MANAGEMENT OF WATER QUALITY OF THE PLASTIRAS RESERVOIR

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Scope

This paper discusses the problems associated with establishing a "safe" minimum level for a reservoir serving multiple and conflicting purposes i.e, hydroelectric power generation, water supply, irrigation and recreation. A comprehensive approach of the problem considers three different criteria. The first criterion is water quantity. Available long-term reservoir inflow data are analyzed to establish 'sustainable" water inputs in relation to demands that have to be satisfied. The second criterion is ecology and landscape and considers how fluctuations of the reservoir level affect the lake banks vegetation. It discusses the implications to aesthetic, touristic and beneficial uses. The third criterion is water quality and considers how the fluctuations in lake volume affect the chemical and biological status of the lake. For this purpose a one-dimensional eutrophication model was used. The minimum water level is established from the synthesis of the above, using a multi-criteria analysis.

Historical background

The Plastiras dam was constructed in 1960 by the Public Power Corporation of Greece on the river Tavropos, which is a tributary of river Acheloos, one of the most important rivers of Greece. The dam itself is an arch dam with a chute of 577 m. Energy generation is estimated at 160 GWh per year, which covers about 2% of Greece's energy needs. The project was designed from the beginning, as a multipurpose scheme to provide hydroelectric power and satisfy water supply and irrigation needs of the area. The reservoir has a surface area of 25 km^2, is located in mountainous surroundings and receives surface runoff from a catchment area of 167 km^2. Its maximum depth is 52 m and the average depth at maximum level is 14 m. The maximum water level is +792 m, the average altitude of the basin is +800 m and the highest peak is at +2150 m. The greatest part of the catchment area is covered by woods (51%) and only 7% of the area is cultivated. The rest is used as pasture land. Animal breeding is important but not critical from an economic point o of view.

The Plastiras reservoir developed very fast into a pristine resort area that attracts tourists both in summer and winter months. The reservoir is included in the NATURA list of protected water bodies (code GR 1410001) and the activities in the catchment area are controlled by presidential decrees. The domestic population is spread around the reservoir in 15 small agglomerations numbering from a 100 to 1500 inhabitants. The permanent population is estimated at 6.600 inhabitants while during tourist seasons the population is increased to around 15.000. A number of small hotels and guesthouses have been built in the last years to accommodate tourist population.

Runoff and water needs

The long-term average runoff in the reservoir is estimated at 153 hm^3. Historical data of reservoir management reveal that water abstraction for the various needs followed closely water inputs (Figure 1), resulting in great yearly fluctuations of the reservoir level. With this practice the long-term flow-balancing role of the reservoir was annihilated. A more rational approach would be to maintain a constant quantity of water to be abstracted every year and also not allow the reservoir level to fall below a minimum level.

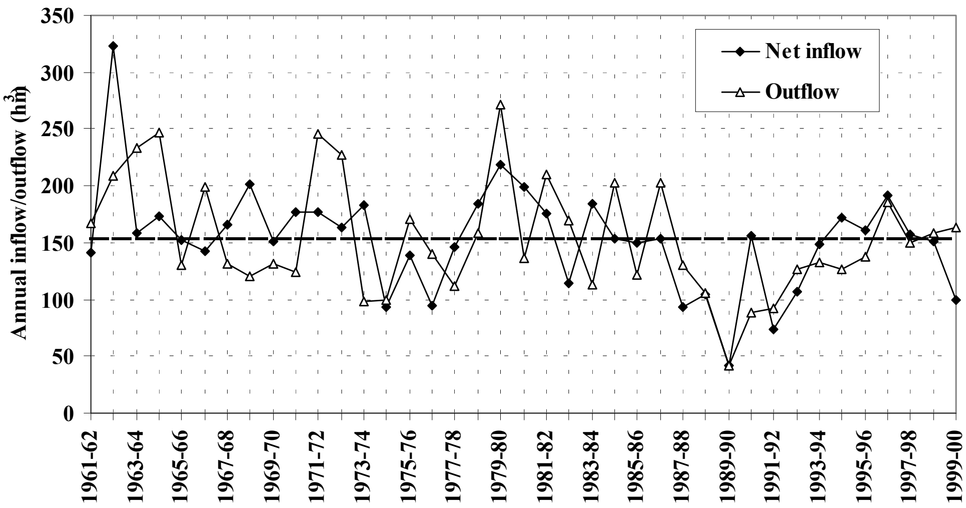

Figure 1. Historical date of input to the reservoir and water abstraction

Using the 40-year historical hydrological data it was possible to estimate the quantity of water that would be yearly available, with a reliability of 90%, for various minimum reservoir water levels and the water level/time distribution. The results for different minimum reservoir water level scenarios, from +776 m to + 790 m, are shown in Figure 2. From a quantitative point of view, a minimum level +780 would give a very satisfactory quantity of water, very close to the long-term average. On the other hand a minimum level of +786 would give an unacceptably low quantity of water.

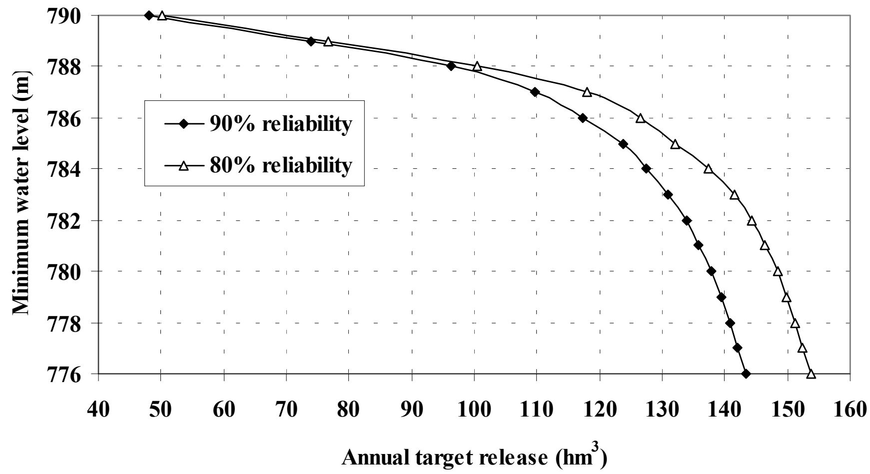

Figure 2. Available water quantity in relation to minimum water level

Esthetic considerations

When the water level is close to maximum level +792 the trees on the lake banks are seen as though emerging from the water giving a very pleasant esthetic effect. With the lowering of the water level however, a large amount of barren land of yellowish color, a "dead zone", is uncovered, which interrupts the continuity of the landscape, and apart from other displeasing effects show the lake to be "empty". To quantify these effects table 1 was prepared for the characteristic water levels mentioned previously.

Table 1: Qualitative characterization of landscape at various water levels

Reservoir level (m)	Landscape quality	Description	Level/time distribution
786-792	Excellent	No alteration, all observers consider the view as 'breathtaking'	100% Excellent
786-788	Very good	The "dead zone" is barely perceivable and the landscape slightly altered,	26% Very good 74% Excellent
784-786	Good	The "dead zone" is discrete, the landscape is altered but visitors find the view very good	10% Good 29% Very good 61% Excellent
782-784	Average	The landscape is strongly altered but casual observers consider the view very satisfactory and local population consider it adequate	8% Average 11% Good 28% Very good 53% Excellent
<782	Bad	The lake looks empty and landscape is severely modified even to the casual viewer	

Water quality

All available water quality data, chemical and biological, showed that the lake is still not polluted and can be classified as oligotrophic. Chlorophyll-α values ranged from 0,7-3,7 μg/L indicating low levels of primary production. The lowest nitrate concentrations in the epilimnion were measured in spring and they were in the order of 4-30 μg/L. Higher concentrations, in the order of 135-202 μg/L, were measured in the winter months. Inorganic phosphorous concentrations were very low, varying between 1- 4 μg/L. In general there was no considerable difference in the chemical constituent concentrations along the water column, indicating that eutrophication in the reservoir is not important.

The lake is stratified during the summer months and has been characterized as warm monomictic type. Temperature varies from 5,5 to 8,0°C near the bottom and from 5,5 to 26°C near the surface. The lowest temperature is recorded in February and the highest in July. The thermocline has an average depth of 6m. Dissolved oxygen concentrations in the hypolimnion varied from 2,7-5,1 mg/L during summer months but were close to saturation in winter months. In the epilimnion DO concentrations remained close to saturation all year round. No signs of DO hyper-concentration due to eutrophication were observed.

The effect of the proposed reservoir management strategy (constant quantity of water abstracted, minimum level) to water quality was investigated by means of a one-dimensional eutrophication mathematical model, developed by members of the department. The model simulates, in addition to dissolved oxygen, chlorophyll-α, ammoniacal nitrogen, organic and inorganic P and BOD. The reservoir was assumed as one fully mixed reactor. Nutrient and organic load inputs to the reservoir, from point and diffuse sources, were calculated from available data. The model was calibrated using actual water quality measurements. . The main land use distribution in the catchment area is as follows: woods 51%, areas covered by water 17%, built areas 1%, cultivated areas 7%, pasture land 24%.

The annual water pollution loads were calculated using pollution generation indices that have derived from similar studies in other Greek lakes.

Chlorophyll-α is universally used as the most important indicator of lake and reservoir classification. A maximum concentration of <5 μg/L is considered to indicate very good quality (class I), whereas concentrations between 5-10 μg/L indicate a good quality (class II). Higher concentrations are taken to stimulate eutrophication. The simulation of chlorophyll-α in the reservoir for 3 water levels is shown in Figure 3. It is evident that although for the higher water level of +786 m the model predicts Chlorophyll-α concentrations consistently below 3 μg/L, the water quality remains satisfactory for the other two levels as well. The predicted Chlorophyll-α concentrations are below 7 μg/L, and for level +784 m almost always below 5 μg/L. Thus from a water quality point of view both water levels are considered acceptable.

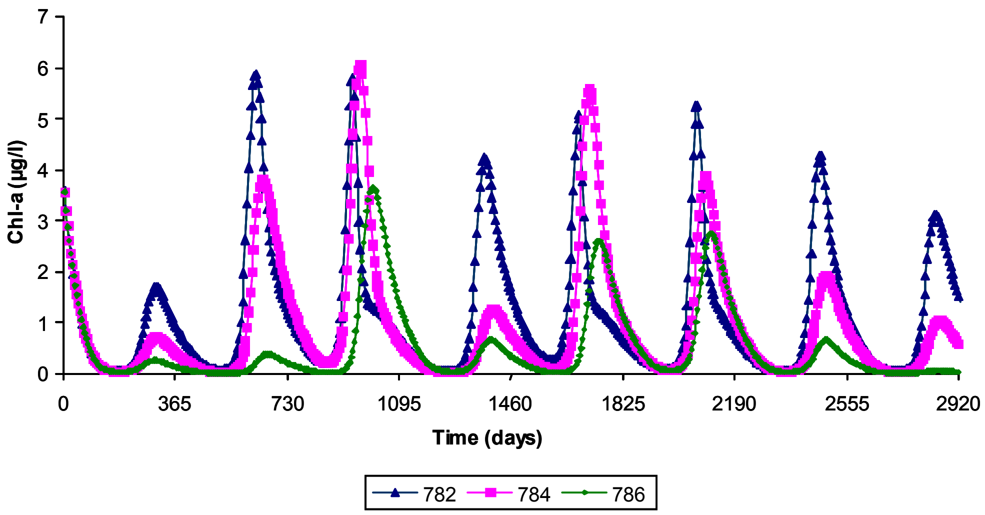

Figure 3. Model simulation of Chlorophyll-α concentration

<u>Establishment of minimum acceptable water level</u>

Using the results of the hydrological analysis, the water quality model results and the landscape site investigations, each of the three "indices", quantity, water quality and landscape were given a value between 0 and 1. A combined index incorporating all three components with appropriate weights resulted in an optimal value for the level of +784 m. Based on these results the recommendations made are:

- Assume a reliability level of 90%
- Abstract a constant quantity of 130 hm^3 every year.
- Maintain a minimum reservoir water level at +784 m. For this level the quality of landscape is very good and eutrophic conditions will not develop.
- For the very dry years, the minimum level should always be maintained at the expense of the quantity of water to be abstracted.