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U.S. GEOLOGICAL SURVEY
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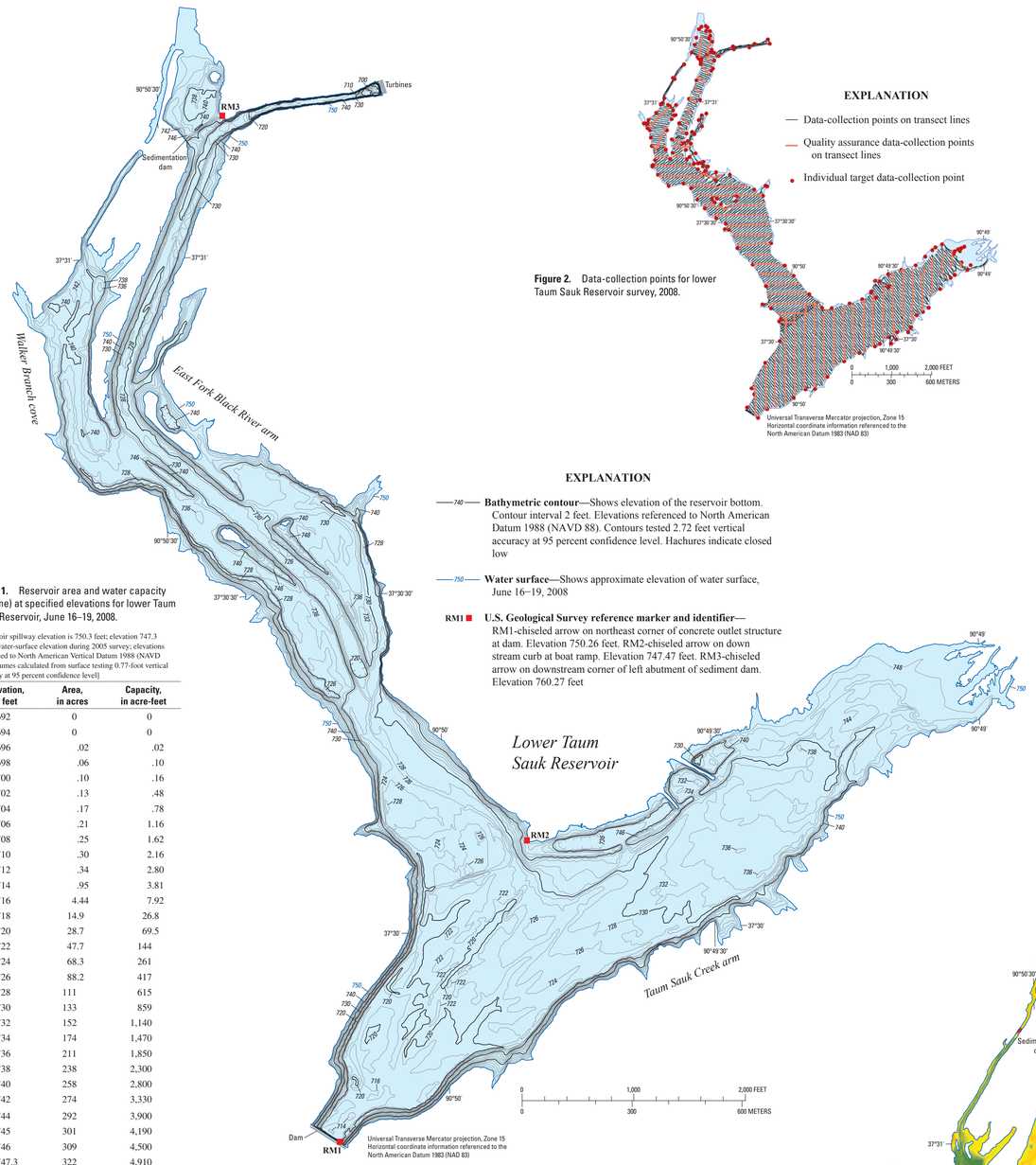
Prepared in collaboration with
ROUX ASSOCIATES INC.

SCIENTIFIC INVESTIGATIONS MAP 3061
Bathymetry, Area, and Capacity Differences for Lower Taum Sauk Reservoir
Wilson, G.L., and Richards, J.M., 2008, Differences in Reservoir Bathymetry, Area, and Capacity Between December 20–22, 2005, and June 16–19, 2008, for Lower Taum Sauk Reservoir, Reynolds County, Missouri



EXPLANATION

—740— **Bathymetric contour**—Shows elevation of the reservoir bottom. Contour interval 2 feet. Elevations referenced to North American Datum 1988 (NAVD 88). Contours tested 2.72 feet vertical accuracy at 95 percent confidence level. Hachures indicate closed low

—750— **Water surface**—Shows approximate elevation of water surface, June 16–19, 2008

RM1 **U.S. Geological Survey reference marker and identifier**—RM1-chiseled arrow on northeast corner of concrete outlet structure at dam. Elevation 750.26 feet. RM2-chiseled arrow on down stream curb at boat ramp. Elevation 747.47 feet. RM3-chiseled arrow on downstream corner of left abutment of sediment dam. Elevation 760.27 feet

Figure 1. Bathymetric contours of lower Taum Sauk Reservoir, June 16–19, 2008.

Table 1. Reservoir area and water capacity (volume) at specified elevations for lower Taum Sauk Reservoir, June 16–19, 2008.

[Reservoir spillway elevation is 750.3 feet; elevation 747.3 feet is water-surface elevation during 2005 survey; elevations referenced to North American Vertical Datum 1988 (NAVD 88); volumes calculated from surface testing 0.77-foot vertical accuracy at 95 percent confidence level]

Elevation, in feet	Area, in acres	Capacity, in acre-feet
692	0	0
694	0	0
696	.02	.02
698	.06	.10
700	.10	.16
702	.13	.48
704	.17	.78
706	.21	1.16
708	.25	1.62
710	.30	2.16
712	.34	2.80
714	.95	3.81
716	4.44	7.92
718	14.9	26.8
720	28.7	69.5
722	47.7	144
724	68.3	261
726	88.2	417
728	111	615
730	133	859
732	152	1,140
734	174	1,470
736	211	1,850
738	238	2,300
740	258	2,800
742	274	3,330
744	292	3,900
745	301	4,190
746	309	4,500
747.3	322	4,910
748	330	5,130
750	358	5,810

Introduction

On December 14, 2005, the embankment of the upper reservoir at the Taum Sauk pump storage facility, Reynolds County, Missouri, catastrophically failed and flooded the East Fork Black River, depositing debris and sediment in Johnson's Shut-Ins State Park, the lower Taum Sauk Reservoir, and downstream in the Black River (location map). A bathymetric survey conducted December 20–22, 2005, documented the bathymetry of the lower Taum Sauk Reservoir after the upper reservoir failure (Rydlund, 2006). After subsequent excavation of sediment and debris from the lower reservoir by Ameren Union Electric (UE), the U.S. Geological Survey (USGS), in collaboration with Roux Associates Inc., conducted a bathymetric survey of the lower Taum Sauk Reservoir on June 16–19, 2008, to prepare a current (2008) bathymetric map (fig. 1) for the lower reservoir, establish a current (2008) elevation-area and capacity table, and determine reservoir area and capacity differences between the 2005 and 2008 bathymetric surveys.

Acknowledgments

The USGS thanks Ameren UE for granting access to their property for the survey.

Methods

Bathymetric data (water depths and positions) were collected on June 16–19, 2008 (fig. 2). Position data were collected using a boat-mounted differentially corrected global positioning system (DGPS). Water depths were collected using a survey-grade 200-kilohertz echo sounder emitting sound pulses that are reflected off the reservoir bottom and received by a transducer. In some areas of the reservoir, water depths were measured manually (target data-collection points) using a steel rod graduated in tenths, because the water depth was below the minimum operating depth [approximately 2.5 feet (ft)] of the echo-sounding equipment. Water-surface edge points were collected using only the DGPS coordinate data with no depth. Approximately 350,000 data points were collected in the 2008 survey. Bathymetric data were collected with the echo sounder along transect lines spaced approximately 50 ft apart, which is approximately 0.5 percent of the longitudinal length of the reservoir. Individual data-collection points along a transect line were approximately 0.7 to 1.6 ft apart. Water-depth data were converted to reservoir-bottom elevation by subtracting the depths at each location from the reference water-surface elevation of the reservoir. The reference water-surface elevation was determined by measuring from surveyed reference marks of known elevation (figs. 1 and 3). Elevations of these reference marks were obtained from the Missouri Department of Natural Resources (O. Lashley, Missouri Department of Natural Resources Division of Geology and Land Survey, oral commun., 2006). The reference marks were not used to establish or verify horizontal datum. The position data were used as collected from the DGPS with a stated positional accuracy of less than 3.28 ft (Trimble Navigation Limited, 1999). The vertical datum is North American Vertical Datum 1988 (NAVD 88) and the horizontal datum is North American Datum 1983 (NAD 83).

Geographic information system (GIS) software was used to produce a three-dimensional surface of the reservoir-bottom elevations from the bathymetric data. The boundary of the reservoir at full pool elevation was determined from laser intensity detection and ranging (LIDAR) data collected in December 2005 (Sanborn, Inc., written commun., 2005). The 2008 boundary was altered where changes were seen from collected edge points and 2008 imagery. The surface between the 2008 and 2005 surveyed data and the full pool boundary was created using established interpolation techniques (Wilson and Richards, 2006). An area and capacity table was produced from the three-dimensional surface (table 1) showing surface area and water volumes at specified elevations. The surface was contoured using GIS software and the contours were cartographically edited to create a bathymetric map (fig. 1).

A bathymetric map (fig. 3) of the lower Taum Sauk Reservoir was created and an elevation-area and capacity table (table 2) was computed from the survey data collected by the USGS in December 2005. After the failure of the upper reservoir (Rydlund, 2006), a bathymetric survey was conducted by the USGS in December 2005. Both the 2008 and the 2005 surveys collected data along similar transect lines (figs. 2 and 4) and both bathymetric maps (figs. 1 and 3) were created using methods documented in Wilson and Richards (2006). Approximately 311,000 data points were collected in the 2005 survey. Additional data points were collected for the 2008 survey because the reservoir water-level was higher in 2008, and debris deposited during the 2005 flood had been removed allowing access to more reservoir area (figs. 2 and 4).

The area and capacity tables from the two surveys were compared by calculating the difference between the two tables for each elevation (table 3). To produce the bathymetric surface difference map (fig. 5), the 2008 and 2005 bathymetric surfaces were first converted into an evenly spaced elevation grid of 3.28-ft cell size, then the difference was computed by subtracting the 2005-surface grid from the 2008-surface grid.

Quality Assurance

Accuracy of the bathymetric surface and contours is a function of the survey data accuracy, density of the survey data (transect interval and data-collection frequency), and the processing steps that occur during their creation. Onsite, a bar check consisting of measurements of depth to a suspended steel plate was performed at the beginning of each day of data collection following established protocols (U.S. Army Corps of Engineers, 2002; Wilson and Richards, 2006) to ensure that the echo sounder was calibrated correctly. The water-surface elevation was determined at the beginning and end of each day of data collection using established reference markers as vertical controls (figs. 1 and 3) to ensure an accurate computation of reservoir-bottom elevation. Survey echo sounder data accuracy also is dependent on factors such as vessel draft/index errors, platform stability, vessel velocity, and subsurface material density (Wilson and Richards, 2006). Though similar, these factors were not exactly the same for the 2008 and 2005 surveys because of weather conditions, instantaneous boat speeds, and consolidation/compaction of bottom sediments.

To assess the quality of the 2008 bathymetric surface and contours, quality-assurance data were collected using similar transect lines that were used to assess quality assurance of the 2005 bathymetric surface. The quality assurance-transects were spaced approximately 250 ft apart (figs. 2 and 4) and were oriented at an oblique angle (about 40 degrees) to the survey transects. Data from the quality-assurance transects were used as an independent data set allowing for computation of accuracy of the bathymetric surface and bathymetric-contour map (Wilson and Richards, 2006). Approximately 54,400 quality-assurance data points were collected for the 2008 survey (fig. 2) and approximately 31,700 quality-assurance data points were collected for the 2005 survey (fig. 4). More quality-assurance data points were collected for the 2008 survey because more reservoir area was open for surveying in 2008. The vertical accuracies of the 2008 and 2005 bathymetric surfaces, from which the elevation-area and capacity tables were derived, were computed to be 0.77 and 1.45 ft at the 95 percent confidence level. The vertical accuracies of the 2008 and 2005 bathymetric contour maps were computed to be 2.72 and 3.38 ft at the 95 percent confidence level. Bathymetric contours are less accurate than the bathymetric surface because of cartographic interpretation of the contours for map display.

Differences in Reservoir Bathymetry, Area, and Capacity

The water-surface elevation of the reservoir was approximately 750.3 ft during the 2008 survey, which is equal to the spillway elevation. For the 2005 survey, the water-surface elevation of the reservoir was 3.0 ft lower at 747.3 ft. Excavation of sediment and debris occurred between the two surveys. Using the area and capacity table for each survey, the difference in the reservoir surface area and capacity (volume) between the 2008 and 2005 surveys was computed at each elevation. At the elevation of 750 ft, the 2008 reservoir surface was 3 acres greater than the 2005 surface and the 2008 capacity was 620 acre-feet (acre-ft)greater than the 2005 capacity (table 3). The small differences in area and capacity between the 2008 reservoir surface and the 2005 reservoir surface at elevations below 714 ft are confined to the tailrace immediately downstream from the power generation turbines at the north end of the reservoir, where the 2005 data coverage is less dense than the coverage in 2008.

The elevation difference map (fig. 5) shows areas of change between the two bathymetric surfaces of the reservoir bottom. Generally, the 2008 reservoir bottom surface is lower than the 2005 surface in the East Fork Black River arm, the Walker Branch cove, the area upstream from the dam, the northeast part of the Taum Sauk Creek arm, and areas identified as sedimentation basins (MACTEC Engineering and Consulting, Inc., oral commun., 2008) on the north side of the Taum Sauk Creek arm of the reservoir. Areas that show the 2008 surface higher than the 2005 surface are areas identified as haul roads (MACTEC Engineering and Consulting, Inc., oral commun., 2008) in the Taum Sauk Creek arm and East Fork Black River arm, the upper end of the Taum Sauk Creek arm, and the reach downstream from the sedimentation dam. Some larger elevation differences near the reservoir shore and at the upper end of some coves are the result of no coincident survey data in these areas for the 2008 and 2005 surveys. Because the water-surface elevation for the 2005 survey was lower and debris made some areas inaccessible, survey data in 2005 could not be collected in areas such as the Walker Branch cove, the upper end of the Taum Sauk Creek arm, upstream from the sedimentation dam, and between elevations 747.3 and 750 ft (figs. 2 and 4), and data interpolation was used to extend the bathymetric surface in these areas. As a result, elevation differences in these areas are less accurate than where the 2008 and 2005 survey data are coincident.

References Cited

Rydlund, P.H., Jr., 2006, Peak discharge, flood profile, flood inundation, and debris movement accompanying the failure of the upper reservoir at the Taum Sauk pump storage facility near Lesterville, Missouri: U.S. Geological Survey Scientific Investigations Report 2006–5284, 45 p.

Trimble Navigation Limited, 1999, AgGPS 124/132 operation manual, revision B: Trimble Precision Agricultural Systems, 218 p.

U.S. Army Corps of Engineers, 2002, Engineering and design-hydrographic surveying manual No. 1110–2–1003: Washington, D.C., 510 p.

Wilson, G.L., and Richards, J.M., 2006, Procedural documentation and accuracy assessment of bathymetric maps and area/capacity tables for small reservoirs: U.S. Geological Survey Scientific Investigations Report 2006–5208, 24 p.

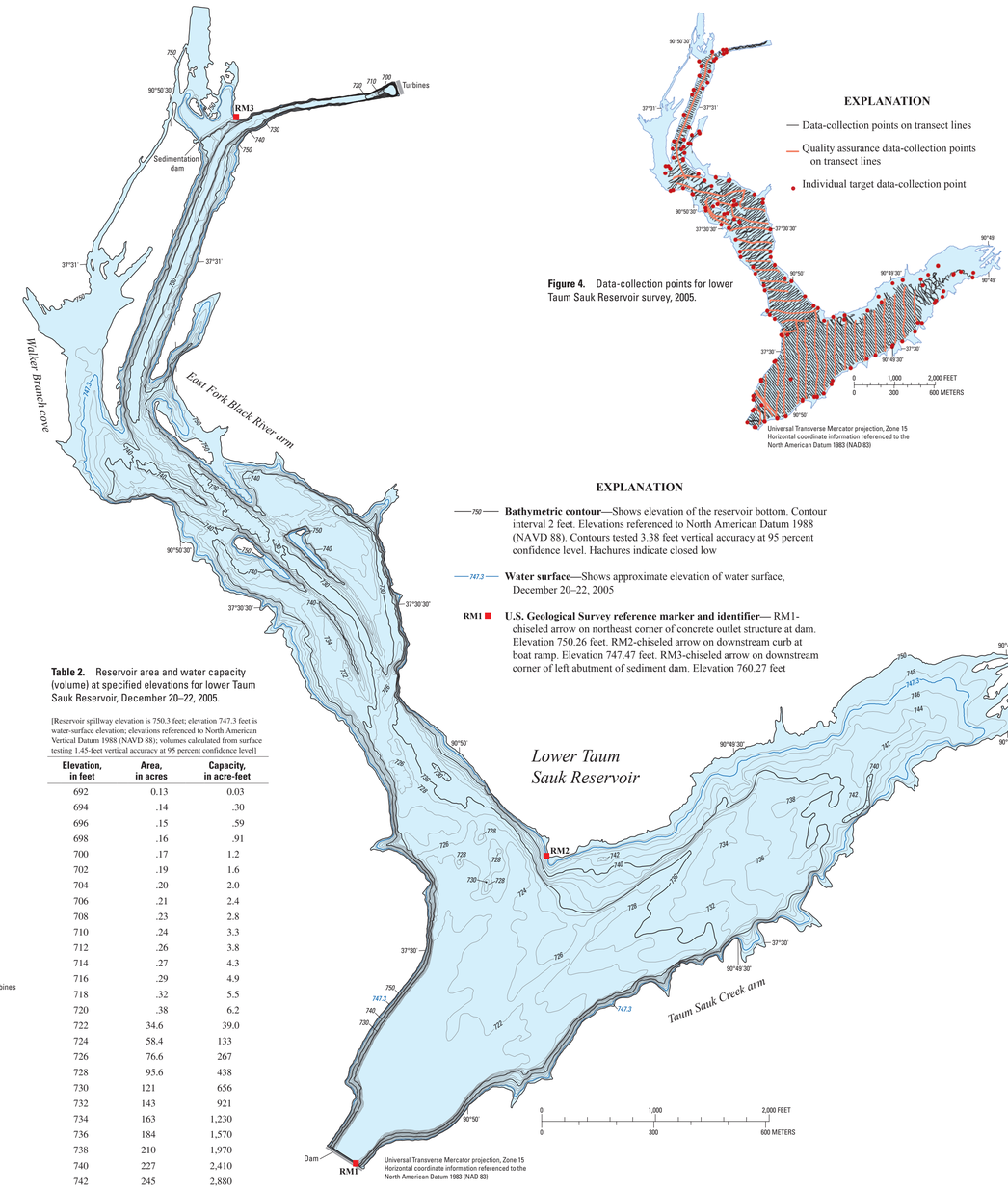
EXPLANATION

— Data-collection points on transect lines

— Quality assurance data-collection points on transect lines

• Individual target data-collection point

Figure 2. Data-collection points for lower Taum Sauk Reservoir survey, 2008.



EXPLANATION

—750— **Bathymetric contour**—Shows elevation of the reservoir bottom. Contour interval 2 feet. Elevations referenced to North American Datum 1988 (NAVD 88). Contours tested 3.38 feet vertical accuracy at 95 percent confidence level. Hachures indicate closed low

—747.3— **Water surface**—Shows approximate elevation of water surface, December 20–22, 2005

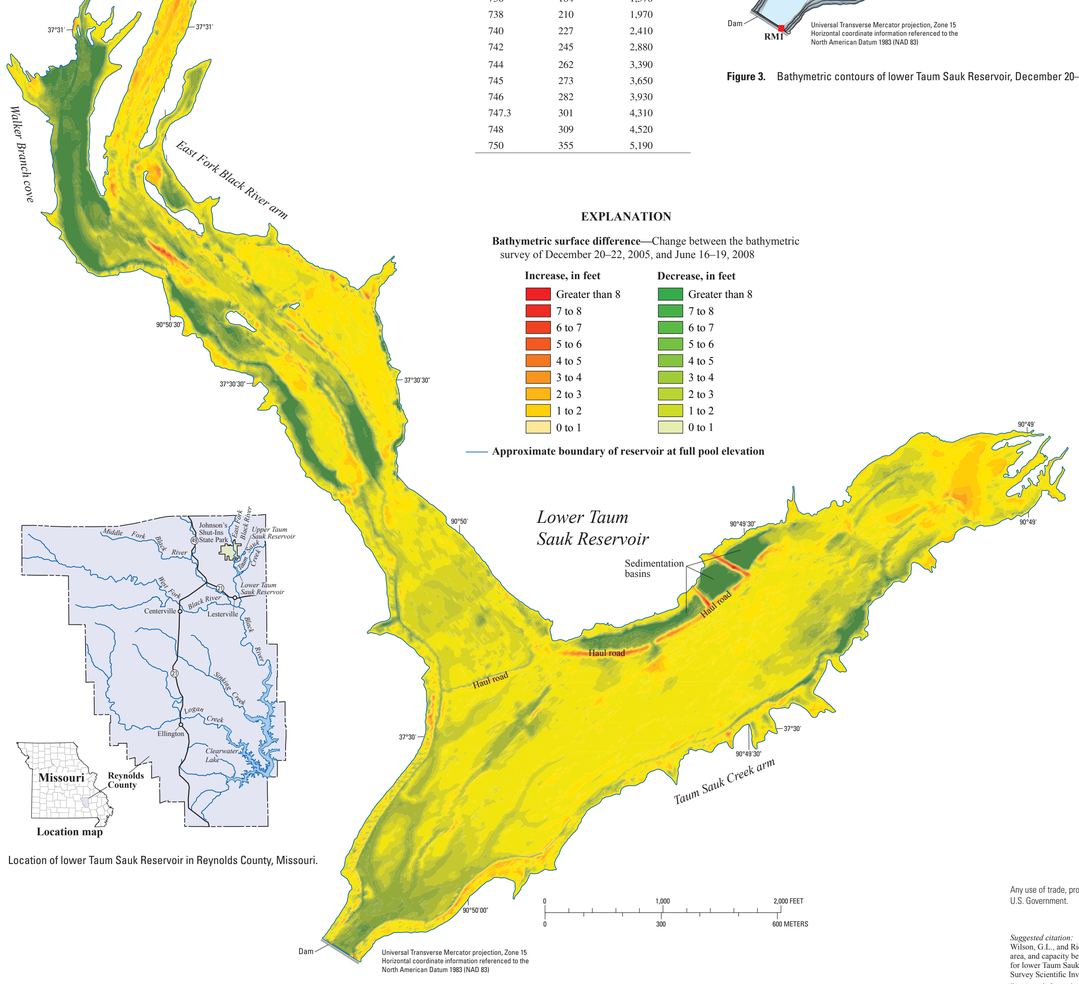
RM1 **U.S. Geological Survey reference marker and identifier**— RM1-chiseled arrow on northeast corner of concrete outlet structure at dam. Elevation 750.26 feet. RM2-chiseled arrow on downstream curb at boat ramp. Elevation 747.47 feet. RM3-chiseled arrow on downstream corner of left abutment of sediment dam. Elevation 760.27 feet

Figure 3. Bathymetric contours of lower Taum Sauk Reservoir, December 20–22, 2005 (modified from Rydlund, 2006).

Table 2. Reservoir area and water capacity (volume) at specified elevations for lower Taum Sauk Reservoir, December 20–22, 2005.

[Reservoir spillway elevation is 750.3 feet; elevation 747.3 feet is water-surface elevation; elevations referenced to North American Vertical Datum 1988 (NAVD 88); volumes calculated from surface testing 1.45-feet vertical accuracy at 95 percent confidence level]

Elevation, in feet	Area, in acres	Capacity, in acre-feet
692	0.13	0.03
694	.14	.30
696	.15	.59
698	.16	.91
700	.17	1.2
702	.19	1.6
704	.20	2.0
706	.21	2.4
708	.23	2.8
710	.24	3.3
712	.26	3.8
714	.27	4.3
716	.29	4.9
718	.32	5.5
720	.38	6.2
722	34.6	39.0
724	58.4	133
726	76.6	267
728	95.6	438
730	121	656
732	143	921
734	163	1,230
736	184	1,570
738	210	1,970
740	227	2,410
742	245	2,880
744	262	3,390
745	273	3,650
746	282	3,930
747.3	301	4,310
748	309	4,520
750	355	5,190



EXPLANATION

Bathymetric surface difference—Change between the bathymetric survey of December 20–22, 2005, and June 16–19, 2008

Increase, in feet	Decrease, in feet
Greater than 8	Greater than 8
7 to 8	7 to 8
6 to 7	6 to 7
5 to 6	5 to 6
4 to 5	4 to 5
3 to 4	3 to 4
2 to 3	2 to 3
1 to 2	1 to 2
0 to 1	0 to 1

Approximate boundary of reservoir at full pool elevation

Location of lower Taum Sauk Reservoir in Reynolds County, Missouri.

Figure 5. Change in the June 16–19, 2008, bathymetric surface from the December 20–22, 2005, bathymetric surface for lower Taum Sauk Reservoir.

Table 3. Differences in reservoir area and capacity (volume) at specified elevations between 2005 and 2008 bathymetric surfaces.

[Reservoir spillway elevation 750.3 feet; elevation 747.3 feet is water-surface elevation during 2005 survey; elevations referenced to North AmericanVertical Datum 1988 (NAVD 88)]

Elevation, in feet	Area, in acres	Capacity, in acre-feet
692	-0.13	-0.03
694	-.14	-.30
696	-.13	-.57
698	-.10	-.81
700	-.07	-1.04
702	-.06	-1.12
704	-.03	-1.22
706	0	-1.24
708	.02	-1.18
710	.06	-1.14
712	.08	-1.00
714	.68	-.49
716	4.15	3.02
718	14.5	21.3
720	28.3	63.3
722	13.1	105
724	9.9	128
726	11.6	150
728	14.9	177
730	12	203
732	9	219
734	11	240
736	27	280
738	28	330
740	31	390
742	29	450
744	30	510
745	28	540
746	27	570
747.3	21	600
748	21	610
750	3	620

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2008