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Bathymetric Surveys of the Neosho River, Spring River, and Elk River, Northeastern Oklahoma and Southwestern Missouri, 2016–17

Scientific Investigations Report 2017–5101
Version 1.1, October 2017

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photographs by Shelby L. Hunter, U.S. Geological Survey, October 5, 2016
Background, Neosho River (left) and Spring River (right) at Twin Bridges State Park, Oklahoma.
Inset, Spring River (left foreground) converges with the Neosho River (right foreground and background) downstream from Twin Bridges State Park, Oklahoma.

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

ADCP	acoustic Doppler current profiler
DEM	digital elevation model
DGPS	differentially corrected Global Positioning System
FERC	Federal Energy Regulatory Commission
GIS	geographic information system
GNSS	global navigation satellite system
GPS	Global Positioning System
GRDA	Grand River Dam Authority
OPUS	National Geodetic Survey Online Positioning User Service
RMSE	root-mean-square error
RTK	real-time kinematic
SBES	single-beam echo sounder

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Abstract

In February 2017, the Grand River Dam Authority filed to relicense the Pensacola Hydroelectric Project with the Federal Energy Regulatory Commission. The predominant feature of the Pensacola Hydroelectric Project is Pensacola Dam, which impounds Grand Lake O' the Cherokees (locally called Grand Lake) in northeastern Oklahoma. Identification of information gaps and assessment of project effects on stakeholders are central aspects of the Federal Energy Regulatory Commission relicensing process. Some upstream stakeholders have expressed concerns about the dynamics of sedimentation and flood flows in the transition zone between major rivers and Grand Lake O' the Cherokees. To relicense the Pensacola Hydroelectric Project with the Federal Energy Regulatory Commission, the hydraulic models for these rivers require high-resolution bathymetric data along the river channels. In support of the Federal Energy Regulatory Commission relicensing process, the U.S. Geological Survey, in cooperation with the Grand River Dam Authority, performed bathymetric surveys of (1) the Neosho River from the Oklahoma border to the U.S. Highway 60 bridge at Twin Bridges State Park, (2) the Spring River from the Oklahoma border to the U.S. Highway 60 bridge at Twin Bridges State Park, and (3) the Elk River from Noel, Missouri, to the Oklahoma State Highway 10 bridge near Grove, Oklahoma. The Neosho River and Spring River bathymetric surveys were performed from October 26 to December 14, 2016; the Elk River bathymetric survey was performed from February 27 to March 21, 2017. Only areas inundated during those periods were surveyed.

The bathymetric surveys covered a total distance of about 76 river miles and a total area of about 5 square miles. Greater than 1.4 million bathymetric-survey data points were used in the computation and interpolation of bathymetric-survey digital elevation models and derived contours at 1-foot (ft) intervals. The minimum bathymetric-survey elevation of the Neosho River was 709.18 ft above North American Vertical Datum of 1988, which corresponds to a maximum depth of 34.22 ft. The minimum bathymetric-survey elevation of the Spring River was 714.18 ft above North American Vertical Datum of 1988, which corresponds to a maximum depth of 29.22 ft. The minimum bathymetric-survey elevation of the Elk River was 715.62 ft above North American Vertical Datum of 1988, which corresponds to a maximum depth of 27.78 ft.

Introduction

In February 2017, the Grand River Dam Authority (GRDA) filed to relicense the Pensacola Hydroelectric Project with the Federal Energy Regulatory Commission (FERC). The predominant feature of the Pensacola Hydroelectric Project (FERC license number 1494) is Pensacola Dam, which impounds Grand Lake O' the Cherokees (locally called Grand Lake) in northeastern Oklahoma (fig. 1*A*,*B*). Identification of information gaps and assessment of project effects on stakeholders are central aspects of the FERC relicensing process (Federal Energy Regulatory Commission, 2012). Some of the upstream stakeholders have expressed concerns about the dynamics of sedimentation and flood flows in the transition zone between major rivers and Grand Lake O' the Cherokees. The Neosho River, Spring River, and Elk River are the largest tributaries to the lake (fig. 1*A*,*B*), and the Neosho River in the vicinity of Miami, Okla., in particular, has been the focus of numerous hydraulic modeling studies (Grand River Dam Authority, 2017). Updates to hydraulic models for these rivers require high-resolution topographic and bathymetric data along the river channels and adjacent flood plains. A high-resolution lidar topographic survey of the river flood plains (U.S. Geological Survey, 2016a) was completed in 2009, but that survey included no bathymetric data for lakes and streams because traditional lidar methods do not penetrate water. Complementary bathymetric surveys were needed to fill a major data gap and produce more accurate and defensible hydraulic models of river and lake interactions in the transition zone. In support of the FERC relicensing process, the U.S. Geological Survey, in cooperation with the GRDA, performed bathymetric surveys of the Neosho River, Spring River, and Elk River in 2016–17 and released the bathymetric-survey data in 2017 (Smith and others, 2017). The bathymetric-survey data may later serve as a baseline to which temporal changes in channel capacity can be compared.

Purpose and Scope

This report describes the methods and results of bathymetric surveys of (1) the Neosho River from the Oklahoma border to the U.S. Highway 60 bridge at Twin Bridges State Park, (2) the Spring River from the Oklahoma border to the U.S. Highway 60 bridge at Twin Bridges State Park, and (3) the Elk River from Noel, Mo., to the Oklahoma State Highway 10 bridge near Grove, Okla. (fig. 1*A*,*B*). The Neosho River and Spring River bathymetric surveys were performed from October 26 to December 14, 2016; the Elk River bathymetric survey was performed from February 27 to March 21, 2017. Only areas inundated during those periods were surveyed.

Description of the Study Area

The Neosho River drains 6,136 square miles (mi^2) of land area, and the Spring River drains 2,590 mi^2 of land area upstream from the U.S. Highway 60 bridges at Twin Bridges State Park (U.S. Geological Survey, 2016b). The Spring River joins the Neosho River about 0.3 mile downstream from the U.S Highway 60 bridge at Twin Bridges State Park (appendix 1–1). The Elk River drains 1,025 mi^2 of land area upstream from the Oklahoma State Highway 10 bridge near Grove, Okla. (fig. 1*B*). The Neosho River, Spring River, and Elk River study areas each included a streamgage that has recorded streamflow from 1939 to present (2017). Streamflow at the Neosho River streamgage near Commerce (07185000, fig. 1*A*) averaged 3,802 cubic feet per second (ft^3/s) and peaked at 267,000 ft^3/s during the period of record (table 1). Streamflow at the Spring River streamgage near Quapaw (07188000, fig. 1*A*) averaged 2,231 ft^3/s and peaked at 230,000 ft^3/s during the period of record (table 1). Streamflow at the Elk River streamgage near Tiff City, Mo. (07189000, fig. 1*B*), averaged 824 ft^3/s and peaked at 137,000 ft^3/s during the period of record (table 1).

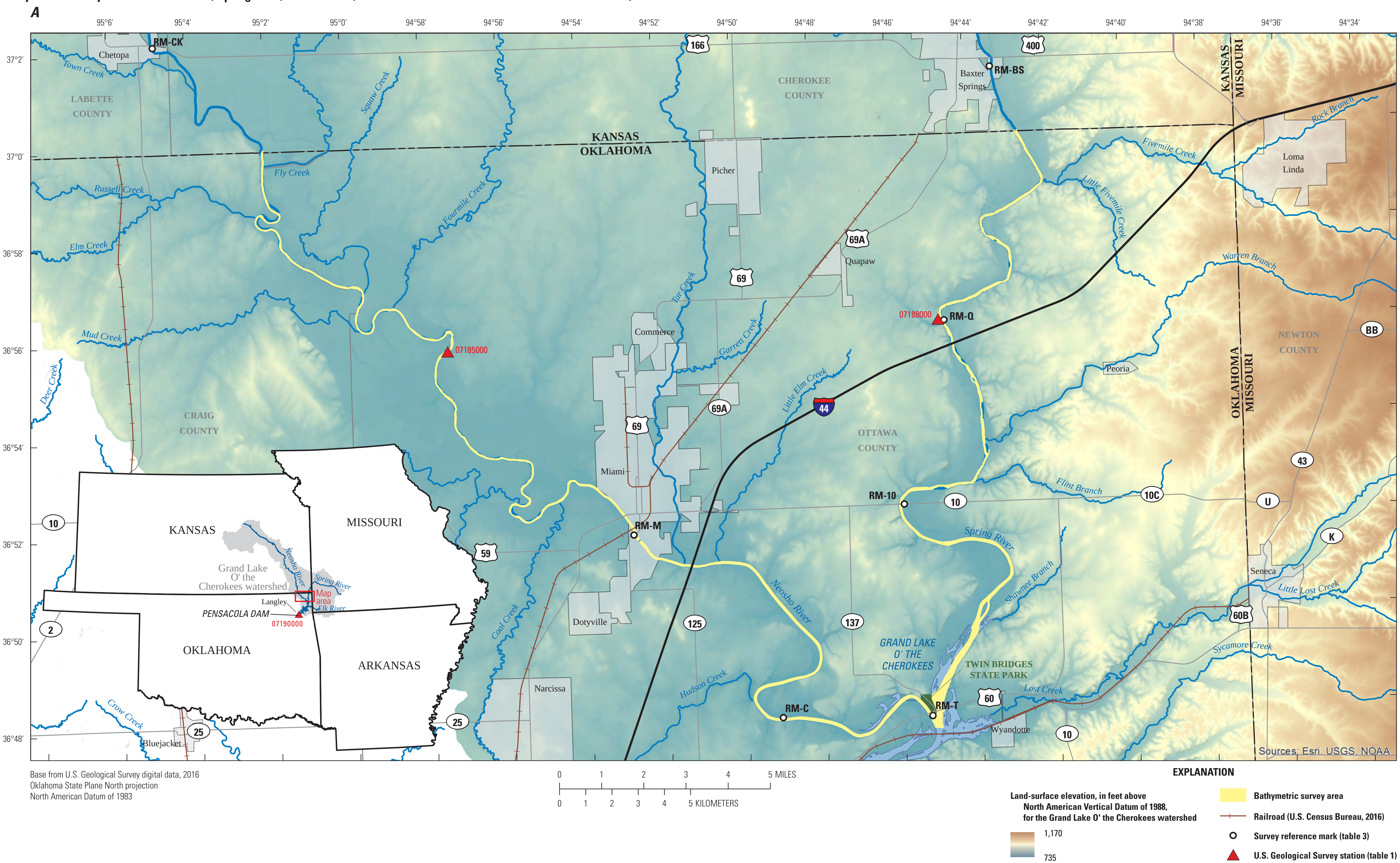

Figure 1. Map showing bathymetric-survey areas for *A*, the Neosho River and Spring River, and *B*, the Elk River, northeastern Oklahoma and southwestern Missouri, 2016–17.

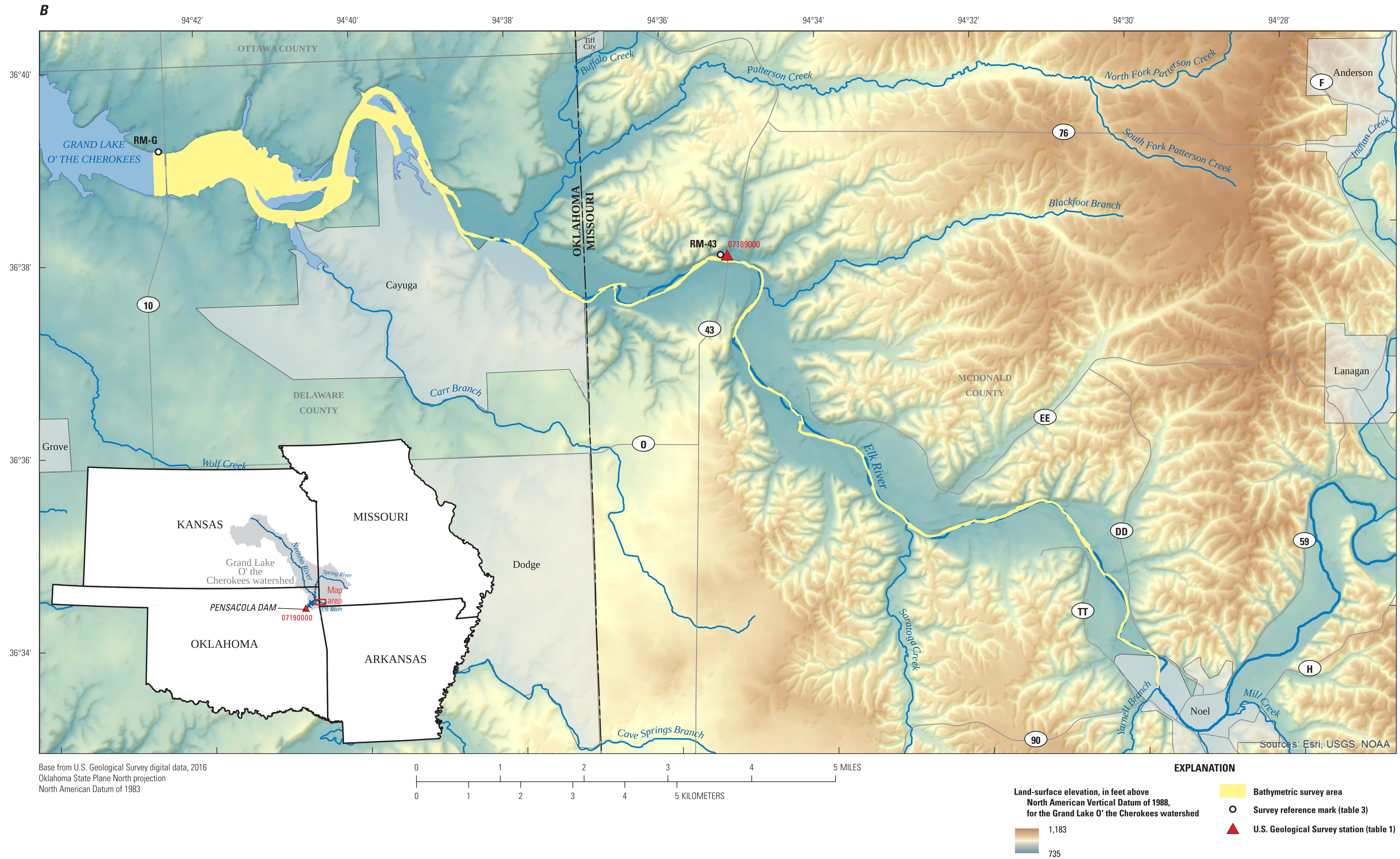

Figure 1. Map showing bathymetric-survey areas for *A*, the Neosho River and Spring River, and *B*, the Elk River, northeastern Oklahoma and southwestern Missouri, 2016–17.—Continued

Table 1. Selected data-collection stations in and near bathymetric-survey areas for the Neosho River, Spring River, and Elk River, northeastern Oklahoma and southwestern Missouri, 2016–17.

[Data from U.S. Geological Survey, 2017; NAVD 88, North American Vertical Datum of 1988; MM/DD/YYYY, month/day/year; ft³/s, cubic foot per second; mi², square mile; --, not applicable]

Station number (fig. 1)	Station name	Station type	Latitude (decimal degrees)	Longitude (decimal degrees)	County	Period of record (MM/DD/YYYY) Begin	End	Mean daily streamflow for the period of record (ft^3/s)	Peak streamflow for the period of record through September 2016 (ft^3/s)	Station drainage area (mi^2)	National Water Information System web address
07185000	Neosho River near Commerce, Okla.	streamgage	36.9287	-94.9575	Ottawa	10/1/1939	present (2017)	3,802	267,000	5,926	https://nwis.waterdata.usgs.gov/ok/nwis/inventory/?site_no=07185000
07188000	Spring River near Quapaw, Okla.	streamgage	36.9345	-94.7472	Ottawa	7/13/1939	present (2017)	2,231	230,000	2,516	https://nwis.waterdata.usgs.gov/ok/nwis/inventory/?site_no=07188000
07189000	Elk River near Tiff City, Mo.	streamgage	36.6315	-94.5869	McDonald	10/1/1939	present (2017)	824	137,000	851	https://nwis.waterdata.usgs.gov/ok/nwis/inventory/?site_no=07189000
07190000	Grand Lake O' the Cherokees at Langley, Okla.	lake stage gage	36.4687	-95.0414	Mayes	3/21/1940	present (2017)	--	--	10,345	https://nwis.waterdata.usgs.gov/ok/nwis/inventory/?site_no=07190000

Bathymetric-Survey Methods

This section describes bathymetric-survey methods used on the Neosho River, Spring River, and Elk River. Data collection, data processing, and quality assurance are described.

Data Collection

Raw bathymetric-survey data (water-depth and position measurements) were collected using methods of Wilson and Richards (2006) and Mueller and others (2013). Two types of equipment were used to collect water-depth measurements. A Hydrographic Systems Echotrac CV100 single-beam echo sounder (SBES) with a dual frequency 200-kilohertz transducer (Odom Hydrographic Systems, Inc., 2008) was used in areas where the flat-bottom boat carrying the SBES was able to operate. These data were organized using the commercial hydrographic software HYPACK (HYPACK, Inc., 2016). The blanking depth, or minimum measurement depth, for the SBES was about 1.1 foot (ft) (table 2). Two Teledyne RD Instruments RiverRay acoustic Doppler current profilers (ADCP; Teledyne RD Instruments, 2016) were towed by kayak in shallow areas that were inaccessible by flat-bottom boat. These data were collected using the hydrographic software WinRiver II (Teledyne RD Instruments, 2016). The blanking depth for the ADCPs was about 0.6 ft (table 2). During the bathymetric survey, position was measured by a differentially corrected Global Positioning System (DGPS) mounted directly above the SBES or ADCP. The stated positional accuracy of the DGPS data at a 95-percent confidence level was 1.97 ft (Hemisphere GNNS, Inc., 2013). The hydrographic software used the time provided by the DGPS to synchronize data from the echo sounder or ADCP and eliminate system latency.

The bathymetric-survey data that were recorded with the SBES were collected along primary transects aligned perpendicular to the riverbanks and separated by about 100 ft. The SBES primary-transect interval decreased to about 25 ft on the upstream side of road and railroad crossings (bridges) and one low-water dam to obtain higher-resolution bathymetric-survey data for these areas of possible localized sediment deposition. The SBES control transects were aligned parallel to the riverbanks so they would cross the primary transects. Other bathymetric-survey data were collected with two ADCPs simultaneously; one was arbitrarily designated the primary transect, and the other was designated the control transect. The ADCPs were towed by kayaks in a sinusoidal pattern, working diagonally bank to bank about every 100 ft. The ADCP primary-transect interval decreased to about 25 ft on the upstream side of road and railroad crossings (bridges).

About 650 water-surface elevations were measured (approximately every 500 ft) along streambanks using a real-time kinematic (RTK) GPS Rover. The RTK GPS Rover averaged elevation points for 3 minutes at a 1-second interval (Rydlund and Densmore, 2012) and received corrections through a virtual real-time station (VRS) network (Missouri Department of Transportation, 2017). Water-surface elevations were measured at shorter intervals in river reaches with rapid elevation drops (riffles). Water-surface elevations of 743.4 ft above North American Vertical Datum of 1988 (NAVD 88) (742.0 ft above Pensacola datum, the normal pool elevation) were the same elevation as Grand Lake O' the Cherokees at the time of survey; however, measured water-surface elevations varied by several tenths of a foot greater or less than 743.4 ft above NAVD 88 because of local pooling from bridges or debris, wind effects, and small GPS survey error. Grand Lake O' the Cherokees remained near a normal pool elevation throughout the bathymetric surveys (U.S. Geological Survey, 2017), and the maximum daily change in lake stage during the data-collection period was about 0.3 ft measured at Grand Lake O' the Cherokees at Langley (07190000) (fig. 1*A*,*B*; table 2; U.S. Geological Survey, 2017).

Nine reference marks were used as elevation control points during the bathymetric surveys (table 3). Each reference mark elevation was established by using a 4-hour static global navigation satellite system (GNSS) occupation (Rydlund and Densmore, 2012), which was processed by using the National Geodetic Survey Online Positioning User Service (OPUS; National Geodetic Survey, 2016). The vertical uncertainty of each reference mark elevation was less than or equal to 0.112 ft as calculated by OPUS (table 3). Throughout the bathymetric surveys, 74 RTK GPS elevations were measured at reference marks. These marks were measured at the beginning and end of each day surveyed. The differences between those RTK GPS observations and the reference mark elevation ranged from -0.341 to 0.295 ft (table 3).

Data Processing

Bathymetric-survey and water-surface elevation data were compiled in a geographic information system (GIS) using Esri ArcGIS 10.3.1 software. The GIS processing methods of Wilson and Richards (2006) were modified to adapt those methods (intended for reservoirs) to rivers. A reservoir water-surface elevation is relatively constant, but a river water-surface elevation generally decreases in a downstream direction; bathymetric-survey depths were converted to elevations by subtracting the depths from the nearest water-surface elevation measurement. The water-surface elevations changed comparatively quickly across some riffle reaches. When the difference between consecutive water-surface elevation measurements was greater than about 0.5 ft, additional water-surface elevations were interpolated in the riffle reach. These interpolated water-surface elevations also were used to convert bathymetric-survey depths to elevations.

Preliminary bathymetric-survey areas were delineated from gaps (representing wide streams and lakes) in lidar-derived land-surface elevation data collected in 2009 (U.S. Geological Survey, 2016a). The preliminary bathymetric-survey areas were then modified in some areas to account for changes to streambanks that have occurred since 2009 (the date of the lidar survey). Generally, the bathymetric-survey areas were enlarged, most commonly on the outside of meander bends, to encompass all bathymetric-survey transects. Some parts of the bathymetric-survey areas contained no bathymetric-survey transects. The largest unsurveyed areas were marked as "Area not surveyed" in the appendixes. These unsurveyed areas either were too shallow to navigate or were occupied by debris or exposed sediment deposits.

A bathymetric-survey digital elevation model (DEM) (at 4-ft resolutions for the Neosho River and Spring River and at a 2-ft resolution for the Elk River) and contours at 1-ft intervals were derived in the GIS using the "Topo To Raster" (Esri, Inc., 2016a) and "Contour" (Esri, Inc., 2016b) tools, respectively. Data inputs to the "Topo to Raster" tool included (1) bathymetric-survey (SBES and ADCP) elevations, (2) GPS water-surface elevations, (3) selected Oklahoma Water Resources Board (2009, 2016) bathymetric-survey elevations in shallow areas (mostly downstream from the U.S. Highway 60 bridge), and (4) contours generated from lidar-derived land-surface elevation data (U.S. Geological Survey, 2016a) within 100 ft of the bathymetric-survey area. Additional control was needed in many areas where the preliminary "Topo To Raster" and "Contour" tool outputs were incorrectly interpolated. Guiding contours were manually digitized in those areas, and the tools were run again with the guiding contours as an additional input. In shallow areas not covered by bathymetric-survey data, the GIS tools were allowed to assume a steady gradient between the bathymetric-survey data and the nearest lidar-derived land-surface elevation data (outside the bathymetric-survey area). The bathymetric-survey DEM and contours in unsurveyed areas were mostly interpolated from the Oklahoma Water Resources Board (2009, 2016). A depth image at 10-ft resolution also was derived from the bathymetric-survey data using the "Topo To Raster" (Esri, Inc., 2016a) tool; this depth image was used for maps presented in appendixes 2–4 of this report to aid in visualization of the bathymetric surface. Bathymetric-survey data, interpolated bathymetric-survey DEMs, and interpolated contours were published in 2017 (Smith and others, 2017) using the Oklahoma State Plane North coordinate system.

Quality Assurance

Accuracy of the bathymetric surface and derived contours is a function of the survey data accuracy, survey data density (transect interval and data-collection frequency), and the processing steps that occur during creation of the bathymetric surface and contours (Wilson and Richards, 2006). Survey data accuracy is also dependent on factors such as vessel draft, platform stability, vessel velocity, and subsurface material density (Wilson and Richards, 2006). According to the manufacturer's specifications, the survey-grade echo sounder used in this study had a resolution of better than

Table 2. Summary statistics and quality-assurance statistics for bathymetric survey data for the Neosho River, Spring River, and Elk River, northeastern Oklahoma and southwestern Missouri, 2016–17.

[MM–DD–YYYY, month–day–year date format; NAVD 88, North American Vertical Datum of 1988; SBES, single-beam echo sounder; ADCP, acoustic Doppler current profiler; RMSE, root-mean-square error; --, not applicable]

Stream	Bathymetric-survey summary statistics													
	Data-collection period (MM–DD–YYYY)	Upstream boundary	Downstream boundary	Drainage area at downstream boundary (U.S. Geological Survey, 2016b) (square miles)	Survey area (square miles)	Data-collection method	Survey length (river miles) (A)		Number of data points	Elevation (feet above NAVD 88)		Depth (feet)		Average streambed gradient (feet per mile) [(B-C)/A]
										Maximum (B)	Minimum (C)	Minimum (approximate blanking depth)	Maximum	
Neosho River	10–26–2016 to 12–14–2016	Oklahoma border	U.S. Highway 60 bridge near Twin Bridges State Park, Okla.	6,136	1.58	SBES	34.16	17.38	344,833	742.65	709.18	1.10	34.22	1.93
						ADCP		16.78	126,199	759.03	734.94	0.68	10.36	1.44
Spring River	10–26–2016 to 12–14–2016	Oklahoma border	U.S. Highway 60 bridge near Twin Bridges State Park, Okla.	2,590	1.39	SBES	21.21	7.52	157,020	742.29	714.18	1.11	29.22	3.74
						ADCP		13.69	185,060	768.31	730.34	0.61	20.11	2.77
Elk River	02–27–2017 to 03–21–2017	Noel, Missouri	Oklahoma State Highway 10 bridge near Grove, Okla.	1,025	1.96	SBES	20.43	5.53	434,081	742.30	715.62	1.10	27.78	4.83
						ADCP		14.90	176,452	792.31	729.82	0.60	13.58	4.19
Total					4.93		75.80		1,423,645					

Stream	Bathymetric-survey summary statistics			Bathymetric-survey quality-assurance statistics										
	Data-collection period (MM–DD–YYYY)	Upstream boundary	Downstream boundary	Number of quality-assurance intersections	RMSE	Vertical accuracy (95 percent confidence level)	Minimum error (feet)	Maximum error (feet)	Percentage of quality-assurance data between:		Maximum daily change in stage, in feet, for the specified data-collection period (U.S. Geological Survey, 2017)			
									1.0 to -1.0 feet	0.5 to -0.5 feet	07190000 Grand Lake O' the Cherokees at Langley, Okla.	07185000 Neosho River near Commerce, Okla.	07188000 Spring River near Quapaw, Okla.	07189000 Elk River near Tiff City, Mo.
Neosho River	10–26–2016 to 12–14–2016	Oklahoma border	U.S. Highway 60 bridge near Twin Bridges State Park, Okla.	520	0.39	0.76	-3.2	1.6	97.3	92.1	0.24	0.43	--	--
				444	0.23	0.45	-0.9	1.5	99.8	92.3				
Spring River	10–26–2016 to 12–14–2016	Oklahoma border	U.S. Highway 60 bridge near Twin Bridges State Park, Okla.	206	0.44	0.85	-3.0	3.8	98.1	93.7	0.24	--	0.63	--
				616	0.19	0.38	-1.1	1.6	99.2	96.4				
Elk River	02–27–2017 to 03–21–2017	Noel, Missouri	Oklahoma State Highway 10 bridge near Grove, Okla.	292	0.30	0.58	-3.7	1.4	99.0	96.9	0.31	--	--	0.17
				623	0.13	0.26	-0.7	0.6	100.0	99.2				
Total				2,701										

0.1 ft for depths less than 600 ft and an accuracy of ±0.1 percent (Odom Hydrographic Systems, Inc., 2008). A hand-held sound velocimeter (Odom Hydrographic Systems, Inc., 2001) was used to measure the speed of sound through the water column, and bar checks were performed daily to calibrate the SBES (U.S. Army Corps of Engineers, 2013) to two known depths (from 3 ft to 27 ft) in the water column. These depths were chosen to span the expected range of most water-depth measurements. Vessel speeds were kept at less than 5 feet per second to ensure adequate point spacing (U.S. Army Corps of Engineers, 2013).

Quality-assurance statistics (table 2) were calculated from bathymetric-survey data within 1 ft of the intersections of primary and control transects; about 2,700 quality-assurance intersections were used. Measurement error ranged from -3.7 to 3.8 ft (table 2) and was calculated as the control transect elevation minus the primary transect elevation. The largest measurement errors (greater than 1.0 or less than -1.0 ft) were for data collected by SBES (fig. 2*A*). The root-mean-square error (RMSE) of the quality-assurance data was less than 0.5 ft for both data-collection methods on all rivers (table 2); the vertical accuracy (at the 95-percent confidence level; Wilson and Richards, 2006) for SBES quality-assurance data ranged from 0.85 to 0.58 ft, and the vertical accuracy for ADCP quality-assurance data ranged from 0.45 to 0.26 ft (table 2).

The water-surface elevations recorded at streamgages (table 2) were fairly stable during the survey periods. The maximum changes in river stage for any day of the survey period were 0.43, 0.63, and 0.17 ft, respectively, for the Neosho River near Commerce (07185000), the Spring River near Quapaw (07188000), and the Elk River near Tiff City (07189000) (table 2; U.S. Geological Survey, 2017). The maximum change in lake stage for any day of the survey period was 0.31 ft for Grand Lake O' the Cherokees at Langley (07190000) (table 2); however, for most days of the survey period, the maximum change in river or lake stage was less than 0.1 ft (U.S. Geological Survey, 2017).

Table 3. Reference mark locations and surveyed elevations, northeastern Oklahoma and southwestern Missouri, 2016–17.

[Latitude and longitude are referenced to North American Datum of 1983; elevations are referenced to North American Vertical Datum of 1988; GNSS, global navigation satellite systems; RTK GPS, real-time kinematic Global Positioning System; OPUS, National Geodetic Survey Online Positioning User Service; ±, plus or minus]

Reference mark name	Description	Reference mark datum established by using static GNSS techniques (Rydlund and Densmore, 2012)						RTK GPS elevation (feet)				Difference between reference mark elevation and RTK GPS elevation (feet)	
		Latitude (decimal degrees)	Longitude (decimal degrees)	x coordinate, in feet (Oklahoma State Plane North coordinate system)	y coordinate, in feet (Oklahoma State Plane North coordinate system)	Elevation (z coordinate) (feet)	OPUS vertical uncertainty (National Geodetic Survey, 2016)	Count	Minimum	Maximum	Average	Minimum	Maximum
RM-M	Concrete anchor bolt at boat ramp near low-water dam in Miami, Oklahoma	36.863683	-94.880224	2881060.27	693105.46	755.059	± 0.033	16	754.731	755.147	754.896	0.088	0.328
RM-T	Concrete anchor bolt at boat ramp near U.S. Highway 60 bridge in Twin Bridges State Park, Oklahoma	36.798319	-94.754926	2918492.54	670521.60	748.553	± 0.023	7	748.430	748.654	748.541	0.101	0.123
RM-C	Concrete anchor bolt at boat ramp near S 590 Road (Connors) bridge near Fairland, Oklahoma	36.799278	-94.818872	2899767.86	670251.11	752.316	± 0.105	13	751.999	752.611	752.376	0.295	0.317
RM-CK	Concrete anchor bolt at boat ramp in Chetopa, Kansas	37.035929	-95.080003	2820755.35	753976.19	787.480	± 0.013	2	787.360	787.445	787.402	0.036	0.120
RM-BS	Concrete anchor bolt at boat ramp in Baxter Springs, Kansas	37.020826	-94.721530	2925530.42	751819.46	790.732	± 0.049	3	790.491	790.598	790.555	0.134	0.241
RM-Q	Concrete anchor bolt at boat ramp near E 57 Road bridge near Quapaw, Oklahoma	36.934169	-94.744659	2919838.90	720057.25	773.373	± 0.059	5	773.171	773.491	773.289	0.118	0.202
RM-10	Concrete anchor bolt at left upstream sidewalk of Oklahoma State Highway 10 bridge near Miami, Oklahoma	36.871323	-94.764159	2914904.90	696997.05	796.060	± 0.026	5	795.943	795.975	795.960	0.085	0.117
RM-G	Concrete anchor bolt at boat ramp at Oklahoma State Highway 10 bridge near Grove, Oklahoma	36.652419	-94.707825	2934077.06	617897.06	754.295	± 0.069	17	753.954	754.226	754.073	0.069	0.341
RM-43	Concrete anchor bolt at boat ramp at Missouri State Highway 43 bridge near Tiff City, Missouri	36.631191	-94.587569	2969604.91	611391.17	769.485	± 0.112	6	769.411	769.552	769.484	0.067	0.074
Average:							± 0.054						

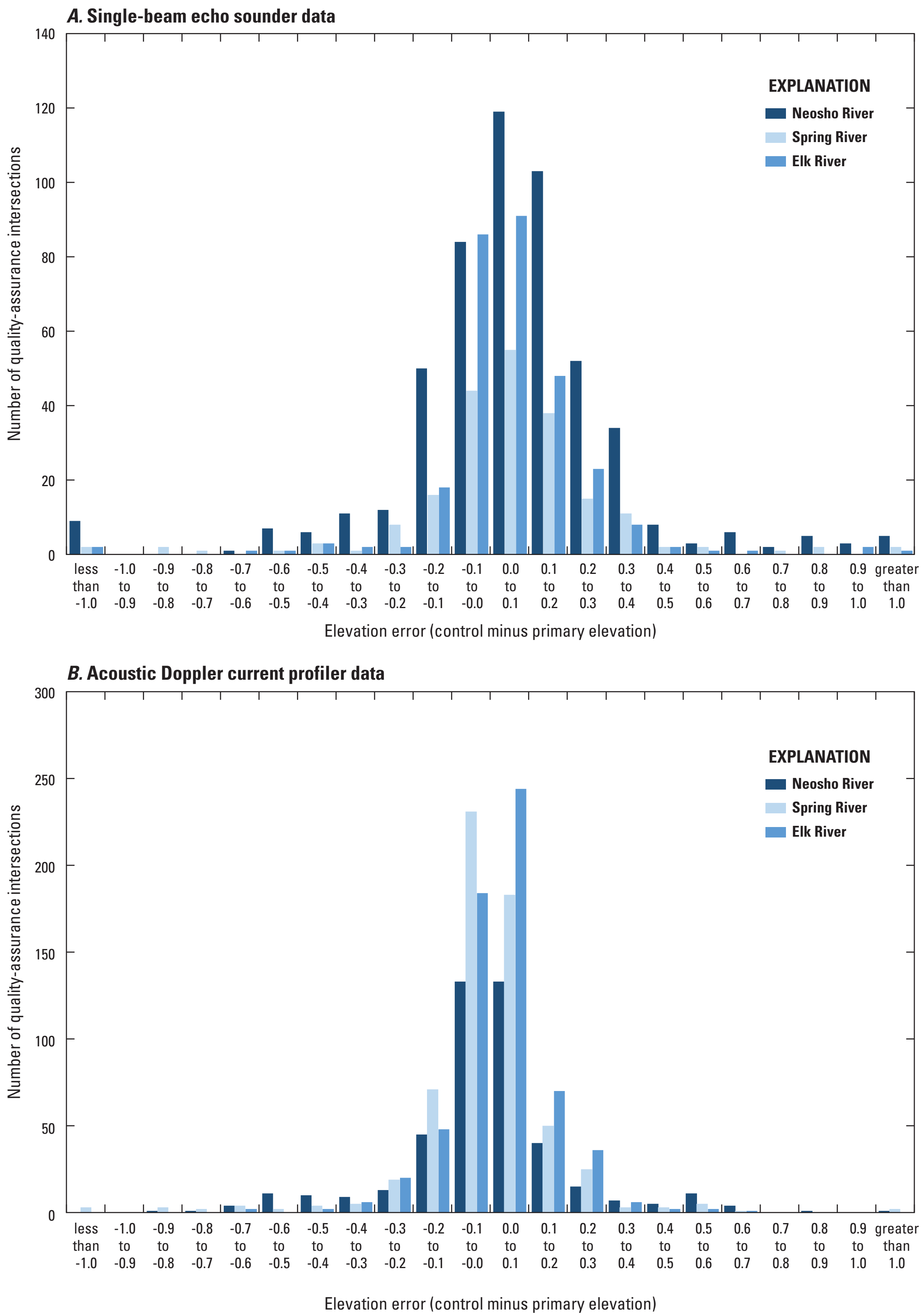

Figure 2. Histograms showing bathymetric survey elevation error for *A*, single-beam echo sounder data and *B*, acoustic Doppler current profiler data from the Neosho River, Spring River, and Elk River, northeastern Oklahoma and southwestern Missouri, 2016–17.

Bathymetric-Survey Results

Appendix 1 shows the extents of maps (presented in the other appendixes) showing the bathymetric survey results. The bathymetric surveys of the Neosho River (appendix 2), Spring River (appendix 3), and Elk River (appendix 4) covered a total distance of about 76 river miles and a total area of about 5 mi^2 (table 2). The RTK GPS water-surface elevations of about 743.4 ft above NAVD 88 extended through appendix map extent 2–10 for the Neosho River (appendix 1–1), through appendix map extent 3–6 for the Spring River (appendix 1–2), and through appendix map extent 4–4 for the Elk River (appendix 1–3). Greater than 1.4 million bathymetric-survey data points were used in the computation and interpolation of bathymetric-survey DEMs (at 4-ft resolutions for the Neosho River and Spring River and at a 2-ft resolution for the Elk River) and derived contours at 1-ft intervals (table 2). The minimum bathymetric-survey elevation of the Neosho River was 709.18 ft, which corresponds to a maximum water depth of 34.22 ft. The minimum bathymetric-survey elevation of the Spring River was 714.18 ft, which corresponds to a maximum water depth of 29.22 ft. The minimum bathymetric-survey elevation of the Elk River was 715.62 ft, which corresponds to a maximum water depth of 27.78 ft. Because of the spacing of the survey transects (100 ft), river-bottom features with a maximum dimension less than 100 ft generally could not be resolved by these bathymetric surveys.

An unusually deep pool (appendix 3–10) was found on the Spring River about halfway between the Oklahoma border and the E 57 county road bridge; the maximum depth of that pool was about 20 ft, or about 15 ft deeper than most pools in that reach. Large changes in bathymetric-survey depths (and elevations) occurred at the at U.S. Highway 60 bridges on the Neosho River and Spring River near Twin Bridges State Park (appendix 2–1); bathymetric-survey depths were shallower on the upstream side of these bridges as compared to the downstream side. Similar changes in bathymetric-survey depths were observed at the Oklahoma State Highway 10 bridge on the Elk River (appendix 4–1). These changes could indicate accumulation of sediment on the upstream sides of the bridges, erosion (scour) of sediment or bedrock on the downstream sides of the bridges, or both. If similar bathymetric surveys are performed in the future, the bathymetric-survey data presented in this report could be used as a baseline for estimating rates of sediment accumulation and erosion over time.

Summary

In February 2017, the Grand River Dam Authority filed to relicense the Pensacola Hydroelectric Project with the Federal Energy Regulatory Commission. The predominant feature of the Pensacola Hydroelectric Project is Pensacola Dam, which impounds Grand Lake O' the Cherokees (locally called Grand Lake) in northeastern Oklahoma. Identification of information gaps and assessment of project effects on stakeholders are central aspects of the Federal Energy Regulatory Commission relicensing process, and some upstream stakeholders have expressed concerns about the dynamics of sedimentation and flood flows in the transition zone between major rivers and Grand Lake O' the Cherokees. To relicense the Pensacola Hydroelectric Project with the Federal Energy Regulatory Commission, the hydraulic models for these rivers require high-resolution bathymetric data along the river channels. In support of the Federal Energy Regulatory Commission relicensing process, the U.S. Geological Survey, in cooperation with the Grand River Dam Authority, performed bathymetric surveys of (1) the Neosho River from the Oklahoma border to the U.S. Highway 60 bridge at Twin Bridges State Park, (2) the Spring River from the Oklahoma border to the U.S. Highway 60 bridge at Twin Bridges State Park, and (3) the Elk River from Noel, Missouri, to the Oklahoma State Highway 10 bridge near Grove, Oklahoma. The Neosho River and Spring River bathymetric surveys were performed from October 26 to December 14, 2016; the Elk River bathymetric survey was performed from February 27 to March 21, 2017. Only areas inundated during those periods were surveyed.

The bathymetric surveys covered a total distance of about 76 river miles and a total area of about 5 square miles. Greater than 1.4 million bathymetric-survey data points were used in the computation and interpolation of bathymetric-survey digital elevation models and derived contours at 1-foot (ft) intervals. The minimum bathymetric-survey elevation of the Neosho River was 709.18 ft, which corresponds to a maximum depth of 34.22 ft. The minimum bathymetric-survey elevation of the Spring River was 714.18 ft, which corresponds to a maximum depth of 29.22 ft. The minimum bathymetric-survey elevation of the Elk River was 715.62 ft, which corresponds to a maximum depth of 27.78 ft. An unusually deep pool was found on the Spring River about halfway between the Oklahoma border and the E 57 county road bridge; the maximum depth of that pool was about 20 ft, or about 15 ft deeper than most pools in that reach. Large changes in bathymetric-survey depths (and elevations) occurred at the U.S. Highway 60 bridges on the Neosho River and Spring River near Twin Bridges State Park; bathymetric-survey depths were shallower on the upstream side of these bridges as compared to the downstream side. Similar changes in bathymetric-survey depths were observed at the Oklahoma State Highway 10 bridge on the Elk River. These changes could indicate accumulation of sediment on the upstream sides of the bridges, erosion (scour) of sediment or bedrock on the downstream sides of the bridges, or both. If similar bathymetric surveys are performed in the future, the bathymetric-survey data presented in this report could be used as a baseline for estimating rates of sediment accumulation and erosion over time.

Acknowledgments

The authors thank U.S. Geological Survey colleagues for their generous contributions to this bathymetric survey. Kevin Smith, Stephen Bradford, Andrew Miller, Aaron Moyer, Justin White, Emily Moyer, and Adam Trevisan helped with data collection and surveying. The authors would also like to thank Billy Heard for travel and boat storage assistance.

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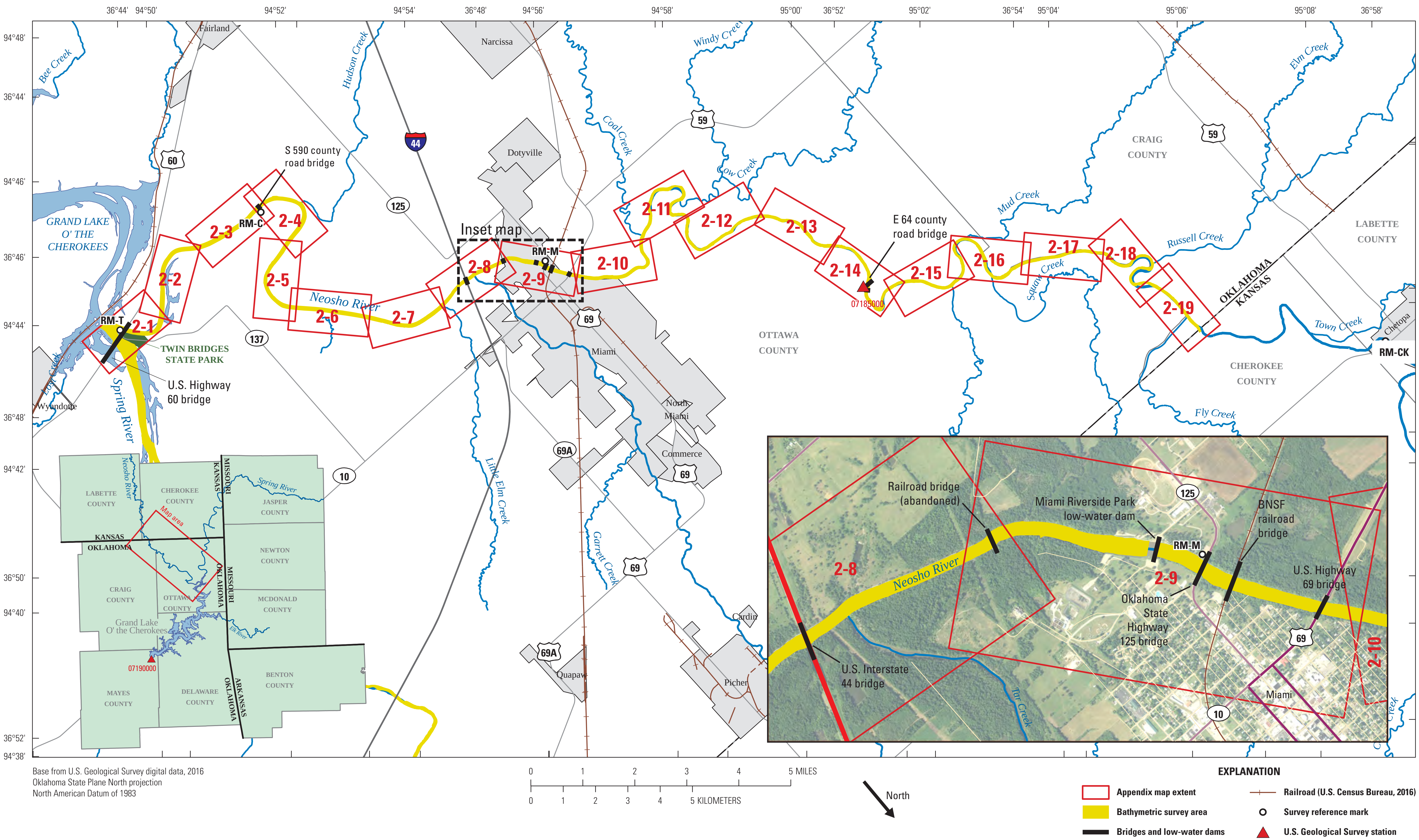
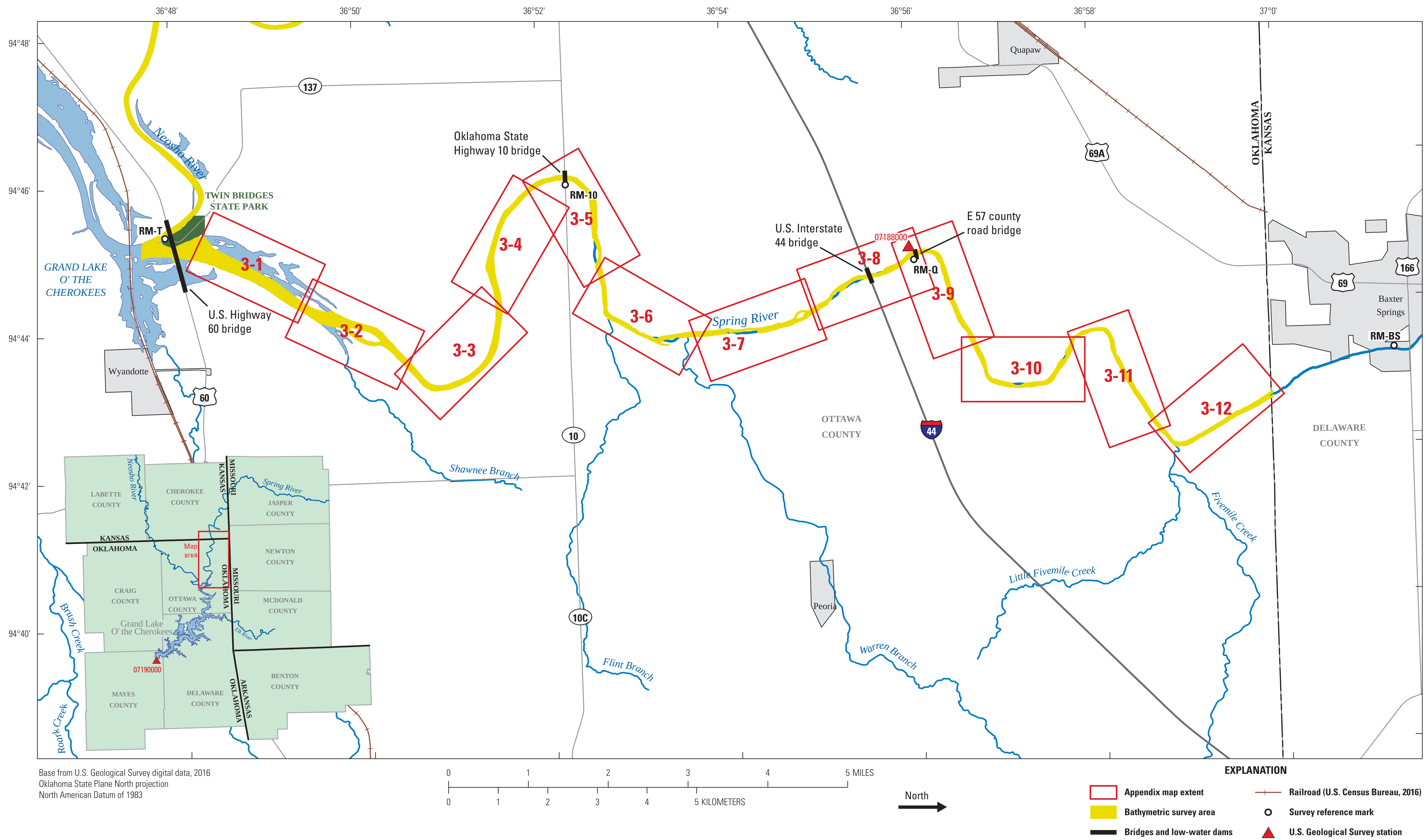
Appendix 1. Maps showing extents for maps in appendixes 2–4 that show bathymetric surveys of the Neosho River, Spring River, and Elk River, northeastern Oklahoma and southwestern Missouri, 2016–17.



Fairland
Narcissa
Bee Creek
Hudson Creek
Windy Creek
Elm Creek
Coal Creek
Cow Creek
Mud Creek
Russell Creek
Squaw Creek
Town Creek
Fly Creek
Little Elm Creek
Garrett Creek
Lost Creek
Spring River
Neosho River
GRAND LAKE O' THE CHEROKEES
TWIN BRIDGES STATE PARK
S 590 county road bridge
U.S. Highway 60 bridge
E 64 county road bridge
07185000
Inset map
Dotyville
Miami
North Miami
Commerce
Cardin
Quapaw
Picher
Wyandotte
Chetopa
CRAIG COUNTY
OTTAWA COUNTY
LABETTE COUNTY
CHEROKEE COUNTY
OKLAHOMA
KANSAS
RM-T
RM-C
RM-M
RM-CK
2-1
2-2
2-3
2-4
2-5
2-6
2-7
2-8
2-9
2-10
2-11
2-12
2-13
2-14
2-15
2-16
2-17
2-18
2-19
Railroad bridge (abandoned)
Miami Riverside Park low-water dam
BNSF railroad bridge
U.S. Highway 69 bridge
Oklahoma State Highway 125 bridge
U.S. Interstate 44 bridge
Tar Creek
LABETTE COUNTY
CHEROKEE COUNTY
JASPER COUNTY
NEWTON COUNTY
CRAIG COUNTY
OTTAWA COUNTY
MCDONALD COUNTY
MAYES COUNTY
DELAWARE COUNTY
BENTON COUNTY
Map area
Grand Lake O' the Cherokees
Elk River
07190000
KANSAS
OKLAHOMA
MISSOURI
ARKANSAS
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Datum of 1983
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS
North
EXPLANATION
Appendix map extent
Bathymetric survey area
Bridges and low-water dams
Railroad (U.S. Census Bureau, 2016)
Survey reference mark
U.S. Geological Survey station

Appendix 1–1.



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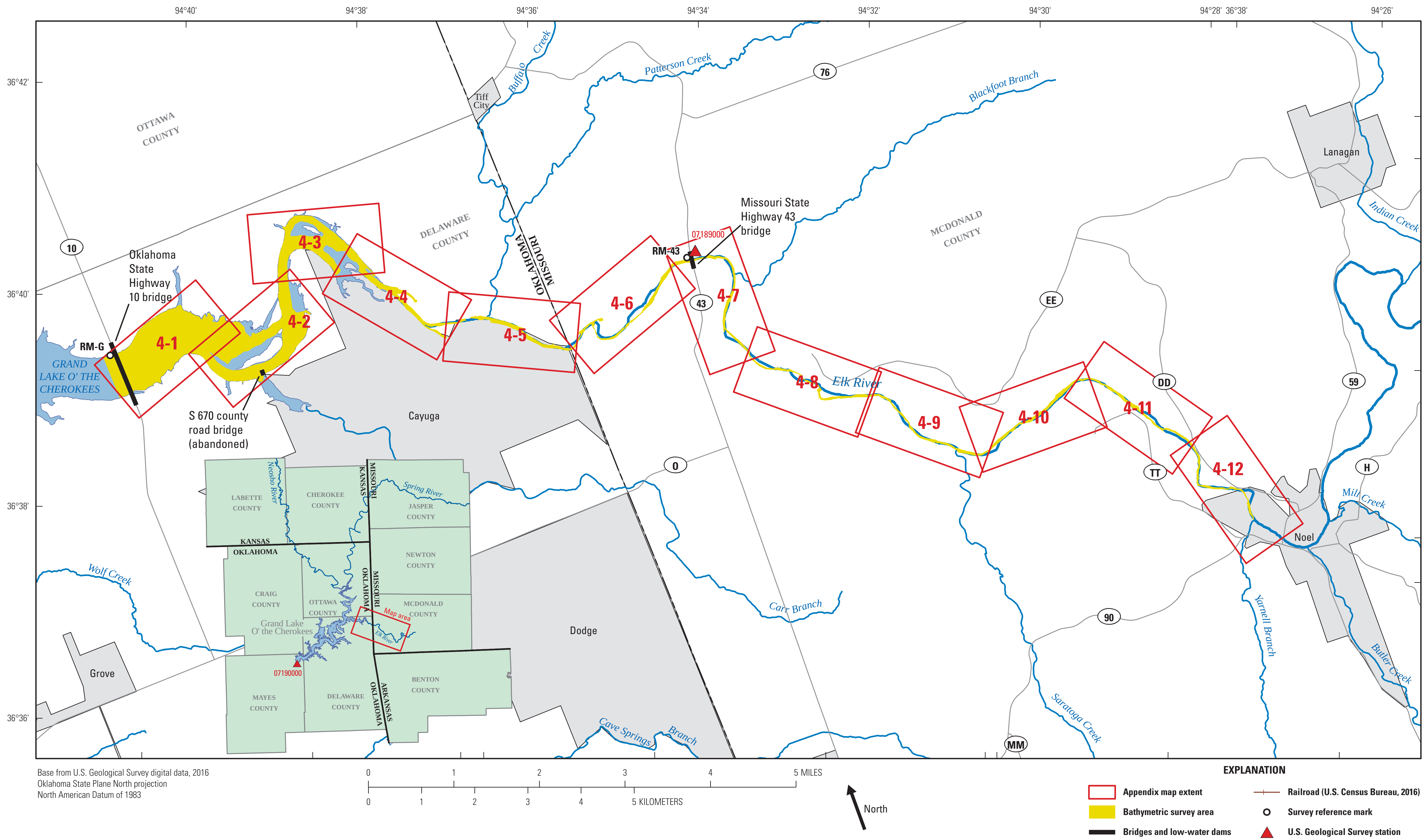
36°52'
36°54'
36°56'
36°58'
37°0'
94°48'
94°46'
94°44'
94°42'
94°40'
137
Neosho River
TWIN BRIDGES STATE PARK
RM-T
GRAND LAKE O' THE CHEROKEES
U.S. Highway 60 bridge
Wyandotte
60
Oklahoma State Highway 10 bridge
RM-10
3-1
3-2
3-3
3-4
3-5
3-6
3-7
3-8
3-9
3-10
3-11
3-12
Spring River
U.S. Interstate 44 bridge
07188000
E 57 county road bridge
RM-Q
Quapaw
69A
OKLAHOMA
KANSAS
166
69
Baxter Springs
RM-BS
OTTAWA COUNTY
DELAWARE COUNTY
44
10
10C
Shawnee Branch
Flint Branch
Peoria
Warren Branch
Little Fivemile Creek
Fivemile Creek
Brush Creek
Roark Creek
LABETTE COUNTY
CHEROKEE COUNTY
JASPER COUNTY
NEWTON COUNTY
MCDONALD COUNTY
CRAIG COUNTY
OTTAWA COUNTY
MAYES COUNTY
DELAWARE COUNTY
BENTON COUNTY
KANSAS
OKLAHOMA
MISSOURI
ARKANSAS
Map area
Grand Lake O' the Cherokees
07190000
Elk River
Spring River
Neosho River
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Datum of 1983
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS
North
EXPLANATION
Appendix map extent
Bathymetric survey area
Bridges and low-water dams
Railroad (U.S. Census Bureau, 2016)
Survey reference mark
U.S. Geological Survey station

Appendix 1–2.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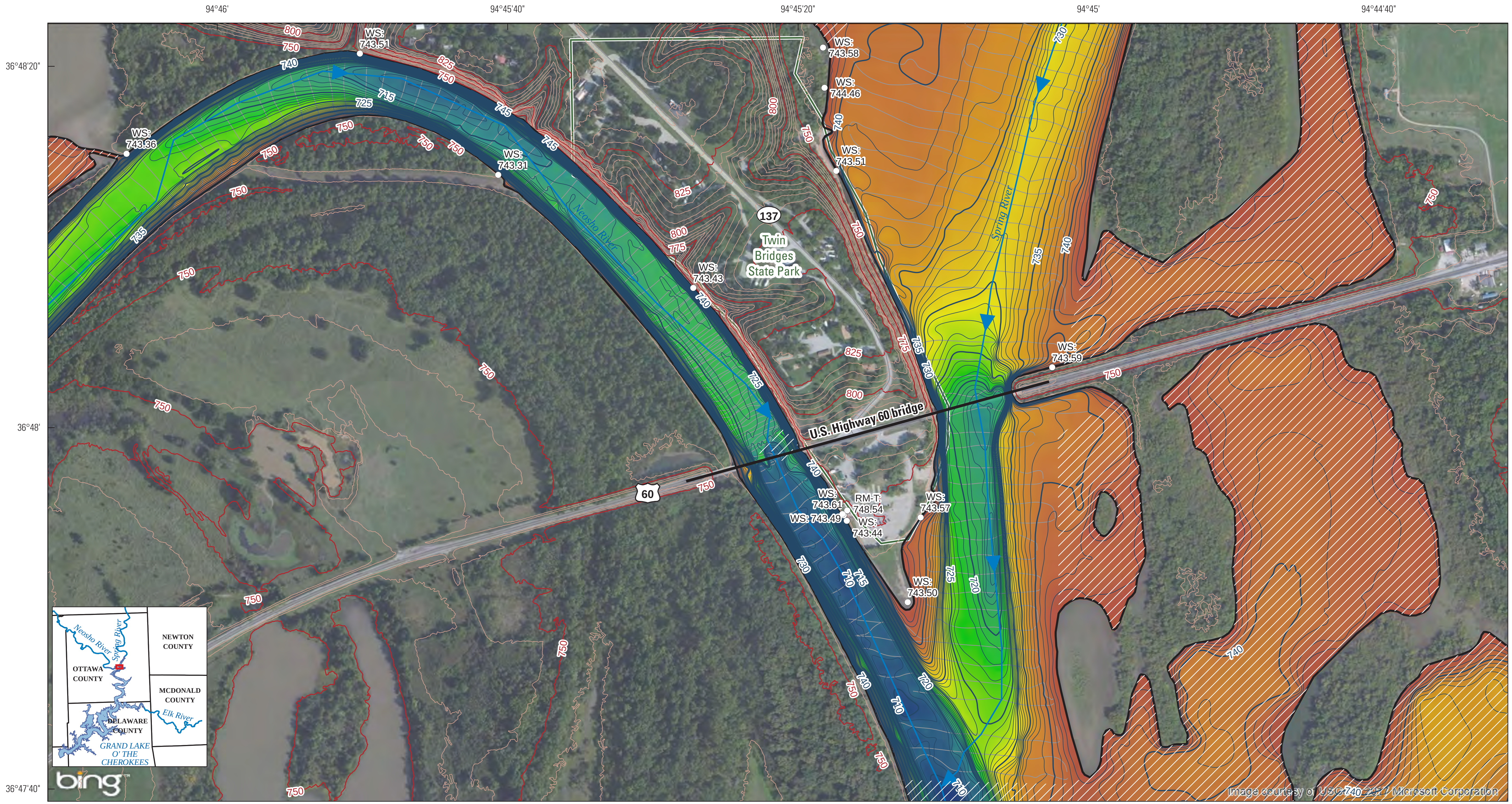
94°36'
94°34'
94°32'
94°30'
94°28'
36°38'
94°26'
36°42'
36°40'
36°38'
36°36'
OTTAWA COUNTY
DELAWARE COUNTY
MCDONALD COUNTY
OKLAHOMA
MISSOURI
Tiff City
Lanagan
Cayuga
Dodge
Grove
Noel
Oklahoma State Highway 10 bridge
Missouri State Highway 43 bridge
S 670 county road bridge (abandoned)
RM-G
RM-43
07189000
GRAND LAKE O' THE CHEROKEES
Elk River
Patterson Creek
Buffalo Creek
Blackfoot Branch
Indian Creek
Mill Creek
Butler Creek
Yarnell Branch
Saratoga Creek
Carr Branch
Cave Springs Branch
Wolf Creek
4-1
4-2
4-3
4-4
4-5
4-6
4-7
4-8
4-9
4-10
4-11
4-12
10
76
43
EE
DD
59
TT
H
O
90
MM
LABETTE COUNTY
CHEROKEE COUNTY
JASPER COUNTY
KANSAS
OKLAHOMA
MISSOURI
NEWTON COUNTY
CRAIG COUNTY
OTTAWA COUNTY
MCDONALD COUNTY
Grand Lake O' the Cherokees
Map area
Elk River
Neosho River
Spring River
07190000
MAYES COUNTY
DELAWARE COUNTY
BENTON COUNTY
ARKANSAS
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Datum of 1983
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS
North
EXPLANATION
Appendix map extent
Bathymetric survey area
Bridges and low-water dams
Railroad (U.S. Census Bureau, 2016)
Survey reference mark
U.S. Geological Survey station

Appendix 1–3.

Appendix 2. Maps showing bathymetric survey of the Neosho River, northeastern Oklahoma, 2016



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE

0 0.1 0.2 0.3 0.4 KILOMETER

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

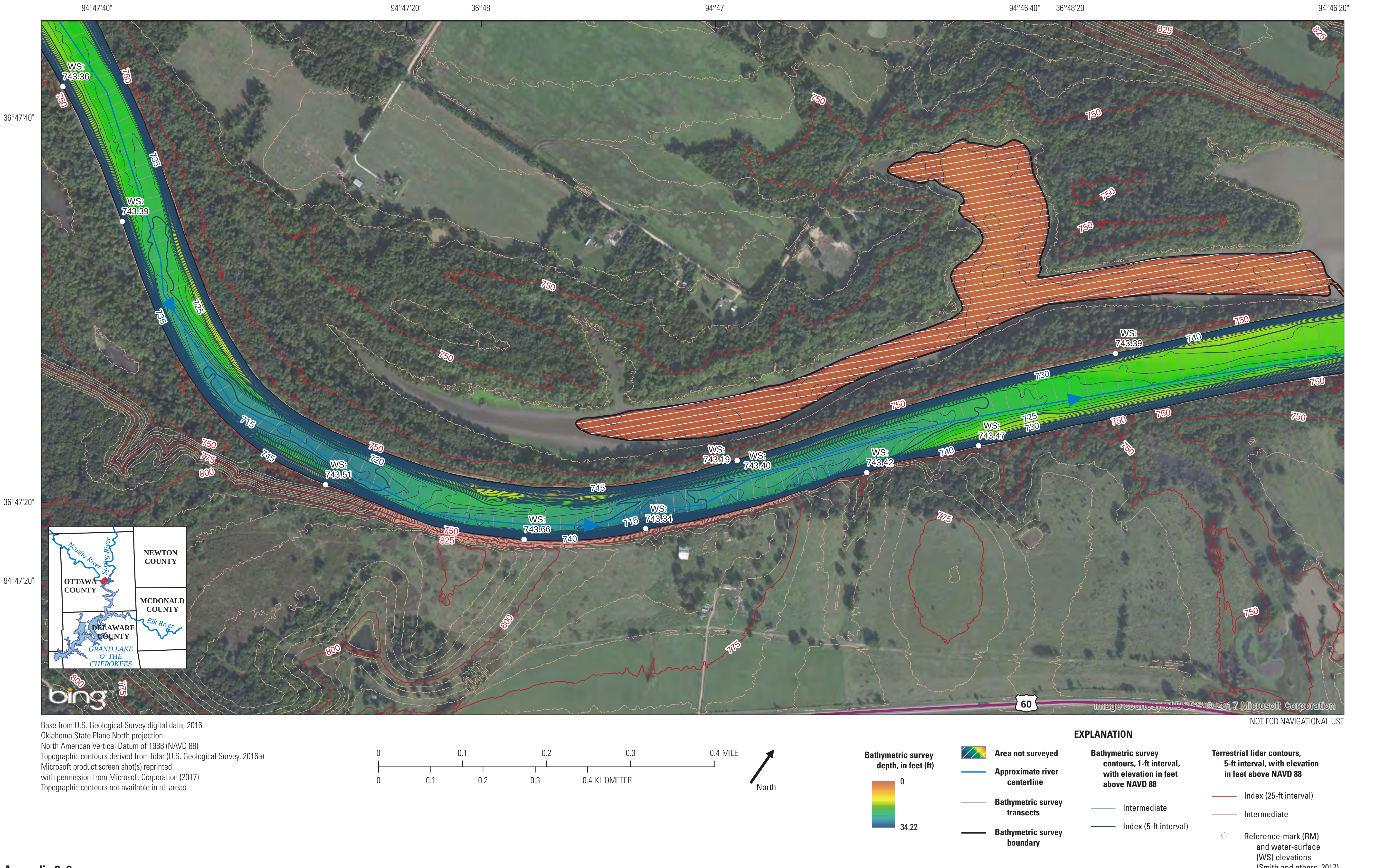
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
- Intermediate
- Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
- Index (25-ft interval)
- Intermediate

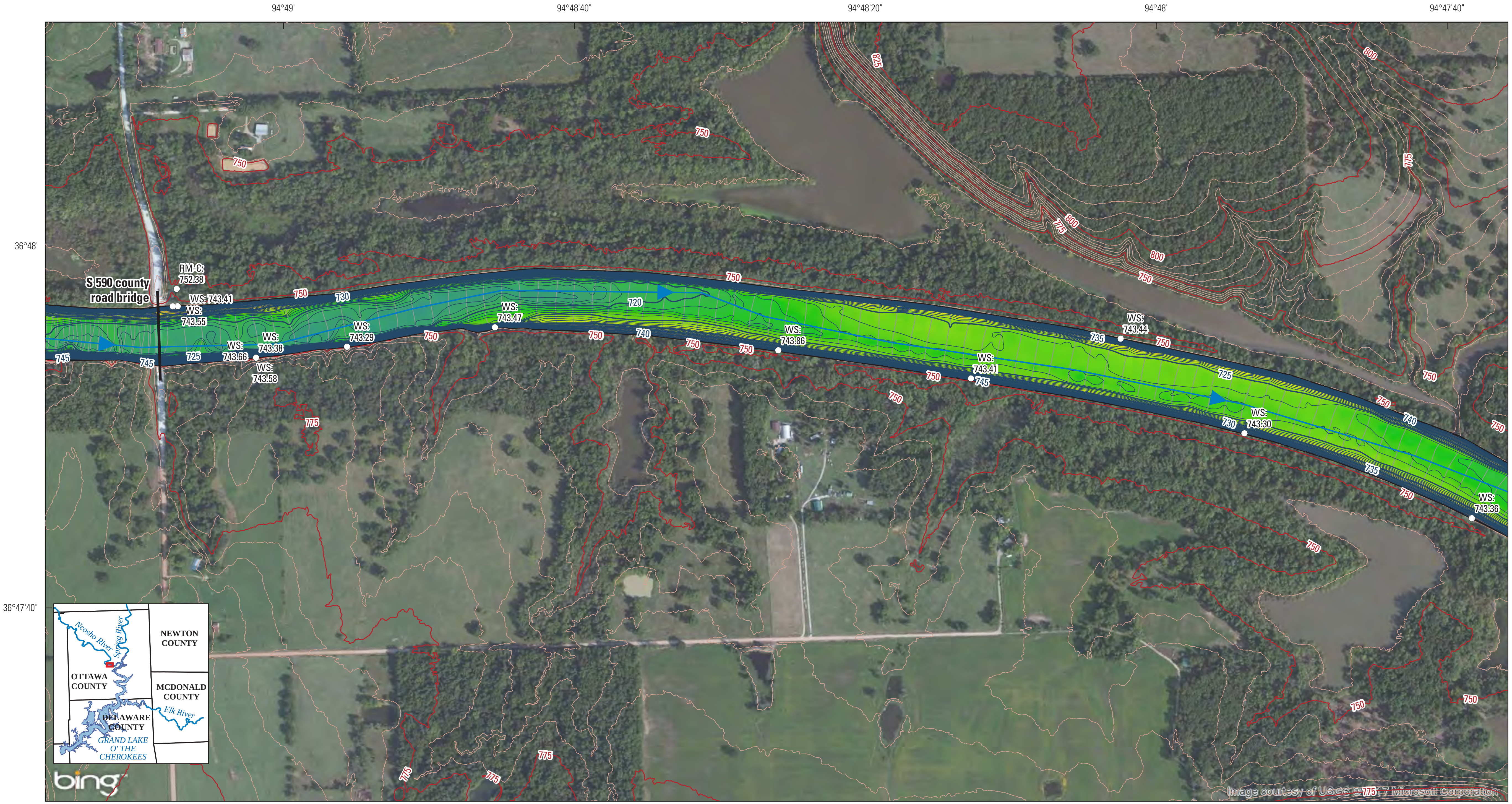
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–1.



94°47'40"
94°47'20"
36°48'
94°47'
94°46'40"
36°48'20"
94°46'20"
36°47'40"
36°47'20"
94°47'20"
NEWTON COUNTY
OTTAWA COUNTY
MCDONALD COUNTY
DELAWARE COUNTY
Neosho River
Spring River
Elk River
GRAND LAKE O' THE CHEROKEES
NOT FOR NAVIGATIONAL USE
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas
0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER
North
EXPLANATION
Bathymetric survey depth, in feet (ft)
0
34.22
Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary
Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–2.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

NOT FOR NAVIGATIONAL USE

0 0.1 0.2 0.3 0.4 MILE

0 0.1 0.2 0.3 0.4 KILOMETER

EXPLANATION

Bathymetric survey depth, in feet (ft)

0

34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88

Intermediate

Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88

Index (25-ft interval)

Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–3.

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–4.

NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

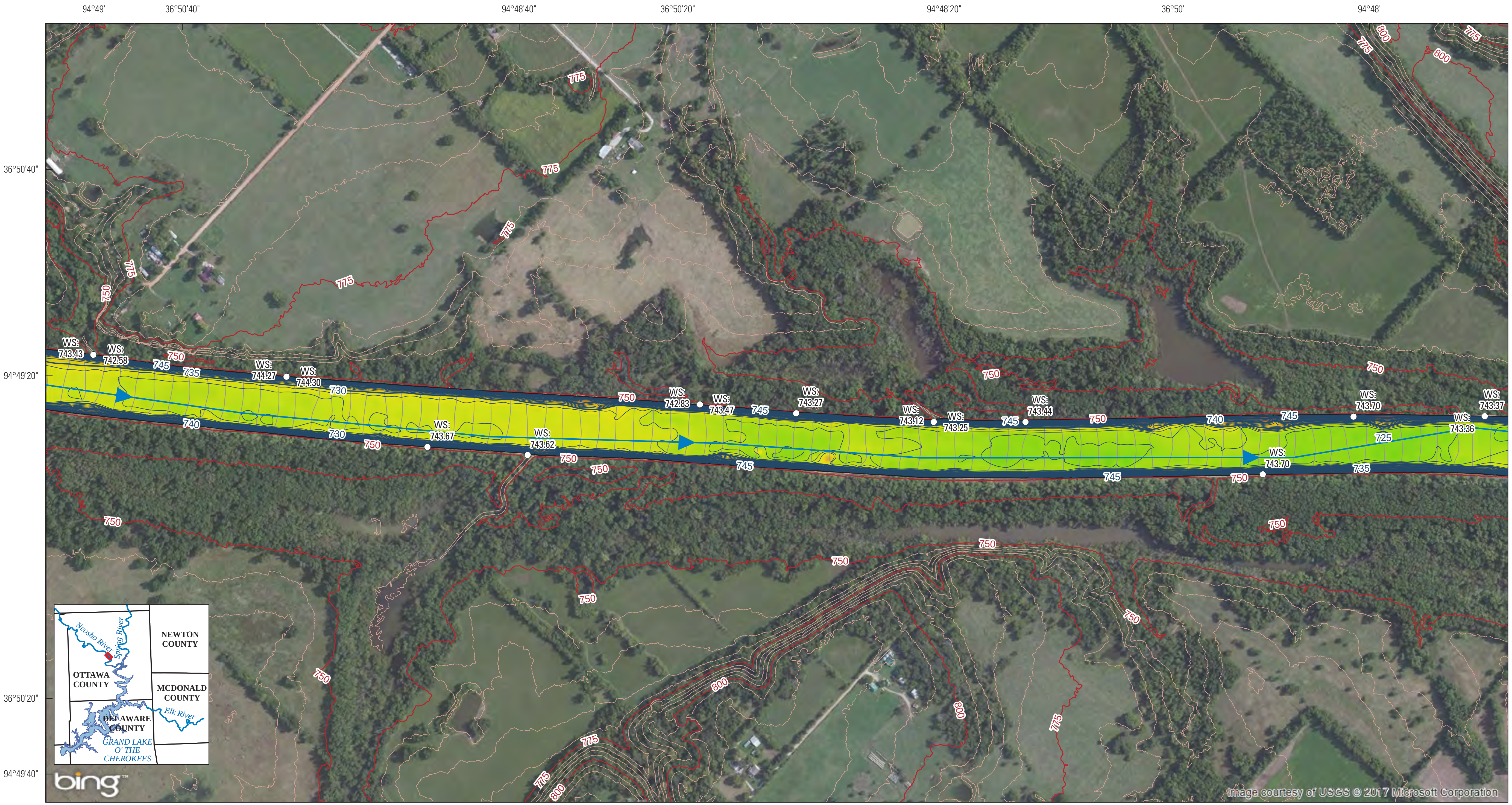
Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–5.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

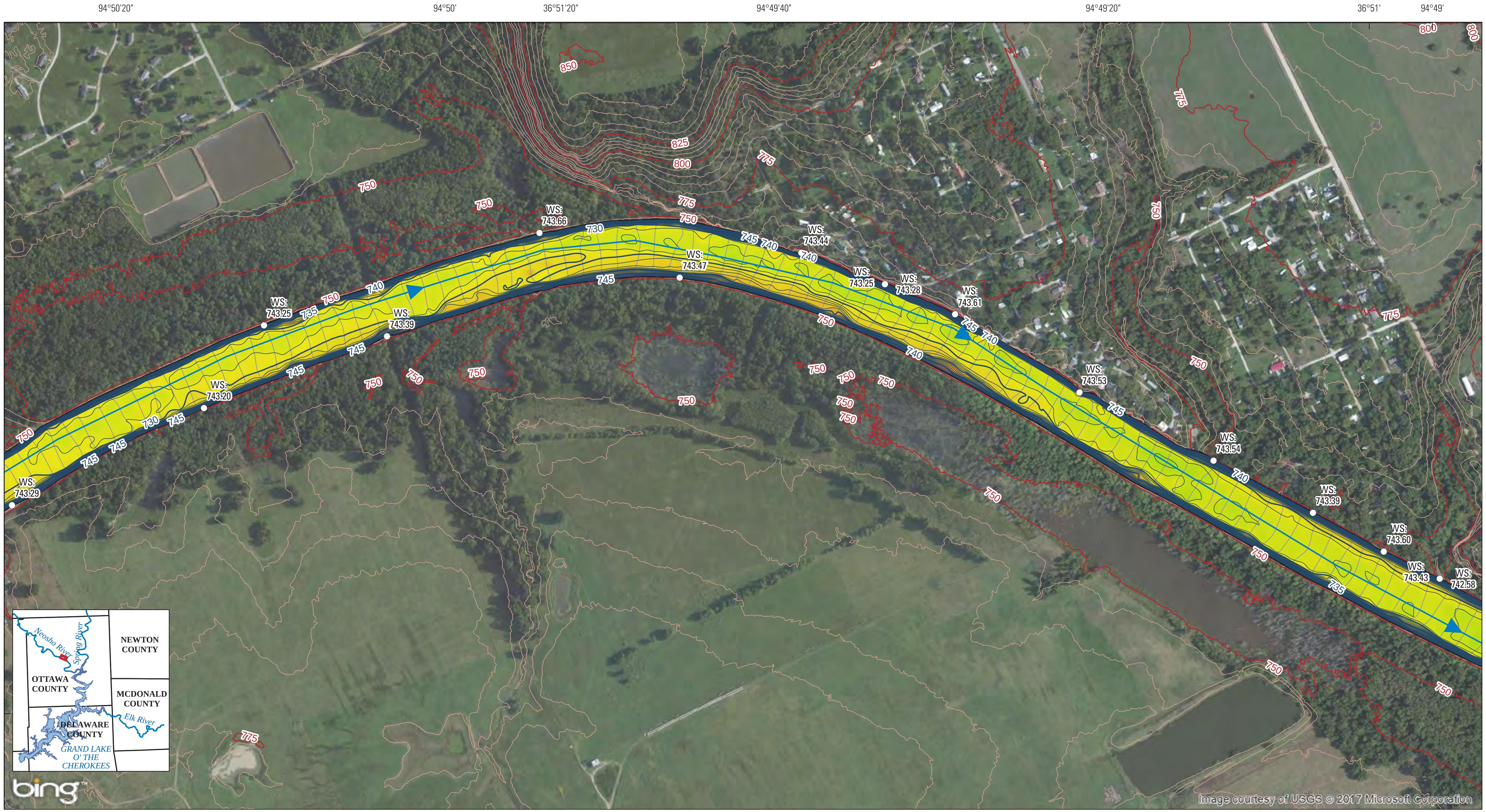
Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–6.



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE

0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88

Intermediate

Index (5-ft interval)

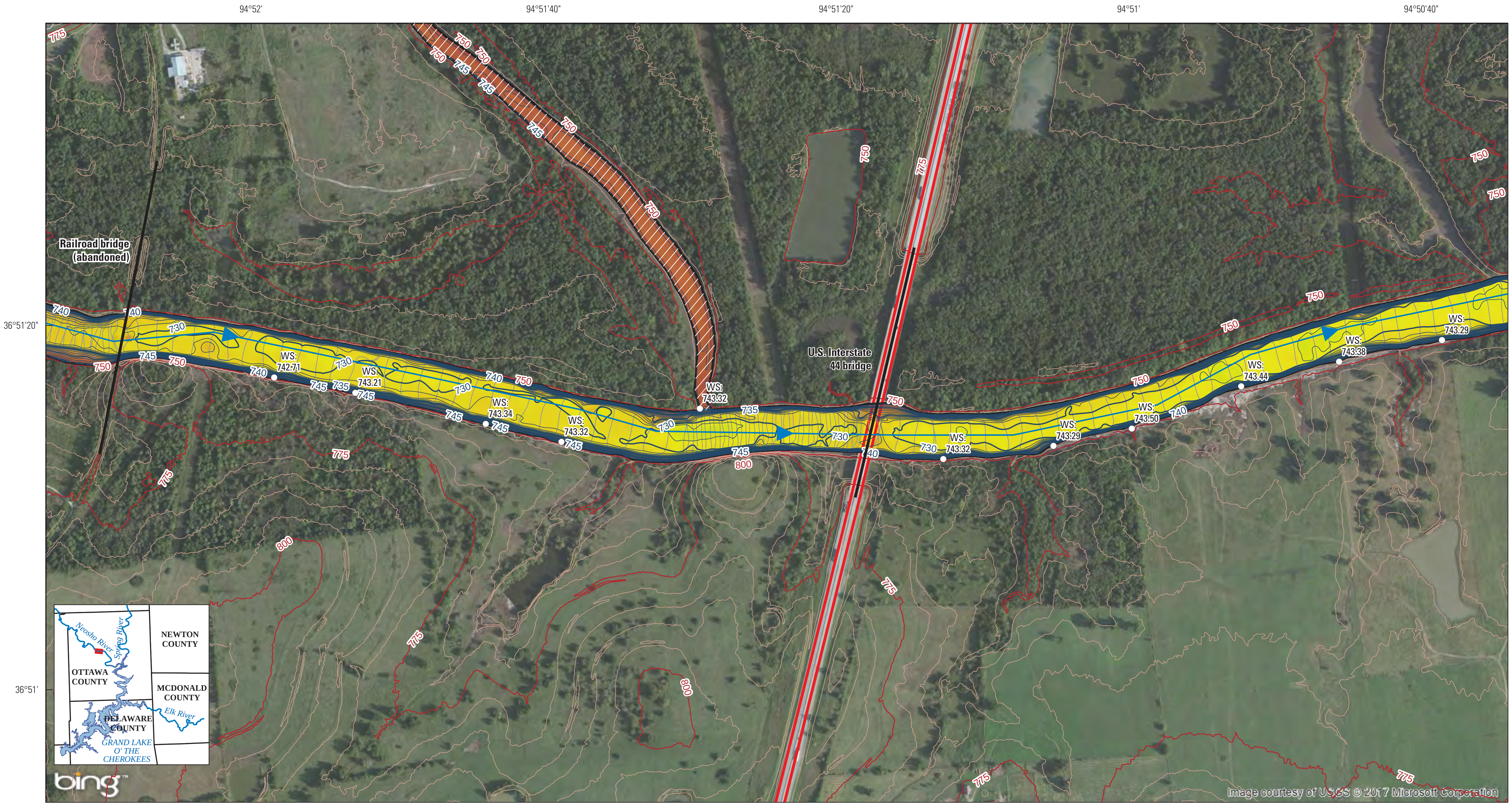
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88

Index (25-ft interval)

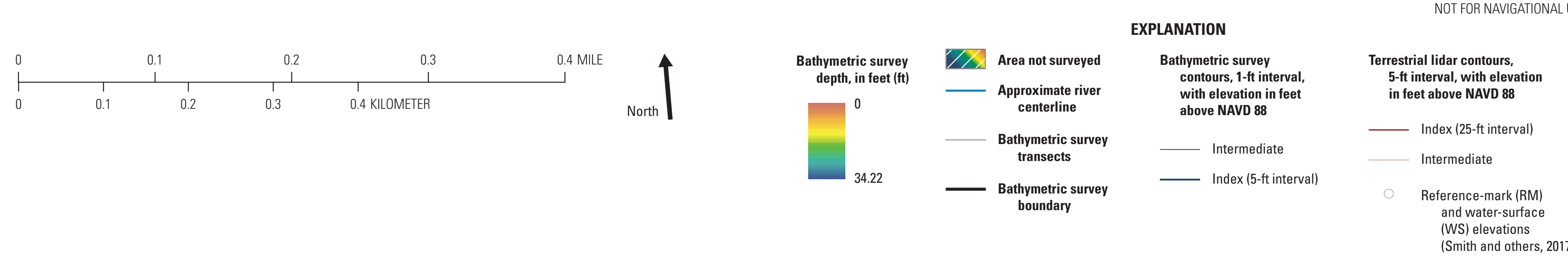
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

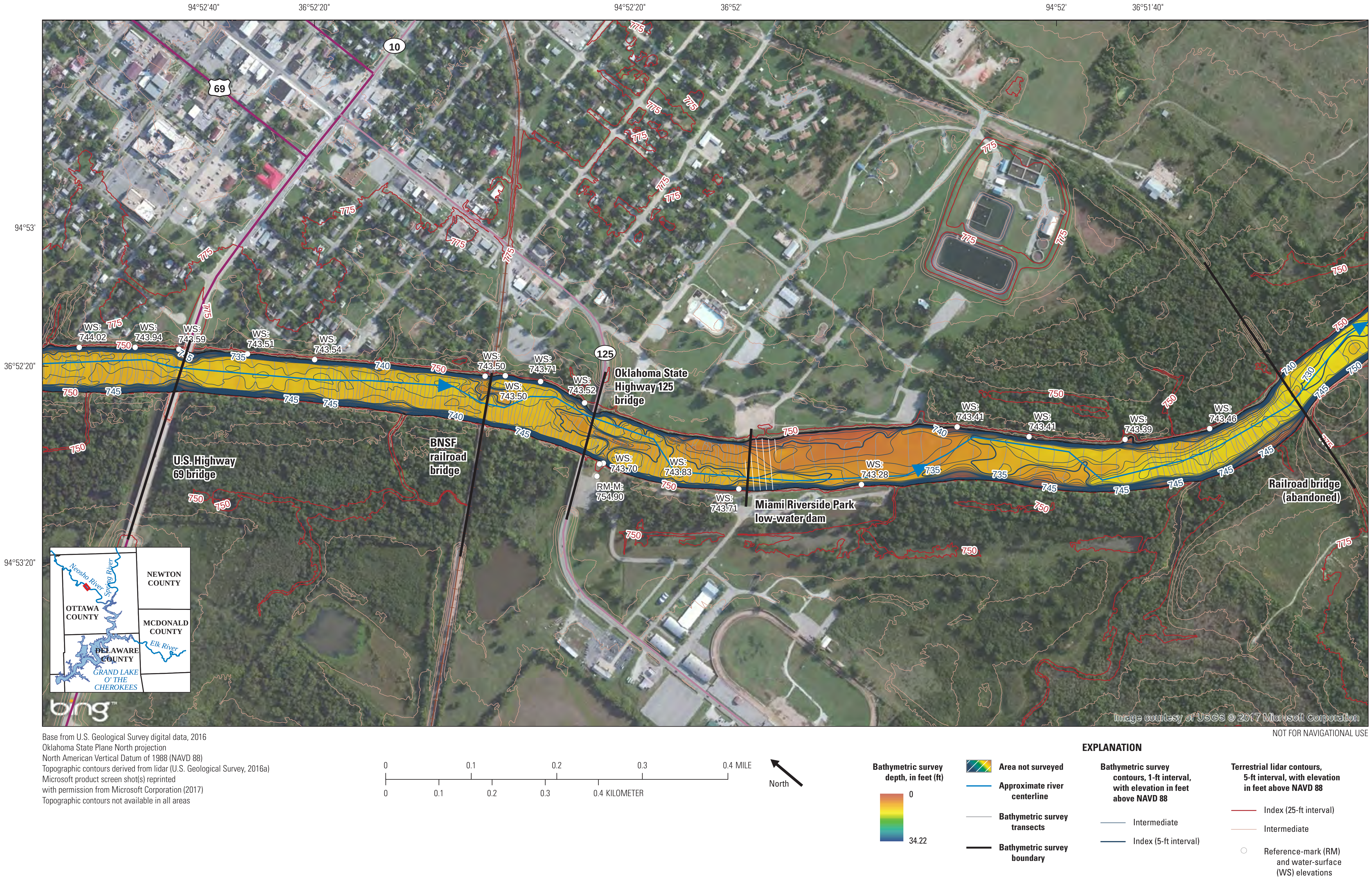
Appendix 2–7.



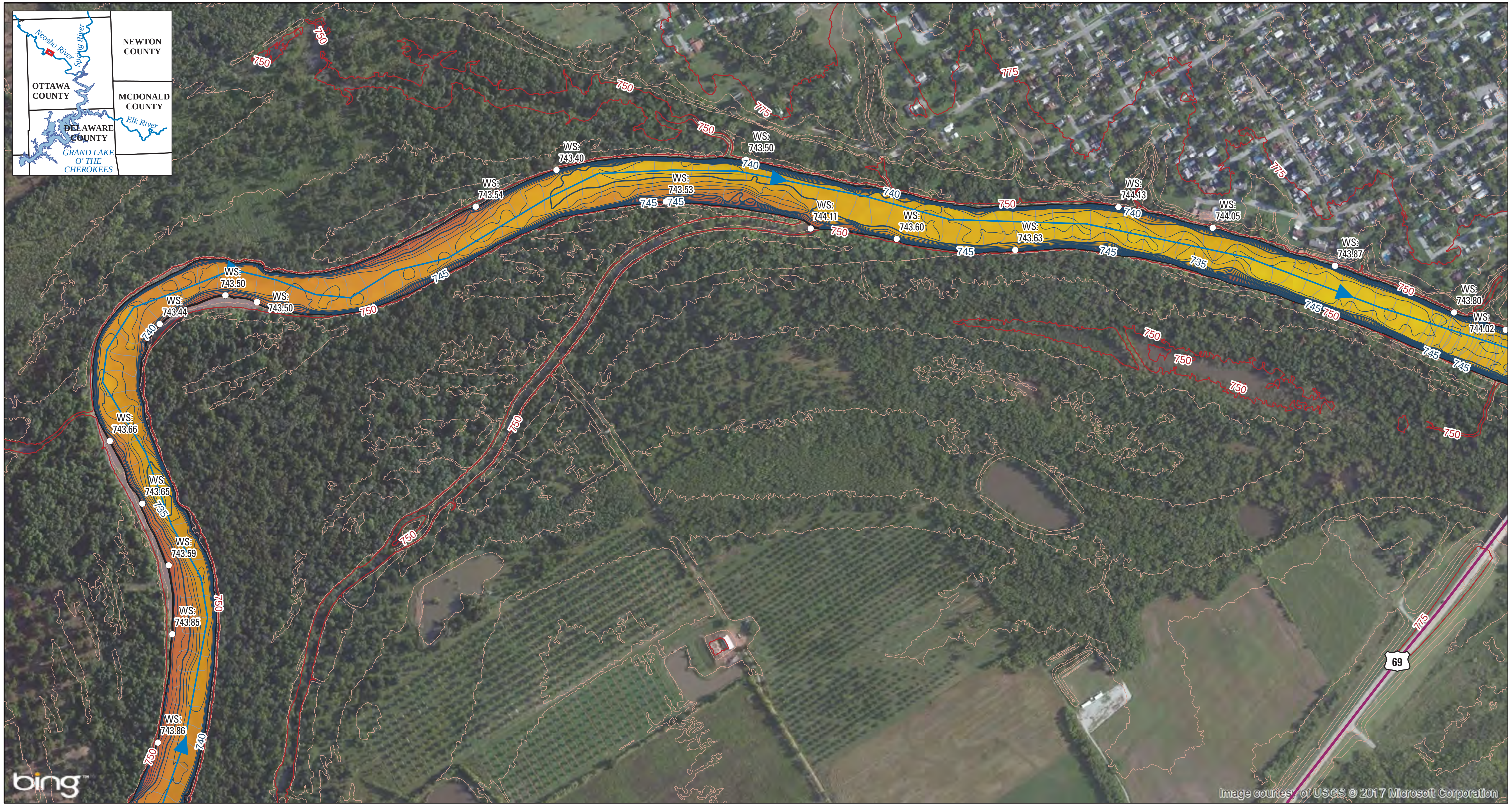
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas



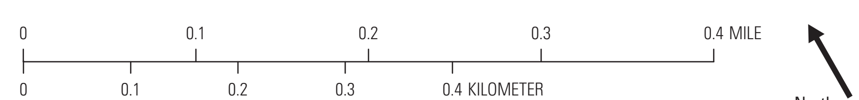
Appendix 2–8.


94°52'40"
36°52'20"
94°52'20"
36°52'
94°52'
36°51'40"
94°53'
36°52'20"
94°53'20"
10
69
125
WS: 744.02
WS: 743.94
WS: 743.59
WS: 743.51
WS: 743.54
WS: 743.50
WS: 743.71
WS: 743.50
WS: 743.52
WS: 743.70
WS: 743.83
WS: 743.71
WS: 743.28
WS: 743.41
WS: 743.41
WS: 743.39
WS: 743.46
RM-M: 754.90
U.S. Highway 69 bridge
BNSF railroad bridge
Oklahoma State Highway 125 bridge
Miami Riverside Park low-water dam
Railroad bridge (abandoned)
Neosho River
Spring River
NEWTON COUNTY
OTTAWA COUNTY
MCDONALD COUNTY
DELAWARE COUNTY
Elk River
GRAND LAKE O' THE CHEROKEES
Image courtesy of USGS © 2017 Microsoft Corporation
NOT FOR NAVIGATIONAL USE
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas
0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER
North
EXPLANATION
Bathymetric survey depth, in feet (ft)
0
34.22
Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary
Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–9.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas



EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–10.

NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

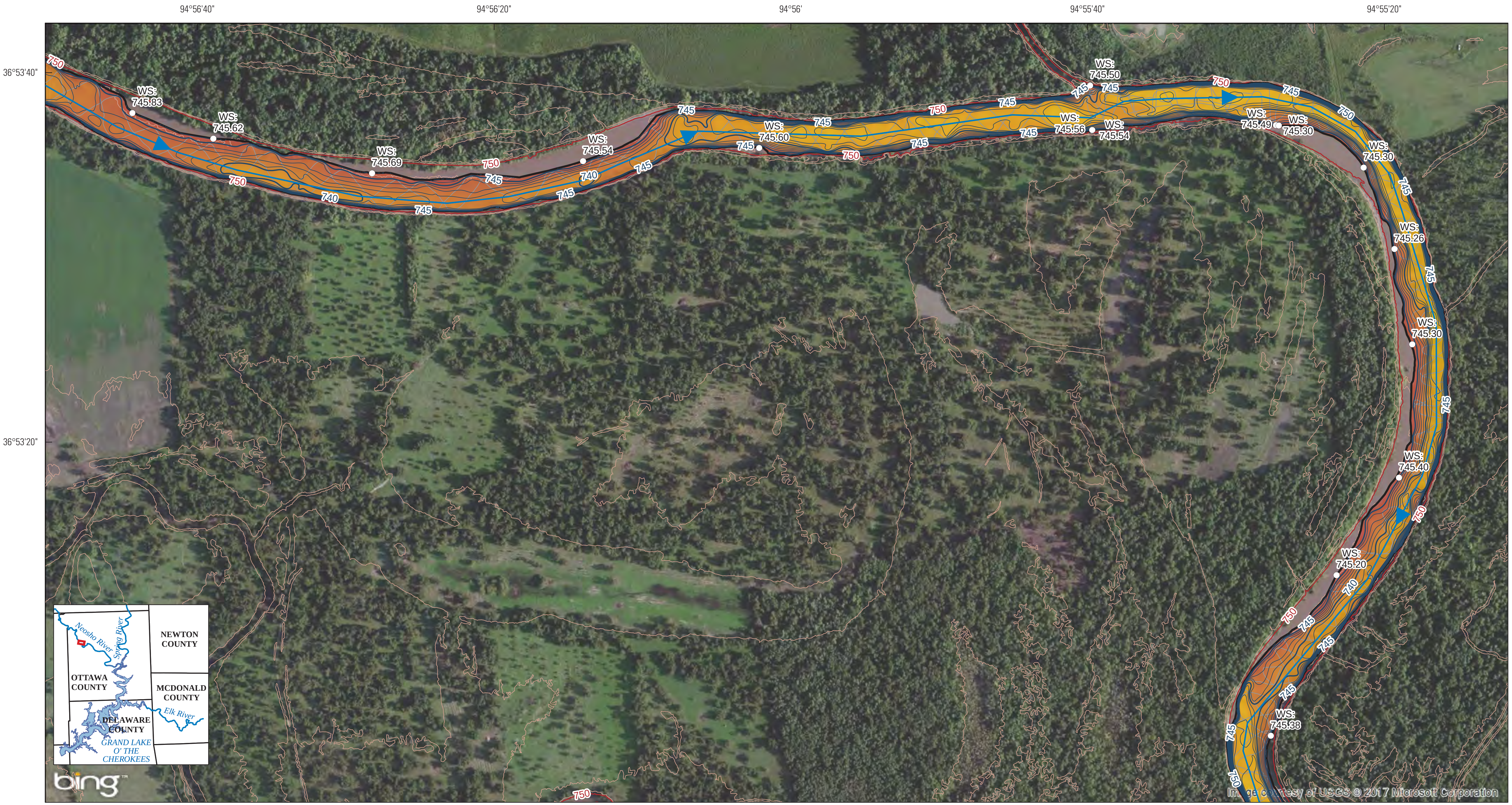
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

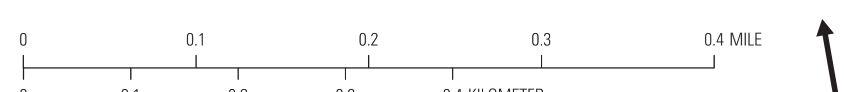
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–11.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas



EXPLANATION

Bathymetric survey depth, in feet (ft) — 0 to 34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
- Intermediate
- Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
- Index (25-ft interval)
- Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–12.

NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

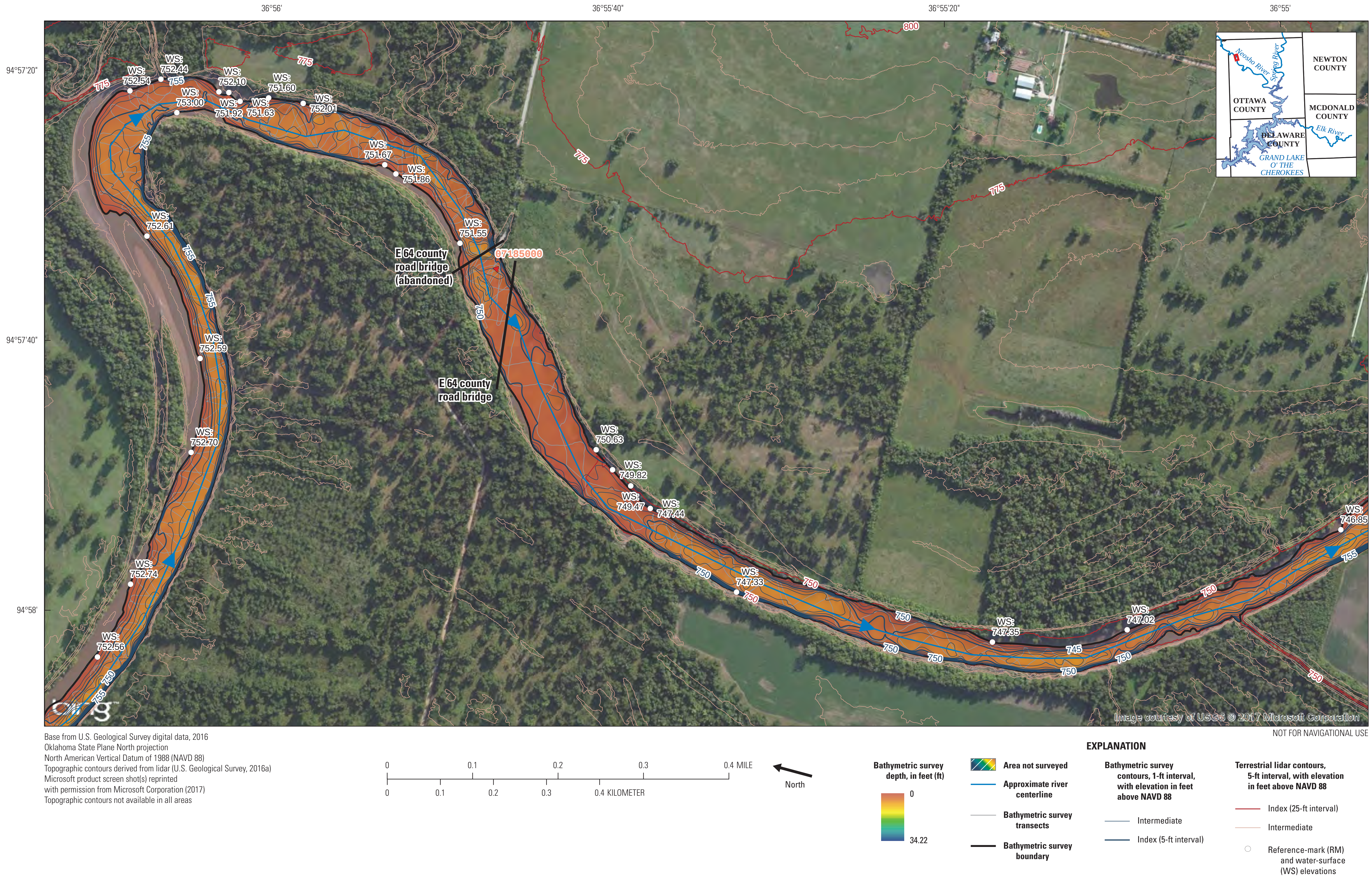
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

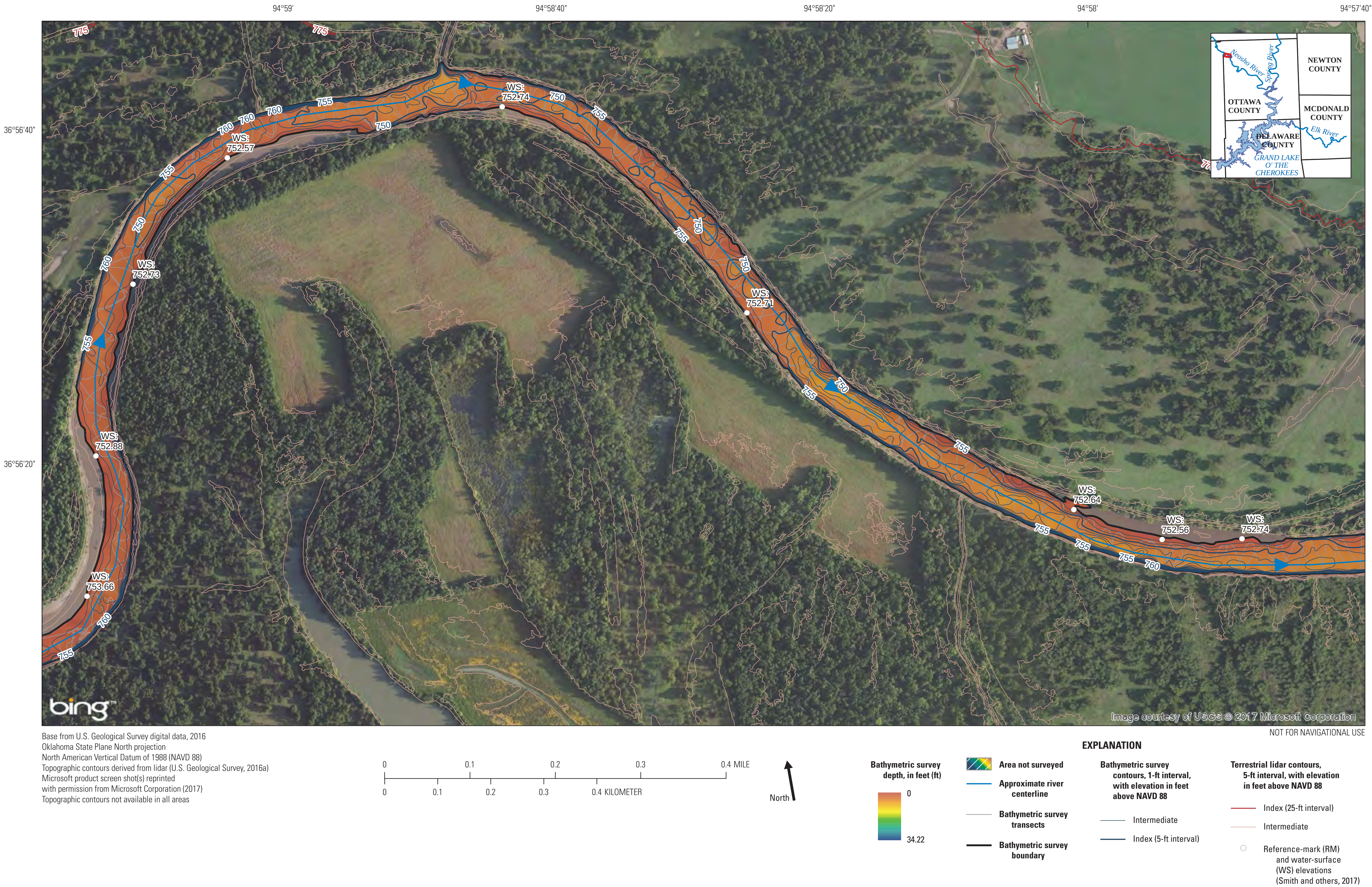
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

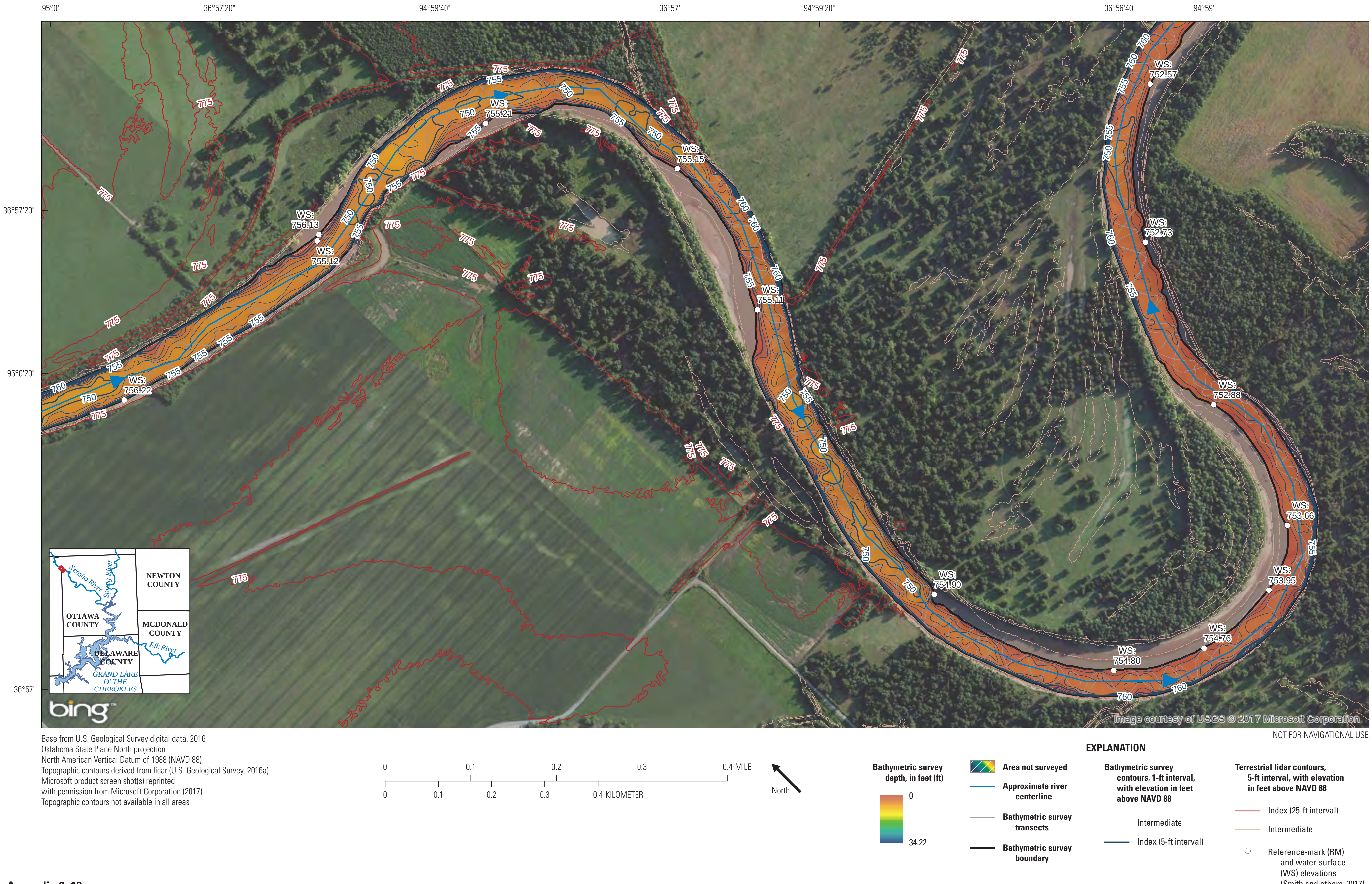
Appendix 2–13.



Appendix 2–14.



Appendix 2–15.



Appendix 2–16.

NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

EXPLANATION

Appendix 2–17.

NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

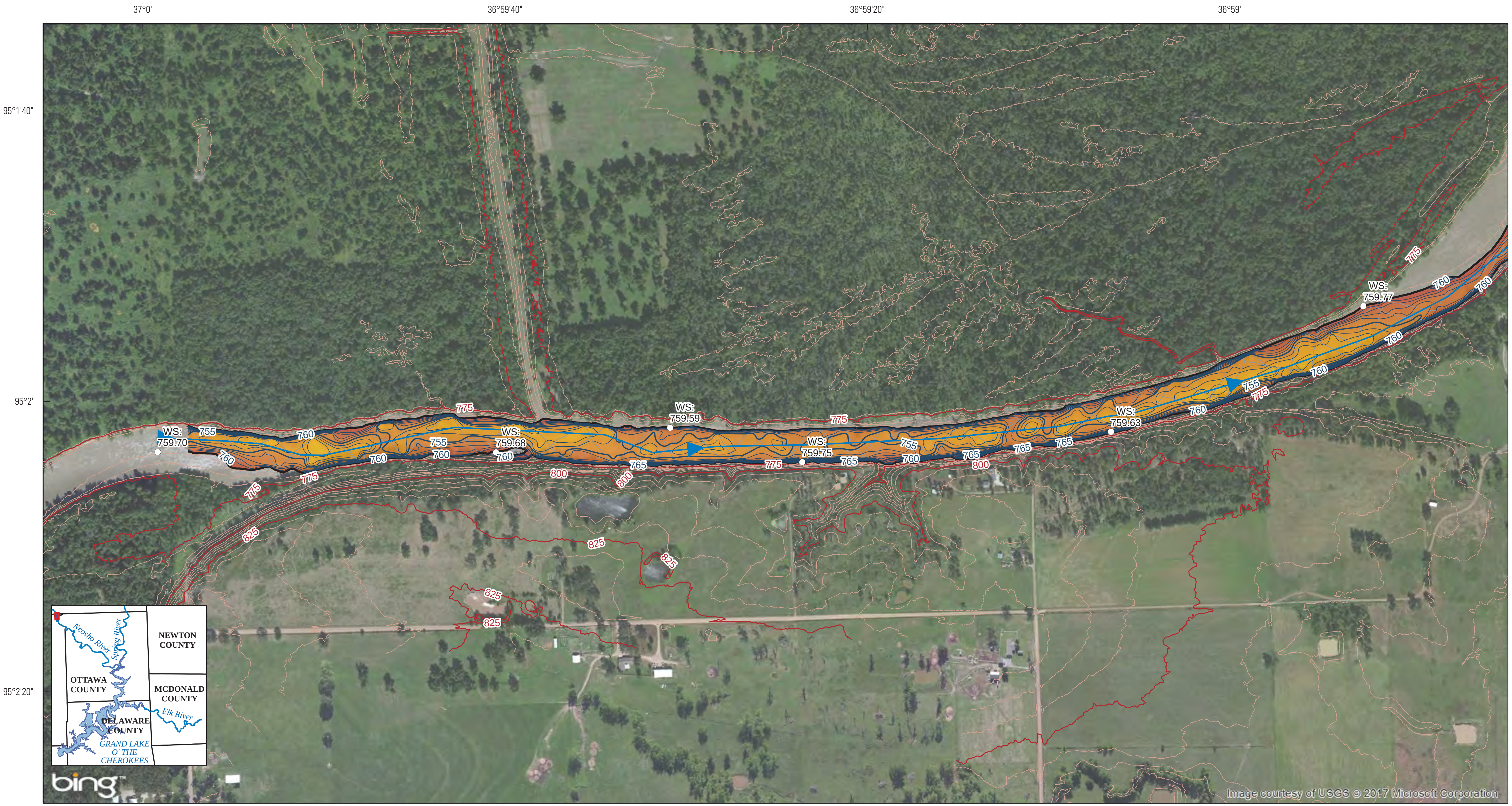
Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–18.



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE

0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

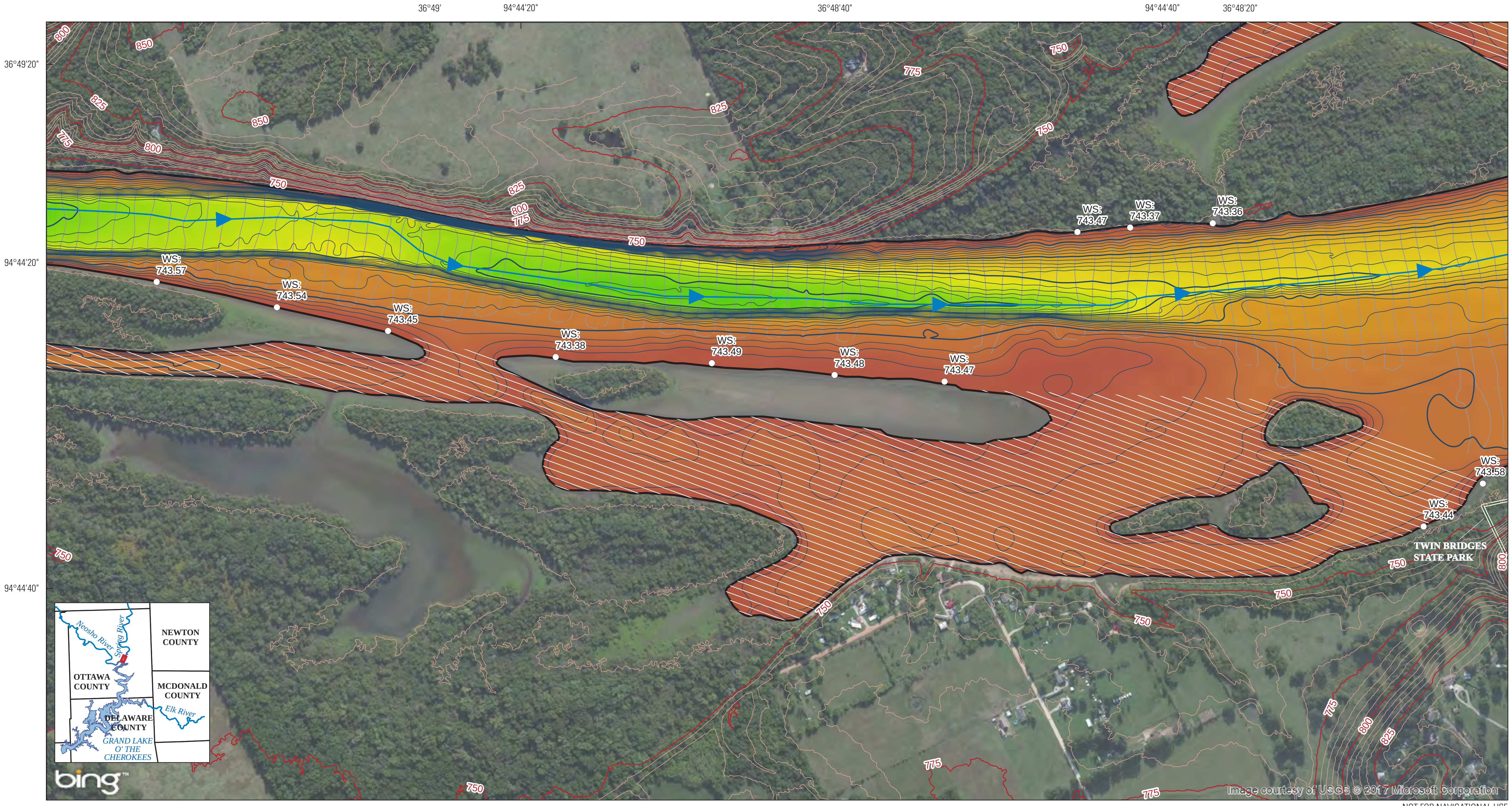
Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 2–19.

Appendix 3. Maps showing bathymetric survey of the Spring River, northeastern Oklahoma, 2016



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

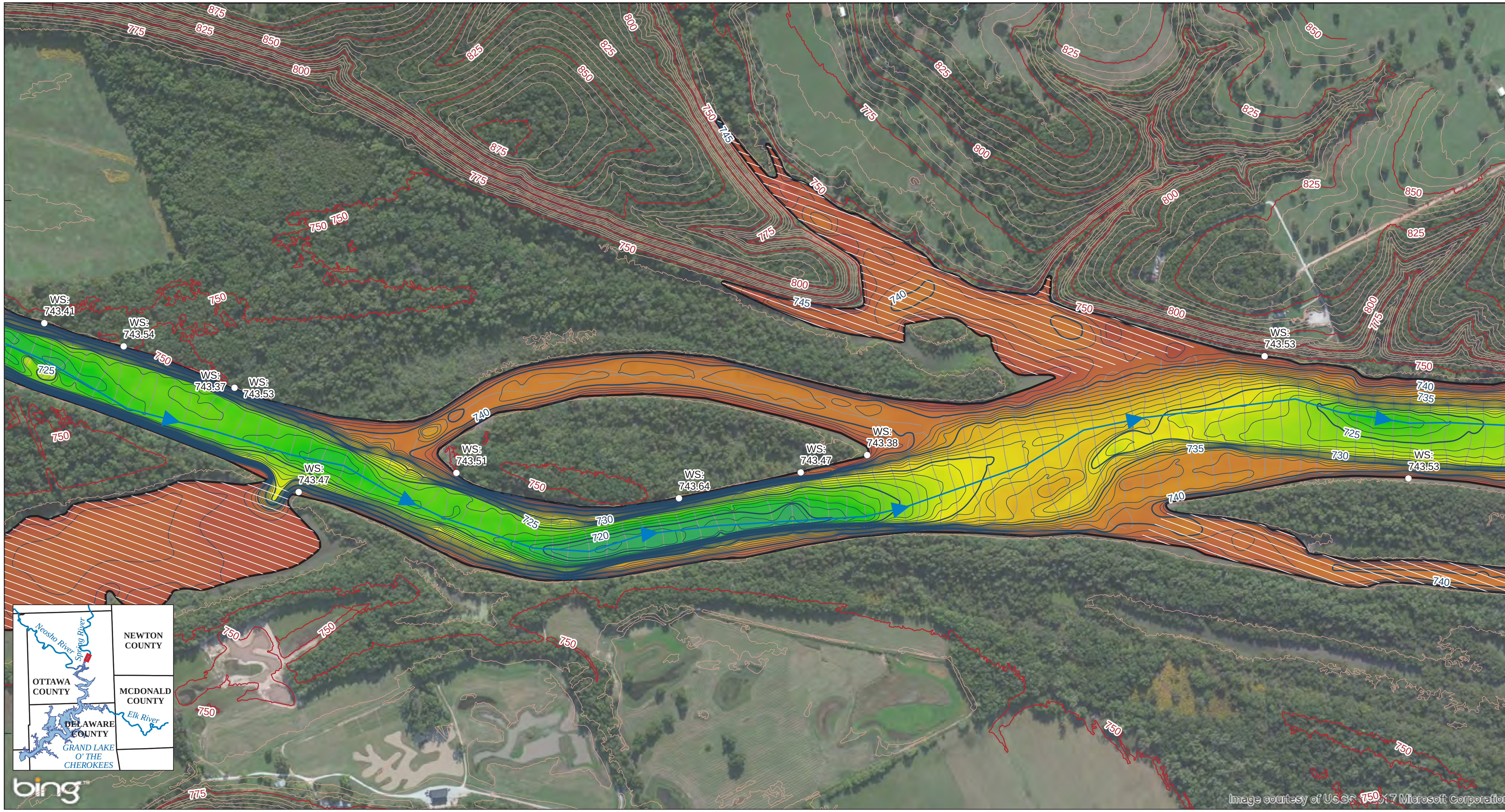
Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 3–1.

36°50'20" 94°43'20" 36°50' 36°49'40" 94°43'40" 36°49'20"

94°43'20" 94°43'40" 36°50'40"



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

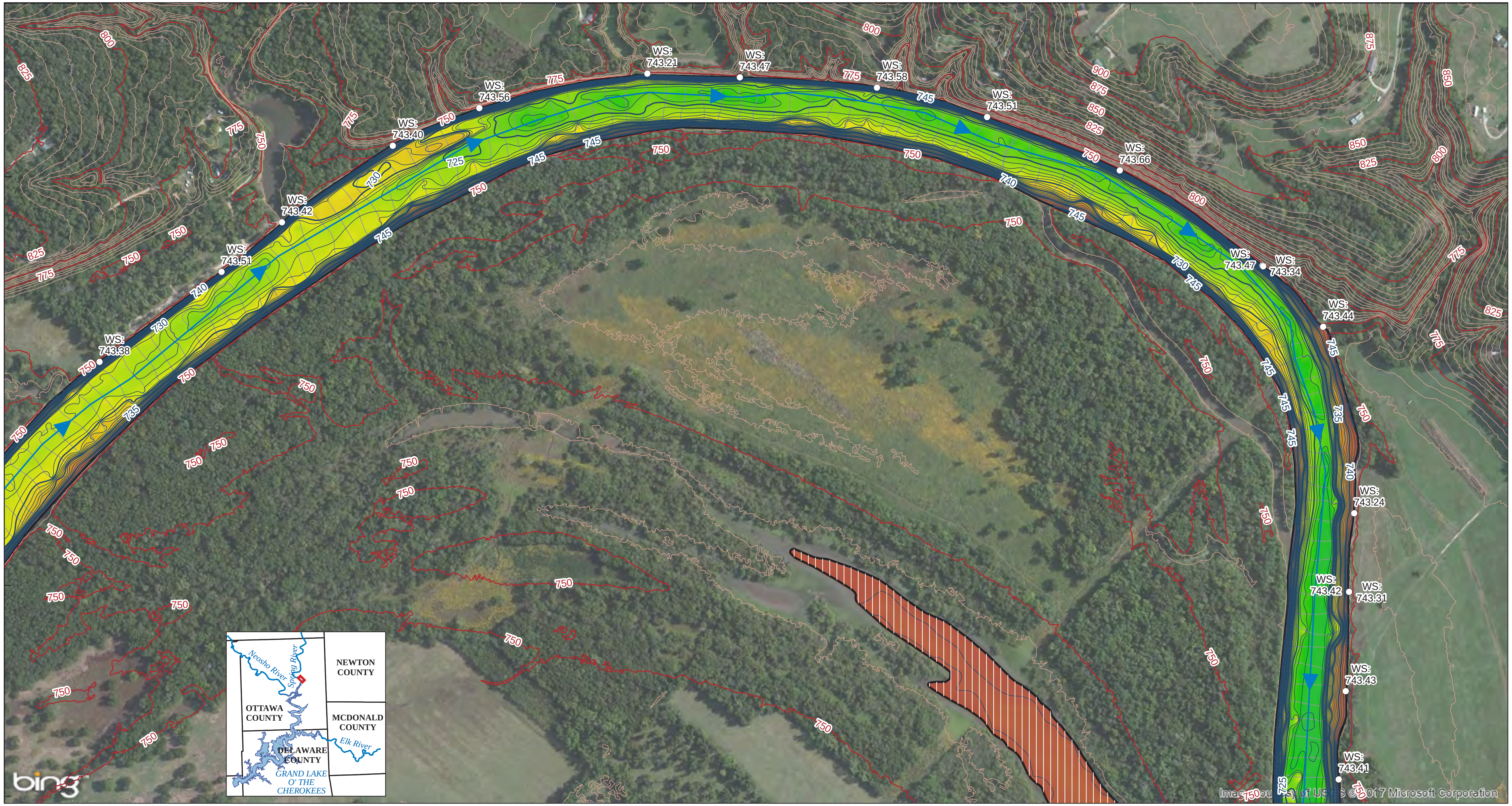
Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 3–2.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE

0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88

Intermediate

Index (5-ft interval)

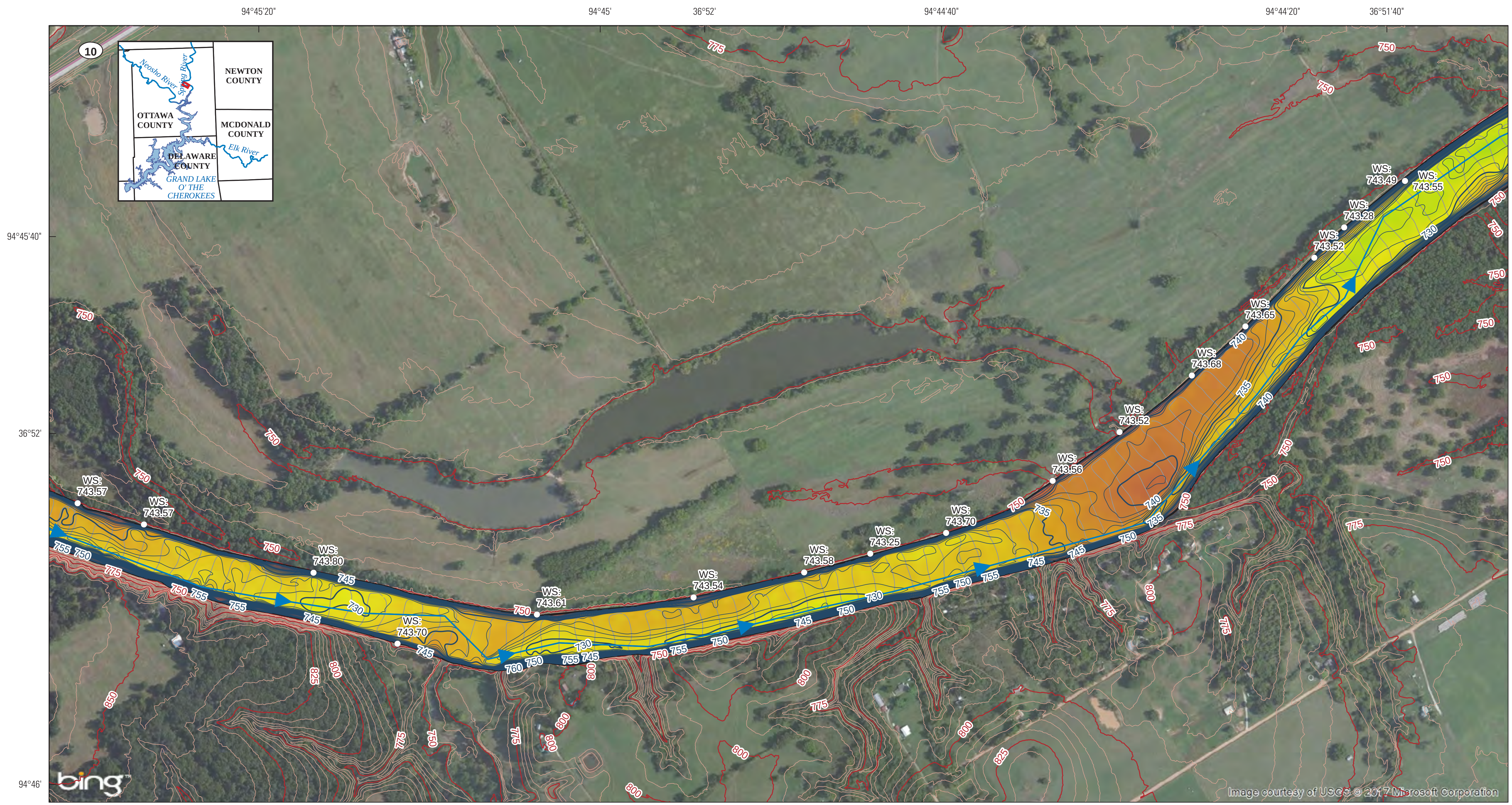
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88

Index (25-ft interval)

Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 3–3.



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88

Intermediate

Index (5-ft interval)

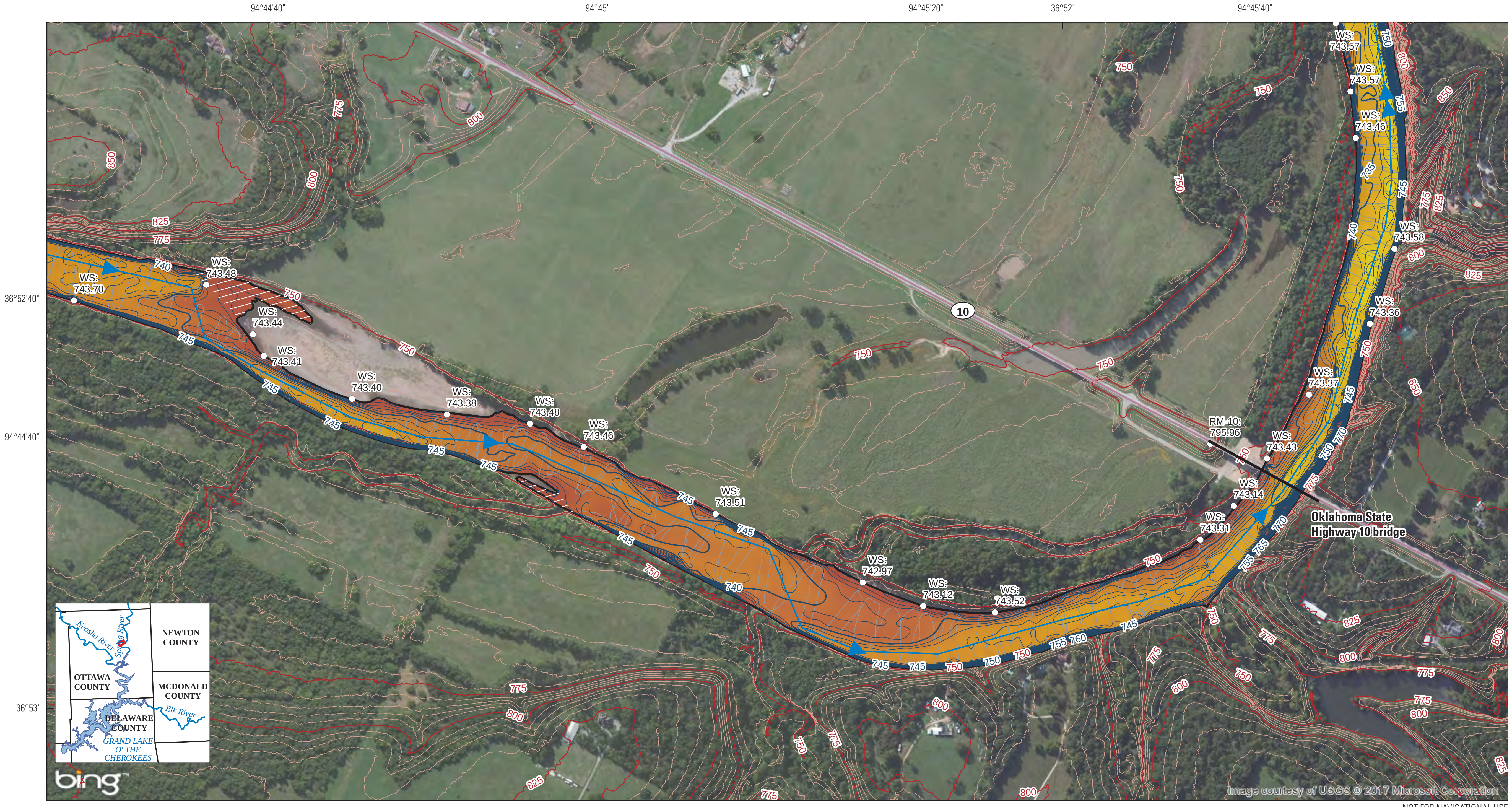
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88

Index (25-ft interval)

Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 3–4.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Aerial photography from Microsoft Corporation (2017)
Topographic contours not available in all areas

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

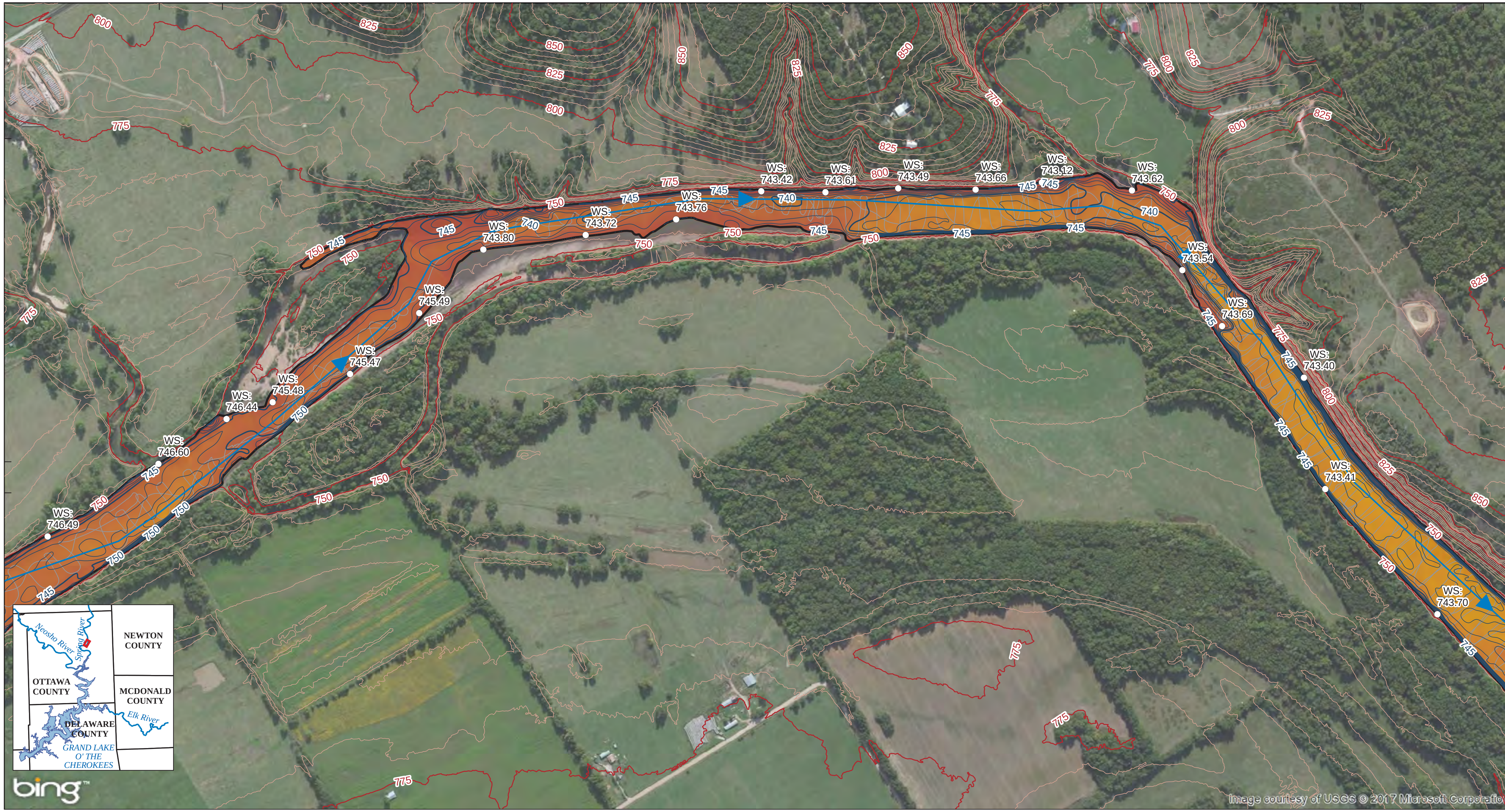
Appendix 3–5.

36°53'20" 94°43'20" 36°53' 94°43'40" 36°52'40" 94°44' 36°52'20"

94°43'20"

36°53'40"

94°43'40"



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE

0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)

0

34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88

Intermediate

Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88

Index (25-ft interval)

Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 3–6.

NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

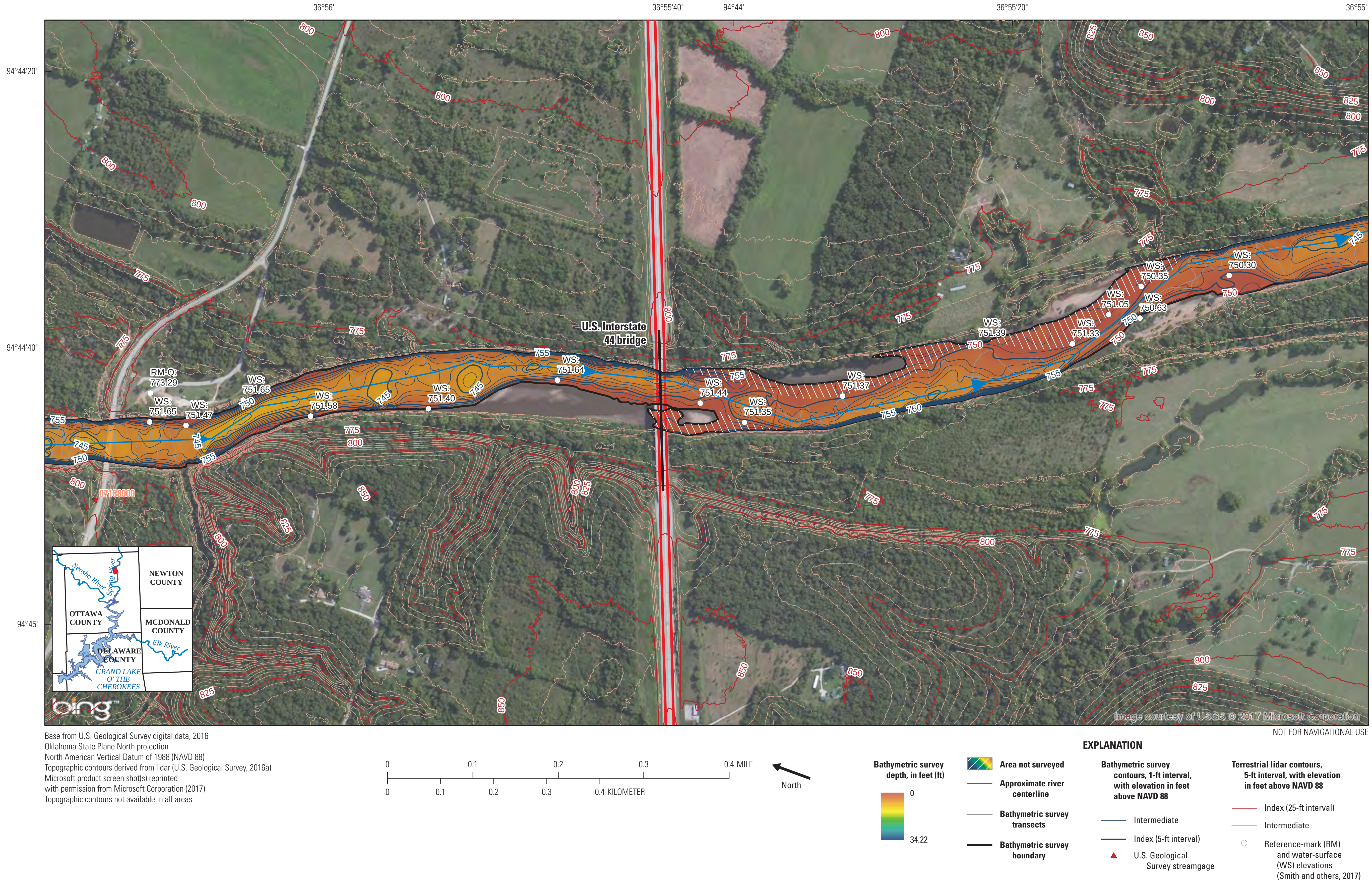
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

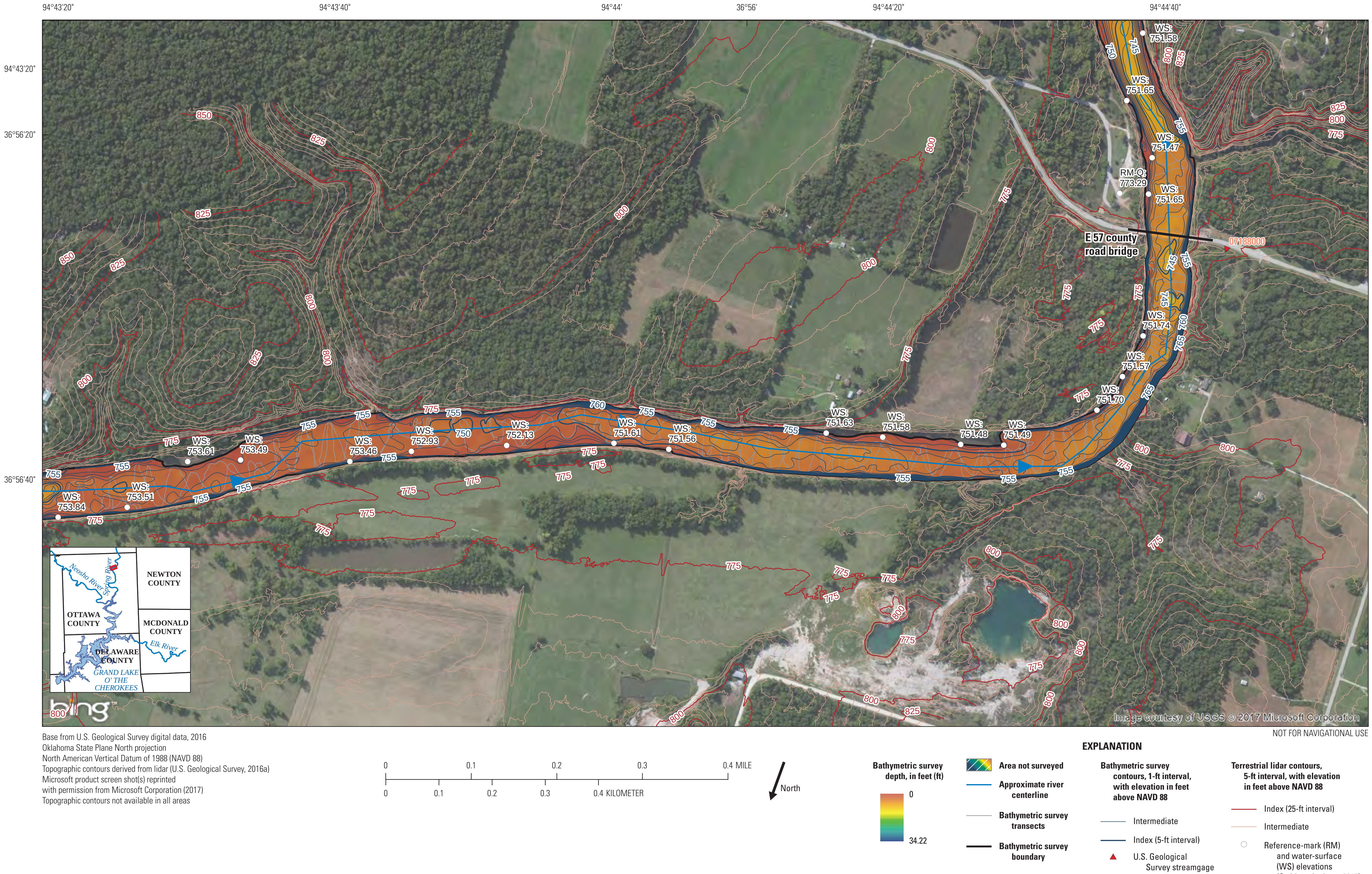
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 3–7.



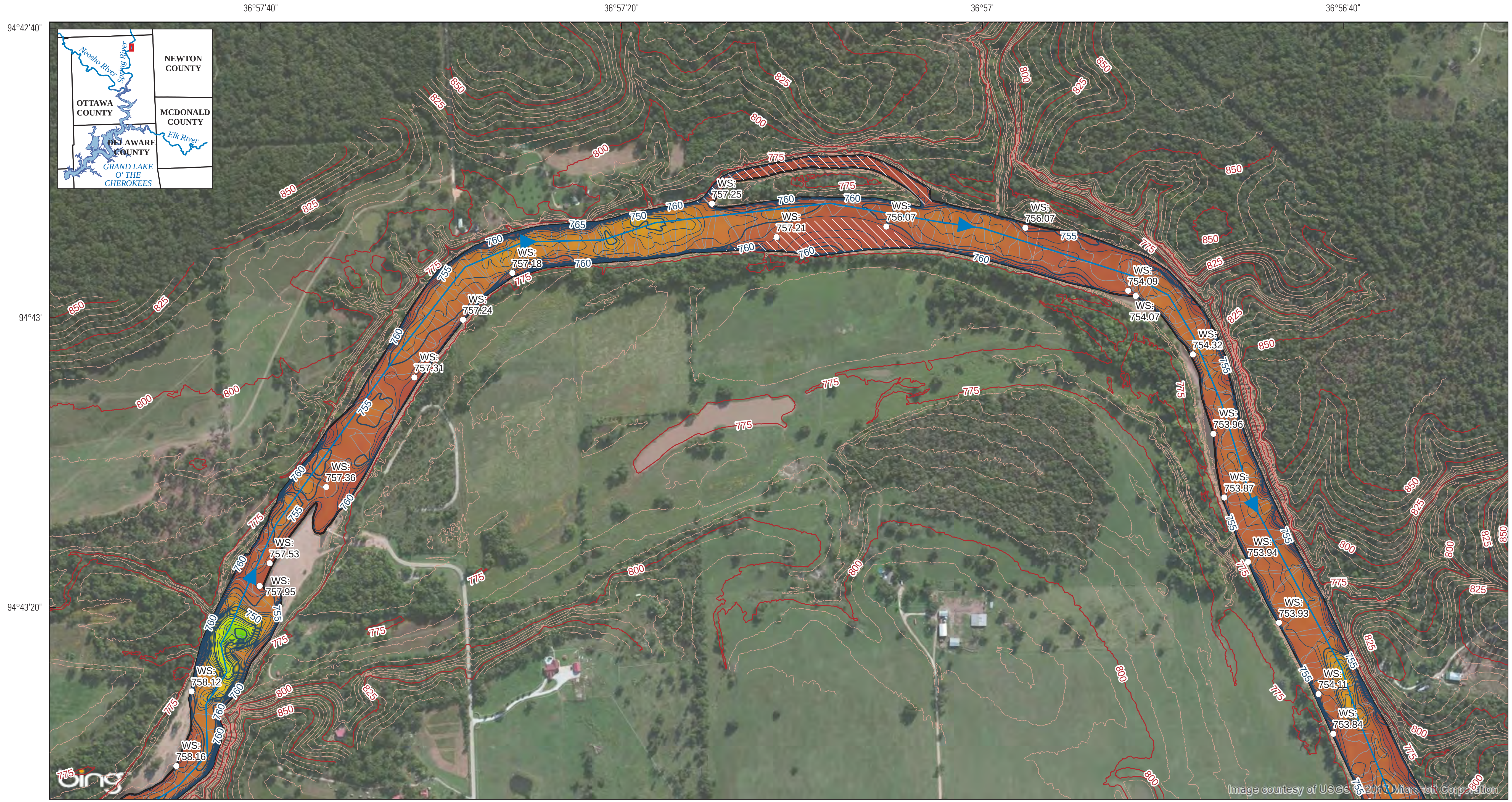
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

Appendix 3–8.



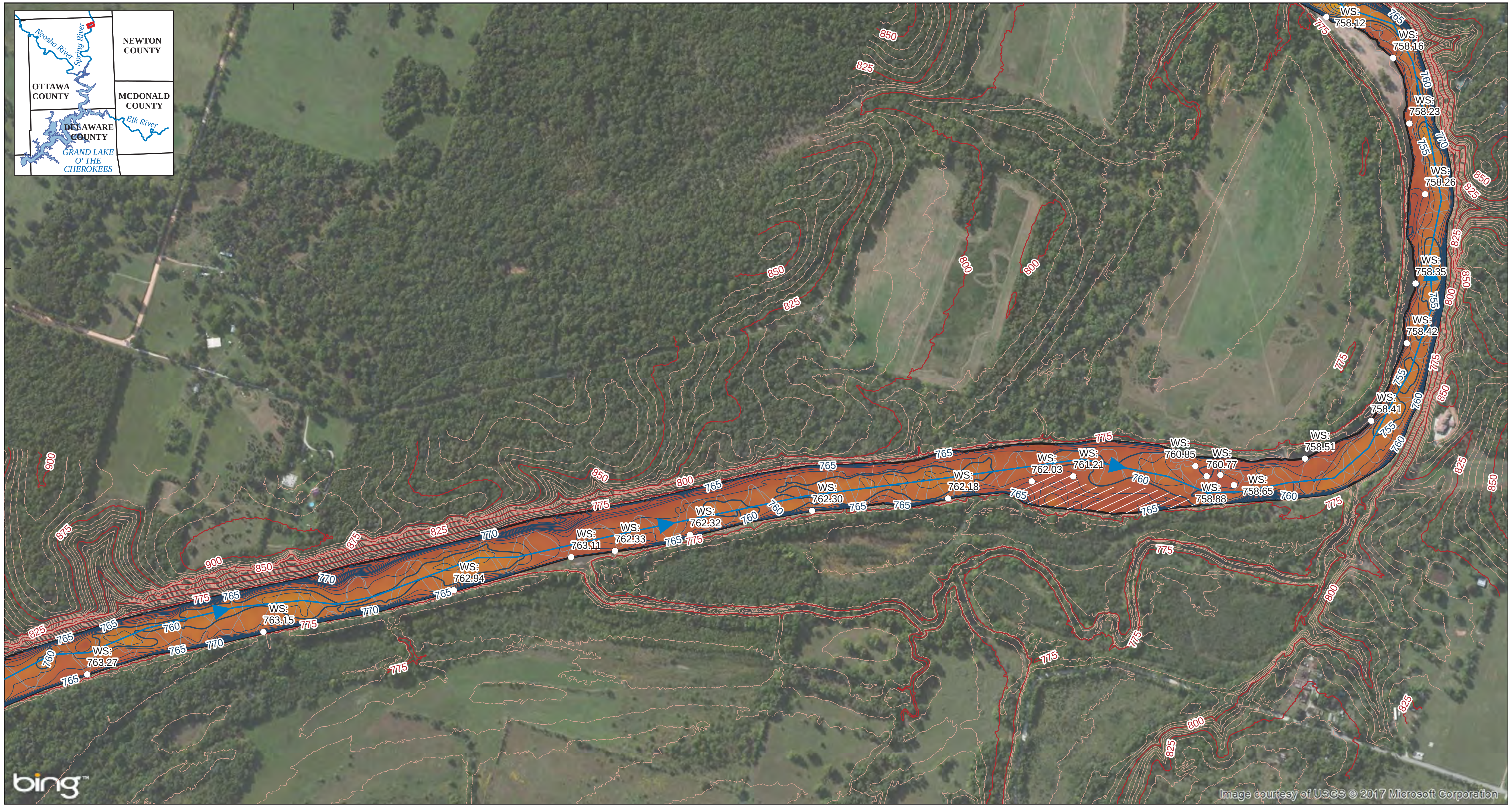
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

Appendix 3–9.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

Appendix 3–10.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE

0 0.1 0.2 0.3 0.4 KILOMETER

North

NOT FOR NAVIGATIONAL USE

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 3–11.

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
34.22

Area not surveyed

Approximate river centerline

Bathymetric survey transects

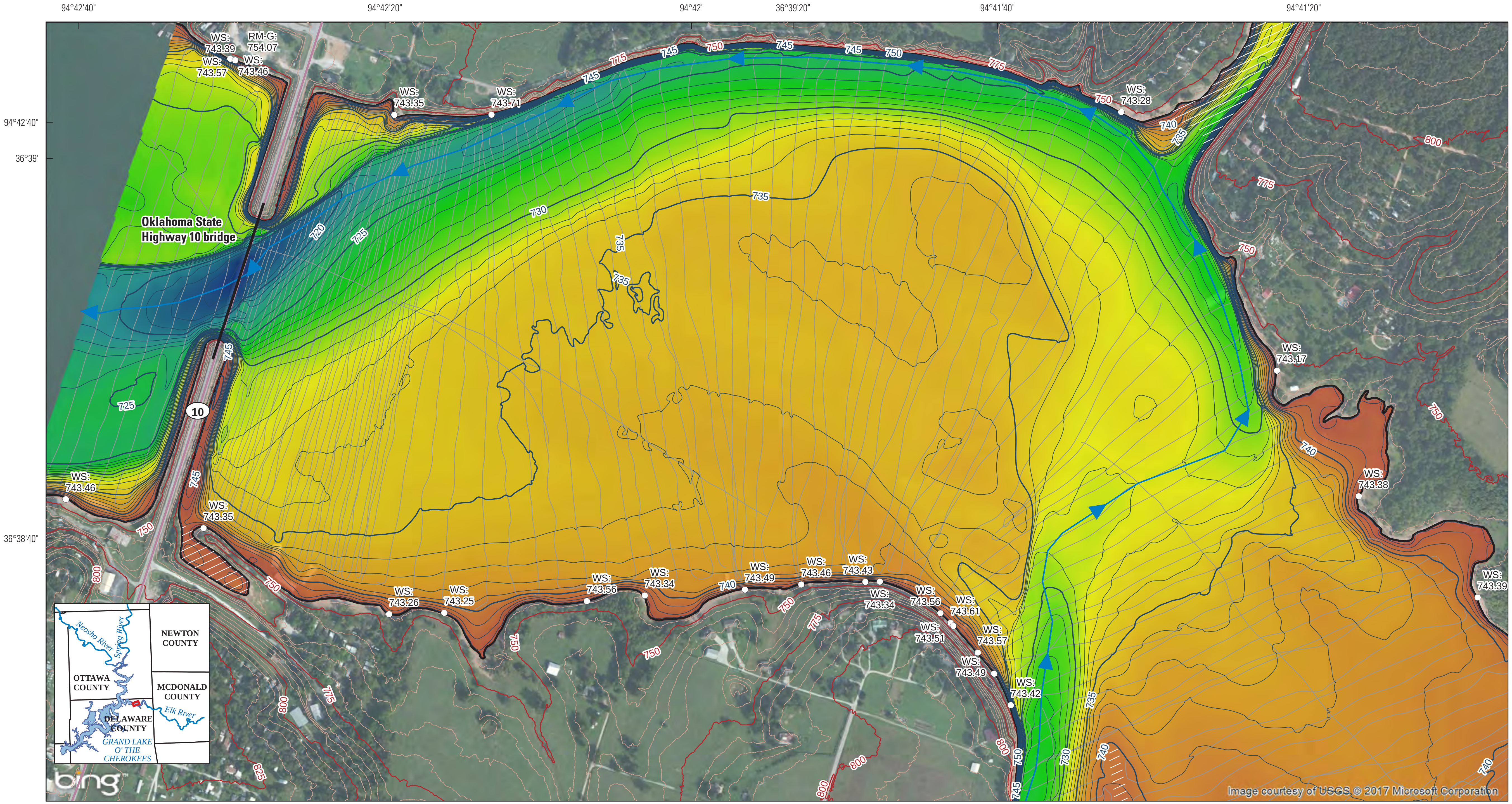
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 3–12.

Appendix 4. Maps showing bathymetric survey of the Elk River, northeastern Oklahoma and southwestern Missouri, 2017



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
27.78

Area not surveyed

Approximate river centerline

Bathymetric survey transects

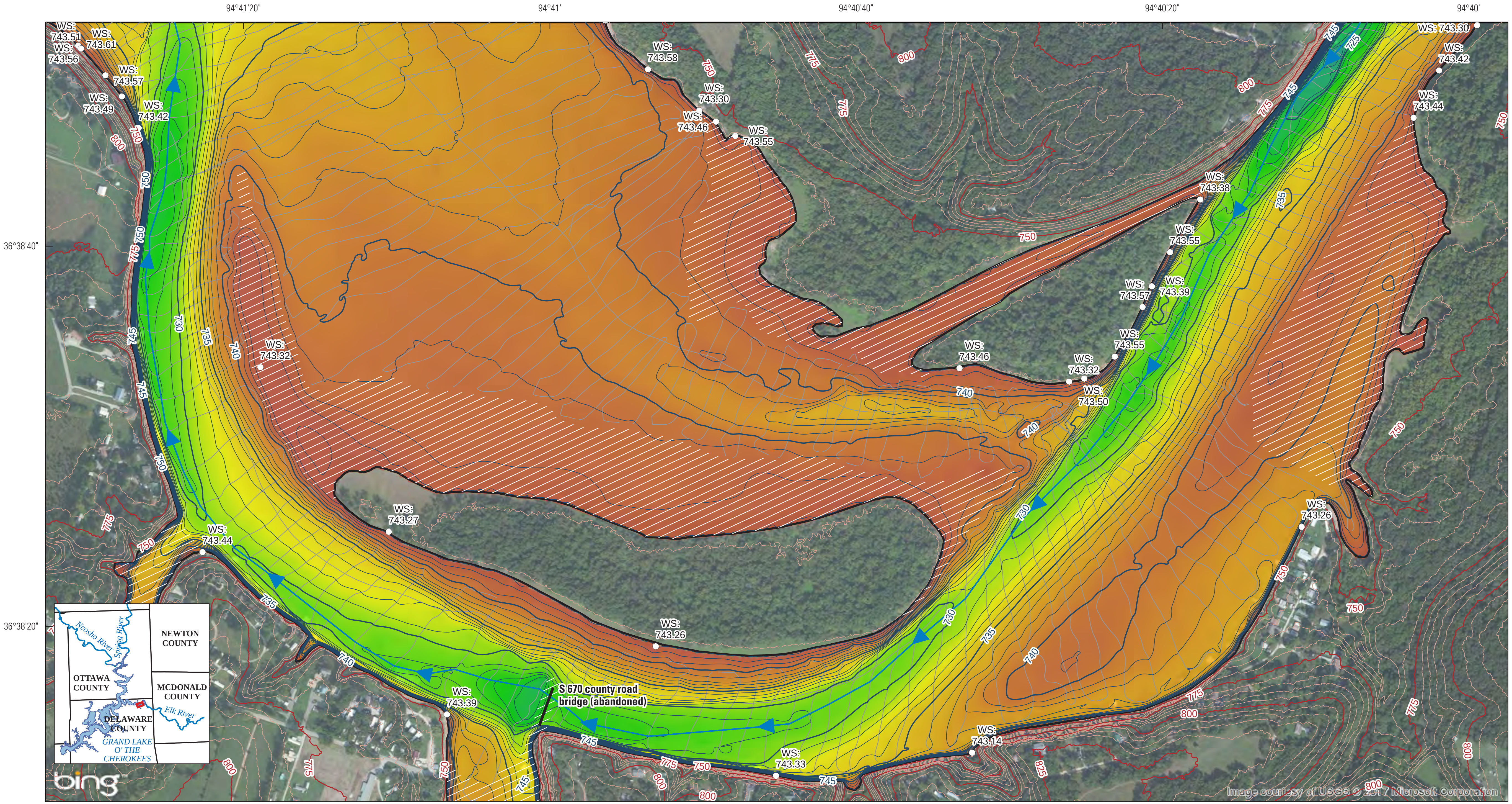
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

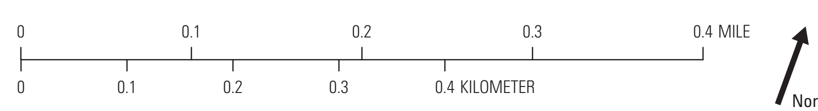
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

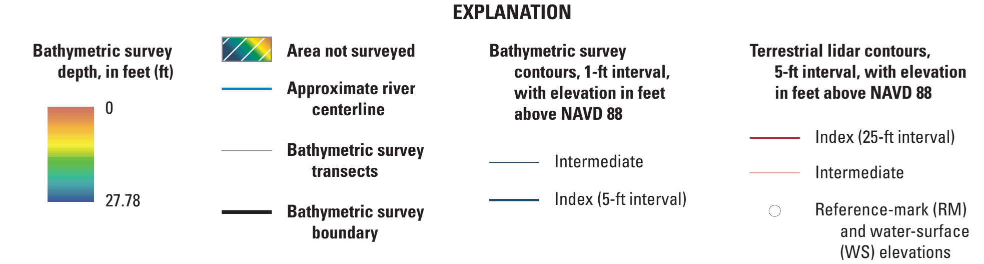
Appendix 4–1.



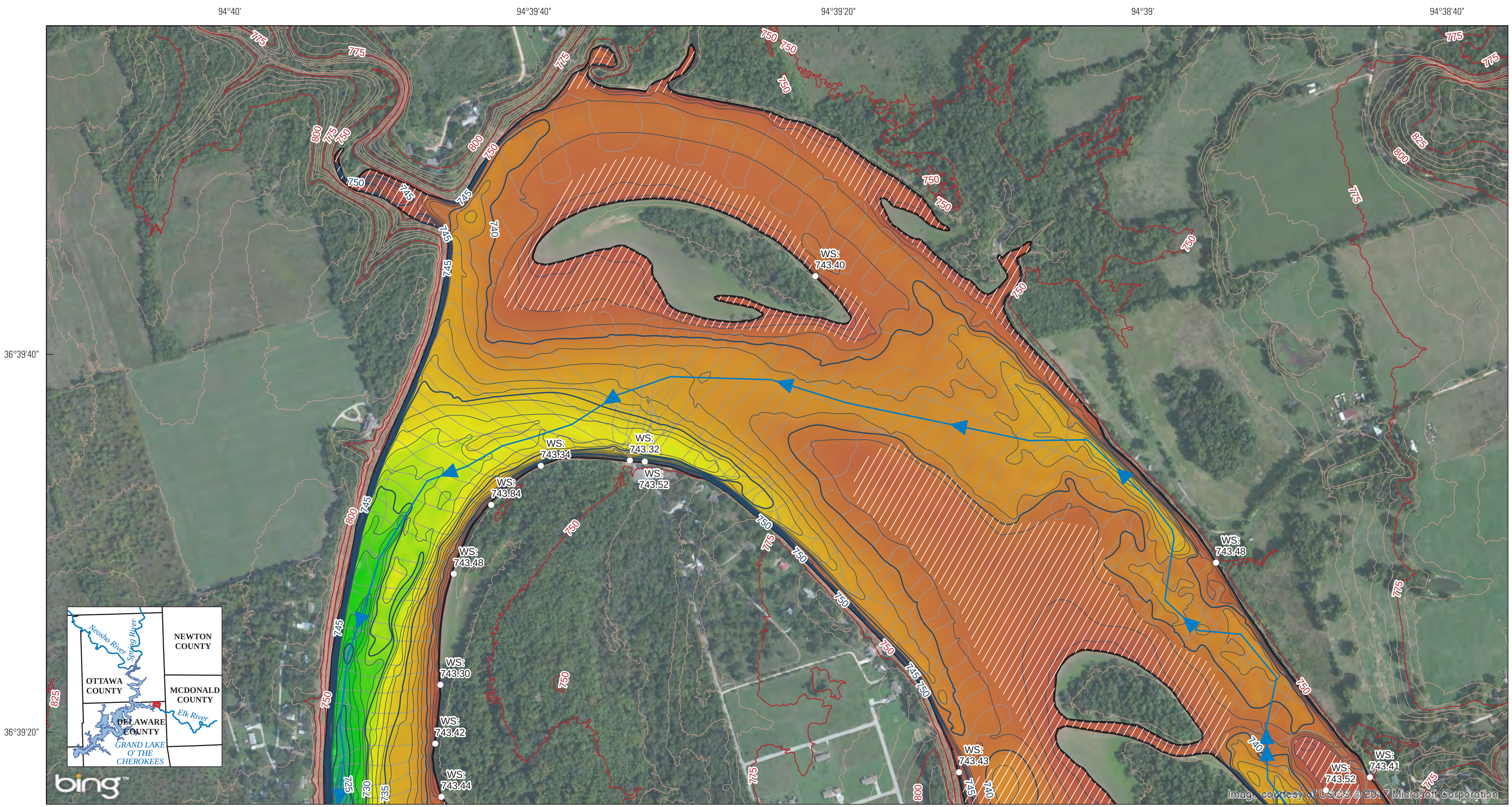
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas



EXPLANATION



Appendix 4–2.



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

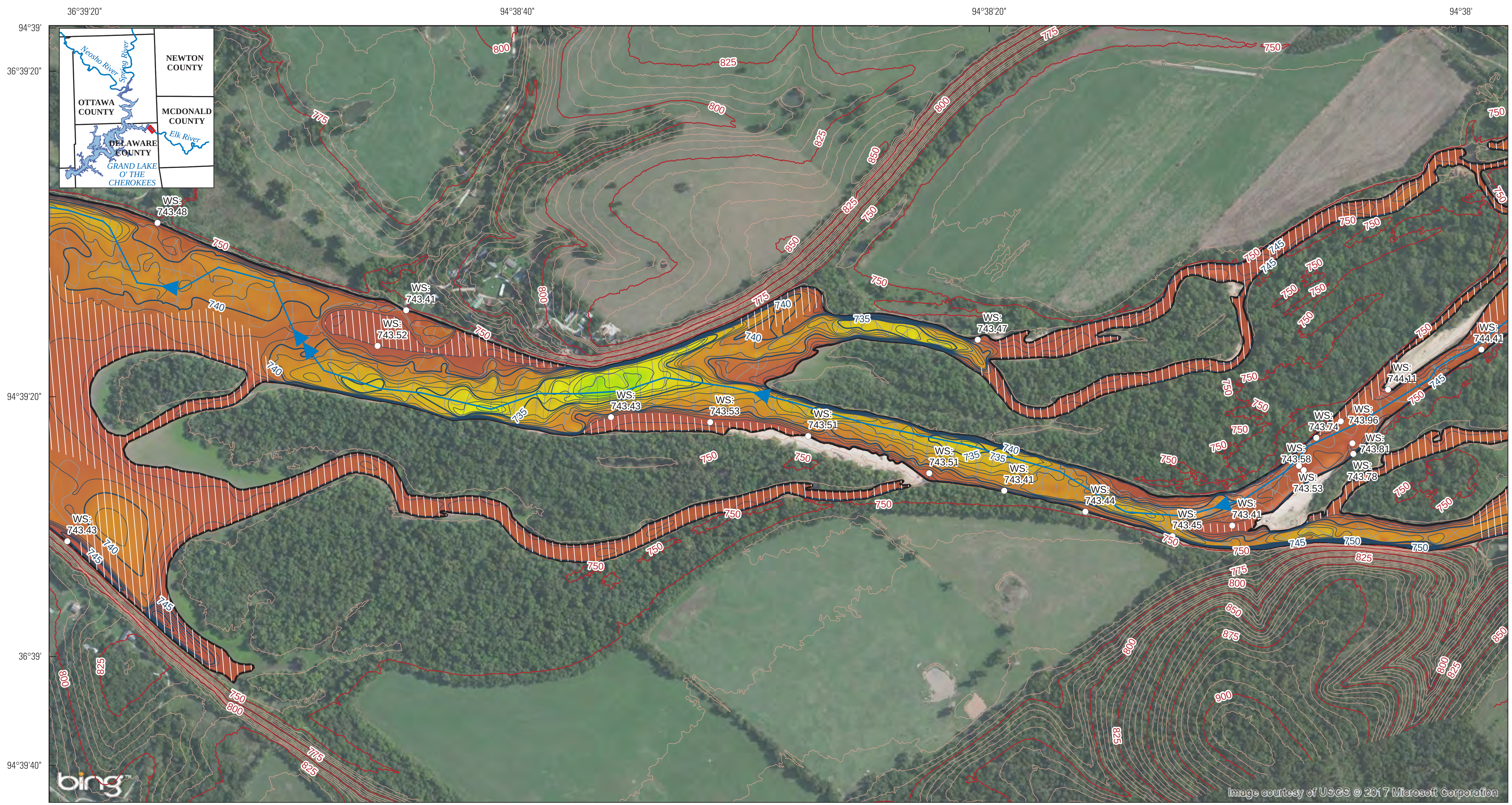
Bathymetric survey depth, in feet (ft)
0
27.78

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 4–3.



Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
27.78

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 4–4.

94°38' 36°38'20" 94°37'40" 94°37'20" 36°38' 94°37'

NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

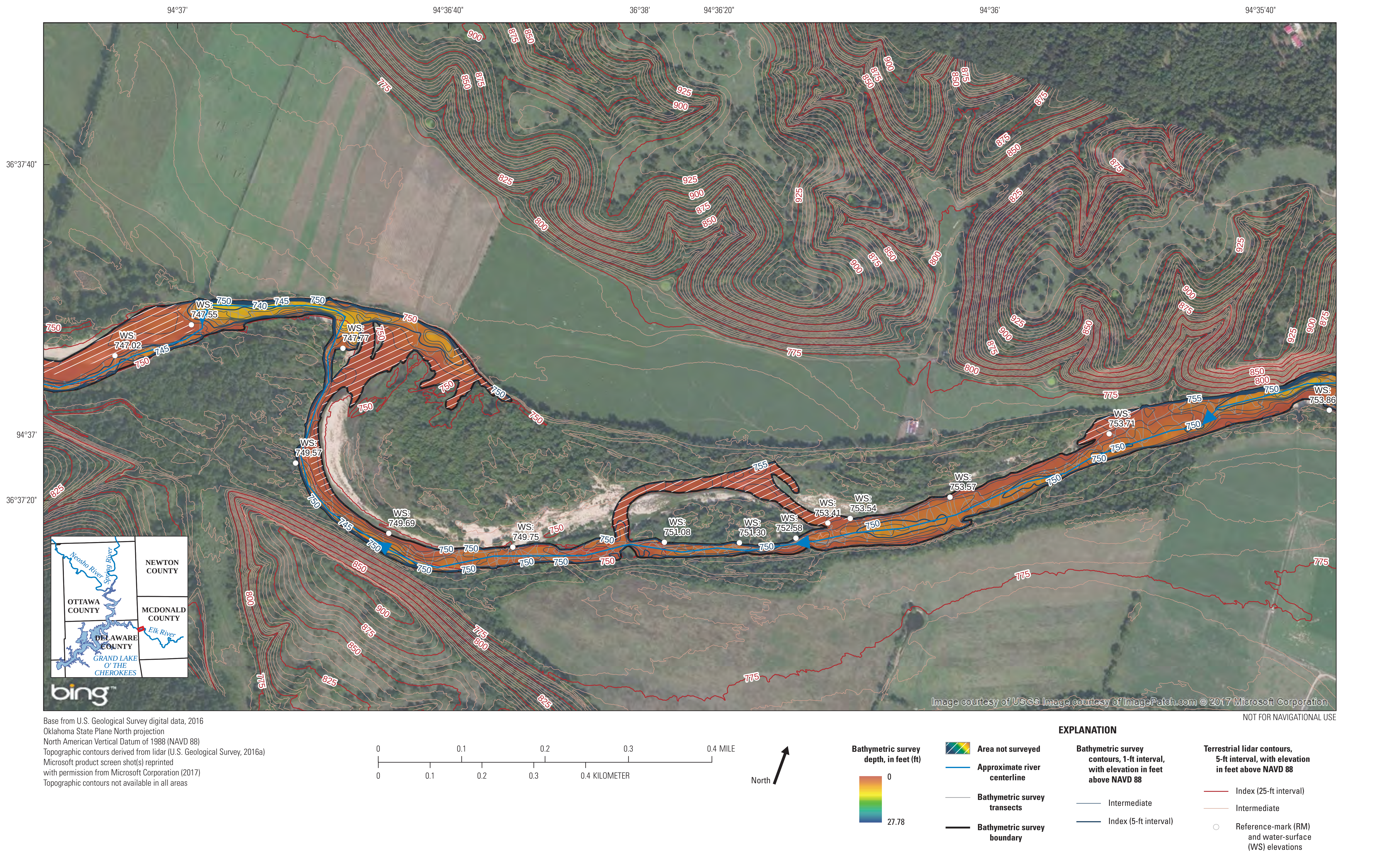
Bathymetric survey depth, in feet (ft)
0
27.78

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

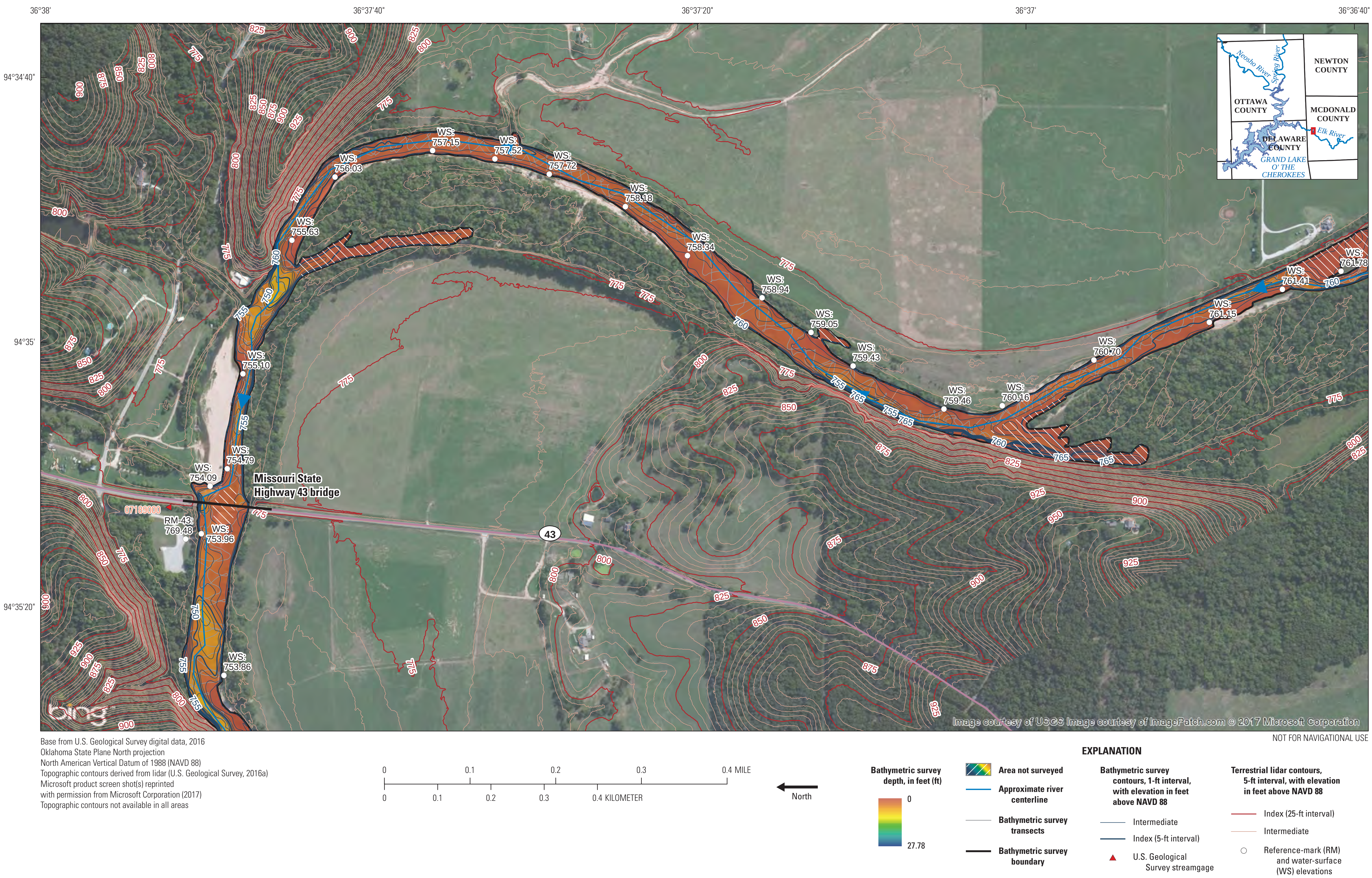
Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 4–5.

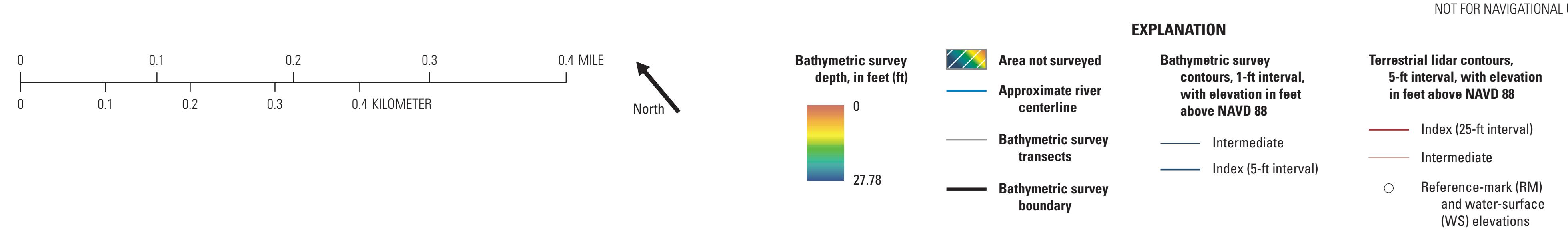

94°37'
94°36'40"
36°38'
94°36'20"
94°36'
94°35'40"
36°37'40"
94°37'
36°37'20"
WS: 747.55
WS: 747.02
WS: 747.77
WS: 749.57
WS: 749.69
WS: 749.75
WS: 751.08
WS: 751.30
WS: 752.58
WS: 753.41
WS: 753.54
WS: 753.57
WS: 753.71
WS: 753.86
NEWTON COUNTY
OTTAWA COUNTY
MCDONALD COUNTY
DELAWARE COUNTY
Neosho River
Spring River
Elk River
GRAND LAKE O' THE CHEROKEES
Image courtesy of USGS Image courtesy of ImagePatch.com © 2017 Microsoft Corporation
NOT FOR NAVIGATIONAL USE
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas
0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER
North
EXPLANATION
Bathymetric survey depth, in feet (ft)
0
27.78
Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary
Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 4–6.


36°38'
36°37'40"
36°37'20"
36°37'
36°36'40"
94°34'40"
94°35'
94°35'20"
NEWTON COUNTY
OTTAWA COUNTY
MCDONALD COUNTY
DELAWARE COUNTY
Neosho River
Spring River
Elk River
GRAND LAKE O' THE CHEROKEES
WS: 757.15
WS: 757.52
WS: 757.72
WS: 756.03
WS: 758.18
WS: 755.63
WS: 758.34
WS: 758.94
WS: 759.05
WS: 759.43
WS: 755.10
WS: 759.46
WS: 760.16
WS: 760.70
WS: 761.15
WS: 761.41
WS: 761.78
WS: 754.79
WS: 754.09
Missouri State Highway 43 bridge
07189000
RM-43: 769.48
WS: 753.96
WS: 753.86
43
Image courtesy of USGS Image courtesy of ImagePatch.com © 2017 Microsoft Corporation
NOT FOR NAVIGATIONAL USE
Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas
0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER
North
EXPLANATION
Bathymetric survey depth, in feet (ft)
0
27.78
Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary
Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)
U.S. Geological Survey streamgage
Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 4–7.

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas



Appendix 4–8.

NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
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Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

Bathymetric survey depth, in feet (ft)
0
27.78

Area not surveyed

Approximate river centerline

Bathymetric survey transects

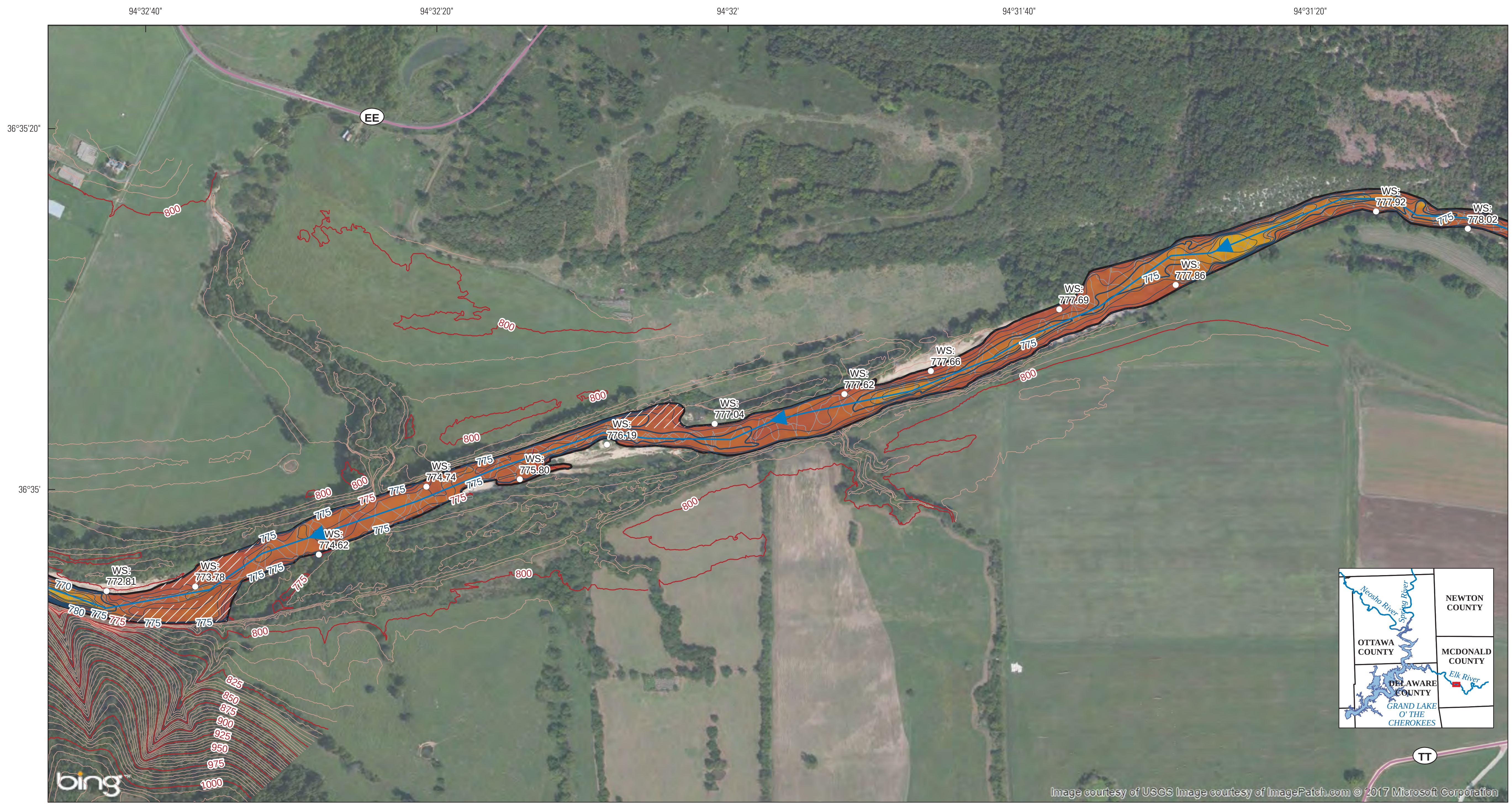
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate

Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 4–9.



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
Microsoft product screen shot(s) reprinted
with permission from Microsoft Corporation (2017)
Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

EXPLANATION

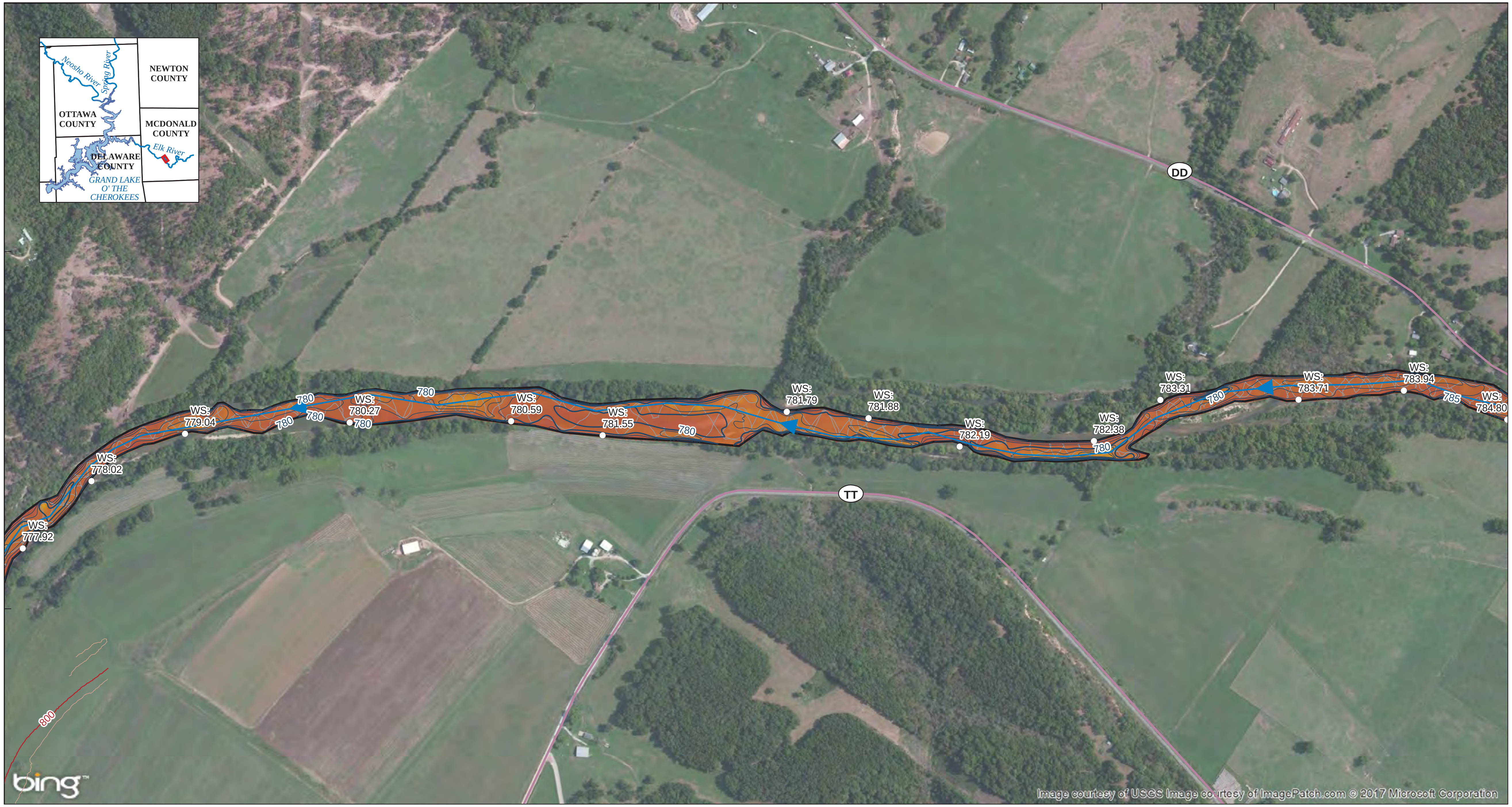
Bathymetric survey depth, in feet (ft)
0
27.78

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 4–10.



NOT FOR NAVIGATIONAL USE

Base from U.S. Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Vertical Datum of 1988 (NAVD 88)
Topographic contours derived from lidar (U.S. Geological Survey, 2016a)
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Topographic contours not available in all areas

0 0.1 0.2 0.3 0.4 MILE
0 0.1 0.2 0.3 0.4 KILOMETER

North

EXPLANATION

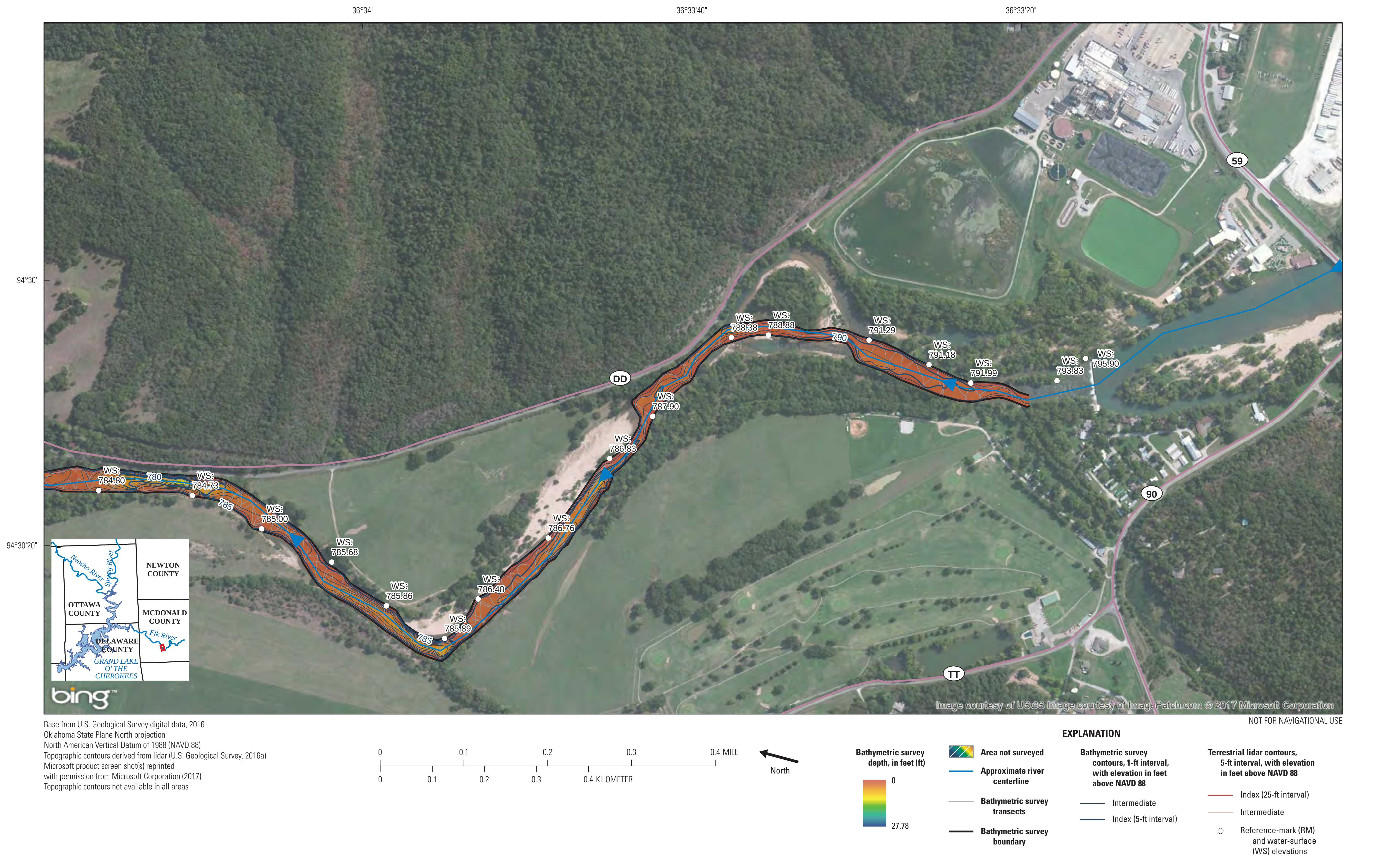
Bathymetric survey depth, in feet (ft)
0
27.78

Area not surveyed
Approximate river centerline
Bathymetric survey transects
Bathymetric survey boundary

Bathymetric survey contours, 1-ft interval, with elevation in feet above NAVD 88
Intermediate
Index (5-ft interval)

Terrestrial lidar contours, 5-ft interval, with elevation in feet above NAVD 88
Index (25-ft interval)
Intermediate
Reference-mark (RM) and water-surface (WS) elevations (Smith and others, 2017)

Appendix 4–11.



Appendix 4–12.

For more information about this publication, contact
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U.S. Geological Survey
202 NW 66th, Building 7
Oklahoma City, OK 73116

For additional information visit https://ok.water.usgs.gov/

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