RECLAMATION

Managing Water in the West

Technical Report No. SRH-2013-23

Brantley Reservoir 2013 Bathymetric Survey

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

August 2013

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Brantley Reservoir 2013 Bathymetric Survey

prepared by

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Bureau of Reclamation
Technical Service Center
Water and Environmental Resources Division
Sedimentation and River Hydraulics Group
Denver, Colorado

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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 the Sedimentation Group conducted the bathymetry survey of the reservoir in April 2013. Ron Ferrari completed the data processing to generate the 2013 topography and area-capacity values presented in this report. Kent Collins of the Sedimentation Group performed the technical peer review of this document.

Mission Statements

The U. S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

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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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14. ABSTRACT

Reclamation surveyed Brantley Reservoir, April 2013, to develop updated reservoir topography and compute present storage-elevation relationships (area-capacity tables). The bathymetric survey, conducted near water surface elevation 3,241.7 feet, was tied to the North American Vertical Datum of 1988 (NAVD88). The survey crew used sonic depth recording equipment interfaced with a real-time kinematic (RTK) global positioning system (GPS) that provided sounding positions throughout the underwater portion of the reservoir covered by the survey vessel. The above-water topography was developed from high altitude bare earth data called Interferometric Synthetic Aperture Radar (IFSAR) collected in 2008. Topography was confirmed and adjusted using contours from a 2001 reservoir survey and digitized reservoir's water edge from aerial photographs collected by the United States Department of Agriculture (USDA).

Study conducted under the direction of the Albuquerque Area Office of Reclamation's Upper Colorado Region with elevations tied to NAVD88, 1.6 feet higher than the constructed features tied to National Geodetic Vertical Datum of 1929 (NGVD29).

As of April 2013, at current active conservation use elevation 3,256.9, the reservoir surface area was 3,483 acres with a capacity of 44,613 acre-feet. Since the 2001 survey, a total capacity change of 751 acre-feet below elevation 3,256.9 was measured. The capacity change is partially due to sediment deposition, but primarily due to methodology differences between the surveys. There were known issues with the original reservoir topography, no sediment computations have been performed since dam closure. Documented conditions in the drainage basin currently restrict portions of the drainage area from contributing sediment to the active zone of Brantley Reservoir.

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Technical Report No. SRH-2013-23

Brantley Reservoir 2013 Bathymetric Survey

Brantley Dam
New Mexico

9/11/13

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Introduction

Brantley Reservoir and Dam, on the Pecos River in Eddy County, are about 13 miles upstream of the city of Carlsbad and 10 miles upstream of Avalon Dam in southeast New Mexico (Figure 1). The reservoir and dam, principal features of the Brantley Project, are operated and maintained by the Carlsbad Irrigation District to provide irrigation water, flood control storage space, and benefits for wildlife and recreation. The reservoir replaced McMillan Dam and reservoir whose storage was significantly reduced by sediment deposition.

Figure 1 - Reclamation Reservoirs located in New Mexico.

Brantley Dam, constructed from 1984 through 1989, was dedicated on May 13 of 1989 with first storage on August 31, 1988 (Figure 2). The design of the dam and original capacity were tied vertically to NGVD29. Since a 2001 reservoir survey however, the dam has operated with the 2001 capacity tables tied to NAVD88. For the 2013 study, all elevations were tied to NAVD88 and listed project feature elevations were shifted from NGVD29 to NAVD88. The 2001 survey used an average shift of 1.70 feet from the project vertical datum to NAVD88 (Bureau of Reclamation, 2003). The 2013 survey determined the shift to be 1.6 feet and was applied to all elevations for this study.

The dam is a zoned earthfill embankment with a concrete gravity midsection and the following dimensions in feet:

Concrete Section:

Structural height[1]	140	Hydraulic height	101
Crest length	730	Crest elevation[2]	3,308.5 (NGVD29)
Top width	15-26.8		3,310.1 (NAVD88)

Earthfill Embankment Section:

Structural height	110	Crest length	20,120
Top width	24	Crest elevation	3,308.0 (NGVD29)
			3,309.6 (NAVD88)

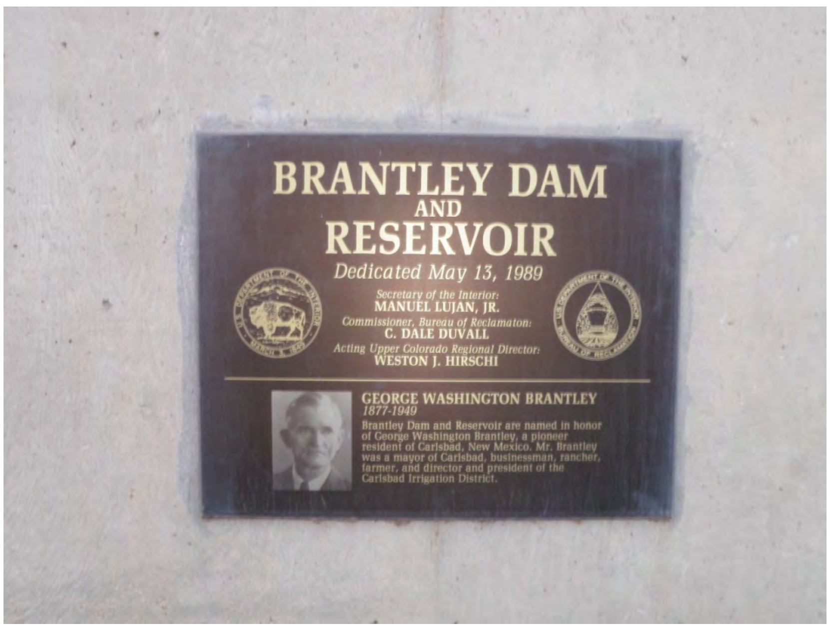

Figure 2 - Brantley Dam and Reservoir dedication plaque.

The total drainage area above Brantley Dam is 17,650 square miles. Excluding the drainage areas above Lake Sumner and Two Rivers Reservoir, up to 12,233 square miles could be considered sediment contributing. Three of the four major tributaries that could potentially contribute sediment are currently not

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[1] Values for concrete dam section. 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 noted, all elevations for this study are based on NAVD88. This study determined the original project datum established during construction was tied to NGVD29 and around 1.6 feet lower than NAVD88.

continuously connected to the Pecos River that drains into Brantley Reservoir (Reclamation, 2008). Brantley Reservoir was developed to replace McMillan Reservoir that experienced significant sediment deposition over its operation life. The McMillan delta and mature vegetation currently dams several of the contributing tributaries. The Kaiser Channel was also developed, replacing the natural Pecos River channel alignment, to directly deliver water to the reservoir. This channel efficiently delivers normal inflows to the active area of Brantley Reservoir, resulting in less eroding of the old McMillan Reservoir delta. McMillan Dam was breached to allow flows to reach Brantley Dam, but the remaining structure currently acts as a hydraulic control where portions of the high flows pond, allowing sediment deposition upstream on top of the previously deposited McMillan Reservoir sediments. Brantley Reservoir has an average width of 1.8 miles and a length of around 11.6 miles at elevation 3,272.

The spillway, located within the dam's concrete section, has a gated ogee-shaped overflow section, inclined chute, and slotted bucket energy dissipater around 350 feet wide. There are six 50-by 25.24-foot radial gates at the overflow section. The spillway crest elevation is 3,261.1. The spillway capacity at maximum reservoir elevation 3,305.1 is 352,000 cubic feet per second (cfs).

The river outlet works consists of two rectangular 4-by 4-foot steel-lined conduits located on each side of the center line within the concrete gravity section. The outlet conduits are controlled by two sets of tandem 4.0-by 4.0-foot regulating and guard gates. The downstream gate on each conduit is used for flow regulation and the upstream (guard) gate is used for emergency closure. The invert elevation is 3,212.3 with design capacity of 1,450 cfs at reservoir elevation 3,261.1 and 1,800 cfs at water surface elevation 3,284.6.

A low flow outlet works is located left of the concrete spillway wall, downstream of the dam. The structure is a 36-inch diameter concrete pipe between the stilling basin and the old Pecos River channel. The outlet is designed to ensure a minimum flow of 20 cfs for fish habitat in the reach of the old Pecos River between the dam and spillway channel junction during non-irrigation releases.

Previous Surveys

Original

The original area-capacity tables, labeled 1992, were generated from 1990 aerial photogrammetry above elevation 3,240 (NGVD29) combined with 10-foot contours from the U.S. Geological 7.5 minute quadrangles of the reservoir area below elevation 3,240 (NGVD29). The vertical datum used for the 1990 aerial collection has been undefined in the past and is still considered unknown, preventing its use for computing sediment deposition since dam closure.

2001 Survey

The 2001 survey was the first since Brantley Dam closure in 1988 (Tetra Tech, August 2001). The underwater survey, conducted near water surface elevation 3,254.5, dealt with windy conditions during the bathymetric portion of the collection. The method used GPS with a single beam sounder at a 5-second collection interval. For the above water, aerial photography collection resulted in 4-foot contours from elevation 3,252.0 through 3,272.0. The combined data sets resulted in 4-foot contour intervals from elevation 3,208.0 through 3,272.0 that was available for the 2013 analysis as AutoCAD 14 drawing files. The 2001 study ended at elevation 3,272.0 and did not develop updated capacity for the flood and surcharge pools of the reservoir that extend to maximum water surface elevation 3,305.1. During the analysis an attempt was made to compare the 2001 Brantley Reservoir survey data with the original or 1992 area-capacity tables. The effort could not resolve the vertical datum issues with the 1990 aerial photos and concluded the sediment deposition could not be computed by comparing the two surveys. The 2001 survey collected elevation data on existing features and the reservoir water surface, concluding the average shift between the project datum and NAVD88 was 1.7 feet. It was noted the water surfaces were measured during windy conditions.

Control Survey Data Information

Prior to the 2013 bathymetric survey the area near the east boat ramp was searched for a control point established during the 2001 survey. The monument was not located and appeared to have been destroyed by the construction of a walkway path in the recreation area. The west boat ramp area was closed at beginning of the 2013 survey so an attempt to locate a 2001 control point was not conducted. The 2013 survey established a temporary control point between the parking lot and east boat ramp area, Figure 3. The point is a labeled aluminum cap mounted on rebar driven into the ground, but is considered temporary because it is located in open recreational area near a highly traveled path where it could be easily disturbed. The on-line positioning user service (OPUS) was used to establish horizontal and vertical control on the temporary point that was used for the entire 2013 survey. OPUS is operated by the National Geodetic Survey (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 OPUS generated coordinates were used to measure position and the vertical difference between NGVD29, NAVD88, and recorded water surface elevations at the dam. Water surface measurements were collected on the first day of the survey during very calm water surface conditions with no wind or wave action from boat activities. The horizontal control was established in New Mexico state plane east coordinates, NAD83, in feet. Following are the computed OPUS coordinates for the temporary point labeled, SRH1-2013:

East 524,742.145
North 567,775.021
Elevation 3,312.989 (NAVD88) (GEOID12A)

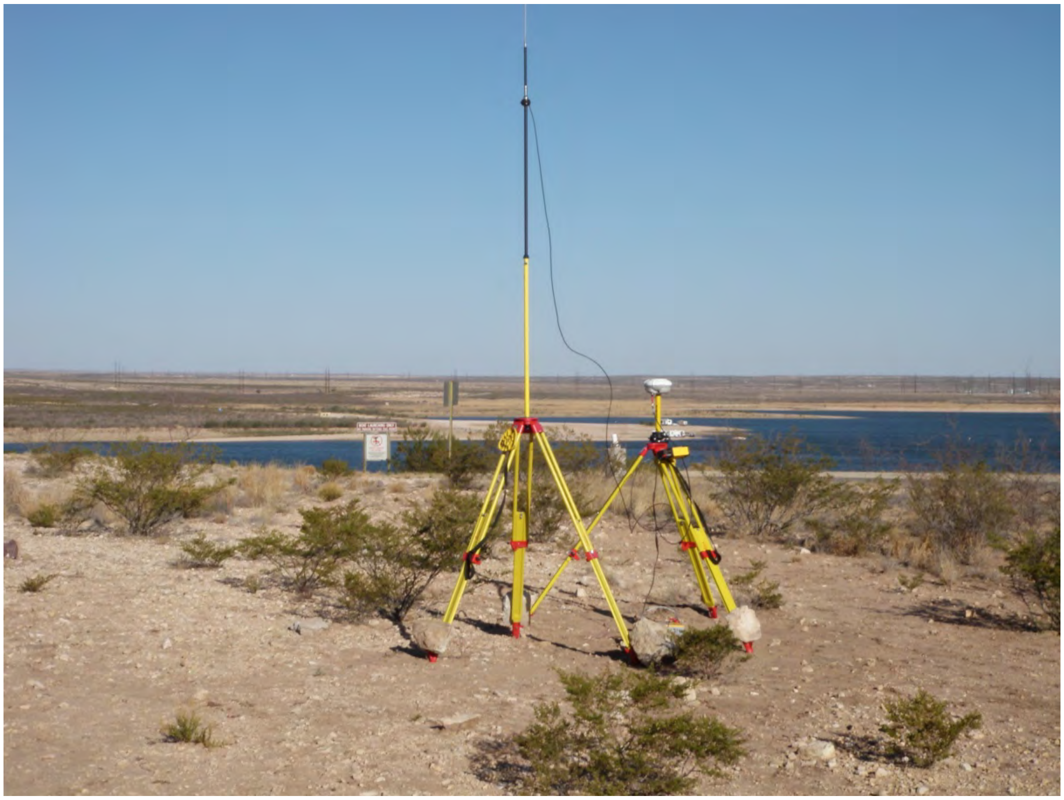

Figure 3 - Temporary control point used as base station for the 2013 hydrographic survey.

As part of the 2013 reservoir survey Brantley Dam piezometer well locations were measured using RTK GPS with the base station set on SRH1-2013 (Figure 3). During the piezometer survey, several Reclamation brass cap monuments and elevations were measured along the top of the concrete portion of the dam, Figures 4, 5, and 6. Except for the one monument labeled “Spill” (Figure 4) located on the left abutment of the concrete portion of the dam, the monuments had no identification labels. The 2013 measured caps were plotted with the 2001 survey data revealing that two of the Reclamation monuments were measured by both studies. The common points were labeled “999” and “1000” in the 2001 survey. The 2013 elevations were within +/- 0.02 feet of the 2001 survey elevations, confirming both surveys were tied to the same vertical datum, NAVD88. Following are a few of the 2013 measured monument coordinates tied to NAD83 New Mexico state plane, east zone, in feet, and elevations tied to NAVD88 (GEOID12A).

	Point "999"	**Point "1000"**	**Point "Spill"**	
East	526,662.505	526,597.822	526,781.156	
North	561,774.769	561,576.879	562,023.671	
Elev.	3,309.947	3,309.983	3,309.999	(NAVD88)
			3,308.4	(NGVD29)
		Difference	1.6	

Figure 4 - BOR cap labeled "Spill" located on left abutment of concrete structure.

Figure 5 - BOR brass caps on top of Brantley Dam with no detailed labeling.

Figure 6 - RTK GPS topo measurement on monument, top of dam.

Information provided to the Sedimentation Group indicated there were original or design elevations on several Reclamation monuments with one marked “Spill” located on the far left and outside edge of the spillway hoist deck. The published Reclamation elevation on that point was 3,308.4 feet, around 1.6 feet lower than the 2013 measured elevation. There were several elevations measured along the top of the concrete portion of dam that averaged around elevation 3,310. The reported design dam crest elevation was 3,308.5 (NGVD29), around 1.5 feet lower than the 2013 measurements. In the study area, the reported NGS average computed vertical shift between NGVD29 and NAVD88 is around 1.54 feet. As previously noted, the 2001 survey measured a vertical shift of 1.7 feet (Reclamation, 2003). Either shift would be acceptable, but since the 2013 survey compared well with the two monuments surveyed in 2001, the gage readings from calm water surface condition measurements, the measured spillway monument labeled “Spill”, and the top of dam points, the 1.6 foot shift was used for this study. Unless noted, all elevations and computations within this report are referenced to NAVD88 and are 1.6 feet higher than Reclamation’s construction datum tied to NGVD29. The presented results and developed topographic maps are tied to NAVD88. There was no shifting of the 2001 results since they were already tied to NAVD88 and the two surveys measured common points whose elevations were within +/- 0.02 feet.

Reservoir Operations

Brantley Reservoir provides irrigation water and flood control storage space along with wildlife and recreation benefits. During periods without irrigation releases the dam passes a mitigation flow of 20 cfs through the low level outlet works. During the irrigation season releases are from Brantley Reservoir to Avalon Reservoir at the necessary rate to support irrigation diversions, between 75 and 350 cfs. The Corp of Engineers initiates flood operations once the reservoir rises into the flood pool, elevation 3,272.6.

The reservoir’s original design included a 134,800 acre-foot allowance for the 100-year projected sediment inflow. March 2008 studies reviewed the formulation of the original estimate (based on limited water and suspended sediment data) and recommend the 100-year value be reduced to 43,700 acre-feet (Reclamation, 2008). The 2008 review included a longer flow period, regulation of flood peaks, reductions in sediment delivery from Pecos River tributaries, and sediment being trapped by upstream reservoirs that the original estimate did not take into account. The April 2013 area-capacity tables show 44,613 acre-feet of storage below current active conservation elevation 3,256.9. As sediments accumulate within the active reservoir zone, the elevation of the active conservation pool will eventually increase to flood pool elevation 3,272.6.

The 2013 area and capacity tables were developed using the 2013 bathymetric data combined with the Interferometric Synthetic Aperture Radar (IFSAR) above water data that covered the entire reservoir area. The IFSAR data was collected in 2008, but was the latest and best available information for the above water area. Area and capacity values were computed from the 2001 survey data up to elevation 3,272.0 where the aerial coverage ended. The IFSAR developed contours compared well with the 2001 developed contours and were used to develop the 2013 area and capacity table for the entire reservoir, including the flood control and surcharge zones up to maximum reservoir operation elevation 3,305.1. The 2013 total capacity at elevation 3,305.1 is 1,010,547 acre-feet. The following values are from the April 2013 capacity table:

- 626,512 acre-feet of surcharge between elevation 3,284.6 and 3,305.1.
- 217,808 acre-feet of flood control between elevation 3,272.6 and 3,284.6.
- 121,614 acre-feet of joint use between elevation 3,256.9 and 3,272.6.
- 43,170 acre-feet of active conservations between elevation 3,226.1 and 3,256.9
- 1,404 acre-feet of inactive storage between elevation 3,212.3 and 3,226.1.
- 39 acre-feet of inactive use storage below elevation 3,212.3.

Brantley Reservoir inflow and end-of-month stage records in Table 1 show the annual fluctuation for available water years from 1988 through 2011. The average reservoir water inflow during the period, 1988 through 2011, was 90,300 acre-feet. USGS gage 08399500, Pecos River (Kaiser Channel) near Lakewood, New Mexico was used to report the annual inflows by water year. During the irrigation season there are diversion and groundwater withdraws upstream of the gage. The inflows are regulated by Lake Sumner and Two Rivers Reservoirs. Water levels listed in Table 1 show fluctuations of Brantley Reservoir over the 1988 through 2001 time period. Since the initial year of operation the levels have ranged from maximum elevation 3,259.3 in September 1991 to minimum elevation 3,226.3 in May 1990.

Hydrographic Survey, Equipment, and Method of Collection

Bathymetric Survey Equipment

The bathymetric survey equipment was mounted on an aluminum vessel with the transducer and GPS unit located over the side, Figure 7. The hydrographic system included a GPS receiver with a built-in radio, a depth sounder, a helmsman display for navigation, a computer, and hydrographic system software for collecting the underwater data. On-board batteries powered all the equipment. The shore equipment included a second GPS receiver with an external radio. The shore GPS receiver and antenna were mounted on survey tripods over a known datum point and powered by a 12-volt battery.

Figure 7 - Survey vessel for reservoir mapping with mounted transducer on side (Lake Sumner-New Mexico, March 2013)

The Sedimentation 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 just like with differential GPS. 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 New Mexico’s state plane east coordinates, NAD83, in feet.

The Brantley Reservoir bathymetric survey was conducted from April 6 through April 8, 2013 between water surface elevations 3,241.7 and 3,241.8. The bathymetric survey used sonic depth recording equipment interfaced with RTK GPS that measured the sounding locations within the reservoir covered by the survey vessel. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved along grid lines established to cover the reservoir. Shoreline data was also collected as the vessel traversed to each grid line and as it returned to port each day. The survey vessel's guidance system provided directions to the boat operator to assist in maintaining a course along the predetermined lines. As each line was traversed, the depth and position data were recorded on the laptop computer hard drive for subsequent processing, resulting in point data at one second intervals. The water surface elevations at the dam from Reclamation gage records and RTK GPS measurements were used to convert the sonic depth measurements to lake-bottom elevations tied to NAVD88 (measured 1.6 feet higher NGVD29). Final processing of the April 2013 bathymetric data resulted in around 37,500 points, Figures 8 through 11.

The underwater data was collected using a depth sounder at 200 kHz calibrated by adjusting the speed of sound through the water column which varies with density, salinity, temperature, turbidity, and other conditions. The data was digitally transmitted to the computer collection system through RS-232 serial ports. The depth sounder produced digital charts of the measured depths and when the charted depths indicated a difference from the computer recorded bottom depths, the computer data files were modified during the analysis. Additional information on collection and analysis procedures is outlined in Chapter 9 of the *Erosion and Sedimentation Manual* (Ferrari and Collins, 2006).

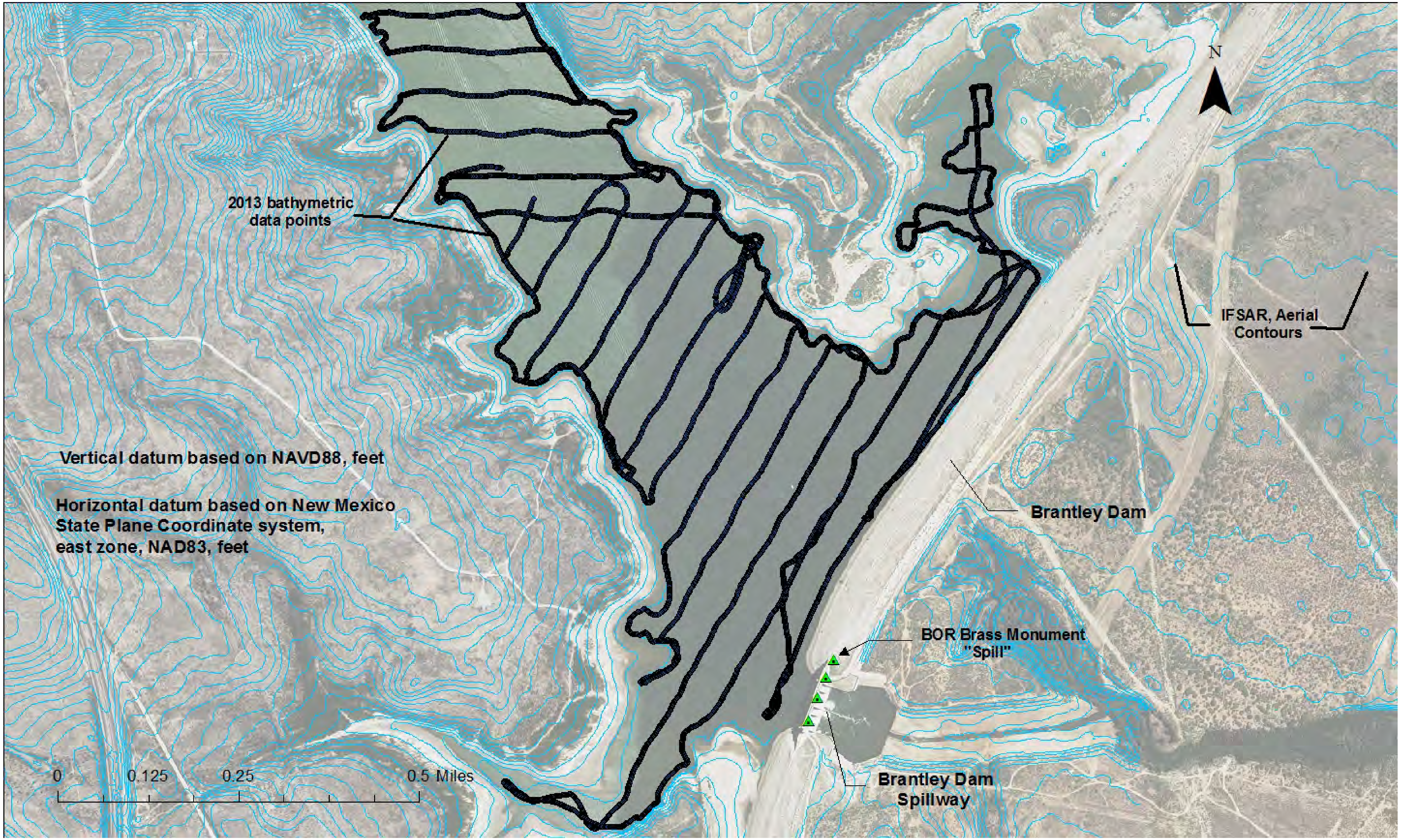

Figure 8 - Brantley Reservoir 2013 data sets (NAVD88).

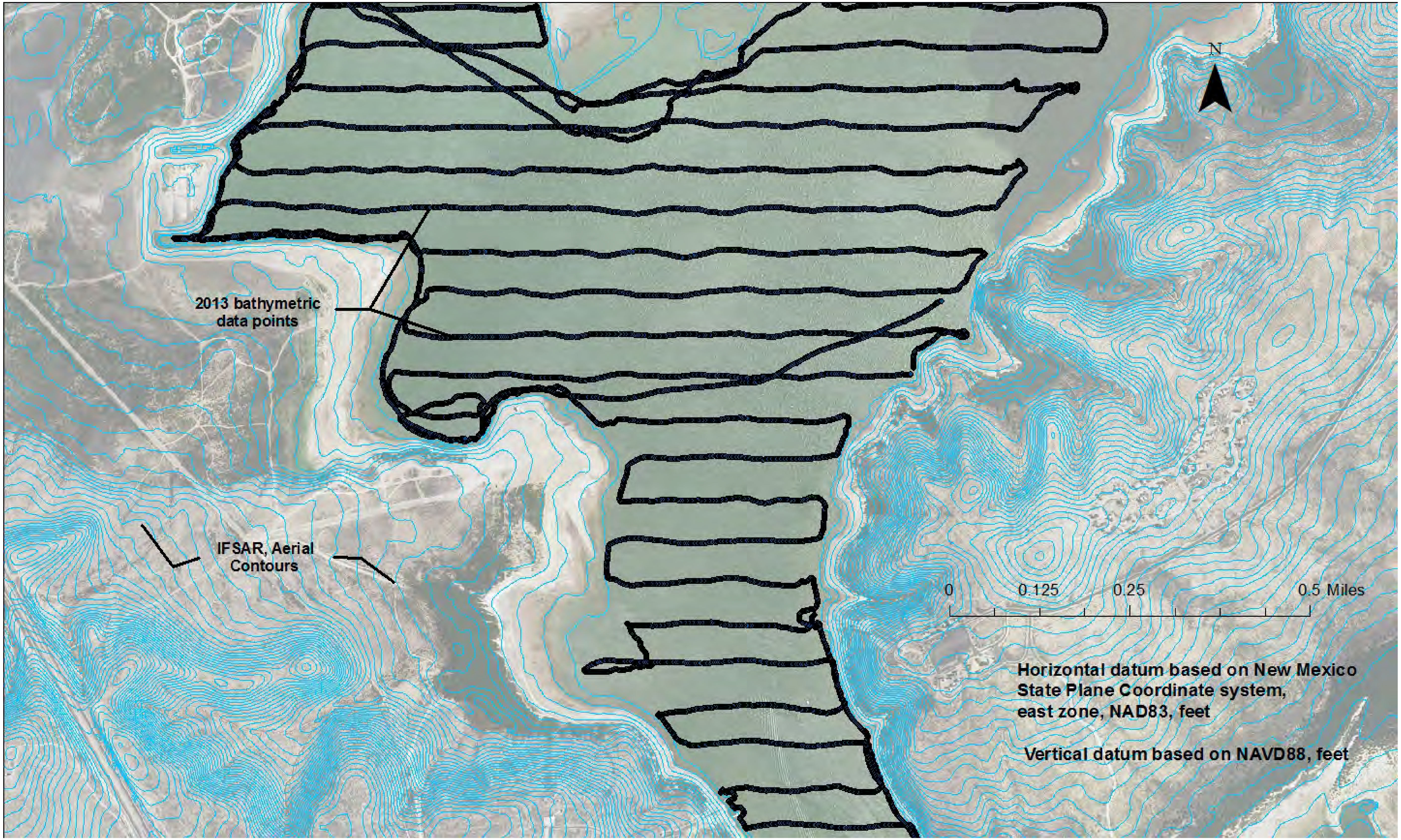

Figure 9 - Brantley Reservoir 2013 data sets (NAVD88).

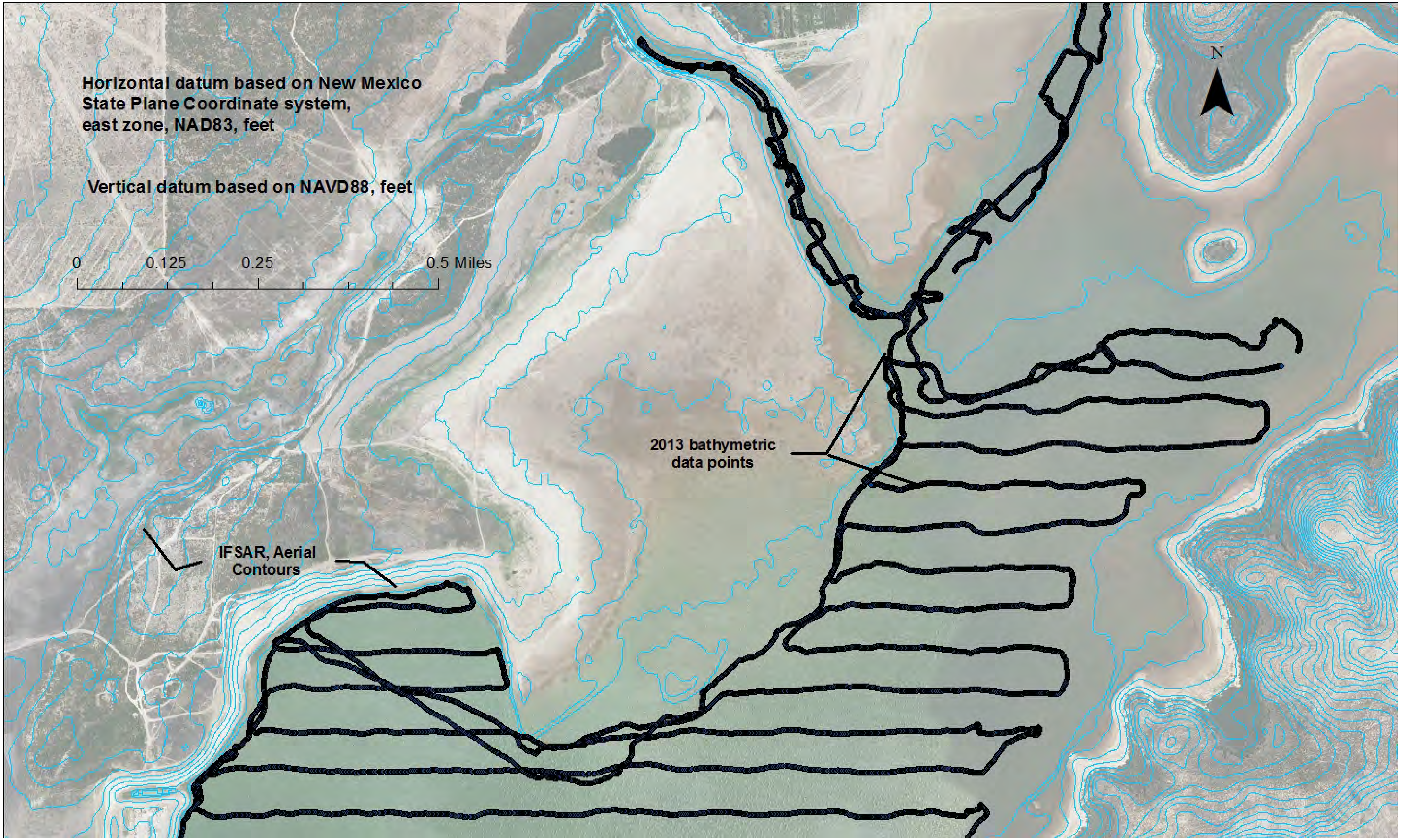

Figure 10 - Brantley Reservoir 2013 data sets (NAVD88).

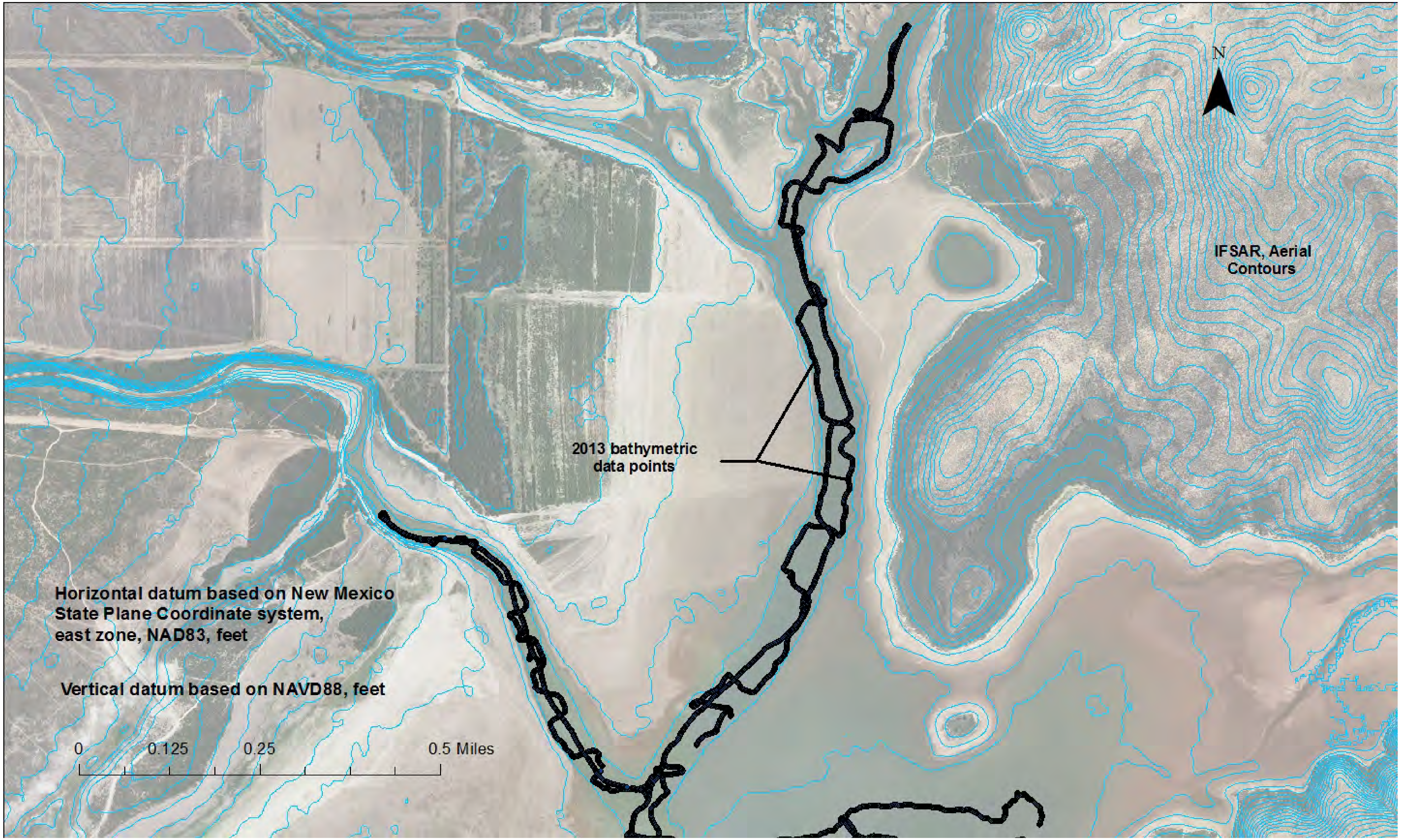

Figure 11 - Brantley Reservoir 2013 data sets (NAVD88).

Reservoir Data

Original Contours

The original area and capacity tables, developed after dam closure in 1988, were labeled 1992. The surface areas above elevation 3,240 (NGVD29) were developed from aerial photogrammetry flown in 1990. Below elevation 3,240, surface areas were developed using 10-foot contours from USGS 7.5 minute quadrangles. There was a known issue with the vertical datum for the 1990 aerial data that has never been resolved. The 2001 analysis attempted to compare the new data with the 1990 aerial, but computing sediment deposition since dam closer was not possible due to the vertical datum issue. The undefined 1990 vertical datum also prevented computation of during the 2013 analysis sediment deposition with the original capacity.

Aerial Photography

The 2013 survey of Brantley Reservoir focused on the collection of the bathymetric or underwater data that was accessible by the survey vessel, requiring acquisition of the best available above water data to complete the topographic development. During processing, orthographic aerial photos collected in 2009 (Figure 12) and 2011 were downloaded from the USDA data web site and used to confirm data sets and develop breaklines for the 2013 contour development (USDA, 2010). The reservoir contours were developed by digitizing the water's edge from these aerial images and assigning an elevation to the portions of the digitized contour lines that were used during reservoir contour development. The water surface elevations on the dates of the flights were not available for the aerial data sets, so elevations were estimated using the overlapping contours from other data sets. The contours with estimated elevations were used during the 2013 topographic development.

2001 Reservoir Contours

In 2001, a hydrographic survey was conducted on Brantley Reservoir by contract overseen by Reclamation's Albuquerque Area Office. The survey produced 4-foot contours from elevation 3,208.0 through 3,272.0 that were available for the 2013 study in AutoCAD drawing file format. The 2001 aerial survey data was used to develop 4-foot contours from elevation 3,252.0 to elevation 3,272.0, meaning the capacity of the flood and surcharge allocation zones was not computed for the 2001 study. The survey results were summarized in a report that included the developed reservoir contours and the resulting area and capacity tables (Tetra Tech, August 2001).

During the 2013 analysis, possible issues were noted with the 2001 contours, so that data set was not used in the development of the 2013 upper elevation contours. To use the upper 2001 contours in the 2013 study, no change in the contours and resulting surface areas above elevation 3,244.0 or 3,248.0 would have to have been assumed. The concerns with the 2001 aerial data involved the development of contours along the shoreline and around the old McMillian Dam site. Also, since the 2001 aerial data only extended to elevation 3,272.0, no capacities were computed within the flood and surcharge zones of the reservoir.

The first step for analyzing the 2001 contours was to convert the AutoCAD contour file into ArcGIS format. The 2001 drawing coverage included contours, breaklines, project features such as the dam and parking lots, and some aerial data points. The original intent of the 2013 study was to merge the 4-foot 2001 contours with the 2013 bathymetric data to develop updated topography. Using ArcGIS tools the 2001 contours that overlapped the 2013 bathymetric data were cut out. Once the overlapping 2001 contours were removed, the 2013 contours would be developed from the two data sets. While merging the 2001 contours with the 2013 bathymetric data, several inconsistencies were identified near the shoreline, Figure 13. As seen on Figure 13 there were several places throughout the reservoir where the 2013 bathymetric data points crossed the 2001 developed contours that were at much higher elevations. Certain 2013 underwater data points at elevation 3,239 or lower crossed over 2001 developed contours at elevation 3,240 and 3,244. Many of the areas where data crossed were within the reservoir where no major shoreline erosion was visible. Even though the majority of the reservoir had no overlap, enough overlapping locations existed to affect the comparison of the 2001 and 2013 surface areas for measuring change. At elevations 3,240 and 3,244, a net gain in surface area was computed between 2001 and 2013, which was not supported by any photographs, field observations, or survey data.

The 2001/2013 data overlap was only found on 2001 bathymetric contours developed at elevations 3,240 and 3,244. The lack of 2001 bathymetric data in portions of the reservoir in this elevation zone likely caused the problem. The 2001 report stated the underwater survey was conducted at reservoir elevation 3,254.6 and below at a five second interval, producing points every 30 to 50 feet where the survey vessel had access. The report noted the 2001 survey was conducted over several days and wind was a major factor during collection, forcing the crew to suspend the survey at times. The windy conditions prevented safe navigation to obtain data along the shorelines even though the collection was conducted at a much higher reservoir elevation. During the first day of the 2013 survey, there was no wind resulting in a calm water surface that allowed the vessel to safely maneuver in the areas where the 2001 contour and 2013 survey data overlap occurred. Despite areas of the reservoir during the 2013 bathymetry survey where large rocks and thick vegetation were present along the shoreline, the survey vessel was able to carefully collect edge data at a more deliberate pace. Due to the lack of 2001 bathymetric data areas along much of the shoreline, the 2001 generated contours were likely truncated. Computed area changes near the shore resulted from the difference in shallow areas mapped in 2001 and 2013 rather than actual bank erosion along the reservoir boundary. Due to the edge discrepancy, the 2001 developed contours were not used with the 2013 bathymetric data to develop the 2013 topography in the upper reservoir areas.

Figure 12 - Brantley Dam and Reservoir aerial image flown in 2009 near elevation 3,242 (USDA, 2010).

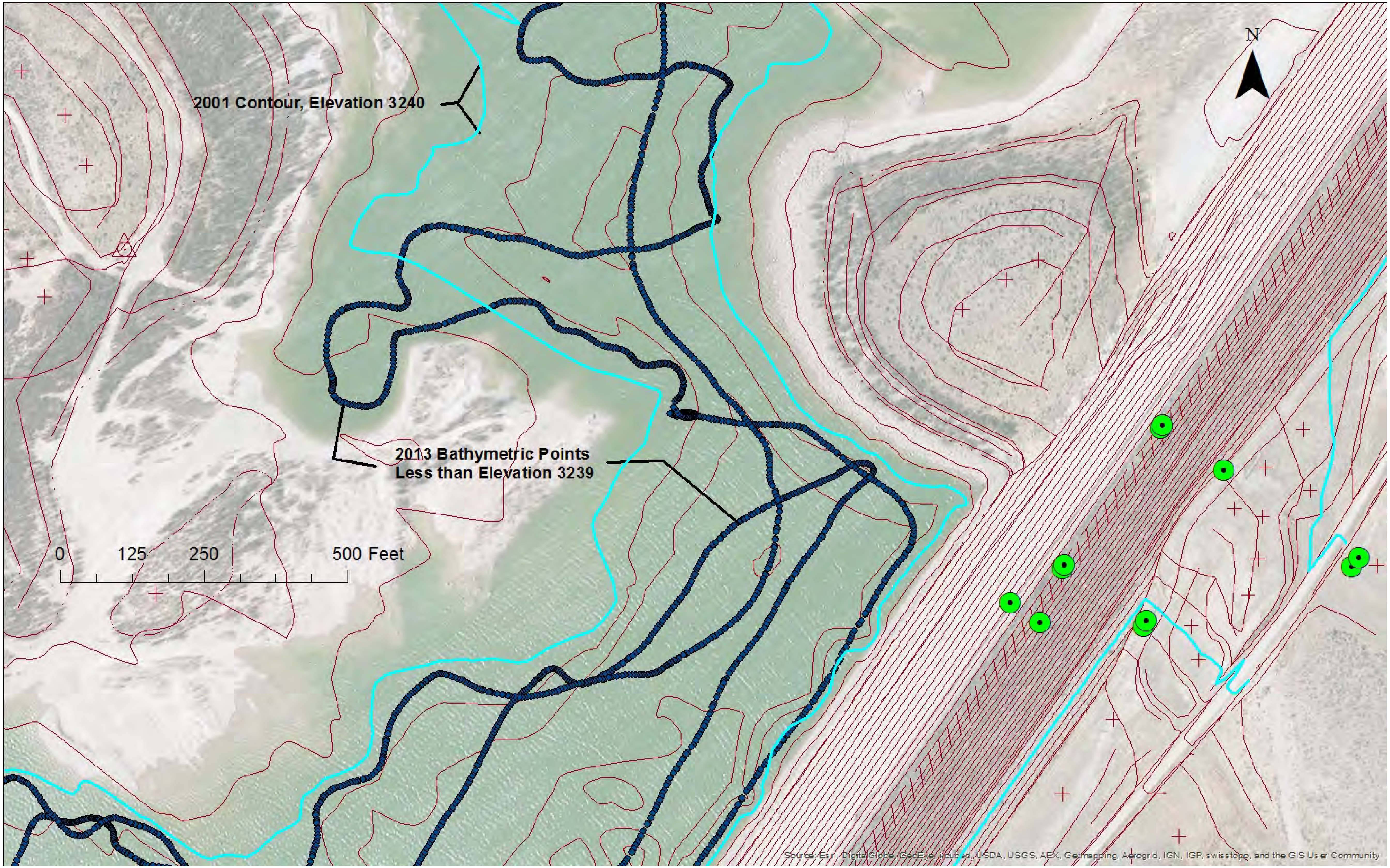

Figure 13 - Brantley Reservoir 2013 bathymetric data overlapping the 2001 contour comparison.

Aerial IFSAR

IFSAR digital bare earth data was obtained in New Mexico's state plane, east zone in NAD83 with vertical elevations tied to NAVD88 in feet. IFSAR airborne technology enables mapping of large areas quickly and efficiently resulting in detailed information at a much lower cost than other technologies such as low altitude detailed aerial photogrammetry and LiDAR. The IFSAR data at Brantley Reservoir was collected in early 2008 near reservoir water surface elevation 3,238. The IFSAR data compared well in areas of overlap with the USDA aerial developed contours, 2013 bathymetric survey points, and 2001 developed contours.

The IFSAR data provided detailed topographic images of the reservoir body with reported accuracies of 2 meters horizontally and 1 meter vertically in areas of unobstructed flat ground (Intermap, 2011). As expected, IFSAR developed contours matched well with the other data sets throughout the reservoir since the reservoir area is mostly flat with minimum vegetation. One area with lack of matching detail was the steep bank slopes of Brantley Dam. For the dam area, the 2001 detailed contours were used for the 2013 topography development. Spot comparison of the IFSAR data against the 2013 bathymetric data points found good elevation agreement; in many cases the elevation differences were in the 1 foot range, much less than the IFSAR reported vertical accuracy of 1 meter. The differences were random so a constant shift of the IFSAR data to reduce the disagreement with the bathymetry could not be determined.

Previous studies conducted by the Sedimentation Group at different project sites were much less successful using IFSAR data. The IFSAR data was initially used for topographic development for these studies, but due to the vertical accuracy issues, the computed surface areas from the IFSAR developed contours were often not included as part of the final reservoir volumes. These studies include Heron Reservoir in New Mexico, Gibson Reservoir in Montana, Jamestown Reservoir in North Dakota, and Swanson Reservoir in Nebraska. The general conclusion was that IFSAR vertical accuracy was inadequate at these locations for valid computations and there were other data sources available to better complete the analyses. Information on these studies can be found on the Sedimentation Group web site (Reclamation, 2013). The Brantley Reservoir topography is similar to some of these previously studied reservoirs, but the Brantley IFSAR data appears to be of better accuracy due to the less vegetated and flatter topography throughout the reservoir. The IFSAR was also the best available data to be used for the 2013 volume computations of the overall reservoir area.

Figures 14 through 16 provide a comparison of the 2001 aerial developed contours at elevations 3,268 and 3,272 with the 2013 developed contours at the same elevations that used the 2008 IFSAR data. As can be seen on the figures, the two developed upper elevation contours lined up very well for the reservoir areas shown. The close agreement also indicates there has been a minimum change between 2001 and 2008. The reservoir water level since dam closure has been below elevation 3,260, so minimum change in the topography at these higher elevations due to reservoir operations would be expected. Due to the similarity of the elevations with the other data sets and since it was the most recent above water data information available, the IFSAR data was used for the 2013 reservoir analysis.

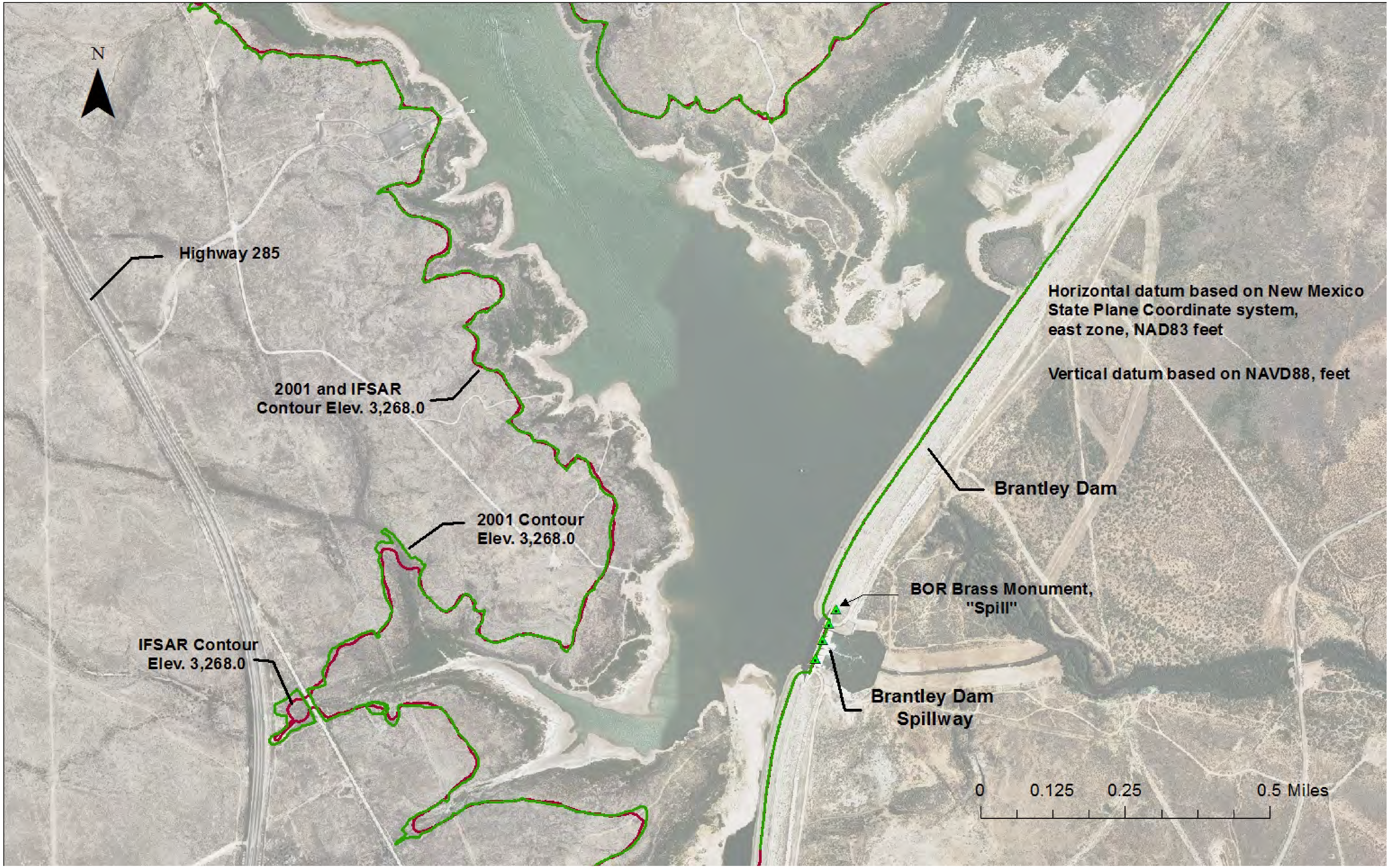

Figure 14 - Brantley Reservoir 2001 and 2013 contour comparison, elevation 3,268.0 (NAVD88).

Figure 15 - Brantley Reservoir 2001 and 2013 contour comparison, elevation 3,272.0 (NAVD88).

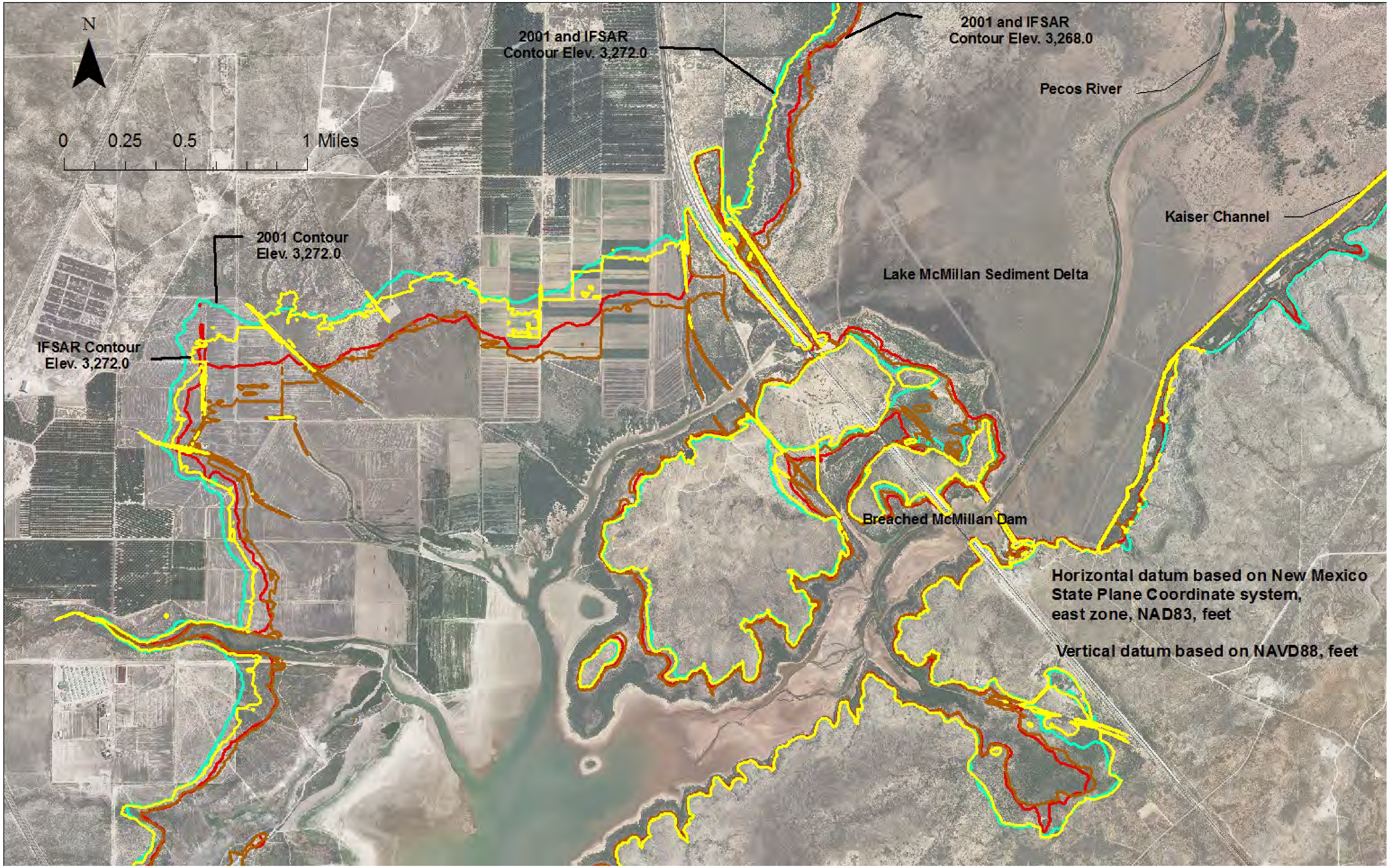

Figure 16 - Brantley Reservoir 2001 and 2013 contour comparison, elevations 3,268.0 and 3,272.0 (NAVD88).

On Figure 17 the plots of the 2001 and 2013 elevation 3,260 contours show a major change or big loss of the 2013 surface area behind the old McMillian dam structure that was breached after closure of Brantley Dam. The area behind McMillian Dam is open and flat, so both methods of aerial collection should have resulted in accurately developed contours. It is assumed the change in the surface areas since the 2001 aerial collection is due to sediments that have deposited behind McMillian Dam. The aerial photo in Figure 17 shows the dam structure was breached, allowing the lower or normal flows to pass with no restrictions via the Kaiser channel. During high flow events where the flows are outside the Kaiser channel, the McMillian structure likely restricts inflows, allowing the sediment laden flows to pond and deposit sediment material in the lower velocity area behind the structure. The IFSAR developed contours reflect the probable sediment deposition, between 2001 and 2008, upstream of the breached dam.

The table below is a comparison of the reported 2001 surface areas and the 2013 computed surface areas developed using the 2008 IFSAR data set. The computed surface area differences between the two data sets for the upper contours, elevations 3,268.0 and 3,272.0, were unexpected since they plotted so close together. To better understand the differences, the 2001 developed contours (labeled 3,268.0 and 3,272.0) were imported into ArcGIS and converted into polygons for surface area computations. It must be pointed out that in some areas of the reservoir engineering judgment was used to complete the enclosed polygons. The resulting surface area of the digitized polygons of the total enclosed areas was surprisingly near the 2001 reported surface areas. As seen on Figure 17, the breached McMillian Dam structure formed a land mass or island within these enclosed polygons and when the island area was removed, the digitized developed areas were within one percent of the 2013 ArcGIS computed surface areas. Additional analysis and data would be required to better understand and make definite conclusions from the 2001 results. The ArcGIS comparison exercise, along with close agreement of the 2001 and 2013 plotted contours, further justified using the 2008 IFSAR data set for the 2013 study. However, analysis of the data from various sources also raises the uncertainty of comparing the results from the 2001 and 2013 surveys to measure change due to sediment deposition.

Elevation		**2001 Surface Areas**	**2013 Surface Areas**	**Difference**
3,256.0		3,370	3,034	336
3,260.0		5,395	4,593	802
3,264.0		7,318	6,769	549
3,268.0		10,543	9,943	600
3,272.0		13,587	12,934	653

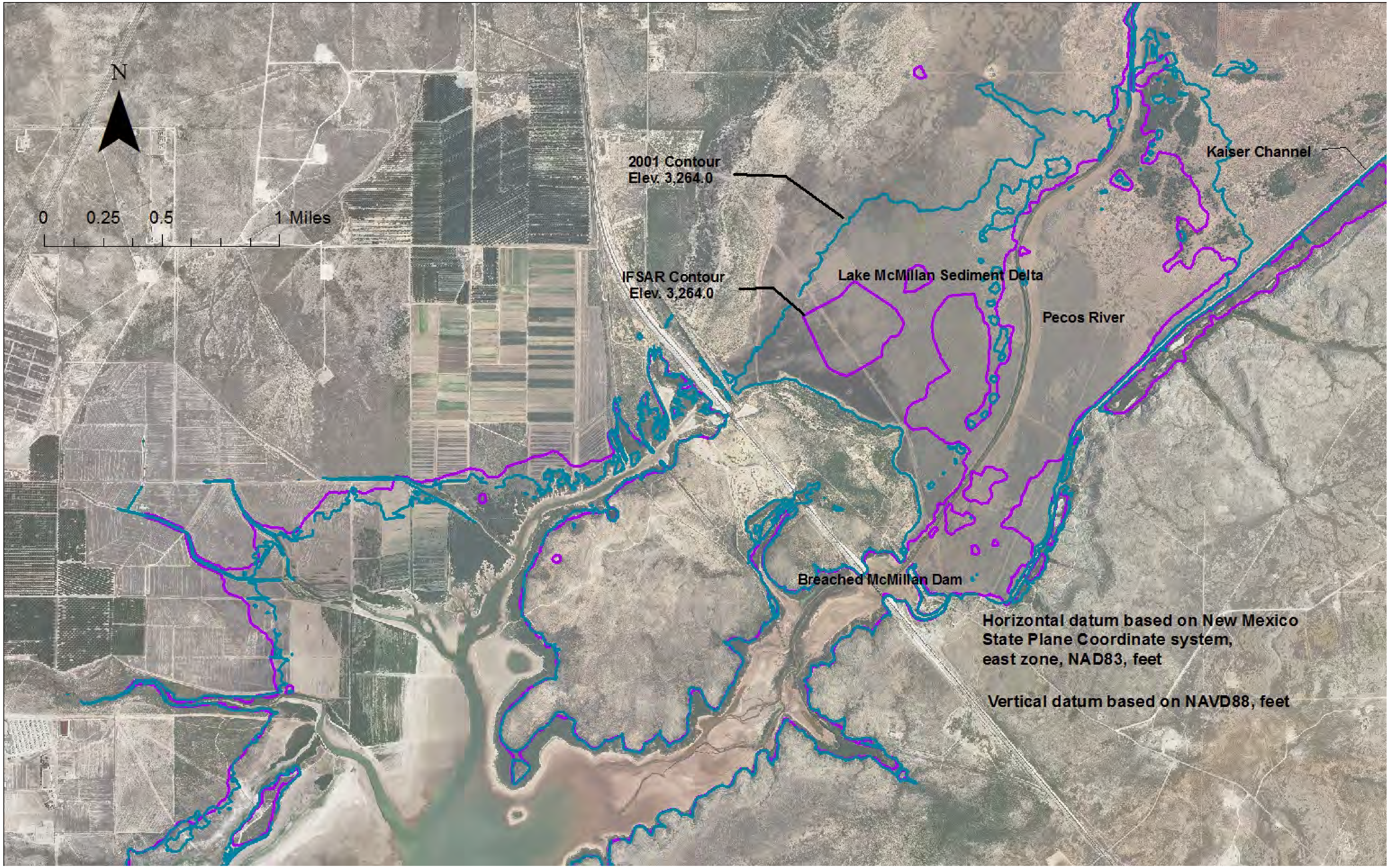

Figure 17 - Brantley Reservoir 2001 and 2013 contour comparison, elevation 3,264.0 (NAVD88).

Reservoir Area and Capacity

Topography Development

The 2013 Brantley Reservoir topographic contours were generated from several data sources including the 2013 bathymetric survey, digitized reservoir water's edges from the USDA aerial photographs, portions of the 2001 developed contours that provided detailed contours around the dam alignment, and the IFSAR data collected in 2008. The areas of these data sets covered by the 2013 bathymetric data points were removed or erased using ArcGIS tools. For the majority of the reservoir area with no 2013 bathymetric data, the 2008 IFSAR data set was the best available source for the 2013 reservoir topography development.

As stated previously, there were areas within the main body of the reservoir where the 2013 bathymetric data overlapped the 2001 developed contours. For some reservoirs this would indicate shoreline erosion, but visual inspection during the 2013 survey showed no signs of any major shoreline erosion occurring on this reservoir. The general conclusion was the 2001 bathymetric collection vessel could not enter some portions of the reservoir mapped by the 2013 bathymetric survey due to windy conditions and large rock hazards. Due to lack of data in these areas, the 2001 developed contours were truncated, affecting the contour development and resulting surface area computations.

The data coverages were processed into a triangulated irregular network (TIN), Figure 18, that was used to develop 2-foot contours, surface areas, and volumes referenced to NAVD88. In preparation for developing the TIN, a polygon was created to enclose the data sets. The polygon enclosed all the data sets, allowing contour development of the reservoir study area along the dam alignment for computations of the reservoir surface areas and resulting volumes. The polygon, not assigned an elevation, was used as a hard boundary preventing development of the 2013 TIN and contours outside of the hardclip.

Contours for Brantley Reservoir 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 elevation 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, preserving all the data points. The TIN method is described in more detail in the ArcGIS user's documentation (ESRI, 2012).

The linear interpolation option of the ArcGIS *TIN* and *CONTOUR* commands was used to interpolate contours from the Brantley Reservoir TIN. The surface areas of the enclosed contour polygons at 2-foot increments were computed for elevation 3,204.0 and above. The reservoir contour topography at 2-foot intervals is presented in Figures 19 through 34 from elevation 3,206.0 through elevation 3,310.0.

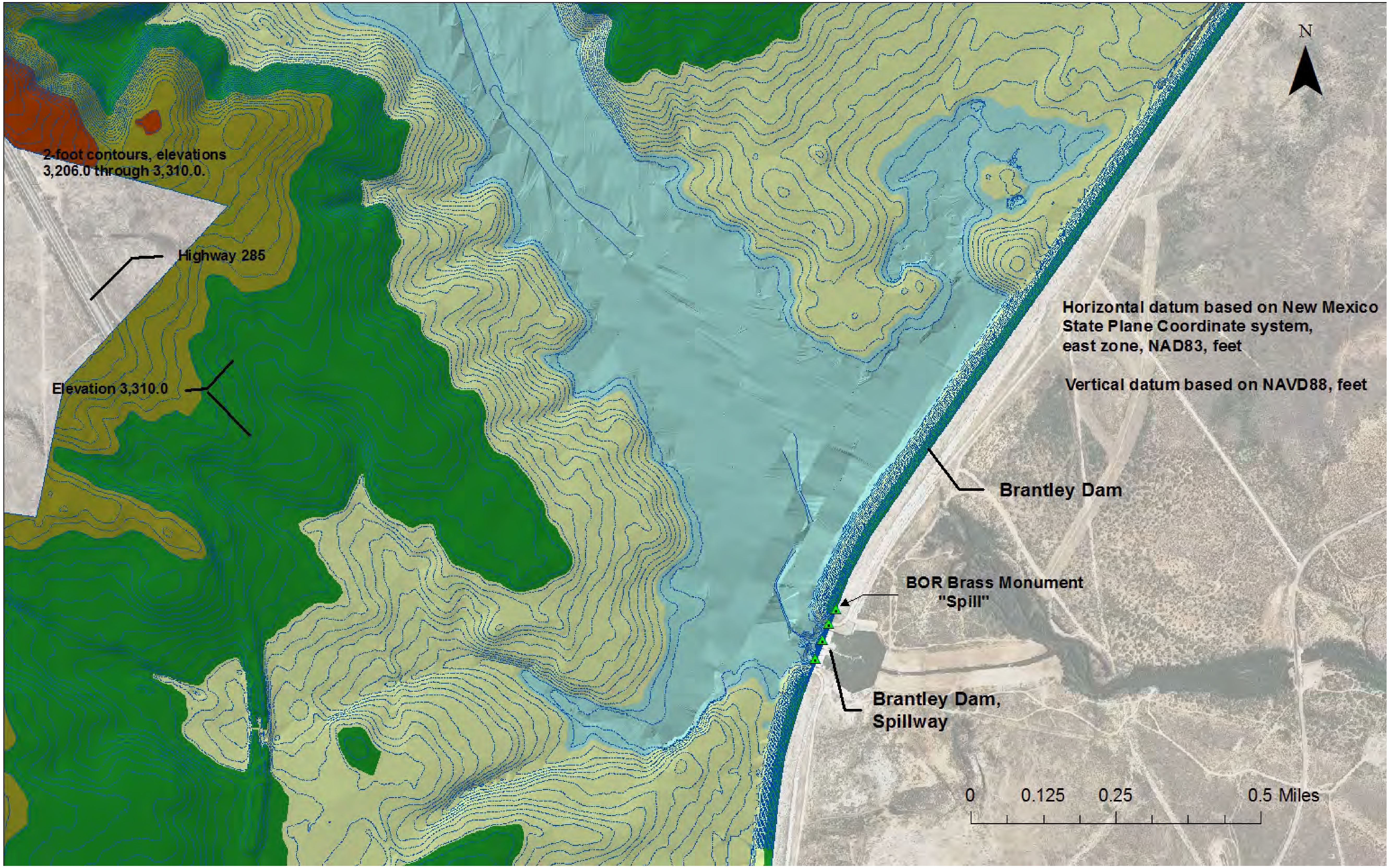

Figure 18 - Brantley Reservoir 2013 developed TIN at Brantley Dam.

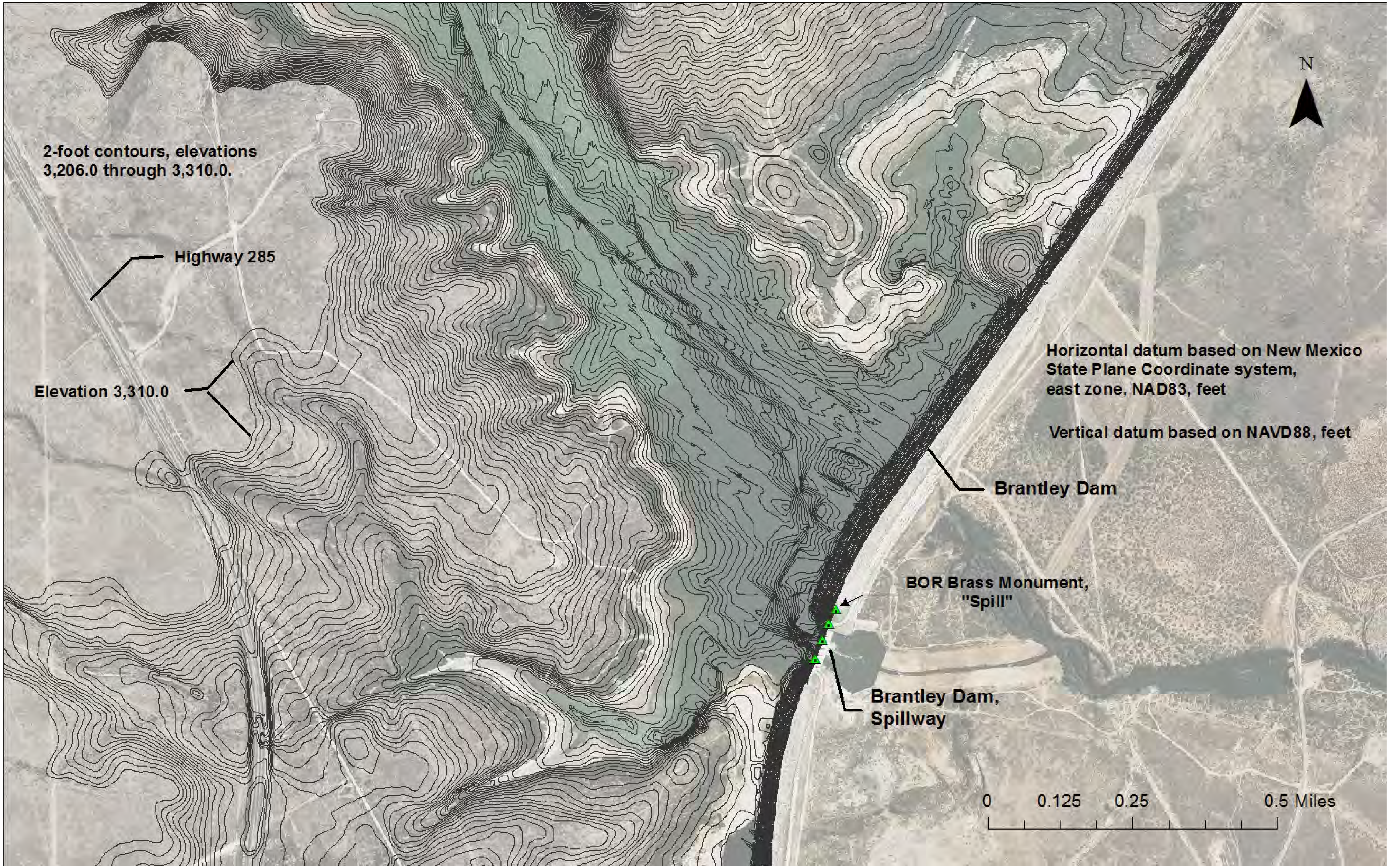

Figure 19 - Brantley Reservoir 2013 contours, NAVD88.

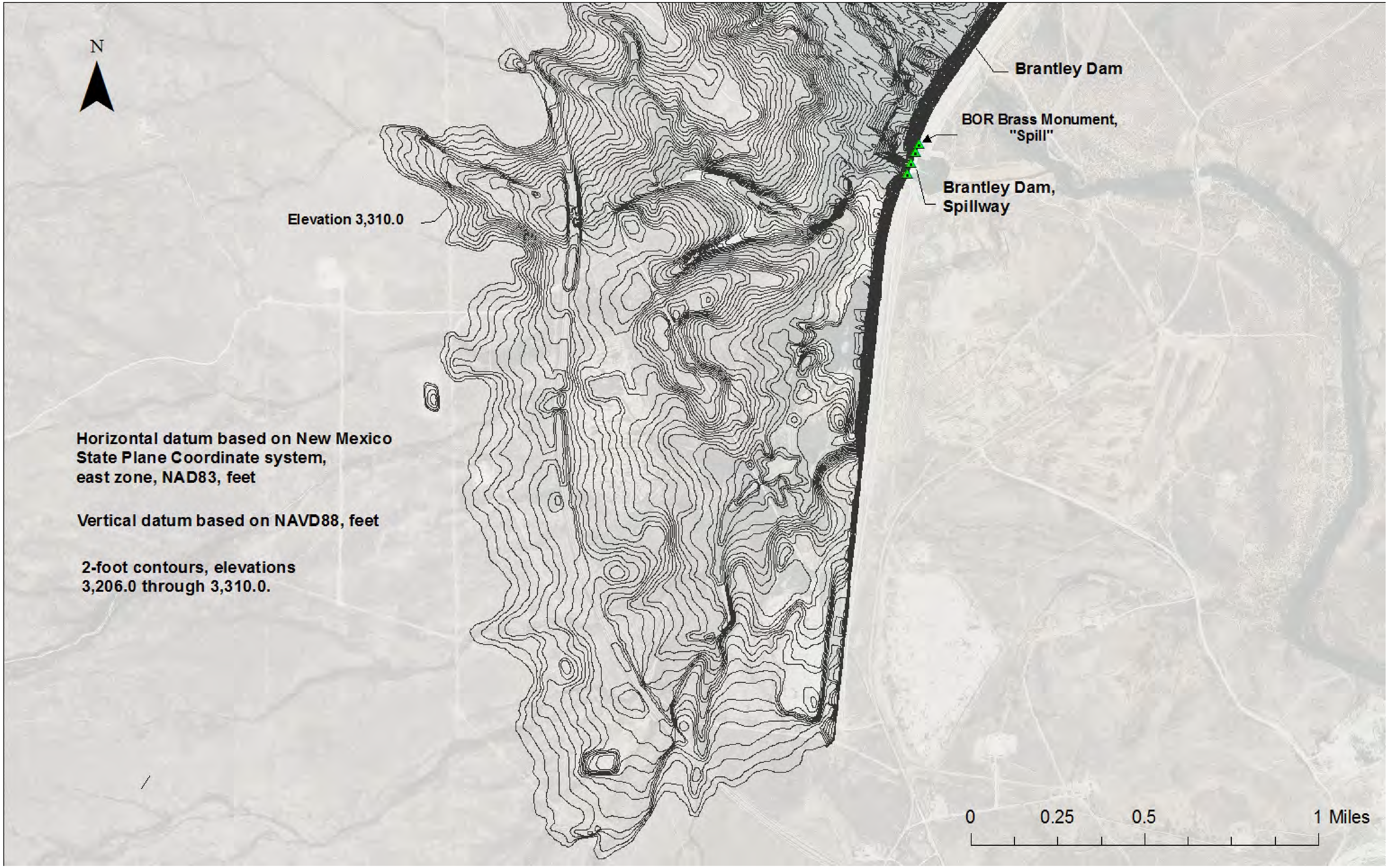

Figure 20 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

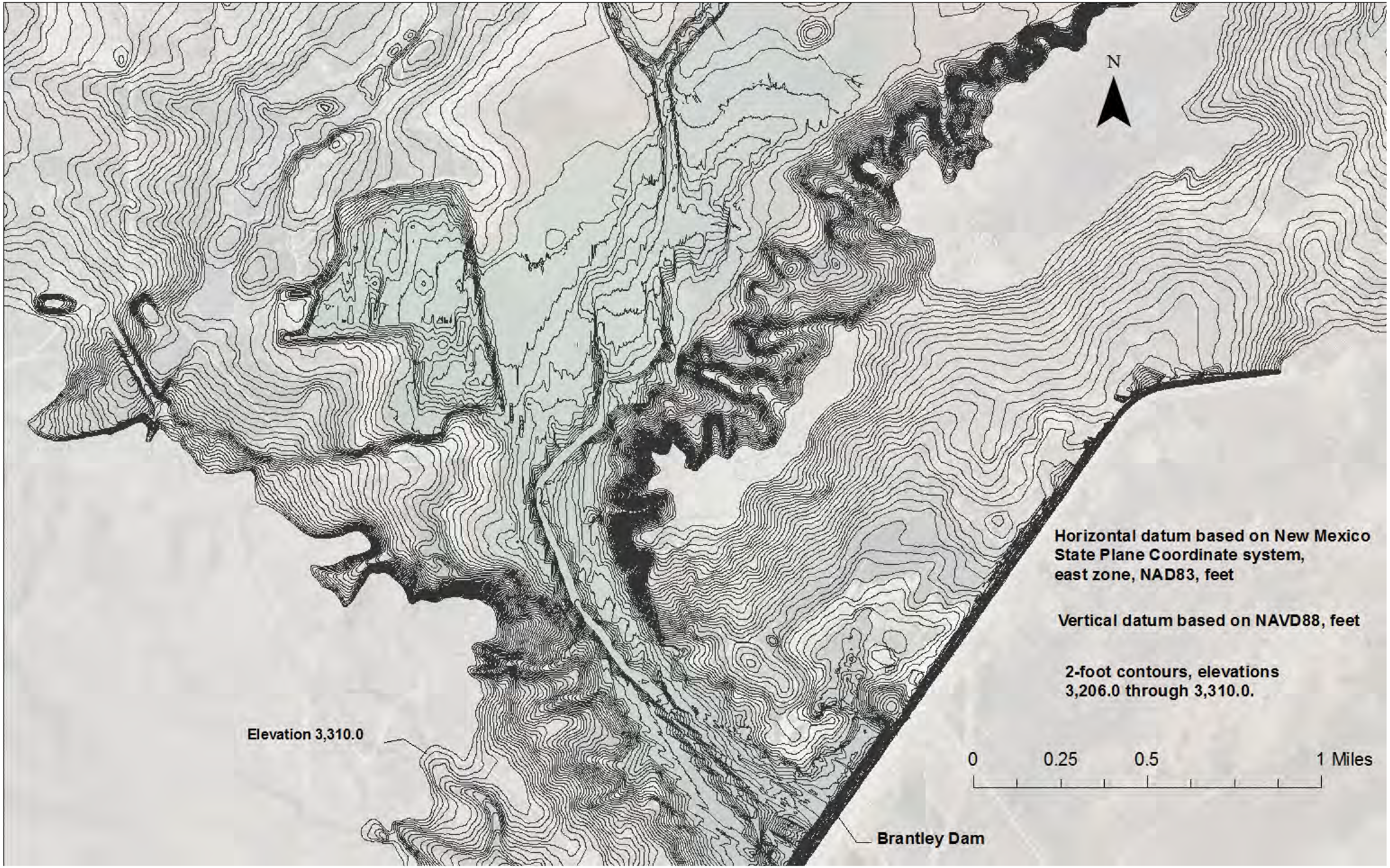

Figure 21 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

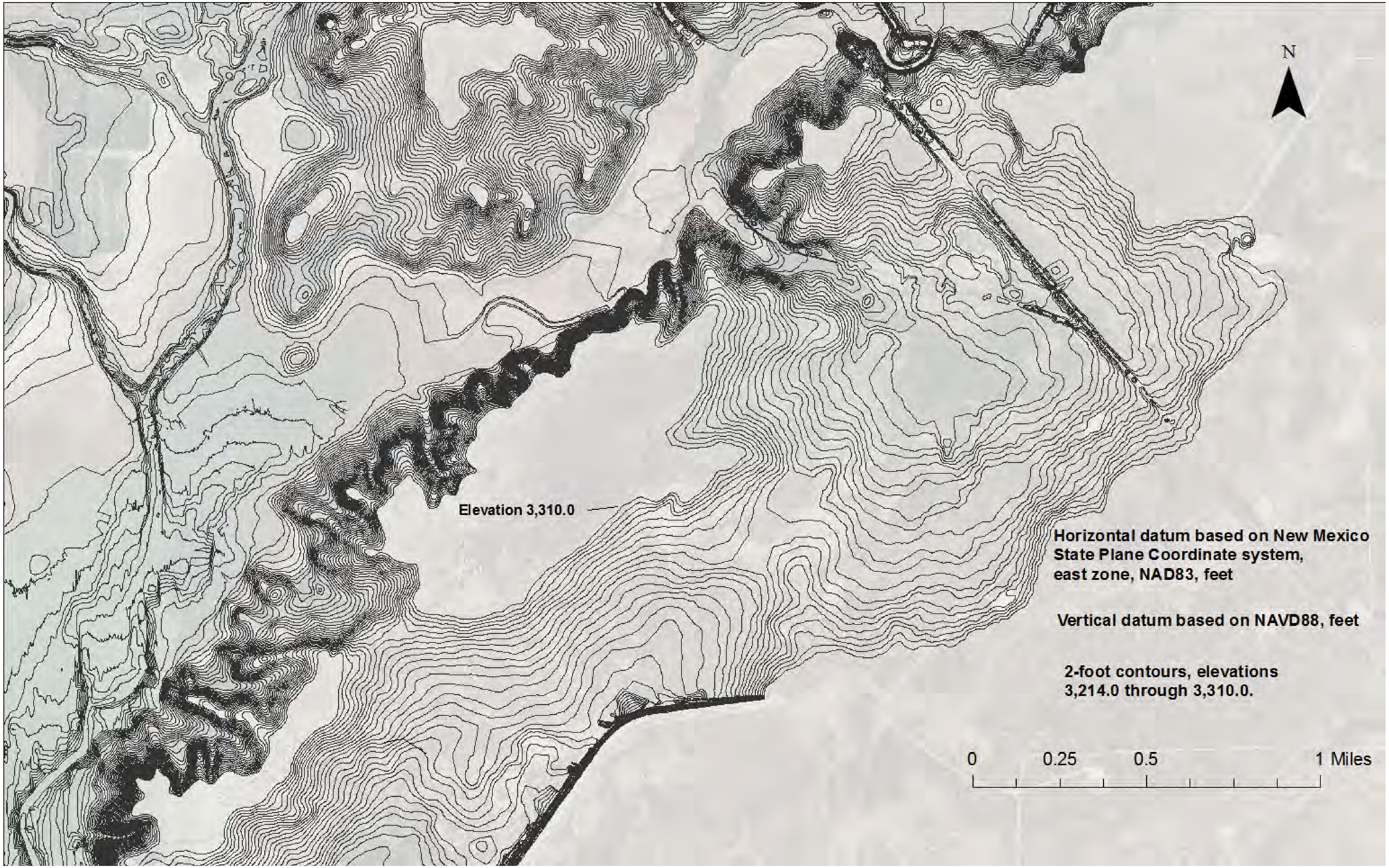

Figure 22 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

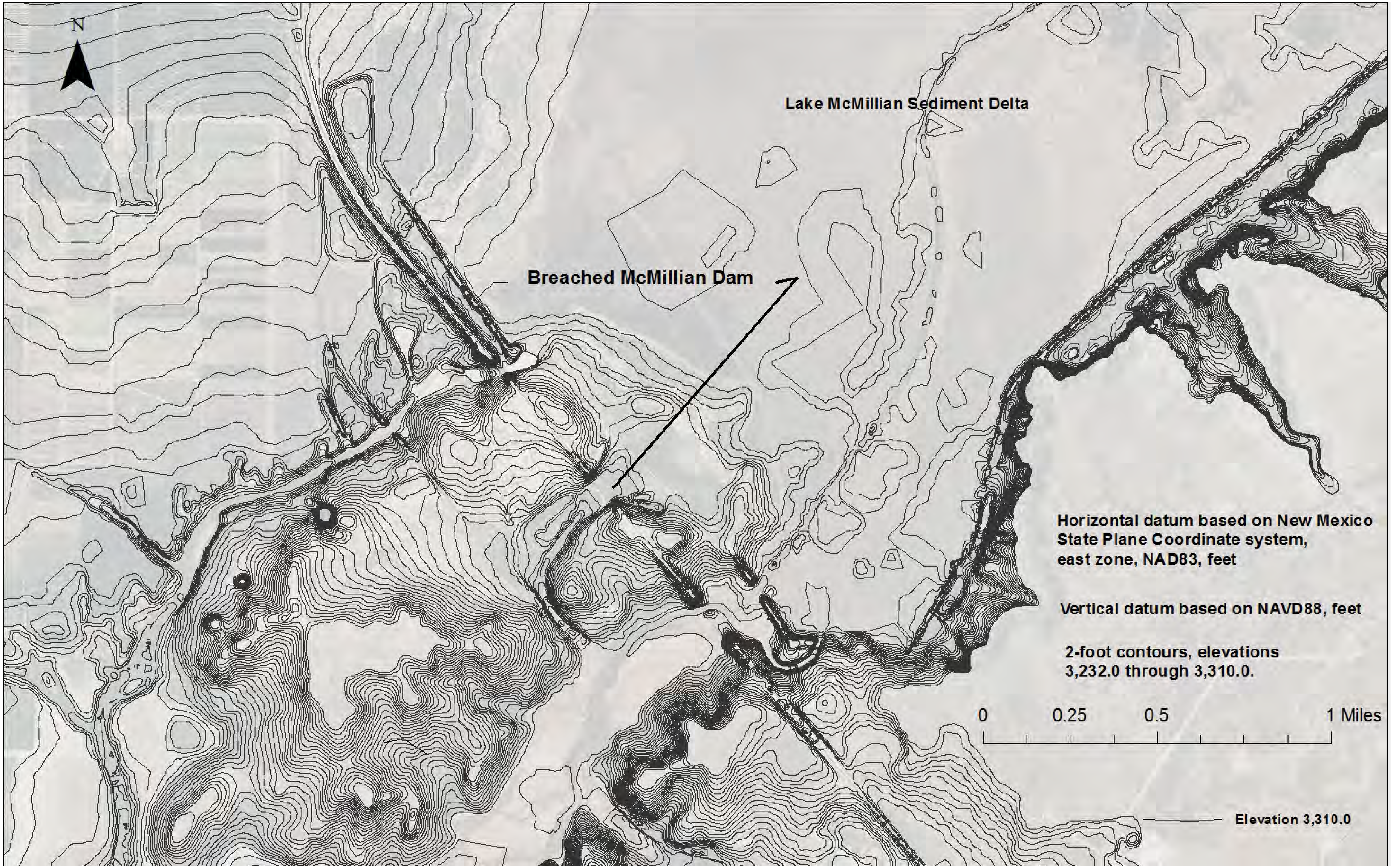

Figure 23 - 2013 Brantley Reservoir 2-foot contours, NAVD88, at breached McMillan Dam site.

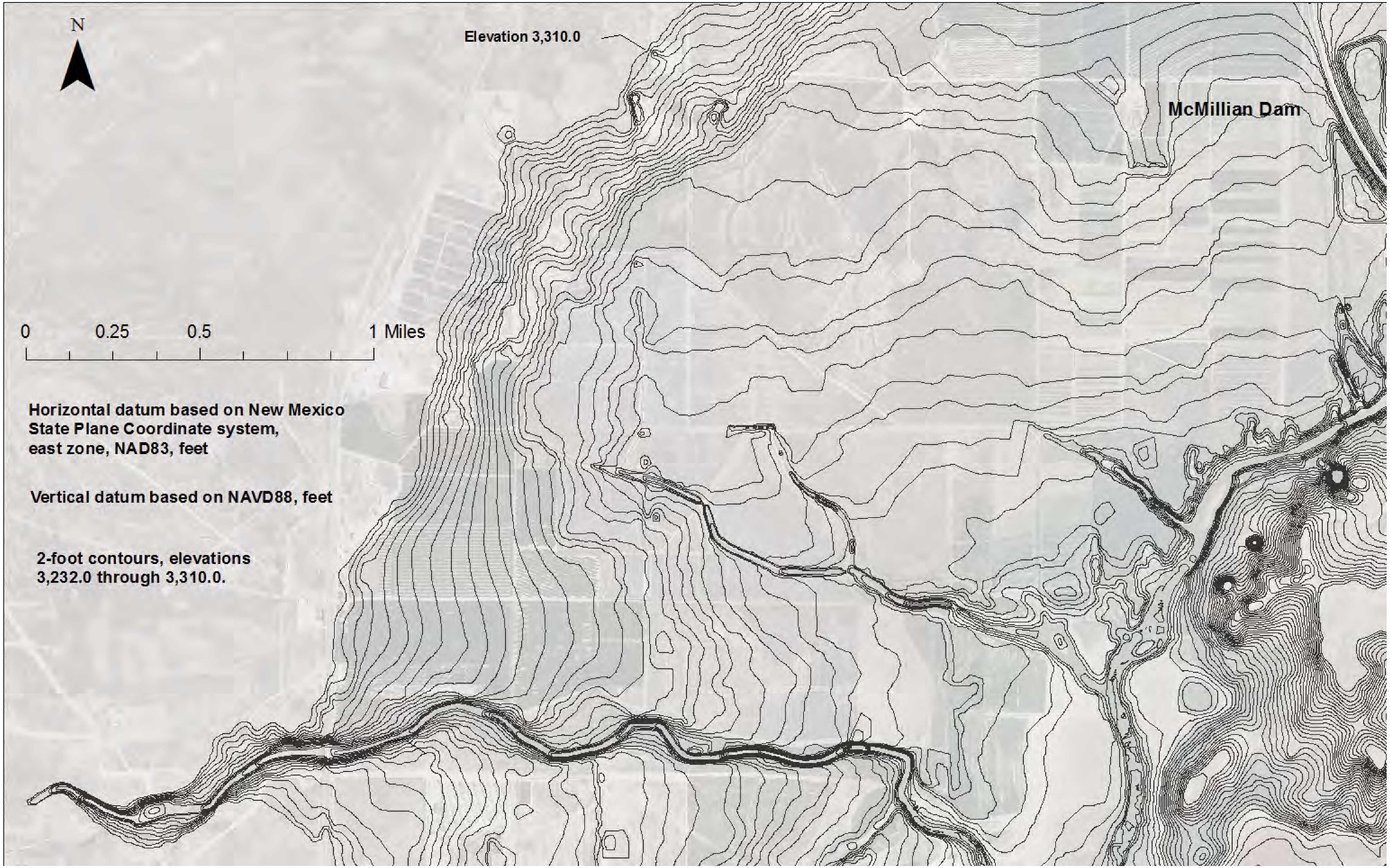

Figure 24 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

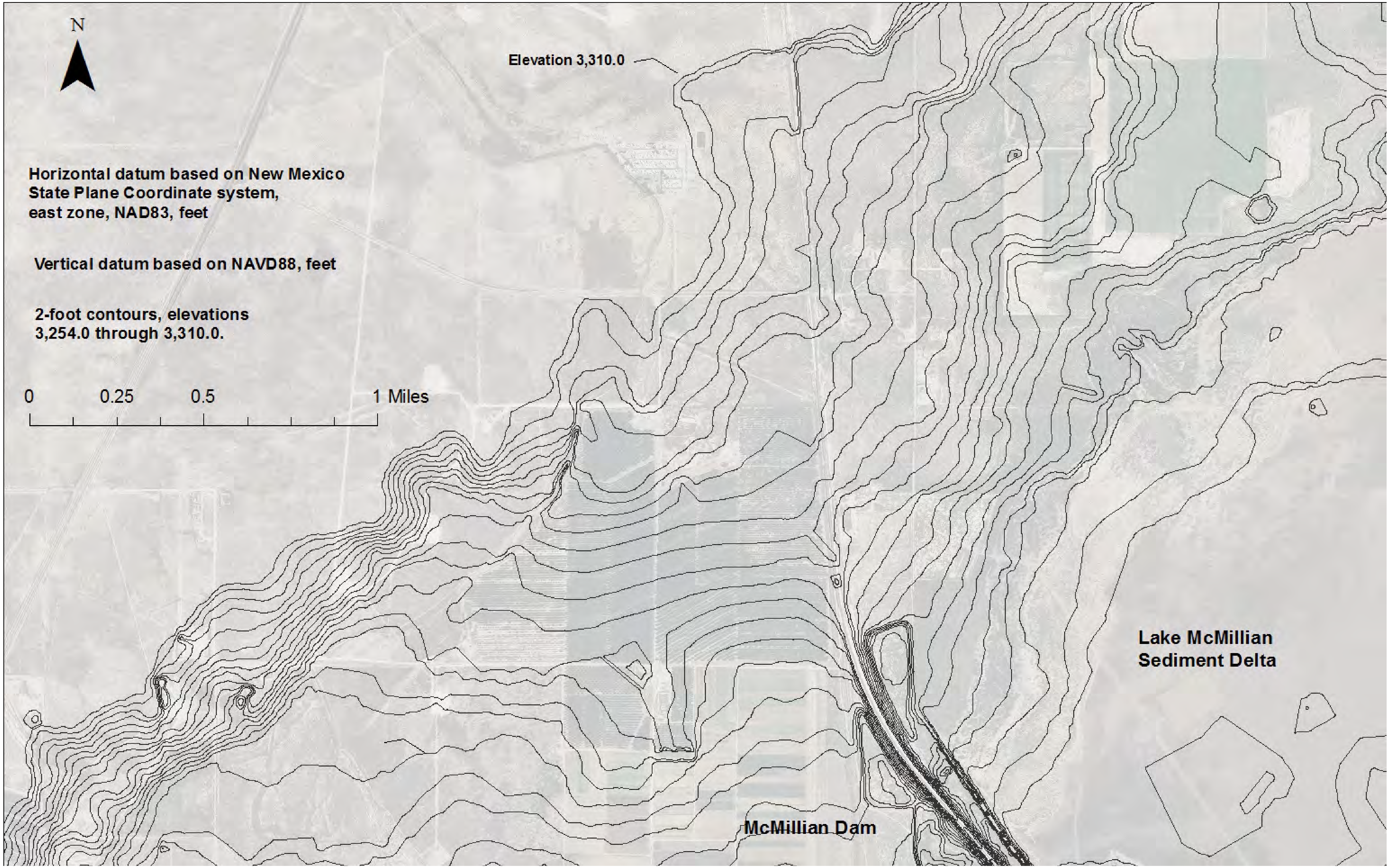

Figure 25 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

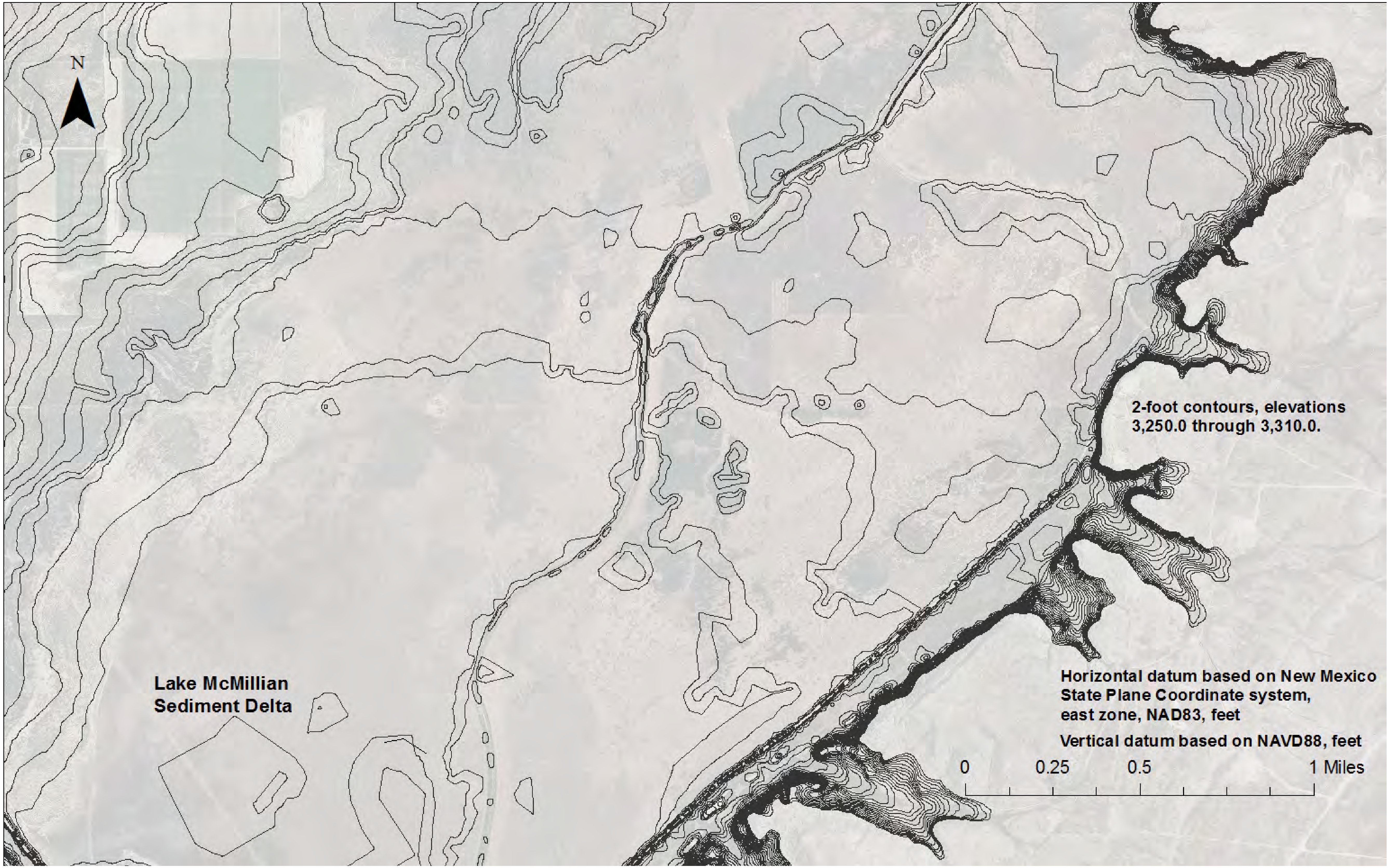

Figure 26 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

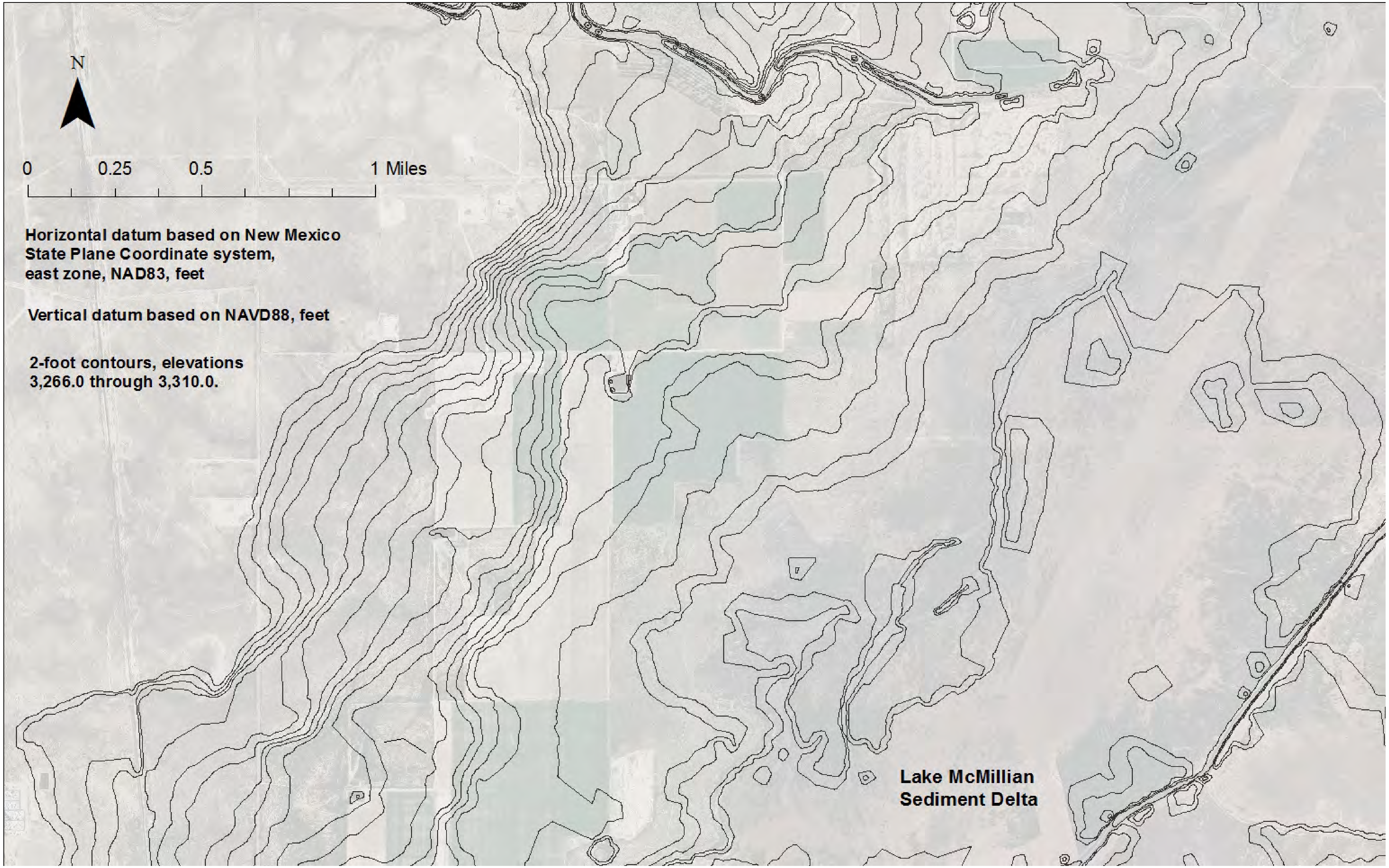

Figure 27 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

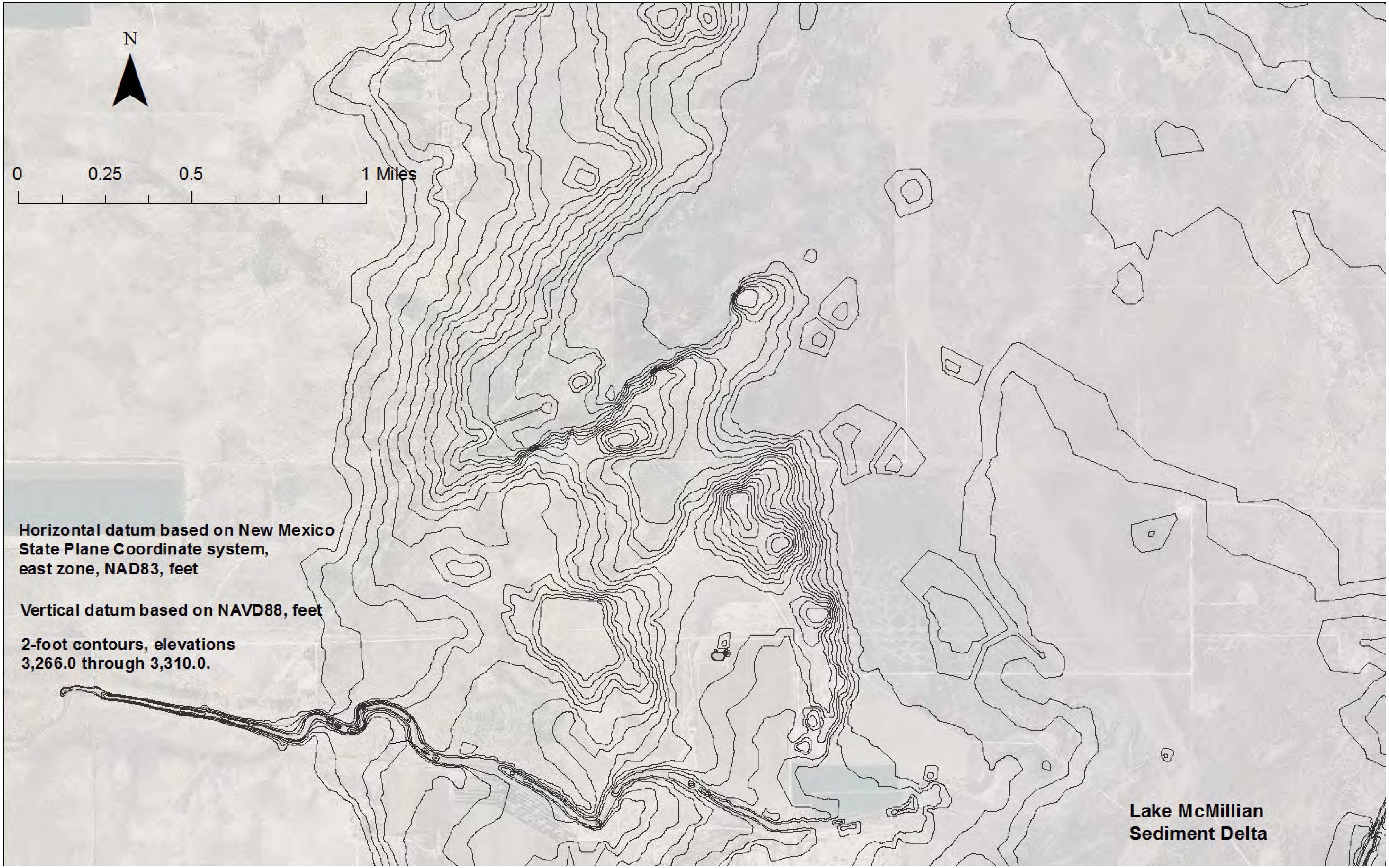

Figure 28 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

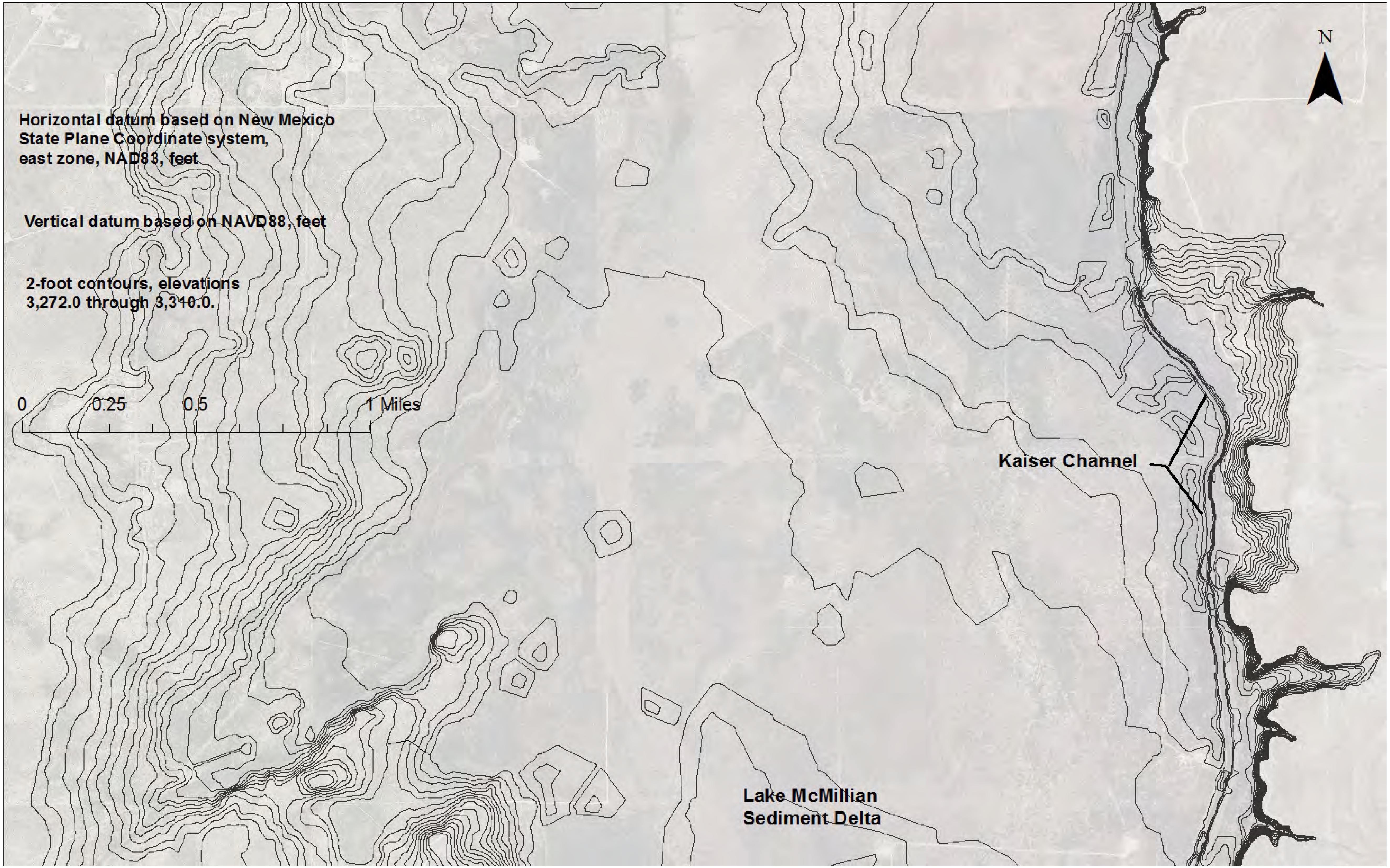

Figure 29 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

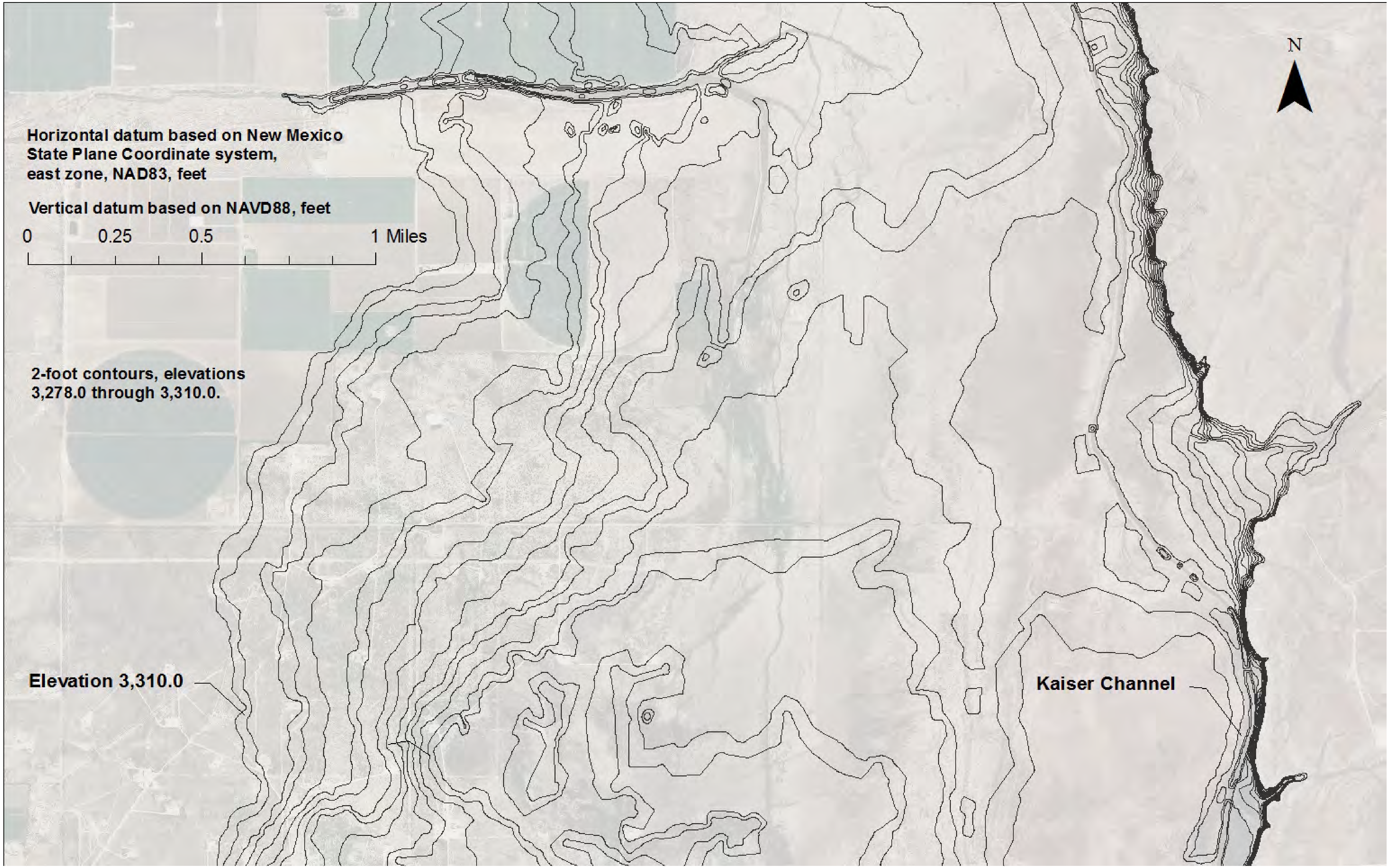

Figure 30 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

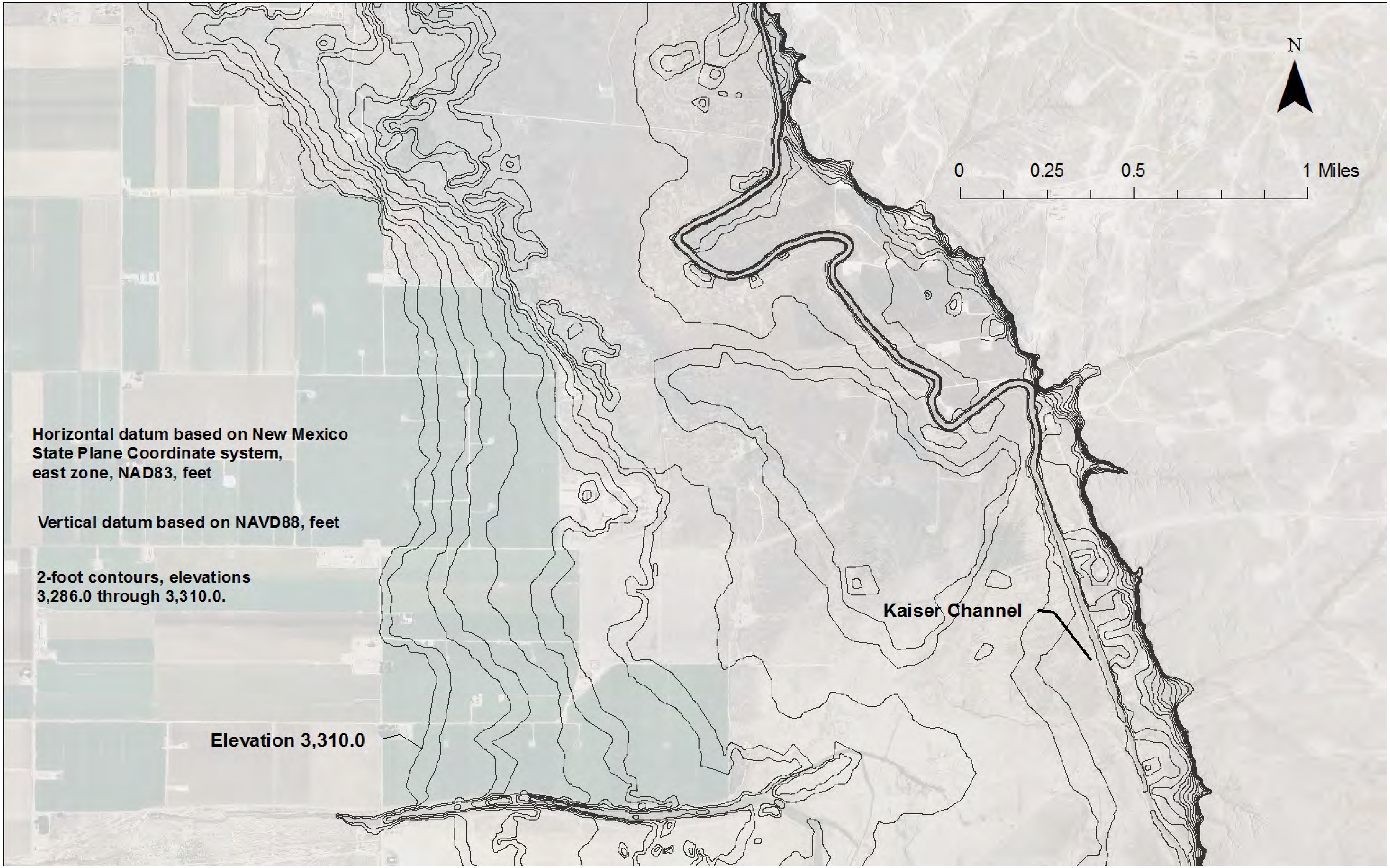

Figure 31 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

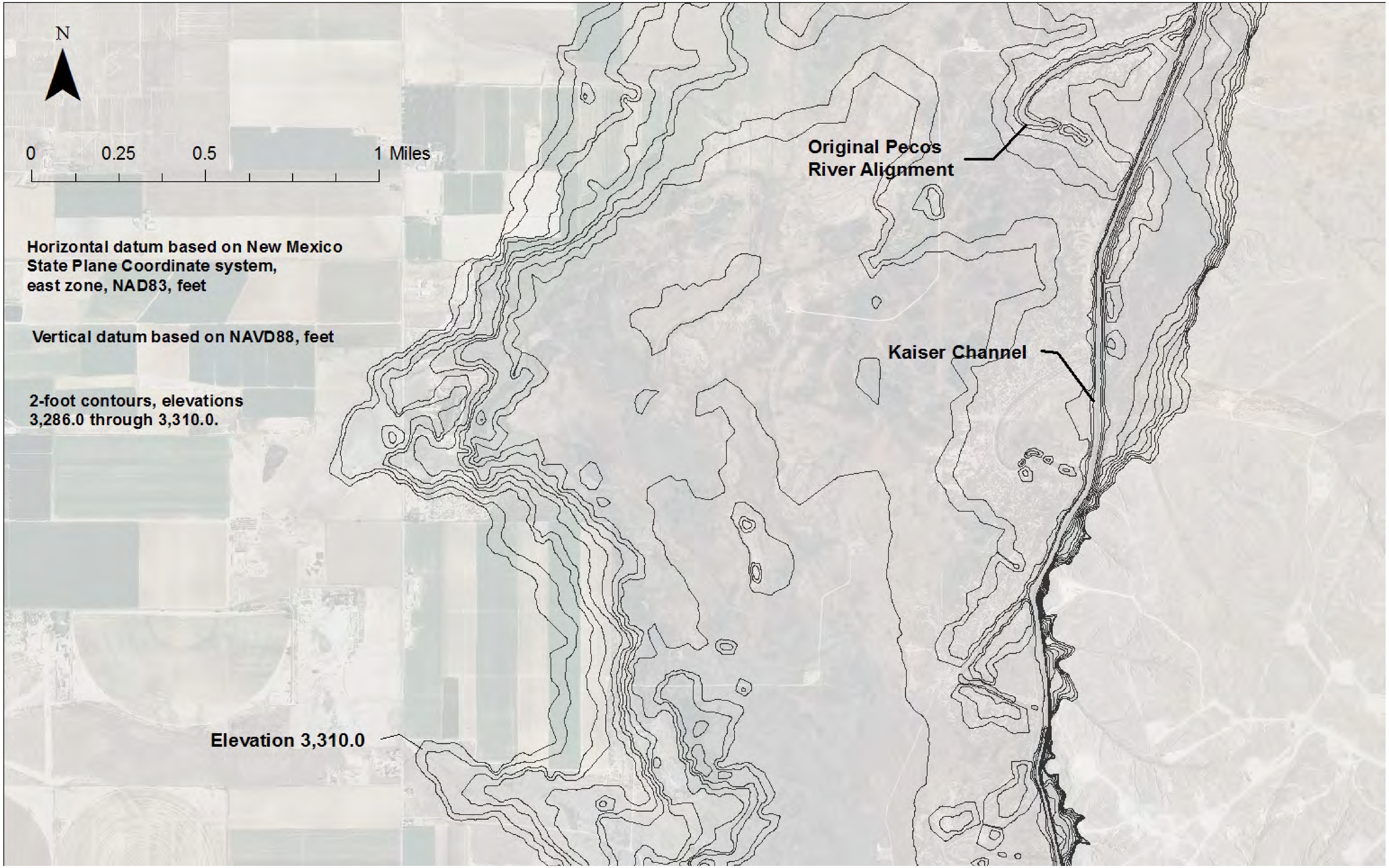

Figure 32 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

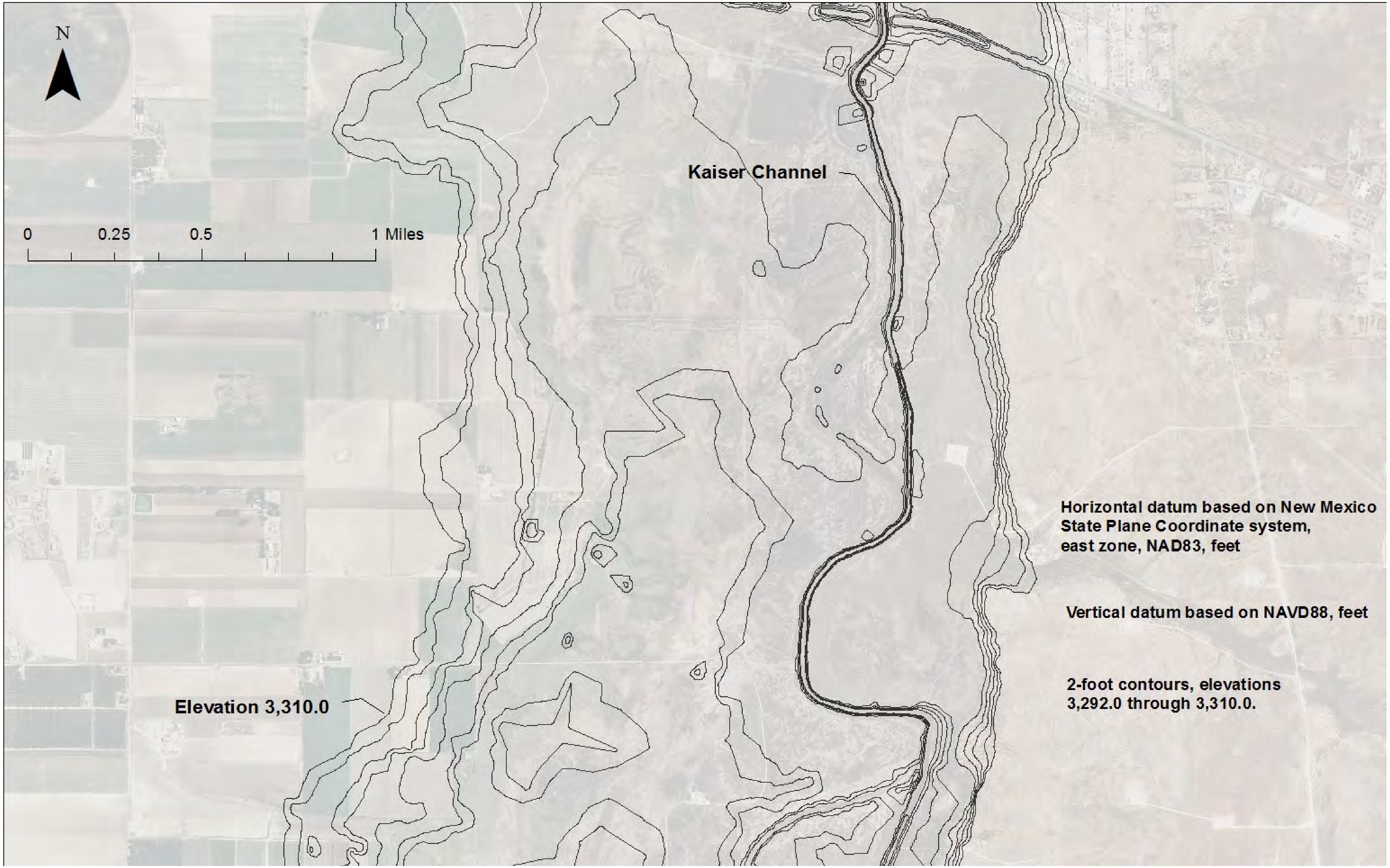

Figure 33 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

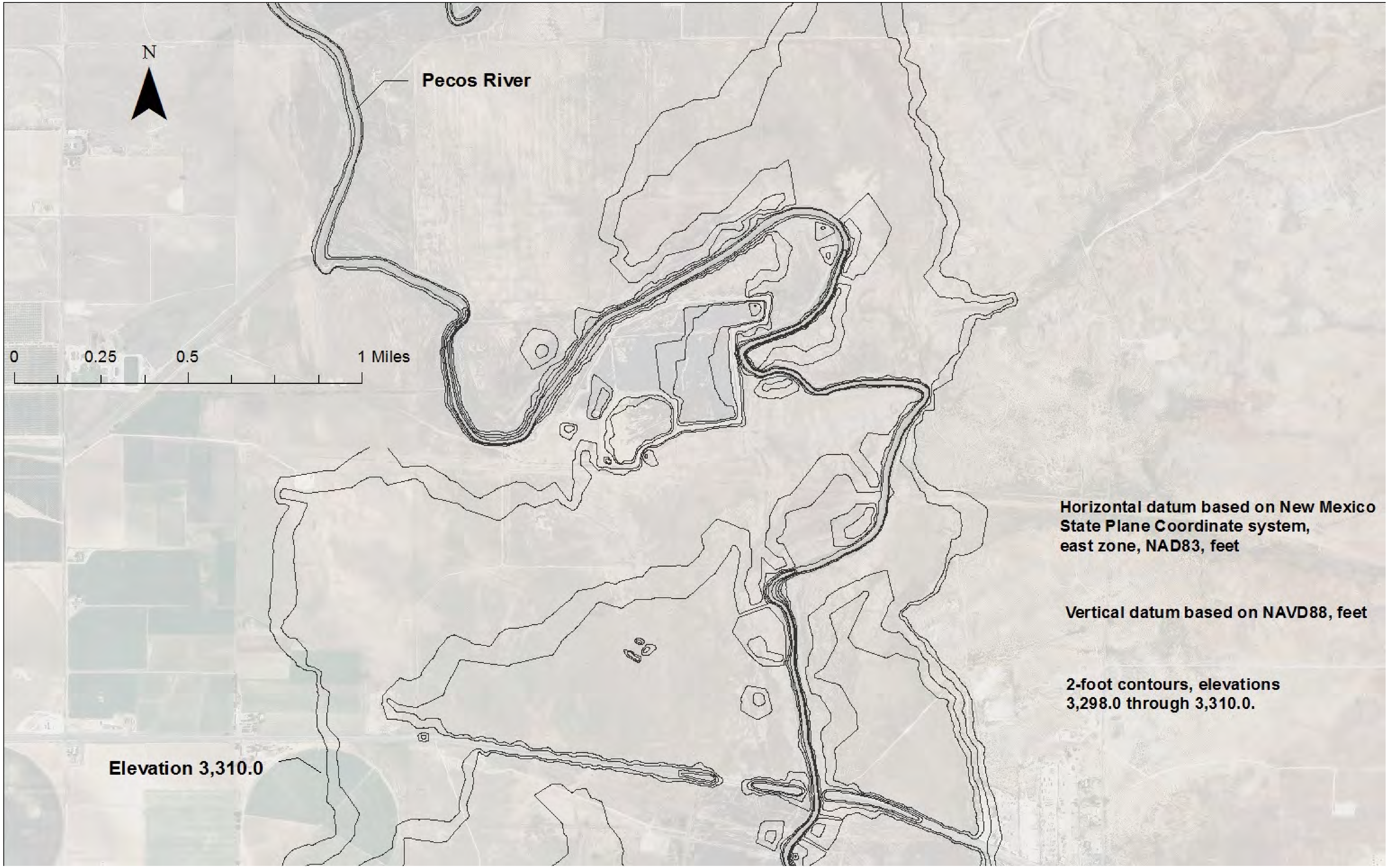

Figure 34 - 2013 Brantley Reservoir 2-foot contours, NAVD88.

2013 Brantley Reservoir Surface Area Methods

Using ArcGIS commands to compute areas at user-specified elevations, the 2013 surface areas for Brantley Reservoir were computed at 2 and 5-foot increments directly from the reservoir TIN from minimum elevation 3,204.0 to elevation 3,310.0.0 to provide information for the area-capacity tables. The upper 2013 surface areas from around elevation 3,240.0 and above were from the 2008 IFSAR data set. A summary of the 2013 survey results and how they compare to previous survey results follows.

2013 Brantley 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. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit. The error limit was set at 0.000001 for Brantley 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 Brantley Reservoir area and capacity computations are listed in a separate set of 2013 area and capacity tables and have been published for 0.01, 0.1, and 1-foot elevation increments (Bureau of Reclamation, April 2013B). A description of the computations and coefficients output from the ACAP program is included with those tables. As of April 2013, at current conservation use elevation 3,256.9, the surface area was 3,483 acres with a total capacity of 44,613 acre-feet. At maximum and top of surcharge elevation 3,305.1, the surface area was 39,011 acres with a total capacity of 1,010,547 acre-feet.

Brantley Reservoir Surface Area and Capacity Results

This section provides 2013 surface area and capacity results for Brantley Reservoir and evaluates changes over time. Table 1 provides a summary of the Brantley Reservoir storage, inflow, and topography between the time of dam closure in August 1988 and the April 2013 topographic survey. The area and capacity curves for the 2001 and 2013 surveys are plotted on Figure 35. Table 2 provides a summary of the 2001 and 2013 surveys computed surface area and capacity values. As stated previously, there were issues with the vertical datum of the original topography and a meaningful sediment computation since dam closure could not be completed. A comparison between the 2001 and 2013 surveys is presented, but as noted above, the differences may be primarily due to methodologies used in the field collection and analyses. The 2013 bathymetric survey and the other data sources summarized in the *Topographic Development* section provided sufficient information for computing the surface areas from elevation 3,304.0 through 3,310.0. The ACAP program was used to compute the area and capacity values from the 2-foot elevation input surface areas.

Longitudinal Distribution

To illustrate the reservoir bottom along the length of the reservoir, the Pecos River thalweg was plotted from the dam upstream to the breached McMillian Dam location then extended to elevation 3,272.0 through the McMillian sediment delta (Figure 36). The 2001 profile was cut through the developed 4-foot contours and was used to determine the thalweg alignment for both surveys. The alignment started at the concrete section of the dam where the spillway and outlet alignment are located. This section of the dam is located outside of the original river channel alignment and is the reason the thalweg plots start near elevation 3,212. As the thalweg alignment proceeds upstream towards the original river channel alignment, the plots drop to around elevation 3,208 when the alignment enters the original river thalweg.

The longitudinal profiles were developed by cutting a line through the 2001 and 2013 developed contours in ArcGIS. The original topography was not available for comparison, but the 2001 and 2013 plots illustrate the change since 2001 and the current bottom condition from the dam upstream. The inlet sill to the outlet works, elevation 3,212.3, is currently above the measured top of sediment deposition near the dam. Once the current reservoir thalweg joins the original river channel, the 2013 thalweg plot shows sediment deposition from elevation 3,210 through 3,240. From elevation 3,240 through 3,245, the 2013 plot shows channel degradation through the 2001 sediment delta before returning to a depositional pattern around elevation 3,246. Starting at the breached McMillian Dam, the 2013 plot shows a large sediment deposit upstream to around elevation 3,257 where both profiles begin to merge together.

RESERVOIR SEDIMENT
DATA SUMMARY

Brantley Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

D	1. OWNER: Bureau of Reclamation	2. STREAM: Pecos River	3. STATE: New Mexico
A	4. SEC 28 TWP. 20 S RANGE 26 E	5. NEAREST P.O. Carlsbad	6. COUNTY Eddy
M	7. LAT 32 ° 32 ' 48 " LONG 104 ° 22 ' 43 "	8. TOP OF DAM ELEVATION: 3,310.1 [1]	9. SPILLWAY CREST EL. 3,261.1 [2]

	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. 2013 SURFACE AREA, ACRES	13. 2013 CAPACITY, AC-FT	14. GROSS STORAGE ACRE-FEET	15. DATE STORAGE BEGAN
R E S	a. SURCHARGE	3,305.1 [3]	39,011	626,512	1,010,547	
E	b. FLOOD CONTROL	3,284.6	22,524	339,422	384,035	8/31/88
R	c. POWER					
V	d. JOINT USE	3,272.6	13,183	121,614	166,227	16. DATE NORMAL OPERATIONS BEGAN
O	e. CONSERVATION	3,256.9	3,483	43,170	44,613	
I	f. INACTIVE	3,226.1	288	1,404	1,443	
R	g. DEAD	3,212.3	18	18	39	8/1988
	17. LENGTH OF RESERVOIR 11.6 [4] MILES		AVG. WIDTH OF RESERVOIR 1.8 MILES			

B	18. TOTAL DRAINAGE AREA 17,650 [5] SQUARE MILES		22. MEAN ANNUAL PRECIPITATION 12.2 [6] INCHES
A	19. NET SEDIMENT CONTRIBUTING AREA 12,233 [5] SQUARE MILES		23. MEAN ANNUAL RUNOFF 0.1 [7] INCHES
S	20. LENGTH MILES	AVG. WIDTH MILES	24. MEAN ANNUAL RUNOFF 90,300 [8] ACRE-FEET
I N	21. MAX. ELEVATION	MIN. ELEVATION	25. ANNUAL TEMP, MEAN 63 °F RANGE -16 °F to 111 °F [6]

	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/I RATIO AF/AF
S U R	1988			Contour (D)			[3]	
V	2001	13		Contour (D)	4-ft	3,876	45,364	0.50
E Y	2013	12		Contour (D)	2-ft	3,483 [9]	44,613 [9]	0.49

	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
D A T A	2001		83,500 [10]	167,800	1,086,000	83,500	1,086,000
	2013		99,000	140,600	989,900	90,300	2,075,900

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.
	[11]					

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.
				[11]	[11]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW AND ABOVE CREST ELEVATION										
									CREST		
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR													
	0-10	10-20	20-30	30-40	50-60	60-70	70-80	80-90	90-100	100-105	105-111	110-115	115-120	120-125
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION													

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

45. RANGE IN RESERVOIR OPERATION [10]							
YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1988	3,242.9	3,221.6		1989	3,257.1	3,240.6	115,800
1990	3,244.0	3,226.3	72,100	1991	3,259.3	3,235.7	167,800
1992	3,258.0	3,241.1	85,100	1993	3,252.2	3,237.9	70,400
1994	3,255.6	3,240.3	79,300	1995	3,255.6	3,240.3	87,100
1996	3,254.8	3,241.8	63,500	1997	3,256.0	3,244.6	68,600
1998	3,257.4	3,243.1	84,000	1999	3,255.2	3,247.5	67,900
2000	3,256.3	3,250.9	73,800	2001	3,254.5	3,245.1	50,600
2002	3,251.9	3,253.7	77,800	2003	3,247.6	3,228.5	54,800
2004	3,254.7	3,228.7	140,600	2005	3,256.5	3,243.4	130,100
2006	3,253.8	3,239.8	125,900	2007	3,255.9	3,243.2	106,700
2008	3,253.8	3,233.5	111,300	2009	3,251.9	3,240.8	81,900
2010	3,253.2	3,241.2	107,200	2011	3,251.8	3,234.6	53,600
2012	3,248.2	3,227.2		2013	3,241.8	3,229.8	

46. ELEVATION - AREA - CAPACITY - DATA								
ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
2013	**SURVEY** [12]							
3,204.0	0.0	0	3,206.0	0.1	0	3,208.0	2.7	2
3,210.0	6.9	12	3,212.0	17.5	33	3,212.3	18.6	39
3,214.0	28.8	78	3,216.0	43.2	147	3,218.0	60.7	249
3,220.0	84.5	393	3,222.0	129.4	606	3,224.0	198.2	928
3,226.0	284.6	1,414	3,226.1	287.9	1,443	3,228.0	352.1	2,050
3,230.0	423.3	2,826	3,232.0	496.6	3,744	3,234.0	588.9	4,828
3,236.0	705.9	6,119	3,238.0	875.0	7,700	3,240.0	1,070.5	9,681
3,242.0	1,342.1	12,038	3,244.0	1,498.9	14,878	3,246.0	1,773.4	18,214
3,248.0	1,922.8	21,910	3,250.0	2,219.4	26,111	3,252.0	2,473.2	30,804
3,254.0	2,653.0	35,930	3,256.0	3,034.0	41,680	3,256.9	3,482.9	44,613
3,258.0	4,031.5	48,746	3,260.0	4,592.5	57,370	3,262.0	6,283.2	68,245
3,264.0	6,769.4	81,298	3,266.0	7,940.8	96,320	3,268.0	9,943.8	114,205
3,270.0	10,654.8	134,804	3,272.0	12,933.6	158,392	3,272.6	13,182.7	166,227
3,274.0	13,763.9	185,090	3,276.0	16,321.9	216,034	3,278.0	18,269.5	250,625
3,280.0	19,095.5	287,990	3,282.0	20,945.2	328,031	3,284.0	21,770.8	370,747
3,284.6	22,523.6	384,035	3,286.0	23,419.4	416,368	3,288.0	25,055.6	464,843
3,290.0	25,940.5	515,839	3,292.0	28,176.6	569,956	3,294.0	30,473.4	628,606
3,296.0	31,399.4	690,479	3,298.0	33,275.6	755,154	3,300.0	34,179.7	822,609
3,302.0	36,336.6	893,125	3,304.0	38,470.4	967,932	3,305.1	39,011.0	1,010,547

47. REMARKS AND REFERENCES

[1] All elevations are in feet tied to NAVD88. Original construction datum tied to NGVD29 that is 1.6 feet lower than NAVD88. Project vertical datum tied to NGVD29. Design dam concrete crest, elev. 3,308.5 (NGVD29) and earthen crest elev. 3,308.0 (NGVD29).

[2] Spillway crest elevation with gates open, tied to NAVD88. Design elev. 3,259.5 (NGVD29). Top closed gate elev. 3,010.1 (NAVD88).

[3] Original values not presented since there were issues with vertical datum used for aerial collection.

[4] Length of reservoir to maximum active conservation elevation 3,272.6.

[5] From USGS water year records, 2001. Net area removes drainage area above Lake Sumner and Two Rivers Reservoirs. Currently 3 of 4 tributaries are not connected directly to the current operation zone of the reservoir. Inflow sediments within these tributaries are depositing before the reservoir area.

[6] Bureau of Reclamation Project Data Book, 1981. Values for Carlsbad Project.

[7] USGS gage, Pecos River near Lakewood, NM (Kaiser Channel). Available Records. Diversions and groundwater withdraws for irrigation upstream of gage during irrigation season.

[8] 1989 through 2011 average value from USGS gage near Lakewood NM. Flow regulated by Lake Sumner and Two River Reservoirs.

[9] Surface area and capacity at elevation 3,256.9.

[10] Maximum & minimum elevations from available USGS records by water year through 2001. Elevations increased 1.6 feet to match NAVD88. For years 2002 through April 2013 daily values from Area Office. There were some missing records and will need to be confirmed if used. For the years 2002 through 2011 the inflow values came from a Reclamation Calendar year 2012 Report to the Pecos River commission. For this study inflow records only available through 2011 at time of report. Elevation values will need to be confirmed.

[11] Total sediment inflow usually by comparing survey values with recomputed capacity from previous surveys. Too many issues to compute.

[12] All capacity computed by Reclamation's ACAP computer program.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE August 2013

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

1	2	3	4	5	6	7	8
					2013		
	2001	2001	2013	2013	Sediment	Percent	Percent
Elevation	Area	Capacity	Area	Capacity	Volume	Computed	Reservoir
Feet	Acres	Ac-Ft	Acres	Ac-Ft	Ac-Ft	Sediment	Depth
3,305.1			39,011	1,010,547			100.0
3,305.0			38,962	1,006,649			99.9
3,300.0			34,180	822,609			95.0
3,295.0			30,936	659,311			90.0
3,290.0			25,941	515,839			85.1
3,285.0			23,026	393,145			80.1
3,280.0			19,096	287,990			75.2
3,275.0			15,901	199,922			70.2
3,272.6			13,183	166,227			67.9
3,272.0	13,587	169,066	12,934	158,392			67.3
3,268.0	10,543	120,805	9,944	114,205			63.3
3,264.0	7,318	85,083	6,769	81,298			59.3
3,260.0	5,395	59,656	4,593	57,370			55.4
3,256.9	3,876	45,364	3,483	44,613	751	100.0	52.3
3,256.0	3,370	42,127	3,034	41,680	447	59.5	51.4
3,252.0	2,492	30,403	2,473	30,804	-401	-53.4	47.5
3,250.0	2,189	25,722	2,219	26,111	-389	-51.8	45.5
3,248.0	1,886	21,646	1,923	21,910	-264	-35.2	43.5
3,246.0	1,666	18,094	1,773	18,214	-120	-16.0	41.5
3,244.0	1,446	14,981	1,499	14,878	103	13.7	39.6
3,240.0	1,040	10,008	1,071	9,681	327	43.5	35.6
3,238.0	886	8,083	875	7,700	383	51.0	33.6
3,236.0	731	6,466	706	6,119	347	46.2	31.7
3,234.0	625	5,109	589	4,828	281	37.4	29.7
3,232.0	519	3,966	497	3,744	222	29.6	27.7
3,230.0	440	3,007	423	2,826	181	24.1	25.7
3,228.0	362	2,205	352	2,050	155	20.6	23.7
3,226.2	297	1,612	291	1,472	140	18.6	22.0
3,226.0	290	1,553	285	1,414	139	18.5	21.8
3,224.0	218	1,045	198	928	117	15.6	19.8
3,222.0	152	675	129	606	69	9.2	17.8
3,220.0	87	436	85	393	43	5.7	15.8
3,218.0	64	285	61	249	36	4.8	13.8
3,216.0	42	179	43	147	32	4.3	11.9
3,214.0	30	107	29	78	29	3.9	9.9
3,212.4	21	65	19	41	24	3.2	8.3
3,212.0	19	57	18	33	24	3.2	7.9
3,210.0	12	26	7	12	14	1.9	5.9
3,208.0	5	8	3	2	6	0.8	4.0
3,206.0	2	1	0	0	1	0.1	2.0
3,204.0	0	0	0	0	0	0.0	0.0

1 Reservoir water surface elevations tied to NAVD88 that is 1.6 higher than project datum that was tied to NGVD29.
2 2001 reservoir surface area.
3 2001 developed reservoir capacity.
4 2013 measured reservoir surface area.
5 2013 reservoir capacity computed using ACAP.
6 2013 measured sediment volume, column (3) - column (5).
7 Percent of total sediment, 751 acre-feet at elevation 3,256.9.
8 Reservoir depth expressed in percentage total depth, 101.1 feet.

Table 2 - Brantley Reservoir 2013 survey summary.

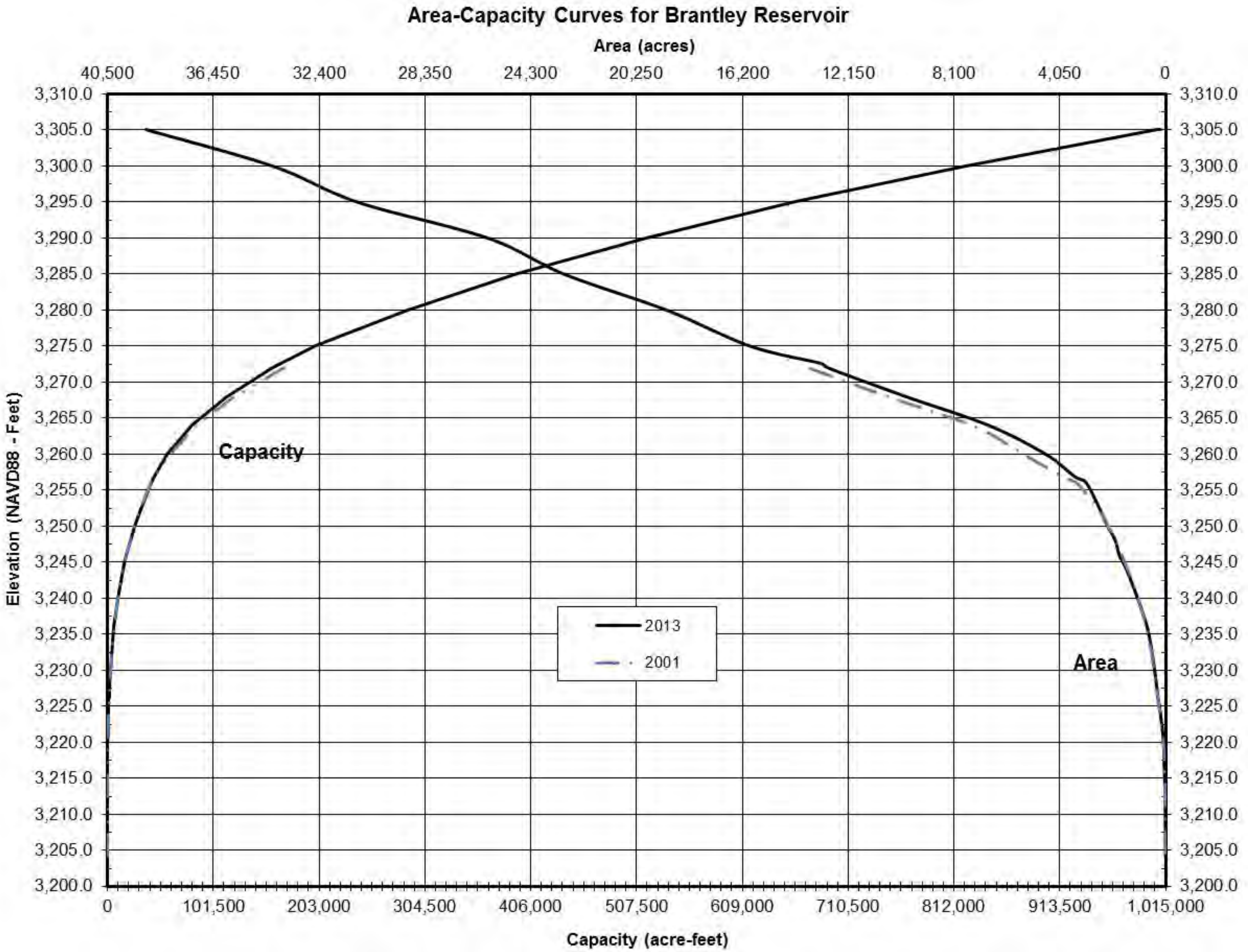

Figure 35 - Brantley Reservoir area and capacity plots.

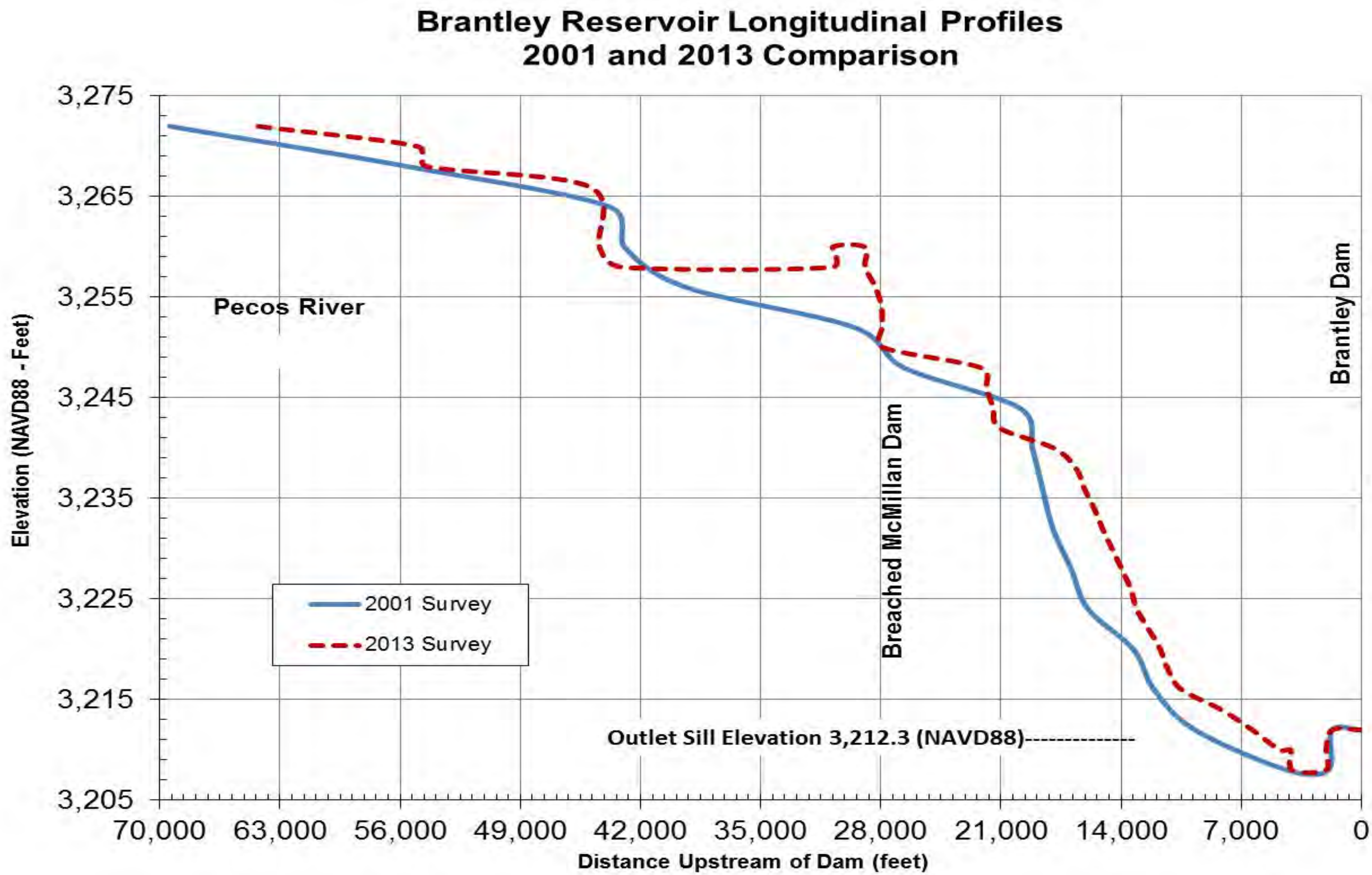

Figure 36 - Longitudinal profile of the Pecos River from the dam upstream.

2013 Brantley Reservoir Analyses

Results of the 2013 Brantley Reservoir area and capacity computations are listed in Table 1 and columns 4 and 5 of Table 2. Columns 2 and 3 in Table 2 list the 2001area and capacity values developed from a contract survey that included a combination of bathymetric and aerial collection to develop 2001 topography along with resulting area and capacity values for Brantley Reservoir from elevation 3,272.0 and below. The original area and capacity values were not listed due to known issues with the vertical datum of the aerial data collected to develop the original capacity tables. Due to these issues with the original capacity computations, the 2001 computed capacity results became the operation values and no sediment computations were completed in 2001. The tables within this report list the area and capacity results for the 2013 survey and are compared to the 2001 results only. Figure 35 plots illustrate the differences in the Brantley Reservoir surface area and capacity values for the 2001 and 2013 surveys.

For this study Table 1 lists elevation 3,256.9 as the current conservation level with elevation 3,272.6 as a joint use level. The reservoir is designed to raise the conservation level to maintain an active volume as the lower elevation volumes are lost due to sediment deposition. The conservation elevation can be raised until it reaches a maximum conservation elevation 3,272.6. For this study the 2013 area and capacity values are listed up to maximum operation elevation 3,305.1. Surface area and volume differences are mainly referenced to current conservation elevation 3,256.9 that is also near the maximum reservoir operation level since dam closure.

The 2013 survey only measured a small decrease in capacity, 751 acre feet, since the 2001 survey at elevation 3,256.9. As stated previously, there may be some issues with the 2001 measured surface area and resulting computed capacities from elevation 3,256.0 through maximum developed elevation 3,272.0. These are the operating elevations where the upper Brantley Reservoir water levels reach above the old McMillian Dam site. It’s possible the island area formed by McMillian Dam was not removed during the 2001 computations. However, there is not enough information available to confirm this. This study also noted that due to conditions during the 2001 bathymetric survey, mainly wind, there were portions of the reservoir not covered in 2001 that affect the computations of 2001 surface areas at elevations 3,240.0 and 3,244.0. Since there wasn’t enough information from the 2001 survey to confirm or resolve any issues with the measured surface areas, the 2013 study lists them only as possible sources of error. Due to these potential issues the 2013 study could not compute a reliable sediment deposition since the 2001 study and Table 1 does not list sediment values.

It is the general conclusion that any issues with the 2001 computations are minor, meaning the comparison of the results for both surveys, as listed in Table 2, provides a general trend of sediment inflow and deposition within the reservoir. Table 2 shows only minor capacity losses from elevation 3,256.9 and below, likely the result of low sediment inflow in the active area of the reservoir. On Figure 17 the 2001 and 2013 developed contour 3,264.0 above McMillian Dam does show a change that is assumed due to sediment deposition along with possible accuracy differences between the surveyed elevations. The thalweg plot of the 2001 and 2013 contours also shows sediment deposition from just above the dam upstream to about elevation 3,240 and from the breached McMillian Dam near elevation 3,251 upstream to elevation 3,258. For the area below McMillian Dam, the contours and resulting surface areas for both surveys indicated the change due to sediment is mainly within the original channel area and is a minimal volume change overall. Comparing the thalweg and developed contours above McMillian Dam does show a deposit of sediment behind the dam, but even there the change appears relatively minor.

A 2008 review by the Sedimentation Group of the original 100-year sediment estimate for Brantley Reservoir reached several conclusions worth noting (Reclamation, 2008):

- Three of the four major tributaries that could potentially contribute sediment are no longer connected to the Pecos River or Brantley Reservoir due to growth of the McMillan reservoir sediment delta, mature vegetation, and the location of the Kaiser channel that replaced the natural Pecos River channel.

- In the future if these tributaries become connected they will begin to contribute sediment to Brantley Reservoir. It is assumed that a major flood event would have to occur to cut through the materials currently damming the tributaries.

- The capacity of the Kaiser channel is estimated to be less than incoming flood magnitudes. As flows spill out onto the adjacent floodplain above McMillan Dam a portion of the suspended sediments will spill out and deposit behind McMillan Dam and not be delivered into the active zone of Brantley Reservoir.

- The 2008 review updated the 100-year projected sediment inflow into Brantley Reservoir to 43,700 acre-feet or 32 percent of the original estimate of 134,800 acre-feet.

The general conclusion is there were too many methodology differences between the 2001 and 2013 surveys to compute a reliable sediment deposition volume during the period between the two surveys. Comparison of the surveys did show that sediments are depositing within the active zone of Brantley Reservoir, elevation 3,256.9 and below, but the current deposition volume is low and is not affecting the operations of the dam. It appears the sediments below the old McMillian Dam site are confined mainly within the original river channel of the Pecos River and currently not affecting the intakes of the outlet works. There is a low flow outlet works located in the original river channel area, but it is protected from sediment buildup by topography assumed put in place during construction (possibly a cofferdam). From the 2013 developed topography it appears the sediment elevation at the dam would need to reach around elevation 3,222 before it would affect the low flow outlet works.

A resurvey should be scheduled in the future if a significant change in the sediment basin runoff is noted. Due to the relatively minor measured change in reservoir capacity since the 2001 survey below the breached McMillian Dam site, it appears the present inflows are not providing high sediment inflows to the reservoir. Major flood events would likely need to occur before all tributaries would contribute sediments to the active zone of Brantley Reservoir. The flood event or events would have to be of great enough magnitude to erode the previous McMillian Reservoir sediment deposits and transport them into the current active zone of Brantley Reservoir.

Summary and Conclusions

This Reclamation report presents the results of the April 2013 survey of Brantley Reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography;
- compute area-capacity relationships; and
- estimate storage depletion by sediment deposition since 2001 survey.

A control survey was conducted using the online positioning user service (OPUS) and RTK GPS to establish a 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 temporary rebar and cap located where it provided continuous radio link throughout the bathymetric survey.

The study's horizontal control was in feet, New Mexico state plane east coordinates, in NAD83. The vertical control, in US survey feet, was tied to NAVD88 (Geoid12A) that is around 1.6 higher than the project's vertical datum reported as tied to NGVD29. Unless noted, all elevations and the developed reservoir topography presented in this report are referenced to NAVD88. The April 2013 underwater survey was conducted near reservoir elevation 3,241.7 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 a RTK GPS for determining sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates as the survey boat navigated along grid lines covering Brantley Reservoir. The positioning system provided information to allow the boat operator to maintain a course along these grid lines. Bottom data was also collected as the vessel maneuvered along the shoreline between range lines and as it moved to and from the boat ramp to the work areas.

The above-water topography for the 2013 study was developed from airborne collected digital data obtained as IFSAR bare-earth information for the reservoir area (Intermap, 2011). The IFSAR aerial was flown in 2008, but was the most recent and best available information for the above water areas of the reservoir. 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 funding was not available for this study to acquire those other data sets. The IFSAR data produced detailed topography of the upper reservoir area and the elevations matched well with the 2013 bathymetric data and 2001 developed contours.

Additional data sources for the 2013 topography development included USDA aerial images flown in 2009 and 2011 (USDA, 2010). The above-water topography for the 2013 field survey was determined by digitizing contour lines from these USDA quads of the reservoir area. These contour outlines were used to assure coverage of the reservoir during the April survey and during analysis; small portions of the digitized water surface edges from orthographic aerial images were used as break lines to assist in contour development.

The 2013 Brantley Reservoir topographic map is a combination of the digitized water surface edge from the USDA photographs, IFSAR data, and 2013 underwater survey data, all tied to NAVD88. The IFSAR and 2013 underwater data were the main sources of information. A computer program was used to generate the 2013 topography and resulting reservoir surface areas at predetermined contour intervals from the combined reservoir data at elevation 3,310.0 and below. The 2013 area and capacity tables were produced using a computer program (ACAP) that calculated area and capacity values at prescribed elevation increments using the measured contour surface areas and a curve-fitting technique.

Tables 1 and 2 contain summaries of the Brantley Reservoir and watershed characteristics for the 2013 survey. The 2013 survey determined the reservoir has a total storage capacity of 1,010,547 acre-feet with a surface area of 39,011 acres at maximum reservoir water surface elevation 3,305.1. At joint use or maximum conservation water surface elevation 3,272.6 the total capacity was 166,227 acre-feet with a surface area of 13,183 acres. At current active conservation elevation 3,256.9 the surface area was 3,483 acres with a total capacity of 44,613 acre-feet.

Due to issues with the original developed area and capacity tables, a comparison with the 2001 and 2013 results could not be conducted to generate sediment deposition since dam closure. This study did compare the capacity results from the 2001 and 2013 surveys but due to differences between methods of collection and analysis, an accurate comparison could not be made. In general the comparison between the two surveys did show there has been minimal change due to sediment below the McMillian Dam site that was breached with the closure of Brantley Dam. Topography maps indicated a change in developed contours between the two surveys above McMillian Dam, but differences in the surface area measurements and resulting capacities made comparison of the surveys to accurately compute the sediment deposition impossible. Comparison of the survey results between 2001 and 2013 did show some sediment deposition, but it also showed that the sediment deposition in the active zone of Brantley Reservoir, below elevation 3,256.9, in not a significant factor.

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