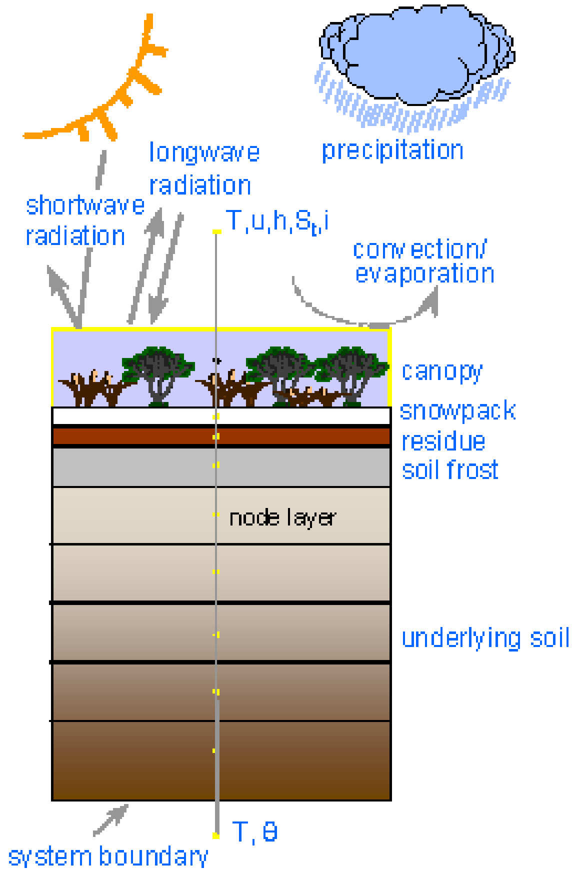
The Simultaneous Heat and Water (SHAW) Model: User's Manual



Gerald N. Flerchinger
Northwest Watershed Research Center
USDA Agricultural Research Service
Boise, Idaho

Technical Report NWRC 2000-10
June 15, 2000

Table of Contents

Background and Overview

The Simultaneous Heat and Water (SHAW) model, originally developed to simulate soil freezing and thawing, simulates heat, water and solute transfer within a one-dimensional profile which includes the effects of plant cover, dead plant residue, and snow. Unique features of the model include: simultaneous solution of heat, water and solute fluxes; detailed provisions for soil freezing and thawing; and a sophisticated approach to simulating transpiration and water vapor transfer through a multi-species plant canopy. Information from the model can be used to assess management and climate effects on biological and hydrological processes, including seedling germination, plant establishment, insect populations, soil freezing, infiltration, runoff, and ground-water seepage.

Wintertime Processes

The SHAW model is one of the most detailed models available for snowmelt and soil freezing and thawing. The model has been shown to accurately simulate frost depth for a wide range of soil, climatic and surface conditions. It is capable of simulating complex wintertime phenomena of freezing effects on moisture and solute migration, solute effects on frost formation, and frozen soil related runoff. Transfer within the soil profile is solved concurrently with the surface energy and mass balance, which includes solar and long-wave radiation exchange, evaporation, and sensible and latent heat transfer.

Evapotranspiration

The model is capable of simulating the effects of a multi-species plant canopy (including standing dead plant material) on heat and water transfer. Temporal variation in plant size, rooting depth, and leaf area index of each plant species is defined by the user. Provisions for a plant canopy in the SHAW model were made using detailed physics of heat and water transfer through the soil-plant-atmosphere continuum. Transpiration is linked mechanistically to soil water by flow through the roots and leaves. Within the plant, water flow is controlled mainly by changes in stomatal resistance, which is computed as a function of leaf water potential.

Input Requirements

Input to the SHAW model includes: initial conditions for snow, soil temperature and water content profiles; daily or hourly weather conditions (temperature, wind speed, humidity, precipitation and solar radiation); general site information; and parameters describing the vegetative cover, snow, residue and soil. General site information includes slope, aspect, latitude, and surface roughness parameters. Residue or litter properties include residue loading, thickness of the residue layer, percent cover and albedo. Input soil parameters are bulk density, saturated conductivity, albedo, and coefficients for the soil water potential-water content relation.

User Interface

A user-interface called ModShell (i.e. Model Shell) has been developed for the SHAW model. ModShell contains menus designed for ease of data entry. ModShell will assist in creating the required input files for the SHAW model and run SHAW. ModShell provides information about input parameters and performs range and error checking for input data.

Getting Started

This section contains information on running the sample input files provided with the model, compiling the model for non-DOS applications, and some other useful information. The model is usually distributed on a floppy diskette or can be downloaded from the SHAW web site (http://www.nwrc.ars.usda.gov/Models/SHAW.html) as a self-extracting compressed file (SHAWZip.exe). Execute this file to extract all of the files to a directory of your choice.

Files included with distribution of the Simultaneous Heat and Water (SHAW) Model include: a "ReadMe.txt" file; an executable image of the SHAW model (SHAW23.EXE); an error interpreter file for the Lahey FORTRAN compiler, just in case the program crashes (Lf90.eer); user-interface software (Model Shell, i.e. ModShell.exe), a sample input file for the user interface (Trialmod.mod); five trial input files for a sample SHAW run (Trial.*); and two directories named "Code" and "Output". The FORTRAN source file for the SHAW model is located in directory "Code"; output from the trial input files are located in the directory "Output". To simplify usage of the SHAW model, place the executable files (ModShell.exe, LF90.eer and SHAW23.exe) into a directory of your choice.

You can run the SHAW model with or without the user-interface software. The user interface has restrictions (such as no options for solute transport and no provisions for changing plant characteristics during the simulation) that can be somewhat limiting. If this is the case, you can use the interface to build the input files, then alter them as needed.

ModShell Sample Input

To run the ModShell user interface, simply double-click on the ModShell.exe file or type 'Modshell' from the command line (don't type quotation marks, capitalization is not necessary). You will then be in the shell program, giving you a choice of menu options to input your data. A sample data set (Trialmod.mod) for ModShell is included with distribution of the model and may be used with the sample weather data file (Trial.wea). Open the Trialmod.mod file from the File Menu. ModShell will create input files for the SHAW 2.3 and will optionally run SHAW from the Run Menu. Output files from the sample ModShell input will be similar to the output files described in the following subsection, but will have an extension of “msh” as specified in the Control Menu. Additional output files may be specified from the Control Menu.

SHAW 2.3 Sample Input

To run the sample input data set without the user-interface software, either double-click on the SHAW23.exe file within Windows or execute SHAW23 from the command line prompt. The five sample input files for the model are:

Trial.inp	input file containing list of input/output files
Trial.wea	input file containing weather data
Trial.sit	input file containing site characteristics
Trial.moi	input file containing soil moisture profiles
Trial.tmp	input file containing soil temperature profiles

Upon executing SHAW23, enter "Trial.inp" when prompted for the file containing the list of input/output files. (The full directory path will need to be entered if the Trial.inp file is not in the same directory as SHAW23.exe.) The trial simulation may take a few seconds depending on the system you are using; the trial data set includes snow, canopy, residue and solutes, so it is likely to run slower than most applications. The trial simulation will generate the following files:

Out.out	output file for general information
Temp.out	simulated soil temperature profiles
Moist.out	simulated soil water profiles
Energy.out	summary of simulated energy balance at the surface
Water.out	simulated water balance summary
Frost.out	simulated frost, thaw, and snow depths

For information on specifying other output files that may be generated or for information on putting together data sets for your own applications, you are referred to either the ModShell user-interface or the section "Input for SHAW 2.3". For information on the ModShell user-interface, see the instructions entitled "SHAW 2.3 User Interface".

Updates and News

Watch the SHAW Home Page on the internet for updates and news on the SHAW model. The address is: http://www.nwrc.ars.usda.gov/Models/SHAW.html. If you do not have access to the internet, you may request this information at the address given below.

Run-time Errors

If for some reason the SHAW model encounters an error, the program will search for the file Lf90.EER to interpret the error and hopefully give the user some clue as to what the problem is. If you get a message that it cannot find this file, make sure it is in a directory where it can be found at the time you run the model.

Compiling the Model

If you wish to run the model on a system other than MS-DOS, you will probably need to compile the program on the particular system you plan to use. The computer code for the model uses standard Fortran 77 and should be transferrable to most any system.

Assistance

If you have questions concerning the model, encounter problems, or need additional information, please contact:

Gerald N. Flerchinger
USDA - ARS
800 Park Blvd, Suite 105
Boise, Idaho 83712
(208) 422-0716
Email: gflerchi@nwrc.ars.usda.gov

SHAW 2.3 User Interface

The SHAW model with user-interface enhancement (MODel SHELL or ModShell) is composed of two distinct programs:

1. A shell (ModShell.exe), which contains menus designed for ease of data entry. This shell will create the required input files for the SHAW model.
2. The SHAW model (Shaw23.exe), which requires input files created by either the shell program (or by the user) along with a user supplied weather data file.

The current version of ModShell is a DOS-based user interface and may seem a bit antiquated compared to Windows-based software. However, the interface can be very efficient for the new user of the SHAW model to set up input files and run the SHAW model. The section of this manual entitled "Input for SHAW 2.3" describes how to create all the input files for the SHAW model without using the user-interface program.

Long file names can cause problems for the interface and the SHAW model. File names and directory names for all ModShell parameter files and SHAW input files should be limited to 8 characters; file extensions are limited to 3 characters.

Data Input

Menu options within the ModShell interface include:

FILE:	allows you to recall input data from a previous simulation or to save the current parameter settings.
CONTROL:	specify dates of simulation and location of input weather file and output files.
SITE:	input general information for the site (latitude, slope, aspect etc.)
VEGETATION:	input data for the plant characteristics.
SOILS:	input data for the soil characteristics.
SURFACE:	input data for residue, snow, and surface characteristics.
RUN MODEL:	invokes the shell program to build all SHAW input files using the current data values, and, optionally, to execute the SHAW model simulation.
EXIT:	exits the program.

By progressing systematically through each of the other menu options prior to the "RUN MODEL" option, the user will be prompted for all of the data necessary to build the input files (with the exception of the weather data file). At any time, and usually prior to invoking the "RUN MODEL" option, the user can save the values input into the interface to a ModShell parameter file, typically giving it an extension of *.mod.

The "RUN MODEL" option may be used to either simply create the input files for the SHAW model, or may be used to run the SHAW model. In either case, this option will build and name the SHAW input data files as follows:

List of Input/Output files	:	*.INP
Moisture Profile Data	:	*.MOI (created optionally)
Temperature Profile Data	:	*.TMP (created optionally)
Site Characteristics	:	*.SIT

where the filename (*) is the same as the ModShell parameter file. The SHAW input files will stored in the same directory as the ModShell parameter file. If the ModShell parameters have not been saved to a file, the default filename for the SHAW input files is SHAW.* and they will be placed in the same directory as the ModShell executable.

Input files for initial temperature and moisture profiles and boundary conditions at the bottom of the soil profile may either be created by the user interface or supplied by the user, in which case the interface will prompt the user for the location of these input files. If desired, ModShell will optionally extend the depth of the profile to 4 meters where soil temperature may be assumed constant. In this case, ModShell will artificially create additional simulation depths down to 4 meters. Temperature at this bottom depth is estimated from the specified annual average air temperature. Initial water content to 4 meters is assumed equal to the deepest input water content.

The user must supply the weather data file in the format described in the “Input for SHAW 2.3“ section of this manual. The name and format (daily or hourly) is specified by the user in the shell program under the “CONTROL” menu option.

Running the Model

Upon selecting the “RUN MODEL” option, the SHAW simulation will begin and the model will create data output files. File extensions and directory paths may be changed in the “CONTROL” menu option. The default names are as follows:

General output information	:	OUT.OUT
Predicted temperature	:	TEMP.OUT
Predicted moisture content	:	MOIST.OUT
Predicted soil water matric potential	:	MATRIC.OUT
Summary of energy flux at surface	:	ENERGY.OUT
Water balance summary	:	WATER.OUT
Water flow between soil nodes	:	WFLOW.OUT
Frost depth and ice content profile	:	FROST.OUT

All the above file names and those for the input files are contained in the List of Input/Output files (SHAW.INP). The user can specify which files are desired and the frequency of output within each file in the "CONTROL" menu option of the user interface.

Input for SHAW 2.3

The SHAW model requires a minimum of five input files: 1) a file containing a list of input and output files; 2) a file containing initial soil moisture profile data; 3) a file containing initial temperature profile data; 4) a file containing weather data; and 5) a file containing general information and site characteristics. Input files specifying plant growth and changing plant parameters are optional. The following sections give a description of the data required in each input file. All data files are read with free format, so data need only be separated with blanks.

List of Input/Output Files

File and directory names for all input and output files should be limited to 8 characters; file extensions are limited to 3 characters. The SHAW model will prompt you for the name of a file containing a list of the input and output files. This file must contain the following information:

<u>Line A</u>

MTSTEP	Flag indicating time step for the weather data. (0 = hourly weather data; 1 = daily weather data; 2 = weather data is at same intervals as NHRPDT in Line D of the Site Characteristics file.
INPH2O	Flag indicating whether input of soil water profiles for initial conditions (and lower boundary if applicable) are in terms of volumetric water content (INPH2O=0) or in matric potential (INPH2O=1).
MWATRXT	Flag indicating if a sink term for water extracted from soil layers will be input. MWATRXT=0 if no sink term is specified; MWATRXT=1 if a sink term is specified. (MWATRXT will be zero for nearly all cases.)

<u>Line A-1</u> Name of input file containing site characteristics. (Limit file path to 80 characters.)

<u>Line A-2</u> Name of input file containing weather data. (Limit file path to 80 characters.)

<u>Line A-3</u> Name of input file containing moisture profile data. (Limit file path to 80 characters.)

<u>Line A-4</u> Name of input file containing temperature profile data. (Limit file path to 80 characters)

<u>Line A-5</u> Name of input file containing soil sink data for water extraction from soil layer. (Omit this line if MATRXT in Line A is zero; limit file path to 80 characters.)

<u>Line B</u>

LVLOUT (1)	Output frequency in hours for entire profile (canopy, snow, residue and soil conditions) in general output file. Value ranges between 0 (no profile output) and 24 (daily output). (However, a value of 1 will result in daily output if daily time steps are used; hourly time steps are required for hourly output.)
LVLOUT (2)	Flag indicating whether side-by side comparison of simulated and measured moisture and temperature profiles is desired (0 if not, 1 if yes).
LVLOUT (3)	Frequency in hours for soil temperature profile output. (Range: 0 to 24.)
LVLOUT (4)	Output frequency in hours for soil water content profile. (Range: 0 to 24)
LVLOUT (5)	Output frequency in hours for soil matric potential. (Range: 0 to 24)
LVLOUT (6)	Output frequency in hours for surface energy balance. (Range: 0 to 24)
LVLOUT (7)	Output frequency in hours for water balance summary. (Range: 0 to 24)
LVLOUT (8)	Output frequency in hours for water flow between soil layers. (Range: 0 to 24)

LVLOUT (9) Output frequency in hours for water extracted by plant roots. (Range: 0 to 24)
LVLOUT (10) Output frequency in hours for snow and frost depth. (Range: 0 to 24)
LVLOUT (11) Output frequency in hours for total salt concentration. (Range: 0 to 24)
LVLOUT (12) Output frequency in hours for soil solution concentration. (Range: 0 to 24)
LVLOUT (13) Time step frequency for updating to screen the day and hour that the program has completed. (Range: ≥0; on faster computers, frequent updating to the screen may significantly increase run times; a value of zero indicates no updating to the screen.)

Line B-1 Name of output file for general output information and hourly or daily temperature, moisture and solute profile. (Limit file path to 80 characters.)

Line B-2 Name of output file for side-by-side comparison of simulated and measured moisture and temperature profiles. (Limit file path to 80 characters.)

Line B-3 Name of output file for simulated temperature profiles. (Limit file path to 80 characters.)

Line B-4 Name of output file for simulated water content profiles. (Limit to 80 characters.)

Line B-5 Name of output file for simulated water potential profiles. (Limit to 80 characters.)

Line B-6 Name of output file for summary of energy flux at surface. (Limit to 80 characters.)

Line B-7 Name of output file for water balance summary. (Limit file path to 80 characters.)

Line B-8 Name of output file for water flow between soil layers. (Limit to 80 characters.)

Line B-9 Name of output file for water extracted by plant roots. (Limit file path to 80 characters.)

Line B-10 Name of output file for frost depth and ice content profile. (Limit to 80 characters.)

Line B-11 Name of output file for total salt concentration profiles. (Limit to 80 characters.)

Line B-12 Name of output file for solute concentration of soil solution. (Limit to 80 characters.)

Moisture Profile Data File

The model requires at least two soil water profiles for the simulation site: one to initialize the profile for the day and hour on which simulation begins; and another on or after the last day of simulation to be used for interpolation of water content at the lower boundary between sampling times (depending on the value of IVLCBC, line J of the site characteristic file). The model will search through the data set for the profile corresponding to the day and hour on which simulation begins, so the file may contain moisture profile data for any number of sampling dates (ordered chronologically) before or after the simulation period. Any moisture profiles in the input file between the start and end of the simulation period will be used to print a comparison of measured and simulated moisture profiles and to interpolate water content at the lower boundary between sampling dates (when IVLCBC is set to 0). Each line within the file should contain the following data:

JDAY		Day of the year
JHR		Approximate hour at which samples were collected
JYR		Year during which samples were collected
VLCDT(I)	$\theta_l + (\rho_i/\rho_l)\theta_i$ or ψ	Soil moisture for each soil node (I=1 to the number of soil nodes, NS). Soil moisture is given as the volumetric water (liquid + ice) content (m^3/m^3) for INPH2O=0 (Line A of Input/Output file) or soil matric potential (m) for INPH2O=1.

Temperature Profile Data File

The discussion for the moisture profile data holds true for the temperature profile data, with the exception that simulated and measured temperature profile comparisons are output only at the moisture sampling times. Each line within the temperature profile data file should contain the following data:

JDAY		Day of the year
JHR		Hour at which temperatures were read
JYR		Year during which temperatures were read
TSDT(I)	T	Temperature data for each soil node (I=1 to the number of soil nodes, NS)

Weather Data File

Format of the weather data depends on the value MTSTEP in Line A of the Input/Output file. For MTSTEP=0, hourly weather data is expected and must be available for every hour during the simulation period. Hourly data must begin on or before hour 1 of the day to start simulation. The format for MTSTEP=2 is identical except data is expected at intervals equal to NHRPDT (line D of the Site Characteristics file) and must start on or before hour NHRPDT of the beginning day of simulation. Each line within the weather data must have the following data (for MTSTEP=0 or 2):

JD		Day of the year
JH		Hour of the day
JYR		Year
TA	T_a	Air temperature in degrees Celsius
WIND	u	Wind speed (mph)
HUM	h	Relative humidity (%)
PRECIP	i	Precipitation (inches)
SNODEN	ρ_{sp}	Density of newly fallen snow if precipitation is snow (g/cm^3) (set to zero if density is unknown -- the model then will calculate a density based on air temperature)
SUNHOR	S_t	Total solar radiation measured on a horizontal surface (W/m^2)

For MTSTEP=1, daily weather data is expected starting on or before the beginning day of simulation. Each line of the daily weather data file must have the following information (for MTSTEP=1):

JD		Day of the year

JYR		Year
TMAX	T_a	Maximum daily air temperature in degrees Celsius
TMIN	T_a	Minimum daily air temperature in degrees Celsius
TDEW	T	Dew-point temperature in degrees Celsius
WIND	u	Total wind run for the day (miles)
PRECIP	i	Daily Precipitation (inches)
SOLAR	S_t	Average daily solar radiation measured on a horizontal surface (W/m^2)

Site Characteristics File

The input file containing site characteristics will vary depending on whether plants, snow or residue are present. The first five lines of the file (Lines A to E) are general input information for: the title of the run; simulation period; location and slope of the site; materials present and number of nodes; and aerodynamic roughness parameters. The next set of lines ("F-series" of lines) are needed only if plants or standing dead plant material are present for the simulation. This data is followed by: snow parameters ("G-series of lines) if snow is likely to be present for the simulation; residue properties ("Line H") if residue is present; solute properties ("I-series" of lines) if solutes are to be considered; and soil properties ("J-series" of lines). Data required for each set of lines are listed below.

<u>Line A</u>

TITLE		Descriptive title (< 80 characters)

<u>Line B</u>

JSTART		Day of year on which simulation begins (may be 1 to 366)
HRSTAR		Hour on which simulation begins (may be 0 to 24)
YRSTAR		Year in which simulation begins
JEND		Day of year on which simulation ends
YREND		Year in which simulation ends

<u>Line C</u>

ALTDEG		Latitude of study site (degrees)
ALTMIN		Latitude of study site (minutes)
SLP	β	Slope of study site (%)
ASPEC	a_s	Aspect of slope (degrees clockwise from due north)
HRNOON	t_o	Time of solar noon. (Mid-point between sunrise and sunset; around 11.5 in the eastern part of the time zone, 12.5 in the western part of the time zone.)
ELEV		Elevation of site above sea level (m)

<u>Line D</u>

NPLANT		Number of different plant species to be simulated. (Include all standing dead plant material as one plant.)
NSP		Number of nodes in snowpack at beginning of simulation
NR		Number of residue nodes ($0 \leq NR \leq 10$). SHAW 2.3 allows a single residue node.
NS		Number of soil nodes ($2 \leq NS \leq 50$)
NSALT		Number of solute types to be simulated ($NSALT \leq 10$)
TOLER		Error tolerance for convergence criteria (ºC for energy balance and fraction of change in matric potential or vapor density for water; suggested value: .001 to

		.01)
NHRPDT		Number of hours per time step (must be evenly divisible into 24 hours, i.e.: 1,2,3,4,6,8,12, or 24 hours)
LEVEL(1)		Debugging output level: 0 = no debugging output is desired; 1 = profile summary every iteration; and 2 = full debugging mode (fluxes, Newton-Raphson matrix, etc.)
LEVEL(2)		Day on which to stop debugging at LEVEL(1) and to start at LEVEL(4)
LEVEL(3)		Hour at which to stop debugging at LEVEL(1) and to start at LEVEL(4)
LEVEL(4)		Secondary level of output (values identical to LEVEL(1))
LEVEL(5)		Day on which to resume debugging at LEVEL(1)
LEVEL(6)		Hour at which to resume debugging at LEVEL(1)

<u>Line E</u>

ZMCM	z_m	Wind-profile surface-roughness parameter for momentum transfer (cm). This parameter is used when there is no plant canopy or snow cover. (Typical value is 0.1 cm for a very smooth surface to 10 cm for a very rough surface.)
HEIGHT		Measurement height for air temperature, windspeed and humidity (m)
PONDMX		Maximum depth of ponding for rainfall or snowmelt (cm)

<u>Line F</u> ("F-series of lines not included if NPLANT=0)

MPLTGRO		Flag indicating whether plant growth curves are input. (0 = no plant growth, i.e. leaf area index and plant height are constant for simulation, and model will determine node spacing within the canopy; 1 = input files for plant growth are specified for each plant; 2 = no plant growth and allows user input of node spacing within plant canopy.)
CANMA	a_c	Coefficient for water potential of dead plant material: $\psi = a_c w_c^{-b_c}$ where w_c is mass basis water content within canopy. (Suggested value: - 53.72 m)
CANMB	b_c	Exponent for water potential of dead plant material. (Suggested value: 1.32)
WCANDT	w	Initial water content of standing dead plant material (kg/kg). (If less than or equal to zero, the model will estimate initial value based on atmospheric humidity.)

<u>Lines F1-1 to F1 - NPLANT</u>

ITYPE(J)		Parameter specifying plant type for plant species *j*: 1 = transpiring plant; 0 = dead plant material. (Only 1 dead plant is allowed.)
LANGLE(J)		Parameter specifying leaf angle for plant species *j*: 0 = vertical leaf angle orientation; 1 = random leaf orientation
CANALB(J)	α_c	Albedo of plant species *j* (<1.0)
TCCRIT(J)	T_c	Temperature above which plant species *j* will transpire (ºC). (Applicable only if ITYPE(J) ≠ 0.)
RSTOM0(J)	r_{so}	Stomatal resistance of plant species *j* with no water stress (s/m). Typical value: 100 s/m.
RSTEXP(J)	n	Empirical exponent relating actual stomatal resistance to leaf potential: $r_s = r_{so} [1 + (\psi_\ell/\psi_c)^n]$. Typical value: 5
PLEAF0(J)	ψ_c	Critical leaf water potential for plant species *j* at which stomatal resistance is twice its minimum value (m). Typical value: -100 m to -300 m.
RLEAF0(J)	r_ℓ	Resistance of leaves for plant species *j* (m^3 s kg^{-1}). Typical value: $1x10^5$ $m^3 s$ kg^{-1} .
RROOT0(J)	r_r	Resistance of roots for plant species *j* (m^3 s kg^{-1}). Typical value: $2x10^5$ m^3 s kg^{-1}.

Lines F2-1 to F2-NPLANT ("F2-series" of lines applicable only if MPLTGRO=0)

PLTHGT(J)		Height of plant species *j* (m)
DCHAR(J)		Characteristic dimension (i.e. width) of leaves of plant species *j* (cm)
PLTWGT(J)		Dry biomass of plant species *j* (kg/m^2)
PLTLAI(J)		Leaf area index of plant species *j*
ROOTDP(J)		Effective rooting depth of plant *j* (m); enter zero if ITYPE(J) = 0.

Line F3-1 to F3-NPLANT ("F3-series" of lines applicable only if MPLTGRO=1)

IFILE(J)		Input file for growth or changing condition of plant species *j*

Line F4-1 to F4-NPLANT ("F4-series" of lines applicable only if MPLTGRO=2)

ROOTDN(J,I) I=1 to NS		Fraction of the total roots for plant species J in soil layer I. (One value for each soil layer)

Line F5 ("F5-series" of lines applicable only if MPLTGRO=2)

NC		Number of desired canopy nodes (NC $\leq$ 10)

Lines F5-1 to F5-NC ("F5-series" of lines applicable only if MPLTGRO=2)

ZC(I)		Distance of node *i* from top of canopy; ZC(1) must be 0.0 (m)
DCHAR(J,I)	d_c	Characteristic dimension of leaves of plant species *j* in canopy layer *i* (cm)
DRYCAN (J,I)		Dry biomass of plant *j* in canopy layer *i* (kg/m^2)
CANLAI(J,I)	L	Leaf area index of plant *j* in canopy layer *i*

Repeat [DCHAR(J,I), DRYCAN(J,I), CANLAI(J,I)] on each line for each plant species, i.e., J = 1 to NPLANT

Lines F5 - NC+1 (Include only if MPLTGRO=2)

ZC(NC+1)		Distance from top of canopy to residue or soil surface (m)

Line G

SNOTMP		Maximum temperature at which precipitation is snow (unless density of snow is supplied in weather data file) (°C)
ZMSPCM	z_m	Wind-profile roughness parameter for momentum transfer with snowcover (cm); suggested value for smooth snow surface: 0.15 cm

Lines G-1 to G-NSP (not included if NSP = 0)

DZSP(I)		Thickness of snow layer *i* at beginning of simulation (m)
TSPDT(I)		Temperature of snow layer *i* at beginning of simulation (°C)
DLWDT(I)		Depth of liquid water stored in snow layer *i* (m)
RHOSP(I)	ρ_{sp}	Bulk density of ice fraction in layer *i* at beginning of simulation (kg/m^3)

Line H (Omit if NR=0)

COVER		Fraction of surface covered by residue
ALBRES	α_r	Albedo of residue; suggested value: 0.25
RLOAD	W	Dry weight of residue on surface (kg/ha)
ZRTHIK		Thickness or depth of residue layer (cm)
GMCDT	w_r	Initial gravimetric water content of residue at start of simulation (kg/kg). (If

		input is less than or equal to zero, the model will estimate initial value based on soil matric potential.)
RESCOF	$1/K_r$	Resistance to vapor transfer (s/m) between residue elements and air voids in residue layer *i*; suggested value 1000-50,000 s/m. (If moisture content of residue layer is not a concern in the simulation, larger resistance values will improve convergence with little effect on the overall simulation.)

<u>Line I-1</u> ("I-series" of lines repeated for each type of solute; omit if NSALT = 0)

SLTDIF(I)	D_o	Diffusion coefficient for solute *i* at 0ºC (m^2/s)
HALFLIF		Half-life of solute *i* in the soil environment (days). (Enter zero if the solute does not degrade over time.

<u>Line I-2</u>

SALTKQ(I,J)	K_d	Partitioning coefficient between soil matrix and soil solution (kg/kg) for solute *i* in soil layer *j* (one value for each soil layer). Values depend on solute and soil type and range from near 0 for chloride, which is not bound to soil particles to about 60 for potassium which is tightly bound to soil particles

<u>Line I-3</u>

SALTDT(I,J)	S	Moles of solute *i* per kg of soil in layer *j* (one value for each soil layer)

<u>Line J</u>

IVLCBC		Flag indicating boundary condition for water flow at bottom of profile: 0 = specified water content; 1 = unit gradient assumed for water flow at lower boundary
ITMPBC		Flag indicating boundary condition for temperature at bottom of profile: 0 = specified temperature; 1 = boundary temperature estimated by model. (If lower temperatures are not available, most accurate simulations may be obtained by extending profile to a depth where temperature can be assumed constant and approximated by mean annual air temperature.)
ALBDRY	α_d	Albedo of dry soil (<1.0). Typical values: 0.15 to 0.30.
ALBEXP	a_α	Exponent for calculating albedo of moist soil: $\alpha = \alpha_d \exp(-a_\alpha\ \theta_l)$. Typical values: 0 to 3.5.

<u>Lines J-1 to J-NS</u>

ZS(I)		Depth in meters of soil node *i;* ZS(1) must be 0.0 (m)
B(I)	b	Cambell's pore-size distribution index for soil layer *i*; $\psi = \psi_e [\theta / \theta_s]^{-b}$
ENTRY(I)	ψ_e	Air-entry potential in meters for soil layer *i* (m)
SATCON	K_s	Saturated conductivity in cm/hr for soil layer *i* (cm/hr)
RHOB(I)	ρ_b	Bulk density in kg/m^3 of soil layer *i* (kg/m^3)
SAT(I)	θ_s	Saturated volumetric moisture content (if greater than calculated porosity, Θ_s is set equal to porosity)
SAND(I)		Percent sand in soil layer *i*
SILT(I)		Percent silt in soil layer *i*
CLAY(I)		Percent clay in soil layer *i*
OM(I)		Percent organic matter in soil layer *i*
ASALT(I)	τ	Molecular diffusion parameter for solutes in soil layer *i*; not required if NSALT=0

DISPER(I)	κ	Parameter for hydrodynamic dispersion coefficient (m); not required if NSALT=0

Plant Growth Files (Optional)

Plant growth files are required only if MPLTGRO=1 (Line F of the Site Characteristics File). One file is required for each plant type, including any standing dead plant material. The name of each file is specified in Lines F3 of the Site Characteristics File. Each line of the plant growth file will contain the plant characteristics for a given day. The model will interpolate values between given days. If a plant is not present for any part of the simulation, a value of zero may given for the leaf area index and plant height. Unlike the temperature and moisture input files, data need not be present for the day on which the simulation begins; the model will interpolate between days to obtain initial conditions at the start of the simulation. Values given in the plant growth files are <u>not</u> adjusted for plant stress or growth-limiting conditions. Each line of the file should contain the following data:

JDAY	Day of year
JYR	Year for observed plant characteristics
PLTHGT(J)	Height of plant species *j* on day JDAY (m)
DCHAR(J)	Characteristic dimension of leaves of plant species *j* on day JDAY (cm)
PLTWGT(J)	Dry biomass of plant species *j* on day JDAY (kg/m^2)
PLTLAI(J)	Leaf area index of plant species *j* on day JDAY
ROOTDP(J)	Effective rooting depth of plant *j* on day JDAY (m)

Soil Source/Sink File (Optional)

The soil source/sink file is used only if MWATRXT (Line A in the List of Input/Output Files) is set to 1 and is not necessary for most model applications. The purpose of the file is to give the user the option to artificially extract (positive) or introduce (negative) water within the soil profile. Examples of where this might be useful is for: sub-surface irrigation; water seeping into the soil profile; and direct input of the output of water extracted by plant roots from a previous run (Line B-9 in the List of Input/Output files). Water extraction from a layer will be limited within the model by the water available within that layer. Introduction of water into the profile is not limited by the model; thus, the user is cautioned that excessive water introduction may cause numerical problems. Input values for each soil layer are assumed to be the cumulative depth of water extracted between observations. Water extracted for each time step between observations will be computed and will be assumed constant. Unlike the temperature and moisture input files, data need not be present for the day on which the simulation begins; there needs to be at least one observation on or before the beginning date of simulation and at least one on or after the ending date.

JDAY	Day of the year
JHR	Hour at which temperatures were read
JYR	Year during which temperatures were read
SOILXT(I)	Cumulative depth of water (m) extracted from for each soil node between current day and hour (JDAY and JHR) and the day and hour on the previous line of data. (I=1 to the number of soil nodes, NS, i.e. one value for each soil node.)

Sample Input Files

List of Input/Output Files

```
0 0 0
TRIAL.SIT
TRIAL.WEA
TRIAL.MOI
TRIAL.TMP
 24  0 24 24  0 24 24  0  0  6  0  0  1
OUT.OUT
PROFIL.OUT
TEMP.OUT
MOIST.OUT
MATRIC.OUT
ENERGY.OUT
WATER.OUT
WFLOW.OUT
ROOTXT.OUT
FROST.OUT
SALTS.OUT
SOLUT.OUT
```

Moisture Profile Data

```
 308  18  86 0.352 0.352 0.337 0.354 0.280 0.290 0.293 0.316 0.364 0.335 0.365
 323  12  86 0.385 0.385 0.366 0.402 0.296 0.317 0.417 0.440 0.503 0.443 0.425
 338  12  86 0.374 0.374 0.365 0.381 0.270 0.290 0.297 0.295 0.336 0.334 0.343
 349  12  86 0.465 0.465 0.353 0.367 0.295 0.310 0.325 0.352 0.433 0.427 0.437
 365  12  86 0.417 0.417 0.350 0.375 0.294 0.311 0.317 0.336 0.376 0.354 0.377
  14  12  87 0.419 0.419 0.335 0.361 0.293 0.301 0.311 0.330 0.372 0.345 0.372
  28  12  87 0.469 0.469 0.364 0.398 0.307 0.318 0.318 0.333 0.372 0.345 0.373
  43  12  87 0.351 0.351 0.357 0.394 0.302 0.324 0.323 0.339 0.381 0.361 0.392
  57  12  87 0.364 0.364 0.352 0.391 0.303 0.313 0.321 0.338 0.375 0.356 0.378
```

Temperature Data

```
 308  18  86    5.7    6.4    7.1    7.8    8.6    9.5   10.3   10.7   11.3   11.8   12.2
 308  21  86    5.3    6.3    7.1 99999    8.6    9.4   10.3   10.7   11.3   11.8   12.2
 309   0  86    5.3    6.2    7.0 99999    8.5    9.4   10.2   10.7   11.3   11.8   12.1
 338   0  86    1.1    1.9    2.8 99999    4.4    5.4    6.2    6.7    7.5    8.4    9.4
 338   6  86    0.5    1.7    2.8 99999    4.5    5.4    6.2    6.7    7.4    8.4    9.4
 338   9  86    0.4    1.5    2.6 99999    4.3    5.3    6.2    6.7    7.4    8.4    9.4
 338  12  86    2.7    2.1    2.8    3.7    4.6    5.4    6.2    6.7    7.5    8.4    9.4
 339  18  86    1.9    2.3    3.0 99999    4.3    5.2    6.0    6.5    7.3    8.3    9.3
 339  24  86    1.9    2.2    3.0 99999    4.3    5.2    6.0    6.4    7.3    8.3    9.3
 340  12  86    2.1    2.3    3.0 99999    4.4    5.1    5.9    6.4    7.3    8.2    9.2
 353   6  86   -0.3    0.3    1.2 99999    2.5    3.5    4.4    5.0    5.9    7.0    8.2
 353  12  86    0.1    0.4    1.2 99999    2.6    3.5    4.4    5.0    5.9    7.0    8.2
 353  18  86    0.1    0.4    1.2 99999    2.5    3.5    4.4    4.9    5.9    7.0    8.2
 354   0  86   -0.5    0.4    1.1 99999    2.6    3.5    4.3    4.9    5.8    7.0    8.1
```

Hourly Weather Data

Hourly weather format is used when MTSTEP (Line A in List of Input/Output Files) is set to 0 or 2.

```
311  0 86   1.4  3.82  98.7 0.02 0        0.0
311  1 86   1.1  4.91 100.5 0.04 0        0.0
311  2 86   0.7  4.59 100.7 0.04 0.10     0.0
311  3 86   0.4  4.81 100.9 0.04 0.10     0.0
311  4 86   0.3  5.66 100.7 0.05 0.10     0.0
311  5 86   0.2  6.35 100.1 0.03 0.10     0.0
                 .
                 .
                 .
338  0 86  -0.8  2.89  99.9 0.00 0       -0.2
338  1 86  -0.6  2.07  99.9 0.00 0       -0.2
338  2 86  -0.5  0.69  99.4 0.00 0       -0.2
338  3 86  -0.3  1.82  98.9 0.00 0       -0.2
338  4 86  -0.7  3.91  97.2 0.00 0       -0.1
338  5 86  -1.0  5.23  97.1 0.00 0       -0.1
338  6 86  -1.4  3.38  98.1 0.00 0       -0.1
338  7 86  -1.3  2.82  98.7 0.00 0       -0.1
338  8 86  -1.1  3.06  97.9 0.00 0        8.8
338  9 86  -1.0  2.29  96.5 0.00 0       55.6
338 10 86  -0.4  1.45  96.3 0.00 0      123.4
338 11 86   0.1  2.66  95.7 0.00 0      157.7
338 12 86   0.7  1.60  95.9 0.00 0      162.2
338 13 86   1.0  1.84  93.1 0.00 0      160.4
338 14 86   1.2  3.71  90.4 0.00 0      131.4
338 15 86   1.5  2.93  90.4 0.00 0       58.6
338 16 86   1.0  1.91  91.5 0.00 0       16.4
338 17 86   0.5  1.05  96.4 0.00 0        0.2
338 18 86   0.0  3.04  99.5 0.00 0       -0.1
338 19 86  -0.1  2.93 100.1 0.00 0       -0.2
338 20 86  -0.1  0.19 100.1 0.00 0       -0.1
338 21 86  -0.2  0.44 100.0 0.00 0        0.0
338 22 86   0.3  0.05  99.9 0.00 0        0.0
338 23 86   0.9  5.02  98.9 0.00 0       -0.1
339  0 86   1.4  7.08  97.5 0.00 0       -0.2
                 .
                 .
                 .
365 21 86   0.2  4.80  80.6 0.00 0        0.0
365 22 86   0.1  7.01  85.3 0.00 0        0.0
365 23 86   0.0  8.51  85.3 0.00 0        0.0
  1  0 87  -0.1  9.09  87.8 0.00 0        0.0
```

Daily Weather Data

Daily weather format is used when MTSTEP (Line A in List of Input/Output Files) is set to 1.

```
337 86    0.0  -1.8  -1.5   87.2   0.00   14.2
338 86    1.5  -1.4  -1.5   61.2   0.00   36.4
339 86    2.7  -1.9  -0.5   95.6   0.35   11.5
340 86   -1.5  -2.0  -1.5   45.0   0.00   22.2
341 86   -1.2  -2.0  -1.4   20.1   0.00   23.0
342 86   -1.1  -8.0  -3.0   57.7   0.02   49.5
343 86   -2.4  -8.0  -8.2   64.3   0.00   54.5
344 86   -1.1  -8.8  -9.1   64.9   0.00   72.1
345 86   -4.9  -7.6  -4.9   22.8   0.00   24.1
346 86   -0.2  -5.4  -3.6   49.2   0.05   18.3
347 86    1.7  -3.0  -3.0  148.1   0.12   29.3
348 86    2.8   0.2   0.2  178.4   0.06   54.0
349 86    1.6  -3.3  -1.6  163.5   0.00   72.5
350 86   -2.2  -4.2  -3.0   60.0   0.00   29.2
```

Site Characteristics

```
PLOT 2-NT, A NO-TILL, HEAVY RESIDUE PLOT  (SITE CHARACTERISTICS)    LINE A
338  12  86  349  86                                                LINE B
46 45  15.0 180. 12.0  750.                                         LINE C
0  0  2 11  0  0.001   1      0   0   0   1   0   0                 LINE D
0.6  2.0  0.00                                                      LINE E
0.0   .15                                        ****** SNOW        LINE G
0.92  0.40 6000.  2.0   1.50  50000.             ****** RESIDUE     LINE H
0  0  0.25  0.0                                  ****** SOIL        LINE J
 0.000  4.35 -0.20 0.12 1360. 0.60    26.  2.8 .005                 LINE J-1
 0.076  4.35 -0.20 0.12 1360. 0.60  10. 64. 26.  0.                 LINE J-2
 0.152  4.35 -0.20 0.12 1350. 0.60  10. 64. 26.  0.                 LINE J-3
 0.254  4.35 -0.20 0.12 1350  0.60  10. 64. 26.  0.                 LINE J-4
 0.381  5.1  -0.21 0.14 1350. 0.60  10. 57. 33.  0.                 LINE J-5
 0.533  4.9  -0.21 0.13 1400. 0.60  10. 57. 33.  0.                 LINE J-6
 0.686  4.8  -0.27 .078 1540. 0.60  12. 60. 28.  0.                 LINE J-7
 0.838  5.2  -0.39 .040 1600. 0.60  12. 60. 28.  0.                 LINE J-8
 1.067  5.7  -0.55 .020 1660. 0.60   6. 54. 35.  0.                 LINE J-9
 1.372  5.1  -0.31 .060 1520. 0.60   9. 67. 24.  0.                 LINE J-10
 1.676  4.4  -0.24 .103 1490. 0.60   9. 65. 26.  0.                 LINE J-11
```

```
SITE WITH HEAVY RESIDUE, SAGEBRUSH CANOPY AND TWO SOLUTES           LINE A
338  12   86 350  86                                                LINE B
46 45   15.  180.0  1970.                                           LINE C
1  0  2 11  2   00.010  1      0   0   0   1   0   0                LINE D
0.6  2.0  0.00                                                      LINE E
 0   -53.72  1.32   1.0                           ***** CANOPY      LINE F
1   1   0.25   7.0  100.  5.0   -300.   6.7E05   1.7E06             LINE F1-1
0.90  0.5  1.5  2.5  1.0                                            LINE F2-1
 1.0  .15                                         ****** SNOW       LINE G
 0.90  0.30  6000.    2.0   0.0  50000.           ****** RESIDUE    LINE H
1.76E-09  0.0                                     ****** SALT #1    LINE I-1
11*5.6                                                              LINE I-2
11*0.008                                                            LINE I-3
9.00E-09  100.                                    ****** SALT #2    LINE I-1
11*0.0                                                              LINE I-2
11*0.007                                                            LINE I-3
 0  0  0.15 0.0                                   ****** SOIL       LINE J
0.00  4.5  -0.31 1.16 1020. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-1
0.05  4.5  -0.31 1.16 1020. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-2
0.10  4.4  -0.34 1.14 1020. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-3
0.15  4.4  -0.35 1.18 1100. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-4
0.20  4.4  -0.35 1.18 1100. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-5
0.30  4.4  -0.35 1.18 1100. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-6
0.50  4.4  -0.35 1.18 1100. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-7
0.70  4.1  -0.39 1.54 1090. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-8
1.00  4.1  -0.39 1.54 1090. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-9
1.25  3.9  -0.40 3.09 1290. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-10
1.50  3.9  -0.40 3.09 1290. 0.60  10. 60. 30. 0.0  2.8 .005         LINE J-11
```

```
SIMULATION FOR ASPEN TREES WITH UNDERLYING GRASS COVER
250  24  89  250  90
46 45   15.  45.0  1970.
3  0  2  9  0   00.001  1        0   0   0   1   0   0
0.6  6.5  0.00
 1   -53.72  1.32   0.0                           ***** CANOPY
1   1   0.25  99.0  100.  5.0   -100.   2.0E05   3.0E05
1   1   0.25   7.0  100.  5.0   -100.   2.0E05   3.0E05
1   1   0.25   7.0  100.  5.0   -300.   6.7E05   1.7E06
limbs.890
aspen.890
grass.890
 1.0  .15                                         ****** SNOW
 0.90  0.30  6000.  5.0   0.0  50000.             ****** RESIDUE
 0  0  0.15 0.0                                   ****** SOIL
0.00  4.5  -0.31 1.16 1020. 0.60  10. 60. 30. 0.0  2.8 .005
0.10  4.4  -0.34 1.14 1020. 0.60  10. 60. 30. 0.0  2.8 .005
0.20  4.4  -0.35 1.18 1100. 0.60  10. 60. 30. 0.0  2.8 .005
0.30  4.4  -0.35 1.18 1100. 0.60  10. 60. 30. 0.0  2.8 .005
0.50  4.4  -0.35 1.18 1100. 0.60  10. 60. 30. 0.0  2.8 .005
0.70  4.1  -0.39 1.54 1090. 0.60  10. 60. 30. 0.0  2.8 .005
1.00  4.1  -0.39 1.54 1090. 0.60  10. 60. 30. 0.0  2.8 .005
1.25  3.9  -0.40 3.09 1290. 0.60  10. 60. 30. 0.0  2.8 .005
1.50  3.9  -0.40 3.09 1290. 0.60  10. 60. 30. 0.0  2.8 .005
```

Plant Growth Files

Input for leaves of aspen trees:

```
250  89  4.5  3.0  6.0  2.0   1.50   SEP 17
260  89  4.5  3.0  6.0  2.0   1.50   OCT
275  89  4.5  3.0  0.0  0.0   1.50   OCT
170  90  4.5  3.0  0.0  0.0   1.50   JUN 19
200  90  4.5  3.0  6.0  2.0   1.50   AUG
250  90  4.5  3.0  6.0  2.0   1.50   SEP 17
```

Input for limbs (and fall foliage) of aspen trees

```
250  89  4.5  5.0  1.0  0.25  .1   SEP 17
260  89  4.5  5.0  1.0  0.25  .1   OCT
275  89  4.5  5.0  1.0  1.25  .1   OCT 2
280  89  4.5  5.0  1.0  0.25  .1   OCT 7
260  90  4.5  5.0  1.0  0.25  .1   OCT
```

Input for growth of grasses

```
200  89  0.3  0.5  6.0  1.0  0.85   AUG
260  89  0.3  0.5  6.0  0.5  0.85   SEP 17
275  89  0.0  0.5  0.0  0.0  0.85   OCT 2
170  90  0.0  0.5  0.0  0.0  0.85   JUN 19
200  90  0.3  0.5  6.0  1.0  0.85   AUG
260  90  0.3  0.5  6.0  0.5  0.85   OCT
```

Model Output

The SHAW model will create up to 12 output files as specified by the user. The following briefly describes the output to the screen and each of the files.

Output to Screen

The SHAW model will generate output to the screen to indicate progress toward completion of the simulation. The model will update to the screen at desired intervals the day and hour for the simulation time, as well as the maximum and minimum number of sub-time steps that were necessary to solve the hourly or daily time steps during the output interval. If the model has difficulty reaching convergence for the energy or water balance equations, a message will flash on the screen indicating the time step where problems were encountered.

General Output File

The general output file is created for every SHAW run. This file contains the title of the run and values for many of the input and hard-coded parameters. A summary of the entire simulated profile may be output at specified intervals. Temporal output to this file represent the last time step prior to output, i.e. output for hour 24 will be average daily values for daily time steps and will be the value for the hour prior to midnight for hourly time steps. Caution: hourly output to this file can create rather large files for lengthy simulations.

Profile Comparison

If desired, the model will create a side-by-side comparison of simulated and measured moisture and temperature profiles for every water content profile present in the moisture input file. Simulated solute concentration profiles will also be included if the simulation includes soil solutes. Caution should be used in using this option; if numerous (hourly) soil water content profiles are input, this file can become quite large.

Soil Profile Output

Output files may be created for simulated soil temperature, water content and/or water potential profiles. Each line in these files contains temperature (C), water content (m^3/m^3) or water potential (m) for all nodes within the simulated profile at the desired output interval. Values represent average values over the output interval regardless of the time step used; if hourly output is desired, hourly time steps must be used.

Simulated water content represents the total water content, i.e. ice plus liquid water content. Ice content for each soil node is output in the snow and frost depth output file. Liquid water content can be computed by the difference after correcting ice content for the density of ice, i.e. multiply ice content by 0.92.

Simulated water potential are given in meters of water potential. While this is not a common unit of water potential, it can easily be converted (1 m = 0.0981 bars).

Surface Energy Flux

A summary of the surface energy balance may be specified for output intervals from hourly up to daily. For each output interval, the net solar and long-wave radiation balance for the vegetation canopy, snow surface, residue and soil surface are given, respectively. Sensible and latent heat values are given as well. Positive values reflect energy transfer to the surface, negative values reflect flux away from the surface resulting in a cooling of the surface. Net ground heat flux can be estimated by summing the solar, long-wave, sensible and latent heat fluxes. The current version of the model outputs the total energy transferred over the output interval in kJ/m^2; hourly output can be converted to hourly W/m^2 by dividing by 3.6.

Water Balance Summary

A summary of the water balance for the simulated profile may be output at intervals from hourly up to daily. Values in mm for each output interval include: cumulative precipitation over the output interval; intercepted precipitation present on the canopy at the end of the interval; total evapotranspiration; total canopy transpiration; change in storage over the output interval within the canopy (not including intercepted precipitation), snow, residue, and soil layers; water lost to deep percolation by moving between the deepest two soil nodes within the soil profile; water lost to runoff; water ponded on the surface at the end of the output interval; cumulative evapotranspiration from the beginning of the simulation; and an error in the water balance for the time period.

Soil Water Flux

Water transfer between soil nodes can be output to the soil water flux file. Cumulative water transfer (liquid plus vapor) over the specified output interval is given in mm; positive values denote downward flux between nodes. Water flux between the bottom two nodes will coincide to the deep percolation output in the Water Balance Summary output file.

Plant Root Extraction

Water extracted from each soil layer by plant roots may be output at specified intervals. Output to this file is meters of water extracted from each soil layer. This output file may be used as input to subsequent SHAW runs as a Soil Source/Sink File after removing the two header lines. In doing so, water extraction by roots can be accounted for on a site where surrounding vegetation impacts the water balance of a site with little or no vegetation.

Frost and Snow Depth

Frost, thaw and snow depth in centimeters may be output at specified intervals. Also contained in this file is ice content (m^3/m^3) for each soil layer. Output to this file represents conditions at the end of the output interval, not the average over the interval. Under conditions where there are several alternating layers of frozen and thawed soil, the thaw depth represents the deepest soil containing no ice that is underlain by frozen soil; output frost depth is the deepest soil depth containing ice.

Thaw and frost depth are computed by interpolating ice content over depth within the layer of maximum thaw or frost. If 100% of the water in a soil layer is ice, then the layer is assumed to completely frozen, and the computed frost depth will be midway between the soil node for that layer and next deepest soil node (assuming the next soil layer is not frozen). However, never is 100% of the water in the soil frozen. Thus, the next soil node will start to freeze before this condition occurs, which may result in a large change in the interpolated frost depth. This is particularly evident with large spacing between soil nodes. Additionally, a layer is assumed frozen only if it contains ice. A layer may have freezing temperature, but if it is sufficiently dry that the water does not freeze, it is assumed to be unfrozen. For these reasons, exercise caution when interpreting simulated frost and thaw depths.

Chemical Concentration Profiles

Output can be specified for total chemical concentration with the soil layer as well as the solute concentration in the soil solution. The total chemical concentration (termed salt concentration) for each species is defined as the total chemical within the soil layer per mass of soil (mole equivalents/kg of soil) and includes the chemical absorbed onto the soil and that in soil solution. A separate file contains the solute concentration in soil solution (mole equivalents/liter). Values from each file can be converted to ppm by dividing by the molecular weight of the chemical species. Output files will have a separate line of output at each output interval for each chemical species.