THE HEAT BALANCE OF THE TRANSDANUBIAN KARSTIC RESERVOIR

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ABSTRACT

Simultaneous modelling of the water, heat and dissolved material transport is just being developed for forecasting and control of the impact of mine drainage activity to the important thermal springs, wells in the Transdanubian karstic region.

In the frame of the preliminary investigation for the above model, the heat balance of the karstic reservoir system hase been prepared.

The terms of the water balance for heat balance investigation were based on the results of finite-difference water seepage model tests carefully fitted to the long term measurement data. The former heat balance approaches were based only on estimated data on lateral water recharge and on the infiltration. For this reason the presented heat balance gives a better approach.

The terms of the heat balance equations are: the conductive heat flow /transported by water input and output/ and the convective heat flux. The change of the heat balance has been eliminated.

The heat balance has been determined in two periods. The year 1957 represents a quasi-original status with small impacts of mine drainage activity.

The year 1978 represents a strongly impacted status of the karstic system.

The error of the heat balance equations is about 15 %, consequently the terms of the heat balance and data concerning it can be used as first approach data for a finite-difference modelling of the heat and mass flow in the Transdanubian area.

INTRODUCTION

According to the order of the Board of Technical Development and the Ministry of Heavy Industry preliminary investigations were carried out for simultaneous modelling of the water, heat and dissolved material transport in the Transdanubian karstic reservoir. The main purpose of the model is the forecasting and control of impacts of mine drainage activity to thermal springs and wells which are medically and balneologically used.

One of the main goals of the preliminary investigations has been the determining of the basic data and processes necessary for the above model.

This preliminary investigation also includes the determining of the regional heat balance.

Former heat balance investigations [1] were based on estimated values of the recharge /infiltration, and lateral output, input/ [4] of the regional water balance.

The presented heat balance is based on a regional finite-difference seepage model of the karstic region, carefully compared and fitted to the empirical data of a 20 years period [3]. This model gives a more detailed and reliable data on the terms of regional water balance.

BASIC DATA AND CONSIDERATIONS

The heat balance is given for two characteristic periods, these are as follows:

Year 1957 was the initial period of the water seepage model. This year can be regarded as a quasi original period when only smaller impacts of mine drainage occured.

The present, strongly impacted status is represented by year 1978.

The global heat balance has been approached by the following equation:

$$Q\Delta\Phi + \sum Q_{+q} + \sum Q_{-q} = 0 \qquad /1/$$

where $Q\Delta\Phi$ is the convective heat flow /10^6 Joule/min/

$\sum Q_{+q}$ is the conductive heat flow /10^6 Joule/min/ transported by the water input

$\sum Q_{-q}$ is the conductive heat flow /10^6 Joule/min/ transported by the water output.

This approach eliminates the change of stored heat $\partial Q/\partial t$ because the yearly change of the rock and water temperature seems to be eliminable.

The terms of the heat balance have been taken into account by the following ways:

- The determination of the convective heat flow term is based on the difference between the average value of geothermal gradient of the Hungarian Basin /gg_o/ and the local value in the Transdanubian karstic region /gg_{DMK}/.

This approach is based on the following considerations:

The regional value of the Hungarian Basin /gg_o/ is valid even for the Transdanubian region, the local change /gg_{DMK}/ is caused by the heat change between the rock and the flowing karstic waters.

According to the above considerations, the difference heat flux

$$\Delta \Phi = \Phi_o - \Phi_{DMK}$$

or

$$\Delta \Phi = \Phi_o \left(1 - \frac{\Phi_{DMK}}{\Phi_o}\right) \qquad /2/$$

where Φ_o is the average heat flux in the Hungarian basin and is considered by Boldizsár as

$$\Phi_o = 1{,}44 \left[\frac{Kal}{m^2\ min}\right] = 6\ 10^3 \left[\frac{Joule}{m^2\ min}\right]$$

Supposing that the heat conductivity of the rock water system can be considered as constant,

$$\frac{\Phi_{DMK}}{\Phi_o} = \frac{gg_{DMK}}{gg_o} \qquad /3/$$

where $gg_o = \frac{1}{20} \quad [C^o/m]$

and according to Liebe 1

$$gg_{DMK} = \frac{1}{37} \quad [C^o/m]$$

Taking place the Eq. /3/ in Eq. /2/ and using the above values

$$\Delta\Phi = 0{,}66 \frac{Kal}{m^2 \cdot min} = 2{,}8 \cdot 10^3 \left[\frac{Joule}{m^2\ min}\right]$$

The total surface of the Transdanubian karstic reservoir

$$F_{DMK} = 15,7 \cdot 10^9 [m^2]$$

and the total convective heat flow:

$$Q\Delta\phi = 10,4 \cdot 10^6 [Kal/min] = 44 \cdot 10^9 [Joule/min]$$

The terms Q_{+q} and Q_{-q} are based on the water input and water output terms of the water balance according to the finite-difference model tests [3] using the following considerations:

- Though the average yearly temperature of the infiltration area is +9°C, the average temperature of the water infiltration is considered as +7°C because the spring is the main period of the infiltration.

- The mine waters, springs, wells are considered as measured. The very small spring inflows being eliminated in the finite-difference model test have also been eliminated in the heat balance investigations /see Table 1/.

- The lateral inflow-outflow temperatures are considered according to Fig. 1 where the isolines of the karstic water temperatures are presented according to the borehole data.

The lateral hydraulic contacts with other sedimentary basins are also shown in the same figure. The data on water balance are presented in Table 2.

- Data on the heat balances based on the above discussed data are presented in Table 3 for years 1957 and 1978.

DISCUSSION

The comparison of the terms on heat balance concerning years 1957 and 1978 and the error of the balances has given some conclusions and considerations. These are as follows:

- The trends of each term of the heat balance are fitted to the terms of the changing of water balance between 1957 and 1978 /see Tables 1, 2 and 3/.

- Though the lateral water outflow and the heat flow from the Transdanubian karstic aquifer to other sedimentary basins have decreased because of the increase in mine drainage activity, even the todays heat balance of the karstic is a positive one.

- As a consequence of the above process, the average temperature of the mine waters is increasing.

- The lateral communication of great depth between the karstic reservoirs and the sedimentary basins may give good conditions for geothermal energy exploitation, while the karstic reservoir of a high water conductivity may serve as a large drainage system of the deep sedimentary basins.

- The error of the total heat balance is about 12-18 %, consequently the terms and basic data of the heat balance can be used as the initial data for the first finite-difference model [5] of the water and heat transport in the Transdanubian karstic area. The main goal of the investigation has been reached.

- The heat balance giving acceptable error can be considered as a checking of the finite-difference water seepage model.

- The determined value of $\Delta\phi$ may also be used for geothermal engineering purpose in this region.

- Some considerations may also be taken on the origin of the error in the water balance. The main uncertainities may be found in the term of $\Delta\phi$ or in the average temperature of the infiltrations.

PROPOSALS

The acceptable error of the presented heat balance allows the use of its terms as initial data for simultaneous modelling of the water and heat transport in the Transdanubian karstic reservoir.

The adaptation of a finite-difference model /the C.C.C. model [4] / has been started for this purpose.

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Table 1

Withdrawal			1957		1978	
Way	Aim	Place	Q [m³/p]	T [C°]	Q [m³/p]	T [C°]
Artificial	Mining	Csordakut	-		5	11,5
		Dorog	63,2	11,5	6	11,5
		Tatabánya	44,2	12	136	12,0
		Kincses-bánya	13,6	12	74	14,5
		Várpalota	2,7	11,5	15	11,5
		Balinka	3,2	11,5	15	11,5
		Dudar	1,6	11,5	2	11,5
		Ajka	18,2	11,5	16	11,5
		Nyirád	4,0	12	307	14,0
		Total	150,7	11,7	576	13,3
	Water supply Total		114,4	11,5	100	11,5
Artificial drainage Total			265,1	11,6	676	13,0
Natural	Springs	Héviz	24,8	33	16,1	29
		Tapolcafő	55,7	16	0	-
		Tata	27,0	21,5	0	-
		Bp.hévf.	69,1	37	32,2	34
		Balaton upper region	111,6	18	20,4	19,0
		Total	278,2	20,1	68,8	28,4

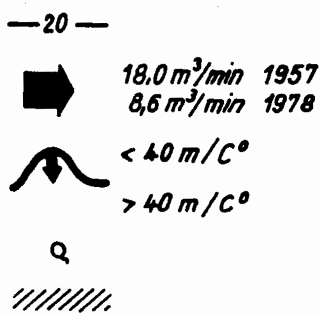
Table 2

Lateral flow data	1957		1978	
	Q [m³/p]	T [C°]	Q [m³/p]	T [C°]
to Zala	0,5	130	-	-
to Keszthely Mnt.	5,7	28	2,2	28
under Érd	55	42	10,2	42
Danube	178,7	12	20,2	12
to Bükk	18	50	8,6	50
Total	257,9	21,6	41,2	28,2
Natural drainage Total	278,2	20,1	68,8	28,4
Artificial drainage Total	265,1	11,6	676,0	13,0
Drainage Total	801,2	17,7	775,0	15,4
Recharge	687,2	8,5	680	8,5

Table 3

Heat balance term	1957			1978		
	q	T	Q	q	T	Q
	[m^3/min]	[°C]	[$\frac{Joule}{min}10^8$]	[m^3/min]	[°C]	[$\frac{Joule}{min}10^8$]
$\Delta\Phi$	-	-	+43,5		-	43,5
Lateral flow data	257,9	21,6	- 2,3		28,2	- 0,5
Natural drainage	278,2	20,1	- 2,3		28,4	- 0,8
Artificial drainage	265,1	11,6	- 1,3		13,0	- 3,7
Infiltration	687,2	7	+ 2,0		7	+ 2,5
Σ			+ 0,7			+ 1,2

LIST OF FIGURES



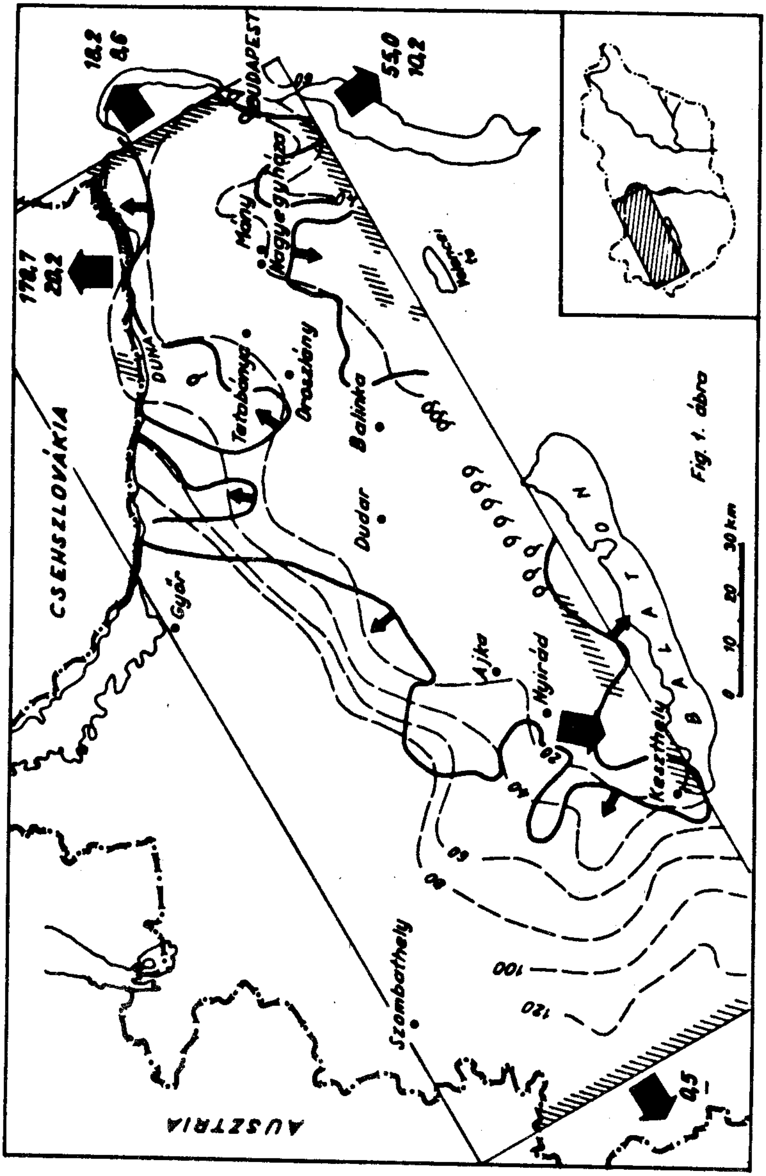
Izotermal linie

Outflow

Geothermal gradient

Springs

Lateral inflow


CSEHSZLOVÁKIA
AUSZTRIA
BUDAPEST
DUNA
178,7
28,2
18,2
4,6
55,0
10,2
0,5
Győr
Mány
Nagyegyháza
Tatabánya
Oroszlány
Balinka
Dudar
Ajka
Nyirád
Keszthely
B A L A T O N
0 10 20 30 km
Fig. 1. ábra