Volumetric and Sedimentation Survey of BELTON LAKE

September – October 2015 Survey

Texas Water Development Board

March 2017

Texas Water Development Board

Prepared for:

Brazos River Authority

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Executive summary

In September 2015, the Texas Water Development Board (TWDB) entered into an agreement with the Brazos River Authority, to perform a volumetric and sedimentation survey of Belton Lake (Bell County, Texas). Surveying was performed using a multi-frequency (208 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.

Belton Dam and Belton Lake are located on the Leon River, a tributary of the Little River which is a tributary of the Brazos River, approximately 3 miles north of the City of Belton, in Bell County, Texas. The conservation pool elevation of Belton Lake is 594.0 feet above mean sea level (NGVD29). The TWDB collected bathymetric data for Belton Lake between September 3 and October 29, 2015, while daily average water surface elevations measured between 592.42 and 599.04 feet above mean sea level (NGVD29).

The 2015 TWDB volumetric survey indicates that Belton Lake has a total reservoir capacity of 432,631 acre-feet and encompasses 12,445 acres at conservation pool elevation (594.0 feet above mean sea level, NGVD29). The original design estimate by the U.S. Army Corps of Engineers indicates Belton Lake encompassed 12,300 acres with a total reservoir capacity of 457,600 acre-feet. The original design was later revised in 1963 to account for the sediment range lines installed in 1953–1954, resulting in a total reservoir capacity estimate of 456,884 acre-feet encompassing 12,416 acres. The U.S. Army Corps of Engineers resurveys of Belton Lake in 1961 and 1966 indicate the lake encompassed 12,420 acres and 12,423 acres with a total reservoir capacity of 447,500 acre-feet and 441,984 acre-feet, respectively. The TWDB previously surveyed Belton Lake in 1994 and 2003. The 1994 and 2003 TWDB surveys were re-evaluated using current processing procedures resulting in updated capacity estimates of 446,505 acre-feet and 446,031 acre-feet, respectively.

Based on two methods for estimating sedimentation rates, the 2015 TWDB sedimentation survey estimates Belton Lake to have an average loss of capacity between 371 and 398 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (594.0 feet NGVD29). The sedimentation survey indicates sediment accumulation varies throughout the reservoir. Sediment accumulation is consistently greater throughout the main thalwegs of Cowhouse Creek and Leon River. The TWDB recommends that a similar methodology be used to resurvey Belton Lake in 10 years or after a major flood event.

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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. Texas Water Code Section 15.804 authorizes the TWDB to perform surveys to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability.

In September 2015, the TWDB entered into an agreement with the Brazos River Authority, to perform a volumetric and sedimentation survey of Belton Lake (Texas Water Development Board, 2015). This report describes the methods used to conduct the volumetric and sedimentation survey in 2015, including data collection and processing techniques. This report serves as the final contract deliverable from the TWDB to the Brazos River Authority and contains as deliverables: (1) a shaded relief plot of the reservoir bottom (Figure 4), (2) a bottom contour map (Figure 6), (3) an estimate of sediment accumulation and location (Figure 10), and (4) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality (Appendices A and B).

Belton Lake general information

Belton Dam and Belton Lake are located on the Leon River, a tributary of the Little River which is a tributary of the Brazos River, approximately 3 miles north of the City of Belton, in Bell County, Texas (Figure 1). Belton Lake lies mainly in Bell County but extends into Coryell County. Belton Dam and Belton Lake are owned by the U.S. Government and operated by the U.S. Army Corps of Engineers, Fort Worth District (Texas Water Development Board, 1973). The U.S. Congress authorized the construction of Belton Lake for flood control, water conservation, and other multipurpose uses with the passage of the Flood Control Act approved July 24, 1946, and modified September 3, 1954 (U.S. Army Corps of Engineers, 2007). Construction on Belton Dam began in July 1949, and deliberate impoundment began on March 8, 1954. Belton Dam was completed on December 15, 1954 (Texas Water Development Board, 1973; U.S. Army Corps of Engineers, 1975). Belton Lake was originally operated at a conservation pool elevation of 569.0 feet. Deliberate impoundment at the current conservation pool elevation of 594.0 feet began on May 1, 1972, after completion of Proctor Lake (U.S. Army Corps of Engineers, 2007). Additional pertinent data about Belton Dam and Belton Lake can be found in Table 1.

Water rights for Belton Lake have been appropriated to the Brazos River Authority through Certificate of Adjudication Nos. 12-2936, 12-2936A, and 12-5160. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

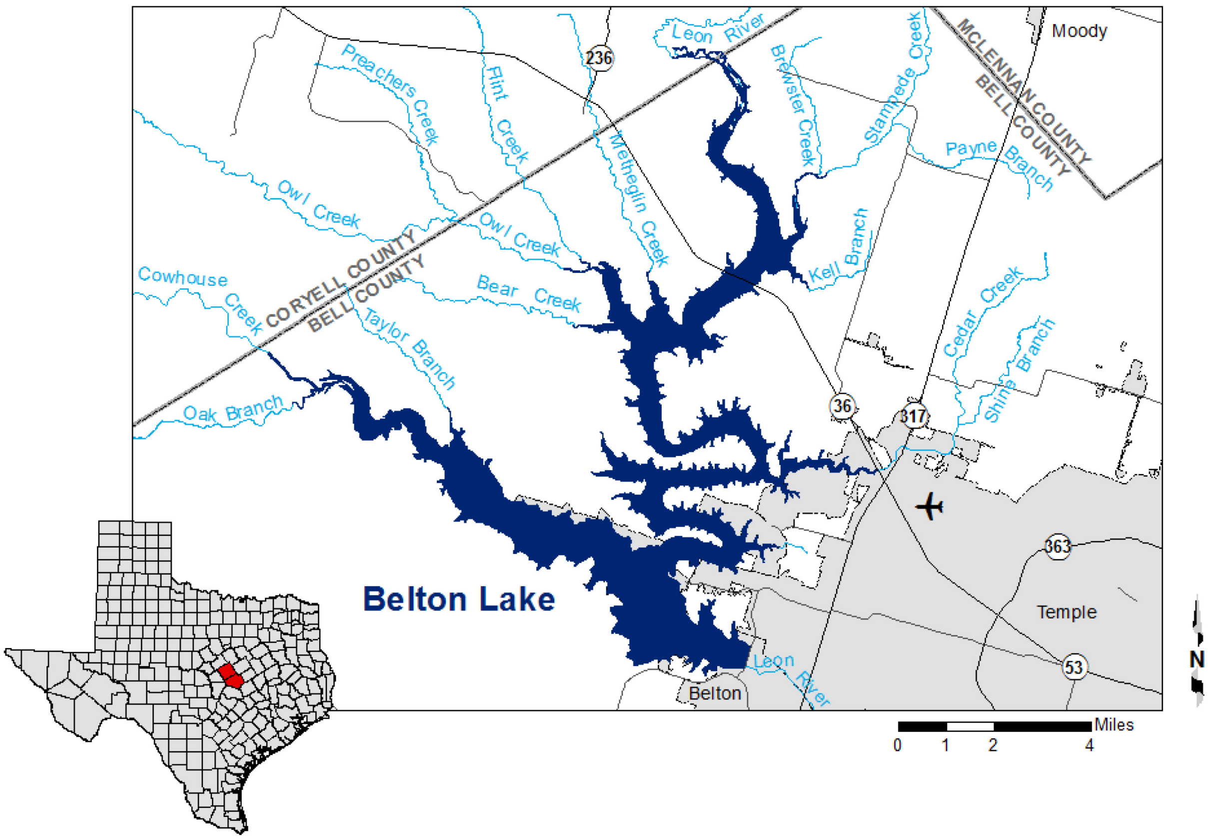


Figure 1. **Location map of Belton Lake.**

Table 1. Pertinent data for De Cordova Bend Dam and Belton Lake.

Owner
The U.S. Government
Operated by the U.S. Army Corps of Engineers, Fort Worth District

Design Engineer
U.S. Army Corps of Engineers

General contractor
J.W. Moorman and Son, Snyder, Texas

Location of dam
On the Leon River in Bell County, 3 miles north of the City of Belton

Drainage area
3,560 square miles (includes lake area and Proctor Lake)

Dam	
Type	Rolled earth fill
Length	5,524 feet (including spillway and 418 feet dike)
Maximum height	192 feet
Top width	30 feet
Spillway	
Type	Broad-crested weir
Control	None
Length	1,300 feet
Crest elevation	631.0 feet above mean sea level
Outlet Works	
Type	1 conduit with 3 gated inlets
Dimension	22-foot diameter
Control	3 Broome-type gates, each 7 feet by 22 feet
Invert elevation	483.0 feet above mean sea level
Low Flow Outlets	
Type	One 3 feet by 3 feet gated outlet discharging into flood control conduit
Invert elevation	540.0 feet above mean sea level (at intake to wet well)

Reservoir data (Based on 2015 TWDB survey)

Feature	**Elevation (feet** NGVD29[a]**)**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam	662.0	N/A	N/A
Top of flood control pool/ emergency spillway crest elevation	631.0	N/A	N/A
Top of conservation pool	594.0	432,631	12,445
Invert outlet works	540.0	49,938	2,911
Invert of low flow outlet	483.0	0	0

Source: (Texas Water Development Board, 1973; U.S. Army Corps of Engineers, 1975; U.S. Army Corps of Engineers, 2016)
[a] NGVD29 = National Geodetic Vertical Datum 1929

Volumetric and sedimentation survey of Belton Lake

Datum

The vertical datum used during this survey is the National Geodetic Vertical Datum 1929 (NGVD29). This datum also is utilized by the United States Geological Survey (USGS) for the reservoir elevation gage *USGS 08102000 Belton Lk nr Belton, TX* (U.S. Geological Survey, 2016). 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 Central Zone (feet).

TWDB bathymetric and sedimentation data collection

The TWDB collected bathymetric data for Belton Lake between September 3 and October 29, 2015, while the daily average water surface elevations measured between 592.42 and 599.04 feet above mean sea level (NGVD29). For data collection, the TWDB used a Specialty Devices, Inc. (SDI), single-beam, multi-frequency (208 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment. Data was collected 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 same survey lines also were used by the TWDB during the 1994 and 2003 surveys. 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 2015 TWDB survey.

On March 8, 2017, the TWDB collected additional bathymetric data to verify the accuracy of data collected during the initial collection period. Data verification was conducted by collecting data along ten previously run transects spaced throughout the lake and comparing the March 8, 2017, data to the initial data. The two data sets displayed uniform depths and cross-sectional profiles, supporting the accuracy of the data collected.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples were 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. After analyzing the sounding data, the TWDB selected eight locations to collect sediment core samples (Figure 2). The sediment core samples were collected on January 27, 2016, 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 surface, through the accumulated sediment, and to the pre-impoundment surface. After retrieving the sample, a stadia rod is inserted into the top of the aluminum tubes to assist in locating the top of the sediment in the tube. This identifies the location of the layer corresponding to the current reservoir-bottom 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.

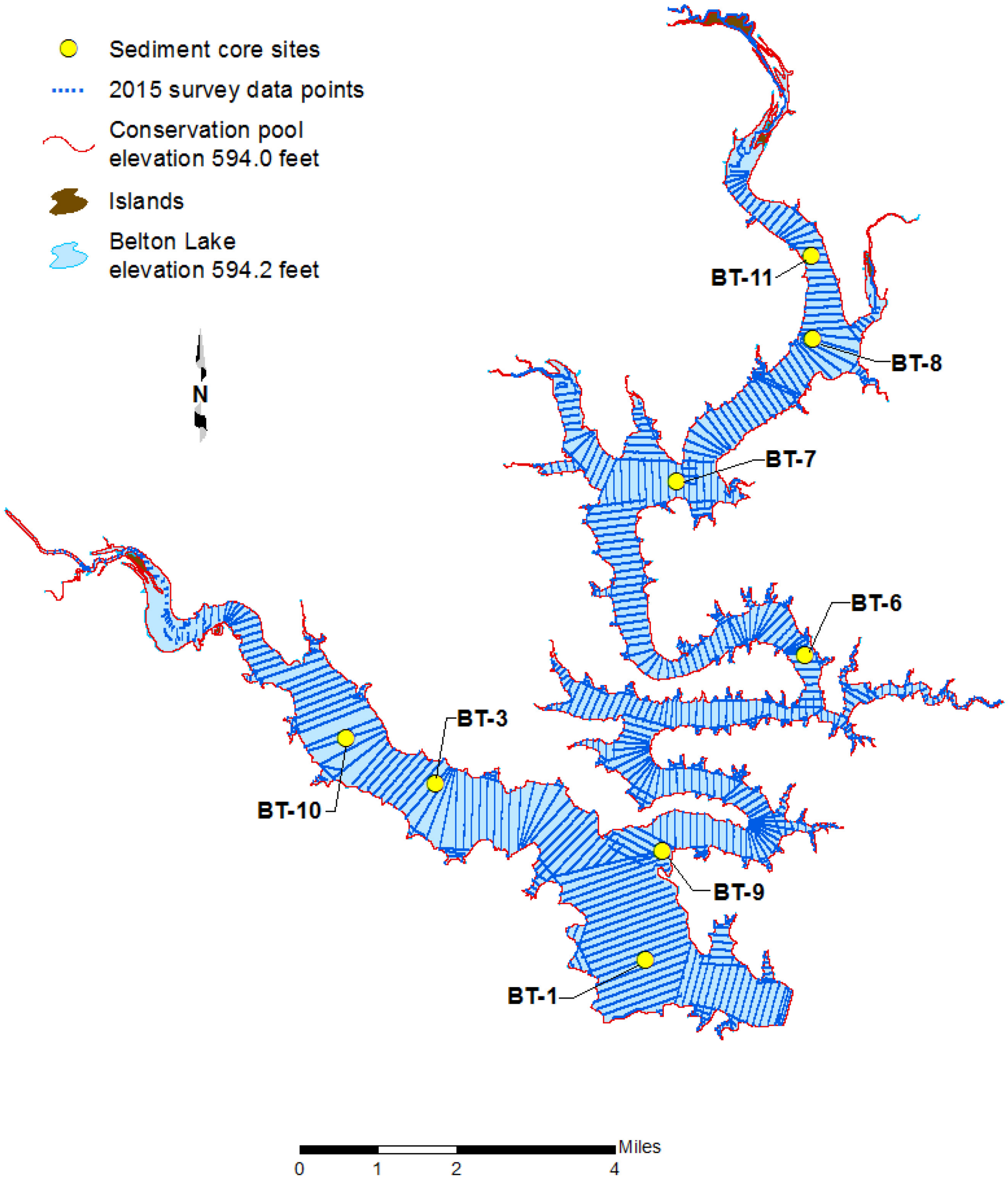


Figure 2. 2015 TWDB Belton Lake survey data (*blue dots*) and sediment coring locations (*yellow circles*).

Data processing

Model boundaries

The reservoir's boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), obtained from the Texas Natural Resources Information System (Texas Natural Resources Information System, 2016a) using Environmental Systems Research Institute's ArcGIS software. The quarter-quadrangles that cover Belton Lake are Belton (NW), Bland (NE, NW, SE, SW), Eagle Springs (SW), Moffat (NW, SE, SW), Nolanville (NE), and Post Oak Mountain (NE). The DOQQs were photographed on August 31and September 8, 2004, while daily average water surface elevation measured 595.86 feet, and 594.2 feet above mean sea level, respectively. According to metadata associated with the 2004 DOQQs, the photographs have a resolution or ground sample distance of 1.0 meters and a horizontal accuracy within ± 5 meters of reference DOQQs from the National Digital Ortho Program (Texas Natural Resources Information System, 2016b; U.S. Department of Agriculture, 2016). The majority of the DOQQs were photographed on September 8, 2004; therefore, the boundary was digitized at the land-water interface in the 2004 photographs and assigned an elevation of 594.2 feet.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by the TWDB were edited to remove data anomalies. DepthPic© software, developed by SDI, Inc., was 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©, HydroTools, a software package developed by TWDB staff, was used to identify the current reservoir-bottom surface, pre-impoundment surface, sediment thickness at each sounding location, and to 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 was then preconditioned by inserting a uniform grid of artificial survey points between the actual survey lines. Bathymetric elevations at these artificial points were determined using an anisotropic spatial interpolation algorithm described in the next section. This technique creates a high resolution, uniform grid of interpolated bathymetric elevation points throughout a majority of the reservoir (McEwen and others, 2011a). 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 (Environmental Systems Research Institute, 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 bathymetry 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, the 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 by directly examining the 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 reservoir bathymetry and sediment accumulation throughout the reservoir. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen and others, 2011a) and in McEwen and others, 2011b.

In areas inaccessible to survey data collection, such as small coves and shallow upstream areas of the reservoir, linear interpolation is used for volumetric and sediment accumulation estimations. Linear interpolation follows a line linking the survey points file to the lake boundary file (McEwen and others, 2011a). Without linearly interpolated 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 interpolation improves the elevation-capacity and elevation-area calculations, although it is not always possible to remove all flat triangles.

Figure 3 illustrates typical results from application of the anisotropic interpolation and linear interpolation techniques to Belton Lake. In Figure 3A, deeper channels and steep slopes 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 in creation of the volumetric TIN model, represented in Figure 3B, directs Delaunay triangulation to better represent the reservoir bathymetry between survey cross-sections. The bathymetry shown in Figure 3C was used in computing reservoir elevation-capacity (Appendix A) and elevation-area (Appendix B) tables.

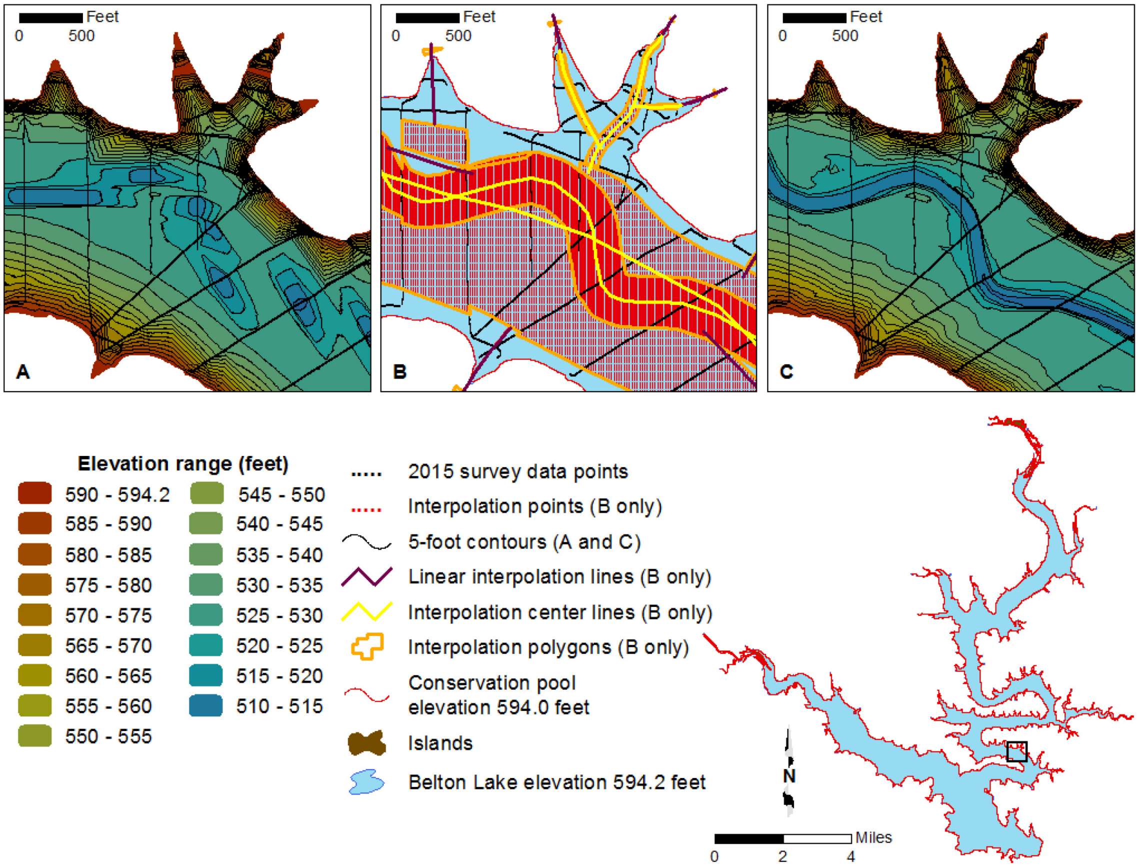


Figure 3. **Anisotropic spatial interpolation and linear interpolation of Belton Lake sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.**

Area, volume, and contour calculation

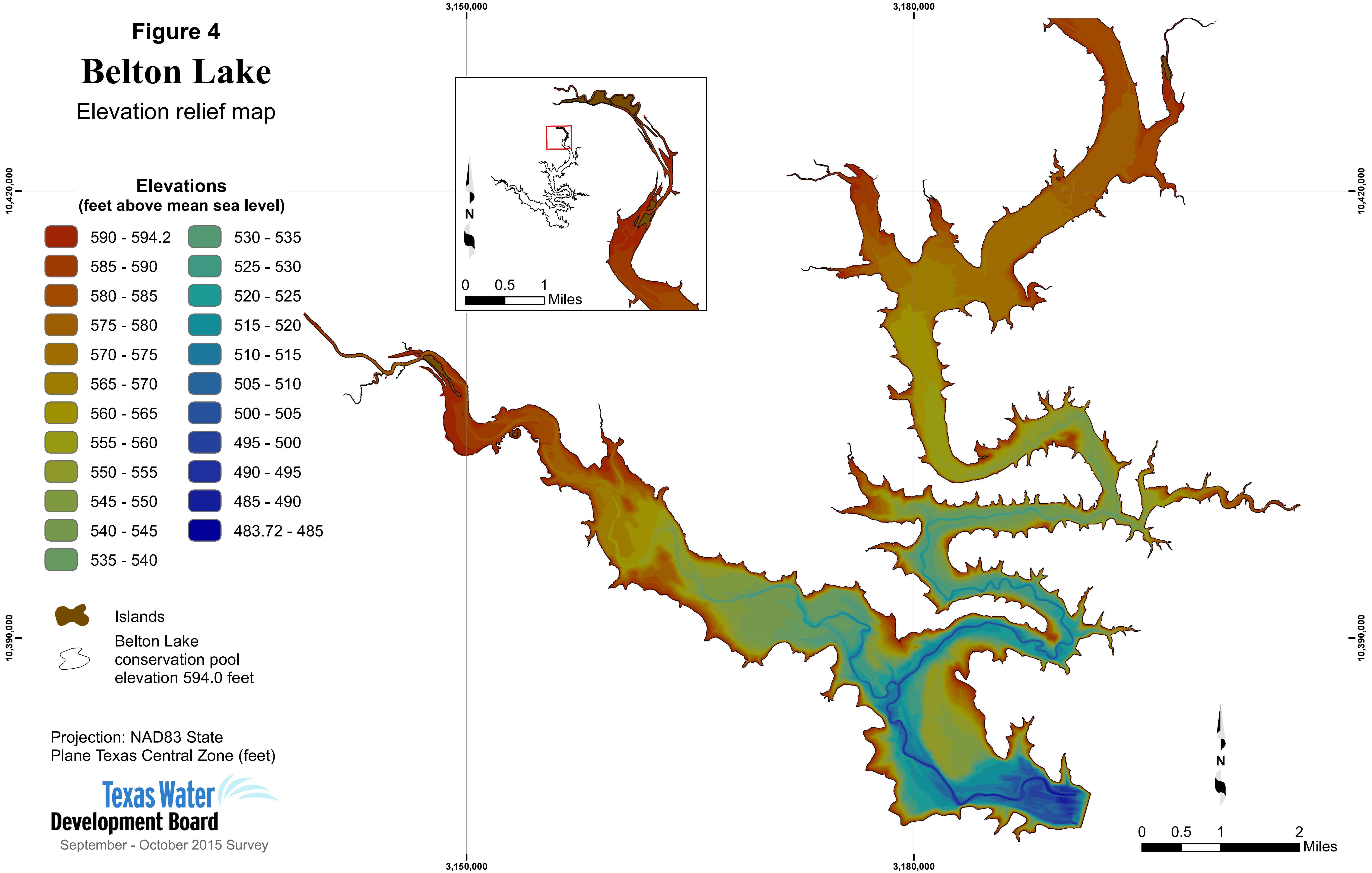
Using ArcInfo software and the volumetric TIN model, volumes and areas were calculated for the entire reservoir at 0.1-foot intervals, from 481.0 to 594.2 feet. While linear interpolation was used to estimate topography in areas that were inaccessible by boat or too shallow for the instruments to work properly, development of some flat triangles (triangles whose vertices all have the same elevation) in the TIN model are unavoidable. The flat triangles in turn lead to anomalous calculations of surface area and volume at the boundary elevation 594.2 feet. To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 591.5 feet and 594.2 feet were linearly interpolated between the computed values, and volumes above elevation 591.5 feet were calculated based on the corrected areas. The elevation-capacity table and elevation-area table, based on the 2015 survey and analysis, are presented in Appendices A and B, respectively. The capacity curve is presented in Appendix C, and the area curve is presented in Appendix D.

The volumetric TIN model was converted to a raster representation using a cell size of one foot by one foot. The raster data then was used to produce three figures: (1) an elevation relief map representing the topography of the reservoir bottom (Figure 4); (2) a depth range map showing shaded depth ranges for Belton Lake (Figure 5); and, (3) a five-foot contour map (Figure 6).

Figure 4

Belton Lake

Elevation relief map



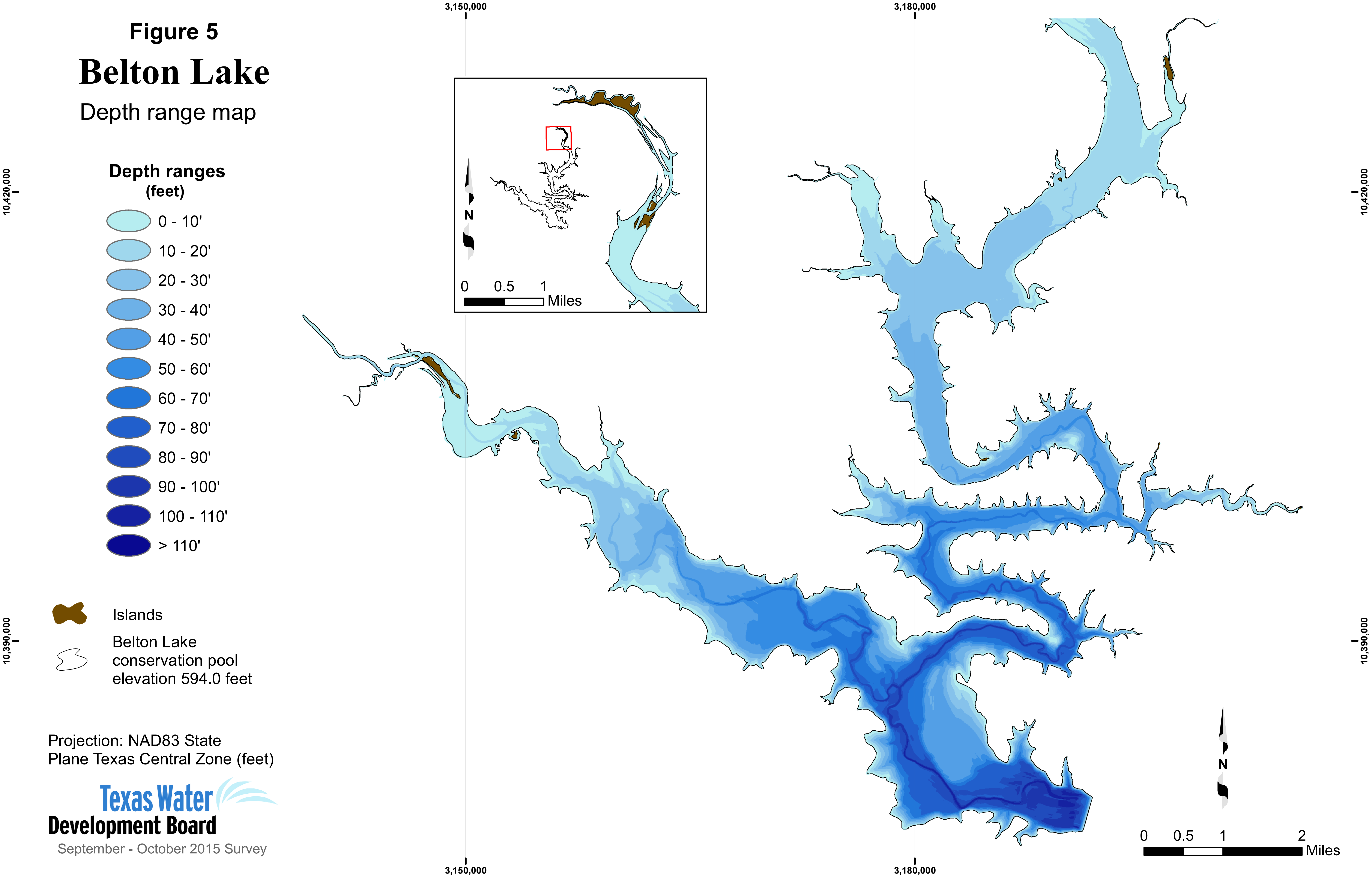


Figure 5
Belton Lake
Depth range map

Analysis of sediment data from Belton Lake

Sedimentation in Belton Lake was determined by analyzing the acoustic signal returns of all three depth sounder frequencies in the DepthPic© software. While the 208 kHz signal is used to determine the current bathymetric surface, all three frequencies, 208 kHz, 50 kHz, and 24 kHz, are 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 are correlated with the acoustic signals in each frequency to assist in identifying the pre-impoundment surface. The difference between the current surface bathymetry and the pre-impoundment surface bathymetry 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 more of the following methods: (1) a visual examination of the sediment core for terrestrial 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 and others, 2004). Total sample length, post impoundment sediment thickness, and pre-impoundment thickness were recorded. Physical characteristics of the sediment core, such as Munsell soil color, texture, relative water content, and presence of organic materials also were recorded (Table 2).

Table 2. Sediment core sampling analysis data for Belton Lake.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
BT-1	3182016.08	10381620.85	30.75"/25.0"	post-impoundment	0.0–4.0" water and fluff	N/A
					4.0–6.5" high water content, loose, loamy sand	2.5Y 3/2
					6.5–14.75" medium-high water content, loamy sand	2.5Y 4/2
					14.75–25.0" medium-high water content, loamy sand, similar texture to layer 3, color change	7.5YR 4/4
				pre-impoundment	25.0–30.75" low water content, texture change, high clay content, sandy clay loam	7.5YR 4/3
BT-3	3167943.42	10393403.63	42.5"/33.5"	post-impoundment	0.0–3.0" water and fluff	N/A
					3.0–3.5" high water content, silt	2.5Y 5/3
					3.5–18.25" higher density, lower water content, mottling, silt	2.5Y 2.5/1
					18.25–33.5" higher density, some hard lumps in material, silt	2.5Y 3/2
				pre-impoundment	33.5–42.5" low water content, higher clay content, silty clay loam	2.5Y 3/2
BT-6	3192653.40	10401993.00	43.0"/36.5"	post-impoundment	0.0–0.75" water and fluff	N/A
					0.75–5.5" high water content, silt	2.5Y 3/2
					5.5–36.5" lower water content, silt loam	2.5Y 2.5/1
				pre-impoundment	36.5–43.0" texture change- higher density, lower water content, silty clay or clay loam	2.5Y 3/1

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

Table 2. Sediment core sampling analysis data for Belton Lake (continued).

Sedimet core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
BT-7	3184070.17	10413643.90	35.0"/28.0"	post-impoundment	0.0–1.5" water and fluff	N/A
					1.5–3.5" very high water content, silt	2.5Y 4/2
					3.5–23.5" high water content, mottling, silt or silty loam	2.5Y 2.5/1
					23.5–28.0" high water content material with lumps of more dense, clay-rich material, mix of upper and lower layers, high organics	2.5Y 2.5/1
				pre-impoundment	28.0–35.0" dense, low water content, clay loam	2.5Y 3/2
BT-8	3193205.13	10423215.95	42.5"/39.5"	pre-impoundment	0.0–1.0" water and fluff	N/A
					1.0–5.75" high water content, silt	2.5Y 4/2
					5.75–39.5" mottled, more dense layer above, med-high water content, silty loam	2.5Y 4/2
				pre-impoundment	39.5–42.5" dense, low water content, clay loam	2.5Y 3/2
BT-9	3183166.51	10388886.97	12.75"/9.0"	post-impoundment	0.0–6.75" water and fluff	N/A
					6.75–7.25" high water content, silt, organics-shells	2.5Y 3/2
					7.25–9.0" lower water content, organics, loam	2.5Y 3/3
				pre-impoundment	9.0–12.75" lower water content than above layer, organics, higher clay content, silty clay	2.5Y 3/3

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

Table 2. Sediment core sampling analysis data for Belton Lake (continued).

Sedimet core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
BT-10	3161959.60	10396432.70	32.5”/23.5”	post-impoundment	0.0–3.5” water and fluff	N/A
					3.5–7.0” very high water content, silt loam	5Y 4/2
					7.0–23.5” high water content, silt or silt loam	2.5Y 3/1
				pre-impoundment	23.5–32.5” significant texture and density change from above layer, organics at boundary, silty clay	2.5Y 4/1
BT-11	3193156.65	10428802.13	51.0”/47.5”	pre-impoundment	0.0–0.75” water and fluff	N/A
					0.75–6.25” high water content, silt	2.5Y 4/2
					6.25–47.5” lower water content than above layer, mottling, higher density, silt loam	2.5Y 4/1
				pre-impoundment	47.5–51.0” lower water content than above layer, increased clay content, dense, clay loam	2.5Y 3/3

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

A photograph of sediment core BT-7 (for location, refer to Figure 2) is shown in Figure 7 and is representative of sediment cores sampled from Belton Lake. The base of the sample is denoted by the blue line. The pre-impoundment boundary (yellow line) was evident within this sediment core sample at 28.0 inches and identified by the change in color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the other seven sediment cores followed a similar procedure.

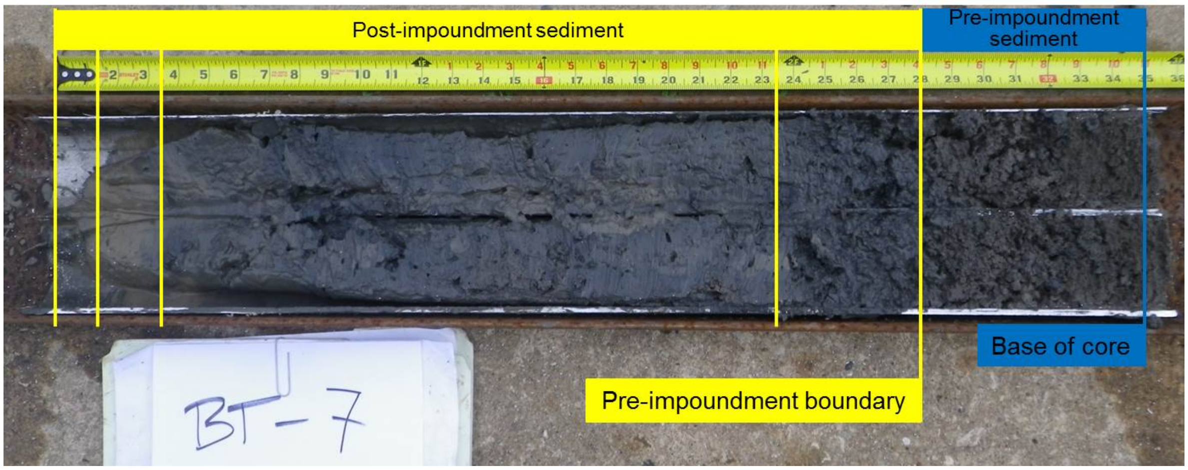


Figure 7. Sediment core BT-7 from Belton Lake. Post-impoundment sediment layers occur in the top 28 inches of this sediment core (identified by yellow boxes). Pre-impoundment sediment layers were identified and are defined by the blue box.

Figures 8 and 9 illustrate how measurements from sediment core samples are used with sonar data to help identify the post- and pre-impoundment layers in the acoustic signal. Figure 8 compares sediment core sample BT-7 with the acoustic signals for all frequencies combined (8A, 8E), and each individual frequency: 208 kHz (8B, 8F), 50 kHz (8C, 8G), and 24 kHz (8D, 8H). Within DepthPic©, the current bathymetric surface is automatically determined based on signal returns from the 208 kHz transducer as represented by the top black line in Figure 8E and red line in Figure 8F–H. The pre-impoundment surface is identified by comparing boundaries observed in the 208 kHz, 50 kHz, and 24 kHz signals to the location of the pre-impoundment surface as determined by the sediment core sample analysis. Many layers of sediment may be identified during core analysis based on changes in observed characteristics, such as water content, organic matter content, and sediment particle size, and each layer is classified as either post-impoundment or pre-impoundment. Each layer of sediment identified in the sediment core sample during analysis (Table 2) is represented in Figures 8 and 9 by a yellow or blue box. A yellow box represents post-impoundment sediments. A blue box indicates pre-impoundment sediments.

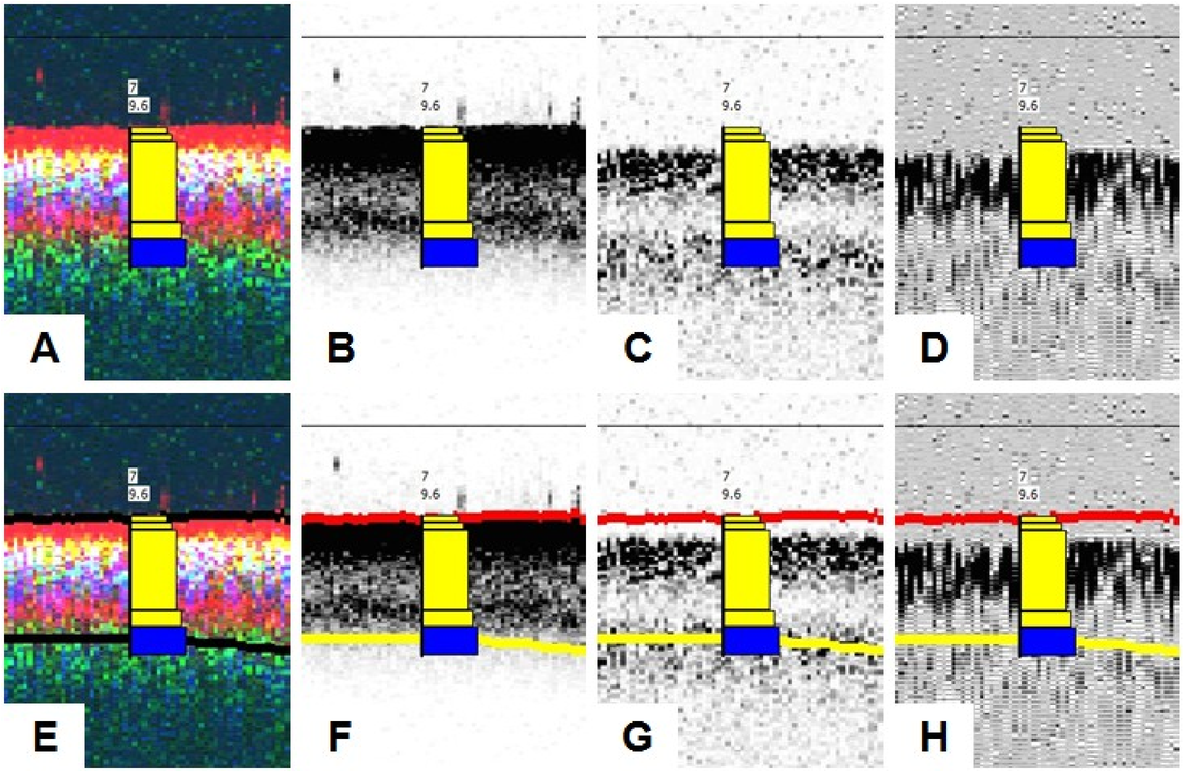


Figure 8. Comparison of sediment core BT-7 with acoustic signal returns A, E) combined acoustic signal returns, B, F) 208 kHz frequency, C, G) 50 kHz frequency, and D, H) 24 kHz frequency.

In this case, the pre-impoundment boundary as identified from the pre-impoundment interface of the sediment core sample was most visible in the combined acoustic signal returns; therefore, the combined acoustic signal returns were used to locate the pre-impoundment surface (yellow line in Figure 8). Figure 9 shows sediment core sample BT-7 correlated with the combined acoustic signal returns of the nearest surveyed cross-section. The pre-impoundment surface is first identified along cross-sections for which sediment core samples have been collected. This information then is used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

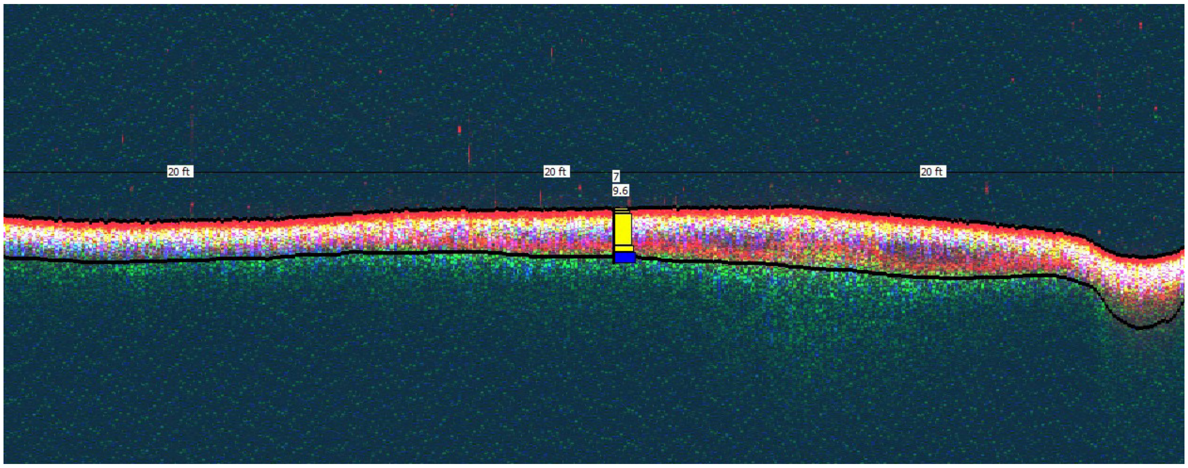


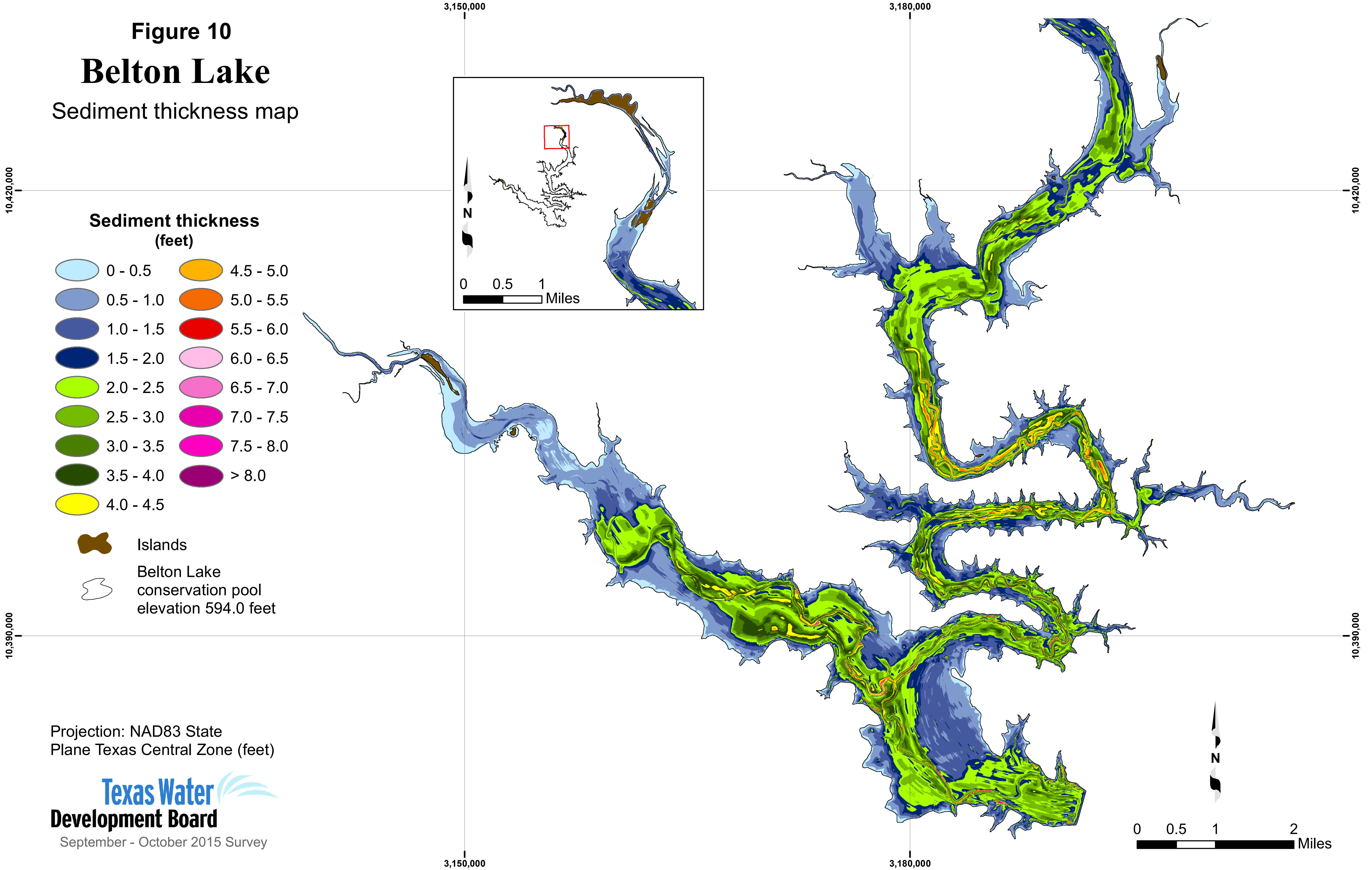
Figure 9. Cross-section of data collected during the 2015 survey, displayed in DepthPic© (combined acoustic signal returns), correlated with sediment core sample BT-7 and showing the current surface as the top black line, and pre-impoundment surface as the bottom black line.

After the pre-impoundment surface for all cross-sections was identified, a sediment thickness TIN model was created following standard GIS techniques (Furnans and Austin, 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 TIN model creation, the TWDB assumed the sediment thickness at the reservoir boundary was 0 feet (defined as the 594.2 foot NGVD29 elevation contour). The sediment thickness TIN model was converted to a raster representation using a cell size of 5 feet by 5 feet and was used to produce a sediment thickness map of Belton Lake (Figure 10).

Figure 10

Belton Lake

Sediment thickness map



Survey results

Volumetric survey

The 2015 TWDB volumetric survey indicates that Belton Lake has a total reservoir capacity of 432,631 acre-feet and encompasses 12,445 acres at conservation pool elevation (594.0 feet above mean sea level, NGVD29). The original design estimate by the U.S. Army Corps of Engineers indicates Belton Lake encompassed 12,300 acres with a total reservoir capacity of 457,600 acre-feet. The original design was later revised in 1963 to account for the sediment range lines installed in 1953–1954, resulting in a total reservoir capacity estimate of 456,884 acre-feet encompassing 12,416 acres. The U.S. Army Corps of Engineers resurveys of Belton Lake in 1961 and 1966 indicate the lake encompassed 12,420 acres and 12,423 acres with a total reservoir capacity of 447,500 acre-feet and 441,984 acre-feet, respectively (U.S. Army Corps of Engineers, 1975). TWDB previously surveyed Belton Lake in 1994 and 2003. Because of differences in survey methodologies, direct comparison of this volumetric survey to others to estimate changes in capacity is difficult and can be unreliable. To properly compare results from the TWDB surveys of Belton Lake, TWDB applied the 2015 data processing techniques to the survey data collected in 1994 and 2003. Specifically, the TWDB applied anisotropic spatial interpolation to the survey data collected in 1994 and 2003 using the same interpolation definition file as was used for the 2015 survey, with minor edits to account for differences in data coverage and boundary conditions.

The original 1994 survey boundary was digitized from the 594.0 foot contour from 7.5 minute USGS quadrangle maps: Belton 1965 (Revised 1993), Bland 1958 (Photo-revised 1978), Eagle Springs 1965 (Revised 1993), Leon Junction 1957 (Photo-revised 1978), Moffat 1965 (Revised 1993), and Nolanville 1958 (Photo-revised 1974), with a stated accuracy of ± ½ the contour interval (U.S. Bureau of the Budget, 1947). However, the archived boundary did not align with the survey data and many survey points were outside the boundary. Therefore, the 1994 survey was recalculated using the 2003 survey boundary. The 2003 survey boundary was digitized from aerial photographs taken on January 19, January 23, and January 31, 1995, while the daily average water surface elevation of the reservoir measured 594.2 feet, 594.18 feet, and 594.18 feet above mean sea level, respectively. The boundary was assigned an elevation of 594.2 feet for modeling purposes. According to the associated metadata, the 1995–1996 DOQQs have a resolution of 1-meter, with a horizontal positional accuracy that meets the National Map Accuracy Standards (NMAS) for 1:12,000-scale products. Additionally, survey data points with anomalous elevations from both surveys were removed from the new models. While linear interpolation was used to estimate the topography in areas without data, flat triangles led to anomalous area and volume calculations at the boundary elevation of 594.2 feet. Therefore, for both surveys, areas between 591.0 feet and 594.2 feet were linearly interpolated between the computed values, and volumes above 591.0 feet were calculated based on the corrected areas. Re-evaluation of the 1994 and 2003 survey resulted in a 2.8 percent and 2.5 percent increase in total capacity estimates at conservation pool elevation 594.0 feet (Table 3). This increase in total capacity is due to the general topography of Belton Lake. Spatial interpolation leads to greater total capacity estimates on lakes dominated by steep walls and prominent submerged stream channels (Texas Water Development Board, 2016).

Table 3. Current and previous survey capacity and surface area data for Belton Lake.

Survey	Surface area (acres)	Capacity (acre-feet)
Original design 1949 [a,b]	12,300	457,600
Revised original design 1949 [b]	12,416	456,884
USACE 1961 Resurvey [b]	12,420	447,500
USACE 1966 Resurvey [b]	12,423	441,984
TWDB 1994 [c]	12,385	434,500
TWDB 1994 (re-calculated)	12,360	446,505
TWDB 2003[d]	12,135	435,225
TWDB 2003 (re-calculated)	12,359	446,031
TWDB 2015	12,445	432,631

[a] Source: (Texas Water Development Board, 1973)
[b] Source: (U.S. Army Corps of Engineers, 1975)
[c] Source: (Texas Water Development Board, 2003)
[d] Source: (Texas Water Development Board, 2005)

Sedimentation survey

Based on two methods for estimating sedimentation rates, the 2015 TWDB sedimentation survey estimates Belton Lake to have an average loss of capacity between 371 and 398 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (594.0 feet NGVD29). The sedimentation survey indicates sediment accumulation varies throughout the reservoir. Sediment accumulation is consistently greater throughout the main thalwegs of Cowhouse Creek and the Leon River.

Comparison of capacity estimates of Belton Lake derived using differing methodologies are provided in Table 4 for sedimentation rate calculation.

Table 4. Capacity loss comparisons for Belton Lake

Survey	Volume comparisons at conservation pool elevation (acre-feet)			
Revised original design[a]	456,884	<>	<>	<>
TWDB 1994 (re-calculated)	<>	446,505	<>	<>
TWDB 2003 (re-calculated)	<>	<>	446,031	<>
TWDB pre-impoundment estimate based on 2015 survey	<>	<>	<>	455,279[b]
2015 volumetric survey	432,631	432,631	432,631	432,631
Volume difference (acre-feet)	24,253 (5.3%)	13,874 (3.1%)	13,401 (3.0%)	22,648 (5.0%)
Number of years	61	21	12	61
Capacity loss rate (acre-feet/year)	398	661	1,117	371

[a] Source: (U.S. Army Corps of Engineers, 1975), note: Deliberate impoundment began on March 15, 1954, and Belton Dam was completed on December 15, 1954.
[b] 2015 TWDB surveyed capacity of 432,631 acre-feet plus 2015 TWDB surveyed sediment volume of 22,648 acre-feet below elevation 594.0 feet

Recommendations

The TWDB recommends a volumetric and sedimentation survey of Belton Lake within a 10 year time-frame or after a major flood event to assess changes in lake capacity and to further improve estimates of sediment accumulation rates.

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:
Hydrosurvey@twdb.texas.gov

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Appendix A

Belton Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD | September - October 2015 Survey

CAPACITY IN ACRE-FEET | Conservation Pool Elevation 594.0 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
481	0	0	0	0	0	0	0	0	0	0
482	0	0	0	0	0	0	0	0	0	0
483	0	0	0	0	0	0	0	0	0	0
484	0	0	0	0	0	0	0	0	0	0
485	1	1	1	1	1	1	2	2	2	3
486	3	3	4	4	5	5	6	7	7	8
487	9	9	10	11	11	12	13	14	15	15
488	16	17	18	20	21	22	23	25	26	27
489	29	30	32	34	35	37	39	41	43	45
490	47	49	51	53	55	57	60	62	65	67
491	70	72	75	78	81	84	87	90	94	97
492	100	104	108	112	115	119	124	128	132	136
493	141	145	150	154	159	164	169	174	179	184
494	189	195	200	206	211	217	223	229	235	241
495	247	253	260	266	273	280	287	293	300	307
496	315	322	329	337	345	352	360	369	377	386
497	394	403	412	422	431	441	450	460	470	481
498	491	502	512	523	535	546	558	570	582	594
499	607	620	633	646	660	674	688	702	716	731
500	746	762	778	794	810	826	843	860	877	895
501	913	931	949	967	986	1,005	1,024	1,044	1,064	1,084
502	1,104	1,124	1,145	1,166	1,188	1,209	1,231	1,253	1,276	1,299
503	1,322	1,345	1,369	1,393	1,417	1,442	1,467	1,492	1,517	1,543
504	1,569	1,595	1,622	1,649	1,677	1,705	1,733	1,762	1,792	1,822
505	1,852	1,884	1,915	1,948	1,980	2,013	2,047	2,080	2,114	2,149
506	2,184	2,219	2,254	2,290	2,326	2,363	2,400	2,437	2,474	2,512
507	2,550	2,589	2,627	2,666	2,706	2,746	2,786	2,826	2,867	2,908
508	2,949	2,991	3,033	3,075	3,118	3,161	3,204	3,248	3,292	3,336
509	3,381	3,426	3,471	3,517	3,563	3,609	3,656	3,703	3,750	3,798
510	3,846	3,894	3,943	3,992	4,041	4,091	4,141	4,192	4,243	4,294
511	4,346	4,398	4,451	4,504	4,558	4,612	4,666	4,721	4,776	4,832
512	4,888	4,945	5,001	5,059	5,116	5,174	5,233	5,292	5,352	5,412
513	5,472	5,533	5,594	5,656	5,718	5,781	5,844	5,908	5,972	6,037
514	6,102	6,168	6,234	6,301	6,369	6,437	6,505	6,574	6,644	6,714
515	6,785	6,856	6,928	7,000	7,073	7,146	7,220	7,295	7,370	7,445
516	7,521	7,598	7,675	7,753	7,832	7,911	7,991	8,071	8,152	8,234
517	8,317	8,400	8,484	8,569	8,654	8,741	8,827	8,915	9,003	9,092
518	9,182	9,273	9,364	9,456	9,549	9,643	9,739	9,835	9,932	10,030
519	10,129	10,229	10,329	10,431	10,534	10,637	10,742	10,847	10,953	11,060
520	11,168	11,277	11,387	11,498	11,610	11,723	11,837	11,951	12,067	12,184
521	12,302	12,420	12,540	12,660	12,781	12,903	13,026	13,150	13,274	13,400
522	13,526	13,653	13,781	13,909	14,039	14,169	14,300	14,432	14,565	14,699
523	14,833	14,968	15,104	15,241	15,379	15,518	15,658	15,798	15,939	16,081
524	16,224	16,368	16,512	16,657	16,803	16,949	17,097	17,245	17,394	17,544
525	17,695	17,846	17,998	18,152	18,306	18,460	18,616	18,772	18,929	19,087
526	19,246	19,405	19,566	19,727	19,889	20,052	20,216	20,381	20,546	20,712
527	20,879	21,047	21,216	21,385	21,556	21,727	21,899	22,071	22,245	22,419
528	22,594	22,770	22,946	23,124	23,301	23,480	23,659	23,839	24,020	24,201
529	24,383	24,565	24,749	24,933	25,117	25,303	25,489	25,676	25,863	26,052
530	26,241	26,430	26,621	26,812	27,005	27,198	27,391	27,586	27,781	27,978
531	28,175	28,373	28,572	28,772	28,972	29,174	29,377	29,580	29,785	29,990
532	30,197	30,404	30,612	30,821	31,031	31,241	31,453	31,665	31,879	32,093
533	32,308	32,524	32,741	32,959	33,177	33,397	33,617	33,838	34,060	34,283
534	34,507	34,732	34,958	35,184	35,412	35,640	35,870	36,101	36,332	36,565
535	36,799	37,033	37,269	37,505	37,743	37,982	38,221	38,462	38,704	38,947
536	39,192	39,437	39,683	39,931	40,180	40,430	40,681	40,933	41,187	41,442

Appendix A (continued)

Belton Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD | September - October 2015 Survey
CAPACITY IN ACRE-FEET | Conservation Pool Elevation 594.0 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
537	41,698	41,955	42,214	42,474	42,735	42,997	43,261	43,526	43,792	44,059
538	44,327	44,597	44,868	45,140	45,414	45,688	45,964	46,241	46,519	46,798
539	47,078	47,360	47,642	47,925	48,210	48,495	48,781	49,069	49,357	49,647
540	49,938	50,229	50,522	50,816	51,111	51,406	51,703	52,002	52,301	52,601
541	52,903	53,205	53,509	53,814	54,120	54,428	54,737	55,048	55,360	55,673
542	55,988	56,304	56,621	56,940	57,260	57,580	57,903	58,226	58,552	58,879
543	59,207	59,537	59,868	60,200	60,534	60,869	61,204	61,541	61,879	62,218
544	62,558	62,899	63,241	63,585	63,931	64,278	64,626	64,975	65,326	65,678
545	66,030	66,384	66,739	67,094	67,451	67,809	68,168	68,529	68,890	69,253
546	69,617	69,983	70,350	70,719	71,089	71,461	71,834	72,209	72,585	72,962
547	73,342	73,723	74,105	74,489	74,875	75,262	75,651	76,041	76,433	76,826
548	77,221	77,617	78,015	78,415	78,816	79,218	79,622	80,027	80,434	80,843
549	81,254	81,666	82,080	82,495	82,912	83,331	83,751	84,173	84,597	85,022
550	85,449	85,877	86,307	86,739	87,173	87,608	88,044	88,482	88,921	89,362
551	89,804	90,248	90,693	91,140	91,588	92,038	92,489	92,942	93,395	93,851
552	94,307	94,766	95,225	95,686	96,148	96,612	97,077	97,543	98,011	98,481
553	98,951	99,424	99,898	100,373	100,850	101,328	101,808	102,289	102,772	103,256
554	103,742	104,228	104,717	105,206	105,696	106,188	106,680	107,174	107,669	108,165
555	108,662	109,160	109,659	110,159	110,661	111,163	111,666	112,170	112,675	113,181
556	113,688	114,196	114,706	115,216	115,727	116,239	116,753	117,267	117,783	118,299
557	118,817	119,335	119,855	120,375	120,898	121,421	121,945	122,471	122,997	123,526
558	124,055	124,586	125,119	125,652	126,186	126,721	127,258	127,796	128,335	128,875
559	129,416	129,959	130,503	131,048	131,595	132,143	132,692	133,243	133,794	134,348
560	134,902	135,458	136,015	136,574	137,134	137,695	138,258	138,822	139,386	139,952
561	140,519	141,087	141,657	142,228	142,801	143,375	143,950	144,526	145,104	145,683
562	146,264	146,846	147,431	148,016	148,604	149,193	149,783	150,376	150,969	151,565
563	152,161	152,759	153,359	153,960	154,563	155,167	155,772	156,380	156,988	157,599
564	158,211	158,824	159,439	160,055	160,674	161,295	161,918	162,543	163,170	163,798
565	164,429	165,060	165,694	166,329	166,966	167,604	168,244	168,886	169,530	170,175
566	170,821	171,469	172,118	172,768	173,420	174,073	174,727	175,383	176,040	176,699
567	177,358	178,019	178,682	179,346	180,011	180,678	181,346	182,016	182,687	183,360
568	184,034	184,709	185,387	186,066	186,746	187,428	188,112	188,798	189,487	190,177
569	190,870	191,565	192,261	192,959	193,660	194,362	195,066	195,772	196,479	197,189
570	197,900	198,614	199,331	200,050	200,772	201,495	202,220	202,948	203,678	204,411
571	205,146	205,884	206,624	207,365	208,110	208,857	209,607	210,361	211,117	211,877
572	212,639	213,403	214,170	214,940	215,712	216,486	217,263	218,043	218,824	219,608
573	220,393	221,181	221,972	222,764	223,560	224,357	225,156	225,958	226,761	227,567
574	228,375	229,184	229,996	230,810	231,625	232,443	233,262	234,084	234,908	235,735
575	236,562	237,392	238,225	239,058	239,895	240,732	241,571	242,413	243,256	244,101
576	244,948	245,796	246,647	247,499	248,353	249,208	250,065	250,924	251,784	252,647
577	253,510	254,376	255,244	256,113	256,985	257,858	258,733	259,612	260,492	261,375
578	262,260	263,148	264,039	264,932	265,828	266,725	267,625	268,528	269,433	270,340
579	271,249	272,161	273,076	273,993	274,913	275,835	276,760	277,688	278,618	279,552
580	280,488	281,427	282,369	283,313	284,260	285,209	286,161	287,114	288,070	289,028
581	289,987	290,948	291,912	292,878	293,847	294,817	295,790	296,766	297,742	298,722
582	299,702	300,685	301,670	302,657	303,645	304,636	305,628	306,623	307,620	308,619
583	309,619	310,623	311,629	312,636	313,646	314,658	315,672	316,688	317,706	318,727
584	319,750	320,774	321,802	322,832	323,865	324,899	325,936	326,975	328,015	329,058
585	330,102	331,149	332,198	333,248	334,302	335,357	336,414	337,473	338,534	339,598
586	340,662	341,729	342,799	343,869	344,943	346,017	347,093	348,172	349,252	350,334
587	351,418	352,504	353,592	354,682	355,774	356,868	357,964	359,063	360,163	361,266
588	362,371	363,478	364,587	365,698	366,811	367,926	369,043	370,163	371,285	372,409
589	373,535	374,662	375,793	376,924	378,059	379,194	380,332	381,472	382,613	383,757
590	384,902	386,049	387,199	388,350	389,504	390,660	391,818	392,978	394,140	395,306
591	396,472	397,641	398,813	399,986	401,162	402,339	403,520	404,702	405,888	407,076
592	408,267	409,460	410,656	411,854	413,055	414,259	415,466	416,675	417,886	419,101
593	420,318	421,537	422,759	423,984	425,211	426,441	427,674	428,909	430,147	431,388
594	432,631	433,877	435,125							

Note: Capacities above elevation 591.5 feet calculated from interpolated areas

Appendix B

Belton Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD | September - October 2015 Survey
AREA IN ACRES | Conservation Pool Elevation 594.0 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
481	0	0	0	0	0	0	0	0	0	0
482	0	0	0	0	0	0	0	0	0	0
483	0	0	0	0	0	0	0	0	0	0
484	0	0	0	0	0	1	1	1	1	1
485	1	1	1	2	2	2	3	3	4	4
486	4	4	5	5	5	6	6	6	6	6
487	7	7	7	7	8	8	8	8	9	9
488	10	10	11	11	12	13	13	14	14	15
489	15	16	16	17	17	18	18	19	19	20
490	20	20	21	22	23	23	24	25	25	26
491	26	27	28	29	30	31	32	33	34	35
492	36	37	38	39	39	40	41	42	43	44
493	45	45	46	47	48	49	49	50	51	52
494	53	54	55	56	57	58	59	60	61	62
495	63	64	65	66	66	67	68	69	70	71
496	72	73	75	77	78	80	81	83	85	86
497	88	90	91	93	95	97	98	100	102	103
498	105	107	109	111	114	116	118	120	123	125
499	127	130	132	134	137	139	141	143	146	149
500	153	156	159	162	164	167	169	171	174	176
501	179	181	184	186	189	191	194	196	198	201
502	203	206	209	212	215	218	221	224	227	230
503	233	235	238	241	244	246	249	253	256	259
504	262	266	270	273	277	282	287	292	299	304
505	309	315	320	324	329	332	336	339	342	345
506	349	353	357	360	364	367	370	373	376	379
507	383	386	389	393	396	399	403	406	409	412
508	415	418	421	424	428	431	434	438	442	446
509	449	452	455	458	461	464	467	471	475	478
510	482	486	489	493	496	500	504	508	512	517
511	521	525	530	534	538	542	546	550	555	559
512	562	566	570	574	578	584	588	593	598	602
513	606	611	615	620	625	630	635	640	645	650
514	655	660	666	672	678	683	688	693	698	704
515	709	714	720	726	731	737	742	747	753	759
516	764	770	776	782	788	795	802	809	816	822
517	830	837	844	851	858	865	872	879	886	894
518	902	910	918	927	936	945	956	966	976	985
519	994	1,003	1,012	1,021	1,031	1,040	1,049	1,058	1,067	1,077
520	1,086	1,095	1,104	1,114	1,123	1,132	1,142	1,152	1,163	1,173
521	1,182	1,190	1,198	1,207	1,216	1,225	1,233	1,242	1,250	1,258
522	1,266	1,274	1,282	1,290	1,299	1,308	1,316	1,324	1,332	1,340
523	1,348	1,357	1,366	1,374	1,383	1,392	1,400	1,409	1,416	1,424
524	1,431	1,439	1,446	1,454	1,462	1,470	1,478	1,486	1,495	1,503
525	1,511	1,519	1,527	1,536	1,544	1,552	1,560	1,567	1,575	1,583
526	1,591	1,599	1,608	1,617	1,625	1,633	1,642	1,650	1,658	1,667
527	1,675	1,683	1,691	1,700	1,707	1,715	1,723	1,731	1,738	1,746
528	1,754	1,761	1,769	1,776	1,782	1,789	1,796	1,802	1,809	1,816
529	1,822	1,829	1,836	1,843	1,851	1,858	1,865	1,872	1,880	1,887
530	1,894	1,902	1,910	1,918	1,926	1,934	1,942	1,950	1,958	1,967
531	1,976	1,985	1,994	2,003	2,012	2,022	2,032	2,040	2,050	2,059
532	2,067	2,076	2,085	2,094	2,103	2,112	2,120	2,129	2,137	2,146
533	2,155	2,164	2,173	2,182	2,191	2,199	2,208	2,216	2,225	2,234
534	2,243	2,252	2,261	2,271	2,281	2,291	2,300	2,312	2,322	2,332
535	2,342	2,351	2,361	2,370	2,380	2,391	2,402	2,415	2,426	2,437
536	2,448	2,459	2,470	2,482	2,494	2,506	2,517	2,530	2,543	2,556

Appendix B (continued)

Belton Lake

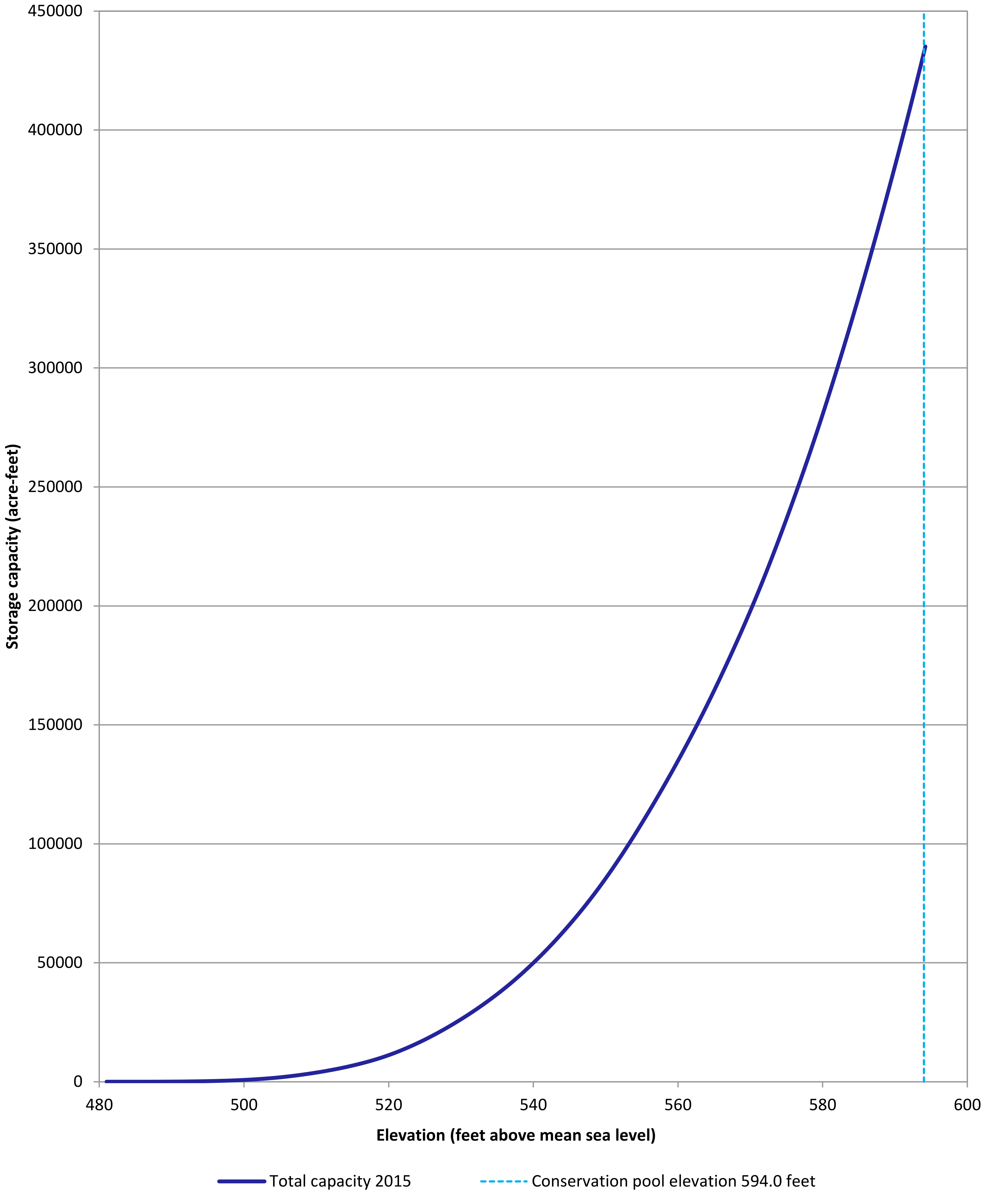
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD
AREA IN ACRES
ELEVATION INCREMENT IS ONE TENTH FOOT

September - October 2015 Survey
Conservation Pool Elevation 594.0 feet NGVD29

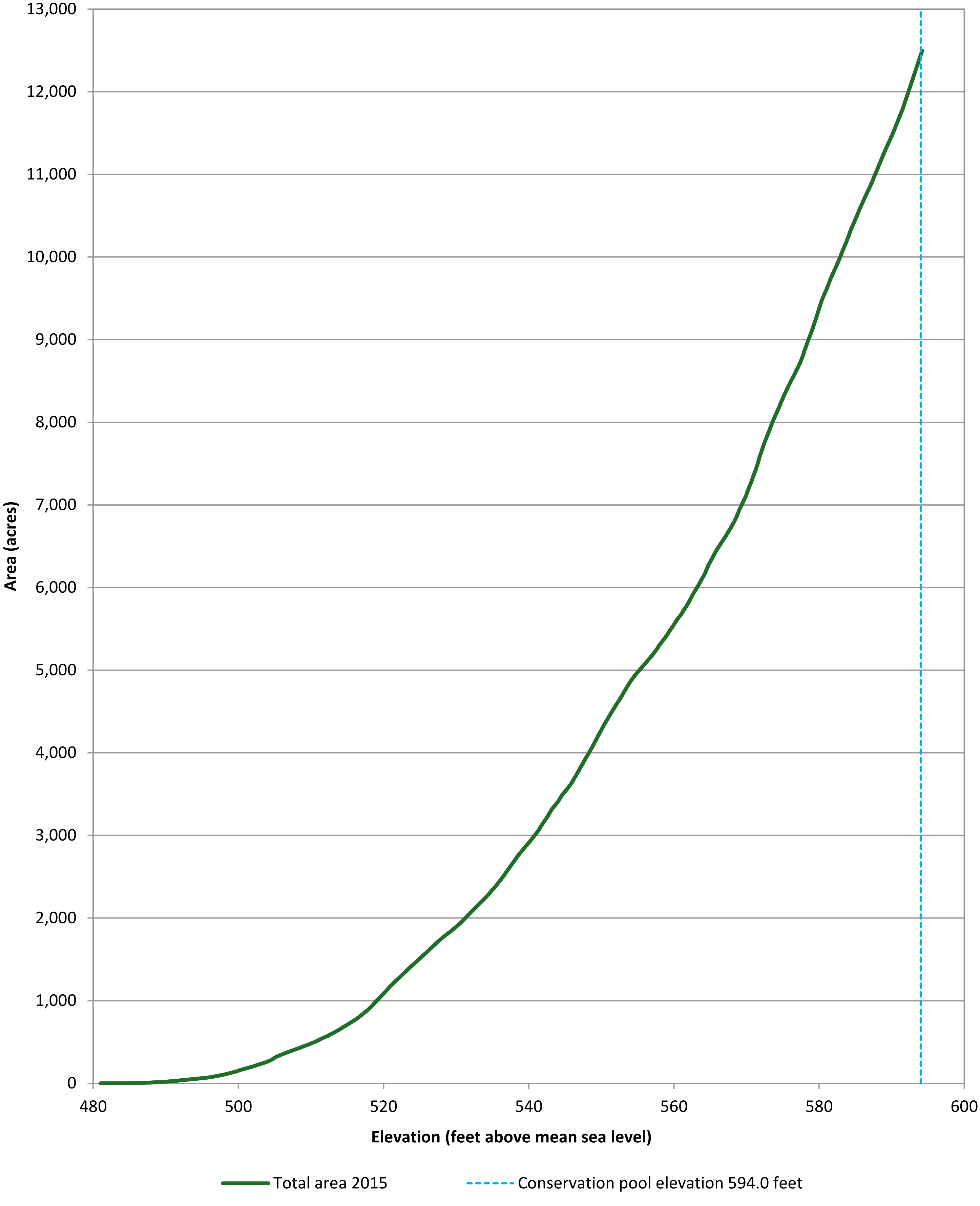
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
537	2,568	2,580	2,592	2,604	2,617	2,630	2,642	2,654	2,666	2,679
538	2,691	2,703	2,716	2,729	2,742	2,754	2,764	2,775	2,785	2,796
539	2,807	2,817	2,827	2,838	2,849	2,859	2,870	2,880	2,890	2,900
540	2,911	2,922	2,932	2,943	2,954	2,965	2,976	2,987	2,998	3,010
541	3,021	3,032	3,044	3,056	3,069	3,083	3,100	3,115	3,128	3,140
542	3,152	3,166	3,179	3,191	3,204	3,216	3,229	3,245	3,261	3,276
543	3,291	3,305	3,318	3,331	3,342	3,352	3,361	3,372	3,384	3,394
544	3,405	3,417	3,432	3,447	3,463	3,476	3,490	3,500	3,511	3,521
545	3,531	3,542	3,552	3,563	3,575	3,586	3,598	3,610	3,622	3,635
546	3,649	3,665	3,680	3,695	3,709	3,723	3,738	3,754	3,769	3,785
547	3,802	3,818	3,834	3,848	3,863	3,878	3,894	3,911	3,927	3,942
548	3,957	3,971	3,986	4,001	4,016	4,032	4,047	4,063	4,080	4,096
549	4,112	4,129	4,146	4,162	4,179	4,196	4,212	4,228	4,245	4,260
550	4,276	4,293	4,310	4,327	4,342	4,357	4,372	4,386	4,400	4,415
551	4,430	4,445	4,460	4,475	4,490	4,504	4,518	4,532	4,546	4,560
552	4,576	4,590	4,603	4,615	4,628	4,642	4,656	4,672	4,686	4,701
553	4,716	4,733	4,747	4,761	4,776	4,790	4,805	4,820	4,834	4,848
554	4,862	4,875	4,887	4,898	4,909	4,922	4,933	4,944	4,955	4,966
555	4,976	4,986	4,995	5,005	5,016	5,026	5,036	5,046	5,057	5,067
556	5,076	5,086	5,096	5,107	5,118	5,129	5,139	5,149	5,159	5,169
557	5,180	5,191	5,202	5,214	5,225	5,239	5,249	5,261	5,274	5,292
558	5,304	5,316	5,326	5,337	5,349	5,360	5,372	5,384	5,396	5,407
559	5,420	5,432	5,446	5,460	5,474	5,486	5,499	5,512	5,525	5,537
560	5,551	5,566	5,580	5,594	5,607	5,619	5,630	5,642	5,653	5,664
561	5,676	5,688	5,704	5,720	5,733	5,745	5,758	5,770	5,786	5,800
562	5,816	5,832	5,849	5,865	5,881	5,901	5,916	5,930	5,944	5,958
563	5,974	5,989	6,004	6,018	6,033	6,049	6,064	6,081	6,097	6,111
564	6,126	6,142	6,157	6,175	6,198	6,220	6,239	6,259	6,278	6,294
565	6,312	6,327	6,343	6,359	6,376	6,393	6,410	6,426	6,442	6,457
566	6,471	6,484	6,497	6,510	6,524	6,538	6,551	6,564	6,577	6,590
567	6,604	6,618	6,632	6,647	6,661	6,677	6,690	6,704	6,718	6,733
568	6,749	6,765	6,781	6,796	6,812	6,831	6,850	6,872	6,892	6,915
569	6,941	6,958	6,973	6,992	7,012	7,031	7,048	7,068	7,086	7,104
570	7,126	7,156	7,179	7,201	7,223	7,244	7,265	7,287	7,316	7,342
571	7,364	7,387	7,409	7,433	7,460	7,485	7,517	7,549	7,582	7,608
572	7,631	7,655	7,683	7,710	7,734	7,757	7,782	7,802	7,825	7,847
573	7,870	7,890	7,915	7,939	7,962	7,984	8,008	8,026	8,045	8,066
574	8,088	8,107	8,126	8,145	8,164	8,187	8,207	8,231	8,252	8,270
575	8,289	8,310	8,331	8,350	8,367	8,386	8,403	8,423	8,442	8,459
576	8,476	8,496	8,513	8,529	8,543	8,561	8,578	8,596	8,614	8,632
577	8,649	8,666	8,687	8,704	8,724	8,744	8,767	8,790	8,813	8,842
578	8,870	8,894	8,917	8,942	8,968	8,991	9,014	9,037	9,059	9,082
579	9,106	9,130	9,160	9,185	9,211	9,236	9,264	9,291	9,320	9,347
580	9,377	9,404	9,431	9,458	9,482	9,503	9,524	9,546	9,566	9,585
581	9,604	9,626	9,650	9,672	9,694	9,719	9,740	9,761	9,780	9,800
582	9,818	9,839	9,857	9,876	9,896	9,916	9,936	9,956	9,977	9,999
583	10,022	10,045	10,067	10,088	10,110	10,130	10,150	10,171	10,194	10,217
584	10,238	10,262	10,289	10,313	10,335	10,356	10,376	10,396	10,415	10,436
585	10,457	10,477	10,497	10,518	10,541	10,562	10,583	10,603	10,622	10,641
586	10,660	10,680	10,700	10,719	10,738	10,757	10,775	10,793	10,811	10,830
587	10,849	10,869	10,889	10,909	10,930	10,953	10,975	10,996	11,017	11,038
588	11,058	11,079	11,100	11,121	11,143	11,164	11,185	11,206	11,227	11,248
589	11,269	11,290	11,310	11,330	11,349	11,367	11,386	11,405	11,425	11,444
590	11,464	11,484	11,505	11,526	11,548	11,570	11,592	11,614	11,636	11,658
591	11,680	11,702	11,724	11,745	11,767	11,789	11,815	11,841	11,867	11,894
592	11,920	11,946	11,972	11,999	12,025	12,051	12,077	12,103	12,130	12,156
593	12,182	12,208	12,235	12,261	12,287	12,313	12,340	12,366	12,392	12,418
594	12,445	12,471	12,497							

Note: Areas between elevations 591.5 and 594.2 feet linearly interpolated



Belton Lake
September - October 2015 Survey
Prepared by: TWDB

Appendix C: Capacity curve



Belton Lake
September - October 2015 Survey
Prepared by: TWDB

Appendix D: Area curve

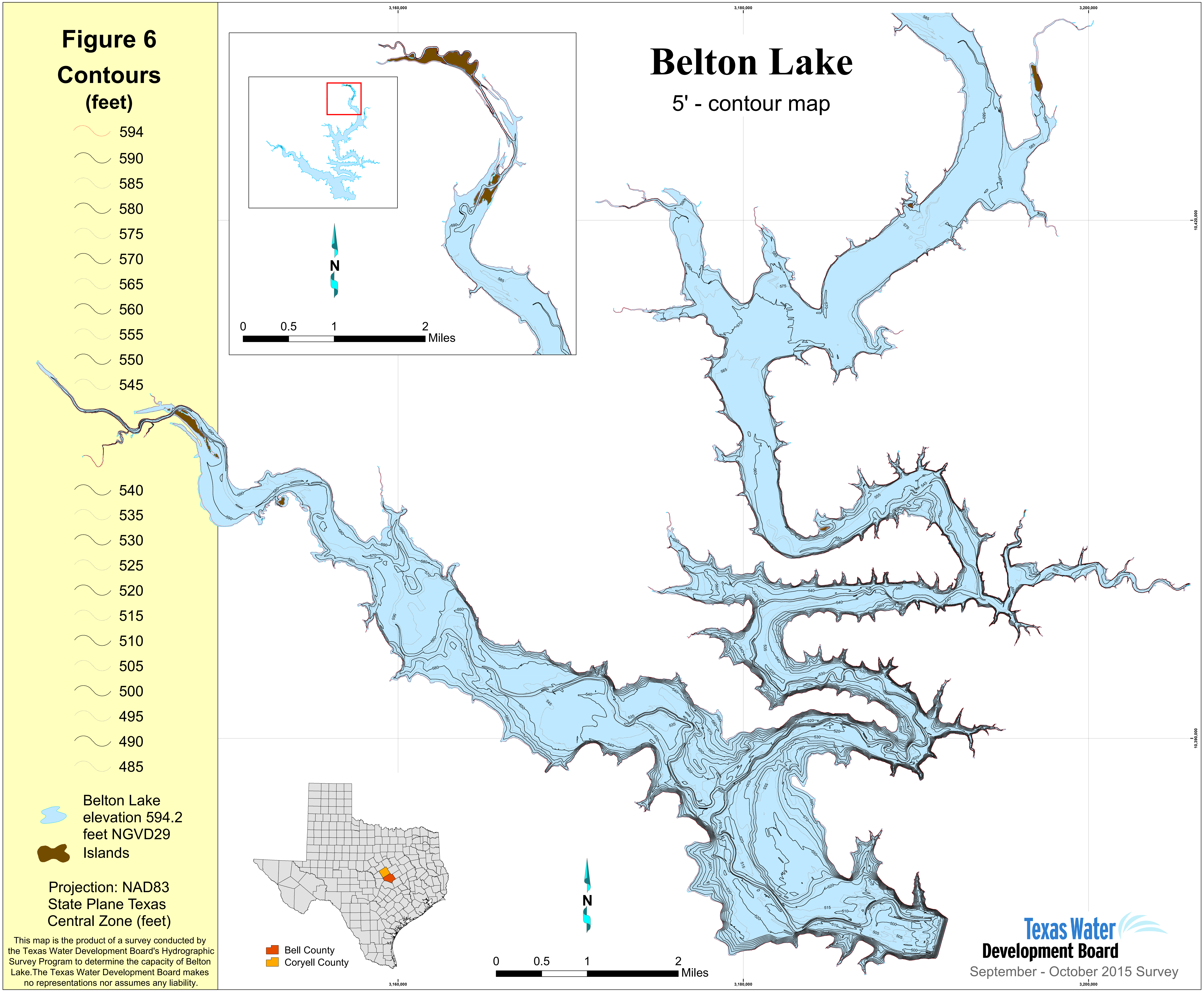


Figure 6
Contours
(feet)
594
590
585
580
575
570
565
560
555
550
545
540
535
530
525
520
515
510
505
500
495
490
485
Belton Lake elevation 594.2 feet NGVD29
Islands
Projection: NAD83
State Plane Texas
Central Zone (feet)
This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Belton Lake.The Texas Water Development Board makes no representations nor assumes any liability.
Belton Lake
5' - contour map
N
0
0.5
1
2
Miles
Bell County
Coryell County
Texas Water
Development Board
September - October 2015 Survey