

INTRODUCTION

GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) was developed to simulate edge-of-field and bottom-of-root-zone loadings of water, sediment, pesticides, and plant nutrients from the complex climate-soil-management interactions. It has evolved through several versions from its inception in 1984 to the present, and has been evaluated in numerous climatic and soil regions of the world. Special studies have resulted in model modifications, and oftentimes the improvements in comprehension resulted in new version releases.

A paper was published by Leonard et al. (1987) to document the basic concepts of hydrology, erosion, and pesticide components in **GLEAMS**. Another paper has been published by Leonard et al. (1990) on representation of pesticide metabolites. Knisel (1993) documented the plant nutrient component as well as some modifications of hydrology to accommodate nutrient simulations.

It has long been recognized that **GLEAMS** (Knisel, 1993.) was not Y2K compliant in that it utilized a 2-digit year and considered leap year every 4 years irrespective of century. Recently, model users requested that the model be made Y2K compliant in order to recognize the 21st century since their agency operations required **GLEAMS** applications beyond 1999. Some additional features had evolved after release of version 2.10 in 1993, and it was decided to incorporate all of these features and Y2K compliance into a new version, 3.0.

All changes are noted below, and include the following features:

- (1) Y2K compliance
- (2) Simulate up to 366 pesticides simultaneously
- (3) A 2-compartment pesticide degradation component
- (4) Increased pesticide database in the pesticide parameter editor
- (5) Remove all biomass in the top 1-cm of soil with sod harvest
- (6) Reduced rainfall energy in Northern and Southern latitudes
- (7) Input solar radiation in metric units

Y2K Compliance

Programming modifications to accommodate proper leap-year testing were made, in accordance with recommended procedure, and tested to make sure that appropriate years and centuries resulted in leap years. Since some model users may have many parameter files that would require needless change to 4-digit year input, the programming was modified to read those files without changes. This was done by assuming simulation beginning in 19XX since climatic data are not yet available for the year 2000 and beyond. Therefore, no changes are needed in existing parameter Files to run the **GLEAMS** model version 3.0. However, users cannot edit existing parameter files with the presently available parameter editors without making the conversion to 4-digit years.

Modifications of the model are such that running existing parameter files will result in the appropriate 7-digit year/day in daily output. That is, an old file parameter **HBDATE** of 73001 will result in storm output date 1973001 if there is rainfall on January 1, 1973. This applies to all components. Also, a statement will be printed to your computer monitor that states the model encountered a 2-digit year simply to alert user, but it will not stop the simulation.

Increased Number of Pesticides to Simulate Simultaneously

The number and size of arrays in **GLEAMS** increased, and some special modifications evolved over time that required special considerations for compiling, such as with OS2 Fortran Compiler, Microsoft Fortran Compiler for Windows 3.1 or Windows NT. These executable files could be trans-

ported to other DOS-based P/Cs or operating systems. One such special feature was a modification to run up to 366 pesticides simultaneously for pesticide screening instead of the nominally maximum of 10. Such change can be accommodated by compilation with Microsoft Developer Studio, a 32-bit Fortran compiler for Windows 95, Windows 98, or Windows NT. It is assumed that all current GLEAMS users have P/Cs with Windows 95, Windows 98, or Windows NT operating systems. Thus, the available executable program, **GLEAMS30.EXE** will not run on DOS-based computers.

It will operate efficiently under the DOS-Prompt in the Windows-based P/Cs. Those users who want to make changes in the source code made available must have a 32-bit Windows-based compiler in order to not exceed storage limitations.

Two-Compartment Pesticide Degradation Component

A 2-compartment pesticide degradation component was developed for **GLEAMS** by Truman, Leonard, and Davis (1998). It better describes the degradation process of those compounds that have a rapid initial degradation but slows considerably in the latter stages. Use of the component requires flow rates between the two compartments which are known for only a few pesticides. It results in continued pesticide runoff and leaching whereas the usual first-order process shows no compound remaining. The pesticide parameter editor includes input capability for the coefficients to describe those rates. If they are left blank by **GLEAMS** users, it defaults to the usual first-order process. The feature is incorporated in version 3.0 mainly as a research tool, and the coefficients are not known for the pesticides listed in the parameter-editor database.

Increased Pesticide Database in the Pesticide Parameter Editor

In the earlier version of **GLEAMS**, there were 243 pesticides built into the pesticide database (parameter editor). Those were from the ARS-NRCS-EXT database. An additional 93 compounds from the Hornsby, Wauchope, and Herner publication (Hornsby et al., 1995). Foliar characteristics were added in accordance with the procedures by Willis et al. (1980), Willis and McDowell (1987), and Willis (1992). The complete list of compounds and their properties are given in the pesticide section of this User Manual.

Removal of Biomass in the Top 1-cm of Soil with Sod Harvest

At the request of Dr. A.B. Bottcher, Soil & Water Engineering Technology, Inc., Gainesville, Florida, **GLEAMS** 2.10 was modified to remove all biomass (residue on the surface and roots) as well as any nutrient pools to represent sod harvest on turf farms. Since this is becoming an increasingly common practice, the feature is incorporated in this version 3.0. If the model user sets the dry matter ratio, DMY in the plant nutrient component, to 100.0, it signals the model to remove the biomass on harvest date. It shows up in the output as a harvest and removal.

Reduced Rainfall Energy in Northern and Southern Latitudes

Rainfall energy is considerably lower in the upper latitudes of the Northern and Southern hemispheres. Studies in Finland were reported by Drs. S. Rekolainen and M. Posch, Ministry of the Environment, Helsinki (Rekolainen and Posch, 1994) for modification of the **CREAMS** model (Knisel, 1980). Their procedures were adapted in **GLEAMS**

2.10 for further studies, and the modifications are incorporated **GLEAMS** 3.0. The procedure is to be published in the Journal of Agricultural Water Management (Knisel and Turtola, 1999).

Input Solar Radiation in Metric Units

Earlier versions of **GLEAMS** required user input of the 12 mean monthly values of solar radiation in Langleys/day even for those who use metric input. In **GLEAMS** 3.0, radiation can (must) be input in MJ/square meter/day. The model will convert to Langleys/day for model calculation. THIS IS THE ONLY KNOWN EXCEPTION WHERE EXISTING PARAMETER FILES CANNOT BE RUN WITH GLEAMS 3.0. IF SOLAR RADIATION IS IN LANGLEYS/DAY, AND THE PARAMETER FLGMET=1, THE MODEL WILL MULTIPLY LANGLEYS/DAY BY 23.9 TO GIVE AN ERRONEOUS VALUE. For developing new parameter files, the metric values can be entered in the parameter editor.

References

- Hornsby, A.G., R.D. Wauchope, and A.E. Herner. 1995. *Pesticide Properties in the Environment*. Springer-Verlag, New York. 217 pp.
- Knisel, W.G. (Ed). 1980. **CREAMS**: A field scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S. Dept. of Agri., Sci. and Edu. Adm., Conservation Research Report No. 26. 640 pp. U.S. Govt. Print. Off., Washington, DC, USA.
- Knisel, W.G. (Ed). 1993. **GLEAMS**: Groundwater Loading Effects of Agricultural Management Systems. Univ. of Georgia, Coastal Plain Expt. Sta, Bio. and Agri. Engr. Dept., Publ. No. 5, 260 pp.
- Knisel, W.G., and E. Turtola. 1999. **GLEAMS** model application on a heavy clay soil in Finland. (Manuscript re-submitted to J. Agri. Water Man. after revisions for reviewers comments)
- Leonard, R.A., W.G. Knisel, and D.A. Still. 1987. **GLEAMS**: Groundwater Loading Effects of Agricultural Management Systems. *Trans., Amer. Soc. of Agri. Engrs.* 30(5):1403-1418.
- Leonard, R.A., W.G. Knisel, F.M. Davis, and A.W. Johnson. 1990. Validating **GLEAMS** with field data for fenamiphos and its metabolites. *J. Irr. And Drain. Engr.* 116:24-35.
- Rekolainen, S., and M. Posch. 1994. Adapting the **CREAMS** model for Finnish conditions. *Nordic Hydrology*, 24:309-322.
- Truman, C.C., R.A. Leonard, and F.M. Davis. 1998. **GLEAMS**-TC: A two-compartment model for simulating temperature and soil water content effects on pesticide losses. *Soil Science*, 163(5):362-373.
- Willis, G.H. 1992. Personal communication, June 17, 1992.
- Willis, G.H., and L.L. McDowell. 1987. Pesticide persistence on foliage. *Environ. Contam. Toxicol. Reviews*. 100:23-73.
- Willis, G.H., W.F. Spencer, and L.L. McDowell. 1980. The interception of applied pesticides by foliage and their persistence and washoff potential. Vol. 3, Ch. 18. In: Knisel, W.G. (Ed), **CREAMS**: A field scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S. Dept. of Agri., Sci. and Edu. Adm., Conservation Research Report No. 26. pp. 595-606. U.S. Govt. Print. Off., Washington, DC, USA.

IMPLEMENTATION OF GLEAMS MODEL VERSION 3.0 ON A MICROCOMPUTER

The latest version of the **GLEAMS** model, Version 3.0, has been implemented on microcomputers with windows-operating systems (Windows95, Windows98, and WindowsNT). The executable code was generated with Microsoft Developer Studio, and can only be run on computers with windows-operating systems. It runs efficiently in batch mode under DOS-PROMPT.

GLEAMS Version 3.0 is written mainly in Fortran 77 with some recent modifications in Fortran 99. Filenames must adhere to the standard DOS convention, and appropriate drive designations should be used where required. 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.

The FORTRAN source code for **GLEAMS** is split into blocks of 40K to 80K, for convenience, as in previous versions. Use of compilers other than Microsoft Developer Studio may require some modification, e.g. in the statements which open the input and output files. The expansion of GLEAMS to consider up to 366 pesticides simultaneously, as mentioned in the introduction, may also result in arrays that cause storage problems with other compilers.

There are 28 files as listed and described below.

GLEAMS30.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
GLMS3PCP.DAT	Daily rainfall data
GLMS3TMP.DAT	Mean daily temperature data
GLMS3HYD.PAR	Hydrology parameters
GLMS3ERO.PAR	Erosion parameters
GLMS3PST.PAR	Pesticide parameters
GLMS3NUT.PAR	Nutrient parameters
GLMS3HYD.OUT	Hydrology output
GLMS3ERO.OUT	Erosion output
GLMS3PST.OUT	Pesticide output
GLMS3NUT.OUT	Nutrient output
GLMS3SEL.OUT	Selected variable output
TEST	Batch file for running GLEAMS30 in batch mode

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.

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 **GLMS3** subdirectory), type **<GLEAMS30>** 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.

GLEAMS version 3.0 can be operated in batch mode which allows specifying data, parameter, and output file names in the batch file rather than entering the filenames as prompted in interactive mode. The batch file named **TEST** is provided for user information. This file was used to execute **GLEAMS30** with the sample data and parameters and generate the sample output files. The order of the files as shown is essential. If only the hydrology and erosion components are to be run, then the pesticide and nutrient parameter files and output files should not be included in the batch file. Likewise, if hydrology, erosion and pesticides are run, the nutrient parameter and output files should not be listed. If selected variables are not specified (in the hydrology parameter file), the selected output file can be eliminated. Inclusion of a selected output file name in the batch file when variables are not selected will not result in a run-time error.

Writing of null files can be done in the batch or interactive modes, but it is not generally recommended. An experienced user, for example a pesticide scientist, may opt to not write hydrology and erosions output files since runoff, percolation, and sediment yield are summarized in the pesticide output. This can be accomplished by entering **< nul >** at the filename prompt for hydrology output and erosion output. Likewise, in the batch file, **< nul >** can be entered where the hydrology and erosion output filenames should be placed. **DO NOT LEAVE THE FILENAMES BLANK IN THE BATCH FILE, OR DO NOT PRESS ENTER WITHOUT A FILENAME IN THE INTERACTIVE MODE.** This would result in a run-time error.

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 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 (ENTER)	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 characteristics. 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 **GLEAMS30**.

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 the hydrology parameter file
ERROR H2	Wilting point must be less than field capacity	Reduce BR15 or increase FC in the hydrology parameter file
ERROR H3	Clay + silt must be ≤ 100.0	Reduce CLAY or SILT fraction in the hydrology parameter file
ERROR H4	Porosity must be ≤ 1.0	Reduce POR in the hydrology parameter file
ERROR H5	Number of horizons must be > 0 and ≤ 5	Change NOSOHZ in the hydrology parameter file
ERROR H6	ICROP must be in the range 0 - 90	Check/change value of ICROP in the 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 the 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 in the parameter file. Pesticide number (I).	Check number of metabolites for ith pesticide in the parameter file. NPEST includes parent and metabolites.
ERROR N1	Underflow in N initialization	Check TN , CNIT , POTMN , and ORGNW --negative values encountered
ERROR N2	Underflow in P initialization	Check TP , CLAB , and ORGPW --negative value encountered
ERROR N3	Overflow in Nitrogen initialization	TN out of range (too large)
ERROR N4	Overflow in Phosphorus initialization	TP out of range (too large)

USER GUIDE

The user guide for **GLEAMS** includes hydrology, erosion, pesticides, and plant nutrients. The entire user manual is presented to describe 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. Even though sensitivity is somewhat site-specific, an indication of relative 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 **GLEAMS** modifications have been internal with little change in input. The 4-digit year for Y2K compliance occurs in each component. The only other change in model parameters is associated with the two-compartment pesticide degradation and are discussed in the pesticide component. Otherwise, model users will recognize essentially the same user manual as in earlier versions.

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 columns 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 periods.

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.

```
|...+...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 centimeters.

```
|...+...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.

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 OR OMIT CARDS! IT WILL BOMB!**

```

|...+....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  °F 01
CPES 36    39.0 40.5 46.0 51.5 61.5 45.0 41.0 46.0 51.0 49.5  °F 02
CPES 36    42.5 53.0 60.5 61.5 61.5 64.5 66.5 45.0 41.0 48.0  °F 03
CPES 36    52.5 55.5 57.5 60.5 48.0 47.0 47.5 53.5 36.5 41.5  °F 04
CPES 36    36.5 45.0 55.0 42.0 45.0 55.5 56.5 62.0 62.5 55.5  °F 05
CPES 36    54.5 58.0 41.0 48.0 44.5 37.5 27.0 37.0 45.0 51.5  °F 06
CPES 36    50.0 57.0 62.5 65.5 68.5 58.0 49.5 55.5 63.0 69.5  °F 07
CPES 36    71.5 71.0 67.0 67.5 63.5 50.5 52.5 44.5 52.0 60.5  °F 08
CPES 36    54.5 52.5 59.0 64.0 68.5 72.0 66.5 67.0 66.0 67.0  °F 09

```

Figure 3. Sample mean daily temperature data (°F) 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  °C 01
CPES 36     3.9  4.7  7.8 10.8 17.5  7.2  5.0  7.8 10.6  9.7  °C 02

```

CPES 36	5.8	11.7	15.8	17.5	17.5	18.1	19.2	7.2	5.0	8.9	°C 03
CPES 36	11.4	13.1	14.2	15.8	8.9	6.7	8.6	11.9	2.5	5.3	°C 04
CPES 36	2.5	7.2	12.8	5.6	7.2	13.1	13.6	16.7	16.9	13.1	°C 05
CPES 36	12.5	14.4	5.0	8.9	6.9	3.1	-2.8	2.8	7.2	10.8	°C 06
CPES 36	10.0	13.9	16.9	18.6	20.3	14.4	9.7	13.1	17.2	20.8	°C 07
CPES 36	21.9	21.7	19.4	19.7	17.5	10.3	11.4	6.9	11.1	15.8	°C 08
CPES 36	12.5	11.4	15.0	17.8	20.3	22.2	19.2	19.4	18.9	19.4	°C 09

Figure 4. Sample mean daily temperature data (°C) 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.

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.

* * * * *

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. 1973138 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 1936000 to initialize soil water before 1936001.

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.

))))))))))))))))))))))))))))))))))))))
* Changed to 4-digit year in version 3.0 for Y2K compliance

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.

Card 5: **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.

Card 6: **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:

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

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

Use field map and calculate **WLW** as follows:

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

or, for metric:

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

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, in³/in³ (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 each soil horizon, 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 in each soil horizon (percent of soil mass), e. g. 1.10

- Card 13: **CLAY(I)** for I = 1 to **NOSOZH** on Card 7
- CLAY()** Percent of soil mass in each soil horizon with particle size equal to or less than 0.002 mm, e. g. 10.0
-
- Card 14: **SILT(I)** for I = 1 to **NOSOZH** on Card 7
- SILT()** Percent of soil mass in each soil horizon 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 **NOSOZH** on Card 7
- PH()** Soil pH in each soil horizon, e. g. 7.0
- If **ISOIL** = 0, 1, or 3 on Card 7, skip Card 15. Do not leave a blank line. The parameter editor, **HYD.EXE**, automatically accepts or skips card 15.
-
- Card 16: **BSAT(I)** for I = 1 to **NOSOZH** on Card 7
- BSAT()** Base saturation, percent, in each soil horizon, e. g. 37.2
- If **ISOIL** = 0, 1, or 3 on Card 7, skip Card 16. Do not leave a blank line. The parameter editor, **HYD.EXE**, automatically accepts or skips card 16.
-
- Card 17: **CACO3(I)** for I = 1 to **NOSOZH** on Card 7
- CACO3()** Calcium carbonate content, %, in each soil horizon, e. g. 4.0
- If **ISOIL** = 0, 2, or 3 on Card 7, skip Card 17. Do not leave a blank line. The parameter editor, **HYD.EXE**, automatically accepts or skips card 17.
-
- Cards 18,19: **TEMPX(1-12)**
- TEMPX()** Mean monthly maximum temperature for each month, °F (°C), e. g. 55.0 61.4 (12.8 16.3)
- Ten values on Card 18; two values 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, °F (°C), e. g. 35.0 38.7 (1.7 4.4)
- Ten values on Card 20; two values on Card 21. 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 22,23: **RAD(1-12)**

RAD() Mean monthly solar radiation for each month, Langleys (MJ/cm²), e. g. 250.0 (10.46)

Ten values on Card 22; two values on Card 23. 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 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; two values on Card 25. 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 26,27: **DEWPT(1-12)**

DEWPT() Mean monthly dew point temperature for each month, °F (°C), e. g. 37.0 45.0 (2.8 7.2)

Ten values on Card 26; two values on Card 27. 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.)

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

HBYR Beginning year of hydrology simulation, used to set rotation for reuse of parameters, four digits, e. g. 1969

HEYR Ending year of hydrology simulation, used to set rotation feature, four digits, e. g. 1976

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. A continuous winter (Northern Hemisphere) small grain or winter cover crop, with a leaf area index (**LAI**) in autumn continuing into the next year requires **IROT** = 2 in order to get the **LAI** from January 1 to harvest and from planting to December 31. In this case, a single crop occurs in 2 successive years.

NYRFOR Number of years in forest before simulation begins, e. g. 5

Leave blank for **FOREST** = 0 or **FLGNUT** = 0.

))))))))))))))))))))))))))))))))))))))
* Changed to 4-digit year in version 3.0 for Y2K compliance

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
(For a winter cover crop, e.g. 1275)
- DHRVST** Date of harvesting crop **ICROP**, year of the rotation cycle plus the Julian day of the year, e. g. 1274
(For a winter cover crop harvested in the spring, e.g. 2150)
- 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 a winter cover crop or a green manure crop plowed down, or corn cut green for silage 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 (**HYD.EXE**) 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.

Card 33: **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

Parameters are described to help 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. 1964000 even though such a date does not exist, or 1963365. 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 1973138 to allow initialization.

Hydrology Output Options--**HYDOUT**

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**

FLGNUT, FLGPST

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. **FLGNUT** = 0 results in skipping plant nutrient simulation while **FLGNUT** = 1 results in plant nutrient simulation. Likewise, **FLGPST** = 0 skips pesticide simulation, and **FLGPST** = 1 results in pesticide simulation.

FLGGEN

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.

FLGPEN

GLEAMS contains two options 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 for **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. If metric values of precipitation are input, the units must be in centimeters instead of the nominal millimeters measurements.

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 application 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, 0 = no, or 1 = yes.

GLEAMS Forest Option--**FOREST**

GLEAMS was modified earlier 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 as many as 366 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. Extra-extra large, unmanageable files could be generated with this selection.

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 output. 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. The weighting can be made with an auxiliary program to operate with the selected output file.

Initial Parameters

Drainage Area--**DAREA**

The drainage area 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, 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 made 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 flatwoods 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 daily soil water accounting procedure estimates the available storage, 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

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

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

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

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

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

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 suspended 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 is 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 management 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 development 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 (below 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, then **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 too 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 phosphorus 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 textural 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 estimates 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% saturation. **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/cm³. Porosity is estimated from bulk density, BD, by assuming the specific gravity of soil particles is 2.65 g/cm³. The relationship is

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

Porosity of most mineral soils generally range from about 0.30 to 0.60 cm³/cm³, but values as high as 0.70 cm³/cm³ have been observed for some forest soils and peat 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 contains 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 appropriate 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, intermediate, 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/cm³. 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. Quartzipsammments, 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 in 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 soils 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 phosphorus.

A new soils data base, "3SD", was developed by the USDA-SCS using the Soil Survey Lab for physical and chemical characteristics. The data base was available on a limited basis in 1995.

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 temperature 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 over 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 (mi or km) 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 °C or °F for dew point temperature.

Updatable Parameters

Rotation Cycles: **HBYSR, HEYSR, IROT, NYRFOR**

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, **HBYSR** and **HEYSR**, 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.

When simulating a forest (**FOREST** > 0, card 4) and plant nutrients are also being simulated (**FLGNUT** = 1, card 4) the model user must estimate the number of years the forest has been growing when simulation begins (**NYRFOR**). This is necessary for the model to estimate the forest biomass at the beginning of simulation with its approximate nitrogen, phosphorus, and carbon content.

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. **HYD.EXE** automatically includes a card with **ICROP** = 0.

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 represented 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 harvesting 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 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 rotation 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 growth period may have a leaf area of 0.5 to 1.0 m²/m² 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, e.g. 1125. The date for ending irrigation is specified by **DEIRR** as year of the rotation cycle and Julian day, e.g. 1260.

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 required and can be left blank.

In western irrigated areas, particularly those areas that have high salt content in the soil, excess irrigation is applied before planting (pre-plant) to leach salts out of the root zone. The pre-plant 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 pre-planting 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. **GLEAMS** considers the active root depth for irrigation rather than total effective root depth, **RD**.

Leaf Area Index and Crop Height—**LAI**, **CROPHT**

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 (canola) 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 appropriate **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** > 78 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.

LAI data for **ICROP** codes 69-71 (conifer and hardwood and conifer-hardwood forests) built into the model should be used ONLY for mature forests and not for new plantings. When representing developing forests from transplanting to harvest, **ICROP** > 79 should be used with input of **LAI** data to represent the approximate growth pattern. For example, at transplanting early in the year (January-March in the southern U.S.) **LAI** values may be as low as 0.01-0.05 with no increase until **BEGGRO**. Then a very slow increase begins until reaching a maximum of possibly 0.15-0.20 at **ENDGRO** and stays constant until **BEGGRO** the following growing season. During the second and successive growing seasons, growth is more rapid each year between **BEGGRO** and **ENDGRO**, reaching the maximum shown in the built-in **LAI** by the 5th - 8th growing season depending upon climate and species. Fertilization and/or control of competing vegetation are factors in estimating **LAI** values during the developing trees. These are management type decisions that must be supplied by the model user.

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 determines the upward movement of soluble N, P, and pesticides, while plant transpiration is the driving force for plant uptake of these soluble elements.

Perennial 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 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.

REFERENCES

- Calhoun, J. W. 1983. Soil survey of Tift County, Georgia. U. S. Department of Agriculture, Soil Conservation Service, Washington, D. C. 129 pp. and plates.
- Hillel, D. 1980. *Fundamentals of Soil Physics*. Academic Press, New York. 413 pp.
- Jensen, M. E., R. D. Burman, and R. G. Allen (Eds.) 1990. Evapotranspiration and Irrigation Water Requirements. American Society of Civil Engineers, Manuals and Reports on Engineering Practice, No. 70. 332 pp.
- Knisel, W. G., R. A. Leonard, F. M. Davis, and J. M. Sheridan. 1991. Water balance components in the Georgia Coastal Plain: A **GLEAMS** model validation and simulation. 46(6):450-456.
- Nutter, W. L., F. M. Davis, R. A. Leonard, and W. G. Knisel. 1993. Simulating forest hydrologic response with **GLEAMS**. Unpublished.
- Perkins, H. F. 1987. Characterization data for selected Georgia soils. Georgia Agricultural Experiment Stations, College of Agriculture, University of Georgia, Athens. Special Publication 43. 545 pp.
- Richardson, C. W., and A. D. Nicks. 1990. Weather generator description. In: A. N. Sharpley and J. R. Williams (eds.), *EPIC--Erosion/Productivity Impact Calculator: 1. Model Documentation*. U.S. Department of Agriculture, Technical Bulletin 1768. pp. 93-104.
- Ritchie, J. T. 1972. A model for predicting evaporation for a row crop with incomplete cover. *Water Resources Research* 8(5):1204-1213.
- Smith, R. E., and J. R. Williams. 1980. Simulation of surface water hydrology. In: W. G. Knisel (ed.), **CREAMS: A Field-Scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems**, U. S. Department of Agriculture, Science and Education Administration, Conservation Research Report No. 26, Vol. I, Chapter 2. pp. 13-35.
- U.S. Department of Agriculture, Soil Conservation Service. 1967. Soil survey laboratory data and descriptions for some soils of Georgia, North Carolina, and South Carolina. *Soil Survey Investigations Report No. 16*. 163 pp.
- U.S. Department of Agriculture, Soil Conservation Service. 1972. *National Engineering Handbook: Section 4, Hydrology*. Washington, D. C. 548 pp.
- U.S. Department of Agriculture, Soil Conservation Service. 1984. User's guide for the **CREAMS** computer model--Washington Computer Center version. Washington, D. C. USDA-SCS TR-72. 160 pp.
- Williams, J. R., R. E. Smith, J. D. Nowlin, and A. D. Nicks. 1980. Hydrology. In: W. G. Knisel (ed.), **CREAMS: A Field-Scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems**, U. S. Department of Agriculture, Science and Education Administration, Conservation Research Report No. 26, Vol. II, Chapter 1. pp. 165-192.

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

Variable	Units	Code
<u>DAILY</u>		
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 thru fall	cm, in	7
Precipitation interception	cm, in	8
Precipitation interception and ET	cm, in	9
Snowmelt	cm, in	10
Minimum temperature	°C, °F	20
Maximum temperature	°C, °F	21
Mean temperature	°C, °F	22
Soil temperature by layer	°C, °F	25
Radiation	Langley's, 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 ₂ O 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
Runoff loss, PO ₄ -P	mg/l	911
Sediment loss, NH ₄ -N	kg/ha	915

* Only for use with old parameter files in **GLEAMS** 3.0. See page 45 for new codes for pesticide output.

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

Variable	Units	Code
<u>Annual, Continued</u>		
Runoff	cm, in	3002
Percolation	cm, in	3003
Evapotranspiration	cm, in	3004
Irrigation	cm, in	3006
Precipitation thru fall	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: (Same as 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/ha	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

* Only for use with old parameter files in GLEAMS 3.0. See page 45 for new codes for pesticide output.

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

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 (g/cm ³)	Porosity (POR) (cm ³ /cm ³)	Field Capacity (FC) (cm/cm)	Wilt. Point (BR15) (cm/cm)	Evap. Const. (CONA) (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*	Hydro- logic Condi- tion	Hydrologic Soil Group											
		A			B			C			D		
<u>Fallow</u>													
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
<u>Row Crops</u>													
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
<u>Small Grain</u>													
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
<u>Close-seeded legumes, or rotation meadow</u>													
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
<u>Pasture or Range</u>													
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
<u>Meadow</u>													
---	good	51	59	66	67	74	78	79	82	84	85	86	87

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		
<u>Woods</u>													
---	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
<u>Farmsteads</u>													
---	----	42	59	67	68	74	78	79	82	84	85	86	87
<u>Roads</u>													
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
109	Fairmont	162	La Junta CAA AP
110	Forest Glen	163	Las Animas 1 N
111	Fresno WB AP	164	Limon
112	Glennville	165	Maybell
113	Haiwee	166	Mesa Verde National Pk.
114	Hayfield Reservoir	167	Montrose No. 2
115	Lava Bed National Mon.	168	Paradox 2 SE
116	Lompoc	169	Parker 9 E
117	Los Angeles WB AP	170	Rifle
118	Manzanita Lake	171	Springfield 7 WSW
119	Mitchell Caverns	172	Stratton
120	Mountain Pass	173	Tacony 10 SE
121	Mount Shasta	174	Timpas 13 SW
122	Needles AP	175	Walden
123	Orick Prairie Creek Pk	176	Walsenburg
124	Orleans		CONNECTICUT
125	Oroville 1 WSW	177	Danbury
126	Paso Robles AP	178	Middletown 4 W
127	Priest Valley		DELAWARE
128	Randsburg	179	Georgetown 5 SW
129	Sacramento WB AP	180	Middletown 2 S
130	Saint Helena		FLORIDA
131	Salinas 3 E	181	Apalachicola WB City
132	San Diego WB AP	182	Avon Park
133	San Francisco WB AP	183	Belle Glade Expt. Sta.
134	Santa Barbara	184	Bradenton
135	Shasta Dam	185	Chipley 3 E
136	Susanville AP	186	Clermont 6 SSW
137	Termo	187	Crestview FAA AP
138	Thermal CAA AP	188	Cross City 2
139	Tiger Creek Ph	189	Everglades
140	Tracy Pumping Plant	190	Fort Drum
141	Tustin Irvine Ranch	191	Fort Myers WB AP
142	Victorville	192	Gainesville 2 SW
143	Willits 1 NE	193	Homestead Expt. Station
144	Willows	194	Jacksonville WB AP
145	Yosemite National Park	195	Key West WB Airport
146	Yreka	196	Live Oak 2 ESE
	COLORADO	197	Milton Expt. Station
147	Akron CAA AP	198	Monticello 2 S
148	Alamosa WB AP	199	Palatka
149	Canon City	200	Tallahassee WB AP
150	Del Norte	201	Titusville 2 W
151	Eagle CAA	202	Vero Beach FAA Airport
152	Fort Collins	203	Weeki Wachee
153	Grand Junction WB AP		GEORGIA
154	Grand Lake	204	Alma CAA Airport
155	Grant	205	Appling 2 NW
156	Greely	206	Atlanta WB Airport

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

Index Number	STATE	Location	Index Number	STATE	Location
GEORGIA, Continued			IDAHO, Continued		
207		Brooklett 1 W	259		Twin Falls WSO
208		Brunswick	260		Wallace Woodland Pk
209		Cornelia	261		Warren
210		Dublin	ILLINOIS		
211		Jasper	262		Aurora College
212		Lafayette	263		Carbondale Airport
213		Macon WB Airport	264		Chicago WB Airport
214		Morgan 1 W	265		Dixon
215		Siloam	266		Elgin
216		Talbotton	267		Fairfield
217		Tifton 2 N	268		Farmer City
HAWAII			269		Galesburg
218		Ewa Plantation	270		Griggsville
219		Halekala Expt. Farm	271		Harrisburg
220		Hana 354	272		Hoopeston
221		Hana 355	273		La Harpe 1 SW
222		Honolulu WSFO 703 AP	274		Moline WB Airport
223		Kaanapali AP 435.1	275		Pana
224		Kahuku 912	276		Paris Waterworks
225		Kainaliu 732 AP	277		Peoria WB Airport
226		Kealia 1112	278		Peru 2 W
227		Kekaha 944	279		Rockford CAA AP
228		Koloa 936	280		Sparta
229		Kualapuu	281		Walnut
230		Kukuihaele 206	282		Windsor
231		Lihue WSO AP	INDIANA		
232		Makapuu Point 724	283		Delphi
233		Maunaloa 511	284		Ft. Wayne WB Baer AP
234		Puako 95.1	285		Greensburg
IDAHO			286		Hartford City
235		Arbon 2 nw	287		Hobart 1 NE
236		Arrowrock Dam	288		Indianapolis WB AP
237		Bruneau	289		Plymouth Power Sub-Sta.
238		Burley CAA AP	290		Salem
239		Cambridge	291		Terre Haute 8 S
240		Cobalt	292		Washington
241		Craters of Moon NM	293		Waterloo
242		Deadwood Dam	294		West Lafayette 6 NW
243		Deer Flat Dam	IOWA		
244		Dubois Expt. Station	295		Castana 4 E
245		Fairfield RS	296		Clarinda
246		Fenn RS	297		Decorah Dry Run
247		Idaho Falls CAA AP	298		Des Moines WB AP
248		Island Park Dam	299		Dubuque QB Airport
249		May RS	300		Forest City
250		Montpelier RS	301		Fort Dodge
251		Moscow U of I	302		Grinnell
252		Orofino	303		Grundy Center 5 NE
253		Palisades Dam	304		Guthrie Center
254		Riggins RS	305		Iowa City
255		Saint Maries	306		Iowa Falls 1 N
256		Salmon 1 N	307		Oakland 2 E
257		Sandpoint Expt. Sta.	308		Oelwein
258		Stanley	309		Osage

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

Index Number	STATE	Location	Index Number	STATE	Location
	IOWA, Continued			LOUISIANA, Continued	
310		Rock Rapids	361		Natchitoches
311		Sibley	362		Oberlin Fire Tower
312		Storm Lake 2 E	363		Ruston L P I
313		Swea City 5 NW	364		Shreveport WB AP
	KANSAS		365		Tallulah
314		Alton 6 E	366		Vermilion Lock
315		Cedar Bluff Dam		MAINE	
316		Centralia	367		Augusta CAA Airport
317		Chanute CAA AP	368		Bangor Dow Field
318		Coldwater	369		Caribou WB Airport
319		Concordia WSO AP	370		Clayton Lake 2
320		Cottonwood Falls	371		Fort Kent
321		Eureka	372		Jonesboro
322		Great Bend	373		Long Falls Dam
323		Hays 1 S	374		Millenocket
324		Hill City CAA AP	375		Portland WB Airport
325		Howard	376		Presque Isle
326		Lakin	377		Ripogenus Dam
327		Leoti	378		Rumford 3 SW
328		McDonald	379		Squa Pan Dam
329		Oberlin		MARYLAND	
330		Ottawa	380		Baltimore WB AP
331		Pratt	381		Frederick Police Bar.
332		Salina CAA AP	382		Hagerstown
333		Scott City	383		Oakland 1 SW
334		Sublette	384		Owings Ferry Land.
335		Tribune 1 W		MASSACHUSETTS	
336		Troy	385		Amherst
337		Wichita WB Airport	386		Clinton
338		Yates Center	387		East Wareham
	KENTUCKY		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		Pascaoula 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	Pahrnagat 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	Pederal	704	Lockport 2 NE
653	Quemado	705	Millbrook
654	Sandia Park	706	Mineola
655	Springer	707	Norwich
656	Taos	708	Old Forge Thendara
657	Torraeon 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	781		P-Ranch Refuge
730		Washington Court House	782		Rome
	OKLAHOMA		783		Roseburg Airport
731		Ada	784		Sexton Summit WB
732		Altus	785		Sprague River
733		Ardmore	786		Suntex
734		Beaver	787		Tillamook
735		Boise City	788		Toketee Falls
736		Cherokee	789		Wallowa
737		Fort Reno	790		Wickiup Dam
738		Elk City		PENNSYLVANIA	
739		Fort Supply Dam	791		Allentown Beth WP AP
740		Goodwell	792		Eagles Mere
741		Guthrie	793		Ebensberg Sewage Plant
742		Idabel	794		Erie Airport
743		Lawton	795		Harrisburg 3 S WB AP
744		Marlow	796		Jamestown 2 NW
745		McAlester CAA AP	797		Lewistown
746		Muskogee	798		Lock Haven 2
747		Mutual	799		Pittsburg WB AP 2
748		Norman	800		Ridgway
749		Okemah 1	801		Salina 3 W
750		Oklahoma City WB AP	802		Tionesta 2 SE Dam
751		Pawhuska	803		Tobyhanna
752		Ponca City CAA AP	804		Wellsboro 3 S
753		Pryor	805		Williamsport 4 E WB AP
754		Seminole		RHODE ISLAND	
755		Smithville	806		Kingston
756		Weatherford		SOUTH CAROLINA	
757		Webbers Falls	807		Aiken
758		Woodward Field Station	808		Anderson
	OREGON		809		Clemson College
759		Austin 3 S	810		Kershaw
760		Brothers	811		Kingstree
761		Cascadia Ranger Station	812		McColl
762		Clatskanie 3 W	813		Newberry
763		Corvallis State College	814		Orangeburg 2 SE
764		Elkton 2 W	815		Santuck 4 SE
765		Gold Beach Ranter Sta.	816		Spartanburg WB AP
766		Hart Mountain Refuge	817		Yemassee 4 W
767		Heppner		SOUTH DAKOTA	
768		Hood River Expt. Sta.	818		Aberdeen
769		Huntington	819		Armour
770		Malheur Refuge HDQ	820		Bridgewater
771		Medford WB AP	821		Brookings
772		Metolius 1 W	822		De Smet
773		Monument 2	823		Eureka

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

Index Number	STATE Location	Index Number	STATE Location
	SOUTH DAKOTA, Continued		TEXAS, Continued
824	Fort Meade	876	Corpus Christi WB AP
825	Highmore 1 W	877	Crane
826	Hopewell 1 SE	878	Del Rio WP AP
827	Hot Springs	879	Dimmitt 2 N
828	Huron WB AP	880	Eagle Pass
829	Long Valley	881	Eastland
830	Madison 1 WNW	882	Falcon Dam
831	Madison Research Farm	883	Follett
832	Milesville	884	Fort Stocton
833	Mobridge	885	Fowlerton
834	Pierre CAA AP	886	Gainesville
835	Porcupine 16 NW	887	Goldthwaite
836	Redig 9 NE	888	Gonzales
837	Sioux Falls WB AP	889	Henrietta
838	Timber Lake	890	Hillsboro
839	Usta 8 WNW	891	Hondo
840	Wasta	892	Jayton
841	Waubay Natl. Wildlife	893	Johnson City
842	Winner	894	Kaufman
843	Wood	895	Laredo No. 2
	TENNESSEE	896	Livingston
844	Allardt	897	Lubbock WB Airport
845	Athens	898	Lufkin CAA Airport
846	Bristol WB Airport	899	Marathon
847	Centerville	900	Marfa 2
848	Cookeville 1 W	901	Marshall
849	Covington	902	Mason
850	Dover 1 NW	903	Matagorda
851	Dresden	904	McCook
852	Jefferson City Evap.	905	McGregor
853	Lexington	906	Mexia
854	Pikeville	907	Miami
855	Samburg Wildlife Ref.	908	Morton
856	Shelbyville 2 SW	909	Ozona
857	Springfield Expt. Sta.	910	Palestine WB City
	TEXAS	911	Pandale
858	Abilene WB Airport	912	Panther Junction
859	Anahuac 6 E	913	Paris
860	Balmorhea Expt. Pan.	914	Pecos
861	Beeville	915	Port Mansfield
862	Benavides 2	916	Port O'Connor
863	Big Spring WB AP	917	Presidio
864	Blanco	918	Roscoe
865	Borger 3 W	919	San Angelo
866	Brownsville WB AP	920	San Antonio WB AP
867	Cameron	921	Seminole
868	Carrizo Springs	922	Seymour
869	Childress	923	Sherman
870	Coleman	924	Silverton
871	College Station CAA	925	Sonora
872	Columbus	926	Spearman
873	Conroe 6 E	927	Stratford
874	Cope Ranch	928	Taylor
875	Cornudas Service Sta.	929	Temple

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

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

))Q

Leaf Area Index, m ² /m ²										
Frac. of Grow. Season	Corn				Winter Small Grain				Spring Small Grain	
	Grain	Pop	Silage	Sweet	Barley	Oats	Rye	Wheat	Barley	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

))Q

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

))Q

Leaf Area Index, m ² /m ²										
Frac. of Grow. Season	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

))Q

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

Leaf Area Index, m ² /m ²										
Frac. of Grow Season	Lettuce		Cucumbers	Watermelon	Cantalope	Alfalfa	Bell Pep.	Carrots	Egg Plant	Sugar Beets
	Leaf	Head								
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

Leaf Area Index, m ² /m ²										
Frac. of Grow Season	Turnips	Broccoli	Cauliflower	Sweet Pot.	Rice	Winter Rape	Pasture	Conifer	Hardwood	Con.+ Hdwd.
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

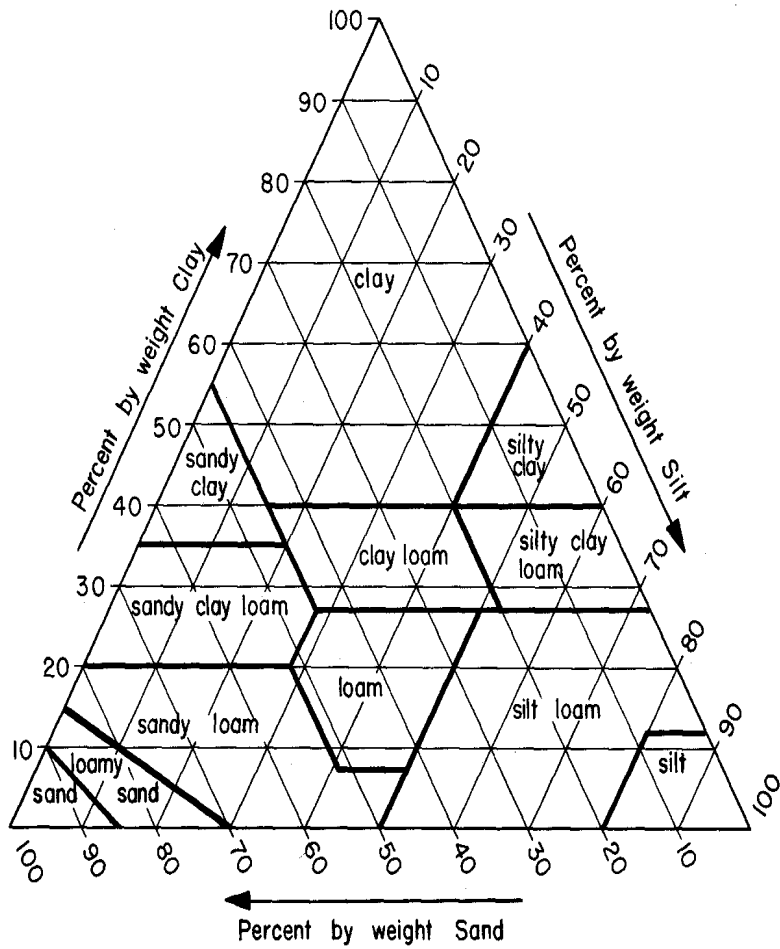


Figure H-1. Soil texture classification triangle (from Hillel, 1980).