Evaluation of Sediment Deposition on Corum Dam Reservoir

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Abstract. In this century, world population is gradually increasing. As a result of this increase, the energy and water need also has increased significantly. Although it is known Turkey as a country with abundant water resources it is actually located in semi-arid region in the world. Nowadays, that water resources are increasingly important for humankind and the biggest role in using these resources more efficiently is dams. The dams can deposit water in their reservoirs as well as allow water to be used in areas such as drinking water, irrigation and electricity generation when necessary. On the other hand, it protects the surrounding habitats from natural disaster like floods. Dam life is estimated to be approximately 30 to 50 years. The most important factor in the end of the dam life is the filling of the dam dead storage by the sediment carried by the stream. In this study, the Çorum Dam built on the Çomar Stream of Yeşilırmak Basin was considered. In order to provide the irrigation and drinking water needs of Çorum, the dam construction started in 1973 and the dam was coming on stream in 1977. The dam has an earth fill body and the height of the thalweg is 49 meters. The lake field is approximately 0.6 km². Bathymetric maps of Çorum Dam belonging to planning stage and 2014 is available. On these maps, cross sections were drawn at intervals of 50 meters from the dam reservoir using NetCad 7.6 program. Floor elevations obtained from the cross sections were examined. The floor profiles obtained from two different maps were compared and the floor profile variation of the dam reservoir was examined over the years. It has been observed that there is an increase of 2 to 9 meters at the floor elevation up to a distance of 400 meters from the dam body. Significant change hasn't been detected at the distance from 400 meters to headwater. Besides, the elevation-volume curves were plotted using the elevation-volume belonging to data of the dam's 1977 and 2014, and comparisons were made between the curves. As a result of these comparisons, approximately, 79.6% decrease in the dead volume, 11.76% decrease in the active volume and 14.58% loss has been found in total volume of the dam. It is expected that the dead volume of the dam will expire within 10 years if the necessary measures are not taken. Finally, current situation of Çorum Dam under sediment effect was investigated, the amount of sediment in dam reservoir was determined and the distribution of this sediment in dam reservoir was examined.

1. Introduction

As 97.5% of the water in the world is salt water, only 2.5% of the remaining water is fresh water. 70% of fresh water is situated in poles and 30% of fresh water consists of surface and ground water. For the basic requirements of people, daily clean water needs vary between 20-50 litters. Considering this data, it is estimated that the world population who cannot find water in 2075 will be 3-7 billion [1].
Although the surface of the earth is surrounded by three quarters of water, the amount of water available is running out day by day.

Even though Turkey is known as some country rich in water resources, is located across the world is a semi-arid region. For this reason, the distribution of rainfall varies according to the regions. There are more than 120 natural lakes, 1159 dam reservoirs and 834 ponds in the existing water resources of our country [2].

Nowadays, depending on population growth, fresh water resources are gradually decreasing due to drinking water, irrigation and energy needs. Besides, global warming causes changes in climatic conditions and decreases in rainfall. Because of these reasons, we need to monitor our available water resources and to store the free flowing fresh water in dams, lakes and pools [3].

Dams store waters coming from headwater and according to operation purposes, provides water use such as drinking water, irrigation and electricity. Dam designs are made taking into account the economic life ranging from 50 to 100 years. The most important factor determining the economic life of the dam is sediment transport. Soil particles may be transported from a flood plain due to rainfall as part of the erosion process [4]. A reservoir is a natural means for the accumulation of sediments carried by water [5]. A reservoir is also an efficient sediment trap. The flow rate of a stream is reduced when it reaches to a reservoir, therefore, making it possible for the sediments to be deposited easily. The location and amount of sediments deposited in a reservoir depends on factors such as sediment load, flow characteristic, storage time, shape and size of the reservoir, operational time and others [6,7]. Figure 1 shows a cross-sectional view of the basic sediment deposits [8].

Numerous researches have been done using different methods to estimate the amount of sediment from the past to present of the dam reservoir and the sediment distribution in the reservoir. As a result of the researches, it was made a bid for reservoir dead, active and total volume reductions depending on the amount of sediment coming from the reservoir.

In recent years, it was benefited from Digital Elevation Model (DEM) in the form of raster grid and Triangulated Irregular Network (TIN) for estimating the sedimentation in dam reservoir [9]. Furthermore, hydrographic surveys, grab sampling and water depth-capacity methods were used to investigate the loss of storage capacity [10]. These studies were supported with NetCAD, Global Mapper and PDS2000 software’s [3]. In the literature, together with aerial photography, satellite photos, bathymetric surveys and sediment tracking modules in ArcGIS and GIS software were used effectively both to determine the amount of sediment and to clearly observe the distribution of the sediment in the reservoir [11,12,13,14].

In this study, bathymetric maps of 1977 and 2014 were obtained to observe the sediment distribution in the Çorum Dam Reservoir in Yeşilirmak Basin. It was attempted to obtain reservoir sections from bathymetric maps and to estimate reservoir sediment characterization using Netcad 7.6 GIS Netsurf module software. In addition to that, elevation-volume curves were drawn by means of the elevation-volume data of 1977 and 2014 of the dam reservoir. Dead, active and total volume
occupancy rates of dam are calculated with these curves. Finally, the remaining useful life of the dam was forecasted approximately. The results showed that remaining of total reservoir capacity is 85.42%. Effective storage capacity and dead storage capacity also decreased, their decreasing capacity are 11.76% and 79.6%, respectively.

2. Study area
Turkey is hydrologically divided into 25 river basins. Çorum Dam was constructed on the Çomar Stream in the Yeşilırmak Basin as shown in Figure 2. In order to provide the irrigation and drinking water needs of Çorum, the dam construction started in 1973 and the dam was came on stream in 1977. The dam has an earthfill body and the height of the thalweg is 49 meters. The lake field is approximately 0.6 km². Satellite Image of Çorum Dam is shown in Figure 3.

3. Material and method
3.1. Bathymetric surveys of field
Belonging to 1977 and 2014 bathymetric maps of the Çorum Dam Reservoir are given in Figure 4. The dam lake length was obtained from the 2014 bathymetric map. The length of the dam is 953 meters. The length of the dam was taken into consideration just as drawing the route for the cross-section and the route was passed through the fields near the thawed line of the dam reservoir.
Figure 4. Belonging to 1977 and 2014 bathymetric maps of the Çorum Dam Reservoir

Cross-sections were drawn on the route at fixed intervals of 50 meters. In cross-section drawing, the reference elevation (lowest elevation) is 880 meters. In order to get a clearer view, 1/10000 horizontally and 1/1000 vertically scale factor were used. Belonging to 1977 and 2014 cross-sections are shown in Figure 5 and Figure 6. The sub-grade profile regarding 1977 and 2014 was defined as orange and blue respectively.

Figure 5. Belonging to 1977 sub-grade profile of Çorum Dam Reservoir
3.2. Elevation/Volume method

It is presented the Çorum Dam elevation/volume data obtained in 1977 and 2014 in Table 1. The elevation / volume changes of the dam reservoir from 1977 to 2014 using the data in this table are shown in Figure 7.

Table 1. Çorum Dam Reservoir elevation and volume values

| Elevation (m) | Volume (hm³)  |
|--------------|--------------|
|              | 1977         | 2014         |
| 896          | 0.4589       | 0.181        |
| 900          | 0.9249       | 0.519        |
| 904          | 1.6704       | 1.161        |
| 908          | 2.7594       | 2.207        |
| 912          | 4.3254       | 3.686        |
| 916          | 6.4519       | 5.673        |

Figure 7. Çorum Dam Reservoir Elevation/Volume Change from 1977 to 2014
4. Results and discussions
The change in the sub-grade profile of the Çorum Dam Reservoir from 1977 to 2014 is given in Figure 8. At the inlet of the reservoir (between 850-900 meters) it seems that a sub-grade scouring of about 1.2 meters originating from the flow velocity of the stream appears. As the dam body is located at 0 point where the cross-section is started to be drawn, there is a 22-meter difference between the two elevations. At a distance of 100 to 400 meters, it was determined that there were elevations increasing from 3 meters to 9 meters at the sub-grade of the reservoir. Obviously, these results, obtained from the cross sections from the bathymetric maps, indicate that the sediment deposition sub-grade of the dam reservoir is elevated. The resulting sub-grade profile shows that there is delta type deposition of sediment in the reservoir.

![Figure 8. Belonging to 1977 and 2014 cross-sections of the Çorum Dam Reservoir](image)

From elevation/volume data, the dead volume equalled to the minimum water elevation, the total volume equalled to the maximum water elevation and the active volume values from total volume minus dead volume are obtained. The values obtained for 1977 and 2014 were compared. As a result of these comparisons, approximately, 79.6% decrease in the dead volume, 11.76% decrease in the active volume and 14.58% loss was found in total volume of the dam. The elevation/volume curves drawn from the current elevation/volume data also show the decrease in reservoir volume between 1977 and 2014.

5. Conclusions
In the present study, the available condition of the Çorum Dam Reservoir under the sediment effect was investigated. In bathymetric surveys, it was observed that from the year the dam started to operate, until 2014 there has been regional elevation increases in the reservoir sub-grade profile. Especially, sediment deposition density was found to be between 100 and 400 meters. It is determined that at the first 50 meters of the inlet of the dam upstream part, the river is carved at the bottom of the reservoir depending on the flow velocity. A sediment deposition map of the dam was obtained in the direction of these data and helpful information was provided on which fields should be taken precautions. According to these results, sediment deposition type is delta which is caused by coarse sediment.

Çorum Dam elevation/volume data of 1977 and 2014 shows that approximately 80% of the dam dead volume is filled with sediment. It is estimated that if the necessary measures are not taken, the economic life of the dam will be completed within 10 years and dam become unusable. This loss will cause problems in the Çorum region in terms of drinking water supply. For this reason, the most appropriate method for removing sediment from the reservoir or preventing reservoir sediment entry (flushing, sluicing, density current flushing, dredging and siphoning etc.) should be selected and applied.
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