Volumetric Survey
of
GRAPEVINE LAKE

September 2011 Survey

Texas Water Development Board

November 2012

Texas Water Development Board

Prepared for:

Dallas County Park Cities Municipal Utility District

With Support Provided by:

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

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Executive summary

In September, 2011, the Texas Water Development Board entered into agreement with Dallas County Park Cities Municipal Utility District and the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric survey of Grapevine Lake. Dallas County Park Cities Municipal Utility District 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 their Texas Water Allocation Assessments Program. Surveying was performed using a multi-frequency (200 kHz, 50 kHz, and 24 kHz), sub-bottom profiling depth sounder; although, only the 200 kHz frequency was analyzed for this report.

Grapevine Dam and Grapevine Lake are located on Denton Creek in Tarrant and Denton Counties, adjacent to the northwestern city limits of Grapevine, Texas. The conservation pool elevation of Grapevine Lake t is 535.0 feet above mean sea level (NGVD29). TWDB collected bathymetric data for Grapevine Lake between September 22, 2011, and September 30, 2011. The daily average water surface elevations during that time ranged between 530.76 and 531.07 feet above mean sea level (NGVD29).

The 2011 TWDB volumetric survey indicates that Grapevine Lake has a total reservoir capacity of 163,064 acre-feet and encompasses 6,707 acres at conservation pool elevation (535.0 feet above mean sea level, NGVD29). Previous capacity estimates based on multiple surveys conducted by the U.S. Army Corps of Engineers in 1946, 1952, 1961, and 1966 indicated Grapevine Lake's total capacity was 188,550, 187,551, 183,639, and 181,109 acre-feet, respectively. A TWDB volumetric survey conducted in 2002 was re-evaluated using current processing procedures that resulted in an updated capacity estimate of 166,802 acre-feet.

TWDB recommends that a similar methodology be used to resurvey Grapevine Lake in 10 years or after a major flood event. To further improve estimates of capacity loss, TWDB recommends a volumetric and sedimentation survey. Sedimentation surveys include additional analysis of the multi-frequency data for post-impoundment sediment by correlation with sediment core samples and a map identifying the spatial distribution of sediment throughout the reservoir.

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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 September, 2011, TWDB entered into agreement with Dallas County Park Cities Municipal Utility District and the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric survey of Grapevine Lake (TWDB, 2011a, TWDB, 2011b). Dallas County Park Cities Municipal Utility District 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 their Texas Water Allocation Assessments Program. This report describes the methods used to conduct the volumetric survey, including data collection and processing techniques. This report serves as the final contract deliverable from TWDB to the Dallas County Park Cities Municipal Utility District and 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 5], and (3) a shaded relief plot of the reservoir bottom [Figure 3].

Grapevine Lake general information

Grapevine Dam and Grapevine Lake are located on Denton Creek, a tributary of Elm Fork Trinity River (Trinity River Basin), in Tarrant and Denton Counties, adjacent to the northwestern city limits of Grapevine, Texas (Figure 1). Grapevine Dam and Grapevine Lake are owned and operated by the U.S. Army Corps of Engineers, Fort Worth District. Grapevine Lake was built primarily for water supply and flood control (TWDB, 2002). Construction on Grapevine Dam began in January, 1948, and was completed on June 6, 1952. Deliberate impoundment began on July 3, 1952 (TWDB, 1973). Additional pertinent data about Grapevine Dam and Grapevine Lake can be found in Table 1.

Water rights for Grapevine Lake have been appropriated to Dallas County Park Cities Municipal Utility District through Certificate of Adjudication and amendment Nos. 08-2363 and 08-2363A; the City of Dallas through Certificate of Adjudication and amendment Nos. 08-2458, 08-2458A, 08-2458B, and 08-2458C; and the City of Grapevine through Certificate of Adjudication and amendment Nos. 08-2362 and 08-2362A. The

complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

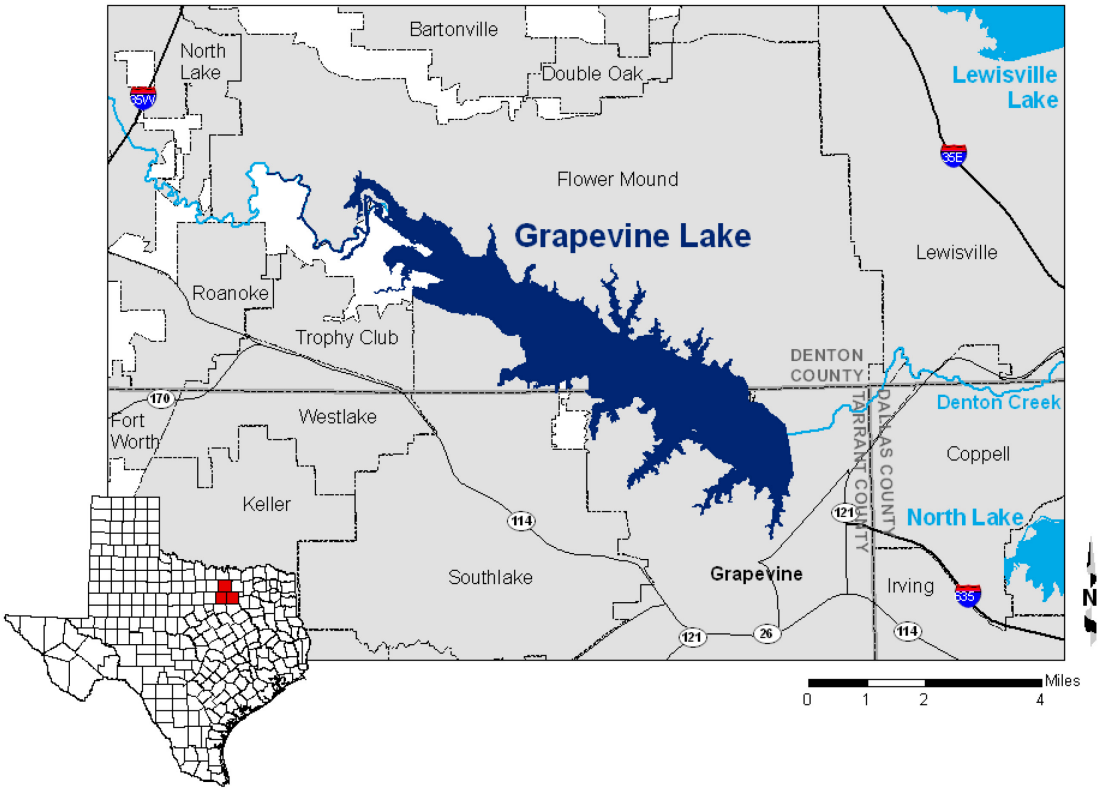

Figure 1. Location of Grapevine Lake

Table 1. Pertinent data for Grapevine Dam and Grapevine 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 Denton Creek in Tarrant County, 2 miles northeast of Grapevine	
Drainage area	695 square miles	
Dam		
	Type	Earthfill
	Length	12,850 feet including the spillway
	Maximum height	137 feet
	Top width	28 feet
Spillway		
	Type	Ogee
	Length	500 feet
	Crest elevation	560.0 feet above mean sea level
	Control	None
Outlet works		
	Type	1 conduit
	Size	13 feet diameter with two inlets
	Control	2 gates, each 6.5 by 13 feet
	Invert elevation	475.0 feet above mean sea level
Low flow outlets		
	Type	2 steel pipes
	Size	Each 30 inches in diameter
	Lowest invert elevation	500.5 feet above mean sea level

Reservoir data (based on 2011 TWDB survey)

Feature	Elevation (feet NGVD29a)	Capacity (acre-feet)	Area (acres)
Top of dam	588.0	N/A	N/A
Maximum design water surface	581.0	N/A	N/A
Top flood control storage space	560.0	N/A	N/A
Top conservation storage space	535.0	163,064	6,707
Invert of lowest outlet	475.0	0	0
Streambed	451.0	0	0
Usable conservation storage space	-	163,064	-

Volumetric and sedimentation survey of Grapevine 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 08054500 Grapevine Lk nr Grapevine, TX* (USGS, 2011). Elevations herein are reported in feet above mean sea level relative to the NGVD29 datum. Volume and area calculations in this report are referenced to water levels provided by the USGS gage. The horizontal datum used for this report is North American

Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas North Central Zone (feet).

TWDB bathymetric data collection

TWDB collected bathymetric data for Grapevine Lake between September 22, 2011, and September 30, 2011. The daily average water surface elevations during that time ranged between 530.76 and 531.07 feet above mean sea level (NGVD29). For data collection, TWDB used a Specialty Devices, Inc., single-beam, multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment. Data collection occurred while navigating along pre-planned 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 2002 survey. The depth sounder was calibrated daily using a velocity profiler to measure the speed of sound in the water column and a weighted tape or stadia rod for depth reading verification. Figure 2 shows where data collection occurred during the 2011 TWDB survey.

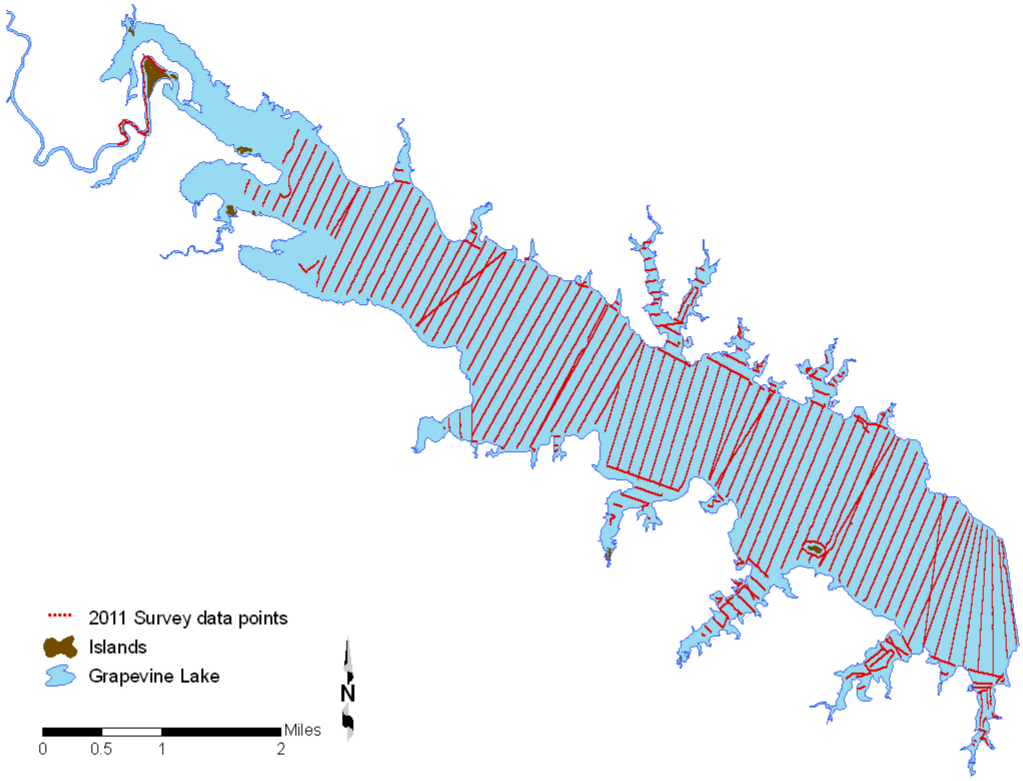

Figure 2. Data collected during 2011 TWDB Grapevine Lake survey

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 (TNIRIS, 2009) using Environmental Systems Research Institute's ArcGIS 9.3.1 software. The quarter-quadrangles that cover Grapevine Lake are Grapevine (NW, NE), Argyle (SW, SE), Colleyville (NE), and Lewisville West (SW). The DOQQs were photographed on July 17, 2010, while the daily average water surface elevation measured 535.02 feet above mean sea level. According to the associated metadata, the 2010 DOQQS have a resolution of 1.0-meters and a horizontal accuracy within + / - 6 meters to absolute ground control (USDA, 2011, TNRIS, 2010). For this analysis, the boundary digitized at the land-water interface in the 2010 photographs is assumed to be a good approximation of the reservoir boundary at conservation pool elevation. Therefore, the delineated boundary was given an elevation of 535.0 feet above mean sea level to facilitate calculating the area-capacity tables up to the conservation pool elevation.

Triangulated Irregular Network model

Following completion of data collection, the raw data was edited using DepthPic. DepthPic is used to display, interpret, and edit the multi-frequency data and to manually identify the current reservoir-bottom surface from the 200 kHz signal returns. Following the identification of this surface, a TWDB software package HydroTools, is used for further processing (McEwen et al., 2011a or b). The software calculates the current reservoir–bottom surface and outputs the data into a single file (McEwen et al., 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 reservoir (McEwen et al., 2011a or b). 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

Using ArcInfo software and the TIN model, volumes and areas were calculated for the entire reservoir at 0.1 feet intervals, from elevation 475.9 to 535.0 feet. 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 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 Grapevine Lake; and a 5-foot contour map (Figure 5 - attached).

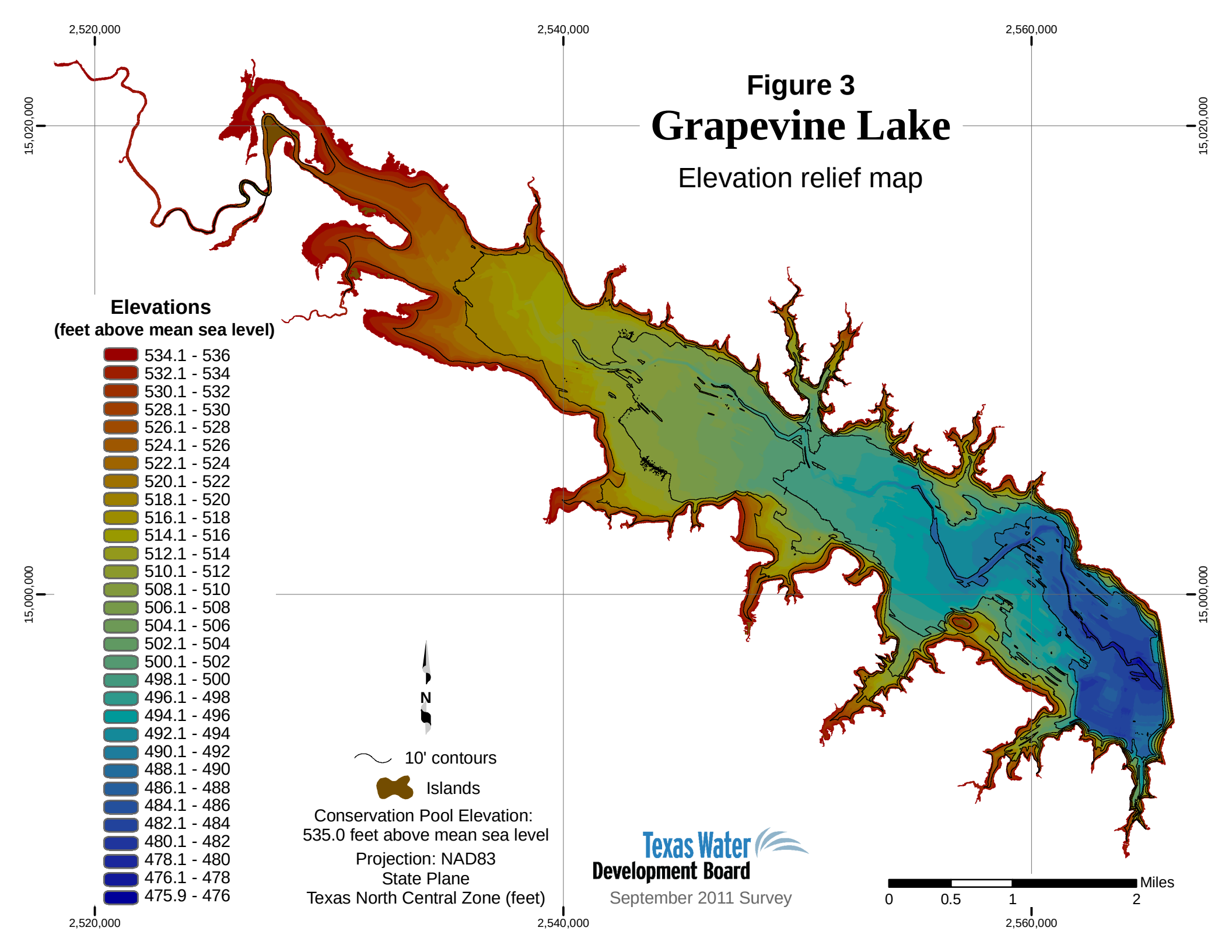
Figure 3
Grapevine Lake
Elevation relief map
2,520,000
2,540,000
2,560,000
15,020,000
15,000,000
Elevations
(feet above mean sea level)
534.1 - 536
532.1 - 534
530.1 - 532
528.1 - 530
526.1 - 528
524.1 - 526
522.1 - 524
520.1 - 522
518.1 - 520
516.1 - 518
514.1 - 516
512.1 - 514
510.1 - 512
508.1 - 510
506.1 - 508
504.1 - 506
502.1 - 504
500.1 - 502
498.1 - 500
496.1 - 498
494.1 - 496
492.1 - 494
490.1 - 492
488.1 - 490
486.1 - 488
484.1 - 486
482.1 - 484
480.1 - 482
478.1 - 480
476.1 - 478
475.9 - 476
N
10' contours
Islands
Conservation Pool Elevation:
535.0 feet above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone (feet)
Texas Water Development Board
September 2011 Survey
Miles
0
0.5
1
2

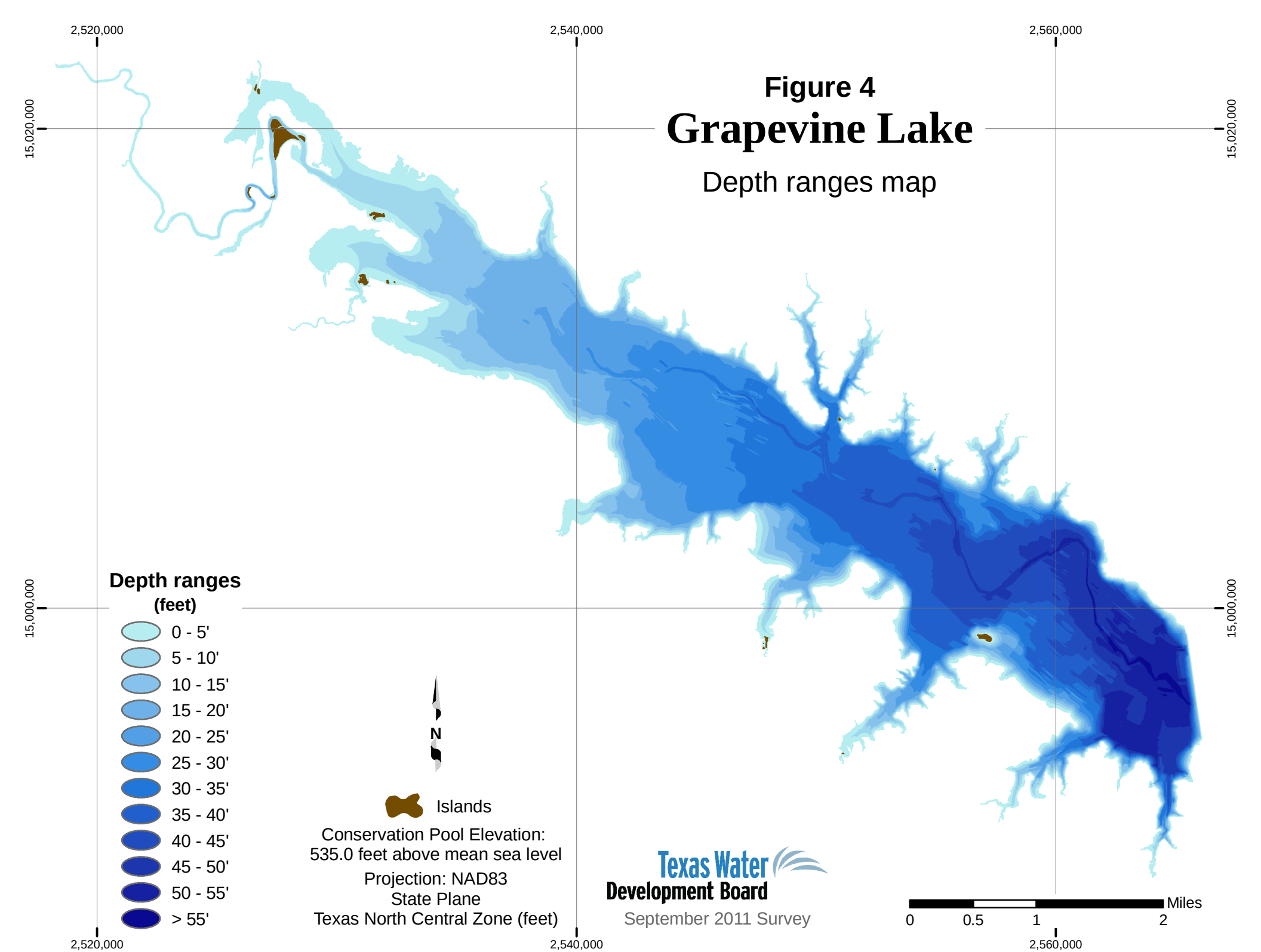
Figure 4
Grapevine Lake
Depth ranges map
2,520,000
2,540,000
2,560,000
15,020,000
15,000,000
Depth ranges
(feet)
0 - 5'
5 - 10'
10 - 15'
15 - 20'
20 - 25'
25 - 30'
30 - 35'
35 - 40'
40 - 45'
45 - 50'
50 - 55'
> 55'
N
Islands
Conservation Pool Elevation:
535.0 feet above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone (feet)
Texas Water Development Board
September 2011 Survey
Miles
0
0.5
1
2

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 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. No known external data sources were available for Grapevine Lake.

Using the survey data, polygons are created to partition the reservoir 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 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 or b).

In areas inaccessible to survey data collection such as small coves and shallow upstream areas of the reservoir, linear extrapolation is used for volumetric estimations. The linear extrapolation follows a linear definition file linking the survey points file to the reservoir boundary file (McEwen et al, 2011a). Figure 6 illustrates typical results from

application of the anisotropic interpolation and line extrapolation techniques to Grapevine Lake. The bathymetry shown in Figure 6C was used in computing reservoir capacity and area tables (Appendix A, B).

In Figure 6B, deeper channels indicated by surveyed cross sections are not continuously represented in areas between survey cross sections. This is an artifact of the TIN generation routine rather than an accurate representation of the physical bathymetric surface. Inclusion of interpolation points, represented in Figure 6C, in creation of the volumetric TIN model directs Delaunay triangulation to better represent the reservoir bathymetry between survey cross-sections.

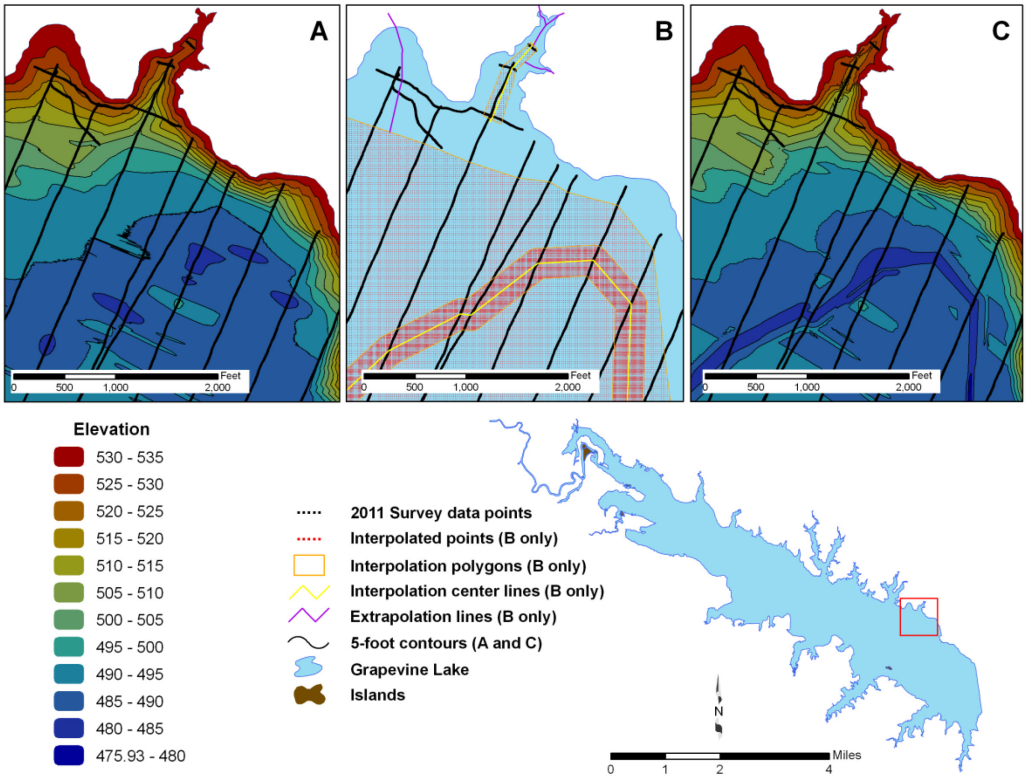

Figure 6. **Anisotropic spatial interpolation and line extrapolation of Grapevine Lake sounding data – A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red), C) bathymetric contours with the interpolated points**

Survey results

Volumetric survey

The results of the 2011 TWDB volumetric survey indicate Grapevine Lake has a total reservoir capacity of 163,064 acre-feet and encompasses 6,707 acres at conservation pool elevation (535.0 feet above mean sea level, NGVD29). Previous capacity estimates include multiple surveys conducted by the U.S. Army Corps of Engineers in 1946, 1952, 1961, and 1966, and a re-analysis of the 2002 TWDB volumetric survey data using current processing procedures (Table 2). Differences in past and present survey methodologies make direct comparison of volumetric surveys difficult and potentially unreliable.

To properly compare results from TWDB surveys of Grapevine Lake, TWDB applied the 2012 data processing techniques to the survey data collected in 2002. Specifically, TWDB applied anisotropic spatial interpolation to the 2002 survey dataset using the same interpolation definition file as was used for the 2011 survey. A revised TIN model was created using the original 2002 survey boundary. The 2002 survey model boundary was created from the 540 feet contour from the USGS 7.5 minute quadrangle maps, with additional boundary information from DOQQs. The DOQQs were photographed on January 19, and 31, 1995, and January 11, 1996, while the daily average water surface elevation of Grapevine Lake measured 534.65, 534.86, and 530.24 feet above mean sea level, respectively. USGS 7.5 minute quadrangle maps have a stated accuracy of ± 1/2 the contour interval (USBB, 1947). 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. Revision of the 2002 survey using current TWDB data processing methods resulted in a 2,099 acre-feet (1.3%) increase in reservoir capacity.

Table 2. Current and previous survey capacity and surface area data

Survey	Surface area (acres)	Capacity (acre-feet)
USACE 1946[a]	7,380	188,550
USACE 1952[b]	7,377	188,543
USACE 1952 revised[b]	7,414	187,551
USACE 1961[b]	7,302	183,639
USACE 1966[b]	7,276	181,109
TWDB 2002	6,893	164,703
TWDB 2002 revised	6,905	166,802
TWDB 2010	6,707	163,064

[a] Source: (TWDB, 1973)
[b] Source: (TWDB, 2002)

In principle, comparing reservoir volumes from multiple reservoir surveys allows for calculation of capacity loss rates. If all lost capacity is due to sediment accumulation, then comparisons of reservoir volumetric surveys would yield sediment accumulation rates. In practice, however, the differences in methodologies used in each reservoir survey may yield greater differences in computed reservoir 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 only, a capacity loss rate, i.e. sedimentation rate, was calculated for the difference between the current volumetric survey and the 1946 estimate; the current volumetric survey and the 1952 revised estimate; the current volumetric survey and the 1961 estimate; the current volumetric survey and the 1966 estimate; as well as the current volumetric capacity estimation and the revised 2002 volumetric capacity estimation (Table 3). The comparison of the current volumetric survey to the 2002 revised volumetric survey suggests the current rate of sedimentation in Grapevine Lake is approximately 426 acre-feet per year. Comparison of capacity estimates of Grapevine Lake derived using differing methodologies are provided in Table 3 for sedimentation rate calculation.

Table 3. Capacity loss comparisons for Grapevine Lake

Survey	Volume comparisons @ CPE (acre-feet)				
USACE 1946[a]	188,550	<>	<>	<>	<>
USACE 1952 (revised)[b]	<>	187,551	<>	<>	<>
USACE 1961[b]	<>	<>	183,639	<>	<>
USACE 1966[b]	<>	<>	<>	181,109	<>
TWDB 2002 (revised)	<>	<>	<>	<>	166,802
TWDB 2011	163,064	163,064	163,064	163,064	163,064
Volume difference (acre-feet)	25,486 (13.5%)	24,487 (13.0%)	20,575 (11.2%)	18,045 (10.0%)	3,838 (2.2%)
Number of years	65	59	50	45	9
Capacity loss rate (acre-feet/year)	392	415	412	401	426

[a] Source: (TWDB, 1973), note: Grapevine Dam was completed on June 6, 1952, and deliberate impoundment began on July 3, 1952.
[b] Source: (USACE, 1971)

Recommendations

To improve estimates of capacity loss rates, TWDB recommends resurveying Grapevine Lake in approximately 10 years or after a major flood event. To further improve estimates of capacity loss, TWDB recommends a volumetric and sedimentation survey. Sedimentation surveys include additional analysis of the multi-frequency data for post-impoundment sediment by correlation with sediment core samples and a map identifying the spatial distribution of sediment throughout the reservoir.

TWDB contact information

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

http://www.twdb.texas.gov/assistance/lakesurveys/volumetricindex.asp

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

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Or

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Director, Surface Water Resources Division
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Email: Ruben.Solis@twdb.texas.gov

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Appendix A

Grapevine Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — September 2011 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 535.0 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
475	0	0	0	0	0	0	0	0	0	0
476	0	0	0	0	1	1	1	2	2	3
477	3	4	5	5	6	7	8	9	10	11
478	12	13	14	15	16	18	19	20	22	23
479	25	26	28	29	31	33	35	37	39	41
480	43	46	48	51	54	56	59	62	65	68
481	71	75	78	81	85	89	93	98	102	108
482	113	119	126	133	141	149	158	168	178	189
483	201	214	227	241	256	272	289	307	326	346
484	367	388	410	433	457	481	507	533	561	590
485	620	651	683	716	750	785	821	858	895	934
486	974	1,014	1,056	1,099	1,143	1,188	1,233	1,280	1,327	1,375
487	1,423	1,473	1,522	1,573	1,624	1,675	1,727	1,780	1,834	1,888
488	1,943	1,999	2,055	2,112	2,169	2,228	2,287	2,347	2,407	2,468
489	2,530	2,593	2,656	2,719	2,783	2,848	2,914	2,980	3,047	3,114
490	3,183	3,252	3,322	3,392	3,463	3,535	3,607	3,680	3,753	3,827
491	3,902	3,978	4,054	4,131	4,209	4,287	4,367	4,447	4,528	4,610
492	4,693	4,776	4,861	4,946	5,032	5,120	5,208	5,298	5,389	5,481
493	5,574	5,668	5,764	5,861	5,959	6,058	6,158	6,260	6,363	6,466
494	6,571	6,677	6,785	6,893	7,003	7,115	7,228	7,342	7,458	7,576
495	7,695	7,816	7,939	8,063	8,189	8,316	8,445	8,577	8,709	8,844
496	8,980	9,118	9,258	9,398	9,541	9,684	9,830	9,976	10,124	10,273
497	10,423	10,575	10,728	10,882	11,037	11,193	11,351	11,510	11,670	11,832
498	11,995	12,159	12,325	12,493	12,662	12,833	13,004	13,178	13,353	13,529
499	13,708	13,888	14,070	14,254	14,439	14,627	14,816	15,006	15,198	15,392
500	15,587	15,783	15,981	16,180	16,380	16,581	16,784	16,988	17,193	17,400
501	17,608	17,816	18,026	18,237	18,449	18,662	18,876	19,091	19,306	19,523
502	19,741	19,960	20,180	20,401	20,623	20,847	21,072	21,297	21,524	21,751
503	21,980	22,210	22,442	22,675	22,909	23,144	23,380	23,617	23,855	24,094
504	24,334	24,575	24,817	25,060	25,304	25,549	25,795	26,043	26,292	26,542
505	26,794	27,048	27,303	27,558	27,816	28,074	28,334	28,594	28,856	29,119
506	29,384	29,650	29,917	30,186	30,456	30,728	31,002	31,278	31,555	31,834
507	32,115	32,398	32,682	32,968	33,255	33,545	33,836	34,128	34,422	34,718
508	35,016	35,316	35,617	35,920	36,224	36,529	36,836	37,145	37,455	37,768
509	38,081	38,396	38,713	39,031	39,351	39,673	39,996	40,320	40,646	40,974
510	41,305	41,637	41,971	42,307	42,644	42,984	43,325	43,668	44,012	44,357
511	44,703	45,051	45,400	45,751	46,103	46,456	46,810	47,166	47,523	47,881
512	48,241	48,602	48,964	49,327	49,692	50,057	50,424	50,792	51,161	51,531
513	51,902	52,274	52,647	53,021	53,396	53,772	54,149	54,527	54,906	55,286
514	55,667	56,048	56,431	56,815	57,199	57,585	57,972	58,360	58,749	59,139
515	59,529	59,921	60,314	60,708	61,104	61,502	61,901	62,302	62,703	63,106
516	63,509	63,915	64,321	64,729	65,138	65,548	65,960	66,374	66,789	67,206
517	67,625	68,045	68,467	68,891	69,315	69,741	70,168	70,597	71,026	71,457
518	71,889	72,322	72,757	73,192	73,629	74,068	74,507	74,948	75,390	75,834
519	76,280	76,726	77,174	77,623	78,074	78,527	78,980	79,435	79,890	80,347
520	80,804	81,263	81,722	82,184	82,646	83,109	83,573	84,039	84,505	84,972
521	85,440	85,908	86,378	86,849	87,321	87,795	88,269	88,745	89,221	89,699
522	90,178	90,659	91,141	91,624	92,108	92,593	93,079	93,567	94,056	94,547
523	95,038	95,530	96,024	96,519	97,016	97,513	98,011	98,511	99,012	99,514
524	100,017	100,521	101,026	101,533	102,041	102,550	103,060	103,571	104,083	104,597
525	105,111	105,627	106,144	106,662	107,181	107,702	108,223	108,746	109,271	109,797
526	110,325	110,854	111,385	111,918	112,453	112,989	113,527	114,066	114,606	115,148
527	115,690	116,234	116,779	117,326	117,873	118,422	118,972	119,523	120,074	120,627
528	121,181	121,736	122,292	122,849	123,407	123,965	124,525	125,086	125,648	126,211

Appendix A (Continued)

Grapevine Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — September 2011 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 535.0 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
529	126,775	127,340	127,906	128,473	129,042	129,611	130,181	130,753	131,325	131,899
530	132,474	133,050	133,627	134,205	134,785	135,366	135,947	136,531	137,115	137,701
531	138,288	138,876	139,466	140,057	140,649	141,243	141,838	142,435	143,032	143,632
532	144,232	144,834	145,438	146,044	146,651	147,259	147,869	148,480	149,093	149,708
533	150,325	150,943	151,563	152,185	152,809	153,434	154,061	154,690	155,321	155,954
534	156,589	157,226	157,866	158,507	159,151	159,796	160,445	161,096	161,749	162,405
535	163,064									

Appendix B

Grapevine Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — September 2011 Survey

AREA IN ACRES — Conservation Pool Elevation 535.0 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
475	0	0	0	0	0	0	0	0	0	0
476	1	1	1	2	3	3	4	5	5	6
477	6	6	7	7	8	9	9	10	10	10
478	11	11	11	12	12	13	13	13	14	15
479	15	16	16	17	18	18	19	20	21	23
480	24	25	26	26	27	28	29	30	30	31
481	32	33	34	35	37	41	43	47	50	53
482	58	63	69	75	80	86	93	101	108	115
483	122	129	138	147	155	163	175	185	193	203
484	211	218	225	233	241	251	261	272	282	294
485	304	315	325	336	346	354	363	372	382	392
486	402	412	423	434	444	453	462	468	475	482
487	488	495	501	506	512	518	525	532	540	546
488	553	559	566	573	580	587	595	602	609	614
489	620	627	633	640	646	652	658	664	671	680
490	687	694	701	707	713	719	725	732	739	746
491	752	759	766	773	781	790	798	807	815	823
492	831	840	849	858	868	879	890	902	915	926
493	938	951	963	976	986	996	1,009	1,021	1,032	1,044
494	1,055	1,066	1,080	1,094	1,107	1,121	1,136	1,152	1,169	1,185
495	1,202	1,218	1,234	1,249	1,266	1,284	1,302	1,320	1,338	1,353
496	1,370	1,387	1,403	1,416	1,430	1,445	1,458	1,471	1,484	1,497
497	1,510	1,523	1,535	1,546	1,556	1,568	1,583	1,598	1,611	1,624
498	1,636	1,652	1,669	1,684	1,697	1,710	1,726	1,742	1,758	1,774
499	1,792	1,810	1,828	1,846	1,865	1,882	1,898	1,913	1,928	1,943
500	1,956	1,970	1,984	1,996	2,007	2,020	2,034	2,048	2,060	2,072
501	2,083	2,093	2,103	2,114	2,124	2,133	2,143	2,154	2,164	2,174
502	2,184	2,194	2,206	2,217	2,229	2,241	2,251	2,260	2,271	2,283
503	2,295	2,308	2,321	2,334	2,346	2,357	2,367	2,376	2,385	2,394
504	2,404	2,414	2,424	2,435	2,445	2,456	2,471	2,483	2,498	2,512
505	2,526	2,540	2,555	2,566	2,577	2,590	2,601	2,613	2,625	2,639
506	2,653	2,666	2,680	2,695	2,711	2,729	2,747	2,765	2,783	2,799
507	2,818	2,835	2,851	2,868	2,884	2,901	2,917	2,934	2,952	2,970
508	2,988	3,004	3,019	3,033	3,047	3,062	3,079	3,096	3,112	3,128
509	3,144	3,160	3,175	3,190	3,207	3,222	3,238	3,254	3,271	3,291
510	3,311	3,331	3,350	3,369	3,388	3,405	3,419	3,432	3,445	3,457
511	3,471	3,486	3,499	3,513	3,525	3,537	3,551	3,565	3,577	3,588
512	3,601	3,616	3,629	3,640	3,650	3,661	3,674	3,685	3,695	3,706
513	3,716	3,725	3,736	3,745	3,755	3,764	3,774	3,784	3,794	3,803
514	3,812	3,822	3,831	3,842	3,853	3,865	3,874	3,883	3,892	3,901
515	3,912	3,924	3,937	3,951	3,970	3,984	3,998	4,009	4,019	4,032
516	4,046	4,059	4,071	4,082	4,098	4,112	4,126	4,148	4,163	4,178
517	4,196	4,212	4,227	4,239	4,252	4,264	4,277	4,290	4,302	4,314
518	4,326	4,339	4,351	4,364	4,376	4,390	4,403	4,416	4,430	4,445
519	4,459	4,472	4,487	4,502	4,516	4,528	4,540	4,552	4,561	4,570
520	4,580	4,589	4,604	4,619	4,629	4,638	4,647	4,656	4,665	4,674
521	4,682	4,691	4,703	4,718	4,729	4,739	4,750	4,761	4,773	4,784
522	4,799	4,812	4,824	4,836	4,847	4,859	4,871	4,883	4,896	4,908
523	4,919	4,932	4,945	4,957	4,968	4,979	4,990	5,002	5,014	5,024
524	5,036	5,047	5,059	5,072	5,085	5,096	5,107	5,118	5,129	5,140
525	5,152	5,162	5,173	5,186	5,198	5,209	5,223	5,238	5,254	5,271
526	5,285	5,301	5,322	5,339	5,356	5,371	5,383	5,395	5,407	5,419
527	5,431	5,446	5,459	5,470	5,481	5,492	5,503	5,513	5,523	5,534
528	5,544	5,554	5,564	5,574	5,584	5,594	5,604	5,614	5,624	5,634

Appendix B (Continued)

Grapevine Lake

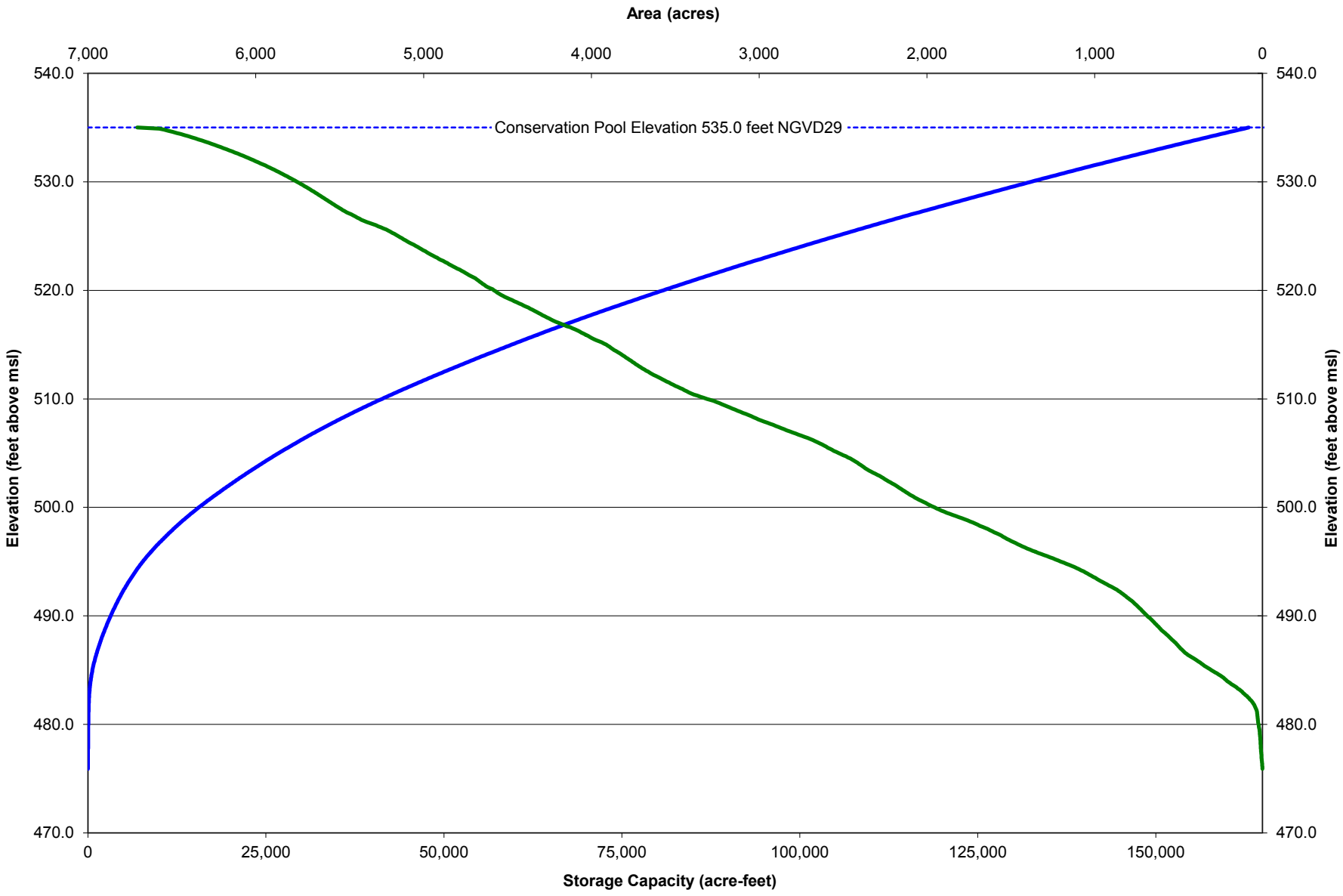
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — September 2011 Survey

AREA IN ACRES — Conservation Pool Elevation 535.0 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
529	5,645	5,655	5,666	5,676	5,687	5,698	5,709	5,720	5,731	5,743
530	5,754	5,766	5,778	5,790	5,802	5,814	5,826	5,839	5,851	5,864
531	5,877	5,890	5,903	5,916	5,930	5,944	5,958	5,972	5,986	6,000
532	6,015	6,030	6,045	6,060	6,076	6,091	6,107	6,124	6,140	6,157
533	6,174	6,191	6,209	6,227	6,245	6,263	6,282	6,300	6,320	6,340
534	6,360	6,381	6,403	6,425	6,447	6,471	6,495	6,521	6,547	6,575
535	6,707									



Grapevine Lake
September 2011 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Grapevine Lake

5' - contour map

Figure 5

CONTOURS
(feet above mean sea level)

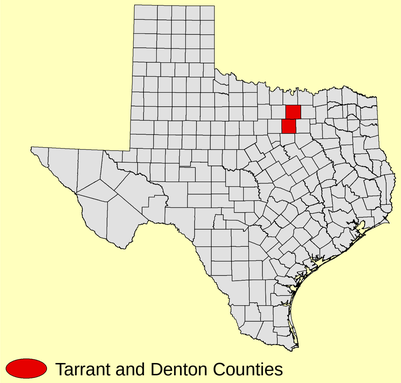
530
525
520
515
510
505
500
495
490
485
480

Islands

Grapevine Lake

Conservation Pool Elevation
535.0 feet above mean sea level

Projection: NAD83
State Plane
Texas North Central Zone



Tarrant and Denton Counties

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

Texas Water Development Board

September 2011 survey

2,380,000 2,390,000 2,400,000 2,410,000

7,060,000 7,050,000 7,040,000

N

0 0.5 1 2 Miles