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Experiments of Conceptual Mathematical Groundwater Dynamics and Runoff Modelling in Latvia

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A mathematical model METUL for estimating the daily groundwater level and drainage, surface and subsurface runoff in small areas is described. Input data for the model are daily mean values of air temperature, precipitation and vapour pressure deficit, as well as the occurrence and disappearance of snow cover. Questions about the determination of the model's parameters are discussed, and the results of the model's application to experimental areas in two drainages are analyzed. The model's usefulness in objectively determining the soil water regime of small areas after only short-term groundwater level observations is shown.

Introduction

Groundwater level fluctuation is dependent on meteorological conditions. This relation increases when the water-table approaches the ground surface. This is seen in the areas with artifical drainage and in the areas where drainage is necessary. Therefore a possibility exists to use a conceptual mathematical model with meteorological input data as a tool for the estimation of the soil hydrological regime. The mathematical model METUL has been developed for this purpose in Latvia.

The main objective of the model METUL is to create a method for the investigation of the groundwater regime, which is characteristic for a long-term period, against short-term measurements in typical meteorological conditions. During the course of the studies it is found, that the model METUL may also be utilized for the solution of other problems: calculation of drainage and total runoff, prolongation of gauged runoff records, short-term forecast in small catchments, etc.

The mathematical model in some assumptions is similar to the S. Bergström model HBV (Bergström and Sandberg 1983, Bergström 1992), although the model METUL was developed independent of the HBV model. Therefore, the authors consider, that the analogies, which exist in the models, are the verification of validity and the applicability of both the models cited. The main difference between the mathemathical model METUL and other conceptual models is the possibility to calculate the small catchment with both natural and man-made drainage.

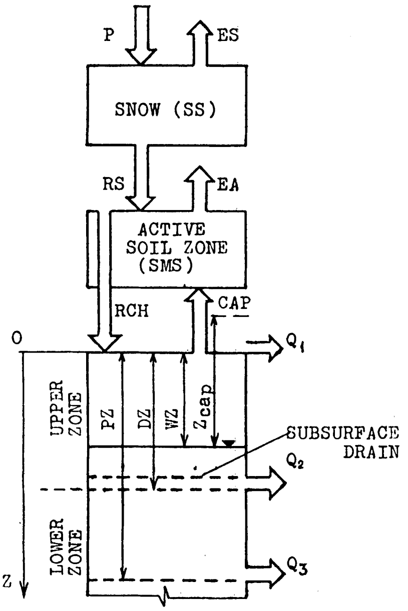
Description of the Model

The METUL model is a conceptual hydrological model with several physically based parameters. Input data include daily mean air temperature and vapour pressure deficit, as well as the total amount of daily preciptation and the days when snow appears and disappears.

The model consists of three parts:

1) estimation of the snow cover,
2) estimation of the active soil zone moisture balance,
3) estimation of the groundwater balance together with capillary fringe.

The model is presented in Fig. 1.



Symbols

P – Precipitation, mm/day
ES – Evaporation from snow, mm/day
RS – Rain and snow-melt water, mm/day
EA – Evaporation from active soil zone, mm/day
RCH – Recharge of groundwater, mm/day
CAP – Evaporation from groundwater surface, mm/day
SS – Water content of snow cover, mm
SMS – Water content of active soil zone, mm
GW – Free pore capacity above groundwater level, mm
Z – Depth from ground surface, cm
DZ – Pipe drain effective depth, cm
PZ – Piezometric pressure level from ground surface, cm
Z_{cap} – Capillary rise height, cm
Q_1, Q_2, Q_3 – Runoff components, mm/day
WZ – Groundwater depth, cm

Fig. 1. Schematic presentation of the METUL conceptual model.

Snow Cover

Estimation of the snow cover accumulation and ablation includes five parameters:

T_1 – daily mean air temperature below which snow accumulation begins, °C,
T_2 – daily mean air temperature above which snow ablation begins, °C,
K_s – evaporation coefficient from snow,
C_{melt} and C_1 – empirical coefficients, which characterize the intensity of the snow melt and the water contribution from the snow, as dependent on daily mean air temperature and snow pack.

In the running of the mathematical model METUL, the C_{melt} and C_1 were determined so, that observed and computed day of snow disappearing coincides. Coefficients can be estimated from experience, if the model is used for a short-term forecast. In Latvia the coefficient C_{melt} usually is between 1.5 and 3.0, and C_1 falls between 0.005 and 0.02. Contribution from rain and snowmelt to the soil *RS* and the balance in the snow cover are computed as follows:

1) if the daily mean air temperature is lower than T_2 ($T \leqslant T_2$), then

$$RS = 0 \tag{1}$$

$$SS_e = SS_b + P - ES \tag{2}$$

2) if the daily mean air temperature falls within the parameters T_1 and T_2 ($T_2 < T < T_1$), then

$$RS = W_{\mathrm{melt}} \tag{3}$$

$$SS_e = SS_b + P - RS - ES \tag{4}$$

3) if the daily mean air temperature is greater than T_1 ($T \geqslant T_1$), then

$$RS = P + W_{\mathrm{melt}} \tag{5}$$

$$SS_e = SS_b + P - RS - ES \tag{6}$$

where

SS_b – water content of snow at the beginning of the day, mm,
SS_e – water content of snow at the end of the day, mm,
RS – contribution from rain and snowmelt, mm,
P – daily total amount of precipitation, mm,
ES – evaporation from snow, mm,
W_{melt} – daily total contribution from snow melt, mm,
T – daily mean air temperature, °C.

Daily total amount of melted snow is computed to the following empirical expression

$$W_{\mathrm{melt}} = C_{\mathrm{melt}}(1 - C_1 SS_b)(T - T_2), \quad \text{if} \quad T \geq T_2 \tag{7}$$

Evaporation from snow

$$ES = K_s\, DEF \qquad (8)$$

where

DEF – the daily mean value of vapour pressure deficit, hPa.

If there is no snow on the day in question, *i.e.* $SS_b = 0$ and $T > T_1$, then the snow routine is omitted.

The Active Soil Zone

The estimation of the water balance in the active soil zone is performed similar to the estimation of soil irrigation regimes (Ziverts and Sauka 1976). The main difference is that the estimations of summary evaporation which have been verified in the experiments and practically tested during the periods of vegetation can, with a few small changes, be applied to a non-vegetative period, as well.

The active soil zone is assumed an upper layer of the soil without a precisely defined lower boundary. This is the zone in which the primary mass of vegetative roots are found and in which the summary evaporation during the period of vegetation is determined primarily by plant transpiration. This zone is not really separated from the upper zone of the ground, as is schematically demonstrated in Fig. 1, but rather it is physically included in the upper part of the ground. A difference is found in the processes of moisture storage in the active soil zone and the upper zone. If in the first of them the determinant factors are transpiration and the soil water tension, then in the second instance the determinant factor is the movement of water under the gravitational force. Some physical explanation of process of this conceptual model is not a rule, it only shows that the following empirical expressions have a physical base.

The equation of water balance in the active soil zone is as follows

$$SMS_e = SMS_b + RS - EA - CAP \qquad (9)$$

where

SMS_b, SMS_e – the water storage of the active soil zone at the beginning and the end of the day respectively, mm.

Other symbols are described in Fig. 1. The quantities SMS_b and SMS_e must be within these limits

$$0 \le SMS_b \le W_{\max} \qquad 0 \le SMS_e \le W_{\max}$$

where

W_{max} – the maximum water storage in the active soil zone, mm.

Thus, if the SMS_e value estimated by Eq. (9) exceeds W_{max}, then it is assumed that $RCH = SMS_e\text{-}W_{max}$ and $CAP = 0$; if the SMS_e value estimated by Eq. (9) finds that $SMS_e < 0$, then it is assumed that $RCH = 0$ and $CAP = -SMS_e$, and the calculation is repeated.

The actual evaporation of each day is estimated depending on the daily mean value of vapour pressure deficit, the water storage of the active soil zone (SMS_b) and the water table depth (WZ_b) at the beginning of the given day. If $SMS_b = W_{max}$, then the actual evaporation is equal to the potential evapotranspiration, which the model calculates as follows

$$EA = K_u \, DEF \tag{10}$$

where

K_u – the upper limit of the evaporation coefficient,

If $SMS_b = 0$ and $WZ_b \geqslant Z_{cap}$, then the actual evaporation is calculated by utilizing the lowest value of the evaporation coefficient during the snowless period K_l

$$EA = K_l \, DEF \tag{11}$$

where

K_l – the lower limit of the evaporation coefficient

Z_{cap} – height of capillary fringe, cm.

If the moisture content in the active soil zone is $SMS_b < W_{max}$ and $WZ_b < Z_{cap}$, then the actual evaporation is estimated by interpolation between the limit values, which are obtained through Eqs. (10) and (11). Then the interpolation formula is

$$EA = \begin{cases} \left[K_u - \frac{WZ_b}{Z_{cap}} (K_u - K_l) \left(1 - \frac{SMS_b}{W_{max}}\right)\right] DEF; & \text{if} \quad WZ_b \leq Z_{cap} \\ \left[K_u - (K_u - K_l) \left(1 - \frac{SMS_b}{W_{max}}\right)\right] DEF & \text{if} \quad WZ_b > Z_{cap} \end{cases} \tag{12}$$

In this way, four parameters are used for the estimation of the water balance in the active soil zone: W_{max}, K_u, K_l, Z_{cap}.

The Groundwater and Capillary Water Zone

The mathematical model METUL assumes that under the water table all ground pores are saturated with water, but above it one portion of the pores are filled with air, another with capillary water, and the rest with the water which is so closely attracted to the soil particles that it is not influenced by the fluctuations of the groundwater level. The capacity of the empty ground pores GW (expressed in mm) above the water table is described as

$$GW = \begin{cases} 5(\alpha_1+\alpha_2)Z_{cap} + 10\alpha_2(WZ-Z_{cap}), & \text{if } WZ > Z_{cap} \\ 5WZ[2\alpha_1+(\alpha_1-\alpha_2)\frac{WZ}{Z_{cap}}], & \text{if } 0 < WZ \le Z_{cap}, \\ 0, & \text{if } WZ \le 0 \end{cases} \tag{13}$$

where

α_1 - effective porosity at the water table,
α_2 – the same at the top of the capillary fringe.

Graphical presentation of Eq. (13) is demonstrated in Fig. 2.

Equation of the water balance in the capillary fringe and the groundwater zone is applied as follows

$$GW_e = GW_b - RCH + CAP + Q_1 + Q_2 + Q_3 \tag{14}$$

where

GW_b , GW_e - capacity of empty ground pores at the beginning and the end of the given day, mm;

other symbols are described in Fig. 1.

The pipe drainage runoff is estimated as follows

$$Q_2 = \begin{cases} A_2(DZ-WZ_e)^2, & \text{if } WZ_e < DZ \\ 0, & \text{if } WZ_e \ge DZ \end{cases} \tag{15}$$

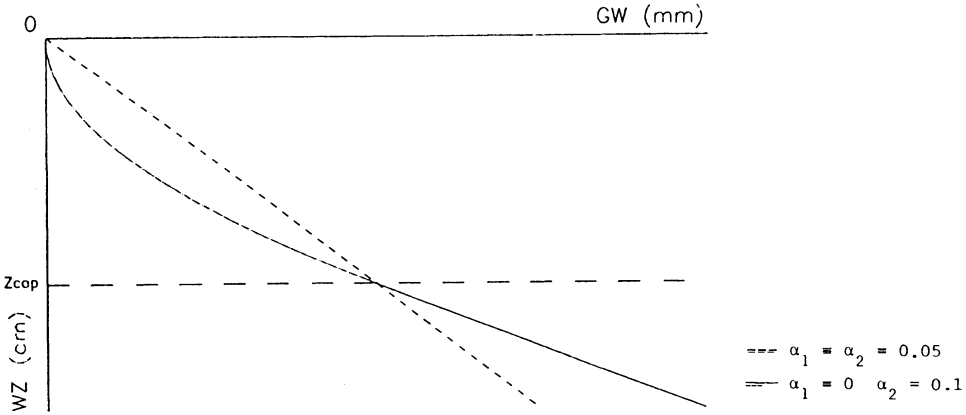


Fig. 2. Schematic presentation of the volume of free ground pores (GW) dependent on the depth of the water table (WZ).

where

A_2 – the coefficient characterizing the pipe drainage intensity,
WZ_b , WZ_e – the depth of groundwater level at the beginning and the end of the day, cm.

The coefficient A_2 has a physical substantiation, which is estimated as follows

$$A_2 \cong \frac{A\,k}{E^2} \tag{16}$$

where

k – hydraulic conductivity, m/day,
E – distance between drains, m.

If drains have been placed on an impermeable layer, the coefficient is $A = 4$. Usually the layer below drains is permeable and so $A > 4$.

The amount of the groundwater runoff is computed as follows

$$Q_3 = A_3(PZ-WZ_e) \tag{17}$$

where

A_3 – the coefficient characterizing the intensity of the groundwater runoff.

The depth of the water table at the end of the day WZ_e and the associated values GW_e , Q_1 , Q_2 , Q_3 are estimated by an iteration, while Q_1 is calculated as follows

$$Q_1 = \begin{cases} 0 & \text{if} \quad GW_e \geq 0 \\ -GW_e & \text{if} \quad GW_e < 0 \quad \text{and} \quad WZ_e = 0 \end{cases} \tag{18}$$

The total runoff of the catchment is

$$Q = Q_1 + Q_2 + Q_3 \tag{19}$$

Thus the calculation of the water balance in the capillary fringe and the groundwater zone utilizes seven parameters: Z_{cap} , α_1 , α_2 , A_2 , A_3 , DZ and PZ.

Input Data and Results

Input data for the model include the daily mean air temperature and value of vapour pressure deficit, daily totals of preciptation as well as reports of snow cover. Daily groundwater level, its duration (%), surface, drainage and groundwater runoff are obtained as result. In addition, all the water balance elements are calculated for each year: the summary evaporation (mm), the precipitation (mm), the runoff (mm), the changes of the water storage in the active soil zone and in the capillary and groundwater zone (mm).

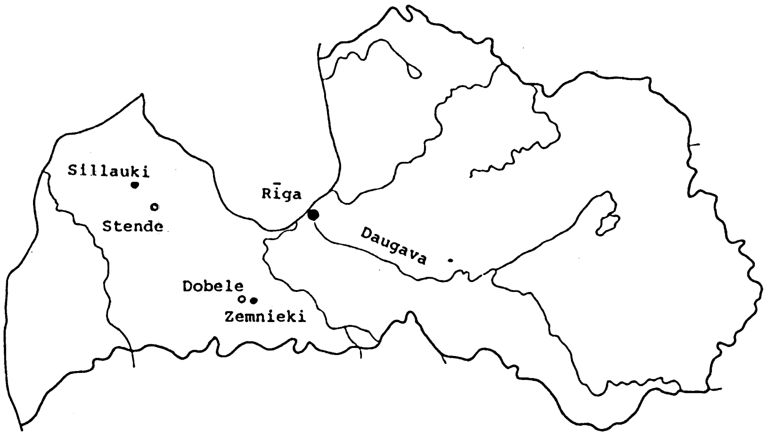


Fig. 3. Location of meteorological stations (○) and experimental drainage basins (●).

Model Calibration and Sensitivity Analysis

As seen from the preceding discussion, the model METUL is characterized by 15 parameters. Some of these parameters are physically based and can be stated independently of the observations of groundwater levels and runoff. The height of a capillary fringe Z_{cap} and an effective pipe drain depth DZ can also be determined independently during the observations. The estimations of other parameters require a certain amount of observation values as well as intermediate results of the modelling.

The calibration of the model at the experimental drainage area Sillauki and Stende meteorological station is given as an example. Their locations are shown in Fig. 3. The distance between the meteorological station and the experimental drainage area is 18 km. The observations of the hydrological year 1990/1991 (September to August) were utilized for the calibration of the model. The Sillauki experimental drainage basin is characteristic with flat territories and homogeneous clay soil. The drains in the experimental basin have been built at varying depths and with varying distances between the drains. The observations were conducted at 40 drain systems, and the reports from the drain systems Nos. 3, 5, 6, 8, and 14 were utilized in our studies. The drains were built at a depth of 120 cm with the distances between the drains ranging from 6 m to 20 m. The drain systems Nos. 3, 6 and 14 had distances of 10 m between the drains.

The drain system No. 3 at Sillauki was analyzed according to the corresponding model parameters as follows. Based on the soil and drain data from the experimental basin, the height of capillary fringe was assumed to be $Z_{cap} = 200$ cm, and the effective drain depth was assumed to be $DZ = 90$ cm. The experiments involving hydrological drainage systems in Latvia (Skinkis 1981 and 1986) have demonstrated that in heavy soils, the early level of drain operation between the drains is at least 30 cm above the drains. For this reason, an effective drain depth of 90 cm was assumed for the drainage built at the depth of 120 cm.

The constants which characterize the accumulation and the ablation of the snow cover were determined based on the observations at Stende meteorological station in the 1990/1991 hydrological year. These were as follows: $T_1 = +0.5$ °C, $T_2 = -1.0$ °C, $K_l = 0.20$, $C_{melt} = 2.3$ and $C_1 = 0.02$. Based on the experience obtained in designing an irrigation regime in Latvia (Ziverts and Sauka 1976), the value of the coefficient characterizing summary evaporation was assumed to be $K_u = 0.55$, and the water capacity in the active soil zone was assumed to be $W_{max} = 30$ mm. The lowest coefficient value for evaporation in a relatively dry soil was assumed $K_l = 0.20$. The parameters characterizing the groundwater runoff intensity were chosen corresponding to the average conditions in drained areas in Latvia: the depth of the piezometric head $PZ = 200$ cm (approximately corresponding to the average depth of main ditches) and $A_3 = 0.4$.

Table 1 – Water balance elements at the Stende meteorological station calculated through the mathematical model METUL and drainage runoff observed at the Sillauki drainage system No. 3

	Quantities calculated through observations at the Stende meteorological station, mm.							
Hydrological year	Precipitation	Evaporation	Water storage fluctuation in soil	Surface runoff	Groundwater runoff	Drainage runoff	Summary runoff	Drainage runoff observed in drain system 3
1	2	3	4	5	6	7	8	9
1975/76	482	360	−37	0	23	136	159	–
1976/77	593	347	+44	5	27	170	202	–
1977/78	886	368	+86	42	38	352	432	–
1978/79	716	354	−37	31	37	331	399	–
1979/80	754	392	+36	6	40	280	326	–
1980/81	859	390	−13	51	41	390	482	–
1981/82	658	372	−105	20	35	336	391	514
1982/83	592	415	−12	0	29	160	189	225
1983/84	727	394	+84	0	32	217	249	230
1984/85	744	375	+9	8	39	313	360	329
1985/86	641	369	−7	0	35	244	279	314
1986/87	627	361	+19	2	37	208	247	251
1987/88	737	432	−7	53	38	221	312	278
1988/89	694	434	−25	15	33	237	285	282
1989/90	808	433	0	26	35	314	375	252
1990/91	816	394	−26	12	41	395	448	393

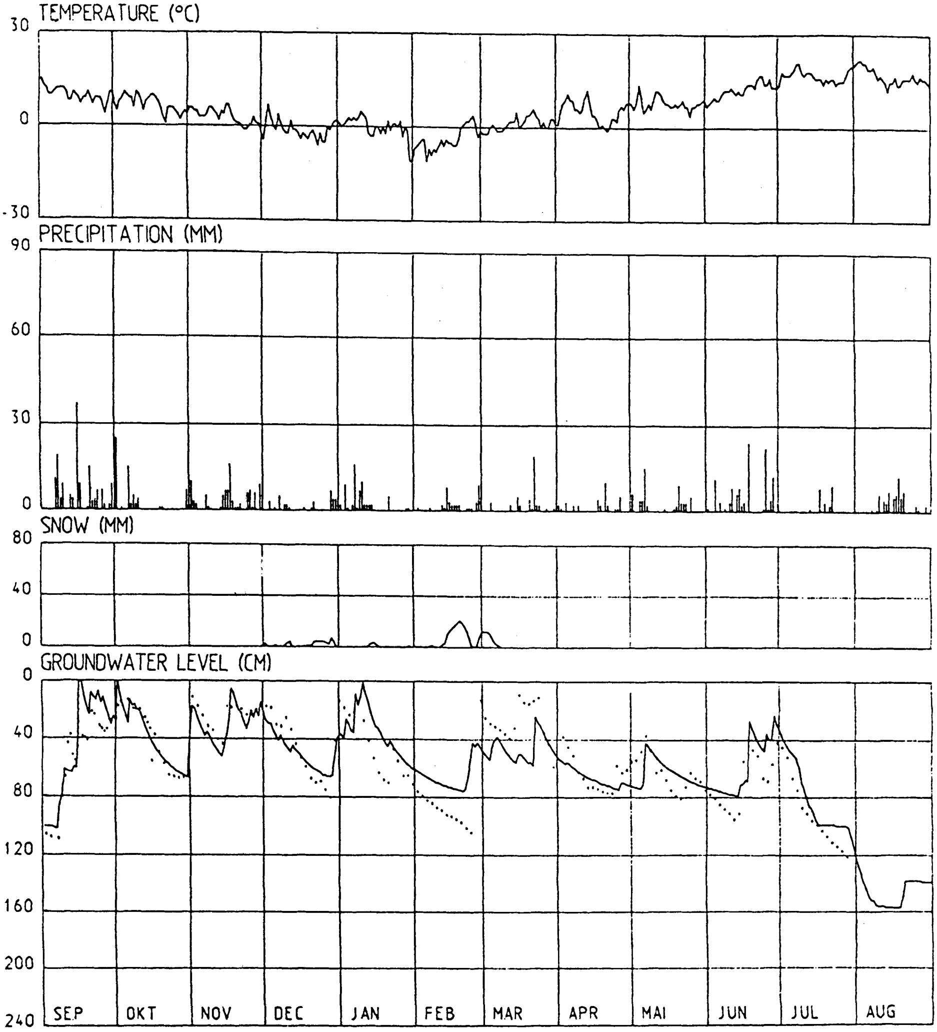


Fig. 4. Simulation of groundwater level for the calibration hydrological year 1990/1991 (dots – observed levels).

The determination of the rest of the parameters α_1, α_2 and A_2 was based on the observations of groundwater level in drain system No. 3. Several values of these parameters were chosen, and the corresponding groundwater level variations obtained by running of the model are demonstrated by a chronological diagram. A visual comparison of the computed groundwater level with the observed groundwater level in drainage system No. 3 in the chronological diagram (Fig. 4) demonstrates the following parameter values: $A_2 = 0.0062$, $\alpha_1 = 0.05$ and $\alpha_2 = 0.05$. As evident from Table 1, the drain runoff for the hydrological year 1990/1991 as

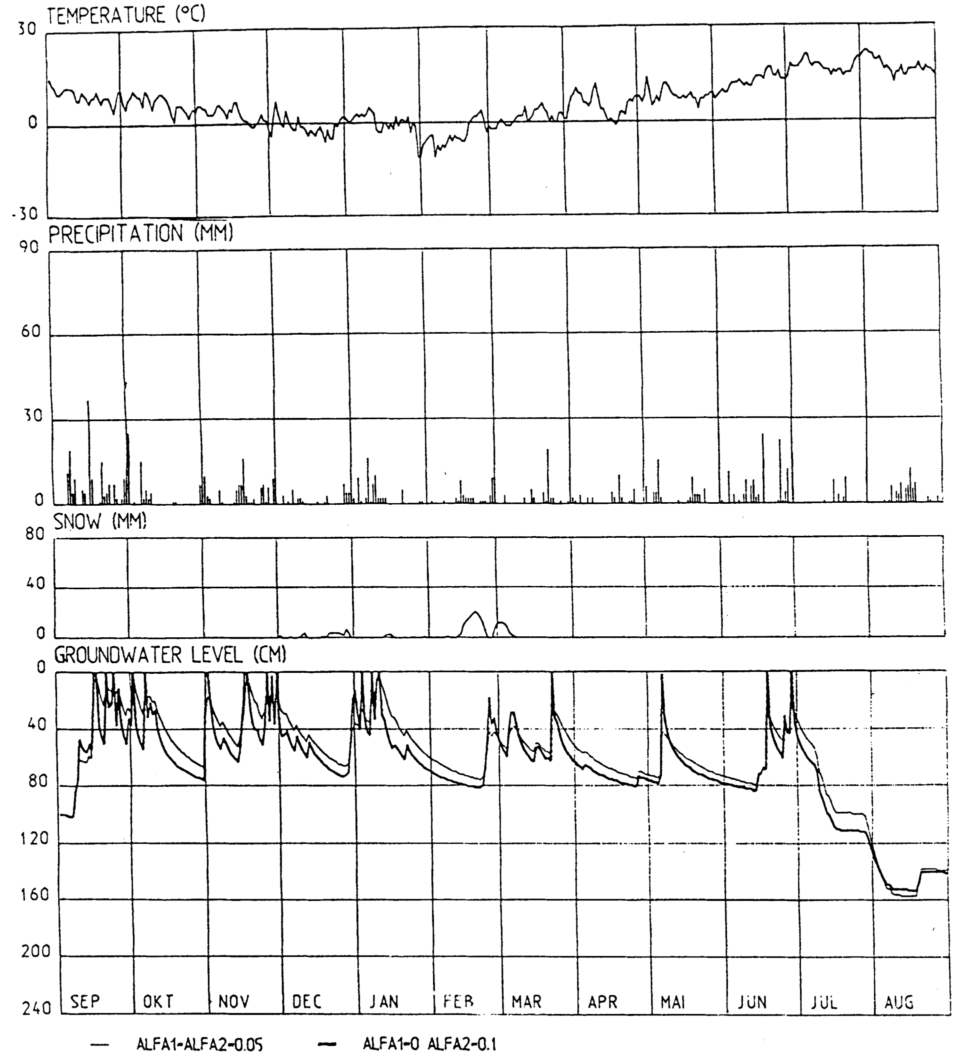


Fig. 5. Sensitivity analysis for the calibration, hydrological year 1990/1991 with variable effective porosity.

estimated by the cited parameters of the model corresponds quite well to the drain runoff observed in the Sillauki drain system No. 3.

Several examples to illustrate the influence of several parameters on the results are given below. Fig. 5 shows the groundwater level fluctuation schedule, if the effective porosity of the capillary fringe is variable ($\alpha_1 = 0$ and $\alpha_2 = 0.10$). The comparison in Fig. 5 demonstrates, that the fluctuation with variable effective porosity is more sudden near to the ground surface and smoother in the deeper

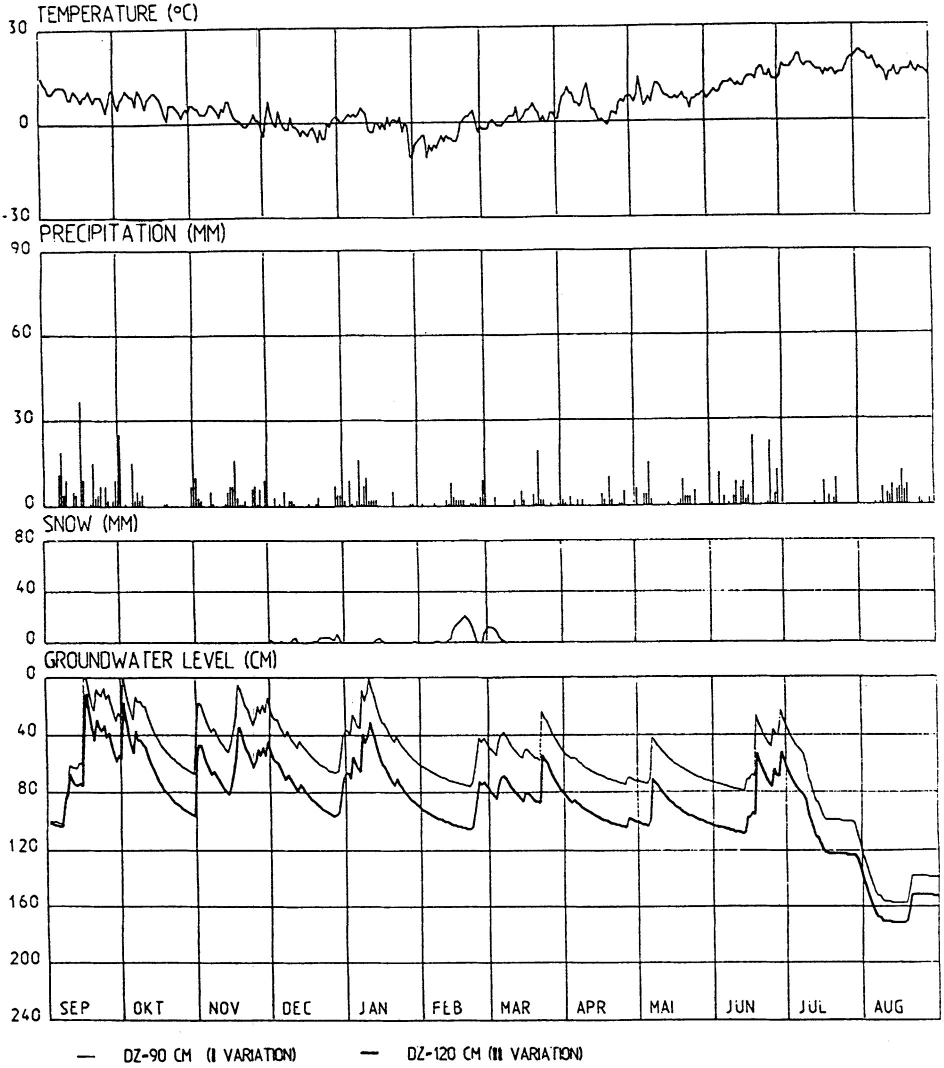


Fig. 6. Sensitivity analysis for the calibration, hydrological year 1990/1991, effective drain depth $DZ = 90$ cm and $DZ = 120$ cm.

layer. Although it was logically assumed that the effective porosity is lower at the water table, where almost all pores should be filled, the examples demonstrate that the model with variable effective porosity has no advantage.

Fig. 6 illustrates how computed groundwater level is influenced by the effective depth of the drains. Variation I utilizes the cited constants for the model, and the results thus obtained are plotted in Fig. 4. Variation II utilizes an effective drain depth more than 30 cm greater, *i.e.* $DZ = 120$ cm.

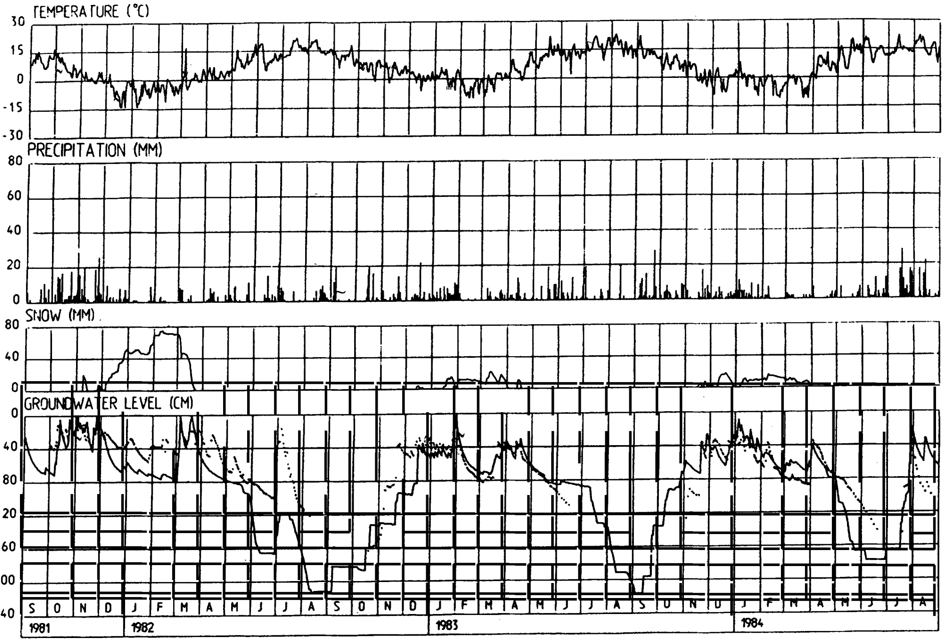


Fig. 7. Simulation of groundwater level for the independent period from September 1981 until August 1984 at Sillauki (dots – observed levels).

Examination of the Model During an Independent Period of Observation

The testing of the model was performed at two meteorological stations and a nearby experimental drainage area (Fig. 3). Comparison of simulated and observed groundwater level at Sillauki experimental drain system No. 3 over a period of nine hydrological years is demonstrated in Figs. 7, 8, 9. Calculations are done on the above mentioned parameters, which are calibrated on the observations in 1990/1991 hydrological year.

As seen in Table 1, the simulated drainage runoff, as well as the summary runoff, correlate satisfactorily with the observed drainage runoff in the Sillauki experimental area. The relatively higher drainage runoff observed in the first hydrological year (1981/1982) could be explained by the initial loss of soil water storage in the first year after land reclamation.

The correlation coefficient between computed and observed annual drainage runoff at Stende-Sillauki is estimated as 0.724. The values of the correlation coefficient of the simulation of groundwater levels at Sillauki are shown in Table 2.

The Zemnieki experimental drainage area is located at a distance of 7 km from Dobele meteorological station. The calculations done by means of the mathematical model METUL were performed over six hydrological years when the ground-

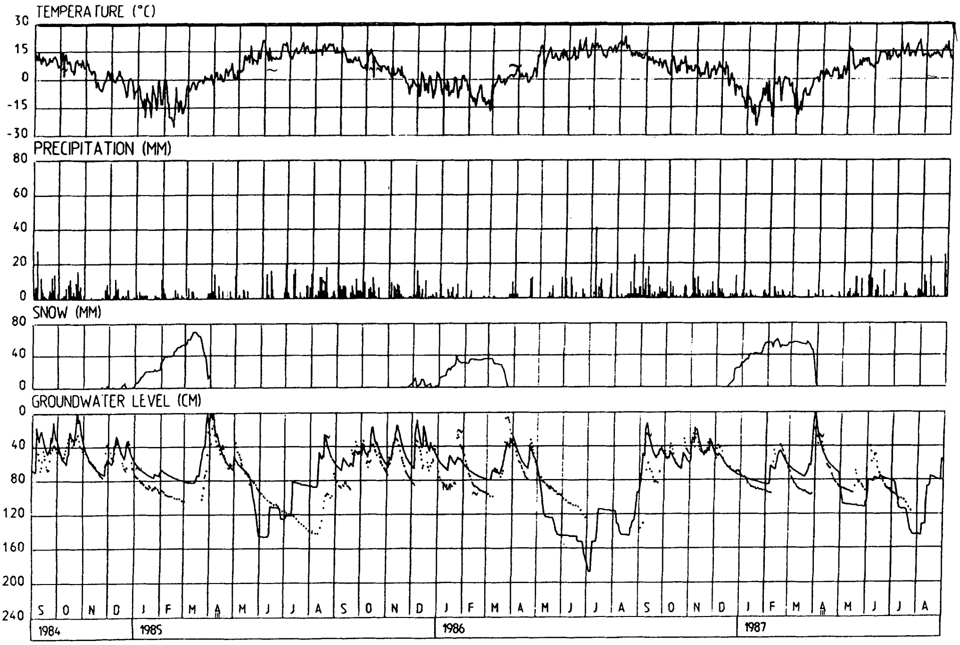


Fig. 8. Simulation of groundwater level for the independent period from September 1984 until August 1987 at Sillauki (dots – observed levels).

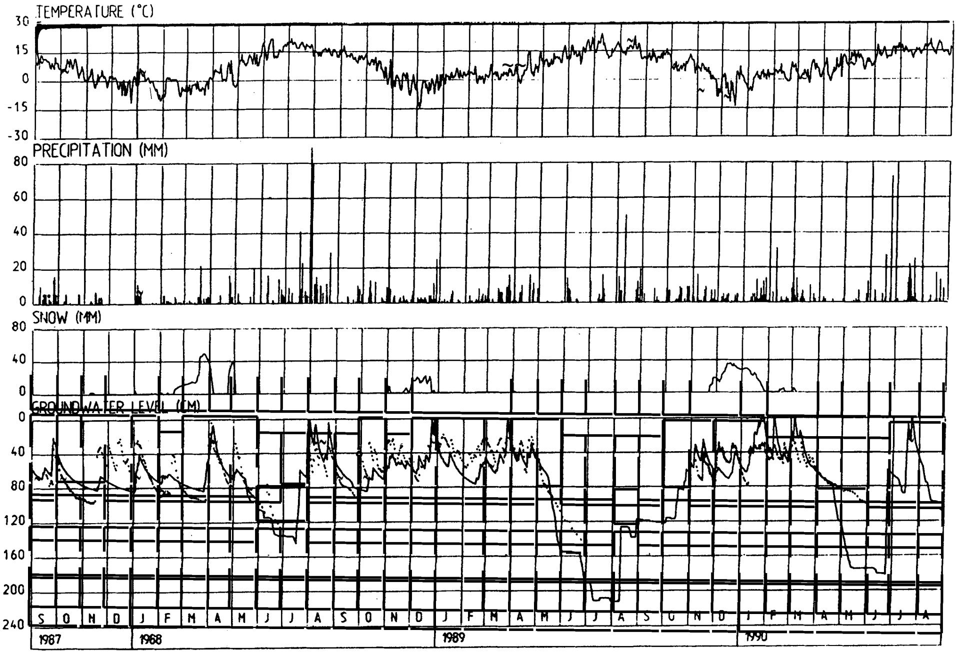


Fig. 9. Simulation of groundwater level for the independent period from September 1987 until August 1990 at Sillauki (dots – observed levels).

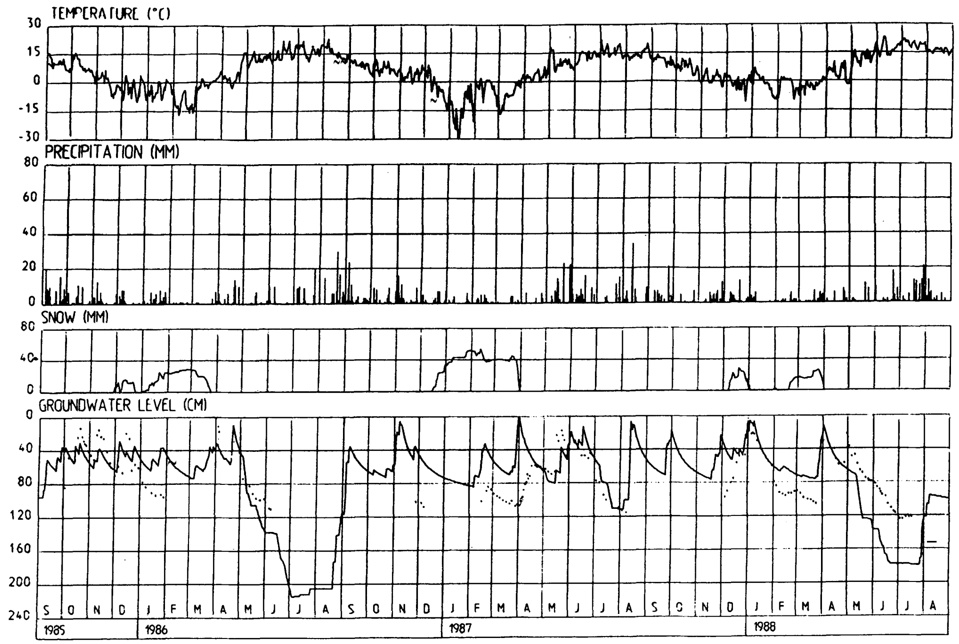


Fig. 10. Simulation of groundwater level for the independent period from September 1985 until August 1988 at Zemnieki (dots – observed levels).

Fig. 11. Simulation of groundwater level for the independent period from September 1988 until August 1991 at Zemnieki (dots – observed levels).

Table 2 – Results of the simulation of groundwater levels expressed as a correlation coefficient at the experimental drainage area Sillauki

Hydrological year	Correlation coefficient
1981/82	0.864
1982/83	0.794
1983/84	0.826
1984/85	0.706
1985/86	0.756
1986/87	0.786
1987/88	0.782
1988/89	0.809
1989/90	0.791
Total for the period of 9 independent years	0.710
1990/91	0.824
Total	0.716

water level was observed at the experimental area. All of the model parameters except A_2, which characterizes the drainage intensity, were assumed to be the same as at Stende-Sillauki. The parameter A_2 at Dobele-Zemnieki was determined through a gradual approach so that the modelled duration (%) of the groundwater level at a depth of 0.5 m would be the same as at Stende-Sillauki. In this way the A_2 parameter is obtained 0.004. The comparison between computed groundwater level using the data from Dobele meteorological station and observed in auger-hole No. 3 at the Zemnieki experimental area is demonstrated in Figs. 10 and 11.

As seen from the figures there is sufficient correlation between the groundwater levels: measured and simulated during the independent periods by the mathematical model METUL. Comparison is given for computed and observed groundwater levels of well-drained fixed spots in Figs. 10 and 11, and it follows, that in the experimental drainage area Zemnieki the water regime is controlled well enough.

Application of the METUL Model for Evaluation of a Soil Water Regime

The description above leads to the following conclusion for evaluating the shallow groundwater regime. Based on long-term groundwater level observations in auger-holes in more than 200 experimental drain systems (Skinkis 1986) and meteorological observations in meteorological stations, the model METUL could be used to calculate the groundwater fluctuations at a standard spot the drainage grade of which could be described as "good", "satisfactory" or "unsatisfactory". These calculations can be performed for the entire meteorological observation period including the final current day. (Utilizing the data from the next week, which has certain meteorological forecasts, there is a possibility to obtain the groundwater level forecasts). In practice, the calculations for Latvia's meteorological stations have been done for the last 17 years since 1975.

In the areas where groundwater regimes must be determined, auger-holes of depths 1.0 to 1.2 m are drilled by using an auger, preferably Edelman type – Soil Survey Institute of Wageningen in the Netherlands. The level observations are established in the auger-holes during characteristic moisture periods, preferably in spring immediately after the melting of snow. Comparison of observed groundwater levels in a specific place with those calculated for the standard spot gives an objective drainage grade for the spot.

The mathematical model METUL also provides the possibility to use the cited short-term observations to construct duration curves for each auger-hole which correspond to a long-term meteorological observation period, because on each day the duration of stay (%) of groundwater level at the respective height and higher is calculated.

Discussion and Conclusions

The results achieved in Latvia by using the mathematical model METUL demonstrate the successful development of a simple conceptual hydrological model which makes it possible to simulate water table fluctuations at various conditions of soil drainage, utilizing daily meteorological observations (mean air temperature, mean air vapour pressure deficit, total precipitation and reports of snow cover appearance and disappearance). Even though the model is fundamentally conceptual, some model parameters characterizing drainage intensity and ground properties have a physical basis. These parameters (drain effective depth, height of capillary fringe) can be determined directly, without calibration. However, the majority of parameters are determined through calibration utilizing groundwater levels and runoff observations in experimental catchments. The work proves that the observations of a single hydrological year make it possible to achieve satisfactory model parameters, which is confirmed by the examinations during an independent observation period. Moreover, the generalization of the parameters and their transference from one meteorological station to another is justified for the examination of a groundwater regime. Utilizing a linear variable effective porosity depending on the groundwater depth did not give better results in comparison with constant effective porosity.

The mathematical model METUL is recommended for an operative and objective evaluation of a soil and the hydrological conditions of agricultural lands. As the mathematical model METUL is in some aspects similar to the model HBV (Bergström), it can be assumed that the mathematical model METUL could also be successfully used for the calculation of runoff in small drainage basins which often lack direct observations of surface, drainage and groundwater runoff.

Acknowledgements

The model METUL was developed during a three-year period from 1989. We thank all our colleagues who assisted in this work. We are grateful to the firm "Meliorprojekts" which offered the opportunity to work on the firm's computers, to the Latvia Hydrometeorological Department for the meteorological data, and to the institute "Polimers in Agriculture and Water Management" for the possibility to make use of the observation data collected at the experimental drainage area at Sillauki.

Our special thanks is to prof. S. Bergström, who promoted the creation of this paper.

List of the model parameters

Parameters	Methods used in estimation of parameters.
	Snow Routine
T_1 T_2 K_s	According to the observations and calculations of snow cover in Latvia, it is assumed that T_1 =+0.5 C°, T_2 =−1.0 C°, K_s =0.2.
C_{melt} C_1	A) For the estimation of the groundwater level regime, calculations are performed based on the occurrence and disappearance of snow cover observed. B) For the forecasts of the groundwater level and runoff, parameters are assumed as follows: Western part of Latvia C_{melt} =3.0, C_1 =0.005 Eastern part of Latvia C_{melt} =1.5, C_1 =0.02
	Active Soil Zone Moisture Routine
$W_{\max}$ K_u K_l	Based on the expierence obtained in estimating the irrigation regime of agricultural lands in Latvia; $W_{\max}$ =30 mm, K_u =0.55, K_l =0.20.
Z_{cap}	Height of capillary fringe is assumed according to the properties of the ground in experimental drainage areas, Z_{cap} =200 cm.
	Groundwater and Capillary Water Zone
DZ	In the experimental drainage area DZ is assumed as to the effective depth of drains.
A_2 A_3 PZ α_1 α_2	Calibrated using observed groundwater levels, drainage and total runoff measured could also be applied for the calibration.

Notation

A – Empirical coefficient characterizing media, where pipe drains have been built.
A_2 – Coefficient characterizing pipe drainage intensity.
A_3 – Coefficient characterizing intensity of groundwater runoff.
C_1 – Empirical coefficient, which characterize water contribution from snow melt, as dependent on snow pack.
C_{melt} – Empirical coefficient, which characterize intensity of snow melt, as dependent on daily mean air temperature.
CAP – Evaporation from groundwater surface, mm/day.
DEF – Daily mean value of vapour pressure deficit, hPa.
DZ – Effective depth of drains, cm.
E – Distance between drains, m.
EA – Evaporation from active soil zone, mm/day.
ES – Evaporation from snow, mm/day.
GW_b – Capacity of free ground pores above groundwater level at the beginning of the day, mm.
GW_e – Capacity of free ground pores above groundwater level at the end of the day, mm.
k – Hydraulic conductivity, m/day.
K_s – Evaporation coefficient from snow.
K_l – Lower limit of the evaporation coefficient.
K_u – Upper limit of the evaporation coefficient.
P – Daily total amount of precipitation, mm.
PZ – Depth of piezometric pressure level, cm.
Q – Total runoff from the cathment, mm.
Q_1 – Surface runoff, mm.
Q_2 – Pipe drainage runoff, mm.
Q_3 – Groundwater runoff, mm.
RCH – Recharge of groundwater, mm.
RS – Contribution from rain and snow melt, mm.
SS_b – Water content of snow at the beginning of the day, mm.
SS_e – Water content of snow at the end of the day, mm.
SMS_b – Water storage of active soil zone at the beginning of the day, mm.
SMS_e – Water storage of active soil zone at the end of the day, mm.
T – Daily mean air temperature, °C.
T_1 – Daily mean air temperature below which snow accumulation begins, °C.
T_2 – Daily mean air temperature above which snow ablation begins, °C.
W_{melt} – Daily total contribution from snow melt, mm.
W_{max} – Maximum water storage in active soil zone, mm.
WZ_b – Depth of groundwater level at the beginning of the day, cm.
WZ_e – Depth of groundwater level at the end of the day, cm.
Z – Depth from ground surface, cm.
Z_{cap} – Height of capillary fringe, cm.
α_1 – Effective porosity at the water table.
α_2 – Effective porosity at the top of the capillary fringe.

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