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CALCULATION OF THE WATER BUDGET OF THE VENETIKOS CATCHMENT AREA

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ABSTRACT

With the help of the computer program MODBIL a water budget of the Venetikos catchment area was calculated. The input data are the area precipitation, the temperature and relative humidity, geological pedological and morphological conditions. The measured mean monthly runoff values of the Venetikos river were compared with calculated values. Trial and error studies enabled the best fittig of the field parameters. At least it was possible to simulate both the total and the groundwater runoff using the MAILLET function.

INTRODUCTION

The Venetikos river is a tributary of the Aliakmonas system, the largest watershed on Greek territory. The following work is part of a research program entitled „Investigation of the anthropogenic solute-transport in the Aliakmonas River Basin". To calculate solute-transports, it is necessary to establish a water budget of the study area by classifying the main parts of surface and groundwater run-offs. In addition to input and output parameters (e.g. precipitation, evapotranspiration, etc.), subsurface conditions, as well as quantity and quality of vegetation are important factors in drainage system developments.

1 THE VENETIKOS CATCHMENT AREA

1.1 General setting

The Aliakmonas river basin up to it's most eastern dam near Asomata extends over 6300 km^2. The catchment area of the Venetikos river up to the gauge station at Grevena bridge exceeds 817 km^2. The Venetikos area belongs to the mountainous region of NW Greece with elevations over 2000 m. The River originates in the Pindos to the west and in the Hasia Mountains to the south. The altitude of the Venetikos at the junction into the Aliakmonas is somewhat more than 400 m. The mean altitude of the area is approximately 900 m.

1.2 Regional Geologic setting (Fig. 1)

The catchment area to the west is described by the Pindos Zone, while the eastern parts are situated in the Hypopelagonic Zone (Mesohellenic Trench). The greater elevations of the Pindos zone to the west of the catchment area mainly consist of Ophiolites. To the north, Flysch sediments are dominating. The Hypopelagonic Zone consists of the Mesohellenic Trench filled with Upper Eocene to Miocene Molasses sediments (conglomerates, sandstones, marls, clays), covered by Pleistocene deposits. The Pleistocene sediments consist of lacust-

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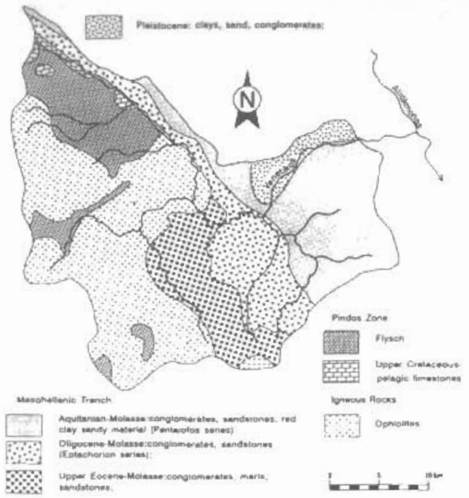

Fig. 1: Geological map of the Venetikos catchment area

rine and continental clays to conglomerates (MOUNTRAKIS 1985).

1.3 Hydrogeological conditions

Precipitation reaching the earth's surface results in surface run-off, infiltration, and groundwater recharge, depending on natural parameters, such as slope, vegetation density, soil type, and lithology, as well as climatic conditions, such as precipitation, evaporation and their intensities.

The previously mentioned Ophiolites and the lithologies of the Flysch are both known as poor aquifers. Their corresponding soils also display inadequate hydraulic conductivities. During periods of heavy precipitation in steeply sloping areas, the surface water runoff dominates. Molasses lithologies are more differentiated. Sands, gravels, and conglomerates display favorable groundwater recharge conditions in gently sloping areas. On the other hand, the marly and silty clay-sediments of the Hypopelagonic Zone primarily display the poor infiltration characteristics of the Flysch series. The Venetikos cat-chment area can be generally divided into 50 % Ophiolite and Flysch lithologies and 50 % Molasses sediments. Of the Molasses sediments 50 % can be classified as poorly, the other 50 % as good to moderately hydraulically conductive. The major part of the catchment area (75 %) consist of lithologies and soils with deficient hydraulic parameters. Only the remaining 25 %, located in the southeast of the area, displays favorable hydraulic conditions.

2 WATER BUDGET

The Venetikos catchment belongs climatically to western Macedonia and is characterized by the change of mediterranean to continental climates of the Balkans (LIVADAS 1976, BALAFUTIS 1977). Precipitation is present throughout the year, reaching the maxima in October through January. During this time total rainfall meets or exceeds 100 mm a month. Potential evapotranspiration controlled by temperature and relative humidity is highest during July and August. Recharge of aquifers starts around the month of October, when precipitation begins to exceed potential evapotranspiration.

The following water budget comprises the years 1963 to 1982, the only years with consistently available meteorological and hydrological data. Using the results of this data analysis in conjunction with the model described in chapter 4, it is now possible to establish water budgets for incomplete or inconsistent data-sets.

2.1 Precipitation

The recordings of 24 rain-gauges in west and central Macedonia were used to prepare an isohyetal map (Fig. 2) taking into consideration the orographic conditions of the region. In order to establish the mean monthly rainfall of the Venetikos catchment the recorded data of weather stations Koniza and Kozani were used. The mean values of both measuring facilities were then referenced

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to the mean value of the area described by the isohyetal map, resulting in an increase of factor F=1.45 for the map values compared to the values established for Koniza and Kozani. Therefore:

Mean Value of Area	=	1242 mm
Mean Value of Kozani	=	686 mm
Mean Value of Koniza	=	1027 mm

$$P_{area} = P(Koniza + Kozani)/2 * 1.45$$

where P is amount of precipitation.

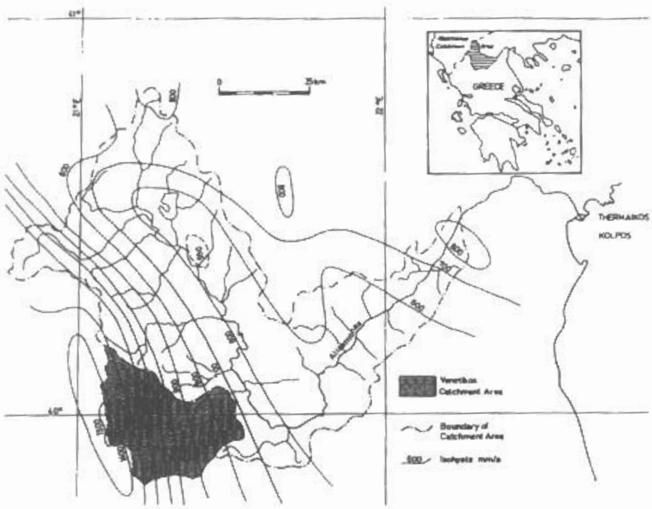

Fig. 2: Isohyetal map of the Aliakmonas and the Venetikos catchment area

2.2 Evapotranspiration

The climatic evapotranspiration (= potential evapotranspiration) was calculated by HAUDE (1952, 1955, 1959) using values of relative humidity and temperature (Fig. 3). Haude wanted to use 2:00pm values for his calculations. Since they were not available, he applied regression mathematics to derive at the 2:00pm values (see Chapter 3).

2.2.1 Temperature

The mean annual temperature at elevation 600 m is 13.5 °C, the lowest mean monthly temperature (January) equals 3.1 °C. The highest monthly mean temperatures are reached during July with 23.7 °C and August with 23.5 °C.

To derive at the mean temperature of the area the temperature values measu-red at Koniza (542 m) and Kozani (630 m) were used. The calculated data is valid for elevation 586 m. To apply temperature values in order to calculate the evapotranspiration for the mean elevation of 900 m, temperature values are reduced by 0.6 °C/100 m vertical increase (see chapter 3).

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2.2.2 Relative Humidity

The main influence on potential evapotranspiration is the relative humidity of the air next to temperature. Local conditions as well as elevation have only minor influences. The main controls of relative humidity are the direct relationships of rainfall, temperature, and soil moisture content.

Average relative humidity during October until end of March is 70 %, whereas through the months of June to September it is below 60 %. The annual average of relative humidity is 63.8 %.

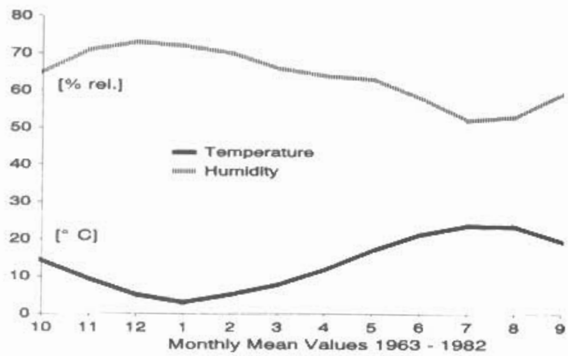

Fig. 3: Monthly mean values of temperature and humidity 1963-1982

2.3 Drainage of the Venetikos

The Venetikos, a perennial tributary of Aliakmonas, contributes to 2/5 of the total discharge measured at the „Ilarion"-station. The mean monthly discharges fluctuate greatly. Highest values were measured in February 1963 with 105 m^3/s, lowest values during July and August with 0.7 m^3/s. Low discharge values during the summer months are beginning to increase by October and highest values are reached during December averaging 40 m^3/s. The rapid decrease to 3 m^3/s during the summer indicates low storage capacities of the underlying aquifer.

3 WATER BUDGET MODELING USING MODBIL

The MODBIL computer model (UDLUFT 1993) calculates drainage characteristics of a river system using natural parameters in connection with meteorological variables. Input data consists of mean monthly values for precipitation, temperature, and relative humidity, as well as data for slope, vegetation density, soil permeability, and storage capacity. Differentiation of precipitation into infiltration and surface run-off depends on hydraulic conductivity of the upper soil layers; deciding factors are the intensities of the single events. If intensities of precipitation are greater then the hydraulic conductivity (under consideration of slope), overland flow results. At the same time highest seepage velocities are reached depending on present soil water contents. When the hydraulic field capacity of the top soil is reached, infiltration continues into the next underlying layer. This process continues (in most cases) downward until the aquifer is reached. The results this procedure are shown in Fig. 4.

3.1 Evapotranspiration (ET)

Applying the evapotranspiration calculations proposed by HAUDE, the 2:00pm values for temperature and relative humidity are necessary. However, this data was not available. To derive the essential values for the temperature, the mean monthly values for daily temperature maxima at some research stations were placed in relation with mean monthly temperature, resulting in:

$$T_{14} = 1.91 + 1.14 * T_m$$

A general correspondence of daily temperature maxima with the 2:00pm tempe-

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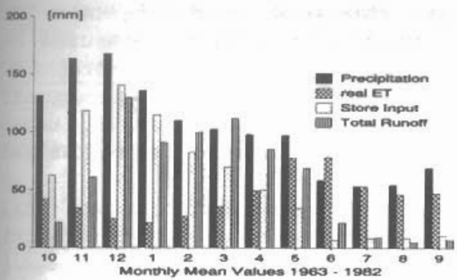

Fig. 4: Water balance with soil storage input (infiltration minus ET)

rature values was assumed. Relative humidity correlates in it's daily rate directly with temperature. Since the relation between temperature and vapor pressure is „non-linear", a comparable function of mean humidity to 2:00pm humidity was established. Evaluation of older reports resulted in the following regression equation:

$$F_{14} = F_m / (1.94 - 0.0088 * F_m)$$

From these values the potential evapotranspiration of the area was computed, using a corresponding correction (DAMMANN 1965) for elevation difference between Koniza/Kozani (586 m) and the mean elevation of the area (900 m).[1]

3.2 Area parameters

The computer model further requests various parameters of the catchment area. Input about the dominant form of vegetation (forest/field) is used to calculate actual evapotranspiration either after RENGER (1974) or SPONAGEL (1980). The field capacity and degree of saturation are evaluated through reduction mathematics for actual evapotranspiration and subsurface seepage in the case of saturation. Subsurface seepage is equated with the groundwater recharge rate in this one-layer model.

Actual evapotranspiration is calculated as follows:

$$V_a = V_{pot} * V_n / 100$$

where

V_{pot} = potential evapotranspiration
$V_n = 8.5 * SP^{expo}$
SP = soil saturation in percent (% of NFK)

The factor „expo" depends on the predominant vegetation (forest or field). Thus

field is expof = 0.53529
forest is expow = 0.57488

Input request for initial saturation is important only for the beginning of the time sequence or for short durations. Of major importance are slope and soil type. Both values are linked through an empirical regression equation and are deciding factors in the differentiation of surface run-off and infiltration according to precipitation.

3.3 Drainage simulation

Interflow of surface lithologies and the aquifer will be computed using a Maillet equation:

$$Q_t = Q_{(t-1)} * e^{-\alpha * t}$$

where

Q_t = Drainage at time t

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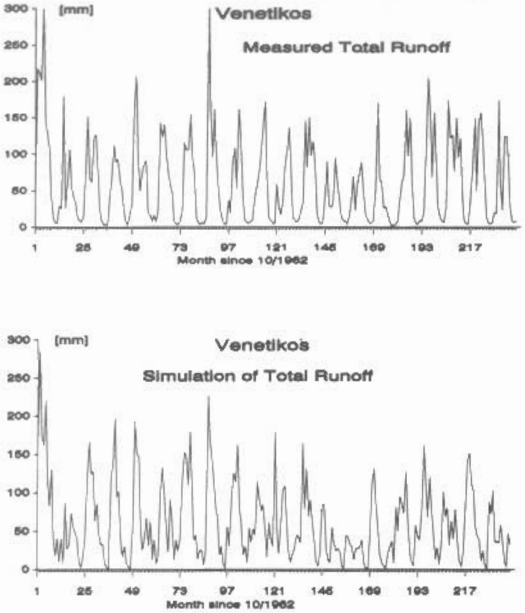

Fig. 5 and 6: Comparision of the simulated with the measured runoff monthly mean values 10/1962 - 9/1982

The plot in Fig.5 shows the Venetikos runoff, measured at „Ilarion"-station. The graphs in Fig. 6 and 7 display the runoff calculated with MODBIL, under consideration of the Maillet equation.

Input parameters are mean total drainage and mean groundwater drainage (subsurface seepage), as well as their starting values. To determine the α coefficient of the MAILLET (1905) equation, the greatest drainage regression during moderate drainage events is used. (UDLUFT & BLASY 1975). For every time interval the presently dominant drainage Q_t is compared with the associated supplementary drainage Q_a. The following can be concluded, if

$Q_a > Q_t$, drainage increases
$Q_a = Q_t$, drainage is unchanged
$Q_a < Q_t$, drainage decreases.

4 CALIBRATION OF THE DRAINAGE MODEL

The calibration of the model (Tab. 1) is based on measured run-off values of the Venetikos. The most consistent observation was made from October 1962 to September 1982. Inadequately known area parameters are

Field capacity	60 to 120 mm range
hydraulic soil conductivity	10-6 to 10-8 m/s range (Soil type II to IV)
slope	6° to 10° range.

Initial saturation was assumed to be 50 % during all simulations.

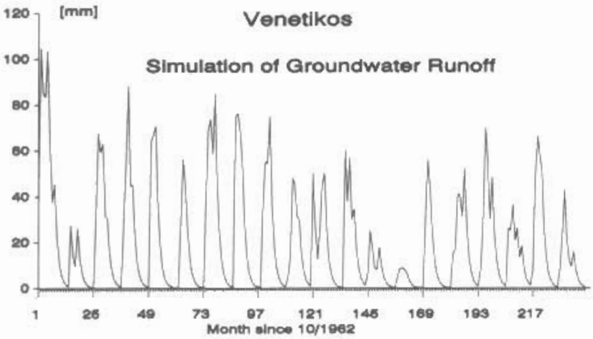

Fig. 7: Calculated groundwater runoff for the time 10/1962 - 9/1983

Analysis of highest monthly drainage regressions at moderate drainage events (61 mm) resulted in values of approx. 53 mm. Corresponding values for groundwater drainage, however, are completely unknown and can only be established through simulation. Even with this, probable events can be differentiated from „*impossible events*". Most important parameters are hydraulic soil conductivity, field capacity and slope.

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Tab. 1: Variations of results for different input parameters as simulated with BILMEN (precipitation = 1242 mm). In the dotted field the best-fit parameters are schown

Field Capacity	60	60	120	60	60	120	60	120	60
Mean Slope	3°	9°	3°	3°	9°	9°	9°	9°	9°
Initial Saturation	50%	50%	50%	50%	50%	50%	50%	50%	50%
Infiltration	122	104	113	102	875	875	747	747	659
	1	9	9	7					
ETpot	933	933	933	933	933	933	933	933	933
Etactual	572	533	604	550	512	554	485	527	461
Total Runoff	670	689	638	692	730	688	757	715	781
Direct Runoff	21	193	103	215	367	367	495	495	583
GW-Runoff	649	496	535	477	363	321	262	220	198

I = Karst, Gravel (10^{-4}); II = Sand (10^{-5}); III = Loam/Sand (10^{-6})
IV = Loam (10^{-7}); V = Clay (10^{-8}) (all values in m/s)

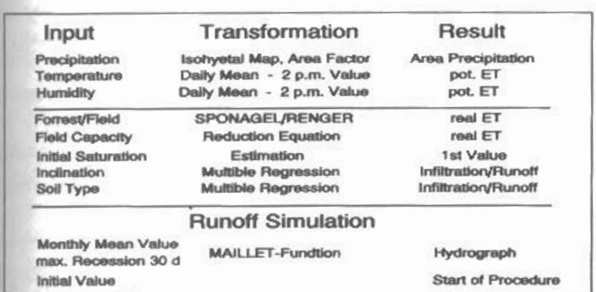

Fig. 8: The modelling scheme of MODBIL

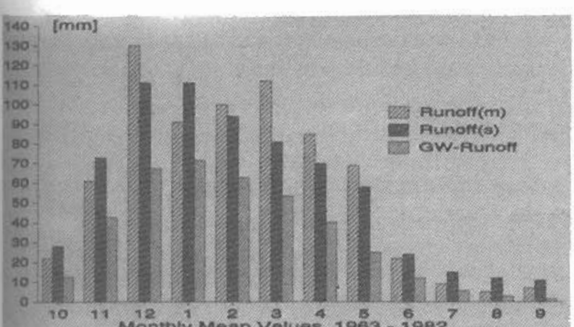

Fig. 9: Comparison of the means of measured (m) to simulated (s) runoff including the simulated groundwater runoff

Using as input values precipitation and potential evapotranspiration, the simulated mean annual drainage should not differ from the measured value by more than 5%. During changes in hydraulic soil conductivities, a regulation of groundwater recharge or groundwater drainage is mainly observed. The change also modifies the actual evapotranspiration and therefore the total drainage of the area.

5 CONCLUSIONS

The water budget model MODBIL is able to simulate precipitation - runoff systems including groundwater. The Venetikos river was selected as an examlpe since there are available long time data of the measured run-off, precipitation, temperature and relative humidity.

Because of the climatic situation of the Venetikos a clear distinction between

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winter and summer drainages can be made. This is also true for groundwater drainage. Drainages of 200mm/30d are common during the winter months. All drainages approach 0 (lowest value 2mm/30d) during summer. A poor correlation between simulated and measured values was obtained for 1975 and 1976. The main reasons for this deviations are due to the lack of precipitation data in the mountain region in the west of the drainage area.

Deviations of the monthly values between measured and simulated data in the winter months are schown because of the missing of a program term dealing with the snow cover. As seen in Fig. 9 there is a snow storage from December including February and an additional runoff by snow melting in March and April which is much higher than the simulated runoff. In future a program part schould be added to MODBIL for the calculation of the snow cover as an important precipitation storage. This part of the model will be controlled by the mean temperature.

To get more accurate results with the MODBIL the observed area should be divided in smaller parts. The most important criteria for the subdivision should be determined by geology, topography, altitude, vegetation cover and exposition.

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