

**Abstract**

The U.S. Geological Survey conducted a sedimentation survey of Lago Lucchetti, Yauco, Puerto Rico, in 2013–14 in cooperation with the Puerto Rico Aqueduct and Sewer Authority. The survey updated a previous survey, conducted in 2000, and provided accurate information regarding reservoir storage capacity and sedimentation rate using bathymetric techniques and a global positioning system coupled with a depth sounder device. The results of the 2013–14 survey indicated a total storage capacity for Lago Lucchetti of 10.21 million cubic meters and a long-term sedimentation rate loss of 0.16 million cubic meters per year based on the original capacity in 1952. Sediment accumulation was about 10.14 million cubic meters over the life of the reservoir, which represents a storage decrease of about 50 percent of the original capacity in 1952. On the basis of a comparison between the 2013–14 and 2000 surveys, the useful life for Lago Lucchetti is projected to end in 2076.

**Introduction**

Lago Lucchetti is located at Yauco, Puerto Rico, and is part of the Southwestern Puerto Rico Project directed by the Puerto Rico Electric Power Authority (formerly named Puerto Rico Water Resources Authority). The project includes six reservoirs originally constructed for hydroelectric power generation and for irrigation of croplands in the southwest part of Puerto Rico. The original (1952) design capacity for Lago Lucchetti at the spillway elevation of 173.74 meters (m) above mean sea level (msl) was about 20.35 million cubic meters (Mm<sup>3</sup>). Over time, the actual capacity decreased to 15.84 Mm<sup>3</sup> by 1986 and to 11.88 Mm<sup>3</sup> by 2000 (Soler-López, 2001). The dam is located on the Río Yauco about 7 kilometers (km) north of the town of Yauco and 10 km east of the town of Sabana Grande (fig. 1). The dam is a concrete-gravity structure, and the reservoir has a drainage area of about 44.81 square kilometers. The outlet structure includes an uncontrolled spillway with a maximum discharge capacity of 1,778 cubic meters per second (m<sup>3</sup>/s) at a design head of 6.10 m above the spillway elevation and an intake for a 3,368-m-long and 3.50-m-diameter power tunnel that conveys water to two hydropower units (Soler-López, 2001) through a 2.44-m-diameter penstock.

Lago Lucchetti is owned and operated by the Puerto Rico Electric Power Authority for power generation and irrigation; however, since the late 1990s the reservoir also has been used as a source for public water supply to sustain local and regional water demands. As a result, Lago Lucchetti releases water through inter-basin transfers to Lago Loco (fig. 1), which in turn releases water for irrigation and public water supply.

Between September 2013 and May 2014, the U.S. Geological Survey (USGS) conducted a sedimentation survey (hereafter referred to as “the 2014 survey”) of Lago Lucchetti in cooperation with the Puerto Rico Aqueduct and Sewer Authority (PRASA) to update estimates of the reservoir storage capacity, determine the reservoir sedimentation rate, and estimate the amount and location of sediment accumulation. The results of the 2014 survey were used to create a bathymetric map showing the reservoir bottom referenced to the spillway elevation. Results of the 2014 survey were also compared with data obtained during a previous survey in 2000 (Soler-López, 2001).

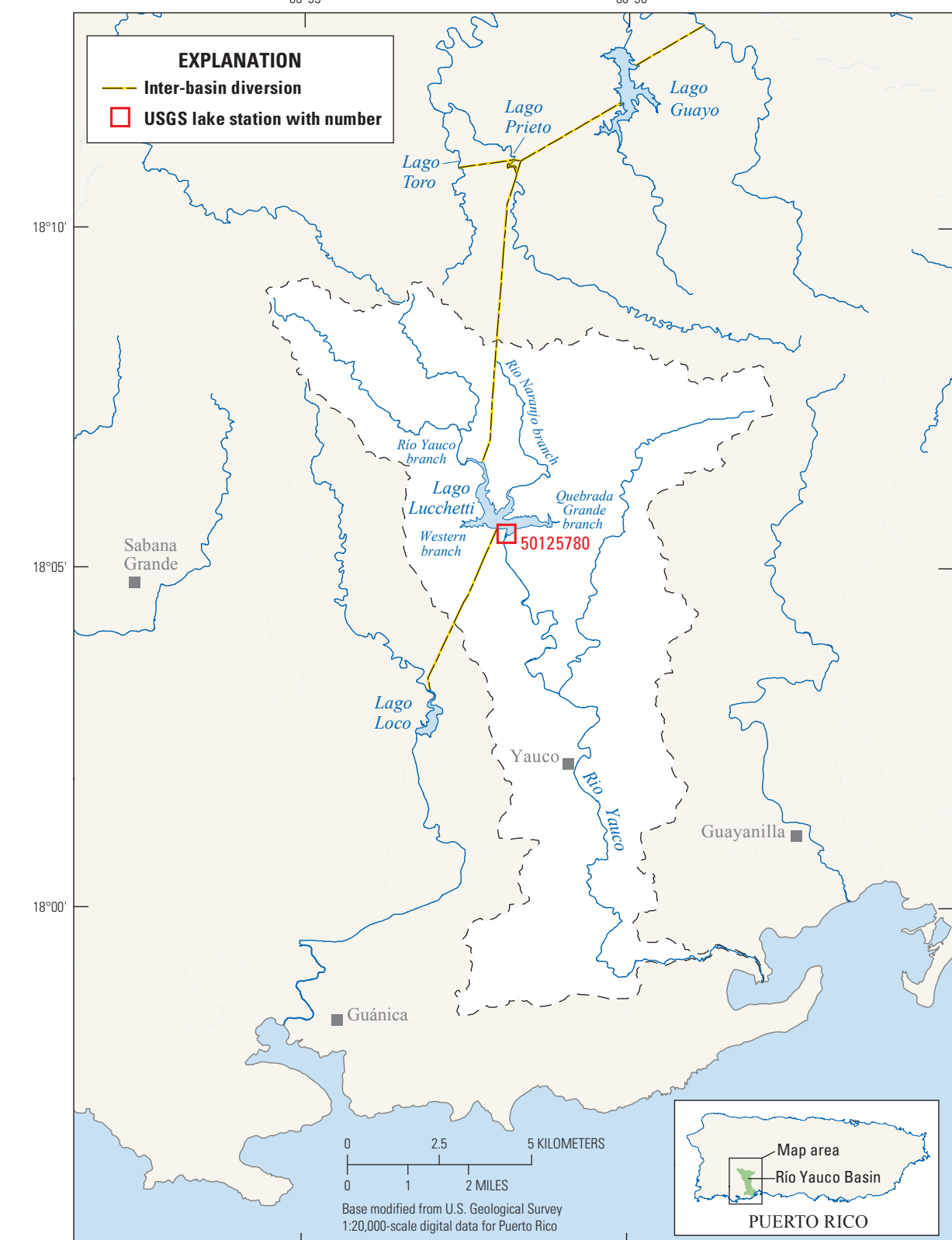
**Method of Survey and Analysis**

The field techniques and survey data processing methods used for the 2014 bathymetric survey were completed following procedures established by the USGS Caribbean-Florida Water Science Center (CFWSC) and described in a report by Soler-López (2001). The 2014 survey was conducted using a bathymetric survey system manufactured by Teledyne Odom Hydrographics, consisting of a global positioning system (GPS) coupled to a digital depth sounder. A total of 111 survey navigation lines were established at approximately 50-m intervals, beginning at the dam and continuing upstream along the main pool of the reservoir and its tributaries. Geographic position (accuracy of less than 2 m) and water depths (accuracy of 2 centimeters [cm] ± 1 percent of the measured depth) were acquired simultaneously using the GPS interfaced with the depth sounder. The reservoir pool elevation was recorded continuously at USGS lake-level station 50125780 (Lago Lucchetti at Dam site near Yauco; fig. 1). The fathometer was calibrated prior to each day of the survey by using a bar check (Wilson and Richards, 2006).

The pool elevation of Lago Lucchetti was corrected to represent depths at a spillway elevation of 173.74 m above msl. The survey data were transferred into the Esri ArcGIS geographic information system (GIS), final analysis and storage volume calculations were made following procedures similar to those used to develop the February 2000 bathymetric map of Lago Lucchetti (Soler-López, 2001). Data points collected along each established navigation line (fig. 2) from the 2014 survey were used to generate a bathymetric map representing the reservoir bottom (fig. 3). Data points were color-coded according to their specific depths, and same-color points were connected with a line to draw depth contours (fig. 3). A triangulated irregular network (TIN) surface model of Lago Lucchetti was generated from the bathymetric map, and the reservoir volume was calculated using the GIS. The 2000 and 2013–14 TIN surface models were used to compare the 2000 and 2014 sedimentation surveys (table 1) and to generate a stage-storage curve for 2014 (fig. 4) and longitudinal profiles along the main pool and tributaries of Lago Lucchetti for 2000 and 2013–14 (fig. 5). The storage capacity table and curve were generated by calculating the TIN volume at 1.00-m elevation intervals and are shown in table 2 and figure 4, respectively.

**Storage Capacity, Sedimentation Rate, and Useful Life**

The Lago Lucchetti was built in 1952 with a storage capacity of 20.35 Mm<sup>3</sup>. The storage capacity progressively decreased from 15.84 Mm<sup>3</sup> in 1986, to 11.88 Mm<sup>3</sup> in 2000 (Soler-López, 2001), and to 10.21 Mm<sup>3</sup> by the 2014 survey. From the construction of the reservoir in 1952 until the 2014 survey, the storage capacity loss of the reservoir has been 10.14 Mm<sup>3</sup>, which is equivalent to a storage loss of about 50 percent. The long-term sedimentation rate (1952–2014) was about 0.16 million cubic meters per year (Mm<sup>3</sup>/yr), which is slightly less than the rate calculated during the 2000 survey (about 0.18 Mm<sup>3</sup>/yr; Soler-López, 2001). However, the inter-survey (2000–14) annual storage capacity loss was about 0.12 Mm<sup>3</sup>/yr, which is about 57 percent lower than the loss of about 0.28 Mm<sup>3</sup>/yr determined for 1986–2000. This sediment rate reduction could be the result of the decline in urban development and associated sediment runoff in the drainage basin of the reservoir. Another contributing factor could be lower rainfall and associated runoff from a decreased frequency and intensity of storm systems affecting the island of Puerto Rico in the last decade. Similar trends were observed after Hurricane Georges in 1998 at four other surveyed reservoirs in Puerto Rico: Lago Patillas, Lago de Cidra, Lago Loiza, and Lago Dos Bocas (Soler-López, 2010a, 2010b, 2012; Soler-López and Licha-Soler, 2012). The general results of the 2000 and 2014 surveys are summarized in table 1.



**Figure 1.** Location of Lago Lucchetti, Yauco, Puerto Rico.

The bottom profiles (fig. 5) along the central part of Lago Lucchetti were generated in an upstream direction from the dam to each of the tributaries of the reservoir (Río Yauco, Western, Río Naranjo, and Quebrada Grande). The results show that most of the sediment accumulation and associated storage capacity loss of Lago Lucchetti has occurred on the Río Yauco and Quebrada Grande tributaries of the reservoir. For Río Yauco, the most noticeable sediment accumulation zone is about 1,300 m upstream from the dam; sediment accumulation ranges from 2 to 4 m (fig. 5A) and extends to the mouth where it enters the reservoir. The sediment accumulation between 2000 and 2014 in the Quebrada Grande ranged from 2 to 4 m, and sediment was distributed along the entire reservoir bottom profile (fig. 3D). For Río Naranjo and Western tributaries, the sedimentation accumulation is mostly distributed near the dam structure and ranges from 0.5 to 2 m.

Comparison of bottom profiles along Río Yauco, Western, and Río Naranjo indicated that substantial sediment deposition occurs in an area about 450 m upstream from the dam structure (fig. 5). As described by Soler-López (2001), deposition of sediments, caused by flood events, may have occurred in the confluence of the reservoir and its tributaries. The 2014 survey results indicated the sediment accumulation has continued in this area over the years.

Using the empirical-based curve developed by Brune (1953), the sediment trapping efficiency of Lago Lucchetti for 2014 was estimated as 95 percent. This method used the ratio of storage capacity to annual water inflow volume, in which the annual inflow was estimated at 25.95 Mm<sup>3</sup> (Soler-López, 2001) and the updated 2014 water storage capacity was about 10.21 Mm<sup>3</sup>. Updated precipitation depth was incorporated in the 2014 study for the annual inflow calculations by using the mean annual precipitation for the period 1981 to 2010 (National Oceanic and Atmospheric Administration, 2010).

The long-term drainage area sediment yield rate of Lago Lucchetti was 1,175 cubic meters per square kilometer per year (m<sup>3</sup>/km<sup>2</sup>/yr) in the 2014 survey. This sediment yield rate represents a decrease of 6 percent compared to the 2000 survey, which had a sediment yield rate of 1,255 (m<sup>3</sup>/km<sup>2</sup>/yr). Inter-survey drainage area sediment yield in turn decreased from 2,013 (m<sup>3</sup>/km<sup>2</sup>/yr) in 2000 to 858 (m<sup>3</sup>/km<sup>2</sup>/yr) in 2014.

On the basis of the current long-term storage-capacity loss of about 0.16 Mm<sup>3</sup>/yr estimated for the 1952–2014 period and assuming a constant sedimentation rate, the projected useful life of Lago Lucchetti is about 62 years, ending in 2076. This predicted useful life (also referred as the year of zero storage) of Lago Lucchetti is nearly equal to the previous estimate of 66 years of useful life calculated by Soler-López (2001). Data release of spatial data associated with the 2014 bathymetric survey is presented in Gómez-Fragoso, 2016.

**Conclusions**

A sedimentation survey was conducted at the Lago Lucchetti, Yauco, Puerto Rico, by the U.S. Geological Survey in cooperation with the Puerto Rico Aqueduct and Sewer Authority during September 2013 and May 2014. The objective of the project was to complete a bathymetric study to update the reservoir storage capacity and estimate the reservoir sedimentation rate by comparing the new survey data with a previous survey completed in 2000.

**Table 1.** Comparison of the 2000 and 2014 sedimentation surveys of Lago Lucchetti, Yauco, Puerto Rico.

Data descriptor	Year of survey	
	2000	2014
Total capacity, in million cubic meters	11.88	10.21
Reservoir surface area, in square kilometers	1.12	1.00
Reservoir surface area difference, in square kilometers	N/A	0.12
Reservoir surface area loss, in percent	N/A	11
Years since construction	48	62
Sediment accumulation since 1952, in million cubic meters	8.47	10.14
Inter-survey (2000–14) sediment accumulation, in million cubic meters	3.96	1.67
Long-term (since 1952) storage loss, in percent	42	50
Long-term (since 1952) annual loss of capacity, in million cubic meters per year	0.18	0.16
Annual loss of capacity, in percent	0.9	0.8
Inter-survey (2000–14) loss of capacity, in million cubic meters per year	0.28	0.12
Sediment trapping efficiency, in percent <sup>1</sup>	96	95
Long-term sediment yield, in cubic meters per square kilometer per year <sup>2</sup>	1,255	1,175
Inter-survey (2000–14) sediment yield, in cubic meters per square kilometer per year <sup>2</sup>	2,013	858
Estimated year the reservoir is expected to fill with sediments <sup>3</sup>	2066	2076

<sup>1</sup>Period between 1986 and 2000 surveys.  
<sup>2</sup>Using the capacity/yield ratio described by Brune (1953).  
<sup>3</sup>Assuming that the reservoir would continue to fill at the average long-term sedimentation rate.

**Table 2.** Storage capacity at 1-meter intervals from spillway elevation for Lago Lucchetti, Yauco, Puerto Rico, 2014.

Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters	Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters	Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters
173.74	10.21	165.74	4.55	157.74	1.39
172.74	9.29	164.74	4.07	156.74	1.10
171.74	8.44	163.74	3.62	155.74	0.84
170.74	7.65	162.74	3.19	154.74	0.60
169.74	6.92	161.74	2.79	153.74	0.39
168.74	6.23	160.74	2.41	152.74	0.20
167.74	5.59	159.74	2.05	151.74	0.08
166.74	5.05	158.74	1.71	150.74	0.01
				149.74	0.00

The Lago Lucchetti storage capacity decreased from 11.88 Mm<sup>3</sup> in March 2000 to 10.21 Mm<sup>3</sup> in May 2014. The survey results show a long-term storage capacity loss of about 50 percent, corresponding to a decrease of about 0.16 Mm<sup>3</sup>/yr since the reservoir was built in 1952. Comparison of the 2014 results with a previous sedimentation survey in 2000 indicated that on a long-term basis, the sedimentation rate remained relatively constant. The inter-survey sediment accumulation was 1.67 Mm<sup>3</sup> between 2000 and 2014; this represents a reservoir sedimentation loss of about 0.12 Mm<sup>3</sup> between 2000 and 2014.

Most of the sediment accumulation and associated storage capacity loss of Lago Lucchetti has occurred along the Río Yauco and Quebrada Grande tributaries of the reservoir. Sediment deposition and scour were observed in 2014 in the vicinity of the dam compared to the 2000 survey.

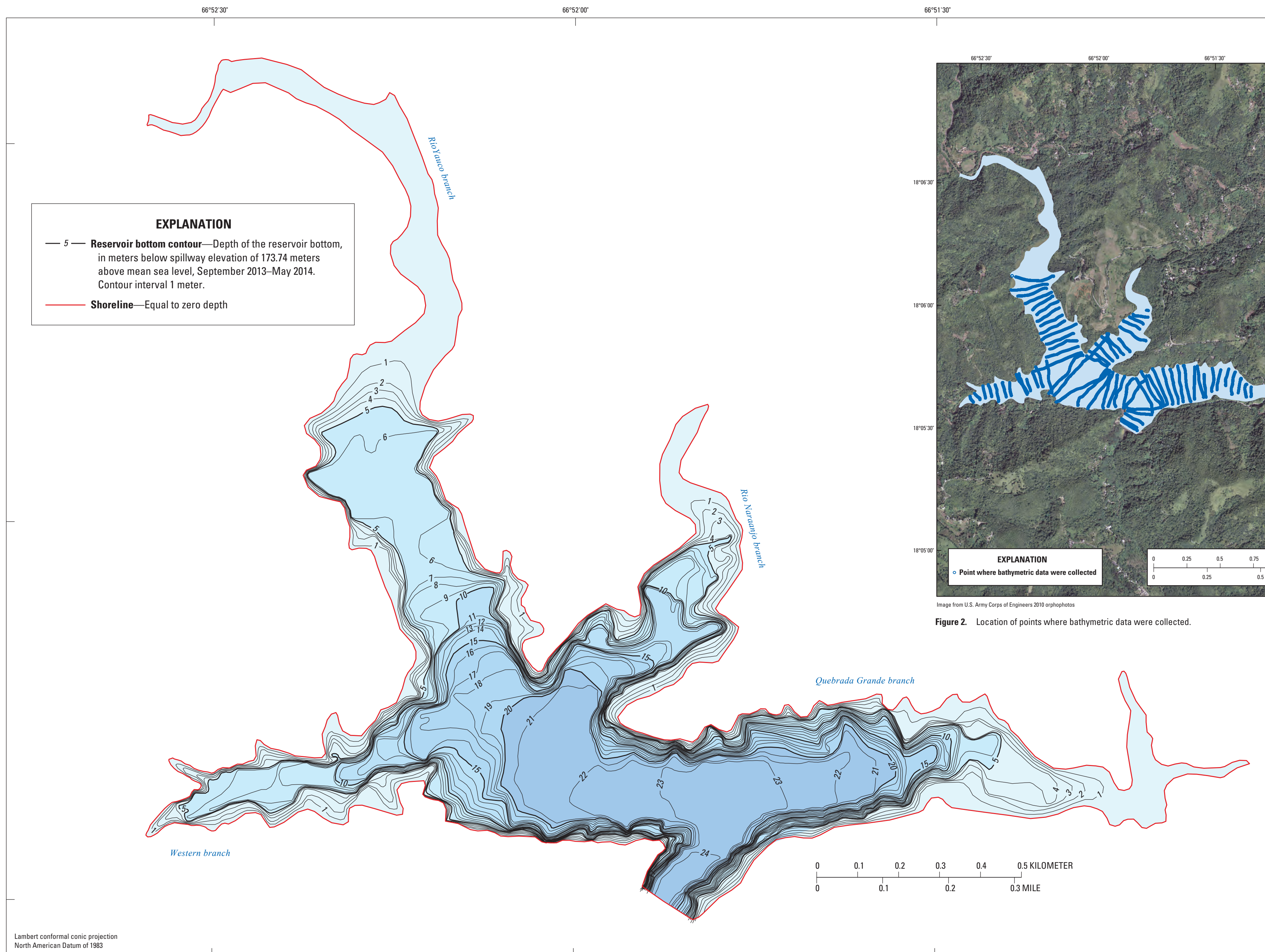
The Lago Lucchetti drainage area sediment yield has decreased by about 6 percent, from 1,255 (m<sup>3</sup>/km<sup>2</sup>/yr) based on 2000 survey to 1,175 (m<sup>3</sup>/km<sup>2</sup>/yr) based on 2014 survey. If the long-term sedimentation rate of 0.16 Mm<sup>3</sup>/yr remains constant, loss of storage capacity will most likely end the useful life of Lago Lucchetti by 2076.

**Acknowledgments**

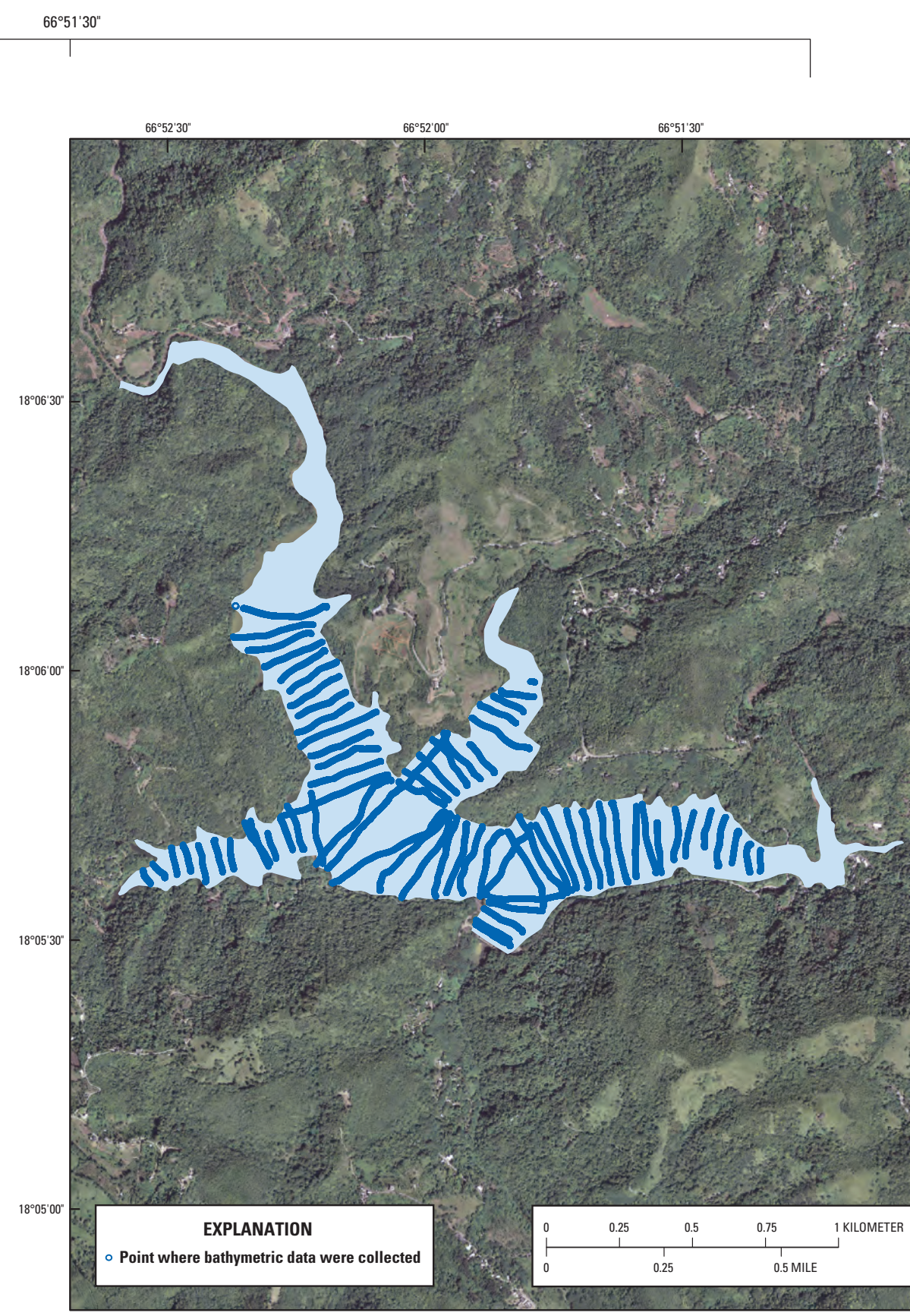
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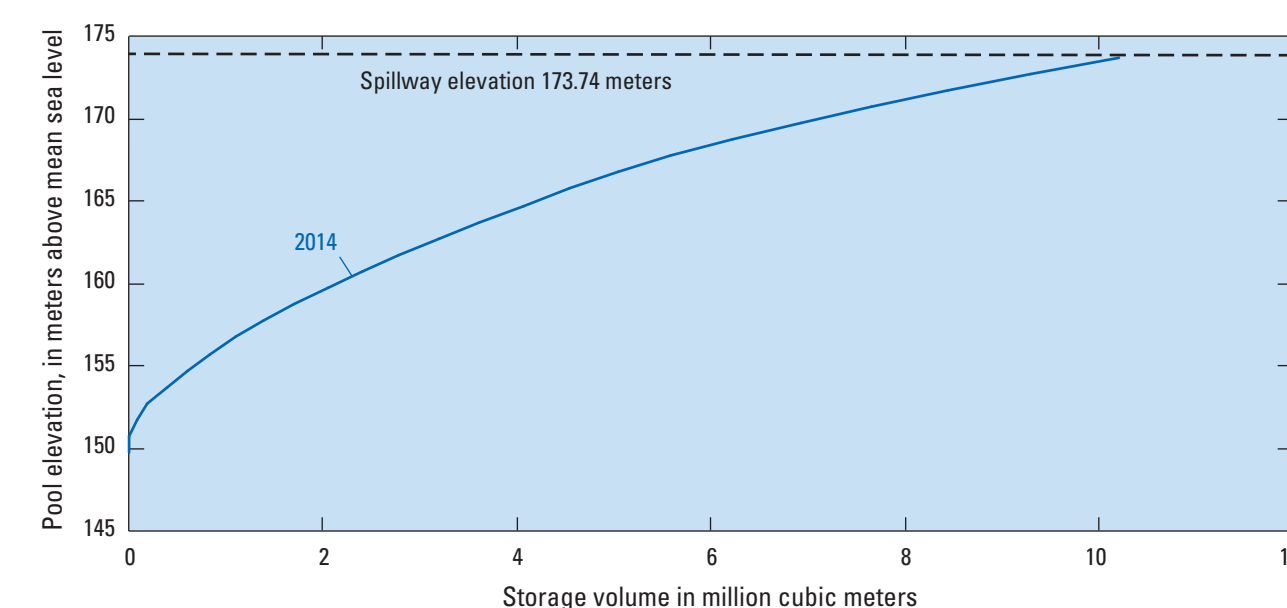
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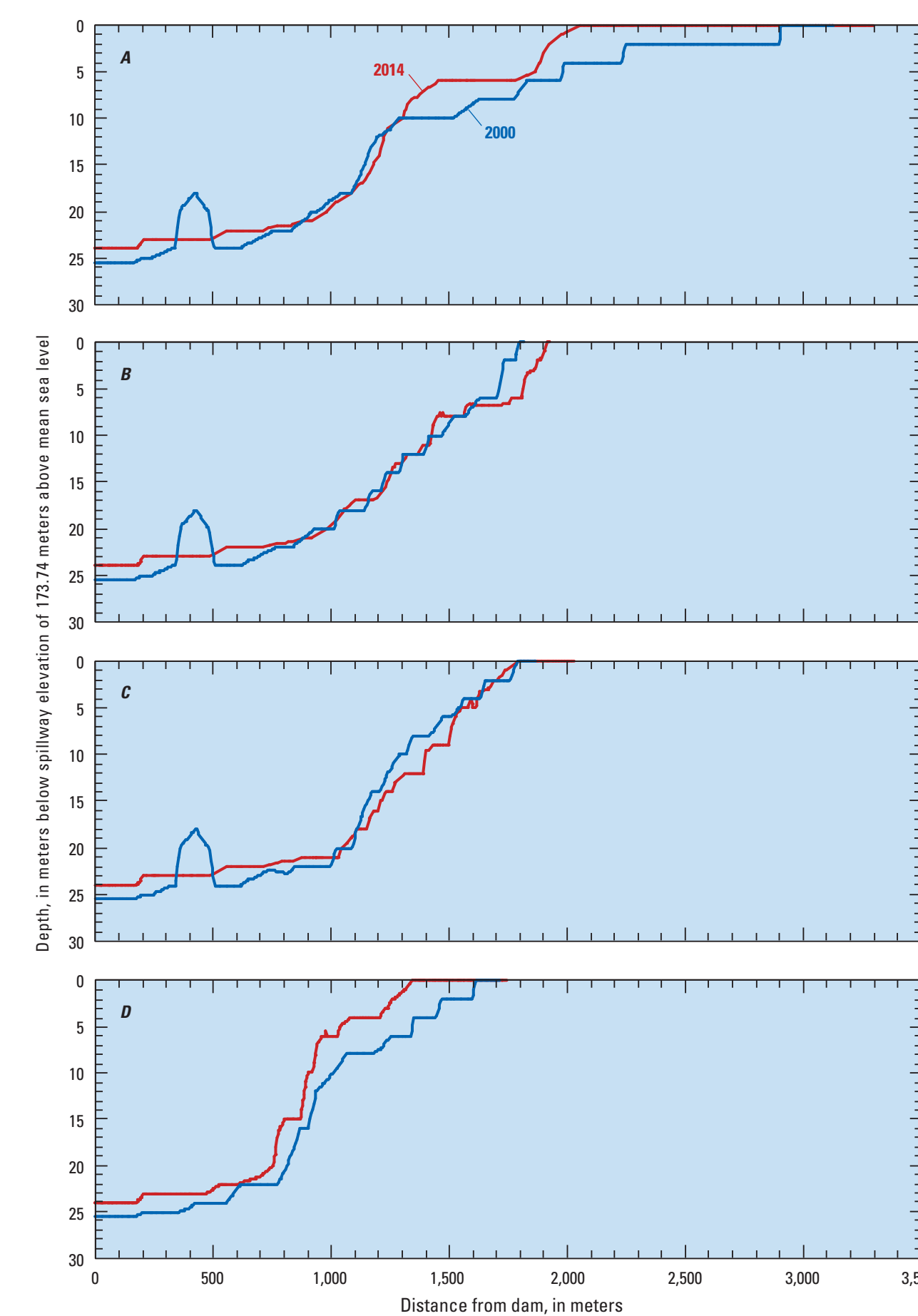
**Figure 3.** Bathymetric map of Lago Lucchetti, Puerto Rico, September 2013–May 2014.



**Figure 2.** Location of points where bathymetric data were collected.



**Figure 4.** Pool elevation and storage volume for the Lago Lucchetti, Yauco, Puerto Rico (survey 2014).



**Figure 5.** Longitudinal bottom profiles for 2000 and 2014 along the A, Río Yauco; B, Western; C, Río Naranjo; and D, Quebrada Grande tributaries of Lago Lucchetti, Yauco, Puerto Rico.

**Sedimentation Survey of Lago Lucchetti, Yauco, Puerto Rico, September 2013–May 2014**

By  
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 2016

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