HYDROGRAPHIC SURVEY of LAKE JEAN NEUSTADT and LAKE SCOTT KING

Lake Jean Neustadt

Lake Scott King

Final Report

June 5, 2009

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LAKE JEAN NEUSTADT and LAKE SCOTT KING HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of Lake Jean Neustadt in March of 2008 and of Lake Scott King in June of 2008. The purpose of these surveys was to collect hydrographic data of the lakes and convert this information into an area-elevation-volume table for each lake. This project was funded by the OWRB's Dam Safety Program.

LAKE BACKGROUND

Lake Jean Neustadt and Lake Scott King are located on tributaries of Caddo Creek in Carter County (see **[Figure 1](#page-4-0)**). Both are currently used as water supply sources for the City of Ardmore. Lake Jean Neustadt was built in 1969. Lake Scott King, formerly known as Rock Creek Reservoir, was built in 1979. The dams on both reservoirs are classified as high hazard dams. 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 they are likely to fail.

Figure 1: Location map for Lakes Jean Neustadt and Scott King.

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 after the survey is completed. 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 files for Lake Jean Neustadt and Lake Scott King were on-screen digitized from the 2006 color digital ortho quarter quad mosaic of Carter County, Oklahoma. The screen scale was set to 1:1,500. The digitized line is 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 1995 DOQQs of the lakes were used as back ground reference. The reservoir boundaries were digitized in NAD 1983 State Plane Coordinates (Oklahoma South-3502).

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-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 72 virtual transects were created for the Lake Jean Neustadt and 30 transects were created for Lake Scott King.

Field Survey

Lake Elevation Acquisition

The lake elevation for Lake Jean Neustadt was obtained by measuring from a temporary monument with a known elevation. Both temporary monuments consist of an "X" chiseled on the boat ramp of each lake. These monuments were obtained through Charles Brady III, GIS Coordinator with the City of Ardmore.

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; Syqwest Bathy 1500 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 Lake Jean Neustadt occurred on March 4 and 5, 2008. Data collection for Lake Scott King occurred on June 18, 2008. The water level elevation in March at Lake Jean Neustadt was 808.95 ft NGVD. The water level elevation on June 18 at Lake Scott King was 807.13 ft NGVD. Data collection began at the dam and moved downstream. 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, the Syqwest Bathy 1500 Echo Sounder was calibrated 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. The average speed of sound in the water column ranged from 4,741.7 ft/sec to 4,747.6 ft/sec during the Lake Jean Neustadt survey. The speed of sound in the water column was 4,891.3 ft/sec to 4,933.6 ft/sec during the Lake Scott King survey. The sound velocity profiles for each date of surveying are shown in **[APPENDIX A:](#page-13-0) [Sound Velocity Profile](#page-13-0)**.

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 should not exceed a tolerance of ± 2.0 ft for this type of survey. This is done to verify compliance with the resultant depth accuracy of ± 2.0 ft at the 95% confidence level. 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 89 cross-sections points at Lake Jean Neustadt were used to compute error estimates. A mean difference of 0.12 ft and a standard deviation of 0.24 ft were computed from intersections. Using the following formulas, a 95% depth accuracy of \pm 0.5 ft was calculated.

$$
RMS = \sqrt{SD^2 + MD^2}
$$

RMS (95%) *depthaccuracy* = $1.96 \times RMS$

where:

 $=$ \times

 $=$ +

 $MD =$ mean difference *SD* = standard deviation *RMS* = root mean square error

An RMS of \pm 0.5 ft with a 95% level is less than the USACE's minimum performance standard of \pm 2.0 ft for this type of survey. A mean difference, or bias, of 0.12 ft is well below the USACE's standard maximum allowable bias of \pm 0.5 ft for this type of survey. The data plotted in **[Figure 2](#page-8-0)** illustrates that the measurements have a high precision and high accuracy (USACE, 2002).

Quality Assurance Cross-line Check

Figure 2: Histogram of relative depth distribution at cross check lines - in standard deviation.

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 surveys is located near Sallisaw, Oklahoma. The reference beacon system transmitted corrected signals in real time, so no post-processing corrections of position data were needed.

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 0.1 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 readings from the sound profiling velocimeter are documented in **[APPENDIX A: Sound](#page-13-0) [Velocity Profile](#page-13-0)**.

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. To accomplish this, the corrected data was resampled spatially at a 10 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 Lakes Neustadt and King are located on the DVD entitled *Neustadt_King 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 9.2, from Environmental System Research Institute (ESRI). All of the GIS datasets created are in Oklahoma State Plane South 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 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. Approximately 27,000 data points were used to create the TIN model for Lake Jean Neustadt. The TIN model for Lake Scott King was created by using approximately 15,170 data points. 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 B: Area-Capacity Data.](#page-16-0)**

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 5-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 C: Lake Jean Neustadt and](#page-24-0) [Lake Scott King Maps](#page-24-0)**.

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 *Neustadt_King HYPACK/GIS Metadata.*

RESULTS

Results from the 2008 OWRB survey indicate that Lake Jean Neustadt encompasses 459 acres and contains a cumulative capacity of 6,400 ac-ft at the normal pool elevation (809.04 ft NGVD). The average depth for Lake Jean Neustadt was 7.2 ft. Results from the 2008 OWRB survey of Lake Scott King indicates that it encompasses 232 acres and contains a cumulative capacity of 3,551 ac-ft at the normal pool elevation (808.08 ft NGVD). The average depth for Lake Scott King was 6.5 ft.

SUMMARY and COMPARISON

[Table](#page-10-2) 1 is comparison of area and volume changes of Lake Jean Neustadt at the normal pool elevation. Based on the design specifications, Lake Jean Neustadt had an area of 462 acres and cumulative volume of 6,106 acre-feet of water at normal pool elevation (809.04 ft NGVD). The surface area of the lake has had a nominal change of less than 1% or approximately 3 acres. The 2008 survey shows that Lake Jean Neustadt has an apparent increase in capacity of 4.8% or approximately 294 acre-feet. Caution should be used when directly comparing between the design specifications and the 2008 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 gain in capacity, which is unlikely to be seen in Oklahoma reservoirs. It is the recommendation of the OWRB that another survey using the same method used in the 2008 survey be conducted in 10-15 years. By using the 2008 survey figures as a baseline, a future survey would allow an accurate sedimentation rate to be obtained.

Feature	Survey Year	
	Design Specifications	2008
Area (acres)	462	459
Cumulative Volume (acre-feet)	6,106	6,400
Mean depth (ft)	13.2	13.9
Maximum Depth (ft)		

Table 1: Area and Volume Comparisons of Jean Neustadt at Normal Pool Elevation (809 ft).

[Table 2](#page-11-0) is comparison of area and volume changes of Lake Scott King at the normal pool elevation. Based on the design specifications, Lake Scott King had an area of 248 acres and cumulative volume of 3,588 acre-feet of water at normal pool elevation (808.08 ft NGVD). The surface area of the lake has decreased 6.5% or approximately 16 acres. Lake Scott King has had a 1% decrease in capacity or a loss of approximately 37 acre-feet. However, caution should be used when directly comparing between the design specifications and the 2008 survey conducted by the OWRB as 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 2008 survey be conducted in 10-15 years. By using the 2008 survey figures as a baseline, a future survey would allow an accurate sedimentation rate to be obtained.

REFERENCES

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

APPENDIX A: Sound Velocity Profile

Table A. 1: Sound Velocity Profile Data (ft/sec) for March 4 & 5 and June 18, 2008.

Figure A. 1: Sound Velocity Profiles for March 4 & 5 and June 18, 2008.

APPENDIX B: Area-Capacity Data

Table B. 4: Lake Scott King Capacity/Area by 0.1-ft Increments.

Lake Scott King

Figure B. 2: Area-Capacity Curve for Lake Scott King

APPENDIX C: Lake Jean Neustadt and Lake Scott King Maps

Figure C. 1: Lake Jean Neustadt Bathymetric Map with 5-foot Contour Intervals.

Figure C. 2: Lake Jean Neustadt Shaded Relief Bathymetric Map.

Figure C. 3: Lake Jean Neustadt Collected Data Points.

Figure C. 4: Lake Scott King Bathymetric Map with 5-foot Contour Intervals.

Figure C. 5: Lake Scott King Shaded Relief Bathymetric Map.

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

Figure C. 6: Lake Scott King Collected Data Points.

