Volumetric and Sedimentation Survey of NIMITZ LAKE

November 2015 Survey

Texas Water Development Board

August 2016

Texas Water Development Board

Prepared for:

City of Kerrville

With Support Provided by:

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Executive summary

In August 2015, the Texas Water Development Board (TWDB) entered into an agreement with the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Nimitz Lake (Kerr County, TX). The City of Kerrville provided 50 percent of the funding for this survey, while the U.S. Army Corps of Engineers, Fort Worth District, provided the remaining 50 percent of the funding through their Planning Assistance to States Program. Surveying was performed using a multi-frequency (208 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.

Nimitz Lake Dam and Nimitz Lake are located on the Guadalupe River, in Kerr County, within the city limits of Kerrville, Texas. The conservation pool elevation of Nimitz Lake is 1,621.0 feet above mean sea level (NGVD29). The TWDB collected bathymetric data for Nimitz Lake on November 10, 2015. Daily average water surface elevation during the survey measured 1,621.5 feet above mean sea level (NGVD29).

The 2015 TWDB volumetric survey indicates that Nimitz Lake has a total reservoir capacity of 735 acre-feet and encompasses 95 acres at conservation pool elevation (1,621.0 feet above mean sea level, NGVD29). According to the Permits to Appropriate State Water issued by the Texas Commission on Environmental Quality, the City of Kerrville is authorized to impound a maximum of 840 acre-feet of water in Nimitz Lake.

The 2015 TWDB sedimentation survey measured 74 acre-feet of sediment below conservation pool elevation (1,621.0 feet NGVD29). Sediment accumulation is greatest in the upper reaches, from Highway 98 to approximately 1,800 feet downstream from the highway where water depths are relatively shallow. Additional heavy deposits occur near the dam beginning 1,800 feet upstream from the dam and continuing towards the dam. The TWDB recommends that a similar methodology be used to resurvey Nimitz 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. Texas Water Code Section 15.804 authorizes the TWDB to perform surveys to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability.

In August 2015, the TWDB entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Nimitz Lake. The City of Kerrville provided 50 percent of the funding for this survey, while the U.S. Army Corps of Engineers, Fort Worth District, provided the remaining 50 percent of the funding through their Planning Assistance to States Program (TWDB 2015). 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 the TWDB to the City of Kerrville and the U.S. Army Corps of Engineers, Fort Worth District, and contains as deliverables: (1) a shaded relief plot of the reservoir bottom (Figure 4), (2) a bottom contour map (Figure 6), (3) an estimate of sediment accumulation and location (Figure 10), and (4) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality (Appendices A and B).

Nimitz Lake general information

Nimitz Lake Dam and Nimitz Lake are located on the Guadalupe River in Kerr County, within the city limits of Kerrville, Texas (Figure 1). The City of Kerrville owns and operates Nimitz Lake and has since April 1998, when the city purchased the reservoir from the Upper Guadalupe River Authority (S. Barron, *pers. comm.*, February 23, 2016). In 2011, the city officially renamed the reservoir Nimitz Lake in honor of World War II Navy Fleet Admiral Chester W. Nimitz (MacCormack 2011). The original plans for the dam were drawn up by Turner Collie & Braden Inc. (TCB) in 1979 (TCB 1979), and the reservoir was completed in 1980 (MacCormack 2011). In 1985, the dam washed out and emergency repairs were drawn up by Espey, Huston & Associates, Inc. (EHA). According to these plans the total length of the spillway is 598 feet long, of which 198 feet is the service spillway at elevation 1621.0 feet and 400 feet is the emergency spillway at elevation 1622.0

feet (TCB 1979, EHA 1985). The primary purpose of the reservoir is municipal water supply for the City of Kerrville and others in Kerr County (TWC 1977).

The municipal water rights for Nimitz Lake are appropriated to the City of Kerrville and the Upper Guadalupe River Authority. The complete permits are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

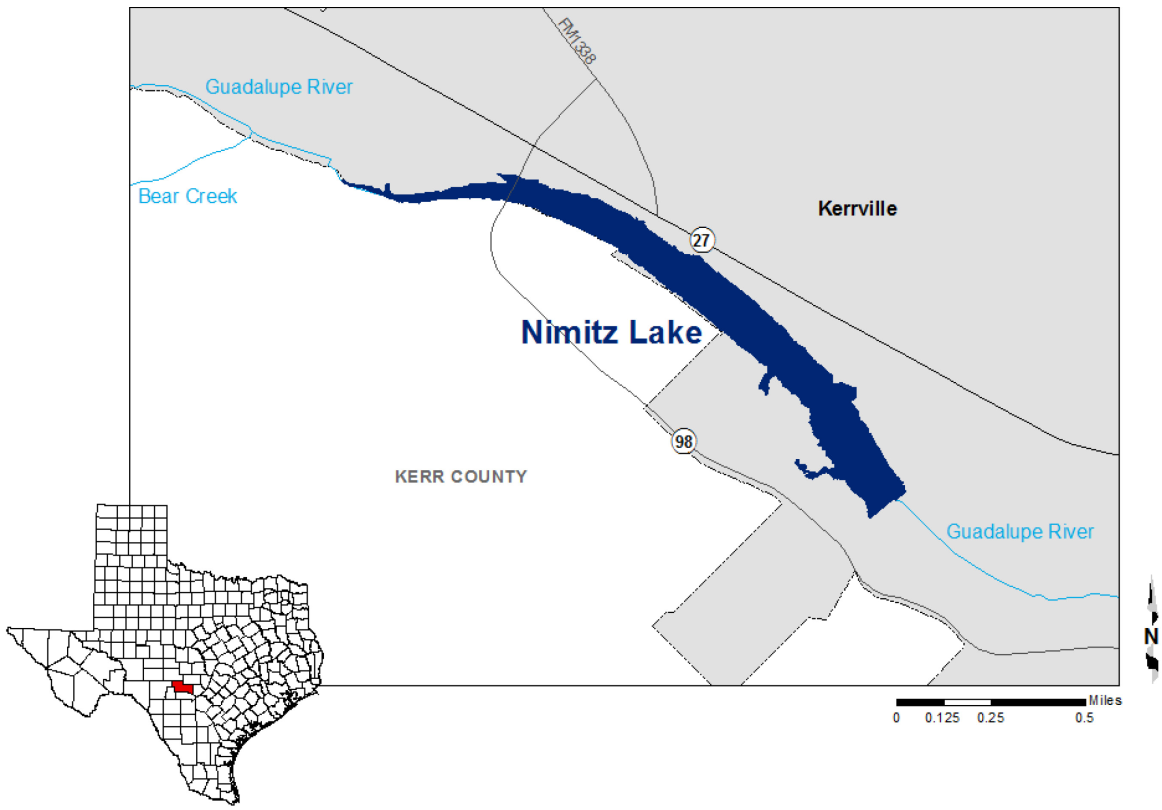


Figure 1. **Location map of Nimitz Lake.**

Volumetric and sedimentation survey of Nimitz Lake

Datum

The vertical datum used during this survey is assumed to be equivalent to the National Geodetic Vertical Datum 1929 (NGVD29). Volume and area calculations in this report are referenced to water levels provided by the City of Kerrville in feet above mean sea level. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas South Central Zone (feet).

TWDB bathymetric and sedimentation data collection

The TWDB collected bathymetric data for Nimitz Lake on November 10, 2015. Daily average water surface elevation during the survey measured 1,621.5 feet above mean sea level (NGVD29). For data collection, the TWDB used a Specialty Devices, Inc. (SDI), single-beam, multi-frequency (208 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment. Data was collected along pre-planned survey lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 250 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 collection occurred during the 2015 TWDB survey of Nimitz Lake.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples are collected at regularly spaced intervals within the reservoir, or at locations where interpretation of the acoustic display would be difficult without site-specific sediment core data. After analyzing the sounding data, the TWDB selected five locations to collect sediment core samples (Figure 2). The sediment core samples were collected on December 1, 2015, 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 the tube must be driven during sediment sampling. The goal is to collect a sediment core sample extending from the current reservoir-bottom surface, through the accumulated sediment, and to the pre-impoundment surface. After retrieving the sample, a stadia rod is inserted into the top of the aluminum tubes to assist in locating the top of the sediment in the tube. This identifies the location of the layer corresponding to the current reservoir-bottom 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.

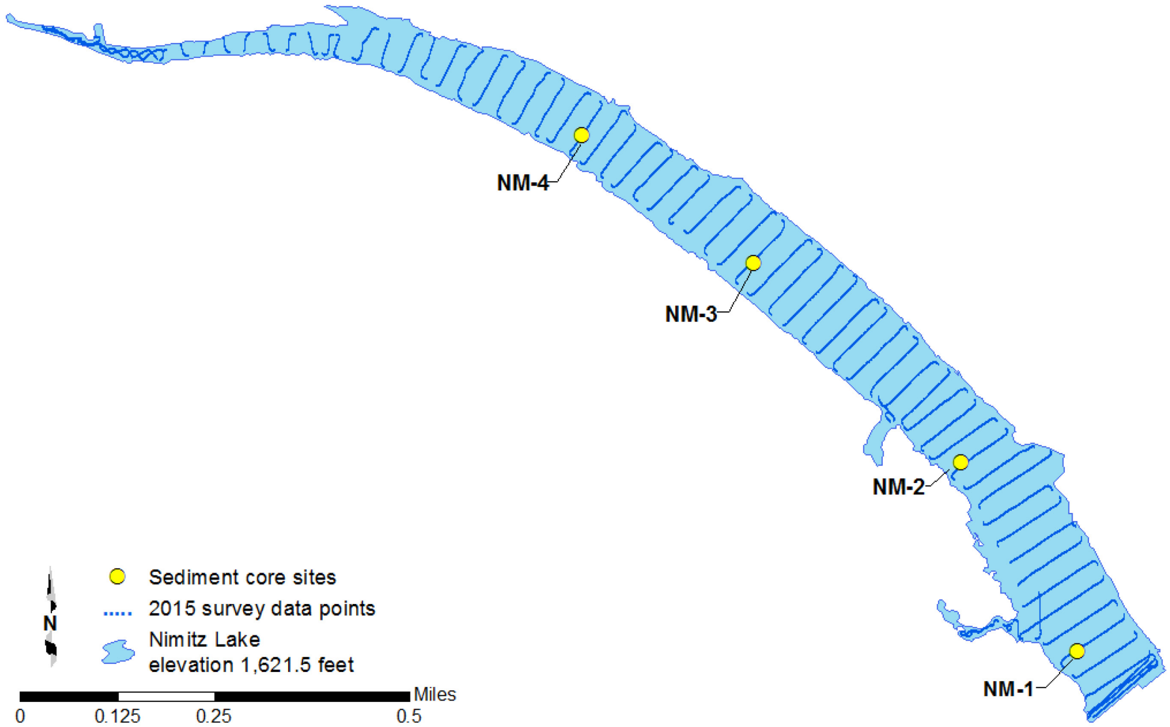


Figure 2. 2015 TWDB Nimitz Lake survey data (*blue dots*) and sediment coring locations (*yellow circles*).

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 2016) using Environmental Systems Research Institute's ArcGIS software. The quarter-quadrangles that cover Nimitz Lake are Kerrville NW, NE, and SE. The DOQQs were photographed on May 20, 2008, while the daily average water surface elevation measured 1,621.46 feet above mean sea level (S. Barron, *pers. comm.*, February 23, 2016). According to metadata associated with the 2008 DOQQs, the photographs have a resolution or ground sample distance of 0.5 meter and a horizontal accuracy within 3-5 meters to true ground (TNRIS 2016, USDA 2016). For this analysis, the boundary was digitized at the land-water interface in the 2008 photographs and assigned an elevation of 1,621.5 feet.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by the TWDB were edited to remove data anomalies. The reservoirs current bottom surface is automatically determined by the data acquisition software. DepthPic© software, developed by SDI, Inc., was used to display, interpret, and edit the multi-frequency data by manually removing data anomalies in the current bottom surface. The TWDB developed an algorithm to automatically determine the pre-impoundment surface, *i.e.*, sediment thickness, based on the intensity of the acoustic returns. Hydropick software, developed by TWDB staff and in collaboration with Enthought, Inc. (GitHub 2015a, 2015b), was used to calibrate the algorithm and manually edit the pre-impoundment surfaces in areas where the algorithm did not perform as expected. For further analysis, all data was exported into a single file, including the current reservoir bottom surface, pre-impoundment surface, and sediment thickness at each sounding location. The water surface elevation at the time of each sounding was used to convert each sounding depth to a corresponding reservoir-bottom elevation. This survey point dataset was then preconditioned by inserting a uniform grid of artificial survey points between the actual survey lines. Bathymetric elevations at these artificial points were determined using an anisotropic spatial interpolation algorithm described in the next section. This technique creates a high resolution, uniform grid of interpolated bathymetric elevation points throughout a majority of the reservoir (McEwen *et al.* 2011a). Finally, the point file resulting from spatial interpolation was used in conjunction with sounding and boundary data to create volumetric and sediment Triangulated Irregular Network (TIN) models utilizing the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithm uses Delaunay's criteria for triangulation to create a grid composed of triangles from non-uniformly spaced points, including the boundary vertices (ESRI 1995).

Spatial interpolation of reservoir bathymetry

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

To improve the accuracy of bathymetric representation between survey lines, the 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 by directly examining the survey data, or more robustly by examining scanned USGS 7.5 minute quadrangle maps (known as digital raster graphics) and hypsography files (the vector format of USGS 7.5 minute quadrangle map contours) when available. Using the survey data, polygons are created to partition the reservoir into segments with centerlines defining directionality of interpolation within each segment. For surveys with similar spatial coverage, these interpolation definition files are in principle independent of the survey data and could be applied to past and future survey data of the same reservoir. In practice, however, minor revisions of the interpolation definition files may be needed to account for differences in spatial coverage and boundary conditions between surveys. Using the interpolation definition files and survey data, the current reservoir-bottom elevation, pre-impoundment elevation, and sediment thickness are calculated for each point in the high resolution uniform grid of artificial survey points. The reservoir boundary, artificial survey points grid, and survey data points are used to create volumetric and sediment TIN models representing the reservoir bathymetry and sediment accumulation throughout the reservoir. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen *et al.* 2011a) and in McEwen *et al.* 2011b.

In areas inaccessible to survey data collection, such as small coves and shallow upstream areas of the reservoir, linear interpolation is used for volumetric and sediment accumulation estimations. Linear interpolation follows a line linking the survey points file to the lake boundary file (McEwen *et al.* 2011a). Without linearly interpolated data, the TIN model builds flat triangles. A flat triangle is defined as a triangle where all three vertices are equal in elevation, generally the elevation of the reservoir boundary. Reducing flat triangles by applying linear interpolation improves the elevation-capacity and elevation-area calculations, although it is not always possible to remove all flat triangles.

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

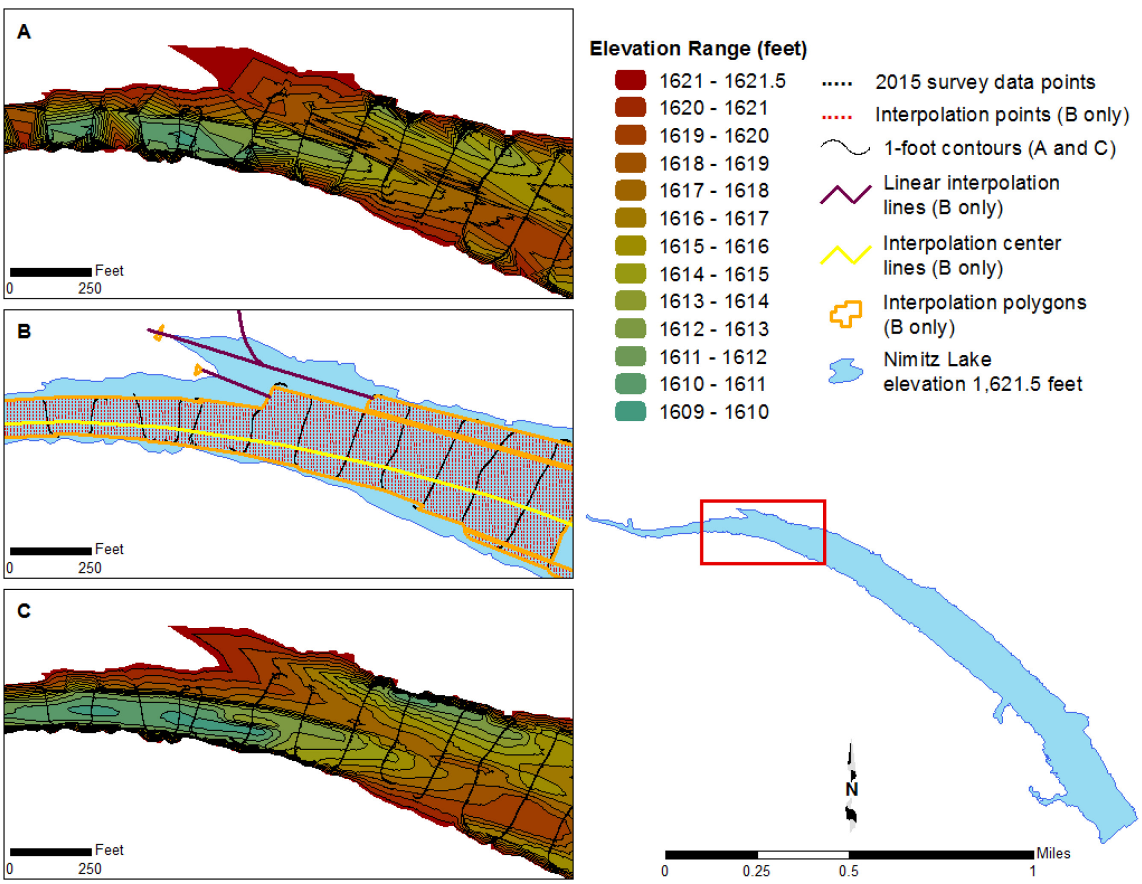


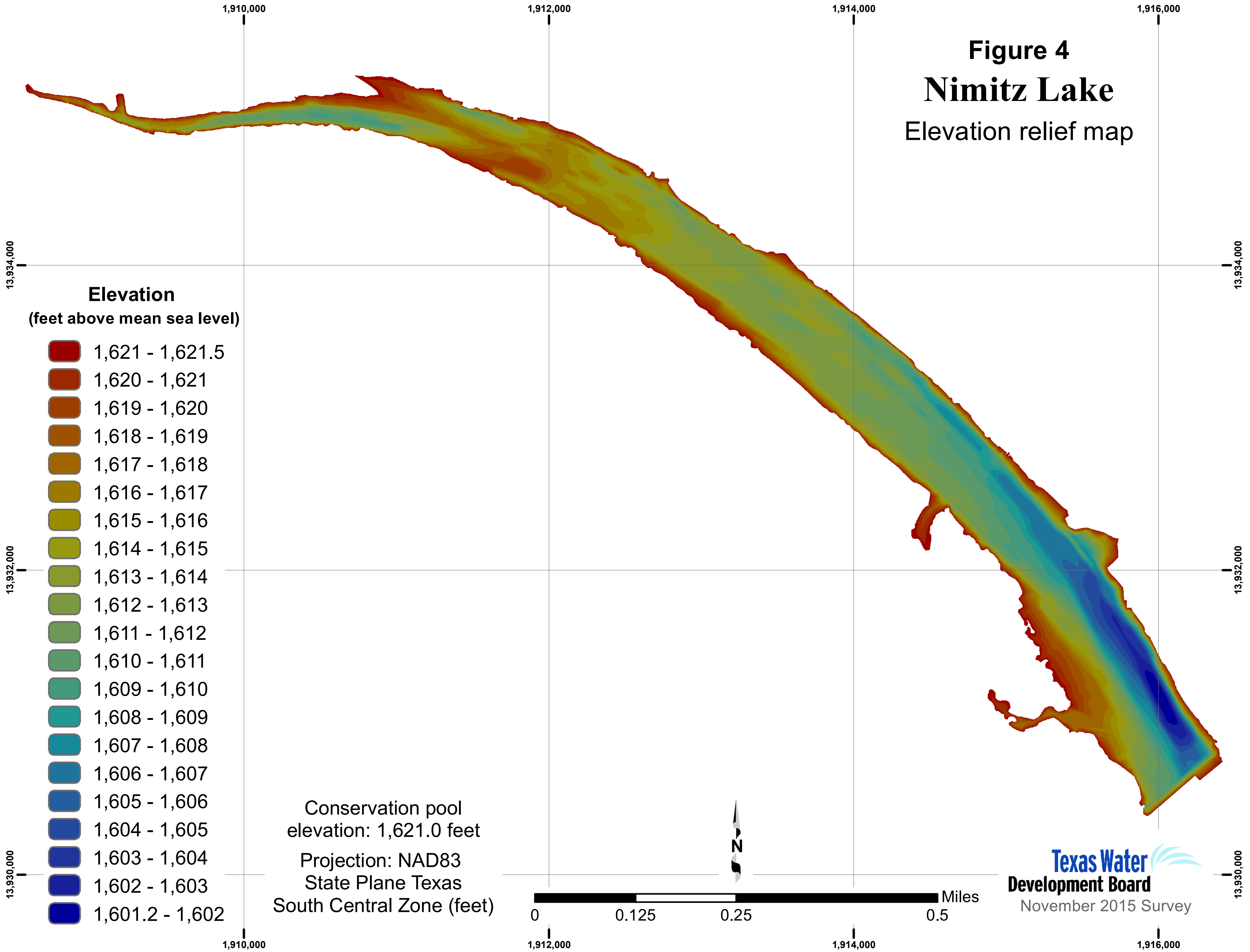
Figure 3. **Anisotropic spatial interpolation and linear interpolation of Nimitz Lake sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.**

Area, volume, and contour calculation

Using ArcInfo software and the volumetric TIN model, volumes and areas were calculated for the entire reservoir at 0.1-foot intervals, from 1,601.1 to 1,621.5 feet. The elevation-capacity table and elevation-area table, updated for 2015, are presented in Appendices A and B, respectively. The capacity curve is presented in Appendix C, and the area curve is presented in Appendix D.

The volumetric TIN model was converted to a raster representation using a cell size of 0.5 foot by 0.5 foot. The raster data was then used to produce three figures: (1) an elevation relief map representing the topography of the reservoir bottom (Figure 4); (2) a depth range map showing shaded depth ranges for Nimitz Lake (Figure 5); and, (3) a two-foot contour map (Figure 6).

Figure 4
Nimitz Lake
Elevation relief map



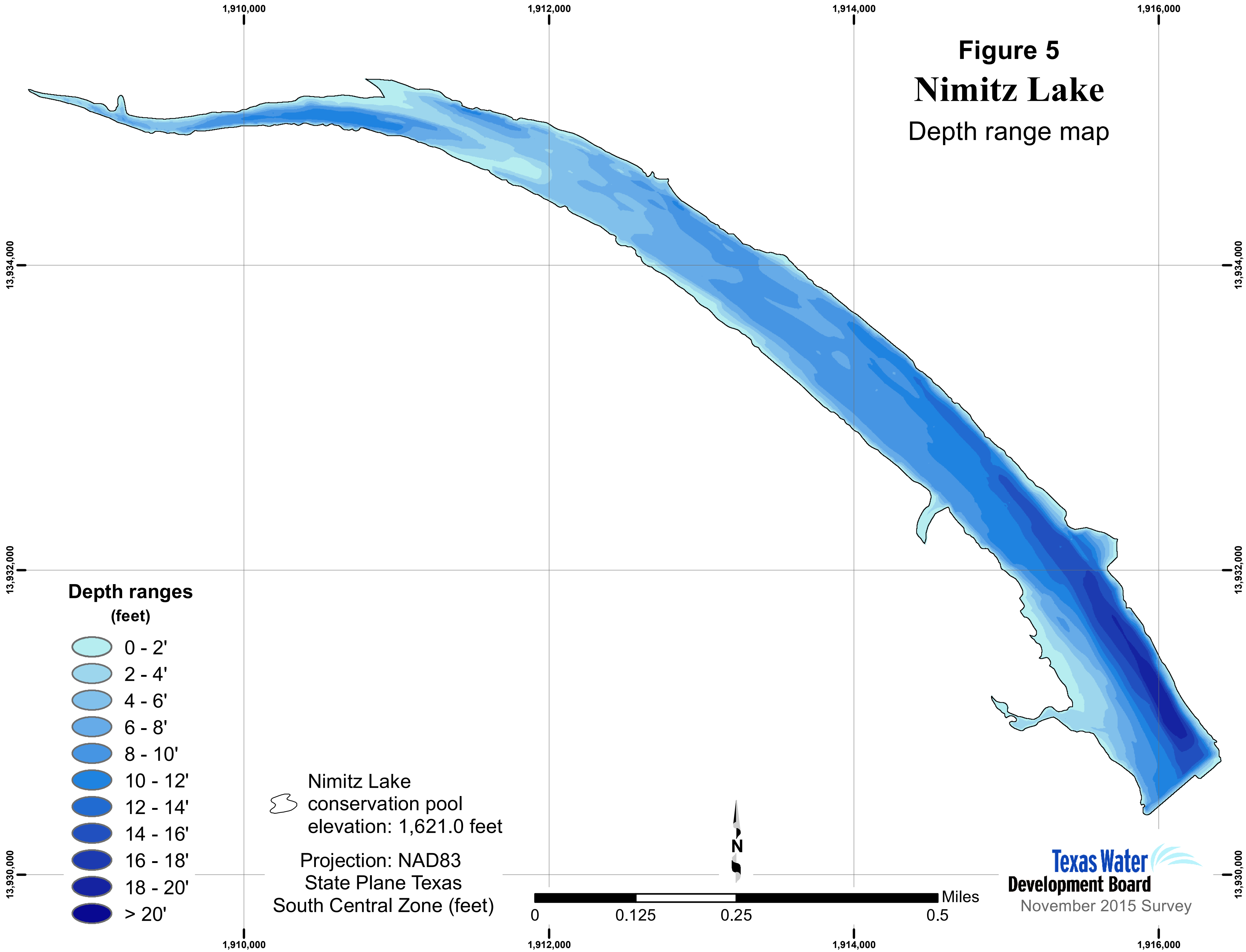


Figure 5
Nimitz Lake
Depth range map
1,910,000
1,912,000
1,914,000
1,916,000
13,934,000
13,932,000
13,930,000
Depth ranges
(feet)
0 - 2'
2 - 4'
4 - 6'
6 - 8'
8 - 10'
10 - 12'
12 - 14'
14 - 16'
16 - 18'
18 - 20'
> 20'
Nimitz Lake
conservation pool
elevation: 1,621.0 feet
Projection: NAD83
State Plane Texas
South Central Zone (feet)
N
Miles
0
0.125
0.25
0.5
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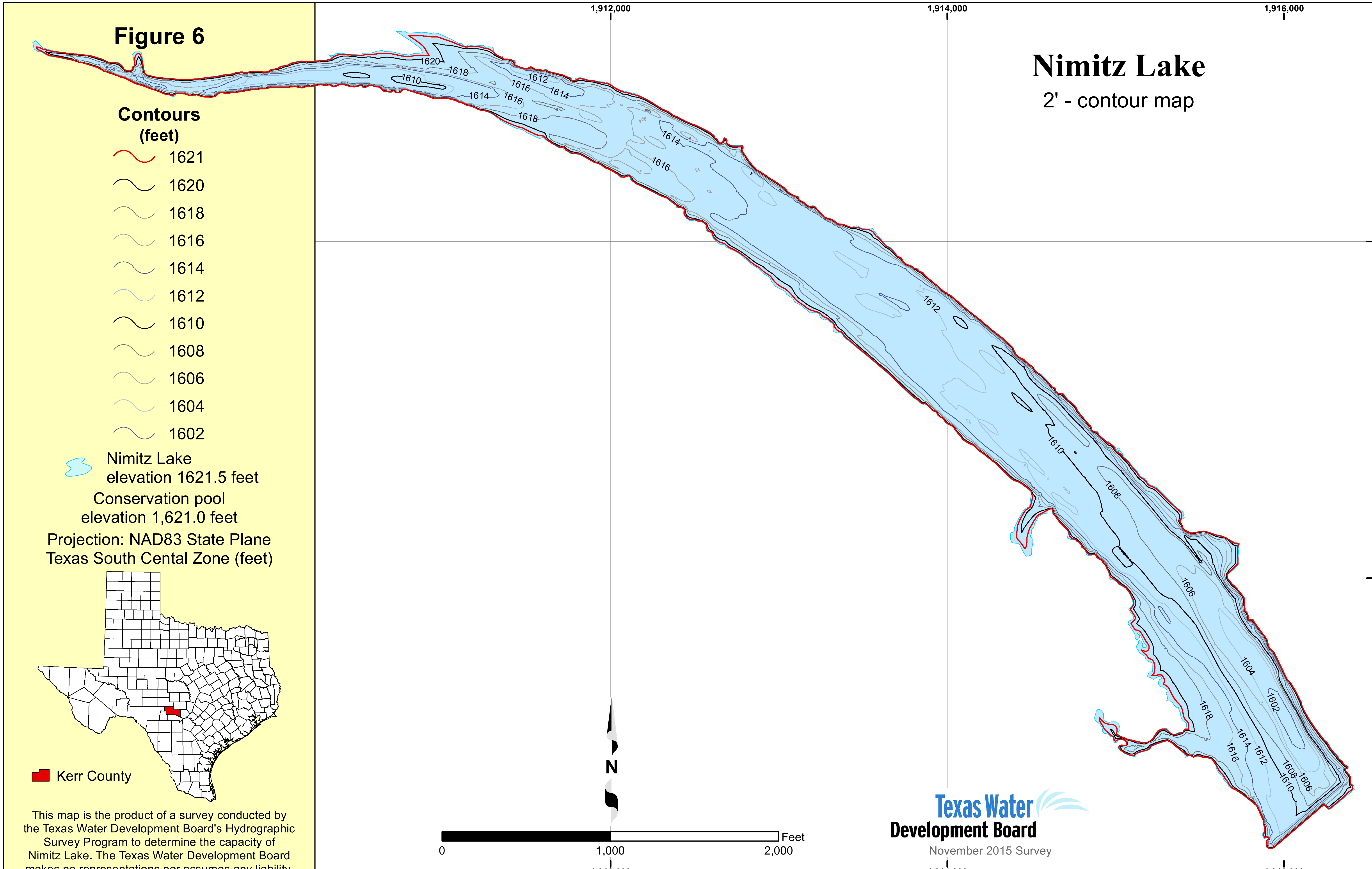
Figure 6
Nimitz Lake
2' - contour map
Contours
(feet)
1621
1620
1618
1616
1614
1612
1610
1608
1606
1604
1602
Nimitz Lake
elevation 1621.5 feet
Conservation pool
elevation 1,621.0 feet
Projection: NAD83 State Plane
Texas South Cental Zone (feet)
Kerr County
This map is the product of a survey conducted by
the Texas Water Development Board's Hydrographic
Survey Program to determine the capacity of
Nimitz Lake. The Texas Water Development Board
makes no representations nor assumes any liability.
1,912,000
1,914,000
1,916,000
13,934,000
13,932,000
N
0
1,000
2,000
Feet
Texas Water
Development Board
November 2015 Survey

Analysis of sediment data from Nimitz Lake

Sedimentation in Nimitz Lake was determined by analyzing the acoustic signal returns of all three depth sounder frequencies using customized software called Hydropick. While the 208 kHz signal is analyzed to determine the current bathymetric surface, all three frequencies, 208 kHz, 50 kHz, and 24 kHz, are 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 are correlated with the acoustic signals in each frequency to assist in identifying the pre-impoundment surface. The difference between the current surface and the pre-impoundment surface yields a sediment thickness value at each sounding location.

Analysis of the sediment core samples was conducted at TWDB headquarters in Austin. Each sample was split longitudinally and analyzed to identify the location of the pre-impoundment surface. The pre-impoundment surface is identified within the sediment core sample by one or more 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 pre-impoundment thickness were recorded. Physical characteristics of the sediment core, including Munsell soil color, texture, relative water content, and presence of organic materials, also were recorded (Table 2).

Table 1. Sediment core sampling analysis data - Nimitz Lake.

Core	Easting[a] (ft)	Northing[a] (ft)	Total core sample/ post-impoundment sediment	Sediment core description	Munsell soil color
NM-1	1915833.46	13930868.53	27.0"/ 5.5"	0-5.5" high water content, 70% organic matter, sandy loam, post-impoundment	5Y 3/2
				5.5-14.0" high density, high water content, large organic matter and shells, sandy loam, pre-impoundment	2.5Y 4/2
				14.0-21.0" high density, loamy sand, pre-impoundment	5Y 4/2
				21.0-27.0" 70% organic matter, coarse structures, sandy loam, pre-impoundment	2.5Y 3/2
NM-2	1915041.06	13932147.82	27.0"/8.0"	0-6.75" high water content top 3", sand, post-impoundment	5Y 4/1
				6.75-8.0" 80% organic matter, sandy loam, post-impoundment	2.5Y 3/2
				8.0-11.5" high density, fine crumb structures, sand, pre-impoundment	5Y 3/2
				11.5-16.5" high water content, fine crumb structures, sandy loam, pre-impoundment	5Y 4/1
				16.5-19.0" high density, medium angular structure, sand, pre-impoundment	5Y 4/1
				19.0-20.5" fine organics present, sand, pre-impoundment	5Y 3/1
				20.5-27.0" high density, coarse rock structure, sand, pre-impoundment	5Y 4/1
NM-3	1913634.07	13933502.00	10.5"/N/A"	0-10.5" high water content, fine to coarse angular structures, loam, post-impoundment	5Y 4/1
NM-4	1912469.84	13934366.29	9.25"/N/A"	0-9.25" high water content, fine to medium angular structures, loam, post-impoundment	5Y 3/2

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

A photograph of sediment core NM-2 (for location refer to Figure 2) is shown in Figure 7 and is representative of the sediment sampled from Nimitz Lake. The base of the sample is denoted by the blue line. The pre-impoundment boundary (yellow line) was evident within this sediment core sample at 8.0 inches and identified by the change in color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the other three sediment cores followed a similar procedure.

Figure 7. **Sediment core NM-2 from Nimitz Lake. Post-impoundment sediment layers occur in the top eight inches of the sediment core (identified by yellow boxes). Pre-impoundment sediment layers were identified and are defined with blue boxes.**

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.

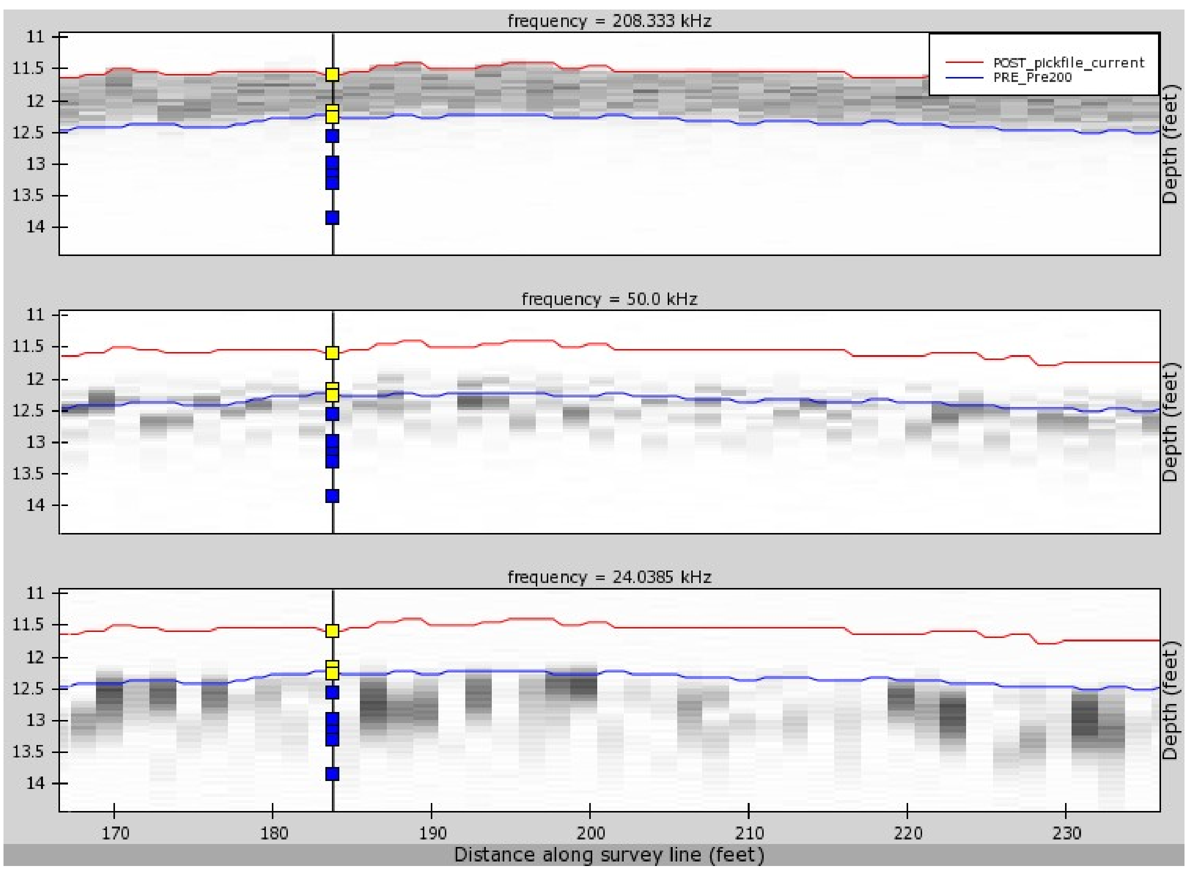

Figure 8. **Comparison of sediment core NM-2 with acoustic signal returns.**

Figure 8 compares sediment core sample NM-2 with the acoustic signals as seen in Hydropick for each frequency: 208 kHz, 50 kHz, and 24 kHz. The current bathymetric surface is automatically determined based on signal returns from the 208 kHz transducer and represented by the red line in Figure 8. The pre-impoundment surface is identified by comparing boundaries observed in the 208 kHz, 50 kHz, and 24 kHz signals to the location of the pre-impoundment surface of the sediment core sample. Many layers of sediment may be identified during analysis based on changes in observed characteristics such as water content, organic matter content, and sediment particle size and each layer is classified as either post-impoundment or pre-impoundment. The boundary of each layer of sediment identified in the sediment core sample during analysis (Table 2) is represented in Figures 8 and 9 by a yellow or blue box. The yellow boxes represent post-impoundment sediment. The blue boxes mark visually identifiable layers in the pre-impoundment sediment and the lower blue box corresponds to the bottom of the sediment core sample.

In this case the boundary in the 208 kHz signal most closely matched the pre-impoundment interface of the sediment core sample; therefore, the 208 kHz signal was used to locate the pre-impoundment surface (blue line in top panel of Figure 8). Figure 9 shows sediment core sample NM-2 correlated with the 208 kHz frequency of the nearest surveyed cross-section. The pre-impoundment surface is first identified along cross-sections for which sediment core samples have been collected and used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

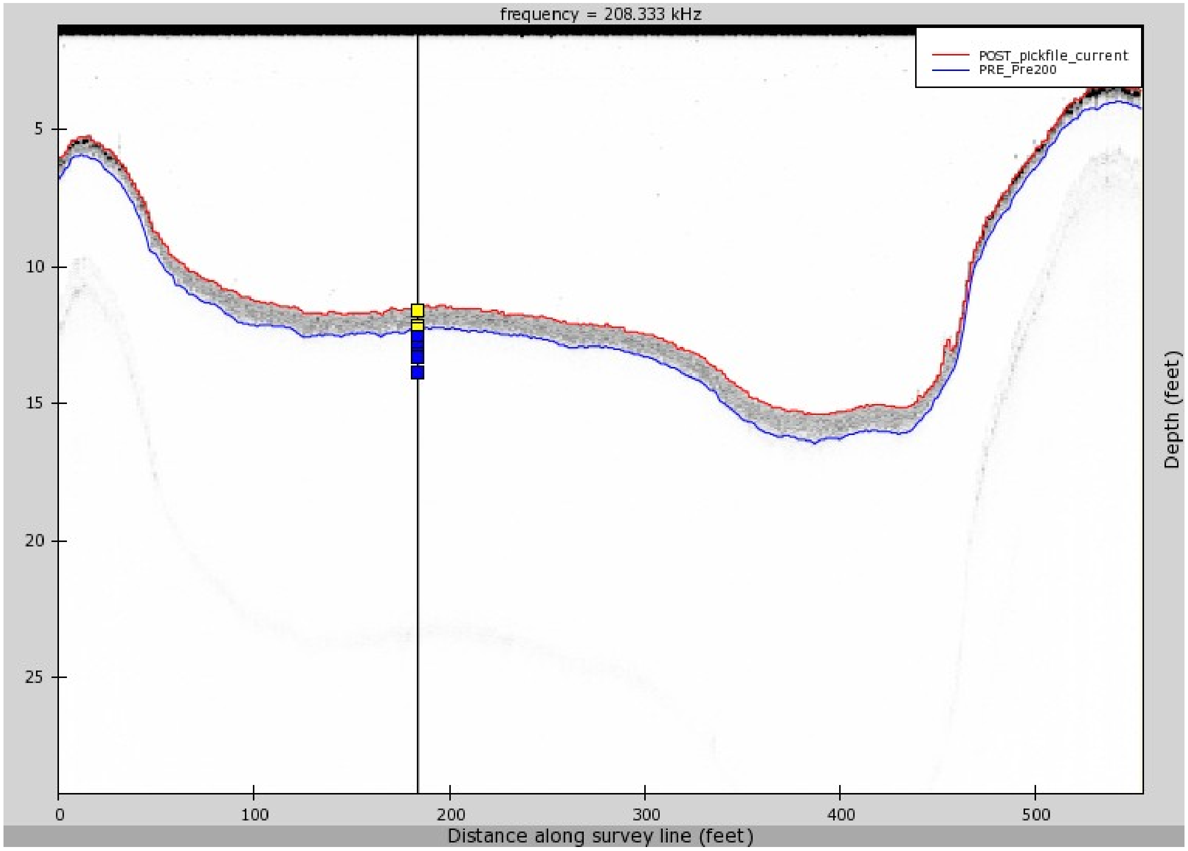

Figure 9. Cross-section of data collected during the November 10, 2015, survey, displayed in Hydropick (208 kHz frequency), correlated with sediment core sample NM-2, and showing the current surface in red and pre-impoundment surface in blue.

The pre-impoundment surface was automatically generated in Hydropick using Otsu's thresholding algorithm of classifying greyscale intensity images into binary (black and white) images based on maximum inter-class variance. The acoustic return images of a selected frequency from each survey line were processed using this technique and the pre-impoundment surface was identified as the bottom black/white interface (where black is the sediment layer) of the resulting binary image (D. Pothina, *pers. comm.*, October 2, 2014). The pre-impoundment surface is then verified and edited manually as needed.

After the pre-impoundment surface for all cross-sections is identified, a sediment thickness TIN model is created following standard GIS techniques (Furnans 2007). Sediment thicknesses were interpolated between surveyed cross-sections using HydroTools with the same interpolation definition file used for bathymetric interpolation. For the purposes of TIN model creation, the TWDB assumed sediment thickness at the reservoir boundary was zero feet (defined as the 1,621.5 elevation contour). The sediment thickness TIN model was converted to a raster representation using a cell size of one foot by one foot and used to produce a sediment thickness map of Nimitz Lake (Figure 10).

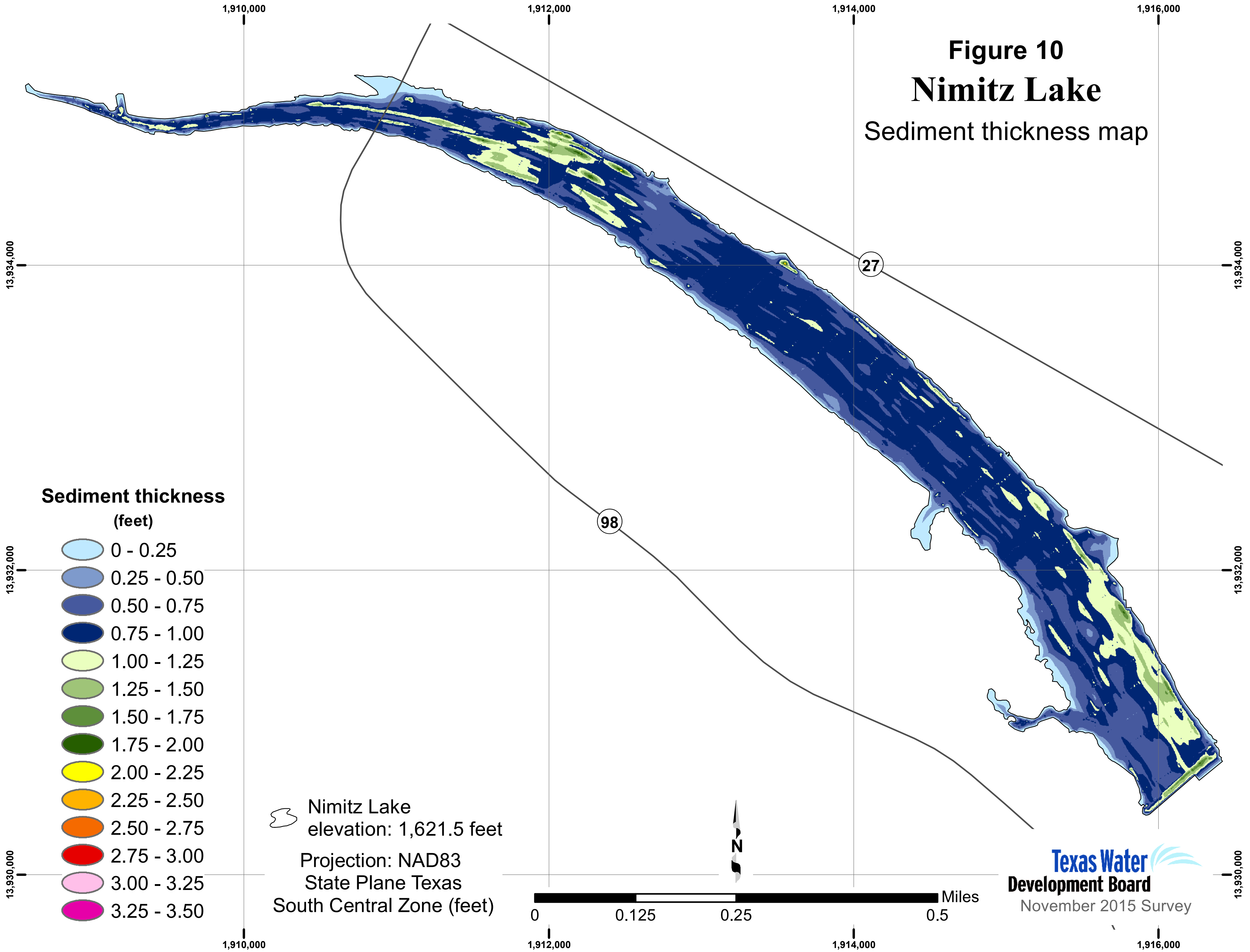
Figure 10
Nimitz Lake
Sediment thickness map
1,910,000
1,912,000
1,914,000
1,916,000
13,934,000
13,932,000
13,930,000
27
98
Sediment thickness
(feet)
0 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.25
1.25 - 1.50
1.50 - 1.75
1.75 - 2.00
2.00 - 2.25
2.25 - 2.50
2.50 - 2.75
2.75 - 3.00
3.00 - 3.25
3.25 - 3.50
Nimitz Lake
elevation: 1,621.5 feet
Projection: NAD83
State Plane Texas
South Central Zone (feet)
N
Miles
0
0.125
0.25
0.5
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Survey results

Volumetric survey

The results of the 2015 TWDB volumetric survey indicate Nimitz Lake has a total reservoir capacity of 735 acre-feet and encompasses 95 acres at conservation pool elevation (1,621.0 feet above mean sea level, NGVD29). According to the Permits to Appropriate State Water issued by the Texas Commission on Environmental Quality, the City of Kerrville is authorized to impound a maximum of 840 acre-feet of water in Nimitz Lake. Because of differences in survey methodologies, direct comparison of this volumetric survey to others to estimate changes in capacity is difficult and can be unreliable.

Sedimentation survey

The 2015 TWDB sedimentation survey measured 74 acre-feet of sediment below conservation pool elevation (1,621.0 feet NGVD29). This represents an average annual loss of capacity below conservation pool elevation of two acre-feet per year since 1979. Sediment accumulation is greatest in the upper reaches where water depths are relatively shallow from Highway 98 to approximately 1,800 feet downstream from the highway. Additional heavy deposits occur near the dam and in the main channel up to approximately 1,800 feet upstream from the dam.

Recommendations

The TWDB recommends another volumetric and sedimentation survey of Nimitz Lake within a 10 year time-frame or after a major flood event to assess changes in lake capacity and to further improve estimates of sediment accumulation rates.

TWDB contact information

More information about the Hydrographic Survey Program can be found at:
http://www.twdb.texas.gov/surfacewater/surveys/index.asp
Any questions regarding the TWDB Hydrographic Survey Program may be addressed to:
Hydrosurvey@twdb.texas.gov

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Appendix A

Nimitz Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — November 2015 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 1,621.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1,601	0	0	0	0	0	0	0	0	0	0
1,602	0	0	0	0	0	1	1	1	1	1
1,603	1	1	1	2	2	2	2	2	3	3
1,604	3	3	4	4	4	5	5	5	6	6
1,605	6	7	7	7	8	8	9	9	10	10
1,606	11	11	12	13	13	14	15	16	16	17
1,607	18	19	20	21	22	22	23	24	25	26
1,608	27	28	30	31	32	33	34	35	37	38
1,609	39	41	42	44	45	47	48	50	51	53
1,610	55	57	59	61	63	65	67	69	72	74
1,611	76	79	82	84	87	90	93	96	99	102
1,612	105	109	112	116	120	124	128	132	136	141
1,613	145	150	155	160	165	170	175	181	186	192
1,614	197	203	208	214	220	226	232	238	244	250
1,615	256	262	269	275	281	288	295	301	308	315
1,616	322	328	335	343	350	357	364	372	379	386
1,617	394	402	409	417	425	432	440	448	456	464
1,618	472	480	488	496	505	513	521	530	538	547
1,619	555	564	572	581	590	598	607	616	625	634
1,620	643	652	661	670	679	688	698	707	716	726
1,621	735	745	754	764	773	783				

Appendix B

Nimitz Lake

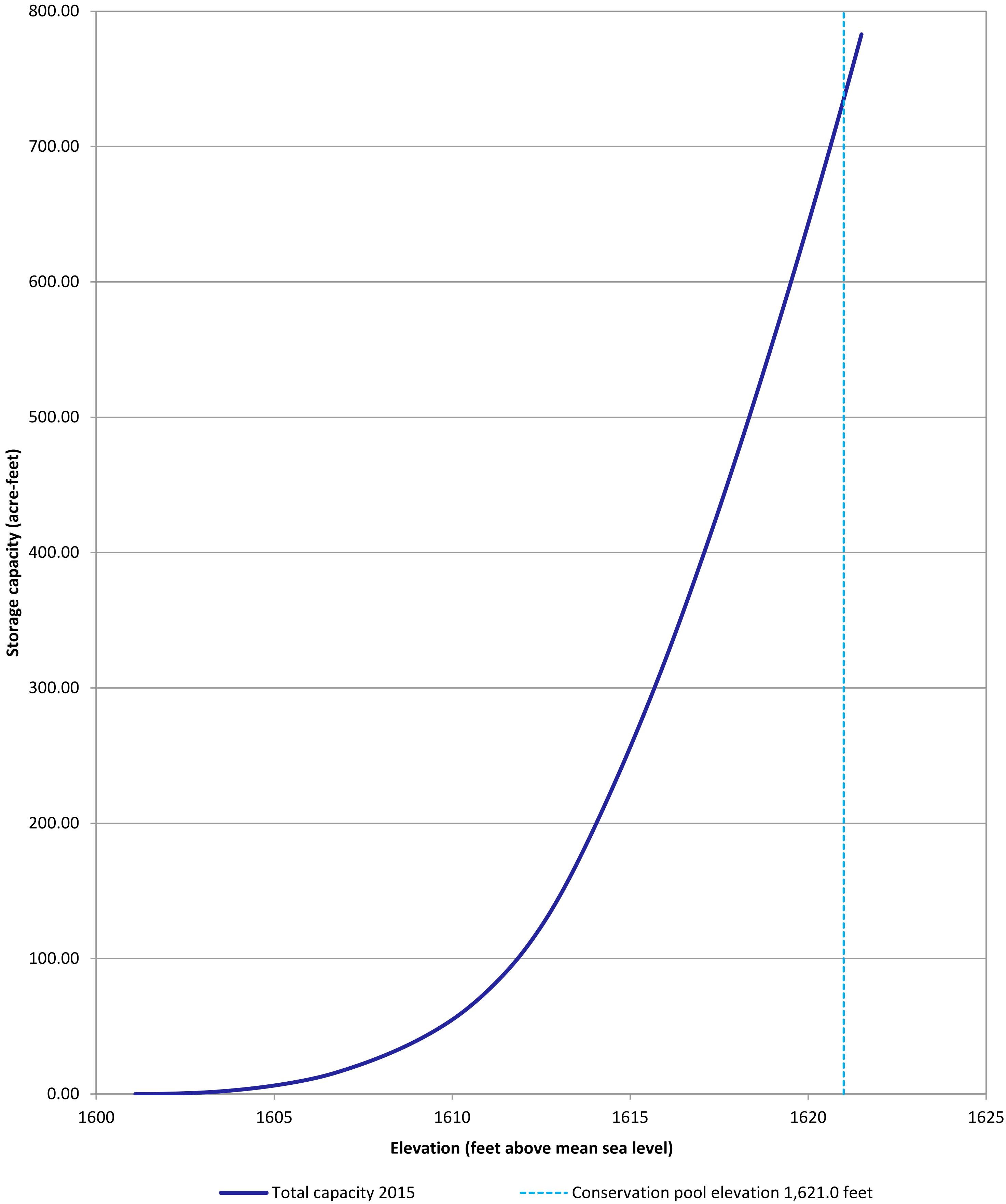
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — November 2015 Survey

AREA IN ACRES — Conservation Pool Elevation 1,621.0 feet NGVD29

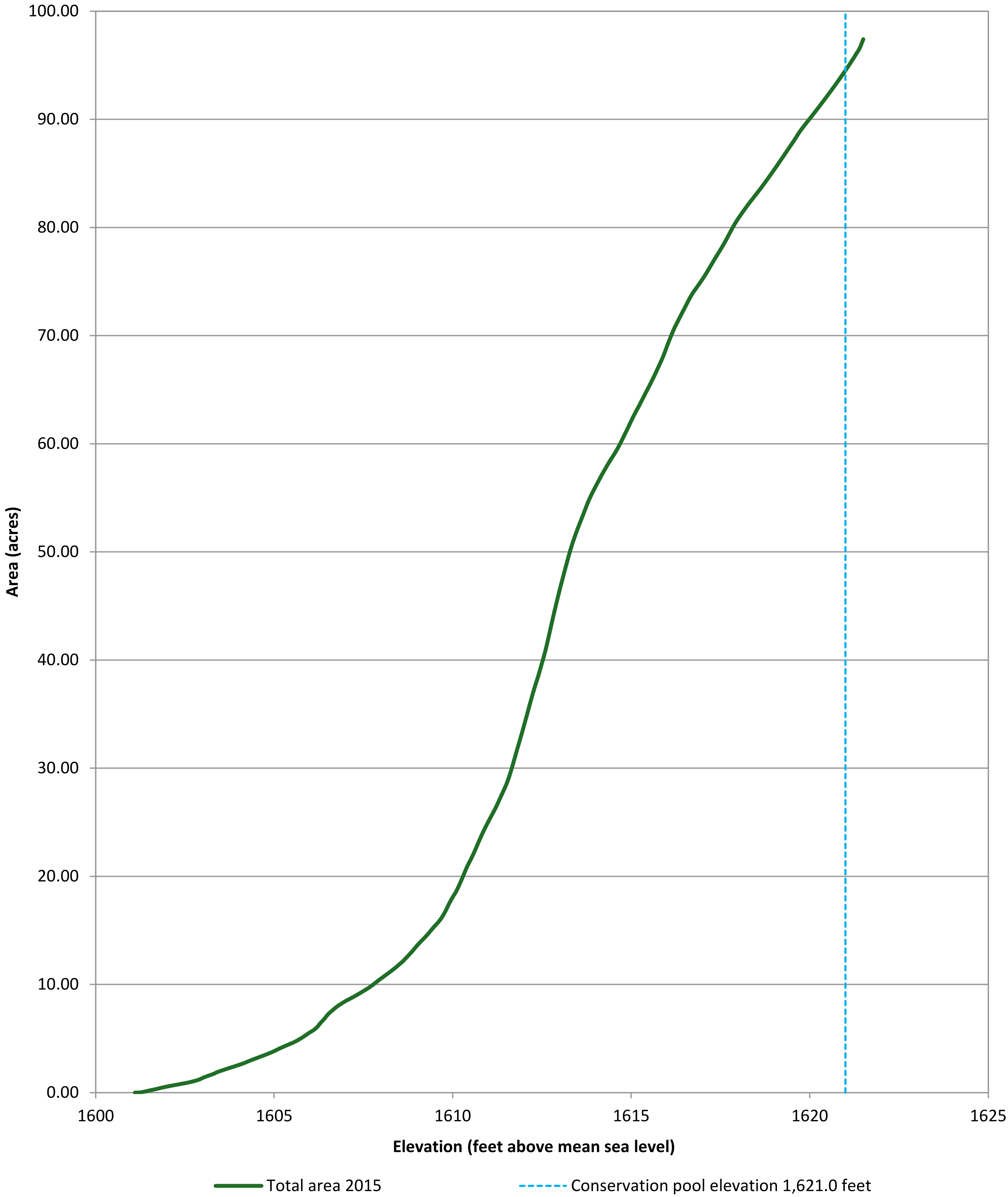
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1,601	0	0	0	0	0	0	0	0	0	0
1,602	1	1	1	1	1	1	1	1	1	1
1,603	1	1	2	2	2	2	2	2	2	2
1,604	3	3	3	3	3	3	3	3	4	4
1,605	4	4	4	4	4	5	5	5	5	5
1,606	6	6	6	6	7	7	8	8	8	8
1,607	8	9	9	9	9	9	10	10	10	10
1,608	11	11	11	11	12	12	12	12	13	13
1,609	14	14	14	15	15	15	16	16	17	17
1,610	18	19	19	20	21	22	22	23	24	24
1,611	25	26	26	27	28	28	29	31	32	33
1,612	34	35	36	38	39	40	41	42	44	45
1,613	47	48	49	50	51	52	53	54	55	55
1,614	56	57	57	58	58	59	59	60	61	61
1,615	62	63	63	64	65	65	66	67	67	68
1,616	69	70	71	71	72	73	73	74	74	75
1,617	75	76	76	77	77	78	79	79	80	80
1,618	81	81	82	82	83	83	84	84	84	85
1,619	85	86	86	87	87	88	88	89	89	90
1,620	90	90	91	91	92	92	93	93	94	94
1,621	95	95	96	96	97	97				



Nimitz Lake
November 2015 Survey
Prepared by: TWDB

Appendix C: Capacity curve



Nimitz Lake
November 2015 Survey
Prepared by: TWDB

Appendix D: Area curve