Volumetric and Sedimentation Survey of CEDAR CREEK RESERVOIR

April – October 2017 Survey

Texas Water Development Board

February 2018

Texas Water Development Board

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Prepared for:

Tarrant Regional Water District

With Support Provided by:

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Executive summary

In August 2016, 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 Cedar Creek Reservoir (Henderson and Kaufman Counties, Texas). The Tarrant Regional Water District 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.

Joe B. Hogsett Dam and Cedar Creek Reservoir are located on Cedar Creek, a tributary of the Trinity River, approximately 3 miles northeast of Trinidad, in Henderson County, Texas. The conservation pool elevation of Cedar Creek Reservoir is 322.0 feet above mean sea level (NGVD29). The TWDB began collecting bathymetric data for Cedar Creek Reservoir on November 9, 2016, while the daily average water surface elevation measured 320.29 feet above mean sea level (NGVD29). Bathymetric data collection for the remainder of the reservoir occurred between April 3 and October 26, 2017, while daily average water surface elevations measured between 320.33 and 322.28 feet above mean sea level (NGVD29).

The 2017 TWDB volumetric survey indicates Cedar Creek Reservoir has a total reservoir capacity of 631,401 acre-feet and encompasses 33,099 acres at conservation pool elevation (322.0 feet above mean sea level, NGVD29). Previous capacity estimates include the original design estimate of 679,200 acre-feet and two TWDB surveys in 1995 and 2005. The 1995 and 2005 TWDB surveys were re-evaluated using current processing procedures resulting in updated capacity estimates of 642,569 acre-feet and 647,432 acre-feet, respectively.

The 2017 TWDB sedimentation survey indicates Cedar Creek Reservoir has lost capacity at an average of 841 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (322.0 feet NGVD29). The sedimentation survey indicates sediment accumulation is fairly uniform throughout the reservoir, with deposits increasing towards the dam. The TWDB recommends that a similar methodology be used to resurvey Cedar Creek Reservoir 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 2016, the TWDB entered into an agreement with the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Cedar Creek Reservoir. The Tarrant Regional Water District 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 (Texas Water Development Board, 2016a). This report provides an overview of the survey methods, analysis techniques, and associated results. Also included are the following contract 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 I and J).

Cedar Creek Reservoir general information

Joe B. Hogsett Dam and Cedar Creek Reservoir are located on Cedar Creek, a tributary of the Trinity River, approximately 3 miles northeast of Trinidad, in Henderson and Kaufman Counties, Texas (Figure 1). Construction of the dam began in April 1961. Deliberate impoundment began on July 2, 1965, and the dam was completed in February 1966 (Texas Water Development Board, 1973). Cedar Creek Reservoir is owned and operated by the Tarrant Regional Water District. Cedar Creek Reservoir is primarily a water supply reservoir. Additional pertinent data about Joe B. Hogsett Dam and Cedar Creek Reservoir can be found in Table 1.

Water rights for Cedar Creek Reservoir have been appropriated to Tarrant Regional Water District through Certificate of Adjudication No. 08-4976 and Amendments to Certificate of Adjudication Nos. 08-4976A, 08-4976B, and 08-4976C. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

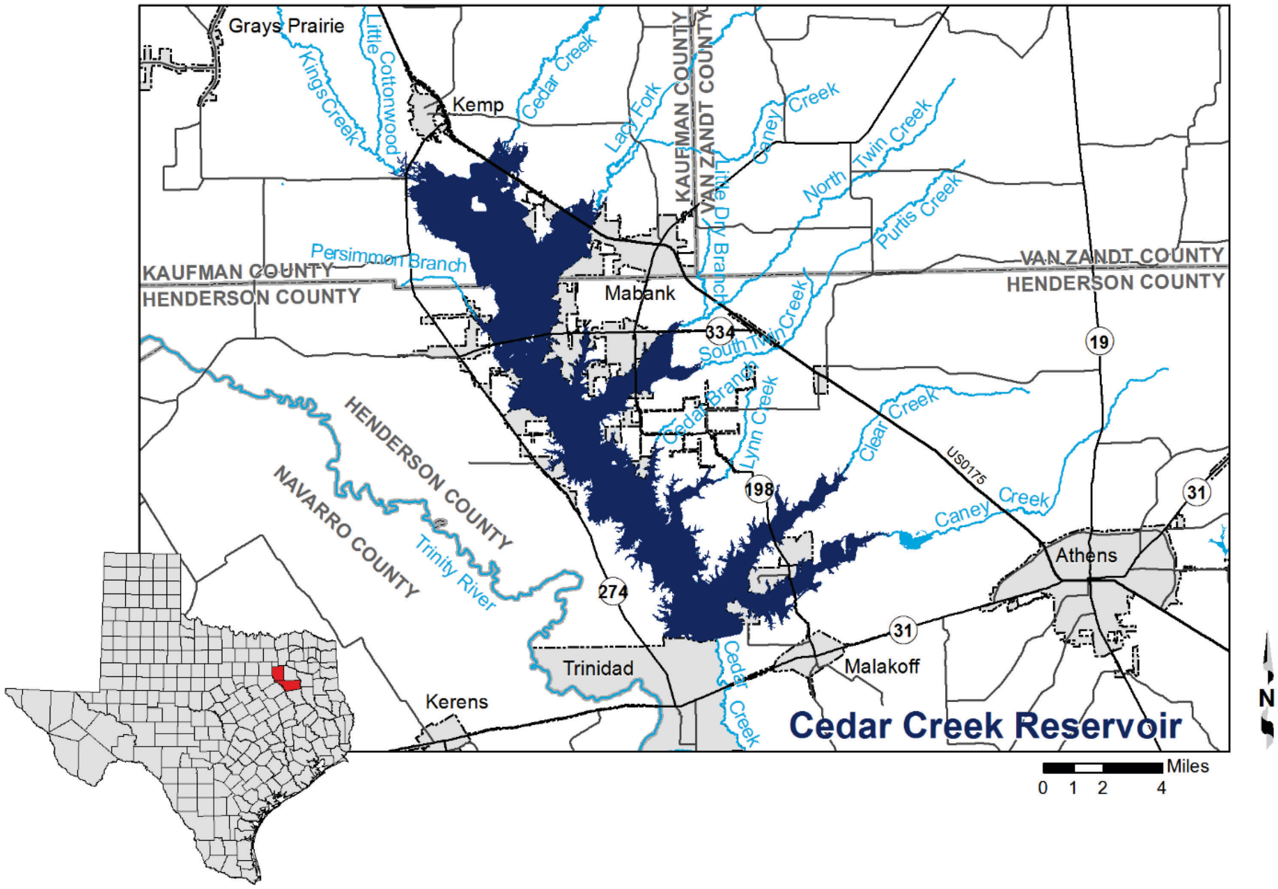


Figure 1. **Location map of Cedar Creek Reservoir.**

Table 1. Pertinent data for Joe B. Hogsett Dam and Cedar Creek Reservoir.

Owner				
Tarrant Regional Water District				
Design Engineer				
Freese, Nichols and Endress				
Location of dam				
On Cedar Creek in Henderson County, 3 miles northeast of Trinidad				
Drainage area				
1,007 square miles				
Dam				
Type	Earthfill			
Length	17,539 feet			
Height	91 feet			
Top width	20 feet			
Spillway				
Location	6 miles upstream on right bank, discharges into Trinity River			
Type	Gated concrete chute			
Control	8 tainter gates, each 40 by 23 feet and 2 bascule (automatic) gates, each 40 by 8.5 feet			
Net length	400 feet			
Crest elevation	302.0 feet above mean sea level			
Reservoir data (Based on 2017 TWDB survey)				
Feature		**Elevation (feet NGVD29[a])**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam		340.0	N/A	N/A
Top of tainter gates		325.0	N/A	N/A
Top of bascule (automatic) gates		322.5	N/A	N/A
Top of conservation pool		322.0	631,401	33,099
Spillway crest automatic gates		314.0	397,276	24,786
Spillway crest tainter gates		302.0	172,517	13,033
Invert of conduit in dam		263.5	56	27
Usable conservation storage[b]		—	631,345	—

Source: (Texas Water Development Board, 1973)

[a] NGVD29 = National Geodetic Vertical Datum 1929

[b] Usable conservation storage equals total capacity at conservation pool elevation minus dead pool capacity. Dead pool refers to water that cannot be drained by gravity through a dam's outlet works.

Volumetric and sedimentation survey of Cedar Creek Reservoir

Datum

The vertical datum used during this survey is the National Geodetic Vertical Datum 1929 (NGVD29). This datum also is utilized by the United States Geological Survey (USGS) for the reservoir elevation gage *USGS 08063010 Cedar Ck Res nr Trinidad, TX* (U.S. Geological Survey, 2017). Elevations herein are reported in feet relative to the NGVD29 datum. Volume and area calculations in this report are referenced to water levels provided by the USGS gage. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas North Central Zone (feet).

TWDB bathymetric and sedimentation data collection

The TWDB began collecting bathymetric data for Cedar Creek Reservoir on November 9, 2016, while the daily average water surface elevation measured 320.29 feet above mean sea level (NGVD29). Bathymetric data collection for the remainder of the reservoir occurred between April 3 and October 26, 2017, while daily average water surface elevations measured between 320.33 and 322.28 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 500 feet apart. Many of the same survey lines also were used by the TWDB during the 1995 and 2005 surveys. The depth sounder was calibrated daily using a velocity profiler to measure the speed of sound in the water column and a weighted tape or stadia rod for depth reading verification. Figure 2 shows the data collection locations for the 2017 TWDB survey.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples were 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 twelve locations to collect sediment core samples (Figure 2). The sediment core samples were collected on September 12-13, 2017, with a custom-coring boat and an 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 into 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.

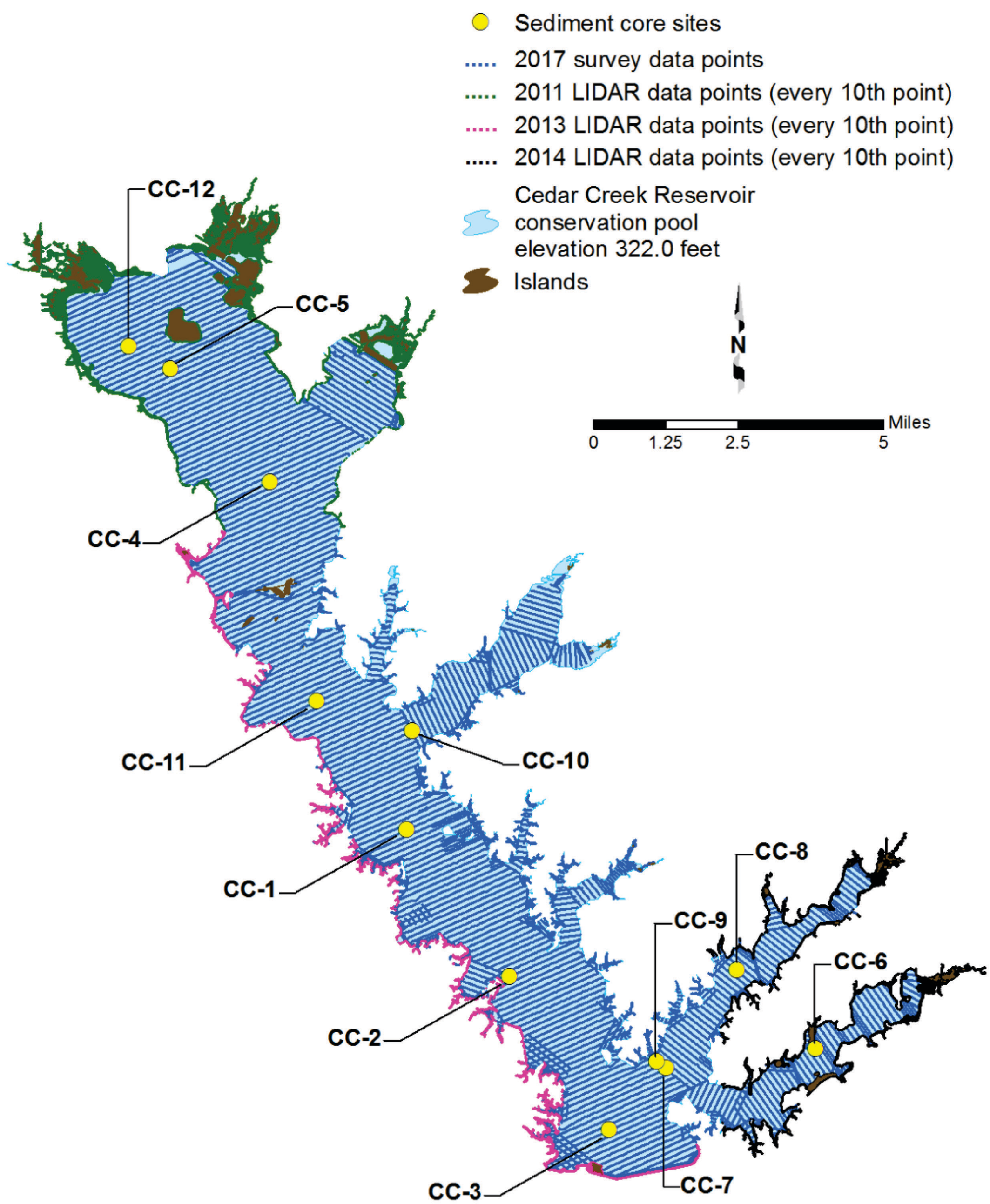


Figure 2. **2017 TWDB Cedar Creek Reservoir survey data (*blue dots*), sediment coring locations (*yellow circles*), 2011 LIDAR data (*green dots*), 2013 LIDAR data (*pink dots*), and 2014 LIDAR data (*black dots*).**

Data processing

Model boundary

The reservoir's model boundary was generated from Light Detection and Ranging (LIDAR) data and digital orthophoto quarter-quadrangle images (DOQQs) available from the Texas Natural Resource Information System (Texas Natural Resources Information System, 2017a, 2017b, 2017c, 2017d). LIDAR data coverage of Cedar Creek Reservoir is incomplete and was collected over multiple years. Data covering most of Clear Creek and Caney Creek branches was collected between January 25 and February 18, 2014, while the daily average water surface elevation of the reservoir measured between 318.33 and 318.55 feet above mean sea level. According to the associated metadata, the 2014 LIDAR data has a fundamental vertical accuracy of 0.076 meters, approximately 0.249 feet, at the 95th percentile and a horizontal accuracy of 1 meter. Data covering the dam and right bank or west bank of the reservoir to just upstream of Persimmon Branch was collected between February 7 and March 6, 2013, while the daily average water surface elevation of the reservoir measured between 318.81 and 319.19 feet above mean sea level. According to the associated metadata, the 2013 LIDAR data has a fundamental vertical accuracy of 0.067 meters, approximately 0.220 feet, at the 95th percentile in open terrain and a horizontal accuracy of 1 meter. Data upstream of Persimmon Branch was collected between January 21 and April 1, 2011, while the daily average water surface elevation of the reservoir measured between 319.32 and 319.67 feet above mean sea level. According to the associated metadata, the 2011 LIDAR data has a tested vertical accuracy of 0.0979 meters, approximately 0.321 feet, at the 95th percentile for the Flood/Soils land cover category and project specifications required a horizontal accuracy less than 0.75 meters. To generate a boundary utilizing the LIDAR data, LIDAR data with a classification equal to 2, or ground, was imported into an Environmental Systems Research Institute's ArcGIS file geodatabase from .las files. A topographical model of the data was generated and converted to a raster using a cell size of 1.0 meters by 1.0 meters. The horizontal datum of the LIDAR data is Universal Transverse Mercator (UTM) North American Datum 1983 (NAD83; meters) Zone 14 and Zone 15, and the vertical datum is North American Vertical Datum 1988 (NAVD88; meters). Therefore, a contour of 98.1376 meters NAVD88, equivalent to 322.0 feet NGVD29, was extracted from the raster. The vertical datum transformation offset for the conversion from NAVD88 to NGVD29 was determined by applying the National Oceanic and Atmospheric Administration National Geodetic Survey's NADCON software (National Geodetic Survey, 2017a) and VERTCON software (National Geodetic Survey, 2017b) to a single reference point in the vicinity of the survey, the reservoir elevation gage *USGS 08063010 Cedar Ck Res nr Trinidad, TX Latitude 32º14'35"N, Longitude 96º08'26"W NAD27.* Horizontal coordinate transformations to NAD83 State Plane Texas North Central Zone (feet) coordinates were done using the ArcGIS Project tool. Additional editing of the 322.0-foot contour was necessary to close the contour across the top of the dam and remove other artifacts. Where LIDAR data was insufficient to generate a proper contour or was not available, the boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), taken on September 21, September 30, and October 21, 2016, while the daily average water surface elevation measured 320.87, 320.65, and 320.36 feet, respectively. According to metadata associated with the 2016 DOQQs, the photographs have a resolution or ground sample distance of 1.0-meters and a horizontal accuracy within ± 6 meters to true ground (Texas Natural Resources Information System, 2016, U.S. Department of Agriculture, 2016).

LIDAR data points

To utilize the LIDAR data below conservation pool elevation, or model boundary elevation, the .las files were converted to text files with x, y, and z values. To reduce computational burden, the LIDAR data was filtered to include only every 10th ground classified point and only data points within the reservoir boundary (Figure 2). The LIDAR data points have a nominal spacing of 0.5 meters, approximately 1.64 feet; therefore, using a thinned point dataset did not significantly affect the modeled topography of the coverage area. Additionally, LIDAR data points not near heavily vegetated areas, such as the upper reaches, with an elevation above conservation pool were removed from the final data set. A misalignment between the LIDAR data and 2016 aerial photographs used to complete the model boundary resulted in anomalous LIDAR data near the shoreline, especially where the shore is highly developed. Although the TWDB survey data and LIDAR data points agreed well where there were overlaps, LIDAR data points in a section of the river channel of Caney Creek had elevations between 2 and 6 feet shallower than the survey data. These LIDAR points were removed from the model. In areas where survey data could not be collected and water was present at the time of LIDAR collection, some interpolation of the data was necessary to prevent flat triangles from forming and to provide a better estimate of true bathymetry. After the points were clipped to within the boundary, the shapefile was projected to NAD83 State Plane Texas North Central Zone (feet). New attribute fields were added to first convert the elevations from meters NAVD88 to meters NGVD29 by adding the VERTCON conversion offset of 0.008 meters, then to feet NGVD29 for compatibility with the bathymetric survey data.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by the TWDB were edited to remove data anomalies. The reservoir's 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 and manually digitizing the reservoir-bottom surface at the time of initial impoundment (*i.e.* pre-impoundment surface). For further analysis, HydroTools, software developed by TWDB staff, was used to merge all the data 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 and others, 2011a). Finally, the point file resulting from spatial interpolation is used in conjunction with sounding and boundary data to create volumetric and sediment Triangulated Irregular Network (TIN) models utilizing the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithm uses Delaunay's criteria for triangulation to create a grid composed of triangles from non-uniformly spaced points, including the boundary vertices (Environmental Systems Research Institute, 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), hypsography files (the vector format of USGS 7.5-minute quadrangle map contours), and historical aerial photographs, 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 reservoir bathymetry and sediment accumulation throughout the reservoir. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen and others, 2011a) and in McEwen and others (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 and others, 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 Cedar Creek Reservoir. In Figure 3A, deeper channels and 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 I) and elevation-area (Appendix J) tables.

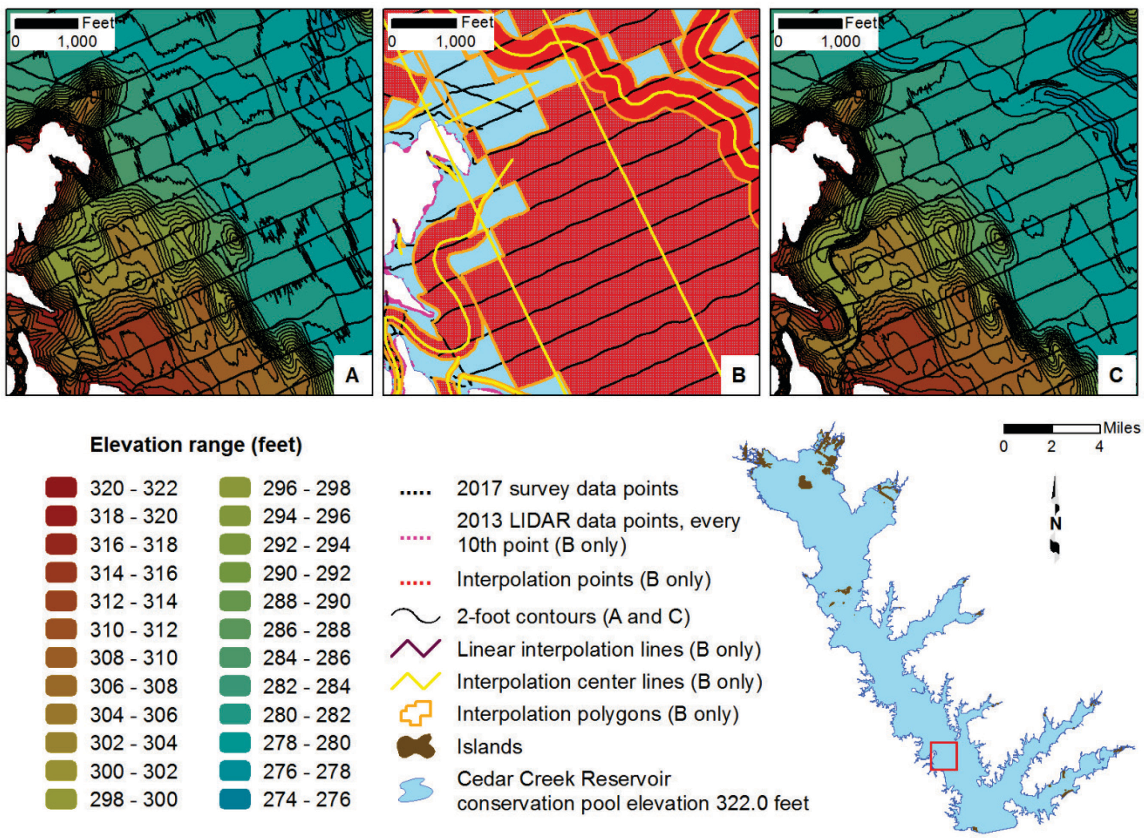


Figure 3. Anisotropic spatial interpolation and linear interpolation of Cedar Creek Reservoir sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.

To standardize results from previous TWDB surveys of Cedar Creek Reservoir, the TWDB applied anisotropic spatial interpolation to the survey data collected in 1995 and 2005 (Texas Water Development Board, 2016b). The original 1995 survey boundary was digitized from the 322.0 foot contour from 7.5 minute USGS quadrangle maps: Kerens, Texas, 1961 (Photo-revised 1981); Malakoff, Texas, 1960 (Photo-revised 1981); Mabank, Texas, 1960 (Photo-revised 1981); Kemp, Texas, 1961 (Photo-revised 1981); and Tool, Texas, 1960 (Photo-revised 1981), with a stated accuracy of ± ½ the contour interval (U.S. Bureau of the Budget, 1947). Additionally, survey data points with anomalous elevations were removed from the new model. The 2005 survey boundary was digitized from aerial photographs taken on February 3, February 21, and March 8, 1995, while the daily average water surface elevation of the reservoir measured 321.99 feet, 321.97 feet, and 321.97 feet above mean sea level, respectively. The boundary was assigned an elevation of 322.0 feet for modeling purposes. According to the associated metadata, the 1995-1996 DOQQs have a resolution of 1-meter, with a horizontal positional accuracy that meets the National Map Accuracy Standards (NMAS) for 1:12,000-scale products. While linear interpolation was used to estimate the topography in areas without data, flat triangles led to anomalous area and volume calculations at the boundary elevation of 322.0 feet. Therefore, areas between 319.8 feet and 322.0 feet were linearly interpolated between the computed values, and volumes above 319.8 feet were calculated based on the corrected areas for the 1995 survey and areas between 319.5 feet and 322.0 feet were linearly interpolated between the computed values, and volumes above 319.5 feet were calculated based on the corrected areas for the 2005 survey (Texas Water Development Board, 2016b). The 1995 re-calculated elevation-capacity table and elevation-area table are presented in Appendices A and B, respectively. The re-calculated capacity curve is presented in Appendix C, and the re-calculated area curve is presented in Appendix D. The 2005 re-calculated elevation-capacity table and elevation-area table are presented in Appendices E and F, respectively. The re-calculated capacity curve is presented in Appendix G, and the re-calculated area curve is presented in Appendix H.

Area, volume, and contour calculation

Using ArcInfo software and the volumetric TIN model, volumes and areas were computed for the entire reservoir at 0.1-foot intervals, from 257.6 to 322.0 feet. The elevation-capacity table and elevation-area table, based on the 2017 survey and analysis, are presented in Appendices I and J, respectively. The capacity curve is presented in Appendix K, and the area curve is presented in Appendix L.

The volumetric TIN model was converted to a raster representation using a cell size of 2 feet by 2 feet. The raster data then was 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 Cedar Creek Reservoir (Figure 5); and, (3) a 5-foot contour map (Figure 6).

Figure 4

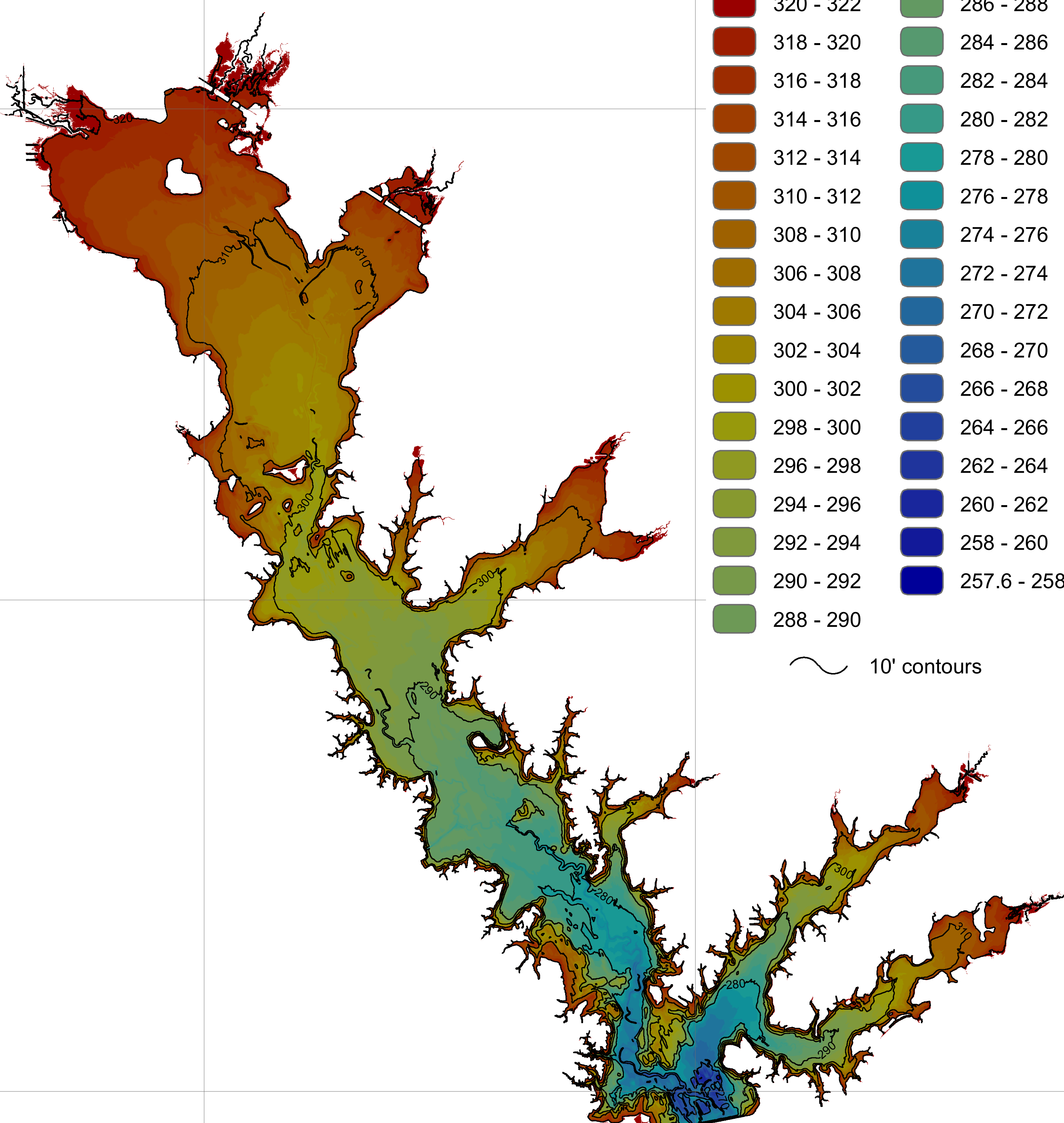
Cedar Creek Reservoir

Elevation relief map

Elevations
(feet above mean sea level)

320 - 322	286 - 288
318 - 320	284 - 286
316 - 318	282 - 284
314 - 316	280 - 282
312 - 314	278 - 280
310 - 312	276 - 278
308 - 310	274 - 276
306 - 308	272 - 274
304 - 306	270 - 272
302 - 304	268 - 270
300 - 302	266 - 268
298 - 300	264 - 266
296 - 298	262 - 264
294 - 296	260 - 262
292 - 294	258 - 260
290 - 292	257.6 - 258
288 - 290	

10' contours



Cedar Creek Reservoir
conservation pool
elevation 322.0 feet

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

N

0 0.5 1 2
Miles

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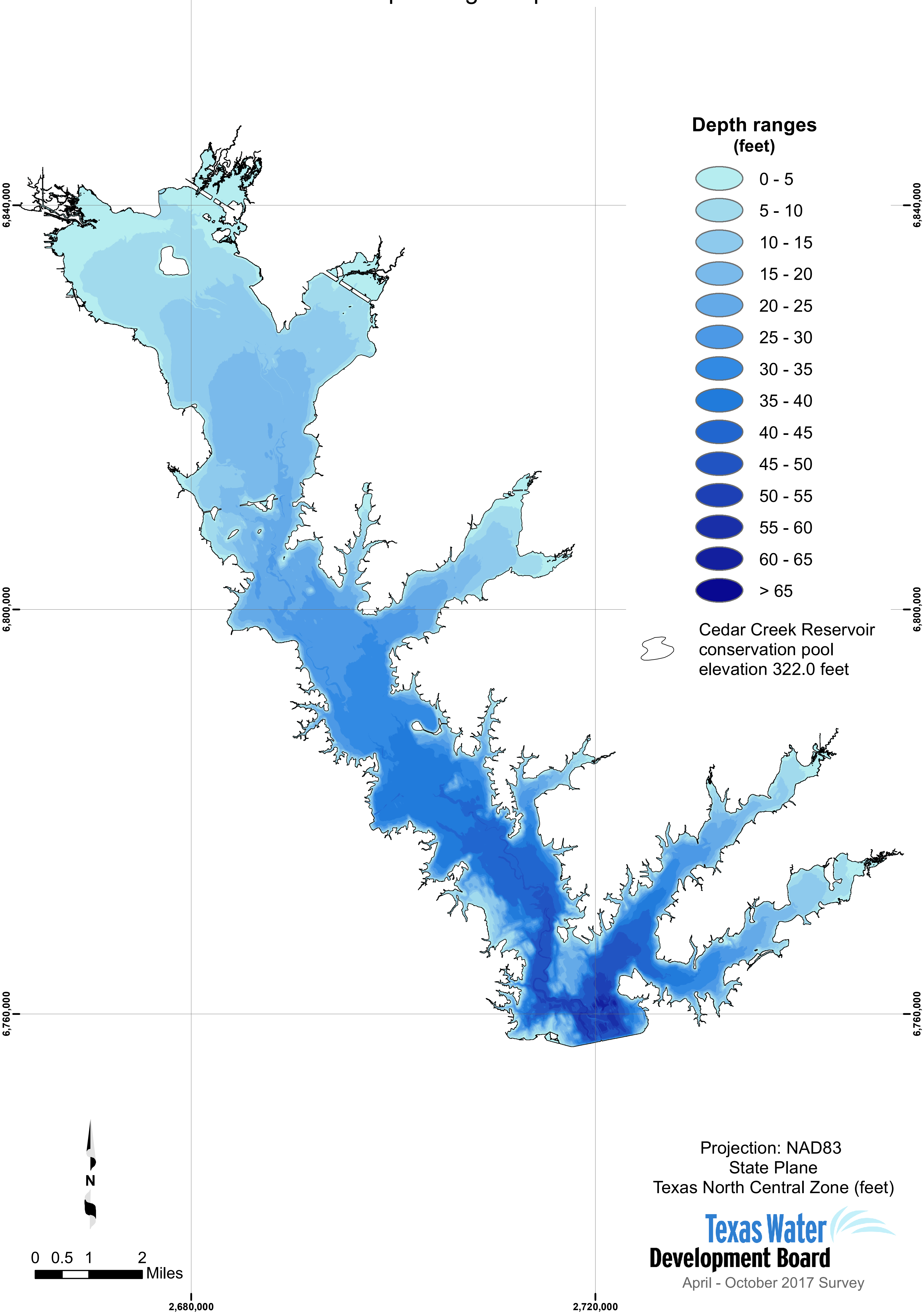
Figure 5

Cedar Creek Reservoir

Depth range map



Analysis of sediment data from Cedar Creek Reservoir

Sedimentation in Cedar Creek Reservoir was determined by analyzing the acoustic signal returns of all three depth sounder frequencies in the DepthPic© software. While the 208 kHz signal is used 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 bathymetry and the pre-impoundment surface bathymetry 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 and others, 2004). Total sample length, post impoundment sediment thickness, and pre-impoundment thickness were recorded. Physical characteristics of the sediment core, such as Munsell soil color, texture, relative water content, and presence of organic materials also were recorded (Table 2).

Table 2. Sediment core sample analysis data for Cedar Creek Reservoir.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
CC-1	2698572.13	6788487.54	30.25”/22.00”	post-impoundment	0.0–5.50” high water content, silty, pudding like consistency	5Y 2.5/2 black
					5.50–22.0” slightly less water content than above layer, less than 1 percent clay clasts – increases toward lower boundary	5Y 4/1 dark gray
				pre-impoundment	22.0–30.25” significant root material (small roots) extending throughout layer, pronounced decrease in water content, much higher density material, approximately 60/40 percent clay/silt	2.5Y 2.5/1 black
CC-2	2707945.12	6775137.88	42.0”/28.0”	post-impoundment	0.0–2.0” very high water content, silt, no gritty material	5Y 2.5/2 black
					2.0–18.0” high water content, silty, not gritty	5Y 2.5/2 black
					18.0–28.0” high water content, silt, no grit	5Y 2.5/2 black
				pre-impoundment	28.0–36.0” sandy, organic material with clay, small roots throughout, significant decrease in water content compared to above layers, much higher density material, 70/30 percent clay/sand	2.5Y 3/1 very dark gray
					36.0–42.0” decreased water and sand content compared to layer above, high density material, organics throughout, approximately 80 percent clay	2.5Y 2.5/1 black
CC-3	2717037.16	6761166.17	27.5”/17.0”	post-impoundment	0–3.0” very high water content, silt, smooth material, not gritty	5Y 3/1 black
					3.0–17.0” high water content, gelatinous texture, smooth	2.5Y 2.5?1 black
				pre-impoundment	17.0–27.5” significant decrease in water content from layers above, organic material (roots) throughout, dense, 70-80 percent clay	2.5Y 3/1 very dark gray

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

Table 2. Sediment core sample analysis data for Cedar Creek Reservoir (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
CC-4	2686187.06	6820171.82	29.5"/25.0"	post-impoundment	0.0–2.0" smooth, silty layer, thick-pudding like	2.5Y 3/2 very dark grayish brown
					21.0–25.0" mixing between silt/clay layers, mottling of color of above/below layers	2.5Y 3/2 very dark grayish brown; 2.5Y 2.5/1 black
				pre-impoundment	25.0–29.5" decreased water content than layers above, minimal organic material (small roots), dense, approximately 70 percent clay	2.5Y 2.5/1 black
CC-5	2677091.53	6830440.86	21.25"/15.0"	post-impoundment	0.0–15.0" smooth, thick, very high water content, silty material, pudding like - gel	5Y 3/1 very dark gray
				pre-impoundment	15.0–21.5" dense, decreased water content than layer above, organic material (roots) at 15.0–17.0 inches	5Y 2.5/1 black
CC-6	2735749.55	6768539.27	39.5"/8.0"	post-impoundment	0.0–8.0" gel/pudding like, high water content, silt	5Y 3/2 dark olive gray
				pre-impoundment	8.0–11.5" dense, less water content than layers above and below, approximately 70 percent sand	2.5Y 3/2 very dark grayish brown
					11.5–18.0" dense, less water content than above, 50/50 percent sand/clay, respectively	5Y 2.5/2 black
					18.0–39.5" decreasing water content with depth, sandy loam mixture, rusty colored spots throughout lower section	5Y 5/1 Gray
CC-7	2722178.82	6766780.02	37.0"/28.0"	post-impoundment	0.0–4.0" very high water content, smooth, silky, silt layer	5Y 3/2 dark olive gray
					4.0–28.0" very high water content, similar as above, color change, texture smooth, silky, pudding like	5Y 2.5/2 black
				pre-impoundment	28.0–37.0" dense, decreased water content from above layers, organic material (small roots) at top of layer	5Y 2.5/1 black

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

Table 2. Sediment core sample analysis data for Cedar Creek Reservoir (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
CC-8	2728607.44	6775700.29	36.0”/14.5”	post-impoundment	0.0–2.0” thick, smooth, gel-like silt, very high water content	5Y 3/2 dark olive gray
					2.0–14.5” thick, smooth, gel-like, silty, high water content, less water than layer above, color change at 9-inch	2.5Y 3/1 very dark gray
				pre-impoundment	14.5–36.0” densely packed sandy substrate, decreased water content throughout layer, less water content than above layer, color change at 14.5 inches, color consistent throughout layer, 50/25/25 percent clay/sand/silt, respectively	5Y 3/2 dark olive gray
CC-9	2721302.69	6767427.41	38.0”/1.5”	post-impoundment	0.0–1.5” smooth, gel-like, very high water content	5Y 3/2 dark olive gray
				pre-impoundment	1.5–6.0” organic material throughout, color and texture change, gritty/sandy texture, breaks apart easily, less water content than layer above	5Y 2.5/2 black
					6.0–33.5” gritty/sandy mixture, decreased water content throughout layer, less water than layer above, organic material throughout, color change	5Y 4/1 dark gray
					33.5–38.0” predominantly sandy/clay mixture, distinct color change from above, less water content than above layers, organic material throughout layer	5Y 5/3 olive
CC-10	2699105.33	6797499.30	27.5”/19.5”	post-impoundment	0.0–6.0” smooth, gel-like consistency, silt, very high water content, distinct color change at 6.0 inches	5Y 3/1 Very dark gray
				pre-impoundment	6.0–19.5” smooth, gel-like consistency, silt, high water content, lower water content than above	5Y 2.5/1 Black
					19.5–27.5” dense, packed consistency, clay, lower water content than above, distinct color and texture change from above layer, organic material throughout	5Y 2.5/1 Black

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

Table 2. Sediment core sample analysis data for Cedar Creek Reservoir (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
CC-11	2690444.60	6800203.67	16.5”/13.0”	post-impoundment	0.0–8.5” smooth, gel-like consistency, silt, very high water content	5Y 3/1 Very dark gray
					8.5–13.0” silt with clay clasts, lower water content than above layer, slight color and texture change, organic material present	5y 2.5/1 Black
				pre-impoundment	13.0–16.5” dense, packed consistency, clay, lower water content than above layer, organic material throughout-sticks and roots of numerous sizes	5Y 2.5/1 Black
CC-12	2673314.50	6832520.70	10.5”/5.5”	post-impoundment	0.0–5.5” smooth, gel-like consistency, silt, high water content, distinct color, texture, water content change between layers	5Y 3/1, Very dark gray
				pre-impoundment	5.5–10.5” dense, packed consistency, clay, lower water content than above layer, organic material at top of layer	5Y, 2.5/1 Black

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

A photograph of sediment core CC-1 (for location, refer to Figure 2) is shown in Figure 7 and is representative of sediment cores sampled from Cedar Creek Reservoir. The base of the sample is denoted by the blue line. The pre-impoundment boundary (right most yellow line) was evident within this sediment core sample at 22.0 inches and identified by the change in color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the other eleven sediment cores followed a similar procedure.

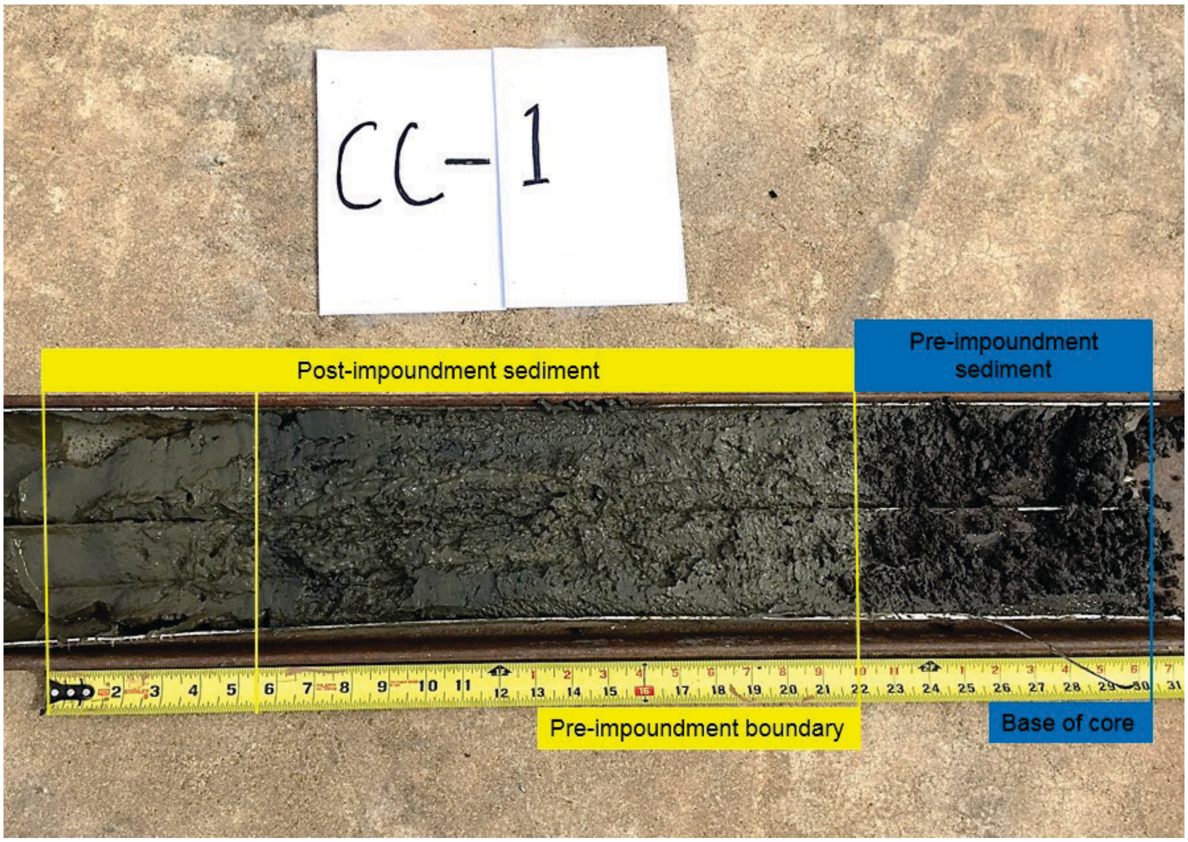


Figure 7. Sediment core CC-1 from Cedar Creek Reservoir. Post-impoundment sediment layers occur in the top 22.0 inches of this sediment core (identified by the yellow box). Pre-impoundment sediment layers were identified and are defined by the blue box.

Figures 8 and 9 illustrate how measurements from sediment core samples are used with sonar data to help identify the post- and pre-impoundment layers in the acoustic signal. Figure 8 compares sediment core sample CC-1 with the acoustic signals for each frequency combined (8A, 8A'), and the individual frequencies: 208 kHz (8B, 8B'), 50 kHz (8C, 8C'), and 24 kHz (8D, 8D'). Within DepthPic©, the current bathymetric surface is automatically determined based on signal returns from the 208 kHz transducer as represented by the top black line in Figure 8A' and red line in Figures 8B', 8C', and 8D'. 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 as determined by the sediment core sample analysis. Many layers of sediment may be identified during core 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. 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. A yellow box represents post-impoundment sediments. A blue box indicates pre-impoundment sediments.

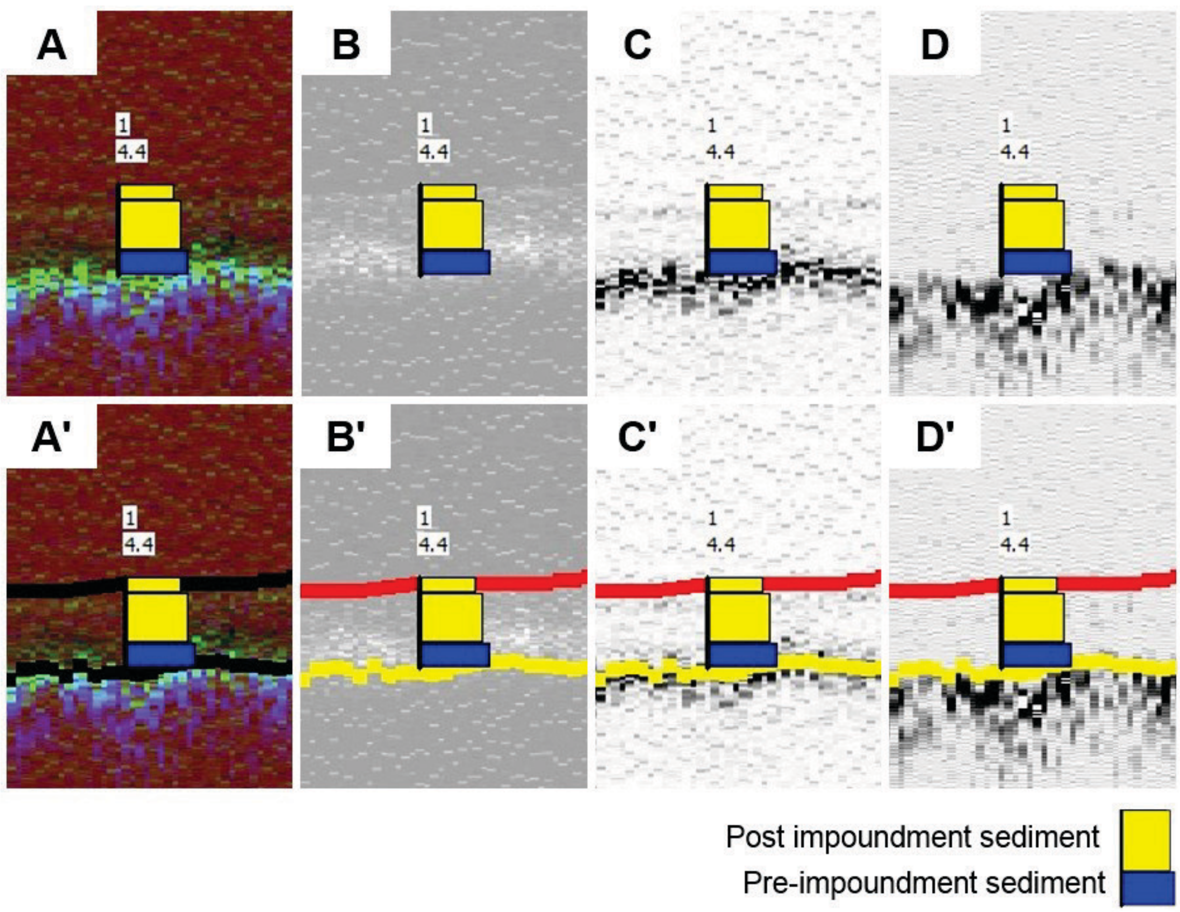


Figure 8. Comparison of sediment core CC-1 with acoustic signal returns A, A') combined acoustic signal returns, B, B') 208 kHz frequency, C, C') 50 kHz frequency, and D, D') 24 kHz frequency.

In this case, the pre-impoundment boundary as identified from the pre-impoundment interface of the sediment core sample was most visible in the combined acoustic signal returns; therefore, the combined acoustic signal returns were used to locate the pre-impoundment surface (yellow line in Figure 8). Figure 9 shows sediment core sample CC-1 correlated with the combined acoustic signal returns of the nearest surveyed cross-section. The pre-impoundment surface was first identified along cross-sections for which sediment core samples have been collected. This information was then used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

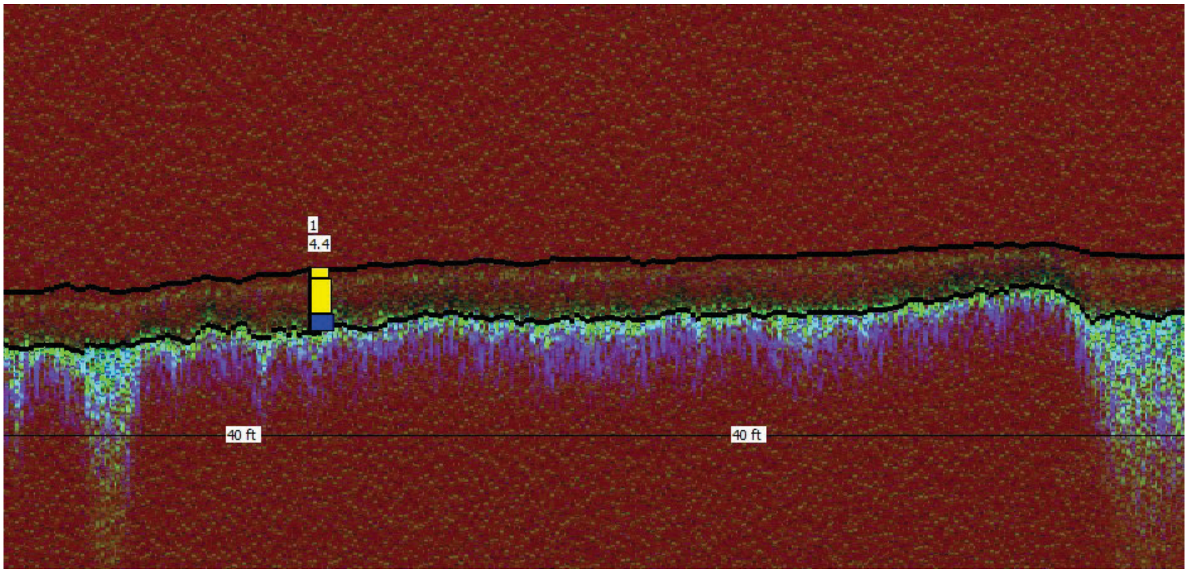
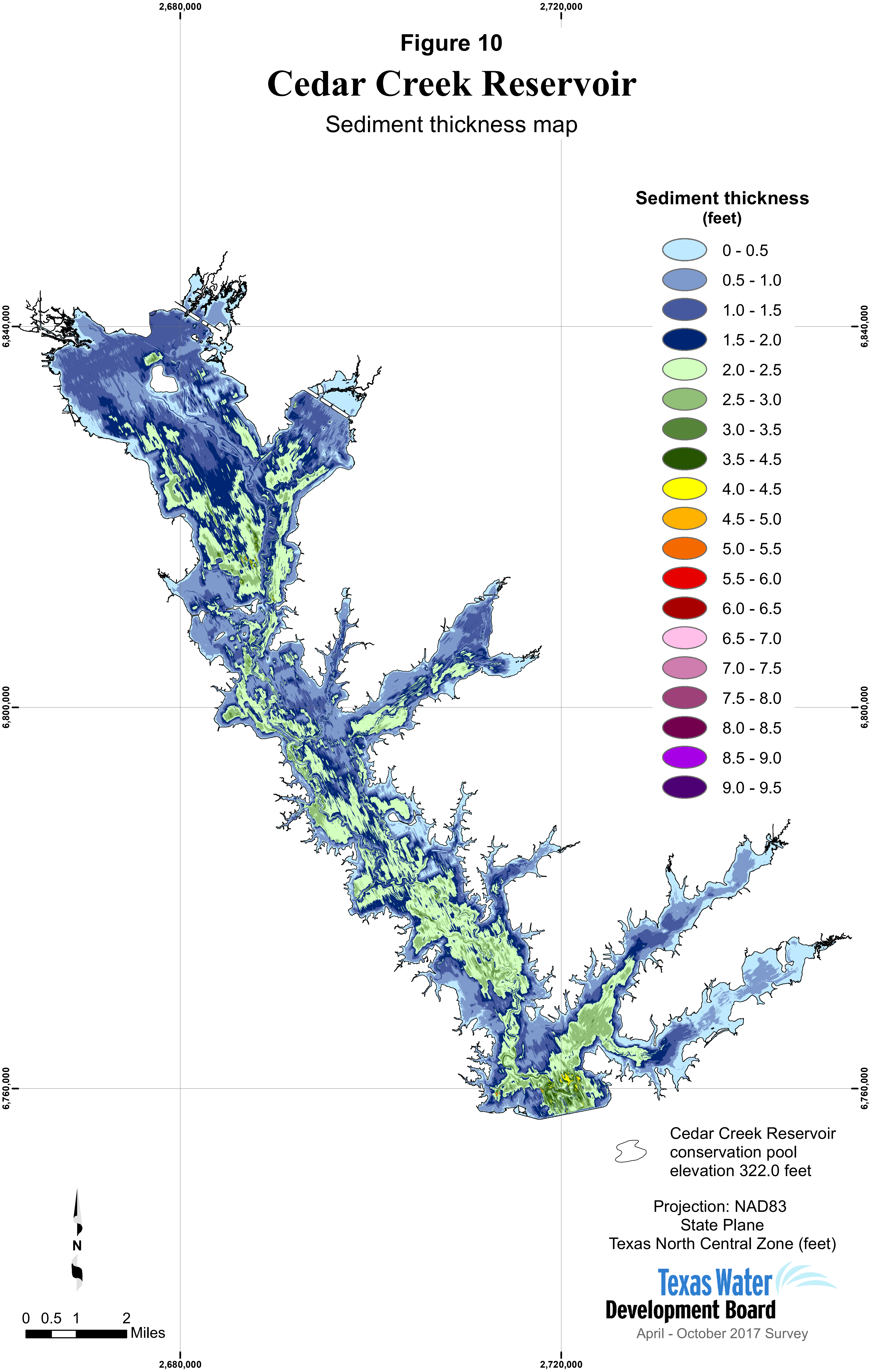


Figure 9. Cross-section of data collected during the 2017 survey, displayed in DepthPic© (combined acoustic signal returns), correlated with sediment core sample CC-1 and showing the current surface as the top black line, and pre-impoundment surface as the bottom black line.

After the pre-impoundment surface for all cross-sections was identified, a pre-impoundment TIN model and a sediment thickness TIN model were created following standard GIS techniques (Furnans and Austin, 2007). Pre-impoundment elevations and sediment thicknesses were interpolated between surveyed cross-sections using HydroTools after modifying the interpolation definition file used for bathymetric interpolation for modeling without the LIDAR data points. For the purposes of TIN model creation, the TWDB assumed the sediment thickness at the reservoir boundary was 0 feet (defined as the 322.0-foot elevation contour). The sediment thickness TIN model was converted to a raster representation using a cell size of 5 feet by 5 feet and was used to produce a sediment thickness map of Cedar Creek Reservoir (Figure 10). Using ArcInfo software, the pre-impoundment TIN model was used to compute elevation-capacity and elevation-area tables for the purpose of calculating the total volume of accumulated sediment.

Although linear interpolation was used to estimate topography in areas inaccessible by boat or too shallow for the instruments to work properly, including those areas that were no longer represented when the LIDAR data was removed, development of some flat triangles (triangles whose vertices all have the same elevation) in the TIN model are unavoidable. The flat triangles in turn lead to anomalous calculations of surface area and volume at the boundary elevation 322.0 feet. To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 317.5 and 322.0 feet were linearly interpolated between the computed values, and volumes above elevation 317.5 feet were calculated based on the corrected areas.

Figure 10
Cedar Creek Reservoir
Sediment thickness map



Survey results

Volumetric survey

The 2017 TWDB volumetric survey indicates that Cedar Creek Reservoir has a total reservoir capacity of 631,401 acre-feet and encompasses 33,099 acres at conservation pool elevation (322.0 feet above mean sea level, NGVD29). Previous capacity estimates include the original design estimate of 679,200 acre-feet. Re-evaluation of the 1995 and 2005 surveys resulted in updated capacity estimates of 642,569 acre-feet and 647,432 acre-feet, respectively, or a 0.85 and 0.41 percent increase in total capacity, respectively (Table 3). Differences in surface area are most likely attributable to differences in reservoir boundary delineation methods. Because of differences in past and present survey methodologies, direct comparison of volumetric surveys to others to estimate loss of area and capacity can be unreliable.

Table 3. Current and previous survey capacity and surface area estimates for Cedar Creek Reservoir.

Top of conservation pool elevation (322.0 feet, NGVD29)			
Survey	**Surface area (acres)**	**Total capacity (acre-feet)**	**Source**
Original design	33,750	679,200	Texas Water Development Board, 1973
TWDB 1995	32,623	637,180	Texas Water Development Board, 1995
TWDB 1995 (re-calculated)	32,556	642,569	Texas Water Development Board, 2016b
TWDB 2005	32,873	644,785	Texas Water Development Board, 2005
TWDB 2005 (re-calculated)	32,873	647,432	Texas Water Development Board, 2016b
TWDB 2017	33,099	631,401	

Sedimentation survey

The 2017 TWDB sedimentation survey indicates Cedar Creek Reservoir has lost capacity at an average of 841 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (322.0 feet NGVD29). The sedimentation survey indicates sediment accumulation is fairly uniform throughout the reservoir, with deposits increasing towards the dam. Comparison of the pre-impoundment surface with previous TWDB surveys of Cedar Creek Reservoir suggests the pre-impoundment surface was not well identified in the upper reaches of the Caney Creek, Clear Creek, and Lynn Creek branches of the reservoir. Sediment range lines 15, 18, 19, 20, and 21, illustrate this. Sediment range lines 19 and 21 are the shallowest cross-sections compared. Cedar Creek Reservoir has gone through several dry periods, most recently from 2013 to 2015, during which time water levels reached approximately 7 feet below conservation pool. Upon inundation and re-saturation, exposed sediment will not return to its original high level of water content (Dunbar and Allen, 2003). Drying of sediment in exposed areas create hard surfaces that cannot be penetrated with gravity coring techniques, and compressive stresses on the sediments may also increase sediment density, inhibiting the measurement of the original, pre-impoundment surface. Density stratification in the sediment layers can also scatter and attenuate acoustic return signals of the multi-frequency depth sounder (U.S. Army Corps of Engineers, 2013). Comparison of capacity estimates of Cedar Creek Reservoir derived using differing methodologies are provided in Table 4 for sedimentation rate calculation.

Table 4. Average annual capacity loss comparisons for Cedar Creek Reservoir.

Survey	**Volume comparisons at top of conservation pool elevation 322.0 feet (acre-feet)**			
Original design[a]	679,200	<>	<>	<>
TWDB 1995 (re-calculated)	<>	642,569	<>	<>
TWDB 2005 (re-calculated)	<>	<>	647,432	<>
TWDB pre-impoundment estimate based on 2017 survey	<>	<>	<>	675,125
2017 volumetric survey	631,401	631,401	631,401	631,401
Volume difference (acre-feet)	47,799 (7.0%)	11,168 (1.7%)	16,031 (2.5%)	43,724 (6.5%)
Number of years	52	22	12	52
Capacity loss rate (acre-feet/year)	919	508	1,336	841
Capacity loss rate (acre-feet/square mile of drainage area of 1,007[a] square miles /year)	0.91	0.50	1.33	0.84

[a] Source: (Texas Water Development Board, 1973), note: Deliberate impoundment began on July 2, 1965, and Joe B. Hogsett Dam was completed in February 1966.

Sediment range lines

In 2005, the TWDB established twenty-four sediment range lines throughout Cedar Creek Reservoir to measure sediment accumulation over time. A cross-sectional comparison of the twenty-four sediment range lines comparing the current and pre-impoundment surfaces from the TWDB 2017 survey, the TWDB 2005 re-calculated survey, and the TWDB 1995 re-calculated survey is presented in Appendix M. Also presented in Appendix M are a map, depicting the TWDB locations of the sediment range lines and Table M1, a list of the endpoint coordinates for each line. Some differences in the cross-sections may be a result of spatial interpolation and the interpolation routine of the TIN Model.

Recommendations

The TWDB recommends a detailed analysis of sediment deposits in the areas where exposure of the lake bottom may have led to identification of a false pre-impoundment using augured-coring techniques, as well as a volumetric and sedimentation survey in 10 years or after a major flood event 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

Cedar Creek Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — March 1995 Survey re-calculated October 2016

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 322.0 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
254	0	0	0	0	0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	0	0	0	0	0
257	0	1	1	1	1	1	1	2	2	2
258	2	3	3	3	4	4	5	5	6	7
259	7	8	9	10	10	11	12	13	14	15
260	16	17	18	20	21	22	24	25	27	28
261	30	31	33	35	37	39	41	43	45	47
262	50	52	55	57	60	63	66	70	73	77
263	81	85	89	93	98	103	107	113	118	124
264	129	136	142	149	156	163	170	178	186	195
265	203	212	222	232	242	253	264	276	288	301
266	314	327	341	356	371	387	403	419	436	454
267	472	491	510	529	549	570	591	612	634	657
268	680	703	727	752	777	803	829	856	883	911
269	940	970	1,000	1,030	1,062	1,094	1,127	1,161	1,195	1,231
270	1,267	1,304	1,342	1,382	1,422	1,463	1,506	1,550	1,595	1,642
271	1,690	1,740	1,792	1,845	1,899	1,955	2,012	2,072	2,132	2,195
272	2,259	2,324	2,391	2,460	2,530	2,603	2,677	2,753	2,831	2,911
273	2,992	3,075	3,160	3,246	3,335	3,425	3,517	3,610	3,705	3,802
274	3,900	4,001	4,104	4,209	4,316	4,426	4,538	4,652	4,770	4,889
275	5,011	5,136	5,263	5,392	5,523	5,657	5,792	5,930	6,070	6,212
276	6,356	6,503	6,652	6,803	6,956	7,112	7,269	7,430	7,593	7,759
277	7,927	8,098	8,272	8,449	8,628	8,811	8,996	9,184	9,376	9,571
278	9,769	9,971	10,175	10,382	10,592	10,805	11,021	11,239	11,461	11,685
279	11,912	12,143	12,377	12,613	12,853	13,096	13,342	13,592	13,844	14,100
280	14,359	14,621	14,887	15,155	15,426	15,700	15,978	16,259	16,543	16,831
281	17,123	17,419	17,719	18,024	18,333	18,647	18,965	19,288	19,614	19,945
282	20,280	20,619	20,963	21,310	21,662	22,018	22,378	22,742	23,111	23,484
283	23,862	24,244	24,631	25,022	25,417	25,817	26,222	26,631	27,044	27,463
284	27,885	28,312	28,744	29,180	29,622	30,068	30,521	30,980	31,444	31,914
285	32,389	32,869	33,355	33,846	34,342	34,843	35,348	35,858	36,372	36,890
286	37,412	37,939	38,469	39,004	39,543	40,087	40,635	41,189	41,746	42,309
287	42,876	43,447	44,023	44,603	45,187	45,775	46,368	46,966	47,568	48,174
288	48,785	49,399	50,017	50,639	51,265	51,896	52,530	53,169	53,812	54,460
289	55,112	55,769	56,432	57,099	57,771	58,448	59,129	59,816	60,507	61,203
290	61,905	62,611	63,321	64,037	64,758	65,484	66,214	66,950	67,692	68,439
291	69,192	69,951	70,714	71,484	72,260	73,041	73,827	74,619	75,416	76,220
292	77,028	77,843	78,662	79,487	80,318	81,155	81,998	82,847	83,701	84,561
293	85,426	86,296	87,170	88,048	88,931	89,819	90,711	91,608	92,509	93,414
294	94,324	95,239	96,157	97,080	98,007	98,939	99,875	100,817	101,762	102,714
295	103,670	104,631	105,597	106,569	107,546	108,529	109,518	110,512	111,511	112,516
296	113,527	114,543	115,565	116,592	117,624	118,661	119,703	120,750	121,801	122,858
297	123,919	124,986	126,058	127,135	128,218	129,307	130,400	131,499	132,602	133,711
298	134,825	135,945	137,069	138,199	139,335	140,476	141,622	142,774	143,931	145,093
299	146,260	147,433	148,612	149,795	150,984	152,179	153,378	154,583	155,793	157,008
300	158,230	159,457	160,691	161,930	163,176	164,428	165,686	166,952	168,224	169,504
301	170,792	172,087	173,390	174,699	176,017	177,341	178,672	180,011	181,357	182,711
302	184,073	185,443	186,823	188,213	189,611	191,017	192,430	193,850	195,277	196,712
303	198,154	199,604	201,062	202,528	204,004	205,488	206,980	208,481	209,990	211,508
304	213,035	214,570	216,116	217,670	219,235	220,809	222,392	223,984	225,585	227,195
305	228,815	230,443	232,081	233,726	235,380	237,044	238,717	240,399	242,089	243,789
306	245,499	247,218	248,945	250,681	252,426	254,179	255,942	257,714	259,496	261,289
307	263,092	264,905	266,729	268,562	270,406	272,262	274,130	276,007	277,894	279,792
308	281,700	283,618	285,546	287,483	289,430	291,387	293,354	295,331	297,317	299,314
309	301,320	303,337	305,363	307,397	309,441	311,494	313,556	315,626	317,705	319,795

Appendix A (Continued)

Cedar Creek Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — March 1995 Survey re-calculated October 2016

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 322.0 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
310	321,893	324,002	326,121	328,251	330,390	332,539	334,696	336,862	339,036	341,218
311	343,409	345,608	347,816	350,031	352,257	354,493	356,738	358,992	361,253	363,525
312	365,806	368,097	370,398	372,709	375,029	377,358	379,697	382,045	384,401	386,767
313	389,143	391,528	393,923	396,327	398,740	401,162	403,593	406,033	408,481	410,940
314	413,407	415,884	418,370	420,866	423,374	425,893	428,423	430,964	433,513	436,073
315	438,643	441,222	443,809	446,405	449,012	451,629	454,256	456,894	459,543	462,203
316	464,873	467,554	470,244	472,943	475,655	478,377	481,109	483,850	486,599	489,359
317	492,128	494,908	497,697	500,495	503,303	506,121	508,949	511,787	514,636	517,495
318	520,363	523,241	526,128	529,023	531,927	534,839	537,759	540,688	543,626	546,573
319	549,529	552,494	555,470	558,454	561,448	564,448	567,456	570,470	573,490	576,519
320	579,559	582,610	585,671	588,743	591,825	594,918	598,021	601,134	604,259	607,393
321	610,539	613,694	616,861	620,037	623,225	626,422	629,631	632,850	636,079	639,319
322	642,569									

Note: Capacities above elevation 319.8 feet calculated from interpolated areas

Appendix B

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — March 1995 Survey re-calculated October 2016

AREA IN ACRES — Conservation Pool Elevation 322.0 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
254	0	0	0	0	0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	0	0	0	1	1
257	1	1	1	1	2	2	2	2	3	3
258	3	3	4	4	5	5	5	6	6	7
259	7	7	8	8	8	9	9	9	10	10
260	11	11	12	12	13	14	14	15	15	16
261	16	17	18	18	19	20	21	21	22	23
262	24	25	26	28	29	31	33	34	36	37
263	39	41	43	44	46	48	50	52	55	57
264	60	63	66	68	71	74	77	79	82	85
265	89	93	97	101	105	110	115	119	124	129
266	134	139	144	149	154	158	163	168	173	178
267	183	188	193	198	203	208	213	217	223	228
268	233	238	243	249	254	260	266	271	277	284
269	291	297	304	311	319	326	334	341	350	358
270	367	377	387	397	409	420	432	446	460	474
271	493	508	521	536	551	567	584	600	615	631
272	646	662	678	695	715	735	753	771	788	804
273	821	838	856	874	893	910	926	942	958	976
274	996	1,017	1,039	1,063	1,085	1,109	1,133	1,159	1,183	1,208
275	1,233	1,257	1,281	1,303	1,325	1,345	1,367	1,389	1,409	1,431
276	1,455	1,478	1,500	1,521	1,543	1,566	1,589	1,618	1,645	1,673
277	1,699	1,725	1,752	1,780	1,810	1,838	1,869	1,901	1,935	1,966
278	1,996	2,028	2,059	2,088	2,115	2,142	2,170	2,199	2,228	2,260
279	2,291	2,321	2,351	2,381	2,412	2,445	2,478	2,512	2,544	2,575
280	2,606	2,636	2,667	2,696	2,727	2,759	2,792	2,828	2,863	2,900
281	2,939	2,980	3,024	3,069	3,115	3,161	3,204	3,246	3,286	3,329
282	3,371	3,414	3,456	3,496	3,537	3,579	3,622	3,666	3,707	3,752
283	3,801	3,845	3,889	3,933	3,978	4,023	4,069	4,113	4,158	4,202
284	4,246	4,292	4,341	4,390	4,441	4,495	4,555	4,619	4,674	4,727
285	4,775	4,827	4,885	4,935	4,984	5,030	5,074	5,119	5,162	5,203
286	5,245	5,285	5,327	5,368	5,412	5,461	5,509	5,555	5,601	5,648
287	5,694	5,736	5,776	5,817	5,861	5,906	5,953	6,002	6,046	6,084
288	6,124	6,162	6,199	6,239	6,282	6,327	6,368	6,409	6,452	6,498
289	6,549	6,599	6,648	6,696	6,744	6,792	6,839	6,887	6,940	6,989
290	7,037	7,084	7,131	7,183	7,234	7,282	7,331	7,386	7,443	7,505
291	7,557	7,609	7,667	7,729	7,782	7,836	7,893	7,947	8,003	8,059
292	8,115	8,167	8,222	8,282	8,340	8,396	8,460	8,521	8,574	8,624
293	8,672	8,719	8,763	8,808	8,853	8,899	8,942	8,987	9,035	9,079
294	9,121	9,165	9,208	9,250	9,295	9,340	9,386	9,436	9,486	9,537
295	9,587	9,637	9,690	9,746	9,801	9,856	9,912	9,966	10,022	10,077
296	10,134	10,191	10,247	10,299	10,348	10,394	10,441	10,491	10,540	10,590
297	10,642	10,695	10,747	10,803	10,855	10,907	10,959	11,010	11,061	11,115
298	11,169	11,222	11,275	11,328	11,382	11,435	11,490	11,543	11,595	11,648
299	11,703	11,755	11,809	11,865	11,919	11,970	12,021	12,074	12,127	12,182
300	12,242	12,303	12,367	12,429	12,490	12,551	12,615	12,687	12,762	12,838
301	12,914	12,990	13,065	13,136	13,206	13,279	13,351	13,423	13,499	13,577
302	13,662	13,748	13,851	13,940	14,022	14,095	14,166	14,237	14,310	14,383
303	14,460	14,540	14,621	14,709	14,799	14,882	14,966	15,051	15,139	15,224
304	15,306	15,401	15,499	15,596	15,693	15,785	15,877	15,965	16,058	16,149
305	16,239	16,330	16,415	16,499	16,588	16,682	16,775	16,865	16,953	17,049
306	17,142	17,229	17,319	17,402	17,489	17,576	17,676	17,776	17,876	17,978
307	18,081	18,181	18,283	18,391	18,501	18,615	18,727	18,826	18,925	19,028
308	19,131	19,229	19,325	19,421	19,520	19,620	19,717	19,814	19,917	20,018
309	20,116	20,212	20,305	20,392	20,482	20,573	20,662	20,750	20,844	20,939

Appendix B (Continued)

Cedar Creek Reservoir

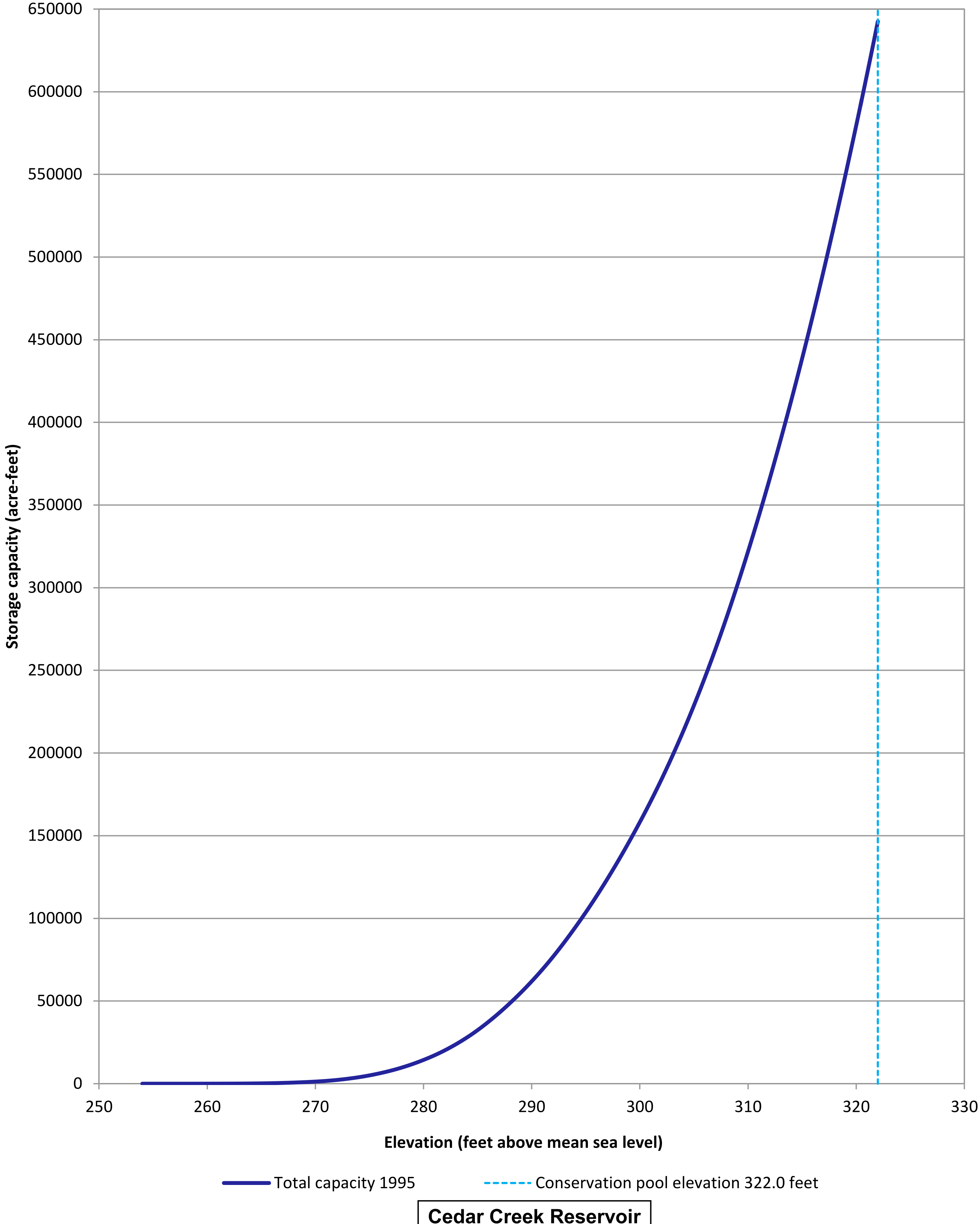
RESERVOIR AREA TABLE

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

March 1995 Survey re-calculated October 2016
Conservation Pool Elevation 322.0 feet NGVD29

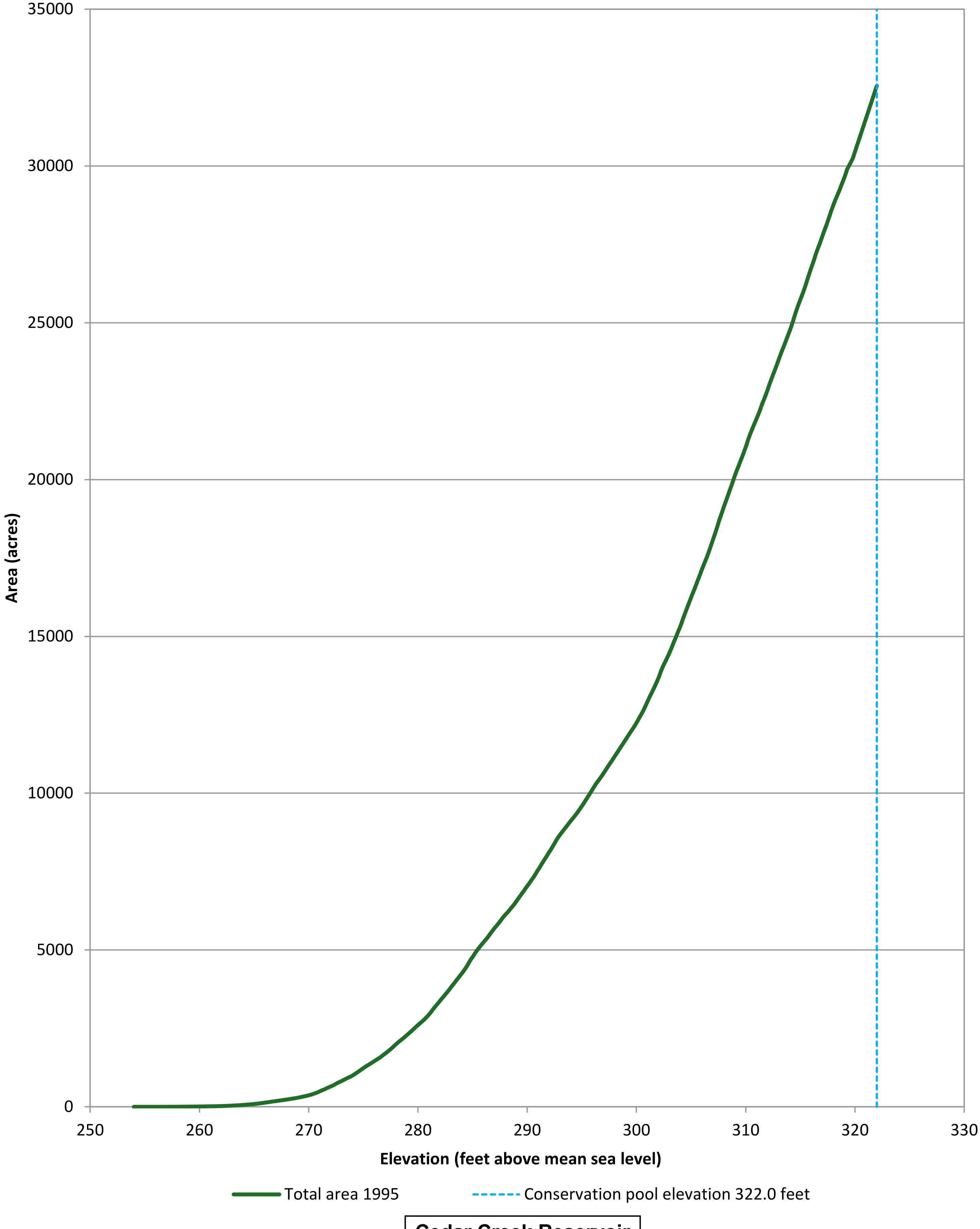
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
310	21,033	21,138	21,248	21,346	21,441	21,529	21,614	21,700	21,785	21,865
311	21,948	22,032	22,118	22,209	22,308	22,405	22,493	22,579	22,668	22,759
312	22,858	22,962	23,062	23,154	23,247	23,340	23,433	23,522	23,614	23,707
313	23,805	23,902	23,996	24,087	24,176	24,263	24,352	24,444	24,536	24,627
314	24,719	24,813	24,913	25,018	25,133	25,244	25,353	25,455	25,552	25,646
315	25,740	25,830	25,919	26,016	26,115	26,217	26,330	26,437	26,544	26,650
316	26,752	26,851	26,950	27,057	27,170	27,269	27,363	27,454	27,546	27,645
317	27,744	27,844	27,940	28,031	28,126	28,227	28,329	28,431	28,541	28,638
318	28,730	28,826	28,913	28,996	29,078	29,160	29,244	29,335	29,427	29,516
319	29,603	29,699	29,805	29,905	29,970	30,037	30,104	30,173	30,243	30,349
320	30,454	30,559	30,664	30,769	30,874	30,979	31,084	31,189	31,295	31,400
321	31,505	31,610	31,715	31,820	31,925	32,030	32,135	32,241	32,346	32,451
322	32,556									

Note: Areas between elevations 319.8 and 322.0 feet linearly interpolated



Cedar Creek Reservoir
March 1995 Survey
re-calculated October 2016
Prepared by: TWDB

Appendix C: Capacity curve



Cedar Creek Reservoir
March 1995 Survey
re-calculated October 2016
Prepared by: TWDB

Appendix D: Area curve

Appendix E

Cedar Creek Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2005 Survey re-calculated October 2016

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 322.0 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
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	0	0	0	0	0
257	0	0	0	0	0	0	0	0	0	0
258	0	0	0	1	1	1	1	1	2	2
259	2	2	3	3	4	4	5	5	6	6
260	7	8	8	9	10	11	12	12	13	14
261	15	17	18	19	20	22	23	24	26	28
262	29	31	33	35	37	39	41	43	46	48
263	51	54	56	59	63	66	69	73	77	81
264	86	90	95	100	106	111	117	123	129	136
265	142	149	156	163	171	178	186	194	203	212
266	221	230	240	251	262	273	285	297	310	323
267	337	352	367	382	398	414	431	449	467	485
268	504	524	544	564	586	607	630	653	677	702
269	727	753	780	808	837	866	897	928	961	994
270	1,028	1,063	1,099	1,136	1,174	1,214	1,255	1,297	1,341	1,386
271	1,434	1,483	1,534	1,586	1,640	1,696	1,753	1,812	1,872	1,934
272	1,997	2,062	2,129	2,197	2,267	2,339	2,413	2,488	2,564	2,642
273	2,722	2,804	2,887	2,972	3,058	3,147	3,237	3,330	3,424	3,520
274	3,619	3,719	3,821	3,926	4,033	4,141	4,251	4,363	4,477	4,593
275	4,711	4,831	4,953	5,076	5,202	5,330	5,460	5,592	5,726	5,862
276	6,000	6,140	6,283	6,427	6,574	6,723	6,874	7,027	7,182	7,339
277	7,497	7,658	7,821	7,987	8,154	8,325	8,497	8,672	8,850	9,030
278	9,213	9,400	9,589	9,782	9,979	10,179	10,382	10,588	10,798	11,011
279	11,228	11,447	11,670	11,895	12,124	12,356	12,592	12,830	13,072	13,318
280	13,567	13,818	14,074	14,332	14,593	14,858	15,126	15,397	15,672	15,951
281	16,235	16,523	16,815	17,111	17,411	17,716	18,024	18,335	18,651	18,970
282	19,294	19,623	19,957	20,295	20,638	20,985	21,336	21,692	22,053	22,418
283	22,788	23,163	23,541	23,923	24,310	24,700	25,096	25,495	25,899	26,307
284	26,719	27,137	27,559	27,986	28,417	28,853	29,294	29,739	30,188	30,643
285	31,104	31,572	32,047	32,527	33,013	33,505	34,002	34,504	35,011	35,523
286	36,039	36,560	37,084	37,613	38,146	38,683	39,225	39,771	40,322	40,878
287	41,438	42,003	42,572	43,146	43,724	44,306	44,892	45,482	46,077	46,675
288	47,278	47,885	48,497	49,112	49,732	50,356	50,985	51,618	52,255	52,896
289	53,542	54,192	54,846	55,505	56,168	56,836	57,509	58,186	58,869	59,557
290	60,249	60,947	61,650	62,358	63,071	63,790	64,514	65,243	65,977	66,718
291	67,463	68,215	68,973	69,736	70,505	71,280	72,063	72,852	73,647	74,449
292	75,256	76,069	76,888	77,712	78,541	79,377	80,218	81,066	81,920	82,780
293	83,646	84,517	85,393	86,274	87,160	88,051	88,947	89,848	90,754	91,665
294	92,581	93,502	94,428	95,358	96,293	97,233	98,179	99,130	100,087	101,050
295	102,017	102,990	103,967	104,950	105,939	106,934	107,935	108,942	109,954	110,972
296	111,995	113,024	114,059	115,098	116,144	117,195	118,251	119,312	120,379	121,451
297	122,528	123,611	124,699	125,791	126,890	127,993	129,102	130,216	131,335	132,460
298	133,590	134,726	135,867	137,014	138,166	139,324	140,487	141,654	142,826	144,004
299	145,187	146,375	147,568	148,766	149,969	151,178	152,391	153,609	154,833	156,062
300	157,296	158,534	159,778	161,027	162,282	163,541	164,807	166,077	167,354	168,637
301	169,927	171,224	172,530	173,847	175,176	176,515	177,864	179,223	180,590	181,966
302	183,351	184,744	186,145	187,553	188,968	190,390	191,818	193,254	194,696	196,146
303	197,605	199,073	200,551	202,036	203,530	205,031	206,541	208,059	209,585	211,118
304	212,658	214,207	215,764	217,329	218,904	220,487	222,079	223,681	225,292	226,914
305	228,548	230,194	231,851	233,518	235,194	236,879	238,572	240,274	241,984	243,705
306	245,435	247,174	248,922	250,679	252,446	254,222	256,008	257,804	259,611	261,430
307	263,260	265,102	266,955	268,817	270,689	272,570	274,460	276,359	278,267	280,186
308	282,115	284,055	286,004	287,962	289,930	291,908	293,895	295,891	297,898	299,916
309	301,944	303,983	306,032	308,090	310,157	312,234	314,321	316,417	318,522	320,637

Appendix E (Continued)

Cedar Creek Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2005 Survey re-calculated October 2016

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 322.0 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
310	322,762	324,897	327,042	329,194	331,357	333,527	335,707	337,896	340,094	342,304
311	344,524	346,755	348,995	351,243	353,501	355,768	358,044	360,329	362,622	364,926
312	367,240	369,564	371,898	374,240	376,592	378,954	381,327	383,710	386,103	388,507
313	390,921	393,345	395,778	398,220	400,671	403,132	405,601	408,079	410,567	413,064
314	415,569	418,082	420,602	423,129	425,664	428,206	430,756	433,314	435,879	438,454
315	441,038	443,632	446,235	448,847	451,469	454,102	456,746	459,400	462,066	464,745
316	467,435	470,138	472,853	475,580	478,320	481,073	483,839	486,617	489,407	492,210
317	495,025	497,852	500,689	503,536	506,395	509,265	512,144	515,034	517,932	520,841
318	523,758	526,683	529,617	532,558	535,509	538,467	541,433	544,407	547,387	550,376
319	553,371	556,373	559,382	562,396	565,418	568,446	571,483	574,530	577,587	580,654
320	583,732	586,820	589,918	593,026	596,144	599,273	602,412	605,561	608,721	611,890
321	615,070	618,260	621,461	624,671	627,892	631,123	634,364	637,616	640,878	644,149
322	647,432									

Note: Capacities above elevation 319.5 feet calculated from interpolated areas

Appendix F

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2005 Survey re-calculated October 2016

AREA IN ACRES — Conservation Pool Elevation 322.0 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
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	0	0	0	0	0
257	0	0	0	0	0	0	0	0	0	1
258	1	1	1	1	2	2	2	2	3	3
259	3	4	4	4	4	5	5	5	6	6
260	6	7	7	8	8	8	9	9	10	10
261	11	11	12	13	13	14	14	15	16	17
262	17	18	19	20	21	22	23	23	24	25
263	26	28	29	31	32	34	37	39	41	43
264	45	48	50	52	54	56	59	61	63	65
265	67	69	71	73	76	78	80	83	87	90
266	94	98	103	107	111	116	120	125	131	136
267	141	147	152	157	162	167	172	177	182	187
268	193	198	204	210	216	222	228	235	242	250
269	257	266	274	283	292	301	310	319	328	337
270	346	355	366	376	388	401	415	430	447	464
271	485	501	517	533	548	564	579	595	610	626
272	643	658	674	692	710	728	743	757	772	790
273	808	823	839	857	875	894	913	933	953	974
274	994	1,014	1,035	1,056	1,077	1,094	1,111	1,128	1,147	1,167
275	1,190	1,210	1,229	1,249	1,269	1,288	1,309	1,330	1,351	1,371
276	1,392	1,413	1,435	1,457	1,478	1,498	1,519	1,539	1,559	1,578
277	1,599	1,620	1,643	1,665	1,688	1,713	1,737	1,764	1,790	1,818
278	1,849	1,879	1,912	1,945	1,983	2,015	2,047	2,081	2,117	2,149
279	2,179	2,210	2,241	2,273	2,305	2,338	2,370	2,403	2,438	2,472
280	2,502	2,534	2,566	2,597	2,630	2,664	2,699	2,731	2,768	2,811
281	2,857	2,900	2,941	2,983	3,025	3,062	3,098	3,134	3,174	3,216
282	3,265	3,315	3,362	3,404	3,448	3,491	3,539	3,584	3,631	3,676
283	3,721	3,764	3,804	3,843	3,884	3,928	3,974	4,016	4,058	4,102
284	4,151	4,198	4,247	4,293	4,337	4,381	4,425	4,472	4,520	4,576
285	4,645	4,715	4,779	4,836	4,889	4,944	4,996	5,045	5,096	5,142
286	5,182	5,221	5,264	5,311	5,354	5,397	5,439	5,485	5,532	5,581
287	5,627	5,671	5,714	5,757	5,799	5,841	5,883	5,924	5,966	6,008
288	6,048	6,092	6,134	6,176	6,221	6,266	6,308	6,350	6,391	6,434
289	6,478	6,522	6,566	6,610	6,655	6,702	6,754	6,802	6,851	6,901
290	6,952	7,002	7,053	7,107	7,162	7,213	7,265	7,318	7,372	7,429
291	7,488	7,547	7,604	7,660	7,720	7,789	7,860	7,923	7,984	8,044
292	8,102	8,159	8,215	8,267	8,322	8,380	8,448	8,512	8,572	8,629
293	8,683	8,734	8,788	8,838	8,886	8,934	8,985	9,035	9,084	9,136
294	9,186	9,232	9,278	9,327	9,374	9,430	9,486	9,543	9,598	9,648
295	9,698	9,750	9,804	9,862	9,919	9,979	10,037	10,094	10,150	10,207
296	10,261	10,317	10,373	10,427	10,481	10,534	10,587	10,641	10,694	10,747
297	10,801	10,852	10,902	10,955	11,009	11,061	11,114	11,167	11,221	11,275
298	11,329	11,384	11,441	11,496	11,549	11,601	11,649	11,698	11,750	11,801
299	11,853	11,907	11,959	12,007	12,057	12,107	12,158	12,210	12,263	12,314
300	12,363	12,412	12,464	12,518	12,570	12,624	12,679	12,738	12,799	12,863
301	12,932	13,013	13,113	13,229	13,343	13,442	13,537	13,631	13,719	13,805
302	13,889	13,968	14,046	14,118	14,184	14,251	14,319	14,388	14,458	14,543
303	14,637	14,733	14,817	14,892	14,973	15,058	15,141	15,220	15,294	15,366
304	15,444	15,528	15,614	15,699	15,787	15,873	15,968	16,064	16,165	16,277
305	16,402	16,518	16,621	16,717	16,803	16,889	16,974	17,062	17,156	17,252
306	17,346	17,438	17,527	17,617	17,712	17,811	17,910	18,014	18,128	18,246
307	18,362	18,475	18,577	18,672	18,763	18,854	18,946	19,037	19,133	19,234
308	19,346	19,444	19,537	19,634	19,728	19,822	19,917	20,018	20,121	20,230
309	20,336	20,439	20,535	20,629	20,719	20,817	20,915	21,008	21,103	21,200

Appendix F (Continued)

Cedar Creek Reservoir

RESERVOIR AREA TABLE

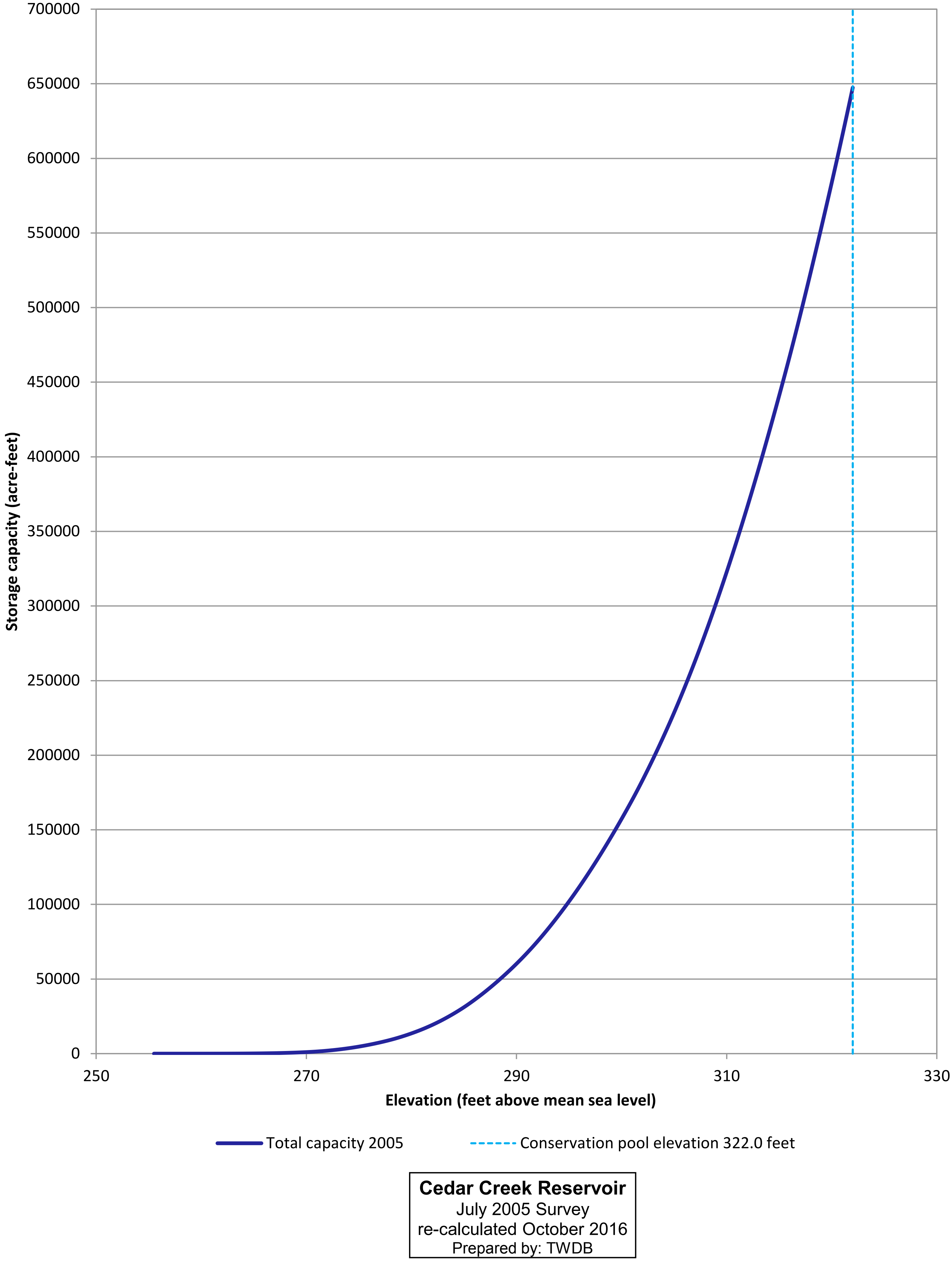
TEXAS WATER DEVELOPMENT BOARD — July 2005 Survey re-calculated October 2016

AREA IN ACRES — Conservation Pool Elevation 322.0 feet NGVD29

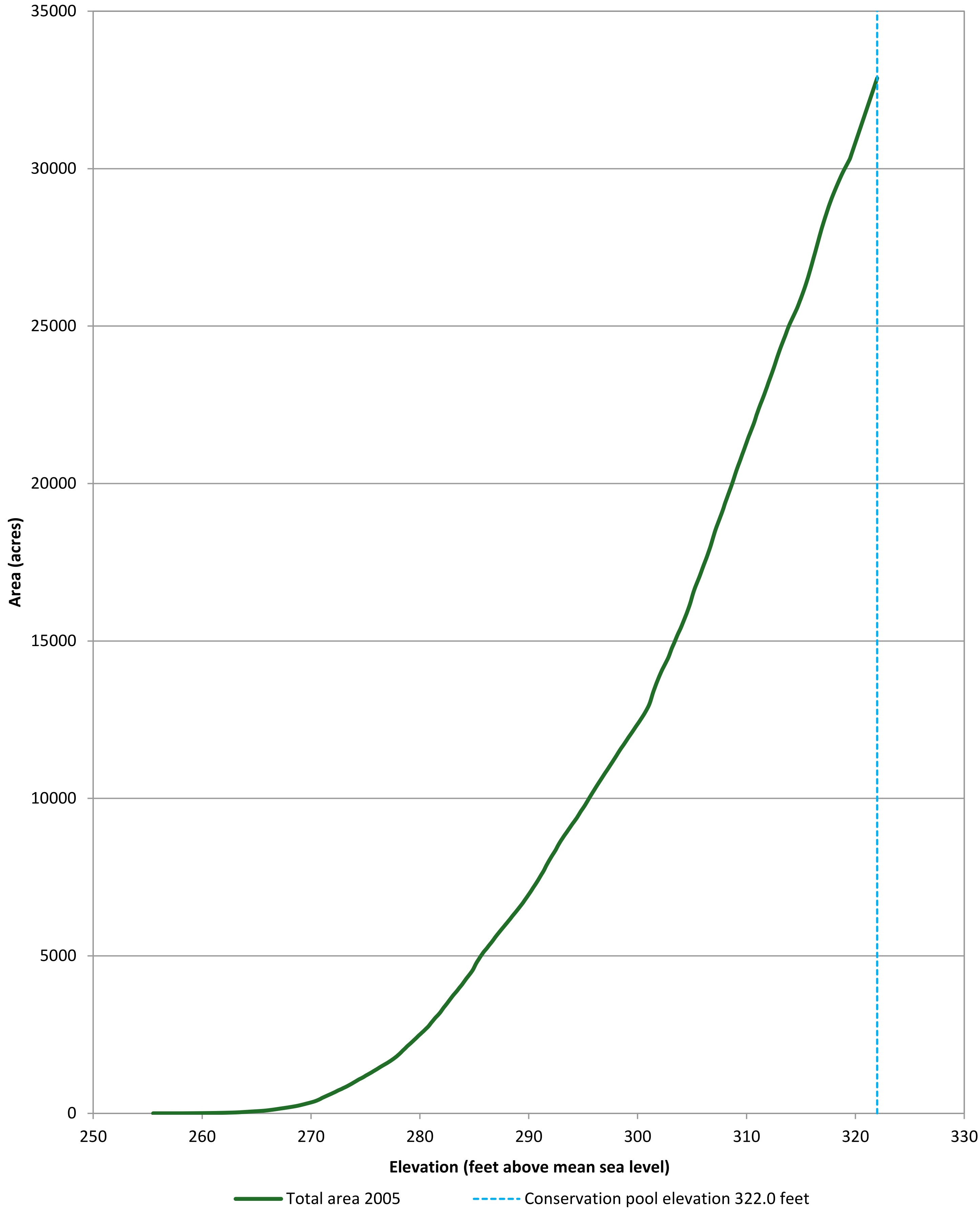
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
310	21,296	21,395	21,490	21,576	21,664	21,753	21,841	21,934	22,039	22,153
311	22,252	22,351	22,445	22,536	22,622	22,710	22,800	22,895	22,991	23,086
312	23,190	23,285	23,379	23,475	23,572	23,671	23,774	23,881	23,989	24,090
313	24,190	24,286	24,378	24,467	24,557	24,645	24,735	24,832	24,926	25,011
314	25,092	25,165	25,239	25,311	25,384	25,459	25,533	25,615	25,705	25,797
315	25,886	25,979	26,076	26,173	26,274	26,381	26,489	26,604	26,723	26,842
316	26,964	27,090	27,214	27,335	27,463	27,591	27,718	27,845	27,969	28,092
317	28,205	28,317	28,427	28,533	28,639	28,745	28,847	28,941	29,036	29,126
318	29,212	29,296	29,378	29,460	29,541	29,620	29,698	29,775	29,849	29,919
319	29,987	30,052	30,116	30,181	30,248	30,316	30,418	30,520	30,623	30,725
320	30,827	30,929	31,032	31,134	31,236	31,339	31,441	31,543	31,645	31,748
321	31,850	31,952	32,055	32,157	32,259	32,361	32,464	32,566	32,668	32,771
322	32,873									

Note: Areas between elevations 319.5 and 322.0 feet linearly interpolated



Appendix G: Capacity curve



Cedar Creek Reservoir
July 2005 Survey
re-calculated October 2016
Prepared by: TWDB

Appendix H: Area curve

Appendix I

Cedar Creek Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — April - Ocober 2017 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 322.0 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
257	0	0	0	0	0	0	0	0	0	0
258	0	0	0	0	0	0	0	0	1	1
259	1	1	1	1	1	2	2	2	2	3
260	3	4	4	5	5	6	7	7	8	9
261	10	11	12	14	15	16	18	19	20	22
262	24	25	27	29	31	33	35	37	39	41
263	43	46	48	51	54	56	59	62	65	68
264	71	75	78	82	85	89	93	98	102	107
265	112	117	122	128	134	139	146	152	158	165
266	172	179	187	195	203	211	219	228	237	246
267	255	265	275	285	296	307	318	331	343	357
268	371	385	400	415	431	447	464	482	500	518
269	537	557	577	598	619	641	664	687	711	735
270	760	785	812	839	867	895	925	955	985	1,017
271	1,050	1,083	1,118	1,153	1,190	1,228	1,268	1,309	1,352	1,396
272	1,442	1,489	1,538	1,589	1,642	1,696	1,751	1,809	1,867	1,928
273	1,990	2,053	2,119	2,186	2,255	2,325	2,398	2,472	2,548	2,626
274	2,706	2,788	2,872	2,957	3,045	3,134	3,225	3,318	3,412	3,508
275	3,606	3,706	3,808	3,912	4,017	4,125	4,234	4,344	4,457	4,572
276	4,688	4,807	4,927	5,050	5,174	5,301	5,429	5,560	5,693	5,827
277	5,964	6,102	6,243	6,386	6,531	6,679	6,828	6,981	7,135	7,292
278	7,451	7,613	7,777	7,943	8,112	8,284	8,459	8,637	8,818	9,002
279	9,190	9,381	9,576	9,774	9,977	10,184	10,394	10,606	10,822	11,041
280	11,263	11,489	11,718	11,951	12,188	12,428	12,672	12,920	13,171	13,425
281	13,682	13,942	14,207	14,474	14,746	15,021	15,301	15,584	15,872	16,165
282	16,461	16,762	17,066	17,373	17,684	17,999	18,318	18,641	18,968	19,300
283	19,636	19,976	20,321	20,669	21,023	21,381	21,743	22,110	22,481	22,857
284	23,236	23,619	24,006	24,397	24,792	25,192	25,596	26,005	26,418	26,836
285	27,258	27,684	28,115	28,549	28,989	29,433	29,881	30,334	30,791	31,253
286	31,721	32,195	32,677	33,166	33,661	34,164	34,672	35,187	35,706	36,229
287	36,757	37,289	37,825	38,364	38,907	39,454	40,005	40,560	41,119	41,683
288	42,252	42,825	43,404	43,987	44,575	45,167	45,764	46,366	46,971	47,581
289	48,194	48,812	49,433	50,058	50,688	51,323	51,962	52,605	53,252	53,904
290	54,559	55,219	55,884	56,553	57,227	57,906	58,591	59,281	59,976	60,676
291	61,383	62,095	62,813	63,536	64,263	64,996	65,734	66,479	67,231	67,988
292	68,752	69,522	70,298	71,080	71,869	72,664	73,466	74,273	75,087	75,907
293	76,732	77,563	78,398	79,238	80,083	80,934	81,791	82,654	83,522	84,395
294	85,274	86,158	87,047	87,940	88,838	89,741	90,649	91,562	92,480	93,403
295	94,331	95,265	96,204	97,147	98,096	99,049	100,008	100,971	101,939	102,912
296	103,890	104,873	105,860	106,853	107,850	108,851	109,858	110,870	111,886	112,909
297	113,937	114,972	116,012	117,058	118,110	119,169	120,235	121,306	122,382	123,464
298	124,552	125,645	126,743	127,846	128,954	130,068	131,188	132,313	133,444	134,582
299	135,726	136,876	138,032	139,193	140,361	141,535	142,714	143,899	145,088	146,283
300	147,482	148,687	149,897	151,111	152,331	153,555	154,785	156,019	157,259	158,503
301	159,753	161,008	162,267	163,530	164,799	166,073	167,351	168,634	169,923	171,217
302	172,517	173,824	175,138	176,459	177,790	179,132	180,485	181,850	183,226	184,612
303	186,008	187,412	188,824	190,244	191,672	193,108	194,551	196,003	197,463	198,931
304	200,407	201,892	203,385	204,885	206,394	207,911	209,437	210,971	212,514	214,067
305	215,627	217,196	218,774	220,360	221,955	223,558	225,170	226,791	228,421	230,064
306	231,717	233,380	235,054	236,737	238,430	240,134	241,847	243,569	245,301	247,042
307	248,794	250,554	252,325	254,104	255,893	257,693	259,502	261,322	263,151	264,991
308	266,842	268,705	270,580	272,466	274,364	276,273	278,194	280,125	282,066	284,019
309	285,983	287,957	289,941	291,935	293,940	295,955	297,981	300,018	302,066	304,125

Appendix I (Continued)

Cedar Creek Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD | April - Ocober 2017 Survey

CAPACITY IN ACRE-FEET | Conservation Pool Elevation 322.0 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
310	306,196	308,278	310,371	312,474	314,590	316,717	318,854	321,001	323,157	325,323
311	327,498	329,683	331,877	334,080	336,293	338,515	340,747	342,989	345,239	347,500
312	349,771	352,052	354,343	356,642	358,952	361,271	363,599	365,937	368,285	370,644
313	373,014	375,393	377,783	380,182	382,592	385,012	387,444	389,887	392,339	394,802
314	397,276	399,760	402,254	404,758	407,272	409,798	412,334	414,882	417,441	420,011
315	422,594	425,188	427,794	430,412	433,042	435,684	438,338	441,004	443,681	446,371
316	449,072	451,784	454,508	457,243	459,990	462,750	465,523	468,307	471,105	473,918
317	476,746	479,589	482,446	485,316	488,199	491,094	493,999	496,916	499,843	502,782
318	505,732	508,692	511,664	514,646	517,639	520,642	523,654	526,675	529,705	532,745
319	535,795	538,857	541,931	545,015	548,110	551,214	554,327	557,449	560,578	563,718
320	566,865	570,022	573,186	576,358	579,539	582,726	585,921	589,123	592,330	595,545
321	598,767	601,995	605,231	608,473	611,724	614,983	618,250	621,525	624,808	628,100
322	631,401									

Appendix J

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — April - Ocober 2017 Survey

AREA IN ACRES — Conservation Pool Elevation 322.0 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
257	0	0	0	0	0	0	0	0	0	0
258	0	0	0	1	1	1	1	1	1	1
259	1	1	1	2	2	3	3	3	3	3
260	4	4	5	6	6	7	8	8	9	10
261	11	11	12	12	13	13	14	15	15	16
262	17	17	18	18	19	20	20	21	22	23
263	24	24	25	26	27	27	28	29	30	31
264	33	34	36	37	39	40	42	44	46	48
265	50	52	54	56	58	60	62	64	66	69
266	71	74	76	79	81	83	86	88	90	93
267	95	98	101	104	108	112	118	125	130	136
268	141	146	151	156	162	166	171	177	182	188
269	194	200	205	211	217	222	228	233	239	246
270	252	259	267	275	282	290	297	305	312	320
271	329	340	351	362	375	389	404	419	433	450
272	466	485	503	518	532	547	562	580	596	611
273	628	645	662	680	698	715	733	751	770	790
274	809	828	847	865	884	901	918	936	954	971
275	989	1,008	1,027	1,047	1,065	1,082	1,098	1,117	1,136	1,155
276	1,175	1,195	1,216	1,236	1,255	1,276	1,296	1,316	1,335	1,355
277	1,376	1,398	1,420	1,441	1,462	1,485	1,510	1,533	1,556	1,580
278	1,604	1,629	1,653	1,678	1,704	1,733	1,764	1,795	1,827	1,859
279	1,893	1,929	1,966	2,009	2,048	2,082	2,112	2,141	2,172	2,205
280	2,239	2,274	2,310	2,349	2,387	2,424	2,459	2,492	2,524	2,557
281	2,589	2,623	2,658	2,696	2,735	2,774	2,816	2,858	2,902	2,945
282	2,985	3,022	3,056	3,091	3,131	3,173	3,212	3,250	3,291	3,341
283	3,383	3,422	3,464	3,510	3,558	3,601	3,645	3,690	3,735	3,776
284	3,814	3,850	3,887	3,929	3,973	4,020	4,066	4,109	4,154	4,200
285	4,242	4,284	4,327	4,371	4,419	4,463	4,506	4,550	4,594	4,645
286	4,709	4,781	4,854	4,920	4,989	5,059	5,119	5,168	5,211	5,256
287	5,298	5,338	5,376	5,414	5,451	5,487	5,527	5,570	5,617	5,664
288	5,712	5,759	5,807	5,855	5,904	5,950	5,992	6,033	6,075	6,117
289	6,156	6,194	6,233	6,276	6,322	6,366	6,410	6,453	6,494	6,536
290	6,578	6,621	6,668	6,717	6,767	6,818	6,872	6,925	6,978	7,037
291	7,095	7,150	7,204	7,251	7,300	7,352	7,413	7,484	7,547	7,607
292	7,668	7,728	7,791	7,855	7,919	7,983	8,045	8,111	8,172	8,224
293	8,275	8,327	8,377	8,426	8,481	8,540	8,597	8,655	8,708	8,761
294	8,814	8,864	8,910	8,959	9,007	9,054	9,102	9,154	9,205	9,255
295	9,308	9,363	9,416	9,462	9,510	9,558	9,606	9,657	9,705	9,755
296	9,805	9,854	9,901	9,947	9,994	10,041	10,089	10,140	10,195	10,256
297	10,316	10,373	10,429	10,491	10,560	10,623	10,681	10,738	10,794	10,849
298	10,901	10,953	11,005	11,059	11,112	11,167	11,223	11,285	11,347	11,409
299	11,470	11,529	11,587	11,645	11,707	11,766	11,819	11,870	11,920	11,971
300	12,022	12,072	12,122	12,170	12,219	12,269	12,319	12,371	12,423	12,473
301	12,521	12,568	12,614	12,662	12,711	12,758	12,807	12,858	12,914	12,970
302	13,033	13,101	13,176	13,261	13,362	13,478	13,587	13,702	13,814	13,911
303	13,998	14,082	14,163	14,244	14,319	14,393	14,476	14,561	14,640	14,721
304	14,804	14,886	14,966	15,048	15,131	15,214	15,298	15,388	15,478	15,564
305	15,647	15,733	15,821	15,905	15,988	16,072	16,161	16,257	16,364	16,476
306	16,582	16,686	16,785	16,887	16,983	17,079	17,176	17,272	17,368	17,463
307	17,559	17,655	17,751	17,844	17,941	18,043	18,146	18,245	18,345	18,456
308	18,568	18,688	18,806	18,923	19,036	19,144	19,257	19,365	19,474	19,581
309	19,686	19,790	19,892	19,996	20,097	20,204	20,316	20,428	20,537	20,650

Appendix J (Continued)

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

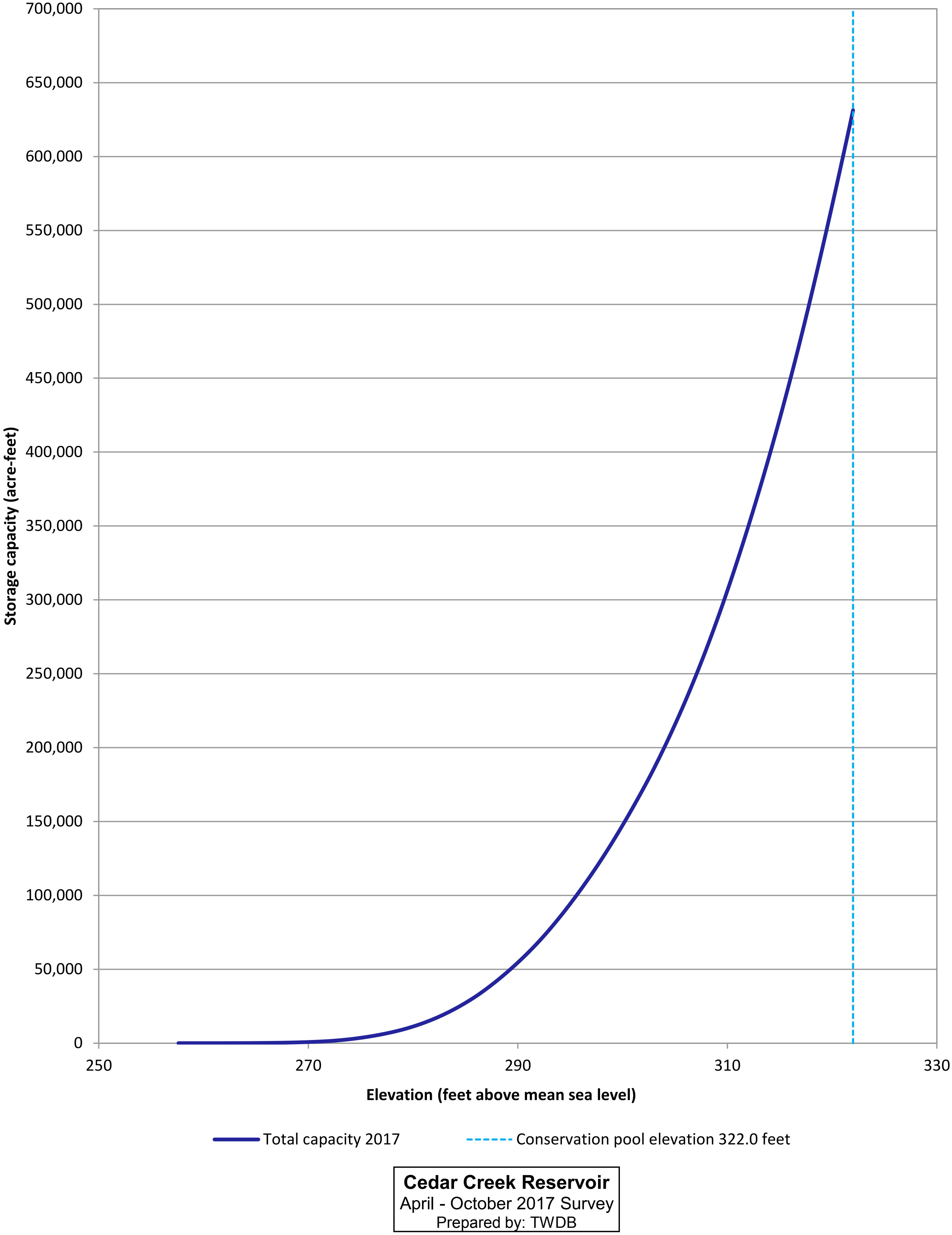
AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

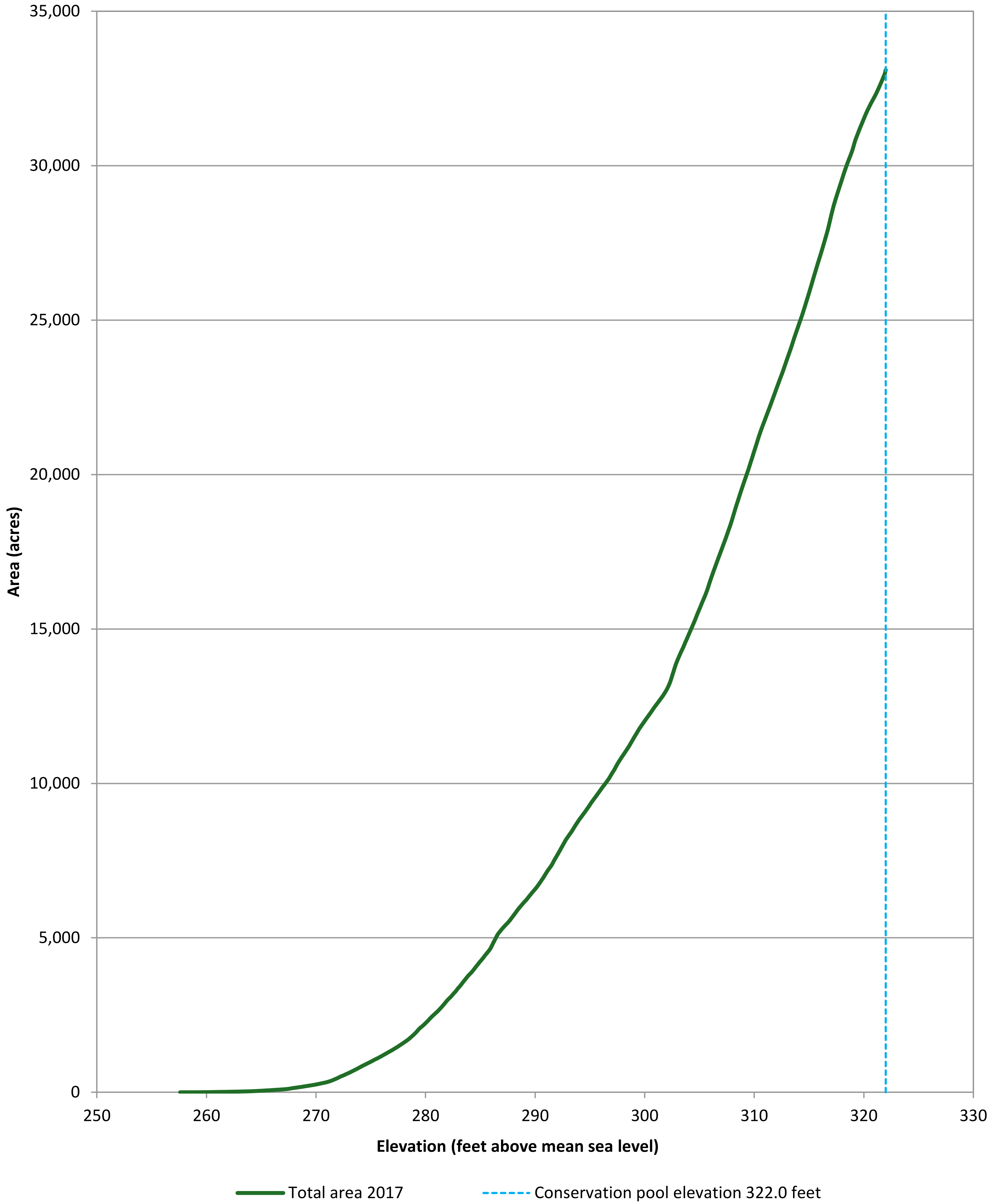
April - Ocober 2017 Survey

Conservation Pool Elevation 322.0 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
310	20,763	20,872	20,984	21,098	21,212	21,316	21,419	21,517	21,613	21,705
311	21,798	21,893	21,989	22,080	22,175	22,270	22,366	22,465	22,560	22,658
312	22,758	22,854	22,950	23,047	23,144	23,234	23,330	23,434	23,537	23,640
313	23,743	23,844	23,945	24,045	24,151	24,261	24,372	24,478	24,581	24,683
314	24,786	24,890	24,991	25,092	25,197	25,307	25,420	25,537	25,649	25,764
315	25,881	26,002	26,118	26,241	26,363	26,480	26,597	26,718	26,835	26,949
316	27,062	27,178	27,296	27,416	27,537	27,660	27,782	27,910	28,053	28,206
317	28,356	28,502	28,639	28,769	28,885	29,001	29,113	29,222	29,331	29,440
318	29,549	29,663	29,772	29,876	29,977	30,075	30,167	30,258	30,350	30,446
319	30,555	30,679	30,798	30,898	30,990	31,083	31,174	31,262	31,346	31,432
320	31,519	31,604	31,686	31,765	31,839	31,911	31,981	32,050	32,116	32,181
321	32,247	32,317	32,390	32,467	32,547	32,627	32,709	32,794	32,880	32,965
322	33,099									



Appendix K: Capacity curve



Cedar Creek Reservoir
April - October 2017 Survey
Prepared by: TWDB

Appendix L: Area curve

Appendix M

Cedar Creek Reservoir

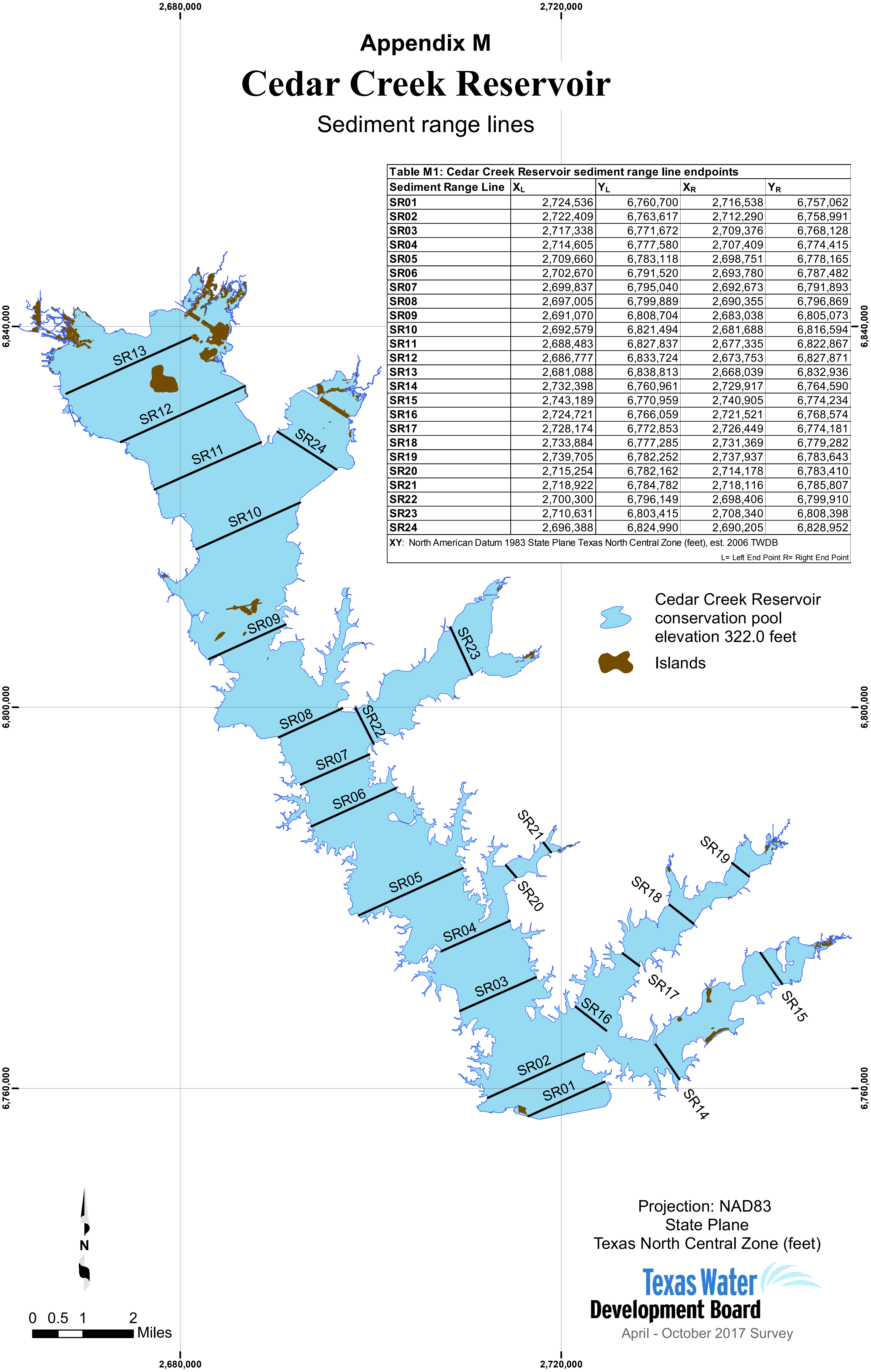
Sediment range lines

Table M1: Cedar Creek Reservoir sediment range line endpoints

Sediment Range Line	X_L	Y_L	X_R	Y_R
SR01	2,724,536	6,760,700	2,716,538	6,757,062
SR02	2,722,409	6,763,617	2,712,290	6,758,991
SR03	2,717,338	6,771,672	2,709,376	6,768,128
SR04	2,714,605	6,777,580	2,707,409	6,774,415
SR05	2,709,660	6,783,118	2,698,751	6,778,165
SR06	2,702,670	6,791,520	2,693,780	6,787,482
SR07	2,699,837	6,795,040	2,692,673	6,791,893
SR08	2,697,005	6,799,889	2,690,355	6,796,869
SR09	2,691,070	6,808,704	2,683,038	6,805,073
SR10	2,692,579	6,821,494	2,681,688	6,816,594
SR11	2,688,483	6,827,837	2,677,335	6,822,867
SR12	2,686,777	6,833,724	2,673,753	6,827,871
SR13	2,681,088	6,838,813	2,668,039	6,832,936
SR14	2,732,398	6,760,961	2,729,917	6,764,590
SR15	2,743,189	6,770,959	2,740,905	6,774,234
SR16	2,724,721	6,766,059	2,721,521	6,768,574
SR17	2,728,174	6,772,853	2,726,449	6,774,181
SR18	2,733,884	6,777,285	2,731,369	6,779,282
SR19	2,739,705	6,782,252	2,737,937	6,783,643
SR20	2,715,254	6,782,162	2,714,178	6,783,410
SR21	2,718,922	6,784,782	2,718,116	6,785,807
SR22	2,700,300	6,796,149	2,698,406	6,799,910
SR23	2,710,631	6,803,415	2,708,340	6,808,398
SR24	2,696,388	6,824,990	2,690,205	6,828,952

XY: North American Datum 1983 State Plane Texas North Central Zone (feet), est. 2006 TWDB

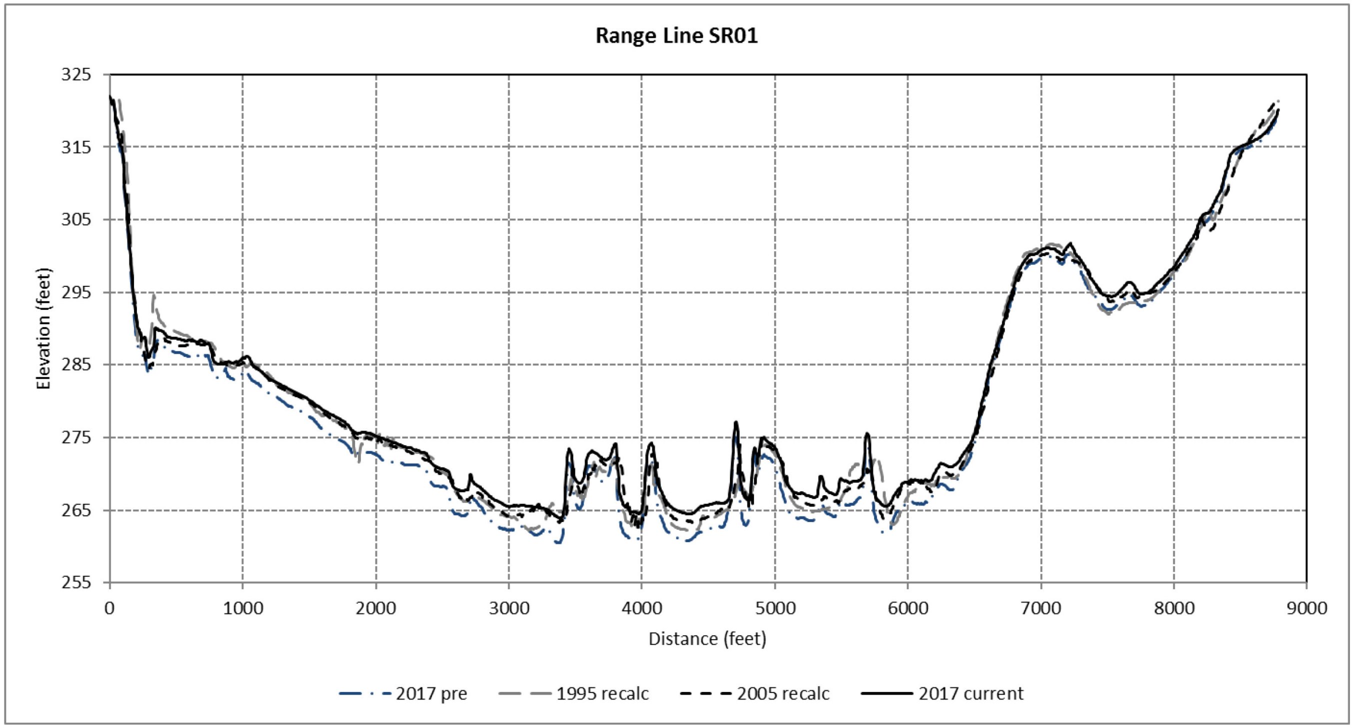
L= Left End Point R= Right End Point

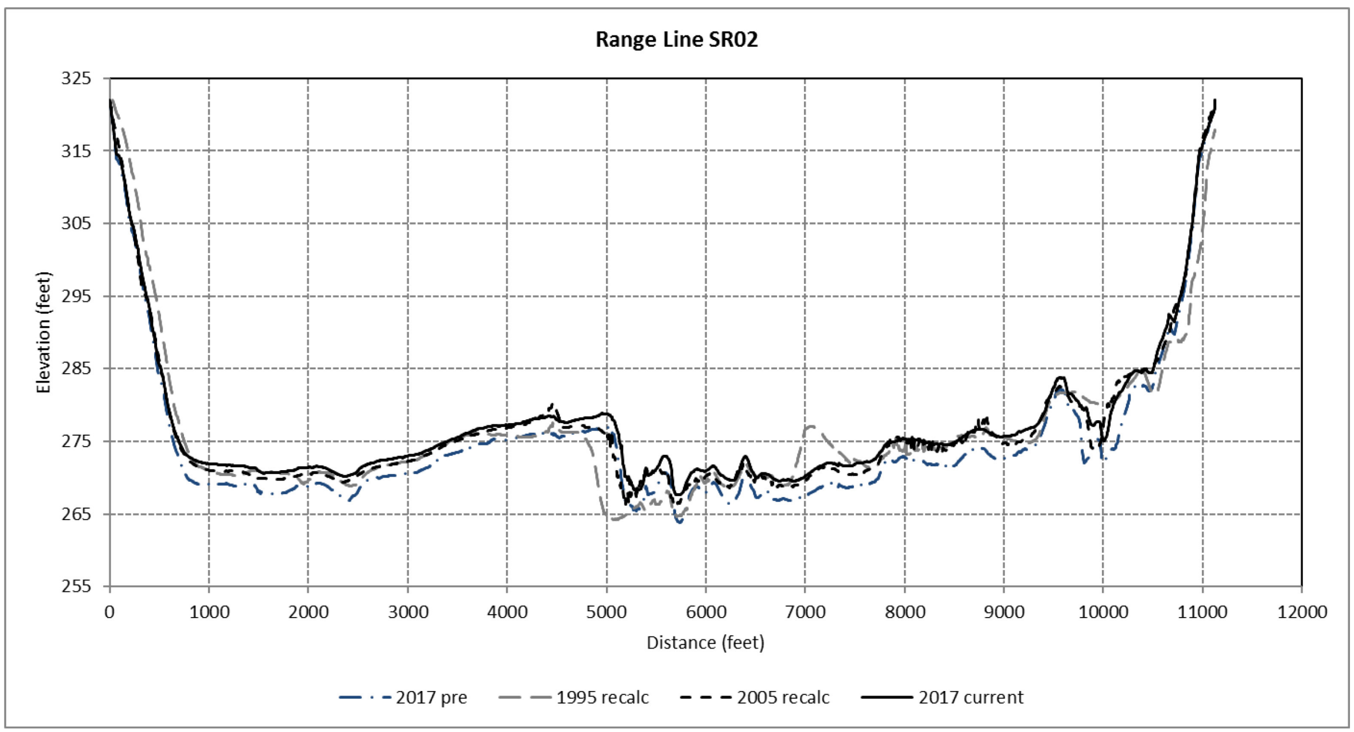


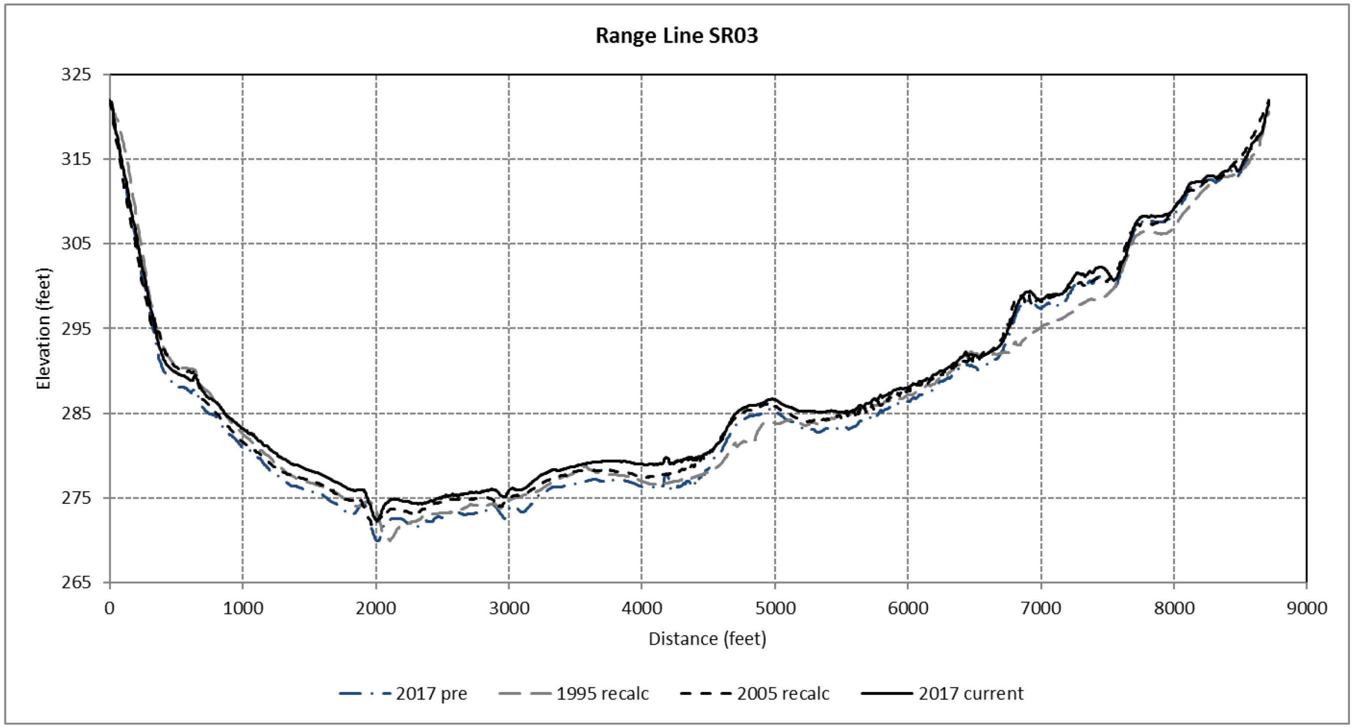
Projection: NAD83
State Plane
Texas North Central Zone (feet)

Texas Water Development Board

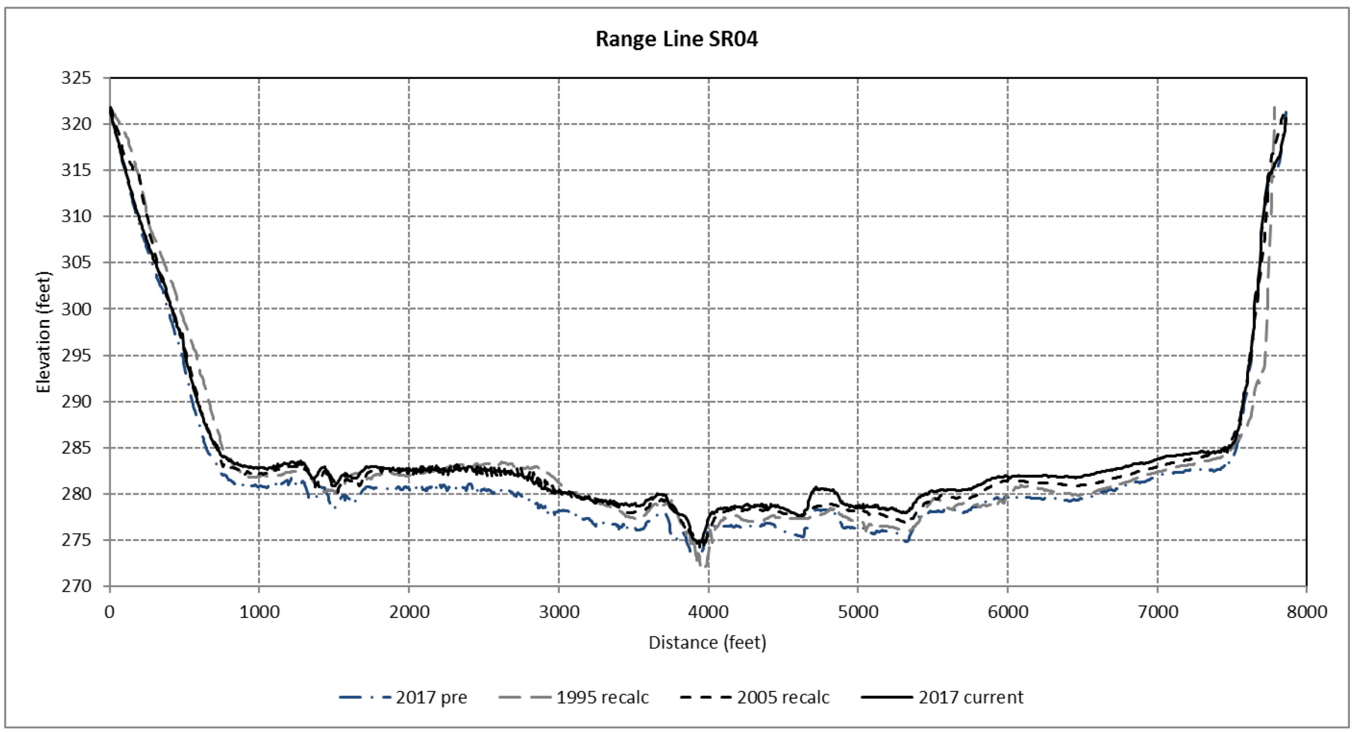
April - October 2017 Survey


Range Line SR01
Elevation (feet)
Distance (feet)
325
315
305
295
285
275
265
255
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
2017 pre
1995 recalc
2005 recalc
2017 current

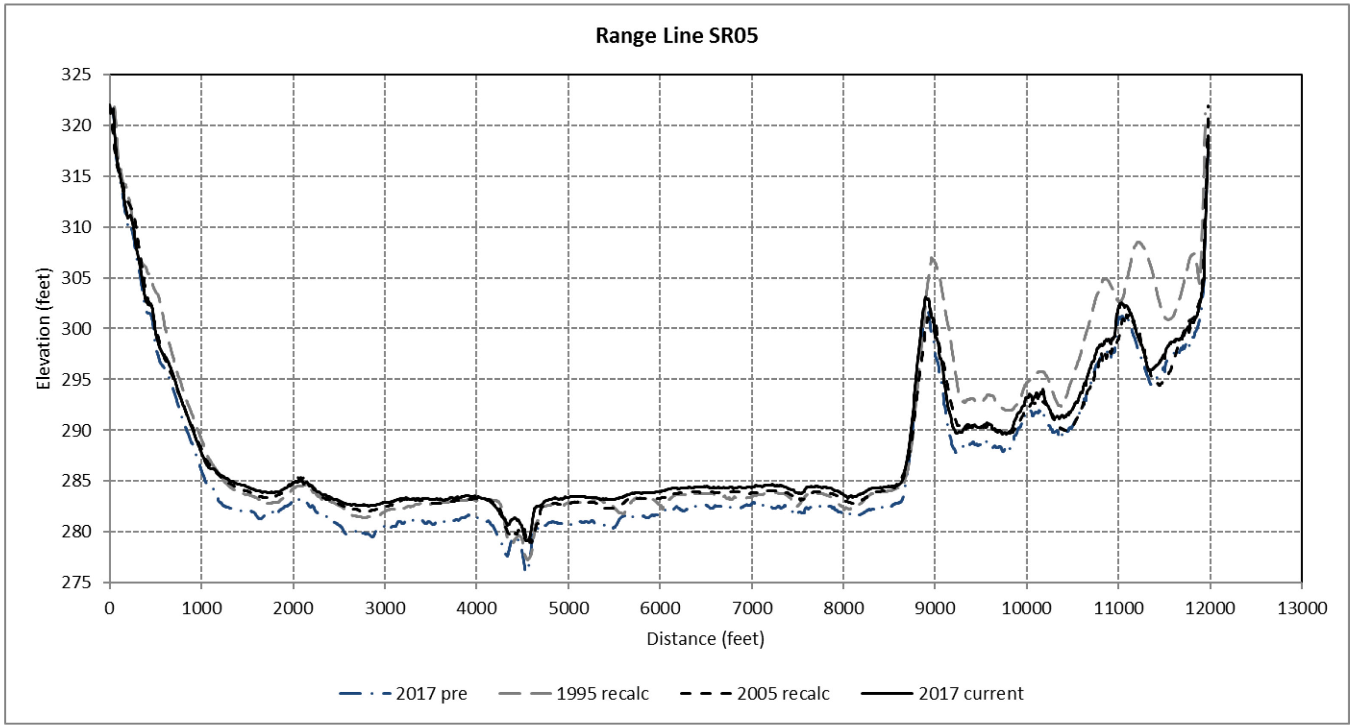

Range Line SR02
Elevation (feet)
Distance (feet)
325
315
305
295
285
275
265
255
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
2017 pre
1995 recalc
2005 recalc
2017 current



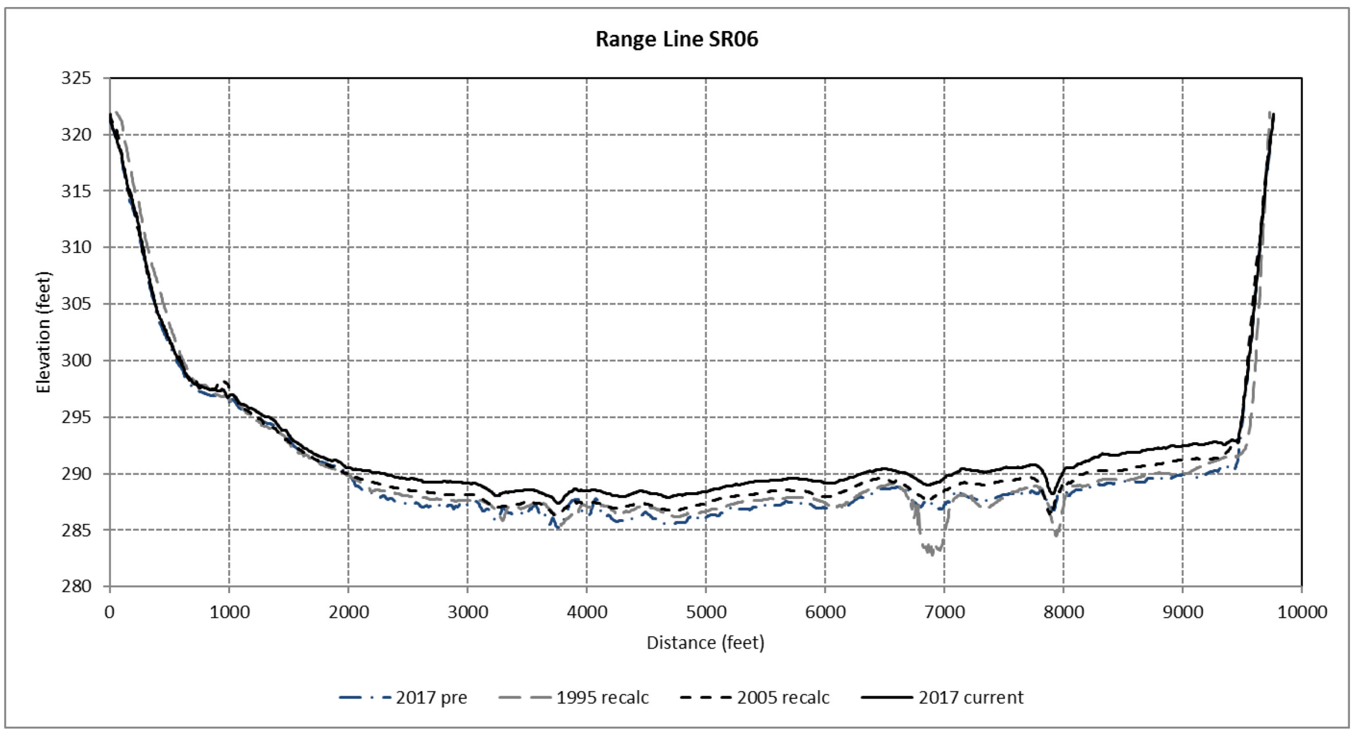
Range Line SR03
Elevation (feet)
325
315
305
295
285
275
265
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current



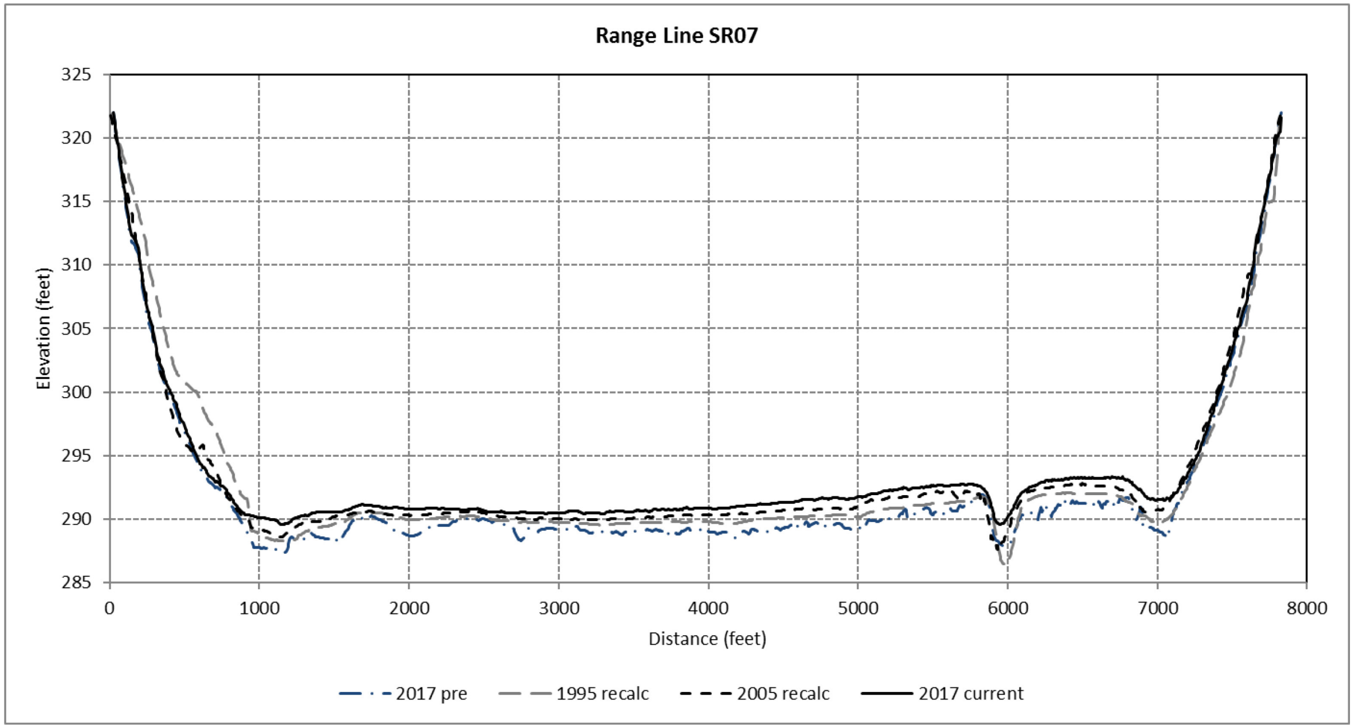
Range Line SR04
Elevation (feet)
325
320
315
310
305
300
295
290
285
280
275
270
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current



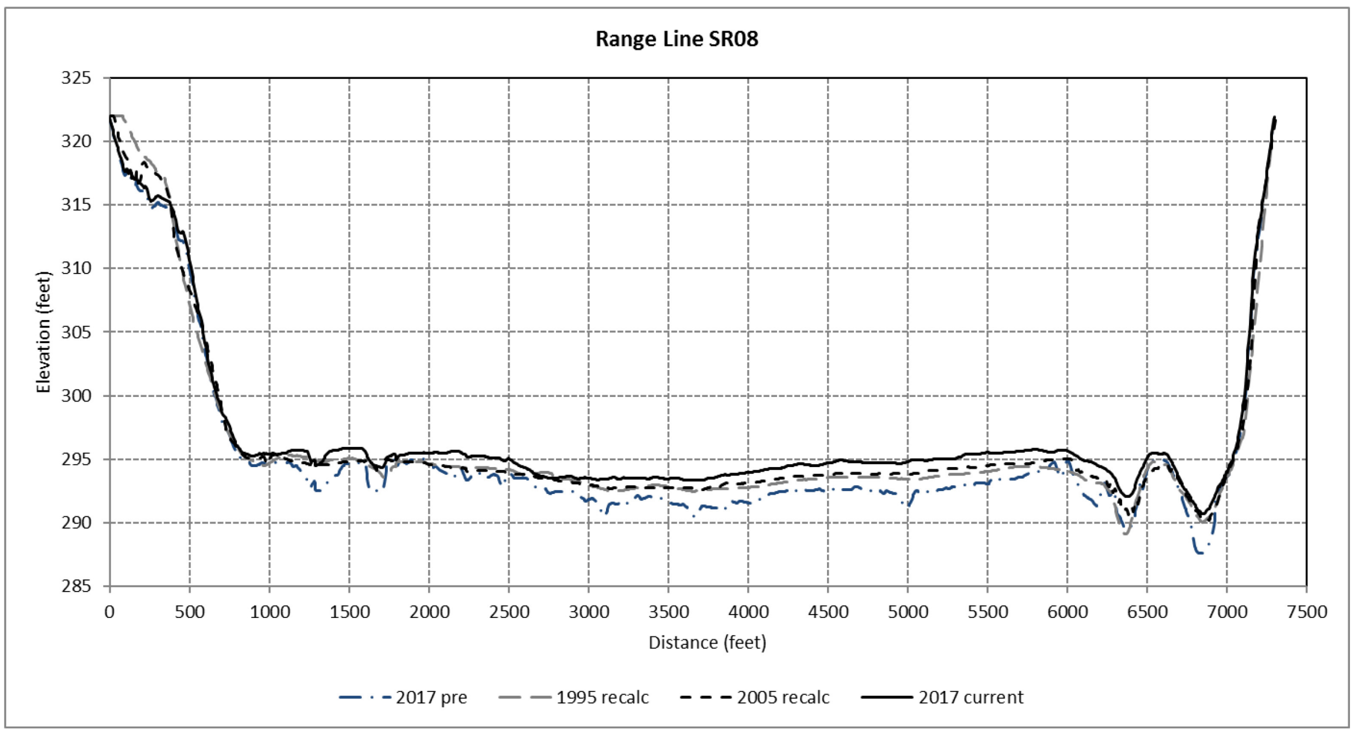
Range Line SR05
Elevation (feet)
325
320
315
310
305
300
295
290
285
280
275
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current



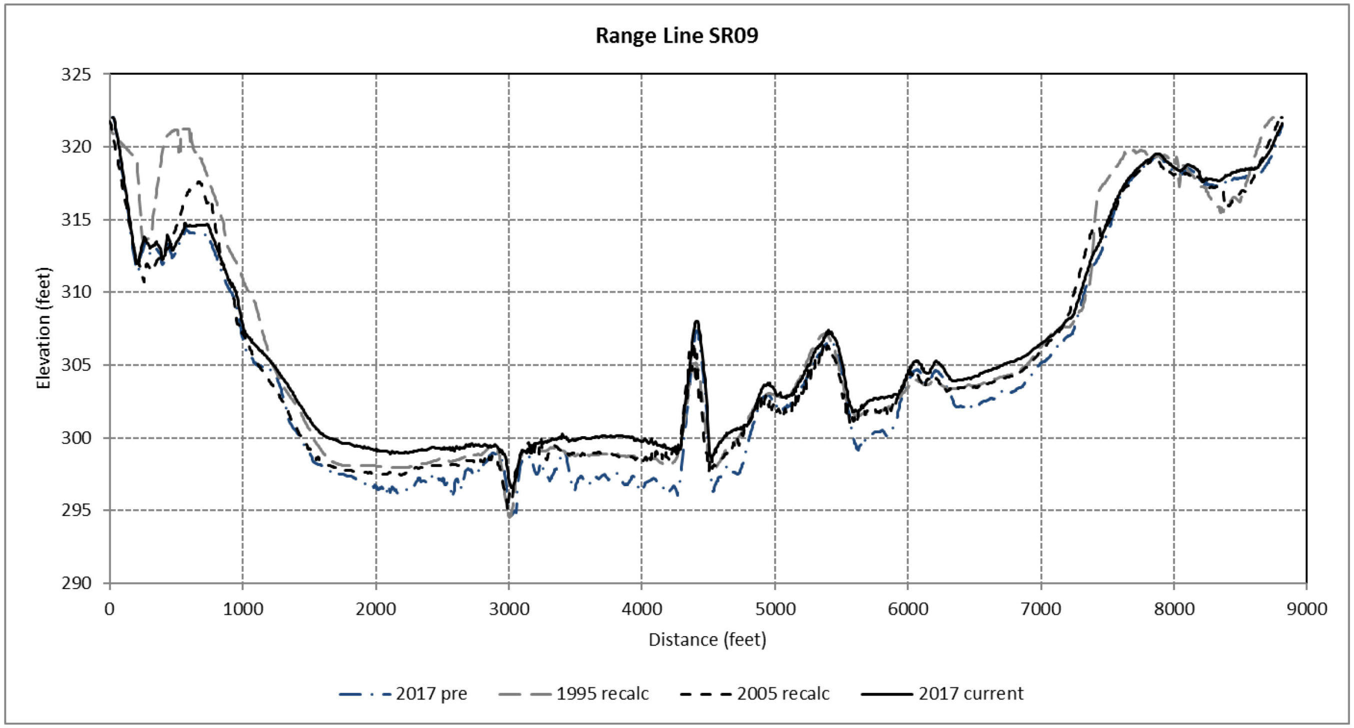
Range Line SR06
Elevation (feet)
325
320
315
310
305
300
295
290
285
280
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

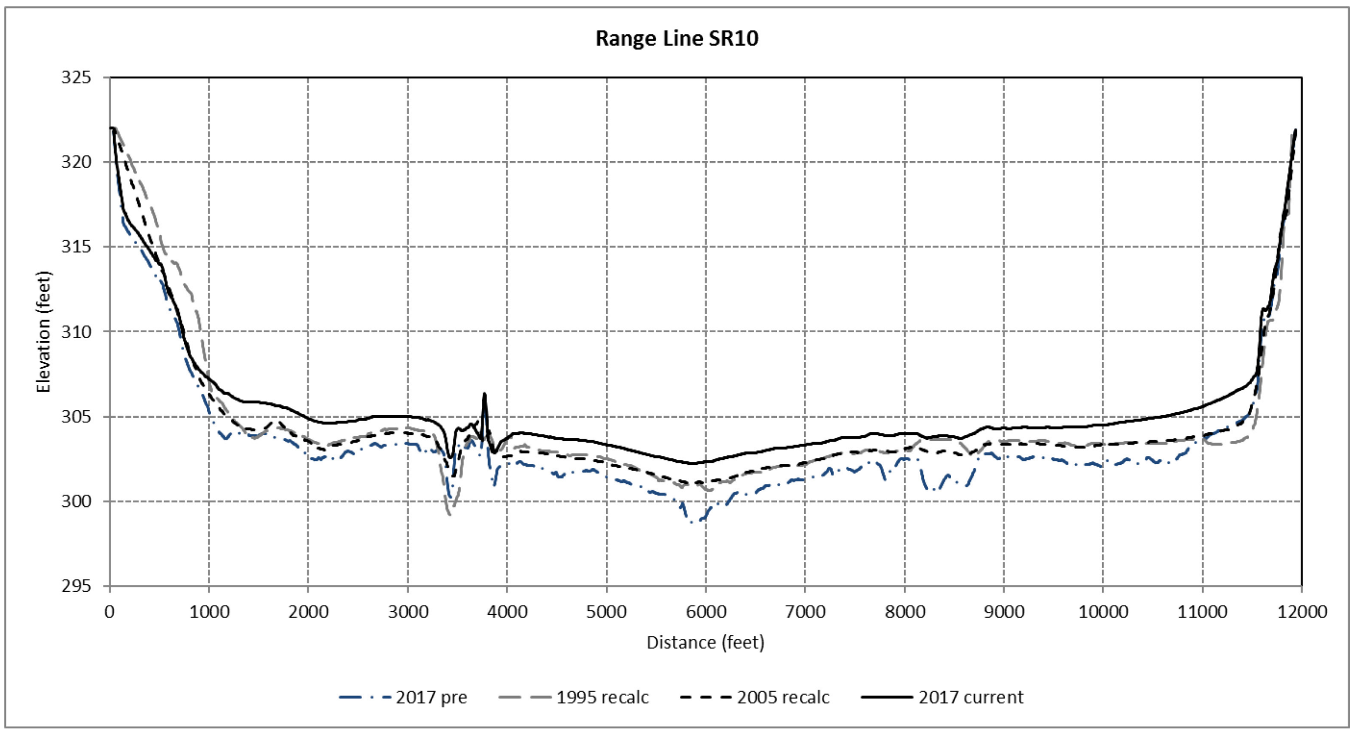


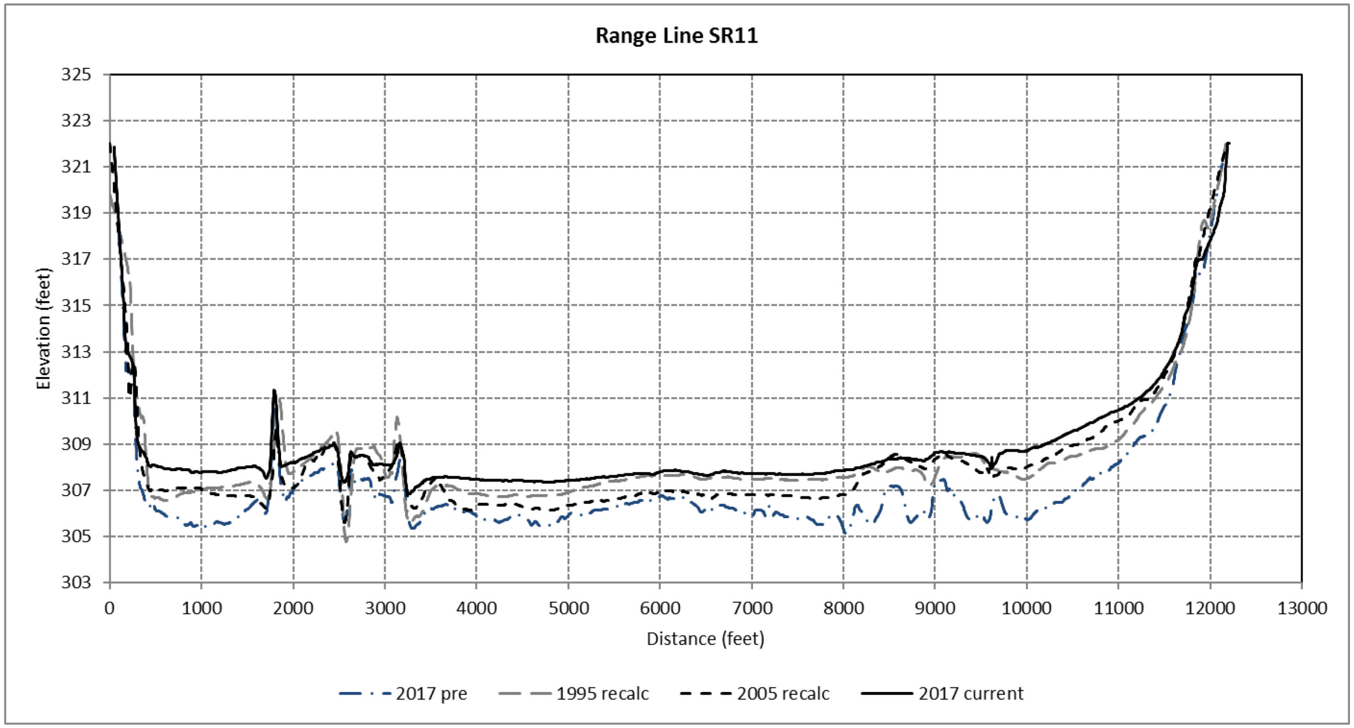
Range Line SR07
325
320
315
310
305
300
295
290
285
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

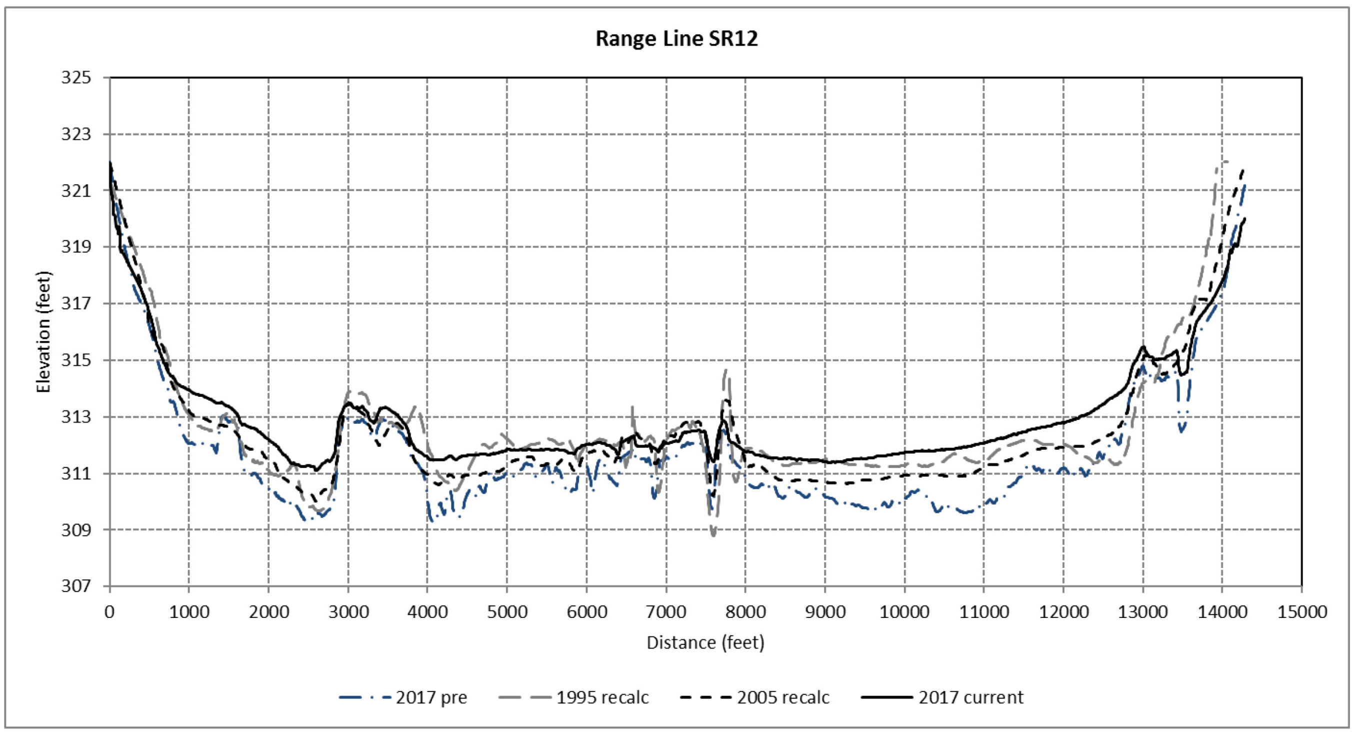


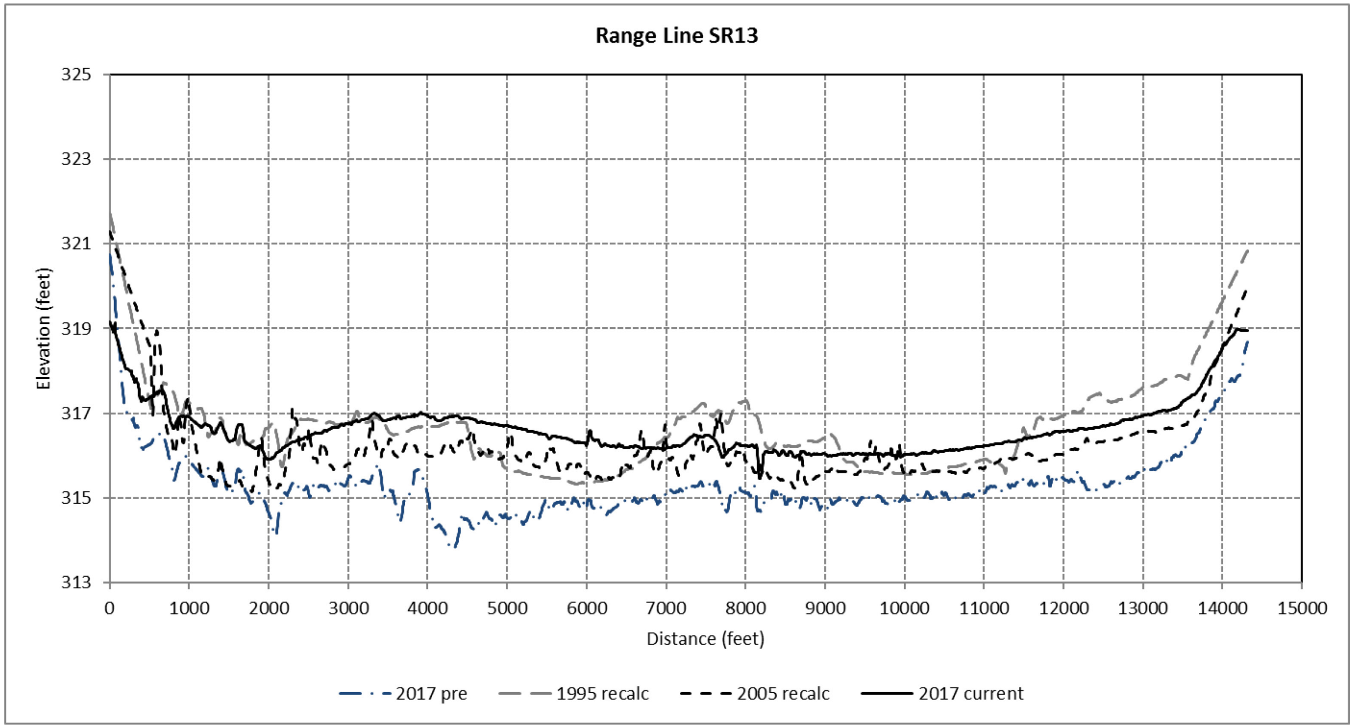
Range Line SR08
325
320
315
310
305
300
295
290
285
Elevation (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

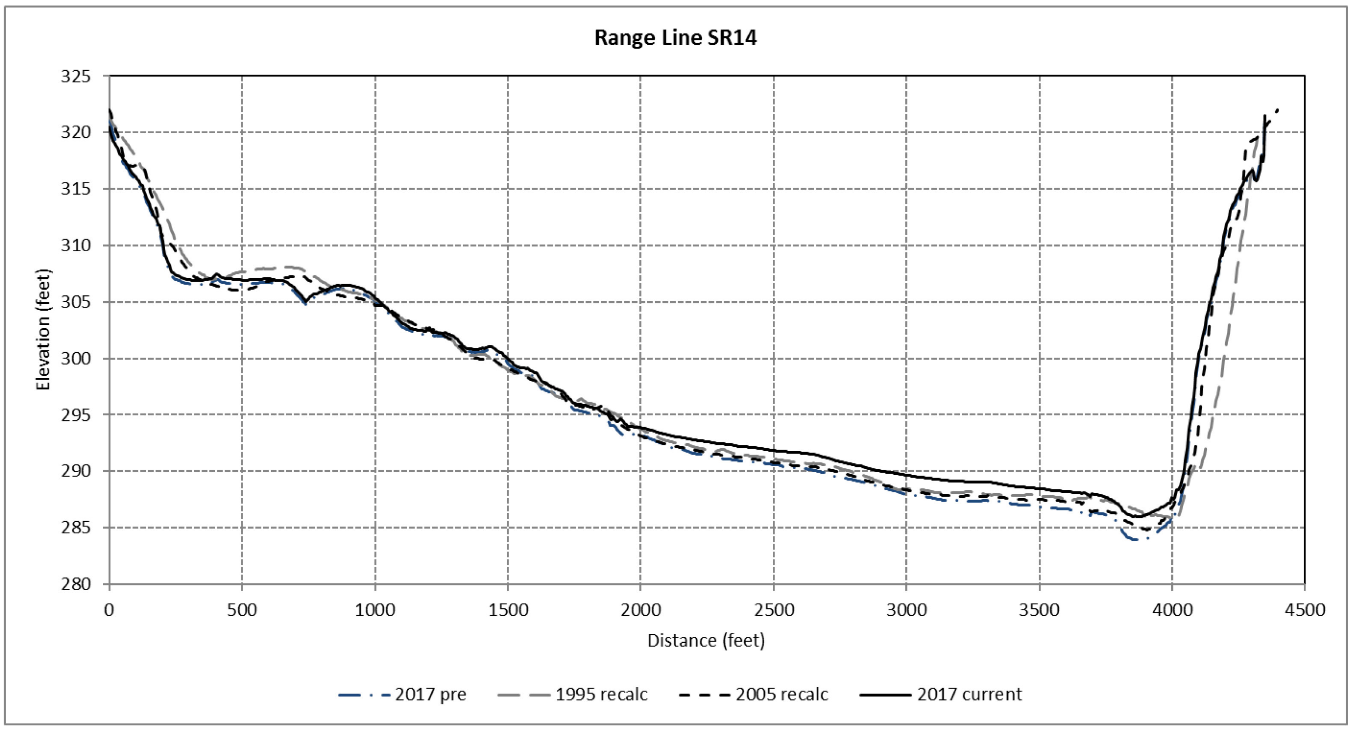

Range Line SR09
Elevation (feet)
325
320
315
310
305
300
295
290
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

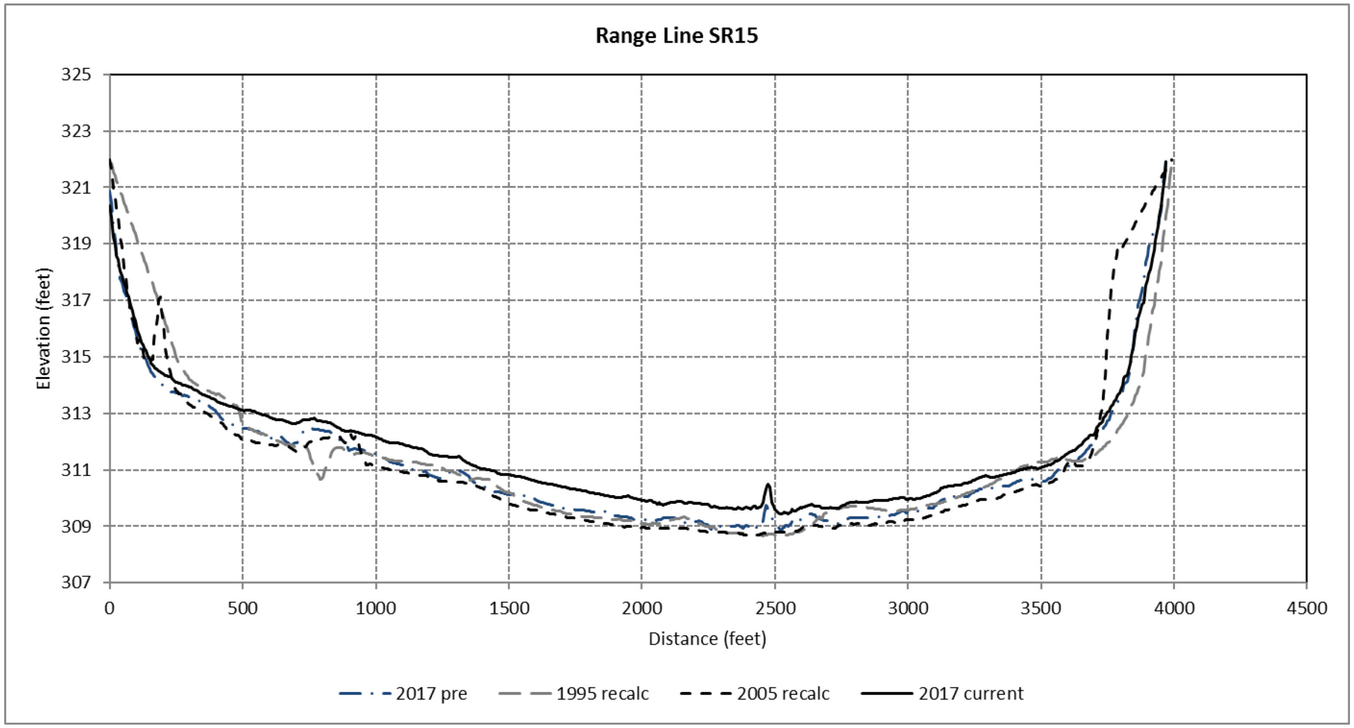

Range Line SR10
Elevation (feet)
325
320
315
310
305
300
295
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

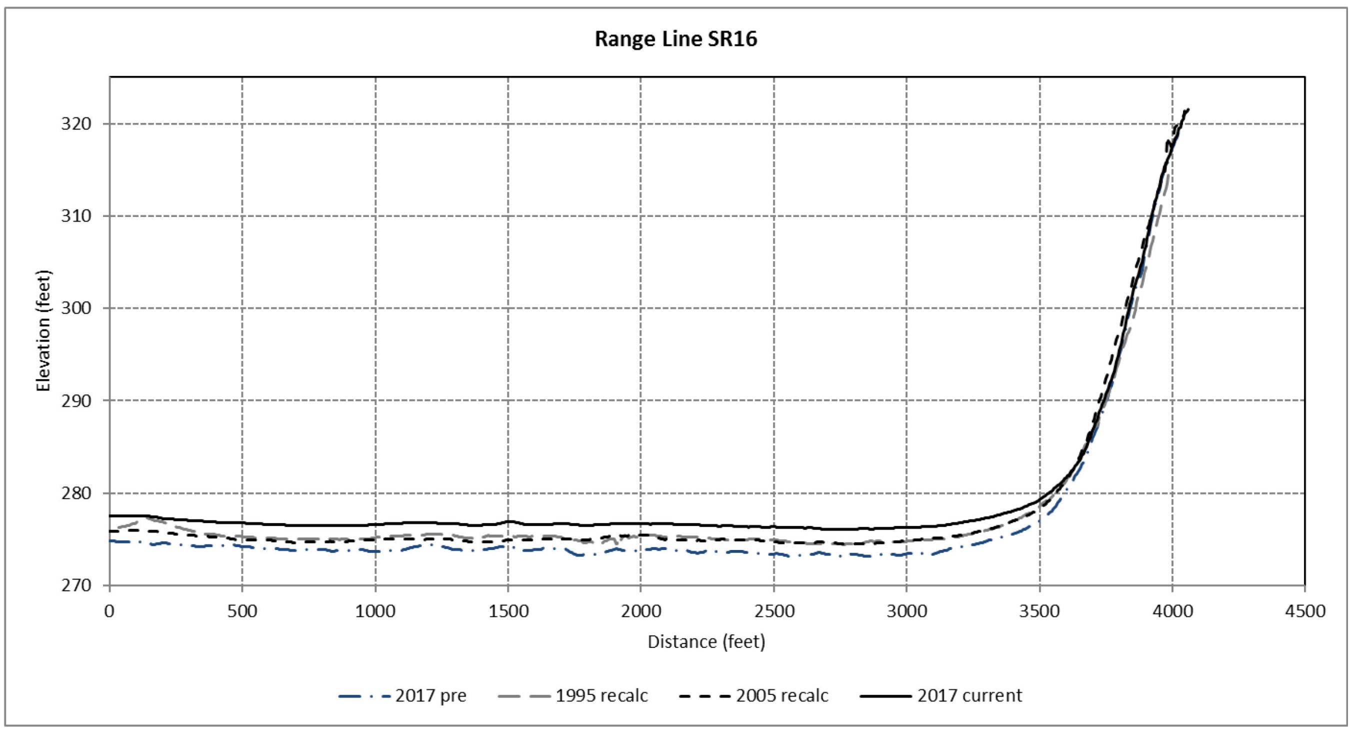

Range Line SR11
Elevation (feet)
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

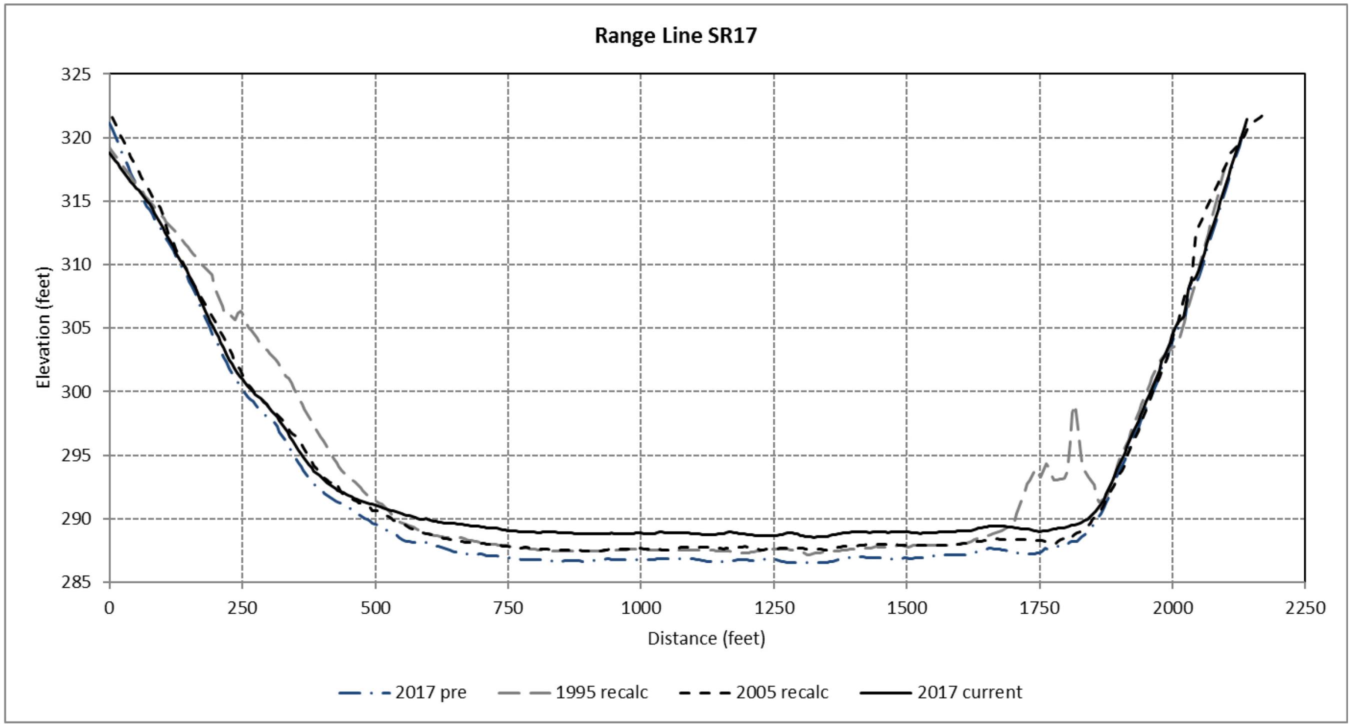

Range Line SR12
Elevation (feet)
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

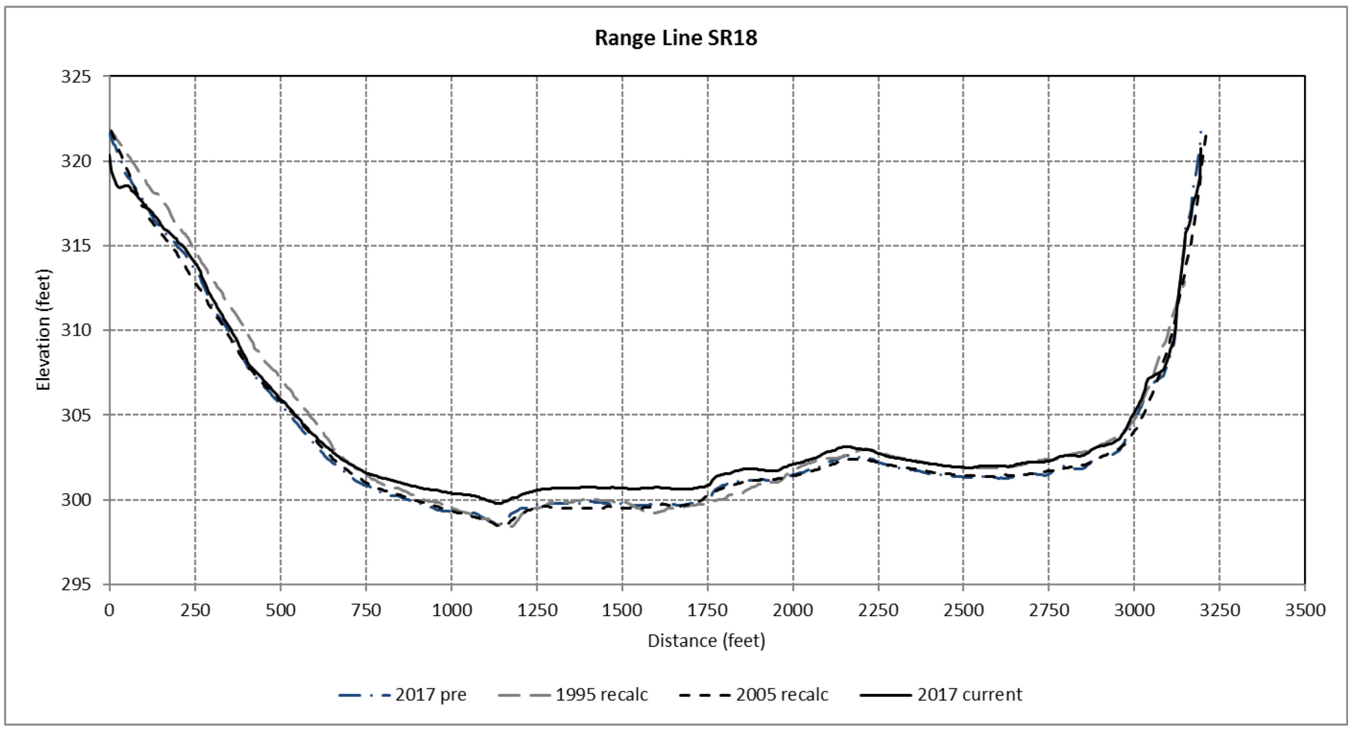

Range Line SR13
Elevation (feet)
325
323
321
319
317
315
313
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

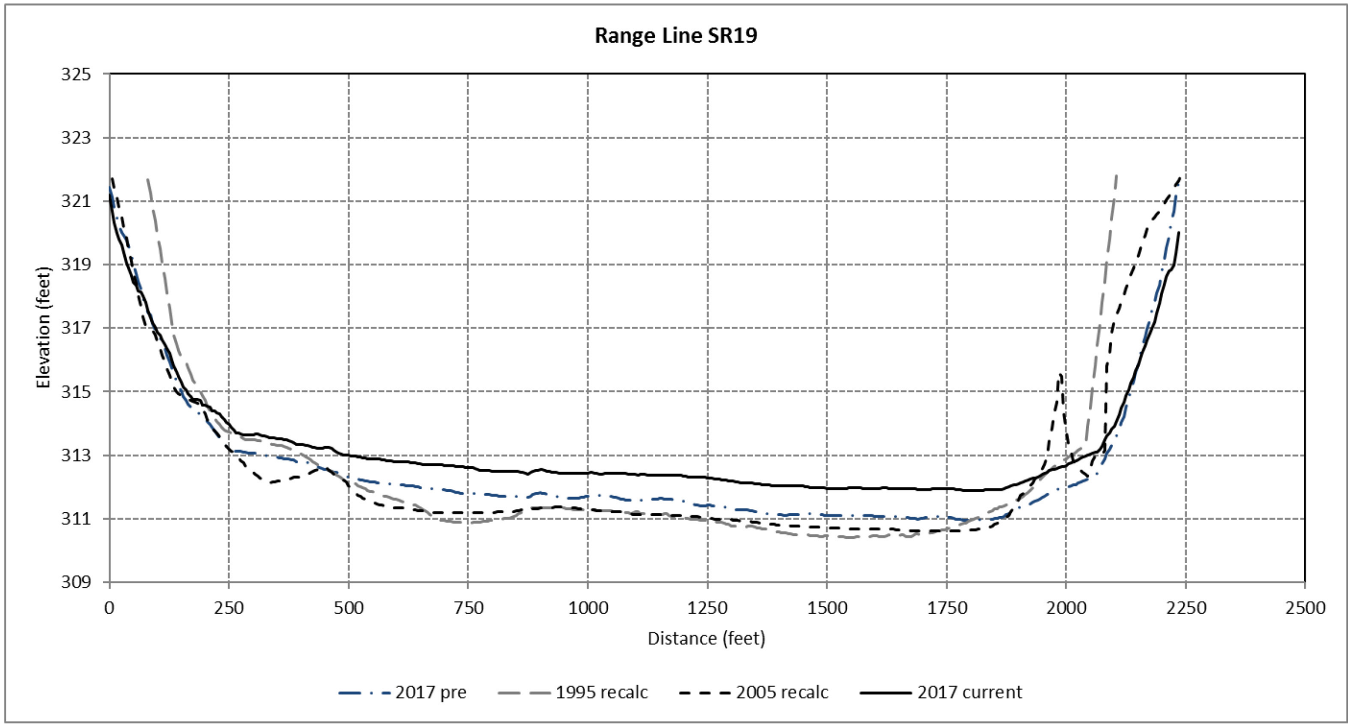

Range Line SR14
Elevation (feet)
325
320
315
310
305
300
295
290
285
280
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

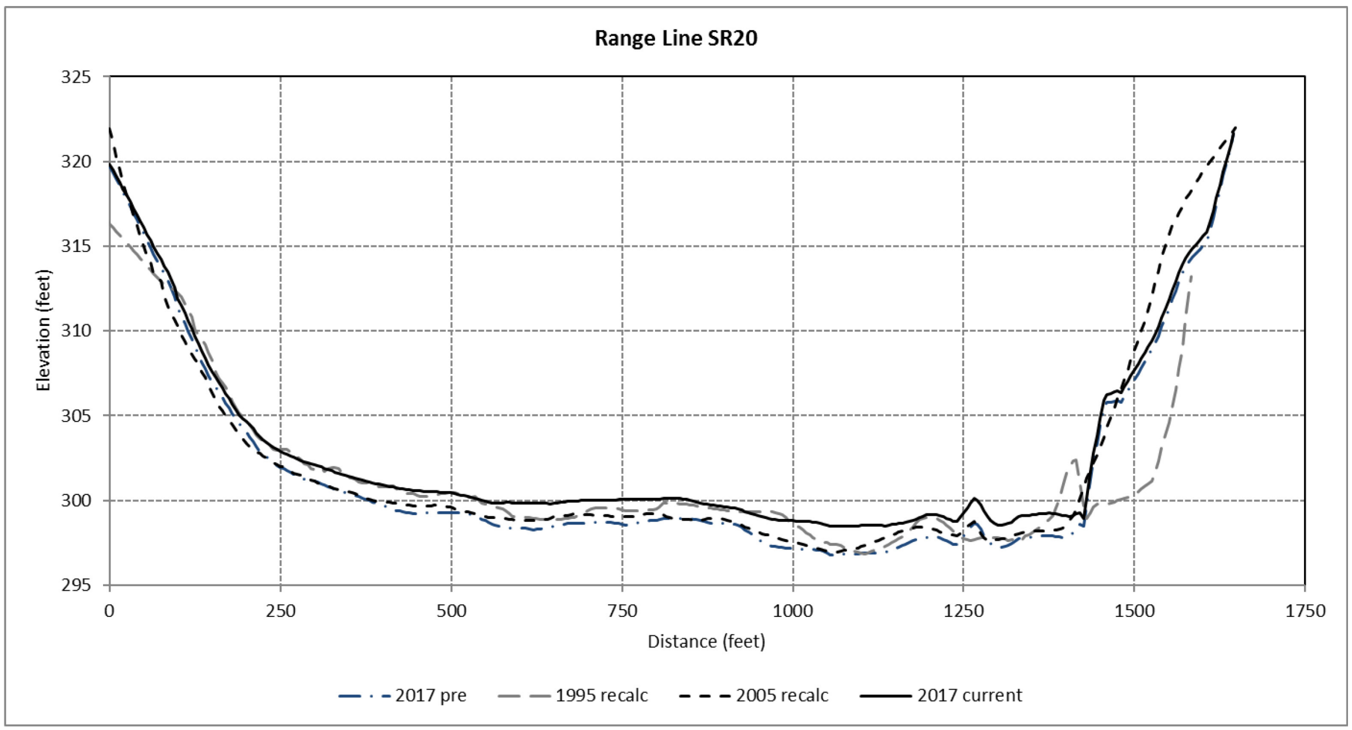

Range Line SR15
Elevation (feet)
325
323
321
319
317
315
313
311
309
307
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

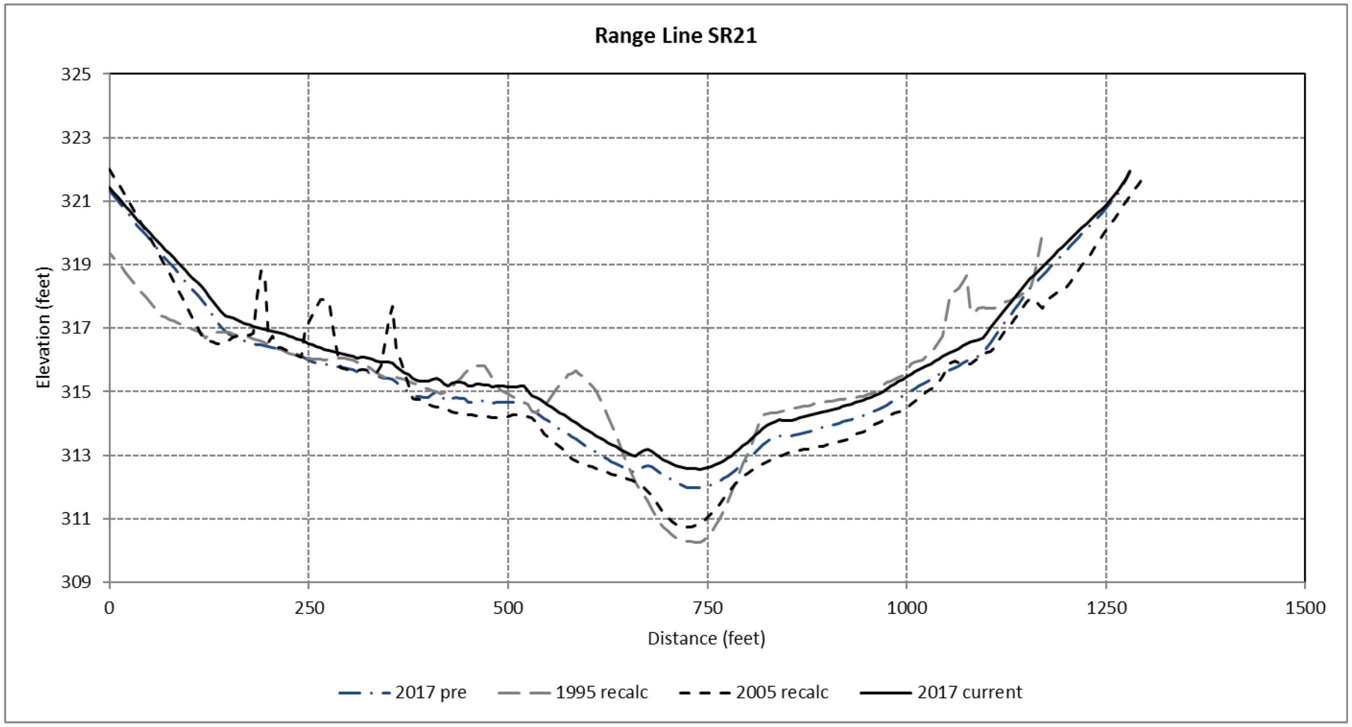

Range Line SR16
Elevation (feet)
320
310
300
290
280
270
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

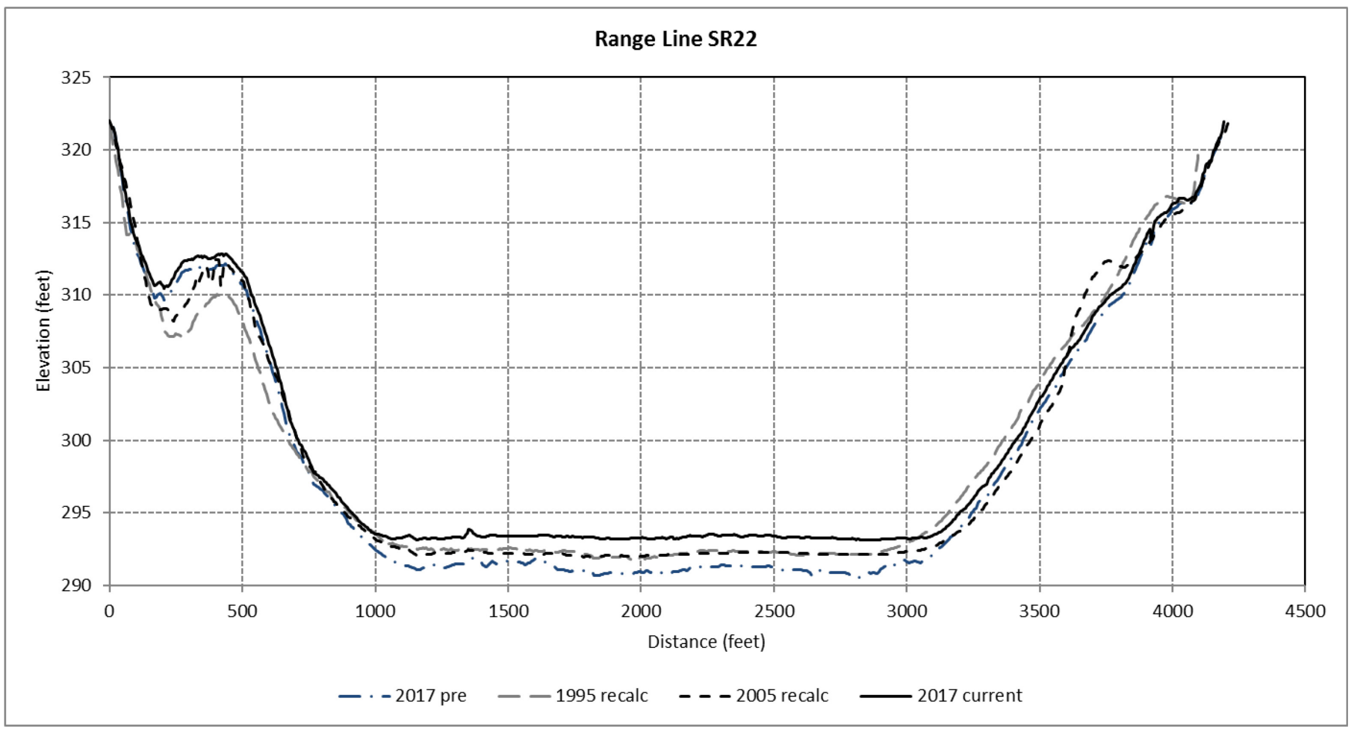

Range Line SR17
Elevation (feet)
325
320
315
310
305
300
295
290
285
0
250
500
750
1000
1250
1500
1750
2000
2250
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

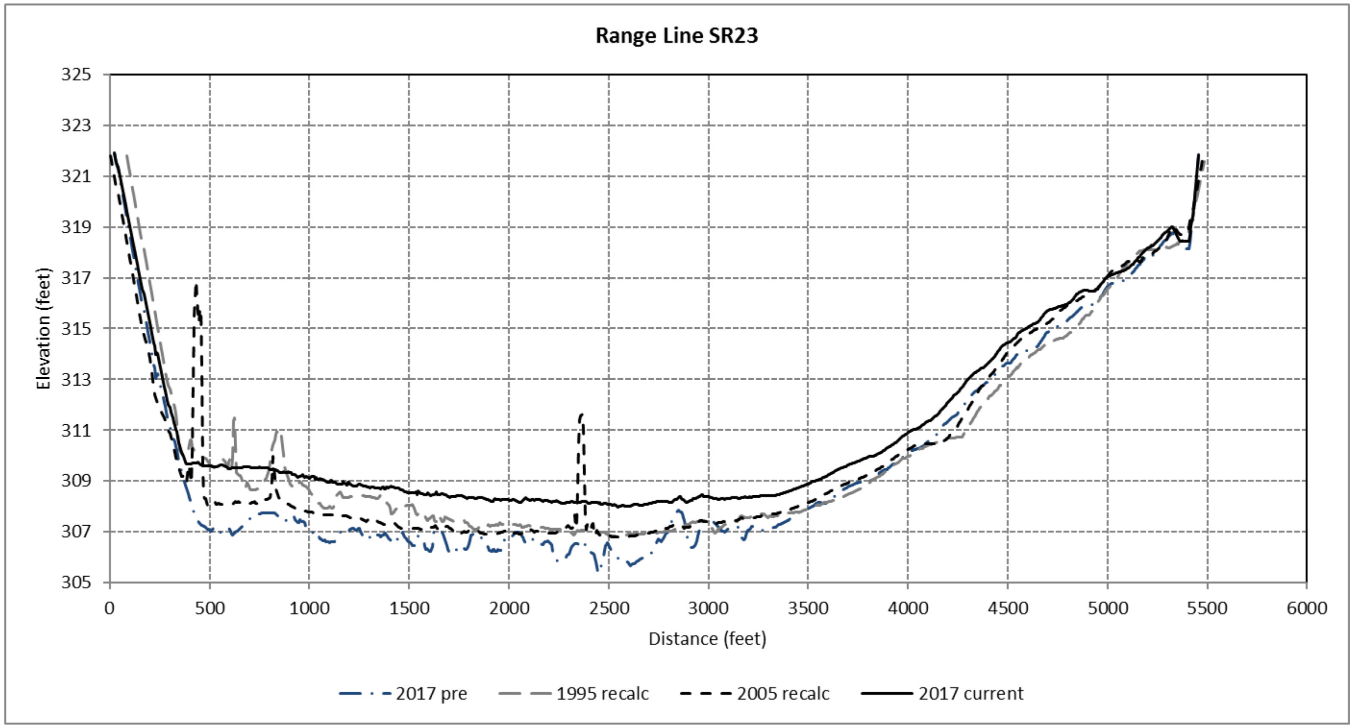

Range Line SR18
Elevation (feet)
325
320
315
310
305
300
295
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current


Range Line SR19
Elevation (feet)
325
323
321
319
317
315
313
311
309
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current


Range Line SR20
Elevation (feet)
325
320
315
310
305
300
295
0
250
500
750
1000
1250
1500
1750
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current


Range Line SR21
Elevation (feet)
325
323
321
319
317
315
313
311
309
0
250
500
750
1000
1250
1500
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current


Range Line SR22
Elevation (feet)
325
320
315
310
305
300
295
290
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current


Range Line SR23
Elevation (feet)
325
323
321
319
317
315
313
311
309
307
305
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

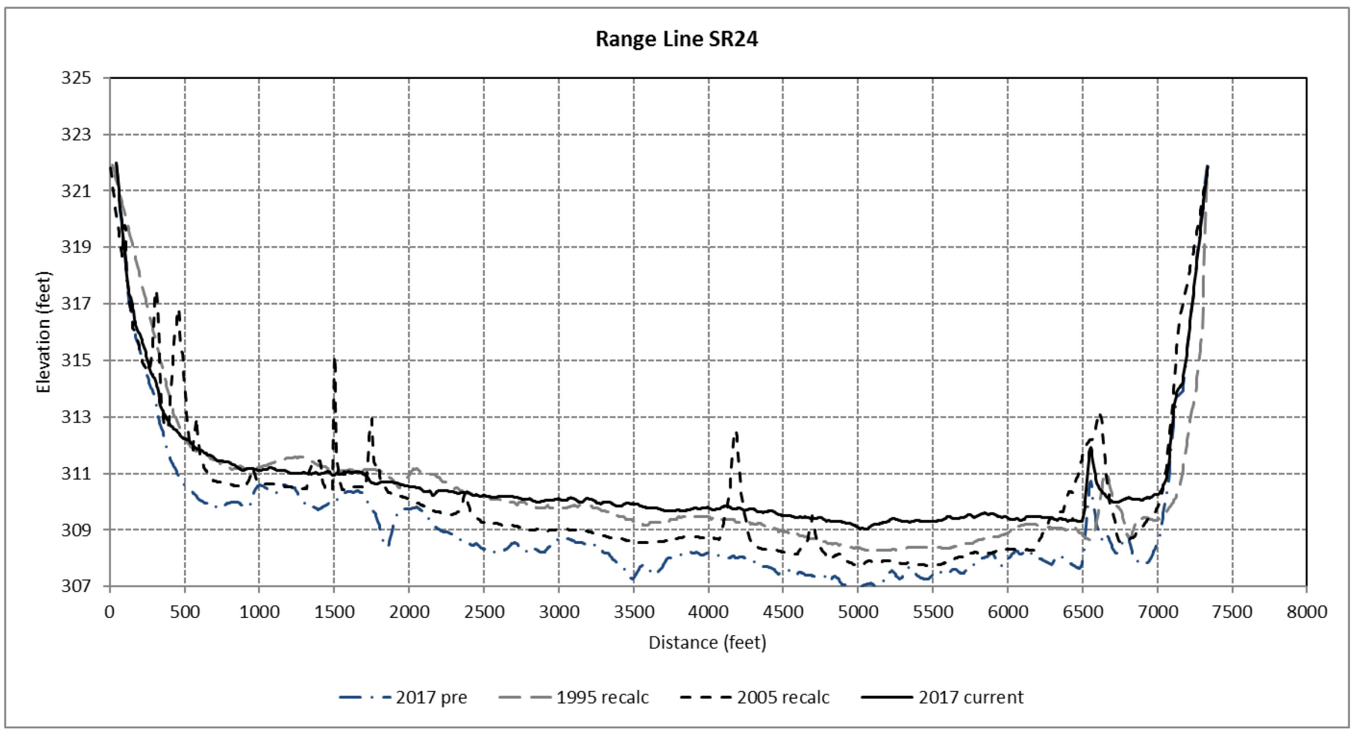
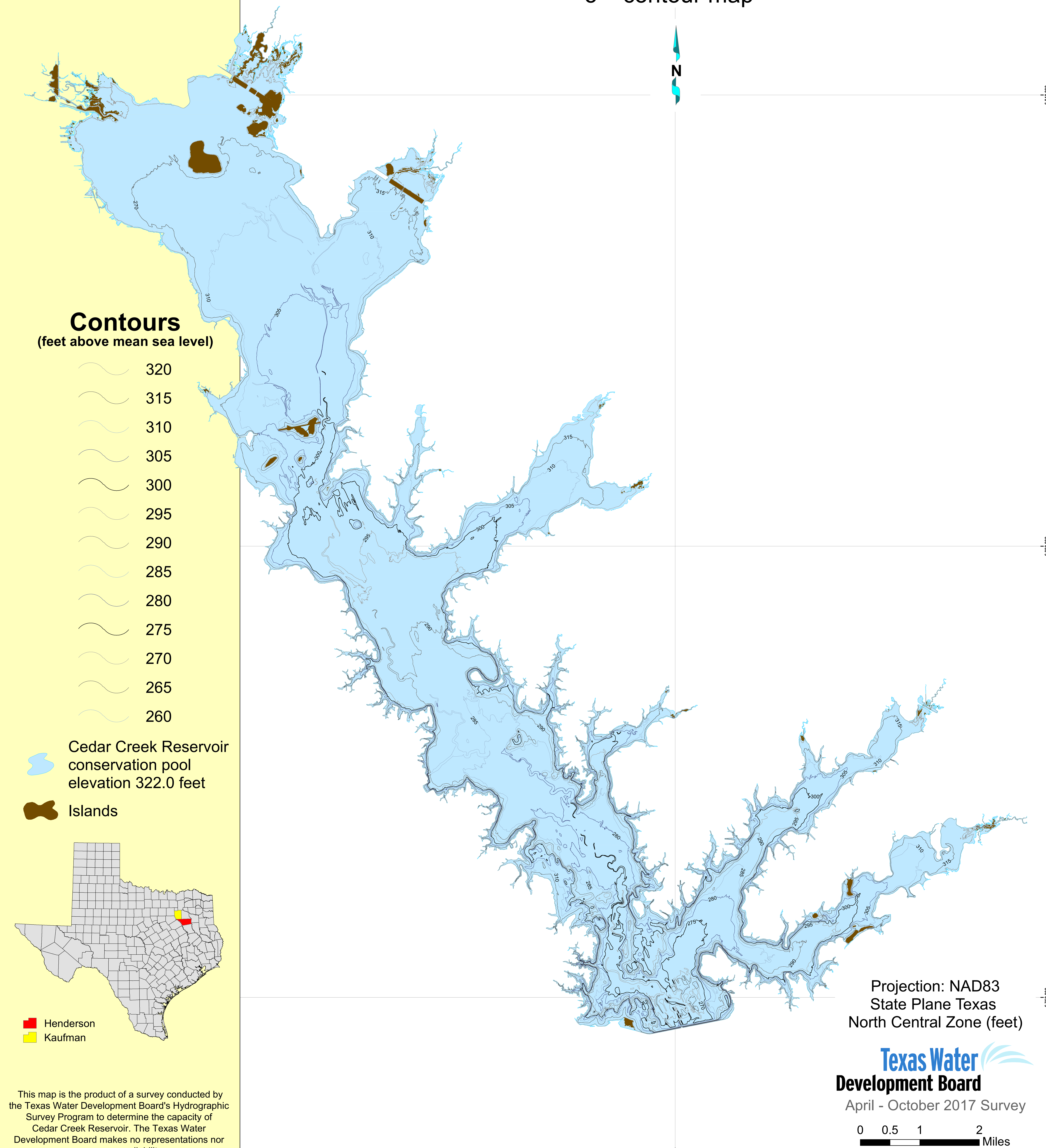

Range Line SR24
Elevation (feet)
325
323
321
319
317
315
313
311
309
307
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Distance (feet)
2017 pre
1995 recalc
2005 recalc
2017 current

Figure 6

Cedar Creek Reservoir

5' - contour map



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