TEMPERATURE REGIME IN THE SAVA R. ALUVION NEAR ZAGREB

Sarnavka, R.

ABSTRACT: To preserve the ground water quality used for Zagreb water supply, the temperature regime of territorial waters has been investigated in order to prevent eventual thermic contamination, because of highgrade pollution of Sava r. that replenishes the alluvial reservoir. The hitherto results prove the immediate relation between Sava r. and ground water and explain certain characteristics relevant to it.

RESUME: Pour la qualité de l'eau souterraine dans la région de Zagreb, on a examiné le régime de ses eaux territoriales, pour prévenir une contamination thermique éventuelle, à cause d'une pollution, à haut degré, de la rivière Sava qui alimente le réservoir alluvial. Les resultats jusqu'ici ont prouvé une relation directe entre la rivière et l'eau souterraine, et ont aussi expliqué quelques détails caracteristiques.

RESUMEN: Para preservar la calidad del agua subterranea, utilizada en la región de Zagreb, se ha investigado el régimen de temperaturas de las aguas territoriales, al objeto de prevenir cualquier eventual contaminación, motivada por el alto grado de polución del río Sava, que alimenta al acuífero aluvial. Los resultados adquiridos, hasta el momento, ponen de manifiesto una relación directa entre el río y las aguas subterráneas, y permiten explicar ciertas características relevantes.

Geodetski Fakultet, Kačićeva 26. 41000 Zagreb. Yugoslavia

INTRODUCTION

The town of Zagreb with its surroundings and cca one million in habitants is an obvious example of urban agglomeration where closely connected, nearly all possible water resources management and hydrotechnical problems are present, often in a very compound form as a consequence of morphological, hydrogeological and hydrological activities in this part of Sava r. alluvial plain. The regime of Sava river, its bed being built in the alluvial strata and partly cut in the water bearing horizon, enabling straight river-underground contact, has direct consequences on the underground flow regime too. 8,13.

The defence of the broader town area from long since repeated floods requires Sava high water regulation influencing in this way directly the underground water level on both river banks. Manifold motivated hydropower utilization in the town area, changing the waterlevel regime by its rising and stabilization, may act corrective on the underground water regime proved of greatest importance in town water supply. 8

It is of prarticular significance that rather extensive town area exploits for drinking purposes, by means of drilled and dug wells, its territorial water resources, still of good quality, from the alluvial reservoir on both river banks.

The progressive population growth and industrial expansion in town result with permanent water consumption and demand increase, but with the intensified pollution of waters simultaneously.

In such a way the necessity to protect waters from pollution, arises as a priority task in water resources development in Zagreb, especially with regard the influences of contaminated waters may have on the underground reservoir and its safe yield.

The above mentioned results with a fact that solving the town water resources management problems, so projects and designs need a complex consideration without partial solutions. That means that complicated definite solutions concernig the water supply of Zagreb area should be looked for in a complex city planning, power utilization and water resources management regional solutions.

Further studies and search of final and lasting solutions of drinking, industrial and public needs water supply for greater Zagreb, ought to be oriented toward:

1) accomplishing the protective technical, economical and legal measures extending over the entire Sava r. alluvium as a pumping site, and

2) working out preparatory sudies enabling to determinate the capacity of this precious good quality water reservoir and its safe yield.

This work excerpts from the 1st targets group of problems only one, comprising the narrow scope of thermic contamination of waters, which but obligatory incorporates into the integral problem of conservation and protection of waters in the water management projects in Zagreb area.

HYDROGEOLOGICAL FEATURES

Numerous works, from 1948 (fragmentary) upto seventies, treat more or less concrete hydrogeological problems in this area. They have been founded on soil mechanical and hydrogeological interpretation of more than 2000 geomechanical, pedological, structural, piezometric & o.mostly temporary boreholes and wells. The basic deficiency of those attempts have been the insufficient depth of holes (rarely over 10 m), the density their at random selected locations, investigations oriented towards tasks and lack of more detailed systematization and analyses of the existing and newly obtained data, as well the lack of joint interpretation of the results 6,11.

Last ten years show more systematism in investigating of underground water regime by means of selecting observation wells, drilling supplementary deeper, structural and piesometric holes, constructing test wells on which long-term pumping test have been accomplished. Geophysical explorations in 1970 proved very usefull. Several prophiles with over 300 electrical resistivity sounds with Schlumberger electrode arrangements AB/2 = 140 m, covered the depths over 100 m (not yet proved by drilling) and were used in construction of isopach map of the water bearing horizon 6,11,13.

In this point of view in 1970 approved water management plan of Sava r. catchment basin, prover as advantageous contribution.

From g e o m o r p h o l o g i c a l standpoint the entire Zagreb area could be devided:
- immediate Sava plain, and
- highlands encompassing it.

The highland close from N (the drainage basis of S slopes of Marija Gorica hills and Zagrebačka Gora) and from S (drainage basins of N slopes of Samoborsko gorje nad Vukomeričke gorice) the alluvial Sava r. plain that again could be divided in 3 separate unities: the area extending from Bregata to Podsused, from Podsused to Rugvica and from Rugvica upto Sisak. The width of the valley increases from W to E, being narrowest at Podsused; then the stream enters into relatively expanded plain of 15 km average width, flowing nearer to the left foot hill. From Rugvica to Sisak the right river bank has approximatly 10 km breadth (left bank not of interest to town targets and included in investigations sporadically). Scarcity of data available from defective investigations results with only informative conclusions, relative to this portion of plain.

L i t h o l o g i c a l l y highland consist of pretertiary (slates, slaty limestones, sandstones, limestones, marly limestones and dolomites) and tertiary layers (conglomerates, breccias, sandstones, sands, sandy clays, clayey and sandy marls multiple alternated).

Only limestones and dolomite are waterbaring in pretertiary formations, characterized by relatively productive springs, even thermal, while in the alternation of tertiary sediments prevail aquicludes.

H y d r o g e o l o g i c a l features of the hilly girdle rocks result with depression or contact mostly intermittend springs of low discharge rate developing subsequently in tipical torrents.

The actual results of geological and geophysical investigations display that the alluvial deposits consists of:

1) water bearing horizon

consisting of well graded gravels and sands its thickness varying from 5 to 100 m. In Podsused area varies from 6-16 m and consists of coarse gravels with intermediate strata and lenses of fine sized materials of lesser importance. From Podsused to Sloboda bridge the thickness increases from 5 to 10 m in average and farther eastwards saltatory upto 73,70 m in Čička Poljana (over 100 m measured geoelectrically, yet mot proved by drilling) These abrupt thickerring of the water bearing horizon have been explained by faulting activities during sedimentation periods, faults being detected seismically below recent sediments. Eastwards with thickness increase of the water bearing horizon, decreases the grain coarsiness, so that by Rugvica sands and fine gravel are dominant and clay lenses are more frequent.

That geomorphologic factors have been dominant and that changes in grain size are the logical consequence of abrupt gradient reduction of Sava r. by Rugvica is undoubted.

The information concerning the waterbearing horizon from Rugvica towards Sisak is partial only, defined by geophysical methods.

The continuity of the horizon,10-40 m in thickness,is noticeable on the NW, whilst towards SE, electrical resistiviti s decrease, that one explains with larger clay and sand particles share.

2) adjacent hanging wall

built up of sand, silty sand, silt and clays in various ratios, its thickness varying frow 0-5 m the Bregana-Podsused area, not exceeding 7 m in Podsused-Rugvica area, being mostly about 6 m farther east.

3) bottom horizon

made up of grey-blue and grey-green clays with occasional occurrences of eat and limestone concretio s. Below the clays,near Podsused drilled bore hole entered marl banatica at 10,6 m already. East of Rugvica, the fottom horizon has not been defined 6,11, 13, Rep 4 .

The results of numerous size analyses and of pumping tests on several locations 6,7,11,13 enabled to obtain the coefficients of permeability writhin sufficient accuracy range:

$1,0 \times 10^{-9}$ to $1,0 \times 10^{-4}$ m/s for top horizon

$4,5 \times 10^{-6}$ to $8,5 \times 10^{-1}$ m/s for waterbearing horizon

$4,5 \times 10^{-10}$ to $6,0 \times 10^{-8}$ m/s for bottom horizon

from grain size analyses, while from pumping test, for steady flow, computations based on Darcy´s law, gave:

$2,0 \times 10^{-3}$ to $1,2 \times 10^{-1}$ m/s

Coefficient of transmissibility computed after Ferris on 20 observation points was:

$1,0 \times 10^{-1}$ to $1,0 \times 10^{0}$ m/s

that corresponds to the permeability coefficient values 11 :

$1,8 \times 10^{-2}$ to $1,1 \times 10^{-1}$ m/s

From all previously mentioned one should come to the conclusion that, in geomorphological and hydrogeological point of view, the 50 km long and 2-15 km wide waterbearing alluvial horizon along loth Sava r. banks, is one c o n t i n u o u s e n t i r e t y. Also, wilh respect to the rccasionally direct contact between the river bed and the waterbearing stratum, one should expect the river regime be directly connected w th the regime in the underground, as well the correspondent immediate influence of hydrometeorological factors of the adjacent catchment basins.

HYDROLOGICAL INVESTIGATIONS

Within the limits of this work one is not permitted but to a sketchy description of hydrographical features, although they are inseparable part of factors, equally valorized, which define this area from a water resources management point of view, especially with respect to the water quality which is the subject of this paper. The drainage basin, with exception of Sutla and Krapina r., NW Sava tributaries, ammounts to 1500 km2 in total, Sava plain -850 km2, highlands -650 km2. It is distinguished by violent shower intensities and by innumerable small water courses of rather diffuse pattern and uncontrolled regime. Floods are frequent, with noticeable sediment discharge 8 . Sava r. flowing through neighbouring Slovenia and through Zagreb area is highly polluted with industrial waste waters -without adequate proeessing. As all water courses in the N and W parts of the area mostly flow through dense populated districts, partly industrial zones, they are collectors of all possible dirt, and together with Sava, whose tributaries they are, risky endanger the quality of the ground water along both river banks. The lateral channels Lomnica and Odra r. receive the waters from N slopes of Vukomeričke gorice 8 therefore it might be expected they will not much affect the quality of underground water.

Within 10 years frame of systematical approacle to h y d r o l o g i c a l investigations, the greatest care, has been given to water level observations on numerous existing and newly erected observation wells. Todlay, the Republican Hydrometeorological Instetute observes the groundwater levels, twice a weeki on 23 wells and 70 piesometric holes, ground water temperatures on 52 localities as well. Sava r. is under observation since many years (temperatures since 1952) twice a day,other hydrometeorological terms after conventional standards. The municipal water works carry oat orderly water level, recordings on 106 observation wells in their pumping site areas, the temperature being recorded only sporadically 1 .

From water level recording data have been constructed groundwater contour maps relative to Sava r. maxima and minima, and therefrom the interrelations between Sava and ground water have been analized 1,2,4,11, Rep. 1,2 & 3 . Taking into consideration that it is a question of momentaneous water level positions-changes are dayly, remarkable moreover during a one day only-the derived conclusions have merely relative significance, while the competent directions of grounduater flow, so as whether Sava r. and how many days in a year recharges the underground, or drains it, could be defined from duration curves.

Generally one should accept the direction of flow is, more or less, congruous to the well known manifestations of river bed meandering in flat pervious strata, thereafter almost parallel to the river, W-E on the left and WNW-ESE on the right river bank.

Using mathematical-statistics methods, one year period of daily records in 1966/67 has been elaborated 2, Rep 1, furthemore the two years period in 1966/68 3, Rep 2. Under the assumption of linear correlation, using the habitual methods, the correlation coeficients r 0,6 has been found on 55% of wells, out of 95 and interpreted as strong correlative relation, 0,6 r 0,4 on 26%, interpreted as good relation, while on the remaining, weak relation or none. The correlative relation decreases with the distance from the stream, increases but from W to E. The most distant wells with strong correlation are 1 km far from river, between Podsused and Sava bridge, 2 km from Sava b. to Jakuševac bridge and 3 km farther east. With respect to derived conclusion upon a strong interrelation between Sava r. and underground waters using the regression equations has been constructed the prognostic high ground water level contours map, relative to area of good correlation, and based on presumed Sava high water levels of 2 days duration, as long as it was necessary to record the reaction on rised Sava levels in the most part of hinterland.

On the basis of records on 60 selected observation wells in 1972, the multiple linear regression has been estimated and analized the mutual correlative relation between 1-3 neighbouring vells. The obtained coefficients of correlation are mostly beyond 0,9 and standard deviation within a range $\pm$ 25 cm, insinuating the very strong relation, thus the uniform groundwater regime 1, Rep 3.

WATER QUALITY

The role of water quality in Zagreb area has been already emphasised in the Intorduction:

- water is consumed for drinking purposes (inter alia)
- available water resources are subject to increasing pollution.

Resulting from hydrogeological relations and hydrological studies, that the alluvial groundwater reservoir is an integral continuity, that direct, even very good connection exists between the regime of Sava r. and by it immediatly influenced regime of ground waters, the above accentuated role and significance of water quality becomes more valourous, so the introductory statement that final, asting solutions of Zagreb water supply, should be purposively oriented to implementation of adequate protective measures in Sava r. alluvium.

Already have been pointed out the drainage area factors, likewise the evident influence of surface water courses: torrents running down the slopes of highlands encircling the plain and Sava r. itself polluted to the utmost degree.

In order to support both the importance of water quality and the danger of contamination to which this area has been intensively exposed, as well as in order to get a clear idea of pollution grade and of conditions that stipulate it, it should have proved satisfactory in continuation, merely to recapitulate the polluters and their influence on ground water reservoir, exploited as drinking water by over one million people.

In addition to previously said the water resources management plan predicts on Sava r. construction of 3 low head power plants, in Podsused, Jarun and Rugvica, and yet we expect from those solutions positive effects only in the water management and hydrotechnical points of view, there should be given particular consideration regarding the water quality, having in mind that Jarun lake is envisaged as huge sport and recreation center, with over 20000 people capacity, heving in mind the former sanitary-technical faillure of artificial lake in this area.

Latest risk in sight are the thermo-nuclear plants located in Sava valley what will be further discussed.

S a v a r. remains further the principal collector of waste waters let out by growing chemical, pharmaceutical and textile industries to the west, the industry in the town itself, as well the chemical, oil, paper, and o. on the east, without any treatment, even regardless of enough precise legal regulations.

It was said enough about t o r r e n t s on urban territory. We may add that in lowlands portion, sereral have been turned into city waste water mains that often drain straight to Sava r., sure enough without treatment.

Taking into consideration that on over 800 km2 large area, the impervious cover is, here and there, considerable thin, or is missing at all, in natural or artificial way, particulary dangerous, especially for municipal pumping sites, including the future ones, south of Sava r. are numerous inhabited areas. They are still of rural character with developed agricultural and live stock production, with insanitary garbage dumps, without convenient sewers.

The danger of the same character is the irresistible penetration of the town to the south, with indispensible accompanying projects, traffic arteries, depots, repositories, workshops, industrial plants, that along witto all negative consequences creates particular difficulties in defining and regular inspection of protective zones of long ago planned pumping sites.

The outright possible catastrophical peril are numerous gravel excavations on the west, but also in the narrower city territories. Pits in some places are up to 30 m deep uncovering the whole water-bearing stratum, thus opening the way to omniferious immediate pollution, dangerous to human health.

The thermic contamination of water is recently ever more rising the interst to reslarch, because the temperature factor is a very significant indicator of water quality. The temperature is one of most conservative characteristics of ground water. With respect to the insulating qualities of earth´s crust, damping out the extreme temperature oscillations at surface, so that under ordinary conditions the groundwater temperature at a depth of 10-20 m are negligible, and according to the analises in USA they don´t exceed the mean annual air temperature by 1-2 °C 12.

It is well known that mean temperatures in open water courses and waters increase when pollution increses. The actual state of pollution of Sava r. in Zagreb area already causes the thermic contamination (there are imminent investigations on that). Taking into consideration that the temperature of Sava r. will be soon substantially raised, being utilized as cooling water in thermonuclear plants upstream of Zagreb, taking into consideration previously accentuated deductions concerning the steady and direct connection between Sava r. and underground, the immediate influence of Sava r. regime on the regime of ground water, finally, taking into consideration so far technical and practice unknowns about movement and eventual accumulation of heat in underground - in distinction from surface water courses, where, subject to large contact surface and considerable velocities,hot water will quickly evaporate and cool off, underground water moves through pore spaces in the soil with imperceptible velocity-on its way to pumping sites of Zagreb water works, then the temperature contamination of good quality drinking water resources in Sava r.alluvium becomes one of most essential water quality factor in Zagreb area.

This work is a pioneering attempt to analize the relation between the temperatures of ground water, Sava r. and air, to initiate systematical ground water temperature recording and to clear the way in setting up mathematical models concerning those mutual relations with an applicable aim to prevent the thermic contamination consequences in the underground reservoir.

METHODOLOGY AND INTERPRETATION

As was said a while ago, efforts have been made to find a suitable methodology to study the temperature regime of one region - Sava plain near Zagreb, using the existing data, to the one hand, and directing further efforts to the optimal definition of those relations, to the other hand, realizing their enormous significance to the quality of water, before all for drinking purposes. One should understand that this task was not a simple one, not an casy one. As distinguished from systematical,over 100 years lasting recording of air temperature and 25 years recording of Sava r., the groundwater temperature recording, twice a week, started in 1973 on 52 observation wells scattered over this area.

The mode of processing was following:

1. On the basis of logical supposition that temperature influence of Sava r. decreases with the distance from river, all observation wells have been grouped in 4 zones. First, including those upto 500 m far from river, the second, 500-1500 m, third, 1500-3500 m, and fourth, 3500-5500, supposing they appropriatly represent the temperature course in underground as a function of distance from the river (Fig.1).

2. The course of temperature in each observation well has been graphically represented during the total recording period, 1.7.1973.-30.6.1977., by each zone separately.

At first sight upon the graphically represented results of temperature records has displayed the necessity of s e l e c t i o n of the representative observation wells, regarding the accuracy and reliability of recordings, its frequency, site etc. The observing reliability is estimated, inter alia, pursuant to the departures from the expected course,in the choice of site the main criterion was to stick to the right river bank only, because of the city development plans, while the noticed blanks, not exceeding 4 months were filled out by means of correlation analysis and medium regression line:

$$y - \bar{y} = a(x - \bar{x})$$

$$a = tg\varphi$$

UNDERGROUND WATER OBSERVATION WELLS
IN SAVA R ALLUVIAL PLAIN NEAR ZAGREB

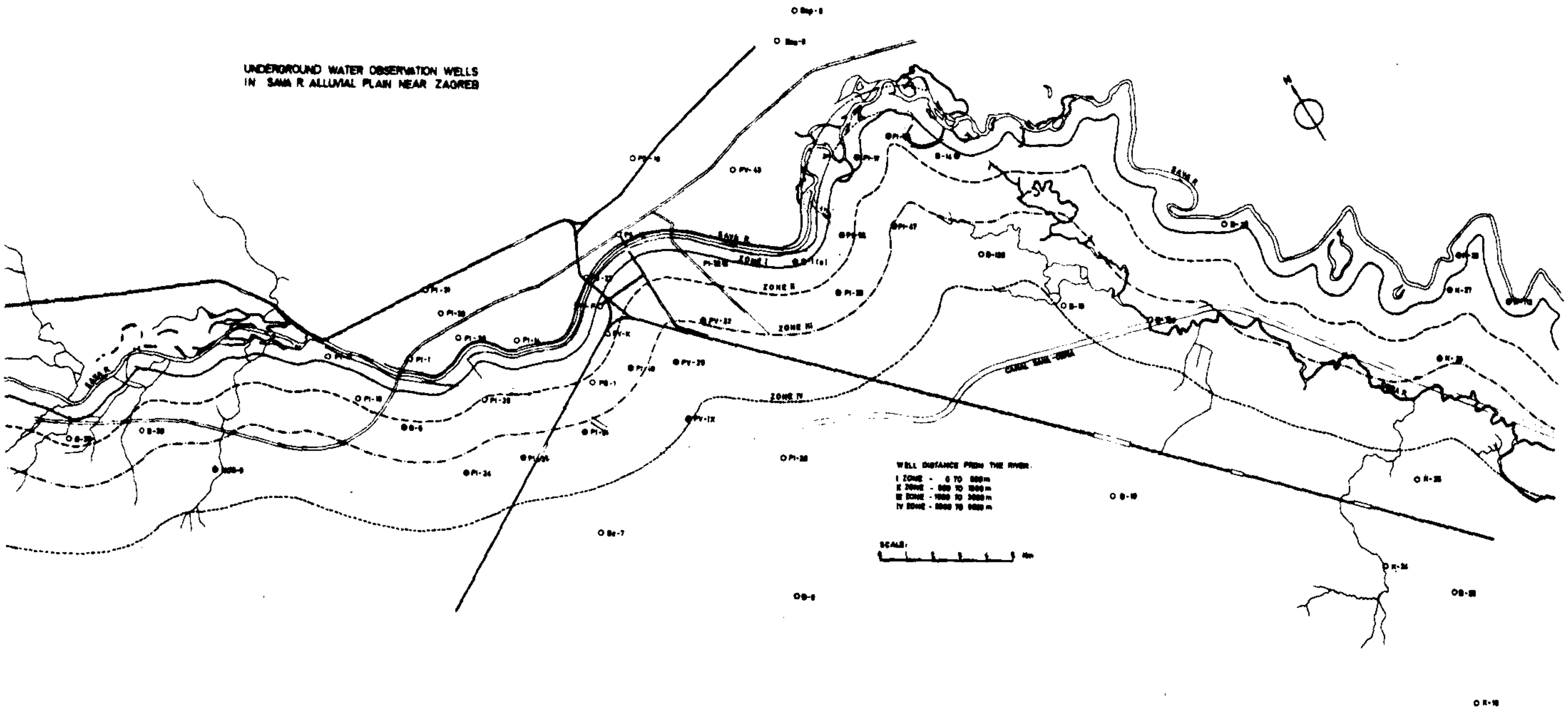

FIG.1

$$tg 2\varphi = \frac{\frac{\sigma_y}{\sigma_x}\left(r + \frac{1}{r}\right)}{1 - \left(\frac{\sigma_y}{\sigma_x}\right)^2}$$

where $\sigma_x = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2}$ $\sigma_y = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (y_i - \bar{y})^2}$ are standard deviations for series x and y, and

$$r = \frac{\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})}{N \sigma_x \sigma_y}$$

the coefficient of correlation between a pair of observation wells chosen to show the strongest correlative relation,and if this was not a case,the well site has been eliminated. Finally,in this way have been adopted 21 observation representative wells, 4 in first, 5 in second, and 6 each in third and fourth zone (black circles in Fig. 1).

Taking into consideration that the statistical dimensions of ground water temperature dispersion are very small, I am of the oppinion that, at this stage of investigations, with such a selected statistical sample: too little number of recording years, the restricted number of observation sites and their disposition in long but narrow area, we could be at least partially satisfied, and that the way has been cut to continue investigation in order to suggest final, competent decisions about relevant temperature relations, that would serve as an indicator of water quality changes.

3. From the recorded temperatures on the selected wells of each zone there have been estimated the zonal mean temperatures for the 4 years period of observation (Fig. 2).

Regular and nearly identical course of temperatures, well expressed periodicity in each zone, almost simultaneous reaction to smaller and bigger changes in temperature,maxima and minima coincidence within a month time, are easy recognizable characteristics of those graphs. Amplitudes range from 8,5°C to 13,0°C in the first,

ZONAL MEAN TEMPERATURES MEASURED EVERY MONDAY AND THURSDAY FROM JULY 1ST 1973 TO JUNE 30TH 1977

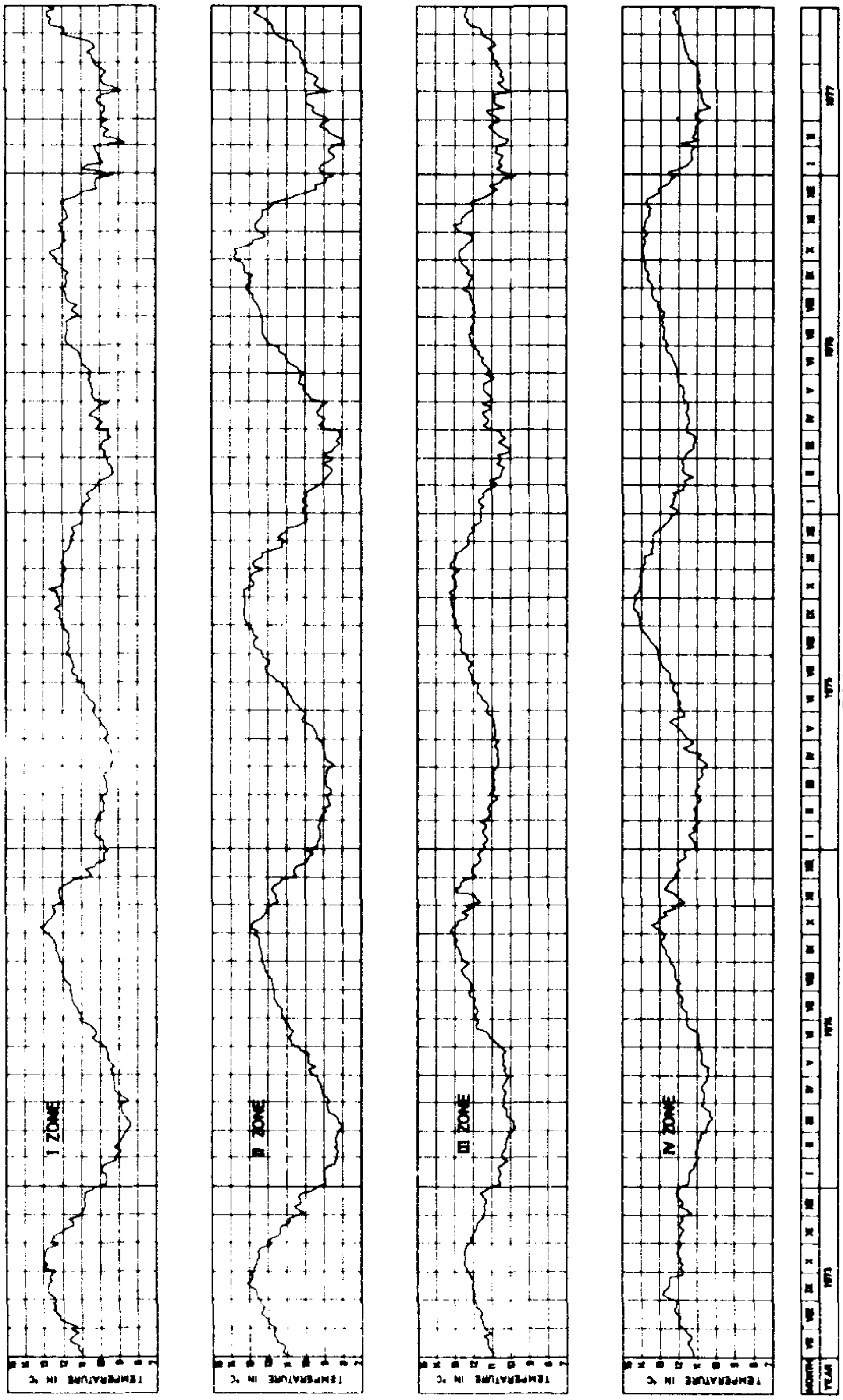

FIG 2

fom 8°C to 14°C in the second, from 10°C to 13°C in the third and from 10,5°C to 14,5°C in the fourth zone. It should be expected that temperatures decrease with the distance from the river, thus apparently unexpected outcome in the second zone should rather be attributed to the sample deficiency, inadequate measurements or choice of representative observation sites, but to the alteration of local circumstances, in the fourth zone.

4. Out of zonal mean temperatures have been estimated the mean decade temperatures for the mean year of four years observation period (Fig. 3).

On the same figure are also shown the estimated four-year mean decade Sava r. and air temperatures. Beside the periodicity, well noticeable are: the interrelation between the temperatures of the 3 environment, the anomalousness of the temperatures in the second zone, and extremes retardation with regard to the Sava r. temperatures, too.

5. With regard to the obvious periodicity of the time series of the ground water, Sava r. and air temperatures, the harmonic functions have been defined by Fourrier series in a form:

$$X_t = \bar{X} + \sum_{i=1}^{3} \left(A_i \cos \frac{2\pi i}{p} t + B_i \sin \frac{2\pi i}{p} t \right)$$

$$A_i = \frac{2}{p} \sum_{t=1}^{p} \Delta x_t \cos \frac{2\pi i}{p} t \qquad B_i = \frac{2}{p} \sum_{t=1}^{p} \Delta x_t \sin \frac{2\pi i}{p} t \qquad \bar{x} = \frac{1}{p} \sum_{1}^{p} x_t$$

and With respect to the period length $p = 36$ (decades) and $i = 1, 2, 3$, all the equations have this common form:

$$X_t = \bar{X} + A_1 \cos \frac{\pi}{18} t + \ldots\ldots A_3 \cos \frac{\pi}{6} t + B_1 \sin \frac{\pi}{18} t + \ldots\ldots B_3 \sin \frac{\pi}{6} t$$

with Fourrier coefficients:

$$A_1 = \frac{1}{18} \sum_{1}^{36} \Delta X_t \cos \frac{\pi}{18} t \ldots\ldots\ldots\ldots \qquad B_1 = \frac{1}{18} \sum_{1}^{36} \Delta X_t \sin \frac{\pi}{18} t \ldots\ldots\ldots$$

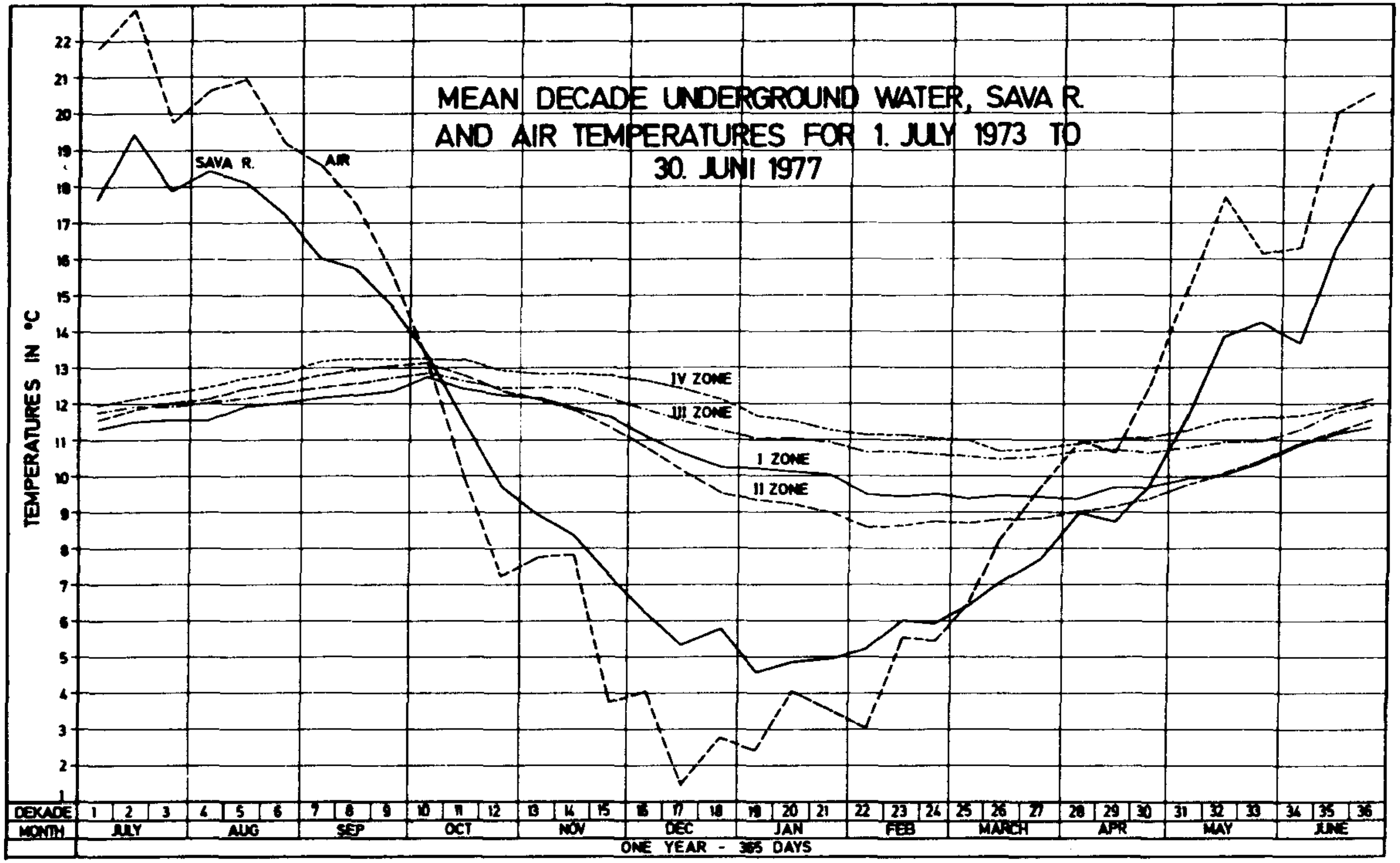
MEAN DECADE UNDERGROUND WATER, SAVA R.
AND AIR TEMPERATURES FOR 1. JULY 1973 TO
30. JUNI 1977
TEMPERATURES IN °C
SAVA R.
AIR
IV ZONE
III ZONE
I ZONE
II ZONE
DEKADE
MONTH
JULY
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MARCH
APR
MAY
JUNE
ONE YEAR - 365 DAYS

FIG. 3

and have been shown of Fig. 4.

CONCLUSION

Although the investigations up to the present and the results obtained should be considered as preliminary, as a first step in studying the temperature relations in the Sava r. plain near Zagreb, not but without ambitions for generalization in similar conditions, one could consider that already have been proved:

- the presumed relation between the temperatures of the ground water, Sava r. and the air: underground water temperatures go along with temperatures of Sava r.

- the expected time shift is defined now more accurately. The maximal temperatures of ground water fall behind the maximal temperature of Sava r., 71 days in the first zone, 61 in the record, 81 in the third and 71 days in the fourth zone, thus showing in the 1 st decade of September and first decades of october respectively. Similarly the minimal temperatures fall behind 65 days in the first, 40 days in the second, 65 days in the third and 59 days in the fourth zone, thus showing in the third february decade (by all means exceptionally, because of already mentioned anomalities in the second zone) and last decade of march respectively.

- the influence of the well distance (zone distance respectively) is evident. Generally it decreases with the distance from the river. Eventual departures are due to errors in the investigation, partly schould be but more analised.

- indirectly, this temperature interrelation veryfied the hydrogeological assumptions of the waterbearing stratum continuity, as well the immediate influence of Sava r. regime on groundwater, already being proved by hydrological analysis.

Such circumstances causing permanent increase of Sava water temperatures, suggest potential thermic contamination of underground water, raising thus the quastion of its exploitation after generally accepted drinking water criteria, and in addition to that, proving the aim and significance of this investigation for the water supply of Zagreb.

Finally, the results of hitherto investigations permit an optimism that resuming those researches we might come to the generalised solutions.

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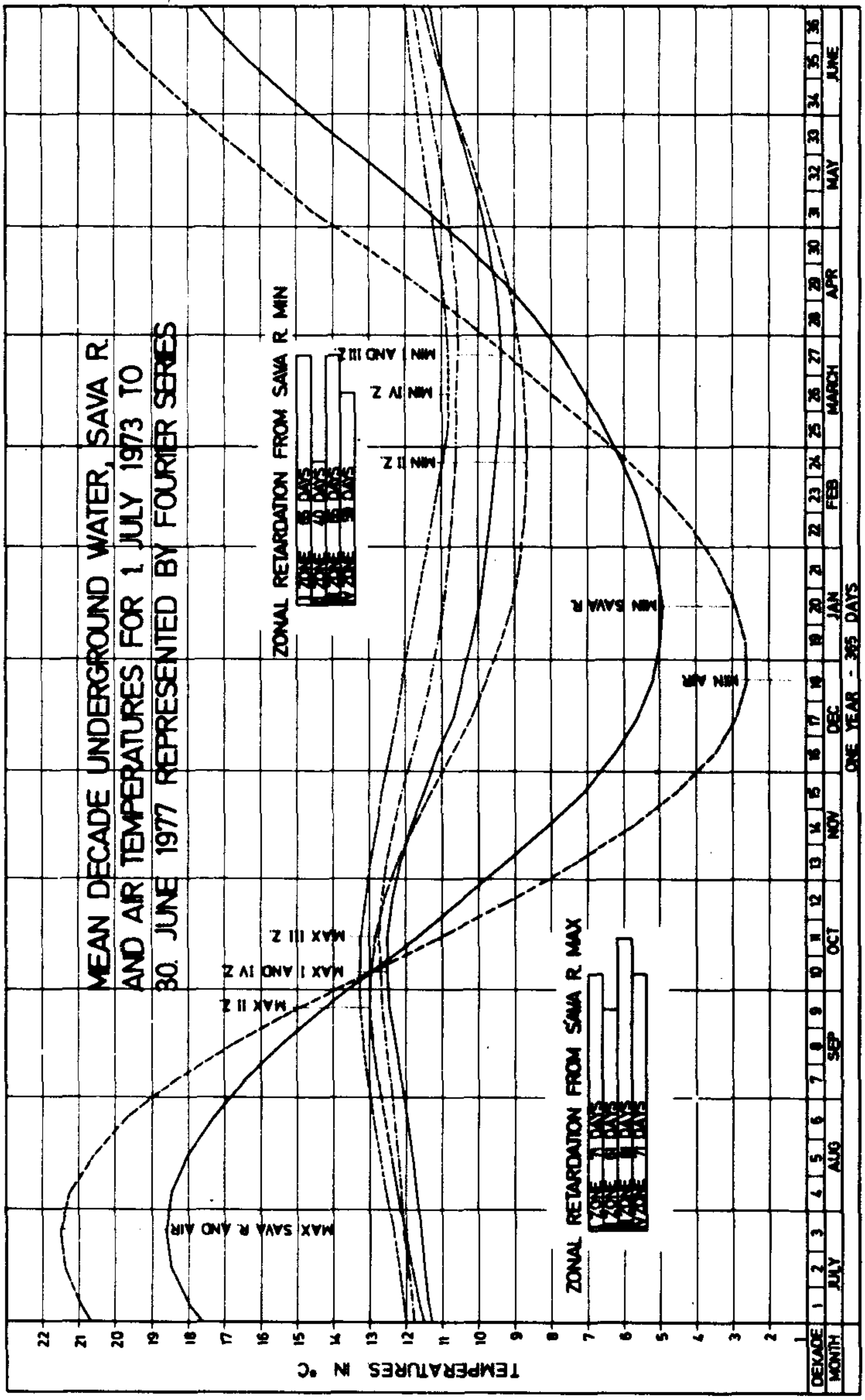
MEAN DECADE UNDERGROUND WATER, SAVA R.
AND AIR TEMPERATURES FOR 1 JULY 1973 TO
30. JUNE 1977 REPRESENTED BY FOURIER SERIES
ZONAL RETARDATION FROM SAVA R. MIN
ZONAL RETARDATION FROM SAVA R. MAX
MIN I AND III Z.
MIN IV Z.
MIN II Z.
MIN SAVA R.
MIN AIR
MAX III Z.
MAX I AND IV Z.
MAX II Z.
MAX SAVA R. AND AIR
TEMPERATURES IN °C
DEKADE
MONTH
JULY
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MARCH
APR
MAY
JUNE
ONE YEAR - 365 DAYS

FIG. 4

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