# Final Report

# Oklahoma Water Resources Research Institute (FY 2007)

**Title: Decision Support Model for Optimal Water Pricing Protocol for Oklahoma Water Planning: Lake Tenkiller Case Study**

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**Publications:** none

Students Trained and Supported:

| Student Status | Number | Disciplines |
|---|---|---|
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| Post Doc | | |
| Total | 5 | |

## Section I: Problem and Research Objectives

### Objectives

The objective of this study was to develop a water pricing model that could be used in the state water planning process. The model considers both monetary and opportunity costs in the allocation of surface water between competing uses. The model was constructed for Tenkiller Ferry Lake in Sequoyah and Cherokee counties. The specific purpose was to develop a water pricing protocol that

(1) internalizes monetary and opportunity costs of water storage, treatment, and delivery systems; and
(2) generates an sustainable supply of water over the 2010-2060 period.

Background

The lake dam is located in the Arkansas River Basin on the Illinois River in Sequoyah County. The lake is among the Oklahoma's 34 major reservoirs that store 13 million acre-feet of water. The structure was federally authorized for flood control and hydroelectric power. Construction was completed by the US Army Corps of Engineers (USACE) in 1953. The lake has 130 miles of shoreline with a mean depth of 51 feet. Capacity is 654,100 acre feet at the normal pool and 1,230,800 at the flood pool (OWRB Fact Sheet). The main beneficial uses of the lake are recreation, flood control, power generation, stream flow maintenance and municipal and industrial use.

The need for an economic model that optimizes net benefits from multiple water uses and tracks water balances for Tenkiller and other lakes is illustrated by statements from the U.S. Army Corps of Engineers (USACE) 2001 report on a proposed water treatment and conveyance study (USACE, 2001). According to the 2001 USACE report Lake Tenkiller had water rights of 29,792 acre feet with 14,739 feet allocated. Applications were pending for 172,714 acre feet. The USACE report found the 9,096 acre feet of water rights owned by the participating systems are insufficient to meet demands by the year 2050. The report further pointed out that "..having sufficient water rights does not guarantee a …. system would have enough water to meet projected demands. Water storage must also be considered"

The optimization model illustrates the tradeoffs between managing for market uses (municipal and hydropower) and managing for all uses including market and recreational uses (non-market) of surface water resources. When non-market uses, in this case, recreation, are ignored, these values are assumed to be zero in the management process. The results of this modeling process illustrate the economic importance of recreational uses by showing that when recreational values are explicitly considered in the optimization model, surface water pool levels are maintained at normal pool level during peak summer months of recreational use. Although securing water supplies, hydropower, and flood control provided the original motivation for creating Tenkiller Dam, like many other reservoirs in the Oklahoma system, the subsequent recreational values prove significant and maintenance of water rights for users and the regional economies should be also explicitly considered in the state water planning process.

Current recreational values for lake use were not available for Oklahoma. Thus this study first conducted a statewide recreational valuation study to provide as input into this model and future state water planning studies. Accordingly, the final report is divided into sub-reports to provide results on the specific objectives of the project as follows:

**Section II Valuation of Oklahoma Lakes**

II.1 Problem and Research Objectives Oklahoma Lake Valuation

II.2 Methodology of Oklahoma Lakes Survey

II.3 Principal Findings and Significance of Oklahoma Lakes Survey

**Section III Construction and Optimization of a Lake Model for Power, Municipal, and Recreation**

III.1 Objectives

III. 2 Review of Lake Management Modeling

III.3 Principal Findings and Significance

**Section IV Extension of Research Results**

IV.1 Methodology

IV.2 Principal Findings and Significance

**Methodology**

## Section II. Valuation of Oklahoma Lakes

The state of Oklahoma has over 300 lakes, more man-made lakes than any other state, with over one million surface acres of water (Oklahoma Tourism and Recreation Department, 2007). Many of lakes are used for several reasons such as hydroelectric power, flood control, agriculture, and recreation. Since the mid 1950s, demand for lake recreation in Oklahoma has increased continuously due to increased convenience of transportation, communication, and other technologies such as types of vehicles and types of new watercrafts available to public (Caneday, 2000). The outdoor recreation business was reported as one of the fastest growing businesses in Oklahoma (Oklahoma Tourism and Recreation Department, 2001). Even though the demand for lake recreation in Oklahoma is increasing, few recent studies have analyzed the demand for lake recreation as well as welfare effects from lake use in term of recreation (Jordan and Badger, 1977). Caneday and Jordan (2003) studied the behavior of Oklahomans traveling to state parks, but they did not estimate economic values for water based amenities such as quality and quantity or estimate total visitation across all water-oriented recreational activities. Therefore, currently, there is no comprehensive explanation for lake recreation demand in Oklahoma.

## II.1 Problem and Research Objectives of Oklahoma Lake Valuation

This study estimated the value of lake recreation for Tenkiller as part of a statewide Oklahoma Lakes Survey conducted in 2007. The research performed in this study focuses on determining what the opportunity cost of diminished recreational value for Tenkiller recreation when there are competing uses for water. Specifically we wished to answer the following question, "What is the recreational value of a trip to Tenkiller Lake?" However, since values for recreation were scant for the entire state of Oklahoma, we wished to determine what factors influence demand for lake recreation statewide and specifically how much does willingness to pay for recreation change according to lake quality improvements?" When no value is assigned to recreational uses, then they are treated as if they were zero.

## II. 2 Methodology of Oklahoma Lakes Survey

Data for this paper were collected by mail on Oklahoma Lake Use (2007) for travel cost and discrete choice experiments. The survey is provided in appendix A. Data on travel distances and lake characteristics were compiled from GIS maps from Oklahoma Water Resource Board (OWRB), lake websites, and phone interview with lake managers.

The survey was mailed to 2,000 individuals, who were randomly chosen, in every county of Oklahoma during fall 2007. A random sample was obtained from Survey Sampling Inc, Fairfield, CT, stratified across 6 regions of Oklahoma.

The survey was first distributed in September 2007 by mail. Standard Dillman procedures were used to elicit the highest possible response rate (Dillman, 2000). The cover letter and follow up letters that accompanied the survey are provided in Appendix A. From 2,000 surveys, 401 were returned. Thirty-nine of them were unusable, and allowing for 150 undeliverable surveys due to no forwarding addresses. The net response rate was 19.57 percent. The survey was designed to collect both revealed preferences for lake visits, i.e., travel cost data, and stated or hypothetical data on preferences for lake amenities. The revealed preference method is often believed to be very credible for valuation since users have actually chosen to spend money and time visiting a site. The hypothetical/stated preference method is helpful in determining potential demand for improvements or management scenarios not currently available.

***Stated preference data***

The Oklahoma Lakes Survey asked hypothetical or stated preference (SP) questions about potential management changes in lake amenities using a discrete choice experiment. Orthogonally designed sets of discrete choice experiments were designed to estimate willingness to pay for quality and amenity improvements at a lake similar to the lake respondents most often visited. The SP questions elicited lake visitor preferences for lake attributes, including availability of lake amenities and distance travelled to the lake. Six measurable attributes associated with lake recreation at 2 to 6 levels each as shown in Table II.1. This created 2,304 possible combinations. Each combination was then randomly paired with another combination to create different options for columns A and B. The third option from which respondents could choose was given as the respondent's most frequently visited lake, or the status quo for that person.

Each respondent was asked to answer two experimental choice questions. Each of them contains two options of hypothetical lakes, options A and B. An example is given in Figure II.1.

**Table II.1. Attributes and Levels in the Discrete Choice Survey (Stated Preference)**

| Attribute | Factor Levels |
|---|---|
| Increase in public boat ramp | None |
| | 1 Boat ramp |
| | 2 Boat ramp |
| | 3 Boat ramp |
| Campsites | None |
| | Available |
| | Available with electric service |
| Public restroom | None |
| | Porta-potties/ Pit toilets |
| | Restroom with flush toilets |
| | Restroom with flush toilets and showers |
| Lodge | None |
| | Available |
| Water clarity | No improvement |
| | 1 foot increase of water visibility dept from surface |
| | 2 foot increase of water visibility dept from surface |
| | 3 foot increase of water visibility dept from surface |
| Increase in distance from home (one-way) | 0 miles increase |
| | 10 miles increase |
| | 20 miles increase |
| | 30 miles increase |
| | 40 miles increase |
| | 50 miles increase |

**Figure II. 1. An Example of Conjoint Question**

**Compared to the lake you most visit, would you choose a lake such as A or B? Or would you choose to stay with the one you currently visit, C? Please choose one.**

| Attribute | Option A | Option B | Option C |
|---|---|---|---|
| **Increase in public boat ramps** | 2 Boat ramp | 1 Boat ramp | **NO CHANGE:** I would rather keep the management of this lake the way it is today |
| **Campsites** | Available with electric service | Available with electric service | |
| **Public restrooms** | Restroom with flush toilets and showers | Restroom with flush toilets and showers | |
| **Lodges** | None | Available | |
| **Water clarity** | 1 foot increase of water visibility dept from surface | No improvement | |
| **Increase in distance from home (one-way)** | 20 miles increase | 40 miles increase | |
| **I would choose (Please check only one)** | ☐ **A** | ☐ **B** | ☐ **C** (I would not want either A or B) |

**Given your choice above, how many trips per year would you take?**

Number of single day trips ☐ same number or ___#less or ___# more

**Modeling**

The marginal values for the attributes listed in Table II.1 were estimated using a conditional logit model based on the Random Utility Model (RUM). We assume that when asked to choose between options A, B and the option of not choosing a lake, our respondents choose the option that gives them highest utility. If

$$U_{ij} > U_{ik} \qquad (1)$$

the respondent will select option $j$ over $k$ only if (1) holds for all $j \neq k$.

However, we do not know real utility of the respondent. We can only observe part of the respondent's utility denoted as $V_{ij}$, and the unobservable part of the utility that is unknown is denoted as $\varepsilon_{ij}$. Therefore, the utility can be represented as

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad (2)$$

where $i$ denotes the respondent, $j$ denotes the option (A, B, or neither A or B).

As mentioned above, the respondents will choose the option or lake that gives them highest utility, and we can observe $V_{ij}$ by giving options A, B, or neither A or B to respondents. Therefore, $V_{ij}$ can be expressed as a function of policy attributes accompanying each alternative, for the stated preference example below:

$$V_{ij} = \beta_1(R_{ij}) + \beta_2(C_{ij}) + \beta_3(CE_{ij}) + \beta_4(P_{ij}) + \beta_5(T_{ij}) + \\ + \beta_6(FS_{ij}) + \beta_7(L_{ij}) + \beta_8(WQ_{ij}) + +\beta_9(F_{ij})\varepsilon_{ij} \quad (3)$$

The equation for the stated preference discrete choice model is as follows: *R* is the number of boat Ramps available; *C* is a dummy for whether a basic campsite is available; *CE* is whether a campsite with electricity is available; *P* is if porta-potties are available only; *T* is a dummy variable if flush toilets are available; *FS* is dummy variable of restroom with flush toilets and showers; and *L* is if a lodge is available, WQ is the water clarity measured by Secchi Disk depth, and F is the price of going to the lake (either a distance converted to a mileage rate or a fee imposed for entry, depending on the model. $\beta's$ are the parameters to be estimated. In addition, in order to calculate the marginal willingness to pay, each attribute coefficient will be divided by the estimated coefficient for distance which functions as the price paid for the trip.

***Revealed preference data (Travel Cost Model)***

Respondents were also asked to report their actual visitation patterns of single-day trips and multiple day trips to 144 public lakes in Oklahoma in 2007 (See Appendix B for the table of lakes in the survey). They were also asked a series of questions about their activities at lakes, features of lakes they prefer, and basic demographic data. Appendix C gives additional statistics on the activities, interest in state provided information on the lakes and demographics of the sample which were not explicitly used in the travel cost valuation.

In order to obtain the effect of water quality on lake recreation demand, water quality data were gathered from Beneficial Use Monitoring Program (BUMP) database of OWRB. Because more detailed chemical analysis data such as phosphorus, nitrate and algal levels were not available, system wide, Sechhi disk depth level is used. A Secchi disk is used to measure how deep a person can see into the water. A black and white patterned disk is lowered into the lake until the observer loses sight of it. Then, the disk is raised until it reappears. The depth of the water where the disk reappears is the Secchi disk reading. Although this is a crude measure, lake users have direct visual experience with lake clarity and may not have awareness of other quality characteristics.

Data on the physical amenities available at each lake (types of restrooms, docks, campsites, boat ramp, etc.) were collected from the lake websites and/ or by phone interview with lake managers. TransCAD software was used to calculate the distance from each zip code to 144 lakes via roads. Then, the distances were expressed as round trip travel cost, which was combined with out-of-pocket expenditure and opportunity cost of time.[1]

Again, as explained above in equations (1) and (2), a conditional logit, random utility travel cost model is estimated for the travel cost model. A random utility travel cost model is focused on measuring the differences in site characteristics as a function of site choice (details on measurement of environmental values and differing methods are available in Freeman, 2003). The "price" of recreation is trip cost, such as mileage in our model. It is assumed that a person chooses the lake with the characteristics that yield the highest utility (or happiness) conditional on the availability of 143 other lakes with a varied set of amenities. A single lake's valuate is estimated by the formula as follows

$$CV = -\frac{1}{\beta_{TC}} \ln\left(exp\left(v_j\right)\right) \qquad (4)$$

where $\beta_{TC}$ is the travel cost coefficient, and $v_j$ is the indirect utility visiting site $j$. In this method, the user has reported actual trips to lakes in Oklahoma.

## II.3 Principle Findings and Significance of the Oklahoma Lakes Survey

Table II.2 below gives the results from the stated preference model. All of the variables included were significantly different from zero at greater than 90% confidence levels except for increases in Boat Ramps, the presence of a state park lodge, portable potties, and improvements in water clarity. These four variables do not induce a significant willingness to pay that is different from zero. The result for park lodges is interesting since Oklahoma has an extensive lodge system that needs constant upgrading due to its age. Table II.3 translates these results into mean willingness to pay for these individual attributes. The entrance fee model shows that having basic campsites at the average lake raises a lake's per trip value $6.48 (2007USD) compared to having none, but campsites with electric hookups add an additional $6.80 per trip. Flush toilets were worth $23.47 per trip compared to having none and restrooms with showers were worth $3.55 per trip more. These results confirm that users of lakes value more services over fewer amenities.

[1] The out-of-pocket expenditure was estimated by multiplying distance with $0.48/ mile, and the opportunity cost of time was calculated as one third of an hourly individual's wage rate time by travel time, which was assumed speed of 50 mile/hour.

**Table II.2 Conditional Logit Entrance Fee Model (Stated Preference)**

| Parameter | DF | Coeff | Std | t-value | p-value |
|---|---|---|---|---|---|
| Boat ramp | 1 | -0.015 | 0.064 | -0.240 | 0.8130 |
| Camp available | 1 | 0.318 | 0.189 | 1.680 | 0.0920 |
| Camp with electric | 1 | 0.651 | 0.185 | 3.520 | 0.0004 |
| Porta-Potties | 1 | 0.363 | 0.243 | 1.500 | 0.1340 |
| Flush toilet | 1 | 1.150 | 0.223 | 5.150 | <0.0001 |
| Flush toilet with showers | 1 | 1.324 | 0.224 | 5.920 | <0.0001 |
| Lodge | 1 | 0.120 | 0.147 | 0.820 | 0.4140 |
| Water clarity | 1 | 0.099 | 0.067 | 1.500 | 0.1342 |
| Entrance fee | 1 | -0.049 | 0.007 | -6.550 | <0.0001 |
| Constant | 1 | -1.680 | 0.277 | -6.080 | <0.0001 |
| Log Likelihood = -553.400 | | | | | |

**Table II.3 Willingness to Pay for Changes in Attributes from the Entrance Fee Model**

| | WTP |
|---|---|
| Boat ramp | NS |
| Camp available | $6.48 |
| Camp with electric | $13.28 |
| Porta-Potties | NS |
| Flush toilet | $23.47 |
| Flush toilet with showers | $27.02 |
| Lodge | NS |
| Water clarity | NS |

NS indicates the variables are not significantly different from zero.

## Travel Cost Model

The results from the Travel Cost Model are given in Tables II.4 and II.5 which give the descriptive statistics and results respectively. Travel Cost is measured in 2007 dollars per person per trip. Travel cost is calculated as the round trip cost of road travel and time travel on the road. This was found by multiplying distance with $0.48/ mile (AAA 2007 rate), and the opportunity cost of time was calculated as one third of an hourly individual's wage rate time by travel time, which was assumed speed of 50 mile/hour. The issue of valuing individuals' time is problematic because of differences in paid versus unpaid time off, among other issues. We take a conservative approach here and value lost time in travel to and from the site. The assumption we make here is that the trip itself is an opportunity cost, but the individual does not view time on site as a cost in lost wages. The mean expenditure for single day trips is $186.18, and $149.34 per trip. However, the value of each lake depends on its characteristics when using the models estimated in Table II.5. Lakes were divided regionally by quadrants dividing the state of Oklahoma by I-40 running East-West and I-35 running North-South.

**Table II.4.** Travel Cost Model: Variable Definitions for Oklahoma Lakes

| Variable | Definition | Mean or % |
|---|---|---|
| *Travel Cost*[1] | $/roundtrip/person | $186.1877 (Single Day Trip)<br>$149.3376 (Multiple Days Trip) |
| *Boat Ramp* | Number | 3.3542 |
| *Porta-Potties* | Number | 3.2500 |
| *Flush-Toilet* | Number | 1.2431 |
| *Flush-Toilet with Shower* | Number | 1.6944 |
| *Lodge* | Number | 0.7153 |
| *Campsite* | Number | 83.2708 |
| *Campsite with Electricity* | Number | 60.4792 |
| *Water Clarity* | Centimeters Secchi Depth | 82.9011 |
| *Shoreline* | Miles | 69.9375 |
| *Swimming Beach* | Available=1, 0 otherwise | 40.28% |
| *Major Lake* | Area>5000 acres =1, 0 otherwise | 15.97% |
| *North East* | If in NE region=1, 0 otherwise | 44.44% |
| *South East* | If in SE region=1, 0 otherwise | 30.56% |
| *South West* | If in SW region=1, 0 otherwise | 15.97% |
| *North West* | If in NW region=1, 0 otherwise | 9.03% |

1 The out-of-pocket expenditure was estimated by multiplying distance with $0.48/ mile, and the opportunity cost of time was calculated as one third of an hourly individual's wage rate time by travel time, which was assumed speed of 50 mile/hour.

Table II.5 gives the conditional logit valuation results for Oklahoma Lakes in 2007 by single Day Users and Multiple Day Users. The willingness to pay for each attribute on average is given in the column next to the coefficient estimate. The dependant variable is the choice of a lake for a trip given all the other substitute sites available and their characteristics.

For the day trip users, lodge and campsites are omitted from the estimation in the first model in Table II.5. Portapotties, boat ramps, and flush toilets proved insignificantly different from zero. Users preferred flush toilets with showers at $6.50/trip per user. Water clarity proved significant and had a willingness to pay of $0.38 per centimeter increased clarity per trip for lakes on average and $0.03/mile increase in lake shoreline available on average. Swimming beaches were highly valued at $56.09/trip per user. Major lakes on average are worth $96 more than lakes that are less than 5000 acres. Among the regions, all regions were significantly preferred to the Northwestern lakes, but the Northeast had the highest value at $59/trip with the Southwest at slightly less at $56/trip. Results would suggest that day users greatly value swimming beaches, larger lakes, and the ability to shower at the end of the day in a full restroom facility.

The results for multiple day users in Table II.5 are similar to those for day trip users. Boat Ramps, basic campsites, and shoreline size were not significantly different from zero. Multiple-day trip users had negative values for porta-potties, lodges, and restroom facilities that lacked shower facilities. They were willing to pay $36/trip for a lake trip where restrooms with showers were available and $1.24 per trip more for lakes with campsites with electricity. Note that these two amenities are usually available at the same lake simultaneously, so it does not indicate that users are simply willing to pay $1.24 to camp overnight, it is the combination of these marginal values of given amenities at a site that adds up to total willingness to pay. Water clarity is valued at $1.70 per centimeter of clarity and a swimming beach is marginally worth $192 per trip to the multiple day user. Large lakes are $129 more valuable on average than lakes under 5000 acres to multiple day users. Southwestern ($269), northeastern ($204), and southwestern ($200) lakes are ranked from most to least favorite for multiple day users over northwestern lakes.

Regional rankings are the one category that differs between day users and multiple day users. Multiple day users rank southwestern lakes highest whereas day users rank northeastern lakes highest. The southeastern area is ranked a distant third for day users, most likely because of the difficulty of travelling there for a day trip.

**Table II.5** Conditional Logit Results for Oklahoma Lakes (2007)
(Dependant Variable is Lake Site Choice)

| Variable | Single Day User | WTP for Single Day User ($) | Multiple Day User | WTP for Multiple Days User ($) |
|---|---|---|---|---|
| *Travel Cost* | -0.0111*** | | -0.0051*** | |
| | (-17.0800) | | (-3.9900) | |
| *Boat Ramp* | 0.0143 | | 0.0047 | |
| | (1.4000) | 1.2895 | (0.1700) | 0.9142 |
| *Porta-Potties* | -0.0140 | | -0.0902*** | |
| | (-1.5000) | -1.2629 | -(3.7300) | -17.5267 |
| *Flush-Toilet* | -0.0162 | | -0.0434 | |
| | (-0.9400) | -1.4544 | (-1.1300) | -8.4394 |
| *Flush-Toilet with Shower* | 0.0726*** | | 0.1883*** | |
| | (3.9300) | 6.5331 | (3.8500) | 36.5863 |
| *Lodge* | | | -0.0319** | |
| | | | (-2.0600) | -6.1936 |
| *Campsite* | | | -0.0024 | |
| | | | (-1.1600) | -0.4603 |
| *Campsite with Electricity* | | | 0.0066** | 1.2867 |
| | | | (2.4200) | |
| *Water Clarity* | 0.0043*** | | 0.0088*** | |
| | (5.6700) | 0.3884 | (5.8700) | 1.7049 |
| *Shoreline* | 0.0004*** | | 0.0004 | |
| | (3.7300) | 0.0381 | (1.2200) | 0.0800 |
| *Swimming Beach* | 0.6233*** | | 0.9918*** | |
| | (4.9100) | 56.0876 | (3.4500) | 192.7010 |
| *Major Lake* | 1.0749*** | | 0.6675** | |
| | (8.0300) | 96.7292 | (2.2600) | 129.6863 |
| *North East* | 0.6615*** | | 1.0543** | |
| | (3.0400) | 59.5277 | (2.1700) | 204.8405 |
| *South East* | 0.4407* | | 1.0311** | |
| | (1.8700) | 39.6550 | (2.0600) | 200.3334 |
| *South West* | 0.6236** | | 1.3873** | |
| | (2.4900) | 56.1190 | (2.4900) | 269.5271 |
| Log-Likelihood | -2026.677 | | -574.311 | |
| No. of Observation | 70128 | | 22032 | |

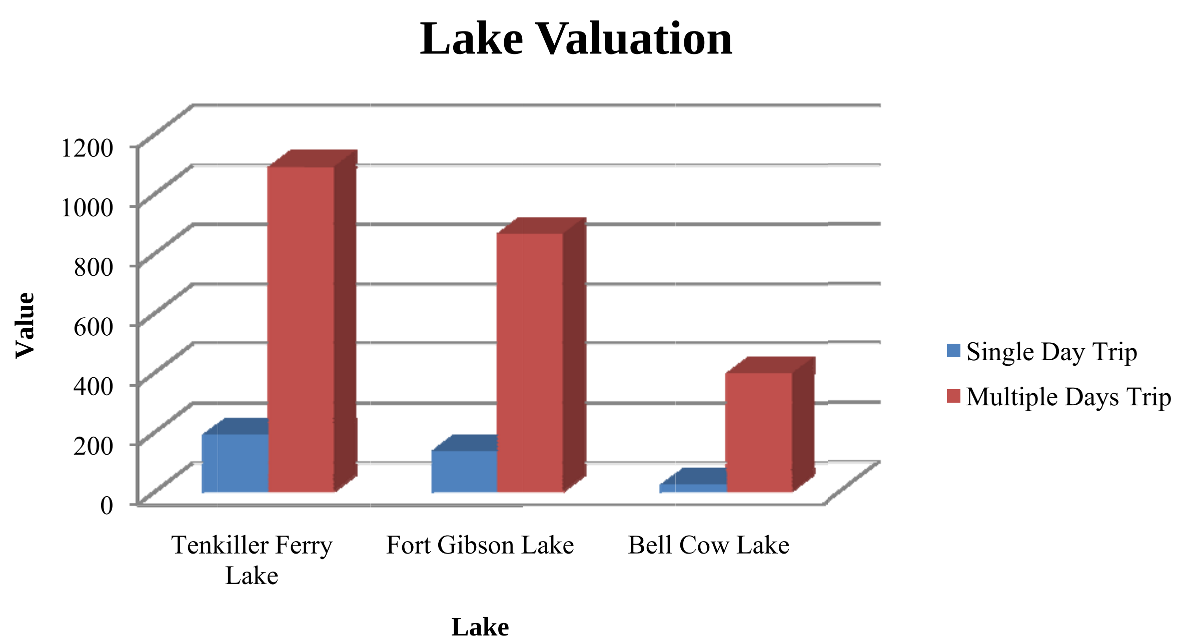
Note: ***, **, and * indicate significant level at the 1%, 5%, and 10%, respectively.

Table II.6 and Figure II.2 give examples of values computed for representative lakes in Oklahoma that might be used for other studies. The value for small lakes such as Bell Cow Lake is obviously smaller because it lacks the same amenities. However, Fort Gibson is valued at $136/day trip which is significantly less than Tenkiller's value at $191/day trip. Because of their size and proximity, these lakes might be considered substitutes for each other, so this result illustrates the unique recreational value that Tenkiller holds for Oklahomans. Multiple day trips draw users from farther away and thus by nature the value of a multiple day trip is higher.

**Table II.6 Estimated Individual Lakes' Per Trip Values per User (Travel Cost)**

| Lake | Single Day ( 2007 Dollars) | Multiple Day Trips (2007 Dollars) |
|---|---|---|
| Tenkiller Ferry Lake | 191.0226 | 1090.5934 |
| Fort Gibson Lake | 136.4034 | 865.8952 |
| Bell Cow Lake | 22.30714 | 396.6928 |

**Figure II.2.** Graph of Relative $ Valuation of Tenkiller, Fort Gibson, and Bell Cow Lakes




On average, the day user in our sample visits Tenkiller Ferry Lake 2.375 times per year but the multiple day trip user visits 8 times per year as shown in Table II.7. Tenkiller Lake's characteristics are listed in Table II.8. Note that the average value of a trip to Tenkiller is $194.34, but the estimated per trip value taking all the substitute sites into consideration is the value of $191/day trip as given in Table II.6. The latter value will be used in section III for the optimization model value per trip.

**Table II.7 Total and Average Trip Numbers for Tenkiller Ferry Lake**

| Trip Characteristic | Tenkiller Ferry Lake |
|---|---|
| Average Single Day Trips/ Person | 2.375 |
| Average Multiple Day Trips/ Person | 8 |

**Table II.8 Tenkiller Ferry Lake's Characteristics**

| Variable | Quality |
|---|---|
| *Travel Cost* | $194.34 (Single Day Trip) on Average<br>$151.45 (Multiple Days Trip) on Average |
| *Boat Ramp* | 2 |
| *Porta-Potties* | 0 |
| *Flush-Toilet* | 0 |
| *Flush-Toilet with Shower* | 7 |
| *Lodge* | 0 |
| *Campsite* | 240 |
| *Campsite with Electricity* | 87 |
| *Water Clarity* | 217 Centimeter |
| *Shoreline* | 130 Mile |
| *Swimming Beach* | 1 (Available) |

Results from the travel cost model for lake managers suggest that swimming beaches are a strong component of user value for both day trip and multiple day trip users and that water quality, while relatively small in value is still significant to users' value. Both models suggest that complete restroom facilities outfitted with showers are important to all users. Boat ramps were not significant which suggests that the majority of users take them for granted or do not use them. And, users on average travel farther in favor of visiting larger lakes with more shoreline and greater size. While this does not diminish the importance of local opportunities, it suggests that large lakes like Tenkiller have greater value to both day and multiple day users and should receive special attention. Figure 3 in Appendix C shows that Tenkiller is the third most popular multiple day user lake in Oklahoma second to Blackwell and Texoma. Figure 4 shows that very few of Oklahomans responding to the survey choose to leave the state of Oklahoma. We have not included the value of non-Oklahomans who visit lakes in Oklahoma since they were not surveyed. Those values for many lakes such as Texoma are likely to be large.

More data on respondents' concerns about lakes in Oklahoma is provided in Appendix C. In light of controversy over sources of pollution leading to bacterial contamination and algal blooms, the researchers wanted to gain a sense of the public's level of concern. Figure 7 shows that respondents believe information on bacterial contamination (88%), fish contamination (87%) and crime (85%) should be provided by the state to users. Of respondents 77% said they should also be informed about algal blooms and 79% lake water levels. Greater than 60% in each of these categories said that information on these subjects would affect their likelihood to visit a lake. Therefore, a high demand for increased information on lake quality and decreased demand for recreation plus greater awareness would likely lead to increased pressure to improve water quality from local businesses dependant on recreation and users. Additional data shown in appendix C, Figure 9 shows that water quality is the highest ranked self reported factor affecting choice to visit a lake followed by crowding and park facilities. Furthermore, Figure 10 in Appendix C shows that bacterial contamination and water odor are the highest ranked water quality factors to users. As seen in the discussion above, recreational values alone can be large ($191/day trip alone to Tenkiller) for users. These estimates only examine direct use of a resource for recreation. We have not included other components of non-market value such as ecosystem services that these users and perhaps non-users (people who stay home) may have for lake values. For one lake, Lake Tenkiller, we will show in section III, how including recreational values which are normally ignored could affect the management of lake levels if managers optimized for highest use to society.

## Section III: Construction and Optimization of a Lake Model of Power, Municipal, and Recreation.

### III.1 Objectives

The objective of the overall study was to develop a water pricing model that could be used in the state water planning process. The model considers both monetary and opportunity costs in the allocation of surface water between competing uses including municipal use, hydropower and recreation. The model was constructed for Tenkiller Ferry Lake in Sequoyah and Cherokee counties. The specific purpose was to develop a water pricing protocol that

(3) internalizes monetary and opportunity costs of water storage, treatment, and delivery systems; and

(4) generates a sustainable supply of water over the 2010-2060 period.

The information on recreational benefits for Tenkiller from section II are integrated into the maximization problem in this section. The optimization shows that pool levels will be kept at normal pool levels during the summer months of highest recreational use.

### III. 2 Review of Lake Management Modeling

Labadie (2008) reviews models for the optimal operation of the multi-reservoir systems. The review discusses the models and software (linear, nonlinear, and dynamic programming, neural networks, fuzzy-rural based systems, and genetic algorithms) used. The review concentrates on the linkage between multi-reservoir systems. The author notes problems related to reduced reservoir benefits at times can be traced to inadequate attention to maintenance and operation issues after completion, development of new projects not in the initial project design, such as municipal and industrial uses, and minimum stream flow requirements for ecological reasons, and recreational uses. Labadie also addresses the gap between theoretical modeling methods and real world applications. Reasons for the gap are attributed to model skepticism by lake operators, model complexity, and variability of model types, methods of solution, and data requirements.

The concept of lake management for recreational purposes is often addressed through limiting the range of lake levels during peak recreational periods (Re Velle, Labadie). The Center for Business and Economic Research (2003) estimated the value of delaying late summer drawdown on seven eastern Tennessee TVA lakes from August to September and to October. A combination of Willingness to Pay (WTP) surveys of visitors and hedonic pricing study of lake property values was used to assess net economic benefits of the delayed drawdown. Daily expenditures per person were expected to range from approximately $9-34 among the eight lakes in the study. The authors estimated a two month delay would increase visitor related expenditures by $12.4 million and increase net income by $2.35 million dollars. The delay was estimated to increase jobs for September and October by 744 and to add about $1100 to the value of each property parcel around the lakes. The WTP (or consumer surplus) values to maintain full pool lake levels during September and October ranged from $3.12 to 11.27 per foot. The aggregate WTP values by all users to maintain full pool lake levels during September

October, and the two month period were 39.7 million, 23.6 million and 39.7 million dollars respectively. The authors did not compare the gains from recreation against any reductions in power generated.

Several models have been applied to Lake Tenkiller. Shrestha (1996) developed a fuzzy rule-based modeling system of reservoir operation. This model develops decisions in terms of releases based on lake level, time of year. The decisions are of the form "If the lake level is x feet above sea level, then release y cubic meters of water". The model mimics existing management policies but does not lend itself to an economic analysis of those policies. Ozelkan et al. (1997) developed a linear quadratic dynamic programming model of the reservoir. The authors developed optimal control releases and levels to meet contracted releases for electrical generation, maintaining volume for flood control, and for municipal use. The stochastic model (unconstrained except with respect to monthly water balances) was tested with monthly data from 1979-1989. The authors note the model was able to obtain a lower value (some improvement) than with existing management. However, the authors noted that the unconstrained model violated maximum and minimum releases about six percent of the time. McKenzie (2003) developed a model of Broken Bow Lake in Oklahoma based on the methodology developed by Re Velle (1999). The model was used to consider the possibility of water sales subject to recreational, flood control, municipal use, and minimal releases.

Badger and Harper (1975) completed an assessment of lake elevation effects on visitation and concession operations at Tenkiller Ferry Lake. The primary objective was to determine numerical effects of lake levels ranging from 640 feet above sea level to 620 feet or less. Marina operators were asked whether changing mean storage levels 632, 635, and 640 feet above sea level would increase or reduce gross sales. All felt the 632 level would increase gross revenue and most felt the higher levels would reduce gross sales. All favored restricting drawdown to no more than 620 feet. Reasons cited were that reduced fluxions would reduce operating expenses, lead to an increased public use of marina facilities, and make the lake more attractive due to smaller exposures of defoliated areas (Badger and Harper, 1975). The authors developed regression equations to estimate overall lake attendance but did not relate attendance levels directly to lake levels. Warner et al. (1973) used the zonal travel cost method to estimate the value of a visitor day at $4.67 in 1972 prices. This would be worth about $24 in 2008 prices (McMahon, 2008).

## Structure of a Monthly Lake Management Model for Lake Tenkiller Ferry

The basic form of the model developed in this study is based on models discussed in the book, Optimizing Reservoir Resources by ReVelle (1999). The model was also used in a previous OSU study by McKenzie (2003). The basic model described by ReVelle (1999) is described below.

It is assumed the purpose of a lake management model is to maximize net benefits from market and non-market products. Net Benefits are measured in terms of Consumers' Surplus + Producers' Surplus + Net Government Revenue. The model can be stated as maximizing the sum of total net monthly benefits from municipal and industrial use, flood control, power generation.

$$\text{Max TNB} = \Sigma_m ( BM_m, BF_m, BP_m, BS_m)$$

Subject to

$$Af_{m+1} = Af_m + In_m - Rl_m - Pr_m - MI_m - Ev_m$$
$$Af_m \leq Vmax_m$$
$$Af_m \geq Vmin_m$$

Where the value variables are:

$BM_m$ is the average benefit from municipal and industrial use in month m.
$BF_m$ is the average flood control benefit in month m,
$BP_m$ is the average power generation in month m, and
$PS_m$ is the average downstream benefit from releases in month m.

Where the monthly quantity variables (measured in acre feet) are:

$Af_m$ is the volume of water in the lake in month m,
$In_m$ is the inflow of water into the lake in month m,
$Rl_m$ is the amount or water released for reasons other than power generation in month m,
$Pr_m$ is the amount of water released for hydropower in month m,
$MI_m$ is the amount of water withdrawn for municipal and industrial use in month m,
$Ev_m$ is amount of water lost from evaporation and seepage in month m, and
$Vmax_m$ and $Vmin_m$ are monthly maximum and minimum volumes in month m.

The multi-period model is obtained by expanding the annual model and by linking the end of year volume of the lake to the beginning volume for the next year. Future net-benefits are discounted. The models defined by ReVelle (p91-95, 1999) recommended meeting recreation objectives by keeping the range of lake levels as narrow as possible. However this guideline does not allow the operator to either determine the optimal range of lake level nor does it provide any assurance that the benefit of maintaining lake levels within an arbitrary range exceeds the opportunity cost of reducing other uses. An objective of this study is to include the value of recreational benefit as an explicit variable when determining the optimal lake use.

## Monthly Lake Balance

The monthly lake balance is calculated as a simple inventory equation.

The beginning balance + inflow + rain fall =
evaporation + releases for power + releases for power + ending inventory.

It was necessary to develop a monthly model of lake inflows, retained volume, and releases. Daily data for the period beginning November 1, 1994 and ending March 31, 2007 were downloaded from the USACE website, http://www.swt-wc.usace.army.mil/TENKcharts.html. During this period of record the single day minimum level was 619.6 feet and the single day maximum level was 652.6 feet. The average daily volume for this 4534 day period was 650,913 acre feet and the average daily lake level was 631.58 feet above sea level.

The variables used from the daily data were the hour_2400_lake_level (feet), volume (acre-feet), releases for power, other releases, surface inches of evaporation, inches of rainfall at dam, and inflow. Data in DSF units for inflow and power releases were converted to acre feet by using the conversion factor 1 af = 1.983439 DSF supplied by the USACE. It was necessary to convert estimates for evaporation and rainfall to acre feet.

A simple double log regression model was used to relate the depth of the lake to volume in acre feet. The form was ln(vol) = a + ln(depth). With values in natural log form the obtained equation was,

Ln(volume af.) = -66.485 + 12.386 ln(depth in feet)
(-2535) (3045)
R-square = .99, with 4532 observations. T values are in parentheses.

After taking the antilog, the equation is Vol af = Vo $D^{12.386}$, where Vo = exp(-66.485) and D is depth in feet. The average, maximum, minimum, and standard deviation of average lake levels for each month were calculated as a method of determining the implicit range of operating parameters upon the lake. The average beginning volume and average inflow and outflow for each month are shown below in Table III.1.

Table III.1.Beginning of Month Volume and Average Inflow and OutFlow from Lake Tenkiller November 1994-March 2007.

| Month | LakeVolume (Beg.OfMo)[b] | Inflow[a] | Releases[b] Power | Other | Evap and Seepage |
|---|---|---|---|---|---|
| | | AcreFeet | | | |
| Jan | 644,642 | 139,529 | 86,551 | 38,101 | 5,517 |
| Feb | 654,002 | 115,190 | 82,287 | 9,345 | 14,776 |
| Mar | 662,784 | 134,488 | 100,303 | 23,780 | 6,055 |
| Apr | 667,134 | 152,338 | 104,362 | 25,362 | 14,218 |
| May | 675,530 | 141,149 | 86,434 | 30,778 | 10,956 |
| Jun | 688,511 | 132,882 | 70,359 | 22,275 | 15,446 |
| Jul | 713,313 | 65,106 | 83,979 | 39,984 | 11,902 |
| Aug | 642,554 | 27,618 | 53,020 | 3,130 | 7,433 |
| Sep | 606,589 | 35,776 | 21,650 | 2,266 | 9,477 |
| Oct | 608,972 | 34,665 | 29,806 | 2,168 | 1,557 |
| Nov | 610,106 | 95,504 | 49,364 | 6,846 | 9,497 |
| Dec | 639,903 | 93,730 | 75,611 | 8,231 | 5,149 |

[a] Includes rainfall
[b] Average for the month

The average monthly levels and the variability the lake levels are shown below in Table III.2 and in Figure III.2. In Table III.2, the average daily level, the standard deviation of the level, the lowest daily observed along with the highest level observed are presented.

Table III.2 Average Daily Level Tenkiller Ferry from November 1994 through 2007, Along with the Standard Deviation, Minimum Level by Month.

| Month | Average Daily Level | Standard Deviation | Minimum Level | Maximum Level |
|---|---|---|---|---|
| | Feet above sea level | | | |
| Jan | 632.5 | 5.50 | 619.9 | 649.6 |
| Feb | 631.6 | 4.30 | 619.7 | 647.3 |
| Mar | 632.6 | 4.70 | 619.9 | 646.7 |
| Apr | 632.9 | 4.50 | 621.8 | 650.2 |
| May | 634.5 | 5.10 | 623.7 | 650.2 |
| Jun | 635.1 | 5.20 | 630.6 | 652.6 |
| Jul | 633.6 | 5.20 | 626.3 | 651.9 |
| Aug | 629.6 | 3.10 | 622.5 | 637.0 |
| Sep | 627.8 | 3.10 | 621.7 | 637.4 |
| Oct | 628.3 | 3.50 | 620.8 | 637.1 |
| Nov | 629.8 | 4.30 | 620.1 | 641.0 |
| Dec | 630.8 | 4.40 | 619.6 | 641.3 |

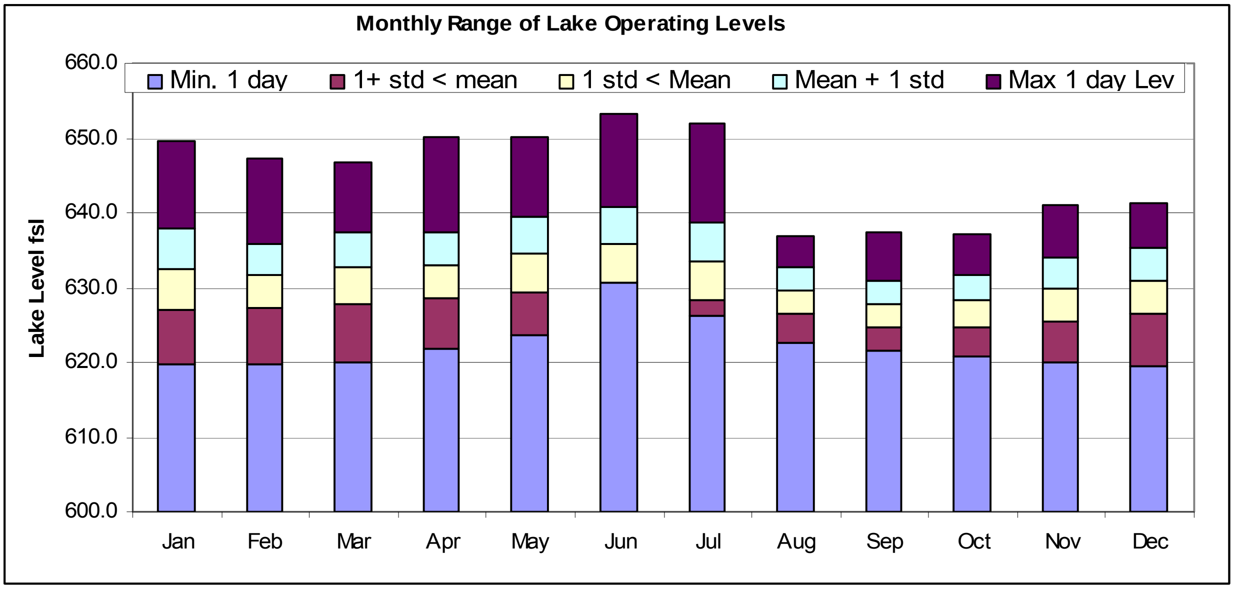



Figure III.1. Operating range of Tenkiller Ferry Lake showing Minimum One day level, Range of One Standard Deviation Below and Above the Mean, and the Maximum One Day Level Observed. (November 1994 - March 2007).

The data in Table III.2 and Figure III.1 above show the highest average lake level occurred during April while the lowest average lake level occurred during September. The smallest deviation of lake levels occurred during August and September. When the mean minus one deviation is compared to the absolute minimum it shows there is a concentrated effort to prevent the lake level from dropping below 620 feet during the heavily used June, July, and August recreation period.

**Lake Visitation Data.**

Current total monthly visitor numbers were obtained from the USACE for the period from 2001 through 2006. Six years is a fairly short for a time model to cover 50 years of projected use, so historic data were also used. Similar data were published by Badger and Harper (1975) covered the period 1955 through 1974. An average of 2.25 million people visited Lake Tenkiller Ferry during the period from 1955 to 1974 and from 2000 through 2004. The peak number of visits occurred from May through August (1.35 million) with an average .4 million visits occurred in July. These data are shown below in Figure III.2.

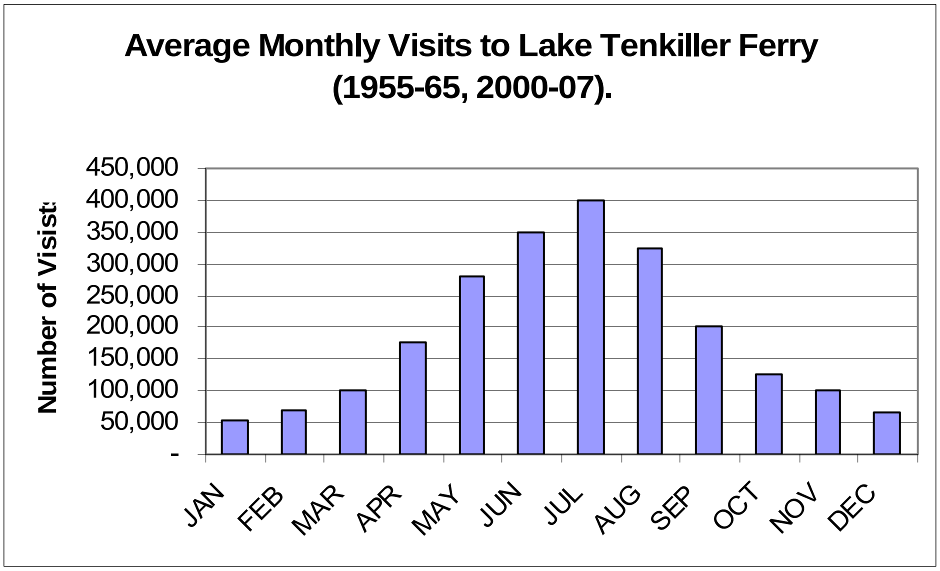



Figure III.2. Average Number of Visitor Days to Lake Tenkiller by Month (1955-1965 and 2000-2007).

The monthly visitor data was regressed against the lake level for the same month to estimate the effect of varying lake levels on visitor attendance. The estimated regression equation used in this study was,

$$\underset{}{Visits} = 103733 + \underset{(4.46)}{83400Apr^*} + \underset{(9.57)}{182031May^*} + \underset{(13.26)}{337142\,June^*} + \underset{(15.31)}{401425\,July^*} +$$

$$\underset{(12.97)}{316164\,Aug^*} + \underset{(6.32)}{117626\,Sep^*}\;\; \underset{(3.28)}{2642\,ALkLv^*} + \underset{(1.57)}{5227LvJun^*} + \underset{(4.30)}{2654\,Tsumr^*} +$$

$$\underset{(-1.95)}{-254\,Lv_{Jn}^{2*}} \quad \underset{(-2.51)}{-1072\,Lv_{Jly}^{2*}} \quad \underset{(-1.95)}{-\;254\,Lv_{Aug}^{2*}}, \quad r^2 = 0.66$$

*Variables significant at 10 percent level or less

- The variables Apr, May, June, July, Aug and Sep are 0-1 dummy variables which are 1 in the indicated months and zero otherwise.
- Tsumr is a time (2000 = 0) trend for months June, July, and August. The other months were not found to significantly vary with time.
- ALkLv is the Average monthly lake level – 632.
- $Lv_{Jun}$ is a discrete variable to test if visits to the lake in June are more sensitive to lake levels than in other months.
- $Lv_{Jn}^2$ is the square of the June lake level – 632, = [Lake level – 632]$^2$
- $Lv_{Jly}^2$ is the square of the July lake level – 632, = [Lake level – 632]$^2$, and
- $Lv_{Aug}^2$ is the square of the August lake level – 632, = [Lake level – 632]$^2$.

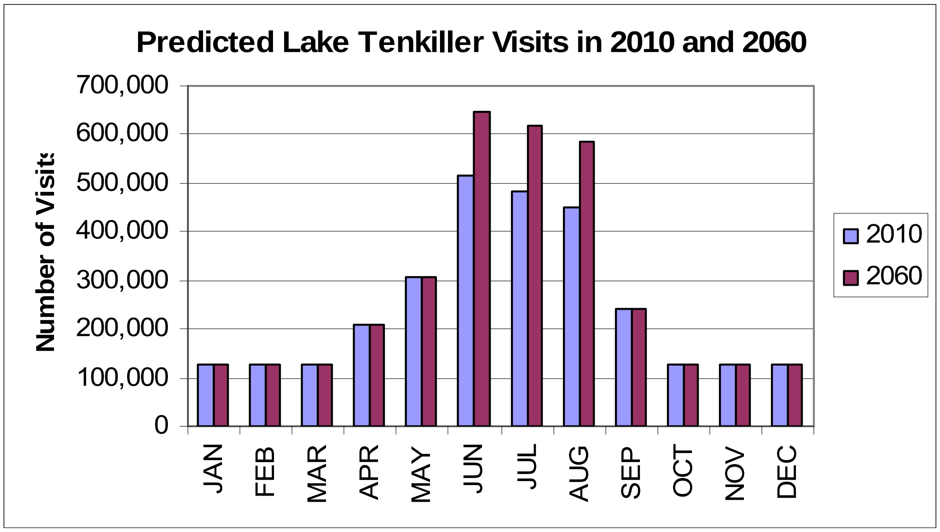



Figure III.3.Regression prediction of Visitor Days in 2010 and 2060.

**<u>Value of a Visitor Day at Lake Tenkiller.</u>**

The recreational value of Lake Tenkiller was as estimated as part of a larger random utility travel cost model for all lakes in Oklahoma as explained in section II . The value or "price" of the trip is the travel cost to a site given its amenities and those of other substitute sites. . Estimation of the trips taken as a function of the fee and lake levels is derived from Roberts et al (2008) is used to show adjust visit value from the travel cost as a function of lake level.

The value of a visitor day to Lake Tenkiller, Lake Fort Gibson, and Bell Cow Lake were estimated to be $191, $136, and $22 per day respectively. Previous analysis had show that values of visitor day as low as $8 per day were sufficient to reduce releases of water for power generation during the summer months in order to hold lake levels near normal levels of 632 feet. In the following analysis, the value of a visitor day at normal lake levels was placed $50 per day. This is a conservative value, well below the estimated value of $191 per day. The study by Roberts et al. (2006) had shown the willingness to pay for a visitor day declined by $0.81 for each foot the lake was below the normal level of 632. The lowest level tested was 624 feet. The value of a visitor day used in this model was taken to be,

$50 per day if the lake level ≥ 632 feet,
$43 + $.82(Lake Level – 624) if the lake level is > 624 and < 632,
$43 per day if the lake level is ≤ 624 feet.

A graphical view of the recreational value used in the model is shown below in Figure III.4.

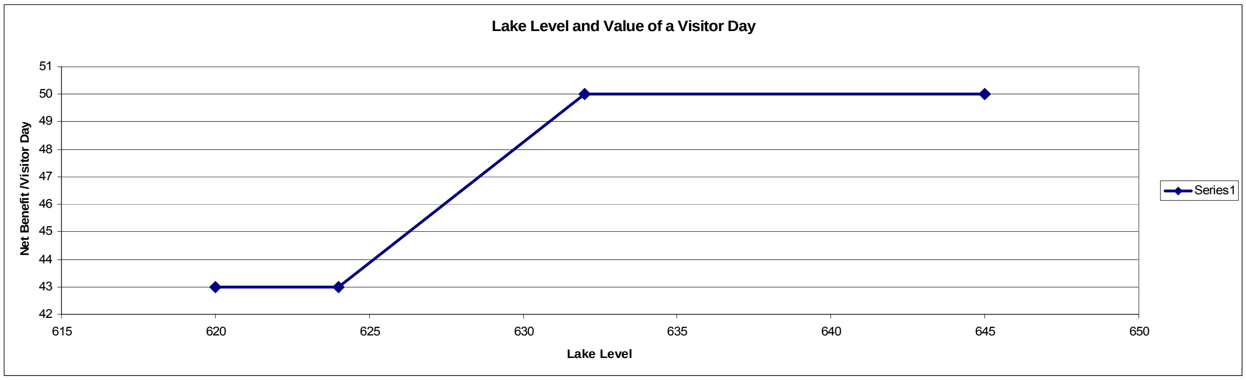



Figure III.4.Value of a Visitor Days as a Function of Lake level Given a Maximum Value of $50.

## Power Generation.

Power Generation was one of the beneficial uses for which the Lake Tenkiller Ferry dam was constructed (USACE, 1999). The amounts of electricity generated shown below in Table III.3 were summed and averaged from daily values provided by the USACE (2008) for the 1995-2000 time period.

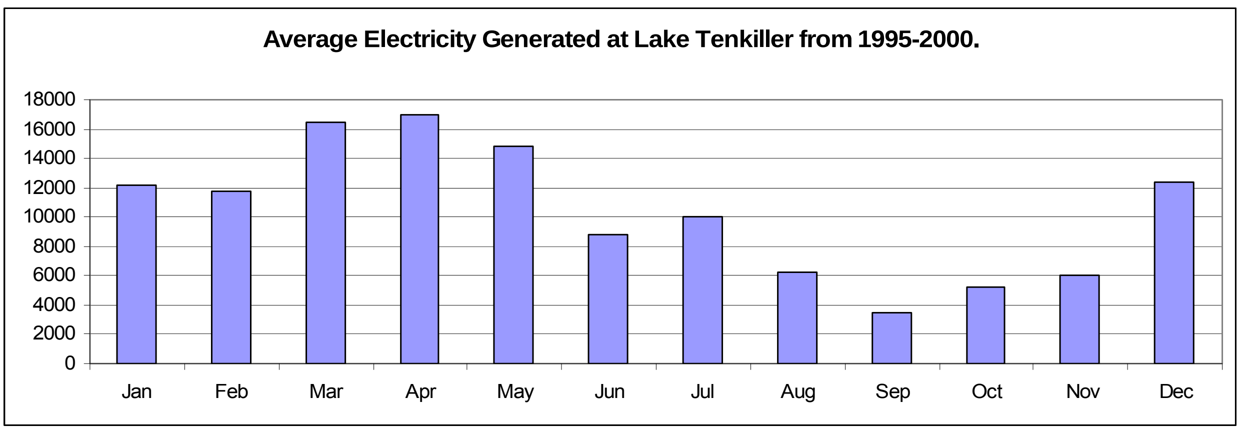



Figure III.5. Average Monthly Hydropower Generated at Lake Tenkiller from 1995-2000 in Thousand kwh.

Table III.3. Electricity Produced by Tenkiller Ferry Lake From 1995-2006.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Thousand kwh | | | | | | | | |
| 1995 | 16835 | 15072 | 21273 | 20089 | 28422 | 11070 | 22754 | 10205 | 2228 | 2189 | 2099 | 3904 | 156140 |
| 1996 | 10928 | 5568 | 3912 | 14107 | 20078 | 6106 | 3719 | 3447 | 4663 | 14052 | 21855 | 27039 | 135474 |
| 1997 | 6154 | 12508 | 25122 | 18592 | 6750 | 9447 | 7958 | 5663 | 3146 | 706 | 3432 | 16170 | 115648 |
| 1998 | 27852 | 17652 | 18316 | 26991 | 8646 | 5706 | 4389 | 3953 | 2911 | 4574 | 4953 | 10998 | 136941 |
| 1999 | 7470 | 15670 | 23222 | 17357 | 15625 | 0 | 0 | 4269 | 2675 | 4090 | 1935 | 477 | 92790 |
| 2000 | 3487 | 4010 | 6823 | 4899 | 9678 | 20411 | 21524 | 9616 | 5373 | 5626 | 2196 | 15761 | 109404 |
| Average | 12121 | 11747 | 16445 | 17006 | 14867 | 8790 | 10057 | 6192 | 3499 | 5206 | 6078 | 12392 | 124400 |
| Std. Dev | 8977 | 5656 | 8918 | 7305 | 8282 | 6851 | 9701 | 2978 | 1235 | 4678 | 7813 | 9551 | 22751 |

Figure III.5 shows that most of the electricity is generated during the months of March through May with the lowest amount of electricity being produced in September. However the results in Table III.3 indicate considerable variability in monthly production from one year to the next. In a previous study of the economic impacts of the Lake Tenkiller, Warner et al. (1973) reported that annual electrical power generation varied from 16.4 to 156.6 million kilowatt hours for the period from 1960-1971. Annual Sales of Electricity varied from 194 to 628 thousand dollars per year for the same period.

ReVelle (1999) presents the formula for power generation as a nonlinear function depending on the product of Release x Head. The function can be expressed as P = aQH where

- Q is the volume of water released through the turbines.
- H is the height of the water above the turbines. The top of the turbines was assumed to be 486.5 feet above sea level.
- a is constant reflecting gravity, viscosity, and turbine efficiency.

Data were available from the USACE website on the daily volume of water released for power and on the amount of power generated from January 1955 through December of 2000. The average lake level for each day was calculated for this period. The head available for power generation on day t was then calculated as ($level_t$ +$level_{t+1}$)/2 – 486.52. The height of the top of the turbines is given as 486.52 feet above sea level. The head was multiplied by the quantity of water released. A simple plot of the quantity of electricity produced plotted against the product of head x Quantity released is shown below.

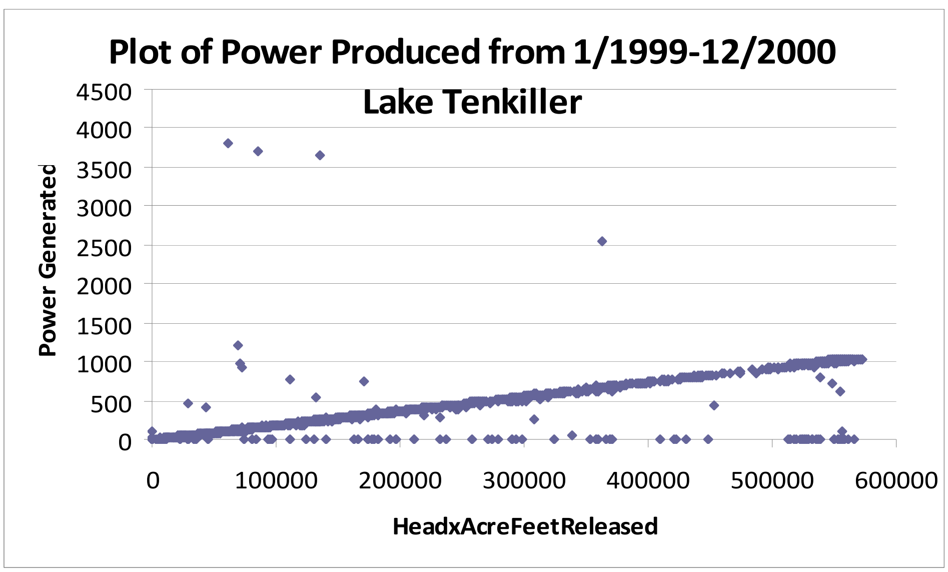



Figure III.6. Historical Relation between Power Generated and the Product of Head times Acre Feet Released.

There are releases for power when no power was generated and sometimes estimates for power generation that are much too high to have been generated by the quantity of water released. These outliers were deleted and an equation of the electrical values along the line in the above Figure III.6 were used to derive the estimate,

KW = 0.232457 (Head x Acre Feet Released), R-Square = 0.99
(1152)

The t-value is in the parenthesis.

This equation was used to estimate the quantity of electricity generated based on average monthly lake level or head times the number of acre feet released for power generation for the month. Power generated under long term contract is more reliably priced than power generated on the spot market. To simulate long term contracts, it was assumed the electrical authority could sell electricity in one or more of a series of four month contracts. The simulated contracts were for January-April, March-June, May-August, July-October, September-December and/or November-February.

Electricity was valued using monthly prices from the year 2000 through 2007 obtained from wholesale prices compiled by the U.S. Department of Energy.

### Lake Tenkiller Wholesale Water Distribution Study

The USACE conducted a study of providing wholesale water to cities and rural water districts to the northwest and to the east of Lake Tenkiller. They estimated the cost of supplying water to some thirty cities and rural water systems at $2.25 per thousand gallons

### Water System Simulation Models

A hydraulic simulation model for a water system is a key tool that can be used to assist rural water districts (RWDs) in long term planning. In general, construction of these models can be expensive, time consuming and out of the reach of smaller RWDs. This study takes advantage of the Oklahoma Rural Water Systems GIS (geographical information systems) data set developed by the Oklahoma Water Resources Board (OWRB) which contains pipelines, facilities and general system capacity information. The available GIS files contain data on the length and diameter of each pipeline. The pipeline shape files have been overlaid on USGS 1/3 second elevation files. This step provides elevation data at points along the pipelines which is essential for estimation of pumping costs. Software programs have been developed to help with editing the apparently unused data set. Editing problems include missing pipes, mislabeled pipes, duplicate pipes, and duplicate nodes. Once the data files have been edited, an input file to EPANET is generated. The simulation model is capable of estimating pressure zones and system performance under various population levels and spatial distributions of that population. The pressure zone data over the area served by a system under alternative population levels can be used to estimate costs for capital investments in pipelines and water treatment facilities. Pipeline files, district boundary files, facility files, and management files have been downloaded, for the water systems below.

| | |
|---|---|
| Burnt Cabin | Cherokee County Rural Water District (RWD) #1 |
| Cherokee County RWD #2 (Keys) | Cherokee County RWD #3 |
| Cherokee County RWD #7 | Cherokee County RWD #8 |
| Cherokee County RWD #13 (Cookson) | Town of Vian |
| East Central Oklahoma Water Authority | Fin and Feather Water Association |
| Lake Tenkiller Harbor | Lost City RWD |
| Muskogee County RWD #4 | Muskogee County RWD #7 |
| Paradise Hills, Inc. | Sequoyah County Water Association |
| Sequoyah County RWSG & SWMD #7 | Stick Ross Mountain Water Company |
| Summit Water | Tahlequah Public Works |
| Lake Region Electric Development | Tenkiller Aqua Park |
| Tenkiller State Park | Town of Gore |

**Monthly Water Demands**

The initial set future water demands in each of the areas was based on the average daily consumption levels calculated for the individual users in the USACE Wholesale Supply study (2001). The estimated average daily values for each user are shown below in Table III.4.

Table III.4. Actual and Projected Water Demands by User Based on Projections by the US Army Corps of Engineers

| Year | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|---|
| | | | (Thousand gallons per day) | | | | |
| Muskogee RWD#4 | 74 | 82 | 85 | 88 | 93 | 97 | 105 |
| Lost City RWD_RWD11 | 215 | 239 | 248 | 255 | 269 | 282 | 303 |
| Cherokee RW 1 | 75 | 84 | 87 | 89 | 94 | 99 | 106 |
| Muskogee RWD#7 | 144 | 160 | 166 | 171 | 180 | 189 | 203 |
| Cherokee RW 8 | 108 | 119 | 124 | 128 | 134 | 141 | 152 |
| Cherokee RW 7 | 108 | 119 | 124 | 128 | 134 | 141 | 152 |
| Cherokee RW 3 | 189 | 209 | 217 | 223 | 235 | 247 | 265 |
| Tahlequah Water | 653 | 722 | 760 | 792 | 841 | 900 | 955 |
| Stick Ross Mt. Water System | 215 | 239 | 248 | 255 | 269 | 282 | 303 |
| Cherokee RW2 | 86 | 95 | 99 | 102 | 107 | 113 | 121 |
| LRED east | 61 | 68 | 71 | 73 | 77 | 81 | 87 |
| Summit Water | 72 | 80 | 83 | 86 | 90 | 94 | 101 |
| Cherokee RW13 | 75 | 84 | 87 | 89 | 94 | 99 | 106 |
| LRED east | 47 | 53 | 55 | 56 | 59 | 62 | 67 |
| Tenkiller State Park | 19 | 21 | 22 | 23 | 24 | 25 | 27 |
| Sequoyah WW | 1492 | 1653 | 1714 | 1768 | 1859 | 1951 | 2098 |
| LRED west | 59 | 66 | 68 | 70 | 74 | 77 | 83 |
| Burnt Cabin | 32 | 36 | 37 | 38 | 40 | 42 | 45 |
| Lake Tenkiller Harbor | 32 | 36 | 37 | 38 | 40 | 42 | 45 |
| Fin & Feather Water | 38 | 42 | 43 | 45 | 47 | 49 | 53 |
| Paradise Hills | 24 | 26 | 27 | 28 | 30 | 31 | 33 |
| Tenkiller Aqua Park | 11 | 12 | 12 | 13 | 13 | 14 | 15 |
| Vian | 194 | 215 | 223 | 230 | 242 | 254 | 273 |
| Gore | 292 | 323 | 335 | 346 | 364 | 382 | 411 |
| East Central OK | 205 | 227 | 235 | 242 | 255 | 268 | 288 |
| Total | 4520 | 5010 | 5207 | 5376 | 5664 | 5962 | 6397 |

The data in Table III.4 differ from those in the USACE 2001 study in that projections were made for 2060 and because demands for Sallisaw, Muldrow, and Roland were deleted. A series of monthly water demands were derived based on precipitation and temperature elasticities obtained from another water demand simulation program IrrMain developed by the USACE. Since the area is mostly residential the single family dwelling elasticities were used. The elasticities used for each month along with the average monthly temperature and precipitation data for the area are given below in Table III.5.

Table III.5. Average Monthly Temperature and Precipitation Values and Elasticities Used to Derive Monthly Water Demands for the Tenkiller Study Area.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall (in) | 2.4 | 2.4 | 4.2 | 4.1 | 5.7 | 5.2 | 3.5 | 3.2 | 5.3 | 4.3 | 4.7 | 3.2 |
| Temperature (F) | 36.8 | 42.4 | 51.5 | 60.3 | 67.9 | 75.6 | 80.4 | 80 | 72.4 | 61.7 | 49.5 | 39.9 |
| Rainfall Elasticity | -0.25 | -0.25 | -0.25 | -0.25 | -0.02 | -0.02 | -0.02 | -0.02 | -0.02 | -0.25 | -0.25 | -0.25 |
| Temp Elasticity | 0.45 | 0.45 | 0.45 | 0.45 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 0.45 | 0.45 | 0.45 |
| Price Elasticity | -0.04 | -0.04 | -0.04 | -0.04 | -0.25 | -0.25 | -0.25 | -0.25 | -0.25 | -0.04 | -0.04 | -0.04 |

Source: IRRWMain, Davis etal. 1987.

The base consumption for month m was assumed to be given by the relation,

$Q_m = Q_a T_m^{em} R_m^{er}$ and that $\Sigma_m Q_m = Q_a$.

This is enforced by letting $r = \Sigma_m Q_m /12Qa$, where r is a ratio that requires the sum of the monthly. The value of r was calculated to be 0.88. The estimated base level of demand for each month was $Qm = r Q_a T_m^{em} R_m^{er}$ .

The total monthly demands shown below were projected using the monthly temperature and rainfall elasticities. The monthly and annual values for each ten year period from 2010 through 2060 are given Table III.6 below. The annual demands increase from 5.6 thousand acre feet per year in 2010 to 7.1 thousand acre feet by 2060. These are similar the USACE projections under alternative 1 which also excluded the Sallisaw area.

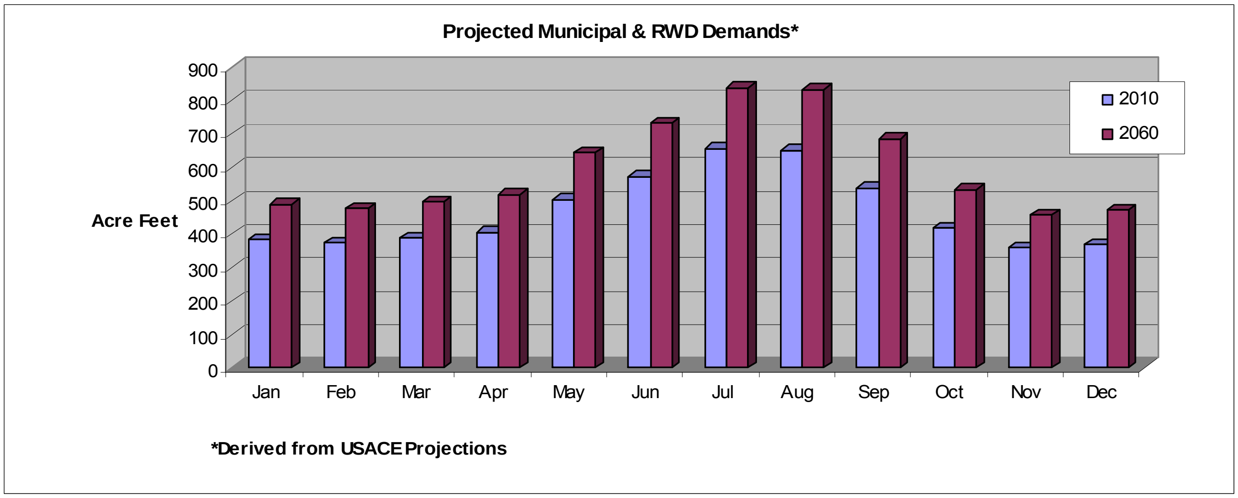



Figure III.7. Projected Municipal and Rural Water District Demand Based on Annual Consumption Estimated Adjusted by Rainfall and Temperature Elasticities.

Table III.6. Projected Monthly Estimates of Water Use by Municipal and Rural Water Districts from Lake Tenkiller from the Year 2010 to 2060.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Acre Feet | | | | | | | | |
| 2010 | 384 | 373 | 388 | 406 | 504 | 574 | 655 | 652 | 537 | 418 | 359 | 370 | 5619 |
| 2020 | 399 | 387 | 403 | 422 | 523 | 596 | 681 | 677 | 559 | 435 | 373 | 385 | 5840 |
| 2030 | 412 | 400 | 416 | 435 | 540 | 616 | 703 | 699 | 577 | 449 | 385 | 397 | 6030 |
| 2040 | 434 | 421 | 439 | 459 | 569 | 649 | 741 | 737 | 608 | 473 | 405 | 419 | 6353 |
| 2050 | 457 | 444 | 462 | 483 | 599 | 683 | 780 | 775 | 640 | 498 | 427 | 441 | 6687 |
| 2060 | 490 | 476 | 496 | 518 | 643 | 733 | 837 | 832 | 686 | 534 | 458 | 473 | 7175 |

**Net Benefits or Consumers and Producers Surplus from Water Consumption**

Linear demand equations were constructed from the quantities shown above in Table III.6 by using the price elasticities from Table III.5 and by using an estimated final price for water. The process uses the definition of a price elasticity ρ, in month m as

$$\rho = \frac{\mathrm{dq}\ \mathrm{P_m}\ .}{dpQ_m}$$

The desired slope ($d_{1m}$) for the demand equation of the form $P_m = do_m + d_{1m}Q_m$, where $d_{1m} = (dp_m/dq_m)\ \rho$. $P_m$ is the retail price of water and $Q_m$ is the quantity consumed. The intercept is then calculated as $do_m = P_m - d_{1m}Q_m$. The first part of the equation for net social benefits from the consumption of Q units of water is obtained by integrating over the price flexibility equation with respect to Q to get $CS' = d_oQ + .5\ d_1\ Q^2$. The equation for CS + PS is obtained by subtracting the total cost of delivering Q units of water. The equation for CS+PS = $d_oQ + 0.5\ d_1Q^2$ - Cost(Q). In the case where the total cost of delivering water to the customer is linear, the term in the objective function for the net benefits of delivering water is

$NSBm = d_{om}Q_m + 0.5\ d_1\ Q^2 - co - c1Q_m$.

## Use of EPANET Simulation to Estimate Water Distribution Costs

The monthly values shown above in Table III.6 were simulated in an EPANET pipeline simulation model. The demands for each of the 12 months were simulated for the years, 2010, 2020, 2030, 2040, 2050, and 2060. The purpose was to determine the power and pumping capacity and the average daily pumping cost over the 50 year planning period.

An outline of the pipeline map is shown below in Figure III.8. The map has been overlaid on a USGS 1/3 second elevation file for the region. The pipeline serves communities around the lake along with the towns of Gore and Vian to the south. The pipeline also partially serves the city of Tahlequah and other RWDs to the north. From the mean lake level of 632 the pipeline reaches 1000 feet at points northwest and southeast of Lake Tenkiller.

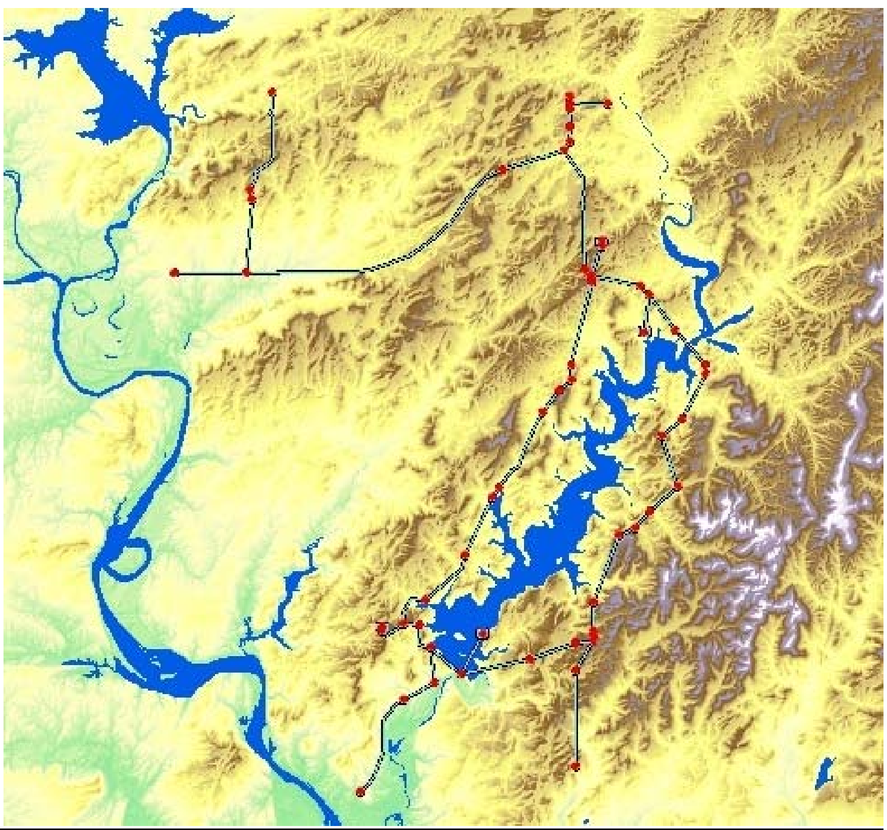


Figure III.8. Pipeline System Serving Municipalities and Rural Water Districts (Represented by Nodes) from Lake Tenkiller.

The variable energy cost of pumping as given by the EPANET model over the 60 year period as given by the following linear equation,

$$\text{Cost} = -458. + \$257.64\ \text{AF}, \quad R^2 = .99.$$
$$\quad\quad\quad (2.5) \quad\quad (760)$$

The variable Cost is the total cost of pumping AF (dollars per acre feet) for the entire system in a month. The values in parentheses are t-values. Since the relationship is linear, the pump efficiency in the EPANET may not be modeled correctly but specific pump curves would be required to improve the estimate. The final delivered price includes payments to amortize the system cost and also local distribution costs by each system. The final marginal delivery cost was derived as shown in Table III.7 below.

Table III.7. Delivery Cost of Water to Municipal and Rural Water Districts Users.

| Item | Cost/1000 Gal | Cost/AF |
|---|---|---|
| Variable pumping cost | $ 0.79 | $ 257.67 |
| Amortized Capital cost of the Regional System | $ 1.43 | $ 465.97 |
| Local Administration and distribution cost | $ 1.28 | $ 416.84 |
| Final delivered (retail) Price | $ 3.50 | $1,140.48 |

The cost of local administration and distribution cost was taken as the difference between the costs as supplied by the Oklahoma Municipal League (2002) and the wholesale cost of $1.22 per 1000 gallons.

## III.3 PRINCIPAL FINDINGS AND SIGNIFICANCE

The first part of this section of results deals with the effect of maximizing net benefits with recreation as one of the variables in the objective function, as opposed to maximizing benefits to municipal and power generation subject to maintaining summer lake levels above between 620 and 632 feet above sea levels. In the latter case, the value of recreation is explicitly estimated from the resulting lake levels after the optimal power and municipal uses have been determined. The first part of the results section establishes that there are gains to be made by directly including recreation values in the objective function of the model. The second part of the results discusses the changes in the monthly and annual allocations of water over the 2010 to 2060 period when recreation values are directly included in the objective function.

The approach in this study was to determine the allocation of Lake Tenkiller water resources among uses for power generation, municipal and rural water demands, and recreational uses. A series of solutions were obtained in which monthly demands were met for the years 2010, 2020, 2030, 2040, 2050, and 2060. Two monetary values for a visitor day were used. The value of $191 per visitor day (obtained from the state-wide survey described above) and as a sensitivity test, a lower value of $50 per day was used. The lower value was used in all solutions because it was sufficient to show that changes could be made in lake level management that would increase overall net public benefits from the lake resources.

**Effect of Directly Including Recreational Values in the Objective Function**

For this analysis recreation was valued at $50 per visitor day. The model was solved for the years 2010, 2020, 2030, 2040, 2050, and 2060. The values for years between the dates were determined by interpolation. NPV were determined by discounting over the 50 year period at 4.875 percent, the discount rate indicated by the Water Resources Council for water projects (2008). The results are shown in Table III.8 below.

Table III.8. Comparison of NPV of Net Benefits from 2010 to 2060 from Lake Tenkiller when Recreational Values are Not Included and When Recreational Values are Directly Included in the Objective Function (Values in thousand dollars)*.

| Recreational Values Post Solution | | Recreational Values in Objective Function | |
|---|---|---|---|
| Item | Value | Item | Value |
| Power Generation | $ 16,120 | Power Generation | $ 15,536 |
| Municipal | 900,180 | Municipal | 873,618 |
| | ______ | Recreation | 2,510,667 |
| Objective Function | 916,300 | Objective Function | 3,399,821 |
| Recreation | 2,422,446 | | |
| Total All Values | $3,338,746 | Total All Values | $ 3,399,821 |

*Recreation valued at $50 per visitor day.

On the left the visitor days were calculated from the lake levels determined by optimizing for power and municipal use. With the recreational visitor day valued at $50, the recreation values were much larger than the values for power generation and municipal use. The results are interesting since neither municipal nor recreation were listed as primary uses when the dam was built. As expected, when recreational values are directly included in the objective function, it is possible to gain nearly 61 million dollars of additional value from the lake resource over the 50 year period. The values in Figure III.10 indicate that the gain in recreation values (at $50/visitor day) that an additional 88 million dollars in recreation benefits are gained with a reduction of $26.6 million in municipal benefit and $0.6 million in power generation over the 50 year period in present value terms. This gives a 3.24 benefit to cost ratio , i.e., for every dollar lost in municipal and hydropower generation in 2007 dollars, 3.25 dollars are gained in recreation. If the value of a recreational day had been placed at $191, rather than the conservative value of $50/visitor day, the value of recreational benefits would have been near $300 million over the 50 year period.

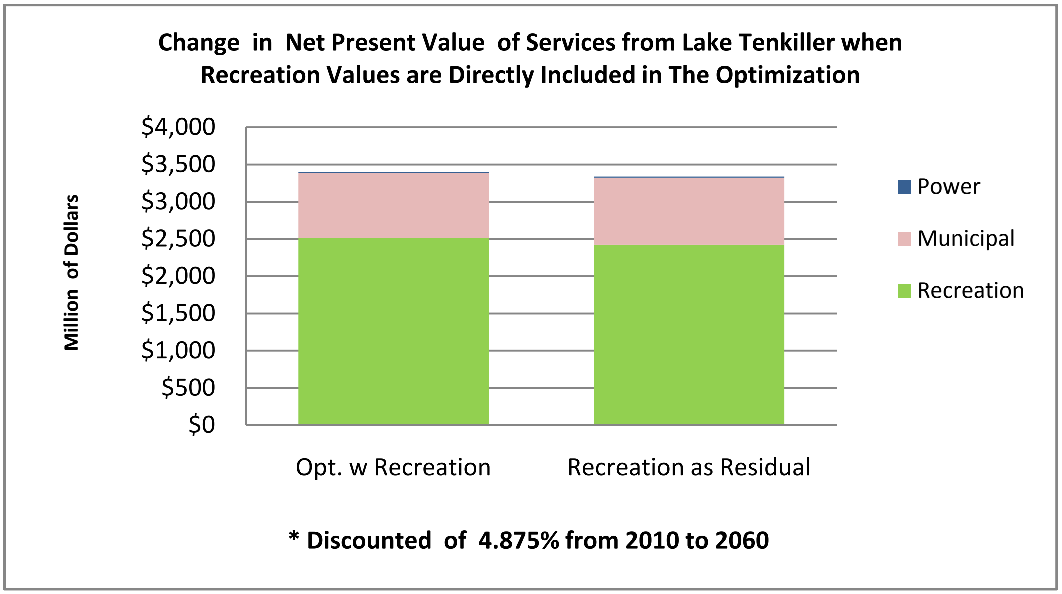



Figure III.9. Comparison in Net Present Value of Services from Lake Tenkiller when Recreation Values are Directly Included in the Optimization, (Recreation Valued at $50).

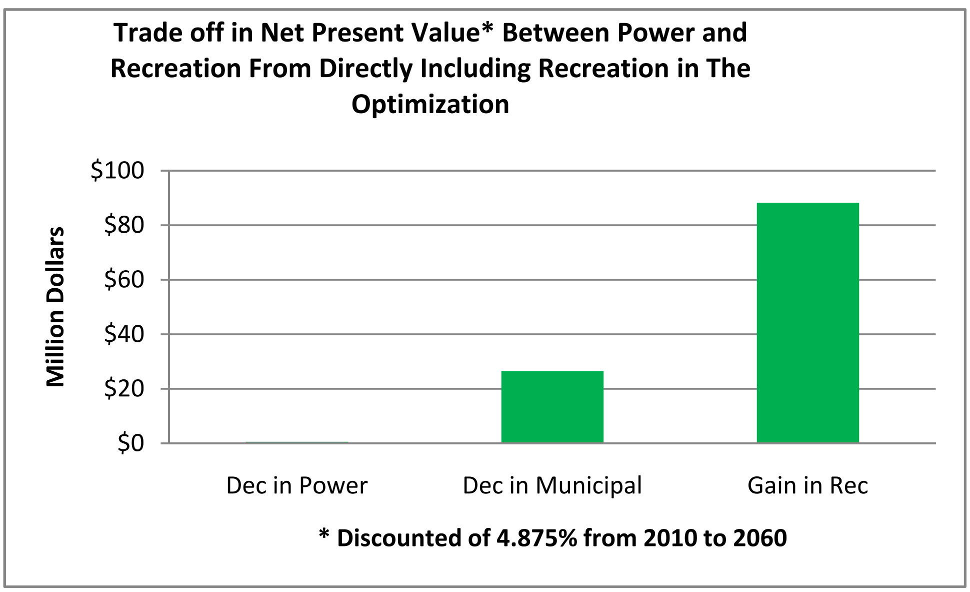



Figure III.10. Tradeoff in the Net Present Value between Power and Recreation Values when Recreation Values are Included in the Objective Function of the Optimization Model.

## Long Term Implications of Directly Including Recreation Values in the Objective Function.

The results indicate that Lake Tenkiller is capable of meeting the power needs, municipal and rural water district consumption and recreational services. The demands for municipal and RWDs is very inelastic with respect to price. The estimated levels of consumption for the years 2010 and 2060 are shown below. The monthly consumption levels for each of the 10 year period are shown below in Table III.9.

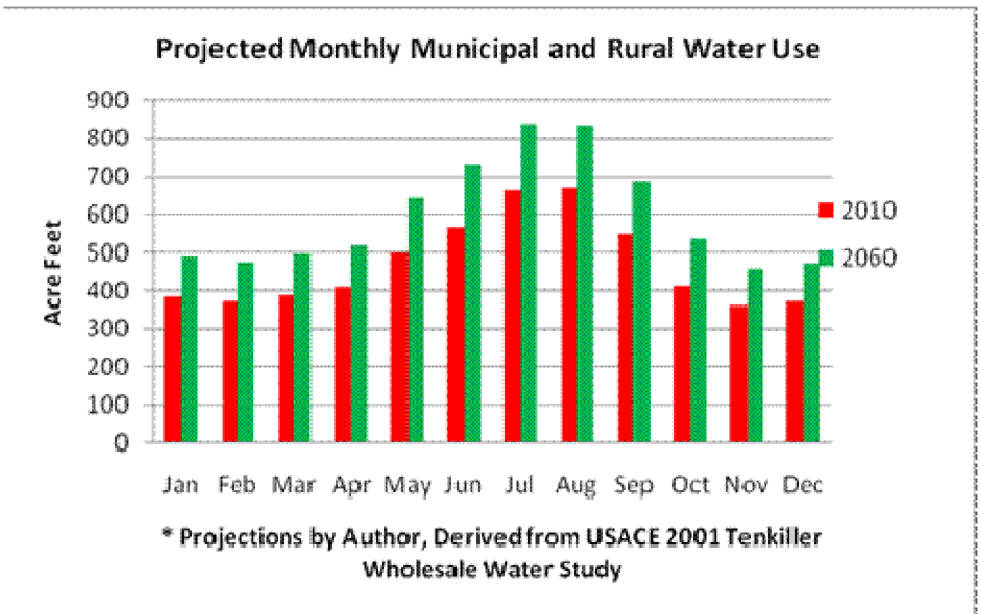



Figure III.11 Estimated Public Water Consumption from Lake Tenkiller for the Years 2010 and 2060.

Table III.9. Estimated Public Water Consumption from Lake Tenkiller by Municipal and Rural Water Districts.

| | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|
| | Acre Feet | | | | | |
| Jan | 384 | 398 | 415 | 434 | 471 | 490 |
| Feb | 372 | 387 | 400 | 421 | 458 | 476 |
| Mar | 388 | 403 | 414 | 439 | 474 | 496 |
| Apr | 408 | 422 | 434 | 458 | 495 | 518 |
| May | 498 | 525 | 536 | 570 | 718 | 643 |
| Jun | 567 | 598 | 611 | 649 | 811 | 733 |
| Jul | 661 | 681 | 702 | 739 | 951 | 837 |
| Aug | 668 | 677 | 699 | 737 | 947 | 832 |
| Sep | 550 | 558 | 572 | 607 | 780 | 686 |
| Oct | 413 | 435 | 451 | 473 | 512 | 534 |
| Nov | 360 | 373 | 385 | 406 | 441 | 458 |
| Dec | 371 | 385 | 398 | 418 | 451 | 473 |

## Lake Levels

The greatest changes in the resource allocation were in the timing of releases for power generation and the resulting effect on recreation visitors. That is the model tended to maximize benefits to recreational users by maintaining lake levels very close to the "normal lake level" of 632 feet above sea level. The lake levels for the years 2010 and 2060 are compared with historical levels in Figure III.12 below.

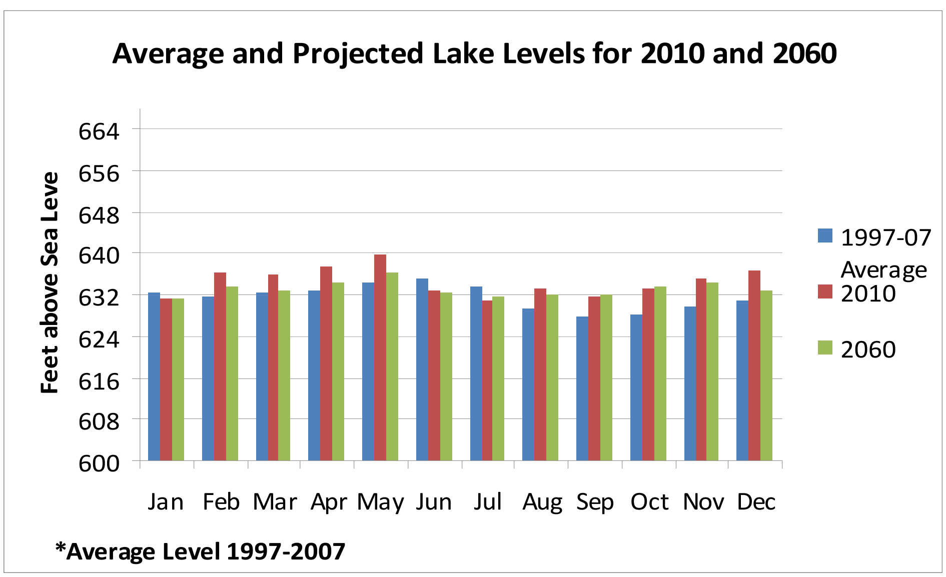



Figure III.12 Estimated Optimal Lake Levels in each month for 2010 and 2060.

The main change from the historical level is that with optimization, the lake levels during the summer months of June, July, and August are maintained very close the normal pool 632 foot level. Lake levels are slightly higher than historical levels for all other months except June.

## Releases for Power Generation

The main visible change in the releases for power generation is the reduction of releases during June, July, and August when recreation is specifically included in the optimization. The reduction in power generation during the summer months is made up in part by increased generation during the remaining months of the year though total power releases are reduced.

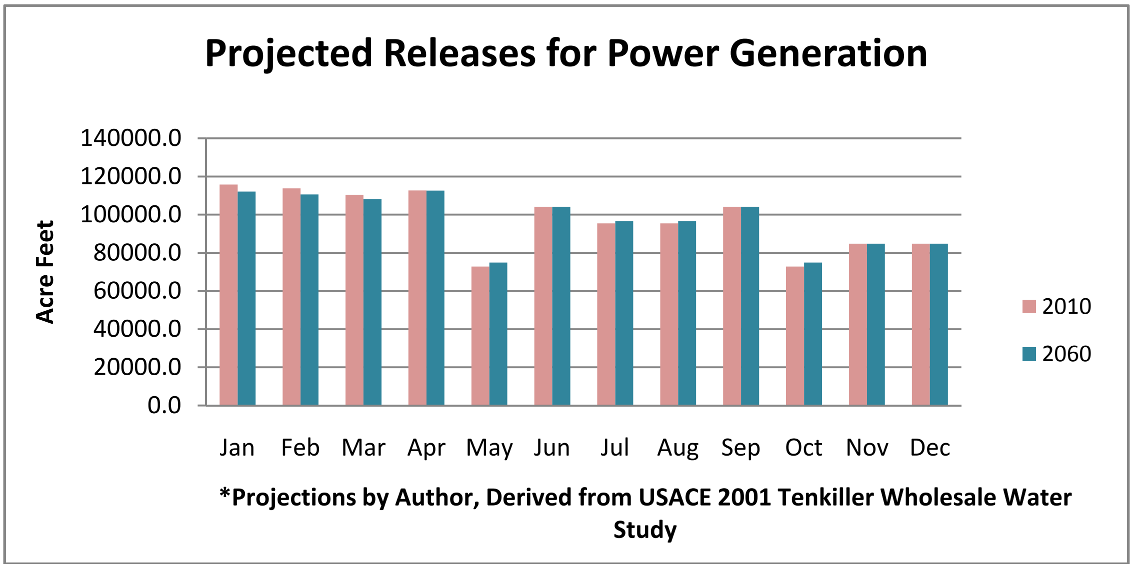



Figure III.13. Optimal Releases of Water for Power Generation in the Years 2010 and 2060.

Table III.10. Actual and Projected Releases for Power Generation for the Years 2010 to 2060.

| | Average* | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|---|
| | | | Acre Feet | | | | |
| Jan | 86,551 | 115752 | 109975 | 109975 | 112061 | 112061 | 112061 |
| Feb | 82,287 | 113769 | 109754 | 109754 | 110619 | 110619 | 110619 |
| Mar | 100,303 | 110465 | 109386 | 109386 | 108216 | 108216 | 108216 |
| Apr | 104,362 | 112709 | 113860 | 113860 | 112580 | 112580 | 112580 |
| May | 86,434 | 72781 | 75822 | 75822 | 74909 | 74909 | 74909 |
| Jun | 70,359 | 104132 | 104132 | 104132 | 104132 | 104132 | 104132 |
| Jul | 83,979 | 95444 | 76191 | 76191 | 96666 | 96666 | 96666 |
| Aug | 53,020 | 95444 | 76191 | 76191 | 96666 | 96666 | 96666 |
| Sep | 21,650 | 104132 | 104132 | 104132 | 104132 | 104132 | 104132 |
| Oct | 29,806 | 72781 | 75822 | 75822 | 74909 | 74909 | 74909 |
| Nov | 49,364 | 84773 | 104132 | 104132 | 84778 | 84778 | 84778 |
| Dec | 75,611 | 84773 | 104132 | 104132 | 84778 | 84778 | 84778 |
| Total | 843,726 | 1166954 | 1163529 | 1163529 | 1164446 | 1164446 | 1164446 |

* Average Years 1999-2007

**Lake Visitors**

The regression analysis indicated the number of lake visitors were dependent upon lake levels between 624 and 632 feet. The value of a visitor day was placed at $43 when the lake level was 624 feet or less and $50 per day when the level is 632 feet or more. Between those levels the price was increased linearly when the level was between 624 and 632 feet. Reductions in the number of lake visitors when lake levels were above or below the above levels were not found to be significant except for the months of June, July, and August. July visitors were projected to exceed 600,000 per in the month of July by the year 2060. The solution estimates for the years 2010 and 2060 are shown below in Figure III.14. The greatest increases are in the months of June, July, and August which were the only months where the historical data indicated there were significant time increases. Table III.11 indicates total visitor days increased from a historical average of 2.2 to 3.1 million per year by 2060.

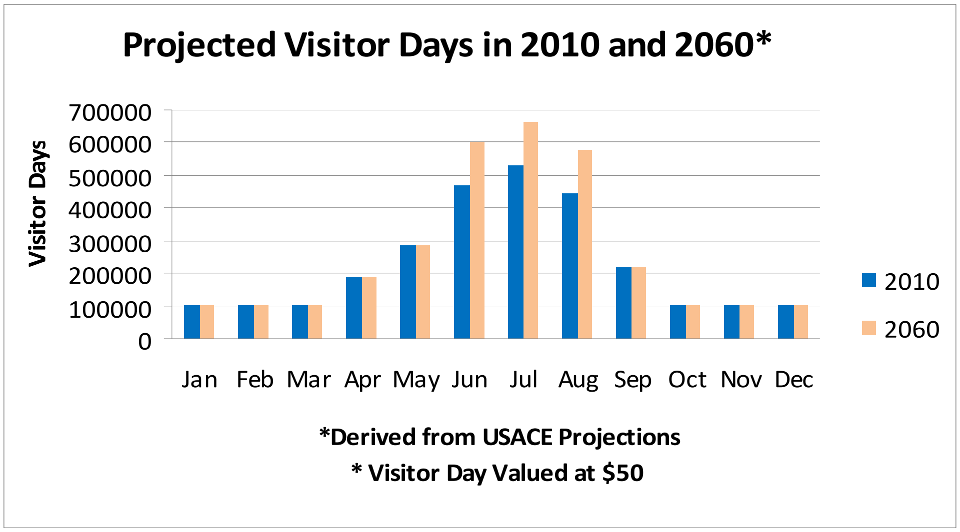



Figure III.14. Optimal Number of Visitor Days in 2010 and 2060.

Table III.11. Actual and Estimated Visitor Days for Lake Tenkiller (2010 – 2060)

| Month | Average | 2010 | 2020 | 2030 | 2040 | 2050 | 2060 |
|---|---|---|---|---|---|---|---|
| | | | | Visitor Days | | | |
| Jan | 54388 | 103733 | 103733 | 103733 | 103733 | 103733 | 103733 |
| Feb | 68579 | 103733 | 103733 | 103733 | 103733 | 103733 | 103733 |
| Mar | 101286 | 103733 | 103733 | 103733 | 103733 | 103733 | 103733 |
| Apr | 176077 | 187133 | 187133 | 187133 | 187133 | 187133 | 187133 |
| May | 281455 | 285764 | 285764 | 285764 | 285764 | 285764 | 285764 |
| Jun | 350397 | 467415 | 493955 | 520495 | 547035 | 573575 | 600115 |
| Jul | 398482 | 531698 | 558238 | 584778 | 611318 | 637858 | 664398 |
| Aug | 324280 | 446437 | 472977 | 499517 | 526057 | 552597 | 579137 |
| Sep | 202888 | 221359 | 221359 | 221359 | 221359 | 221359 | 221359 |
| Oct | 125943 | 103733 | 103733 | 103733 | 103733 | 103733 | 103733 |
| Nov | 101211 | 103733 | 103733 | 103733 | 103733 | 103733 | 103733 |
| Dec | 66944 | 103733 | 103733 | 103733 | 103733 | 103733 | 103733 |
| Total | 2251931 | 2762204 | 2841824 | 2921444 | 3001064 | 3080684 | 3160304 |

## IV. Extension of Research Results

IV.1 Methodology

- Results from the recreational survey were presented at the Oklahoma Clean Lakes and Water Association meeting in Tulsa, Ok from April 9-11, 2008 to individuals from state agencies, volunteer environmental groups, and academics.

- An in service workshop in Kellyville, OK, provided an opportunity for delivery of Lake Tenkiller research findings to OCES professionals from the counties in and around the Lake Tenkiller area. The program included presentations on:

    1. Current water rights and law, and the potential for changes as the Comprehensive State Water Plan is underway;
    2. The economics of water use in Oklahoma, including the Tenkiller region;
    3. A comparison of water rates by selected water district; and,
    4. Lake and river recreation and non-market valuation in the Tenkiller area.

- A presentation of the optimization results was given at the Oklahoma Water Resources Research Institute Symposium, October 29, 2008 entitled, "Managing Water Resources Given Competing Uses - A Lake Tenkiller Case Study." In Midwest City, OK.

- A poster entitled, "Optimal Allocation of Reservoir Water" by Deepayan Debnath, Art Stoecker, Tracy Boyer, and Larry Sanders was presented at the Oklahoma Water Resources Research Institute Symposium, October 29, 2008.

IV.2 Principal Findings of Extension

These presentations stimulated discussion on competing uses for the region's water resources, as well as the need for future research and development of extension and outreach programs outside of this grant activity. As a result, several activities are planned:

1. A survey of the rural water districts in the Tenkiller to determine the factors that affect water rates;
2. Meetings with the water districts and the public to discuss results of the Boyer, Stoecker, Sanders research, and the water rates survey results;
3. Development of fact sheets, other educational materials, a website and public meetings to address the perceived needs of county educators.
4. Further research and extension projects and proposals to follow up on questions brought about by this research indicated a need for further study.

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Appendices

Appendix A: Letter to Oklahoma Lakes Survey Respondents
Appendix B: Oklahoma Lakes Survey 2007
Appendix C: Oklahoma Lakes Survey 2007: Additional Statistics on Responses

## Appendix A

**First Cover Letter**

Name and Address of addressee

September x, 2007

Dear X

Would you do us a favor?

I am writing to ask you to help in a study of recreational lakes in Oklahoma. This study examines how lakes are used and what factors influence people's selection of lakes to visit.

We are contacting a random sample of residents from every county in the state to ask whether they visit lakes in Oklahoma, how often, and why.

Your participation will require several minutes to complete the enclosed questionnaire. Results from the survey will help Oklahoma agencies such as the Oklahoma Water Resources Board and Oklahoma State Parks manage and protect our lake resources. Even if you do not visit Oklahoma lakes, your response to the survey will help us understand why you have not visited the lakes and improve your satisfaction with them.

Your answers will remain completely confidential, and no individual's answers can be identified. Your information will be stored securely and will be available only to persons conducting the study. No reference will be made on written reports which could link you to the study. After this study is completed, your name will be deleted and never connected to your answer in any way. This survey is voluntary. There are no known risks associated with this survey which are greater than those ordinarily encountered in daily life. Your answers will help us very much to share your lake visiting experience. If for some reason you prefer not to respond, please let us know by returning the blank questionnaire in the enclosed stamped envelope.

If you have questions about your rights as a research volunteer, you may contact Dr. Sue C. Jacobs, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-1676 or irb@okstate.edu.

Thank you very much for helping with this important study.

Sincerely,

Tracy Boyer

Assistant Professor

Tracy.Boyer@okstate.edu

**Postcard Reminder**

In the last two weeks, a questionnaire seeking your opinion about Oklahoma Lakes was mailed to you.

If you have already completed and returned the questionnaire to us, please accept our sincere thanks. If not, please do so today. We are especially grateful for your help because it is only by asking people like you to share experiences that we can understand why people decide to visit or not visit lakes in state of Oklahoma. If you did not visit any lakes recently your response is still important and we'd appreciate answers to questions 1 and 14-25!

If you did not receive a questionnaire, or if it was misplaced, please call us at (405) 744-6169 or email us at Tracy.boyer@okstate.edu, and we will get another one in the mail to you.

Tracy Boyer

Assistant Professor
Department of Agricultural Economics

Oklahoma State University

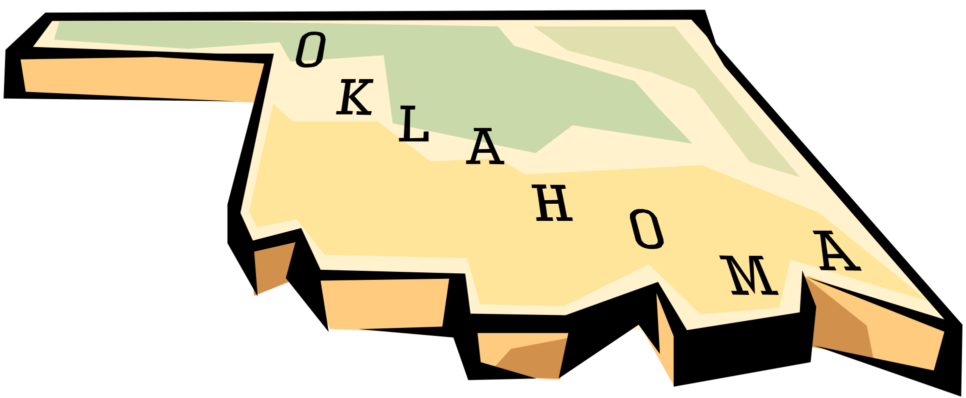
Stillwater, OK 74078

# Appendix B
# Oklahoma Lakes Survey

OSU
OKLAHOMA STATE

# Oklahoma Lakes Survey 2007

order to make sound decisions concerning the future of Oklahoma lakes, it is important to understand how the lakes are used, as well as what factors influence your selection of lakes to visit. The answers you give to the questions in this survey are very important. Even if you have not visited any lakes in Oklahoma, please complete and return the questionnaire. It is critical to understand the characteristics and views of both those who use and those who do not use the lakes




Participating in this survey will take only a few minutes of your time.

Your participation is voluntary and answers will remain strictly confidential.

Department of Agricultural Economics

Oklahoma State University

**In this first section, we would like to find out which of the lakes you visited and what you did there. A map is provided at the end of the survey if you need it.**

1. **Please indicate how often you or other members of your household visited each of the following lakes in the current and past year. Also, indicate the number of trips you anticipate making to each of the lakes in 2008. If you have not visited any lakes in Oklahoma, and do not plan to visit any in the upcoming year, please check this box and skip to question 2.**

❑ I have not, and do not plan to visit any lakes in Oklahoma

**If you visited lakes in Oklahoma that are not on this list, please count them in the "other" category at the end of the list.**

| Name of Lake | County | Number of visits (January-December) in: | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2006 (last year) | | 2007 (this year) | | 2008 (next year) | |
| | | Single day | Over night | Single day | Over night | Single day | Over night |
| *Example (Perry Lake)* | *Nobel* | *2 trips* | *3 trips* | *7 trips* | *0 trips* | *4 trips* | *1 trip* |
| Altus/Lugert Lake | Kiowa | | | | | | |
| American Horse Lake | Blaine | | | | | | |
| Arbuckle Lake | Murray | | | | | | |
| Arcadia Lake | Oklahoma | | | | | | |
| Ardmore City Lake | Carter | | | | | | |
| Atoka Lake | Atoka | | | | | | |
| Bell Cow Lake | Lincoln | | | | | | |
| Birch Lake | Osage | | | | | | |
| Bixhoma Lake | Wagoner | | | | | | |
| Bluestem Lake | Osage | | | | | | |
| Boomer Lake | Payne | | | | | | |
| Broken Bow Lake | McCurtain | | | | | | |
| Brushy Creek Lake | Sequoyah | | | | | | |
| Burtschi Lake | Grady | | | | | | |
| Canton Lake | Rogers | | | | | | |
| Carl Albert Lake | Latimer | | | | | | |
| Carl Blackwell Lake | Payne | | | | | | |
| Carlton Lake | Latimer | | | | | | |
| Carter Lake | Marshall | | | | | | |
| Cedar Lake | Canadian | | | | | | |
| Chambers Lake | Beaver | | | | | | |
| Chandler Lake | Lincoln | | | | | | |
| Chickasha Lake | Caddo | | | | | | |
| Chouteau Lake | Nowata | | | | | | |
| Claremore Lake | Rogers | | | | | | |
| Clayton Lake | Pushmataha | | | | | | |
| Clear Creek Lake | Stephens | | | | | | |
| Cleveland City Lake | Cleveland | | | | | | |
| Clinton Lake | Washita | | | | | | |

| Name of Lake | County | Number of visits (January-December) in: | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2006 (last year) | | 2007 (this year) | | 2008 (next year) | |
| | | Single day | Over night | Single day | Over night | Single day | Over night |
| ***Example (Perry Lake)*** | ***Nobel*** | ***2 trips*** | ***3 trips*** | ***7 trips*** | ***0 trips*** | ***4 trips*** | ***1 trip*** |
| Coalgate City Lake | Coal | | | | | | |
| Comanche Lake | Comanche | | | | | | |
| Copan Lake | Washington | | | | | | |
| Crowder Lake | Washita | | | | | | |
| Cushing Municipal Lake | Payne | | | | | | |
| Dave Boyer Lake | Cotton | | | | | | |
| Dead Indian Lake | Roger Mills | | | | | | |
| Dripping Springs Lake | Okmulgee | | | | | | |
| Duncan Lake | Stephens | | | | | | |
| El Reno Lake | Canadian | | | | | | |
| Elk City Lake | Beckham | | | | | | |
| Ellsworth Lake | Alfalfa | | | | | | |
| Elmer Lake | Kingfisher | | | | | | |
| Elmer Thomas Lake | Comanche | | | | | | |
| Etling Lake | Cimarron | | | | | | |
| Eucha Lake | Delaware | | | | | | |
| Eufaula Lake | Pittsburg | | | | | | |
| Fairfax City Lake | Osage | | | | | | |
| Fort Cobb Lake | Caddo | | | | | | |
| Fort Gibson Lake | Cherokee | | | | | | |
| Fort Supply Lake | Woodward | | | | | | |
| Foss Lake | Custer | | | | | | |
| Frances Lake | Marshall | | | | | | |
| Frederick Lake | Tillman | | | | | | |
| Fuqua Lake | Stephens | | | | | | |
| Grand Lake | Delaware | | | | | | |
| Great Salt Plains Lake | Alfalfa | | | | | | |
| Greenleaf Lake | Muskogee | | | | | | |
| Guthrie Lake | Logan | | | | | | |
| Hall Lake | Harmon | | | | | | |
| Healdton City Lake | Carter | | | | | | |
| Hefner Lake | Oklahoma | | | | | | |
| Henryetta Lake | Okmulgee | | | | | | |
| Heyburn Lake | Creek | | | | | | |
| Holdenville Lake | Hughes | | | | | | |
| Hominy Municipal Lake | Osage | | | | | | |
| Hudson Lake | Osage | | | | | | |
| Hugo Lake | Choctaw | | | | | | |
| Hulah Lake | Osage | | | | | | |
| Humphreys Lake | Stephens | | | | | | |
| Jap Beaver Lake | Jefferson | | | | | | |
| Jean Neustadt Lake | Carter | | | | | | |
| John Wells Lake | Haskell | | | | | | |
| Kaw Lake | Choctaw | | | | | | |
| Keystone Lake | Pawnee | | | | | | |
| Konawa Lake | Seminole | | | | | | |

| Name of Lake | County | Number of visits (January-December) in: | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2006 (last year) | | 2007 (this year) | | 2008 (next year) | |
| | | Single day | Over night | Single day | Over night | Single day | Over night |
| ***Example (Perry Lake)*** | ***Nobel*** | ***2 trips*** | ***3 trips*** | ***7 trips*** | ***0 trips*** | ***4 trips*** | ***1 trip*** |
| Langston Lake | Logan | | | | | | |
| Lawtonka Lake | Comanche | | | | | | |
| Liberty Lake | Logan | | | | | | |
| Lloyd Church Lake | Latimer | | | | | | |
| Lone Chimney Lake | Payne | | | | | | |
| McAlester Lake | Pittsburg | | | | | | |
| McGee Creek Lake | Atoka | | | | | | |
| McMurtry Lake | Noble | | | | | | |
| Meeker Lake | Lincoln | | | | | | |
| Mountain Lake | Carter | | | | | | |
| Murray Lake | Carter | | | | | | |
| Nanih Waiya Lake | Pushmataha | | | | | | |
| New Spiro Lake | Le Flore | | | | | | |
| Newt Graham Lake | Oklahoma | | | | | | |
| Okemah Lake | Okfuskee | | | | | | |
| Okmulgee Lake | Okmulgee | | | | | | |
| Oologah Lake | Nowata | | | | | | |
| Optima Lake | Texas | | | | | | |
| Overholser Lake | Oklahoma | | | | | | |
| Ozzie Cobb Lake | Pushmataha | | | | | | |
| Pauls Valley City Lake | Garvin | | | | | | |
| Pawhuska Lake | Osage | | | | | | |
| Pawnee Lake | Pawnee | | | | | | |
| Perry Lake | Noble | | | | | | |
| Pine Creek Lake | McCurtain | | | | | | |
| Ponca Lake | Kay | | | | | | |
| Prague City Lake | Lincoln | | | | | | |
| Purcell Lake | McClain | | | | | | |
| Quanah Parker Lake | Comanche | | | | | | |
| R.C. Longmire Lake | Garvin | | | | | | |
| Raymond Gary Lake | Choctaw | | | | | | |
| Robert S. Kerr Lake | Sequoyah | | | | | | |
| Rock Creek Lake | Carter | | | | | | |
| Rocky Lake | Washita | | | | | | |
| Sahoma Lake | Creek | | | | | | |
| Sardis Lake | Latimer | | | | | | |
| Schooler Lake | Choctaw | | | | | | |
| Shawnee Twin Lake | Pottawatomie | | | | | | |
| Shell Lake | Osage | | | | | | |
| Skiatook Lake | Osage | | | | | | |
| Sooner Lake | Noble | | | | | | |
| Spavinaw Lake | Mayes | | | | | | |
| Sportsman Lake | Custer | | | | | | |
| Spring Creek Lake | Roger Mills | | | | | | |
| Stanley Draper Lake | Oklahoma | | | | | | |
| Stroud Lake | Lincoln | | | | | | |
| Talawanda Lake | Pittsburg | | | | | | |

Number of visits (January-December) in:

| Name of Lake | County | 2006 (last year) | | 2007 (this year) | | 2008 (next year) | |
|---|---|---|---|---|---|---|---|
| | | Single day | Over night | Single day | Over night | Single day | Over night |
| *Example (Perry Lake)* | *Nobel* | *2 trips* | *3 trips* | *7 trips* | *0 trips* | *4 trips* | *1 trip* |
| Taylor Lake | Nowata | | | | | | |
| Tecumseh Lake | Pottawatomie | | | | | | |
| Tenkiller Ferry Lake | Cherokee | | | | | | |
| Texoma Lake | Cleveland | | | | | | |
| Thunderbird Lake | Cleveland | | | | | | |
| Tom Steed Lake | Kiowa | | | | | | |
| Vanderwork Lake | Washita | | | | | | |
| Veterans Lake | Murray | | | | | | |
| Vincent Lake | Ellis | | | | | | |
| W.R. Holway Lake | Mayes | | | | | | |
| Watonga Lake | Blaine | | | | | | |
| Waurika Lake | Osage | | | | | | |
| Waxhoma Lake | Osage | | | | | | |
| Wayne Wallace Lake | Latimer | | | | | | |
| Webbers Falls Lake | Muskogee | | | | | | |
| Weleetka Lake | Okfuskee | | | | | | |
| Wes Watkins Lake | Oklahoma | | | | | | |
| Wetumka Lake | Hughes | | | | | | |
| Wewoka Lake | Seminole | | | | | | |
| Wiley Post Memorial Lake | McClain | | | | | | |
| Wister Lake | Le Flore | | | | | | |
| Yahola Lake | Tulsa | | | | | | |

## OUTSIDE OF OKLAHOMA:

**2. Please indicate how often you or other members of your household visited lakes or rivers in each of the following locations in the current and past year. Also, indicate the number of trips you anticipate making to each of these locations in 2008.**

| Lake Name | Number of Visits January-December | | | | | |
|---|---|---|---|---|---|---|
| | 2006 (last year) | | 2007 (this year) | | 2008 (next year) | |
| | Single Day | Overnight | Single Day | Overnight | Single Day | Overnight |
| *Example (Lake in Alaska)* | *0 trips* | *2 trips* | *0 trips* | *1 trip* | *0 trips* | *1 trip* |
| Lakes in Kansas | | | | | | |
| Lakes in Texas | | | | | | |
| Lakes in Arkansas | | | | | | |
| Lakes in Missouri | | | | | | |
| Lakes in Colorado | | | | | | |
| Lakes in Mississippi | | | | | | |
| Other Lakes | | | | | | |

**If you chose other Lakes, what state(s) were these lakes in? ______________________________**

**3. What is your 5 digit postal ZIP code at your permanent residence? ____________________**

**4. What activities did you and your family typically engaged in when visiting a lake? Please Check all that apply.**

- ❑ Boating
- ❑ Camping
- ❑ Hunting
- ❑ Golfing
- ❑ Sightseeing
- ❑ Jet-skiing/wave running
- ❑ Sailing
- ❑ Canoeing/Kayaking
- ❑ Nature appreciation/wildlife viewing
- ❑ Hiking
- ❑ Picnicking
- ❑ Fishing
- ❑ Swimming and Beach Use
- ❑ Other __________________

**5. How frequently do you or your family swim in Oklahoma lakes?**

❑ Never ❑ Rarely ❑ Sometimes ❑ Frequently

## In this section we would like to find out what features of lakes are important to you.

**6. To what extent do you agree or disagree with the following statement: "Potential crowding and congestion affect my choice of lake and/or the days of the week or weekends of the year to visit my favorite lake?" Please circle a number below to indicate your answer (1 being strongly disagree and 10 being strongly agree).**

| Strongly disagree | | | | Neutral | | | | | Strongly agree |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

**7. Indicate whether you believe the state should provide public information on lakes with respect any of these factors.**

| Factor | Should it be provided? | | Would it affect your decision to visit a lake? | |
|---|---|---|---|---|
| Public safety (crime rate) | ❑ Yes | ❑ No | ❑ Yes | ❑ No |
| Fish contamination | ❑ Yes | ❑ No | ❑ Yes | ❑ No |
| Bacterial or related lake water contamination | ❑ Yes | ❑ No | ❑ Yes | ❑ No |
| Algal blooms/turbidity | ❑ Yes | ❑ No | ❑ Yes | ❑ No |
| Lake water levels | ❑ Yes | ❑ No | ❑ Yes | ❑ No |

8. **How important are the following factors for you in choosing a lake for recreation? Please circle appropriate number to indicate your answer on a scale of 1-10 (1 being not important and 10 being very important).**

| | **Not important** | | | | **Neutral** | | | | | **Very important** |
|---|---|---|---|---|---|---|---|---|---|---|
| Sandy or hard bottom in swimming area | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Diversity of fish species/ habitat | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Quantity of fish caught | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Crowding/ Congestion | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Distance to where you live | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Park facilities | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Activities at the lake | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Activities in Town nearby | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Water quality | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Location of friends/ relatives | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Other (please specify) ________________________ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

9. **This question asks for the importance of water quality in lakes. Please rank each of the following water quality factors with regard to influence you in choosing a lake for recreation. Please rank them 1st, 2nd, 3rd, and 4th in their relative importance to your choice.**

__________ Lack of water odor

__________ Bacteria/ contamination at levels posing health risks

__________ Increase in water clarity

__________ No algal boom

**In the section starting on the next page, we would like to ask you several questions about potential management scenarios being considered to improve Oklahoma lake recreation. There are four different sets of management scenarios (question 10 to 13). Please consider one as a separate question.**

**Turn over page and please answer questions in the next section. ➔ ➔ ➔ ➔ ➔ ➔ ➔ ➔**

**10.Compared to the lake you most visit, would you choose a lake such as A or B? Or would you choose to stay with the one you currently visit, C? Please choose one.**

| Attribute | Option A | Option B | Option C |
|---|---|---|---|
| **Increase in public boat ramps** | 1 Boat ramp | 1 Boat ramp | **NO CHANGE:** I would rather keep the management of this lake the way it is today |
| **Campsites** | Available with electric service | Available with electric service | |
| **Public restrooms** | Restroom with flush toilets and showers | Restroom with flush toilets and showers | |
| **Lodges** | Available | Available | |
| **Water clarity** | 1 foot increase of water visibility dept from surface | 1 foot increase of water visibility dept from surface | |
| **Increase in distance from home (one-way)** | 40 miles increase | 40 miles increase | |
| **I would choose (Please check only one)** | ☐ **A** | ☐ **B** | ☐ **C** (I would not want either A or B) |

**Given your choice above, how many trips per year would you take?**

Number of single day trips ☐ same number or ___#less or ___# more

Number of multiple day trips ☐ same number or ___# less ___# more

**11. Compared to the lake you most visit, would you choose a lake such as A or B? Or would you choose to stay with the one you currently visit, C? Please choose one independent of your previous choices.**

| Attribute | Option A | Option B | Option C |
|---|---|---|---|
| **Increase in public boat ramp** | 1 Boat ramp | 1 Boat ramp | **NO CHANGE:** I would rather keep the management of this lake the way it is today. |
| **Campsites** | Available with electric service | Available with electric service | |
| **Public restrooms** | Restroom with flush toilets and showers | Restroom with flush toilets and showers | |
| **Lodges** | Available | Available | |
| **Water clarity** | 1 foot increase of water visibility dept from surface | 1 foot increase of water visibility dept from surface | |
| **Increase in distance from home (one-way)** | 40 miles increase | 40 miles increase | |
| **I would choose (Please check only one)** | ☐ **A** | ☐ **B** | ☐ **C** (I would not want either A or B) |

**Given your choice above, how many trips per year would you take?**

Number of single day trips ☐ same number or ___#less or ___# more

Number of multiple day trips ☐ same number or ___# less ___# more

**12. Compared to the lake you most visit, would you choose a lake such as A or B? Or would you choose to stay with the one you currently visit, C? Please choose one independent of your previous choices.**

| Attribute | Option A | Option B | Option C |
|---|---|---|---|
| **Increase in public boat ramp** | 1 Boat ramp | 1 Boat ramp | **NO CHANGE:** I would rather keep the management of this lake the way it is today. |
| **Campsites** | Available with electric service | Available with electric service | |
| **Public restrooms** | Restroom with flush toilets and showers | Restroom with flush toilets and showers | |
| **Lodges** | Available | Available | |
| **Water clarity** | 1 foot increase of water visibility dept from surface | 1 foot increase of water visibility dept from surface | |
| **Increase in entrance fee/ camping fee (per trip)** | $30 increase | $30 increase | |
| **I would choose (Please check only one)** | ☐ **A** | ☐ **B** | ☐ **C** (I would not want either A or B) |

**Given your choice above, how many trips per year would you take?**

Number of single day trips ☐ same number or ___#less or ___# more

Number of multiple day trips ☐ same number or ___# less ___# more

**13. Compared to the lake you most visit, would you choose a lake such as A or B? Or would you choose to stay with the one you currently visit, C? Please choose one independent of your previous choices.**

| Attribute | Option A | Option B | Option C |
|---|---|---|---|
| **Increase in public boat ramp** | 1 Boat ramp | 1 Boat ramp | **NO CHANGE:** I would rather keep the management of this lake the way it is today. |
| **Campsites** | Available with electric service | Available with electric service | |
| **Public restrooms** | Restroom with flush toilets and showers | Restroom with flush toilets and showers | |
| **Lodges** | Available | Available | |
| **Water clarity** | 1 foot increase of water visibility dept from surface | 1 foot increase of water visibility dept from surface | |
| **Increase in entrance fee/ camping fee (per trip)** | $30 increase | $30 increase | |
| **I would choose (Please check only one)** | ☐ **A** | ☐ **B** | ☐ **C** (I would not want either A or B) |

**Given your choice above, how many trips per year would you take?**

Number of single day trips ☐ same number or ___#less or ___# more

Number of multiple day trips ☐ same number or ___# less ___# more

**Information about you and other members of your household will help us better understand how household characteristics affect an individual's use of Oklahoma lakes and attitudes towards changes in them. It will also help us to determine how representative respondents are of people in the state of Oklahoma.**

All of your answers are strictly confidential. **The information will only be used to report comparisons among groups of people. We will never identify individuals or households with their responses. Please be as complete as possible. Thank you.**

**14. What is your age in years?**

- ❑ Under 18
- ❑ 18 – 25
- ❑ 26 – 34
- ❑ 35 – 49
- ❑ 50 – 59
- ❑ 60 – 75
- ❑ 76 +

**15. Are you**

❑ Male ❑ Female

**16. What is the highest level of schooling that you have completed? (Please check only one)**

- ❑ Some high school or less
- ❑ High school graduate
- ❑ Some college or trade/vocational school
- ❑ College graduate (B.A., B.S.)
- ❑ Advanced degree (M.D., J.D. M.A., M.S., or PhD)

**17. How many adults (including yourself) live in your household? _______**

**18. How many children live in your household (18 or under)?________**

**19. If you are currently employed, how many hours a week do you typically work? _______**

**20. If you are currently employed, do you have the option of working additional hours to increase your total income?**

- ❑ No
- ❑ Yes—if so, what would your hourly wage be? $_______per hour

**21. If you answered "no" to question 20, and you could have the option of working more or less hours, which would you prefer?**

- ❑ Work more hours
- ❑ Work the same number of hours
- ❑ Work less hours

**22. What was your total household income (before taxes) for 2006?**

- ❑ Under $10,000
- ❑ $10,000-$14,999
- ❑ $15,000-$19,999
- ❑ $20,000-$24,999
- ❑ $25,000-$29,999
- ❑ $30,000-$34,999
- ❑ $35,000-$39,999
- ❑ $40,000-$49,999
- ❑ $50,000-$59,999
- ❑ $60,000-$74,999
- ❑ $75,000-$99,999
- ❑ $100,000-$124,999
- ❑ $125,000-$149,999
- ❑ Over $150,000

**23. Do you own a home on or near a lake in Oklahoma?**

- ❑ No
- ❑ Yes, →**If yes, are you a year-round resident?**
  - ❑ Yes
  - ❑ No

**24. Do you own a home on a lake outside of Oklahoma?**

❑ Yes ❑ No

**25. Do you belong to a lake protection association?**

❑ Yes ❑ No

COMMENTS? COMMENTS ABOUT LAKES AND RECREATION IN OKLAHOMA?

**THANK YOU!**

If you have any questions about this survey, please contact:

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321 Agriculture Hall

Oklahoma State University

Stillwater, OK 74078

(405) 744-6169

Tracy.boyer@okstate.edu

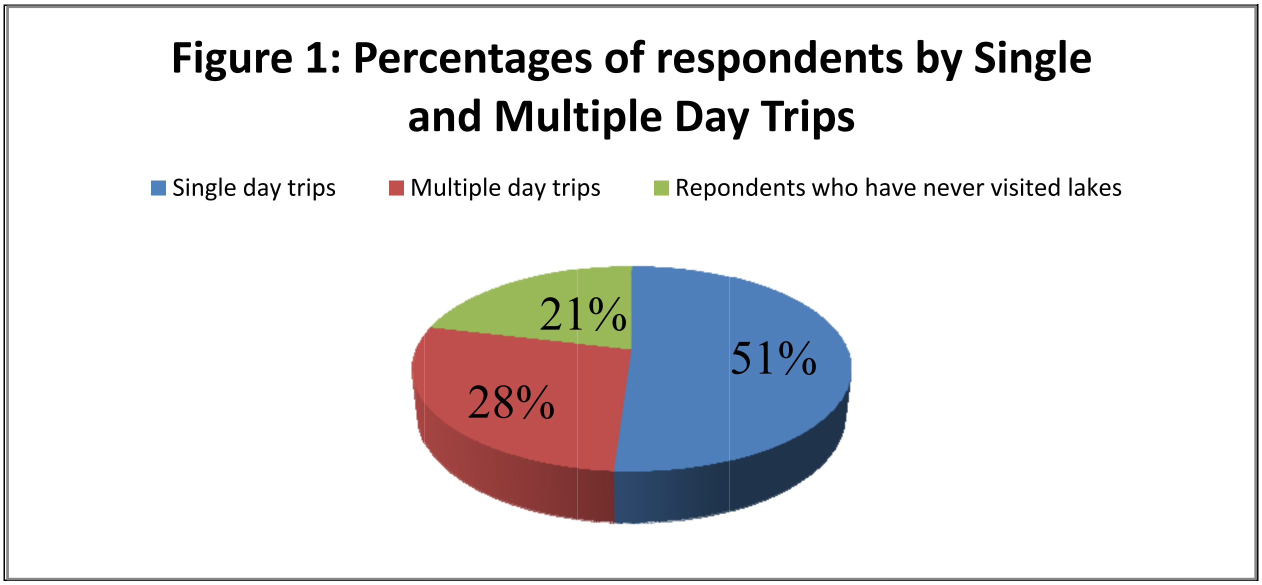
*MAP OF LAKES INCLUDED IN SURVEY HAS BEEN OMITTED*

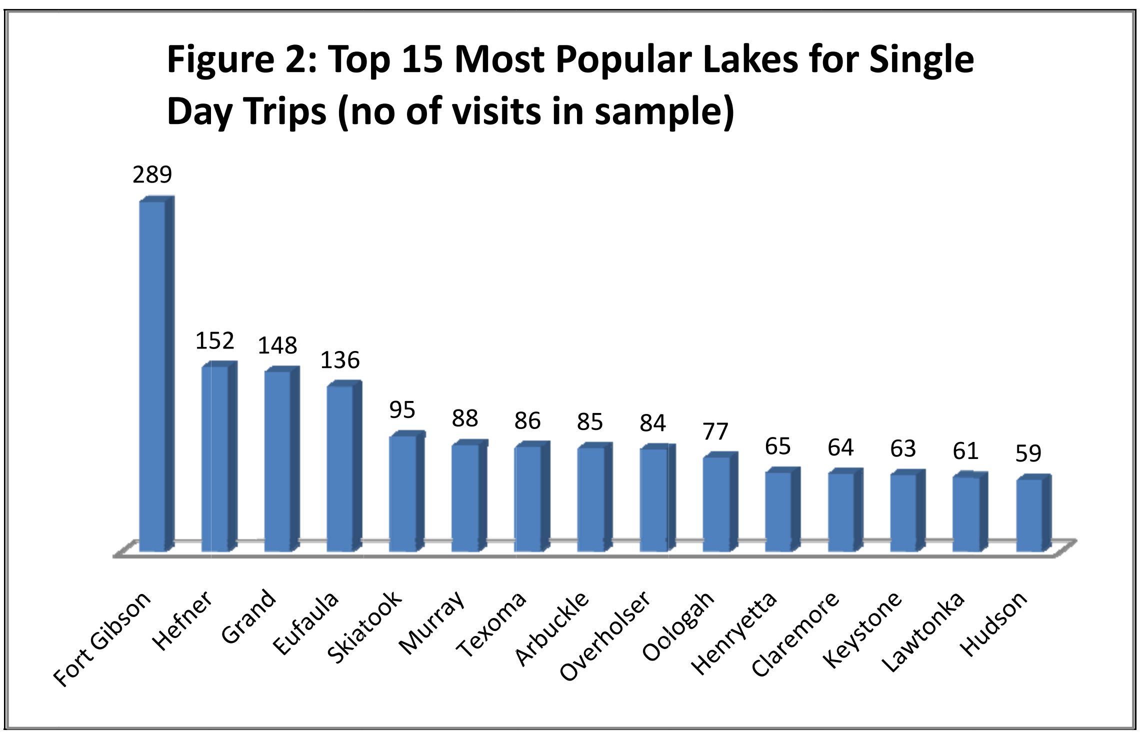
# APPENDIX C

# OKLAHOMA LAKES SURVEY 2007:
# ADDITIONAL STATISTICS ON RESPONSES

Table 1: Day and Multiple Day Trips and Visitors Averages

| | Total Single day trips | Total Multiple day trip |
|---|---|---|
| Total | 2,777 | 1,053 |
| Average/person | 14 | 10 |



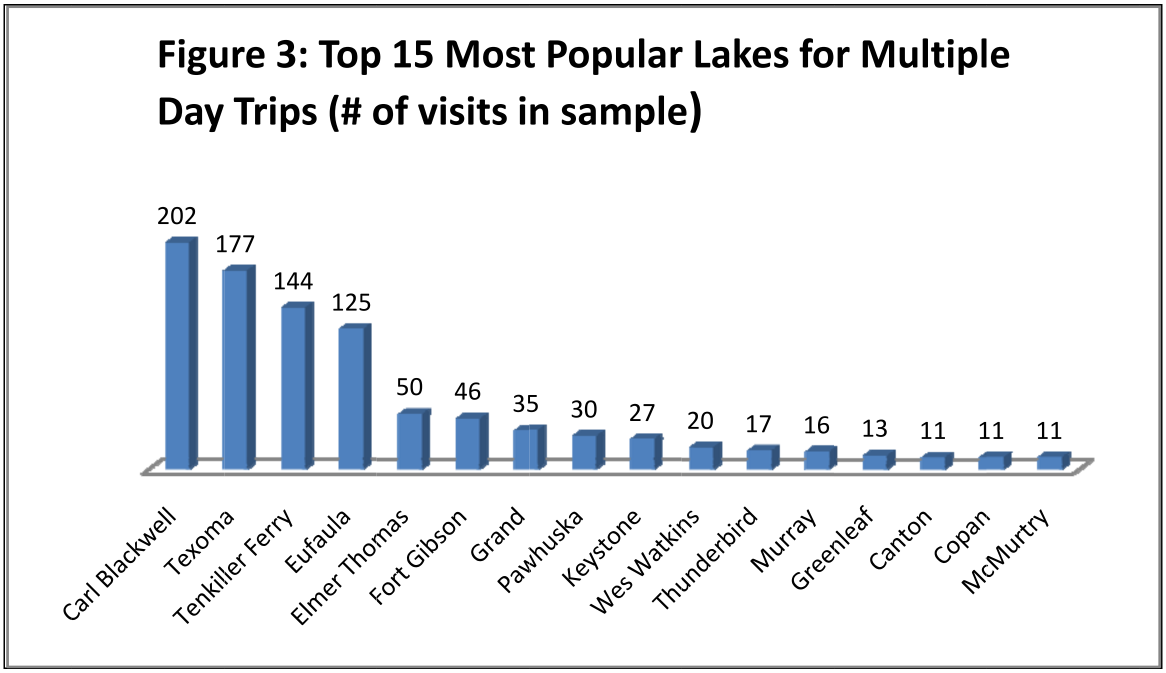
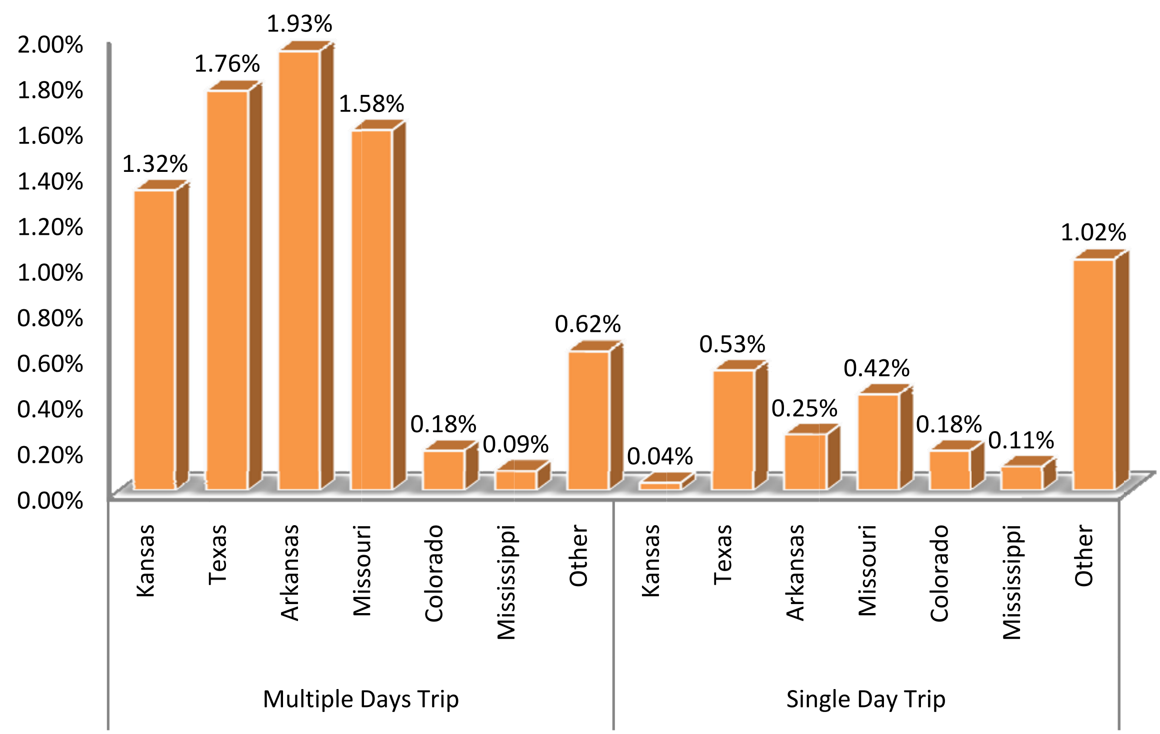



**Figure 4: Percentage of Total Trips Reported to Lakes Outside of Oklahoma in 2007(as a percentage of all trips in and out of state)**



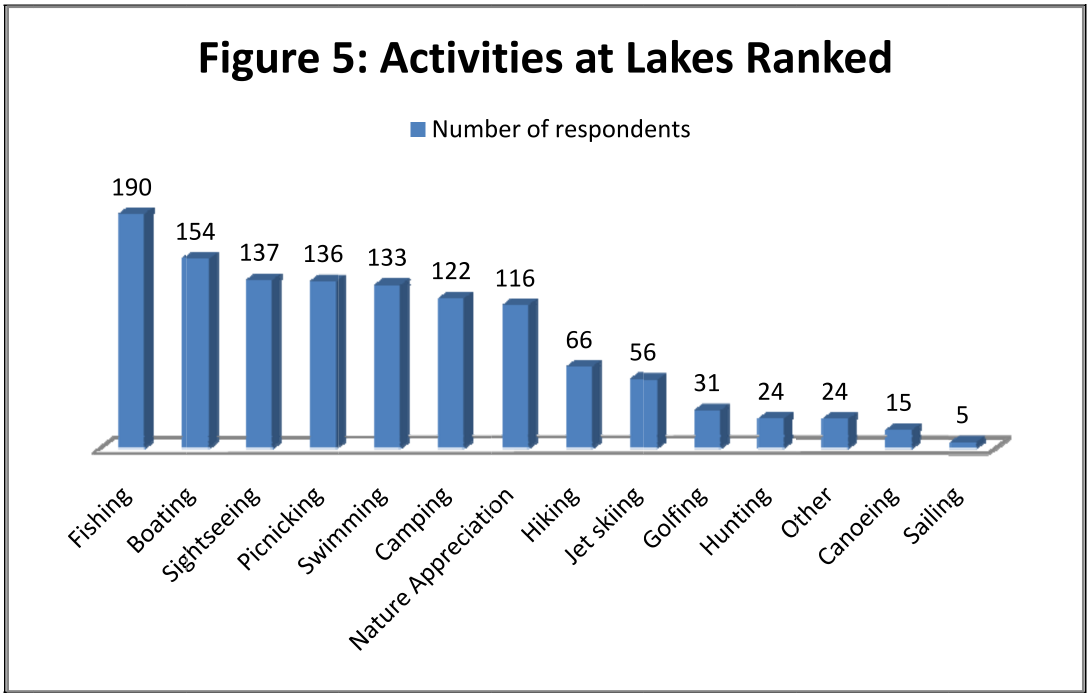


Figure 5: Activities at Lakes Ranked
Number of respondents
190
154
137
136
133
122
116
66
56
31
24
24
15
5
Fishing
Boating
Sightseeing
Picnicking
Swimming
Camping
Nature Appreciation
Hiking
Jet skiing
Golfing
Hunting
Other
Canoeing
Sailing

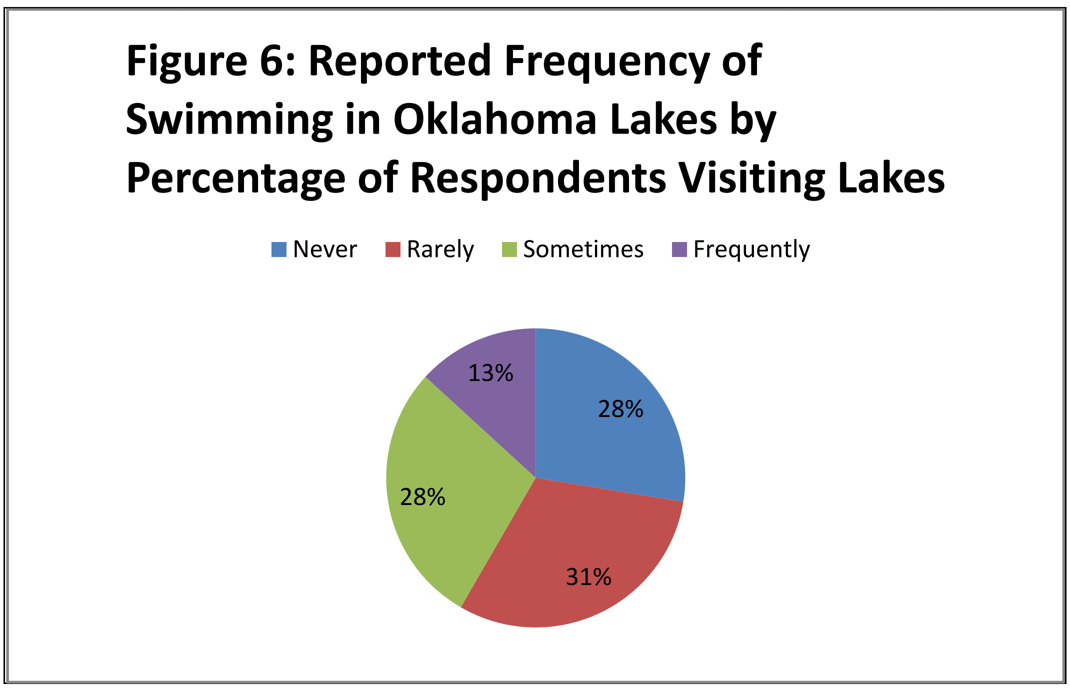


Figure 6: Reported Frequency of Swimming in Oklahoma Lakes by Percentage of Respondents Visiting Lakes
Never
Rarely
Sometimes
Frequently
13%
28%
28%
31%

**Figure 7: Percentage of All Respondents Who Believe Lake Condition Information Should Be Provided by the State by Subject**

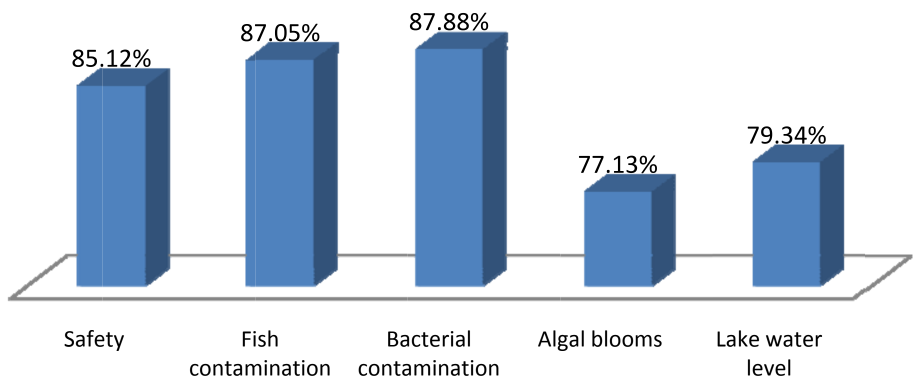
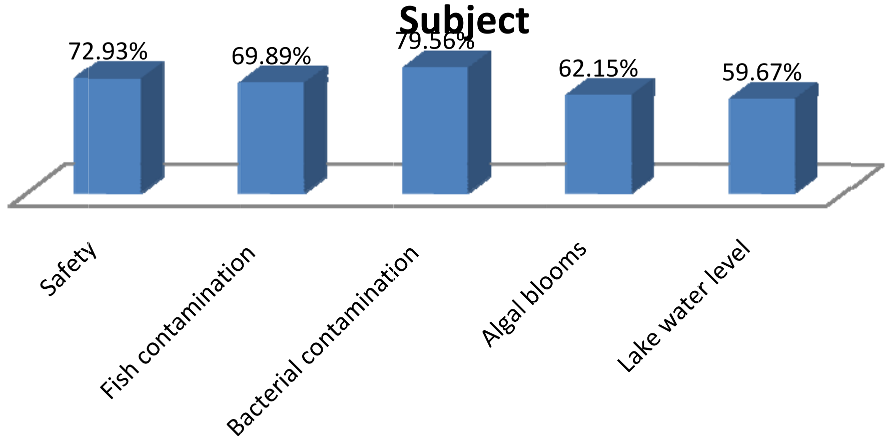



**Figure 8: Percentage of All Respondents Who Believe Lake Condition Information Given by the State Would Affect Their Visitation Rate by Subject**



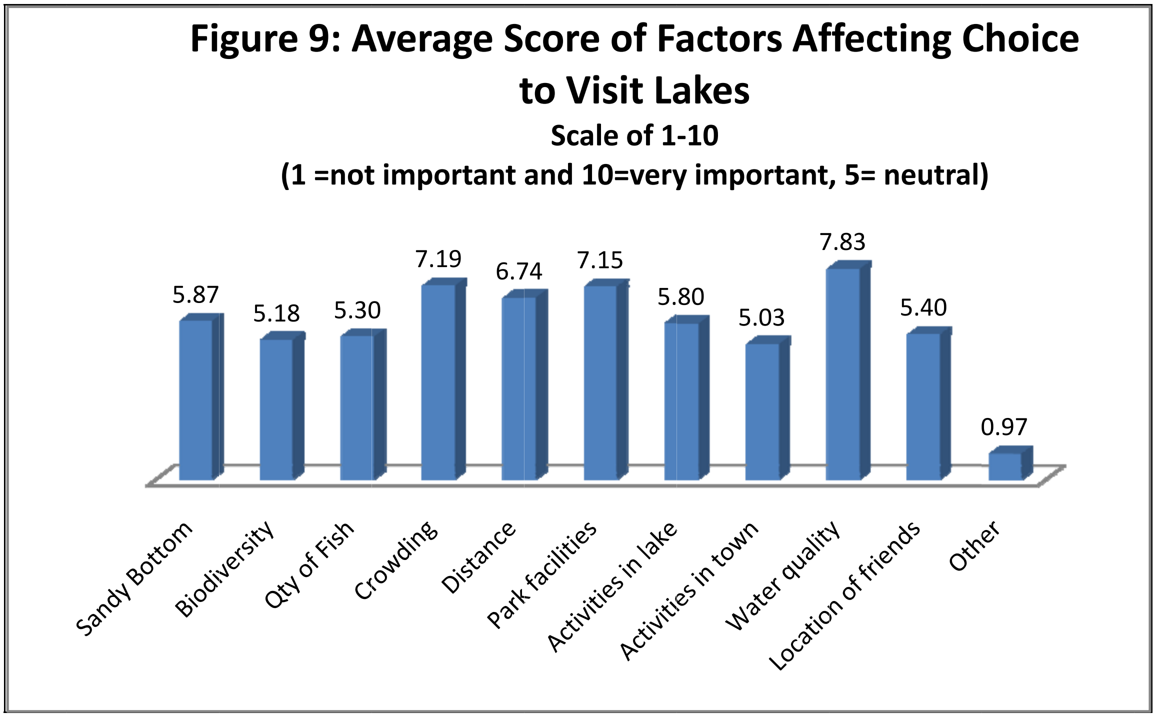


Figure 9: Average Score of Factors Affecting Choice to Visit Lakes
Scale of 1-10
(1 =not important and 10=very important, 5= neutral)
5.87
5.18
5.30
7.19
6.74
7.15
5.80
5.03
7.83
5.40
0.97
Sandy Bottom
Biodiversity
Qty of Fish
Crowding
Distance
Park facilities
Activities in lake
Activities in town
Water quality
Location of friends
Other

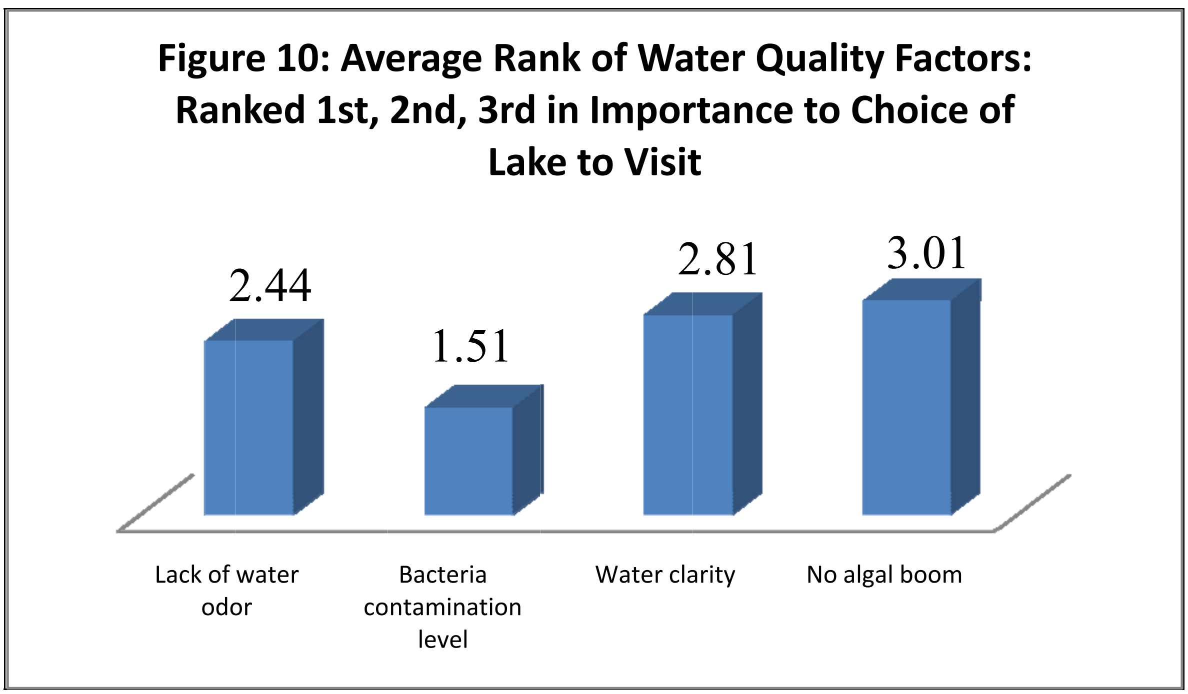


Figure 10: Average Rank of Water Quality Factors: Ranked 1st, 2nd, 3rd in Importance to Choice of Lake to Visit
2.44
1.51
2.81
3.01
Lack of water odor
Bacteria contamination level
Water clarity
No algal boom

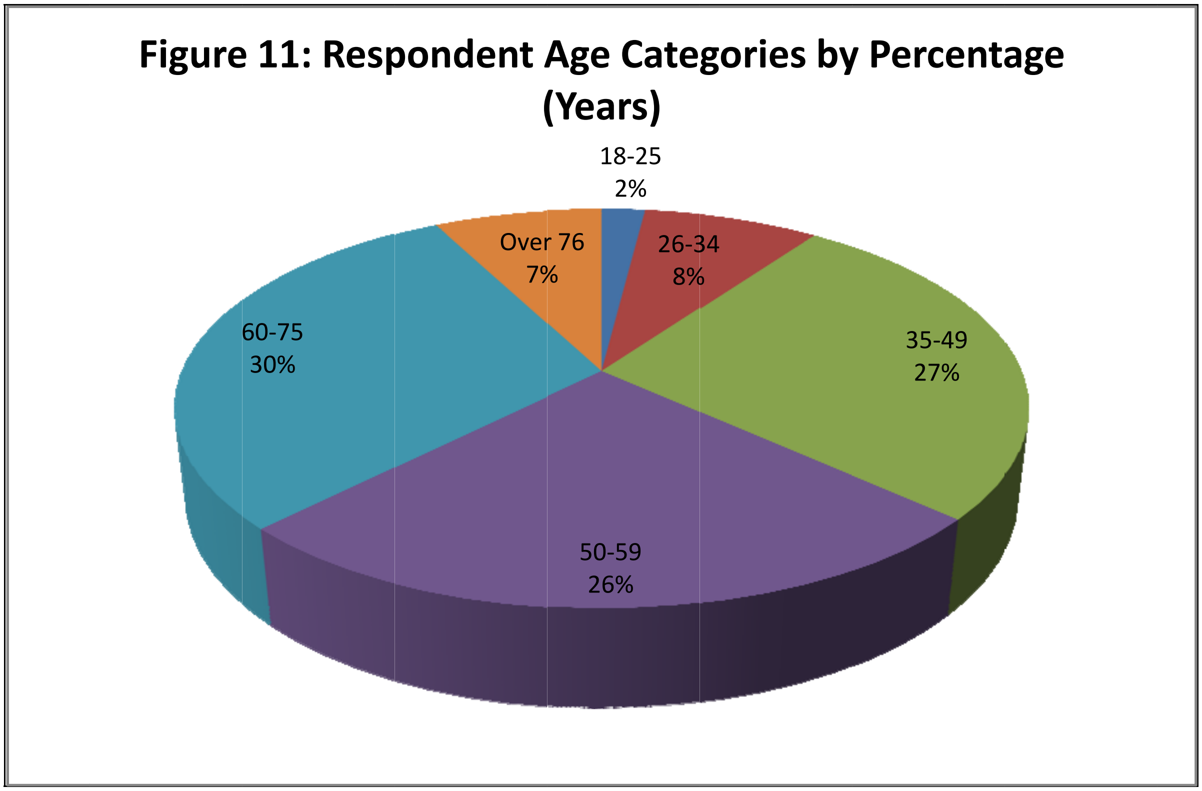


Figure 11: Respondent Age Categories by Percentage (Years)
18-25
2%
26-34
8%
35-49
27%
50-59
26%
60-75
30%
Over 76
7%

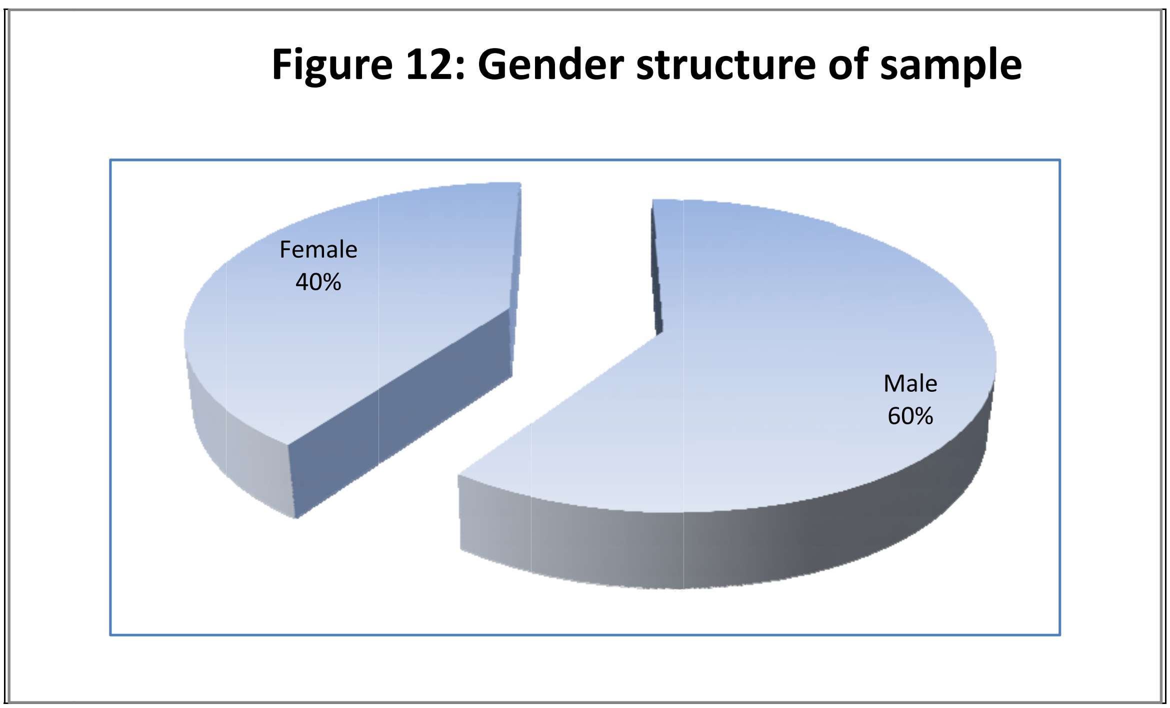


Figure 12: Gender structure of sample
Female
40%
Male
60%

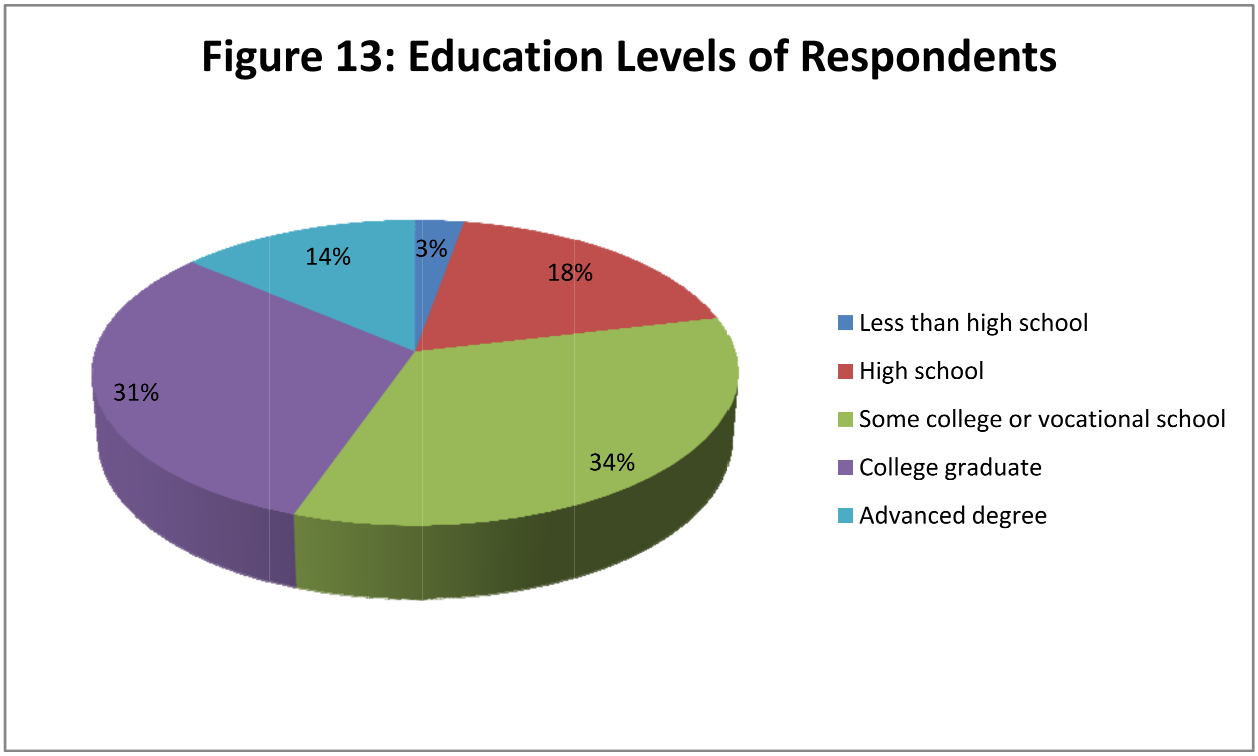


Figure 13: Education Levels of Respondents
3%
18%
34%
31%
14%
Less than high school
High school
Some college or vocational school
College graduate
Advanced degree

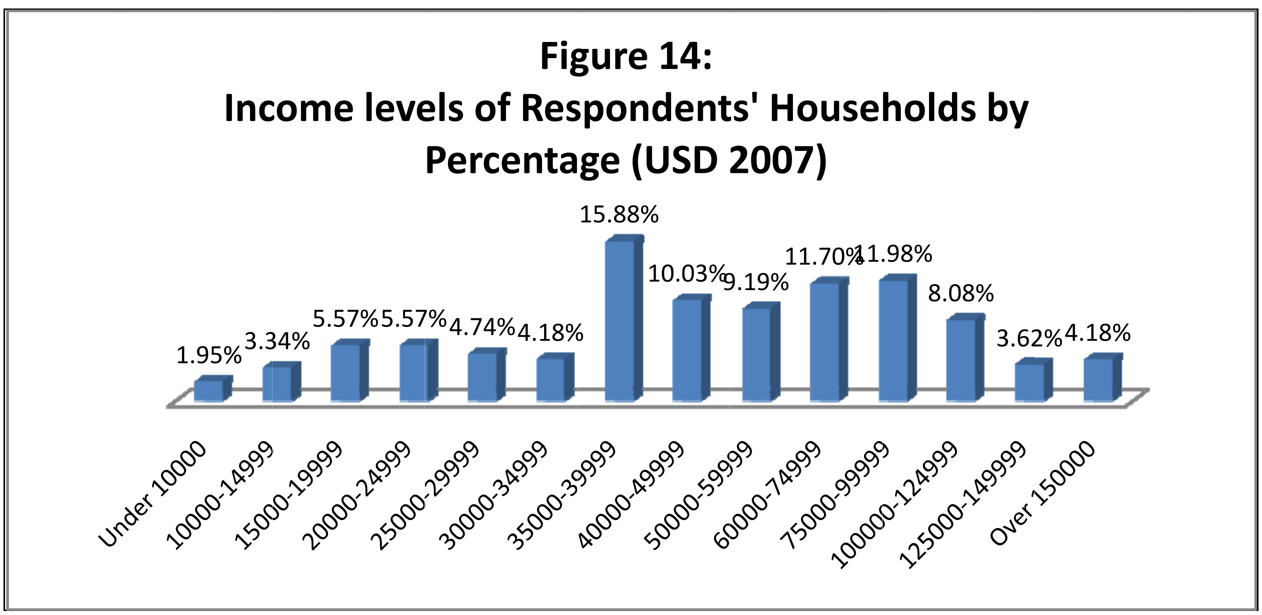



Figure 14:
Income levels of Respondents' Households by Percentage (USD 2007)
1.95%
3.34%
5.57%
5.57%
4.74%
4.18%
15.88%
10.03%
9.19%
11.70%
11.98%
8.08%
3.62%
4.18%
Under 10000
10000-14999
15000-19999
20000-24999
25000-29999
30000-34999
35000-39999
40000-49999
50000-59999
60000-74999
75000-99999
100000-124999
125000-149999
Over 150000

# Figure 15: Percentage of Respondents Closely Linked to Lakes