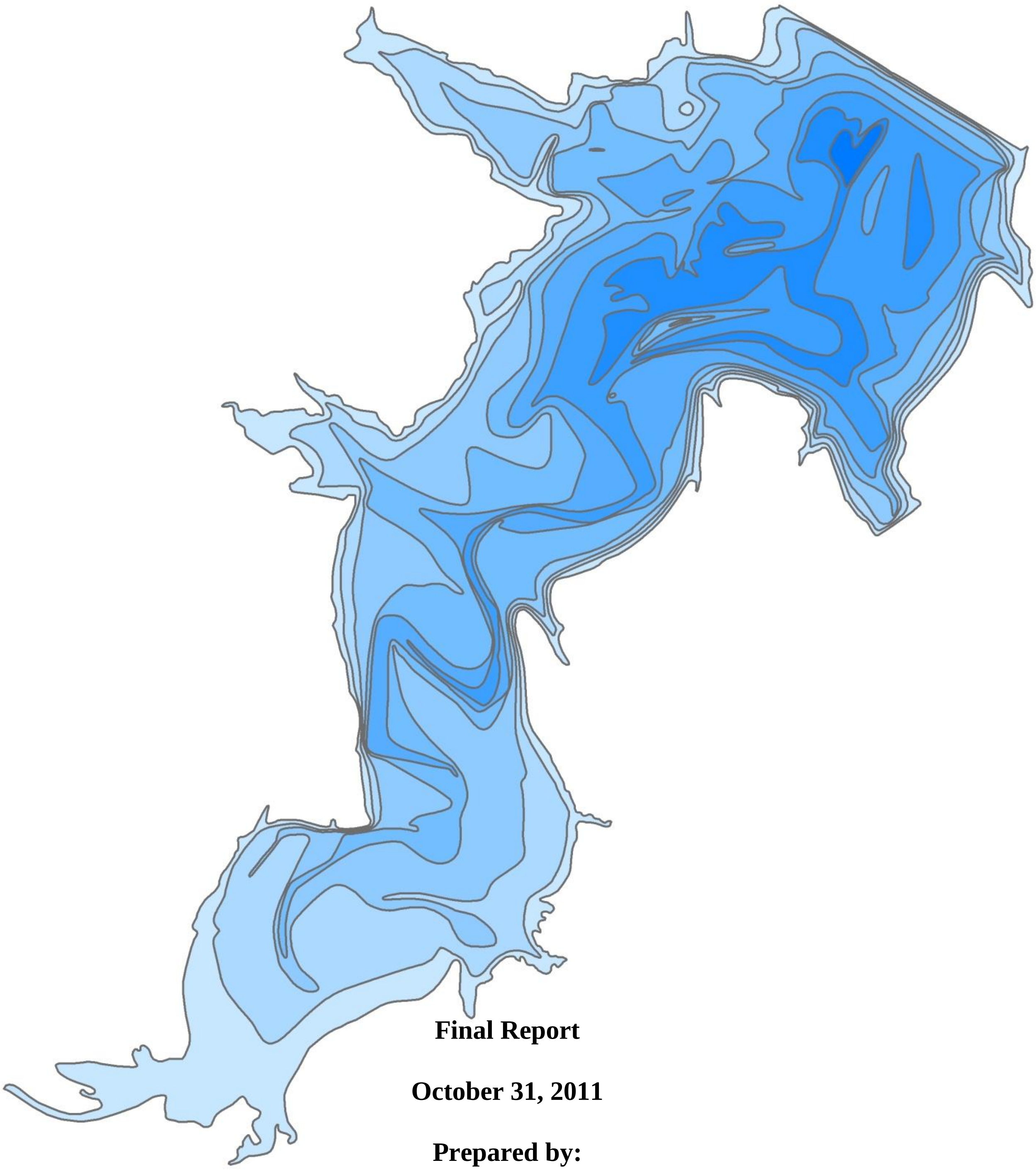
HYDROGRAPHIC SURVEY of DURANT LAKE



Final Report

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DURANT LAKE
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of Durant Lake in March 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

Durant Lake is located on the Lower Little Blue River in Bryan County, OK (**Figure 1**). The dam is located in Sec. 32-T5S-R9EI, approximately 7.6 miles north of the City of Durant. The dam was constructed in 1993. The dam on this reservoir is classified as a high hazard dam. The "high hazard" classification means that dam failure, if it occurred, may cause loss of life, serious damage to homes, industrial or commercial buildings, important public utilities, main highways or railroads. This classification does not mean that it is likely to fail.

Figure 1: Location map for Durant 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

<u>Boundary File</u>

The boundary file for Durant Lake was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) mosaic of Bryan 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 South-3502).

<u>Set-up</u>

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-3502 Oklahoma South 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 24 virtual transects were created for the Durant Lake.

Field Survey

<u>Lake Elevation Acquisition</u>

The lake elevation for Durant Lake was obtained by collecting positional data over a period of approximately 84 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 Durant Lake occurred in March of 2011. The water level elevation for Durant Lake was 623.8 ft NAVD 88. 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 22 cross-sections points at Durant Lake were used to compute error estimates. A mean difference (arithmetic mean) of 0.01 ft and a standard deviation of 0.195 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 ± 0.38 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 0.01 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 0.4 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. The elevation of the lake during the survey was 623.8 ft North American Vertical Datum of 1988 (NAVD 88).

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 Durant Lake are located on the DVD entitled *FEMA 2011 HYPACK/GIS Metadata Disk 1*.

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 5-ft depth ranges across the lake. The bathymetric maps of the lakes are shown with 5-ft contour intervals in **APPENDIX B: Durant 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 HYPACK/GIS Metadata Disk 1*.

RESULTS

Results from the 2011 OWRB survey indicate that Durant Lake encompasses 278.9 acres and contains a cumulative capacity of 4,309.1 ac-ft at the normal pool elevation (624.5 ft NAVD 88). The average depth for Durant Lake was 15.0 ft.

SUMMARY and COMPARISON

Table 1 is comparison of area and volume changes of Durant Lake at the normal pool elevation. Based on the design specifications, Durant Lake had an area of 307 acres and cumulative volume of 4,121 acre-feet of water at normal pool elevation (624.5 ft NAVD 88). The surface area of the lake has had a decrease of 28.1 acres or approximately 9%. The 2011 survey shows that Durant Lake has had an apparent increase in capacity of 4.6% or approximately 188 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. 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 Durant Lake at normal pool (624.5 ft NAVD 88).

Feature	Survey Year	
	1993 Design Specifications	2011
Area (acres)	307	278.9
Cumulative Volume (acre-feet)	4,121	4,309
Mean depth (ft)	15.0	15.4
Maximum Depth (ft)	--	39.0

REFERENCES

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

APPENDIX A: Area-Capacity Data

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

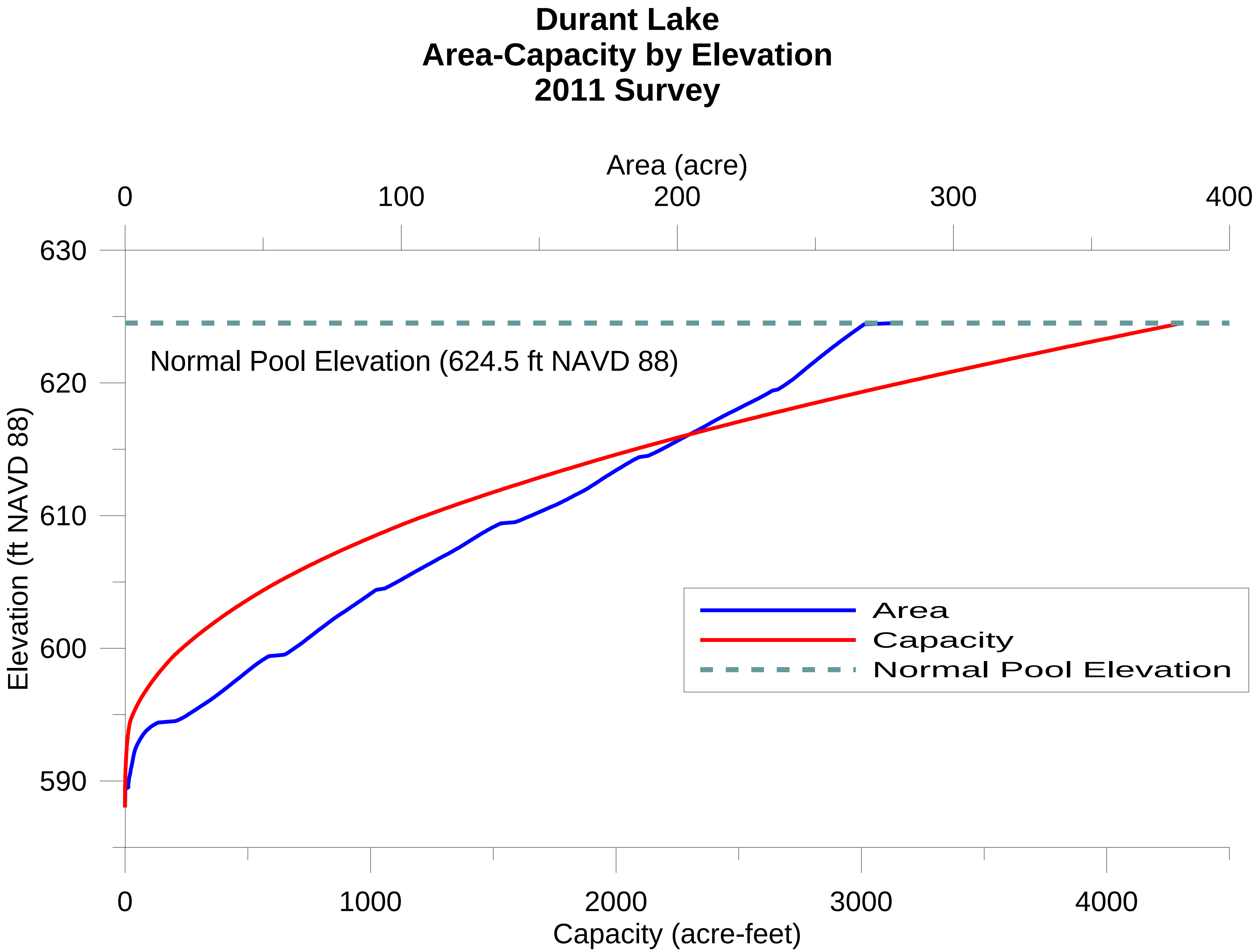
DURANT LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2011 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NAVD 88)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
588	Area	0.0000	0.0016	0.0055	0.0111	0.0177	0.0250	0.0332	0.0421	0.0517	0.0621
	Capacity	0.0000	0.0001	0.0004	0.0012	0.0026	0.0048	0.0077	0.0114	0.0161	0.0218
589	Area	0.0731	0.0847	0.0971	0.1101	0.1239	1.1469	1.1853	1.2197	1.2553	1.2924
	Capacity	0.0286	0.0364	0.0455	0.0559	0.0676	0.0807	0.1974	0.3177	0.4414	0.5688
590	Area	1.3334	1.3883	1.4736	1.5906	1.6943	1.7866	1.8786	1.9675	2.0547	2.1478
	Capacity	0.7001	0.8359	0.9788	1.1318	1.2963	1.4704	1.6536	1.8461	2.0471	2.2574
591	Area	2.2461	2.3415	2.4338	2.5237	2.6145	2.7065	2.7982	2.8912	2.9922	3.0957
	Capacity	2.4770	2.7064	2.9453	3.1932	3.4502	3.7162	3.9914	4.2760	4.5701	4.8747
592	Area	3.2003	3.3095	3.4241	3.5666	3.7335	3.9180	4.1136	4.3439	4.5857	4.8313
	Capacity	5.1894	5.5148	5.8516	6.2008	6.5658	6.9484	7.3496	7.7724	8.2189	8.6898
593	Area	5.0936	5.3691	5.6650	5.9787	6.2923	6.6208	6.9716	7.3633	7.8252	8.3439
	Capacity	9.1859	9.7089	10.261	10.843	11.456	12.102	12.781	13.498	14.256	15.065
594	Area	8.8999	9.5091	10.243	11.088	12.039	18.230	19.419	20.402	21.289	22.107
	Capacity	15.927	16.846	17.833	18.899	20.055	21.316	23.203	25.196	27.281	29.453
595	Area	22.861	23.595	24.332	25.075	25.819	26.555	27.292	28.033	28.783	29.515
	Capacity	31.701	34.023	36.421	38.891	41.437	44.055	46.747	49.515	52.355	55.272
596	Area	30.234	30.938	31.620	32.279	32.927	33.566	34.204	34.841	35.474	36.099
	Capacity	58.259	61.318	64.447	67.642	70.904	74.228	77.616	81.070	84.586	88.166
597	Area	36.718	37.329	37.938	38.539	39.136	39.741	40.351	40.957	41.562	42.170
	Capacity	91.807	95.509	99.274	103.10	106.98	110.93	114.93	119.00	123.12	127.31
598	Area	42.778	43.391	44.000	44.600	45.195	45.787	46.397	47.018	47.652	48.311
	Capacity	131.56	135.87	140.24	144.67	149.16	153.71	158.32	162.99	167.72	172.52
599	Area	49.012	49.739	50.490	51.286	52.163	57.655	58.544	59.308	60.023	60.714
	Capacity	177.39	182.33	187.34	192.43	197.60	202.87	208.68	214.57	220.54	226.58
600	Area	61.398	62.098	62.804	63.486	64.126	64.753	65.366	65.978	66.594	67.212
	Capacity	232.68	238.86	245.11	251.42	257.80	264.25	270.75	277.32	283.95	290.65
601	Area	67.837	68.463	69.089	69.720	70.355	71.002	71.651	72.288	72.923	73.561
	Capacity	297.40	304.21	311.09	318.03	325.04	332.11	339.24	346.44	353.70	361.03
602	Area	74.200	74.841	75.495	76.168	76.874	77.599	78.339	79.068	79.789	80.501
	Capacity	368.41	375.87	383.39	390.97	398.62	406.35	414.14	422.02	429.96	437.98
603	Area	81.209	81.906	82.606	83.317	84.038	84.744	85.440	86.137	86.834	87.526
	Capacity	446.06	454.22	462.45	470.74	479.11	487.55	496.06	504.64	513.29	522.01
604	Area	88.208	88.887	89.571	90.267	90.981	94.053	95.028	95.937	96.850	97.739
	Capacity	530.80	539.65	548.58	557.57	566.64	575.77	585.23	594.78	604.42	614.15
605	Area	98.629	99.518	100.39	101.23	102.07	102.90	103.72	104.55	105.43	106.29
	Capacity	623.97	633.88	643.88	653.96	664.13	674.38	684.71	695.12	705.62	716.21
606	Area	107.16	108.04	108.93	109.82	110.69	111.55	112.42	113.28	114.14	115.01
	Capacity	726.89	737.64	748.50	759.43	770.46	781.58	792.77	804.06	815.43	826.90
607	Area	115.93	116.85	117.73	118.61	119.46	120.29	121.11	121.90	122.68	123.46
	Capacity	838.44	850.08	861.82	873.63	885.54	897.53	909.60	921.75	933.98	946.30
608	Area	124.24	125.00	125.76	126.52	127.29	128.08	128.87	129.68	130.50	131.33
	Capacity	958.7	971.1	983.7	996.3	1009.0	1021.8	1034.6	1047.5	1060.5	1073.6

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

DURANT 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
609	Area	132.20	133.10	134.05	135.03	136.04	141.26	142.69	143.84	144.96	146.09
	Capacity	1,086.8	1,100.1	1,113.4	1,126.9	1,140.5	1,154.1	1,168.3	1,182.7	1,197.1	1,211.7
610	Area	147.20	148.31	149.46	150.56	151.63	152.71	153.77	154.90	156.13	157.11
	Capacity	1,226.3	1,241.1	1,256.0	1,271.0	1,286.1	1,301.3	1,316.6	1,332.1	1,347.6	1,363.3
611	Area	158.07	159.02	159.97	160.90	161.81	162.72	163.63	164.60	165.53	166.43
	Capacity	1,379.1	1,394.9	1,410.9	1,426.9	1,443.1	1,459.3	1,475.6	1,492.0	1,508.5	1,525.1
612	Area	167.26	168.05	168.81	169.54	170.27	171.01	171.74	172.48	173.20	173.94
	Capacity	1,541.8	1,558.6	1,575.4	1,592.3	1,609.3	1,626.4	1,643.5	1,660.8	1,678.0	1,695.4
613	Area	174.69	175.47	176.27	177.05	177.85	178.65	179.44	180.23	181.01	181.81
	Capacity	1,712.8	1,730.3	1,747.9	1,765.6	1,783.4	1,801.2	1,819.1	1,837.1	1,855.1	1,873.3
614	Area	182.64	183.48	184.34	185.25	186.31	189.49	190.62	191.64	192.61	193.55
	Capacity	1,891.5	1,909.8	1,928.2	1,946.7	1,965.3	1,984.0	2,003.0	2,022.1	2,041.3	2,060.6
615	Area	194.49	195.42	196.32	197.21	198.09	198.99	199.88	200.77	201.66	202.57
	Capacity	2,080.0	2,099.5	2,119.1	2,138.8	2,158.6	2,178.4	2,198.3	2,218.4	2,238.5	2,258.7
616	Area	203.49	204.42	205.35	206.28	207.20	208.10	208.99	209.86	210.72	211.57
	Capacity	2,279.0	2,299.4	2,319.9	2,340.5	2,361.2	2,381.9	2,402.8	2,423.8	2,444.8	2,465.9
617	Area	212.43	213.27	214.14	215.02	215.93	216.85	217.79	218.74	219.69	220.65
	Capacity	2,487.1	2,508.4	2,529.8	2,551.2	2,572.8	2,594.4	2,616.1	2,638.0	2,659.9	2,681.9
618	Area	221.63	222.58	223.53	224.47	225.42	226.38	227.34	228.31	229.26	230.17
	Capacity	2,704.0	2,726.3	2,748.6	2,771.0	2,793.5	2,816.1	2,838.7	2,861.5	2,884.4	2,907.4
619	Area	231.05	231.92	232.77	233.61	234.45	236.51	237.30	238.05	238.76	239.48
	Capacity	2,930.5	2,953.6	2,976.8	3,000.2	3,023.6	3,047.1	3,070.8	3,094.5	3,118.4	3,142.3
620	Area	240.19	240.88	241.54	242.16	242.75	243.34	243.93	244.51	245.09	245.67
	Capacity	3,166.3	3,190.3	3,214.5	3,238.6	3,262.9	3,287.2	3,311.6	3,336.0	3,360.5	3,385.0
621	Area	246.25	246.84	247.42	248.00	248.59	249.18	249.76	250.36	250.95	251.55
	Capacity	3,409.6	3,434.3	3,459.0	3,483.8	3,508.6	3,533.5	3,558.4	3,583.5	3,608.5	3,633.7
622	Area	252.16	252.76	253.37	253.99	254.61	255.23	255.85	256.48	257.11	257.75
	Capacity	3,658.8	3,684.1	3,709.4	3,734.8	3,760.2	3,785.7	3,811.2	3,836.9	3,862.6	3,888.3
623	Area	258.38	259.03	259.67	260.32	260.97	261.63	262.29	262.95	263.62	264.29
	Capacity	3,914.1	3,940.0	3,965.9	3,991.9	4,018.0	4,044.1	4,070.3	4,096.6	4,122.9	4,149.3
624	Area	264.97	265.64	266.32	267.01	267.70	278.91				
	Capacity	4,175.8	4,202.3	4,228.9	4,255.6	4,282.3	4,309.1				

Figure A. 1. Area-Capacity Curve for Durant Lake



APPENDIX B: Durant Lake Maps

Figure B. 1: Durant Lake Bathymetric Map with 5-foot Contour Intervals.

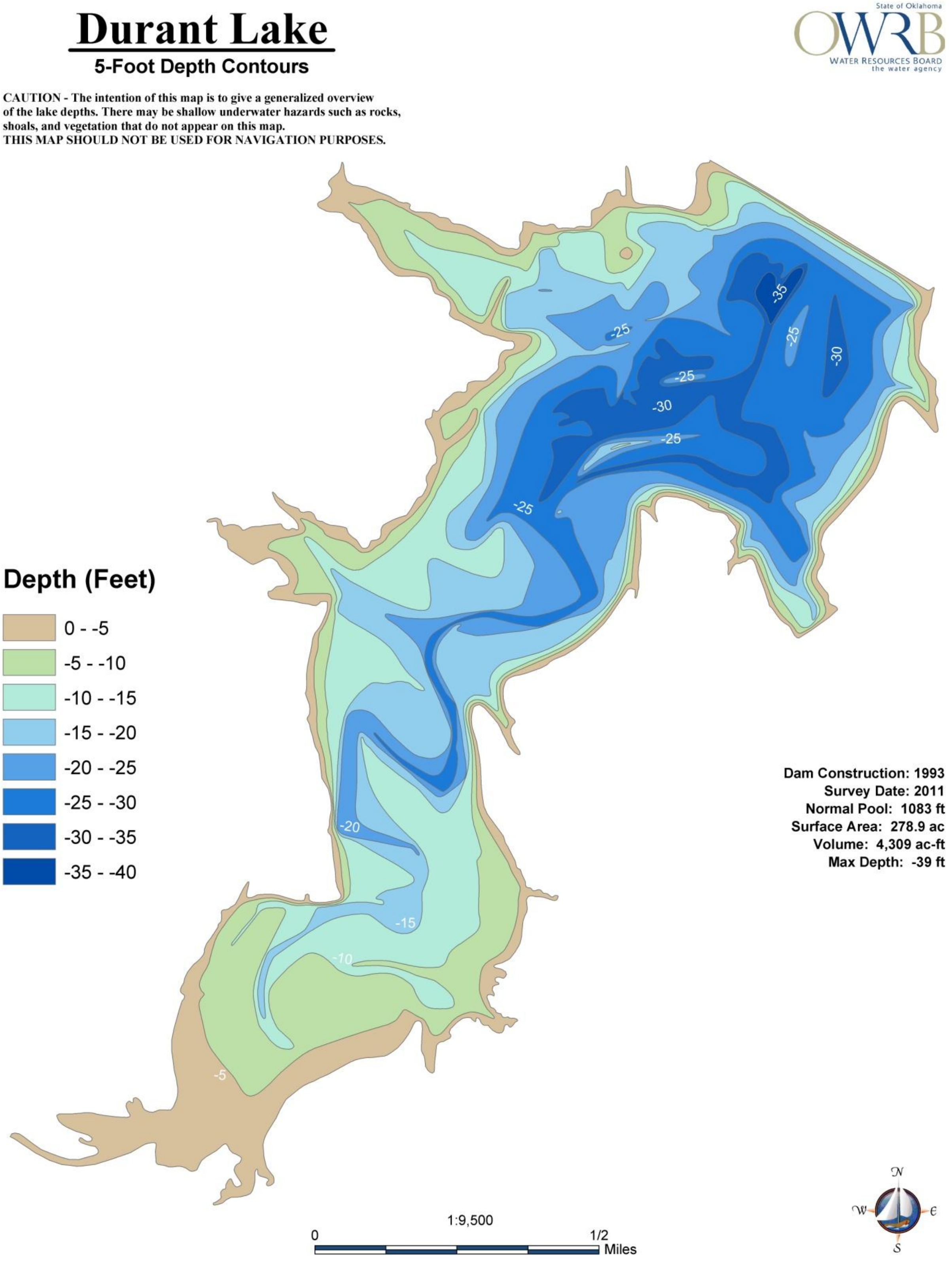


Figure B. 2: Durant Lake Shaded Relief Bathymetric Map.

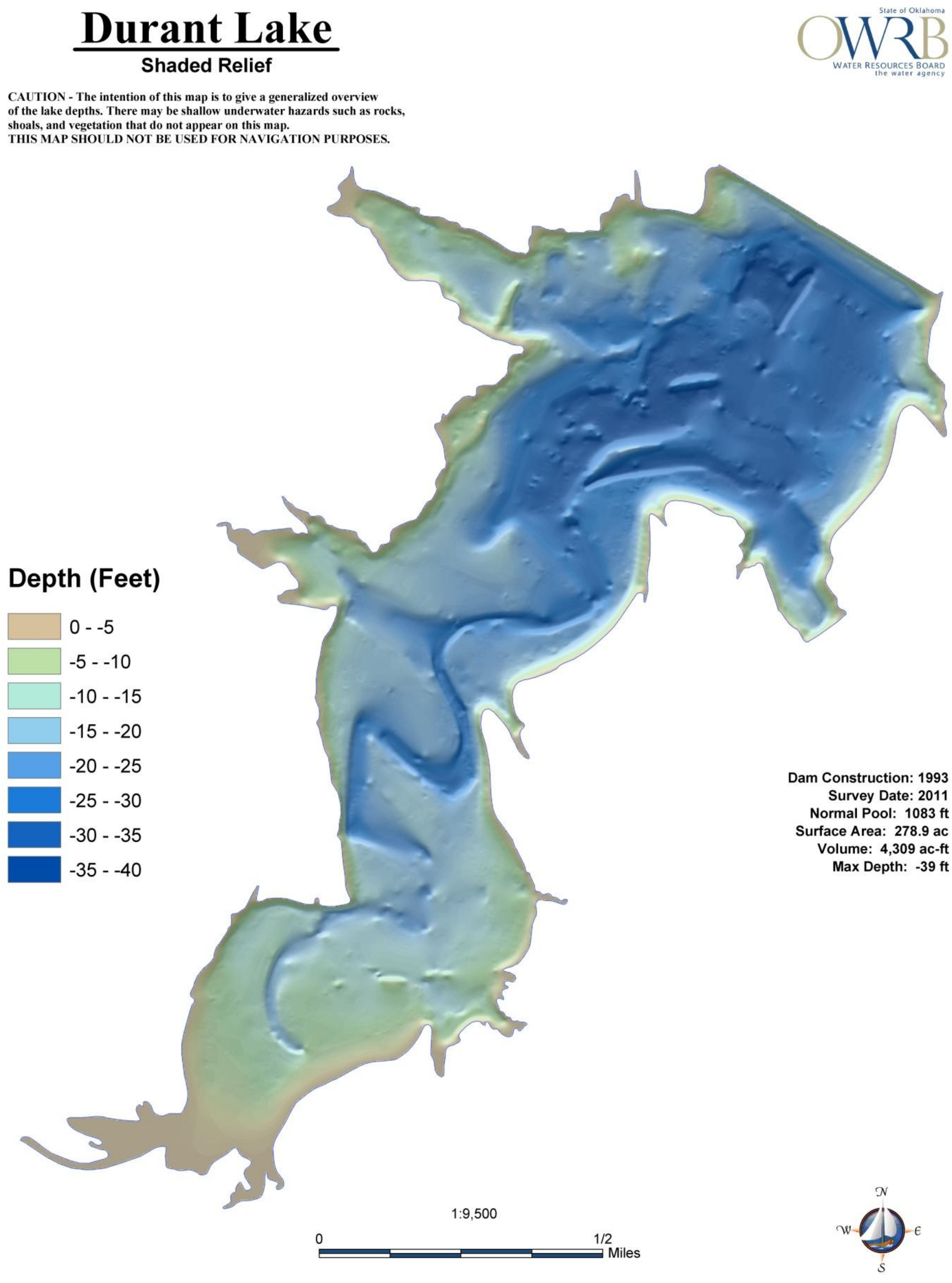


Figure B. 3: Durant Lake Collected Data Points.