Volumetric and Sedimentation Survey of CHOKE CANYON RESERVOIR

June 2012 Survey

Texas Water Development Board

August 2013

Texas Water Development Board

Prepared for:

City of Corpus Christi

This report was prepared by staff of the Surface Water Resources Division:

Ruben S. Solis, Ph.D., P.E.
Jason J. Kemp, Team Lead
Tony Connell
Holly Holmquist
Nathan Brock
Michael Vielleux
Khan Iqbal
Bianca Whitaker
Kyle Garmany

STATE OF TEXAS
RUBEN S. SOLIS
73094
REGISTERED PROFESSIONAL ENGINEER
10/9/14

Published and distributed by the

Texas Water Development Board

P.O. Box 13231, Austin, TX 78711-3231

Executive summary

In March 2012 the Texas Water Development Board (TWDB) entered into agreement with the City of Corpus Christi, Texas, to perform a volumetric and sedimentation survey of Choke Canyon Reservoir. Surveying was performed using a multi-frequency (200 kHz, 50 kHz, and 24 kHz), sub-bottom profiling depth sounder. In addition, sediment core samples were collected in select locations and correlated with the multi-frequency depth sounder signal returns to estimate sediment accumulation thicknesses and sedimentation rates.

Choke Canyon Dam and Choke Canyon Reservoir are located on the Frio River in Live Oak and McMullen Counties, approximately 3.5 miles northwest of the City of Three Rivers, Texas. The conservation pool elevation of Choke Canyon Reservoir is 220.5 feet (NGVD29). TWDB collected bathymetric data for Choke Canyon Reservoir between June 5, 2012, and June 27, 2012. The daily average water surface elevations during the survey ranged between 207.11 and 207.66 feet (NGVD29).

The 2012 TWDB volumetric survey indicates that Choke Canyon Reservoir has a total reservoir capacity of 662,821 acre-feet and encompasses 25,438 acres at conservation pool elevation (220.5 feet above mean sea level, NGVD29). Previous capacity estimates include the original design estimate of 691,130 acre-feet at the time of impoundment in 1982, an area-capacity table from the U.S. Bureau of Reclamation dated 1983 indicating a capacity of 695,125 acre-feet, and a 1993 TWDB volumetric survey estimate of 695, 271 acre-feet.

Based on two methods for estimating sedimentation rates, the 2012 TWDB sedimentation survey estimates Choke Canyon Reservoir loses between 944 and 1,708 acre-feet of capacity per year below conservation pool elevation (220.5 feet NGVD29) due to sedimentation. The sedimentation survey indicates sediment accumulation is somewhat consistent throughout the reservoir. The heaviest accumulations measured by this survey are within the submerged river channels. Accumulation in the Frio River channel becomes heavier as it approaches the dam. TWDB recommends that a similar methodology be used to resurvey Choke Canyon Reservoir in 10 years or after a major flood event.

Table of Contents

List of Tables

List of Figures

Appendices

Note: References to brand names throughout this report do not imply endorsement by the Texas Water Development Board

Introduction

The Hydrographic Survey Program of the Texas Water Development Board (TWDB) was authorized by the 72nd Texas State Legislature in 1991. The Texas Water Code authorizes TWDB to perform surveys to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability.

In March 2012 TWDB entered into agreement with the City of Corpus Christi, Texas, to perform a volumetric and sedimentation survey of Choke Canyon Reservoir (TWDB, 2012). This report describes the methods used to conduct the volumetric and sedimentation survey, including data collection and processing techniques. This report serves as the final contract deliverable from TWDB to the City of Corpus Christi, Texas and contains as deliverables: (1) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality [Appendix A, B], (2) a bottom contour map [Figure 5], (3) a shaded relief plot of the reservoir bottom [Figure 3], and (4) an estimate of sediment accumulation and location [Figure 10].

Choke Canyon Reservoir general information

Choke Canyon Dam and Choke Canyon Reservoir are located on the Frio River in Live Oak and McMullen Counties, approximately 3.5 miles northwest of Three Rivers, Texas, and approximately 80 miles south of San Antonio, Texas (TPWD, 2012) (Figure 1). Choke Canyon Dam and Choke Canyon Reservoir are owned by the U.S. Department of the Interior, Bureau of Reclamation, and operated by the City of Corpus Christi (COCC, 2013). Construction on Choke Canyon Dam began on August 10, 1978. The dam was considered substantially complete on May 18, 1982, and the official dedication ceremony was held on June 8, 1982 (USBR, 2013).

Choke Canyon Reservoir gets its name from the low-lying hills that force the confluence of the three rivers, the Frio, Nueces, and Atascosa Rivers, into a constricted channel. Choke Canyon Dam and Reservoir, in conjunction with Lake Corpus Christi, was built primarily as a water supply reservoir for the Cities of Corpus Christi and Three Rivers, and the Nueces River Authority, supplying water for municipal and industrial purposes, as well as recreational purposes (USBR, 2013). Additional pertinent data about Choke Canyon Dam and Choke Canyon Reservoir can be found in Table 1.

Water rights for Choke Canyon Reservoir have been appropriated to the City of Corpus Christi, the Nueces River Authority, and the City of Three Rivers through

Certificate of Adjudication No. 21-3214 and Amendment to Certificate of Adjudication No. 21-3214A. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

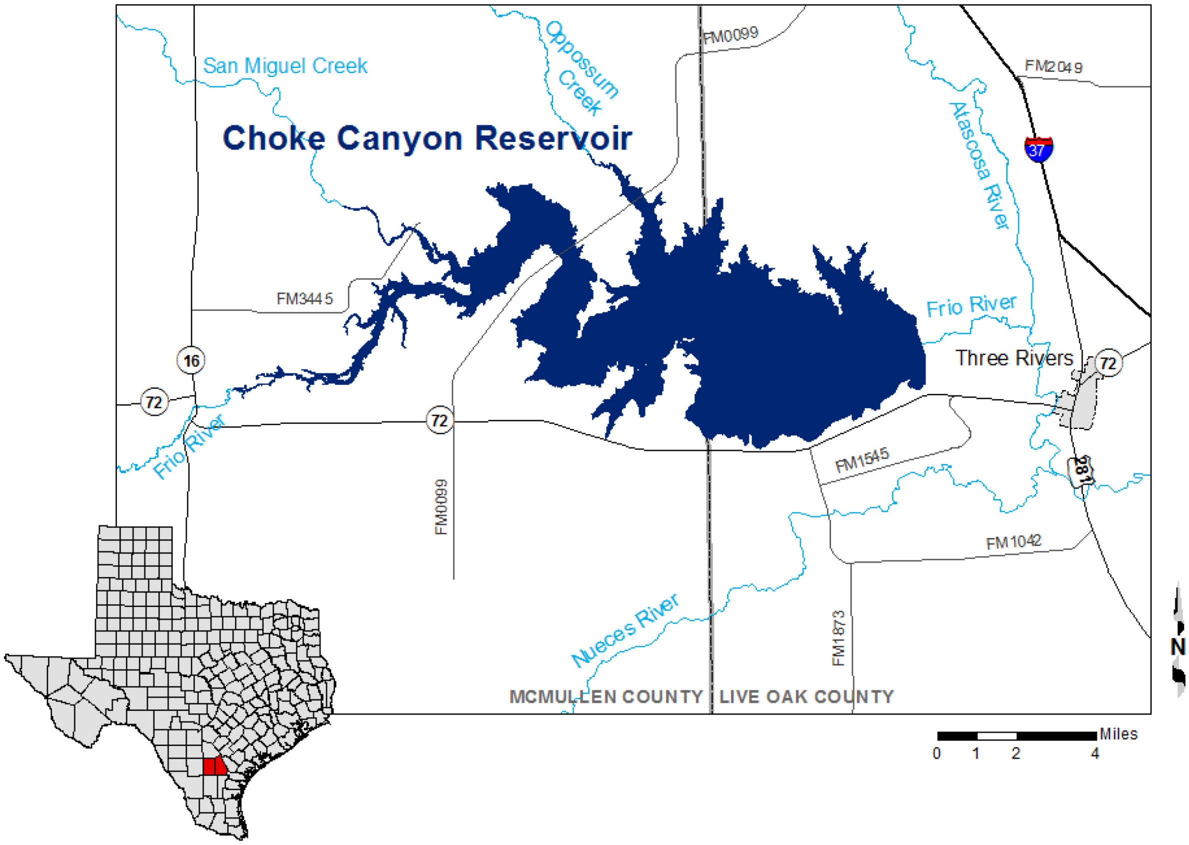


Figure 1. Location of Choke Canyon Reservoir

Table 1.	Pertinent data for Choke Canyon Dam and Choke Canyon Reservoir		
Owner			
U.S. Department of the Interior, Bureau of Reclamation			
Engineer (design)			
U.S. Department of the Interior, Bureau of Reclamation			
General contractor			
Holloway Construction Company			
Location of dam			
On the Frio River in Live Oak County, approximately 3.5 miles northwest of Three Rivers, Texas			
Dam			
Type	Rolled earthfill		
Length (total)	3.5 miles		
Height	114.14 feet		
Crest elevation	241.14 feet above mean sea level		
Spillway (service/ emergency)			
Type	Concrete ogee		
Width	368 feet		
Sill elevation	199.5 feet above mean sea level		
Control for water release	7 radial gates each 49.2 feet by 23.7 feet		
Top-of-gate elevation	223.2 feet above mean sea level		
Outlet works			
The intake tower for the river outlet works is a concrete structure outfitted with four multilevel gates at elevations 203.0, 181.5, 150.0, and 136.38 feet			
Reservoir data (Based on 2012 TWDB survey)			
Feature	**Elevation (feet NGVD29[a])**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam	241.14	N/A	N/A
Top of maximum water surface	232.18	N/A	N/A
Top of conservation pool elevation	220.5	662,821	25,438
Outlet works	203.0	302,657	16,144
	181.5	65,796	6,334
Top of inactive pool	150.0	467	103
Outlet works/ Top of dead pool	136.38	1	2
Conservation storage capacity [b]	-	662,820	-

Source: (TWDB, 2003, USBR, 2012)

[a] NGVD29 = National Geodetic Vertical Datum 1929

[b] Conservation storage capacity equals total capacity at conservation pool elevation minus dead pool capacity. Dead pool refers to water that cannot be drained by gravity through a dam's outlet works.

Volumetric and sedimentation survey of Choke Canyon Reservoir

Datum

The vertical datum used during this survey is the National Geodetic Vertical Datum 1929 (NGVD29). This datum is also utilized by the United States Geological Survey (USGS) for the reservoir elevation gage *USGS 08206900 Choke Canyon Res nr Three Rivers, TX* (USGS, 2013). Elevations herein are reported in feet relative to the NGVD29 datum. Volume and area calculations in this report are referenced to water levels provided by the USGS gage. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas South Central Zone (feet).

TWDB bathymetric and sedimentation data collection

TWDB collected bathymetric data for Choke Canyon Reservoir between June 5, 2012, and June 27, 2012. The daily average water surface elevations during the survey ranged between 207.11 and 207.66 feet (NGVD29). For data collection, TWDB used a Specialty Devices, Inc. (SDI), single-beam, multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment. Data collection occurred while navigating along pre-planned survey lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. Many of the survey lines were also surveyed by TWDB during the 1993 survey. The depth sounder was calibrated daily using a velocity profiler to measure the speed of sound in the water column and a weighted tape or stadia rod for depth reading verification. Figure 2 shows where data collection occurred during the 2012 TWDB survey.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples are collected at regularly spaced intervals within the reservoir, or at locations where interpretation of the acoustic display would be difficult without site-specific sediment core data. Following the analysis of the sounding data, TWDB selected eight locations to collect sediment core samples (Figure 2). The sediment core samples were collected on June 17, 2013, with a custom-coring boat and SDI VibeCore system.

Sediment cores are collected in 3-inch diameter aluminum tubes. Analysis of the acoustic data collected during the bathymetric survey assists in determining the depth of penetration the tube must be driven during sediment sampling. The goal is to collect a sediment core sample extending from the current reservoir-bottom, through the accumulated sediment, and to the pre-impoundment surface. After retrieving the sample, a stadia rod is inserted into the top of the tube to assist in locating the top of the sediment in the tube. This identifies the location of the layer corresponding to the current reservoir surface. The aluminum tube is cut to this level, capped, and transported back to TWDB headquarters for further analysis. During this time, some settling of the upper layer can occur.

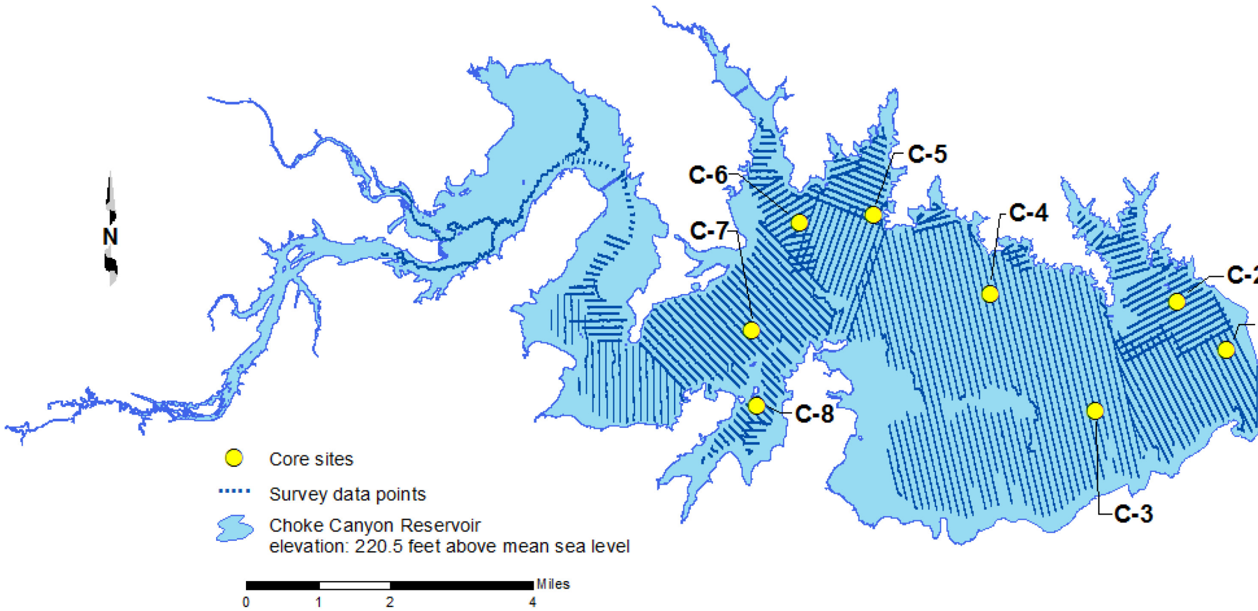


Figure 2. Data collected during 2012 TWDB Choke Canyon Reservoir survey

Data processing

Model boundaries

The reservoir boundary was determined using multiple sources. For the portion of the boundary at conservation pool elevation within Live Oak County, the boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), obtained from the Texas Natural Resources Information System (TNIRIS, 2009) using Environmental Systems Research Institute's ArcGIS software. The quarter-quadrangles that cover Choke Canyon Reservoir in Live Oak County are Three Rivers (NW), Willow Hollow Tank (SW, SE), and Calliham (NW, NE).The DOQQs were photographed on October 11, 2004, while the daily average water surface elevation measured 220.53 feet (NGVD29). The 2004 DOQQs have a resolution or ground sample distance of 1.0-meters and a horizontal accuracy within ± 5 meters to existing mosaicked digital orthorectified imagery (USDA, 2013). For this analysis, the boundary was digitized at the land-water interface in the 2004 photographs and given an elevation of 220.5 feet for modeling purposes. The portion of the boundary at conservation pool elevation within McMullen County was extracted from a raster created using Light Detection and Ranging (LIDAR) data. The LIDAR data for McMullen County was collected between June 17, 2009, and July 15, 2009, while the daily average water surface elevation of the reservoir measured between 212.36 feet and 213.1 feet above mean sea level. More information about the LIDAR data and how it was used in the reservoir model can be found in the section on LIDAR below.

Additional boundary information was obtained from aerial photographs taken on April 24, 2010, while the water surface elevation measured 216.78 feet, and May 22, 2012, while the water surface elevation measured 207.98 feet. Contours were digitized at the land-water interface in the photos and added to the model as point data. A boundary at elevation 216.78 feet was added only to the Live Oak County part of the reservoir where LIDAR data is unavailable. The contour at elevation 207.98 feet was digitized for the entire reservoir. According to metadata associated with the 2010 and 2012 DOQQs, the photographs have a resolution or ground sample distance of 1.0-meters and a horizontal accuracy within ± 6 meters to true ground (USDA, 2013, TNRIS 2010, TNRIS, 2012).

LIDAR

Light Detection and Ranging Data is available from the Texas Natural Resource Information System (TNRIS, 2013). LIDAR for McMullen County was collected between June 17, 2009, and July 15, 2009. The daily average water surface elevation of the reservoir during this period varied between 212.36 feet and 213.1 feet above mean sea level during this time. The LIDAR data was used to generate a boundary for the reservoir at conservation pool elevation in McMullen County and to add additional LIDAR points within the boundary. To generate the boundary, LIDAR data with a classification equal to 2, or ground, was imported into an ArcGIS file geodatabase from .las files. A topographical model of the data was generated and converted to a raster using a cell size of 5 meters by 5 meters. The horizontal datum of the LIDAR data is Universal Transverse Mercator (UTM) North American Datum 1983 (NAD83) Zone 14 and the vertical datum is North American Vertical Datum 1988 (NAVD88). According to the associated metadata, the LIDAR data has a vertical accuracy of ±18 centimeters.

To make the LIDAR data compatible with the bathymetric survey data, it was necessary to transform the LIDAR data to NGVD29 (vertical) and NAD83 (horizontal) coordinates. Horizontal coordinate transformations were done using the ArcGIS Project tool. Vertical coordinate transformations were done by applying a single vertical offset to all LIDAR data. The offset was determined by applying the National Oceanic and Atmospheric Administration National Geodetic Survey's NADCON software (NGS, 2013a) and VERTCON software (NGS, 2013b) to single reference point in the vicinity of the survey, the reservoir elevation gage *USGS 08206900 Choke Canyon Res nr Three Rivers, TX,* of Latitude 28º29’01”, Longitude 98º14’44” NAD27. The resulting conversion factor of 0.026 meters was subtracted from all LIDAR data elevations to obtain the transformed vertical elevations.

To reduce computational burden, the LIDAR data was filtered to include only every 10th point before clipping to include only data points within the reservoir boundary. The LIDAR data points have an average spacing of 0.6 meters; therefore, using a thinned point dataset did not significantly affect the modeled topography of the coverage area. No interpolation of the data in the areas of LIDAR coverage was necessary. After the points were clipped to within the boundary, the shapefile was projected to NAD83 State Plane Texas South Central Zone (feet), and new attribute fields were added to first convert the elevations from meters NAVD88 to meters NGVD29, then to feet NGVD29.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by TWDB were edited to remove data anomalies. DepthPic©, software developed by SDI, Inc., is used to display, interpret, and edit the multi-frequency data by manually removing data anomalies in the current bottom surface and manually digitizing the reservoir-bottom surface at the time of initial impoundment (i.e. pre-impoundment surface). For processing outside of DepthPic©, an in-house software package, HydroTools, is used to identify the current reservoir-bottom surface, pre-impoundment surface, sediment thickness at each sounding location, and output the data into a single file. The water surface elevation at the time of each sounding was used to convert each sounding depth to a corresponding reservoir-bottom elevation. This survey point dataset is then preconditioned by inserting a uniform grid of artificial survey points between the actual survey lines. Bathymetric elevations at these artificial points are determined using an anisotropic spatial interpolation algorithm described in the spatial interpolation of reservoir bathymetry section below. This technique creates a high resolution, uniform grid of interpolated bathymetric elevation points throughout a majority of the reservoir (McEwen et al., 2011). Finally, the point file resulting from spatial interpolation is used in conjunction with sounding and boundary data to create volumetric and sediment Triangulated Irregular Network (TIN) models utilizing the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithm uses Delaunay’s criteria for triangulation to create a grid composed of triangles from non-uniformly spaced points, including the boundary vertices (ESRI, 1995).

Spatial interpolation of reservoir bathymetry

Isotropic spatial interpolation techniques such as the Delaunay triangulation used by the 3D Analyst extension of ArcGIS are, in many instances, unable to suitably interpolate bathymetries between survey lines common to reservoir surveys. Reservoirs and stream channels are anisotropic morphological features where bathymetry at any particular location is more similar to upstream and downstream locations than to transverse locations. Interpolation schemes that do not consider this anisotropy lead to the creation of several types of artifacts in the final representation of the reservoir bottom surface and hence to errors in volume. These include: artificially-curved contour lines extending into the reservoir where the reservoir walls are steep or the reservoir is relatively narrow; intermittent representation of submerged stream channel connectivity; and oscillations of contour lines in between survey lines. These artifacts reduce the accuracy of the resulting volumetric and sediment TIN models in areas between actual survey data.

To improve the accuracy of bathymetric representation between survey lines, TWDB developed various anisotropic spatial interpolation techniques. Generally, the directionality of interpolation at different locations of a reservoir can be determined from external data sources. A basic assumption is that the reservoir profile in the vicinity of a particular location has upstream and downstream similarity. In addition, the sinuosity and directionality of submerged stream channels can be determined from direct examination of survey data or more robustly by examining scanned USGS 7.5 minute quadrangle maps (known as digital raster graphics) and hypsography files (the vector format of USGS 7.5 minute quadrangle map contours), when available. Using the survey data, polygons are created to partition the reservoir into segments with centerlines defining directionality of interpolation within each segment. For surveys with similar spatial coverage, these interpolation definition files are in principle independent of the survey data and could be applied to past and future survey data of the same reservoir. In practice, however, minor revisions of the interpolation definition files may be needed to account for differences in spatial coverage and boundary conditions between surveys. Using the interpolation definition files and survey data, the current reservoir-bottom elevation, pre-impoundment elevation, and sediment thickness are calculated for each point in the high resolution uniform grid of artificial survey points. The reservoir boundary, artificial survey points grid, and survey data points are used to create volumetric and sediment TIN models representing the reservoir bathymetry and sediment accumulation throughout the reservoir. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen et al., 2011a) and in McEwen et al., 2011b.

In areas inaccessible to survey data collection such as small coves and shallow upstream areas of the reservoir, linear extrapolation is used for volumetric and sediment accumulation estimations. The linear extrapolation follows a linear definition file linking the survey points file to the lake boundary file (McEwen et al., 2011a). Without extrapolated data, the TIN Model builds flat triangles. A flat triangle is defined as a triangle where all three vertices are equal in elevation, generally the elevation of the reservoir boundary. Reducing flat triangles, by applying linear extrapolation, improves the elevation-capacity and elevation-area calculations. It may not be possible to remove all flat triangles, and linear extrapolation is only applied where adding bathymetry is deemed reasonable. For example, linear extrapolation was deemed reasonable and applied to Choke Canyon Reservoir in the following situations: in small coves of the main body of the reservoir and in obvious channel features. Linear extrapolation was applied up to the conservation pool elevation boundary in the Live Oak County portion of the reservoir only. To reduce flat triangles at elevation 207.98 feet, the contour elevation from the 2012 DOQQs, linear extrapolation was applied up to the 2012 boundary in McMullen County (Figure 3).

Figure 3 illustrates typical results from application of the anisotropic interpolation and linear extrapolation techniques to Choke Canyon Reservoir. In Figure 3A, deeper channels indicated by surveyed cross sections are not continuously represented in areas between survey cross sections. This is an artifact of the TIN generation routine rather than an accurate representation of the physical bathymetric surface. Inclusion of interpolation points, represented in Figure 3C, in creation of the volumetric TIN model directs Delaunay triangulation to better represent the reservoir bathymetry between survey cross-sections. The bathymetry shown in Figure 3C was used in computing reservoir capacity and area tables (Appendix A, B).

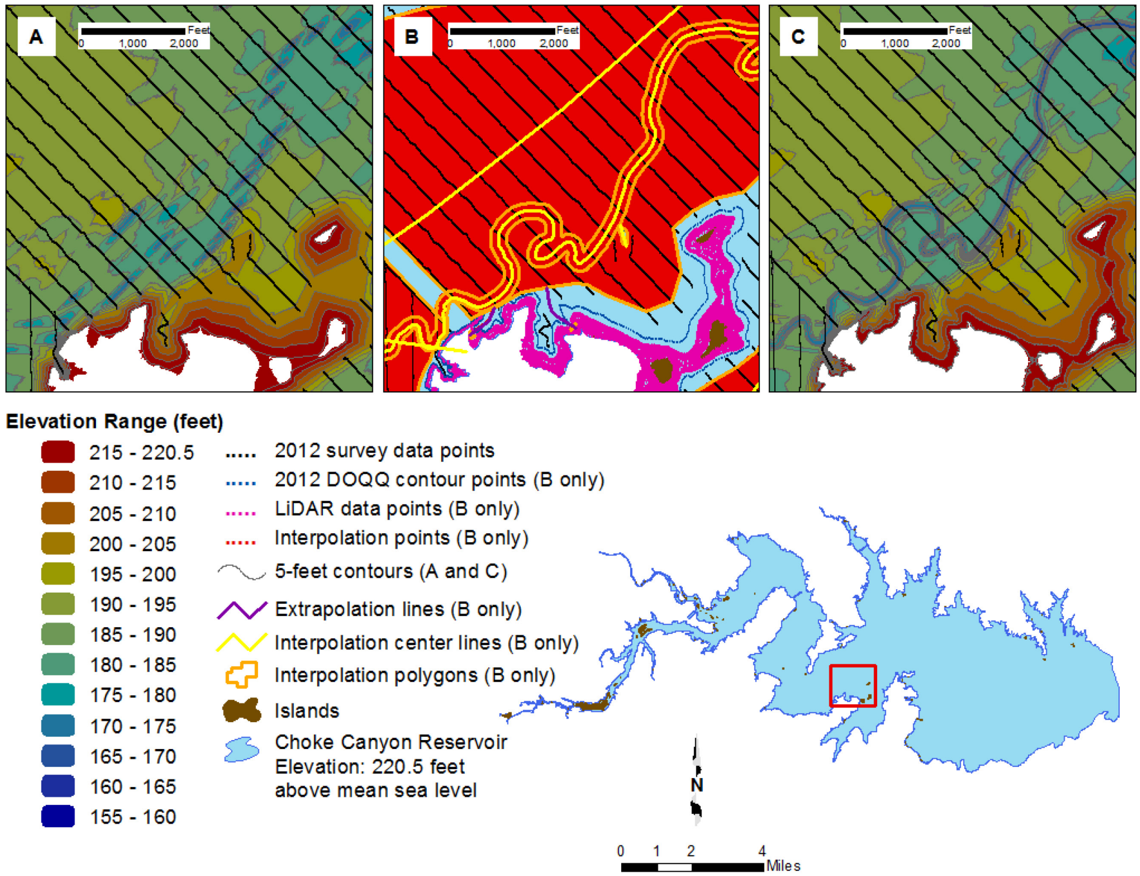


Figure 3. Anisotropic spatial interpolation and linear extrapolation of Choke Canyon Reservoir sounding data – A) bathymetric contours without interpolated points, B) sounding points(black) and interpolated points (red), C) bathymetric contours with the interpolated points

Area, volume, and contour calculations

Using ArcInfo software and the volumetric TIN model, volumes and areas were calculated for the entire reservoir at 0.1 feet intervals, from elevation 135.3 to 220.5 feet. The use of LIDAR data helped provide otherwise unavailable topographic data that was within the reservoir footprint but above the water surface elevation while conducting the hydrographic survey. However, there remained some areas approximately between elevations 207.0 feet and 212.0 feet for which no data could be obtained, primarily in shallow areas along the periphery of the lake that were inaccessible by boat or too shallow for the instruments to work properly. The TIN models developed in this range of elevations led to the creation of anomalous "flat triangles", that is triangles whose three vertices all have the same elevation. The flat triangles in turn lead to anomalous calculations of surface area and volume in these elevation ranges. To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 207.0 feet and 212.0 feet were linearly interpolated between the computed values, and volumes above elevation 207.0 feet were recalculated based on the corrected areas. The elevation-capacity table and elevation-area table, updated for 2012, are presented in Appendices A and B, respectively. The area-capacity curves are presented in Appendix C.

The volumetric TIN model was converted to a raster representation using a cell size of 2 feet by 2 feet. The raster data was then used to produce an elevation relief map (Figure 4), representing the topography of the reservoir bottom; a depth range map (Figure 5), showing shaded depth ranges for Choke Canyon Reservoir; and a 5-foot contour map (Figure 6 - attached).

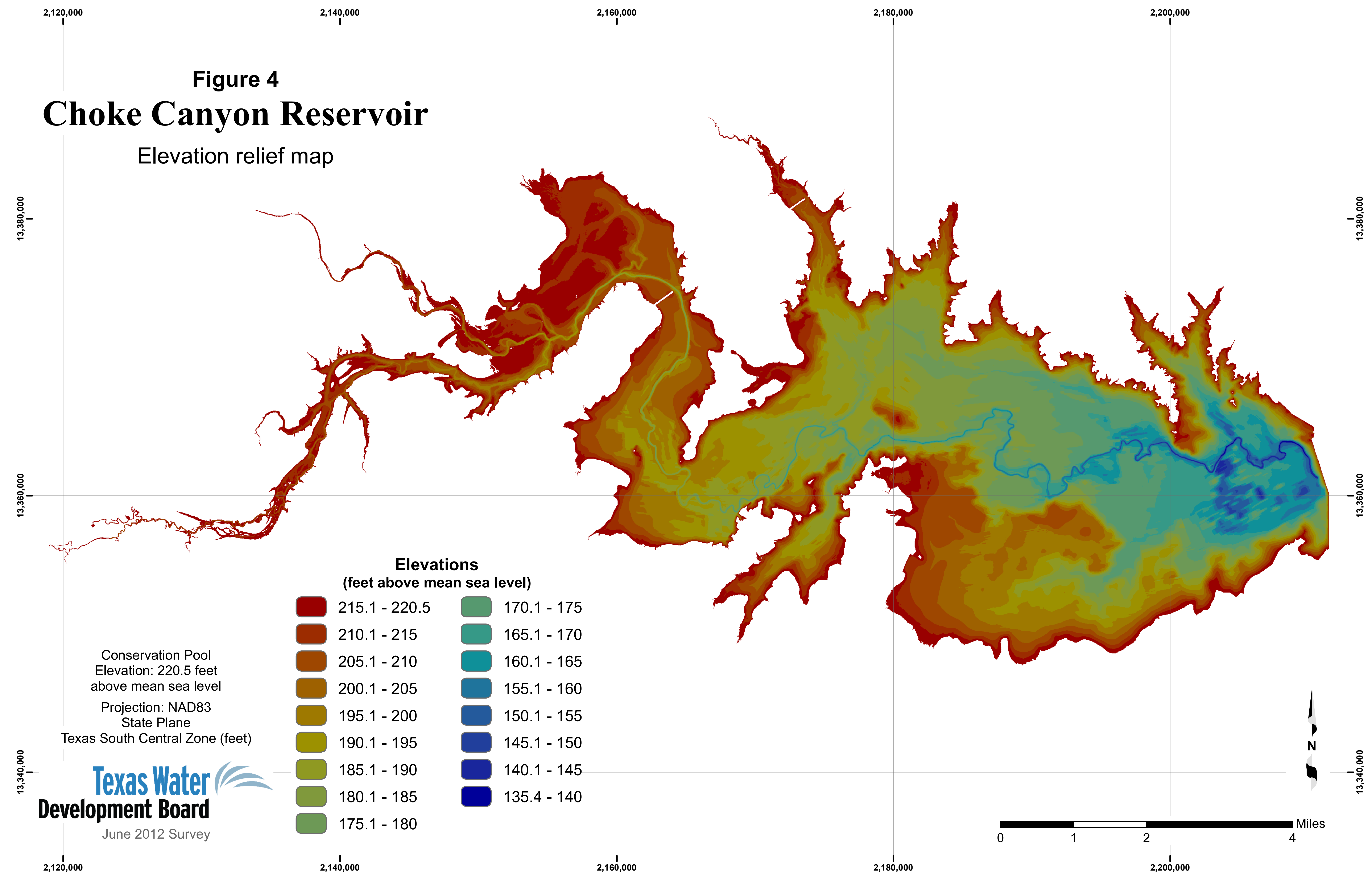


Figure 4
Choke Canyon Reservoir
Elevation relief map
Elevations
(feet above mean sea level)
215.1 - 220.5
210.1 - 215
205.1 - 210
200.1 - 205
195.1 - 200
190.1 - 195
185.1 - 190
180.1 - 185
175.1 - 180
170.1 - 175
165.1 - 170
160.1 - 165
155.1 - 160
150.1 - 155
145.1 - 150
140.1 - 145
135.4 - 140
Conservation Pool
Elevation: 220.5 feet
above mean sea level
Projection: NAD83
State Plane
Texas South Central Zone (feet)
Texas Water
Development Board
June 2012 Survey
N
Miles
0
1
2
4
2,120,000
2,140,000
2,160,000
2,180,000
2,200,000
13,380,000
13,360,000
13,340,000

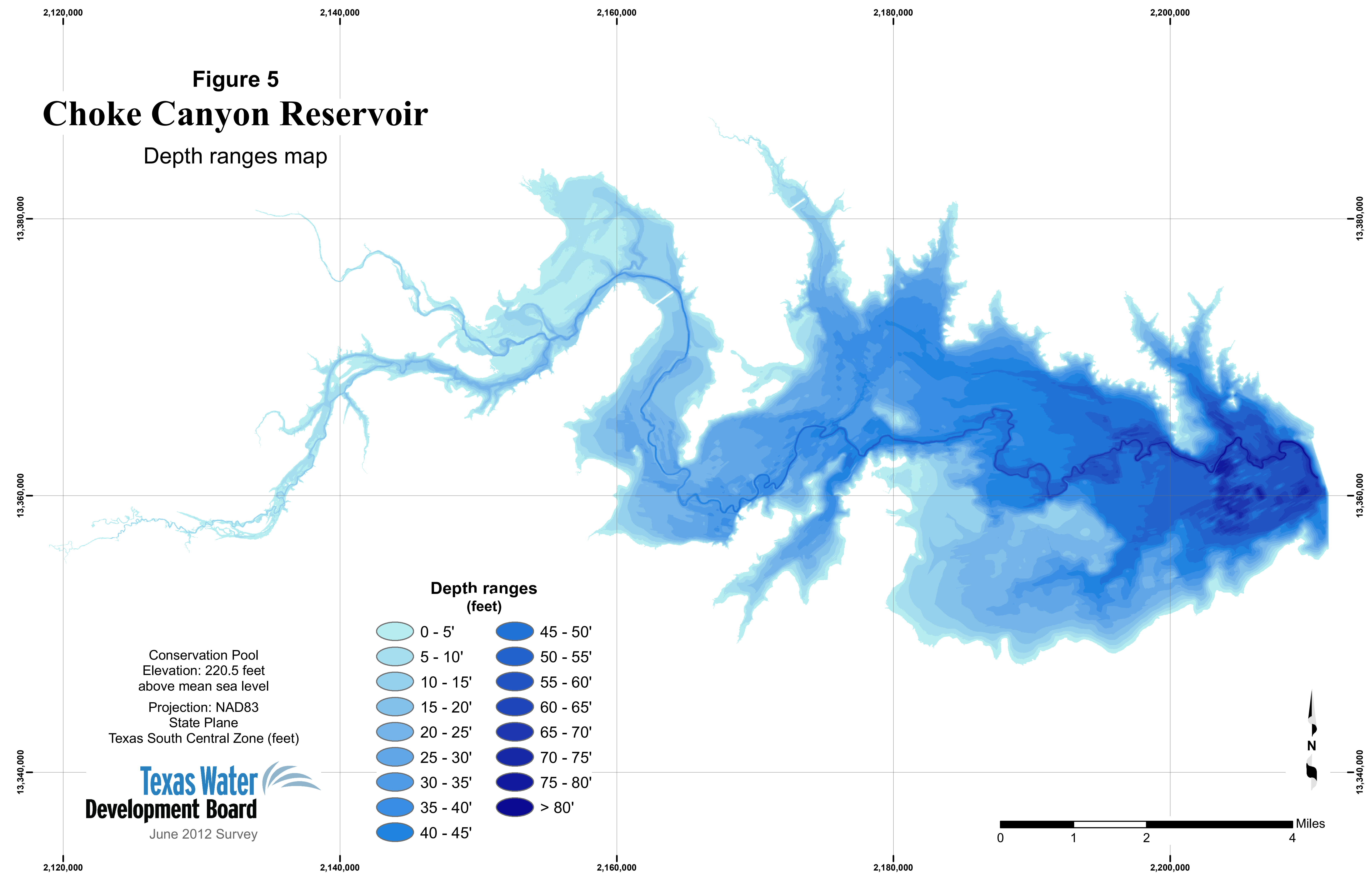


Figure 5
Choke Canyon Reservoir
Depth ranges map
2,120,000
2,140,000
2,160,000
2,180,000
2,200,000
13,380,000
13,360,000
13,340,000
Depth ranges
(feet)
0 - 5'
5 - 10'
10 - 15'
15 - 20'
20 - 25'
25 - 30'
30 - 35'
35 - 40'
40 - 45'
45 - 50'
50 - 55'
55 - 60'
60 - 65'
65 - 70'
70 - 75'
75 - 80'
> 80'
Conservation Pool
Elevation: 220.5 feet
above mean sea level
Projection: NAD83
State Plane
Texas South Central Zone (feet)
Texas Water
Development Board
June 2012 Survey
N
Miles
0
1
2
4

Analysis of sediment data from Choke Canyon Reservoir

Sedimentation in Choke Canyon Reservoir was determined by analyzing the acoustic signal returns of all three depth sounder frequencies in the DepthPic© software. The 200 kHz signal was analyzed to determine the current bathymetric surface of the reservoir, while all three frequencies, 200 kHz, 50 kHz, and 24 kHz, were analyzed to determine the reservoir bathymetric surface at the time of initial impoundment (i.e. pre-impoundment surface). Sediment core samples collected in the reservoir were used to assist in identifying the location of the pre-impoundment surface in the acoustic signals. The difference between the current surface and the pre-impoundment surface yields a sediment thickness value at each sounding location.

Analysis of the sediment core samples was conducted at TWDB headquarters in Austin. Each sample was split longitudinally and analyzed to identify the location of the pre-impoundment surface. The pre-impoundment surface is identified within the sediment core sample by one or both of the following methods: (1) a visual examination of the sediment core for organic materials, such as leaf litter, tree bark, twigs, intact roots, etc., concentrations of which tend to occur on or just below the pre-impoundment surface; (2) changes in texture from well sorted, relatively fine-grained sediment to poorly sorted mixtures of coarse and fine-grained materials; and (3) variations in the physical properties of the sediment, particularly sediment water content and penetration resistance with depth (Van Metre et al., 2004). The total sample length, sediment thickness, and the pre-impoundment thickness were recorded. Physical characteristics of the sediment core, including color, texture, relative water content, and presence of organic materials, were also recorded (Table 2).

Table 2. Sediment core sampling analysis data – Choke Canyon Reservoir

Core	Easting[a] (ft)	Northing[a] (ft)	Total core sample/ post-impoundment sediment	Sediment core description	Munsell soil color
C-1	2208882.14	13362009.91	22.5”/13”	0-1.5” muddy water/ very loose, suspended sediment	N/A
				1.5-7” high water content, silty with some fine sand	10YR 3/2
				7-8.5” high water content, clay loam	5Y 2.5/1
				8.5-13” high water content, silty with some fine sand	10YR 3/2
				13-22.5” lower water content, higher density soil with peds present, organics present	5Y 2.5/2
C-2	2205251.33	13365536.06	28”/18”	0-18” muddy water/ loose suspended sediment	N/A
				18-28” high water content, silty soil, some roots/ organics present	2.5Y 4/2
C-3	2199221.75	13357528.51	28.5”/17.5”	0-0.5” muddy water/suspended sediment	N/A
				0.5-17.5” high water content, silty clay sediment	10YR 3/2
				17.5-28.5” lower water content, higher density soil with peds present, roots and organics present	2.5Y 2.5/2
C-4	2191533.74	13366153.01	25.5”/10”	0-10” high water content, silty clay sediment	10YR 3/1
				10-25.5” lower water content, higher density soil, organics present	5Y 2.5/2
C-5	2182914.44	13371974.17	27”/19”	0-1” Muddy water/suspended sediment	N/A
				1-19” high water content, silty clay sediment	10YR 3/1
				19-27” lower water content, clay soil, organics present	2.5Y 2.5/1
C-6	2177447.27	13371375.51	19”/11”	0-1” muddy water/ suspended sediment	N/A
				1-8” high water content, silty sediment	10YR 3/2
				8-9.5” high water content, clay sediment with some organics	5Y 2.5/1
				9.5-11” high water content, silty sediment	10YR 3/2
				11-19” lower water content, clay soil with peds present, roots and organics present	5Y 2.5/2
C-7	2173969.18	13363486.84	9.5”/5.5”	0-5.5” high water content, silty sediment	10YR 3/2
				5.5-9.5” lower water content, dense clay soil with peds present, organics present	5Y 2.5/1
C-8	2174348.78	13357927.85	35.5”/27.5”	0-3” lost out top when cutting to length	N/A
				3-27.5” high water content, silty sediment	10YR 3/1
				27.5-35.5” lower water content, dense clay soil with peds, organics and roots present	5Y 2.5/2

[a] Coordinates are based on NAD83 State Plane Texas South Central System (feet)

A photograph of sediment core C-8 is shown in Figure 7 and is representative of the sediment cores sampled from Choke Canyon Reservoir. The 200 kHz frequency measures the top layer as the current bottom surface of the reservoir.

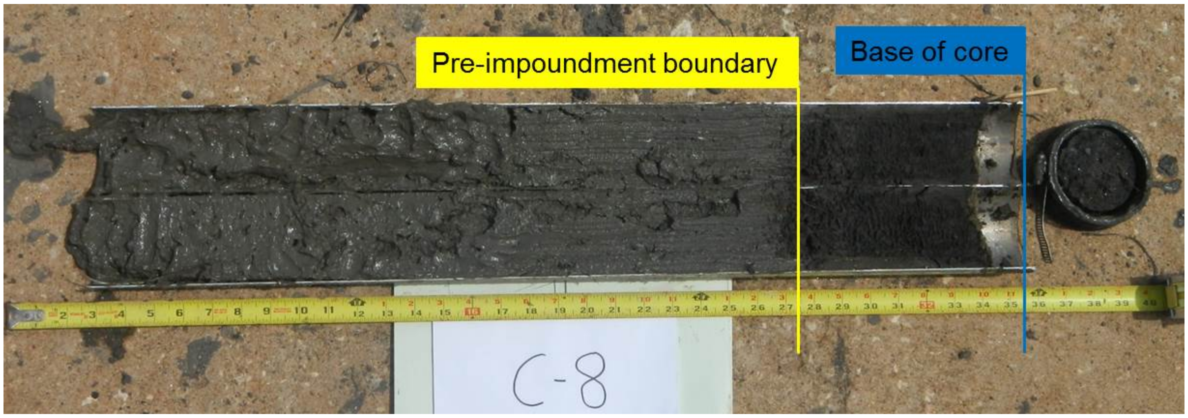


Figure 3. Sediment core C-8 from Choke Canyon Reservoir

Sediment core sample C-8 consisted of 35.5 inches of total sediment. The upper sediment layer (horizon), 0–3.0 inches, was lost when the core tube was cut to length (in Figure 7, the tape measure was extended three inches to compensate for the lost sediment when the core tube was cut too short). The second horizon, beginning at 3.0 inches and extending to 27.5 inches below the surface, consisted of a silty sediment with a high water content and 10YR 3/1 Munsell soil color. The third horizon, from 27.5 inches to 35.5 inches consisted of a dense clay soil with peds, organics, and roots present, a lower water content, and 5Y 2.5/2 Munsell soil color. The base of the sample is denoted by the blue line in Figure 7.

The pre-impoundment boundary (yellow line in Figure 7) was evident within this sediment core sample at 27.5 inches and identified by the change in soil color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the remaining sediment cores followed a similar procedure.

Figures 8 and 9 illustrate how measurements from sediment core samples are used with sonar data to help identify the interface between the post- and pre-impoundment layers in the acoustic signal. Within DepthPic©, the current surface is automatically determined based on signal returns from the 200 kHz transducer and verified by TWDB staff, while the pre-impoundment surface must be determined visually. The pre-impoundment surface is first identified along cross-sections for which sediment core samples have been collected.

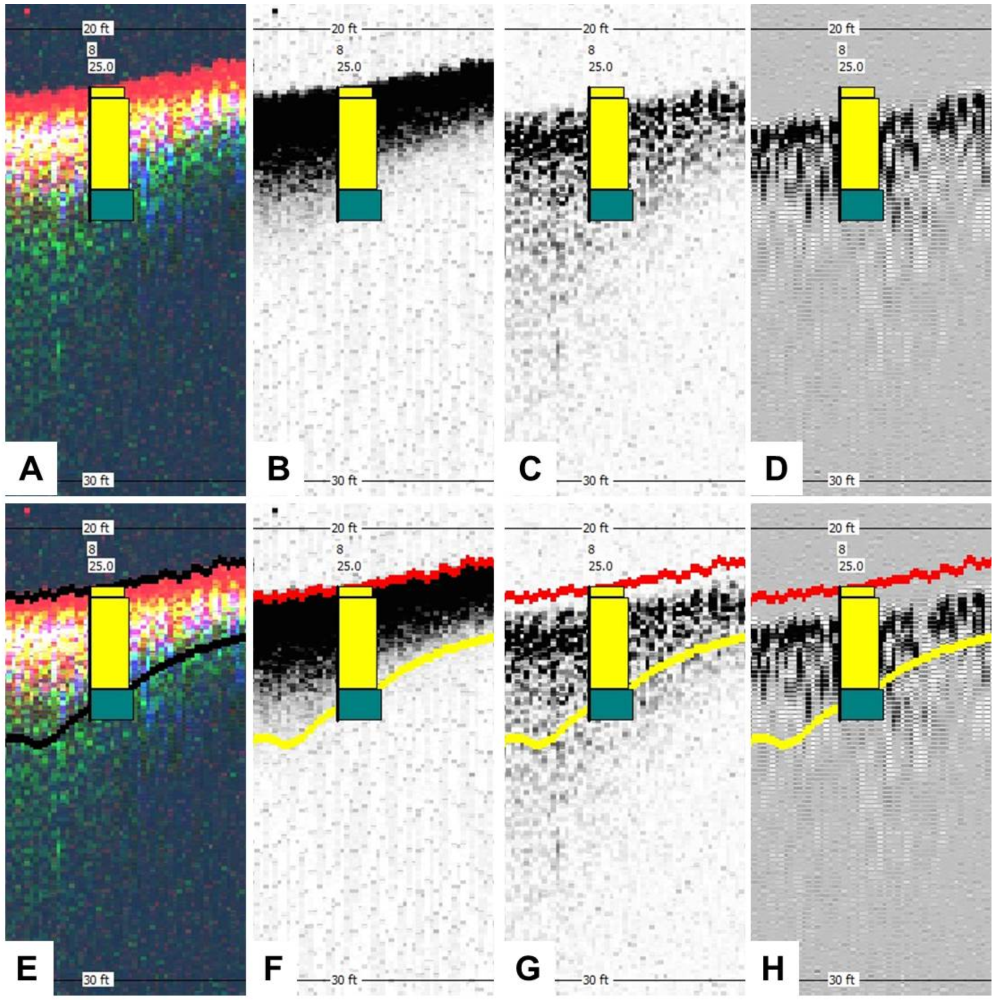


Figure 4. Comparison of sediment core C-8 with acoustic signal returns A,E) combined acoustic signal returns, B,F) 200 kHz frequency, C,G) 50 kHz frequency, D,H) 24 kHz frequency

Figure 8 compares sediment core sample C-8 with the acoustic signals for all frequencies combined (A, E), 200 kHz (B, F), 50 kHz (C, G), and 24 kHz (D, H). The sediment core sample is represented in each figure as colored boxes. The yellow boxes represent post-impoundment sediment, and the blue box represents the pre-impoundment sediment. In Figure 8A-D, the bathymetric surfaces are not shown. In Figure 8E, the current bathymetric surface is represented as the top black line and in Figures 8 F-H as the top red line. The pre-impoundment surface is identified by comparing boundaries observed in the 200 kHz, 50 kHz, and 24 kHz signals to the location of the pre-impoundment surface of the sediment core sample. Each sediment core sample was compared to all three frequencies and the boundary in the 200 kHz signal most closely matched the pre-impoundment interface of the sediment core samples; therefore, the 200 kHz signal was used to locate the pre-impoundment layer. The pre-impoundment surface was manually drawn and is represented by the bottom black line in Figure 8E, and by the yellow line in Figures 8F-H.

Figure 9 shows sediment core sample C-8 correlated with the 200 kHz frequency of the nearest surveyed cross-section. The pre-impoundment surface identified along cross-sections where sediment core samples were collected is used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

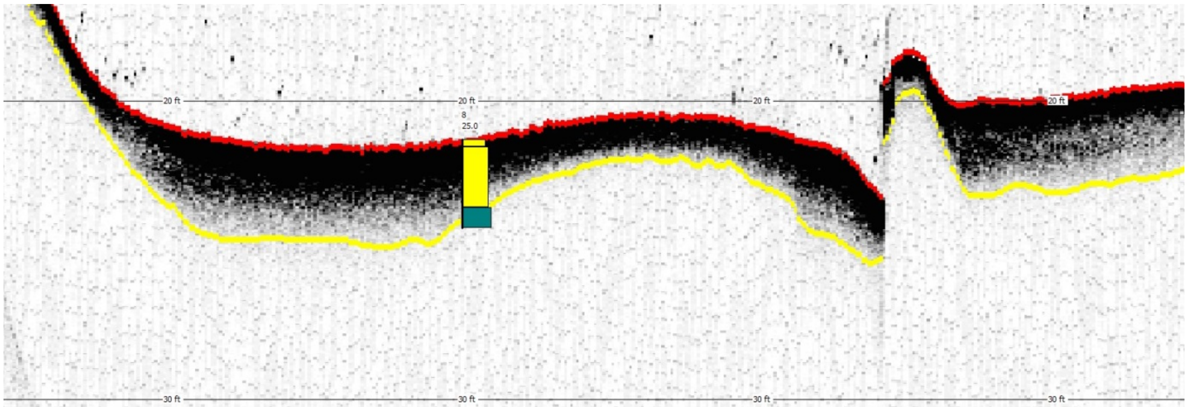


Figure 5. Cross-section of data collected during 2012 survey, displayed in DepthPic© (200 kHz frequency), correlated with sediment core sample C-8 and showing the current surface in red and pre-impoundment surface in yellow

After the pre-impoundment surface from all cross-sections was identified, a sediment thickness TIN model is created following standard GIS techniques (Furnans, 2007). Sediment thicknesses were interpolated between surveyed cross-sections using HydroTools with the same interpolation definition file used for bathymetric interpolation. For the purposes of the TIN model creation, TWDB assumed sediment thickness at the reservoir boundary and contours was zero feet (defined as the 220.5 foot NGVD29, 216.78 foot, and 207.98 foot elevation contours). The sediment thickness TIN model was converted to a raster representation using a cell size of 5 feet by 5 feet and used to produce a sediment thickness map of Choke Canyon Reservoir (Figure 10).

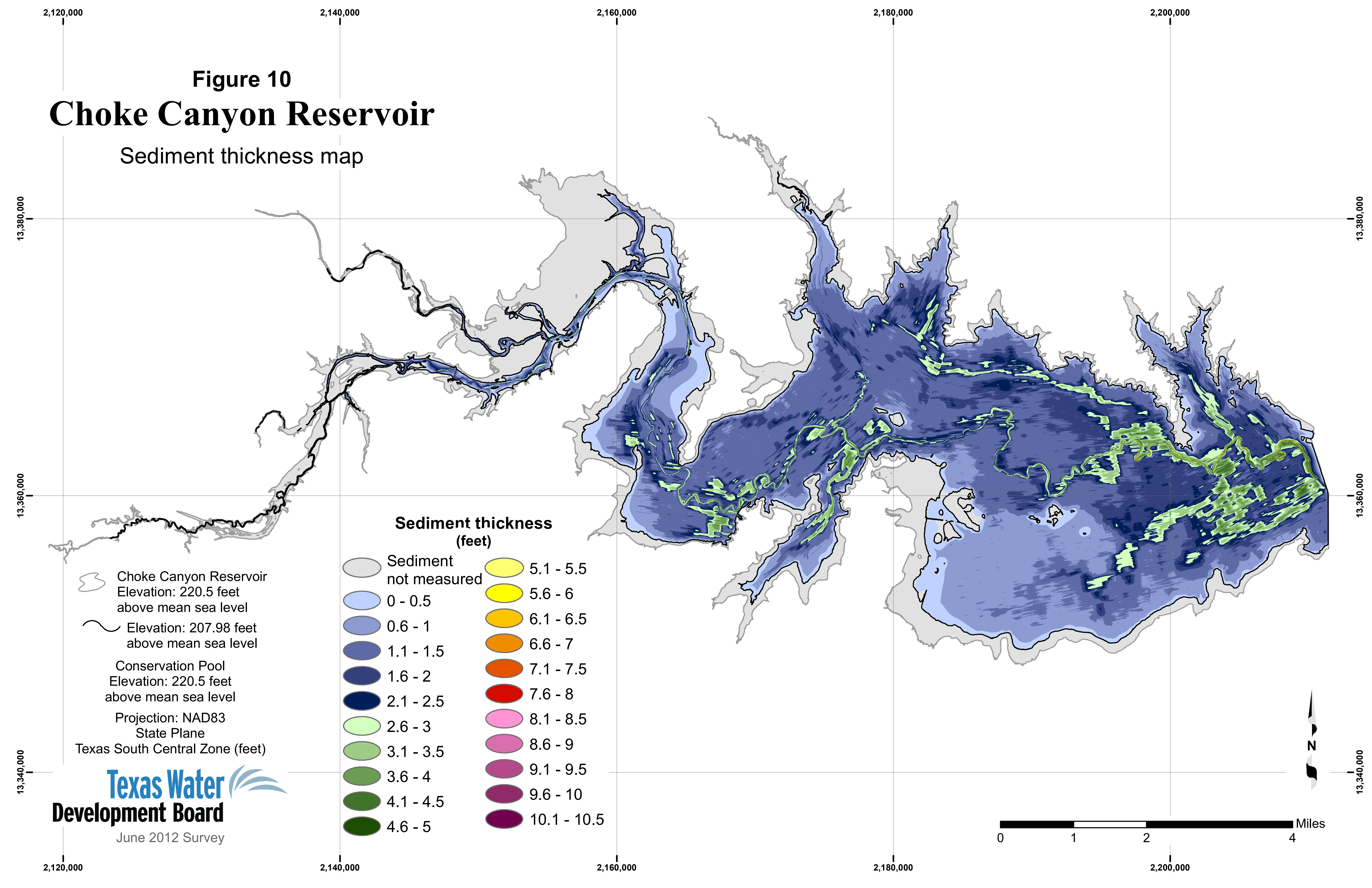


Figure 10

Choke Canyon Reservoir

Sediment thickness map

Survey results

Volumetric survey

The results of the 2012 TWDB volumetric survey indicate Choke Canyon Reservoir has a total reservoir capacity of 662,821 acre-feet and encompasses 25,438 acres at conservation pool elevation (220.5 feet NGVD29). The original design estimate indicates Choke Canyon Reservoir had a total capacity of 691,130 acre-feet and encompassed 25,733 acres at the time of impoundment in 1982. An area-capacity table provided to TWBD by the U.S. Bureau of Reclamation dated 1983 indicates Choke Canyon Reservoir had a total reservoir capacity of 695,125 acre-feet and encompassed 25,989 acres. A previous survey of Choke Canyon Reservoir by TWDB in 1993 indicated Choke Canyon Reservoir had a total capacity of 695,271 acre-feet and encompassed 25,989 acres. Because of differences in past and present survey methodologies, direct comparison of volumetric surveys to estimate loss of capacity is difficult and can be unreliable.

Table 3. Current and previous survey capacity and surface area data

Survey*	Surface area (acres)	Total capacity (acre-feet)
Original, 1982[a]	25,733	691,130
USBR 1983[b]	25,989	695,125
TWDB 1993	25,989	695,271
TWDB 2012	25,438	662,821

[a] Source: (TWDB, 2003)
[b] Source: (WDFT, 2013)

Sedimentation survey

Based on two methods for estimating sedimentation rates, the 2012 TWDB sedimentation survey estimates Choke Canyon Reservoir loses between 944 and 1,708 acre-feet per year of capacity below conservation pool elevation (220.5 feet above mean sea level, NGVD29) due to sedimentation (Table 4). The sedimentation survey indicates sediment accumulation is somewhat consistent throughout the reservoir. The heaviest accumulations measured by this survey are within the submerged river channels. Accumulation in the Frio River channel becomes heavier as it approaches the dam. Comparison of capacity estimates of Choke Canyon Reservoir derived using differing methodologies are provided in Table 4 for sedimentation rate calculation.

Table 4. **Capacity loss comparisons for Choke Canyon Reservoir**

Survey	Volume comparisons at conservation pool elevation, 220.5 feet (acre-feet)				Volume comparison at elevation 207.98 feet (acre-feet)		Pre-impoundment below elevation 207.98 feet (acre-feet)
Original 1982[a]	691,130	<>	<>	<>	<>	<>	<>
USBR 1983[b]	<>	695,125	<>	<>	413,291	<>	<>
TWDB 1993	<>	<>	695,271	<>	<>	413,365 [d]	<>
TWDB pre-impoundment estimate based on 2012 survey	<>	<>	<>	696,239 [c]	<>	<>	414,405[e]
2012 volumetric survey	662,821	662,821	662,821	662,821	388,395	388,395	388,395
Volume difference (acre-feet)	28,309 (4.1%)	32,304 (4.6%)	32,450 (4.7%)	33,418 (4.8%)	24,896 (6.0%)	24,970 (6.0%)	26,010 (6.3%)
Number of years	30	29	19	30	29	19	30
Capacity loss rate (acre-feet/year)	944	1,114	1,708	1,114	830	1,314	867

[a] Source: (TWDB, 2003), note: Choke Canyon Dam was completed in 1982
[b] Source: (WDFT, 2013)
[c] 2012 TWDB surveyed capacity of 662,821 acre-feet plus 2012 TWDB surveyed sediment volume of 26,010 acre-feet at elevation 207.98 feet and the calculated volume difference from the 1983 and 2012 surveys between elevations 207.98feet and 220.5 feet of 7,408 acre-feet
[d] Derived using linear interpolation of values at 207.9 and 208.0 feet from 1993 TWDB capacity table
[e] 2012 TWDB surveyed capacity of 388,395 acre-feet plus 2012 TWDB surveyed sediment volume of 26,010 acre-feet at elevation 207.98 feet

Recommendations

To improve estimates of sediment accumulation rates, TWDB recommends resurveying Choke Canyon Reservoir in approximately 10 years or after a major flood event. To further improve estimates of sediment accumulation, TWDB recommends another sedimentation survey. A resurvey would allow a more accurate quantification of the average sediment accumulation rate for Choke Canyon Reservoir.

TWDB contact information

More information about the Hydrographic Survey Program can be found at:
http://www.twdb.texas.gov/surfacewater/surveys/index.asp
Any questions regarding the TWDB Hydrographic Survey Program may be addressed to:

Jason J. Kemp
Team Lead, TWDB Hydrographic Survey Program
Phone: (512) 463-2456
Email: Jason.Kemp@twdb.texas.gov

Or

Ruben S. Solis, Ph.D., P.E.
Director, Surface Water Resources Division
Phone: (512) 936-0820
Email: Ruben.Solis@twdb.texas.gov

References

COCC (City of Corpus Christi), 2013, Water Supply History, http://www.cctexas.com/government/water/general-info-water-qualitysupply/supply-and-planning/water-supply-history/index, accessed August 2013.

Environmental Systems Research Institute, 1995, *ARC/INFO Surface Modeling and Display, TIN Users Guide*, ESRI, 380 New York Street, Redlands, CA 92373.

Furnans, J., Austin, B., 2007, *Hydrographic survey methods for determining reservoir volume*, Environmental Modeling & Software, doi:10.1016/j.envsoft.2007.05.011.

McEwen, T., Brock, N., Kemp, J., Pothina, D. & Weyant, H., 2011a, *HydroTools User's Manual*, Texas Water Development Board.

McEwen, T., Pothina, D. & Negusse, S., 2011b, *Improving efficiency and repeatability of lake volume estimates using Python*, submitted, Proceedings of the 10th Python for Scientific Computing Conference (SciPy 2011).

NGS (National Geodetic Survey), 2013a, NADCON computations, http://www.ngs.noaa.gov/cgi-bin/nadcon.prl, accessed August 2013.

NGS (National Geodetic Survey), 2013b, Orthometric Height Conversion, http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl, accessed August 2013.

TNRIS (Texas Natural Resources Information System), 2009, http://www.tnris.org/, accessed March 2011.

TNRIS (Texas Natural Resources Information System), 2010, http://www.tnris.org/node/39, accessed August 2013.

TNRIS (Texas Natural Resources Information System), 2012, http://www.tnris.org/node/199, accessed August 2013.

TNRIS (Texas Natural Resources Information System), 2013, http://www.tnris.org/node/98, accessed August 2013.

TPWD (Texas Parks and Wildlife Department), July 2012, Performance Report, As Required by Federal Aid in Sport Fish Restoration Act, Texas, Federal Aid Project F-221-M-2, Inland Fisheries Division Monitoring and Management Program, 2011 Survey Report, Choke Canyon Reservoir, http://www.tpwd.state.tx.us/publications/pwdpubs/media/lake_survey/pwd_rp_t320_1269_2011.pdf.

TWDB (Texas Water Development Board), March 2003, Volumetric Survey of Choke Canyon Reservoir, http://www.twdb.texas.gov/hydro_survey/ChokeCanyon/1993-03/ChokeCanyon1993_FinalReport.pdf

TWDB (Texas Water Development Board), 2012, *Contract No. R1248011441* with the City of Corpus Christi, Texas.

USBR (U.S. Department of the Interior, Bureau of Reclamation), 2012, Choke Canyon Reservoir Allocations, http://www.usbr.gov/gp/aop/resaloc/choke_canyon.pdf.

USBR (U.S. Department of the Interior, Bureau of Reclamation), 2013a, Project details – Nueces River Project – Bureau of Reclamation, http://www.usbr.gov/projects/Project.jsp?proj_Name=Nueces River Project, accessed August 2013.

USDA (US Department of Agriculture), 2013, *National Agricultural Imagery Program (NAIP) Information Sheet*, http://www.fsa.usda.gov/Internet/FSA_File/naip_info_sheet_2013.pdf.

USGS (United States Geological Survey), 2013, U.S. Geological Survey National Water Information System: Web Interface, *USGS Real-Time Water Data for USGS 08206900 Choke Canyon Res nr Three Rivers, TX*, http://waterdata.usgs.gov/tx/nwis/uv/?site_no=08206900&PARAmeter_cd=00062,72020,00054, accessed March 2012.

Van Metre, P.C., Wilson, J.T., Fuller, C.C., Callender, Edward, and Mahler, B.J., 2004, *Collection, analysis, and age-dating of sediment cores from 56 U.S. lakes and reservoirs sampled by the U.S. Geological Survey, 1992-2001: U.S. Geological Survey Scientific Investigations Report 2004-5184,* United States Geological Survey, 180p.

WDFT (Water Data for Texas), 2013, Water Data for Texas, Rating curve data, Choke Canyon, http://www.waterdatafortexas.org/reservoirs/individual/choke-canyon/rating-curve/usbr/1983-01-01, assessed August 2013.

Appendix A

Choke Canyon Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — June 2012 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 220.5 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
135	0	0	0	0	0	0	0	0	0	0
136	0	0	0	1	1	1	1	1	1	2
137	2	2	2	3	3	3	3	4	4	4
138	4	5	5	5	6	6	6	7	7	7
139	8	8	8	9	9	10	10	11	11	12
140	13	13	14	15	15	16	17	18	19	20
141	21	22	23	24	26	27	28	30	31	33
142	35	37	39	41	43	45	47	49	51	54
143	56	58	61	63	66	68	71	74	77	80
144	83	86	89	92	95	99	103	106	110	114
145	118	122	126	131	135	140	144	149	154	159
146	165	170	176	181	187	193	199	205	211	217
147	223	229	236	242	249	256	263	270	277	284
148	292	299	307	315	323	331	339	347	355	364
149	372	381	390	399	408	417	427	436	446	456
150	467	477	488	498	509	521	533	545	557	570
151	584	598	612	626	641	656	672	687	703	720
152	737	754	771	789	807	825	844	863	883	903
153	923	944	965	986	1,008	1,030	1,053	1,076	1,099	1,122
154	1,146	1,171	1,196	1,221	1,247	1,273	1,299	1,326	1,353	1,381
155	1,409	1,438	1,467	1,496	1,526	1,557	1,588	1,619	1,651	1,683
156	1,716	1,750	1,784	1,818	1,853	1,889	1,925	1,961	1,998	2,036
157	2,074	2,113	2,152	2,192	2,233	2,274	2,316	2,358	2,401	2,445
158	2,490	2,535	2,580	2,627	2,674	2,722	2,771	2,821	2,871	2,922
159	2,974	3,026	3,080	3,134	3,188	3,244	3,301	3,358	3,416	3,475
160	3,535	3,596	3,658	3,722	3,786	3,852	3,919	3,987	4,056	4,127
161	4,199	4,272	4,346	4,421	4,497	4,575	4,654	4,734	4,815	4,897
162	4,980	5,065	5,152	5,239	5,328	5,418	5,509	5,602	5,696	5,791
163	5,888	5,986	6,086	6,187	6,290	6,394	6,500	6,608	6,718	6,830
164	6,944	7,060	7,178	7,298	7,420	7,544	7,670	7,798	7,927	8,058
165	8,191	8,326	8,463	8,602	8,743	8,886	9,031	9,177	9,325	9,474
166	9,625	9,778	9,932	10,088	10,245	10,404	10,565	10,728	10,892	11,058
167	11,226	11,396	11,567	11,741	11,917	12,094	12,274	12,455	12,639	12,824
168	13,011	13,200	13,391	13,584	13,780	13,978	14,178	14,380	14,586	14,795
169	15,007	15,222	15,439	15,658	15,880	16,105	16,331	16,561	16,794	17,029
170	17,267	17,508	17,751	17,997	18,245	18,497	18,752	19,009	19,270	19,533
171	19,799	20,068	20,340	20,614	20,892	21,174	21,458	21,746	22,038	22,332
172	22,629	22,929	23,231	23,537	23,845	24,157	24,471	24,788	25,109	25,432
173	25,758	26,087	26,420	26,756	27,095	27,438	27,785	28,134	28,487	28,844
174	29,203	29,565	29,931	30,300	30,671	31,046	31,424	31,805	32,190	32,578
175	32,968	33,362	33,760	34,160	34,564	34,971	35,381	35,794	36,211	36,630
176	37,053	37,479	37,907	38,339	38,773	39,209	39,649	40,091	40,536	40,984
177	41,435	41,889	42,347	42,808	43,271	43,739	44,210	44,685	45,164	45,647
178	46,134	46,625	47,119	47,619	48,123	48,632	49,145	49,662	50,182	50,707
179	51,236	51,769	52,306	52,847	53,392	53,942	54,495	55,053	55,615	56,181
180	56,751	57,326	57,905	58,487	59,074	59,665	60,260	60,859	61,462	62,069
181	62,680	63,295	63,915	64,538	65,165	65,796	66,432	67,071	67,715	68,363
182	69,015	69,671	70,332	70,998	71,668	72,342	73,021	73,703	74,390	75,080
183	75,774	76,472	77,175	77,881	78,591	79,305	80,024	80,746	81,472	82,202
184	82,936	83,674	84,416	85,163	85,915	86,671	87,431	88,196	88,966	89,740
185	90,518	91,301	92,089	92,881	93,677	94,479	95,284	96,095	96,909	97,728
186	98,551	99,379	100,212	101,049	101,891	102,737	103,588	104,443	105,302	106,165
187	107,033	107,905	108,781	109,661	110,545	111,432	112,324	113,220	114,119	115,023
188	115,931	116,842	117,758	118,678	119,602	120,531	121,463	122,400	123,341	124,285
189	125,234	126,186	127,143	128,104	129,069	130,038	131,012	131,990	132,972	133,958

Appendix A (Continued)

Choke Canyon Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — June 2012 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 220.5 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
190	134,948	135,943	136,941	137,944	138,950	139,960	140,974	141,992	143,015	144,041
191	145,071	146,106	147,145	148,187	149,234	150,284	151,339	152,397	153,460	154,526
192	155,597	156,671	157,750	158,832	159,918	161,009	162,104	163,203	164,306	165,414
193	166,527	167,644	168,766	169,893	171,025	172,162	173,304	174,451	175,602	176,758
194	177,918	179,083	180,252	181,425	182,602	183,785	184,971	186,162	187,358	188,558
195	189,763	190,973	192,188	193,408	194,633	195,863	197,097	198,337	199,582	200,832
196	202,086	203,345	204,609	205,878	207,152	208,430	209,713	211,000	212,292	213,589
197	214,890	216,196	217,506	218,822	220,142	221,467	222,797	224,131	225,471	226,815
198	228,164	229,517	230,875	232,238	233,606	234,978	236,355	237,738	239,125	240,518
199	241,915	243,319	244,729	246,145	247,569	249,001	250,439	251,884	253,336	254,794
200	256,259	257,729	259,206	260,689	262,177	263,671	265,171	266,676	268,186	269,701
201	271,222	272,748	274,279	275,815	277,357	278,904	280,455	282,012	283,575	285,141
202	286,713	288,289	289,869	291,453	293,042	294,634	296,231	297,831	299,436	301,045
203	302,657	304,274	305,894	307,518	309,146	310,778	312,414	314,054	315,698	317,346
204	318,997	320,653	322,313	323,977	325,645	327,318	328,994	330,674	332,359	334,048
205	335,741	337,439	339,141	340,847	342,558	344,274	345,994	347,718	349,447	351,181
206	352,920	354,663	356,411	358,164	359,922	361,685	363,453	365,226	367,005	368,788
207	370,577	372,372	374,172	375,977	377,788	379,604	381,425	383,251	385,083	386,921
208	388,763	390,611	392,465	394,323	396,188	398,057	399,932	401,812	403,697	405,588
209	407,484	409,386	411,293	413,205	415,122	417,045	418,973	420,907	422,846	424,790
210	426,740	428,695	430,655	432,621	434,592	436,568	438,550	440,537	442,529	444,527
211	446,530	448,539	450,552	452,572	454,596	456,626	458,661	460,702	462,748	464,799
212	466,855	468,917	470,982	473,052	475,129	477,214	479,307	481,407	483,515	485,629
213	487,750	489,877	492,010	494,148	496,292	498,440	500,592	502,749	504,910	507,075
214	509,245	511,420	513,599	515,783	517,972	520,166	522,366	524,571	526,782	528,998
215	531,219	533,447	535,680	537,918	540,162	542,412	544,669	546,931	549,200	551,475
216	553,757	556,046	558,341	560,643	562,952	565,267	567,590	569,919	572,257	574,603
217	576,956	579,315	581,681	584,053	586,430	588,814	591,204	593,599	596,000	598,406
218	600,818	603,235	605,658	608,085	610,519	612,958	615,402	617,852	620,307	622,768
219	625,234	627,706	630,183	632,665	635,153	637,646	640,144	642,646	645,152	647,663
220	650,179	652,698	655,222	657,749	660,282	662,821				

Note: Capacities from 207.0 feet to 220.5 feet have been re-calculated based on corrected areas. See Appendix B.

Appendix B

Choke Canyon Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — June 2012 Survey

AREA IN ACRES — Conservation Pool Elevation 220.5 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
135	0	0	0	0	0	0	0	0	0	1
136	1	1	1	2	2	2	2	2	2	2
137	2	2	2	2	2	2	3	3	3	3
138	3	3	3	3	3	3	3	3	4	4
139	4	4	4	4	5	5	5	6	6	6
140	6	7	7	7	8	8	9	9	10	10
141	11	11	11	12	12	13	14	17	17	18
142	18	19	20	20	21	21	22	22	23	23
143	23	24	24	25	26	26	27	28	28	29
144	30	31	32	33	34	36	37	38	39	40
145	41	42	43	44	45	47	48	49	51	52
146	53	54	55	56	57	58	59	60	61	62
147	63	64	65	66	67	69	70	71	72	73
148	75	76	77	78	79	80	81	83	84	85
149	86	88	89	91	92	94	96	98	99	101
150	103	105	107	109	112	116	120	124	128	132
151	136	140	143	146	149	153	156	159	163	166
152	169	173	176	179	183	186	190	194	198	201
153	205	208	212	216	219	223	227	231	235	238
154	243	247	251	255	259	263	267	271	275	280
155	284	288	293	297	302	306	311	316	321	327
156	332	337	342	347	352	358	363	368	373	379
157	384	390	396	402	409	415	421	428	435	442
158	448	455	462	469	476	484	491	499	507	515
159	522	529	537	544	552	560	568	577	586	596
160	606	617	627	639	651	663	675	687	699	712
161	724	736	747	758	769	781	793	805	817	829
162	842	856	868	880	893	906	920	934	948	962
163	976	990	1,004	1,020	1,036	1,052	1,068	1,088	1,107	1,129
164	1,152	1,172	1,191	1,210	1,229	1,249	1,268	1,286	1,303	1,321
165	1,341	1,361	1,380	1,399	1,419	1,437	1,455	1,471	1,486	1,501
166	1,517	1,533	1,550	1,566	1,583	1,599	1,617	1,634	1,652	1,670
167	1,689	1,708	1,727	1,746	1,766	1,786	1,805	1,824	1,843	1,863
168	1,881	1,901	1,921	1,944	1,966	1,988	2,012	2,041	2,076	2,106
169	2,132	2,159	2,184	2,207	2,231	2,255	2,282	2,310	2,339	2,367
170	2,395	2,419	2,445	2,473	2,502	2,532	2,559	2,589	2,618	2,647
171	2,676	2,703	2,731	2,763	2,797	2,831	2,864	2,896	2,927	2,955
172	2,984	3,012	3,040	3,069	3,099	3,130	3,160	3,188	3,217	3,247
173	3,278	3,309	3,343	3,377	3,412	3,446	3,478	3,514	3,548	3,579
174	3,609	3,640	3,671	3,702	3,733	3,763	3,797	3,830	3,861	3,892
175	3,924	3,955	3,990	4,023	4,054	4,085	4,118	4,148	4,180	4,211
176	4,241	4,270	4,300	4,328	4,355	4,381	4,408	4,435	4,464	4,495
177	4,527	4,558	4,591	4,623	4,656	4,691	4,729	4,769	4,809	4,849
178	4,889	4,929	4,971	5,019	5,068	5,108	5,148	5,186	5,226	5,269
179	5,310	5,351	5,391	5,430	5,472	5,514	5,555	5,598	5,642	5,685
180	5,726	5,766	5,807	5,847	5,889	5,930	5,971	6,011	6,051	6,089
181	6,131	6,171	6,212	6,252	6,293	6,334	6,374	6,414	6,457	6,500
182	6,542	6,587	6,633	6,676	6,723	6,765	6,807	6,847	6,884	6,922
183	6,961	7,001	7,041	7,082	7,124	7,164	7,202	7,241	7,279	7,318
184	7,359	7,402	7,447	7,492	7,537	7,583	7,628	7,673	7,718	7,762
185	7,807	7,851	7,897	7,944	7,991	8,036	8,080	8,122	8,166	8,210
186	8,257	8,304	8,350	8,396	8,441	8,484	8,527	8,569	8,613	8,656
187	8,697	8,738	8,781	8,821	8,860	8,897	8,936	8,976	9,016	9,056
188	9,096	9,137	9,179	9,221	9,263	9,305	9,347	9,388	9,427	9,466
189	9,506	9,546	9,587	9,629	9,673	9,715	9,757	9,800	9,841	9,883

Appendix B (Continued)

Choke Canyon Reservoir

RESERVOIR AREA TABLE

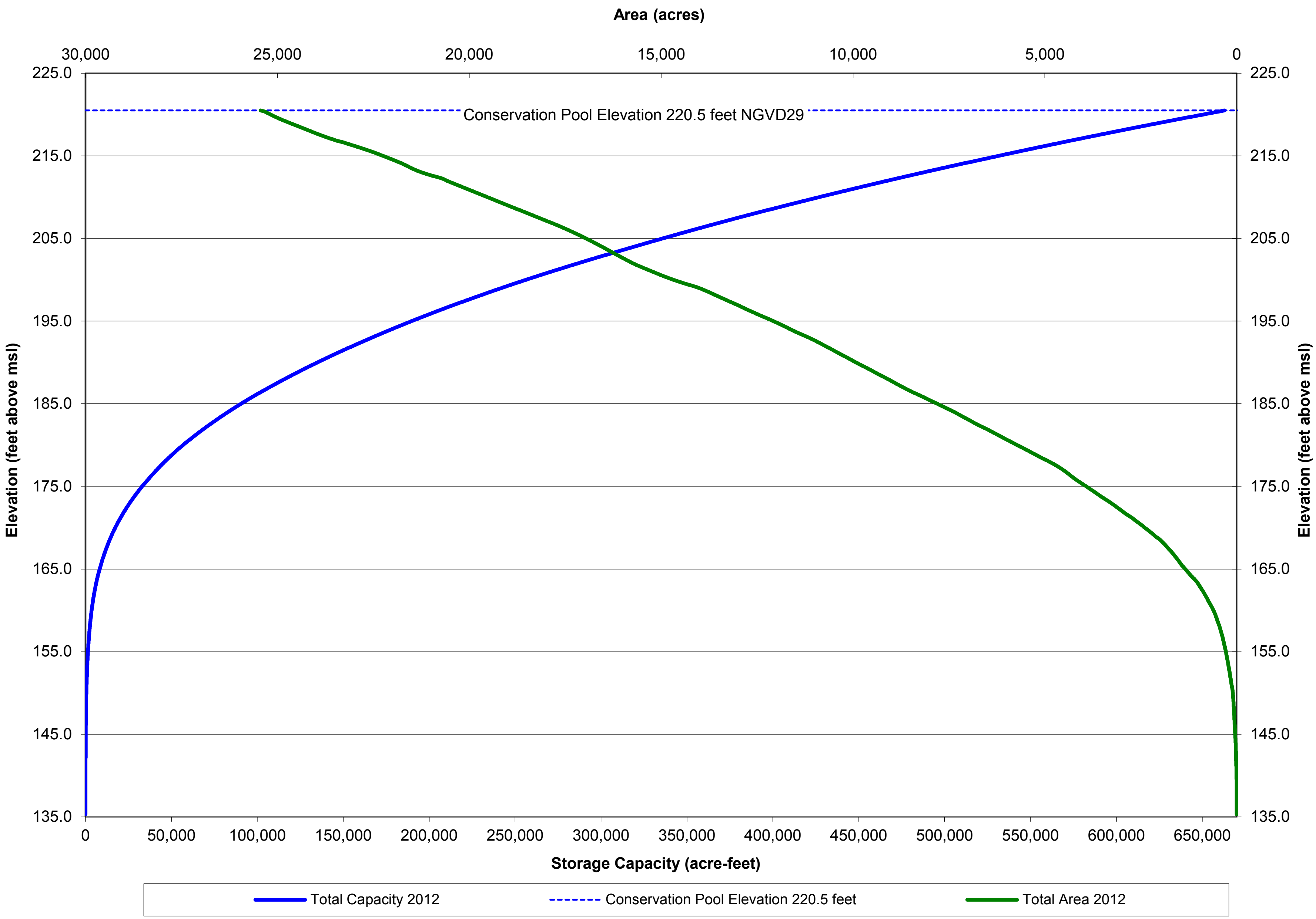
TEXAS WATER DEVELOPMENT BOARD | June 2012 Survey

AREA IN ACRES | Conservation Pool Elevation 220.5 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
190	9,924	9,964	10,004	10,043	10,083	10,122	10,161	10,200	10,243	10,285
191	10,325	10,366	10,406	10,445	10,486	10,525	10,564	10,605	10,646	10,685
192	10,725	10,765	10,804	10,843	10,885	10,927	10,970	11,013	11,057	11,102
193	11,149	11,196	11,244	11,296	11,345	11,394	11,443	11,490	11,535	11,580
194	11,626	11,668	11,710	11,754	11,799	11,842	11,887	11,934	11,980	12,027
195	12,076	12,124	12,174	12,223	12,272	12,324	12,374	12,423	12,471	12,520
196	12,567	12,615	12,664	12,714	12,761	12,807	12,852	12,897	12,943	12,988
197	13,035	13,082	13,131	13,179	13,225	13,273	13,321	13,369	13,417	13,465
198	13,512	13,559	13,606	13,653	13,700	13,747	13,797	13,848	13,900	13,952
199	14,005	14,064	14,131	14,202	14,278	14,350	14,418	14,485	14,550	14,613
200	14,676	14,736	14,797	14,856	14,914	14,970	15,023	15,075	15,128	15,180
201	15,232	15,284	15,337	15,390	15,443	15,492	15,544	15,597	15,645	15,692
202	15,737	15,780	15,822	15,864	15,905	15,946	15,987	16,027	16,067	16,106
203	16,144	16,183	16,222	16,261	16,300	16,340	16,379	16,419	16,459	16,499
204	16,539	16,579	16,620	16,660	16,701	16,743	16,784	16,826	16,868	16,911
205	16,954	16,998	17,042	17,086	17,131	17,176	17,222	17,268	17,315	17,362
206	17,409	17,457	17,506	17,555	17,604	17,655	17,706	17,758	17,810	17,864
207	17,919	17,972	18,026	18,079	18,133	18,186	18,240	18,293	18,346	18,400
208	18,453	18,507	18,560	18,614	18,667	18,721	18,774	18,828	18,881	18,935
209	18,988	19,042	19,095	19,149	19,202	19,256	19,309	19,363	19,416	19,470
210	19,523	19,576	19,630	19,683	19,737	19,790	19,844	19,897	19,951	20,004
211	20,058	20,111	20,165	20,218	20,272	20,325	20,379	20,432	20,486	20,539
212	20,593	20,631	20,676	20,733	20,805	20,888	20,969	21,042	21,110	21,177
213	21,242	21,304	21,356	21,406	21,455	21,503	21,546	21,589	21,632	21,678
214	21,722	21,767	21,815	21,867	21,917	21,969	22,022	22,078	22,134	22,188
215	22,244	22,302	22,358	22,413	22,470	22,531	22,595	22,657	22,721	22,786
216	22,853	22,917	22,984	23,053	23,123	23,191	23,260	23,329	23,430	23,494
217	23,558	23,623	23,689	23,749	23,808	23,867	23,926	23,981	24,036	24,090
218	24,145	24,198	24,250	24,305	24,362	24,416	24,470	24,524	24,580	24,635
219	24,689	24,744	24,799	24,853	24,904	24,952	25,000	25,045	25,088	25,130
220	25,173	25,215	25,257	25,301	25,346	25,438				

Note: Values from 207.0 feet to 212.0 feet are linear interpolations between computed values.



Choke Canyon Reservoir
June 2012 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Figure 6

CONTOURS
(feet above mean sea level)

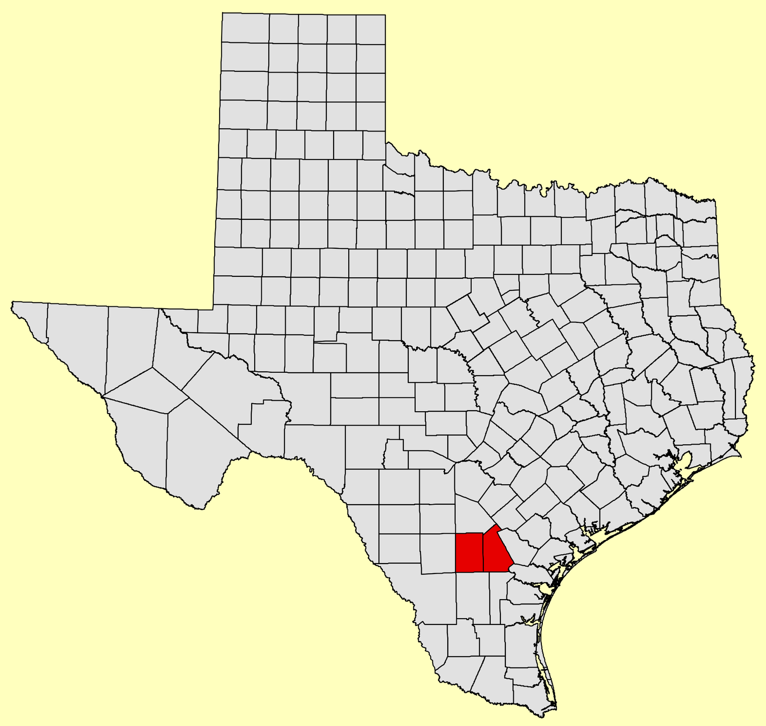
220
215
210
205
200
195
190
185
180
175
170
165
160
155
150
145
140

Islands

Choke Canyon Reservoir

Conservation Pool Elevation
220.5 feet above mean sea level

Projection: NAD83
State Plane
Texas South Central Zone



Live Oak and McMullen Counties

This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Choke Canyon Reservoir. The Texas Water Development Board makes no representations nor assumes any liability.