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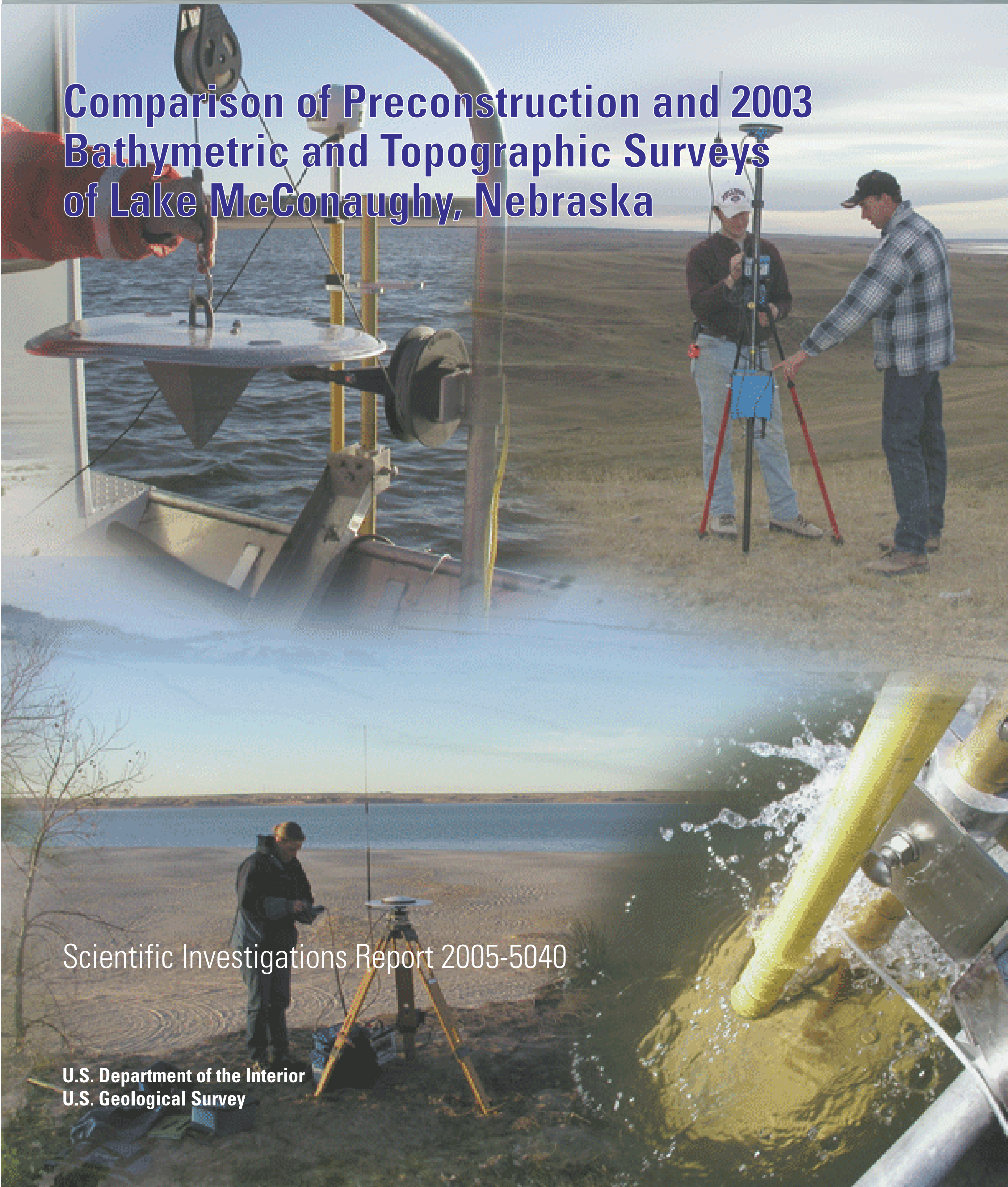
Comparison of Preconstruction and 2003 Bathymetric and Topographic Surveys of Lake McConaughy, Nebraska



Scientific Investigations Report 2005-5040

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

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Comparison of Preconstruction and 2003 Bathymetric and Topographic Surveys of Lake McConaughy, Nebraska

By W.H. Kress, S.K. Sebree, G.R. Littin, M.A. Drain, and M.E. Kling

Prepared in cooperation with

The Central Nebraska Public Power and Irrigation District

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U.S. Geological Survey

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Contents

Plate

[In pocket]

Figures

Table

Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch	2.54	centimeter
foot	0.3048	meter
mile	1.609	kilometer
yard	0.9144	meter
	Area	
acre	0.4047	hectare
square mile	2.590	square kilometer
	Volume	
acre-foot	1,233	cubic meter
acre-foot	1,613.3	cubic yard

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).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Please note that the North American Vertical Datum of 1988 (NAVD 88) utilized in this report differs from the local vertical datum used by Central. The Central datum is an average 1.4 feet lower than NAVD 88 datum. To convert vertical elevations from NAVD 88 to Central vertical datum, CORPSCON software is utilized to convert Geoid99, NAVD88 to WGS84 minus 1.4 feet (Lee Wells, Central Nebraska Public Power and Irrigation District, written commun., 2004).

Comparison of Preconstruction and 2003 Bathymetric and Topographic Surveys of Lake McConaughy, Nebraska

By W.H. Kress, S.K. Sebree, G.R. Littin, M.A. Drain, and M.E. Kling

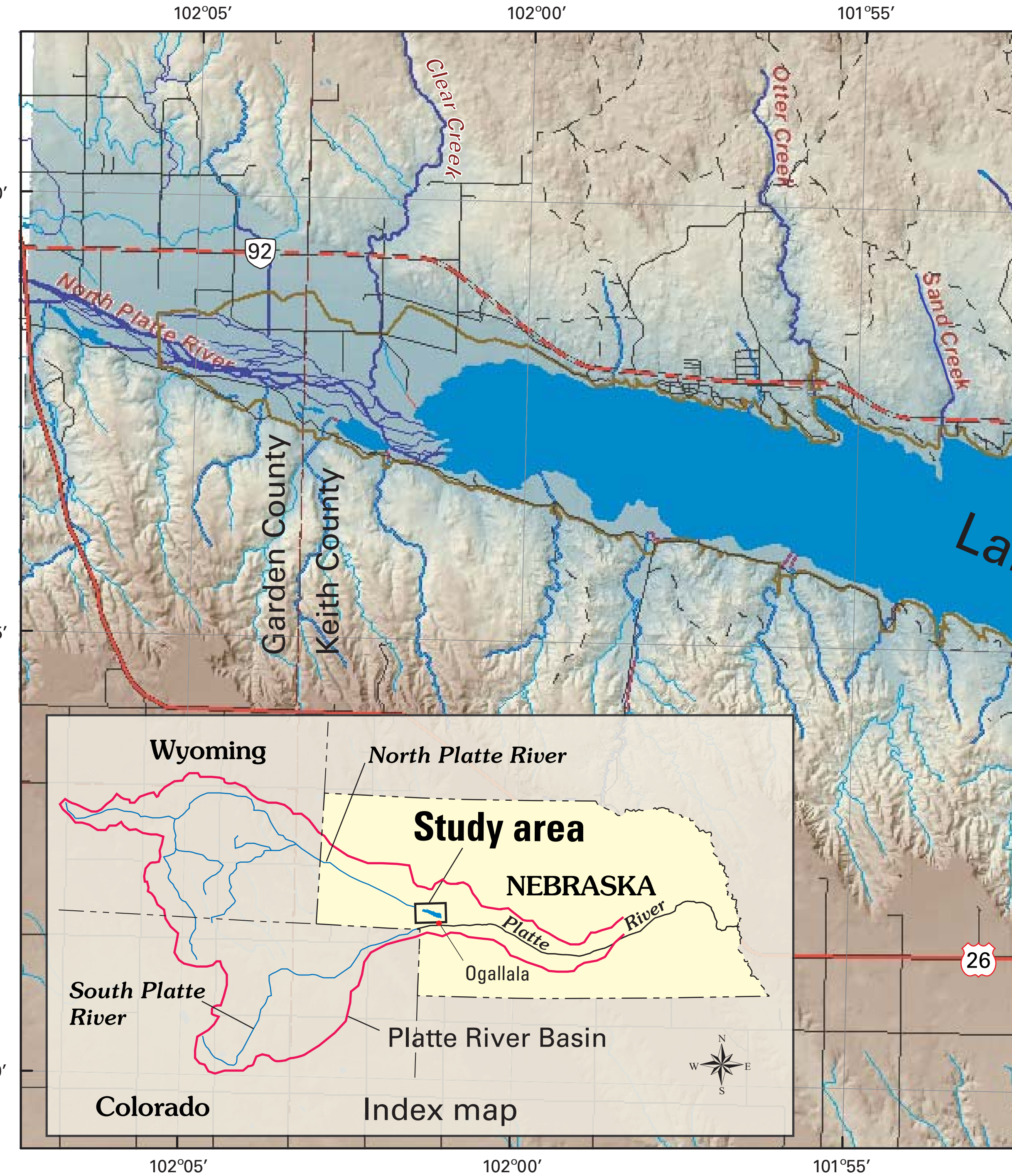
Abstract

The U.S. Geological Survey, in cooperation with The Central Nebraska Public Power and Irrigation District, conducted a study that used bathymetric and topographic surveying in conjunction with Geographical Information Systems techniques to determine the 2003 physical shape, current storage capacity, and the changes in storage capacity of Lake McConaughy that have occurred over the past 62 years. By combining the bathymetric and topographic survey data, the current surface area of Lake McConaughy was determined to be 30,413.0 acres, with a volume of 1,756,300 acre-feet at the lake conservation-pool elevation of 3,266.4 feet above North American Vertical Datum of 1988 (3,265.0 feet above Central datum). To determine the changes in storage of Lake McConaughy, the 2003 survey Digital Elevation Model (DEM) was compared to a preconstruction DEM compiled from historical contour maps. This comparison showed an increase in elevation at the dam site due to the installation of Kingsley Dam. Immediately to the west of the Kingsley Dam is an area of decline where a borrow pit for Kingsley Dam was excavated. The comparison of the preconstruction survey to the 2003 survey also was used to estimate the gross storage capacity reduction that occurred between 1941 and 2002. The results of this comparison indicate a gross storage capacity reduction of approximately 42,372 acre-feet, at the lake conservation-pool elevation of 3,266.4 feet in NAVD 88 (3,265.0 feet in Central datum). By comparing preconstruction and 2003 survey data and subtracting the Kingsley Dam and borrow pit, the total estimated net volume of sediment deposited over the past 62 years is 53,347,124 cubic yards, at an annual average rate of 860,437 cubic yards per year. The approximate decrease in the net storage capacity occurring over the past 62 years is 33,066 acre-feet, at an annual average decrease of approximately 533 acre-feet per year, which has resulted in a 1.8 percent decrease in storage capacity of Lake McConaughy. The lake has accumulated most of the sediment in the original river channel and in the west end of the delta area on the upstream end of the lake.

Introduction

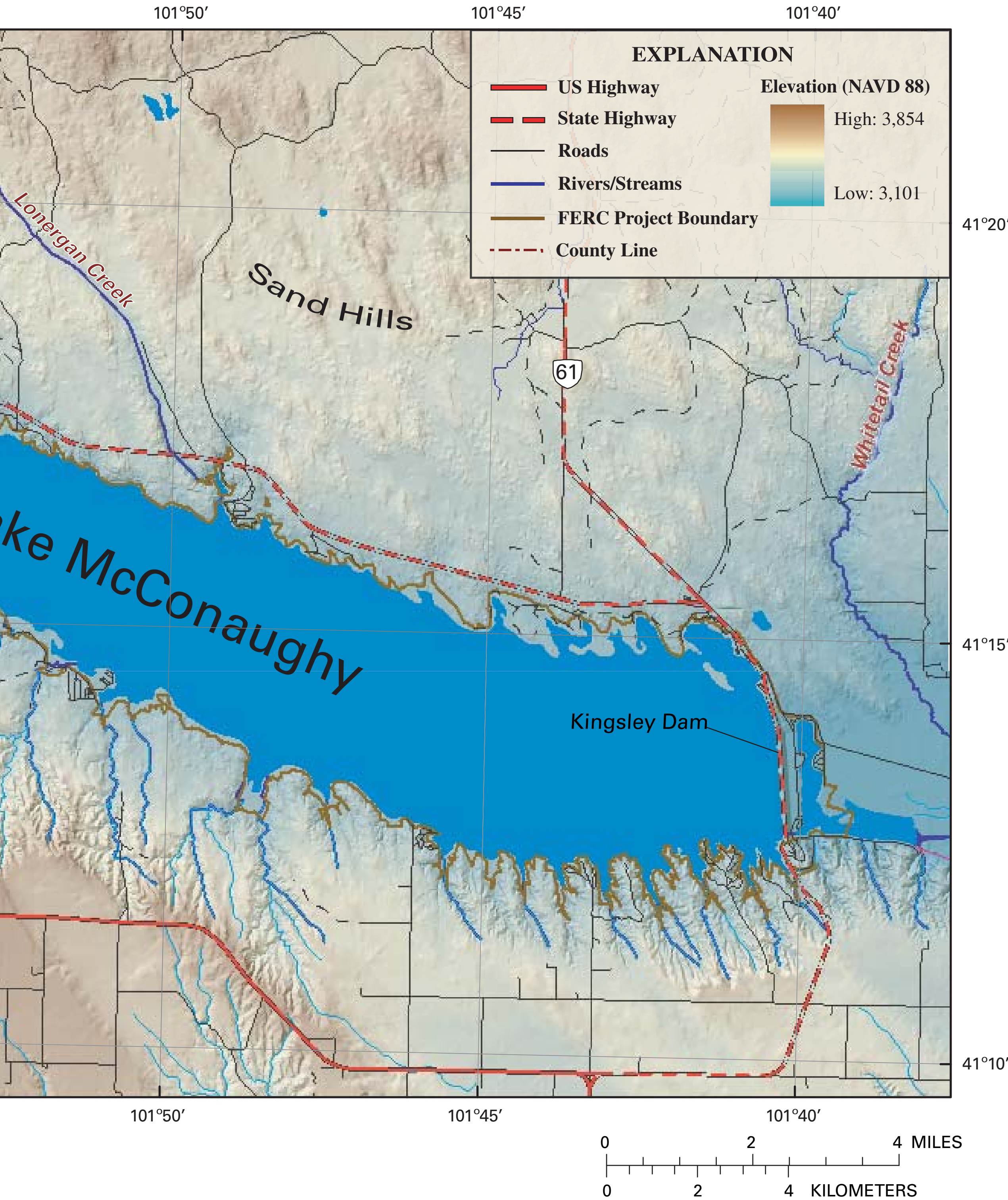
Lake McConaughy located near Ogallala, Nebraska (fig. 1), is owned and operated by The Central Nebraska Public Power and Irrigation District (Central). Lake McConaughy provides a number of benefits, including water storage for irrigation, hydropower production, fish and wildlife habitat, and recreational use. Wildlife habitat includes shoreline nesting areas for the endangered interior least tern and the threatened piping plover (Michael Drain, Central Nebraska Public Power and Irrigation District, written commun., 2004).

Understanding the hydrologic and topographic characteristics of Lake McConaughy, and how those characteristics have changed over time, is essential for the efficient management and protection of this valuable resource. Lake McConaughy has experienced various physical changes as a result of sediment deposition, shoreline erosion, and wind processes during its more than 60 years of operation. Wave erosion is affecting valuable recreational and habitat lands associated with the lake's beaches and shoreline. Much of the topography that defines the bed and shoreline of the lake is subject to continuous change as the result of eolian and hydrologic processes. The amount of sediment deposition in the lower parts of the lake, and by consequence the storage capacity lost, is generally unknown. By combining a bathymetric survey of the landforms below the water surface with a topographic survey of landforms above the water surface, a complete and accurate representation of the current lake topography can be developed. By comparing the new bathymetric and topographic surveys to preconstruction surveys using Geographic Information System (GIS) methodology, quantities and locations of topographic and bathymetric change can be determined. The U.S. Geological Survey (USGS), in cooperation with Central, conducted a study to determine these changes and the storage capacity of Lake McConaughy. The study period to collect new bathymetric and topographic survey data was from December 2002 through August 2003.



Base from U.S. Geological Survery digital data, 1:100,000, 1972
Universal Transverse Mercator projection, Zone 14
Central Meridian -102°

Figure 1. Location of Lake McConaughy, near Ogallala, Nebraska.


101°50′
101°45′
101°40′
EXPLANATION
US Highway
State Highway
Roads
Rivers/Streams
FERC Project Boundary
County Line
Elevation (NAVD 88)
High: 3,854
Low: 3,101
41°20′
41°15′
41°10′
Lonergan Creek
Sand Hills
Whitetail Creek
61
ke McConaughy
Kingsley Dam
0
2
4 MILES
0
2
4 KILOMETERS

The objectives of this study were to (1) document the current 2003 physical shape of Lake McConaughy through a combination of bathymetric and topographic surveys, (2) compare the current 2003 physical shape of the lake to preconstruction 1936 topographic conditions using GIS methods, and (3) provide the bathymetric and topographic information in formats that would facilitate their use in the efficient management and protection of the water and land resources of the lake.

Purpose and Scope

The purpose of this report is to describe a comparison of bathymetric and topographic surveys, particularly with respect to objectives 1 and 2. The methods used to compile preconstruction (1936) survey data and to collect new (2002-2003) survey data also are described. Current conditions, as used in this report, refers to the 2003 conditions based on bathymetric data collected in 2003 and topographic data collected in December 2002.

Description of Lake McConaughy

Lake McConaughy is located along the North Platte River, about 5 miles north of Ogallala, Nebraska (fig. 1). The lake is approximately 22 miles long, 3 miles wide, and includes approximately 30,500 acres at the maximum storage capacity of nearly 2 million acre-feet. Lake McConaughy is the main storage reservoir for Central and is contained by Kingsley Dam, a 3.1-mile long hydraulic-fill dam completed in 1941, and is operated under a license issued by the Federal Energy Regulatory Commission (FERC) (The Central Nebraska Public Power and Irrigation District, 2004). The "normal maximum surface elevation" established by FERC for Lake McConaughy is 3,265.0 feet (Central datum). The North Platte River Basin drains parts of northern Colorado, southern and central Wyoming, and western Nebraska. The North Platte River Basin or basin upstream from Lake McConaughy covers approximately 28,000 square miles. In addition to the North Platte River, a number of small streams including Otter Creek, Sand Creek, and Lonergan Creek flow directly into Lake McConaughy (fig. 1).

Fenneman (1931) defined the physical divisions within the North Platte River Basin. The upstream half of the basin is in the Rocky Mountain System, while the lower half is in the High Plains section of the Great Plains Province. The High Plains section is typified by flat plains with limited stream dissection and little local relief. This section is underlain by fluvial (stream) and eolian (windblown) deposits that consist of sand, gravel, silt, and clay (Fenneman, 1931).

Long-term mean annual precipitation at Lake McConaughy is 18.61 inches (High Plains Regional Climate Center, 2004). Most of the annual precipitation is received during the growing season from April to September.

Methods

Bathymetric and topographic survey data were obtained for preconstruction and 2003 conditions. Preconstruction survey linens were used to produce a preconstruction Digital Elevation Model (DEM) of the area near Lake McConaughy. Linens, as used in this report, are the original media used as a stable base for topographic surveyors. A combination of bathymetric and topographic surveys in conjunction with GIS was used to produce a DEM of Lake McConaughy's 2003 physical shape. Bathymetric surveys included the use of a boat-mounted dual-frequency echo sounder in conjunction with a Differentially corrected Global Positioning System (DGPS). Topographic surveys included available information from preconstruction survey linens provided by Central and new data collected in 2002 using a Real-Time Kinematic Global Positioning System (RTK GPS).

Data collection for both the topographic and the bathymetric surveys were based on a planned-line system (fig. 2). The planned-line system is a series of transects or planned survey lines, across the lake approximately perpendicular to the old riverbed that extend to an elevation of 3,285.0 feet above the North American Vertical Datum of 1988 (NAVD 88) with a 300-meter interval between lines. This interval was determined by reviewing preconstruction maps to maximize the amount of data collected in areas of complex topography.

After a DEM for the preconstruction survey and a DEM for the 2003 survey were completed, the difference between the preconstruction survey and the 2003 survey could be used to estimate changes due to sedimentation and erosion throughout the lake.

Datum

NAVD 88 was used to reference new elevation data collected for this study. The NAVD 88 used in this report differs from the local vertical datum used by Central. According to written communication from Central's surveyor, "The lowering of ... work by 1.4' is a mean I have been using for the District datum for the historical water elevation reference" (Lee Wells, written commun., 2004). This means that the locally utilized Central datum is 1.4 feet lower than NAVD 88 datum.

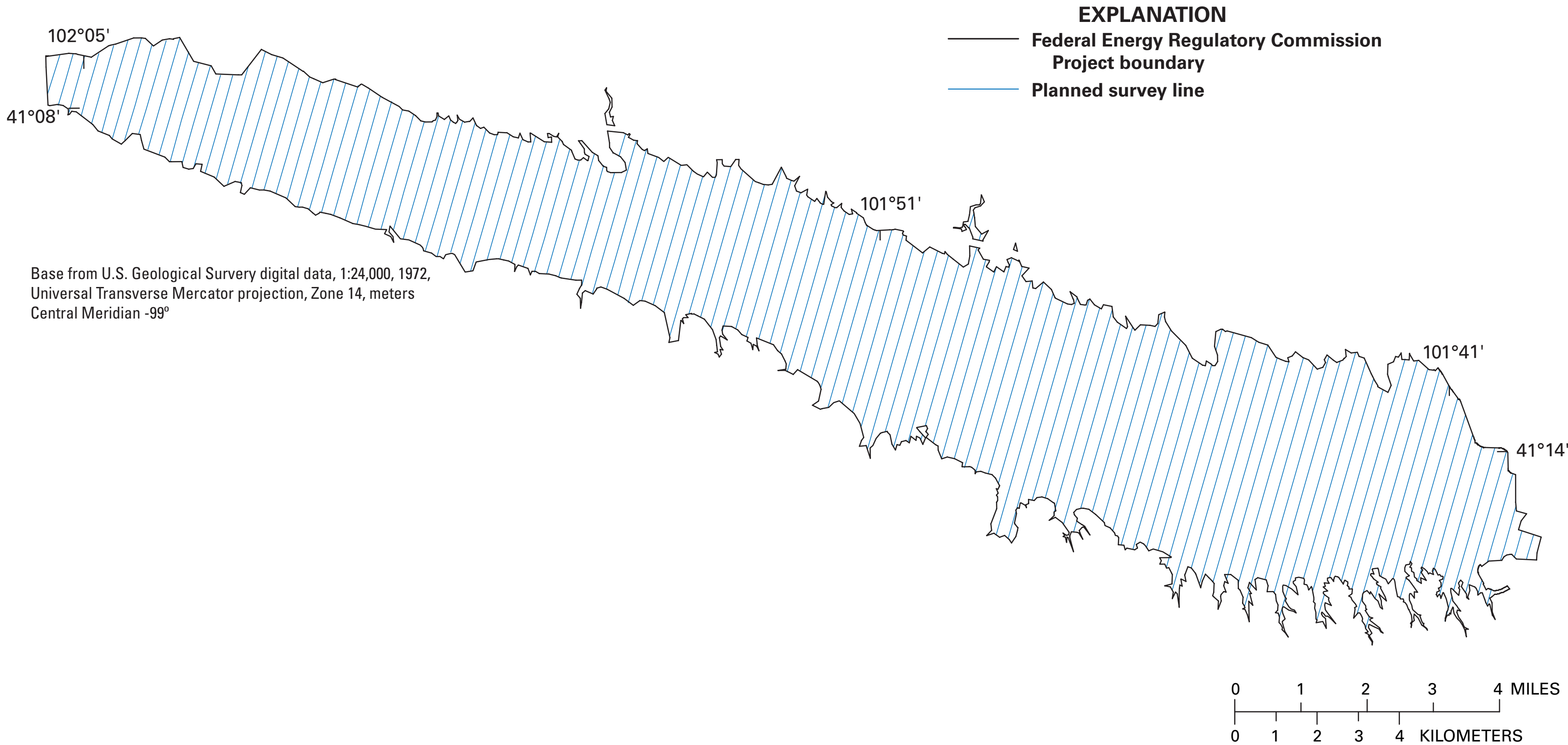


Figure 2. Diagram of planned-line transects, Lake McConaughy, Nebraska.

Preconstruction Survey Compilation

To compare the 2003 physical shape of the lake to preconstruction topographic conditions Central provided scanned files of ninety-nine 1936 preconstruction survey linens. The original 1936 linen sectional contour maps were scanned at 300 dots per inch (dpi) by Central and delivered as black and white Tagged Image File Format (TIFF) image files to the USGS Mid-Continent Mapping Center, Rolla, Missouri (fig. 3). Surveying methods used to develop the preconstruction linen contour maps were very time intensive and could only provide general topographic information to effectively map such an extensive area. In some cases where linens from two 1936 independent surveying groups for this study were joined, topographic contours had been interpreted differently and did not match well.

The TIFF image files were georeferenced so that they could be used as source data for DEMs. Horizontal coordinates for the section corners were not available as part of the scanned linens, so the section corner locations were identified on USGS Digital Raster Graphics (DRGs) and the North American Datum of 1927 (NAD 27), Universal Transverse Mercator (UTM) horizontal coordinates of the section corners were recorded. In the cases where section corners were not shown on the map, positions were estimated from the other section corners in the vicinity. This was done with as much accuracy as possible; however, the calculation of a root mean square error is not possible, and the final accuracy is unknown. The section corner coordinates were then translated into NAD 83 using geographic conversion software.

The TIFF images were georeferenced using the translated section corner coordinates in a proprietary image processing software package. After some automated raster clean up, the images were vectorized. Elevation attributes were added to as many of the contour line segments as possible. The contour lines were then exported as Map Overlay and Statistical System (MOSS) vector files. All of the lines vectorized from the TIFF images were exported as Tagged Vector Contour (TVC) files in a Digital Line Graph-3 (DLG3) format.

Tiles of 4 kilometer by 4 kilometer were created to organize the data into a workable file size. The MOSS contour files were imported into the tiles and were edited. An attempt was made to join all section edges, but in many cases the original linen contour sheets were not edge-joined. Broken contour lines were repaired when it was necessary to create a smooth surface. River bank vectors were added from the TVC files to help confirm and produce the DEM surface. Finally, the DEMs were exported and combined. Some areas of the DEM were filtered to help smooth the areas where contours did not join. The river banks were used again to help enforce the river channel in the DEM surface. After the DEMs were edited, 2-foot contours were generated, and unneeded vertices were removed.

The resulting DEM and contours were sufficient for the purposes of estimating preconstruction lake volumes and changes. DEMs and contours that more accurately reproduce the source contour maps could be produced by using all of the non-contour data on the section maps and by having the exact section corner coordinates available, but this process would require significantly greater effort, and probably would only

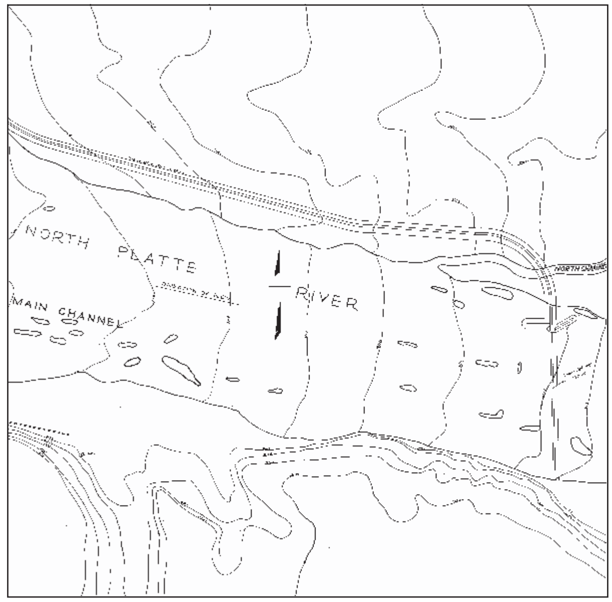


Figure 3. Example of a scanned 1936 section of survey linen, Lake McConaughy, Nebraska.

slightly improve the accuracy and quality of the resulting DEM surface. Because the accuracy of the original surveying is unknown, this additional effort was not justified.

After the completion of the preconstruction DEM (fig. 4), Central located the true coordinates for the section corners that previously were not known. The estimated section corners from the DRGs were then transformed to the true section corner coordinates. ERDAS© software (Leica Geosystems, 2003) was used to perform a linear rubber sheeting of the DEM that was constructed with inaccurate section corner coordinates. Inspection of the rubber sheeted DEM showed that the DEM had changed, and that the changes were consistent with the expected results, but the changes were minor and the preconstruction DEM shown in figure 4 was used in comparison with the 2003 DEM.

Bathymetric Survey

The current bathymetric (lakebed elevation) survey of Lake McConaughy was conducted by the USGS during the spring of 2003. The survey included 123 transects. Depth data were collected using an Innerspace Technologies 456 survey grade dual-frequency echo sounder (Innerspace Technology, 2001) mounted on a USGS boat. Geographic positioning of the sounder was accomplished with a DGPS antenna mounted over the sounder transducer. The dual frequency transducer uses a high frequency (200 kilohertz (kHz)) pulse, which was used to map the present lake bottom, and a low frequency (24 kHz) pulse, which was used in an attempt to map the preconstruction land surface. Using the low frequency data, a DEM could be constructed and compared to the preconstruction DEM. Comparisons of the low frequency DEM and the preconstruction DEM could be used to ascertain the potential success of using a single low frequency (24 kHz) to map preconstruction surfaces in similar lakes that do not have detailed preconstruction surveys.

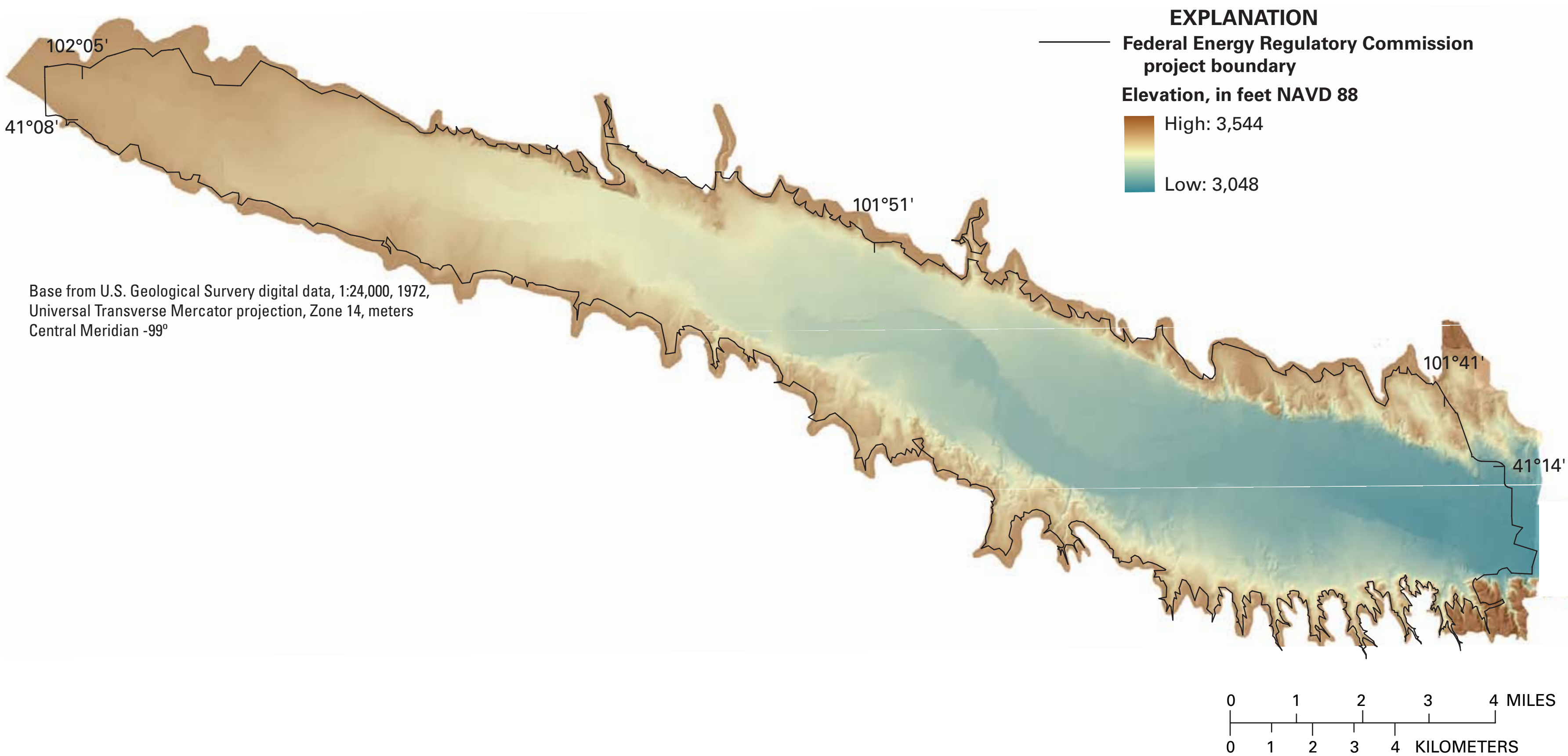


Figure 4. Preconstruction survey Digital Elevation Model (DEM) representing the preconstruction topographic surface, Lake McConaughy, Nebraska.

Dual-frequency echo-sounder systems are sometimes used to estimate sediment thickness underlying lake bottoms. The dual-frequency system uses two transducers that convert electronic energy into two simultaneous acoustic pulses, one high-frequency and one low-frequency pulse. As the two pulses propagate through the water column, a proportion of the acoustic energy from both frequencies is absorbed. The remaining high-frequency energy pulse becomes reflected at the water-lakebed interface (top of the lake sediment), while a proportion of the low-frequency energy pulse continues to propagate through the lakebed sediment until it is reflected at the next competent change in material density, which is presumed to be the preconstruction surface (hardpan top).

Acoustic depth measurement systems measure the elapsed time that an acoustic pulse (sound wave) takes to travel from a generating transducer to the bottom material (signal reflector) and back.

$$D=1/2 * v * t \qquad (1)$$

The depth to each reflector (D) in equation 1 is a function of the two-way traveltime (t) (the time it takes for the signal to travel from the transducer to the reflective layer and back to the transducer) and the velocity of sound in water (v) (eq. 1).

Water-surface elevation was measured twice a day using the RTK GPS. Measurements of the water-surface elevation were collected at the edge of the lake near the location where bathymetric data were being collected. The water-surface elevation data were collected in NAVD 88 and input into a bathymetric processing software package that corrected the depth values collected by the echo sounder to elevation values. Because the original elevations of the bathymetric points were recorded by the echo sounder in meters, elevation and depth attributes (in feet) were added to the coverage.

Topographic Survey

The current topographic survey was conducted in December 2002, when the lake water level was near its yearly low. The topographic survey extended the bathymetric transects to an elevation of 3,285.0 feet (NAVD 88) and was designed to provide information on the present physical shape of the lake bed above the water surface and the changes caused by erosion and other processes. The data above water surface, or topographic land survey, was collected using an RTK GPS. The RTK GPS base station was established using existing benchmarks and a rover GPS was used to extend data collection above the water surface along each transect in the planned-line system. This original planned-line file was supplemented by a high concentration of survey points collected in areas of gradual and steep slopes.

For survey purposes, a network of benchmarks (BMs) was used to establish horizontal and vertical control at Lake McConaughy. No first order vertical and horizontal control was available at the lake. Datum from BM MM0333, at the Searle Field Airport (OGA) near Ogallala, was used to establish control at existing benchmarks along the lake (fig. 5). A base station GPS was set-up on BM MM0333 and was checked against rover data collected at BM MM0334 and AB4116. The base station GPS was then moved to BM MM0481 and the rover was set up on MM0333, at the Searle Field Airport (OGA), to back check the accuracy of BM MM0481. After MM0481 was checked, datum was carried out to BMs MM0476 and AB4115. A base station was then set up on MM0481 to establish a temporary BM named EAGLE. BM MM0476 was used to create a temporary benchmark named West Martin Bay 1 (WMB1). All data from base station setups were stored and processed using National Geodetic Surveys (NGS) Online Positioning User System (OPUS) (National Geodetic Survey, 2004) to verify the base station setups. Benchmarks were selected for data collection depending on the proximity to the area being mapped. When a benchmark was used as a base station, data were verified by comparing rover data from another nearby benchmark.

Quality Assurance/Quality Control

Two bathymetric transects were collected during different data collection events to check the repeatability of the bathymetric data. Bar checks were conducted during crew changes and equipment movement. Bar checks correct for velocity variations, draft variations, and index errors in the echo sounding system (U.S. Army Corps of Engineers, 2002). A bar check is a quality-control procedure in which a plate is suspended to a known depth below the water surface and under the transducer. A series of depth intervals are observed down to the approximate maximum depth to be surveyed. Differences between the bar checks and recorded depths represent corrections to be made to the recorded soundings (U.S. Army Corps of Engineers, 2002). Soundings from the transducer were corrected for water-surface elevation changes by collecting water-surface elevation data using an RTK GPS near the area where the bathymetric survey was being conducted.

The water level of Lake McConaughy fluctuates throughout the year, primarily reflecting an irrigation season drawdown and a non-irrigation season fill. The lake is usually at its minimum level when the irrigation season ends, and maximum water-level elevations usually occur in late spring. The topographic data were collected when the lake elevation was near its annual minimum and bathymetric data were collected when the lake elevation was near its annual maximum. This process provided an overlapping zone of bathymetric and topographic data (fig. 5) that could be compared to determine the accuracy of each method.

Data from the 2003 bathymetric and 2002 topographic surveys were plotted onto a 2003 Digital Orthophoto Quadrangle (DOQ) in ArcMap (ESRI, 2003), to ensure the points were plotting in the correct horizontal position. For a vertical data inspection, ArcScene (ESRI, 2003) was used to display with exaggeration the local elevation trends of the lakebed based on surveyed points. The topographic points were plotted onto a 10-meter DEM to check for anomalies. Approximately 1 percent of the points were identified as anomalies and removed.

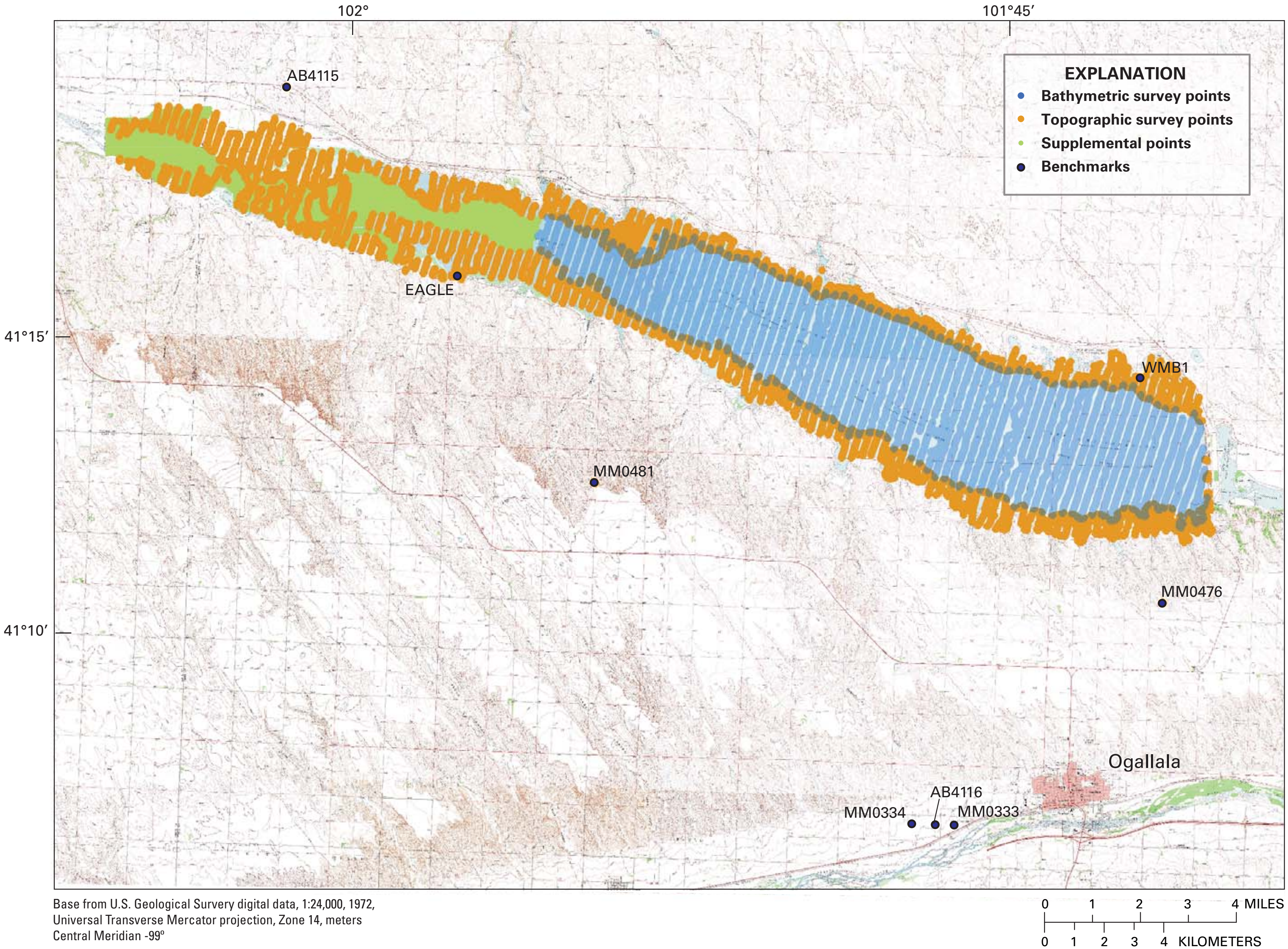


Figure 5. Bathymetric, topographic, supplemental, and benchmark locations, Lake McConaughy, Nebraska.

2003 Survey Compilation

The 2003 survey Triangulated Irregular Network (TIN) was developed by combining the 200 kHz bathymetric data points with the topographic survey data points. Before combining the two sets of points, the bathymetric points were thinned using an algorithm that only retained elevation (Z) values with at least 0.3 foot difference. This reduced the number of original bathymetric points from 1.2 million to less than 0.3 million, or 77 percent. The bathymetric and topographic points were combined and used to generate a TIN. The TIN was converted to a DEM and supplemental data added. Supplemental data were used on the west end of the lake (fig. 5), where survey equipment was not able to penetrate dense vegetation and shallow water. The data, Shuttle Radar Topography Mission (SRTM), was collected from the space shuttle in 2000, and has a vertical accuracy of +/- 18 in. The SRTM data was added as a second DEM surface. The two DEM surfaces were mosaiced into a final DEM surface. The 2003 survey DEM was then used to construct elevation contours of the 2003 lakebed surface and surrounding topography.

Bathymetric and Topographic Surveys

GIS methods were used to develop and compare DEMs of the preconstruction topographic surface (fig. 4) to current bathymetric and topographic surfaces (fig. 6). A volume table for Lake McConaughy for 2003 was developed to show lake volume at various water-surface elevations. Data were extracted from the DEMs to determine the usefulness of low-frequency (24 kHz) echo-sounding techniques to measure sediment deposition.

Contour Map

The 2003 contour map (plate 1, in pocket at back of report) was generated from the 2003 survey DEM at 5-foot intervals. The lakebed contours below the pool elevation of 3,265.0 ft (NAVD 88) are symbolized in blue line, while the topographic elevation above 3,265.0 feet (NAVD 88) are shown in a thinner brown line. The lowest lakebed elevation contour shown is 3,105.0 feet near the northeast part of the dam (plate 1).

Volume Table

The lake volume table (table 1) was calculated from the TIN, which was developed from the 2003 survey DEM. The minimum elevation of the volume table is 3,097.0 feet in NAVD 88 (3,095.6 feet in Central datum), and the maximum elevation is 3,266.4 feet in NAVD 88 (3,265.0 feet in Central datum) (table 1). The surface area at elevation 3,266.4 feet in NAVD 88 (3,265.0 feet in Central datum) is 30,413.0 acres, with a volume of 1,756,300 acre-feet.

Low Frequency Data Evaluation

A low-frequency DEM was constructed from the low-frequency echo sounder bathymetric point data (fig. 7). Shallow near-shore areas were not sounded due to draft limitations of the boat and acoustic sensitivity of the low-frequency signal at shallow depths. Therefore, the low-frequency DEM data do not extend to the shoreline.

The low frequency data generally follow the lake bed contours in water depths greater than 10 feet and less than 50 feet. GIS was used to develop four representative cross sections along the lake at intervals to evaluate the effectiveness of the low-frequency data (fig. 8). Cross sections were selected such that they were representative of conditions in the shallow upstream end of the lake where bathymetric data collection started, and in the deeper parts in the lower section of the lake.

It was anticipated that the low-frequency data would closely follow the original preconstruction survey surface. However, in cross sections A-A′, C-C′, and D-D′ (fig. 9), the low-frequency data do not indicate the ability to penetrate the lakebed deposits. In fact, the data either track closely with the high-frequency data or show a shallower elevation than the high frequency data. Cross section B-B′ shows some penetration into the lake deposits; however, it does not closely follow the preconstruction survey surface.

Comparison of Preconstruction Survey to 2003 Survey

A change in storage map (fig. 10) was calculated by subtracting the preconstruction DEM (fig. 4) from the 2003 survey DEM (fig. 6). Land-surface elevations were approximately 160 feet greater in 2003 than preconstruction at the dam site due to the installation of Kingsley Dam. Immediately to the west of the Kingsley Dam is an area of decline, as much as 160 feet, where a borrow pit was excavated to complete the earthen dam. Areas of apparent erosion occur along the southeast and northern shoreline. Areas of increases in elevation of 5 to 20 feet, indicating sedimentation, occurred in the original North Platte stream channel. Although extensive areas of the lakebed with slight (0.5 to 3.0 feet) declines in elevation could be interpreted as indicating erosion, these areas may reflect minor inaccuracies (both horizontal and vertical) in the original datasets, or problems with the gridding algorithms used.

Figure 6. Current survey Digital Elevation Model (DEM), 2003, Lake McConaughy, Nebraska.

Table 1. Volume table of current survey Digital Elevation Model (DEM) for Lake McConaughy, 2003.

[NAVD 88, North American Vertical Datum of 1988; Central, Central Nebraska Public Power and Irrigation District vertical datum]

Water-surface elevation (feet) (NAVD 88)	Water-surface elevation (feet) (Central)	Lake area (acres)	Lake volume (acre-feet)	Water-surface elevation (feet) (NAVD 88)	Water-surface elevation (feet) (Central)	Lake area (acres)	Lake volume (acre-feet)
3,097.0	3,095.6	0.0	0.0	3,139.0	3,137.6	508.9	6,021.6
3,098.0	3,096.6	0.4	0.2	3,140.0	3,138.6	600.7	6,576.5
3,099.0	3,097.6	1.6	1.1	3,141.0	3,139.6	689.5	7,222.1
3,100.0	3,098.6	3.8	3.8	3,142.0	3,140.6	777.4	7,955.1
3,101.0	3,099.6	6.5	8.9	3,143.0	3,141.6	876.3	8,781.6
3,102.0	3,100.6	10.1	17.1	3,144.0	3,142.6	1,001.5	9,718.6
3,103.0	3,101.6	15.9	30.0	3,145.0	3,143.6	1,125.5	10,782
3,104.0	3,102.6	21.5	48.7	3,146.0	3,144.6	1,245.7	11,967
3,105.0	3,103.6	27.7	73.3	3,147.0	3,145.6	1,373.9	13,275
3,106.0	3,104.6	33.2	103.9	3,148.0	3,146.6	1,534.5	14,730
3,107.0	3,105.6	38.4	139.6	3,149.0	3,147.6	1,668.6	16,333
3,108.0	3,106.6	43.6	180.6	3,150.0	3,148.6	1,840.6	18,085
3,109.0	3,107.6	49.1	226.9	3,151.0	3,149.6	2,004.8	20,009
3,110.0	3,108.6	54.7	278.8	3,152.0	3,150.6	2,134.0	22,079
3,111.0	3,109.6	60.7	336.4	3,153.0	3,151.6	2,268.3	24,278
3,112.0	3,110.6	67.1	400.3	3,154.0	3,152.6	2,417.3	26,619
3,113.0	3,111.6	74.4	471.0	3,155.0	3,153.6	2,607.8	29,131
3,114.0	3,112.6	82.8	549.5	3,156.0	3,154.6	2,786.1	31,828
3,115.0	3,113.6	95.0	637.9	3,157.0	3,155.6	2,995.7	34,718
3,116.0	3,114.6	107.0	739.0	3,158.0	3,156.6	3,204.9	37,815
3,117.0	3,115.6	117.8	851.5	3,159.0	3,157.6	3,406.9	41,123
3,118.0	3,116.6	127.8	974.4	3,160.0	3,158.6	3,586.2	44,623
3,119.0	3,117.6	137.1	1,106.9	3,161.0	3,159.6	3,764.1	48,296
3,120.0	3,118.6	146.4	1,248.6	3,162.0	3,160.6	3,958.9	52,157
3,121.0	3,119.6	156.4	1,400.0	3,163.0	3,161.6	4,184.8	56,222
3,122.0	3,120.6	165.8	1,561.1	3,164.0	3,162.6	4,457.1	60,546
3,123.0	3,121.6	175.1	1,731.6	3,165.0	3,163.6	4,696.4	65,127
3,124.0	3,122.6	184.3	1,911.2	3,166.0	3,164.6	4,916.6	69,933
3,125.0	3,123.6	193.7	2,100.3	3,167.0	3,165.6	5,174.3	74,978
3,126.0	3,124.6	203.2	2,298.7	3,168.0	3,166.6	5,440.1	80,286
3,127.0	3,125.6	212.7	2,506.7	3,169.0	3,167.6	5,708.5	85,862
3,128.0	3,126.6	222.3	2,724.2	3,170.0	3,168.6	5,940.9	91,686
3,129.0	3,127.6	232.1	2,951.3	3,171.0	3,169.6	6,169.2	97,741
3,130.0	3,128.6	241.8	3,188.2	3,172.0	3,170.6	6,408.0	104,030
3,131.0	3,129.6	251.6	3,434.9	3,173.0	3,171.6	6,635.8	110,550
3,132.0	3,130.6	261.4	3,691.4	3,174.0	3,172.6	6,858.0	117,300
3,133.0	3,131.6	271.2	3,957.7	3,175.0	3,173.6	7,085.6	124,270
3,134.0	3,132.6	281.2	4,233.8	3,176.0	3,174.6	7,309.4	131,470
3,135.0	3,133.6	293.0	4,520.6	3,177.0	3,175.6	7,549.4	138,900
3,136.0	3,134.6	316.9	4,824.5	3,178.0	3,176.6	7,800.1	146,570
3,137.0	3,135.6	362.8	5,161.3	3,179.0	3,177.6	8,033.8	154,490
3,138.0	3,136.6	427.5	5,555.4	3,180.0	3,178.6	8,256.7	162,630

Table 1. Volume table of current survey Digital Elevation Model (DEM) for Lake McConaughy, 2003.—Continued

[NAVD 88, North American Vertical Datum of 1988; Central, Central Nebraska Public Power and Irrigation District vertical datum]

Water-surface elevation (feet) (NAVD 88)	Water-surface elevation (feet) (Central)	Lake area (acres)	Lake volume (acre-feet)	Water-surface elevation (feet) (NAVD 88)	Water-surface elevation (feet) (Central)	Lake area (acres)	Lake volume (acre-feet)
3,181.0	3,179.6	8,480.7	171,000	3,224.0	3,222.6	18,507.3	747,230
3,182.0	3,180.6	8,716.3	179,600	3,225.0	3,223.6	18,691.2	765,830
3,183.0	3,181.6	8,929.2	188,420	3,226.0	3,224.6	18,888.9	784,620
3,184.0	3,182.6	9,140.7	197,450	3,227.0	3,225.6	19,089.7	803,610
3,185.0	3,183.6	9,333.3	206,690	3,228.0	3,226.6	19,299.6	822,800
3,186.0	3,184.6	9,512.5	216,120	3,229.0	3,227.6	19,537.5	842,220
3,187.0	3,185.6	9,748.5	225,730	3,230.0	3,228.6	19,770.9	861,880
3,188.0	3,186.6	10,012.5	235,610	3,231.0	3,229.6	20,010.1	881,760
3,189.0	3,187.6	10,280.5	245,760	3,232.0	3,230.6	20,290.8	901,920
3,190.0	3,188.6	10,517.8	256,170	3,233.0	3,231.6	20,510.9	922,320
3,191.0	3,189.6	10,729.6	266,790	3,234.0	3,232.6	20,760.5	942,950
3,192.0	3,190.6	10,983.9	277,650	3,235.0	3,233.6	20,969.0	963,820
3,193.0	3,191.6	11,175.6	288,730	3,236.0	3,234.6	21,176.7	984,900
3,194.0	3,192.6	11,361.6	300,000	3,237.0	3,235.6	21,399.5	1,006,200
3,195.0	3,193.6	11,569.7	311,470	3,238.0	3,236.6	21,662.9	1,027,700
3,196.0	3,194.6	11,729.0	323,120	3,239.0	3,237.6	21,911.3	1,049,500
3,197.0	3,195.6	11,909.9	334,930	3,240.0	3,238.6	22,146.7	1,071,500
3,198.0	3,196.6	12,145.0	346,960	3,241.0	3,239.6	22,383.7	1,093,800
3,199.0	3,197.6	12,351.9	359,210	3,242.0	3,240.6	22,620.8	1,116,300
3,200.0	3,198.6	12,569.7	371,670	3,243.0	3,241.6	22,871.5	1,139,000
3,201.0	3,199.6	12,836.5	384,370	3,244.0	3,242.6	23,109.9	1,162,000
3,202.0	3,200.6	13,099.9	397,340	3,245.0	3,243.6	23,394.2	1,185,300
3,203.0	3,201.6	13,353.0	410,560	3,246.0	3,244.6	23,693.6	1,208,800
3,204.0	3,202.6	13,625.4	424,050	3,247.0	3,245.6	24,009.5	1,232,700
3,205.0	3,203.6	13,910.4	437,820	3,248.0	3,246.6	24,350.6	1,256,800
3,206.0	3,204.6	14,196.3	451,870	3,249.0	3,247.6	24,669.2	1,281,400
3,207.0	3,205.6	14,484.2	466,210	3,250.0	3,248.6	25,000.3	1,306,200
3,208.0	3,206.6	14,776.2	480,840	3,251.0	3,249.6	25,356.3	1,331,400
3,209.0	3,207.6	15,064.4	495,770	3,252.0	3,250.6	25,973.6	1,356,900
3,210.0	3,208.6	15,291.0	510,940	3,253.0	3,251.6	26,539.3	1,383,200
3,211.0	3,209.6	15,491.8	526,340	3,254.0	3,252.6	26,957.5	1,410,000
3,212.0	3,210.6	15,690.2	541,930	3,255.0	3,253.6	27,347.1	1,437,100
3,213.0	3,211.6	15,896.6	557,720	3,256.0	3,254.6	27,706.2	1,464,600
3,214.0	3,212.6	16,143.4	573,730	3,257.0	3,255.6	28,022.3	1,492,500
3,215.0	3,213.6	16,393.2	590,010	3,258.0	3,256.6	28,318.0	1,520,700
3,216.0	3,214.6	16,620.2	606,510	3,259.0	3,257.6	28,638.2	1,549,200
3,217.0	3,215.6	16,858.3	623,250	3,260.0	3,258.6	28,949.3	1,577,900
3,218.0	3,216.6	17,124.0	640,250	3,261.0	3,259.6	29,236.6	1,607,000
3,219.0	3,217.6	17,346.0	657,480	3,262.0	3,260.6	29,490.5	1,636,400
3,220.0	3,218.6	17,598.4	674,950	3,263.0	3,261.6	29,740.0	1,666,000
3,221.0	3,219.6	17,848.0	692,670	3,264.0	3,262.6	29,987.5	1,695,900
3,222.0	3,220.6	18,083.0	710,640	3,265.0	3,263.6	30,202.6	1,726,000
3,223.0	3,221.6	18,290.1	728,830	3,266.4	3,265.0	30,413.0	1,756,300

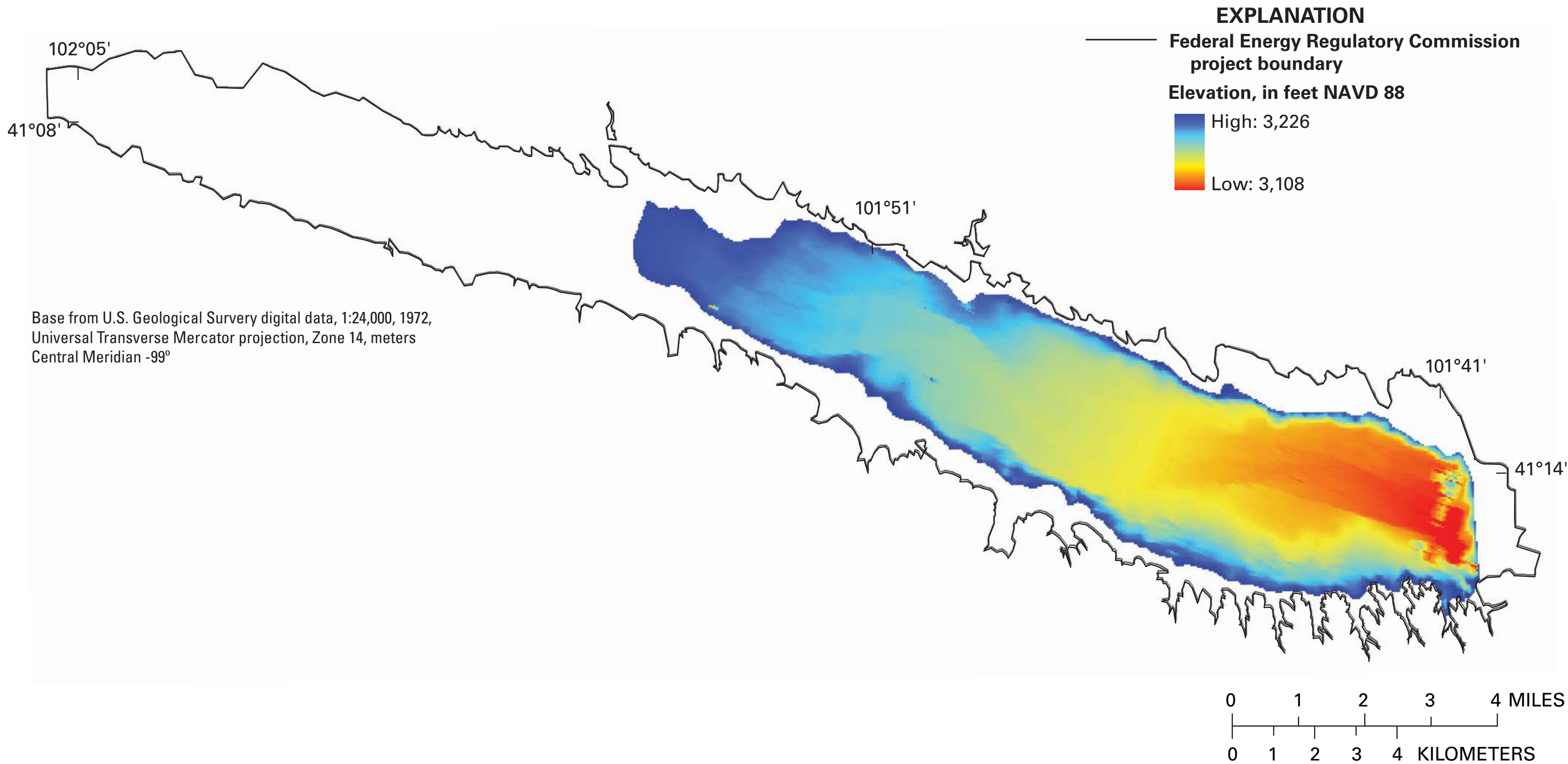


Figure 7. Low-frequency Digital Elevation Model (DEM) representing the estimated 2003 lakebed surface, Lake McConaughy, Nebraska.

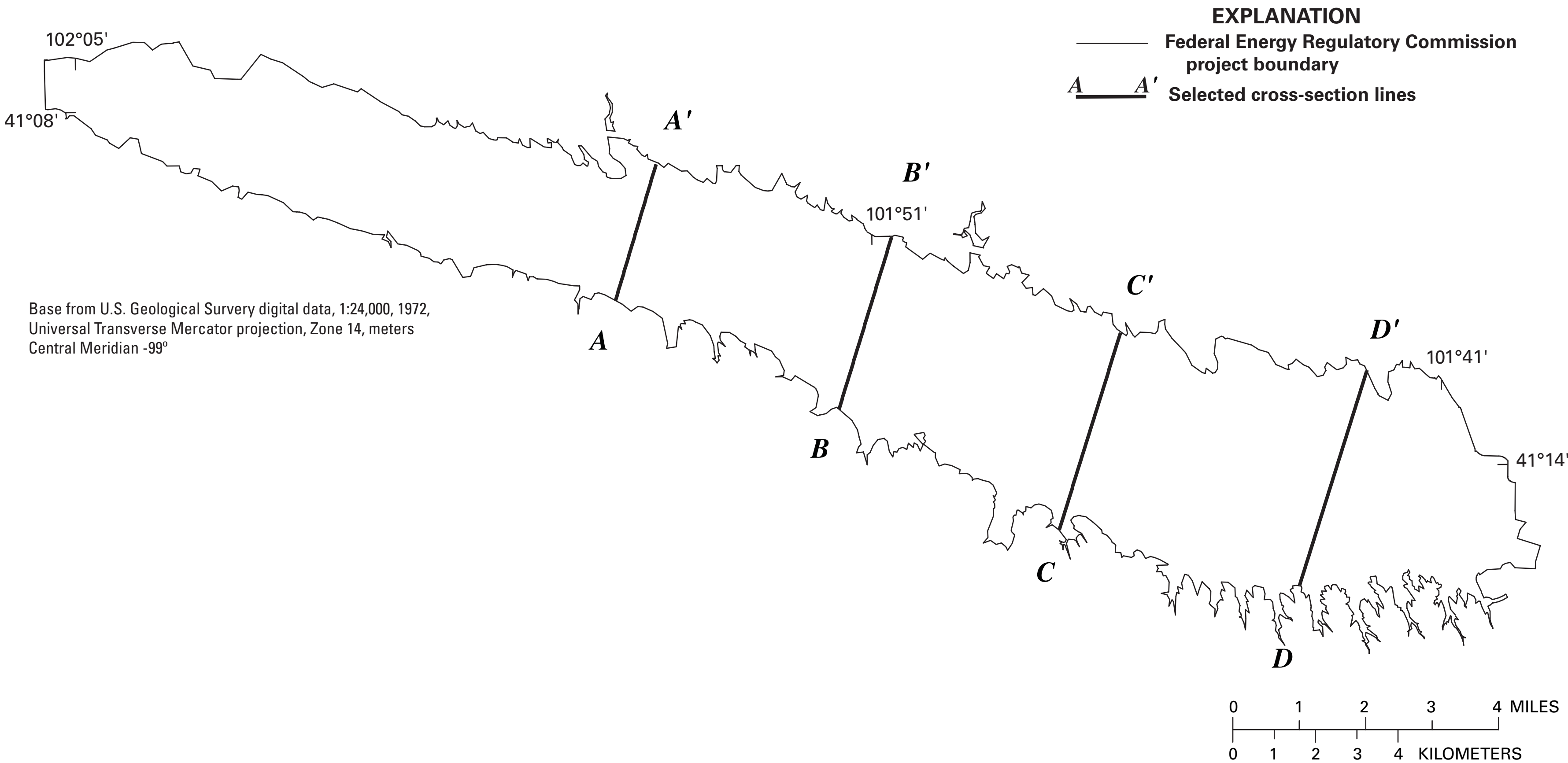


Figure 8. Locations of select cross sections of Lake McConaughy, Nebraska.

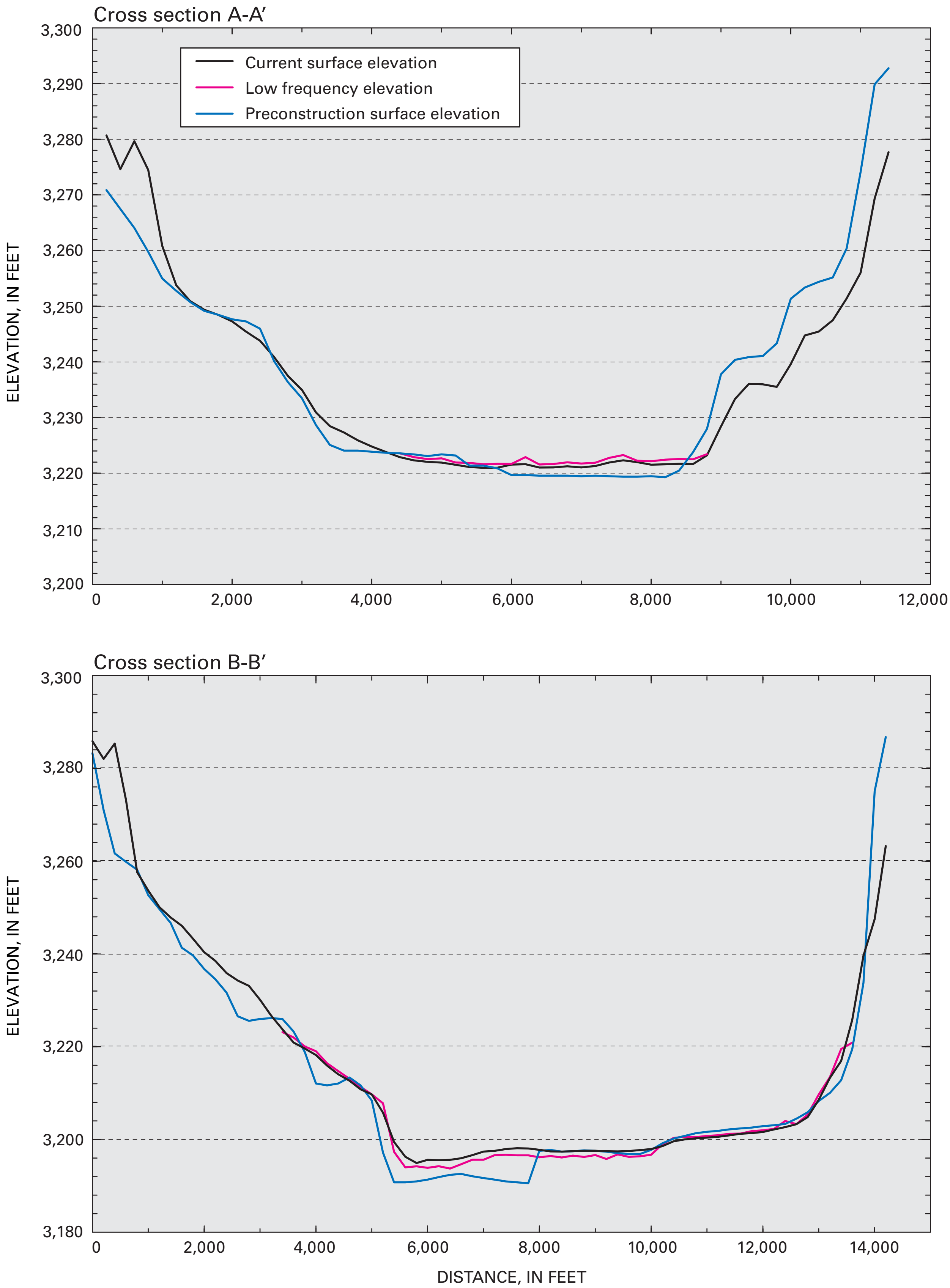
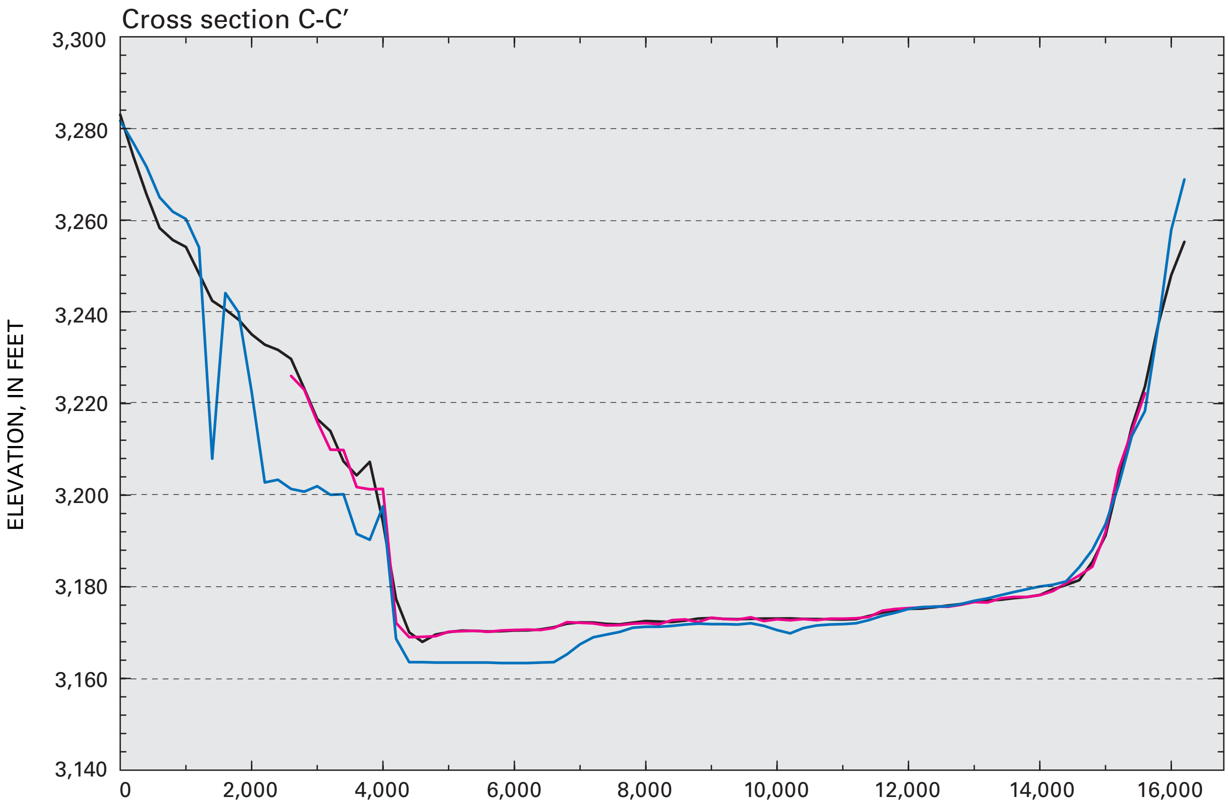


Figure 9. Selected cross sectional profiles of the lake showing dual-frequency data, Lake McConaughy, Nebraska.



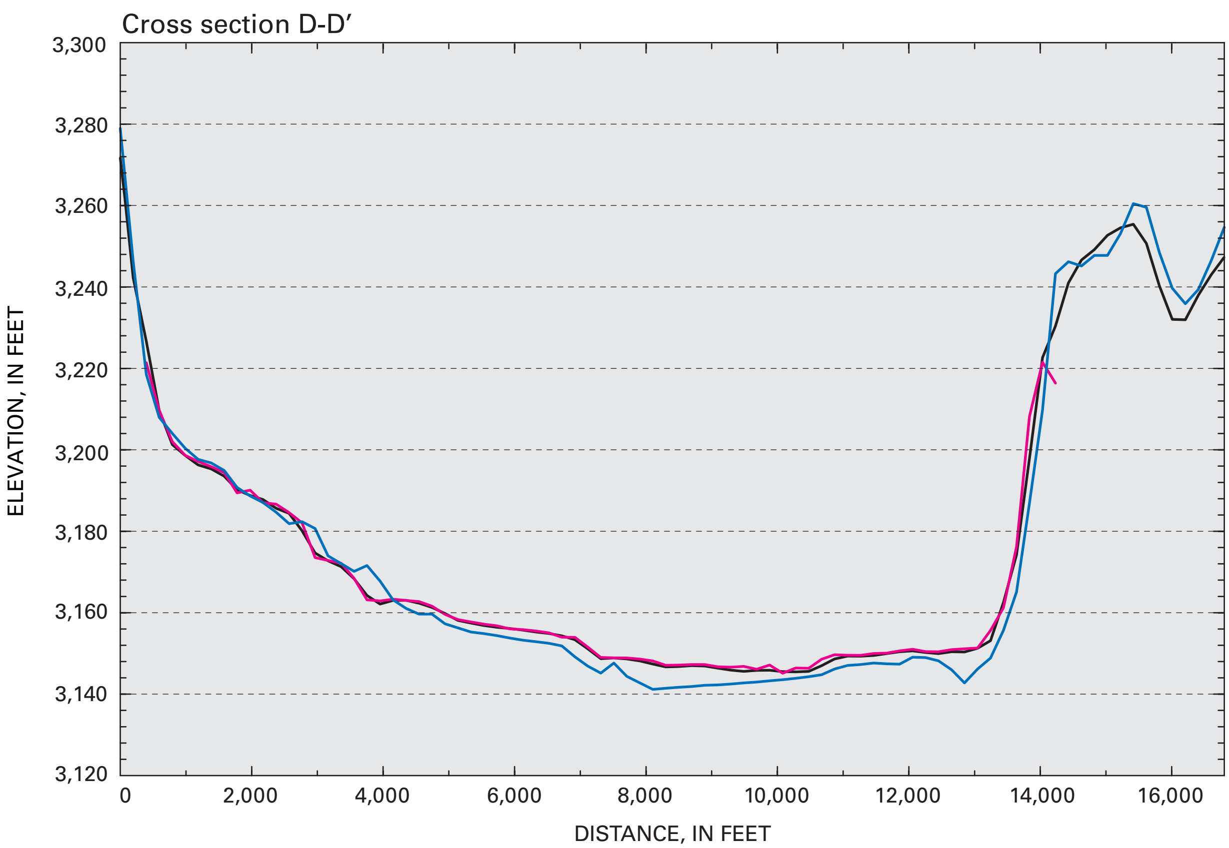


Figure 9. Selected cross sectional profiles of the lake showing dual-frequency data, Lake McConaughy, Nebraska.—Continued

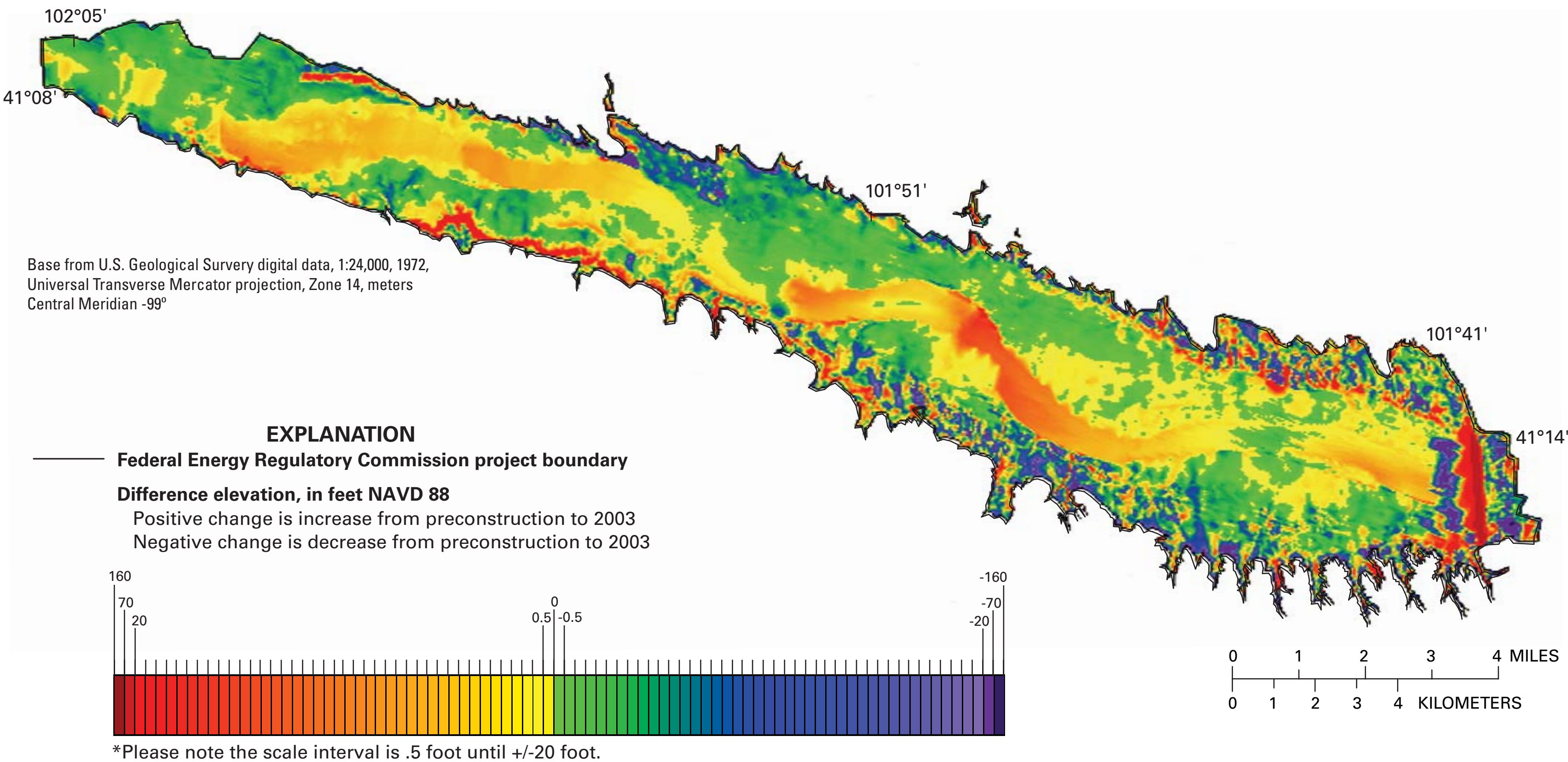


Figure 10. Change in storage from preconstruction to 2003, Lake McConaughy, Nebraska.

Changes in Storage Capacity and Sedimentation

The gross change in lake storage capacity was calculated by comparing the lake preconstruction survey DEM to the 2003 survey DEM. Between 1941 and 2003 there was a gross storage capacity reduction of about 42,372 acre-feet in Lake McConaughy at the lake conservation-pool elevation of 3,266.4 feet in NAVD 88 (3,265.0 feet in Central datum), or about a 2.4 percent decrease over the past 62 years. However, this gross change includes changes associated with construction of Kingsley Dam. The net change in reservoir capacity was calculated by comparing the lake preconstruction survey DEM to the 2003 survey DEM and subtracting out the Kingsley Dam structure and the borrow pit, which results in a net storage capacity reduction of about 33,066 acre-feet at lake conservation-pool elevation of 3,266.4 feet in NAVD 88 (3,265.0 feet in Central datum), resulting in an annual average decrease in storage capacity of approximately 533 acre-feet per year, or about a 1.8 percent decrease over the past 62 years. The resulting sediment accumulation is approximately 53,347,124 cubic yards, at an annual average rate of 860,437 cubic yards per year. Much of the loss in capacity has occurred in the original river channel and in the west end of the delta area on the upstream end of the lake. Localized increases in capacity appear to have occurred in the vicinity of the shoreline and as a consequence of the construction borrow area immediately west of the dam.

Summary

Lake McConaughy has experienced various physical changes as a result of sediment deposition, shoreline erosion, and wind processes during its more than 60 years of operation. The U.S. Geological Survey (USGS), in cooperation with The Central Nebraska Public Power and Irrigation District (Central), conducted a study to determine the 2003 physical shape, current storage capacity, and the changes in storage capacity of Lake McConaughy. This study used bathymetric and topographic surveying in conjunction with GIS techniques to report the current physical shape of Lake McConaughy, compare the preconstruction survey to the 2003 survey of the lake, and provide the bathymetric and topographic information to facilitate its use in the efficient management and protection of the water and land resources of the lake.

The bathymetric and topographic survey data were used to construct a contour map and volumetric table of Lake McConaughy. The volumetric calculations of Lake McConaughy at lake conservation-pool elevation 3,266.4 feet in NAVD 88 (3,265.0 feet in Central datum) report the surface area of Lake McConaughy to be 30,413.0 acres, with a volume of 1,756,300 acre-feet. A comparison of the preconstruction survey to the 2003 survey DEM showed an increase in topographic elevation of approximately 160 feet at the dam site due to the installation of Kingsley Dam. Immediately to the west of the Kingsley Dam is an area of decline, as much as 160 feet, where a borrow pit for Kingsley Dam was excavated. The comparison of the preconstruction survey to the 2003 survey also was used to estimate the gross storage capacity reduction that occurred between 1941 and 2002. The results of this comparison indicate a gross storage capacity reduction of approximately 42,372 acre-feet, at the lake conservation-pool elevation of 3,266.4 feet in NAVD 88 (3,265.0 feet in Central datum). To approximate the net change in storage capacity of Lake McConaughy the Kingsley Dam structure and the borrow pit were subtracted from the comparison of the lake preconstruction survey DEM to the 2003 survey DEM. This resulted in a net change in storage capacity of about 33,066 acre-feet, 533 acre-feet annually, or an estimated 1.8 percent decrease over the past 62 years. Total sediment accumulation is approximately 53,347,124 cubic yards, or an annual average rate of about 860,437 cubic yards per year. The lake has accumulated most of the sediment in the original river channel and in the west end of the delta area on the upstream end of the lake.

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