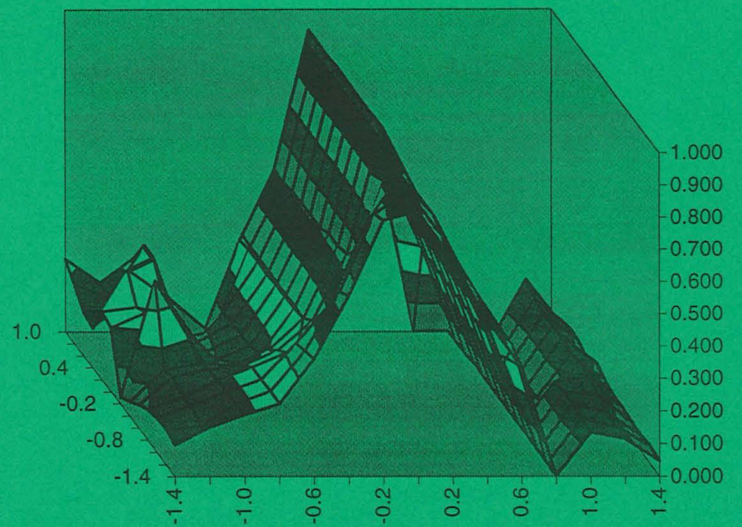
The effect of soil hydraulic properties on ground water fluctuations in a heavy clay soil

Measurements and simulations

Mladen Vukovic



Examensarbete
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Institutionen för markvetenskap
Avdelningen för lantbrukets hydroteknik

Swedish University of Agricultural Sciences
Department of Soil Sciences
Division of Agricultural Hydrotechnics

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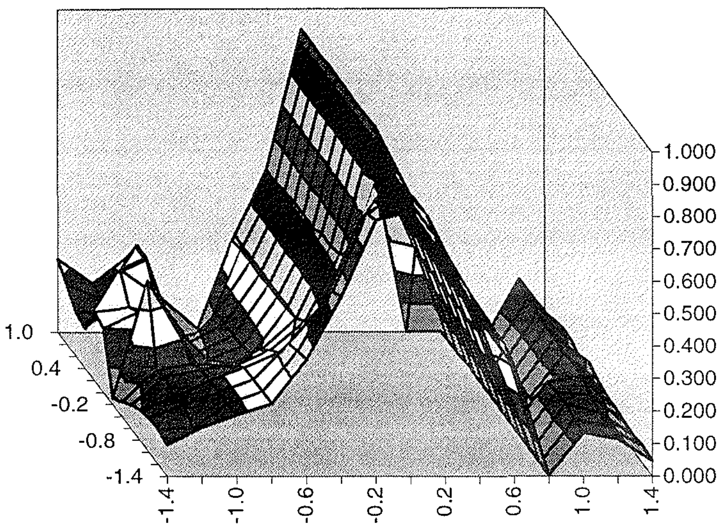

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ABSTRACT

THE EFFECT OF SOIL HYDRAULIC PROPERTIES ON GROUND WATER FLUCTUATIONS IN A HEAVY CLAY SOIL, Measurements and simulations.

Mladen Vukovic, Department of Soil Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden.

A detailed and intensive study was made within the Ultuna watershed during the months of November 1996 through February 1997. Groundwater levels and soil temperatures were measured as well as the total watershed discharge. A one-dimensional mathematical model was used to simulate the hydrological conditions in the field and study the effects of changes of soil physical parameters on simulated ground water levels (sensitivity analysis).

A comparison was made between model calculations and field measurements to establish which model and soil parameters most influence ground water simulations. A comparison was also made of simulated and measured discharge to determine the relationship of one soil as compared to an expected range of spatial heterogeneity within the whole watershed.

More extensive measured climate data was required for reliable winter simulations, especially measured longwave radiation and snow cover. Without such data the model simulated soil temperatures that tended to be lower than measured, especially during periods of snow.

The changing of parameter values influenced the behaviour and movement of ground water. Changes in the saturated matrix conductivity (influencing sorption properties) of a soil had little or no effect on the results. The partitioning of the infiltrating water into bypass flow or saturated matrix flow induced no great changes in the simulated ground water level. This was explained by the fact that the infiltrating water caused changes in the saturated zone with the same delay independent of the partitioning of velocities in different pore sizes. The only observed difference was in the response time of the ground water level to infiltration, while the overall shape of the curve remained the same. Changes in the total saturated hydraulic conductivity, however, strongly affected simulated ground water levels, not only in the overall shape of the curve, but also in its response time and mean change of depth.

Simulated discharge was three times greater than measured. This may be explained both by the watersheds topography and water storage capacities. The watersheds areal mean storage capacity may be larger than for the specific investigation plot. Measured data also implied that a certain amount of water was lost below the drainage system and this was not measurable at the discharge station.

REFERAT

EFFEKTER AV MARKENS HYDRAULISKA EGENSKAPER PÅ GRUNDVATTEN-FLUKTUATIONER I STYVA LEROR, Mätningar och simulationer.

Mladen Vukovic, Institutionen för markvetenskap, Sveriges Lantbruksuniversitet, Uppsala, Sverige.

En detaljerad och intensiv undersökning gjordes på Ultunas avrinningsområde från November 1996 till Februari 1997. Grundvattenståndet, marktemperaturerna samt den totala avrinningen uppmättes under denna period. En matematisk modell användes för att simulera de hydrauliska förhållandena i fält, samt för att testa effekter av förändringar i markfysikaliska egenskaper på simulerade grundvattennivåer (sensitivitets analys).

För att bestämma vilka modell- och markparametrar som mest påverkar grundvattennivån jämfördes simulerade och uppmätta värden. En jämförelse av uppmätt och simulerad avrinning gjordes för att bestämma förhållandet mellan en punkt och hela avrinningsområdet.

Det krävdes många typer av uppmätta klimatdata för pålitliga vintersimuleringar, speciellt uppmätt långvågsstrålning och snödjup. Temperatursimuleringar utan sådana data gav lägre värden än de uppmätta, speciellt när marken var täckt av snö.

Ändringar av den mättade matrixkonduktiviteten, som påverkar markens sorption, hade liten eller ingen effekt på resultatet. Uppdelningen av det infiltrerande vattnet mellan makroporflöde och mättad matrixflöde hade ingen större påverkan på det simulerade grundvattnet. Detta kan förklaras genom att det infiltrerande vattnet påverkade den mättade zonen med samma tidsfördröjning oberoende av dess uppdelning mellan olika hastigheter och porstorlekar. Den enda skillnaden som kunde visas var grundvattnets responstid till infiltrationen men detta ändrade inte kurvans utseende i stort. Ändringar i den mättade konduktiviteten hade stor påverkan på grundvattensimuleringarna när det gällde både responstid och hur kurvan såg ut.

Den simulerade avrinningen var tre gånger större än den uppmätta. Detta kan förklaras genom avrinningområdets topografi och vattenförrådskapacitet. Avrinningområdets vattenförrådskapacitet i medeltal kan vara större än det som råder i en särskild punkt. Uppmätta data visar att en viss mängd vatten förloras under dränneringssystemet och detta kan inte mätas av avrinningsstationen.

INTRODUCTION

The study of ground water has its importance in crop production and the maintaining of the qualitative and quantitative needs for human consumption. The behaviour and movement of ground water is influenced by many factors: climate, type of soil, topography and geology. Heavy soils have high clay contents and low hydraulic conductivities. The behaviour of ground water is especially important in such a medium due to possible slow response times. On the other hand these clay soils have low effective porosities which may cause a rapid response. The occurrence of frost during winter is a limiting factor to ground water formation as well as the fact that it induces high rates of surface runoff.

The occurrence of subsurface water can be divided into zones of unsaturation and saturation. The unsaturated zone which has air and water in its pore system is subdivided into the soil water zone, the intermediate vadose zone, and the capillary zone. The saturated zone extends from the upper surface of saturation down to the impermeable rock. In the absence of overlying impermeable strata, the water table forms the upper surface of the zone of saturation. This is defined as the surface of atmospheric pressure. Actually, saturation extends slightly above the water table due to capillary attraction, however, water is held here at less than atmospheric pressure (Todd, 1980). The basis of this paper is the linkage between the zones of unsaturation and saturation.

A problem that immediately arises is soil spatial heterogeneity. In the Swedish soil database, there exists thirteen clay soils in the Ultuna area where the soil physical properties were measured both on- site and in the laboratory. An interesting question that arises is how does one soil compare to the whole area as far as discharge rates are concerned?

Simulation models may be useful tools to study ground water response. By changing model parameters a fit may be obtained between the measured and simulated data. Once this is achieved a study of the influence of different soil properties on ground water levels can be performed. This is called a sensitivity analysis (Miller, 1974). Interesting questions are: How does the model calculate water loss and how important is it in this case? How does the model calculate soil temperatures and how are the temperature simulations related to the hydrological conditions?

The purpose of this paper was to clarify which soil properties most influence ground water fluctuations on heavy soils. To achieve this, a numerical model was used to solve the physical equations for soil water flows with realistic boundary conditions and soil properties. In order to test the model, measured data is also necessary. A detailed field investigation was performed to test the model and the sensitivity for different assumptions.

MATERIALS AND METHODS

The site

This experiment was conducted in the Ultuna watershed which is drained by a system of subsurface pipes. The location and soil variability of the Ultuna watershed are shown in Fig. 1.

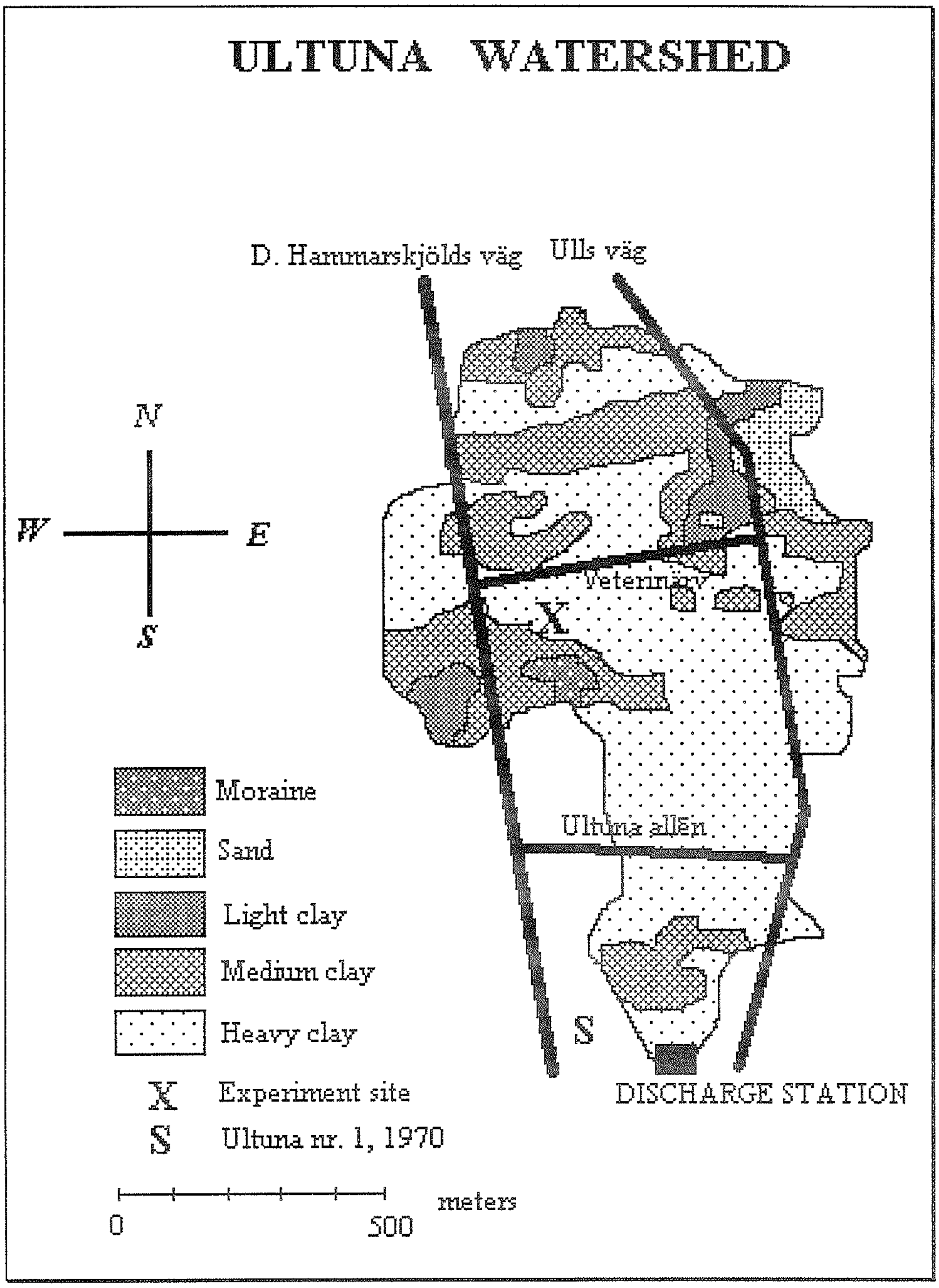

Fig. 1. Map of the Ultuna watershed.

The experimental plot

The experiment consisted of measuring the ground water levels and soil temperatures at the site located approximately 100 m east of D. Hammarskjölds väg and 60 m south of Veterinär väg (see Fig. 1). To measure the ground water levels, six holes were drilled in a south-easterly direction which is at right angles to the drainage pipe which stretches in a north-easterly direction. In these holes, plastic tubes with a diameter of 4 cm and a length of 2-4 m were placed. Each tube was closed at the bottom and eight 1 mm holes were drilled at 10 cm intervals from the bottom up. A filter cloth was wrapped around each tube to prevent soil particles entering. A pressure transducer was placed in each tube and connected to a Campbell data logger. The tubes were placed in a transect crossing the drainage pipe (Fig. 2). The pressure transducers measured the pressure caused by the water column formed inside the tube by soil water coming in through the holes in the tube. The drainage pipes lie at a depth of 1 m below the surface and are spaced 20 m apart. The difference between the levels of the six tubes is explained by the fact that the water table is lowered to the depth of the drain pipe in its immediate vicinity and slopes upward and outward until it intersects the drawdown curves of the adjacent drains (Donnan & Schwab, 1974). It should be noted that all figures of measured ground water levels are at a depth below a reference horizontal plane which lies at the soil surface directly above the drainage pipe.

Ground water levels were measured every hour for the period from the 12th of November 1996 to the 21st of February 1997. It should also be noted that there was a one month long interruption with the measurements of tube 6 from the 15th of December.

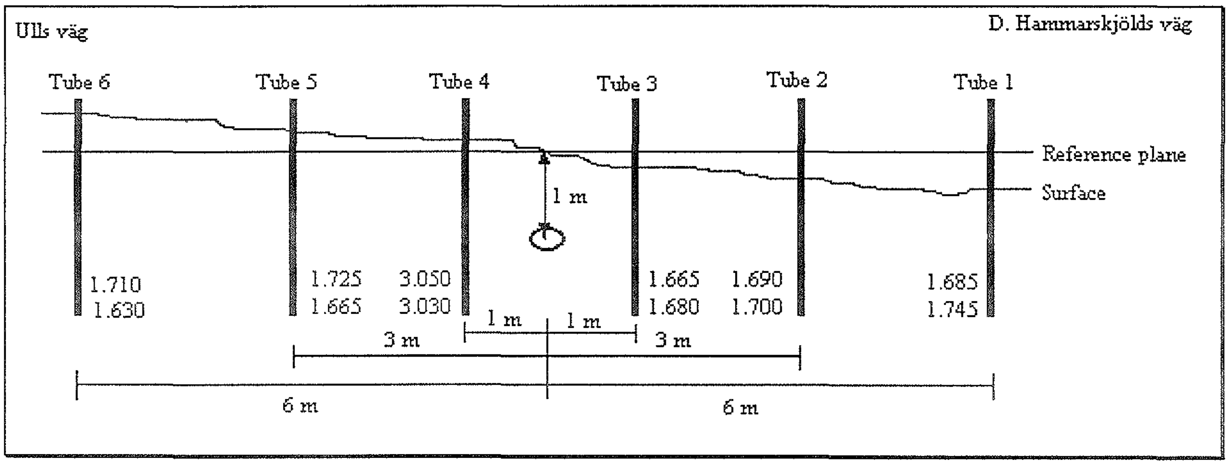

Fig. 2. Placement of the pressure transducers in the field. The upper figures represent the depth below the surface, while the lower represent the depth below the reference plane.

The soil temperatures were measured by placing six thermistors at a depth of 1, 2, 5, 10, 20 and 40 cm from the soil surface (Fig. 3), which were also connected to a Campbell data logger. The temperature was measured 4 m north of tube 5. The temperatures were measured every half hour from the 16th of November 1996 to the 21st of February 1997.

The climate data, which consisted of daily mean values for air temperature, relative humidity, wind speed and global radiation for this period, were obtained from the meteorological station at the Department of Soil Sciences. Daily values of precipitation were obtained from the meteorological station at Ultuna. No snow measurements were available.

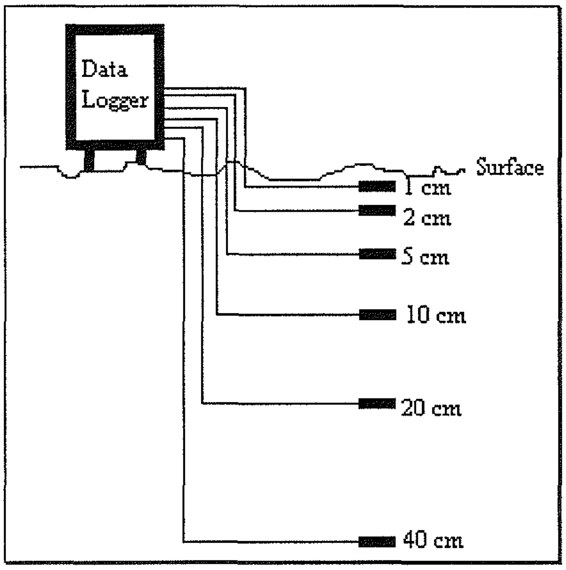

Fig. 3. Placement of the thermistors.

The discharge rates were measured for the whole watershed which has an area of 80 ha and all results are presented as equivalent water depths in mm (Djodjic, 1997).

Soil description

Information on thirteen soil profiles and their physical characteristics in the Ultuna area is presented in "Studier av markprofiler i svenska åkerjordar" (Wiklert et al, 1983). Sampling of these soils was conducted from 1955 through 1970 and they are spread out over an area covering the Ultuna watershed and a 500 m radius around it. These are all clay soils that vary in the clay content of the topsoil (from 12 to 51%) and the subsoil (from 28 to 73%). Due to the textural differences of these soils there is also a wide range of hydraulic conductivities.

Based on preliminary simulations of all Ultuna soils, Ultuna NR. 1, 1970 was selected as the most suitable reference soil for this investigation. The location where samples for this soil were taken is shown in Fig. 1. The geology of the site is post- glacial clay over glacial clay. A complete description of this soil can be found in Wiklert et al (1983). Figures of the soils most important physical properties are shown in Fig. 4 - 7. As can be seen from Fig. 4. the pF curve deviates from the other horizons in the uppermost layers. By looking at the textural data (Fig. 7) and applying the Soil Survey Staff soil texture triangle (Donnan & Schwab, 1974), we find that the 0 - 20 cm layer has a silty clay loam texture (40% clay), the 20 - 40 cm layer has a silty clay texture (45% clay), while the rest of the profile has a clay texture (> 60% clay). This textural difference affects both the water retention curve and the hydraulic conductivity of the topsoil.

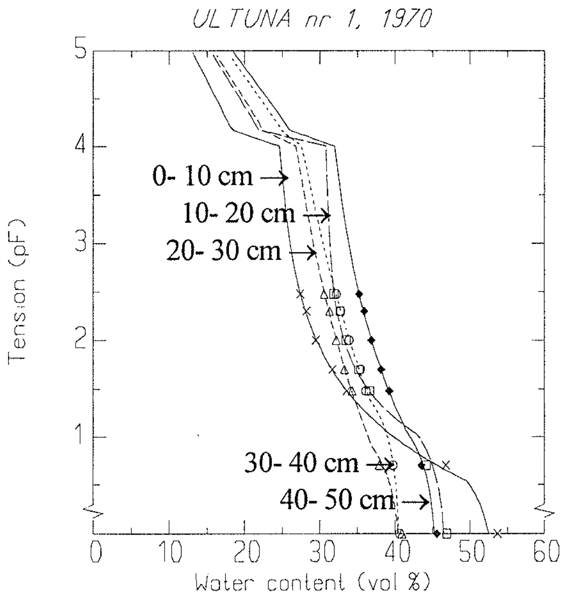

Fig. 4. pF-curve including measured points for five soil layers.

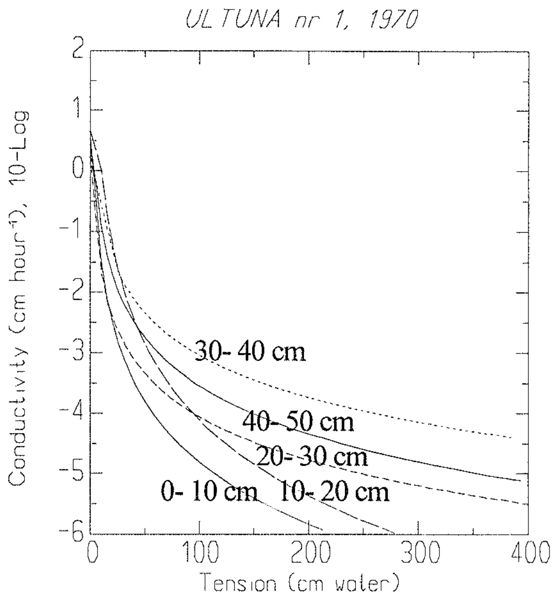

Fig. 5. Unsaturated conductivity f (water tension) for five soil layers.

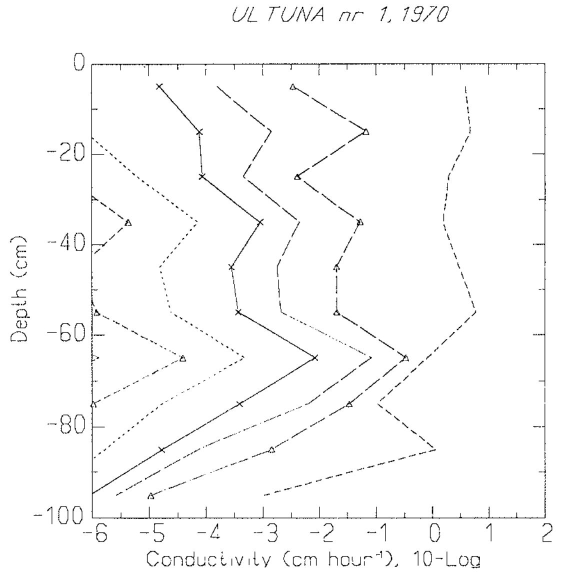

Fig. 6. Unsaturated conductivity at different tensions. From left to right at tensions of: 1000 cm, 300 cm, 15 000 cm, 50 cm, 20 cm and 0 cm.

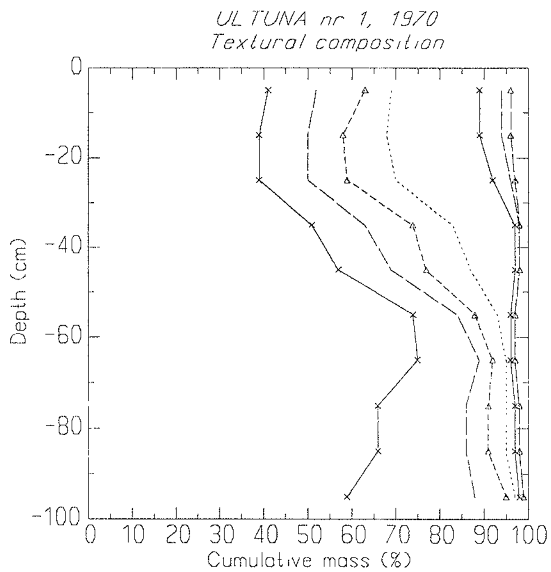

Fig. 7. Textural composition. From left to right in mm: < 0.002 mm, < 0.006 mm, < 0.020 mm, < 0.060 mm, < 0.2 mm, < 0.6 mm and < 2 mm.

Model description

The mathematical model used in this study was the SOIL model version 9.35 (Jansson, 1996). All model descriptions were taken from this publication. This is a one- dimensional model based on well- known physical equations which are used to calculate and solve hydrological and thermal processes in a soil profile. The central part of the model is represented by two coupled differential equations for water and heat flow. The two equations in question are the law of conservation of mass and energy, and that flows occur as a result of gradients in water potential (Darcy's law) or temperature (Fourier's law).

Essential data for the running of the model is contained in separate climate and soil properties data bases. By setting a variety of values for the model specific parameters, the model can be made to represent field conditions to a certain extent. The whole idea was to set reasonable values for model parameters. Once this was achieved the settings of the model were saved in a parameter file which was used for further simulations and evaluations of field conditions. Since the model has a variety of uses and combinations, a theoretical overview will be given only of the ones used and which were considered of the highest importance to this study. This model used the data from driving variable files in order to successfully complete the simulations. Two such crucial driving variable files contain the soils physical properties and the climate data for the studied time period. In order to get reliable results, these input files should not be altered to get a better fit of the model.

Bypass flow in the macropores

The one dimensional water flow through a soil profile when the CRACK switch is set to ON is calculated as shown in Fig. 8.

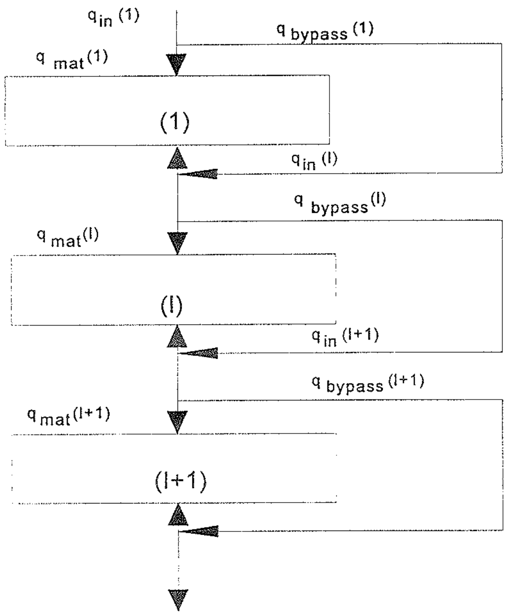

Fig 8. Water flow paths when CRACK= ON (Jansson, 1996).

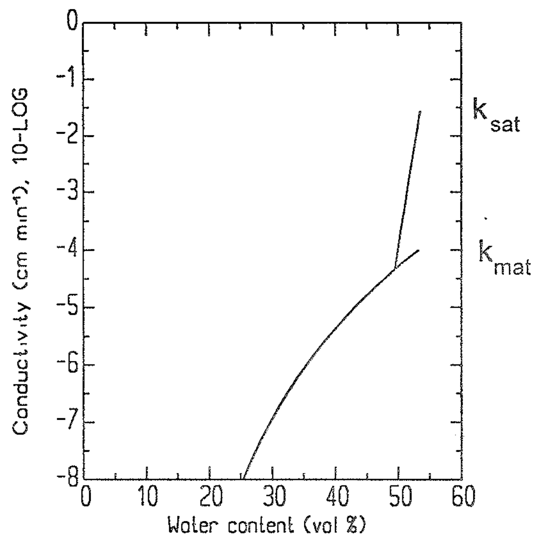

Fig. 9. Unsaturated conductivity of a clay soil as a function of water content (Jansson, 1996).

When the inflow q_{in} exceeds the sorptive capacity of the soil it is partitioned into bypass flow q_{bypass} which is the rapid flow mainly through macropores and cracks. This occurs during conditions when the smaller matrix pores are only partially filled with water. The sorptive capacity of a soil, S_{mat} , is the capacity of soil aggregates to transport water and is defined as:

$$S_{mat} = a_{scale} a_r k_{mat} pF \qquad (1)$$

where k_{mat} is the maximum conductivity of smaller pores (i.e. matrix pores), a_r is the ratio between compartment thickness and the unit horizontal area represented by the model, pF is $^{10}\log$ of ψ and a_{scale} is an empirical scaling coefficient accounting for the geometry of aggregates and can be varied in the model by an additional scaling factor ASCALEL.

When the inflow is greater or equal to the sorptive capacity then the matrix flow q_{mat} is equal to the sorptive capacity. In this case the difference between the inflow and the matrix flow is the bypass flow.

The water retention curve and the unsaturated conductivity are unique functions of the water content. Experimental data of the water retention (Ultuna NR. 1,1970) was used when estimating coefficients in the function proposed by Brooks & Corey (1964) in equation 2 (Jansson, 1996) for an intermediate range of the water retention curve.

$$S_e = \left(\frac{\psi}{\psi_a}\right)^{-\lambda} \qquad (2)$$

where ψ_a is the air-entry tension and λ is the pore size distribution index. Effective saturation is defined as:

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \qquad (3)$$

where θ_s is the porosity and θ_r is the residual water content. Estimation of the parameters λ, ψ_a and θ_r is done by least squares fittings of Eqs. (2) and (3) to experimental data. Following Mualem (1976) (Jansson, 1996), and using the analytical expressions according to Brooks & Corey (2) and (3), the unsaturated conductivity is given by:

$$k_w = k_{mat} S_e^{\left(n+2+\frac{2}{\lambda}\right)} \qquad (4)$$

and

$$k_w = k_{mat} \left(\frac{\psi_a}{\psi}\right)^{2+(2+n)\lambda} \qquad (5)$$

where k_{mat} is saturated conductivity and n is a parameter accounting for pore correlation and flow path tortuosity. Eqs. (2) and (3) are used for water contents in the matrix pores. The k_w value is also scaled by using a logarithmic parameter SCALECOND. In addition, a temperature function is used to account for effects on the viscosity. To account for the macropores, an additional contribution to the hydraulic conductivity is considered (Fig. 9) when the water content exceeds θ_s - θ_m (porosity - macropore volume).

Ground water outflow

Groundwater in its natural state is invariably moving. This movement is governed by established hydraulic principles (Todd, 1980). The ground water outflow calculations in this study are based on the Hooghoudt (1940) equation (Jansson, 1996). The assumption behind this equation (Eq. 6) is that if the impermeable layer is absent or at a great depth, it is assumed that the flow around a pipe drain is radial (Fig. 10).

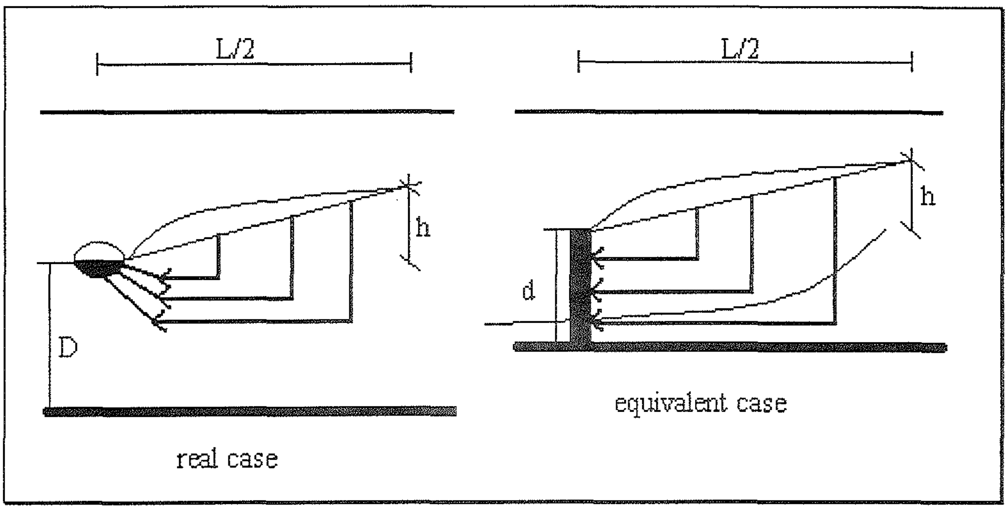

Fig. 10. The Hooghoudt idea of transformation.

By approximating a pipe drainage system underlain with an impermeable layer by an open drainage system with the impermeable layer at a reduced depth, the theory of horizontal flow can be used to approximate the combination of horizontal and radial flow. By dividing the flow zone into two layers, one above and one below the drainage layer, with two different hydraulic conductivities, the following is obtained:

$$q_{wp} = \frac{4k_{s1}(z_{sat} - z_p)^2}{d_p^{\,2}} + \frac{8k_{s2}z_D(z_{sat} - z_p)}{d_p^{\,2}} \qquad (6)$$

where k_{s1} and k_{s2} are the saturated conductivities in the horizon above and below the drainage pipes respectively, z_p is the depth of the drainage pipe, z_{sat} is the simulated depth of the ground water table, z_D is the thickness of the layer below the drains and d_p is the spacing between parallel drain pipes. In the model, the flows for specific layers above the drain depth are calculated based on the horizontal seepage flow for heterogeneous aquifers (Youngs, 1980, in Jansson, 1996) corresponding to the first term in the Hooghoudt equation:

$$q_{wp1}(z) = \frac{8k_s(z)\left(hu - hl + \frac{(hl^2 - hu^2)}{2(z_{sat} - z_p)}\right)(z_{sat} - z_p)}{d_p^{\,2}} \qquad (7)$$

where *hu* and *hl* are the heights of the top and bottom of the compartment above the drain level z_p. Below the drain depth the flow is calculated for each layer as:

$$q_{wp2}(z) = \frac{8k_s(z)z_D(z_{sat} - z_p)r_{corr}(z)}{d_p^{\ 2}} \tag{8}$$

The correction factor r_{corr} is based on the estimated sums of the radial (r_r) , horizontal (r_h) and vertical (r_v) resistances for each layer. The correction factor is then:

$$r_{corr}(z) = \frac{(r_v(z) + r_h(z) + r_r(z))\Delta z}{r_{href} z_D} \tag{9}$$

where the r_{href} is the horizontal resistance as included in Eq. (8).

Seepage

Seepage is a term which describes the loss of water from the watershed, that is, water flows at the bottom of the profile. This loss can be calculated in both the horizontal and vertical directions.

Horizontal seepage is calculated assuming an impermeable layer at the bottom of the soil profile (UNITG 3) then we have horizontal seepage. In the model a net horizontal water flow is given as a sum of base and peak flow. Base flow is a constant horizontal water loss while the higher peak flow water loss is dependent on the amounts of water reaching the bottom of the profile. Horizontal seepage is defined as:

$$q_{gr} = q_1 \frac{\max(0, z_1 - z_{sat})}{z_1} + q_2 \frac{\max(0, z_2 - z_{sat})}{z_2} \tag{10}$$

where q_1, $q2$, z_1, z_2 are parameters obtained by fitting techniques, and z_{sat} is defined as the level where the matric potential is zero.

Vertical seepage is calculated if no impermeable layer exists or lies at a greater depth (UNITG 4). The flow is then defined as vertical within the considered soil profile and calculated as:

$$q_{deep} = \frac{8k_s(z_{sat} - z_{p2})^2}{d_{p2}^{\ 2}} \tag{11}$$

where k_s is the conductivity of lowest layer, z_{sat} is the simulated depth of the ground water table, z_{p2} is the depth of a drain level with a parallel geometry at a spacing distance of d_{p2}.

This is a more correct method of calculating the seepage since it is directly related to the soil hydraulic conductivity.

Boundary conditions for heat flow calculations in the soil

When calculating soil surface temperatures the model provides us with three options. These are chosen by using the SUREBAL switch. The first option is by setting the switch to SUREBAL= 0. This means that the soil surface temperature will be put to the same as the air temperature found in the climate file except in situations when snow occurs on the ground. For periods with snow cover, soil surface temperature is given by assuming steady state heat flow. When the snow depth is below a certain value the soil surface temperature is calculated as a weighted sum between the calculated temperature below the snow and an estimated soil surface temperature from bare areas.

When the switch is put to SUREBAL= 1 the soil surface temperature is calculated from the energy balance at the soil surface using the Penman- Monteith equation (Kutilek & Nielsen, 1994). When the third option SUREBAL= 2 is used, the soil surface temperature will be calculated from the energy balance at the soil surface using an iterating procedure taking detailed account of both aerodynamic properties in the air and thermal properties in the soil.

Parameterization of the model

By changing certain model parameters a similarity is obtained between measured and simulated data. This is usually called the fitting of the model. As mentioned before, once this is achieved to a satisfactory level the data is saved in a parameter file which is then used for further simulations. A description of the parameter file and a short explanation of the chosen calculations are presented below, while a detailed version, and all outputs, are presented in the appendix. Model parameters not discussed below are set to default values in the model.

The soil profile that was created for this study consists of 22 layers from the soil surface to a depth of 4 meters. It should be stated that the soil properties file contains data for a soil profile 1 m deep, and since the soil profile in the model is 4 m deep all layers below 1 m will assume the physical properties of the deepest layer in the soil properties data file. All references concerning the model are taken from the description of the soil model (Jansson, 1996). The initial temperature was set to seven degrees Celsius (value on the 16th of November), while the initial soil water pressure head was set to -100 cm. The initial ground water level was set to 2.2 m below the soil surface. For correct water balance calculations, the effects of a plant covering were taken into account. Transpiration was calculated for a plant covering of a certain height with a defined leaf area index and root distribution. Upward water movement and the effect of water interception due to this plant covering were also calculated as well as the evaporation from the soil surface.

Since these simulations were performed for winter conditions the effects of snow and freezing were also taken into account. Snow dynamics were simulated based on climate input data. The interaction between temperature and moisture at and below zero temperatures was taken into account, and thus, the infiltration capacity was minimised during freezing. The upward movement of water towards a frozen layer and the frost induced soil swelling were also taken into account, as well as the occurrence of frost preferential flows.

The effects of bypass flow and hysteresis were also taken into account for this soil profile. Drainage was calculated (Eq. 6) for a pipe drainage system at a depth of 1 m and with a spacing of 20 m which are the actual site values. For the calculation of vertical seepage a second pipe drainage system was assumed at a depth of 4 m with a spacing of 4.25 m.

Sensitivity analysis

In hydrological studies, the hydraulic conductivity of the soil plays a very important role. To calculate soil water flows it is necessary to obtain reliable values for this soil property. Saturated hydraulic conductivity can be determined both in the field and the laboratory, but since time, labour and computer capacity are often limited, modelling must be restricted to some mean value. There is also the added problem of spatial heterogeneity. The natural spatial heterogeneity of a soil results in variations of well above 100% in units of just a few ha or less (Kutilek & Nielsen, 1994). To see what effects a reduction of variations has on the model a sensitivity analysis can be performed. A sensitivity analysis is the process of introducing planned perturbations into a model and observing their effect (Miller, 1974). By this method important parameters and interactions are identified (Hermann, 1967, in Miller) and a relative worth of improving various parts of a data base is decided on (Meyer, 1971, in Miller). If a sensitivity analysis shows that variations in a parameter are of little importance, large gains can be made in computer efficiency through making the model coarser and allowing smaller parameter contrasts (Follin, 1992).

This study deals with the effects of varying saturated hydraulic conductivity and saturated conductivity of the soil matrix on the hydrological conditions of the Ultuna watershed. The multiple run option of the SOIL- model was used to scale (ASCALEL) the default value of ASCALE= 0.5 in thirteen equidistant logarithmic steps from $10^{-1.4}$ to $10^{1.0}$, while all hydraulic conductivities were scaled (SCALECOND) in fifteen equidistant logarithmic steps from $10^{-1.4}$ to $10^{1.4}$. This resulted in 195 simulations, each of which, was compared to the measured data to obtain an r^2 value. By studying all the obtained r^2 values conclusions can be drawn as to the effects of changing these parameters.

RESULTS AND DISCUSSION

Measured data

The measured ground water levels (Fig. 11) showed an expected difference in depth while above the drainage pipe at 1 m depending on how far away they were from that same pipe. When the ground water levels were below the drainage pipe they showed a tendency of evening out at approximately the same level. Not all the fluctuations of the ground water levels are due to infiltrating water. Many small scale fluctuations occurred most probably due to variations in temperature, atmospheric pressure, frost and even tides (Todd, 1980).

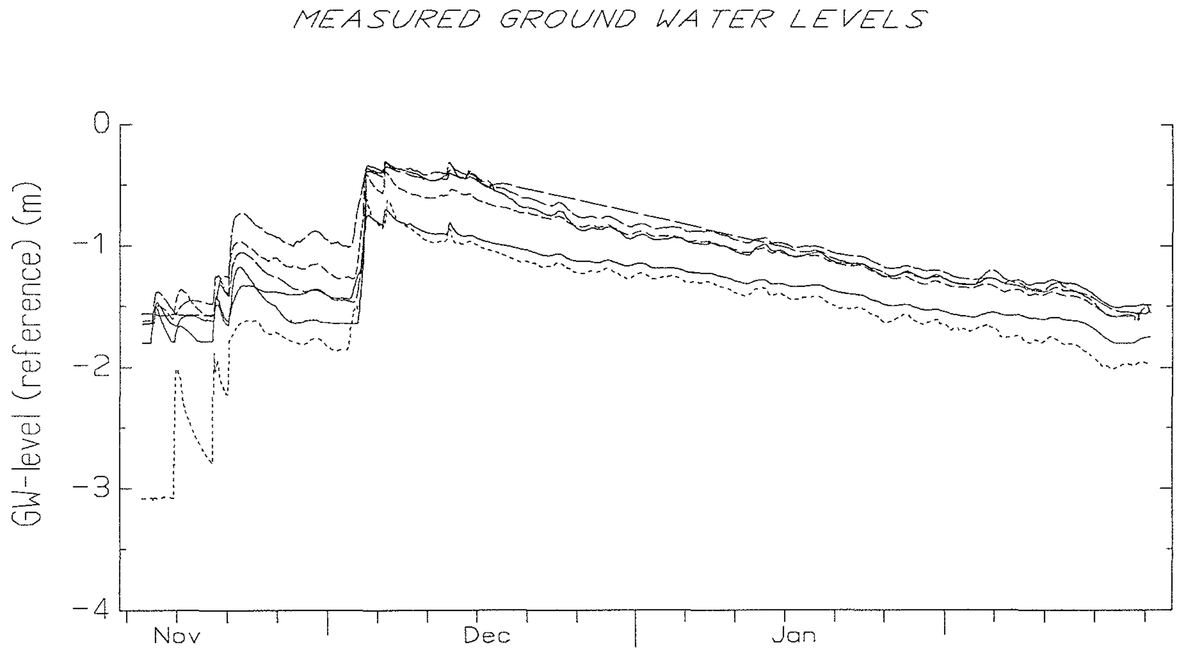

Fig. 11. Measured ground water levels for all six tubes.

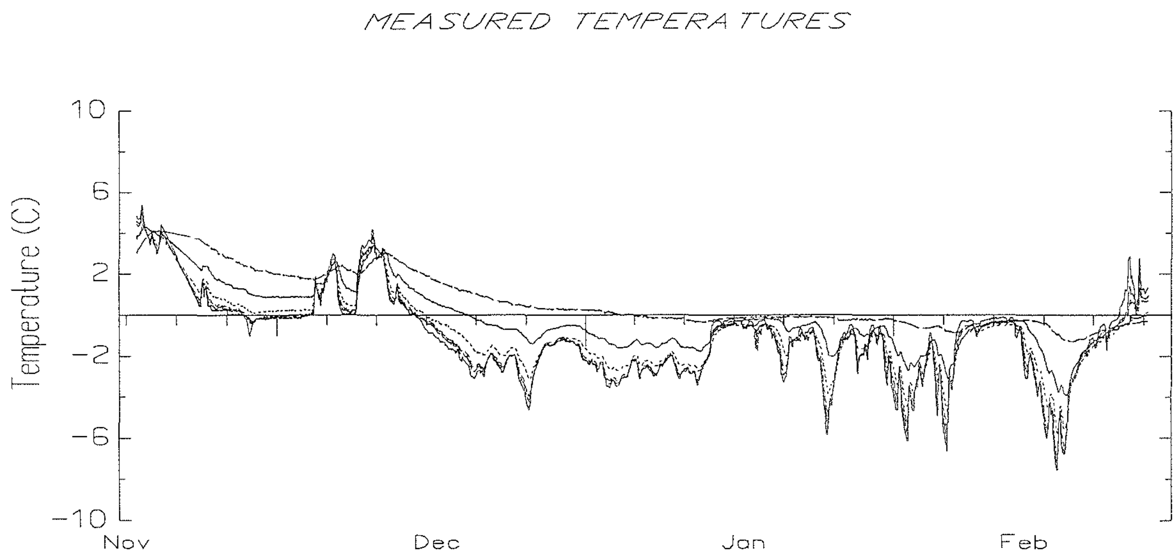

Fig. 12. Measured temperatures from 0 - 40 cm soil depth for all six thermistors.

The measured temperatures (Fig. 12) showed the greatest fluctuations in the surface layers. Not counting two short warm periods the soil water was frozen for most of the studied period where the frost boundary reached down to, and below 40 cm depth.

The accumulated daily values of the measured discharge (Fig. 13) show characteristic periodical surface runoff induced peaks for the studied period.

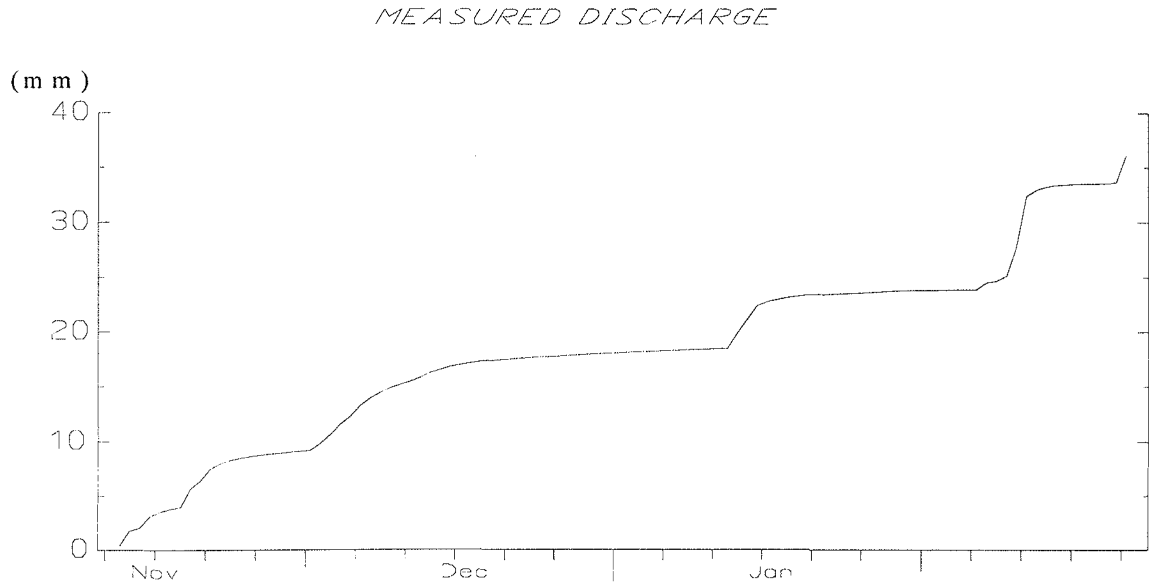

Fig. 13. Measured discharge. Accumulated daily mean values in mm (Djodjic, 1997).

Heat flow calculations

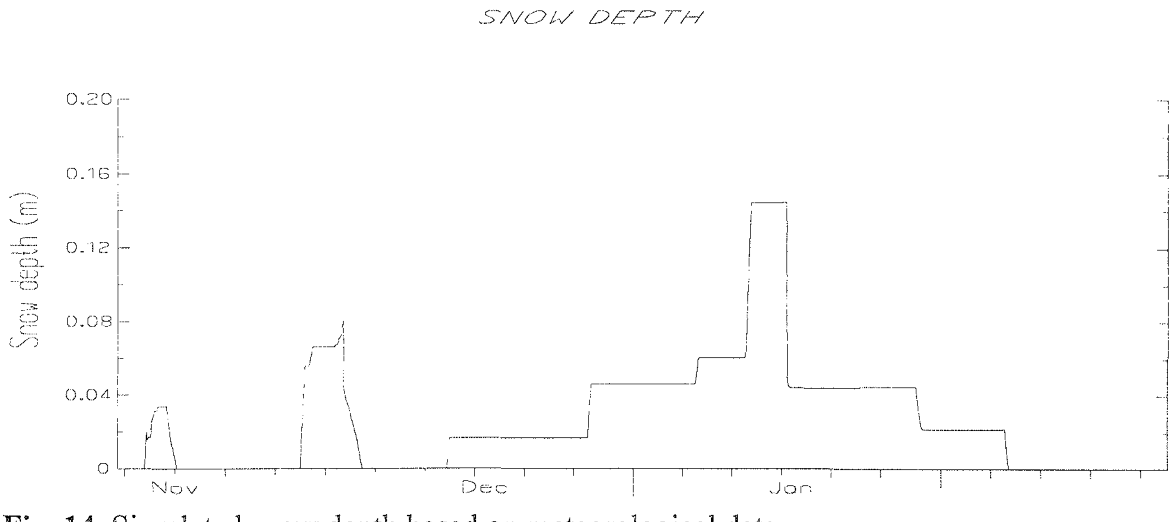

Fig. 14. Simulated snow depth based on meteorological data.

Before discussing the temperature simulations it is important to show how the model calculated snow depth (Fig. 14) based on measured precipitation during periods with temperatures at and below zero. The decrease of snow depth is explained by melting, and it was at these times that both surface runoff and infiltration occurred.

The effects on simulated temperature of using different assumptions concerning the soil-atmosphere boundary are shown in Fig. 15.

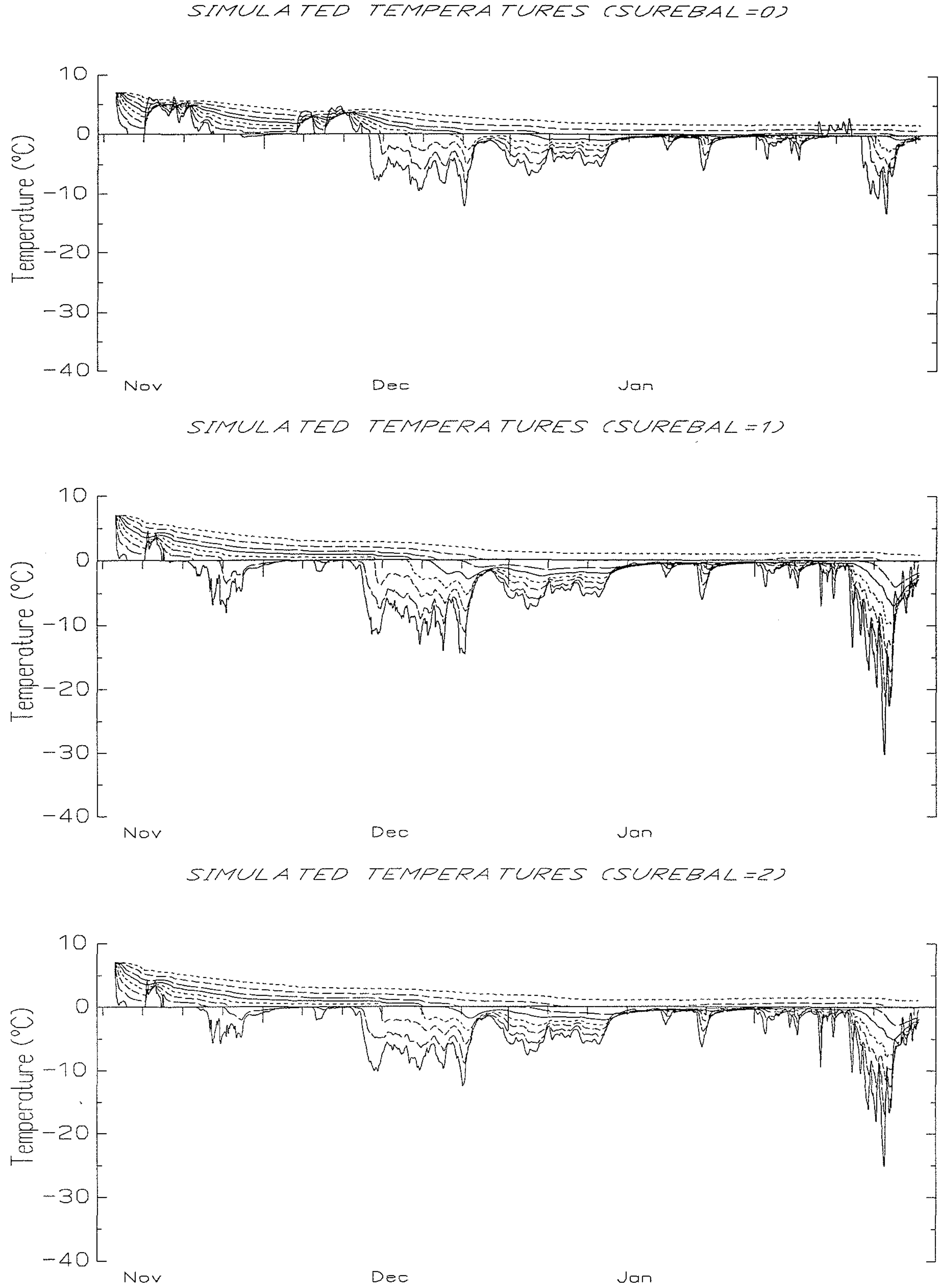

Fig. 15. Simulated soil temperatures for depth 0 - 50 cm (8 soil layers) when using different assumptions concerning the upper boundary conditions according to the SUREBAL switch.

Differences in simulated temperatures occurred especially during periods of snow cover (see Fig. 14). A three- week period was chosen in December to clarify these differences (Fig. 16).

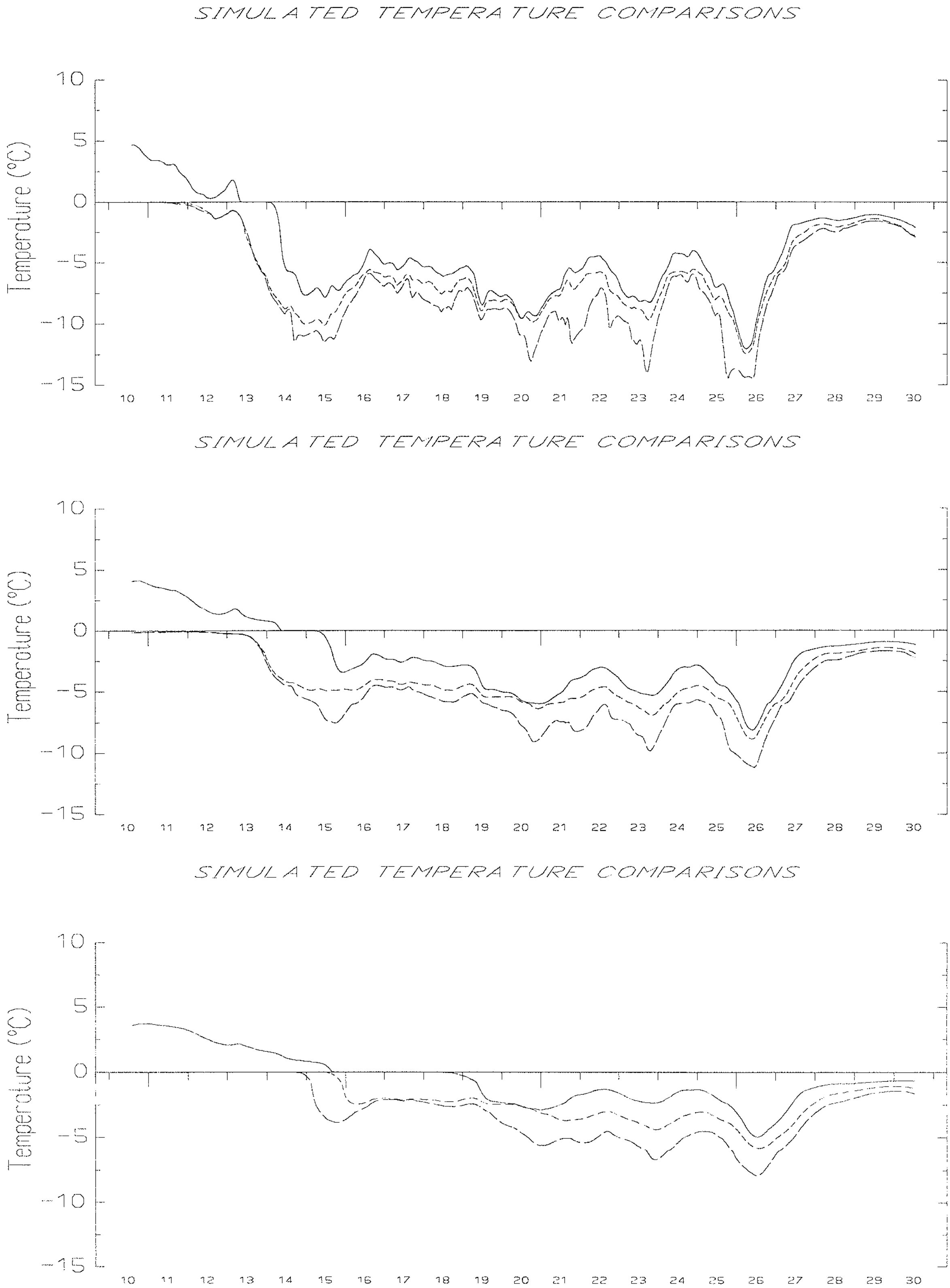

Fig. 16. Simulated temperature comparison for three depths: 0- 5 cm (upper graph), 5- 10 cm (middle graph) and 10-15 cm (lower graph) soil depth at three SUREBAL values (0- full line, 1- broken line, 2- dotted line) for the period from the 10^{th} to the 30^{th} of December 1996.

The warmest simulated soil temperatures were obtained when the air temperature at a reference height was assumed equal to the snow/atmosphere interface, lower simulated temperatures were calculated when the energy balance approach based on the net radiation gave substantially lower soil temperatures during this period with negative net radiation. Only the simulated temperatures with SUREBAL= 0 are compared with the measured temperatures at three different depths in Fig. 17.

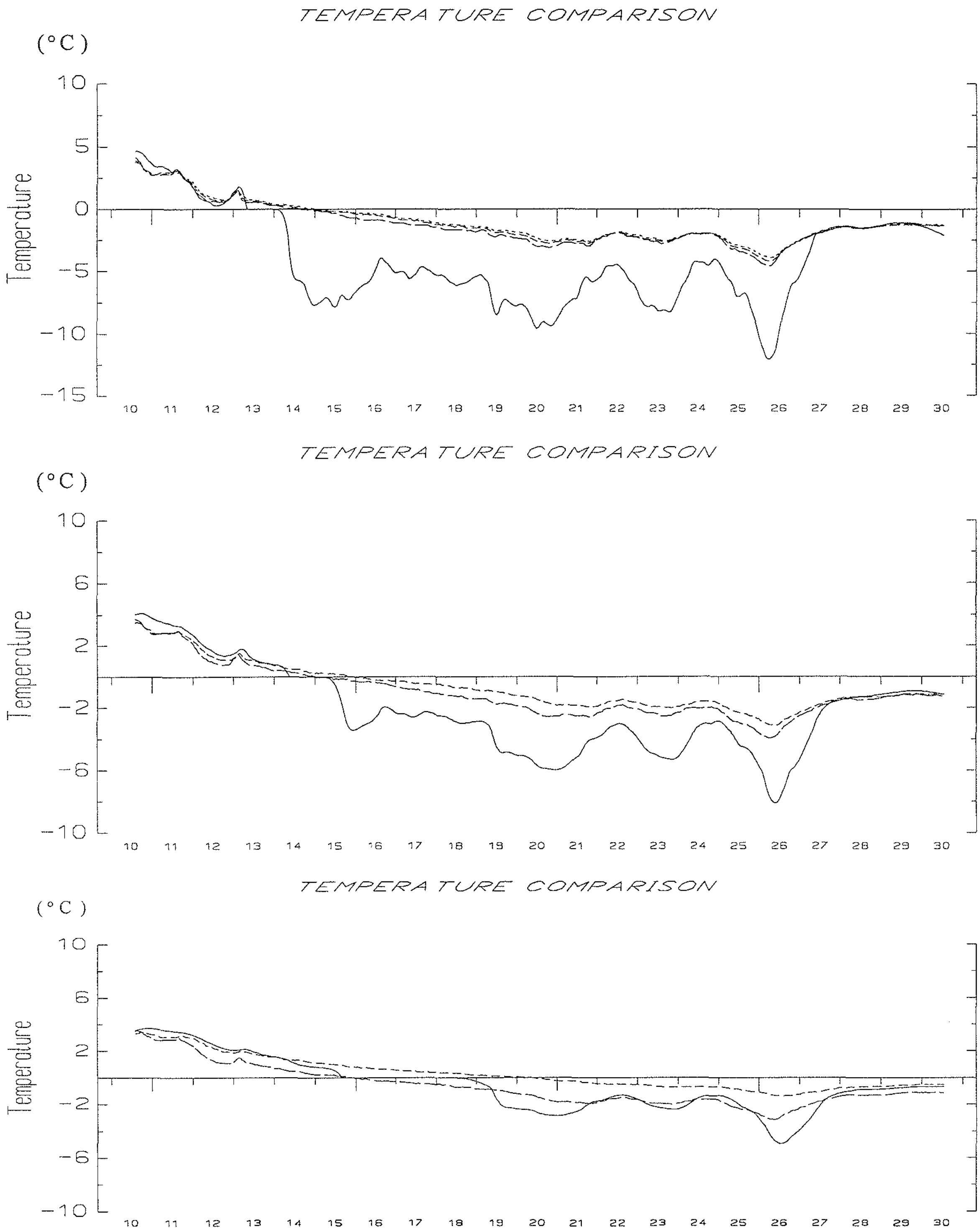

Fig. 17. Simulated (SUREBAL= 0, full line) and measured temperatures (broken lines) for three different depths: 0- 5 cm (upper graph), 5- 10 cm (middle graph) and 10-15 cm (lower graph) soil depth, for the period from the 10th to the 30th of December 1996.

The simulated temperatures were lower than the measured. This discrepancy especially occurred during periods with snow cover. The thermal conductivity of snow is a property which depends on such factors as the density, temperature and the microstructure of the snow. It should be noted that the thermal conductivity of snow, even when dense, is very low compared to that of ice or liquid water; therefore snow is a good insulator (Langham, 1981). Two major problems are linked with the simulation of snow formation: (a) The monitoring of precipitation. Usually, standard rain gauges are unable to quantify snow precipitation accurately. The major source of error is wind drift. In addition, such rain gauges are usually constructed to measure liquid water which makes it impossible to measure snow at the moment it accumulates. (b) At temperatures close to the freezing point it is difficult to predict if precipitation falls as snow or rain (Stähli & Jansson, 1997). All this influenced the uncertainty of the simulation of snow cover at the site. Since the model simulated snow based on measured precipitation and air temperatures from the climate station, it is reasonable to assume that the snow depth on the site (not measured) differed from the simulated snow depth due to wind drift. In other words, it was assumed that there was either more snow in the field or the same amount as in the model but with a lower density.

Once the model calculated lower soil temperatures during the first snow fall than in reality the simulated initial soil temperature was lower for every succeeding snow fall. Not only that, but, due to the lower simulated soil temperatures the model simulated deeper soil freezing. Simulated temperatures were important for this study because of the effects of soil water freezing on water flows. This is why a 1 cm humus layer was added to the model to minimise heat loss, because, if the simulated frost boundary came too close to the simulated ground water level it would have distorted its curve due to the fact that from thermodynamic principles a freezing soil can be considered as being similar to a drying soil, thus forming a water tension gradient which may cause considerable water redistribution towards the frozen zone (Stähli & Jansson, 1997).

Due to the limited amount of climate input data, especially the lack of measured long- wave radiation which is an important factor during winter conditions (when using the energy balance equation), it was decided to rely on the simulated soil temperatures based on the air temperature only, without using the energy balance approach.

Simulated and measured ground water

When all the model parameters have been set to achieve a similarity between simulated and measured ground water levels a reasonable agreement was obtained (Fig. 18). The simulated ground water level had the same response and dynamics as the measured ones and it lay within the range of the highest and lowest measured values. The discrepancies are relatively small, besides a small- scale variation in the measurements which was not possible to simulate.

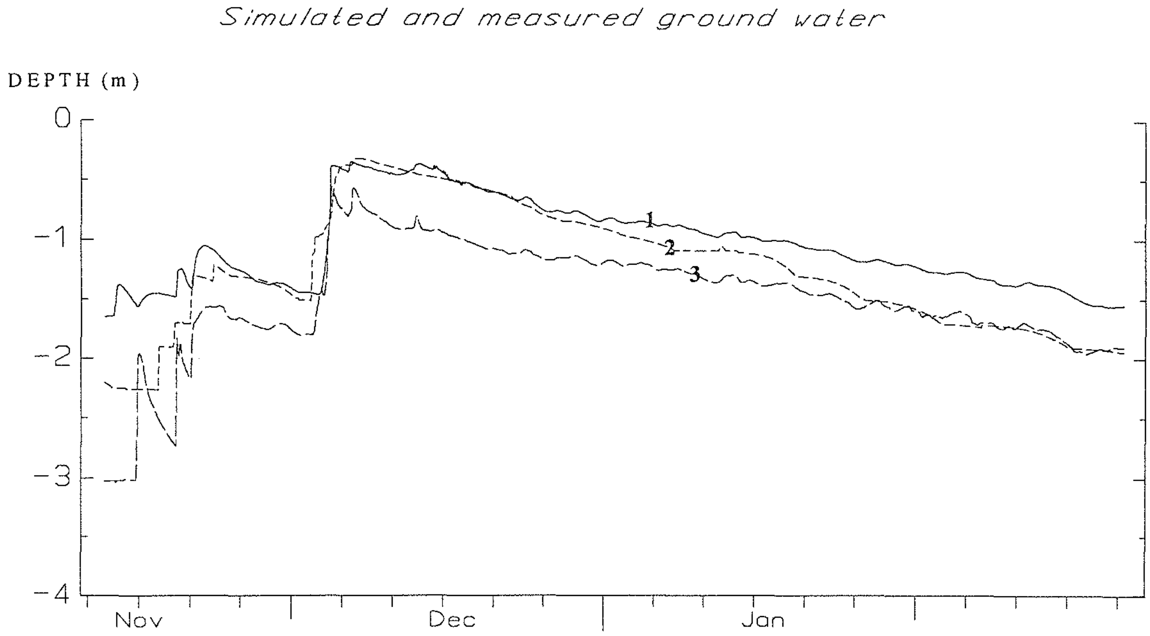

Fig. 18. Comparison of simulated ground water (curve 2) with measured levels in tube 2 (curve 1) and tube 4- (curve 3).

Sensitivity analysis

The measured ground water levels for six tubes were compared with every simulation in the sensitivity analysis to clarify the importance of the soil hydraulic properties. A three-dimensional plot of the r^2 dependence to changes in ASCALEL and SCALECOND is featured on the title page, but since it is difficult to show and explain the results on such a figure, a more simplified figure will be presented. In Fig. 19 the r^2 values are presented both as a function of variation of the sorptive capacity (ASCALEL) and the saturated hydraulic conductivity (SCALECOND). Results are presented for tubes 1 - 5 since there was a one-month period of missing data for tube 6. With the r^2 dependence based on changes of conductivity, only the best and worst ASCALEL fits are shown (Fig. 19, left side). All other ASCALEL curves lie between them. When r^2 is ASCALEL dependant it will be shown for values when SCALECOND is -1.4, 0 and 1 (4%, 100% and 1000% of the original saturated hydraulic conductivity value respectively) (Fig. 19, right side).

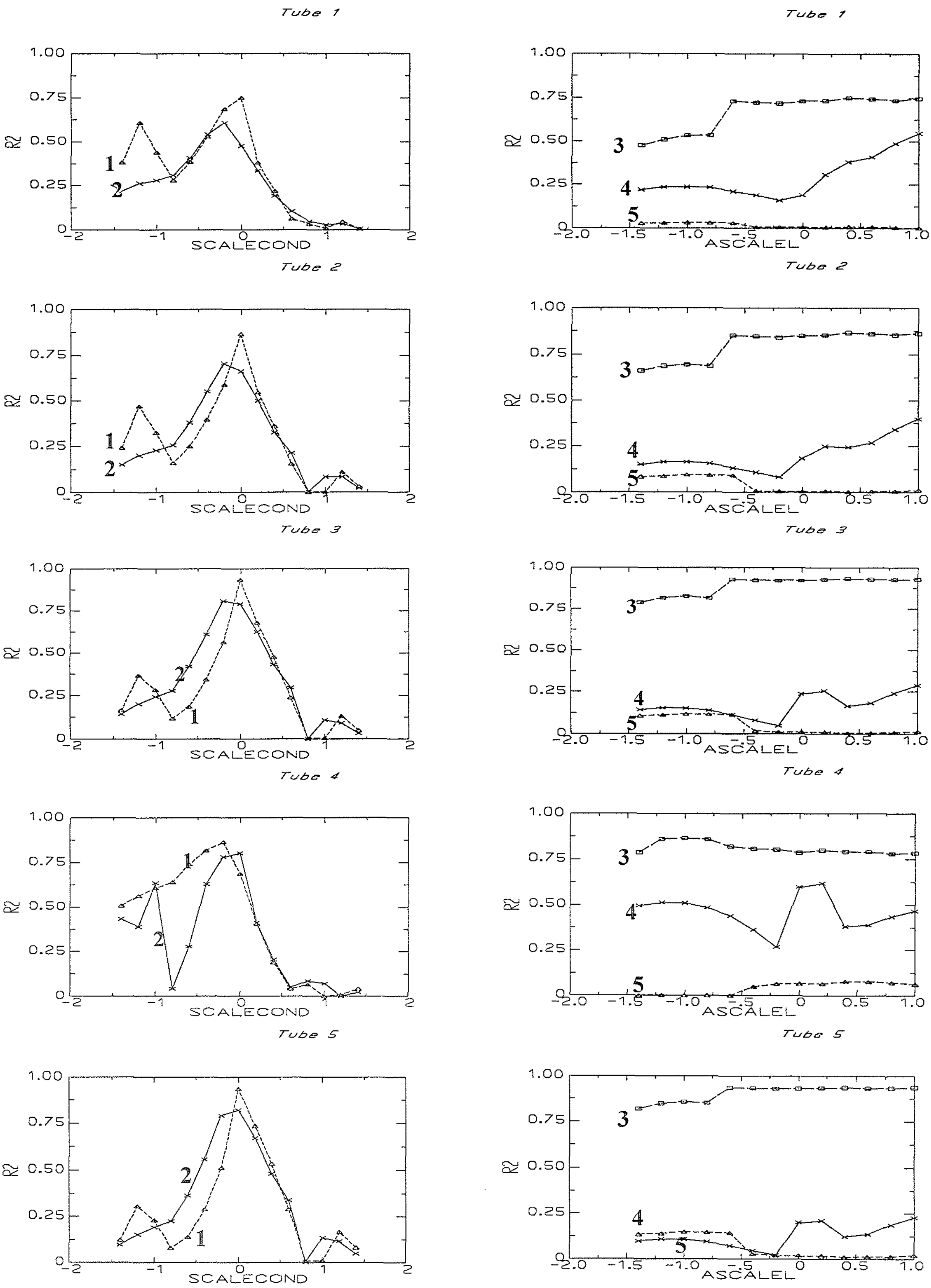

Fig. 19. Agreements as r^2 values for five different tubes versus simulation. Different values of ASCALEL= -1.4 (curve 2) and ASCALEL= 0.4 (curve 1) are presented to the left, while, values of SCALECOND (-1.4 -curve 4, 0-curve 3, and 1- curve 5), are to the right.

Presenting the results as r^2 values is an abstract comparison of measured and simulated results. r^2 values show how well the two curves are correlated. A noticeable pattern emerges for the displayed results when looking at all five tubes. A slightly different pattern for tube 4 is explained by the fact that the measured curve has a different shape due to the much lower initial ground water level as compared to the rest of the tubes.

By looking at Fig. 19 we can see that there is very little effect of changing the soils sorptive capacity when simulating ground water. This is especially noticeable in Fig. 19 (left side) where the two curves follow each other well. This is explained by the fact that the infiltrating water will reach the ground water in any case, either largely as bypass flow when the sorptive capacity is low, or largely through the soil matrix when the sorptive capacity is high. The only difference is in the speed of response of the ground water curve.

With high bypass flow the ground water curve rises sharply as can be seen in Fig. 20 (curve 2). A slight discrepancy is noticed when the saturated hydraulic conductivity is decreased to 6% of the original value (SCALECOND= -1.2), when the sorptive capacity is increased to 251% of the original value (ASCALEL= 0.4). Four ground water simulation curves are presented in Fig. 20 for this increase of the sorptive capacity and four SCALECOND values of 0, -0.8, -1.2 and -1.4 (100%, 16%, 6% and 4% of the original value respectively). The best r^2 value was obtained for curve 1 where no scaling of the hydraulic conductivity was done. A decreased r^2 is obtained for curve 2 when the saturated hydraulic conductivity is decreased to 16% of the original value due to the fact that its response differs to curve 1 (note the sharp rises due to bypass flow) and this is to be expected. A slightly improved r^2 value is obtained when the saturated hydraulic conductivity is decreased to 6% of the original value (curve 3) since it has similar dynamics to curve 1 but at a much greater depth and a much lesser range. There is no bypass response as in curve 2 since it lies deeper in the profile, and most of the infiltrating water is absorbed by the soil. Curve 4 is when the saturated hydraulic conductivity is decreased to 4% of the original value and does not resemble curve 1 at all, therefore resulting in the decreased r^2 value.

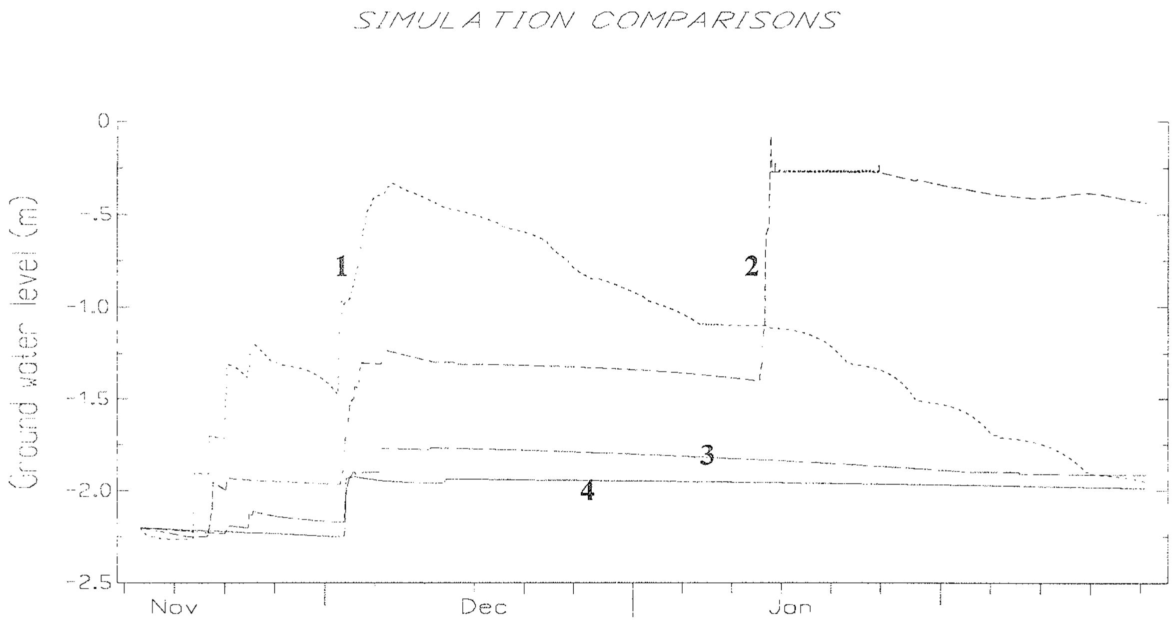

Fig. 20. Simulated ground water levels for ASCALEL= 0.4 when SCALECOND varies. SCALECOND= 0 - curve 1, SCALECOND= -0.8 - curve 2, SCALECOND= -1.2 - curve 3 and SCALECOND= -1.4 - curve 4.

However, when looking at the effects of the changes in conductivity, we see huge variations in the r^2 values (Fig 19, right side). When the saturated hydraulic conductivity is 100% of the original value, good r^2 values are achieved with increasing sorptive capacity. The same can be observed when the saturated hydraulic conductivity is decreased to 4% of the original value, while there is no effect when the saturated hydraulic conductivity is increased to 1000% of the original value. In the first two cases this can be explained by the fact that when bypass flow occurs due to the low sorptive capacity of the matrix pore system the r^2 values worsen due to the shape of the simulated curve (see curve 2, Fig. 20). No change in the third case is explained by the fact that no bypass flow occurs due to a high hydraulic conductivity which gives high flow rates in both the matrix and the macropore domain.

Discharge

All values that will be discussed in this section are accumulated daily values and are expressed as mm. The simulated value for the total evapotranspiration was 0.08 mm which is explained by the greater occurrence of condensation, while the simulated evaporation of intercepted precipitation was 0.69 mm. These are very low values due to winter conditions and will not be taken into account when discussing the water balance. It is apparent that the simulated discharge (92.59 mm) is almost three times greater than the measured (36.08 mm) for this time period (Fig. 21). How is this difference explained? Due to the spatial heterogeneity of soil hydraulic properties in the watershed, it is assumed that the watershed as a whole has a greater water storage capacity than the studied soil. This combined with the fact that a greater part of the soil profile is saturated at points which are in the lower part of the watersheds topography accounts for the lesser measured discharge.

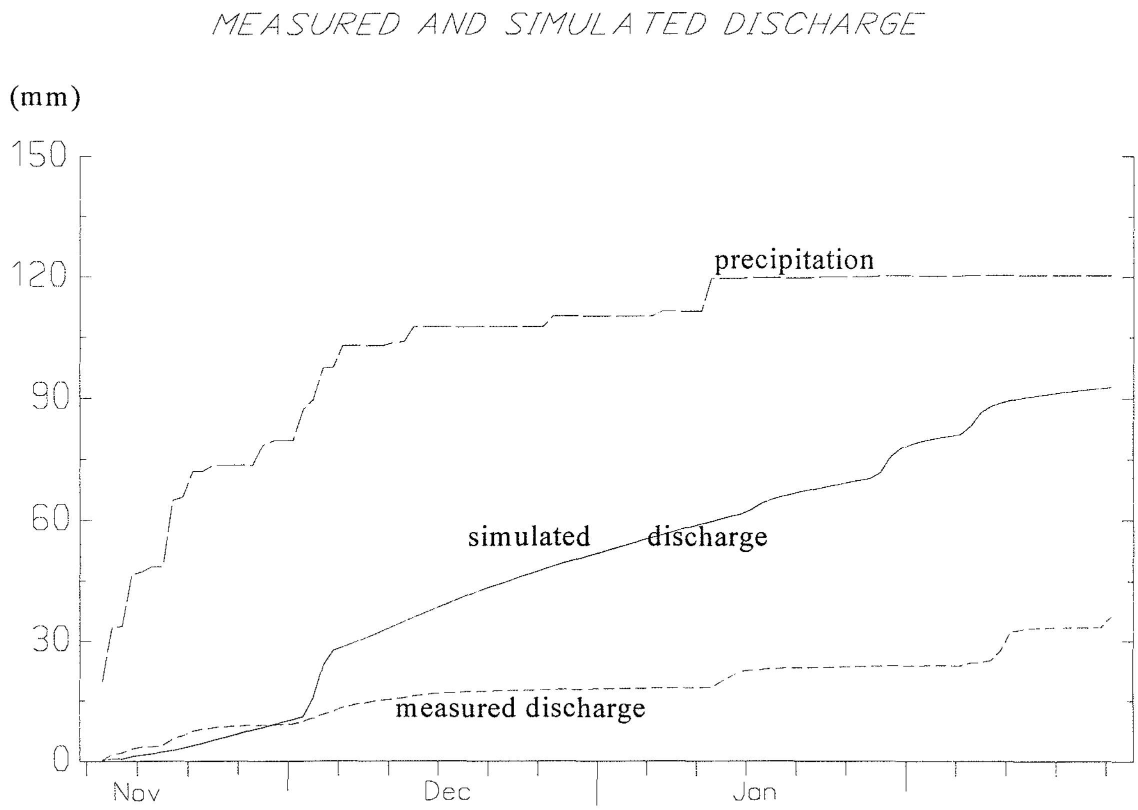

Fig. 21. Measured and simulated accumulated discharge rates.

The quantity of discharged water is not the only difference between the two discharges. A difference in the occurrence and rate of surface runoff is observed as well as in the amounts of deep percolation (Fig. 21 and 22). The simulated surface runoff (31.53 mm) is much larger than the measured and should in reality be even larger if 23% soil cover was added as an effect of road and building covering (Djodjic, 1997). This difference can be accounted for by the fact that, in reality, a larger part of the surface runoff infiltrates into the soil along the way. This can especially be seen for the period from the 27th of January to the 1st of February where an occurrence of surface runoff was simulated, while in reality none was observed. This occurred shortly after a short period of above- zero air temperatures. Snow melt occurred both in the simulation and in reality, but, the situation in the field differed slightly. Since the field was not completely covered in snow and most of the lower watershed has a southerly exposure, it is probable that the snow at the soil surface melted in some parts and contributed to an increase in infiltration.

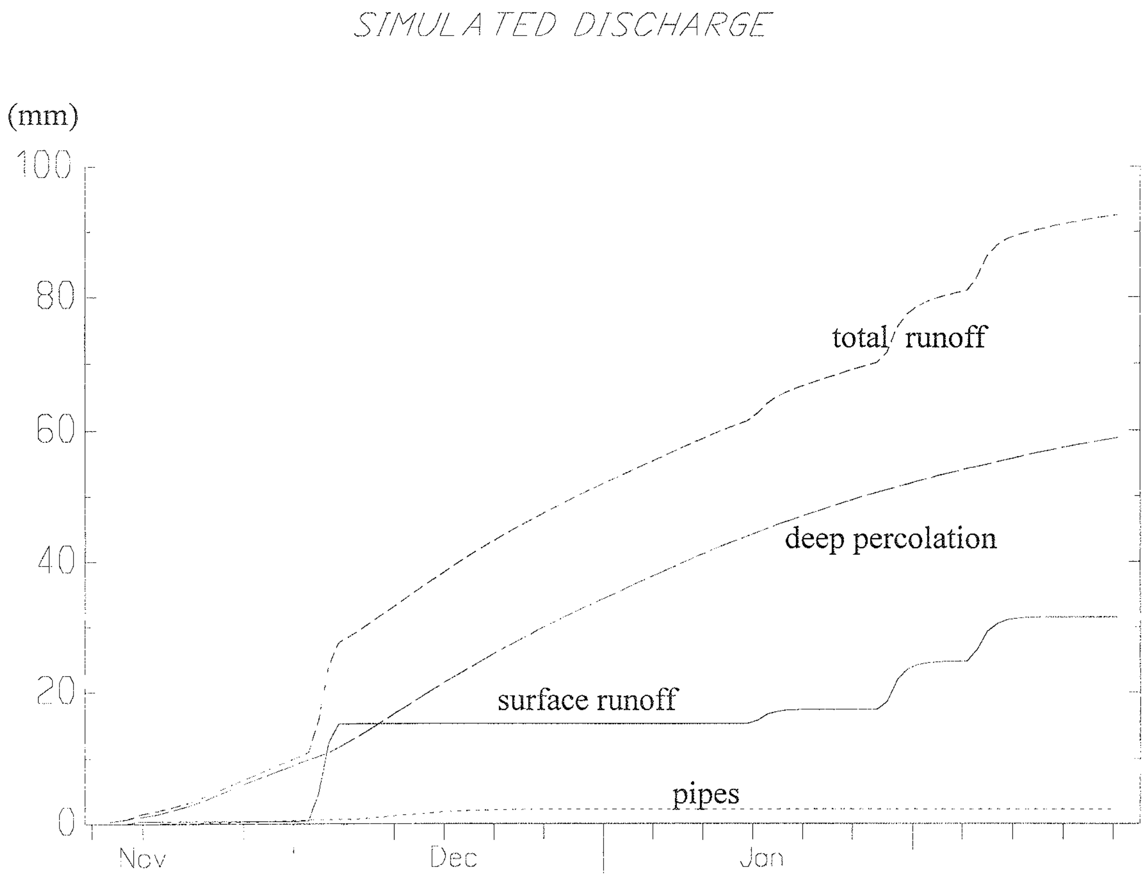

Fig. 22. Total simulated runoff and its components expressed in mm.

The other observed difference is in the amount of deep percolation (58.81 mm total). Simulated values show a steady rise in the total runoff while very little is observed with the measured. This is explained by the fact that all deep percolation in the model contributes to the total runoff, while it is safe to assume that, in reality, a substantial amount of water is lost below the drainage system. The total simulated discharge from the drainage pipes is negligible (2.25 mm). This is due to the fact that the ground water table was above the drainage depth for a very short time. In reality, the drainage pipe discharge contributes more to the total runoff due to the topography (as explained earlier) since the ground water table is most probably above the drainage depth for longer periods of time.

Seepage

One general uncertainty was the ground water response when the ground water was located beneath the drainage pipes at 1 m depth. Different assumptions were tested and gave fairly similar results (Fig. 23).

During the fitting of the model, two options were considered when calculating seepage. When horizontal seepage was calculated values of 0.6 mm/day base flow and 0.7 mm/day peak flow were most representative for the location for depths of -3 m and -2 m respectively. Compared to the precipitation and simulated discharge rates these are fairly high values. But, since this type of calculation is not related to the soil and the values are arbitrarily obtained by trial and error, it was not used for any further studies.

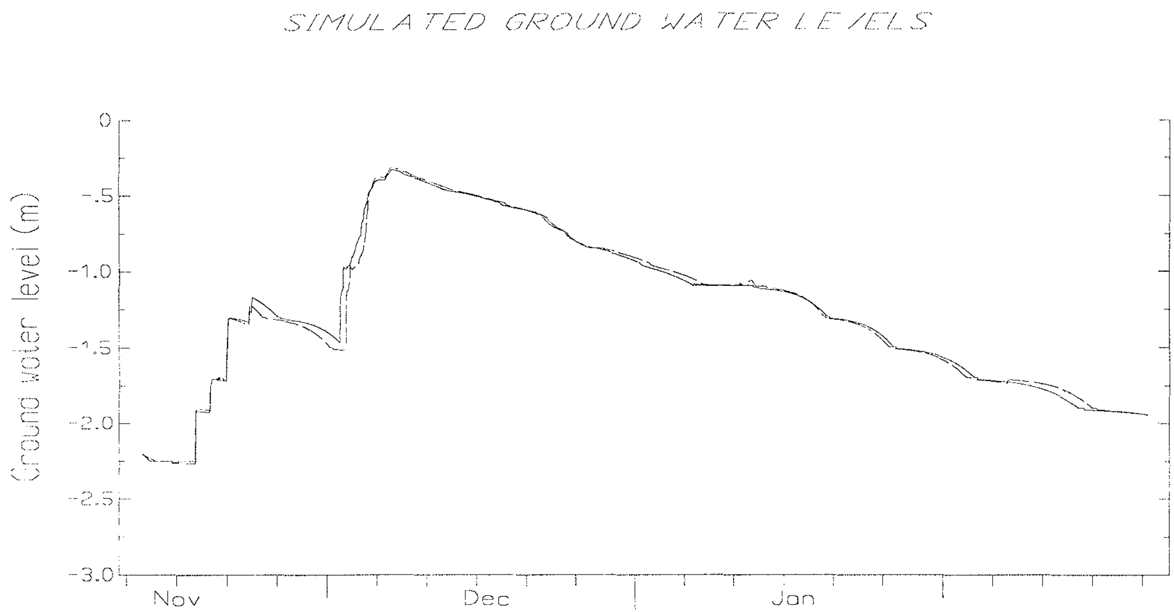

Fig. 23. Simulated ground water levels. Horizontal seepage full line. Vertical seepage dotted.

Since this study was based on the hydraulic conductivity of the soil, it was decided that the assumption based on vertical seepage flow theory should be used instead. As explained earlier, this calculation is based on the assumption that a parallel drainage system exists at a greater depth. The values obtained for this assumption were: a secondary drainage depth of 4 m with a spacing of 4.25 m. A spacing of 4.25 m is a very small value, which is explained by a unit gravitational gradient as the main driving force for the vertical flow from the lowest soil compartment

CONCLUSIONS

When simulating ground water levels it is preferable to relate all model parameters to the soil properties especially to the hydraulic conductivity of the soil. Thus, more reliable results are obtained which can be directly related to the soil properties and their effect easily explained.

Simulating soil temperatures without using the energy balance equation gave systematic discrepancies in the results when compared to measured data. Therefore, it was recommended that the energy balance equation be used, but, attempting winter simulations without measured long- wave radiation resulted in an even more pronounced underestimation of the soil temperature. This may strongly influence the simulated ground water levels especially if they are close to the simulated frost boundary.

Changes in the sorption capacity of the matrix pore region have little or no effect on ground water simulations. The only noticeable difference is the sharper rise of the simulated ground water curve with increased bypass when lowering the sorption rates of the matrix pore system. Changes in the saturated hydraulic conductivity, however, greatly influenced simulated ground water levels. It is therefore of greater importance to know the total saturated hydraulic conductivity than it is to know the sorption capacity of heavy soils if we are interested in the ground water response. However, it is important to note that this conclusion may not be true if we are interested in solute transport or the actual movement of the water molecules.

Simulated discharge was representative for just one point in the watershed for set conditions, but when related to the whole area, large differences occurred. Variations in the topography, temperature conditions, exposure and soil heterogeneity greatly influenced the results. A few improvements could be made for such studies. One improvement would be more recent soil data, since 27 year old data can not be completely relied upon. Another improvement would be the repetition of this study at different points in the watershed.

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Faruk Djodjic

And a special thanks to my supervisor, Per- Erik Jansson, who, with a deft hand and sharp mind led me through all encountered queries and problems, without whom none of this would be possible.

REFERENCES

Djodjic, F. 1997. Changes in discharge response during 40 years in a small agricultural- urban basin. Uppsala: Swedish University of Agricultural Sciences. Department of Soil Sciences. Division of Agricultural Hydrotechnics. Report 97: 2.

Donnan, W. W. & Schwab, G. O. 1974. Current Drainage Methods in the USA. In: Schilfgaarde, J. V. (ed.). Drainage for Agriculture. Agronomy no 17. p 93- 113.

Follin, S. 1992. Numerical Calculations on Heterogeneity of Ground Water Flow. Stockholm: Royal Institute of Technology.

Jansson, P- E. 1996. Simulation Model for Soil Water and Heat Conditions. Uppsala: Swedish University of Agricultural Sciences. Department of Soil Sciences. Division of Agricultural Hydrotechnics. Communications 94: 3.

Kutilek, M. & Nielsen, D. R. 1994. Soil Hydrology. Cremlingen: Catena Verlag.

Langham, E. J. 1981. Physics and Properties of Snow Cover. In: Gray D. M. & Male, D. H. (eds.). Handbook of Snow. Pergamon Press. p 275- 329.

Miller, D. R. 1974. Sensitivity Analysis and Validation of Simulation Models. Journal of Theoretical Biology vol. 48. p 345- 360.

Stähli, M. & Jansson, P- E. 1997. Thermal dynamics at the snow surface and its impact on the simulation of water flows in the frozen soil, manuscript. Uppsala: Swedish University of Agricultural Sciences. Department of Soil Sciences. Division of Biogeophysics.

Todd, D. K. 1980. Ground Water Hydrology. Berkeley: University of California.

Wiklert, P. , Andersson, S. & Weidow, B. (Bearbetning och publicering: Karlsson, I. och Håkansson, A.) 1983. Studier av Markprofiler i Svenska Åkerjordar, del 1. Ultunajordar. Uppsala: Swedish University of Agricultural Sciences. Department of Soil Sciences. Division of Hydrotechnics. Report 132, 128 p.

Literature not referred to in the text but necessary for the running of the model:

Jansson, P- E. 1995. PLOTPF User's Manual. Uppsala: Swedish University of Agricultural Sciences. Department of Soil Sciences. Division of Biogeophysics.

Jansson, P- E. 1996. Soil Model (ver. 9.35) User's Manual. Uppsala: Swedish University of Agricultural Sciences. Department of Soil Sciences. Division of Biogeophysics.

Jansson, P- E. 1996. Pgraph v1.3 User's manual. Uppsala: Swedish University of Agricultural Sciences. Department of Soil Sciences. Division of Biogeophysics.

APPENDIX

Presented here is a summary of the parameter file used in all the simulations. Listed are all parameter values and output values.

```
# ---------------------------------------------------------------------------
# SOIL_001.SUM Wed Mar 12 12:45:29 1997
# ---------------------------------------------------------------------------
# ---------------------------------------------------------------------------
# Switches
# ---------------------------------------------------------------------------
  ADDSIM              OFF   ALBEDOV             OFF   ATIRRIG             OFF
  AVERAGED             ON   AVERAGEG             ON   AVERAGET             ON
  AVERAGEX             ON   CHAPAR              OFF   CRACK                ON
  DDAILY              OFF   DRIVDRAIN           OFF   DRIVPG                1
  EVAPOTR               3   FRINTERA             ON   FRLIMINF              1
  FRLIMUF              ON   FRLOADP              ON   FRPREFL              ON
  FRSWELL              ON   FURROW                0   GWFLOW                3
  HEATEQ               ON   HEATPUMP              0   HEATWF              OFF
  HYSTERES              3   INHEAT                0   INSTATE             OFF
  INTERCEPT            ON   INWATER               1   LISALLV              ON
  NETLSURF            OFF   NUMMETHOD           OFF   OUTFORN             OFF
  OUTSTATE            OFF   PLANTDEV            OFF   ROOTDIST              3
  ROUGHNESS             0   RSCALC                2   SALT                OFF
  SNOW                  1   SUREBAL               2   UNITG                 4
  UNITPOT             OFF   VALIDPG             OFF   VAPOUR                2
  VISALLOUT           OFF   WATEREQ              ON   WUPTAKE               2
# ---------------------------------------------------------------------------
# Parameters
# ---------------------------------------------------------------------------

# Initial conditions --------------------------------------------------------

  IGWLEV             -2.2   IPOT                100   ITEMPS                7

# Soil profile --------------------------------------------------------------

  NUMLAY               22   THICK(1)           0.05   THICK(2)           0.05
  THICK(3)           0.05   THICK(4)           0.05   THICK(5)           0.05
  THICK(6)           0.05   THICK(7)            0.1   THICK(8)            0.1
  THICK(9)            0.1   THICK(10)           0.1   THICK(11)           0.1
  THICK(12)           0.1   THICK(13)           0.1   THICK(14)           0.2
  THICK(15)           0.2   THICK(16)           0.2   THICK(17)           0.2
  THICK(18)           0.2   THICK(19)           0.5   THICK(20)           0.5
  THICK(21)           0.5   THICK(22)           0.5   UNUM                 11
  UPROF                48   UTHICK(1)             0   VC                    1

# Soil properties -----------------------------------------------------------

  A0T                0.54   A1T               0.023   ASCALE              0.5
  ASCALEL               0   DNOTVAP       2.29e-005   DVAPB               1.5
  HYSKEXP             0.5   HYSMAX(1)            -1   HYSMAX(2)            -1
  HYSMAX(3)            -1   HYSMAX(4)            -1   HYSMAX(5)            -1
  HYSMAX(6)            -1   HYSMAX(7)            -1   HYSMAX(8)            -1
  HYSMAX(9)            -1   HYSMAX(10)           -1   HYSMAX(11)           -1
```

```
  HYSMAX(12)          -1   HYSMAX(13)          -1   HYSMAX(14)          -1
  HYSMAX(15)          -1   HYSMAX(16)          -1   HYSMAX(17)          -1
  HYSMAX(18)          -1   HYSMAX(19)          -1   HYSMAX(20)          -1
  HYSMAX(21)          -1   HYSMAX(22)          -1   HYSMAXC            0.5
  HYSPF(1)           1.5   HYSPF(2)             4   HYSTHETD           0.2
  HYSTHETM            10   MINUC           1e-012   SCALE(1)             0
  SCALE(2)             0   SCALE(3)             0   SCALE(4)             0
  SCALE(5)             0   SCALE(6)             0   SCALE(7)             0
  SCALE(8)             0   SCALE(9)             0   SCALE(10)            0
  SCALE(11)            0   SCALE(12)            0   SCALE(13)            0
  SCALE(14)            0   SCALE(15)            0   SCALE(16)            0
  SCALE(17)            0   SCALE(18)            0   SCALE(19)            0
  SCALE(20)            0   SCALE(21)            0   SCALE(22)            0
  SCALECOND            0

# Numerical --------------------------------------------------------------

  XADIV                2   XLOOP                1   XNLEV                2

# Driving variables ------------------------------------------------------

  ANGSTR(1)         0.22   ANGSTR(2)          0.5   BRUNT(1)          0.56
  BRUNT(2)       0.00779   BRUNT(3)           0.1   BRUNT(4)           0.9
  CNUMD                1   HEIGHT               2   PRECA0            1.07
  PRECA1            0.08   SIFRAC               0   SOILCOVER            0
  YCH             365.25   YPHAS                0   YTAM                10
  YTAMP               10

# Evapotranspiration -----------------------------------------------------

  ALBEDO              20   CONDMAX           0.02   CONDRIS         5e+006
  CONDVPD            100   DAYNUM(1)           50   DAYNUM(2)            0
  DAYNUM(3)            0   DAYNUM(4)            0   DAYNUM(5)            0
  DISPLV(1)          0.1   INTLAI             0.2   INTRS                2
  LAIV(1)            0.1   LATID             58.5   ROUGHV(1)         0.01

# Water uptake -----------------------------------------------------------

  RFRACLOW          0.05   ROOTDEP(1)        -0.1   ROOTDEP(2)        -0.8
  ROOTDEP(3)        -1.2   ROOTT(1)           121   ROOTT(2)           180
  ROOTT(3)           250   ROOTT(4)           260   UPMOV              0.5
  WUPATE             0.8   WUPBTE             0.4   WUPCRI             400
  WUPCRISAT            1   WUPF               0.2   WUPFB                0
  WUPREDSAT            0

# Ground water and surface pool ------------------------------------------

  DDIST               20   DDIST2            4.25   DDRAIN              -1
  DDRAIN2             -4   DLAYER               3   GFLEV(1)            -3
  GFLEV(2)            -2   GFLOW(1)             0   GFLOW(2)             0
  GWSOF                0   GWSOL                3   RPIPE             0.15
  SPCOVTOT            50   SPOOLMAX          0.01   SURDEL             0.8

# Surface E-balance ------------------------------------------------------

  ALBDRY              30   ALBKEXP              1   ALBWET              15
  ARICH               16   EGPSI                1   MAXNEGEG          -0.5
  RALAI               50   RNTLAI             0.5   SURFDEF             -2
```

```
  SURFEXC              1

# Thermal properties ------------------------------------------------------------

  GEOTER              10   HUMUS                  1   THSCALE(1)            1
  THSCALE(2)           1   THSCALE(3)             1   THSCALE(4)            1
  THSCALE(5)           1   THSCALE(6)             1   THSCALE(7)            1
  THSCALE(8)           1   THSCALE(9)             1   THSCALE(10)           1
  THSCALE(11)          1   THSCALE(12)            1   THSCALE(13)           1
  THSCALE(14)          1   THSCALE(15)            1   THSCALE(16)           1
  THSCALE(17)          1   THSCALE(18)            1   THSCALE(19)           1
  THSCALE(20)          1   THSCALE(21)            1   THSCALE(22)           1

# Frost -------------------------------------------------------------------------

  ALPHAHT           0.11   FCOND                  0   FDF                  20
  FDF0                 0   FWFRAC               0.5   MAXSWELL           0.05
  SHRINKR          0.001

# Snow --------------------------------------------------------------------------

  CCSNOW            0.02   PRLIM                  2   PSLIM                 0
  SAGEM1               2   SAGEM2               0.1   SAGEZP                5
  SAGEZQ             0.9   SD1OL                200   SD2OM               0.5
  SDENS              100   SLWL0                  3   SMAFR               0.1
  SMELTG               0   SMRIS            1.5e-007  SMTEM                 2
  SRET              0.07   STCON           2.86e-006

# Plotting on line --------------------------------------------------------------

  PMAX                20   XTGD                   0
# -------------------------------------------------------------------------------
# Control variables
# -------------------------------------------------------------------------------
  STARTDAT       "1996-11-12 13:30"
  ENDDAT         "1997-02-21 13:30"
  OUTINTD              0
  OUTINTM             60
  NUMITER            768
  RUNID          ""
# -------------------------------------------------------------------------------
# Selected output variables
# -------------------------------------------------------------------------------

# Flow variables ----------------------------------------------------------------

  WFLOW          [5]

# Auxiliary variables -----------------------------------------------------------

  BYPASS         [5]
  PIPEQ          [1]
  SATLEV         [1]
  TEMP           [1-22]
  THETA          [5]
# -------------------------------------------------------------------------------
# Files
# -------------------------------------------------------------------------------
```

```
# Driving variable file ---------------------------------------------------------
  FILE(1)   WIN_9697.BIN
# Parameter file ----------------------------------------------------------------
  FILE(2)   FINAL.PAR
# Translation file --------------------------------------------------------------
  FILE(3)   SOIL.TRA
# Hydraulic soil properties -----------------------------------------------------
  FILE(8)   ULT19701.DAT
# Thermal soil properties -------------------------------------------------------
  FILE(9)   THCOEF.DAT

;

 Driving variable file : WIN_9697     5 variables in  5402 records
 From 19960709-1330  to  19970221-1330

Air temperature     oC                          MEAN
Relative humidity   %                           MEAN
Wind speed          m/s                         MEAN
Precipitation       mm/day                      TRS1
Global radiation    J/m2/day                    MEAN
No        soil        parameters        found        in        file        :
ULT19701.DAT
The data file contains profile:  48: 50Your profile was: 48: 11
Values of UPROF and UNUM has changed to: 48: 50

 Distribution of groundwater flow to pipes within D-layer
 Depth - Horisontal Radial Vertical & total resistances (days)
 ------------------------------------------------------------
    95.   50173.6   79466.6     416.7  130056.9
   110.   50179.7   79466.6    1250.0  130896.3
   130.   50325.2   79466.6    2083.3  131875.2
   150.   50664.1   79466.6    2916.7  133047.4
   170.   51194.5   79466.6    3750.0  134411.1
   190.   51913.5   79466.6    4583.3  135963.4
   225.   54506.1   79466.6    6666.7  140639.4
   275.   58145.6   79466.6    8750.0  146362.2
   325.   62664.2   79466.6   10833.3  152964.2
   375.   67819.5   79466.6   12916.7  160202.8

 The Brooks & Corey equation will be used for soil properties

      SOIL IDENTIFICATION: ULTUNA          50     C 48   6634740/1603660  40

      SOIL PARAMETERS AT BOUNDARIES BETWEEN LAYERS
    DEPTH     N     SATC    SATCT LAMBDA RESIDAL PORO   PSIE   BLB    TCON   TCONF
 -------------------------------------------------------------------------------
      5.0   1.0    888.0    888.0    .46   24.1    53.7    2.5    4.0     .2     .2
     10.0   1.0    974.5    974.5    .57   26.9    50.9    4.5    4.0     .2     .2
     15.0   1.0   1082.5   1082.5    .71   30.3    47.5    6.8    4.0     .2     .3
     20.0   1.0    810.3    810.3    .49   26.7    44.5    4.9    4.0     .2     .3
     25.0   1.0    486.3    486.3    .19   21.5    41.5    2.1    4.0     .2     .3
     30.0   1.0    424.0    424.0    .12   19.6    40.8    2.4    4.0     .2     .3
     40.0   1.0    498.3    498.3    .16   22.9    42.9    3.6    4.0     .2     .3
     50.0   1.0    956.3    956.3    .19   28.7    47.5    2.6    4.0     .2     .3
     60.0   1.0    734.0    734.0    .10   14.9    49.9    5.4    4.0     .3     .3
     70.0   1.0    108.0    108.0    .07   16.6    49.3    7.7    4.0     .3     .4
     80.0   1.0    144.0    144.0    .07   24.2    48.8    3.6    4.0     .3     .4
```

90.0	1.0	132.1	132.1	.03	8.1	46.8	2.9	4.0	.3	.4
100.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	.7	1.0
120.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.3	2.1
140.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.3	2.1
160.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.3	2.1
180.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.3	2.1
200.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.3	2.1
250.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.4	2.2
300.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.4	2.2
350.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.4	2.2
400.0	1.0	.2	.2	.02	.4	44.6	5.3	4.0	1.4	2.2

SOIL PARAMETERS IN THE MIDDLE OF LAYERS

DEPTH	ROOTF	LAMBDA	RESIDAL	PORO	PSIE	WILTP	BUB	BLB	HCAP	HCAPI
2.5	.12	.46	24.1	53.7	2.5	18.2	10000.	4.	2.17	1.49
7.5	.11	.46	24.1	53.7	2.5	18.2	10000.	4.	2.17	1.49
12.5	.10	.69	29.8	48.0	6.4	21.1	10000.	4.	2.41	1.66
17.5	.08	.73	30.9	46.9	7.2	21.7	10000.	4.	2.46	1.69
22.5	.07	.25	22.6	42.1	2.7	22.2	10000.	4.	2.44	1.74
27.5	.07	.13	20.5	40.9	1.5	22.3	10000.	4.	2.54	1.80
35.0	.11	.11	17.7	40.6	4.0	24.7	10000.	4.	2.61	1.83
45.0	.09	.21	28.1	45.1	3.1	25.7	10000.	4.	2.62	1.79
55.0	.07	.17	29.4	50.0	2.1	30.8	10000.	4.	2.69	1.77
65.0	.05	.03	.4	49.9	8.6	34.6	10000.	4.	2.94	1.88
75.0	.00	.10	32.7	48.7	6.8	35.2	10000.	4.	2.91	1.88
85.0	.00	.03	15.8	48.9	.5	32.5	10000.	4.	2.87	1.86
95.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.86	1.90
110.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.86	1.90
130.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.86	1.90
150.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.87	1.91
170.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.88	1.91
190.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.89	1.92
225.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.98	1.96
275.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.98	1.96
325.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.98	1.96
375.0	.00	.02	.4	44.6	5.3	30.2	10000.	4.	2.98	1.96

State Variables

Number	Variable	Initial	Final	Min	Max	Mean	Cumulated
1	WATER(1)	1.48E+01	1.77E+01	1.47E+01	2.09E+01	1.91E+01	1.93E+03
2	WATER(2)	1.48E+01	1.78E+01	1.48E+01	2.16E+01	1.80E+01	1.82E+03
3	WATER(3)	1.63E+01	2.03E+01	1.63E+01	2.05E+01	1.94E+01	1.96E+03
4	WATER(4)	1.66E+01	2.19E+01	1.65E+01	2.28E+01	2.08E+01	2.10E+03
5	WATER(5)	1.52E+01	1.68E+01	1.47E+01	1.94E+01	1.69E+01	1.71E+03
6	WATER(6)	1.62E+01	1.71E+01	1.61E+01	1.96E+01	1.76E+01	1.78E+03
7	WATER(7)	3.38E+01	3.69E+01	3.38E+01	4.06E+01	3.73E+01	3.76E+03
8	WATER(8)	3.63E+01	3.88E+01	3.63E+01	4.51E+01	4.03E+01	4.07E+03
9	WATER(9)	4.03E+01	4.28E+01	3.99E+01	5.00E+01	4.37E+01	4.42E+03
10	WATER(10)	4.62E+01	4.73E+01	4.60E+01	4.99E+01	4.76E+01	4.81E+03
11	WATER(11)	4.49E+01	4.66E+01	4.48E+01	4.87E+01	4.69E+01	4.74E+03
12	WATER(12)	4.40E+01	4.79E+01	4.40E+01	4.90E+01	4.72E+01	4.77E+03
13	WATER(13)	4.17E+01	4.46E+01	4.17E+01	4.48E+01	4.42E+01	4.46E+03
14	WATER(14)	8.35E+01	8.85E+01	8.35E+01	8.92E+01	8.73E+01	8.82E+03
15	WATER(15)	8.36E+01	8.58E+01	8.36E+01	8.92E+01	8.72E+01	8.81E+03
16	WATER(16)	8.39E+01	8.54E+01	8.39E+01	8.92E+01	8.78E+01	8.87E+03
17	WATER(17)	8.43E+01	8.54E+01	8.43E+01	8.92E+01	8.84E+01	8.93E+03
18	WATER(18)	8.50E+01	8.74E+01	8.46E+01	8.92E+01	8.89E+01	8.98E+03

19	WATER(19)	2.23E+02	2.23E+02	2.22E+02	2.23E+02	2.23E+02	2.25E+04
20	WATER(20)	2.23E+02	2.23E+02	2.23E+02	2.23E+02	2.23E+02	2.25E+04
21	WATER(21)	2.23E+02	2.23E+02	2.23E+02	2.23E+02	2.23E+02	2.25E+04
22	WATER(22)	2.23E+02	2.23E+02	2.23E+02	2.23E+02	2.23E+02	2.25E+04
23	HEAT(1)	7.56E+05	-3.77E+06	-6.81E+06	7.56E+05	-4.44E+06	-4.49E+08
24	HEAT(2)	7.58E+05	-4.43E+06	-5.99E+06	7.58E+05	-3.80E+06	-3.84E+08
25	HEAT(3)	8.42E+05	-5.14E+06	-6.21E+06	8.42E+05	-3.47E+06	-3.50E+08
26	HEAT(4)	8.60E+05	-5.63E+06	-6.34E+06	8.60E+05	-3.47E+06	-3.50E+08
27	HEAT(5)	8.53E+05	-3.68E+06	-4.11E+06	8.54E+05	-1.75E+06	-1.77E+08
28	HEAT(6)	8.89E+05	-3.09E+06	-3.64E+06	8.89E+05	-9.58E+05	-9.68E+07
29	HEAT(7)	1.83E+06	-1.75E+06	-1.75E+06	1.83E+06	3.44E+05	3.47E+07
30	HEAT(8)	1.84E+06	2.79E+05	2.78E+05	1.84E+06	6.80E+05	6.87E+07
31	HEAT(9)	1.88E+06	5.53E+05	5.32E+05	1.88E+06	9.19E+05	9.28E+07
32	HEAT(10)	2.06E+06	8.48E+05	8.36E+05	2.06E+06	1.18E+06	1.19E+08
33	HEAT(11)	2.04E+06	1.09E+06	1.08E+06	2.04E+06	1.38E+06	1.39E+08
34	HEAT(12)	2.01E+06	1.35E+06	1.31E+06	2.04E+06	1.57E+06	1.59E+08
35	HEAT(13)	2.00E+06	1.57E+06	1.57E+06	2.04E+06	1.73E+06	1.75E+08
36	HEAT(14)	4.00E+06	3.44E+06	3.42E+06	4.00E+06	3.68E+06	3.71E+08
37	HEAT(15)	4.01E+06	3.57E+06	3.57E+06	4.01E+06	3.82E+06	3.86E+08
38	HEAT(16)	4.02E+06	3.76E+06	3.76E+06	4.10E+06	3.99E+06	4.03E+08
39	HEAT(17)	4.03E+06	3.95E+06	3.95E+06	4.23E+06	4.15E+06	4.19E+08
40	HEAT(18)	4.05E+06	4.21E+06	4.05E+06	4.39E+06	4.30E+06	4.35E+08
41	HEAT(19)	1.04E+07	1.15E+07	1.04E+07	1.17E+07	1.14E+07	1.15E+09
42	HEAT(20)	1.04E+07	1.26E+07	1.04E+07	1.27E+07	1.24E+07	1.25E+09
43	HEAT(21)	1.04E+07	1.37E+07	1.04E+07	1.38E+07	1.35E+07	1.36E+09
44	HEAT(22)	1.49E+07	1.48E+07	1.43E+07	1.49E+07	1.48E+07	1.49E+09
45	PLANT	1.03E-05	1.48E-02	1.03E-05	1.48E-02	1.34E-02	1.36E+00
46	STREAM	1.72E-04	7.05E+01	1.72E-04	7.05E+01	3.84E+01	3.88E+03
48	HSNOW	0.00E+00	0.00E+00	0.00E+00	1.44E-01	2.74E-02	2.77E+00
49	WSNOW	0.00E+00	0.00E+00	0.00E+00	1.57E+01	4.68E+00	4.73E+02
50	WATP(1)	0.00E+00	0.00E+00	-7.18E-17	4.54E+00	1.44E-01	1.45E+01
51	WATP(2)	0.00E+00	0.00E+00	-1.45E-19	3.01E+00	6.25E-02	6.31E+00
52	WATP(3)	0.00E+00	0.00E+00	-1.27E-19	2.36E+00	1.09E-01	1.10E+01
53	WATP(4)	0.00E+00	0.00E+00	-5.78E-19	7.36E-03	1.05E-04	1.06E-02
54	WATP(5)	0.00E+00	0.00E+00	-1.39E-19	1.32E+00	1.50E-02	1.51E+00
55	WATP(6)	0.00E+00	0.00E+00	-1.17E-19	1.09E+00	2.09E-02	2.11E+00
56	WATP(7)	0.00E+00	0.00E+00	-3.85E-20	9.46E-01	7.89E-03	7.97E-01

-------------------- Flow Variables -----------------------------------

Number	Variable	Initial	Final	Min	Max	Mean	Cumulated
72	WFLOW(1)	2.36E-03	5.23E-02	-1.18E+00	4.15E+02	1.55E-01	1.56E+01
73	WFLOW(2)	7.24E-03	3.38E-02	-3.03E+01	3.92E+02	6.05E-01	6.11E+01
74	WFLOW(3)	1.20E-02	-6.59E-03	-1.62E+01	3.61E+02	5.65E-01	5.71E+01
75	WFLOW(4)	8.45E-02	6.83E-03	-2.78E+00	3.30E+02	8.61E-01	8.70E+01
76	WFLOW(5)	2.45E-02	-1.62E-02	-1.80E+00	3.17E+02	8.46E-01	8.55E+01
77	WFLOW(6)	3.47E-02	-1.08E-02	-1.99E+00	3.06E+02	8.36E-01	8.45E+01
78	WFLOW(7)	1.60E-01	-2.76E-02	-5.00E+00	2.88E+02	9.44E-01	9.53E+01
79	WFLOW(8)	6.53E-02	1.19E-02	-5.00E+00	2.56E+02	9.31E-01	9.41E+01
80	WFLOW(9)	3.52E+00	6.27E-02	-5.00E+00	1.51E+02	8.88E-01	8.97E+01
81	WFLOW(10)	1.20E+00	8.11E-02	-1.41E+01	1.31E+02	8.73E-01	8.81E+01
82	WFLOW(11)	1.36E-01	3.68E-01	-2.11E+01	1.28E+02	8.44E-01	8.52E+01
83	WFLOW(12)	1.43E-02	-1.63E+01	-3.53E+01	1.35E+02	7.88E-01	7.96E+01
84	WFLOW(13)	1.66E-04	1.59E-01	-2.13E-03	1.81E+02	7.51E-01	7.58E+01
85	WFLOW(14)	8.99E-05	6.89E-02	-1.39E-03	1.83E+02	7.01E-01	7.08E+01
86	WFLOW(15)	-5.05E-07	1.83E-03	-1.84E-02	1.53E+02	6.78E-01	6.85E+01
87	WFLOW(16)	-4.72E-07	1.32E-03	-1.63E-02	1.62E+02	6.63E-01	6.70E+01
88	WFLOW(17)	-4.18E-07	8.55E-04	-1.28E-02	1.52E+02	6.52E-01	6.58E+01
89	WFLOW(18)	2.65E-01	3.45E-01	-5.75E-04	4.06E+02	6.28E-01	6.34E+01

90	WFLOW(19)	2.65E-01	3.45E-01	2.45E-01	1.12E+00	6.28E-01	6.34E+01
91	WFLOW(20)	2.65E-01	3.45E-01	2.45E-01	1.12E+00	6.28E-01	6.34E+01
92	WFLOW(21)	2.65E-01	3.45E-01	2.45E-01	1.12E+00	6.28E-01	6.34E+01
93	EFLOW(1)	0.00E+00	8.00E+05	-4.42E+06	1.70E+06	-5.08E+05	-5.13E+07
94	EFLOW(2)	0.00E+00	3.35E+05	-3.28E+06	5.57E+05	-4.57E+05	-4.62E+07
95	EFLOW(3)	0.00E+00	3.09E+04	-2.40E+06	1.08E+05	-3.98E+05	-4.02E+07
96	EFLOW(4)	0.00E+00	-1.06E+05	-1.87E+06	3.48E+04	-3.34E+05	-3.37E+07
97	EFLOW(5)	0.00E+00	-2.87E+05	-1.44E+06	0.00E+00	-2.89E+05	-2.92E+07
98	EFLOW(6)	0.00E+00	-4.79E+05	-8.82E+05	0.00E+00	-2.49E+05	-2.52E+07
99	EFLOW(7)	0.00E+00	-2.43E+05	-2.94E+05	1.94E+01	-2.14E+05	-2.16E+07
100	EFLOW(8)	0.00E+00	-2.35E+05	-2.59E+05	0.00E+00	-1.98E+05	-2.00E+07
101	EFLOW(9)	0.00E+00	-2.25E+05	-2.42E+05	1.71E+03	-1.85E+05	-1.87E+07
102	EFLOW(10)	0.00E+00	-2.16E+05	-2.30E+05	2.88E+03	-1.73E+05	-1.75E+07
103	EFLOW(11)	0.00E+00	-2.08E+05	-2.22E+05	3.07E+04	-1.64E+05	-1.66E+07
104	EFLOW(12)	0.00E+00	-2.01E+05	-2.17E+05	1.61E+04	-1.57E+05	-1.59E+07
105	EFLOW(13)	0.00E+00	-2.00E+05	-2.15E+05	0.00E+00	-1.53E+05	-1.55E+07
106	EFLOW(14)	-6.43E-01	-1.98E+05	-2.10E+05	2.23E+04	-1.48E+05	-1.49E+07
107	EFLOW(15)	-1.24E+00	-1.97E+05	-2.05E+05	8.26E+04	-1.43E+05	-1.45E+07
108	EFLOW(16)	-1.15E+00	-1.95E+05	-1.98E+05	3.40E+04	-1.41E+05	-1.42E+07
109	EFLOW(17)	-1.04E+00	-1.93E+05	-2.12E+05	7.38E+04	-1.40E+05	-1.41E+07
110	EFLOW(18)	-4.79E-01	-1.81E+05	-1.86E+05	1.49E+03	-1.41E+05	-1.43E+07
111	EFLOW(19)	0.00E+00	-1.78E+05	-1.78E+05	0.00E+00	-1.52E+05	-1.53E+07
112	EFLOW(20)	0.00E+00	-1.75E+05	-2.11E+05	0.00E+00	-1.73E+05	-1.75E+07
113	EFLOW(21)	-6.93E+05	-1.71E+05	-6.93E+05	-1.53E+05	-2.06E+05	-2.08E+07
114	WUPRATE(1)	7.12E-03	8.86E-05	0.00E+00	1.12E-02	6.26E-05	6.32E-03
115	WUPRATE(2)	1.59E-03	0.00E+00	0.00E+00	2.41E-03	2.14E-05	2.16E-03
124	DRIVF	-2.64E+06	4.12E+06	-7.35E+06	6.98E+06	-5.53E+05	-5.59E+07
125	INFIL	0.00E+00	0.00E+00	0.00E+00	4.38E+02	1.17E+00	1.19E+02
126	EVAG	1.27E+00	1.34E+00	-5.00E-01	6.46E+00	-6.06E-04	-6.12E-02
129	DFLOW(3)	0.00E+00	0.00E+00	0.00E+00	7.90E-02	5.26E-06	5.31E-04
130	DFLOW(4)	0.00E+00	7.64E-06	0.00E+00	4.22E-02	3.29E-04	3.32E-02
132	DFLOW(6)	0.00E+00	0.00E+00	0.00E+00	3.79E-03	2.41E-05	2.43E-03
133	DFLOW(7)	0.00E+00	0.00E+00	0.00E+00	5.26E-02	1.02E-03	1.03E-01
134	DFLOW(8)	0.00E+00	0.00E+00	0.00E+00	2.21E-01	9.11E-03	9.20E-01
135	DFLOW(9)	0.00E+00	0.00E+00	0.00E+00	2.66E-01	1.80E-02	1.82E+00
136	DFLOW(10)	0.00E+00	0.00E+00	0.00E+00	5.40E-02	4.86E-03	4.91E-01
137	DFLOW(11)	0.00E+00	0.00E+00	0.00E+00	9.25E-02	1.15E-02	1.16E+00
138	DFLOW(12)	0.00E+00	0.00E+00	0.00E+00	1.04E-01	1.66E-02	1.67E+00
139	DFLOW(13)	0.00E+00	4.24E-02	0.00E+00	1.84E-01	8.49E-03	8.58E-01
140	DFLOW(14)	0.00E+00	0.00E+00	0.00E+00	2.42E-04	3.69E-05	3.73E-03
141	DFLOW(15)	0.00E+00	0.00E+00	0.00E+00	2.42E-04	3.70E-05	3.73E-03
142	DFLOW(16)	0.00E+00	0.00E+00	0.00E+00	2.41E-04	3.69E-05	3.73E-03
143	DFLOW(17)	0.00E+00	0.00E+00	0.00E+00	2.40E-04	3.68E-05	3.72E-03
144	DFLOW(18)	0.00E+00	0.00E+00	0.00E+00	4.18E-04	6.42E-05	6.48E-03
145	DFLOW(19)	0.00E+00	0.00E+00	0.00E+00	5.85E-04	8.98E-05	9.07E-03
146	DFLOW(20)	0.00E+00	0.00E+00	0.00E+00	5.74E-04	8.81E-05	8.90E-03
147	DFLOW(21)	0.00E+00	0.00E+00	0.00E+00	5.62E-04	8.63E-05	8.72E-03
148	DFLOW(22)	0.00E+00	0.00E+00	0.00E+00	1.16E-02	1.76E-03	1.78E-01
152	DEEPPERC	2.65E-01	3.45E-01	2.45E-01	1.11E+00	6.26E-01	6.32E+01
153	WFLOWP(1)	0.00E+00	0.00E+00	0.00E+00	2.39E+01	5.10E-01	5.15E+01
154	WFLOWP(2)	0.00E+00	0.00E+00	0.00E+00	2.38E+01	5.10E-01	5.15E+01
155	WFLOWP(3)	0.00E+00	0.00E+00	0.00E+00	1.13E+01	1.61E-01	1.63E+01
156	WFLOWP(4)	0.00E+00	0.00E+00	0.00E+00	1.13E+01	1.61E-01	1.63E+01
157	WFLOWP(5)	0.00E+00	0.00E+00	0.00E+00	1.25E+01	1.61E-01	1.63E+01
158	WFLOWP(6)	0.00E+00	0.00E+00	0.00E+00	2.83E+00	2.15E-02	2.18E+00
174	WFLOWPN(1)	0.00E+00	0.00E+00	-1.10E-13	5.60E+01	4.80E-01	4.85E+01
175	WFLOWPN(2)	0.00E+00	0.00E+00	-2.56E-54	8.65E-22	5.78E-26	5.84E-24
176	WFLOWPN(3)	0.00E+00	0.00E+00	-1.09E-32	2.36E+01	3.49E-01	3.52E+01

177	WFLOWPN(4)	0.00E+00	0.00E+00	-5.88E-54	1.52E-21	6.17E-25	6.23E-23
178	WFLOWPN(5)	0.00E+00	0.00E+00	-3.52E-55	9.74E-23	5.34E-27	5.39E-25
179	WFLOWPN(6)	0.00E+00	0.00E+00	-9.23E-20	1.21E+01	1.39E-01	1.41E+01
180	WFLOWPN(7)	0.00E+00	0.00E+00	-7.69E-18	1.78E+00	2.15E-02	2.18E+00
216	INFREEZE(1)	0.00E+00	0.00E+00	-3.08E-16	2.11E+03	1.39E-02	1.40E+00
217	INFREEZE(2)	0.00E+00	0.00E+00	-2.22E-16	2.60E-03	3.23E-05	3.27E-03
218	INFREEZE(3)	0.00E+00	0.00E+00	-1.96E-16	7.90E-02	1.97E-04	1.99E-02
219	INFREEZE(4)	0.00E+00	0.00E+00	-8.88E-16	4.22E-02	4.30E-05	4.34E-03
220	INFREEZE(5)	0.00E+00	0.00E+00	-2.13E-16	6.94E-03	6.14E-05	6.21E-03
221	INFREEZE(6)	0.00E+00	0.00E+00	-1.80E-16	3.35E-03	2.27E-05	2.29E-03
222	INFREEZE(7)	0.00E+00	0.00E+00	-5.92E-17	6.23E-05	3.83E-08	3.87E-06

--------------------Auxiliary Variables ------------------------------------

Number	Variable	Initial	Final	Min	Max	Mean	Cumulated
238	TEMP(1)	7.00E+00	-3.71E-01	-2.52E+01	7.00E+00	-3.11E+00	-3.14E+02
239	TEMP(2)	7.00E+00	-1.77E+00	-1.69E+01	7.00E+00	-2.16E+00	-2.18E+02
240	TEMP(3)	7.00E+00	-2.25E+00	-1.14E+01	7.00E+00	-1.29E+00	-1.30E+02
241	TEMP(4)	7.00E+00	-2.33E+00	-7.78E+00	7.00E+00	-5.83E-01	-5.89E+01
242	TEMP(5)	7.00E+00	-2.10E+00	-5.01E+00	7.00E+00	6.27E-02	6.33E+00
243	TEMP(6)	7.00E+00	-1.54E+00	-2.77E+00	7.00E+00	6.69E-01	6.76E+01
244	TEMP(7)	7.00E+00	-2.62E-02	-2.62E-02	7.00E+00	1.49E+00	1.51E+02
245	TEMP(8)	7.00E+00	1.02E+00	1.02E+00	7.00E+00	2.42E+00	2.45E+02
246	TEMP(9)	7.00E+00	1.97E+00	1.95E+00	7.01E+00	3.22E+00	3.25E+02
247	TEMP(10)	7.00E+00	2.84E+00	2.83E+00	7.01E+00	3.93E+00	3.97E+02
248	TEMP(11)	7.00E+00	3.66E+00	3.66E+00	7.00E+00	4.59E+00	4.63E+02
249	TEMP(12)	7.00E+00	4.46E+00	4.46E+00	7.00E+00	5.22E+00	5.27E+02
250	TEMP(13)	7.00E+00	5.26E+00	5.26E+00	7.00E+00	5.84E+00	5.90E+02
251	TEMP(14)	7.00E+00	5.79E+00	5.79E+00	7.00E+00	6.25E+00	6.32E+02
252	TEMP(15)	7.00E+00	6.13E+00	6.13E+00	7.00E+00	6.51E+00	6.57E+02
253	TEMP(16)	7.00E+00	6.48E+00	6.48E+00	7.00E+00	6.75E+00	6.82E+02
254	TEMP(17)	7.00E+00	6.81E+00	6.81E+00	7.09E+00	6.99E+00	7.06E+02
255	TEMP(18)	7.00E+00	7.15E+00	6.88E+00	7.36E+00	7.23E+00	7.31E+02
256	TEMP(19)	7.00E+00	7.69E+00	7.00E+00	7.83E+00	7.66E+00	7.74E+02
257	TEMP(20)	7.00E+00	8.45E+00	7.00E+00	8.53E+00	8.31E+00	8.39E+02
258	TEMP(21)	7.00E+00	9.20E+00	7.00E+00	9.24E+00	9.05E+00	9.14E+02
259	TEMP(22)	9.97E+00	9.93E+00	9.59E+00	1.00E+01	9.93E+00	1.00E+03
260	THQUAL(1)	0.00E+00	6.32E-01	0.00E+00	7.73E-01	6.45E-01	6.52E+01
261	THQUAL(2)	0.00E+00	7.16E-01	0.00E+00	7.51E-01	6.00E-01	6.06E+01
262	THQUAL(3)	0.00E+00	7.23E-01	0.00E+00	7.40E-01	5.06E-01	5.11E+01
263	THQUAL(4)	0.00E+00	7.35E-01	0.00E+00	7.51E-01	4.67E-01	4.72E+01
264	THQUAL(5)	0.00E+00	6.17E-01	0.00E+00	6.41E-01	3.22E-01	3.25E+01
265	THQUAL(6)	0.00E+00	5.11E-01	0.00E+00	5.83E-01	1.83E-01	1.84E+01
266	THQUAL(7)	0.00E+00	1.41E-01	0.00E+00	1.41E-01	5.79E-03	5.85E-01
282	THETA(1)	2.95E+01	1.31E+01	9.10E+00	4.19E+01	1.34E+01	1.36E+03
283	THETA(2)	2.95E+01	1.01E+01	9.10E+00	4.33E+01	1.45E+01	1.46E+03
284	THETA(3)	3.26E+01	1.13E+01	1.06E+01	4.11E+01	1.88E+01	1.89E+03
285	THETA(4)	3.32E+01	1.16E+01	1.08E+01	4.11E+01	2.12E+01	2.15E+03
286	THETA(5)	3.05E+01	1.29E+01	1.20E+01	3.88E+01	2.32E+01	2.34E+03
287	THETA(6)	3.23E+01	1.68E+01	1.43E+01	3.92E+01	2.88E+01	2.91E+03
288	THETA(7)	3.38E+01	3.17E+01	3.17E+01	4.06E+01	3.71E+01	3.74E+03
289	THETA(8)	3.63E+01	3.88E+01	3.63E+01	4.51E+01	4.03E+01	4.07E+03
290	THETA(9)	4.03E+01	4.28E+01	3.99E+01	5.00E+01	4.37E+01	4.41E+03
291	THETA(10)	4.62E+01	4.73E+01	4.60E+01	4.99E+01	4.76E+01	4.81E+03
292	THETA(11)	4.49E+01	4.66E+01	4.48E+01	4.87E+01	4.69E+01	4.74E+03
293	THETA(12)	4.40E+01	4.79E+01	4.40E+01	4.90E+01	4.72E+01	4.77E+03
294	THETA(13)	4.17E+01	4.46E+01	4.17E+01	4.48E+01	4.42E+01	4.46E+03
295	THETA(14)	4.17E+01	4.43E+01	4.17E+01	4.46E+01	4.37E+01	4.41E+03
296	THETA(15)	4.18E+01	4.29E+01	4.18E+01	4.46E+01	4.36E+01	4.40E+03

297	THETA(16)	4.20E+01	4.27E+01	4.20E+01	4.46E+01	4.39E+01	4.44E+03
298	THETA(17)	4.22E+01	4.27E+01	4.22E+01	4.46E+01	4.42E+01	4.47E+03
299	THETA(18)	4.25E+01	4.37E+01	4.23E+01	4.46E+01	4.45E+01	4.49E+03
300	THETA(19)	4.46E+01	4.46E+01	4.44E+01	4.46E+01	4.46E+01	4.50E+03
301	THETA(20)	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.50E+03
302	THETA(21)	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.50E+03
303	THETA(22)	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.50E+03
304	PSI(1)	1.00E+02	1.37E+04	3.72E+00	3.16E+05	5.57E+04	5.63E+06
305	PSI(2)	1.00E+02	3.43E+04	5.77E+00	3.06E+05	7.76E+04	7.84E+06
306	PSI(3)	1.00E+02	1.75E+05	-2.19E+01	3.60E+05	1.32E+05	1.33E+07
307	PSI(4)	1.00E+02	-3.50E+01	-3.51E+01	3.98E+05	7.68E+04	7.75E+06
308	PSI(5)	1.00E+02	1.42E+05	4.90E+00	2.70E+05	4.49E+04	4.54E+06
309	PSI(6)	1.00E+02	4.08E+04	3.29E+00	1.60E+05	1.04E+04	1.06E+06
310	PSI(7)	1.00E+02	3.04E+02	-3.95E+00	3.04E+02	2.44E+01	2.47E+03
311	PSI(8)	1.00E+02	2.85E+01	-1.40E+01	1.01E+02	1.97E+01	1.99E+03
312	PSI(9)	1.00E+02	2.78E+01	-2.40E+01	1.24E+02	3.04E+01	3.07E+03
313	PSI(10)	1.00E+02	2.62E+01	-3.40E+01	1.24E+02	2.87E+01	2.90E+03
314	PSI(11)	1.00E+02	1.21E+01	-4.40E+01	1.05E+02	1.62E+01	1.64E+03
315	PSI(12)	1.00E+02	8.64E+00	-5.40E+01	1.00E+02	1.01E+01	1.02E+03
316	PSI(13)	1.00E+02	-4.24E-01	-6.40E+01	1.00E+02	-4.40E+00	-4.44E+02
317	PSI(14)	1.00E+02	1.71E+00	-7.90E+01	1.00E+02	-5.48E-02	-5.53E+00
318	PSI(15)	9.00E+01	1.48E+01	-9.90E+01	9.00E+01	-7.41E+00	-7.48E+02
319	PSI(16)	7.00E+01	2.06E+01	-1.19E+02	7.00E+01	-2.31E+01	-2.34E+03
320	PSI(17)	5.00E+01	2.03E+01	-1.39E+02	5.00E+01	-4.21E+01	-4.26E+03
321	PSI(18)	3.00E+01	4.38E+00	-1.59E+02	4.09E+01	-6.21E+01	-6.27E+03
322	PSI(19)	-5.00E+00	-3.06E+01	-1.94E+02	1.38E+00	-9.71E+01	-9.81E+03
323	PSI(20)	-5.50E+01	-8.06E+01	-2.44E+02	-4.86E+01	-1.47E+02	-1.49E+04
324	PSI(21)	-1.05E+02	-1.31E+02	-2.94E+02	-9.86E+01	-1.97E+02	-1.99E+04
325	PSI(22)	-1.55E+02	-1.81E+02	-3.44E+02	-1.49E+02	-2.47E+02	-2.50E+04
326	INTCAP	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.02E+00
327	INTERC	0.00E+00	0.00E+00	-4.01E-12	2.00E-02	5.03E-03	5.08E-01
328	EINTPOT	4.58E-02	1.57E-01	1.00E-03	8.66E-01	4.21E-02	4.25E+00
329	EACTI	0.00E+00	0.00E+00	-6.15E-09	2.38E-01	6.00E-03	6.06E-01
330	ISTORE	0.00E+00	0.00E+00	-4.01E-12	2.00E-02	5.03E-03	5.08E-01
331	RA	1.69E+02	5.09E+01	2.35E+01	3.28E+02	1.38E+02	1.39E+04
332	ROUGH	1.00E-02	1.00E-02	1.00E-02	1.00E-02	9.99E-03	1.01E+00
333	DISPL	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01
334	RS	1.00E+03	1.00E+03	9.01E+02	1.00E+03	9.99E+02	1.01E+05
335	WUPPOT	1.06E-02	1.37E-02	1.00E-03	4.29E-02	3.72E-03	3.76E-01
336	EACT	8.71E-03	8.86E-05	0.00E+00	1.36E-02	8.40E-05	8.48E-03
337	ETR	8.25E-01	6.45E-03	0.00E+00	8.25E-01	3.16E-02	3.20E+00
338	EVAPO	1.28E+00	1.34E+00	-5.00E-01	6.46E+00	5.47E-03	5.53E-01
339	VPD	1.12E+02	1.13E+02	3.46E+01	8.25E+02	1.37E+02	1.38E+04
340	RNTG	2.38E+06	8.56E+06	-1.29E+07	1.07E+07	-5.16E+06	-5.21E+08
341	SENS	1.94E+06	1.14E+06	-2.17E+07	5.37E+06	-1.18E+06	-1.19E+08
342	LATENT	3.12E+06	3.29E+06	-4.75E+06	1.58E+07	-4.45E+04	-4.50E+06
343	SURFMOS	-7.54E-04	-6.07E-01	-1.59E+00	1.00E+00	7.53E-01	7.61E+01
344	LAI	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01
345	SATLEV	-2.20E+00	-1.94E+00	-2.26E+00	-3.10E-01	-1.28E+00	-1.29E+02
346	PREC	0.00E+00	0.00E+00	0.00E+00	6.16E+01	1.18E+00	1.19E+02
347	TOTQ	2.65E-01	3.88E-01	2.45E-01	1.92E+00	6.98E-01	7.05E+01
348	PIPEQ	0.00E+00	4.24E-02	0.00E+00	8.09E-01	7.22E-02	7.29E+00
351	TQUALP	2.06E-01	0.00E+00	0.00E+00	1.00E+00	6.95E-01	7.02E+01
352	DENSS	0.00E+00	3.13E+02	0.00E+00	4.96E+02	2.66E+02	2.68E+04
353	SWATS	0.00E+00	0.00E+00	0.00E+00	1.10E+00	2.71E-02	2.73E+00
354	SAGE	0.00E+00	0.00E+00	0.00E+00	2.58E+01	5.61E+00	5.66E+02
355	SWELL	0.00E+00	7.77E-05	0.00E+00	7.77E-05	1.54E-05	1.55E-03
356	FROSTBU(1)	0.00E+00	-1.50E-02	-2.50E-02	0.00E+00	-8.19E-04	-8.27E-02

358	FROSTBL(1)	0.00E+00	-4.36E-01	-4.36E-01	0.00E+00	-2.69E-01	-2.72E+01
360	TTSTEP	-3.19E+00	-3.19E+00	-3.19E+00	-2.89E+00	-3.18E+00	-3.21E+02
361	DINFIL	0.00E+00	0.00E+00	0.00E+00	4.38E+02	1.17E+00	1.19E+02
362	RAC	1.16E+02	5.49E+01	2.92E+01	4.36E+02	1.66E+02	1.67E+04
363	VPS	8.07E+02	7.77E+02	1.82E+01	9.93E+02	4.15E+02	4.19E+04
364	VPA	5.81E+02	6.64E+02	9.12E+01	9.94E+02	4.15E+02	4.19E+04
365	ROOTDEPTH	-1.00E-01	-1.00E-01	-1.00E-01	-1.00E-01	-1.00E-01	-1.01E+01
366	RICH	-1.62E-01	-4.06E-03	-1.07E+00	8.00E-02	2.63E-02	2.65E+00
367	EBAL	-4.07E+04	-5.75E+03	-5.00E+04	5.00E+04	1.51E+02	1.52E+04
368	ETRPSI	1.00E+00	8.09E-01	0.00E+00	1.00E+00	2.26E-01	2.29E+01
369	ETRTEM	8.25E-01	7.97E-03	7.97E-03	8.25E-01	3.79E-02	3.83E+00
370	THETATOT(1)	2.95E+01	3.77E+01	2.95E+01	4.70E+01	4.10E+01	4.14E+03
371	THETATOT(2)	2.95E+01	3.82E+01	2.95E+01	4.42E+01	3.83E+01	3.87E+03
372	THETATOT(3)	3.26E+01	4.35E+01	3.25E+01	4.82E+01	4.10E+01	4.14E+03
373	THETATOT(4)	3.32E+01	4.69E+01	3.31E+01	4.70E+01	4.37E+01	4.42E+03
374	THETATOT(5)	3.05E+01	3.56E+01	2.93E+01	3.88E+01	3.49E+01	3.53E+03
375	THETATOT(6)	3.23E+01	3.60E+01	3.22E+01	3.92E+01	3.58E+01	3.62E+03
376	THETATOT(7)	3.38E+01	3.75E+01	3.38E+01	4.06E+01	3.73E+01	3.77E+03
377	THETATOT(8)	3.63E+01	3.88E+01	3.63E+01	4.51E+01	4.03E+01	4.07E+03
378	THETATOT(9)	4.03E+01	4.28E+01	3.99E+01	5.00E+01	4.37E+01	4.41E+03
379	THETATOT(10)	4.62E+01	4.73E+01	4.60E+01	4.99E+01	4.76E+01	4.81E+03
380	THETATOT(11)	4.49E+01	4.66E+01	4.48E+01	4.87E+01	4.69E+01	4.74E+03
381	THETATOT(12)	4.40E+01	4.79E+01	4.40E+01	4.90E+01	4.72E+01	4.77E+03
382	THETATOT(13)	4.17E+01	4.46E+01	4.17E+01	4.48E+01	4.42E+01	4.46E+03
383	THETATOT(14)	4.17E+01	4.43E+01	4.17E+01	4.46E+01	4.37E+01	4.41E+03
384	THETATOT(15)	4.18E+01	4.29E+01	4.18E+01	4.46E+01	4.36E+01	4.40E+03
385	THETATOT(16)	4.20E+01	4.27E+01	4.20E+01	4.46E+01	4.39E+01	4.44E+03
386	THETATOT(17)	4.22E+01	4.27E+01	4.22E+01	4.46E+01	4.42E+01	4.47E+03
387	THETATOT(18)	4.25E+01	4.37E+01	4.23E+01	4.46E+01	4.45E+01	4.49E+03
388	THETATOT(19)	4.46E+01	4.46E+01	4.44E+01	4.46E+01	4.46E+01	4.50E+03
389	THETATOT(20)	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.50E+03
390	THETATOT(21)	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.50E+03
391	THETATOT(22)	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.46E+01	4.50E+03
392	BYPASS(1)	0.00E+00	0.00E+00	0.00E+00	4.14E+02	2.22E-02	2.24E+00
393	BYPASS(2)	0.00E+00	0.00E+00	0.00E+00	3.77E+02	5.63E-03	5.68E-01
394	BYPASS(3)	0.00E+00	0.00E+00	0.00E+00	3.47E+02	3.98E-03	4.02E-01
395	BYPASS(4)	0.00E+00	0.00E+00	0.00E+00	3.16E+02	2.69E-03	2.71E-01
396	BYPASS(5)	0.00E+00	0.00E+00	0.00E+00	3.03E+02	6.68E-03	6.74E-01
397	BYPASS(6)	0.00E+00	0.00E+00	0.00E+00	2.92E+02	8.01E-03	8.09E-01
398	BYPASS(7)	0.00E+00	0.00E+00	0.00E+00	2.73E+02	1.26E-02	1.27E+00
399	BYPASS(8)	0.00E+00	0.00E+00	0.00E+00	2.45E+02	1.81E-03	1.83E-01
400	BYPASS(9)	0.00E+00	0.00E+00	0.00E+00	1.50E+02	9.69E-04	9.78E-02
401	BYPASS(10)	0.00E+00	0.00E+00	0.00E+00	1.31E+02	8.41E-04	8.50E-02
402	BYPASS(11)	0.00E+00	0.00E+00	0.00E+00	1.28E+02	4.15E-01	4.19E+01
403	BYPASS(12)	0.00E+00	0.00E+00	0.00E+00	1.02E+02	6.59E-04	6.65E-02
404	BYPASS(13)	0.00E+00	0.00E+00	0.00E+00	1.02E+02	1.72E+00	1.73E+02
405	BYPASS(14)	0.00E+00	0.00E+00	0.00E+00	1.02E+02	3.81E+00	3.84E+02
406	BYPASS(15)	0.00E+00	0.00E+00	0.00E+00	1.02E+02	2.29E-01	2.31E+01
407	BYPASS(16)	0.00E+00	0.00E+00	0.00E+00	1.02E+02	1.30E-01	1.32E+01
408	BYPASS(17)	0.00E+00	0.00E+00	0.00E+00	1.02E+02	5.95E-02	6.01E+00
409	BYPASS(18)	0.00E+00	0.00E+00	0.00E+00	1.02E+02	8.09E-03	8.17E-01
413	GTHICK(1)	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.05E+00
414	GTHICK(2)	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.05E+00
415	GTHICK(3)	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.05E+00
416	GTHICK(4)	5.00E-02	5.01E-02	5.00E-02	5.01E-02	5.00E-02	5.05E+00
417	GTHICK(5)	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.05E+00
418	GTHICK(6)	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.05E+00
419	GTHICK(7)	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01

420	GTHICK(8)	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01
421	GTHICK(9)	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01
422	GTHICK(10)	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01
423	GTHICK(11)	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01
424	GTHICK(12)	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01
425	GTHICK(13)	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.01E+01
426	GTHICK(14)	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.02E+01
427	GTHICK(15)	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.02E+01
428	GTHICK(16)	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.02E+01
429	GTHICK(17)	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.02E+01
430	GTHICK(18)	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.00E-01	2.02E+01
431	GTHICK(19)	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.05E+01
432	GTHICK(20)	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.05E+01
433	GTHICK(21)	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.05E+01
434	GTHICK(22)	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.05E+01
436	VAPOURF(1)	0.00E+00	5.23E-02	-2.31E-01	9.13E-02	-1.40E-02	-1.41E+00
437	VAPOURF(2)	0.00E+00	3.38E-02	-1.50E-01	4.58E-02	-8.96E-03	-9.05E-01
438	VAPOURF(3)	0.00E+00	-6.59E-03	-7.65E-02	1.46E-02	-1.04E-02	-1.05E+00
439	VAPOURF(4)	0.00E+00	6.83E-03	-4.58E-02	6.83E-03	-8.67E-03	-8.75E-01
440	VAPOURF(5)	0.00E+00	-1.62E-02	-5.09E-02	0.00E+00	-1.20E-02	-1.21E+00
441	VAPOURF(6)	0.00E+00	-1.08E-02	-2.38E-02	0.00E+00	-5.67E-03	-5.72E-01
442	VAPOURF(7)	0.00E+00	-5.05E-03	-7.80E-03	1.04E-06	-4.21E-03	-4.25E-01
443	VAPOURF(8)	0.00E+00	-7.10E-03	-8.94E-03	0.00E+00	-5.27E-03	-5.32E-01
444	VAPOURF(9)	0.00E+00	-4.97E-03	-6.77E-03	7.02E-05	-3.80E-03	-3.84E-01
445	VAPOURF(10)	0.00E+00	-2.42E-03	-3.74E-03	6.44E-05	-1.82E-03	-1.83E-01
446	VAPOURF(11)	0.00E+00	-1.60E-03	-4.28E-03	2.46E-04	-1.59E-03	-1.61E-01
447	VAPOURF(12)	0.00E+00	-5.09E-04	-3.58E-03	1.43E-04	-9.75E-04	-9.84E-02
448	VAPOURF(13)	0.00E+00	-7.58E-05	-8.24E-04	0.00E+00	-2.43E-04	-2.46E-02
449	VAPOURF(14)	-2.62E-07	-2.56E-04	-5.05E-04	5.23E-05	-1.56E-04	-1.57E-02
450	VAPOURF(15)	-5.04E-07	-4.64E-04	-5.13E-04	1.78E-04	-1.40E-04	-1.41E-02
451	VAPOURF(16)	-4.69E-07	-4.95E-04	-5.01E-04	9.01E-05	-8.51E-05	-8.59E-03
452	VAPOURF(17)	-4.23E-07	-3.71E-04	-3.71E-04	1.50E-04	-3.04E-05	-3.07E-03
453	VAPOURF(18)	-1.95E-07	-1.17E-04	-1.17E-04	2.08E-06	-3.99E-06	-4.03E-04
454	VAPOURF(19)	0.00E+00	-7.91E-09	-9.36E-06	0.00E+00	-1.42E-07	-1.43E-05
455	VAPOURF(20)	0.00E+00	0.00E+00	-5.45E-10	0.00E+00	-3.11E-12	-3.15E-10
457	TDSNOW	0.00E+00	1.00E-04	-1.45E+01	1.00E-04	-2.31E+00	-2.34E+02
458	VAPOURFS	-1.15E-01	7.34E-02	-1.90E-01	9.10E-02	-2.30E-02	-2.32E+00

-------------------- Driving Variables ----------------------------------

Number	Variable	Initial	Final	Min	Max	Mean	Cumulated
459	EPOT	1.06E-02	1.37E-02	1.00E-03	4.29E-02	4.20E-03	4.24E-01
460	PRECMM	0.00E+00	0.00E+00	0.00E+00	5.76E+01	1.08E+00	1.09E+02
461	TA	1.59E+00	3.19E+00	-1.80E+01	8.56E+00	-2.18E+00	-2.21E+02
462	TD	3.71E+00	3.78E+00	-3.11E+01	6.69E+00	-3.60E+00	-3.64E+02
463	HR	8.39E+01	8.54E+01	1.46E+01	9.08E+01	7.45E+01	7.52E+03
464	WS	9.67E-01	3.22E+00	5.00E-01	6.97E+00	1.99E+00	2.01E+02
465	RNT	2.51E+06	8.99E+06	-1.36E+07	1.13E+07	-5.42E+06	-5.47E+08
466	CLOUDN	0.00E+00	0.00E+00	0.00E+00	9.81E-01	3.01E-01	3.04E+01
467	RIS	1.52E+07	2.71E+07	0.00E+00	3.03E+07	3.37E+06	3.40E+08

The simulation occupied the computer during:

TIME USED 0 h 24 m 51 sec

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