Volumetric and Sedimentation Survey of LAKE CONROE

June – August 2010 Survey

Texas Water Development Board

July 2012

Texas Water Development Board

Prepared for:

San Jacinto River Authority

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U.S. Army Corps of Engineers, Fort Worth District

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Executive summary

In June, 2010, the Texas Water Development Board entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Lake Conroe. The U.S. Army Corps of Engineers, Fort Worth District, provided 50% of the funding for this survey through their Planning Assistance to States Program, while the San Jacinto River Authority of Texas provided the remaining 50%. 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 throughout the reservoir.

Conroe Dam and Lake Conroe are located on the West Fork San Jacinto River in Montgomery County, seven miles northwest of Conroe, Texas. The conservation pool elevation of Lake Conroe is 201.0 feet above mean sea level (NGVD29). TWDB collected bathymetric data for Lake Conroe between June 17, 2010, and August 10, 2010. The daily average water surface elevations during that time ranged between 200.36 and 200.80 feet above mean sea level (NGVD29).

The 2010 TWDB volumetric survey indicates that Lake Conroe has a total reservoir capacity of 411,022 acre-feet and encompasses 19,640 acres at conservation pool elevation (201.0 feet above mean sea level, NGVD29). Previous capacity estimates include an original design estimate of 430,260 acre-feet at the time of impoundment in 1973, and a re-analysis of the 1996 TWDB volumetric survey data using current processing procedures that resulted in an updated capacity estimate of 420,659 acre-feet.

Based on two methods for estimating sedimentation rates, TWDB estimates that Lake Conroe loses between 520 and 688 acre-feet per year of capacity due to sedimentation. Sediment accumulation is greater in the submerged flood plains and adjacent to Conroe Dam. TWDB recommends that a similar methodology be used to resurvey Lake Conroe 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. 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 June, 2010, TWDB entered into agreement with U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Lake Conroe. The U.S. Army Corps of Engineers, Fort Worth District, provided 50% of the funding for this survey through their Planning Assistance to States Program, while the San Jacinto River Authority of Texas provided the remaining 50% (TWDB, 2010). 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 U.S. Army Corps of Engineers, Fort Worth District and contains as deliverables: (1) an elevation-area-capacity table of the lake 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 lake bottom [Figure 3], and (4) an estimate of sediment accumulation and location [Figure 11].

Lake Conroe general information

Conroe Dam and Lake Conroe are located on the West Fork San Jacinto River (San Jacinto River Basin) in Montgomery County, seven miles northwest of Conroe, Texas (Figure 1). Lake Conroe inundates parts of Montgomery and Walker Counties. Lake Conroe is primarily a water supply reservoir and Conroe Dam and Lake Conroe are operated by the San Jacinto River Authority. The San Jacinto River Authority was created by the Texas Legislature in 1937 to be an official agency of the State of Texas for the purpose of developing, conserving, and protecting the water resources of the San Jacinto River Basin (SJRA, 2011). The San Jacinto River Authority provides water to municipal and industrial users within the watershed of the San Jacinto River and its tributaries, outside of Harris County. The watershed spans all of Montgomery County and parts of Walker, Waller, San Jacinto, Grimes, and Liberty Counties. The San Jacinto River Authority is also responsible for managing water quality, treating wastewater, and water and soil conservation (SJRA, 2011).

Construction on Conroe Dam began on February 9, 1970 and was completed in January, 1973 (TWDB, 1973). Additional pertinent data about Conroe Dam and Lake Conroe can be found in Table 1.

Water rights for Lake Conroe have been appropriated to the San Jacinto River Authority and the City of Houston through Certificate of Adjudication and amendment Nos. 10-4963 and 10-4963A. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

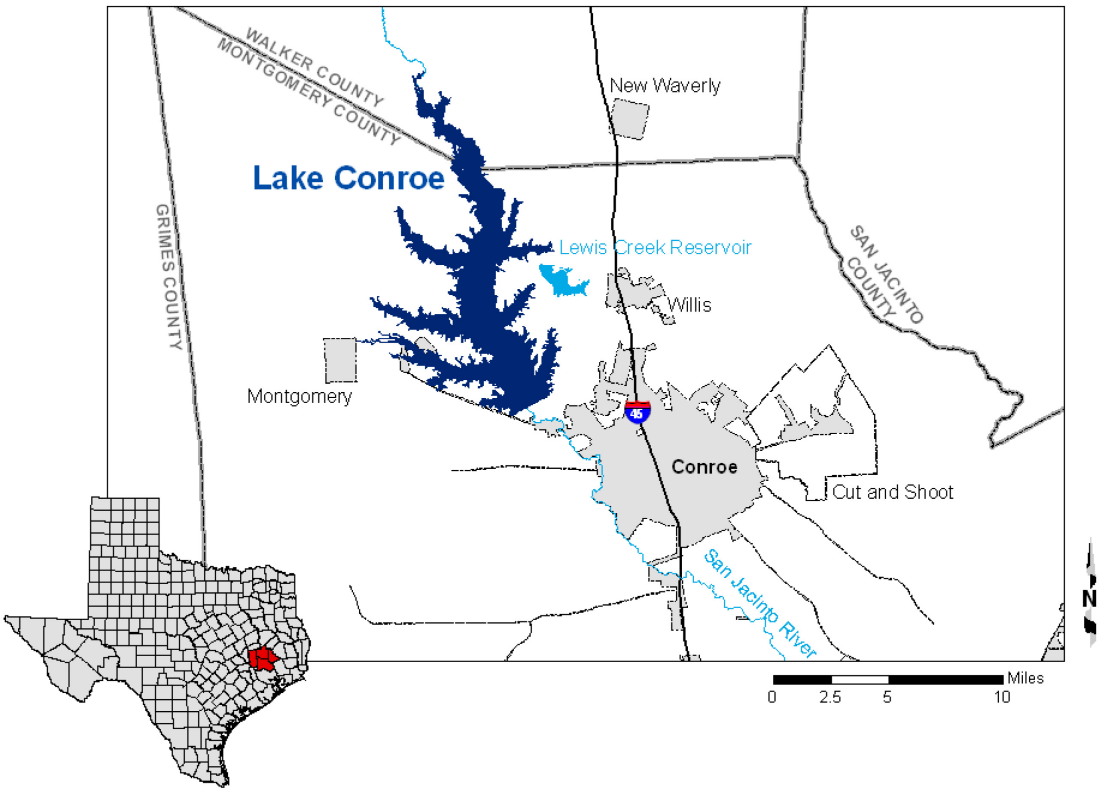


Figure 1. Location map –Lake Conroe

Table 1.	**Pertinent data for Conroe Dam and Lake Conroe**		
Owner			
San Jacinto River Authority			
Engineer (Design)			
Freese, Nichols, and Endress			
Location of dam			
On the West Fork San Jacinto River in Montgomery County, 7 miles northwest of Conroe, Texas			
Drainage area			
445 square miles			
Dam			
Type	Earthfill		
Length including levees	11,300 feet		
Height above river channel	82 feet		
Top width	20 feet		
Spillway (emergency)			
Location	Near right end of the main dam		
Type	Concrete ogee		
Length (net)	200 feet		
Crest elevation	173.0 feet above mean sea level		
Control	5 tainter gates, each 40 by 30 feet		
Service outlet			
Type	Concrete tower and stilling basin		
Inlets	3 with sluice gates		
Gate size	Two 4 by 6 feet and one 5 by 5 feet		
Discharge	Concrete conduit, variable size to 10-feet diameter		
Reservoir data (Based on 2010 TWDB survey)			
Feature	**Elevation (feet NGVD29[a])**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam	212.0	N/A	N/A
Top of spillway gates	202.5	N/A	N/A
Conservation pool elevation	201.0	411,022	19,640
Invert of high outlet	191.0	243,886	14,126
Invert of low outlet	145.0	34	15
Usable conservation storage space	-	410,988	-

Source: (TWDB, 1973)
[a] NGVD29 = National Geodetic Vertical Datum 1929

Volumetric and sedimentation survey of Lake Conroe

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 08067600 Lk Conroe nr Conroe, TX* (USGS, 2011). Elevations herein are reported in feet above mean sea level 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

TWDB collected bathymetric data for Lake Conroe between June 17, 2010, and August 10, 2010. The daily average water surface elevation during that time ranged between 200.36 and 200.80 feet above mean sea level (NGVD29). Depth soundings were collected using a Specialty Devices, Inc., 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 range lines oriented perpendicular to the assumed location of the submerged river channels and spaced approximately 500 feet apart. Many of the survey lines closely matched lines surveyed by TWDB during the 1996 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 the locations of the 2010 TWDB survey lines.

All sounding data was collected and reviewed before sediment core sample sites were selected and sediment cores were collected. Sediment core samples are normally collected at regularly spaced intervals within the lake, or at locations where interpretation of the acoustic display would be difficult without site-specific sediment core data. Following analysis of the sounding data, TWDB selected six locations where sounding data had been previously collected (Figure 2) to collect sediment core samples. The sediment core samples were collected on April 12 and 13, 2011, with a custom coring boat and SDI VibraCore system.

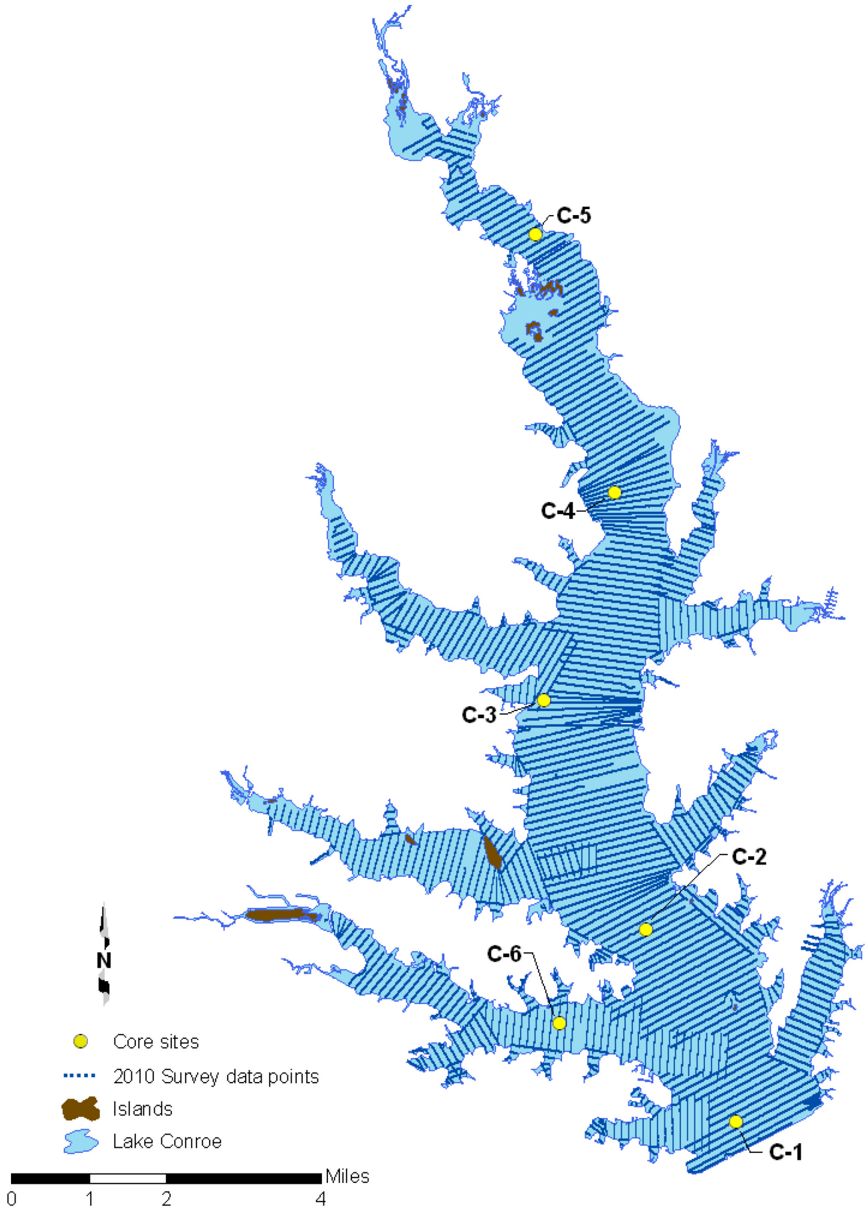


Figure 2. Data collected during the 2010 TWDB Lake Conroe survey

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 to which the tube must be driven during sediment sampling. The goal is to collect a core sample extending from the current lake 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.

Data processing

Model boundaries

The reservoir boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), obtained from the Texas Natural Resources Information System (TNRIS, 2009) using Environmental Systems Research Institute's ArcGIS 9.3.1 software. The quarter-quadrangles that cover Lake Conroe include Shephard Hill (NW, NE, SW, SE), Montgomery (NE, SE), Cowl Spur (NW, NE), San Jacinto (SE), Moore Grove (SW), and Keenan (NE). The DOQQs were photographed on January 8, 2009, while the daily average water surface elevation measured 199.95 feet above mean sea level. According to the associated metadata, the 2009 DOQQS have a resolution of 0.5-meters with a horizontal accuracy of three to five meters to absolute ground control (TNRIS, 2010). For this analysis, the boundary digitized at the land-water interface in the 2009 photographs is assumed to be a good approximation of the lake boundary at conservation pool elevation. Therefore, the delineated boundary was given an elevation of 201.0 feet above mean sea level to facilitate calculating the area-capacity tables up to the conservation pool elevation.

Triangulated Irregular Network model

Following completion of data collection, the raw data was edited using DepthPic. DepthPic is used to display, interpret, and edit the multi-frequency data and to manually identify the current reservoir-bottom surface and the reservoir-bottom surface at the time of initial impoundment (i.e. pre-impoundment surface). Following the identification of these surfaces, several processing steps are undertaken using an in-house TWDB software package, HydroTools (McEwen, 2011). The software is first used to identify the current reservoir–bottom surface, pre-impoundment surface and sediment thickness at each sounding location; remove data anomalies; and output the data into a single file. It is then used to convert each sounding depth to a corresponding reservoir-bottom elevation using the water surface elevation at the time each sounding was taken. This survey point dataset is then preconditioned by inserting artificial survey points between the actual survey lines. Bathymetric elevations at these artificial points are determined using an anisotropic spatial interpolation scheme described in the spatial interpolation of reservoir bathymetry section below. This technique creates a high resolution, quasi-uniform grid of interpolated bathymetric elevation points throughout the extent of the lake (McEwen et al., 2011).

Finally, the point file resulting from the spatial interpolation is used in conjunction with sounding and boundary data to create a Triangulated Irregular Network (TIN) model 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).

Area, volume, and contour calculations

Volumes and areas were calculated for the entire reservoir at 0.1 feet intervals, from elevation 137.8 to 201.0 feet, using ArcInfo software and the TIN model. The corresponding elevation-capacity and elevation-area tables are presented in Appendices A and B, respectively. Area and capacity curves are presented in Appendix C.

The 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 3) representing the topography of the reservoir bottom, a depth range map (Figure 4) showing shaded depth ranges for Lake Conroe, and a 5-foot contour map (Figure 5 – attached).

Spatial interpolation of reservoir bathymetry

Isotropic spatial interpolation techniques such as the Delaunay triangulation used by the 3D Analyst extension of ArcGIS are inherently unable to suitably interpolate bathymetries between survey lines. Reservoirs and stream channels are anisotropic morphological features where bathymetry at any particular location is similar more 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; oscillations of contour lines in between survey lines. These artifacts reduce the accuracy of the resulting TIN model in areas between actual survey data.

To improve the accuracy of the representation of the bathymetry between survey lines, TWDB has developed various anisotropic spatial interpolation techniques. Generally, the directionality of interpolation at different locations in a reservoir can be determined from external data sources. A basic assumption is that the reservoir profile in the vicinity of

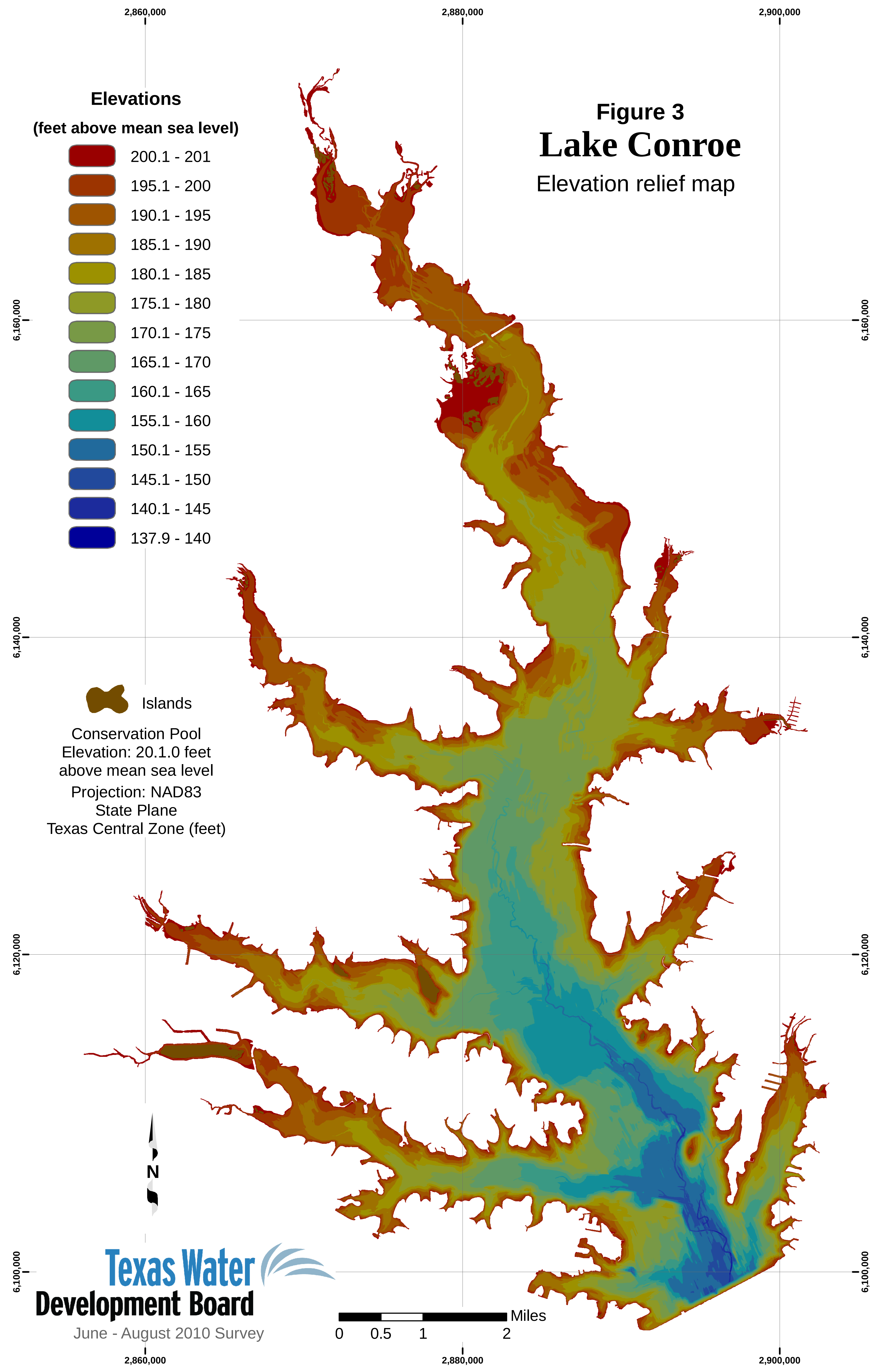


Figure 3
Lake Conroe
Elevation relief map
Elevations
(feet above mean sea level)
200.1 - 201
195.1 - 200
190.1 - 195
185.1 - 190
180.1 - 185
175.1 - 180
170.1 - 175
165.1 - 170
160.1 - 165
155.1 - 160
150.1 - 155
145.1 - 150
140.1 - 145
137.9 - 140
Islands
Conservation Pool
Elevation: 20.1.0 feet
above mean sea level
Projection: NAD83
State Plane
Texas Central Zone (feet)
N
Texas Water
Development Board
June - August 2010 Survey
0
0.5
1
2
Miles
2,860,000
2,880,000
2,900,000
6,160,000
6,140,000
6,120,000
6,100,000

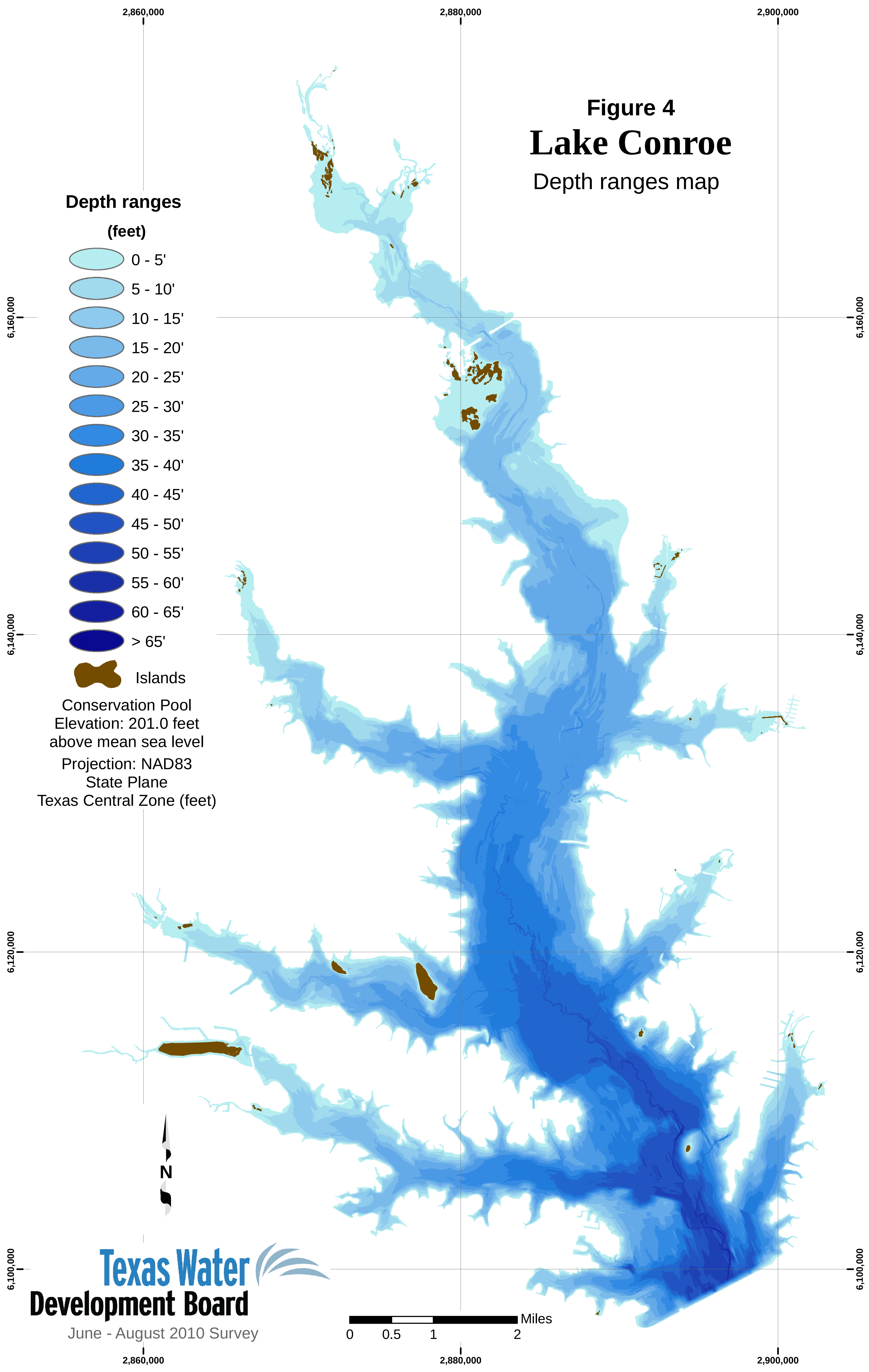


Figure 4
Lake Conroe
Depth ranges map

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 (USGS, 2007). Using this information about directionality, an anisotropy definition file is created that partitions the lake into polygon segments and defines the directionality in each segment through the use of a centerline and other attributes. It is important to note that this definition file is independent of survey data and hence can be used to conduct the spatial interpolation in a repeatable manner on multiple surveys of the same reservoir. Using this anisotropy definition file and the survey data, a high resolution quasi-uniform grid of artificial survey points is created. This grid is used in conjunction with the reservoir boundary to create a TIN model that better represents the reservoir bathymetry between survey lines through its incorporation of anisotropy. Details of the specifics of this interpolation technique can be found in the HydroTools manual (McEwen, 2011) and in McEwen et al, 2011.

Figure 6 illustrates typical results from application of the anisotropic interpolation technique to Lake Conroe. The bathymetry shown in Figure 6C was used in computing reservoir capacity and area tables (Appendix A, B).

In Figure 6B, 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 6C, in creation of the TIN model directs Delaunay triangulation to better represent the lake bathymetry between survey cross-sections.

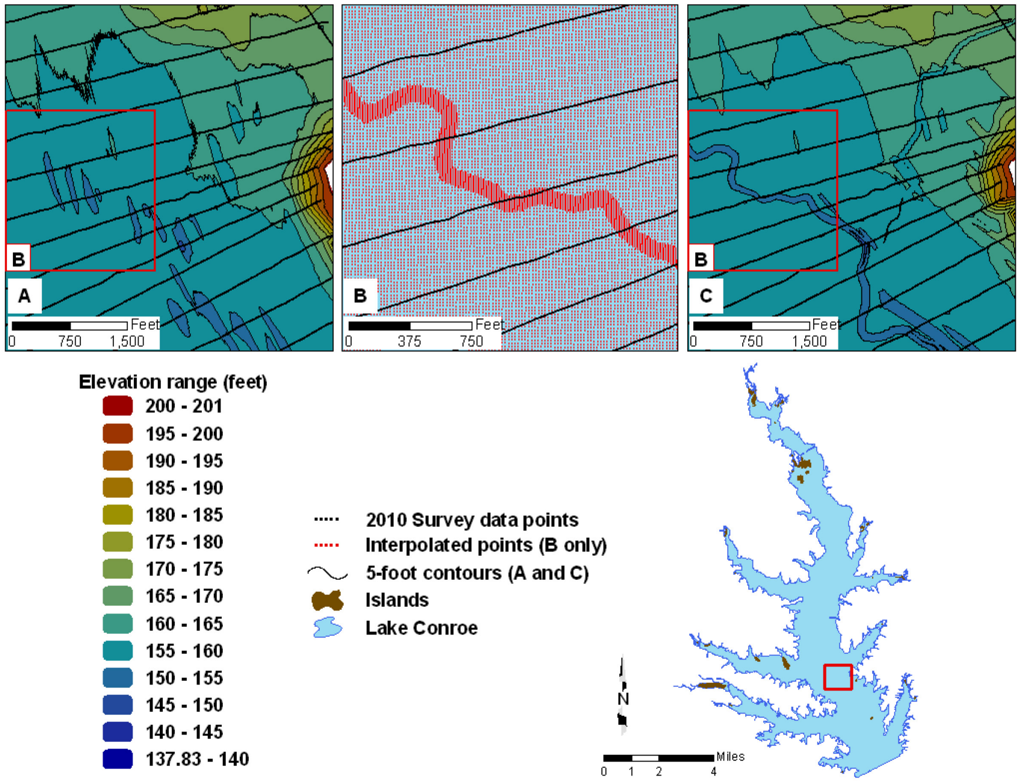


Figure 6. **Anisotropic spatial interpolation of Lake Conroe sounding data – A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red), C) bathymetric contours with the interpolated points**

Analysis of sediment data from Lake Conroe

Sedimentation in Lake Conroe was determined by analyzing all three depth sounder frequencies in the DepthPic software. The 200 kHz signal was used to determine the current bathymetric surface of the lake, while the 200 kHz, 50 kHz and 24 kHz frequencies were used to determine the reservoir bathymetric surface at the time of initial impoundment (i.e. pre-impoundment surface). Sediment core samples collected in the lake 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 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 of the following methods: (1) a visual examination of the sediment core for in-place 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 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 – Lake Conroe

Core	Easting[a] (ft)	Northing[a] (ft)	Total sediment/ post-impoundment sediment	Core description	Munsell soil color
C-1	3799433.13	10127590.69	23"/14"	0-14" high water content, silty clay soil, no soil structure (no peds)	5Y 4/1
				14-23" low water content, loamy clay, dense soil structure with peds, organics (roots) present	2.5Y 4/1
C-2	3793136.68	10140601.34	23.5"/17"	0-17" high water content, silty clay soil with striations, no soil structure	5Y 3/2 with 5Y 3/1
				17-23.5" low water content, silty clay, dense soil structure with peds, organics (roots) presernt	2.5Y 2.5/1
C-3	3785939.28	10156066.19	25"/20"	0-20" high water content, silty clay, no soil structure (no peds)	5Y 3/2 (15%)
				20-25" low water content, silty clay, dense soil structure with peds	2.5Y 3/1
C-4	3790515.83	10170245.31	14.5"/11.5"	0-11.5" high water content, silty loam, no soil structure (no peds)	2.5Y 3/2
				11.5-14.5" low water content, silty clay, dense soil structure with peds	2.5Y 2.5/1
C-5	3784916.84	10187787.08	23.5"/18.5"	0-18.5" high water content, silty clay, no soil structure (no peds)	2.5Y 4/2
				18.5-23.5" low water content, clay soil, dense soil structure with peds, numerous organics (roots) present	2.5Y 2.5/1
C-6	3787354.21	10134151.37	43"/N/A	0-42" high water content, silty clay, no soil structure (no peds)	5Y 4/2
				42-43" clay loam, no soil structrure, dense peds with organic material found at 43"	2.5Y 2.5/1

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

A photograph of sediment core C-5 is shown in Figure 7 and is representative of the sediment cores sampled from Lake Conroe.

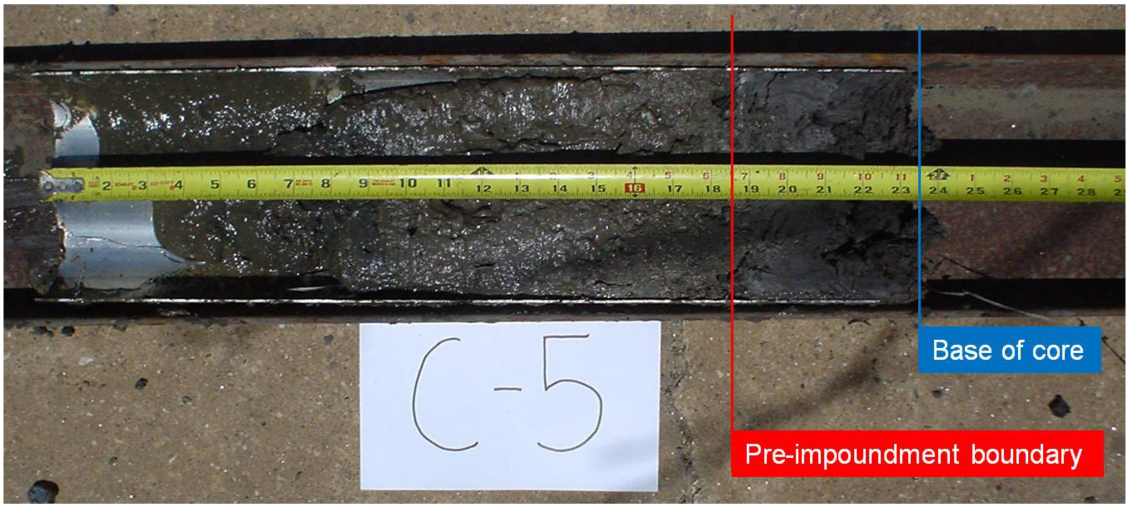


Figure 7. Sediment Core C-5 from Lake Conroe

Sediment core sample C-5 consisted of 23.5 inches of total sediment corresponding to the length of the aluminum sampling tube. The upper sediment layer (horizon) , 0 – 18.5 inches, had high water content, no soil structure, consisted of silty clay soil, and was a 2.5Y 4/2 color on the Munsell soil color chart. The second horizon, beginning at 18.5 inches and extending to 23.5 inches below the surface, consisted of a clay soil with a 2.5Y 2.5/1 Munsell soil color, lower water content, and well defined, dense soil structure with peds present. The base of the sample is denoted by the blue line in Figure 7.

The pre-impoundment boundary (red line in Figure 7) was evident within this sediment core sample at 18.5 inches and is 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 the sediment thickness identified from a sediment core sample is used with the sounding data to help identify the post-impoundment sediment interface in the acoustic signal. Within DepthPic, the current surface is automatically determined based on the 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.

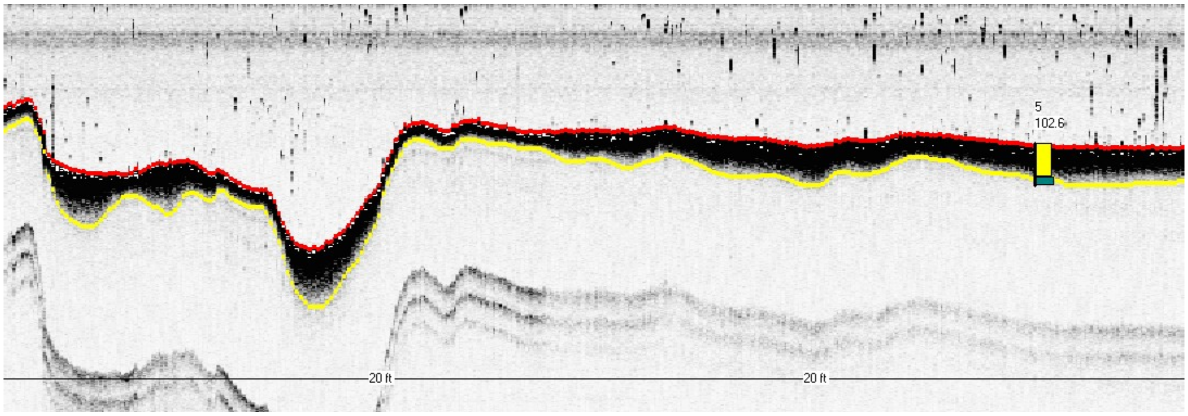


Figure 8. Cross-section of data collected during 2010 survey, displayed in DepthPic (200 kHz frequency), correlated with sediment core sample C-5 and showing the current surface in red and pre-impoundment surface in yellow

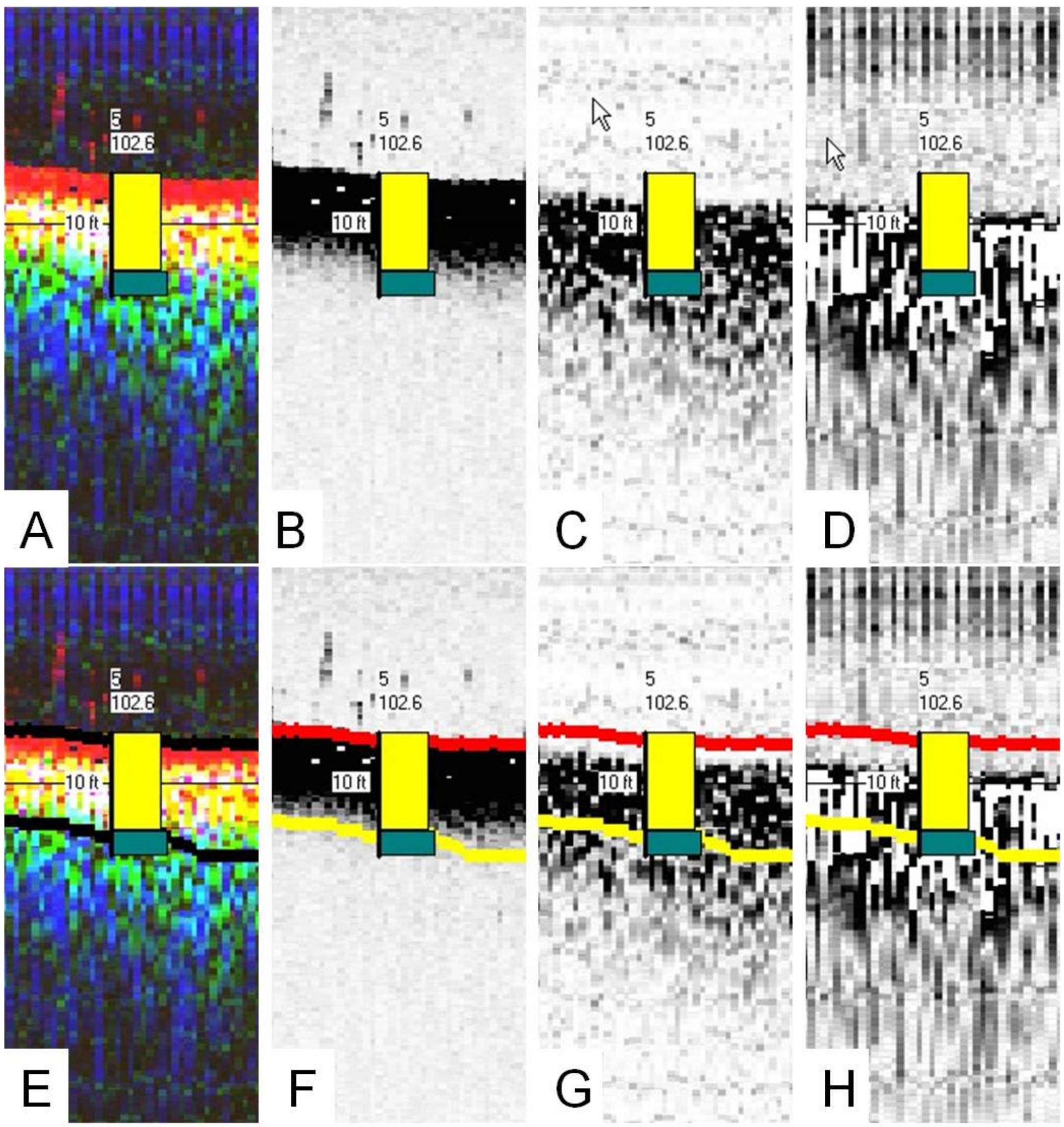
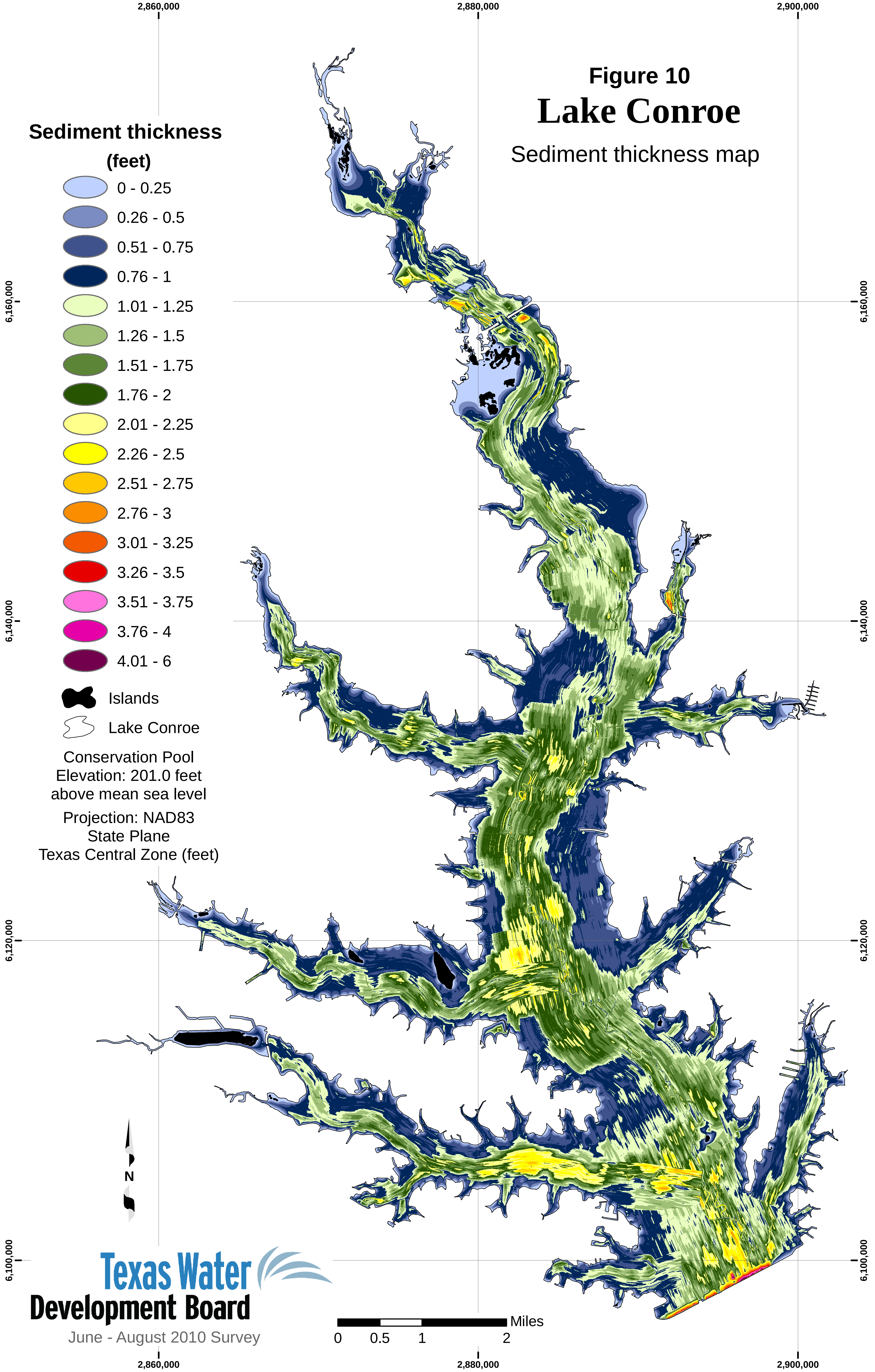


Figure 9. Comparison of sediment core C-5 with acoustic signal returns A,E) combined acoustic signal returns, B,F) 200 kHz frequency, C,G) 50 kHz frequency, D,H) 24 kHz frequency

Figure 9 shows 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 box represents post-impoundment sediment, and is 18.5 inches in length based on analysis of Sample C-5 (Figure 7, Table 2).The blue box represents the pre-impoundment sediment with a well defined soil structure. In figure 9A-D, the bathymetric surfaces are not shown. In figure 9E, the current bathymetric surface is represented as the top black line and in Figures 9F-H as the top red line. The pre-impoundment surface is visually identified by comparing boundaries observed in the 200 kHz, 50 kHz and 24 kHz signals to the location of the pre-impoundment surface based on the core sample (designated by the location of the interface between the yellow and blue boxes). In this example, the boundary in the 200 kHz signal most closely matched the pre-impoundment interface based on the core sample, so the 200 kHz signal was used to locate the pre-impoundment layer. The pre-impoundment surface was manually drawn in and is represented by the bottom black line in Figure 9E, and by the yellow line in Figures 9F-H. The location of the pre-impoundment surface relative to the gradient in the acoustic signal in cross-sections where sediment core samples were collected is used as a guide for identifying the location of the pre-impoundment surface in cross-sections where sediment core samples were not collected.

After manually digitizing the pre-impoundment surface from all cross-sections, 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 anisotropy definition file used for the bathymetric interpolation. For the purposes of the TIN model creation, TWDB assumed sediment thickness at the model boundary was zero feet (defined as the 201.0 foot NGVD29 elevation contour). This 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 (Figure 10) representing sediment accumulation throughout Lake Conroe.

Figure 10
Lake Conroe
Sediment thickness map



Texas Water Development Board

June - August 2010 Survey

Survey results

Volumetric survey

The 2010 TWDB volumetric survey indicates that Lake Conroe has a total reservoir capacity of 411,022 acre-feet and encompasses 19,640 acres at conservation pool elevation (201.0 feet above mean sea level, NGVD29). The San Jacinto River Authority estimated the original design capacity of Lake Conroe to be 430,260 acre-feet encompassing 20,985 acres at elevation 201.0 feet (TWDB, 1973). Differences in past and present survey methodologies make direct comparison of volumetric surveys difficult and potentially unreliable.

To properly compare results from TWDB surveys of Lake Conroe, TWDB applied the 2010 data processing techniques to the survey data collected in 1996. Specifically, TWDB applied anisotropic spatial interpolation to the 1996 survey dataset using the same anisotropy definition file as was used for the 2010 survey. A revised TIN model was created using the original 1996 survey boundary. The 1996 survey boundary was created from 7.5 minute USGS quadrangle maps, with a stated accuracy of ± 1/2 the contour interval (USBB, 1947). Revision of the 1996 survey using current TWDB data processing methods resulted in a 4,431 acre-feet (1.1%) increase in reservoir capacity (Table 3).

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

Survey	Surface area (acres)	Capacity (acre-feet)
SJRA[a]	20,985	430,260
TWDB 1996[b]	20,118	416,228
TWDB 1996 revised	20,118	420,659
TWDB 2010	19,640	411,022

[a] Source: (TWDB, 1973)
[b] Source: (TWDB, 2003)

Sedimentation survey

Based on two methods for estimating sedimentation rates, the 2010 TWDB sedimentation survey estimates Lake Conroe loses between 520 and 688 acre-feet per year of capacity due to sedimentation (Table 4). Sediment accumulation is greater in the submerged flood plains and adjacent to Conroe Dam.

In principle, comparing lake volumes from multiple lake surveys allows for calculation of capacity loss rates. If all lost capacity is due to sediment accumulation, then comparisons of lake volumetric surveys would yield sediment accumulation rates. In practice, however, the differences in methodologies used in each lake survey may yield greater differences in computed lake volumes than the true volume differences. In addition, because volumetric surveys are not exact, small losses or gains in sediment may be masked by the imprecision of the computed volumes. For this reason, TWDB prefers to estimate sediment accumulation rates through sedimentation surveys, which directly measure the sediment layer thicknesses throughout the reservoir. The sediment accumulation rates derived from such surveys reflect the average rate of sediment accrual since the time of impoundment.

Sedimentation rates were calculated based on the difference between the current (2010) volume and the original design volume (Table 4, Comparison 1), the current volume and the revised 1996 volume (Table 4, Comparison 2), and the current volume and the 2010 pre-impoundment volume (Table 4, Comparison 3). These three calculations lead to sedimentation rates of 520 acre-feet/year, 688 acre-feet/year, and 596 acre-feet/year, respectively.

Table 4. Capacity loss comparisons for Lake Conroe

Survey	**Comparisons @ CPE**		
	Volume (acre-ft)		**Pre-impoundment (acre-ft)**
	Comparison #1	**Comparison #2**	**Comparison #3**
Original design estimate[a]	430,260	<>	<>
TWDB pre-impoundment estimate based on 2010 survey	<>	<>	433,081[b]
1996 TWDB volumetric survey (revised)	<>	420,659	<>
2010 volumetric survey	411,022	411,022	411,022
Volume difference (acre-feet)	19,238 (4.5%)	9,637 (2.3%)	22,059 (5.1%)
Number of years	37	14	37
Capacity loss rate (acre-feet/year)	520	688	596

[a] Source: (TWDB, 1973), note: Conroe Dam was completed, and deliberate impoundment began, in January, 1973.
[b] 2010 TWDB surveyed capacity of 411,022 acre-feet plus 2010 TWDB surveyed sediment volume of 22,059 acre-feet.

Recommendations

To adequately monitor changes in reservoir capacity over time and to improve estimates of sediment accumulation rates, TWDB recommends resurveying and conducting additional sediment surveys of Lake Conroe in approximately 10 years or after a major flood event.

TWDB contact information

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

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Appendix A

Lake Conroe

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD
CAPACITY IN ACRE-FEET
ELEVATION INCREMENT IS ONE TENTH FOOT

June - August 2010 Survey
Conservation Pool Elevation 201.0 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
137	0	0	0	0	0	0	0	0	0	0
138	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0	0
140	0	0	1	1	1	1	1	1	2	2
141	2	2	3	3	3	4	4	4	5	5
142	6	6	7	7	8	8	9	10	10	11
143	12	13	14	15	15	16	17	18	19	20
144	21	23	24	25	26	27	29	30	31	33
145	34	36	37	39	41	42	44	46	48	50
146	52	54	56	59	61	64	66	69	72	75
147	78	81	85	89	93	97	102	106	111	117
148	122	128	135	141	148	155	163	171	179	188
149	197	207	217	228	239	251	264	277	292	307
150	324	342	360	380	401	422	445	468	493	519
151	547	575	605	636	669	703	738	775	814	854
152	896	939	984	1,031	1,079	1,130	1,182	1,235	1,291	1,348
153	1,407	1,467	1,529	1,592	1,657	1,723	1,790	1,859	1,930	2,002
154	2,076	2,153	2,231	2,311	2,393	2,477	2,563	2,650	2,739	2,830
155	2,922	3,015	3,109	3,204	3,301	3,399	3,498	3,598	3,700	3,803
156	3,907	4,013	4,120	4,228	4,337	4,448	4,561	4,675	4,791	4,909
157	5,029	5,150	5,275	5,401	5,531	5,663	5,798	5,935	6,076	6,220
158	6,366	6,515	6,666	6,819	6,975	7,133	7,293	7,456	7,621	7,788
159	7,958	8,131	8,306	8,484	8,664	8,847	9,033	9,221	9,413	9,607
160	9,804	10,003	10,206	10,410	10,617	10,828	11,041	11,258	11,477	11,699
161	11,924	12,151	12,380	12,612	12,847	13,084	13,323	13,564	13,808	14,053
162	14,301	14,551	14,803	15,058	15,315	15,575	15,837	16,102	16,370	16,641
163	16,914	17,190	17,469	17,751	18,036	18,325	18,615	18,909	19,206	19,506
164	19,810	20,117	20,429	20,744	21,063	21,385	21,711	22,041	22,373	22,709
165	23,047	23,389	23,734	24,081	24,432	24,786	25,144	25,505	25,870	26,237
166	26,608	26,984	27,363	27,746	28,134	28,525	28,920	29,318	29,720	30,124
167	30,532	30,943	31,357	31,774	32,194	32,616	33,042	33,470	33,901	34,335
168	34,772	35,211	35,654	36,099	36,547	36,998	37,452	37,910	38,371	38,835
169	39,303	39,774	40,248	40,726	41,207	41,693	42,182	42,674	43,170	43,669
170	44,172	44,678	45,188	45,702	46,221	46,743	47,269	47,798	48,331	48,868
171	49,408	49,952	50,499	51,049	51,603	52,161	52,721	53,285	53,852	54,422
172	54,995	55,572	56,152	56,735	57,322	57,913	58,507	59,104	59,706	60,311
173	60,920	61,533	62,150	62,771	63,396	64,024	64,656	65,292	65,931	66,574
174	67,220	67,870	68,524	69,181	69,841	70,505	71,173	71,845	72,521	73,201
175	73,886	74,576	75,271	75,971	76,677	77,388	78,105	78,827	79,555	80,287
176	81,026	81,772	82,524	83,283	84,048	84,819	85,597	86,381	87,171	87,965
177	88,766	89,571	90,381	91,195	92,015	92,839	93,668	94,502	95,341	96,185
178	97,033	97,886	98,743	99,604	100,470	101,341	102,217	103,097	103,982	104,872
179	105,766	106,666	107,570	108,479	109,392	110,310	111,233	112,159	113,090	114,025
180	114,964	115,907	116,854	117,806	118,762	119,722	120,687	121,656	122,629	123,606
181	124,587	125,573	126,562	127,557	128,555	129,559	130,567	131,579	132,596	133,616
182	134,641	135,670	136,703	137,739	138,779	139,823	140,870	141,921	142,975	144,033
183	145,095	146,160	147,228	148,300	149,375	150,454	151,537	152,622	153,712	154,805
184	155,902	157,004	158,109	159,219	160,333	161,452	162,576	163,704	164,837	165,973
185	167,113	168,258	169,406	170,559	171,716	172,878	174,044	175,214	176,390	177,570
186	178,755	179,945	181,139	182,338	183,542	184,751	185,965	187,183	188,406	189,634
187	190,866	192,104	193,345	194,592	195,844	197,100	198,362	199,628	200,899	202,175
188	203,456	204,741	206,031	207,326	208,625	209,929	211,237	212,550	213,867	215,188
189	216,514	217,844	219,177	220,515	221,857	223,203	224,552	225,906	227,264	228,625
190	229,991	231,361	232,735	234,113	235,496	236,883	238,275	239,670	241,071	242,476

Appendix A (Continued)

Lake Conroe

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD
CAPACITY IN ACRE-FEET
ELEVATION INCREMENT IS ONE TENTH FOOT

June - August 2010 Survey
Conservation Pool Elevation 201.0 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
191	243,886	245,301	246,721	248,145	249,574	251,008	252,447	253,891	255,340	256,794
192	258,253	259,717	261,186	262,661	264,141	265,626	267,117	268,613	270,114	271,620
193	273,131	274,647	276,167	277,694	279,225	280,762	282,305	283,854	285,407	286,966
194	288,531	290,101	291,677	293,258	294,846	296,439	298,039	299,645	301,256	302,873
195	304,496	306,124	307,758	309,398	311,043	312,694	314,352	316,014	317,683	319,357
196	321,037	322,722	324,413	326,108	327,809	329,514	331,224	332,938	334,657	336,382
197	338,111	339,846	341,585	343,328	345,076	346,828	348,584	350,345	352,110	353,879
198	355,653	357,431	359,214	361,001	362,792	364,588	366,389	368,194	370,003	371,816
199	373,635	375,458	377,285	379,117	380,954	382,796	384,642	386,494	388,350	390,211
200	392,078	393,950	395,826	397,708	399,595	401,487	403,384	405,286	407,193	409,105
201	411,022									

Appendix B

Lake Conroe

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — June - August 2010 Survey

AREA IN ACRES — Conservation Pool Elevation 201.0 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
137	0	0	0	0	0	0	0	0	0	0
138	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	1	1
140	1	1	1	1	1	2	2	2	2	2
141	3	3	3	3	3	3	4	4	4	4
142	5	5	5	6	6	7	7	7	8	8
143	8	8	9	9	9	9	10	10	10	11
144	11	11	12	12	12	13	13	13	14	14
145	15	15	16	17	17	18	18	19	20	21
146	21	22	23	23	24	25	26	28	29	31
147	32	35	37	39	42	44	47	49	52	55
148	58	61	64	67	71	75	78	82	85	89
149	94	99	104	110	117	124	132	140	150	161
150	172	181	191	201	211	221	231	243	254	266
151	279	292	305	320	334	347	361	377	393	409
152	426	443	459	476	494	511	529	547	563	579
153	595	611	625	639	653	667	682	698	715	734
154	753	771	791	811	831	849	866	882	897	912
155	925	937	949	961	973	985	997	1,010	1,023	1,036
156	1,049	1,062	1,075	1,088	1,102	1,118	1,134	1,152	1,169	1,187
157	1,206	1,228	1,255	1,283	1,308	1,334	1,361	1,390	1,421	1,451
158	1,475	1,498	1,522	1,548	1,571	1,592	1,614	1,637	1,662	1,686
159	1,711	1,738	1,764	1,790	1,817	1,844	1,871	1,900	1,928	1,956
160	1,982	2,008	2,034	2,059	2,087	2,118	2,150	2,180	2,208	2,234
161	2,258	2,283	2,309	2,333	2,357	2,379	2,402	2,424	2,445	2,467
162	2,489	2,512	2,536	2,558	2,583	2,610	2,636	2,665	2,692	2,719
163	2,746	2,776	2,807	2,838	2,866	2,895	2,924	2,953	2,984	3,016
164	3,055	3,095	3,135	3,172	3,208	3,243	3,276	3,308	3,340	3,371
165	3,401	3,431	3,462	3,492	3,524	3,561	3,596	3,628	3,660	3,693
166	3,729	3,771	3,813	3,855	3,894	3,931	3,968	4,000	4,030	4,062
167	4,095	4,126	4,154	4,183	4,212	4,240	4,269	4,297	4,326	4,353
168	4,381	4,408	4,436	4,466	4,497	4,528	4,559	4,593	4,626	4,659
169	4,692	4,725	4,762	4,798	4,833	4,871	4,908	4,941	4,974	5,009
170	5,045	5,082	5,122	5,163	5,203	5,239	5,275	5,313	5,350	5,384
171	5,419	5,454	5,490	5,523	5,557	5,589	5,621	5,652	5,685	5,718
172	5,750	5,782	5,816	5,852	5,887	5,922	5,957	5,997	6,036	6,072
173	6,110	6,150	6,189	6,228	6,266	6,302	6,339	6,375	6,410	6,445
174	6,482	6,517	6,552	6,586	6,622	6,660	6,699	6,738	6,779	6,825
175	6,873	6,925	6,977	7,030	7,083	7,142	7,196	7,249	7,297	7,354
176	7,424	7,490	7,556	7,619	7,682	7,749	7,810	7,867	7,922	7,976
177	8,026	8,075	8,123	8,170	8,218	8,269	8,316	8,365	8,414	8,460
178	8,504	8,547	8,592	8,639	8,685	8,733	8,780	8,826	8,872	8,921
179	8,969	9,017	9,065	9,113	9,159	9,202	9,246	9,289	9,328	9,368
180	9,409	9,451	9,495	9,539	9,583	9,625	9,667	9,710	9,750	9,791
181	9,834	9,876	9,920	9,965	10,010	10,057	10,102	10,145	10,187	10,230
182	10,269	10,309	10,345	10,382	10,418	10,453	10,488	10,525	10,562	10,598
183	10,633	10,668	10,703	10,736	10,770	10,805	10,841	10,877	10,913	10,951
184	10,992	11,033	11,077	11,121	11,168	11,214	11,260	11,303	11,343	11,382
185	11,424	11,466	11,509	11,551	11,592	11,636	11,680	11,730	11,779	11,826
186	11,874	11,922	11,969	12,015	12,062	12,111	12,159	12,207	12,256	12,303
187	12,349	12,395	12,442	12,491	12,541	12,591	12,639	12,687	12,735	12,782
188	12,830	12,877	12,924	12,970	13,016	13,060	13,105	13,149	13,192	13,234
189	13,276	13,317	13,358	13,398	13,438	13,477	13,517	13,556	13,596	13,637
190	13,678	13,720	13,762	13,805	13,849	13,893	13,937	13,981	14,028	14,077

Appendix B (Continued)

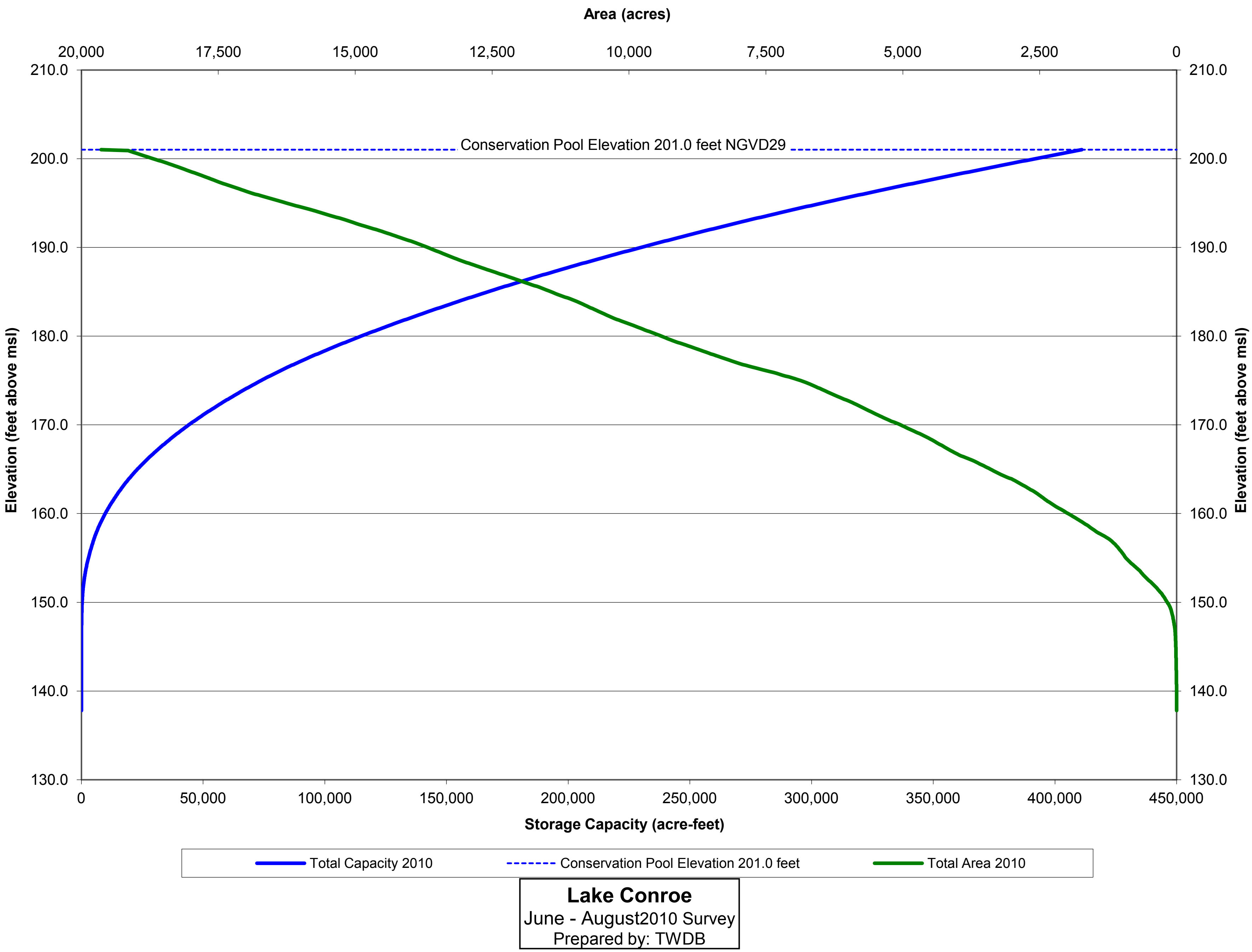
Lake Conroe

RESERVOIR AREA TABLE

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

June - August 2010 Survey
Conservation Pool Elevation 201.0 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
191	14,126	14,173	14,220	14,268	14,316	14,364	14,415	14,466	14,514	14,564
192	14,615	14,666	14,718	14,772	14,825	14,883	14,936	14,986	15,034	15,083
193	15,133	15,182	15,234	15,288	15,343	15,400	15,457	15,511	15,565	15,619
194	15,674	15,728	15,785	15,843	15,904	15,968	16,027	16,084	16,142	16,199
195	16,256	16,311	16,367	16,425	16,484	16,542	16,599	16,658	16,715	16,770
196	16,826	16,879	16,930	16,980	17,027	17,073	17,120	17,169	17,218	17,271
197	17,320	17,367	17,412	17,456	17,499	17,542	17,585	17,628	17,672	17,716
198	17,760	17,804	17,848	17,893	17,937	17,982	18,026	18,070	18,115	18,160
199	18,205	18,251	18,298	18,345	18,393	18,441	18,490	18,539	18,589	18,640
200	18,690	18,741	18,792	18,843	18,893	18,944	18,995	19,045	19,096	19,147
201	19,640									



Appendix C: Area and Capacity Curves

Figure 5

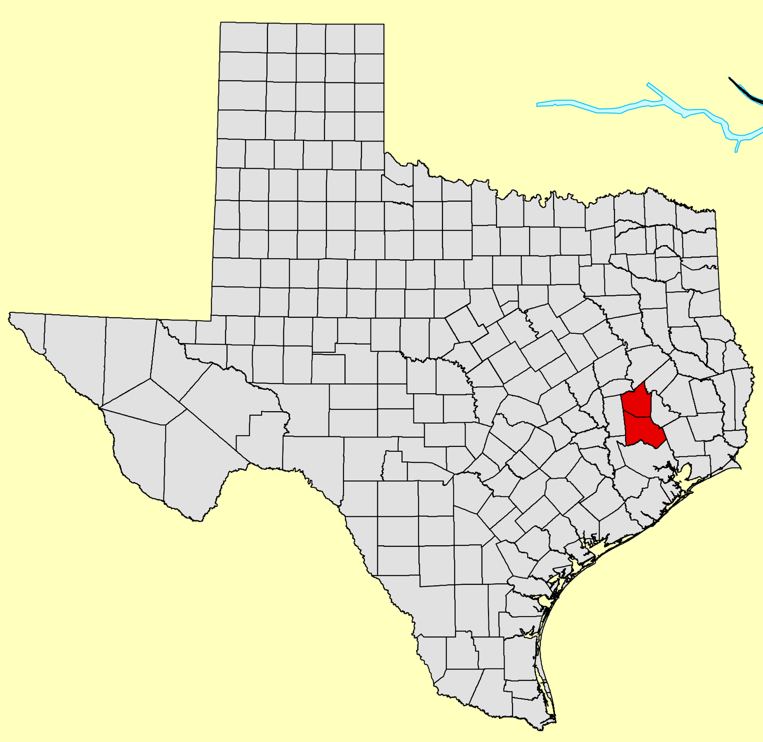
CONTOURS
(feet above mean sea level)

200
195
190
185
180
175
170
165
160
155
150
145
140

Islands
Lake Conroe

Conservation Pool Elevation
201.0 feet above mean sea level

Projection: NAD83
State Plane
Texas Central Zone (feet)



Montgomery and Walker 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 Lake Conroe. The Texas Water Development Board makes no representations nor assumes any liability.