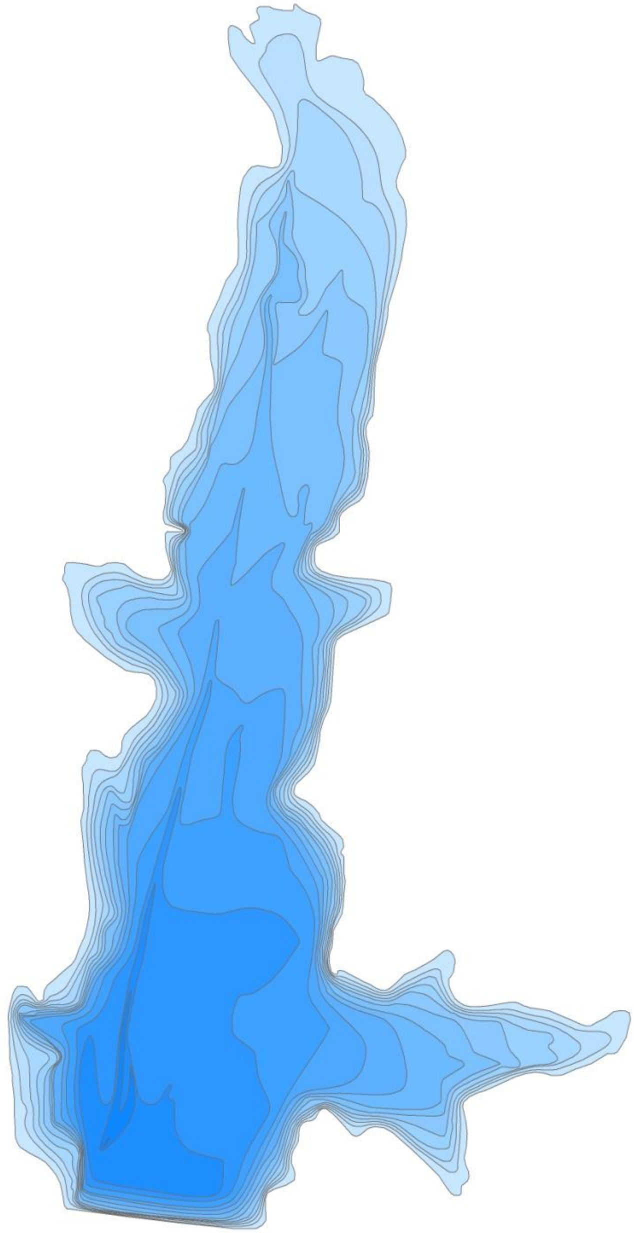
HYDROGRAPHIC SURVEY of CHANDLER CITY LAKE



Final Report

October 31, 2011

Prepared by:

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

TABLE OF CONTENTS

TABLE OF CONTENTS 2
TABLE OF FIGURES 3
TABLE OF TABLES 3
INTRODUCTION 4
LAKE BACKGROUND 4
HYDROGRAPHIC SURVEYING PROCEDURES 6
Pre-survey Planning 6
Boundary File 6
Set-up 6
Field Survey 6
Lake Elevation Acquisition 6
Method 7
Technology 7
Survey 7
Quality Control/Quality Assurance 7
Data Processing 9
GIS Application 10
RESULTS 10
SUMMARY and COMPARISON 10
REFERENCES 12
APPENDIX A: Area-Capacity Data 13
APPENDIX B: Chandler City Lake Maps 17

TABLE OF FIGURES

Figure 1: Location map for Chandler City Lake. 5
Figure A. 1. Area-Capacity Curve for Chandler City Lake 16
Figure B. 1: Chandler City Lake Bathymetric Map with 5-foot Contour Intervals. 18
Figure B. 2: Chandler City Lake Shaded Relief Bathymetric Map. 19
Figure B. 3: Chandler City Lake Collected Data Points. 20

TABLE OF TABLES

Table 1: Area and Volume Comparisons of Chandler City Lake. 11
Table A. 1: Chandler City Lake Capacity/Area by 0.1-ft Increments. 14
Table A. 2: Chandler City Lake Capacity/Area by 0.1-ft Increments (cont). 15
Table A. 3: Chandler City Lake Capacity/Area by 0.1-ft Increments (cont). .... **Error! Bookmark not defined.**

CHANDLER CITY LAKE
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of Chandler City Lake beginning in April of 2011. The purpose of this survey was to collect hydrographic data of the lake and convert this information into an elevation-area-capacity table. This project was funded by the OWRB's Dam Safety Program.

LAKE BACKGROUND

Chandler City Lake is located on Bellcalf Creek in Lincoln County (**Figure 1**). The dam was completed in 1954 (with repairs made in/around 1974) and is located approximately two miles northwest of the City of Chandler, OK. Its purposes are water supply, and recreation.

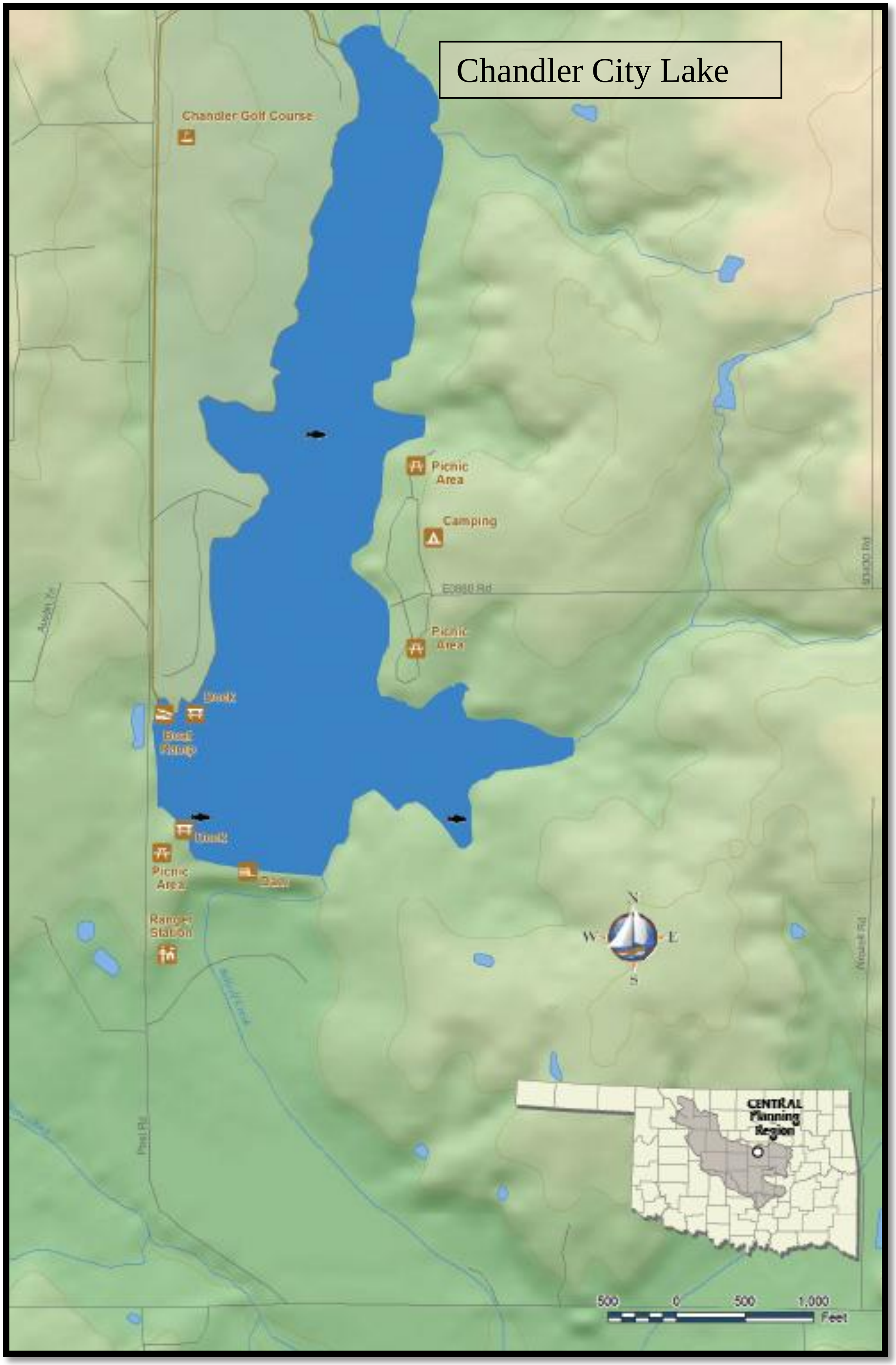


Figure 1: Location map for Chandler City Lake.

HYDROGRAPHIC SURVEYING PROCEDURES

The process of surveying a reservoir uses a combination of Geographic Positioning System (GPS) and acoustic depth sounding technologies that are 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 brought to the office for editing. During editing, data "noise" is removed or corrected, and average depths are converted to elevation readings based on the daily-recorded lake level elevation on the day the survey was performed. Accurate estimates of area-capacity can then be determined for the lake by building a 3-D model of the reservoir from the corrected data. The process of completing a hydrographic survey includes four steps: pre-survey planning, field survey, data processing, and GIS application.

Pre-survey Planning

Boundary File

The boundary file for Chandler City Lake was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) mosaic of Lincoln County, Oklahoma. The screen scale was set to 1:1,500. A line was to represent the shoreline as closely as possible. Due to the photography being a summer photo, it was difficult to determine the actual shoreline when there are trees and other vegetation hanging over the lake. The 2008 and 2010 DOQQs of the lakes were used as back ground reference. The reservoir boundaries were digitized in NAD 1983 State Plane Coordinates (Oklahoma North-3501).

Set-up

HYPACK software from Hypack, Inc. was used to assign geodetic parameters, import background files, and create virtual track lines (transects). The geodetic parameters assigned were State Plane NAD 83 Zone OK-3501 Oklahoma North with distance units and depth as US Survey Feet. The survey transects were spaced according to the accuracy required for the project. The survey transects within the digitized reservoir boundary were at 300 ft increments and ran perpendicular to the original stream channels and tributaries. Approximately 20 virtual transects were created for Chandler City Lake.

Field Survey

Lake Elevation Acquisition

The lake elevation for Chandler City Lake was obtained by collecting positional data over a period of approximately 222 minutes with a survey-grade Global Positioning System (GPS) receiver. The receiver was placed over the water's surface. A measurement was taken from the antenna to the surface of the water. The collected data and antenna height was then uploaded to the On-line Positioning Users Service (OPUS) website. The National Geodetic Survey (NGS) operates OPUS as a means to provide GPS users 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.

Calculated coordinates are averaged from three independent single-baseline solutions computed by double-differenced, carrier-phase measurements between the collected data file and 3 surrounding Continuously Operating Reference Stations (CORS). Under ideal conditions, OPUS can easily resolve most positions to within centimeter accuracy. A report containing the newly calculated positional data was electronically returned via email. This report contained the elevation of the surface of the water corrected for the antenna height.

Method

The procedures followed by the OWRB during the hydrographic survey adhere to U.S. Army Corps of Engineers (USACE) standards (USACE, 2002). The quality control and quality assurance procedures for equipment calibration and operation, field survey, data processing, and accuracy standards are presented in the following sections.

Technology

The Hydro-survey vessel is an 18-ft aluminum Silverstreak hull with cabin, powered by a single 115-Horsepower Mercury outboard motor. Equipment used to conduct the survey included: a ruggedized notebook computer; Innerspace 456Xpe Echo Sounder, with a depth resolution of 0.1 ft; Trimble Navigation, Inc. Pro XR GPS receiver with differential global positioning system (DGPS) correction; and an Odom Hydrographics, Inc, DIGIBAR-Pro Profiling Sound Velocimeter. The software used was HYPACK.

Survey

A two-man survey crew was used during the project. Data collection for Chandler City Lake occurred in April of 2011. The water level elevation for Chandler City Lake was 890.8 ft Geodetic Vertical Datum (NAVD88). 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. Data was also collected along a path parallel to the shoreline at a distance that was determined by the depth of the water and the draft of the boat – generally, two to three feet deep. Areas with depths less than this were avoided.

Quality Control/Quality Assurance

While on board the Hydro-survey vessel, a sound velocity profile was collected each day using a DIGIBAR-Pro Profiling Sound Velocimeter, by Odom Hydrographics. The sound velocimeter measures the speed of sound at incremental depths throughout the water column. The factors that influence the speed of sound—depth, temperature, and salinity—are all taken into account. Deploying the unit involved lowering the probe, which measures the speed of sound, 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 1 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 to the raw depth readings.

A quality assurance cross-line check was performed on intersecting transect lines and channel track lines to assess the estimated accuracy of the survey measurements. The overall accuracy of an observed bottom elevation or depth reading is dependent on random and systematic errors that are present in the measurement process. Depth measurements contain both random errors and systematic bias. Biases are often referred to as systematic errors and are often due to observational errors. Examples of bias include a bar check calibration error, tidal errors, or incorrect squat corrections. Bias, however, does not affect the repeatability, or precision, of results. The precision of depth readings is affected by random errors. These are errors present in the measurement system that cannot be easily reduced by further calibration. Examples of random error include uneven bottom topography, bottom vegetation, positioning error, extreme listing of survey vessel, and speed of sound variation in the water column. An assessment of the accuracy of an individual depth or bottom elevation must fully consider all the error components contained in the observations that were used to determine that measurement. Therefore, the ultimate accuracy must be estimated (thus the use of the term "estimated accuracy") using statistical estimating measures (USACE, 2002).

The depth accuracy estimate is determined by comparing depth readings taken at the intersection of two lines and computing the difference. This is done on multiple intersections. The mean difference of all intersection points is used to calculate the mean difference (MD). The mean difference represents the bias present in the survey. The standard deviation (SD), representing the random error in the survey, is also calculated. The mean difference and the standard deviation are then used to calculate the Root Mean Square (RMS) error. The RMS error estimate is used to compare relative accuracies of estimates that differ substantially in bias and precision (USACE, 2002). According the USACE standards, the RMS at the 95% confidence level should not exceed a tolerance of ± 2.0 ft for this type of survey. This simply means that on average, 19 of every 20 observed depths will fall within the specified accuracy tolerance.

HYPACK Cross Statistics program was used to assess vertical accuracy and confidence measures of acoustically recorded depths. The program computes the sounding difference between intersecting lines of single beam data. The program provides a report that shows the standard deviation and mean difference. A total of 60 cross-sections points at Chandler City Lake were used to compute error estimates. A mean difference (arithmetic mean) of 0.025 ft and a standard deviation of 0.073 ft were computed from intersections. The following formulas were used to determine the depth accuracy at the 95% confidence level.

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

where:

Random error = Standard deviation
Bias = Mean difference
RMS = root mean square error (68% confidence level)

and:

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

An RMS of ± 0.151 ft with a 95% confidence level is less than the USACE's minimum performance standard of ± 2.0 ft for this type of survey. A mean difference, or bias, of 0.025 ft is well below the USACE's standard maximum allowable bias of ± 0.5 ft for this type of survey.

The GPS system is an advanced high performance geographic data-acquisition tool that uses DGPS to provide sub-meter positional accuracy on a second-by-second basis. Potential errors are reduced with differential GPS because additional data from a reference GPS receiver at a known position are used to correct positions obtained during the survey. Before the survey, Trimble's Pathfinder Controller software was used to configure the GPS receiver. To maximize the accuracy of the horizontal positioning, the horizontal mask setting was set to 15 degrees and the Position Dilution of Precision (PDOP) limit was set to 6. The position interval was set to 1 second and the Signal to Noise Ratio (SNR) mask was set to 4. The United States Coast Guard reference station used in the survey is located near Sallisaw, Oklahoma.

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 0.4 seconds was produced and adjustments were applied to the raw data in the EDIT program.

Data Processing

The collected data was transferred from the field computer onto an OWRB desktop computer. After downloading the data, each raw data file was reviewed using the EDIT program within HYPACK. The EDIT program allowed the user to assign transducer 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.

Offset correction values of 3.2 ft. starboard, 6.6 ft. forward, and -1.1 ft. vertical were applied to all raw data along with a latency correction factor of 0.1 seconds. The speed of sound corrections were applied during editing of raw data.

A correction file was produced using the HYPACK TIDES program to account for the variance in lake elevation at the time of data collection. Within the EDIT program, the corrected depths were subtracted from the elevation reading to convert the depth in feet to an elevation.

After editing the data for errors and correcting the spatial attributes (offsets and tide corrections), a data reduction scheme was needed due to the large quantity of collected data.. To accomplish this, the corrected data was resampled spatially at a 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 Chandler City Lake are located on the DVD entitled *FEMA 2011 Disk 1 HYPACK/GIS Metadata.*

GIS Application

Geographic Information System (GIS) software was used to process the edited XYZ data collected from the survey. The GIS software used was ArcGIS Desktop and ArcMap, version 9.3.1, from Environmental System Research Institute (ESRI). All of the GIS datasets created are in Oklahoma State Plane North Coordinate System 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 ArcMap point coverage format. The point coverage contains the X and Y horizontal coordinates and the elevation and depth values associated with each collected point.

Volumetric and area calculations were derived using a Triangulated Irregular Network (TIN) surface model. The TIN model was created in ArcMap, using the collected survey data points and the lake boundary inputs. 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 map were derived from a constructed digital elevation model grid. This grid was created using the ArcMap Topo to Raster Tool and had a spatial resolution of five feet. A low pass 3x3 filter was run to lightly smooth the grid to improve contour generation. The contours were created at a 2-ft interval using the ArcMap Contour Tool. The contour lines were edited to allow for polygon topology and to improve accuracy and general smoothness of the lines. The contours were then converted to a polygon coverage and attributed to show 2-ft depth ranges across the lake. The bathymetric maps of the lakes are shown with 2-ft contour intervals in **APPENDIX B: Chandler City** Lake Maps.

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 both lakes is located at on the DVD entitled *FEMA 2011 Disk 1 HYPACK/GIS Metadata.*

RESULTS

Results from the 2011 OWRB survey indicate that Chandler City Lake encompasses 178 acres and contains a cumulative capacity of 2,131 ac-ft at the normal pool elevation (892.5 ft NAVD88). The average depth for Chandler City Lake was 11.97 ft.

SUMMARY and COMPARISON

Table 1 is a comparison of area and volume changes of Chandler City Lake at the normal pool elevation. Based on the design specifications, Chandler City Lake had an area of 192 acres and cumulative volume of 2,778 acre-feet of water at conservation pool elevation (892.5 ft NAVD88). The surface area of the lake has had a decrease of 14 acres or approximately 7%. The 2011 survey shows that Chandler City Lake has had an apparent decrease in capacity of 23.3% or approximately 647 acre-feet. Caution should be used when directly comparing between the design specifications and the 2011 survey conducted by the OWRB because different methods were used to collect the data and extrapolate capacity and area figures. This could account for the apparent loss in capacity. It is the recommendation of the OWRB that another survey using the same method used in the 2011 survey be conducted in 10-15 years. By using the 2011 survey figures as a baseline, a future survey would allow an accurate sedimentation rate to be obtained.

Table 1: Area and Volume Comparisons of Chandler City Lake at normal pool (892.5 ft NAVD88).

Feature	Survey Year	
	1954 Design Specifications	2011
Area (acres)	192	178
Cumulative Volume (acre-feet)	2,778	2,131
Mean depth (ft)	14.47	11.97
Maximum Depth (ft)	--	26.06

REFERENCES

U.S. Army Corps of Engineers (USACE). 2002. Engineering and Design - Hydrographic Surveying, Publication EM 1110-2-1003, 3rd version.

Oklahoma Water Resources Board (OWRB). 1978. Phase 1 Inspection Report; National Dam Safety Program.

Oklahoma Water Resources Board (OWRB). 2010. Lakes of Oklahoma.

APPENDIX A: Area-Capacity Data

Table A. 1: Chandler City Lake Capacity/Area by 0.1-ft Increments.

CHANDLER CITY LAKE AREA-CAPACITY TABLE

OKLAHOMA WATER RESOURCES BOARD

2011 Survey

Capacity in acre-feet by tenth foot elevation increments

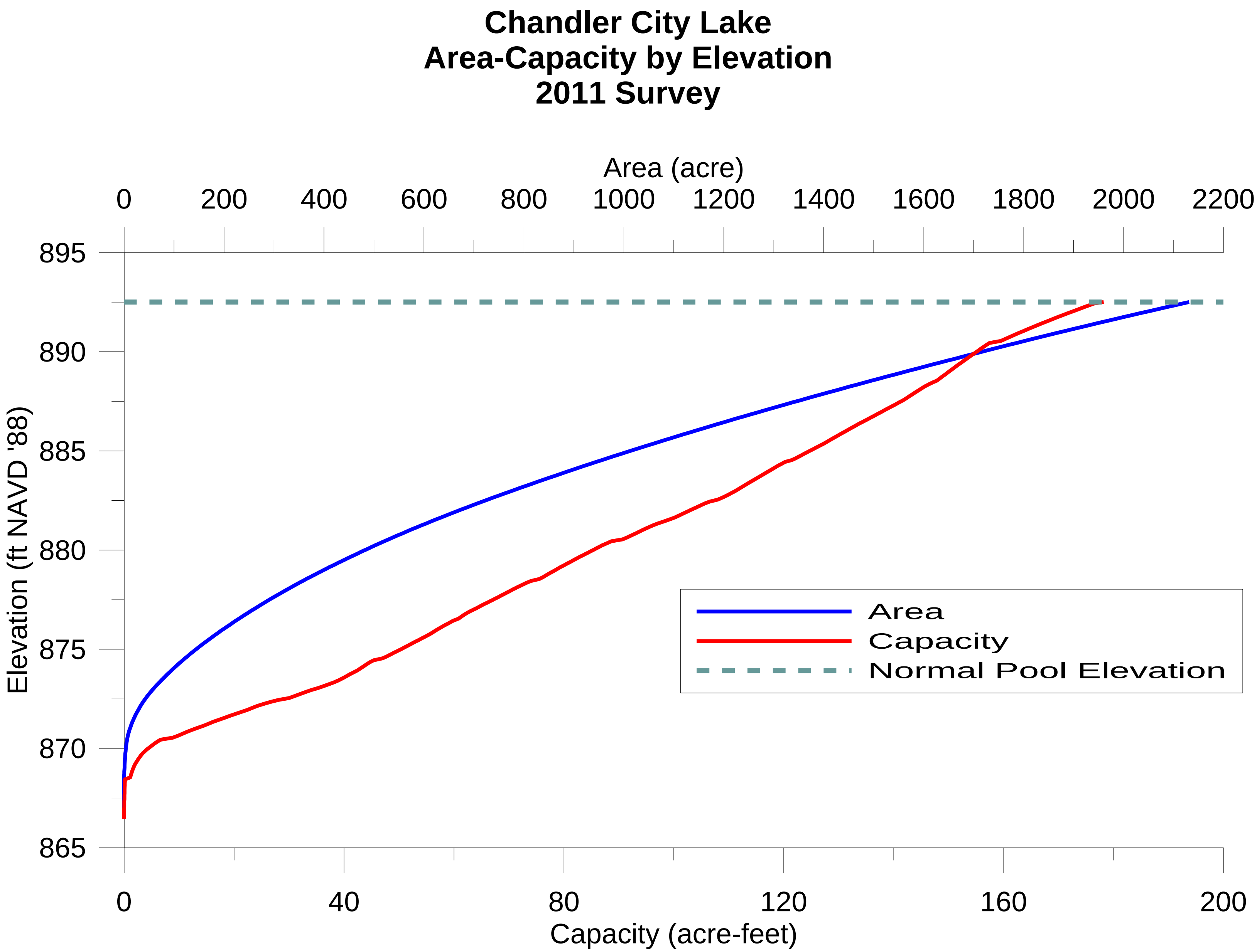
Area in acres by tenth foot elevation increments

Elevation (ft NAVD '88)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
866	Area	0.0000	0.0000	0.0000	0.0000	0.0000	0.0143	0.0183	0.0224	0.0267	0.0313
	Capacity	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0022	0.0042	0.0067	0.0096
867	Area	0.0362	0.0413	0.0468	0.0526	0.0589	0.0662	0.0743	0.0829	0.0921	0.1024
	Capacity	0.0129	0.0168	0.0212	0.0262	0.0318	0.0380	0.0450	0.0529	0.0616	0.0713
868	Area	0.1142	0.1277	0.1431	0.1629	0.1877	1.1337	1.2342	1.3419	1.4588	1.5856
	Capacity	0.0822	0.0942	0.1078	0.1230	0.1405	0.1968	0.3153	0.4440	0.5840	0.7361
869	Area	1.7260	1.8903	2.0883	2.3140	2.5514	2.7898	3.0445	3.3537	3.7190	4.1169
	Capacity	0.9015	1.0822	1.2808	1.5008	1.7441	2.0111	2.3028	2.6224	2.9765	3.3675
870	Area	4.6052	5.0470	5.5265	6.0523	6.6216	8.8601	9.8124	10.679	11.529	12.393
	Capacity	3.8021	4.2844	4.8130	5.3919	6.0250	6.7788	7.7139	8.7387	9.8498	11.045
871	Area	13.421	14.431	15.349	16.208	17.205	18.259	19.269	20.275	21.360	22.395
	Capacity	12.333	13.727	15.216	16.795	18.462	20.237	22.114	24.090	26.173	28.362
872	Area	23.301	24.245	25.372	26.634	28.095	30.026	31.070	32.053	33.005	34.066
	Capacity	30.647	33.024	35.503	38.103	40.838	43.744	46.801	49.958	53.213	56.564
873	Area	35.226	36.343	37.352	38.266	39.101	39.825	40.457	41.124	41.803	42.488
	Capacity	60.028	63.610	67.295	71.079	74.948	78.896	82.912	86.990	91.139	95.353
874	Area	43.059	43.584	44.134	44.719	45.389	47.059	47.813	48.525	49.238	49.958
	Capacity	99.630	103.97	108.35	112.80	117.30	121.91	126.66	131.47	136.36	141.32
875	Area	50.668	51.378	52.061	52.717	53.420	54.120	54.841	55.510	56.115	56.686
	Capacity	146.35	151.46	156.63	161.87	167.18	172.55	178.00	183.52	189.10	194.74
876	Area	57.265	57.901	58.561	59.234	59.912	60.828	61.371	61.888	62.489	63.169
	Capacity	200.44	206.20	212.02	217.92	223.87	229.91	236.02	242.18	248.40	254.69
877	Area	63.888	64.597	65.263	66.006	66.760	67.468	68.162	68.862	69.550	70.237
	Capacity	261.04	267.47	273.96	280.52	287.16	293.87	300.66	307.51	314.43	321.42
878	Area	70.936	71.657	72.401	73.181	74.024	75.568	76.235	76.855	77.485	78.131
	Capacity	328.48	335.61	342.81	350.10	357.45	364.93	372.52	380.18	387.90	395.68
879	Area	78.780	79.426	80.087	80.765	81.431	82.102	82.776	83.486	84.221	84.959
	Capacity	403.52	411.44	419.41	427.46	435.57	443.74	451.99	460.30	468.69	477.14
880	Area	85.627	86.309	87.041	87.830	88.654	90.693	91.582	92.348	93.084	93.833
	Capacity	485.67	494.27	502.94	511.69	520.51	529.46	538.58	547.78	557.05	566.40
881	Area	94.600	95.380	96.204	97.089	98.212	99.239	100.18	100.98	101.74	102.52
	Capacity	575.82	585.32	594.90	604.57	614.33	624.20	634.18	644.24	654.38	664.59
882	Area	103.27	104.02	104.80	105.61	106.50	108.01	108.85	109.60	110.29	110.96
	Capacity	674.88	685.25	695.69	706.22	716.82	727.54	738.39	749.31	760.31	771.37
883	Area	111.58	112.19	112.79	113.40	114.01	114.62	115.24	115.84	116.45	117.07
	Capacity	782.50	793.69	804.94	816.26	827.63	839.06	850.56	862.11	873.73	885.40
884	Area	117.68	118.30	118.93	119.58	120.25	121.52	122.29	123.00	123.64	124.34
	Capacity	897.14	908.94	920.80	932.74	944.73	956.80	969.00	981.26	993.60	1006.0
885	Area	125.05	125.73	126.43	127.12	127.77	128.40	129.03	129.67	130.31	130.95
	Capacity	1018.5	1031.0	1043.6	1056.3	1069.0	1081.9	1094.7	1107.7	1120.7	1133.7
886	Area	131.59	132.23	132.87	133.53	134.20	134.93	135.60	136.27	136.94	137.60
	Capacity	1146.9	1160.1	1173.3	1186.6	1200.0	1213.5	1227.0	1240.6	1254.3	1268.0

Table A. 2: Chandler City Lake Capacity/Area by 0.1-ft Increments (cont).

CHANDLER CITY LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2011 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NAVD '88)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
887	Area	138.27	138.96	139.64	140.33	141.02	141.66	142.26	142.82	143.37	143.92
	Capacity	1281.8	1295.7	1309.6	1323.6	1337.7	1351.8	1366.0	1380.2	1394.6	1408.9
888	Area	144.49	145.06	145.64	146.29	147.05	147.89	148.36	148.84	149.32	149.81
	Capacity	1423.3	1437.8	1452.4	1467.0	1481.6	1496.4	1511.2	1526.1	1541.0	1555.9
889	Area	150.29	150.78	151.28	151.77	152.27	152.77	153.28	153.79	154.30	154.81
	Capacity	1570.9	1586.0	1601.1	1616.3	1631.5	1646.7	1662.0	1677.4	1692.8	1708.2
890	Area	155.33	155.85	156.37	156.90	157.43	159.51	160.31	161.12	161.94	162.77
	Capacity	1723.7	1739.3	1754.9	1770.6	1786.3	1802.1	1818.1	1834.2	1850.4	1866.6
891	Area	163.61	164.47	165.33	166.21	167.10	168.00	168.91	169.84	170.77	171.72
	Capacity	1882.9	1899.3	1915.8	1932.4	1949.1	1965.8	1982.7	1999.6	2016.6	2033.8
892	Area	172.68	173.65	174.63	175.62	176.62	178.21				
	Capacity	2051.0	2068.3	2085.7	2103.2	2120.8	2131.5				

Figure A. 1. Area-Capacity Curve for Chandler City Lake



APPENDIX B: Chandler City Lake Maps

Figure B. 1: Chandler City Lake Bathymetric Map with 2-foot Contour Intervals.

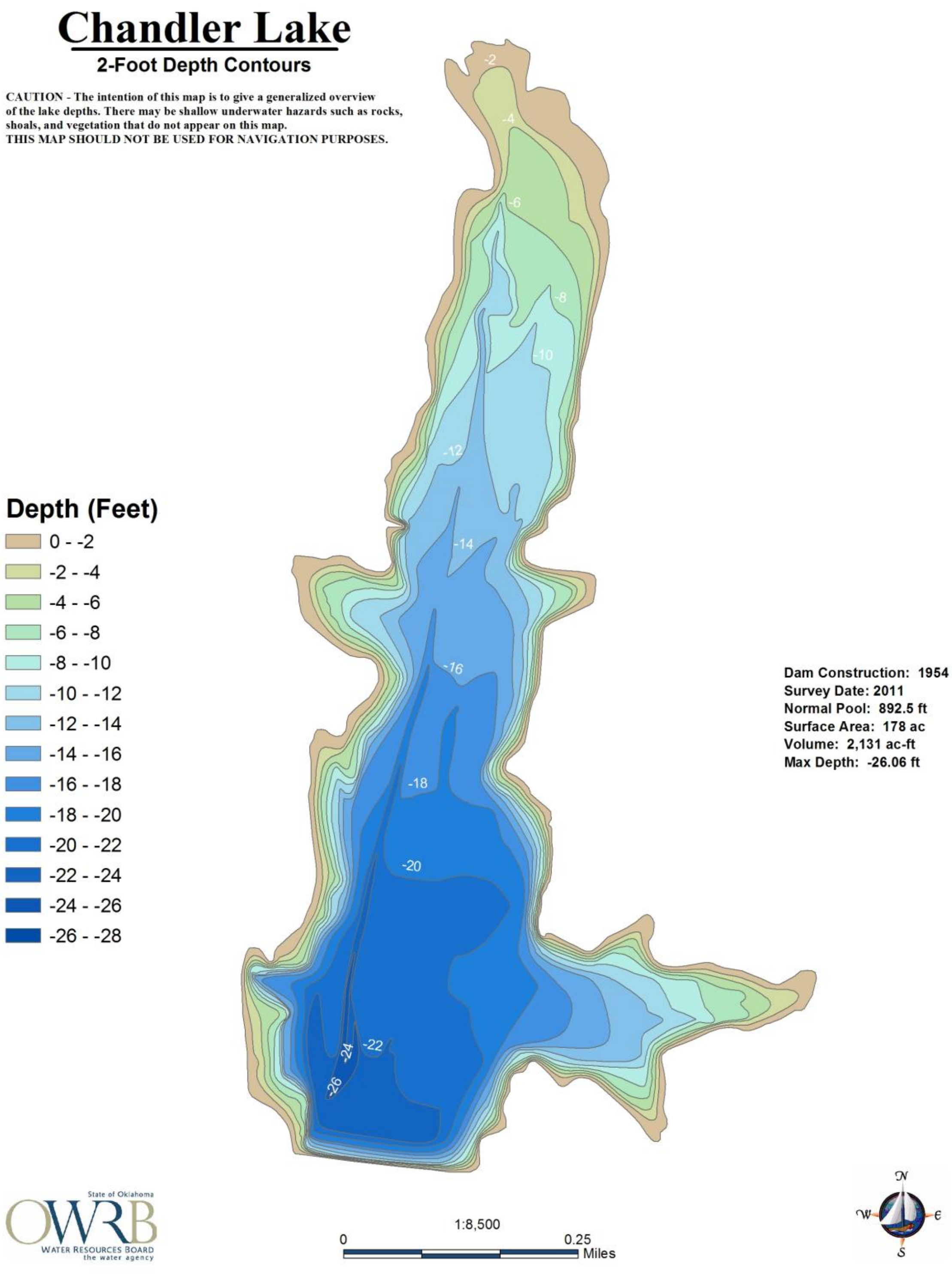


Figure B. 2: Chandler City Lake Shaded Relief Bathymetric Map.

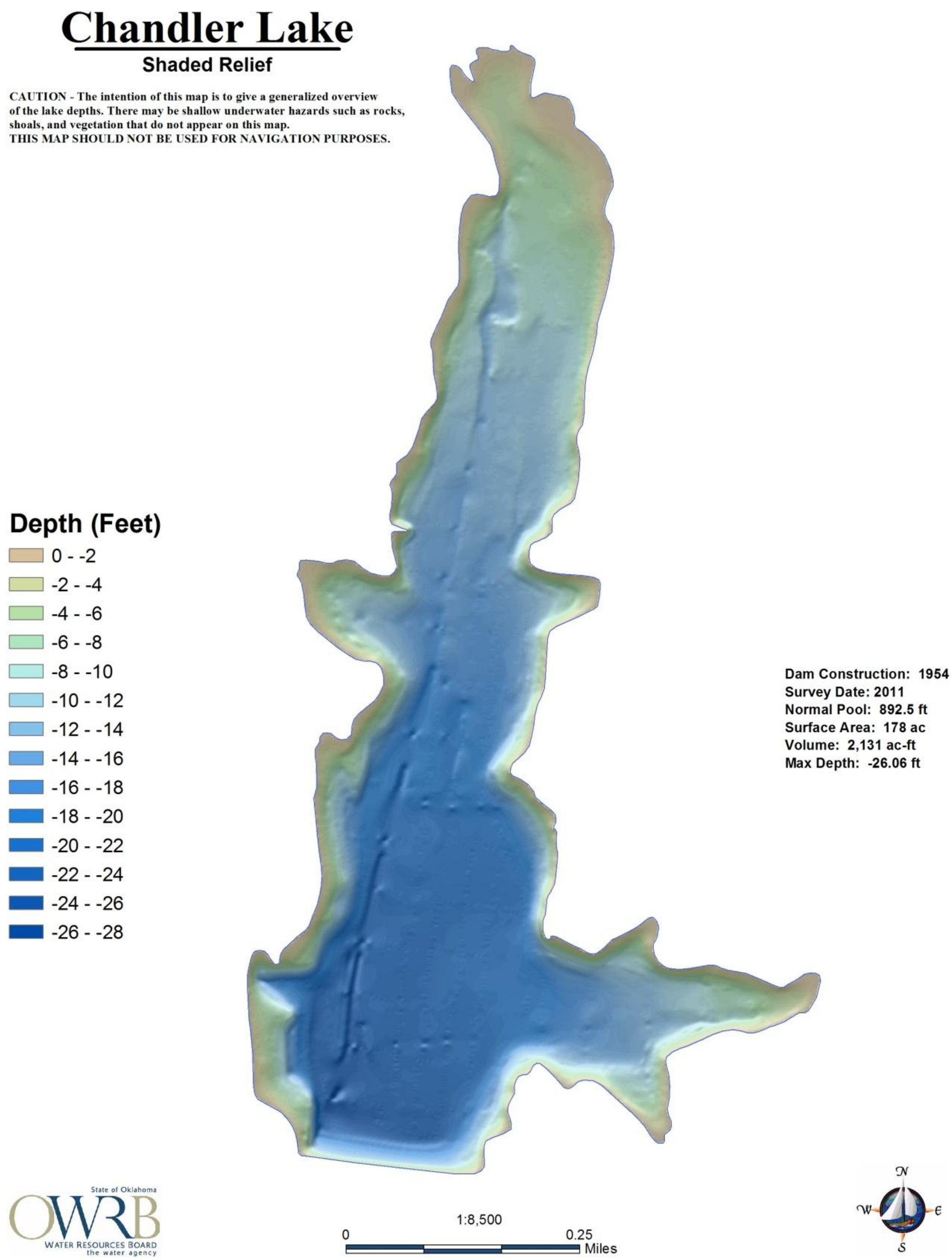


Figure B. 3: Chandler City Lake Collected Data Points.