Bathymetric Survey of Select Dissolved Oxygen Impaired Reservoirs

FY 2017

PROJECT #3 FY16/17 §106 I-006400-15
TABLE A-1 LAKES

Q-TRAK #17-085

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OKLAHOMA WATER RESOURCES BOARD

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Final Report
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INTRODUCTION

Project

The Oklahoma Water Resources Board (OWRB) was contracted by the Oklahoma Department of Environmental Quality (ODEQ) to conduct hydrographic surveys of three Oklahoma reservoirs impaired for dissolved oxygen. The three reservoirs include Clinton Lake, Crowder Lake, and Fairfax City Lake. The purpose of this project was to produce current elevation-area-capacity tables, to allow for volumetric determination of dissolved oxygen for beneficial use assessment.

Reservoirs

Clinton Lake

Clinton Lake is located on Turkey Creek, a tributary of the Washita River. It is located in Washita County, approximately three miles east of the City of Canute **Figure 1**. The dam was constructed in 1931, and the reservoir is owned by the City of Clinton. The dam is located at Lat. 35° 26’ 05.34” Long. 099° 13’ 11.18” in Sec. 16 T11N R19W. Clinton Lake’s designated beneficial uses include Agriculture, Aesthetics, Fish and Wildlife Propagation, Recreation, and Public and Private Water Supply. Clinton Lake is also designated as both a Sensitive Water Supply and a Nutrient Limited Watershed (OAC, 785:45, Appendix A).

Crowder Lake

Crowder Lake is located on Cobb Creek, a tributary of the Washita River. It is located in Washita County, approximately nine miles south of the City of Weatherford **Figure 2**. The dam was constructed in 1959, and the reservoir is owned by Southwestern Oklahoma State University. The dam is located at Lat. 35° 23’ 40.50” Long. 098° 42’ 02.96” in Sec. 29 T11N R14W. Crowder Lake’s designated beneficial uses include Agriculture, Aesthetics, Fish and Wildlife Propagation, Recreation, and Public and Private Water Supply. Crowder Lake is also designated as both a Sensitive Water Supply and a Nutrient Limited Watershed (OAC, 785:45, Appendix A).

Fairfax City Lake

Fairfax City Lake is located on Wild Creek, a tributary of the Arkansas River. It is located in Osage County, approximately three miles northwest of the City of Fairfax **Figure 3**. The dam was constructed in 1936, and the reservoir is owned by the City of Fairfax. The dam is located at Lat. 36° 36’ 24.85” Long. 096° 43’ 38.51” in Sec. 35 T25N R5E. Fairfax City Lake’s designated beneficial uses include Agriculture, Aesthetics, Fish and Wildlife Propagation, Recreation, and Public and Private Water Supply. Fairfax City Lake is also designated as a Sensitive Water Supply (OAC, 785:45, Appendix A).

Figure 1: Location map for Clinton Lake.

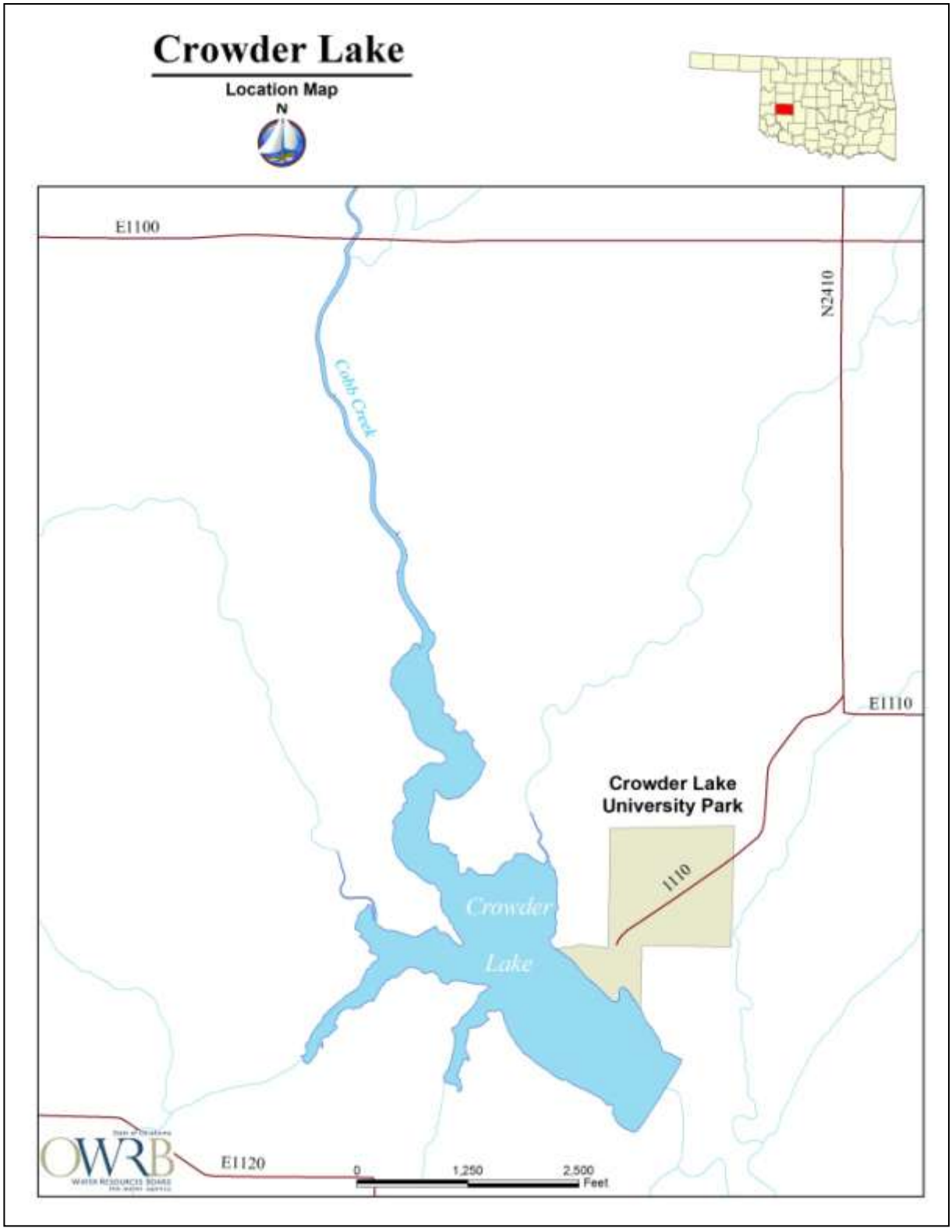


Figure 2: Location map of Crowder Lake

Figure 3: Location map of Fairfax City Lake

HYDROGRAPHIC SURVEYING PROCEDURES

The process of surveying a reservoir uses a combination of Geographic Positioning System (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. The depth readings are stored on the survey vessel's on-board computer along with the 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 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 or 5 ft sort radius. Using ArcGIS, accurate estimates of area-capacity can then be determined for the lake by building a 3-D 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

Clinton Lake

The boundary for Clinton Lake was derived from 2-meter DEM lidar data (Washita County, OK, lidar02m35099d2) downloaded from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Geospatial Data Gateway (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 contours from the lidar file. A lake boundary line shapefile was created from the 1730.5 ft NAVD88 contour line, this elevation was most representative of Clinton Lake at or near normal pool elevation. This boundary file was verified using both National Agriculture Imagery Program (NAIP) orthophoto and measured elevation readings.

Crowder Lake

The boundary for Crowder Lake was derived from 2-meter DEM lidar data (Washita County, OK, lidar02m35098d6) downloaded from the USDA NRCS Geospatial Data Gateway (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 contours from the lidar file. A lake boundary line shapefile was created from the 1520.5 ft NAVD88 contour line, this elevation was most representative of Crowder Lake at or near normal pool elevation. In addition, other aerial imagery such as an ESRI basemap flown on 2/28/2011 and a Google Maps aerial flown on 5/20/2012 were used to inform any needed editing of this contour line.

Fairfax City Lake

Contour lines created from available 2 meter Lidar data were created for Fairfax City Lake; however after evaluation of these lines it was determined that they were quite erroneous. This determination was based upon visual inspection when overlaid upon an aerial photo and

compared with shore point elevations taken at the lake's boat ramp. These contours were **not used** due to these errors.
It was decided that the most accurate method for creating a shapefile of the normal pool elevation (890.35 ft., NAVD88) would be by heads-up digitizing the visible shoreline shown on a National Agriculture Imagery Program (NAIP) orthophoto flown in 2013. The lake shoreline shown in this aerial imagery appeared to best correlate with the normal pool elevation. This was determined by utilizing the shore points taken at the boat ramp, as well as indentifying in the imagery a small amount of water discharging around the lake's spillway. In addition, other aerial imagery such as an ESRI basemap flown on 3/5/2011 and a Google Maps aerial flown on 2/25/2014 were used to inform the digitizing process.

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). 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 (http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html). The 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.

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

Track Line Coverage				
Lake	Line Spacing	Transect Lines	Stream Lines	Additional QC Lines
Clinton Lake	75 ft	134	3	0
Crowder Lake	75 ft	104	7	0
Fairfax City Lake	75 ft	93	6	0

The survey transects within the digitized reservoir boundary ran perpendicular to the original stream channels and tributaries. Stream lines were placed in the stream channels 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.

Field Survey

Lake Elevation Acquisition

The lake elevations for Clinton Lake, Crowder Lake, and Fairfax City 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 and controlled using Trimble

TSC1 survey controller. This data was then uploaded to the On-line Positioning Users Service-Rapid Static (OPUS-RS) website. 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-RS 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, 2016).

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, 2016). 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, 2016).

Technology

The Hydro-survey vessel is a 16-ft aluminum hull, powered by a single 40-horsepower outboard motor. Equipment used to conduct the survey included: a rugged notebook computer running Hypack's 2016 survey data collection software, Knudsen 1614 Echo Sounder, with a depth resolution of 0.1 ft, Hemisphere R131 receiver with differential global positioning system (DGPS) correction, and an Odom Hydrographics, Inc., DIGIBAR-Pro Profiling Sound Velocimeter. 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; a zigzag pattern was used 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)
Clinton Lake	03/27/2017	1729.49-1729.51 ft
	03/28/2017	1729.52 ft
Crowder Lake	04/17/2017	1519.40 ft
Fairfax City Lake	05/17/17	889.17-889.10 ft

Quality Assurance/Quality Control

Sound Velocity

The hydrographic surveys followed the quality control procedures presented in the approved QAPP (OWRB, 2016) 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, which measures the SOS, 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 (ft/sec) at one ft increments on both the deployment and retrieval phases. The data was then reviewed for any erroneous readings, which were then edited out of the sample. The sound velocity corrections were then applied to the raw depth readings during the editing process.

Bar-Check

The bar-check procedure adheres to USACE methods (USACE, 2013). The bar-check setup used consists of a steel plate attached to two poles that span the width of the boat, and lowered using chains measured and marked in five ft increments. The bar-check setup is lowered initially to 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 speed of sound at five ft is also entered. The bar-check setup is then lowered to 25 ft to check for variations. Data is collected at both 25 ft and 5 ft depths, and this data processed in order to validate the calibration procedure. The bar-check echograms can be found in **Figure 4** for each individual lake and survey date. **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**.

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

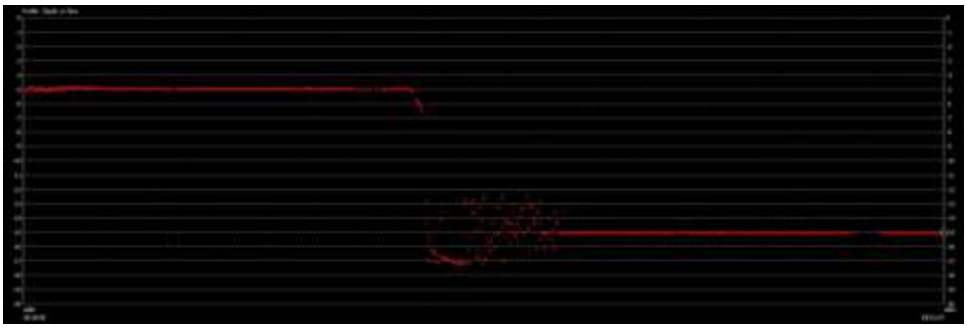
Minimum Performance Standards and Quality Assurance Practices for the Hydrographic Survey		
Repeatability (Bias)	0.3 ft	0.5 ft
Standard Deviation (± ft at 95%)	± 0.8 ft	
Resultant Elevation/Depth Accuracy (95%)(15>d<40 ft)	± 2.0 ft	
Horizontal Positioning System Accuracy (95%)	5 m (16 ft)	
Minimum Survey Coverage Density	Not to Exceed 500 ft (150 m)	
Quality Control and Assurance Criteria	--	
➢ 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 EM 1110-2-1003	From the **2013** version of EM 1110-2-1003	

Cross-Line Check

Depth observations contain both random errors (σ Random Error) and systematic biases (σ 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 a 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, 2016). 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 tabulated and statistically analyzed the depth differences between intersecting 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 check include the number of QC intersections, arithmetic mean (Bias), and the standard deviation (Random Error) for all reservoirs can be found in **APPENDIX E: Additional Survey Data Tables**.

a)



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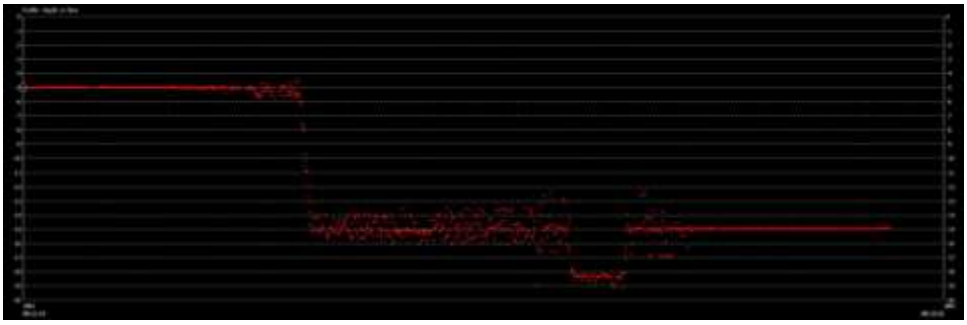

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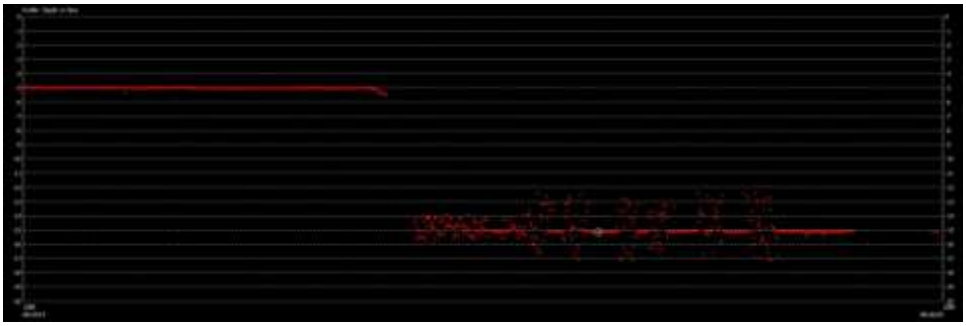

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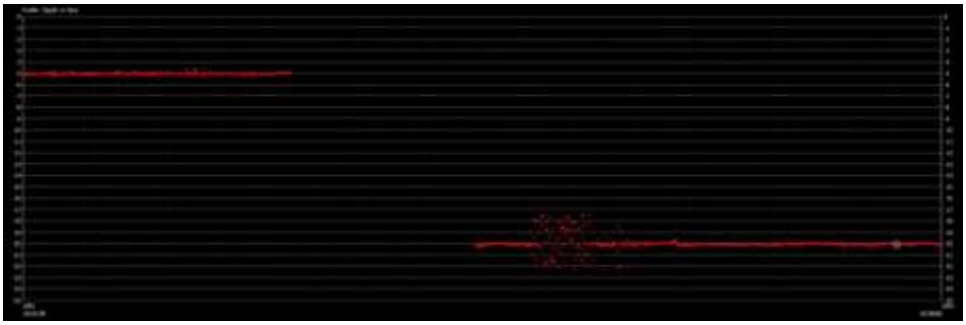

Figure 4: Digital Echogram of All Lake Bar-checks a) Clinton 03/27/17 b) Clinton 03/28/17 c) Crowder 04/04/17 d) Fairfax City 05/17/17

Depth Accuracy Calculation

The mean difference and the standard deviation can be used to calculate the Root Mean Square (RMS) error employing the following calculation. 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 ± 2.0 ft for reservoir surveys (OWRB, 2016). This simply means that on average, 19 of every 20 observed depths will fall within the specified accuracy tolerance.

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

where:

Random error = standard deviation
Bias = mean difference
RMS = Root Mean Square error (68% confidence level)

and:

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

All reservoirs resulted in an RMS of < ±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	
Lake	RMS at 95% Confidence
Clinton Lake	±0.2 ft
Crowder Lake	±0.6 ft
Fairfax City Lake	±0.7 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 configure the GPS receiver. To maximize the accuracy of the horizontal positioning, the horizontal mask setting was set to 6 degrees and the MaxDGPSAge was set to 300. The GGA and VTG were both set to 1 Hz. The RTCM option was enabled with all other options disabled. The United States Coast Guard reference station used in the survey is located near Sallisaw, Oklahoma.

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. A position latency of 0.2 seconds was produced and adjustments were applied to the raw data, Hypack's Single Beam Editor Program, during data processing.

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, 2016).

The DGPS latency correction factor was set to 0.25 seconds. The Echosounder was corrected for a 0.5-0.7 ft 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 using 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.

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 either a 1 or 5 ft interval using the Sounding Selection program in Hypack. The resultant data was saved and exported out as a xyz.txt file. The Hypack raw and corrected data files for all reservoirs are stored and made 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 X and Y 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. 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. The TIN consists of connected data points that form a network of triangles representing the bottom surface of the lake. The lake volume was calculated by slicing the TIN horizontally into planes 0.1 ft thick. The cumulative volume and area 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. The contours were created at a 2, 5, or 10 ft interval using the ArcGIS contour tool.

The contour lines were edited to allow for polygon topology and to improve 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 located on the DVD entitled *FY17 DO Impairment Study Hypack & GIS Metadata.*

RESULTS

Clinton Lake
Results from the 2017 OWRB survey indicate that Clinton Lake encompasses 280.34 surface acres and contains a cumulative capacity of 3140.47 acre-ft at the normal pool elevation of 1730.5 ft (NAVD88). The mean depth for Clinton Lake is 11.2 ft, while the deepest point measured was 27.3 ft. Lake Maps can be found in **APPENDIX B: Clinton Lake Maps**.

Crowder Lake
Results from the 2017 OWRB survey indicate that Crowder Lake encompasses 142.74 surface acres and contains a cumulative capacity of 1647.70 acre-ft at the normal pool elevation of 1520.6 ft (NAVD88). The average depth for Crowder Lake is 11.54 ft, while the deepest point measured was 26.23 ft. Lake Maps can be found in **APPENDIX C: Crowder Lake Maps**.

Fairfax City Lake
Results from the 2017 OWRB survey indicate that Fairfax City Lake encompasses 109.63 surface acres and contains a cumulative capacity of 1978.70 acre-ft at the normal pool elevation of 890.4 ft (NAVD88). The average depth for Fairfax City Lake is 18.05 ft, while the deepest point measured was 37.5 ft. Lake Maps can be found in **APPENDIX D: Fairfax City Lake Maps**.

SUMMARY and COMPARISON

Table 5 displays areas and volumes calculated at normal pool elevations for both design specifications and the 2017 survey. Percent change was then calculated for area, capacity, and average depth. Caution should be used when directly comparing between the design specifications and the 2017 surveys conducted by the OWRB because different methods were used to collect the data and extrapolate capacity and area. It is the recommendation of the OWRB that additional surveys using the same methods used in the 2017 survey be conducted in 10-15 years. By using the 2017 survey figures as a baseline, a future survey would allow for an accurate mean sedimentation rate to be obtained.

Table 5: Areas and Volumes at normal pool elevations for all lakes at design specifications and 2017 survey periods (OWRB, 1990).
***Numbers for Clinton Lake are from 1939 Sedimentation Survey of Clinton Lake (USDA, 1940)**

Feature	Survey Year		Change (%)
	Design Specifications	2017	
Clinton Lake			
Area (acres)	336*	280.34	-16.57
Capacity (acre-ft)	4415*	3140.47	-28.87
Mean depth (ft)	13.14*	11.2	-14.75
Crowder Lake			
Area (acres)	158	142.74	-9.66
Capacity (acre-ft)	2094	1647.70	-21.31
Mean depth (ft)	13.25	11.54	-12.90
Fairfax City Lake			
Area (acres)	111	106.63	-1.23
Capacity (acre-ft)	1795	1978.70	+10.23
Mean depth (ft)	16.17	18.05	+11.61

Clinton Lake
The surface area of Clinton Lake has decreased 55.66 acres or 16.57%. The 2017 survey shows that Clinton Lake had an apparent decrease in capacity of 1274.53 acre-ft or 28.87%. Average depth for the reservoir has decreased 1.94 ft or 1.23%. Clinton Lake calculations were done using design specifications from a sedimentation survey performed in 1938; calculations from this survey were not used for comparison as they were not derived in a comparable method (USDA, 1940). 2017 changes appear abnormally high due to modifications made in the Clinton Lake Watershed since impoundment. Modifications made include but are not limited to addition of several flood control reservoirs on the main tributaries as well as installation of a highway through the southern tributary. This reservoir serves as an excellent example of the importance of current bathymetric surveys to ensure correct data is available when needed.

Crowder Lake
The surface area of Crowder Lake has decreased 15.26 acres or 9.66%. The 2017 survey shows that Crowder Lake had an apparent decrease in capacity of 446.30 acre-ft or 21.31%. Average depth for the reservoir has decreased 1.71 ft or 12.90%. Crowder Lake calculations were done using design specifications for the original dam construction in 1958. The dam at Crowder Lake was rehabilitated in 2011 through a cooperative project by the Natural Resources Conservation Service (NRCS), Oklahoma Conservation Commission (OCC), Southwestern Oklahoma State University (SWOSU), and the Deer Creek Conservation District. However, updated information regarding area and volume calculations were not included in the summary document that was located (OCC, 2011).

Fairfax City Lake

The surface area of Fairfax City Lake has decreased 1.37 acres or 1.23%. The 2017 survey shows that Fairfax City Lake had an apparent increase in capacity of 183.7 acre-ft or 10.23%. Average depth for the reservoir has increased 1.88 ft or 11.6%. Fairfax City Lake calculations were done using design specifications from the Oklahoma Water Atlas (OWRB, 1990). Increases in area and volume may be attributed to using a more accurate method of calculation than used when the reservoir was constructed.

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APPENDIX A: Area-Capacity Data

Table A- 1: Clinton Lake Area by 0.1 ft Increments.

Clinton Lake Area Table Area in Acres by 0.1 ft Elevation Increments 2017 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
1707	0.0000	0.0000	0.0008	0.0045	0.0095	0.0157	0.0232	0.0317	0.0415	0.0537
1708	0.0682	0.0840	0.1014	0.1207	0.1462	0.1898	0.2375	0.2951	0.3687	0.4977
1709	0.8577	1.8586	3.1248	4.5580	5.6900	6.6625	7.5714	8.6694	9.9234	11.3372
1710	12.6470	14.0124	15.4246	16.9279	18.3971	20.9191	23.3382	25.3983	27.5683	29.4649
1711	31.2480	33.1466	34.9276	36.8277	38.6828	40.6372	42.5923	44.3024	45.9408	47.6449
1712	49.4309	51.2579	52.8952	54.5669	56.2112	58.0502	59.9897	61.7399	63.4725	65.1680
1713	66.6900	68.0985	69.4200	70.7033	71.9295	73.1062	74.3152	75.5685	76.7965	77.9898
1714	79.0697	80.0554	81.0017	81.9072	82.8470	83.7490	84.6213	85.5156	86.3874	87.2589
1715	88.1561	89.1144	90.0383	90.9426	91.8813	92.8818	93.9083	95.0226	96.3275	97.7061
1716	98.9160	100.0922	101.2120	102.3221	103.4233	104.5043	105.6162	106.7257	107.8262	108.9472
1717	110.0587	111.1759	112.2866	113.3674	114.4456	115.5483	116.6552	117.8718	119.0557	120.2068
1718	121.3341	122.4246	123.4951	124.5426	125.6331	126.8257	128.0051	129.2685	130.4612	131.6364
1719	132.8571	134.0748	135.3097	136.5552	137.8144	139.0510	140.3811	141.6959	142.9748	144.2757
1720	145.6138	146.9669	148.2511	149.4987	150.7411	151.9701	153.2227	154.5404	155.8648	157.1423
1721	158.4038	159.6953	161.0387	162.3612	163.6985	165.0189	166.3906	167.7209	169.0580	170.3867
1722	171.6809	172.9190	174.1060	175.2868	176.4695	177.6815	178.9206	180.1860	181.4848	182.8355
1723	184.2849	185.7202	187.1766	188.6972	190.2353	191.7664	193.3706	195.0188	196.7007	198.4012
1724	200.0720	201.7292	203.3450	204.9953	206.6034	208.2357	209.9477	211.6558	213.2526	214.8851
1725	216.4902	217.9838	219.4210	220.8591	222.2800	223.7204	225.1676	226.6022	228.0172	229.4040
1726	230.7573	232.1121	233.4486	234.7372	236.0072	237.2184	238.3913	239.5534	240.7098	241.8637
1727	243.0171	244.1722	245.3296	246.4891	247.6506	249.6522	250.6519	251.6538	252.6577	253.6638
1728	255.0660	256.2067	257.3471	258.4872	259.6270	261.1347	262.1790	263.2304	264.2889	265.3544
1729	266.5574	267.4438	268.3381	269.2403	270.1504	272.3741	273.2196	274.0750	274.9404	275.8156
1730	276.7008	277.5959	278.5010	279.4159	280.3408	283.5476				

Table A- 2: Clinton Lake Capacity by 0.1 ft Increments.

Clinton Lake Capacity Table Volume in Acre-Feet by 0.1 ft Elevation Increments 2017 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
1707	0.0000	0.0000	0.0000	0.0000	0.0003	0.0010	0.0022	0.0041	0.0069	0.0105
1708	0.0153	0.0213	0.0289	0.0382	0.0493	0.0625	0.0794	0.1007	0.1272	0.1602
1709	0.2025	0.2683	0.3982	0.6493	1.0343	1.5505	2.1683	2.8795	3.6909	4.6175
1710	5.6814	6.8807	8.2115	9.6828	11.2995	13.0633	15.0119	17.2298	19.6668	22.3151
1711	25.1669	28.2041	31.4242	34.8276	38.4149	42.1907	46.1579	50.3190	54.6651	59.1747
1712	63.8546	68.7090	73.7429	78.9489	84.3214	89.8587	95.5698	101.4721	107.5598	113.8191
1713	120.2532	126.8471	133.5873	140.4637	147.4699	154.6020	161.8539	169.2245	176.7190	184.3374
1714	192.0773	199.9312	207.8877	215.9412	224.0867	232.3239	240.6542	249.0728	257.5795	266.1749
1715	274.8570	283.6275	292.4908	301.4489	310.4978	319.6384	328.8764	338.2158	347.6613	357.2262
1716	366.9316	376.7630	386.7137	396.7793	406.9559	417.2438	427.6405	438.1458	448.7632	459.4909
1717	470.3292	481.2798	492.3416	503.5145	514.7977	526.1878	537.6876	549.2976	561.0226	572.8691
1718	584.8327	596.9099	609.0978	621.3942	633.7962	646.3040	658.9270	671.6689	684.5329	697.5199
1719	710.6233	723.8484	737.1947	750.6635	764.2564	777.9751	791.8185	805.7891	819.8932	834.1272
1720	848.4892	862.9833	877.6128	892.3742	907.2615	922.2736	937.4091	952.6688	968.0556	983.5772
1721	999.2278	1015.0051	1030.9100	1046.9470	1063.1167	1079.4198	1095.8555	1112.4259	1129.1315	1145.9705
1722	1162.9428	1180.0464	1197.2771	1214.6284	1232.0983	1249.6856	1267.3929	1285.2229	1303.1782	1321.2613
1723	1339.4765	1357.8328	1376.3331	1394.9772	1413.7708	1432.7177	1451.8172	1471.0735	1490.4927	1510.0785
1724	1529.8336	1549.7574	1569.8482	1590.1018	1610.5189	1631.0985	1651.8396	1672.7484	1693.8293	1715.0749
1725	1736.4814	1758.0508	1779.7754	1801.6455	1823.6595	1845.8167	1868.1166	1890.5609	1913.1497	1935.8809
1726	1958.7520	1981.7602	2004.9037	2028.1821	2051.5915	2075.1290	2098.7911	2122.5717	2146.4690	2170.4822
1727	2194.6108	2218.8549	2243.2143	2267.6894	2292.2803	2316.9873	2341.9026	2366.9178	2392.0330	2417.2486
1728	2442.5646	2468.0142	2493.5778	2519.2555	2545.0472	2570.9530	2597.0145	2623.1801	2649.4505	2675.8264
1729	2702.3085	2728.9203	2755.6203	2782.4093	2809.2882	2836.2576	2863.4532	2890.7328	2918.0974	2945.5481
1730	2973.0858	3000.7116	3028.4263	3056.2311	3084.1269	3112.1146				

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

Crowder Lake Area Table Area in Acres by 0.1 ft Elevation Increments 2017 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
1489									0.0000	0.0000
1490	0.0000	0.0000	0.0000	0.0002	0.0009	0.0024	0.0045	0.0074	0.0114	0.0169
1491	0.0227	0.0282	0.0337	0.0395	0.0456	0.0521	0.0591	0.0667	0.0750	0.0840
1492	0.0939	0.1053	0.1209	0.1532	0.2422	0.3590	0.5641	0.7970	1.0440	1.2903
1493	1.5448	1.7519	1.9655	2.1608	2.3211	2.5478	2.7532	2.9812	3.1796	3.3594
1494	3.5415	3.7625	4.0422	4.3092	4.5509	4.7885	5.0238	5.2691	5.5199	5.7792
1495	6.0319	6.2648	6.4910	6.7413	6.9917	7.2710	7.5703	7.8522	8.1547	8.4463
1496	8.7260	9.0056	9.2771	9.5355	9.7942	10.0667	10.3505	10.6442	10.9840	11.3941
1497	11.8115	12.2851	12.7393	13.1941	13.6818	14.1485	14.5667	14.9753	15.3945	15.8034
1498	16.1952	16.5897	16.9900	17.3949	17.8068	18.2239	18.6530	19.1758	19.6363	20.1015
1499	20.5508	21.0062	21.4525	21.9200	22.4136	23.1451	23.8376	24.4288	25.0028	25.6053
1500	26.1758	26.7080	27.2061	27.6893	28.1715	28.6102	29.1249	29.5845	30.0498	30.5208
1501	31.0823	31.5608	32.0091	32.4191	32.7938	33.1492	33.5018	33.8454	34.1712	34.4901
1502	34.8009	35.1218	35.4624	35.8142	36.1839	36.5228	36.8552	37.1900	37.5468	37.9776
1503	38.4386	38.8940	39.3243	39.7454	40.1552	40.5407	40.9143	41.2949	41.6660	42.0227
1504	42.3776	42.7284	43.0823	43.4372	43.7995	44.1749	44.5555	44.9188	45.2349	45.5543
1505	45.8752	46.2007	46.5364	46.8740	47.2102	47.5407	47.8797	48.3184	48.7558	49.2147
1506	49.6895	50.1497	50.6122	51.0999	51.6232	52.1633	52.7786	53.3894	54.0134	54.5978
1507	55.1697	55.7283	56.3044	56.9226	57.5341	58.1467	58.7603	59.3642	59.9808	60.6147
1508	61.2214	61.8145	62.3591	62.8996	63.4109	63.9088	64.4157	64.9149	65.3946	65.8854
1509	66.3659	66.8447	67.3460	67.9253	68.4905	69.0832	69.6468	70.1886	70.7209	71.2833
1510	71.8961	72.5265	73.1199	73.6882	74.2410	74.7650	75.2794	75.7871	76.3542	77.0661
1511	77.7546	78.4472	79.1257	79.7945	80.4620	81.1310	81.7657	82.3541	82.9086	83.4472
1512	83.9861	84.5463	85.1130	85.6905	86.2885	86.8974	87.5114	88.1119	88.7315	89.3236
1513	89.8630	90.3872	90.9048	91.4316	91.9655	92.5082	93.0633	93.6174	94.1650	94.7154
1514	95.2624	95.8005	96.3393	96.8761	97.3987	97.9211	98.4449	98.9745	99.5074	100.0445
1515	100.5971	101.2294	101.9196	102.5788	103.2450	103.9264	104.6457	105.3475	106.1018	106.8729
1516	107.6488	108.3439	108.9892	109.6013	110.2123	110.8243	111.4460	112.1133	112.8003	113.4815
1517	114.2119	114.9507	115.6940	116.4544	117.2450	118.1001	119.1077	120.0014	120.6806	121.3622
1518	122.0455	122.7292	123.4133	124.0978	124.7828	125.4682	126.1540	126.8402	127.5268	128.2139
1519	128.9014	129.5893	130.2776	130.9663	131.6554	132.3450	133.0350	133.7254	134.4162	135.1075
1520	135.7991	136.4912	137.1837	137.8766	138.5700	139.2637	142.7427			

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

Crowder Lake Capacity Table Volume in Acre-Feet by 0.1 ft Elevation Increments 2017 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
1489									0.0000	0.0000
1490	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0006	0.0011	0.0021	0.0035
1491	0.0055	0.0080	0.0111	0.0147	0.0190	0.0239	0.0294	0.0357	0.0428	0.0507
1492	0.0596	0.0696	0.0808	0.0943	0.1134	0.1431	0.1886	0.2563	0.3488	0.4652
1493	0.6075	0.7724	0.9589	1.1647	1.3889	1.6324	1.8974	2.1839	2.4921	2.8192
1494	3.1641	3.5288	3.9188	4.3367	4.7797	5.2468	5.7373	6.2518	6.7911	7.3561
1495	7.9467	8.5620	9.1996	9.8613	10.5478	11.2602	12.0026	12.7738	13.5739	14.4041
1496	15.2627	16.1492	17.0635	18.0042	18.9706	19.9636	20.9844	22.0340	23.1146	24.2333
1497	25.3935	26.5984	27.8497	29.1462	30.4899	31.8823	33.3180	34.7952	36.3136	37.8737
1498	39.4737	41.1129	42.7918	44.5111	46.2711	48.0725	49.9162	51.8072	53.7479	55.7351
1499	57.7677	59.8455	61.9685	64.1368	66.3532	68.6299	70.9804	73.3937	75.8655	78.3951
1500	80.9856	83.6308	86.3269	89.0716	91.8648	94.7039	97.5906	100.5261	103.5082	106.5357
1501	109.6161	112.7488	115.9280	119.1497	122.4105	125.7078	129.0403	132.4080	135.8090	139.2421
1502	142.7066	146.2027	149.7315	153.2952	156.8953	160.5309	164.1998	167.9019	171.6387	175.4140
1503	179.2350	183.1014	187.0127	190.9660	194.9613	198.9962	203.0691	207.1796	211.3277	215.5122
1504	219.7323	223.9875	228.2781	232.6040	236.9657	241.3646	245.8009	250.2758	254.7835	259.3229
1505	263.8944	268.4981	273.1349	277.8055	282.5098	287.2473	292.0180	296.8277	301.6815	306.5798
1506	311.5251	316.5171	321.5550	326.6403	331.7764	336.9654	342.2124	347.5207	352.8913	358.3221
1507	363.8105	369.3554	374.9567	380.6180	386.3410	392.1249	397.9703	403.8766	409.8435	415.8737
1508	421.9657	428.1175	434.3265	440.5895	446.9052	453.2712	459.6873	466.1541	472.6696	479.2336
1509	485.8462	492.5066	499.2160	505.9799	512.8006	519.6795	526.6166	533.6085	540.6540	547.7538
1510	554.9122	562.1334	569.4158	576.7565	584.1531	591.6033	599.1055	606.6588	614.2642	621.9353
1511	629.6764	637.4864	645.3649	653.3110	661.3239	669.4038	677.5491	685.7553	694.0187	702.3366
1512	710.7081	719.1346	727.6176	736.1576	744.7564	753.4153	762.1357	770.9168	779.7591	788.6621
1513	797.6216	806.6343	815.6988	824.8155	833.9853	843.2089	852.4874	861.8214	871.2105	880.6544
1514	890.1534	899.7066	909.3135	918.9745	928.6883	938.4543	948.2726	958.1435	968.0676	978.0452
1515	988.0769	998.1667	1008.3249	1018.5499	1028.8410	1039.1996	1049.6287	1060.1281	1070.7001	1081.3493
1516	1092.0749	1102.8753	1113.7421	1124.6718	1135.6625	1146.7143	1157.8276	1169.0053	1180.2511	1191.5649
1517	1202.9491	1214.4073	1225.9390	1237.5467	1249.2308	1260.9974	1272.8567	1284.8164	1296.8504	1308.9525
1518	1321.1229	1333.3616	1345.6688	1358.0443	1370.4883	1383.0009	1395.5820	1408.2317	1420.9501	1433.7371
1519	1446.5928	1459.5174	1472.5107	1485.5729	1498.7040	1511.9040	1525.1730	1538.5110	1551.9181	1565.3943
1520	1578.9396	1592.5541	1606.2379	1619.9909	1633.8132	1647.7049	1661.9791			

Table A- 5: Fairfax City Lake Area by 0.1 ft Increments.

Fairfax City Lake Area Table Area in Acres by 0.1 ft Elevation Increments 2017 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
852								0.0000	0.0000	0.0146
853	0.0447	0.0727	0.1079	0.1521	0.2091	0.2918	0.3673	0.4535	0.5825	0.8082
854	0.9701	1.1341	1.2881	1.4326	1.5694	1.7106	1.8769	2.1073	2.3283	2.5366
855	2.7285	2.9105	3.0877	3.2781	3.4765	3.6634	3.8523	4.0263	4.2082	4.4020
856	4.5832	4.7581	4.9243	5.0858	5.2452	5.4063	5.5687	5.7307	5.8934	6.0642
857	6.2806	6.5131	6.7464	6.9937	7.2406	7.4783	7.7581	8.0110	8.2589	8.5162
858	8.7622	9.0058	9.2552	9.5099	9.7736	10.0450	10.3237	10.6056	10.8818	11.1511
859	11.4310	11.7099	11.9982	12.3010	12.6223	12.9512	13.2639	13.5596	13.8619	14.1625
860	14.4677	14.7718	15.0792	15.3930	15.6963	15.9899	16.2867	16.5966	16.8919	17.1738
861	17.4543	17.7322	18.0219	18.3612	18.6945	19.0058	19.3143	19.6348	19.9716	20.2958
862	20.6073	20.9114	21.2120	21.5094	21.7979	22.0767	22.3498	22.6198	22.8883	23.1597
863	23.4366	23.7237	24.0192	24.3156	24.6106	24.9097	25.2319	25.5320	25.8183	26.0992
864	26.3759	26.6500	26.9209	27.1924	27.4840	27.7661	28.0476	28.3236	28.5938	28.8616
865	29.1271	29.3921	29.6610	29.9387	30.2168	30.4914	30.7645	31.0385	31.3134	31.6009
866	31.9005	32.2096	32.5372	32.8839	33.2491	33.6160	33.9975	34.3855	34.7585	35.1264
867	35.5950	36.1204	36.5402	36.9281	37.3274	37.7451	38.1601	38.6088	39.1406	39.7039
868	40.1685	40.6549	41.2042	41.8947	42.4032	42.8147	43.2066	43.5928	43.9490	44.2729
869	44.5771	44.8745	45.1718	45.4654	45.7554	46.0414	46.3264	46.6110	46.9025	47.2047
870	47.5094	47.8281	48.1563	48.4828	48.8042	49.1280	49.4534	49.7787	50.1045	50.4374
871	50.7725	51.0969	51.4176	51.7414	52.0715	52.4116	52.7421	53.0730	53.4090	53.7511
872	54.1101	54.5166	54.9144	55.2812	55.6376	55.9752	56.3133	56.6487	56.9986	57.3694
873	57.7467	58.1256	58.5124	58.9081	59.3112	59.7000	60.0647	60.4241	60.7794	61.1518
874	61.5871	61.9878	62.3590	62.7310	63.0534	63.3562	63.6701	63.9822	64.2874	64.5927
875	64.8993	65.2017	65.5022	65.8043	66.1111	66.4191	66.7320	67.0504	67.3648	67.6812
876	67.9853	68.2850	68.5849	68.8852	69.1992	69.5513	69.9397	70.3353	70.7095	71.0592
877	71.4037	71.7649	72.1264	72.4909	72.8711	73.2712	73.7619	74.2074	74.6162	75.0112
878	75.3906	75.7626	76.1342	76.5119	76.9013	77.2959	77.6018	77.9133	78.2151	78.5175
879	78.8165	79.1163	79.4167	79.7109	79.9953	80.2767	80.5549	80.8310	81.1063	81.3869
880	81.6615	81.9387	82.2176	82.4940	82.7652	83.0393	83.3267	83.6033	83.8752	84.1445
881	84.4133	84.6812	84.9505	85.2234	85.4992	85.7805	86.0666	86.3437	86.6186	86.8885
882	87.1598	87.4308	87.6972	87.9671	88.2549	88.5337	88.8088	89.0812	89.3517	89.6301
883	89.9311	90.2655	90.6099	90.9825	91.3542	91.6990	92.0322	92.3661	92.7110	93.0578
884	93.4049	93.7449	94.0812	94.4054	94.7202	95.0277	95.3336	95.6168	95.8939	96.1752
885	96.4662	96.7655	97.0574	97.3437	97.6307	97.9146	98.1966	98.5136	98.8569	99.1258
886	99.3751	99.6183	99.8454	100.0655	100.2859	100.5066	100.7294	100.9530	101.1760	101.3981
887	101.6181	101.8362	102.0525	102.2672	102.4804	102.6926	102.9044	103.1158	103.3270	103.5377
888	103.7482	103.9583	104.1680	104.3774	104.5865	104.7953	105.0037	105.2117	105.4195	105.6269
889	105.8339	106.0406	106.2470	106.4530	106.6587	106.8641	107.0691	107.2738	107.4781	107.6821
890	107.8858	108.0891	108.2921	108.4948	109.6282					

Table A- 6: Fairfax City Lake Capacity by 0.1 ft Increments.

Fairfax City Lake Capacity Table Volume in Acre-Feet by 0.1 ft Elevation Increments 2017 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
852								0.0000	0.0000	0.0000
853	0.0002	0.0033	0.0092	0.0181	0.0310	0.0489	0.0738	0.1068	0.1475	0.1989
854	0.2688	0.3579	0.4631	0.5842	0.7204	0.8706	1.0345	1.2133	1.4126	1.6346
855	1.8780	2.1415	2.4235	2.7235	3.0414	3.3793	3.7363	4.1122	4.5062	4.9178
856	5.3483	5.7976	6.2648	6.7490	7.2495	7.7660	8.2986	8.8473	9.4123	9.9935
857	10.5912	11.2081	11.8477	12.5107	13.1971	13.9091	14.6450	15.4068	16.1954	17.0088
858	17.8477	18.7117	19.6000	20.5130	21.4512	22.4154	23.4062	24.4246	25.4711	26.5455
859	27.6471	28.7761	29.9332	31.1185	32.3334	33.5794	34.8582	36.1693	37.5104	38.8814
860	40.2826	41.7141	43.1760	44.6686	46.1921	47.7467	49.3310	50.9448	52.5889	54.2636
861	55.9669	57.6983	59.4577	61.2449	63.0640	64.9172	66.8023	68.7182	70.6656	72.6456
862	74.6591	76.7044	78.7804	80.8866	83.0227	85.1882	87.3820	89.6033	91.8518	94.1272
863	96.4296	98.7593	101.1172	103.5043	105.9211	108.3674	110.8433	113.3506	115.8889	118.4565
864	121.0524	123.6762	126.3275	129.0061	131.7117	134.4453	137.2079	139.9984	142.8172	145.6631
865	148.5358	151.4353	154.3612	157.3139	160.2937	163.3015	166.3370	169.3997	172.4899	175.6075
866	178.7531	181.9281	185.1335	188.3707	191.6415	194.9482	198.2914	201.6719	205.0911	208.5484
867	212.0426	215.5766	219.1621	222.7958	226.4693	230.1819	233.9357	237.7309	241.5689	245.4551
868	249.3996	253.3934	257.4336	261.5278	265.6809	269.8971	274.1580	278.4589	282.7993	287.1765
869	291.5878	296.0304	300.5030	305.0053	309.5372	314.0983	318.6882	323.3066	327.9535	332.6289
870	337.3343	342.0700	346.8368	351.6360	356.4679	361.3323	366.2289	371.1580	376.1196	381.1137
871	386.1406	391.2012	396.2948	401.4205	406.5784	411.7690	416.9932	422.2509	427.5416	432.8657
872	438.2236	443.6164	449.0471	454.5188	460.0288	465.5749	471.1555	476.7700	482.4180	488.1001
873	493.8185	499.5742	505.3678	511.1997	517.0706	522.9815	528.9324	534.9208	540.9453	547.0054
874	553.1017	559.2374	565.4171	571.6344	577.8889	584.1786	590.4991	596.8501	603.2330	609.6464
875	616.0904	622.5651	629.0701	635.6053	642.1706	648.7664	655.3929	662.0504	668.7396	675.4603
876	682.2127	688.9961	695.8097	702.6532	709.5266	716.4307	723.3677	730.3421	737.3560	744.4084
877	751.4971	758.6202	765.7784	772.9730	780.2038	787.4717	794.7787	802.1289	809.5280	816.9693
878	824.4509	831.9711	839.5288	847.1236	854.7559	862.4263	870.1371	877.8822	885.6581	893.4645
879	901.3012	909.1679	917.0645	924.9912	932.9477	940.9330	948.9466	956.9882	965.0575	973.1544
880	981.2791	989.4316	997.6115	1005.8194	1014.0550	1022.3180	1030.6081	1038.9265	1047.2731	1055.6470
881	1064.0480	1072.4759	1080.9306	1089.4122	1097.9209	1106.4570	1115.0209	1123.6133	1132.2339	1140.8820
882	1149.5574	1158.2598	1166.9893	1175.7458	1184.5289	1193.3400	1202.1795	1211.0466	1219.9412	1228.8628
883	1237.8117	1246.7895	1255.7992	1264.8428	1273.9223	1283.0393	1292.1922	1301.3788	1310.5987	1319.8524
884	1329.1409	1338.4641	1347.8216	1357.2130	1366.6374	1376.0937	1385.5812	1395.0994	1404.6470	1414.2225
885	1423.8259	1433.4579	1443.1195	1452.8107	1462.5308	1472.2794	1482.0568	1491.8623	1501.6967	1511.5658
886	1521.4654	1531.3905	1541.3402	1551.3136	1561.3091	1571.3267	1581.3663	1591.4281	1601.5122	1611.6187
887	1621.7474	1631.8982	1642.0710	1652.2654	1662.4814	1672.7188	1682.9774	1693.2573	1703.5583	1713.8804
888	1724.2237	1734.5880	1744.9733	1755.3796	1765.8069	1776.2551	1786.7242	1797.2141	1807.7249	1818.2565
889	1828.8088	1839.3818	1849.9756	1860.5900	1871.2250	1881.8805	1892.5567	1903.2534	1913.9705	1924.7081
890	1935.4661	1946.2445	1957.0433	1967.8623	1978.7017					

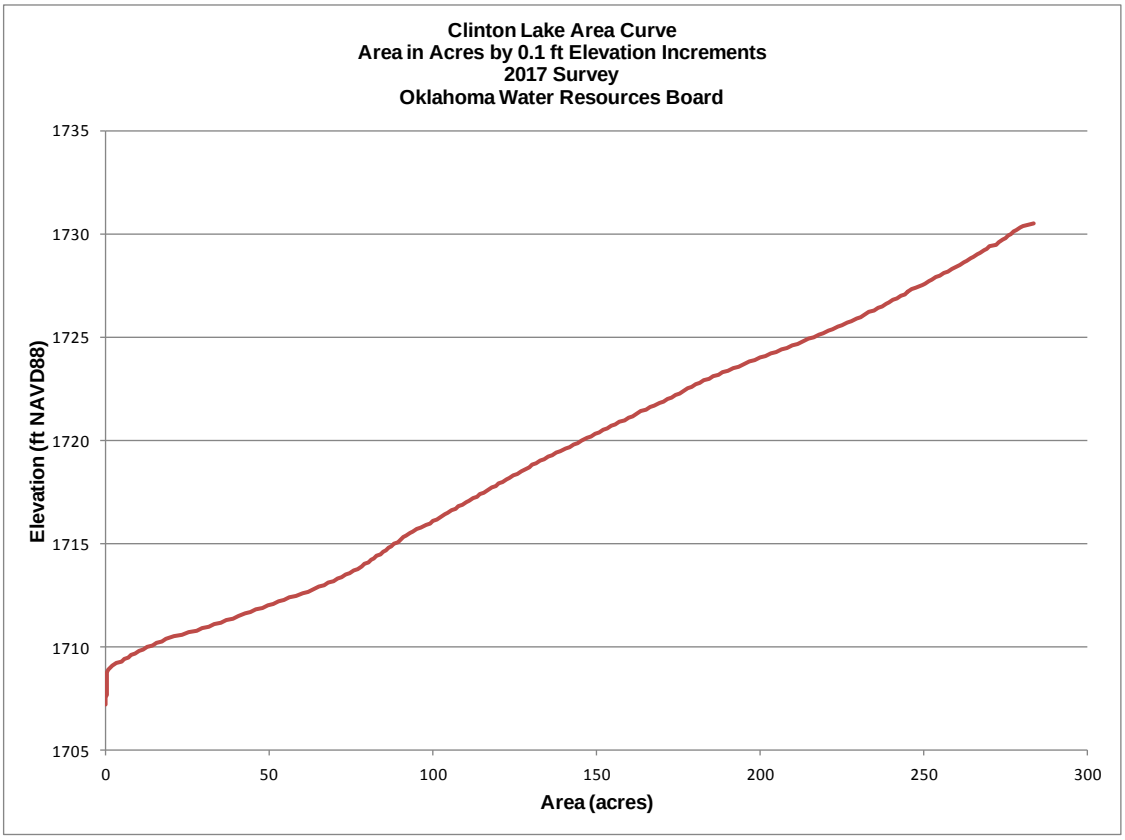

Figure A- 1: Area Curve for Clinton Lake.

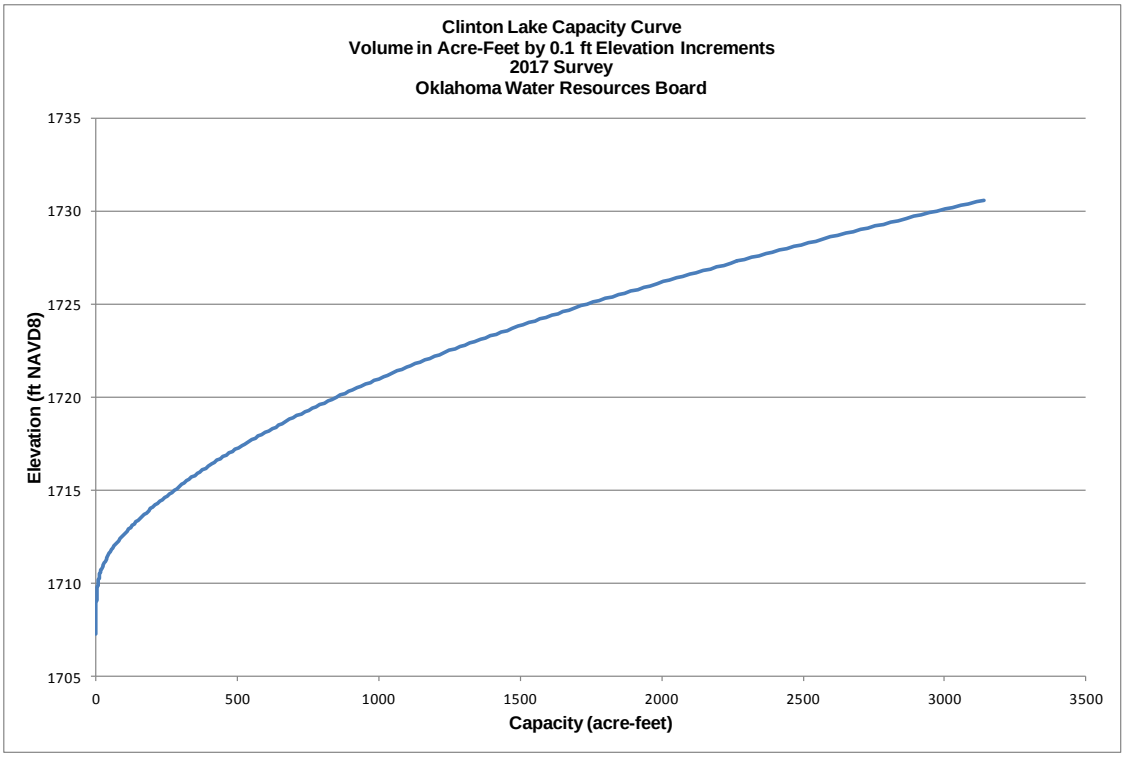

Figure A- 2: Cumulative Capacity Curve for Clinton Lake.

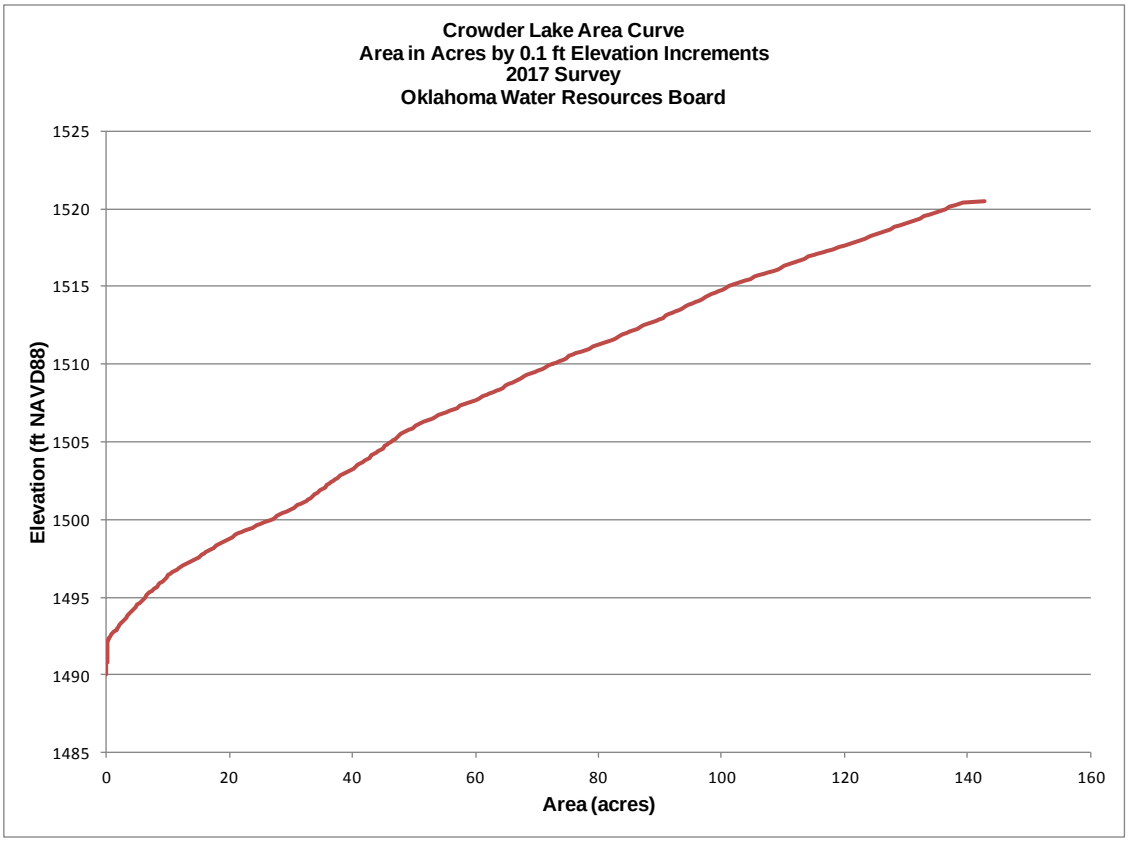

Figure A- 3: Area Curve for Crowder Lake.

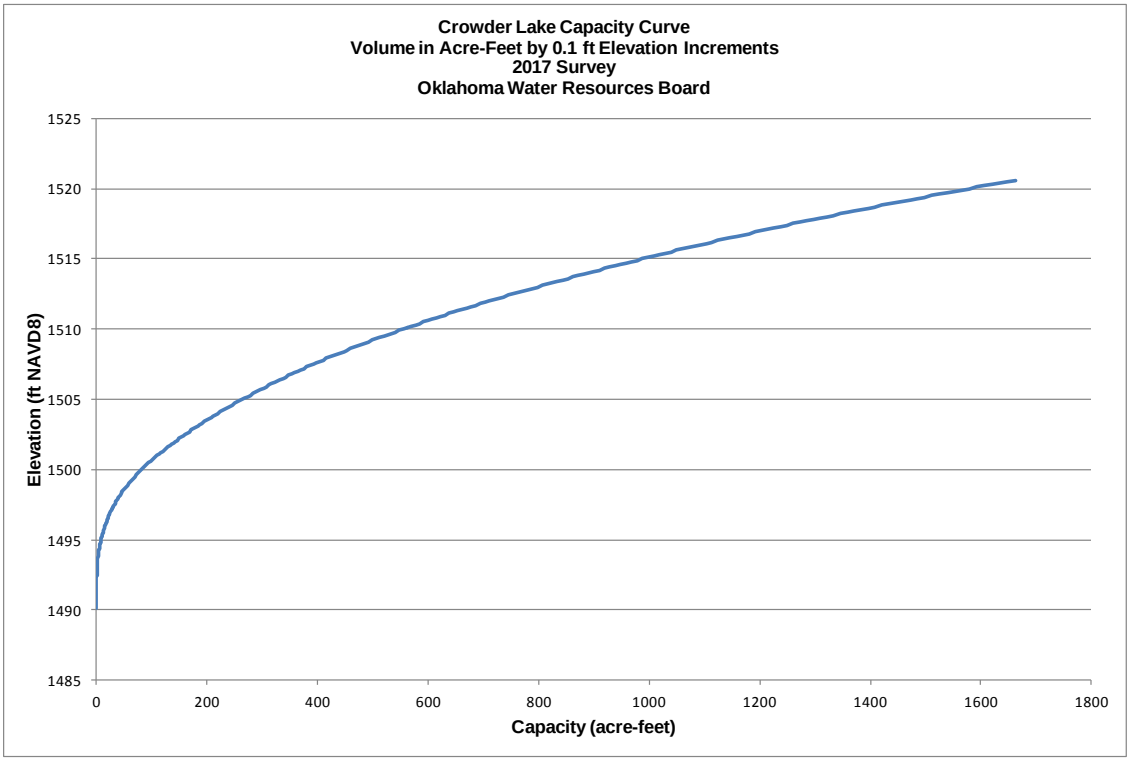

Figure A- 4: Cumulative Capacity Curve for Crowder Lake.

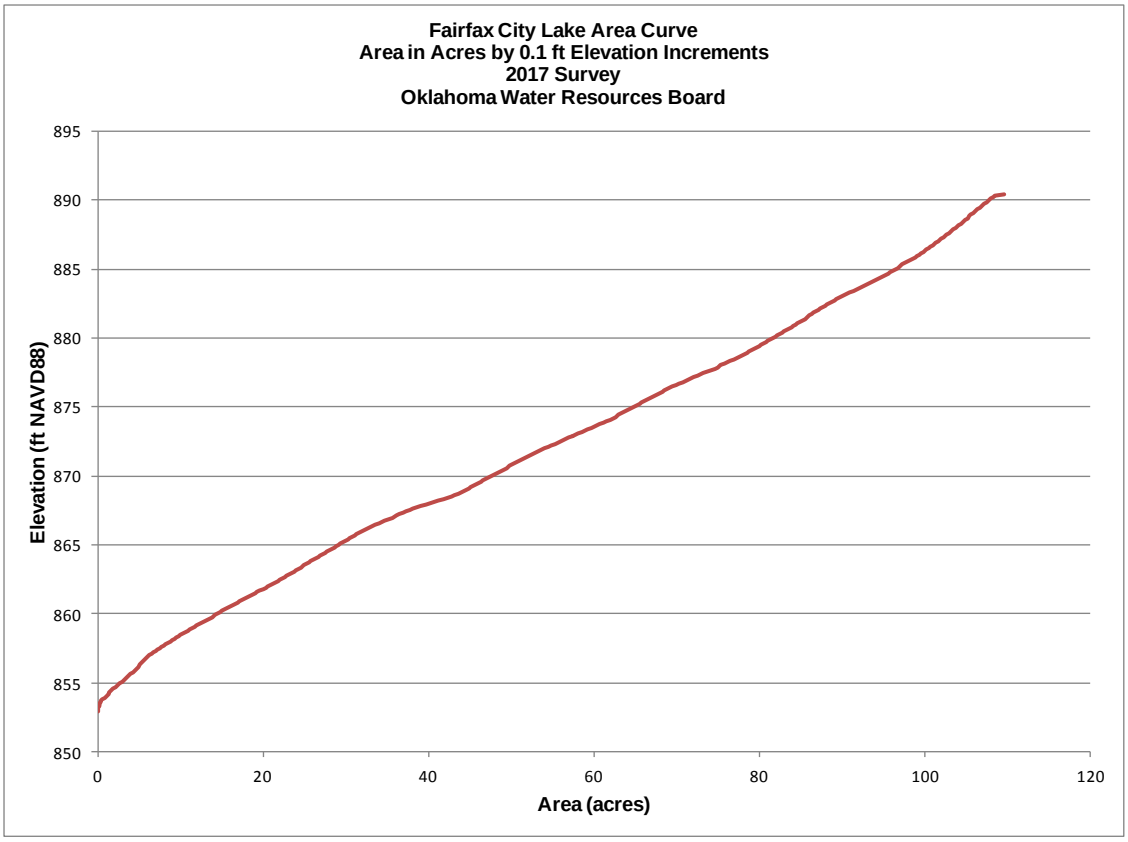

Figure A- 5: Area Curve for Fairfax City Lake.

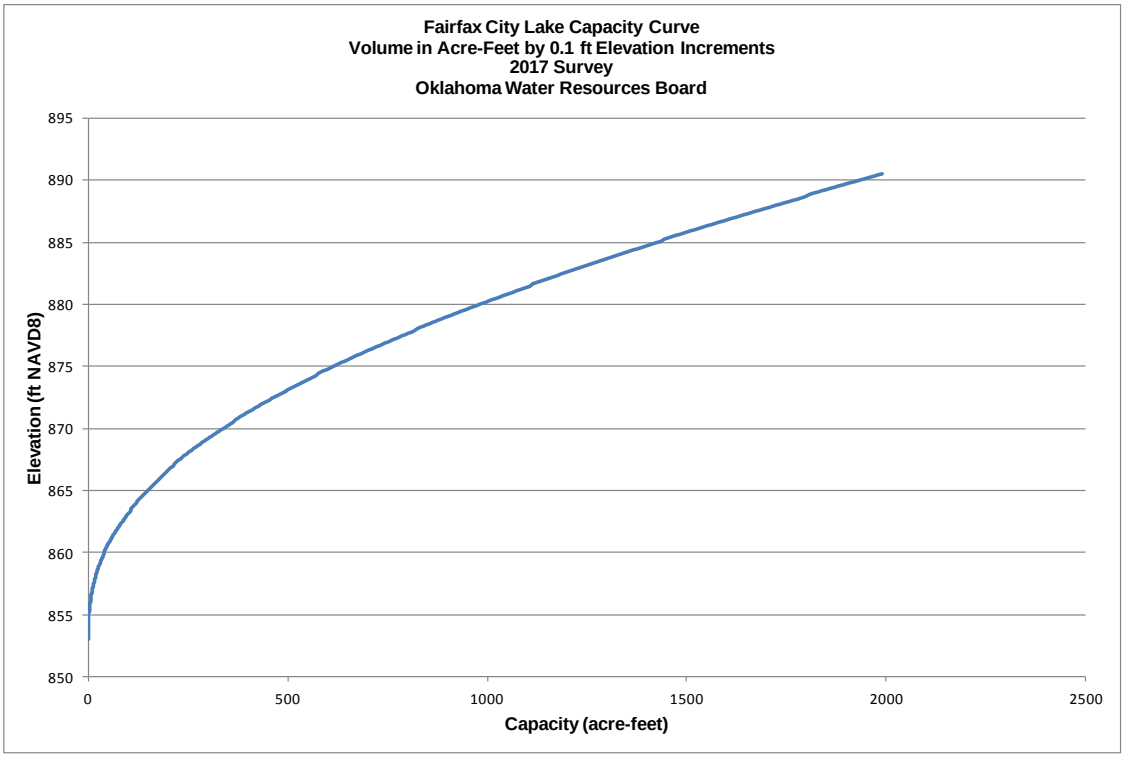

Figure A- 6: Cumulative Capacity Curve for Fairfax City Lake.

APPENDIX B: Clinton Lake Maps

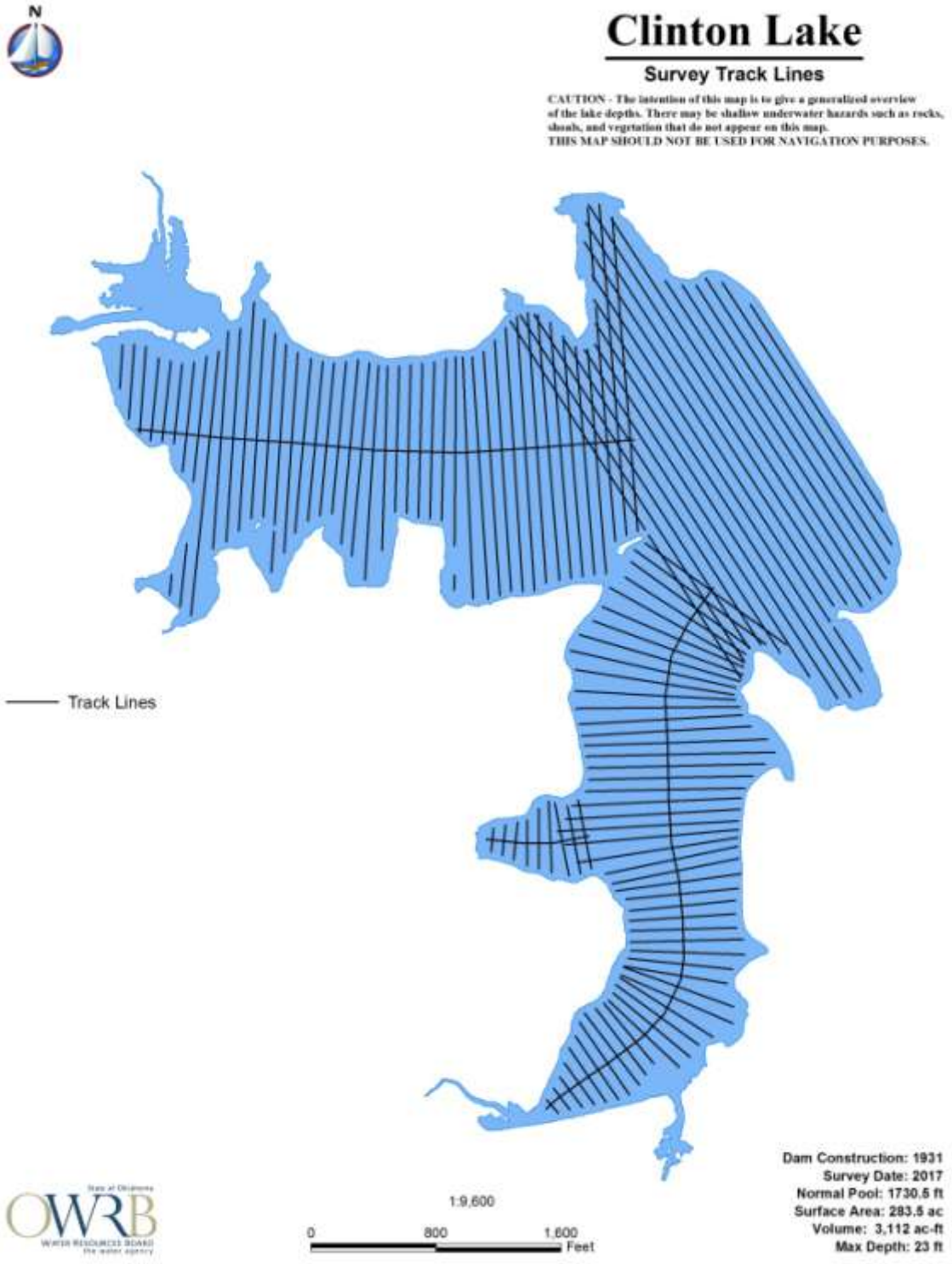

Figure B- 1: Clinton Lake Survey Track Lines.

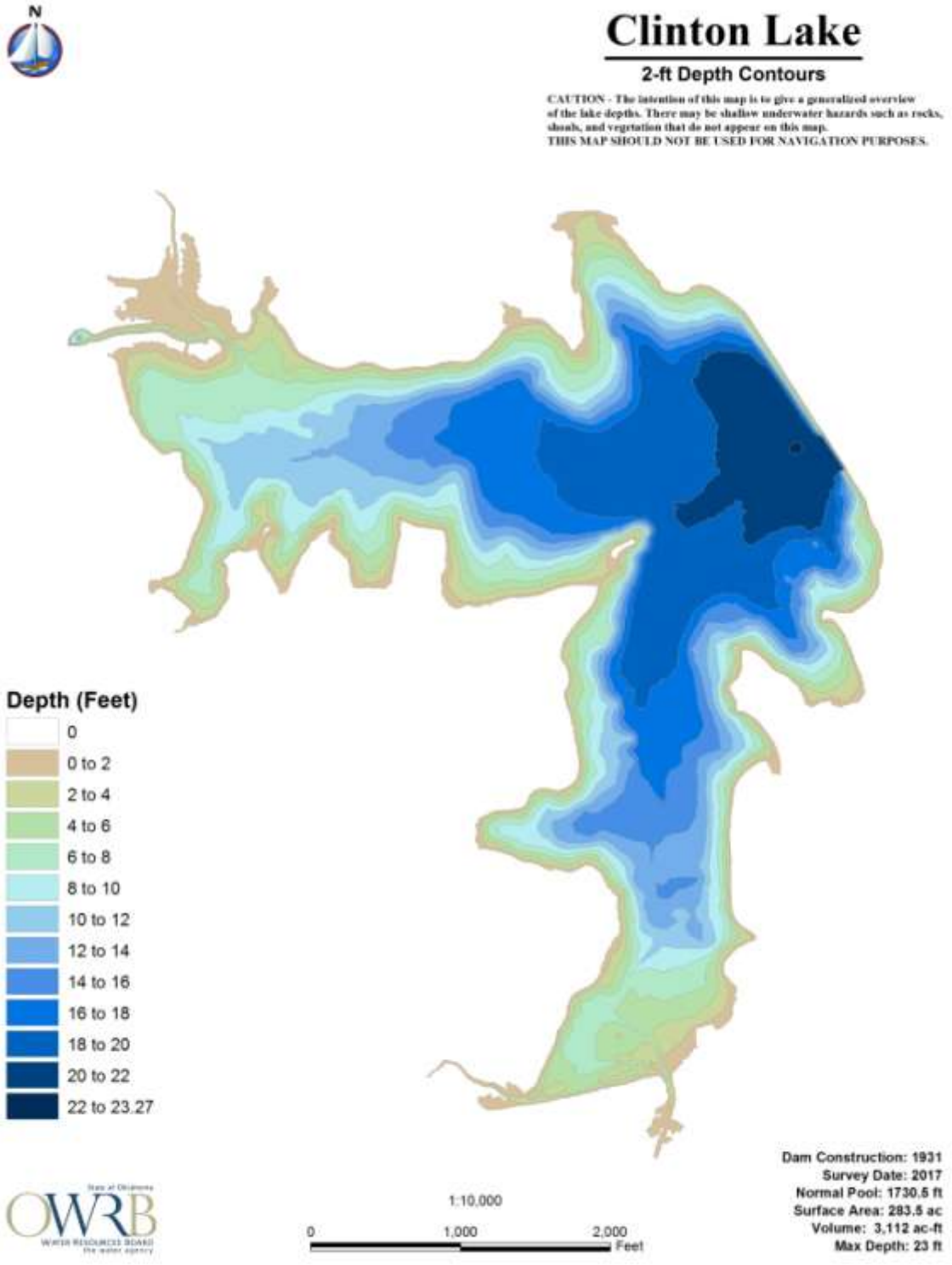

Figure B- 2: Clinton Lake Contour Map with 2 ft Intervals.

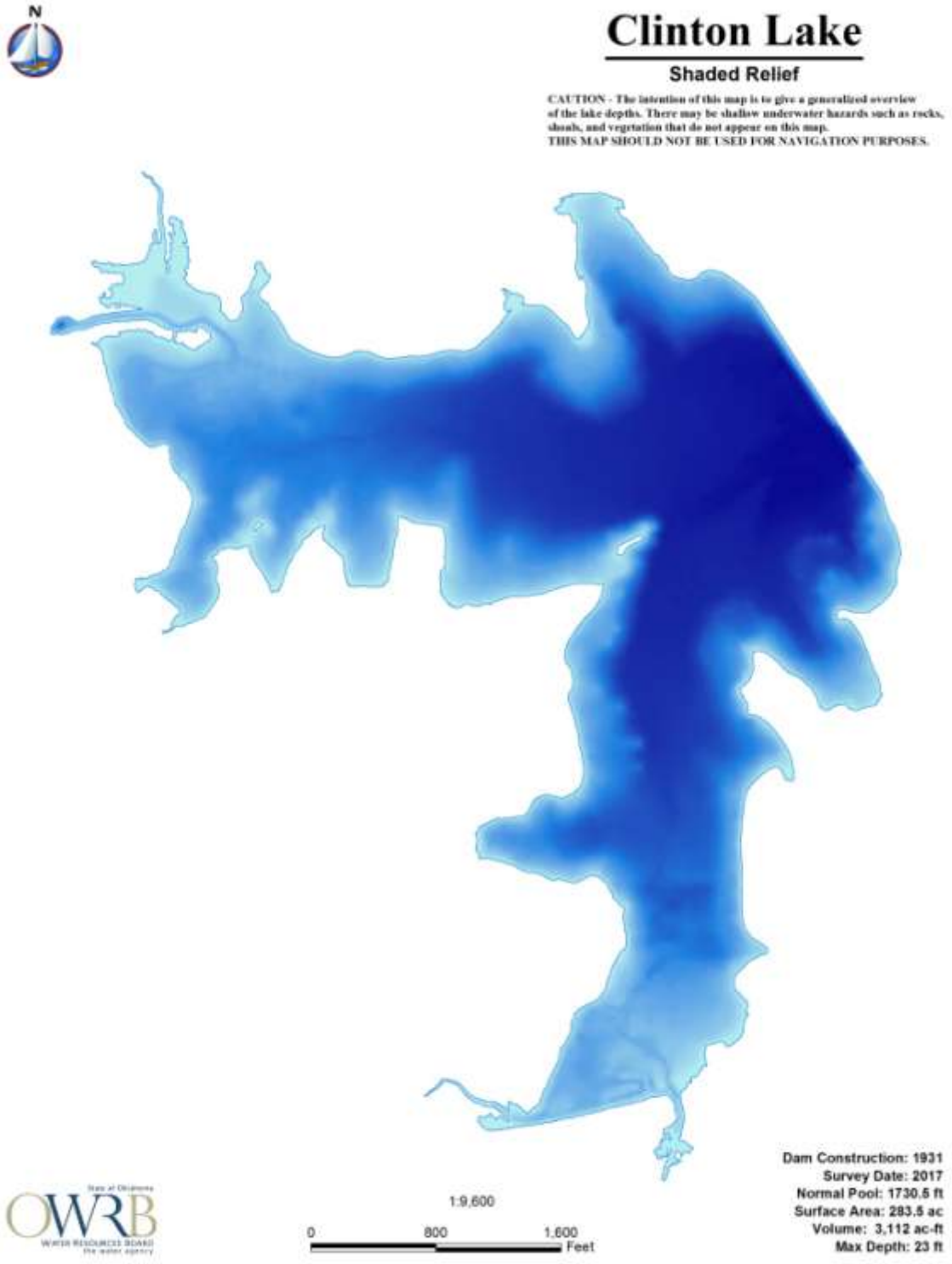

Figure B- 3: Clinton Lake Shaded Relief Map.

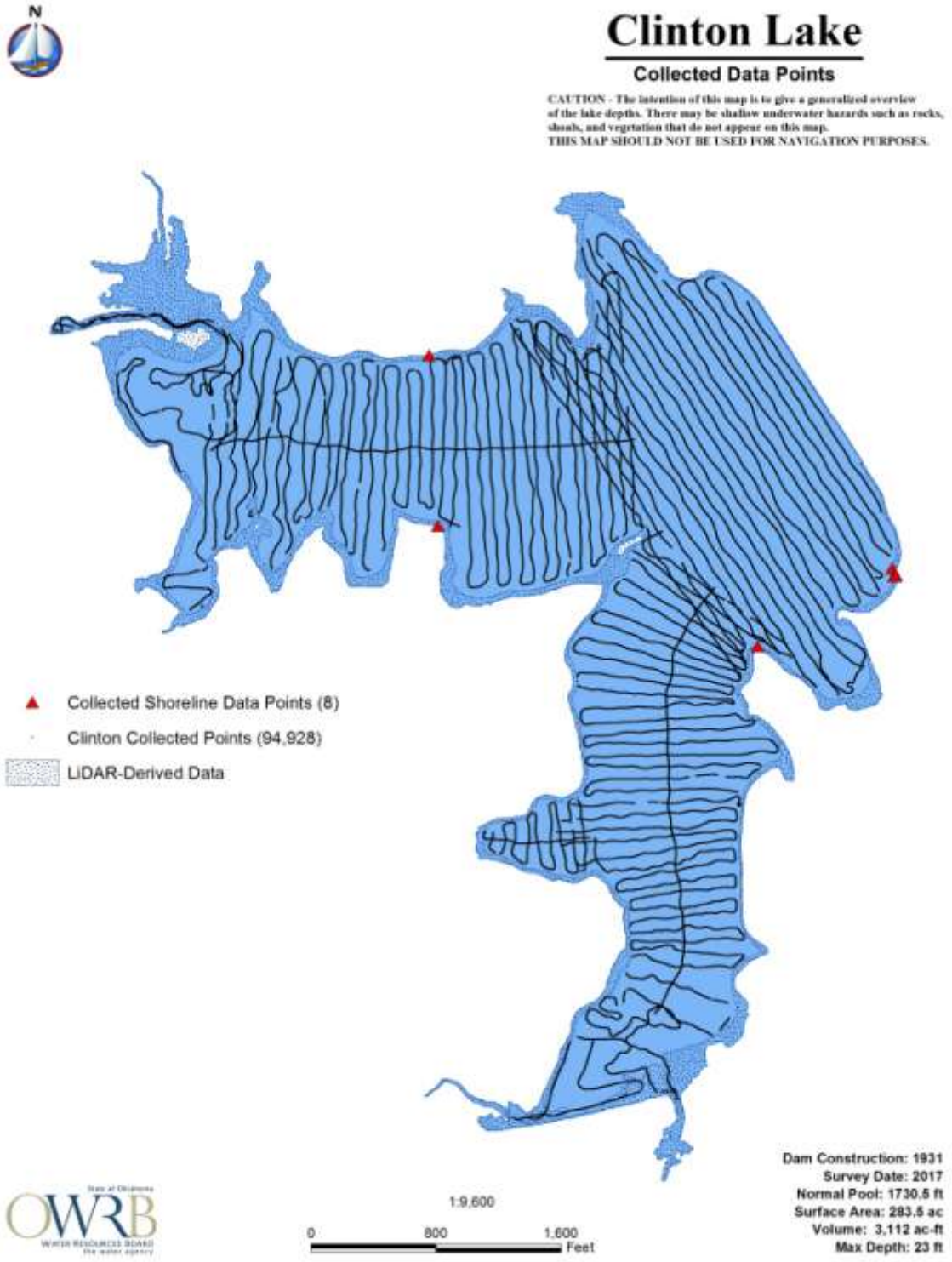

Figure B- 4: Clinton Lake Collected Data Points Map.

APPENDIX C: Crowder Lake Maps

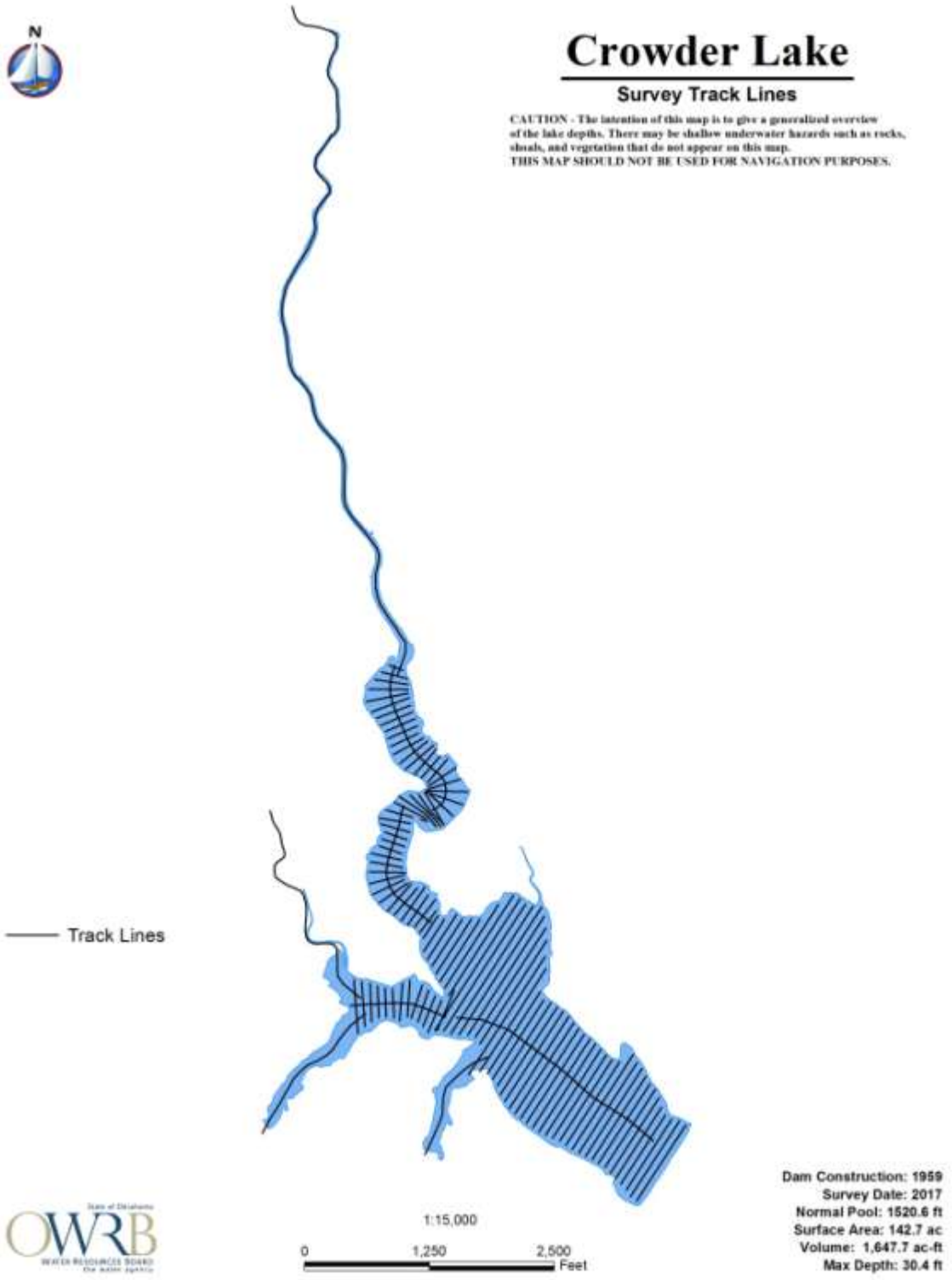

Figure C- 1: Crowder Lake Survey Track Lines Map.

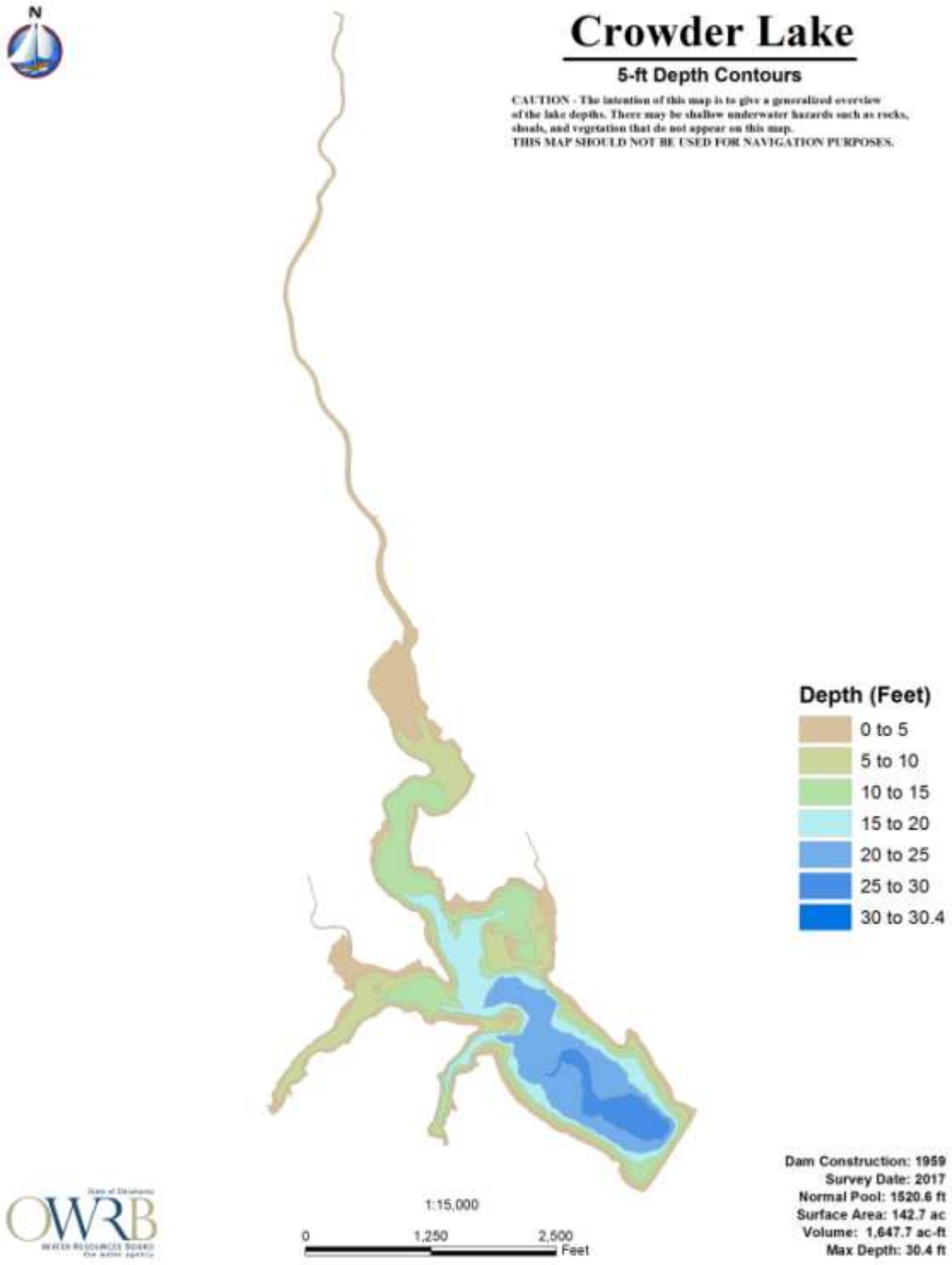

Figure C- 2: Crowder Lake Contour Map with 5 ft Intervals.

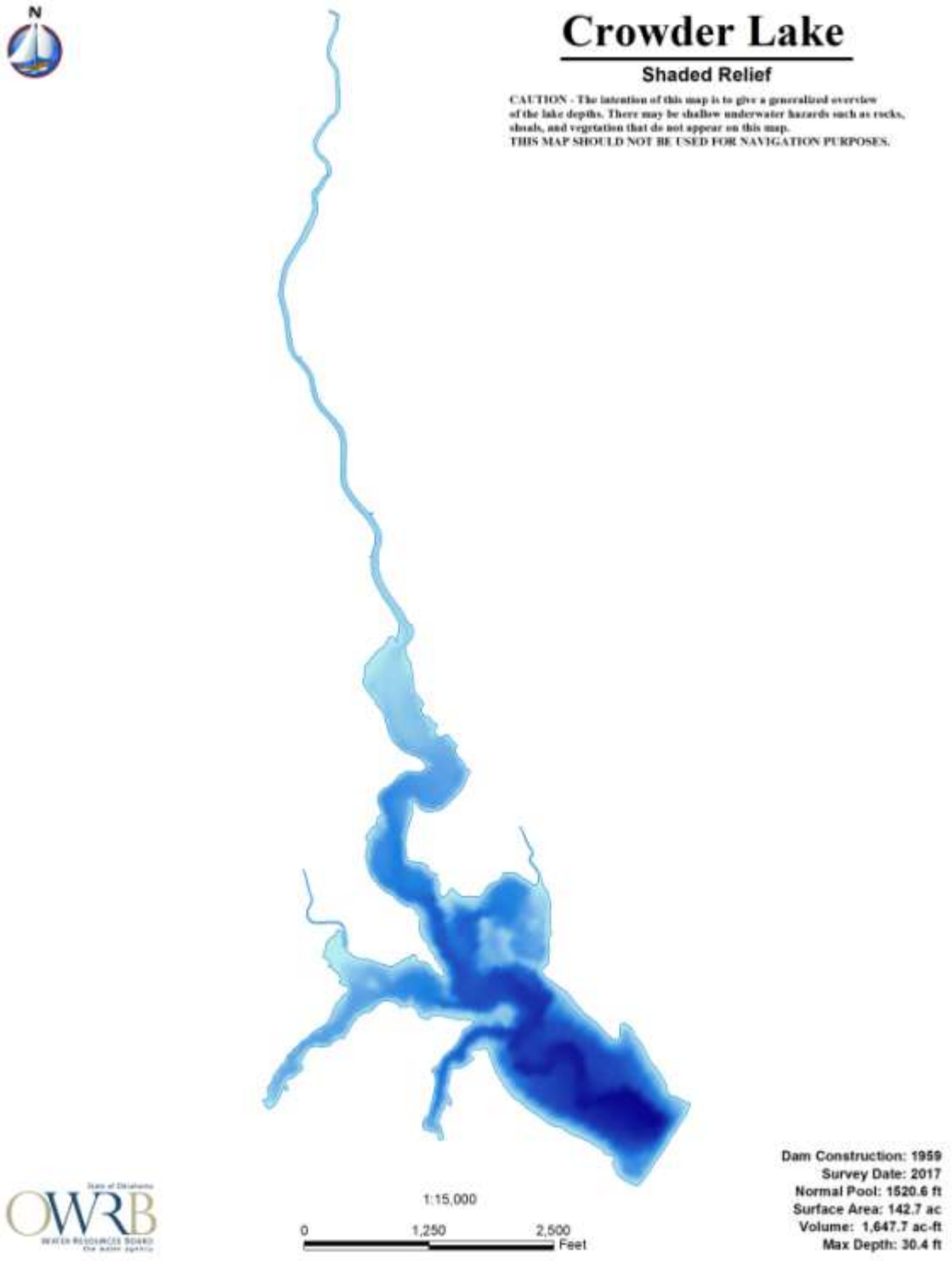

Figure C- 3: Crowder Lake Shaded Relief Map.

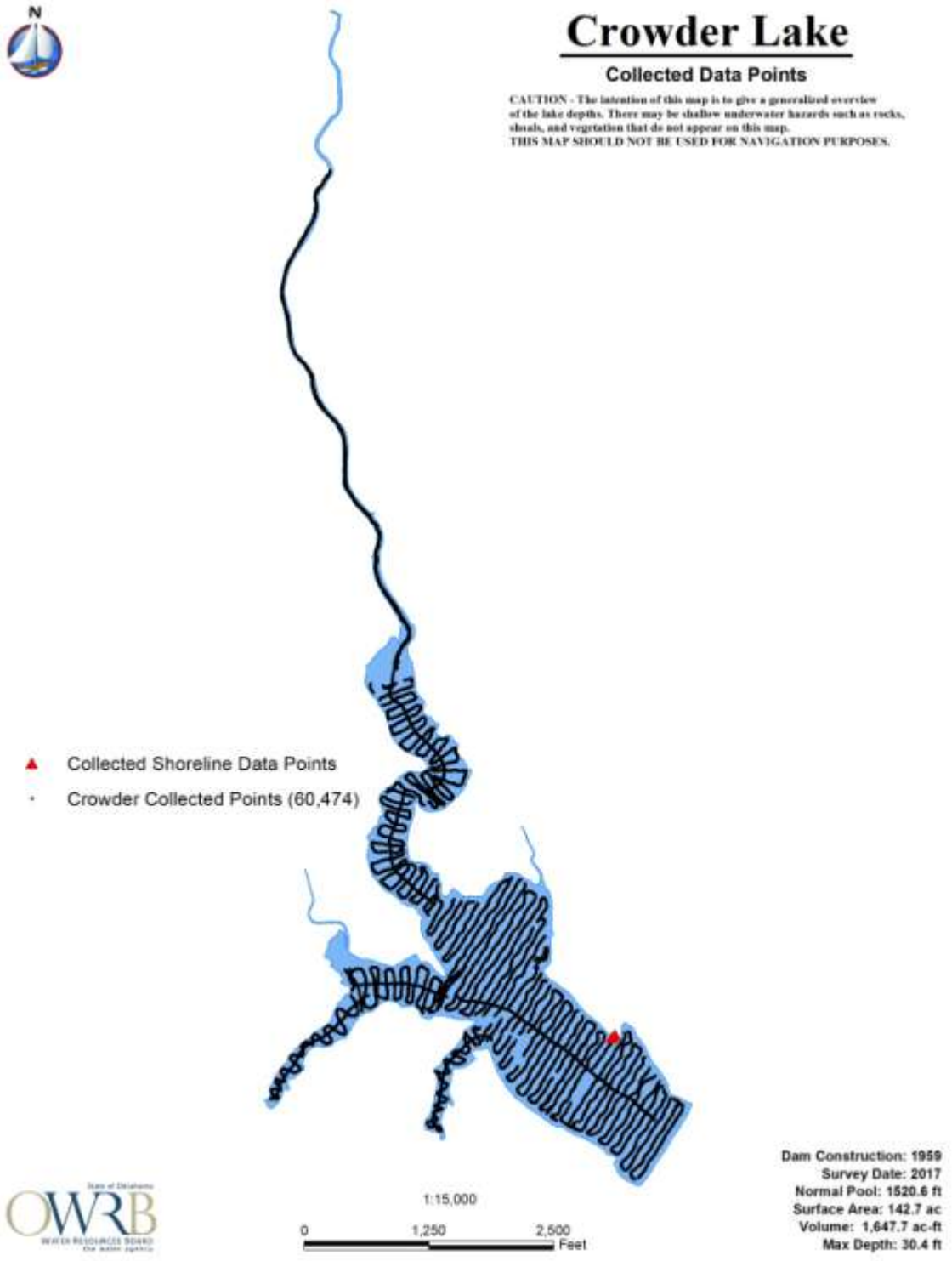

Figure C- 4: Crowder Lake Collected Data Points Map.

APPENDIX D: Fairfax City Lake Maps

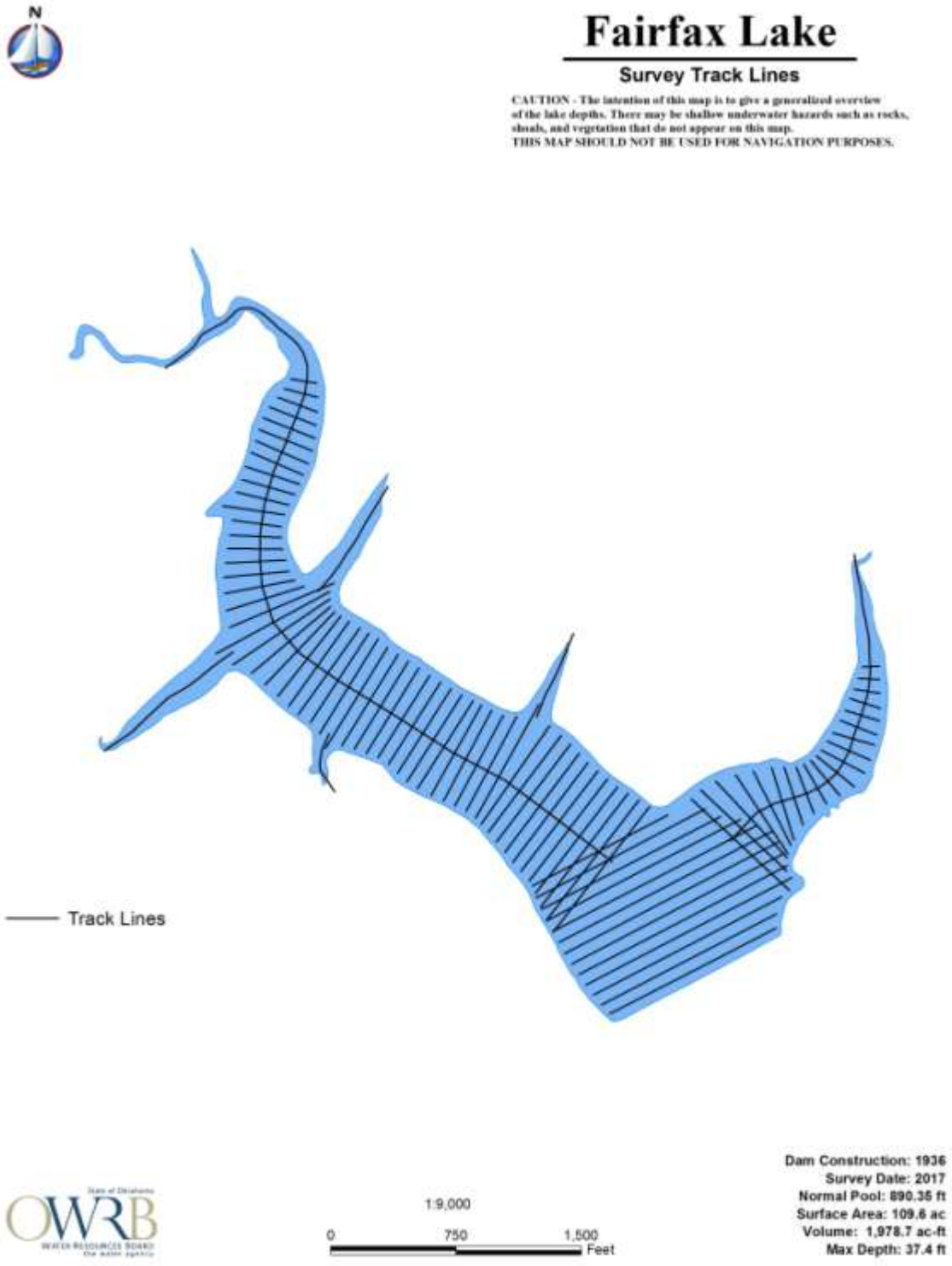

Figure D- 1: Fairfax City Lake Survey Track Lines Map.

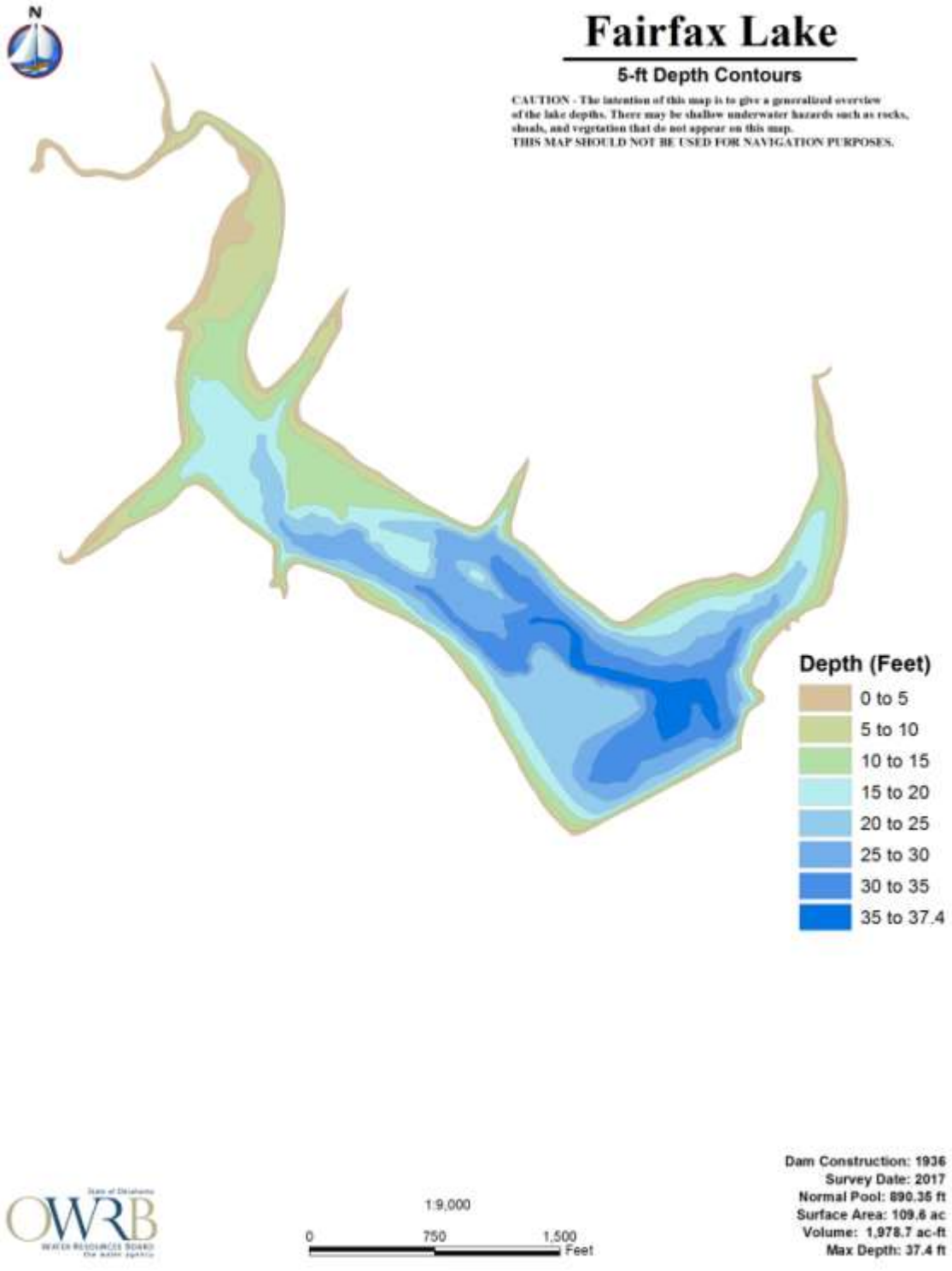

Figure D- 2: Fairfax City Lake Contour Map with 5 ft Intervals.

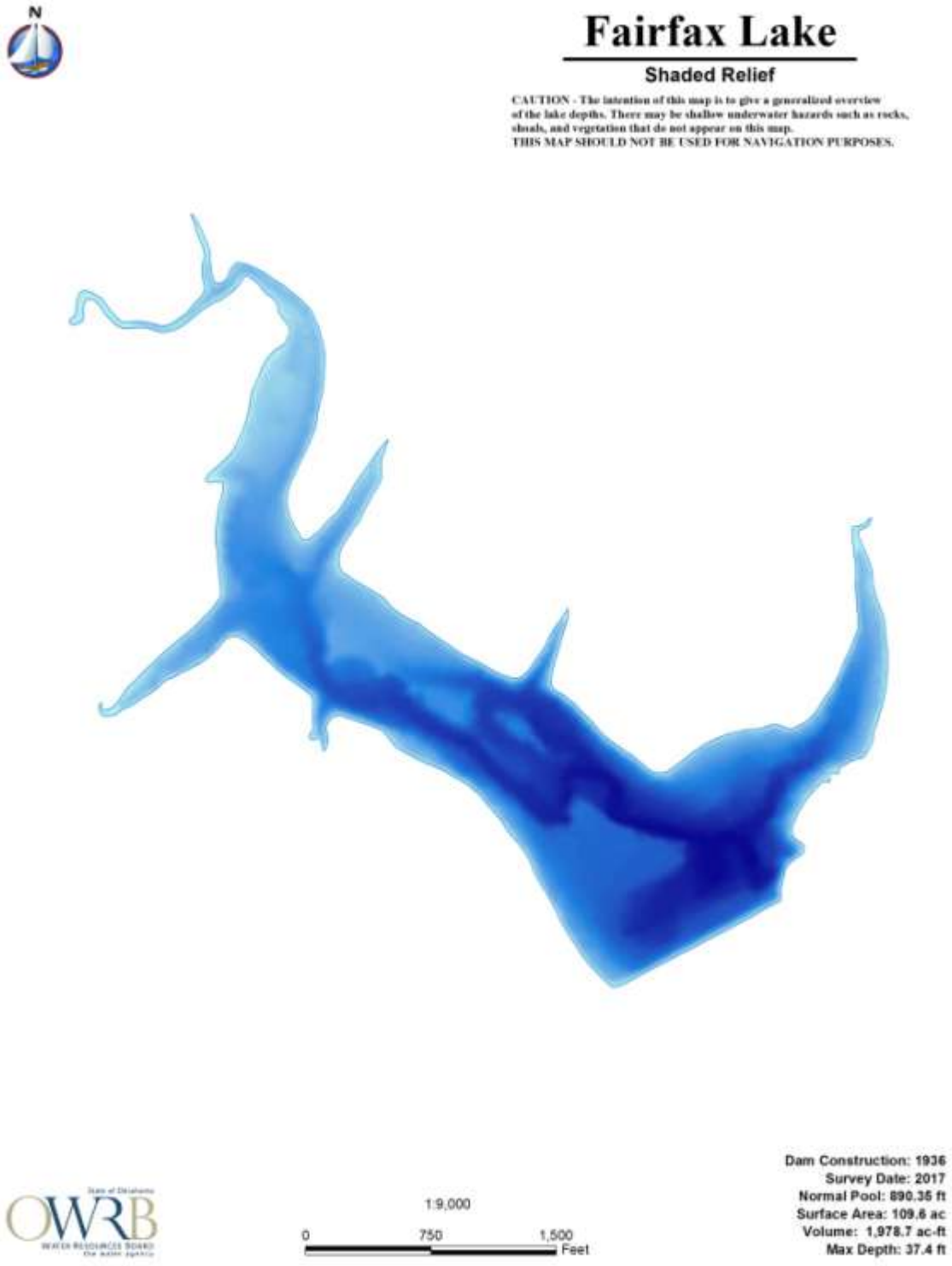

Figure D- 3: Fairfax City Lake Shaded Relief Map.

Figure D- 4: Fairfax City 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	Clinton Lake (3/27/17)	Clinton Lake (3/28/17)	Crowder Lake (4/4/17)	Fairfax City Lake (6/17/17)
Static Draft (ft)	0.6	0.5	0.7	0.6
Average SOS (m/s)	1468.44	1468.19	1464.38	1471.66
Echosounder SOS (m/s)	1468.22	1467.91	1464.26	1471.57

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

Cross Check Statistics			
Lake	Clinton Lake	Crowder Lake	Fairfax City Lake
# of Intersections	150	290	260
Arithmetic Mean (ft)	0.019	0.068	0.073
Standard Deviation (ft)	0.113	0.294	0.365