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Scientific Investigations Map 3499
Sheet 1 of 3

Introduction

Table Rock Lake was completed in 1958 on the White River in southwestern Missouri and northwestern Arkansas (fig. 1) for flood control, hydroelectric power, public water supply, and recreation. The surface area of Table Rock Lake is about 42,400 acres (table 1), and about 715 miles of shoreline are at the conservation pool level (915 feet [ft] above the North American Vertical Datum of 1988; U.S. Army Corps of Engineers, 2022). Sedimentation in reservoirs can result in reduced water storage capacity and a reduction in usable aquatic habitat; therefore, accurate and up-to-date estimates of reservoir water capacity are important for managing pool levels, power generation, recreation, and downstream aquatic habitat. Many of the lakes operated by the U.S. Army Corps of Engineers are periodically surveyed to monitor bathymetric changes that affect water capacity. In October and November 2020, the U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers, completed one such survey of Table Rock Lake using a multibeam echosounder (MBES). The echosounder data were combined with USGS 1/3 arc-second digital elevation model (DEM) data and light detection and ranging (lidar) data, where present, to prepare a bathymetric map and a surface area and capacity table.

Methods

A bathymetric survey of Table Rock Lake was completed between October 13 and November 11, 2020, using methods similar to those described by Richards and others (2019). The average water-surface elevation of Table Rock Lake during the survey was about 915.5 ft. A bathymetric surface and a surface area and capacity table were created from a combination of the bathymetric survey data with the DEM data for the upland area above the average water-surface elevation.

Bathymetric Data Collection

Bathymetric data (water depths and positions; fig. 2) were collected using high-resolution multibeam mapping systems (MBMSs). The data were collected concurrently by four boats surveying different sections of Table Rock Lake. The various components of the MBMSs used for this study are described in more detail in reports on the Missouri and Mississippi Rivers in Missouri (not shown; Huizinga, 2010, 2022; Huizinga and others, 2010) and Sugar Creek water supply lake near Moberly, Missouri (not shown; Richards and others, 2019). The survey methods used to obtain the data for Table Rock Lake were similar to these studies, as were the methods used to ensure data quality.

An MBMS is an integration of several individual components—the MBES, an inertial navigation system (INS), and a data-collection and data-processing computer. The MBES systems used were the NORBIT iWBMSh, the NORBIT iWBMSc, and the R2Sonic 2024, all operated at a frequency of 400 kilohertz (NORBIT, 2020; R2Sonic LLC, 2014). The iWMBSh and R2Sonic 2024 are similar in performance and operation to the MBES systems used in previous studies in Missouri (Huizinga, 2010, 2022; Huizinga and others, 2010, 2022; Richards and others, 2019). The iWBMSc also is similar to systems used in previous studies but has a less accurate INS.

The NORBIT MBES systems have a curved receiver array that enables bathymetric data to be collected throughout a swath range of 210 degrees. Optimum data generally are collected in a swath of less than 160 degrees (80 degrees on each side of nadir, or straight down below the MBES); nevertheless, the swath can be electronically rotated to either left or right of nadir, enabling data to be captured along sloping banks up to a depth just below the water surface. The R2Sonic system has a flat receiver array and is limited to a swath range of 160 degrees (80 degrees on each side of nadir) but can be physically tilted to enable data to be collected along sloping banks. The INS—Applanix OceanMaster for the iWBMSh and R2Sonic (Applanix Corporation, 2017) and NovAtel MarineSPAN with OEM–STIM300 for the iWBMSc (NovAtel, 2021)—provides position in three-dimensional space and measures the heave, pitch, roll, and heading of the vessel (and, thereby, the MBES) to accurately position the data received by the MBES. Survey data were collected using HYPACK/HYSWEEP software (HYPACK, Inc., 2020).

Real-time navigation during the survey used a real-time kinematic differential global positioning system solution. The navigation information from the iWBMSh and R2Sonic systems was postprocessed using the POSPac Mobile Mapping Suite software (Applanix Corporation, 2021). The iWBMSc navigation information was postprocessed with the Waypoint Inertial Explorer software (NovAtel, 2019). POSPac Mobile Mapping Suite and Waypoint Inertial Explorer provide tools to identify and compensate for sensor and environmental errors. These programs compute an optimally blended navigation solution from the global navigation satellite systems (GNSSs) and inertial-measurement unit raw data from the INS. The location solution was further enhanced by collecting static GNSS data with a GNSS base receiver set up over a temporary reference mark near Table Rock Lake, the coordinates for which were determined using techniques detailed in Rydlund and Densmore (2012), corresponding to a Level I survey. The blended navigation solution (called a smoothed best estimate of trajectory, or SBET, file) generated by postprocessing the daily navigation data was applied to the corresponding daily survey data.

Most of the bathymetric survey data within Table Rock Lake were collected with the swath range limited to 140 degrees (70 degrees on each side of nadir); however, along the banks and in the shallow areas at the upstream ends of the lake arms, the swath range was widened to 160 degrees to cover a wider swath of the bottom. The receiver array also was electronically or physically tilted to port or starboard as needed to enhance acquisition of bathymetric data in the shallow areas near the shoreline, in coves, and in the upper reaches of the lake arms. The electronically tilted swath from the NORBIT systems was generally about 160 degrees wide, extending from about 10 degrees above horizontal on the landward side of the survey vessel to about 60 degrees past nadir below the vessel.

The bathymetric data generally were collected along longitudinal transect lines in the main lake area, following the dominant valley orientation. The transects were spaced to create about 10- to 25-percent overlap of the survey swaths to ensure complete coverage of the lake bottom and minimize sonic shadows. Data along the shoreline were collected by navigating the boat parallel to the shore while overlapping the data collected in the main body of the lake. Cove data were collected by navigating into a cove along the approximate centerline of the cove as far as practical (generally the point at which forward progress was blocked by vegetation or water depth decreased to less than about 10 ft [or 3.0 meters]), pivoting the boat 180 degrees, and egressing the cove along the ingress line.

The speed of sound in water needs to be known to accurately determine the depths acquired by an MBES. In a lake, the speed of sound in the water commonly varies in space and time. To mitigate variations in sound speed near the water surface, sound velocity data are collected at the MBES head continuously throughout the survey; however, the speed of sound also can vary over the water column because of water temperature variations with depth. Therefore, sound velocity profiles were measured with a sound velocity probe at various locations throughout each survey day and were applied during postprocessing in the HYPACK/HYSWEEP software.

Preparation for the bathymetric survey, data collection during the survey, and postprocessing were done in HYPACK/HYSWEEP software (HYPACK, Inc., 2020). During postprocessing, the data were georeferenced using the navigation and position solution data in the SBET file and visualized in HYPACK/HYSWEEP as a triangulated irregular network (TIN) surface or a point cloud. The acquired depth data were processed further to apply sound velocity profiles, to apply patch test corrections, and to remove data spikes and other spurious points, often caused by fish and submerged woody debris. The georeferenced point data were then filtered and reduced to a 6.56-ft (2-meter) data resolution and exported to a comma-delimited text file.

Bathymetric Surface and Contour Map Creation

About 38,000,000 data points, spaced 6.56-ft horizontally, were exported from the raw data collected during the 2020 survey (Rivers and others, 2022). For the survey, the vertical datum was the North American Vertical Datum of 1988 using the geoid model GEOID18, and the horizontal datum was the North American Datum of 1983. Geographic information system (GIS) software was used to filter the 6.56-ft spaced bathymetric data points so that the points would be spaced about 19.7 ft (6 meters) apart. The data reduction retained about 4,370,000 surveyed data points from the 2020 MBES survey.

Data outside the MBES survey extent (fig. 2) and between about 915 and 940 ft in elevation (hereinafter referred to as “upland data”) were obtained from the USGS National Elevation Dataset (U.S. Geological Survey, 2017). The upland data were sourced from USGS 1/3 arc-second DEM data and, where present, lidar data collected in 2010 and 2017 were combined and resampled to a 19.7-ft (6-meter) spacing. About 1,710,000 upland data points were used.

In addition to the MBES and upland data, additional data in bathymetric surface analyses were developed using the linear enforcement techniques described in Wilson and Richards (2006). About 208,000 points were created based on surrounding MBES, DEM, and lidar data values to anchor the bathymetric surface in areas of sparse data along some shoreline areas and in the upper ends of coves where the water was too shallow for the MBES equipment.

The MBES, DEM, lidar, and linearly enforced point datasets (a total of about 6,290,000 points) were used to produce a three-dimensional TIN surface (also referred to as a “bathymetric surface”) of the lake-bottom elevations. A surface area and capacity table at specified lake water-surface elevations was produced from the three-dimensional TIN surface (table 1). The surface was contoured at a 20-ft interval using GIS software, and the contours were cartographically smoothed and edited to create a bathymetric contour map (fig. 2) using the techniques of Wilson and Richards (2006).

Bathymetric Data-Collection Quality Assurance

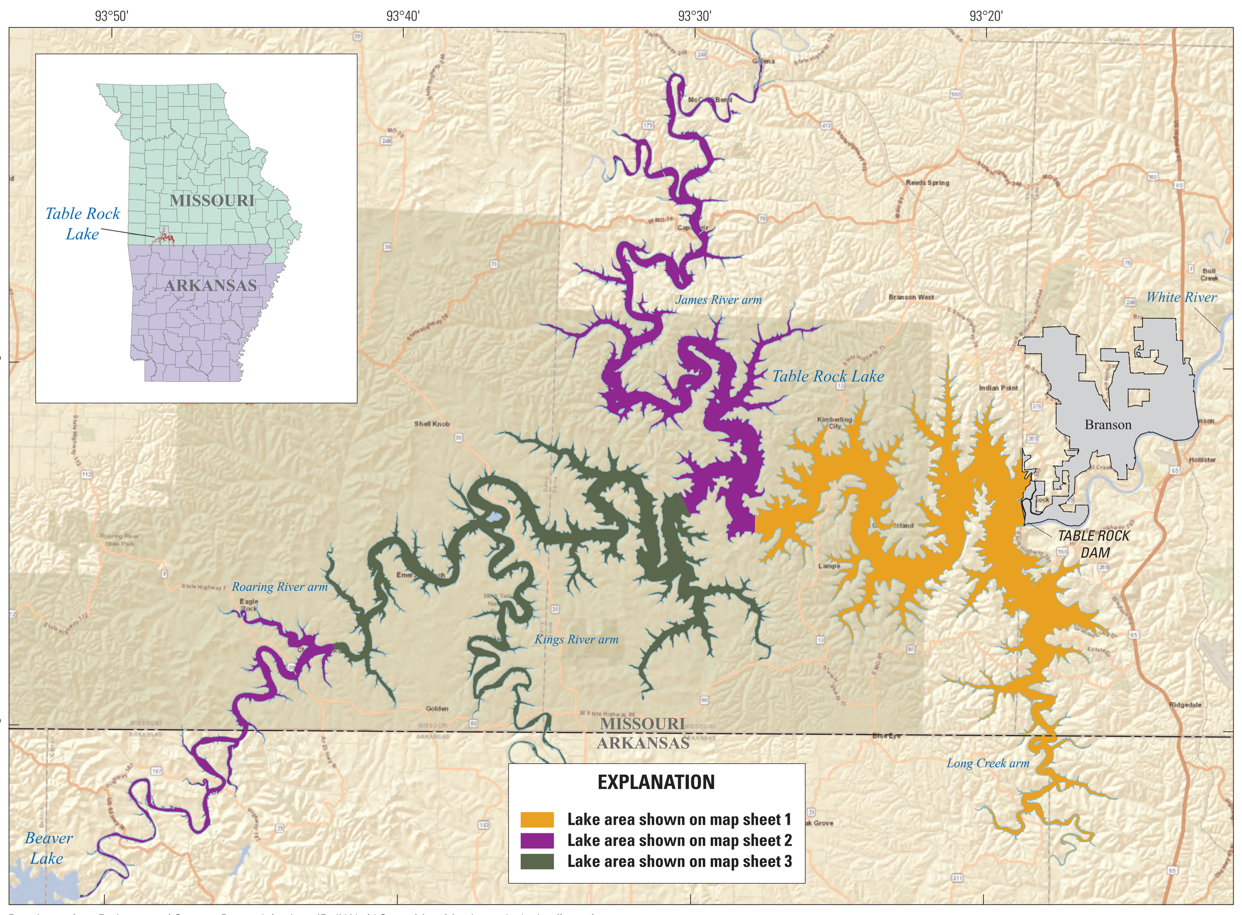
The principal quality-assurance measures for the MBMS were assessed in real time during the survey. The MBMS operator continuously assessed the quality of the data collected during the survey by making observations of across-track swaths (such as convex, concave, or skewed bed returns in flat, smooth bottoms), noting data-quality flags and alarms from the MBES and the INS, and inspecting comparisons between adjacent overlapping swaths. In addition to the real-time quality-assurance assessments during the survey, a suite of patch tests was done for each MBMS during the survey to ensure that quality data were acquired from the MBMS. Beam-angle checks also were done for each MBMS.

Patch Tests

Patch tests are a series of dynamic calibration tests that are used to check for subtle variations in the orientation and timing of the MBES with respect to the INS and real-world coordinates. The patch tests are used to determine timing offsets caused by latency between the MBES and the INS and angular offsets to roll, pitch, and yaw caused by the alignment of the transducer head (Huizinga and others, 2010). These offsets have been observed to be essentially constant for a given survey, barring an event that causes the mount to change such as striking a floating or submerged object (see Huizinga, 2022). The offsets determined in the patch test are applied when processing the data collected during a survey. Patch tests were completed for each MBMS at various times during the Table Rock Lake survey, and angular offsets were determined to be constant for a given system throughout the survey and entered in the data-collection software as appropriate. This study did not have any measured timing offsets for any system, which is consistent with latency test results for survey boats and for similar equipment configurations used in other surveys (Huizinga, 2010, 2022; Huizinga and others, 2010, 2022).

Beam-Angle Checks

A beam-angle check is used to determine the accuracy of the depth readings obtained by the outer beams (greater than 25 degrees from nadir) of the MBES (U.S. Army Corps of Engineers, 2013). The accuracy of the outer beams may change with time because of inaccurate sound velocities, physical configuration changes, and water depth. A beam-angle check was done for each MBMS during the survey; the R2Sonic system check was done on October 13, 2020; the Missouri iWBMSh system check was done on October 21, 2020; the Oklahoma iWBMSh system check was done on November 10, 2020; and the iWBMSc system check was done on November 11, 2020. Each test included a sound velocity cast to document and quantify any stratification in the water column near the reference surface. The results of the R2Sonic beam-angle check were within the recommended performance standards used by the U.S. Army Corps of Engineers for hydrographic surveys for all the representative angles less than 70 degrees (U.S. Army Corps of Engineers, 2013); therefore, the central 140 degrees of the echosounder swath for that system could be used with confidence. The results of the Missouri iWBMSh beam-angle check were determined to be outside the recommended performance standards used by the U.S. Army Corps of Engineers for hydrographic surveys for all the representative angles because the depth of the beam-angle check area was substantially deeper than the recommended depth of 100 ft in the standards. However, a beam-angle check for the Missouri iWBMSh system had been done on June 23, 2020, at Mozingo Lake near Maryville, Mo. (not shown; Huizinga and others, 2022), with depths of less than 100 ft, and the results of that beam-angle check were within the recommended performance standards for all the representative angles less than 70 degrees, permitting the use of the central 140 degrees of the echosounder swath with confidence. The results of the Oklahoma iWBMSh system and the iWBMSc system checks were determined to be within the recommended performance standards for all the representative angles less than 55 degrees, permitting the use of the central 110 degrees of the echosounder swath with confidence for these systems. Points acquired outside of the central 100–110 degrees of the echosounder swath (regardless of the system) generally had overlap with adjacent swaths, which increases the quality of the survey in the overlapped areas because of duplication.



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Universal Transverse Mercator projection, zone 15 North

Figure 1. Location of Table Rock Lake near Branson, Missouri.

Table 1. Surface area and capacity at specified water-surface elevations for Table Rock Lake near Branson, Missouri, from a survey on October 13 to November 11, 2020.

[The average water-surface elevation during the survey was 915.5 feet, the conservation pool elevation is 915 feet (row shaded blue in the table), the flood pool elevation is 931 feet, and the upper vertical limit of the survey is 931 feet; --, no data; all elevations are referenced to the North American Vertical Datum of 1988]

Water-surface elevation, in feet	Surface area, in acres	Capacity, in acre-feet	Water-surface elevation, in feet	Surface area, in acres	Capacity, in acre-feet	Water-surface elevation, in feet	Surface area, in acres	Capacity, in acre-feet
698	0.121	0.047	778	4,300	115,000	858	19,100	963,000
700	0.936	0.672	780	4,520	123,000	860	19,700	1,000,000
702	6.43	6.92	782	4,760	133,000	862	20,300	1,040,000
704	18.4	30.8	784	4,990	142,000	864	20,900	1,080,000
706	36.7	83.5	786	5,220	153,000	866	21,500	1,130,000
708	67.2	186	788	5,440	163,000	868	22,200	1,170,000
710	97.2	351	790	5,700	174,000	870	22,800	1,210,000
712	119	568	792	6,000	186,000	872	23,500	1,260,000
714	150	834	794	6,300	198,000	874	24,200	1,310,000
716	198	1,180	796	6,580	211,000	876	24,900	1,360,000
718	256	1,630	798	6,860	225,000	878	25,600	1,410,000
720	315	2,200	800	7,150	239,000	880	26,300	1,460,000
722	362	2,880	802	7,450	253,000	882	27,100	1,510,000
724	420	3,660	804	7,780	269,000	884	27,900	1,570,000
726	476	4,560	806	8,100	284,000	886	28,600	1,620,000
728	551	5,580	808	8,410	301,000	888	29,400	1,680,000
730	636	6,770	810	8,740	318,000	890	30,300	1,740,000
732	728	8,130	812	9,080	336,000	892	31,100	1,800,000
734	834	9,690	814	9,400	354,000	894	31,900	1,870,000
736	938	11,500	816	9,750	373,000	896	32,800	1,930,000
738	1,040	13,400	818	10,100	393,000	898	33,600	2,000,000
740	1,150	15,600	820	10,500	414,000	900	34,500	2,070,000
742	1,280	18,100	822	10,800	435,000	902	35,400	2,140,000
744	1,420	20,800	824	11,200	457,000	904	36,300	2,210,000
746	1,560	23,800	826	11,600	480,000	906	37,200	2,280,000
748	1,690	27,000	828	12,000	504,000	908	38,100	2,360,000
750	1,850	30,600	830	12,400	528,000	910	39,100	2,430,000
752	2,000	34,400	832	12,800	553,000	912	40,300	2,510,000
754	2,140	38,600	834	13,200	579,000	914	41,600	2,590,000
756	2,290	43,000	836	13,600	606,000	915	42,400	2,640,000
758	2,460	47,700	838	14,100	634,000	916	43,000	2,680,000
760	2,620	52,800	840	14,500	662,000	918	44,100	2,770,000
762	2,790	58,200	842	15,000	692,000	920	45,300	2,860,000
764	2,960	64,000	844	15,400	722,000	922	46,600	2,950,000
766	3,130	70,100	846	15,900	754,000	924	47,800	3,040,000
768	3,320	76,500	848	16,400	786,000	926	49,000	3,140,000
770	3,510	83,300	850	16,900	819,000	928	50,200	3,240,000
772	3,700	90,500	852	17,400	853,000	930	51,400	3,340,000
774	3,910	98,100	854	17,900	889,000	931	52,000	3,390,000
776	4,100	106,000	856	18,500	925,000	--	--	--

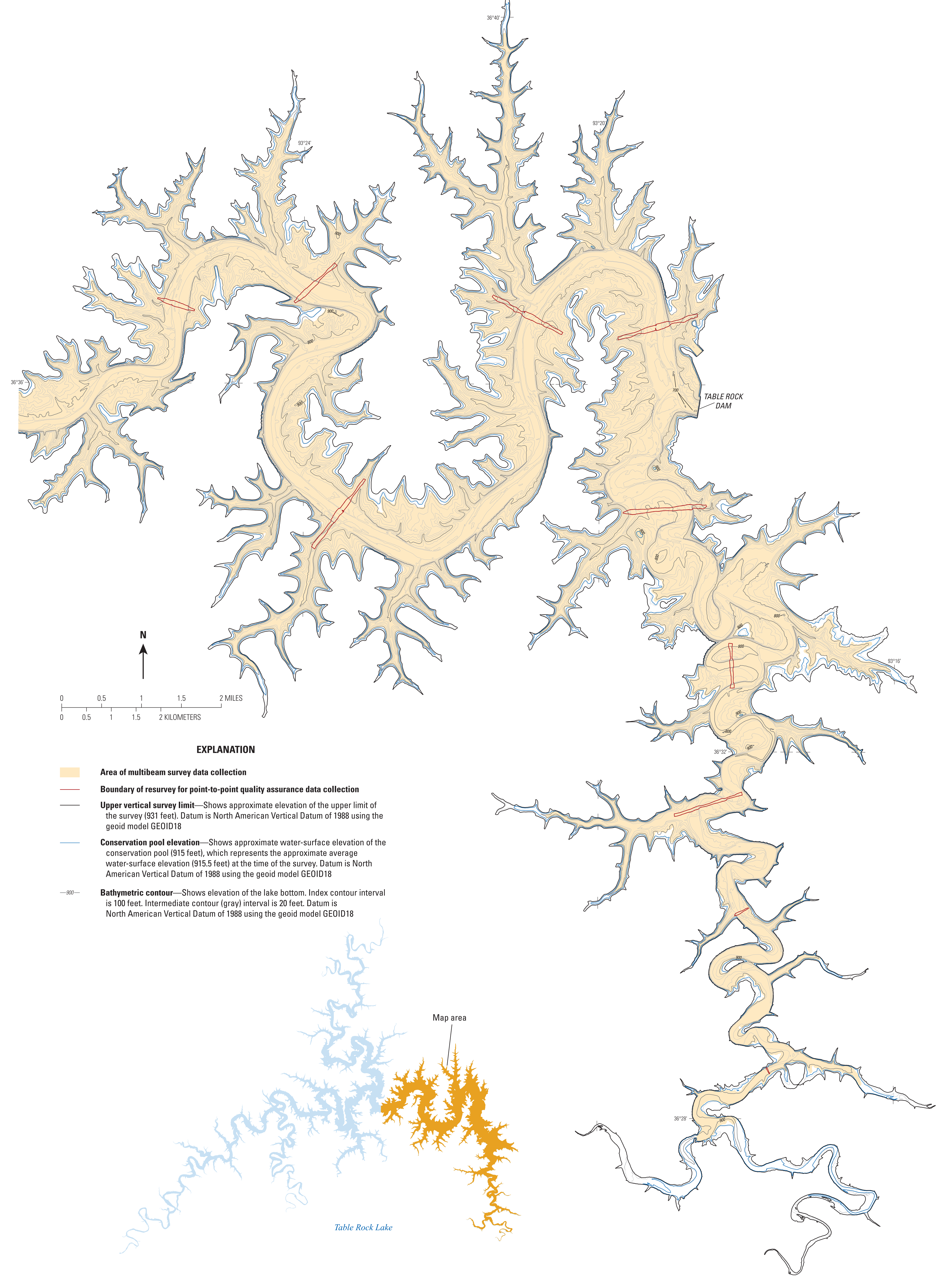

Figure 2. Bathymetric contours for Table Rock Lake near Branson, Missouri, resulting from a survey on October 13 to November 11, 2020.

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Bathymetric Map and Surface Area and Capacity Table for Table Rock Lake near Branson, Missouri, 2020

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