G L E A M S

V E R S I O N 2.10

Part III: User Manual

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IMPLEMENTATION OF **GLEAMS** MODEL ON A MICROCOMPUTER

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Version 2.10

The latest version of the **GLEAMS** model, Version 2.10, has been implemented on the IBM, COMPAQ, Zenith, NCR, CompuAdd, Gateway, and other IBM-compatible personal computers at the USDA-ARS-Southeast Watershed Research Lab, and the University of Georgia-Coastal Plain Experiment Station-Biological & Agricultural Engineering Department, Tifton, Georgia.

Version 2.10/PC of **GLEAMS** is similar to its mainframe counterpart. A few changes to the code were made for the execution of file definitions at the beginning of the program. Output format for **GLEAMS** requires a printer with 132 character record length capability. The program does not issue printer controls due to the wide variety of printers on the market. To obtain an output to the printer, the user should preset the printer to condensed mode or 132 characters, whichever is applicable in your case. At the end of this document are sample basic programs that use control codes to toggle a printer in and out of condensed mode. After the printer has been set to condensed mode, the standard DOS commands will work with the appropriate output files. Input data sets constructed for the mainframe version of **GLEAMS** will execute on the micro version with no modification.

In the conversion, all source code was down-loaded from the mainframe model version. Two changes from the mainframe source code are very apparent in the P/C source code, and these are the additions of two subroutines. The first subroutine is called "INTRO" which introduces the specific **GLEAMS** component that is being used. The next is "FILES" which allows the interactive selection of input and output data files. Filenames must adhere to the standard DOS convention, and appropriate drive designations should be used where required.

The FORTRAN source code for **GLEAMS** is split into blocks of 40K to 80K. This step was necessary for compilation purposes since the mainframe program was too large to compile as one block. The mainframe source code was modified for compilation using the Microsoft FORTRAN compiler, version 5.0. No modifications to the source code provided are necessary with use of this compiler. Use of other compilers may require some modification, e.g. in the statements which open the input and output files.

The addition of the plant nutrient component into the **GLEAMS** model results in 24 files. The files are listed and described below.

GLMS2.EXE	Machine executable code - model
GLMS0.FOR]	
GLMS1.FOR]	
GLMS2.FOR]	
GLMS3.FOR]	
GLMS4.FOR]	
GLMS5.FOR]	Source FORTRAN code
GLMS6.FOR]	
GLMS7.FOR]	
GLMS8.FOR]	
GLMS9.FOR]	
GLMS10.FOR]	
HYD.EXE	Hydrology parameter editor
ERO.EXE	Erosion parameter editor
PST.EXE	Pesticide parameter editor
NUT.EXE	Nutrient parameter editor
GLMS2PCP.DAT	Daily rainfall

GLMS2TMP.DAT	Mean daily temperature
GLMS2HYD.PAR	Hydrology parameters
GLMS2ERO.PAR	Erosion parameters
GLMS2PST.PAR	Pesticide parameters
GLMS2NUT.PAR	Nutrient parameters
GLMS2HYD.OUT	Hydrology output
GLMS2ERO.OUT	Erosion output
GLMS2PST.OUT	Pesticide output
GLMS2NUT.OUT	Nutrient output

The four parameter editor files are machine executable code. Source code is not supplied since one character addition or deletion in a line could destroy the integrity of the program.

The programs are designed to run on the IBM PC-AT or IBM-compatible systems having 512K or greater RAM. Program compilation requires at least 384K of RAM; more than 384K is preferable. Use of the 8087 Arithmetic Coprocessor chip in the system is recommended. Systems having this chip will execute programs much more rapidly (up to 10 times). The executable code provided will run on systems with or without the 8087 chip.

Execution of the programs is quite straightforward, but the user should be familiar with standard DOS conventions. Since the appropriate data sets are constructed and stored on disk, the largest chore is keeping the various input and output files in some sensible order. It is recommended that a file-naming convention be established and followed. To execute the programs (operating in the **GLMS2** subdirectory), type **<GLMS2>** and press **<ENTER>**. The program will load into memory and execute, issuing prompts for the required file names. **GLEAMS** contains a utility to input file names and check file status. The utility checks filenames to make sure they exist for input files, or they are not write-protected for output files. To help with forgotten file names, a directory file list for any drive or subdirectory can be shown on the screen. Users who modify the FORTRAN source code and want to use the filename handling utility will need further information.

Filename Utility Commands

Valid command keys in the name fields:

ESC in any name field	ends the utility and starts the model
UP, DOWN, RETURN	move between name fields
F1 or ALT + H in any name field	prompts user for a drive and directory to display

Options at the help prompt:

Press ENTER to select the current drive and directory.

Enter any valid DOS drive and directory name. Wildcard characters can be included in the path name.

If the desired directory has been previously displayed, press ENTER to continue selecting files from the directory list.

Valid command keys in the directory file list:

ESC	returns to name field without selecting file
RETURN	returns to name field and selects file
UP, DOWN, END, PGUP, PGDN, HOME	move selector through file names
LEFT, RIGHT	move selector through file list and scroll file list left and right as needed.

The four executable parameter editors for developing hydrology, erosion, pesticide, and nutrient parameter files contain several help tables for user convenience. However, it is stressed that local data, where available, are recommended in all cases. Data in the help tables will not let you get into trouble, but some data are particularly site specific, e. g. pesticide char-acteristics. Browse the READ.ME file for a brief explanation to implement the parameter editors. The parameter editors are used externally to develop parameter sets and file them for execution of GLMS2.

Sample BASIC Programs

Sample BASIC programs that use printer control codes to toggle in and out of condensed mode.

```
10  '---- CONTROL CODE SI ----
20  'Selects condensed print
30  '
40  LPRINT CHR$(15)
50  'condensed mode set


10  '---- CONTROL CODE DC2 ----
20  'Cancels condensed print
30  '
40  LPRINT CHR$(18)
50  'condensed mode canceled
```

Diagnostics

A few diagnostics have been incorporated into **GLEAMS** to aid the user in locating and correcting errors in attempted model execution. They are minimal but have proven helpful in designating the particular component and problem. The diagnostics are listed and defined in Table G-1.

Table G-1. Diagnostics and error messages included in the **GLEAMS** model.

Error	Message	Action Required
WARNING H1	Effective rooting depth should equal bottom of last horizon	Change RD or BOTHOR in the hydrology parameter file
ERROR H1	Field capacity must be less than porosity	Reduce FC or increase POR in hydrology parameter file
ERROR H2	Wilting point must be less than field capacity	Reduce BR15 or increase FC in hydrology parameter file
ERROR H3	Clay + silt must be # 100.0	Reduce CLAY or SILT fraction in hydrology parameter file
ERROR H4	Porosity must be # 1.0	Reduce POR in hydrology parameter file
ERROR H5	Number of horizons must be > 0 and # 5	Change NOSOHZ in hydrology parameter file
ERROR H6	ICROP must be in the range 0 - 90	Check/change value of ICROP in hydrology parameter file
ERROR H7	Porosity must be # 1.0	Reduce POR in hydrology parameter file
ERROR H8	Bottom of horizon (i) must be > 0.0	Reset BOTHOR of ith horizon in hydrology parameter file
ERROR H9	Bottom of horizon (i) must be greater than horizon (I-1)	Check/reset BOTHOR of soil horizons in the hydrology parameter file
ERROR P1	Parent plus Metabolites must be less than NPEST. Pesticide number: (I)	Check number of metabolites for ith pesticide in the parameter file NPEST # 10, and includes parent and metabolites
ERROR N1	Underflow in Nitrogen initial-ization	Check TN, CNIT, POTMN, and ORGNW--negative values encountered
ERROR N2	Underflow in Phosphorus init-ialization	Check TP, CLAB, and ORGPW--negative value encountered
ERROR N3	Overflow in Nitrogen initial-ization	TN out of range (too large)
ERROR N4	Overflow in Phosphorus init-ialization	TP out of range (too large)

U S E R G U I D E

INTRODUCTION

The user guide for **GLEAMS** has been expanded to include plant nutrients as well as hydrology, erosion, and pesticides. Since earlier versions were not formally published, a complete manual was not distributed with the model. Now that the model is complete, the entire user manual is presented that describes the parameters as well as their sensitivity and availability. Although with the parameter editors, it may not really be necessary to include details of format and abbreviated information as once needed, that information is repeated here for user convenience. Also included in this printing of the user manual is a brief discussion of each parameter in the hydrology, erosion, and pesticide components as well as in nutrients. Even though sensitivity is somewhat site-specific, an indication of sensitivity is included in the description. Parameter definition and availability or methods of initialization are given in the discussion. Tables of parameter estimates and supporting data are included for user convenience.

Most of the parameters remain the same as those in **CREAMS** Version 1.8, but some have been changed to make **GLEAMS** better represent the field system with less user dependence. The same basic surface representation and sensitivity in **CREAMS** have been retained in **GLEAMS**. The only exception is that the infiltration option of **CREAMS** (option 2) was deleted. Since it was considered that **GLEAMS** would be linked with a vadose zone model and/or a saturated zone model, it was felt that the daily rainfall option would require less computer time and fulfill the basic requirement for a layered soil system. Thus, the infiltration option was deleted.

A paper documenting the new concepts of **GLEAMS** was published in the Transactions of the American Society of Agricultural Engineers. Another paper has been published by the American Society of Civil Engineers on representation of pesticide metabolites.

Some recent changes have been made in hydrology that are slightly different from earlier versions. Users of the present version can input saturated conductivity by soil horizon. Some additional soil characteristics are needed for the nutrient component, and for consistency, these parameters are included as input following saturated conductivity in the hydrology component. The hydrology component was changed such that a preplant irrigation can be specified by day and amount as is often practiced in western flood and furrow irrigation systems. Also, when the model-applied irrigation is selected, the base soil water content is used for the actual simulated rooting depth rather than that for the entire effective root zone. When irrigation is applied, the runoff process is now applied to estimate any potential runoff. This eliminates the assumption that any irrigation specified greater than field capacity is applied at rates less than the saturated conductivity.

A soil temperature component was added to simulate daily temperature in each soil computational layer.

Validation of the **CREAMS** hydrology component was made by Dr. Wade L. Nutter, School of Forest Resources, University of Georgia, for application on forest sites. Some modifications were needed to adequately represent forest sites. These changes were made in **GLEAMS**, and those changes are included in this version (2.10). A manuscript describing these new concepts is in progress.

Potential improvement of the snowmelt runoff component is included. Input of mean daily temperature is included as an option for better estimation of the mid-winter thaw (melt) that oftentimes occurs. The fitting of mean monthly minimum temperature data is still used for estimation of beginning and end of frozen soil conditions.

The parameter editors supplied with the model is thought to be helpful in developing and editing parameter files for **GLEAMS**. Proper input format and sequencing are particularly helpful as well as generalized "help" tables. However, use of local data for parameters is highly reccommended where they are available. For example, site specific data for soil parameters and pesticide characteristics are more reliable than values averaged over some range of conditions that may not be well documented. Half-life of a specific pesticide may be much longer in a soil with a high organic carbon content than in the same soil with a lower organic carbon content. Several parameters are management dependent, and thus local data would be significant. This version includes a more extensive pesticide data base.

A plant nutrient component has been added to the present version of **GLEAMS** to simulate nitrogen and phosphorus cycling. Some of the transformation processes are similar to those in the EPIC model with some specific differences because of model objectives. The nutrient component bears little or no resemblence to that in **CREAMS**. It considers nitrogen mineralization as a two-step process: ammonification and nitrification. This makes it possible to consider ammonia volatization from surface-applied animal waste application. Nitrogen fixation by legumes is simulated.

CLIMATE

Precipitation

Daily precipitation data are required for input to the **GLEAMS** model, and the format is the same as that for **CREAMS**, i. e. 37 cards per year with 10 values per card (ten 5-column fields, columns 11-60). The first 10 coluns are available for user-supplied identification data. The last 20 columns (61-80) are available for identification data, also. It is recommended that card number be included on the card, such as in columns 79-80. Any information in the first 10 columns and last 20 columns are not read by the model.

The READ format for rainfall is: 10X,10F5.2,20X. It is not necessary to enter the decimal when the data in each field are right justified. However, it is recommended that the decimals be entered; The user can quickly glance over the file to determine if the data are out of format fields. Since **GLEAMS** has been modified to accept metric input, it is more important to have the decimal punched. Rainfall data in English units are in inches, and the metric units are centimeters. DO NOT ENTER METRIC UNITS IN MILLIMETERS.

A full year's set of 37 cards must be included for each year of simulation even though the simulation can begin on any specified day during the year. Likewise, 37 cards are required for the last year of simulation even though data may not be available for the last part of the year. Those days without data in the first part of the beginning year and the last part of the ending year must be included with blank or zero fields for the respective unmeasured period.

Sample rainfall data are shown in Figure 1 for the first 100 days of 1936 at the Coastal Plain Experiment Station (CPES). The card number is given in columns 69-70 in this particular example in order to not extend too far to the right side of the page. Rainfall amounts are in inches.

Temperature

Temperature data for **GLEAMS** normally consist of mean monthly maximum and mean monthly minimum values entered in the hydrology parameter file. These data are fitted with Fourier series for interpolating daily values. However, this results in smoothed data without the potential for representing the mid-winter snowmelt period that oftentimes occur in the northern states.

A compromise was made in **GLEAMS** to allow mean daily temperature to be entered (not daily max and min). This feature gives the cold region users an option for better representation, but it also allows warm region users to continue using fitted (smoothed) data. Mean daily temperature input does not ignore the fitting of mean monthly max and min values. This is still used to estimate when frozen soil begins and ends.

Mean daily temperature data are entered in a similar format as for rainfall, i.e., 10X, 10F5.1, 20X. Temperature data must conform to the designated English-metric units for hydrology input/output.

A sample partial year of mean daily temperature data in fahrenheit are shown in Figure 3, and the same file is shown in centigrade in Figure 4. Just as in the case with rainfall data, the model reads a full year (365 or 366 values on 37 cards) at a time. If only a part year is available for simulation, remaining days of the year must be filled with zeros or left blank to complete the 37 cards. DO NOT DELETE CARDS! IT WILL BOMB!

```
|...+....1....+....2....+....3....+....4....+....5....+....6....+
* * * TOP OF FILE * * *
CPES 36    0.07 0.0  1.10 0.0  0.23 0.04 1.48 0.0  0.40 0.05   01
CPES 36    0.0  0.0  0.0  0.06 0.68 0.0  0.0  0.0  0.55 0.0    02
CPES 36    0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.53   03
CPES 36    0.08 0.0  0.0  0.52 0.0  1.45 0.50 0.84 0.0  0.0    04
CPES 36    0.0  0.0  0.0  0.0  0.61 0.0  0.40 0.0  0.0  0.0    05
CPES 36    0.0  0.50 0.14 0.0  0.0  0.0  0.0  0.08 0.14 0.0    06
CPES 36    0.0  0.0  0.0  0.0  0.62 0.02 0.0  0.0  0.0  0.12   07
CPES 36    0.09 0.0  0.0  0.0  0.0  0.0  1.07 0.0  0.0  0.50   08
CPES 36    0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.65 0.0  0.0    09
CPES 36    0.10 0.85 0.05 1.10 0.0  0.08 0.0  0.0  0.83 0.0    10
```

Figure 1. Sample rainfall data (inches) for the first 100 days of 1936 at the Coastal Plain Experiment Station.

A metric equivalent of the CPES partial rainfall data set are shown in figure 2. Note that the metric values are in centimenters.

```
|...+....1....+....2....+....3....+....4....+....5....+....6....+
* * * TOP OF FILE * * *
CPES 36    0.18 0.0  2.79 0.0  0.58 0.10 3.76 0.0  1.02 0.13   01
CPES 36    0.0  0.0  0.0  0.15 1.73 0.0  0.0  0.0  1.40 0.0    02
CPES 36    0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.35   03
CPES 36    0.20 0.0  0.0  1.32 0.0  3.68 1.27 2.13 0.0  0.0    04
CPES 36    0.0  0.0  0.0  0.0  1.55 0.0  1.02 0.0  0.0  0.0    05
CPES 36    0.0  1.27 0.36 0.0  0.0  0.0  0.0  0.20 0.36 0.0    06
CPES 36    0.0  0.0  0.0  0.0  1.57 0.05 0.0  0.0  0.0  0.30   07
CPES 36    0.23 0.0  0.0  0.0  0.0  0.0  6.91 0.0  0.0  3.23   08
CPES 36    0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.65 0.0  0.0    09
CPES 36    0.25 2.16 0.13 2.79 0.0  0.20 0.0  0.0  2.11 0.0    10
```

Figure 2. Sample rainfall data, centimeters, for the first 100 days of 1936 at the Coastal Plain Experiment Station.

```
|...+....1....+....2....+....3....+....4....+....5....+....6....+..
* * * TOP OF FILE * * *
CPES 36    47.0 61.0 53.5 52.5 43.0 45.5 48.5 55.5 56.5 50.0  EF 01
CPES 36    39.0 40.5 46.0 51.5 61.5 45.0 41.0 46.0 51.0 49.5  EF 02
CPES 36    42.5 53.0 60.5 61.5 61.5 64.5 66.5 45.0 41.0 48.0  EF 03
CPES 36    52.5 55.5 57.5 60.5 48.0 47.0 47.5 53.5 36.5 41.5  EF 04
CPES 36    36.5 45.0 55.0 42.0 45.0 55.5 56.5 62.0 62.5 55.5  EF 05
CPES 36    54.5 58.0 41.0 48.0 44.5 37.5 27.0 37.0 45.0 51.5  EF 06
CPES 36    50.0 57.0 62.5 65.5 68.5 58.0 49.5 55.5 63.0 69.5  EF 07
CPES 36    71.5 71.0 67.0 67.5 63.5 50.5 52.5 44.5 52.0 60.5  EF 08
CPES 36    54.5 52.5 59.0 64.0 68.5 72.0 66.5 67.0 66.0 67.0  EF 09
```

Figure 3. Sample mean daily temperature data (EF) for the first 90 days of 1936 at the Coastal Plain Experiment Station.

```
|...+....1....+....2....+....3....+....4....+....5....+....6....+..
* * * TOP OF FILE * * *
CPES 36     6.7 16.1 11.9 11.4  6.1  7.5  9.2 13.1 13.6 10.0  EC 01
CPES 36     3.9  4.7  7.8 10.8 17.5  7.2  5.0  7.8 10.6  9.7  EC 02
CPES 36     5.8 11.7 15.8 17.5 17.5 18.1 19.2  7.2  5.0  8.9  EC 03
CPES 36    11.4 13.1 14.2 15.8  8.9  6.7  8.6 11.9  2.5  5.3  EC 04
CPES 36     2.5  7.2 12.8  5.6  7.2 13.1 13.6 16.7 16.9 13.1  EC 05
CPES 36    12.5 14.4  5.0  8.9  6.9  3.1 -2.8  2.8  7.2 10.8  EC 06
```

```
CPES 36    10.0 13.9 16.9 18.6 20.3 14.4  9.7 13.1 17.2 20.8  EC 07
CPES 36    21.9 21.7 19.4 19.7 17.5 10.3 11.4  6.9 11.1 15.8  EC 08
CPES 36    12.5 11.4 15.0 17.8 20.3 22.2 19.2 19.4 18.9 19.4  EC 09
```

Figure 4. Sample mean daily temperature data (EC) for the first 90 days of 1936 at the Coastal Plain Experiment Station.

Solar Radiation, Wind Movement, and Dew Point Temperature

Mean monthly solar radiation data always have been used as input for **CREAMS** and **GLEAMS.** Earlier versions had tabulated values for a limited number of locations in the USA. With the addition of the Penman-Monteith option for estimating potential evapotranspiration, mean monthly wind movement and dew point temperature data are required, also. These data and mean monthly maximum and minimum temperature data are included in the data base for the **CLIGEN** climate generator (Richardson and Nicks, 1990) for an extended list of more than 1,000 locations in the USA. These monthly data are now included in the hydrology parameter editor climate data base, and can be entered in the hydrology parameter file automatically from that data base by selecting the desired location. Even though a specific location desired may not be included in the data base, a nearby station can be selected within the climatic region with satisfactory results. The model user can enter local data when available.

HYDROLOGY PARAMETERS

This section describes the parameters for the hydrology component and gives the appropriate data fields for the respective parameters. All parameter fields (except title cards) are 8-column fields. Example values (numbers following the "e. g." notation) are given for each parameter. Decimals are indicated for floating point numbers. It should be remembered that data should be right justified. This is handled for you automatically in the parameter editor, but development of parameter files on mainframe computers or minicomputers, or with use of text editors on a P/C, integer variables MUST be right justified.

Since this version of **GLEAMS** can accept parameters in metric, two units and example values are given for each parameter that has units. The English units are shown with metric units in parentheses.

The present version includes an option for forested areas based upon the work on **CREAMS** hydrology by Dr. Wade L. Nutter, forest hydrologist, University of Georgia, Athens. This addition results in some additional input, but the changes will not affect the use of existing hydrology parameter files for agricultural applications.

Additional soils input is included in **GLEAMS** Version 2.10. Saturated conductivity, soil pH, clay content, silt content, base saturation, and calcium carbonate content are input by horizon. Although pH, base saturation, and calcium carbonate content are used only in the nutrient component, these data are input in the hydrology component along with the physical characteristics.

An option is provided to simulate potential evapotranspiration by the Penman-Monteith method or the previously-used Priestly-Taylor method.

Other changes in hydrology include use of crop rotation information such that only leaf area data are required only for the crop rotation cycle. That is, a corn-soybeans rotation simulated for 50 years only requires LAI data for the 2-year rotation cycle, and the model automatically repeats the information in a dummy file for the next 24 cycles.

*

Cards 1 - 3: **TITLE**

TITLE Three 80-character lines of alphanumeric information that identifies the particular computer run. For example, the soil type, the crop location, the tillage practices, may be useful in identifying the file. This title will be reproduced on the hydrology output file.

Card 4: **HBDATE, HYDOUT, FLGPEN, FLGNUT, FLGPST, FLGGEN, FLGMET, FLGTMP, BCKEND, FOREST**

HBDATE The beginning date (year and Julian day) for hydrology simulation, e. g. 73138 HBDATE must be less than the first storm date to initialize soil water storage before that storm. If the rainfall record begins January 1, 1936 (figure 1), and it is not known if rainfall occurs that day, HBDATE should be 36000 to initialize soil water before 36001.

HYDOUT Code to designate the level of printed hydrology output.

0 for annual summary hydrology output;
1 for storm-by-storm hydrology output.

FLGPEN Code to designate Priestly-Taylor or Penman-Monteith method method of simulating potential ET.

0 for Priestly-Taylor
1 for Penman-Monteith

FLGNUT Code for simulation of nutrients.

0 if nutrients are not run in this simulation;
1 if nutrient simulation is to be made.

FLGPST Code for simulation of pesticides.

0 if pesticides are not to be simulated;
1 if pesticides are to be simulated.

FLGGEN Code for daily max and min temperature data generation.

0 if temperature data are to be read from hydrology parameter file;
1 if climate generator is used, and temperature radiation files have been generated.

FLGMET Code for designating English/metric units for parameters.

0 if climate and parameter data are in English units;
1 if climate and parameter data are in metric units.

FLGMET represents hydrology and erosion components.

FLGTMP Code to indicate if mean daily temperature is to be read.

0 if mean daily temperature file is not to be read;
1 if mean daily temperature file is to be read.

BCKEND Code to indicate selection of variables for output.

0 if output of selected variable not wanted;
1 if selected output is desired.

FOREST Code to indicate agricultural or forestry site (field).

0 for agricultural field application;
1 for long leaf conifer forest;
2 for short leaf conifer and cedar forest;
3 for mixed pine-hardwood forest;
4 for hardwood forest.

<u>Card 5:</u> **IBACK(I)** for I = 1 to 20.

IBACK() Codes for variables selected from table.

From 1 to 20 variables can be selected from the list of over 200 variables. The list is included in the hydrology parameter editor as a help table. If **BCKEND** = 0 on Card 4, no Cards 5 are needed. If **BCKEND** = 1 on Card 4, two Cards 5 are required even if only one variable is selected.

<u>Card 6:</u> **DAREA, RC, BST, CONA, CN2, CHS, WLW, RD, ELEV, LAT**

DAREA Total drainage area of the field, ac (ha), e. g. 10.7 (4.33)

RC Effective saturated conductivity of the soil horizon immediately below the root zone, in/hr (cm/hr), e. g. 0.20 0.51)

A restricting layer such as a spodic layer, clay pan, or a plow pan may determine the effective root depth. **RC** is the effective saturated conductivity of that restricting layer.

BST Fraction of plant available water in the soil when simulation begins, e. g. 0.50

A full wet condition (field capacity) would have BST = 1.0; for completely dry (wilting point), BST = 0.0.

CONA Soil evaporation parameter, dependent upon soil texture, e. g. 3.75

CN2 SCS curve number for moisture condition II, e. g. 80.0

CHS Hydraulic slope of the field, ft/ft (m/m) 0.022

Use field map and calculate CHS as follows:

$$\mathbf{CHS} = \frac{\text{Maximum difference in field elevation, ft (m)}}{\text{Length of longest flow path in field, ft (m)}}$$

WLW Ratio of field length to field width, e. g. 2.1

Use field map and calculate WLW as follows:

$$\mathbf{WLW} = \frac{(\text{Length of longest flow path in field, ft})^2}{\text{DAREA (ac)} * 43560\ (\text{ft}^2/\text{ac})}$$

or, for metric:

$$\mathbf{WLW} = \frac{(\text{Length of longest flow path in field, m})^2}{\text{DAREA (ha)} * 10000\ (\text{m}^2/\text{ha})}$$

RD Effective rooting depth, in (cm), e. g. 18.0 (45.7)

(Not necessarily the maximum rooting depth of a crop nor the maximum depth to which roots are described in a soil survey. Only one value is input for a simulation even though more than one crop is used in a rotation. Use the maximum effective depth among the crops to be represented. **RD** generally should be determined from soils data except in the case of shallow-rooted vegetable crops, such as radishes, onions, celery, etc.)

ELEV Mean sea level elevation, ft (m), of the field outlet, e. g. 695.00 (211.84)

If **ELEV** is not readily available, leave blank if mean monthly climatic data are input from the internal data base (Cards 18-27).

LAT Latitude, degrees, e. g. 32.27

North latitude designated by positive value, South latitude designated by negative value, -32.27 Latitude of USWB locations included in the data base that includes **LAT**.

Card 7: **ISOIL, NOSOHZ, BOTHOR(I)** for I = 1 to NOSOHZ

ISOIL Code for soil phosphorus sorption.

0 if **FLGNUT** = 0 on Card 4
1 calcareous
2 slightly weathered
3 highly weathered (quartzipsamments, ultic of alfisols, oxisols, ultisols, and acidic ochrepts).

NOSOHZ Number of soil horizons in the rootzone, e. g. 2

Maximum number of soil horizons is 5, used to distinguish different soil characteristics.

BOTHOR() Depth to bottom of each soil horizon, in (cm), e. g., 6.0 and 18.0 (15.0 and 45.0)

The last value must equal **RD** on Card 6. If **NOSOHZ** is 2, and the depths to bottom are 6 in and 18 in, Card 7 should be:

2 6.0 18.0 or in metric: 2 15.0 45.0

Card 8: **POR(I)** for I = 1 to **NOSOHZ** on Card 7

POR() Porosity for each soil horizon, in^3/in^3 (cc/cc), e. g. 0.41

Card 9: **FC(I)** for I = 1 to **NOSOHZ** on Card 7

FC() Field capacity of each soil horizon, in/in (cm/cm), e. g. 0.25

FC represented by water retention at 0.33 or 0.10 bar tension (33 or 10 kPa) depending upon soil type, texture, organic matter, etc.

Card 10: **BR15(I)** for I = 1 to **NOSOHZ** on Card 7

BR15() Wilting point (immobile soil water content) of each soil horizon, in/in (cm/cm), e. g. 0.04 (0.10)

BR15 represented by water retention at 15 bar tension (1500 kPa).

Card 11: **SATK(I)** for I = 1 to **NOSOHZ** on Card 7

SATK() Saturated conductivity in soil horizon I, in/hr (cm/hr), e. g. 0.50 (1.27)

Card 12: **OM(I)** for I = 1 to **NOSOHZ** on Card 7

OM() Organic matter content of each soil horizon (percent of soil mass), e. g. 1.10

Card 13: **CLAY(I)** for I = 1 to **NOSOHZ** on Card 7

CLAY() Percent of soil mass in horizon I with particle size equal to or less than 0.002 mm, e. g. 10.0

Card 14: **SILT(I)** for I = 1 to **NOSOHZ** on Card 7

SILT() Percent of soil mass in horizon I with particle size greater than 0.002 mm and less than 0.05 mm, e. g. 15.0

Card 15: **PH(I)** for I = 1 to **NOSOHZ** on Card 7

PH() Soil pH in horizon I, e. g. 7.0

If **ISOIL** = 0, 1, or 3 on Card 7, skip Card 15. Do not leave a blank line.

Card 16: **BSAT(I)** for I = 1 to **NOSOHZ** on Card 7

BSAT() Base saturation, percent, in horizon I, e. g. 37.2

If **ISOIL** = 0, 1, or 3 on Card 7, skip Card 16. Do not leave a blank line.

Card 17: **CACO3(I)** for I = 1 to **NOSOHZ** on Card 7

CACO3() Calcium carbonate content, %, in soil horizon I, e. g. 4.0

If **ISOIL** = 0, 2, or 3 on Card 7, skip Card 17. Do not leave a blank line.

Cards 18,19: **TEMPX(1-12)**

TEMPX() Mean monthly maximum temperature for each month, EF (EC), e. g. 55.0 61.4 (12.8 16.3)

Ten values on Card 18; 2 on Card 19. Long-term average or year-by-year values can be used--see Card 33 for update information. (Can be obtained from climate database in parameter editor.)

Cards 20,21: **TEMPN(1-12)**

TEMPN() Mean monthly minimum temperature for each month, EF (EC), e. g. 35.0 38.7 (1.7 4.4)

Ten values on Card 20; 2 on Card 21. Long-term average or year-byyear values can be used--see Card 33 for update information. (Can be obtained from climate database in parameter editor.)

Cards 22,23: **RAD(1-12)**

RAD() Mean monthly solar radiation for each month, Langleys (MJ/cm^2), e. g. 250.0

Ten values on Card 22; 2 on Card 23. Long-term average or year-byyear values can be used--see Card 33 for update information. (Can be obtained from climate database in parameter editor.)

Cards 24,25: **WIND(1-12)**

WIND() Mean monthly wind movement for each month, miles/day (km/day), e. g. 125.0 140.0 (201.2 225.3)

Ten values on Card 24; 2 on Card 25. Long-term average or year-byyear values can be used--see Card 33 for update information. (Can be obtained from climate database in parameter editor.)

Cards 26,27: **DEWPT(1-12)**

DEWPT() Mean monthly dew point temperature for each month, EF (EC), e. g. 37.0 45.0 (2.8 7.2)

Ten values on Card 26; 2 on Card 27. Long-term average or year-byyear values can be used--see Card 33 for update information. (Can be obtained from climate database in parameter editor.)

Card 28: **HBYR, HEYR, IROT**

HBYR Beginning year of hydrology simulation, used to set rotation for reuse of parameters, two digits, e. g. 69

HEYR Ending year of hydrology simulation, used to set rotation feature, two digits, e. g. 76

IROT Number of years in the rotation cycle, e. g. 2

If a 10-year period of observed data are to be simulated for a continuous crop with different planting and harvest dates each year, **IROT** = 10. For that same 10-year period for simulation of continuous crop with the same planting and harvest dates each year, **IROT** = 1.

Card 29: **ICROP, DPLANT, DHRVST, DTRUN, CCRD, CRPHTX, PERNNL, BEGGRO, ENDGRO**

ICROP Crop identification code corresponding to the ID number in Table N-2, e. g. 17

Leaf area index data are stored in the model data base for 78 crops. If the desired crop is not included in Table N-2, or different values are desired, use other numbers from 79 to 90. For those crops, the user must enter LAI data, and all the crop-specific data in the nutrient component.

DPLANT Date of planting crop **ICROP**, year of the rotation cycle plus the Julian day of the year, e. g. 1120

DHRVST Date of harvesting crop **ICROP**, year of the rotation cycle plus the Julian day of the year, e. g. 1274

DTRUNC Date of truncation of crop **ICROP**, year of the rotation cycle plus the Julian day of the year, e. g. 1200

DTRUNC is an intermediate date between **DPLANT** and **DHRVST** when a crop such as winter cover, green manure crop, or corn silage plowed down or cut before **DHRVST**.

CCRD Current crop (**ICROP**) rooting depth, in (cm), e. g. 12.0 (30.0) Leave blank if **CCRD** = **RD** (See Table N-2)

CRPHTX Maximum height of **ICROP**, ft (m), e. g. 3.00 (0.91)
Leave blank if **ICROP** < 79

PERNNL Code to designate perennial crops. Leave blank if **ICROP** < 79

0 for annual (non-perennial) crop
1 for perennial crop

BEGGRO Julian day for beginning of growth for hardwood or pine-hardwood mixture, or perennial agricultural crop such as grass, e.g. 120

ENDGRO Julian day for end of growth of perennial agricultural crops and for hardwood or pine-hardwood mixture, e.g. 290

Card 30: **IROPT, DBIRR, DEIRR, DPREIR, PREIRR, BASEI, TOPI**

IROPT Code for model to consider irrigation date and amount.

0 if irrigation is not to be applied by the model;
1 if irrigation is to be applied on demand by the model.

If an observed record is being used to compare model simulation, and irrigation was applied, the equivalent depth in inches (cm) must be entered on the appropriate date in the rainfall file and 0 coded for **IROPT**.

DBIRR Date model is to begin considering soil moisture for automatic irrigation if **IROPT** = 1, year of rotation cycle and Julian day, e. g. 1130

If a crop is grown in the rotation that is not irrigated, such as a rye winter-cover crop, leave **DBIRR** blank.

DEIRR Date model is to quit considering automatic irrigation such as 75 days before corn harvest, year of rotation cycle and Julian day, e. g. 1200

If a crop is not irrigated automatically, leave **DEIRR** blank.

DPREIR Date preplanting irrigation is to be applied to leach salt from the root zone, year of rotation cycle and Julian day, e. g. 1095

PREIRR Equivalent depth of preplanting irrigation to be applied, in (cm), e. g. 6.0 (15.0)

BASEI Fraction of plant available water content in the root-zone when the model is to apply irrigation, e. g. 0.25

Leave blank if **IROPT** = 0

TOPI Fraction of plant available water content in the root-zone desired after irrigation, e. g. 0.85

Leave blank if IROPT = 0

Cards 29 and 30 are required for each crop in a rotation, including weeds if they are significant in nutrient uptake and produce a biomass that contains N & P in residue for nutrient cycling. A Card 29 with **ICROP** = 0 (no crop) signals the end of the crop cards, and this value is defaulted when the parameter editor is executed. To enter **ICROP** cards, use the F2 key to add cards 29 and 30. Then the help table will be available with F1 for **ICROP**. Each additional set of cards 29 and 30 must be initiated the same way by use of the F2 key to add a card (See bottom bar of the parameter editor.)

Card 31: **ICROP, NOLAI**

ICROP Crop identification code corresponding that on Card 29, not in the data base and greater than 78, for which the user must enter leaf area index (LAI) data, e. g. 79

NOLAI The number of data points to be entered on Card 32 to describe the LAI between **DPLANT** and **DHRVST**, e. g. 7

Card 32: **USRFRC, USRLAI, CROPHT**

USRFRC Fraction of the growing season, specified by the user, for which LAI is specified, e. g. 0.10

The first **USRFRC** value for a crop should be 0.0, and the last value should be 1.0.

USRLAI User-specified LAI at the fraction of the growing season specified, e. g. 0.25

CROPHT Crop height, ft (m), e. g. 0.50 (0.15)

This is an optional input that the user may specify the crop height during the growing season from observed data rather than have the model to "grow" the crop to **CRPHTX** input on card 29. Leave blank if the model is to grow the crop.

As many Cards 32 must be used as **NOLAI** on Card 31. LAI data input is not required for **ICROP** = 1, 78. The LAI data in the data base will be used. The model checks the **ICROP** codes on the Cards 26 to see which ones and how many are not included in the data base list of 78.

<u>Card 33:</u> **NEWT, NEWR, NEWW, NEWD**

NEWT Code for reading new mean monthly maximum and mean monthly minimum temperature data the the next year.

0 Do not read new temperature data;
1 Read new monthly temperature data, Cards 18, 19, and Cards 20, 21;
-1 Stops the program--ends simulation.

NEWR Code for reading new mean monthly radiation data

0 Do not read new radiation data;
1 Read new monthly radiation data, Cards 22, 23.

NEWW Code for reading new mean monthly wind movement data

0 Do not read new wind movement data;
1 Read new monthly wind movement data, Cards 24, 25.

NEWD Code for reading new mean monthly dew point temperature data

0 Do not read new dew point temperature data;
1 Read new monthly dew point temperature data, Cards 26, 27.

A Card 33 is needed for each year of simulation. The last card in the hydrology parameter file is Card 33 with **NEWT** = -1

There must be as many Cards 33 as years of simulation (**HEYR** - **HBYR** + 1), including the one with **NEWT** = -1 (The hydrology parameter editor <HYD.EXE> takes care of this automatically.)

HYDROLOGY PARAMETER DESCRIPTION

The hydrology component has been changed significantly to (1) consider crop rotations without repeating leaf area index each year, (2) include a data base of leaf area index for major crops, (3) input saturated conductivity by soil genetic horizon, and (4) input soils data used in the nutrient component. The model irrigation option has been enhanced to allow preplant irrigation for leaching of salts and seedbed preparation. These features make the model more comprehensive as well as better user oriented.

Parameters have not been adequately defined previously, and this section provides descriptions that should be helpful to users who may not have a hydrology background.

Model Options

Beginning Date of Simulation--HBDATE

The beginning date of simulation allows the user to consider full year simulations or a partial year corresponding to some period of observed record for model comparison. HBDATE should be one day before the first day of rainfall in order for the model to initialize soil water content before the rainfall event. For long-term simulation, it may not be known in advance if rain occurred on January 1. In order to consider it, HBDATE should be set one day before, i. e. 64000 even though such a date does not exist, or 63365. If the last day of the previous year is used, a full year of monthly values of zeros will be generated, and that year will be considered as one of the total number of years. Thus, it is better to use the 000 Julian day for HBDATE. If the precipitation data begins on day 139 of 1973, for example, HBDATE should be 73138 to allow initialization.

Hydrology Output Options

The model user can select the desired level of output, either monthly and annual summary tables of the water balance components, or storm output, by appropriate coding of HYDOUT. The storm output also includes the monthly and annual summaries. The storm output includes, on each day of rainfall, snowmelt, or irrigation, the amount of rainfall, snowmelt, or irrigation, runoff, and percolation amount and the number of days on which it occurred since the last storm. Average soil water in the root zone and average air temperature since the last storm are also given. Actual and potential soil evaporation, plant transpiration, and total evapotranspiration are given. Depth of chemigation water is included as well as irrigation.

Model Component Options--FLGNUT, FLGPST, FLGGEN, FLGPEN

Users can specify whether or not they want to simulate plant nutrients and pesticides. Both can be simulated simultaneously, either, or neither, simulated by setting the appropriate value for the flags.

A climate generator, such as CLIGEN (Richardson and Nicks, 1990), can be used to generate precipitation, temperature, and radiation data instead of using long-term observed climate. The climate generator is not run as a part of **GLEAMS**, but external generation of the climatic data determines if monthly temperature and radiation data are input and fitted for daily interpolation.

An option has been added in **GLEAMS** for simulating potential evapotranspiration. Model users can select between the Priestly-Taylor or Penman-Monteith (Jensen et al., 1990) methods by coding FLGPEN 0 or 1, respectively. The Penman-Monteith method requires additional data input described below (mean sea level elevation, and mean monthly wind movement and dewpoint temperature).

FLGMET

In countries other than the United States, precipitation is generally measured in metric units. The user can select English or metric input to fit the individual needs. Since most professional journals use SI (System International) units, users may prefer to use metric input to **GLEAMS**. It should be pointed out that use of metric units in the parameter file requires that precipitation data be metric, also. FLGMET is coded 0 for English units, or 1 for metrication.

FLGTMP

It has been shown that use of long-term mean monthly maximum and minimum temperature results in equally good simulation results in climatic regions not concerned with snow and frozen soil (Knisel et al., 1991; Nutter et al., 1993). Mean daily temperature is used to determine if precipitation occurs as rain or snow. Fitting mean monthly temperature data does not allow mid-winter warming that may occur in cold climatic regions. The use of observed mean daily temperature data as input results in improved estimates of runoff and percolation. FLGTMP allows the user to input mean daily temperature data.

Designation of Special Output File--BCKEND

The user can select output to be written in a special file for later appli- cation in statistical analyses or for external graphical presentation. The file contains only those selected variables without blank lines, without headings and units, and without other data. Code numbers designated for specific variables are shown in the file for identification. This output, independent of the normally printed file (such as designated in HYDOUT) may contain up to 20 daily, monthly, or annual variables from each of the four model components. BCKEND is a code for the user to designate the selection of the special output.

GLEAMS Forest Option--FOREST

GLEAMS version 1.8.55 was modified to include an option for application on forested areas. The modifications (Nutter et al., 1993) include rainfall interception as a function of forest type and leaf area index. Dates of beginning and ending growth of deciduous trees is needed to differentiate from a non-transpiring leaf area index representing tree trunks and branches intercepting rainfall. FOREST is a code to distinguish among agricultural, long leaf conifers, short leaf conifer, and hardwood or mixed pine-hardwood forest applications. The codes, which provide the appropriate conditional paths within the model, are:

0 agricultural field;
1 long leaf conifer forest;
2 short leaf conifer and cedar forest;
3 hardwood or mixed pine-hardwood forest.

Selected Variable Output--IBACK

Up to 20 variables can be selected by the user from more than 200 available for special output. These include daily, monthly, and annual values as well as seven soil-related constants needed in making some external computations and interpretations of results. The list of variables and their respective codes are given in the hydrology parameter editor help table, and are shown here in Table H-1. They are separated into daily, monthly, annual, and constant categories. It should be pointed out that daily data for a 50-year simulation, such as pesticide concentration by soil computational layer for 10 pesticides generates an extremely large file. Such output could easily take 5MB storage with 12 computational soil layers. This must be kept in mind when selecting special output for analysis.

As shown in Table H-1, groups of codes are given for pesticides since a maximum of 10 pesticides can be simulated simultaneously. For example, codes 601-610 are shown for daily pesticide runoff losses. If 10 pesticides are represented in a simulation run, 601 would represent daily runoff for pesticide 1, 602 would represent pesticide 2, and etc. Runoff losses may not be significant for all pesticides simulated, or leaching losses may not be important for all compounds. For example, if a simulation included aldicarb (Timek) which is very mobile and is incorporated in the soil, runoff and sediment losses are negligible and would not be included in the selected output. Likewise, leaching of paraquat is zero for all practical purposes, and would not be included in the selected variable output. However, concentrations of both these pesticides in each soil computational layer may be important.

One exception to the group of codes representing the successive pesticide code numbers are the groups 3401-3410, and 3411-3420, the codes for annual maximum concentrations. The last two digits, i. e. 01-10 and 11-20, indicate the number of days for which the maximum concentrations are desired. For example, code 3404 will result in the annual maximum 4-day concentration of all pesticides in the simulation. The data will include concentration in runoff, concentration of runoff plus sediment expressed as concentration in the runoff volume, and concentration in percolation. The dates of occurrence of these annual maximums are also ouput. Runoff, runoff+sediment, and percolation losses may all occur on different dates. Code 3414 results in the same 4-day concentrations except that the 4-day count begins the first day with pesticide runoff. Both selections can be included in a single GLEAMS simulation, but if they are, the same n-days must be used for both codes. For example, if 3404 is selected, then 3414 would be the appropriate companion IBACK code. You cannot select 3406 and 3414, for example.

When model simulation results are to be compared with observed field data, soil sample layers very seldom, if ever, correspond to model computational layers. Pesticide concentrations by layer are needed along with the layer thicknesses and soil mass to calculate weighted concentrations for a layer corresponding to the sample data. These weightings can be made with an auxiliary program to operate with the selected output file.

Initial Parameters

Drainage Area--DACRE

The drainage are of the field is the area of a selected natural drainage pattern, and may not coincide with the four fences of a farmer's field. It is determined from a topographic map to depict the delivery of water, sediment, and chemicals to an outlet (culvert, drainage ditch, etc). It is considered representative of the larger field, and management practices such as cropping system, tillage, fertilizer application, or irrigation practice.

Saturated Conductivity--RC and SATK

Previous versions of GLEAMS used a single value of saturated conductivity to represent the root zone. That value, designated RC, represented the most restrictive soil horizon, and may have represented a horizon immediately below the root zone that determined the effective root depth, RD as described below. This version (2.10) allows input for each genetic soil horizon, designated SATK, and input with soil physical properties. In many soils, a restricting layer such as clay pan, argillic layer, or spodic layer may determine the effective rooting depth and control the drainage from above. Earlier model versions used this restricted conductivity throughout the root zone. Herein the input parameter RC is retained, but it only represents the saturated conductivity of the horizon immediately below the root zone. The model compares the value of RC with the last value of SATK entered for the lowest horizon, and uses the relative values to estimate approximate values of porosity and 33 kPa water content.

RC and SATK are not used to calculate percolation volume. However, if the values are very low, generally less than 0.13 cm/h (0.05 in/h), drainage may be restricted for large percolation volumes. For example, field capacity is defined as the water that can be retained in the soil after 24 hours of drainage following saturation. GLEAMS assumes that unrestricted drainage allows excess water to drain in one day. If RC = 0.13 cm/h, 3.12 cm (1.23 in) of water can drain in 24 hours. If rainfall or irrigation is in excess of field capacity by more than that amount, the time required for drainage is greater than 24 hours. When this occurs, the model limits the drainage out of the computational layer and simulates a high water table within the root zone. If the rainfall exceeds the drainable porosity of the layer (porosity minus field capacity), then the free water extends into the layer above. Evapotranspiration increases during the days with excess storage. This is the only time that RC and SATK affect the volume of percolation out of the root zone. Likewise, this is the only time that RC or SATK are sensitive parameters.

If site-specific or pedon data are not available, the soil profile description in the soils-5 data can be used to estimate RC. Data in Table H-2 were taken from USDA-SCS (1984) as representative ranges of saturated conductivity for each hydrologic soil group. If a hydrologic soil group A soil overlies a clay layer, and pedon data are not available, SATK and RC can be estimated. SATK might be estimated as 15 cm/h (6 in/h), or 1.27 cm/h from Table H-2, and RC for the clay layer may be estimated as that for a hydrologic soil group D, i. e. 0.13 cm/h (0.05 in/h). The soil horizon descriptions can be used to estimate intermediate values of SATK.

It must be remembered that model output is no better than the input data. This should be kept in mind in making relative comparisons between simulated management alternatives when parameter estimates are made.

Initial Soil Water Content--BST

An initial estimate of soil water content must be made at the beginning of simulation. This simply establishes some level of soil water to begin the accounting procedure. If BST is over-estimated, runoff will generally be over-estimated resulting in an under-estimate of infiltration. This will continue until the simulated soil water approaches the actual. The opposite is also true: an under-estimate of BST results in an under-estimate of runoff and an over-estimate of soil water, eventually coming together as before. The length of time for the estimated soil water to approach the actual value varies with total rainfall and rainfall distribution. If a rainy season begins near the end of the year as is the case in the humid southeastern U. S., soil water may be largely recharged (at or near field capacity) when simulation begins on January 1. At the opposite end of the scale, an extended dry period may result in soil water content near wilting point on January 1 as might be the case in west Texas and New Mexico.

BST is not a sensitive parameter except if a major rainfall event of interest occurs soon after the beginning of simulation. There is little sensitivity in long-term simulations.

Evaporation Constant--CONA

CONA is a soil evaporation constant dependent upon the water transmission characteristics (Ritchie, 1978). Since water transmission is a function of soil texture, among other factors, the parameter is listed in Table H-3 along with other average or representative characteristics. CONA is not a sensitive parameter in the water balance computations.

Soil Conservation Service Curve Number--CN2

Williams and LaSeur (1976) modified the USDA-SCS (1972) curve number procedure for estimating surface runoff from daily rainfall. Although the modified procedure does not calculate a curve number (CN) for each day of rainfall, it uses CN to estimate maximum available storage in the water accounting procedure. The modified procedure is basis for the hydrology component of GLEAMS. The CN for moisture condition II is an input parameter, CN2.

CN2 is a function of land use, management, and hydrologic condition, and averages have been tabulated (USDA-SCS, 1972) by hydrologic soil group. All soils mapped in the United States are assigned to one of the groups. The groups are defined as follows:

A. (Low runoff potential.) Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. (High runoff potential.) Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. The soils have a very slow rate of water transmission.

Model users outside the U. S. can use the above information to aid in estimating the hydrologic soil group to obtain CN2. It is obvious from the descriptions above that soil texture alone cannot be used to designate soil groups, i. e. group D. However, if hydrologic data are not available, a first estimate can be make with the data in Table H-3. For example, without further data on water table and impervious layers, the first 5 textural classes (through loamy coarse sand) could be in group A. Group B could include the next 6 classes through fine sandy loam. The next 5, through sandy clay loam, would represent group C, and the last 5 textural classes would be in group D. The texture classes in Table H-3 represent individual soil horizons, whereas a soil categorized into a hydrologic soil group is comprised of more than one horizon. The attempt here to group soils by texture in Table H-3 assumes the textural classification is the surface horizon, and that a "normal" soil profile exists. Any complexities would obviously change the group estimate. For example, a coarse sandy surface horizon with low runoff potential would initially be in group A. If that horizon overlies a relatively shallow clay layer, the restricted drainage may result in a temporarily perched water table. This could result in a higher runoff potential during rainy seasons, and it may be assigned to group C in an undrained condition. This is very common in coastal plain and flatwood physiographic areas. One management alternative is a drainage system (tile or open ditch) that would result in a much lower CN2. The same soil occurring where there is good lateral subsurface flow without a perched water table would be in hydrologic soil group A.

There is a dilemma among users of the curve number procedure in the U. S. where soils are grouped by series name. For example, a Cecil soil in the Piedmont physiographic area is in hydrologic soil group B. The SCS engineering handbook (USDA-SCS, 1972) gives a curve number of 78 for row crops with straight rows in good hydrologic condition for group B soils. It does not distinguish between a Cecil sandy loam and a Cecil clay loam, which certainly have different runoff potential. There may be more difference within a soil series than between soil series.

In an attempt to give the user an objective method of estimating CN2, an expanded table of curve numbers are shown in Table H-4. The approximate midpoint between curve numbers given for each soil group by USDA-SCS (1972) was used to extrapolate values for each group as shown in Table H-4. This allows the user to distinguish between similar soils such as for the Cecil given above. For example, CN2 for Cecil sandy loam using row crops with straight rows in good hydrologic condition could be 78, and 82 for Cecil clay loam. Adjustments like this certainly should give better relative results than using 78 for both soils.

A single value of CN2 is input for **GLEAMS** simulations even though row crops and small grain may be used in a crop rotation to be evaluated. For example, a common management system in the Georgia Coastal Plain is a rye winter cover planted in the fall and disked in the spring prior to planting corn. If rye is planted following harvesting peanuts and baling the peanut hay, little cover will be on the soil and it may be in poor hydrologic condition. Using the mid value of CN2 for hydrologic soil group B with small grain on the contour, a value of 74 would be selected. For corn on the contour in poor hydrologic condition, the mid value would be 79. What value should be used: low? high? average? Since the input value of CN2 is used only to estimate the maximum available soil water storage (Smith and Williams, 1980), the lowest value (74) should be used. The soil water accounting procedure estimates the available storage daily, and thus estimates the storage available for retention when rainfall occurs.

CN2 is a sensitive parameter in the simulation of runoff volume in **GLEAMS**. The higher the value of CN2, the more sensitive it is because maximum available storage is relatively small. A change of curve number from 89 to 90 has a much larger percentage affect than changing from 69 to 70. S_{mx}, the maximum value of storage used as a multiplication factor in estimating a depth-weighted retention parameter (Smith and Williams, 1980), for CN2 = 89 is 3.02, and for CN2 = 90, S_{mx} = 2.74, which is a 9.27% reduction. For CN2 = 69, S_{mx} is 10.36, and for CN2 = 70, S_{mx} = 9.90, which is only a 4.40% reduction. Therefore, runoff estimates for small changes in high curve numbers are more sensitive than equivalent small changes in low curve numbers.

Since the curve number is a sensitive parameter, the model user should exercise care and objectivity when selecting values for alternative management systems. Documentation of selection might be justified if one user supplies parameter sets to another, or works infrequently on model applications.

Hydraulic Slope--CHS

The hydraulic slope of a field is defined as the slope of the longest flow path. The longest flow path is the flow line from the most remote point on the field (drainage) boundary to the outlet of the field. This length and difference in elevation from the most remote point to the outlet are the same as those used in estimating a time of concentration of a drainage area. Then CHS is

$$CHS = \frac{ELEV_{mx} - ELEV_{mn}}{LFP} \qquad \textbf{[1]}$$

where $ELEV_{mx}$ is maximum elevation of the drainage, m (ft), $ELEV_{mn}$ is the minimum elevation (elevation of the field outlet), m (ft), and LFP is the length of the longest flow path, m (ft).

The hydraulic slope is used in an empirical relation to estimate the peak flow rate for daily runoff. It is not used to estimate runoff volume, and therefore is not a sensitive parameter in runoff computations, but it is sensitive in sediment transport. The peak rate is used in the erosion component for calculating the characteristic discharge rate, sediment transport capacity, and shear stress in a concentrated flow. The length of flow path may increase significantly for a terraced field as compared with the same field without terraces.

Watershed Length Width Ratio--WLW

The ratio of the watershed, or field, length to the width is a relative measure of the elongation, and it is used in the empirical relationship to estimate peak rate of daily runoff. Like the hydraulic slope, it is not used in estimating runoff volume, but the peak rate is used in the erosion component. As WLW increases, the peak rate of runoff decreases, i. e. runoff is attenuated and the runoff peak occurs later in the runoff period. This may be demonstrated when considering a terraced field compared with the same field that is not terraced. The hydraulic flow path may be considerably longer for a terraced field than for the same field without terraces.

WLW is calculated by using the length of the longest flow path (described above for parameter CHS) and the total drainage area as

$$WLW = \frac{(LFP)^2}{DAREA * 10000} \qquad [2]$$

where DAREA is drainage area, ha, and LFP is length of longest flow path, m. The English equivalent is

$$WLW = \frac{(LFP)^2}{DAREA * 43560} \qquad [3]$$

where LFP is in ft, and DAREA is in acres.

An example of extreme WLW and its associated effect is an application of CREAMS (Knisel, 1980) for a land-formed field in the Mississippi delta area. A ridge-furrow tillage system was used to provide a drained seed drill. The side of the ridge represented the overland flow path, and the furrow represented a channel. The 0.91 m (36 in) row spacing and 426.5 m (1,300 ft) row length gives a drainage area of 0.039 ha (0.096 ac). WLW for the representation is approximately 470. With a slope of 0.004 m/m (0.4%), it is easily seen that a very low attenuated peak rate of runoff will result in little capacity for sediment transport other than the clay and organic matter fractions. WLW is not a sensitive parameter in hydrology, but it is sensitive in the erosion component.

Effective Rooting Depth--RD

Determination of the effective rooting depth for GLEAMS simulations is a function of crop and/or soil. It is not necessarily the maximum rooting depth of the crop unless a restricting layer exists in the soil profile. The effective root depth was defined in CREAMS as that which gives the best estimate of surface runoff. For example, the Houston black clay soil in Texas has about 1.64 m of heavy montmorillonitic clay over a marl or chalk aquiclude. There is evidence of cotton roots extending to the marl in soil pits. However, the best correlation between runoff and rainfall as a function of antecedent soil water occurs with a soil depth of 0.91 m (36 in). Obviously the cotton crop extracts some water from the entire 1.64 m (5 ft) to sustain the crop (not sufficient for crop growth) when there is a prolonged water deficit. Most of the crop roots, and water and nutrient uptake, occur in the plow layer, but this is not the optimum soil water reservoir for runoff estimation.

Alfalfa grown on Gila adobe clay in the Rio Grande River alluvium may extend to a depth of 2 m where a very dense clay layer was deposited by the ancient river. The effective root depth certainly would not be 2 m, but more nearly 1 m even though the absolute, or maximum, root depth is 2 m. There is little water uptake from the 1-2 m depth except to sustain the crop during prolonged dry periods. There certainly would not be optimum forage production.

Another extreme might be a Mexico soil in Missouri with about 0.25-0.35 m of silt loam overlying a claypan. Corn or soybeans, which may root to 1-1.25 m under "normal" conditions, would have an RD of 0.25 or 0.35 m for the claypan condition.

The effective root depth for citrus trees in Florida may be about 0.5 m due to root pruning by fluctuating high water table conditions (personal communication with Dr. Herman Reitz, University of Florida, IFAS, Lake Alfred, 1972). Trees are generally thought to have deep root systems, and certainly the citrus trees do root much deeper than 0.5 m. When the water table is low, the trees are sustained by soil water to a depth of 1-1½ m. However, the only time that runoff occurs on those sandy soils is when the water table near the soil surface during the rainy season.

Soil descriptions in pedon data such as in the Soil Survey Investigations Reports published by the USDA-SCS for each state, county soil surveys, or Soils-5 data can be used to help estimate RD. Generally in the profile descriptions of the horizons, there is some indication of root characteristics: many common roots; common roots; many fine roots; or few fine roots. These can be used as indicators. For example, one may see "many common roots" in the surface horizon, "common roots" in the second horizon, and "few fine root" in the third genetic soil horizon. This would be a good indication that the effective root depth would be the depth at the bottom of the second horizon. Root descriptions are not always given in soil profile descriptions.

Another indicator in the profile description might be a dense clay layer as mentioned above. Also, soil pH by horizon may be an indicator, but care must be exercised in this regard because the plow layer of a well managed soil may have a pH of 6.8 with the second and successive horizons with a pH of 5.0 or less. All of these factors must be considered in total context.

A single value of RD is used throughout a simulation period. Some manage-ment practices, such as deep chiseling, may result in a different effective root depth. Different management practices that include different tillage must be represented by separate simulations. For example, if a soil is prone to develop- ment of a plowpan, such as the Niger silt loam in Louisiana, the common tillage practice results in an RD = 0.25 m. An alternate practice of chiseling to depth of 0.4 m every 3 or 4 years may result in an RD = 0.5 or 0.6 m.

The effect of increasing the root depth in a GLEAMS simulation is a greater potential soil water storage and, without irrigation, higher evapotranspiration. Simulated runoff will be greater for shallow root depths.

Estimation of effective root depths must consider potential percolation (be- low the root depth) as well as surface runoff. The correct proportioning of rainfall and irrigation into runoff, soil water, and percolation is necessary to adequately represent pesticide and plant nutrient fate. With the same soil water retention characteristics, the shallow root depth will result in both increased runoff and percolation. A large root depth will result in less runoff and less percolation, depending upon rainfall amount and distribution.

Some consideration must be given to the water quality problem when selecting RD. If surface runoff and surface delivery of chemicals are the principal problem, them RD should be selected to give the best estimate of runoff. If groundwater quality, particularly shallow groundwater, is the problem, then RD should be estimated to give the best estimate of percolation. Unfortunately, percolation is generally never measured except as tile outflow, interceptor drain outflow, or lysimeter percolate. Some compromise is estimating RD is oftentimes required--not to deep to give the best estimate of runoff, and not too shallow to give the best estimate of percolation. This generally requires several model simulation runs for "fine tuning". It should be remembered in making interpretations of model results that percolation leaving the bottom of the effective root depth is not necessarily what enters groundwater.

From these comments, it is obvious that RD is a sensitive parameter in hydrology as well as in plant nutrients and pesticides. It should be stressed that consistency and objectivity are important in parameter estimation. RD should be the same for alternative management practices except for those which are designed to specifically increase rooting depth such as chiseling or tile drainage.

Mean Sea Level Elevation and Latitude--ELEV, LAT

The Penman-Monteith (Jensen et al., 1990) method of estimating potential evapotranspiration uses elevation and declination angle of the sun to calculate some forms of radiation. Mean sea level elevation of the field, field outlet, or the nearest climatic station can be input for ELEV. If topographic maps available for the field of interest is not referenced to the mean sea level (msl) elevation, do not use the "assumed" benchmark elevation, generally assumed to be 100.0 ft (30.48 m). ELEV is used to estimate local atmospheric pressure, and the local surveyor's assumed reference may entirely unsatisfactory. If local data are not available, the data base accessed in **HYD.EXE** contains ELEV of the USWB station as well as the latitude (LAT) of the station. ELEV and LAT are used only if the Penman-Monteith method of estimating potential ET is selected (FLGPEN = 1, Card 4).

Soil Classification and Characteristics--Horizon Description

A soil classification is needed to enable the proper calculation of phos- phorus adsorption. Sorption relations of soils are grouped into (1) calcareous soils, (2) slightly weathered soils, and (3) highly weathered soils. The highly weathered group include oxisols, ultisols, quartzipsamments, the ultic subgroup of alfisols, and acidic ochrepts. The three soil designations are coded as parameter ISOIL to allow the model to read the proper soil chemical characteristics, i. e. calcium carbonate content for calcareous soils, and pH and base saturation for slightly weathered soils.

Soil physical and chemical data are input into **GLEAMS** by soil genetic horizon, and the model distributes the respective data into the computational soil layers. Generally there are significant differences in some characteristics from one horizon to the next. Differences in organic matter occur in depth due to rooting characteristics of plants. As discussed above under effective root depth, most root development occurs in the plow layer resulting in higher organic matter than in lower horizons. Aggregation of soil particles and water retention and transmission characteristics are functions of organic matter.

After examining a large number of soil pedon descriptions, five horizons were considered adequate to represent the relatively wide range of profiles. This was set as the upper limit of horizons for data input into the model. Five horizons are not required, but the user must decide upon the best representation. Some profiles may have 6 or 7 horizons described in the depth selected as the effective root depth. In those situations, the user must decide which horizons to combine--those with the least significant differences. For example, in a forest application on a Pomona fine sand in Florida, there are 6 horizons described above an argillic layer that restricts root development and water transmission. The profile includes two thin zones of elutriation (E horizons) that are practically pure sand with very similar low water retention and transmission characteristics. These two E horizons were combined for model input.

The depth from the soil surface to the bottom of each soil horizon, BOTHOR, is needed to define the profile physical dimensions. The number of horizons and their thickness enable the model to set the computational layers within the horizons.

The number of soil horizons specified in the hydrology parameter file are also used to control input of pesticide and plant nutrient data. If the number of soil horizons, NOSOHZ, is set at three in hydrology, then three must be used in the pesticide and nutrient components. Since the parameter files are separate and independent, it is possible for the user to specify nutrient input for 4 horizons. However, nutrient data for the 4th horizon will not be read. Likewise, if NOSOHZ is set at 3 in hydrology, and if nutrient or pesticide data are entered for only two horizons, zeros will be read for the 3rd horizon in nutrients or pesticides, and the model will bomb. The hydrology parameter editor, HYD.EXE, uses NOSOHZ to automatically set the number of input fields for soil characteristics. This control cannot be achieved between parameter files.

Soil Physical Properties--POR, FC, WP, OM, CLAY, SILT

Soil physical properties for model input should be for the specific field of interest except when making generalized model applications. As discussed above, soil characteristics vary considerably within a series, even within the same field. Data are entered for one soil profile only, and therefore the best estimate is needed to represent the entire field. Researchers generally sample several locations within research plots or watersheds, and weighted properties can be determined for model application. This intensity of data are not normally available, and published values such as SSIR pedon data (USDA-SCS, 1967), county soil surveys (Calhoun, 1983), or soils-5 data. If these or other data are not available, the user must make estimates from such information as those by tex- tural classification in Table H-3. Special publication of data may be available at many of the land-grant universities, such as that of Perkins (1987). Data may not be as readily available in countries other than the United States, and esti- mates from Table H-3 may be useful.

Soil porosity, POR, is the volumetric ratio of total pore space (voids) per unit volume of soil, cm^3/cm^3. The value represents the maximum amount of water that a unit volume of soil can hold without any drainage, i. e. at 100% satura- tion. POR may not be specified as such in data publications, and the user must make some simple calculations. For example, bulk density may be given instead of porosity, and bulk density is the opposite of porosity--the weight of soil particles per unit volume, g/cm^3. Porosity is estimated from bulk density, BD, by assuming the specific gravity of soil particles is 2.65 g/cm^3. The relationship is

$$POR = 1 - \left(\frac{BD}{2.65}\right) \qquad \textbf{[4]}$$

Porosity of most mineral soils generally range from about 0.30 to 0.60 cm^3/cm^3, but values as high as 0.70 cm^3/cm^3 have been observed for some forest soils.

If water content at saturation is given, that value expressed volumetrically can be used for porosity. It is determined as the volume of water that can be drained from a unit volume of saturated soil.

The agronomic definition of field capacity (FC) is used in **GLEAMS**, i. e. the volumetric water content after 24 hours of drainage. It is approximated by the water content at 10 or 33 kPa matric potential for clay and other texture soils, respectively. Similarly, the wilting point (BR15) is defined as the volumetric water content at 1,500 kPa matric potential. If complete pedon data are not available, soils-5 or county soil survey data can be used, but those data give ranges of plant available water for each horizon instead of field capacity and wilting point. The volume of water at wilting is needed since that water con- tains pesticides and nutrients that reacts with each chemical pulse. Heavy texture soils and those with high organic matter content may contain significant amounts of un-usable chemical "sponges". BR15 can be estimated for the appro- priate textural class from Table H-3. Then the volumetric plant available water content can be added to BR15 to estimate FC. Water retention is a function of soil texture and organic matter, and organic matter is a function of management to some degree. For example, the Tifton soil series ranges in texture from loamy sand to sandy loam, and the plant available water may be given as 0.14-0.19 cm/cm (in/in) for the Ap horizon. This range can be interpreted as 0.14 cm/cm for a loamy sand and 0.19 cm/cm for a sandy loam, or 0.14 cm/cm for poorly managed soil and 0.19 for a well managed soil. These guides can be used to select low, inter- mediate, or high values within a series. Likewise, the data in Table H-3 should be considered as mere guides, not necessarily absolute values. Users are cautioned, however, about using this guideline to represent differences between management alternatives. A rule of thumb is that when a new management system is imposed, it requires about three rotation cycles for the field and production system to equilibrate to the new level of management. This is particularly true for those practices that might affect organic matter content of the soil.

Some soils data give gravimetric water content (percent by weight) at 33 pKa and 1,500 kPa instead of volumetric content. In order to convert from gravimetric to volumetric, it must be multiplied by the bulk density. For example, a gravimetric water content at field capacity may be 32%, and the bulk density 1.25 g/cm^3. Then volumetric water content is 0.32 x 1.25 or 0.40 cm/cm. Again, users are cautioned to check units when obtaining data.

POR and FC are sensitive parameters in the water balance computations in **GLEAMS**. They should be estimated with care since they affect runoff, percolation, evaporation, and plant transpiration. These four components are sensitive in pesticide and nutrient fate, and runoff is a sensitive input in erosion for sediment yield, which in turn is sensitive in chemical transport.

As indicated above, organic matter content of the soil is soil, climate, and management dependent. Quartzipsamments, i. e. very sandy soils with little water retention capacity, are low in OM no matter what climatic region. Such soil in Florida, Georgia, New York, Nebraska, Minnesota, or Texas all have about 1-1½% OM in the Ap horizon, and no management practice will result in much increase. Organic matter content in soils-5 and county soil surveys are given as ranges for plant available soil water. The same general guidelines are applicable here as well. Pedon data generally give organic carbon instead of organic matter. **GLEAMS** requires OM input even though it is converted to organic carbon internally. If organic carbon is given, it can be converted to OM by multiplying by 1.724 g OM/g OC, which is approximate and says that all OM (corn stalk or wheat straw residue, soil organic matter, etc) has the same composition.

Organic matter is not sensitive in hydrology except indirectly as it affects water retention. It is sensitive in erosion since it affects soil particle aggregation and sediment transport as well as sediment enrichment ratio. OM is sensitive in pesticide adsorption and, extending from sediment yield, pesticide transport. Organic matter is also sensitive in nitrogen cycling, i. e. mineralization and denitrification.

The primary soil particles--sand, silt, and clay--are important characteristics in **GLEAMS**. The relative amounts determine the textural classification, and as discussed above, are sensitive is estimating porosity and field capacity. The particle fractions are sensitive in estimating soil erodibility, aggregation, and sediment transport and enrichment ratio. Just as pesticide adsorption is mainly on organic carbon, phosphorus and ammonia are partially adsorbed on the clay fraction of the soil, particularly if it is montmorillonite as opposed to kaolinite. The clay and silt contents, CLAY and SILT, are input into the model and the sand is determined by difference. Most soil data bases include the primary particle fractions for each genetic horizon. If they do not, then the best estimate is the centroid of the textural classes shown in the triangular diagram of Figure H-1. For example, if a horizon is described as a clay loam, the approximate center of clay loam in the textural triangle shows about 35% (0.35) clay, 30% silt, and 35% sand. As can be seen in Figure H-1, there is a considerable range of particle constituency in most textural classifications. If soils data are not available for a specific field of interest, an experienced specialist can make an excellent estimate of texture by the "feel" method, i. e. the feel of sand grains or their absence when ribboning moist soil between the thumb and forefinger to get a "feel" for the silt or clay content. This may be crude, but it can be used to estimate texture to enter figure H-1. However, good data are needed since the two parameters are sensitive, either directly or indirectly, in each component of the model.

Clay, silt, and sand content are given in Table H-5 for the 21 textural classifications shown in Table H-3. The values in Table H-5 represent the center of each textural class.

Soil Chemical Properties--PH, BSAT, CACO3

Soil chemical properties, except pH, are the least available data required for input into the **GLEAMS** model. The "acidity", "reaction", or "pH', as it may be labeled in different data bases, is generally available in SSIR (USDA-SCS, 1967), soils-5, and county soil surveys (Calhoun, 1983). Base saturation and calcium-carbonate content are not as readily available because they were not routinely measured in the soils laboratories. The data were not generally used in applications other than soil treatment recommendations by soil specialists until the more recent water quality modeling developments. It is not as though soil scientists were not aware of soil chemistry--far from it. Soil chemical data simply were not in as high demand as soil water characteristics. Soil chemical analyses are more time consuming and difficult to make than water extractions. Considerable data are available at land-grant universities, such as the work of Perkins (1987).

If base saturation data are not available for a particular soil, and a value is required, the best estimate might be obtained from a similar complimentary soil, i. e. a "geographically associated" soil. For example, the Tifton and Dothan soils are described as geographically associated, and the main difference between the two is that Tifton typically has more ironstone nodules than the Dothan (Calhoun, 1983). Although base saturation data are not needed for either of these soils since they are considered highly weathered, if BSAT was available for Dothan and not for Tifton, the same value could be used for both series. There is no known surrogate for BSAT, that is, it cannot be approximated from any other commonly measured parameter.

It appears at first glance of the parameter list that the user is being asked to supply pH, base saturation, and calcium carbonate data for every soil. This is not the case. In fact, soils with a pH less than about 6.8 or 7.0 do not have free calcium carbonate. Likewise, soils with pH greater than this value do not have a base saturation. The parameter editor is structured to opt on two conditions: (1) if FLGNUT = 0, input for PH, CACO3, and BSAT is disregarded; and (2) if FLGNUT = 1, input of appropriate values are conditioned upon ISOIL. If a soil is calcareous, only CACO3 is needed. If a soil is slightly weathered, PH and BSAT are both needed, and neither value is needed for highly weathered soils.

PH, CACO3, and BSAT are not highly sensitive in **GLEAMS**. The phosphorus coefficients determined from these parameters are limited in range from 0.05 to 0.75. Thus, sensitivity is reduced for runoff, leaching, and adsorbed P. A new soils data base, "3SD", is being developed by the USDA-SCS using the Soil Survey Lab for physical and chemical characteristics. The data base will be available early in 1994.

Climatic Data--Temperature, Radiation, Wind Movement, and Dew Point Temperature

Mean monthly maximum and minimum temperature data input for **GLEAMS** are readily available in the United States from National Oceanographic and Atmospheric Administration (NOAA) climatological data publications. Temperature data are not as readily available as precipitation, but certainly are available within a climatic region of each state. Monthly data are used to alleviate the data entry requirement for a 50-year simulation. Temperature is not sensitive in areas where snow and frozen soil is not significant. Annual updates of monthly temperature data are not justified in warm climatic regions. However, mean daily temperatures estimated by interpolation of fitted monthly data do not allow short periods above freezing that often occur in the winter. Mean daily temperature is used to determine if precipitation is rainfall or snow. Precipitation occurring on days with mean temperature below freezing is considered as snow, and it is accumulated as snowpack until the mean daily temperature is above freezing. This partitioning between rain and snow is sensitive in the water balance calculations in cold climatic regions. Either long-term observed data can be entered, or they can be generated with a climate generator. Obviously when a user desires to compare model simulation results with observed hydrology, sediment, or chemical data, the best available input should be used, including observed mean daily temperature data.

Soil temperatures simulated in **GLEAMS** are derived from mean daily air tem-perature data. However, soil, water, and cover dampen the day-to-day fluctuations of air temperature, and air temperature data are not sensitive. The soil temperature model uses a 5-day moving average for damping to reduce sensitivity.

Radiation data are used to drive the potential evaporation and partitioning evaporation between soil and plant (transpiration). The model output is not sensitive to changes in radiation, and therefore long-term mean-monthly data are sufficient. The data can be updated annually just as for temperature. However, this is seldom justified except when comparing simulated and observed data.
Radiation data are given in Table H-6 for a number of locations in the U. S. where data are readily available.

The Penman-Monteith method of estimating potential evapotranspiration requires daily wind movement (wind speed) and daily dew point temperature data (Jensen et al., 1990). Mean monthly values are fitted with a Fourier series as is maximum and minimum temperature and radiation data (Kothandaraman and Evans, 1972). If local data are not readily available, long-term mean monthly values of wind movement and dew point temperature, as well as max and min temperatures, for more than 1,000 locations in the U.S. are readily available to **GLEAMS** users (Richardson and Nicks, 1990). These data can be entered into the hydrology parameter file within the hydrology parameter editor. If local data, or year-to-year data are available, they can be entered into the parameter file by use of the parameter editor. English or metric units are input as specified by FLGMET. Units for wind movement are km/day or mi/day, and EC or EF for dew point temperature.

Updateable Parameters

Rotation Cycles

Crop rotation information is used to eliminate entering leaf area index (LAI) data for every year of simulation except for monoculture systems, i. e. one continuous crop such as trees. The beginning and ending years of simulation, HBYR and HEYR, respectively, and the number of years in a rotation cycle, IROT, are required. These parameters enable the model to determine how many rotation cycles will be repeated during the simulation, and writes an internal file with the respective years and appropriate LAI data for all rotation periods.

Use of a rotation cycle implies that planting and harvesting of a particular crop is the same each year that crop is represented in the rotation. Without actual records, planting and harvest dates are not known for a 50-year period. This is not important for simulations to compare management practices. In fact, a change in management practices may simply entail changing planting date for some crop within a planting "window".

For example, in cold climatic regions with short growing seasons, crops may be planted as soon as frost is out of the ground to gain an early start. This is the case of potatoes grown in central Wisconsin, for example. If there is a late snowmelt, soil water content may be high and the potential is high for leaching of fertilizer or pesticides. One or two weeks delay in planting and chemical application may significantly reduce the leaching potential. This would be a valid management alternative for comparison.

If simulation results are to be compared with observed field data, the actual planting and harvest dates should be used each year of simulation. If a 10-year continuous crop period is simulated, and planting and harvest dates are different each year, IROT would be 10.

A continuous annual crop planted and harvested between January 1 and December 31 can be represented by IROT = 1, for example, corn planted on April 1 and harvested on August 15 of each year. The exception to this is a continuous winter small grain (winter wheat) that is planted October 15 and harvested the next year, say June 15. In order to set this as a continuous crop, the user should set IROT = 2. Corresponding planting and harvest dates for an example continuous wheat rotation is given in the next section.

Crop and Management Data--ICROP, DPLANT, DHRVST, DTRUNC, CCRD, CRPHTX

Idealized leaf area index data are stored in data statements in the model for 78 crops. The crops are listed in Table N-2. If these LAI data are to be used, the appropriate crop should be designated for ICROP. However, if the user has better local data, then ICROP should be designated as a code greater than 78. For example, the code for corn for grain is 17, but if the user has better LAI data, then ICROP should be 79 and the appropriate LAI entered on the next card. This gives the greatest possible flexibility, and provide for crops other than those in Table N-2. Many crops are not included and must be identified with numbers for ICROP from 79 through 90, for example, crotalaria, flax, hops, lima beans, etc.

Any number of crops may be specified for a simulation. For a continuous cropping system such as continuous corn without a winter cover crop, only one ICROP card is needed. In multiple cropping systems, there may be as many as 10 or 15 crops grown in a rotation cycle. To signal the end of crop data for the rotation cycle, a card with ICROP = 0 must be included at the end. The model will continue by reading the next set of data.

DPLANT and DHRVST are the planting and harvesting dates for each crop. The date includes the year within the rotation cycle and the Julian day, e. g. 1090 would be day 90 in the first year of the rotation cycle. The year of the rotation cycle is used with HBYR and IROT above to get the correct calendar year written in the internal file for each rotation cycle. DPLANT for a winter small grain might be 1305 and DHRVST might be 2165, indicating it is planted in the first year of the rotation cycle and harvested in the second year.

Some crops are not grown to maturity, but are harvested at an earlier stage, e. g. corn silage, alfalfa hay, meadow, etc. Others such as winter rye grown as a cover crop, is plowed under (disk or moldboard) before maturity. Their growth period is shortened or "truncated" at some date that can be specified by DTRUNC. The truncation date cannot be specified as DHRVST, or the full LAI will be repre- sented over the shorter time period. This is a true representation of the growth and nutrient uptake. Therefore, the harvest date is specified as DHRVST for a normal maturity, and a truncation is specified as DTRUNC, the year of the rotation cycle and the Julian day. For the example winter small grain cited above, a common management practice in the Georgia Coastal Plain is to plant winter rye, such as day 305, and disk the rye about day 75 prior to planting corn about day 91. Thus, there would be a DTRUNC of 2075, and the LAI data for winter rye would be set between 1305 and 2165. The DTRUNC would truncate the growth on day 2075. Corn grown for silage, alfalfa grown for hay, etc, would have truncation dates. Crops grown to maturity are not truncated, and DTRUNC is disregarded by leaving the parameter field blank.

A continuous winter wheat rotation, with IROT = 2, would be given as follows for planting on October 1 and harvesting on June 15 (Cards 29):

ICROP	DPLANT	DHRVST
74	0274	1166
74	1274	2166
74	2274	3166

The appropriate cards 30 would have to be included. This simply shows the cards 29 necessary to achieve a continuous winter wheat crop.

Multiple cuttings of alfalfa hay, bermudagrass hay, or other multiple har- vesting dates for one crop can be simulated using the truncation feature. An example of DPLANT, DHRVST, and DTRUNC for four cuttings of alfalfa could be rep- represented as shown below:

DPLANT	DHRVST	DTRUNC
0274	1140	1121
1122	1185	1166
1167	1225	1206
1207	1275	1253

The DPLANT on 0274 shows the planting on October 1 of the zero year of the rota- tion cycle (the year before simulation begins). Alfalfa is generally cut for hay when approximately one-fourth or one-third in bloom. The LAI has normally peaked and flattened, but senescence of leaves has not really begun. DHRVST is shown on May 20 for full maturity, but hay is cut (DTRUNC) on May 1. If soil water is not limiting, growth really begins immediately, thus DPLANT is set the day after cutting, or May 2 (1122). DTRUNC dates of 1166, 1206, and 1253 represent 2nd, 3rd, and 4th cuttings on June 15, July 25, and September 10, respectively.

Alfalfa cut for seed generally follows one or two cuttings of hay. An example of such DPLANT, DHRVST, and DTRUNC for two hay crops plus a seed crop could be as shown:

DPLANT	DHRVST	DTRUNC
0274	1140	1121
1122	1190	1170
1171	1263	

The blank value for DTRUNC on the last line shows that the alfalfa is grown to maturity.

Rooting depth of some crops do not extend to the effective rooting depth, RD, described above. This is especially true of some vegetable crops such as radishes, carrots, leaf lettuce, and etc. The present version of **GLEAMS** allows rooting depth to change from one crop in a rotation to the next. The effective rooting depth, RD, is used as the maximum, and when a crop is entered with a lesser rooting depth, only transpiration is limited to the current crop rooting depth, CCRD. The other processes, routing chemicals, soil evaporation, chemical transformations, and etc., continue to the effective depth, RD. The result is that less crop uptake of chemicals will take place in the CCRD, and leaching of chemicals out of the bottom of RD will potentially be greater.

CCRD cannot be included in the internal data base, because some soils may have a maximum thickness (RD) less than a data base value. For example, the organic soils in the Homestead, Florida area are only about 12-15 cm deep overlying limestone rock. Any crop grown on those soils will have the same CCRD as RD, i. e. 12-15 cm. If CCRD is left blank in the parameter file, it is assumed to be the same as RD. A value of zero is not allowed.

Data for the 78 crops listed in Table N-2 include the maximum height of crop. The user can specify a different height as CRPHTX. For crops not listed in Table N-2, the user **must** specify CRPHTX when using the Penman-Monteith method of simulating potential ET. The model generates a crop height up to CRPHTX on the date when LAI is maximum. The height growth increases as the fraction of accumulated actual LAI to total idealized LAI for the crop on the date when LAI is maximum. Model users can specify the crop height during the growing season when giving LAI data for crops 79-90. CRPHTX is not a sensitive parameter except in estimating potential ET.

Hardwood Forest and Perennial Crop Growing Season--BEGGRO, ENDGRO

Growth of agricultural crops and conifer forests occurs when leaf area index is greater than zero. Nutter et al. (1993) stated hardwood and mixed pine-hardwood forests had and LAI throughout the year representing hardwood trunks and limbs. Although the hardwoods are not transpiring during winter, the LAI is needed for rainfall interception. In order to distinguish dormant and growing season in the model when LAI is greater than zero, dates are input for beginning and ending of growing season, BEGGRO and ENDGRO.

In the southern regions of the U. S., hardwood growth begins about March 15 and ends about October 15. The growing season is shorter in northern regions with most of the difference in the spring. BEGGRO could be about a month later, April 15, and ENDGRO is about October 1. Obviously this would not reflect higher elevations in either region. Intermediate regions would have dates between those given for the northern and southern regions.

Pasture grasses, meadows, alfalfa, clover, and other perennial agricultural crops may have significant LAI during the dormant season and not actually transpire. For example, warm-season pasture grasses that are grazed only during the the growth period may have a leaf area of 0.5 to 1.0 m^2/m^2 at the beginning of the year in the northern hemisphere. The total leaf area provides an evaporation suppressant but does not transpire even with the indicated LAI. This may be true of cool-season grasses that are dormant or near dormant during the summer, for example fescue grass. The beginning (BEGGRO) and ending (ENDGRO) of the growing period for these perennials is important in distinguishing the times when transpiration is and is not occurring.

BEGGRO and ENDGRO are not sensitive parameters for water balance calculations since LAI only partitions evapotranspiration between the two separate components. There would be significant sensitivity for pesticides and plant nutrients since transpiration drives chemical uptake.

Irrigation Management Data--IROPT, DBIRR, DEIRR, DPREIR, PREIRR, BASEI, TOPI

IROPT is a code to specify if the model is to automatically irrigate based upon some user-designated threshold level of soil water content. If simulation is made for comparison with observed data which includes irrigation, the observed irrigation depths should be included in the precipitation file, and IROPT set at zero. For simulation purposes, irrigation dates and amounts would not be known ahead of time unless a rigid schedule is used. Therefore, IROPT can be set to allow the model to compare soil water with the threshold value, and when that level is reached, the amount of irrigation needed to raise the soil water content to some user-supplied upper limit.

Crops other than possibly hay are never irrigated from planting to harvest. Adding water by irrigation only results in delay of harvest, and possibly results in disease and fungi. Different crops have different levels of sensitivity, and the length of irrigation season is also a function of climate. In some climatic regions with very sandy soils, high value crops may be irrigated at low levels of soil water in the root zone from planting date. Other crops in other regions may not be irrigated until 30-45 days after crop emergence to "stress" the crop into extending roots deeper. This is a common practice in western irrigated areas, for example in cotton production.

When the user specifies the "model to irrigate" (IROPT = 1) based upon the soil water criteria, the beginning and ending dates are needed for considering irrigation. DBIRR is the beginning date with the year of the rotation cycle and Julian day. The date for ending irrigation is specified by DEIRR as year of the rotation cycle and Julian day.

In the present version of GLEAMS, irrigation requirements for automatic irrigation consider the soil water content only in the active depth of rooting on the specific day rather than in the entire effective rooting depth. If root growth extends only to a depth of 15 cm, irrigation should not be based upon available water in the entire 60 cm effective rooting depth, for example. This may result in some very small irrigation amounts when simulated root growth extends to only a few cm. There is a minimum 0.64 cm irrigation depth that will be applied by the model.

Generally DEIRR for corn is about 45-60 days before harvest. Irrigation of vegetable crops may be within 3-7 days before harvest depending upon the method of harvest and the climate and soil conditions. Irrigation of hay crops is generally discontinued about a week before cutting in order for the soil to be easily trafficable. Irrigation is resumed again on the day of baling or the day after baling. Multiple harvests are made for some crops in some regions. Tobacco grown in the Georgia Coastal Plain may have some leaves picked to maintain a top quality, then irrigated and picked again once or twice. In areas with shorter growing season, such as Ohio and Pennsylvania, tobacco is harvested only once. Irrigation is not generally applied on tobacco in those states, but if it is a consideration, DBIRR and DEIRR must be supplied. (LAI for multiple harvests of tobacco will be discussed later.)

When comparing model simulation results with observed data where irrigation is supplied, the irrigation amount must be included in the precipitation file. IROPT must be set to zero for this condition, i. e. the model does not determine when to irrigate. If IROPT = 0, DBIRR and DEIRR are not needed.

In western irrigated areas, particularly those areas that have high salt content in the soil, excess irrigation is applied before planting (preplant) to leach salts out of the root zone. The preplant irrigation also serves to raise the soil water content in the seed drill, and then warming of the seed zone occurs by planting time. The date of preplanting irrigation, DPREIR, and the depth of irrigation applied, PREIRR, are specified for each crop or season. This specification is superior to including irrigation in the rainfall file in order for the rainfall file to contain only precipitation data.

Irrigation practices in humid areas may have more potential for water quality impairment than other areas. Larger rainfall events generally occur in humid regions. If they occur on the day that irrigation is applied to fill the available soil water storage, large runoff and percolation volumes may transport large masses of chemical movement. For this reason, particularly with center pivot systems, water deficit management is recommended. If criteria are specified with IROPT (irrigation option) set, **GLEAMS** will check the soil water content daily to determine when irrigation should be applied. That threshold level is specified by BASEI, the fraction of plant available water when irrigation is needed.

GLEAMS uses a two-stage soil water uptake (Smith and Williams, 1980). Uptake continues at the potential rate until the water content reaches 25% of plant available, then reduced uptake begins in the second stage. Above this level, there is no advantage of irrigation except that some crops, such as cucumbers, wilt above this level and crop yield may be reduced. Although BASEI = 0.25 is generally recommended, this may need to be adjusted depending upon the availability and amount of water.

The upper level to which soil water is to be increased by irrigation is less than field capacity for water deficit management. Although a 10% deficit is generally recommended, this depends upon the frequency with which irrigation can be applied again. This upper limit, TOPI, may also be a function of soil variability. **GLEAMS** can consider only one soil in a simulation, and if the field is highly variable, some compromise may be needed for irrigation application and/or water retention characteristics. If irrigation is intended to raise the water level in the root zone (the depth to which the model has generated root growth), TOPI should be 1.0. This version of **GLEAMS** considers the active root depth for irrigation rather than total effective root depth, RD.

Leaf Area Index and Crop Height

LAI data are in data statements in the model for the 78 crops included in Table N-2, and these can be used without entering them in the hydrology parameter file (see discussion for ICROP above). However, some discussion is presented here on proper use of those data for specific application. Some discussion was given for DPLANT, DHRVST, and DTRUNC above. The stored data are shown in Table H-7 user convenience. Some crops are included in Table H-7 that may require some special consideration.

The LAI data shown in Table H-7 are for full maturity and normal harvest. For example, LAI data for alfalfa is for excellent management for seed harvest (maturity). The same LAI data are also used for alfalfa hay with a cutting date given for DTRUNC. Also, successive hay cuttings generally yield less tonnage due to a combination of climatic and physiologic conditions.

Crops grown in different climatic regions may have somewhat different growth and/or harvest characteristics. The LAI given in Table H-7 (those included in the model data statements) may not adequately represent that same crop grown in a specific region. The model will accept user-defined LAI specified as ICROP > 78. For example, tobacco grown in Ohio or Pennsylvania is harvested one time by cutting the entire stalk and taking it to the slat barn for air drying. In Georgia and Florida, two or three pickings are made to harvest only the mature bottom leaves each time. The LAI data in Table H-7 does not really represent the Georgia/Florida harvest system. The model user should set ICROP > 78, and represent an abrupt decrease in LAI for the 1st and 2nd harvests followed by additional growth with generally lower LAI similar to cutting hay.

Another example is winter rape grown in the southeastern U. S. compared with that grown in Europe. Growth patterns are different in the two continents, and the LAI data in Table H-7 more nearly represents the U. S. climate. Northern areas of the U. S. probably approximate the European regions. Model users should be aware of the need to make these adjustments. Adjustments are not sensitive for water balance computations, but may be important in nutrient uptake.

Some cultural practices are used in different climatic regions to overcome certain climatic or pest problems. For example, some progressive farming systems use 4 rows of peanuts planted on wide beds (sometimes called "cantaloupe" beds) to get faster developing crop canopy. The customary practice is 2 rows per bed. These two systems are included in Table H-7.

Considerable work has been done in Mississippi and Alabama on broadcast soybean production systems. Broadcast soybeans develop full canopy quicker and provide more protection from erosion even when using the same rate of seeds per acre. Thus, row and broadcast soybeans are included in the LAI data for user convenience.

LAI data in Table H-7 are given by fraction of the growing season. There is no attempt to distinguish between cultivars. The user must make these distinctions by designating DHRVST and DTRUNC. For example, corn grown in Minnesota may generally be the 75-day varieties compared with 90-day varieties in southern Indiana, or even 120-day full-season varieties grown for silage in Georgia. Even though LAI data are included in the model data statements for user convenience and ease in establishing rotation cycles, the user must make decisions concerning growing seasons.

The model steps through the ICROP data and writes a file with the appro- priate LAI data between planting and harvest with or without truncation. For those crops with ICROP > 78, the model expects user-defined LAI data to be entered. The user must enter enough pairs (NOLAI) of data, USRFRC and USRLAI, fraction of growing season and LAI, respectively, to define the growth and harvest pattern. The USRFRC need not necessarily be at tenths of the growing season as is shown in Table H-7. For example, the conifer forest LAI can just as easily be represented with two entries: one at Julian day 001 (required), and one at Julian day 366 (also required), both with LAI = 5.50. Conversely, as many as 30 or 40 pairs (NOLAI = 30 or 40) to represent rotational grazing of pastures containing both cool season and warm season grasses. The LAI data shown in Table H-7 for pasture obviously represents no grazing. Periodic or continuous grazing can be represented by reducing the LAI data to some fraction of the table value over the appropriate period. For example, continuous grazing might be intended to remove one-half of the forage produced, and the table value might cut in half for the period over which the pasture grows. It should be remembered that the values entered are without soil water and nutrient stress. The model will adjust the "actual" LAI for the stress factors, and the biomass production will not be the potential yield entered in the nutrient component. Thus, the user must enter the number of LAI points (NOLAI) for each crop with ICROP > 60 followed by that number of USRFRC and USRLAI entries.

Year-long bare fallow, as practiced in some wheat production systems, can now be represented with LAI = 0.0 on day 001 and on day 366. In earlier model versions, this resulted in division by zero for potential water uptake for the year, and a fatal run-time error occurred. This has been revised in the present version. An example of a 3-year winter wheat-fallow rotation would be represented by giving only the years of the rotation cycle and the respective planting and harvest dates. Wheat may be planted on October 1 (Julian day 274) and harvested on June 15 (Julian day 166) the next year, the field maintained in a bare fallow either chemically or by tillage through the remainder of the year and throughout the following year. Then wheat planted again in the next year on day 274. This would be represented for a 20 year simulation, 1969-88, as follows:

Card 28:	69	88	3
Card 29:	74	0274	1166
Card 30:	(blank)		
Card 29:	74	3274	4166
Card 30:	(blank)		
Card 29:	0		

This results in winter wheat planted on October 1 in 1968 (rotation year 0) prior to the date simulation begins. Wheat is harvested on June 15, 1969. The field is fallow from June 16, 1969 through September 30, 1971 (rotation year 3). Wheat is planted on October 1, 1971 to be harvested on June 15, 1972. The third Card 29 signals the end of the crop rotation data.

A 2-yr sorghum-fallow rotation for the 20-yr simulation with sorghum planted on May 1 (Julian day 121) and harvested on September 15 (Julian day 258) would be represented as follows:

Card 28:	69	88	2
Card 29:	56	1121	1258
Card 30:	(blank)		
Card 29:	0		

This results in grain sorghum grown in 1969, 1971, 1973, etc., and fallow in 1970, 1972, 1974, etc.

It can be seen from this discussion that considerable flexibility is afforded the **GLEAMS** user, yet simplicity is provided where possible. The tables and internal data are provided as helpful guidelines, not as "the" way it must be done. The best representation of the physical system is desired.

Leaf area data are not sensitive parameters in hydrology for water balance computations. For soil water abstractions, LAI only partitions daily evapotranspiration into soil evaporation and plant transpiration. The sensitivity of LAI occurs in the pesticide and plant nutrient component. Soil evaporation deter- mines the upward movement of soluble N, P, and pesticides, while plant trans- piration is the driving force for plant uptake of these soluble elements.

Perrenial crops such as grazed pasture may have some non-transpiring LAI and a crop height some portions of the year. If model users want to specify the LAI data, they can also specify the crop height, CROPHT, during the year along with the LAI data. Also, the user can specify the crop height that may be observed during the growing season rather than let the model "grow" the crop as described above. Crop height data are used only in the Penman-Monteith method of estimating potential evapotranspiration. Crop height is not a sensitive parameter except in the estimate of potential ET.

Sample parameter files are shown in an appendix of of this manual to depict some common, but slightly unique, cropping systems and conditions. The model user is cautioned to use these sample parameter files only as a guide, not as a "standard" parameter file for any one situation.

Updating Temperature, Radiation, Wind Movement, and Dew Point Temperature Data

Comparison of management alternatives can be made from long-term **GLEAMS** simulations using long-term mean monthly maximum and minimum temperatures and radiation. The relative differences in simulation results are the important things rather than actual temperature data input. However, model simulations are to be compared with observed data, the best estimate of input data is needed. In warm climatic regions, annual updates of monthly temperature and radiation are desirable. This option is available for the user to use long term averages without update, or update annually. These options are available by entering the respective values for NEWT and/or NEWR. Either data set can be updated independently, or neither data set has to be updated. Mean monthly temperature update applies to both maximum and minimum.

These options of updating temperature and radiation are independent of mean daily temperature input. The FLGTMP code described above applies only to mean daily temperature and not to mean monthly data. Mean daily temperature input specified by FLGTMP requires that the input file contains mean daily temperature data for the entire period of simulation. Use of average daily values from a long-term record would defeat the purpose of daily determination of precipitation state and allow mid-winter thaw. This must be done on a year-to-year basis.

Mean monthly wind movement and mean monthly dew point temperature can be updated each year of simulation if the user desires. These options are available by entering codes for NEWW and/or NEWD.

Temperature, radiation, and wind movement data are not sensitive in the hydrology component even though they are used to estimate potential ET. They are sensitive in the plant nutrient component in estimation of soil temperatures and the associated temperature adjustment factors for the nutrient cycling processes.

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Table H-1. Variables available for user-selected output.

Variable	Units	Code
DAILY		
Precipitation	cm, in	1
Runoff	cm, in	2
Percolation	cm, in	3
Evapotranspiration	cm, in	4
Chemigation	cm, in	5
Irrigation	cm, in	6
Precipitation thrufall	cm, in	7
Precipitation interception	cm, in	8
Precipitation interception and ET	cm, in	9
Snowmelt	cm, in	10
Minimum temperature	EC, EF	20
Maximum temperature	EC, EF	21
Mean temperature	EC, EF	22
Soil temperature by layer	EC, EF	25
Radiation	MJ/cm^2	30
Leaf area index	m^2/m^2	40
Soil water depth by layer	in	50
Soil water depth by layer	cm	51
Actual transpiration	cm, in	60
Potential transpiration	cm, in	61
Actual soil evaporation	cm, in	70
Potential soil evaporation	cm, in	71
Actual evapotranspiration	cm, in	80
Potential evapotranspiration	cm, in	81
Sediment yield - overland	t/ha, t/ac	301
Enrichment ratio - overland		302
Sediment yield - channel 1	t/ha, t/ac	311
Enrichment ratio - channel 1		312
Sediment yield - channel 2	t/ha, t/ac	321
Enrichment ratio - channel 2		322
Sediment yield - pond	t/ha, t/ac	331
Enrichment ratio - pond		332
Runoff loss, pesticide 1-10	g/ha	601-610
Runoff loss, pesticide 1-10	mg/l	611-620
Sediment loss, pesticide 1-10	g/ha	651-660
Sediment loss, pesticide 1-10	µg/g	661-670
Percolate loss, pesticide 1-10	g/ha	701-710
Percolate loss, pesticide 1-10	mg/l	711-720
Total loss, pesticide 1-10	g/ha	751-760
Pesticide mass by soil layer, pesticide 1-10	kg/ha	801-810
Pesticide concentration by soil layer, pesticide 1-10	µg/g	811-820
Pesticide concentration in H_2O by soil layer, pesticide 1-10	mg/l	821-830
Pesticide concentration in soil by soil layer, pesticide 1-10	µg/g	831-840
Runoff loss, NO_3-N	kg/ha	900
Runoff loss, NO_3-N	mg/l	901
Runoff loss, NH_4-N	kg/ha	905
Runoff loss, NH_4-N	mg/l	906
Runoff loss, PO_4-P	kg/ha	910

Table H-1, continued. Variables available for user-selected output.

Variable	Units	Code
<u>Daily, continued</u>		
Runoff loss, PO_4-P	mg/l	911
Sediment loss, NH_4-N	kg/ha	915
Sediment loss, NH_4-N	µg/g	916
Sediment loss, PO_4-P	kg/ha	920
Sediment loss, PO_4-P	µg/g	921
NO_3-N leached	kg/ha	925
NO_3-N leached	mg/l	926
NH_4-N leached	kg/ha	930
NH_4-N leached	mg/l	931
PO_4-P leached	kg/ha	935
PO_4-P leached	mg/l	936
Total loss, NO_3-N	kg/ha	940
Total loss, NH_4-N	kg/ha	941
Total loss, PO_4-P	kg/ha	942
Sediment loss, organic N	kg/ha	945
Sediment loss, organic P	kg/ha	946
NO_3-N mass by soil layer	kg/ha	950
NO_3-N concentration by soil layer	µg/g	951
NH_4-N mass by soil layer	kg/ha	955
NH_4-N concentration by soil layer	µg/g	956
TKN (Total N - NO_3-N) mass by soil layer	kg/ha	957
TKN concentration by soil layer	µg/g	958
PO_4-P mass by soil layer	kg/ha	960
PO_4-P concentration by soil layer	µg/g	961
TP (Total P) mass by soil layer	kg/ha	962
TP concentration by soil layer	µg/g	963
Organic nitrogen mass by soil layer		
Crop residue	kg/ha	965
Animal waste	kg/ha	966
Organic phosphorus mass by soil layer		
Crop residue	kg/ha	970
Animal waste	kg/ha	971
Soil nitrogen mass by layer		
Active mineralizable	kg/ha	975
Stable	kg/ha	976
Soil phosphorus mass by layer		
Active mineral	kg/ha	980
Stable mineral	kg/ha	981
Organic humus	kg/ha	982
NH_4-N volatilization	kg/ha	985
<u>Monthly</u>		
Precipitation	cm, in	2001
Runoff	cm, in	2002
Percolation	cm, in	2003
Evapotranspiration	cm, in	2004
Irrigation	cm, in	2006
Precipitation thrufall	cm, in	2007
Precipitation interception	cm, in	2008
Precipitation interception + ET	cm, in	2009

Table H-1, continued. Variables available for user-selected output.

Variable	Units	Code

Monthly, continued

Snowmelt	cm, in	2010
Mean minimum temperature	EC, EF	2020
Mean maximum temperature	EC, EF	2021
Mean daily temperature	EC, EF	2022
Mean soil temperature by layer	EC, EF	2023
Mean radiation	$MJ/cm^2/d$	2030
Actual transpiration	cm, in	2060
Potential transpiration	cm, in	2061
Actual soil evaporation	cm, in	2070
Potential soil evaporation	cm, in	2071
Actual evapotranspiration	cm, in	2080
Potential evapotranspiration	cm, in	2081
Sediment yield - overland	t/ha, t/ac	2301
Enrichment ratio - overland		2302
Sediment yield - channel 1	t/ha, t/ac	2311
Enrichment ratio - channel 1		2312
Sediment yield - channel 2	t/ha, t/ac	2321
Enrichment ratio - channel 2		2322
Sediment yield - pond	t/ha, t/ac	2331
Enrichment ratio - pond		2332
Runoff loss, pesticide 1-10	g/ha	2601-2610
Sediment loss, pesticide 1-10	g/ha	2651-2660
Percolate loss, pesticide 1-10	g/ha	2701-2710
Total loss, pesticide 1-10	g/ha	2751-2760
Rainfall nitrogen	kg/ha	2901
Fertilizer nitrate	kg/ha	2902
Fertilizer ammonia	kg/ha	2903
Fertilizer phosphorus	kg/ha	2904
Animal waste NO_3-N	kg/ha	2905
Animal waste NH_4-N	kg/ha	2906
Animal waste organic N	kg/ha	2907
Animal waste PO_4-P	kg/ha	2908
Animal waste organic P	kg/ha	2909
Runoff NO_3-N	kg/ha	2910
Runoff NH_4-N	kg/ha	2911
Runoff PO_4-P	kg/ha	2912
Sediment NH_4-N	kg/ha	2915
Sediment PO_4-P	kg/ha	2916
Sediment organic N	kg/ha	2917
Sediment organic P	kg/ha	2918
NO_3-N leached	kg/ha	2920
NH_4-N leached	kg/ha	2921
PO_4-P leached	kg/ha	2922
Ammonia volatilization	kg/ha	2925
Denitrification	kg/ha	2926
Nitrogen uptake	kg/ha	2927
Phosphorus uptake	kg/ha	2928
Nitrogen fixation	kg/ha	2929

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Table H-1, continued. Variables available for user-selected output.

))

Variable	Units	Code

))

Annual

Precipitation	cm, in	3001
Runoff	cm, in	3002
Percolation	cm, in	3003
Evapotranspiration	cm, in	3004
Irrigation	cm, in	3006
Precipitation thrufall	cm, in	3007
Precipitation interception by canopy	cm, in	3008
Precipitation interception + ET	cm, in	3009
Snowmelt	cm, in	3010
Actual transpiration	cm, in	3060
Potential transpiration	cm, in	3061
Actual soil evaporation	cm, in	3070
Potential soil evaporation	cm, in	3071
Actual evapotranspiration	cm, in	3080
Potential evapotranspiration	cm, in	3081
Sediment yield - overland	t/ha, t/ac	3301
Enrichment ratio - overland		3302
Sediment yield - channel 1	t/ha, t/ac	3311
Enrichment ratio - channel 1		3312
Sediment yield - channel 2	t/ha, t/ac	3321
Enrichment ratio - channel 2		3322
Sediment yield - pond	t/ha, t/ac	3331
Enrichment ratio - pond		3332
Annual maximum n-day pesticide concentrations: runoff; runoff + sediment; percolation, n=1-10	mg/L	3401-3410
Annual maximum n-day pesticide concentrations: (Sames 3401-3410 except beginning date is a day with pesticide runoff)	mg/L	3411-3420
Runoff loss, pesticide 1 - 10	g/ha	3601-3610
Sediment loss, pesticide 1 - 10	g/ha	3651-3660
Percolation loss, pesticide 1 - 10	g/ha	3701-3710
Total loss, pesticide 1 - 10	g/ha	3751-3760
Rainfall nitrogen	kg/ha	3901
Fertilizer nitrate	kg/ha	3902
Fertilizer ammonia	kg/ha	3903
Fertilizer phosphorus	kg/ha	3904
Animal waste NO_3-N	kg/na	3905
Animal waste NH_4-N	kg/ha	3906
Animal waste organic N	kg/ha	3907
Animal waste PO_4-P	kg/ha	3908
Animal waste organic P	kg/ha	3909
Runoff NO_3-N	kg/ha	3910
Runoff NH_4-N	kg/ha	3911
Runoff PO_4-P	kg/ha	3912
Sediment NH_4-N	kg/ha	3915
Sediment PO_4-P	kg/ha	3916
Sediment organic N	kg/ha	3917
Sediment organic P	kg/ha	3918
NO_3-N leached	kg/ha	3920
NH_4-N leached	kg/ha	3921

Table H-1, continued. Variables available for user-selected output.

Variable	Units	Code
<u>Annual, continued</u>		
PO_4-P leached	kg/ha	3922
Ammonia volatilization	kg/ha	3925

Denitrification	kg/ha	3926
Nitrogen uptake	kg/ha	3927
Phosphorus uptake	kg/ha	3928
Nitrogen fixation	kg/ha	3929

<u>Constants</u>

Number of soil computational layers		4001
Computational soil layer thickness	in	4002
Computational soil layer thickness	cm	4003
Bottom of computational soil layer	in	4004
Bottom of computational soil layer	cm	4005
Soil mass by computational soil layer	t/ac	4011
Soil mass by computational soil layer	t/ha	4012

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Table H-2. Ranges of saturated conductivity by hydrologic soil group.

Hydrologic Soil Group	Saturated Conductivity (in/hr)	Saturated Conductivity (cm/hr)
A	0.30 - 0.50	0.76 - 1.27
B	0.15 - 0.30	0.38 - 0.76
C	0.05 - 0.15	0.13 - 0.38
D	0.005 - 0.05	0.013 - 0.13

Table H-3. Mean physical properties of soils by textural classification (USDA-SCS, 1984; Ritchie, 1972).

Texture	Bulk Density	Porosity (POR)	Field Capacity (FC)	Wilt. Point 1500 kPa (BR15)	Evap. Const. (CONA)
	g/cm^3	cm^3/cm^3	cm/cm	cm/cm	$mm/d^{0.5}$
Coarse sand	1.6	0.40	0.11	0.03	3.3
Sand	1.6	0.40	0.16	0.03	3.3
Fine sand	1.5	0.43	0.18	0.03	3.3
Very fine sand	1.5	0.43	0.27	0.03	3.3
Loamy coarse sand	1.6	0.40	0.16	0.05	3.3
Loamy sand	1.6	0.40	0.19	0.05	3.3
Loamy fine sand	1.6	0.40	0.22	0.05	3.3
Loamy very fine sand	1.6	0.40	0.37	0.05	3.3
Coarse sandy loam	1.6	0.40	0.19	0.08	3.3
Sandy loam	1.6	0.40	0.22	0.08	3.5
Fine sandy loam	1.7	0.36	0.27	0.08	3.5
Very fine sandy loam	1.6	0.40	0.37	0.08	3.5
Loam	1.6	0.40	0.26	0.11	4.5
Silt loam	1.5	0.43	0.32	0.12	4.5
Silt	1.4	0.47	0.27	0.13	4.0
Sandy clay loam	1.6	0.40	0.30	0.18	4.0
Clay loam	1.6	0.40	0.35	0.22	4.0
Silty clay loam	1.4	0.47	0.36	0.20	4.0
Sandy clay	1.6	0.40	0.28	0.20	3.5
Silty clay	1.5	0.43	0.40	0.30	3.5
Clay	1.4	0.47	0.39	0.28	3.5

Table H-4. Runoff curve numbers for hydrologic soil-cover complexes for antecedent moisture condition II (CN2).

Land Use Treatment or Practice*	Hydrologic Condition	Hydrologic Soil Group A	B	C	D
Fallow					
SR		70 77 81	82 86 88	89 91 92	93 94 95
SR+CT	poor	68 75 80	81 84 86	87 89 90	91 92 93
SR+CT	good	67 74 79	80 83 89	86 87 88	89 90 91
Row Crops					
SR	poor	65 72 77	78 81 85	86 87 88	90 91 92
SR	good	60 67 73	74 78 82	83 85 87	88 89 90
SR+CT	poor	66 71 75	76 79 83	84 86 87	88 89 90
SR+CT	good	57 64 70	71 75 79	80 82 83	84 85 86
CNT	poor	64 70 75	76 79 81	82 84 86	87 88 89
CNT	good	59 65 70	71 75 79	80 82 84	85 86 87
CNT+CT	poor	63 69 74	75 78 80	81 83 85	86 87 88
CNT+CT	good	58 64 69	70 74 77	78 80 82	83 84 85
CNT+TER	poor	60 66 70	71 74 77	78 80 81	81 82 83
CNT+TER	good	56 62 66	67 71 74	75 78 79	80 81 82
CNT+TER+CT	poor	59 65 69	70 73 76	77 79 80	80 81 82
CNT+TER+CT	good	55 61 66	67 70 73	74 76 77	78 79 80
Small Grain					
SR	poor	60 65 70	71 76 80	81 84 86	87 88 89
SR	good	57 63 69	70 75 79	80 83 85	86 87 88
SR+CT	poor	58 64 69	70 74 78	79 82 84	85 86 87
SR+CT	good	53 60 67	68 72 76	77 80 82	83 84 85
CNT	poor	57 63 68	69 74 78	79 82 83	84 85 86
CNT	good	55 61 67	68 73 77	78 81 82	83 84 85
CNT+CT	poor	56 62 67	68 73 77	78 81 82	83 84 85
CNT+CT	good	53 60 66	67 72 75	76 79 80	81 82 83
CNT+TER	poor	56 61 66	67 72 75	76 79 80	81 82 83
CNT+TER	good	54 59 64	65 70 74	75 78 79	80 81 82
CNT+TER+CT	poor	55 60 65	66 71 74	75 78 79	80 81 82
CNT+TER+CT	good	53 58 63	64 69 72	73 76 77	78 79 80
Close-seeded legumes, or rotation meadow					
SR	poor	61 66 71	72 77 81	82 85 87	88 89 90
SR	good	51 58 65	66 72 76	77 81 83	84 85 86
CNT	poor	59 64 69	70 75 78	79 83 84	85 85 86
CNT	good	48 55 62	63 69 73	74 78 80	81 83 85
CNT+TER	poor	58 63 68	69 73 76	77 80 81	82 83 84
CNT+TER	good	43 51 59	60 67 71	72 76 78	79 80 81
Pasture or Range					
Non-CNT	poor	60 68 73	74 79 82	83 86 87	88 89 90
Non-CNT	fair	35 49 60	61 69 74	75 79 81	82 84 86
Non-CNT	good	25 39 51	52 61 67	68 74 77	78 80 83
CNT	poor	32 47 58	59 67 74	75 81 84	85 88 90
CNT	fair	5 25 45	46 59 67	68 75 78	79 83 87
CNT	good	1 6 23	24 35 55	56 70 74	75 79 83

Table H-4, Continued. Runoff curve numbers for hydrologic soil-cover complexes for antecedent moisture condition II (CN2).

Land Use Treatment or Practice*	Hydro-logic Condi-tion	Hydrologic Soil Group A	B	C	D
Meadow					
---	good	51 59 66	67 74 78	79 82 84	85 86 87
Woods					
---	poor	33 45 55	56 66 71	72 77 80	81 83 85
---	fair	22 36 48	49 60 66	67 73 76	77 79 81
---	good	8 25 41	42 55 62	63 70 73	74 77 80
Farmsteads					
---	----	42 59 67	68 74 78	79 82 84	85 86 87
Roads					
Dirt	----	66 72 77	78 82 84	85 87 88	88 89 90
Hard surface	----	68 74 79	80 84 87	88 90 91	91 92 93

* SR = Straight Row; CT = Conservation Tillage; CNT = Contoured; TER = Terraced

Table H-5. Average fractions of primary soil particles by textural classification.

Texture	Clay (%)	Silt (%)	Sand (%)
Coarse sand	5	5	90
Sand	5	5	90
Fine sand	5	5	90
Very fine sand	5	5	90
Loamy coarse sand	8	8	84
Loamy sand	8	8	84
Loamy fine sand	8	8	84
Loamy very fine sand	8	8	84
Coarse sandy loam	15	25	60
Sandy loam	15	25	60
Fine sandy loam	15	25	60
Very fine sandy loam	15	25	60
Loam	20	35	45
Silt loam	20	60	20
Silt	10	85	5
Sandy clay loam	25	20	55
Clay loam	35	30	35
Silty clay loam	35	50	15
Sandy clay	40	10	50
Silty clay	45	45	10
Clay	50	30	20

Table H-6. Locations for climatological data in the hydrology parameter editor.

Index Number	STATE Location	Index Number	STATE Location
	ALABAMA		ARIZONA, Continued
0	Bankhead Lock	52	Canelo RS
1	Birmingham WB AP	53	Douglas B D AP
2	Brantley	54	Eloy
3	Frisco City	55	Heber
4	Greensboro	56	Jacob Lake
5	Heflin	57	Keams Canyon
6	Huntsville WSO AP	58	Klagetoh 12 WNW
7	Mobile WB AP	59	Kofa Mountains
8	Montgomery WB AP	60	Lees Ferry
9	Muscle Shoals CAA	61	Litchfield Park
10	Opelika	62	Lukachukai
11	Ozark	63	Montezuma Castle NM
12	Robertsdale 7 E	64	Oracle 4 SE
13	Valley Head	65	Prescott
	ALASKA	66	Saint Johns
14	Adak	67	San Carlos Reservoir
15	Ambler West	68	Sasabe
16	Annette WSO AP	69	Seligman
17	Barrow WSO AP	70	Stewart Mountain
18	Barter Island WSO AP	71	Tacna 3 NE
19	Bethel WSO AP	72	Tombstone
20	Bettles FAA AP	73	Tucson WBO
21	Cape Lisburne	74	Tumacacori
22	Cape Newenham	75	Tuweep
23	Cape Romanzof	76	Wikieup
24	Circle City	77	Wupatki National Mon.
25	Clear Water	78	Yuma WB AP
26	Cold Bay WSO AP		ARKANSAS
27	Dillingham FAA AP	79	Benton
28	Dutch Harbor	80	Clarksville
29	Eagle	81	Corning
30	Fairbanks WSFO AP	82	Dumas 1
31	Gambell	83	Eureka Springs
32	Homer WSO AP	84	Fordyce
33	Iliamna FAA AP	85	Fort Smith WB AP
34	Indian Mountain	86	Hope
35	Juneau FAA AP	87	Jonesboro
36	Klawock	88	Mammoth Spring
37	Kodiak WSO AP	89	Morrilton
38	Kotzebue WSO AP	90	Mount Ida 1
39	Mantanuska AG EX STN	91	Mountain HMC of ENG
40	McGrath WSO AP	92	Newport
41	Nome WSO AP	93	Siloam Springs
42	Northway FAA AP	94	Stuttgart 9 ESE
43	St. Paul Island WSO AP		CALIFORNIA
44	Talkeetna WSO AP	95	Alturas
45	Valdez WSO AP	96	Ash Mountain
46	Yakutat WSO AP	97	Baker
	ARIZONA	98	Bishop WBO
47	Aguila	99	Blythe AP
48	Ajo	100	Bowman Dam
49	Betatakin	101	Bridgeport
50	Black River Pumps	102	Buttonwillow
51	Bowie	103	Daggett AP

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE Location	Index Number	STATE Location
	CALIFORNIA, Continued		COLORADO, Continued
104	Death Valley	157	Gunnison
105	Denair	158	Hayden
106	El Capitan Dam	159	Hermit 9 SE
107	El Centro	160	Holly
108	Eureka WBO	161	Holyoke

Index Number	STATE / Location
109	Fairmont
110	Forest Glen
111	Fresno WB AP
112	Glennville
113	Haiwee
114	Hayfield Reservoir
115	Lava Bed National Mon.
116	Lompoc
117	Los Angeles WB AP
118	Manzanita Lake
119	Mitchell Caverns
120	Mountain Pass
121	Mount Shasta
122	Needles AP
123	Orick Prairie Creek Pk
124	Orleans
125	Oroville 1 WSW
126	Paso Robles AP
127	Priest Valley
128	Randsburg
129	Sacramento WB AP
130	Saint Helena
131	Salinas 3 E
132	San Diego WB AP
133	San Francisco WB AP
134	Santa Barbara
135	Shasta Dam
136	Susanville AP
137	Termo
138	Thermal CAA AP
139	Tiger Creek Ph
140	Tracy Pumping Plant
141	Tustin Irvine Ranch
142	Victorville
143	Willits 1 NE
144	Willows
145	Yosemite National Park
146	Yreka
	COLORADO
147	Akron CAA AP
148	Alamosa WB AP
149	Canon City
150	Del Norte
151	Eagle CAA
152	Fort Collins
153	Grand Junction WB AP
154	Grand Lake
155	Grant
156	Greely
162	La Junta CAA AP
163	Las Animas 1 N
164	Limon
165	Maybell
166	Mesa Verde National Pk.
167	Montrose No. 2
168	Paradox 2 SE
169	Parker 9 E
170	Rifle
171	Springfield 7 WSW
172	Stratton
173	Tacony 10 SE
174	Timpas 13 SW
175	Walden
176	Walsenburg
	CONNECTICUT
177	Danbury
178	Middletown 4 W
	DELAWARE
179	Georgetown 5 SW
180	Middletown 2 S
	FLORIDA
181	Apalachicola WB City
182	Avon Park
183	Belle Glade Expt. Sta.
184	Bradenton
185	Chipley 3 E
186	Clermont 6 SSW
187	Crestview FAA AP
188	Cross City 2
189	Everglades
190	Fort Drum
191	Fort Myers WB AP
192	Gainesville 2 SW
193	Homestead Expt. Station
194	Jacksonville WB AP
195	Key West WB Airport
196	Live Oak 2 ESE
197	Milton Expt. Station
198	Monticello 2 S
199	Palatka
200	Tallahassee WB AP
201	Titusville 2 W
202	Vero Beach FAA Airport
203	Weeki Wachee
	GEORGIA
204	Alma CAA Airport
205	Appling 2 NW
206	Atlanta WB Airport

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE / Location
	GEORGIA, Continued
207	Brooklett 1 W
208	Brunswick
209	Cornelia
210	Dublin
211	Jasper
212	Lafayette
213	Macon WB Airport
214	Morgan 1 W
215	Siloam
216	Talbotton
217	Tifton 2 N
	HAWAII
218	Ewa Plantation
219	Haleckala Expt. Farm
220	Hana 354
221	Hana 355
222	Honolulu WSFO 703 AP
223	Kaanapali AP 435.1
	IDAHO, Continued
259	Twin Falls WSO
260	Wallace Woodland Pk
261	Warren
	ILLINOIS
262	Aurora College
263	Carbondale Airport
264	Chicago WB Airport
265	Dixon
266	Elgin
267	Fairfield
268	Farmer City
269	Galesburg
270	Griggsville
271	Harrisburg
272	Hoopeston
273	La Harpe 1 SW
274	Moline WB Airport
275	Pana

224	Kahuku 912
225	Kainaliu 732 AP
226	Kealia 1112
227	Kekaha 944
228	Koloa 936
229	Kualapuu
230	Kukuihaele 206
231	Lihue WSO AP
232	Makapuu Point 724
233	Maunaloa 511
234	Puako 95.1
	IDAHO
235	Arbon 2 nw
236	Arrowrock Dam
237	Bruneau
238	Burley CAA AP
239	Cambridge
240	Cobalt
241	Craters of Moon NM
242	Deadwood Dam
243	Deer Flat Dam
244	Dubois Expt. Station
245	Fairfield RS
246	Fenn RS
247	Idaho Falls CAA AP
248	Island Park Dam
249	May RS
250	Montpelier RS
251	Moscow U of I
252	Orofino
253	Palisades Dam
254	Riggins RS
255	Saint Maries
256	Salmon 1 N
257	Sandpoint Expt. Sta.
258	Stanley
276	Paris Waterworks
277	Peoria WB Airport
278	Peru 2 W
279	Rockford CAA AP
280	Sparta
281	Walnut
282	Windsor
	INDIANA
283	Delphi
284	Ft. Wayne WB Baer AP
285	Greensburg
286	Hartford City
287	Hobart 1 NE
288	Indianapolis WB AP
289	Plymouth Power Sub-Sta.
290	Salem
291	Terre Haute 8 S
292	Washington
293	Waterloo
294	West Lafayette 6 NW
	IOWA
295	Castana 4 E
296	Clarinda
297	Decorah Dry Run
298	Des Moines WB AP
299	Dubuque QB Airport
300	Forest City
301	Fort Dodge
302	Grinnell
303	Grundy Center 5 NE
304	Guthrie Center
305	Iowa City
306	Iowa Falls 1 N
307	Oakland 2 E
308	Oelwein
309	Osage

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE Location
	IOWA, Continued
310	Rock Rapids
311	Sibley
312	Storm Lake 2 E
313	Swea City 5 NW
	KANSAS
314	Alton 6 E
315	Cedar Bluff Dam
316	Centralia
317	Chanute CAA AP
318	Coldwater
319	Concordia WSO AP
320	Cottonwood Falls
321	Eureka
322	Great Bend
323	Hays 1 S
324	Hill City CAA AP
325	Howard
326	Lakin
327	Leoti
328	McDonald
329	Oberlin
330	Ottawa
331	Pratt
332	Salina CAA AP
333	Scott City
334	Sublette
335	Tribune 1 W
336	Troy
337	Wichita WB Airport
338	Yates Center
	KENTUCKY
	LOUISIANA, Continued
361	Natchitoches
362	Oberlin Fire Tower
363	Ruston L P I
364	Shreveport WB AP
365	Tallulah
366	Vermilion Lock
	MAINE
367	Augusta CAA Airport
368	Bangor Dow Field
369	Caribou WB Airport
370	Clayton Lake 2
371	Fort Kent
372	Jonesboro
373	Long Falls Dam
374	Millenocket
375	Portland WB Airport
376	Presque Isle
377	Ripogenus Dam
378	Rumford 3 SW
379	Squa Pan Dam
	MARYLAND
380	Baltimore WB AP
381	Frederick Police Bar.
382	Hagerstown
383	Oakland 1 SW
384	Owings Ferry Land.
	MASSACHUSETTS
385	Amherst
386	Clinton
387	East Wareham
388	Rockport 1 ESE

339	Campbellsville	389	Stockbridge
340	Carrollton Lock 1	390	Worcester CAA AP
341	Heidelberg Lock 14		MICHIGAN
342	Hopkinsville 2 E	391	Alberta Ford FRCNTR
343	Leitchfield	392	Alma
344	Madisonville	393	Alpena State Forest
345	Middlesboro	394	Ann Arbor U of Mich.
346	Murray	395	Big Rapids Waterworks
347	Scottsville	396	Caro
348	Tomahawk	397	Chatham Expt. Farm
349	Vanceburg Dam 32	398	Cheboygan
350	Waynesburg 6 E	399	Fayette Sack Bay
351	Williamstown	400	Fife Lake State Park
	LOUISIANA	401	Gull Lake Expt. Farm
352	Belah Fire Tower	402	Hale Five Channels Dam
353	Boothville WSBO City	403	Hesperia
354	DeRidder	404	Houghton FAA AP
355	Hackberry 8 SSW	405	Houghton Lake State For.
356	Hammond 3 NW	406	Ironwood Power Co.
357	Houma 1	407	Ishpeming
358	Lake Charles WSO AP	408	Jackson CAA Airport
359	Melville	409	Manistee Power Co.
360	Morgan City	410	Newberry State Hospital

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE Location	Index Number	STATE Location
	MICHIGAN, Continued		MISSISSIPPI, Continued
411	St. James Beaver Is.	463	Saucier Experimental For.
412	Sandusky	464	State College
413	Sault St. Marie WB AP	465	Tunica
414	South Haven Expt. Farm	466	University
415	Stephenson 5 W	467	Vicksburg WB City
416	Watersmeet US Forest	468	Waynesboro 1 E
	MINNESOTA	469	Winona 3 ENE
417	Argyle		MISSOURI
418	Artichoke Lake	470	Anderson 1 SW
419	Babbitt 2 SE	471	Arcadia
420	Baudette 21 SSE	472	Bethany
421	Cambridge EPLTC Col.	473	Canton Lock & Dam 20
422	Canby	474	Carrollton
423	Cass Lake Forest Sta.	475	Doniphan
424	Cook 18 W	476	Edgerton
425	Fosston Power Plant	477	Grant City
426	Glenwood	478	Harrisonville
427	Grand Marais Coast Guard	479	Jackson
428	Gunflint Lodge	480	Jefferson City Radio KWS
429	Hibbing FAA AP	481	Kirksville
430	International Falls WP AP	482	Lamar
431	Isle 8 N	483	Lebanon
432	Minneapolis-St. Paul WBAP	484	Moberly
433	Moose Lake 1 SE	485	Princeton
434	Morris WC School	486	Saint Joseph WB AP
435	North Mankato	487	Saint Louis WB AP
436	Park Rapids	488	Salem
437	Pine River Dam Creeks Lake	489	Springfield
438	Pokegama Dam	490	Tarkio CAA AP
439	Red Lake Falls	491	Union 2 SE
440	Rosemount Ag. Expt. Station	492	Vandalia
441	Rothsay	493	Warsaw No. 1
442	St. Cloud WB AP		MONTANA
443	Sandy Lake Dam Libby	494	Austin 1 W
444	Stewart	495	Babb 6 NE
445	Tracy Power Plant	496	Billings WB AP
446	Wadena	497	Branderberg
447	Wannaska 8 SE	498	Broadus
448	Willmar State Hospital	499	Carlyle 12 NW
449	Winnebago	500	Circle
450	Zumbrota	501	Conrad
	MISSISSIPPI	502	Content
451	Booneville	503	Cut Bank CAA AP
452	Brookhaven	504	Deer Lodge 3 W

453	Canton	505	Divide 2 NW
454	Collins	506	Drummond Aviation
455	Forest Post Office	507	Ekalaka
456	Holly Springs Expt. Station	508	Flatwillow 4 ENE
457	Meredian WSO AP	509	Forks 5 NE
458	Moorhead	510	Geraldine
459	Natchez	511	Gibson Dam
460	Pascagoula Junior High	512	Glasgow WSO AP
461	Port Gibson	513	Glendive
462	Russell 2 WNW	514	Great Falls WB AP

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE Location	Index Number	STATE Location
	MONTANA, Continued		NEBRASKA, Continued
515	Harlem	568	Walthill
516	Havre WSO AP		NORTH CAROLINA
517	Helena WSO AP	569	Asheville WB City
518	Hysham	570	Cape Hatteras WB
519	Iliad	571	Clayton 3 W
520	Ingomar 11 NE	572	Cullowhee
521	Joplin 6 N	573	Elizabeth City
522	Jordan 22 E Van Norm	574	Elizabethtown Lock 2
523	Kalispell WB AP	575	Greenville
524	Lakeview	576	Hatteras WB City
525	Libby 1 NE RS	577	Henderson 2 SW
526	Lima	578	Hickory Airways
527	Livingston CAA AP	579	Jackson
528	Medicine Lake 3 SE	580	Laurinburg
529	Miles City CAA AP	581	Mount Airy
530	Mosby 18 N	582	Plymouth Expt. Station
531	Mystic Lake	583	Raleigh WB City
532	Norris Madison PH	584	Reidsville 2 NW
533	Rock Springs	585	Salisbury
534	Roy 8 NE	586	Siler City
535	Ryegate 18 NNE	587	Statesville 2 W
536	Saint Ignatius	588	Transou
537	Savage	589	Wilmington CAA AP
538	Seely Lake RS	590	Winston-Salem WB AP
539	Stevensville		NORTH DAKOTA
540	Townsend	591	Amidon
541	Trout Creek RS	592	Bismark WB AP
542	Utica 11 WSW	593	Carson 2 SW
543	Wisdom	594	Dunn Center
544	Wolf Point	595	Edmore 1 W
545	Yellowtail Dam	596	Fessenden
	NEBRASKA	597	Foxholm Wildlife Refuge
546	Broken Bow No. 1	598	Grafton State School
547	Columbus	599	Grenora
548	Crescent Lake Game RF	600	La Moure
549	Curtis	601	Leeds
550	Fort Robinson	602	Mayville
551	Fremont	603	McClusky
552	Geneva	604	McHenry 5 N
553	Grand Island WB AP	605	McLeod 3 E
554	Hay Springs 12 S	606	Mott Railroad Station
555	Holdrege	607	Napoleon 2 SE
556	Imperial	608	Powers Lake
557	Kingsley Dam	609	Underwood
558	Mullen 21 NW	610	Upham Wildlife Refuge
559	Newport	611	Watford City 20 SE
560	North Loup		NEW HAMPSHIRE
561	O'Neill	612	Concord WB AP
562	Osmond	613	First Connecticut Lake
563	Scottsbluff CAA AP	614	Lancaster
564	Stapleton	615	Mount Washington WB
565	Syracuse	616	Plymouth 2 E
566	Valentine LKS Game		NEW JERSEY
567	Wahoo	617	Essex Fells Sewage Plt

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE Location	Index Number	STATE Location
	NEW JERSEY, Continued		NEVADA, Continued
618	Freehold	670	Fallon Expt. Station
619	High Point Park	671	Hawthorne Babbitt
620	Indian Mills 2 W	672	Key Pittman WMA
621	Newark WSO AP	673	Las Vegas WB AP
622	Somerville	674	Lehman Caves Nat. Mon.
623	Tuckerton 1 S	675	Leanord Creek Ranch
624	Woodstown 2 NW	676	Logandale UN Expt. Farm
	NEW MEXICO	677	Lovelock FAA AP
625	Alamogordo	678	Lund
626	Animas	679	McDermitt
627	Augustine	680	Pahranagat Wildlife RF
628	Beaverhead RS	681	Pequop
629	Bell Ranch	682	Pioche
630	Bitter Lakes Wildlife RF	683	Reno WFSO AP
631	Bosque Del Apache	684	Ruby Lake
632	Carlsbad CAA AP	685	Rye Patch Dam
633	Carrizozo	686	Searchlight
634	Clayton WB AP	687	Silverpeak
635	Crossroads 1 NNE	688	Smokey Valley
636	El Vado Dam	689	Snowball Ranch
637	Elephant Butte Dam	690	Sutcliff-Warrior Pt.
638	Florida	691	Tonopah AP
639	Fort Sumner	692	Tuscarora
640	Fruitland	693	Winnemucca WBO
641	Hickman		NEW YORK
642	Hope	694	Arcade
643	Jemez Springs	695	Aurora Research Farm
644	Jornada Exptl. Range	696	Bath
645	Las Vegas CAA AP	697	Binghamton WB AP
646	Lordsburg	698	Bridgehampton
647	Lybrook	699	Canton WB City
648	McGaffey	700	Cooperstown
649	Melrose	701	Geneva SCS
650	Moutainair	702	Ithaca Cornell Univ.
651	Pearl	703	Liberty
652	Pedernal	704	Lockport 2 NE
653	Quemado	705	Millbrook
654	Sandia Park	706	Mineola
655	Springer	707	Norwich
656	Taos	708	Old Forge Thendara
657	Torreaon Navajo Mission	709	Oswego WB City
658	Tucumcari 3 NE	710	Plattsburgh
	NEVADA	711	Rochester WB AP
659	Austin	712	Syracuse WB AP
660	Battle Mountain AP	713	Troy Lock and Dam
661	Blue Jay Hiway Station	714	Tupper Lake Sunmount
662	Caliente	715	Utica CAA AP
663	Carson City	716	Westfield
664	Contact	717	Whitehall
665	Deeth		OHIO
666	Dufferena	718	Akron-Canton WB AP
667	Elko WBO	719	Caldwell 6 NW
668	Ely WBO	720	Celina 3 NE
669	Eureka	721	Cleveland WB AP

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE Location	Index Number	STATE Location
	OHIO, Continued		OREGON, CONTINUED
722	Dayton	774	Moro
723	Defiance	775	North Bend CAA AP
724	Fredricktown Sewage Plant	776	Mitchell 17 SW OCH
725	Kenton 2 W	777	Owyhee Dam
726	New Lexington 2 NW	778	Paisley
727	New Philadelphia	779	Pilot Rock
728	Sandusky WB City	780	Portland WB AP

729		Toledo Express WS AP
730		Washington Court House
	OKLAHOMA	
731		Ada
732		Altus
733		Ardmore
734		Beaver
735		Boise City
736		Cherokee
737		Fort Reno
738		Elk City
739		Fort Supply Dam
740		Goodwell
741		Guthrie
742		Idabel
743		Lawton
744		Marlow
745		McAlester CAA AP
746		Muskogee
747		Mutual
748		Norman
749		Okemah 1
750		Oklahoma City WB AP
751		Pawhuska
752		Ponca City CAA AP
753		Pryor
754		Seminole
755		Smithville
756		Weatherford
757		Webbers Falls
758		Woodward Field Station
	OREGON	
759		Austin 3 S
760		Brothers
761		Cascadia Ranger Station
762		Clatskanie 3 W
763		Corvallis State College
764		Elkton 2 W
765		Gold Beach Ranter Sta.
766		Hart Mountain Refuge
767		Heppner
768		Hood River Expt. Sta.
769		Huntington
770		Malheur Refuge HDQ
771		Medford WB AP
772		Metolius 1 W
773		Monument 2
781		P-Ranch Refuge
782		Rome
783		Roseburg Airport
784		Sexton Summit WB
785		Sprague River
786		Suntex
787		Tillamook
788		Toketee Falls
789		Wallowa
790		Wickiup Dam
	PENNSYLVANIA	
791		Allentown Beth WP AP
792		Eagles Mere
793		Ebensberg Sewage Plant
794		Erie Airport
795		Harrisburg 3 S WB AP
796		Jamestown 2 NW
797		Lewistown
798		Lock Haven 2
799		Pittsburg WB AP 2
800		Ridgway
801		Salina 3 W
802		Tionesta 2 SE Dam
803		Tobyhanna
804		Wellsboro 3 S
805		Williamsport 4 E WB AP
	RHODE ISLAND	
806		Kingston
	SOUTH CAROLINA	
807		Aiken
808		Anderson
809		Clemson College
810		Kershaw
811		Kingstree
812		McColl
813		Newberry
814		Orangeburg 2 SE
815		Santuck 4 SE
816		Spartanburg WB AP
817		Yemassee 4 W
	SOUTH DAKOTA	
818		Aberdeen
819		Armour
820		Bridgewater
821		Brookings
822		De Smet
823		Eureka

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE	Location
	SOUTH DAKOTA, Continued	
824		Fort Meade
825		Highmore 1 W
826		Hopewell 1 SE
827		Hot Springs
828		Huron WB AP
829		Long Valley
830		Madison 1 WNW
831		Madison Research Farm
832		Milesville
833		Mobridge
834		Pierre CAA AP
835		Porcupine 16 NW
836		Redig 9 NE
837		Sioux Falls WB AP
838		Timber Lake
839		Usta 8 WNW
840		Wasta
841		Waubay Natl. Wildlife
842		Winner
843		Wood
	TEXAS, Continued	
876		Corpus Christi WB AP
877		Crane
878		Del Rio WP AP
879		Dimmitt 2 N
880		Eagle Pass
881		Eastland
882		Falcon Dam
883		Follett
884		Fort Stocton
885		Fowlerton
886		Gainesville
887		Goldthwaite
888		Gonzales
889		Henrietta
890		Hillsboro
891		Hondo
892		Jayton
893		Johnson City
894		Kaufman
895		Laredo No. 2

	TENNESSEE
844	Allardt
845	Athens
846	Bristol WB Airport
847	Centerville
848	Cookeville 1 W
849	Covington
850	Dover 1 NW
851	Dresden
852	Jefferson City Evap.
853	Lexington
854	Pikeville
855	Samburg Wildlife Ref.
856	Shelbyville 2 SW
857	Springfield Expt. Sta.
	TEXAS
858	Abilene WB Airport
859	Anahuac 6 E
860	Balmorhea Expt. Pan.
861	Beeville
862	Benavides 2
863	Big Spring WB AP
864	Blanco
865	Borger 3 W
866	Brownsville WB AP
867	Cameron
868	Carrizo Springs
869	Childress
870	Coleman
871	College Station CAA
872	Columbus
873	Conroe 6 E
874	Cope Ranch
875	Cornudas Service Sta.
896	Livingston
897	Lubbock WB Airport
898	Lufkin CAA Airport
899	Marathon
900	Marfa 2
901	Marshall
902	Mason
903	Matagorda
904	McCook
905	McGregor
906	Mexia
907	Miami
908	Morton
909	Ozona
910	Palestine WB City
911	Pandale
912	Panther Junction
913	Paris
914	Pecos
915	Port Mansfield
916	Port O'Connor
917	Presidio
918	Roscoe
919	San Angelo
920	San Antonio WB AP
921	Seminole
922	Seymour
923	Sherman
924	Silverton
925	Sonora
926	Spearman
927	Stratford
928	Taylor
929	Temple

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE Location
	TEXAS, Continued
930	Thompson 3 WSW
931	Tyler 5 NE
932	Van Horn
933	Vega
934	Victoria WB Airport
935	Weatherford
936	Ysleta
	UTAH
937	Altamont
938	Alton
939	Bear River Refuge
940	Black Rock
941	Blanding
942	Boulder
943	Desert Exptl. Range
944	Hanksville Airport
945	Heber
946	Jensen
947	Koosharem
948	Lucin
949	Moab
950	Monument Valley Mission
951	Moroni
952	Oak City
953	Park Valley
954	Partoun
955	Sunnyside
956	Thompson
957	Tooele
958	Veyo Power House
959	Wendover
960	Woodruff
	VIRGINIA
	WASHINGTON, Continued
980	Cedar Lake
981	Clearwater
982	Colville WB Airport
983	Conconully
984	Concrete
985	Ellensburg
986	Ellensburg WB Airport
987	Ephrata CAA Airport
988	Grays River Hatchery
989	Harrington 4 ENE
990	Hatton 10 E
991	Lind 3 NE Expt. Sta.
992	Long Beach Expt. Sta.
993	Mazama 2 W
994	Olympia WB Airport
995	Packwood
996	Pomeroy
997	Port Angeles
998	Republic
999	Richland 2 NW
1000	Sappho 8 EESSniders
1001	Spokane WB Airport
1002	Tatoosh Island WB
1003	Wenatchee
1004	Yakima WB Airport
	WEST VIRGINIA
1005	Beckley VA Hospital
1006	Charleston Kan AP
1007	Clarksburg 1
1008	Huntington WSO Airport
1009	Kearneysville 1 NW
1010	Lewisburg
1011	Parkersburg WB City

961	Big Meadows	1012	Romney
962	Blacksburg 2	1013	Rowlesburg 1
963	Buchanan	1014	Spruce Knob
964	Burkes Garden	1015	Webster Springs
965	Columbia		WISCONSIN
966	Manassas	1016	Ellsworth
967	Mathews 2 ENE	1017	Kewaunee
968	Monterey	1018	Lake Geneva
969	Painter 2 W	1019	Laona Ranger Station
970	Pennington Gap 1 W	1020	Mellen Power Co. Dam
971	Richmond WB Airport	1021	Mondovi
972	Winchester Research Lab	1022	Neillsville
973	Wise 1 SE	1023	New London
	VERMONT	1024	Portage Lock
974	Burlington	1025	Prentice 5 W
975	Montpelier Airport	1026	Rhinelander Water Works
976	Woodstock	1027	St. Croix Falls
	WASHINGTON	1028	Solon Springs
977	Aberdeen 20 NNE	1029	Stevens Point
978	Anacortes	1030	Viroqua
979	Bremerton Navy Yard	1031	West Bend

Table H-6, Cont'd. Locations for climatological data in the parameter editor.

Index Number	STATE Location	Index Number	STATE Location
	WISCONSIN, Continued		WYOMING, Continued
1032	Weyerhauser	1056	Redbird
	WYOMING	1057	Reno
1033	Alva 5 SSE	1058	Rock Springs WB AP
1034	Bitter Creek	1059	Saratoga
1035	Black Mountain	1060	Thermopolis 24 WNW
1036	Border 3 N		DISTRICT OF COLUMBIA
1037	Buffalo Bill Dam	1061	Washington, D. C.
1038	Burgess Junction		PACIFIC ISLANDS
1039	Casper WB Airport	1062	Canton Island
1040	Clearmont 2 SW	1063	Guam WSMO
1041	Douglas Aviation	1064	Johnston Island WB AP
1042	Dubois	1065	Koror WB Airport
1043	Gillette	1066	Kwajalein WB Airport
1044	Jackson	1067	Majuro WB Airport
1045	Kemmerer	1068	Pago Pago WB Airport
1046	Lake Yellowstone	1069	Ponape Weather Bureau
1047	Lander WB Airport	1070	Truk Moen Island WSO AP
1048	Laramie CAA Airport	1071	Wake Island WSO Airport
1049	Lusk	1072	Yap Island WB
1050	Midwest		PUERTO RICO
1051	Muddy Gap	1073	Gurado Substation
1052	Phillips	1074	Humacao
1053	Pinedale	1075	Isabella Substation
1054	Powell	1076	Nanati
1055	Rawlins CAA Airport	1077	Utuado

Table H-7. Idealized leaf area index data for representative crops.

Frac. of Grow. Season	Leaf Area Index, m^2/m^2: Corn Grain	Corn Pop	Corn Silage	Corn Sweet	Winter Small Grain Barley	Winter Small Grain Oats	Winter Small Grain Rye	Winter Small Grain Wheat	Spring Sm Gr Barley	Spring Sm Gr Oats
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.09	0.09	0.09	0.09	0.44	0.42	0.47	0.47	0.34	0.32
0.2	0.19	0.18	0.20	0.18	0.88	0.84	0.90	0.90	0.58	0.54
0.3	0.23	0.22	0.32	0.22	0.90	0.90	0.90	0.90	0.90	0.90
0.4	0.49	0.40	0.55	0.40	0.90	0.90	0.90	0.90	1.25	1.20
0.5	1.16	1.05	1.30	1.05	1.58	0.98	0.90	0.90	1.80	1.60
0.6	2.97	2.80	3.00	2.80	3.00	2.62	1.75	1.62	2.50	2.30
0.7	3.00	2.85	3.00	2.85	3.00	3.00	3.00	3.00	3.00	3.00
0.8	2.72	2.80	2.90	2.90	3.00	3.00	3.00	3.00	3.00	3.00
0.9	1.83	1.80	2.00	1.80	2.14	3.00	3.00	3.00	2.25	2.90
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Frac. of Grow. Season	Leaf Area Index, m^2/m^2: Spring Wheat	Sorghum Grain	Sorghum Forage	Millet Row	Millet Bdcst	Peanuts 2-Row	Peanuts 4-Row	Soybeans Row	Soybeans Bdcst	Cotton
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.37	0.09	0.10	0.16	0.20	0.15	0.20	0.15	0.19	0.13
0.2	0.60	0.19	0.30	0.45	0.60	0.42	0.55	0.40	0.48	0.28
0.3	0.90	0.23	0.80	1.20	1.50	1.80	2.00	1.90	2.10	1.05
0.4	1.28	0.54	1.50	2.10	2.25	2.80	2.95	2.60	2.70	2.15
0.5	1.70	1.35	2.80	2.90	3.00	3.00	3.00	3.00	3.00	2.96
0.6	2.30	2.98	3.00	3.00	3.00	3.00	3.00	2.96	3.00	3.00
0.7	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.92	2.95	2.96
0.8	3.00	2.72	3.00	2.95	2.96	3.00	3.00	2.30	2.35	2.92
0.9	3.00	1.84	2.80	2.30	2.45	2.80	2.85	1.15	1.25	1.78
1.0	0.00	1.00	2.00	1.80	1.85	2.60	2.65	0.50	0.50	1.00

Frac. of Grow. Season	Leaf Area Index, m^2/m^2: Tobacco	Squash	Cabbage	Mustard	Onions	Potatoes	Tomatoes	Snap Beans	South. Peas	Spinach
0.0	0.03	0.00	0.02	0.00	0.02	0.00	0.04	0.00	0.00	0.00
0.1	0.18	0.07	0.08	0.15	0.15	0.10	0.30	0.09	0.15	0.15
0.2	0.40	0.30	0.18	0.40	0.45	0.25	0.60	0.40	0.45	0.40
0.3	1.50	1.00	0.30	1.00	1.00	0.43	1.20	1.00	1.80	1.00
0.4	2.00	1.80	0.60	1.80	1.75	0.63	2.30	2.00	2.85	1.80
0.5	3.00	2.20	1.00	2.45	1.90	2.23	3.00	2.50	3.00	2.45
0.6	3.00	2.40	1.35	2.85	2.00	2.62	3.00	2.80	2.95	2.85
0.7	2.90	2.50	1.60	3.00	1.96	3.00	2.70	3.00	2.80	3.00
0.8	2.70	2.45	1.80	3.00	1.50	2.76	2.00	2.70	2.20	3.00
0.9	1.50	2.30	1.95	2.65	1.10	2.48	1.50	2.00	1.30	2.65
1.0	0.20	1.80	2.00	2.20	0.70	2.15	0.90	1.10	0.80	2.20

Table H-7, Continued. Idealized leaf area index data for representative crops.

Frac. of Grow Season	Leaf Area Index, m^2/m^2: Lettuce Leaf	Lettuce Head	Cucumbers	Watermelon	Cantalope	Alfalfa	Bell Pep.	Carrots	Egg Plant	Sugar Beets
0.0	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.00	0.05	0.00
0.1	0.10	0.09	0.05	0.05	0.05	0.15	0.15	0.09	0.18	0.10
0.2	0.40	0.25	0.10	0.10	0.10	0.40	0.45	0.15	0.60	0.25
0.3	1.00	0.45	0.35	0.30	0.30	1.00	1.10	0.35	1.50	0.50

0.4	1.80	0.75	0.95	0.90	0.95	1.70	1.90	0.60	2.10	1.95
0.5	2.45	1.15	1.45	1.25	1.35	2.50	2.50	1.20	2.80	2.30
0.6	2.85	1.50	2.10	2.00	2.05	3.00	3.00	1.80	3.00	2.80
0.7	3.00	2.00	2.80	2.70	2.75	3.00	3.00	2.10	3.00	3.00
0.8	3.00	2.20	2.90	2.80	2.80	3.00	3.00	2.15	2.95	3.00
0.9	2.75	2.30	2.50	2.00	2.40	2.90	2.80	1.95	2.80	2.95
1.0	2.40	2.40	2.20	1.00	1.20	2.70	2.20	1.85	2.25	2.40

Frac. of Grow Season	Leaf Area Index, m^2/m^2									
	Turn- ips	Broc- coli	Cauli- flower	Sweet Pot.	Rice	Winter Rape	Pas- ture	Coni- fer	Hard- wood	Con.+ Hdwd.
0.0	0.00	0.04	0.04	0.02	0.00	0.00	0.00	5.50	0.50	2.50
0.1	0.15	0.12	0.10	0.08	0.10	0.25	0.70	5.50	0.50	2.50
0.15	0.25	0.20	0.16	0.13	0.15	0.32	1.20	5.50	4.00	4.50
0.2	0.40	0.30	0.25	0.20	0.30	0.40	1.80	5.50	4.00	4.50
0.3	1.00	0.75	0.65	0.45	0.80	0.80	3.00	5.50	4.00	4.50
0.4	1.80	1.25	1.10	2.00	1.20	0.80	3.00	5.50	4.00	4.50
0.5	2.45	1.80	1.60	2.80	1.75	1.10	3.00	5.50	4.00	4.50
0.6	2.85	2.25	2.00	3.00	2.50	1.80	2.90	5.50	4.00	4.50
0.7	3.00	2.45	2.40	3.00	2.90	2.45	2.70	5.50	4.00	4.50
0.8	3.00	3.00	2.55	3.00	3.00	2.90	1.96	5.50	4.00	4.50
0.85	2.90	2.95	2.61	2.92	3.00	2.90	1.50	5.50	4.00	4.50
0.9	2.65	2.90	2.70	2.85	3.00	2.90	0.90	5.50	0.50	2.50
1.0	2.20	2.00	2.20	1.90	2.80	2.40	0.50	5.50	0.50	2.50