Volumetric and Sedimentation Survey of LAVON LAKE

June – July 2011 Survey

Texas Water Development Board

January 2013

Prepared for:

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

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Executive summary

In May, 2011, 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 Lavon Lake. The U.S. Army Corps of Engineers, Fort Worth District, provided 100% of the funding for this survey through their 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.

Lavon Dam and Lavon Lake are located on the East Fork of the Trinity River in Collin County, approximately 3 miles east of Wylie and 22 miles northeast of Dallas, Texas. The conservation pool elevation of Lavon Lake is 492.0 feet above mean sea level (NGVD29). TWDB collected bathymetric data for Lavon Lake between June 3, 2011, and July 21, 2011. The daily average water surface elevations during that time ranged between 486.50 and 489.95 feet above mean sea level (NGVD29).

The 2011 TWDB volumetric survey indicates that Lavon Lake has a total reservoir capacity of 409,360 acre-feet and encompasses 20,559 acres at conservation pool elevation (492.0 feet above mean sea level, NGVD29). In 1970, the U.S. Army Corps of Engineers estimated a modified Lavon Lake encompassed 21,357 acres with a total reservoir capacity of 456,527 acre-feet.

Based on comparison of the 2011 TWDB survey with the 1970 USACE survey and on direct measurements of sediment accumulation, Lavon Lake has lost between 1,212 and 1,310 acre-feet of capacity per year due to sedimentation since 1975. Sediment accumulation is found throughout the lake; however, the thickest deposits of sediment measured were north of U.S. Highway 380 and near the dam. TWDB recommends that a similar methodology be used to resurvey Lavon 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 May, 2011, TWDB entered into agreement with U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Lavon Lake. The U.S. Army Corps of Engineers, Fort Worth District, provided 100% of the funding for this survey through their Texas Water Allocation Assessment Program (TWDB, 2011). 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 10].

Lavon Lake general information

Lavon Dam and Lavon Lake are located on the East Fork of the Trinity River (Trinity River Basin) in Collin County, approximately three miles east of Wylie and 22 miles northeast of Dallas, Texas (Figure 1). Lavon Dam and Lavon Lake are owned by the U.S. Government and operated by the U.S. Army Corps of Engineers, Fort Worth District. Lavon Lake is primarily a water supply reservoir, storing water for the member cities of the North Texas Municipal Water District (USACE, 2012a). Lavon Lake also provides flood control to parts of Collin, Dallas, and Rockwall Counties (USACE, 2012a).

In 1951, the Texas Legislature created the North Texas Municipal Water District as a conservation and reclamation district. The North Texas Municipal Water District is responsible for providing drinking water, wastewater treatment, and solid waste disposal to its member cities and customers, encompassing approximately 1.6 million people (NTMWD, 2011a, NTMWD, 2011b). Lavon Lake is the main raw water supply source of the North Texas Municipal Water District (NTMWD, 2011c). Other sources include Lake Texoma, Jim Chapman Lake, Lake Tawakoni, Lake Bonham, the Upper Sabine Basin Supply Project, and the East Fork Raw Water Supply Project (Wetland) (NTMWD, 2011b).

Construction on Lavon Dam began in January, 1948, and the dam was completed in September, 1953. Deliberate impoundment began on September 14, 1953 (TWDB, 1973). On May 15, 1970, construction began on a modification of Lavon Dam that increased the conservation storage pool from elevation 472.0 feet to the current elevation of 492.0 feet by raising the top of the dam 12 feet. The modification was completed and deliberate impoundment began December 1, 1975 (USACE, 2012b). Additional pertinent data about Lavon Dam and Lavon Lake can be found in Table 1.

Water rights for Lavon Lake have been appropriated to the North Texas Municipal Water District through Certificate of Adjudication No. 08-2410 and amendments to Certificate of Adjudication Nos. 08-2410A, 08-2410B, 08-2410C, 08-2410D, 08-2410E, 08-2410F, and 08-2410G. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

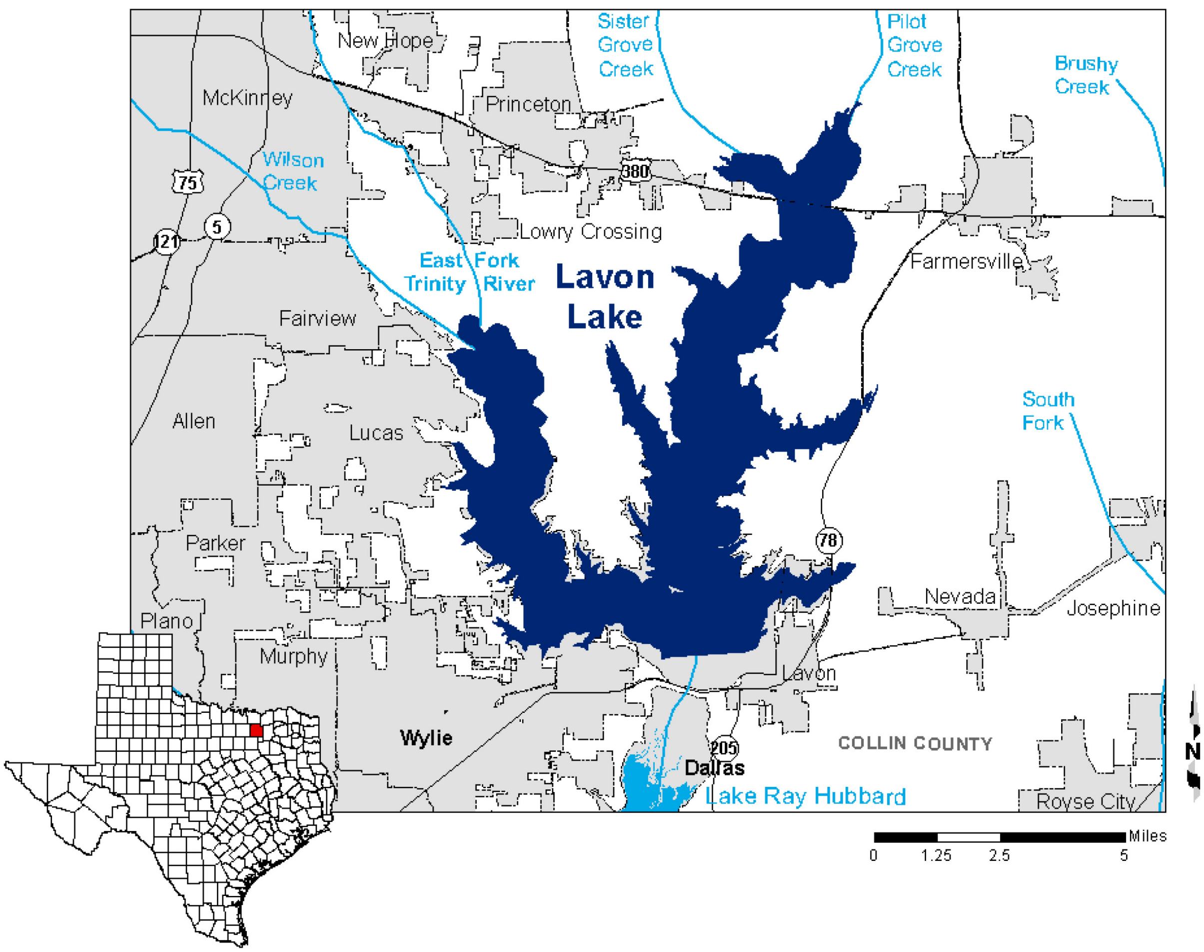


Figure 1. **Location of Lavon Lake**

Table 1. Pertinent data for Lavon Dam and Lavon Lake

Owner

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

Engineer (design)

U.S. Army Corps of Engineers

Location of dam

On the East Fork of the Trinity River in Collin County, approximately 3 miles east of Wylie and 22 miles northeast of Dallas, Texas

Drainage area

770 square miles

Dam

Type	Rolled earthfill
Length including spillway	19,493 feet
Maximum height	81 feet
Top width	30 feet

Spillway

Type	Ogee
Length (net)	480 feet net at the crest
Crest elevation	475.5 feet above mean sea level
Control	12 tainter gates, each 40 by 28 feet

Outlet works

Type	5 gate controlled sluices through spillway piers
Size	Each 36-inch diameter
Control	5 manually operated slide gates
Invert elevation	453.0 feet above mean sea level

Reservoir data (based on 2011 TWDB survey)

Feature	**Elevation (feet NGVD29[a])**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam	514.0	N/A	N/A
Maximum design water surface	509.0	N/A	N/A
Top of flood control storage space and top of gates	503.5	N/A	N/A
Top of conservation storage space	492.0	409,360	20,559
Spillway crest	475.5	145,566	11,461
Invert of lowest intake	453.0	2,972	1,585
Streambed	433.0	0	0

Source: (USACE, 2008, USACE, 2012b)

[a] NGVD29 = National Geodetic Vertical Datum 1929

Volumetric and sedimentation survey of Lavon 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 08060500 Lavon Lk nr Lavon, TX* (USGS, 2012). 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 North Central Zone (feet).

TWDB bathymetric and sedimentation data collection

TWDB collected bathymetric data for Lavon Lake between June 3, 2011, and July 21, 2011. The daily average water surface elevations during that time ranged between 486.50 and 489.95 feet above mean sea level (NGVD29). Data was collected with 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. 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 was collected during the 2011 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 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 to collect sediment core samples (Figure 2). The sediment core samples were collected on January 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 of penetration to which the tube must be driven during sediment sampling. The goal is to collect a sediment 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.

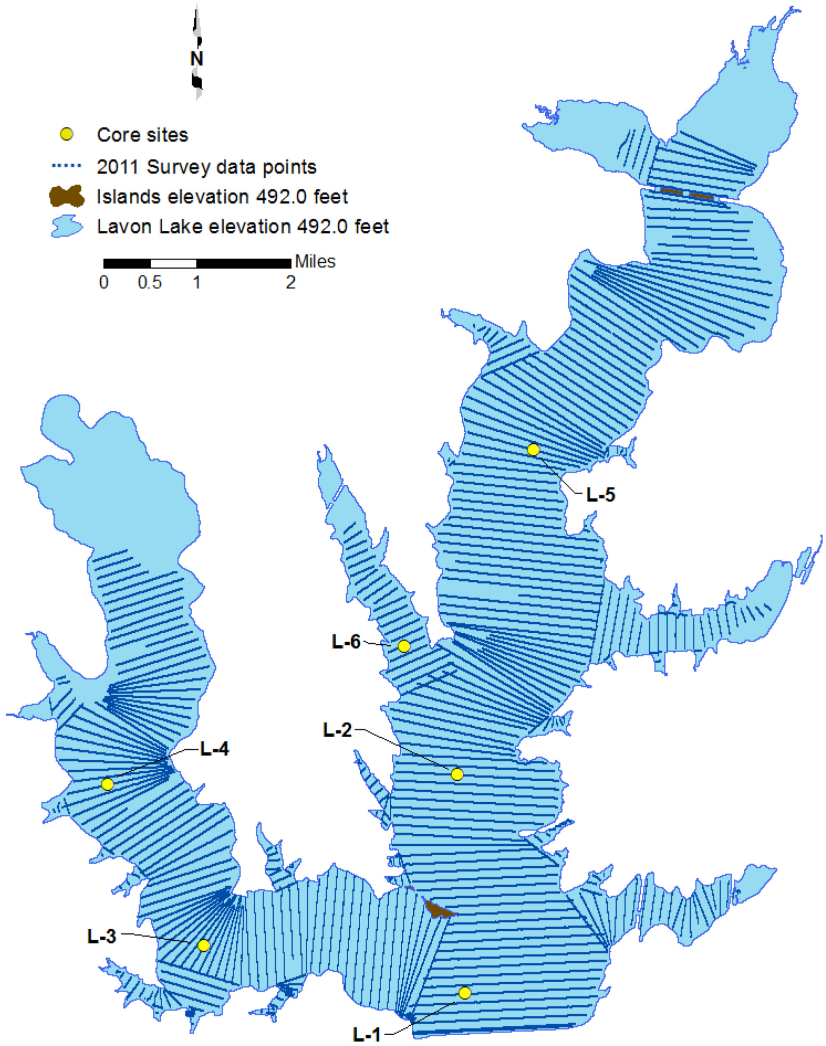


Figure 2. **Data collected during 2011 TWDB Lavon Lake survey**

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, 2012) using Environmental Systems Research Institute's ArcGIS 9.3.1 software. The quarter-quadrangles that cover Lavon Lake are Lavon (NW, NE, SW, SE), Wylie (NE, SE), Culleoka (NW, NE, SW, SE), and McKinney East (SE). The DOQQs were photographed on July 22, 2008, and July 28, 2008, while the daily average water surface elevation measured 490.01 and 489.57 feet above mean sea level, respectively. According to metadata associated with the 2008 DOQQS, the photographs have a resolution or ground sample distance of 1.0-meters and a horizontal accuracy within + / - 6 meters to true ground (USDA, 2011, TNRIS, 2010a). Therefore, the boundary digitized at the land-water interface in the 2008 photographs was labeled 489.79

feet, the average of the water surface elevations. However, because this boundary averaged 2.21 feet below the conservation pool elevation of 492.0 feet, additional boundary information was needed.

Additional elevation information was obtained from the 2010 DOQQs in areas of the reservoir where data could not be collected due to low water surface elevations at the time of the survey. The DOQQs were photographed on August 3, 2010, while the daily average water surface elevation measured 488.76 feet above mean sea level. According to the metadata associated with the 2010 DOQQS, the photographs have a resolution or ground sample distance of 1.0-meters and a horizontal accuracy within + / - 6 meters to true ground (USDA, 2011, TNRIS, 2010b). These contour segments were input into the lake model as hard lines.

For the outer boundary of the lake model, high resolution LiDAR (Light Detection and Ranging) data is available for areas of Collin County including the area surrounding Lavon Lake. Most of the data near the lake was collected between March 29, 2009, and April 14, 2009. More recent data collected between January 21, 2011, and April 1, 2011 completes coverage of the area surrounding Lavon Lake (TNRIS, 2011). According to the associated metadata, the LiDAR data has a vertical accuracy of between 0.7 and 0.15 meters and is measured in the North American Vertical Datum of 1988 (NAVD88). The LiDAR data has a horizontal projection of UTM NAD83 Zone 14. The data is available from TNRIS as LAS point files.

For use in the lake model, the LAS files were filtered as they were imported into ArcGIS to include only those points classified as "Ground" and used to build a terrain. The terrain was exported to a raster so contour information could be extracted. To convert the LiDAR data to the same vertical datum as the survey data, from NAVD88 to NGVD29, the conversion factor of -0.012 meters was obtained from the National Oceanic and Atmospheric Administration National Geodetic Survey VERTCON software using the coordinates of the USGS lake gage: Latitude 33º01'54.42984" Longitude 96º28'56.95526" NAD83 (NGS, 2012a). These coordinates were converted from Latitude 33º01'54" Longitude 96º28'56" NAD27, as reported by USGS, using the National Oceanic and Atmospheric Administration National Geodetic Survey NADCON software (NGS, 2012b).

To extract a continuous contour from the LiDAR data, it was necessary to use a contour above conservation pool elevation. The 493.0-feet or 150.2664-meter NGVD29 contour was selected. To convert to the proper datum, 0.012 meters was subtracted and the

150.2544-meter NAVD88 contour was extracted from the raster for use as the outer boundary of the lake model. Some modification of this contour was necessary to close the boundary across the dam spillway, remove all contours outside the main lake contour, and remove small contours representing plants within or close to the 489.79-feet digitized contour.

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). An in-house TWDB software package, HydroTools, is used to identify the current reservoir–bottom surface, pre-impoundment surface, and sediment thickness at each sounding location; and output the data into a single file (McEwen, 2011a). The water surface elevation at the time of each sounding is 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 lake (McEwen et al., 2011). Finally, the point file resulting from spatial interpolation is used in conjunction with sounding and boundary data to create volumetric and sediment Triangulated Irregular Network (TIN) models utilizing the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithm uses Delaunay's criteria for triangulation to create a grid composed of triangles from non-uniformly spaced points, including the boundary vertices (ESRI, 1995).

Area, volume, and contour calculations

Reservoir volumes and areas were calculated at 0.1 feet intervals, from elevation 448.3 to 493.0 feet using ArcInfo software and the volumetric TIN model. The elevation-capacity table and elevation-area table, updated for 2011, 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

3), representing the topography of the reservoir bottom, a depth range map (Figure 4), showing shaded depth ranges for Lavon Lake, and a 2-foot contour map (Figure 5 - attached).

Figure 3

Lavon Lake

Elevation relief map

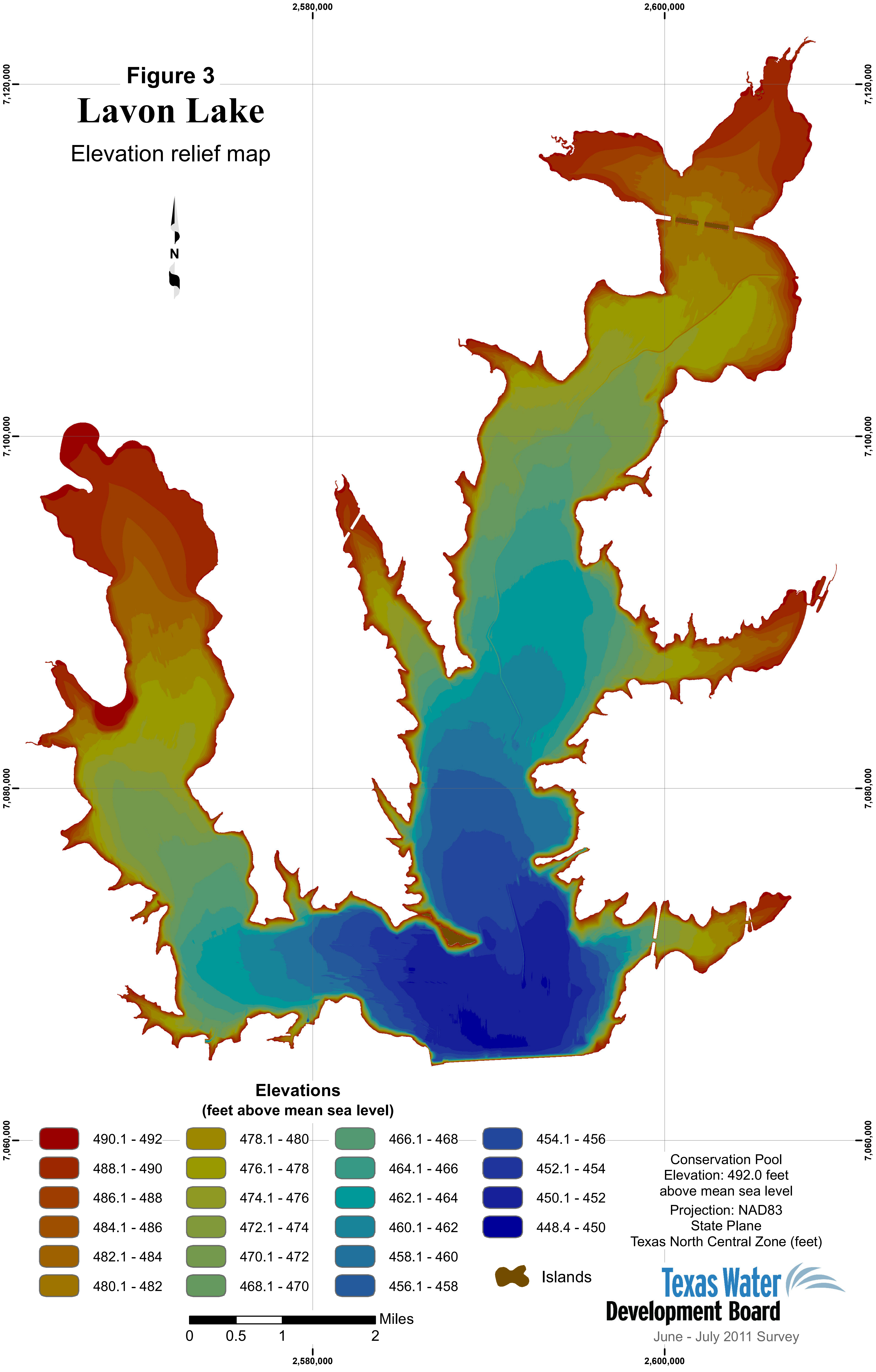
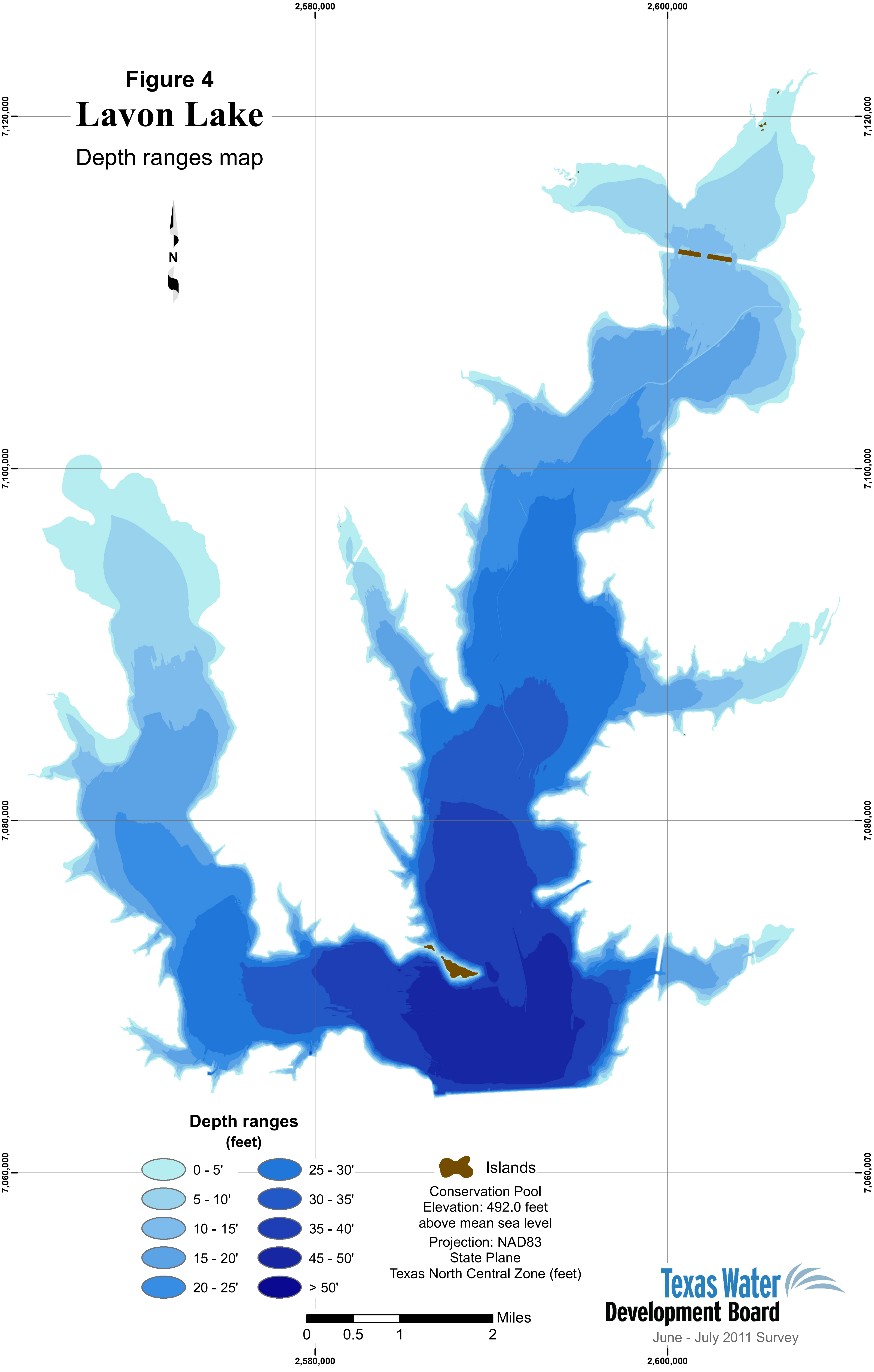


Figure 4
Lavon Lake
Depth ranges map



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 lake surveys. 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 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 (USGS, 2007). Using the survey data, polygons are created to partition the lake into segments with centerlines defining directionality of interpolation within each segment. These interpolation definition files are independent of survey data and can be applied to past and future data of the same reservoir. Using the interpolation definition files and survey data, the current lake-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). Figure 6 illustrates typical results from application of the anisotropic interpolation and line extrapolation techniques to Lavon Lake. The bathymetry shown in Figure 6C was used in computing reservoir capacity and area tables (Appendix A, B).

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

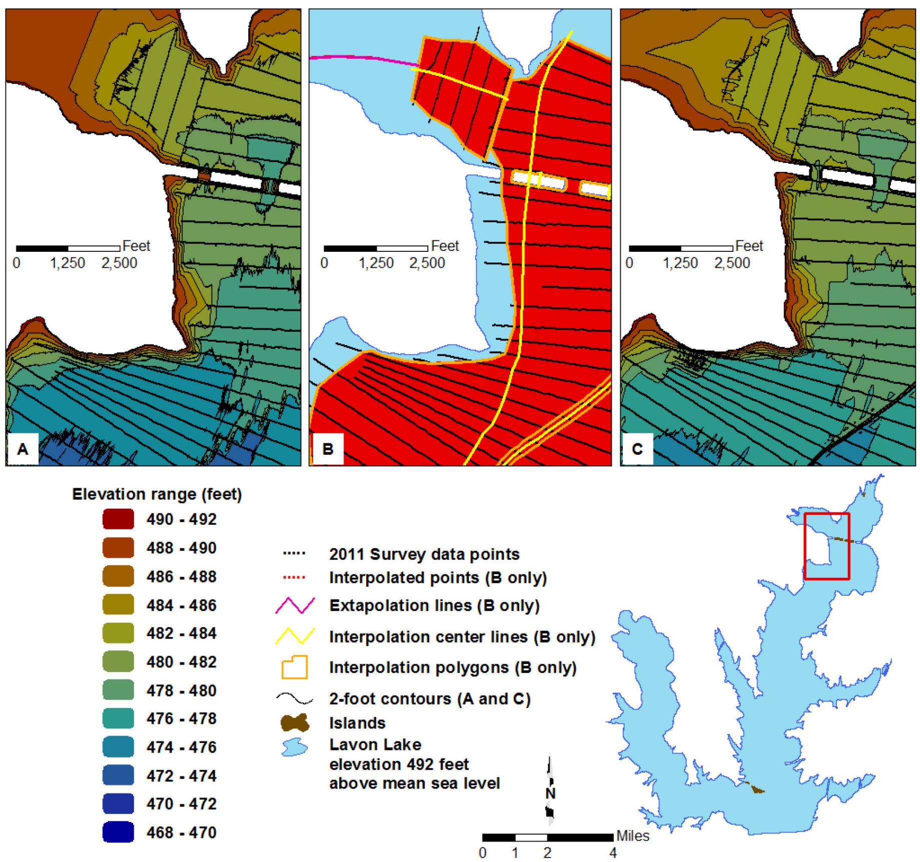


Figure 6. **Anisotropic spatial interpolation and line extrapolation of Lavon Lake sounding data – A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red), C) bathymetric contours with the interpolated points**

Analysis of sediment data from Lavon Lake

Sedimentation in Lavon 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 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 – Lavon Lake**

Core	Easting[a] (ft)	Northing[a] (ft)	Total core sample/ post-impoundment sediment	Sediment core description	Munsell soil color
L-1	2589628.02	7066807.50	47”/40”	0-40” highly saturated, loose, gelatinous sediment with no structure	2.5y 4/1 (50%) 5y 2.5/1 (50%)
				40-47” decreased moisture, silty clay soil, very dense with root materials and other organics present	2.5y 4/1
L-2	2589203.50	7079173.96	40”/34.5”	0-34.5” highly saturated, loose, gelatinous sediment with no structure	2.5y 4/1 (60%) 5y 2.5/1 (40%)
				34.5-40” decreased moisture, silty clay soil, very dense with organics present	2.5y 4/1
L-3	2574874.93	7069503.51	35”/21.5”	0-21.5” highly saturated, loose sediment with no structure	5y 5/3(20%) 2.5y 4/1 (40%) 5y 2.5/1 (40%)
				21.5-35” silty clay soil with organics present, dense structure	2.5y 4/1
L-4	2569446.70	7078638.66	30”/17”	0-5” loose, water logged sediment	5y 5/3
				5-17” highly saturated, loose sediment with no structure	2.5y 4/1 (50%) 5y 2.5/1 (50%)
				17-30” silty clay soil with organics present, dense soil structure	2.5y 4/1
L-5	2593492.70	7097586.87	26”/21”	0-8” loose, water logged sediment	5y 5/3
				8-21” loose, water logged sediment, no structure	2.5y 4/1 (50%) 5y 2.5/1 (50%)
				21-26” silty clay soil, dense soil structure, organics present	2.5y 4/1
L-6	2586209.14	7086467.39	43.5”/34.5”	0-17” loose gelatinous sediment	5y 2.5/1 (80%) 2.5y 4/1 (20%)
				17-34.5” loamy clay, loose sediment, lower water content	2.5y 4/1
				34.5-43.5” dense silty clay soil, organics present	2.5y 4/1

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

A photograph of sediment core L-1 is shown in Figure 7 and is representative of the sediment cores sampled from Lavon Lake. The 200 kHz frequency measures the top layer as the current bottom surface of the reservoir.

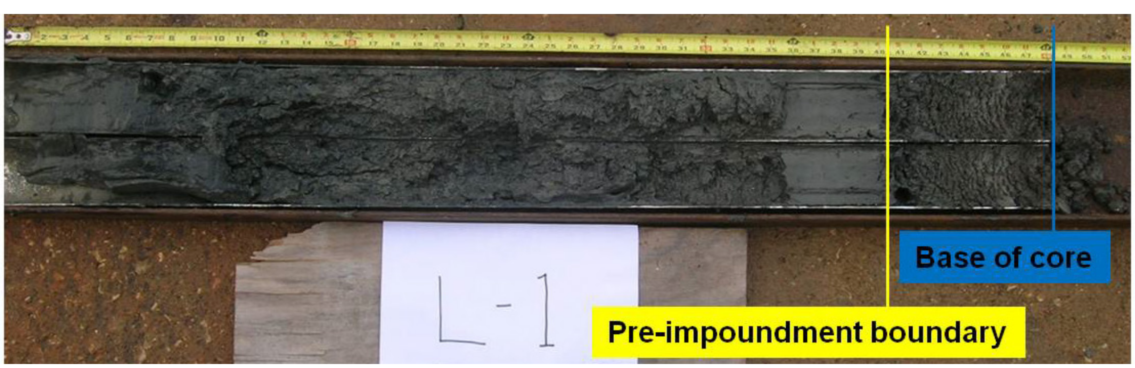


Figure 7. **Sediment core L-1 from Lavon Lake**

Sediment core sample L-1 consisted of 47.0 inches of total sediment corresponding to the length of the aluminum sampling tube. The upper sediment layer (horizon), 0–40.0 inches, consisted of highly saturated, gelatinous, loose sediment, and measured 2.5y 4/1 (50%) and 5y 2.5/1 (50%) on the Munsell soil color chart. The second horizon, beginning at 40.0 inches and extending to 47.0 inches below the surface, consisted of very dense silty clay soil with decreased moisture content. Root and organic materials were present and the sediment measured 2.5y 4/1 on the Munsell soil color chart. 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 40.0 inches and identified by the change in soil color, texture, moisture, porosity and structure. Identification of the pre-impoundment surface for the remaining sediment cores followed a similar procedure.

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

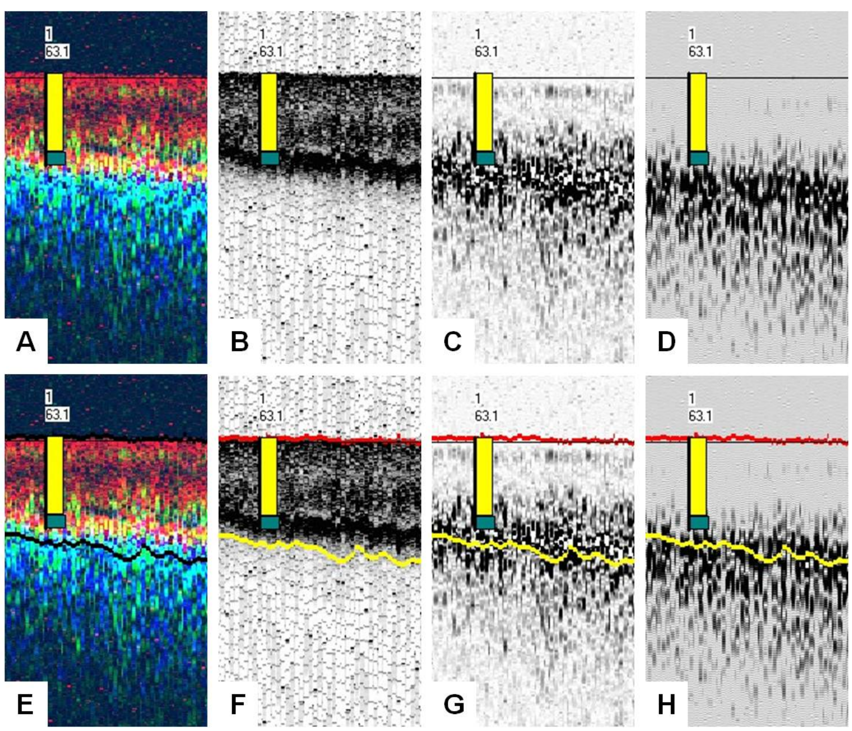


Figure 8. **Comparison of sediment core L-1 with acoustic signal returns A,E) combined acoustic signal returns, B,F) 200 kHz frequency, C,G) 50 kHz frequency, D,H) 24 kHz frequency**

Figure 8 compares sediment core sample L-1 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 box represents post-impoundment sediment, and the blue box represents the pre-impoundment sediment. In figure 8A-D, the bathymetric surfaces are not shown. In figure 8E, the current bathymetric surface is represented as the top black line and in Figures 8 F-H as the top red line. The pre-impoundment surface is identified by comparing boundaries observed in the 200 kHz, 50 kHz and 24 kHz signals to the location of the pre-impoundment surface of the sediment core sample. Each sediment core sample was compared to all three frequencies and the boundary in the 200 kHz signal most closely matched the pre-impoundment interface of the sediment core samples. Therefore, the 200 kHz signal was used to locate the pre-impoundment layer. The pre-impoundment surface was manually drawn and is represented by the bottom black line in Figure 8E, and by the yellow line in Figures 8F-H. Figure 9 shows sediment core sample L-1 correlated with the 200 kHz frequency of the nearest surveyed cross-section. The pre-impoundment surface identified along cross-sections where sediment core samples were collected is used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

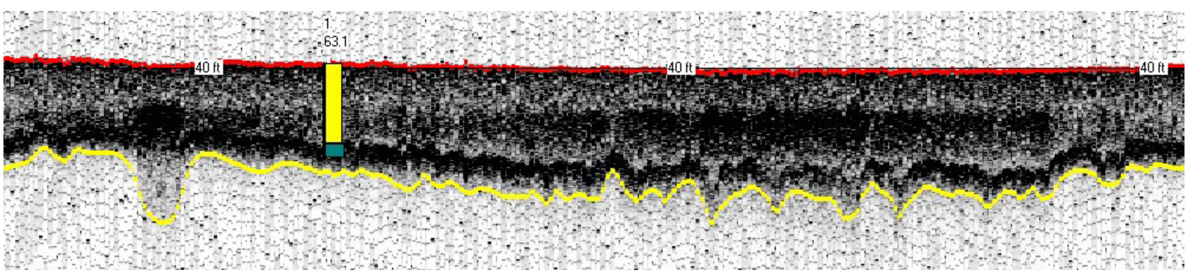


Figure 9. **Cross-section of data collected during 2011 survey, displayed in DepthPic (200 kHz frequency), correlated with sediment core sample L-1 and showing the current surface in red and pre-impoundment surface in yellow**

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 interpolation definition file used for bathymetric interpolation. For the purposes of the TIN model creation, TWDB assumed sediment thickness at the lake boundary was zero feet (defined as the 489.79 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 used to produce a sediment thickness map of Lavon Lake (Figure 10).

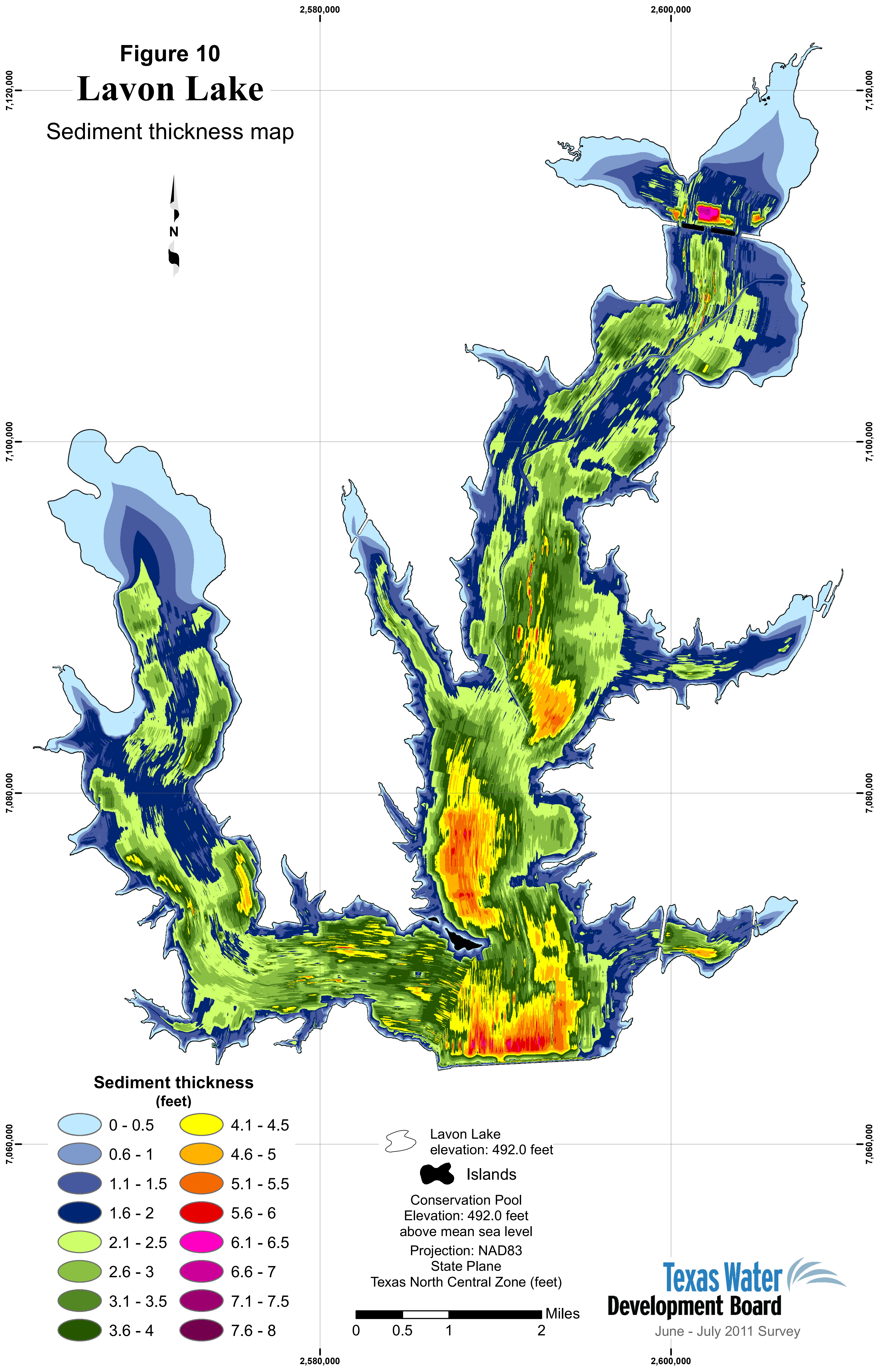


Figure 10
Lavon Lake
Sediment thickness map
N
2,580,000
2,600,000
7,120,000
7,100,000
7,080,000
7,060,000
Sediment thickness
(feet)
0 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
Lavon Lake
elevation: 492.0 feet
Islands
Conservation Pool
Elevation: 492.0 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone (feet)
0
0.5
1
2
Miles
Texas Water
Development Board
June - July 2011 Survey

Survey results

Volumetric survey

The 2011 TWDB volumetric survey indicates that Lavon Lake has a total reservoir capacity of 409,360 acre-feet and encompasses 20,559 acres at conservation pool elevation (492.0 feet above mean sea level, NGVD29). In 1970, the U.S. Army Corps of Engineers estimated a modified Lavon Lake encompassed 21,357 acres with a total reservoir capacity of 456,527 acre-feet (USACE, 1974).

Sedimentation survey

Based on comparison of the 2011 TWDB survey with the 1970 USACE survey and on direct measurements of sediment accumulation, Lavon Lake has lost between 1,212 and 1,310 acre-feet of capacity per year due to sedimentation since 1975 (Table 3). Sediment accumulation is found throughout the lake; however, the thickest deposits of sediment measured were north of U.S. Highway 380 and near the 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. For informational purposes, comparison of capacity loss estimates of Lavon Lake derived using differing methodologies are provided in Table 3.

Table 3. Capacity loss comparisons for Lavon Lake

Survey	Volume comparisons at 472.0ft (ac-ft)					Pre-impoundment at 472.0 ft (ac-ft)	Volume comparison at 492.0 ft (ac-ft)	Pre-impoundment at 492.0 ft (ac-ft)
1946 Original[a,b]	143,600	<>	<>	<>	<>	<>	<>	<>
1951 Revised[a,b]	<>	150,324		<>	<>	<>	<>	<>
USACE 1959[a,b]	<>	<>	143,297	<>	<>	<>	<>	<>
USACE 1965[b]	<>	<>		133,776	<>	<>	<>	<>
USACE 1970[c]	<>	<>	<>		136,847	<>	456,527	<>
TWDB pre-impoundment estimate based on 2011 survey	<>	<>	<>	<>	<>	138,654[d]	<>	453,005[e]
2011 volumetric survey	107,962	107,962	107,962	107,962	107,962	107,962	409,360	409,360
Volume difference (acre-feet)	35,638 (24.8%)	42,362 (28.2%)	35,335 (24.7%)	25,814 (19.3%)	28,885 (21.1%)	30,692 (22.1%)	47,167 (10.3%)	43,645 (9.6%)
Number of years	58*	58*	52	46	41	58*	36ǂ	36ǂ
Capacity loss rate (acre-feet/year)	614	730	680	561	705	529	1,310	1,212

Note: Lavon Dam was completed in September 1953, and deliberate impoundment began on September 14, 1953. Modification to raise the dam 12 feet and conservation pool elevation 20 feet started on May 15, 1970 and deliberate impoundment on the modified dam began on December 1, 1975.

*Number of years based on difference between 2011 survey date and impoundment date of 1953.

ǂNumber of years based on difference between 2011 survey date and impoundment date of 1975.

[a] Source: (USACE, 1961, USACE, 1975)

[b] Source: (USACE, 1975)

[c] Source: (USACE, 1974)

[d] 2011 TWDB surveyed capacity of 107,962 acre-feet plus 2011 TWDB surveyed sediment volume of 30,692 acre-feet

[e] 2011 TWDB surveyed capacity of 409,360 acre-feet plus 2011 TWDB surveyed sediment volume of 43,645 acre-feet.

Recommendations

To improve estimates of sediment accumulation rates, TWDB recommends resurveying Lavon 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 Lavon 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

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

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

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

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

NGS (National Geodetic Survey), 2012a, Orthometric Height Conversion, http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl, accessed May 2012.

NGS (National Geodetic Survey), 2012b, NADCON computations, http://www.ngs.noaa.gov/cgi-bin/nadcon.prl, accessed May 2012.

NTMWD (North Texas Municipal Water District), 2011a, North Texas Municipal Water District – About NTMWD, http://www.ntmwd.com/about_NTMWD.html, accessed August 2011.

NTMWD (North Texas Municipal Water District), 2011b, Our Water Supply – North Texas Municipal Water District, http://northtexas.wateriqknowyourwater.org/water_supply.php, accessed August 2011.

NTMWD (North Texas Municipal Water District), 2011c, North Texas Municipal Water District – About Our Water System, http://www.ntmwd.com/watersystem.html, accessed August 2011.

TNRIS (Texas Natural Resources Information System), 2010a, https://www.tnris.org/2008-09-1m-Orthoimagery, accessed August 2011.

TNRIS (Texas Natural Resources Information System), 2010b, https://www.tnris.org/node/39, accessed August 2011.

TNRIS (Texas Natural Resources Information System), 2011, http://www.tnris.org/LidarReleaseNews, accessed May 2012.

TNRIS (Texas Natural Resources Information System), 2012, http://www.tnris.org/, accessed May 2012.

TWDB (Texas Water Development Board), 2011, Contract No. R1148011291 with the United States Army Corps of Engineers, Fort Worth District.

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

USACE (U.S. Army Corps of Engineers, Fort Worth District), 1961, *Report of Sedimentation Resurvey Lavon Reservoir East Fork of Trinity River, Texas 1959 Trinity River Basin*.

USACE (U.S. Army Corps of Engineers, Fort Worth District), 1974, Elevation – capacity table for 1970 conditions (Projected), Lavon Lake modification.

USACE (U.S. Army Corps of Engineers, Fort Worth District), 1975, *Report on Sedimentation Lavon Lake East Fork of Trinity River Trinity River Basin, Texas Resurvey of October 1965*.

USACE (U.S. Army Corps of Engineers, Fort Worth District), 2008, U.S. Army Corps of Engineers – Lake Information, http://www.swf-wc.usace.army.mil/lavon/Information/index.asp, accessed August 2011.

USACE (U.S. Army Corps of Engineers, Fort Worth District), 2012a, U.S. Army Corps of Engineers – Lavon Lake, http://www.swf-wc.usace.army.mil/lavon/, accessed June 2012.

USACE (U.S. Army Corps of Engineers, Fort Worth District), 2012b, Pertinent Data Sheet for Lavon Lake, http://www.swf-wc.usace.army.mil/pertdata/lvnt2.pdf, accessed June 2012.

USBB (United States Bureau of the Budget), 1947, United States National Map Accuracy Standards, http://rockyweb.cr.usgs.gov/nmpstds/acrodocs/nmas/NMAS647.PDF.

USDA (US Department of Agriculture), 2011, *National Agricultural Imagery Program (NAIP) Information Sheet*, http://www.fsa.usda.gov/Internet/FSA_File/naip_2010_infosheet.pdf.

USGS (United States Geological Survey), 2007, *USGS – National Geospatial Data Standards – Digital Line Graph Standards*, http://rockyweb.cr.usgs.gov/nmpstds/dlgstds.html

USGS (United States Geological Survey), 2012, U.S. Geological Survey National Water Information System: Web Interface, *USGS Real-Time Water Data for USGS 08060500 Lavon Lk nr Lavon, TX*, http://waterdata.usgs.gov/tx/nwis/uv/?site_no=08060500&PARAmeter_cd=00062,72020,00054, accessed April 2012.

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

Appendix A

LAVON LAKE

RESERVOIR CAPACITY TABLE

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

June - July 2011 Survey
Conservation Pool Elevation 492.0 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
448	0	0	0	0	0	0	0	0	0	0
449	0	0	0	0	0	0	1	1	3	8
450	16	29	48	75	109	152	203	262	329	404
451	485	572	663	759	859	963	1,071	1,183	1,299	1,418
452	1,542	1,670	1,802	1,937	2,075	2,217	2,362	2,510	2,661	2,815
453	2,972	3,132	3,295	3,461	3,629	3,800	3,974	4,151	4,329	4,510
454	4,693	4,878	5,067	5,257	5,451	5,647	5,847	6,049	6,256	6,467
455	6,686	6,910	7,139	7,373	7,611	7,853	8,099	8,349	8,604	8,862
456	9,125	9,392	9,663	9,938	10,217	10,501	10,789	11,082	11,378	11,678
457	11,982	12,291	12,604	12,920	13,240	13,562	13,889	14,219	14,553	14,889
458	15,228	15,570	15,916	16,264	16,617	16,973	17,333	17,697	18,065	18,437
459	18,812	19,191	19,574	19,962	20,354	20,751	21,151	21,556	21,963	22,374
460	22,790	23,209	23,632	24,059	24,489	24,923	25,360	25,801	26,246	26,696
461	27,151	27,611	28,076	28,546	29,022	29,503	29,989	30,480	30,976	31,478
462	31,986	32,498	33,015	33,538	34,066	34,599	35,137	35,681	36,229	36,783
463	37,344	37,909	38,480	39,058	39,644	40,237	40,836	41,441	42,051	42,667
464	43,287	43,913	44,544	45,180	45,821	46,468	47,119	47,776	48,437	49,104
465	49,775	50,451	51,132	51,816	52,504	53,197	53,894	54,596	55,301	56,012
466	56,729	57,450	58,176	58,907	59,641	60,379	61,122	61,868	62,618	63,372
467	64,129	64,889	65,653	66,421	67,192	67,968	68,749	69,535	70,326	71,122
468	71,922	72,726	73,535	74,347	75,164	75,986	76,812	77,644	78,479	79,319
469	80,164	81,013	81,867	82,726	83,590	84,459	85,332	86,211	87,094	87,983
470	88,878	89,778	90,685	91,597	92,515	93,437	94,365	95,299	96,240	97,187
471	98,140	99,099	100,063	101,033	102,009	102,990	103,975	104,965	105,960	106,959
472	107,962	108,970	109,981	110,996	112,015	113,037	114,063	115,093	116,127	117,166
473	118,209	119,257	120,309	121,364	122,423	123,487	124,554	125,625	126,699	127,778
474	128,861	129,947	131,037	132,131	133,230	134,332	135,437	136,547	137,659	138,776
475	139,897	141,022	142,152	143,285	144,423	145,566	146,715	147,869	149,029	150,195
476	151,367	152,545	153,730	154,923	156,122	157,328	158,540	159,758	160,983	162,213
477	163,449	164,691	165,939	167,195	168,457	169,726	171,003	172,287	173,578	174,875
478	176,177	177,484	178,797	180,114	181,436	182,763	184,094	185,430	186,770	188,115
479	189,466	190,820	192,180	193,543	194,912	196,286	197,664	199,048	200,437	201,831
480	203,230	204,633	206,041	207,454	208,873	210,297	211,726	213,161	214,600	216,045
481	217,495	218,949	220,409	221,874	223,345	224,820	226,301	227,787	229,278	230,775
482	232,277	233,785	235,297	236,813	238,334	239,861	241,393	242,930	244,473	246,023
483	247,578	249,138	250,704	252,274	253,851	255,433	257,020	258,612	260,208	261,809
484	263,415	265,025	266,639	268,258	269,881	271,508	273,140	274,774	276,412	278,054
485	279,699	281,348	283,000	284,656	286,316	287,979	289,647	291,319	292,994	294,675
486	296,360	298,049	299,743	301,441	303,145	304,853	306,567	308,286	310,010	311,740
487	313,475	315,216	316,963	318,716	320,475	322,240	324,011	325,789	327,573	329,364
488	331,162	332,967	334,779	336,597	338,423	340,256	342,097	343,946	345,802	347,666
489	349,538	351,419	353,308	355,205	357,111	359,026	360,951	362,885	364,832	366,827
490	368,825	370,825	372,828	374,833	376,841	378,852	380,866	382,883	384,902	386,924
491	388,949	390,977	393,008	395,041	397,078	399,118	401,160	403,206	405,254	407,305
492	409,360	411,417	413,478	415,541	417,607	419,677	421,750	423,826	425,904	427,987
493	430,072									

Appendix B

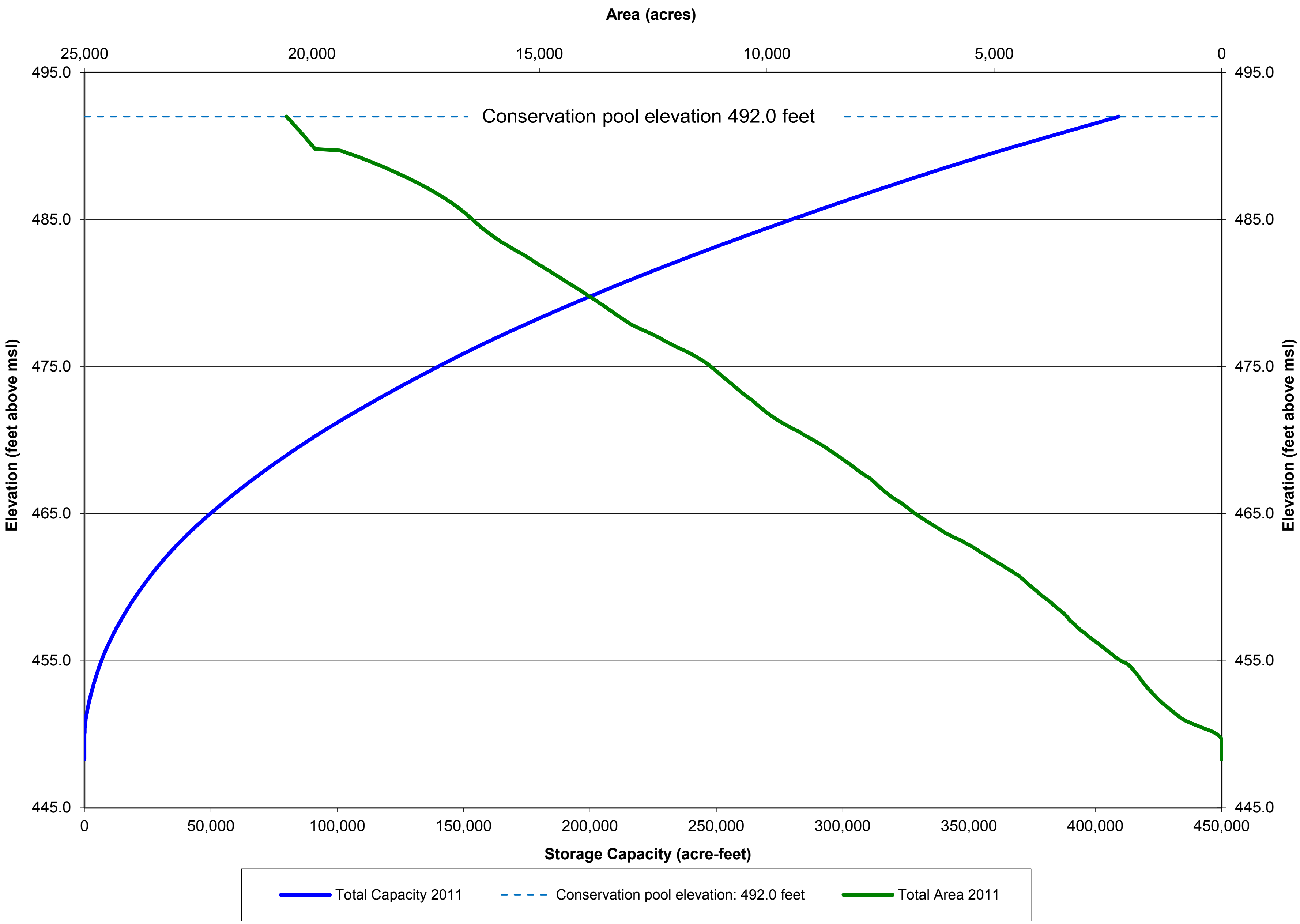
LAVON LAKE

RESERVOIR AREA TABLE

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

June - July 2011 Survey
Conservation Pool Elevation 492.0 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
448	0	0	0	0	0	0	0	0	0	0
449	0	0	0	1	1	2	3	7	32	64
450	104	161	225	301	387	471	550	631	709	782
451	841	894	939	979	1,022	1,060	1,097	1,137	1,177	1,218
452	1,259	1,299	1,335	1,368	1,400	1,433	1,464	1,495	1,525	1,554
453	1,585	1,616	1,644	1,671	1,698	1,726	1,751	1,773	1,796	1,819
454	1,843	1,869	1,895	1,921	1,949	1,979	2,010	2,044	2,086	2,151
455	2,214	2,271	2,315	2,358	2,401	2,442	2,481	2,523	2,565	2,605
456	2,647	2,688	2,731	2,773	2,817	2,861	2,903	2,942	2,982	3,021
457	3,067	3,107	3,145	3,179	3,212	3,245	3,285	3,324	3,351	3,376
458	3,403	3,434	3,470	3,505	3,541	3,583	3,622	3,661	3,699	3,735
459	3,771	3,810	3,854	3,900	3,943	3,988	4,025	4,057	4,094	4,134
460	4,172	4,212	4,250	4,287	4,322	4,355	4,390	4,429	4,469	4,524
461	4,574	4,624	4,678	4,732	4,783	4,834	4,886	4,938	4,992	5,047
462	5,097	5,148	5,201	5,254	5,306	5,356	5,405	5,458	5,514	5,573
463	5,628	5,682	5,744	5,821	5,891	5,959	6,022	6,081	6,131	6,180
464	6,231	6,283	6,336	6,387	6,436	6,487	6,540	6,592	6,641	6,690
465	6,738	6,783	6,825	6,864	6,904	6,948	6,994	7,035	7,082	7,137
466	7,190	7,239	7,284	7,324	7,363	7,404	7,443	7,480	7,518	7,555
467	7,589	7,622	7,658	7,693	7,734	7,781	7,836	7,886	7,935	7,980
468	8,023	8,065	8,106	8,147	8,190	8,241	8,289	8,334	8,377	8,422
469	8,472	8,518	8,567	8,615	8,662	8,709	8,758	8,809	8,862	8,919
470	8,976	9,032	9,094	9,153	9,204	9,252	9,306	9,375	9,440	9,500
471	9,558	9,615	9,676	9,731	9,781	9,830	9,878	9,924	9,969	10,012
472	10,053	10,092	10,132	10,171	10,207	10,243	10,280	10,319	10,365	10,411
473	10,454	10,497	10,536	10,575	10,614	10,652	10,691	10,728	10,765	10,804
474	10,844	10,884	10,923	10,962	11,000	11,038	11,074	11,112	11,149	11,191
475	11,230	11,271	11,312	11,354	11,406	11,461	11,515	11,569	11,628	11,691
476	11,748	11,815	11,891	11,959	12,026	12,089	12,153	12,215	12,272	12,331
477	12,392	12,452	12,514	12,592	12,657	12,731	12,805	12,874	12,937	12,996
478	13,048	13,097	13,149	13,198	13,246	13,291	13,336	13,380	13,429	13,478
479	13,523	13,569	13,617	13,665	13,712	13,758	13,811	13,865	13,916	13,962
480	14,008	14,056	14,108	14,159	14,213	14,267	14,317	14,372	14,423	14,472
481	14,521	14,572	14,626	14,678	14,729	14,780	14,834	14,887	14,940	14,995
482	15,048	15,097	15,143	15,189	15,239	15,293	15,347	15,400	15,462	15,522
483	15,575	15,631	15,682	15,737	15,790	15,847	15,894	15,940	15,987	16,033
484	16,078	16,123	16,168	16,211	16,252	16,291	16,328	16,364	16,400	16,434
485	16,469	16,505	16,541	16,578	16,617	16,656	16,696	16,738	16,781	16,824
486	16,869	16,915	16,962	17,010	17,060	17,110	17,162	17,215	17,270	17,325
487	17,382	17,439	17,499	17,559	17,620	17,682	17,746	17,811	17,876	17,944
488	18,012	18,081	18,152	18,224	18,296	18,371	18,446	18,523	18,601	18,681
489	18,763	18,846	18,931	19,018	19,107	19,197	19,291	19,386	19,934	19,960
490	19,987	20,014	20,041	20,069	20,096	20,124	20,152	20,180	20,208	20,236
491	20,265	20,293	20,322	20,351	20,380	20,410	20,439	20,469	20,499	20,529
492	20,559	20,589	20,619	20,650	20,681	20,712	20,743	20,774	20,806	20,837
493	21,620									



Lavon Lake
June - July 2011 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Figure 5

CONTOURS
(feet above mean sea level)

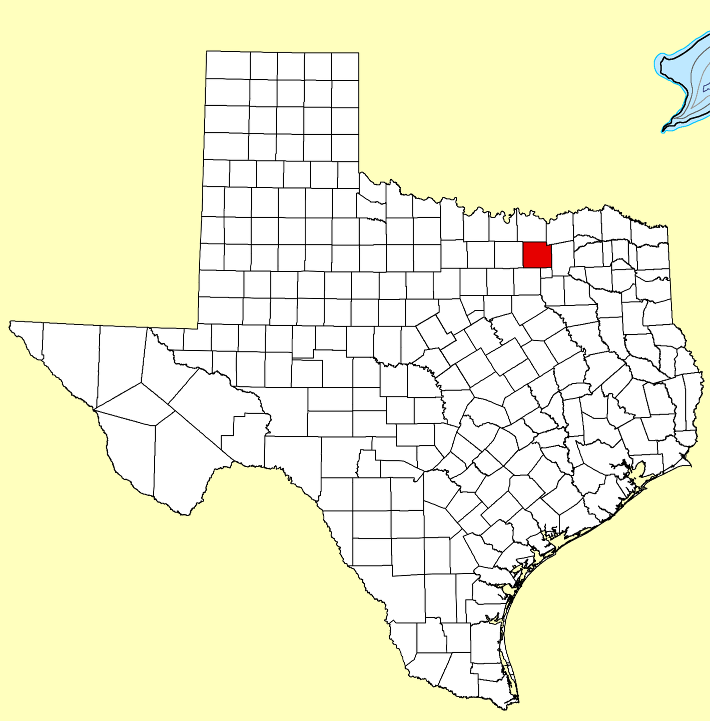
490
488
486
484
482
480
478
476
474
472
470
468
466
464
462
460
458
456
454
452
450

Conservation Pool
Elevation 492.0 feet
above mean sea level

Projection: NAD83
State Plane Texas
North Central Zone (feet)

Islands
elevation: 492.0 feet

Lavon Lake
elevation: 492.0 feet

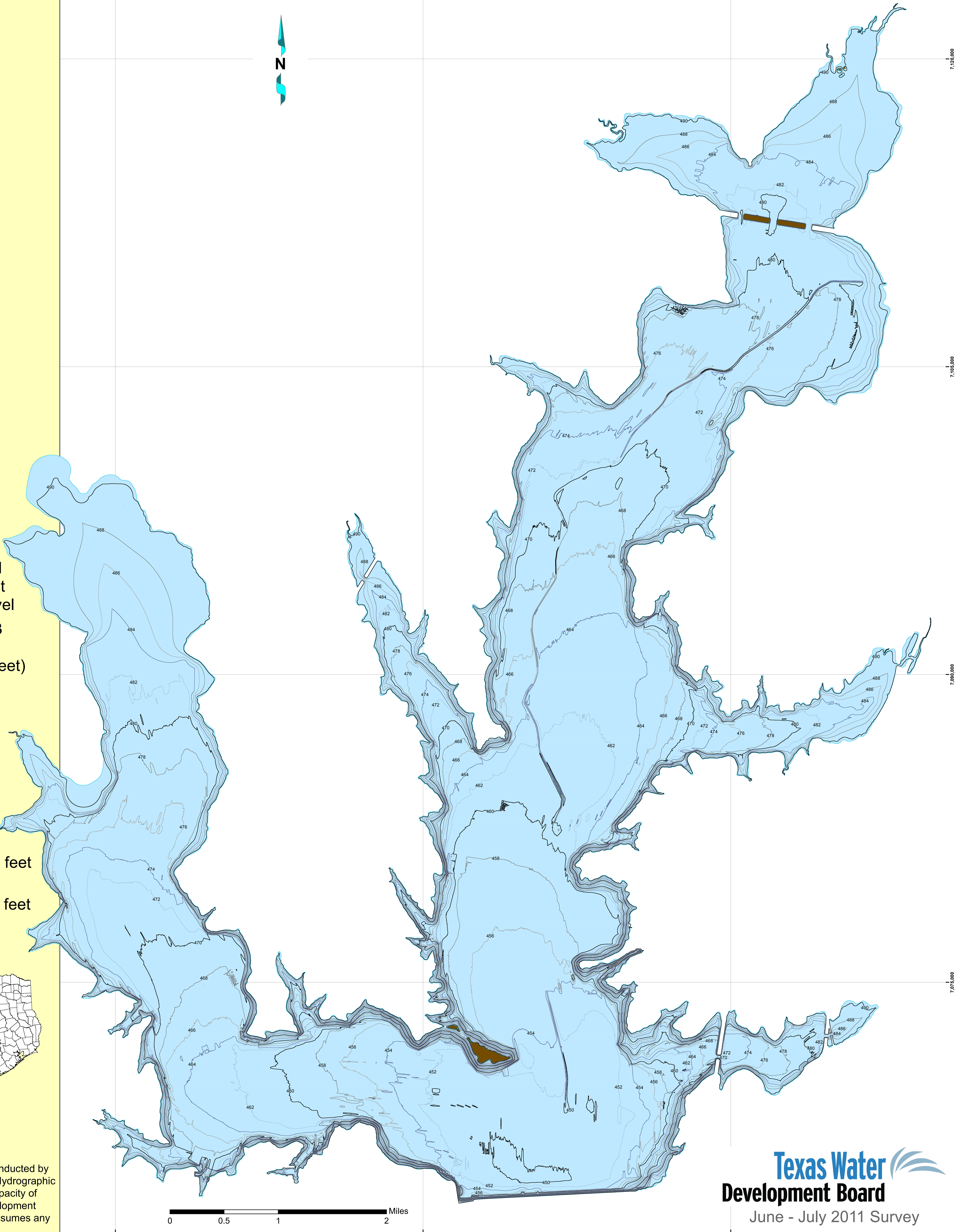


Collin County

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

Lavon Lake

2' - contour map



Texas Water Development Board

June - July 2011 Survey