RECLAMATION
Managing Water in the West

Technical Report No. SRH-2014-10

Pinewood Reservoir - Rattlesnake Dam 2012 Bathymetric Survey

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

February 2014

ACKNOWLEDGMENTS

The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics (Sedimentation) Group of the Technical Service Center (TSC) prepared and published this report. Kent Collins and Ron Ferrari of Reclamation's Sedimentation Group conducted the bathymetry survey of the reservoir in June 2012. Ron Ferrari of the Sedimentation Group completed the data processing to generate the 2012 reservoir topography and area-capacity information presented in this report. Kent Collins of the Sedimentation Group performed the technical peer review of this document.

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Reclamation Report

This report was produced by the Bureau of Reclamation's Sedimentation and River Hydraulics Group (Mail Code 86-68240), PO Box 25007, Denver, Colorado 80225-0007, www.usbr.gov/pmts/sediment/.

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Pinewood Reservoir - Rattlesnake Dam 2012 Bathymetric Survey

prepared by

Ronald L. Ferrari

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Water and Environmental Resources Division
Sedimentation and River Hydraulics Group
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14. ABSTRACT

Reclamation surveyed Pinewood Reservoir in June 2012 to develop updated reservoir topography and compute the present storage-elevation relationship (area-capacity tables). The bathymetric survey, conducted near water surface elevation 6,576.9 (project datum in feet), used sonic depth recording equipment interfaced with a real-time kinematic (RTK) global positioning system (GPS) that provided continuous sounding positions throughout the underwater portion of the reservoir covered by the survey vessels. The above-water topography was developed using the digitized reservoir water's edge from aerial photographs collected by the United States Department of Agriculture (USDA) and digital bare earth Interferometric Synthetic Aperture Radar (IFSAR) data.

As of June 2012, at conservation pool elevation 6,580.0, the reservoir surface area was 97 acres with a capacity of 2,104 acre-feet. At maximum reservoir elevation 6,589.0 the reservoir surface area was 124 acres with a capacity of 3,095 acre-feet. Since 1954 dam closure, a total capacity change of 84 acre-feet below elevation 6,589.0 was measured, equal to an average annual reduction of 1.4 acre-feet. The capacity change is due to sediment deposition and methodology differences between the surveys.

15. SUBJECT TERMS

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

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Pinewood Reservoir – Rattlesnake Dam 2012 Bathymetric Survey

Rattlesnake Dam
Colorado

1/30/2015
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Introduction

Rattlesnake Dam and Pinewood Reservoir are part of the Colorado-Big Thompson Project (CBT) that provides storage capacity for irrigation along with flood control, recreation, fish, wildlife, and power generation benefits. The CBT Project consists of over 100 structures integrated into an intermountain water diversion system that stores, regulates, and diverts water from the Colorado River on the western slope of the Continental Divide to the eastern slope of the Rocky Mountains.

Pinewood Reservoir and Rattlesnake Dam are located on a tributary of Cottonwood Creek about 14 miles southwest of Loveland Colorado as shown in Figure 1. In 1966 the name was officially changed from Rattlesnake to Pinewood Reservoir. It is the connecting reservoir between Pole Hill and Flatiron Powerplants, providing storage for both the regulating and peaking demands of Flatiron Powerplant. The inflows consist of outflow from the Pole Hill Powerplant through Rattlesnake Tunnel and a tributary of Cottonwood Creek with a drainage basin of 3.5 square miles.

Normal releases from Pinewood Reservoir are through two pipe structures: one pipeline at the dam releases water into Cottonwood Creek; and at upper end of the reservoir, water flows through the Bald Mountain Pressure Tunnel to the Flatiron Powerplant (Figure 2). Excessive flows spill over the uncontrolled spillway.

Reclamation's Eastern Colorado Area Office administers and operates the dam and lake while Larimer County Park District operates the recreational facilities. At elevation 6,589 the reservoir length is around 1.0 miles with an average width of 0.2 miles.

Figure 3 shows the zoned and compacted rock earthfill-type dam, located in an erosional gap cut by Rattlesnake Creek, which was constructed from 1950 through 1952 and became operational in 1954. Rattlesnake Dam has the following dimensions:

Structural height[1]	130 feet	Hydraulic height	100 feet
Crest length	1,951 feet	Crest elevation[2]	6,595 feet
Top width	30 feet		

[1] The definition of such terms as "top width, "structural height," etc. may be found in manuals such as Reclamation's *Design of Small Dams* and *Guide for Preparation of Standing Operating Procedures for Dams and Reservoirs*, or ASCE's *Nomenclature for Hydraulics.*

[2] Elevations in feet. Unless otherwise noted, all elevations are based on the original project datum established during construction of Pinewood Reservoir. Project datum is around 2 feet lower than the National Geodetic Vertical Datum of 1929 (NGVD29) and 5.54 feet lower than the North American Vertical Datum of 1988 (NAVD88).

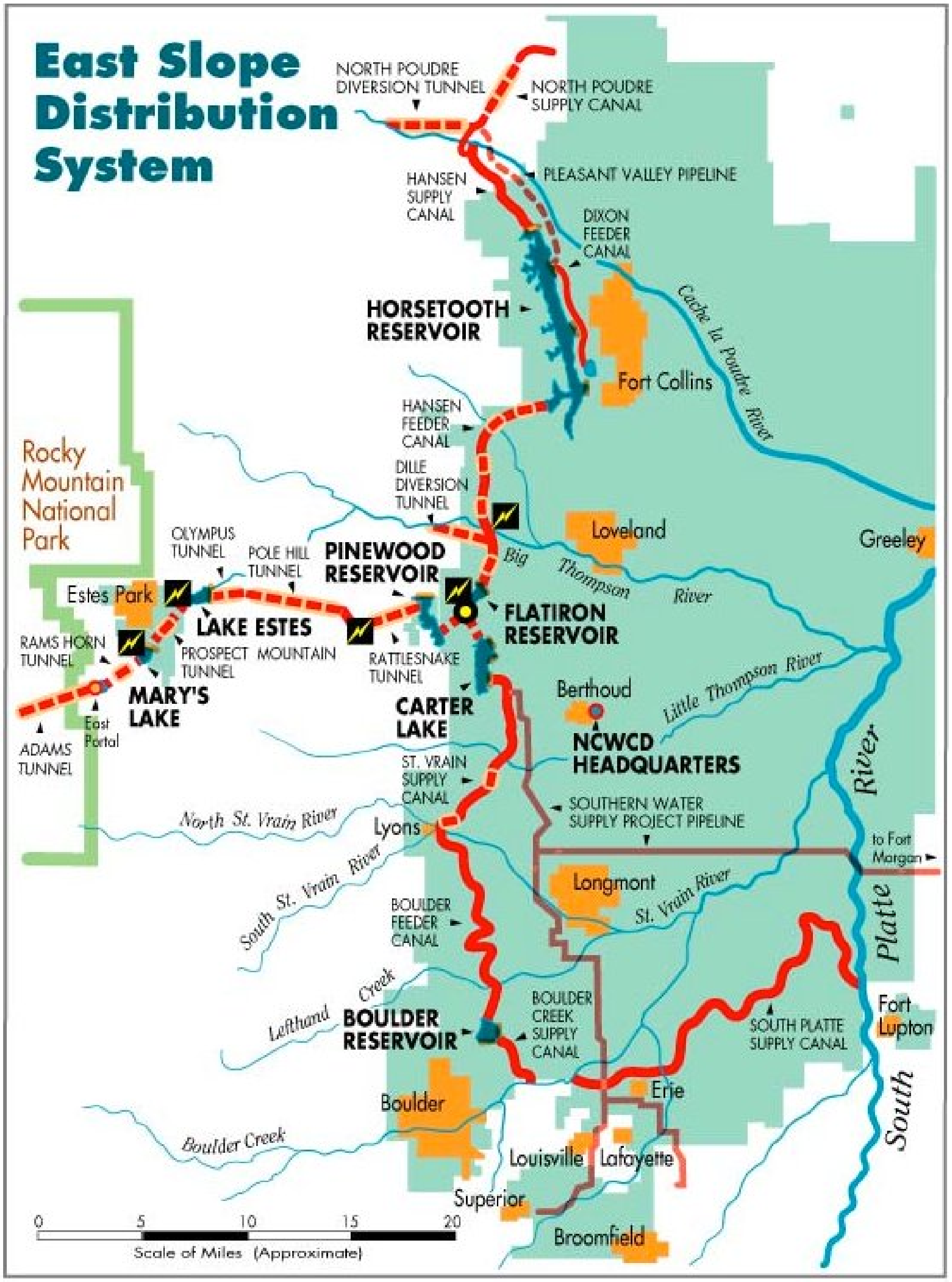

Figure 1 - Pinewood Reservoir – Colorado Big Thompson Project (CBT).

Figure 2 - Intake to Bald Mountain Pressure Tunnel to the Flatiron Powerplant with reservoir drawndown about 20 feet below normal full pool elevation 6,580.

Rattlesnake Dam's spillway, located in the right end of the embankment (Figure 3), is a concrete-lined, open-channel, uncontrolled-type spillway with crest elevation 6,580.0. The design discharge capacity is 10,400 cubic feet per second (cfs) at maximum water surface elevation 6,589.0

The outlet works, located in the right abutment, is designed to meet downstream requirements. The design flow is 10 cfs at water surface elevation 6,556 and 23 cfs at elevation 6,589. Based on past records of Cottonwood Creek the minimum release from the outlet works is 0.5 cfs.

Figure 3 - Rattlesnake Dam and spillway with reservoir drawndown about 20 feet.

Control Survey Data Information

Prior to the 2012 bathymetric survey, a control network was established using the on-line positioning user service (OPUS) and RTK GPS to set a temporary horizontal and vertical control point near Flatiron Reservoir and to confirm control points near Pinewood Reservoir for the hydrographic survey. OPUS, operated by the National Geodetic Survey (NGS), allows users to submit GPS data files that are processed with known point data to determine positions relative to the national control network. The OPUS generated coordinates were used to determine position and vertical difference between the North American Vertical Datum of 1988 (NAVD88), recorded water surface elevations at the dam, and monument points.

The horizontal control was established in Colorado state plane north coordinates on the North American Datum of 1983 (NAD83) in US survey feet. The vertical control was tied to Reclamation's project vertical datum and NAVD88 computed using the geoid model of 2009 (GEOID09). RTK GPS water surface measurements collected during the bathymetric survey in NAVD88 were around 5.5 feet higher than the water surface gage readings. Unless noted, all elevation computations within this report are referenced to Reclamation's project datum that is around 2 feet lower than NGVD29 and around 5.54 feet lower than NAVD88 (GEOID09). The developed reservoir topography elevations are tied to NAVD88 (GEOID09). The computed surface area values from this topography were shifted down 5.54 feet to match the project vertical datum and were used for the development of the area and capacity tables for operational purposes.

When setting up the control network, an aluminum monument stamped "SRH-May 2012" was set on a ½ inch rebar near the left abutment of Flatiron Dam. This monument was used during the Flatiron Reservoir 2012 survey and was tied to monuments with known elevations near Pinewood Reservoir. The OPUS computed coordinates for SRH-May2012, using Geoid 2009, were:

East 3,074,958.430
North 1,379,246.011
Elev. 5,486.452 (NAVD88/GEOID09)

With the GPS base, set over SRH-May2012, measurements were taken on two Larimer (LAR) County monuments (Figure 4 and Figure 5) and a 1950 Reclamation brass cap stamped elevation 6,778.997 (Figure 6). These measurements helped confirm the OPUS generated coordinates and the vertical datum shift between NAVD88 and the project vertical datum. Table 1 lists the May 2012 measurements on these monuments and compares them to published coordinates and elevations.

Table 1 - Control points used for May 2012 survey of Pinewood Reservoir

Monument Designation		**May 24, 2012 Measurements (NAVD88)**	**Published Coordinates**	**Difference** (ft)
LAR – MacFarlene 97 (Figures 4 and 5)	Easting	3,063,896.21	3,063,896.29	-0.08
	Northing	1,373,975.250	1,373,975.17	+0.08
	Elevation	6,783.028	6,783.04 (NAVD88)	-0.01
LAR – CP5 (used as a based during Pinewood survey)	Easting	3,060,556.35	n/a	n/a
	Northing	1,375,497.02	n/a	n/a
	Elevation	6,607.37	n/a	n/a
BOR BM-RS2; 1950; EL 6,788.997	Easting	3,063,892.01	n/a	n/a
	Northing	1,373,989.90	n/a	n/a
	Elevation	6,784.54	6,778.997[3]	+5.54

[3] Elevation 6,778.997 was stamped on the BOR cap and is assumed to be referenced to project elevation.

Figure 4 - Larimer County location sign for monument "MacFarlene."

During the surveys of Pinewood and Flatiron Reservoirs, RTK GPS water surface measurements were collected in NAVD88 and compared to the water surface gages maintained by Reclamation. At Flatiron Reservoir the differences between water surface measurements and gage records were 5.3 to 5.4 feet while at Pinewood Reservoir the differences were 5.4 to 5.5 feet. These water surface elevations were measured during fairly calm conditions, but water levels at Flatiron Reservoir vary more due to lake size and operations while water levels are more stable with operation changes at the larger Pinewood Reservoir. Using US Army Corps of Engineers software CORPSCON, vertical differences of 3.39 and 3.54 feet were computed between NAVD88 and NGVD29 at Flatiron and Pinewood Reservoirs respectively. Reclamation documents indicate that the reservoir designs were tied to mean sea level, but the 2012 survey found the project vertical datum was around two feet lower than NGVD29 which would have been the implied sea level during construction. For computational purposes, a project or construction vertical datum 5.54 feet below NAVD88 was used for this study. In most cases the shift was rounded to 5.5 feet.

Figure 5 - Larimer County monument "MacFarlene"

Figure 6 - Bureau of Reclamation Bench Mark RS 2, 1950, elevation 6,778.997

Reservoir Operations

Pinewood Reservoir is part of the CBT Project whose primary purpose is providing water storage for diversion through the Bald Mountain Pressure Tunnel for power generation at the downstream Flatiron Powerplant. Pinewood also provides water for irrigation, flood control, recreation, fish, and wildlife. The June 2012 total capacity was 3,095 acre-feet below elevation 6,589.0. The minimum bottom elevation measured during the 2012 survey was 6,511.9. The following values are from the June 2012 capacity table:

991 acre-feet of surcharge pool storage between elevation 6,580.0 and 6,589.0.
1,561 acre-feet of active conservation storage between elevation 6,556.0 and 6,580.0.
193 acre-feet of inactive use storage between elevation 6,550.0 and 6,556.0.
350 acre-feet of dead pool storage below elevation 6,550.0.

Available end-of-month stage records for Pinewood Reservoir in Table 2 show the annual fluctuation for the limited period of operation from 1986 through 2012 with multiple years having no available records. The average inflow during the life of the reservoir could not be easily computed, but it is noted that the majority of the inflow consists of diverted flows from the western slope.

Hydrographic Survey, Equipment, and Method of Collection

Bathymetric Survey Equipment

The bathymetric survey equipment was mounted on two different boats for the Pinewood survey: a 9-foot cataraft powered by an electric trolling motor was used to measure shallow depths along the shoreline (Figure 7); and a second 12-foot cataraft powered by a 5 horse outboard was used for the deeper water in the main reservoir body. The hydrographic systems included GPS receivers with built-in radios, depth sounders, helmsman displays for navigation, computers, and hydrographic system software for collecting the underwater data. All equipment was powered by on-board batteries. The shore equipment included a second GPS receiver with an external radio. The shore GPS receiver and antenna were mounted on a survey tripod over datum point "LAR-CP5" with a 12-volt battery providing power.

Figure 7 - Vessel used to collect depth data for Flatiron Reservoir.

The Sedimentation and River Hydraulics Group uses RTK GPS with the major benefit being precise heights measured in real time to monitor water surface elevation changes. The RTK GPS system employs two receivers that track the same satellites simultaneously. The basic outputs from a RTK receiver are precise 3-D coordinates in latitude, longitude, and height with accuracies on the order of 2 centimeters horizontally and 3 centimeters vertically. The output is on the GPS WGS-84 datum that the hydrographic collection software converted into Colorado's state plane north coordinates, NAD83, in feet for the Pinewood Reservoir survey.

The Pinewood Reservoir bathymetric survey was conducted on June 4, 2012 near water surface elevation 6,576.9 (project vertical datum). The bathymetric survey was conducted using sonic depth recording equipment interfaced with a RTK GPS capable of determining sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boats moved along established grid lines and the shoreline throughout the reservoir. The survey vessel's guidance system provided directions to the boat operator to assist in maintaining course along predetermined lines to assure a uniform coverage of the underwater portion of the reservoir. The outlet area in the upper reservoir was closed off by a boom line for safety and could not be accessed. The topography in the restricted outlet area was developed by projecting breaklines using data sets from the surrounding area. As the survey vessels traversed the reservoir area, the depth and position data were recorded on either a laptop computer hard drive or a field collection controller for subsequent processing. The water surface elevations at the dam, recorded by a Reclamation gage and RTK GPS measurements, were used to convert the sonic depth measurements to lake-bottom elevations. The RTK GPS measured elevations were tied to NAVD88 (GEOID09). A downward shift of 5.5 feet is necessary to match the project or construction vertical datum. Final processing of the June 4 2012 data sets resulted in around 12,600 points, Figures 8 through 11.

The 2012 underwater data was collected using depth sounders that were calibrated by adjusting the speed of sound through the water column, which can vary with density, salinity, temperature, turbidity, and other conditions. The collected data were digitally transmitted to the computer collection system through a RS-232 serial port. The larger boat depth sounder produced a digital chart of the measured depths. These charts were analyzed during post-processing and when the charted depths indicated a difference from the computer recorded bottom depths, the computer data files were modified. Additional information on collection and analysis procedures is outlined in Chapter 9 of the *Erosion and Sedimentation Manual* (Ferrari and Collins, 2006).

Above-water Data

Aerial Photography

The 2012 study of Pinewood Reservoir focused on the collection of bathymetric or underwater data in areas accessible by the survey vessels. Acquisition of the best available above-water data was necessary to complete development of the topographic map. During analysis, orthographic aerial images collected in 2005 at water surface elevation 6,575.9, in 2006 at water surface elevation 6,576.8, in 2009 at water surface elevation 6,571.1, in July 2011 at water surface elevation 6,572.7 and in August of 2011 at water surface elevation 6,566.5 were downloaded from the USDA (USDA, 2010). Reservoir contours were developed by digitizing the water's edge from these aerial images and assigning the water surface elevation from the day of each flight. The 6,566.5 contour from the August 2011 photo was the lowest elevation of all available photographs and was of the best quality to determine the water's edge. The 2006 photo at elevation 6,576.5 was the highest elevation, but was difficult to determine true water's edge in some places. Using the 2006 aerial photo along with the high-water mark on the August 2011 photograph, the contour elevation 6,576.5 was developed and used for map development during this study. The digitized 6,576.5 contour enclosed the 2012 bathymetric data. Only portions of the 6,566.5 (2011) contour were used for map development, including the upper reservoir area roped off for safety due to releases from the outlet works and a few areas with no bathymetric data for contour development. The other years of aerial photos were only used for contour development in the upper reservoir outlet area.

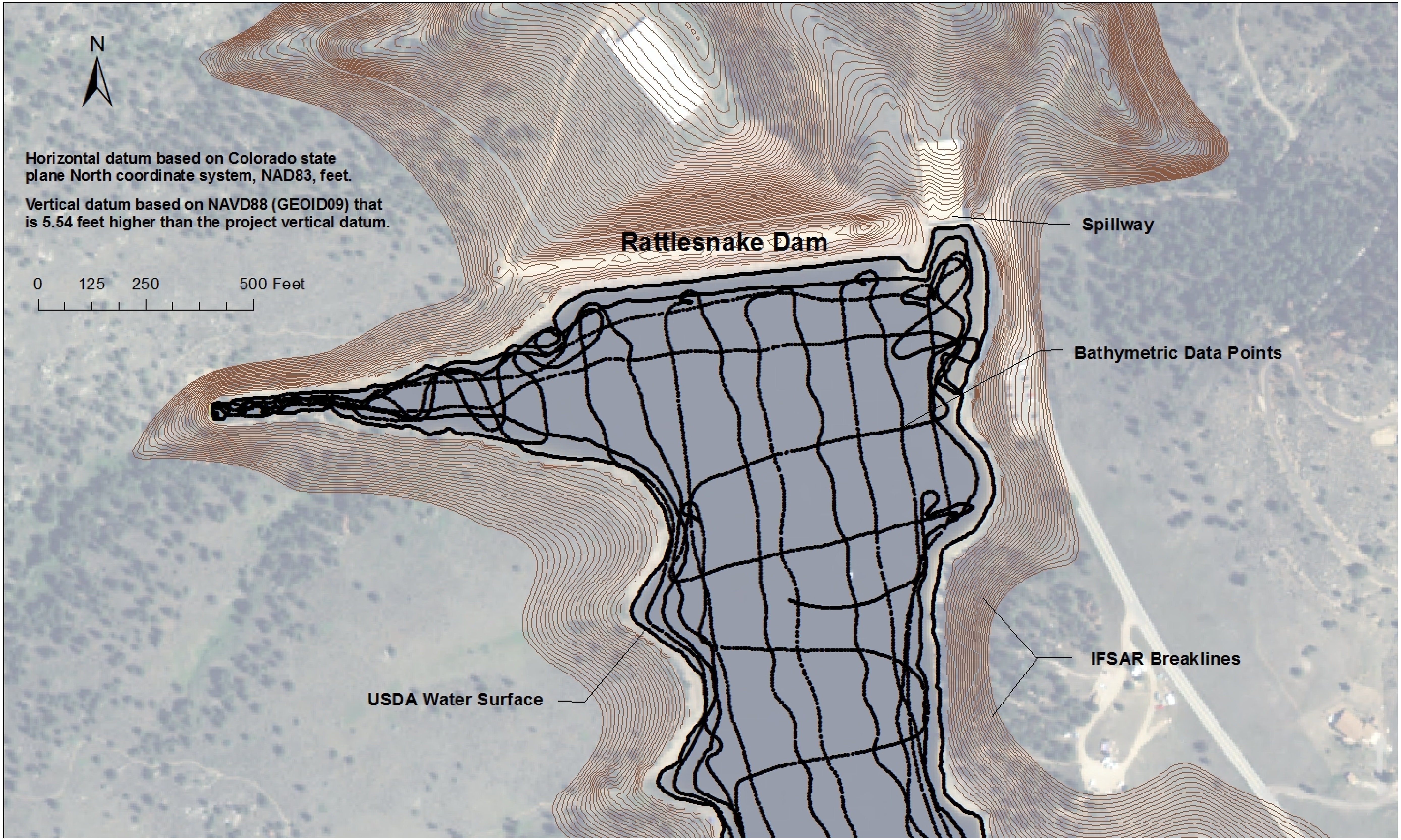

Figure 8 - Pinewood Reservoir, 2012 bathymetric data and imported data coverages, 1 of 4 (NAVD88/GEOID09).

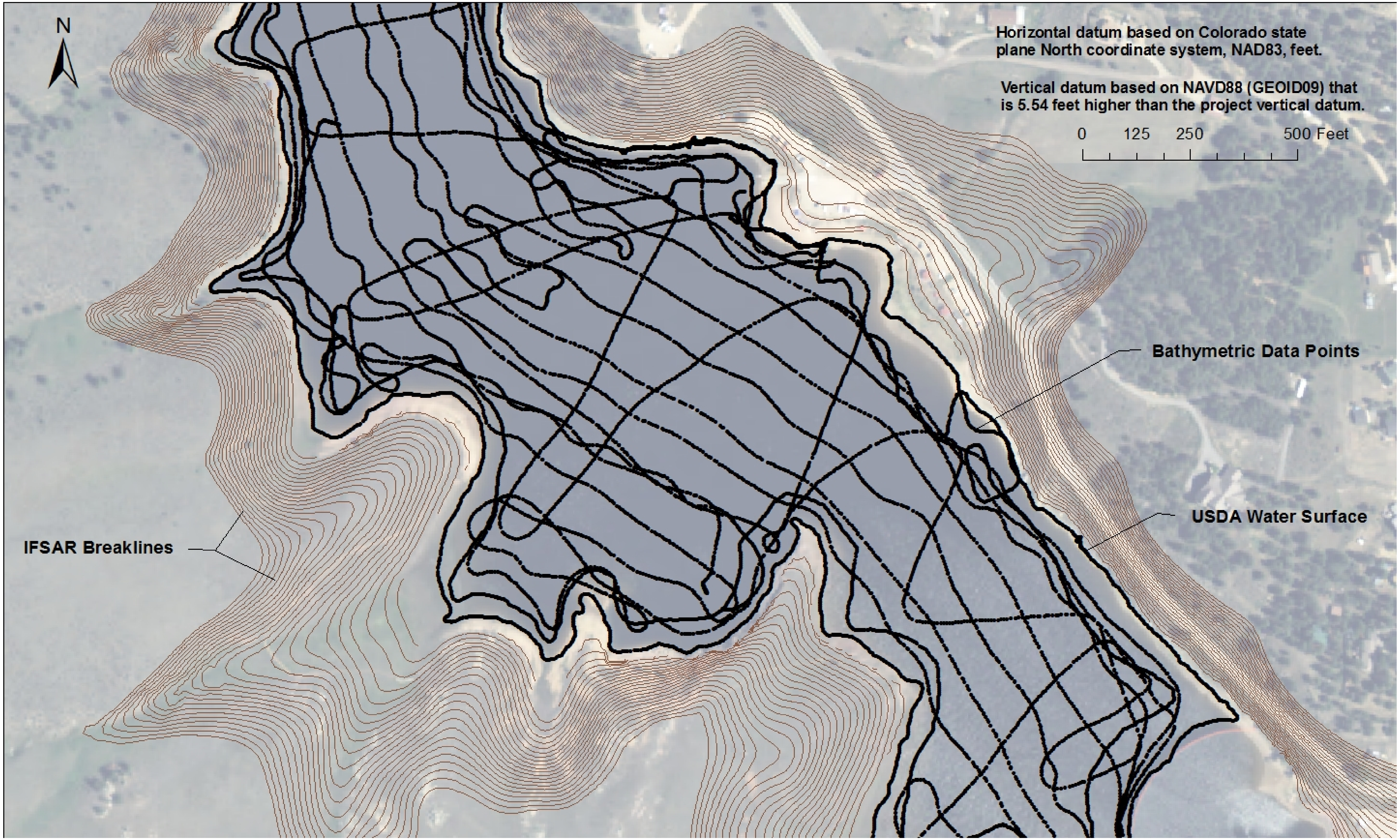

Figure 9 - Pinewood Reservoir, 2012 bathymetric data and imported data coverages, 2 of 4 (NAVD88/GEOID09).

Figure 10 - Pinewood Reservoir, 2012 bathymetric data and imported data coverages, 3 of 4 (NAVD88/GEOID09).

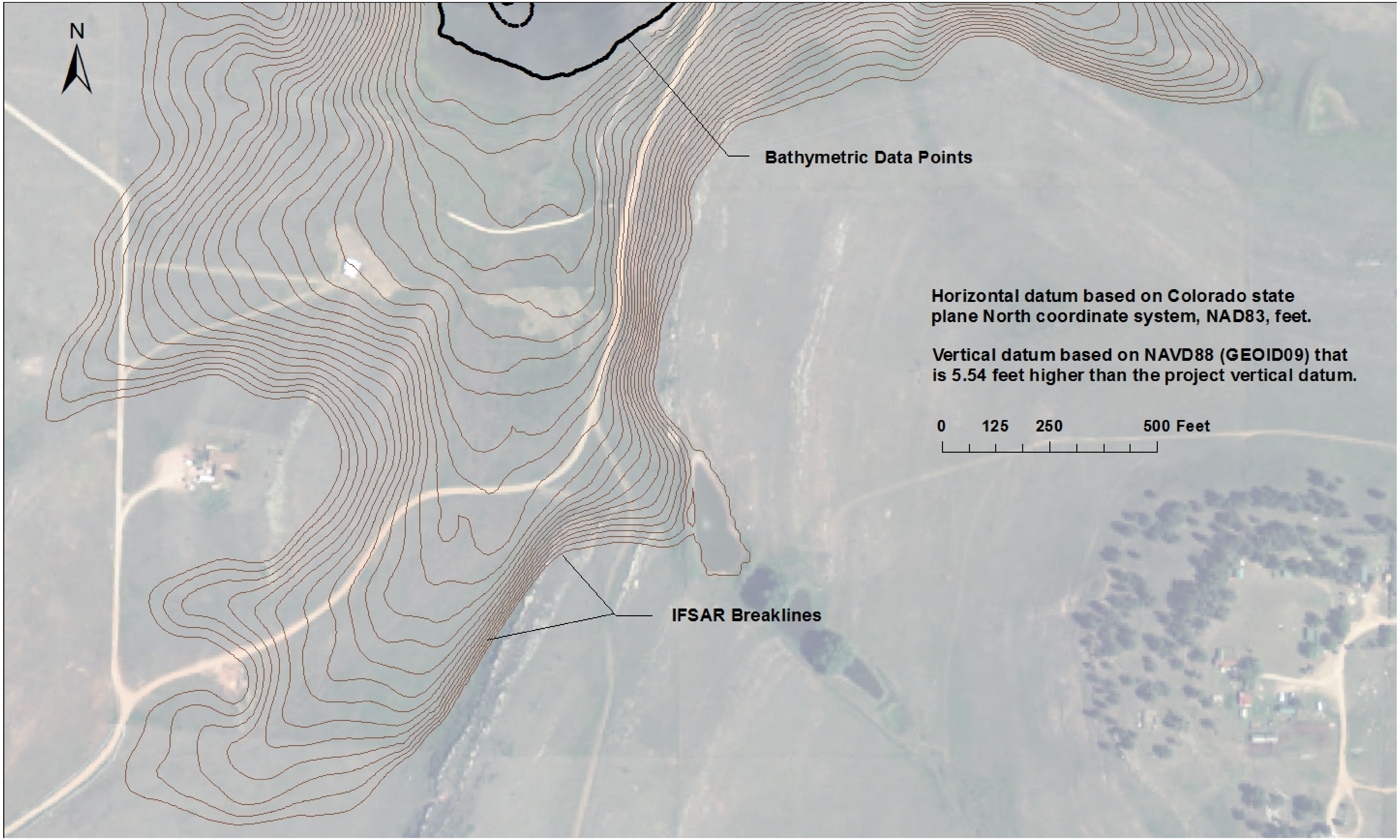

Figure 11 - Pinewood Reservoir, 2012 bathymetric data and imported data coverages, 4 of 4 (NAVD88/GEOID09).

Aerial IFSAR

As part of this analysis, Interferometric Synthetic Aperture Radar (IFSAR) was obtained as digital bare earth data tied horizontally to NAD83 with elevations tied to NAVD88. IFSAR airborne technology enables mapping of large areas quickly and efficiently, resulting in detailed information at much lower costs than other technologies such as aerial photogrammetry and LiDAR. The IFSAR data were collected when the reservoir was near elevation 6,582 (NAVD88). The IFSAR data provided detailed topography of the shoreline of the main reservoir body, coves, and area around the dam. The IFSAR reported accuracies are 2-meters horizontally and 1-meter vertically in areas of unobstructed flat ground (Intermap, 2011). During processing, portions of the IFSAR data overlapped by the other data sets were removed and the remaining IFSAR used in the final 2012 topographic development. Areas of overlap occurred mainly along the steeper bank portions of the reservoir. Figures 8 through 11 show the breaklines used around the reservoir and downstream of the dam used in developing the reservoir contours.

Reservoir Area and Capacity

Topography Development

This section discusses the methods used for generating topographic contours of Pinewood Reservoir. The data sources included the 2012 bathymetric data points, digitized reservoir water surface edges from USDA aerial photographs, digitized breaklines projected from the data sources for areas of the reservoir not accessible during the boat survey, and IFSAR developed breaklines above all of these data sets. The breaklines were projected for the roped-off area around the intake where waters are released through the Bald Mountain pressure tunnel to Flatiron Reservoir. All data were processed into a triangulated irregular network (TIN) that was then used to develop 2-foot contours tied vertically to NAVD88 (GEOID09). See Figures 12 and 13.

The breaklines assisted in contour development and had minimal effect on the surface area calculations. All the data layers were merged together and were processed into a triangulated irregular network (TIN) that was used to develop 2-foot contours tied vertically to the project vertical datum. The resulting surface areas and volumes presented in this report are from the developed TIN and tied to the project vertical datum. These elevations can be shifted upward 5.5 feet to match NAVD88. In preparation for developing the TIN, a polygon or hardclip was created to enclose all of the data sets. This polygon, not assigned an elevation, was used as a hardclip or boundary for the 2012 developed contours, allowing mapping only within the hardclip polygon by preventing interpolation outside it. For surface area computations the polygon was developed along the alignment of Rattlesnake Dam to enclose the data within the reservoir boundary only. The resulting surface areas and volumes presented in this report are from the developed TIN with the elevations shifted down 5.5 feet from NAVD88 (GEOID09) to match the project vertical datum for reservoir operation use.

Contours for the reservoir including downstream from Rattlesnake Dam were developed from the TIN generated within ArcGIS. A TIN is a set of adjacent non-overlapping triangles computed from irregularly spaced points with x,y coordinates and z values. A TIN is designed to deal with continuous data such as elevations. ArcGIS uses a method known as Delaunay's criteria for triangulation where triangles are formed among all data points within the polygon clip. The method requires that a circle drawn through the three nodes of a triangle will contain no other point, meaning that all the data points are connected to their nearest neighbors to form triangles. This method preserves all the collected data points. The TIN method is described in more detail in the ArcGIS user’s documentation (ESRI, 2011).

The linear interpolation option of the ArcGIS TIN and CONTOUR commands was used to interpolate contours from the Pinewood Reservoir TIN. The surface areas of the enclosed contour polygons at 1-foot increments were computed for elevation 6,520.0 (NAVD88) and below. The reservoir contour topography at 2-foot intervals is presented on Figures 14 through 17. The ArcGIS software was used to develop contours directly from the TIN using all the enclosed data points presented in this report.

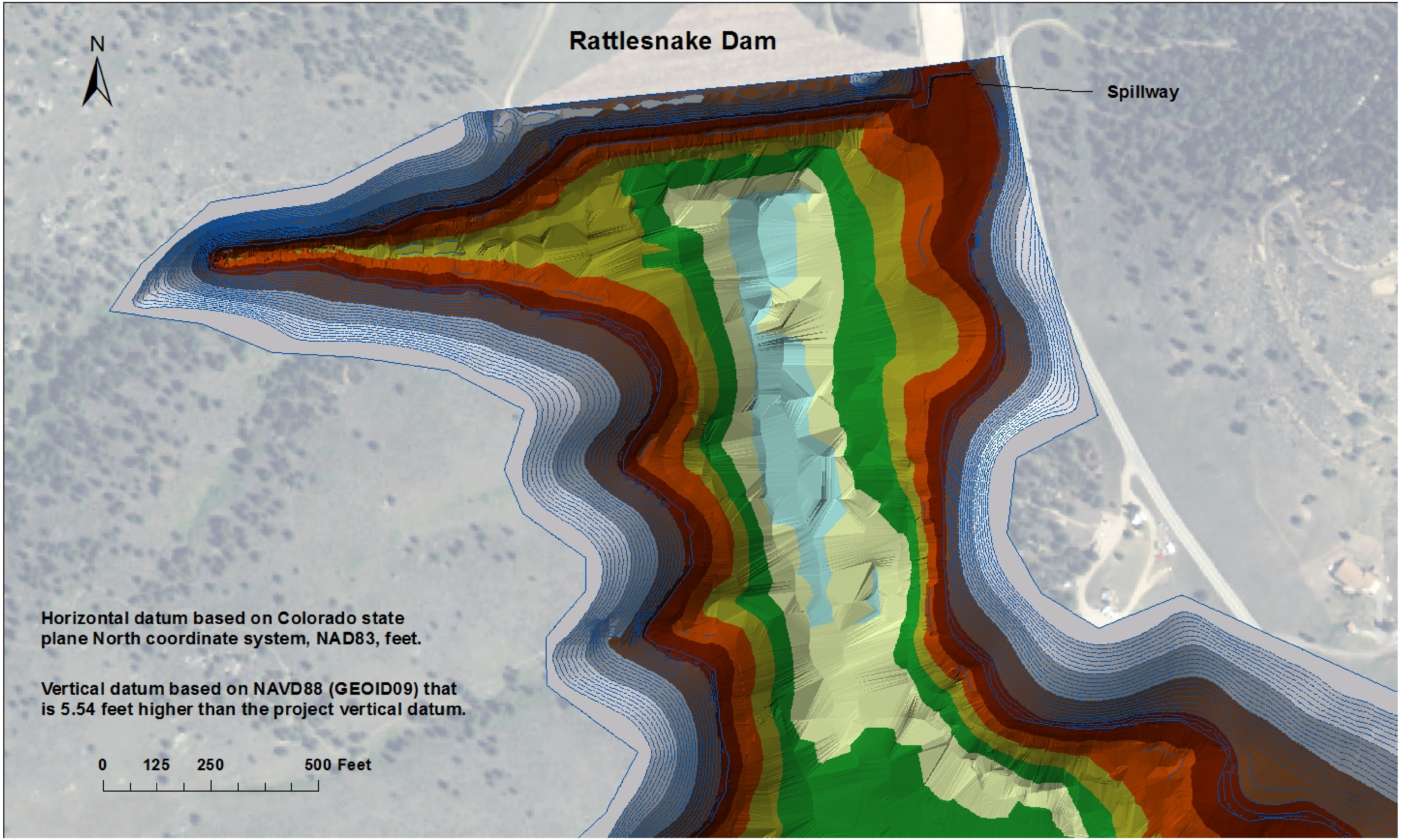

Figure 12 - Pinewood Reservoir developed TIN from 2012 bathymetric survey and imported data coverages, 1 of 2 (NAVD88/GEOID09).

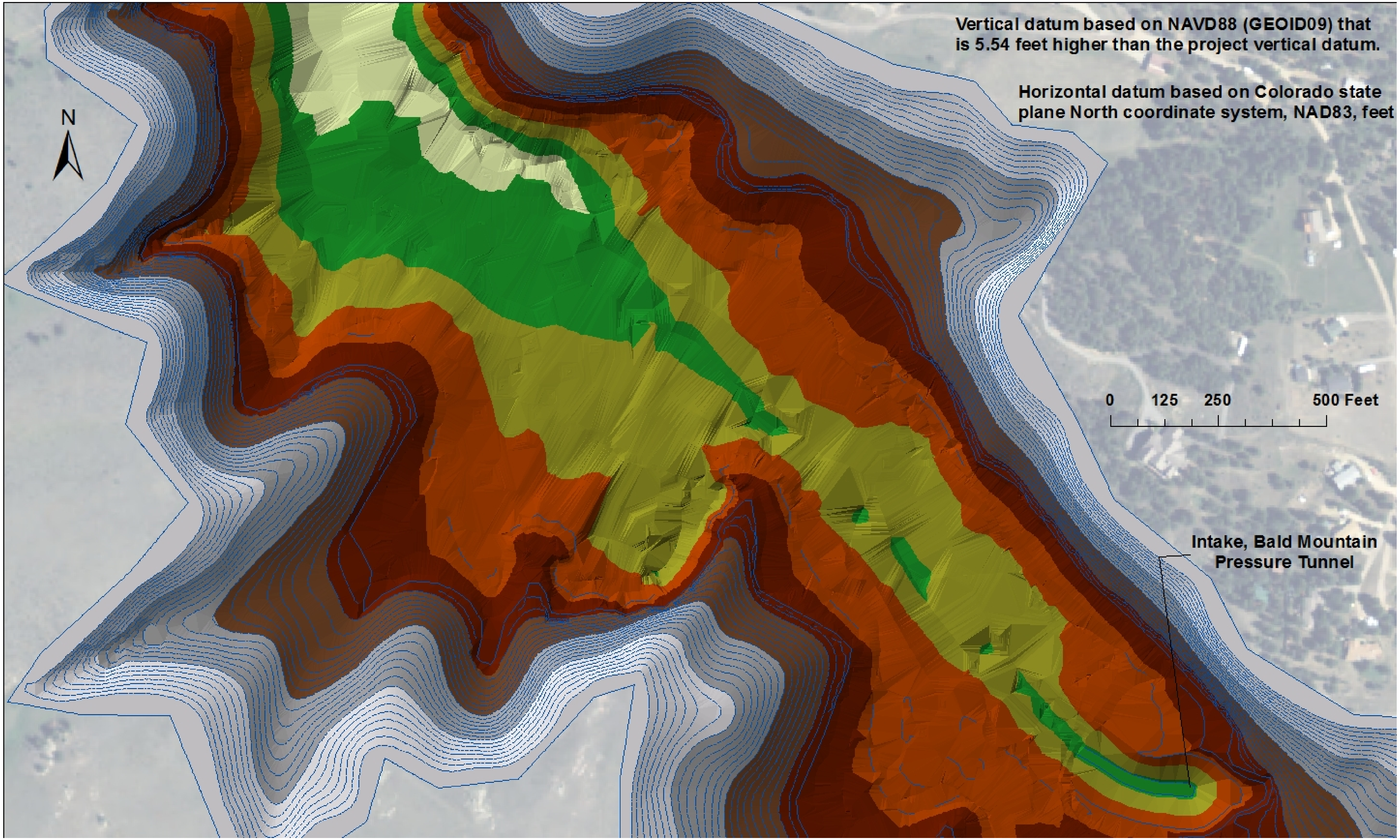

Figure 13 - Pinewood Reservoir developed TIN from 2012 bathymetric survey and imported data coverages, 2 of 2 (NAVD88/GEOID09).

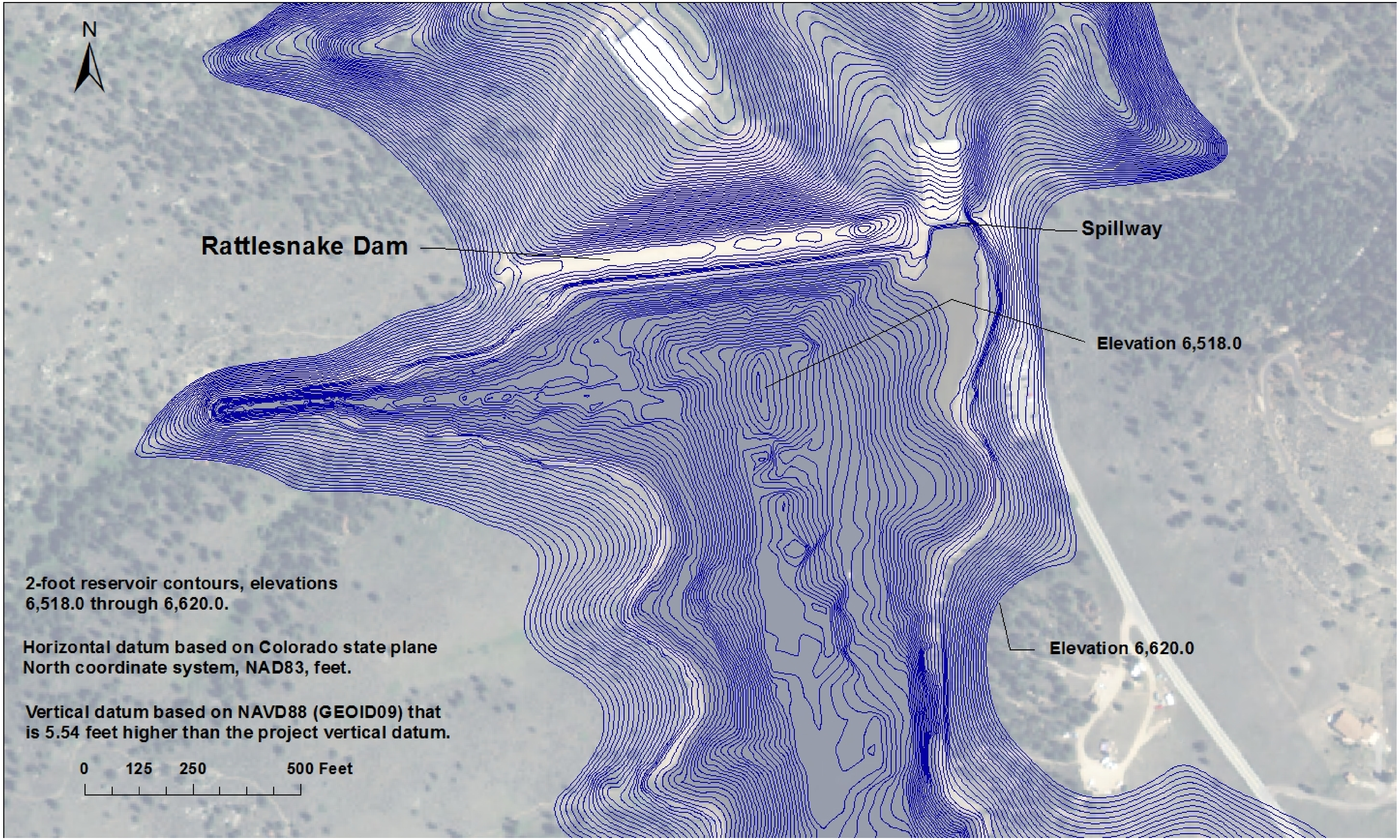

Figure 14 - Pinewood Reservoir, developed 2-foot contours from 2012 bathymetric survey and imported data coverages, 1 of 4 (NAVD88/GEOID09).

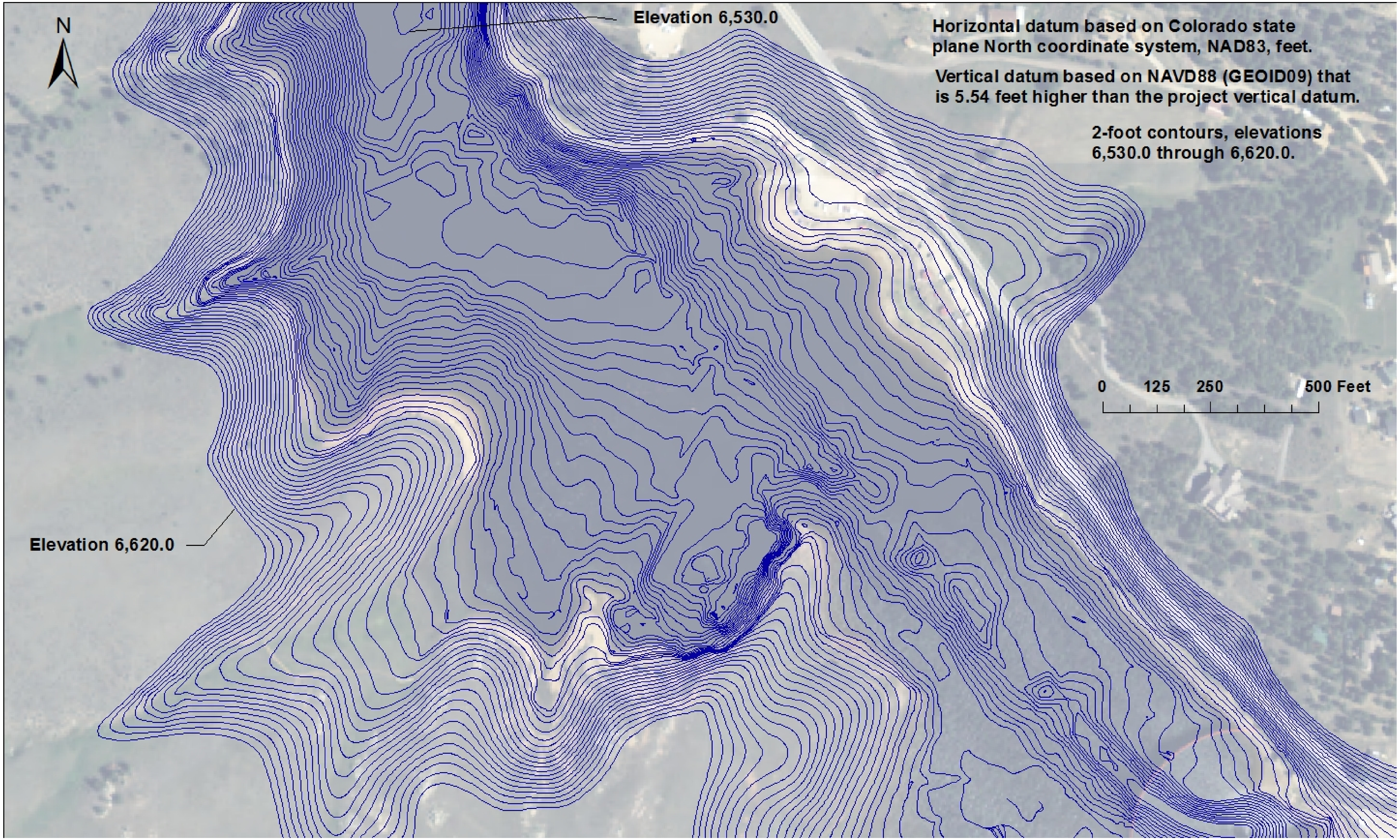

Figure 15 - Pinewood Reservoir, developed 2-foot contours from 2012 bathymetric survey and imported data coverages, 2 of 4 (NAVD88/GEOID09).

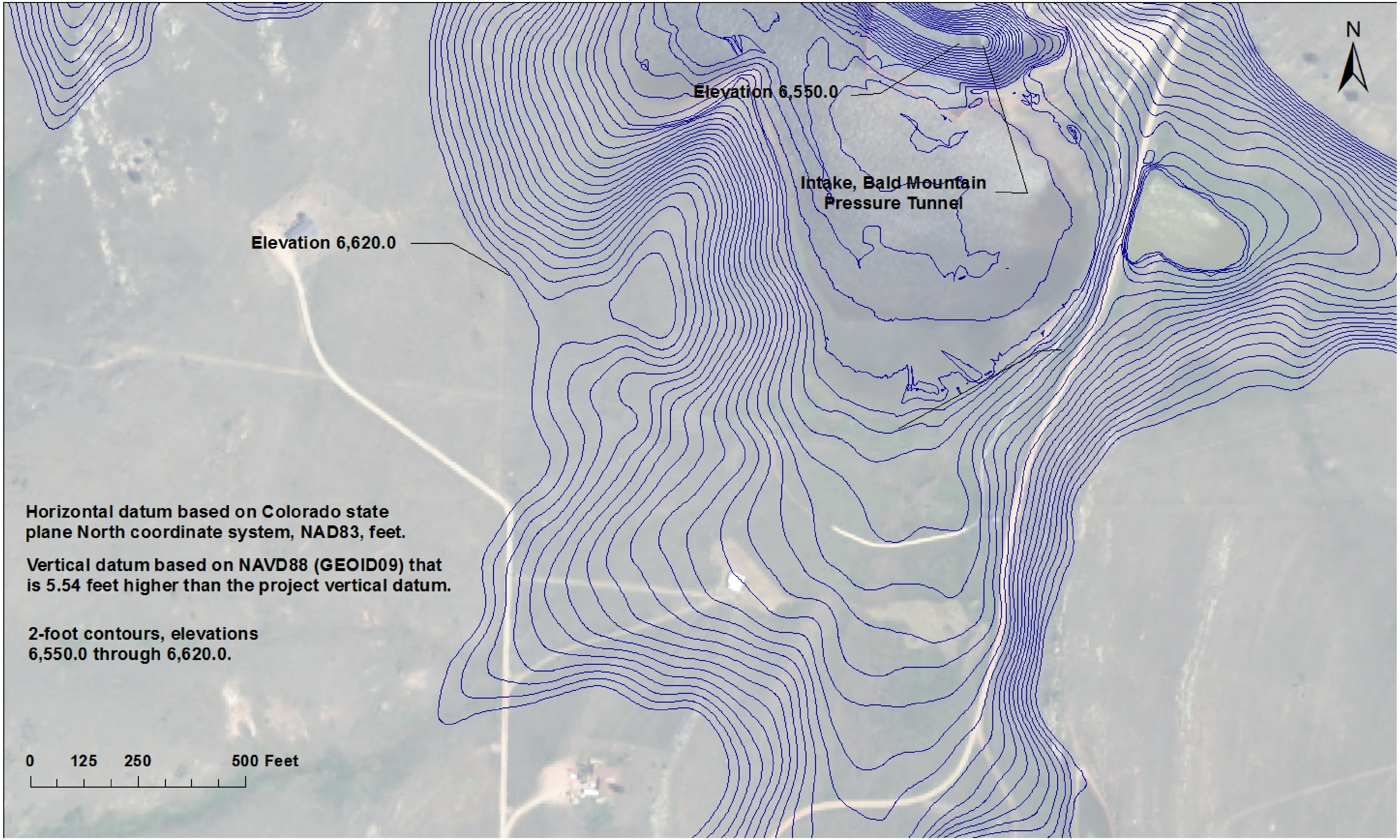

Figure 16 - Pinewood Reservoir, developed 2-foot contours from 2012 bathymetric survey and imported data coverages, 3 of 4 (NAVD88/GEOID09).

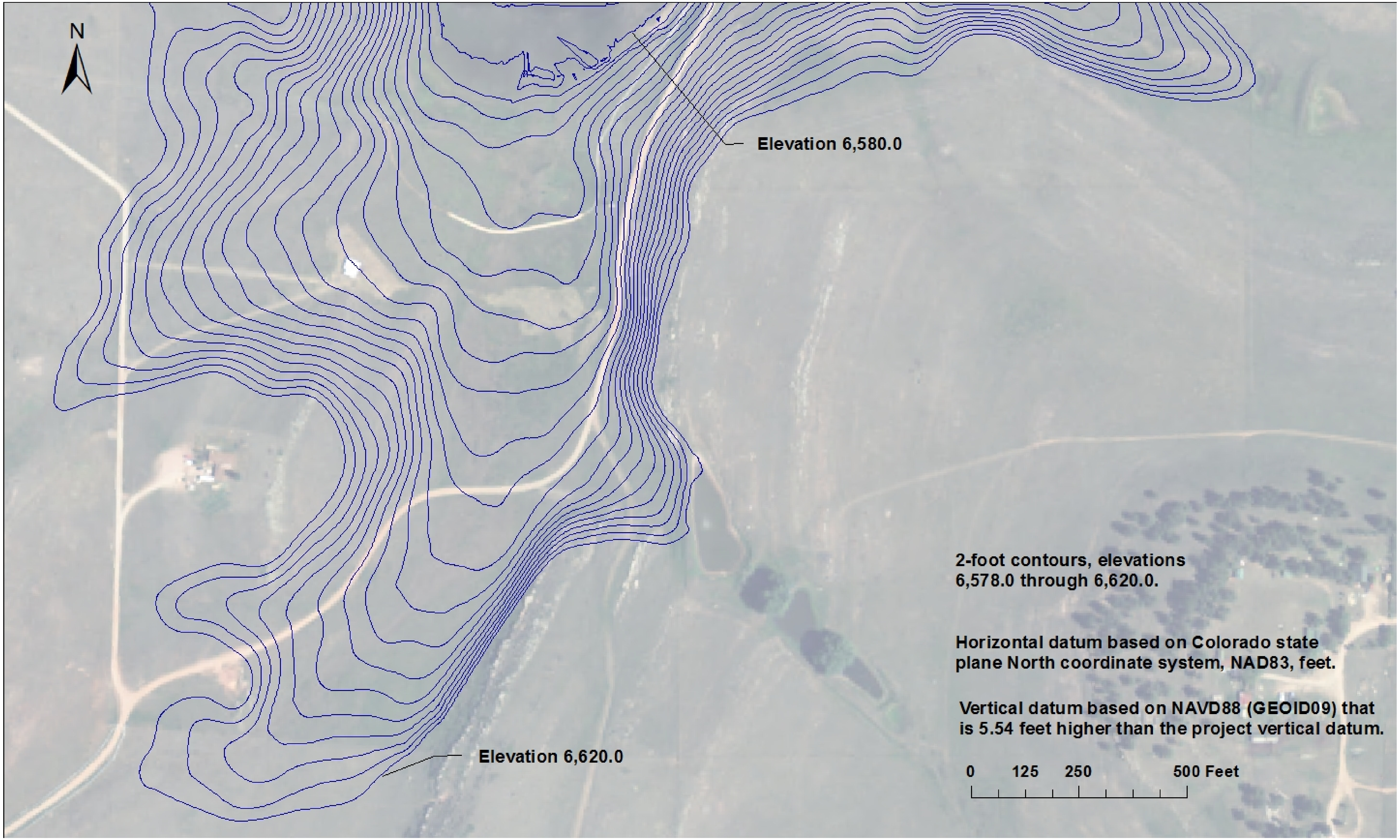

Figure 17 - Pinewood Reservoir, developed 2-foot contours from 2012 bathymetric survey and imported data coverages, 1 of 4 (NAVD88/GEOID09).

2012 Pinewood Reservoir Storage Capacity Methods

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP (Bureau of Reclamation, 1985). The ACAP program can compute the area and capacity at elevation increments from 0.01 to 1.0 foot by linear interpolation between the given contour surface areas. For this study the 2-foot computed surface areas from elevation 6,512.0 through 6,595.0 were used. The zero surface area was at elevation 6,510.5. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit that was set at 0.000001 for Pinewood Reservoir. The capacity equation is then used over the full range of intervals fitting within the allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from basic area curve over that interval) is utilized until it exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. Through differentiation of the capacity equations, which are of second order polynomial form, final area equations are derived:

$$y = a_1 + a_2x + a_3x^2$$

where:
y = capacity
x = elevation above a reference base
a_1 = intercept
a_2 and a_3 = coefficients

Results of the Pinewood Reservoir area and capacity computations are listed in a separate set of 2012 area and capacity tables and have been published for 0.01, 0.1, and 1-foot elevation increments (Bureau of Reclamation, 2013). A description of the computations and coefficients output from the ACAP program is included with those tables. As of June 2012, at conservation use elevation 6,580.0, the surface area was 97 acres with a total capacity of 2,104 acre-feet. At maximum and top of surcharge elevation 6,589.0, the surface area was 124 acres with a total capacity of 3,095 acre-feet.

Pinewood Reservoir Surface Area and Capacity Results

This section provides 2012 surface area and capacity results along with volume changes over time for Pinewood Reservoir. Table 2 provides a summary of the changes in Pinewood Reservoir storage between the time of dam closure in 1954 and the May 2012 topographic survey. The area and capacity curves for the original and 2012 surveys are plotted on Figure 18. Table 3 provides a summary of the original and 2012 surface areas and capacities. The 2012 bathymetric survey and the other data sources summarized in the *Topography Development* section provided adequate information for computing the surface areas from elevation 6,510.5 through top of dam elevation 6,595.0. The ACAP program was used to interpolate and compute the area and capacity values between elevations from the surface area inputs.

RESERVOIR SEDIMENT
DATA SUMMARY

Pinewood Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM

1. OWNER Bureau of Reclamation	2. STREAM Rattlesnake	3. STATE Colorado
4. SEC 30 TWP. 5N RANGE 70W	5. NEAREST P.O. Loveland	6. COUNTY Larimer
7. LAT 40 ° 22 ' 4.5 " LONG 105 ° 17 ' 15 "	8. TOP OF DAM ELEVATION 6,595.0 [1]	9. SPILLWAY CREST EL 6,580.0 [2]

RESERVOIR

10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, AC-FT	13. ORIGINAL CAPACITY, AC-FT	14. GROSS STORAGE ACRE-FEET	
a. FREEBOARD	6,595.0 [3]				15 DATE STORAGE BEGAN
b. SURCHARGE	6,589.0	124	998	3,179	1954
c. FLOOD CONTROL					
d. JOINT USE					16 DATE NORMAL OPERATIONS BEGAN
e. CONSERVATION	6,580.0	97	1,568	2,181	
f. INACTIVE	6,556.0	38	197	613	
g. DEAD	6,550.0	28	416	416	1954
17. LENGTH OF RESERVOIR	1.0 MILES	AVG. WIDTH OF RESERVOIR	0.2 MILES		

BASIN

18. TOTAL DRAINAGE AREA	3.5 [4] SQUARE MILES	22. MEAN ANNUAL PRECIPITATION	13 [3] INCHES
19. NET SEDIMENT CONTRIBUTING AREA	3.5 SQUARE MILES	23. MEAN ANNUAL RUNOFF	[4] INCHES
20. LENGTH MILES	AVG. WIDTH MILES	24. MEAN ANNUAL INFLOW	[5] ACRE-FEET
21. MAX. ELEVATION	MIN. ELEVATION	25. ANNUAL TEMP, MEAN	50 °F RANGE -39 °F to 114 °F [3]

SURVEY DATA

26. DATE OF SURVEY	27. PER. YRS	28. PER. YRS	29. TYPE OF SURVEY	30. NO. OF RANGES OR INTERVALS	31. SURFACE AREA, AC.	32. CAPACITY ACRE - FEET	33. C/ RATIO AF/AF
1954			Contour (D)	5-ft	124 [6]	3,179 [6]	
5/12	58		Contour (D)	2-ft	124 [7]	3,095 [7]	

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIPITATION	35. PERIOD WATER INFLOW, ACRE-FEET a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	36 WATER INFLOW TO DATE, AF a. MEAN ANN.	b. TOTAL
5/12	13 [3]	[5]				

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET a. TOTAL	b. AVG. ANN.	c. /MI.^{2}-YR.	38. TOTAL SEDIMENT DEPOSITS TO DATE, AF a. TOTAL	b. AVG. ANN.	c. /MI.^{2}-YR.
5/12	84	1.4		58	1.4	

26. DATE OF SURVEY	39. AVG. DRY WT. (#/FT^3)	40. SED. DEP. TONS/MI.^{2}-YR a. PERIOD	b. TOTAL TO DATE	41. STORAGE LOSS, PCT. a. AVG. ANNUAL	b. TOTAL TO DATE	42 SEDIMENT INFLOW, PPM a. PER.	b. TOT.
5/12				0.044 [8]	2.64 [8]		

Table 2 - Reservoir sediment data summary (page 1 of 2).

45. RANGE IN RESERVOIR OPERATION

YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1986	6,579.3	6,568.6	[9]	1987	6,579.2	6,569.4	
1988	6,579.6	6,570.0		1989	6,579.6	6,569.4	
1990	6,579.4	6,552.0		1991	6,579.5	6,563.2	
1992	6,579.7	6,557.4		1993	6,979.5	6,557.2	
1994	6,578.9			1995	6,979.4	6,575.7	
1996	6,578.6	6,575.7		1997			
1998				1999			
2000				2001			
2002				2003	6,576.6	6,565.3	
2004	6,579.1	6,565.6		2005	6,578.5	6,556.3	
2006	6,578.2	6,555.7		2007	6,578.4	6,560.9	
2008	6,578.5	6,560.0		2009	6,578.3	6,555.7	
2010	6,579.2	6,568.1		2011			
2012	6,579.2	6,555.7					

46. ELEVATION - AREA - CAPACITY - DATA FOR 2009

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
2012	**SURVEY**		6,510.5	0.0	0	6,513.0	0.1	0
6,514.0	0.1	0	6,516.0	0.2	1	6,518.0	0.6	1
6,520.0	1.3	3	6,522.0	2.1	7	6,524.0	3.3	12
6,526.0	4.3	20	6,528.0	5.2	29	6,530.0	6.2	40
6,532.0	7.6	54	6,534.0	9.1	71	6,536.0	11.1	91
6,538.0	13.5	115	6,540.0	15.6	145	6,542.0	17.3	177
6,544.0	19.2	214	6,546.0	21.4	254	6,548.0	23.9	300
6,550.0	26.7	350	6,552.0	30.0	407	6,554.0	34.0	471
6,556.0	38.0	543	6,558.0	41.6	622	6,560.0	45.2	709
6,562.0	48.7	803	6,564.0	52.2	904	6,566.0	56.9	1,013
6,568.0	61.8	1,132	6,570.0	67.3	1,261	6,572.0	75.6	1,403
6,574.0	82.9	1,562	6,576.0	87.8	1,733	6,578.0	93.0	1,914
6,580.0	97.4	2,104	6,582.0	102.5	2,304	6,584.0	108.5	2,515
6,586.0	114.5	2,738	6,588.0	120.6	2,973	6,589.0	123.7	3,095
6,590.0	126.9	3,220	6,592.0	133.5	3,481	6,594.0	139.8	3,754
6,595.0	143.1	3,896						

47. REMARKS AND REFERENCES

[1] Top of dam 6,595.0 that design tied to project vertical datum, 5.54 feet lower than NAVD88.

[2] Spillway crest elevation 6,580.0. Concrete-lined, open-channel, uncontrolled.

[3] Bureau of Reclamation's Project Data Book, www.usbr.gov and SOP for Rattlesnake Dam and Pinewood Reservoir.

[4] Total drainage area. Most water supplied from diverted water as part of Colorado - Big Thompson Project.

[5] Majority of inflow from diverted water and passed through system to Flatiron Reservoir and beyond. No available records.

[6] Surface area and capacity at elevation 6,589.0. Original recomputed by BOR ACAP program.

[7] Surface area and capacity at elevation 6,589.0. Surface areas from 2012 bathymetric survey.

[8] Capacity loss or difference due to sedimentation and method of collection differences.

[9] Maximum and minimum elevations by water year. From available years from BOR web site. No inflow values available.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE February 2014

Table 2 - Reservoir sediment data summary (page 2 of 2).

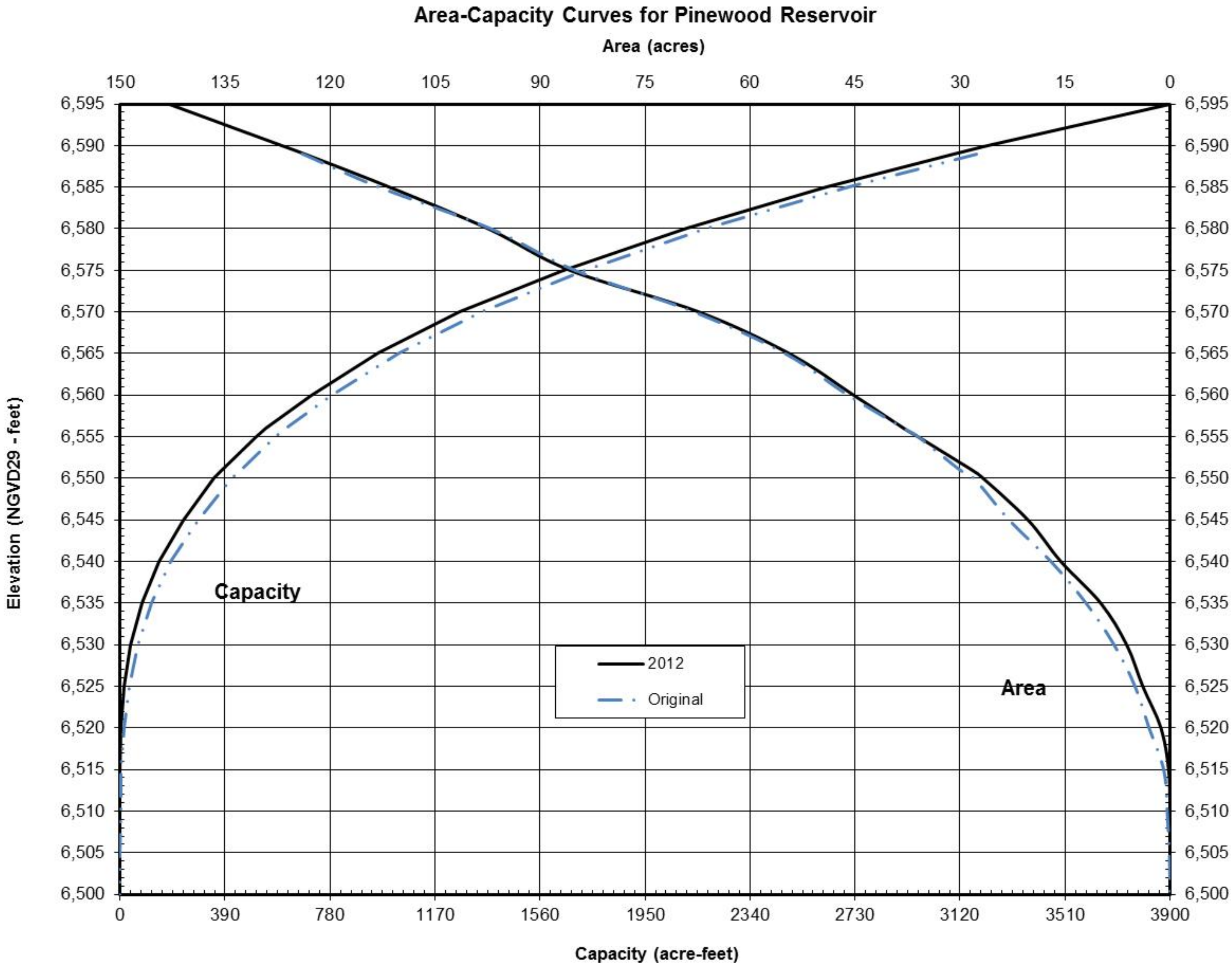

Figure 18 - Area and Capacity Curves, Pinewood Reservoir.

1	2	3	4	5	6	7	8
					2012		
	Original	Original	2012	2012	Sediment	Percent	Percent
Elevation	Area	Capacity	Area	Capacity	Volume	Computed	Reservoir
Feet	Acres	Ac-Ft	Acres	Ac-Ft	Ac-Ft	Difference	Depth
6,595.0			143	3,896			100.0
6,590.0			127	3,220			94.7
6,589.0	124.0	3,180	124	3,095	84	100.0	93.7
6,585.0	113.0	2,706	112	2,625	81	95.5	89.5
6,580.0	97.0	2,181	97	2,104	76	90.2	84.2
6,575.0	85.0	1,726	86	1,647	79	93.6	78.9
6,570.0	68.0	1,343	67	1,261	82	97.5	73.7
6,565.0	55.0	1,036	54	957	78	92.7	68.4
6,560.0	46.0	783	45	709	74	87.4	63.2
6,556.0	38.0	615	38	543	72	85.5	58.9
6,555.0	36.0	578	36	506	72	85.5	57.9
6,551.0	30.0	446	28	378	68	81.0	53.7
6,550.0	28.0	417	27	350	67	79.1	52.6
6,545.0	23.0	290	20	234	56	66.2	47.4
6,540.0	17.0	190	16	145	45	53.3	42.1
6,535.0	12.0	117	10	80	37	43.5	36.8
6,530.0	8.0	67	6	40	27	31.5	31.6
6,525.0	5.0	35	4	15	19	22.6	26.3
6,520.0	3.0	15	1	3	11	13.5	21.1
6,515.0	0.9	5	0	0	5	5.3	15.8
6,510.0	0.4	2	0	0	2	1.8	10.5
6,505.0	0.1	0	0	0	0	0.2	5.3
6,500.0	0.0	0	0	0	0	0.0	0.0

1 Reservoir water surface elevations tied to project datum that is 5.54 feet lower than NAVD88.
2 Original reservoir surface area.
3 Original reservoir capacity recomputed using ACAP.
4 2012 measured reservoir surface area.
5 2012 reservoir capacity computed using ACAP.
6 2012 measured change in volume, column (3) - column (5).
7 Percent of total sediment, 84.4 acre-feet at elevation 6,589.0.
8 Reservoir depth expressed in percentage total depth, 95 feet.

Table 3 - Summary of 2012 reservoir survey results.

2012 Pinewood Reservoir Analyses

Results of the 2012 Pinewood Reservoir area and capacity computations are listed in Table 2 and columns 4 and 5 of Table 3. Columns 2 and 3 in Table 3 list the original area and capacity values recomputed using the ACAP program. Figure 18 is a plot of the Pinewood Reservoir surface area and capacity values for the surveys and illustrates the differences in surface area and storage. Table 2 shows the total surcharge capacity at elevation 6,589.0 for both surveys along with the computed differences due to sediment deposition and methods of collection. Table 3 compares results from the original and 2012 surveys along with computation differences from maximum water surface elevation 6,589.0 and below. The 2012 measured surface area at elevation 6,589.0 was 124 acres, matching the original area at the same elevation.

At maximum or surcharge water surface elevation 6,589.0 the computed total change in reservoir volume was 84 acre-feet between 1954 and 2012. It is assumed the measured change is due to sediment accumulation during the years of reservoir operation and differences in methods of collection.

Summary and Conclusions

This Reclamation report presents the results of the May 2012 survey of Pinewood Reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography;
- compute area-capacity relationships; and
- calculate capacity change due to sediment accumulation.

A control survey was conducted using the online positioning user service (OPUS) and RTK GPS to confirm the horizontal and vertical control network near the reservoir for the hydrographic survey. OPUS is operated by the NGS and allows users to submit GPS data files that are processed with known point data to determine positions relative to the national control network. The GPS base was set over a Larimar County monument “LAR-CP5 located near the boat ramp where it provided continuous radio link throughout the hydrographic survey.

The study’s horizontal control was in US survey feet, Colorado state plane coordinates, north zone, in NAD83. The vertical control, in US survey feet, was tied to the project’s vertical datum that is about 5.54 feet lower than NAVD88 (GEOID09). Unless otherwise noted, all elevations in this report are referenced to the project vertical datum. The developed reservoir topography presented in this report is tied to NAVD88 (GEOID09).

The June 2012 underwater survey was conducted near reservoir elevation 6,576.9 as measured by the Reclamation gage at the dam and confirmed by RTK GPS measurements. The bathymetric survey used sonic depth recording equipment interfaced with RTK GPS for determining sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates as the survey boat navigated along set grid lines and the shoreline covering Pinewood Reservoir.

The above-water 2012 topography was developed using multiple sources including digitized water surface edges from orthographic aerial images of the reservoir (USDA, 2010) and airborne digital data obtained as IFSAR bare-earth information for the reservoir area (Intermap, 2011). IFSAR technology enables mapping of large areas quickly and efficiently, resulting in detailed information at a much reduced cost compared to other technologies such as aerial photogrammetry and LiDAR. The reported accuracies for the IFSAR data are 2-meters or better horizontally and 1-meter or better vertically in unobstructed flat-ground areas. Other technologies would produce more accurate data than IFSAR, but the funding was not available for this study to acquire these other data sets. In the open, above-water areas of the reservoir, the IFSAR data points matched well with known elevation information and were retained for this analysis. In areas around the reservoir, mainly steeper shoreline topography, the IFSAR data did not match well and was removed for this analysis. The remaining IFSAR data points along with the other data sources were used to develop the 2012 Pinewood Reservoir topography. For the reservoir areas where the IFSAR data was removed, the topographic mapping software was used to interpolate contours from the surrounding data sources.

The final 2012 Pinewood Reservoir topographic map is a combination of the digitized water surface edge from the USDA aerial photographs, IFSAR data, and the 2012 hydrographic survey data, all tied vertically to NAVD88 (GEOID09). A computer program was used to generate the 2012 topography and resulting reservoir surface areas at predetermined contour intervals from the combined reservoir data from elevation 6,620.0 and below. The 2012 surface area at elevation 6,589.0 was 124 acres, matching the original surface area at the same elevation. The input from the 2012 surface areas from elevation 6,595.0 and below was used to develop the area and capacity tables. The 2012 area and capacity tables were produced using the computer program (ACAP) that calculated area and capacity values at prescribed elevation increments using the measured contour surface areas and a curve-fitting technique that interpolated values between the input elevation surface areas.

Tables 2 and 3 contain summaries of the Pinewood Reservoir and watershed characteristics for the 2012 survey. The 2012 survey determined the reservoir has a total storage capacity of 3,095 acre-feet with a surface area of 124 acres at maximum reservoir water surface elevation 6,589.0. At conservation water surface elevation 6,580.0 the total capacity was 2,104 acre-feet with a surface area of 97 acres. Since closure of Pinewood Dam in 1954, this survey measured an 84 acre-foot reduction in reservoir capacity below elevation 6,589.0 by comparing the original and 2012 capacities for the reservoir. It is assumed the measured difference was primarily due to sediment deposition, with some variation in results attributed to data accuracy differences between methods of collection and analysis.

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