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Animation of water balance data: The software package BALANCE

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ABSTRACT

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The software package BALANCE shows the output of a transient one-dimensional numerical model for the simulation of soil moisture flow on the screen of a Personal Computer. The components of the water balance are presented as well as the pressure head and soil moisture content profile. Presenting these data continuously in time, an impression of animation is created.

Keywords: animation, components of the water balance, 1-dimensional transient water flow, pressure head profile, moisture content profile.

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Project 461 *[JGW/02.92]*

CONTENTS

PREFACE

Nowadays a lot of numerical models are available for calculating the soil moisture distribution of a one-dimensional profile. These models compute the terms of the water balance from meteorological and soil physical data. Usually the output is limited to tables of data. To present these data, separate programs are developed to make figures on a printer or on a plotter. As the solution of the transient soil moisture flow consists of a set of values for each time under consideration, we thought it should be possible to present these data a different way. The impression of animation was created by presenting the data continuously on the (graphical) screen of a Personal Computer. After quite a lot of experimental programming, discussions and try-outs with an LCD-projector on courses and lectures, the present program is considered to present the data in an adequate way.

SUMMARY

A tremendous amount of soil moisture flow simulation software was developed by various research institutes during the past decades. Most of these programs present their output in a numerical form. Our software package, BALANCE, shows the components of the water balance on a graphical screen, together with the pressure head- and soil moisture profile. It is not a simulation model, but merely a tool to assist in the interpretation of the output of numerical simulation models. It is most appropriate for educational and research purposes, as the interaction between the different components of the water balance can be seen immediately.

INTRODUCTION

Nowadays, there is a number of numerical models available that simulate the water balance of a soil and the pressure head profile in the soil. These numerical models have been developed for research as well as educational purposes. Most of these models give numerical output only, which can be directed either to a file, to a printer or to a terminal screen. Usually the user of such a program is interested in seeing the course of the pressure head profile and soil moisture profile in time, as well as the different components of the water balance.

Graphical representations of the output of water balance programs are interesting when they show the changes of the components of the water balance in time, especially for demonstration and educational purposes. To obtain such a graphical representation of the output, some additional programs have to be prepared by the user. We have developed a software package to show the components of the water balance continuously in time. The components shown graphically can be divided into two categories: those at the upper boundary (precipitation and infiltration, potential and actual transpiration, potential and actual evaporation) and those at the lower boundary (subsurface infiltration, drainage, percolation and seepage). The change in water content of the profile can be seen as well as the course of the ground water level. The profiles of the pressure head and the moisture content are visualized in time. The components of the water balance and the pressure head and moisture content profiles can be obtained from any numerical model which is adapted to generate these data, or the model SWATRE (Feddes et al., 1978, Belmans et al., 1983, Wesseling et al., 1989, Elbers, 1990, personal communication) can be applied. The version of 1989 generates the datafile required by BALANCE automatically, for the 1990 version a conversion program is available.

This report consists of four parts:

1. The water balance of a one-dimensional soil profile.
   In this part the terms of the water balance of a one-dimensional soil profile are discussed as well as the moisture flow in the soil profile.
2. The Installation Guide.
   The Installation guide describes the required hardware to run the program package and how to install it on your PC.
3. The Users Guide.
   This is a manual on how the package should be used and how the input files should be built.
4. An example.
   The example that is supplied on the distribution diskette is discussed.

Part 1 The water balance of a one-dimensional soil profile

1 The water balance of a one-dimensional soil profile

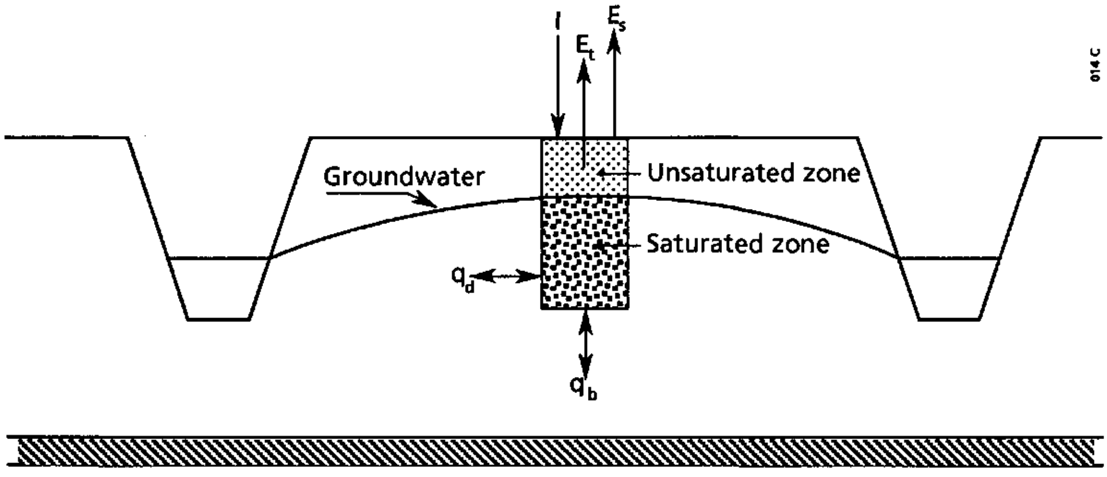

Figure 1.1. ***The components of the water balance. The one-dimensional soil profile is assumed to be in the middle between two ditches or drains. I = Infiltration, E_t = transpiration, E_s = evaporation, q_d = drainage / subsurface infiltration, q_b = percolation / seepage. All units are in mm.d^{-1}.***

Consider the one-dimensional soil profile presented in Figure 1.1. The water balance of the profile for the period from day t_1 to day t_2 can be written as

$$\Delta W = \int_{t_1}^{t_2} (q_b + q_d - I - E_s - E_t)dt \qquad (1)$$

where

ΔW = change in water content of the soil profile during period t_1 to t_2 (mm),
q_b = flux density through the bottom of the profile (mm.d^{-1}),
q_d = lateral flux density to or from the drain/ditch system (mm.d^{-1}),
I = actual infiltration flux density through the soil surface (mm.d^{-1}),
E_s = actual soil evaporation flux density (mm.d^{-1}),
E_t = actual transpiration flux density (mm.d^{-1}),
t = time (d).

All fluxes in Equation (1) have a positive value when they are directed upward. This notation implies that the infiltration I will always be zero or negative. The fluxes q_b and q_d may have either positive or negative values, representing seepage and percolation for q_b and subsurface irrigation and drainage for q_d.

The actual infiltration is calculated by Eq. (2):

$$I = -(P - I_c - R) \tag{2}$$

where
- P = precipitation ($mm.d^{-1}$),
- I_c = interception by plant leaves ($mm.d^{-1}$),
- R = surface runoff ($mm.d^{-1}$).

The actual evaporation and transpiration fluxes are either measured or can be calculated from the potential fluxes according to

$$E_s = f_1(E_{sp}, \textit{soil moisture}) \tag{3}$$

and

$$E_t = f_2(E_{tp}, \textit{soil moisture}) \tag{4}$$

where
- E_{sp} = potential soil evaporation ($mm.d^{-1}$),
- E_{tp} = potential transpiration ($mm.d^{-1}$);

The potential fluxes are obtained from meteorological data. Several equations are known that calculate these values (Feddes et al., 1978, Belmans et al., 1983). Most of these equations compute the potential evapotranspiration, from which the potential transpiration and the potential evaporation are calculated by some distribution function:

$$E_p = E_{sp} + E_{tp} \tag{5}$$

where E_p = potential evapotranspiration ($mm.d^{-1}$).

The water content of the soil profile can be obtained by integrating the volumetric moisture content at each depth over the entire profile:

$$W = \int_{z_b}^{0} 10\theta \, dz \tag{6}$$

where
- z = vertical position, directed positive upward with zero-value at the soil surface (cm),
- z_b = position of bottom of profile under consideration (cm),
- θ = volumetric moisture content at depth z and time t ($cm^3.cm^{-3}$),
- W = water content at time t (mm).

The number 10 is required to convert the units from cm to mm. As the moisture content θ and the pressure head h are related by the so-called soil moisture retention curve, the soil water content can be computed when the pressure head distribution with depth is known. The pressure head distribution is governed by the extended Richards' equation:

$$C(h)\frac{\partial h}{\partial t} = \frac{\partial}{\partial z}\left(K(h)\left(\frac{\partial h}{\partial z}+1\right)\right) - S(h) \qquad (7)$$

where

h	= pressure head at depth z and time t (cm),
$K(h)$	= hydraulic conductivity as a function of h ($cm.d^{-1}$),
$S(h)$	= sink term representing water uptake by plant roots (d^{-1}),
$C(h)$	= soil moisture capacity (cm^{-1}), calculated as the slope of the soil moisture retention curve:

$$C(h) = \frac{\partial \theta}{\partial h} \qquad (8)$$

The partial differential equation can be solved numerically by introducing the fluxes described in Equation (1) as boundary conditions of Equation (7), yielding the h- and θ-values in time and depth. Because of the interaction between the boundary fluxes and the h-values in the soil profile, these fluxes should also be calculated while solving the equation. Numerous computer programs have been developed to solve Eq. (7) with its boundary conditions (Feddes et al., 1978, De Laat, 1980, Belmans et al., 1983). El-Kadi and Beljin (1987) reviewed some of these programs.

Part 2 Installation Guide

2 Installation Guide

The software package BALANCE has been developed for use on a PC or compatible computer. It requires MS-DOS version 3 or higher and a graphical display (preferably Hercules, EGA or VGA, as it has not been tested with other displays, except CGA, which gives a very poor result). BALANCE is delivered on either a 3½" or a 5¼" diskette. The contents of the diskette is listed in Table 2.1.

Table 2.1 The contents of the distribution diskette

File	Description
BALANCE.BAT	BATCH-file containing the required commands to run the programs. Deletes the intermediate files after use.
WHAT.EXE	Program that welcomes the user and asks which options and files have to be chosen. Creates two intermediate files.
BARBAL.EXE	Program to show the components of the water balance when the bar-option bars is chosen.
LINBAL.EXE	Program to show the components of the water balance when the line-option is chosen.
ATT.BGI CGA.BGI EGAVGA.BGI HERC.BGI IBM8514.BGI PC3270.BGI	Graphics drivers for different types of video displays.
GOTH.CHR LITT.CHR TRIP.CHR	Different character fonts, required by the programs.
CP76.WB	Sample file with components of the water balance
CP76.SOL	Sample file with pressure head and moisture content data

The software package BALANCE can either be run from the diskette or from harddisk. It is advised to create a directory on harddisk and run the program from there. When running from diskette, data-input will slow down the program and the animation effect will be decreased.

To run the package from harddisk, simply copy all files from diskette to harddisk. However, the programs do not need all graphics drivers. Only the one corresponding to your display is required. In case of doubt, either one of two options can be chosen:

1. Copy all drivers. BALANCE will select the one it requires. The other drivers will not be used.

2. Do not copy any driver at all. Copy only the *.BAT and *.EXE files. Then type BALANCE. A series of error messages will appear on the screen. The first one is caused by the missing driver, stating the name of the required file.

As different character fonts are used in BALANCE, all three fonts should be present on the default directory.

One example is supplied on the diskette. It consists of two files: CP76.WB and CP76.SOL. The examples were prepared with the program SWATRE (Feddes et al., 1978, Belmans et al., 1983, Wesseling et al., 1989, Elbers, 1990, personal communication). The example will be discussed later on. The files containing the examples may be copied to the default directory on harddisk as well, but they are not required to run the package. The files are just intended to present an example. When running BALANCE for the first time, it is advised to use the example, as the output of it is described in Part 4 of this report.

Part 3 Users Guide

3 Users Guide

3.1 INTRODUCTION

The software package BALANCE has been developed to present the output data of a numerical simulation program. It does not calculate the components of the water balance itself, and always has to be used in cooperation with a program that calculates the soil moisture distribution and the components of the water balance, e.g. SWATRE (Feddes et al., 1978, Belmans et al., 1983, Wesseling et al., 1989, Elbers, 1990, personal communication). Because there are many types of graphical screens available nowadays, the program has been written such that it is able to select the correct driver for a particular screen itself. It will run on any PC-compatible with a graphical screen. For Hercules, EGA and VGA screens, the results were perfect. For a CGA-screen however, the package needs to be adapted because of the low resolution of the screen. Although the package has been written in Turbo-Pascal Version 6, this compiler is not required for the application of the package as it is distributed as a stand-alone version. Turbo-Pascal was chosen because of the speed of the compiler and the ease of introducing graphical options.

In this part it will first be explained how to run the program. Then the output of the package will be descriped. Finally the required input will be discussed. This unusual order was kept because the user then has a better insight in the input requirements of the software package.

3.2 RUNNING BALANCE

To obtain full benefit of all the possibilities of the package, it should always be started from the batch file. When running the package, two intermediate files are created: RUNRUN.BAT and BALANCE.FIL. If the procedure is finished in the normal way, these files are automatically deleted when BALANCE is finished. If, for some reason, the program is interrupted, these files may be deleted by the user.

BALANCE should always be started by typing

BALANCE <ENTER>

at the DOS-prompt, where <ENTER> means: 'Press the ENTER-key'.

The first thing BALANCE shows on the screen is its identification. After a few seconds the first question appears. This is the question whether the data should be shown as bars (answer '1' or 'b') or as lines (answer '2' or 'l'). See the Figures 3.1a and 3.1b of this report for the differences between these options. A third option is to exit the program and return to DOS (answer '3' or 'x'). After typing the answer, it is not necessary to press the <ENTER>-key.

On the following screen the user is asked to type the name of the file containing the components of the water balance. These files should be prepared by a water balance program beforehand. Three possible answers can be given here:

a. The name of the file can be typed in (preferably with extension .WB), followed by pressing the <ENTER>-key.
b. The default file-name (BALANCE.WB) can be chosen by just pressing the <ENTER>-key;
c. A list of available files with extension .WB can be obtained by typing ? followed by pressing the <ENTER>-key. Pressing <ENTER> again will cause the previous screen to appear again.

When running balance for the first time, the name of the file with the example can be typed here: CP76.WB.

After reading the file-name from the keyboard, the program will check its existence. If the file does not exist, an error message will be given, and the question will be asked once more. This will continue until a correct filename is typed.

When the file with water balance data is present, the corresponding file with soil data is searched for. It is assumed that this file has the same name as the water balance file, but it has the extension .SOL. If the file is not present, an error message is generated, and the user of the program has to type the correct file name. Typing ? followed by the <ENTER>-key lists all the files with extension .SOL on the screen.

Depending on the choice of output, the next screen identifies the program that is running: BARBAL for the representation with bars or LINBAL for the representation with lines. This identification remains on the screen while the components of the water balance are being read. After reading these data, the output will be presented on the screen.

3.3 THE OUTPUT

3.3.1 General

The output of the software package BALANCE can be seen as a series of graphical images, one for each day of input. The images appear consecutively on the screen of the PC, yielding the impression of a live animation of data. The two possible forms of output (bar and line) are discussed separately later. The components of the water balance are shown in squares on the screen. When running the program, the bars and lines are adapted each day. On a colour screen the various lines or bars each have different colours. These colours can easily be changed by the user. A clock shown in the centre of the screen (Figures 3.1a and 3.1b) keeps track of the Julian day number for which the data are presented on the screen. There are 4 numbers around the clock: 0, 91, 183 and 275. These numbers represent the quarters of a year: the first quarter goes from day 0 to day 91, the second from day 91 to day 183, etc. The clock indicates the first and the last day of simulation by a line. Each day a segment is filled in with a user-defined colour until the last day of simulation. The size of this segment represents the number of days between the present day and the first day of simulation. The present day of simulation is shown as a number below the clock as well.

In both the line and the bar-option the presentation can be temporarily stopped by pressing any key. Then the clock will stop and the cumulative values of the components of the water balance from the beginning of presentation to present day are shown. The presentation can be continued by pressing any key (except the F1 to F10 keys). To exit the program before all data is shown, just press one of the function keys (F1 to F10). The program will stop immediately and control will be returned to MS-DOS.

At the end of the presentation the clock will stop, the values are written to the screen and a bell will sound. Pressing any key will return control to MS-DOS.

3.3.2 First option: bars

There are 2 rows of rectangles shown on the screen (see Fig. 3.1a for an example). Inside each rectangle two components of the water balance of the soil profile are drawn.

In the top row the following items are shown:

- Precipitation (P) and infiltration (I)
- Potential (E_{tp}) and actual (E_t) transpiration
- Potential (E_{sp}) and actual (E_s) evaporation
- The pressure head (h) profile

The bottom row shows:

- The flux to (q_d^-) and from the drains (q_d^+)
- The flux through the bottom of the profile (q_b^+ and q_b^-)
- The clock
- The ground water level
- The moisture content profile (θ)

All water balance components are presented as cumulative values (mm), starting with 0 at the first day of simulation. The components of the water balance are shown as bars inside the squares, the size of the bars being adapted for each day of output. The components of the water balance at the top row have the same vertical scale and similarly do the components of the water balance at the bottom row.

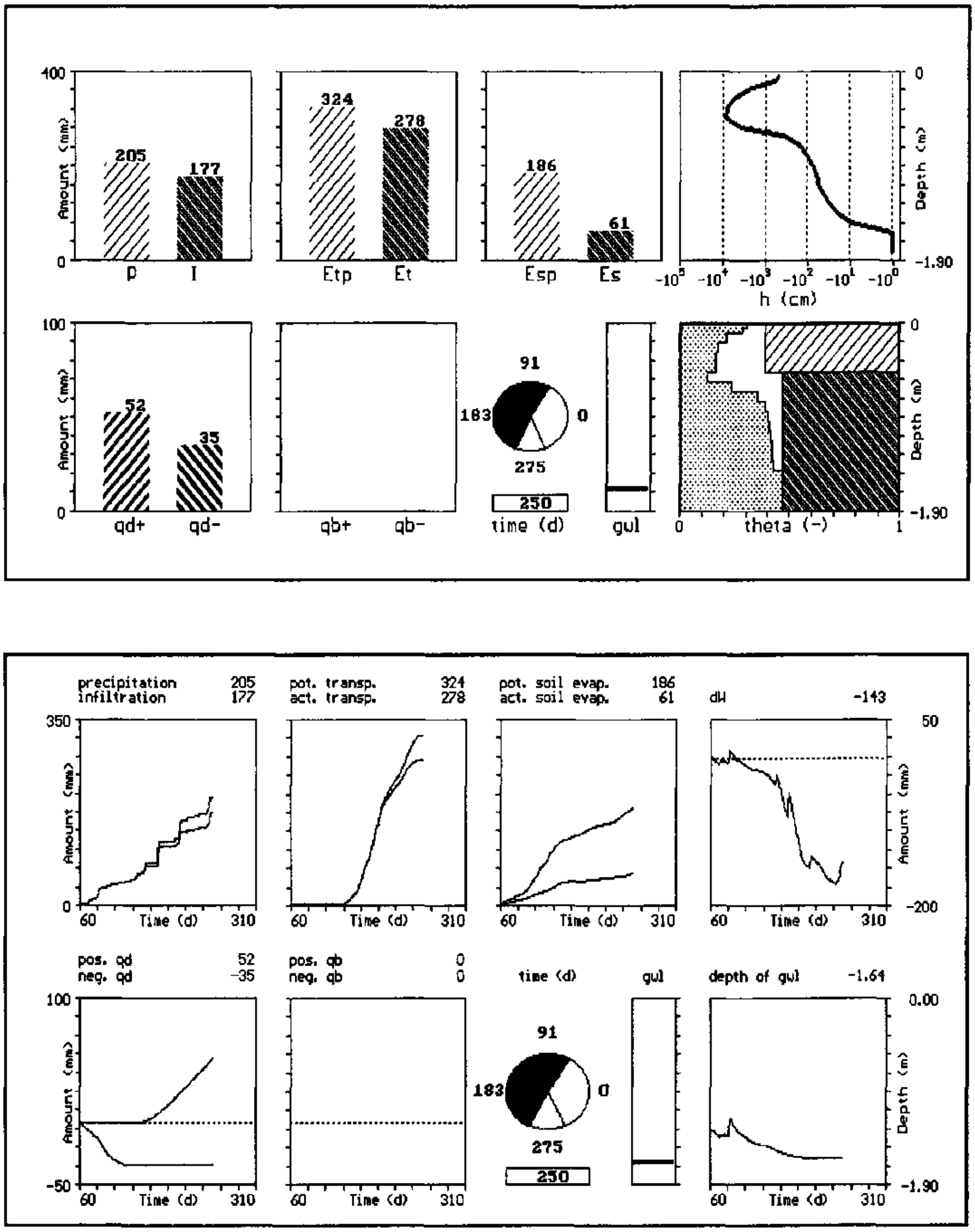

Figure 3.1 ***A hardcopy of the videoscreen when the output was stopped at day 250: a. the bar option was chosen; b. the line option was chosen. These picture were obtained by temporarily stopping the program. Normally a series of these pictures is shown in sequence for each day of simulation.The letters represent the different components of the water balance (in mm) and soil moisture status: P = precipitation; I = infiltration; E_{tp} = potential transpiration; E_t = actual transpiration; E_{sp} = potential evaporation; E_s = actual evaporation; q_{d+} = subsurface infiltration; q_{d-} = drainage; q_{b+} = seepage; q_{b-} = percolation; dW = change in water content of the profile; h = pressure head (cm); gwl = depth of groundwater level (m); theta = moisture content (-)***

The pressure head profile is presented on a logarithmic scale. The minimum and maximum value of h are selected by the program. The vertical axis represents the position in the profile, with 0 at the top of the profile.

The horizontal axis of the soil moisture profile varies from $\theta = 0$ to $\theta = 1$. The scale of the vertical axis is the same as that of the pressure head profile. The liquid phase is represented by a dotted area and the solid phase is drawn in a hatch-pattern, distinguishing the different soil layers in the profile. The air phase of the profile has the same colour as the background of the screen.
Both the pressure head- and the soil moisture profile are redrawn each day so that the effects of evapotranspiration and infiltration can be clearly seen.

3.3.3 Second option: lines

An example of the screen after choosing the line option is given in Figure 3.1b. Here the values of the components of the water balance are drawn as lines. The time is shown as a Julian day number from commencement to end of simulation on the horizontal axes and the values of the cumulative fluxes can be seen on the vertical axes. Comparing Figures 2 and 3 it can be seen that the components of the water balance are presented at the same position. However, neither the pressure head profile nor the moisture content profile are presented in case of lines. Instead, two new blocks are added: one shows the change in water content of the profile (ΔW in Equation (1), dW in Fig. 3.1b) and the other the depth of the ground water level in time. The vertical axis of the top row is the same for all squares, except the square on the far right, representing the change in water content which has a different vertical scale. The dotted line in the squares represents the zero-level.

3.4 THE REQUIRED INPUT

When solving the partial differential equation for one-dimensional soil moisture flow with specified boundary conditions as presented in Part 1 of this report, two types of results can be distinguished.

The first type consists of the components of the water balance, both as potential and as actual values, generally presented on a daily basis. The potential fluxes at the top of the soil profile are calculated from meteorological data. The actual fluxes take into account the soil moisture content of the soil profile and will be less than or equal to the potential values (in the absolute sense).

The second type of results consists of data representing the soil moisture: the moisture content and the pressure head. The soil profile is assumed to be discretized into a number of compartments, each represented by a node in the centre of the compartment (see e.g. Feddes et al., 1978; Belmans et al., 1983). For each node the moisture content and pressure head are calculated a daily basis.

The input data required for the software package BALANCE consists of two files: one file (with extension .WB) for the components of the water balance, and a file (with extension .SOL) for the soil moisture data. All these data is to be given on a daily basis. In general the data are obtained directly from a numerical model.

3.4.1 The water balance file

It is advised to name the file containing the components of the water balance with the extension .WB, as the package shows all files with this extension when a directory of water balance files is asked for. The contents of this file are described in this section. Variables listed between the solid lines are to be written on one line. The input is expected for every day in units of $mm.d^{-1}$. All numbers are positive, unless indicated otherwise.

Type of variable	Description
Integer	First day of input
Integer	Last day of input
Integer	daynumber for which the following data are valid
Real	Precipitation ($mm.d^{-1}$)
Real	Infiltration ($mm.d^{-1}$)
Real	Potential transpiration ($mm.d^{-1}$)
Real	Actual transpiration ($mm.d^{-1}$)
Real	Potential evaporation ($mm.d^{-1}$)
Real	Actual evaporation ($mm.d^{-1}$)
Real	Flux from/towards irrigation/drainage system ($mm.d^{-1}$), a positive value indicating subsurface irrigation.
Real	Flux through the bottom of the soil profile ($mm.d^{-1}$), a positive value indicating an upward flux

The last line should be repeated for each day of input.

Note: The data should be written to the file with sufficient accuracy. If the number of decimal places is too low, rounding-off errors may occur, causing a deviation in the components of the water balance up to several mm. Therefore it is advised to write the components of the water balance with at least one decimal place.

Example 3.1 presents part of a file with water balance data.

61	300							
61	0.0	0.0	0.0	0.0	1.0	0.5	-0.6	0.0
62	0.0	0.0	0.0	0.0	1.2	0.5	-0.6	0.0
63	0.0	0.0	0.0	0.0	1.1	0.3	-0.7	0.0
64	0.0	0.0	0.0	0.0	1.0	0.3	-0.6	0.0
65	0.0	0.0	0.0	0.0	0.8	0.2	-0.6	0.0
66	0.0	0.0	0.0	0.0	0.4	0.1	-0.6	0.0
67	0.0	0.0	0.0	0.0	0.6	0.2	-0.6	0.0
68	0.0	0.0	0.0	0.0	0.8	0.2	-0.5	0.0
69	0.0	0.0	0.0	0.0	0.4	0.1	-0.5	0.0
70	0.0	0.0	0.0	0.0	0.7	0.2	-0.5	0.0
71	0.0	0.0	0.0	0.0	0.6	0.2	-0.5	0.0
72	6.8	6.8	0.0	0.0	0.5	0.5	-0.4	0.0
73	0.2	0.2	0.0	0.0	1.3	0.7	-0.4	0.0
74	0.0	0.0	0.0	0.0	0.3	0.3	-0.4	0.0
		.						
		.						
		.						
		.						
		.						
296	4.2	4.2	0.0	0.0	0.4	0.4	0.6	0.0
297	0.5	0.5	0.0	0.0	0.5	0.5	0.6	0.0
298	0.0	0.0	0.0	0.0	0.4	0.3	0.6	0.0
299	0.0	0.0	0.1	0.0	0.0	0.0	0.6	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0

Example 3.1** **A (partial) example of an input file with water balance data

3.4.2 The soil data file

It is advised to name the file containing the soil data with the extension .SOL, as the program lists these files when a directory of files with soil data is asked for. The contents of this file are described in this section. Variables listed between solid lines are to be written on one input line.

Type of variable	Description
Integer	First day of input
Integer	Last day of input
Integer	Number of nodes
Integer	Number of soil layers (maximally 10).

Integer	Last node of each layer. Maximally 10 numbers can be given on this line.
Real	Position of node (cm, negative values, because zero is at the surface), maximally 8 values per line. So several lines may be required.
Real	Porosity at each node (fraction), maximally 8 values per line. So several lines may be required.
Integer	Day number which the following pressure head and moisture content data correspond to.
Real	Pressure head for each node (cm). For each node the pressure head should be given, 8 values per line. So several lines may be required.
Real	Moisture content ($cm^3.cm^{-3}$) at every node, maximally 8 values per line. So several lines may be required.

The last three line-groups are to be repeated for each day of input.

Example 3.2 presents a (partial) example of a file with soil data.

```
      61       300
      20
       2
       6        20
  -2.500    -7.500   -15.000   -25.000   -35.000   -45.000   -55.000   -65.000
 -75.000   -85.000   -95.000  -105.000  -115.000  -125.000  -135.000  -145.000
-155.000  -165.000  -175.000  -185.000
    0.39      0.39      0.39      0.39      0.39      0.39      0.47      0.47
    0.47      0.47      0.47      0.47      0.47      0.47      0.47      0.47
    0.47      0.47      0.47      0.47
61
   -96.2     -85.2     -77.5     -72.2     -69.5     -68.8     -67.1     -62.8
   -56.4     -48.3     -39.5     -30.1     -20.3     -10.5      -0.5       9.4
    19.4      29.4      39.4      49.4
   0.349     0.350     0.351     0.352     0.353     0.353     0.408     0.411
   0.413     0.417     0.420     0.424     0.428     0.438     0.469     0.470
   0.470     0.470     0.470     0.470
62
  -129.5    -113.4     -97.1     -85.6     -80.2     -75.6     -69.8     -63.6
   -56.3     -48.1     -39.2     -29.8     -20.0     -10.2      -0.3       9.7
    19.7      29.6      39.6      49.6
   0.345     0.347     0.349     0.350     0.351     0.352     0.407     0.410
   0.413     0.417     0.421     0.425     0.429     0.438     0.469     0.470
   0.470     0.470     0.470     0.470
                 .
                 .
299
  -140.0    -137.7    -138.8    -158.1    -238.8    -615.9    -421.4    -184.0
  -120.8     -92.2     -74.5     -61.1     -49.4     -38.5     -28.2     -17.9
    -7.9       2.2      12.2      22.2
   0.344     0.344     0.344     0.342     0.333     0.288     0.229     0.322
   0.373     0.394     0.404     0.411     0.416     0.421     0.425     0.429
   0.470     0.470     0.470     0.470
300
  -151.5    -149.5    -150.8    -171.3    -248.4    -565.8    -409.7    -182.5
  -120.4     -92.0     -74.4     -61.0     -49.3     -38.5     -28.1     -17.9
    -7.9       2.2      12.2      22.2
   0.343     0.343     0.343     0.340     0.332     0.294     0.231     0.323
   0.374     0.394     0.404     0.411     0.416     0.421     0.425     0.429
   0.470     0.470     0.470     0.470
```

Example 3.2 A (partial) example of the input file with soil data

3.5 CHANGING THE COLOURS

The user of the software package BALANCE is free to alter the colours of the presentation when he is not satisfied with the colours that are defined by default. The default colours for the bar and line options are presented in Table 3.1 and Table 3.2 respectively.

Table 3.1 The default colour settings for the bar option

Variable	Symbol	Def. colour	Description
P	P	Blue	Precipitation
I	I	Red	Infiltration
Etp	E_{tp}	Blue	Potential transpiration
Et	E_t	Red	Actual transpiration
Esp	E_{sp}	Blue	Potential evaporation
Es	E_s	Red	Actual evaporation
h	h	Yellow	Pressure head
Qdp	q_d^+	Green	Subsurface irrigation
Qdn	q_d^-	LightGreen	Drainage
Qbp	q_b^+	Green	Seepage
Qbn	q_b^-	LightGreen	Percolation
Clock		Magenta	Pie-slice within clock
Gwl		Yellow	Groundwater level
Solid		Red	Solid phase in moisture content profile
Liquid		Yellow	Liquid phase in moisture content profile
Numbers		White	Values written above bars
Background		Black	Background colour of screen
Squares		White	Squares around bars

If one or more of these colours have to be changed, a file should be created with the name BARS.COL (for the bar option) or LINES.COL (for the line option). This file is setup with the following construction:

<variable> = <colon>

where
<variable> = one of the variable names in the first column of Table 3.1 (bar option) or Table 3.2 (line option).
<colon> = one of the colours presented in Table 3.3.

The variables that are not re-defined will be presented in their default colour. Suppose the file BARS.COL contains only 1 line:

P = Red

then the bar representing the precipitation will be drawn in a red colon. The other variables will be drawn in their default colours, as presented in Table 3.1.

If the file BARS.COL (for bars) or LINE.COL (for lines) are not present on the directory, the default colours will be used.

Table 3.2 The default colour settings for the line option

Variable	Symbol	Default colour	Description
P	P	Blue	Precipitation
I	I	Red	Infiltration
Etp	E_{tp}	Blue	Potential transpiration
Et	E_t	Red	Actual transpiration
Esp	E_{sp}	Blue	Potential evaporation
Es	E_s	Red	Actual evaporation
dW	ΔW	Blue	Change in moisture content of the profile
Qdp	q_d^+	Cyan	Subsurface irrigation
Qdn	q_d^-	LightGreen	Drainage
Qbp	q_b^+	Cyan	Seepage
Qbn	q_b^-	LightGreen	Percolation
Clock		Magenta	Pie-slice within clock
Gwl		Yellow	Groundwater level
Background		Black	Background colour of screen
Squares		White	Squares around bars

Black
Blue
Brown
Cyan
Darkgray
Green
LightGray
LightBlue
LightGreen
LightCyan
LightRed
LightMagenta
Magenta
Red
White
Yellow

Table 3.3 The colours that can be used in BALANCE

3.6 FINAL REMARK

When running BALANCE, do not try to interrupt it by pressing <CONTROL>-BREAK, as though control will return to MS-DOS, the display may remain in graphics mode. This way it will be impossible to read the DOS-prompt. Either a graphical program should be started then or the PC has to be reset. Always use one of the function-keys F1 to F10 to stop the presentation of data and return to MS-DOS.

Part 4 An example

4 An example

The data presented in the example files CP76.WB and CP76.SOL were obtained from the model SWATRE (Feddes et al., 1978, Belmans et al., 1983, Wesseling et al., 1989, Elbers, 1990, personal communication). The 1989-version was adapted to automatically generate the data-files required for the BALANCE-package. The 1990-version (which is still being tested) can create a large (unformatted) data file containing all the calculated data on a daily basis from which the input-files for the BALANCE-package can then be generated in a simple way.

The soil in the examples consisted of a two-layer profile of clay on sand. The meteorological data for the 10% dry year 1976 were taken from the station De Bilt in The Netherlands. Simulation commenced at day 60 and ended at day 300. Potatoes were grown as a crop. Crop growth commenced at day 131 and harvest was at day 255. The boundary flux at the bottom was calculated from drainage characteristics and the position of the ground water level at each day. Both subsurface irrigation and drainage were allowed to occur.

In Fig. 4.1a the presentation of data was stopped temporarily at day 250. The amount of water that has infiltrated into the soil profile was nearly equal to the potential infiltration: only 205 - 177 mm = 28 mm has been lost by interception or runoff. Actual transpiration was nearly potential: 278 mm versus 324 mm for the potential value. The crop could not transpire optimally for some days because of drought. The same occurred with evaporation: 61 mm actual, 186 mm potential. The pressure head profile indicates that there had been some recent precipitation, because the upper soil layer was wetter than the deeper soil layer. The bottom row shows that there had been 35 mm of drainage up to now, and 52 mm of subsurface infiltration had taken place. No seepage or deep percolation had occurred. The ground water level is at about -1.65 m. A slight discrepancy between the depth of the ground water level (which is calculated from the pressure head profile) and the soil moisture profile is caused by the division of the profile into a number of compartments. The soil moisture profile clearly shows the division of the soil profile into two layers. Here too the higher moisture content at the top of the profile implies that there must have been some recent precipitation.

The data presented in Figure 4.1b were exactly the same as described in the previous paragraph (the same data file was used). The presentation was also temporarily stopped at day 250. This figure shows that there was an identical amount of precipitation and infiltration until the crop started growing. This implies that the difference was mainly caused by interception by the leaves. The occurrence of precipitation can be deduced from the change in water content of the profile, when its value became less negative. The water content in the profile decreases from day 70 to approximately day 130. As the slope of the line indicates, the water content of the profile decreased even faster when the crop started to transpire. Some initial drainage (from day 60 to day 129) has occurred, as can be seen from the square where the drainage is presented.

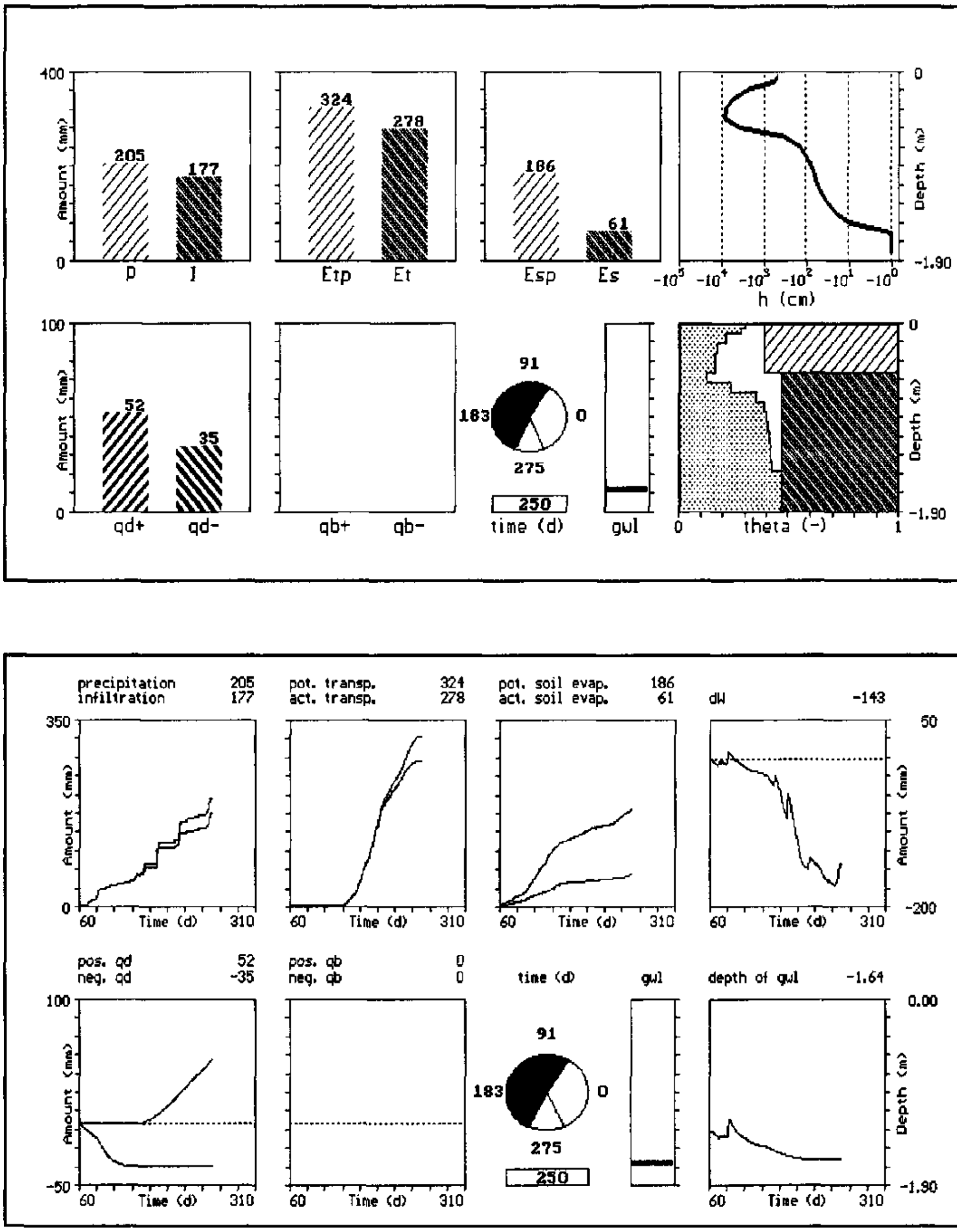

***Figure 4.1** A hardcopy of the videoscreen when the output was stopped at day 250: a. the bar option was chosen; b. the line option was chosen. These picture were obtained by temporarily stopping the program. Normally a series of these pictures is shown in sequence for each day of simulation. The letters represent the different components of the water balance (in mm) and soil moisture status: P = precipitation; I = infiltration; E_{tp} = potential transpiration; E_t = actual transpiration; E_{sp} = potential evaporation; E_s = actual evaporation; q_{d+} = subsurface infiltration; q_{d-} = drainage; q_{b+} = seepage; q_{b-} = percolation; dW = change in water content of the profile; h = pressure head (cm); gwl = depth of groundwater level (m); theta = moisture content (-)*

Then the ground water level reached the level of the drains, and no more drainage occurred. From day 143 on, the ground water level dropped below the drain level, and subsurface infiltration began. This allowed the ground water level to remain almost stable.

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APPENDIX LIST OF VARIABLES

$C(h)$ = soil moisture capacity (cm^{-1})
E_p = potential evapotranspiration ($mm.d^{-1}$).
E_s = actual soil evaporation flux density ($mm.d^{-1}$),
E_{sp} = potential soil evaporation ($mm.d^{-1}$),
E_t = actual transpiration flux density ($mm.d^{-1}$),
E_{tp} = potential transpiration ($mm.d^{-1}$);
h = pressure head at depth z and time t (cm),
I = actual infiltration flux density through the soil surface ($mm.d^{-1}$),
I_c = interception by plant leaves ($mm.d^{-1}$),
$K(h)$ = hydraulic conductivity as a function of h ($cm.d^{-1}$),
P = precipitation ($mm.d^{-1}$),
q_b = flux density through the bottom of the profile ($mm.d^{-1}$),
q_d = lateral flux density to or from the drain/ditch system ($mm.d^{-1}$),
R = surface runoff ($mm.d^{-1}$).
$S(h)$ = sink term representing water uptake by plant roots (d^{-1}),
t = time (d).
W = water content at time t (mm).
z = vertical position, directed positive upward with zero-value at the soil surface (cm),
z_b = position of bottom of profile under consideration (cm),
ΔW = change in water content of the soil profile during period t_1 to t_2 (mm),
θ = volumetric moisture content at depth z and time t ($cm^3.cm^{-3}$),