UCDAVIS
Center for Watershed Sciences

Modoc National Wildlife Refuge pond bathymetry: Dorris Reservoir bathymetric model generated from topographic data collected with a recreational sonar fish finder in support of the USFWS Water Resources Inventory and Assessment program

for

United States Fish & Wildlife Service

Center for Watershed Sciences
University of California, Davis
One Shields Avenue
Davis, CA 95616

1 5 July 2014

Technical report authored by Eric J. Holmes[1], Andrew L. Nichols[1], and Joshua H. Viers[1,2]

[1]Center for Watershed Sciences, University of California, Davis

[2]School of Engineering, University of California, Merced

Suggested citation: Holmes, EJ, AL Nichols, and JH Viers. 2014. Modoc National Wildlife Refuge pond bathymetry: Dorris Reservoir bathymetric model generated from topographic data collected with a recreational sonar fish finder in support of the USFWS Water Resources Inventory and Assessment program. Davis, CA 10 ppd.

Executive Summary

Dorris Reservoir is a vital component of the water infrastructure at the U.S. Fish and Wildlife Service's (U.S. FWS) Modoc National Wildlife Refuge (MNWR). This report intends to provide detailed bathymetric data collected efficiently with a Lowrance HDS Gen2 sonar fish finder and compare results to previously assessed bathymetry.

A Lowrance HDS Gen2 sonar unit with an 83/200 kHz transducer was used to survey Dorris Reservoir on during the peak annual water surface elevation on May 6th and 7th, 2013. Due to the timing of the study with the WSE about 6 feet below the spillway crest elevation, resulting in reduced area accessible by the sonar system, the water's edge at the time of the sonar survey was surveyed using a Trimble GeoXH with sub-meter accuracy after post-processing. The timing of this project coincided with a severe multi-year drought (2012-2013), and despite planning the survey during the maximum annual water level of 2013, the reservoir was about 6 feet below the spillway crest elevation.

A Digital Elevation Model (DEM) of the reservoir was developed from reservoir bottom topographic data generated from the sonar survey and water's edge points in the geographic information system (GIS) ArcMap 10.2. The GIS datasets and maps provide higher resolution bathymetric data in the form of DEMs and contours of the reservoir bottom, than what was available from the previous survey.

The sonar survey using the recreational Lowrance HDS Gen2 sonar fish finder produced similar results to that of the existing survey. The surface area of Dorris Reservoir at the maximum normal pool (water surface elevation = 4398.5 ft). Volume of the maximum normal pool calculated from the derived bathymetric surface was 10,947 acre-feet. Compared to the maximum normal pool surface area of 843 acres and volume of 11,870 acre-feet from a previous investigation, there is a percent difference of 20.8% and -7.8% respectively.

Mean and maximum depth of derived Dorris Reservoir DEM was calculated at 10.3 and 21.05 feet, respectively. The distribution of depth is fairly uniform likely due to gradually sloping shorelines and complex perimeter geometry, with a high perimeter to surface area ratio, indicating a relatively large proportion of shallow area.

Introduction

Dorris Reservoir is a vital component of the water infrastructure at the U.S. Fish and Wildlife Service's (U.S. FWS) Modoc National Wildlife Refuge (MNWR). The primary purpose of Dorris reservoir is to provide water critical for year-round wetland habitat management purposes on the Refuge to support migratory birds and other waterbirds. As outlined in the Modoc Water Resources Inventory and Assessment (WRIA), predicted increases in the climate water deficit (CWD) are likely to increase water demand in the Modoc Basin, further increasing the motivation to store early season runoff (Esralew and others, 2013). If too much water is stored early in the season, there is increased risk of water overtopping Dorris Dam, leading to infrastructure damage and flooding in nearby Alturas. In contrast, if not enough water is sequestered and there is not enough rain in the spring, water scarcity will adversely affect wetland habitat management, potentially leading to reduced productivity for waterfowl. Due to the risks associated with both flooding and water scarcity, it is essential to provide accurate and efficient estimates for Modoc National Wildlife Refuge's water storage capacity. This report intends to provide detailed bathymetric data collected efficiently with a Lowrance HDS Gen2 sonar fish finder (Lowrance Marine Electronics, http://www.lowrance.com/en-US/) and compare results to those presented in the Dorris Standard Operating Procedure Manual.

Study Site

The reservoir was established in the 1930 by the Dorris Family to provide water storage for their ranch. The U.S. FWS acquired the reservoir in 1960 and completed modifications to the dam in 1973 and 1983 which included a new spillway and outlet works (Dorris Dam SOP, 2009). According the MNWR Comprehensive Conservation Plan, Dorris Reservoir is a 1,100 surface acre (only 547 acres of which are owned by the Refuge) storage facility used to supply water to the Refuge. The MNWR can store up to 11,500-acre feet of water within Dorris Reservoir. At spillway elevation, depths average 11.4 feet with a maximum depth of 22 feet. Nearly 40 percent of the Reservoir is less than 10 feet deep. Approximately 11 miles of shoreline exist at spillway elevation. Emergent vegetation is scarce except in the upper arms and shallow bays. The primary purpose of Dorris Reservoir is to provide water for habitat management purposes on other areas of the Refuge. Withdrawals of water to meet the irrigation needs of the Refuge cause large seasonal fluctuations in water levels. Dorris Reservoir is not specifically managed as habitat for wildlife (MNWR CCP, 2009).

Dorris reservoir has storage rights for 800 acre-feet per year from Stockdill Slough, 6,100 acre-feet per year from Parker Creek and 4,200 acre-feet per year from Pine Creek tributaries (Esralew et al, 2013). During periods of drought, the reservoir does not refill each year (Dorris Dam SOP, 2009). The timing of this project coincided with a severe multi-year drought (2012-2013), and despite planning the survey during the maximum annual water level of 2013, the reservoir was about 6 feet below the spillway crest elevation.

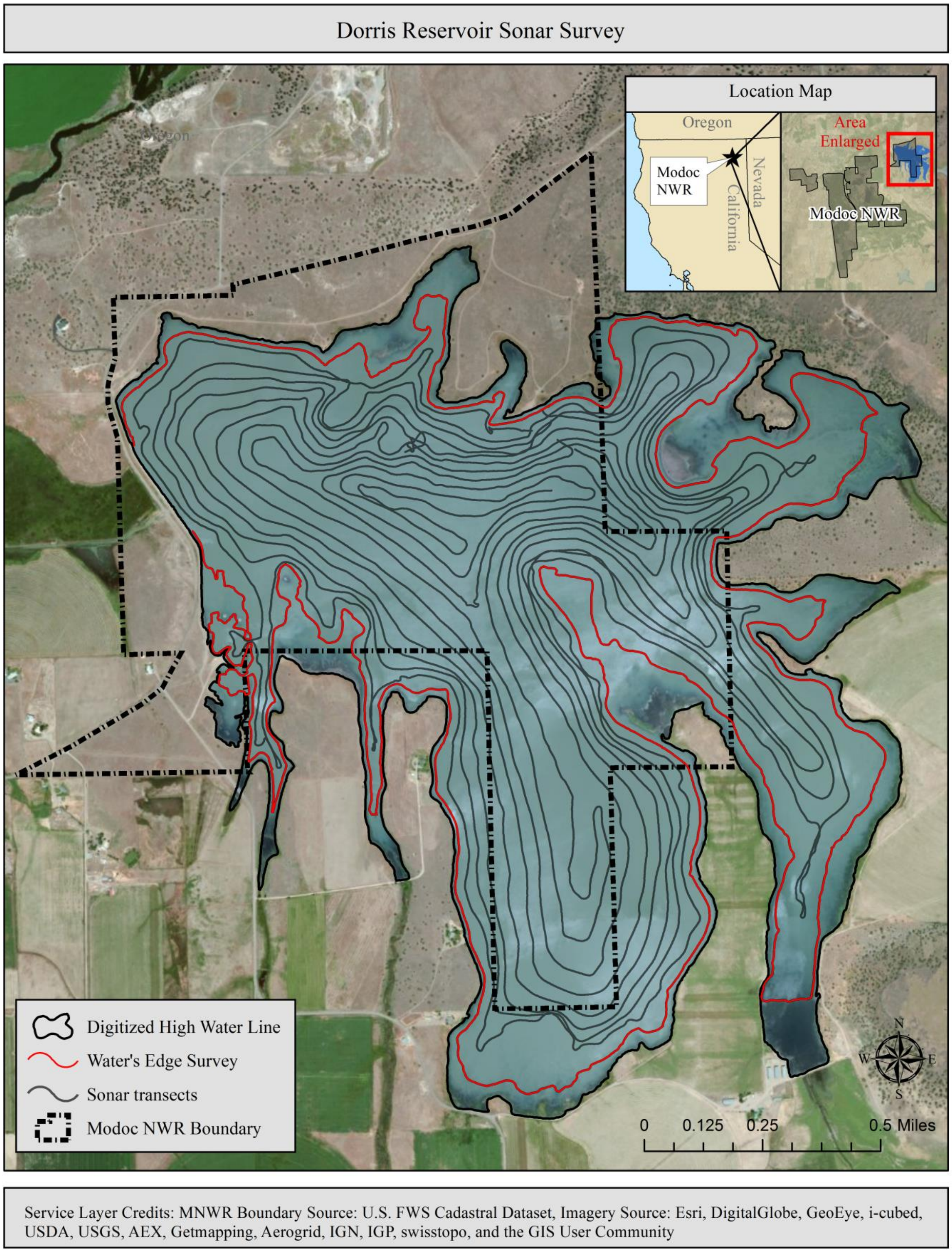

Figure 1. Dorris Reservoir bathymetric survey overview including sonar transects, surveyed water's edge, and digitized high water perimeter.

Methods:

Sonar Survey

A Lowrance HDS Gen2 sonar unit with an 83/200 kHz transducer was used to survey Dorris Reservoir on during the peak annual water surface elevation on May 6th and 7th, 2013. The sonar unit was mounted onto an aluminum flat bottom boat equipped with a 25hp outboard gas motor. The sonar transducer was set to 200kHz (for shallow water) and sonar data was collected passively with a refresh rate of 15 times per second. Transects were driven in the boat in a spiral pattern from the outside of the reservoir to the inside, with a desired spacing of 25 m (82 feet). A Lowrance LGC 2000 external GPS receiver was affixed onto the transducer mount directly above the transducer to eliminate the horizontal bias due to the distance from the sonar transducer to the sonar head unit (with internal GPS). The LGC 2000 receiver has a GPS refresh rate of 5 times per second and utilizes the Wide Area Augmentation System (WAAS) which improves the accuracy of the GPS data. The specified error for WAAS enabled GPS systems is less than three meters in good conditions. The conditions during the surveying period were satisfactory to expect less than 3 m (9.8 feet) error. The sonar unit also integrates heading information measured with an internal compass to improve the sensitivity of the GPS.

GPS and sonar data are saved as a sonar log file ((‘.sl2’ file extension) to an SD Card mounted on the sonar unit. These data are downloaded to a personal computer and read using the Lowrance Sonar Viewer (LSV) software. The LSV software allows for csv output which stores depth and position information in a spreadsheet format. Rounding of location coordinate values to whole meters in the LSV software resulted in multiple soundings per unique coordinate. The R Statistical Program (www.r-project.org) was used to average these multiple records for each unique location coordinate, generating an average water depth for each location. The measured depths were adjusted for sensor depth by adding 4 inches to the recorded depths. Reservoir bottom elevations were calculated by subtracting the adjusted water depths from a planar water surface elevation measured from a USFWS water surface elevation measurement station on the outlet works at the dam.

Water’s Edge Mapping

Dorris Reservoir high water line was digitized from the ESRI aerial imagery service layer, provided by Microsoft (imagery date 7/10/2011). This perimeter was assumed to be at the spillway crest elevation indicating the maximum normal pool water surface elevation (WSE) of 4398.5 feet. The perimeter polygon was used for reservoir surface area calculation, as a clipping boundary for derived rasters, and as a source of points for subsequent surface interpolation by converting polygon vertices to points. These points were assigned an elevation value equal to the spillway crest elevation of 4398.5 feet as per the previous maximum normal pool assumption.

Due to the timing of the study with the WSE about 6 feet below the spillway crest elevation, resulting in reduced area accessible by the sonar system, the water’s edge at the time of the sonar survey was surveyed using a Trimble GeoXH with sub-meter accuracy after post-processing. A polyline with 2 meter horizontal tolerance was collected continuously. The polyline vertices were converted to points and assigned the elevation of the WSE at the time of the survey (4392.74 feet). This additional survey was done in an effort to minimize the gap between the digitized high water line and the sonar points. In some areas this gap was substantial due to the gradually sloping shape of the edge of the reservoir. This extra survey would not have been necessary had the WSE been at or near the level of the spillway crest (4398.5 feet), which would have been more likely to occur in a wetter year.

Sonar Data Transformation

Due to the boat rocking from wave action on the reservoir (especially as wind picked up in the afternoon), the raw sonar depth data showed some additional variability. In an effort to reduce this variability and achieve a smoother surface for analysis and display, a moving window average was applied to the raw sonar data. The span of the moving window was set to 1 second centered on the point of interest (Figure 2). Transformed sonar data was used for all subsequent DEM generation and analysis.

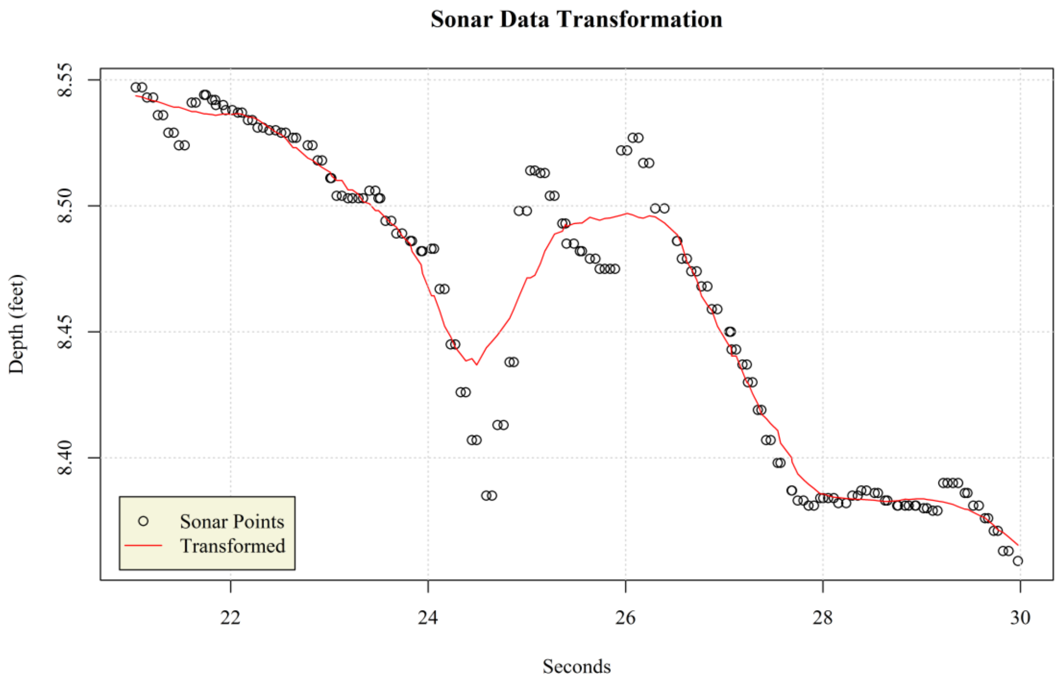

Figure 2. Sample of the raw sonar data transformation using a moving window average with a span of 1 second.

Reservoir Digital Elevation Model (DEM) Generation

A Digital Elevation Model (DEM) of the reservoir was developed from reservoir bottom topographic data generated from the sonar survey and water's edge points in the geographic information system (GIS) ArcMap 10.2 by interpolating triangular irregular network (TIN) from topographic data points, and subsequently editing the TIN and converting the TIN to a 3 m (9.8 feet) resolution raster using a linear interpolation method (see Bangen, et al. 2014). The TIN was manually edited with the addition of hard breaklines to remove artifacts of the data and to better represent the shape of the reservoir edges where data points were sparse. The derived DEM was clipped to the high water line for analysis and display. Additionally, for display only, the focal statistics tool in ArcMap 10.2 was used to smooth the pixels using a mean of a circle with a 3 pixel radius around the focal pixel. The smoothed DEM was used for contour creation and for graphical display (Figure 3), but was not used for analysis.

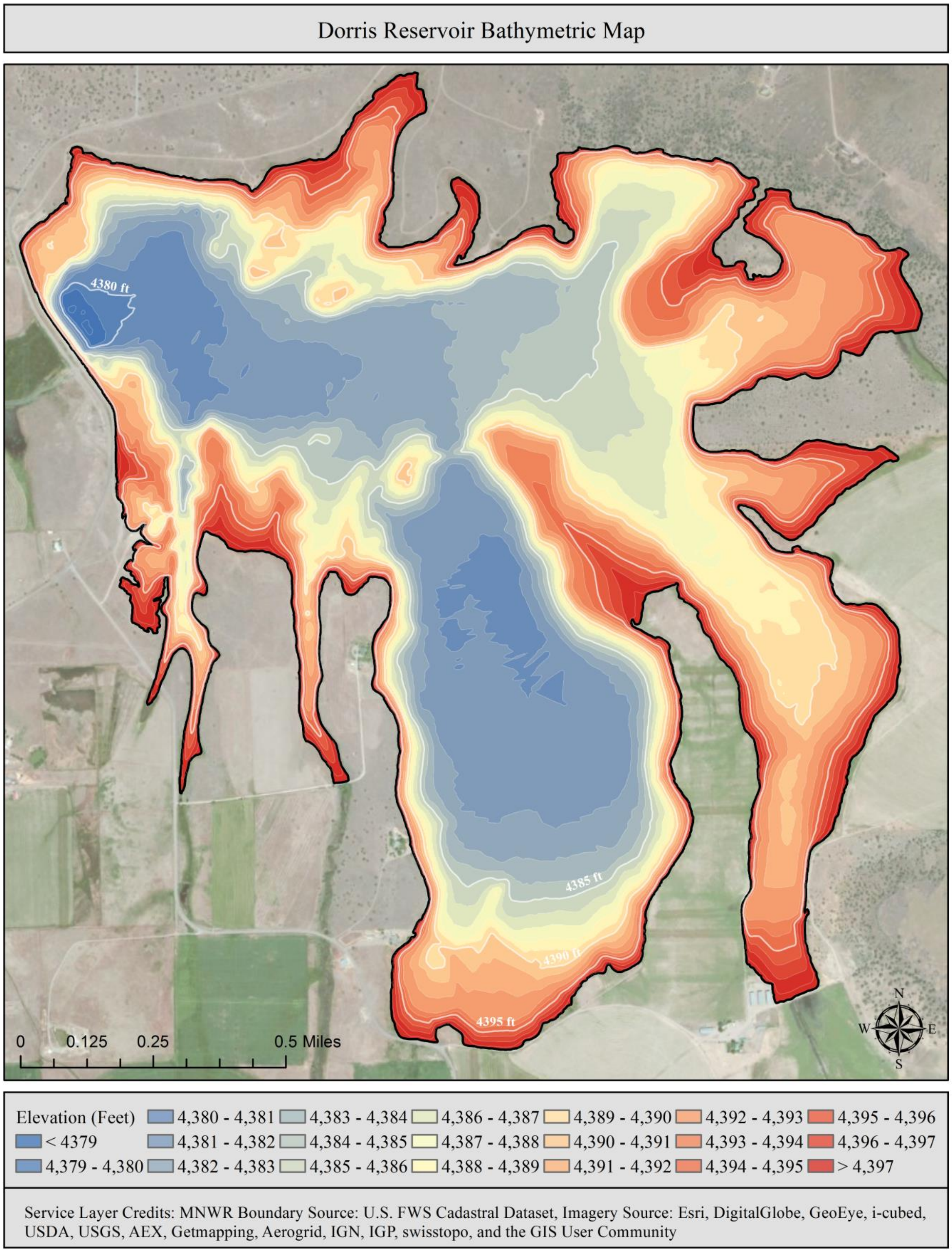

Figure 3. Dorris Reservoir bathymetric map.

Results

Surface Area and Volumetric Calculation

Surface area of Dorris Reservoir at the maximum normal pool (water surface elevation = 4398.5) calculated from the digitized high water line was 1064 acres (see Table 1). Volume of the maximum normal pool calculated from the derived bathymetric surface was 10,947 acre-feet. Compared to the maximum normal pool surface area of 843 acres and volume of 11,870 acre-feet from the SOP manual, there is a percent difference of 20.8% and -7.8% respectively.

Table 1. Surface Area and Volume Comparison

	Spillway Crest Elevation (feet)	Surface Area (acres)	Normal Pool Capacity (acre-feet)
Dorris Dam SOP	4398.5	843	11,870
Sonar Survey		1,064	10,947
Sonar - SOP Difference	NA	221 (20.8%)	1,015 (-7.8%)

Reservoir Depth Distribution

Mean depth of derived Dorris Reservoir DEM is 10.3 feet with a maximum depth of 21.05 feet. The distribution is fairly uniform likely due to gradually sloping shorelines and complex perimeter geometry with a high perimeter to surface area ratio leading to a relatively large proportion of shallow area. The largest proportion of the depth distribution occurs in the 17 to 18 foot range, likely due to the relatively flat topography of the bottom of the reservoir.

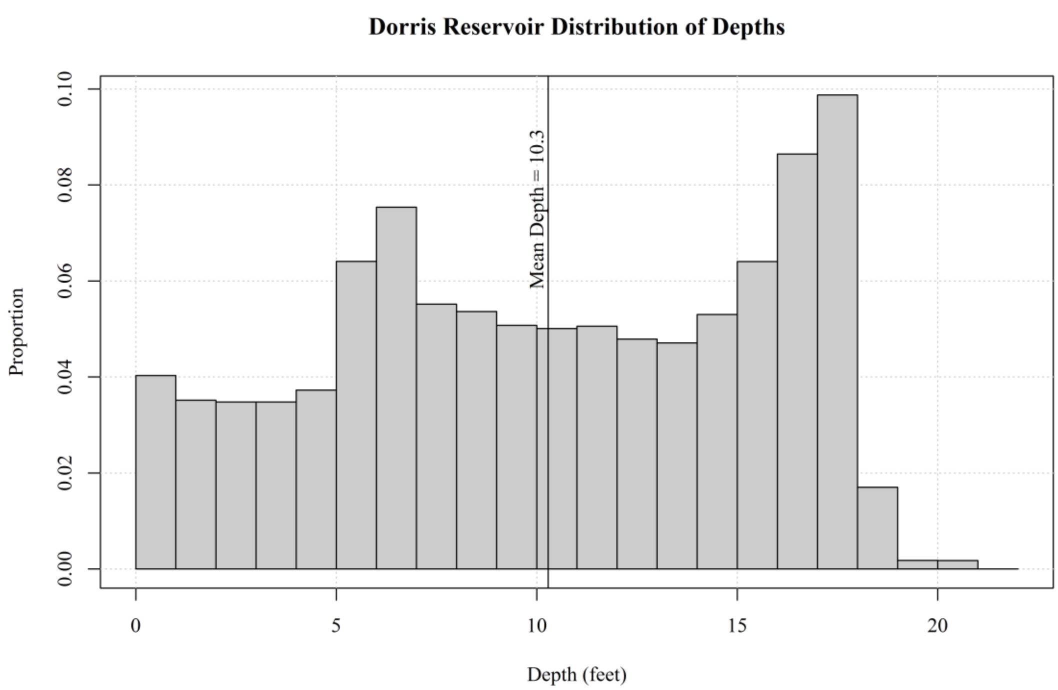

Figure 4. Histogram of the distribution of depths for Dorris Reservoir.

Reservoir Capacity Curve

A reservoir capacity curve was constructed from the bathymetric model for comparison to the existing capacity curve from the Dorris Dam SOP manual (Figure 5). The curves are similar except for the 7.8 percent difference in the value at the maximum normal pool capacity and the steeper rise of the elevation/capacity relationship from the sonar derived curve at lower elevation. Additionally, the sonar survey was designed to assess reservoir capacity up to the normal pool capacity, so no comparison can be made for the capacity above spillway elevation.

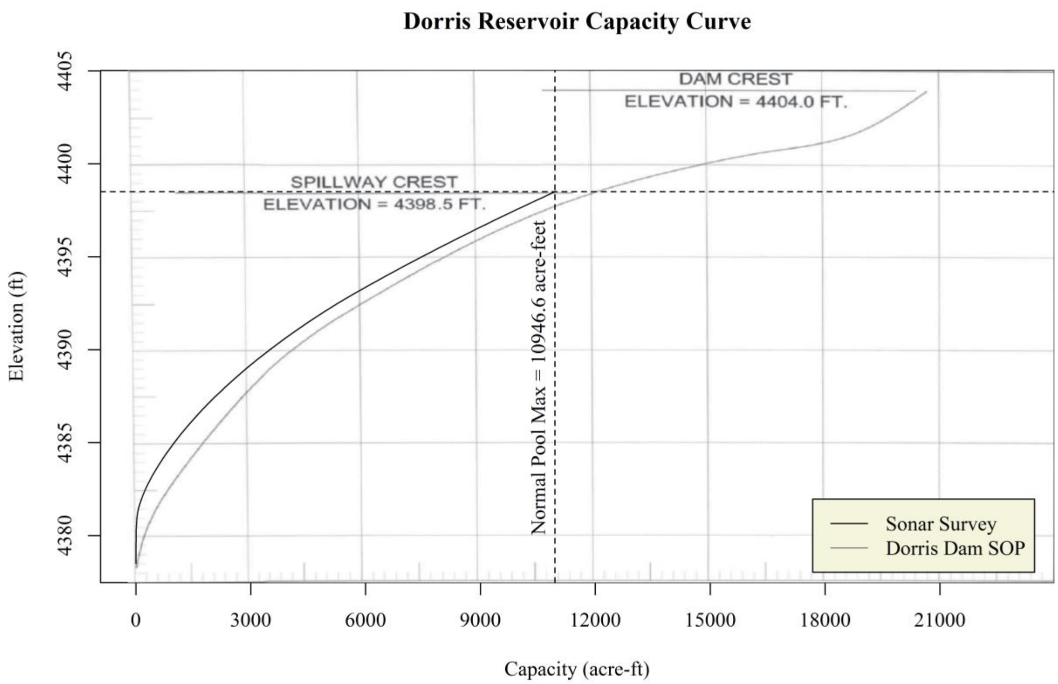

Figure 5. Reservoir storage curve from the sonar survey plotted over the existing storage curve from the Dorris SOP document for comparison. There is some minor distortion in the background image, but the general trends can be compared.

Survey Efficiency

The Dorris Reservoir field survey involved 10 hours of sonar surveying from a boat and 4 hours of surveying the water's edge with a handheld GPS unit. The high water line digitization from aerial imagery took 3 hours to complete. The survey time per acre at Dorris Reservoir including high water line digitization was less than 1 minute per acre. Data processing and bathymetric surface production took an additional 16 hours to complete.

Discussion

The sonar survey using the recreational Lowrance HDS Gen2 sonar fish finder produced similar results to that of the existing survey. The GIS datasets and maps provide higher resolution bathymetric data in the form of DEMs and contours of the reservoir bottom, than what was available from the previous survey.

Future improvements to the bathymetric DEM could include but are not limited to: 1) conduct a sonar survey in the shallow areas when the water surface elevation is at or very close to the spillway crest elevation (4,398.5 feet); 2) survey shoreline with handheld GPS when water surface elevation is at or very close to the spillway crest elevation; 3) add vertices from digitization of islands and shoreline using imagery collected at known dates that correspond to water surface elevations between the survey elevation (4,392.74 feet) and the spillway crest elevation; 4) develop a control point model for raw data transformation using control points generated with a GPS and depths surveyed by sounding line or tall stadia rod. Additional survey points can be added to the existing data by merging processed survey data to the existing survey points and creating a new TIN and subsequent DEM raster. Care should be taken when merging new datasets as both datasets need to be referenced to the same elevation benchmark and offsets need to be taken into account.

Due to the efficiency of the method, repeat or follow up surveys could be conducted quickly and economically. Targeted surveys over areas of interest could be conducted with narrower transect widths to increase the resolution of the model and inform management decisions such as where dredging would be most effective. Possible areas of interest could include the area near the outlet works structure on the dam and the narrow constriction adjacent to the largest peninsula which could reduce the effective holding capacity by cutting off areas of lower elevation.

References

Bangen, S.G., Wheaton.J.M., Bouwes, N. Bouwes B. Jordan, C., 2014. "A methodological intercomparison of topographic survey techniques for characterizing wadeable streams and rivers." Geomorphology (206), 343-361.

U.S. Fish and Wildlife Service, 2009. “Dorris Dam Standard Operating Procedure (SOP) Manual”. Revision No.2.

U.S. Fish and Wildlife Service, 2009. “Modoc National Wildlife Refuge Final Comprehensive Conservation Plan” U.S. Fish and Wildlife Service Open-Access Report, 152 p.

Esralew, R.E, Holmes, E.J., Boyle, E., 2013. “Modoc National Wildlife Refuge Water Resources Inventory and Assessment”. U.S. Fish and Wildlife Service Open-Access Report. 175 p.

Wheaton, J. M., Brasington, J., Darby, S. E. and Sear, D. A. (2010), Accounting for uncertainty in DEMs from repeat topographic surveys: improved sediment budgets. Earth Surf. Process. Landforms, 35: 136–156. doi: 10.1002/esp.1886