SIMULATION OF THE WATER LEVEL REGULATION OF THE LAKE BALATON

by

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The water level changes of the Lake Balaton raise many problems, ranging from the selection of the hydrological system to the estimation of the water level regulation and the management costs. Economic evaluation is likely to be the only objective possibility to find the best solution.

The cost factors intervening in the choice of the water regulators are: investment costs, operation costs of the regulating works, and damages due to a too high or too low water level, in spite of regulation. The above cost factors depend on the water consumption of the regulating works, the sum of damages pertinent to each water level, the accuracy in determining the hydraulic elements and the operation of the regulating works.

The effect on the hydrological system of the different plan varieties worked out for the regulation of the Lake Balaton has been tested by means of a simulation model where element of the water balance of the lake has been substituted by observed data.

It was investigated to what extent the different technical interventions of water management affect the water level of the Lake Balaton at a given level of knowledge of the hydrological system (for a forecast of one month) considering the proposed range of water levels as fixed.

To assure recreation possibilities and to avoid flood damages, the water level in the lake has to be kept between certain limits. For regulation purposes, establishment and operation of water drawoff and feed structures are necessary. Deviations from an economic optimum of the water level entail certain damages. The above cost factors depend on the regulating works capacity; the sum of losses correlated to the different water levels; the accuracy of forecast for the hydrological factors; and the operation specifications of the regulation works. For testing by a simulation model the investment project varieties, the hydrological system is represented by the time sequence of the natural water reserve variation.

The monthly water reserve variation in terms of the water level of Lake Balaton was available for each month from 1867 to 1966 (W_{ij}, where i = year, j = month). The test consisted in computer simulating the sequel of events, according to different projects.

Varieties for the project of water drawoff through the Sió were as follows:

Mark	Drawoff capacity	
	m³/s	cm/month
A	20	9.0
B	40	18.0
C	85	40.0

The following quantities were fed in, irrespective of the technical solution:

Mark	Feeding capacity	
	m³/s	cm/month
1	0	0
2	5	2.25
3	12.5	6
4	25.0	12

The above values represent technically possible maxima, therefore these are possibilities.

In the present program neither the forecast, nor the optimation of the water level range was taken into consideration but the forecast for one month and the given to proposed water level range was used for the test. The "Operation specification" indicates the optimum for a drawoff.

The computer algorithm of the program was as follows. Knowing the water level H_i of the previous month and the expected change in the reserve W_i, provided the resulting water level $H^*_{i+1} = H_i + W_i$ is between the permitted upper and lower water levels F_j and A_j, respectively, proposed for the month in question, no intervention is needed. For $H^*_{i+1} > F_j$ the water level has to be lowered through the Sió but not below the level $(F_j + A_j) : 2$. For $H^*_{i+1} < A_j$ the water level has to be raised as possible by artificial feed-in, but not higher than the level $(F_j + A_j) : 2$.

In Fig. 1 the varieties $B1$, $C1$, $C4$ are shown for operation specification No 3. According to it the proposed water levels are — measured on the Siófok water-gauge: January 90 cm; February, March 100 cm; April, May, June 90 cm; July, August, September 80 cm; October, November 70 cm; December 80 cm.

Based on the 100-year time sequel, the recurrence of each water level per annum and month has been calculated. Of these water level data an empirical frequency diagram was plotted for water level probabilities of 15%, 50% and 85% (Fig. 1).

Using the 15% and 85% probability levels and approximating the distribution function with a uniform distribution, the frequency function has a constant value $1(H_{\max} - H_{\min})$ in the interval $H_{\max}$ to $H_{\min}$ (Fig. 2a).

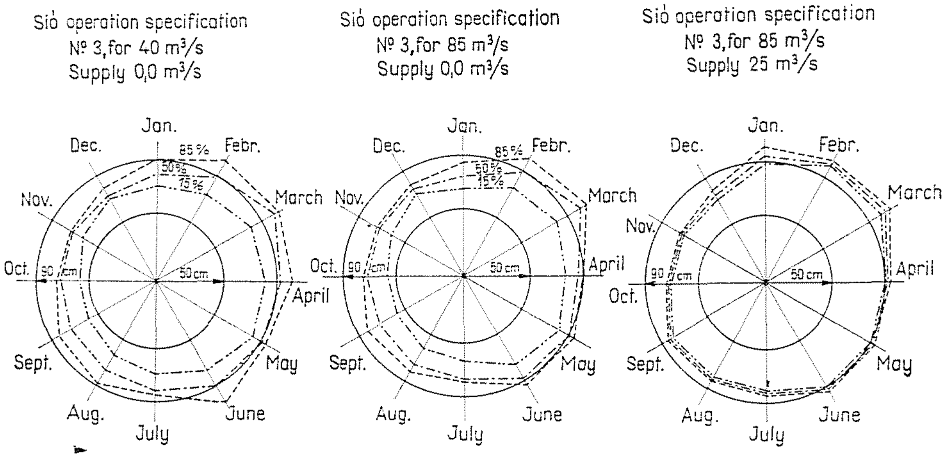

Fig. 1

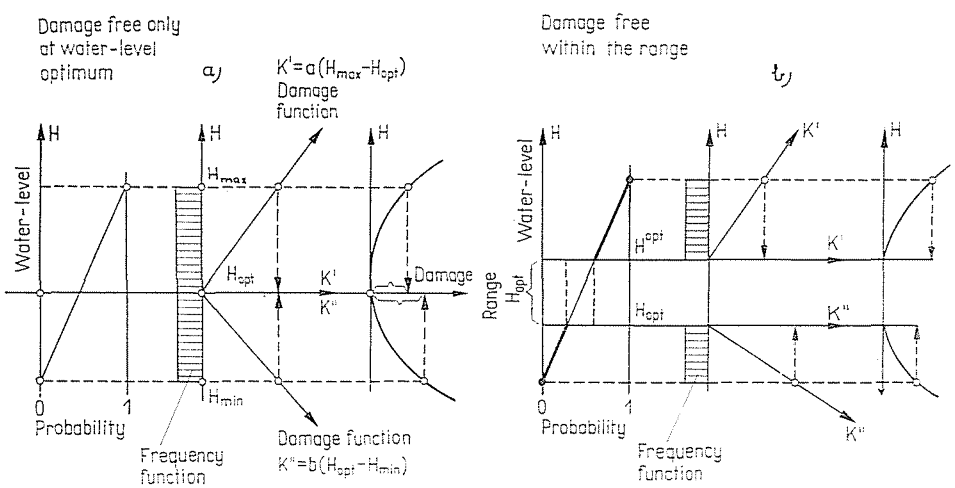

Fig. 2

If away from the optimum water level the damage function is varying linearily, then the damage functions $K' = a(H_{\max} - H_{\text{opt}})$ and $K'' = b(H_{\text{opt}} - H_{\min})$ are valid up and down, respectively. The total damage is

$$\frac{a(H_{\max} - H_{\text{opt}})^2}{2(H_{\max} - H_{\min})} + \frac{b(H_{\text{opt}} - H_{\min})^2}{2(H_{\max} - H_{\min})}.$$

Provided within a certain water level range no damage has to be reckoned with (Fig. 2b) an upper limit H^{opt} and a lower limit H_{opt} can be established and the damage function between the two is zero.

Based on the above, the costs were computed for the varieties $B1$, $C1$, $C4$ (first assumption — single water level optimum) with the values $a = 2[Pe/\text{cm}]$ and $b = 4[Pe/\text{cm}]$ where the symbol Pe stands for some monetary unit.

The costs apply to one month each. Of course the cost data are used here merely as an illustration.

Results are plotted in Fig. 3. In spite of having tested but three varieties, it is clear that to increase the drawoff capacity involves the possibility of

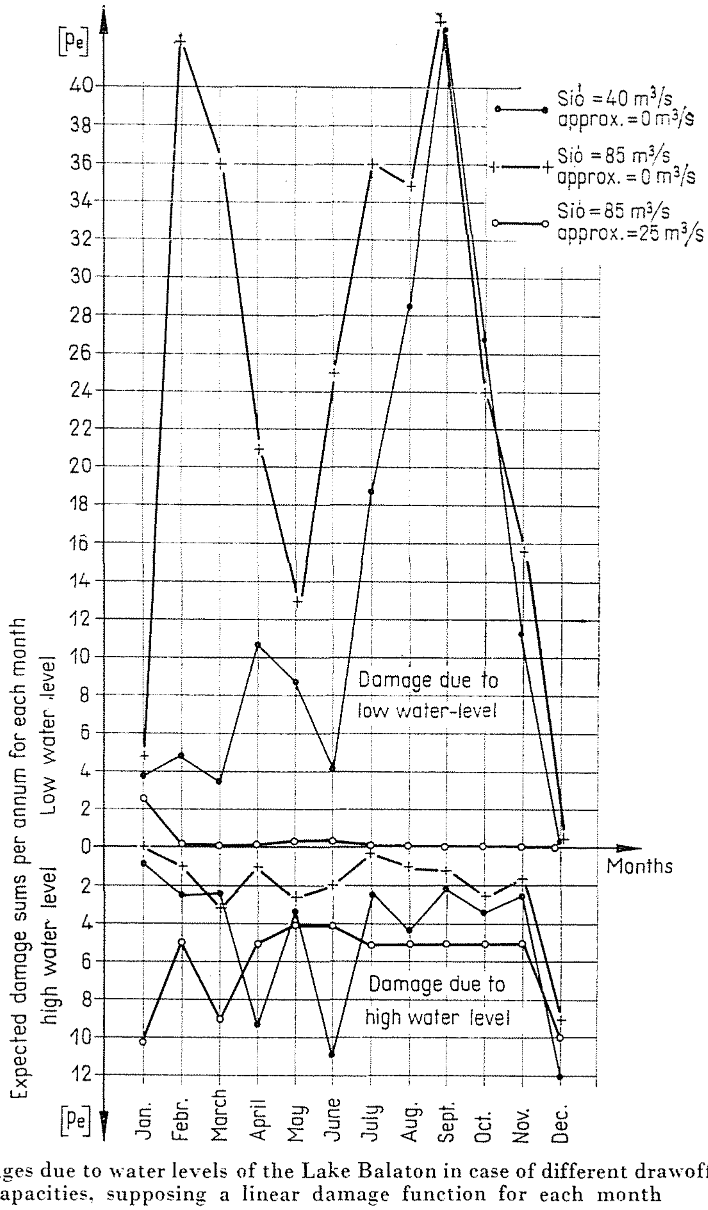

Fig. 3. Damages due to water levels of the Lake Balaton in case of different drawoff and feed-in capacities, supposing a linear damage function for each month

more damages from low water levels, though high water levels might be nearly completely avoided. With artificial supply of water reserves of the Balaton, damages due to low water levels can be perfectly avoided, but in the high water level range the situation is less favourable, compared to the previous condition. After all, the quantity investigated of both the drawoff and feeding possibility, neither intervention can be disregarded as they are considerably interacting.

The discussed investigations should be continued to prepare an economic technical decision based on actual economic parameters.

Summary

Fluctuation of the water level of Lake Balaton depends — beside the hydrological — meteorological factors and the realisation of the water level regulation — on the technical possibilities of water level regulation. A simulation model is applied to investigate the effect of the different technical facilities on the water level of the Lake Balaton. To prepare the economic optimation, a linear damage function is presented.

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