U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

science for a changing world

Prepared in cooperation with the
PUERTO RICO AQUEDUCT AND SEWER AUTHORITY

SCIENTIFIC INVESTIGATIONS MAP 2010-3118
Sedimentation Survey of Lago de Cidra, Puerto Rico, August 2007
By Luis R. Soler-López, 2010

Figure 1. Location of Lago de Cidra in the Río de Bayamón basin, Puerto Rico.

EXPLANATION

50047550 ⬠ LAKE-ELEVATION STATION AND NUMBER
◼ TOWN OR CITY
— — DRAINAGE BASIN BOUNDARY

Figure 2. Bathymetric map of Lago de Cidra, Puerto Rico, for August 2007.

EXPLANATION

RESERVOIR BOTTOM CONTOUR- Depth of the reservoir bottom, in 2007, in meters below spillway elevation of 403.00 meters above mean sea level. Contour interval variable.
Shoreline shown as red line equal to zero depth or spillway elevation of 403.00 meters above mean sea level.

Shoreline modified from the U. S. Geological Survey quadrangles Caguas and Comerío, Puerto Rico, 1941, Lambert Conic Conformal Projection.
Puerto Rico State Plane coordinate system (Puerto Rico Datum, 1940 adjustment)

Introduction

Lago de Cidra is a reservoir located on the confluence of Río de Bayamón, Río Sabana, and Quebrada Prieta, in the municipality of Cidra in east-central Puerto Rico, about 3.0 kilometers northeast of the town of Cidra (fig. 1). The dam is owned and operated by the Puerto Rico Aqueduct and Sewer Authority (PRASA), and was constructed in 1946 as a 6.54-million-cubic-meter supplemental water supply for the San Juan metropolitan area.

The reservoir impounds the waters of Río de Bayamón, Río Sabana and Quebrada Prieta. The reservoir has a drainage area of 21.4 square kilometers. The dam is a concrete gravity and earthfill structure with a length of approximately 165 meters and a structural height of 24 meters. The spillway portion of the dam is an ungated ogee crest about 40 meters long with a crest elevation of 403.00 meters above mean sea level. Additional information and operational procedures are listed in Soler-López (1999).

During August 14-15, 2007, the U.S. Geological Survey (USGS), Caribbean Water Science Center (CWSC), in cooperation with the PRASA, conducted a bathymetric survey of Lago de Cidra to update the reservoir storage capacity and actualize the reservoir sedimentation rate by comparing the 2007 data with the previous 1997 bathymetric survey data. The purpose of this report is to describe and document the USGS sedimentation survey conducted at Lago de Cidra during August 2007, including the methods used to update the reservoir storage capacity, sedimentation rates, and areas of substantial sediment accumulation since 1997.

Method of Survey and Analysis

The field techniques and bathymetric data reduction processes used for the 2007 survey were performed following procedures established by the USGS CWSC, and described in the previous bathymetric survey report of Lago de Cidra (Soler-López, 1999). The August 2007 bathymetric survey was conducted using a differential global positioning system (DGPS) coupled to a digital depth sounder similar to the setup used for the survey conducted in November 1997 (Soler-López, 1999). Survey navigation lines were established at a spacing of about 50 meters, beginning at the dam and continuing upstream along the different river branches of the reservoir. Geographic position and water depths were acquired simultaneously using the DGPS interfaced to the depth sounder. The pool elevation of the reservoir was recorded at USGS lake-level station 50047550, Lago de Cidra at Damsite near Cidra. The soundings were subsequently adjusted to represent water depths below the spillway crest elevation.

The 2007 data were stored and transferred into the USGS geographic information system (GIS) where final analysis and volume calculations were made following similar procedures used to develop the November 1997 bathymetric map of Lago de Cidra (Soler-López, 1999). Field data from the August 2007 survey were used to generate a bathymetric map representing the reservoir bottom in August 2007 (fig. 2). A triangulated irregular network (TIN) surface model of Lago de Cidra was then generated from the bathymetric map, and the reservoir volume was calculated using the GIS. The TIN surface model was used with the digital data for 1997 and 2007 to generate a stage-storage curve and longitudinal profiles along the different river branches of Lago de Cidra. A storage capacity table and curve were generated by calculating the TIN volume at 1.00 meter elevation intervals.

Storage Capacity, Sedimentation Rates, and Useful Life

Bathymetric data indicate the storage capacity of Lago de Cidra decreased slightly from 5.76 million cubic meters in November 1997 (Soler-López, 1999) to 5.63 million cubic meters in August 2007 (table 1). The inter-survey (1997-2007) storage capacity loss is about 2.3 percent, for a decrease of about 0.23 percent per year. This decrease represents a reduction of 130,000 cubic meters between 1997 and 2007, for an annual storage capacity loss rate of about 13,000 cubic meters. However, the long term Lago de Cidra capacity loss rate due to sedimentation has not changed measurably since 1997 (table 1), and may be a result of the relatively small drainage area (21.4 square kilometers, fig. 3) contributing to Lago de Cidra. An actualized storage capacity table and curve are shown on table 2 and figure 4, respectively.

The comparison of longitudinal bottom profiles for 1997 and 2007 indicates that sediment accumulation in Lago de Cidra for this period was minimal (fig. 5). The greatest accumulation (averaging about 3 meters) occurred along the riverine zone of Lago de Cidra in the Río Sabana approximately 3,200 to 4,000 meters upstream from the dam, and in the Quebrada Prieta approximately 2,200 to 2,800 meters upstream from the dam . Sediment deposition from 1997 to 2007 was minimal along the Río de Bayamón branch and near the dam. The sediment deposition rate from 1997 to 2007 was about 30 centimeters per year along the Río Sabana and Quebrada Prieta branches. The more noticeable effect of sediment accumulation is that the reservoir surface area (flooded area) has been reduced on the Río Sabana and Quebrada Prieta riverine zones (fig. 5). Figure 6 shows an aerial photograph of the Lago de Cidra dam and the spillway section.

The long-term drainage area sediment yield rate of Lago de Cidra has remained nearly constant, decreasing from 768 cubic meters per square kilometer per year in 1997 (Soler-López, 1999) to 765 cubic meters per square kilometer per year in 2007 (table 1). The inter-survey drainage area sediment yield, however, decreased by about 13 percent from 768 to 666 cubic meters per square kilometer per year. According to the current storage capacity loss of about 13,000 cubic meters per year estimated for the 1997-2007 period, the projected useful life of Lago de Cidra is about 433 years, to the year 2440.

Summary and Conclusions

During August 2007, the USGS Caribbean Water Science Center, in cooperation with the Puerto Rico Aqueduct and Sewer Authority, conducted a bathymetric survey of Lago de Cidra to update the reservoir storage capacity and actualize the reservoir sedimentation rate by comparing 2007 bathymetric survey data with 1997 data.

The Lago de Cidra storage capacity was 5.76 million cubic meters in November 1997, which decreased to 5.63 million cubic meters by August 2007. The inter-survey (1997-2007) storage capacity loss is about 2.3 percent, for a decrease of about 0.23 percent per year. This loss represents a reservoir sedimentation rate of about 13,000 cubic meters per year between 1997 and 2007. On a long-term basis (1946–2007), however, the sedimentation rate has remained constant at about 15,000 cubic meters per year.

Most of the storage capacity loss of Lago de Cidra has occurred along the Río Sabana and Quebrada Prieta branches, where an average of about 3 meters of sediment has been accumulated between 1997 and 2007. Sediment accumulation has been minimal along the Río de Bayamón branch and in the vicinity of the dam.

The Lago de Cidra drainage area sediment yield has decreased about 13 percent from 768 cubic meters per square kilometer per year between 1946 and 1997 to 666 cubic meters per square kilometer per year between 1997 and 2007. On a long-term basis, however, the sediment yield has remained unchanged at about 765 cubic meters per square kilometer per year as a result of the relatively small sediment-contributing Lago de Cidra drainage area of 21.4 square kilometers.

Although the life expectancy of about 433 years for Lago de Cidra is not a pressing concern, sediment accumulation in the Río Sabana and Quebrada Prieta branches of the reservoir will continue forward towards the deepest parts of Lago de Cidra, and will eventually start filling the reservoir near the dam. If the 1997-2007 sedimentation rate remains constant, the useful life of Lago de Cidra may end by the year 2440.

References Cited

Brune, G. M. 1953: Trap efficiency of reservoirs. Transactions of the American Geophysical Union 34, 407-418.

Soler-López, Luis R., 1999, Sedimentation survey of Lago de Cidra, Puerto Rico, November 1997: U.S. Geological Survey Water-Resources Investigations Report 99-4144, 19 p., 1 pl.
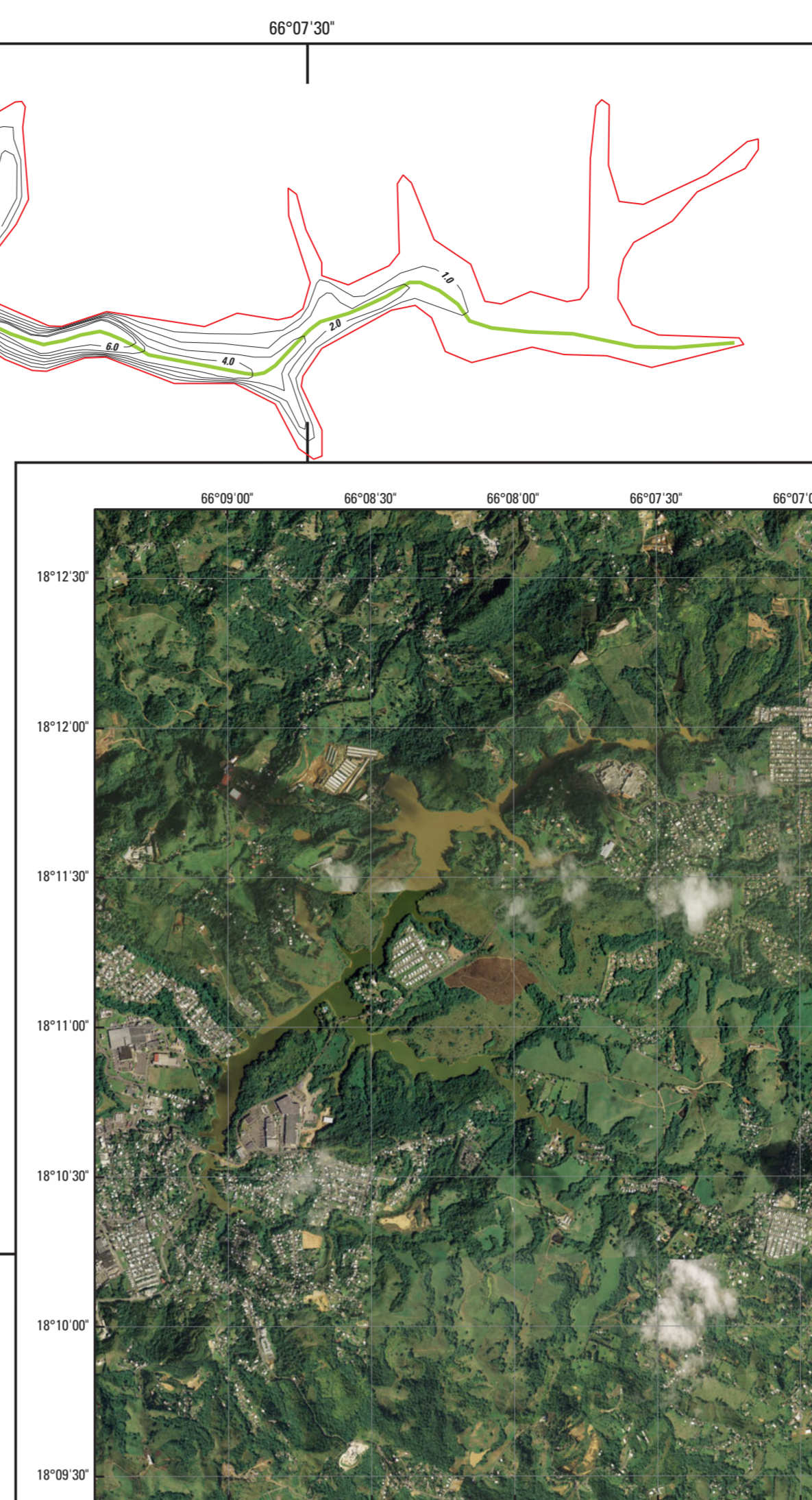
Figure 3. Aerial photograph of Lago de Cidra and its immediate surroundings showing development. Photograph from the U.S. Army Corps of Engineers, Puerto Rico, 2007.
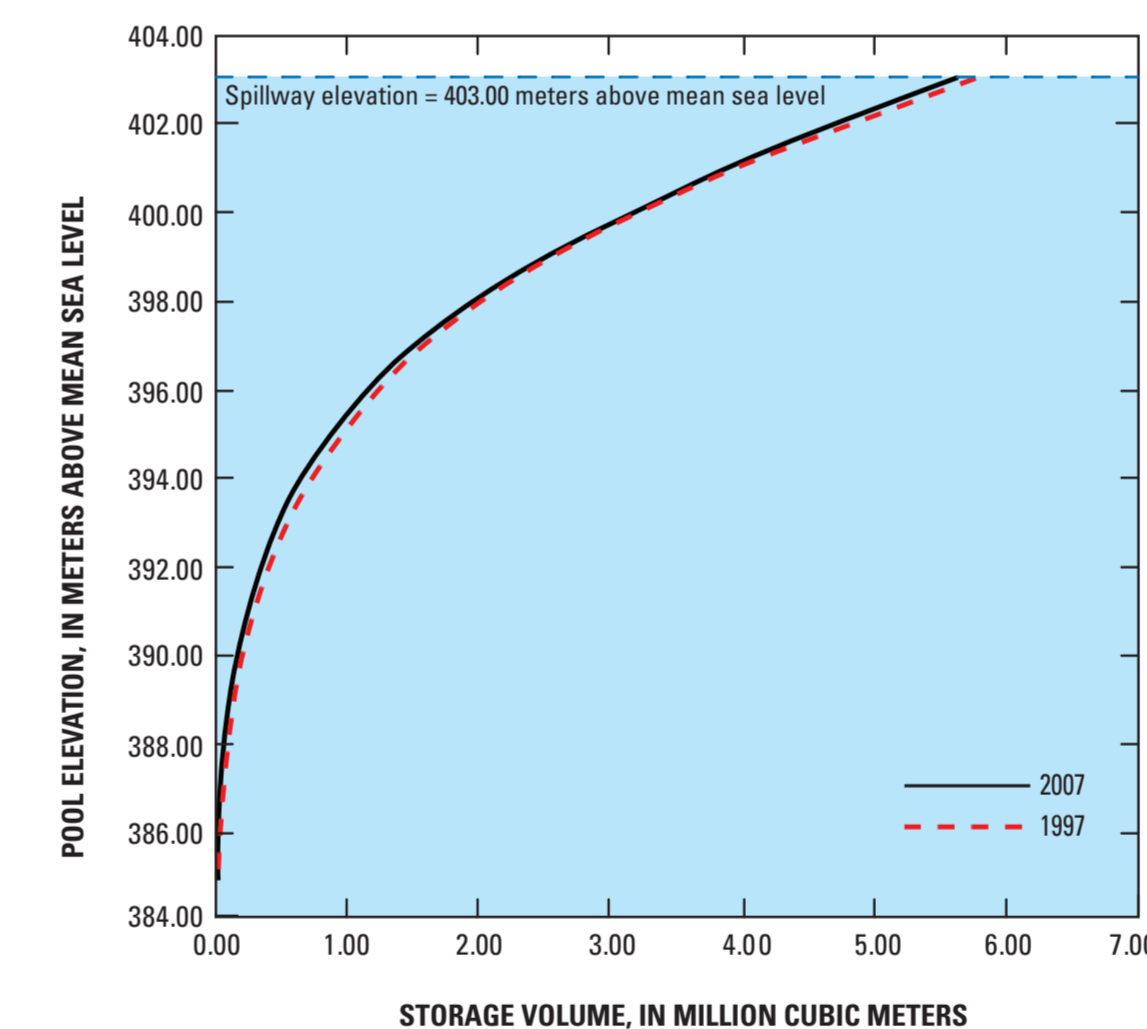
Table 1. Comparison of the 1997 and 2007 sedimentation surveys of Lago de Cidra, Puerto Rico.

Data descriptor	Year of survey		
	1946	1997	2007
Total capacity, in million cubic meters	6.54	5.76	5.63
Years since construction	0	51	61
Sediment accumulation since construction, in million cubic meters	—	0.78	0.91
Sediment accumulation since previous survey, in million cubic meters	—	0.78	0.13
Storage loss since construction, in percent	—	11.9	13.9
Annual loss of capacity since construction in cubic meters	—	15,294	14,918
Annual loss of capacity since construction, in percent	—	0.23	0.23
Years since previous survey	—	51	10
Inter-survey loss of capacity, in cubic meters per year	—	15,294	13,000
Estimated sediment trapping efficiency, in percent [1]	—	98	96
Inter-survey basin sediment yield, in cubic meters per year	—	768	666
Long-term basin sediment yield, in cubic meters per square kilometer per year	—	768	765
Estimated year the reservoir would fill with sediments	—	2374	2440

[1] Using the relation established by Brune (1953).

Table 2. Storage capacity table for Lago de Cidra, Puerto Rico, August 2007.

Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters
403.00	5.63
402.00	4.70
401.00	3.89
400.00	3.18
399.00	2.54
398.00	1.97
397.00	1.51
396.00	1.15
395.00	0.88
394.00	0.66
393.00	0.49
392.00	0.36
391.00	0.25
390.00	0.17
389.00	0.10
388.00	0.06
387.00	0.03
386.00	0.01
385.00	0.00

Figure 4. Relation between water-storage capacity and pool elevation of Lago de Cidra, for 1997 and 2007.

Spillway elevation = 403.00 meters above mean sea level

2007
1997

POOL ELEVATION, IN METERS ABOVE MEAN SEA LEVEL
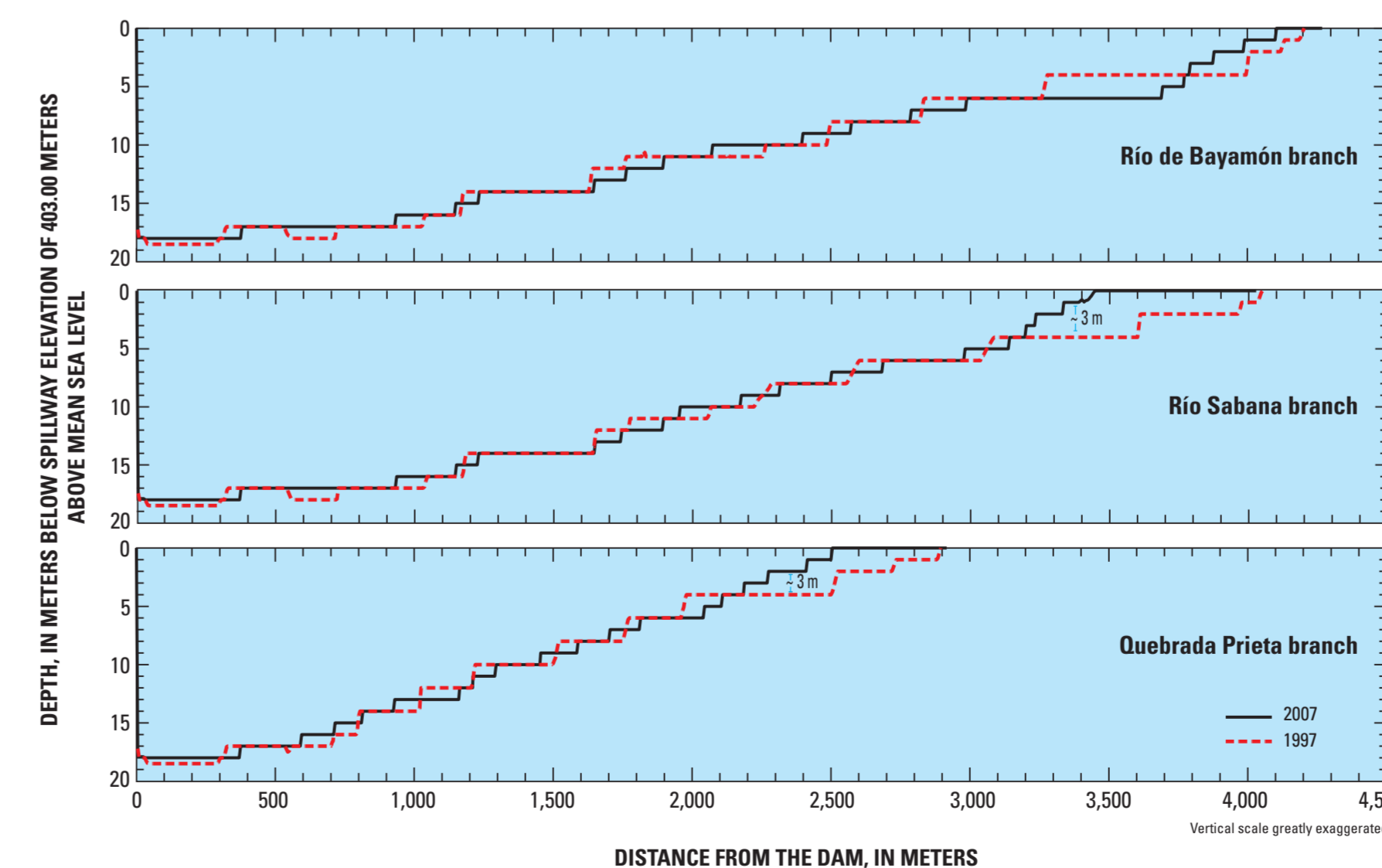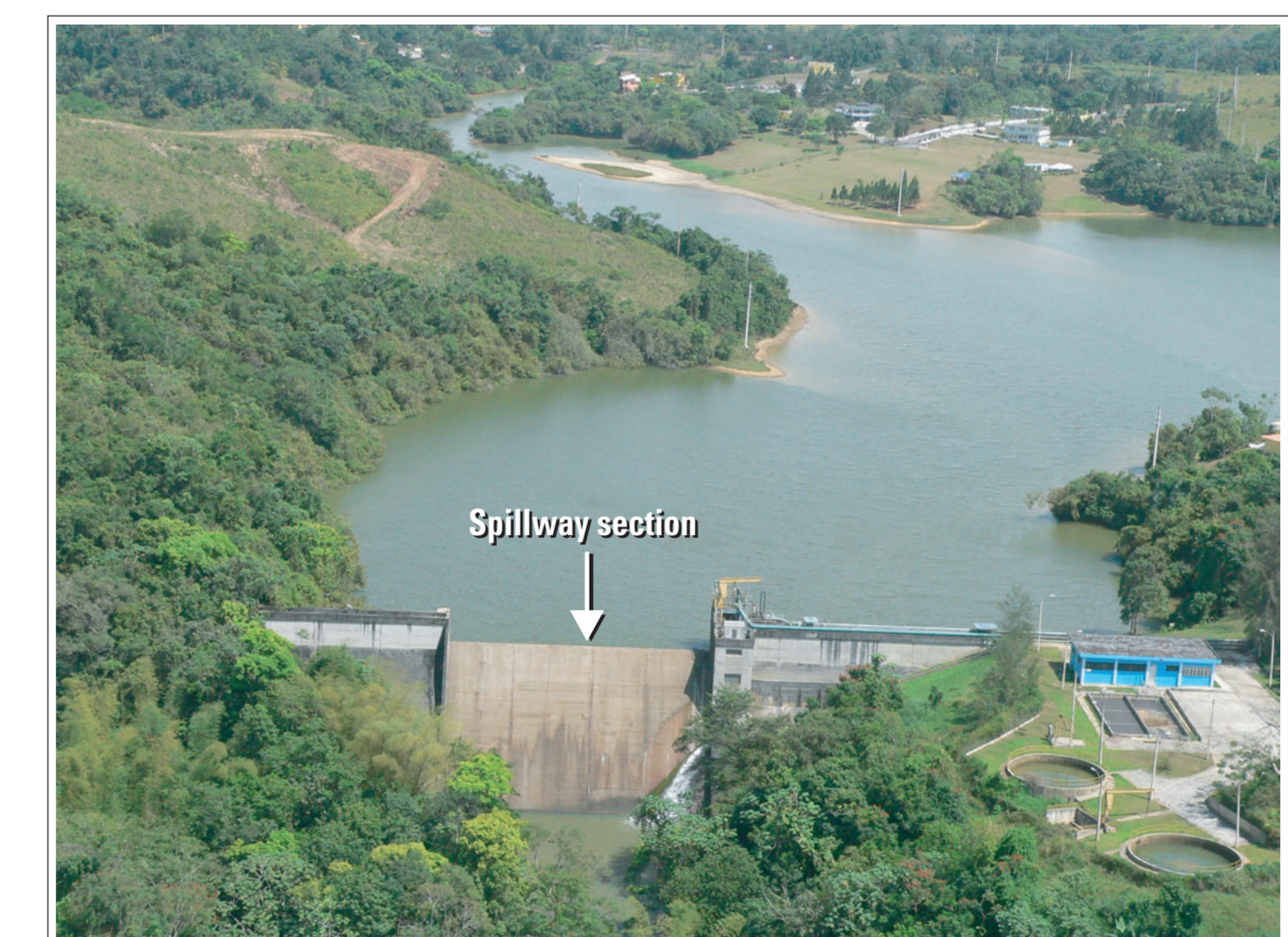STORAGE VOLUME, IN MILLION CUBIC METERS

Figure 5. Longitudinal bottom profiles along the thalweg of the Río de Bayamón, Río Sabana, and Quebrada Prieta branches of Lago de Cidra, Puerto Rico, for 1997 and 2007.

Río de Bayamón branch
Río Sabana branch
Quebrada Prieta branch

2007
1997

DEPTH, IN METERS BELOW SPILLWAY ELEVATION OF 403.00 METERS ABOVE MEAN SEA LEVEL
DISTANCE FROM THE DAM, IN METERS
Vertical scale greatly exaggerated

Figure 6. Aerial photograph of the Lago de Cidra concrete dam and spillway section. Photograph courtesy of the Puerto Rico Electric Power Authority, May 2006.

Spillway section

DAM