Volumetric and Sedimentation Survey of LAKE BUCHANAN

July 2019 Survey

Texas Water Development Board

July 2020

Texas Water Development Board

Prepared for:

Lower Colorado River Authority

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Executive summary

In September 2018, the Texas Water Development Board (TWDB) entered into an agreement with the Lower Colorado River Authority to perform a volumetric and sedimentation survey of Lake Buchanan (Burnet and Llano counties, Texas). Surveying was performed using a multi-frequency (208 kHz, 50 kHz, and 12 kHz), sub-bottom profiling depth sounder. Sediment core samples were collected in select locations and correlated with sub-bottom acoustic profiles to estimate sediment accumulation thicknesses and sedimentation rates.

Buchanan Dam and Lake Buchanan are located on the Colorado River in Burnet County, 13 miles west of Burnet, Texas. The conservation pool elevation of Lake Buchanan is 1,020.0 feet above mean sea level. The TWDB collected bathymetric data for Lake Buchanan between May 15 and July 16, 2019, while daily average water surface elevations measured between 1,017.91 and 1,018.12 feet above mean sea level.

The 2019 TWDB volumetric survey indicates Lake Buchanan has a total reservoir capacity of 880,356 acre-feet and encompasses 22,452 acres at conservation pool elevation (1,020.0 feet above mean sea level). The 2019 TWDB volumetric survey measured 13,674 acre-feet of capacity below elevation 937.0 feet above mean sea level, or dead pool elevation. Dead pool refers to the water that cannot be drained by gravity through a dam's outlet works. The useable conservation pool storage, total reservoir capacity minus dead pool capacity, of Lake Buchanan is 866,691 acre-feet. The accuracy of the TWDB survey was assessed using the root mean square error (RMSE). The RMSE between the axial profile points and the model surface is 0.93 feet. The value 0.93 was added to and subtracted from all model inputs to find the range of uncertainty for the volumetric survey. Results at conservation pool elevation suggest the total reservoir capacity estimate is accurate to within +/-2.38 percent.

Previous capacity estimates at elevation 1,020.0 feet include an original design estimate of 981,592 acre-feet, two U.S. Department of Agriculture estimates of 970,010 acre-feet and 954,859 acre-feet in 1937 and 1941, respectively, a 1997 Lower Colorado River Authority estimate of 877,674 acre-feet, and a 2006 TWDB estimate of 875,588 acre-feet. 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. The 2019 TWDB survey results do not mean the reservoir has gained capacity since 2006.

Rather it is a result of data collected over a larger area and improved methods. Information from past surveys are presented here for informational purposes only.

The 2019 TWDB sedimentation survey measured 49,812 acre-feet of sediment. Comparison of the 2019 sedimentation survey results with historical records suggest the TWDB sedimentation survey results are likely an underestimate of the total sediment volume in Lake Buchanan. The sedimentation survey indicates sediment accumulation is greatest in the river channels. Accumulation is also occurring in the floodplains below elevation 980.0 feet. The TWDB recommends that a similar methodology be used to resurvey Lake Buchanan 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 September 2018, the TWDB entered into an agreement with the Lower Colorado River Authority, to perform a volumetric and sedimentation survey of Lake Buchanan (Texas Water Development Board, 2018). 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 A and B).

Lake Buchanan general information

Buchanan Dam and Lake Buchanan are located on the Colorado River in Burnet County, 13 miles west of Burnet, Texas (Figure 1). Lake Buchanan is owned and operated by the Lower Colorado River Authority. Construction of the dam began in April 1931, and the dam was completed in 1938. Deliberate impoundment of water began on May 20, 1937 (Texas Water Development Board, 1971). The reservoir was built primarily for water supply and hydroelectric power (Dowell, 1964; Lower Colorado River Authority, 2019). Additional pertinent data about Buchanan Dam and Lake Buchanan can be found in Table 1.

Water rights for Lake Buchanan have been appropriated to the Lower Colorado River Authority through Certificate of Adjudication No. 14-5478 and Amendments to Certificate of Adjudication Nos. 14-5478A, 14-5478B, and 14-5478C. The complete permits are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

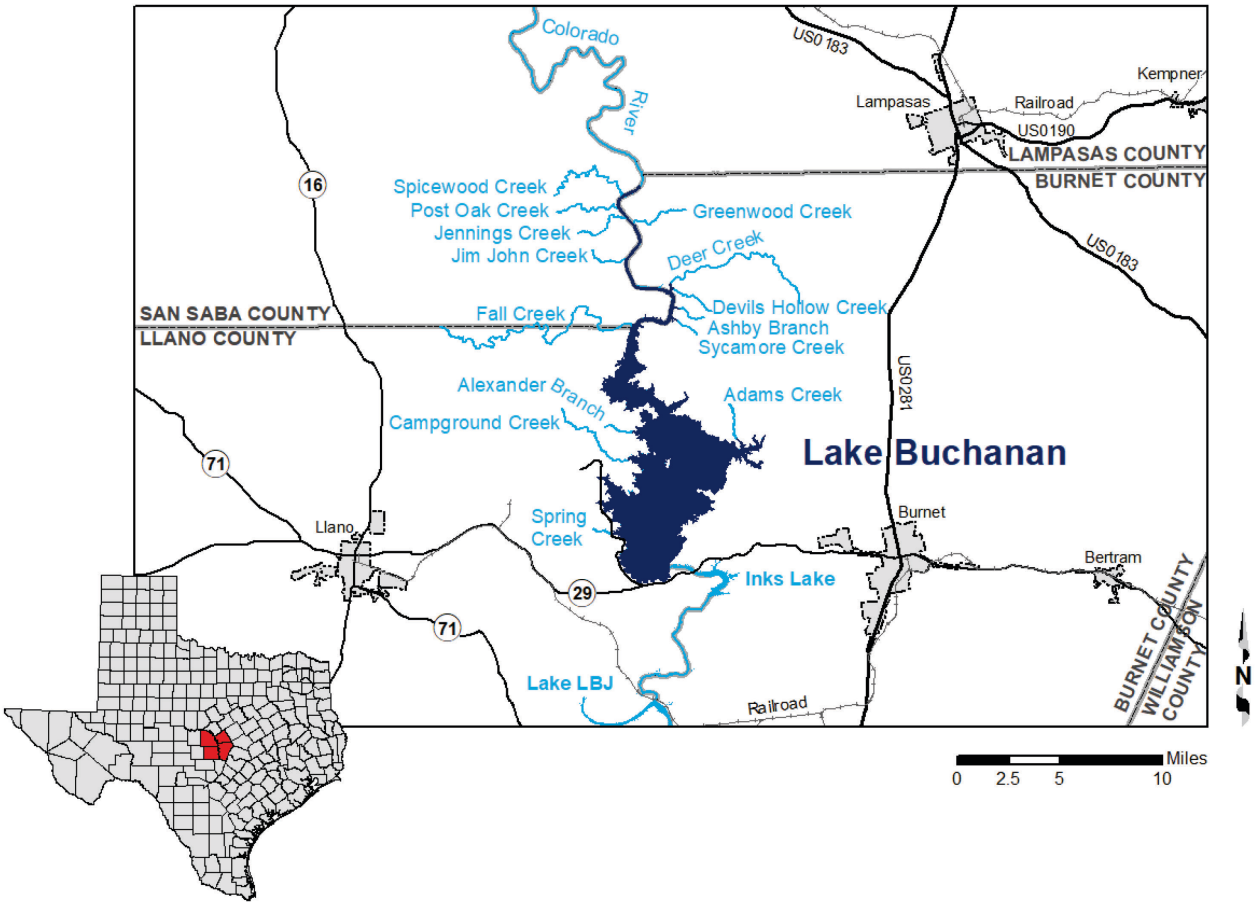

Figure 1. Location map of Lake Buchanan.

Table 1. Pertinent Data for Buchanan Dam and Lake Buchanan

Owner	
Lower Colorado River Authority	
Engineer (Design)	
Fargo Engineering Company U.S. Bureau of Reclamation Lower Colorado River Authority	
Location of Dam	
On the Colorado River in Burnet County, 13 miles west of Burnet. Lake shoreline is in Burnet, Llano, and San Saba Counties.	
Drainage Area	
31,250 square miles of which 11,900 square miles is probably noncontributing	
Dam	
Type	Multiple concrete arch, gated and gravity sections
Length	10,987 feet plus 1,700 feet of natural ground
Height	145.5 feet
Top width	Varies, with the maximum 33.8 feet
Base width	215.11 feet
Type	3 sections with tainter gates
Section 1 (near left or north end)	
Crest elevation	1,005.0 feet above mean sea level
Control	16 gates, each 33 by 15.5 feet
Discharge capacity	6,200 cubic feet per second each
Section 2 (center)	
Crest elevation	1,005.0 feet above mean sea level
Control	14 gates, each 33 by 15.5 feet
Discharge capacity	6,800 cubic feet per second each
Section 3 (nearest powerhouse)	
Crest elevation	995.0 feet above mean sea level
Control	7 gates, each 40 by 25.5 feet
Discharge capacity	18,800 cubic feet per second each
Section 4 (overflow no control far left or north end)	
Crest elevation	1,020.35 feet above mean sea level
Crest length	1,100 feet
Total flood gates	37
Discharge capacity	326,700 cubic feet per second
Outlet works	
None. Water is released through turbines. 3 turbines with a discharge capacity of 1,500 cubic feet per second each	
Power features	
3 generating units, each 8.3megawatts for a plant total rating of 54.9 megawatts	

Table 1 (continued). Pertinent Data for Buchanan Dam and Lake Buchanan

Reservoir data (Based on 2019 TWDB survey)

Feature	Elevation (feet abv MSL[a])	Capacity (acre-feet)	Area (acres)
Top of dam	1,025.5	1,008,636	24,168
Top of gates	1,021.5	914,351	22,907
Top of gravity overflow	1,020.35	888,230	22,540
Conservation pool elevation/operating elevation November 1-May 1	1,020.0	880,356	22,452
Conservation pool elevation/operating elevation May 1-November 1	1,018.0	835,869	22,057
Sill of 15-feet gates	1,005.0	573,837	17,768
Sill of 25-feet gates	995.0	415,497	14,225
Invert to penstocks	937.0	13,662	1,444
Conservation storage capacity[b]	—	866,694	—

Source: (A. Dillender, written commun(s)., 2020, Dowel, 1964; Lower Colorado River Authority, 2020a; Texas Water Development Board, 1971; Texas Water Development Board, 2006)

[a] feet abv MSL = feet above mean sea level. This is the Lower Colorado River Authority's legacy datum for Lake Buchanan. Feet above mean sea level + 0.01 = NGVD29 (National Geodetic Vertical Datum of 1929). Feet above mean sea level + 0.26 = NAVD88 (North American Vertical Datum of 1988).

[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 Lake Buchanan

Datum

The vertical datum used during this survey is feet above mean sea level. This is the legacy datum used by the Lower Colorado River Authority (LCRA). The legacy datum is based on elevation benchmarks set for construction of the dams forming the Highland Lakes that have not been adjusted to a standard datum (Lower Colorado River Authority, 2020b). Water surface elevation data was downloaded from the United States Geological Survey (USGS) for the reservoir elevation gage *TX071 08148000 LCRA Lk Buchanan nr Burnet, TX.* The USGS provides LCRA data adjusted to the North American Vertical Datum of 1988 (NAVD88). The NAVD88 datum is 0.26 feet higher than the LCRA legacy datum (U.S. Geological Survey, 2020). Elevations herein are reported in feet relative to the legacy datum. Volume and area calculations in this report are referenced to water levels provided by the USGS gage adjusted to the legacy datum. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas Central Zone (feet).

TWDB bathymetric and sedimentation data collection

The TWDB collected bathymetric data for Lake Buchanan between May 15 and July 16, 2019, while daily average water surface elevations measured between 1,017.91 and 1,018.12 feet above mean sea level. For data collection, the TWDB used a Specialty Devices, Inc. (SDI), single-beam, multi-frequency (208 kHz, 50 kHz, and 12 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 for the *Volumetric and Sedimentation Survey of Lake Buchanan, April 2006 Survey* (Texas Water Development Board, 2006). 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. Each speed of sound profile, or velocity cast, is saved for further data processing. Figure 2 shows the data collection locations for the 2019 TWDB survey.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples are collected throughout the reservoir to assist with

interpretation of the sub-bottom acoustic profiles. After analyzing the sounding data, the TWDB selected 20 locations to collect sediment core samples (Figure 2). Sediment cores were collected on December 4, 2019, and January 23-24, 2020, 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. A sediment core extends from the current reservoir-bottom surface, through the accumulated sediment, and into the pre-impoundment surface. After the sample is retrieved, the core tube is cut to the level of the sediment core. The tube is capped and transported to TWDB headquarters for further analysis.

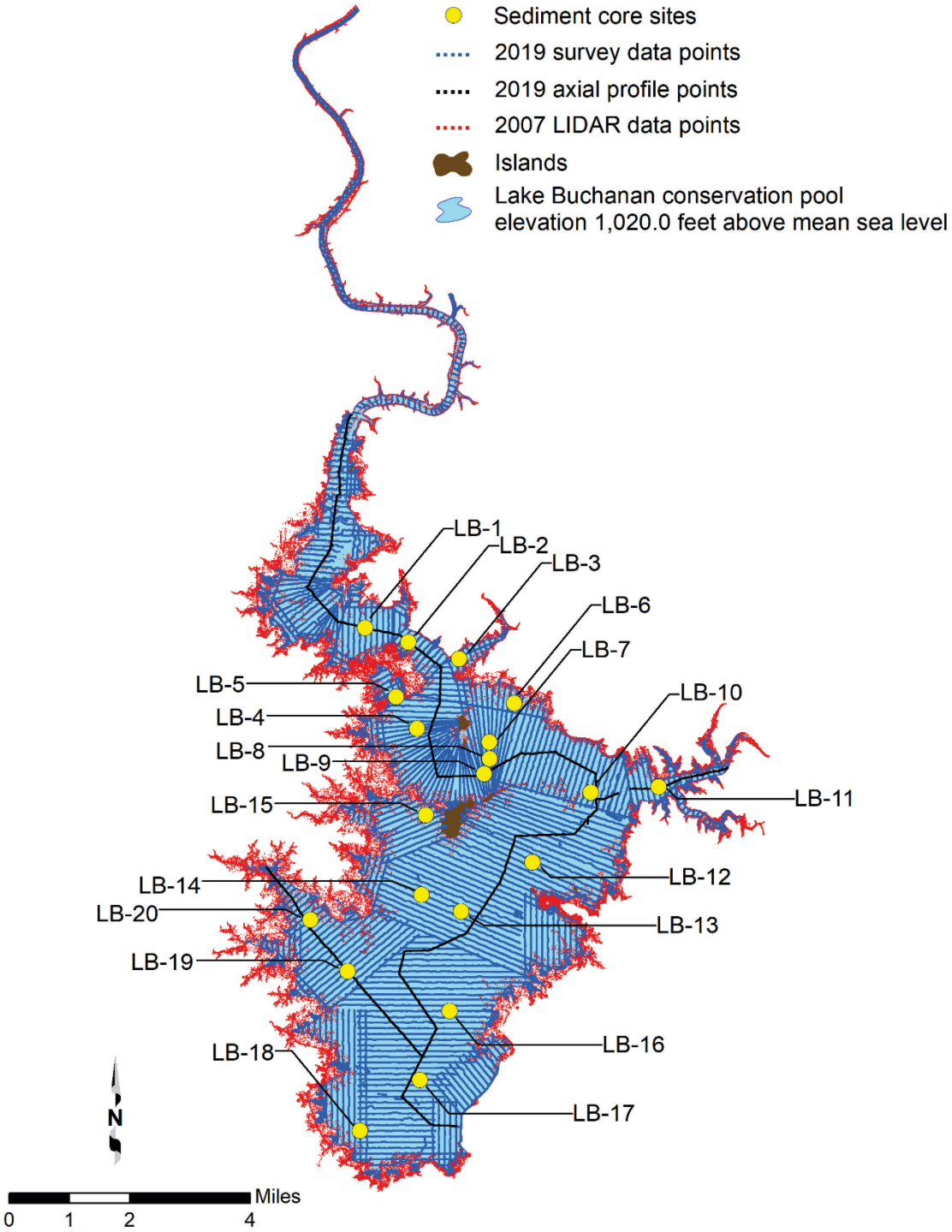

Figure 2. **2019 TWDB Lake Buchanan survey data (*blue dots*), sediment coring locations (*yellow circles*), and 2007 LIDAR data (*red dots*).**

Data processing

Model boundary

The reservoir's model boundary was generated with Light Detection and Ranging (LIDAR) Data available from the Texas Natural Resource Information System. The LIDAR data was collected on December 31, 2006, and January 1, 2007 (Texas Water Development Board, 2006), while the daily average water surface elevation of the reservoir measured 998.07 and 998.04 feet, respectively. This same LIDAR data was utilized for the 2006 TWDB survey of Lake Buchanan, but was reprocessed for modeling and analyses with the 2019 survey data. The LIDAR data .las files were converted to text files containing only data classified as ground points. The text files were imported into an Environmental Systems Research Institute's ArcGIS file geodatabase. 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 the vertical datum is North American Vertical Datum 1988 (NAVD88; meters). Two contours of 317.37 and 304.57 meters NAVD88, equivalent to 1,040.99 and 998.99 feet above mean sea level, respectively, were extracted from the raster. The vertical datum transformation offset of 0.26 feet, provided by the LCRA, was used to convert from feet NAVD88 to feet above mean sea level. Both contours were edited to close the contours across the top of the dam. Horizontal coordinate transformations to NAD83 State Plane Texas Central Zone (feet) coordinates were done using the ArcGIS Project tool.

LIDAR data points

To utilize the LIDAR data in the reservoir model, the ArcGIS tool Terrain to Points was used to extract points from the Terrain, or topographical model of the reservoir. The Terrain was created using the z-tolerance Pyramid Type. The points were extracted at the smallest pyramid resolution of 0.5 meters to reduce computation burden without significantly affecting the modeled topography of the coverage area. New attribute fields were added to convert the elevations from meters to feet NAVD88 and then to feet above mean sea level for compatibility with the bathymetric survey data. LIDAR data outside of the 1,040.99-foot contour and inside the 998.99-foot contour were deleted and the shapefile projected to NAD83 State Plane Texas Central Zone (feet). The LIDAR data agreed

well with the TWDB survey data in areas of overlap. No further interpolation of the data in the areas with only LIDAR coverage was necessary.

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. The speed of sound profiles, also known as velocity casts, were used to further correct the measured depths. For each location velocity casts are collected, the harmonic mean sound speed of all the casts are calculated. From this, depths collected using one average speed of sound are corrected with an overall optimum speed of sound for each specific depth (Specialty Devices, Inc., 2018).

Hydropick software, developed by TWDB staff, was used to display, interpret, identify, and manually edit the pre-impoundment surfaces in the multi-frequency data. 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 (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, 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).

Typically, 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. However, with LIDAR data coverage, linear interpolation was not necessary.

Figure 3 illustrates typical results from application of the anisotropic interpolation as applied to Lake Buchanan. 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 A) and elevation-area (Appendix B) tables.

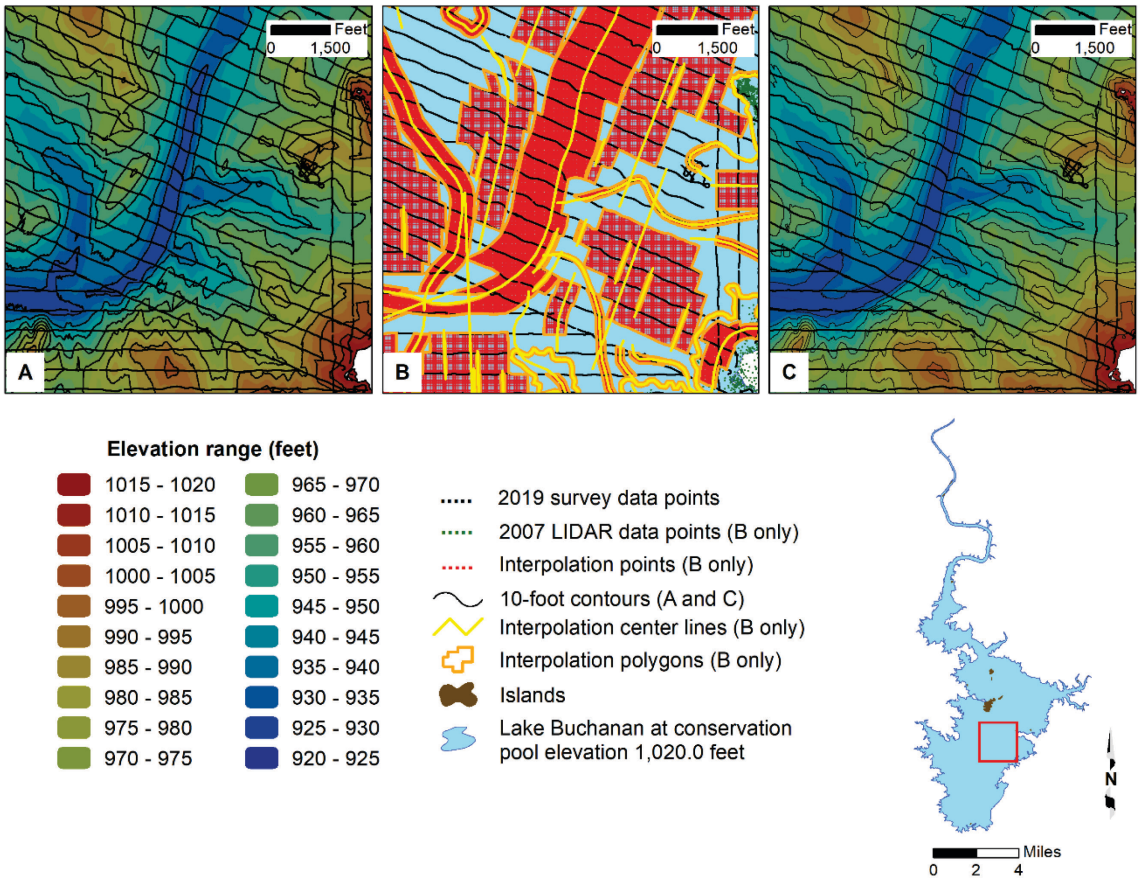

Figure 3. Anisotropic spatial interpolation as applied to Lake Buchanan sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.

Area, volume, and contour calculation

Using the Surface Volume Tool in the 3D Analyst Extension of ArcGIS and the volumetric TIN model, volumes and areas were computed for the entire reservoir at 0.1-foot intervals, from 913.7 to 1,040.0 feet above mean sea level. The elevation-capacity table and elevation-area table, based on the 2019 survey and analysis, 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 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 Lake Buchanan (Figure 5); and, (3) a 10-foot contour map (Figure 6).

Figure 4

Lake Buchanan

Elevation relief map

Elevation
feet above mean sea level

1,015 - 1,020	960 - 965
1,010 - 1,015	955 - 960
1,005 - 1,010	950 - 955
1,000 - 1,005	945 - 950
995 - 1,000	940 - 945
990 - 995	935 - 940
985 - 990	930 - 935
980 - 985	925 - 930
975 - 980	920 - 925
970 - 975	915 - 920
965 - 970	913.45 - 915

25-foot contours

Lake Buchanan
conservation pool elevation
1,020.0 feet above mean sea level

Projection: NAD83 State Plane
Texas Central Zone (feet)

1000
975
950
925

2,880,000
2,900,000
2,920,000
10,340,000
10,320,000
10,300,000
10,280,000
10,260,000
10,240,000

N

0 0.5 1 2 Miles

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Figure 5

Lake Buchanan

Depth range map

Depth ranges
(feet)

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- > 100

Lake Buchanan
conservation pool elevation
1,020.0 feet above mean sea level

Projection: NAD83 State Plane
Texas Central Zone (feet)

2,880,000
2,900,000
2,920,000
10,340,000
10,320,000
10,300,000
10,280,000
10,260,000
10,240,000

N

0 0.5 1 2
Miles

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Analysis of sediment data from Lake Buchanan

Sedimentation in Lake Buchanan 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 used to determine the current bathymetric surface, the 208 kHz, 50 kHz, and 12 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.

Sediment cores were analyzed at TWDB headquarters in Austin. Each core was split longitudinally and analyzed to identify the location of the pre-impoundment surface. The pre-impoundment surface was identified within the sediment core using 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) recording changes in texture from well sorted, relatively fine-grained sediment to poorly sorted mixtures of coarse and fine-grained materials; and, (3) identifying variations in the physical properties of the sediment, particularly sediment water content and penetration resistance with depth (Van Metre and others, 2004). Total sediment core 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 were recorded (Table 2).

Table 2. Sediment core sample analysis data for Lake Buchanan.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
LB-1	2889646.61	10285981.21	20.0”/11.0”	post-impoundment	0.0–11.0” high water content, loose silty clay, uniform consistency, bits of harder clay throughout	10YR 3/1 very dark gray
				pre-impoundment	11.0–20.0” very low water content, dense silty clay, fibrous roots, sticky, organic matter present throughout	10YR 3/1 very dark gray
LB-2	2893429.23	10284735.58	103.0”/N/A	post-impoundment	0.0–3.0” high water content, silt, very soupy	10YR 3/2 very dark grayish brown
					3.0–103.0” moderate water content and decreasing with depth, organic matter present at top, texture uniform throughout, silt, pudding like, some organic matter near top	10YR 3/2 very dark grayish brown to 10YR 3/3 dark brown (color gets lighter from top to bottom)
LB-3	2897873.34	10283283.51	117.0”/116.0”	post-impoundment	0.0–3.0” high water content, silt, smooth and soupy	10YR 3/2 very dark grayish brown
					3.0–116.0” moderate water content, silt, pudding like, uniform texture throughout	10YR 3/3 dark brown, mottled color from 67.0–116.0” with 10YR 3/2 very dark grayish brown
				pre-impoundment	116.0–117.0” very low water content, sandy clay, dense, fibrous roots, organic matter present	10YR 2/2 very dark brown
LB-4	2894174.85	10277170.19	92.0”/N/A	post-impoundment	0.0–92.0” moderate water content, smooth, silt, water content decreasing with depth, pudding like, hard sand in bottom cap of sediment core	10YR 3/1-3/2 transitioning with depth
LB-5	2892355.71	10279942.96	77.0”/55.0”	post-impoundment	0.0–2.0” very high water content, silt, soupy	10YR 3/2 very dark grayish brown
					2.0–38.0” moderate water content, silt, pudding like, consistent texture throughout	10YR 3/2 very dark grayish brown
					38.0–55.0” moderate water content, silt, pudding like, consistent texture throughout, smooth	10YR 4/3 brown
				pre-impoundment	55.0–77.0” very low water content, coarse sand, dense, fibrous roots at 55”, organic matter present	10YR 3/1 very dark gray

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

Table 2. Sediment core sample analysis data for Lake Buchanan (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
LB-6	2902709.84	10279375.6	12.0”/10.0”	post-impoundment	0–10.0” moderate water content decreasing with depth, silty sand, dense, organic matter present at top	7.5YR 4/2 brown
				pre-impoundment	10.0–12.0” very low water content, sandy clay, dense, malleable, fibrous roots, organic matter present	7.5YR 4/4 brown
LB-7	2900503.28	10275981.86	27.0”/19.0”	post-impoundment	0.0–8.0” very low water content, silty sand, very dense, consistent color and texture throughout	7.5YR 3/2 dark brown
					8.0–19.0” low water content, silty sand with some clay, very dense, some rock, water content decreasing with depth	7.5YR 4/2 brown
				pre-impoundment	19.0–27.0” very low water content, very dense, sandy clay, malleable	7.5YR 3/4 dark brown
LB-8	2900543.40	10274514.76	100.0”/50.0”	post-impoundment	0.0–3.0” high water content, silt, soupy, organic matter present	7.5YR 4/2 brown
					3.0–42.0” moderate water content, silt, pudding like, no organic matter present	7.5YR 4/2 brown
					42.0–50.0” low water content, dense, sandy silt, fibrous roots, organic matter present	7.5YR 3/1 very dark gray
				pre-impoundment	50.0–100.0” very low water content, dense, sandy clay, fibrous roots, organic matter present	7.5YR 4/4 brown
LB-9	2900065.57	10273218.10	120.0”/N/A	post-impoundment	0.0–120.0” moderate water content, silt, density increases with depth, water content decreases with depth	7.5YR 3/1 very dark gray to 4/2 very dark grayish brown, mottled
LB-10	2909382.09	10271557.44	44.0”/34.0”	post-impoundment	3.0–4.0” very high water content, soupy, pudding like, silt, smooth	7.5YR 3/2 dark brown
					4.0–20.0” high water content, smooth, silt, pudding like, uniform color and water content throughout	7.5YR 3/2 dark brown
					20.0–34.0” low water content, decreasing water content with depth, dense sandy clay, small gravel mixed in, band of black organic material at 20-inch, organic matter present	7.5YR 3/1 very dark gray
				pre-impoundment	34.0–44.0” very low water content, dense compacted silty clay, fibrous roots, uniform consistency, organic matter present	7.5YR 6/4 light brown

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

Table 2. Sediment core sample analysis data for Lake Buchanan (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
LB-11	2915336.07	10272042.19	117.0”/N/A	post-impoundment	0.0–7.0” very high water content, silt, soupy	10YR 3/2 very dark grayish brown
					7.0–117.0” moderate water content, silt, pudding like, uniform throughout	Mottled, 10YR 3/3 dark brown, 3/2 very dark grayish brown
LB-12	2904305.01	10265446.24	21.0”/N/A	post-impoundment	0.0–21.0” very high water content, coarse sand with silt, dendritic roots scattered throughout layer, uniform consistency, silt decreases with depth, organic matter present	10YR 5/3 brown
LB-13	2898047.88	10261160.19	27.0”/21.0”	post-impoundment	0.0–9.0” high water content, loose silt, very smooth, pudding like, uniform consistency, organic matter present	5YR 2.5/1 black
					9.0–21.0” low water content, coarse sand with silt and bits of clay, dendritic roots present, band of organic matter at 9-inch, possible burned, organic matter present	5YR 3/1 very dark gray
				pre-impoundment	21.0–27.0” very low water content, coarse sandy clay, fibrous and dendritic roots throughout, uniform consistency, organic matter present	5YR 3/1 very dark gray
LB-14	2894557.09	10262600.98	103.0”/88.0”	post-impoundment	0.0–3.0” high water content, silt, smooth, soupy	10YR 4/2 dark grayish brown
					3.0–88.0” moderate water content, silt, pudding like, uniform in texture, color changes with depth	10YR 2/1 black- 10YR 3/2 very dark grayish brown
				pre-impoundment	88.0–103.0” low water content, dense coarse sand with rock	10YR 5/2 grayish brown
LB-15	2894938.96	10269581.53	15.0”/6.0”	post-impoundment	0.0–6.0” low/moderate water content, dense sandy clay, fibrous roots throughout, organic matter present	5YR 4/3 reddish brown
				pre-impoundment	6.0–15.0” very low water content, dense coarse, silty sand with some bits of hard clay, fibrous roots at top of layer, organic matter present	5YR 4/6 yellowish red

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

Table 2. Sediment core sample analysis data for Lake Buchanan (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
LB-16	2897045.33	10252425.31	18.0”/N/A	post-impoundment	0.0–6.0” low water content, sand with silt, densely packed, clay present	5YR 4/2 dark reddish gray
					6.0–18.0” low water content, coarse sand with silt, fibrous roots throughout, some mixed gravel, loosely packed, no distinct clay, organic matter present	5YR 4/2 dark reddish gray
LB-17	2894439.23	10246396.36	70.0”/N/A	post-impoundment	0.0–2.0” very high water content, smooth silt, soupy	10YR 2/2 very dark brown
					2.0–59.0” moderate water content, mottled color, darker toward top, smooth, silt, pudding like, uniform consistency	10YR 2/2 very dark brown, 10YR 3/2 very dark grayish brown, 10YR 2/1 black
					59.0–70.0” low water content, loose small gravel, silty sand, few small fibrous roots, organic matter present	10YR 3/2 very dark grayish brown
LB-18	2889201.12	10241950.80	25.0”/0.0”	pre-impoundment	0.0–25.0” very low water content, very densely packed coarse sand with clay, fibrous roots throughout, organic matter present	7.5YR 5/2
LB-19	2888105.47	10255908.20	67.0”/59.0”	post-impoundment	0.0–33.0” moderate water content, silt, pudding like, organic matter at bottom of layer	10YR 3/1 very dark gray
					33.0–59.0” low water content, sandy silt, dense, compact, fibrous roots throughout, band of black organic material at 33-inch	10YR 3/1 very dark gray
				pre-impoundment	59.0–64.0” low water content, dense coarse sandy clay, medium sized gravel at 59-inch, rock with 1-inch diameter	10YR 3/1 very dark gray
					64.0–67.0” very low water content, dense coarse sand	10YR 5/2 grayish brown
LB-20	2884833.66	10260413.04	12.0”/4.0”	post-impoundment	0.0–4.0” high water content, coarse sand with gravel, average 3mm-4mm in size, silt present	10YR 3/1 very dark gray
				post-impoundment	4.0–12.0” very low water content, dense clay with small gravel mixed, fibrous roots at top of layer, organic matter present	10YR 4/4 dark yellowish brown

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

A photograph of sediment core LB-8 (for location, refer to Figure 2) is shown in Figure 7 and is representative of sediment cores sampled from Lake Buchanan. 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 50.0 inches and identified by the change in color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for each sediment core followed a similar procedure.

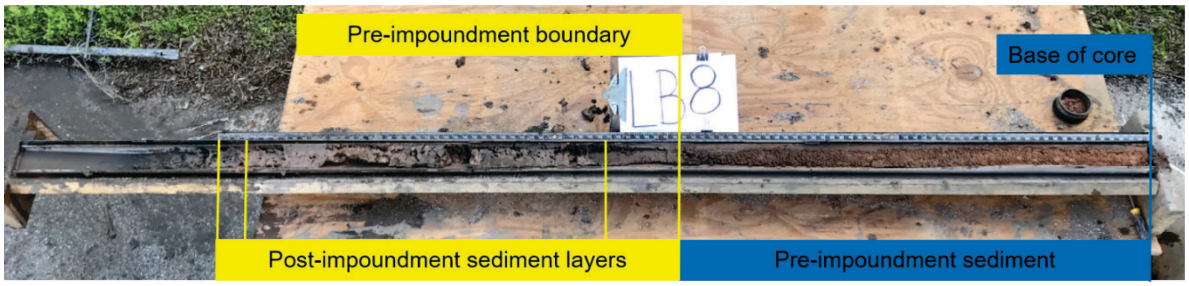


Figure 7. Sediment core LB-8 from Lake Buchanan. Post-impoundment sediment layers occur in the top 50.0 inches of this sediment core (identified by the yellow box). Pre-impoundment sediment layers were identified and are defined by the blue box.

Figure 8 compares sediment core sample LB-8 with the acoustic signals as seen in Hydropick for each frequency: 208 kHz, 50 kHz, and 12 kHz. The current bathymetric surface is automatically determined based on signal returns from the 208 kHz transducer as represented by the top red line in Figure 8. The pre-impoundment surface is identified by comparing boundaries observed in the 208 kHz, 50 kHz, and 12 kHz signals to the location of the pre-impoundment surface of the sediment core sample. Many layers of sediment were 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. A yellow box represents post-impoundment sediments. A blue box indicates pre-impoundment sediments that were identified.

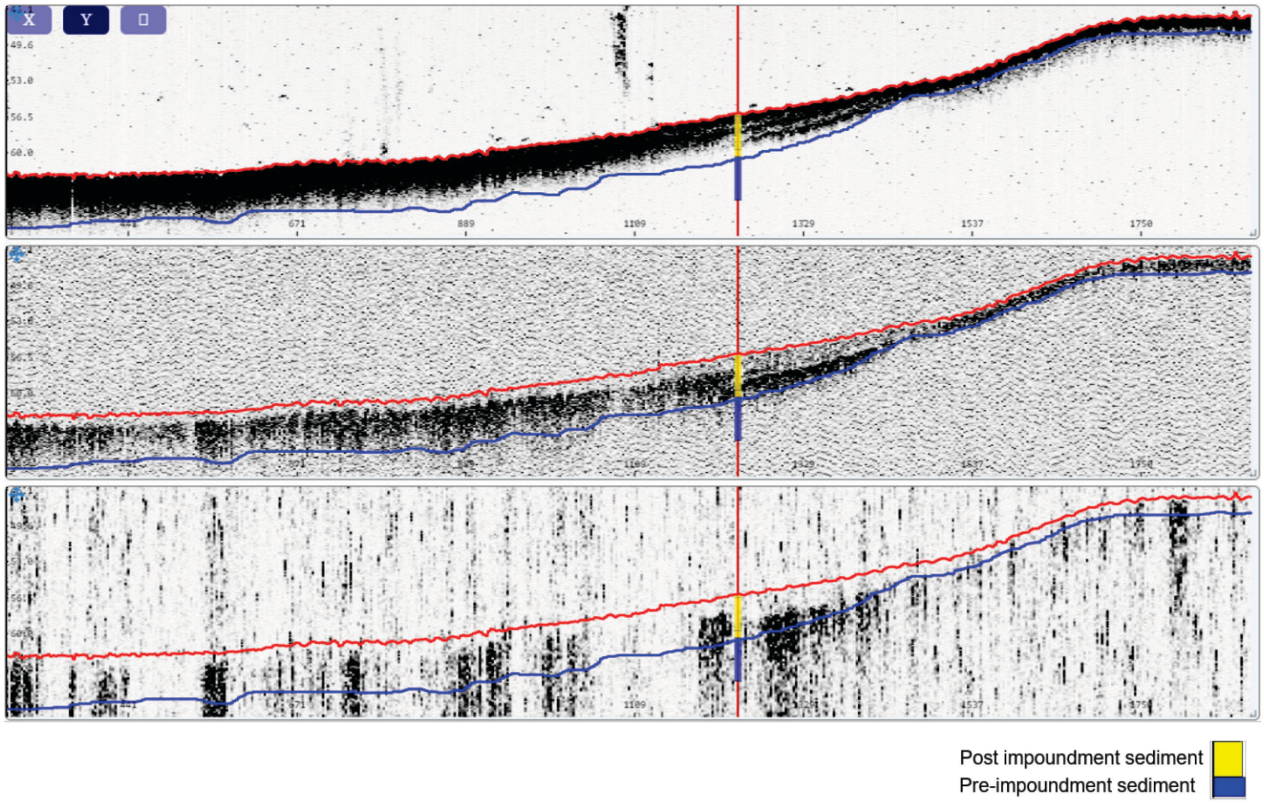


Figure 8. Comparison of sediment core LB-8 with acoustic signal returns. A) 208 kHz frequency, B) 50 kHz frequency, and C) 12 kHz frequency. The current surface in red and pre-impoundment surface in blue.

In this case, the boundary in the 50 kHz signal most closely matched the pre-impoundment interface of the sediment core sample; therefore, the 50 kHz signal was used to locate the pre-impoundment surface (blue line in the top panel in Figure 8). Figure 9 shows sediment core sample LB-8 correlated with the 50 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. This information then is used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

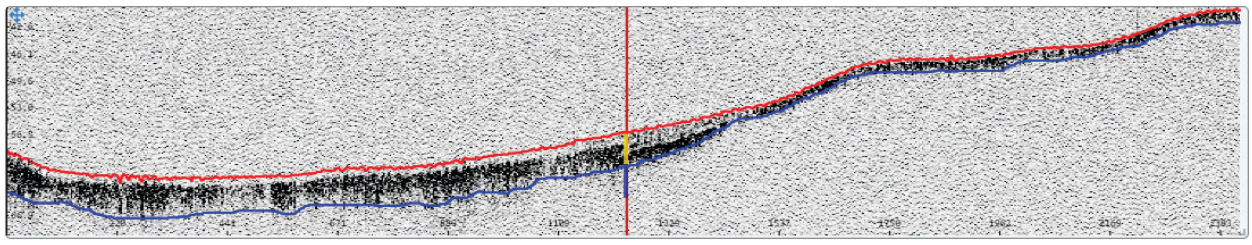


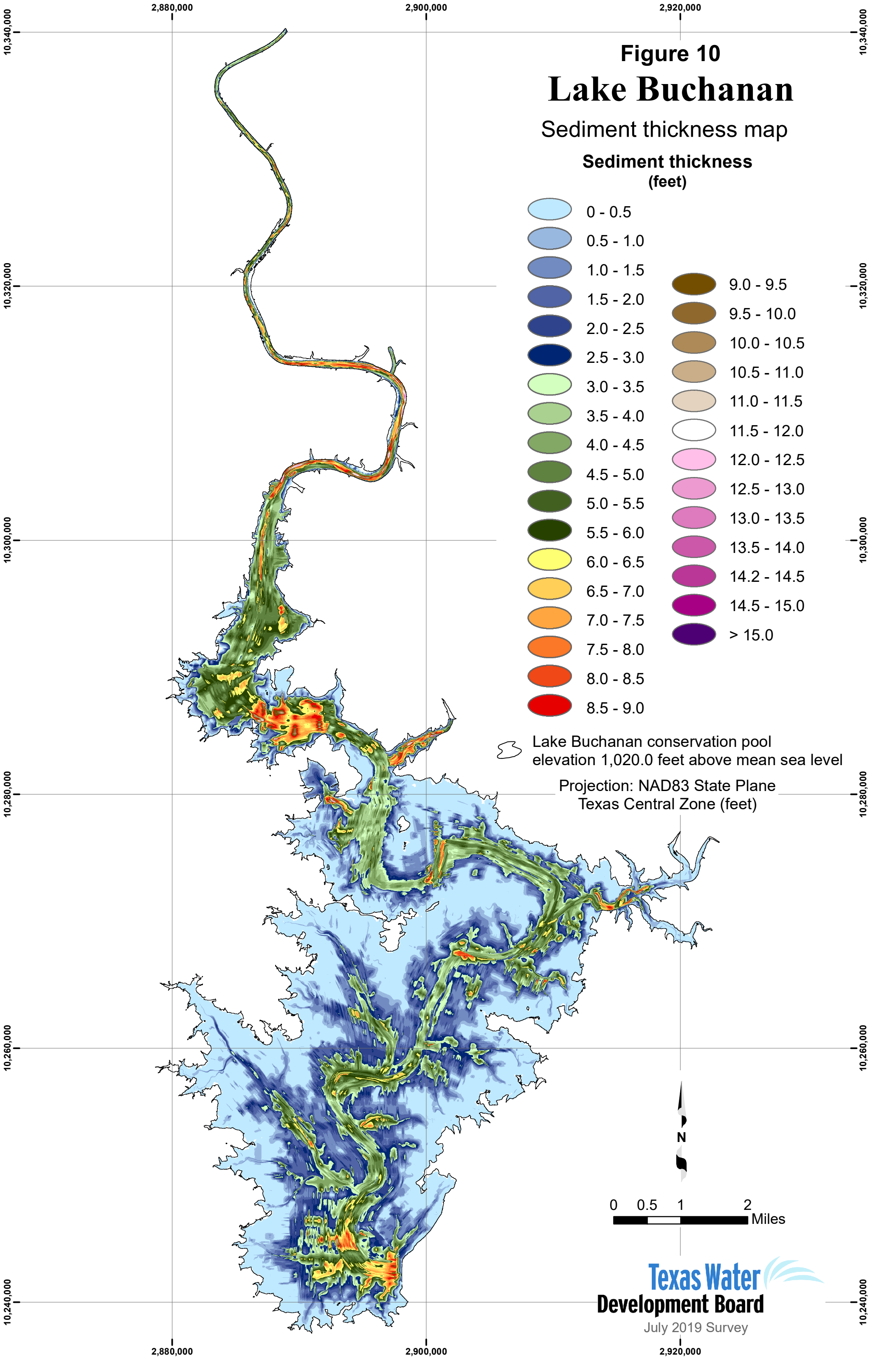
Figure 9. Cross-section of data collected during survey, displayed in Hydropick (50 kHz frequency), correlated with sediment core sample LB-8 and showing the current surface in red and pre-impoundment surface in blue.

After the pre-impoundment surface for all cross-sections is identified, a pre-impoundment TIN model and a sediment thickness TIN model are created following standard GIS techniques (Furnans and Austin, 2007). Pre-impoundment elevations and sediment thicknesses are 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 the sediment thickness at each LIDAR data point and the reservoir boundary was 0 feet (defined as the 1,040.99-foot elevation contour). LIDAR data points overlapping survey data were deleted from the pre-impoundment and sediment thickness TIN models. 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 Lake Buchanan (Figure 10). The Surface Volume Tool in the 3D Analyst Extension of ArcGIS and the pre-impoundment TIN model were used to compute elevation-capacity and elevation-area tables for the purpose of calculating the total volume of accumulated sediment.

Figure 10

Lake Buchanan

Sediment thickness map



Texas Water Development Board

July 2019 Survey

Survey results

Volumetric survey

The 2019 TWDB volumetric survey indicates that Lake Buchanan has a total reservoir capacity of 880,356 acre-feet and encompasses 22,452 acres at conservation pool elevation (1,020.0 feet above mean sea level). Current area and capacity estimates are compared to previous area and capacity estimates at different elevations in Table 3. 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 Lake Buchanan.

Survey	Surface area (acres)	Total capacity (acre-feet)	Source
Top of water surface elevation (1,020.5 feet above mean sea level)			
LCRA original design[a]	23,060	992,000	Texas Water Development Board, 1971
LCRA 1997[b]	22,387	888,865	M. Luna, P.E., written commun(s)., 2007
TWDB 2006	22,137	886,626	Texas Water Development Board, 2006
TWDB 2019	22,581	891,614	
Top of overflow spillway elevation (1,020.35 feet above mean sea level)			
LCRA original design	23,020	988,989	M. Luna, P.E., written commun(s)., 2007
LCRA 1987	N/A	918,807	M. Luna, P.E., written commun(s)., 2007
LCRA 1997	22,333	885,507	M. Luna, P.E., written commun(s)., 2007
TWDB 2006[c]	22,098	883,309	Texas Water Development Board, 2006
TWDB 2019	22,540	888,230	

[a]Note: Original estimates based on 1925 USGS topographical 20-foot contour maps, 1939 LCRA survey data, and 1965 USGS datum adjustment to mean sea level.
[b]Note: Developed from a combination of 1991 LCRA survey data and 1997 aerial photographs. To report the area and capacity at 1,020.5 feet for comparative purposes, the reported areas and capacities between elevations 1,020.0 and 1,021.0 feet were linearly interpolated.
[c]Note: To report the area and capacity at 1,020.35 feet for comparative purposes, the reported areas and capacities between elevations 1,020.3 and 1,020.4 feet were linearly interpolated.

Table 3 (continued). Current and previous survey capacity and surface area estimates for Lake Buchanan.

Survey	Surface area (acres)	Total capacity (acre-feet)	Source
Top of conservation pool elevation (1,020.0 feet above mean sea level)			
LCRA original design[d]	22,919	981,592	M. Luna, P.E., written commun(s)., 2007
USDA 1937	23,490	970,010	U.S. Department of Agriculture, 1951
USDA 1941	23,490	954,859	U.S. Department of Agriculture, 1951
LCRA 1987[e]	N/A	910,961	M. Luna, P.E., written commun(s)., 2007
LCRA 1997	22,208	877,674	M. Luna, P.E., written commun(s)., 2007
TWDB 2006	22,017	875,588	Texas Water Development Board, 2006
TWDB 2019	22,452	880,356	

[d]Note: To report the area and capacity at 1,020.0 feet for comparative purposes, the reported areas and capacities between elevations 1,018.00 and 1,020.35 feet were linearly interpolated.
[e]Note: To report the area and capacity at 1,020.0 feet for comparative purposes, the reported areas and capacities between elevations 1,018.00 and 1,020.35 feet were linearly interpolated.

Volumetric survey accuracy assessment

Axial profile data was collected at the culmination of the survey to evaluate the accuracy of the volumetric survey. For location of the axial profile points see Figure 2. For other uses of the axial profile data see the section below titled “Axial profile”. First, the accuracy of the survey data was assessed by calculating the root mean square error (RMSE) of the differences between the axial profile points and the survey data points within 1.5 feet. Second, the accuracy of the interpolated data was assessed by calculating the RMSE of the differences between the axial profile points and the model surface. The RMSE of the survey data points is 0.35 feet and the RMSE of the model surface is 0.93 feet. Using the RMSE value of 0.93 as the range of uncertainty for the volumetric survey, 0.93 feet was added to and subtracted from all model inputs, including survey data, interpolated data, and LIDAR data points. Elevation-area-capacity tables of the resulting models provide the range of potential error throughout the survey. Results at conservation pool elevation suggest the total reservoir capacity estimate is accurate to within +/- 2.38 percent. As depth increases the percent of uncertainty increases as a small change in elevation can lead to a much larger percent change in area, and therefore, capacity.

Sedimentation survey

The 2019 TWDB sedimentation survey measured 49,812 acre-feet of sediment. The sedimentation survey indicates sediment accumulation is greatest in the river channels. Accumulation is also occurring in the floodplains below elevation 980.0 feet. Comparison of capacity estimates of Lake Buchanan derived using differing methodologies are provided in Table 4 for sedimentation rate calculation. The 2019 TWDB sedimentation survey indicates Lake Buchanan has lost capacity at an average of 609 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (1,020.0 feet above mean sea level). Previous capacity estimates and comparison with historical cross sections (see section below titled "Historical range lines") suggest the TWDB sedimentation survey results are likely an underestimate of the total sediment volume in Lake Buchanan. Lake Buchanan has periodically experienced low water levels leading to the desiccation of any exposed sediment. 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). Long-term trends indicate Lake Buchanan loses capacity at an average of 1,266 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (1,020.0 feet above mean sea level) (Figure 11). However, the capacity estimates of 1997, 2006, and 2019, suggest sedimentation has slowed considerably. Construction of O. H. Ivie Reservoir upstream in 1990 likely reduced the contributing watershed area from 19,350 acres to 6,703 acres, effectively reducing the sedimentation rate in Lake Buchanan. Based on the accuracy assessment of the 2019 TWDB volumetric survey, the differences between the 2019 TWDB survey, 2006 TWDB survey, and 1997 LCRA survey fall within the range of uncertainty. Differences in methodology may also contribute to differences between these surveys.

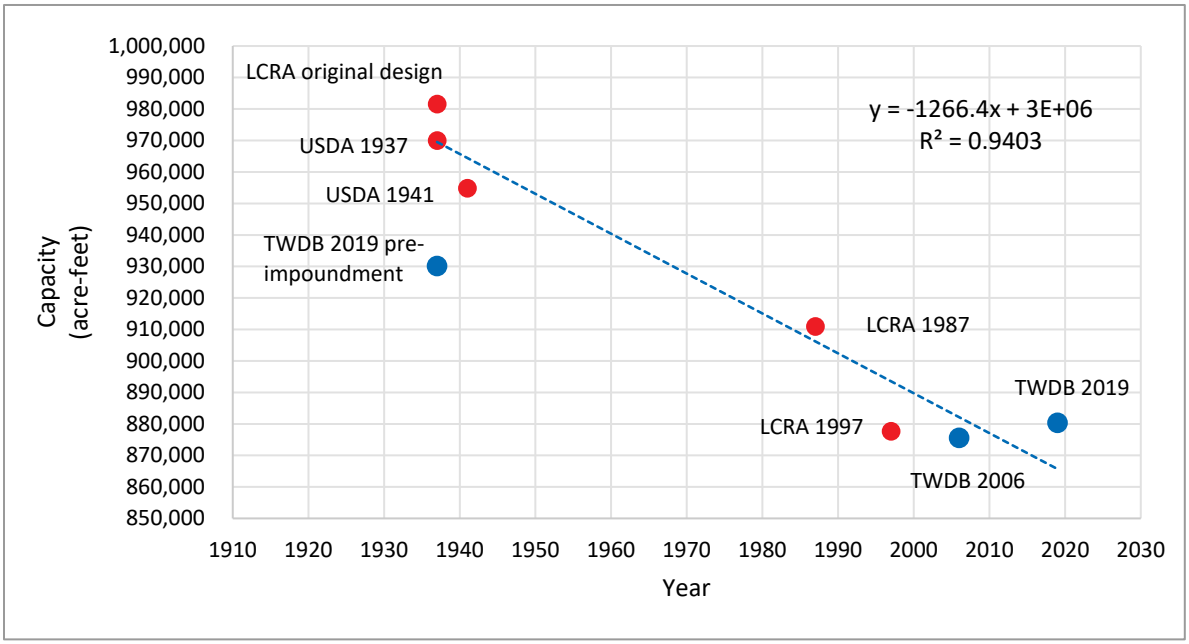


Figure 11. Plot of current and previous capacity estimates (acre-feet) at elevation 1,020.0 feet for Lake Buchanan. Capacity estimates for each TWDB survey plotted as blue dots and other surveys as red dots. The blue trend line illustrates the total average loss of capacity through 2019.

Table 4. Average annual capacity loss comparisons for Lake Buchanan.

Survey	Top of conservation pool elevation 1,020.0 feet above mean sea level (acre-feet)					
LCRA original design[a]	981,592	<>	<>	<>	<>	<>
USDA 1937[b]	<>	970,010	<>	<>	<>	<>
USDA 1941[b]	<>	<>	954,859	<>	<>	<>
LCRA 1997[c]	<>	<>	<>	877,674	<>	<>
TWDB 2006	<>	<>	<>	<>	875,588	<>
TWDB pre-impoundment estimate based on 2019 survey	<>	<>	<>	<>	<>	930,168
2019 volumetric survey	880,356	880,356	880,356	880,356	880,356	880,356
Volume difference (acre-feet) Percent change	101,236 10.3%	89,654 9.2%	74503 7.8%	-2,682 0.3%*	-4,768 0.5%*	49,812 5.4%
Number of years	82	82	78	22	13	82
Capacity loss rate (acre-feet/year)	1,235	1,093	955	-122	-367	607
Capacity loss rate (acre-feet/square mile of drainage area of 19,350 square miles /year)	0.06	0.06	0.05	-0.01	-0.02	0.03
Capacity loss rate not including 12,647 square mile drainage area of O.H. Ivie Reservoir[d] located upstream (acre-feet/square mile of drainage area of 6,703 square miles /year)	<>	<>	<>	-0.02	-0.05	<>

[a] Source: (M. Luna, P.E., written commun(s)., 2007), note: To report the capacity at 1,020.0 feet for comparative purposes, the reported capacities between elevations 1,018.00 and 1,020.35 feet were linearly interpolated. Lake Buchanan Dam was completed in 1938, and the deliberate impoundment began on May 20, 1937.

[b] Source: (U.S. Department of Agriculture, 1951)

[c] Source: (M. Luna, P.E., written commun(s)., 2007), note: To report capacity at 1,020.5 feet for comparative purposes, the reported capacities between elevations 1,020.0 and 1,021.0 feet were linearly interpolated.

[d]Source: (Texas Water Development Board, 2020)

*Based on the accuracy assessment of the 2019 TWDB volumetric survey, the differences between the 2019 TWDB survey, 2006 TWDB survey, and 1997 LCRA survey fall within the range of uncertainty. Differences in methodology may also contribute to differences between these surveys.

Historical range lines

Range lines plotted in a 1991 dredging feasibility analysis study of Lake Buchanan showing bottom surfaces for 1991 and 1938 were digitized and plotted in Appendix E. Also presented in Appendix E are a map, depicting the locations of the range lines and Table E1, a list of the endpoint coordinates for each line. For comparison, the 2006 and 2019 TWDB current bottom surfaces are also plotted. The 1991 and 1938 surfaces were generated from an LCRA 1991 5-foot interval contour map of the lake bottom surface and a 1938 20-foot

contour interval topographic map of the as-built lake bottom surface, respectively. These maps were assumed to have the standard precision of plus or minus one-half the contour interval (Engitech Inc., 1991; U.S. Bureau of the Budget, 1947).

Sediment range lines

The TWDB developed 28 sediment range lines in 2006 that closely coincided with the Lower Colorado River Authority's cross-sections designed for modeling Lake Buchanan using HEC-RAS (Texas Water Development Board, 2006). A cross-sectional comparison of the sediment range lines comparing the current bottom surface from the 2019 TWDB survey and the 2006 TWDB survey is presented in Appendix F. Also presented in Appendix F are a map, depicting the locations of the sediment range lines and Table F1, 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.

Axial profile

The axial profile of the reservoir, showing both the 2019 current and pre-impoundment surfaces, is plotted in Appendix G. Also presented in Appendix G are a map, depicting the TWDB location of the axial profile, and a table listing the coordinates of each vertex defining the axial line.

Identification of the pre-impoundment surface on the axial profile was based on the acoustic returns identified in the cross-sections where sediment cores were collected. Sediment core sites were selected to recollect cores where previously collected in 2006 and to correlate with unique acoustic returns throughout the reservoir. Axial profile data points within 1.5 feet of survey data points were compared to refine identification of the pre-impoundment surface along survey transects. Pre-impoundment acoustic signature interpretation was refined based on the agreement between intersecting data and applied during pre-impoundment identifications throughout the reservoir.

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

Lake Buchanan

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2019 Survey

CAPACITY IN ACRE-FEET — Conservation pool elevation 1,020.0 feet above mean sea level

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
913	0	0	0	0	0	0	0	0	0	0
914	0	0	0	0	0	0	1	2	3	5
915	6	9	11	13	16	19	22	25	29	33
916	38	43	50	56	64	72	80	88	97	106
917	116	126	137	148	160	171	184	196	209	222
918	236	250	265	280	295	311	327	344	362	380
919	398	416	435	455	474	495	516	537	559	582
920	605	629	653	678	704	730	757	785	813	842
921	871	901	931	962	994	1,026	1,059	1,092	1,126	1,161
922	1,196	1,231	1,267	1,303	1,340	1,377	1,415	1,453	1,491	1,530
923	1,570	1,610	1,650	1,690	1,731	1,773	1,815	1,858	1,901	1,944
924	1,988	2,033	2,078	2,124	2,170	2,217	2,264	2,312	2,360	2,408
925	2,457	2,507	2,558	2,609	2,661	2,713	2,767	2,821	2,876	2,931
926	2,987	3,043	3,101	3,159	3,218	3,277	3,338	3,399	3,460	3,523
927	3,586	3,650	3,714	3,780	3,846	3,913	3,980	4,049	4,118	4,188
928	4,258	4,329	4,402	4,474	4,548	4,622	4,697	4,772	4,849	4,926
929	5,003	5,081	5,160	5,240	5,320	5,400	5,482	5,564	5,646	5,729
930	5,813	5,897	5,982	6,067	6,153	6,240	6,327	6,415	6,504	6,593
931	6,683	6,774	6,865	6,957	7,050	7,144	7,239	7,334	7,430	7,527
932	7,625	7,723	7,822	7,922	8,023	8,125	8,227	8,330	8,434	8,539
933	8,644	8,751	8,858	8,967	9,076	9,187	9,299	9,411	9,525	9,640
934	9,756	9,873	9,991	10,110	10,229	10,350	10,471	10,593	10,716	10,841
935	10,966	11,092	11,218	11,346	11,475	11,604	11,735	11,866	11,999	12,132
936	12,266	12,401	12,538	12,675	12,813	12,952	13,092	13,233	13,375	13,518
937	13,662	13,807	13,953	14,100	14,249	14,398	14,548	14,699	14,851	15,004
938	15,158	15,313	15,469	15,627	15,785	15,944	16,104	16,265	16,428	16,591
939	16,755	16,921	17,087	17,254	17,423	17,592	17,763	17,934	18,107	18,280
940	18,456	18,632	18,810	18,988	19,168	19,349	19,531	19,714	19,899	20,084
941	20,271	20,458	20,647	20,837	21,028	21,221	21,414	21,609	21,806	22,003
942	22,202	22,402	22,603	22,805	23,009	23,214	23,421	23,629	23,839	24,049
943	24,261	24,475	24,690	24,906	25,123	25,342	25,562	25,783	26,005	26,229
944	26,455	26,681	26,909	27,138	27,369	27,601	27,834	28,069	28,305	28,542
945	28,781	29,022	29,263	29,507	29,752	29,998	30,246	30,495	30,746	30,999
946	31,252	31,508	31,765	32,023	32,283	32,545	32,807	33,072	33,338	33,605
947	33,874	34,145	34,417	34,691	34,966	35,243	35,522	35,803	36,085	36,369
948	36,654	36,942	37,231	37,522	37,814	38,109	38,405	38,702	39,002	39,303
949	39,606	39,911	40,217	40,525	40,835	41,146	41,459	41,774	42,090	42,408
950	42,727	43,048	43,371	43,696	44,021	44,349	44,678	45,008	45,341	45,674
951	46,010	46,347	46,685	47,025	47,367	47,711	48,056	48,403	48,751	49,101
952	49,453	49,806	50,161	50,517	50,875	51,235	51,597	51,960	52,325	52,692
953	53,060	53,430	53,802	54,176	54,551	54,928	55,307	55,687	56,070	56,454
954	56,839	57,227	57,616	58,007	58,399	58,793	59,189	59,587	59,987	60,389
955	60,792	61,198	61,605	62,015	62,426	62,839	63,254	63,671	64,089	64,510
956	64,932	65,356	65,783	66,211	66,642	67,075	67,509	67,946	68,386	68,827
957	69,270	69,716	70,164	70,614	71,066	71,520	71,977	72,435	72,896	73,359
958	73,824	74,291	74,761	75,233	75,706	76,182	76,661	77,141	77,623	78,108
959	78,595	79,084	79,575	80,068	80,563	81,061	81,561	82,063	82,567	83,074
960	83,583	84,094	84,607	85,123	85,641	86,161	86,683	87,208	87,734	88,263

Appendix A (continued)

Lake Buchanan

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2019 Survey

CAPACITY IN ACRE-FEET — Conservation pool elevation 1,020.0 feet above mean sea level

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
961	88,794	89,327	89,863	90,400	90,940	91,482	92,027	92,573	93,122	93,673
962	94,226	94,782	95,340	95,900	96,463	97,027	97,595	98,164	98,737	99,311
963	99,888	100,468	101,050	101,634	102,220	102,809	103,400	103,994	104,590	105,188
964	105,789	106,392	106,997	107,604	108,214	108,827	109,441	110,058	110,678	111,300
965	111,924	112,551	113,180	113,811	114,445	115,082	115,720	116,361	117,005	117,650
966	118,299	118,949	119,602	120,256	120,914	121,573	122,236	122,900	123,567	124,236
967	124,908	125,583	126,260	126,939	127,620	128,305	128,991	129,680	130,371	131,065
968	131,762	132,460	133,162	133,865	134,571	135,279	135,990	136,703	137,418	138,135
969	138,855	139,577	140,302	141,029	141,758	142,489	143,223	143,960	144,698	145,439
970	146,183	146,929	147,677	148,428	149,181	149,936	150,694	151,454	152,216	152,981
971	153,748	154,517	155,289	156,063	156,840	157,619	158,401	159,186	159,973	160,763
972	161,555	162,350	163,148	163,948	164,751	165,557	166,366	167,177	167,991	168,808
973	169,628	170,450	171,275	172,102	172,932	173,765	174,600	175,438	176,279	177,122
974	177,969	178,818	179,669	180,524	181,381	182,242	183,105	183,972	184,841	185,714
975	186,589	187,467	188,349	189,233	190,120	191,011	191,904	192,800	193,699	194,601
976	195,506	196,413	197,323	198,236	199,151	200,070	200,991	201,914	202,841	203,770
977	204,703	205,638	206,576	207,516	208,459	209,405	210,353	211,304	212,257	213,213
978	214,171	215,132	216,096	217,062	218,031	219,002	219,976	220,953	221,932	222,914
979	223,899	224,886	225,876	226,869	227,864	228,862	229,862	230,865	231,870	232,878
980	233,889	234,902	235,917	236,935	237,956	238,978	240,004	241,032	242,062	243,095
981	244,131	245,169	246,209	247,252	248,298	249,346	250,397	251,450	252,506	253,565
982	254,626	255,689	256,755	257,824	258,895	259,968	261,045	262,123	263,205	264,289
983	265,375	266,465	267,557	268,651	269,749	270,848	271,951	273,056	274,164	275,274
984	276,387	277,503	278,621	279,742	280,866	281,992	283,121	284,253	285,387	286,524
985	287,664	288,806	289,951	291,099	292,249	293,403	294,558	295,717	296,878	298,042
986	299,208	300,378	301,550	302,725	303,902	305,082	306,265	307,451	308,639	309,829
987	311,023	312,219	313,418	314,619	315,824	317,031	318,240	319,452	320,667	321,885
988	323,105	324,328	325,553	326,781	328,012	329,245	330,481	331,720	332,961	334,204
989	335,451	336,700	337,951	339,206	340,463	341,722	342,985	344,250	345,518	346,789
990	348,063	349,339	350,618	351,900	353,185	354,472	355,761	357,054	358,349	359,646
991	360,947	362,249	363,555	364,864	366,175	367,490	368,808	370,129	371,454	372,782
992	374,113	375,448	376,785	378,126	379,470	380,818	382,168	383,522	384,879	386,239
993	387,602	388,969	390,339	391,712	393,088	394,467	395,849	397,234	398,622	400,013
994	401,407	402,804	404,203	405,605	407,010	408,418	409,828	411,241	412,657	414,075
995	415,497	416,920	418,347	419,776	421,208	422,642	424,079	425,519	426,962	428,407
996	429,855	431,305	432,759	434,215	435,674	437,135	438,599	440,066	441,536	443,009
997	444,485	445,963	447,444	448,927	450,414	451,903	453,394	454,889	456,386	457,885
998	459,387	460,892	462,400	463,910	465,423	466,939	468,458	469,979	471,503	473,031
999	474,562	476,096	477,633	479,173	480,717	482,264	483,814	485,368	486,925	488,486
1,000	490,051	491,619	493,191	494,767	496,347	497,931	499,519	501,112	502,709	504,310
1,001	505,916	507,526	509,140	510,760	512,384	514,013	515,647	517,285	518,929	520,577
1,002	522,230	523,888	525,551	527,219	528,892	530,569	532,251	533,937	535,629	537,324
1,003	539,024	540,728	542,437	544,149	545,866	547,587	549,312	551,040	552,772	554,508
1,004	556,248	557,991	559,737	561,487	563,241	564,998	566,759	568,523	570,290	572,062
1,005	573,837	575,615	577,398	579,184	580,973	582,767	584,564	586,364	588,168	589,975
1,006	591,785	593,599	595,417	597,238	599,063	600,893	602,726	604,563	606,405	608,250
1,007	610,100	611,955	613,813	615,675	617,542	619,412	621,286	623,164	625,046	626,931
1,008	628,821	630,715	632,613	634,514	636,420	638,329	640,243	642,160	644,083	646,009

Appendix A (continued)

Lake Buchanan

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2019 Survey

CAPACITY IN ACRE-FEET — Conservation pool elevation 1,020.0 feet above mean sea level

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
1,009	647,940	649,875	651,815	653,758	655,707	657,659	659,615	661,575	663,538	665,506
1,010	667,477	669,452	671,432	673,415	675,402	677,393	679,387	681,385	683,386	685,392
1,011	687,401	689,415	691,432	693,453	695,477	697,506	699,538	701,574	703,614	705,657
1,012	707,703	709,754	711,807	713,864	715,924	717,988	720,056	722,126	724,200	726,277
1,013	728,357	730,440	732,527	734,616	736,709	738,804	740,903	743,005	745,110	747,217
1,014	749,328	751,442	753,559	755,678	757,801	759,927	762,055	764,186	766,320	768,457
1,015	770,596	772,738	774,883	777,030	779,180	781,332	783,487	785,644	787,804	789,966
1,016	792,130	794,297	796,466	798,638	800,812	802,988	805,166	807,347	809,529	811,714
1,017	813,900	816,089	818,280	820,472	822,666	824,862	827,060	829,260	831,461	833,664
1,018	835,869	838,076	840,284	842,494	844,706	846,920	849,135	851,352	853,571	855,792
1,019	858,015	860,240	862,467	864,696	866,926	869,159	871,394	873,631	875,871	878,112
1,020	880,356	882,603	884,852	887,103	889,357	891,614	893,873	896,136	898,401	900,670
1,021	902,942	905,217	907,495	909,777	912,062	914,351	916,644	918,940	921,240	923,543
1,022	925,850	928,160	930,474	932,792	935,113	937,437	939,765	942,097	944,431	946,769
1,023	949,111	951,456	953,804	956,155	958,509	960,867	963,227	965,591	967,958	970,327
1,024	972,700	975,076	977,455	979,836	982,221	984,608	986,998	989,391	991,787	994,185
1,025	996,587	998,991	1,001,398	1,003,808	1,006,220	1,008,636	1,011,054	1,013,475	1,015,899	1,018,325
1,026	1,020,754	1,023,186	1,025,621	1,028,059	1,030,499	1,032,942	1,035,388	1,037,837	1,040,288	1,042,742
1,027	1,045,199	1,047,658	1,050,120	1,052,585	1,055,053	1,057,523	1,059,996	1,062,472	1,064,951	1,067,432
1,028	1,069,916	1,072,403	1,074,893	1,077,385	1,079,880	1,082,378	1,084,878	1,087,381	1,089,887	1,092,395
1,029	1,094,907	1,097,421	1,099,937	1,102,456	1,104,978	1,107,503	1,110,030	1,112,560	1,115,093	1,117,628
1,030	1,120,166	1,122,706	1,125,250	1,127,796	1,130,344	1,132,896	1,135,450	1,138,007	1,140,566	1,143,128
1,031	1,145,692	1,148,260	1,150,830	1,153,402	1,155,978	1,158,555	1,161,136	1,163,719	1,166,305	1,168,893
1,032	1,171,484	1,174,078	1,176,675	1,179,274	1,181,876	1,184,481	1,187,088	1,189,698	1,192,311	1,194,927
1,033	1,197,545	1,200,166	1,202,789	1,205,415	1,208,044	1,210,676	1,213,310	1,215,947	1,218,587	1,221,229
1,034	1,223,874	1,226,522	1,229,172	1,231,825	1,234,481	1,237,140	1,239,802	1,242,466	1,245,133	1,247,802
1,035	1,250,475	1,253,150	1,255,827	1,258,508	1,261,191	1,263,876	1,266,565	1,269,256	1,271,950	1,274,646
1,036	1,277,345	1,280,047	1,282,751	1,285,458	1,288,168	1,290,880	1,293,596	1,296,314	1,299,034	1,301,758
1,037	1,304,484	1,307,213	1,309,945	1,312,680	1,315,417	1,318,157	1,320,900	1,323,645	1,326,394	1,329,145
1,038	1,331,898	1,334,654	1,337,413	1,340,175	1,342,939	1,345,706	1,348,475	1,351,247	1,354,022	1,356,799
1,039	1,359,579	1,362,361	1,365,146	1,367,934	1,370,724	1,373,517	1,376,312	1,379,110	1,381,911	1,384,714
1,040	1,387,519									

Appendix B

Lake Buchanan

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2019 Survey

AREA IN ACRES — Conservation pool elevation 1,020.0 feet above mean sea level

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
913	0	0	0	0	0	0	0	0	0	0
914	0	0	0	0	2	5	8	11	13	17
915	19	21	23	25	27	30	32	34	38	44
916	52	60	66	71	75	80	83	87	91	96
917	100	105	109	113	116	120	123	126	130	134
918	139	144	148	152	156	162	167	172	176	180
919	184	188	191	195	200	206	211	217	222	229
920	236	242	248	255	260	266	272	278	284	290
921	296	302	307	313	319	325	331	337	342	347
922	352	356	361	365	370	374	379	383	387	392
923	396	400	404	409	413	418	423	428	433	438
924	443	448	455	460	465	469	474	479	484	489
925	494	501	509	516	523	531	537	543	549	555
926	563	570	579	586	592	599	605	613	620	628
927	635	643	650	657	664	672	680	688	695	702
928	710	717	725	732	738	745	752	759	766	773
929	779	785	791	797	804	810	816	822	828	833
930	839	845	851	857	863	870	876	883	890	897
931	904	911	918	925	933	942	949	957	965	973
932	980	988	996	1,004	1,012	1,019	1,027	1,035	1,043	1,052
933	1,061	1,070	1,080	1,090	1,101	1,112	1,123	1,133	1,144	1,154
934	1,164	1,174	1,183	1,192	1,200	1,209	1,218	1,228	1,237	1,246
935	1,255	1,264	1,273	1,282	1,291	1,300	1,309	1,319	1,329	1,338
936	1,348	1,357	1,367	1,376	1,386	1,396	1,405	1,415	1,425	1,436
937	1,446	1,456	1,465	1,476	1,486	1,496	1,506	1,516	1,526	1,536
938	1,546	1,557	1,568	1,578	1,587	1,597	1,607	1,617	1,627	1,638
939	1,648	1,658	1,668	1,679	1,689	1,700	1,710	1,720	1,731	1,744
940	1,758	1,770	1,782	1,793	1,805	1,815	1,826	1,837	1,848	1,860
941	1,871	1,882	1,893	1,905	1,917	1,931	1,945	1,957	1,969	1,981
942	1,993	2,005	2,018	2,031	2,045	2,060	2,074	2,088	2,101	2,114
943	2,127	2,141	2,154	2,167	2,180	2,193	2,206	2,220	2,233	2,246
944	2,259	2,272	2,285	2,299	2,312	2,326	2,341	2,354	2,368	2,382
945	2,397	2,411	2,426	2,441	2,456	2,472	2,487	2,501	2,516	2,531
946	2,547	2,562	2,577	2,592	2,607	2,621	2,636	2,651	2,666	2,682
947	2,697	2,714	2,730	2,747	2,763	2,779	2,797	2,813	2,831	2,848
948	2,865	2,882	2,900	2,918	2,935	2,952	2,969	2,986	3,004	3,021
949	3,038	3,055	3,072	3,088	3,105	3,121	3,138	3,155	3,171	3,187
950	3,203	3,219	3,236	3,251	3,267	3,282	3,298	3,313	3,329	3,345
951	3,361	3,377	3,394	3,410	3,427	3,443	3,460	3,476	3,492	3,508
952	3,524	3,540	3,556	3,573	3,590	3,607	3,624	3,641	3,658	3,675
953	3,693	3,710	3,728	3,745	3,762	3,779	3,796	3,814	3,831	3,848
954	3,865	3,882	3,900	3,917	3,934	3,952	3,970	3,989	4,007	4,026
955	4,046	4,065	4,084	4,103	4,121	4,139	4,158	4,176	4,195	4,214
956	4,234	4,254	4,275	4,296	4,317	4,337	4,358	4,380	4,402	4,423
957	4,447	4,468	4,490	4,511	4,532	4,553	4,574	4,596	4,618	4,641
958	4,663	4,684	4,706	4,727	4,749	4,771	4,792	4,814	4,835	4,857
959	4,878	4,899	4,921	4,943	4,965	4,987	5,010	5,032	5,055	5,078
960	5,101	5,123	5,146	5,168	5,190	5,211	5,233	5,255	5,277	5,299

Appendix B (continued)

Lake Buchanan

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2019 Survey

AREA IN ACRES — Conservation pool elevation 1,020.0 feet above mean sea level

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
961	5,321	5,343	5,365	5,388	5,411	5,433	5,455	5,477	5,499	5,522
962	5,544	5,567	5,590	5,613	5,637	5,661	5,685	5,710	5,734	5,759
963	5,783	5,806	5,830	5,853	5,877	5,901	5,924	5,948	5,971	5,994
964	6,017	6,041	6,064	6,088	6,111	6,135	6,158	6,181	6,206	6,231
965	6,255	6,279	6,303	6,328	6,352	6,375	6,399	6,423	6,446	6,469
966	6,492	6,515	6,538	6,561	6,585	6,609	6,633	6,657	6,682	6,707
967	6,732	6,756	6,780	6,804	6,829	6,853	6,878	6,902	6,926	6,951
968	6,975	7,000	7,024	7,048	7,071	7,094	7,117	7,140	7,163	7,186
969	7,210	7,233	7,256	7,280	7,304	7,327	7,351	7,375	7,399	7,423
970	7,447	7,471	7,495	7,518	7,541	7,564	7,588	7,611	7,635	7,658
971	7,682	7,707	7,731	7,756	7,781	7,806	7,831	7,858	7,885	7,912
972	7,938	7,964	7,990	8,017	8,045	8,073	8,100	8,127	8,154	8,182
973	8,208	8,234	8,260	8,287	8,314	8,340	8,367	8,394	8,421	8,449
974	8,476	8,504	8,532	8,560	8,589	8,618	8,649	8,679	8,710	8,740
975	8,770	8,799	8,828	8,859	8,889	8,918	8,947	8,976	9,004	9,032
976	9,059	9,087	9,114	9,141	9,168	9,196	9,224	9,251	9,280	9,309
977	9,338	9,365	9,391	9,417	9,443	9,469	9,494	9,520	9,546	9,572
978	9,597	9,623	9,649	9,675	9,701	9,727	9,754	9,781	9,807	9,833
979	9,859	9,886	9,912	9,939	9,964	9,990	10,016	10,041	10,067	10,092
980	10,118	10,143	10,168	10,192	10,217	10,242	10,267	10,292	10,317	10,342
981	10,367	10,393	10,418	10,444	10,469	10,494	10,520	10,546	10,572	10,597
982	10,623	10,648	10,673	10,698	10,723	10,749	10,774	10,800	10,826	10,853
983	10,880	10,907	10,934	10,960	10,986	11,012	11,038	11,065	11,091	11,117
984	11,143	11,169	11,196	11,222	11,249	11,276	11,303	11,330	11,357	11,384
985	11,410	11,437	11,464	11,491	11,518	11,545	11,572	11,599	11,625	11,652
986	11,679	11,707	11,734	11,761	11,789	11,816	11,842	11,868	11,894	11,921
987	11,948	11,975	12,002	12,029	12,056	12,082	12,109	12,136	12,163	12,189
988	12,215	12,241	12,267	12,294	12,319	12,346	12,372	12,397	12,423	12,450
989	12,476	12,503	12,530	12,557	12,585	12,612	12,639	12,667	12,694	12,722
990	12,750	12,777	12,805	12,832	12,858	12,884	12,910	12,936	12,962	12,989
991	13,016	13,043	13,071	13,100	13,132	13,164	13,197	13,229	13,263	13,296
992	13,328	13,360	13,393	13,425	13,457	13,490	13,523	13,554	13,585	13,617
993	13,648	13,683	13,714	13,745	13,775	13,806	13,838	13,867	13,896	13,924
994	13,952	13,980	14,008	14,036	14,063	14,090	14,117	14,144	14,171	14,198
995	14,225	14,251	14,277	14,304	14,331	14,358	14,385	14,412	14,439	14,466
996	14,493	14,520	14,547	14,574	14,601	14,629	14,657	14,685	14,713	14,741
997	14,769	14,796	14,823	14,850	14,877	14,903	14,930	14,957	14,983	15,010
998	15,036	15,063	15,090	15,117	15,144	15,171	15,200	15,229	15,259	15,291
999	15,325	15,356	15,388	15,421	15,452	15,485	15,519	15,555	15,591	15,628
1,000	15,665	15,702	15,739	15,778	15,820	15,863	15,907	15,949	15,991	16,032
1,001	16,077	16,124	16,171	16,217	16,266	16,314	16,362	16,410	16,459	16,508
1,002	16,557	16,606	16,655	16,702	16,749	16,796	16,842	16,888	16,933	16,977
1,003	17,020	17,064	17,107	17,148	17,188	17,228	17,266	17,304	17,340	17,377
1,004	17,413	17,448	17,483	17,518	17,553	17,588	17,624	17,659	17,695	17,732
1,005	17,768	17,805	17,841	17,878	17,916	17,951	17,986	18,020	18,054	18,088
1,006	18,122	18,157	18,194	18,233	18,273	18,313	18,353	18,393	18,435	18,479
1,007	18,523	18,563	18,604	18,643	18,683	18,721	18,760	18,798	18,837	18,878
1,008	18,918	18,958	18,997	19,036	19,075	19,115	19,155	19,199	19,243	19,287

Appendix B (continued)

Lake Buchanan

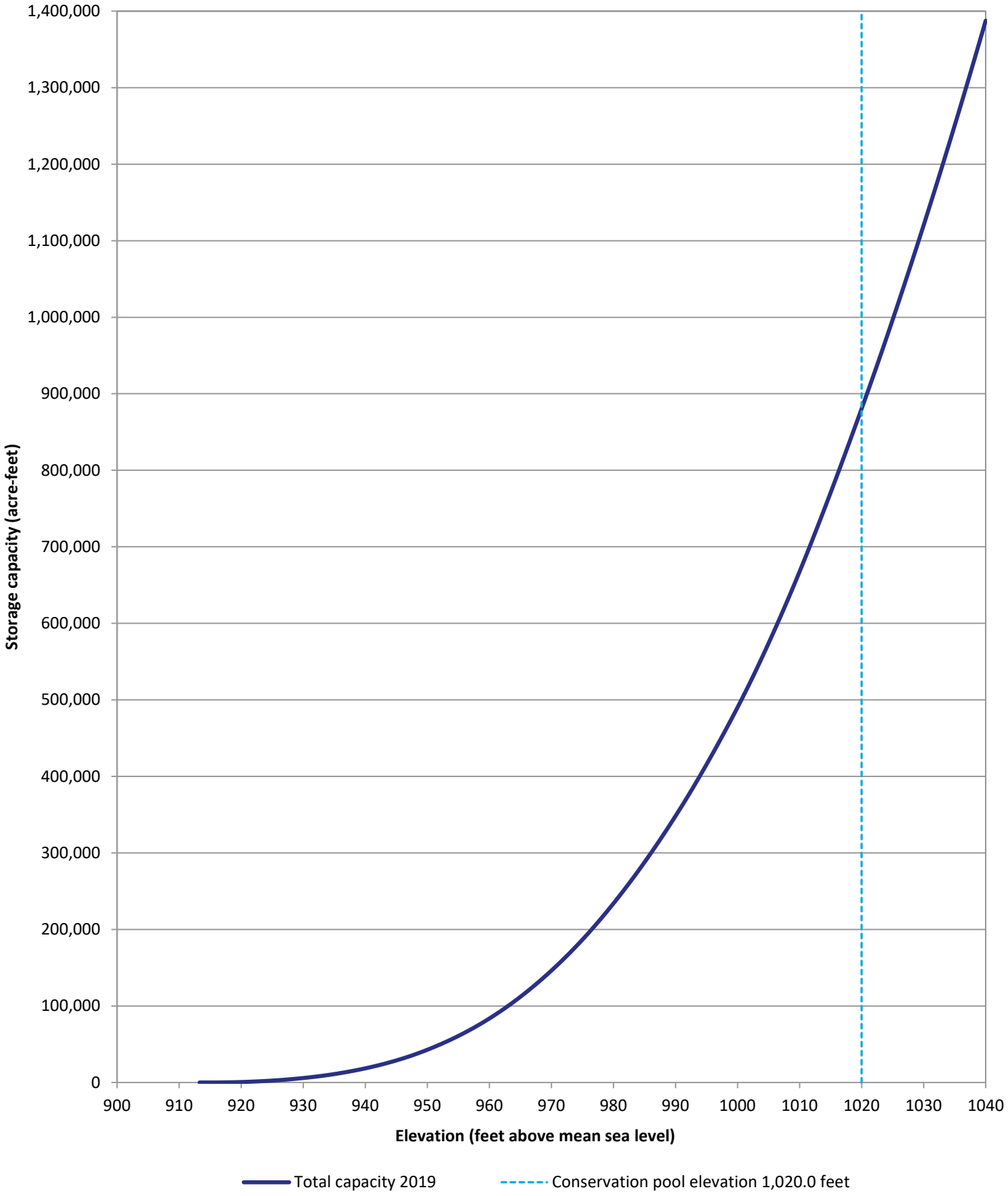
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2019 Survey

AREA IN ACRES — Conservation pool elevation 1,020.0 feet above mean sea level

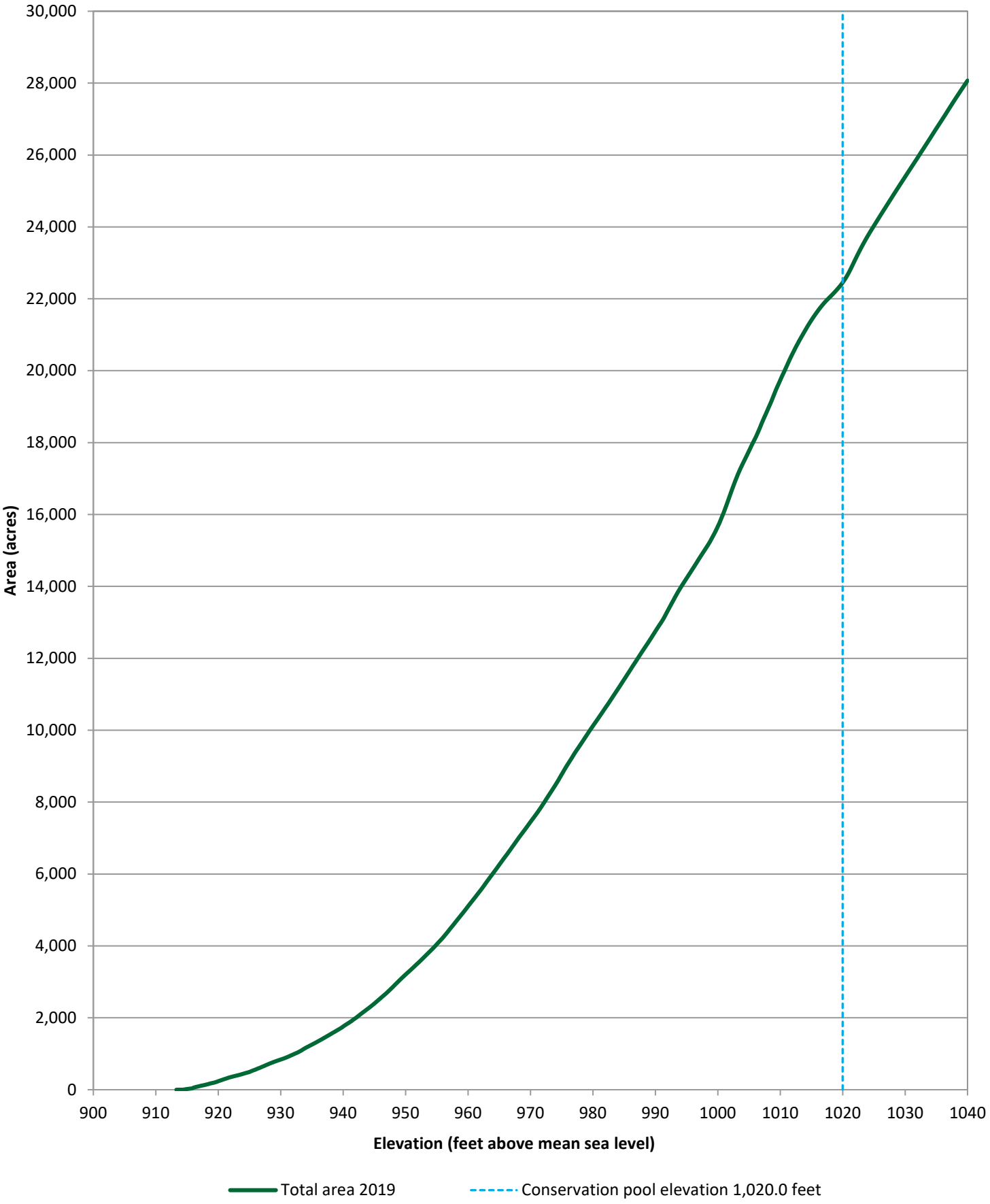
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1,009	19,330	19,373	19,417	19,461	19,502	19,541	19,579	19,617	19,655	19,694
1,010	19,734	19,773	19,812	19,851	19,888	19,924	19,961	19,998	20,036	20,075
1,011	20,113	20,151	20,189	20,228	20,267	20,305	20,342	20,377	20,413	20,449
1,012	20,483	20,518	20,552	20,587	20,622	20,656	20,688	20,720	20,752	20,785
1,013	20,819	20,850	20,880	20,911	20,941	20,972	21,002	21,033	21,062	21,092
1,014	21,123	21,152	21,182	21,212	21,242	21,270	21,298	21,325	21,353	21,380
1,015	21,407	21,433	21,459	21,485	21,511	21,536	21,560	21,585	21,609	21,633
1,016	21,657	21,681	21,704	21,727	21,750	21,772	21,794	21,815	21,835	21,856
1,017	21,876	21,896	21,915	21,934	21,952	21,970	21,987	22,005	22,022	22,040
1,018	22,057	22,074	22,092	22,109	22,127	22,145	22,163	22,181	22,200	22,219
1,019	22,239	22,258	22,278	22,298	22,319	22,339	22,360	22,382	22,405	22,428
1,020	22,452	22,476	22,501	22,527	22,554	22,581	22,610	22,639	22,670	22,701
1,021	22,734	22,767	22,801	22,836	22,871	22,907	22,943	22,980	23,016	23,051
1,022	23,087	23,122	23,158	23,192	23,227	23,262	23,296	23,331	23,364	23,398
1,023	23,431	23,464	23,496	23,528	23,559	23,590	23,621	23,652	23,683	23,713
1,024	23,743	23,772	23,802	23,831	23,859	23,887	23,916	23,944	23,972	24,000
1,025	24,028	24,056	24,084	24,112	24,140	24,168	24,195	24,223	24,251	24,279
1,026	24,307	24,334	24,362	24,389	24,417	24,444	24,472	24,499	24,526	24,554
1,027	24,581	24,608	24,636	24,663	24,691	24,718	24,745	24,772	24,800	24,827
1,028	24,855	24,882	24,909	24,937	24,964	24,991	25,018	25,045	25,072	25,098
1,029	25,125	25,152	25,179	25,206	25,232	25,259	25,286	25,313	25,339	25,366
1,030	25,393	25,420	25,447	25,474	25,500	25,527	25,554	25,580	25,607	25,633
1,031	25,660	25,686	25,713	25,739	25,765	25,792	25,818	25,845	25,871	25,898
1,032	25,925	25,952	25,979	26,007	26,034	26,061	26,088	26,114	26,141	26,168
1,033	26,195	26,221	26,248	26,275	26,302	26,329	26,356	26,383	26,410	26,437
1,034	26,464	26,491	26,518	26,546	26,574	26,601	26,629	26,656	26,683	26,710
1,035	26,737	26,763	26,790	26,817	26,843	26,870	26,897	26,924	26,950	26,977
1,036	27,004	27,030	27,057	27,084	27,111	27,139	27,166	27,194	27,222	27,250
1,037	27,277	27,305	27,332	27,359	27,387	27,414	27,441	27,468	27,495	27,522
1,038	27,549	27,575	27,602	27,628	27,654	27,681	27,707	27,733	27,759	27,785
1,039	27,812	27,837	27,863	27,889	27,915	27,941	27,967	27,992	28,018	28,044
1,040	28,070									



Lake Buchanan
July 2019 Survey
Prepared by: TWDB

Appendix C: Capacity curve



Lake Buchanan
July 2019 Survey
Prepared by: TWDB

Appendix D: Area curve

Appendix E

Lake Buchanan

Historical range lines

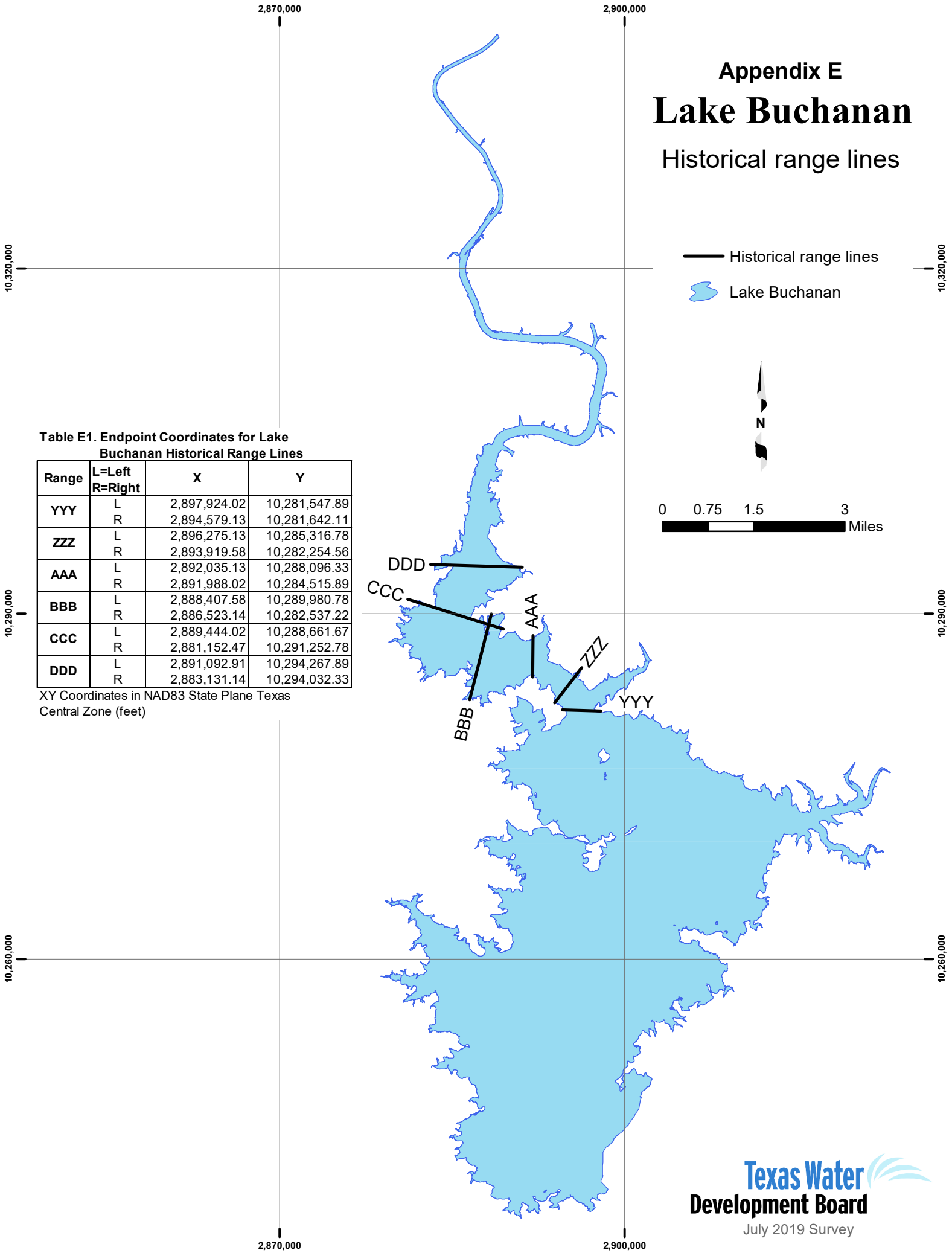


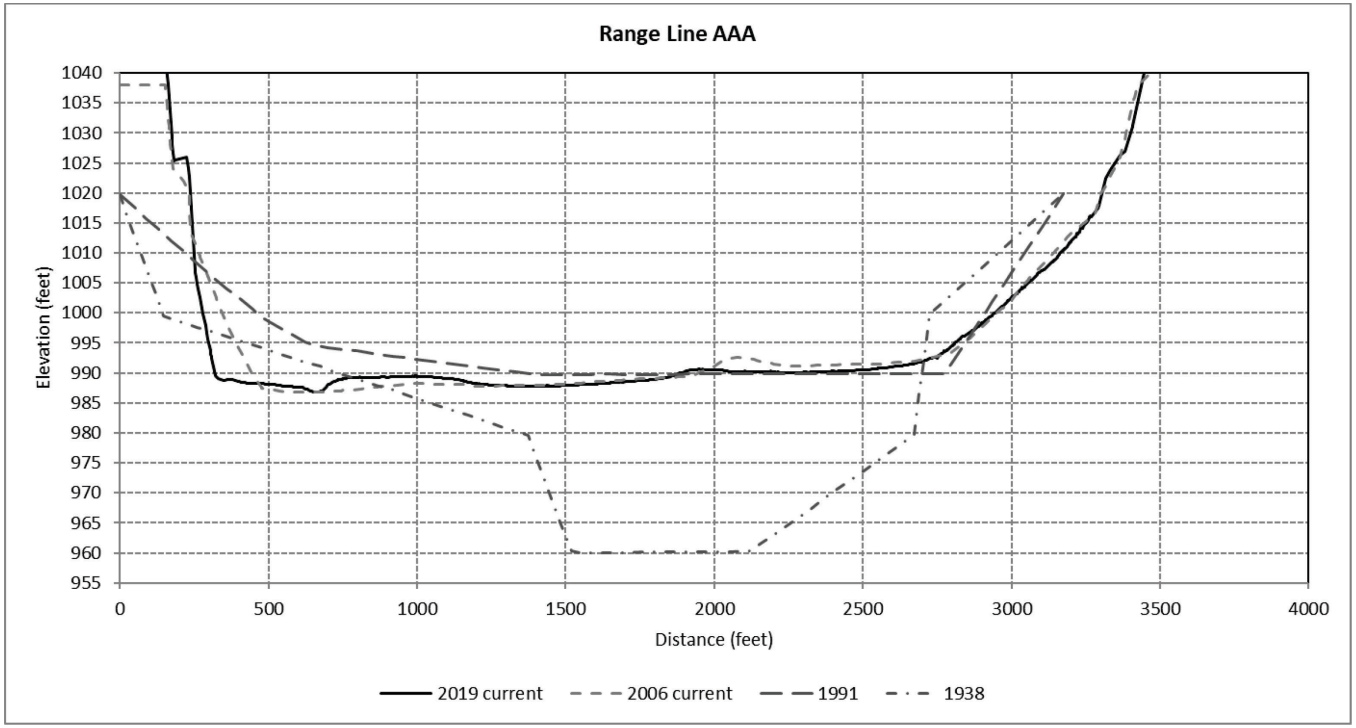
Table E1. Endpoint Coordinates for Lake Buchanan Historical Range Lines

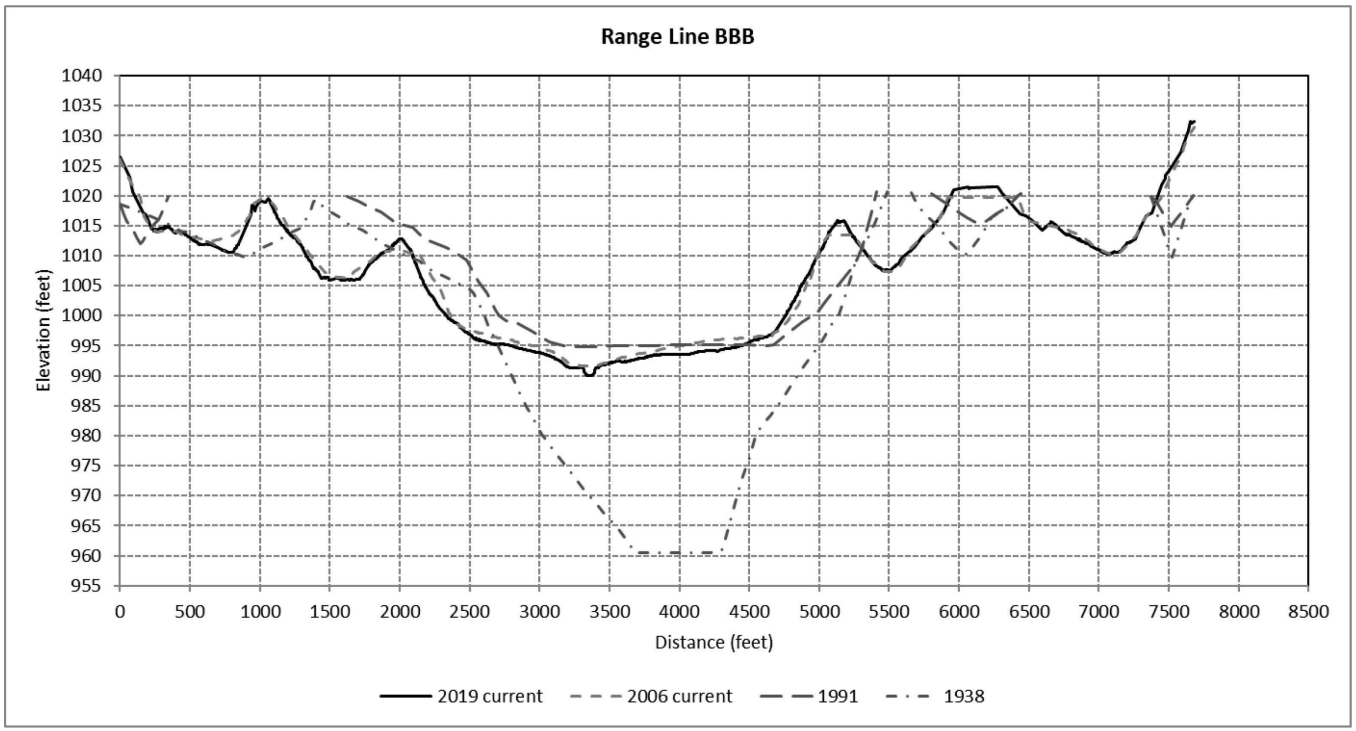
Range	L=Left R=Right	X	Y
YYY	L	2,897,924.02	10,281,547.89
	R	2,894,579.13	10,281,642.11
ZZZ	L	2,896,275.13	10,285,316.78
	R	2,893,919.58	10,282,254.56
AAA	L	2,892,035.13	10,288,096.33
	R	2,891,988.02	10,284,515.89
BBB	L	2,888,407.58	10,289,980.78
	R	2,886,523.14	10,282,537.22
CCC	L	2,889,444.02	10,288,661.67
	R	2,881,152.47	10,291,252.78
DDD	L	2,891,092.91	10,294,267.89
	R	2,883,131.14	10,294,032.33

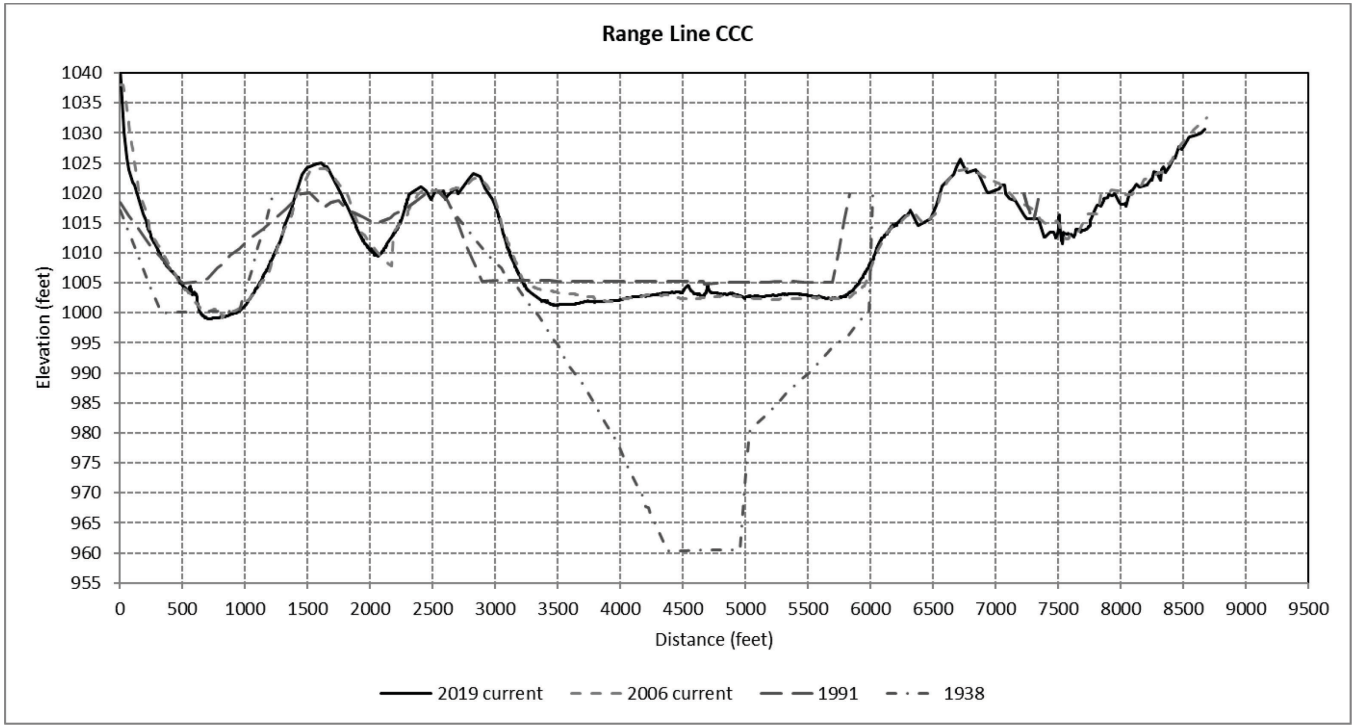
XY Coordinates in NAD83 State Plane Texas Central Zone (feet)

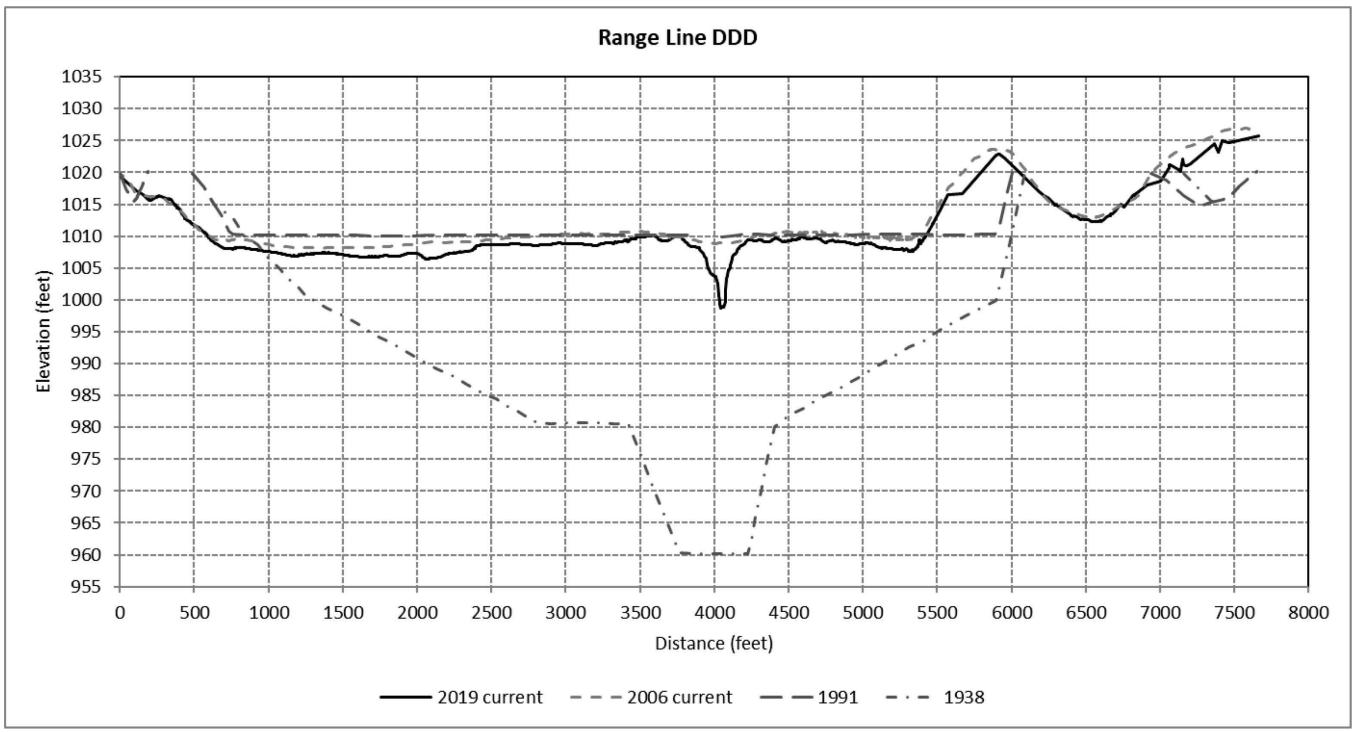
Texas Water Development Board

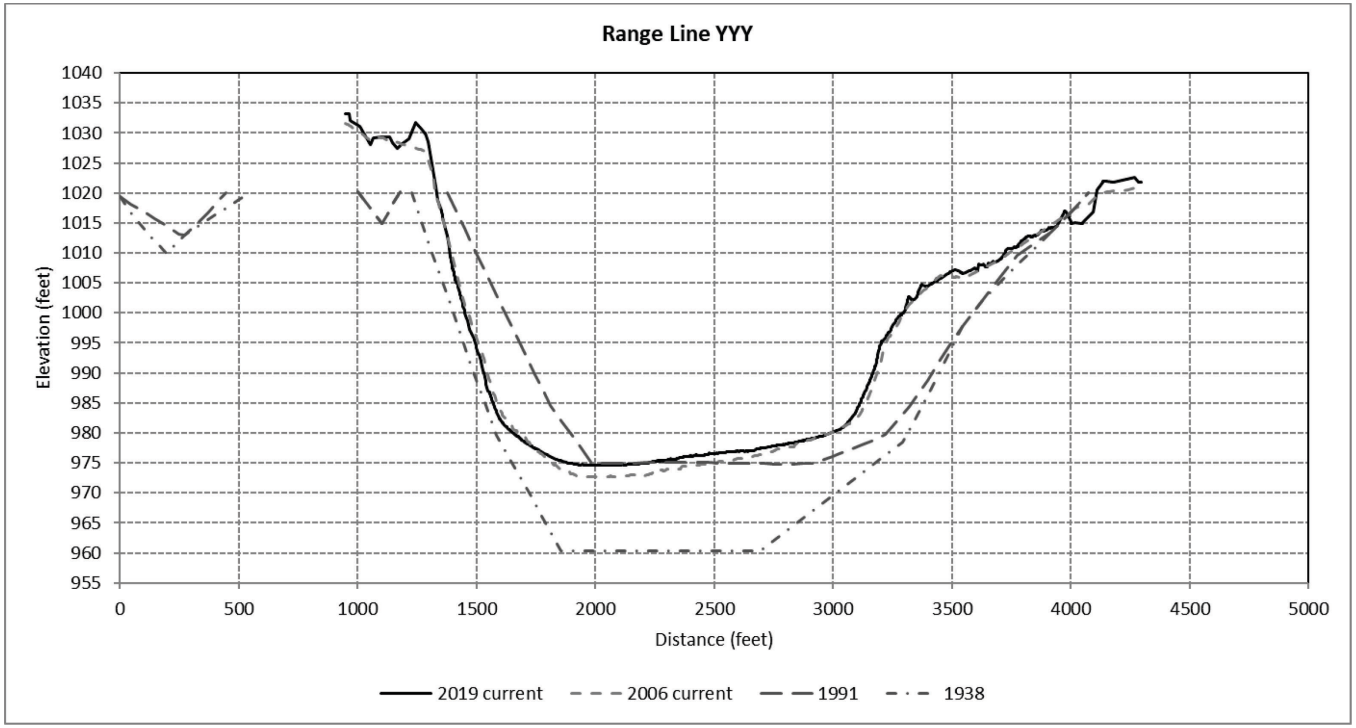
July 2019 Survey

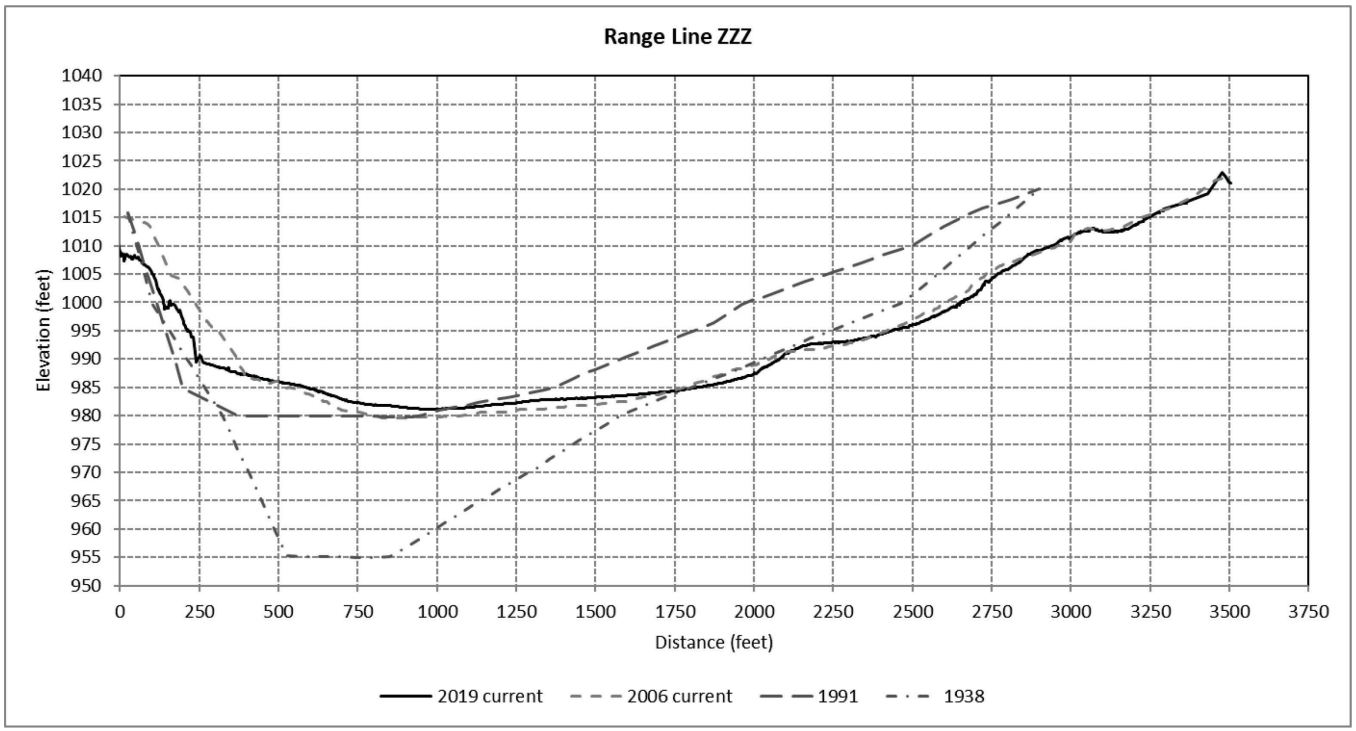

Range Line AAA
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (feet)
2019 current
2006 current
1991
1938


Range Line BBB
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
Distance (feet)
2019 current
2006 current
1991
1938


Range Line CCC
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
Distance (feet)
2019 current
2006 current
1991
1938


Range Line DDD
Elevation (feet)
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Distance (feet)
2019 current
2006 current
1991
1938


Range Line YYY
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance (feet)
2019 current
2006 current
1991
1938


Range Line ZZZ
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
950
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
Distance (feet)
2019 current
2006 current
1991
1938

Appendix F

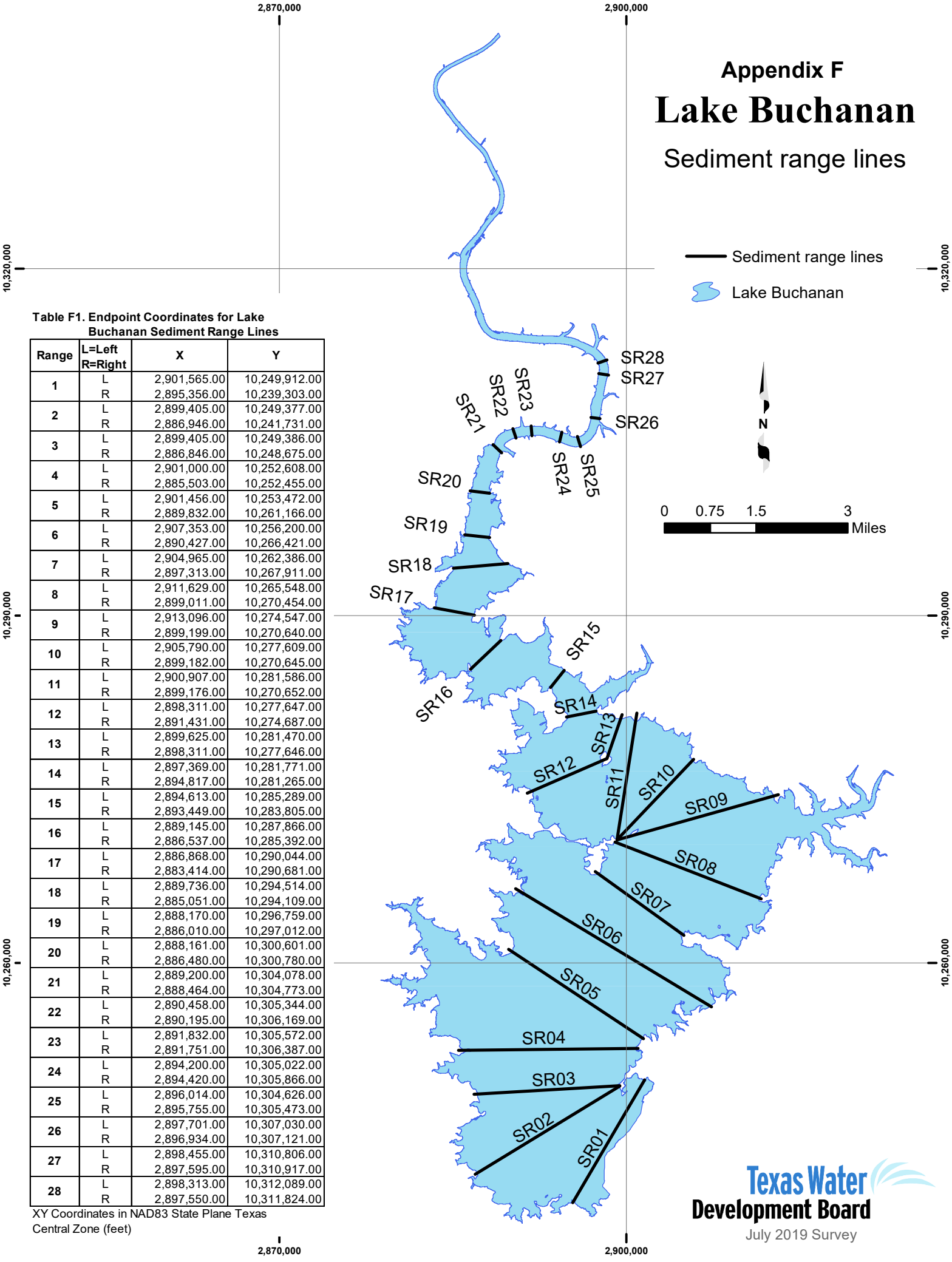
Lake Buchanan

Sediment range lines

Table F1. Endpoint Coordinates for Lake Buchanan Sediment Range Lines

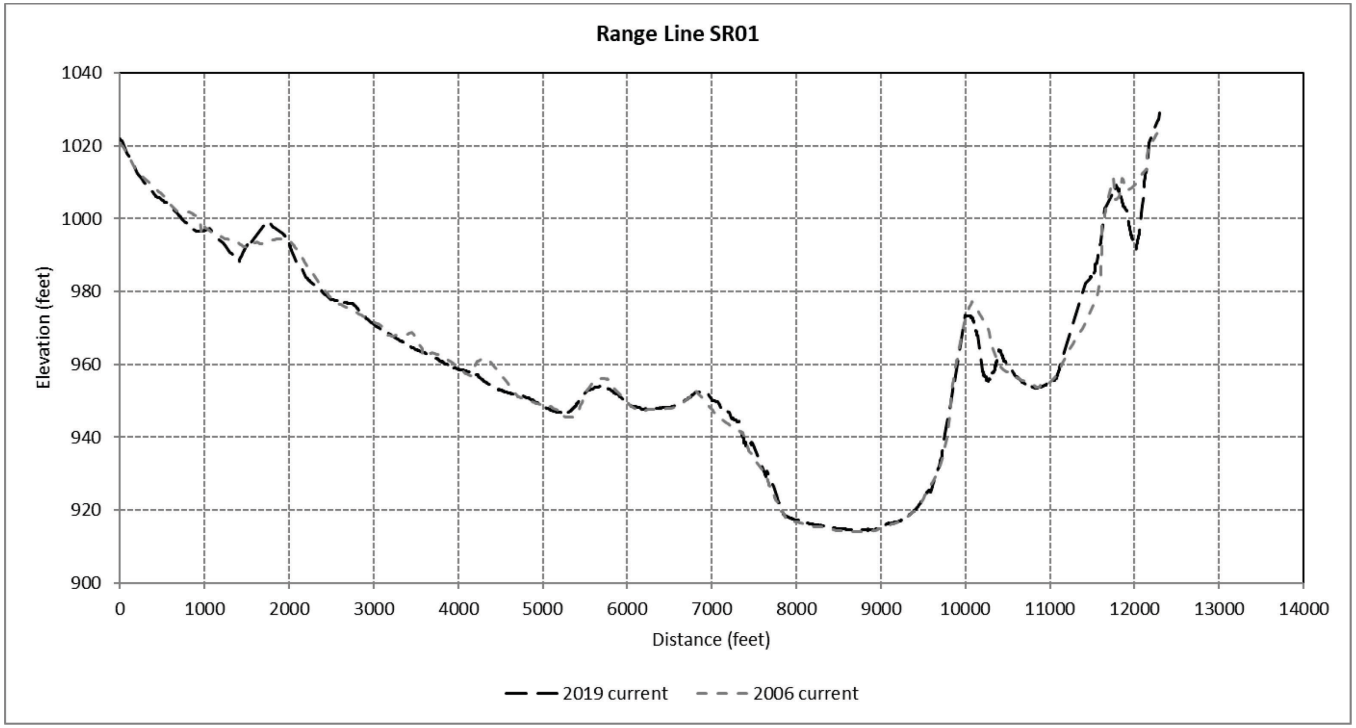
Range	L=Left R=Right	X	Y
1	L	2,901,565.00	10,249,912.00
	R	2,895,356.00	10,239,303.00
2	L	2,899,405.00	10,249,377.00
	R	2,886,946.00	10,241,731.00
3	L	2,899,405.00	10,249,386.00
	R	2,886,846.00	10,248,675.00
4	L	2,901,000.00	10,252,608.00
	R	2,885,503.00	10,252,455.00
5	L	2,901,456.00	10,253,472.00
	R	2,889,832.00	10,261,166.00
6	L	2,907,353.00	10,256,200.00
	R	2,890,427.00	10,266,421.00
7	L	2,904,965.00	10,262,386.00
	R	2,897,313.00	10,267,911.00
8	L	2,911,629.00	10,265,548.00
	R	2,899,011.00	10,270,454.00
9	L	2,913,096.00	10,274,547.00
	R	2,899,199.00	10,270,640.00
10	L	2,905,790.00	10,277,609.00
	R	2,899,182.00	10,270,645.00
11	L	2,900,907.00	10,281,586.00
	R	2,899,176.00	10,270,652.00
12	L	2,898,311.00	10,277,647.00
	R	2,891,431.00	10,274,687.00
13	L	2,899,625.00	10,281,470.00
	R	2,898,311.00	10,277,646.00
14	L	2,897,369.00	10,281,771.00
	R	2,894,817.00	10,281,265.00
15	L	2,894,613.00	10,285,289.00
	R	2,893,449.00	10,283,805.00
16	L	2,889,145.00	10,287,866.00
	R	2,886,537.00	10,285,392.00
17	L	2,886,868.00	10,290,044.00
	R	2,883,414.00	10,290,681.00
18	L	2,889,736.00	10,294,514.00
	R	2,885,051.00	10,294,109.00
19	L	2,888,170.00	10,296,759.00
	R	2,886,010.00	10,297,012.00
20	L	2,888,161.00	10,300,601.00
	R	2,886,480.00	10,300,780.00
21	L	2,889,200.00	10,304,078.00
	R	2,888,464.00	10,304,773.00
22	L	2,890,458.00	10,305,344.00
	R	2,890,195.00	10,306,169.00
23	L	2,891,832.00	10,305,572.00
	R	2,891,751.00	10,306,387.00
24	L	2,894,200.00	10,305,022.00
	R	2,894,420.00	10,305,866.00
25	L	2,896,014.00	10,304,626.00
	R	2,895,755.00	10,305,473.00
26	L	2,897,701.00	10,307,030.00
	R	2,896,934.00	10,307,121.00
27	L	2,898,455.00	10,310,806.00
	R	2,897,595.00	10,310,917.00
28	L	2,898,313.00	10,312,089.00
	R	2,897,550.00	10,311,824.00

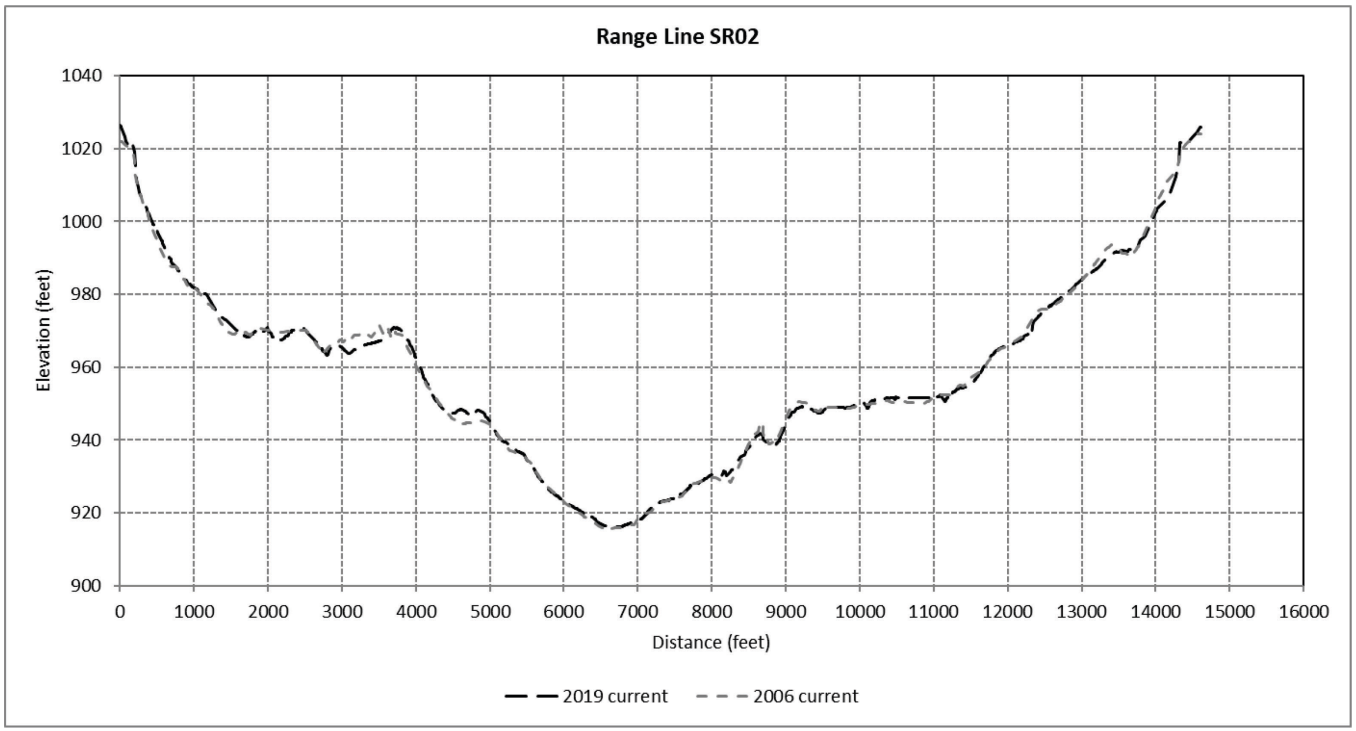
XY Coordinates in NAD83 State Plane Texas Central Zone (feet)

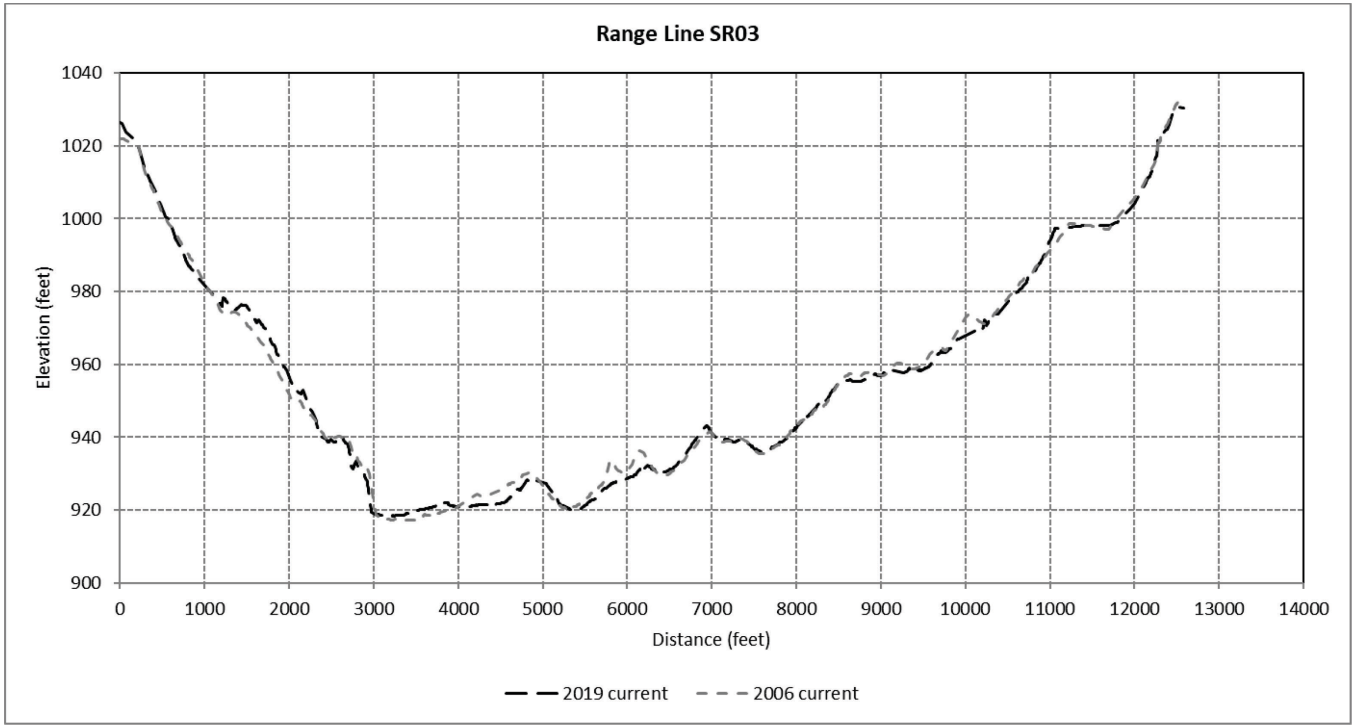


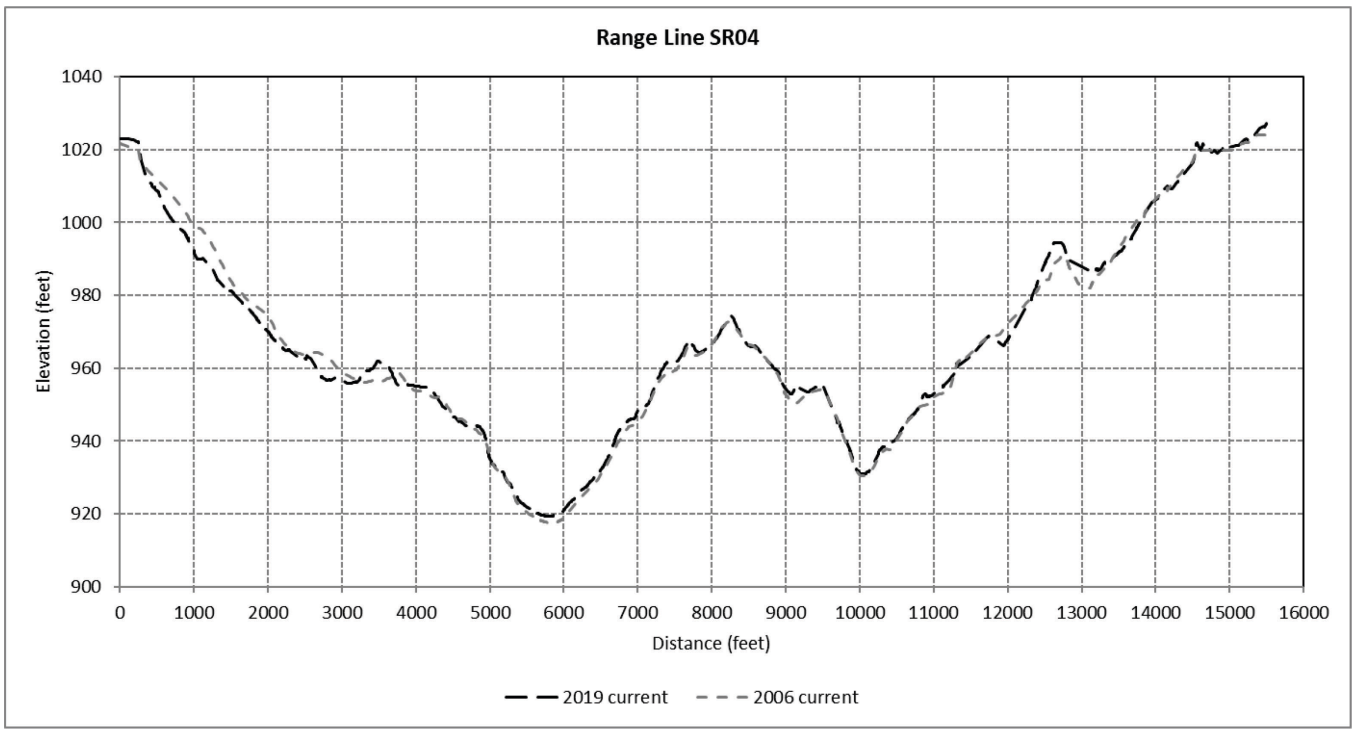
Texas Water Development Board

July 2019 Survey


Range Line SR01
Elevation (feet)
1040
1020
1000
980
960
940
920
900
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Distance (feet)
2019 current
2006 current


Range Line SR02
Elevation (feet)
1040
1020
1000
980
960
940
920
900
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
Distance (feet)
2019 current
2006 current


Range Line SR03
Elevation (feet)
1040
1020
1000
980
960
940
920
900
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Distance (feet)
2019 current
2006 current


Range Line SR04
Elevation (feet)
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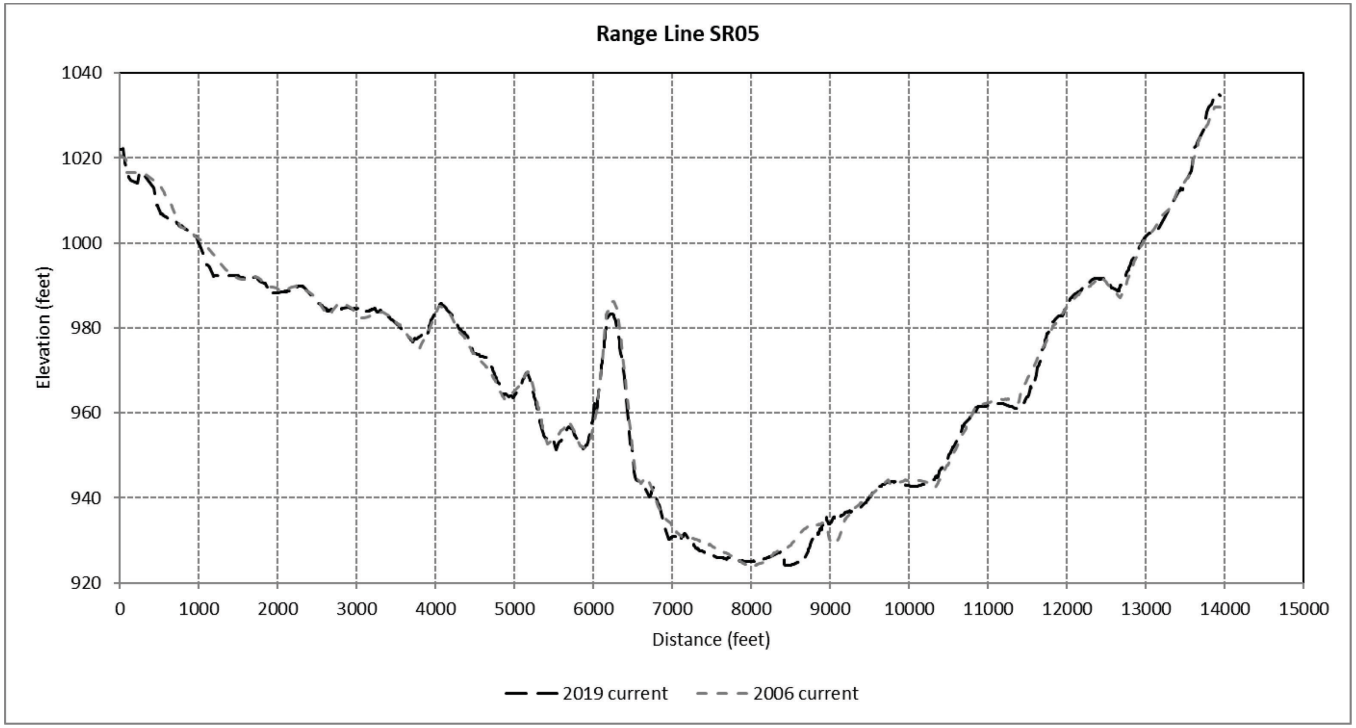
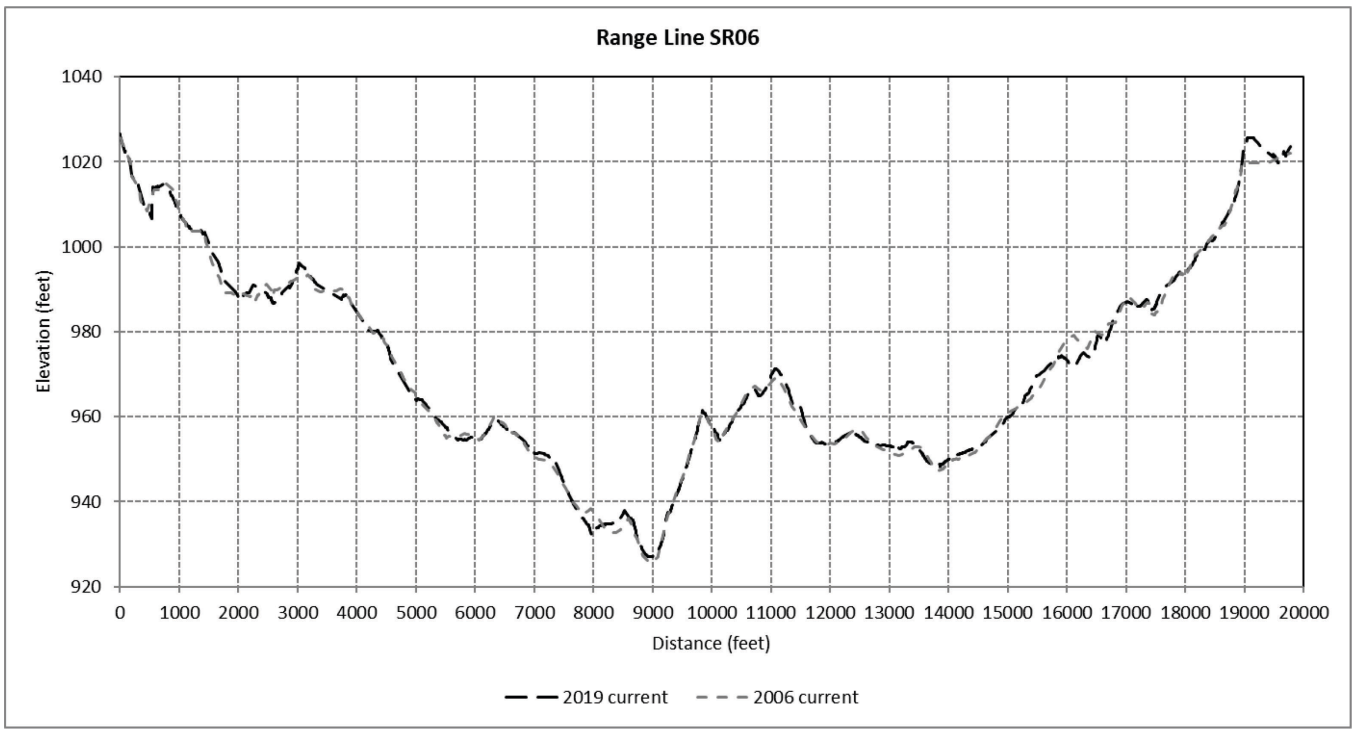
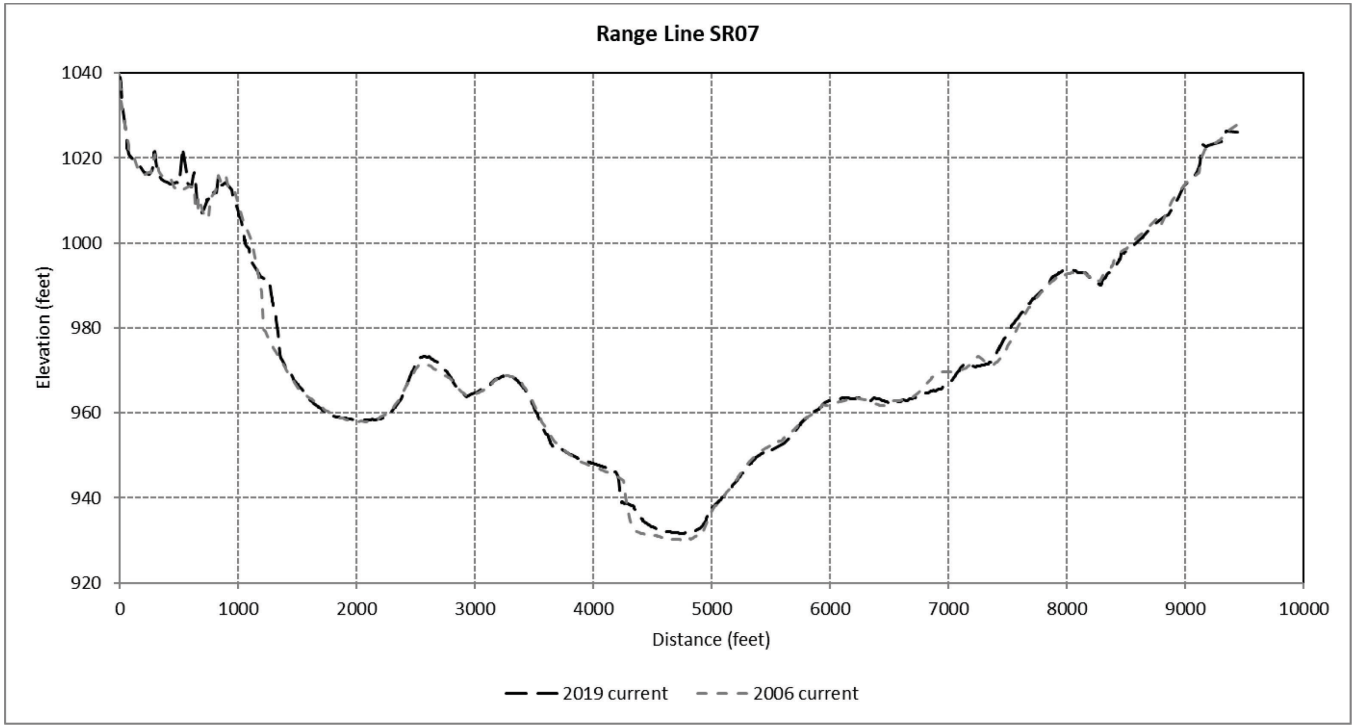
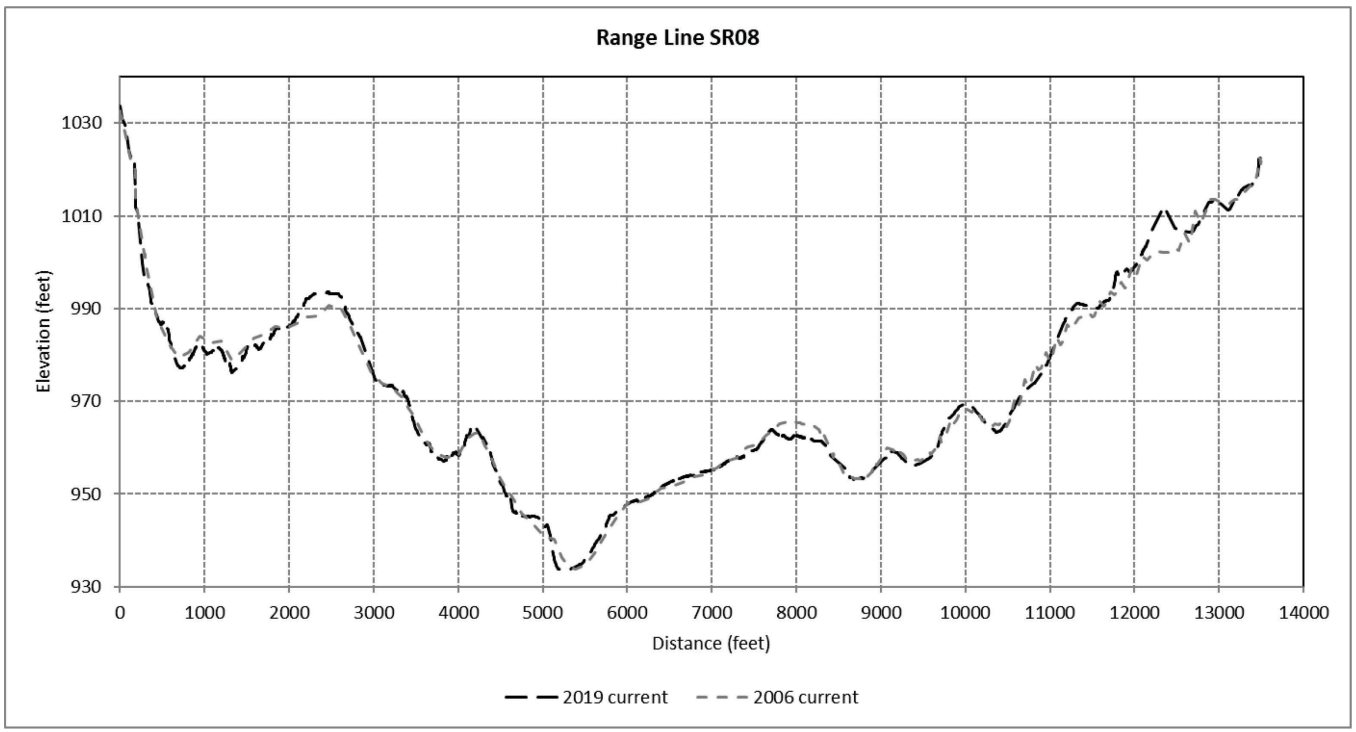
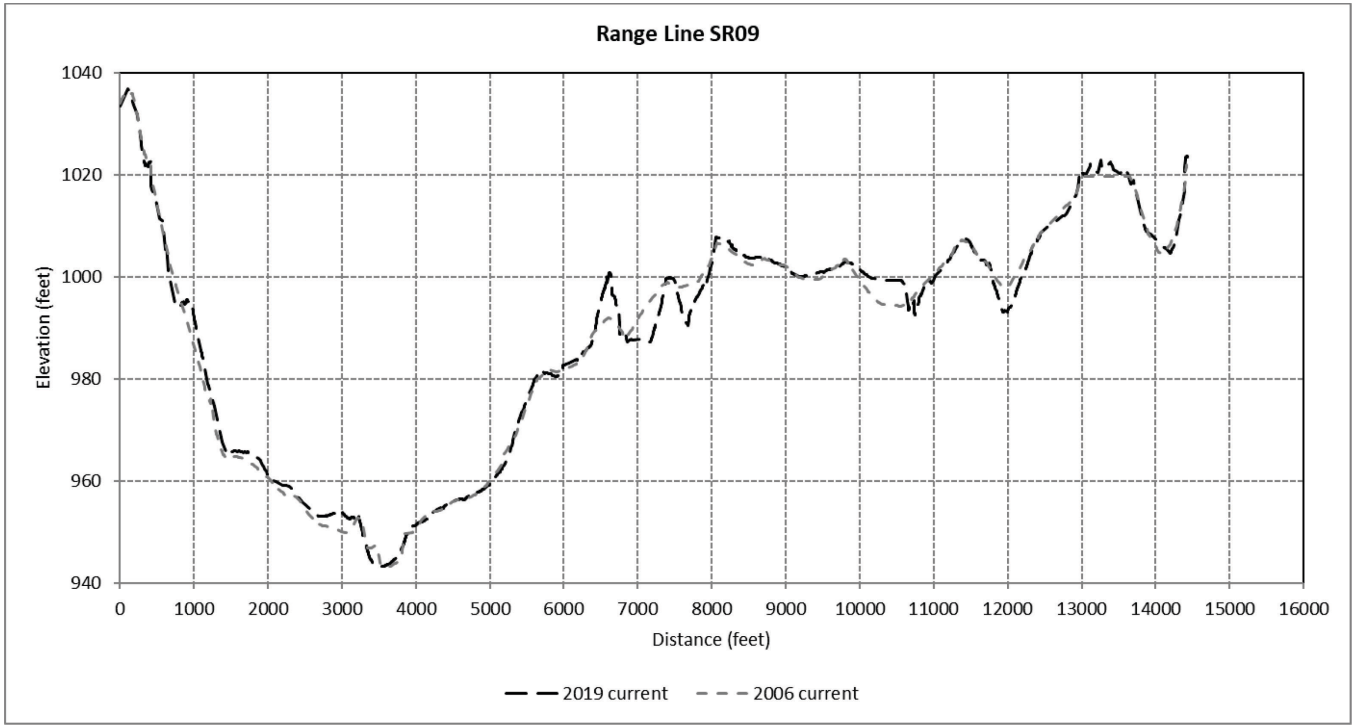
1020
1000
980
960
940
920
900
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
Distance (feet)
2019 current
2006 current

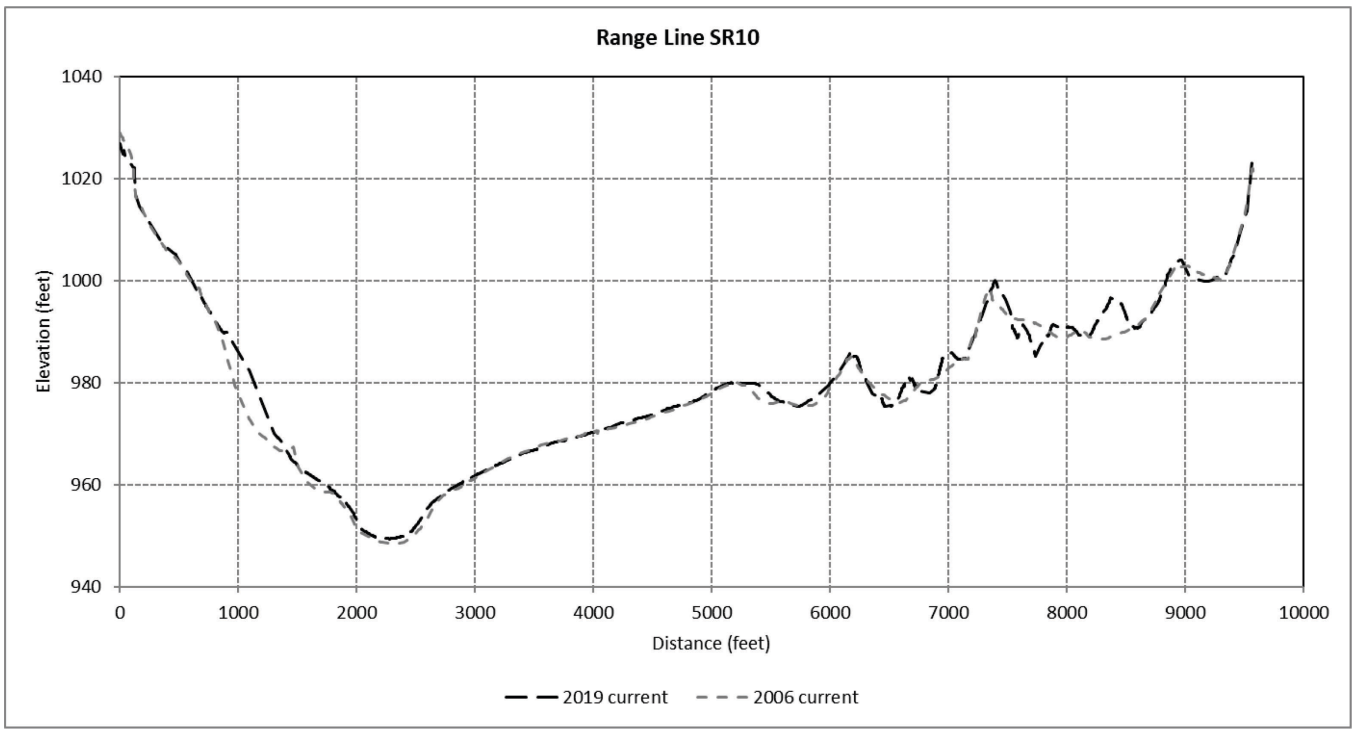

Range Line SR05
1040
1020
1000
980
960
940
920
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
Distance (feet)
2019 current
2006 current

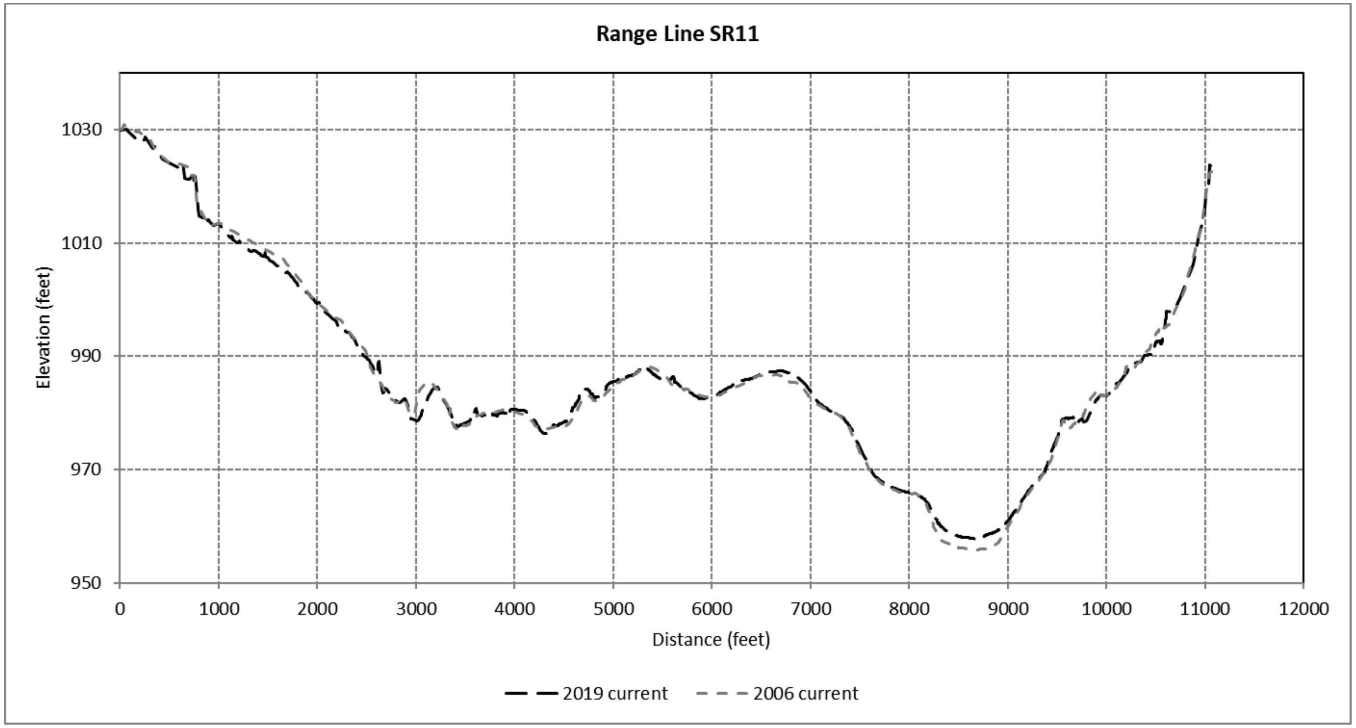

Range Line SR06
1040
1020
1000
980
960
940
920
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
Distance (feet)
2019 current
2006 current

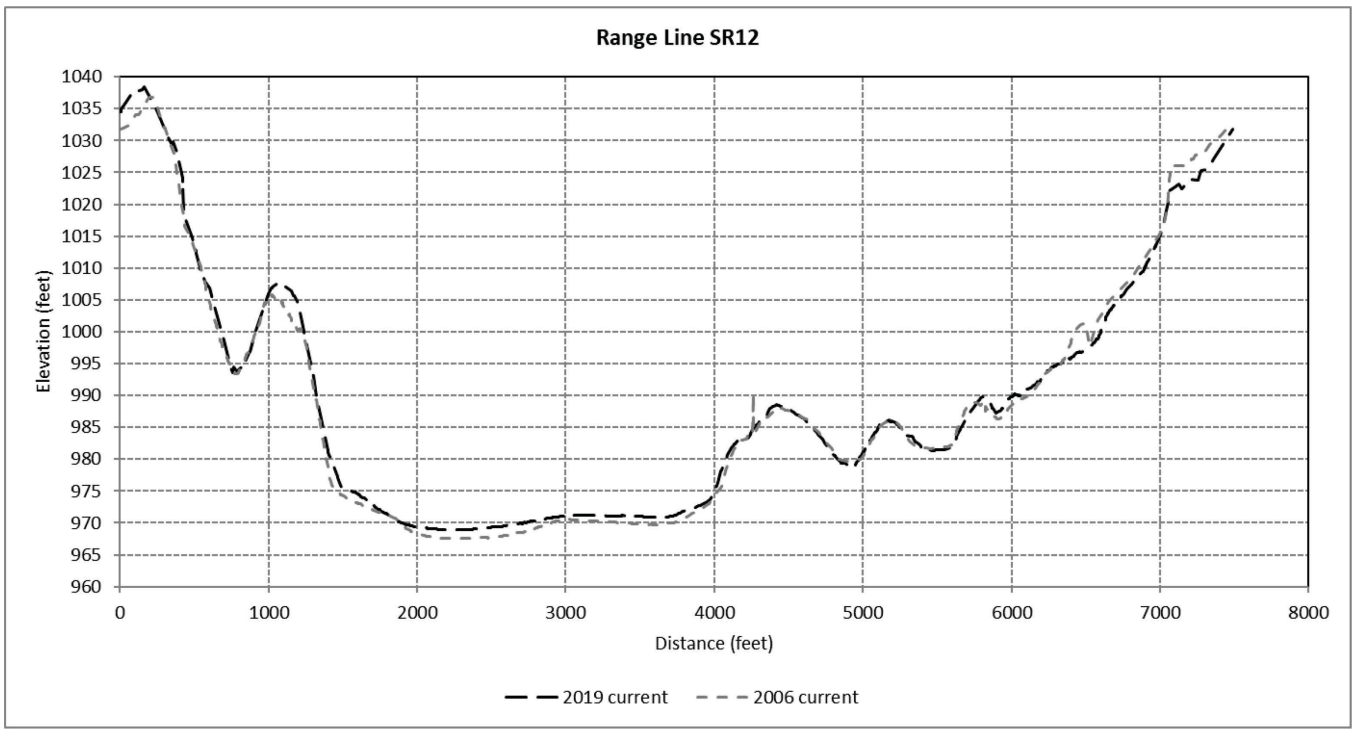

Range Line SR07
1040
1020
1000
980
960
940
920
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (feet)
2019 current
2006 current

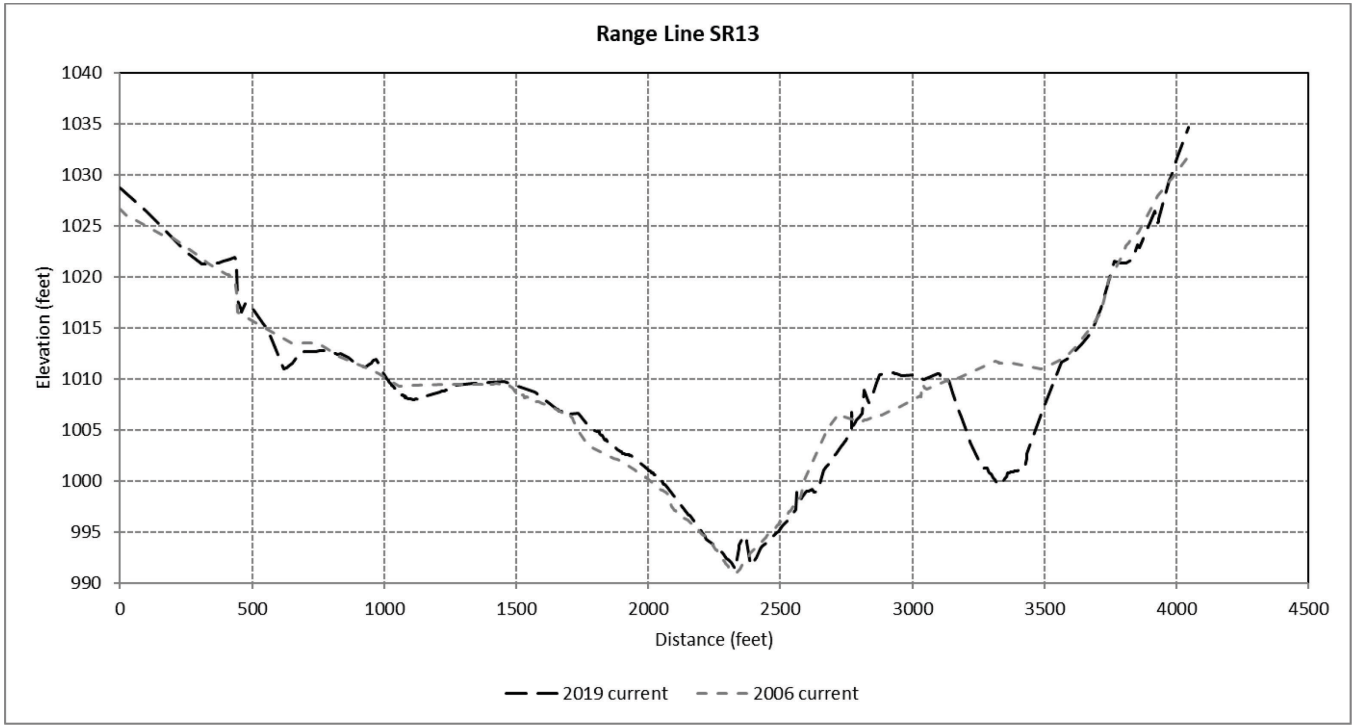

Range Line SR08
1030
1010
990
970
950
930
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Distance (feet)
2019 current
2006 current

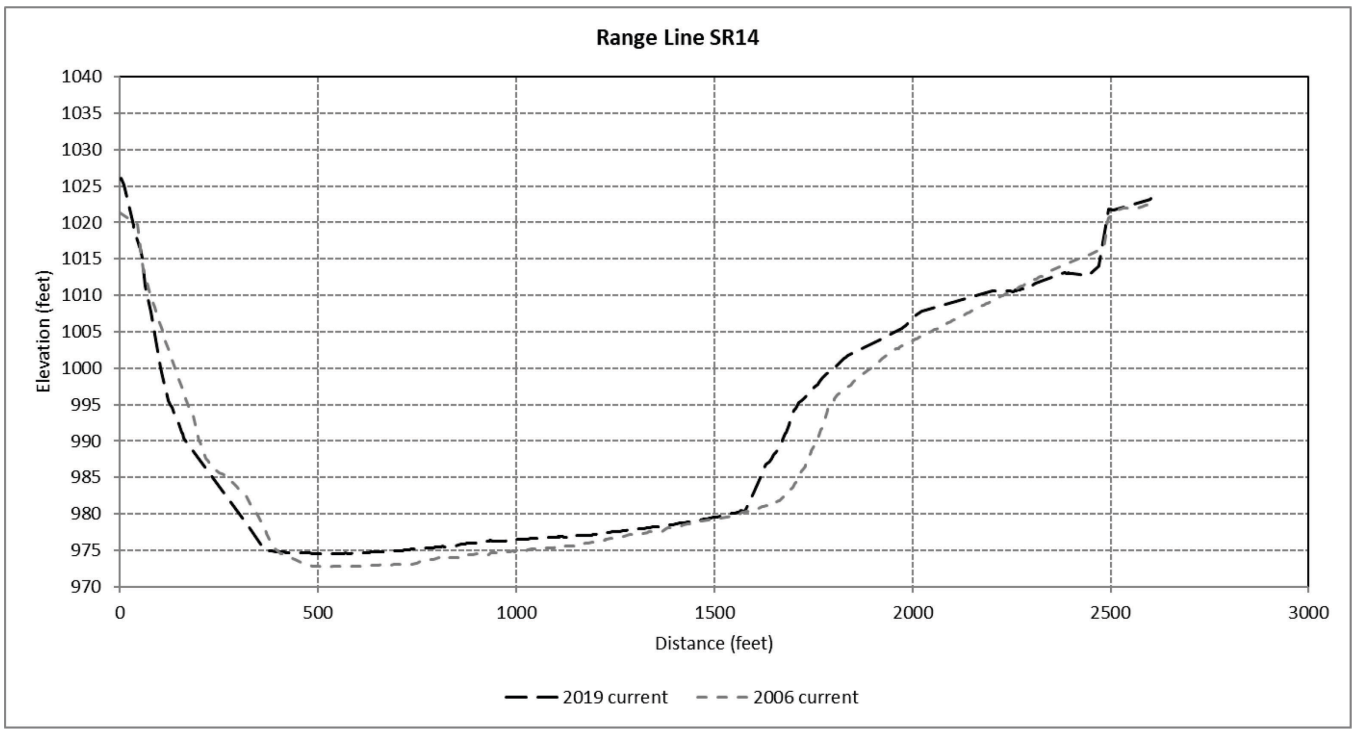

Range Line SR09
1040
1020
1000
980
960
940
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
Distance (feet)
2019 current
2006 current

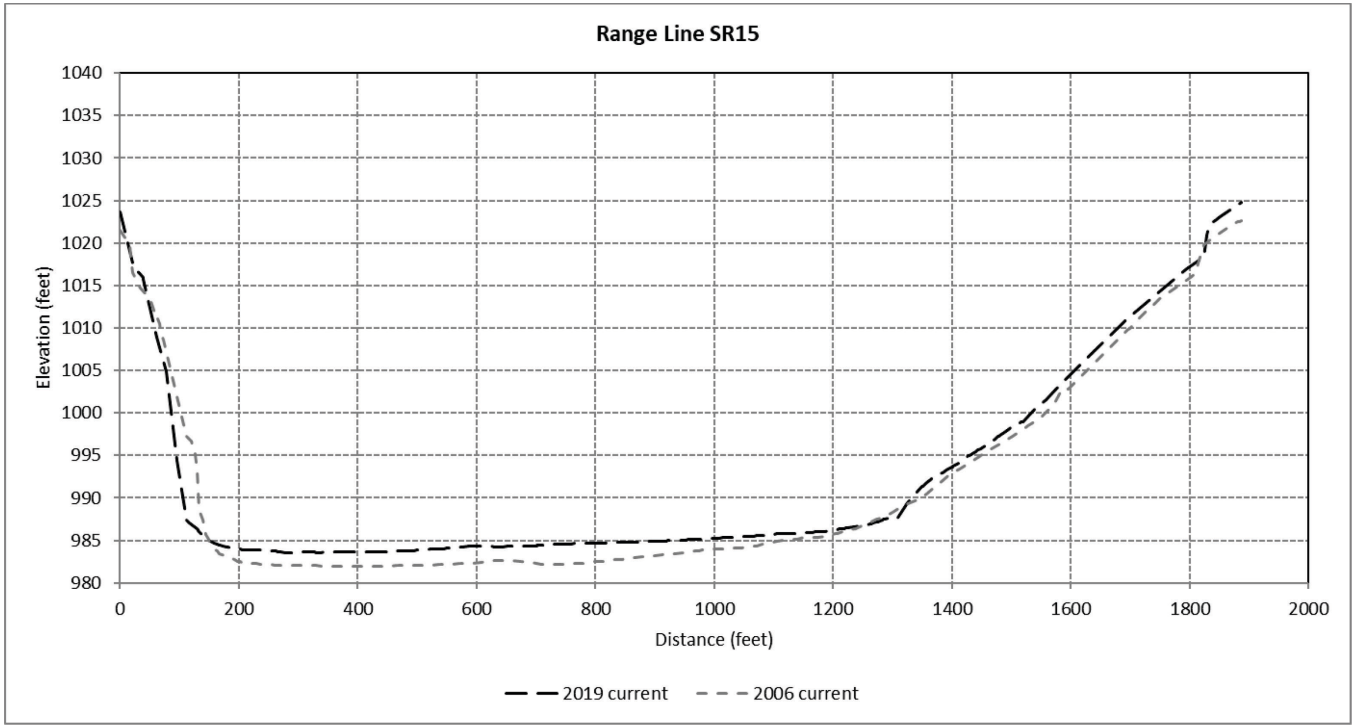

Range Line SR10
1040
1020
1000
980
960
940
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (feet)
2019 current
2006 current

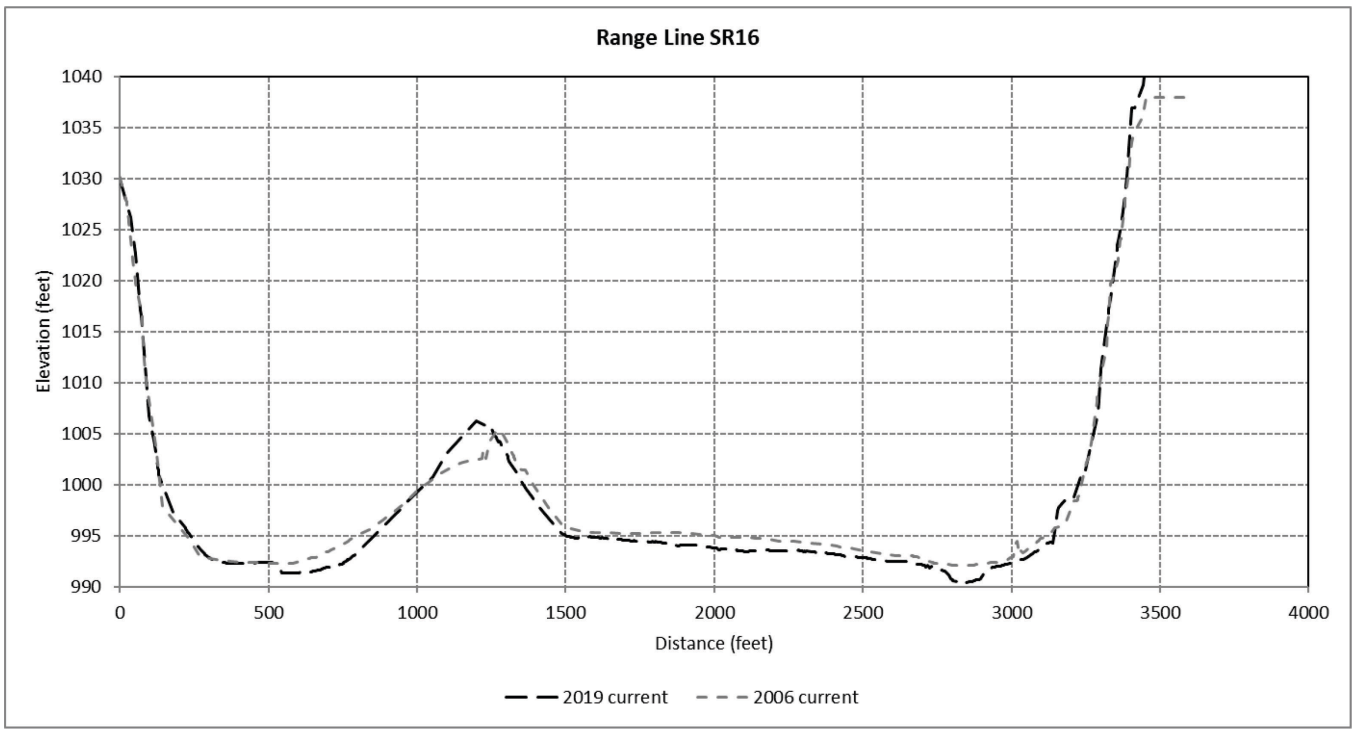

Range Line SR11
Elevation (feet)
1030
1010
990
970
950
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
Distance (feet)
2019 current
2006 current

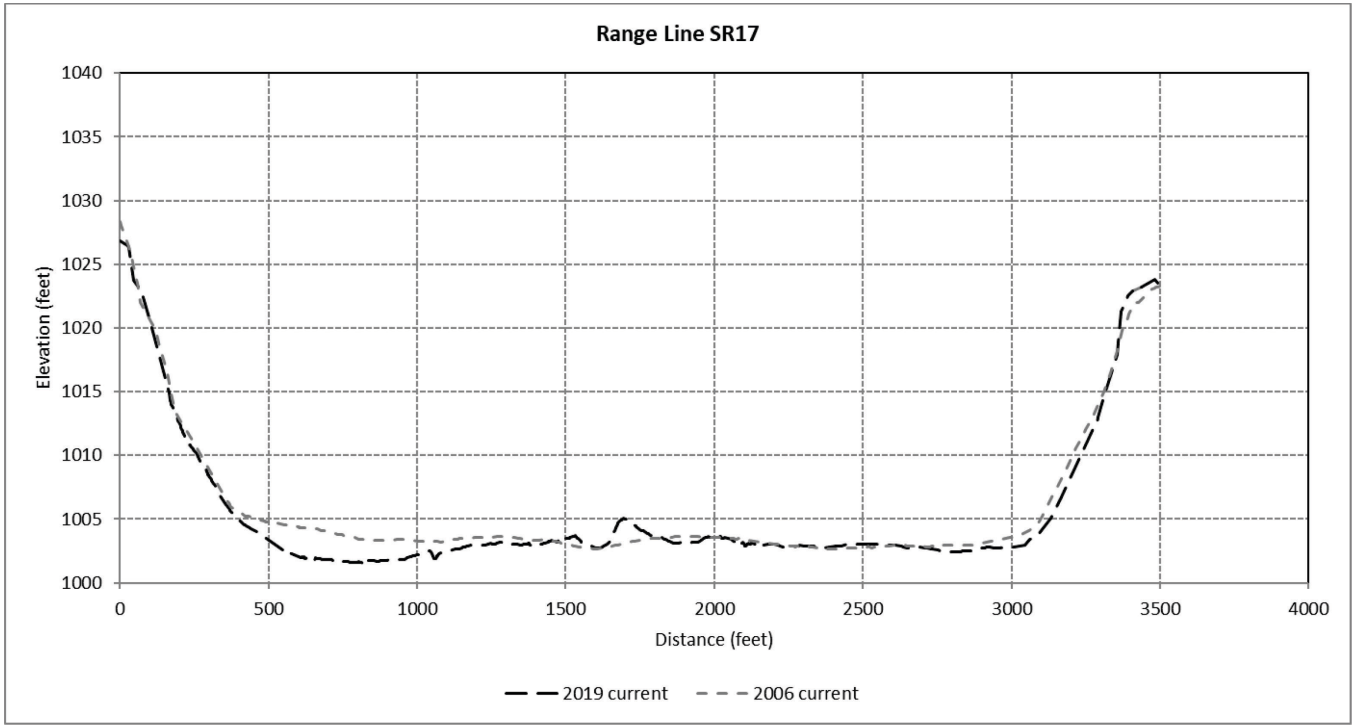

Range Line SR12
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance (feet)
2019 current
2006 current

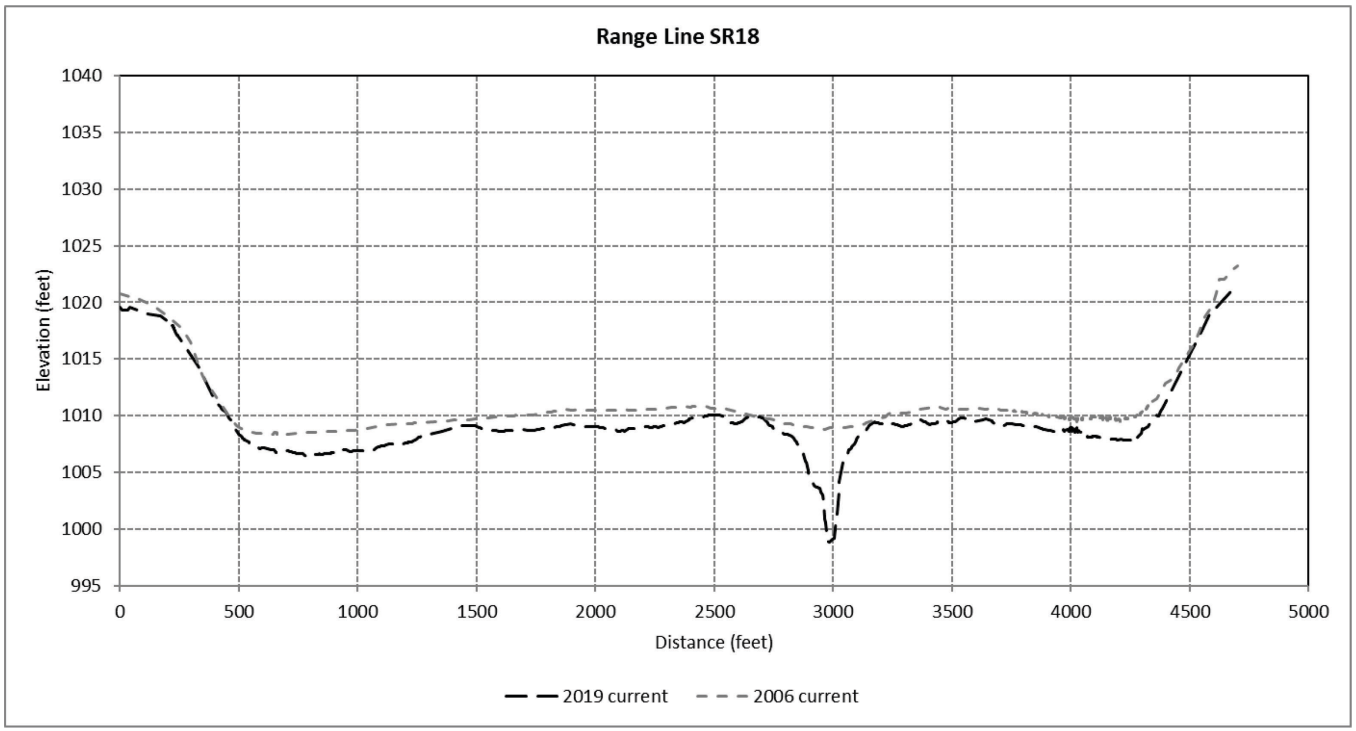

Range Line SR13
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Distance (feet)
2019 current
2006 current

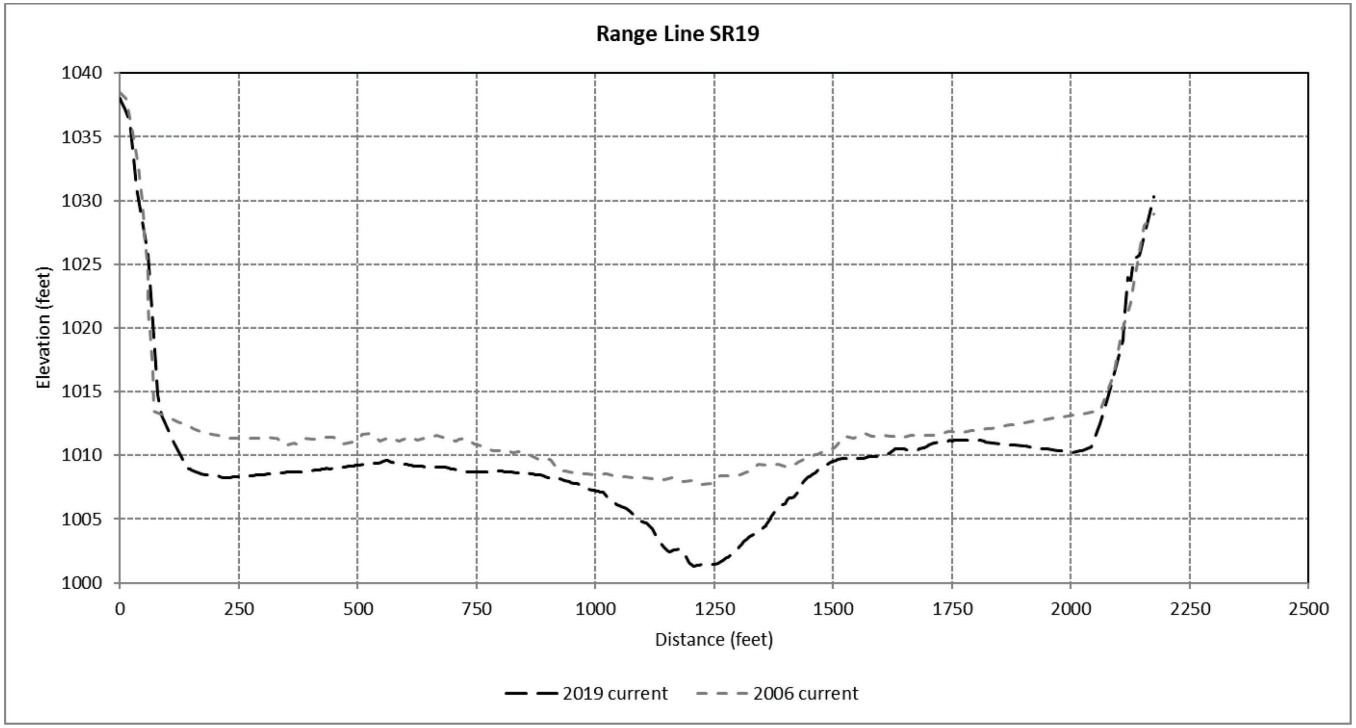

Range Line SR14
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
0
500
1000
1500
2000
2500
3000
Distance (feet)
2019 current
2006 current

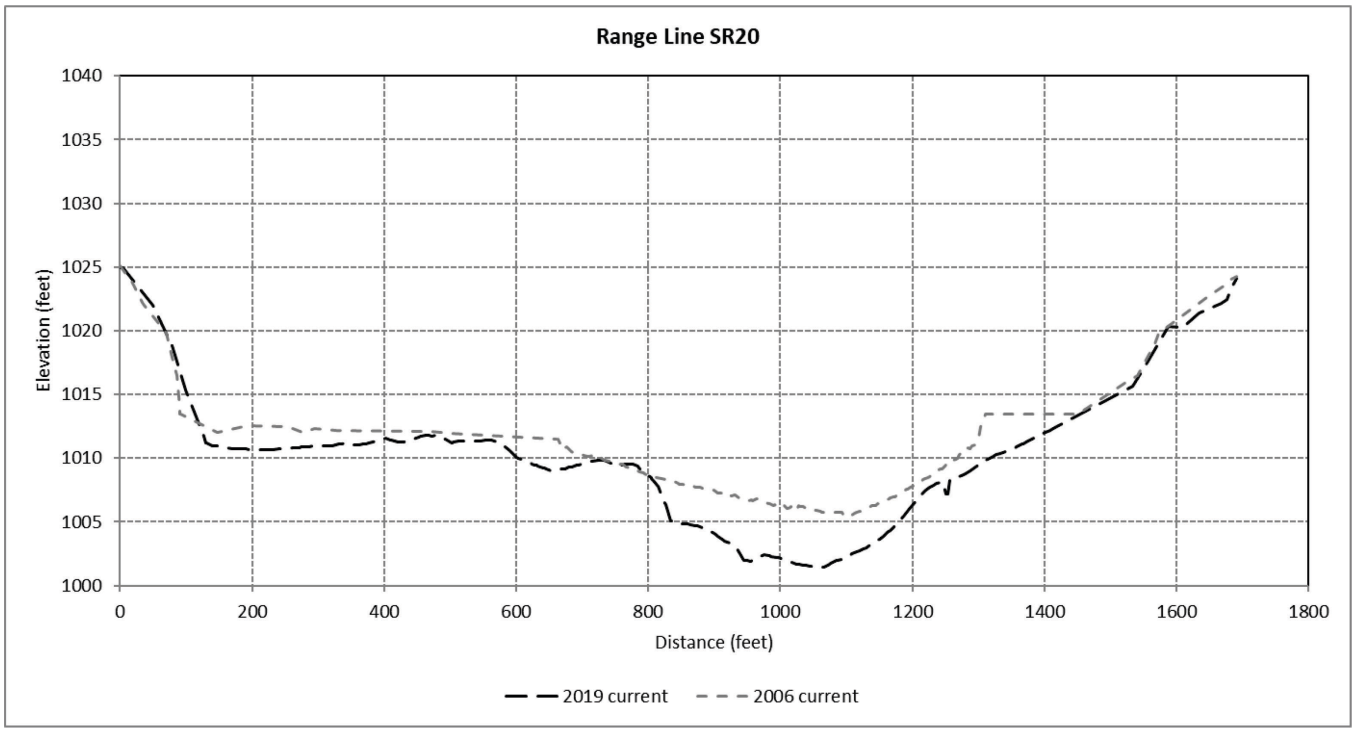

Range Line SR15
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance (feet)
2019 current
2006 current

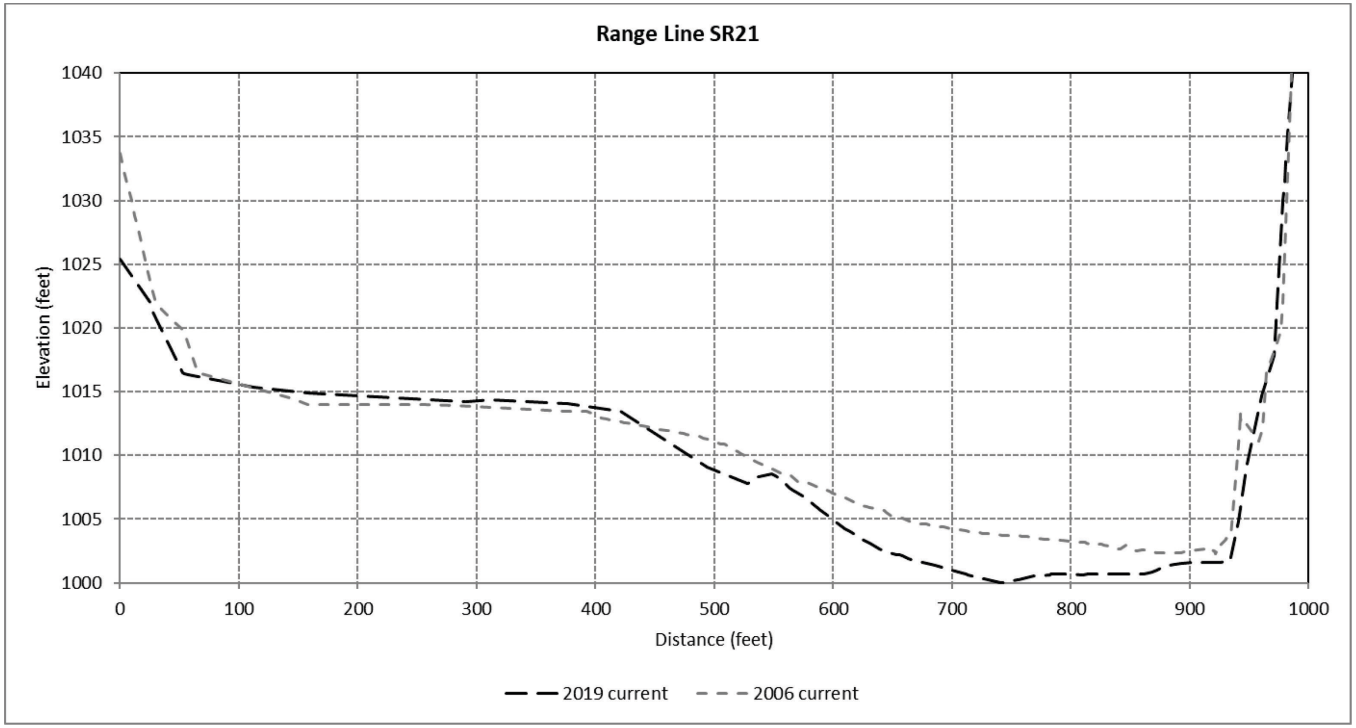

Range Line SR16
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (feet)
2019 current
2006 current

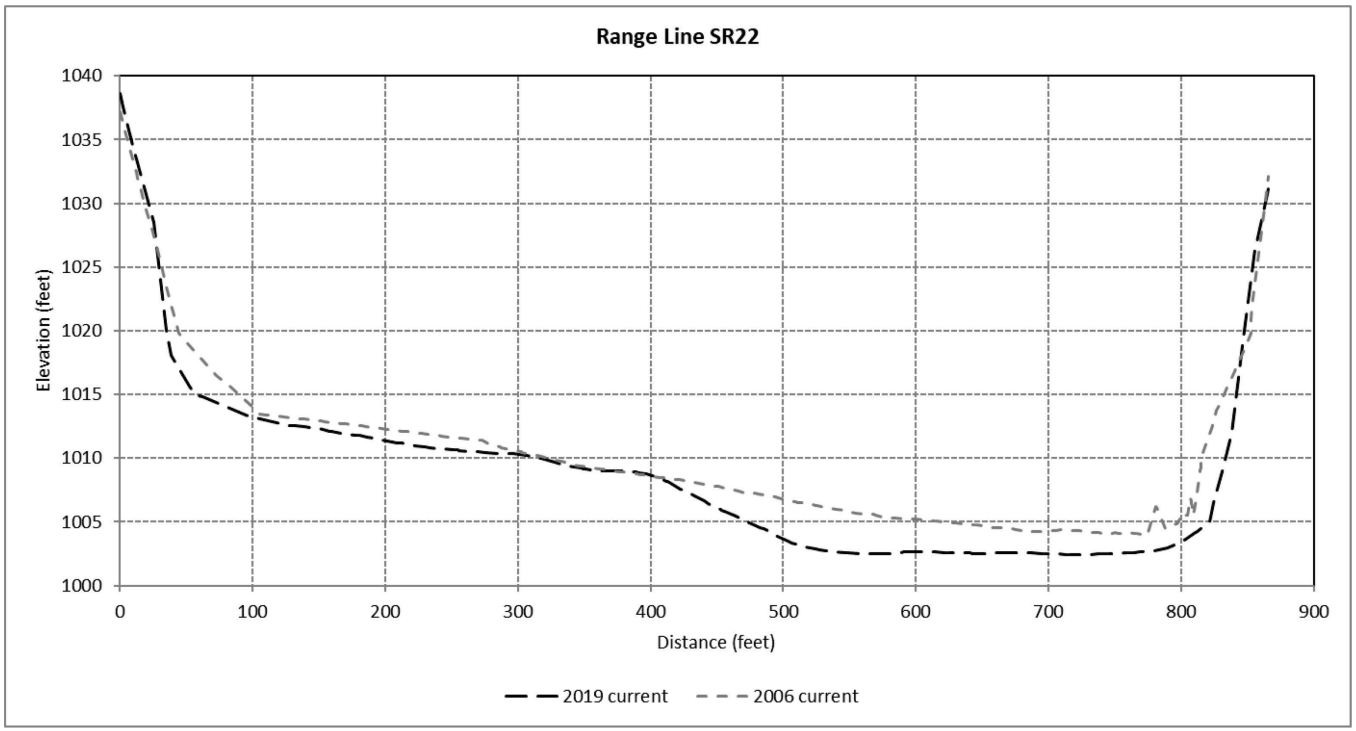

Range Line SR17
1040
1035
1030
1025
1020
1015
1010
1005
1000
Elevation (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (feet)
2019 current
2006 current

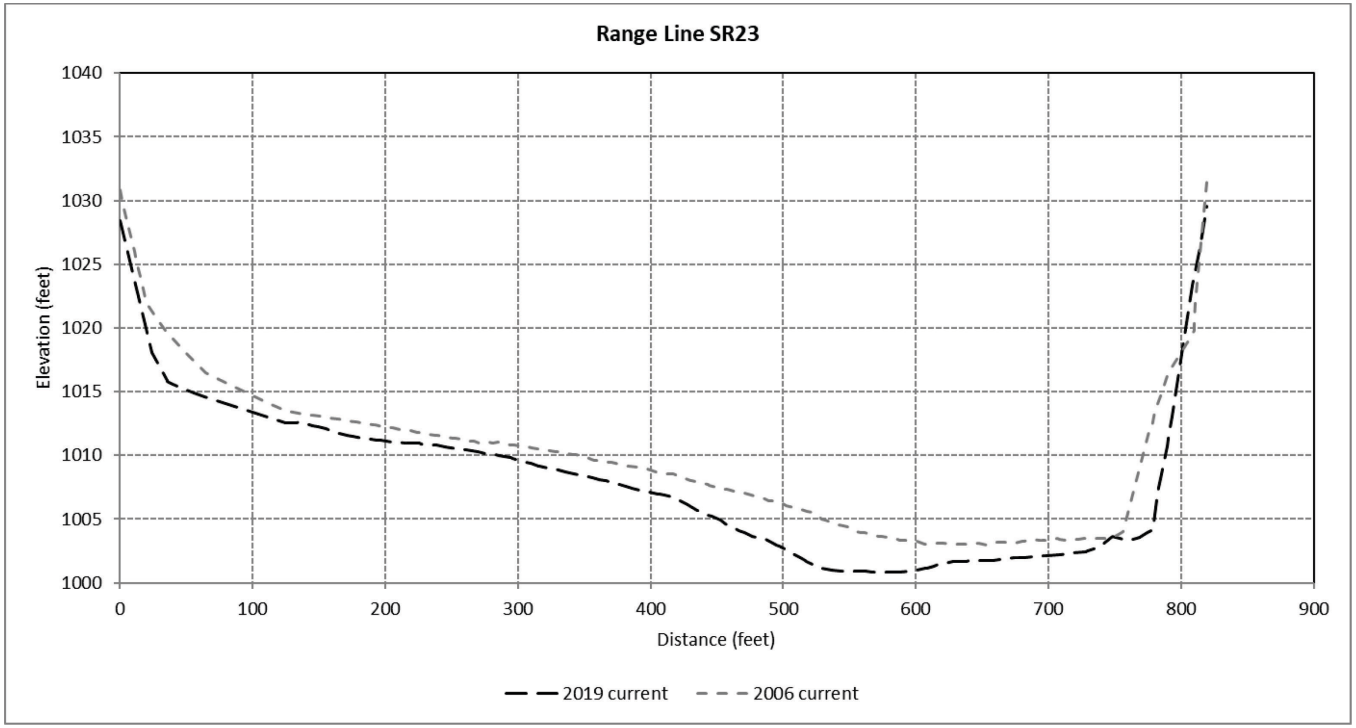

Range Line SR18
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
Elevation (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance (feet)
2019 current
2006 current

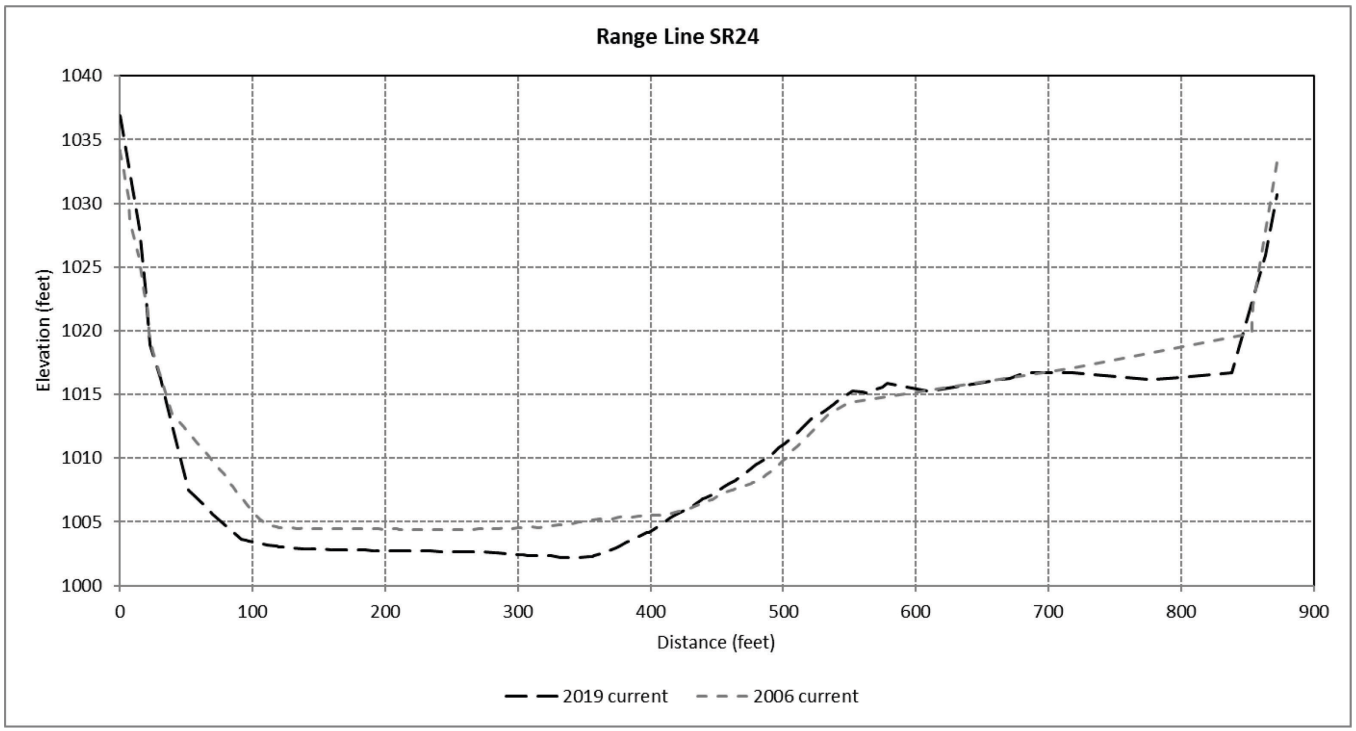

Range Line SR19
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
Distance (feet)
2019 current
2006 current

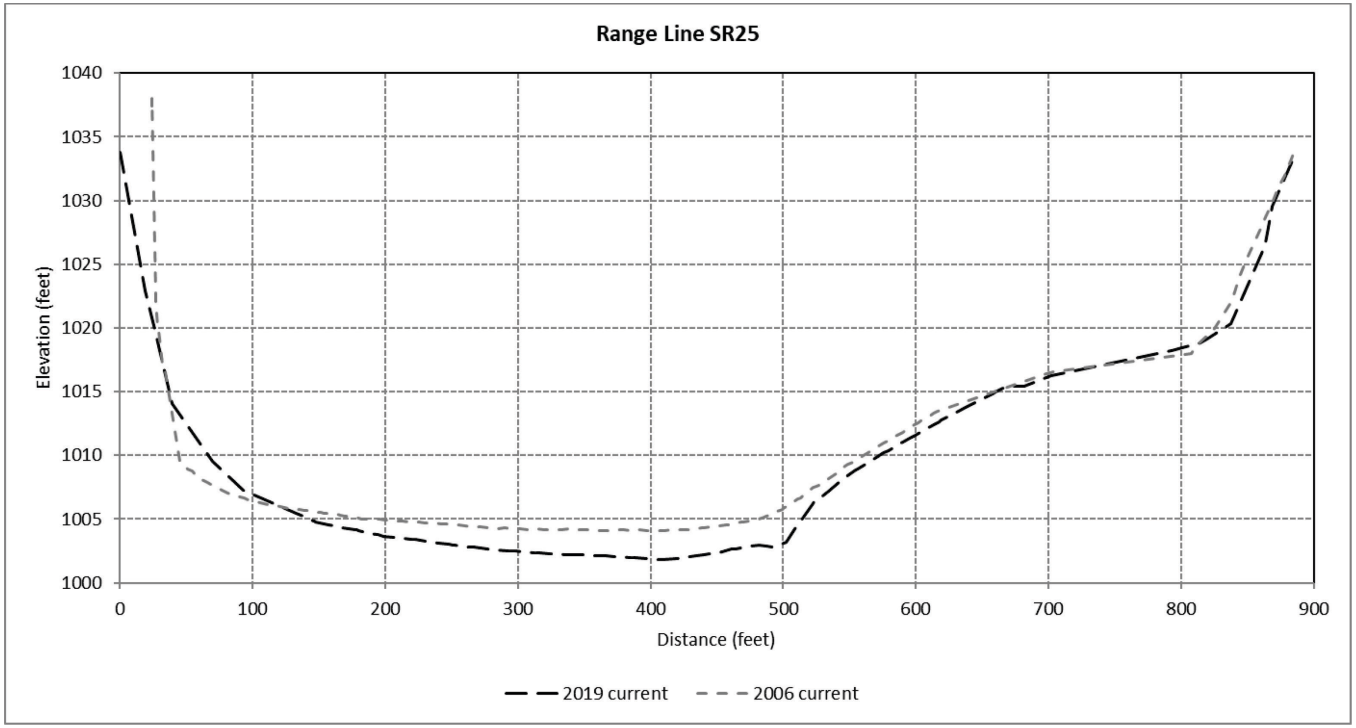

Range Line SR20
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
0
200
400
600
800
1000
1200
1400
1600
1800
Distance (feet)
2019 current
2006 current

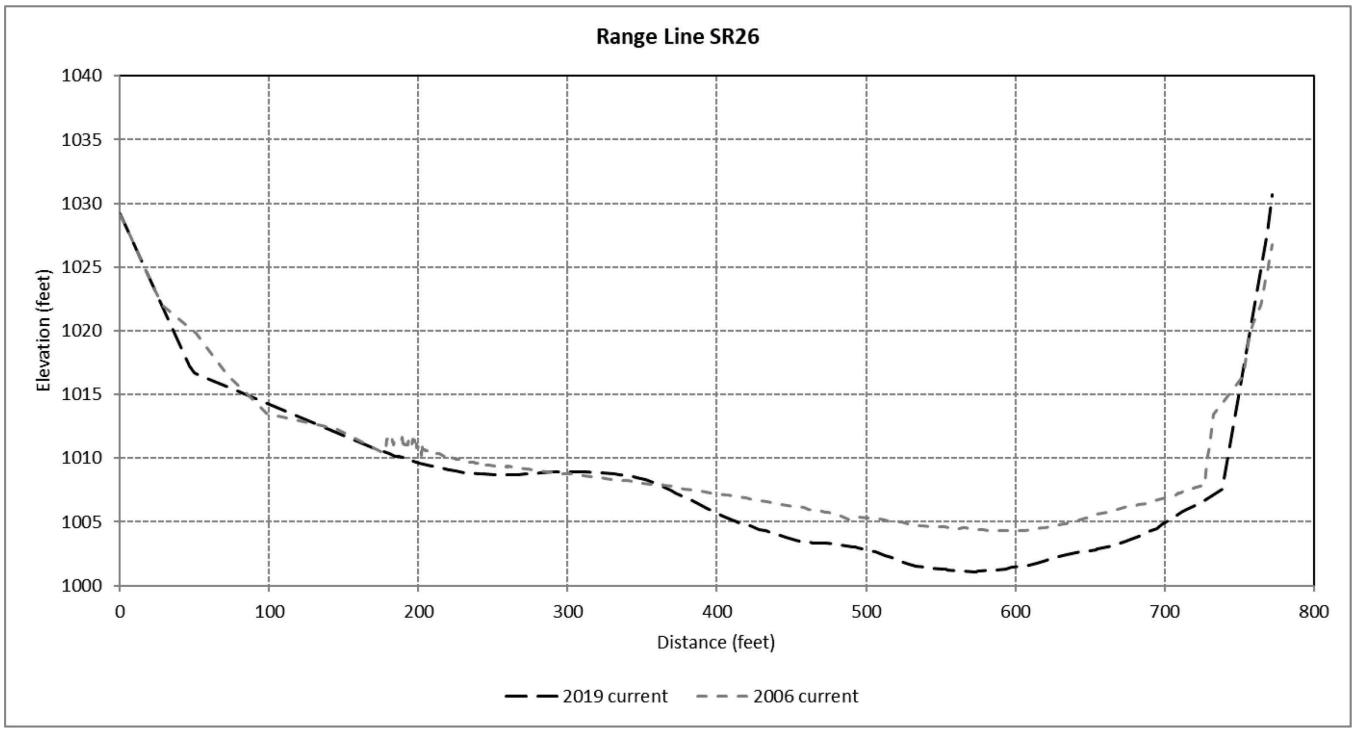

Range Line SR21
1040
1035
1030
1025
1020
1015
1010
1005
1000
Elevation (feet)
0
100
200
300
400
500
600
700
800
900
1000
Distance (feet)
2019 current
2006 current

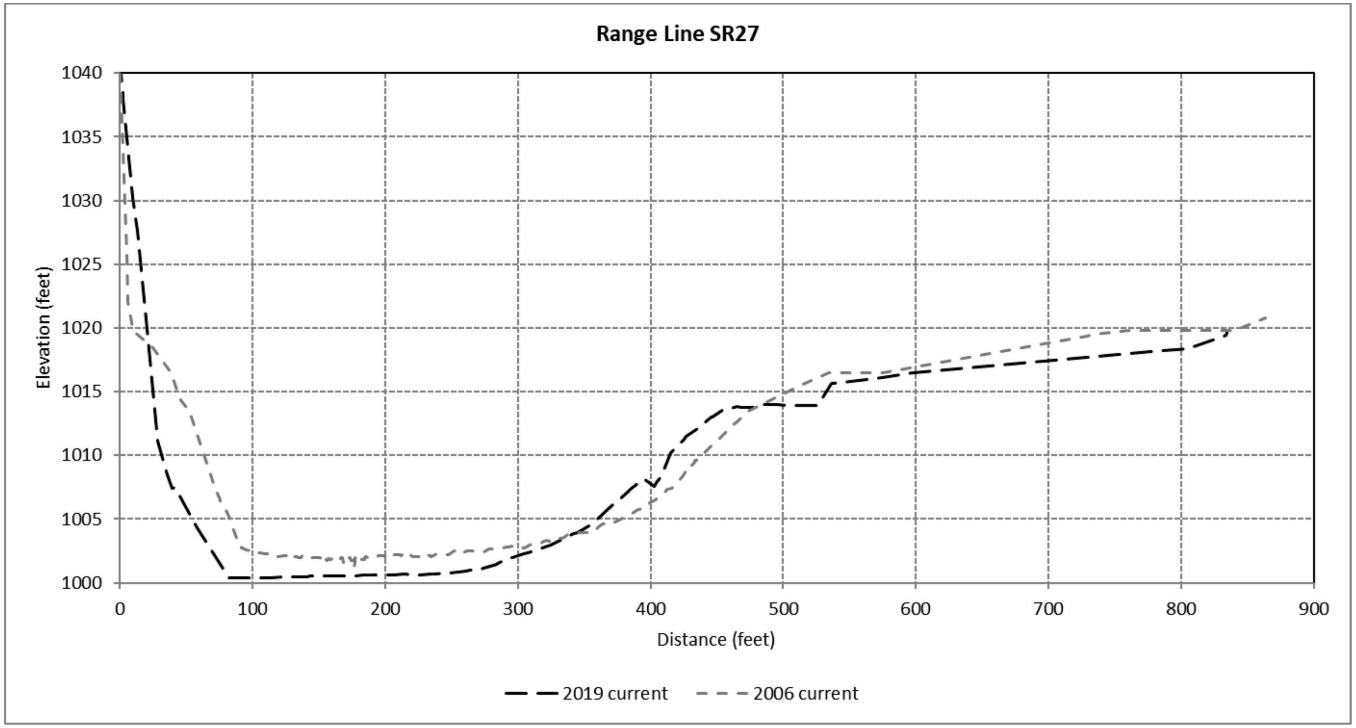

Range Line SR22
1040
1035
1030
1025
1020
1015
1010
1005
1000
Elevation (feet)
0
100
200
300
400
500
600
700
800
900
Distance (feet)
2019 current
2006 current

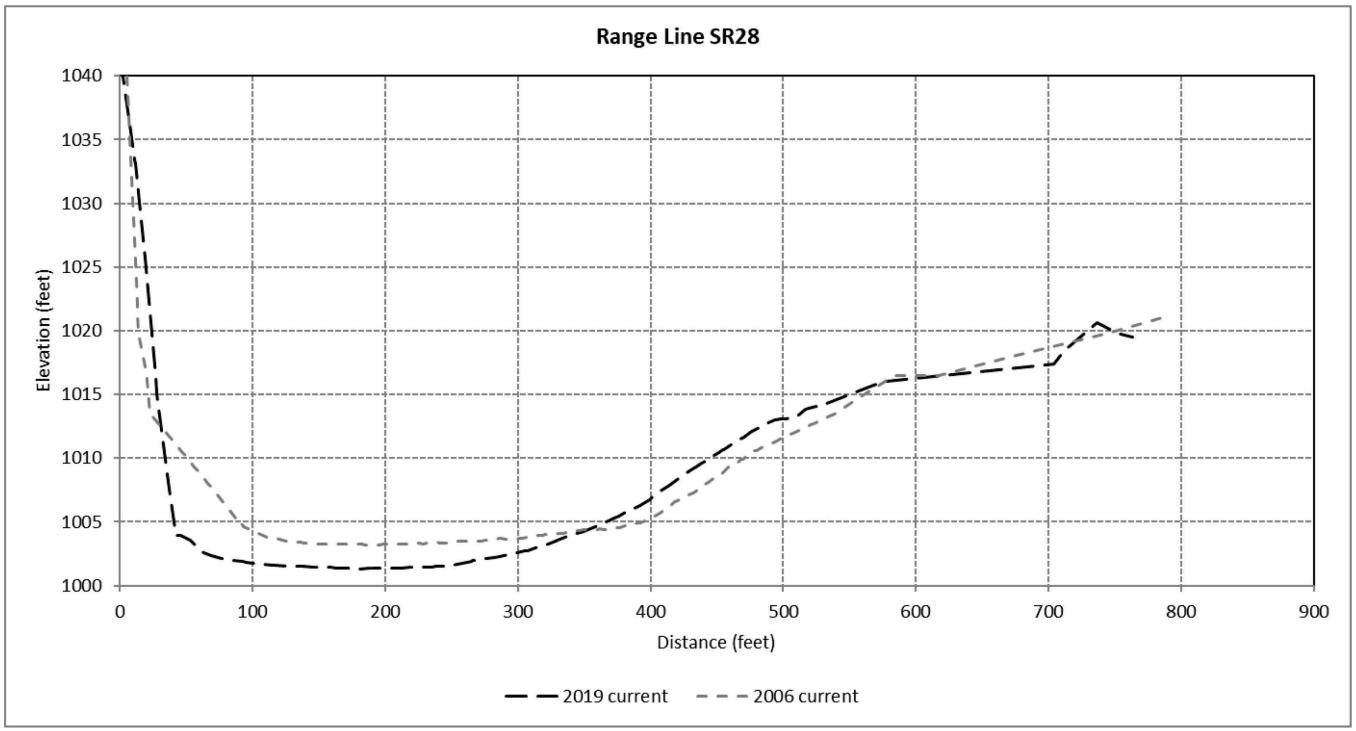

Range Line SR23
1040
1035
1030
1025
1020
1015
1010
1005
1000
Elevation (feet)
0
100
200
300
400
500
600
700
800
900
Distance (feet)
2019 current
2006 current


Range Line SR24
1040
1035
1030
1025
1020
1015
1010
1005
1000
Elevation (feet)
0
100
200
300
400
500
600
700
800
900
Distance (feet)
2019 current
2006 current


Range Line SR25
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
0
100
200
300
400
500
600
700
800
900
Distance (feet)
2019 current
2006 current


Range Line SR26
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
0
100
200
300
400
500
600
700
800
Distance (feet)
2019 current
2006 current


Range Line SR27
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
0
100
200
300
400
500
600
700
800
900
Distance (feet)
2019 current
2006 current


Range Line SR28
Elevation (feet)
1040
1035
1030
1025
1020
1015
1010
1005
1000
0
100
200
300
400
500
600
700
800
900
Distance (feet)
2019 current
2006 current

Appendix G Axial profile

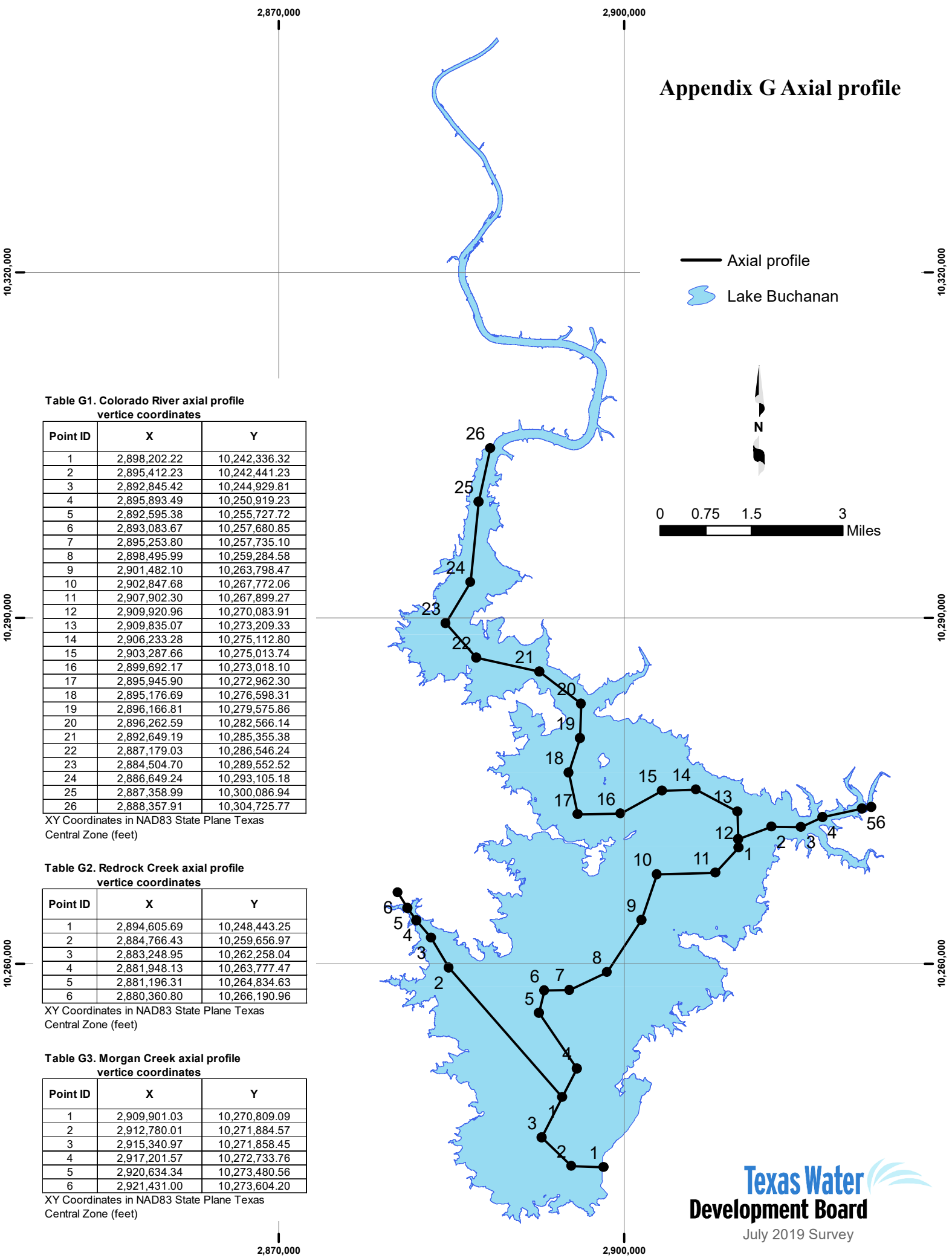


Table G1. Colorado River axial profile vertice coordinates

Point ID	X	Y
1	2,898,202.22	10,242,336.32
2	2,895,412.23	10,242,441.23
3	2,892,845.42	10,244,929.81
4	2,895,893.49	10,250,919.23
5	2,892,595.38	10,255,727.72
6	2,893,083.67	10,257,680.85
7	2,895,253.80	10,257,735.10
8	2,898,495.99	10,259,284.58
9	2,901,482.10	10,263,798.47
10	2,902,847.68	10,267,772.06
11	2,907,902.30	10,267,899.27
12	2,909,920.96	10,270,083.91
13	2,909,835.07	10,273,209.33
14	2,906,233.28	10,275,112.80
15	2,903,287.66	10,275,013.74
16	2,899,692.17	10,273,018.10
17	2,895,945.90	10,272,962.30
18	2,895,176.69	10,276,598.31
19	2,896,166.81	10,279,575.86
20	2,896,262.59	10,282,566.14
21	2,892,649.19	10,285,355.38
22	2,887,179.03	10,286,546.24
23	2,884,504.70	10,289,552.52
24	2,886,649.24	10,293,105.18
25	2,887,358.99	10,300,086.94
26	2,888,357.91	10,304,725.77

XY Coordinates in NAD83 State Plane Texas Central Zone (feet)

Table G2. Redrock Creek axial profile vertice coordinates

Point ID	X	Y
1	2,894,605.69	10,248,443.25
2	2,884,766.43	10,259,656.97
3	2,883,248.95	10,262,258.04
4	2,881,948.13	10,263,777.47
5	2,881,196.31	10,264,834.63
6	2,880,360.80	10,266,190.96

XY Coordinates in NAD83 State Plane Texas Central Zone (feet)

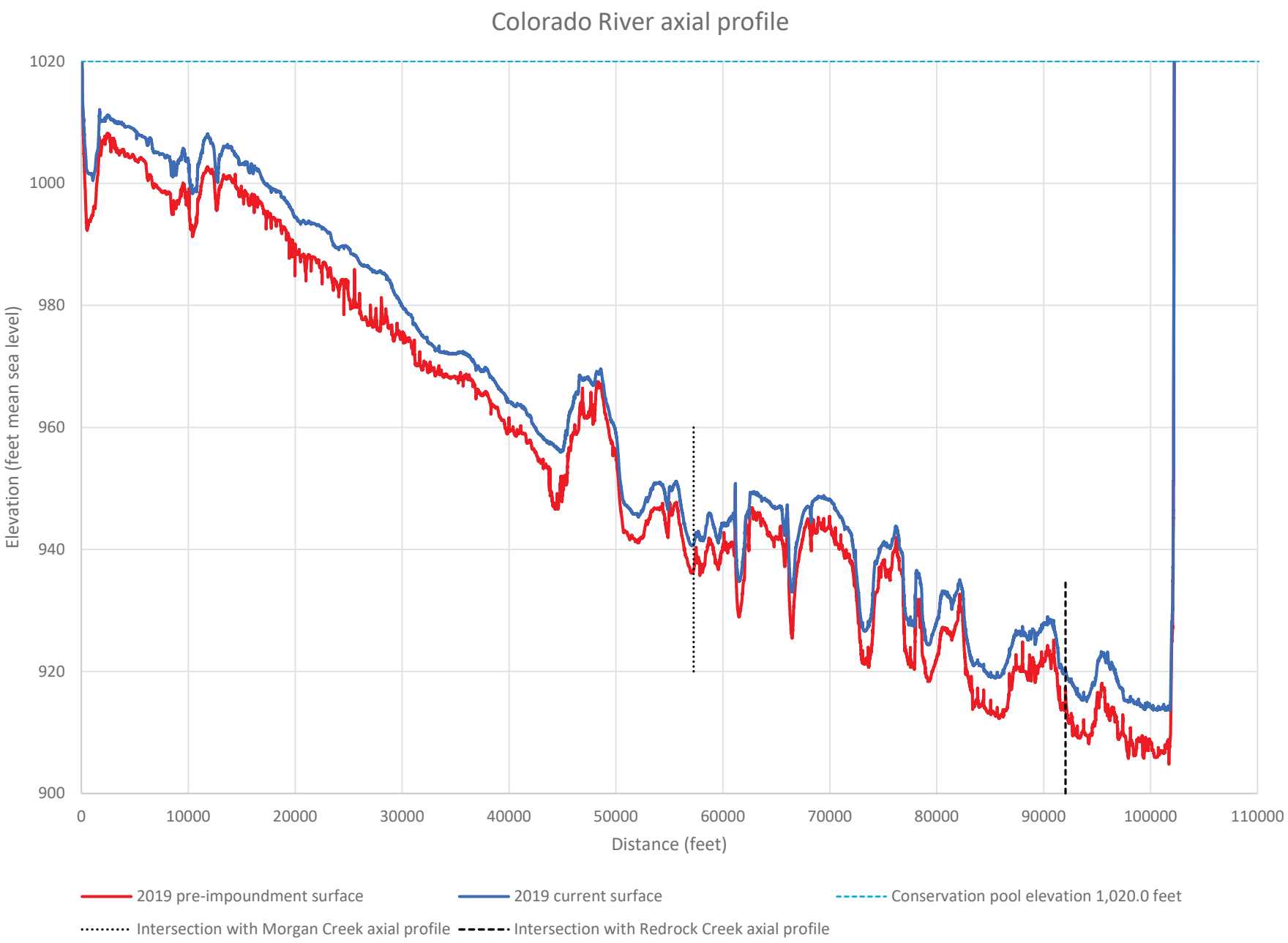
Table G3. Morgan Creek axial profile vertice coordinates

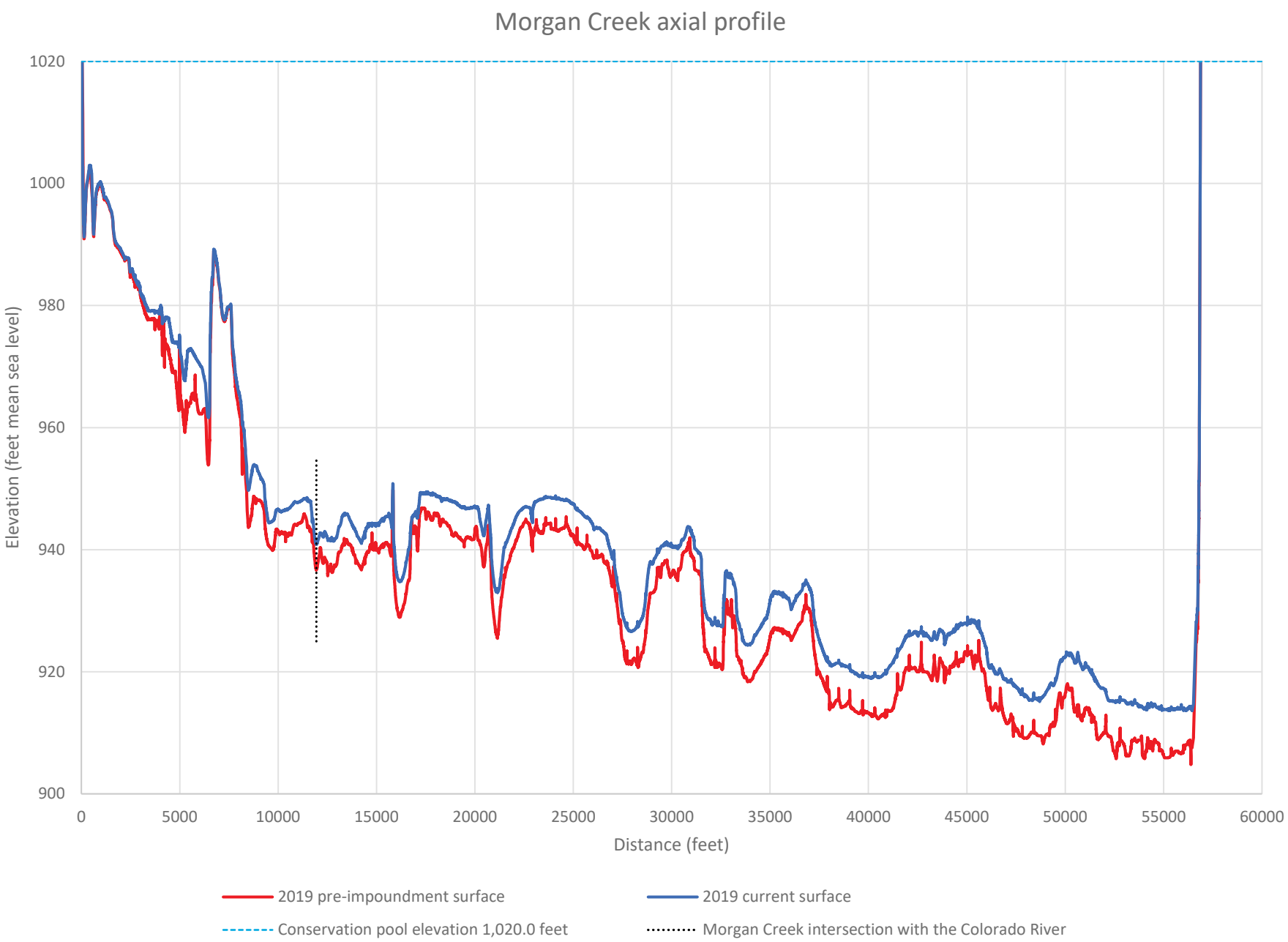
Point ID	X	Y
1	2,909,901.03	10,270,809.09
2	2,912,780.01	10,271,884.57
3	2,915,340.97	10,271,858.45
4	2,917,201.57	10,272,733.76
5	2,920,634.34	10,273,480.56
6	2,921,431.00	10,273,604.20

XY Coordinates in NAD83 State Plane Texas Central Zone (feet)

Texas Water Development Board

July 2019 Survey


Colorado River axial profile
Elevation (feet mean sea level)
1020
1000
980
960
940
920
900
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
110000
Distance (feet)
2019 pre-impoundment surface
2019 current surface
Conservation pool elevation 1,020.0 feet
Intersection with Morgan Creek axial profile
Intersection with Redrock Creek axial profile


Morgan Creek axial profile
Elevation (feet mean sea level)
1020
1000
980
960
940
920
900
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
60000
Distance (feet)
2019 pre-impoundment surface
2019 current surface
Conservation pool elevation 1,020.0 feet
Morgan Creek intersection with the Colorado River

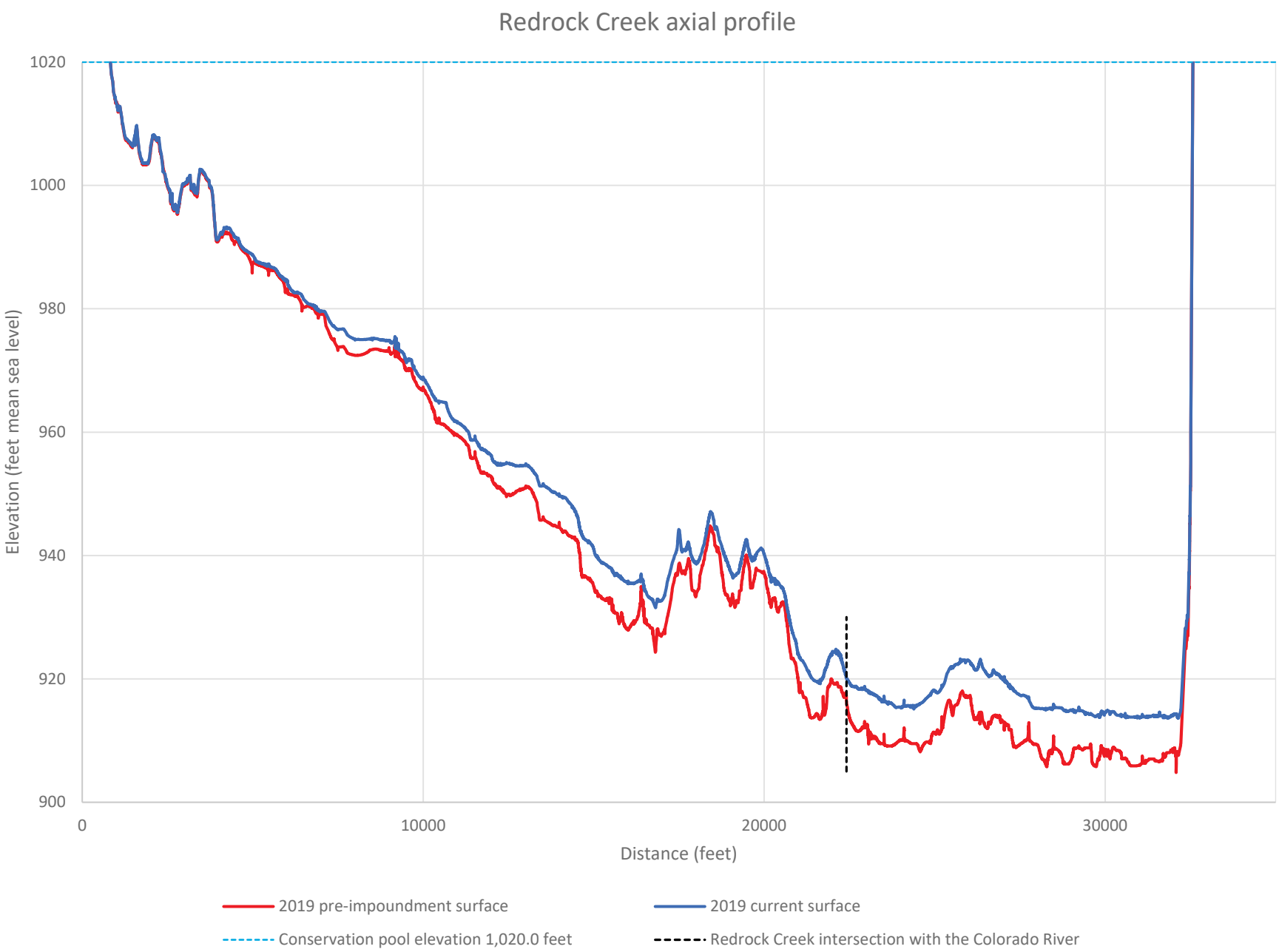

Redrock Creek axial profile
Elevation (feet mean sea level)
1020
1000
980
960
940
920
900
0
10000
20000
30000
Distance (feet)
2019 pre-impoundment surface
2019 current surface
Conservation pool elevation 1,020.0 feet
Redrock Creek intersection with the Colorado River

Figure 6

Contours

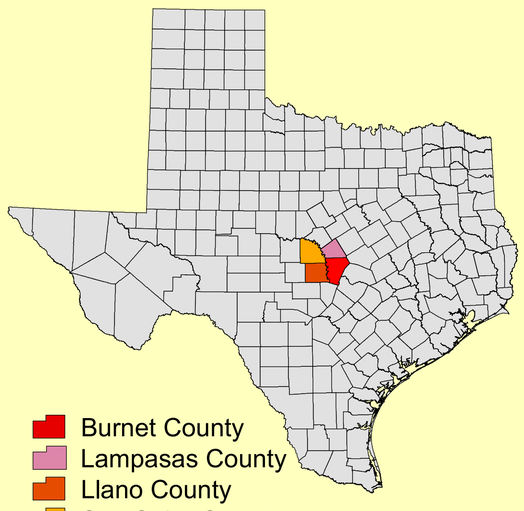
feet above mean sea level

- 1010
- 1000
- 990
- 980
- 970
- 960
- 950
- 940
- 930
- 920

Islands

Lake Buchanan conservation pool elevation 1,020.0 feet above mean sea level

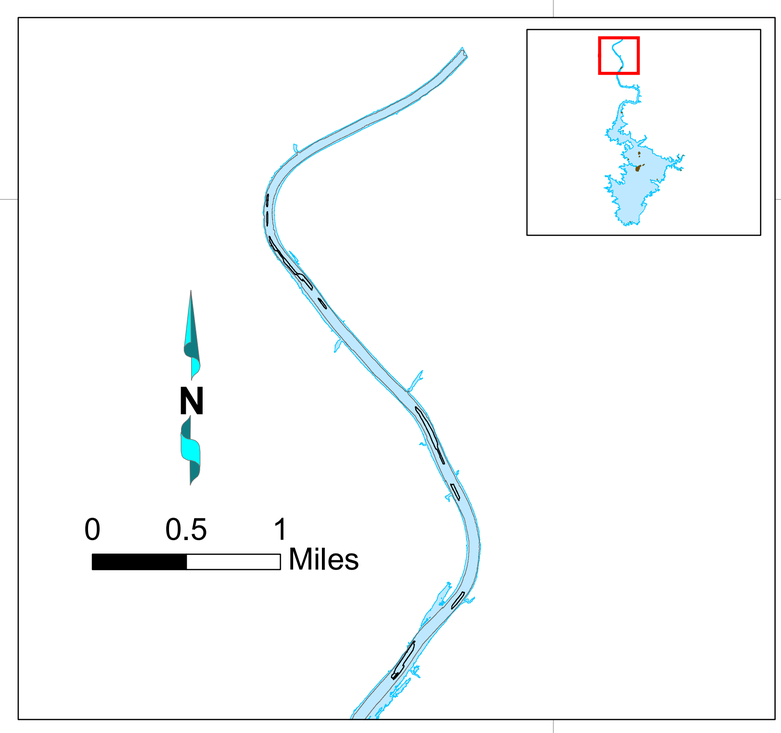
Projection: NAD83
State Plane Texas
Central Zone (feet)



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

Lake Buchanan

10' - contour map



2,880,000 2,900,000 2,920,000

10,320,000 10,300,000 10,280,000 10,260,000 10,240,000

0 0.5 1 2
Miles

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