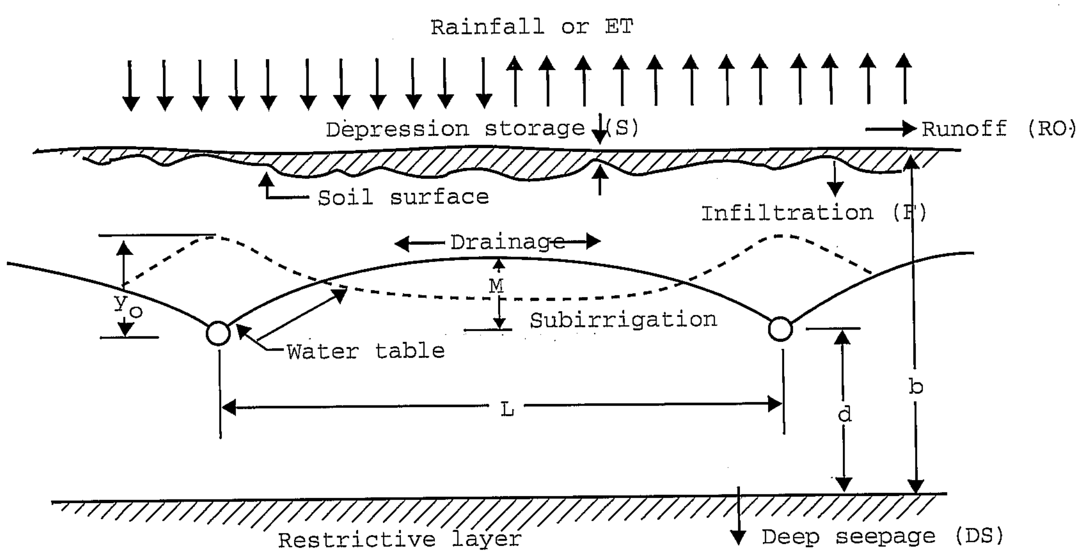
United States
Department of
Agriculture

Natural
Resources
Conservation
Service

DRAINMOD

User's Guide



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The DRAINMOD User's Guide was prepared at North Carolina State University by **Dr. Stephen R. Workman**, USDA-ARS, Ohio State University, Columbus, OH, and **Dr. John E. Parsons, Dr. George M. Chescheir**, and **Dr. R. Wayne Skaggs**, North Carolina State University, Raleigh, NC, and **John F. Rice** (retired), drainage engineer, NRCS, Lincoln, NE. Valuable technical input was also provided by **Otto W. Baumer**, research soil scientist, National Soils Laboratory, NRCS, Lincoln, NE. The principal NRCS reviewers of this publication were:

Rodney White and **Thomas Keep**, drainage engineers, from the NRCS National Technical Centers.

Richard D. Wenberg (retired), national water management engineer, and **Ronald L. Marlow**, water management engineer, NRCS Engineering Division, Washington, DC.

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Contents

Overview

What is DRAINMOD?

DRAINMOD is a computer model that was developed to simulate the performance of drainage, subirrigation, and controlled drainage systems.

How will it benefit me?

DRAINMOD is a design tool that allows you to simulate the performance of alternative drainage and associated water management practices and investigate their effects on water use, crop response, land treatment of wastewater, and pollutant movement from agricultural fields. The information obtained from this use of the model allows you to do actual design of drainage water table control, and several other water management systems.

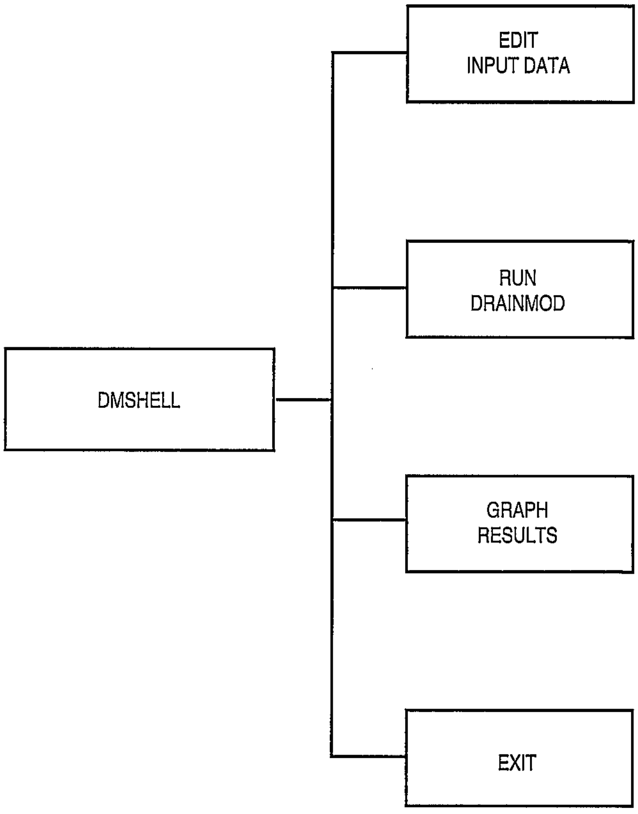
What experience do I need?

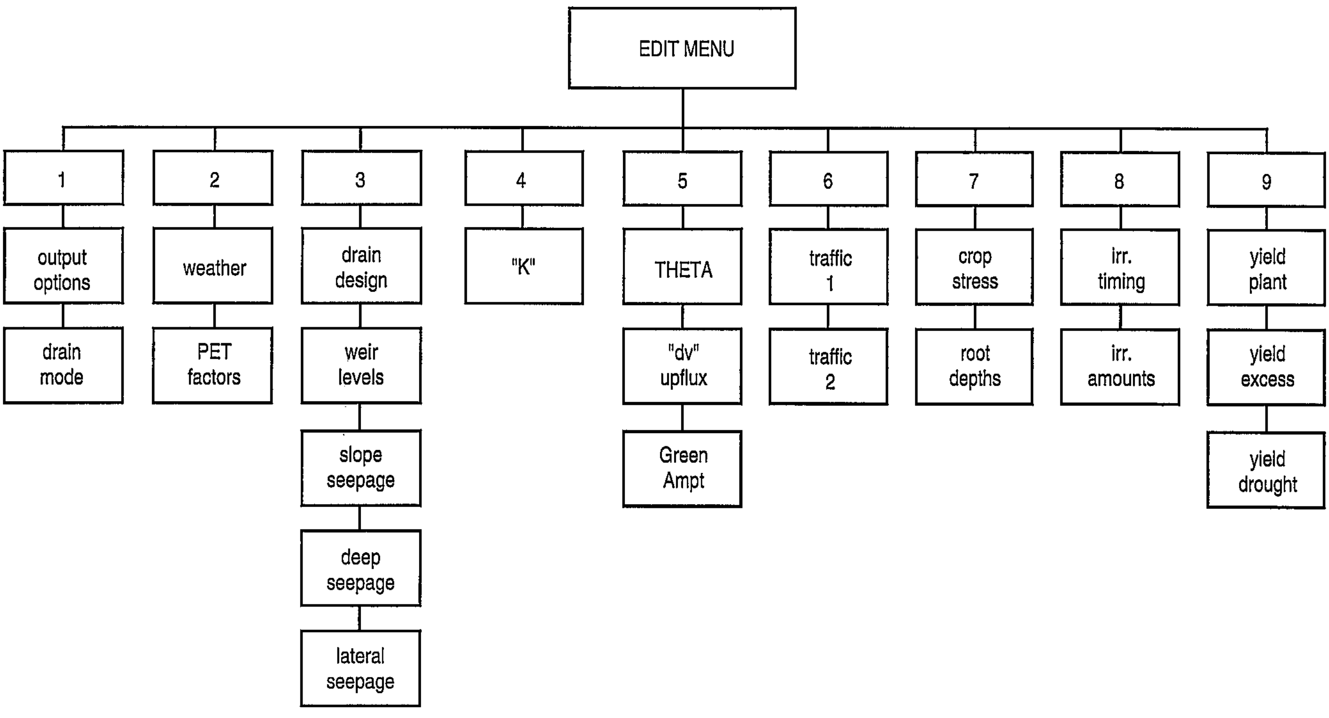
To use DRAINMOD, you should understand water management systems and be familiar with current design procedures. You should have a working knowledge of how the soil water characteristic property and the hydraulic conductivity of soils relates to soil water movement.

What improvements will I find?

Since 1985, several PC versions of DRAINMOD have evolved with improvements to make the program more flexible and easier to use. The program has been restructured to better organize input information. The "YIELD" component has been incorporated into the model. The model is no longer restricted to application on slopes less than 5 percent and has the capability to simulate lateral and deep seepage from the field. Daily potential evapotranspiration data may be directly input to the model if these data are available. The ability to input data for several simulations and execute them in batch mode has been included in this latest version of the model. This latest version includes modifications made to facilitate its use for the hydrologic analysis of wetlands. Programming of the new version was done primarily by Dr. J.E. Parsons and K.D. Konyha. K.D. Robbins was primarily responsible for rewriting the weather data section of the model.

Finding your way





A Closer Look

DRAINMOD is a computer model that was developed by Dr. R.W. Skaggs to simulate the performance of water table management systems. DRAINMOD was first used as a research tool to investigate the performance of drainage and subirrigation systems and their effects on water use, crop response, land treatment of wastewater, and pollutant movement from agricultural fields. Some applications of the model for actual design of drainage and subirrigation systems were made in North Carolina in the late 1970's.

The foundation for application of the model on a wide scale was laid in 1979 when, under the leadership of Walter J. Ochs, the United States Department of Agriculture, Natural Resources Conservation Service, formerly the Soil Conservation Service accepted the modeling concept and supported development of the DRAINMOD Reference Report, "Methods for Design and Evaluation of Drainage-Water Management Systems for Soils with High Water Tables." DRAINMOD was installed on the USDA computer in Washington, D.C. where it was accessible from all Natural Resources Conservation Service State offices. P. Lucas and R. Wenberg, Natural Resources Conservation Service regional drainage engineers in the Midwest and South, respectively, had leadership roles in developing the Natural Resources Conservation Service DRAINMOD User's Manual and in conducting training sessions for the application of the model.

Dr. B.H. Nolte of The Ohio State University and a group of Cooperative State Extension Service, university, and USDA agricultural engineers in the midwest contributed to the development and application of the model via a project sponsored by the North Central Computer Institute (NCCI). The objective of the project was to provide DRAINMOD design documentation for application in the North Central Region. As part of the project, a PC version of the model was written. By the end of the NCCI project in 1985, FORTRAN compilers were available for the PC, and both the YIELD and standard versions of DRAINMOD were made available in FORTRAN on the PC. The NCCI project resulted in a design document (Nolte et al., 1986) and an improved user's manual. These documents, together with BASIC and FORTRAN PC versions of the model, were distributed by NCCI, The Ohio State University, and North Carolina State University.

Version 4.0 incorporates several improvements developed in the water management program at North Carolina State University. This version should return identical results as earlier versions. No attempts were made to change algorithms. Additional algorithms have been added in DRAINMOD 4.0 to consider seepage, slope, and other elements discussed elsewhere. Alternate algorithms for some existing routines are being discussed for inclusion in future versions.

Before using the program, you must obtain specific climate and soils data for the site being considered.

Installation of DRAINMOD, version 4.0

Requirements for DRAINMOD 4.0 are:

- A hard disk with 1 Mbyte free space
- A math coprocessor (recommended)
- DOS 3.0 or higher
- FILES=20 in the CONFIG.SYS
- At least 320K bytes of memory (RAM)
- The directory containing the DOS commands in the DOS Path (namely the EDLIN line editor supplied with DOS)

The following is a walk-through of the first-time installation process.

Step 1 Determine how many hard drives are addressable by your system. Generally, these start at C: and go upward. In some cases, one hard disk may have partitions C:, D:, etc. You must select one hard drive or partition to install DRAINMOD. Your choices, depending on what is available on your system may be C:, D:, E:, or F:. Also determine which floppy drive you will use to install the diskettes. This is usually A: or B:. The following example installs DRAINMOD version 4.0 from the A: floppy to hard disk C:.

Step 2 With your computer on, insert the floppy disk labeled "Program Disk 1" in disk drive a: and shut the drive door.

Step 3 Install the DRAINMOD program from the floppy disk to the hard drive by typing in **install A: C:** and pressing **RETURN**.

Note: **If you want DRAINMOD to be installed on the partition or hard drive associated with D:, then you should substitute D: for C:**

At this point, version 4.0 of DRAINMOD is installed on your hard disk in a directory, such as C:\DM40\EXEFILES, depending on what drive you specified in step 1.

A message of "Batch file not found" at the end of installation is normal. If after inserting disk 3 you receive messages of "File not found," then you probably do not have the DOS command edlin in the path. You can check this by typing **edlin**, then pressing **RETURN** at the DOS prompt. If you are using floppy drive B:, then substitute B: for A:. If disks are used, you should see the note for information about the use of 3.5-inch floppies. Installation takes less than 5 minutes on an 80286 based personal computer.

DRAINMOD can be run by typing the following:

C: chdir C:\dm40\exefiles and pressing **RETURN**. Then type **dmshell** and press **RETURN**.

Step 4 The final step in the installation procedure is to enable DRAINMOD to be accessible from other areas on your hard disk. This assumes some knowledge of DOS. First, edit the AUTOEXEC.BAT file from your root directory on drive C:, and add the directory, C:\DM40\EXEFILES, to the path command. Typically, the path may look similar to this at the start:

PATH C:\;C:\UTIL;C:\BIN

After editing:

PATH C:\;C:\UTIL;C:\BIN;C:\DM40\EXEFILES

You will specify D:\DM40\EXEFILES instead of C:\DM40\EXEFILES if you installed DRAINMOD on D:.

Step 5 Reboot your system to invoke the new path (usually by holding down the Ctrl and Alt keys and pressing the Del key). DMSHELL may be run from any directory or drive by typing DMSHELL and pressing **RETURN**.

If you have problems running the DMSHELL program from another directory other than DM40\EXEFILES, then the path information did not get installed correctly. The following should only be done by those who feel comfortable with DOS. You might try some of the following, proceeding to the next step as needed.

a) Ask your PC expert to assist you with these items.
b) Reboot your system and observe the messages on the screen during the booting process (Do you see an 'out of environment space'?, write this stuff down).
c) Try running DMSHELL again.
d) Rename AUTOEXEC.BAT to AUTOEXEC.OLD

Type the following at the DOS prompt.

copy con autoexec.bat
path c:\dm40\exefiles
<Ctrl>Z

Note: Specify hard drive where DRAINMOD is installed if other than C:

Reboot the system. Try running DMSHELL again. If it works correctly, then you probably ran out of environment space or typed something wrong in the AUTOEXEC.BAT file. Check the AUTOEXEC.BAT file, if this is correct, then study your DOS manual to learn how to expand your environment space. Remember to rename AUTOEXEC.OLD to AUTOEXEC.BAT.

Note: We have successfully run the programs from other directories and disk drives on a number of different versions of DOS and different machines. This includes IBM PC-XT, Zenith 150, 248, 386, and Compaq running DOS versions 3.2 and 3.3 from these manufacturers. File management (proper paths and subdirectories) is controlled by the DMSHELL program. As a result, running the programs within the DMSHELL manager is easier than in earlier versions. The path and subdirectory information to direct the execution of the DRAINMOD package is maintained in a file called CONFIG.DM. Modifications to the CONFIG.DM file are described in the section on advanced user configuration.

Contents of the diskettes

BATCHBLD.EXE—The program to run DRAINMOD, supporting single and multiple runs.

DMSHELL.EXE—The program to manage data input, run DRAINMOD and graph yearly data.

NDMGPH.EXE—The program to produce yearly graphs of water table depths, rainfall, and drainage outflows.

CONVDMF.EXE—The program to convert old PC format DRAINMOD input data (version 3.0) and earlier) to the new format (copies to CONVDMF.EXE in the input data directory).

INSTALL.EXE—The batch file to install the DRAINMOD system.

INSTALL.INF—Notes and details describing the installation process.

INPUTS—The directory containing sample input data for some types of applications.

NDMINP.EXE—The program to enter and edit data for DRAINMOD, version 4.0.

WEATHER—The directory containing sample weather data.

CONFIG.DM—The file for defining locations of various files.

NEWDMY.EXE—The DRAINMOD 4.0 program.

Files contained in the directory INPUTS

BSOIL	SIN	1073	10-22-88	6:47a
CORN130	YIN	417	10-22-88	6:40a
DCNVBN	GEN	1193	10-23-88	12:10p
DCNVBN	LIS	55	10-23-88	12:10p
DCTLBN	GEN	1182	10-23-88	12:10p
DCTLBN	LIS	55	10-23-88	12:10p
DSIBN	GEN	1175	10-23-88	12:10p
DSIBN	LIS	54	10-23-88	12:10p
DWASBN	GEN	1197	10-23-88	12:10p
DWASBN	LIS	55	10-23-88	12:10p
YCNVBN	GEN	1208	10-23-88	12:10p
YCNVBN	LIS	84	10-23-88	12:10p
YCTLBN	GEN	1197	10-23-88	12:10p
YCTLBN	LIS	84	10-23-88	12:10p
YSIBN	GEN	1189	10-23-88	12:10p
YSIBN	LIS	83	10-23-88	12:10p
YSIVS EEP	GEN	1195	10-23-88	12:10p
YSIVSEEP	LIS	86	10-23-88	12:10p

The first letter of the filename is either a D, for non-yield simulations, or a Y, for simulations with yield calculations. The next two or three characters indicate the water management:

CNV - Conventional drainage
CTL - Controlled drainage
SI - Subirrigation
VSEEP - Seepage application

The last two characters are BN, denoting a narrow drain spacing.

The remaining two files are

BSOIL.SIN—Soil inputs for a Rains sandy loam from eastern North Carolina.
CORN130.YIN—Parameters for corn yield simulations

Files contained in the directory WEATHER

WBNCH1.RAI and WBNCH1.TEM—Six years of weather data selected from Wilson, NC, representing two 'wet' years, two 'dry' years, and two 'average' years. The years were renumbered from January 1959 to December 1964 in order to be used to test DRAINMOD. We have found these data helpful in exercising the model for debug purposes. You can get other weather data files for DRAINMOD from NCSU or USDA-NRCS.

The number of .LIS, .GEN, .SIN, and .YIN files is limited to 128 each in the subdirectories. When you reach this limit, three options exist: (a) to delete some of the files using the MS-DOS command (del), (b) backup some of the files to floppy disk for later recall using the MS-DOS command (copy, which is the preferred method), and (c) to create another CONFIG.DM file containing new directories and copying any needed files to the new directories.

The input program offers the choice of writing data to create graphics using the graphing option on the manager program. This option is selected on the first input screen, General Information Screen 1 of 2. The names of these files correspond to the first level of the .LIS file with an extension of .Pyy, where yy is the year (P61 for year 1961). The graphs will display on any monochrome or color monitor connected to a color graphics adapter or an enhanced graphics adapter. If you also have a printer compatible with the IBM graphics printer, you can also get a printed copy of the display graphs. To do this, you must run the equivalent of GRAPHICS.COM (IBM DOS external command) before entering the DRAINMOD manager program. If this is done, pressing Shift and PrtSc simultaneously will print a copy of the graph.

What is created after installing DRAINMOD?

The computer simulation model DRAINMOD consists of the simulation model DRAINMOD and a number of supporting programs. The installation procedure creates an environment in which DRAINMOD simulations can be executed in a convenient and organized manner. The DRAINMOD environments located on the hard disk in a directory called DM40. The DM40 directory is divided into the following four subdirectories:

1) EXEFILES: A subdirectory containing the executable files for DRAINMOD and the support programs.
2) INPUT40: A subdirectory containing input files for DRAINMOD simulations.
3) OUTPUT40: A subdirectory containing output files generated by DRAINMOD.
4) WEATHER: A subdirectory containing weather input files.

The DRAINMOD simulation environment is controlled by the program DMSHELL.EXE. This program provides a menu to select programs for creating and editing input data, executing single and multiple (batch) DRAINMOD simulations, and viewing daily water table depths in relation to rainfall and drainage. The program NDMINP enables the creation and editing of input data sets. The program BATCHBLD is used to execute single and multiple simulations with DRAINMOD. The program NDMGPH creates graphs of water table depths versus time for each year of a given simulation. Daily rainfall or drainage may also be plotted on the graph. The monitor and monitor adapter must be capable of displaying graphics with a resolution of 640 by 200 pixels (commonly referred to as CGA).

Input files

The input data for DRAINMOD are organized into the subdirectory INPUT40. There are four file types for DRAINMOD simulations. The .LIS file contains a list of the filenames for a simulation. This file will contain two or three filenames. The first two file names are the general input data file with extension .GEN and the soils input data file with extension .SIN. The third file name in the list file occurs only when crop relative yield simulations are done and has an extension of .YIN.

The general input file (extension .GEN) contains most of the data inputs that vary during the system design evaluations. The parameters include the title of the simulation, printing and weather data options, water management options, weather data filenames, drainage system design parameters, weir control parameters, saturated hydraulic conductivity, optional slope and seepage inputs, excess and deficit water, trafficability windows, and crop root depths.

The soils input file (extension .SIN) contains the soils data. These data include the soil water characteristic, the relationship of volume drained and upward flux with water table depth, and the Green-Ampt infiltration parameters.

The optional yield input parameter file (extension .YIN) contains the necessary data for simulating relative crop yields. This file contains the information to determine the effects of planting date delay, excess water, and deficit water on crop yield.

If you have soils data that were used with versions before DRAINMOD 4.0, these data can be converted to the DRAINMOD 4.0 format. A program (CONVDMF.EXE) has been included with the installation that generates the new soil input files. Use of the CONVDMF.EXE program to convert files is described in the appendix.

Output files

A number of output summary options are available from the DRAINMOD simulations. All of the output files are created with the same filename as the .LIS file of the simulation. The file extensions indicate the type of output. These files are stored in the output subdirectory OUTPUT40. The ranking file, extension .RNK, contains yearly rankings of parameters, such as number of working days and relative yields. Yearly summaries of a number of simulated parameters are available in the files with extension .YR. Other options enable the selection of daily (extension .DAY) and monthly (extension .MON) summaries of many of the output parameters. If the relative crop yields are simulated, then these are summarized in a file with extension .YLD. A summary of the input data set can also be stored in files with extension .OUT. Another output option enables creation of a file containing daily water table depths and drainage volumes for each year simulated. These files have extension .Pyy where yy is the year (.P61 for year 1961).

Conventions

The main menu is used to access, enter, or edit data in the input files. Ten options are available by selecting a number between 0 and 9. The topics can be edited in any order. Help screens are available for each edit screen displayed during the input or edit session.

Keystrokes

Move the cursor

- From one data entry field to the next. Use the ENTER or the down arrow keys to move forward or the up arrow key to move backward.
- Within a data entry field, use the arrow keys to move forward or backward.

Some fields present default values, such as printing options, that defaults to yearly and rankings. Press return to enter the value in the field where the cursor is positioned. On most screens, any blank field will prevent you from exiting the screen. The editor is initially in the insert mode. This can be changed to the overstrike mode by pressing the insert key which changes the highlight at the top of the screen to OVRSTK.

Function keys

At the bottom of each data entry screen is a display of function (F) keys and their use.

F1 displays help for current screen.
F2 resets the values to those at the time of entry into the screen.
F3 recalculates variables where required.
F5 exits the edit session temporarily and executes DOS commands. Type exit at the DOS prompt to return to the edit session.
F6 exits to the save file options screen.
F7 aborts program.

F8 clears the current edit entry to blank.
F9 pages back one screen.
F10 advances to the next screen.

Key terms

controlled drainage
Is implemented by placing a control structure in the drainage outlet such that the water level in the outlet must rise to a set level (weir elevation) before drainage can occur.

conventional drainage
Subsurface drainage provided by evenly spaced parallel drains with a free (not submerged) outlet. Either drain tubing or drainage ditches may be considered.

dry days
Any day in which actual ET is less than PET because of limited or deficient soil water conditions.

potential evapotranspiration (PET)
The sum of the evaporation from the soil and plant surfaces and transpiration from the plants when there is sufficient supply of soil water.

relative yield
The ratio (expressed as a percent) of the actual yield to the potential yield.

SEW
A value which stands for "Sum of Excess Water" is a way to quantify plant stress due to high water tables.

soil-water characteristic
A measure of how tightly water is held in the soil matrix in the unsaturated state.

subirrigation
Similar to the controlled drainage mode. The main difference is that water is pumped into the drainage outlet to maintain the outlet water level at the set point, or weir elevation.

upward flux
The rate of water movement upward from the water table.

volume drained
The volume of air or water free pore space in the soil profile after the free or gravitational water has moved down to the water table.

working days
The number of days determined by the model during two specified intervals when soil water conditions are suitable for field work such as tillage harvesting, etc.

Advanced user configuration

The DMSHELL program accesses a file called CONFIG.DM in order to direct the execution of DRAINMOD 4.0. The CONFIG.DM file provides a road map for the new version of DRAINMOD to find and store datasets. A sample CONFIG.DM file is given below.

-DMEXE=D:\DM40\EXEFILES
-SHELLEXE=D:\DM40\EXEFILES
-LISGEN=D:\DM40\LISGEN
-SOILS=D:\DM40\SOILS
-YIELD=D:\DM40\YIELDS
-WEATHER=D:\DM40\WEATHER
-OUTPUT=D:\DM40\OUTPUT
-GRAPHOUT=
-MONITOR=MONO
-PRINTER=TTY
-WET=WLAND (This key word is added to the CONFIG.DM file of DRAINMOD version 4.6 for hydrologic analysis of wetland.)

The '-' in the first column denotes a keyword will follow. The programs ignore lines starting with any other character. The executable files can be installed in two possible directories defined by the keywords, DMEXE and SHELLEXE. The directory specified by DMEXE must contain the file NEWDMY.EXE, the actual simulation model DRAINMOD version 4.0. DMSHELL.EXE, NDMINP.EXE, BATCHBLD.EXE, and NDMGPH.EXE are in the directory specified by the SHELLEXE keyword. In the above example, both of these directories are D:\DM40\EXEFILES.

The input datasets may be in different subdirectories specified by the keywords: LISGEN, SOILS, YIELD, and WEATHER. LISGEN specifies the directory that contains the input data files with extensions LIS and GEN. The soils data, extension SIN, are in the directory specified by the keyword SOILS. Crop yield parameter datasets, with extension YIN, are in the directory defined by the keyword YIELD. Weather datasets are in the directory specified by the WEATHER keyword. Currently, the input editor and processing programs can accommodate up to about 128 files of each of the extensions; that is 128 *.LIS, *.GEN, *.SIN, *.YIN, *.RAI, *.TEM, and *.PET files.

The simulation output files are written to the directory specified by the keyword, OUTPUT. The remaining keywords, GRAPHOUT, MONITOR, WET, and PRINTER, are reserved for future use.

In the CONFIG.DM files created by the installation program, the directories for DMEXE and SHELLEXE are the same. In addition, all input datasets are in the INPUT40 subdirectory, and the weather data files are in the WEATHER subdirectory.

The DMSHELL manager program looks for CONFIG.DM in three different places. The first and preferred place is the current directory. Next, DMSHELL reads the MS-DOS environment variables and looks at the execution path for DM40. If the path is found, DMSHELL scans for a directory containing EXEFILES. This directory is extracted from the path and searched for CONFIG.DM. If CONFIG.DM is not found at this point, DMSHELL looks for an environment variable defined as DMPRG and if found, scans this directory for CONFIG.DM.

The first method follows the procedure setup by the installation process. The CONFIG.DM file is in the directory containing DMSHELL.EXE and the path command locates the CONFIG.DM. However, in the case where multiple users are using the same system, a CONFIG.DM file may be in each user's respective subdirectory containing a road map specific to their files. The only restriction is that users must always run DMSHELL from the directory containing their personal CONFIG.DM.

Limitation

The batch building program to run DRAINMOD will only show the first 50 files with a .LIS extension. If this limit is reached, then either copy some .LIS files to another directory or floppy disk or delete some.

The DRAINMOD Model

DRAINMOD is based on a water balance in the soil profile and uses climatological records to simulate the performance of drainage and water table control systems. The model was developed specifically for shallow water table soils. Approximate methods are used to quantify the hydrologic components: subsurface drainage, subirrigation, infiltration, evapotranspiration (ET), and surface runoff. Equations developed by Hooghoudt, Luthin, Kirkham, and Ernst are used to calculate drainage and subirrigation rates, and infiltration rates are predicted by the Green and Ampt equation. Complex numerical methods are avoided by assuming a drained to equilibrium state for the soil water distribution above the water table. Inputs to the model include soil properties, weather data, crop variables, and site parameters. Soil property inputs include the saturated hydraulic conductivity (by layers), the relationships between drainage volume and water table depth, and information concerning upward flux from the water table. The effective root zone depth as a function of time is also an input.

Hourly precipitation and daily maximum and minimum temperatures are read from weather records, and the water balance is conducted on an hour-by-hour basis. Summaries of the model predictions for hydrologic components, such as rainfall, infiltration, drainage, and ET, are available on a daily, monthly, or annual bases. The performance of a given system design or management alternative may be simulated for a long period of climatological record, say 20 to 40 years to consider the effects of the year-to-year and seasonal variability. The effects of water management system design on yields may also be evaluated. Trafficability and planting date are predicted, and stress-day-index methods are used to calculate yield response to excessive and deficient soil water conditions. Use of the yield components is an option and can be omitted if desired.

The reliability of DRAINMOD has been tested for a wide range of soil, crop, and climatological conditions. Results of tests in North Carolina, Ohio, Louisiana, Florida, Michigan, Virginia, and Belgium indicate that the model can be used to reliably predict water table elevations and drain flow rates. The model also performed well for irrigated California soils when seepage losses were considered.

DRAINMOD limitations

Snow, snowmelt, and the effects of frozen conditions on soil water processes are not considered in DRAINMOD. Therefore, application is confined to periods when the soil is not frozen.

The program was designed for use in humid regions, and its routine application is limited to those regions. It may be used for irrigated, arid regions where the water table is shallow and drainage is required. The rainfall files or the irrigation routine must be modified to insure that the irrigation amounts and timing are correct for this application of the model.

DRAINMOD applications

DRAINMOD simulates the performance of a given system for a long period of weather record. It predicts water table depth, drainage rates, surface runoff and ET on a continuous basis. Alternative system designs may be simulated to select the one that best satisfies the system design objectives. Several drainage and associated water management practices can be analyzed with DRAINMOD. A short discussion of these follow.

Conventional drainage

Subsurface drainage is considered to be that drainage provided by evenly spaced, parallel drains with a free (not submerged) outlet. Either drain tubing or drainage ditches may be considered. Surface drainage is characterized by the average depth of depressional storage, with poor surface drainage for large depressional storage and good surface drainage when the amount of water that can be stored in surface depressions is small.

The performance of a drainage system consisting of both surface and subsurface components may be analyzed. By conducting simulations for several combinations of surface and subsurface drainage, the best depth-spacing combination of subsurface drains can be determined in terms of the drainage objectives.

Controlled drainage

Controlled drainage is used to conserve water and reduce pollutant loading from drained lands. It is implemented by placing a control structure in the drainage outlet such that the water level in the outlet must rise to a set level (weir elevation) before drainage can occur. The water level in the outlet raises to the weir elevation because of surface runoff and subsurface drainage during wet periods. During dry periods water stored in the outlet flows through the drain into the soil profile to satisfy ET demand. This lowers the water level in the outlet and provides potential storage for subsequent drainage events.

The effectiveness of controlled drainage depends on the elevation and timing of the water level control (weir depths), depth and spacing of the drains, soil properties, and other system parameters, such as layout and the dimensions of the outlet ditch or canal. The effects of these factors can be determined by conducting simulations for a range of parameter values.

Subirrigation

This is similar to the controlled drainage mode. The main difference is that water is pumped into the drainage outlet to maintain the outlet water level at the set point, or weir elevation.

The effects of depth and spacing of the drains, elevation and timing of the outlet water levels (weirs), and surface drainage intensity can be determined by conducting simulations for a range of parameters. In addition to hydrologic components and yields, the volume of water pumped for subirrigation is computed.

Surface (sprinkler) irrigation (wastewater irrigation)

Sprinkler irrigation is an option for the model. This option was originally intended to analyze drainage for wastewater irrigation. Conventional irrigation can be analyzed for some cases. Two periods can be specified in that irrigation will not be simulated. The effect of depth and spacing of the subsurface drains and surface drainage intensity on number of days of irrigation and loading rates may be determined.

The minimum drained (air) volume required for irrigation is specified as an input. This is the minimum air volume in the soil profile for irrigation and is a function of the water table depth and the soil porosity. For safety, this should be set at 1 cm more than irrigation amount. The amount of rainfall sufficient to cause postponement of irrigation is also an input (AMTRN).

DRAINMOD outputs: The objective functions

Several objective functions are calculated in DRAINMOD to quantify the performance of the system that is simulated. Annual values of these functions are summarized and ranked. Monthly and daily summaries are also available at the option of the user.

Working days

The model determines the number of days during two specified intervals when soil water conditions are suitable for such field work as tillage or harvesting. Normally one of the periods is for seedbed preparation in the spring, and the second is for harvest in the fall. A day is counted as a working day if the drained or water free pore space is greater than a threshold value, if there is less than a given amount of rain that day, and if rainfall sufficient to delay field work has not occurred within a given number of days.

SEW

Stress due to high water tables (excessive soil water conditions) is quantified by the SEW value, that stands for "Sum of Excess Water." Normally SEW_{30} is calculated as follows:

$$SEW_{30} = \sum_{i=1}^{N} \left(30 - X_i\right)$$

where:
N=number of days in the growing season
X_i=water table depth in centimeters on day i

Negative terms in the summation are ignored. No stress is calculated for water table depths greater than 30 cm (12 in.).

While the SEW_{30} values seem to be appropriate for corn, it should be emphasized that the SEW concept is approximate. Different depths may be more appropriate for other crops. For instance, shallow rooted crops may have the water table closer to the surface without damage. Conversely, crops with deeper rooting systems may be stressed by water tables 45 or 60 cm deep. The depth of the SEW threshold is a DRAINMOD input, thus SEW_{45} or SEW_{XX} can be determined. The SEW value is calculated for each growing season from planting to crop maturity.

Dry days

A dry day is any day in that actual ET is less than PET because of limited or deficient soil water conditions. The sum of dry days that occur during a specified period, usually the growing season, is a DRAINMOD output and is listed in the summary for each year of the simulation.

Relative yield

To evaluate the effects of combinations of stresses, a relative yield may be calculated in DRAINMOD at the option of the user. The relative yield is the ratio (expressed as a percent) of the actual yield to the potential yield. The potential yield is the long-term average yield that would occur if soil water conditions are not limiting, that is if there are not yield reductions due to deficient soil water conditions, excessive soil water conditions or delays in planting.

Separate models for crop response to excessive and deficient soil water conditions, as well as to delays in the planting date, have been incorporated into DRAINMOD (Skaggs et al, 1982). The general crop response model may be written as

$$YR = \frac{Y}{Y_o} = YR_W \times YR_d \times YR_p$$

where:

YR = relative yield

$$YR_W = \frac{Y_W}{Y_o}$$

$$YR_d = \frac{Y_d}{Y_o}$$

$$YR_p = \frac{Y_p}{Y_o}$$

Y = yield for a given year

Y_o = base yield or potential yield

Y_w = yield that would be obtained if only wet stresses occur

Y_d = yield that would be obtained if only drought stresses occur

Y_p = yield that would be obtained if the only reduction is due to a delay in planting date

Individual submodels are used to calculate the relative yields; YR_w, YR_d, and YR_p.

Irrigation volume

When the irrigation option is used to evaluate the potential for wastewater irrigation, the objective function is the irrigation volume, or depth, that can be applied. You specify the interval between irrigations, the time period for the irrigation, the application rate of irrigation water, and the starting and ending dates for irrigation during the calendar year.

The model simulates irrigation at the scheduled time according to the irrigation interval specified if there is a specified minimum amount of drained pore space, or air volume, in the soil profile. If the drained pore space is less than the specified minimum, the scheduled irrigation is canceled and the soil conditions are evaluated at the next scheduled event.

DRAINMOD manager program

The DRAINMOD manager program is used to manage the operation of DRAINMOD by easily preparing and editing a DRAINMOD input data set, running DRAINMOD simulations, or graphing DRAINMOD results. The manager program displays screens on the monitor to allow you to interact with the computer. The first screen displayed by the manager program is shown in the following screen.

```
File:    DRAINMOD MANAGER PROGRAM
Screen:  OPTIONS

 DRAINMOD MANAGER 4.05, (QuickBASIC 4,0 (c) 1987, MICROSOFT CORP.)

SELECT ONE:
        1. Prepare a dataset for DRAINMOD
        2. Run DRAINMOD (allows a batch of simulations)
        3. Graph rainfall and water table depths
        4. Exit

      F1    F2    F3      F4    F5    F6     F7    F8     F9     F10
               OUTPUTS                 EXIT
```

You simply make a selection by typing a number from 1 to 4.

1. Option 1 enables editing, initial input, printing, and inspection of DRAINMOD datasets.
2. Option 2 is used to run DRAINMOD simulations.
3. Option 3 graphs selected results.
4. Option 4 exits the manager program, or you can press F6.

You can temporarily exit the manager program using the F3. Selecting this option places you in the subdirectory containing the outputs from DRAINMOD. Other programs can be run to further analyze the results provided the computer has enough memory. The DRAINMOD system requires 64k of memory. You type **EXIT** followed by the **RETURN** key to return to the DRAINMOD sytem.

Preparation of new or editing existing input files

Task 1
of 2

Method

Prepare an input data set to run a DRAINMOD simulation.

Selection of option 1 on the Program manager screen calls or executes the NDMINP.EXE program that is used to edit DRAINMOD data sets. The input file selection screen is displayed. The input file selection screen directs you to identify four input data files. The stars represent the available space for inputting the data set names. If you are preparing new data sets, simply type in the new data set names in the input fields.

Move through Menus

```
File:    DRAINMOD INPUT PROGRAM
Screen:  INPUT FILE SELECTION

File containing list of input files                    ********.LIS
General input file                                     ********.GEN
Soils input file                                       ********.SIN
Crop input file                                        ********.YIN

Instructions for file input screen
  Instructions:
Enter your filenames in the above fields. Make choice from directory (F4)
or create new files. If existing files are changed during the editing
session, they may be saved under different names on the SAVE screen later.
Cursor and function keys are active. F1 gives this message. F6 exits
immediately to the MANAGER program and F7 aborts to DOS. To accept the
selected files use F10.

   F1     F2     F3     F4     F5     F6     F7     F8     F9     F10
  HELP                 DIR           EXIT  ABORT                  DONE
```

If you are going to edit existing data sets, type these names into the available fields or press **F4** to display and select existing files. The following screen will display if you press **F4.**

```
File:     DRAINMOD INPUT PROGRAM
Screen:   INPUT FILE SELECTION

File containing list of input files                        ********.LIS

General input file                                         ********.GEN

Soils input file                                           ********.SIN

Crop input file                                            ********.YIN

 <-->) :            Right (<-)          :        Left        <Return>
:  Select           <ESC>: Cancel

E:\DM40\INPUT40\*.LIS files                         Page  1  of 1 pages
DCNVBN DCTLBN    DSIBN      DWASBN     YCNVBN     YCTLBN     YSIBN
YWASBN

      F1     F2     F3      F4     F5     F6     F7     F8      F9     F10
     HELP                   DIR           EXIT  ABORT                  DONE
```

The .LIS file is a list of the files to be used in the DRAINMOD simulation. The .GEN file contains general information including printout controls, weather station identification, drainage design parameters, and trafficability parameters. The .SIN file contains soil property inputs. These include the soil water characteristic of the primary horizon in the root zone, a table of drainage volume and upward flux as functions of water table depth, and the Green-Ampt infiltration parameters. The .YIN file contains parameters necessary for estimating relative yield. If the YIELD component is to be used in DRAINMOD, you must select a crop input file (.YIN). However if yields are not to be simulated, the crop input file should be blank.

If you select the .LIS file YSIBN from the list of existing files, the following screen example is the results.

```
File:     DRAINMOD INPUT PROGRAM
Screen:   INPUT FILE SELECTION

File containing list of input files                  YSIBN    .LIS  OLD

General input file                                   YSIBN    .GEN  OLD

Soils input file                                     BSOIL    .SIN  OLD

Crop input file                                      CORN130  .YIN  OLD

      F1     F2     F3      F4     F5     F6     F7     F8      F9     F10
     HELP                   DIR           EXIT  ABORT                  DONE
```

Use the arrow key and press **F10** to make the input file selection. These files may be renamed before exiting the preparation and edit program. After file selection is completed, press **F10** again to proceed to the Main Menu.

Preparation of new or editing existing input files

Task 2
of 2

Prepare an input data set to run a DRAINMOD simulation. Access and edit data in the input files.

The Main Menu is used to access and edit data in the DRAINMOD input files.

Move through Menus

```
File:     E:\DM40\INPUT40\YSIBN.LIS
Screen:   Main Menu

                  EDIT MENU
          Select Topic to Edit
  0       Edit All Screens
  1       General Information
  2       Weather Inputs
  3       Drainage Design Parameters
  4       Lateral Saturated Hydraulic Conductivity
  5       Soils Data
  6       Trafficability Inputs
  7       General Crop Inputs
  8       Sprinkler (Waste) Irrigation
  9       Crop Yield Parameters

  Press function key F6 when done.

    F1    F2    F3    F4    F5    F6    F7     F8    F9    F10
    HELP                        DOS   EXIT  ABORT             NEXTSCR
```

Ten options are available. Select a number between 0 and 9 to gain access to the operations. A flowchart showing each of the screens accessible by the Main Menu is presented at the beginning of this manual. The topics can be edited in any order. The Main Menu is redisplayed after the completion of the editing of a topic. Options 1-9 are discussed in individual operations.

If you choose option 0 you can edit all of the input data. You should use this option when setting up new data sets.

General information

Task 1

of 2

Complete the general information for an input data set. On the general information screens enter the title of the simulation, select output options, specify weather data to be used for evapotranspiration calculations, and specify the water management options. The first general information screen is displayed when either options 0 or 1 are chosen from the Main Menu.

Move through Menus

```
File:     E:\DM40\INPUT40\YSIBN.GEN
Screen:   General Information - 1 of 2


Title to Identify Run:
BENCH V3.0 BENCH RUN -- STANDARD
DRAINMOD-SUBIRRIGATION************************
*******RAINS (NC) SOIL, WILSON (NC) DATA, 130 DAY CORN, (2 WET, 2 DRY,
2 AVE YRS)

Printing Options (Y/N):

       (*)  Rankings Only
       (*)  Yearly and Rankings
       (Y)  Monthly, Yearly and Rankings
       (*)  Daily, Monthly, Yearly and Rankings

     (*)   Output file for each year for daily watertable graphs (Y/N)

Weather Data Options (Y/N):
       (Y)  Temperature File
       (*)  Potential Evapotranspiration File

     F1     F2     F3     F4     F5     F6     F7     F8      F9       F10
    HELP   RESET                       EXIT   ABORT  CLEAR  LASTSCR  NEXTSCR
```

Identify input data set

Type in your title to identify the input data set. Two lines are available. The title should be a unique description of the case being simulated. Information that might be included in the title are location, soil series, date, drain spacing, drain depth, surface storage, and water management mode.

Select output printing option

Press **RETURN** or use down arrow to move cursor to select option and press **Y**. The printing options include rankings, yearly summaries, monthly summaries, and daily summaries.

The rankings option produces output files with the objective parameters ranked for each simulation year. The ranked parameters depend on the type of water management option selected (drainage, controlled drainage, subirrigation, and sprinkler irrigation). The next output level also includes yearly summaries of some of the parameters. The parameters again are dependent of the water management option selected. Monthly and daily output summaries can also be added. If daily outputs are selected, the amount of output can be large, about one printed page per month. Details and examples of the output parameters are presented in the appendix. Relative yield determinations are done whenever a relative yield data set is specified with the DRAINMOD input data.

An output file containing the rainfall, drainage, and water table depth for each day can be created for each year of the simulation. These files are used by the plotting program to display water table depth and drainage versus time by years (option 3 on the DRAINMOD shell program). You must also indicate on this screen the type of weather data to be used by DRAINMOD for evapotranspiration calculations. Press Y for your selected weather data option.

When you have chosen the appropriate printing options and weather data options, press **F10** to move to screen 2.

General information

Task 2
of 2

You select the surface and subsurface water management options from the second screen. Only one subsurface water management option should be selected. Press **RETURN** or use down arrow to move cursor to select option and press **Y**.

Move through Menus

```
File:    E:\DM40\INPUT40\YSIBN.GEN
Screen:  General Information - 2 of 2

  Subsurface Water Management Options:

     (*)   Conventional Drainage    Move cursor to select option
     (*)   Controlled Drainage      and press <Y>
     (Y)   Subirrigation


     Surface Water Management Option (Y/N) :

     (*)   Waste Water Irrigation Application

     F1    F2     F3     F4     F5    F6    F7     F8      F9      F10
     HELP  RESET                      EXIT  ABORT  CLEAR  LASTSCR NEXTSCR
```

Conventional drainage—This option is used when surface and subsurface drainage alternatives are to be studied. A free (not submerged) outlet is assumed for the subsurface drains.

Controlled drainage mode—A control structure is placed in the drainage outlet such that the water level in the outlet must rise to a set level (weir elevation) before drainage can occur. This mode differs from subirrigation in that water is not pumped into the drainage outlet to maintain the water level at the weir elevation. The water level in the outlet raises to the weir elevation due to surface runoff and subsurface drainage during wet periods. During dry periods water stored in the outlet flows through the drain into the soil profile to satisfy ET demand. Ditch dimensions and weir levels need to be specified in the drainage design section.

Subirrigation mode—This is similar to the controlled drainage mode except that water is pumped into the drainage outlet. DRAINMOD computes the volume of water required to maintain the water level in the drainage outlet at the weir elevation. Ditch dimensions and weir levels need to be specified in the drainage design section.

Wastewater irrigation—This is used to analyze drainage requirements for wastewater irrigation, but may also be used to simulate conventional irrigation. Parameters for simulating irrigation are specified in the surface irrigation section.

To move to the next screen press **F10**.

Climate data entry—Weather station information, temperature, or evapotranspiration file

Task 1

of 2

Enter rain and temperature file names, weather station identifications, latitude, and heat index for temperature station and simulation starting and ending times.

Method

Access the climate data screens by selection option 2 from the Main Menu and enter data.

The first Weather Inputs screen displayed depends on the type of weather file specified in the General Information screen. The first screen is the Weather Inputs screen for a DRAINMOD simulation that calculates Potential Evapotranspiration (PET) from a temperature file.

Move through Menus

```
File:    E:\DM40\INPUT40\YSIBN.GEN
Screen:  Weather Inputs (Temperature File) - 1 of 2
______ Name _______ Value ______ Description
___________________________________

File Names and Station Identifications :
          RAINID                WBNCH1**.RAIRainfall file name
          RID                   319476 6 character rainfall station number
          TEMPID                **WBNCH1.TEMTemperature file name
          TID                   319476 6character temperature station number

Thornthwaite PET Parameters :
          LAT                   3547   Latitude of Temperature Station
          HIDX                  ******75Heat Index for Temperature Station

Simulation Times :
          IMST                  *1 Starting Month of Simulation
          IYST                  1959   Starting Year of Simulation
          IMED                  12 Ending Month of Simulation
          IYED                  1964   Ending Year of Simulation

     F1     F2     F3     F4     F5     F6     F7     F8       F9       F10
    HELP  RESET                        EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

You must enter data on this screen to proceed on to the next screen. If data is not entered, you cannot exit this screen without exiting the program. Press RETURN or the down arrow to move through the screen. Press F10 to move to the the next screen.

Enter the rainfall and temperature files names and station numbers you want to use. Enter latitude and a previously calculated heat index value for the weather station selected. Enter the starting and ending month and year for the simulation.

Note: DRAINMOD simulates complete years of weather data. You must have both rainfall and temperature data for the entire period.

The Weather Inputs screen for a DRAINMOD simulation with a PET file specified is shown.

Note: If you are a first time user, you may refer to Appendix for a more detailed explanation of weather data entries.

Climate data entry—Weather station information, temperature, or evapotranspiration file

Task 2

of 2

Method

Enter PET multiplier factors greater than zero for each month. If you selected to let DRAINMOD estimate PET from a temperature file, you should enter multiplier factors to adjust the PET. The factors must be greater than zero. Factors less than 1.0 will decrease the PET and factors greater than 1.0 will increase the PET. (See appendix A.) If you do not want to adjust the DRAINMOD calculated PET values, enter a multiplier of 1.0 for each month.

Move through Menus

```
File:    E:\DM40\INPUT40\YSIBN.GEN
Screen:  Weather Inputs (Monthly PET Multiplication Factors) - 2 of 2


                  PET Multiplier
January              1***
February             ***1
March                ***1
April                ***1
May                  ***1
June                 ***1
July                 ***1
August               ***1
September            ***1
October              ***1
November             ***1
December             ***1

       F1     F2     F3     F4     F5     F6     F7     F8      F9       F10
      HELP   RESET                        EXIT   ABORT  CLEAR  LASTSCR  NEXTSCR
```

Select drainage design parameters

Task 1

of 4

Method

Enter drainage design parameters.

Access the Drainage Design screens by selecting option 3 from the Main Menu, then move through the screens entering the appropriate data. Press **Return** or the down arrow to move through the screens. Press **F10** to move to the next screen.

Enter Data

```
File:     E:\DM40\INPUT40\YSIBN.GEN
Screen:   Drainage Design Parameters - 1 of 5

_______ Name _______ Value ______ Description ______________________
Subsurface Design:
     DDRAIN                  100****      depth from soil surface to drain (cm)
     SDRAIN                  ***2000      spacing between drains (cm)
     EFFRAD                  ****1.5      effective radius of drains (cm)
     ADEPTH                  ****140      actual distance from the drain to
                                          imperm. layer (cm)
     HDRAIN      (recalc)    **36.47      equivalent depth from drain to imperm.
                                          layer (cm)
     DC                      ****2.5      drainage coefficient (cm/day)
     GEE         (recalc)    **10.97      Kirkham's coefficient G
     DTWT                    *****50      initial depth to water table (cm)

Surface Design:
     STMAX                   *****.5      maximum surface storage (cm)
     STORRO                  *****.5      Kirkham's depth for flow to drains (cm)

Seepage              (Y/N):
  (*) Down Slope             (*) Vertical              (*) Lateral

      F1     F2     F3      F4    F5    F6    F7     F8      F9       F10
     HELP  RESET  RECALC                EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

Subsurface Drainage

A number of input parameters describing the subsurface drainage system are required for each simulation. These include DDRAIN, SDRAIN, EFFRAD, ADEPTH, DC, and GEE. DDRAIN is the depth from the soil surface to the drain in cm. The drain spacing is represented by SDRAIN and is specified in centimeters. The effective radius (EFFRAD) of the drains is used in the input processing program by pressing **F3** to compute the Hooghoudt equivalent depth from the drain to an impermeable layer. The effective radius of the drain is the radius of a completely open tube with the same resistance to inflow as the real drain tube. Standard 4-inch (100 mm) corrugated plastic drain tubing has been shown experimentally to offer the same resistance to inflow as a completely open tube with a radius between 5 mm and 20 mm, depending on opening area (Mohammed and Skaggs, 1983). A summary of some effective radii is presented in table 6 in Appendix G.

Most soils have a restricting layer. The distance from the drain to this layer is ADEPTH. To correct for convergence near the drains, Moody's equations are used to compute the Hooghoudt equivalent depth to the drainage barrier that will be less than the depth to the actual barrier. This adjusted depth is a function of the drain depth, radius, and spacing and the actual depth to the barrier. The distance from the drain to the effective drainage barrier is HDRAIN in the model. HDRAIN is computed in the input processing program by pressing **F3**.

The drainage coefficient, DC, (in cm / day) reflects the hydraulic capacity of the drains, that is, the design flow capacity. This is a function of the drain diameter and the slope of the installed drain. DRAINMOD limits the drainage flux to the value of DC. The outlet capacity can also affect DC; however, this is not treated in DRAINMOD. The user must adjust DC to reflect limitations caused by outlet conditions. Typically, with a standard 4-inch drainage tile, the DC would be approximately 2.0 cm / day. The DC can be computed with an application of the Manning's formula as follows:

$$DC = \frac{8,640,000 R^{\frac{2}{3}} S^{\frac{1}{2}} A_t}{\left(A_d n\right)}$$

where:

- R = hydraulic radius (cross sectional area of the tile divided by the wetted perimeter) (m)
- S = slope of the tile
- A_t = cross sectional area of the tile (m^2)
- A_d = area drained by the tile (m^2)
- n = roughness coefficient of the tile.

For circular drain tile flowing to capacity, the hydraulic radius, R, is equal to one-fourth the drain diameter. Typical values for the roughness coeficient are 0.013 for clay or concrete tile, 0.015 for 3- to 8-inch diameter plastic tubing, 0.018 for 10- to 12-inch diameter plastic tubing, and 0.022 for plastic tubing that is more than 12-inches in diameter.

The parameter DTWT is the depth from the soil surface to the water table at the start of the simulation. The importance of this parameter depends on the type of simulation. DTWT will have no effect on the results of long term (20 to 40 year) simulations. However, DTWT may affect results for a simulation of less than one year. If the initial depth to the water table is not known, a value of one-half the drain depth is a good approximation.

Surface design

STMAX and STORRO are used to describe the surface drainage design. STMAX represents the maximum surface storage in centimeters that must be filled before surface runoff occurs. STORRO is the storage in local depressions such that water is prevented from moving freely to a position over the subsurface drain. This parameter determines whether DRAINMOD uses Hooghoudt's equation or Kirkham's equation. If the depth of water on the surface is less than STORRO, then Houghoudt's equation is used. Kirkham's equation is used when the depth of water on the surface exceeds STORRO (water moves freely on the surface to positions over the drains). Some guidelines for estimating STMAX are given in table 7, appendix G.

Kirkham's ponded water equations require the g-factor, GEE. GEE is a function of drain spacing, radius, and the depth of the profile. The input processing program computes the GEE based on the input parameters when **F3** is pressed.

Seepage

You can select any of three seepage options: downslope, vertical, or lateral. To select an option press **y** in the appropriate field.

Select drainage design parameters

Task 2
of 4

Enter outlet ditch dimensions and outlet control weir settings.

Enter Data

```
File:     E:\DM40\INPUT40\YSIBN.GEN
Screen:   Drainage Design Parameters - 2 of 5

 DITCHB 20****    Bottom Width of the Ditch (cm)
 DITCHS ****.1    Ditch Side Slope (Ratio of Run over Rise)

                          Day of Month         New Weir Setting
                                               (cm from surface)
                  January        *1                 ***120
                  February       *1                 ***120
                  March          *1                 ***120
                  April          15                 ****60
                  May            *1                 ****60
                  June           *1                 ****60
                  July           *1                 ****60
                  August         *1                 ****60
                  September      *1                 ****60
                  October        *1                 ***120
                  November       *1                 ***120
                  December       *1                 ***120

    F1     F2     F3     F4     F5     F6     F7     F8       F9      F10
   HELP   RESET                        EXIT   ABORT  CLEAR  LASTSCR NEXTSCR
```

Outlet Weir settings

The drain outlet control water levels are used for controlled drainage and subirrigation simulations. The ditch dimensions and weir levels are edited with the second screen under Drainage Design Parameters. The ditch dimensions required as inputs are effective dimensions for the lateral drains. When the laterals are drain tubes with a ditch collector or outlet, the effective bottom width and side slope of the laterals should be selected such that the storage in these laterals is the same as that stored in the section of the outlet ditch between adjacent laterals. The ditch bottom width in centimeters and the ditch side slope as a ratio of run to rise are specified. The ditch storage is computed with these values. One weir setting per month is allowed. The weir setting requires two inputs the depth from the soil surface (cm) and the day of the month for that setting to become effective. If conventional drainage is chosen, you should specify weir levels equal to or greater than the depth to drains (DDRAIN).

Select drainage design parameters

Task 3
of 4

Enter Data

Enter seepage parameters for sloping areas.

```
File:    E:\DM40\INPUT40\YSIBN.GEN
Screen:  Drainage Design Parameters - 3 of 5

Seepage Parameters for Sloping Areas :

  SLOP      .02**     Hillside slope as a decimal (% slope/100)
  SLENGTH ***10000    Length of slope (cm)

     F1     F2     F3      F4     F5     F6     F7     F8      F9      F10
    HELP  RESET  RECALC                 EXIT  ABORT  CLEAR  LASTSCR NEXTSCR
```

Downslope seepage

Downslope seepage considers the effect of installing the drains on the contour of sloping lands. DRAINMOD was originally developed for relatively flat lands and was restricted to slopes less than 5 percent. However, subsurface drainage is often used on slopes greater than 5 percent. For example, subsurface drainage is installed as an erosion control practice in some areas of western Oregon. Subsurface drainage of these soils, with land slopes that may exceed 15 percent, lowers the water table and reduces surface runoff and erosion from the long duration, low intensity rainfall that is common in that region.

Modifications, based on research by G. Fipps and R.W. Skaggs, were made to DRAINMOD to consider the effects of slope on drainage rates and water table drawdown between parallel drains. The results showed that drain flow rates were essentially independent of slope as long as the water table was above the drains and all drains were functioning. When the water table falls below the drains, downslope seepage will still occur. This flow rate can be estimated by assuming uniform flow and using the following equation first suggested by M. Muskat:

$$q_{ds} = \frac{K_e\, D\, SLOP}{SLENGTH}$$

where:

D	= height of the water table above the impermeable layer
K_e	= effective hydraulic conductivity
SLOP	= land slope as a decimal (%/100)
SLENGTH	= length of the slope in centimeters

The lateral saturated hydraulic conductivity is specified in the Lateral Saturated Hydraulic Conductivity section.

Select drainage design parameters

Task 4
of 4

Enter parameters for vertical deep seepage losses and lateral seepage losses.

Enter Data

```
File:    E:\DM40\INPUT40\YSIBN.GEN
Screen:  Drainage Design Parameters - 4 of 5

   Parameters for Vertical Deep Seepage Losses :

   DEEPH      500.0***    Piezometric Head (cm) of Aquifer at the bottom
                                of the Impeding layer
  DEPTHV      ****1000    Thickness of the Impeding Layer (cm)
   VERTK      *****.02    Vertical Conductivity (cm/hr) of the Impeding
                                Layer

      F1     F2     F3     F4     F5     F6     F7     F8      F9       F10
     HELP  RESET  RECALC                EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

```
File:    E:\DM40\INPUT40\YSIBN.GEN
Screen:  Drainage Design Parameters - 5 of 5

   Parameters for Lateral Seepage Losses :

  DEPTHH50******    Thickness of the Transmissive Layer (cm)
  RIVERH******10    Hydraulic Head of the Receiving Waters (sink) (cm)
                          relative to the top of the restrictive layer
  RIVERL***10000    Distance to the Receiving Waters (cm)
  HORTK******.2     Horizontal Hydraulic Conductivity of the
                          Transmissive Layer (cm/hr)

      F1     F2     F3     F4     F5     F6     F7     F8      F9       F10
     HELP  RESET  RECALC                EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

Vertical seepage

Vertical seepage losses become important if the restricting layer confines a ground water aquifer with a hydraulic head different from the shallow water table. Parameters for the vertical seepage approximation in DRAINMOD are input in the fourth screen displayed. A straightforward application of Darcy's law is performed in DRAINMOD using

$$q_v = \frac{-\mathrm{VERTK}\left(\mathrm{DEEPH} - \mathrm{H_t}\right)}{\mathrm{DEPTHV}}$$

where:

VERTK = vertical saturated conductivity of the restrictive layer (cm/hr)

DEEPH = hydraulic head of the ground water aquifer at the bottom of the restrictive layer (assumed to be constant) (cm)

H_t = average hydraulic head at the top of the restrictive layer (cm)

DEPTHV = thickness of the restrictive layer (cm)

H_t is approximated in DRAINMOD by

$$H_t = DEPTHV + d + y$$

where:

y = mean water table elevation above the drains

d = distance from the drains to the restrictive layer

Lateral seepage

Lateral seepage to a stream or river located a distance RIVERL in centimeters from the drained field may also be simulated. The rate of lateral seepage to or from the stream is approximated using the Dupuit-Forchhiemer assumptions. The equation used in DRAINMOD is

$$q_1 = \frac{HORTK\left[\left(DEPTHH + y\right)^2 - RIVERH^2\right]}{\left(2\,RIVERL\right)}$$

where:

HORTK = effective lateral hydraulic conductivity (cm/hr)

y = height of the water table above the drains

RIVERH = elevation of the water level in the stream (cm)

DRAINMOD also requires the thickness of the transmissive layer, DEPTHH, in centimeters.

Enter lateral saturated hydraulic conductivity

Task

Enter the lateral saturated hydraulic conductivity (k) for each discrete layer to the effective drainage barrier.

Method

These values are input in the Lateral Saturated Hydraulic Conductivity screen that is accessed by selecting option 4 from the Main Menu.

Enter Data

```
File:     E:\DM40\INPUT40\YSIBN.GEN
Screen:   Lateral Saturated Hydraulic Conductivity - 1 of 1

 Layer No.         Bottom Depth        Lateral Hydraulic Saturated
 From Surface      of Layer (cm)             Conductivity (cm/hr)
      1              110****                    *****4.3
      2              ****140                    *******1
      3              *******                    ********
      4              *******                    ********
      5              *******                    ********

     F1      F2      F3      F4      F5      F6      F7      F8        F9        F10
    HELP   RESET                            EXIT   ABORT   CLEAR   LASTSCR   NEXTSCR
```

Model outputs are very sensitive to hydraulic conductivity values. On sensitivity analyses, errors in hydraulic conductivity ranked next to potential evapotranspiration in having the greatest effect on results.

Field evaluations of hydraulic conductivity should be done for any detailed site specific design analysis. Recommended methods to obtain field hydraulic conductivity are either the auger-hole method or the well permeameter method. Depending on the conditions, additional methods, such as the packer type-after drilling and pumping-out test using observation wells, may be more feasible. Explanation and procedures to perform these tests are in the National Engineering Handbook, section 16, chapter 2.

Hydraulic conductivity values can be specified for up to a maximum of five layers. The first parameter, bottom depth of the layer, is the depth (cm) from the soil surface to the bottom of each discrete soil layer. The bottom depth of the last layer should be at least as great as the effective depth of the profile, such as DDRAIN+HDRAIN. The hydraulic conductivities for each layer are specified in centimeters per hour.

Note: **(For users of estimated hydraulic conductivity values) Bracketed numbers appearing in the hydraulic conductivity field [xxxx], where xxxx is a number, represent K values predicted by a USDA-Natural Resources Conservation Service method (DMSOIL) based on soil type, texture and other features. These programs are available from USDA-Natural Resources Conservation Service in Lincoln, Nebraska. Values are predicted for vertical saturated conductivities and should be used with caution. Measured values for lateral K on the site considered should be used if possible.**

Entering soils data

DRAINMOD soils data are very important for reliable simulations of system design and performance. Approximate procedures for estimating unsaturated hydraulic conductivities, volume drained, upward flux, and Green-Ampt values versus water table depth are supplied in a series of soils data preparation programs. The documentation for these programs is in appendix B.

Task 1
of 3

Enter soil-water characteristic data.

Method

These values are edited in three screens, which are accessible by selecting option 5 from the Main Menu. Press **F10** to move to the next screen.

Enter Data

```
File:     E:\DM40\INPUT40\BSOIL.SIN
Screen:   Soils Data (Soil Water Characteristic) - 1 of 3

Soil Title:
RAINS.SIN, EXAMPLE SOIL FROM EASTERN NC************************************

          Theta              Head              Theta             Head
       (cm^3/cm^3)           (cm)           (cm^3/cm^3)          (cm)
         ****.37           *****0.0           ****.15          **-2000
         *****.3           *****-10           *******          *******
         ***.282           *****-20           *******          *******
         ***.272           *****-30           *******          *******
         ***.266           *****-40           *******          *******
         ***.258           *****-50           *******          *******
         ***.254           *****-60           *******          *******
         ***.248           *****-70           *******          *******
         ***.244           *****-80           *******          *******
         ***.238           ****-100           *******          *******
         ***.228           ****-150           *******          *******
         ***.224           ****-200           *******          *******

     F1     F2     F3     F4     F5     F6     F7     F8      F9      F10
    HELP  RESET                         EXIT  ABORT  CLEAR  LASTSCR NEXTSCR
```

Soil-water characteristic

The soil-water characteristic is a measure of how tightly water is held in the soil matrix in the unsaturated state. The soil water characteristic is a basic soil property that is second in importance to only hydraulic conductivity in modeling soil water movement. It is usually determined in the laboratory using tension tables or pressure plates. Several values should be obtained between 0 tension and -1 bar (-1000 cm), with the greatest concentration of values between 0.0 and -150 centimeter, for example at 0 centimeter head, 20, 50, 100, 150, 300, 500, 1,000 and 15 bar.

Soil-water characteristic (THETA) values are entered for the top layer of the soil profile along with the corresponding negative pressure head in the SOILS DATA section. The last value of the pressure head should be -1000 centimeter or less; i.e. a larger negative number.

Entering soils data

Task 2

of 3

Enter volume drained and upward flux values for various water table depths.

Enter Data

```
File:     E:\DM40\INPUT40\BSOIL.SIN
Screen:   Soils Data (Watertable/ Volume Drained/ Upward Flux) - 2 of 3

  WTD   Vol Drained  Upward Flux                WTD    Vol Drained  Upward Flux
  (cm)     (cm)        (cm/hr)                  (cm)      (cm)        (cm/hr)
 0*****    ******0    *******.2                **1000    ****100     ********0
 ****10    ****.25    *******.1                ******    *******     *********
 ****20    *****.8    ******.08                ******    *******     *********
 ****30    ****1.6    *****.025                ******    *******     *********
 ****40    ****2.3    ****.0112                ******    *******     *********
 ****50    ******3    ****.0058                ******    *******     *********
 ****60    ****3.6    ****.0031                ******    *******     *********
 ****70    ****4.4    ****.0018                ******    *******     *********
 ****80    ****5.2    *****.001                ******    *******     *********
 ***100    ****6.9    ****.0004                ******    *******     *********
 ***120    ******9    ********0                ******    *******     *********
 ***150    ***12.5    ********0                ******    *******     *********
 ***200    *****20    ********0                ******    *******     *********
 ***300    *****35    ********0                ******    *******     *********
 ***500    *****50    ********0                ******    *******     *********

      F1      F2      F3       F4       F5      F6      F7      F8       F9      F10
     HELP   RESET                              EXIT   ABORT   CLEAR  LASTSCR  NEXTSCR
```

Volume drained

This is the volume of air or water free pore space in the soil profile after the free or gravitational water has moved down to the water table. Values of air volume (Vol Drained) corresponding to various water table depths (WTD) are input in the second screen of Soils Data. DRAINMOD uses the volume drained relationship to determine rise and fall of the water table when a given amount of water is removed or added. Drainage volume can be derived from the soil water characteristic values using the soil preparation programs discussed in appendix B.

Note: The methods used for indexing in the program requires the last entry for Vol Drained to be 100 and the last entry for WTD to be 1000 for the volume drained relationship.

The slope of the Vol Drained-WTD relationship is the drainable porosity. Therefore this relationship can be obtained very simply from drainable porosity if it is known or if it can be estimated. See the Reference Report (Skaggs, 1980) for details.

Upward flux

Upward flux is the rate of water movement upward from the water table. Upward flux is synonymous with the term capillary movement. This value is quite important since there may be insufficient water in the root zone for PET. In these cases the upward flux into the root zone may limit ET causing stress to the crop.

Upward flux may be determined mathematically from the unsaturated hydraulic conductivity functions of the soil horizons. These functions can be estimated from the soil water characteristics and the saturated "K" values using the soil preparation programs discussed in appendix B. The methods used for indexing in the program requires the last value for depth to the water table to be 1000 cm and 0 for upward flux.

Entering soils data

Task 3

of 3

Enter Green-Ampt parameters for various depths.

Enter Data

```
File:     E:\DM40\INPUT40\BSOIL.SIN
Screen:   Soils Data (Green-Ampt Infiltration Parameters) - 3 of 3



Depth (cm)      A (cm^2/hr)    B (cm/hr)
0******          *******0      *******0
*****50          *****1.2      *******1
****100          *****3.3      *******1
****150          *******6      *******1
****200          *****9.2      *******1
****500          ******25      *******1
***1000          ******25      *******1
*******          ********      ********
*******          ********      ********
*******          ********      ********


       F1    F2     F3      F4     F5     F6     F7     F8       F9      F10
      HELP  RESET                        EXIT   ABORT  CLEAR  LASTSCR NEXTSCR
```

Green-Ampt equation parameters

The Green-Ampt equation is used to determine the rate of infiltration. Two coefficients (A and B) are used in the equation. Values for the A and B coefficients may be derived mathematically from the saturated vertical hydraulic conductivity and the soil water characteristic. The coefficients A and B are entered along with depth to the water table in soils data. Again, the last set of values should correspond to a water table depth of 1,000 cm.

The Reference Report (Skaggs, 1980) discusses four methods to determine the Green-Ampt parameters. The recommended method is #4: calculation of S_{av} using prediction equations for K and measured soil characteristic data. The equations for A and B are:

$$A = K_s \, M \, S_{av}$$

$$B = K_s$$

where:

K_s = vertical saturated hydraulic conductivity
M = fillable porosity (water content at saturation in cm^3/cm^3 minus the water content at the desired water table depth)
S_{av} = suction at the wetting front in centimeters

If you only have a lateral saturated conductivity, K_L, (the K determined with the auger–hole method, for example), then a choice of one-half K_L is a starting estimate for the vertical saturated conductivity, K_s. Typical S_{av} values by soil textural class are given in table 8, Appendix G. Effects of tillage and management practices on S_{av}, K_s, and the soil water retention function were analyzed by W.J. Rawls et al.

Note: The present DRAINMOD shell program (DMSHELL) will not allow a change in the number of lines in soil properties when editing a data set. The number of entries or lines can be changed by using an editor outside of DMSHELL. An alternative is to enter as a new data set. This will be changed in the next release of DRAINMOD.

Trafficability inputs

Task 1

Enter Trafficability Parameters for soil tillage and seedbed preparation period.

Method

The screens for editing these data are accessed by selecting option 6 from the Main Menu. Press **F10** to move to the next screen.

Edit Data

```
File:     E:\DM40\INPUT40\YSIBN.GEN
Screen:  Trafficability Inputs - 1 of 2
______ Name ______ Value ______ Description

1st Work Period :

     MOBW1           4*     Month Number to begin counting work days
    IDABW1          *1      Day to begin counting work days
     MOEW1          10      Month Number to end counting work days
    IDAEW1          *1      Day to end counting work days
    SWKHR1          *8      Starting hour of work day
    EWKHR1          20      Ending hour of work day
     AMIN1     ******3.9    Minimum air volume (cm) required to work land
    ROUTA1     ******1.2    Minimum rain (cm) to delay work
    ROUTT1     ********2    Delay (days) after rain to recommence work

   F1    F2    F3    F4    F5    F6    F7    F8     F9      F10
  HELP  RESET                   EXIT  ABORT CLEAR LASTSCR NEXTSCR
```

Two periods are specified in DRAINMOD, a spring and fall period, for calculating trafficable conditions in the field. The inputs for each period are the month and day to start counting work days (MOBWx and IDABWx), the month and day to stop counting work days (MOEWx and IDAEWx), and the starting and ending hours for working (SWKHRx and EWKHRx). The "x" is either 1 for the spring period or 2 for the fall period. The final inputs are the drained volume (or water free pore space) in centimeters needed to work the soil (AMINx), the amount of rainfall in centimeters to postpone field operations (ROUTAx), and the number of days following postponement to recommence field operations (ROUTTx). Typical values for some North Carolina soils are shown in table 9, appendix G.

Enter Trafficability Parameters for crop harvest period.

Enter data then press **F10** to move to the next screen

Enter Data

```
File:    E:\DM40\INPUT40\YSIBN.GEN
Screen:  Trafficability Inputs - 2 of 2
_____ Name ______ Value _____ Description

2nd Work Period :

        MOBW2         12   Month Number to begin counting work days
        IDABW2        32   Day to begin counting work days
        MOEW2         12   Month Number to end counting work days
        IDAEW2        32   Day to end counting work days
        SWKHR2        *8   Starting hour of work day
        EWKHR2        20   Ending hour of work day
        AMIN2   ******3.9  Minimum air volume (cm) required to work land
        ROUTA2  ******1.2  Minimum rain (cm) to delay work
        ROUTT2  ********2  Delay (days) after rain to recommence work

    F1    F2    F3     F4     F5     F6    F7     F8     F9      F10
   HELP  RESET                      EXIT  ABORT  CLEAR LASTSCR NEXTSCR
```

If DRAINMOD is computing relative yields for a design, you should use a long spring trafficability window since work days are accounted for in the planting date delay calculations. In this case the model starts simulation of crop response to deficit and excess soil water stresses only after a preset number of working days have been accumulated. Working days are counted only within the trafficability window. Therefore if the window is too short, the required number of working days may not occur in some years. In this case the crop will not be planted and the yield will be zero.

General crop inputs

Task 1
of 2

Enter Crop Stress Condition input parameters.

Method

These values are input in the General Crop Input screens which are accessed by selecting option 7 from the Main Menu. Enter data and press **F10** to move to the next screen.

Enter Data

```
File:     E:\DM40\INPUT40\YSIBN.GEN
Screen:  General Crop Inputs - 1 of 2
_______ Name _______ Value ______ Description
___________________________________________

  WP     .09**    Lower limit of water content (cm3/cm3) in root zone

Wet Stress Parameters :
        ISEWMS            *4    Starting Month to begin counting wet stress
        ISEWDS            10    Day to begin counting wet stress
        ISEWME            *8    Month Number to end counting wet stress
        ISEWDE            18    Day to end counting wet stress
        SEWX         *****30    Limiting water table Depth. Wet Stresses are
                                calculated for water table depths less than SEWX
Drought Stress Parameters :
        IDRYMS            *4    Starting Month to begin counting dry stress
        IDRYDS            10    Day to begin counting dry stress
        IDRYME            *8    Month Number to end counting dry stress
        IDRYDE            18    Day to end counting dry stress

      F1     F2     F3      F4      F5     F6     F7     F8      F9      F10
    HELP   RESET                          EXIT   ABORT  CLEAR  LASTSCR NEXTSCR
```

Stress conditions for a crop can be determined without specifying a relative yield input file. In this case DRAINMOD computes the amount of excess soil water (SEW) and the number of dry days. The parameters for computing these excess and deficit soil water conditions are specified in the General Crop Inputs section accessed by selecting option 7 from the Main Menu.

The first input required for this section is the lower limit water content (usually assumed to be the wilting point), WP, in cm^3/cm^3 of the soil horizon containing the maximum crop root depth. This value is generally chosen close to the 15 bar soil water content. WP may occur at less than the 15 bar soil water content for crops that cannot tolerate drought stresses. This value sets the lower limit for water extraction from the root zone by the crop.

The next set of inputs determine how excessive water conditions are evaluated. The inputs needed for the SEW concept include the period of the year to assess wet conditions and the minimum water table depth for no crop damage (SEWX in cm). Wet stresses are computed whenever the water table is between the surface and the value of SEWX. A value of 30 cm for SEWX is generally chosen for corn. The period to evaluate wet stresses is input as the starting month and day (ISEWMS and ISEWDS) and the ending month and day (ISEWME and ISEWDE).

The DRAINMOD reference report indicates that corn, which can have root depths to 2 feet, can produce satisfactorily if the water table can be generally kept out of the top 30 centimeters. It should be stressed that the top 30 centimeters should not be considered as a sacred figure. For instance, shallow rooted crops may have the water table nearer the surface without loss in yield. Conversely, crops with extensive root systems deeper in the soil should have the water table maintained at a lower level. All such water table criteria are approximate and dependent on soil properties as well as the crop. A 30 cm depth may be too shallow for corn on some soils.

SEW_{30} is calculated for the crop growing period from seeding until crop maturity. SEW_{30} is the summation of the days times water table encroachment in centimeters. If for instance on May 30, the water table has encroached 4 cm into the top 30 cm of the profile and on May 31, 6 cm, the total SEW_{30} for these 2 days would be:

$$\begin{aligned} 1 \times 4 &= 4 \\ 1 \times 6 &= 6 \\ SEW_{30} &= 10 \end{aligned}$$

For drought conditions, you should specify the starting month and day (IDRYMS and IDRYDS) and the ending month and day (IDRYME and IDRYDE) of the period to count drought stresses. A "dry day" is computed in DRAINMOD whenever ET is less than PET because of limiting soil water conditions.

If crop relative yields are being evaluated, these periods (for excess and deficient water conditions) should be set large enough to accommodate any planting date delays that may occur because of poor trafficability conditions. Otherwise, these factors will not reflect the real stresses since these periods are not adjusted when crop relative yields are simulated.

General crop inputs

Task 2

of 2

Enter Data

Enter crop rooting depth versus time after planting relationships.

```
File:     E:\DM40\INPUT40\YSIBN.GEN
Screen:   General Crop Inputs - 2 of 2

  Month    Day   Root Depth (cm)    Month  Day      Root Depth (cm)
  1*       *1       *******3        12     31        *******3
  *4       16       *******3        **     **        ********
  *5       *4       *******4        **     **        ********
  *5       17       ******15        **     **        ********
  *6       *1       ******25        **     **        ********
  *6       20       ******30        **     **        ********
  *7       18       ******30        **     **        ********
  *8       20       ******20        **     **        ********
  *9       24       ******10        **     **        ********
  *9       25       *******3        **     **        ********

   F1     F2     F3     F4     F5     F6     F7     F8      F9      F10
  HELP  RESET                        EXIT  ABORT  CLEAR  LASTSCR NEXTSCR
```

Rooting depth

These values indicate the rooting depth attained at different times of the calendar year. A good source of root depth values is a local agricultural experiment station. Use a value of 3 to 4 centimeters for the fallow periods to reflect the soil depth from which water will be evaporated in the absence of a crop.

Maximum depth for the majority of feeder roots for various crops are presented in table 10, appendix G. Root depths are affected by many factors including the presence of chemical and physical barriers, such as a clay pan or acid subsoil. The graph in appendix G shows the relationship for corn root depth versus time after planting for a soil without noted physical or chemical barriers. For the water table management mode (and a reliable water source), root depth can be maintained at a much lower value and not affect production substantially. Use of the 60 percent line for corn on the graph has generally been successful in use of the model. In general the effective root depth to be used in the model should be less than the values given in table 10. Furthermore it should be input as a function of time after planting. Methods for estimating the change in root depth with time are discussed in the Reference Report.

Surface irrigation

Task 1
of 2

Enter the parameters used to specify the timing of irrigation on the first Surface Irrigation screen.

Method

These two screens are accessed by selecting option 8 from the Main Menu.

Enter Data

```
File:    E:\DM40\INPUT40\YSIBN.GEN
Screen:  Surface (Sprinkler) Irrigation - 1 of 2
______ Name _______ Value ______ Description

Irrigation Dates:
   MOFDA         1*         Month Number to begin wastewater irrigation
   IDAFDA        *1         Day to begin wastewater irrigation
   INTDAY        *10        Interval between irrigation events (days)
   IHRSTA        *1         Starting Hour of irrigation on each day
   IHREND        *6         Ending Hour of irrigation on each day

No Irrigation Dates:
                                              1st Period       2nd Period
Month to Stop Irrigation                         *0               *0
   Day to Stop Irrigation                        *0               *0
Month to Restart Irrigation                      *0               *0
   Day to Restart Irrigation                     *0               *0

      F1    F2     F3     F4     F5     F6    F7     F8     F9      F10
     HELP  RESET                       EXIT  ABORT  CLEAR  LASTSCR NEXTSCR
```

The day (IDAFDA) and month (MOFDA) when irrigation is initiated along with the irrigation interval (INTDAY) are input. The starting and ending hours of irrigation are also specified. Since ET is set to zero during irrigation events, the starting and ending hours of irrigation should usually be specified for periods other than 0600 to 1800 hours. Up to two periods may be specified during which no irrigation will be simulated by DRAINMOD.

Surface irrigation

Task 2
of 2

Enter on the second screen the minimum drained volume required for irrigation (REQDAR), the minimum rainfall to delay irrigation (AMTRN), and the hourly irrigation rates.

Method

Enter Data

Enter the data and press **F10** to move to the next screen.

```
File:     E:\DM40\INPUT40\YSIBN.GEN
Screen:   Surface (Sprinkler) Irrigation Parameters - 2 of 2

 REQDAR 7***      Minimum Drained (Air) Volume (cm) required for Irrigation
 AMTRN  ***1      Minimum Rainfall (cm) to Delay Irrigation

                       AMTSIM (cm/hr) - Hourly irrigation rate

 January                 **.4
 February                **.4
 March                   **.4
 April                   **.4
 May                     **.4
 June                    **.4
 July                    **.4
 August                  **.4
 September               **.4
 October                 **.4
 November                **.4
 December                **.4

     F1     F2     F3      F4      F5     F6      F7     F8       F9      F10
    HELP  RESET                          EXIT   ABORT  CLEAR  LASTSCR  NEXTSCR
```

REQDAR is the minimum air volume or drained water free pore space (cm) required for irrigation to be simulated. If rainfall in excess of minimum rainfall to delay irrigation (AMTRN) occurs prior to the time of the scheduled irrigation event, it is assumed to be "rained out" and the event is postponed until the next day. The hourly irrigation rate (AMTSIM) is the rate of irrigation in centimeters per hour specified for each month during the irrigation period. The values shown on screen 1 and 2 would result in irrigation between the hours of 1:00 to 6:00 a.m. every 10 days at a rate of 0.4 centimeters per hour, if the water free pore space on the scheduled day was 7.0 cm or more.

If a negative value is used for AMTSIM, the maximum amount possible will be irrigated at each scheduled irrigation. DRAINMOD uses the negative value as a safety factor by assuming AMTSIM is the amount of pore space to leave available for rainfall events. For example, assume that there are 12 centimeters of water free pore space (air volume) available in the soil profile and the application time is still 5 hours. If you specify a 2 cm safety factor, a negative 2 would be input for that month. Actual application rate would then be:

$$12\text{ cm} - 2\text{ cm} = \frac{10\text{ cm}}{5\text{ hr}} = 2\text{ cm / hr}$$

Some typical parameters for wastewater application are presented in table 11, appendix G. Some typical loading rates of a Wagram sandy loam are given in table 12, appendix G.

Enter crop yield input parameters

Task 1

of 3

Enter a crop yield input data set for a relative yield simulation.

Method

Crop relative yields can be simulated in DRAINMOD by including a yield input data set (.YIN) in the list of data sets for a simulation (.LIS file). The yield input data are edited by selecting option 9 from the Main Menu. Enter on the first screen relative crop yield parameters associated with a delay in planting.

Enter Data

```
File:    E:\DM40\INPUT40\CORN130.YIN
Screen:  Crop Yield Parameters - 1 of 3
______ Name _______ Value ______ Description
________________________________________

General Crop Information :

JLAST      100****     Last Day of Year to plant without yield loss
IGROW      ****130     Length of the growing season

Planting Date Reduction Parameters    :

PD         ****105     Desired planting date
REQWRK     ******5     Days required to prepare seed bed and plant
PDRF       ****.87     1st stage reduction factor
DELAY1     *****42     Days to use 1st stage reduction factor
PDRF2      ****1.7     2nd stage reduction factor

     F1     F2     F3     F4     F5     F6     F7     F8      F9       F10
    HELP   RESET                        EXIT   ABORT  CLEAR  LASTSCR  NEXTSCR
```

The equation used by DRAINMOD for computing crop relative yields is

$$YR = \frac{Y}{Y_o} = YR_p \times YR_w \times YR_d$$

where:

- YR = relative yield
- Y = yield for a given year
- Y_o = optimum long-term average yield
- YR_p = relative yield that would be obtained if only reduction due to planting date delay is considered
- YR_w = relative yield if only reduction due to excessive soil water conditions is considered
- YR_d = relative crop yield if the only reduction is due to deficient soil water

Planting delays

General inputs for computing yield are the desired planting date (PD), the length of the growing season (IGROW), and the last day of the year to plant without yield loss (JLAST). PD delays are characterized on a specified planting period for optimum yields. The model considers the number of days to prepare the seedbed and plant (REQWRK) as prerequisite for planting.

Using the first window shown in Trafficability Inputs, DRAINMOD keeps track of work days with REQWRK as the minimum needed for planting. When enough working days have occurred to complete the operation, the PD is fixed, the length of PD delay is determined, and the relative yield is computed. Two yield reduction factors are used, PDRF and PDRF2. If planting occurs after the optimum period, but prior to the end of the first reduction period (with length DELAY1), then yields are reduced by PDRF. When planting is delayed after the first reduction period, yield is adjusted using PDRF2.

The relative yield considering planting date delays independent of other stresses can be written as

$$YR_p = 100 - PDRF \times PDELAY, \text{ if } PDELAY < DELAY1$$

$$YR_P = 100 - PDRF \times DELAY1 - PDRF2 \times (PDELAY - DELAY1), \quad \text{if } PDELAY > DELAY1$$

where:

PDELAY = number of days since the last day of the year to plant without yield reduction.

Parameters for several locations were summarized by Seymour (1986) and are presented in table 13 in appendix G. A consideration with yield calculations is that the spring trafficability window should be large since the planting delay factor will account for the working days.

Enter crop yield input parameters

Task 2
of 3

Enter Data

Enter on the second screen relative crop yield parameters associated with excess water stress.

```
File:    E:\DM40\INPUT40\CORN130.YIN
Screen:  Crop Yield Parameters - 2 of 3

Parameters for Excess Water Stress:

YRDMAX     100        Yield Intercept (%) for crop
DSLOPE     0.71       Slope for Yield versus Wet Stress-Day-Index

         Day after                                  Day after
         Planting   Susceptibility                  Planting           Susceptibility
Period   to begin      Factor              Period   to begin               Factor
  1         **0       ***.20                  7      *70                   ***.19
  2         *10       **.21                   8      *80                    **.14
  3         *30       **0.22                  9      *90                   ***.08
  4         *40       **.27                  10      100                    **.05
  5         *50       **.32                  11      110                    **.02
  6         *60       **.26                  12      120                    **.01

    F1     F2     F3     F4     F5     F6     F7     F8      F9      F10
   HELP  RESET                        EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

Note: This screen is an example for 130 day corn.

```
File:    *:\DM40\INPUT40\CORN125.YIN
Screen: Crop Yield Parameters - 2 of 3

Parameters for Excess Water Stress:

    YRDMAX     100        Yield Intercept (%) for crop
    DSLOPE     0.71       Slope for Yield versus Wet Stress-Day-Index

         Days after                           Days after
         Planting   Susceptibility            Planting      Susceptibility
Period   to begin      Factor         Period  to begin          Factor
  1         **0       ***.20             7       xxx            xxxxx
  2         *30       **.22              8       xxx            xxxxx
  3         *50       **.32              9       xxx            xxxxx
  4         *70       **.19             10       xxx            xxxxx
  5         *90       **.08             11       xxx            xxxxx
  6         *110      **.02             12       xxx            xxxxx

    F1     F2     F3     F4     F5     F6     F7     F8      F9      F10
   HELP  RESET                        EXIT  ABORT  CLEAR  LASTSCR  NEXTSCR
```

Note: This screen is an example for 125 day corn.

```
*:\DM40\INPUT40\SOYB140.YIN
Screen: Crop Yield Parameters - 2 of 3

Parameters for Excess Water Stress:
      YRDMAX     100****    Yield Intercept (%) for crop
      DSLOPE     ****.65    Slope for Yield versus Wet Stress-Day-Index

           Days after                              Days after
           Planting    Susceptibility              Planting   Susceptibility
Period     to begin       Factor          Period   to begin       Factor
  1           **0         **.19             7        120          **.01
  2           *25         **.13             8        130          ****0
  3           *55         **.19             9        ***          *****
  4           *75         **.26            10        ***          *****
  5           *95         **.25            11        ***          *****
  6           110         **.08            12        ***          *****

     F1    F2     F3     F4     F5     F6     F7     F8      F9      F10
    HELP  RESET                       EXIT   ABORT  CLEAR  LASTSCR NEXTSCR
```

Note: This screen is an example for relative crop yield parameters associated with excess water stress (140 day soybean).

Excess water reductions

The method for quantifying the effect of high water tables on corn yields uses the stress day index concept (SDI) developed by Hiler (1969). The model for predicting corn yield response to excessive soil water conditions was developed by Hardjoamidjojo et al. (1982). The equation relating relative yields to wet stresses may be summarized as,

$$YR_w = YDRMAX - DSLOPE \times SDI_w$$

where:

YDRMAX = intercept

DSLOPE = slope of the linear relationship relating stress to relative yields

It should be noted that YR_w is between 0 and 100 percent. YRDMAX may be larger than 100 for cases where the crop can tolerate some excess water conditions without yield loss. SDI_w is the stress day index for excess water conditions and can be expressed as

$$SDI_w = \sum_{j=1}^{N} CS_{wj} \times SDW_j$$

where:

- N = number of days in the growing season
- CS_{wj} = crop susceptibility factor for excess soil water on day j
- SDW_j = stress day factor for day j

In DRAINMOD, the SEW value is used for the stress day factor, SDW_j. Crop susceptibility factors for corn and soybeans were obtained from studies by Evans et al. (1990a) and are given in table 14, appendix G. These factors are dependent on the stage of plant development. They were normalized so that the sum of the factors for the five growth stages is 1.0. These values are based on data collected since the original study by Hardjoamidjojo et. al., 1982. Re-evaluation of these results plus new data on corn and soybean response to flooding resulted in the following equation parameters for yield response to excessive soil water stresses (Evans et al., 1990b):

YRDMAX = 102 and DSLOPE = 0.75 for corn
YRDMAX = 103 and DSLOPE = 0.70 for soybean

Enter crop yield input parameters

Task 3

of 3

Enter Data

Enter on the third screen relative crop yield parameters associated with deficient soil water stress.

```
File:     E:\DM40\INPUT40\CORN130.YIN
Screen:   Crop Yield Parameters - 3 of 3


Parameters for the Effect of Deficient Soil Water Stresses:

     YRIMAX     100****** Yield Intercept (%)  YSLOPE ***1.22  Deficit slope
     SF         ******1.5  Factor for 2 successive periods of deficient soil water
     IGR        ******130 Susceptibility Period Length in Days
                      CROP SUSCEPTIBILITY FACTORS FOR EACH PERIOD
Period Factor      Period     Factor     Period     Factor     Period     Factor
1       ****0       11        ****1       21        **1.2       31        *****
2       ****0       12        ****1       22        ****1       32        *****
3       ****0       13        *1.75       23        ***.5       33        *****
4       ****0       14        ****2       24        ****0       34        *****
5       ****0       15        ****2       25        ****0       35        *****
6       ****0       16        **1.3       26        ****0       36        *****
7       ***.5       17        **1.3       27        ****0       37        *****
8       ***.5       18        **1.3       28        *****       38        *****
9       ****1       19        **1.3       29        *****       39        *****
10      ****1       20        **1.3       30        *****       40        *****


     F1     F2     F3     F4     F5     F6     F7     F8      F9      F10
    HELP  RESET                        EXIT  ABORT  CLEAR  LASTSCR NEXTSCR
```

Deficient soil water stresses

Yield reductions due to deficient soil water stresses are computed using procedures described by Shaw (1978). The relative yield equation may be written as,

$$YR_d = 100 - 1.22 \times SDI_d$$

where:

SDI_d = stress day index for drought conditions

The coefficients of the equation given for corn of 100 and 1.22 are the values for YRIMAX and YSLOPE. The equation to describe the stress day index is,

$$SDI_d = \sum_{j=1}^{N} SD_{dj} \times CS_{dj}$$

where:

SD_{dj} = stress day index
CS_{dj} = crop susceptibility factor for growth period j
N = number of 5-day periods in the growing season

For each 5-day period, the stress day index is defined as,

$$SD_{dj} = \sum_{k=1}^{n} \left(\frac{1.0 - AET_k}{PET_k} \right)$$

where:

- n = number of days in the growth period j
- AET_k = actual evapotranspiration on the day k of the growth stage
- PET_k = potential evapotranspiration on the day k of the growth stage

For Shaw's work, the length of a growth period is 5 days. The crop susceptibility factors were developed by Shaw for each growth period relative to the silking stage and are presented in table 15, appendix G. Under severe stress conditions lasting more than one period, Shaw found that an additional adjustment was required. Thus, if SD_{dj} exceeds 4.5 for two periods, the index for those periods, CS_{dj}, are multiplied by 1.5.

Saving files and exiting the edit program

Task 1
of 2

Save and rename files

Method

The Save Options screen is displayed by pressing **F6** from the Main Menu. The three options available to you are save the files, save and print the files, or discard the files.

Move through Menus

```
File:     Drainmod Input Program
Screen:   Save Options

                              1         Save Files

                              2         Print and Save Files

                              3         Discard Files

Instructions:
     F1 - Gives this message
     F6 - EXITs to the MANAGER program
     F7 - ABORTs to DOS
     Enter the number of the option

     F1     F2     F3     F4     F5     F6     F7     F8     F9     F10
    HELP                               EXIT  ABORT                  DONE
```

The Save File selection screen will be displayed after the selection of either option 1 or 2. The filenames included in the editing session are displayed on the save file selection screen. The manager program identifies the files which have been altered during the editing session with a "<changed>" attribute. You may rename the files that have been edited by moving the cursor to the appropriate file and typing a new name. The files may be accepted and saved by pressing **F10**.

```
File:     DRAINMOD INPUT PROGRAM
Screen:   SAVE FILE SELECTION

YSIBN       .LIS       <CHANGED>    File containing list of input files

YSIBN       .GEN       <CHANGED>    General input file

RAINS       .SIN          Soils input file

CORN130     .YIN          Crop input file

 Instructions:
      F1 - Gives this message
      F7 - ABORTs to DOS
      F10 - Accepts the files and saves the data
      Cursor and function keys are active.
      <changed> indicates that the file has been edited.

      F1    F2    F3    F4    F5    F6    F7    F8     F9    F10
     HELP                                  ABORT                DONE
```

Saving files and exiting the edit program

Task 2

of 2

Make Selection

You may re-edit the data sets that were saved, edit different data sets, or exit to the DRAINMOD manager.

```
File:     Drainmod Input Program
Screen:   EXIT OPTIONS


  SELECT ONE:

      1  Re-edit the same datasets

      2  Edit different datasets

      3  Exit to DRAINMOD Manager


  Instructions:
      F1 - Gives this message
      F6 - EXITs to the MANAGER program
      F7 - ABORTs to DOS

      Enter the number of the option

     F1     F2     F3     F4     F5     F6     F7     F8     F9     F10
    HELP                                EXIT   ABORT                 DONE
```

The final screen displayed during the editing session is the Exit Options screen. This screen is displayed after the files have been saved.

Running DRAINMOD

Task

Set up single or multiple simulations to run with DRAINMOD.

Method

Select option 2 from the options screen of the DRAINMOD manager program. The manager program executes the BATCHBLD.EXE program that sets up single or multiple simulations with DRAINMOD. The initial screen displayed by the BATCHBLD program is shown. The screen is split into two parts.

Make Selection

Make your selection from the list of options by using the appropriate function key.

```
Program: BATCHBLD.EXE
Running DRAINMOD  -  1 of 2

List of      OPTIONS                    Directory of     <SELECT> files
Simulations                             *.LIS files

             F2: <SELECT> file          DCNVBN           Use cursor keys to
                to simulate             DCTLBN           highlight a file.
                                        DSIBN
             F3: <REMOVE> file          DWASBN           Use '+' key to select
                from list               YCNVBN
                                        YCTLBN
             F7: <ABORT> program,       YSIBN            [Up to 50 files
                return to Manager       YWASBN           can be selected]

             F9:<CREATE> batchfile
                to run DRAINMOD
                at a later time
                                                         F1:  <sorts> files
             F10: <RUN> DRAINMOD                         alphabetically

                on selected files

      F1     F2     F3      F4     F5     F6      F7      F8      F9      F10
           SELECT REMOVE                         ABORT           STORE    RUN
```

Use the up and down arrow keys to highlight files, then use the "+" key to select a file from the directory of *.LIS files.

The current option is located in the upper right hand corner of the screen. The BATCHBLD.EXE program is initially in the <select> option. Other available options are <remove>, <abort>, <create>, and <run>. The right half of the display screen changes with each option. The left half of the display screen includes an area for listing selected simulations (.LIS files) and the options menu.

The <select> files option includes a display listing the available files created for a DRAINMOD simulation. The list includes all files in the INPUT40 directory with a *.LIS filename extension. Up to 50 files may be selected and run with DRAINMOD. Press **F1** to sort the files alphabetically.

Press **F3**, <remove> option, to highlight and remove files from the list of simulations. The <remove> option can only be selected if files exist in the list of simulations. The up and down arrow keys are used to move through the list. The "-" key is used to remove a file from the list. After the removal of a file, the display screen returns to the default, <select> options, screen.

After all files have been selected for the simulations, two options are available for running DRAINMOD. Press **F9** to create and store a batch file to run DRAINMOD on all selected files at a later time. The computer prompts you for a filename for the batch file to be created. Press **F10** to run DRAINMOD on the selected files.

Note: A yes response is required before the simulations are initiated.

When screen 2 is displayed, you must select the method to be used to display the General Outputs and diagnostic messages.

```
Program:  BATCHBLD.EXE
Running DRAINMOD   -   2 of 2

  OUTPUTS OF DRAINMOD   (selected in Data Preparation program)

  filename.DAY    daily hydrology
  filename.MON    monthly summaries
  filename.YR     yearly summaries
  filename.RNK    ranking of output data
  filename.YLD    annual yield summary
  filename.Yxx    plot of data for year xx (1 file for each year)


  Diagnostic messages and checks on inputs are also produced.
  These General Outputs can be written into a .GEN file.


  Direct GENERAL OUTPUTS to (S)creen, (P)rinter or (F)ile?




       F1     F2     F3      F4     F5     F6      F7     F8       F9      F10
```

After the batch filename has been specified in the <create> option or the yes response in the <run> option, screen 2 is displayed. This screen lists for you the 6 possible output files available from DRAINMOD (discussed in the general information section). Only the output files selected by you in the general information section of the data preparation program are created by DRAINMOD. The default option for displaying the information is the computer screen (by pressing any key except the P or F keys). (The information created by DRAINMOD moves rapidly across the computer screen.) The DRAINMOD information may be written to a file by pressing the **F** key. The file is created in the \OUTPUT40 directory with the file extension .OUT. A sample of the output file is in appendix D. The information created by DRAINMOD may be directed to the printer by pressing the **P** key.

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Appendix A
Preparation of climate data

The DRAINMOD model requires climatic data. The climatic data is available from the Natural Resources Conservation Service Climatic Data Access Facility. Your local State Natural Resources Conservation Service office has a climatic data liaison (CDL) who will have access to the data in the proper format for the program.

Potential evapotranspiration (PET) is the sum of the evaporation from the soil and plant surfaces and transpiration from the plants when there is a sufficient supply of soil water. PET demands may be satisfied with the upward movement of water from the water table (upward flux) and available soil water in the root zone. If the sum of upward flux and the water in the root zone is less than PET, the actual evapotranspiration (ET) will be less than PET. Otherwise PET and ET will be the same.

Two options are available for PET. You can create PET data files or use daily maximum and minimum air temperature data files to estimate PET. If the temperature data files are used, then DRAINMOD computes PET using Thornthwaite's equation. This method uses the latitude and heat index for the location along with the temperature data.

The Thornthwaite PET estimates can be adjusted on a monthly basis if more reliable monthly average values for crop ET are known for a specific area. Screen 2 of weather inputs is used to input multiplication factors to adjust the PET. The factors must be greater than zero. Factors less than 1.0 will decrease the PET, and those more than 1.0 will increase the PET. In order to obtain the PET factors an initial run should be done with wet conditions prevailing so that the output ET will coincide with the Thornthwaite PET. Average monthly values of PET are calculated from the output. The multiplication or correction factors for each month is then computed as the ratio of the known monthly average to that predicted by Thornthwaite using DRAINMOD. The factors should be set to 1.0 if the user is inputting PET values directly into DRAINMOD.

The DRAINMOD input file for temperature consists of daily maximum and minimum air temperature in degrees Fahrenheit for each day. These are organized by year, month, and a six-digit station identifier. Table 1 is an excerpt from the benchmark weather data included on the distribution disk (WBENCH1.TEM).

Each month requires two input lines. For example, January 1959 daily maximum and minimum temperatures are contained in lines 1 and 2 of table 1. On the first line, the station ID code is in the first six columns, and is used only for identification purposes. DRAINMOD version 4.0 checks this code with the inputs to verify the temperature data is for the specified station. The next input, which occupies four columns (columns 8-11), is the year. This is followed by the month (1-12) contained in columns 12-13. The station ID, year and month are only on the first line of the data for the month. For our example, the station ID is 319476, the year is 1959 and the month is 1 (January). This is followed by the daily maximum and minimum temperatures. Each temperature can occupy a maximum of three columns and must be right-justified. The maximum and minimum for the first day of the month begins in column 19 with the maximum temperature in columns 19-21 and the minimum temperatures in columns 22-24. The temperatures for day 2 of the month follow with the maximum in columns 25-27 and the minimum in columns 28-30.

The explanation of the format of the first line is shown in table 2. On January 17, 1959, the maximum air temperature was 31 and the minimum was 16.

Table 1 Excerpt from the distribution disk temperature file

```
319476     1959        1          62 36 52 39 56 35 60 30 30 20 37 14 56 23 46 29 33 22 35 17 44 22 48 20 63 35
5527
 70 40  56 20 31  16 36 12 50 15 66 29 76 50 72 31 48 27 56 23 65 40 65 33 62 39 41 35 58 41 62 44 55 34

319476  1959  2       45 30 36 25 35 28 47 35 60 36 51 29 53 22 68 41 50 45 74 46 70 35 50 31 68 41 70 54
 68 46  59 33 63  44 62 42 42 27 33 20 51 16 63 27 62 44 59 35 48 29 54 36 52 36 63 36  0  0  0  0  0  0

319476  1959  3       64 43 47 32 65 30 61 33 60 30 69 47 56 37 56 27 65 31 63 36 56 31 60 36 57 33 69 38
 64 47  58 40 63  40 50 27 64 24 68 34 65 51 57 36 59 28 76 33 81 46 80 56 75 53 54 32 57 25 54 42 65 47

319476  1959  4       76 47 67 45 72 37 61 39 74 35 79 49 76 41 87 49 86 64 85 60 77 59 59 40 42 38 58 37
 73 41  76 44 81  49 80 53 72 61 83 63 72 53 58 45 59 43 72 39 77 47 79 57 81 62 80 62 79 58 85 59  0  0

319476  1959  5       82 57 88 54 93 63 84 62 79 50 83 49 89 59 82 57 79 49 77 55 84 61 86 63 81 67 78 59
 68 47  72 44 77  51 78 56 87 62 84 65 83 68 88 70 89 70 89 68 80 56 84 52 86 58 88 61 88 63 89 66 78 66

319476  1959  6       80 66 80 68 82 66 81 61 82 58 84 58 89 58 90 61 91 63 92 63 92 65 88 66 94 68 77 56
 82 52  84 60 74  52 76 50 82 52 88 57 90 63 92 68 94 71 90 70 88 70 94 72 96 71 99 74 99 73102 74  0  0
```

Table 2 Example of the temperature inputs

```
                          Line 1 of a Month
                   Day of month
 ID      Year  M   1     2     3     4     5     6     7     8     9    10    11    12    13    14
319476    1959  1  62  36 52  39 56  35 60  30 30  20 37  14 56  23 46  29 33  22 35  17 44  22 48  20 63  35 55
27

                          Line 2 of a Month
Day of month
 15   16   17   18   19    20    21    22    23    24    25    26    27    28    29    30    31
7040 56 20 31 16 36 12 50 15 66 29 76 50 72 31 48 27 56 23 65 40 65 33 62 39 41 35 58 41 62 44 55 34
```

The rainfall input data is hourly amounts in hundredths of inches. An excerpt of this file is presented in table 3. Each line of data contains the station ID in columns 1-6, the year in columns 8-11, and the month in columns 12-13. The remainder of the line contains the hourly rainfall amounts. These are specified as day (2 columns), hour (2 columns), and amount (4 columns) with all data right-justified. There are a maximum of 12 Day-Hour-Rainfall values per line. A new line is started whenever the month changes.

Potential evapotranspiration format

DRAINMOD 4.0 can also use files containing daily PET data. An example from a PET file is shown in table 4. There are two lines for each month. The first line contains the station ID in columns 1-6, the year in columns 8-11 and the month in columns 12-13. The daily PET in inches for day 1 of the month is in columns 17-20. PET for day 2 is in columns 21-24 and so on. Line 1 contains the daily PET for days 1-14 and line 2 for days 15-31 (table 5). Hints and notes on drainmod weather files

1) Use your favorite editor to look at your rainfall and temperature or PET files. Note the station ID code in each file. Write down the starting month, day, and year of each file. Go to the end of each file and note the ending month, day, and year.

2) Check the DRAINMOD input data to be sure you have the correct station ID for the rainfall and temperature or PET files. This input data occurs on the Weather Inputs screen. Version 4.0 of DRAINMOD simulates complete years. If your last year does not end on December 30 (12/30), then you will not receive summary data for that year. Monthly and daily files will reflect the periods up to the ending date of the year.

3) Check the starting and ending times of your .GEN data set using the DRAINMOD manager program. You must have both rainfall and temperature weather data for the period.

4) If you are receiving errors from your weather input files, then compare the file format of your files with those given.

5) DRAINMOD reads the weather files for each month of the simulations. The FORTRAN statements to read the Weather files are:

Temperature:

```
        READ(7,700,END=300)
ITDA,IYDAT,IMDAT,(TMAX(I),TMIN(I),I=1,31)
700     FORMAT (I6,1X,I4,I2,5X,28I3/34I3)
```

where:
ITDA = station ID
IYDAT = the year

Table 3 Excerpt from the distribution disk hourly rainfall file*

ID	Year	M	D	H	rf	D	H	rf	D	H	rf	D	H	rf	D	H	rf	D	H	rf	D	H	rf	D	H	rf	D	H	rf	D	H	rf	D	H	rf	D	H	rf
319476	1959	1	1	14	9	1	15	2	1	16	2	1	17	3	1	18	16	1	19	22	1	20	4	1	23	1	1	24	4	2	1	5	2	2	3	2	3	1
319476	1959	1	2	4	2	8	16	6	8	17	6	8	18	5	8	19	8	8	20	1	8	21	5	8	22	1	8	24	1	16	8	1	16	9	1	16	11	5
319476	1959	1	16	12	3	16	13	1	16	14	4	22	2	67	22	3	13	22	4	12	22	5	8	28	11	1	28	12	1	28	13	3	31	2	1	31	3	1
319476	1959	1	31	4	2	31	5	1	31	6	1	31	7	1	31	8	1																					
319476	1959	2	3	8	4	3	9	3	3	10	5	3	11	7	3	12	5	3	13	3	3	14	2	3	15	1	3	18	1	3	19	2	4	1	1	4	2	3
319476	1959	2	4	3	3	4	6	4	4	7	4	4	8	2	4	9	1	4	10	4	4	11	11	4	12	24	4	13	45	4	14	38	4	15	27	4	16	10
319476	1959	2	4	17	16	4	18	14	4	19	10	4	20	4	4	21	10	4	22	2	4	24	1	5	1	1	9	3	1	9	8	1	9	9	1	9	10	2
319476	1959	2	12	23	1	12	24	3	13	1	5	13	2	3	13	3	9	13	4	6	13	5	6	13	6	10	13	7	5	13	8	19	13	9	4	14	10	2
319476	1959	2	14	11	1	15	7	2	15	8	2	15	9	1	18	7	1	18	8	1	18	9	2	23	6	1	23	7	4	23	8	8	23	9	7	23	10	6
319476	1959	2	23	11	1	25	24	2	26	1	11	26	2	12	26	3	3	26	4	22	6	8	22	6	9	12	8	24	1									
319476	1959	3	1	3	1	1	7	1	1	8	1	1	10	1	1	11	1	12	4	4	2	1	4	2	2	7	2	3	10	2	4	11	2	5	4	2	6	3
319476	1959	3	2	7	17	2	8	12	2	9	10	2	10	8	2	11	8	2	12	4	2	13	3	2	14	2	2	15	1	3	21	10	3	22	6	3	23	4
319476	1959	3	3	24	3	5	23	2	5	24	13	6	1	23	6	2	45	6	3	24	6	4	15	6	5	8	6	8	2	6	9	1	10	18	2	11	24	4
319476	1959	3	12	2	1	12	3	1	12	4	1	12	7	1	12	8	16	12	9	11	5	7	2	15	8	3	15	10	7	15	11	11	15	12	2	21	3	12

* M is month, D is day of the month, H is hour, and rf is rainfall in hundredths of inches.

IMDAT = the month
TMAX(I) = the maximum temperature in degrees Fahrenheit for day I
TMIN(I) = the minimum temperature in degrees Fahrenheit for day I

Rainfall:

```
262     READ(9,710,END=310)
IRDA,IRECTY,IYDAR,IMDAR,(IDDARY(L),IHRARY(L),
        $        RDA(L),L=1,12)
710     FORMAT (I6,A1,I4,I2,1X,12(2I2,F4.2))
```

where:
IRDA = station ID
IRECTY = an indicator for estimated data
IYDAR = the year
IMDAR = the month
IDDARY(L) = the day of the month for entry L
IHRARY(L) = the hour of entry L
RDA(L) = the amount in hundredths of inches for entry L

PET:

```
        READ(7,705,END=300)
ITDA,IYDAT,IMDAT,(ET(I),I=1,31)
705     FORMAT (I6,1X,I4,I2,3X,14(1X,F3.2)/
17(1X,F3.2))
```

where:
ITDA = station ID
IYDAT = the year
IMDAT = the month
ET(I) = the PET in inches for day I

6) If you are still unable to get your weather data to work, you may contact us. More than likely we will need a copy of your files to resolve the problem.

Table 4 Excerpt of a PET file

```
99999 1983  9 .13 .04 .11 .18 .23 .24 .22 .20 .19 .20 .21 .18 .13 .02
.10 .09 .14 .15 .15 .11 .07 .10 .11 .11 .10 .09 .11 .10 .05 .03

99999 1983 10 .11 .12 .13 .15 .13 .13 .12 .08 .09 .09 .02 .07 .09 .09
.09 .10 .09 .08 .09 .03 .03 .04 .02 .08 .03 .08 .06 .08 .09 .07 .06

99999 1983 11 .07 .02 .07 .01 .03 .05 .04 .07 .06 .04 .08 .05 .02 .04
.02 .04 .04 .04 .06 .05 .07 .06 .04 .03 .05 .05 .04 .03 .07 .04

99999 1983 12 .04 .04 .01 .04 .02 .01 .04 .03 .03 .04 .04 .01 .04 .04
.01 .04 .03 .02 .02 .02 .01 .02 .03 .03 .03 .03 .01 .01 .00 .01 .00

99999 1984  1 .02 .02 .02 .03 .01 .03 .02 .03 .03 .01 .00 .01 .00 .01
.01 .01 .01 .00 .01 .01 .01 .00 .02 .02 .02 .04 .04 .04 .03 .03 .03

99999 1984  2 .02 .04 .05 .01 .02 .00 .00 .01 .04 .06 .06 .08 .06 .02
.08 .08 .08 .10 .07 .08 .06 .07 .01 .10 .08 .06 .01 .05 .04

99999 1984  3 .04 .04 .05 .06 .01 .01 .04 .07 .04 .04 .07 .06 .01 .09
.09 .12 .10 .09 .03 .10 .12 .13 .11 .11 .07 .08 .10 .05 .03 .11 .09
```

Table 5 Example of the daily PET inputs

			Day of month													
ID	YEAR	M*	1	2	3	4	5	6	7	8	9	10	11	12	13	14
99999	1983	9	.13	.04	.11	.18	.23	.24	.22	.20	.19	.20	.21	.18	.13	.02

			Line 2 of a Month												
Day of month															
1516	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
.10	.09	.14	.15	.15	.11	.07	.10	.11	.11	.10	.09	.11	.10	.05	.03

* M is the Month, 1-12

Appendix B
Preparation of Soil Input Data

The model DRAINMOD requires the following soil dependent data:

1. Wilting point (or lower limit water content)
2. Soil water content versus pressure head (pf curve)
3. Lateral conductivity of each soil layer
4. The Green-Ampt infiltration parameters versus water table depth
5. Volume drained versus water table depth
6. Upward flux versus water table depth

1 and 2—Usually determined by standard laboratory procedures made on soil cores

3—An important factor in the overall water balance. It is site specific and should be determined by field measurement techniques, such as the Auger Hole method.

4—Can be estimated using the methods described in the DRAINMOD users manual or with these soil preparation programs.

5—"Drained to equilibrium" conditions (steady state). The program WTVOLDRN uses the soil water characteristic of each layer of the soil to produce "volume drained" values for water table positions ranging from the surface to the bottom of the soil profile. The soil structure in the plow layer is dependent on crop and tillage practices that may cause that layer to have a relatively high porosity. This porosity would be calculated if soil water characteristic data are obtained from samples that include the macropores caused by plant roots and other biological activity. If the plow layer is not sampled, then the volume drained from the top 15-30 cm may be lower. The extra pore volume could be added, but with caution. The slope of the drainage volume-water table depth relationship is the drainable porosity. Therefore the relationship can be approximated by relatively simple methods if the drainable porosity is known.

6—Limits the soil water available to the plant. The program UPFLUX calculates the maximum water table depth that will support a given upward flux value. The program inputs are average depth of the root zone (that must be less than the depth of the top layer for this program), depth of each layer, the maximum tension in the root zone when it is dry (usually not a sensitive parameter), and each layer's unsaturated conductivity versus tension relationship.

Because the unsaturated conductivity is often not known, the program MILNQRK is included to obtain estimates. This is the Millington and Quirk procedure. There are alternate methods that may be used as well, such as Brooks and Corey's graphical procedure or Rawls and Brackensiek's estimates from soil texture. Otto Baumer of the USDA-Natural Resources Conservation Service has developed a method of predicting K(h) from soil texture. He has programmed this method for DRAINMOD. For any of these methods, it is important to remember that vertical conductivities should be used, not lateral. Typically, vertical hydraulic conductivities are one-half to one-fourth of lateral conductivities.

Note: **Soil hysteresis makes the relationship between conductivity and soil tension nonsingular. The conductivity at a given tension can assume any value between the two extremes shown by the drainage and the imbibition branches of the K-h curve. The actual value will depend on antecedent moisture conditions. Upward flux during the day is a drainage or drying process while the soil moisture is being depleted and it may be an imbibition process during the night while the root zone recharges. Average conductivity values should be used if possible.**

Generally, unsaturated conductivity curves, either in the literature or predicted by the methods above, are for the drainage branch of the curve and using them may overestimate the daily upward flux. To adjust for this, it has been our experience that using conductivity values that are one-half of the drainage curve values provides conservative upward flux estimates.

(If using MILNQRK or Brooks and Corey, just make the saturated conductivities 1/2 of the measured values.)
The necessary inputs to DRAINMOD are stored in the .SIN and can be checked with graphs of the output of WTVOLDRN and UPFLUX. DRAINMOD uses straight line interpolation between points. Generally, 15-25 points are sufficient.

Description of the Soilprep Programs

There are five programs that can be used to help prepare input data for the hydrologic model DRAINMOD. These programs are:

1. WTVOLDRN—A program to prepare a volume drained versus water table depth table from the soil water characteristic curves of each layer in the soil

2. MILNQRK—A program to approximate the unsaturated conductivity of each layer in the soil using the soil water characteristic and saturated vertical conductivity. The method used is from Millington and Quirk

3. UPFLUX—A program to calculate the steady state upward flux versus water table depth curve from the unsaturated conductivity function of each soil layer

4. GRNAMPT—A program to produce Green-Ampt parameters versus water table

depth

5 DMINPUT—Reads files created by programs 1 through 4 and produces output file with extension SIN for DRAINMOD

6 SOILPREP.BAT—The batch file to execute programs 1 through 5 with one input program.

The outputs from VOLDRN and UPFLUX can be graphed and any adjustments to DRAINMOD inputs can be done using the input option on the DRAINMOD manager program. This allows a good visual verification of the results. This is encouraged to avoid the error of assuming that results from these programs are absolutely correct. They are not. They make reasonable approximations using the input data provided, which may not be correct. If field observations do not agree with the modeled predictions then most likely the field observations are better and should be used.

A file similar to the example is the only one required for all programs. Any other intermediate files are created and deleted when the batch program finishes. If you wish to use the programs separately, the FORTRAN source code is included and sample data for the programs are given at the end.

Running the programs

The steps to run the programs are:

1 Copy the files to the \INPUT40 subdirectory
(Usually C:\DM40\INPUT40)

2 Prepare an input dataset such as GILFORDS
(Follow the description given with the sample dataset in the next section)
(Do not put an extension on the filename)

3 Type
SOILPREP GILFORDS C:

An Example Input Data Set For Gilfords FSL

```
4 LAYER- GILFORD FSAL, INDIANA, P. 49                    :1) title for the run
04                                                       :2) number of layers
09             2.0             20.0                      :3) ....
0.459                          0.0                       :4) ....
0.355                          50.0
0.303                          100.0
0.244                          200.0
0.214                          330.0
0.204                          500.0
0.194                          1000.0
0.142                          5000.0
0.130                          15000.0
11             0.20            30.0                      :3) ....
0.339                          0.0                       :4) ....
0.310                          30.0
0.285                          50.0
0.246                          100.0
0.223                          150.0
0.197                          200.0
0.176                          330.0
0.166                          500.0
0.163                          1000.0
0.114                          5000.0
0.082                          15000.0
08             0.20            70.0                      :3) ....
0.367                          0.0                       :4) ....
0.284                          50.0
0.229                          100.0
0.157                          200.0
0.109                          500.0
0.105                          1000.0
0.062                          5000.0
0.047                          15000.0
09             0.20            500.0                     :3) ....
0.386                          0.0                       :4) ....
0.251                          50.0
0.185                          100.0
0.111                          200.0
0.080                          330.0
0.066                          500.0
0.049                          1000.0
0.022                          5000.0
0.013                          15000.0
45, 30,  1                                               :5)
```

1) Title
2) Number of layers
3) Number of inputs for the layer, saturated conductivity in cm/hr, depth of at the bottom of the layer in cm
4) Volumetric water content and tension (cm), including a 15000 cm for each layer
5) Maximum root depth in cm for the Green-Ampt calculations, root depth in cm, and the layer of the soil water characteristic to use for DRAINMOD's maximum root depths

<return>

This will execute all of the programs and create a file named GILFORDS.SIN. This assumes DRAINMOD inputs are in C:\DM40\INPUT40 and the SOILPREP programs are in the current drive.

The following text will be displayed on the computer screen during the preparation of a soil input data set.

```
   **** WATER TABLE VS VOLUME DRAINED ****

 ENTER FILE NAME OF THE SOIL CHARACTERISTIC DATA
 ENTER THE FILE NAME FOR EXTENDED OUTPUT LIST
 ENTER THE FILE NAME FOR SHORT OUTPUT LIST
   OUTPUT FILES:
     - DETAILED LISTING OF OUTPUTS : g:GILFORDS.WTD
     - SHORT DRAINMOD FORMAT LIST  : g:XVOLDRN.OUT
Stop - Program terminated.

   **** MILLINGTON & QUIRK ESTIMATES OF CONDUCTIVITY ****

 ENTER FILE NAME OF THE SOIL CHARACTERISTIC DATA
 ENTER THE OUTPUT FILE NAME-
   OUTPUT FILES:
     - DETAILED LISTING OF OUTPUTS : g:GILFORDS.MQ
Stop - Program terminated.

   **** UPWARD FLUX CALCULATIONS ****

 ENTER THE MILLINGTON-QUIRK FILE NAME
 ENTER THE FILE NAME FOR COMPLETE OUTPUT LIST
 ENTER THE FILE NAME FOR SHORT OUTPUT LIST
   OUTPUT FILES:
     - DETAILED LISTING OF OUTPUTS : g:GILFORDS.UPQ
     - SHORT DRAINMOD FORMAT LIST  : g:XUPFLUX.OUT
Stop - Program terminated.

   **** GREEN-AMPT CALCULATIONS ****

 ENTER NAME OF MILLINGTON AND QUIRK FILE
 ENTER OUTPUT FILENAME
   OUTPUT FILES:
     - LISTING OF G-A PARAMETERS: g:XGRNAMPT.OUT
Stop - Program terminated.

   **** DRAINMOD SOIL INPUT FORM ****

 ENTER NAME OF THE ORIGINAL SOILDATA FILE
 ENTER NAME OF MILLINGTON-QUIRK FILE
 ENTER NAME OF VOLUME DRAINED FILE
 ENTER NAME OF UPFLUX FILE
 ENTER NAME OF GREEN-AMPT FILE
 ENTER NAME OF OUTPUT FILE
   OUTPUT FILES:
     - DRAINMOD SOIL INPUT FILE : g:GILFORDS.SIN

Stop - Program terminated.
```

Appendix C: Converting Old Datasets to the New Format

CONVDMF.EXE Documentation (Version 0.2, 11/10/87)

The CONVDMF program converts PC-format DRAINMOD and Yield Version data files to the format compatible with versions 3.6 and later. The new file structure consists of four files. The first file always has an extension of '.LIS,' denoting a list of input files. The DRAINMOD input files consist of general input (with extension '.GEN'), soil inputs (with extension '.SIN'), and yield inputs (with extension '.YIN,' only present for yield simulations). The contents of the general input file are title lines (2), printout and input control, climate files and information, drainage system design parameters, seepage (lateral, deep, and sloping confining layer) (new after version 3.6), weir control settings (controlled drainage and subirrigation), lateral saturated hydraulic conductivities, trafficability parameters, general crop information (wilting point, root depth, etc.), and wastewater irrigation parameters. The contents of the soil input file are volumetric water content versus hydraulic head information, volume drained and upward flux versus water table depth data, and Green-Ampt infiltration parameters. The contents of the yield input file include crop growing season information, stress weighting information, and functions relating stresses due to planting delays, wet conditions, and dry conditions to crop relative yields.

Conversion examples

Non-yield inputs

A file, DMTEST1.DAT, exists for version 2.0 of DRAINMOD (non-yield version). The new DRAINMOD files are on Hard Disk C:. First, copy DMTEST1.DAT to the C:\DM40\INPUT40 subdirectory. Then execute CONDMF.

The first request of CONVDMF is the file name. You enter

DMTEST1.DAT <RETURN>

Since this is not a yield data file, you enter

N **<RETURN>**

Next, select names for the general, soils, and list datasets. You decide to name the general dataset PLYMTH1, so at the next prompt you enter

PLYMTH1 <RETURN>

For the soils dataset, you decide the soil was a Wagram sandy loam, so at the soils prompt, you enter

WAGSL <RETURN>

At the list of input datasets prompt,

you decide to call this run PLYMTH1, and enter:

PLYMTH1 <RETURN>

After the program completes execution you have three files PLYMTH1.GEN (containing the general input information), WAGSL.SIN (containing the soils inputs), and PLYMTH1.LIS (containing the two filenames, one per line, PLYMTH1.GEN and WAGSL.SIN).

Yield inputs

A file, YMTEST1.DAT, exists for the yield version 2.0 of DRAINMOD. First, copy YMTEST1.DAT to the C:\DM40\INPUT40 subdirectory. Then execute CONDMF.

The first request of CONVDMF is the file name. You enter

YMTEST1.DAT <RETURN>

Next, since this file is a yield data file you enter

Y <RETURN>

You select names for the general, soils, yield, and list datasets. You decide to name the general dataset YMTH1, so at the next prompt you enter

YMTH1 <RETURN>

For the soils dataset, you decide that the soil was Portsmouth sandy loam, so at the soils prompt, you enter

PORTSL <RETURN>

The original input dataset YMTEST1.DAT contains the yield input parameters for determining relative yields for a 130 day corn crop. At the yield input filename prompt, you enter

CORN130 <RETURN>

At the list of input datasets prompt, you decide to call this run YMTH1, and enter:

YMTH1 <RETURN>

After the program completes execution you have three files YMTH1.GEN (containing the general input information), PORTSL.SIN (containing the soils inputs), CORN130.YIN (containing the information required for relative yield computations) and YMTH1.LIS (containing the three filenames, one per line, YMTH1.GEN, PORTSL.SIN, and CORN130.YIN). The files are stored in c:\dm40\input40. Each file should be examined and saved using the input preparation program (Option 1 on the DMSHELL program).

Appendix D

Description of DRAINMOD 4.0 outputs

Output parameters summarized in the rankings file.

Parameter	Description
	Without Relative Yields
Work Days	Number of days available for tillage as specified in the trafficability input periods.
SEW	Amount of excess soil wetness, centimeter-days, for the year during the periods specified in the general crop information inputs.
Dry Days	Number of days when soil moisture conditions do not satisfy potential evapotranspiration during the periods specified in the general crop information inputs.
IRRIG.	Amount of water (in centimeters) irrigated in the sprinkler irrigation mode.
	With Relative Yields
SEW	Amount of excess soil wetness, centimeter-days, for the year during the periods specified in the general crop information inputs.
Dry Days	Number of days when soil moisture conditions do not satisfy potential evapotranspiration during the periods specified in the general crop information inputs.
IRRIG.	Amount of water, centimeters, irrigated in the sprinkler irrigation mode.
Relative Yields	The net relative crop yields factoring the reductions for excess and deficient soil water and planting date delays. Expressed as percent of the optimum crop yield with no stresses.

Output parameters summarized in the yearly file without relative yield simulations.

Parameter	Description
Rainfall	Total rainfall in centimeters for the year. In sprinkler irrigation the amount includes amount irrigated.
Infiltration	Amount of rainfall in centimeters which infiltrates.
ET	Amount of evapotranspiration in centimeters (soil evaporation and plant transpiration).
Drainage	Net amount of water entering (positive) and leaving (negative) the drains in centimeters.
Runoff	Amount of surface runoff in centimeters.
SEW	Sum of excess water in centimeter-days.
IRR VOL	Amount of surface irrigation in centimeters.
Pump VOL	Amount of water pumped in the subirrigation mode or the amount leaving the outlet and entering the soil in controlled drainage. The units are centimeters. Shown as negative values (indicating negative drainage).

Output parameters summarized in the yearly file with relative yield simulations.

Parameter	Description
Rainfall	Total rainfall in centimeters for the year. In sprinkler irrigation the amount includes amount irrigated.
Infiltration	Amount of rainfall in centimeters which infiltrates.
ET	Amount of evapotranspiration in centimeters (soil evaporation and plant transpiration).
Drainage	Net amount of water entering (positive) and leaving (negative) the drains in centimeters.
Runoff	Amount of surface runoff in centimeters.
DRYDAYS	Number of days when soil moisture conditions do not satisfy potential evapotranspiration during the periods

	specified in the general crop information inputs.
WORKDAYS	Number of days available for tillage as specified in the trafficability input periods.
SEW	Sum of excess water in centimeter-days.
Pump VOL	Amount of water pumped in the subirrigation mode or the amount leaving the outlet and entering the soil in controlled drainage. The units are centimeters. Shown as negative values (indicating negative drainage).

Output parameters summarized in the monthly file without relative yield simulations.

Parameter	**Description**
Month	Month of simulation.
Rain	Total rainfall in centimeters for the month. In sprinkler irrigation the amount includes surface irrigation.
INFIL	Amount of rainfall in centimeters which infiltrates.
ET	Amount of evapotranspiration in centimeters (soil evaporation and plant transpiration).
DRAIN	Net amount of water entering (positive) and leaving (negative) the drains in centimeters.
Runoff	Amount of surface runoff in centimeters.
SEW	Sum of excess water in centimeter-days.
MIR	Amount of water irrigated in surface irrigation in centimeters.
PUMP	Amount of water pumped in the subirrigation mode or the amount leaving the outlet and entering the soil in controlled drainage. The units are centimeters.

MPT	Number of surface irrigation events postponed.

Output parameters summarized in the monthly file with relative yield simulations.

Parameter	Description
Month	Month of simulation.
Rain	Total rainfall in centimeters for the month. In sprinkler irrigation the amount includes surface irrigation.
INFIL	Amount of rainfall in centimeters which infiltrates.
ET	Amount of evapotranspiration in centimeters (soil evaporation and plant transpiration).
DRAIN	Net amount of water entering (positive) and leaving (negative) the drains in centimeters.
Runoff	Amount of surface runoff in centimeters.
Dry Days	Number of days when soil moisture conditions do not satisfy potential evapotranspiration during the periods specified in the general crop information inputs.
WRK DAYS	Number of days available for tillage as specified in the trafficability input periods.
SEW	Sum of excess water in centimeter-days.
PUMP	Amount of water pumped in the subirrigation mode or the amount leaving the outlet and entering the soil in controlled drainage. The units are centimeters.

Output parameters summarized in the daily file.

Parameter	Description
DAY	Day of the month.
RAIN	Rainfall in centimeters. In sprinkler irrigation the

	amount includes surface irrigation.
INFIL	Amount of rainfall in centimeters which infiltrates.
ET	Amount of evapotranspiration in centimeters (soil evaporation and plant transpiration)
DRAIN	Net amount of water entering (positive) and leaving (negative) the drains in centimeters.
TVOL	Total air volume in the soil in centimeters.
DDZ	Depth of the dry zone in centimeters.
DTWT	Depth to the water table from the soil surface in centimeters.
STOR	Depth of water in surface depressional storage in centimeters.
RUNOFF	Amount of surface runoff in centimeters.
WLOSS	Water leaving the system including drainage and surface runoff in centimeters.

Output file for daily water table depth, drainage graphs (one/year).

Parameter	Description
Rainfall	Contains the total rainfall for the day plus the amount of irrigation if sprinkler irrigation is being done, the units are centimeters.

Drainage	The amount of drain outflow in centimeters.
W. T. depth	The water table depth in centimeters

(The three parameters above are on each line (1/day) separated by commas)

Output parameters summarized by year in the yield file.

Parameter	**Description**
Stress Index (Excess)	Total stress due to excess water computed using SEW concept.
Stress Index (Drought)	Total stress due to deficient soil water.
Plant Date	Day of year the crop was planted.
Plant Delay	Number of days after the desired planting date.
Harvest Date	Day of year the crop was harvested.
Relative Yields	Percent of optimum yield for the excess water component, drought stress component, delay in planting component, and the overall relative yield.

Note: **The first time you run DRAINMOD, you will need to enter the data set section of the dm shell and edit and save each file you wish to execute. This updates the directory information contained in your .lis and .gen files in the input46 subdirectory.**

Appendix E

DRAINMOD 4.0 Example Simulations

Sample subirrigation run from ysibn.out.

```
********************************************************************************

D R A I N M O D

VERSION: NORTH CAROLINA MICRO 4.00
LAST UPDATE: SEPT 1988
LANGUAGE: MS FORTRAN V 4.01

            DRAINMOD IS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR
            THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS
            DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND
            AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY
            UNDER THE DIRECTION OF R. W. SKAGGS.
```

```
******************************************************************************

                    *******************
                    * D R A I N M O D *
                    *******************

 DATA READ FROM INPUT FILE: C:\DM40\INPUT40\YSIBN.LIS

                        TITLE OF RUN
                        ************


 BENCH V3.0 RUN -- STANDARD DRAINMOD-SUBIRRIGATION
 RAINS (NC) SOIL, WILSON (NC) DATA, 130 DAY CORN (2 WET, 2 DRY, 2 AVE YRS)


                       CLIMATE INPUTS
                       ******* ******

     DESCRIPTION                          (VARIABLE)            VALUE     UNIT
 ------------------------------------------------------------------------------
 FILE FOR RAINDATA ............. C:\DM40\WEATHER\WBNCH1.RAI
 FILE FOR TEMPERATURE/PET DATA .. C:\DM40\WEATHER\WBNCH1.TEM
 RAINFALL STATION NUMBER .......................... (RAINID)    319476
 TEMPERATURE/PET STATION NUMBER ................... (TEMPID)    319476
 STARTING YEAR OF SIMULATION .................. (START YEAR)      1959     YEAR
 STARTING MONTH OF SIMULATION ................ (START MONTH)         1     MONTH
 ENDING YEAR OF SIMULATION ...................... (END YEAR)      1964     YEAR
 ENDING MONTH OF SIMULATION .................... (END MONTH)        12     MONTH
 TEMPERATURE STATION LATITUDE ................... (TEMP LAT)     35.47     DEG.MIN
 HEAT INDEX ........................................ (HID)     75.00


ET MULTIPLICATION FACTOR FOR EACH MONTH
  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
```

```
                         DRAINAGE SYSTEM DESIGN
                         **********************

                   *** SUBIRRIGATION-DRAINAGE SYSTEM ***

 JOB TITLE:

        BENCH V3.0 RUN -- STANDARD DRAINMOD-SUBIRRIGATION
        RAINS (NC) SOIL, WILSON (NC) DATA, 130 DAY CORN (2 WET, 2 DR


         STMAX =  .50 CM                       SOIL SURFACE
  __/)____________________________________________________________/)__
       :                                            :
       :                                            :
       :                                            :
       :                                            :
       :                                            :
 ADEPTH =140. CM                              DDRAIN =100. CM
       :                                            :
       :                                            :
       :     O------SDRAIN = 2000. CM ------O       -
       :     \                                      :
       :  EFFRAD =1.50 CM                           :
       :                                      HDRAIN = 36. CM
       :                                            :
       :                                            :
  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
       :
       :
       :
       :                               IMPERMEABLE LAYER
  _________________________________________________________________
  /////////////////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 110.0	4.300
110.0 - 140.0	1.000

```
DEPTH TO DRAIN = 100.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER =  36.5 CM
DISTANCE BETWEEN DRAINS =  2000.0 CM
MAXIMUM DEPTH OF SURFACE PONDING =   .50 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER =  136.5 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) =  2.50 CM/DAY
ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 140.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
  CAN MOVE TO DRAIN =  .50 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 =10.97

  ** SEEPAGE LOSS INPUTS ***

   No seepage due to field slope

   No seepage due to vertical deep seepage

   No seepage due to lateral deep seepage

  *** end of seepage inputs ***
```

WIDTH OF DITCH BOTTOM = 20.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .10 : 1.00

INITIAL WATER TABLE DEPTH = 50.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 15	5/ 1	6/ 1	
WEIR DEPTH	120.0	120.0	120.0		60.0	60.0	60.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	60.0	60.0	60.0	120.0	120.0	120.0

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)		WATER TABLE DEPTH (CM)
.0		.0
1.0		22.5
2.0		35.7
3.0		50.0
4.0		65.0
5.0	mx	77.5
6.0		89.4
7.0		101.0
8.0		110.5
9.0		120.0
10.0		128.6
11.0		137.1
12.0		145.7
13.0		153.3
14.0		160.0
15.0		166.7
16.0		173.3
17.0		180.0
18.0		186.7
19.0		193.3
20.0		200.0
21.0		206.7
22.0		213.3
23.0		220.0
24.0		226.7
25.0		233.3
26.0		240.0
27.0		246.7
28.0		253.3
29.0		260.0
30.0		266.7
35.0		300.0
40.0		366.7
45.0		433.3
50.0		500.0
60.0		600.0
70.0		700.0
80.0		800.0
90.0		900.0

TABLE 2

SOIL WATER CHARACTERISTIC VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3700	.00	.2000
10.0	.3000	.25	.1000
20.0	.2820	.80	.0800
30.0	.2720	1.60	.0250
40.0	.2660	2.30	.0112
50.0	.2580	3.00	.0058
60.0	.2540	3.60	.0031
70.0	.2480	4.40	.0018
80.0	.2440	5.20	.0010
90.0	.2410	6.05	.0007
100.0	.2380	6.90	.0004
110.0	.2360	7.95	.0002
120.0	.2340	9.00	.0000
130.0	.2320	10.17	.0000
140.0	.2300	11.33	.0000
150.0	.2280	12.50	.0000
160.0	.2272	14.00	.0000
170.0	.2264	15.50	.0000
180.0	.2256	17.00	.0000
190.0	.2248	18.50	.0000
200.0	.2240	20.00	.0000
210.0	.2236	21.50	.0000
220.0	.2232	23.00	.0000
230.0	.2228	24.50	.0000
240.0	.2224	26.00	.0000
250.0	.2219	27.50	.0000
260.0	.2215	29.00	.0000
270.0	.2211	30.50	.0000
280.0	.2207	32.00	.0000
290.0	.2203	33.50	.0000
300.0	.2199	35.00	.0000
350.0	.2178	38.75	.0000
400.0	.2158	42.50	.0000
450.0	.2137	46.25	.0000
500.0	.2117	50.00	.0000
600.0	.2076	60.00	.0000
700.0	.2034	70.00	.0000
800.0	.1993	80.00	.0000
900.0	.1952	90.00	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	1.000
100.000	3.300	1.000
150.000	6.000	1.000
200.000	9.200	1.000
500.000	25.000	1.000
1000.000	25.000	1.000

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.90	3.90
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00
WORKING TIMES		
-DATE TO BEGIN COUNTING WORK DAYS:	4/ 1	12/32
-DATE TO STOP COUNTING WORK DAYS:	10/ 1	12/32
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP
****

SOIL MOISTURE AT CROP WILTING POINT = .09

HIGH WATER STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 8/18
CROP IS IN STRESS WHEN WATER TABLE IS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 8/18

MO	DAY	ROOTING DEPTH(CM)
1	1	3.0
4	16	3.0
5	4	4.0
5	17	15.0
6	1	25.0
6	20	30.0
7	18	30.0
8	20	20.0
9	24	10.0
9	25	3.0
12	31	3.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

```
                              YIELD INPUTS
                              ************

last planting day without yield loss (JLAST)  :       105
length of growing season (IGROW)              :       130
1st planting day reduction factor (PDRF)      :   8.700000E-01
days using 1st planting delay fact (DELAY1)   :    42.000000
2nd planting day reduction factor (PDRF2)     :     1.700000
total days of work before planting (REQWRK)   :     5.000000
IOW:          30
IOH:          12
SI :       11.160000
D  :       -1.170000
E  :     5.800000E-02
FO :    -5.000000E-04
YI :      100.000000
SF :        1.500000
YRMAX :     0.000000E+00
YSLOPE:          1.220000
YRDMAX:        108.000000
DSLOPE:     8.700000E-01
PD :          100
IGR:          130
SDF:          1
IPS(I),IPE(I),CSD(I),I=1,IOH
   0     9      .2000
  10    29      .2100
  30    39      .2300
  40    49      .2700
  50    59      .3100
  60    69      .2800
  70    79      .2000
  80    89      .1400
  90    99      .1000
 100   109      .0600
 110   119      .0300
 120   130      .0100
CSI(I),I=1,IOW
          .0000       .0000       .0000       .0000       .0000
          .0000       .5000       .5000      1.0000      1.0000
         1.0000      1.0000      1.7500      2.0000      2.0000
         1.3000      1.3000      1.3000      1.3000      1.3000
         1.2000      1.0000       .5000       .0000       .0000
          .0000       .0000       .0000       .0000       .0000


****************************** END OF INPUTS ******************************

  ----------RUN STATISTICS ----------             time:  5/15/1990  @  6:14
  input file:  C:\DM40\INPUT40\YSIBN.LIS
  parameters:    subirrigation run          and yields calculated
                 drain spacing =   2000. cm   drain depth =  100.0 cm
--------------------------------------------------------------------------


**> Total simulation time=   3.327 minutes.
```

Sample from ysibn.day, the daily output file.

```
BENCH V3.0 RUN -- STANDARD DRAINMOD-SUBIRRIGATION
RAINS (NC) SOIL, WILSON (NC) DATA, 130 DAY CORN (2 WET, 2 DRY, 2 AVE YRS)
********************************************************************************


  ----------RUN STATISTICS ----------          time:  5/15/1990  @  6:14
 input file:   C:\DM40\INPUT40\YSIBN.LIS
 parameters:    subirrigation run       and yields calculated
               drain spacing =    2000. cm   drain depth =  100.0 cm
------------------------------------------------------------------------


      1959         1
```

DAY	RAIN	INFIL	ET	DRAIN	TVOL	DDZ	DTWT	STOR	RUNOFF	WLOSS
1	1.60	1.60	.04	.51	1.94	.00	34.91	.00	.00	.69
2	.28	.28	.04	.70	2.40	.00	41.48	.00	.00	.70
3	.00	.00	.04	.54	2.99	.00	49.86	.00	.00	.54
4	.00	.00	.04	.42	3.45	.00	57.53	.00	.00	.42
5	.00	.00	.00	.33	3.78	.00	62.31	.00	.00	.33
6	.00	.00	.00	.28	4.07	.00	65.84	.00	.00	.28
7	.00	.00	.02	.24	4.33	.00	69.08	.00	.00	.24
8	.84	.84	.01	.24	3.73	.00	61.64	.00	.00	.24
9	.00	.00	.00	.29	4.02	.00	65.27	.00	.00	.29
10	.00	.00	.00	.25	4.27	.00	68.40	.00	.00	.25
11	.00	.00	.00	.22	4.49	.00	71.12	.00	.00	.22
12	.00	.00	.00	.19	4.68	.00	73.52	.00	.00	.19
13	.00	.00	.07	.17	4.91	.11	76.14	.00	.00	.17
14	.00	.00	.02	.14	5.08	.08	78.27	.00	.00	.14
15	.00	.00	.11	.12	5.31	.38	80.44	.00	.00	.12
16	.38	.38	.01	.12	5.06	.00	78.25	.00	.00	.12
17	.00	.00	.00	.13	5.19	.00	79.84	.00	.00	.13
18	.00	.00	.00	.11	5.30	.00	81.19	.00	.00	.11
19	.00	.00	.00	.10	5.41	.00	82.41	.00	.00	.10
20	.00	.00	.06	.09	5.56	.12	83.90	.00	.00	.09
21	.00	.00	.18	.08	5.82	.70	85.68	.00	.00	.08
22	2.54	2.54	.08	.33	3.69	.00	61.10	.00	.00	.33
23	.00	.00	.01	.30	3.99	.00	64.92	.00	.00	.30
24	.00	.00	.02	.25	4.26	.00	68.29	.00	.00	.25
25	.00	.00	.09	.22	4.57	.17	71.71	.00	.00	.22
26	.00	.00	.07	.18	4.82	.27	74.57	.00	.00	.18
27	.00	.00	.08	.16	5.05	.43	77.10	.00	.00	.16
28	.13	.13	.01	.14	5.07	.00	78.40	.00	.00	.14
29	.00	.00	.07	.12	5.27	.16	80.42	.00	.00	.12
30	.00	.00	.10	.11	5.47	.42	82.23	.00	.00	.11
31	.20	.20	.03	.10	5.41	.00	82.42	.00	.00	.10

.
.
.

Sample output from ysibn.yr.

```
BENCH V3.0 RUN -- STANDARD DRAINMOD-SUBIRRIGATION
RAINS (NC) SOIL, WILSON (NC) DATA, 130 DAY CORN (2 WET, 2 DRY, 2 AVE YRS)
*****************************************************************************


  ----------RUN STATISTICS ----------          time:  5/15/1990  @  6:14
 input file:   C:\DM40\INPUT40\YSIBN.LIS
 parameters:    subirrigation run       and yields calculated
               drain spacing =    2000. cm   drain depth =  100.0 cm
-----------------------------------------------------------------------


YEAR  RAINFALL  INFILTR    ET     DRAIN   RUNOFF  DRYDAYS WORKDAYS  SEW   PUMP VOL
1959   155.30   137.43   75.11   64.69   17.87   11.00    109.56 254.2   -6.84
1960   146.13   126.22   72.99   51.13   19.91   26.00    140.62   1.8  -12.91
1961    82.37    80.39   70.60   11.89    1.99   27.00    148.77    .0  -12.13
1962    76.45    76.45   60.13   12.00     .00   56.00    154.40    .0  -14.74
1963   113.16   106.61   67.22   42.01    6.54   24.00    124.95  92.1   -7.67
1964   109.83   102.72   62.19   41.78    7.11   22.00    135.68 107.0   -7.82

AVG    113.87   104.97   68.04   37.25    8.90   27.67    135.66  75.9  -10.35
```

Sample output from ysibn.yld.

```
BENCH V3.0 RUN -- STANDARD DRAINMOD-SUBIRRIGATION
RAINS (NC) SOIL, WILSON (NC) DATA, 130 DAY CORN (2 WET, 2 DRY, 2 AVE YRS)
*****************************************************************************


  ----------RUN STATISTICS ----------          time:  5/15/1990  @  6:14
 input file:   C:\DM40\INPUT40\YSIBN.LIS
 parameters:    subirrigation run       and yields calculated
               drain spacing =    2000. cm   drain depth =  100.0 cm
-----------------------------------------------------------------------

       SDI - STRESS   plant   plant  harv.         RELATIVE YIELDS (%)
     excess drought   date    delay  date     excess    drought    delay    overall
       -------------   ----    ----   ----     ------------------------------


1959   35.4     .0     100     0.     230       77.2     100.0     100.0      77.2
1960     .0    5.6     100     0.     230      100.0      93.2     100.0      93.2
1961     .0     .1     100     0.     230      100.0      99.9     100.0      99.9
1962     .0   21.0     100     0.     230      100.0      74.4     100.0      74.4
1963   19.4    2.3     100     0.     230       91.1      97.1     100.0      88.5
1964   24.5     .0     100     0.     230       86.7     100.0     100.0      86.7

AVG    13.2    4.8     100.    0.    230.       92.5      94.1     100.0      86.7
```

Sample output ysibn.rnk.

```
BENCH V3.0 RUN -- STANDARD DRAINMOD-SUBIRRIGATION
RAINS (NC) SOIL, WILSON (NC) DATA, 130 DAY CORN (2 WET, 2 DRY, 2 AVE YRS)
********************************************************************************


  ----------RUN STATISTICS ----------          time:  5/15/1990  @  6:14
 input file:   C:\DM40\INPUT40\YSIBN.LIS
 parameters:    subirrigation run       and yields calculated
               drain spacing =    2000. cm   drain depth =  100.0 cm
--------------------------------------------------------------------------

  RANK      SEW    YEAR  : DRY DAYS    YEAR  : IRRIG.      YEAR   :   REL YLD   YEAR

     1    254.24    1959  :   56.00     1962  :     .00     1959   :    99.86    1961
     2    106.95    1964  :   27.00     1961  :     .00     1960   :    93.23    1960
     3     92.12    1963  :   26.00     1960  :     .00     1961   :    88.52    1963
     4      1.84    1960  :   24.00     1963  :     .00     1962   :    86.73    1964
     5       .00    1961  :   22.00     1964  :     .00     1963   :    77.21    1959
     6       .00    1962  :   11.00     1959  :     .00     1964   :    74.43    1962

AVERAGE   75.86              27.67                .00                  86.66
```

Sample output file ysibn.mon.

```
BENCH V3.0 RUN -- STANDARD DRAINMOD-SUBIRRIGATION
RAINS (NC) SOIL, WILSON (NC) DATA, 130 DAY CORN (2 WET, 2 DRY, 2 AVE YRS)
******************************************************************************

 ---------RUN STATISTICS ----------           time:  5/15/1990  @  6:14
 input file:   C:\DM40\INPUT40\YSIBN.LIS
 parameters:    subirrigation run      and yields calculated
               drain spacing =    2000. cm   drain depth =  100.0 cm
----------------------------------------------------------------------
```

MONTHLY VOLUMES IN CENTIMETERS FOR YEAR 1959

MONTH	RAIN	INFIL	ET	DRAIN	RUNOFF	DRY DAYS	WRK DAYS	SEW	PUMP
1	5.97	5.97	1.19	7.18	.00	.00	.00	.00	.00
2	10.59	10.59	1.45	8.75	.00	.00	.00	.00	.00
3	12.17	12.17	2.48	8.68	.00	.00	.00	.00	.00
4	18.77	17.47	6.03	11.86	1.30	2.00	7.84	106.23	-.03
5	4.93	4.93	9.85	-2.32	.00	9.00	28.42	.00	-2.32
6	6.93	6.93	13.72	-3.25	.00	.00	23.08	.00	-3.25
7	46.38	29.81	13.49	8.68	16.57	.00	7.20	148.00	-1.20
8	12.88	12.88	12.50	2.32	.00	.00	19.44	.02	-.05
9	6.53	6.53	6.43	2.30	.00	.00	22.58	.00	.00
10	17.12	17.12	4.06	10.30	.00	.00	1.00	.00	.00
11	6.10	6.10	2.61	4.45	.00	.00	.00	.00	.00
12	6.93	6.93	1.29	5.71	.00	.00	.00	.00	.00
TOTALS	155.30	137.43	75.11	64.69	17.87	11.00	109.56	254.24	-6.84

MONTHLY VOLUMES IN CENTIMETERS FOR YEAR 1964

MONTH	RAIN	INFIL	ET	DRAIN	RUNOFF	DRY DAYS	WRK DAYS	SEW	PUMP
1	8.48	8.48	.69	10.10	.00	.00	.00	.00	.00
2	2.79	2.79	.52	.90	.00	.00	.00	.00	.00
3	6.81	6.81	3.07	5.63	.00	.00	1.00	.00	.00
4	5.69	5.69	4.49	-.70	.00	11.00	26.75	.00	-2.18
5	7.16	7.16	8.53	-2.05	.00	4.00	23.97	.00	-2.28
6	16.84	15.33	13.03	5.98	1.51	.00	12.72	85.12	-.66
7	15.47	15.44	14.98	2.19	.02	.00	16.91	16.04	-1.63
8	17.30	14.54	10.80	4.52	2.75	7.00	23.33	5.79	-1.06
9	.51	.51	.00	.09	.00	.00	30.00	.00	.00
10	14.73	11.92	2.28	5.48	2.82	.00	.00	.00	.00
11	9.19	9.19	2.97	6.42	.00	.00	.00	.00	.00
12	4.85	4.85	.82	3.21	.00	.00	1.00	.00	.00
TOTALS	109.83	102.72	62.19	41.78	7.11	22.00	135.68	106.95	-7.82

Sample output from a plot file, ysibn.p59.

File contains daily rainfall in cm, water table depth in cm, and outflow in cm for each day. Bottom two lines contain total SEW, ISEWMS, ISEWDS, ISEWME, ISEWDE, SEWX, total rainfall, and total PET.

```
 1.60,    35.,    .686        DAY 1
  .28,    41.,    .696        DAY 2
  .00,    50.,    .543
  .00,    58.,    .421
  .00,    62.,    .333
  .00,    66.,    .283
  .00,    69.,    .243
  .84,    62.,    .236
  .00,    65.,    .290
  .00,    68.,    .250
  .00,    71.,    .217
  .00,    74.,    .190
  .00,    76.,    .166
  .00,    78.,    .143
  .00,    80.,    .124
  .38,    78.,    .124
  .00,    80.,    .127
  .00,    81.,    .114
  .00,    82.,    .104
  .00,    84.,    .093
  .00,    86.,    .081
 2.54,    61.,    .325
  .00,    65.,    .296
  .00,    68.,    .253
    .
    .
    .
  .00,    91.,    .047
 5.16,    28.,    .353
  .56,    32.,    .875
  .00,    42.,    .683
  .00,    50.,    .535
  .00,    57.,    .422
  .00,    62.,    .337
  .00,    66.,    .285
  .00,    69.,    .243
  .00,    72.,    .207
  .00,    75.,    .176
  .28,    76.,    .151
  .00,    78.,    .144
  .00,    80.,    .125
  .00,    82.,    .111    DAY 365
  .00,     0.,    .000    DAY 366, IF A LEAP YEAR, ELSE ALL 0'S
    254.243500            4           10          8        18
    30.000000       155.295600        89.119170
```

Appendix F

DRAINMOD 4.6

Hydrologic analysis of wetlands

DRAINMOD describes the soil water balance for shallow water table soils. Water table depth is predicted on a day-by-day basis. Thus, it can be used to characterize the hydrology of certain types of wetlands. Further, DRAINMOD simulations can be used to determine if the hydrology of a particular site has been modified so that wetland hydrologic criteria are no longer satisfied.

This appendix presents a brief description of modifications made to DRAINMOD to facilitate its use for wetland analysis.

Note: **DRAINMOD was developed for describing the water balance between parallel drainage ditches or drain tubes. Thus, it will be reliable for wetland analysis only for those lands that have parallel drainage systems. With careful attention to the inputs, it is possible to analyze some lands that have very poor natural drainage. However, DRAINMOD cannot be directly applied to lands that receive runoff from adjacent areas, such as potholes or large depressions. It is possible to analyze the hydrology of such areas, and DRAINMOD may be a useful tool for such analyses, but it could not be applied directly.**

Installation of DRAINMOD ver. 4.6

Replace steps 2 and 3 of the installation instructions for version 4.0.

The diskette(s) contain a number of subdirectories which need to be copied to your hard disk. These directories are:

\dm46\exefiles
\dm46\input46
\dm46\output46
\dm46\soilprep
\dm46\weather

If you are running MS-DOS 3.3 or greater (also IBM PC-DOS), use the DOS command xcopy.

Step 1 Insert your DRAINMOD floppy disk in drive A.

Step 2 Type **xcopy a: c: / s**

This will create the directories and copy all the files to the proper place.

Variations:

1. If you received more than one disk, repeat steps 1 and 2 for each disk.
2. If your floppy disk drive is B, then execute **xcopy b: c: / s**
3. If you want DRAINMOD on

another hard disk, for example D, execute
xcopy a: d: /s

Getting ready to run DRAINMOD, version 4.6.

Step 1 Change directories by typing **cd \dm46.**

Step 2 type **cd exefiles**

Step 3 Select one of the following commands

For hard drive c: type
copy config.dmc config.dm

For hard drive d: type
copy config.dmd config.dm

DRAINMOD is now ready to run.

To execute the DRAINMOD system, change to the hard drive containing the directory dm46, then type **cd \dm46\exefiles**, and type **dmshell.**

Note: **The first time you run DRAINMOD, you will need to enter the data set section of the dm shell and edit and save each file you wish to execute. This updates the directory information contained in your .lis and .gen files in the input46 subdirectory.**

Inputs

Inputs for wetland analysis are needed on four data screens that are accessed through DMSHELL. Two of the screens are the General Information screens that have been modified to include information necessary for wetland analysis. Screen 1 allows a constant monthly PET value to be read in as a weather data option. Screen 2 provides a choice for making hydrologic analyses for wetlands. If yes (Y) is chosen for the Hydrologic Analysis for Wetlands, information is required for the analysis on a third screen.

Wetland hydrologic criteria have the following general form:

A site has wetland hydrology if the water table is less than a given depth (WTDWET) for a certain number of consecutive days (DAYSWET) during the growing season under average conditions, which is interpreted to mean that the criteria are met in at least 50% of the years (10 out of 20, 15 out of 30).

The inputs required (screen 3) are:

- IWST (Julian day)-first day of the growing season
- IWEND-last day of the growing season
- WTDWET (centimeters)–threshold water table depth
- DAYSWET–number of consecutive days required

The other modification allows daily average PET values to be read in for each month (screen 4). The values are read as centimeters.

Note: **A temperature file is still required but the PET values read in will be used in the calculations.**

Outputs

All outputs available for the general DRAINMOD program are also available for this application. In addition, an output with the extension .wet is printed in the output file. The summary includes a year-by-year list of the number of periods meeting the criteria and the longest period in each

Screen 1 General inputs

```
File:     c:\dm46\inputs\wetintro.gen
Screen:   General Information - 1 of 2


Title to Identify Run:


Printing Options (Y/N):

    (N) Rankings Only
    (N) Yearly and Rankings
    (Y) Monthly, Yearly and Rankings
    (N) Daily, Monthly, Yearly and Rankings
    (N) Mrank Version of Rankings (Adv. Option)

 (N) Output for each year for daily water table graphs (Y/N)

 Weather Data Options (Y/N):
    (Y) Temperature File";
    (N) Potential Evapotranspiration File ";
    (N) Constant Monthly PET ";

F1     F2     F3    F4     F5     F6    F7     F8     F9      F10
HELP   RESET                      EXIT  ABORT  CLEAR  LASTSCR NEXTSCR
```

Screen 2

```
File:     c:\dm46\inputs\wetintro.gen
Screen:   General Information - 2 of 2"


Subsurface Water Management Options:


    (Y) Conventional Drainage          Move cursor to select option
    (N) Controlled Drainage            and press <Y>
    (N) Subirrigation
    (N) Combo: Drainage-Controlled Drainage-Subirrigation
                 NOTE: COMBO Must be on in Config.dm (Advanced Option)

 Surface Water Management Option (Y/N)        :

    (N) Waste Water Irrigation Application

 (Y)   Hydrologic Analysis for Wet Soil Conditions (Advance Option)

F1     F2     F3    F4     F5     F6     F7     F8     F9      F10
HELP   RESET                      EXIT   ABORT  CLEAR  LASTSCR NEXTSCR
```

Screen 3 Inputs required for wetland analysis

```
File:     c:\dm46\inputs\wetintro.gen
Screen:   Hydrology Analysis for Wet Conditions 1 of 1

          Name   Value    Description

Starting and Ending days for Checking:
          IWST    66      Starting Day of the Year
          IWEND  332      Ending Day of the Year

   Maximum Allowable Water Table Depth and Lenth of Period:

   WTDWET       30        Water Table Depth in cm
   DAYSWET      14        Length of period to count in days

 ************************************************************************************
 ***WARNING===> This is an experimental release. Tests and                     ***
 *** evaluations of this version of DRAINMOD are being done                    ***
 ************************************************************************************

F1     F2      F3   F4     F5       F6      F7     F8      F9       F10
HELP   RESET                        EXIT    ABORT  CLEAR   LASTSCR  NEXTSCR
```

Screen 4 Average daily PET values may be read in for each month

```
File:     c:\dm46\inputs\wetintro.gen
Screen:   Weather Inputs (Monthly PET Option) - 2 of 2

          Average Daily PET (cm)

          January       0.08
          February      0.15
          March         0.23      **************************************************
          April         0.31      *NOTE:  VALID TEMPERATURE FILES  *
          May           0.38      *       ARE REQUIRED.  THIS      *
          June          0.43      *       SCREEN PROVIDES THE      *
          July          0.40      *       ACTUAL PET VALUES USED   *
          August        0.36      *       BY DRAINMOD              *
          September     0.31      **************************************************
          October       0.18
          November      0.13
          December      0.08

F1     F2      F3    F4     F5     F6     F7      F8      F9       F10
HELP   RESET                       EXIT   ABORT   CLEAR   LASTSCR  NEXTSCR
```

Sample output for wetland analysis

```
---------------------------------------------------------------
*              DRAINMOD version 4.60a                         *
*              Copyright 1990-91 North Carolina State University *
---------------------------------------------------------------

ANALYSIS OF WETLAND HYDROLOGIC CRITERIA FOR portswet SOIL AT WILMINGTON N.C. for
FOREST:100m D/SPACING, STMAX=4.0cm, thwtd=3ocm/14days, Ksat=6
*****************************************************************************************

-----------RUN STATISTICS------------                  time: 10/ 6/1991  @ 22:46
input file:                       c:\DM46\INPUT45\P10S4D4.LIS
parameters:        free drainage                         and yields not calculat
              drain spacing= 10000. cm                    drain depth= 120.0 cm
-----------------------------------------------------------------------------------
                                    --
```

D R A I N M O D --- HYDROLOGY EVALUATION
******** INTERIM EXPERIMENTAL RELEASE*****

Number of periods with water table closer than 30.00 cm
for at least 14 days. Counting starts on day
68 and ends on day 332 of each year

YEAR	Number of Periods of 14 days or more with WTD <30.00 cm	Longest Consecutive Period in Days
1968	0.	0.
1969	2.	26.
1970	2.	37.
1971	1.	16.
1972	0.	0.
1973	2.	21.
1974	2.	28.
1975	0.	7.
1976	0.	12.
1977	0.	11.
1978	0.	8.
1979	2.	34.
1980	1.	26.
1981	0.	13.
1982	0.	13.
1983	1.	28.
1984	2.	25.
1985	0.	0.
1986	1.	14.
1987	1.	14.

Number of Years with at least one period = 11.

Appendix G: Tables and Graphs

Table 6 Effective radii for various drain tubes

	Drain Diameter (O.D. cm)	r_e (cm)	
3-in corrugated [1/]	8.9	0.35	
4-in corrugated	11.4	0.51	(openings of 38 cm^2/m)
4-in corrugated	11.4	1.1	(openings of 55 cm^2/m)
4-in corrugated	11.4	2.0	(openings of 77 cm^2/m)
4-in corrugated with synthetic filter	11.4	4.0	(assuming filter holds soil outside of corrugations)
5-in corrugated	14.0	1.0	(openings of 45 cm^2/m)
6-in corrugated	16.5	1.5	(openings of 60 cm^2/m)
4-in clay - 1/16 in crack between joints	12.7	0.30	
4-in clay - 1/8 in crack between joints	12.7	0.48	
Drain tube surrounded by gravel envelope with square cross-section of length 2a on each side	2 [1/]	1.177 [1/]	

[1/] Based on 5 rows of slots with total opening of 1.5 to 2.0 percent of the wall area.

Table 7 General Guidelines for estimating field surface depressional storage (STMAX)

Field surface drainage quality	Depressional storage	Field description
Good	0.2 -0.5 cm	Surface relatively smooth and on grade so that water does not remain ponded in field after heavy rainfall. No potholes—adequate outlets.
Fair	1.0 - 1.5 cm	Some shallow depressions, water remains in a few shallow pools after heavy rainfall. Micro-storage caused by disking or cultivation may cause surface drainage to be only fair even when field surface is on grade.
Poor	> 2.0	Many depressions or potholes of varying depth. Widespread ponding of water after heavy rainfall. Inadequate surface outlets such as berms around field ditches.

Table 8 S_{av} and bubbling pressure by soil textural class

Soil texture	Bubbling pressure 1/ (cm)	S_{av} 2/ (cm)
Sand	7.3	5.0
Loamy sand	8.7	6.1
Sandy loam	14.7	11.0
Loam	11.2	8.9
Silt loam	20.8	16.7
Sandy clay loam	28.1	21.9
Clay loam	25.9	20.9
Silty clay loam	32.6	27.3
Sandy clay	29.2	23.9
Silty clay	34.2	29.2
Clay	37.3	31.6

1/ Soil water characteristics from Rawls, Brakensiek, and Saxton (1982).
2/ Brakensiek and Rawls (1982).

Table 9 Trafficability parameters for plowing and seedbed preparation for some North Carolina soils

Soil	Water content [1/] in plow layer (cm^3/cm^3)	Corresponding pressure head (cm)	AMIN (cm)	ROUTA (cm)	ROUTT (days)
Cape Fear l.	0.395	-65	3.3	1.2	2
Lumbee s.l.	0.265	-70	2.8	1.5	1
Coxville-Ogeechee l.	0.39	-80	3.4	1.2	2
Goldsboro s.l.	0.23	-80	3.2	1.5	1
Rains s.l.	0.25	-70	3.9	1.2	2
Wagram l.s.	0.15	-65	3.5	1.5	1
Bladen s.l.	0.40	-60	3.0	1.0	2
Portsmouth s.l.	0.32	-75	3.0	1.2	2

[1/] Water content in plow layer when soil is just dry enough for plowing and seed bed preparation.

Table 10 Plant feeder root depths [1/] (from Sprinkler Irrigation Handbook, Rain Bird Mfg. Corp., Glendora, California)

Crop	Root depth	Crop	Root depth
Alfalfa	3 to 6 ft	Nuts	3 to 6 ft
Beans	2 ft	Onions	1 1/2 ft
Beets (Cane)	2 to 3 ft	Orchard	3 to 5 ft
Berries	3 feet	Pasture (grasses only)	1 1/2 ft
Cabbage	1 1/2 to 2 ft		
Carrots	1 1/2 to 2 ft	Pasture (with clover)	2 ft
Corn	2 1/2 ft		
Cotton	4 ft	Peanuts	1 1/2 ft
Cucumber	1 1/2 to 2 ft	Peas	2 1/2 ft
Grain	2 to 2 1/2 ft	Potatoes	2 ft
Grain, sorghum	2 1/2 ft	Soybeans	2 ft
Grapes	3 to 6 ft	Strawberries	1 to 1 1/2 ft
Lettuce	1 ft	Sweet potatoes	1 to 1 1/2 ft
Melons	2 1/2 to 3 ft	Tobacco	2 1/2 ft
		Tomatoes	1 to 2 ft

[1/] Majority of feeder roots.

Table 11 Typical wastewater application parameter values

Application interval, INTDAY	3 days	7 days	10 days
Irrigation amount	1.05 cm	2.5 cm	5.0 cm
Time irrigation starts	1000	1000	1000
Time irrigation ends	1200	1200	1200
Drained (air) volume required in the profile, REQDAR	2.05 cm	3.5 cm	6.0 cm
Amount of rain to postpone irrigation, AMTRAN	1.0 cm	1.0 cm	1.0 cm

Table 12 Wastewater irrigation parameter values for three different loading rates on Wagram l.s

Loading rate*	2.5 cm/wk	5.0 cm/wk	10.0 cm/wk
Application interval (INTDAY)	3 days	3 days	3 days
Irrigation amount [1/] (per application)	1.07 cm	2.14 cm	4.28 cm
Time irrigation starts (IHRSTA)	10	10	10
Time irrigations ends (IRHEND)	12	12	12
Intervals when no irrigation is applied			
MONO1/IDANO1	1/1	1/1	1/1
Interval 1			
MONO2/IDANO2	3/15	3/15	3/15
MONO3/IDANO3	11/15	11/15	11/15
Interval 2			
MONO4/IDANO4	12/31	12/31	12/31
Drained (air) volume required in profile, REQDAR	2.07 cm	3.14 cm	5.28 cm
Amount rain to postpone irrigation, AMTRN	1 cm	1 cm	1 cm
Irrigation rate [2/]	0.53 cm/hr	1.07 cm/hr	2.14 cm/hr

1/ Not a direct input to this model.
2/ Constant for all months in that wastewater is to be applied.

Figure 1 Relationships for depth above which 50. 60, 70, and 80 percent of the total root length exists vs. time after planting corn (Mengel and Barber 1974)

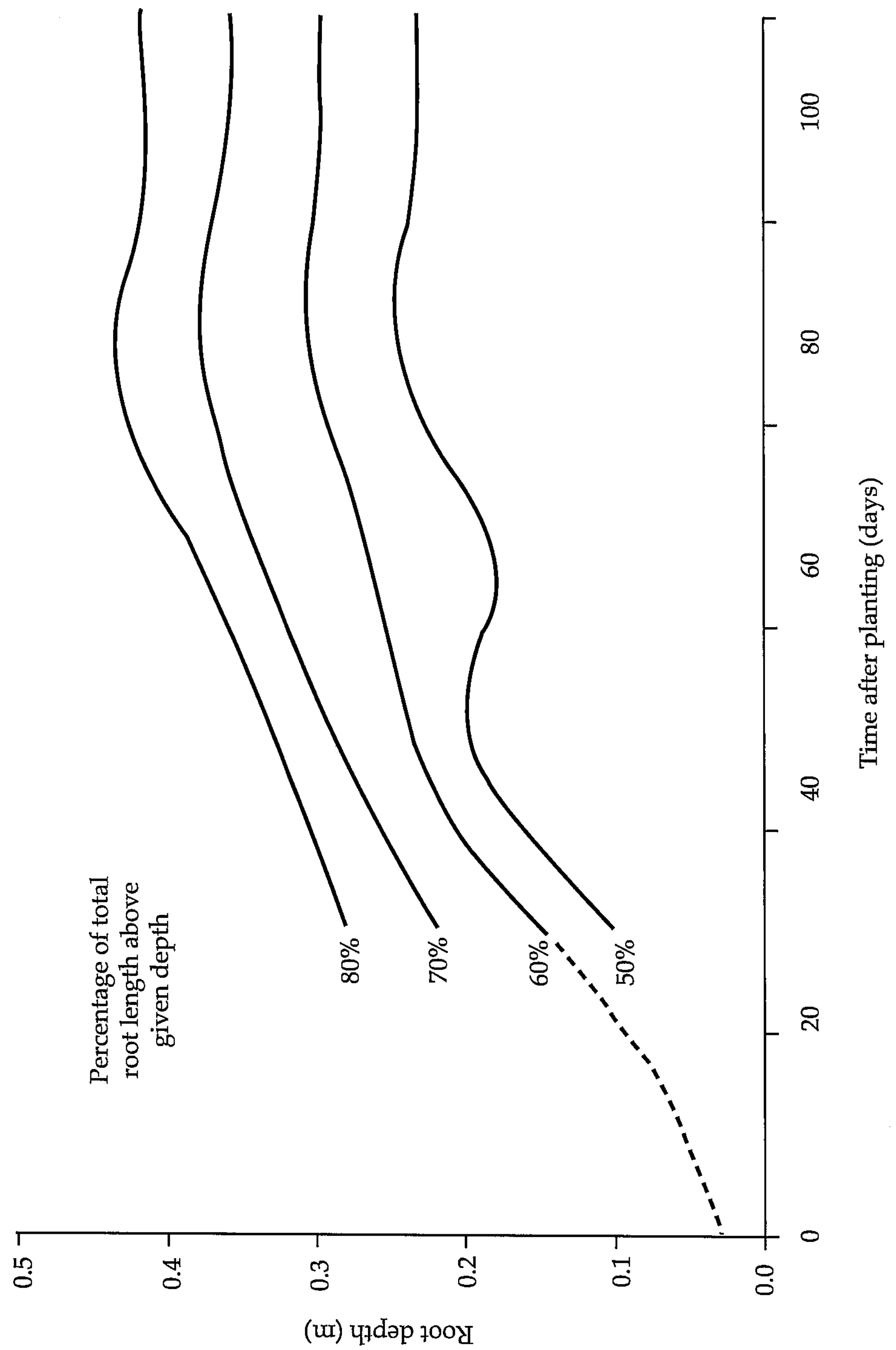

Table 13 Corn yield response factors for planting date delays (adapted from Seymour 1986)

Location	Optimum Planting Date	DELAY1	PDRF	PDRF2
England	4-30	30	0.95	3.6
Illinois	4-30	31	0.81	----
Iowa	5-15	30	0.76	2.1
Kansas	5-5	20	0.62	----
Louisiana	3-15	45	0.72	----
New York	5-1	13	0.89	1.32
North Carolina	4-10	42	0.88	1.62
North Dakota	5-17	38	0.79	----
Ohio	5-1	22	0.60	1.8
MEAN VALUES (Excludes England)		30	0.76	1.71

Table 14 Crop susceptibility factors (corn and soybean) for excessive soil water conditions

CORN Growth stage	Days after planting 130 day maturity DAP	110 day maturity	Crop susceptibility factor, CS_w
Establishment	0 - 29	0 - 19	0.20
Early vegetative	30 - 49	20 - 35	0.22
Late vegetative	50 - 69	36 - 50	0.32
Flowering	70 - 89	51 - 69	0.19
Yield formation	90 - 109	70 - 89	0.08
Ripening	110 - [1/]	90 - [1/]	0.02

Soybean Growth Stage	Development Stage	Days after [2/] planting	Crop Susceptibility factor, CS_w
Establishment	V2	0 - 24	0.19
Vegetative	V5-V6	25 - 54	0.13
Flowering	V9-R1	55 - 74	0.19
Pod Development	R3	75 - 94	0.26
Pod Filling	R5	95 - 109	0.25
Ripening (Pods w/full size beans)	R6	110 - 119	0.08
(Pods yellowing)	R7	120 - 129	0.01
(Pods brown)	R8	130 - 140	0.00

* Use growing season length as end of growth stage.

** Values are for soybean in maturity group V. Initiation of flowering is daylength sensitive and depends on maturity group. Adjust days after planting accordingly.

Table 15 Crop susceptibility factors for deficient soil water conditions for corn (Shaw 1974)

Period [1/]	CSd	Period	CSd
-8	0.50	+1	2.00
-7	0.50	+2	1.30
-6	1.00	+3	1.30
-5	1.00	+4	1.30
-4	1.00	+5	1.30
-3	1.00	+6	1.30
-2	1.75	+7	1.20
-1	2.00	+8	1.00
		+9	0.50

[1/] 5-day periods relative to silking stage, where silking occurs in the 10 day period from -1 to +1; for example, period -8 is the period from 35 to 40 days prior to silking and period +3 would be from 10 to 15 days after silking. Also, note that CS_d is assumed to be zero for any periods prior to -8 and after +9. These zero values must be entered as inputs to DRAINMOD.

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