

# Bathymetric Survey of Select Dissolved Oxygen Impaired Reservoirs FY 2019

PROJECT 03 FY18/19 §106 I-006400-17

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# Bathymetric Survey of Select Dissolved Oxygen Impaired Reservoirs FY 2019

## INTRODUCTION

### Project

The Oklahoma Water Resources Board (OWRB) was contracted by the Oklahoma Department of Environmental Quality (ODEQ) to conduct hydrographic surveys on three Oklahoma reservoirs listed on the state's 303(d) list as impaired for dissolved oxygen. These reservoirs include Clear Creek Lake, Duncan Lake, and Wewoka Lake. The purpose of this project is to produce current elevation-area-capacity tables, to allow for volumetric determination of dissolved oxygen for beneficial use assessment.

### Reservoirs

#### Clear Creek Lake

Clear Creek Lake is located on Clear Creek, a tributary of the Washita River. It is located in Stephens County, approximately seven miles east of the City of Marlow **Error! Reference source not found.** The dam (NID ID: OK10736) was completed in 1948 and the reservoir (Waterbody ID: 310810040120) is owned by the City of Duncan. The dam is Located at Latitude 34° 35' 04.6" Longitude 097° 50' 35.6" in Sec. 4-T1N-R6W. Clear Creek's designated beneficial uses include Agriculture, Aesthetics, Fish and Wildlife Propagation, Recreation, and Public and Private Water Supply. Clear Creek is also designated as a Sensitive Water Supply (OAC, 785:45, Appendix A).

#### Duncan Lake

Duncan Lake is located on Fitzpatrick Creek, a tributary of the Washita River. It is located in Stephens County, approximately nine miles east of the City of Duncan **Figure 2**. The dam (NID ID: OK10023) was completed in 1937, and the reservoir (Waterbody ID: 310810040080) is owned by the City of Duncan. The dam is located at Latitude 34° 31' 17.1" Longitude 097° 48' 35.4" in Sec. 34-T1N-R6W. Duncan's designated beneficial uses include Agriculture, Aesthetics, Fish and Wildlife Propagation, Recreation, and Public and Private Water Supply. Duncan Lake is also designated as a Sensitive Water Supply (OAC, 785:45, Appendix A).

#### Wewoka Lake

Wewoka Lake is located on Coon Creek, a tributary of the North Canadian River. It is located in Seminole County, approximately two miles northwest of the City of Wewoka **Figure 3**. The dam (NID ID: OK10487) was originally completed in 1925, and rebuilt in 1945 after failure due to overtopping. The reservoir (Waterbody ID: 520500020190) is owned by the City of Wewoka. The dam is located at Latitude 35° 10' 50.2" Longitude 096° 31' 30.6" in Sec. 12-T8N-R7E. Wewoka's designated beneficial uses include Agriculture, Aesthetics, Fish and Wildlife Propagation, Recreation, and Public and Private Water Supply. Wewoka Lake is also designated as a Sensitive Water Supply (OAC, 785:45, Appendix A).

# Clear Creek Reservoir

Location Map

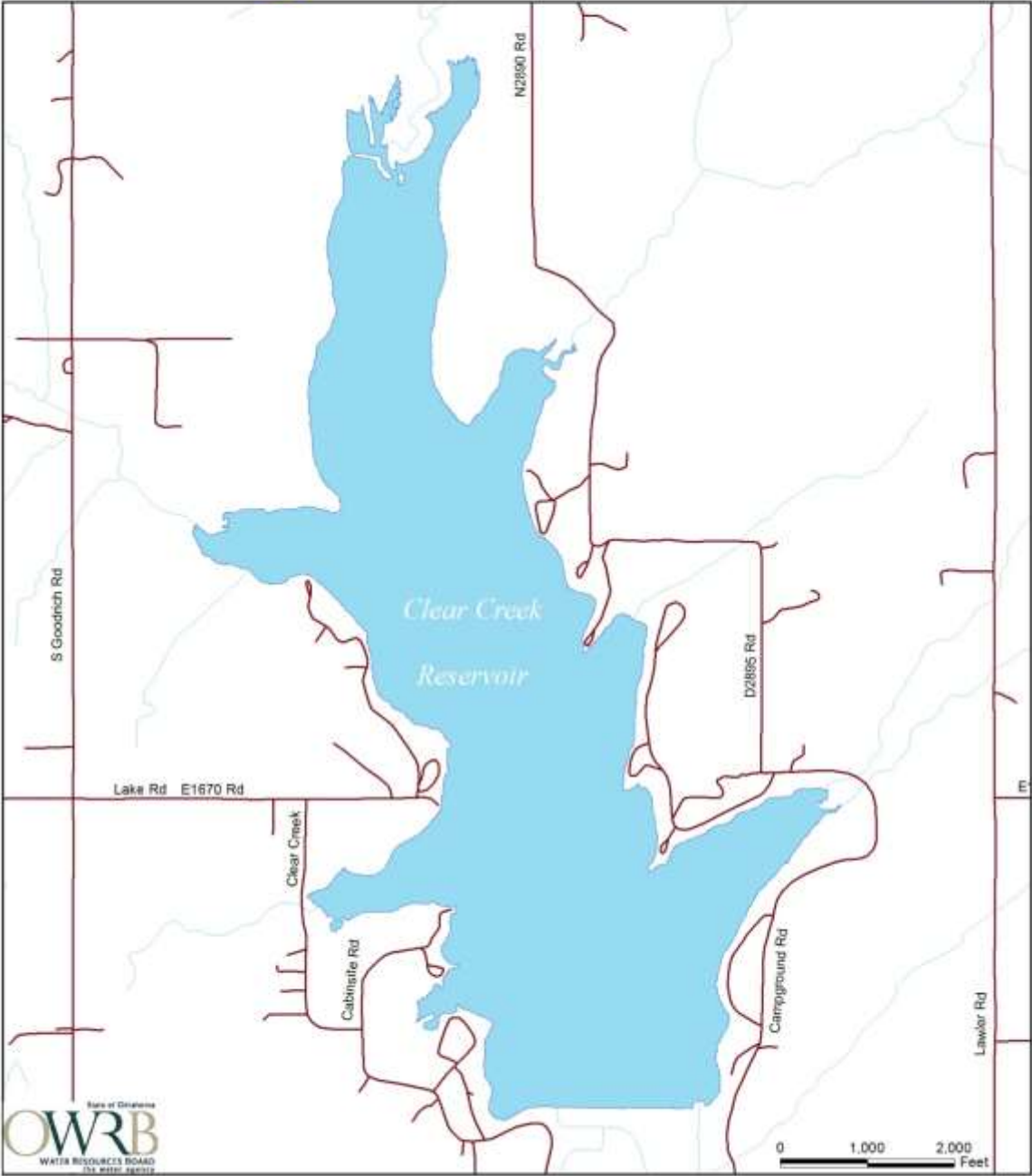
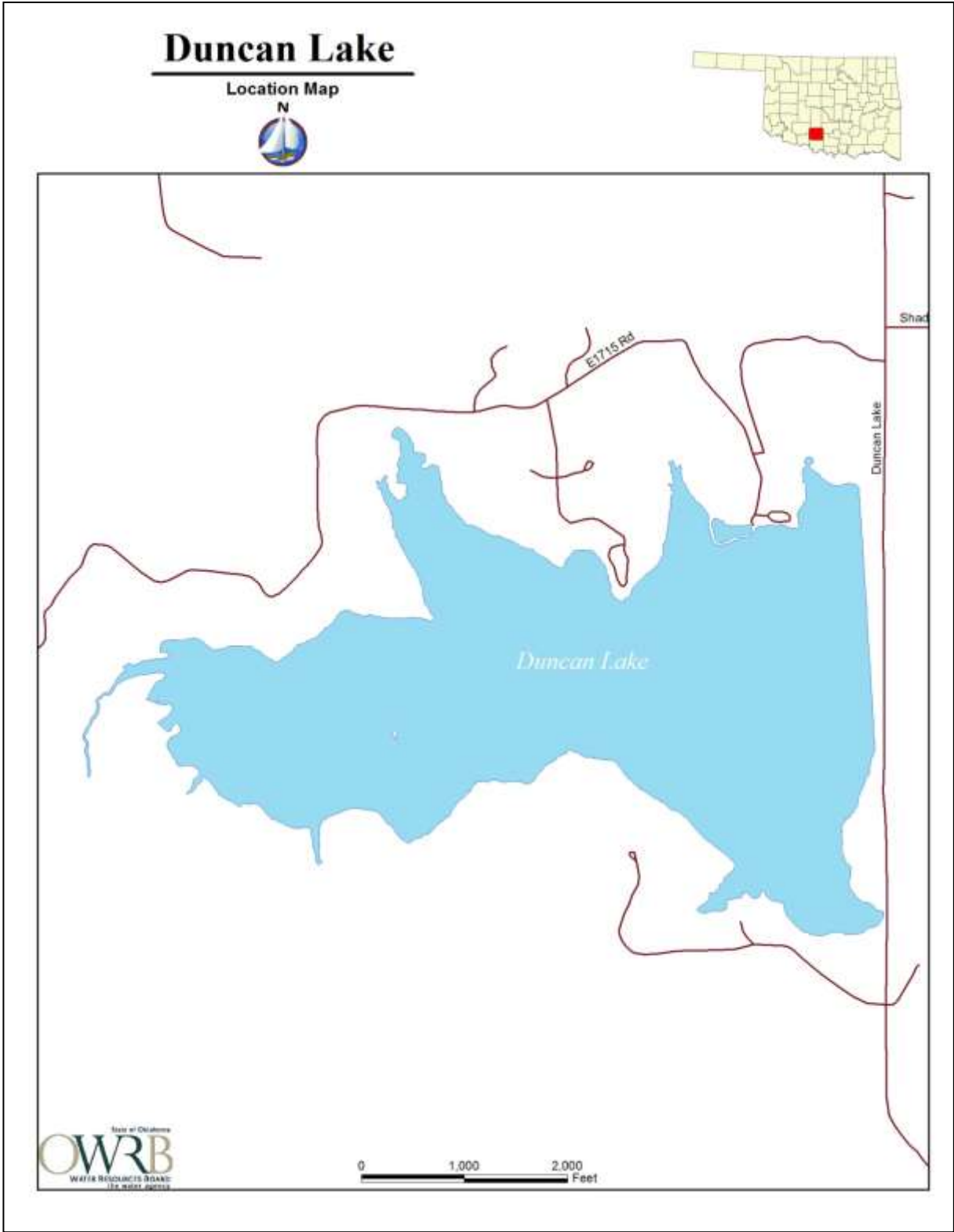


Figure 1: Location map for Clear Creek Lake



**Figure 2: Location map of Duncan Lake**



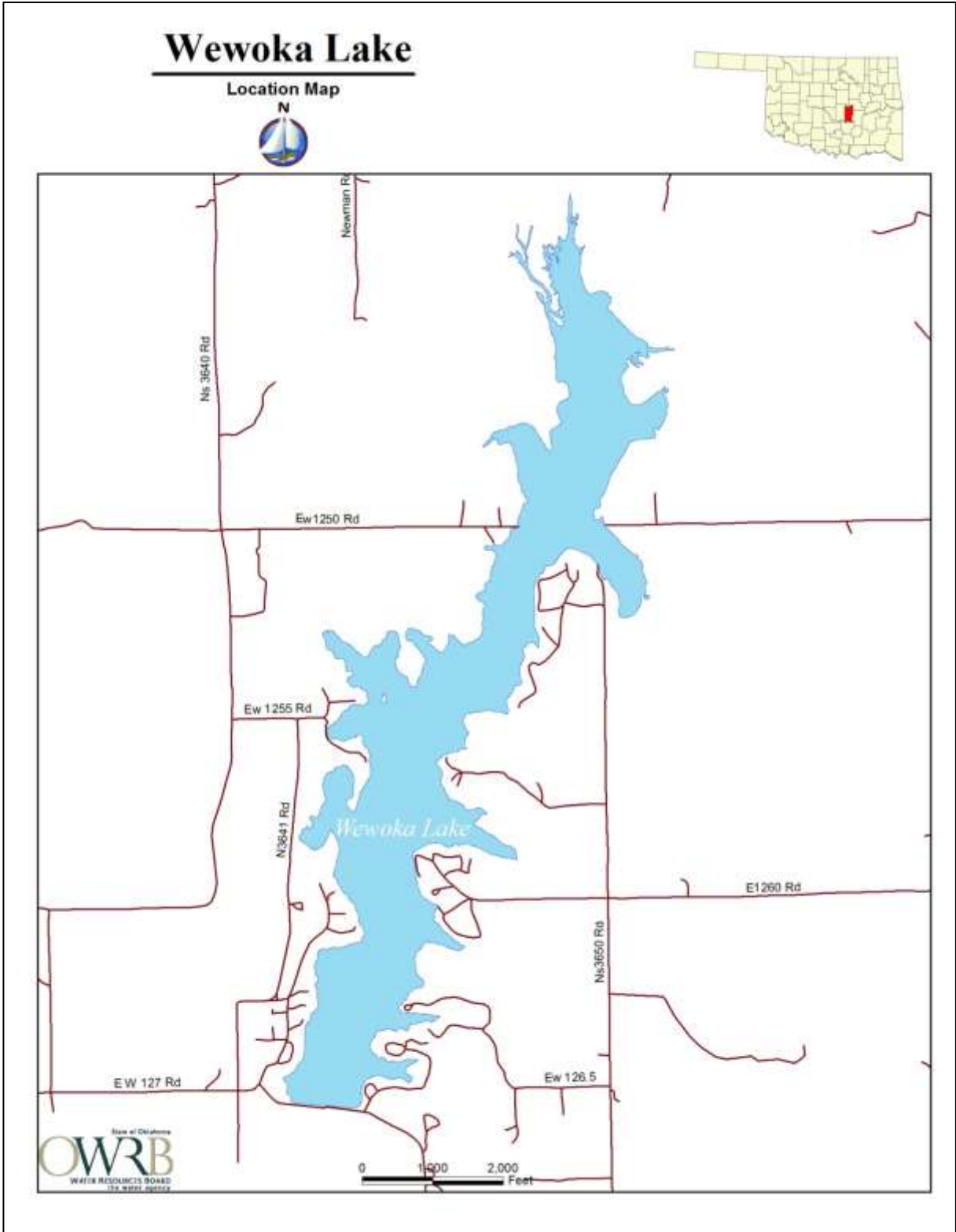


Figure 3: Location map of Wewoka Lake

## **HYDROGRAPHIC SURVEYING PROCEDURES**

The process of surveying a reservoir uses a combination of Geographic Positioning Systems (GPS) and acoustic depth sounding technologies incorporated into a hydrographic survey vessel. As the survey vessel travels across the lake's surface, the echosounder gathers multiple depth readings every second. Depth readings are stored on the survey vessel's on-board computer along with positional data generated from the vessel's GPS receiver. The collected data files are downloaded daily from the computer and edited upon returning to the office. During editing, data "noise" is removed or corrected and depth readings are converted to elevation readings based on the water level elevation recorded on the day the survey was performed. The edited data sets are then thinned to manageable sizes using Hypack's "Sounding Selection-Sort Program" using a 1 sort radius. Using ArcGIS, accurate estimates of area-capacity can then be determined for the lake by building a three-dimensional model of the reservoir from the sorted data set. The process of completing a hydrographic survey includes four steps: pre-survey planning, field survey, data processing, and model construction.

### **Pre-Survey Planning Boundary File**

#### **Clear Creek Lake**

The shoreline boundary for Clear Creek Lake was derived from 2-meter DEM LiDAR<sup>1</sup> data downloaded from OKMaps at <https://okmaps.org/OGI/search.aspx>. The LiDAR raster file TIFF was clipped and contours were generated. The NRCS Contour Tool v10x, which utilizes the ArcGIS Spatial Analyst extension, was used to generate 0.5 ft contours from the LiDAR file. A lake boundary line shapefile was created from the 1150.5 ft contour line; this elevation was most representative of Clear Creek Lake at or near normal pool elevation (1150.335 ft). This boundary file was verified using both orthophotos and measured elevation readings.

#### **Duncan Lake**

The shoreline boundary for Duncan Lake was derived from 2-meter DEM LiDAR<sup>2</sup> data downloaded from OKMaps at <https://okmaps.org/OGI/search.aspx> and 2017 NAIP Ortho imagery<sup>3</sup> downloaded from the USDA Geospatial Gateway at <https://gdg.sc.egov.usda.gov/>. The LiDAR raster file TIFF was clipped and contours were generated. The NRCS Contour Tool v10x, which utilizes the ArcGIS Spatial Analyst extension, was used to generate 0.5 ft contours from the LiDAR file. A lake boundary line shapefile was created from the 1095.0 ft contour line; this elevation was most representative of Clear Creek Lake at or near normal pool elevation (1095.299 ft). Due to extensive anomalies in this contour line it was very heavily edited using the 2017 NAIP ortho-imagery. This image was chosen due to the water level being close to normal pool elevation when the imagery was collected, confirmed by

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<sup>1</sup> Stephens County, OK, NRCS\_2M\_DEM\_Bare\_Earth\_e5a3e963-f4b9-4f0c-9fab-b1227c4e7fde\_selection\_EPSG\_2268\_2\_meters

<sup>2</sup> Stephens County, OK, NRCS\_2M\_DEM\_Bare\_Earth\_34247ffb-7624-4c60-b584-d91b47af8200\_selection\_EPSG\_2268\_2\_meters

<sup>3</sup> Stephens County, OK, ortho\_1-1\_1n\_s\_ok137\_2017\_1

water actively going over the auxiliary spillway. This boundary file was verified using measured elevation readings.

### **Wewoka Lake**

The shoreline boundary for Wewoka Lake was derived from 2-meter DEM LiDAR<sup>4</sup> data downloaded from OKMaps at <https://okmaps.org/OGI/search.aspx>. The LiDAR raster file TIFF was clipped and contours were generated. The NRCS Contour Tool v10x, which utilizes the ArcGIS Spatial Analyst extension, was used to generate 0.5 ft contours from the LiDAR file. A lake boundary line shapefile was created from the 826.5 ft contour line; this elevation was most representative of Wewoka Lake at or near normal pool elevation (826.66 ft). A small amount of editing of this line was needed at the spillway and a few locations around the lake where boathouses or very steep banks created errors in the contour. This boundary file was verified using both orthophotos and measured elevation readings.

### **Hypack Set-up**

Hypack software from Xylem, Inc. was used to assign geodetic parameters, import background files, and create virtual track lines (transect and crosscheck) (Hypack, 2017). The geodetic parameters assigned were ellipsoid World Geodetic System of 1984 (WGS-84) in State Plane North American Datum of 1983 (NAD-83) Zone OK-3501 Oklahoma North or OK-3502 Oklahoma South, depending on location of the reservoir in regards to Highway Interstate 40 (I40). The distance and depth units used were US Survey Feet. The vertical datum was set to the North American Vertical Datum of 1988 (NAVD88), and any measurements in the National Geodetic Vertical Datum of 1929 (NGVD29) were converted. Vertical datum conversions were done using the National Geodetic Survey (NGS) VERTCON tool at <http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html>.

**Table 1: Summary of track line coverage for all lakes surveyed.**

Track Line Coverage				
Lake	Line Spacing	Transect Lines	Stream Lines	Additional QC Lines
Clear Creek Lake	120 ft	137	2	12
Duncan Lake	100 ft	105	1	15
Wewoka Lake	100 ft	168	3	10

Survey transects were spaced according to the size and shape of each individual lake **Table 1** in order to maintain a high level of accuracy and coverage. The survey transects within the digitized reservoir boundary ran perpendicular to the original stream channels and tributaries. Stream lines were placed along the center of channels in areas deemed too small for transect coverage, as well as perpendicular to transect lines down the center of any major lake arms. These stream lines were used for data collection in difficult to navigate areas as well as for quality control (QC) purposes. Additional track lines set perpendicular to the transect lines were added to be used for QC cross check statistics if needed.

<sup>4</sup> Seminole County, OK, NRCS\_2M\_DEM\_Bare\_Earth\_5206d438-fcc2-423e-98d3-0c24b050c2a\_selection\_EPSG\_2268\_2\_meters

## **Field Survey**

### **Lake Elevation Acquisition**

The lake elevations for Clear Creek Lake, Duncan Lake, and Wewoka Lake were obtained by collecting positional data over a period of time. Data collection was done using a Trimble Zephyr Geodetic Antenna connected to Trimble 5700 receiver controlled using Trimble TSC1 survey controller (Trimble, 2008). This data was then uploaded to the On-line Positioning Users Service (OPUS) website (<https://www.ngs.noaa.gov/OPUS>). The National Geodetic Survey (NGS) operates the OPUS as a means to provide GPS users with easier access to the National Spatial Reference System (NSRS). OPUS allows users to submit their GPS data files to NGS, where the data is processed to determine a position using NGS computers and software. Each data file that is submitted is processed with respect to at least three Continuously Operating Reference Stations (CORS). All collection and processing of elevation data followed methods covered in full detail in the OWRB Standard Operating Procedures (SOP) for lake elevation measurement found in the approved project Quality Assurance Project Plan (QAPP) (OWRB, 2018).

### **Method**

The procedures followed by the OWRB during the hydrographic survey adhere to U.S. Army Corps of Engineers (USACE) standards EM 1110-2-1003 (USACE, 2013) as stated in the approved project QAPP (OWRB, 2018). The quality assurance and quality control (QA/QC) procedures for equipment calibration and operation, field survey, data processing, and accuracy standards are presented in the following sections and covered in more detail in the approved project QAPP (OWRB, 2018).

### **Technology**

The Hydro-survey vessel is a 16-ft aluminum hull boat, powered by a single 40-horsepower outboard motor. Equipment used to conduct the survey included: a rugged notebook computer running Hypack's 2017 survey data collection software (Hypack, 2017), Knudsen 1614 Echo Sounder (Knudsen, 2010), with a depth resolution of 0.1 ft, Hemisphere R131 receiver with differential global positioning system (DGPS) correction (Hemisphere, 2013), an Odom Hydrographics Inc. DIGIBAR-Pro Profiling Sound Velocimeter (Odom, 2001), and an EXO2 Sonde (YSI, 2017). All field equipment was used in accordance with their corresponding manuals.

### **Survey**

A two-man survey crew was used throughout the duration of the project. Data collection began at the dam and moved upstream. The survey crew followed the parallel transects created during the pre-survey planning while collecting depth soundings and positional data. In areas of the lake that were too narrow for pre-planned transect lines; stream lines were followed both straight and with a zigzag pattern to collect data. These areas included small tributaries as well as the upstream section of the reservoir. Similar to the shoreline data collection procedure, upstream data was collected until depths were too shallow for the boat to navigate and/or an obstruction prevented travel past a certain point. All lake surveys followed the aforementioned procedure for survey data collection. Survey dates and water level elevations can be found in **Table 2**.

**Table 2: Summary of water elevations measured or recorded for all survey dates.**

Survey Dates and Water Elevations		
Lake	Date	Water Elevations (NAVD88)
Clear Creek Lake	03/19/2019	1150.79 ft
	03/20/2019	1150.78 ft
Duncan Lake	03/11/2019	1095.24 ft
	03/18/2019	1095.68 ft
Wewoka Lake	04/22/2019	826.88 ft
	04/23/2019	826.76 ft

**Quality Assurance/Quality Control**

**Sound Velocity**

The hydrographic surveys followed the quality control procedures presented in the approved QAPP (OWRB, 2018) and summarized in **Table 3**. While on board the Hydro-survey vessel, the Knudsen 1614 Echo Sounder was calibrated using both a DIGIBAR-Pro Profiling Sound Velocimeter and a bar-check setup. The sound velocimeter measures the speed of sound (SOS) at incremental depths throughout the water column. The factors that influence the SOS—depth, temperature, and salinity—are all taken into account. Deploying the unit involved lowering the probe into the water to the calibration depth mark to allow for acclimation and calibration of the depth sensor. The unit was then gradually lowered at a controlled speed to a depth just above the lake bottom, and then was raised to the surface. The unit collected sound velocity measurements in feet/seconds at one ft increments on both the deployment and retrieval phases. The data was then reviewed for any discrepancies, which were subsequently edited out of the sample. Sound velocity profiles calibrated collected raw depth readings during the editing process.

**Table 3: Summary of Relevant Minimum Performance Standards (MPS) and Quality Assurance (QA) Practices for the Hydrographic Survey (USACE, 2002&2013).**

Minimum Performance Standards and Quality Assurance Practices for the Hydrographic Survey		
Repeatability (Bias)	0.3 ft	0.5 ft
Standard Deviation ( $\pm$ ft at 95%)	$\pm$ 0.8 ft	
Resultant Elevation/Depth Accuracy (95%)(15>d<40 ft)	$\pm$ 2.0 ft	
Horizontal Positioning System Accuracy (95%)	5 m (16 ft)	
Minimum Survey Coverage Density	Not to Exceed 500 ft (150 m)	
<b>Quality Control and Assurance Criteria</b>		
➤ Bar-check	1/project	
➤ Sound Velocity QC calibration	2/day	
➤ Squat Test	1/year	
➤ Position calibration QC check	1/project	
From the 2002 version of <a href="#">EM 1110-2-1003</a>	From the 2013 version of <a href="#">EM 1110-2-1003</a>	

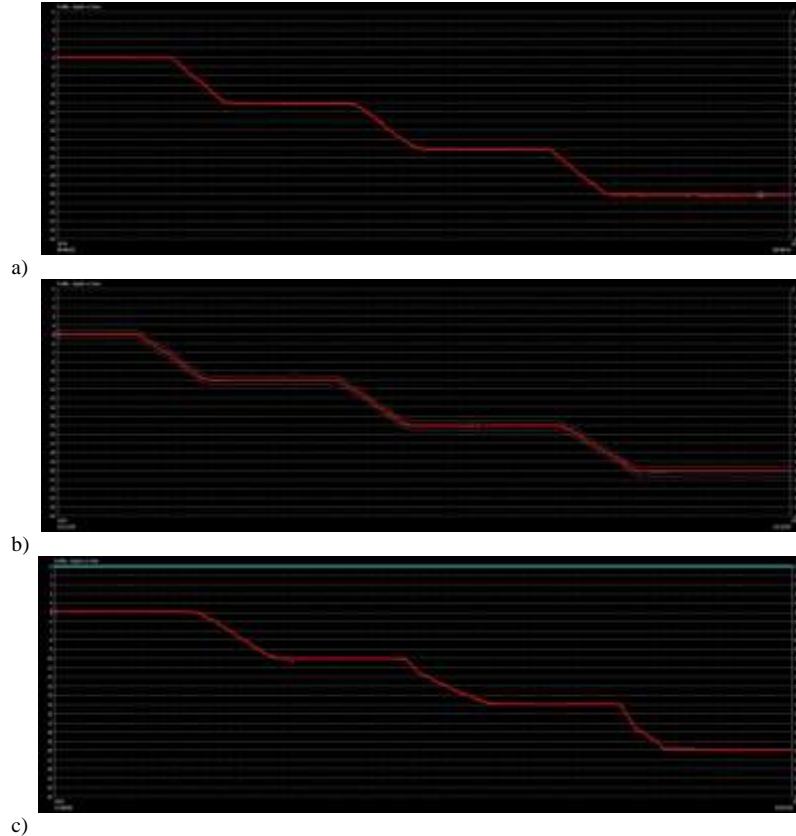
### **Bar-Check**

The bar-check procedure adheres to USACE methods (USACE, 2013). The bar-check setup used consists of a steel plate lowered using chains measured and marked in five ft increments. The bar-check setup is lowered initially to a depth of five ft from the surface of the water. Taking the five ft depth and subtracting the unmodified depth from the echosounder provides the static draft or depth of the transducer in reference to the water's surface. This offset was measured and recorded by the Knudsen echosounder using its Bar-Check Mode where the SOS at five ft depth is also entered. The bar-check setup is then lowered to 25 ft to check for variations. Data is collected at both 5 ft and 25 ft depths and processed with the correlating sound velocity profile to validate the calibration. Bar-check echograms can be found in **Error! Reference source not found.** for each individual lake surveys. **Table E- 1** containing Static draft, average SOS, as well as SOS set in the echosounder for all survey dates can be found in **APPENDIX E: Additional Survey Data Tables.**

### **Cross-Line Check**

Depth observations contain both random errors ( $\sigma$  Random Error) and systematic biases ( $\sigma$  Bias). Biases are often referred to as systematic or external errors and may contain observational oversight. A constant error in tide or stage would be an example of a bias. Biases are reduced as much as possible by using the quality control measures previously discussed. Random errors are those errors present in the measurement system that cannot be easily minimized by additional calibration. Examples include echo sounder resolution, water sound velocity variations, tide/staff gage reading resolution, etc. The precision of the observations is a measure of the closeness of a set of measurements--or their internal agreement. Accuracy relates to the closeness of measurements to their true or actual value.

Accuracy and precision were assessed utilizing a cross-line check method referenced in the approved QAPP (OWRB, 2018). The cross-line check was performed by collecting depth readings along survey track lines perpendicular to, and intersecting the survey transect lines. Hypack's Cross Check Statistics program was used to assess vertical accuracy and confidence measures of the recorded depths at the points where the lines intersected. This program tabulates and statistically analyzed the depth differences between overlapping points of single beam data. The program provides a report calculating the standard deviation and mean difference. **Table E- 2** containing the results of the cross-line checks; include the number of QC intersections, arithmetic mean (Bias), and the standard deviation (Random Error) for all reservoirs which can be found in **APPENDIX E: Additional Survey Data Tables.**



**Figure 4: Digital Echogram of Bar-checks for All Lakes Surveyed a) Clear Creek Lake 03/19/2019 b) Duncan Lake 03/11/2019 c) Wewoka Lake 04/22/2019**

### Depth Accuracy Calculation

Mean difference and the standard deviation can be used to calculate the Root Mean Square (RMS) error employing **Equation 1**. The RMS error estimate is used to compare relative accuracies of estimates that differ substantially in bias and precision (USACE, 2002). According to the recommended standards in the approved QAPP; the RMS at the 95% confidence level should not exceed a tolerance of  $\pm 2.0$  ft for reservoir surveys (OWRB, 2018). This simply means that on average, 19 of every 20 observed depths will fall within the specified accuracy tolerance.

### Equation 1: Depth/Elevation Accuracy Calculation

$$RMS = \sqrt{\sigma^2_{Random\ error} + \sigma^2_{Bias}}$$

where:

*Random error = standard deviation*

*Bias = mean difference*

*RMS = Root Mean Square error (68% confidence level)*

and:

$$RMS (95\%) \text{ depth accuracy} = 1.96 \times RMS(68\%)$$

All reservoirs resulted in an RMS of  $< \pm 2.0$  ft with a 95% confidence level meeting the QAPP's MPS for reservoir surveys. The calculated 95% RMS for all reservoirs can be found in **Table 4**.

**Table 4: Calculated Depth Accuracies for All Lakes Surveyed.**

Calculated Depth Accuracy	
Reservoir	RMS at 95% Confidence
Clear Creek Lake	$\pm 0.44$ ft
Duncan Lake	$\pm 0.39$ ft
Wewoka Lake	$\pm 0.56$ ft

### GPS

The GPS system is an advanced high performance geographic data-acquisition tool that uses differential GPS (DGPS) to provide sub-meter positional accuracy on a second-by-second basis. Potential errors are reduced with DGPS because additional data from a reference GPS receiver at a known position are used to correct positions obtained during the survey. Prior to the survey, the settings on the Hemisphere R131 were checked to ensure correct configuration of the GPS receiver. These settings are discussed in more detail in the OWRB SOP for hydrographic surveying found in the approved project QAPP (OWRB, 2018).

### Latency Test

A latency test was performed to determine the fixed delay time between the GPS and single beam echo sounder. The timing delay was determined by running reciprocal survey lines over a channel bank. The raw data files were downloaded into Hypack - LATENCY TEST program. The program varies the time delay to determine the "best fit" setting. Position latency in seconds was produced and adjustments were applied to the raw data using Hypack's Single Beam Editor Program, during data processing. **Table E- 1** contains all latency offsets for all survey dates and can be found in **APPENDIX E: Additional Survey Data Tables**.

### Data Processing

After uploading the collected data to an OWRB desktop, each raw data file was reviewed using the Single Beam Editor program within Hypack. The Single Beam Editor program allows the user to assign equipment offsets, latency corrections, tide corrections, display the raw data profile, and review/edit all raw depth information. Raw data files are checked for gross inaccuracies that occur during data collection. Data editing is covered in more detail in the approved project QAPP (OWRB, 2018).

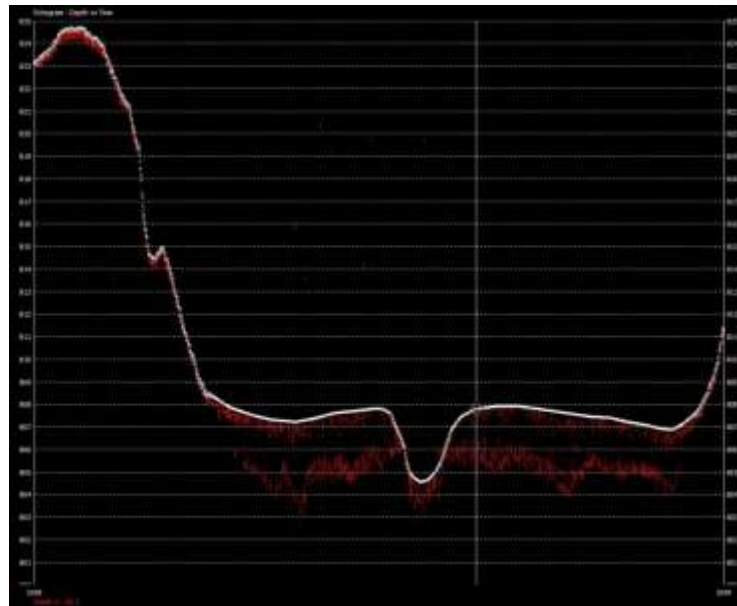
The DGPS latency offset was applied. The Echosounder was corrected for the static vertical draft. These offsets were applied to all raw data sets. The SOS corrections were applied during editing of raw data using the sound velocity correction files created with the sound velocity tool.

An elevation correction file was produced using the Hypack's Manual Tides program to account for the variance in lake elevation at the time of data collection. The corrected depths



were subtracted from the elevation reading to convert their depth in feet to an elevation within the Single Beam Editor program.

During the editing process of the Wewoka dataset any areas with unconsolidated bottom returns were manually digitized. This was done using the digital echogram of the data and Hypack's Digitize tool as seen in **Figure 5**. The bottom was digitized on the first return, which was verified as bottom surface using multiple manual measurements over various unconsolidated bottom areas. The measurements were performed using a lead weight on a measure chain while simultaneously collecting echograms, then comparing them to identify the depth to solid bottom.



**Figure 5: Example Wewoka echogram showing results after manual bottom digitization**

After editing the data for errors and correcting the spatial attributes (offsets and tide corrections), a data reduction scheme was utilized due to the large quantity of collected data. To accomplish this, the corrected data was sorted spatially at a 1 ft interval using the Sounding Selection program in Hypack. The resultant data was saved and exported out as a xyz.txt file containing X and Y horizontal coordinates as well as the Z elevations for all data points. The Hypack raw and corrected data files for all reservoirs are stored and available upon request.

### **GIS Application and Model Construction**

Geographic Information Systems (GIS) software was used to process the edited XYZ data collected from the survey. The GIS software used was ArcGIS Desktop, version 10.2, from Environmental Systems Research Institute (ESRI). All of the GIS datasets created are in Oklahoma State Plane Coordinate System (North or South) referenced to the North American Datum 1983. Horizontal and vertical units are in feet. The edited data points in XYZ text file format were converted into a point feature class in an ArcGIS file geodatabase. The point feature class contains the horizontal coordinates and the elevation and depth values associated with each collected point.

Volumetric and area calculations were derived from a Triangulated Irregular Network (TIN) surface model. A TIN consists of connected data points that form a network of triangles representing the bottom surface of the lake. The TIN model was created with ArcGIS using the collected survey data points; 2, 5, or 10 ft contours derived from a raster file interpolated from the collected survey data points; and inputs representing the lake boundary at normal pool elevation. Lake area and cumulative volume were calculated by slicing the TIN horizontally into planes 0.1 ft thick. The area and cumulative volume of each slice are shown in **APPENDIX A: Area-Capacity Data**.

Contours, depth ranges, and the shaded relief maps were derived from a constructed digital elevation model grid. This grid was created using the ArcGIS Topo to Raster Tool and had a spatial resolution of 1 ft. Contours were created at a 2, 5, or 10 ft interval using the ArcGIS contour tool. Contour lines were edited to allow for polygon topology improving accuracy and general smoothness of the lines. The contour lines were edited visually paying close attention to the channel area, while also ensuring the lines matched the original data set. The contours were then converted to a polygon feature class and attributed to show 2, 5, or 10 ft depth ranges across the lake.

All geographic datasets derived from the survey contain Federal Geographic Data Committee (FGDC) compliant metadata documentation. The metadata describes the procedures and commands used to create the datasets. The GIS metadata file for all reservoirs are stored and available upon request along with all GIS Data.

## **RESULTS**

### **Clear Creek Lake**

Results from the March 2019 OWRB survey indicate that Clear Creek Lake encompasses 677.21 surface acres and contains a cumulative capacity of 9349.04 acre-ft at the normal pool elevation of 1150.3 ft (NAVD88). The mean depth for Clear Creek Lake is 13.81 ft, while the deepest point measured was 31.40 ft. Lake Maps can be found in **APPENDIX B: Clear Creek Lake Maps**.

### **Duncan Lake**

Results from the March 2019 OWRB survey indicate that Duncan Lake encompasses 395.35 surface acres and contains a cumulative capacity of 5387.89 acre-ft at the normal pool elevation of 1095.3 ft (NAVD88). The average depth for Duncan Lake is 13.63 ft, while the deepest point measured was 25.74 ft. Lake Maps can be found in **APPENDIX C: Duncan Lake Maps**.

### **Wewoka Lake**

Results from the April 2019 OWRB survey indicate that Wewoka Lake encompasses 382.99 surface acres and contains a cumulative capacity of 4177.56 acre-ft at the normal pool elevation of 826.7 ft (NAVD88). The average depth for Duncan Lake is 10.91 ft, while the deepest point measured was 27.28 ft. Lake Maps can be found in **APPENDIX D: Wewoka Lake Maps**.

## SUMMARY and COMPARISON

**Table 5** displays areas and volumes calculated at normal pool elevations for both design specifications and the current surveys. Percent change was then calculated for area, capacity, and average depth. Caution should be used when directly comparing between the design specifications and the current surveys conducted by the OWRB as different methods were used to collect the data and extrapolate capacity and area. In order to make the most accurate comparison across surveys, it is the recommendation of the OWRB that additional/future surveys utilizing the same methods used in the current surveys be conducted in 10 years. By using the current survey figures as a baseline, similarly performed future surveys would allow for accurate mean sedimentation rates to be determined. All current calculated changes are only estimations and can be verified by performing additional surveys as mentioned above.

**Table 5: Areas and Volumes calculated at normal pool elevations during design specifications and current survey periods for all lakes (OWRB, 1990).**

**\*These values are listed as normal pool elevation values, but may actually be flood elevation values (could not verify).**

Feature	Survey Year		Change (%)
	Design Specifications	Current Survey	
<b>Clear Creek Lake – March 2019</b>			
Area (acres)	722	677.21	-6.20
Capacity (acre-ft)	7710	9349.04	21.26
Mean depth (ft)	10.68	13.81	29.28
<b>Duncan Lake – March 2019</b>			
Area (acres)	500*	395.35	-20.93
Capacity (acre-ft)	7200*	5387.89	-25.17
Mean depth (ft)	14.40	13.63	-5.36
<b>Wewoka Lake – April 2019</b>			
Area (acres)	425	382.99	-9.89
Capacity (acre-ft)	5000	4177.56	-16.45
Mean depth (ft)	11.76	10.91	-7.28

### Clear Creek Lake

The surface area of Clear Creek Lake shows an apparent decrease of 44.79 acres or 6.20%. The March 2019 survey shows that Clear Creek Lake had an apparent increase in capacity of 1639.04 acre-ft or 21.26%. Average depth for the reservoir increased 3.13 ft or 29.18%. Clear Creek Lake calculations were done using design specifications from the Oklahoma Water Atlas (OWRB, 1990). Estimation of the average annual capacity loss was not calculated due to the increase in capacity; this increase in capacity may be attributed to updated survey methods.

**Duncan Lake**

The surface area of Duncan Lake shows an apparent decrease of 104.65 acres or 20.93%. The March 2019 survey shows that Duncan Lake had an apparent decrease in capacity of 1812.11 acre-ft or 25.17%. Average depth for the reservoir decreased 0.77 ft or 5.36%. Duncan Lake calculations were done using design specifications from the 2017 dam inspection (Freese and Nichols, 2017). The validity of the design specifications is questionable due to the dramatic change in area. We were unable to locate original design documents to verify them as design specifications at normal pool elevation, and believe them to be specifications at flood pool elevation. The estimated average annual loss in capacity is 22.10 acre-ft or 0.31% over the 82-year life of the reservoir.

**Wewoka Lake**

The surface area of Wewoka Lake shows an apparent decrease of 42.01 acres or 9.89%. The April 2019 survey shows that Wewoka Lake had a decrease in capacity of 822.44 acre-ft or 16.45%. Average depth for the reservoir has decreased 0.86 ft or 7.28%. Wewoka Lake calculations were done using design specifications from lake historic signage placed after dam reconstruction. The estimated average annual loss in capacity is 11.11 acre-ft or 0.22% over the 74-year life of the reservoir.

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## **APPENDIX A: Area-Capacity Data**

**Table A- 1: Clear Creek Lake Area by 0.1 ft Increments.**

Clear Creek Area Table										
Area in Acres by 0.1 ft Elevation Increments										
2019 Survey										
Oklahoma Water Resources Board										
Elevation in Feet	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1118							0.000	0.000	0.000	0.024
1119	0.142	0.338	0.713	1.133	1.500	1.860	2.230	2.647	3.148	3.625
1120	4.169	4.774	5.287	5.878	6.828	7.712	8.430	9.224	9.950	10.649
1121	11.343	12.058	12.857	13.586	14.405	15.360	16.799	18.584	20.396	22.630
1122	25.706	28.425	31.112	33.617	36.223	38.900	41.780	45.015	49.007	52.677
1123	56.582	59.731	62.797	65.606	68.228	70.949	73.476	76.001	78.615	81.183
1124	83.708	85.946	88.129	90.324	92.574	94.323	96.376	98.413	100.693	103.071
1125	105.638	108.562	110.984	113.360	115.553	117.699	119.741	121.672	123.658	125.633
1126	127.743	129.813	131.780	133.664	135.491	137.307	139.171	141.288	143.557	145.510
1127	147.182	148.829	150.447	152.009	153.713	155.490	157.158	158.917	160.579	162.147
1128	163.637	165.137	166.788	168.551	170.289	172.541	175.150	177.508	179.466	181.307
1129	183.393	185.588	187.625	189.824	191.683	193.421	195.167	196.763	198.282	199.891
1130	201.483	203.110	204.808	206.495	208.243	209.925	211.643	213.444	215.419	217.301
1131	219.181	220.950	222.836	225.184	227.409	229.195	231.070	232.879	234.673	236.376
1132	238.146	240.135	242.126	243.989	245.964	247.998	250.462	252.679	254.769	256.941
1133	259.039	261.422	263.956	266.416	268.763	271.015	273.153	275.237	277.330	279.513
1134	281.623	283.614	285.638	287.686	289.667	291.555	293.523	295.440	297.453	299.374
1135	301.273	303.292	305.482	307.733	310.002	312.380	314.587	316.644	318.563	320.458
1136	322.528	324.511	326.579	328.692	330.778	332.767	334.704	336.596	338.533	340.517
1137	342.470	344.466	346.472	348.446	350.346	352.218	354.182	356.288	358.196	360.231
1138	362.310	364.567	366.710	368.784	370.957	373.018	375.329	377.792	380.415	382.891
1139	385.253	387.445	389.734	392.075	394.532	397.016	399.656	402.344	405.167	407.899
1140	410.583	413.122	415.787	418.393	420.833	423.206	425.527	427.747	429.816	431.917
1141	434.073	436.210	438.481	440.485	442.410	444.325	446.264	448.266	450.300	452.367
1142	454.721	457.042	459.138	460.951	462.812	464.613	466.376	468.181	470.036	471.877
1143	473.726	475.596	477.514	479.434	481.379	483.332	485.297	487.273	489.268	491.277
1144	493.306	495.350	497.409	499.525	501.705	503.907	506.139	508.415	510.694	512.956
1145	515.303	517.881	520.542	523.279	526.095	528.969	531.691	534.146	536.398	538.545
1146	540.844	543.289	545.667	547.763	549.873	551.985	554.100	556.221	558.345	560.514
1147	562.745	565.010	567.295	569.619	571.959	574.310	576.670	579.047	581.445	583.847
1148	586.249	588.661	591.081	593.514	595.958	598.413	600.880	603.360	605.852	608.358
1149	610.876	613.408	615.953	618.511	621.082	623.666	626.264	628.874	631.498	634.135
1150	636.785	639.449	642.125	677.213						



**Table A- 2: Clear Creek Lake Capacity by 0.1 ft Increments.**

Clear Creek Capacity Table										
Volume in Acre-Feet by 0.1 ft Elevation Increments										
2019 Survey										
Oklahoma Water Resources Board										
Elevation in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1118							0.000	0.000	0.000	0.000
1119	0.001	0.008	0.031	0.082	0.175	0.307	0.475	0.679	0.922	1.211
1120	1.550	1.940	2.387	2.891	3.447	4.080	4.810	5.617	6.499	7.458
1121	8.488	9.587	10.757	12.003	13.325	14.724	16.210	17.811	19.582	21.529
1122	23.680	26.087	28.798	31.775	35.014	38.505	42.257	46.294	50.623	55.332
1123	60.407	65.872	71.693	77.824	84.247	90.941	97.897	105.121	112.593	120.330
1124	128.322	136.565	145.050	153.754	162.677	171.822	181.169	190.701	200.441	210.396
1125	220.585	231.014	241.725	252.703	263.921	275.367	287.032	298.904	310.974	323.240
1126	335.704	348.372	361.250	374.330	387.603	401.061	414.701	428.524	442.542	456.788
1127	471.244	485.879	500.679	515.644	530.767	546.051	561.511	577.145	592.945	608.921
1128	625.058	641.347	657.786	674.380	691.147	708.088	725.218	742.610	760.250	778.101
1129	796.140	814.369	832.818	851.479	870.351	889.429	908.685	928.115	947.713	967.464
1130	987.374	1007.442	1027.670	1048.067	1068.631	1089.368	1110.277	1131.354	1152.608	1174.053
1131	1195.689	1217.514	1239.521	1261.707	1284.105	1306.744	1329.575	1352.591	1375.787	1399.167
1132	1422.719	1446.444	1470.357	1494.472	1518.775	1543.273	1567.969	1592.889	1618.048	1643.421
1133	1669.005	1694.808	1720.826	1747.097	1773.612	1800.373	1827.363	1854.572	1881.992	1909.620
1134	1937.460	1965.519	1993.781	2022.242	2050.910	2079.778	2108.839	2138.093	2167.541	2197.185
1135	2227.027	2257.059	2287.285	2317.725	2348.385	2379.271	2410.391	2441.739	2473.302	2505.063
1136	2537.013	2569.162	2601.514	2634.068	2666.832	2699.807	2732.985	2766.359	2799.925	2833.681
1137	2867.633	2901.783	2936.129	2970.675	3005.423	3040.362	3075.490	3110.809	3146.333	3182.057
1138	3217.977	3254.103	3290.445	3327.010	3363.786	3400.771	3437.970	3475.388	3513.040	3550.952
1139	3589.117	3627.527	3666.162	3705.019	3744.108	3783.438	3823.016	3862.848	3902.948	3943.322
1140	3983.976	4024.902	4066.087	4107.532	4149.242	4191.206	4233.408	4275.845	4318.512	4361.391
1141	4404.476	4447.778	4491.290	4535.025	4578.974	4623.119	4667.456	4711.985	4756.711	4801.640
1142	4846.773	4892.123	4937.713	4983.527	5029.531	5075.719	5122.091	5168.640	5215.368	5262.278
1143	5309.374	5356.654	5404.120	5451.776	5499.623	5547.663	5595.899	5644.330	5692.958	5741.785
1144	5790.812	5840.041	5889.474	5939.112	5988.958	6039.019	6089.300	6139.802	6190.529	6241.485
1145	6292.667	6344.078	6395.736	6447.656	6499.845	6552.313	6605.065	6658.100	6711.394	6764.923
1146	6818.670	6872.638	6926.843	6981.296	7035.967	7090.849	7145.942	7201.246	7256.763	7312.490
1147	7368.433	7424.596	7480.983	7537.598	7594.444	7651.522	7708.836	7766.385	7824.171	7882.195
1148	7940.460	7998.965	8057.710	8116.697	8175.927	8235.400	8295.119	8355.083	8415.295	8475.755
1149	8536.466	8597.427	8658.642	8720.109	8781.833	8843.812	8906.049	8968.546	9031.303	9094.321
1150	9157.603	9221.149	9284.960	9349.039						

**Table A- 3: Duncan Lake Area by 0.1 ft Increments.**

Duncan Area Table										
Area in Acres by 0.1 ft Elevation Increments										
2019 Survey										
Oklahoma Water Resources Board										
Elevation in Feet	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1069			0.000	0.000	0.000	0.000	0.002	0.007	0.013	0.020
1070	0.276	1.508	3.365	6.162	9.345	12.238	14.477	16.854	19.693	22.350
1071	25.286	27.946	30.528	32.807	34.992	37.026	38.969	41.084	43.248	45.430
1072	47.446	49.440	51.354	53.514	55.529	57.774	59.918	61.989	64.168	66.587
1073	68.872	71.145	73.470	75.718	77.927	80.178	82.415	84.713	87.062	89.402
1074	91.737	93.927	96.057	98.274	100.423	102.393	104.270	106.088	107.734	109.352
1075	110.924	112.493	114.068	115.637	117.232	118.722	120.134	121.494	122.817	124.207
1076	125.625	127.003	128.346	129.615	130.866	132.137	133.367	134.548	135.704	136.836
1077	137.931	139.009	140.067	141.105	142.136	143.261	144.414	145.553	146.702	147.848
1078	148.954	150.048	151.120	152.174	153.231	154.312	155.448	156.543	157.630	158.732
1079	159.944	161.283	162.584	163.902	165.303	166.590	167.832	169.115	170.430	171.702
1080	172.953	174.210	175.480	176.732	177.905	179.082	180.271	181.478	182.727	184.011
1081	185.377	187.085	188.702	190.195	191.627	193.019	194.496	196.037	197.853	199.411
1082	201.018	202.589	204.091	205.527	207.014	208.518	210.128	211.965	213.708	215.565
1083	217.308	219.034	220.682	222.390	224.156	226.109	227.675	229.053	230.455	231.968
1084	233.583	235.153	236.779	238.600	240.396	242.201	244.173	246.110	248.002	250.126
1085	252.366	254.602	256.746	258.850	260.940	262.742	264.417	266.073	267.860	269.922
1086	271.782	273.804	275.932	277.689	279.310	280.814	282.299	283.699	285.052	286.431
1087	287.867	289.722	291.250	292.721	294.135	295.535	297.007	298.535	300.010	301.462
1088	302.818	304.204	305.472	306.651	307.796	308.937	310.110	311.325	312.481	313.633
1089	314.787	315.810	316.820	317.848	318.888	319.898	320.902	321.901	322.912	323.940
1090	324.907	325.877	326.841	327.805	328.769	329.741	330.723	331.706	332.693	333.684
1091	334.680	335.680	336.683	337.694	338.706	339.720	340.739	341.760	342.784	343.812
1092	344.842	345.877	346.915	347.958	349.005	350.060	351.116	352.177	353.242	354.311
1093	355.385	356.463	357.546	358.633	359.724	360.821	361.921	363.026	364.136	365.250
1094	366.369	367.492	368.619	369.751	370.887	372.028	373.174	374.324	375.478	376.637
1095	377.800	378.968	395.351	395.351						

**Table A- 4: Duncan Lake Capacity by 0.1 ft Increments.**

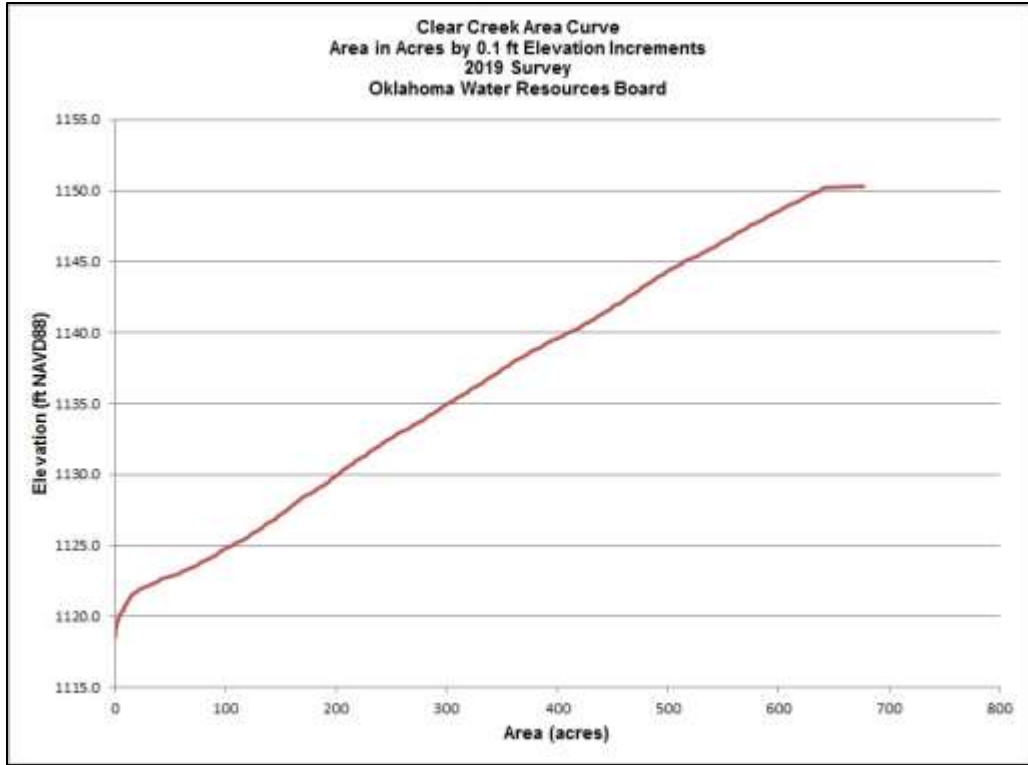
Duncan Capacity Table										
Volume in Acre-Feet by 0.1 ft Elevation Increments										
2019 Survey										
Oklahoma Water Resources Board										
Elevation in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1069			0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002
1070	0.003	0.013	0.096	0.334	0.802	1.577	2.657	3.996	5.558	7.389
1071	9.489	11.869	14.535	17.458	20.628	24.024	27.624	31.420	35.421	39.636
1072	44.075	48.715	53.562	58.600	63.839	69.292	74.953	80.842	86.937	93.244
1073	99.780	106.553	113.555	120.785	128.245	135.928	143.834	151.965	160.319	168.909
1074	177.732	186.791	196.076	205.574	215.289	225.225	235.367	245.700	256.219	266.911
1075	277.766	288.780	299.950	311.279	322.764	334.407	346.206	358.149	370.231	382.446
1076	394.797	407.288	419.920	432.688	445.587	458.611	471.761	485.037	498.432	511.945
1077	525.573	539.311	553.158	567.112	581.171	595.333	609.602	623.986	638.484	653.097
1078	667.824	682.664	697.615	712.673	727.838	743.108	758.485	773.973	789.573	805.281
1079	821.099	837.031	853.093	869.286	885.611	902.068	918.665	935.386	952.232	969.210
1080	986.317	1003.550	1020.908	1038.392	1056.003	1073.735	1091.584	1109.552	1127.639	1145.849
1081	1164.186	1182.654	1201.273	1220.065	1239.010	1258.101	1277.334	1296.707	1316.234	1335.928
1082	1355.792	1375.813	1395.994	1416.329	1436.810	1457.436	1478.214	1499.144	1520.247	1541.531
1083	1562.993	1584.638	1606.456	1628.442	1650.594	1672.921	1695.433	1718.127	1740.964	1763.939
1084	1787.059	1810.336	1833.773	1857.369	1881.137	1905.087	1929.216	1953.536	1978.050	2002.755
1085	2027.659	2052.784	2078.136	2103.703	2129.483	2155.474	2181.660	2208.019	2234.543	2261.236
1086	2288.125	2315.210	2342.487	2369.975	2397.659	2425.510	2453.517	2481.673	2509.974	2538.411
1087	2566.985	2595.699	2624.584	2653.634	2682.832	2712.176	2741.659	2771.286	2801.063	2830.990
1088	2861.064	2891.279	2921.630	2952.115	2982.722	3013.444	3044.281	3075.233	3106.304	3137.494
1089	3168.799	3200.224	3231.754	3263.386	3295.119	3326.956	3358.895	3390.935	3423.075	3455.316
1090	3487.658	3520.101	3552.640	3585.276	3618.008	3650.837	3683.762	3716.785	3749.907	3783.127
1091	3816.445	3849.864	3883.382	3917.000	3950.719	3984.539	4018.460	4052.483	4086.608	4120.835
1092	4155.165	4189.597	4224.133	4258.773	4293.516	4328.365	4363.318	4398.376	4433.541	4468.812
1093	4504.190	4539.674	4575.267	4610.967	4646.776	4682.694	4718.721	4754.858	4791.105	4827.463
1094	4863.933	4900.514	4937.206	4974.012	5010.930	5047.962	5085.108	5122.368	5159.743	5197.233
1095	5234.839	5272.560	5310.399	5348.355						

**Table A- 5: Wewoka Lake Area by 0.1 ft Increments.**

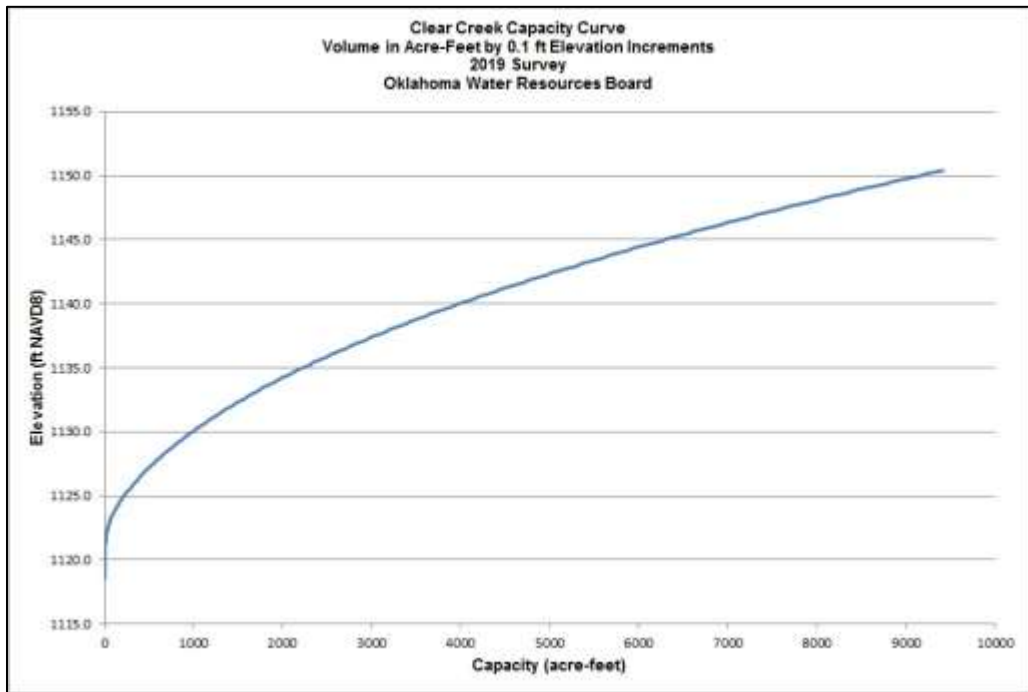
Wewoka Area Table										
Area in Acres by 0.1 ft Elevation Increments										
2019 Survey										
Oklahoma Water Resources Board										
Elevation in Feet	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
799		0.000	0.000	0.000	0.000	0.001	0.004	0.036	0.096	0.148
800	0.204	0.267	0.354	0.460	0.579	0.710	0.858	1.015	1.185	1.377
801	1.854	2.311	2.809	3.391	4.008	4.519	5.060	5.659	6.299	6.875
802	7.441	8.072	8.713	9.489	10.396	11.316	12.263	13.310	14.598	15.796
803	16.859	17.807	18.785	19.877	20.999	22.048	23.098	24.353	25.628	26.959
804	28.360	30.067	31.862	33.448	34.741	36.106	37.315	38.372	39.246	40.099
805	40.983	41.849	42.642	43.451	44.261	45.050	45.894	46.742	47.622	48.580
806	49.587	50.581	51.709	53.123	54.713	56.334	57.836	59.357	60.956	62.604
807	63.975	65.114	66.245	67.347	68.475	69.757	71.019	72.490	73.877	75.277
808	76.836	78.412	80.086	81.546	83.244	84.328	85.337	86.526	88.148	89.702
809	90.930	92.051	93.198	94.320	95.442	96.515	97.674	98.900	100.156	101.343
810	102.509	103.644	104.936	106.258	107.595	109.212	110.936	112.553	114.001	115.476
811	116.817	118.233	119.410	120.450	121.552	122.629	123.692	124.727	125.778	126.836
812	127.865	129.032	130.409	132.010	133.730	135.505	137.239	139.151	141.348	143.931
813	146.123	148.589	150.465	151.606	152.709	153.737	154.733	155.721	156.694	157.693
814	158.750	159.895	161.052	162.333	163.616	164.889	166.195	167.574	168.947	170.345
815	171.563	172.754	173.922	175.061	176.185	177.349	178.617	179.660	180.764	181.855
816	182.931	183.968	184.999	186.043	187.023	188.143	189.329	190.431	191.580	192.697
817	193.708	194.683	195.646	196.571	197.490	198.399	199.281	200.140	201.013	201.893
818	202.752	203.616	204.614	205.807	207.193	208.577	209.927	211.487	213.087	214.909
819	216.897	219.182	221.805	224.105	226.113	227.961	229.846	231.714	233.631	235.815
820	238.092	240.213	242.475	244.756	246.935	249.062	251.114	253.200	255.331	257.751
821	261.711	263.423	265.027	266.704	268.854	272.618	274.549	276.393	278.286	280.457
822	283.866	285.730	287.416	289.091	291.024	293.874	295.593	297.244	298.955	300.997
823	304.088	305.814	307.449	309.168	311.258	314.863	317.518	320.040	322.510	325.228
824	329.058	331.401	333.580	335.819	338.277	341.971	344.488	346.851	348.972	351.532
825	355.596	357.696	359.668	361.659	363.684	366.711	368.206	369.707	371.214	372.727
826	374.792	375.833	376.885	377.948	379.023	380.109	382.987	382.987		

**Table A- 6: Wewoka Lake Capacity by 0.1 ft Increments.**

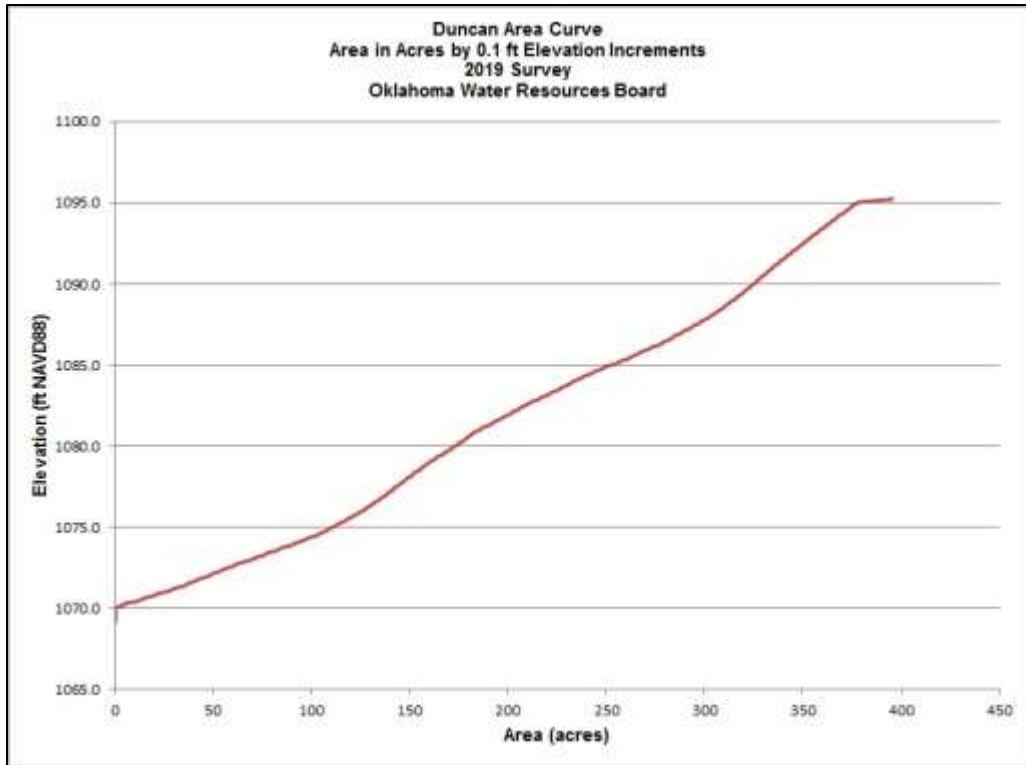
Wewoka Capacity Table										
Volume in Acre-Feet by 0.1 ft Elevation Increments										
2019 Survey										
Oklahoma Water Resources Board										
Elevation in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
799		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.008
800	0.020	0.038	0.061	0.092	0.133	0.185	0.249	0.327	0.421	0.531
801	0.658	0.818	1.025	1.280	1.591	1.961	2.388	2.866	3.402	4.000
802	4.659	5.375	6.150	6.989	7.898	8.891	9.977	11.155	12.432	13.827
803	15.349	16.985	18.718	20.546	22.478	24.522	26.674	28.930	31.304	33.803
804	36.431	39.196	42.115	45.212	48.482	51.890	55.431	59.105	62.889	66.771
805	70.738	74.792	78.934	83.159	87.463	91.850	96.315	100.861	105.493	110.211
806	115.020	119.929	124.937	130.049	135.289	140.679	146.230	151.940	157.798	163.813
807	169.992	176.327	182.781	189.349	196.028	202.820	209.730	216.768	223.941	231.262
808	238.718	246.322	254.087	262.007	270.091	278.327	286.712	295.194	303.784	312.518
809	321.412	330.446	339.595	348.857	358.232	367.722	377.319	387.027	396.856	406.809
810	416.885	427.077	437.385	447.812	458.372	469.064	479.903	490.911	502.088	513.416
811	524.889	536.503	548.255	560.140	572.134	584.233	596.443	608.759	621.181	633.706
812	646.337	659.072	671.915	684.886	698.002	711.289	724.753	738.391	752.208	766.225
813	780.497	795.000	809.732	824.699	839.803	855.019	870.342	885.766	901.288	916.909
814	932.628	948.449	964.381	980.428	996.596	1012.894	1029.319	1045.873	1062.561	1079.387
815	1096.352	1113.449	1130.665	1147.999	1165.448	1183.010	1200.686	1218.485	1236.398	1254.419
816	1272.551	1290.790	1309.135	1327.583	1346.136	1364.790	1383.543	1402.419	1421.407	1440.507
817	1459.722	1479.042	1498.462	1517.979	1537.590	1557.293	1577.088	1596.972	1616.943	1637.001
818	1657.146	1677.379	1697.697	1718.108	1738.626	1759.276	1780.065	1800.990	1822.057	1843.286
819	1864.683	1886.274	1908.068	1930.122	1952.421	1974.939	1997.640	2020.530	2043.609	2066.875
820	2090.346	2114.043	2137.959	2162.089	2186.452	2211.037	2235.837	2260.847	2286.061	2311.488
821	2337.138	2363.135	2389.395	2415.817	2442.402	2469.176	2496.265	2523.626	2551.172	2578.905
822	2606.838	2635.071	2663.553	2692.211	2721.036	2750.037	2779.297	2808.771	2838.413	2868.221
823	2898.215	2928.484	2958.981	2989.644	3020.474	3051.489	3082.805	3114.422	3146.304	3178.430
824	3210.814	3243.543	3276.569	3309.818	3343.288	3376.988	3411.017	3445.339	3479.912	3514.702
825	3549.719	3585.101	3620.767	3656.635	3692.701	3728.968	3765.507	3802.253	3839.149	3876.195
826	3913.392	3950.782	3988.313	4025.949	4063.691	4101.539	4139.496	4177.561		



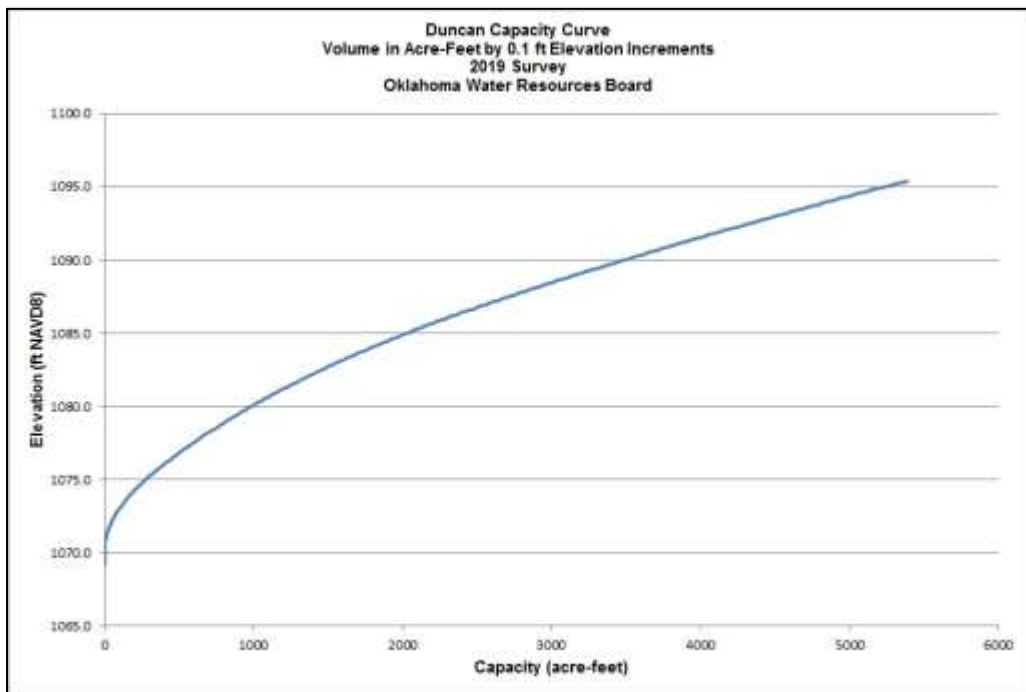
**Figure A- 1: Area Curve for Clear Creek Lake.**



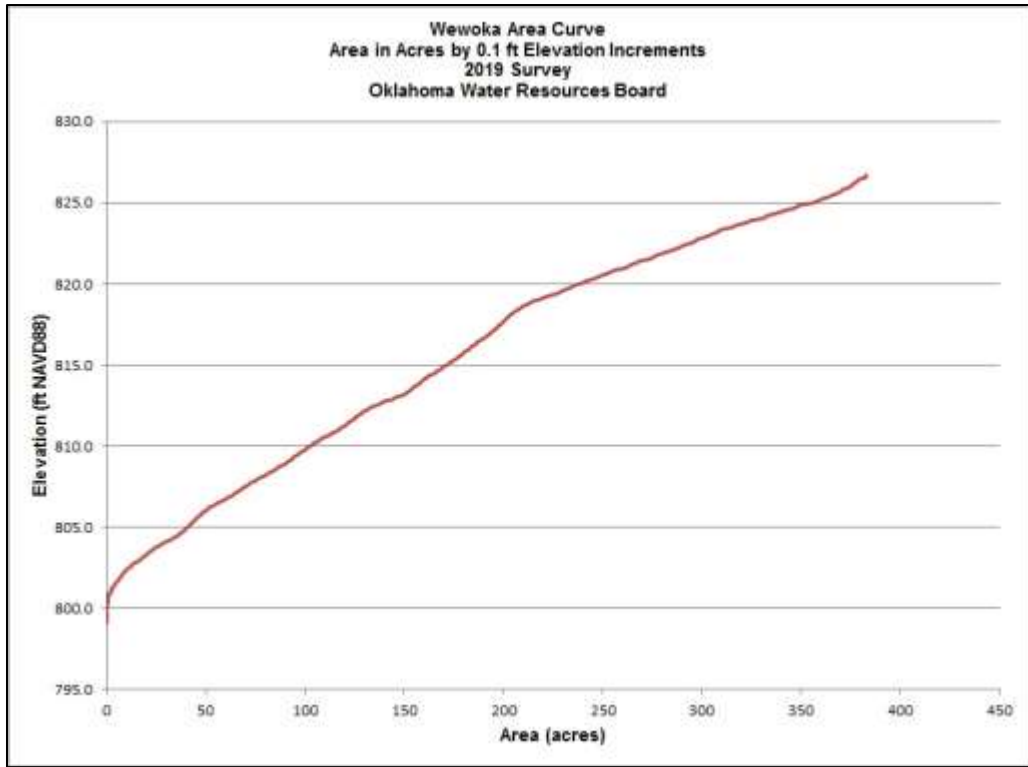
**Figure A- 2: Cumulative Capacity Curve for Clear Creek Lake.**



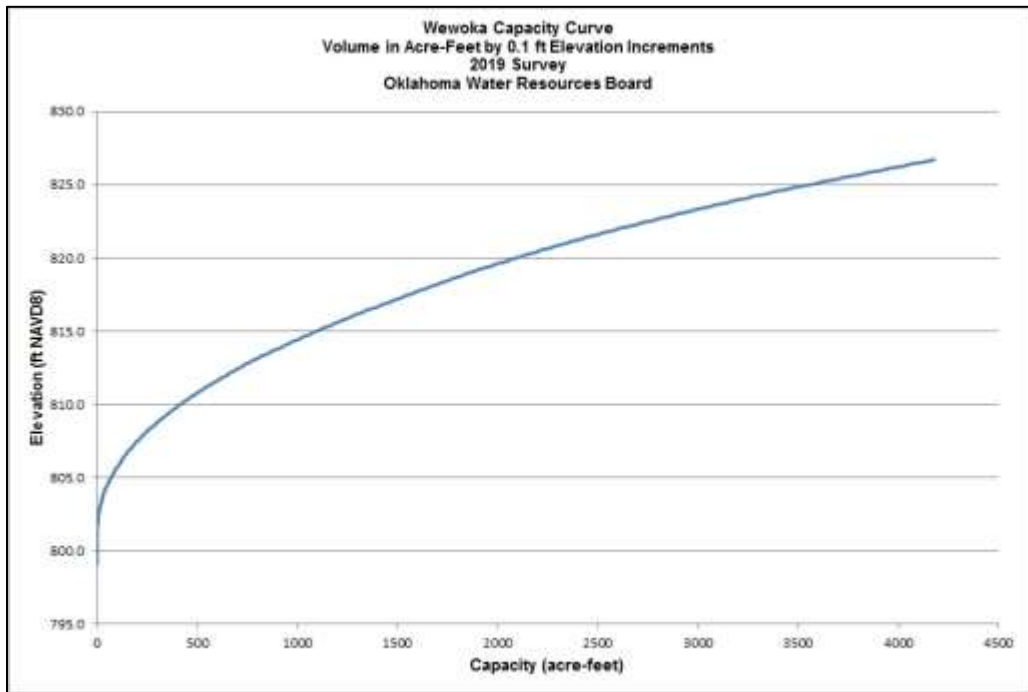
**Figure A- 3: Area Curve for Duncan Lake.**



**Figure A- 4: Cumulative Capacity Curve for Duncan Lake.**



**Figure A- 5: Area Curve for Wewoka Lake.**



**Figure A- 6: Cumulative Capacity Curve for Wewoka Lake.**



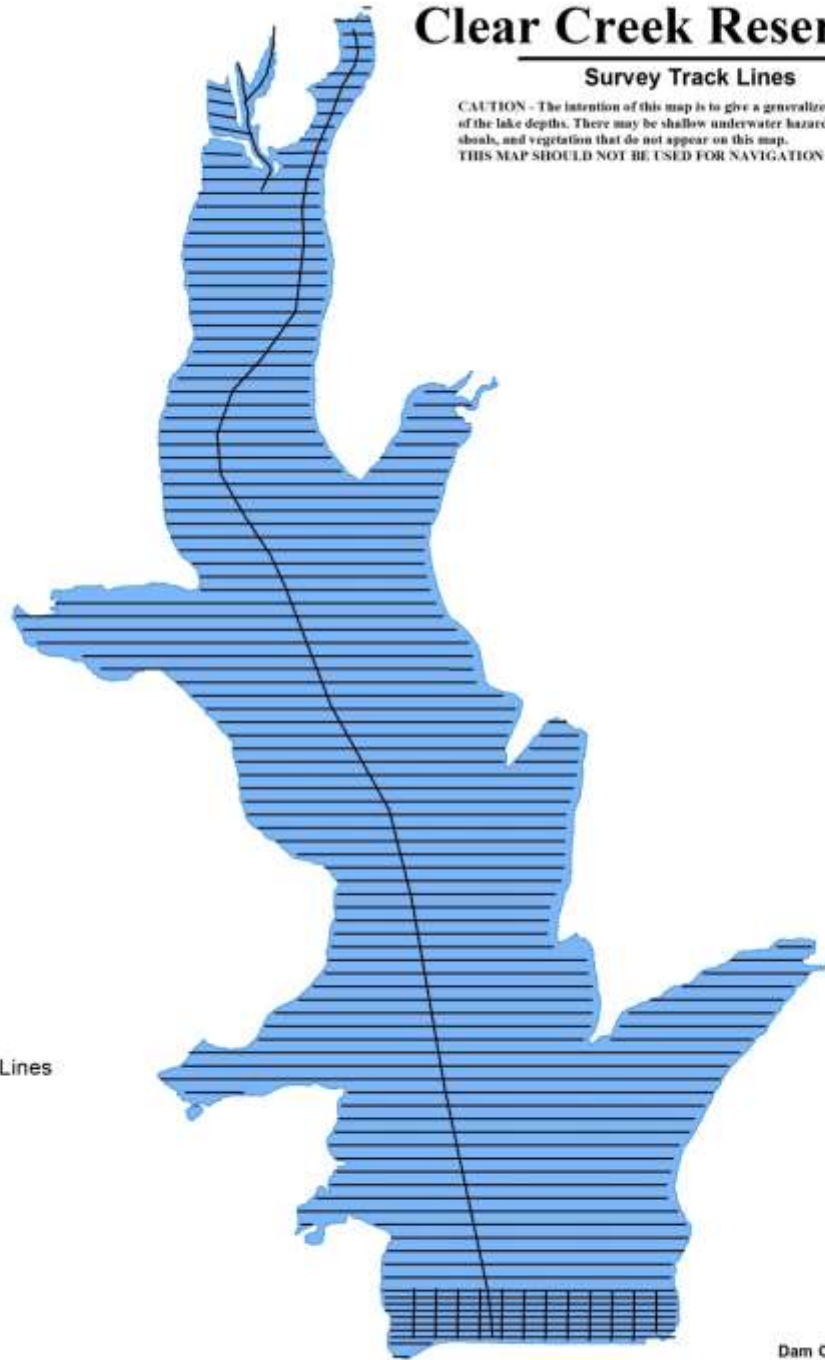
**APPENDIX B: Clear Creek Lake Maps**



# Clear Creek Reservoir

## Survey Track Lines

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



— Track Lines



Dam Construction: 1948  
Survey Date: 2019  
Normal Pool: 1160.33 ft  
Surface Area: 677.2 ac  
Volume: 9,349 ac-ft  
Max Depth: 31.39 ft

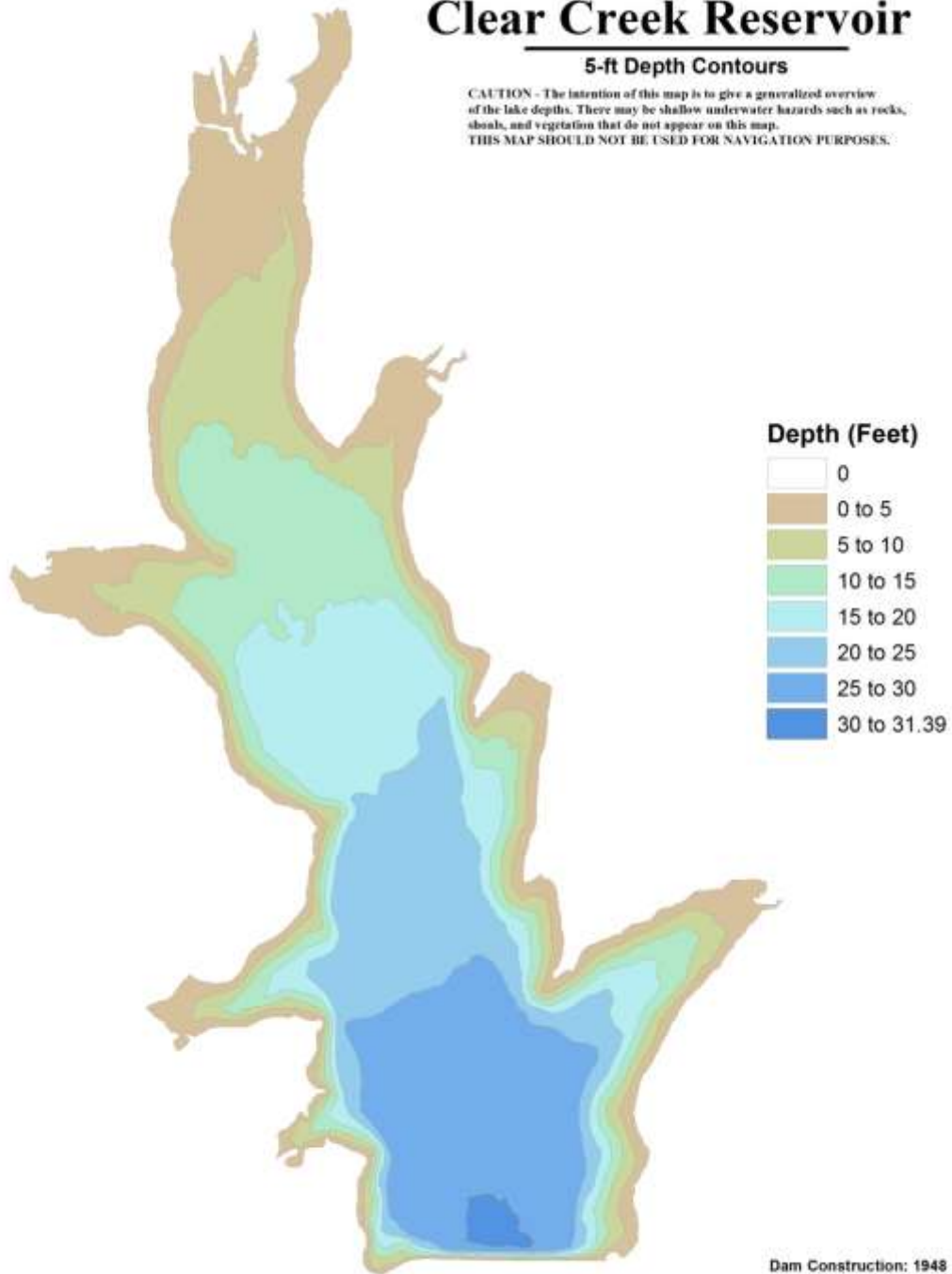
Figure B- 1: Clear Creek Lake Survey Track Lines.



# Clear Creek Reservoir

## 5-ft Depth Contours

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



### Depth (Feet)

0
0 to 5
5 to 10
10 to 15
15 to 20
20 to 25
25 to 30
30 to 31.39



Dam Construction: 1948  
Survey Date: 2019  
Normal Pool: 1160.33 ft  
Surface Area: 677.2 ac  
Volume: 9,349 ac-ft  
Max Depth: 31.39 ft

Figure B- 2: Clear Creek Lake Contour Map with 5 ft Intervals.



# Clear Creek Reservoir

## Shaded Relief

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map.  
THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



Dam Construction: 1948  
Survey Date: 2019  
Normal Pool: 1160.33 ft  
Surface Area: 677.2 ac  
Volume: 9,349 ac-ft  
Max Depth: 31.39 ft

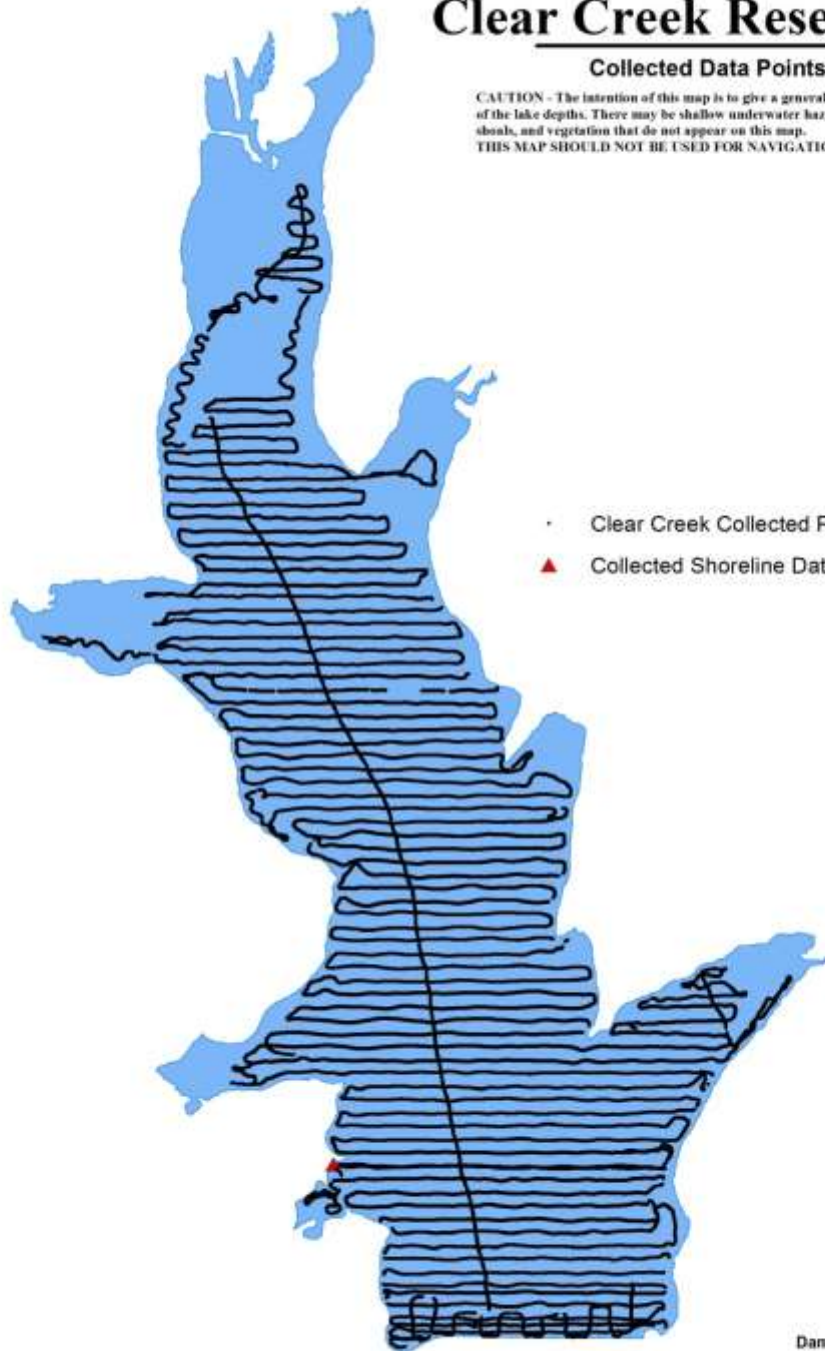
Figure B- 3: Clear Creek Lake Shaded Relief Map.



# Clear Creek Reservoir

## Collected Data Points

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



1:16,000  
0 1,000 2,000  
Feet

Dam Construction: 1948  
Survey Date: 2019  
Normal Pool: 1160.33 ft  
Surface Area: 677.2 ac  
Volume: 9,349 ac-ft  
Max Depth: 31.39 ft

Figure B- 4: Clear Creek Lake Collected Data Points Map.

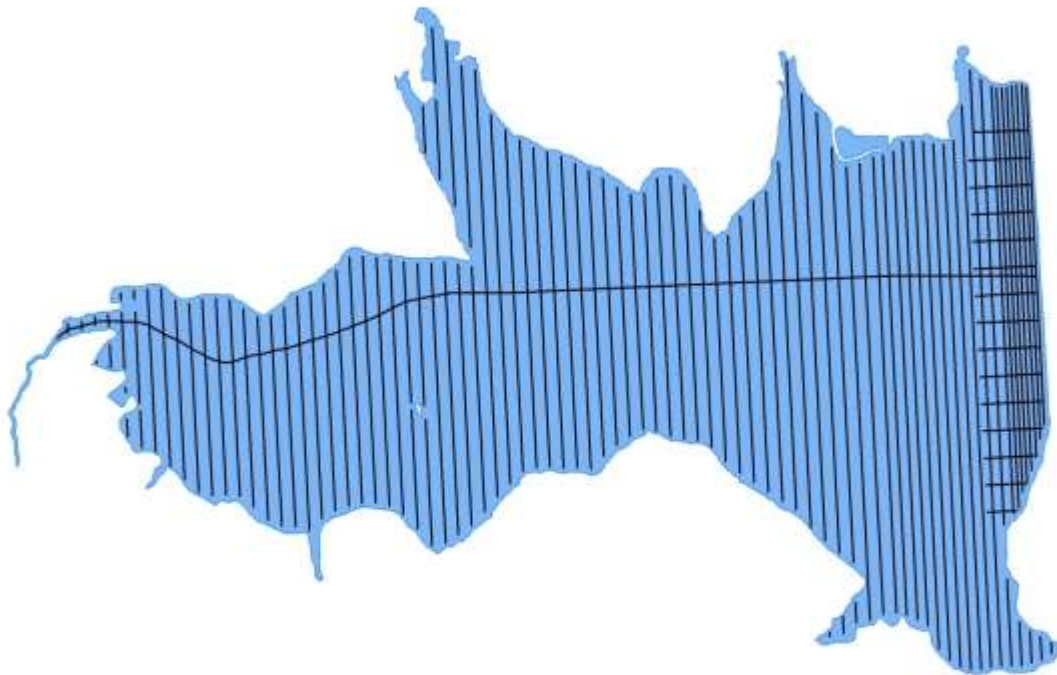
## **APPENDIX C: Duncan Lake Maps**



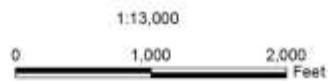
# Duncan Lake

## Survey Track Lines

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



— Track Lines



Dam Construction: 1937  
Survey Date: 2019  
Normal Pool: 1095.29 ft  
Surface Area: 395.3 ac  
Volume: 5,348 ac-ft  
Max Depth: 25.72 ft

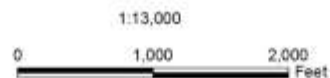
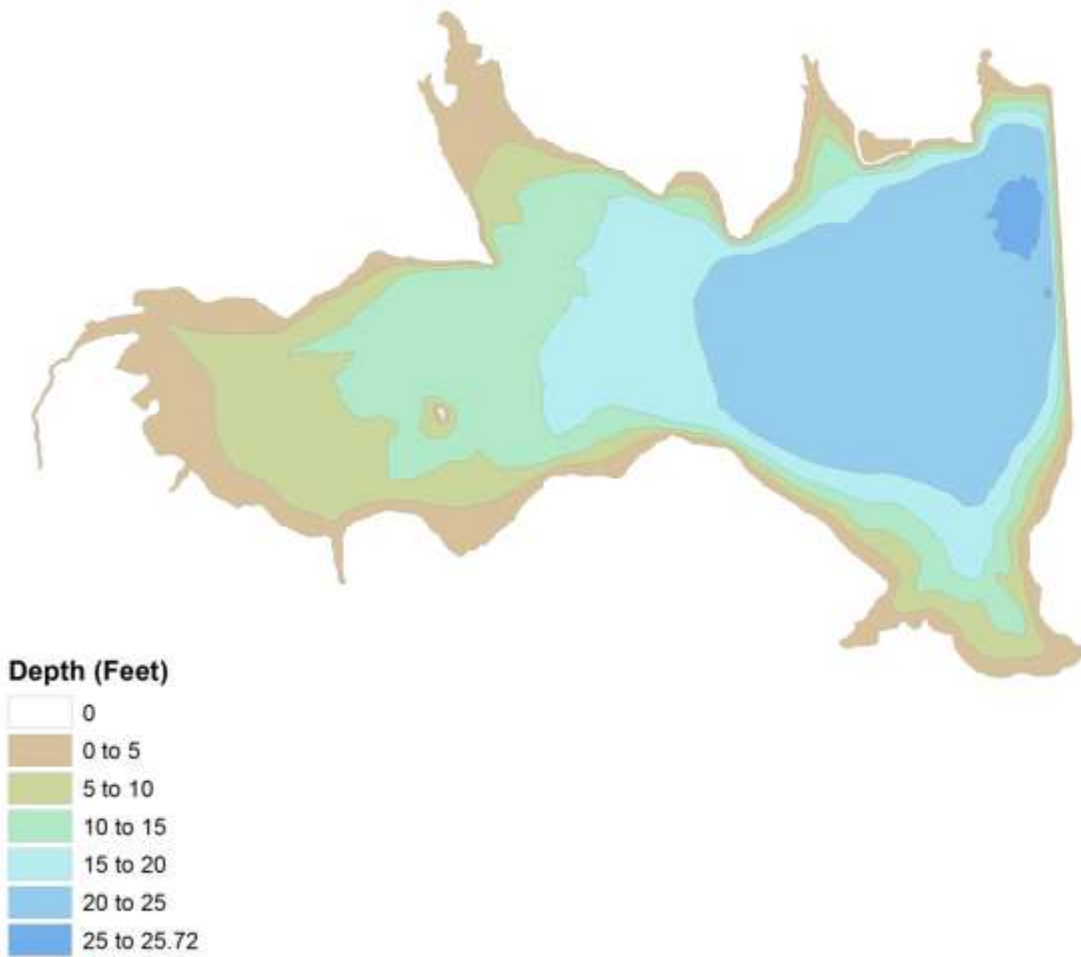
Figure C- 1: Duncan Lake Survey Track Lines Map.



# Duncan Lake

## 5-ft Depth Contours

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



Dam Construction: 1937  
Survey Date: 2019  
Normal Pool: 1095.29 ft  
Surface Area: 395.3 ac  
Volume: 5,348 ac-ft  
Max Depth: 25.72 ft

Figure C- 2: Duncan Lake Contour Map with 5 ft Intervals.

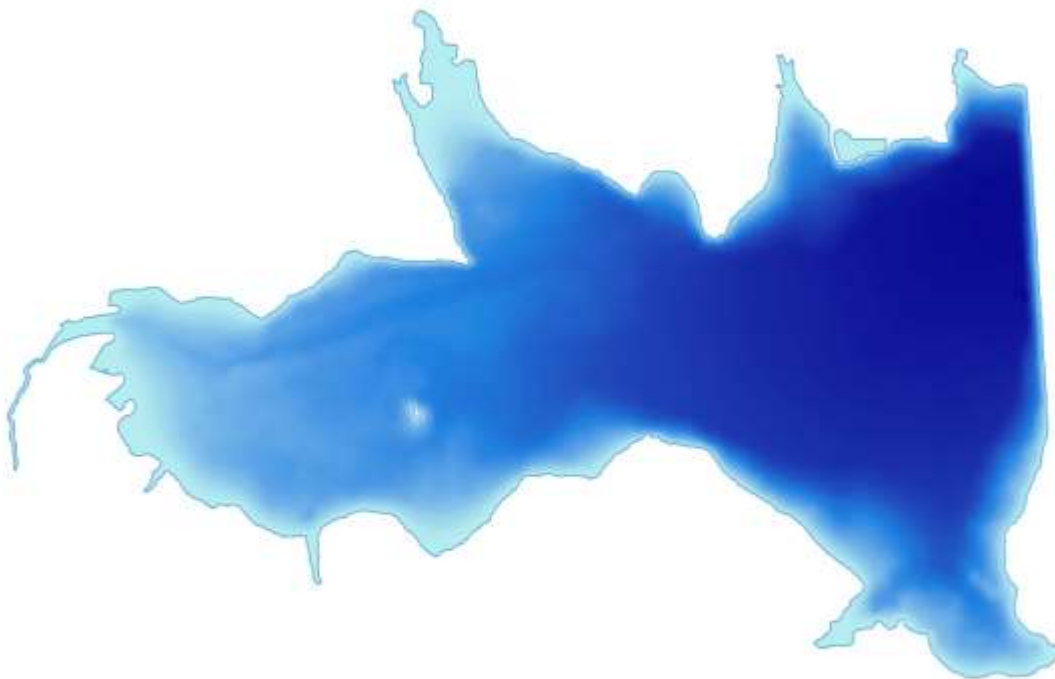




# Duncan Lake

## Shaded Relief

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



Dam Construction: 1937  
Survey Date: 2019  
Normal Pool: 1095.29 ft  
Surface Area: 395.3 ac  
Volume: 5,348 ac-ft  
Max Depth: 25.72 ft

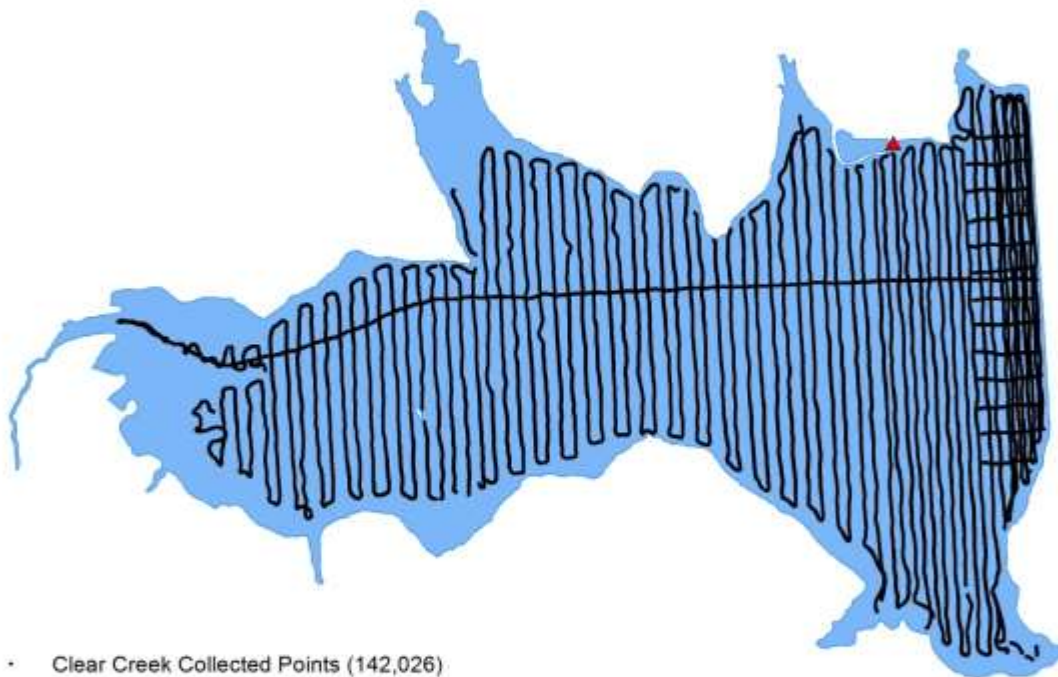
Figure C- 3: Duncan Lake Shaded Relief Map.



# Duncan Lake

## Collected Data Points

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



- Clear Creek Collected Points (142,026)
- ▲ Collected Shoreline Data Points



Dam Construction: 1937  
Survey Date: 2019  
Normal Pool: 1095.29 ft  
Surface Area: 395.3 ac  
Volume: 5,348 ac-ft  
Max Depth: 25.72 ft

Figure C- 4: Duncan Lake Collected Data Points Map.

## **APPENDIX D: Wewoka Lake Maps**



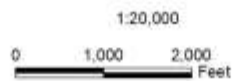
# Wewoka Lake

## Survey Track Lines

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



— Track Lines



Dam Construction: 1925  
Dam Rebuilt: 1945  
Survey Date: 2019  
Normal Pool: 826.66 ft  
Surface Area: 382.9 ac  
Volume: 4,177 ac-ft  
Max Depth: 27.28 ft

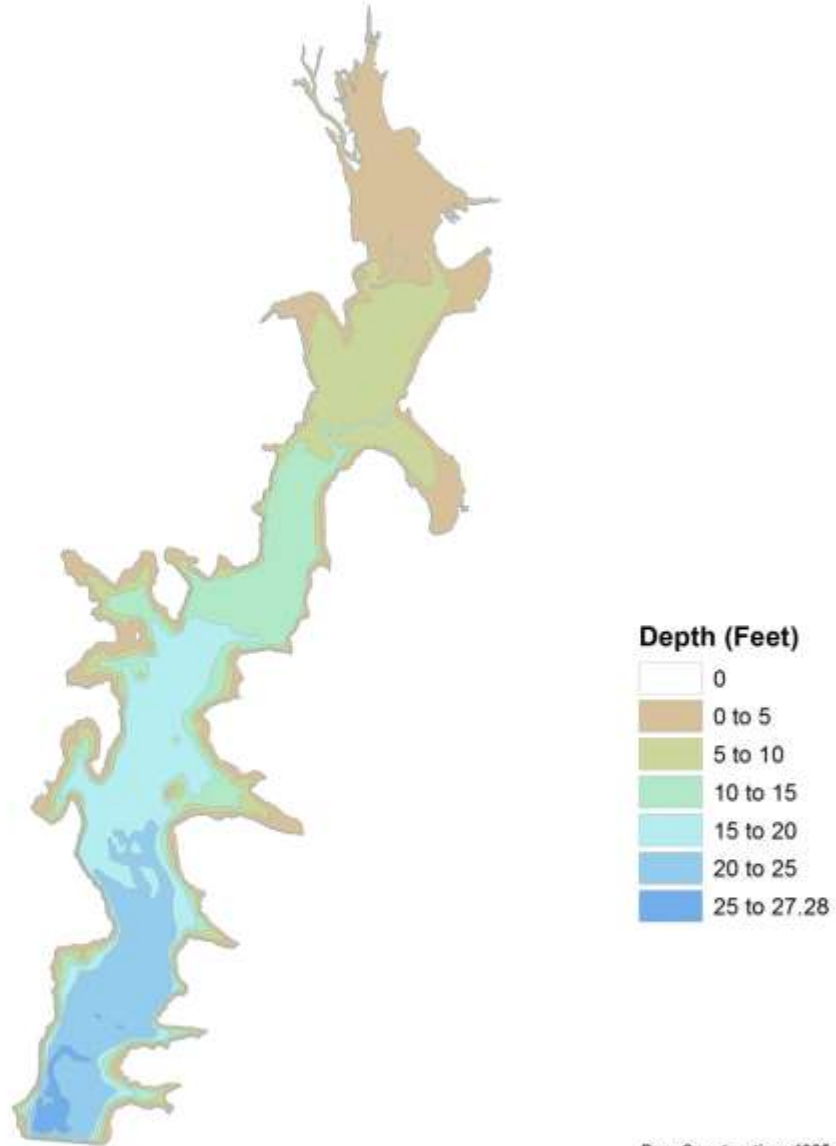
Figure D- 1: Wewoka Lake Survey Track Lines Map.



# Wewoka Lake

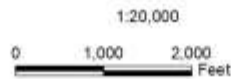
## 5-ft Depth Contours

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



### Depth (Feet)

0
0 to 5
5 to 10
10 to 15
15 to 20
20 to 25
25 to 27.28



Dam Construction: 1925  
Dam Rebuilt: 1945  
Survey Date: 2019  
Normal Pool: 826.66 ft  
Surface Area: 382.9 ac  
Volume: 4,177 ac-ft  
Max Depth: 27.28 ft

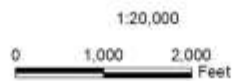
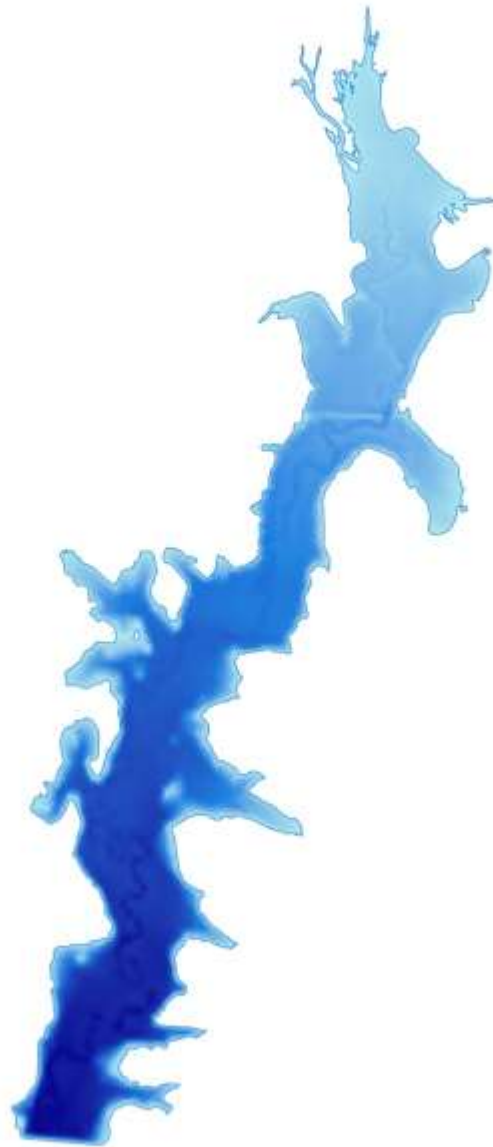
Figure D- 2: Wewoka Lake Contour Map with 5 ft Intervals.



# Wewoka Lake

## Shaded Relief

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



Dam Construction: 1925  
Dam Rebuilt: 1945  
Survey Date: 2019  
Normal Pool: 826.66 ft  
Surface Area: 382.9 ac  
Volume: 4,177 ac-ft  
Max Depth: 27.28 ft

Figure D- 3: Wewoka Lake Shaded Relief Map.



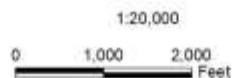
# Wewoka Lake

## Collected Data Points

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map. THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.



- Wewoka Collected Points (131,498)
- ▲ Collected Shoreline Data Points



Dam Construction: 1925  
Dam Rebuilt: 1945  
Survey Date: 2019  
Normal Pool: 826.66 ft  
Surface Area: 382.9 ac  
Volume: 4,177 ac-ft  
Max Depth: 27.28 ft

Figure D- 4: Wewoka Lake Collected Data Points Map.

**APPENDIX E: Additional Survey Data Tables.**



**Table E- 1: Survey offsets used during the calibration and editing process.**

Survey Offsets				
Lake	Clear Creek Lake (03/19/19)	Clear Creek Lake (12/5/17)	Duncan Lake (12/6/17)	Duncan Lake (3/13/18)
Static Draft (ft)	0.65	0.65	0.65	0.6
Average SOS (m/s)	1445.35	1450.24	1432.36	1445.51
Echosounder SOS (m/s)	1451.46	1450.24	1432.26	1448.08
Latency Offset (sec)	0.25	0.25	0.25	0.25
Lake	Wewoka Lake (04/22/19)	Wewoka Lake (04/23/19)		
Static Draft (ft)	0.75	0.75		
Average SOS (m/s)	1470.52	1473.00		
Echosounder SOS (m/s)	1471.27	1476.45		
Latency Offset (sec)	0.25	0.25		

**Table E- 2: Cross check statistic results showing accuracy of the survey data sets.**

Cross Check Statistics			
Lake	Clear Creek Lake	Duncan Lake	Wewoka Lake
# of Intersections	105	181	186
Arithmetic Mean (ft)	0.042	0.107	-0.057
Standard Deviation (ft)	0.222	0.165	0.281