Volumetric and Sedimentation Survey of PROCTOR LAKE

February 2012 Survey

Texas Water Development Board

June 2014

Prepared for:

Brazos River Authority

With Support Provided by:

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

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Executive summary

In October, 2011, the Texas Water Development Board entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, and in November, 2011, entered into agreement with the Brazos River Authority to perform a volumetric and sedimentation survey of Proctor Lake. The Brazos River Authority provided 50% of the funding for this survey, while the U.S. Army Corps of Engineers, Fort Worth District provided the remaining 50% of the funding through the Texas Water Allocation Assessment Program. Surveying was performed using a multi-frequency (200 kHz, 50 kHz, and 24 kHz), sub-bottom profiling depth sounder. In addition, sediment core samples were collected in select locations and correlated with the multi-frequency depth sounder signal returns to estimate sediment accumulation thicknesses and sedimentation rates.

Proctor Dam and Proctor Lake are located on the Leon River in Comanche County, approximately 8.0 miles northeast of Comanche, Texas. The conservation pool elevation of Proctor Lake is 1,162.0 feet above mean sea level (NGVD29). TWDB collected bathymetric data for Proctor Lake between February 2, 2012, and February 8, 2012. The daily average water surface elevations during the survey ranged between 1,163.49 and 1,163.54 feet above mean sea level.

The 2012 TWDB volumetric and sedimentation survey indicates that Proctor Lake has a total reservoir capacity of 54,762 acre-feet and encompasses 4,615 acres at conservation pool elevation (1,162.0 feet above mean sea level, NGVD29). Previous capacity estimates include the original design estimate by the U.S. Army Corps of Engineers of 59,387 acre-feet, a U.S. Army Corps of Engineers resurvey in 1986 of 56,225 acre-feet, and two TWDB surveys in 1993 and 2002. The TWDB volumetric surveys conducted in 1993 and 2002 were re-evaluated using current processing procedures that resulted in updated capacity estimates of 56,617 acre-feet and 57,398 acre-feet, respectively.

Based on two methods for estimating sedimentation rates, the 2012 TWDB sedimentation survey estimates Proctor Lake loses between 56 and 264 acre-feet of capacity per year due to sedimentation below conservation pool elevation (1,162.0 feet above mean sea level, NGVD29). The sedimentation survey indicates that sediment accumulation varies throughout the reservoir. The greatest accumulation of sediment is north of Promontory Park. Significant accumulation of sediment was also measured in the Rush Creek arm of the reservoir between 0.2 and 0.5 miles west of the dam adjacent to Copperas Creek Park and Promontory Park. TWDB recommends that a similar methodology be used to resurvey Proctor 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. 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 October, 2011, the Texas Water Development Board entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, and in November, 2011, entered into agreement with the Brazos River Authority to perform a volumetric and sedimentation survey of Proctor Lake. (TWDB, 2011a, TWDB, 2011b). 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 Brazos River Authority and the U.S. Army Corps of Engineers, Fort Worth District, and contains as deliverables: (1) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality [Appendix A, B], (2) a bottom contour map [Figure 6], (3) a shaded relief plot of the reservoir bottom [Figure 4], and (4) an estimate of sediment accumulation and location [Figure 10].

Proctor Lake general information

Proctor Dam and Proctor Lake are located on the Leon River in Comanche County, approximately 8.0 miles northeast of Comanche, Texas (Figure 1). Proctor Dam and Proctor Lake are owned by the U.S. Government and operated by the U.S. Army Corps of Engineers, Fort Worth District (TWDB, 1973). The U.S. Congress authorized the construction of Proctor Lake for flood control and water supply for communities in Comanche, Erath, and Hamilton Counties and for other multipurpose uses with the passage of the Flood Control Act of September 3, 1954 (USACE, 2012, USACE, 2013). The construction of Proctor Dam began on June 29, 1960. The deliberate impoundment of water began on September 30, 1963, and the dam was completed on January 2, 1964 (TWDB, 1973). Additional pertinent data about Proctor Dam and Proctor Lake can be found in Table 1.

Water rights for Proctor Lake have been appropriated to the Brazos River Authority (BRA) through Certificate of Adjudication No. 12-5159. The complete certificate is on file in the Information Resources Division of the Texas Commission on Environmental Quality.

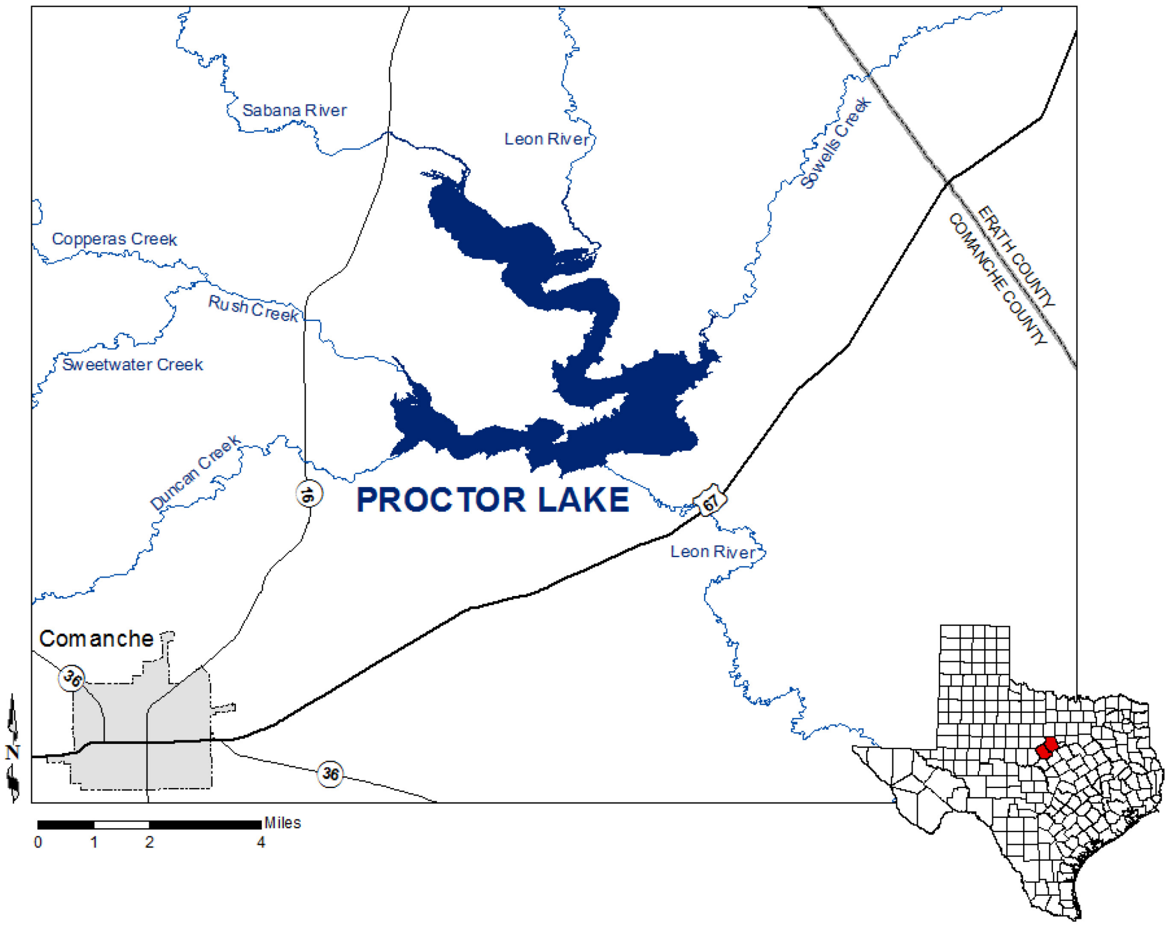


Figure 1. Location of Proctor Lake

Table 1. Pertinent data for Proctor Dam and Proctor Lake	
Owner	
The U.S. Government	
Operated by the U.S. Army Corps of Engineers, Fort Worth District	
Engineer	
U.S. Army Corps of Engineers	
General contractor	
Armstrong, Armstrong, and J.H. Ryan and Son, Inc., Roswell, New Mexico	
Location of dam	
River mile 238.9 on the Leon River in Comanche County, about 8 miles northeast of Comanche, Texas and 3.5 miles west of Proctor, Texas	
Drainage area	
1,265 square miles	
Dam	
Type	Rolled earth fill with concrete spillway in right abutment ridge
Length (including spillway)	13,460 feet
Maximum height	86 feet
Top width	30 feet
Spillway	
Type	Ogee
Length	440.0 feet net at crest
Crest elevation	1,162.0 feet above mean sea level
Control	11 tainter gates, each 40 by 35 feet
Outlet works	
Type	2 conduits, each 36-inch diameter
Control	2 slide gates, 3 feet by 3 feet diameter
Invert elevation	1,128.0 feet above mean sea level

Reservoir data (Based on 2012 TWDB survey)

Feature	**Elevation (feet** NGVD29[a]**)**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam	1,206.0	N/A	N/A
Maximum design water surface	1,201.0	N/A	N/A
Top of flood control storage space	1,197.0	N/A	N/A
Top of conservation storage space	1,162.0	54,762	4,615
Invert of low-flow outlet	1,128.0	0	0
Usable conservation storage space[b]	-	54,762	-

Source: (TWDB1973, TWDB 2003b, USACE 2007, USACE, 2013)
[a] NGVD29 = National Geodetic Vertical Datum 1929
[b] Usable conservation storage space equals total capacity at conservation pool elevation minus dead pool capacity. Dead pool refers to water that cannot be drained by gravity through a dam's outlet works.

Volumetric and sedimentation survey of Proctor Lake

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 08099400 Proctor Lk nr Proctor, TX* (USGS, 2013). Elevations herein are reported in feet relative to the NGVD29 datum. Volume and area calculations in this report are referenced to water levels provided by the USGS gage. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas Central Zone (feet).

TWDB bathymetric and sedimentation data collection

TWDB collected bathymetric data for Proctor Lake between February 2, 2012, and February 8, 2012. The daily average water surface elevations during the survey ranged between 1,163.49 and 1,163.54 feet above mean sea level (NGVD29). For data collection, TWDB used a Specialty Devices, Inc. (SDI), single-beam, multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment. Data collection occurred while navigating along pre-planned survey lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. Many of the survey lines were also surveyed by TWDB during the 1993 and 2002 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 2012 TWDB survey.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples are collected at regularly spaced intervals within the reservoir, or at locations where interpretation of the acoustic display would be difficult without site-specific sediment core data. Following the analysis of the sounding data, TWDB selected six locations to collect sediment core samples (Figure 2). The sediment core samples were collected on December 11, 2012, 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 to which the tube must be driven during sediment sampling. The goal is to collect a sediment core sample extending from the current reservoir-bottom, through the accumulated sediment, and to the pre-impoundment surface. After retrieving the sample, a stadia rod is inserted into the top of the tube to assist in locating the top of the sediment in the tube. This identifies the location of the layer corresponding to the current reservoir surface. The aluminum tube is cut to this level, capped, and transported back to TWDB headquarters for further analysis. During this time, some settling of the upper layer can occur.

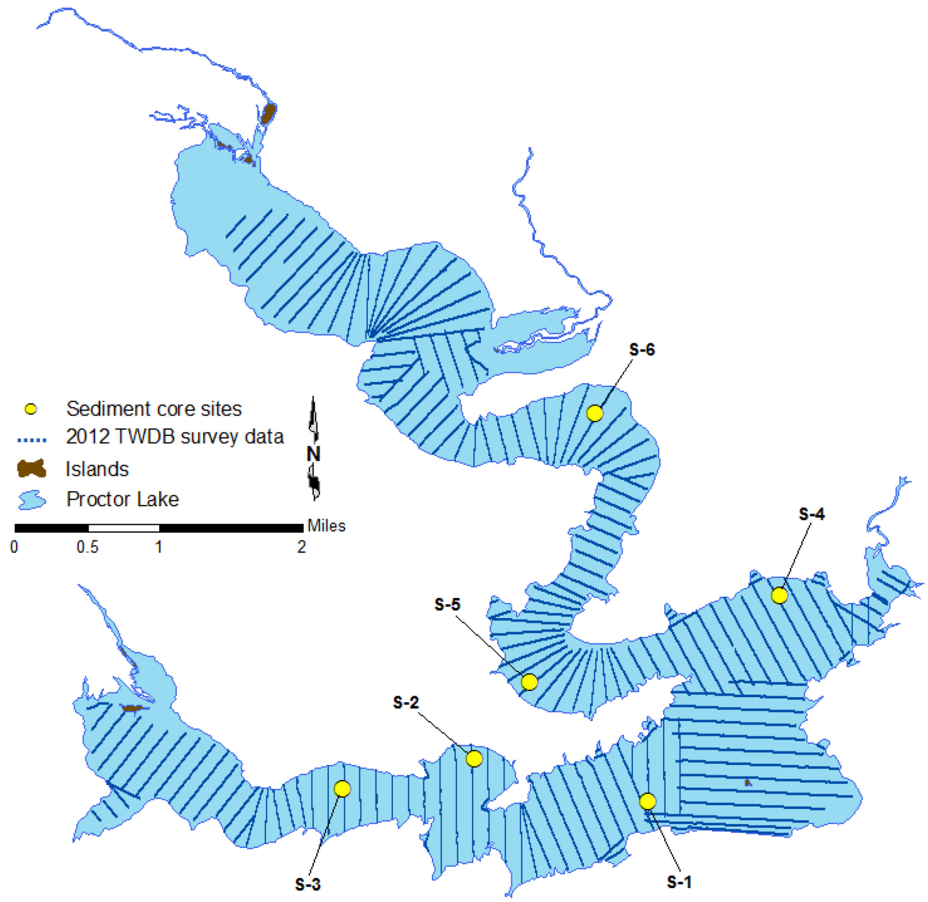


Figure 2. Data collection during 2012 TWDB Proctor Lake survey

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 software. The quarter-quadrangles that cover Proctor Lake are De Leon (SE), Comyn (SW), Comanche (NE), and Proctor (NW). The DOQQs were photographed on January 9, 1995, and January 23, 1995, while the daily average water surface elevation measured 1,162.22 feet and 1,162.29 feet (NGVD29). According to metadata associated with the 1995 DOQQs, the photographs have a resolution or ground sample distance of 1.0-meters, with a horizontal positional accuracy that meets the National Map Accuracy Standards (NMAS) for 1:12,000-scale products. For this analysis, the boundary was digitized at the land-water interface in the 1995 photographs and given an elevation of 1,162.3 feet. This boundary was also used to model the reservoir when TWDB surveyed

Proctor Lake in 2002. Additional boundary information obtained from aerial photographs taken on July 17, 2010, July 31, 2010, and July 20, 2012, while the daily average water surface elevation measured 1,159.83 feet, 1,159.41feet, and 1,160.0 feet, respectively, was added to the 2012 lake model as points of known elevation.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by TWDB were edited to remove data anomalies. DepthPic©, software developed by SDI, Inc., is used to display, interpret, and edit the multi-frequency data by manually removing data anomalies in the current bottom surface and manually digitizing the reservoir-bottom surface at the time of initial impoundment (i.e. pre-impoundment surface). For processing outside of DepthPic©, an in-house software package, HydroTools, is used to identify the current reservoir-bottom surface, pre-impoundment surface, sediment thickness at each sounding location, and output the data into a single file. The water surface elevation at the time of each sounding was used to convert each sounding depth to a corresponding reservoir-bottom elevation. This survey point dataset is then preconditioned by inserting a uniform grid of artificial survey points between the actual survey lines. Bathymetric elevations at these artificial points are determined using an anisotropic spatial interpolation algorithm described in the spatial interpolation of reservoir bathymetry section below. This technique creates a high resolution, uniform grid of interpolated bathymetric elevation points throughout a majority of the reservoir (McEwen et al., 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 (ESRI, 1995).

Spatial interpolation of reservoir bathymetry

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

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

Specific details of this interpolation technique can be found in the HydroTools manual (McEwen et al., 2011a) and in McEwen et al., 2011b.

In areas inaccessible to survey data collection such as small coves and shallow upstream areas of the reservoir, linear extrapolation is used for volumetric and sediment accumulation estimations. The linear extrapolation follows a linear definition file linking the survey points file to the lake boundary file (McEwen et al., 2011a). Without extrapolated data, the TIN Model builds flat triangles. A flat triangle is defined as a triangle where all three vertices are equal in elevation, generally the elevation of the reservoir boundary. Reducing flat triangles by applying linear extrapolation improves the elevation-capacity and elevation-area calculations. It is not possible to remove all flat triangles, and linear extrapolation is only applied where adding bathymetry is deemed reasonable. For example, linear extrapolation was deemed reasonable and applied to Proctor Lake in the following situations: in small coves of the main body of the lake and in obvious channel features visible in the aerial photographs taken on July 17, 2010, July 31, 2010, and July 20, 2012.

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

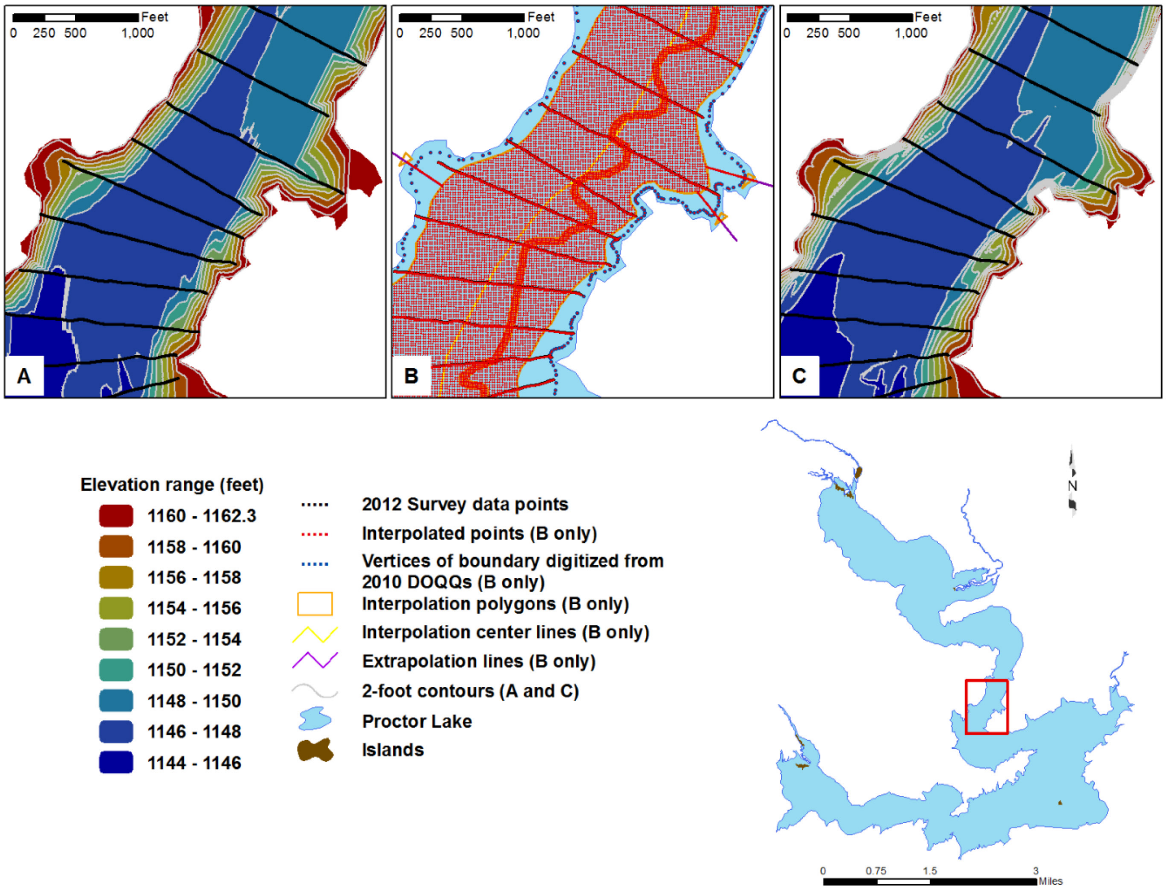


Figure 3. **Anisotropic spatial interpolation and linear extrapolation of Proctor Lake sounding data - A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red), C) bathymetric contours with the interpolated points**

Area, Volume, and Contour Calculation

Using ArcInfo software and the volumetric TIN model, volumes and areas were calculated for the entire reservoir at 0.1 feet intervals, from 1,133.0 to 1,162.3 feet. The elevation-capacity table and elevation-area table, updated for 2012, are presented in Appendices A and B, respectively. The area-capacity curves are presented in Appendix C.

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

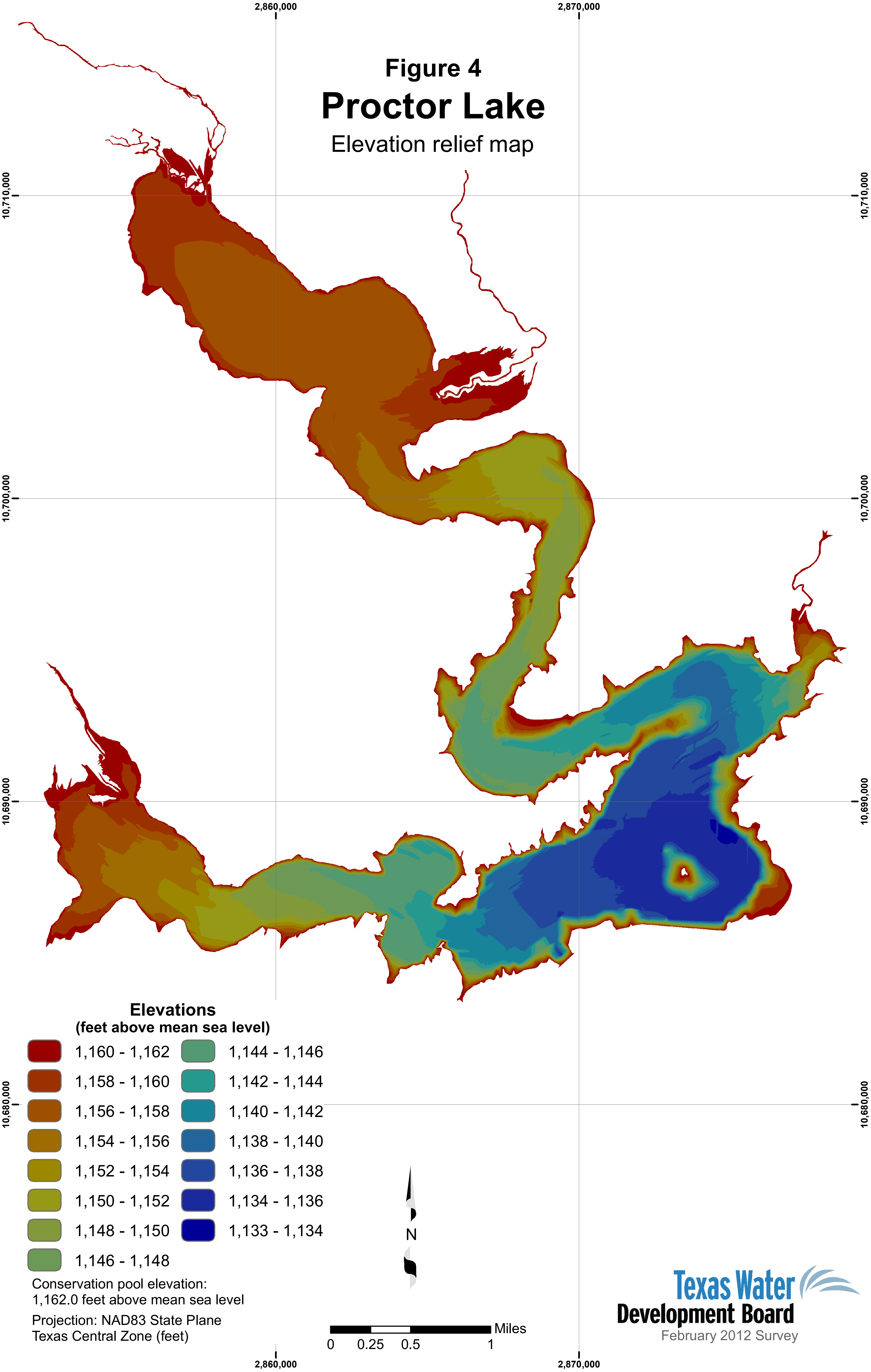


Figure 4
Proctor Lake
Elevation relief map

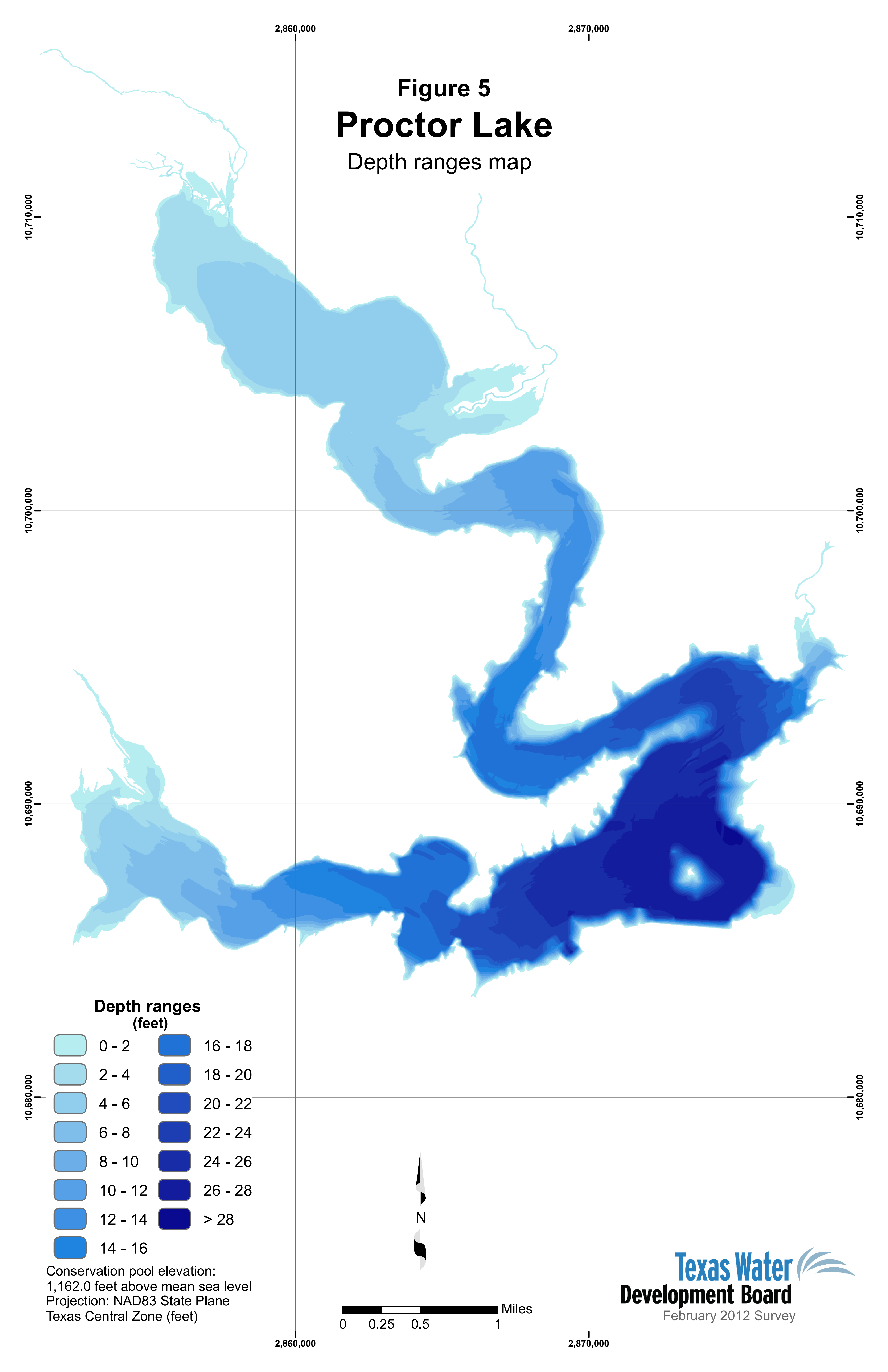


Figure 5
Proctor Lake
Depth ranges map
2,860,000
2,870,000
10,710,000
10,700,000
10,690,000
10,680,000
Depth ranges
(feet)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
20 - 22
22 - 24
24 - 26
26 - 28
> 28
Conservation pool elevation:
1,162.0 feet above mean sea level
Projection: NAD83 State Plane
Texas Central Zone (feet)
N
0
0.25
0.5
1
Miles
Texas Water
Development Board
February 2012 Survey

Analysis of sediment data from Proctor Lake

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

Analysis of the sediment core samples was conducted at TWDB headquarters in Austin. Each sample was split longitudinally and analyzed to identify the location of the pre-impoundment surface. The pre-impoundment surface is identified within the sediment core sample by one or a combination 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 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 - Proctor Lake

Core	Easting[a] (ft)	Northing[a] (ft)	Total core sample/ post-impoundment sediment	Sediment core description	Munsell soil color
P-1	2870352.61	10686914.75	44.5”/42”	0-42” thin loose sediment, silty clay with band of sediment at 23-25”	10YR 2/2 with band of 5Y 4/1
				42”-44.5” dense sediment with organics present, clay loam	7.5YR 4/1
P-2	2864921.28	10688422.67	40.25”/36”	0-36” loose sediment, silty clay, band of sediment from 12-18”	5Y 4/1 with band of 10YR 2/2
				36-40.25” dense sediment with organics present, clay soil with peds	7.5YR 4/2
P-3	2860832.39	10687235.64	33”/28.5”	0-4” loose sediment, silt	2.5Y 4/2
				4-14” loose sediment, silty clay	10YR 2/2
				14-28.5” dense sediment, clay loam	5Y 4/1
				28.5-33” dense sediment with peds and organics present, clay loam	7.5YR 4/2
P-4	2874369.76	10694532.30	36”/30”	0-8” loose sediment, silt	2.5Y 4/2
				8-15.5” loose sediment, silty clay	5Y 4/1
				15.5-30” loose sediment, silty clay	10YR 2/1
				30-36” dense clay sediment with organics and peds present	7.5YR 4/2
P-5	2866607.81	10691252.95	16.5”/11”	0-11” silty clay soil, loose sediment	5Y 4/1
				11-16.5” very dense clay soil with peds present, organics present	7.5YR 4/2
P-6	2868467.50	10701116.23	19.5”/14.5”	0-9” loose sediment, silt	2.5y 4/2
				9-14.5” loose sediment, silty clay	5y 4/2
				14.5-19.5” dense clay soil with peds and roots present	7.5yr 4/1

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

A photograph of sediment core P-3 is shown in Figure 7 and is representative of the sediment cores sampled from Proctor Lake. The 200 kHz frequency measures the top layer as the current bottom surface of the reservoir.

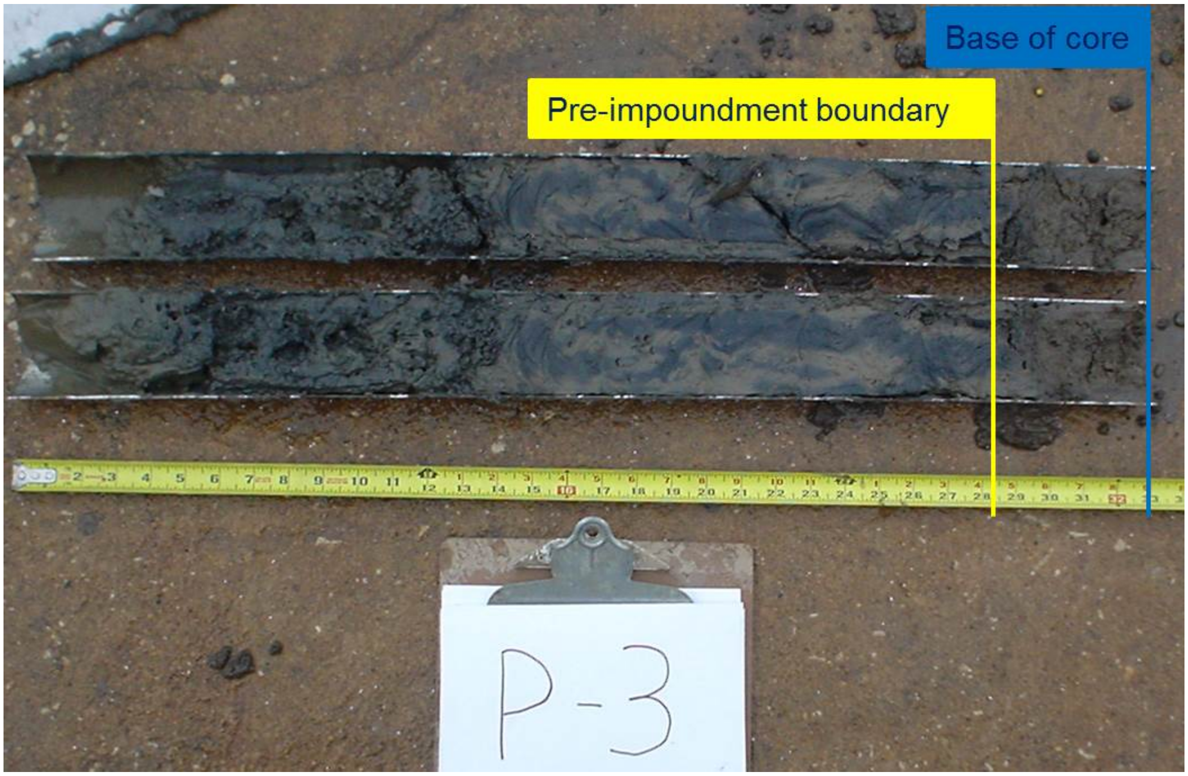


Figure 7. Sediment core P-3 from Proctor Lake

Sediment core sample P-3 consisted of 33 inches of total sediment corresponding to the length of the aluminum sampling tube. The upper sediment layer (horizon), 0-4.0 inches, consisted of loose silt and measured 2.5Y 4/2 on the Munsell soil color chart. The second horizon, beginning at 4.0 inches and extending to 14.0 inches below the surface, consisted of loose silty clay sediment and measured 10YR 2/2 on the Munsell soil color chart. The third horizon, beginning at 14.0 inches and extending to 28.5 inches below the surface, consisted of a dense clay loam sediment with a 5Y 4/1 Munsell soil color. The forth horizon, from 28.5 inches to 33.0 inches, consisted of dense clay loam sediment with peds and organics present and a 7.5YR 4/2 Munsell soil color. The base of the sample is denoted by the blue line in Figure 7.

The pre-impoundment boundary (yellow line in Figure 7) was evident within this sediment core sample at 28.5 inches and identified by the change in texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the remaining sediment cores followed a similar procedure.

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

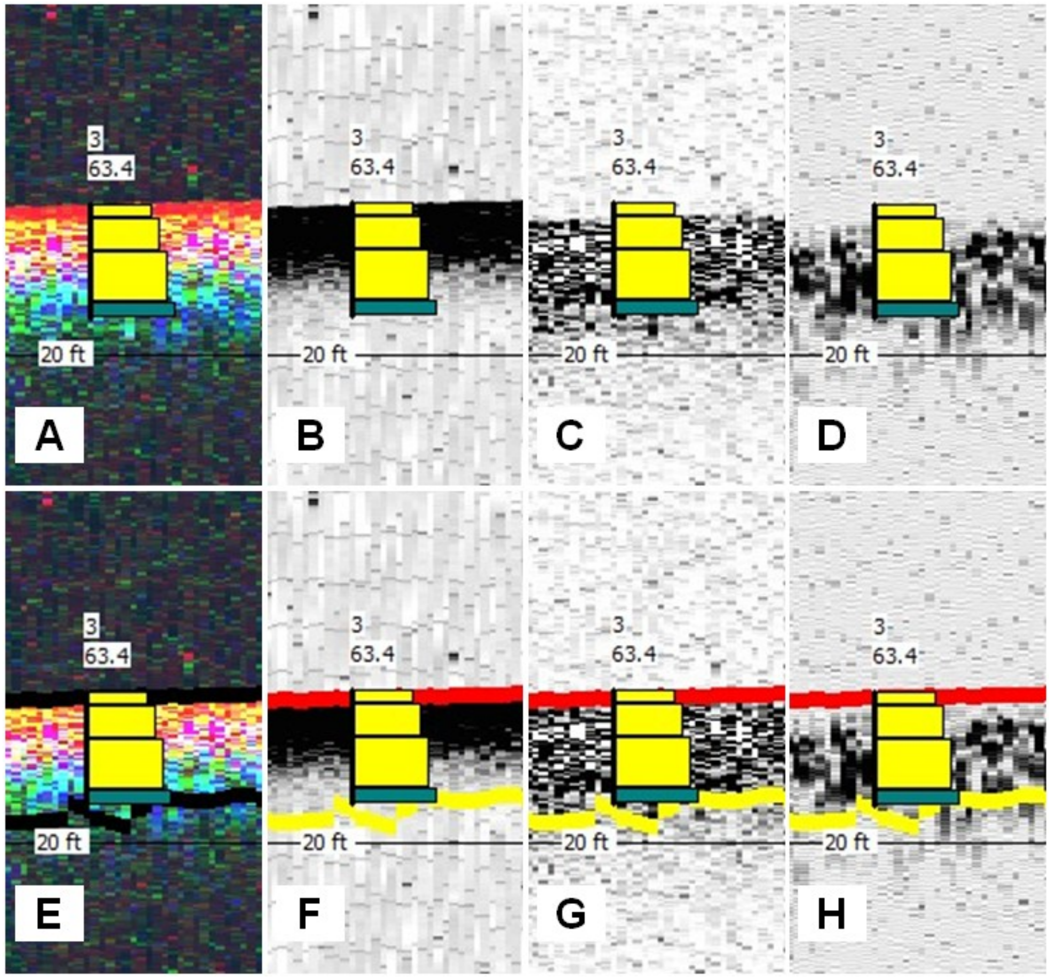


Figure 8. Comparison of sediment core P-3 with acoustic signal returns A,E) combined acoustic signal returns, B,F) 200 kHz frequency, C,G) 50 kHz frequency, D,H) 24 kHz frequency

Figure 8 compares sediment core sample P-3 with the acoustic signals for all frequencies combined (A, E), 200 kHz (B, F), 50 kHz (C, G), and 24 kHz (D, H). The sediment core sample is represented in each figure as colored boxes. The yellow boxes represent post-impoundment sediment, and the blue box represents the pre-impoundment sediment. In Figure 8A-D, the bathymetric surfaces are not shown. In Figure 8E, the current bathymetric surface is represented as the top black line and in Figures 8 F-H as the top red line. The pre-impoundment surface is identified by comparing boundaries observed in the 200 kHz, 50 kHz and 24 kHz signals to the location of the pre-impoundment surface of the sediment core sample. Each sediment core sample was compared to all three frequencies and the boundary in the 50 kHz signal most closely matched the pre-impoundment interface of the sediment core samples; therefore, the 50 kHz signal was used to locate the pre-impoundment layer. The pre-impoundment surface was manually drawn and is represented by the bottom black line in Figure 8E, and by the yellow line in Figures 8F-H. Figure 9 shows sediment core sample P-3 correlated with the 50 kHz frequency of the nearest surveyed cross-section. The pre-impoundment surface identified along cross-sections where sediment core samples were collected is used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

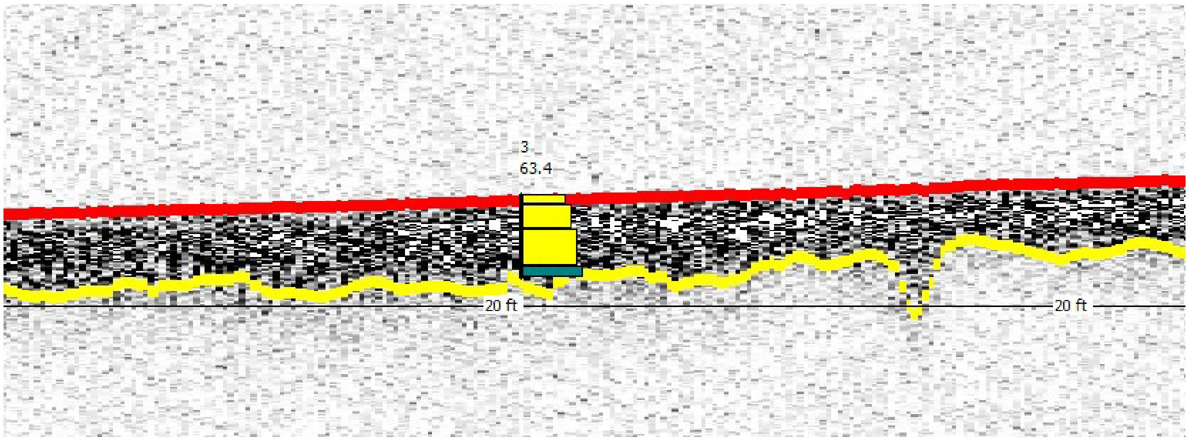
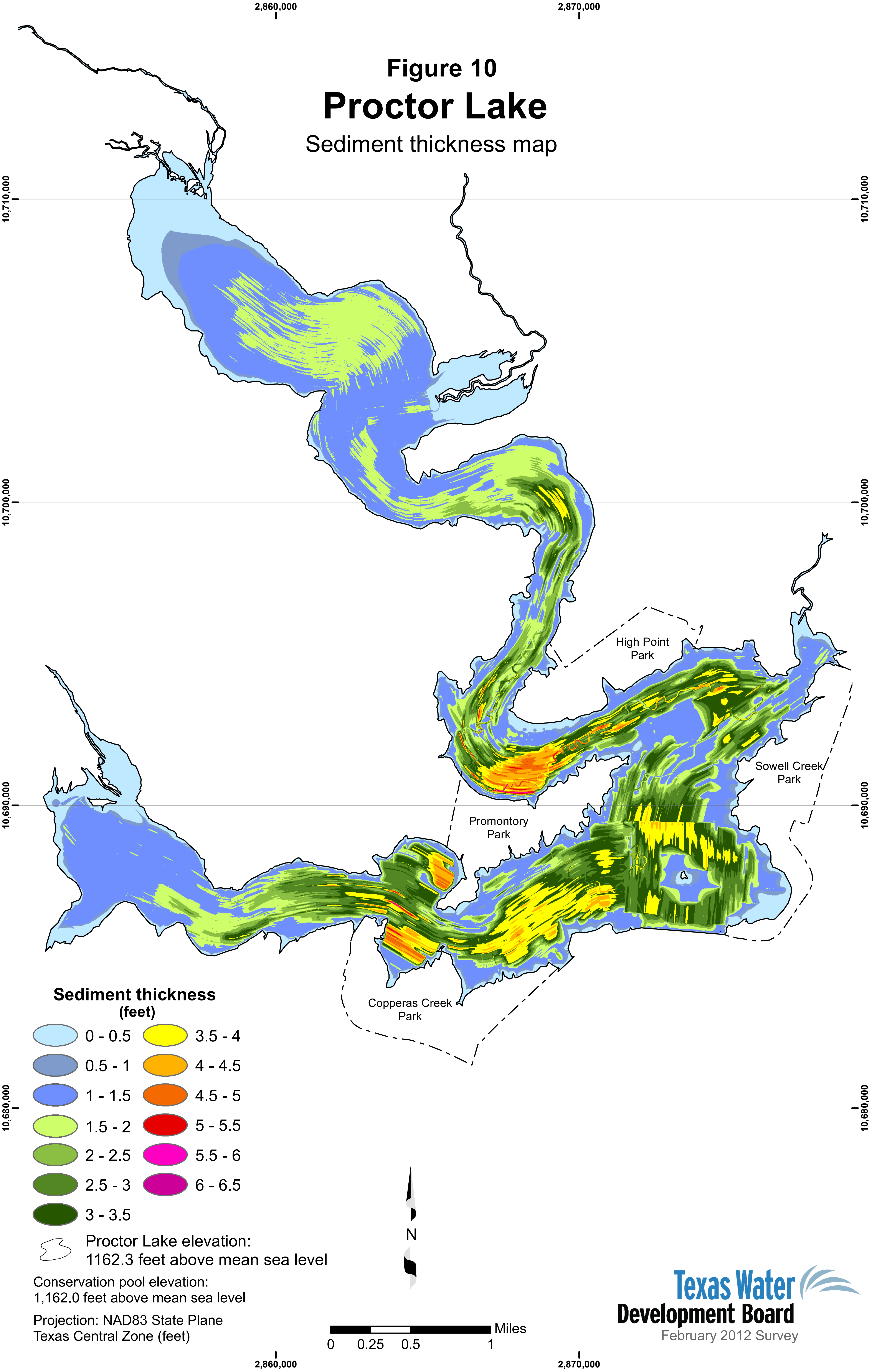


Figure 9. Cross-section of data collected during 2012 survey, displayed in DepthPic© (50 kHz frequency), correlated with sediment core sample P-3 and showing the current surface in red and pre-impoundment surface in yellow

After the pre-impoundment surface from all cross-sections was identified, a sediment thickness TIN model is created following standard GIS techniques (Furnans, 2007). Sediment thicknesses were interpolated between surveyed cross-sections using HydroTools with the same interpolation definition file used for bathymetric interpolation. For the purposes of the TIN model creation, TWDB assumed sediment thickness at the reservoir boundary was zero feet (defined as the 1,162.3 foot NGVD29 digitized elevation contour). The sediment thickness at each boundary point added from the 2010 and 2012 aerial photographs was also assumed to be zero. The sediment thickness TIN model was converted to a raster representation using a cell size of 5 feet by 5 feet and used to produce a sediment thickness map of Proctor Lake (Figure 10).

Figure 10
Proctor Lake
Sediment thickness map



Survey results

Volumetric survey

The results of the 2012 TWDB volumetric survey indicate Proctor Lake has a total reservoir capacity of 54,762 acre-feet and encompasses 4,615 acres at conservation pool elevation (1,162.0 feet above mean sea level, NGVD29). Previous capacity estimates include the original design estimate by the U.S. Army Corps of Engineers of 59,387 acre-feet, a U.S. Army Corps of Engineers resurvey in 1986 of 56,225 acre-feet, and two TWDB surveys in 1993 and 2002. The TWDB volumetric surveys conducted in 1993 and 2002 were re-evaluated using current processing procedures that resulted in updated capacity estimates of 56,617 acre-feet and 57,398 acre-feet, respectively. Because of differences in past and present survey methodologies, direct comparison of volumetric surveys to estimate loss of capacity is difficult and can be unreliable.

Previous surveys of Proctor Lake by TWDB were conducted in 1993 and 2002. To properly compare results of TWDB surveys, TWDB applied the 2013 data processing techniques to the data collected in 1993 and 2002. Specifically, TWDB applied anisotropic spatial interpolation to the survey data collected in 1993 and 2002 using the same interpolation definition file as was used for the 2012 survey with minor edits to account for differences in data coverage and boundary conditions. Additionally, data points from the 1993 survey that did not adhere to the pre-planned survey design were deleted. New TIN models were created using the original boundaries. The 1993 survey boundary was digitized from the 1,162.0-feet contour from 7.5 minute USGS quadrangle maps (Proctor-1979, De Leon-1969, Comyn-1979 and Comanche-1969), with a stated accuracy of ± ½ the contour interval (USBB, 1947). The 2002 survey boundary was digitized from aerial photographs taken on January 9, 1995, and January 23, 1995, while the water surface elevation of the reservoir measured 1,162.22 and 1,162.29 feet above mean sea level. The boundary was defined as 1,162.3 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. Re-evaluation of the 1993 and 2002 surveys resulted in a 1.9 percent and 3.5 percent increase, respectively, in total capacity estimates (Table 3).

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

Survey	Surface area (acres)	Total capacity (acre-feet)
Original[a]	4,610	59,387
USACE 1986 Resurvey	4,611	56,225
TWDB 1993[b]	4,761	55,588
TWDB 1993 (re-calculated)	4,728	56,617
TWDB 2002[c]	4,537	55,457
TWDB 2002 (re-calculated)	4,602	57,398
TWDB 2012	4,615	54,762

[a] Source: (USACE, 1987) Note: In previous TWDB survey reports (TWDB, 2003a, TWDB, 2003b), TWDB Report 126 (TWDB, 1973), and the USACE pertinent data sheet for Proctor Lake (USACE, 2013), the original area and capacity estimates are reported as 4,610 acres and 59,400 acre-feet. This capacity is not the original surveyed capacity, but rather the amount of water the Brazos River Authority is authorized to impound in Proctor Lake per Certificate of Adjudication No. 12-5159 issued by the Texas Water Commission, now the Texas Commission on Environmental Quality, on December 14, 1987.
[b] Source: (TWDB, 2003a)
[c] Source: (TWDB, 2003b)

Sedimentation survey

Based on two methods for estimating sedimentation rates presented in Table 4, the 2012 TWDB sedimentation survey estimates Proctor Lake loses between 56 and 264 acre-feet per year of capacity due to sedimentation below conservation pool elevation (1,162.0 feet NGVD29). The sedimentation survey indicates sediment accumulation varies throughout the reservoir. The greatest accumulation of sediment is north of Promontory Park. Significant accumulation of sediment was also measured in the Rush Creek arm of the reservoir between 0.2 and 0.5 miles west of the dam adjacent to Copperas Creek Park and Promontory Park.

Sedimentation rates were calculated for the differences between the current volumetric survey and the original capacity estimate, the USACE 1986 resurvey capacity estimate, as well as the re-calculated 1993 and 2002 TWDB capacity estimates (Table 4). Based on the 2012 estimated sediment volume, Proctor Lake lost an average of approximately 161 acre-feet of capacity per year from 1963 to 2012. Comparison of capacity estimates of Proctor Lake derived using differing methodologies are provided in Table 4 for sedimentation rate calculation.

Table 4. Capacity loss comparisons for Proctor Lake

Survey	Volume comparisons at conservation pool elevation (ac-ft)				Pre-impoundment (ac-ft)
Original	59,387	<>	<>	<>	<>
USACE 1986 Resurvey		56,225	<>	<>	<>
TWDB 1993 (re-calculated)	<>	<>	56,617	<>	<>
TWDB 2002 (re-calculated)	<>	<>	<>	57,398	<>
TWDB pre-impoundment estimate based on 2012 survey	<>	<>	<>	<>	62,631[b]
2012 volumetric survey	54,762	54,762	54,762	54,762	54,762
Volume difference (acre-feet)	4,625 (7.8%)	1,463 (2.6%)	1,855 (3.3%)	2,636 (4.6%)	7,869 (12.6%)
Number of years	49[a]	26	19	10	49[a]
Capacity loss rate (acre-feet/year)	94	56	98	264	161

Note: Proctor Dam was completed on January 2, 1964, and deliberate impoundment began on September 30, 1963

[a] Number of years based on difference between 2012 survey date and deliberate impoundment date of 1963

[b] 2012 TWDB surveyed capacity of 54,762 acre-feet plus 2012 TWDB surveyed sediment volume of 7,869 acre-feet

Recommendations

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

TWDB contact information

More information about the Hydrographic Survey Program can be found at: http://www.twdb.texas.gov/surfacewater/surveys/index.asp

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References

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

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

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

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

TWDB (Texas Water Development Board), 1973, Proctor Dam and Proctor Lake, Report 126, Engineering Data on Dams and Reservoirs in Texas, Part II.

TWDB (Texas Water Development Board), 2011a, Contract No. 1248011395 with U.S. Army Corps of Engineers, Fort Worth District.

TWDB (Texas Water Development Board), 2011b, Contract No. 1248011396 with Brazos River Authority.

TWDB (Texas Water Development Board), March 2003a, Volumetric Survey of Proctor Lake, http://www.twdb.texas.gov/hydro_survey/proctor/1993-12/Proctor1994_FinalReport.pdf

TWDB (Texas Water Development Board), May 2003b, Volumetric Survey Report of Proctor Lake, http://www.twdb.texas.gov/hydro_survey/proctor/2002-07/Proctor2002_FinalReport.pdf

USACE (U.S. Army Corps of Engineers), October 1987, Proctor Lake, Leon River, Texas, Brazos River Basin, Texas, Resurvey of May 1986, Report on Sedimentation, U.S. Army Corps of Engineers, Fort Worth District.

USACE (U.S. Army Corps of Engineers), 2007, U.S. Army Corps of Engineers - Lake Information, Lake Information, http://www.swf-wc.usace.army.mil/proctor/Information/index.asp, accessed July 2013.

USACE (U.S. Army Corps of Engineers), 2012, U.S. Army Corps of Engineers – Proctor Lake Home Page, http://www.swf-wc.usace.army.mil/proctor/, accessed July 2013.

USACE (U.S. Army Corps of Engineers), 2013, http://www.swf-wc.usace.army.mil/pertdata/pctt2.pdf, accessed July 2013.

USBB (United States Bureau of the Budget), 1947, United States National Map Accuracy Standards, http://nationalmap.gov/standards/pdf/NMAS647.PDF.

USGS (United States Geological Survey), 2013, U.S. Geological Survey National Water Information System: Web Interface, USGS Real-Time Water Data for USGS 08099400 Proctor Lk nr Proctor, TX, http://waterdata.usgs.gov/tx/nwis/uv/?site_no=08099400&PARAmeter_cd=00062,72020,00054, accessed July 2013.

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

Appendix A

Proctor Lake

RESERVOIR CAPACITY TABLE

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

February 2012 Survey
Conservation Pool Elevation 1,162.0 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
1,133	0	0	0	0	0	0	0	0	0	1
1,134	2	3	4	5	7	9	12	16	21	27
1,135	35	44	55	68	83	101	122	146	173	203
1,136	234	267	303	341	381	423	467	513	561	611
1,137	663	716	771	827	885	944	1,003	1,064	1,126	1,188
1,138	1,251	1,315	1,380	1,446	1,513	1,581	1,650	1,719	1,789	1,860
1,139	1,932	2,004	2,077	2,151	2,225	2,301	2,378	2,456	2,536	2,617
1,140	2,699	2,783	2,868	2,954	3,041	3,130	3,219	3,310	3,402	3,495
1,141	3,589	3,685	3,782	3,880	3,979	4,079	4,180	4,282	4,385	4,488
1,142	4,592	4,697	4,803	4,910	5,018	5,127	5,237	5,347	5,459	5,570
1,143	5,683	5,797	5,911	6,026	6,141	6,258	6,375	6,492	6,611	6,731
1,144	6,853	6,976	7,102	7,230	7,361	7,494	7,629	7,765	7,904	8,044
1,145	8,185	8,326	8,469	8,613	8,757	8,903	9,050	9,198	9,348	9,500
1,146	9,654	9,810	9,967	10,126	10,286	10,447	10,609	10,773	10,937	11,102
1,147	11,268	11,435	11,603	11,773	11,943	12,114	12,287	12,460	12,635	12,810
1,148	12,987	13,164	13,343	13,523	13,704	13,886	14,069	14,254	14,439	14,626
1,149	14,813	15,001	15,190	15,380	15,571	15,763	15,956	16,151	16,348	16,546
1,150	16,745	16,947	17,150	17,355	17,562	17,771	17,981	18,193	18,406	18,620
1,151	18,836	19,052	19,270	19,489	19,710	19,931	20,154	20,378	20,604	20,830
1,152	21,057	21,285	21,515	21,746	21,977	22,210	22,444	22,679	22,915	23,153
1,153	23,391	23,630	23,870	24,111	24,354	24,596	24,840	25,085	25,332	25,579
1,154	25,827	26,076	26,327	26,579	26,832	27,087	27,342	27,599	27,858	28,117
1,155	28,378	28,641	28,904	29,170	29,437	29,707	29,978	30,250	30,525	30,801
1,156	31,080	31,360	31,642	31,931	32,227	32,532	32,845	33,166	33,492	33,824
1,157	34,162	34,505	34,854	35,208	35,565	35,928	36,294	36,663	37,037	37,412
1,158	37,790	38,170	38,552	38,936	39,322	39,711	40,101	40,494	40,890	41,287
1,159	41,687	42,090	42,496	42,905	43,317	43,734	44,153	44,574	44,998	45,424
1,160	45,852	46,284	46,718	47,153	47,589	48,026	48,465	48,905	49,347	49,789
1,161	50,234	50,679	51,126	51,576	52,026	52,478	52,931	53,386	53,843	54,302
1,162	54,762	55,225	55,689	56,156						

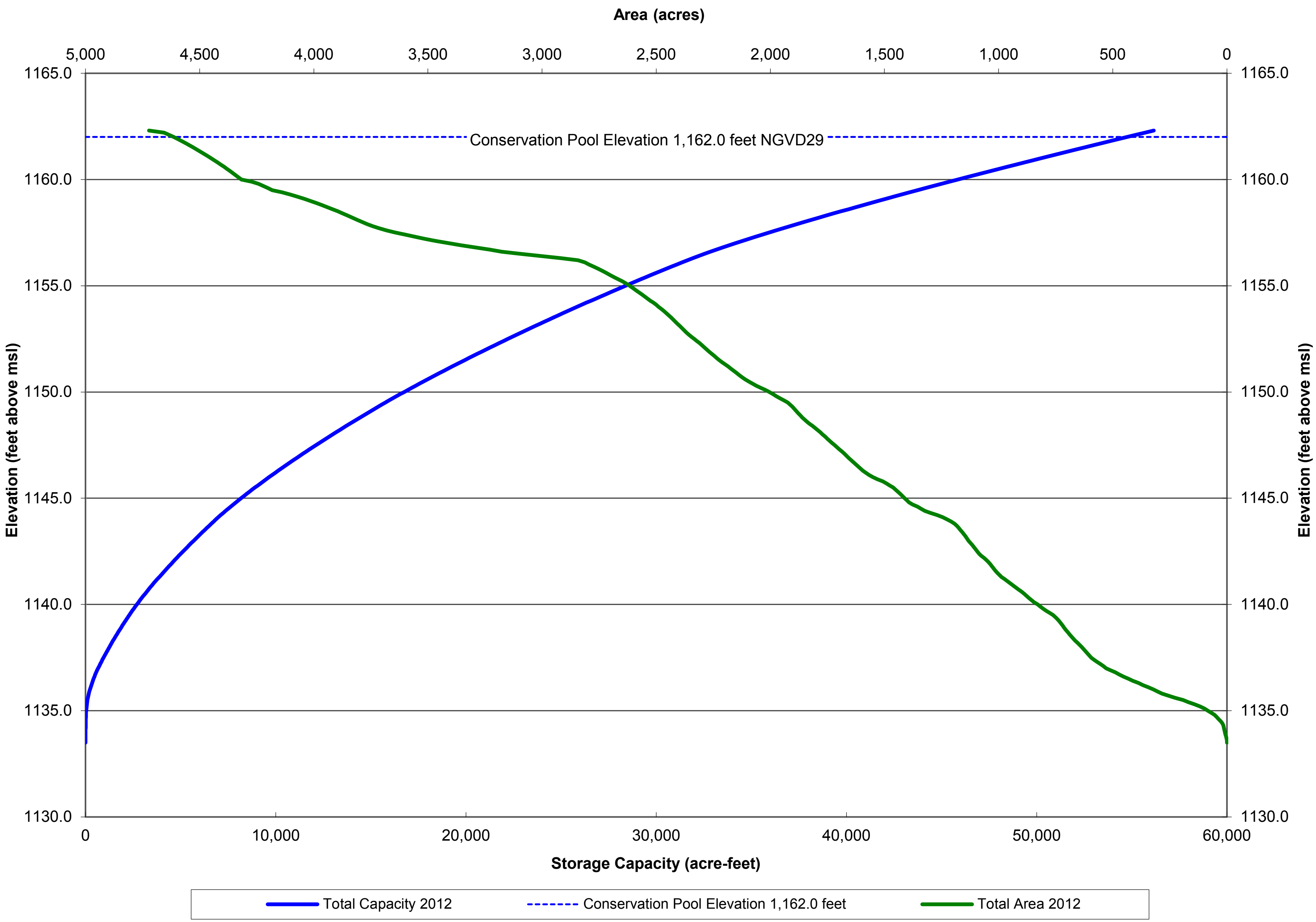
Appendix B

Proctor Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD | February 2012 Survey
AREA IN ACRES | Conservation Pool Elevation 1,162.0 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
1,133	0	0	0	0	0	0	0	1	4	7
1,134	9	11	13	16	19	27	36	44	54	68
1,135	84	98	118	142	169	192	226	255	284	304
1,136	322	344	368	387	411	431	453	472	488	510
1,137	529	540	554	568	582	594	603	611	620	628
1,138	636	645	655	665	674	682	690	698	705	712
1,139	719	726	734	742	751	762	776	792	805	817
1,140	828	844	856	867	878	888	899	913	925	938
1,141	950	963	975	988	997	1,006	1,015	1,022	1,030	1,037
1,142	1,045	1,054	1,064	1,076	1,087	1,094	1,101	1,108	1,116	1,124
1,143	1,132	1,138	1,145	1,152	1,159	1,167	1,175	1,183	1,193	1,208
1,144	1,225	1,244	1,268	1,297	1,323	1,339	1,355	1,377	1,392	1,402
1,145	1,412	1,422	1,431	1,441	1,451	1,463	1,476	1,491	1,508	1,531
1,146	1,551	1,568	1,581	1,595	1,606	1,616	1,626	1,637	1,647	1,657
1,147	1,666	1,676	1,686	1,697	1,708	1,719	1,729	1,740	1,750	1,760
1,148	1,771	1,781	1,792	1,804	1,815	1,829	1,840	1,850	1,860	1,869
1,149	1,878	1,886	1,895	1,904	1,913	1,924	1,940	1,958	1,975	1,989
1,150	2,004	2,022	2,042	2,062	2,078	2,095	2,111	2,124	2,136	2,148
1,151	2,160	2,173	2,185	2,198	2,211	2,223	2,235	2,246	2,257	2,268
1,152	2,279	2,289	2,300	2,310	2,322	2,334	2,346	2,357	2,368	2,378
1,153	2,387	2,396	2,407	2,416	2,426	2,435	2,445	2,455	2,466	2,477
1,154	2,489	2,500	2,513	2,526	2,538	2,551	2,563	2,577	2,590	2,603
1,155	2,616	2,631	2,647	2,665	2,683	2,701	2,718	2,736	2,754	2,774
1,156	2,794	2,813	2,842	2,919	3,006	3,093	3,176	3,230	3,292	3,353
1,157	3,408	3,463	3,512	3,556	3,598	3,643	3,681	3,713	3,742	3,767
1,158	3,789	3,811	3,832	3,853	3,874	3,895	3,917	3,940	3,965	3,990
1,159	4,016	4,044	4,074	4,104	4,138	4,182	4,201	4,222	4,243	4,272
1,160	4,317	4,330	4,342	4,355	4,367	4,380	4,393	4,407	4,421	4,436
1,161	4,450	4,465	4,480	4,495	4,511	4,527	4,543	4,560	4,577	4,596
1,162	4,615	4,635	4,656	4,722						



Proctor Lake
February 2012 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Proctor Lake

2' - contour map

Figure 6

Contours
(feet above mean sea level)

- 1,162
- 1,160
- 1,158
- 1,156
- 1,154
- 1,152
- 1,150
- 1,148
- 1,146
- 1,144
- 1,142
- 1,140
- 1,138
- 1,136
- 1,134

Islands

Proctor Lake elevation: 1,162.3 feet above mean sea level

Conservation pool elevation 1,162.0 feet above mean sea level

Projection: NAD83 State Plane Texas Central Zone (feet)