions could pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was sampled for, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body contact Recreation (PBCR) beneficial use. Samples were collected at five sites for E. coli, fecal coliform and enterococci during the recreation season of May through September. Of the 10 samples collected one (1) or 10% of the samples exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2003-2004 was 0.91 mg/L at the lake surface and 2.29 mg/L at the lake bottom. The TN at the surface ranged from 0.48 mg/L to 1.83 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was recorded in the spring. The lake-wide total phosphorus (TP) average for sample year 2003-2004 was 0.091 mg/L at the lake surface and 0.109 at the lake bottom. The surface TP ranged from 0.023 mg/L to 0.373 mg/L. The highest surface TP value was reported in the fall and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 10:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Stilwell Lake was eutrophic, indicative of high primary productivity and nutrient conditions (Plate 107). This is consistent with results from 2001 monitoring (TSI=58), indicating no significant increase or decrease in productivity has occurred. Water clarity was good at this lake during the study period. The lake was fully supporting its Aesthetics beneficial use based on its trophic state and partially supporting for true color. The lake was fully supporting its FWP beneficial use based on pH and not supporting based on low D.O. values in both spring and summer quarters. Although 25% of the collected values exceeded 25 NTU, available flow and rainfall data suggest the elevated turbidity are due to seasonal storm events. Stilwell Lake is therfore considered supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Bacteriological samples were also collected to assess the Primary Body contact Recreation (PBCR) beneficial use. Of the 10 samples collected one (1) or 10% of the samples exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Stilwell Lake was constructed in 1965 and is owned and operated by the City of Stilwell. The lake serves as a municipal water supply, for flood control and offers numerous recreational opportunities to the public. Other than the occurrence of low D.O. in the water column, the lake is one of the nicer small municipal lakes in Oklahoma.

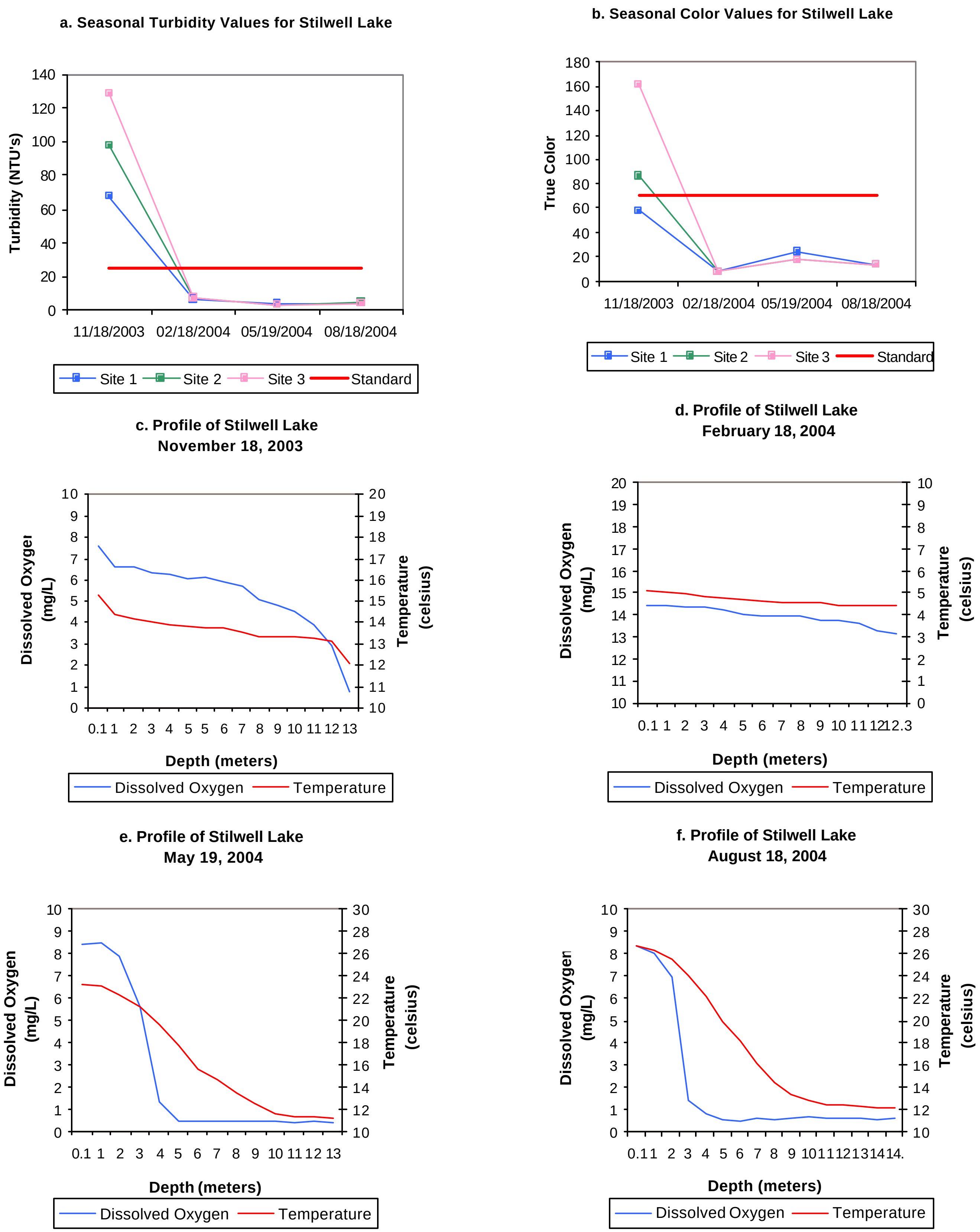



**Figure 239a- 239f.** Graphical representation of data results for Stilwell Lake.


| Lake Data | |
|---|---|
| Owner | City of Stilwell |
| County | Adair |
| Constructed | 1965 |
| Surface Area | 188 acres |
| Volume | 3,110 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 16.54 feet |
| Watershed Area | 4,693 acres |



Plate 107 - Lake Water Quality for
Stilwell Lake

# Stroud Lake

Stroud Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones as well as any major arms of the reservoir. Water quality samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 8 NTU (Plate 108), true color was 17 units, and secchi disk depth was 130 centimeters in. Based on these three parameters the lake had excellent water clarity in comparison to other Oklahoma lakes. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 47 (Plate 108), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. The TSI values varied seasonally with the lake being oligotrophic in the fall and winter quarters to mesotrophic in the spring and bordering eutrophic in the summer (see Figure 240. The highest value occurred in the summer at site 3. All turbidity values collected were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 241a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Stroud Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 241b. All of the true color values were below the Aesthetics numeric criteria of 70 units. Collected information indicates that the lake is fully supporting its Aesthetics use for true color.

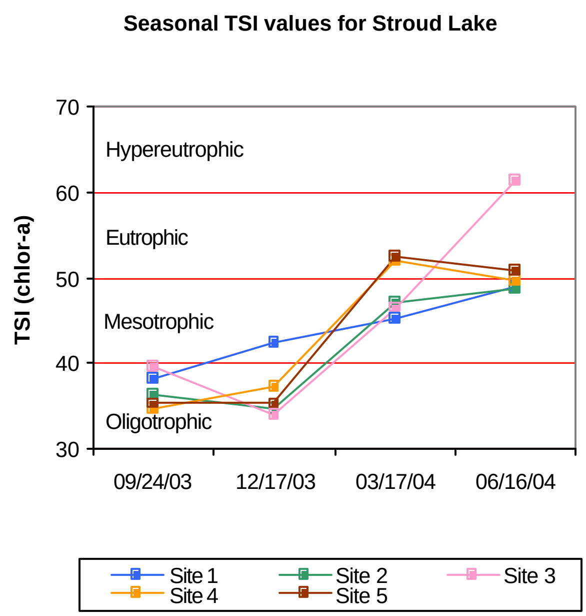



**Figure 240.** TSI values for Stroud Lake.

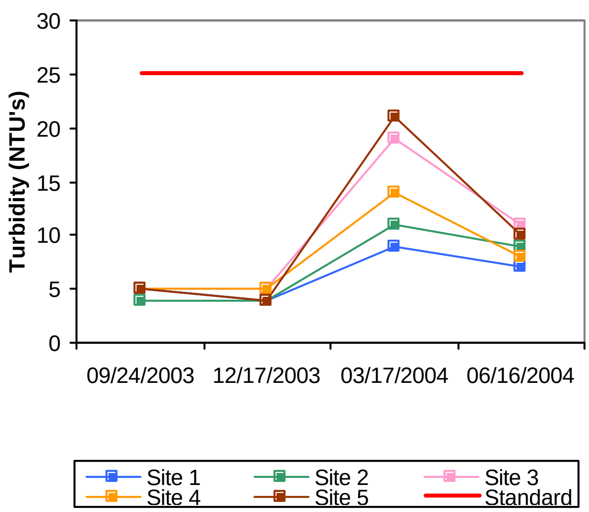
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.06 parts per thousand (ppt) to 0.08 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 132.3 mS/cm in the spring quarter to 200.8 mS/cm in the fall, indicating low levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, ranging from 6.92 to 8.18 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 208 mV at the sediment-water interface in the spring to 518 mV in the fall quarter. Redox readings indicate that reducing conditions were not present in the reservoir during sampling events in 2003-2004. The lake was thermally stratified in the fall near the lake bottom at sites 1 and 4, between 9 and 10 meters with dissolved oxygen (D.O.) falling below 2.0 mg/L from 11 meters in depth to the lake bottom of 11.9, (see Figure 241c). In the summer quarter, the lake was also thermally stratified between 9 and 10 meters below the lake surface at site 1, the dam. Water column D.O. values were less than 2.0 mg/L from 10 meters in depth to the lake bottom at 10.4 meters (see Figure 241e). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Stroud Lake as 15.4% of the water column was anoxic at site 1 in the fall and 8% was anoxic in the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2003-2004.

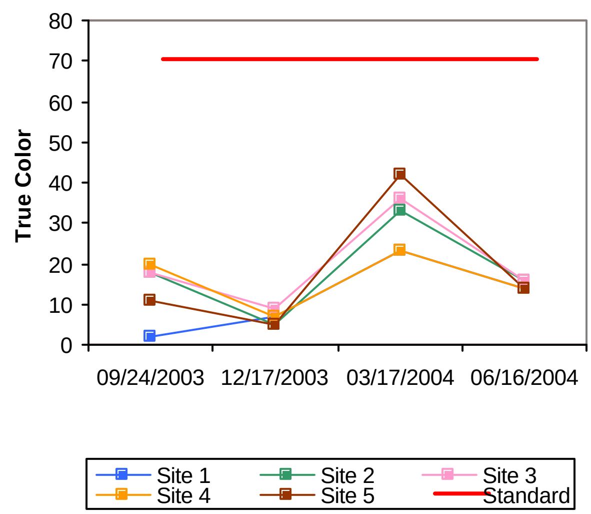
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2003-2004 was 0.39 mg/L at the lake surface and 0.49 mg/L at the lake bottom. The TN at the surface ranged from 0.30 mg/L to 0.62 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was also recorded in the summer. The lake-wide total phosphorus (TP) average for sample year 2003-2004 was 0.019 mg/L at the lake surface and 0.020 mg/L at the lake bottom. The surface TP ranged from 0.009 mg/L to 0.025 mg/L. The highest surface TP value was reported in the summer and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 27:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Stroud Lake was mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 108). The calculated TSI was very similar to the sample year 2002 (TSI=43), indicating no significant change in productivity has occurred. Water clarity was excellent based on secchi disk depth, turbidity and true color values. The lake was fully supporting its Aesthetics beneficial use based on its trophic state and for true color. The lake was also fully supporting its FWP beneficial use based on nephelometric turbidity, pH and dissolved oxygen. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. The PBCR beneficial use is considered fully supported for sample year 2003-2004. Stroud Lake was constructed in 1968 and is owned and operated by the City of Stroud. The lake serves as a municipal water supply, for flood control and offers numerous recreational opportunities to the public. Other than the occurrence of low D.O. in the water column, the lake is one of the nicer small municipal lakes in Oklahoma.

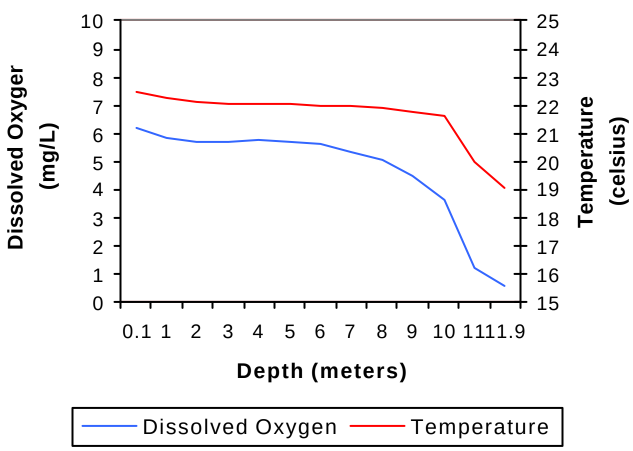
a. Seasonal Turbidity Values for Stroud Lake



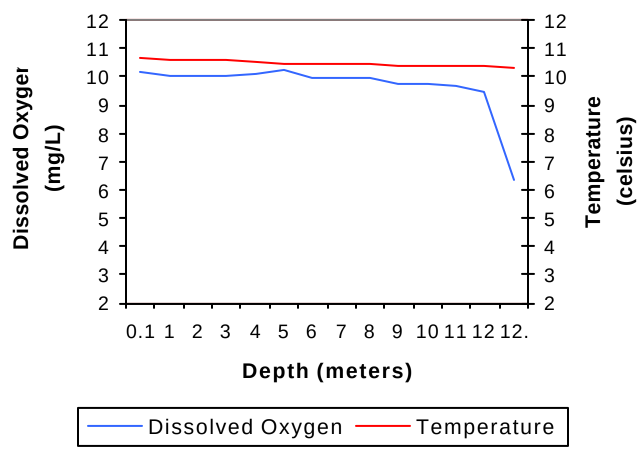

b. Seasonal Color Values for Stroud Lake




c. Profile of Stroud Lake
September 24, 2003




d. Profile of Stroud Lake
March 17, 2004




e. Profile of Stroud Lake
June 16, 2004

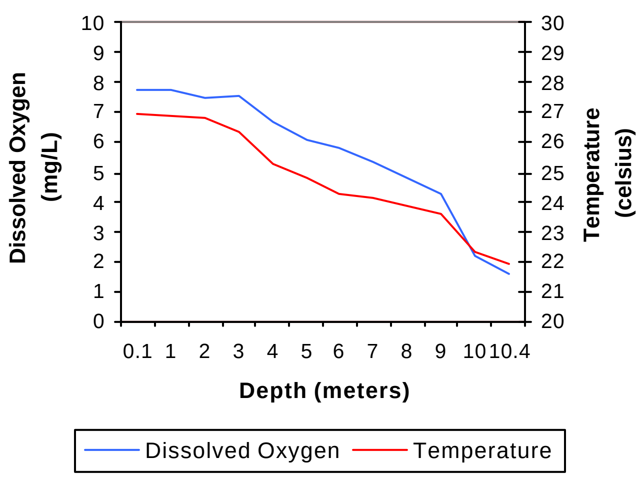
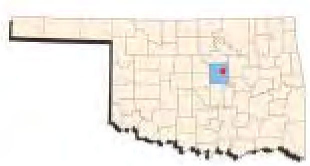



**Figure 241a-241e.** Graphical representation of data results for Stroud Lake.

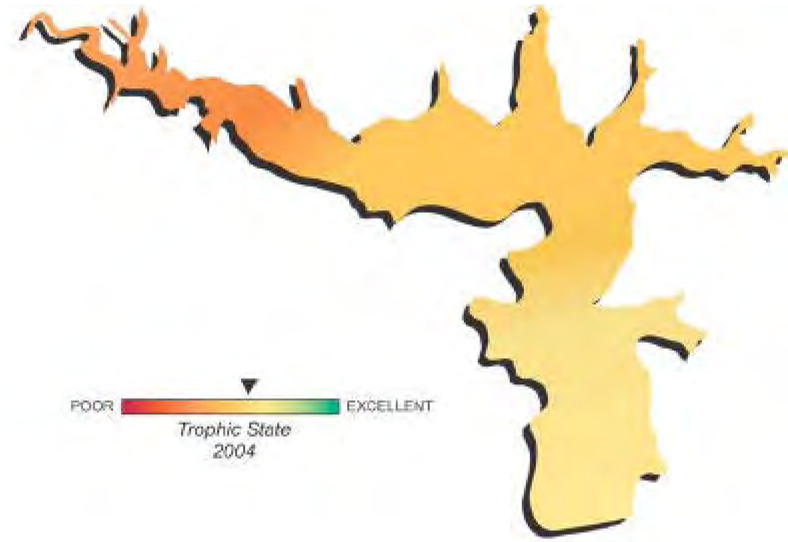

Stroud Lake and Watershed

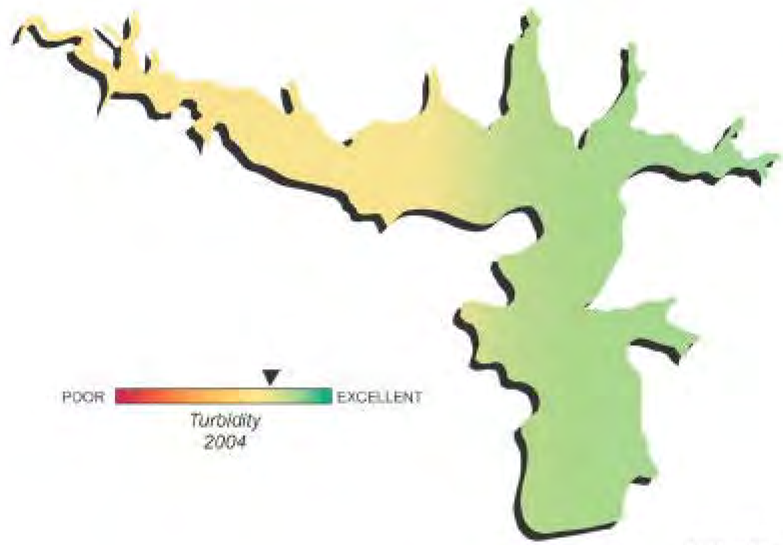
Stroud Lake Location

Lake Data

| | |
|---|---|
| Owner | City of Stroud |
| County | Lincoln |
| Constructed in | 1968 |
| Surface Area | 600 acres |
| Volume | 8,800 acre/feet |
| Shoreline Length | 13 miles |
| Mean Depth | 14.67 feet |
| Watershed Area | 16 square miles |




Trophic State 2004




Turbidity 2004

Plate 108 - Lake Water Quality for
## Stroud Lake

# <u>Talawanda Lake No.1</u>

Talawanda Lake No.1 was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at 3 sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The average lake-wide turbidity value was 4 NTU (Plate 109), true color was 18 units, and secchi disk depth was 190 centimeters. Based on these three parameters, Talawanda Lake No.1 had excellent water clarity, very similar to values in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 45 (Plate 109), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. This value is exactly the same as the one calculated in 2001 (TSI=45) indicating no change in trophic status has occurred over time. All TSI values were in the mesotrophic category in 2003 and are displayed in Figure 242. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and are displayed in Figure 243a. The Fish and Wildlife Propagation (FWP) beneficial use is considered fully supported based on turbidity. All of the true color values were well below the numeric criteria of 70 units in 2003. Currently, the Aesthetics beneficial use is considered fully supported.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.09 ppt, which is lower than the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 60.7 mS/cm to 195.7 mS/cm, indicative of low levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.24 to 7.43, representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 10% of the collected values less than 6.5, the lake should be listed as partially supporting beneficial uses. Oxidation-reduction potentials (ORP) ranged from 144 mV to 551 mV indicating reducing conditions were not present at this reservoir in sample year 2002-2003. In the fall, the lake was stratified at site 1 between 4 and 5 meters at which point dissolved oxygen (D.O.) dropped below 2.0 mg/L to the lake bottom of 7.8

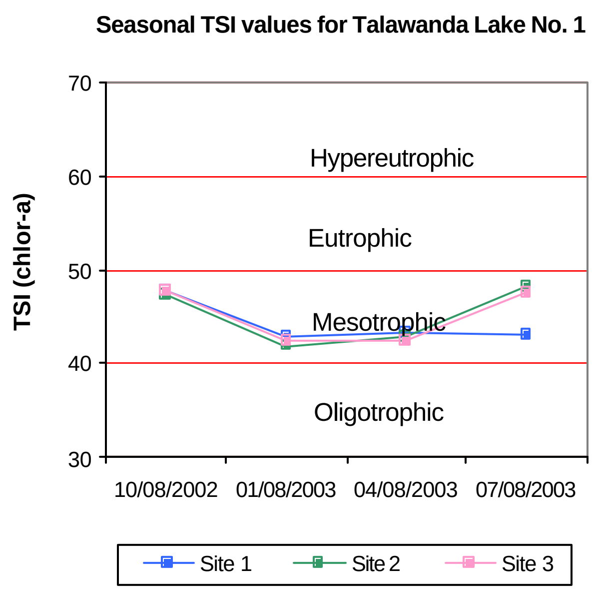



**Figure 242.** TSI values for Talawanda Lake No.1

meters. In the winter quarter the water column was well mixed with dissolved oxygen (D.O.) values generally above 8.0 mg/L (see Figure 243d). In the spring, the lake was weakly stratified, only approaching 2.0 mg/L near the sediment-water interface (Figure 243e). Thermal stratification w s evident and anoxic conditions were present throughout the lake in the summer. Stratification occurred between 3 and 4 meters, accounting for 50 to 60 % of the water column to be anoxic (Figure 243f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Talawanda Lake No.1 is considered to be partially supporting the FWP beneficial use based on anoxic conditions present in the summer and fall. These conditions could pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.43 mg/L at the surface and 0.94 mg/L at the lake bottom. Surface TN ranged from 0.26 mg/L to 0.58 mg/L with the highest values recorded in the fall quarter and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.013mg/L at the surface and 0.024 mg/L at the lake bottom. The surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.007 mg/L to 0.016 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 34:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Talawanda Lake No.1 was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in sample year 2003. This is consistent with historical data collection efforts, indicating no significant increase or decrease in productivity has occurred. Water clarity was excellent based on turbidity, true color, and secchi disk depth. The FWP beneficial use is supported based on turbidity, but partially supported based on dissolved oxygen values and pH. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values. Talawanda Lake No. 1, owned by the City of McAlester, was constructed in 1902 for the purpose of recreation.

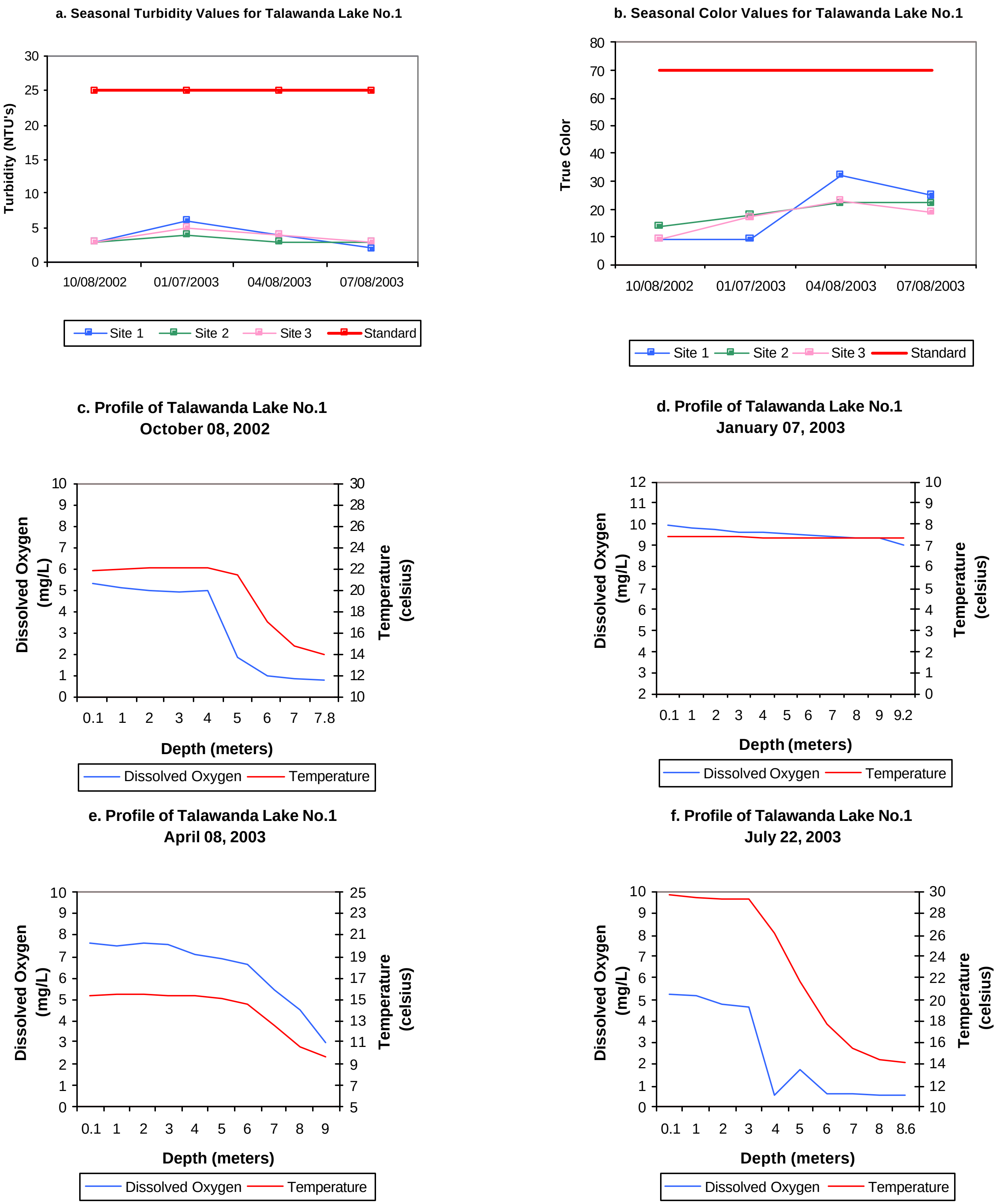
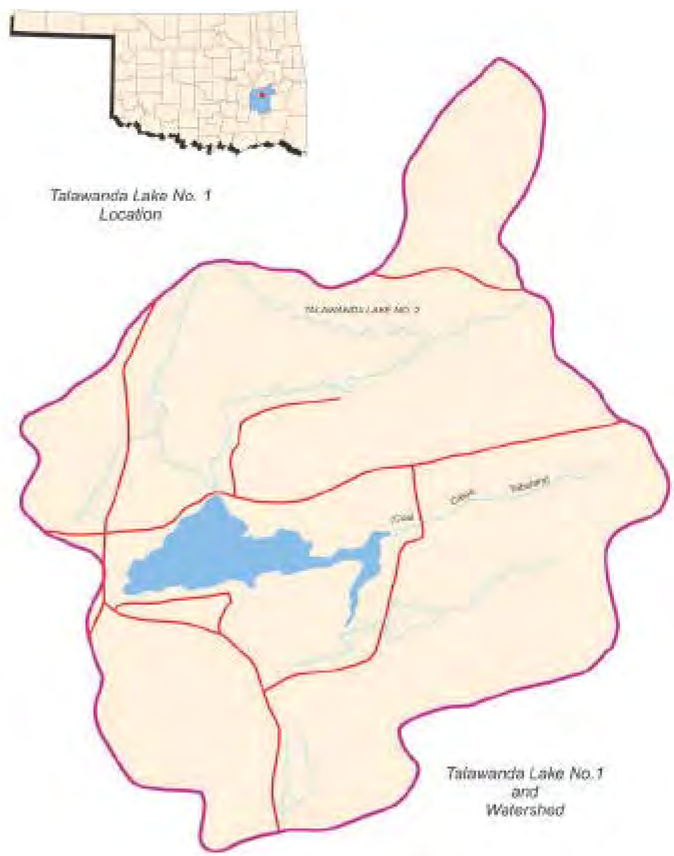
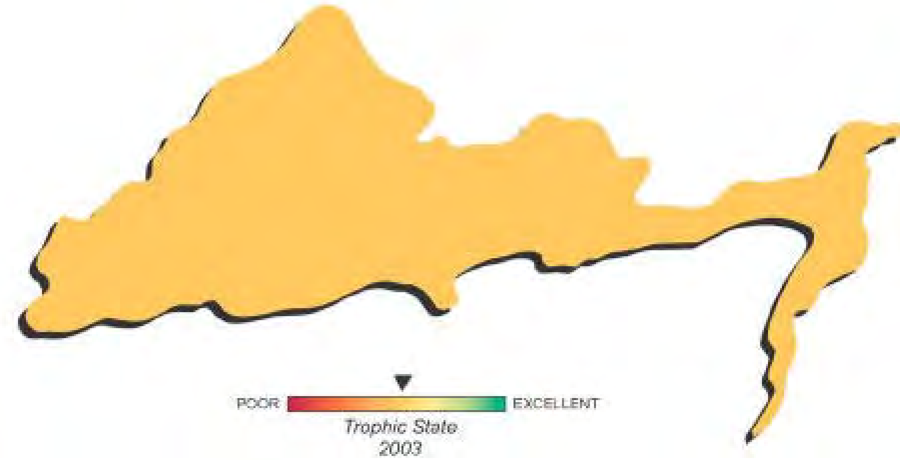


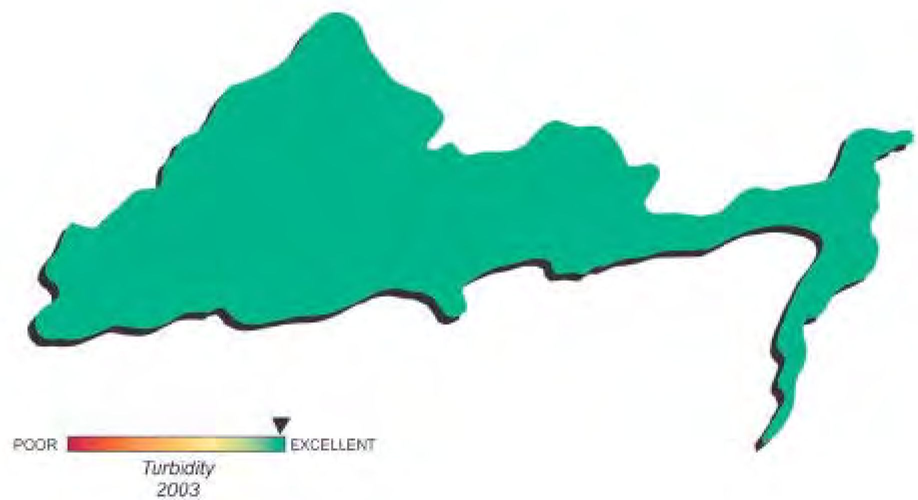

**Figure 243a-243f.** Graphical representation of data results for Talawanda Lake No.1



Talawanda Lake No. 1
Location

Talawanda Lake No.1
and
Watershed




Lake Data

| | |
|---|---|
| Owner | City of McAlester |
| County | Pittsburg |
| Constructed | 1902 |
| Surface Area | 91 acres |
| Volume | 1,200 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 14.10 feet |
| Watershed Area | 1,271 acres |

Plate 109 - Lake Water Quality for
# Talawanda Lake No. 1

# Talawanda Lake No. 2

Talawanda Lake No. 2 was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at 3 sites to represent the reservoir. Samples were collected at the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity value was 6 NTU (Plate 110), true color was 12 units, and secchi disk depth was 162 centimeters. Based on these three parameters, Talawanda Lake No. 2 had excellent water clarity, similar to the values reported in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 39 (Plate 110), classifying the lake as oligotrophic, indicative of low levels of primary productivity and nutrients. This value is similar to the one calculated in 2001 (TSI=40) indicating no significant increase or decrease in productivity has occurred since the 2001 evaluation. TSI values were primarily oligotrophic with all sites in the mesotrophic category in the winter sampling quarter (Figure 244). The TSI of 39 seems to accurately represent conditions at Talawanda Lake No. 2. Seasonal turbidly values are displayed in Figure 245a. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, therefore meeting the Fish and Wildlife Propagation (FWP) beneficial use in regards to turbidity. The lake-wide annual turbidity average of 6 NTU seems to accurately represent the conditions at this lake. All of the true color values were well below the numeric criteria of 70 units in 2003 and are displayed in Figure 245b. The Aesthetics beneficial use is considered fully supported based on true color values.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.05 ppt, which is lower than the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 60.3 mS/cm to 125.8 mS/cm, indicative of extremely low levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.48 to 7.76, representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With approximately 2% of the collected values less than 6.5, the lake is supporting the FWP

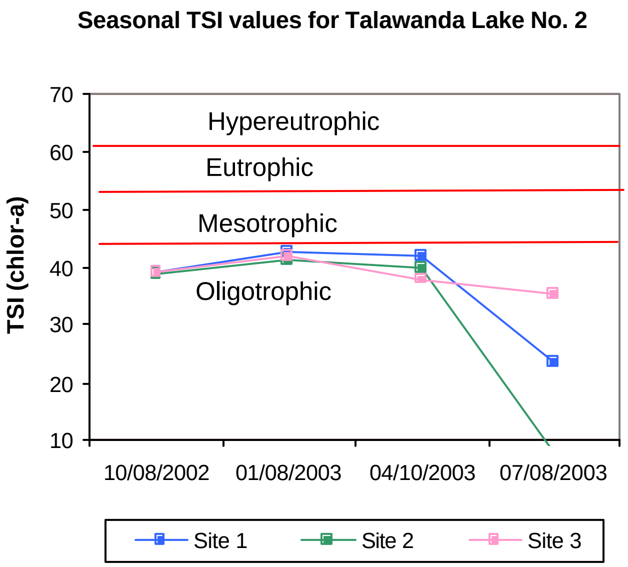



**Figure 244.** TSI values for Talawanda Lake No.2

beneficial use. The low pH values recorded at Talawanda Lake No.2 only occurred in the summer quarter and may be due to natural conditions. Oxidation-reduction potentials (ORP) ranged from 161 mV to 503 mV indicating reducing conditions were not present at this reservoir in sample year 2002-2003. In the fall, the lake was stratified at site 1 between 8 and 9 meters at which point dissolved oxygen (D.O.) dropped below 2.0 mg/L to the lake bottom of 13.2 meters (Figure 245c). In the winter and spring quarters the water column was well mixed with dissolved oxygen (D.O.) values generally above 8.0 mg/L (see Figure 245d-245e). Thermal stratification was evident and anoxic conditions were present throughout the lake in the summer. Stratification occurred between 6 and 7 meters, with 36 to 54 % of the water column experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Talawanda Lake No.2 is considered to be partially supporting the FWP beneficial use based on anoxic conditions present in the summer and fall. These conditions could pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.18 mg/L at the surface and 0.38 mg/L at the lake bottom. Surface TN ranged from 0.05 mg/L to 0.32 mg/L with the highest values recorded in the fall quarter and the lowest in the summer. The lake-wide total phosphorus (TP) average was 0.011mg/L at the surface and 0.022 mg/L at the lake bottom. The surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.005 mg/L to 0.018 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Talawanda Lake No.2 was classified as oligotrophic, indicative of low primary productivity and nutrient conditions in sample year 2003. This is consistent with historical data collection efforts, indicating no significant increase or decrease in productivity has occurred. Water clarity was excellent based on turbidity, true color, and secchi disk depth. The FWP beneficial use is supported based on turbidity and pH, but partially supporting based on dissolved oxygen values. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values. Talawanda Lake No. 2, owned by the City of McAlester, serves as a water supply and recreational reservoir.

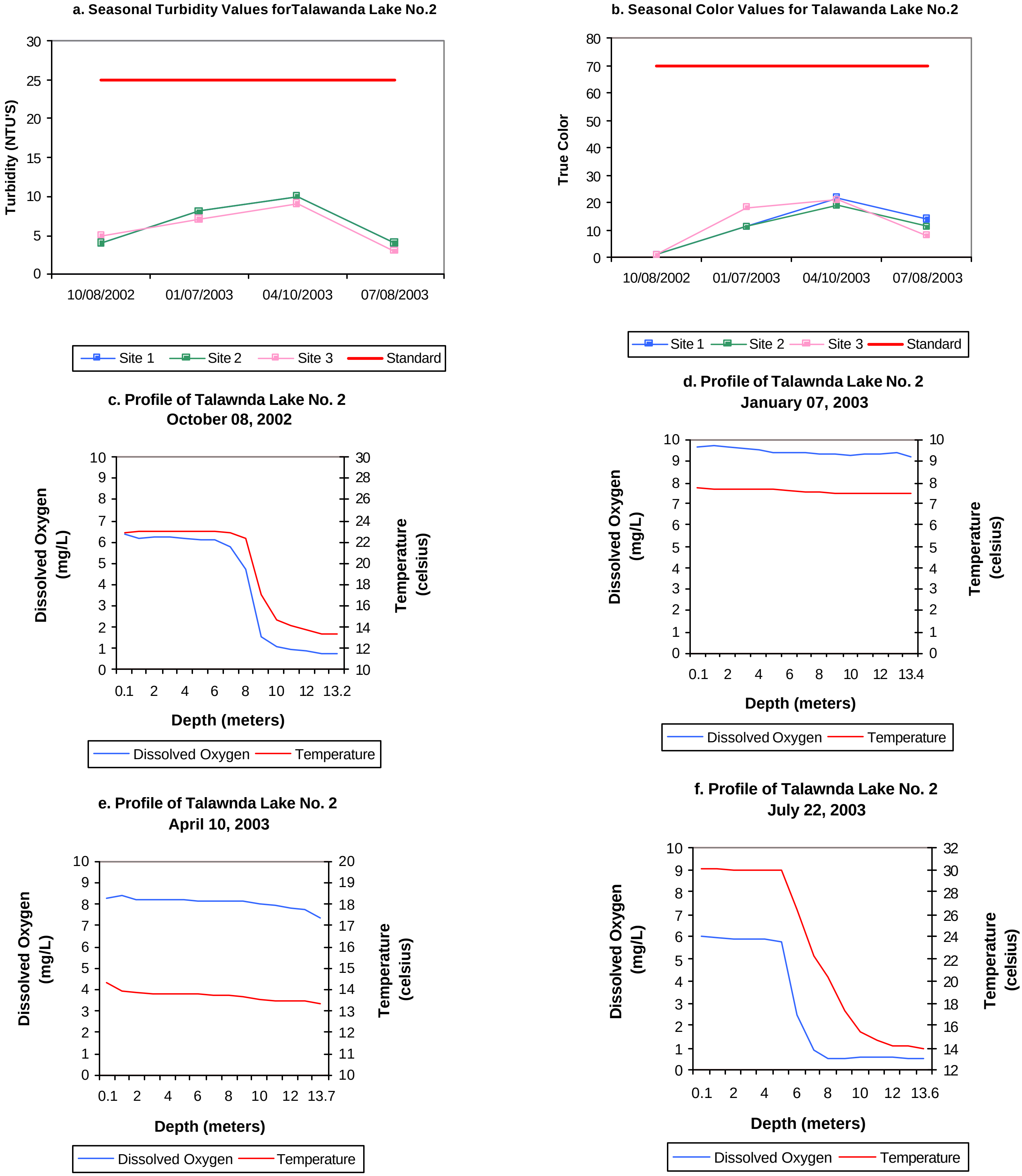
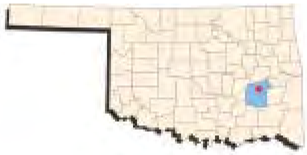
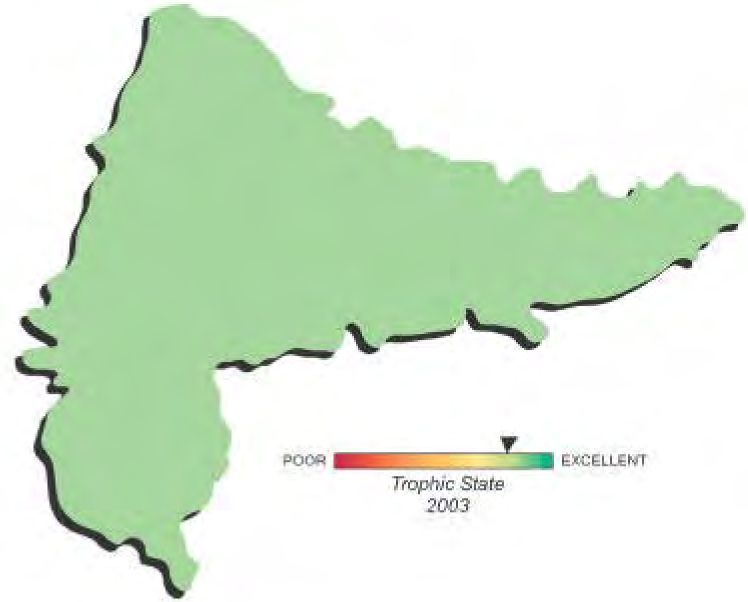
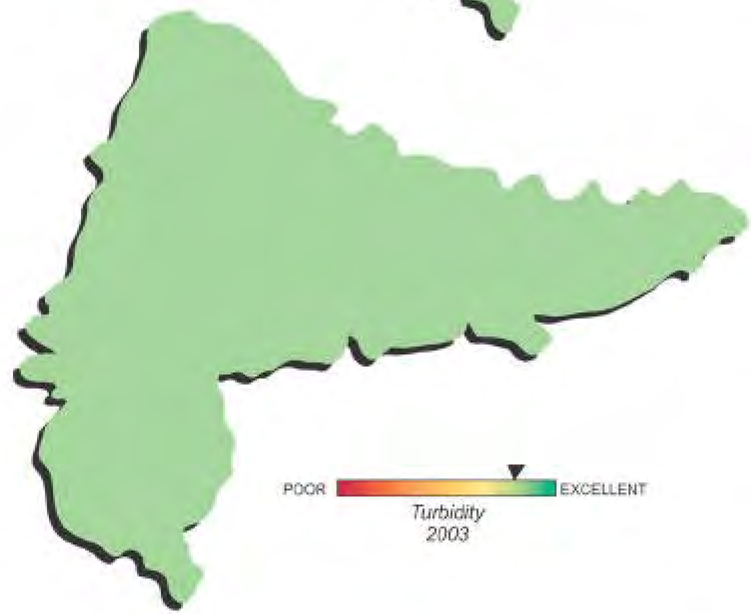



**Figure 245a-245f** Graphical representation of data results for Talawanda Lake No.2








Lake Data

| | |
|---|---|
| Owner | City of McAlester |
| County | Pittsburg |
| Constructed | 1924 |
| Surface Area | 195 acres |
| Volume | 2750 acre/feet |
| Shoreline Length | 4 miles |
| Mean Depth | 14.10 feet |
| Watershed Area | 2,304 acres |

Plate 110 - Lake Water Quality for

# Talawanda Lake No. 2

# Taylor Lake

Taylor Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected from three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 17 NTU (Plate 111), true color was 21 units, and average secchi disk depth was 47 centimeters. Based on these three parameters, Taylor Lake had average water clarity in 2002-2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 62 (Plate 111), classifying the lake as hypereutrophic, indicative of excessive primary productivity and nutrient levels. This value is similar to the one calculated in 2000 (TSI=65) indicating no significant increase or decrease in productivity has occurred since the 2001 evaluation. TSI values were fairly consistent with values ranging from upper eutrophic in the winter to hypereutrophic the remainder of the year (Figure 246). Currently, the lake listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient threatened and a nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 247a. Turbidity values ranged from a low of 7 NTU to a maximum of 33 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (OWQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is not supported at Taylor Lake with 33% of the values above the turbidity standard of 25 NTU. Seasonal true color values were all well below the OWQS of 70 and are displayed in Figure 247b. Applying the same default protocol, the Aesthetics beneficial use is fully supported based on true color values.

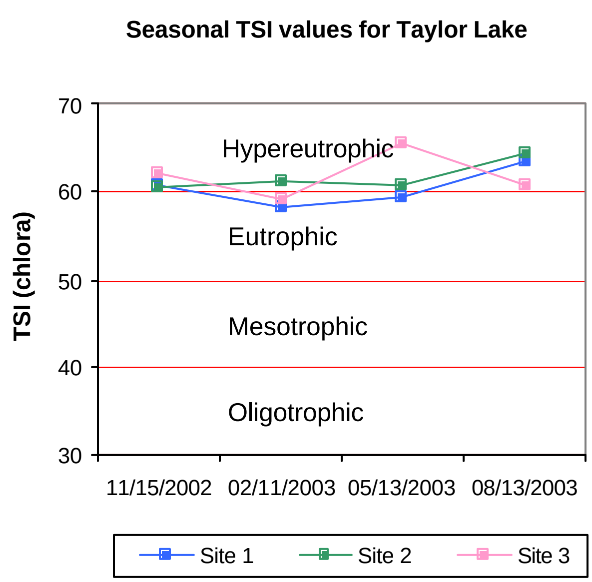



**Figure 246.** TSI values for Taylor Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.24 parts per thousand (ppt) to 0.31 ppt, which is within the range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 476.6 mS/cm to 614.7 mS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 7.10 to 8.52, representing a neutral to slightly alkaline system. According to USAP

(OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With all of the collected values within the acceptable range, the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 386 mV to 460 mV indicating the absence of reducing conditions in sample year 2002-2003. The lake was not stratified during the fall, winter, or spring sampling quarters and the water column was well mixed (see Figure 247c-247e). In the summer, thermal stratification was evident and anoxic conditions were present (Figure 247f). Stratification occurred between 3 and 4 meters, with 33% of the water column experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 33% of the collected dissolved oxygen values below 2.0 mg/L, Taylor Lake is considered partially supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.11 mg/L at the surface and 1.11 mg/L at the lake bottom. Surface TN ranged from 0.67 mg/L to 1.47 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.128mg/L at the surface and 0.142 mg/L at the lake bottom. The surface TP was highest in the summer quarter and lowest in the fall with values ranging from 0.047 mg/L to 0.204 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Taylor Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels in sample year 2002-2003. The calculated TSI was similar to that in 2000 (TSI=65), indicating no significant increase or decrease has occurred since the last evaluation. Water clarity was average based on true color, turbidity, and secchi disk depth. The FWP beneficial use is supported based on pH, partially supporting based on dissolved oxygen, but not supporting based on turbidity with 33% of the values exceeding the OWQS of 25 NTU. The Aesthetics beneficial use is supported based on its true color, but not supporting based on its trophic status. Currently, the lake is listed as a Nutrient Limited Watershed (NLW) and a nutrient impairment study should be conducted to determine if uses are threatened. Taylor Lake is leased to the City of Marlow and serves as a flood control, water supply, and recreational reservoir.

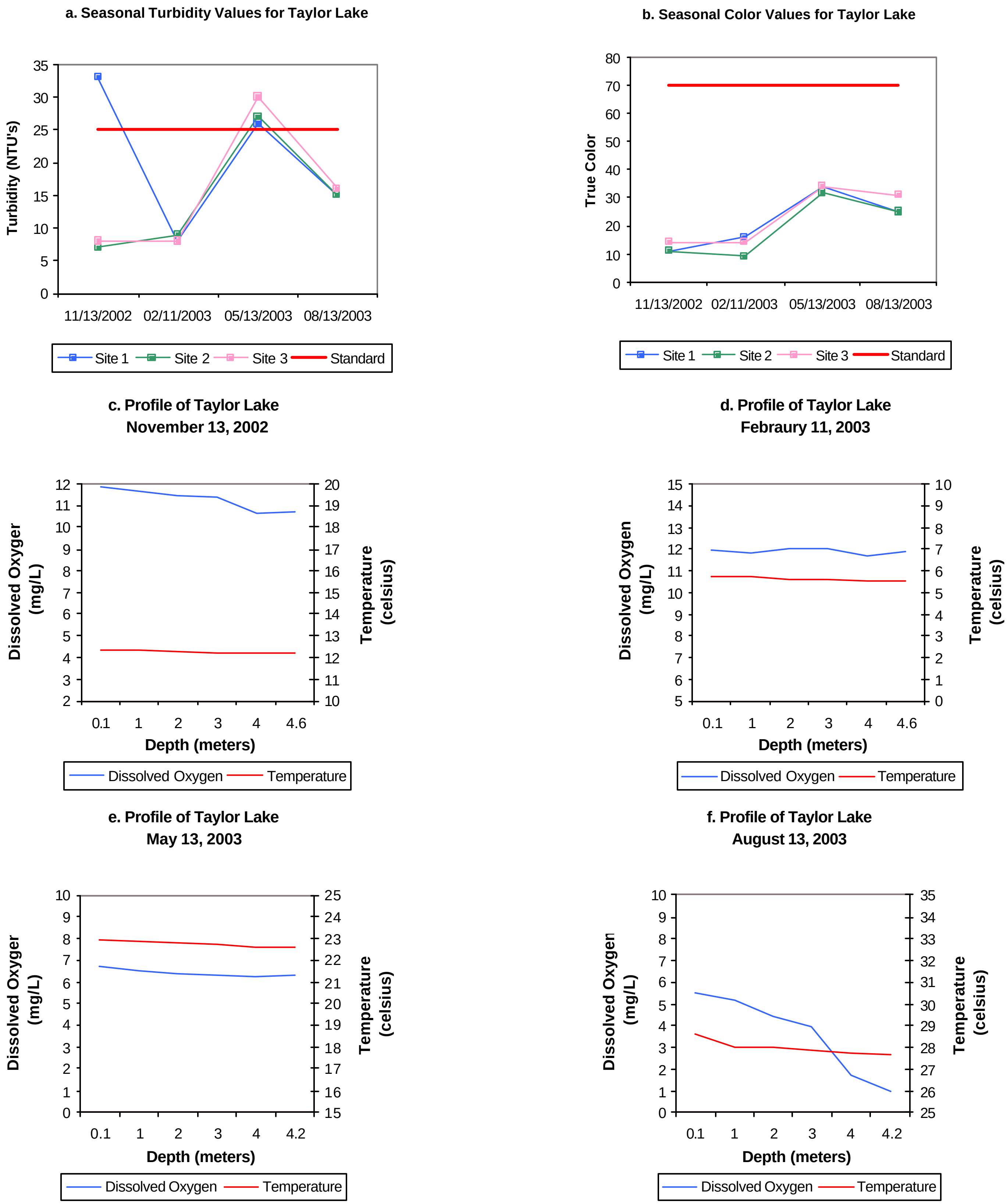



**Figure 247a-247f.** Graphical representation of data results for Taylor Lake.


| Lake Data | |
|---|---|
| Owner | Leased to City of Marlow |
| County | Grady |
| Constructed in | 1960 |
| Surface Area | 227 acres |
| Volume | 1,877 acre/feet |
| Shoreline Length | 7 miles |
| Mean Depth | 8.27 feet |
| Watershed Area | 21 square miles |

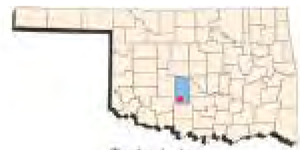






Plate 111 - Lake Water Quality for
# Taylor Lake

# Tecumseh Lake

Tecumseh Lake was sampled for three quarters, from November 2003 through August 2004. Lakes levels were such that a boat could not be launched during the winter sampling event. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 87 NTU (Plate 112), true color was 106 units, and secchi disk depth was 18 centimeters. Based on these three parameters, Tecumseh Lake had poor water clarity. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=9). The average TSI was 57 (Plate 112), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. Although based on a smaller data set this value is similar to the one calculated in 2002 (TSI=51), indicating that no significant change in productivity has occurred since the last evaluation. TSI values for this lake varied seasonally from hypereutrophic to oligo-mesotrophic in the spring and to meso-eutrophic in the summer quarter (see Figure 248). Unlike the vast majority of Oklahoma reservoirs, Tecumseh Lake was most productive in the late fall early winter, which is not commonly seen. This correlates with the fact that turbidity readings were much lower than those seen in both spring and summer quarters. With the increased availability of light to the biota the lake became much more productive. All turbidity values were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 249a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although the minimum data requirements for a lake of this size were not met it is likely that Tecumseh Lake would not be supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 249b. With 66% of the true color values well above the numeric criteria of 70 units, the lake should be listed as not supporting its Aesthetics beneficial use based on true color values; however due to data requirements not being met a definitive assessment can not be made at this time.

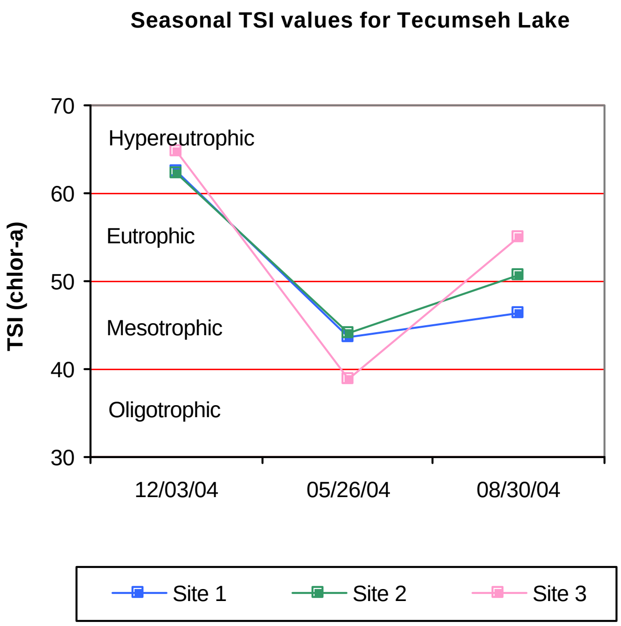



**Figure 248.** TSI values for Tecumseh Lake

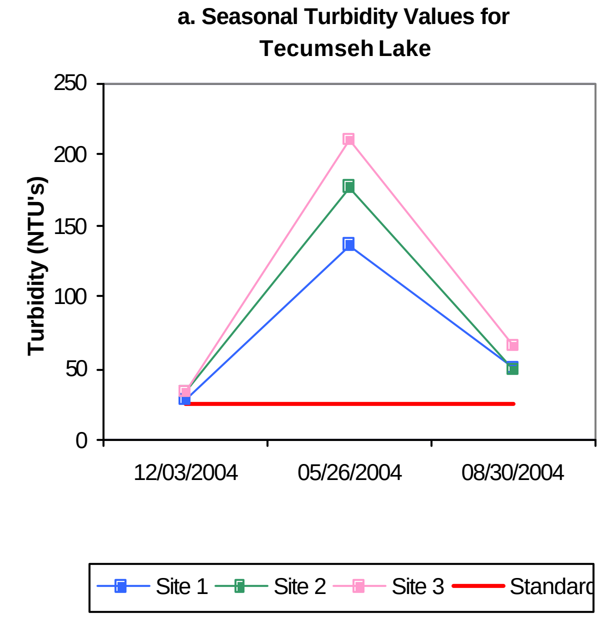
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.08 parts per thousand (ppt) to 0.18 ppt, indicating low to moderate salt content compared to most Oklahoma lakes. Specific conductance ranged from 185.1 mS/cm in the summer to 360.1 mS/cm in the fall quarter, indicating minimal to moderate levels of electrical conducting compounds (salts) were present in the lake system, corresponding with the recorded salinity values. In general, pH values were neutral to slightly alkaline, ranging from 7.11 to 8.69 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Tecumseh Lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 175 mV at the sediment-water interface in the fall quarter to 509 mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir at any point during any of the sampling events. The lake was not thermally stratified in any point during the study period and dissolved oxygen (D.O.) values were generally above 6.0 mg/L throughout the water column (see Figure 249c-249e). In the spring, there is one instance where D.O. was below 2.0 mg/L at the bottom of the lake, however this is likely due to the probe being in the sediment (See Figure 249d). In a lake as shallow as Tecumseh, thermal stratification is generally not encountered due to wind mixing of the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Tecumseh Lake as only 20% of the water column had D.O. concentrations less than 2.0 mg/L. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

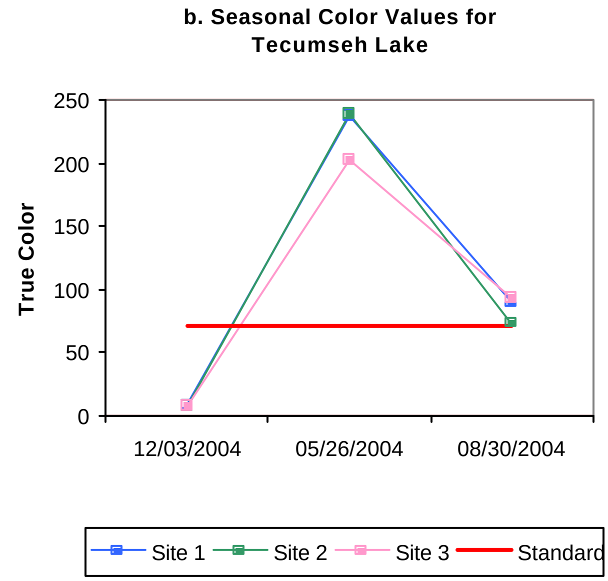
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2003-2004.

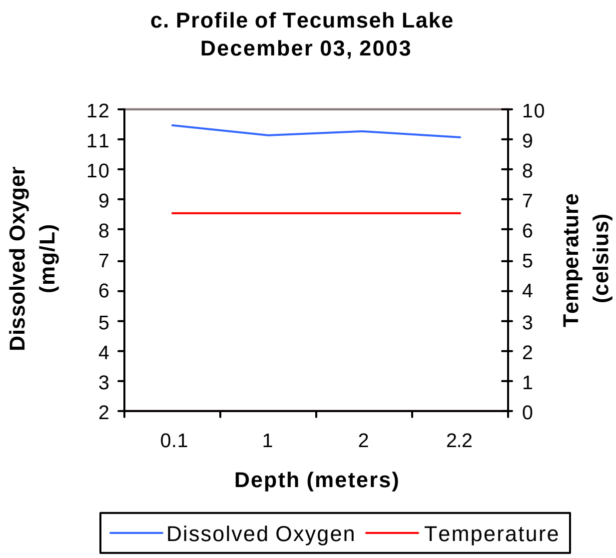
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.97 mg/L at the lake surface. The TN at the surface ranged from 0.45 mg/L to 1.62 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the summer. The lake-wide total phosphorus (TP) average was 0.090 mg/L at the lake surface. The surface TP ranged from 0.046 mg/L to 0.181 mg/L. Similar to TN, the highest surface TP value was reported in the spring and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 10:1 for sample year 2003-2004. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

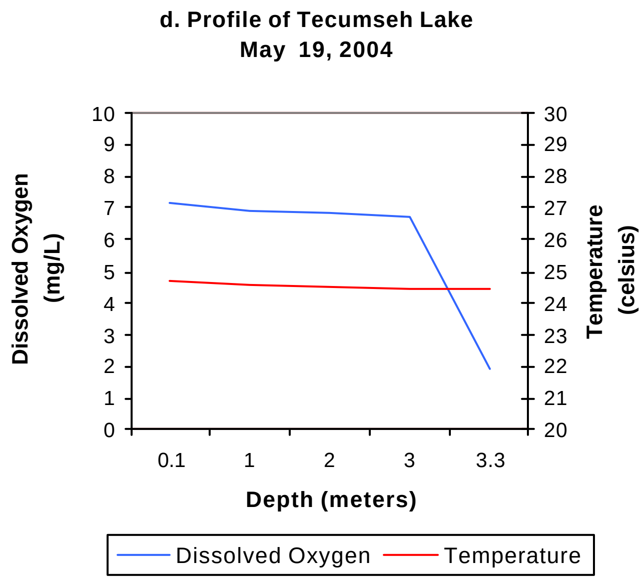
In summary, Tecumseh Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 112). Although the current TSI of 57 is slightly higher than that in 2002 (TSI=51), it is with the same trophic category, indicating no significant change in productivity has occurred since the last evaluation. Water clarity was extremely poor at this lake, which seemed to be serving a useful purpose in limiting the amount of light available to the system, thus limiting productivity. With increasing clarity in this lake, it is quite likely that it could become hypereutrophic in nature. Tecumseh Lake is fully supporting the FWP beneficial use for

D.O. and pH, and although minimum data requirement were not met for turbidity, it is likely that the use would not be supported based on current and historical data. The Aesthetics beneficial use is fully supported based on its trophic status, however minimum data requirements were not met for true color and a use determination cannot be made at this time. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. The PBCR beneficial use is considered fully supported for sample year 2003-2004.Tecumseh Lake was constructed in 1934 and is owned and operated by the City of Tecumseh. The lake is managed as a municipal water supply and offers recreational opportunities to the public.



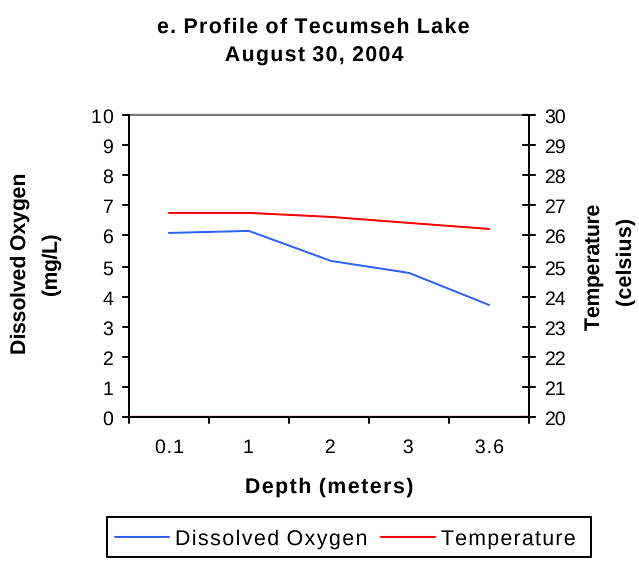




**Figure 249a-249e.** Graphical representation of data results for Tecumseh Lake.


Lake Data

| | |
|---|---|
| Owner | City of Tecumseh |
| County | Pottawatomie |
| Constructed | 1934 |
| Surface Area | 127 acres |
| Volume | 1,118 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 8.80 feet |
| Watershed Area | 3,124 acres |



Plate 112 - Lake Water Quality for
Tecumseh Lake

# Tenkiller Ferry Lake

Tenkiller Ferry Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at seven (7) sites to represent the riverine, transitional, and lacustrine zones of the lake as well as major arms. Samples were collected at the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 8 NTU (Plate 113), true color was 8 units, and secchi disk depth was 120 centimeters. Based on these three parameters, Tenkiller Ferry Lake had excellent water clarity when compared to other Oklahoma lakes. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=28). The average TSI was 56 (Plate 113), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. This value is exactly the same as the calculated TSI in 2002, indicating no significant change in productivity has occurred. TSI values varied from season to season and from site to site. Closer to the dam area TSI values were generally mesotrophic in the fall and eutrophic in the winter, spring and summer. As you moved up the lake values were generally hypereutrophic in the fall, eutrophic in the winter and spring to hypereutrophic in the summer. At the upper end of the lake TSI values were generally eutrophic or hypereutrophic year round (see Figure 250). All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 251a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Tenkiller Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 251b. All of the true color values were well below the numeric criteria of 70 units and the Aesthetics beneficial use is considered fully supported.

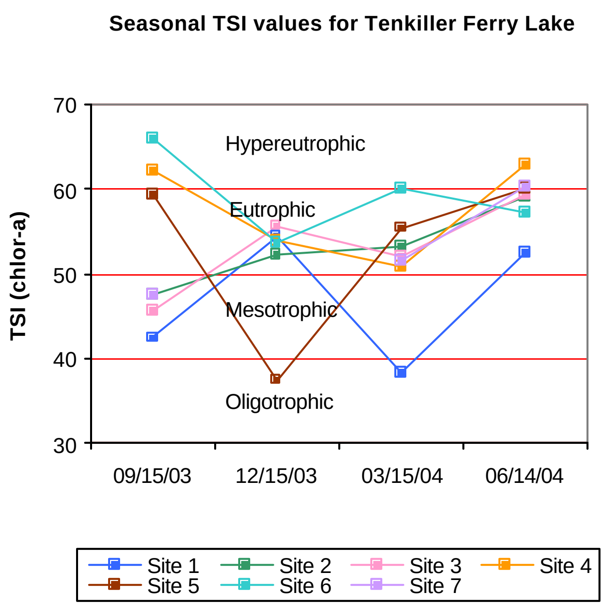



**Figure 250.** TSI values for Tenkiller Ferry Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.13 ppt, indicating low to moderate salt content compared to most Oklahoma lakes. Salinity values varied based on the site location with higher salinity occurring in the upper end of the lake. Specific conductance ranged from 155.2 mS/cm in the summer quarter to 276.5 mS/cm in the fall, indicating minimal to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, ranging from 6.65 to 8.78 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All pH values were within the acceptable range therefore Tenkiller Ferry Lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 218 mV to 520 mV in the fall. Redox readings indicated that reducing conditions were not present in the reservoir during any sampling events. The lake was not thermally stratified in the winter or spring quarters and dissolved oxygen (D.O.) readings were generally above 6.0 mg/L in the majority of the water column (Figure 251d-213e). The lake was thermally stratified in the fall quarter between 13 and 14 meters below the lake surface and D.O. values were below 2.0 mg/L from the 14 meter depth to the lake bottom at 37.8 meters at sites 1, 2 and 7 (Figure 251d). In the summer, the lake was thermally stratified at several discrete 1-meter intervals among the seven monitoring sites. the first between 6 and 7 meters with the water temperature dropping from 29.11° Celsius at 6 meters to 21.9° Celsius at 11 meters. From the 8-meter depth to the lake bottom at 38.4 meters D.O. values were all less than 2.0 mg/L (see Figure 251f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Tenkiller Ferry Lake as 50 to 64% of the water column was anoxic in the fall at site s 1,2 and 7. In the summer quarter, the percent of the water column experiencing anoxic conditions varied from 17% at site 1 to 54% at site 2, which was also resulted in a partially supporting designation. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.13 mg/L at the lake surface, which is a very high value to have as a lake average. The TN at the surface ranged from 0.0.24 mg/L to 2.90 mg/L, which is a very high nitrogen concentration to have in a lake at the surface. The highest value was observed in the spring quarter and the lowest value was in the fall. The lake-wide total phosphorus (TP) average was 0.041 mg/L at the lake surface. The surface TP ranged from 0.014 mg/L to 0.0.077 mg/L. Similar to total nitrogen, the highest surface TP value was reported in the spring and the lowest was reported in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 27:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Tenkiller Ferry Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 113). Water clarity was excellent at this lake primarily due to the absence of inorganic turbidity levels that are commonly seen in Oklahoma reservoirs. The lake was fully supporting its Aesthetics beneficial use based on trophic status and true color values. A Total Maximum Daily Load (TMDL) is currently being developed for the lake to mitigate the effects of nutrients to the system. A high level of total nitrogen in the lake was documented which should be mitigated. Tenkiller Ferry Lake was supporting its FWP beneficial use based on nephelometric turbidity and pH. The lake was partially supporting its FWP beneficial use based on low D.O. concentrations in the water column. The very low D.O. values seen in both the summer time in the lake are a cause for serious concern. Any time a larger portion of the water column has D.O. less than 2.0 mg/L you have a serious problem that should be further addressed. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported. The United States Army Corps of Engineers constructed Tenkiller Ferry Lake in 1953. The lake was authorized to serve for flood control and hydroelectric power. Today the lake serves many other purposes and is one of the most heavily used recreational lakes in Oklahoma. Tenkiller Ferry Lake is one of the lake jewels of Oklahoma and it should be managed and maintained in that fashion.

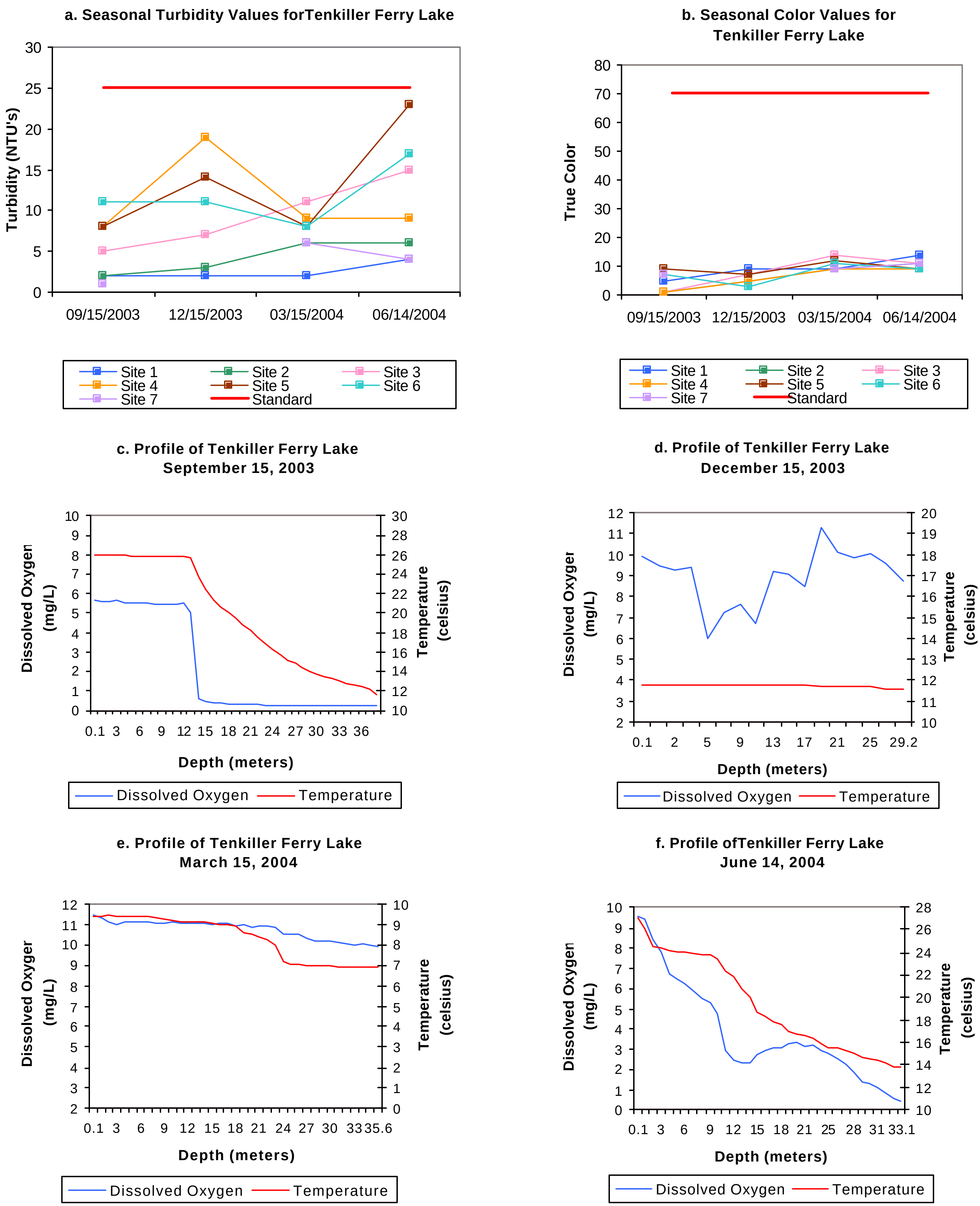
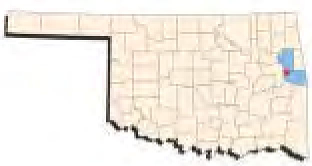



**Figure 251a-251f.** Graphical representation of data results for Tenkiller Ferry Lake.


Tenkiller Ferry Lake
and
Watershed



Tenkiller Ferry Lake
Location

Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Sequoyah |
| Constructed in | 1953 |
| Surface Area | 12,900 acres |
| Volume | 654,100 acre/feet |
| Shoreline Length | 130 miles |
| Mean Depth | 50.7 feet |
| Watershed Area | 1,610 square miles |

POOR EXCELLENT
*Turbidity*
*2004*

POOR EXCELLENT
*Trophic State*
*2004*

Plate 113 - Lake Water Quality for
## Tenkiller Ferry Lake

# Lake Texoma

Lake Texoma was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected from thirteen (13) sites to represent the riverine, transition, and lacustrine zones and major arms of the reservoir. Samples were collected at the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The average lake-wide turbidity value was 10 NTU (Plate 114), true color was 16 units, and secchi disk depth was 115 centimeters. Based on these three parameters, Lake Texoma had excellent water clarity compared to other Oklahoma lakes. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=52). The average TSI was 54 (Plate 114), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient conditions. This is similar to the TSI from 2000 (TSI=57), indicating no significant increase or decrease in productivity has occurred since the last evaluation. TSI values varied from season to season and from site to site. In the fall and winter, values spanned all four trophic categories (see Figure 252). Sites 8-13 (Red River arm) were generally eutrophic to hypereutrophic throughout the sample year. Closer to the dam area, TSI values were generally mesotrophic in the fall, winter, and spring. In the summer quarter, sites were divided between the eutrophic and hypereutrophic categories. Seasonal turbidity values ranged from a low of 2 NTU to a maximum of 42 NTU and are displayed in Figure 253a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Texoma is partially supporting its Fish and Wildlife Propagation (FWP) beneficial use with 10% of the collected turbidity values exceeding the standard. Seasonal true color values are displayed in Figure 253b. All of the true color values were well below the numeric criteria of 70 units and the Aesthetics beneficial use is considered fully supported.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.50 parts per thousand (ppt) at site 4 (Washita River arm) to 1.67 ppt at site 11 (Red River arm), which is higher than the range of values recorded in

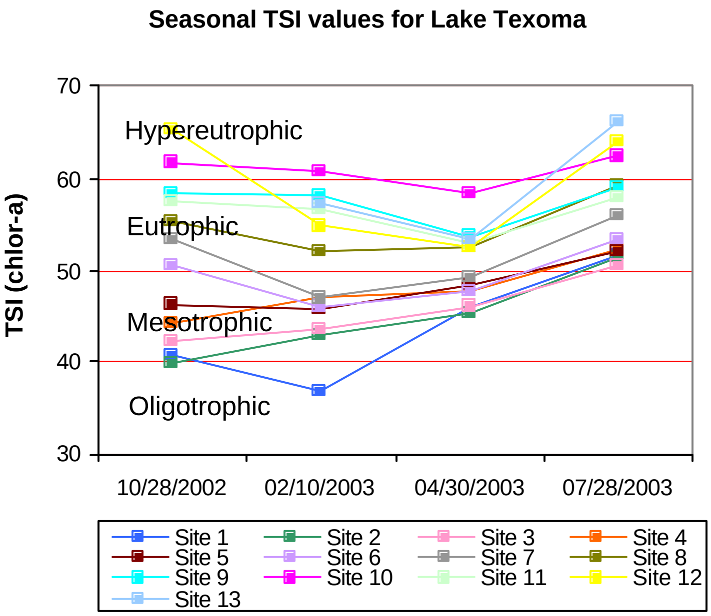



**Figure 252.** TSI values for Lake Texoma.

Oklahoma reservoirs. Specific conductance ranged from 959.5 mS/cm to 3086 mS/cm, indicative of high levels of current conducting ions (chlorides and salts) in the lake system, consistent with salinity values. The recorded values for pH ranged from 6.71 to 8.34, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all of the collected values within the acceptable range, the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 22 mV in the hypolimnion during the fall to 634 mV in the winter. Reducing conditions were not present at this reservoir with values above generally 100 mV except for a couple of values recorded at the lake bottom at the sediment-water interface. Stratification was not evident during the fall, winter, or spring sampling quarters and the water column was well mixed (see Figure 253c-215e). In the fall, collected dissolved oxygen (D.O.) values are suspect with all values at site 1 and site 6 at or below 2.0 mg/L while all other sites are generally above 5.0 mg/L. Although the Hydrolab was calibrated before the sample trip the values recorded at these two sites are unusually low and seem questionable. In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline. Stratification occurred between 9 and 10 meters throughout the lake, with 23 to 60% of the water column experiencing anoxic conditions (Figure 253f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Lake Texoma is considered partially supporting the FWP beneficial use based on low dissolved oxygen values recorded during the summer. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.55 mg/L at the surface and 0.52 mg/L at the lake bottom. Surface TN ranged from 0.14 mg/L to 1.04 mg/L with the highest values recorded in the summer quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.035mg/L at the surface and 0.055 mg/L at the lake bottom. The surface TP ranged from 0.015 mg/L to 0.086 mg/L with both high and low values recorded in the summer. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Texoma was classified as eutrophic, indicative of high primary productivity and nutrient conditions in sample year 2002-2003. These results are similar to those of 2000 (TSI=57), indicating no significant increase or decrease in productivity has occurred over time. Water clarity was excellent based on turbidity, true color, and secchi disk depth. The FWP beneficial use is fully supported based on pH, but partially supported based on turbidity and dissolved oxygen values. The Aesthetics beneficial use is supported based on its trophic status and true color values. Lake Texoma, constructed by the United States Army Corps of Engineers

(USACE) is utilized for flood control, water supply, hydroelectric power, flow regulation, navigation, and recreation purposes.

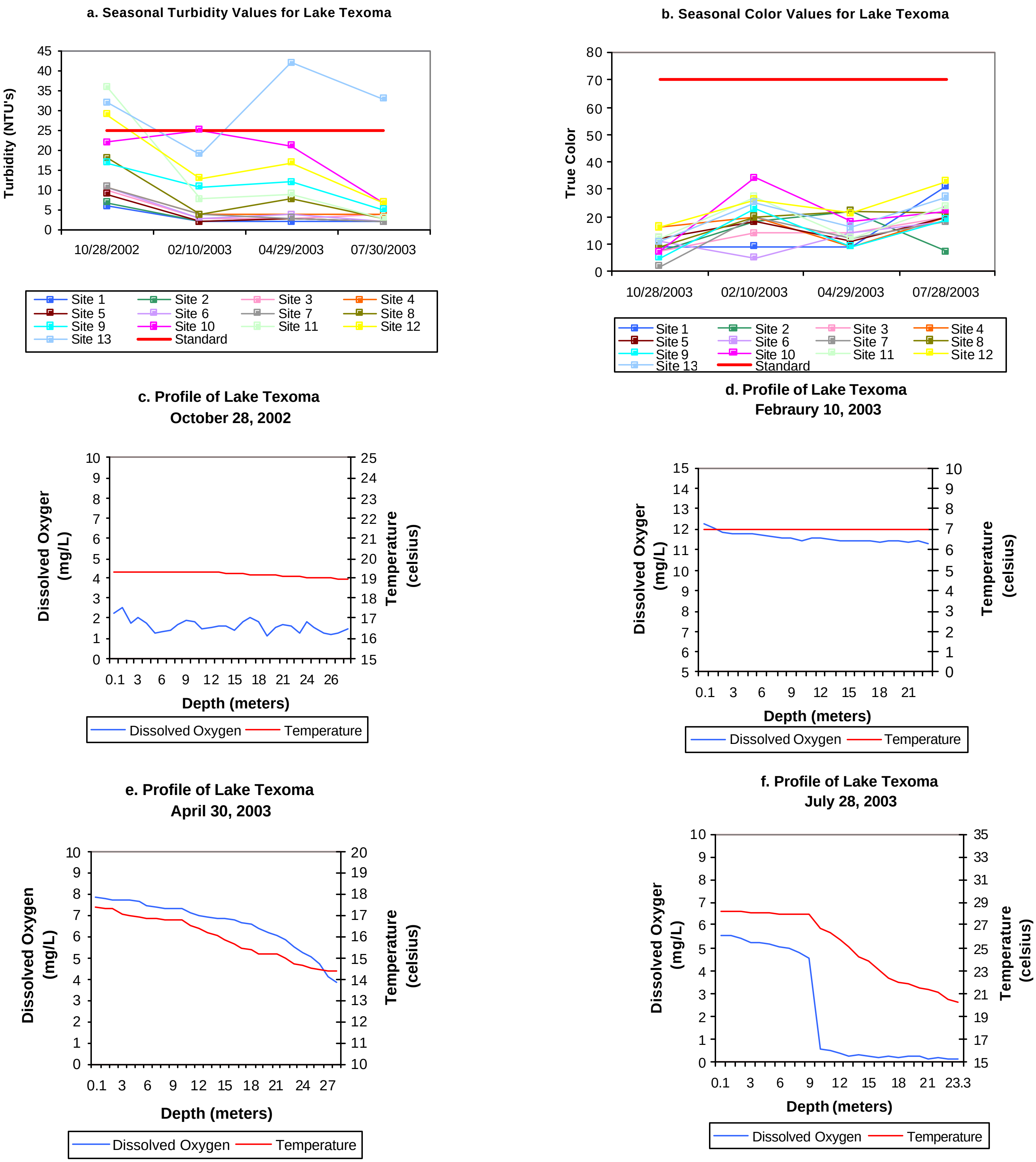
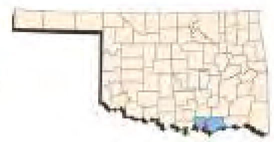
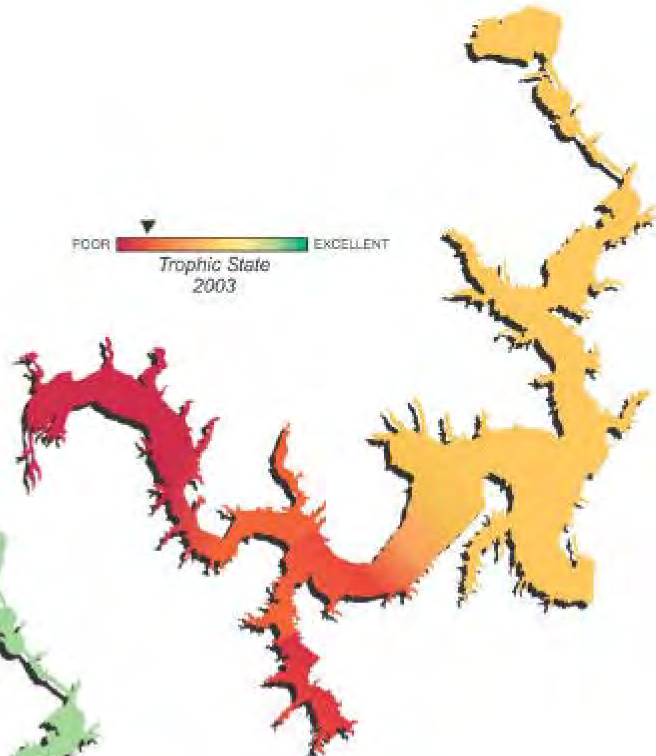
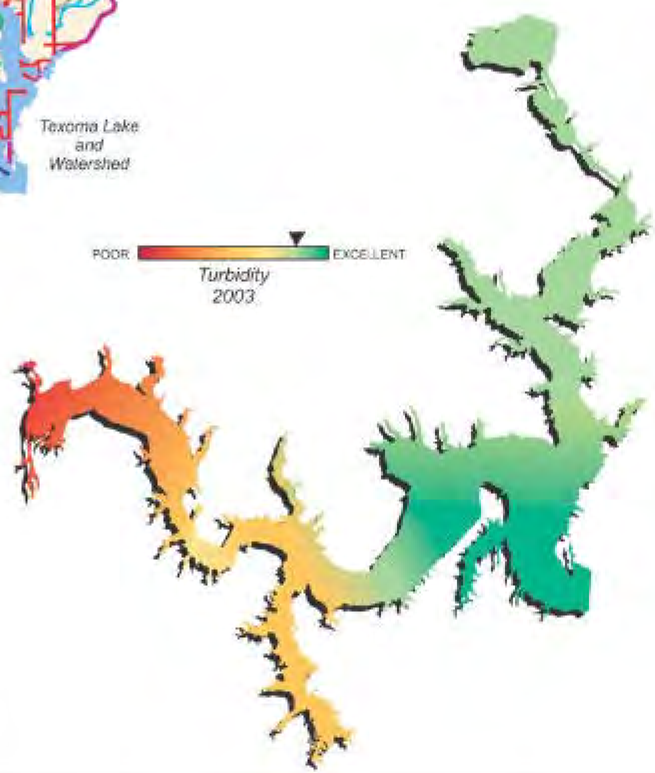



**Figure 253a-253f.** Graphical representation of data results for Lake Texoma.


Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Bryan |
| Constructed in | 1949 |
| Surface Area | 88,000 acres |
| Volume | 2,643,300 acre/feet |
| Shoreline Length | 580 miles |
| Mean Depth | 30.6 feet |
| Watershed Area | 39,719 square miles |

Plate 114 - Lake Water Quality for

## Texoma Lake

# Lake Thunderbird

Lake Thunderbird was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at seven (7) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major arms. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 24 NTU (Plate 115), true color was 15 units, and secchi disk depth was 55 centimeters in 2003-2004. Based on these three parameters, Lake Thunderbird had average water clarity, similar to water clarity in 2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=28). The average TSI was 58 (Plate 115), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is slightly higher than the TSI in 2001 (TSI=56), although in the same trophic category. The TSI varied seasonally from hypereutrophic in the fall and summer to mesotrophic and eutrophic in the winter and spring quarters (Figure 254). The chlorophyll-a concentrations were generally lower at the dam site and lacustrine areas of the lake (sites 1, 2, and 4) and higher at the upper end, or riverine zones of the lake (sites 5, 6, and 7). Seasonal turbidity values are displayed in (Figure 255a). Only six of the 28 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU; however, this constitutes a listing as partially supporting the Fish & Wildlife Propagation (FWP) beneficial use as 22% of the samples were above the criteria. According to USAP (OAC 785:46-15-5), a beneficial use is considered not supported if =25% of the samples exceeds the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Seasonal true color values are displayed in (Figure 255b). All true color values were below the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.16 parts per thousand (ppt) to 0.23 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 308.6 mS/cm in the fall quarter to 461.3 mS/cm in the spring, indicating low to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, ranging from 7.19 to 8.38 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake

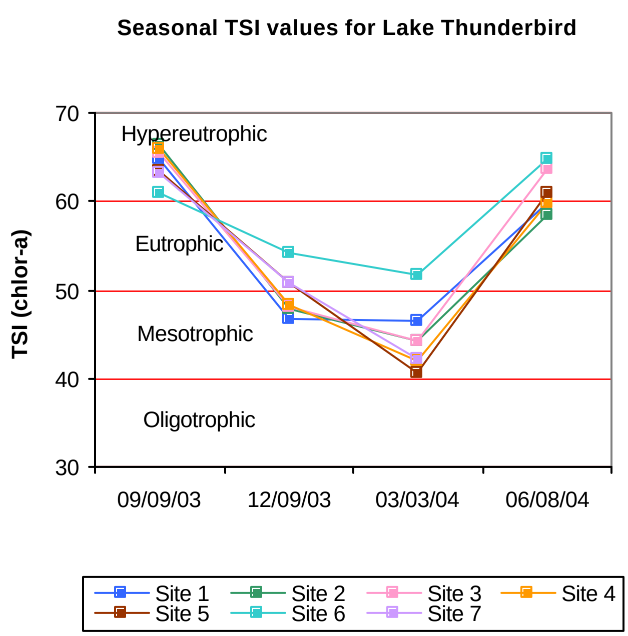



**Figure 254. TSI values for Lake Thunderbird.**

should be listed as partially supporting its FWP beneficial use. The lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 326 mV at the sediment-water interface in the winter to 551 mV in the spring quarter. Redox readings indicate that reducing conditions were not present in the reservoir during sampling events. The lake was thermally stratified in the fall near the lake bottom at sites 1,2 and 4, between 8 and 9 meters with dissolved oxygen (D.O.) falling below 2.0 mg/L from 9 meters in depth to the lake bottom of 10.3, (see Figure 255c). In the summer quarter, the lake was thermally stratified between 8 and 9 meters and again between 10 and 11 meters below the lake surface at site 1, the dam. Water column D.O. values were less than 2.0 mg/L from 11 meters in depth to the lake bottom at 12.6 meters (see Figure 255f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Lake Thunderbird, as 25% of the water column was anoxic at site 1 in the fall and 20% was anoxic in the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body contact Recreation (PBCR) beneficial use. Samples were collected at five sites for E. coli, fecal coliform and enterococci during the recreation season of May through September. Of the 10 samples collected one (1) or 10% of the samples exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.11 mg/L at the lake surface and 0.83 mg/L at the lake bottom. The TN at the surface ranged from 0.49 mg/L to 1.25 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was recorded in the summer. The lake-wide total phosphorus (TP) average was 0.041 mg/L at the lake surface and 0.038 mg/L at the lake bottom. The surface TP ranged from 0.025 mg/L to 0.087 mg/L. The highest surface TP value was reported in the fall and the lowest was in the spring quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 27:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Thunderbird was eutrophic, indicative of high primary productivity and nutrient conditions (Plate). The calculated TSI was very similar to that sample year 2002 (TSI=56), indicating no significant change in productivity has occurred. Water clarity was average based on secchi disk depth, turbidity and true color values. The lake was fully supporting its Aesthetics beneficial use based on its trophic state and true color. The lake was also fully supporting its FWP beneficial use based on pH and dissolved oxygen; however it is partially supporting based on turbidity readings. Bacteriological samples were also collected to assess the Primary Body contact Recreation (PBCR) beneficial use. Of the 10 samples collected one (1) or 10% of the samples exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Lake Thunderbird was constructed in 1965 and is owned by the Bureau of Reclamation. The lake serves as a municipal water supply for flood control, fish and wildlife and offers numerous recreational opportunities to the public. In 2001 a bathymetric survey (Figure 256) was conducted to determine current capacity and assess sedimentation rates due to lake Thunderbird's turbidity problems. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

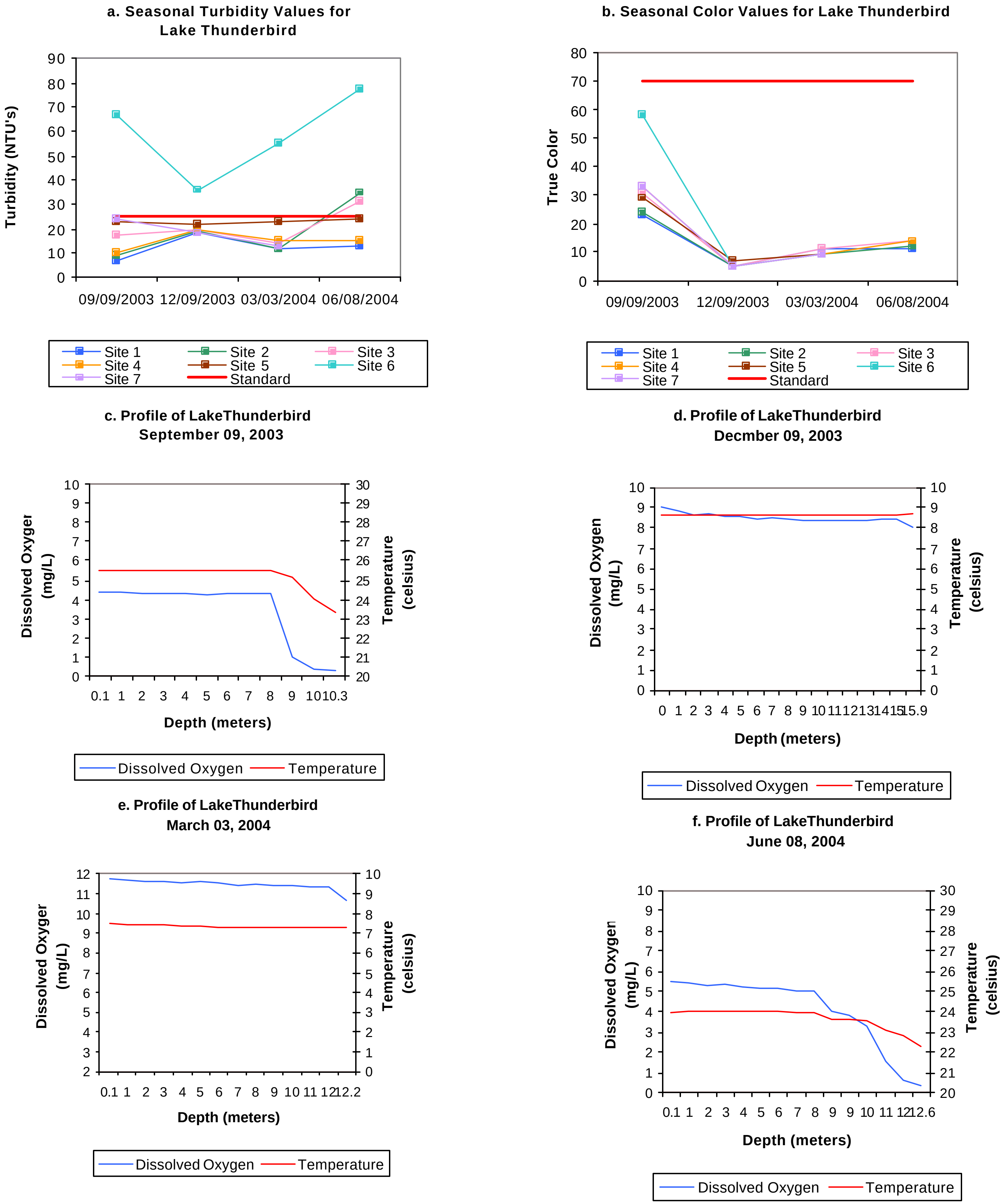



**Figure 255a-255f. Graphical representation of data results for Lake Thunderbird.**

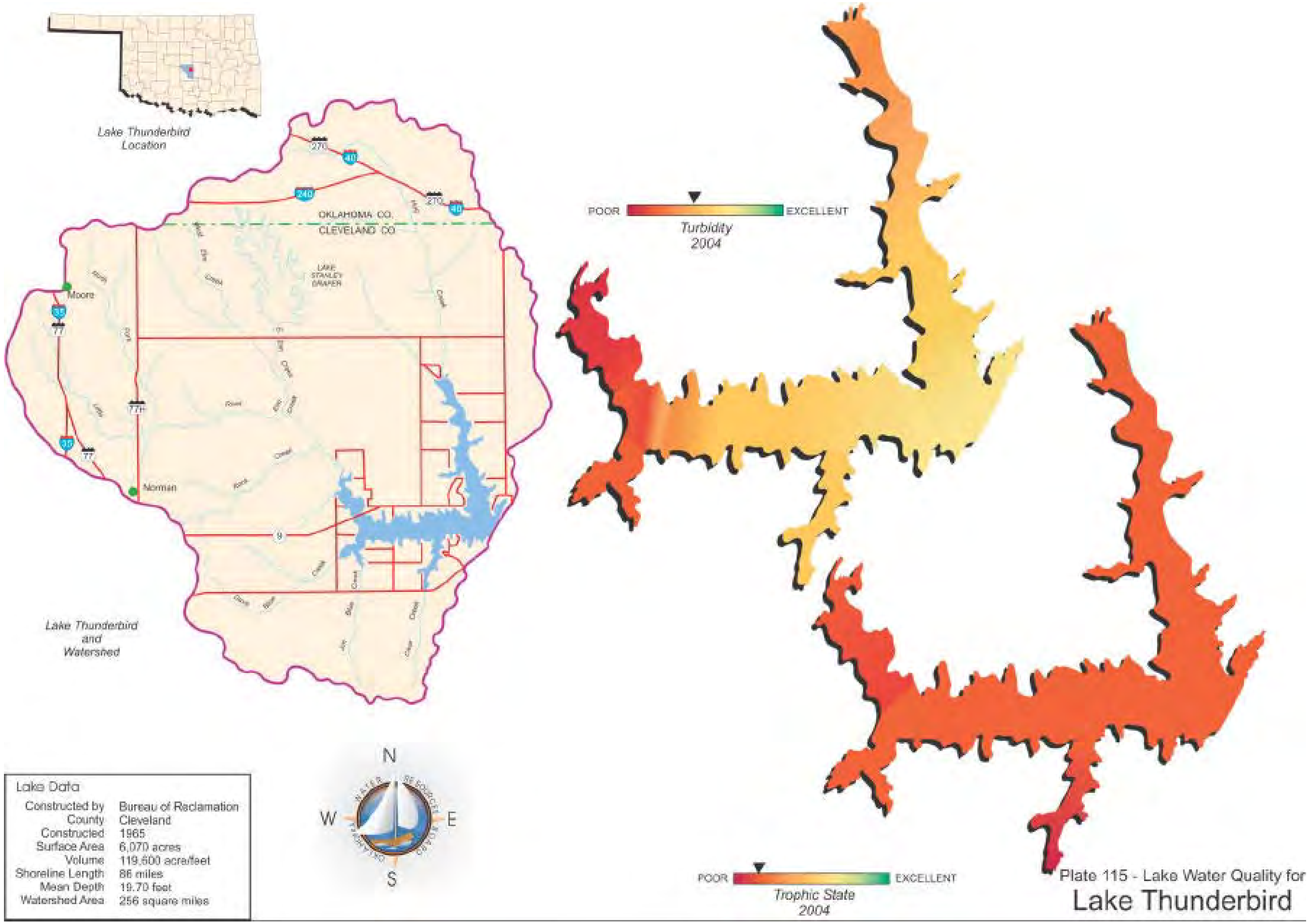



Plate 115 - Lake Water Quality for
Lake Thunderbird

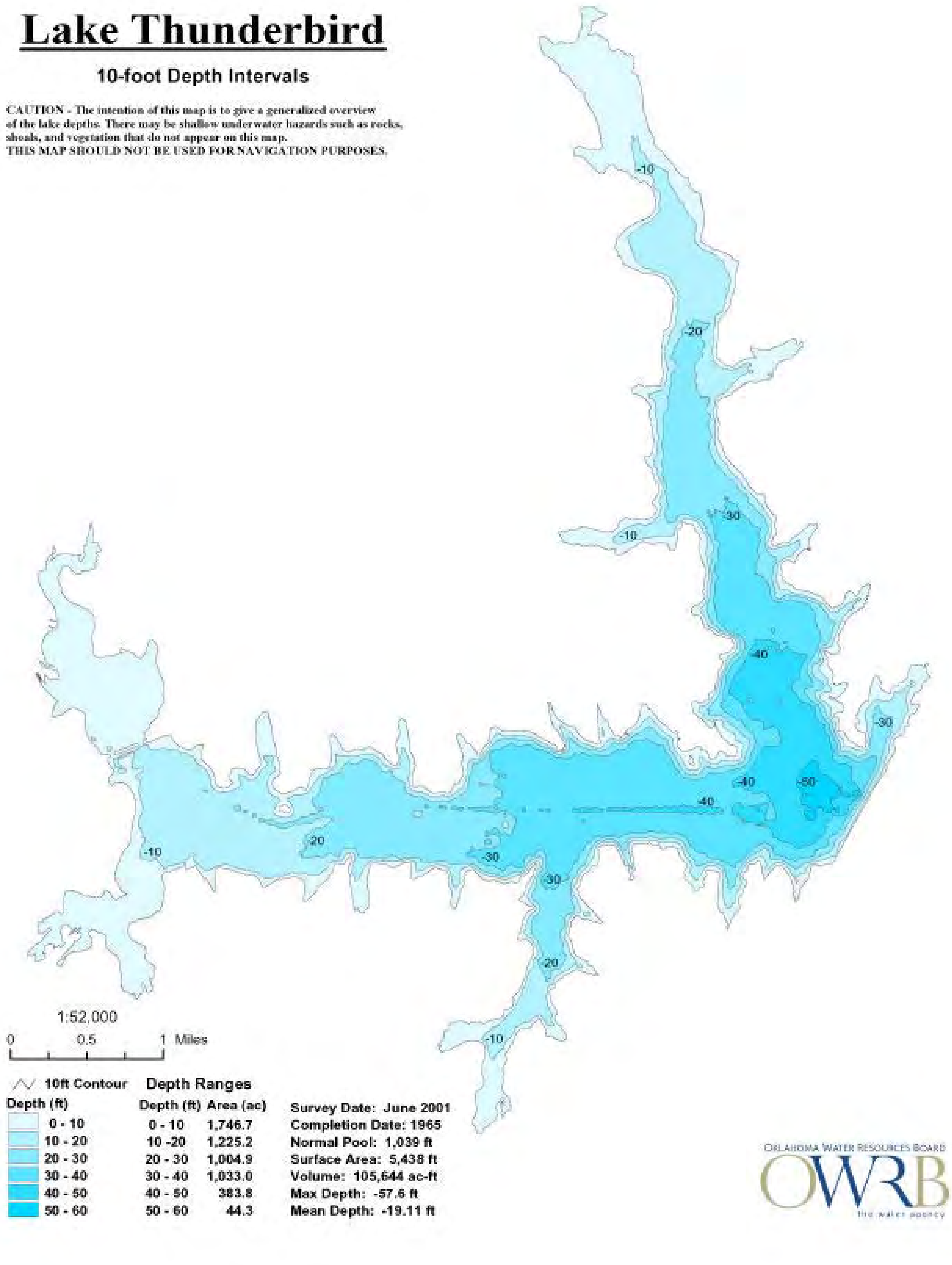



**Figure 256.** Bathymetric map of Lake Thunderbird.

# Tom Steed Reservoir

Tom Steed Reservoir was sampled for four quarters, from October 2002 through June 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the summer and spring to represent the riverine, transition, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a lake greater than 250 surface acres. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 52 NTU (Plate 116), true color was 36 units, and average secchi disk depth was 43 centimeters. Based on these three parameters Tom Steed Reservoir had average to poor water clarity in sample year 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using values collected at all sites four quarters (n=20). The TSI was 52 (Plate 116), indicating the lake was eutrophic with high primary productivity and nutrient conditions. This is similar to the TSI in 2000 (TSI=56), indicating no significant increase or decrease in productivity has occurred since the last evaluation. The TSI values were eutrophic in the fall, winter, and summer quarters and mesotrophic in the winter (Figure 257). The only exceptions being sites, 4 and 5, which were classified, as oligotrophic in the winter quarter. Seasonal turbidity values are displayed in Figure 258a. Turbidity values ranged from a low of 25 NTU to a maximum of 62 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. With 100% of the samples exceeding 25 NTU, the beneficial use of Fish and Wildlife propagation (FWP) should be considered not supported in regards to turbidity; however due to an accident in the lab there is not enough data to make an assessment. Seasonal true color values are displayed in Figure 258b. All color values were well below the aesthetics OWQS of 70 units. Appling the same default protocol the Aesthetics beneficial use is considered fully supported.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.42 parts per thousand (ppt) to 0.52 ppt for this sample year. Specific conductance ranged from 807.6 to 986.8 mS/cm, which is higher than most Oklahoma reservoirs. These values indicate moderate to high levels of electrical current conducting compounds (salts) in the lake, consistent with higher salinity concentrations. The pH values at Tom Steed Reservoir were slightly acidic,

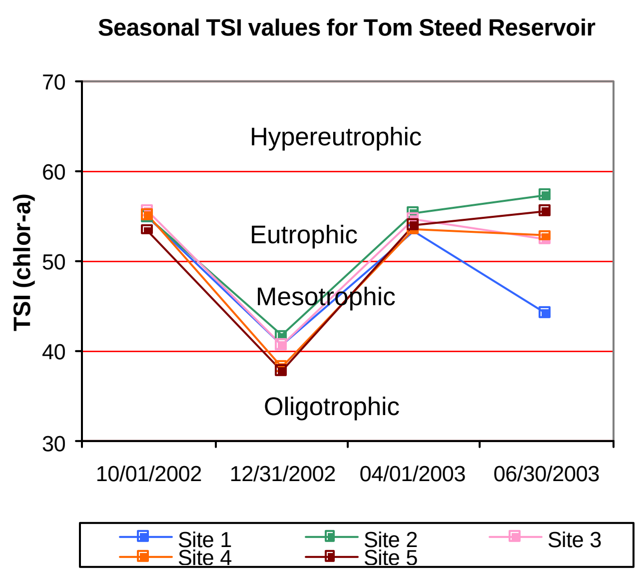



**Figure 257.** TSI values for Tom Steed Reservoir.

ranging from 4.97 in the winter to 8.43 in the spring. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 25% of the values recorded being less than 6.5 the lake is not supporting the FWP beneficial use based on pH. Oxidation-reduction potentials ranged from 367 mV in the fall to 562 mV in the spring, indicating the absence of reducing conditions in sample year 2002-2003. Due to the shallow nature of the lake thermal stratification was not present during any of the sampling quarters and the water column was well mixed with dissolved oxygen (D.O.) values generally above 6 mg/L (see Figure 258c-258f). With 100% of the collected values greater than 2.0 mg/L, the lake is considered fully supporting its FWP beneficial use based on dissolved oxygen. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.65 mg/L at the surface and 0.64 mg/L at the lake bottom. Surface TN ranged from 0.42 mg/L to 1.02 mg/L with the highest values recorded in the summer quarter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.059 mg/L at the surface and 0.057 mg/L at the lake bottom. The surface TP ranged from 0.015 mg/L to 0.086 mg/L with the highest values recorded in the summer and lowest values recorded in the winter. The nitrogen to phosphorus ratio (TN:TP) was 11:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Tom Steed Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient conditions. This is consistent with data collection efforts in sample year 2000 (TSI=56) indicating no change in trophic status has occurred over time. Water clarity was fair to poor based on turbidity, true color, and secchi disk depth in 2003. The lake is supporting the FWP beneficial use based on dissolved oxygen, however a use determination based on turbidity could not be made due to insufficient data. Although the minimum data requirements of 20 samples for lakes greater than 250 surface was not met, the collected data suggests that the FWP would not be supported with 100% of the collected values exceeding the OWQS of 25 NTU. Low pH values recorded in the winter may be due to natural causes and therefore the lake will be listed as “provisionally not supporting”***** the FWP. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values. The Bureau of Reclamation constructed Tom Steed Reservoir for municipal and industrial water supply, flood control, and fish and wildlife purposes.

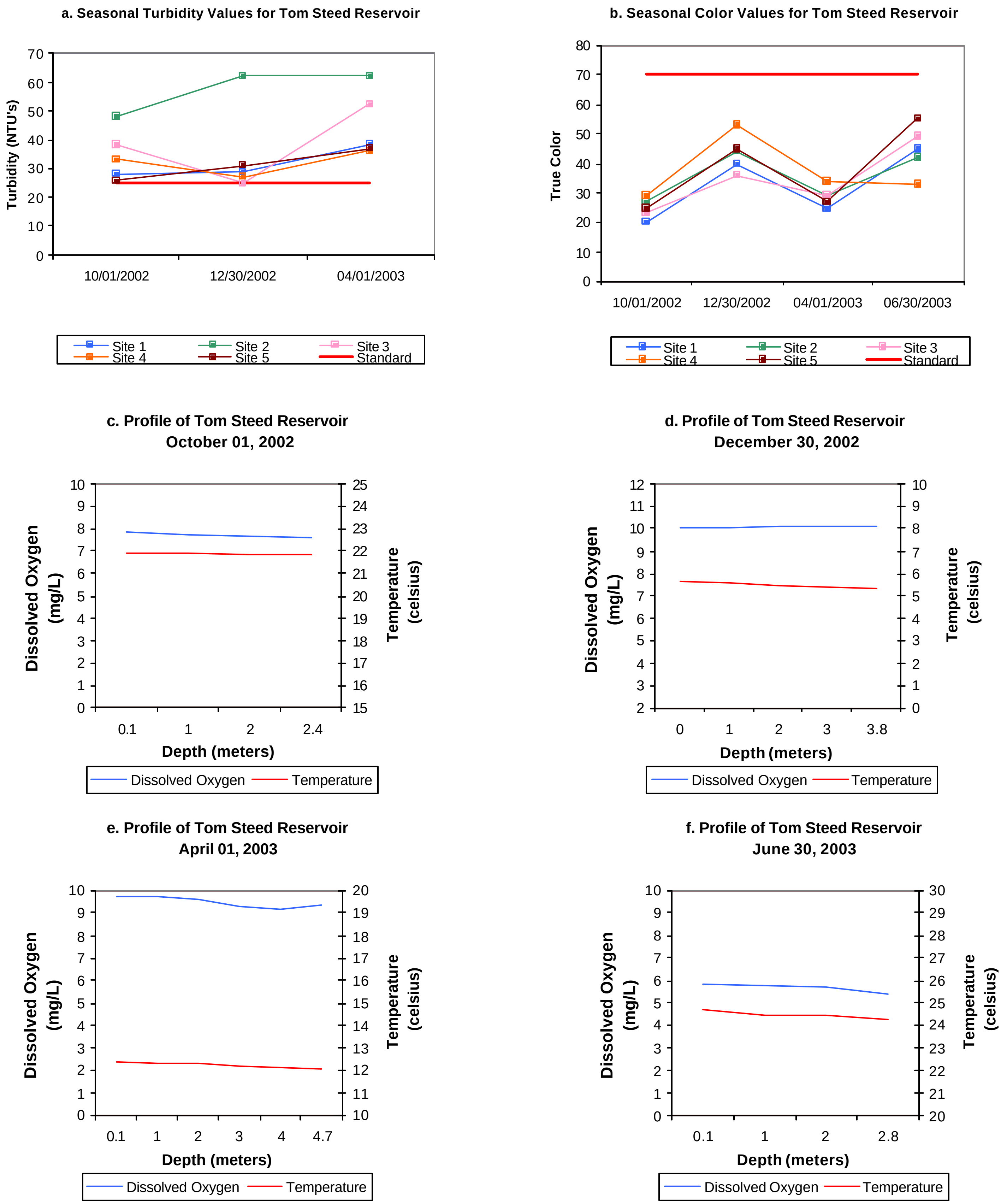
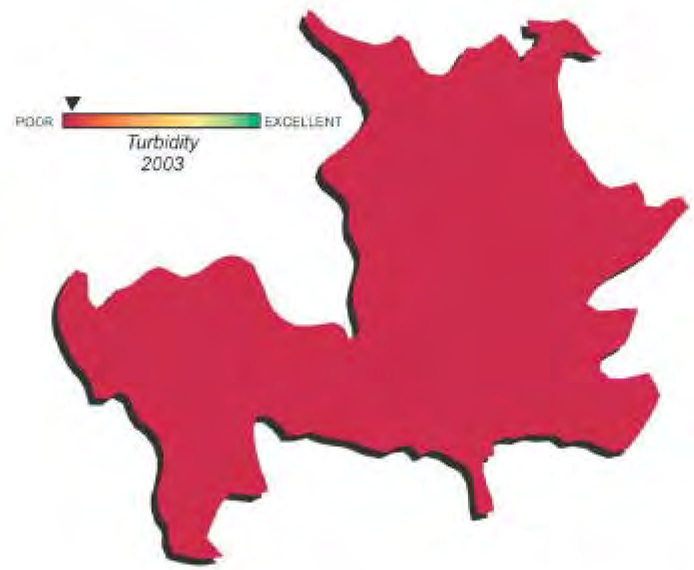



**Figure 258a-258f.** Graphical representation of data results for Tom Steed Reservoir.


Tom Steed Reservoir
and
Watershed

Tom Steed Reservoir
Location


Lake Data

| | |
|---|---|
| Constructed by | Bureau of Reclamation |
| County | Kiowa |
| Constructed in | 1980 |
| Surface Area | 6,400 acres |
| Volume | 88,970 acre/feet |
| Shoreline Length | 31 miles |
| Mean Depth | 15.08 feet |
| Watershed Area | 681 square miles |

Plate 116 - Lake Water Quality for
## Tom Steed Reservoir

# Lake Vanderwork

Lake Vanderwork was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 8 NTU (Plate117), true color was 11 units, and secchi disk depth was 71 centimeters in 2003-2004. Based on these three parameters, Lake Vanderwork had average to good water clarity in comparison to other Oklahoma lakes. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 60 (Plate 117), classifying the lake as eutrophic bordering hypereutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values varied seasonally with the fall quarter characterized by hypereutrophic conditions and the other three quarters at the upper end of eutrophy bordering at hypereutrophy (see Figure 259). These results are slightly lower than in the previous evaluation in 2002 (TSI=63). Lake Vanderwork is currently listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW). This listing means the lake is considered threatened due to nutrients and a nutrient impairment study should be initiated to determine if the Aesthetics beneficial use is supporting or not supporting. All turbidity values were below the OWQS of 25 NTU (see Figure 260a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Vanderwork is fully supporting its Fish and Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 260b. All true color values were less than the Aesthetics criteria of 70 units, therefore, the use is considered fully supported.

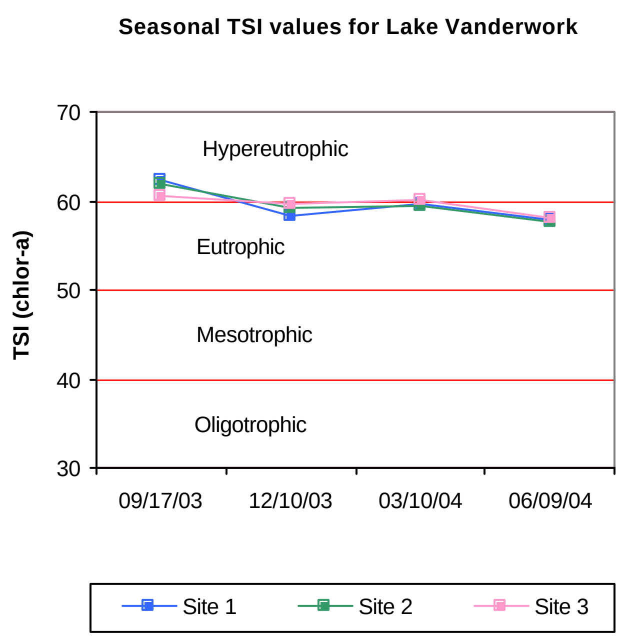



**Figure 259.** TSI values for Lake Vanderwork.

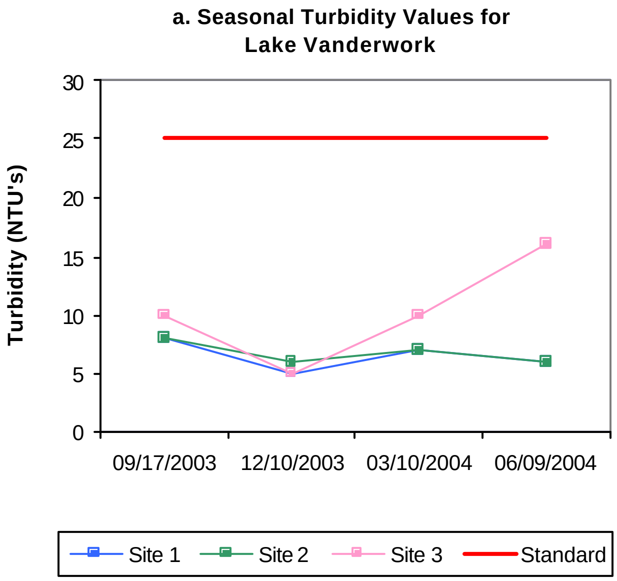
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 1.03 parts per thousand (ppt) to 1.09 ppt. Values were higher than the range of expected values for Oklahoma lakes, reflecting the presence of high concentrations of chlorides or other salts in the lake. Specific conductance values were also elevated above the expected range for Oklahoma reservoirs, indicative of high salinity concentrations. Values ranged from 1923 mS/cm in the spring quarter to 2031 mS/cm at site 1 in the winter, indicating that high levels of electrical conducting compounds (salts) were present in the lake system. Oxidation-reduction potentials (redox) ranged from 377 mV at the sediment-water interface in the winter to 528 mV in the spring, indicating reducing conditions were not present in the lake during the study period. The pH values were neutral to slightly alkaline with values ranging from 7.36 units in the spring quarter to 8.07 recorded in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. None of the collected pH values were outside the acceptable range; therefore the lake is fully supporting its FWP beneficial use based on pH. Thermal stratification was not evident in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L throughout the water column (see Figure 260c-260e). Due to equipment failure there is no profile data available for the summer sampling interval. However it is likely that thermal stratification occurred and anoxic conditions would be present based on seasonality and previous evaluations. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lake Vanderwork with all values in the first three quarters well above 2.0 mg/L. Because the summer profile data is missing an assessment for that season cannot be made at this time. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

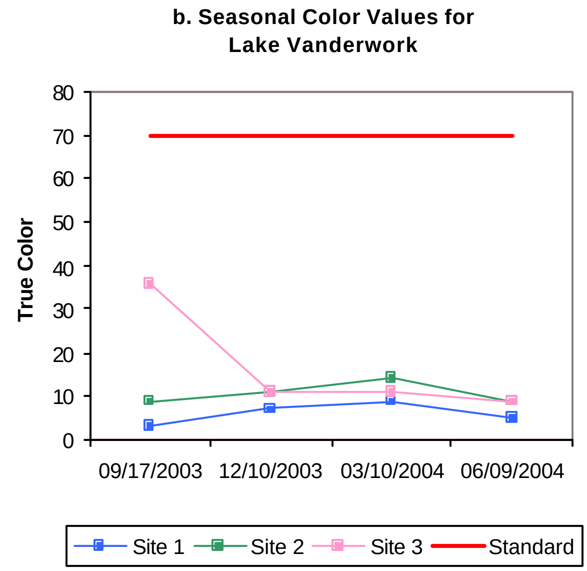
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for E. coli, fecal coliform and enterococci analysis during the recreation season of May through September. Of the 10 samples collected one (1) or 10% of the samples collected exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

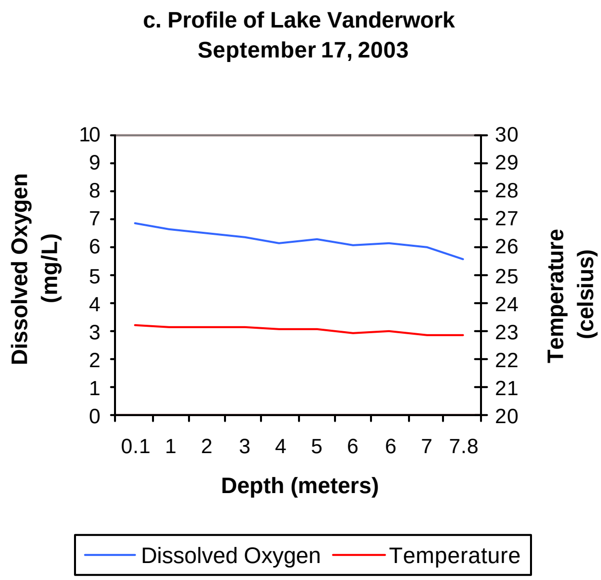
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.40 mg/L at the lake surface and 1.56 mg/L at the lake bottom. The TN at the surface ranged from 1.01 mg/L to 1.77 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the summer. The lake-wide total phosphorus (TP) average was 0.044 mg/L at the lake surface and 0.049 mg/L at the lake bottom. The surface TP ranged from 0.007 mg/L to 0.63 mg/L. Both the highest and lowest reported values occurred in the summer. The nitrogen to phosphorus ratio (TN: TP) was approximately 32:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

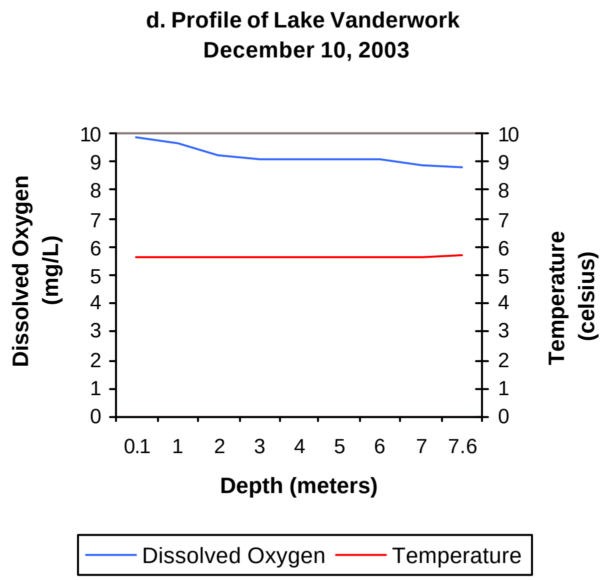
In summary, Lake Vanderwork was classified as eutrophic bordering hypereutrophic, indicative of excessive primary productivity and nutrient rich conditions (Plate). The Aesthetics beneficial use is considered fully supported based on true color values, however a determination cannot be made based on trophic status. Currently, the lake is listed in the OWQS as a NLW indicating that the Aesthetics beneficial use is considered threatened by nutrients. The lake should be monitored intensively to determine if the Aesthetics beneficial use is supported for nutrients. The FWP beneficial use is fully supported based on nephelometric turbidity, pH, and D.O.

concentrations in the water column. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples collected one (1) or 10% of the samples collected exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Lake Vanderwork was constructed in 1968 and is owned and operated by the State of Oklahoma. This lake is managed by the Oklahoma Department Wildlife Conservation and serves as a fishery.



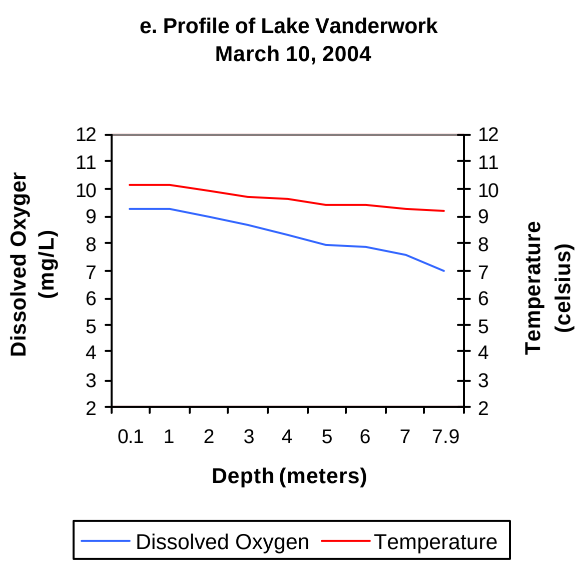
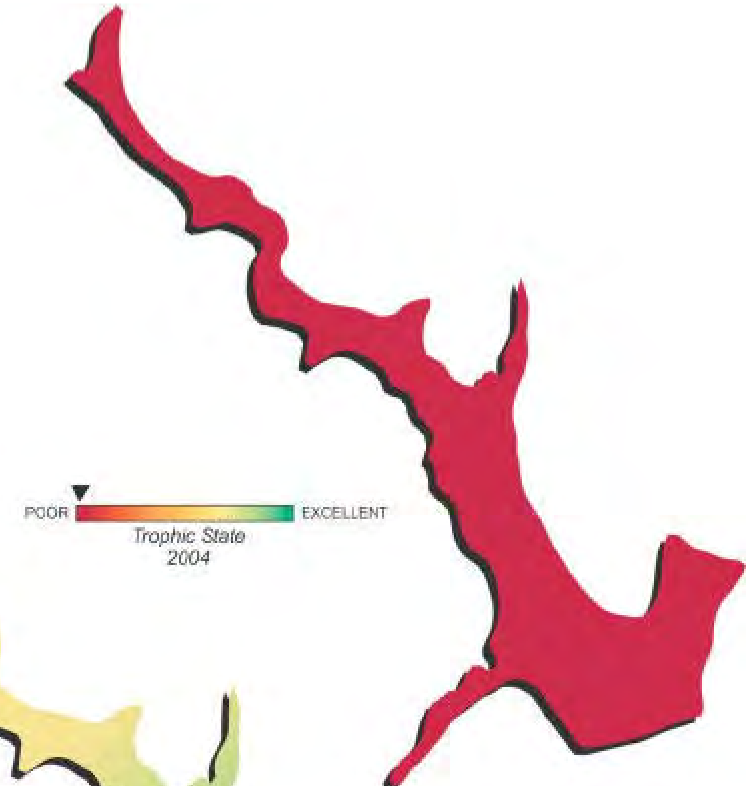
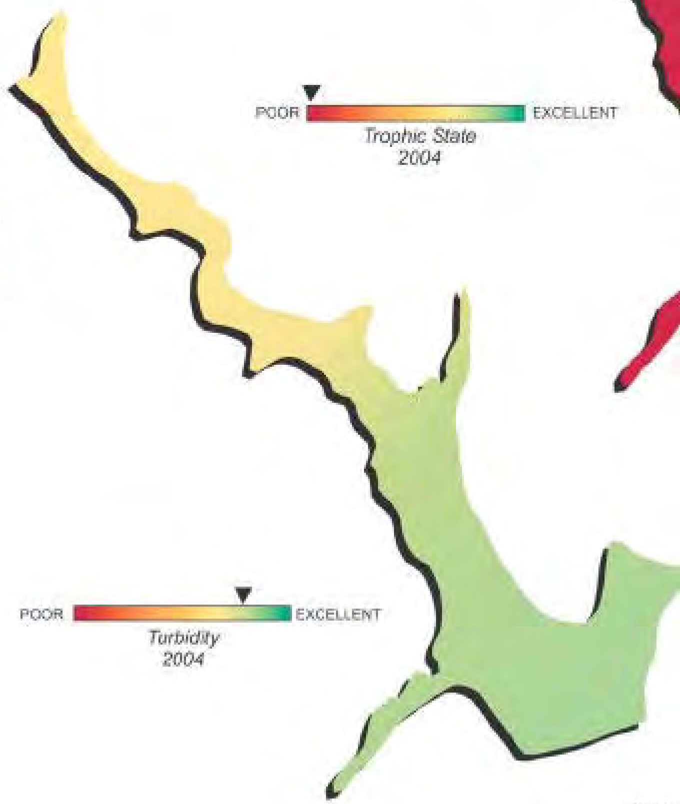




**Figure 260a-260e.** Graphical representation of data results for Lake Vanderwork.






Lake Data

| | |
|---|---|
| Owner | State of Oklahoma |
| County | Washita |
| Constructed in | 1968 |
| Surface Area | 135 acres |
| Volume | 1,578 acre/feet |
| Shoreline Length | 6 miles |
| Mean Depth | 11.69 feet |
| Watershed Area | 10 square miles |

Plate 117 - Lake Water Quality for
## Vanderwork Lake

# Lake Vincent

Lake Vincent was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The average lake-wide turbidity value was 11 NTU (Plate 118), true color was 15 units, and secchi disk depth was 109 centimeters. Based on these three parameters, Lake Vincent had excellent water clarity in comparison to other Oklahoma lakes. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 42 (Plate 118), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. This is similar to results in 2000 (TSI=48), indicating no significant increase or decrease in productivity has occurred over time. The TSI values were primarily mesotrophic throughout the year except in the spring when values for all sites were in the oligotrophic category (see Figure 261). The TSI of 42 seems to accurately represent conditions at Lake Vincent. Seasonal turbidity values are displayed in Figure 262a. Turbidity values ranged from a low of 4 NTU to a maximum of 30 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 8% of the collected values above the OWQS of 25 NTU, Lake Vincent is fully supporting its Fish and Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure. All true color values were less than the Aesthetics criteria of 70 units, therefore, the use is considered fully supported (Figure 262b).

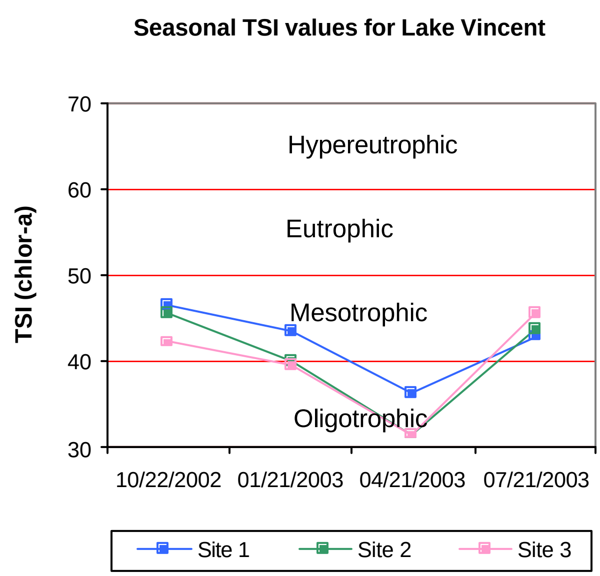



**Figure 261.** TSI values for Lake Vincent.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.38 parts per thousand (ppt) to 0.42 ppt, which is higher than the average range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 736.6 mS/cm to 801.4 mS/cm, indicative of moderate to high levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 7.16 to 8.33, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With all of the collected values within the acceptable range, the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 38 mV in the hypolimnion in the summer to 609 mV in the fall. In general, reducing conditions were not present with recorded values above 100 mV, except in the hypolimnion at site 1 during the summer. The lake was not stratified during the fall, winter, or spring sampling quarters and the water column was well mixed (see Figure 262c-262e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline. The lake was stratified between 4 and 5 meters throughout the lake, with up to 58% of the water column experiencing anoxic conditions (Figure 262f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 58% of the collected dissolved oxygen values below 2.0 mg/L, Lake Vincent is considered partially supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the surface and 0.62 mg/L at the lake bottom. Surface TN ranged from 0.12 mg/L to 0.69 mg/L with the highest values recorded in the winter quarter and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.020 mg/L at the surface and 0.031 mg/L at the lake bottom. The surface TP was highest in the fall quarter and lowest in the spring with values ranging from 0.013 mg/L to 0.029 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 23:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Vincent was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. This is consistent with past data collection efforts in 2000 (TSI=48), indicating that no significant increase or decrease in productivity has occurred over time. Water clarity was excellent based on true color, turbidity, and secchi disk depth. The FWP beneficial use is fully supported based on turbidity and pH, but only partially supported based on anoxic conditions present in the summer. The Aesthetics beneficial use is fully supported based on its trophic status and true color values. Lake Vincent is located in Ellis County and is utilized for recreation.

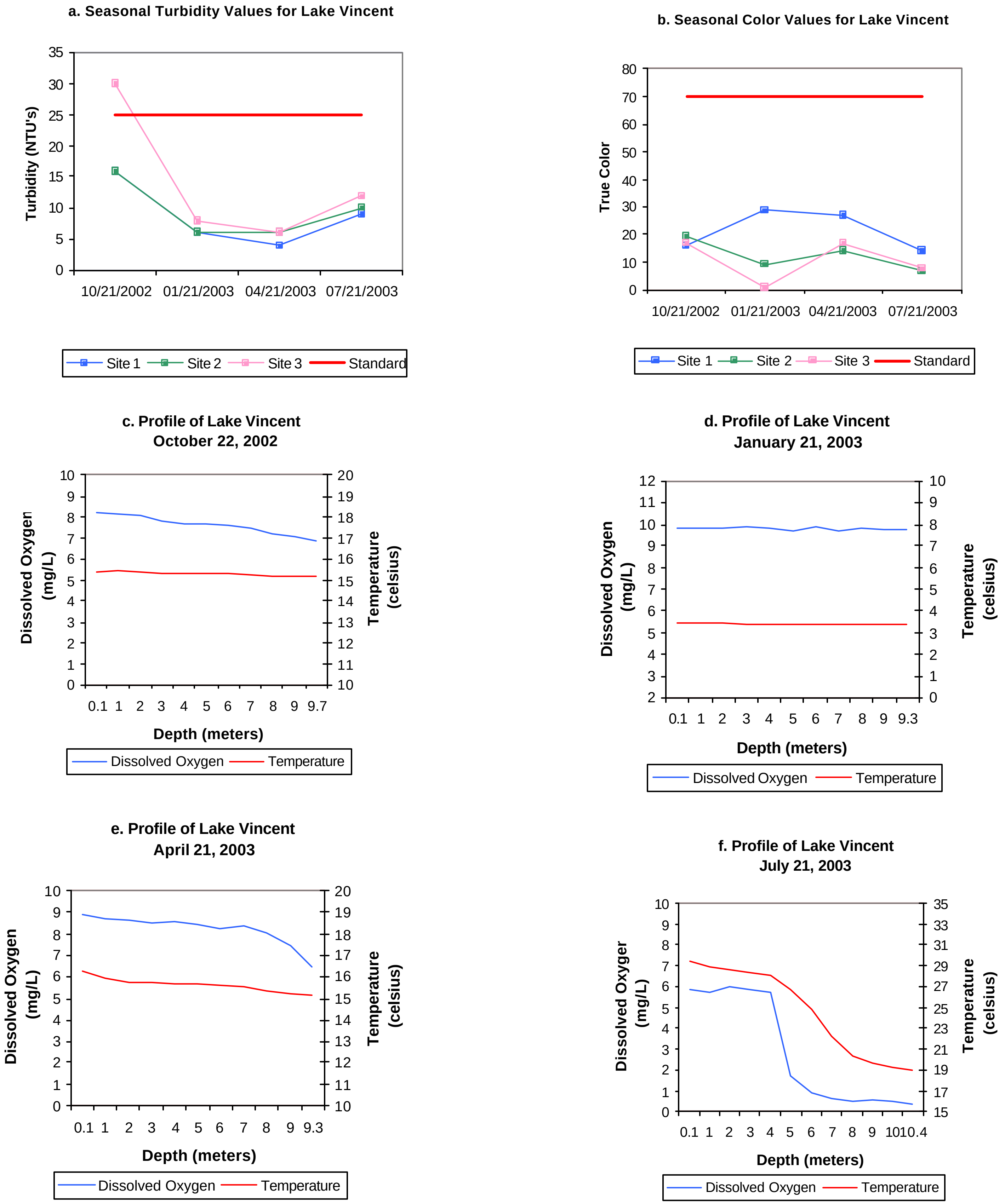
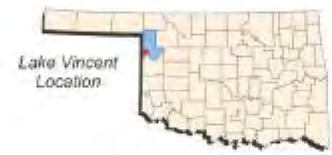



**Figure 262a-262f.** Graphical representation of data results for Lake Vincent.







Lake Data

| | |
|---|---|
| Owner | State of Oklahoma |
| County | Ellis |
| Constructed in | 1961 |
| Surface Area | 160 acres |
| Volume | 2,579 acre/feet |
| Shoreline Length | 5 miles |
| Mean Depth | 16.12 feet |
| Watershed Area | 13 square miles |

Plate 118 - Lake Water Quality for
Lake Vincent

# W.R. Holway Reservoir

W.R. Holway Reservoir was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition, and lacustrine zone of the reservoir. Additional sites were added to ensure sample size was representative for lakes larger than 250 surface acres. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 5 NTU (Plate 119), true color was 16 units, and average secchi disk depth was 151 centimeters. Based on theses three parameters, W.R. Holway Reservoir had excellent water clarity, similar to that in 2000. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 50 (Plate 119), classifying the lake as mesotrophic, bordering eutrophic, with moderate levels of productivity and nutrient conditions. This is lower than results in 2000 (TSI=57), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values were fairly consistent and ranged from mesotrophic in the first three quarters to eutrophic in the summer (see Figure 263). Seasonal turbidity values are displayed in Figure 264a. Turbidity values ranged from a low of 3 NTU to a maximum of 13 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With all collected values well below the OWQS of 25 NTU, W.R. Holway is fully supporting its Fish and Wildlife Propagation (FWP) beneficial use in regards to turbidity. Seasonal true color values are displayed in Figure 264b. All true color values were less than the Aesthetics criteria of 70 units, however the minimum data requirements (20 samples) were not met and a use determination cannot be made at this time.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.22 ppt in sample year 2002-2003. This is within the average the range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 230 mS/cm to 436.9 mS/cm, indicating the presence of low levels of current conducting

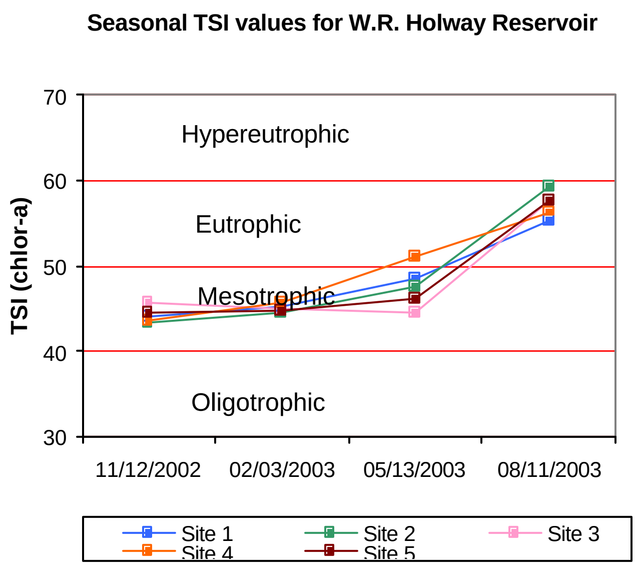



**Figure 263.** TSI values for W.R. Holway Reservoir**.**

ions (salts) in the lake system. The pH values ranged from 6.38 in the summer to 9.22 in the spring. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. The pH values that were outside the range only occurred at site 4, near the dam site, and only constituted 0.9 % of the total collected values therefore the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 274 mV to 505 mV, indicating reducing conditions were not present at this reservoir in sample year 2002-2003. In the fall and winter quarters the water column was well mixed with dissolved oxygen (D.O.) values generally above 7.0 mg/L (Figure 264c-264d). The only exception to this occurred at site 1 where a value of 2.16 mg/L was recorded at the lake bottom, near the sediment-water interface. In the spring, the lake was weakly stratified however dissolved oxygen remained above 4.0 mg/L throughout the water column (Figure 264e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline, as is to be expected in a reservoir this deep. Stratification occurred at several 1-meter intervals throughout the lake, with 21 to 38% of the water column experiencing anoxic conditions (Figure 264f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Currently, W.R. Holway Reservoir considered partially supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the surface and 0.59 mg/L at the lake bottom. Surface TN ranged from 0.30 mg/L to 0.62 mg/L with the highest values recorded in the summer quarter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.047 mg/L at the surface and 0.062 mg/L at the lake bottom. The surface TP was highest in the fall quarter and lowest in the summer with values ranging from 0.039 mg/L to 0.082 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, W.R. Holway Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. The current TSI is slightly lower than that of 2000 (TSI=57), although in the same trophic category, it is likely a more accurate depiction of productivity as it is based on data collected year round instead of growing season only. Water clarity continues to be excellent based on true color, turbidity, and secchi disk depth. The FWP beneficial use is considered fully supported based on turbidity and pH, but is partially supported due to the presence of anoxic conditions in the summer quarter. The Aesthetics beneficial use is supported based on its trophic status, however minimum data requirements were not met for true color and a use determination cannot be made. W.R. Holway Reservoir is owned by the Grand River Dam Authority (GRDA) and serves as a water supply, hydroelectric, and recreational reservoir.

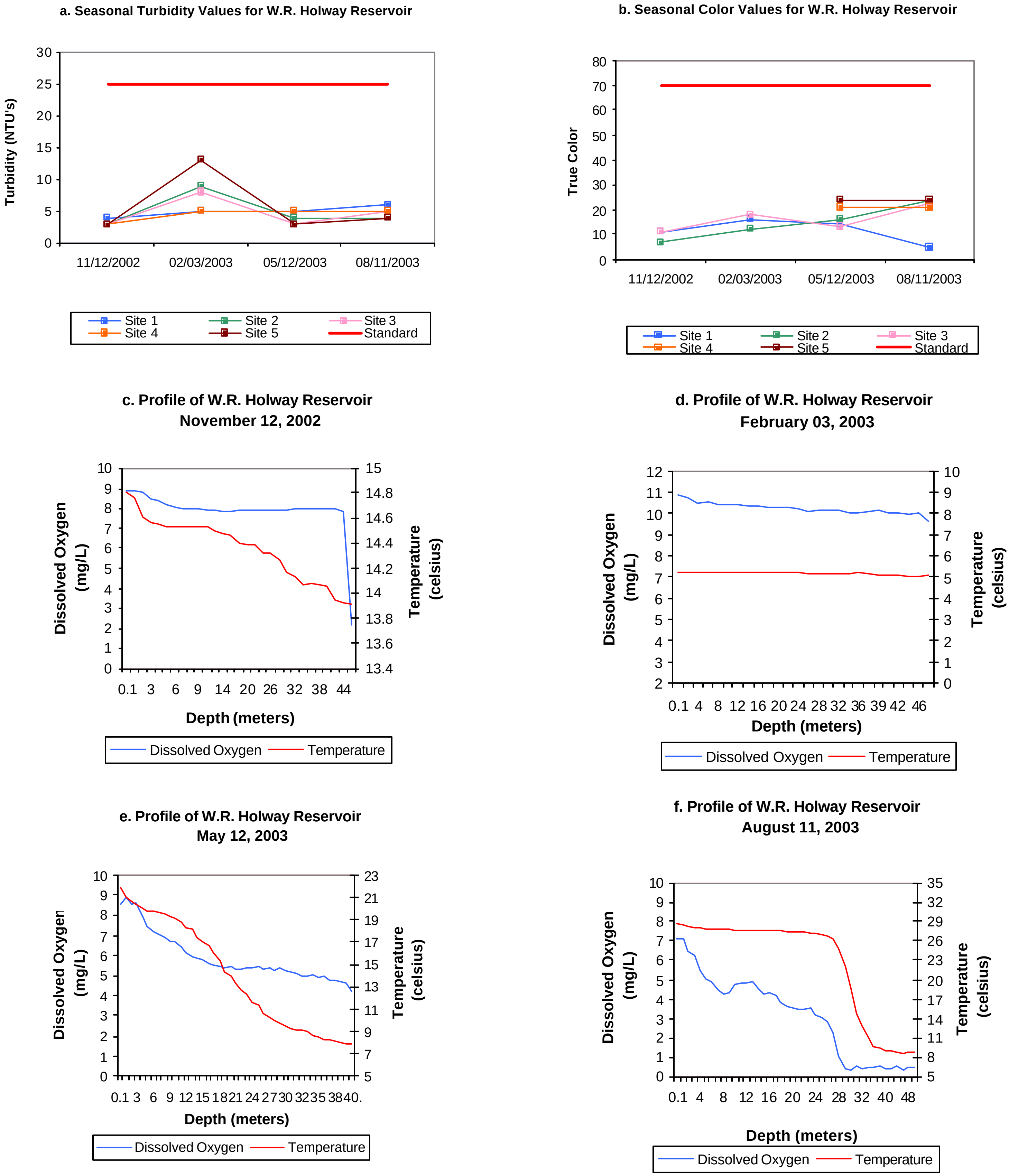



**Figure 264a-264f.** Graphical representation of data results for W.R. Holway Reservoir.






Lake Data

| | |
|---|---|
| Owner | GRDA |
| County | Mayes |
| Constructed in | 1968 |
| Surface Area | 712 acres |
| Volume | 48,000 acre/feet |
| Shoreline Length | 21 miles |
| Mean Depth | 67.42 feet |
| Watershed Area | 3490 acres |

Plate 119- Lake Water Quality for
W. R. Holway Reservoir

# Waurika Lake

Waurika Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected from five (5) sites to represent the riverine, transition, and lacustrine zone of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 30 NTU (Plate 121), true color was 28 units, and average secchi disk depth was 48 centimeters. Based on these three parameters, Waurika Lake had average water clarity in 2002-2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 56 (Plate 121), classifying the lake as eutrophic, with high levels of primary productivity and nutrient conditions. This is lower than results in 2000 (TSI=61), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values were primarily eutrophic with values ranging from mesotrophic (sites 4 and 5) in the winter to hypereutrophic (sites 2 and 3) in the summer (see Figure 265). Turbidity values ranged from a low of 6 NTU to a maximum of 75 NTU with higher values reported at sites 4 and 5 in the upper end of the reservoir (Figure 266a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 40% of the values exceeding the OWQS of 25 NTU, Waurika Lake is not supporting its Fish and Wildlife Propagation (FWP) beneficial use in regards to turbidity. Seasonal true color values are displayed in Figure 266b. All true color values were less than the Aesthetics criteria of 70 units, therefore the beneficial use is considered supported.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.26 parts per thousand (ppt) to 0.34 ppt in sample year 2002-2003. This is slightly higher than the average range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 518.7 mS/cm to 596.2 mS/cm, indicating the presence moderate levels of current conducting ions (salts) in the lake system. The pH values ranged from 7.14 to 8.47 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and should be listed as not supporting beneficial

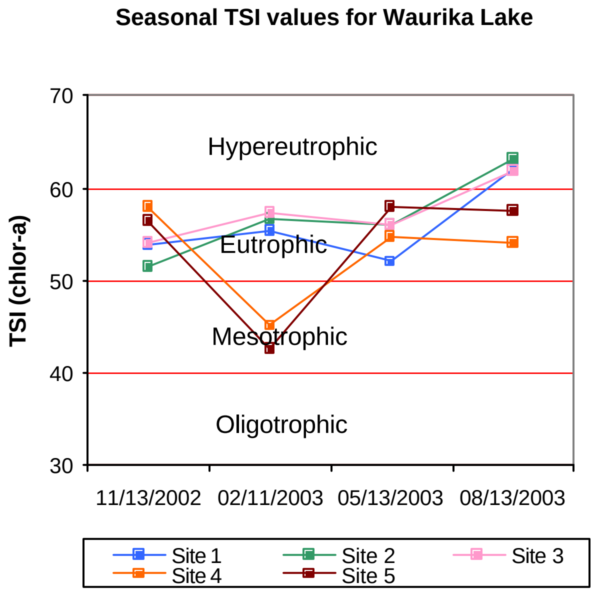



**Figure 265.** TSI values for Waurika Lake.

uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of the collected values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 214 mV to 664 mV, indicating reducing conditions were not present at this reservoir in sample year 2002-2003. In the fall and winter quarters stratification was not evident and the water column was well mixed with dissolved oxygen (D.O.) values generally above 7.0 mg/L (Figure 266c-266d). In the spring, the lake was stratified at several 1-meter intervals at site 1, however dissolved oxygen only dropped below 2.0 mg/L near the lake bottom of 14.8 meters (Figure 266e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline, at both sites 1 and 2 (Figure 266f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 33 to 43% of the water column less than 2.0 mg/L in the summer, Waurika Lake is considered partially supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.75 mg/L at the surface and 0.87 mg/L at the lake bottom. Surface TN ranged from 0.43 mg/L to 1.08 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.072 mg/L at the surface and 0.135 mg/L at the lake bottom. The surface TP was highest in the summer quarter and lowest values were reported in both spring and summer with values ranging from 0.045 mg/L to 0.150 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Waurika Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This classification differs from 2000 (TSI=61), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. Based on turbidity, true color, and secchi disk depth, water clarity was average in comparison to other Oklahoma reservoirs. The FWP beneficial use is supported based on pH, partially supported based on dissolved oxygen, but not supported based on turbidity. The lake is supporting the Aesthetics beneficial use based on its trophic status and reported true color values. Waurika Lake, located in Jefferson County, was constructed by the United States Army Corps of Engineers (USACE) and is utilized for flood control, irrigation, water supply and quality and recreational purposes.

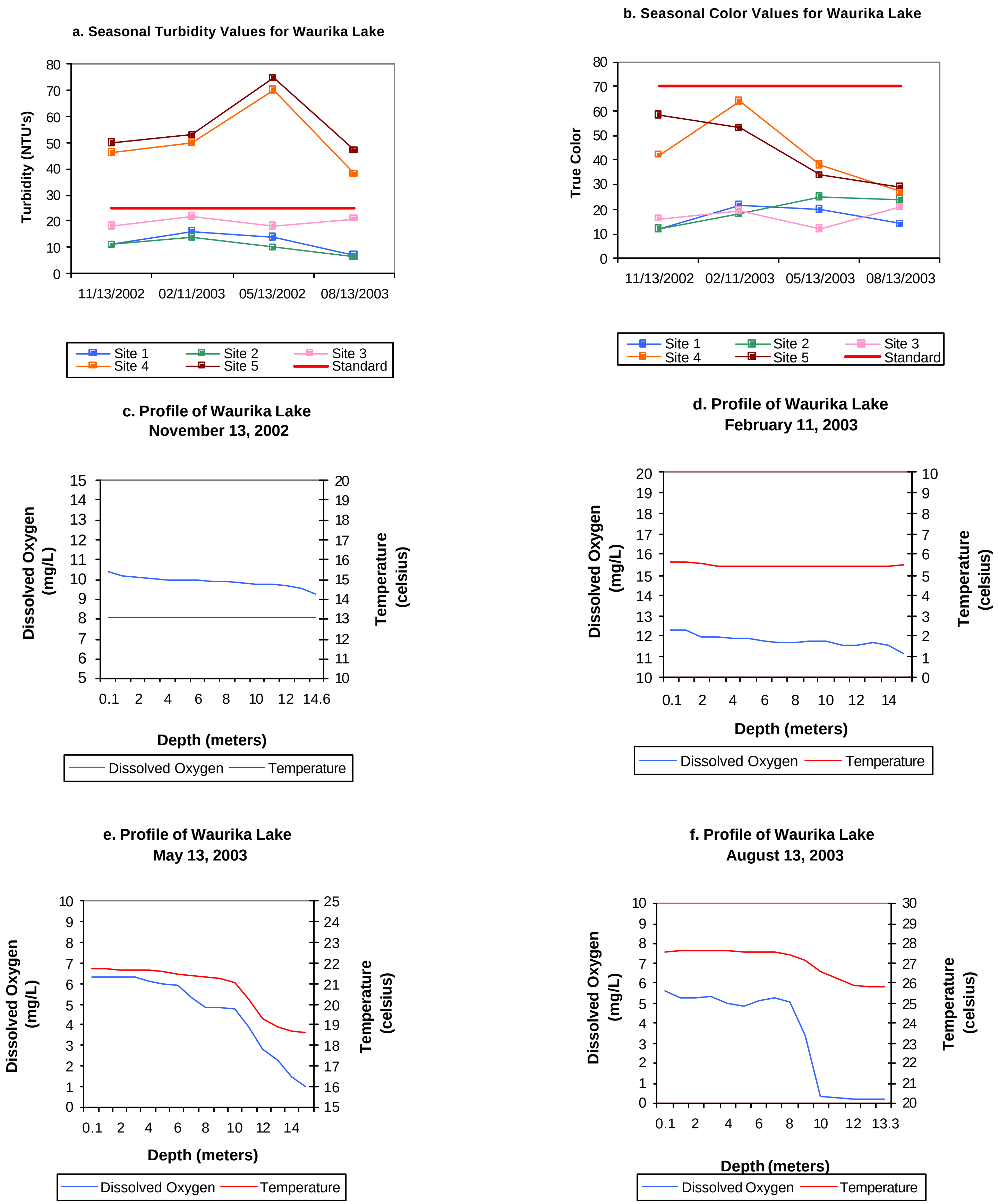
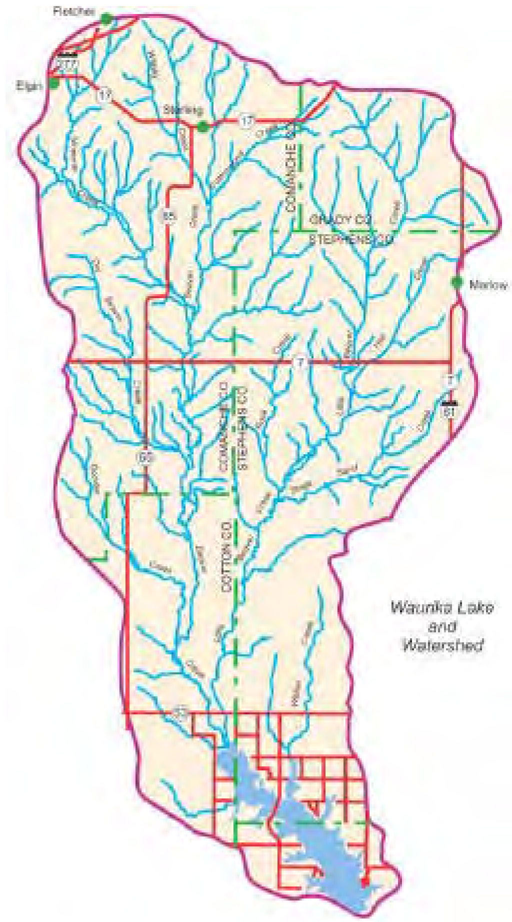
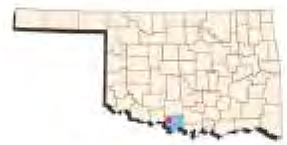



**Figure 266a-266f.** Graphical representation of data results for Waurika Lake.




Waurika Lake
and
Watershed



Waurika Lake
Location

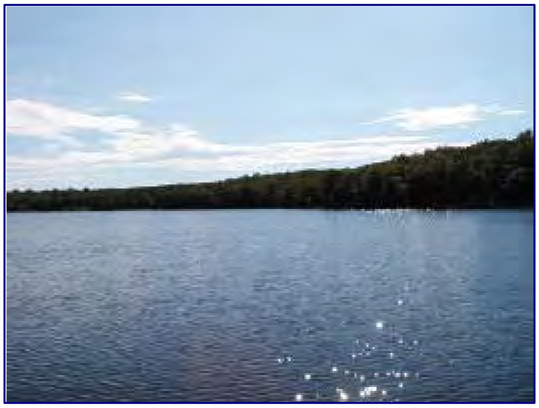



Lake Data

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Jefferson |
| Constructed in | 1980 |
| Surface Area | 10,100 acres |
| Volume | 203,100 acre/feet |
| Shoreline Length | 80 miles |
| Mean Depth | 19.4 feet |
| Watershed Area | 562 square miles |

Plate 121 - Lake Water Quality for
## Waurika Lake

# Lake Waxhoma



Lake Waxhoma was sampled for four seasons extending from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 23 NTU (Plate 122), true color was 52 units, and secchi disk depth was 82 centimeters. Based on these three parameters, Lake Waxhoma had average water clarity in sample year 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 43 (Plate 122), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient rich conditions. The TSI varied seasonally with the lake being at the lower end of mesotrophy in the fall and winter quarters and oligotrophic in the spring. During the summer quarter the lake was again experiencing mesotrophic conditions (see Figure 267). Of the 12 turbidity samples collected four (33%) of the nephelometric turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 268a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow data suggest that the elevated turbidity readings in March are likely due to seasonal storm events, therefore the lake wil be considered supporting the Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 268b. Similar to turbidity, a peak in true color occurred in the spring quarter and is likely due to seasonal storm events and the Aesthetics beneficial use is considered supported at Lake Waxhoma.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2003-2004. Salinity values ranged from 0.04 parts per thousand (ppt) to 0.12 ppt. Salinity readings were within the range of expected values for Oklahoma lakes and reflected the presence of minimal amounts of chlorides or other salts in the lake. Specific conductance values were also well within the range of values recorded in Oklahoma reservoirs, if not slightly lower. Values ranged from 103.2 mS/cm recorded

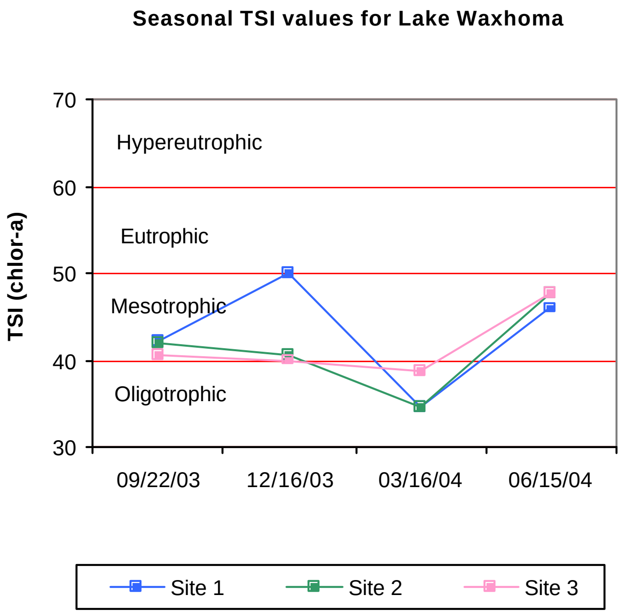



**Figure 267.** TSI values for Lake Waxhoma.

in the spring quarter to 259.9 mS/cm in the winter, indicating low levels of electrical conducting compounds (salts) were present in the lake. Oxidation-reduction potentials (redox) ranged from 316 mV in the summer to 598 mV in the fall. Redox showed that reducing conditions were not present in the lake during the study period. The pH values were neutral to slightly alkaline with values ranging from 6.75 to 8.05 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Waxhoma is supporting its FWP beneficial use for pH as all collected data fell within the allowable range. Thermal stratification was not evident in the lake in the winter or spring quarters and dissolved oxygen (D.O.) values were above 8.0 mg/L throughout the water column at all sites (see Figure 268d-268e). In the fall quarter the lake was thermally stratified between 6 and 7 meters below the lake surface, with D.O. values falling below 2.0 mg/L at sites 1 and 2 (see Figure 268c). The lake was also strongly thermally stratified in the summer quarter between 3 and 4 meters below the lake surface. From the 5-meter depth at site 1 to the lake bottom at 11.9 meters, all recorded D.O. values were less than 2.0 mg/L (see Figure 268f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is partially supported at Lake Waxhoma as 33-46% of the water column had D.O. values less than 2.0 mg/L in the fall and 44-61% in the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected five (50%) exceeded the screening level of 61 cfu/ml for enterococci and the geometric mean of 48.5 cfu/ml exceeded the prscribed mean of 33 cfu. The PBCR beneficial use is considered not supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.57 mg/L at the lake surface and 1.13 mg/L at the bottom. The TN at the surface ranged from 0.40 mg/L to 0.87 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the winter. The lake-wide total phosphorus (TP) average was 0.027 mg/L at the lake surface and 0.051 mg/L at the bottom. The surface TP ranged from 0.014 mg/L to 0.051 mg/L. The highest surface TP value was reported in the spring and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 21:1 for sample year 2003-2004. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Waxhoma was classified as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions (Plate 122). Based on turbidity, true color, and secchi disk depth water clarity was average in sample year 2004. The lake was fully supporting its FWP beneficial use for pH and partially supported D.O. values less than 2.0 mg/L in the fall and summer sampling intervals. Available flow data suggest that the elevated turbidity readings in March are likely due to seasonal storm events, therefore the lake wil be considered supporting the Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. The lake was fully supporting its Aesthetics beneficial use based on its trophic status. Similar to turbidity, a peak in true color occurred in the spring quarter and is likely due to seasonal storm events and the Aesthetics beneficial use is considered supported at Lake Waxhoma. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected five (50%) exceeded the screening level of 61 cfu/ml for enterococci. The PBCR beneficial use is considered not supported. Lake Waxhoma was constructed in 1955 and is owned and operated by the City of Barnsdall. The lake is managed as a municipal water supply and offers numerous recreational opportunities to the public.

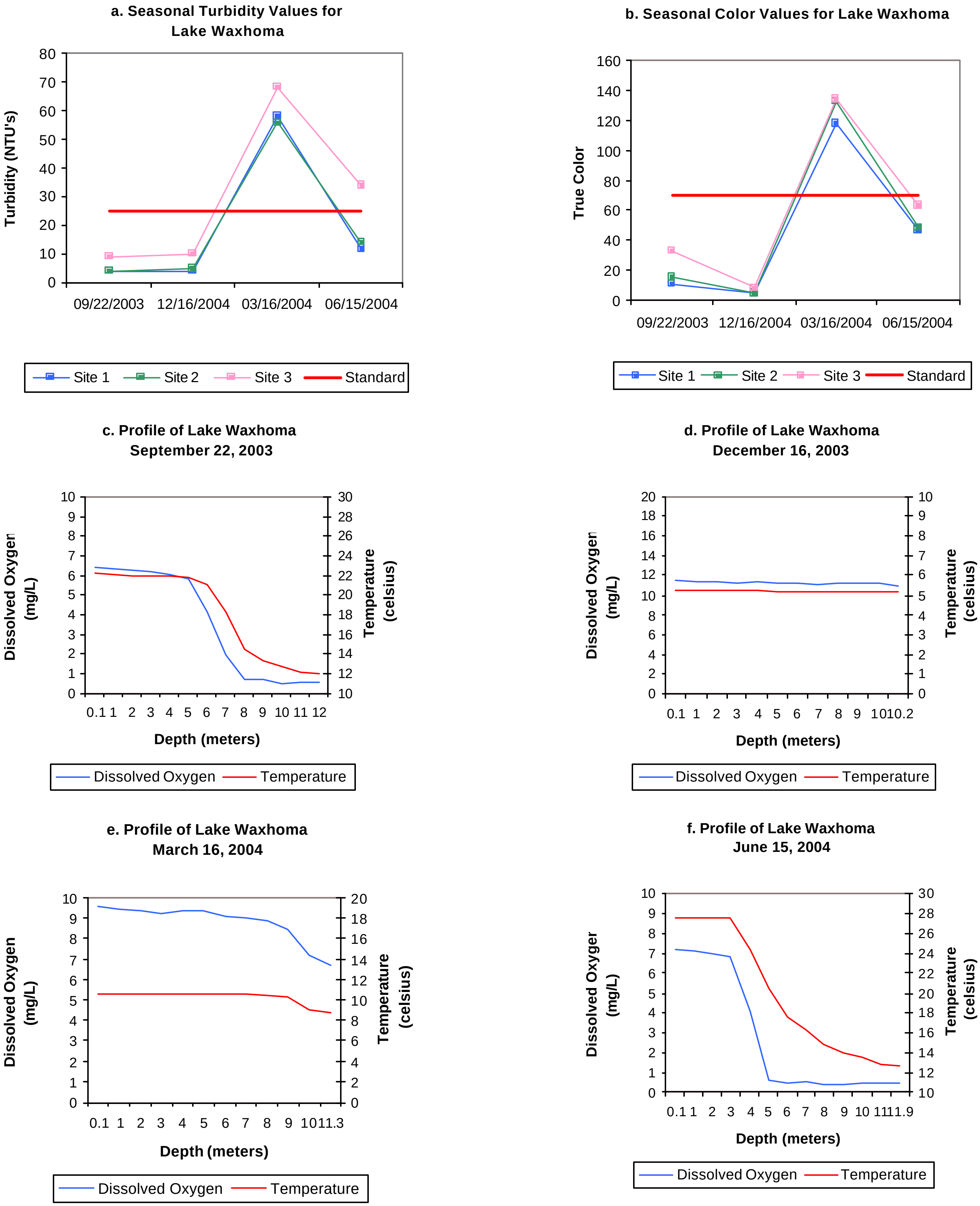
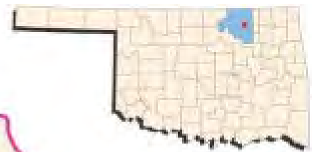


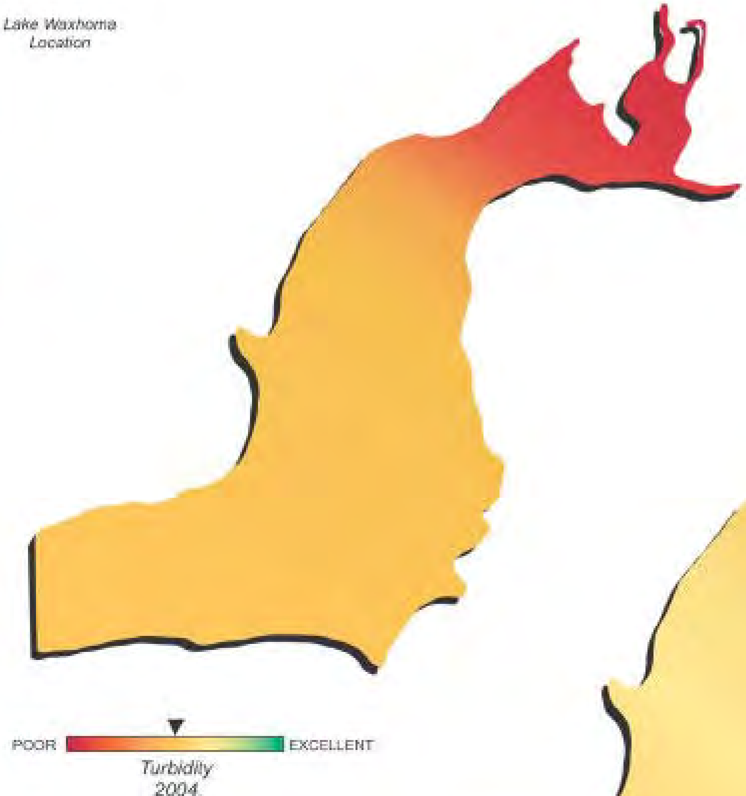

**Figure 268a-268f.** Graphical representation of data results for Lake Waxhoma.





Lake Data

| | |
|---|---|
| Owner | City of Barnsdall |
| County | Osage |
| Constructed | 1955 |
| Surface Area | 197 acres |
| Volume | 2,000 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 10.15 feet |
| Watershed Area | 2,467 acres |



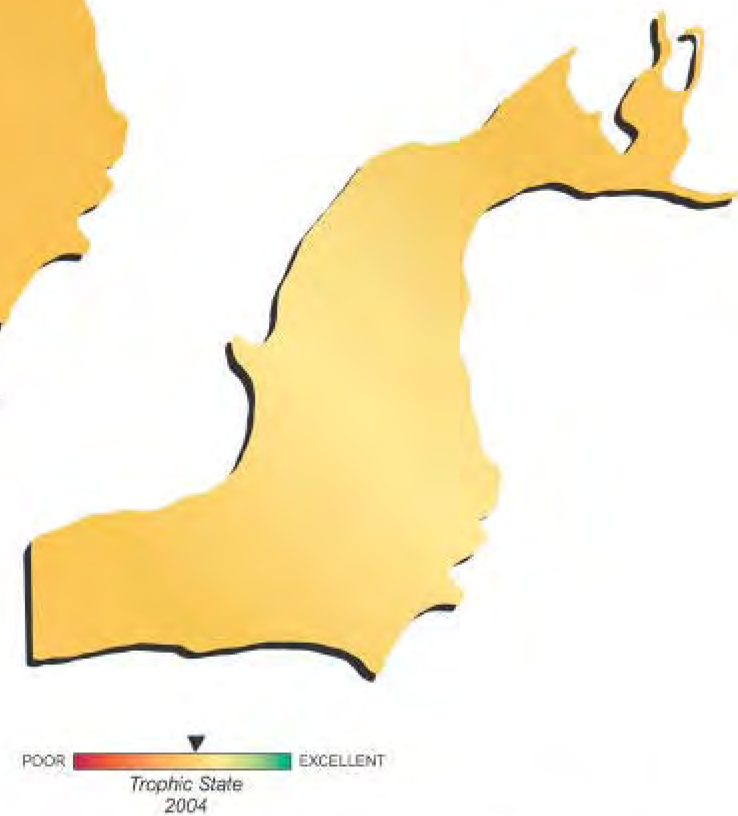




Plate 122 - Lake Water Quality for
# Lake Waxhoma

# Lake Wayne Wallace

Lake Wayne Wallace was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The average lake-wide turbidity was 13 NTU (Plate 123), true color was 58 units, and average secchi disk depth was 105 centimeters. Based on these three parameters, Lake Wayne Wallace had good water clarity. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 44 (Plate 123), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. This classification differs from 2000 (TSI=56), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values were fairly consistent ranging from mesotrophic in the first three sampling quarters to oligotrophic at sites 2 and 3 the summer (see Figure 269). Seasonal turbidity values are displayed in Figure 270a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Wayne Wallace is currently supporting Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 270b. Of the twelve true color values collected, five (42%) were above the OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered not supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.00 parts per thousand (ppt) to 0.02 ppt in sample year 2002-2003. This is lower than the average the range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 21.3 mS/cm to 71.1 mS/cm, indicating the presence low levels of current conducting ions (salts or chlorides) in the lake system. The pH values ranged from 5.92 to 7.05 representing a slightly acidic to neutral system. According to USAP (OAC

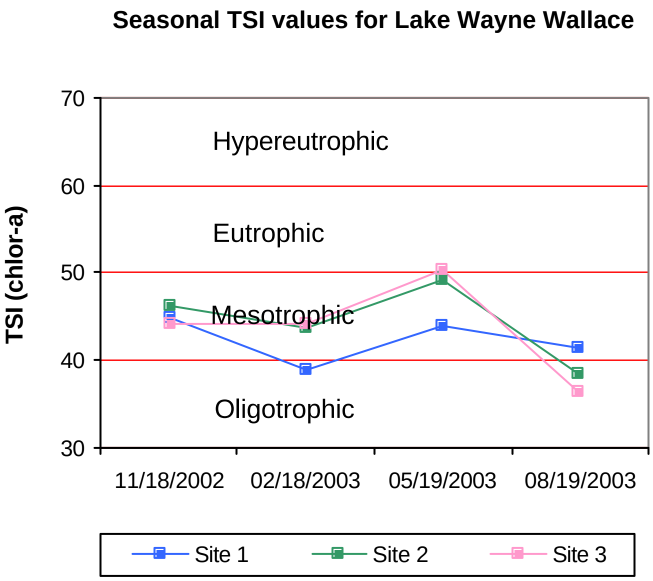



**Figure 269.** TSI values for Lake Wayne Wallace.

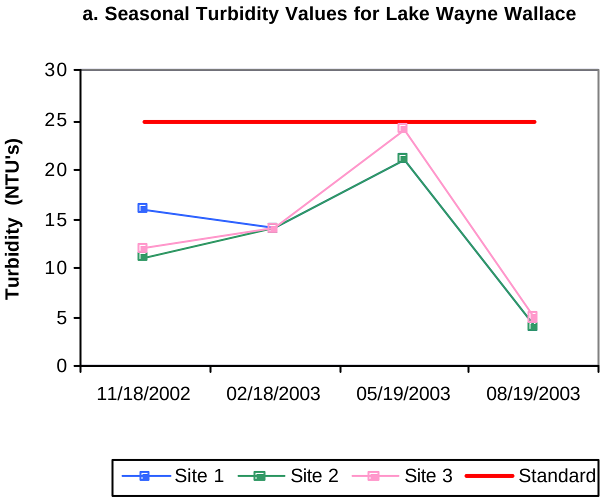
785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With approximately 39% of the values recorded being less than 6.5 the lake should be listed as not supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (ORP) ranged from 313 mV to 552 mV, indicating reducing conditions were not present at this reservoir in sample year 2002-2003. During the fall and winter sampling intervals stratification was not evident and the water column was well mixed with dissolved oxygen (D.O.) values generally above 7.0 mg/L (Figure 270c-270d). In the spring, the lake was stratified at several 1-meter intervals at site 1, however dissolved oxygen never dropped below 2.0 mg/L (Figure 270e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline, at both sites 1 and 2 (Figure 270f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 56 to 69% of the water less than 2.0 mg/L in the summer, Lake Wayne Wallace is considered partially supporting the FWP beneficial use and should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. The Agriculture beneficial use was fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

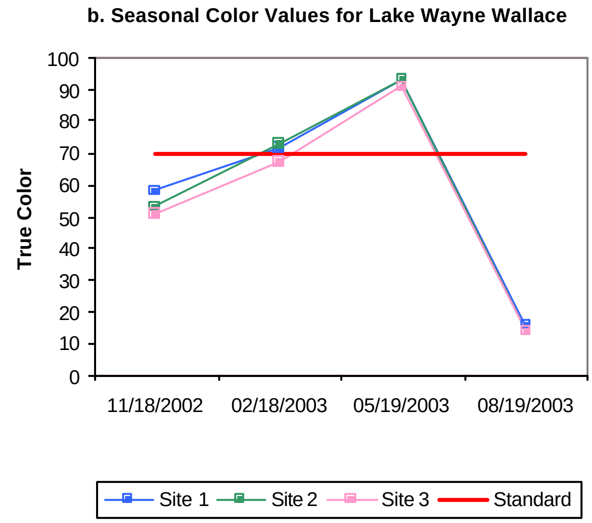
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

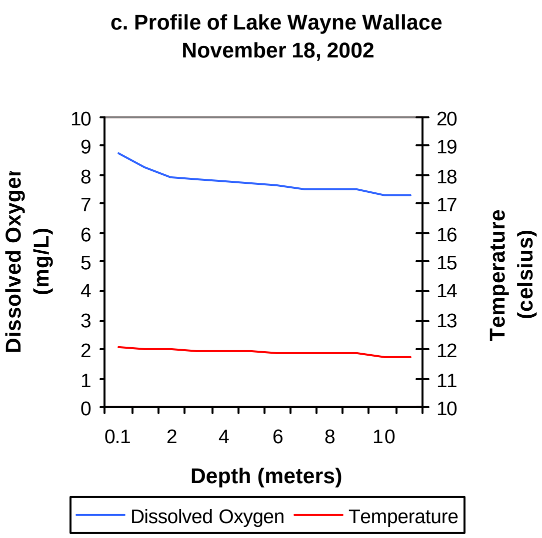
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.64 mg/L at the surface and 0.65 mg/L at the lake bottom. Surface TN ranged from 0.31 mg/L to 2.18 mg/L with the highest values recorded in the spring quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.021 mg/L at the surface and 0.080 mg/L at the lake bottom. The surface TP was highest in the spring quarter but the lowest value was reported in the summer with values ranging from 0.014 mg/L to 0.030 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 29:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

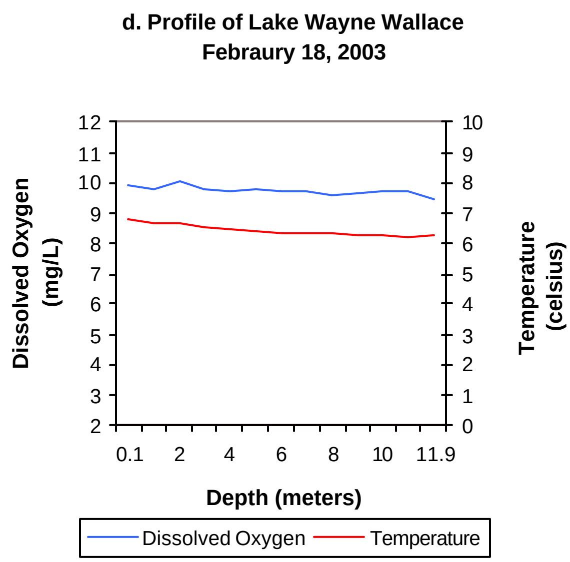
In summary, Lake Wayne Wallace was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in 2002-2003. This classification differs from 2000 (TSI=56), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. Water clarity was good based on turbidity, true color, and secchi disk depths. The FWP beneficial use is supported based on turbidity and partially supported based on dissolved oxygen. With 39% of the pH values less than 6.5 the lake will is not supporting the FWP. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is considered supported in regards to trophic status and true color. Lake Wayne Wallace, located in Latimer

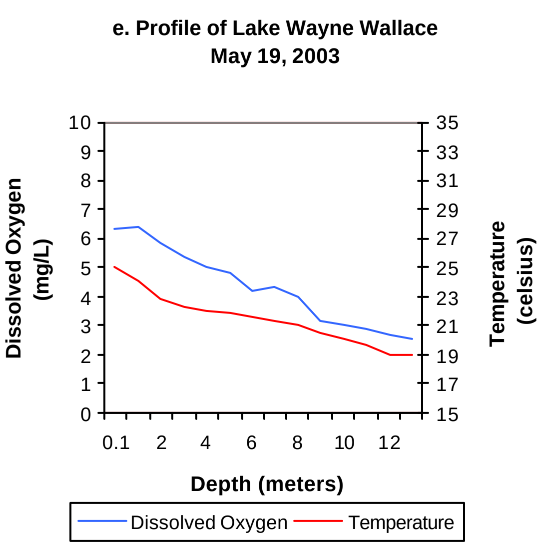
County is owned by the State of Oklahoma and is utilized for flood control and recreation purposes.



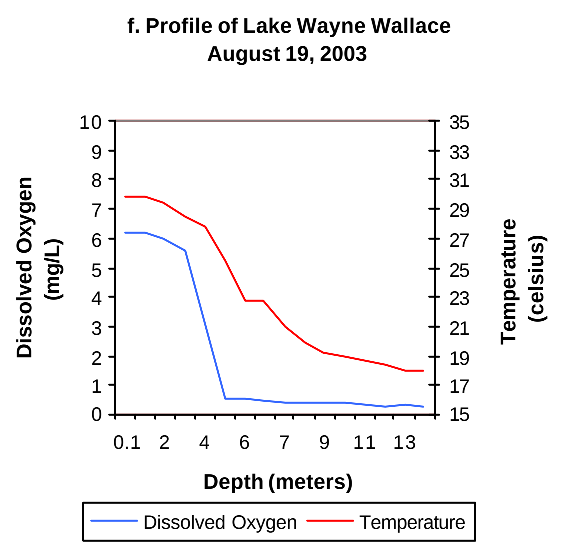
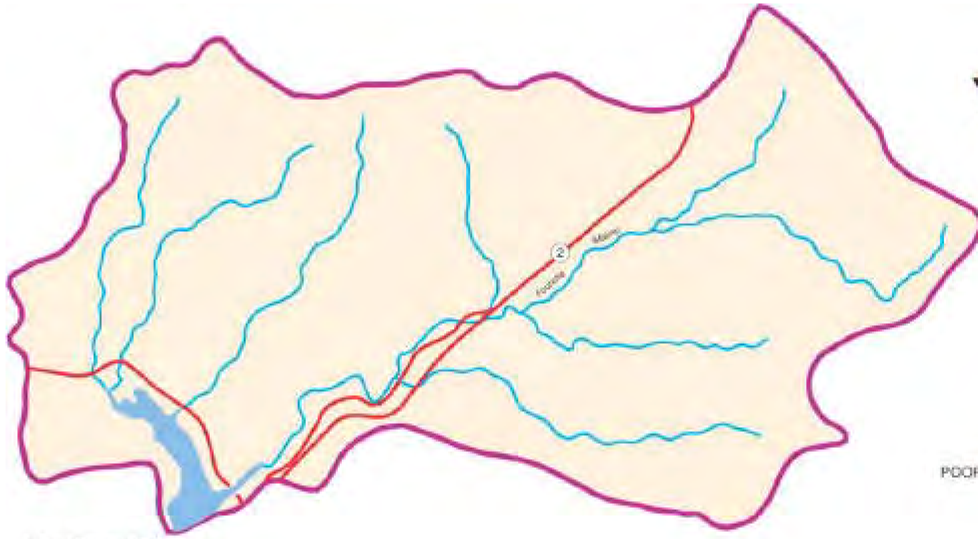
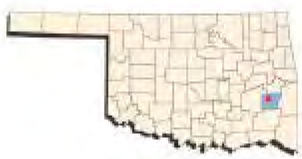



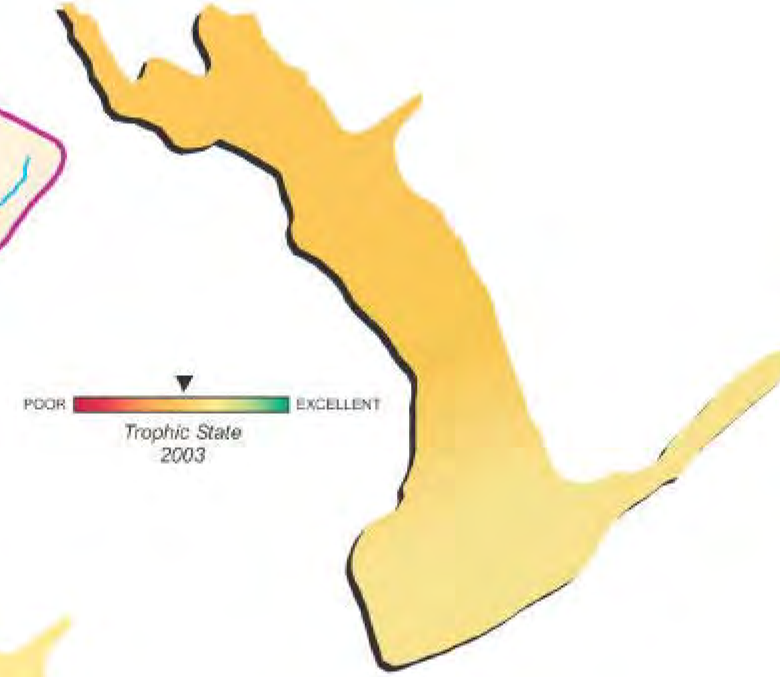

**Figure 270a-270f.** Graphical representation of data results for Lake Wayne Wallace.

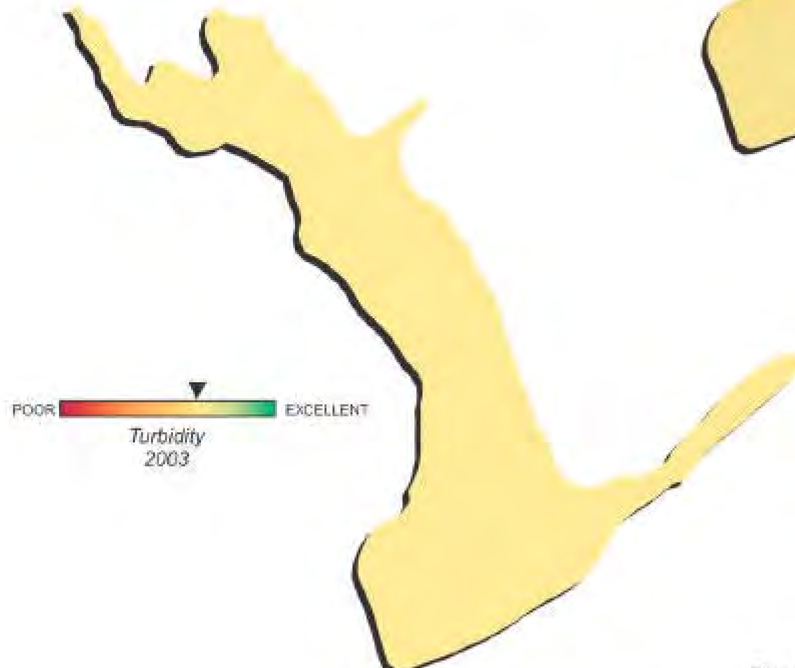


Lake Wayne Wallace
and
Watershed



Lake Wayne Wallace
Location




Lake Data

| | |
|---|---|
| Owner | State of Oklahoma |
| County | Latimer |
| Constructed in | 1969 |
| Surface Area | 94 acres |
| Volume | 1,746 acre/feet |
| Shoreline Length | 3 miles |
| Mean Depth | 18.57 feet |
| Watershed Area | 11 square miles |

Plate 123 - Lake Water Quality for
Lake Wayne Wallace

# Webbers Falls Reservoir

Webbers Falls Reservoir was sampled from October 2003 through July 2004. Water quality samples were collected at six (6) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major arms. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 36 NTU (Plate 124), true color was 40 units, and secchi disk depth was 38 centimeters in 2004. Based on these three parameters, Webbers Falls Reservoir had average to poor water clarity. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=24). The average TSI was 59 (Plate 124), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to the TSI in 2001 (TSI=57), indicating no significant changed in productivity has occurred since the previous evaluation. The TSI values were primarily eutrophic throughout the year at all sites (see Figure 271). The TSI at several sites was hypereutrophic in the fall (sites 2-6) and approximately 50% of the samples were mesotrophic in the summer (sites 1, 3, and 5 respectively). Site 1 exhibited the most variability throughout the year, which can be expected, as this is the location of the lock and dam on the Arkansas River. Seasonal turbidity values are displayed in Figure 272a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Sixteen of the 24 turbidity values (66%) exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU in 2003-2004. Available flow and rainfall data suggest that elelvated turbidity readings in three of the four sampling intervals are likely due to storm events therefore, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported. Seasonal true color values are displayed in Figure 272b. Approximately 8% of the collected values exceeded the OWQS numeric criteria of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered supported.

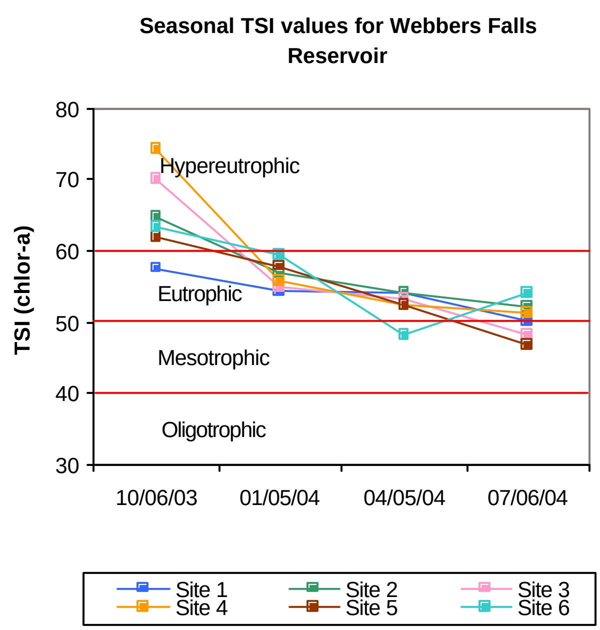



**Figure 271. TSI values for Webbers Falls Reservoir.**

Vertical profiles for dissolved oxygen, pH, temperature; specific conductance, oxidation-reduction potential, and salinity were recorded at all six sample sites in sample year 2003-2004. Salinity values ranged from 0.18 parts per thousand (ppt) to 0.50 ppt. This is higher than the average the range of values recorded in Oklahoma reservoirs and indicative of moderate to high levels of salts. Specific conductance ranged from 363 mS/cm to 954.3 mS/cm, indicating the presence moderate to high levels of current conducting ions (salts or chlorides) in the lake system. The pH values ranged from 7.33 to 8.67 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range, the lake should be listed as supporting the FWP based on pH. Oxidation-reduction potentials (ORP) ranged from 336 mV to 532 mV, indicating reducing conditions were not present at this reservoir in sample year 2003-2004. Thermal stratification was not evident during any of the sampling intervals and dissolved oxygen levels remained above 5.3 mg/L throughout the water column at all sites (see Figure 272c-272f). This may be attributed to the fact that Webbers Falls Reservoir is very riverine in nature as it is a portion of the Arkansas River. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With the absence of anoxic conditions throughout the study period the lake is considered supporting the FWP beneficial use. The lake was also sampled for chlorides and sulfates to assess its Agriculture beneficial use. The Agriculture beneficial use was fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected 100% of the samples exceeded the screening level of 61 cfu/ml and the geometric mean of 33 for enterococci. The PBCR beneficial use is therefore considered not supported for sample year 2003-2004.

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2000 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.12 mg/L at the surface and 1.03 mg/L at the lake bottom. Surface TN ranged from 0.62 mg/L to 1.66 mg/L with the highest values recorded in the spring quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.125 mg/L at the surface and 0.132 mg/L at the lake bottom. The surface TP was highest in the fall quarter and the lowest value was reported in the winter with values ranging from 0.091 mg/L to 0.155 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2003-2004. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Webbers Falls Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2003-2004. This classification is similar to that in 2001 (TSI=57), indicating little or no significant change has occurred since the previous evaluation. Water clarity was average to poor based on turbidity, true color, and secchi disk depths. The FWP beneficial use is supported based dissolved oxygen and pH readings recorded during the study period. Available flow and rainfall data suggest that elelvated turbidity readings in three of the four sampling intervals are likely due to storm events therefore, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported. The Aesthetics beneficial use is considered supported in regards to both trophic status and true color. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected 100% of the samples exceeded the screening level of 61 cfu/ml and the geometric mean of 33 for enterococci. The PBCR beneficial use is therefore considered not supported for sample year 2003-2004.The Webbers Falls lock and dam was constructed by the United States Army Corps of Engineers (USACE) on the Arkansas River for the purpose of navigation and generation of hydroelectric power.

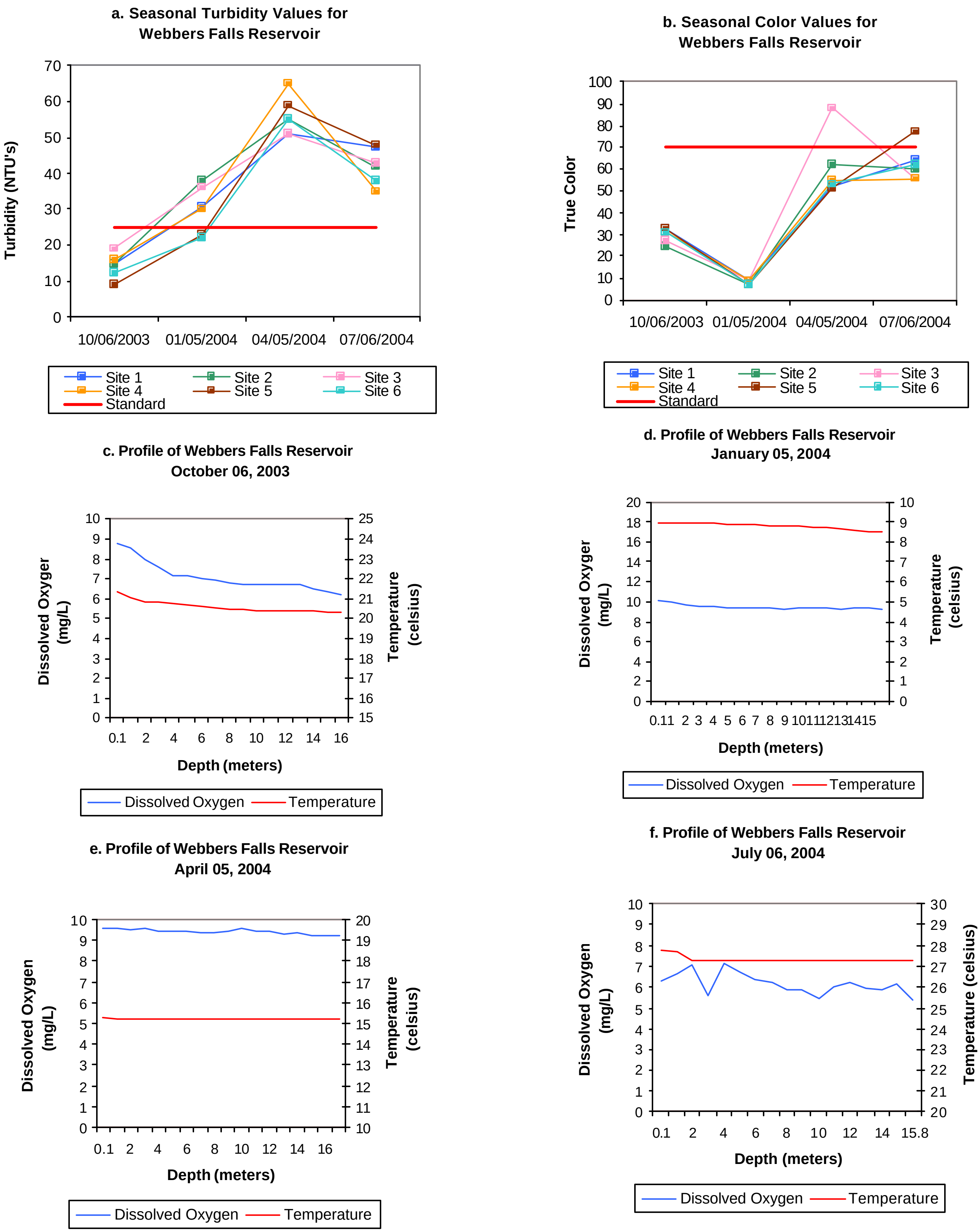
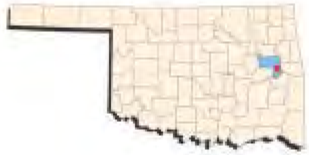



**Figure 272a-272f.** Graphical representation of data results for Webbers Falls Reservoir.



Webbers Falls Lake Location


Webbers Falls Lake and Watershed

**Lake Data**

| | |
|---|---|
| Constructed by | Corps of Engineers |
| County | Muskogee |
| Constructed in | 1970 |
| Surface Area | 11,600 acres |
| Volume | 170,100 acre/feet |
| Shoreline Length | 175 miles |
| Mean Depth | 15.2 |
| Watershed Area | 97,033 square miles |


*Turbidity 2004*


*Trophic State 2004*

Plate 124 - Lake Water Quality for

# Webbers Falls Reservoir

# Wes Watkins (North Deer Creek) Reservoir

Wes Watkins (North Deer Creek) Reservoir was sampled for four quarters from September 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major arms. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 10 NTU (Plate 125), true color was 23 units, and secchi disk depth was 88 centimeters. Based on these three parameters, Wes Watkins (North Deer Creek) Reservoir had good water clarity, slightly better than that in 2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 50 (Plate 125), classifying the lake as mesotrophic bordering eutrophic, indicative of moderate to high levels of productivity and nutrient rich conditions. The TSI values varied by season and site location, but in general the lake was mesotrophic in the fall and summer quarters and eutrophic during the other two quarters (see Figure 273). Only one of the 20 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 274a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. All turbidity values were below the standard of 25 NTU except in the summer, when a turbidity value of 42 NTU was recorded at site 5, with only 5% of the values exceeding the criteria; the lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 274b. All true color values throughout the year were below the Aesthetics criteria of 70 units; therefore the Aesthetics beneficial use is fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.18 ppt, well within the range of expected values for Oklahoma lakes, reflecting moderate levels of chlorides or other salts in the lake. Specific conductance values were also within the range of expected values recorded in Oklahoma reservoirs. Values ranged from 238.8 mS/cm in the fall quarter to 325.4 mS/cm in the spring quarter, indicating that moderate levels of electrical conducting compounds (salts) were

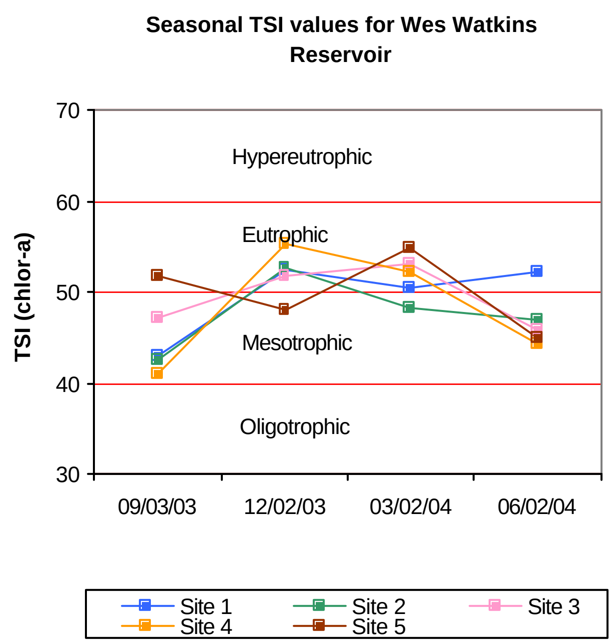



**Figure 273.** TSI values for Wes Watkins Reservoir.

present in the lake system. Oxidation-reduction potentials ranged from 303 mV in the winter to 515 mV in the fall quarter, indicating that reducing conditions were absent during the study period. The pH values were neutral to slightly alkaline with values ranging from 6.91 units to 8.23 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all of the pH values within the acceptable range, the lake is fully supporting its FWP beneficial use based on pH. Thermal stratification was not evident in the winter or spring quarters (see Figure 274d-274e). Generally the water column was fairly well oxygenated and mixed with D.O. values in the winter and spring staying well above 8.0 mg/L. In the fall the lake was weakly stratified and dissolved oxygen (D.O.) values were below 2.0 mg/L at site 1 from 5-meters below the lake surface to the lake bottom of 7.7 meters. In the summer the lake was thermally stratified between 5 and 6 meters below the lake surface. From the 7 meters depth to the lake bottom at 8 meters at site 1, D.O. values were all less than 2.0 mg/L (see Figure 274f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Wes Watkins (North Deer Creek) Reservoir with only 25% of the water column with D.O. values less than 2.0 mg/L in the fall quarter and 22% in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2003-2004, with all collected values at or below the detection limit

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.77 mg/L at the lake surface. The TN at the surface ranged from 0.70 mg/L to 1.20 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the fall. The lake-wide total phosphorus (TP) average for sample was 0.031 mg/L at the lake surface. The surface TP ranged from 0.021 mg/L to 0.078 mg/L. The highest surface TP value was reported in the spring quarter and lowest in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 25:1 for sample year 2003-2004. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Wes Watkins (North Deer Creek) Reservoir was classified as mesotrophic bordering on eutrophic, indicative of moderate to high levels of primary productivity and nutrient rich conditions (Plate 125). Based on true color, turbidity, and secchi disk depth water clarity was good at Wes Watkins Reservoir in sample year 2004. The lake was fully supporting its Aesthetics beneficial use based on its trophic state and true color. With only 5% of the water column exceeding the turbidity criteria the lake is fully supporting its FWP beneficial use for nephelometric turbidity and all of the pH values were within the acceptable range so it was fully supporting for pH. The FWP beneficial use was also fully supported for D.O. based on collected data. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. The PBCR beneficial use is considered fully supported for sample year 2003-2004, with all collected values at or below the detection limit. The Natural

Resource Conservation Service (NRCS) constructed Wes Watkins Reservoir for the purpose of flood control, water supply, recreation and fish and wildlife purposes.

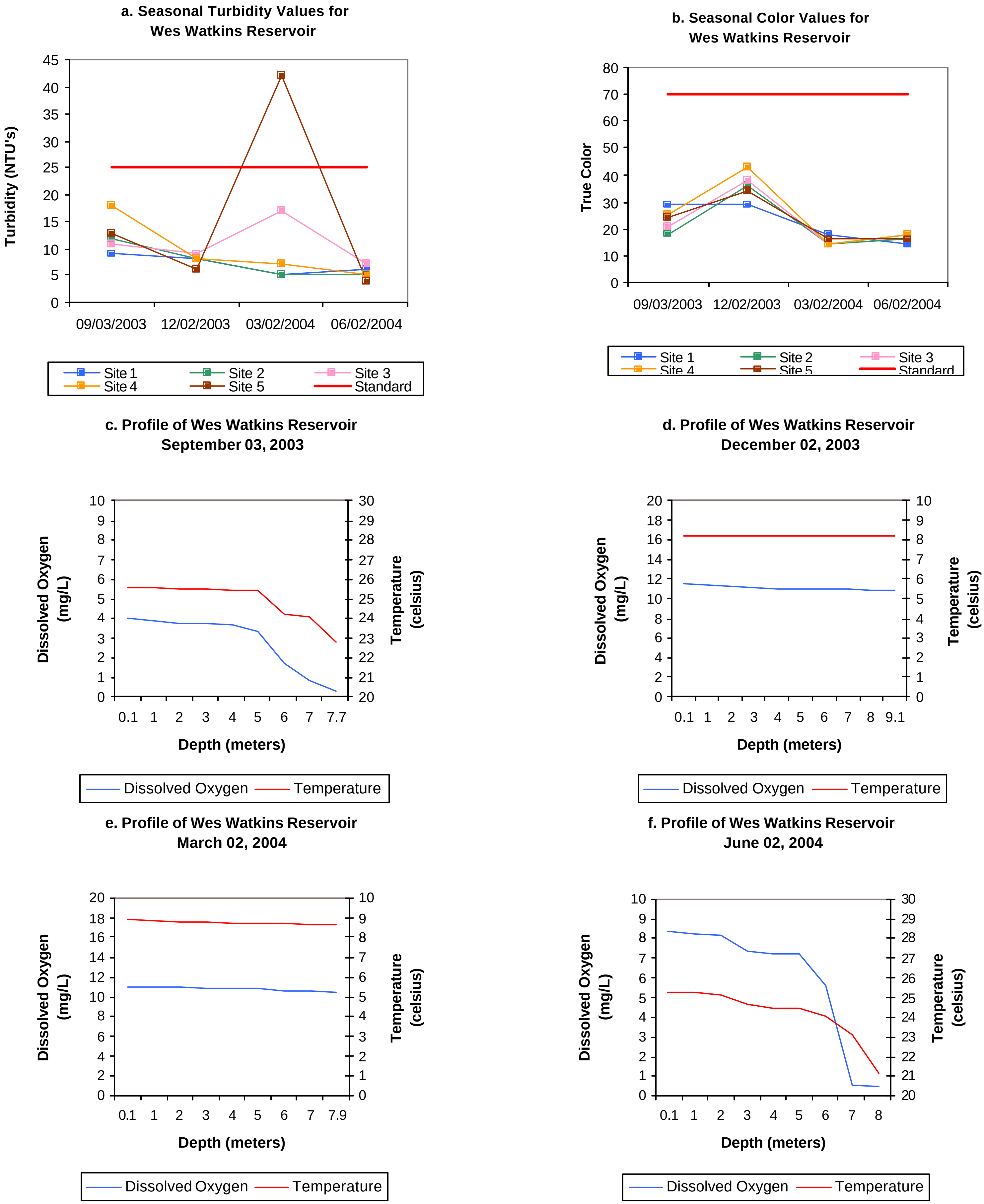



**Figure 274a-274f.** Graphical representation of data results for Wes Watkins (North Deer Creek) Reservoir.

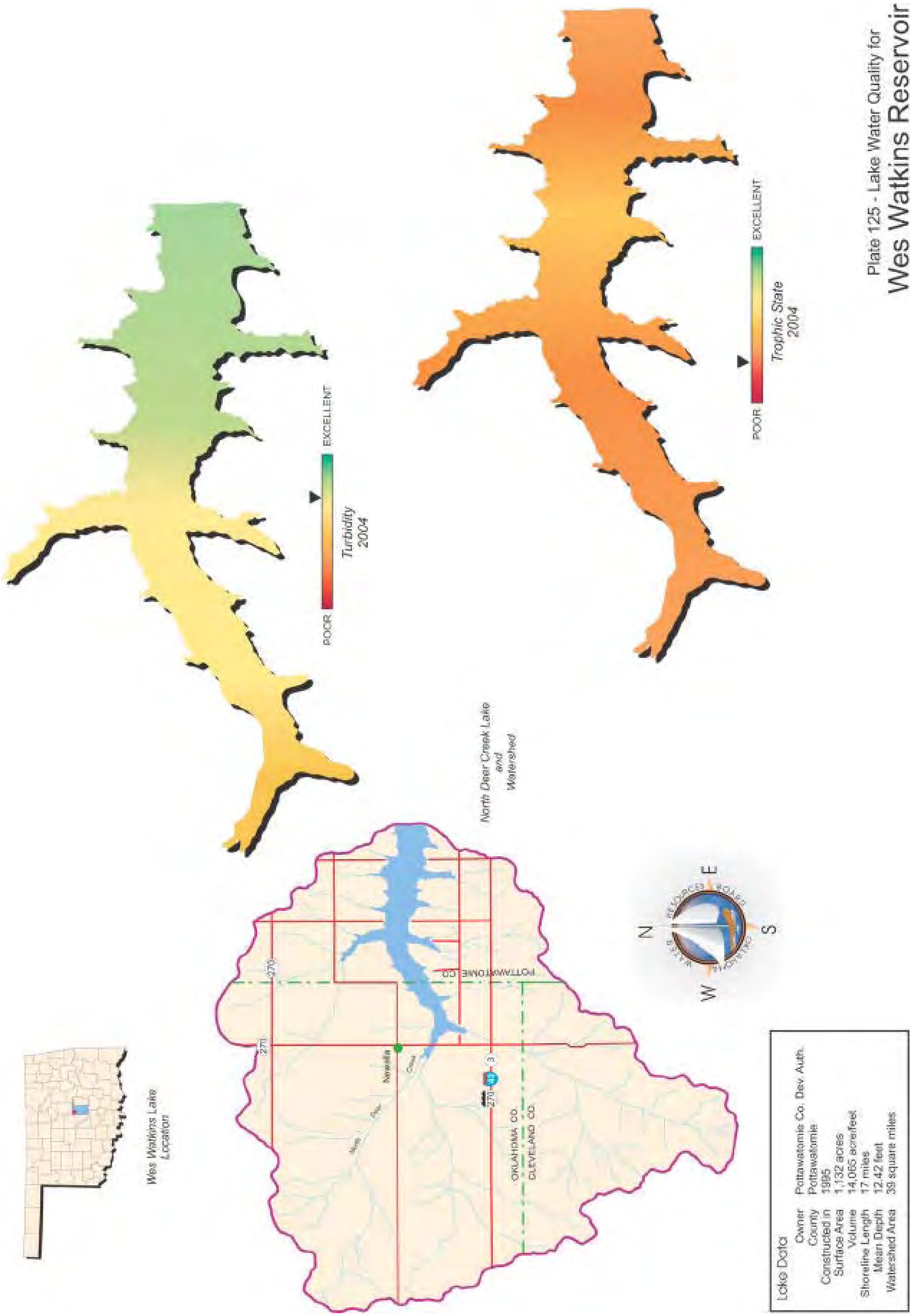


Plate 125 - Lake Water Quality for
Wes Watkins Reservoir
POOR
EXCELLENT
Turbidity
2004
POOR
EXCELLENT
Trophic State
2004
Wes Watkins Lake
Location
North Deer Creek Lake
and
Watershed
POTTAWATOMIE CO.
OKLAHOMA CO.
CLEVELAND CO.
270
3
N
E
S
W
Lake Data
Owner Pottawatomie Co. Dev. Auth.
County Pottawatomie
Constructed in 1995
Surface Area 1,132 acres
Volume 14,065 acre/feet
Shoreline Length 17 miles
Mean Depth 12.42 feet
Watershed Area 39 square miles

# Wetumka Lake

Wetumka Lake was sampled for four quarters, from October 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 12 NTU (Plate 126), true color was 27 units, and secchi disk depth was 76 centimeters. Based on these three parameters, Wetumka Lake had good water clarity, similar to previous values in 2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The calculated TSI was 50 (Plate 126), classifying the lake as mesotrophic, bordering on eutrophic, indicative of moderate to high levels of primary productivity and nutrient rich conditions. This value is slightly lower than the one calculated in 2001 (TSI=52). TSI values ranged from mesotrophic in the fall, eutrophic in the winter to mesotrophic/eutrophic in the spring and summer (see Figure 275). The peak in chlorophyll-a that occurred in the winter is uncommon in most lakes, but has been seen across the state. Seasonal turbidity values are displayed in Figure 276a . According to USAP (OAC 785:46-15-5), a beneficial use is considered not supported if =25% of the samples exceeds the screening level prescribed in OWQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples collected in 2003-2004 below the standard, the lake is fully supporting the Fish & Wildlife Propagation (FWP) beneficial use. True color values were below the aesthetics OWQS of 70 throughout the year (see Figure 276b). Applying the same default protocol, the Aesthetics beneficial use is considered fully supported at Wetumka Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.05 parts per thousand (ppt) to 0.07 ppt, which was well within the expected range for most Oklahoma lakes. Specific conductance ranged from 113.2 mS/cm in the spring quarter to 167.9 mS/cm in the winter quarter, indicative of minimal levels of electrical current conducting compounds or salts in the lake system. Oxidation-reduction potentials ranged from 353 mV to 652 mV, indicating reducing conditions were not present at any point in the sample year. The pH was neutral to alkaline with values ranging from 6.74 to 7.75 units.

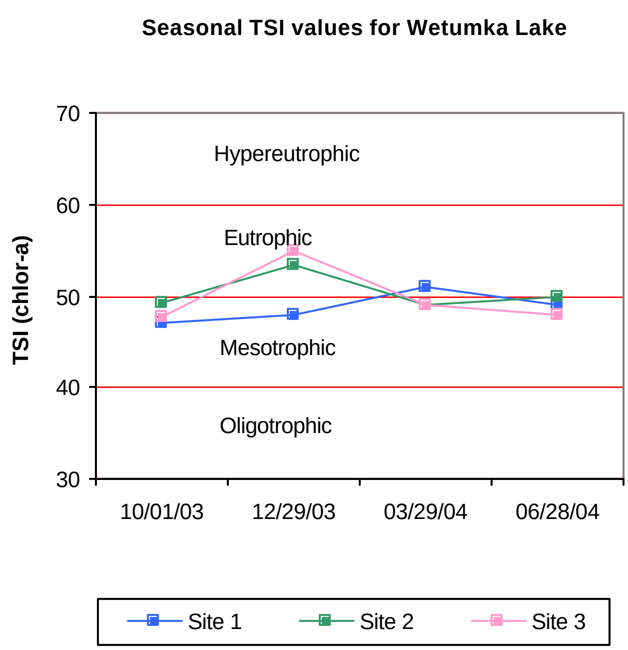



**Figure 275.** TSI values for Wetumka Lake.

According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting beneficial uses. With all values within the acceptable range Wetumka Lake is meeting its FWP beneficial use based on pH. The lake was not thermally stratified and the water column appeared to be well mixed in the fall, winter, and spring sampling events (see Figure 276c-276e). Dissolved oxygen (D.O.) values generally remained above 5.0 mg/L. In the summer, thermal stratification was evident and anoxic conditions were present at two of the three sites. Stratification occurred between 2-3 meters below the lake surface at site 1 at which point D.O. levels fell below 2.0 mg/L to the lake bottom of 6.2 meters (Figure 276f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Approximately 40-62% of the water column was experiencing anoxic conditions at sites 1 and 2 in the summer sampling interval. Wetumka Lake is considered partially supporting its FWP beneficial use based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E. coli,* fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected three (30%) of the samples exceeded the screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the lake surface and 0.55 at the lake bottom. The TN at the surface ranged from 0.21 mg/L to 0.60 mg/L. The highest surface TN values occurred in the spring quarter and the lowest was reported in the winter quarter. The lake-wide total phosphorus (TP) average was 0.030 mg/L at the lake surface and 0.030 at the lake bottom. The TP ranged from 0.021 mg/L to 0.035 mg/L at the lake surface. Similar to total nitrogen the highest TP values were reported in the spring quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 16:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Wetumka Lake was classified as mesotrophic bordering eutrophic, indicative of moderate to high primary productivity and nutrient levels (Plate 126). Water clarity was good in sample year 2004 based on turbidity, true color and secchi disk depth. The Aesthetics beneficial use was fully supporting for trophic state and true color with 100% of the collected values below the numeric criteria of 70 true color units. The FWP beneficial use is considered fully supported for pH and turbidity. Based on anoxic conditions present in the summer the lake is considered partially supporting the FWP beneficial use. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected three (30%) of the samples exceeded the screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Wetumka Lake, located in Hughes County, is owned by the city of Wetumka and serves as a water supply and recreational reservoir.

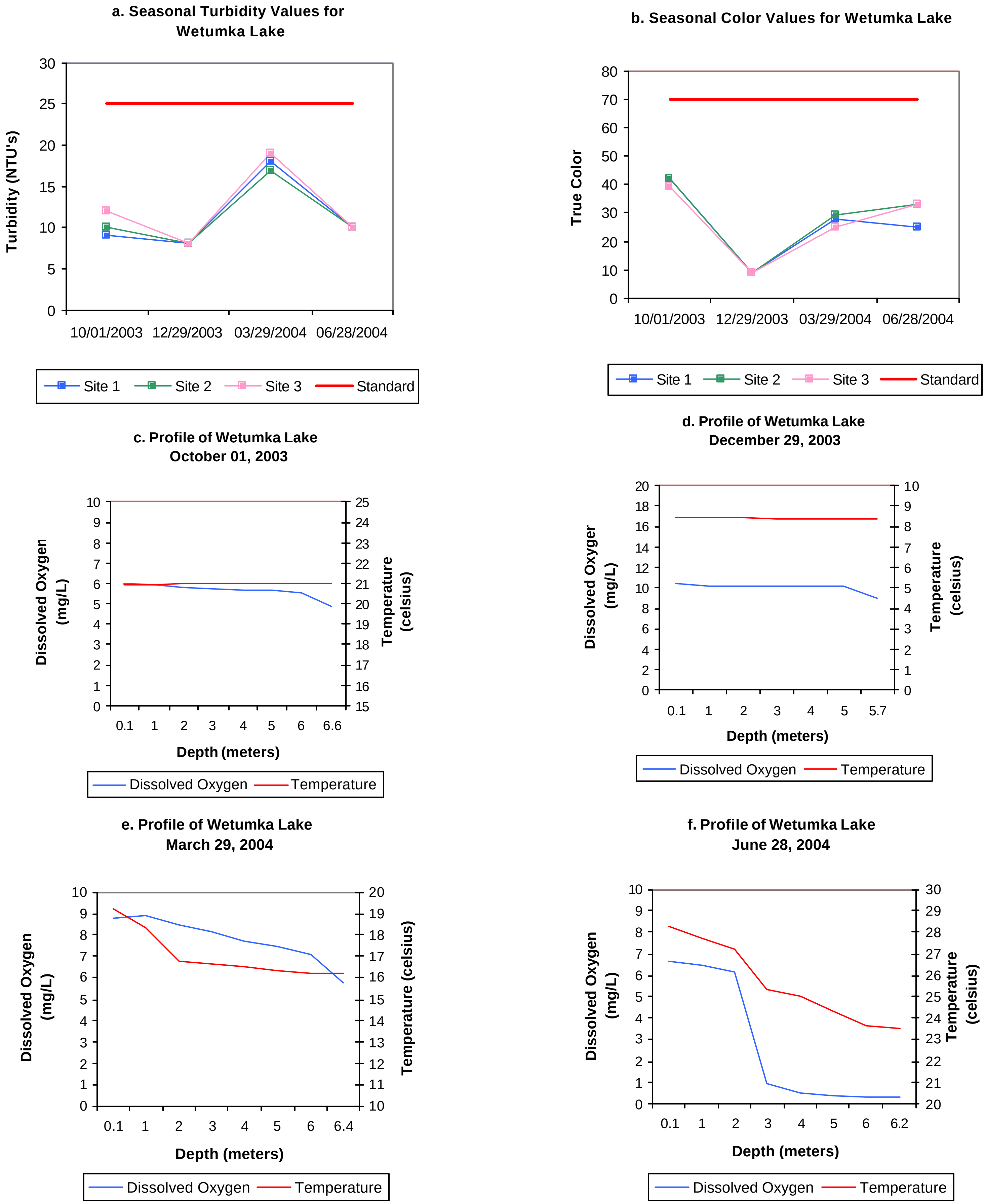
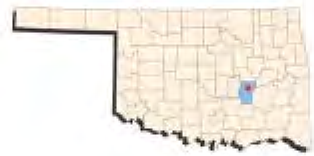
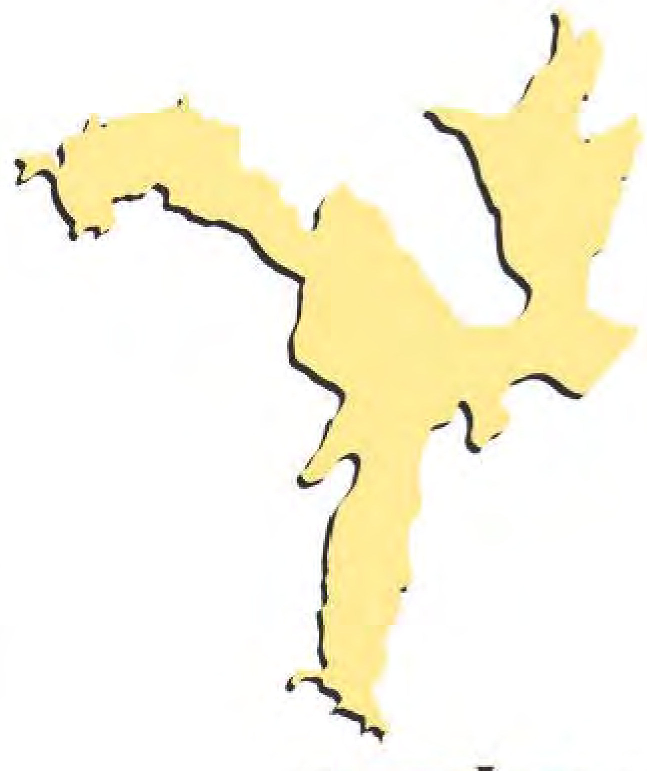



**Figure 276a-276f.** Graphical representation of data results for Wetumka Lake.

Wetumka Lake and Watershed


Wetumka Lake Location

| Lake Data | |
|---|---|
| Owner | City of Wetumka |
| County | Hughes |
| Constructed | 1939 |
| Surface Area | 169 acres |
| Volume | 1,839 acre/feet |
| Shoreline Length | 6 miles |
| Mean Depth | 10.88 feet |
| Watershed Area | 2,689 acres |



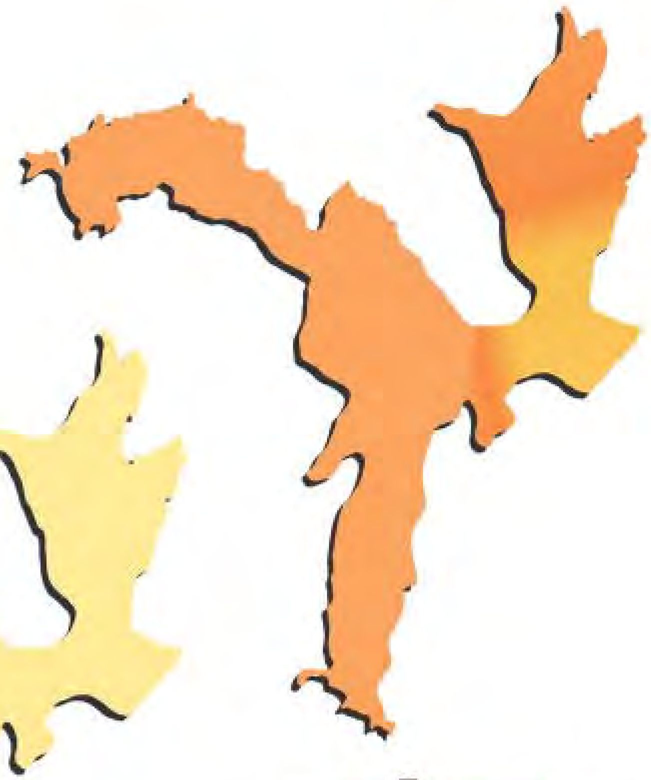




Plate 126 - Lake Water Quality for
# Wetumka Lake

# Wewoka Lake

Wewoka Lake was sampled from October 2003 through June 2004 for four quarters. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water chemistry samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 17 NTU (Plate 127), true color was 27 units, and secchi disk depth was 56 centimeters. Based on these three parameters, Wewoka Lake had average to good water clarity, slightly better than that observed in 2001. A trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The calculated TSI was 49 (Plate 127), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. The TSI values for the lake were primarily mesotrophic in the fall, winter and spring quarters with eutrophic conditions present during the summer quarter (see Figure 277). Site 3 was eutrophic in three of the four sampling intervals. Of the 20 turbidity values generated, 10% of them exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 278a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Wewoka Lake is currently supporting its Fish & Wildlife Propagation (FWP) beneficial use for nephelometric turbidity. Seasonal true color values are displayed in Figure 278b. Of the true color values collected, 100% were below the Aesthetics numerical criteria of 70 units. Applying the same default protocol, the lake is supporting the Aesthetics beneficial use for true color.

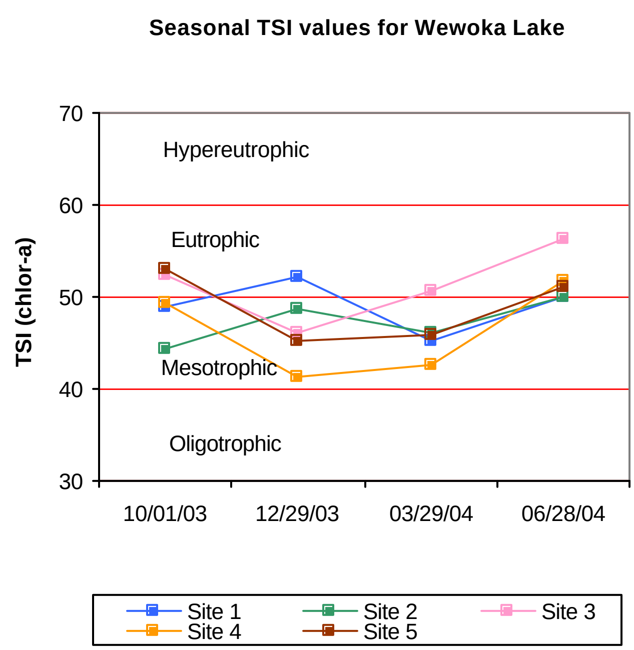



**Figure 277.** TSI values for Wewoka Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Lake salinity values ranged from 0.08 parts per thousand (ppt) to 0.11 ppt, which is within the range of expected values for Oklahoma lakes, reflecting minimal amounts of chlorides or other salts in the lake system. Specific conductance values were also consistent with the expected range of values recorded in Oklahoma reservoirs, if not somewhat lower. Values ranged from 173.4 mS/cm in to 239 mS/cm in the summer quarter near the lake bottom, indicating that low levels of electrical conducting compounds (salts) were present in the lake. Oxidation-reduction potentials (redox) ranged from 362 mV in the winter quarter to 516 mV in the fall quarter, indicating reducing conditions were not present during the study period. The pH values were generally neutral to slightly alkaline with values ranging from 7.20 units to 8.18 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All recorded pH values were all within the acceptable range supporting the FWP beneficial use. Thermal stratification was not evident in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values never fell below 6.0 mg/L in the water column at any site (see Figure 278c-278e). In the summer quarter, the lake was strongly thermally stratified between 4 and 5 meters below the surface at both sites 1 and 2. From 4 meters to the lake bottom of 7.6 meters, D.O. values were below 2.0 mg/L at site 1, constituting 44% of the water column to be experiencing anoxic conditions (see Figure 278f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 44% of the water column less than 2.0 mg/L in the summer the FWP beneficial use is fully supported at Wewoka Lake. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E. coli,* fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected one (10%) of the samples exceeded the screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the lake surface and 0.45 mg/L at the lake bottom. The TN at the surface ranged from 0.15 mg/L to 0.58 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the winter. The lake-wide total phosphorus (TP) average was 0.028 mg/L at the lake surface and 0.029 mg/L at the lake bottom. The surface TP ranged from 0.020 mg/L to 0.040 mg/L. The highest surface TP value was reported in the spring and summer quarters and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 15:1 for sample year 2003-2004. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Wewoka Lake was classified as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions (Plate). This differs from the classification from the 2001 evaluation, which found the lake to be eutrophic (TSI=52). Water clarity was average to good in comparison to other lakes based on turbidity, true color and secchi disk depth. The lake was fully supporting its Aesthetics beneficial use for trophic state and true color as all collected values were below the numeric criteria of 70 color units. Wewoka Lake was fully supporting its FWP beneficial use for nephelometric turbidity and pH. In the summer only 44% of the water column was exhibiting anoxic conditions therefore the FWP is also supported based on D.O. concentrations in the water column. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected one (10%) of the samples exceeded the screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Wewoka Lake was constructed in 1925 and is owned and operated by the City of Wewoka. The lake is utilized as a municipal water supply and offers numerous recreational opportunities to the public.

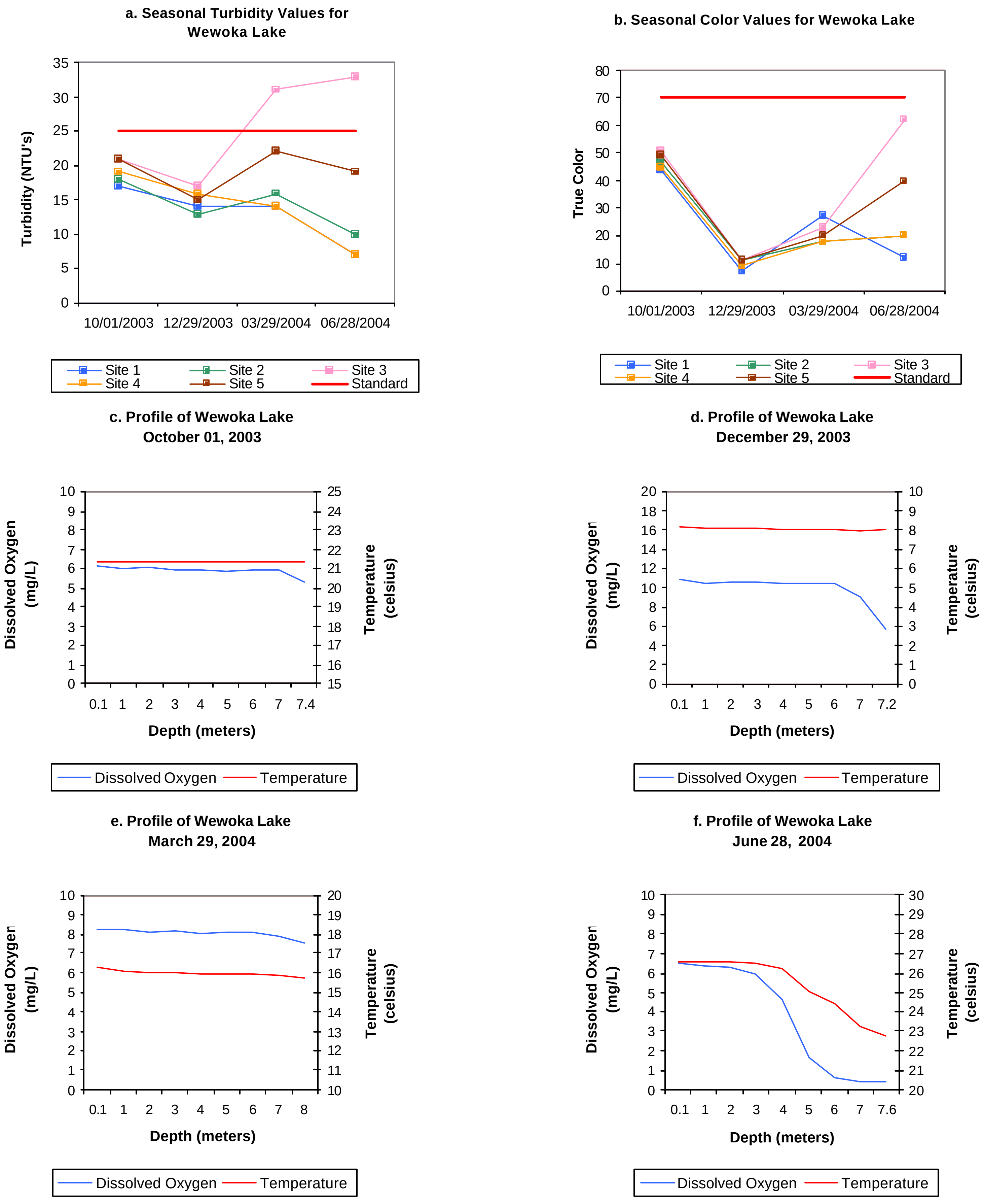
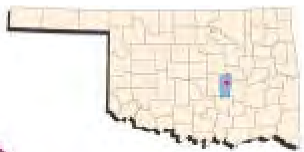



**Figure 278a-278f.** Graphical representation of data results for Wewoka Lake.


N
W
E
S

Lake Data

| | |
|---|---|
| Owner | City of Wewoka |
| County | Seminole |
| Constructed in | 1925 |
| Surface Area | 371 acres |
| Volume | 3,301 acre/feet |
| Shoreline Length | 10 miles |
| Mean Depth | 8.90 feet |
| Watershed Area | 16 square miles |



Plate 127 - Lake Water Quality for
Wewoka Lake

# Wister Lake

Wister Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a lake greater than 250 surface acres. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The average lake-wide turbidity was 72 NTU (Plate 129), true color was 177 units, and average secchi disk depth was 26 centimeters. Based on these three parameters, Wister Lake had poor water clarity in comparison to other Oklahoma reservoirs. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 54 (Plate 129), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient conditions. This is similar to 2000 (TSI=59), indicating no significant increase or decrease in productivity has occurred since the 2000 evaluation. The TSI values were fairly consistent ranging from eutrophic in the fall, winter and spring quarters to mesotrophic in the spring. The only exception was site 3, which was classified hypereutrophic in the summer (Figure 279). Wister Lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW) indicating that its Aesthetics use is threatened due to nutrients (based on trophic status). A nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 280a. Turbidity values ranged from a low of 24 NTU to a maximum of 126 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if =25% of the samples exceed the screening level prescribed in the OWQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 90% of the collected values exceeding the standard Wister Lake is considered not supporting the Fish and Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 280b. All true color values were above the OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered not supported based on true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.02 ppt in sample year 2002-2003. This is lower than the average the range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 41.6 mS/cm to 66.1 mS/cm, indicating the presence of low levels of current conducting ions (salts or chlorides) in the lake system. The pH values ranged from 6.04 to 7.49 representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP

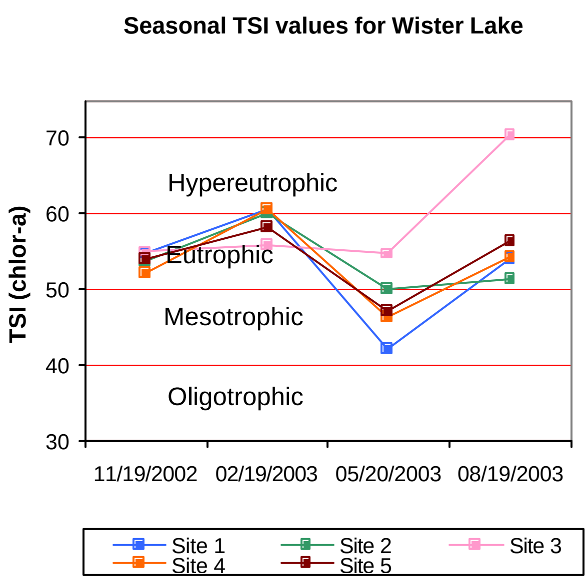



**Figure 279.** TSI values for Wister Lake.

beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With approximately 58% of the values recorded being less than 6.5 the lake is not supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (ORP) ranged from 455 mV to 574 mV, indicating reducing conditions were not present at this reservoir in sample year 2002-2003. During the fall, winter, and spring sampling intervals, stratification was not evident and the water column was well mixed (Figure 280c-280e). In the summer, the lake exhibited weak stratification with dissolved oxygen (D.O.) levels only dropping below 2.0 mg/L at the sediment-water interface (Figure 280f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Wister Lake is considered to be fully supporting the FWP beneficial use with less than 20% of the recorded values falling below 2.0 mg/L. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.64 mg/L at the surface and 0.62 mg/L at the lake bottom. Surface TN ranged from 0.05 mg/L to 1.95 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.113 mg/L at the surface and 0.184 mg/L at the lake bottom. Similar to TN, the surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.041 mg/L to 0.182 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 6:1 for sample year 2003. This value is slightly less than 7:1, characterizing the lake as nitrogen limited (Wetzel, 1983).

In summary, Wister Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions. This is similar to 2000 (TSI=59), indicating no significant increase or decrease in productivity has occurred since the 2000 evaluation. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient threatened and a nutrient impairment study should be conducted to determine if uses are impaired. Water clarity was poor based on turbidity, true color and secchi disk depth. The FWP beneficial use is supported based on dissolved oxygen, but not supported based on high turbidity values recorded throughout the year. With 58% of the recorded pH values less than 6.5 the lake is also not supporting the FWP as it relates to pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is considered supported in regards to trophic status but not supported based on true color values. In 2002, the OWRB conducted a bathymetric survey of Wister Lake (Figure 281) to obtain current conservation pool elevations to assist in identifying management alternatives to improve conditions such as nutrient reduction at Wister Lake. Outputs of this study included the annual hydraulic residence time, identification of sediment suspension zones, depth-selective flow-routed outflow and aeration techniques. For further information on bathymetric mapping please visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800. Wister Lake, constructed by the United States Army Corps of Engineers (USACE), is utilized for flood control, water supply, low flow augmentation, water conservation and sedimentation purpose.

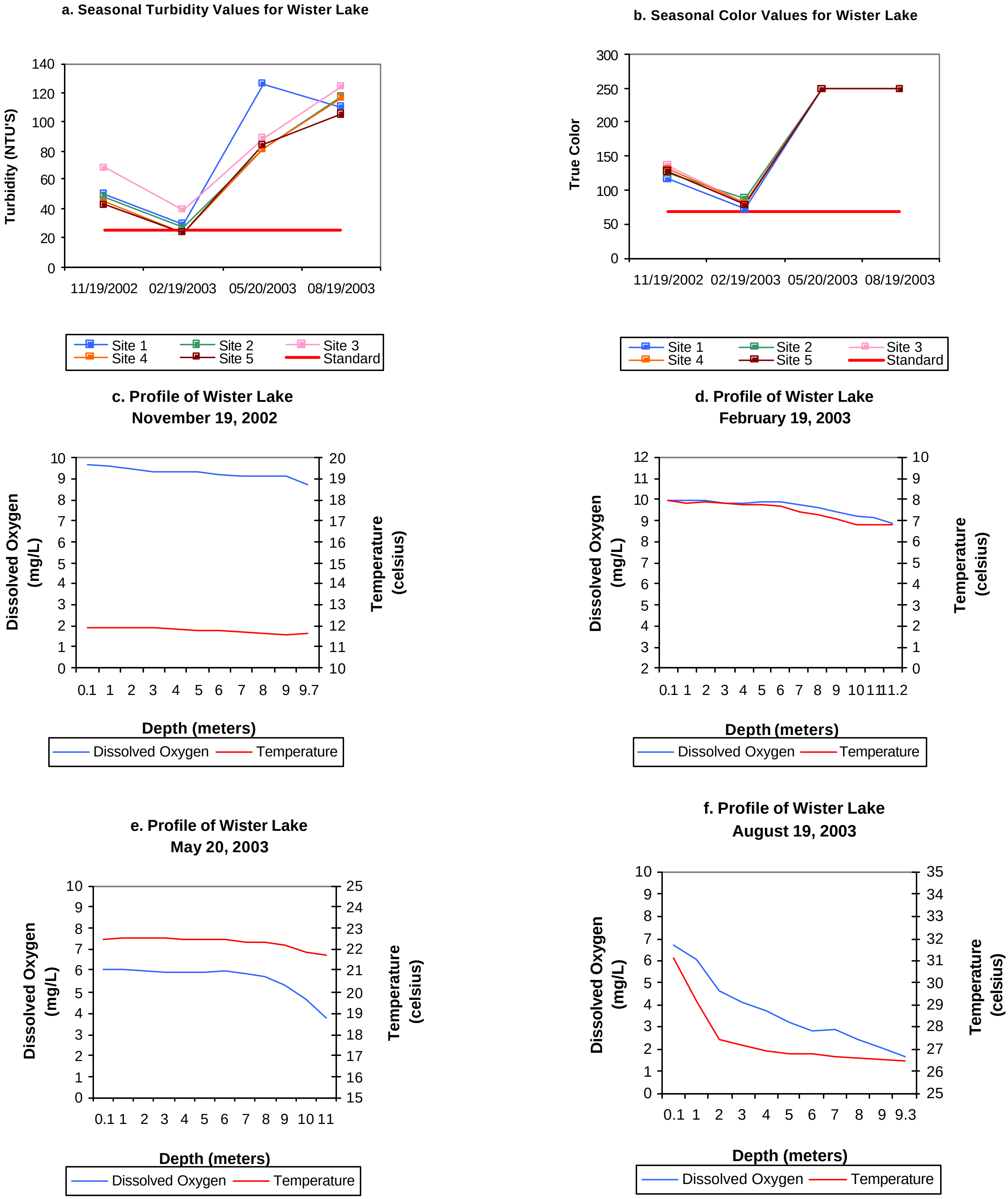
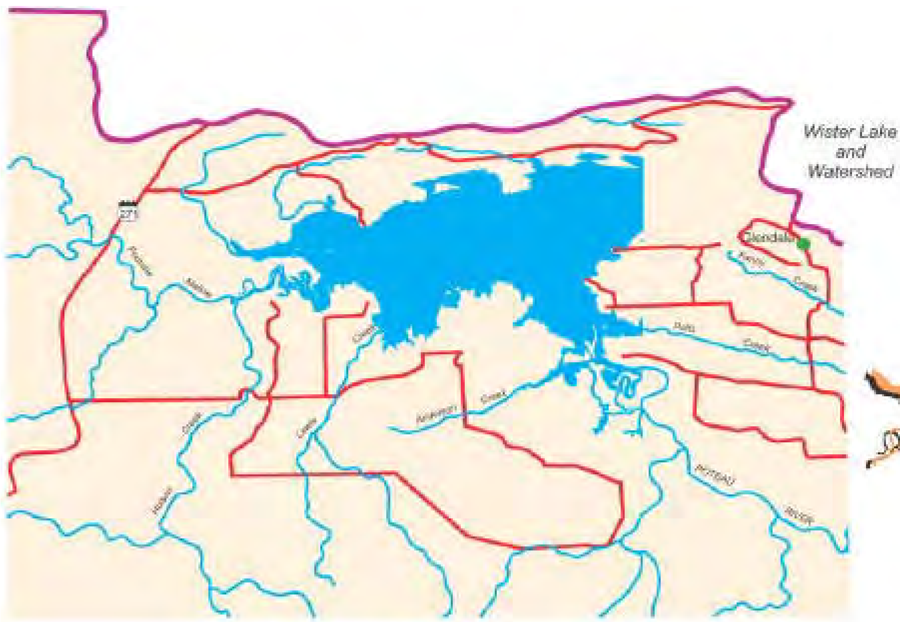
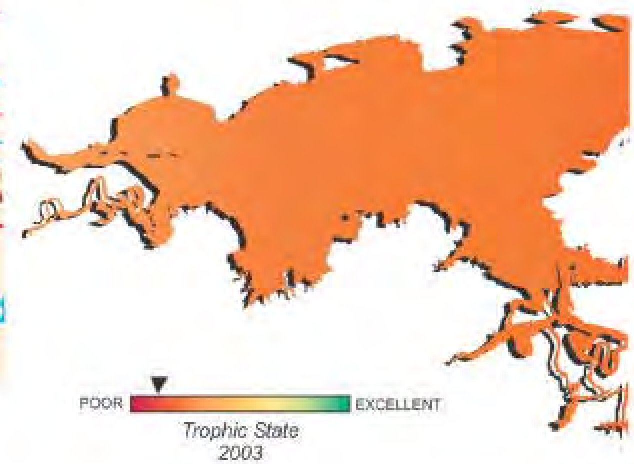
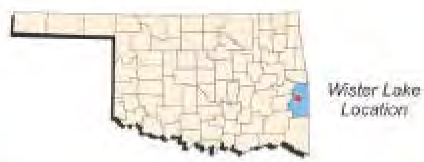


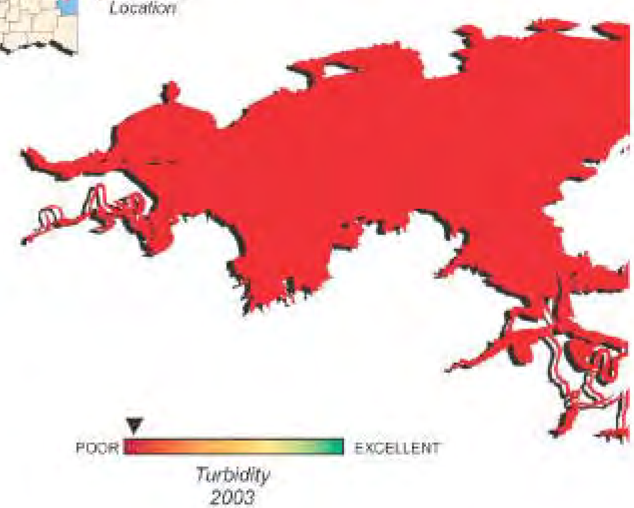

**Figure 280a-280f.** Graphical representation of data results for Wister Lake.








Lake Data

| | |
|---|---|
| Owner | Corps of Engineers |
| County | LeFlore |
| Constructed in | 1949 |
| Surface Area | 6,077 acres |
| Volume | 47,414 acre/feet |
| Shoreline Length | 93.89 miles |
| Mean Depth | 7.40 feet |
| Watershed Area | 993 square miles |

Plate 129- Lake Water Quality for
Wister Lake

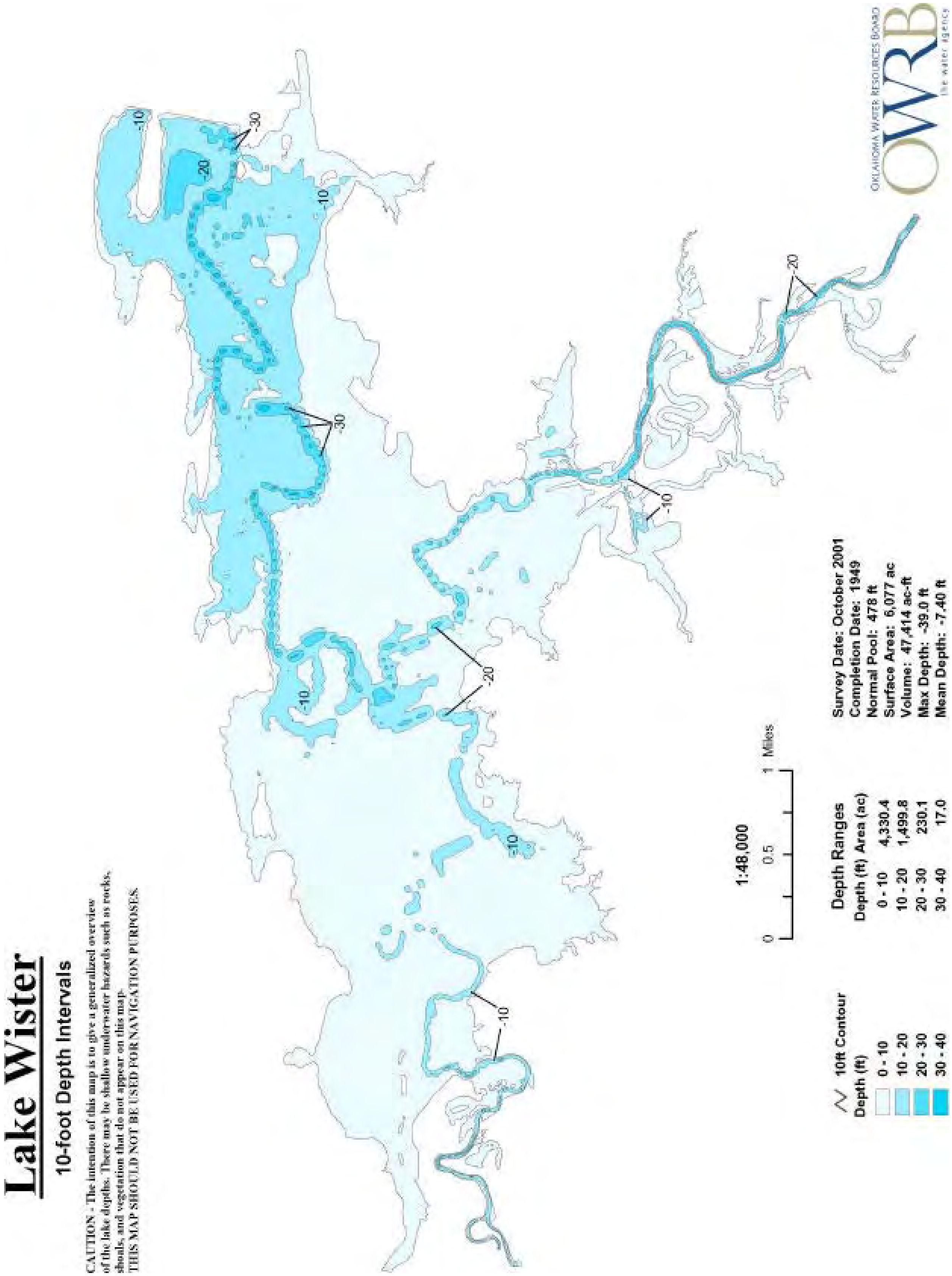



**Figure 281.** Bathymetric Map of Wister Lake.

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## INDEX

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### E

## F



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## P



## R



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## T



## V



## W

# APPENDIX A

## Oklahoma's Use Support Assessment Protocols

Proposed Amendments as of 11/17/2003
Under consideration for adoption in 2004

**TITLE 785. OKLAHOMA WATER RESOURCES BOARD**
**CHAPTER 46. IMPLEMENTATION OF OKLAHOMA'S WATER QUALITY STANDARDS**

**SUBCHAPTER 15. USE SUPPORT ASSESSMENT PROTOCOLS**

**785:46-15-1. Scope and applicability**
(a) **General.** The rules in this Subchapter provide protocols, which shall be used on and after October 1, 2000 to determine whether certain beneficial uses of waters of the state designated in OAC 785:45 are being supported. Such determinations shall be made only to the extent that pertinent provisions of OAC 785:45 apply to a waterbody or its designated uses. The rules in this Subchapter are not intended and should not be construed to limit any actions by federal or state agencies or citizens to prevent pollution or to limit remedies to abate pollution from a single incident or activity or series of incidents or activities.
(b) **Significance of assessment that a use is other than fully supported.** A determination based upon application of the rules in this Subchapter that a waterbody's beneficial use is not supported or is partially supported creates a presumption that the use is impaired <u>or not attained for that waterbody and that the waterbody segment is a water quality limited segment</u>.

**785:46-15-5. Assessment of Fish and Wildlife Propagation support**
(a) **Scope.** The provisions of this Section shall be used to determine whether the beneficial use of Fish and Wildlife Propagation or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.
(b) **Dissolved oxygen.**

(1) **Screening levels for DO in streams.**

(A) Screening levels for DO in habitat limited aquatic communities shall be 4.0 mg/L from April 1 through June 15 each year and 3.0 mg/L for the remainder of the year.
(B) Screening levels for DO in warm water aquatic communities shall be 4.0 mg/L from June 16 through October 15 each year and 5.0 mg/L for the remainder of the year.
(C) Screening levels for DO in cool water aquatic communities and trout fisheries shall be 5.0 mg/L from June 1 through October 15 each year and 6.0 mg/L for the remainder of the year.

(2) **Screening levels for DO in lakes.**

(A) If greater than 70% of the water column at any given sample site in a lake or an arm of a lake is less than 2 mg/L <u>due to other than naturally occurring conditions</u>, the Fish and Wildlife Propagation beneficial use shall be deemed to be not supported.
(B) If 50% or more, but not greater than 70%, of the water column at any given sample site in a lake or arm of a lake is less than 2 mg/L <u>due to other than naturally occurring conditions</u>, the Fish and Wildlife Propagation beneficial use shall be deemed to be partially supported.
(C) The screening level for surface DO in a lake or arm of a lake shall be 4 mg/L from June 16 through October 15 each year and 5.0 mg/L for the remainder of the year.

(3) **Support tests.**

(A) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to the DO criterion if no more than 10% of the samples from a waterbody are less than the screening level for DO prescribed in (b)(1) or (b)(2)(C) of this Section <u>and such result is due to other than naturally occurring conditions</u>.

(B) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be partially supported with respect to the DO criterion if greater than 10% but less than 25% of the samples from a waterbody are less than the screening level for DO prescribed in (b)(1) or (b)(2)(C) of this Section.

(C) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to the DO criterion if at least 5% of the samples from a waterbody are less than the screening level for DO prescribed in (b)(1) or (b)(2)(C) of this Section.

(c) **Toxicants.**

(1) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to any individual toxicant parameter if no more than one of the sample concentrations from the waterbody exceeds the acute or chronic criterion for that toxicant prescribed in the numerical criteria for toxic substances in OAC ~~785:45-5-12(f)(6)(G)~~ <u>785:45-5-12(f)(6)(D), (E) and (G)</u> and 785:45 Appendix G, Table 2.

(2) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be partially supported with respect to any individual toxicant parameter if more than one but not greater than 10% of the sample concentrations from the waterbody exceed the acute or chronic criterion for that toxicant prescribed in the numerical criteria for toxic substances in OAC ~~785:45-5-12(f)(6)(G)~~ <u>785:45-5-12(f)(6)(D), (E) and (G)</u> and 785:45 Appendix G, Table 2.

(3) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to any individual toxicant parameter if greater than 10% of the sample concentrations from that waterbody exceed the acute or chronic criterion for that toxicant prescribed in the numerical criteria for toxic substances in OAC ~~785:45-5- 12(f)(6)(G)~~ <u>785:45-5-12(f)(6)(D), (E) and (G)</u> and 785:45 Appendix G, Table 2.

(d) **pH.**

(1) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to pH occurring other than by natural causes if no more than 10% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(f)(3).

(2) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be partially supported with respect to pH occurring other than by natural causes if greater than 10% but less than 25% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(f)(3).

(3) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to pH occurring other than by natural causes if at least 25% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(f)(3).

(e) **Biological criteria.**

(1) If data demonstrate that an assemblage of fish or macro invertebrates from a waterbody is significantly degraded, according to 785:45-5-12(f)(5), from that expected for the subcategory of Fish and Wildlife Propagation designated in OAC 785:45 for that waterbody, then that subcategory may be deemed by the appropriate state environmental agency to be not supported.

(2) All physical assessments and biological collections shall be performed in accordance with the requirements set forth in OWRB Technical Report No. 99-3 entitled "Standard Operating Procedures for Stream Assessments and Biological Collections Related to Biological Criteria in Oklahoma".

(3) Evaluation of the biological collections shall include identification of fish samples to species level. Determinations of tolerance level shall be made according to Jester et al. 1992, "The Fishes of Oklahoma, Their Gross Habitats, and Their Tolerance of Degradation in Water Quality and Habitat", Proceedings of Oklahoma Academy of Sciences, 72:7-19.

(4) The determination of whether the use of Fish and Wildlife Propagation is supported in wadable streams in Oklahoma ecoregions shall be made according to all of the requirements of this subsection (e), the application of Appendix C of this Chapter, and the special provisions in subsections (g)(h) through (i) (l), where applicable, of this Section. Streams with undetermined use support status shall be subject to additional investigation that considers stream order, habitat factors and local reference streams before the use support determination is made.

(f) **Turbidity.** The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

(g) **Oil and grease.**

(1) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to oil and grease if a visible sheen or bottom deposits of oil or grease are observed on that waterbody in 10% or less of the observations.

(2) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to oil and grease if a visible sheen or bottom deposits of oil or grease are observed on that waterbody in more than 10% of the observations.

(h) **Special provisions for Ouachita Mountains wadable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadable streams located in the Ouachita Mountains ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 24 or less. If a score is 25 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Habitat Limited Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 27 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 18 or less. If a score is 19 to 26 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

~~(h)~~(i) **Special provisions for Arkansas Valley wadable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadable streams located in the Arkansas Valley ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 24 or less. If a score is 25 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Habitat Limited Aquatic Community shall be

deemed fully supported if the application of Appendix C produces a score of 27 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 18 or less. If a score is 19 to 26 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

~~(i)~~(j) **Special provisions for Boston Mountains and Ozark Highlands wadable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadable streams located in the Boston Mountains and Ozark Highlands ecoregions shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Cool Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 37 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 29 or less. If a score is 30 to 36 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 31 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 22 or less. If a score is 23 to 30 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

~~(j)~~(k) **Special provisions for Central Irregular Plains wadable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadable streams located in the Central Irregular Plains ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Cool Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 28 or less. If a score is 29 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 30 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 22 or less. If a score is 23 to 29 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(3) Where designated, the subcategory of Habitat Limited Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 25 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 16 or less. If a score is 17 to 24 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(l) **Special provisions for Central Oklahoma - Texas Plains wadable streams.** The determination of whether the Warm Water Aquatic Community subcategory of the Fish and Wildlife Propagation beneficial use is supported for wadable streams located in the Central Oklahoma - Texas Plains ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Such subcategory shall be deemed fully supported if the application of Appendix C produces a score of 26 or more.

(2) Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 19 or less.

(3) If the application of Appendix C produces a score of 20 to 25 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

**785:46-15-6. Assessment of Primary Body Contact Recreation support**

(a) **Scope.** The provisions of this Section shall be used to determine whether the subcategory of Primary Body Contact of the beneficial use of Recreation designated in OAC 785:45 for a waterbody is supported during the recreation season from May 1 through September 30 each year. <u>Where data exist for multiple bacterial indicators on the same waterbody or waterbody segment, the determination of use support shall be based upon the use and application of all applicable tests and data.</u>

(b) **Screening levels.**

(1) The screening level for fecal coliform shall be a density of 400 colonies per 100ml.

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(c) **Fecal coliform.**

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

(2) The parameter of fecal coliform is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is not met, or greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(d) **Escherichia coli (*E. coli*).**

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to *E. coli* if the geometric mean of 126 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The parameter of *E. coli* is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to *E. coli* if the geometric mean of 126 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

(e) **Enterococci.**

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The parameter of enterococci is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to enterococci if the geometric mean of 33

colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

**785:46-15-7. Assessment of Public and Private Water Supply support**

(a) **Scope.** The provisions of this Section shall be used to determine whether the beneficial use of Public and Private Water Supply or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(b) **Toxicants.**

(1) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be fully supported with respect to any substance with criteria for such use listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ OAC 785:45 Appendix G if the sample concentrations from that waterbody do not exceed the criterion for that substance prescribed in ~~785:45-5-10~~ OAC 785:45 Appendix G more than 10% of the time, or drinking water use restrictions are not in effect, or both such conditions exist.

(2) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be partially supported with respect to any substance with criteria for such use listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ OAC 785:45 Appendix G if the sample concentrations from that waterbody exceed the criterion for that substance prescribed in ~~785:45-5-10~~ OAC 785:45 Appendix G more than 10% but less than 25% of the time, or drinking water use restrictions imposed by an agency with jurisdiction in effect require more than conventional treatment, or both such conditions exist.

(3) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be not supported with respect to any substance with criteria for such use listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ OAC 785:45 Appendix G if the sample concentrations from that waterbody exceed the criterion for that substance prescribed in ~~785:45-5-10~~ OAC 785:45 Appendix G more than 25% of the time, or drinking water use restrictions imposed by an agency with jurisdiction in effect require closure of the water supply, or both such conditions exist.

(c) **Bacteria.** The screening level for fecal coliform bacteria shall be 5000 colonies per 100 ml. The tests for use support shall follow the default protocol in 785:46-15-4.

(d) **Threatened water supplies.** Waters of the state designated in OAC 785:45 as Public and Private Water Supply shall be presumed to be threatened when toxicants are detected but do not exceed the applicable criteria prescribed in ~~785:45-5-10~~ OAC 785:45 Appendix G, or some drinking water use restrictions have been put into effect by an agency with jurisdiction, or the potential for adverse impacts to water quality exists, or more than one such conditions exist.

(e) **Oil and grease.**

(1) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be fully supported with respect to oil and grease if a visible sheen or bottom deposits of oil or grease are observed on that waterbody in 10% or less of the observations, and drinking water use restrictions that require more than conventional treatment related to oil and grease have not been put into effect by an agency with jurisdiction.

(2) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be not supported with respect to oil and grease if a visible sheen or bottom deposits of oil or grease are observed on that waterbody in more than 10% of the observations, or drinking water use restrictions that require more than conventional treatment related to oil and grease has been put into effect by an agency with jurisdiction.

**785:46-15-10. Nutrients**

(a) **General.** OAC 785:45-3-2(c) prohibits water quality degradation by nutrients, which will interfere with the attainment or maintenance of any existing or designated beneficial use. OAC 785:46-13-3(a)(1) requires maintenance of any existing or designated beneficial use. This Section provides a framework, which shall be used in assessing threats or impairments to beneficial uses and waterbodies and watersheds caused by nutrients, and the consequences of such assessments.

(b) **Determining whether a stream is nutrient-threatened.** The dichotomous process stated in this subsection shall be used in the determination of whether a stream is nutrient-threatened.

(1) The stream order shall be identified. If the stream order is 1, 2 or 3, then proceed to paragraph (2). If the stream order is not 1, 2 or 3, then proceed to paragraph (9).

(2) The stream slope shall be identified. If the stream slope is greater than or equal to 17 feet per mile, then proceed to paragraph (3). If the stream slope is less than 17 feet per mile, then proceed to paragraph (4).

(3) Subject to the application of the foregoing paragraphs of this subsection, if ~~phosphorous~~ phosphorus concentrations in the stream are greater than 0.24 mg/L or if nitrite plus nitrate concentrations in the stream are greater than 4.95 mg/L, then proceed to paragraph (5). If such nutrient concentrations are less than the levels specified in this paragraph, then the stream is not threatened by nutrients.

(4) Subject to the application of the foregoing paragraphs of this subsection, if ~~phosphorous~~ phosphorus concentrations in the stream are greater than 0.15 mg/L or if nitrite plus nitrate concentrations in the stream are greater than 2.4 mg/L, then proceed to paragraph (5). If such nutrient concentrations are less than the levels specified in this paragraph, then the stream is not threatened by nutrients.

(5) Subject to the application of the foregoing paragraphs of this subsection, if the percentage of canopy shading is greater than or equal to 80%, then the stream is not threatened by nutrients. If the percentage of canopy shading is less than 80%, then proceed to paragraph (6).

(6) Subject to the application of the foregoing paragraphs of this subsection, if the stream's turbidity is organic, then proceed to paragraph (7). If the stream's turbidity is inorganic, then proceed to paragraph (8).

(7) Subject to the application of the foregoing paragraphs of this subsection, if turbidity measured at seasonal base flow conditions is less than 20 NTU, then the stream is not threatened by nutrients. If turbidity measured at seasonal base flow conditions is 20 or more NTU, then the stream is threatened by nutrients.

(8) Subject to the application of the foregoing paragraphs of this subsection, if turbidity measured at seasonal base flow conditions is less than 20 NTU, then the stream is threatened by nutrients. If turbidity measured at seasonal base flow conditions is 20 or more NTU, then the stream is not threatened by nutrients.

(9) Subject to the application of the foregoing paragraphs of this subsection, if the stream slope is greater than or equal to 17 feet per mile, then proceed to paragraph (10). If the stream slope is less than 17 feet per mile, then proceed to paragraph (11).

(10) Subject to the application of the foregoing paragraphs of this subsection, if ~~phosphorous~~ phosphorus concentrations in the stream are greater than 1.00 mg/L, or if nitrite plus nitrate concentrations in the stream are greater than 4.65 mg/L, then proceed to paragraph (12). If such nutrient concentrations are less than the levels specified in this paragraph, then the stream is not threatened by nutrients.

(11) Subject to the application of the foregoing paragraphs of this subsection, if ~~phosphorous~~ phosphorus concentrations in the stream are greater than 0.36 mg/L, or if nitrite plus nitrate concentrations in the stream are greater than 5.0 mg/L, then proceed

to paragraph (12). If such nutrient concentrations are less than the levels specified in this paragraph, then the stream is not threatened by nutrients.

(12) Subject to the application of the foregoing paragraphs of this subsection, if the stream's inorganic turbidity measured at seasonal base flow conditions is greater than or equal to 20 NTU, then the stream is not threatened by nutrients. If the stream's inorganic turbidity measured at seasonal base flow conditions is less than 20 NTU, then the stream is threatened.

(c) **Alternative to dichotomous process for streams.**

(1) A wadable stream shall be deemed threatened by nutrients if the arithmetic mean of benthic chlorophyll-a data exceeds 100 mg per square meter under seasonal base flow conditions, or if two or more benthic chlorophyll-a measurements exceed 200 mg per square meter under seasonal base flow conditions. A non-wadable stream shall be deemed threatened by nutrients if planktonic chlorophyll-a values in the water column indicate it has a Carlson's Trophic State Index of 62 or greater.

(2) If clear and convincing evidence indicates a result for a stream different from that obtained from application of the dichotomous process in (b) of this Section, then the appropriate state environmental agency may, after completing the public participation process developed by the Secretary of Environment pursuant to 27A O.S. 1-2-101, accordingly identify the stream as threatened or not threatened by nutrients.

(d) **Demonstration that nutrients may be adversely impacting a beneficial use in a lake.** If it is demonstrated that nutrient loading in a lake may be adversely impacting a beneficial use designated for that waterbody, then the Board may determine that the lake and its watershed is an NLW, and shall identify the lake and watershed as NLW in Appendix A of OAC 785:45.

(e) **Consequence of identification as NLW; results of study.** If a lake or its watershed is identified as NLW in Appendix A of OAC 785:45, then the Board or other appropriate state environmental agency may cause an NLW Impairment Study to be performed. The beneficial uses designated for lakes identified in OAC 785:45 Appendix A as NLW shall be presumed to be fully supported but threatened, unless an NLW Impairment Study demonstrates that the uses are partially supported or not supported; provided, if an NLW Impairment Study demonstrates that the uses are not threatened, then the Board shall consider deleting the NLW identification.

(f) **Consequence of assessment that use is threatened by nutrients.** If it is determined that one or more beneficial uses designated for a waterbody are threatened by nutrients, then that waterbody shall be presumed to be nutrient-threatened. If it is determined or presumed, in accordance with this Section, that a waterbody is nutrient-threatened, then before the waterbody is determined to be nutrient-impaired, an NLW Impairment Study if a lake or an impairment study if a stream must be completed by the appropriate state environmental agency.

(g) **Result of impairment study.**

(1) **Impaired or threatened.** If, independent of or in addition to the process set forth in (b) of this Section, an impairment study of a waterbody demonstrates that a waterbody is impaired or threatened by nutrients, then the appropriate state environmental agency shall initiate the appropriate listing procedure developed by the Secretary of Environment pursuant to 27A O.S. 1-2-101.

(2) **Not threatened nor impaired.** If, independent of or in addition to the process set forth in (b) of this Section, an impairment study of a waterbody demonstrates that a waterbody is neither threatened nor impaired by nutrients, then the appropriate state environmental agency shall initiate the appropriate de-listing procedure developed by the Secretary of Environment pursuant to 27A O.S. 1-2-101.

**785:46-15-11. Assessment of Hydroelectric Power Generation support**

The Hydroelectric Power Generation beneficial use designated for a waterbody shall be deemed to be fully supported for the purpose of water quality reporting.

**785:46-15-12. Assessment of Industrial and Municipal Process and Cooling Water support**

The Industrial and Municipal Process and Cooling Water beneficial use designated for a waterbody shall be deemed to be fully supported for the purpose of water quality reporting.

**785:46-15-13. Assessment of Navigation support**

The Navigation beneficial use designated for a waterbody shall be deemed to be fully supported for the purpose of water quality reporting.