Prepared in cooperation with the
Chester County Water Resources Authority and the County of Chester

INTRODUCTION

Chambers Lake is a manmade reservoir on Birch Run, a tributary to West Branch Brandywine Creek in Chester County, Pennsylvania. The lake was created in 1994 after the completion of Multi-Purpose Dam PA-436F (Hibernia Dam), which was built under the Watershed Protection & Flood Control Prevention Act (U.S. Soil Conservation Service, 1991). Hibernia dam is 1,700 feet upstream from the confluence of Birch Run with West Branch Brandywine Creek. The primary objectives for Hibernia Dam were to provide (1) flood control, (2) a supplemental source of water supply for the greater City of Coatesville public water system, and (3) recreational opportunities. The drainage basin of Chambers Lake encompasses approximately 4.5 square miles, and the lake covers a surface area of about 95 acres at normal pool, which is at an elevation of 579.2 feet above the North American Vertical Datum of 1988 (NAVD 88) [580.0 feet above the National Geodetic Vertical Datum of 1929 (NGVD 29)]. The crest of the auxiliary spillway of the dam is 586.6 feet above NAVD 88. The elevation of the auxiliary spillway is important to this investigation because this elevation defines the flood storage capacity of Chambers Lake. Water levels exceeding this elevation are routed through the auxiliary spillway and flow through adjoining woodland to Birch Run.

The U.S. Geological Survey (USGS), in cooperation with Chester County Water Resources Authority (CCWRA) and the County of Chester, surveyed the bathymetry and selected above-water features of Chambers Lake in September 2014. The purpose of the survey was to develop an accurate representation of the surface of the bottom of Chambers Lake and to determine the stage and reservoir-storage capacity relation as of September 2014. CCWRA is responsible for operation of the dam and water-supply reservoir. Since construction, CCWRA has used a stage–storage capacity relation developed from the original survey conducted in the 1990s to estimate the volume of water available for water supply and the available flood storage. The bathymetric mapping effort was initiated due to interest in potential changes in current (2014) storage capacity when compared to the stage–storage capacity relation developed during design. The generated bathymetric surface may serve as a baseline to which temporal changes in storage capacity, owing to sedimentation and other factors, can be compared. In addition, these data will improve the overall accuracy of the stage–storage capacity table that CCWRA uses for reservoir and flood management operations.

This report describes the methods used to create a bathymetric map of Chambers Lake for the computation of reservoir storage capacity as of September 2014. The product is a bathymetric map (fig. 1) and a table (table 1) showing the storage capacity of the reservoir at 2-foot increments from minimum usable elevation up to full capacity at the crest of the auxiliary spillway.

METHODS

Bathymetry was measured relative to the water surface and an established gage datum. The water-surface elevation at the time of the bathymetric survey was monitored by real-time continuous-record water-level gaging station (gage) 01480399, Chambers Lake near Wagontown, PA, which is operated by the USGS. The gage has a recording interval of 15 minutes and is attached to the riser, which is just upstream from the dam (fig. 1). The riser is a concrete structure serving as the conduit for water flowing out of Chambers Lake into Birch Run. Gage datum was established using static Global Positioning System (GPS) techniques (Rydlund and Densmore, 2012) over a single control point, Reference Mark 1 (RM1), which is near the boat ramp on the southern side of the lake (fig. 1). RM1 is a thick shanked nail with a stainless steel washer stamped "USGS survey marker." A total of 11.5 hours of static GPS observations were made at RM1 over 2 days. Three separate occupations were processed using the National Geodetic Survey's Online Positioning Software (OPUS), and a time-weighted average elevation of 581.23 feet above NAVD 88 was computed. The estimated uncertainty of these static observations was 0.07 feet, and all requirements were met for a Level I survey (Rydlund and Densmore, 2012). Peak to peak errors ranged from 0.013 to 0.028 meters or 0.04 to 0.09 feet. Peak to peak errors are an estimate of uncertainty for GPS observations and are based on the minimum and maximum elevations determined for a point during post-processing. Differential levels were then run from this reference mark to the water surface near the boat ramp, and a backup reference mark (RM2) was established along Wagontown Road (fig. 1). A surveying instrument called a total station was used to determine the elevation of the riser and the water surface near the dam. Gage readings throughout data collection (September 8–12, 2014) ranged from 580.08 to 579.98 feet, gage datum (NGVD 29), whereas average surveyed water-surface elevations ranged from 579.23 to 579.13 feet above NAVD 88. A mean water-surface elevation of 579.2 feet above NAVD 88 was used for this survey. The adjustment from NGVD 29 to NAVD 88 is -0.85 feet, as computed by the National Geodetic Survey's online vertical datum transformation utility Vertcon v. 2.1 (National Geodetic Survey, 2003).

Bathymetric data (water depths and positions) were collected September 8–12, 2014, using a variety of methods. The use of commercial hydrographic software Hydrosurveyor™ (Xylem, Inc., 2013) allowed pre-planned transect lines to be developed and followed during the survey. Most of the water-depth measurements were made using a Sontek M9 5-beam Acoustic Doppler Current Profiler (ADCP) tethered alongside a 14-foot Jon boat. An ADCP emits sound pulses that are reflected off the lake bottom and received by a transducer. The water-surface elevation assigned during data collection was 0.00 feet for all surveys. Elevation relative to NAVD 88 was computed during post-processing. Bathymetric data were collected with the ADCP along transect lines spaced approximately 50 feet apart, which is roughly 1-percent of the longitudinal length of the lake (Wilson and Richards, 2006). In order for an ADCP to accurately measure depths, the speed of sound must be computed from measurements of water temperature (Mueller and others, 2013). The shallow depths and low salinity typically encountered in freshwater lakes are not major factors affecting sound speed (U.S. Army Corps of Engineers, 2002). For Chambers Lake, effects of water temperature stratification are considered minimal because of the time of year this survey was completed. Therefore, the standard correction for sound speed was used. To assess depth measurement errors caused by incorrect water temperature and speed of sound, all soundings were processed again using a fixed water temperature 10 degrees lower than actually measured during the bathymetric survey. In the deepest part of the lake, a difference of 0.5 feet (1-percent of total depth) was noted.

Position data were collected using a differentially corrected Global Positioning System (DGPS) mounted directly above the ADCP. The positional accuracy of the DGPS data is less than 1 meter (Hemisphere GNNS, Inc., 2013). In some areas of the lake, especially in areas of heavy aquatic growth, Real-Time Network (RTN) and Real-Time Kinematic (RTK) GPS techniques were required to define the lake bottom. These methods were also used to define selected above-water features, including the dam breast and auxiliary spillway. RTK observations were post-processed using the computed OPUS static positions previously discussed, and objective points were adjusted accordingly. RTN surveys use real-time corrections broadcast over the Internet. Approximately 151,000 data points were collected during the 2014 survey. All points were loaded into ArcScene [Environmental Systems Research Institute, Inc. (ESRI) 2014a] and obviously erroneous data were removed from the dataset before any additional processing.

For land-surface elevations above the water surface (579.2 feet above NAVD 88, normal-pool elevation), Light Detection and Ranging (lidar) data, collected as part of the PAMAP program and included in the National Elevation Dataset were used. The Pennsylvania Map Program (PAMAP) is a multi-agency effort and part of the U.S. Geological Survey National Map Program, administered by the Pennsylvania Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey that enabled the collection of a statewide set of high-resolution lidar elevation data and digital orthophotographs. The vertical accuracy of this dataset is 18.5-centimeter root mean square error (RMSE; PAMAP Program, 2008). The lidar data were also used to define the extent of this analysis by creating contours within ArcGIS of the shoreline at the time of the survey (579.2 feet above NAVD 88), along with the elevation of the auxiliary spillway (586.6 feet above NAVD 88). Selected above-water features surveyed using GPS were compared with the lidar elevations where feasible. Differences between these two datasets are less than 0.10 foot for the selected features.

Geographic information system (GIS) software produced a three-dimensional surface of the reservoir-bottom elevations from the bathymetric data and ground survey. A 1.6-foot x 1.6-foot grid was interpolated using the "topo to raster" technique (ESRI, 2014b) and snapped to the lidar raster, which assured cell alignment between the two datasets. Computed elevations of the bathymetric surface ranged from 533.4 to 579.2 feet above NAVD 88. The bathymetric surface and lidar surface were merged to create a surface model of the lake from the minimum usable elevation up to the auxiliary spillway. A table was then produced from the three-dimensional surface (table 1) using the surface-volume toolset in ArcGIS (ESRI, 2014). Table 1 lists surface area and water volumes of reservoir capacity at selected elevations. The bathymetric surface was contoured using GIS software and smoothed to produce 2-foot contours that were cartographically edited to create the bathymetric map (fig. 1).

QUALITY ASSURANCE

Accuracy of the bathymetric surface and contours is a function of the survey data accuracy, density of the survey data (transect interval and data-collection frequency), and the processing steps that occur during creation of the bathymetric surface and contours. As previously discussed, the water-surface elevation was measured by real-time continuous-record gage 01480399 to ensure depth soundings from the water surface would provide an accurate elevation of the lake bottom. Survey ADCP data accuracy also is dependent on factors such as vessel draft, platform stability, vessel velocity, and subsurface material density (Wilson and Richards, 2006). To reduce these errors, the draft (depth of ADCP in water column) was measured daily, as was the water temperature. The temperature measured by the ADCP is read and compared with an independent simultaneous temperature measurement made adjacent to the ADCP (Mueller and others, 2013). Calibrating the internal magnetic compass of instruments with an internal compass is encouraged prior to all ADCP measurements but is mandatory when using GPS as the navigation reference (Mueller and others, 2013). The compass was calibrated daily to provide accurate headings or after any changes in deployment or setup. Vessel speed was kept at less than 5 feet per second to assure adequate point spacing.

To assess the quality of the 2014 bathymetric surface and contours, quality-assurance data were collected using transect lines that were spaced at 5 times the original survey spacing (approximately 250 feet apart) and oriented at an oblique angle to the survey transects. Approximately 14,250 quality-assurance data points were collected during the 2014 survey. Data from these transects were used as an independent dataset allowing for computation of the accuracy of the bathymetric surface and contour map (Wilson and Richards, 2006). For this analysis, quality-assurance points are considered coincidental if they are within 0.33 foot of either the bathymetric surface or a contour.

The accuracy of the bathymetric surface and contours was calculated using the quality-assurance dataset and is expressed in terms of the RMSE (Wilson and Richards, 2006), which is a statistical measure of the differences between measured data predicted by a model and the values actually observed. The computed RMSE of the bathymetric surface was 0.80 foot (1.57 feet at the 95-percent confidence interval or 2-sigma) using the 14,254 quality-assurance data points, meaning that 95 percent of all points on the surface are within 1.57 feet of the true elevation. The computed RMSE of the bathymetric contours was 1.03 feet (2.02 feet at the 95-percent confidence interval) using 524 quality-assurance data points.

Bathymetric contours are less accurate than the bathymetric surface because of cartographic interpretation of the contours for map display. Analysis indicates the greatest error between the bathymetric surface and quality-assurance transects occurred in shallow areas, which are rockier and more erratic than deep areas.

RESULTS

Lake water-surface elevation ranged from 579.23 to 579.13 feet above NAVD 88 during data collection. Lake depth generally increases from west to east toward the dam where the lowest point of the lake bottom was 533.4 feet above NAVD 88. The lowest points are in a linear, trench-like feature leading to the riser. The banks and old stream channel of Birch Run, as well as other small tributaries, are well defined throughout the reservoir, especially near the dam.

Results of the bathymetric survey indicate that at the normal pool elevation of 579.2 feet above NAVD 88 the lake covers a surface area of 95.7 acres and holds about 1,175 acre-feet of freshwater (table 1). Reservoir storage capacity at normal pool, as determined by the current survey, is about 4 percent less than the original storage capacity estimated at the time of construction (fig. 2, table 1). The difference in computed storage capacity between the current and original surveys is attributed to a combination of the differences in accuracy between the current and original surveys and possibly sedimentation, although no previous information on sediment accumulation in this watershed is available. The difference in accuracy between the current and original surveys is considered the main cause of the apparent loss in storage capacity. The original survey is likely less accurate because of its lower resolution, and the resulting stage–storage capacity relation would reflect the less accurate survey. With improvements in technology, a dense dataset has been used to create the new bathymetric surface that was used to develop the stage–storage capacity relation presented in this report. If the difference in storage were all the result of sediment accumulation, the sediment accumulation rate would be 2.22 acre-feet per year over the last 23 years (1991–2014) or 0.023 foot per year. Although it is possible the reservoir may have lost storage capacity between 1994 and 2014 owing to sedimentation, the loss was probably not as high as that computed. Also, the recently created bathymetric map of the reservoir still clearly identifies the location and banks of the old stream channel, indicating that the reservoir probably has not experienced a substantial amount of sedimentation. A sediment transport study and (or) sediment cores may help in quantifying the degree to which the reservoir has actually filled in since 1994. Regardless of the cause, the current survey provides detailed documentation to assess changes in storage in the future.

SUMMARY

The U.S. Geological Survey, in cooperation with Chester County Water Resources Authority and the County of Chester, conducted a bathymetric survey of Chambers Lake from September 8 to September 12, 2014. Chambers Lake is a manmade reservoir that was created in 1994 when Hibernia Dam was built on Birch Run, a tributary to West Branch Brandywine Creek. The survey was conducted to develop an accurate representation of the surface of the bottom of Chambers Lake. The products developed include a map illustrating the submerged surface of the lake bottom using 2-foot contours and a table for calculating the capacity of the reservoir at different water-surface elevations. Bathymetric data were collected using a differential global positioning system, an acoustic doppler current profiler, and commercially available hydrographic software. The data were exported into a geographic information system for mapping and calculation of reservoir storage volume. At a water-surface elevation of 579.2 feet above North American Vertical Datum of 1988 (580.0 feet above National Geodetic Vertical Datum of 1929), reservoir storage capacity for the current survey was about 1,175 acre-feet, 4 percent less than the original survey, which was completed around the time the dam was built in the early 1990s. The loss of storage is attributed to differences in accuracy and methods between the current (2014) and the original surveys, and possibly sedimentation of the lake.

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REFERENCES CITED

Environmental Systems Research Institute, Inc. (ESRI), 2014a, ArcGIS Desktop Help 10.2: Environmental Systems Research Institute, Inc., accessed February 2015 at http://resources.arcgis.com/en/help/main/10.2.

Environmental Systems Research Institute, Inc. (ESRI), 2014b, ArcGIS Desktop Help 10.2 Topo to Raster (Spatial Analyst): Environmental Systems Research Institute, Inc., accessed February 2015 at http://resources.arcgis.com/en/help/main/10.1/index.html#//009z0000006s000000ArcGIS Help 10.1.

Hemisphere GNNS, Inc. 2013, A101 Smart Antenna User Guide: Scottsdale, Ariz., Hemisphere GNNS, Inc., 34 p.

Mueller, D.S., Wagner, C.R., Rehmel, M.S., Oberg, K.A,, and Rainville, Francois, 2013, Measuring discharge with acoustic Doppler current profilers from a moving boat (ver. 2.0, December 2013): U.S. Geological Survey Techniques and Methods, book 3, chap. A22, 95 p. [Available at http://dx.doi.org/10.3133/tm3A22]

National Geodetic Survey, 2003, Vertcon v2.1 – Vertical Datum Conversion Program, accessed February 2015 at http://www.ngs.noaa.gov/PC_PROD/VERTCON/.

PAMAP Program, 2008, 3.2 ft Digital Elevation Model of Pennsylvania, accessed February 2015 at http://www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=PAMAP_DEM.xml&dataset=1247.

Pennsylvania Department of Transportation, 2015, PaLocalRoads2015_01, accessed July 2015 at ftp://www.pasda.psu.edu/pub/pasda/padot/local/.

Rydlund, P.H., Jr., and Densmore, B.K., 2012, Methods of practice and guidelines for using survey-grade global navigation satellite systems (GNSS) to establish vertical datum in the United States Geological Survey: U.S. Geological Survey Techniques and Methods, book 11, chap. D1, 102 p. with appendixes, accessed June 2015 at http://pubs.usgs.gov/tm/11d1/.

U.S. Army Corps of Engineers, 2002, Engineering and design—Hydrographic surveying, Publication No. EM 1110-2-1003, chap. 9, 46 p., accessed February 2015 at http://www.publications.usace.army.mil/USACEPublications/EngineerManuals.aspx?udt_43544_param_page=4.

U.S. Geological Survey, 2010, National Hydrography Dataset (NHD): U.S. Geological Survey, accessed July 2015 at http://nhd.usgs.gov.

U.S. Soil Conservation Service and Chester County Water Resources Authority, 1991, Final Design Report Hibernia Dam PA-436F: West Chester, Pa., Soil Conservation Service, April 1991, 46 p.

Wilson, G.L., and Richards, J.M., 2006, Procedural documentation and accuracy assessment of bathymetric maps and area/capacity tables for small reservoirs: U.S. Geological Survey Scientific Investigations Report 2006–5208, 24 p., accessed June 2015 at http://pubs.usgs.gov/sir/2006/5208/.

Xylem, Inc., 2013, Hydrosurveyor™ 1.0, Hydrographic survey software user's manual (Version 2.00): San Diego, Calif., Xylem, Inc., 138 p.

Table 1. Stage-reservoir storage capacity relation and surface area at selected water-surface elevations, Chambers Lake, Chester County, Pennsylvania, September 2014.

[NAVD 88, North American Vertical Datum of 1988; NGVD 29, National Geodetic Vertical Datum of 1929]

Elevation (Stage; feet above NAVD 88)	Elevation (Stage; feet above NGVD 29)	Reservoir capacity (acre-feet)	Surface area (acres)
536.0	536.8	0.0	0.0
538.0	538.8	0.1	0.1
540.0	540.8	0.4	0.2
542.0	542.8	1.1	0.5
544.0	544.8	2.5	1.1
546.0	546.8	6.0	2.4
548.0	548.8	12.4	4.2
550.0	550.8	22.7	6.2
552.0	552.8	37.6	8.8
554.0	554.8	58.4	12.3
556.0	556.8	87.3	16.8
558.0	558.8	125.7	21.6
560.0	560.8	173.0	25.5
562.0	562.8	227.8	29.7
564.0	564.8	292.3	34.6
566.0	566.8	366.3	39.5
568.0	568.8	450.6	44.8
570.0	570.8	546.7	51.6
572.0	572.8	656.6	58.2
574.0	574.8	778.6	63.5
576.0	576.8	910.6	69.3
578.0	578.8	1,063.0	87.0
[1]579.2	580.0	1,175.4	95.7
580.0	580.8	1,252.4	97.0
582.0	582.8	1,451.3	102.3
584.0	584.8	1,666.5	111.9
586.0	586.8	1,899.2	120.9

[1]Normal pool elevation.

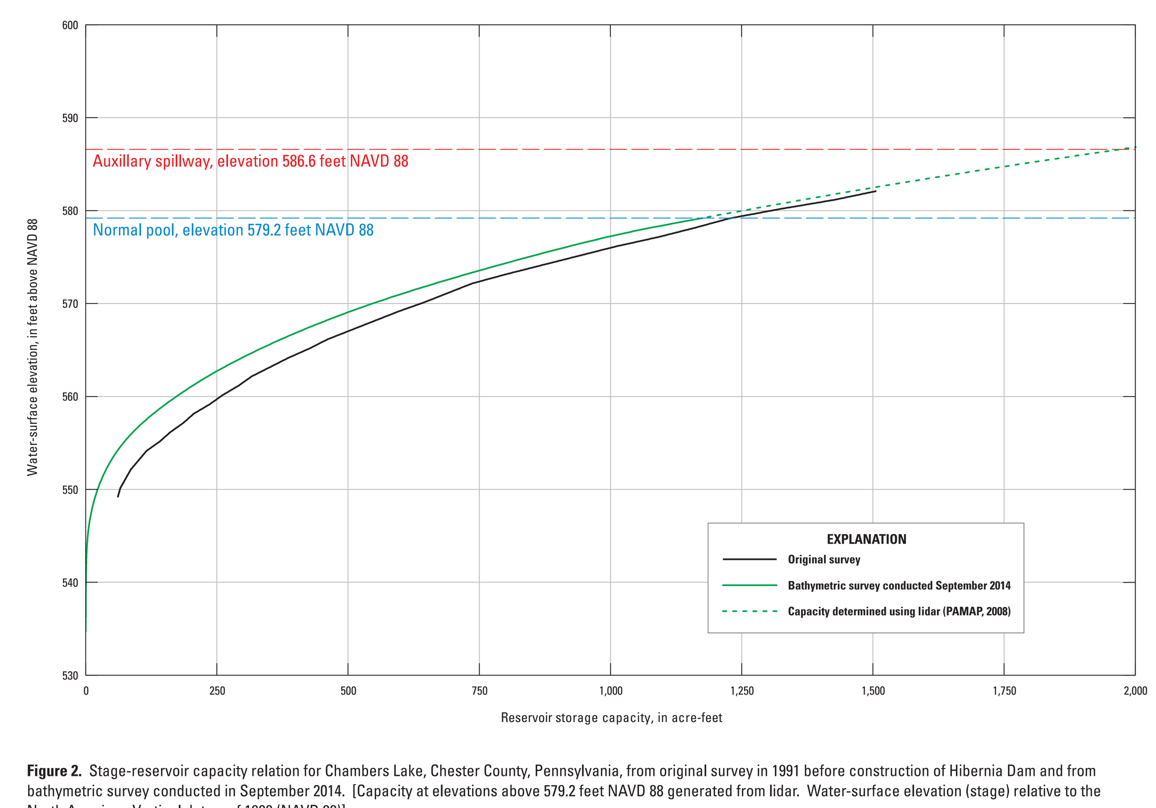

Figure 2. Stage-reservoir capacity relation for Chambers Lake, Chester County, Pennsylvania, from original survey in 1991 before construction of Hibernia Dam and from bathymetric survey conducted in September 2014. [Capacity at elevations above 579.2 feet NAVD 88 generated from lidar. Water-surface elevation (stage) relative to the North American Vertical datum of 1988 (NAVD 88)]

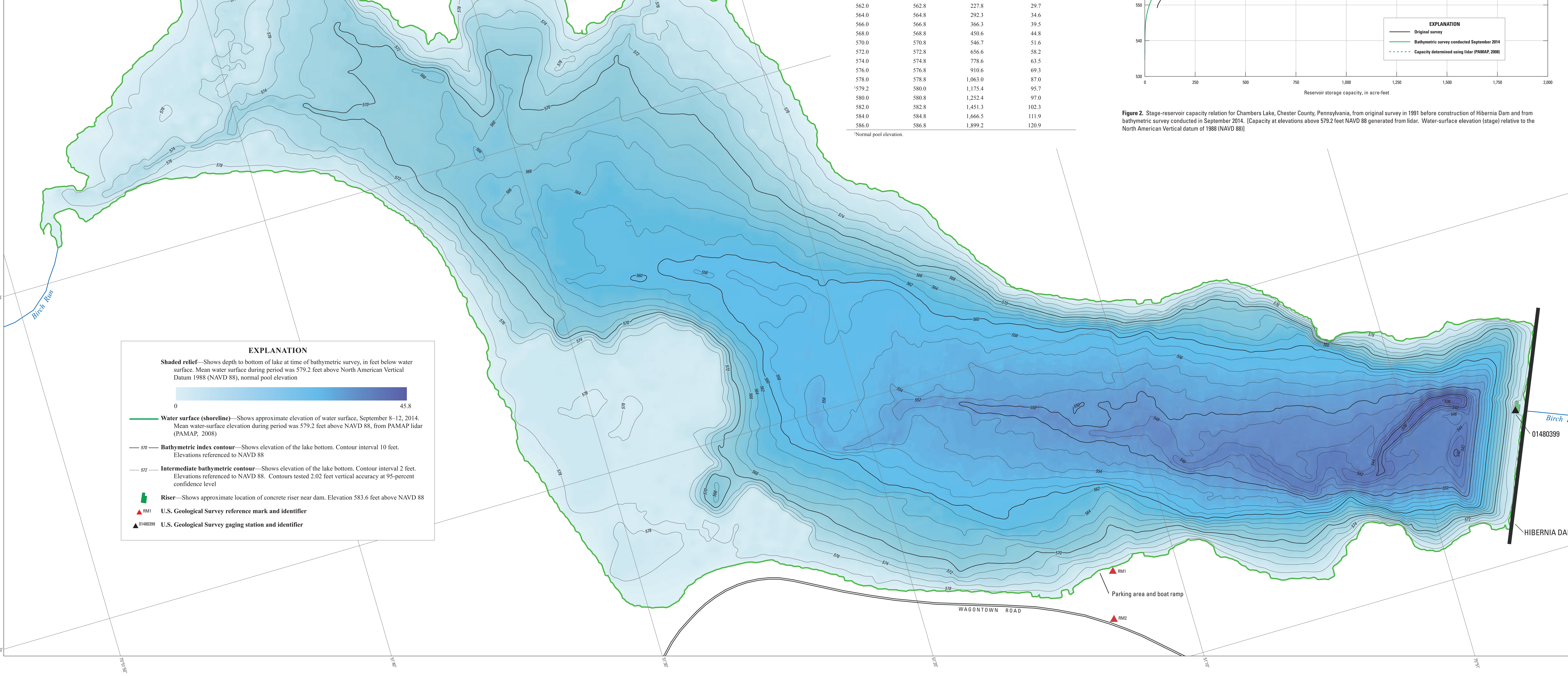

Figure 1. Bathymetric map of Chambers Lake, Chester County, Pennsylvania, September 2014.

Base from U.S. Geological Survey National Hydrography Dataset (NHD) and Pennsylvania Department of Transportation (2015)
Pennsylvania State Plane South projection, feet, NAD83

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Bathymetry and Capacity of Chambers Lake, Chester County, Pennsylvania

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