BUREAU OF RECLAMATION

Technical Report No. ENV-2020-036

El Vado Reservoir 2018 Sedimentation Survey

Middle Rio Grande Project, New Mexico

Upper Colorado Region

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Sedimentation and River Hydraulics Group
Denver, Colorado

March 2020

Mission Statements

The Department of the Interior conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Acknowledgements

The reservoir survey was funded by Upper Colorado Region, Denver Safety Office, Bureau of Reclamation. The survey was performed by Kent Collins, Robert Hilldale, and Caroline Ubing of the Sedimentation and River Hydraulics Group, Technical Service Center. Kent Collins also provided Appendix A and Appendix B. Jack Truax helped create the map of bathymetric survey data coverage.

Disclaimer

Cover: El Vado Reservoir, New Mexico (Reclamation)

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
Report Date: 02/01/2020	Final report	Survey Date: April 23-26, 2018

4. TITLE AND SUBTITLE
Technical Report No. ENV-2020-036
Middle Rio Grande, New Mexico
Upper Colorado Region

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Jianchun “Victor” Huang

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Bureau of Reclamation
Technical Service Center
Sedimentation and River Hydraulics Group
Building 67, Mail Code: 86-68240
Denver, Colorado

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
https://www.usbr.gov/tsc/techreferences/reservoir.html

13. SUPPLEMENTARY NOTES

14. SHORT ABSTRACT

The 2018 multibeam bathymetric survey of El Vado Reservoir was combined with 2016 LiDAR to produce a combined digital surface of the reservoir bottom. Analysis of this data indicates that at the top of survey control pool elevation (6908.6 ft, Reclamation project vertical datum), the reservoir would have a surface area of 3,602 acres and a storage capacity of 214,091 acre-ft. Since the original filling in 1935, the reservoir is estimated to have lost 7,189 acre-ft of storage capacity (3.3%) due to sedimentation. The inactive storage pool volume has reduced to 6 percent of the original dead storage volume. The sedimentation level at the dam is at 6,770 ft (Reclamation project vertical datum), which is the elevation of lower intake outlet.

15. SUBJECT TERMS
El Vado Reservoir survey, sedimentation, capacity,

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Jianchun “Victor” Huang
a. REPORT U	b. ABSTRACT U	THIS PAGE U		61	19b. TELEPHONE NUMBER *(Include area code)* 303-445-2158

BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Sedimentation and River Hydraulics Group, 86-68240

Technical Report No. ENV-2020-036

El Vado Reservoir 2018 Sedimentation Survey

JIANCHUN HUANG

Digitally signed by JIANCHUN HUANG
Date: 2020.05.05 11:06:49 -06'00'

Prepared by: Jianchun "Victor" Huang, P.E., Ph.D., Sedimentation and River Hydraulics Group, 86-68240

BLAIR GREIMANN

Digitally signed by BLAIR GREIMANN
Date: 2020.05.05 12:43:35 -06'00'

Peer Reviewed by: Blair P. Greimann P.E., Ph.D., Sedimentation and River Hydraulics Group, 86-68240

Acronyms and Abbreviations

ACAP	Area-Capacity
AF	acre-feet
cfs	cubic feet per second
DOI	Department of the Interior
ft	feet
GIS	Geographic Information System
GPS	Global Positioning System
HUC	Hydrologic Unit Code
LiDAR	Light Detection and Ranging
mi^2	square miles
NAD 1983	North American Datum, established 1983
NGD	National Geodetic Survey
NID	National Inventory of Dams
NGVD 1929	National Geodetic Vertical Datum, established 1929
NGVD 1988	National Geodetic Vertical Datum, established 1988
OPUS	Online Positioning User Service
%	percent
®	Registered Trademark
Reclamation	Bureau of Reclamation
RPVD	Reclamation Project Vertical Datum
RSI	Reservoir Sedimentation Information
RTK	Real-Time Kinematic
TSC	Technical Service Center
USGS	U.S. Geological Survey

Executive Summary

El Vado Reservoir, located on the Rio Chama, is about 10 miles southwest of the town of Tierra Amarilla, 78 miles northwest of Santa Fe, and 28 miles south of the Colorado-New Mexico state line (Figure ES.1).

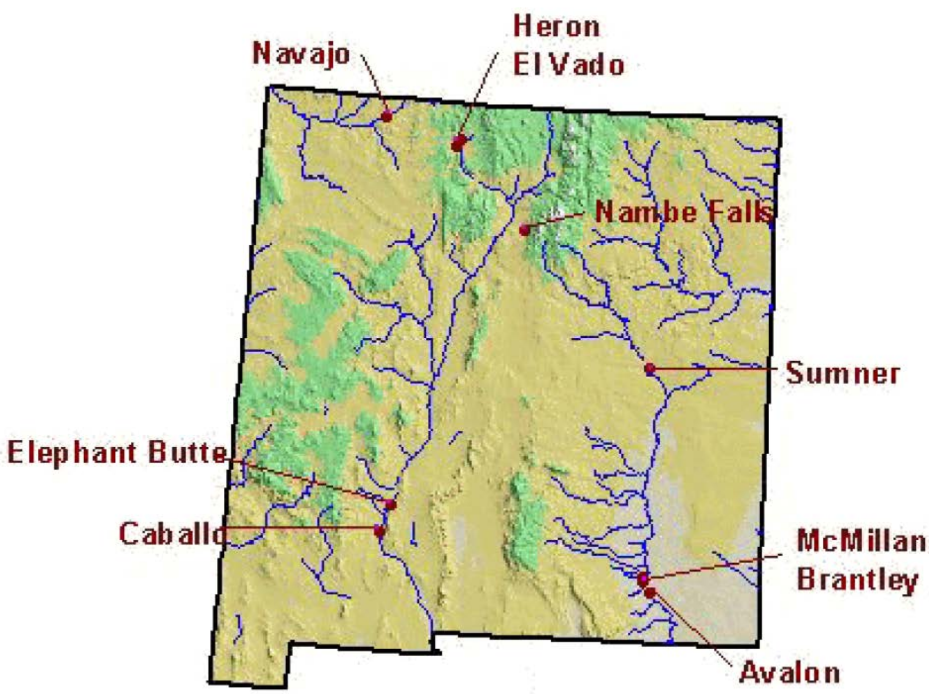


Figure ES.1 Reclamation reservoirs located in New Mexico (Reclamation, 2007).

A bathymetric survey of El Vado Reservoir was conducted from April 23 through April 26, 2018 with these primary objectives:

1. Estimate reservoir sedimentation volume since the original reservoir filling began in 1935 and since the previous surveys in 1944, 1967, 1984, and 2007 and
2. Determine new reservoir surface area and storage capacity tables for the full elevation range of dam and reservoir operations.

The bathymetric survey was conducted from a boat using a multibeam depth sounder that was interfaced with real-time kinematic (RTK) global positioning system (GPS) instruments (for horizontal positioning) to map the reservoir bottom. The 2018 multibeam bathymetric survey of El Vado Reservoir was combined with 2016 aerial Light Detection and Ranging (LiDAR) to produce a combined digital surface of the reservoir bottom.

During the survey, the reservoir water surface elevation ranged between 6860.46 and 6860.51 feet in Reclamation Project Vertical Datum (RPVD), 41.5 feet below the conservation pool elevation of 6902 feet. The above-water topographic data were measured by LiDAR in 2016.

Analysis of the combined data sets indicates the following results:

- At reservoir water surface elevation 6,855 feet (RPVD), which is 5.5 feet below the water surface at the time of survey, the reservoir surface area was 1,739 acres with a storage capacity of 72,236 acre-feet (AF).
- At the top of conservation pool (6,902 feet, RPVD), the reservoir would have a surface area of 3,384 acres with a storage capacity of 191,050 acre-feet.
- At the top of surcharge elevation (6,908.60 feet, RPVD), the reservoir would have a surface area of 3,602 acres and a storage capacity of 214,091 acre-feet.
- Since the original filling of the reservoir in 1935, the reservoir is estimated to have lost 7,189 acre-feet of storage capacity (3.3 percent) due to sedimentation below the top of conservation pool.
- Since the last reservoir survey in 2007, The storage capacity under the reservoir inactive elevation (6,775 feet) is estimated to have lost 167 acre-feet of storage capacity, however the storage under the surcharge elevation (6,908.6 feet) is estimated to have gained 1,001 acre-feet of storage capacity due to lower reservoir operation levels.
- Under operations since 2007, the reservoir has not trapped any significant amounts of sediment and instead has acted as a source of sediment.

A summary description of the dam, reservoir, and survey results are presented in Table ES-1.

Table ES-1. Reservoir Survey Summary Information

Reservoir Name	El Vado	**Region**	Middle Rio Grande
Owner	Bureau of Reclamation	**Area Office**	AAO-NM
Stream	Rio Chama	**Vertical Datum**	RPVD
County	Rio Arriba	**Top of Dam (ft)**	6,914.5
State	New Mexico	**Spillway Crest (ft)**	6,906.0
Lat (deg min sec)	36 35 38	**Power Penstock Elevation (ft)**	NA
Long (deg min sec)	-106 44 00	**Low Level Outlet (ft)**	6,770
HUC4	1302	**Hydraulic Height (ft)**	156.5
HUC8	13020102	**Total Drainage Area (mi^2)**	783
NID ID	NM10008	**Date Storage Began**	1935
Dam Purpose	Irrigation, Municipal and industrial Water, Recreation, Flood Control	**Date for Normal Operations**	1936

HUC = Hydrologic Unit Code; NID = National Inventory of Dams

Table ES-2. Original Design

Storage Allocation	Elevation (ft)	Surface Area (acres)	Capacity (acre-ft)	Gross Capacity (acre-ft)
SURCHARGE	6,908.60		23,078[1]	221,280
FLOOD CONTROL				
CONSERVATION	6,902	3,320	193,583	198,202
INACTIVE	6,775	349	4,619	4,619

Table ES-3. Current Surface Area and Storage Capacity

Storage Allocation	Elevation (ft)	Surface Area (acres)	Capacity (acre-ft)	Gross Capacity (acre-ft)
SURCHARGE	6,908.60	3,602	23,041	214,091
FLOOD CONTROL				
CONSERVATION	6,902	3,384	190,793	191,050
INACTIVE	6,775	89	257	257

Table ES-4. Survey Summary

Survey Date	Type of Survey	No. of Range lines or Contour Intervals	Contributing Sediment Drainage Area (mi^2)	Period Sediment-ation Volume (acre-ft)	Cumulative Sediment-ation (acre-ft)	Lowest Reservoir Elevation (ft)	Remaining Portion of Dead Storage (%)
1/1935	Contour(D)		587[2]				88.5%
1944	Range(D)	21[3]	587[2]				21.0%
11/1967			587[2]				
6/1984	Range(D)	21[3]	587[2]	11,950	11,950[4]		9.5%
6/2007	Contour(D)	2-ft	587[2]	-3,760[6]	8,190[5]		8.4%
4/2018	Contour(D)	2-ft	587[2]	-1,001[7]	7,189[5]	6,770	5.1%

Notes

[1]Original capacity values adjusted using 1944 survey results. 1984 study projected 23,078 AF of capacity between elevation 6902.0 (Top Active Conservation Pool) to elevation 6908.6.

[2]The sediment contribution basin of 492 mi^2 from Rio Chama and 95 mi^2 from Boulder Creek. The Heron Reservoir drainage basin of 193 mi^2 and 83 mi^2 of non-contributing area is not included. Heron Reservoir closure in Oct. 1970.

[3]21 range lines currently identified, with range lines 6, 7, and 8 cover both Rio Chama and Boulder Creek arms.

[4]Loss below elevation 6,902.0 feet. Uncertainty of validity of original and following values. Some studies considered 1944 most accurate.

[5]Capacity lost below elevation 6,908.6 feet.

[6]2007 detailed contour survey computed a greater volume than 1984 range line survey. Range line comparisons (1984 and 2007) show minimum change between surveys.

[7]2018 survey computed a greater volume than 2007 survey.

Contents

Appendices

Tables

Figures

1. Introduction

El Vado Dam, located on the Rio Chama in New Mexico, is about 10 miles southwest of the town of Tierra Amarilla, 78 miles northwest of Santa Fe, and 28 miles south of the Colorado-New Mexico state line (Figure 1). El Vado Dam, designated a New Mexico Civil Engineering Landmark, was built by the Middle Rio Grande Water Conservancy District in 1934-35 and rehabilitated by Reclamation in 1954-55. Reclamation installed new enlarged outlet works in 1965-66 to accommodate additional water for the San Juan-Chama Project that is diverted through the upstream located Heron Reservoir. The reservoir's primary purpose is to provide storage for supplemental water to the Middle Rio Grande Valley and San Juan-Chama Project for irrigation, municipal, and industrial uses. The project also provides flood control, hydroelectric power, recreation, and benefits for fish and wildlife.

All rivers transport sediment particles (e.g., clay, silt, sand, gravel, and cobble) and reservoirs tend to trap sediment, diminishing the reservoir storage capacity over time. Reservoir sedimentation affects all elevations of the reservoir, even above and upstream of the full pool elevations. Cobble, gravel, and sand particles tend to deposit first forming deltas at the upstream ends of the reservoir while silt and clay particles tend to deposit along the reservoir bottom between the delta and dam. Periodic reservoir surveys measure the changing reservoir surface area and storage capacity and provide information for forecasting when important dam and reservoir facilities will be impacted by sedimentation.

As part of ongoing operations and sediment monitoring activities, the Upper Colorado Regional office requested the Technical Service Center's (TSC) Sedimentation and River Hydraulics Group (86-68240) to conduct a bathymetric survey of the underwater portions of the reservoir that were accessible by boat. A complete bathymetric survey was conducted from April 23 to 26, 2018 with these primary objectives:

1. Estimate reservoir sedimentation volume since the original reservoir filling began in 1936 and since the previous surveys in 1944, 1967, 1984, and 2007 and

2. Determine new reservoir surface area and storage capacity tables for the full elevation range of dam and reservoir operations.

Figure 1. Location map of El Vado Reservoir, 10 miles southwest of the town of Tierra Amarilla, New Mexico.

2.Watershed and Reservoir Description

El Vado Dam impounds natural drainage waters from the Rio Chama and Boulder Creek along with diverted San Juan basin water released through Heron Reservoir that is located upstream on the Rio Chama arm. The total drainage above El Vado Reservoir is 873 square miles (mi^2) bounded by the Continental Divide on the west and San Juan Mountains on the east (Figure 2). The basin can be divided into four sub-basins where Boulder Creek basin flows directly into El Vado Reservoir and is 95 mi^2, Willow Creek basin is controlled by Heron Dam (closure in October 1970) and is 193 mi^2 and Rio Chama basin is 492 mi^2. The fourth sub-basin is located west of El Vado Reservoir, drains into Stinking Lake and is considered non-contributing (Reclamation, 2004; Ferrari, 2008).

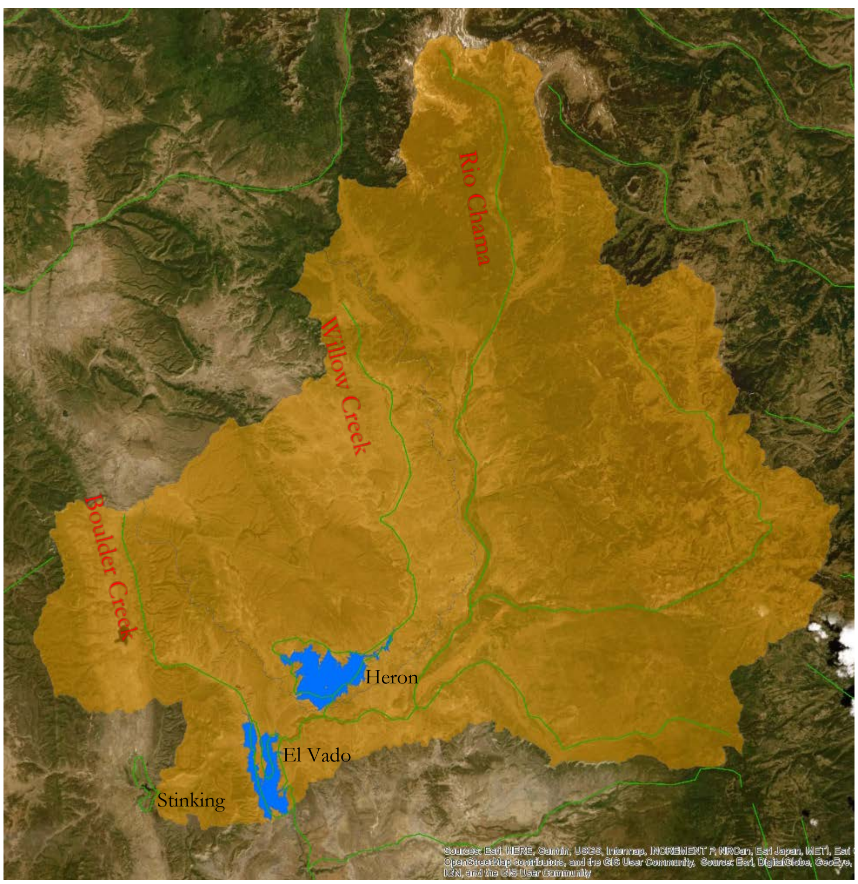


Figure 2. The watershed above El Vado Reservoir has a total drainage area of 873 mi^2 and a sediment-contributing drainage area of 587 mi^2.

2.1 Runoff

Two gages can be used to measure the flows entering the reservoir and one gage can be used to measure flows released from the reservoir downstream (Table 1). USGS gage 08284100, Rio Chama near La Puente, New Mexico, is about 13.5 miles upstream of the dam. The Rio Chama is the major source of inflows into the reservoir. The gage records daily incoming flows from Rio Chama and covers approximately 480 mi^2 of the total watershed area above El Vado Dam of 873 mi^2. Outflows from Heron Dam that enter the Rio Chama upstream of El Vado Reservoir can be developed from Reclamations Upper Colorado Region Water Operations data (https://www.usbr.gov/rsvrWater/HistoricalApp.html). USGS gage 08285500 Rio Chama below El Vado Dam, New Mexico is located downstream of the dam. This gage represents the water released from El Vado Dam.

Figure 3 through Figure 5 present the annual outflow volume, cumulative outflow volume, and monthly average outflows from El Vado Reservoir. Cumulative inflow volume from Rio Chama is also presented in Figure 4. The mean daily flow from Rio Chama is 337 cubic feet per second (cfs) or 244,000 acre-feet per year which accounts for about 80 percent of incoming flows of El Vado Reservoir. The other source of inflows are from Boulder Creek which is not gaged. The mean daily flow downstream of El Vado Dam is 421 cfs or 305,000 acre-feet per year. The current reservoir capacity at the top of conservation pool (6,902 feet) is 191,050 acre-feet which gives a Capacity versus Inflow ratio of approximately 0.63. The relatively small reservoir volume in comparison to the inflow suggests that trap efficiency of the reservoir is limited.

Table 1. Nearby Streams with USGS gages.

Stream Gage			Drainage Area (mi^2)	Mean Daily Flow (cfs)	Period of Record
Name	Operator	Number			
Rio Chama near La Puente, New Mexico	USGS	08284100	480	337	1955-10-01 to present
Heron Reservoir Outflow	Reclamation	N/A	193	140	2008-1-1 to present
Rio Chama below El Vado Dam, New Mexico	USGS	08285500	873	421	1935-10-30 to present

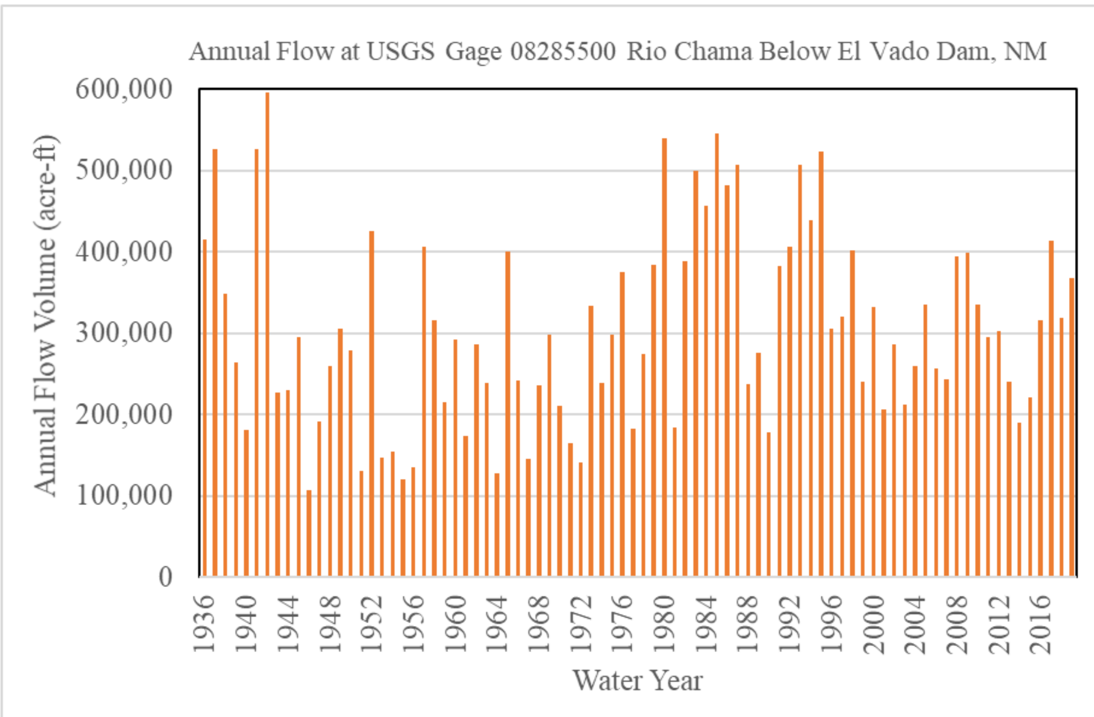


Figure 3. Historic annual outflow volume from El Vado Reservoir as recorded by USGS gage 08285500 Rio Chama below El Vado Dam, New Mexico.

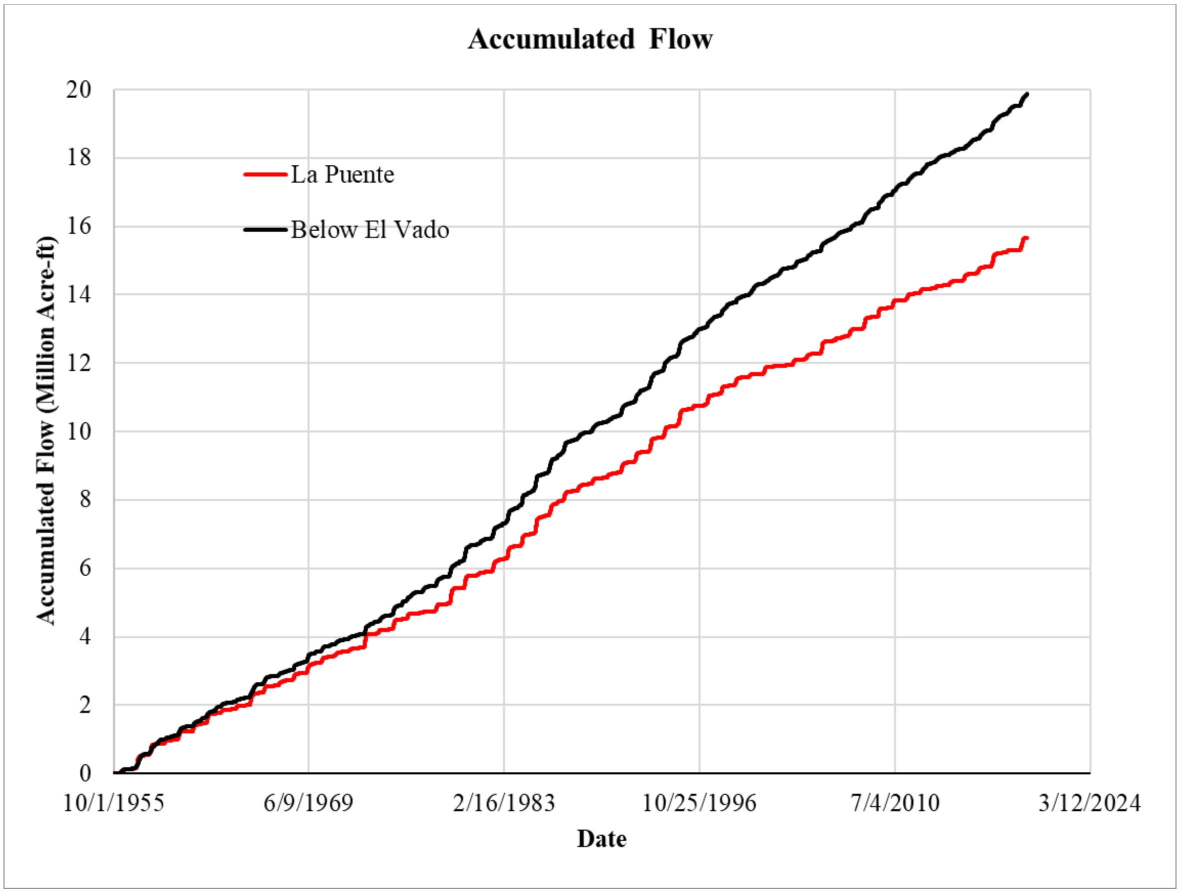


Figure 4. Cumulative flow volume upstream of the El Vado Reservoir as recorded by USGS gage 08284100 Rio Chama near La Puente, New Mexico and released from El Vado Reservoir as recorded by USGS gage 08285500 Rio Chama below El Vado Dam, New Mexico.

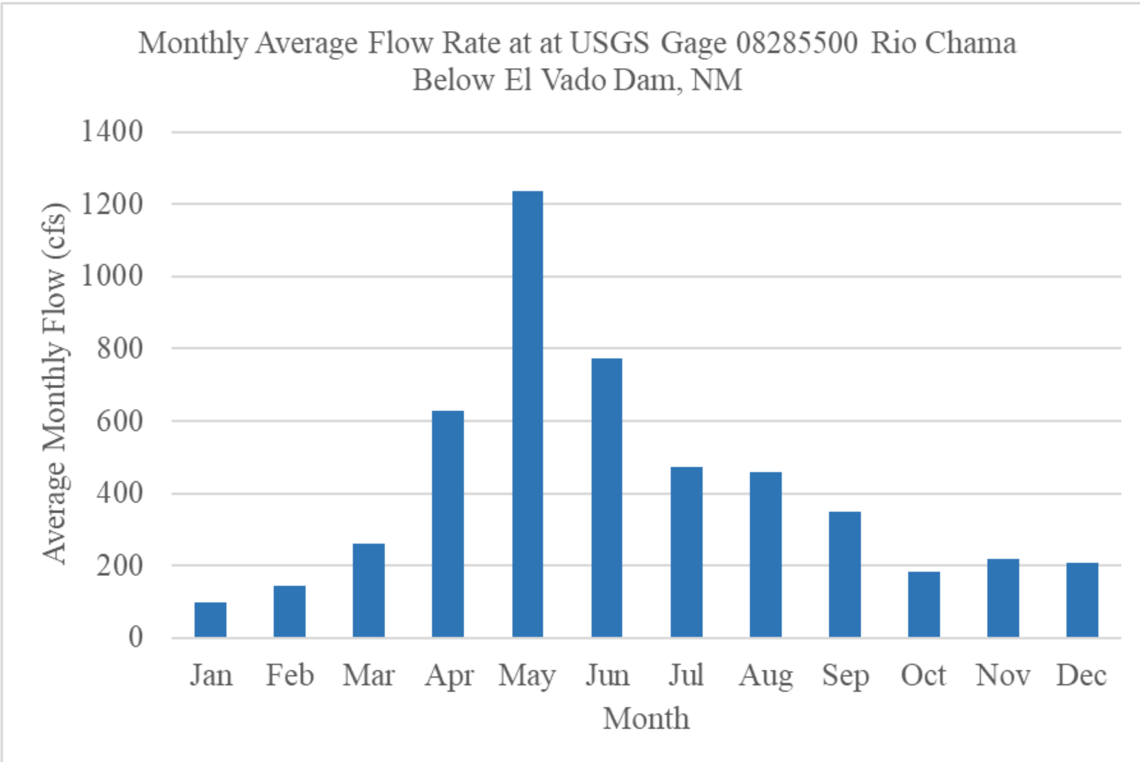


Figure 5. Historic Monthly Average Outflows from El Vado Reservoir as recorded by USGS gage 08285500 Rio Chama below El Vado Dam, New Mexico.

2.2. Dam Operations and Reservoir Characteristics

El Vado Dam is a rolled gravel filled dam with a steel membrane on the upstream face. It was built by the Middle Rio Grande Water Conservancy District in 1934-35 and rehabilitated by the Bureau of Reclamation in 1954-55. A new outlet works was installed by Reclamation to accommodate additional water for the San Juan-Chama Project that is diverted through the upstream located Heron Reservoir. The dam has a hydraulic height of 156.5 feet and a structure height of 175 feet. The crest of the dam has a length of 1,326 feet and elevation of 6,914.5 feet. The lower outlet elevation is 6,770 feet and has a capacity of 6,850 cfs at reservoir elevation 6,908.6 feet. A concrete lined spillway has a length of 36 feet and sill elevation of 6,879.0 feet, and is capable of releasing a flow of 17,800 cfs at a reservoir elevation of 6,908.6 feet.

El Vado Reservoir is part of the Middle Rio Grande Project that was designed to provide storage for irrigation, municipal water, and flood control. The reservoir's primary purpose is to provide storage for supplemental irrigation to the Middle Rio Grande Valley and San Juan-Chama Project water for irrigation, along with municipal and industrial uses. The 2018 survey determined that the reservoir has a total storage capacity of 214,091 acre-feet with a surface area of 3,602 acres at surcharge pool elevation 6,908.6 feet. The 2018 survey measured a minimum lake bottom elevation of 6,770 feet.

The following values are from the June 2018 capacity table:

- 23,041 acre-feet of surcharge pool storage between elevation 6,992.0 and 6,908.6 feet.
- 190,793 acre-feet of multiple use pool storage between elevation 6,775.0 and 6,902.0 feet.
- 257 acre-feet of dead pool storage below elevation 6,775.0 feet.

The historic reservoir water surface elevations (RPVD) are presented in Figure 6. The average annual reservoir water surface fluctuation is about 46 feet but the annual fluctuations can be as little as 7 feet or as great as 90 feet.

The reservoir has two major arms, 7.1 miles of Rio Chama and 4.6 miles of Boulder Creek. The width of each of the two arms varies between approximately 0.5 to 1 mile.

There is no record of past reservoir sediment management activities.

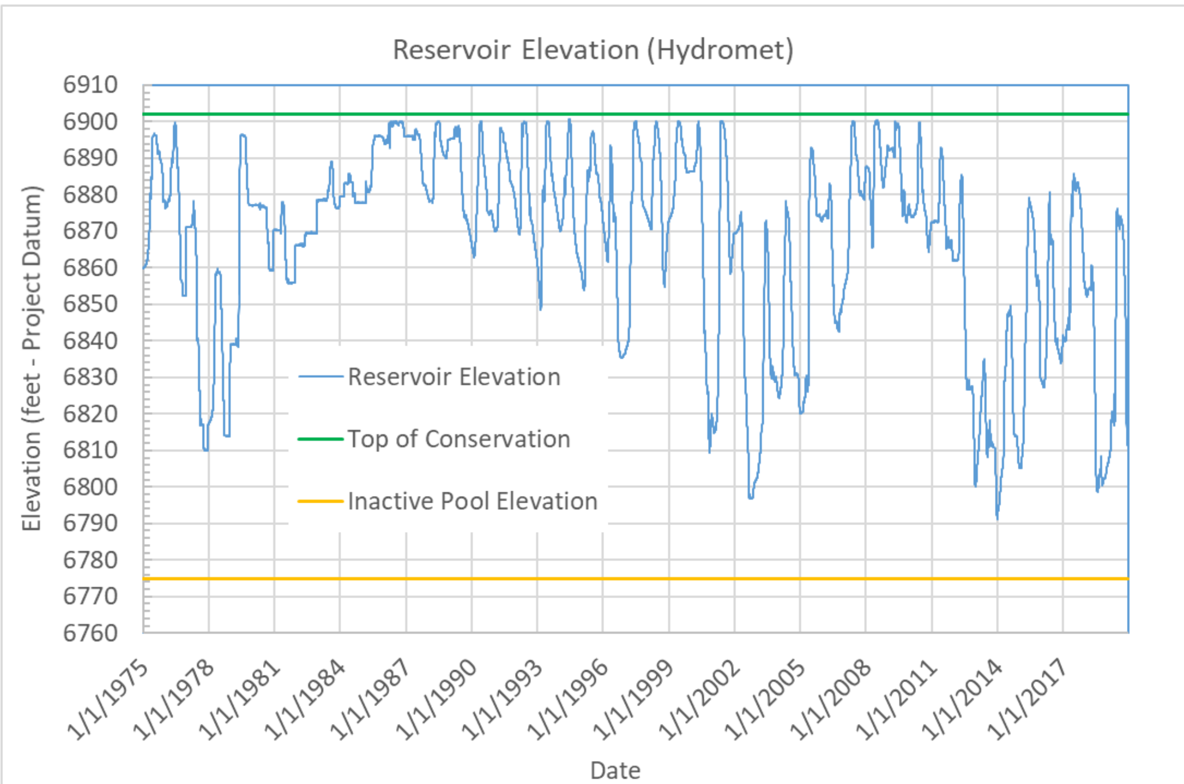


Figure 6. Historic El Vado Reservoir water surface elevations (project datum). Data web source: https://www.usbr.gov/uc/water.

3.Previous Reservoir Surveys

Prior to dam closure and initial reservoir filling, a survey was conducted in 1935. No documentation of the survey was found, and no area table was available. The capacity table is given in 10-foot intervals. No data between elevation 6,902.0 feet (Conservation Pool) and elevation 6908.6 feet (Surcharge Pool) were measured.

In 1944, a reservoir survey was conducted at 23 range lines, of which only 21 lines are currently identified. These range lines include 14 lines on the Rio Chama arm and 10 lines on the Boulder Creek arm; range lines 6, 7, and 8 cover both arms. No documentation of the survey was found. Area and capacity tables were given in 5-foot intervals. No data between elevation 6902.0 feet (Conservation Pool) and elevation 6908.6 feet (Surcharge Pool) was measured. Range line plots and locations are presented in the associated report, which is not found. The digital range line plots were recreated by digitizing the 1944 sedimentation range plots as presented in a 1987 Reclamation memorandum which is not found during the writing of this report.

In 1967, another reservoir survey was conducted. No documentation of the survey was found. Area and capacity tables given in 5-foot intervals and digital range line plots are available in the 2007 survey report (Ferrari, 2008) and associated files. No data between elevation 6902.0 feet (Conservation Pool) and elevation 6908.6 feet (Surcharge Pool) was measured.

A reservoir survey was conducted in 1984 and a 5-foot contour interval map was produced. Range line plots and locations were provided in the 1984 associated report, which is not available. The range lines followed the same locations of the 1944 survey. The range line plots were also digitalized in the same effort in the 1987 Reclamation memorandum. The 1984 contour map can be found in the 2007 survey report (Ferrari, 2008).

Another survey was conducted in June 2007 by the Sedimentation and River Hydraulics Group, Technical Service Center, Bureau of Reclamation (Ferrari, 2008). The underwater survey was conducted near reservoir elevation 6,900 feet, measured by the Reclamation gage at the dam. The bathymetric survey used sonar depth recording equipment interfaced with a RTK GPS for determining sounding locations within the reservoir. This survey used a multibeam depth sounder for most grid lines, however, due to time and budget limiations some of the reservoir areas were surveyed with a single beam depth sounder. Area and capacity tables in 5-foot intervals were created in the 2007 survey along with range line plots.

Table 2. Previous Bathymetric Reservoir Surveys

Survey Year	Extent of Survey	Survey Method	Depth Sounder	Above Water Survey
1935	Full	Surface mapping		
1944	Full	Range	NA	NA
1967	Full	N/A		
1984	Full	Surface mapping	NA	NA
2007	Full	Surface mapping	Multibeam and single beam	USGS contour map

Details on these previous surveys are described in Ferrari (2008).

4.Survey Control and Datum

For the 2018 survey, all bathymetry and GPS control measurements were collected in North American Datum 1983 (NAD 1983)(2011) State Plane (horizontal) coordinates, New Mexico Central Zone FIPS 3002, US survey feet and North American Vertical Datum 1988 (NAVD 1988, Geoid 12A, US survey feet elevations). During processing, all bathymetry and GPS measurements were converted to Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir. The RPVD was determined to be 7.8 feet lower than the NGVD 1929 and 12.0 feet lower than NAVD 1988 (Geoid 12A). The difference between NGVD 1929 and NAVD 1988 at El Vado Dam was computed using the US Army Corps of Engineers conversion program Corpscon v6.0.1. Corpscon uses NGS data and algorithms to convert between various horizontal projections and vertical datums (https://www.agc.army.mil/What-we-do/Corpscon/). The RPVD at El Vado Reservoir was determined from RTK GPS measurements of water surface elevations and comparing them to measured water stage at the dam.

All elevations in this report are presented in RPVD if not otherwise specified.

The GPS base station receiver was set up over a temporary monument located in the El Vado Lake State Park near the reservoir (Figure 7). State plane and elevation coordinates for the GPS base station were computed using the Online Positioning User Service (OPUS) developed by the National Geodetic Survey (NGS) (www.ngs.noaa.gov/OPUS/).

Figure 7. Location of GPS base station along El Vado Reservoir.

Table 3. GPS base location for El Vado Reservoir Survey.

State Plane Coordinates in US survey feet	Easting: 1496025.876	Northing: 2041750.165
Latitude and Longitude	Lat: N36°36'36.63072"	Long: W106°44'31.13369"

5. Methods Summary

A complete bathymetric survey was conducted from April 23 to 26, 2018 from a boat using a Teledyne® MB1 multibeam beam depth sounder to continuously measure water depths. The horizontal position of the moving boat was continually tracked using RTK GPS. A map of the data points collected is presented in Figure 8. The water surface elevation varied between 6860.46 to 6860.51 feet (RPVD) at the time of collection.

Appendix A provides more details of the hydrographic survey methods. These bathymetric data were combined with 2016 LiDAR data collected above water to produce a digital surface of the reservoir bottom surface.

Appendix B provides more details about above-the-water survey data.

Appendix C provides more details about the methods used to generate surface area and storage capacity tables.

Appendix D contains a contour map derived from the surface of the bathymetric and LiDAR data.

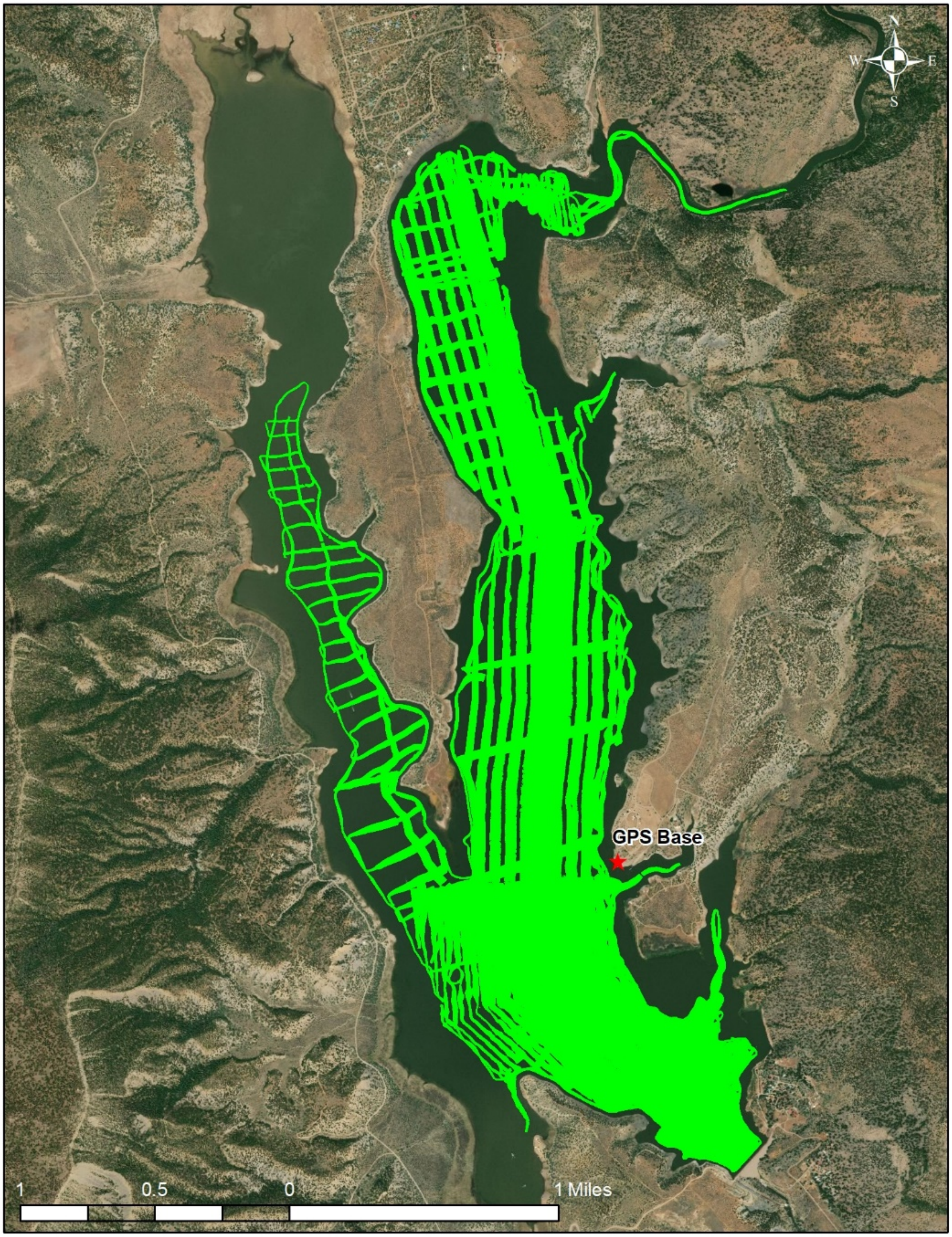


Figure 8. Map of bathymetric survey data coverage.

6. Reservoir Surface Area and Storage Capacity

Detailed tables of reservoir surface area and storage capacity for every 0.01 foot of elevation change were produced for the full range of reservoir elevations. Plots of the 2018 area and capacity curves are presented in Figure 9 along with curves from 1935, 1944, 1967, 1984, and 2007 surveys. No 1935 area curve is available. Between elevations 6,902 feet and 6,908.6 feet, no survey data were available in surveys prior to the 1984 survey. The original capacity values between elevations 6,902 feet and 6,908.6 feet were adjusted using 1984 survey results. For the 2018 survey, area and capacity are based on the bathymetric (below-water) survey up to the 6,855.5 feet elevation (5 feet below the water surface elevation during survey) data (RPVD), while area and capacity above this elevation are based on 2016 aerial LiDAR survey.

A summary of the elevation versus surface area table is given in Table 4 and a summary of the elevation versus capacity table is given in Table 5. The sedimentation volumes and rates since dam construction in 1935 are given in Table 6 and the sedimentation volumes and rates since other surveys are given in Table 7 through Table 10.

.

A comparison of the 2018 and 1935 data indicates that the sedimentation volume was 7,189 acre-feet below the top of surcharge pool (6,908.6 feet) and 7,152 acre-feet below the top of the conservation pool (6902.0 feet) since construction in 1935. The average sedimentation rate over this 83-year period is 86.6 acre-feet/year below the top of surcharge pool and 86.2 acre-feet/year below the top of the conservation pool. The total percent capacity lost below the top of surcharge pool is 3.3 percent.

2018 survey showed an increase in the conservation pool and surcharge pool volumes since 2007 survey. The increased storage capacity was also reported from 1984 to 2007 in Ferrari, 2008. Ferrari (2008) contributed the increased storage capacity partially to the uncertainty introduced from the unknown quality of the previous survey data. Since the 2007 survey used both single beam and multibeam depth sounders, and the 2018 survey used only multibeam, uncertainty exists in the comparison of 2007 and 2018 surveys. However, it is likely that the reservoir capacity did increase from 2007 to 2018 due to lower operation pool level. Because the reservoir was drawdown to below 6790 feet in 2014, which is its lowest level since 1975, it is likely that significant amounts of sediment were evacuated from the reservoir. The reservoir was also relatively low from 2012 to 2015 because of drought conditions, which would limit the amount of sedimentation occurring during this period.

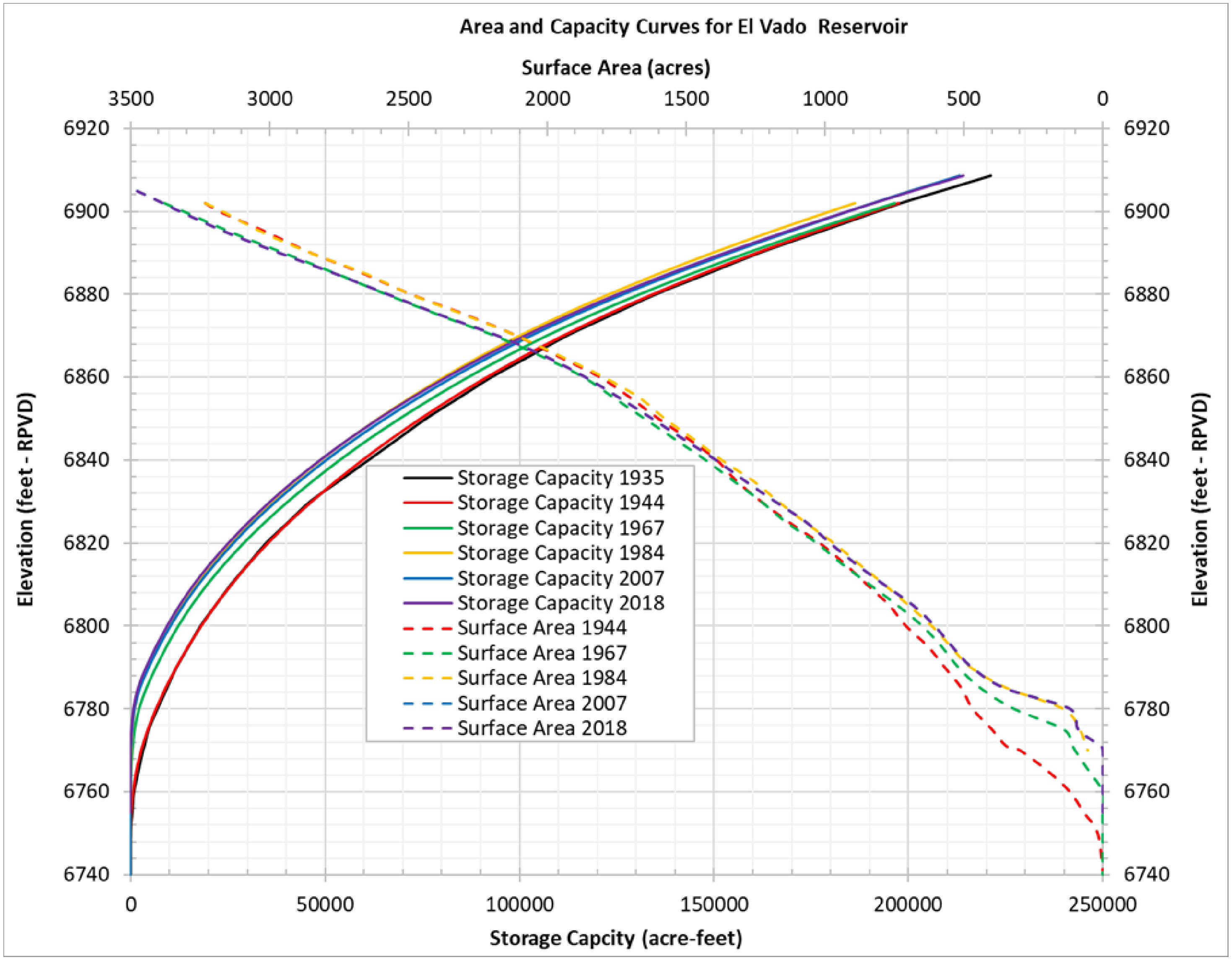


Figure 9. Plot of El Vado Reservoir surface area and storage capacity versus elevation (Project Datum).

Table 4. Elevation versus Area Table.

Survey date	1944	1967	1984	2007	2018
Vertical Datum	RPVD	RPVD	RPVD	RPVD	RPVD
Elevation (ft)	Area (acre)	Area (acre)	Area (acre)	Area (acre)	Area (acre)
6,908.6	-	-	-	3,517	3,602
6,905	-	-	-	3,361	3,479
6,902	3,230	3,380	3,232	3,232	3,384
6,900	3,180	3,310	3,170	3,136	3,323
6,895	3,010	3,140	3,027	3,051	3,157
6,890	2,850	2,950	2,853	2,927	2,965
6,885	2,660	2,760	2,655	2,744	2,764
6,880	2,490	2,580	2,493	2,563	2,574
6,875	2,290	2,390	2,296	2,369	2,384
6,870	2,110	2,190	2,111	2,166	2,178
6,865	1,960	2,020	1,950	2,000	2,006
6,860	1,810	1,870	1,797	1,856	1,863
6,855	1,700	1,760	1,668	1,739	1,739
6,850	1,600	1,650	1,578	1,630	1,622
6,845	1,490	1,540	1,473	1,517	1,508
6,840	1,390	1,430	1,373	1,399	1,393
6,835	1,320	1,330	1,260	1,296	1,289
6,830	1,230	1,230	1,169	1,200	1,179
6,825	1,130	1,140	1,073	1,082	1,067
6,820	1,020	1,030	970	985	982
6,815	930	940	880	903	890
6,810	850	840	788	809	789
6,805	770	740	701	715	684
6,800	710	650	617	631	605
6,795	630	580	548	557	542
6,790	570	520	477	497	472
6,785	510	440	346	386	354
6,780	470	320	144	165	119
6,775	349	140	84	92	89
6,771	-	-	-	-	7
6,770	300	100	56	38	0
6,765	200	50	-	-	-
6,760	120	0	-	-	-
6,755	70	0	-	-	-
6,750	20	0	-	-	-
6,740	0	0	-	-	-

*values calculated using 2001 areas above 1050 feet.

Table 5. Elevation versus Capacity Table

Survey date	1935 (Original)	1944	1967	1984	2007	2018
Vertical Datum	RPVD	RPVD	RPVD	RPVD	RPVD	RPVD
Elevation	Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)	Volume (acre-ft)
6,908.6	221,280	-	-	-	213,090	214,091
6,905	-	-	-	-	200,710	201,341
6,902	198,202	197,533	196,500	186,252	190,820	191,050
6,900	-	191,154	189,810	179,849	184,452	184,343
6,895	-	175,719	173,690	164,358	168,983	168,127
6,890	161,750	161,019	158,470	149,658	154,009	152,815
6,885	-	147,155	144,210	135,887	139,820	138,489
6,880	135,053	134,286	130,850	123,017	126,565	125,164
6,875	-	122,285	118,430	111,044	114,202	112,746
6,870	112,194	111,253	107,000	100,026	102,868	101,354
6,865	-	101,044	96,490	89,873	92,464	90,900
6,860	92,808	91,649	86,770	80,506	82,830	81,242
6,855	-	82,825	77,690	71,843	73,849	72,236
6,850	75,979	74,618	69,160	63,727	65,436	63,843
6,845	-	66,886	61,180	56,098	57,569	56,015
6,840	61,183	59,680	53,770	48,982	50,276	48,756
6,835	-	52,912	46,880	42,399	43,552	42,068
6,830	46,183	46,603	40,480	36,328	37,314	35,916
6,825	-	40,729	34,540	30,725	31,598	30,305
6,820	34,886	35,358	29,110	25,619	26,448	25,185
6,815	-	30,455	24,180	20,992	21,718	20,493
6,810	25,788	26,005	19,730	16,828	17,437	16,297
6,805	-	21,904	15,770	13,106	13,633	12,622
6,800	17,987	18,191	12,290	9,810	10,273	9,405
6,795	-	14,805	9,240	6,897	7,310	6,549
6,790	11,793	11,765	6,510	4,333	4,667	4,007
6,785	-	9,015	4,100	2,275	2,422	1,912
6,780	6,924	6,577	2,190	1,051	1,006	753
6,775	4,619	4,472	1,060	480	424	257
6,771	-	-	-	-	-	4
6,770	3,182	2,765	490	129	41	0
6,765	-	1,502	130	-	-	-
6,760	855	691	-	-	-	-
6,755	-	210	-	-	-	-
6,750	23	23	-	-	-	-
6,740	0	-	0	-	-	-

Table 6. Sedimentation in Various Reservoir Storage Zones Between 1935 and 2018.

Storage Allocation Zone	Elevation (ft)	Sedimentation Within Zone (acre-ft)	Percent of Volume Lost Within Zone (%)	Cumulative Sedimentation (acre-ft)	Cumulative Annual Rate (acre-ft/yr)
SURCHARGE	6,908.60	37	0.5	7,189	86.6
FLOOD CONTROL					
CONSERVATION	6,902	2,790	38.8	7,152	86.2
INACTIVE	6,775	4,362	60.7	4,362	52.6

Table 7. Sedimentation in Various Reservoir Storage Zones Between 1944 and 2018.

Storage Allocation Zone	Elevation (ft)	Sedimentation Within Zone (acre-ft)	Percent of Volume Lost Within Zone (%)	Cumulative Sedimentation (acre-ft)	Cumulative Annual Rate (acre-ft/yr)
SURCHARGE	6,908.60				
FLOOD CONTROL					
CONSERVATION	6,902	2,268	35.0	6,483	87.6
INACTIVE	6,775	4,215	65.0	4,215	57.0

Table 8. Sedimentation in Various Reservoir Storage Zones Between 1967 and 2018.

Storage Allocation Zone	Elevation (ft)	Sedimentation Within Zone (acre-ft)	Percent of Volume Lost Within Zone (%)	Cumulative Sedimentation (acre-ft)	Cumulative Annual Rate (acre-ft/yr)
SURCHARGE	6,908.60				
FLOOD CONTROL					
CONSERVATION	6,902	4,647	85.3	5,450	106.9
INACTIVE	6,775	803	14.7	803	15.7

Table 9. Sedimentation in Various Reservoir Storage Zones Between 1984 and 2018.

Storage Allocation Zone	Elevation (ft)	Sedimentation Within Zone (acre-ft)	Percent of Volume Lost Within Zone (%)	Cumulative Sedimentation (acre-ft)	Cumulative Annual Rate (acre-ft/yr)
SURCHARGE	6,908.60	37		-4,761	-140.0
FLOOD CONTROL					
CONSERVATION	6,902	-5,021		-4,798	-141.1
INACTIVE	6,775	223		223	6.6

Table 10. Sedimentation in Various Reservoir Storage Zones Between in 2007 and 2018.

Storage Allocation Zone	Elevation (ft)	Sedimentation Within Zone (acre-ft)	Percent of Volume Lost Within Zone (%)	Cumulative Sedimentation (acre-ft)	Cumulative Annual Rate (acre-ft/yr)
SURCHARGE	6,908.6	-771		-1,001	-91.0
FLOOD CONTROL					
CONSERVATION	6,902	-397		-230	-20.9
INACTIVE	6,775	167		167	15.2

7. Reservoir Sedimentation Volume Spatial Distribution

Longitudinal profiles and representative cross sections of the 2018 reservoir bottom surface were developed in GIS along the alignments presented in Figure 10, Figure 11, and Figure 12 shows the reservoir profile in both Rio Chama and Boulder Creek arms. Reservoir cross section plots (Figure 13 through Figure 35) show the lateral distribution of sedimentation.

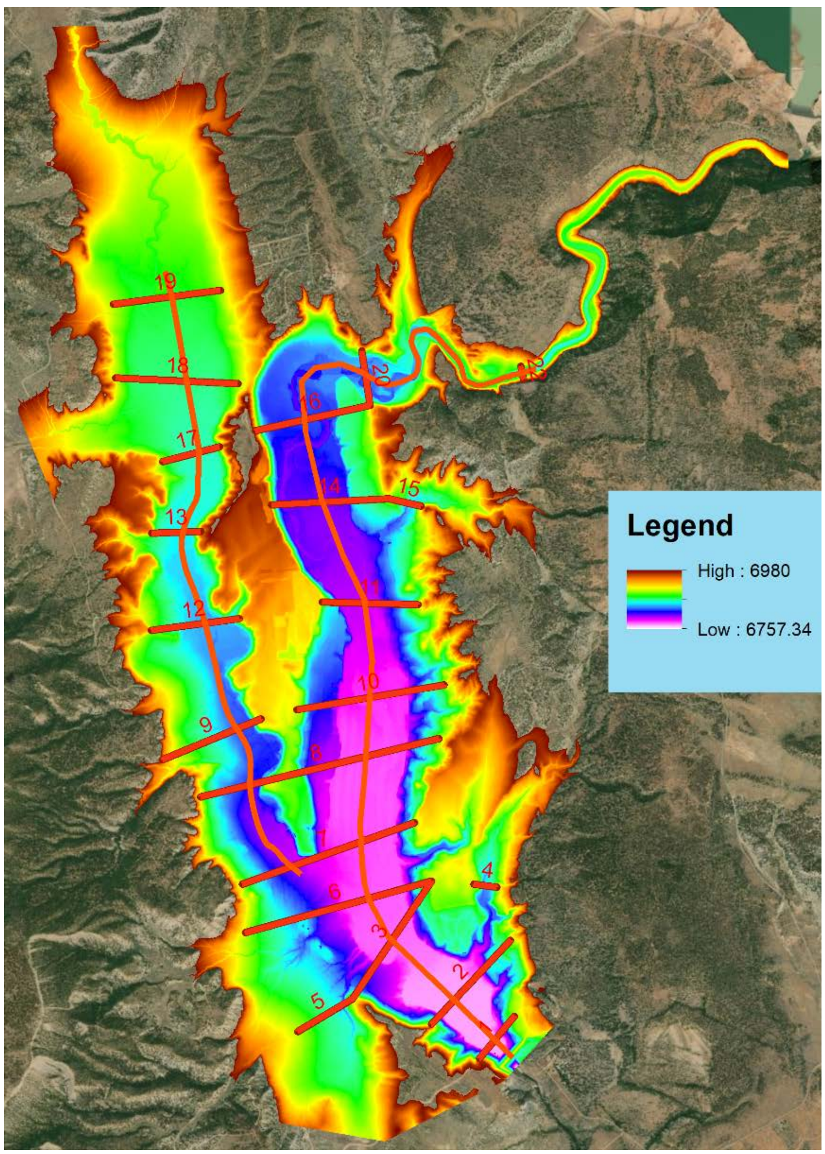


Figure 10. Reservoir surface elevation map and alignments of longitudinal profiles and representative cross sections.

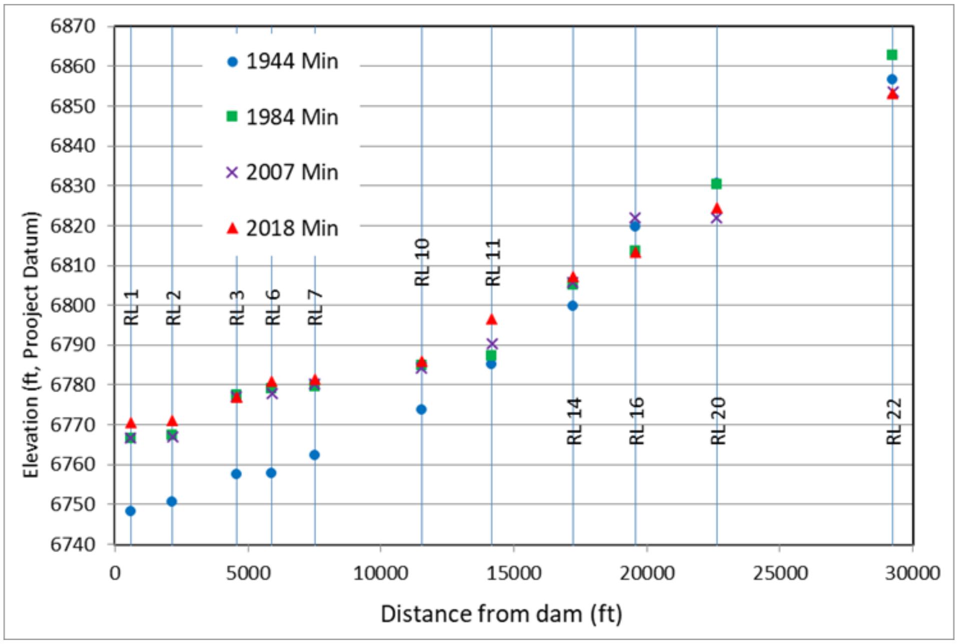


Figure 11. Longitudinal profile of El Vado Reservoir bottom in the Rio Chama arm.

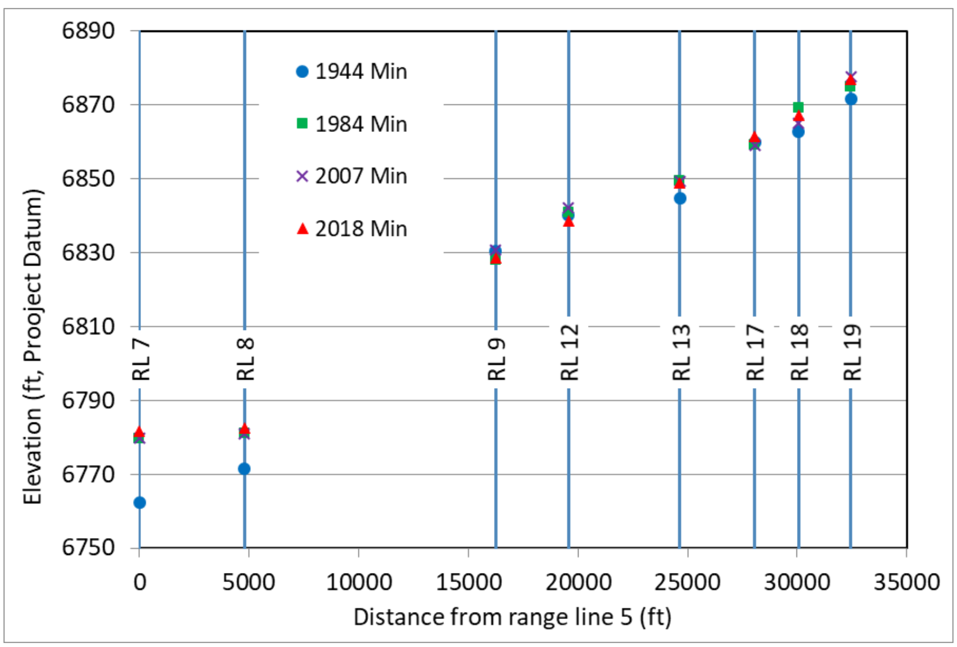


Figure 12. Longitudinal profile of El Vado Reservoir bottom in the Boulder Creek arm.

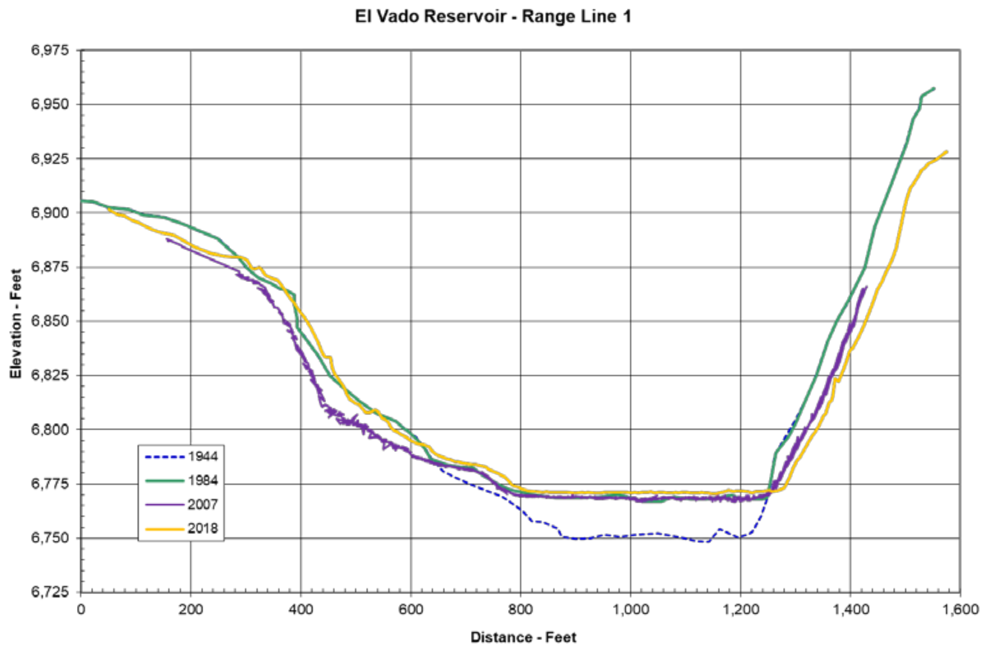


Figure 13. Range Line 1, Rio Chama.

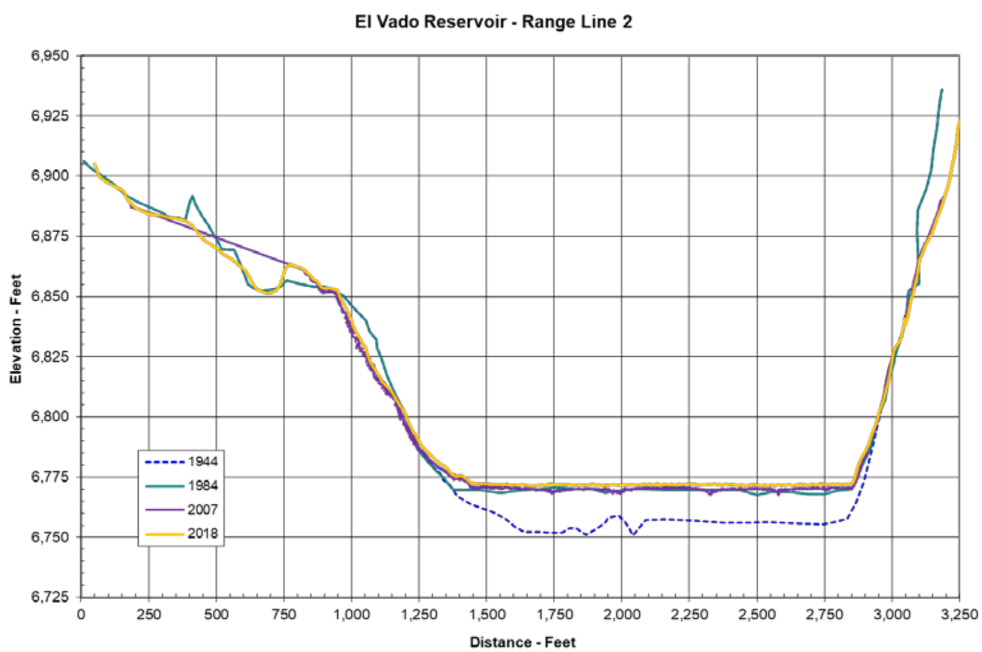


Figure 14. Range Line 2, Rio Chama.

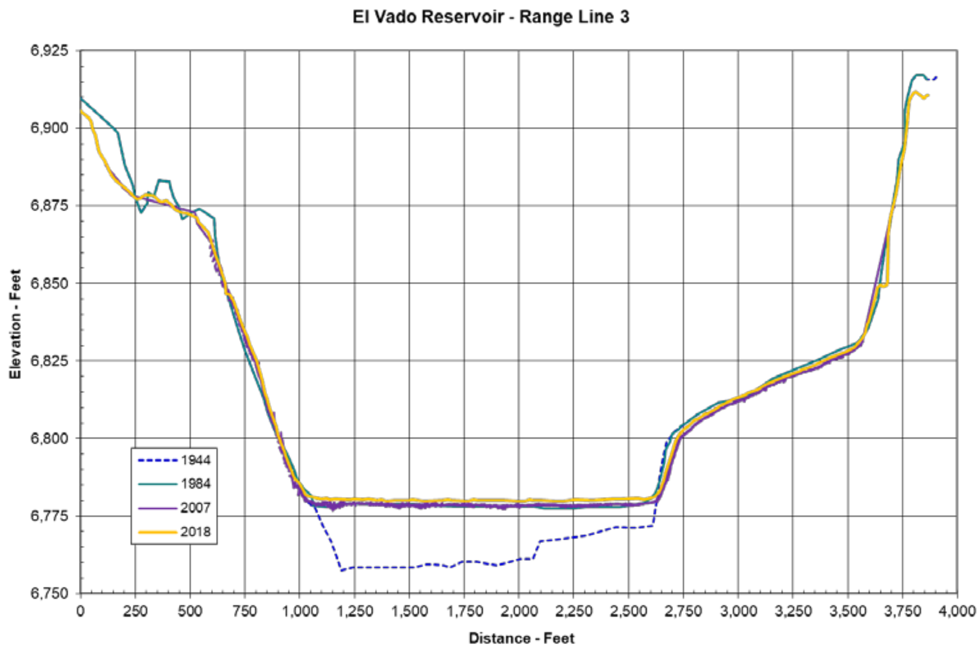


Figure 15. Range Line 3, Rio Chama.

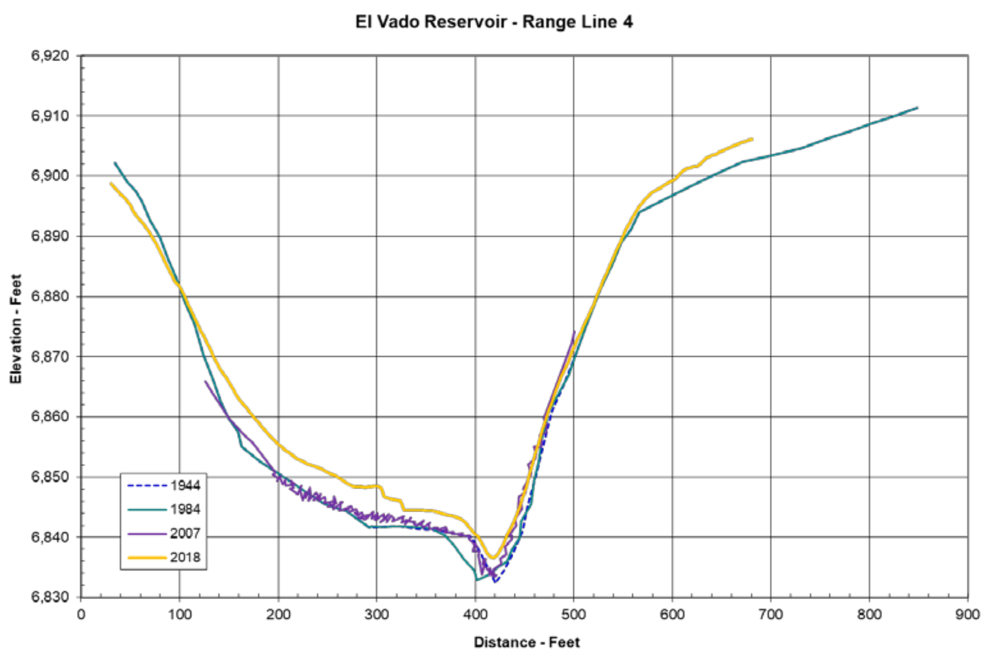


Figure 16. Range Line 4, Rio Chama.

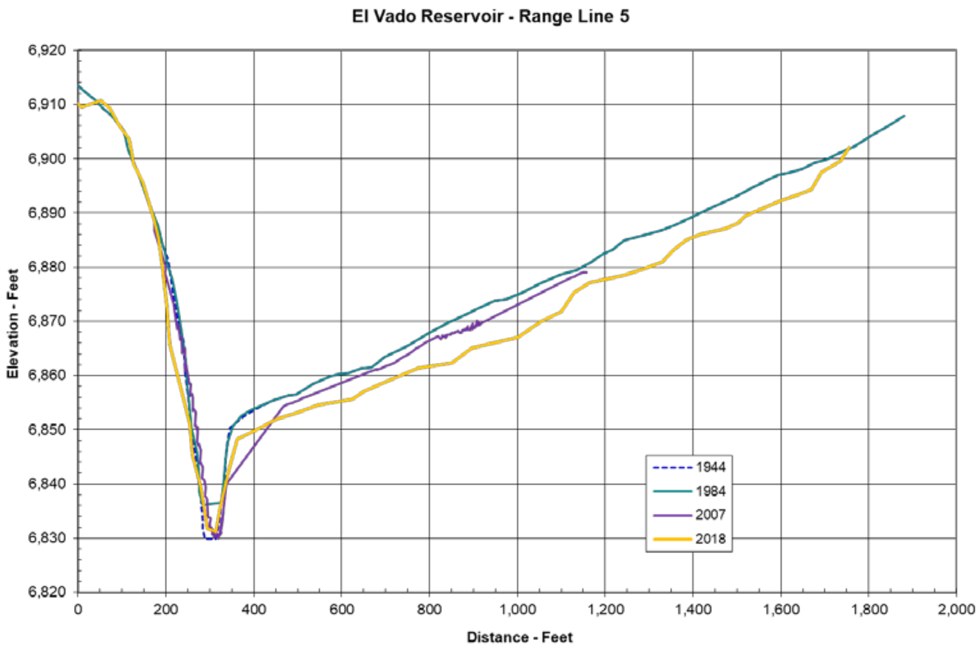


Figure 17. Range Line 5, Rio Chama.

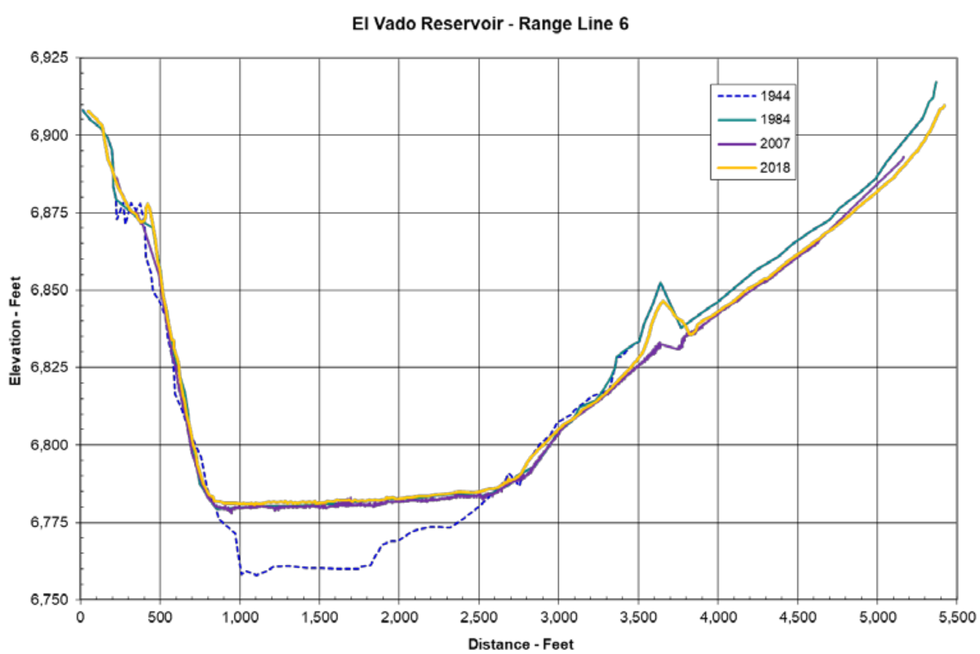


Figure 18. Range Line 6, Rio Chama.

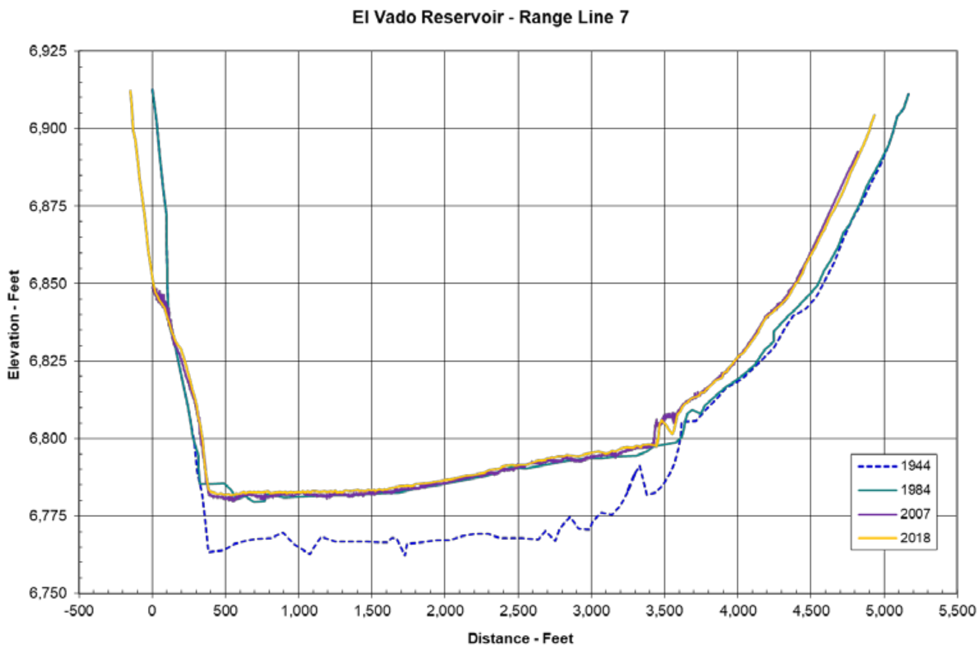


Figure 19. Range Line 7, Rio Chama

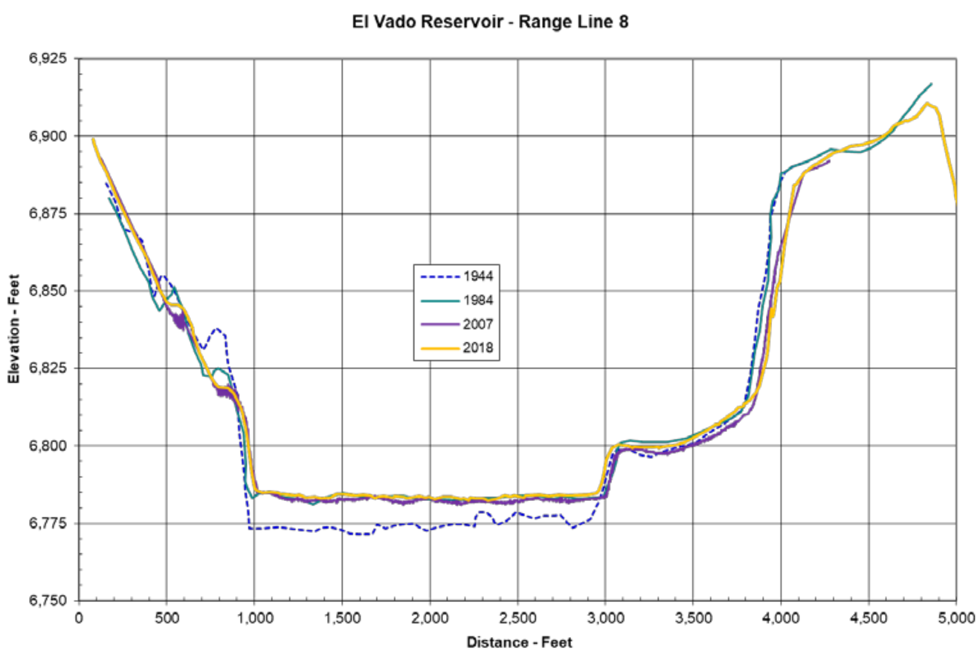


Figure 20. Range Line 8, Rio Chama.

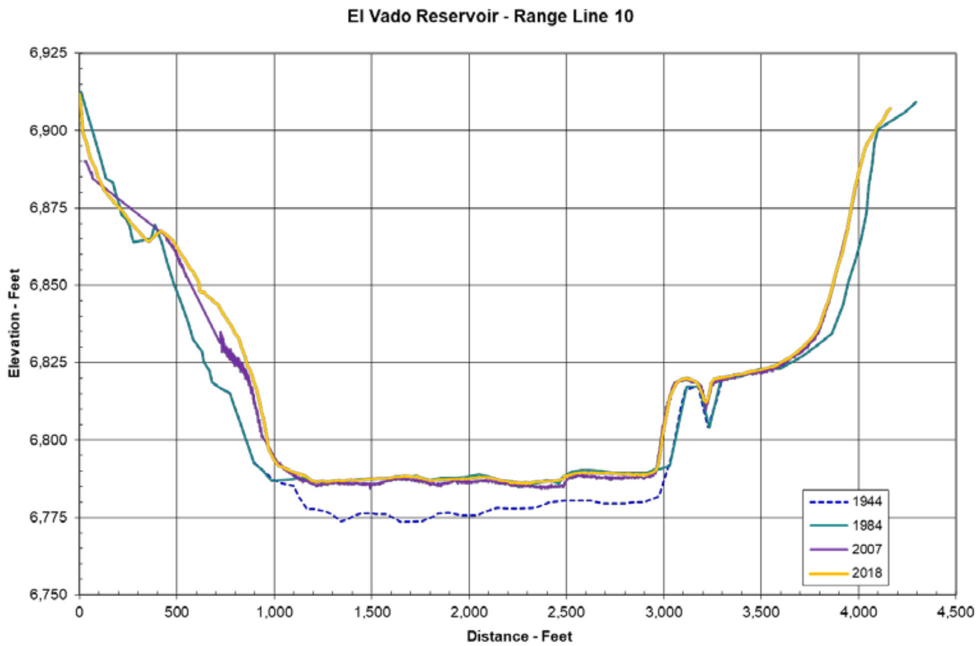


Figure 21. Range Line 10, Rio Chama.

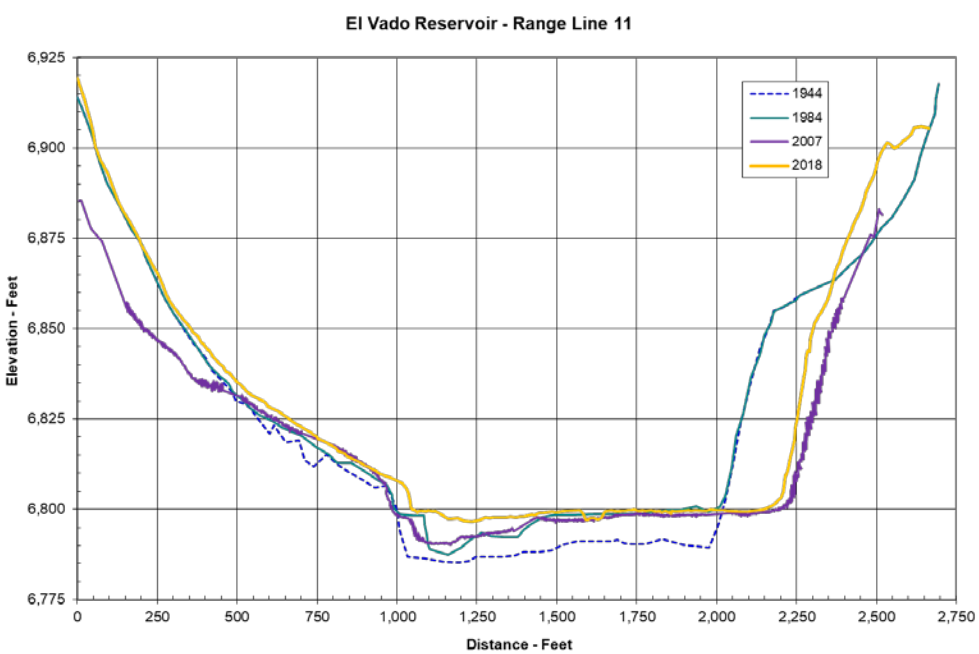


Figure 22. Range Line 11, Rio Chama.

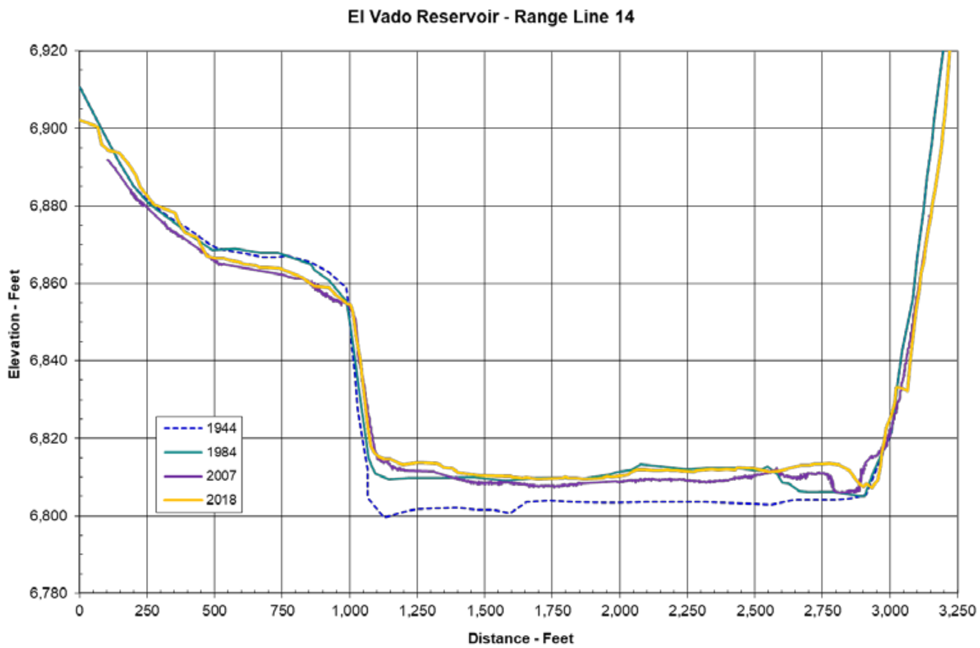


Figure 23. Range Line 14, Rio Chama.

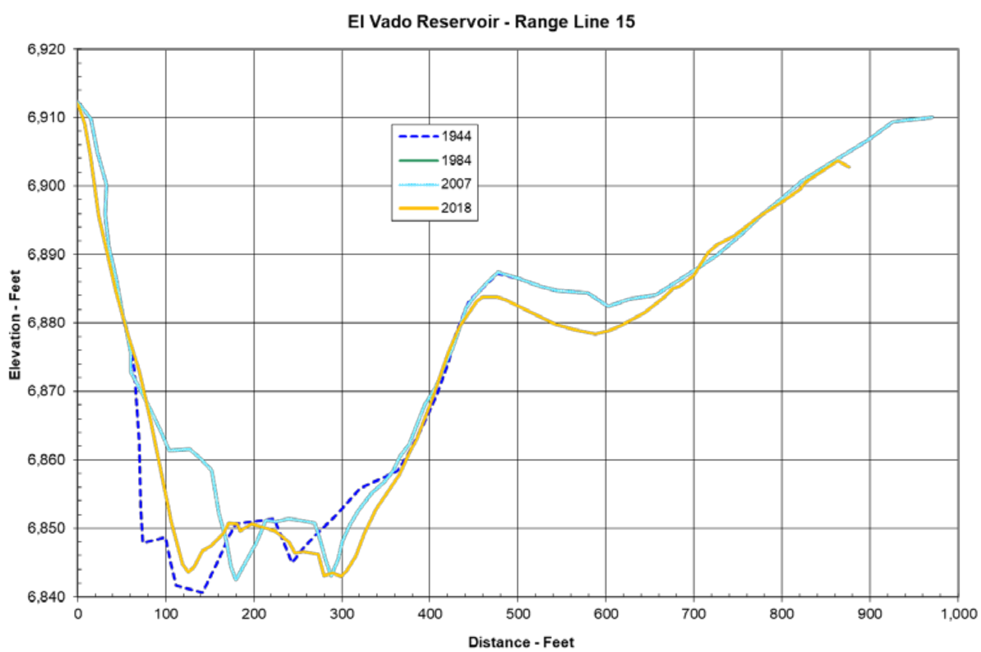


Figure 24. Range Line 15, Rio Chama.

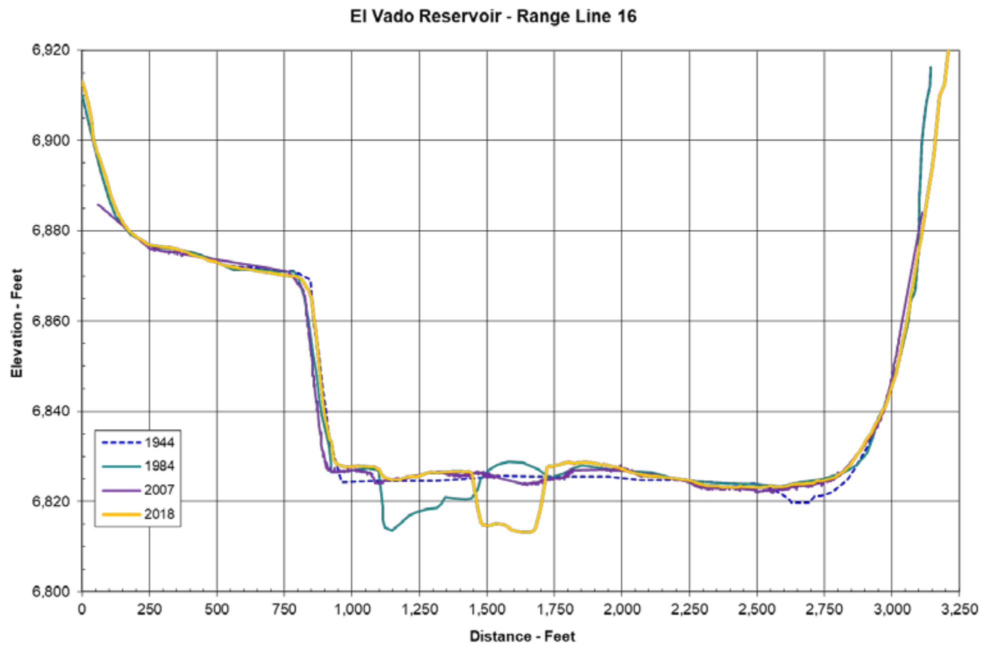


Figure 25. Range Line 16, Rio Chama.

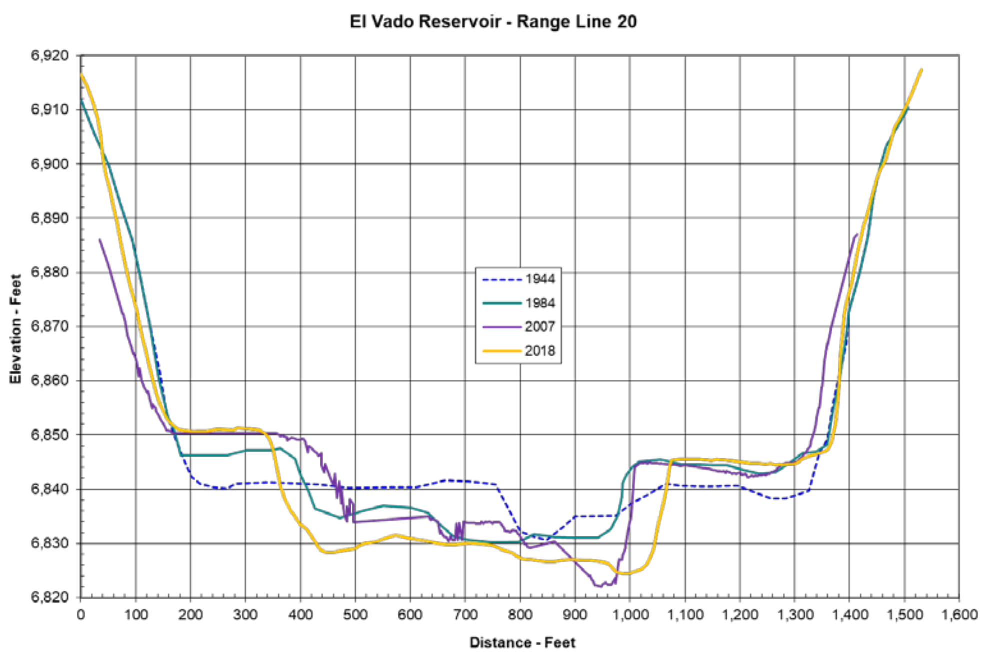


Figure 26. Range Line 20, Rio Chama.

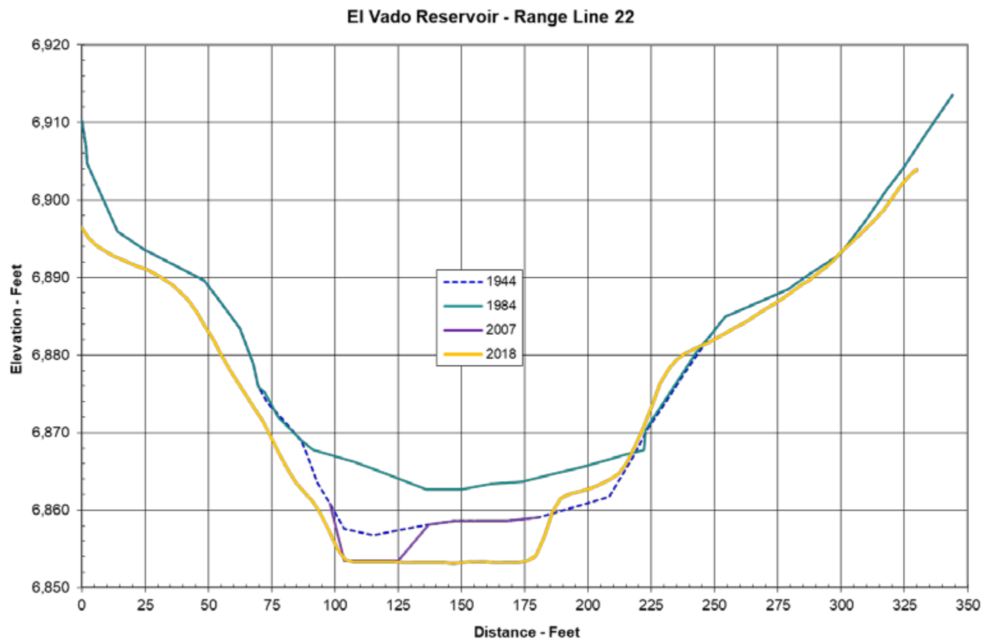


Figure 27. Range Line 22, Rio Chama.

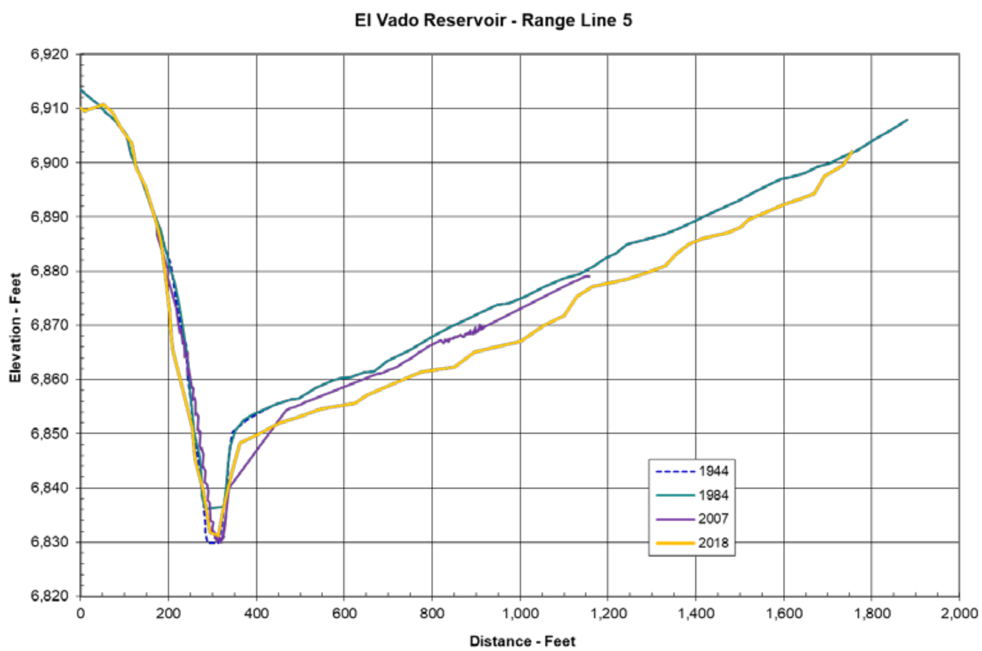


Figure 28. Range Line 5, Boulder Creek.

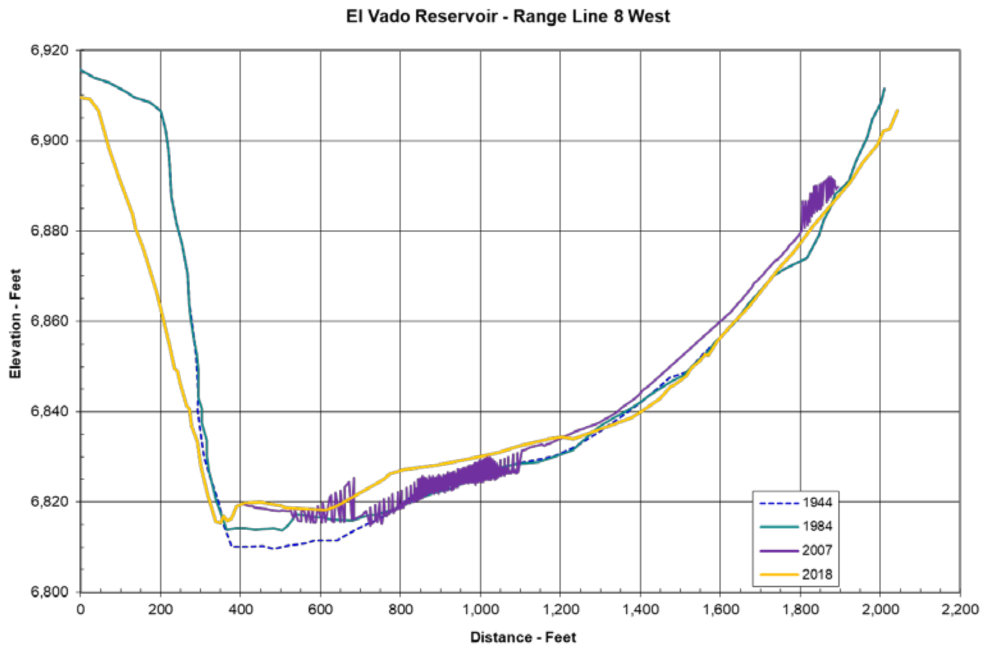


Figure 29. Range Line 8, Boulder Creek.

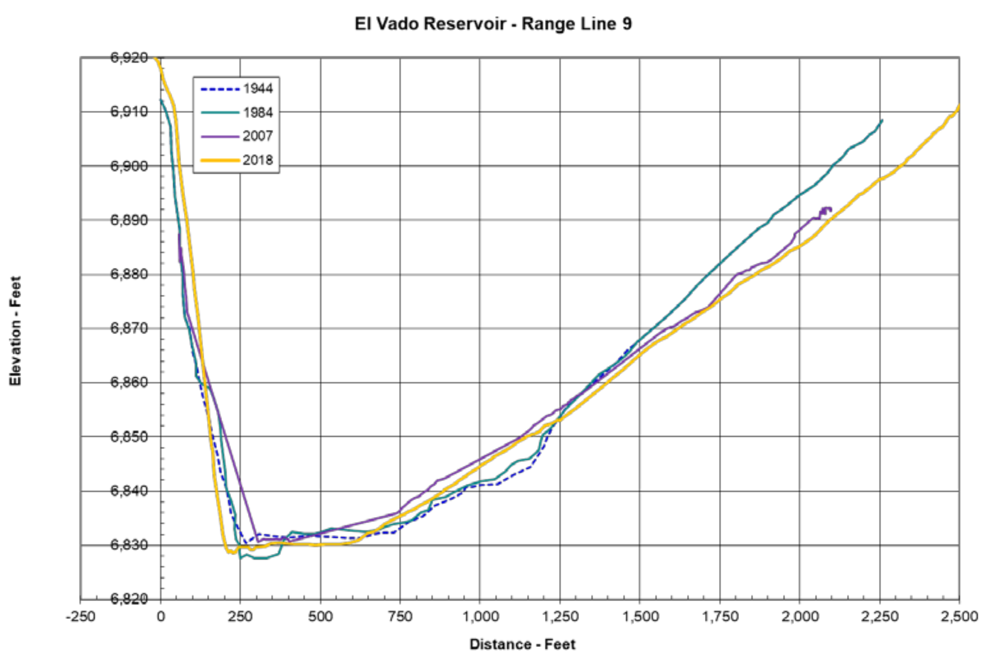


Figure 30. Range Line 9, Boulder Creek.

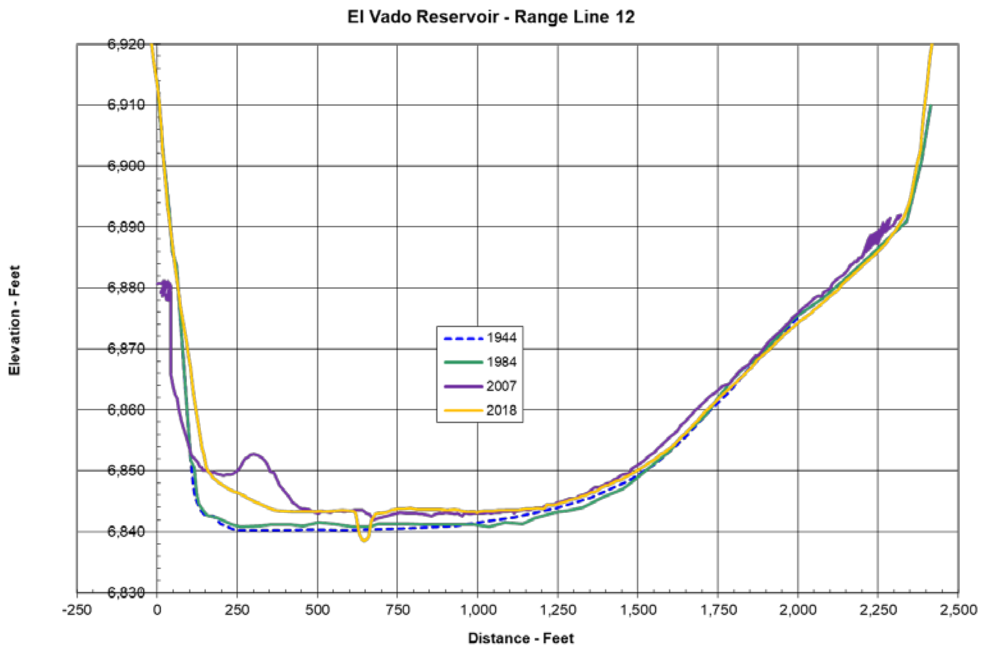


Figure 31. Range Line 12, Boulder Creek.

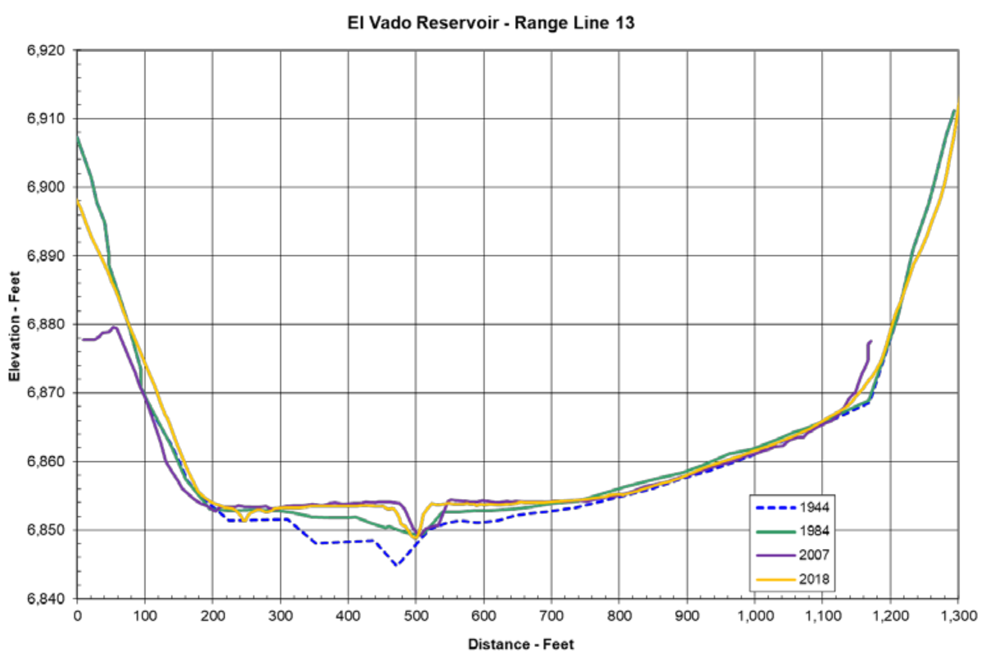


Figure 32. Range Line 13, Boulder Creek.

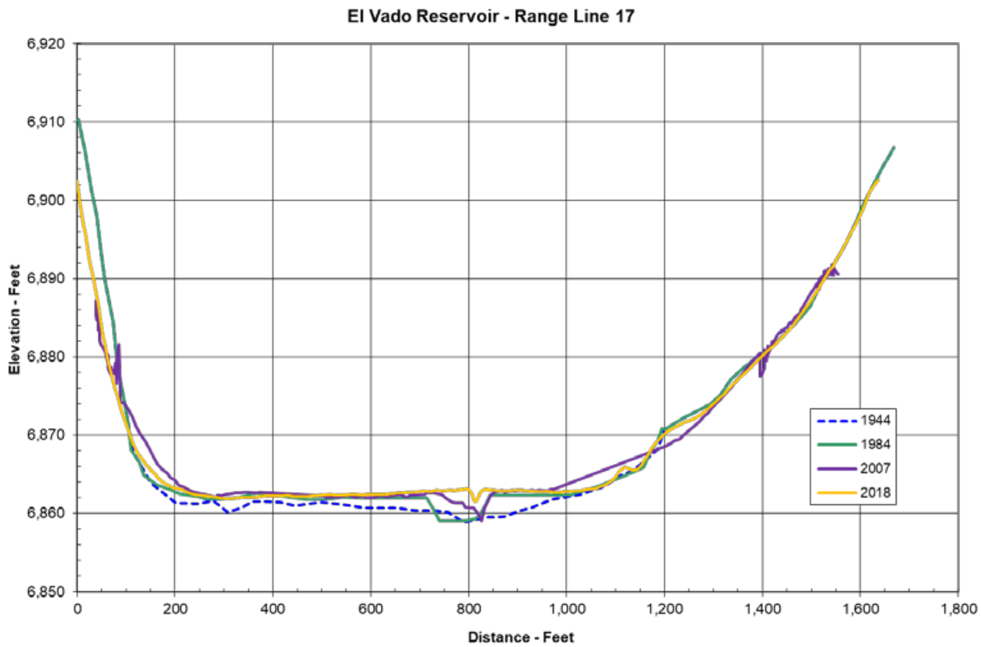


Figure 33. Range Line 17, Boulder Creek.

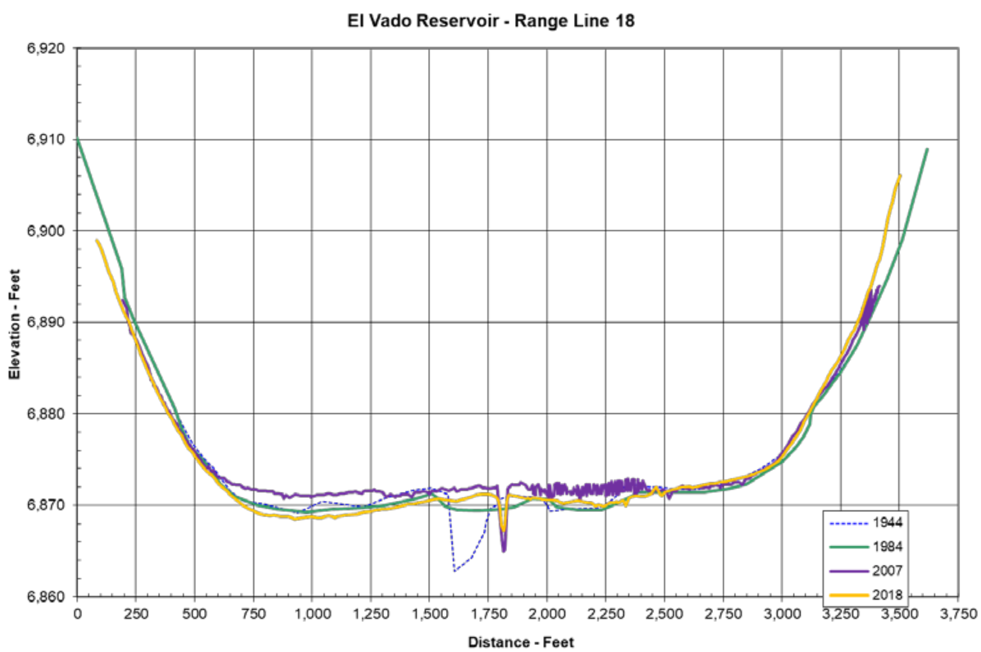


Figure 34. Range Line 18, Boulder Creek.

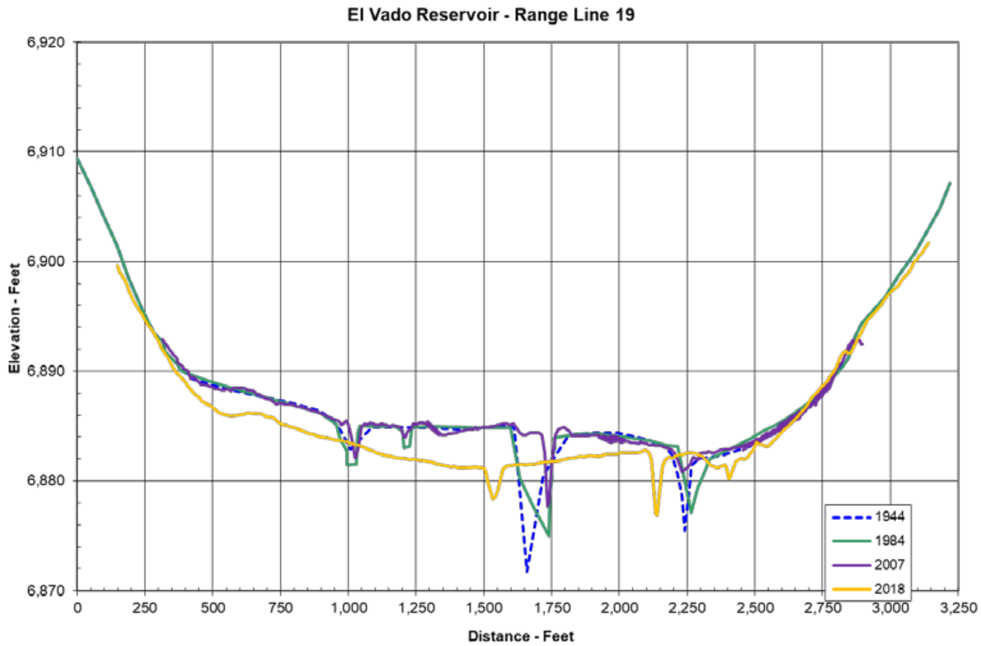


Figure 35. Range Line 19, Boulder Creek.

8. Conclusions and Recommendations

8.1. Survey Methods and Data Analysis

The 2018 bathymetric survey, combined with 2016 LiDAR data of the above-water topography, has been used to produce an accurate digital surface of the reservoir bottom. Surface areas at 1-foot contour intervals were computed using GIS software and the computer program the was used to produce the reservoir surface area and capacity tables at 0.01-foot increments. The difference in reservoir surfaces over time can be attributed to sedimentation, but also the differences in survey methods. The latest surface area and storage capacity curves compare reasonably well with the original curves and with curves from previous surveys.

8.2. Sedimentation Progression and Location

Since the original filling of the reservoir in 1935, the reservoir is estimated to have lost 7,189 acre-feet of storage capacity (3.3 percent) due to sedimentation. This volume represents a sedimentation rate of 86.6 acre-feet per year (acre-feet/year).

Since the last reservoir survey in 2007, the storage capacity under the reservoir inactive elevation (6,775 feet) is estimated to have lost 167 acre-feet of storage capacity, however the storage under the surcharge elevation (6,908.6 feet) is estimated to have gained 1,001 acre-feet of storage capacity. Because the reservoir was drawdown to below 6790 feet in 2014, which is its lowest level since 1975, it is likely that significant amounts of sediment were evacuated from the reservoir. The reservoir was also relatively low from 2012 to 2015 because of drought conditions, which would limit the amount of sedimentation occurring during this period.

At the top of surcharge elevation (6,908.6 feet, RPVD), the reservoir would have a surface area of 3,602 acres and a storage capacity of 214,091 acre-feet.

8.3. Recommendation for Next Survey

The frequency of survey is partially dependent upon the risks imposed by loss of capacity and loss of operational flexibility. The annual loss of reservoir capacity is relatively low; the reservoir, however, has lost most of its inactive storage. Currently only 257 acre-feet of inactive storage (below elevation 6,775 feet) is left out of original about 4,619 acre-feet. The sediments have moved to the dam up to the level equivalent to the lower outlet elevation (6,770 feet). There is a potential that the outlet could be blocked by sediment and debris. Another survey is recommended by 2028, approximately 10 years after the last one.

References

Ferrari, R. L., 2008. El Vado Reservoir 2007 Sedimentation Survey. Sedimentation and River Hydraulics Group, Technical Service Center, Bureau of Reclamation, Denver, Colorado

Reclamation, 2004. Hydrologic Hazard, El Vado Dam New Mexico. Flood Hydrology and Meteorology Group, Technical Service Center, Bureau of Reclamation, Denver, Colorado.

Reclamation, 2006. Erosion and Sedimentation Manual. Sedimentation and River Hydraulics Group, Technical Service Center, Bureau of Reclamation, Denver, Colorado

Appendix A — Hydrographic Survey Equipment and Methods

Appendix A – Hydrographic Survey Equipment and Methods

The 2018 bathymetric survey was conducted from April 23 through 26, 2018. During this period, reservoir water surface elevations varied between 6860.46 and 6860.51 feet (RPVD).

The survey was conducted along a series of predetermined cross section, longitudinal, and shoreline survey lines (Figure 8). The survey lines were spaced closely enough so there would overlapping coverage from the multibeam depth sounder or close enough that liner interpolation between survey lines would be adequate.

The survey employed an 18-foot, flat-bottom aluminum Wooldridge boat powered by outboard jet and kicker motors (Figure 36). Reservoir depths were measured using a multibeam echo sounder system which consisted of the following equipment:

- variable-frequency transducer with integrated motion reference unit,
- near-surface sound velocity probe,
- two GPS receivers to measure the boat position and heading,
- an external GSP radio,
- processor box for synchronization of all depth, sound velocity, position, heading, and motion sensor data, and
- laptop with hydrographic surveying software to integrate and store the bathymetry data.

Figure 36. Wooldridge boat with RTK-GPS and multibeam depth sounder system.

The multibeam transducer emits up to 512 beams (user selectable) capable of projecting a swath width up to 120 degrees in 390 feet (120 meters) of water. Sound velocity profiles were collected over the full water depth at various locations throughout the reservoir. These sound velocity profiles measure the speed of sound through the water column, which can be affected by multiple characteristics such as water temperature and salinity. These sound velocity profiles were used to calibrate the depth sounder during post-processing.

RTK GPS survey instruments were used to continuously measure the survey boat position and measure other ground control points. The GPS base receiver was set up on a tripod over a point overlooking the reservoir (Figure 7). The coordinates of this point were computed using the Online Positioning User Service (OPUS) developed by the National Geodetic Survey (NGS) (www.ngs.noaa.gov/OPUS/). During the survey, position corrections were transmitted to the GPS rover receiver using an external GPS radio and UHF antenna (Figure 37). The base station was powered by a 12-volt battery.

Figure 37. The RTK-GPS base station set-up used during the survey El Vado Reservoir in New Mexico is typical of the set up used for other reservoir surveys.

The GPS rover receivers include an internal or external radio and external antenna mounted on a range pole (ground survey) or survey vessel (bathymetric survey). The rover GPS units receive the same satellite positioning data as the base station receiver, and at the same time. The rover units also receive real-time position correction information from the base station via radio transmission. This allows rover GPS units to measure accurate positions with precisions of

±2 cm horizontally and ±3 cm vertically for stationary points. Positions measured on a moving survey vessel are less accurate.

During the survey, a laptop computer was connected to the GPS rover receivers and echo sounder system. Corrected positions from one GPS rover receiver and measured depths from the multibeam transducer were transmitted to the laptop computer through cable connections to the processor box. Using real-time GPS coordinates, the HYPACK software provided navigational guidance to the boat operator to steer along the predetermined survey lines.

The HYPACK hydrographic survey software was used to combine horizontal positions and depths to map the reservoir bathymetry in the North American Datum of 1983 (NAD83) (2011) State Plane (horizontal) coordinates, New Mexico Central Zone, FIPS 3002, in US survey feet and North American Vertical Datum of 1988 (NAVD88), Geoid 12A, US survey feet elevations. Water surface elevations from dam gage records and RTK GPS measurements were used to convert the sonar depth measurements to reservoir-bottom elevations in RPVD. The multibeam depth sounder generated many millions of data points. Due to underwater vegetation, signal interference, or other anomalies, a small percentage of the depth measurements did not represent the actual reservoir bottom and were deleted during the post-processing. Final processing of the bathymetric data resulted in tens of millions of data points used in the development of the reservoir surface. Filtering of the large raw data file was necessary, so a raster mesh was created in GIS using 2-foot square cells. For each raster mesh cell, the reservoir bottom elevation is assigned equal to the median elevation of all available data points within that raster cell. The use of the median value reduces the influence of the highest and lowest elevations measured within the cell.

Appendix B — Above Water Survey Methods

Appendix B – Above Water Survey Methods

FEMA conducted a LiDAR survey in northern New Mexico, including El Vado Reservoir and the surrounding area, during fall/winter 2016. The LiDAR was collected during leaf-off conditions at a horizontal spacing of 0.7 meters with a stated vertical accuracy of 3.98 centimeters (https://coast.noaa.gov/inventory/index.html?layers=1,2,3,4,6,9,5&zoom=13&center=-106.73269271850586,36.59458146560139&basemap=esrigray). The 2016 LiDAR at El Vado was a small portion of a much larger collection covering much of New Mexico and Colorado, so the exact dates of the El Vado LiDAR were not given. However, El Vado Reservoir elevations fell below elevation 6,855 feet RPVD (the highest elevation of the 2018 bathymetry) by the end of July 2016 and dropped below elevation 6,834 feet in November, remaining below 6,845 feet until March 2017 (Figure 38). Water surface elevations ranged from elevation 6,860.46 to 6,860.51 feet during the 2018 bathymetric survey, resulting in approximately 20 feet of vertical overlap between 2016 LiDAR and 2018 bathymetry data.

Due to the general agreement between LiDAR and bathymetry data and the more recent date of bathymetry collection, the 2018 bathymetry was used instead of the 2016 LiDAR in areas of overlap to develop the digital surface for mapping and analysis. Bathymetry data were used below elevation 6,855 feet and LiDAR was used above that.

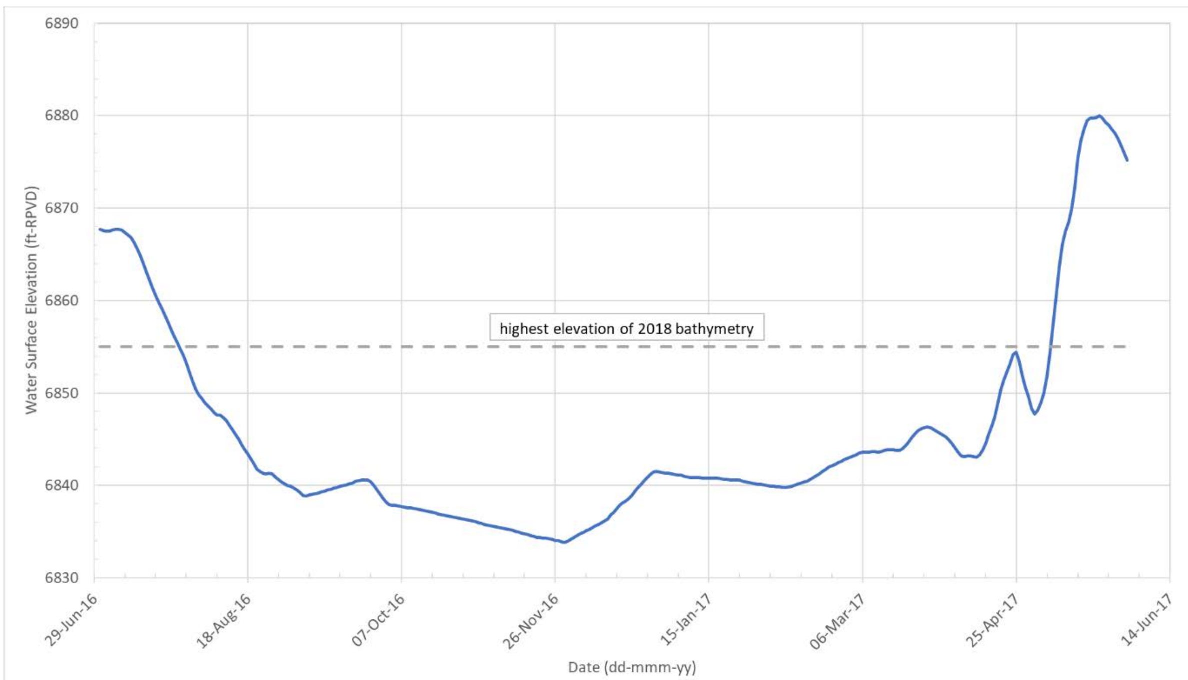


Figure 38. Water surface elevation at El Vado Reservoir during fall/winter 2016 when LiDAR survey was conducted

Appendix C — Computation of Reservoir Surface Area, Storage Capacity, and Sedimentation Volume

Appendix C – Computation of Reservoir Surface Area, Storage Capacity, and Sedimentation Volume

A digital surface of the reservoir bottom was generated in GIS using the processed bathymetric data points (easting, northing, and elevation) combined with available above-water data. Horizontal surface areas were then computed at 1-foot increments, using functions within ArcGIS Pro, for the complete range of remaining reservoir elevations (6770 to 6908.6 feet, RPVD). These reservoir surface areas were then used in Reclamation's Area-Capacity (ACAP) Program, 1985 Version (Reclamation, 1985), to compute the storage capacity at these increments and then interpolate surface areas and storage capacities at 0.01-foot increments between each 1-foot interval.

The program uses the least squares method to predict the reservoir storage capacity between 1-foot intervals using the following equation over a certain elevation interval:

$$V = A_1 + A_2(y - y_b) + A_3(y - y_b)^2$$

where: V = storage capacity (acre-feet)

y = reservoir elevation

y_b = reservoir elevation at bottom of elevation increment

A_1 = intercept and storage capacity at elevation y_b (acre-feet)

A_2 = surface area at elevation y_b (acres) and coefficient for linear rate of increase in storage capacity

A_3 = coefficient (feet) for nonlinear rate of increase in storage capacity

The reservoir surface area is computed from the derivative of the volume equation:

$$S = A_2 + 2A_3(y - y_b)$$

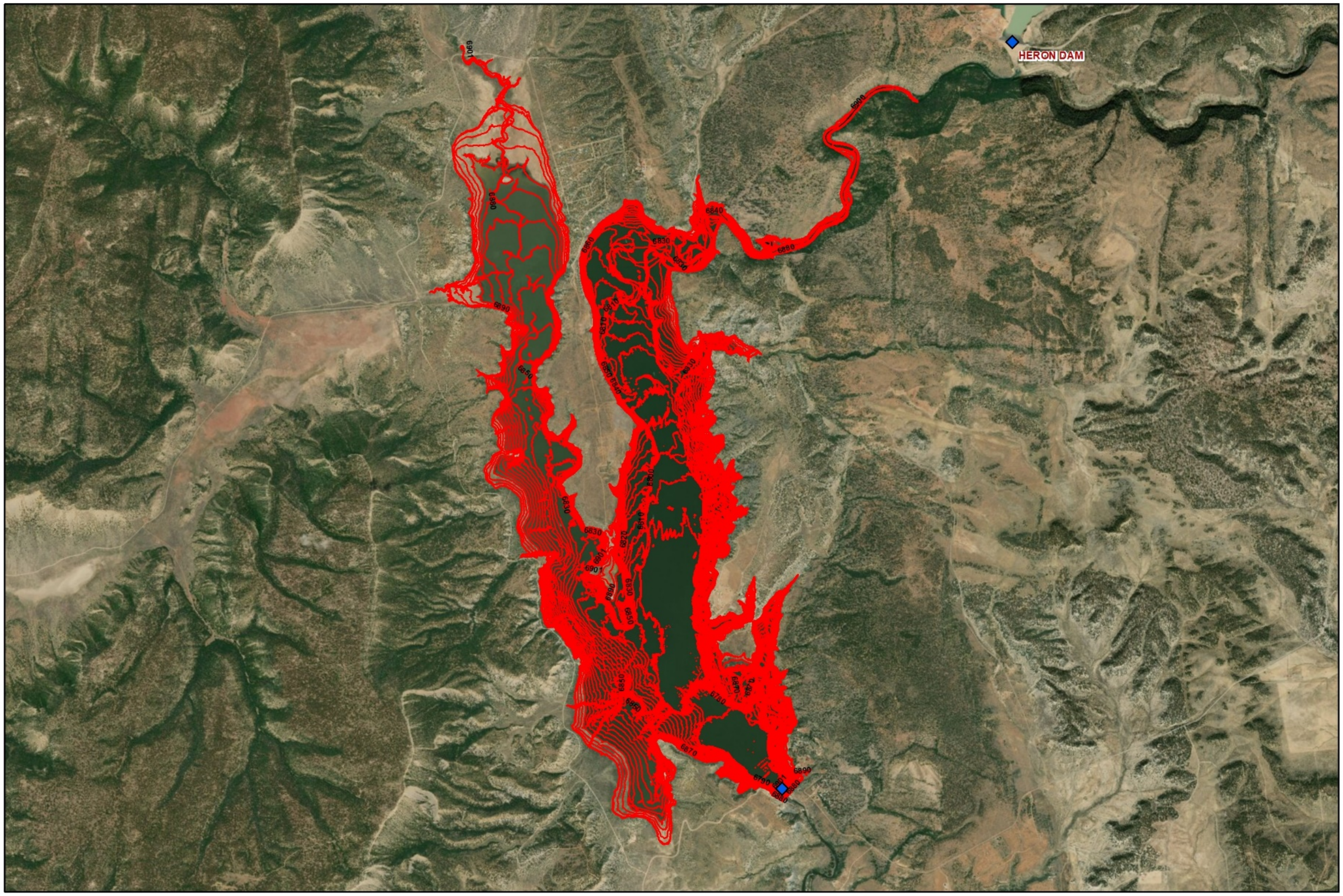
where: S = surface area (acres).

This method ensures that the given surface areas, and corresponding storage capacities, at the 1-foot intervals are not changed and there is a smooth transition in the interpolated values at the 0.01-foot intervals. The ACAP program produces the area and capacity tables for the full range of reservoir elevations.

The sedimentation volume can be computed by subtracting digital surfaces of the predam reservoir surface from the 2018 digital reservoir surface. However, a predam topographic map and surface digital is not always available. The next option is to subtract the storage volume curve produced from the predam surface from the storage volume curve of the 2020 surface. This method works well when the topographic map of the predam surface has good accuracy and precision. In some cases, the original topographic map significantly underestimated the actual storage capacity and subsequent surveys show an increased storage capacity even though reservoir sedimentation had reduced the actual storage capacity. In other cases, the predam topographic map significantly overestimated the actual storage capacity and comparison with subsequent surveys show too large a sedimentation volume. Comparison of predam and post dam digital surface maps can help reveal these problems and provide ideas for correcting the original surface maps.

Sedimentation volumes can be computed for the range of elevations surveyed. In some cases, the sedimentation volumes can only be computed for the bathymetric survey because there was no new above water survey.

Appendix D – Contour Maps



El Vado Reservoir
New Mexico
Elevation
Contour Map

Overview Map

Horizontal Datum Based on NAD83(2011) State Plane coordinates New Mexico Central Zone FIPS 3002, US survey feet

Vertical Datum Based on Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

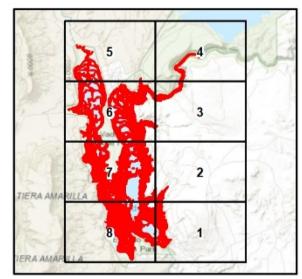
Five Foot Contour Interval

Primary Data Source:
El Vado 2018 Reservoir Survey

N

Scale 1:40,000

0 1,550 3,100 6,200 Feet



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

BUREAU OF RECLAMATION

El Vado Reservoir New Mexico Elevation Contour Map

Sheet 1

Horizontal Datum Based on NAD83(2011) State Plane coordinates New Mexico Central Zone FIPS 3002, US survey feet

Vertical Datum Based on Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

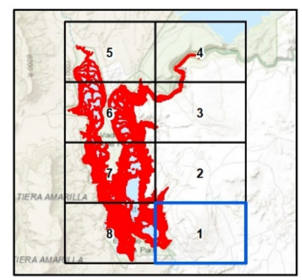
Five Foot Contour Interval

Primary Data Source:
El Vado 2018 Reservoir Survey

N

Scale 1:10,000

0 387.5 775 1,550 Feet



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

BUREAU OF RECLAMATION

El Vado Reservoir
New Mexico
Elevation
Contour Map

Sheet 2

Horizontal Datum Based on NAD83(2011) State Plane coordinates New Mexico Central Zone FIPS 3002, US survey feet

Vertical Datum Based on Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

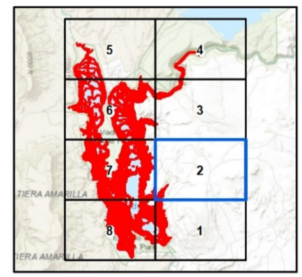
Five Foot Contour Interval

Primary Data Source:
El Vado 2018 Reservoir Survey

N

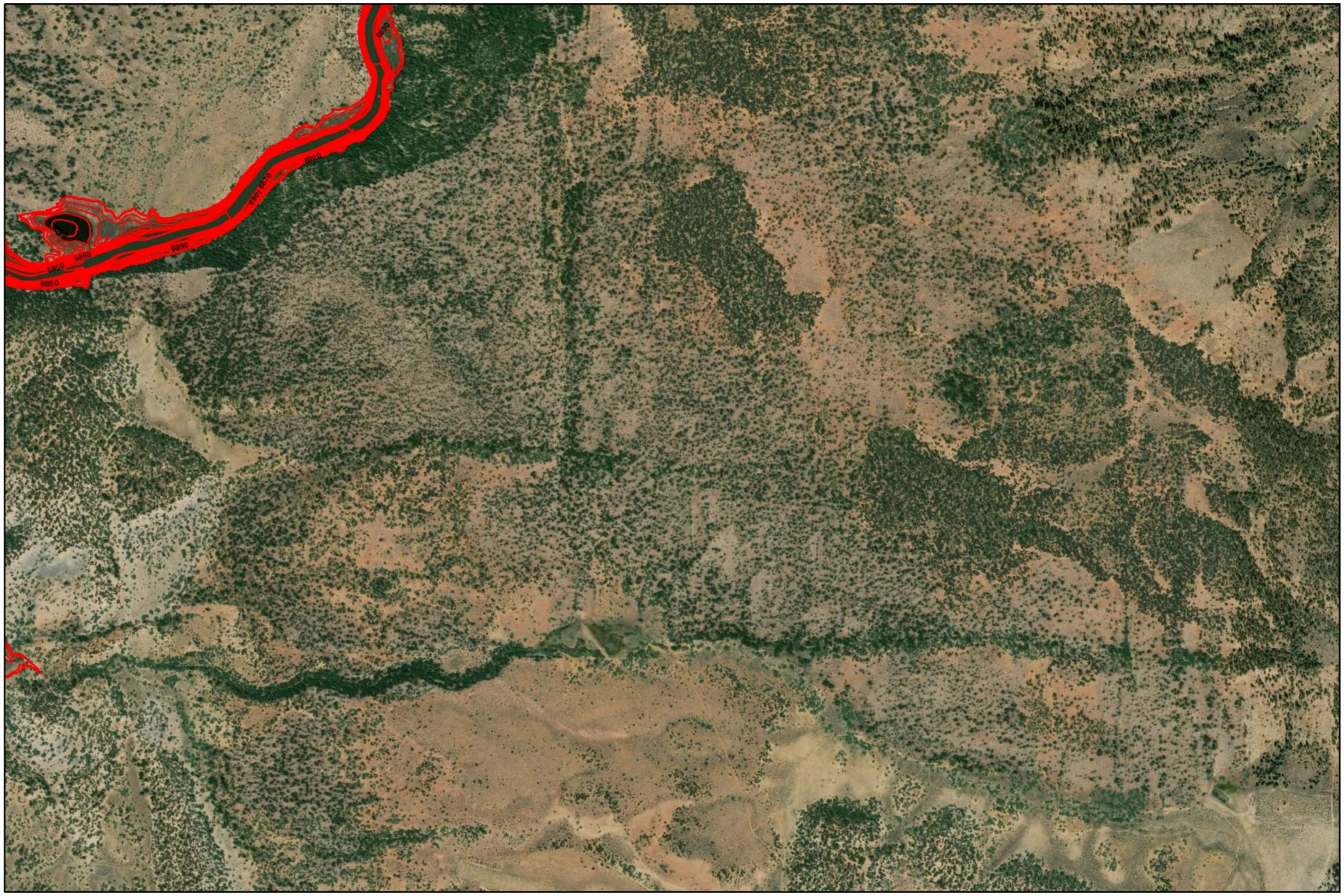
Scale 1:10,000

0 387.5 775 1,550 Feet



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

BUREAU OF RECLAMATION



El Vado Reservoir New Mexico Elevation Contour Map

Sheet 3

Horizontal Datum Based on
NAD83(2011) State Plane coordinates
New Mexico Central Zone FIPS 3002,
US survey feet

Vertical Datum Based on
Reclamation Project Vertical Datum
(RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

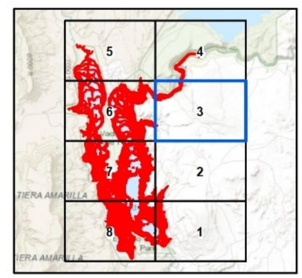
Five Foot Contour Interval

Primary Data Source:
El Vado 2018 Reservoir Survey

N

Scale 1:10,000

0 387.5 775 1,550 Feet



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

BUREAU OF RECLAMATION

El Vado Reservoir
New Mexico
Elevation
Contour Map

Sheet 4

Horizontal Datum Based on NAD83(2011) State Plane coordinates New Mexico Central Zone FIPS 3002, US survey feet

Vertical Datum Based on Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

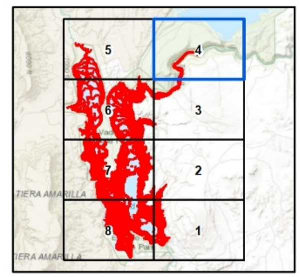
Five Foot Contour Interval

Primary Data Source:
El Vado 2018 Reservoir Survey

N

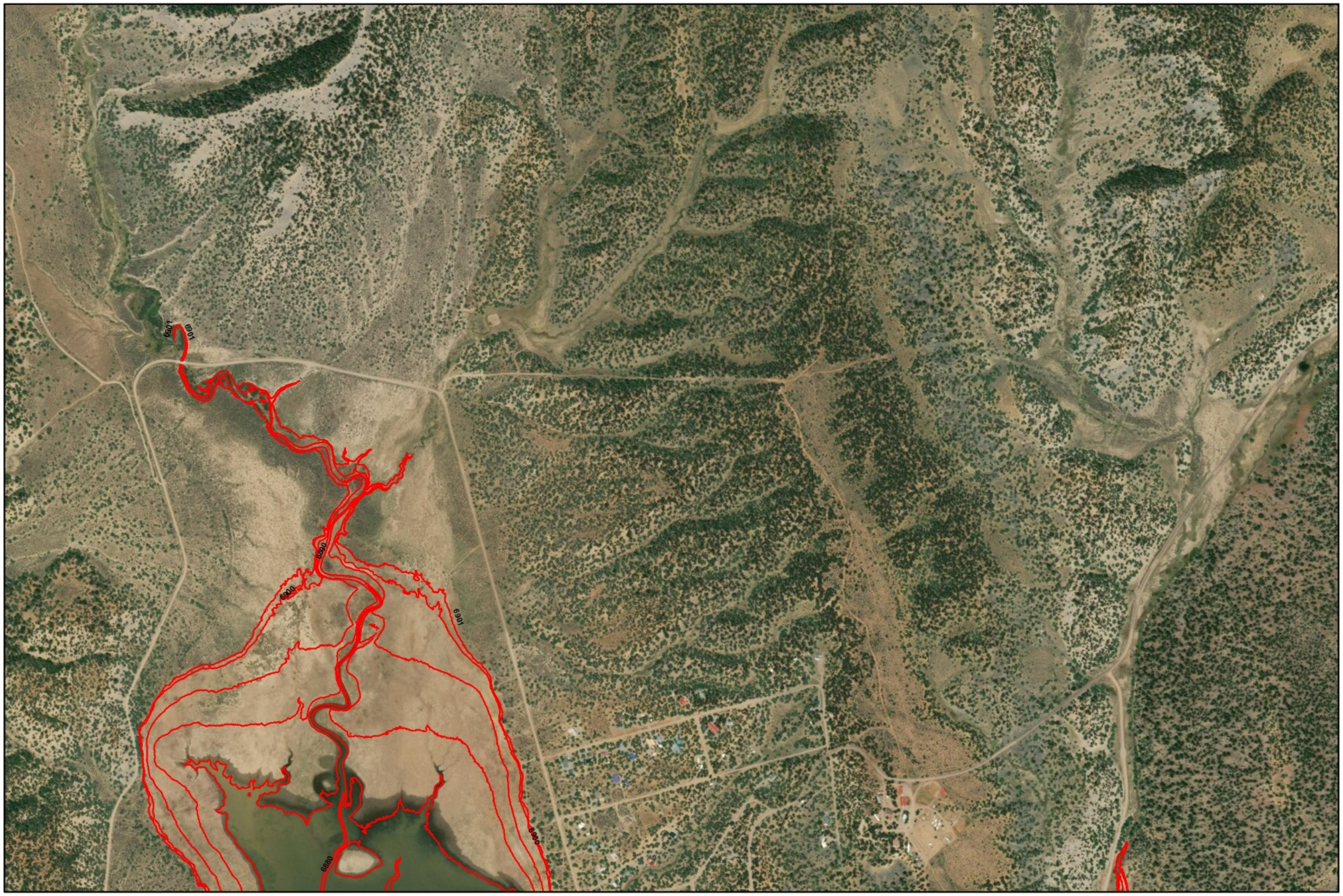
Scale 1:10,000

0 387.5 775 1,550 Feet



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

BUREAU OF RECLAMATION



El Vado Reservoir
New Mexico
Elevation
Contour Map

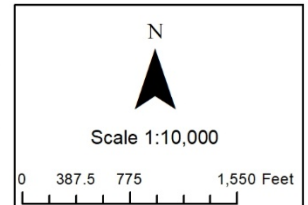
Sheet 5

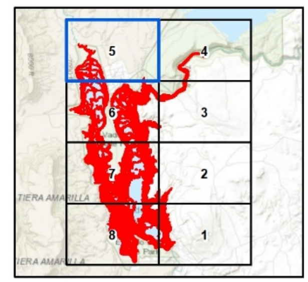
Horizontal Datum Based on NAD83(2011) State Plane coordinates New Mexico Central Zone FIPS 3002, US survey feet

Vertical Datum Based on Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

Five Foot Contour Interval

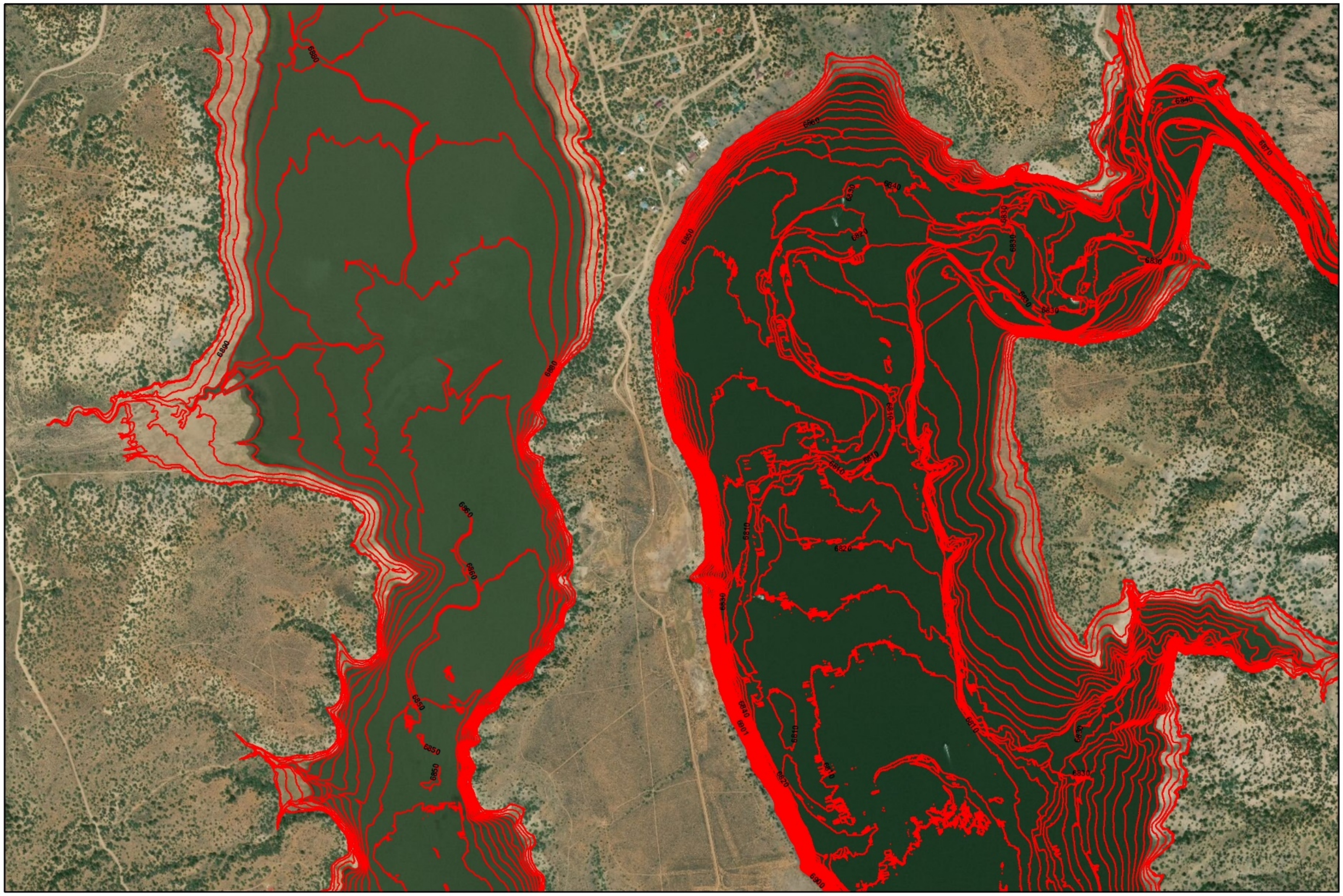
Primary Data Source:
El Vado 2018 Reservoir Survey





Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

BUREAU OF RECLAMATION



El Vado Reservoir New Mexico Elevation Contour Map

Sheet 6

Horizontal Datum Based on NAD83(2011) State Plane coordinates New Mexico Central Zone FIPS 3002, US survey feet

Vertical Datum Based on Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

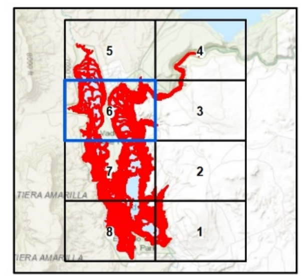
Five Foot Contour Interval

Primary Data Source:
El Vado 2018 Reservoir Survey

N

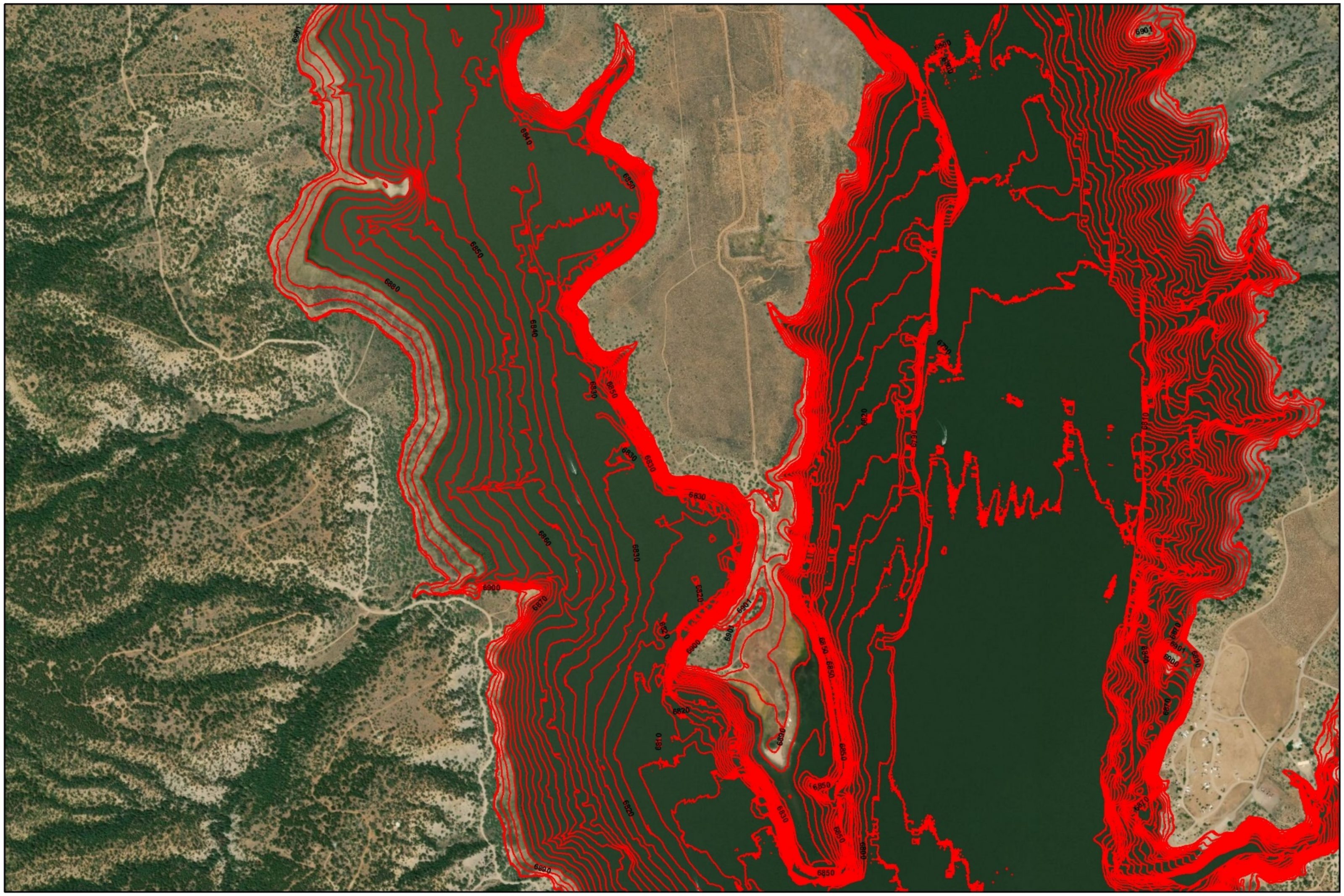
Scale 1:10,000

0 387.5 775 1,550 Feet



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

BUREAU OF RECLAMATION



El Vado Reservoir New Mexico Elevation Contour Map

Sheet 7

Horizontal Datum Based on NAD83(2011) State Plane coordinates New Mexico Central Zone FIPS 3002, US survey feet

Vertical Datum Based on Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

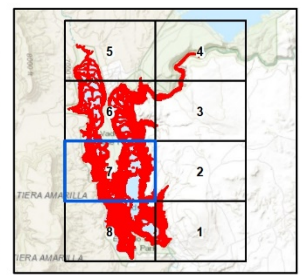
Five Foot Contour Interval

Primary Data Source:
El Vado 2018 Reservoir Survey

N

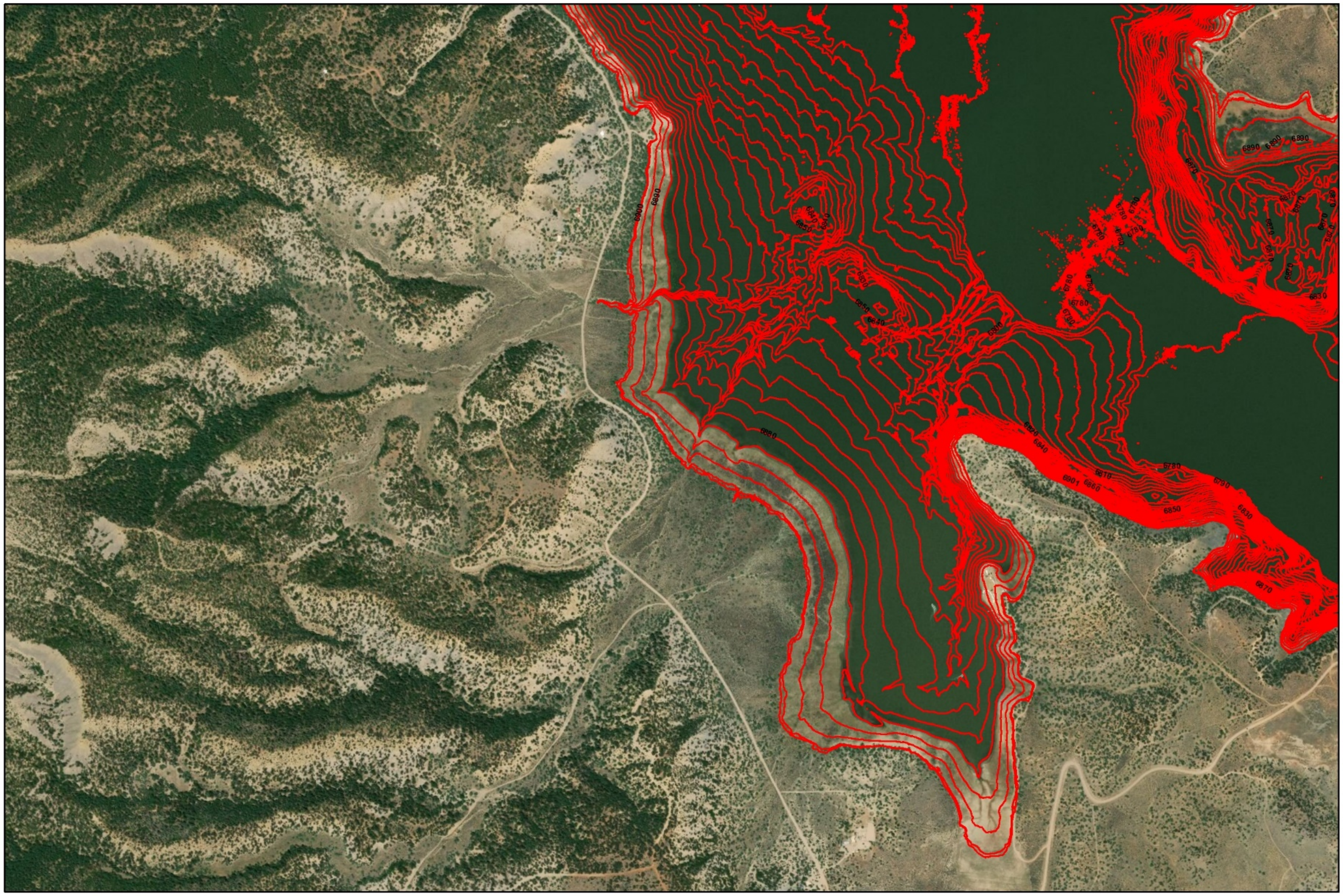
Scale 1:10,000

0 387.5 775 1,550 Feet



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

BUREAU OF RECLAMATION



El Vado Reservoir New Mexico Elevation Contour Map

Sheet 8

Horizontal Datum Based on NAD83(2011) State Plane coordinates New Mexico Central Zone FIPS 3002, US survey feet

Vertical Datum Based on Reclamation Project Vertical Datum (RPVD) for El Vado Reservoir
NGVD29-RPVD= 7.8 ft
NAVD88-RPVD= 12.0 ft

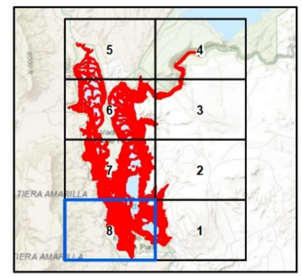
Five Foot Contour Interval

Primary Data Source:
El Vado 2018 Reservoir Survey

N

Scale 1:10,000

0 387.5 775 1,550 Feet



BUREAU OF RECLAMATION