# Volumetric and Sedimentation Survey of LAKE CYPRESS SPRINGS

## July 2007 Survey

Prepared by:

The Texas Water Development Board

October 2008

# Texas Water Development Board

J. Kevin Ward, Executive Administrator



Prepared for:

**Franklin County Water District**

With Support Provided by:

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



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## Executive Summary

In 2007, the Texas Water Development Board entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, for the purpose of performing a volumetric and sediment survey of Lake Cypress Springs. This survey 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 selected locations and were used in interpreting the multi-frequency depth sounder signal returns to derive sediment accumulation estimates.

Franklin County Dam and Lake Cypress Springs are located on Big Cypress Creek in the Cypress River Basin 8 miles southeast of Mount Vernon in Franklin County, Texas. Bathymetric data collection for Lake Cypress Springs occurred on June 21st, June 27th-June 29th, July 10th, and July 11th of 2007, while the water surface elevation ranged between 378.22 feet and 379.42 feet above mean sea level (NGVD29). The conservation pool elevation of Lake Cypress Springs is 378.0 feet above mean sea level (NGVD 29).

**The results of the TWDB 2007 Volumetric Survey indicate Lake Cypress Springs has a total reservoir capacity of 66,756 acre-feet and encompasses 3,252 acres at conservation pool elevation (378.0 feet above mean sea level, NGVD29).** In 1998 TWDB estimated the capacity of Lake Cypress Springs (at conservation pool elevation) at 67,690 acre-feet.[1] Due to differences in the methodologies used in calculating areas and capacities from this and previous Lake Cypress Springs surveys, comparison of these values is not recommended.[2] The TWDB considers the 2007 survey to be a significant improvement over previous methods and recommends that a similar methodology be used to resurvey Lake Cypress Springs in 10 to 20 years or after a major flood event.

**The results of the TWDB 2007 Sediment Survey indicate Lake Cypress Springs has accumulated 3,807 acre-feet of sediment since impoundment in 1970.** Based on this measured sediment volume and assuming a constant sediment accumulation rate, Lake Cypress Springs loses approximately 100 acre-feet of capacity per year. The majority of the sediment accumulation has occurred within the main body of the lake, with the thickest deposits in the submerged Big Cypress Creek channel. The maximum sediment thickness observed in Lake Cypress Springs was 7.2 feet.

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# Lake Cypress Springs General Information

Franklin County Dam and Lake Cypress Springs are located on Big Cypress Creek in the Cypress River Basin 8 miles southeast of Mount Vernon in Franklin County, Texas.[3] (Figure 1) Lake Cypress Springs is maintained and operated by the Franklin County Water District.[4] Construction on Franklin County Dam began in July of 1968, with deliberate impoundment beginning on July 7, 1970. The project was completed on February 15, 1971.[3] Lake Cypress Springs serves mainly as water supply storage for municipal and industrial uses. Additional pertinent data about Franklin County Dam and Lake Cypress Springs can be found in Table 1.

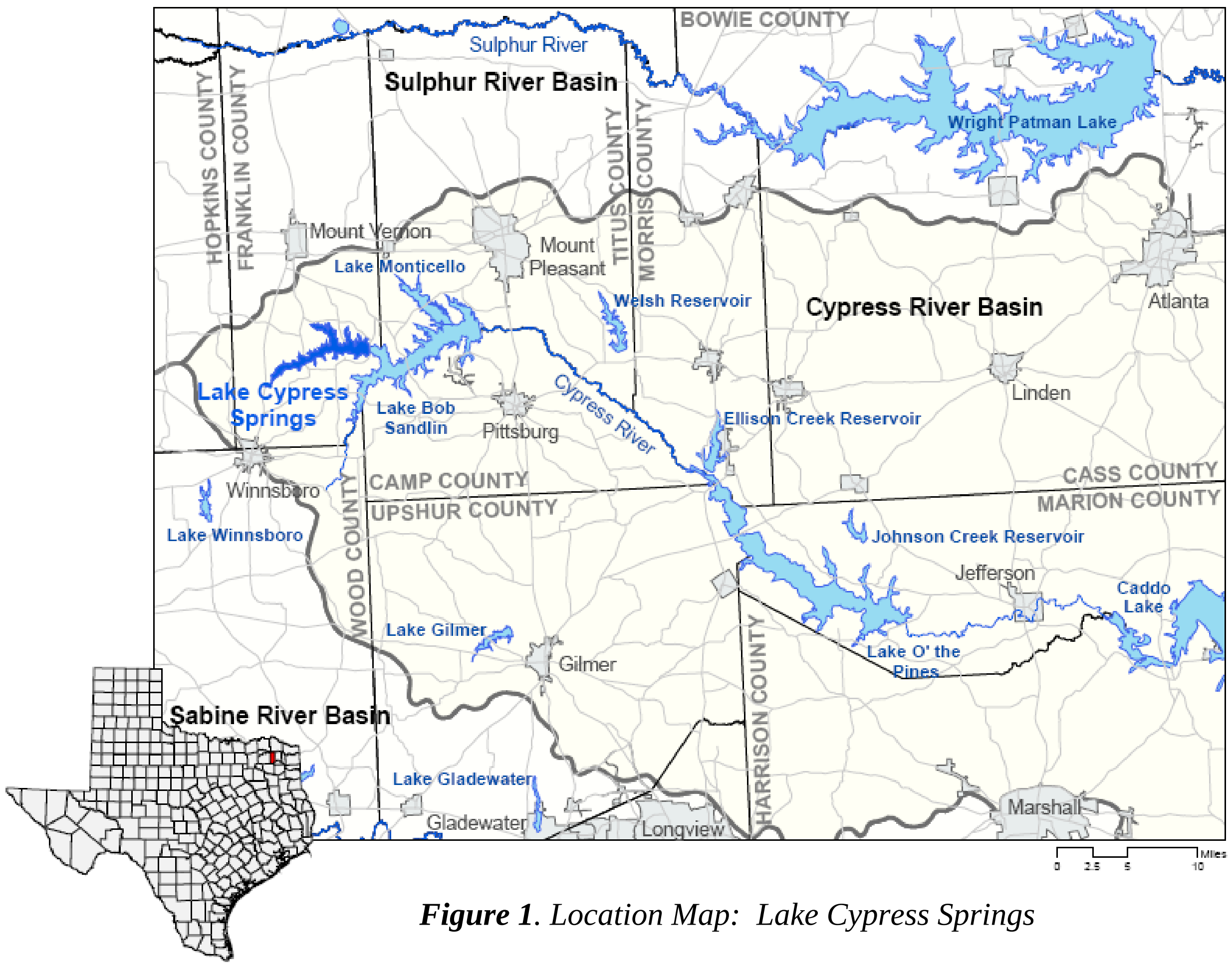



***Figure 1**. Location Map: Lake Cypress Springs*

**Table 1. Pertinent Data for Franklin County Dam and Lake Cypress Springs**[3]

| | |
|---|---|
| **Owner** | |
| Franklin County Water District | |
| **Engineer (Design)** | |
| Wisenbaker, Fix, and Associates | |
| **Location of Dam** | |
| On Big Cypress Creek in Franklin County, 8 miles southeast of Mount Vernon | |
| **Drainage Area** | |
| 75 square miles | |
| **Dam** | |
| Type | Earthfill |
| Length | 5,230 feet |
| Maximum Height | 74 feet |
| Top Width | 44 feet |
| Top elevation (varies) | 395.0 to 397.0± feet above mean sea level |
| **Spillway (emergency)** | |
| Location | To left of the dam |
| Type | Excavated and graded area |
| Crest length | 1,000 feet |
| Crest elevation | 385.0 feet above mean sea level (NGVD29) |
| **Spillway (service)** | |
| Location | Right end of main embankment |
| Type | Rectangular drop inlet, 23 by 23 feet |
| Control | None |
| Crest elevation | 378.0 feet above mean sea level (NGVD29) |
| Outlet | Box culvert, 10 by 10 feet |
| Discharge | To stilling basin |
| **Outlet Works** | |
| Type | Concrete pipe, 18-inch diameter |
| Invert elevation | 317.75 feet above mean sea level (NGVD29) |
| Control | Duplicate valves with vertical stems |
| Discharge | To service spillway conduit |

## Water Rights

The water rights for Lake Cypress Springs have been appropriated to the Franklin County Water District through Certificate of Adjudication No. 04-4560 and its amendments. A brief summary of the certificate and each amendment follows. The complete certificates are on file in the Records Division of the Texas Commission on Environmental Quality.

### Certificate of Adjudication No. 04-4560
Issued: October 13, 1986

Authorizes the Franklin County Water District to maintain an existing dam and reservoir (Lake Cypress Springs) and impound therein a maximum of 72,800 acre-feet of water. Franklin County Water District is authorized to divert and use up to 9,300 acre-feet of water per year for municipal purposes, of which 5,000 acre-feet of water may be diverted into the Sabine River Basin and 2,185 acre-feet into the Sulphur River Basin, 5,940 acre-feet of water per year for industrial purposes, and up to 60 acre-feet per year for irrigation purposes. The impounded water may also be used for recreational purposes. The priority dates of the owners' rights are January 31, 1966 for Lake Cypress Springs and the transbasin diversion of 1,000 acre-feet of water directed to the City of Mount Vernon for municipal purposes; July 20, 1970 for the diversion and use of 60 acre-feet of water per year for irrigation purposes, 8,300 acre-feet per year for municipal purposes, of which 4,173 acre-feet per year relates to transbasin diversion, and 5,940 acre-feet per year for industrial purposes; October 6, 1980 for an increase of the diversion rate from 27.0 cubic feet per second to 40.4 cubic feet per second and to transfer 2,012 acre-feet for municipal use from the Cypress Creek Basin to the Sabine River Basin; and April 18, 1983 for the increase of the diversion rate from 40.4 cubic feet per second to 161.5 cubic feet per second.

**Amendment to Certificate of Adjudication No. 04-4560A**
Granted: December 12, 1989

Authorizes a change in purpose of use of 300 acre-feet of the 5,940 acre-feet of water per annum for industrial use to irrigation use; thereby authorizing the Franklin County Water District to divert and use a maximum of 5,640 acre-feet of water per year for industrial purposes and 360 acre-feet per year for irrigation purposes. The time priority for these diversions remains July 20, 1970.

**Amendment to Certificate of Adjudication No. 04-4560B**
Granted: June 5, 1998

In lieu of the Franklin County Water District's authorization to divert and use from Lake Cypress Springs a maximum 2,050 acre-feet of water per year for industrial use, 360 acre-feet per year for irrigation use, and 9,300 acre-feet of water per year for municipal purposes (of which 2,185 acre-feet may be used in the Sulphur River Basin), Franklin County Water District is authorized to divert and use a maximum 11,500 acre-feet of water per year for municipal purposes (of which 4,385 acre-feet of water per year may be used in the Sulphur River Basin) and 210 acre-feet of water per year for irrigation purposes.

# Volumetric and Sediment Survey of Lake Cypress Springs

## Introduction

The Texas Water Development Board's (TWDB) Hydrographic Survey Program was authorized by the 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 2007, TWDB entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, for the purpose of performing a volumetric and sediment survey of Lake Cypress Springs. This survey was performed using a single-beam multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder. The 200 kHz return indicates the current bathymetric surface, while the combination of the three frequencies is analyzed for evidence of sediment accumulation throughout the reservoir. Sediment core samples are collected in order to validate the interpretation of the multi-frequency acoustic signals and to verify the identification of the reservoir bathymetric surface at the time of initial impoundment.

## Datum

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the reservoir elevation gauge USGS 07344484 Lk Cypress Spgs nr Mount Vernon, TX.[5] The datum for this gauge is reported as National Geodetic Vertical Datum 1929 (NGVD29) or mean sea level, thus elevations reported here are in feet above mean sea level. Volume and area calculations in this report are referenced to water levels provided by the USGS gauge. The horizontal datum used for this report is NAD83 State Plane Texas North Central Zone.

## TWDB Bathymetric Data Collection

Bathymetric data collection for Lake Cypress Springs occurred on June 21st, June 27th-June 29th, July 10th, and July 11th of 2007, while the water surface elevation ranged between 378.22 feet and 379.42 feet above mean sea level (NGVD29). For data collection, TWDB used a Specialty Devices, Inc., 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 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. During the 2007 survey, team members collected 70,445 data points over cross-sections totaling nearly 72 miles in length. Figure 2 shows where data points were collected during the TWDB 2007 survey.

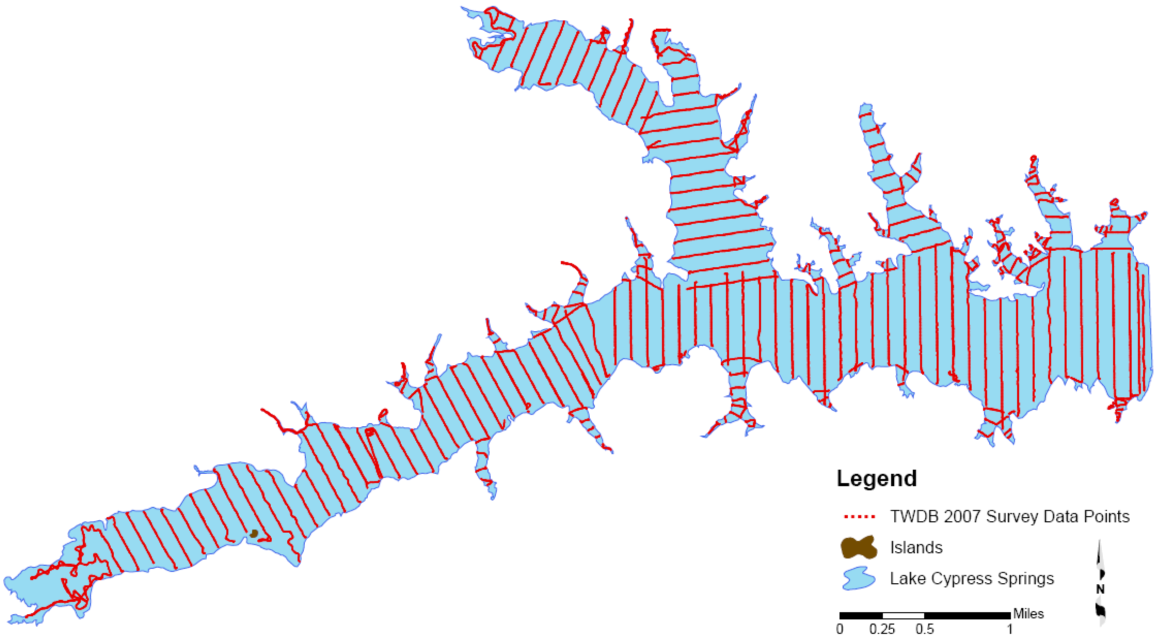



***Figure 2**. Data points collected during TWDB 2007 Survey*

## Data Processing

### Model Boundaries

The reservoir boundary was digitized from aerial photographs, or digital orthophoto quarter-quadrangle images (DOQQs)[6,7], using Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 software. The quarter-quadrangles that cover Lake Cypress Springs are Purley SE, New Hope NW, New Hope NE, New Hope SW, and New Hope SE. These images were photographed on September 30, 2004, during which time the water surface elevation at Lake Cypress Springs measured 376.98 feet above mean sea level (NGVD29). Although the water surface elevation measured approximately one foot below conservation pool elevation at the time of the photos, TWDB determined that there was not a significant difference in lake area between 376.98 feet and 378.00 feet, as discernable from the photographs and given the photographs have a 1-meter resolution. Therefore, the Lake Cypress Springs boundary was digitized from the land water interface in the aerial photos and labeled 378.00 feet to allow area and volume to be calculated to the conservation pool elevation.

**Triangulated Irregular Network (TIN) Model**

Upon completion of data collection, the raw data files collected by TWDB were edited using DepthPic and HydroEdit to remove any data anomalies. DepthPic is used to display, interpret, and manually-edit the multi-frequency data, while HydroEdit is used to automatically edit the multi-frequency data and to convert the depth measurements to bathymetric elevations using the known water surface elevation at the time of each sounding. For processing outside of DepthPic and HydroEdit, the sounding coordinates (X,Y,Z) are exported as a MASS points file. TWDB also created a MASS points file of interpolated data located in-between surveyed cross sections. This points file is described in the section entitled "Self-Similar Interpolation."

To create a surface representation of the Lake Cypress Springs bathymetry, the 3D Analyst Extension[8] of ArcGIS (ESRI, Inc.) is used. With this extension, a triangulated irregular network (TIN) model of the bathymetry is created following the Delaunay[8] criteria, where each MASS point and boundary node becomes the vertex of a triangular portion of the reservoir bottom surface. From the TIN model, reservoir capacities and areas are calculated at one-tenth of a foot (0.1 foot) intervals, from elevation 325.0 feet to elevation 378.0 feet.

The Elevation-Capacity and Elevation-Area Tables, updated for 2007, are presented in Appendices A and B, respectively. An Elevation-Area-Capacity graph is presented in Appendix C.

The TIN model was interpolated and averaged using a cell size of 1 foot by 1 foot and converted to a raster. The raster was used to produce Figure 3, an Elevation Relief Map representing the topography of the reservoir bottom, Figure 4, a map showing shaded depth ranges for Lake Cypress Springs, and Figure 5, a 5-foot contour map (attached).

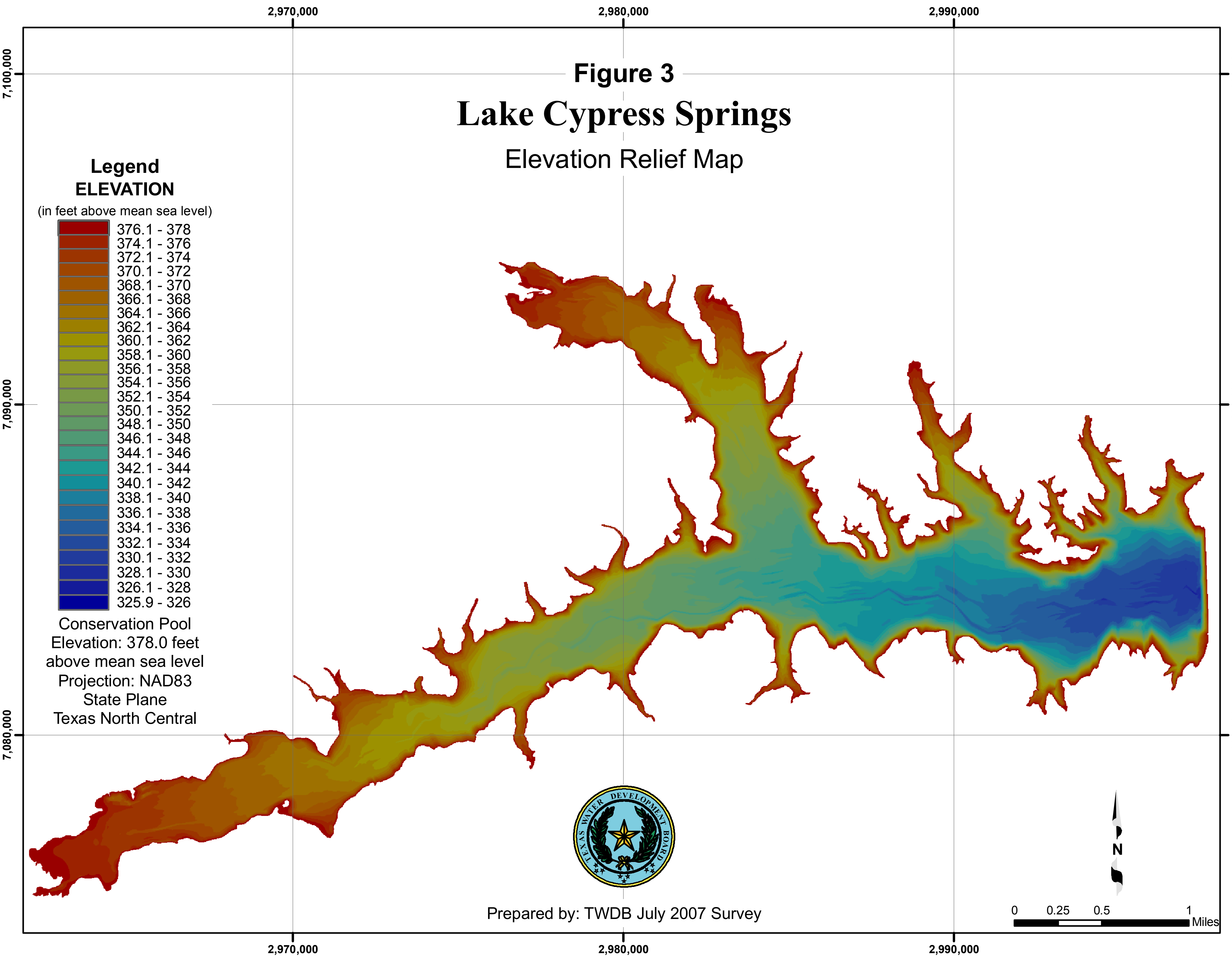


Figure 3
Lake Cypress Springs
Elevation Relief Map
Legend
ELEVATION
(in feet above mean sea level)
376.1 - 378
374.1 - 376
372.1 - 374
370.1 - 372
368.1 - 370
366.1 - 368
364.1 - 366
362.1 - 364
360.1 - 362
358.1 - 360
356.1 - 358
354.1 - 356
352.1 - 354
350.1 - 352
348.1 - 350
346.1 - 348
344.1 - 346
342.1 - 344
340.1 - 342
338.1 - 340
336.1 - 338
334.1 - 336
332.1 - 334
330.1 - 332
328.1 - 330
326.1 - 328
325.9 - 326
Conservation Pool
Elevation: 378.0 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central
2,970,000
2,980,000
2,990,000
7,100,000
7,090,000
7,080,000
TEXAS WATER DEVELOPMENT BOARD
N
0
0.25
0.5
1
Miles
Prepared by: TWDB July 2007 Survey

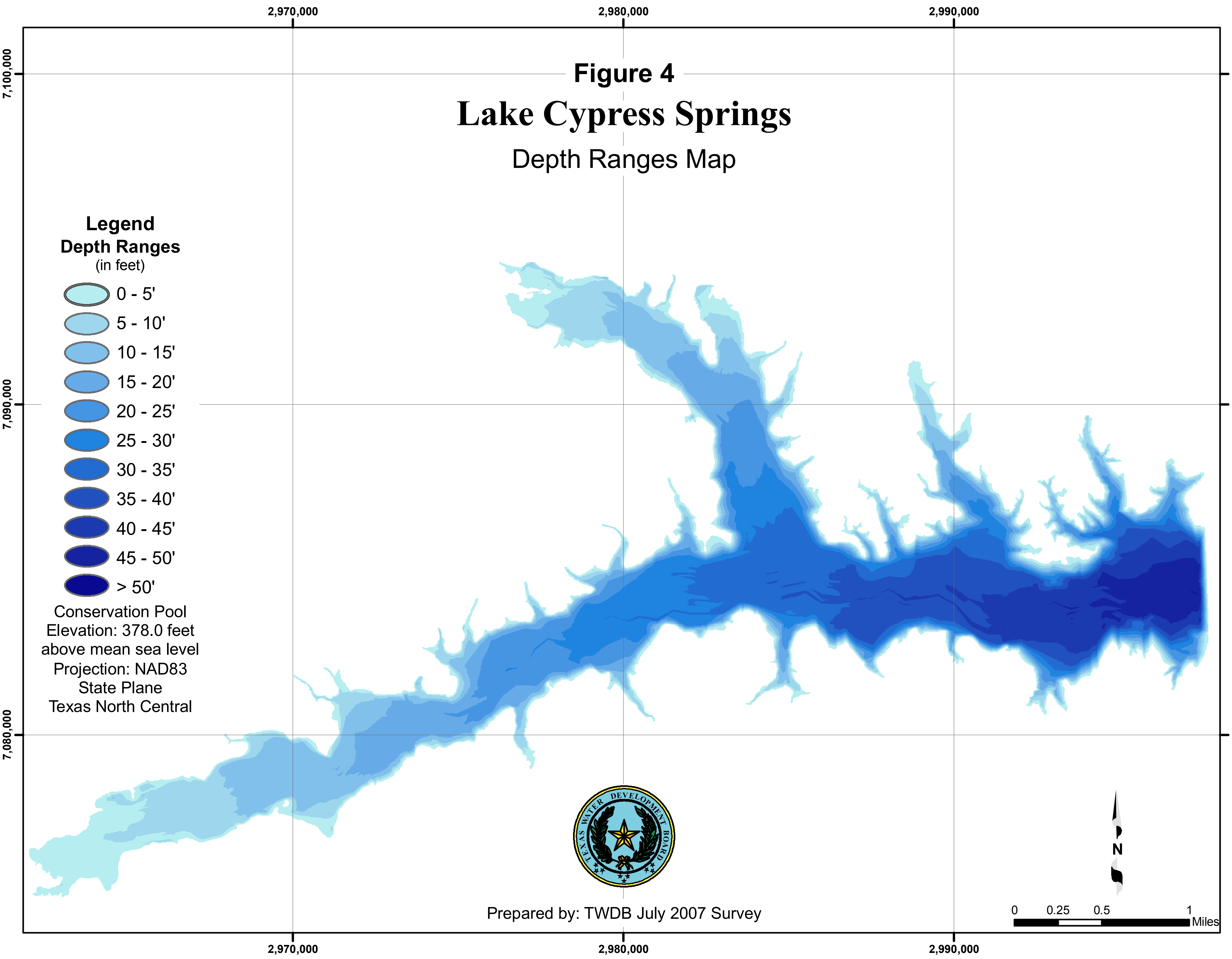


Figure 4
Lake Cypress Springs
Depth Ranges Map
Legend
Depth Ranges
(in feet)
0 - 5'
5 - 10'
10 - 15'
15 - 20'
20 - 25'
25 - 30'
30 - 35'
35 - 40'
40 - 45'
45 - 50'
> 50'
Conservation Pool
Elevation: 378.0 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central
TEXAS WATER DEVELOPMENT BOARD
N
0
0.25
0.5
1
Miles
Prepared by: TWDB July 2007 Survey
2,970,000
2,980,000
2,990,000
7,100,000
7,090,000
7,080,000

**Self-Similar Interpolation**

A limitation of the Delaunay method for triangulation when creating TIN models results in artificially-curved contour lines extending into the reservoir where the reservoir walls are steep and the reservoir is relatively narrow. These curved contours are likely a poor representation of the true reservoir bathymetry in these areas. Also, if the surveyed cross sections are not perpendicular to the centerline of submerged river channel (the location of which is often unknown until after the survey), then the TIN model is not likely to well-represent the true channel bathymetry.

To ameliorate these problems, a self-similar interpolation routine (developed by TWDB) was used to interpolate the bathymetry in between many 500 foot-spaced survey lines. The self-similar interpolation technique effectively increases the density of points input into the TIN model, and directs the TIN interpolation to better represent the reservoir topography.[9] In the case of Lake Cypress Springs, the application of self-similar interpolation helped represent the lake morphology near the banks and improved the representation of the submerged river channel (Figure 6). In areas where obvious geomorphic features indicate a high-probability of cross-section shape changes (e.g. incoming tributaries, significant widening/narrowing of channel, etc.), the assumptions used in applying the self-similar interpolation technique are not likely to be valid; therefore, self-similar interpolation was not used in areas of Lake Cypress Springs where a high probability of change between cross-sections exists.[9] Figure 6 illustrates typical results of the application of the self-similar interpolation technique in Lake Cypress Springs, and the bathymetry shown in Figure 6C was used in computing reservoir capacity and area tables (Appendix A, B).

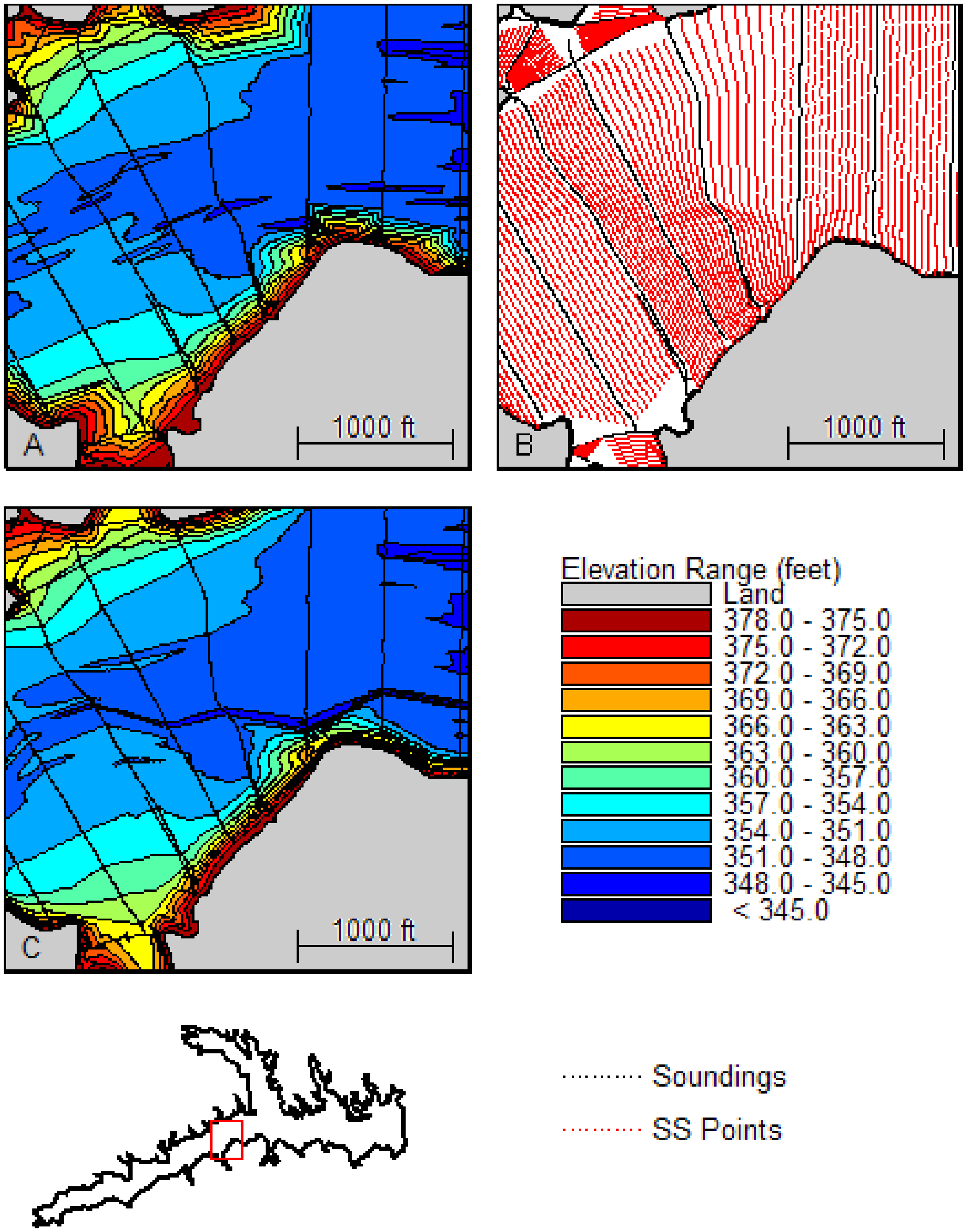



***Figure 6*** *Application of the Self-Similar Interpolation technique to Lake Cypress Springs 2007 sounding data – A) bathymetric contours without interpolated points, B) Sounding points (black) and interpolated points (red) with reservoir boundary shown at elevation 378.0 feet (black), C) bathymetric contours with the interpolated points. Note: In 6A the steep banks indicated by the surveyed cross sections are not represented for the areas in-between the cross sections. This is an artifact of the TIN generation routine when data points are too far apart. Inclusion of the interpolated points (6C) corrects this and smoothes the bathymetric contours. The submerged river channel is also apparent in 6C where it is discontinuous in 6A.*

## Volumetric Survey Results - 2007

**The results of the TWDB 2007 Volumetric Survey indicate Lake Cypress Springs has a total reservoir capacity of 66,756 acre-feet and encompasses 3,252 acres at conservation pool elevation (378.0 feet above mean sea level, NGVD29).** In 1998 TWDB estimated the capacity of Lake Cypress Springs (at conservation pool elevation) at 67,690 acre-feet.[1] Due to differences in the methodologies used in calculating areas and capacities from this and previous Lake Cypress Springs surveys, comparison of these values is not recommended.[2] The TWDB considers the 2007 survey to be a significant improvement over previous methods and recommends that a similar methodology be used to resurvey Lake Cypress Springs in 10 to 20 years or after a major flood event.

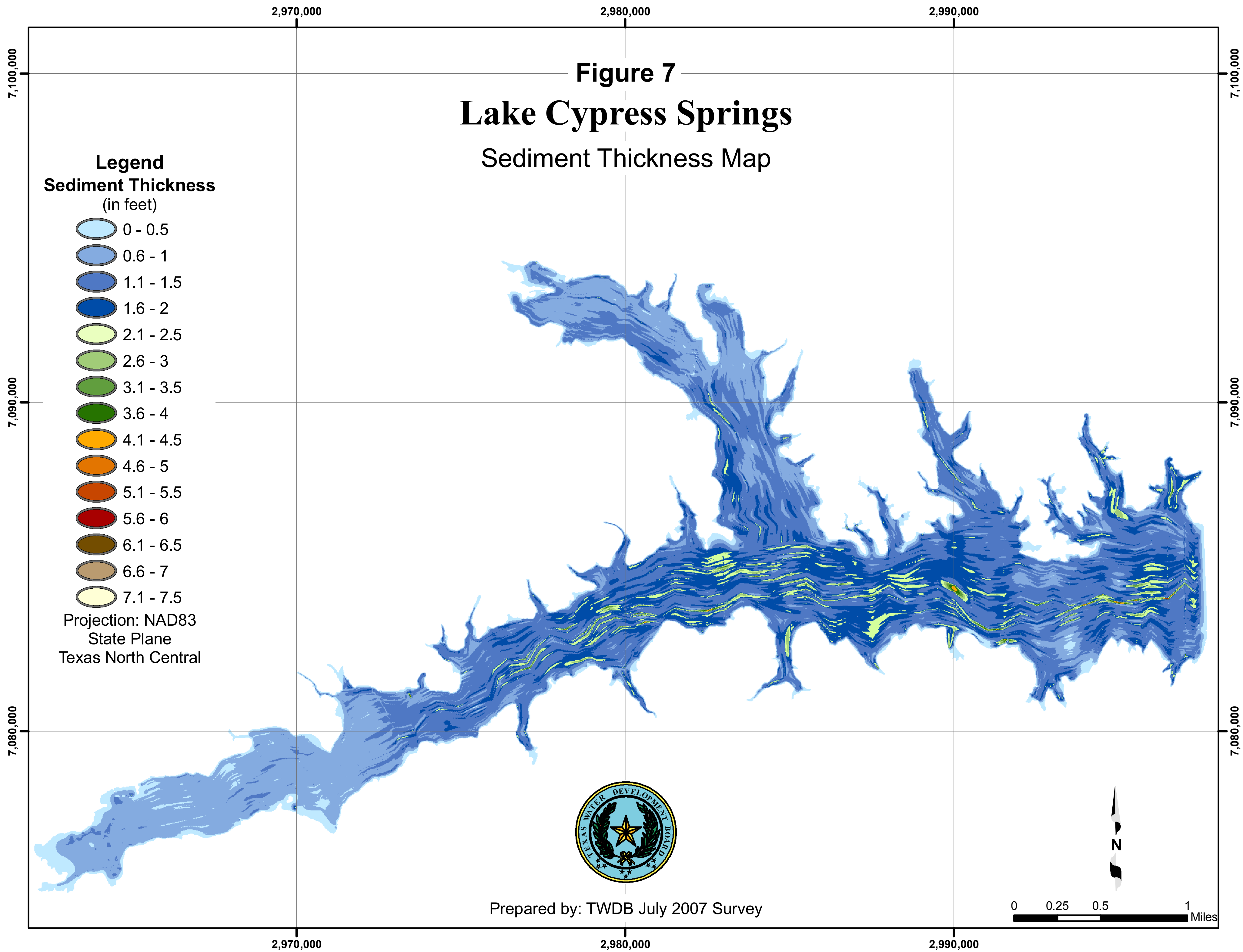
## Sediment Survey Results - 2007

The 200 kHz, 50 kHz, and 24 kHz frequency data were used to interpret sediment distribution and accumulation throughout Lake Cypress Springs. Figure 7 shows the thickness of sediment throughout the lake. To assist in the interpretation of post-impoundment sediment accumulation, ancillary data was collected in the form of five core samples. Sediment cores were collected on May 20, 2008 using a Specialty Devices, Inc. VibeCore system.

**The results of the TWDB 2007 Sediment Survey indicate Lake Cypress Springs has accumulated 3,807 acre-feet of sediment since impoundment in 1970.** Based on this measured sediment volume and assuming a constant sediment accumulation rate, Lake Cypress Springs loses approximately 100 acre-feet of capacity per year. The majority of the sediment accumulation has occurred within the main body of the lake, with the thickest deposits in the submerged Big Cypress Creek channel. The maximum sediment thickness observed in Lake Cypress Springs was 7.2 feet.

A complete description of the sediment measurement methodology and sample results is presented in Appendix D.

# Figure 7
# Lake Cypress Springs
## Sediment Thickness Map




Prepared by: TWDB July 2007 Survey

## TWDB Contact Information

More information about the Hydrographic Survey Program can be found at:

http://www.twdb.state.tx.us/assistance/lakesurveys/volumetricindex.asp

Any questions regarding the TWDB Hydrographic Survey Program may be addressed to:

Barney Austin, Ph.D., P.E.
Director of the Surface Water Resources Division
Phone: (512) 463-8856
Email: Barney.Austin@twdb.state.tx.us

Or

Jason Kemp
Team Leader, TWDB Hydrographic Survey Program
Phone: (512) 463-2465
Email: Jason.Kemp@twdb.state.tx.us

## References


1. Texas Water Development Board (1998) “Volumetric Survey of Lake Cypress Springs”

2. United States Department of Agriculture, Natural Resource Conservation Service, National Engineering Handbook, Section 3, Sedimentation, Chapter 7, Field Investigations and Surveys, December 1983.

3. Texas Water Development Board, Report 126, Engineering Data on Dams and Reservoirs in Texas, Part I, October 1974.

4. Franklin County Water District, viewed March 18, 2008, http://www.fcwd.com/.

5. United States Geological Survey, http://tx.usgs.gov/ 07 June 2006.

6. Texas Natural Resources Information System (TNRIS), viewed 31 October 2007, http://www.tnris.state.tx.us/.

7. U.S Department of Agriculture, Farm Service Agency, Aerial Photography Field Office, National Agriculture Imagery Program, viewed February 10, 2006 http://www.apfo.usda.gov/NAIP.html.

8. ESRI, Environmental Systems Research Institute. 1995. ARC/INFO Surface Modeling and Display, TIN Users Guide.

9. Furnans, Jordan. Texas Water Development Board. 2006. “HydroEdit User’s Manual.”

Appendix A

# Lake Cypress Springs

## RESERVOIR CAPACITY TABLE

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

JULY 2007 SURVEY
Conservation Pool Elevation 378.0 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 325 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 326 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 327 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 328 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 329 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 330 | 2 | 2 | 2 | 2 | 3 | 3 | 4 | 5 | 6 | 7 |
| 331 | 9 | 10 | 12 | 14 | 16 | 19 | 22 | 25 | 29 | 33 |
| 332 | 37 | 42 | 47 | 53 | 59 | 66 | 74 | 82 | 90 | 99 |
| 333 | 109 | 119 | 130 | 141 | 153 | 165 | 178 | 191 | 205 | 219 |
| 334 | 233 | 249 | 264 | 280 | 296 | 313 | 330 | 348 | 366 | 384 |
| 335 | 403 | 422 | 441 | 461 | 481 | 502 | 523 | 545 | 567 | 589 |
| 336 | 613 | 636 | 660 | 684 | 708 | 733 | 759 | 784 | 810 | 836 |
| 337 | 863 | 890 | 917 | 945 | 974 | 1,003 | 1,032 | 1,062 | 1,092 | 1,122 |
| 338 | 1,153 | 1,184 | 1,216 | 1,248 | 1,280 | 1,313 | 1,346 | 1,380 | 1,414 | 1,449 |
| 339 | 1,484 | 1,520 | 1,556 | 1,592 | 1,629 | 1,667 | 1,705 | 1,744 | 1,783 | 1,823 |
| 340 | 1,863 | 1,904 | 1,946 | 1,989 | 2,032 | 2,077 | 2,122 | 2,168 | 2,215 | 2,262 |
| 341 | 2,310 | 2,359 | 2,408 | 2,458 | 2,508 | 2,559 | 2,611 | 2,662 | 2,715 | 2,768 |
| 342 | 2,821 | 2,875 | 2,930 | 2,985 | 3,040 | 3,097 | 3,153 | 3,211 | 3,269 | 3,327 |
| 343 | 3,386 | 3,445 | 3,505 | 3,566 | 3,627 | 3,689 | 3,751 | 3,814 | 3,877 | 3,942 |
| 344 | 4,006 | 4,072 | 4,138 | 4,204 | 4,271 | 4,338 | 4,406 | 4,475 | 4,544 | 4,613 |
| 345 | 4,683 | 4,753 | 4,824 | 4,896 | 4,968 | 5,041 | 5,115 | 5,190 | 5,265 | 5,341 |
| 346 | 5,418 | 5,496 | 5,574 | 5,653 | 5,733 | 5,813 | 5,895 | 5,977 | 6,059 | 6,142 |
| 347 | 6,226 | 6,311 | 6,396 | 6,482 | 6,569 | 6,656 | 6,744 | 6,833 | 6,922 | 7,012 |
| 348 | 7,103 | 7,194 | 7,287 | 7,380 | 7,474 | 7,569 | 7,664 | 7,760 | 7,857 | 7,954 |
| 349 | 8,052 | 8,150 | 8,249 | 8,349 | 8,449 | 8,550 | 8,651 | 8,753 | 8,855 | 8,958 |
| 350 | 9,062 | 9,166 | 9,270 | 9,375 | 9,481 | 9,587 | 9,694 | 9,801 | 9,910 | 10,019 |
| 351 | 10,128 | 10,239 | 10,349 | 10,461 | 10,573 | 10,686 | 10,799 | 10,913 | 11,028 | 11,143 |
| 352 | 11,259 | 11,376 | 11,493 | 11,611 | 11,729 | 11,848 | 11,968 | 12,088 | 12,209 | 12,331 |
| 353 | 12,453 | 12,576 | 12,700 | 12,824 | 12,949 | 13,075 | 13,201 | 13,328 | 13,456 | 13,584 |
| 354 | 13,712 | 13,842 | 13,972 | 14,102 | 14,233 | 14,365 | 14,497 | 14,630 | 14,764 | 14,898 |
| 355 | 15,033 | 15,168 | 15,305 | 15,442 | 15,580 | 15,719 | 15,858 | 15,998 | 16,139 | 16,280 |
| 356 | 16,422 | 16,565 | 16,708 | 16,852 | 16,997 | 17,143 | 17,289 | 17,436 | 17,583 | 17,732 |
| 357 | 17,881 | 18,031 | 18,181 | 18,332 | 18,484 | 18,636 | 18,789 | 18,943 | 19,097 | 19,251 |
| 358 | 19,407 | 19,563 | 19,720 | 19,877 | 20,035 | 20,194 | 20,353 | 20,513 | 20,673 | 20,835 |
| 359 | 20,997 | 21,159 | 21,322 | 21,486 | 21,650 | 21,816 | 21,981 | 22,148 | 22,315 | 22,482 |
| 360 | 22,651 | 22,820 | 22,990 | 23,160 | 23,331 | 23,503 | 23,676 | 23,850 | 24,024 | 24,199 |
| 361 | 24,374 | 24,551 | 24,728 | 24,906 | 25,084 | 25,264 | 25,444 | 25,625 | 25,807 | 25,990 |
| 362 | 26,174 | 26,358 | 26,543 | 26,729 | 26,915 | 27,102 | 27,290 | 27,478 | 27,667 | 27,857 |
| 363 | 28,047 | 28,238 | 28,430 | 28,623 | 28,816 | 29,010 | 29,205 | 29,400 | 29,597 | 29,794 |
| 364 | 29,992 | 30,191 | 30,391 | 30,591 | 30,793 | 30,995 | 31,198 | 31,402 | 31,606 | 31,812 |
| 365 | 32,018 | 32,225 | 32,433 | 32,642 | 32,852 | 33,063 | 33,275 | 33,488 | 33,702 | 33,917 |
| 366 | 34,133 | 34,350 | 34,568 | 34,786 | 35,006 | 35,226 | 35,447 | 35,669 | 35,892 | 36,116 |
| 367 | 36,342 | 36,568 | 36,795 | 37,023 | 37,253 | 37,483 | 37,714 | 37,947 | 38,180 | 38,414 |
| 368 | 38,649 | 38,885 | 39,123 | 39,360 | 39,599 | 39,839 | 40,080 | 40,321 | 40,563 | 40,807 |
| 369 | 41,051 | 41,296 | 41,542 | 41,788 | 42,036 | 42,284 | 42,534 | 42,784 | 43,035 | 43,287 |
| 370 | 43,540 | 43,794 | 44,048 | 44,304 | 44,560 | 44,817 | 45,076 | 45,335 | 45,594 | 45,855 |
| 371 | 46,116 | 46,379 | 46,642 | 46,906 | 47,171 | 47,437 | 47,704 | 47,972 | 48,240 | 48,510 |
| 372 | 48,781 | 49,053 | 49,325 | 49,599 | 49,874 | 50,150 | 50,426 | 50,704 | 50,983 | 51,262 |
| 373 | 51,543 | 51,825 | 52,107 | 52,391 | 52,675 | 52,961 | 53,248 | 53,536 | 53,824 | 54,114 |
| 374 | 54,405 | 54,698 | 54,991 | 55,285 | 55,580 | 55,876 | 56,173 | 56,472 | 56,772 | 57,072 |
| 375 | 57,374 | 57,676 | 57,980 | 58,284 | 58,589 | 58,895 | 59,201 | 59,508 | 59,816 | 60,124 |
| 376 | 60,433 | 60,743 | 61,053 | 61,364 | 61,676 | 61,988 | 62,301 | 62,615 | 62,929 | 63,244 |
| 377 | 63,560 | 63,876 | 64,193 | 64,511 | 64,829 | 65,148 | 65,468 | 65,789 | 66,110 | 66,433 |
| 378 | 66,756 | | | | | | | | | |

Appendix B

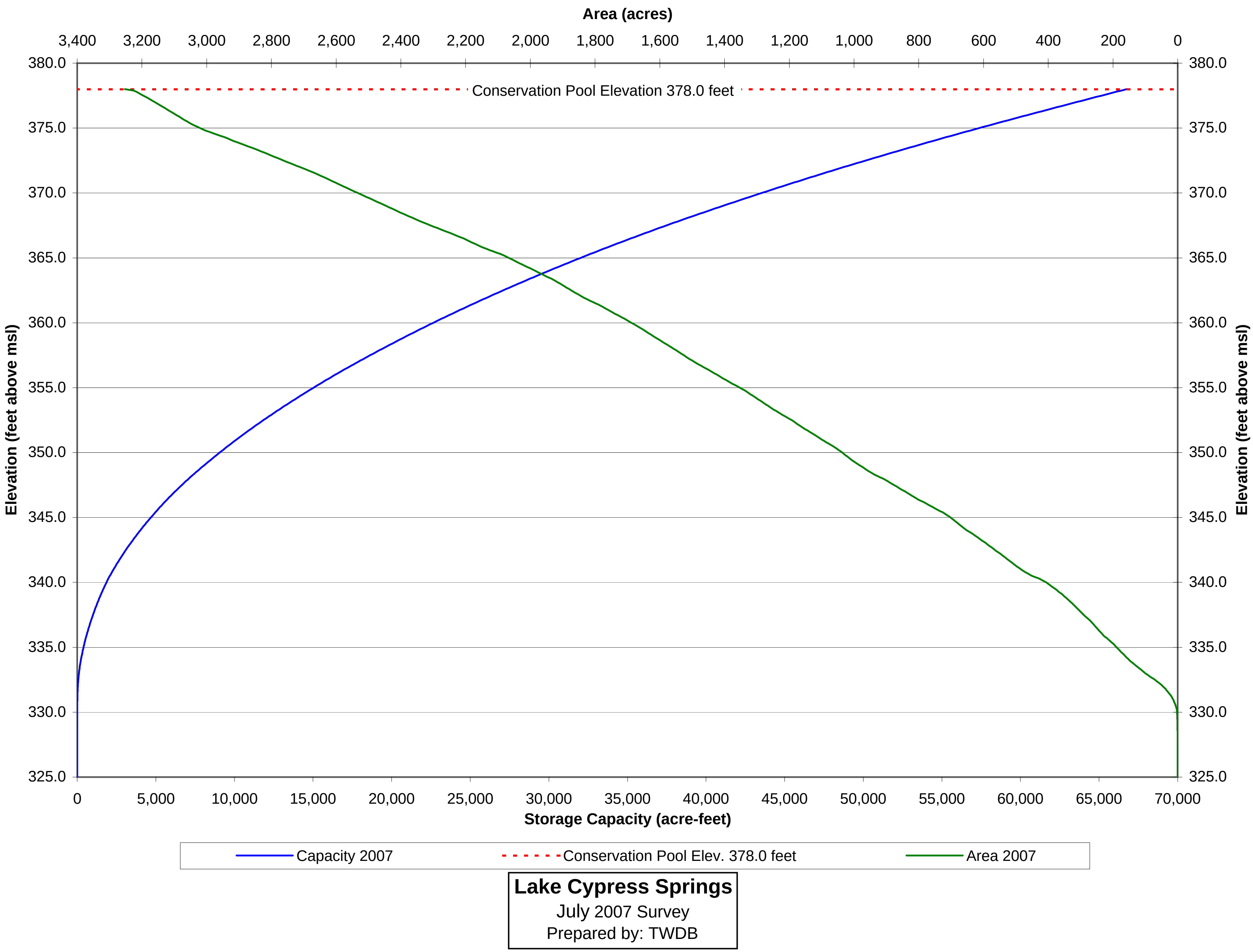
# Lake Cypress Springs

## RESERVOIR AREA TABLE

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

JULY 2007 SURVEY
Conservation Pool Elevation 378.0 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 325 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 326 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 327 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 328 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 329 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 330 | 2 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 11 | 13 |
| 331 | 15 | 17 | 19 | 21 | 25 | 28 | 31 | 35 | 38 | 42 |
| 332 | 46 | 51 | 55 | 60 | 66 | 71 | 77 | 83 | 88 | 94 |
| 333 | 100 | 105 | 109 | 114 | 119 | 125 | 130 | 135 | 139 | 144 |
| 334 | 149 | 153 | 157 | 161 | 165 | 169 | 173 | 177 | 181 | 185 |
| 335 | 189 | 193 | 196 | 200 | 205 | 209 | 214 | 219 | 224 | 229 |
| 336 | 233 | 236 | 240 | 243 | 247 | 250 | 254 | 257 | 261 | 265 |
| 337 | 268 | 273 | 277 | 282 | 286 | 290 | 294 | 298 | 302 | 306 |
| 338 | 310 | 314 | 318 | 322 | 327 | 331 | 335 | 340 | 345 | 349 |
| 339 | 353 | 358 | 364 | 369 | 373 | 378 | 385 | 390 | 395 | 401 |
| 340 | 407 | 413 | 421 | 429 | 441 | 449 | 457 | 465 | 472 | 478 |
| 341 | 484 | 489 | 495 | 501 | 506 | 511 | 516 | 522 | 527 | 532 |
| 342 | 537 | 542 | 548 | 553 | 560 | 565 | 570 | 575 | 581 | 586 |
| 343 | 592 | 597 | 603 | 609 | 615 | 620 | 626 | 631 | 638 | 645 |
| 344 | 650 | 656 | 662 | 667 | 672 | 677 | 682 | 687 | 692 | 697 |
| 345 | 702 | 707 | 713 | 720 | 726 | 734 | 742 | 750 | 757 | 764 |
| 346 | 772 | 779 | 786 | 795 | 803 | 809 | 816 | 822 | 829 | 836 |
| 347 | 842 | 849 | 856 | 863 | 870 | 876 | 883 | 890 | 897 | 903 |
| 348 | 911 | 920 | 929 | 937 | 944 | 950 | 957 | 963 | 969 | 975 |
| 349 | 981 | 988 | 994 | 1,000 | 1,005 | 1,011 | 1,016 | 1,021 | 1,026 | 1,031 |
| 350 | 1,037 | 1,042 | 1,048 | 1,053 | 1,059 | 1,065 | 1,072 | 1,079 | 1,086 | 1,093 |
| 351 | 1,099 | 1,105 | 1,111 | 1,118 | 1,124 | 1,131 | 1,137 | 1,144 | 1,151 | 1,157 |
| 352 | 1,163 | 1,170 | 1,175 | 1,181 | 1,186 | 1,193 | 1,200 | 1,207 | 1,213 | 1,220 |
| 353 | 1,227 | 1,234 | 1,240 | 1,247 | 1,253 | 1,260 | 1,266 | 1,272 | 1,278 | 1,284 |
| 354 | 1,290 | 1,296 | 1,302 | 1,308 | 1,314 | 1,320 | 1,326 | 1,332 | 1,339 | 1,346 |
| 355 | 1,353 | 1,360 | 1,368 | 1,375 | 1,383 | 1,390 | 1,397 | 1,404 | 1,410 | 1,417 |
| 356 | 1,424 | 1,431 | 1,438 | 1,445 | 1,452 | 1,459 | 1,466 | 1,473 | 1,480 | 1,487 |
| 357 | 1,495 | 1,501 | 1,507 | 1,514 | 1,520 | 1,526 | 1,532 | 1,538 | 1,544 | 1,551 |
| 358 | 1,557 | 1,564 | 1,570 | 1,577 | 1,583 | 1,590 | 1,596 | 1,602 | 1,609 | 1,616 |
| 359 | 1,622 | 1,629 | 1,635 | 1,641 | 1,647 | 1,654 | 1,660 | 1,667 | 1,674 | 1,680 |
| 360 | 1,688 | 1,695 | 1,702 | 1,709 | 1,716 | 1,723 | 1,731 | 1,739 | 1,746 | 1,753 |
| 361 | 1,760 | 1,767 | 1,775 | 1,782 | 1,790 | 1,798 | 1,807 | 1,816 | 1,824 | 1,832 |
| 362 | 1,839 | 1,847 | 1,854 | 1,861 | 1,867 | 1,874 | 1,881 | 1,887 | 1,894 | 1,900 |
| 363 | 1,907 | 1,914 | 1,921 | 1,928 | 1,936 | 1,944 | 1,953 | 1,961 | 1,969 | 1,977 |
| 364 | 1,985 | 1,993 | 2,002 | 2,010 | 2,018 | 2,026 | 2,034 | 2,042 | 2,050 | 2,058 |
| 365 | 2,066 | 2,075 | 2,083 | 2,093 | 2,103 | 2,115 | 2,126 | 2,136 | 2,146 | 2,155 |
| 366 | 2,164 | 2,173 | 2,182 | 2,190 | 2,198 | 2,207 | 2,216 | 2,227 | 2,237 | 2,247 |
| 367 | 2,256 | 2,267 | 2,278 | 2,288 | 2,298 | 2,308 | 2,318 | 2,329 | 2,338 | 2,347 |
| 368 | 2,356 | 2,366 | 2,375 | 2,384 | 2,393 | 2,402 | 2,411 | 2,419 | 2,428 | 2,436 |
| 369 | 2,445 | 2,454 | 2,463 | 2,471 | 2,480 | 2,489 | 2,498 | 2,507 | 2,515 | 2,524 |
| 370 | 2,533 | 2,542 | 2,551 | 2,560 | 2,568 | 2,577 | 2,585 | 2,594 | 2,602 | 2,611 |
| 371 | 2,619 | 2,628 | 2,637 | 2,645 | 2,654 | 2,664 | 2,673 | 2,682 | 2,692 | 2,702 |
| 372 | 2,713 | 2,723 | 2,733 | 2,743 | 2,753 | 2,762 | 2,772 | 2,782 | 2,792 | 2,801 |
| 373 | 2,811 | 2,821 | 2,831 | 2,840 | 2,851 | 2,862 | 2,873 | 2,883 | 2,894 | 2,906 |
| 374 | 2,916 | 2,926 | 2,935 | 2,945 | 2,957 | 2,969 | 2,980 | 2,992 | 3,002 | 3,011 |
| 375 | 3,021 | 3,030 | 3,038 | 3,046 | 3,053 | 3,060 | 3,067 | 3,074 | 3,080 | 3,087 |
| 376 | 3,093 | 3,100 | 3,107 | 3,113 | 3,120 | 3,126 | 3,133 | 3,140 | 3,147 | 3,153 |
| 377 | 3,160 | 3,167 | 3,174 | 3,181 | 3,188 | 3,195 | 3,203 | 3,210 | 3,218 | 3,226 |
| 378 | 3,252 | | | | | | | | | |




Appendix C: Area and Capacity Curves

**Appendix D**

Analysis of Sediment Accumulation Data from Lake Cypress Springs

## Executive Summary

The results of the TWDB 2007 Sedimentation Survey indicate Lake Cypress Springs has accumulated 3,807 acre-feet of sediment since impoundment in 1970. Based on this measured sediment volume and assuming a constant rate of sediment accumulation, Lake Cypress Springs loses approximately 100 acre-feet of capacity per year. The majority of the sediment accumulation has occurred within the main body of the lake, with the thickest deposits in the submerged Big Cypress Creek channel. The maximum sediment thickness observed in Lake Cypress Springs was 7.2 feet.

## Introduction

This appendix includes the results of the sediment investigation using multi-frequency depth sounder data collected on June 21st, June 27th-June 29th, July 10th, and July 11th of 2007 by the Texas Water Development Board (TWDB). Through careful analysis and interpretation of the multi-frequency signal returns, it is possible to discern the pre-impoundment bathymetric surface, as well as the current surface and sediment thickness. Such interpretations are aided and validated through comparisons with sediment core samples which provide independent measurements of sediment thickness. On May 20, 2008 TWDB collected five core samples of the impoundment bottom throughout the reservoir. The remainder of this appendix presents a discussion of the results from and methodology used in the core sampling and multi-frequency data collection efforts, followed by a composite analysis of sediment measured in Lake Cypress Springs.

## Data Collection & Processing Methodology

TWDB conducted the Lake Cypress Springs bathymetric survey on June 21st, June 27th-June 29th, July 10th, and July 11th of 2007, while the water surface elevation ranged between 378.22 feet and 379.42 feet above mean sea level (NGVD29). For all data collection efforts, TWDB used a Specialty Devices, Inc., 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 original river channels and spaced approximately 500 feet apart. For all data collection efforts, 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. During the 2007 survey, team members collected 70,445 data points over cross-sections totaling nearly 72 miles in length. Figure E1 shows where data points were collected during the TWDB 2007 survey. The coordinates and a description of each core sample are provided in Table E1.

Core samples collected by TWDB were collected at locations where sounding data had been previously collected (Figure E1). All cores were collected with a custom-coring boat and SDI VibraCore system. Cores were analyzed by TWDB, and both the sediment thickness and the distance the core penetrated the pre-impoundment boundary were recorded. Figure E2 shows the cross-section of sediment core #1. At this location, TWDB collected 18” of sediment, with the upper sediment layers (Figure E2) having a high water content, consisting of clay material and lacking in vegetation. The pre-impoundment boundary was evident from this core at a distance of 10” above the core base; above this location, the moisture content in the sediment greatly increases (Figure E2).

*Table D1 – Core Sampling Analysis Data*

| Core | Easting** (ft) | Northing** (ft) | Description |
|---|---|---|---|
| 1 | 2984546.46 | 7083312.15 | 18" of muddy sediment with plant material visible. |
| 2 | 2972427.51 | 7079991.96 | 18" of alternating muddy and sandy sediment, dry clay found 32" below pre-impoundment boundary |
| 3 | 2968465.25 | 7077895.17 | 15" of clay sediment, dark color with orange spots. |
| 4 | 2983536.81 | 7089095.45 | 12" of wet, fine grained sediment (clay) |
| 5 | 2995017.84 | 7086446.74 | 16" of sediment with little plant material visible. |

** Coordinates are based on NAD 1983 State Plane Texas North Central system

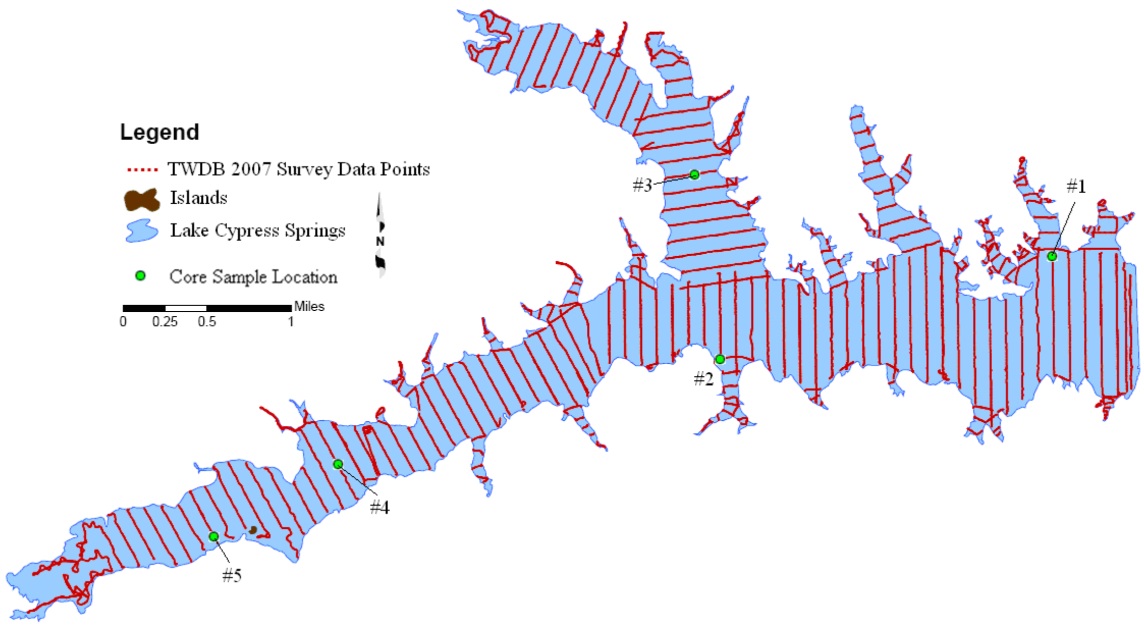



*Figure E1 – TWDB 2007 survey data points for Lake Cypress Springs*

*Figure E2 – Upper portion of core #1 from Lake Cypress Springs, showing the pre-impoundment boundary 10" above the base of the core (left).*

All sounding data is processed using the DepthPic software, within which both the pre-impoundment and current bathymetric surfaces are identified and digitized manually. These surfaces are first identified along cross-sections for which core samples have been collected – thereby allowing the user to identify color bands in the DepthPic display that correspond to the sediment layer(s) observed in the core samples. This process is illustrated in Figure E3 where core sample #1 is shown with its corresponding sounding data. Core sample #1 contained 18" of sediment above the pre-impoundment bathymetry, as indicated by the yellow & green boxes, respectively, representing the core sample in Figure E3. The pre-impoundment surface is usually identified within the core sample by one of the following methods: (1) a visual examination of the 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.

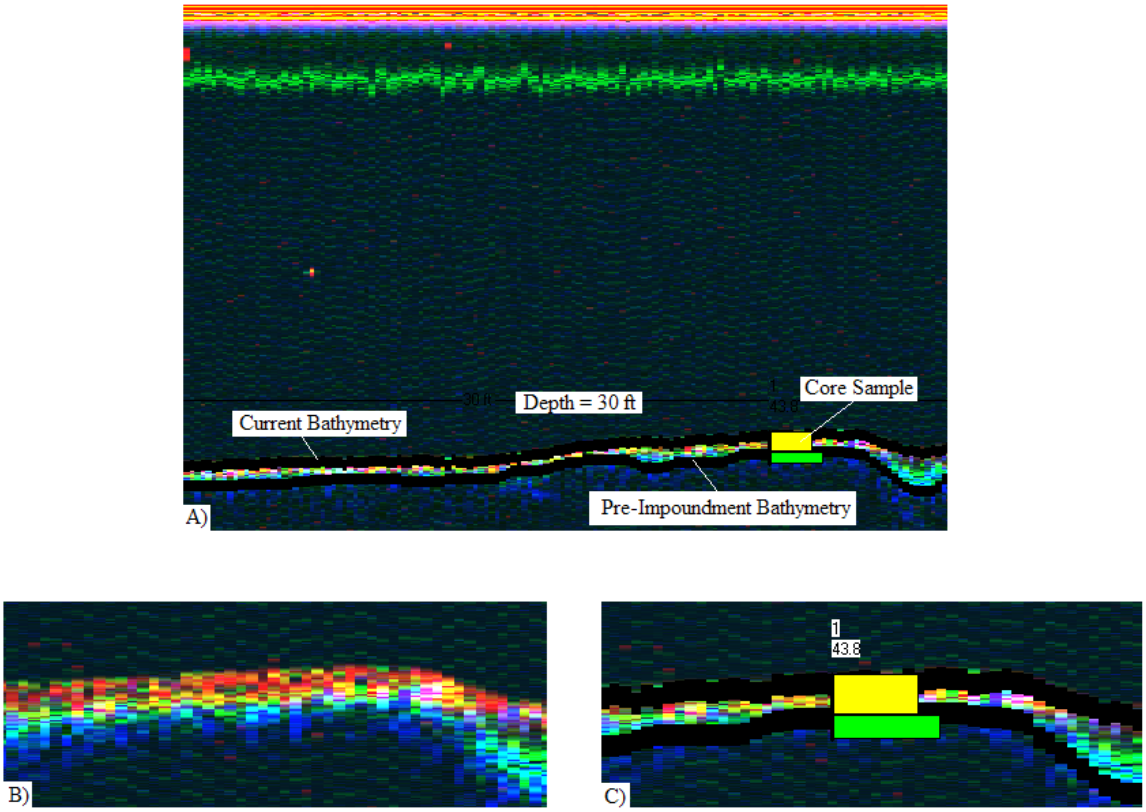



*Figure E3 – DepthPic & core sample use in identifying the pre-impoundment bathymetry.*

Within DepthPic, the current surface is automatically determined based on the signal returns from the 200 kHz transducer. The pre-impoundment surface must be determined visually based on the pixel color display and any available core sample data. Based on core sample #1, it is clear that the pre-impoundment bathymetric surface for this cross-section may be identified as the base of the bright-colored blue pixels in the DepthPic display. The top of the sediment layer is also clearly identifiable as the band of red and green pixels (Figure E3).

In analyzing data from cross-sections where core samples were not collected, the assumption is made that sediment layers may be identified in a similar manner as when core sample data is available. To improve the validity of this assumption, core samples are collected at regularly spaced intervals within the lake, or at locations where interpretation of the DepthPic display would be difficult without site-specific core data. For this reason, all sounding data is collected and reviewed before core sites are selected and cores are collected.

After manually digitizing the pre-impoundment surface from all cross-sections, both the pre-impoundment and current bathymetric surfaces are exported as X-,Y-,Z-coordinates from DepthPic into text files suitable for use in ArcGIS. Within ArcGIS, the sounding points are then processed into TIN models following standard GIS techniques[1].

## Results

**The results of the TWDB 2007 Sediment Survey indicate Lake Cypress Springs has accumulated 3,807 acre-feet of sediment since impoundment in 1970.** Based on this measured sediment volume and assuming a constant sediment accumulation rate, Lake Cypress Springs loses approximately 100 acre-feet of capacity per year. The majority of the sediment accumulation has occurred within the main body of the lake, with the thickest deposits in the submerged Big Cypress Creek channel. The maximum sediment thickness observed in Lake Cypress Springs was 7.2 feet.

The accumulated sediment volume for Lake Cypress Springs was calculated from a sediment thickness TIN model created in ArcGIS. Sediment thicknesses were computed as the difference in elevations between the current and pre-impoundment bathymetric surfaces as determined with the DepthPic software. Sediment thicknesses were interpolated for locations between surveyed cross-sections using the TWDB self-similar interpolation technique[2]. For the purposes of the TIN model creation, TWDB assumed 0-feet sediment thicknesses at the model boundaries (defined as the 378.0 foot NGVD29 elevation contour). Figure E4 depicts the sediment thickness in Lake Cypress Springs.

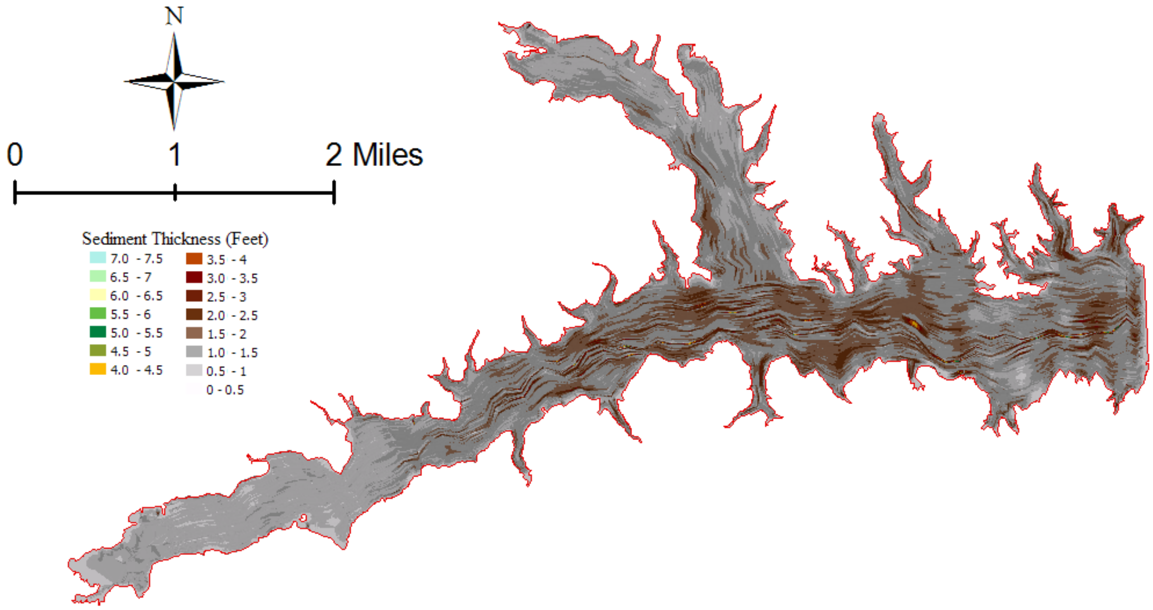



*Figure E4 - Sediment thicknesses in Lake Cypress Springs derived from multi-frequency sounding data.*

## References

1. Furnans, J., Austin, B., Hydrographic survey methods for determining reservoir volume, Environmental Modelling & Software (2007), doi: 10.1016/j.envsoft.2007.05.011
2. Furnans, Jordan. Texas Water Development Board. 2006. “HydroEdit User’s Manual.”

# Figure 5

**CONTOURS**

**(in feet above mean sea level)**

375
370
365
360
355
350
345
340
335
330

Islands

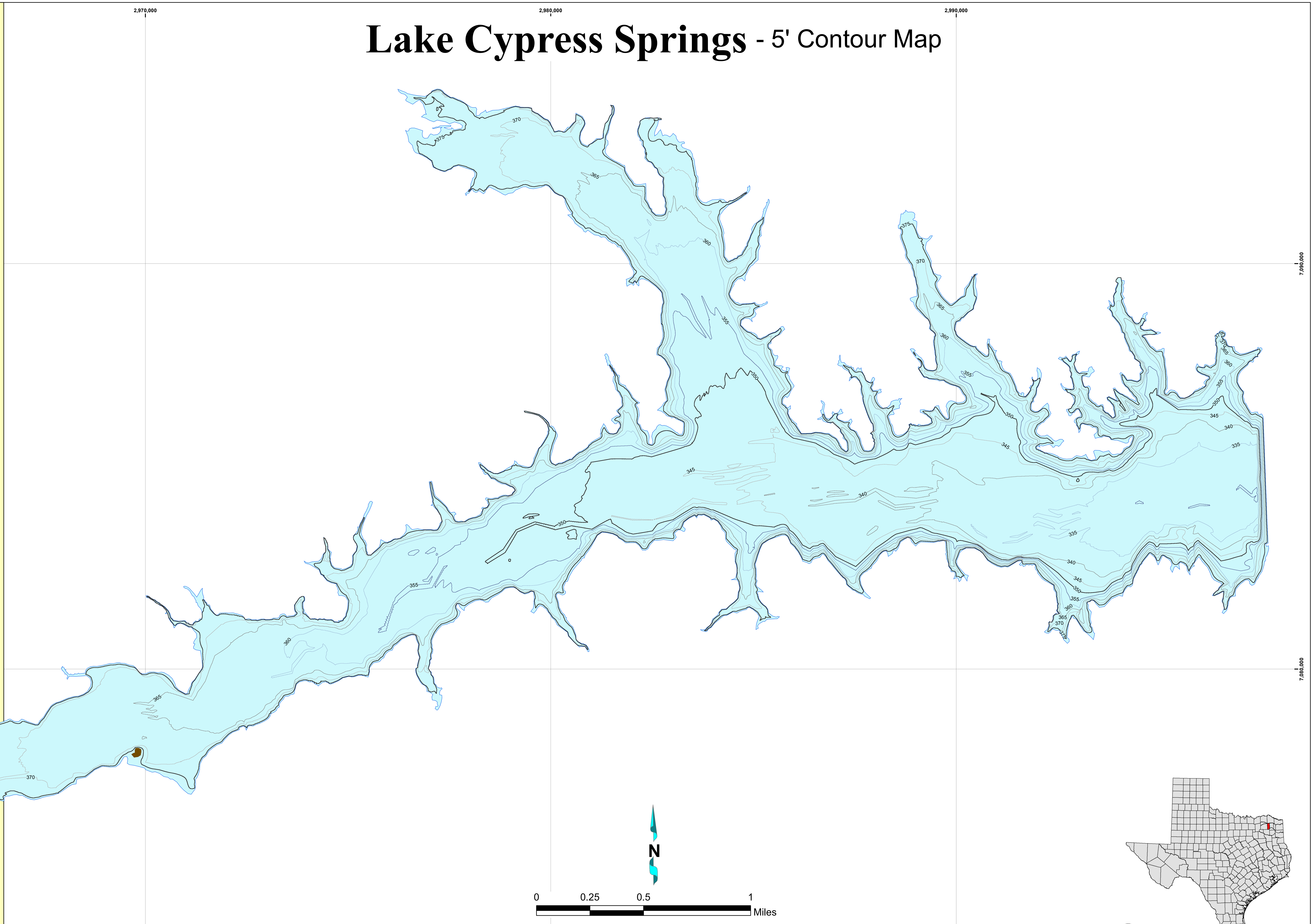
Lake Cypress Springs

Conservation Pool Elevation: 378 feet above mean seal level

Projection: NAD83
State Plane
Texas North Central

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 Cypress Springs. The Texas Water Development Board makes no representation or assumes any liability.

# Lake Cypress Springs - 5' Contour Map




Prepared by: TEXAS WATER DEVELOPMENT BOARD July 2007 Survey