BATHYMETRICAL CHARTING OF THE BUDEASA RESERVOIR

Emanuel MAILAT[1], Daniel Constantin DIACONU[2]

[1]Romanian Waters National Administration Water Directorate Argeş Vedea
Pitesti, Romania emanuel.daav @ yahoo.com
[2]Faculty of Geography, University of Bucharest, Bucharest, Romania
diaconudc@hotmail.com

Abstract

The study of the bathymetrical characteristics of lake basins aroused interest long ago, leading to a continuos evolution of the investigation methods. Technical instruments and processing of data gathered on site have evolved and the results can be observed in the accurate reproduction of lake basin morphology. At present, the introduced method for bathymetrical mapping is based on highly accurate instruments, with a possibility of future layouts based on the same profiles. The information is rendered in a precise and expressive form.

Keywords: lake, accumulation, sediments, bathymetric

1 Introduction

Studying the clogging of reservoirs is a very important step towards measuring the exact volume of water and therefore ensuring efficient exploitation and management of water resources.

The main purpose of a bathymetrical chart is to visualize the accumulation capacity curve (rendered in both table and graphic form), to determine the extent of clogging, to map the basin and to draw up the regulations for exploiting a storage reservoir. This will provide adequate knowledge of the available water volume according to the water level and manner of exploitation.

This article is intended as an overview of modern techniques and methodology, presently used in our country, for calculating the water volume in a storage reservoir.

The equipment used to realize a bathymetrical chart are: motor boat and

auxiliary equipment, sonar (single beam or multibeam), a system of three GPS units (2 on the banks and one integrated into the sonar), a total topometry station, laptop and specific software (specific downloading and data processing programs), a power source for 12V and other auxiliary materials.

2 Metodology

The methodology used to realize a bathymetrical chart comprises three stages: one stage is represented by on site data gathering and two stages are performed in the laboratory (one stage is necessary in order to prepare the informational support, before the actual field work, the other represents the processing of the data gathered on site, both above and below water level)

During the first stage - the office stage - a draft will be prepared based on a GIS map or a orthophoto map of the storage reservoir. A number of elements with known XYZ coordinates will be superimposed on either of this maps. To achieve this objective, a sheep type file will be set up for each group of items which will be useful during the field stage: boundary posts, markings, islands, obstacles that may hinder navigation, transversal profiles for guiding the ships.

In order to identify the existing boundary posts and markings, we need to introduce the XY coordinates in a portable GPS unit, which will help us determine their exact location.

After completing the initial stage - preparation of the informational support (HYPACK program and sheep files), we will be able to continue with the field work stage, during which we will gather the required data.

During the filed work stage, the total station will be used for conducting the topographical mapping of the banks. Following the previously established profile lines, we will probe the submerged areas using the sonar. On one of the banks, preferably the left bank, we will use tags to mark the end points of the topographic profile. The exact position can be visualized on the GIS map, after introducing the XY coordinates in the HYPACK program.

The quotas and distances of the batyhmetric profiles will be revised in the laboratory. Based on the results we can calculate the depth, length, width, volume and surface of the accumulation, correcting or deleting the improbable values.

2.1 Topographical field work

The precision, accuracy and volume of the acquired data are essential elements for elaborating a highly precise bathymetrical map.

In order to obtain very precise data, at least one GPS must be installed on a

point with known XYZ coordinates. This point will be used during the entire process of bathymetrical charting. This will be the starting point of the charting process and also the point where the marking of one of the banks will begin. The marking is necessary in order to establish the direction of the profiles, in case there are no other markings with known XYZ coordinates. Markings that would have been established during previous batymetrical charting.

In case the lake presents markings already introduced in a sheep file while preparing for the field work stage, the position of this markings will be visible on the GIS map and can be identified on site with the help of the GPS.

As soon as the markings have been identified, we can establish the transversal profiles and proceed with the topographical mapping of the banks within the marked section. The direction of the measurements will be perpendicular to the direction of the water flow.

Below the water surface, the data will be gathered with the help of the echo-sounder. The echo-sounder can be of two types (single beam o multi-beam) based on the number of radar beams emitted towards the lake basin. The single beam sonars emit only one radar beam, performing a single reading of the depth, while a multi-beam sonar functions similar to a scanner, gathering information regarding the depth of the lake from multiple points simultaneously, therefore offering a highly accurate description of the lake basin morphology.

The order of installation and connection of equipment:- link all cables (power-PWR, GPS, Serial-USB connector and echo sensor) to the echo-sounder;- link and fix the terminals to the car battery;- start the echo-sounder;- open the previously created project; - start the measuring module (Survey);- connect the USB-Serial adapter to the computer.

Disconnecting the equipment once the measurements are finalized will be done in reversed order. Failure to follow this sequence can lead to the damaging of the echo-sounder or the laptop and therefore the data gathering will no longer be possible.

After the boat has been launched and the connection of the GPS and sonar to the echo - sounder and laptop has been established, we will wait for the correction of the position using a minimum of two satellites and we will track the given position on the GIS map.

The echo-sounder will have to be set up in order to receive corrections from the GPS satellites (EGNOS or ARTEMIS), settings which will be operated in the Position menu.

We will check the correlation between the depth registered by the echo-sounder, which we can follow on the laptop screen and the depth measured manually (for control purposes) using the hydrometer. The eventual differences between these to measurements, will be noted for future corrections or will be corrected from the menu of the echo-sounder (Offsets).

At the same time the standard speed of sound in water will be set. The speed of sound varies according to salinity, temperature or turbidity.   The standard speed of sound is 1470 m / s in salt water and 1430 m / s in freshwater. The frequency on which the sound is emitted (50 kHz or 200kHz) will be set depending on the depth and nature of the basin bed (frequency of 50 kHz is used in areas with abundant vegetation, and the 200 kHz frequency is used where the surface of the basin is firm).

After registering the corrections, the echo-sounder begins relaying data to the informational system regarding depth, latitude, longitude and movement speed at the point where it is positioned.

On the laptop, using the Survey measurement mode, position and depth should be actualized every second. If this actualization does not occur, we need to verify the cables and connections; if all connections are correct we have to restart the echo-sounder.

With the help of the informational system of the HYPACK program we can visualize on the GIS map or the orthophoto map the position of the boat on the lake, the boundary posts or the markings, the transversal profiles required for maintaining the direction of the boat, the islands and eventual obstacles if they were previously introduced in the system.

If all the relayed information is accurate we can start gathering the data and we will sail along the established profile cuts, using a speed of maximum 4-5 km/h in order to register the depth in as many points as possible.

Still in the Survey mode start the registering of data by pushing the Start Logging button and stop registering, by pushing the Stop Logging button. The HYPACK program automatically creates a file with the extension .RAW and saves it in the initial draft.

After gathering all the data below water level along the transversal and longitudinal profiles, and in order to obtain an accurate image of the depths, we sometimes need to gather data from additional profile sections or golfs, which could not be included on the direction of the initial profiles.

All the data we have gathered will be automatically saved in a file containing raw data corresponding to each transversal profile. The saving of the data is automatically carried out when the sounding of a profile is started.

During the bathymetric charting we can mark a certain area of the lake which may present interest for future studies or we can mark obstacles which were not present in the initial draft (alluvial deposits, areas with highly developed vegetation, islands that can appear due to low water levels).

2.2 Office Stage

The office stage includes the processing of raw data (topographical and bathymetrical) with the help of software applications, and the filtering and deleting of improbable values in order to elaborate the digital blue-print of the terrain. This blue-print is used as a base for calculating the elements of interest on the lake we are studying.

After each profile has been analyzed and adapted (transversal, longitudinal and supplementary) we will create a file which will contain the XYZ coordinates of all the points mapped on site, be it on the banks or on the basin surface.

With the help of the HYPACK program, we will create the digital blue-print of the terrain. We will use the blue-print to calculate the volume of the lake at different levels, the maximum depth, the surface depending on the level in the lake, and we will emit a series of text reports concerning all this elements.

The digital blue-print of the terrain is created by drawing triangles between the XY coordinates of adjacent points, following certain criteria defined in the HYPACK program.

One of this criteria is the definition of the maximum distance between three united points. Any point set beyond this distance will not be utilized in the elaboration of the digital blue-print.

Considering this criterion and depending on the proportions of the basin and the required accuracy of the results, it is preferable to set the profiles as close to each other as possible. On site it is recommended to determine a minimum of three transversal profiles, as well as diagonal profiles so that the final results are highly accurate.

The next step after completing the digital blueprint of the terrain is the graphical representation of the basin as a 2D or 3D image and the drawing of the bathymetrical curves considering the desired divergence.

The final results of a bathymetrical chart, the capacity curve of the basin and the surface of the lake depending on the water level are generated automatically. The information is presented in a text file, considering the divergence defined by the user of the HYPACK program.

3 Case study

Budeasa lake is situated in Argeş county, at the limit of Budeasa and Bascov settlements, in the north - east of the town Piteşti. It is located on the Argeş river, downstream from the Valcele basin and represents the confluence of the Argeş river and the Valsan river.

The hydro-technical facility is ranked I class of importance according to STAS

4273/83 and was determined at discharge quantity with the probability of exceedance Q 0.1% (Q = 1300 m³/s). The verification was performed at discharge quantity with a probability of exceedance 0.01% Q (Q = 1850 m³/s) according to STAS 4068/2-87.

The facility was put into operation in 1978, but construction work continued until 1985 when Budeasa accumulation was filled for the first time to the normal retention level.

The basin fulfills the main functions of supplying water to the town Pitesti and the villages located downstream, producing electricity, providing the necessary volumes of water for irrigating the adjacent fields and to provide defense against flooding by directing the excess water to the Galasesti facility in a controlled manner. Galasesti is located close to the left bank of the basin.

Initially the basin presented the following characteristics:
- normal retention level - 301,00 mdMN; maximum level of exploitation- 306.00 mdMN; the gross volume NRL (normal retention level) - 27.9 mil.m³; lake surface at NRL - 412.9 ha; length of the lake at NRL - 5.5 kilometers; the dam on the left bank is 934 m long and the one on the right bank is 4625 m long; the maximum height of the dams is 25 m; the main outlet located on the right bank of the basin presents an utilizable discharge of 6,0 m³/s and supplies raw water to the water treatment station Budeasa, which in turn provides treated water to the Pitesti area; in case the main outlet is damaged, the station will switch the flow to the secondary outlet located on the left bank of the basin, in order to continue providing water to the Pitesti area; the secondary outlet also presents an utilizable discharge of 6,0 m³/s; the water intake valve at Budeasa Hidroenergetic plant presents a utilizable discharge of 90,0 m³/s; the intake valves at bottom level used for backup water supply, are located at the oppenings 1 and 3 of the dam; they insure the interception of underground water; every intake can capture a maximum discharge of 6,0 m³/s; the hydroelectric plant - located at the right intake of the dam is equipped with two Kaplan turbines.

In order to realize the bathymetric chart of the Budeasa basin we have determined the XYZ coordinates for the markings at the end points of the transversal profiles situated on the concrete dam, on the right bank. We will use two GPS units, a stationary one on the boundary post 211 and a mobile one stationed on each marking in turn.

The topographical mapping of the banks, reaching down to the normal retention water level (NRL - quota 301.00 mdMN), is done with the help of the total topographical station. The coordinates of the topographical points are adapted and exported to a .DFX type file, used by the Autocad program.

For the bathymetrical chart of the Budeasa basin, we have done topographical measurements of 11 transversal profiles and bathymetrical measurements of 26 transversal profiles, and 6 longitudinal profiles. We have established the XYZ coordinates for a total of 30274 points, located on the banks

and on the surface on the basin bed.

The sounding of the submerged surface was done along the transversal and the longitudinal profiles every 2 m. The maximum depth of the basin, along the studied routs, was 18.7 m.

We can represent the lay-out of the profiles that were sounded inside the Budeasa basin on a orthophoto plan (fig.1). In case a future bathymetrical chart will be required, the charting of the submerged surface can be done using the initial profile cross-cuts, therefore obtaining a exact image of the basin evolution.

After processing the data with the help of the HYPACK program, we have calculated the volume of the Budeasa basin at 25.9 million m^3 at normal retention level (301 mdMN). Surprisingly, considering other basins on the Argeş river, the volume of the lake has not decreased significantly compared to the volume calculated in 1985 - 27,9 millions m^3.

This situation is due to the fact that in the time frame 1985-1998, huge quantities of ballast have been exploited.

Figure 1. Budeasa reservoir - lines of the bathymetrical profile

The calculations show that the clogging is at 7.2 % compared to the initial volume. This represents a growth rate of the annual clogging process of 0.3% -

meaning about 86,957 m³/year.

The bathymetrical charting of the Budeasa reservoir, performed in 1999 with the help of a PEL echo-sounder, shows that the volume of the basin was 31.2 millions m³. Due to the important differences compared to the initial volume, a new charting was requested but it was delayed until 2008.

By comparative analyses to the volume calculated in 1999, the clogging of the basin increased with 17%, the rate of the yearly clogging being established at 1.7%. This value is much more plausible considering the alluvia transported by the Vâlsan river, calculated at the hydrometrical station at Malureni, up-stream from the Budeasa basin.

The medium multi-annual solid discharge in the time frame 1981-2006 was 4.04 kg / s and the maximum solid discharge was 4770 kg / s recorded in 2005 - an exceptional year with regard to the scale of flooding.

As you can observe on the graphical representation of the basin (fig 2 and 3), the maximum depth is located at the front part of the basin, on the right hand side of the lake. The main intake valve for capturing drinking water supplies is located here.

At the tail end of the basin we can observe two distinct areas. One area, situated on the left hand side of the basin, presents clogging and a depth of 0.6 m. The Valsan river deposited an impressive amount of alluvia, covering a distance of 1000 m towards the front of the dam. A second area is situated on the right hand side at the end of the escape channel of the Valcele dam. Here the depths are greater, reaching 4.5 m.   This area presents greater depths due to the Valcele basin located up-stream. The alluvia transported by the Arges river are deposited in the Valcele basin and the affluent stream flowing towards the Budeasa basin has its source in the processed waters of the Valcele basin.

The strong clogging at the tail of Budeasa basin, towards the left bank (fig 3), is owed to the flowing speeds of the Valsan river which decrease significantly upon entering the basin, leading to rapid depositing of alluvia.

The data processing program allows a 3D representation of the basin. The representation can be viewed from any angle, so that one can see the original geomorphological features of the valley covered by the basin (Figure 4).

Even by processing the data using the Excel application one can represent the transversal and the longitudinal profiles of the basin, thus showing the surfaces eroded or clogged over time and also the micro relief forms of the basin (Figure 5 and 6).

One of the most important products is the limnimetric key that can be rendered with great precision in both table form and graphically (figure 7).

This is of great importance to the exploitation of the basin in order to calculate the exact amount of water stored and the accumulated potential, but also to calculate the turbine efficiency.
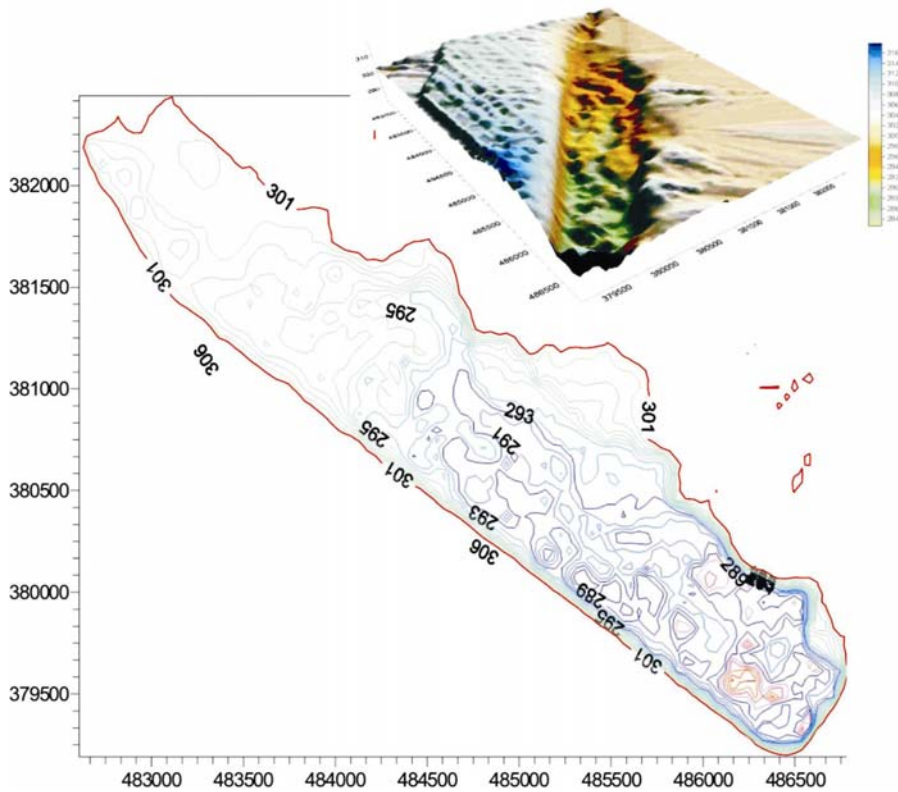
Figure 2. Budeasa reservoir - bathymetrical curves (down); Figure 4. 3D representation of Budeasa basin (up)
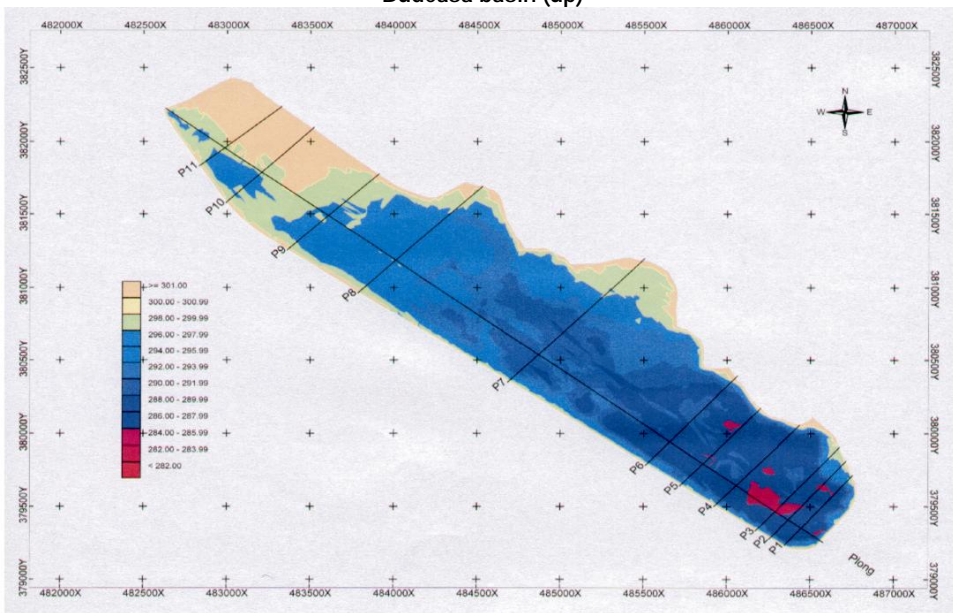

Figure 3 Budeasa reservoir - 2D representation
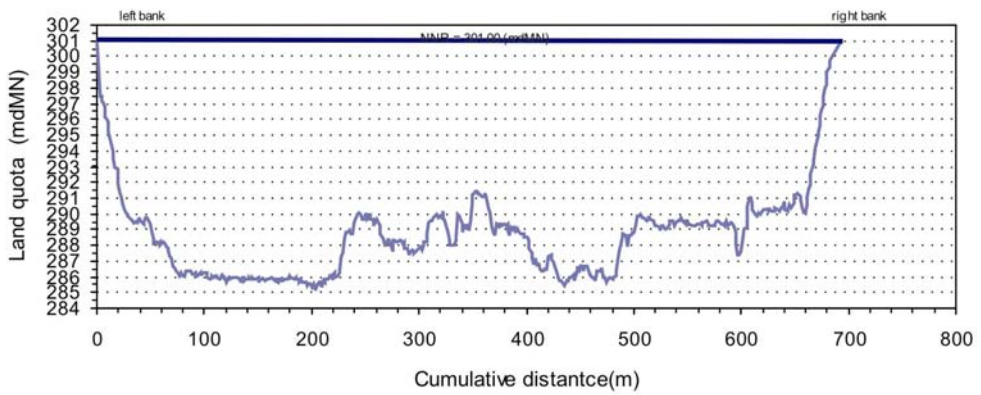
Photo 1 Areal Image of Budeasa reservoir

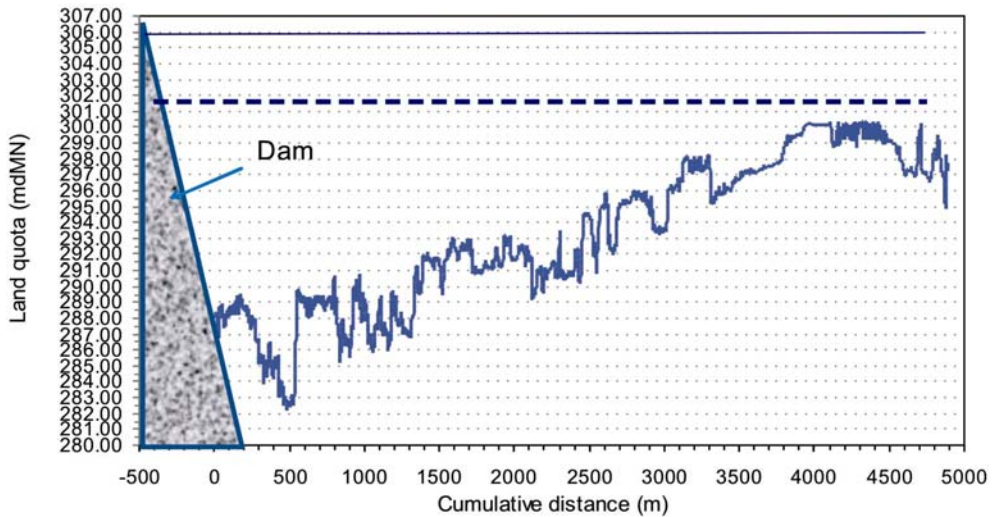Figure 5. Bathymetric Profile No 5, Budeasa reservoir (December 2008

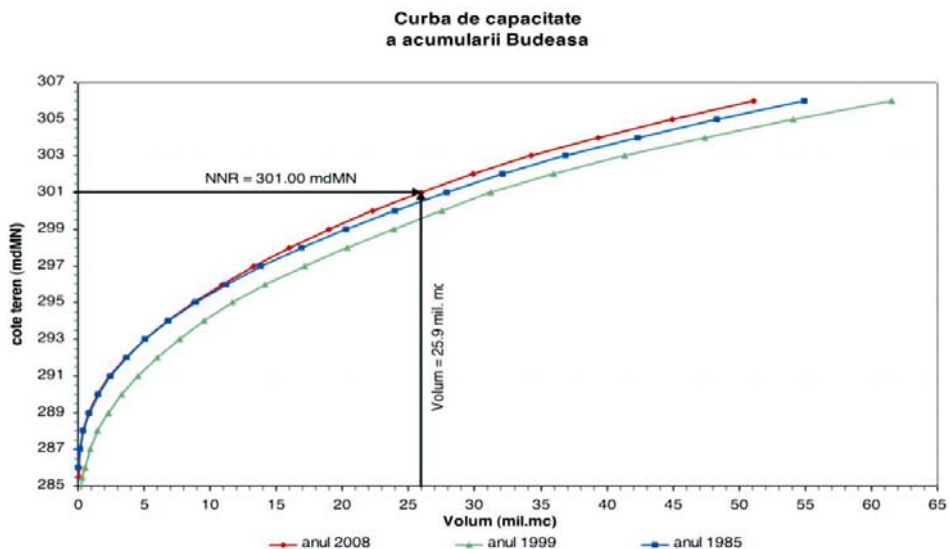Figure 6. Longitudinal profile of Budeasa reservoir (December 2008)

Figure 7. Capacity curve of Budeasa reservoir(1985 - 2008)

4. Conclusion

The method described above for realizing bathymetric charts is one that requires accurate data and good knowledge of GIS, familiarization with equipment and specialized software and well trained staff. As long as one can count on the above elements, the results are according to the effort invested - accurate data, multiple possibilities for processing and representing of the data, exact analyses of the evolution of the basin when performing subsequent chartings.

This method is very effective especially in case of basins spread on large areas, because it is easy to keep the direction in accordance to the alignment of the transversal profiles. The position inside the basin is transmitted via GPS and can be viewed in real time on the laptop screen, where the lines of the profile are predefined.

The disadvantages resulting from the practical activity so far, are generated by the sensitivity of the recording equipment to water, by the energy consumption and by the capacity to process the data.

Among the beneficiaries of this method we may include hydrologists, enginers, shipping agents and owners of basins developed for fishing.

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