SOIL AND WATER ASSESSMENT TOOL USER'S MANUAL

VERSION 2000

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CHAPTER 1

SWAT INPUT DATA: OVERVIEW

SWAT is a comprehensive model that requires a diversity of information in order to run. Novice users may feel a little overwhelmed by the variety and number of inputs when they first begin to use the model. However, many of the inputs are used to simulate special features that are not common to all watersheds.

This chapter provides an overview of model inputs. The inputs are organized by topic and emphasis is given to differentiating required inputs from optional inputs. This chapter focuses on assisting the user in identifying inputs that must be defined for their particular dataset. The remaining chapters list variables by file and discuss methods used to measure or calculate values for the input parameters.

1.1 WATERSHED CONFIGURATION

The first step in setting up a watershed simulation is to partition the watershed into subunits. SWAT allows several different subunits or objects to be defined within a watershed.

- Subbasins
    - unlimited number of HRUs (1 per subbasin required)
    - one pond (optional)
    - one wetland (optional)
- Reach/main channel segments (1 per subbasin)
- Impoundments on main channel network (optional)
- Point sources (optional)

1.1.1 SUBBASINS

The first level of subdivision is the subbasin. Subbasins possess a geographic position in the watershed and are spatially related to one another, e.g. outflow from subbasin #5 enters subbasin #7. The subbasin delineation may be obtained from subwatershed boundaries that are defined by surface topography so that the entire area within a subbasin flows to the subbasin outlet. Alternatively, the subbasin delineation may be obtained from grid cell boundaries. Since most spatial input is grid-based (i.e. DEM, NEXRAD, LULC), grid cells are an appealing approach for subbasin delineation. However unlike the subwatershed discretization, grid cells do not preserve routing reaches and topographic flow paths.

A subbasin will contain at least one HRU, a tributary channel and a main channel or reach. Two types of impoundments, a pond and/or wetland, may also be defined in a subbasin. These features are reviewed in the following sections.

1.1.2 HYDROLOGIC RESPONSE UNITS

The land area in a subbasin may be divided into hydrologic response units (HRUs). Hydrologic response units are portions of a subbasin that possess unique landuse/management/soil attributes. HRUs were incorporated into SWAT as part of the HUMUS (Hydrologic Unit Model for the United States) project. HUMUS used U.S.G.S. 2-digit hydrologic boundaries to divide the contiguous United

States into watersheds while 8-digit hydrologic boundaries were used to define subbasins within the watersheds. Only percentages of soil and landuse were known within the 8-digit hydrologic units. The geographic location of the landuse and soils within each subbasin was unknown. To capture the diversity of land use and soils that could be encompassed in an 8-digit hydrologic unit, a method was needed to account for the complexity of the landscape within the boundaries of the subbasins. The inclusion of HRUs allowed SWAT to account for this diversity. Prior to the HUMUS project, only one landuse/management/soil combination could be defined per subbasin in SWAT.

An HRU is not synonymous to a field. Rather it is the total area in the subbasin with a particular landuse, management and soil. While individual fields with a specific landuse, management and soil may be scattered throughout a subbasin, these areas are lumped together to form one HRU. HRUs are used in most SWAT runs since they simplify a run by lumping all similar soil and land use areas into a single response unit. It is often not practical to simulate individual fields.

Implicit in the concept of the HRU is the assumption that there is no interaction between HRUs in one subbasin. Loadings (runoff with sediment, nutrients, etc. transported by the runoff) from each HRU are calculated separately and then summed together to determine the total loadings from the subbasin. If the interaction of one landuse area with another is important, rather than defining those landuse areas as HRUs they should be defined as subbasins. It is only at the subbasin level that spatial relationships can be specified.

The benefit of HRUs is the increase in accuracy it adds to the prediction of loadings from the subbasin. The growth and development of plants can differ greatly among species. When the diversity in plant cover within a subbasin is accounted for, the net amount of runoff entering the main channel from the subbasin will be much more accurate.

As a general rule, a given subbasin should have 1-10 HRUs. For those wishing to incorporate more complexity into a dataset, we would recommend that the user define a greater number of subbasins in the watershed rather than many HRUs within a few subbasins. Of course, there are exceptions to this rule. An example of such an exception would be the requirement that the project uses a particular subbasin delineation that doesn't allow the user to capture landuse diversity without the incorporation of many HRUs.

1.1.3 REACH/MAIN CHANNELS

One reach or main channel is associated with each subbasin in a watershed. Loadings from the subbasin enter the channel network of the watershed in the associated reach segment. Outflow from the upstream reach segment(s) will also enter the reach segment. Processes involved in routing water, sediment and other constituents through the reach are reviewed in Section 7 of the theoretical documentation.

1.1.4 TRIBUTARY CHANNELS

The term tributary channel is used to differentiate inputs for channelized flow of surface runoff generated in a subbasin. Tributary channel inputs are used to calculate the time of concentration for channelized flow of runoff generated within the subbasin and transmission losses from runoff as it flows to the main channel.

Tributary channel inputs define the longest flow path in the subbasin. For some subbasins, the main channel may be the longest flow path. If so, tributary channel dimensions will be the same as those for the main channel. In other subbasins, the tributary channel dimensions will be significantly different than the main channel.

1.1.5 PONDS/WETLANDS/RESERVOIRS

In order to process USGS landuse maps, the GIS interfaces will allow HRUs to be created with water as the land use. If at all possible this should be avoided. Water bodies within a watershed should be modeled as ponds, wetlands or reservoirs.

Water bodies located on the stream network of the watershed are modeled as reservoirs. While the term “reservoir” is commonly used for man-made structures and “lake” for naturally occurring water bodies, the use of the term “reservoir” in SWAT is not meant to imply that the water body is man-made. With the terms “reservoir” and “pond” we are differentiating impoundments by location. Because impoundments on the main channel network tend to be larger than impoundments off the main channel network, a difference in size is also implied with the use of these terms. It would probably be more appropriate to refer to the different types of water bodies as main channel impoundments and subbasin impoundments, but the need for different file extensions to store inputs makes the use of these two terms convenient.

Two water bodies (pond/wetlands) may be defined in each subbasin. Water entering these impoundments is generated within the subbasin—they cannot receive water originating in other subbasins. In contrast, reservoirs receive water contributed to the channel network from all upstream subbasins.

1.1.6 POINT SOURCES

SWAT directly models the loading of water, sediment and nutrients from land areas in a watershed. However, some watersheds will have loadings to the stream network from sources not associated with a land area. These are referred to as point sources. The most common point source is a sewage treatment plant.

In order to account for the loadings from a point source, SWAT allows users to add daily or average daily loading data for point sources to the main channel network. These loadings are then routed through the channel network along with the loadings generated by the land areas.

With the GIS interfaces, the interface produces a map of the subbasins which allows the user to easily see the spatial relationship between subbasins. In the Windows (non-GIS) interface, the user can set up the spatial positioning of subbasins with drag and drop objects and connecting arrows to show direction of flow. The core SWAT program is not able to access maps or displays. Instead, it uses the information provided in the watershed configuration file (.fig) to link the individual subbasins together in the watershed. The watershed file is an ASCII or text file. The file format is described in Chapter 2 and example watershed configurations are provided in Appendix B.

1.2 OVERVIEW OF INPUT FILES

Input for SWAT is defined at one of several different levels of detail: watershed, subbasin, or HRU. Unique features such as reservoirs or point sources must have input data provided for each individual feature included in the watershed simulation.

Watershed level inputs are used to model processed throughout the watershed. For example, the method selected to model potential evapotranspiration will be used in all HRUs in the watershed. Subbasin level inputs are inputs set at the same value for all HRUs in the subbasin if the input pertains to a process modeled in the HRU. Because there is one reach per subbasin, input data for main channels is defined at the subbasin level also. An example of subbasin level data is rainfall and temperature information. The same rainfall and maximum and minimum temperature are used for all HRUs, the main channel and any ponds or wetlands located within the subbasin. HRU level inputs are inputs that can be set to unique values for each HRU in the watershed. An example of an HRU input is the management scenario simulated in an HRU.

An attempt was been made to organize input information according to the type of input. However, there are a few files that have had to serve as "catch-alls". These files contain input data for various processes modeled in the watershed that do not fit into any of the specialized files.

Input files for SWAT include:

.fig (watershed level file)	Watershed configuration file. This required file defines the routing network in the watershed.
file.cio (watershed level file)	Control input/output file. This required file contains names of input files for all watershed level variables and subbasin level variables.

.cod (watershed level file)	Input control code file. This required file specifies the length of the simulation, the printing frequency, and selected options for various processes.
.bsn (watershed level file)	Basin input file. Required file for watershed level parameters. Catch-all file.
.pcp (watershed level file)	Precipitation input file. This optional file contains daily measured precipitation for a measuring gage(s). Up to 18 precipitation files may be used in each simulation and each file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in file.cio.
.tmp (watershed level file)	Temperature input file. This optional file contains daily measured maximum and minimum temperatures for a measuring gage(s). Up to 18 temperature files may be used in each simulation and each file can hold data for up to 150 stations. The data for a particular station is assigned to a subbasin in file.cio.
.slr (watershed level file)	Solar radiation input file. This optional file contains daily solar radiation for a measuring gage(s). The solar radiation file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in file.cio.
.wnd (watershed level file)	Wind speed input file. This optional file contains daily average wind speed for a measuring gage(s). The wind speed file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in file.cio.
.hmd (watershed level file)	Relative humidity input file. This optional file contains daily relative humidity values for a measuring gage(s). The relative humidity file can hold data for up to 300 stations. The data for a particular station is assigned to a subbasin in file.cio.
.pet (watershed level file)	Potential evapotranspiration input file. This optional file contains daily PET values for the watershed.
crop.dat (watershed level file)	Land cover/plant growth database file. This required file contains plant growth parameters for all land covers simulated in the watershed.
till.dat (watershed level file)	Tillage database file. This required file contains information on the amount and depth of mixing caused by tillage operations simulated in the watershed.

pest.dat (watershed level file)	Pesticide database file. This required file contains information on mobility and degradation for all pesticides simulated in the watershed.
fert.dat (watershed level file)	Fertilizer database file. This required file contains information on the nutrient content of all fertilizers and manures simulated in the watershed.
urban.dat (watershed level file)	Urban database file. This required file contains information on the build-up/wash-off of solids in urban areas simulated in the watershed.
.sub (subbasin level file)	Subbasin input file. Required file for subbasin level parameters. Catch-all file.
.wgn (subbasin level file)	Weather generator input file. This required file contains the statistical data needed to generate representative daily climatic data for the subbasins.
.pnd (subbasin level file)	Pond/wetland input file. This optional file contains information for impoundments located within the subbasin.
.wus (subbasin level file)	Water use input file. This optional file contains information for consumptive water use in the subbasin.
.rte (subbasin level file)	Main channel input file. This required file contains parameters governing water and sediment movement in the main channel of the subbasin.
.wwq (watershed level file)	Watershed water quality input file. This optional file contains parameters used to model QUAL2E transformations in the main channels.
.swq (subbasin level file)	Stream water quality input file. This optional file contains parameters used to model pesticide and QUAL2E nutrient transformations in the main channel of the subbasin.
.hru (HRU level file)	HRU input file. Required file for HRU level parameters. Catch-all file.
.mgt (HRU level file)	Management input file. This required file contains management scenarios and specifies the land cover simulated in the HRU.
.sol (HRU level file)	Soil input file. This required file contains information about the physical characteristics of the soil in the HRU.
.chm (HRU level file)	Soil chemical input file. This optional file contains information about initial nutrient and pesticide levels of the soil in the HRU.

.gw (HRU level file)	Groundwater input file. This required file contains information about the shallow and deep aquifer in the subbasin. Because land covers differ in their interaction with the shallow aquifer, information in this input file is allowed to be varied at the HRU level.
.res (reservoir file)	Reservoir input file. This optional file contains parameters used to model the movement of water and sediment through a reservoir.
.lwq (reservoir file)	Lake water quality input file. This optional file contains parameters used to model the movement of nutrients and pesticides through a reservoir.
recday.dat recmon.dat recyear.dat reccnst.dat (point source file)	Point source input file. These optional files contain information about loadings to the channel network from a point source. The type of file used to store the data depends on how the data is summarized (daily, monthly, yearly, or average annual).

1.3 MODEL INPUTS BY TYPE

The following tables group inputs by type. Detailed explanations of the variables are given in the input file chapter. Please keep in mind that in the GIS interfaces, some of these variables are automatically set by the interface and users will not be allowed to edit them.

Watershed Dimensions

Variable	File	
DA_KM	.bsn	Chapter 5
HRUTOT	.sub	Chapter 6
HRU_FR	.hru	Chapter 19

Length of Simulation

Variable	File	
NBYR	.cod	Chapter 4
IYR	.cod	Chapter 4
IDAF	.cod	Chapter 4
IDAL	.cod	Chapter 4

Output Print Options/Output Summary Options

Variable	File	
IPD	.cod	Chapter 4
NYSKIP	.cod	Chapter 4
IPRN	.cod	Chapter 4
ILOG	.cod	Chapter 4
IPRP	.cod	Chapter 4
IPDVAR(1-20)	.cod	Chapter 4
IPDVAB(1-20)	.cod	Chapter 4
IPDVAS(1-20)	.cod	Chapter 4
TITLE	file.cio	Chapter 3
BIGSUB	file.cio	Chapter 3
SBSOUT	file.cio	Chapter 3
RCHOUT	file.cio	Chapter 3
RSVOUT	file.cio	Chapter 3
LWQOUT	file.cio	Chapter 3
WTROUT	file.cio	Chapter 3
PESTOUT	file.cio	Chapter 3
EVENT	file.cio	Chapter 3

Random Number Generator

Variable	File	
IGN	.cod	Chapter 4

Special Project Flag

Variable	File	
ISPROJ	.cod	Chapter 4

CLIMATE

Precipitation

Variable	File	
PCPSIM	.cod	Chapter 4
IDT	.cod	Chapter 4
IDIST	.cod	Chapter 4
REXP	.cod	Chapter 4
IEVENT	.cod	Chapter 4
NRGAGE	file.cio	Chapter 3
NRTOT	file.cio	Chapter 3
NRGFIL	file.cio	Chapter 3
RFILE(1-18)	file.cio	Chapter 3

Precipitation, cont.

Variable	File	
IRGAGE	file.cio	Chapter 3
RAIN_YRS	.wgn	Chapter 13
PCPMM(1-12)	.wgn	Chapter 13
PCPSTD(1-12)	.wgn	Chapter 13
PCPSKW(1-12)	.wgn	Chapter 13
PR_W(1,1-12)	.wgn	Chapter 13
PR_W(2,1-12)	.wgn	Chapter 13
PCPD(1-12)	.wgn	Chapter 13
RAINHHMX(1-12)	.wgn	Chapter 13
PRECIPITATION	.pcp	Chapter 7
PLAPS	.sub	Chapter 6
RFINC(1-12)	.sub	Chapter 6

Snow Processes

Variable	File	
SFTMP	.bsn	Chapter 5
SMTMP	.bsn	Chapter 5
SMFMX	.bsn	Chapter 5
SMFMN	.bsn	Chapter 5
TIMP	.bsn	Chapter 5
SNOCOVMX	.bsn	Chapter 5
SNO50COV	.bsn	Chapter 5
SNO_SUB	.sub	Chapter 6
SNOEB(1-10)	.sub	Chapter 6

Temperature

Variable	File	
TMPSIM	.cod	Chapter 4
NTGAGE	file.cio	Chapter 3
NTTOT	file.cio	Chapter 3
NTGFIL	file.cio	Chapter 3
TFILE(1-18)	file.cio	Chapter 3
ITGAGE	file.cio	Chapter 3
TMPMX(1-12)	.wgn	Chapter 13
TMPMN(1-12)	.wgn	Chapter 13
TMPSTDMX(1-12)	.wgn	Chapter 13
TMPSTDMN(1-12)	.wgn	Chapter 13
MAX TEMP	.tmp	Chapter 8
MIN TEMP	.tmp	Chapter 8

Temperature, cont.

Variable	File	
TLAPS	.sub	Chapter 6
TMPINC	.sub	Chapter 6

Solar Radiation

Variable	File	
SLRSIM	.cod	Chapter 4
NSTOT	file.cio	Chapter 3
SLRFILE	file.cio	Chapter 3
ISGAGE	file.cio	Chapter 3
SOLARAV(1-12)	.wgn	Chapter 13
SOL_RAD	.slr	Chapter 9
LATITUDE	.sub	Chapter 6
RADINC(1-12)	.sub	Chapter 6

Relative Humidity Input

Variable	File	
RHSIM	.cod	Chapter 4
NHTOT	file.cio	Chapter 3
RHFILE	file.cio	Chapter 3
IHGAGE	file.cio	Chapter 3
DEWPT(1-12)	.wgn	Chapter 13
RHD	.hmd	Chapter 11
HUMINC(1-12)	.sub	Chapter 6

Wind Speed Input

Variable	File	
WNDSIM	.cod	Chapter 4
NWTOT	file.cio	Chapter 3
WNDFILE	file.cio	Chapter 3
IWGAGE	file.cio	Chapter 3
WNDAV(1-12)	.wgn	Chapter 13
WND_SP	.wnd	Chapter 10

Elevation Bands

Variable	File	
WELEV	.wgn	Chapter 13
ELEVATION	.pcp	Chapter 7
ELEVATION	.tmp	Chapter 8
ELEVB(1-10)	.sub	Chapter 6
ELEV_FR(1-10)	.sub	Chapter 6
SNOEB(1-10)	.sub	Chapter 6
PLAPS	.sub	Chapter 6
TLAPS	.sub	Chapter 6

Climate Change

Variable	File	
CO2	.sub	Chapter 6
RFINC(1-12)	.sub	Chapter 6
TMPINC(1-12)	.sub	Chapter 6
RADINC(1-12)	.sub	Chapter 6
HUMINC(1-12)	.sub	Chapter 6
CO2HI	crop.dat	Chapter 14
BIOEHI	crop.dat	Chapter 14

HYDROLOGIC CYCLE

Potential and Actual Evapotranspiration

Variable	File	
IPET	.cod	Chapter 4
PETFILE	file.cio	Chapter 3
ESCO	.bsn, .hru	Chapter 5, 19
EPCO	.bsn, .hru	Chapter 5, 19
PET_MEAS	.pet	Chapter 12
ELEV	.sub	Chapter 6
CANMX	.hru	Chapter 19
SOL_ALB	.sol	Chapter 22
GW_REVAP	.gw	Chapter 24
REVAPMN	.gw	Chapter 24

Surface Runoff

Variable		File
IEVENT	.cod	Chapter 4
SURLAG	.bsn	Chapter 5
CN2	.mgt	Chapter 20
CNOP (***plant operation***)	.mgt	Chapter 20
CNOP (***harv & kill op***)	.mgt	Chapter 20
CNOP (***tillage operation***)	.mgt	Chapter 20

Time of Concentration

Variable		File
CH_L(1)	.sub	Chapter 6
CH_S(1)	.sub	Chapter 6
CH_N(1)	.sub	Chapter 6
SLSUBBSN	.hru	Chapter 19
OV_N	.hru	Chapter 19

Crack Flow

Variable		File
ICRK	.cod	Chapter 4
SOL_CRK	.sol	Chapter 22

Transmission Losses from Surface Runoff

Variable		File
CH_L(1)	.sub	Chapter 6
CH_W(1)	.sub	Chapter 6
CH_K(1)	.sub	Chapter 6

Soil Water

Variable		File
FFCB	.bsn	Chapter 5
SOL_Z	.sol	Chapter 22
SOL_BD	.sol	Chapter 22
SOL_AWC	.sol	Chapter 22
SOL_K	.sol	Chapter 22
irrigation operation	.mgt	Chapter 20
auto-irrigation operation	.mgt	Chapter 20

Lateral Flow

Variable		File
SLOPE	.hru	Chapter 19
LAT_TTIME	.hru	Chapter 19
SLSOIL	.hru	Chapter 19

Groundwater

Variable		File
SHALLST	.gw	Chapter 24
DEEPST	.gw	Chapter 24
GW_DELAY	.gw	Chapter 24
ALPHA_BF	.gw	Chapter 24
GWQMN	.gw	Chapter 24
GW_REVAP	.gw	Chapter 24
REVAPMN	.gw	Chapter 24
RCHRG_DP	.gw	Chapter 24
WUSHAL(1-12)	.wus	Chapter 21
WUDEEP(1-12)	.wus	Chapter 21

SEDIMENT

Sediment Erosion

Variable		File
APM	.bsn	Chapter 5
SLSUBBSN	.hru	Chapter 19
SLOPE	.hru	Chapter 19
LAT_SED	.hru	Chapter 19
FILTERW	.hru	Chapter 19
CLAY	.sol	Chapter 22
SILT	.sol	Chapter 22
SAND	.sol	Chapter 22
ROCK	.sol	Chapter 22
USLE_K	.sol	Chapter 22
USLE_P	.mgt	Chapter 20
USLE_C	crop.dat	Chapter 14

NUTRIENTS

Nitrogen Cycle/Runoff

Variable	**File**	
RCN	.bsn	Chapter 5
CMN	.bsn	Chapter 5
UBN	.bsn	Chapter 5
NPERCO	.bsn	Chapter 5
RSDCO	.bsn	Chapter 5
ANION_EXCL	.sol	Chapter 22
SOL_NO3	.chm	Chapter 23
SOL_ORGN	.chm	Chapter 23
SOL_CBN	.sol	Chapter 22
ERORGN	.hru	Chapter 19
FILTERW	.hru	Chapter 19
BIOMIX	.mgt	Chapter 20
fertilizer application	.mgt	Chapter 20
FMINN	fert.dat	Chapter 17
FORGN	fert.dat	Chapter 17
FNH3N	fert.dat	Chapter 17
tillage operation	.mgt	Chapter 20
EFFMIX	till.dat	Chapter 15
DEPTIL	till.dat	Chapter 15
grazing operation	.mgt	Chapter 20
auto-fertilization operation	.mgt	Chapter 20
BN(1)	crop.dat	Chapter 14
BN(2)	crop.dat	Chapter 14
BN(3)	crop.dat	Chapter 14
GWNO3	.gw	Chapter 24

Phosphorus Cycle/Runoff

Variable	**File**	
UBP	.bsn	Chapter 5
PPERCO	.bsn	Chapter 5
PHOSKD	.bsn	Chapter 5
PSP	.bsn	Chapter 5
RSDCO	.bsn	Chapter 5
SOL_LABP	.chm	Chapter 23
SOL_ORGP	.chm	Chapter 23
ERORGP	.hru	Chapter 19
FILTERW	.hru	Chapter 19
BIOMIX	.mgt	Chapter 20

Phosphorus Cycle/Runoff, cont.

Variable	File	
fertilizer application	.mgt	Chapter 20
FMINP	fert.dat	Chapter 17
FORGP	fert.dat	Chapter 17
tillage operation	.mgt	Chapter 20
EFFMIX	till.dat	Chapter 15
DEPTIL	till.dat	Chapter 15
grazing operation	.mgt	Chapter 20
auto-fertilization operation	.mgt	Chapter 20
BP(1)	crop.dat	Chapter 14
BP(2)	crop.dat	Chapter 14
BP(3)	crop.dat	Chapter 14
GWSOLP	.gw	Chapter 24

PESTICIDE

Pesticide in Soil/Runoff

Variable	File	
PERCOP	.bsn	Chapter 5
PESTNUM	.chm	Chapter 23
PLTPST	.chm	Chapter 23
SOLPST	.chm	Chapter 23
FILTERW	.hru	Chapter 19
PSTENR	.chm	Chapter 23
BIOMIX	.mgt	Chapter 20
pesticide application	.mgt	Chapter 20
SKOC	pest.dat	Chapter 16
WOF	pest.dat	Chapter 16
HLIFE_F	pest.dat	Chapter 16
HLIFE_S	pest.dat	Chapter 16
AP_EF	pest.dat	Chapter 16
WSOL	pest.dat	Chapter 16
tillage operation	.mgt	Chapter 20
EFFMIX	till.dat	Chapter 15
DEPTIL	till.dat	Chapter 15

BACTERIA

Bacteria in Soil/Runoff

Variable	File	
WDPQ	.bsn	Chapter 5
WGPQ	.bsn	Chapter 5
WDLPQ	.bsn	Chapter 5
WGLPQ	.bsn	Chapter 5
WDPS	.bsn	Chapter 5
WGPS	.bsn	Chapter 5
WDLPS	.bsn	Chapter 5
WGLPS	.bsn	Chapter 5
BACTKDQ	.bsn	Chapter 5
THBACT	.bsn	Chapter 5
FILTERW	.hru	Chapter 19
BIOMIX	.mgt	Chapter 20
tillage operation	.mgt	Chapter 20
EFFMIX	till.dat	Chapter 15
DEPTIL	till.dat	Chapter 15
fertilizer application	.mgt	Chapter 20
BACTPDB	fert.dat	Chapter 17
BACTLPDB	fert.dat	Chapter 17
BACTKDDB	fert.dat	Chapter 17
auto-fertilization operation	.mgt	Chapter 20

PLANTS

Plant Growth

Variable	File	
SOL_ZMX	.sol	Chapter 22
PHU/HEAT UNITS	.mgt	Chapter 20
plant operation	.mgt	Chapter 20
harvest & kill operation	.mgt	Chapter 20
harvest operation	.mgt	Chapter 20
kill operation	.mgt	Chapter 20
grazing operation	.mgt	Chapter 20
IDC	crop.dat	Chapter 14
BIO_E	crop.dat	Chapter 14
HVSTI	crop.dat	Chapter 14
BLAI	crop.dat	Chapter 14
FRGRW1	crop.dat	Chapter 14
LAIMX1	crop.dat	Chapter 14
FRGRW2	crop.dat	Chapter 14
LAIMX2	crop.dat	Chapter 14

Plant Growth, cont.

Variable	File	
DLAI	crop.dat	Chapter 14
CHTMX	crop.dat	Chapter 14
RDMX	crop.dat	Chapter 14
T_OPT	crop.dat	Chapter 14
T_BASE	crop.dat	Chapter 14
CNYLD	crop.dat	Chapter 14
CPYLD	crop.dat	Chapter 14
BN(1)	crop.dat	Chapter 14
BN(2)	crop.dat	Chapter 14
BN(3)	crop.dat	Chapter 14
BP(1)	crop.dat	Chapter 14
BP(2)	crop.dat	Chapter 14
BP(3)	crop.dat	Chapter 14
WSYF	crop.dat	Chapter 14
GSI	crop.dat	Chapter 14
VPDFR	crop.dat	Chapter 14
FRGMAX	crop.dat	Chapter 14
WAVP	crop.dat	Chapter 14

Residue

Variable	File	
RSDIN	.hru	Chapter 19
RSDCO	.bsn	Chapter 5
harvest & kill operation	.mgt	Chapter 20
harvest operation	.mgt	Chapter 20
kill operation	.mgt	Chapter 20
grazing operation	.mgt	Chapter 20
RSDCO_PL	crop.dat	Chapter 14

MANAGEMENT

Management-Land Cover

Variable	File	
IGRO	.mgt	Chapter 20
NROT	.mgt	Chapter 20
NCRP	.mgt	Chapter 20
ALAI	.mgt	Chapter 20
BIO_MS	.mgt	Chapter 20
PHU	.mgt	Chapter 20
BIO_MIN	.mgt	Chapter 20

Management-Land Cover, cont.

Variable		**File**
plant operation	.mgt	Chapter 20
HEAT UNITS	.mgt	Chapter 20
NCR	.mgt	Chapter 20
HITAR	.mgt	Chapter 20
BIO_TARG	.mgt	Chapter 20
ALAINIT	.mgt	Chapter 20
BIO_INIT	.mgt	Chapter 20
harvest & kill operation	.mgt	Chapter 20
harvest operation	.mgt	Chapter 20
HIOVR	.mgt	Chapter 20
HARVEFF	.mgt	Chapter 20
kill operation	.mgt	Chapter 20
grazing operation	.mgt	Chapter 20
BMEAT	.mgt	Chapter 20
NDGRAZ	.mgt	Chapter 20
BMTRMP	.mgt	Chapter 20

Management-Nutrients

Variable		**File**
fertilizer application	.mgt	Chapter 20
FRT_LY1	.mgt	Chapter 20
FERT_ID	.mgt	Chapter 20
FERT_KG	.mgt	Chapter 20
tillage operation	.mgt	Chapter 20
TILLAGE_ID	.mgt	Chapter 20
grazing operation	.mgt	Chapter 20
WMANURE	.mgt	Chapter 20
IGFTYP	.mgt	Chapter 20
auto-fertilization operation	.mgt	Chapter 20
AUTO_NSTR	.mgt	Chapter 20
FERT_ID	.mgt	Chapter 20
AUTO_NMXS	.mgt	Chapter 20
AUTO_NMXA	.mgt	Chapter 20
AUTO_EFF	.mgt	Chapter 20
AFRT_LY1	.mgt	Chapter 20

Management-Pesticide

Variable		File
pesticide application	.mgt	Chapter 20
PEST_ID	.mgt	Chapter 20
FERT_KG	.mgt	Chapter 20
tillage operation	.mgt	Chapter 20
TILLAGE_ID	.mgt	Chapter 20

Management-Water

Variable		File
IRR	.hru	Chapter 19
IRRNO	.hru	Chapter 19
FLOWMIN	.hru	Chapter 19
DIVMAX	.hru	Chapter 19
FLOWFR	.hru	Chapter 19
DDRAIN	.hru	Chapter 19
TDRAIN	.hru	Chapter 19
GDRAIN	.hru	Chapter 19
IPOT	.hru	Chapter 19
POT_FR	.hru	Chapter 19
POT_TILE	.hru	Chapter 19
POT_VOLX	.hru	Chapter 19
POT_VOL	.hru	Chapter 19
EVLAI	.bsn	Chapter 5
irrigation operation	.mgt	Chapter 20
IRR_AMT	.mgt	Chapter 20
auto-irrigation operation	.mgt	Chapter 20
AUTO_WSTR	.mgt	Chapter 20
release/impound operation	.mgt	Chapter 20
IREL_IMP	.mgt	Chapter 20

Management-Urban

Variable		File
IURBAN	.hru	Chapter 19
URBLU	.hru	Chapter 19
street sweeping operation	.mgt	Chapter 20
SWEEPEFF	.mgt	Chapter 20
AVWSP	.mgt	Chapter 20
FIMP	urban.dat	Chapter 18
FCIMP	urban.dat	Chapter 18
CURBDEN	urban.dat	Chapter 18
URBCOEF	urban.dat	Chapter 18

Management-Urban, cont.

Variable	File	
DIRTMX	urban.dat	Chapter 18
THALF	urban.dat	Chapter 18
TNCONC	urban.dat	Chapter 18
TPCONC	urban.dat	Chapter 18
TNO3CONC	urban.dat	Chapter 18

CHANNEL PROCESSES

Channel Water Routing

Variable	File	
IEVENT	.cod	Chapter 4
IRTE	.cod	Chapter 4
EVRCH	.bsn	Chapter 5
MSK_CO1	.bsn	Chapter 5
MSK_CO2	.bsn	Chapter 5
MSK_X	.bsn	Chapter 5
CH_W(2)	.rte	Chapter 25
CH_D	.rte	Chapter 25
CH_S(2)	.rte	Chapter 25
CH_L(2)	.rte	Chapter 25
CH_N(2)	.rte	Chapter 25
CH_K(2)	.rte	Chapter 25
ALPHA_BNK	.rte	Chapter 25
WURCH(1-12)	.wus	Chapter 21

Channel Sediment Routing

Variable	File	
IDEG	.cod	Chapter 4
PRF	.bsn	Chapter 5
SPCON	.bsn	Chapter 5
SPEXP	.bsn	Chapter 5
CH_W(2)	.rte	Chapter 25
CH_D	.rte	Chapter 25
CH_S(2)	.rte	Chapter 25
CH_EROD	.rte	Chapter 25
CH_COV	.rte	Chapter 25
CH_WDR	.rte	Chapter 25

Channel Nutrient Routing

Variable	File	
IWQ	.cod	Chapter 4
AI1	.wwq	Chapter 26
AI2	.wwq	Chapter 26
P_N	.wwq	Chapter 26
RS2	.swq	Chapter 27
RS3	.swq	Chapter 27
RS4	.swq	Chapter 27
RS5	.swq	Chapter 27
BC1	.swq	Chapter 27
BC2	.swq	Chapter 27
BC3	.swq	Chapter 27
BC4	.swq	Chapter 27

Channel Water Quality Indices

Variable	File	
IWQ	.cod	Chapter 4
LAO	.wwq	Chapter 26
IGROPT	.wwq	Chapter 26
AI0	.wwq	Chapter 26
AI1	.wwq	Chapter 26
AI2	.wwq	Chapter 26
AI3	.wwq	Chapter 26
AI4	.wwq	Chapter 26
AI5	.wwq	Chapter 26
AI6	.wwq	Chapter 26
MUMAX	.wwq	Chapter 26
RHOQ	.wwq	Chapter 26
TFACT	.wwq	Chapter 26
K_L	.wwq	Chapter 26
K_N	.wwq	Chapter 26
K_P	.wwq	Chapter 26
LAMBDA0	.wwq	Chapter 26
LAMBDA1	.wwq	Chapter 26
LAMBDA3	.wwq	Chapter 26
RS1	.swq	Chapter 27
RK1	.swq	Chapter 27
RK2	.swq	Chapter 27
RK3	.swq	Chapter 27
RK4	.swq	Chapter 27

Channel Pesticide Routing Input

Variable	File	
IRTPEST	.bsn	Chapter 5
CHPST_REA	.swq	Chapter 27
CHPST_VOL	.swq	Chapter 27
CHPST_KOC	.swq	Chapter 27
CHPST_STL	.swq	Chapter 27
CHPST_RSP	.swq	Chapter 27
CHPST_MIX	.swq	Chapter 27
SEDPST_CONC	.swq	Chapter 27
SEDPST_REA	.swq	Chapter 27
SEDPST_BRY	.swq	Chapter 27
SEDPST_ACT	.swq	Chapter 27

IMPOUNDMENT PROCESSES

Impoundment Water Routing—Pond

Variable	File	
PND_FR	.pnd	Chapter 28
PND_PSA	.pnd	Chapter 28
PND_PVOL	.pnd	Chapter 28
PND_ESA	.pnd	Chapter 28
PND_EVOL	.pnd	Chapter 28
PND_VOL	.pnd	Chapter 28
PND_K	.pnd	Chapter 28
IFLOD1	.pnd	Chapter 28
IFLOD2	.pnd	Chapter 28
NDTARG	.pnd	Chapter 28
WUPND(1-12)	.wus	Chapter 21

Impoundment Water Routing—Wetland

Variable	File	
WET_FR	.pnd	Chapter 28
WET_NSA	.pnd	Chapter 28
WET_NVOL	.pnd	Chapter 28
WET_MXSA	.pnd	Chapter 28
WET_MXVOL	.pnd	Chapter 28
WET_VOL	.pnd	Chapter 28
WET_K	.pnd	Chapter 28

Impoundment Water Routing—Pothole

Variable	File	
IPOT	.hru	Chapter 19
POT_FR	.hru	Chapter 19
POT_TILE	.hru	Chapter 19
POT_VOLX	.hru	Chapter 19
POT_VOL	.hru	Chapter 19
EVLAI	.bsn	Chapter 5

Impoundment Water Routing—Reservoir

Variable	File	
RES_SUB	.res	Chapter 29
MORES	.res	Chapter 29
IYRES	.res	Chapter 29
RES_ESA	.res	Chapter 29
RES_EVOL	.res	Chapter 29
RES_PSA	.res	Chapter 29
RES_PVOL	.res	Chapter 29
RES_VOL	.res	Chapter 29
RES_K	.res	Chapter 29
IRESCO	.res	Chapter 29
OFLOWMX(1-12)	.res	Chapter 29
OFLOWMN(1-12)	.res	Chapter 29
RES_RR	.res	Chapter 29
RESMONO	.res	Chapter 29
IFLOD1R	.res	Chapter 29
IFLOD2R	.res	Chapter 29
NDTARGR	.res	Chapter 29
STARG(1-12)	.res	Chapter 29
RESDAYO	.res	Chapter 29
WURESN(1-12)	.res	Chapter 29
WURTNF	.res	Chapter 29
RES_OUTFLOW	resdayo.dat	Chapter 29
RESOUT	resmono.dat	Chapter 29

Impoundment Sediment Routing

Variable		File
PND_SED	.pnd	Chapter 28
PND_NSED	.pnd	Chapter 28
WET_SED	.pnd	Chapter 28
WET_NSED	.pnd	Chapter 28
POT_NSED	.hru	Chapter 19
RES_SED	.res	Chapter 29
RES_NSED	.res	Chapter 29

Impoundment Nutrient Routing—Pond

Variable		File
PSETL1	.pnd	Chapter 28
PSETL2	.pnd	Chapter 28
NSETL1	.pnd	Chapter 28
NSETL2	.pnd	Chapter 28
PND_NO3	.pnd	Chapter 28
PND_SOLP	.pnd	Chapter 28
PND_ORGN	.pnd	Chapter 28
PND_ORGP	.pnd	Chapter 28
IPND1	.pnd	Chapter 28
IPND2	.pnd	Chapter 28

Impoundment Nutrient Routing—Wetland

Variable		File
PSETLW1	.pnd	Chapter 28
PSETLW2	.pnd	Chapter 28
NSETLW1	.pnd	Chapter 28
NSETLW2	.pnd	Chapter 28
WET_NO3	.pnd	Chapter 28
WET_SOLP	.pnd	Chapter 28
WET_ORGN	.pnd	Chapter 28
WET_ORGP	.pnd	Chapter 28
IPND1	.pnd	Chapter 28
IPND2	.pnd	Chapter 28

Impoundment Nutrient Routing—Reservoir

Variable		File
IRES1	.lwq	Chapter 30
IRES2	.lwq	Chapter 30
PSETLR1	.lwq	Chapter 30
PSETLR2	.lwq	Chapter 30
NSETLR1	.lwq	Chapter 30
NSETLR2	.lwq	Chapter 30
RES_ORGP	.lwq	Chapter 30
RES_SOLP	.lwq	Chapter 30
RES_ORGN	.lwq	Chapter 30
RES_NO3	.lwq	Chapter 30
RES_NH3	.lwq	Chapter 30
RES_NO2	.lwq	Chapter 30

Impoundment Water Quality Indices

Variable		File
CHLA	.pnd	Chapter 28
SECCI	.pnd	Chapter 28
CHLAW	.pnd	Chapter 28
SECCIW	.pnd	Chapter 28
CHLAR	.lwq	Chapter 30
SECCIR	.lwq	Chapter 30

Impoundment Pesticide Routing—Reservoir

Variable		File
LKPST_CONC	.lwq	Chapter 30
LKPST_REA	.lwq	Chapter 30
LKPST_VOL	.lwq	Chapter 30
LKPST_KOC	.lwq	Chapter 30
LKPST_STL	.lwq	Chapter 30
LKPST_RSP	.lwq	Chapter 30
LKPST_MIX	.lwq	Chapter 30
LKSPST_CONC	.lwq	Chapter 30
LKSPST_REA	.lwq	Chapter 30
LKSPST_BRY	.lwq	Chapter 30
LKSPST_ACT	.lwq	Chapter 30

CHAPTER 2

SWAT INPUT DATA: WATERSHED CONFIGURATION

The first step in setting up a watershed simulation is to define the relative arrangement of the parts or elements, i.e. the configuration, of the watershed. If the watershed has only one primary channel and there is very little variation in topography and climate across the watershed, there may not be a need to partition the watershed into smaller units. However, the majority of watersheds will exhibit enough complexity in the stream network, topography or climate to warrant subdivision for modeling purposes.

There are several techniques used to discretize a watershed. In the past, models could only apply one type of discretization scheme to a watershed. This resulted in the development of several models that differ only in the watershed discretization scheme used.

2.1 DISCRETIZATION SCHEMES

The three most common techniques used to discretize a watershed are:

- Grid cell. This configuration allows the user to incorporate significant spatial detail into a simulation. Models which use this technique include AGNPS (Young et al., 1987), ANSWERS (Beasley et al., 1980) and the WEPP grid version (Foster, 1987).
- Representative hillslope. This configuration is useful for modeling hillslope processes. This technique is used in APEX (Williams, et al., 1998) and the WEPP hillslope version (Lane and Nearing, 1989).
- Subwatershed. This configuration preserves the natural channels and flow paths of the watershed. This technique is used in the WEPP watershed version (Foster, 1987), HYMO (Williams and Hann, 1973) and SWRRB (Arnold et al., 1990).

All of these schemes have strengths and weaknesses and applications for which they are most appropriate. SWAT uses the subwatershed configuration as the primary discretization scheme for a watershed. However, because of the routing command language utilized in SWAT, it is possible to use any of these three, alone or in combination, to model a watershed.

2.2 WATERSHED CONFIGURATION FILE (.FIG)

The watershed configuration file contains information used by SWAT to simulate processes occurring within the HRU/subbasin and to route the stream loadings through the channel network of the watershed. A reach routing command structure, similar to that developed for HYMO (Williams and Hann, 1973), is utilized to route and add flows through the watershed. The following sections review the different features of the watershed configuration file.

2.2.1 INCORPORATION OF COMMENTS

To assist the user in interpreting the watershed configuration file, an unlimited number of comment lines are allowed. These comments can be used to isolate the routing commands for different reaches, etc. To included comments in the watershed configuration file, a line must have an asterisk (*) in the 1st space on the line. When SWAT reads the asterisk, it will skip to the next line.

2.2.2 COMMAND LINES

Thirteen different commands may be used in the watershed configuration file. The commands, along with their numeric codes, are:

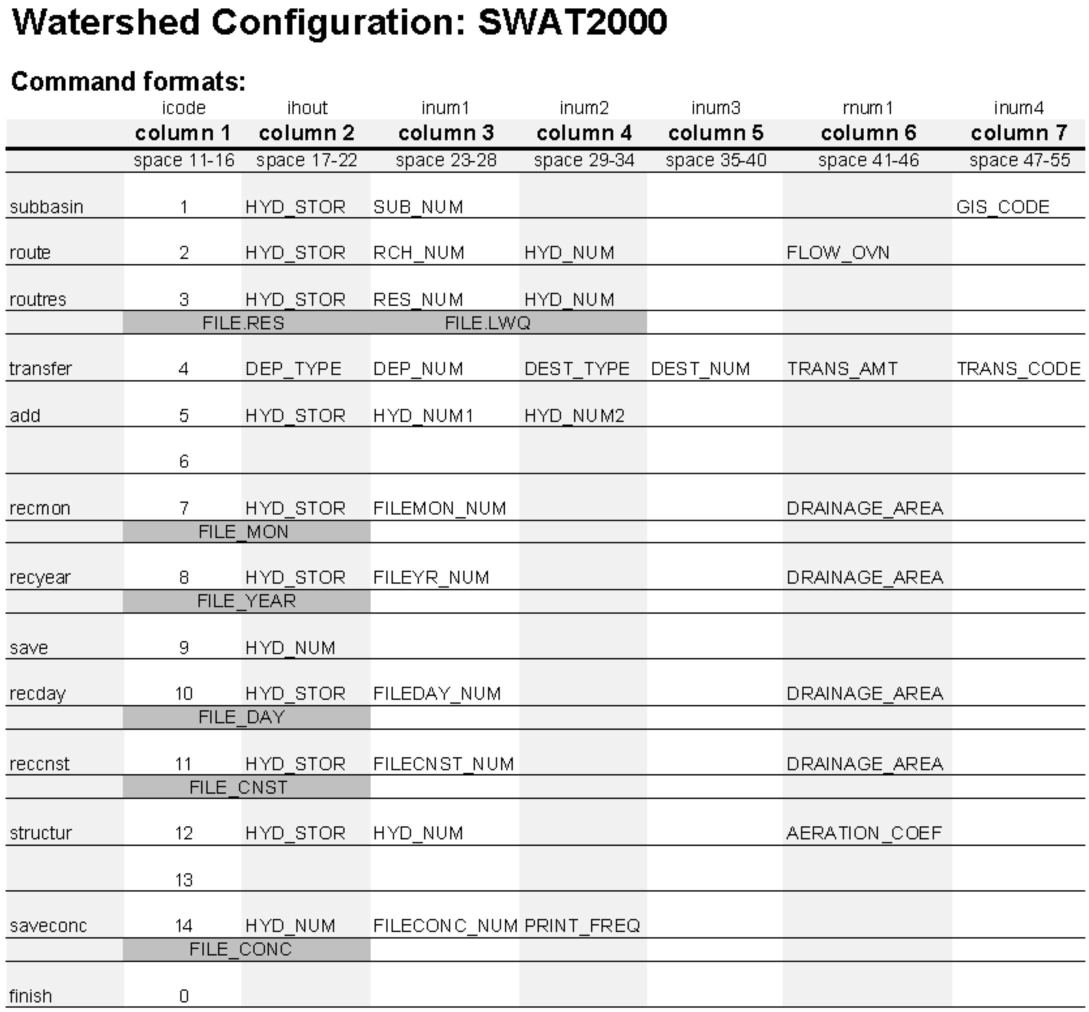
finish	0
subbasin	1
route	2
routres	3
transfer	4
add	5
recmon	7
recyear	8
save	9
recday	10
reccnst	11
structure	12
saveconc	14

The format of the commands is illustrated in Figure 2-1.

The most commonly used commands are: subbasin, route, add, and finish. In brief, these commands simulated the land phase of the hydrologic cycle and determine the loadings to the reach (subbasin), model the movement and transformations occurring in the reach (route), allow the output from different subbasins to be summed together (add), and identify the end of the routing command sequence (finish).

The remaining commands are utilized to model more unique configurations. This set of commands can be divided several subgroups: routing of water through a reservoir (routres), humanly contrived movement of water (transfer), aeration of water resulting from flow through structures along the channel (structure), incorporation of point source data (rechour, recday, recmon, recyear, reccnst), formatting of watershed outflow for input into a different SWAT simulation (save), and formatting of water quality simulation results at specified points in the reach network (saveconc).

Figure 2-1: Commands included in watershed configuration file



Watershed Configuration: SWAT2000

Command formats:

	icode	ihout	inum1	inum2	inum3	rnum1	inum4
	column 1	**column 2**	**column 3**	**column 4**	**column 5**	**column 6**	**column 7**
	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	1	HYD_STOR	SUB_NUM				GIS_CODE
route	2	HYD_STOR	RCH_NUM	HYD_NUM		FLOW_OVN	
routres	3	HYD_STOR	RES_NUM	HYD_NUM			
	FILE.RES		FILE.LWQ				
transfer	4	DEP_TYPE	DEP_NUM	DEST_TYPE	DEST_NUM	TRANS_AMT	TRANS_CODE
add	5	HYD_STOR	HYD_NUM1	HYD_NUM2			
	6						
recmon	7	HYD_STOR	FILEMON_NUM			DRAINAGE_AREA	
	FILE_MON						
recyear	8	HYD_STOR	FILEYR_NUM			DRAINAGE_AREA	
	FILE_YEAR						
save	9	HYD_NUM					
recday	10	HYD_STOR	FILEDAY_NUM			DRAINAGE_AREA	
	FILE_DAY						
reccnst	11	HYD_STOR	FILECNST_NUM			DRAINAGE_AREA	
	FILE_CNST						
structur	12	HYD_STOR	HYD_NUM			AERATION_COEF	
	13						
saveconc	14	HYD_NUM	FILECONC_NUM	PRINT_FREQ			
	FILE_CONC						
finish	0						

The watershed configuration file is a fixed format file. With fixed format, the model looks for data only in a particular location on a command line. Spaces not allocated to variable inputs for a specific command are not processed by the model. The interfaces commonly use the extra space to write other data or they insert zeros in the unused columns. Appendix B steps through the set up of example watershed configuration files and will be very helpful to users trying to familiarize themselves with the logic of this file.

2.2.2.1 SUBBASIN COMMAND (1)

The subbasin command simulates all processes involved in the land phase of the hydrologic cycle and computes runoff, sediment, and chemical loadings from each HRU within the subbasin. Variables required on the subbasin command line are:

Variable name	Definition
COMMAND	The command code = 1 for the subbasin command.
HYD_STOR	The hydrograph storage location number. After a command is executed, the results are stored in an array at the position defined by this number. It is crucial that all hydrograph storage location numbers are unique. If the same number is used twice, output from one command line will be overwritten by that from another and simulation results will be incorrect.
SUB_NUM	Subbasin number. This number is assigned in file.cio. Every subbasin in the watershed has a different number.
GIS_CODE	GIS code printed to output files (optional)

The format of the subbasin command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
HYD_STOR	space 17-22	6-digit integer	i6
SUB_NUM	space 23-28	6-digit integer	i6
GIS_CODE	space 47-55	9-digit integer	i9

2.2.2.2 ROUTE COMMAND (2)

The route command routes the water, sediment, and chemical loadings through a main channel or reach. Variables required on the route command line are:

Variable name	Definition
COMMAND	The command code = 2 for the route command.
HYD_STOR	The hydrograph storage location number. After a command is executed, the results are stored in an array at the position defined by this number. It is crucial that all hydrograph storage location numbers are unique. If the same number is used twice, output from one command line will be overwritten by that from another and simulation results will be incorrect.
RCH_NUM	Reach number. The reach number is the same as the subbasin number.
HYD_NUM	Inflow hydrograph storage location number. The data that is to be routed through the reach.
FLOW_OVN	Fraction of overland flow (0.000 to 1.000). If flow leaving a subbasin is completely channelized, FLOW_OVN = 0.000. In cases where a hillslope is being simulated, overland flow from one subbasin to another occurs and the value of FLOW_OVN can be increased to account for the amount of non-channelized overland flow taking place between the subbasins. The overland flow to the next subbasin is added to the rainfall of the receiving subbasin and allowed to infiltrate or run off. The sediment and chemical loadings associated with the overland flow are assumed to be deposited on the upper soil layer of the receiving subbasin. The fraction of the flow in the channel is routed directly to the reach of the receiving subbasin.

The format of the route command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
HYD_STOR	space 17-22	6-digit integer	i6
RCH_NUM	space 23-28	6-digit integer	i6
HYD_NUM	space 29-34	6-digit integer	i6
FLOW_OVN	space 41-46	decimal (xx.xxx)	f6.3

2.2.2.3 ADD COMMAND (5)

The add command is used to sum the water, sediment, and chemical loadings of any two flows. Variables required on the add command line are:

Variable name	Definition
COMMAND	The command code = 5 for the add command.
HYD_STOR	The hydrograph storage location number for the results.
HYD_NUM1	The hydrograph storage location number of the 1st set of data to be added.
HYD_NUM2	The hydrograph storage location number of the 2nd set of data to be added.

The format of the add command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
HYD_STOR	space 17-22	6-digit integer	i6
HYD_NUM1	space 23-28	6-digit integer	i6
HYD_NUM2	space 29-34	6-digit integer	i6

2.2.2.4 FINISH COMMAND (0)

The last command line in the .fig file must be a finish command line. The finish command notifies the model that the end of the command lines in the watershed configuration file has been reached. Variables required on the finish command line are:

Variable name	Definition
COMMAND	The command code = 0 for the finish command

The format of the finish command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6

2.2.2.5 ROUTRES COMMAND (3)

The routres command routes water, sediment, and chemical loadings through a reservoir. The routres command requires two lines. Variables required on the routres command lines are:

Variable name	Definition
COMMAND	The command code = 3 for the routres command.
HYD_STOR	The hydrograph storage location number for results.
RES_NUM	Reservoir number. Each reservoir modeled in the watershed must be assigned a unique consecutive number beginning at 1.
HYD_NUM	Inflow hydrograph storage location number. The data that is to be routed through the reservoir.
RESFILE	Name of reservoir input file (.res)
LWQFILE	Name of reservoir water quality input file (optional) (.lwq)

The format of the routres command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
RES_NUM	1	space 23-28	6-digit integer	i6
HYD_NUM	1	space 29-34	6-digit integer	i6
RESFILE	2	space 11-23	character	a13
LWQFILE	2	space 24-36	character	a13

2.2.2.6 TRANSFER COMMAND (4)

While water is most typically removed from a water body for irrigation purposes, SWAT also allows water to be transferred from one water body to another. This is performed with a transfer command in the watershed configuration file.

The transfer command can be used to move water from any reservoir or reach in the watershed to any other reservoir or reach in the watershed. The user must input the type of water source, the location of the source, the type of water body receiving the transfer, the location of the receiving water body, and the amount of water transferred.

Three options are provided to specify the amount of water transferred: a fraction of the volume of water in the source; a volume of water left in the source; or the volume of water transferred. The transfer is performed every day of the simulation.

Originally, the transfer command was the only method available to irrigate an HRU. While the irrigation scenarios are now handled primarily in the management files, the transfer command was retained for flexibility. This command should not be used with hourly stream routing. Variables required on the transfer command line are:

Variable name	**Definition**
COMMAND	The command code = 4 for the transfer command.
DEP_TYPE	Water source type: 1 reach 2 reservoir
DEP_NUM	Water source number. The number of the reach or reservoir from which the flow will be diverted.
DEST_TYPE	Destination type. Defines the receiving body. 1 reach 2 reservoir

Variable name	Definition
DEST_NUM	Destination number. Number of reach or reservoir receiving the water.
TRANS_AMT	The flow amount transferred. (defined by TRANS_CODE)
TRANS_CODE	The rule code governing the transfer of water: 1 A fraction of the flow or volume to be transferred out of the reach or reservoir is specified 2 A minimum flow (reach) or volume (reservoir) to leave in the reach or reservoir is specified (m^3/day) 3 An exact amount of water to be transferred is specified (m^3/day)

The format of the transfer command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
DEP_TYPE	space 17-22	6-digit integer	i6
DEP_NUM	space 23-28	6-digit integer	i6
DEST_TYPE	space 29-34	6-digit integer	i6
DEST_NUM	space 35-40	6-digit integer	i6
TRANS_AMT	space 41-46	decimal (xx.xxx)	f6.3
TRANS_CODE	space 47-55	9-digit integer	i9

2.2.2.7 STRUCTURE COMMAND (12)

The structure command simulates aeration caused by the tumbling of water as it moves over weirs or other structures along the stream network. In highly polluted streams, the aeration of the stream by this method is a significant source of oxygen. The structure command alters the dissolved oxygen content based on the aeration coefficient input by the user. Variables required on the structure command line are:

Variable name	**Definition**
COMMAND	The command code = 12 for the structure command.
HYD_STOR	The hydrograph storage location number for data.
HYD_NUM	Inflow hydrograph storage location number. The data that is to be adjusted to reflect aeration. (Dissolved oxygen content is the only value that is altered with this command.)
AERATION_COEF	Aeration coefficient. Butts and Evans (1983) documents the following relationship that can be used to estimate the reaeration coefficient: $rea = 1 + 0.38 \cdot coef_a \cdot coef_b \cdot h_{fall} \cdot (1 - 0.11 \cdot h_{fall}) \cdot (1 + 0.046 \cdot \bar{T}_{water})$ where rea is the reaeration coefficient, $coef_a$ is an empirical water quality factor, $coef_b$ is an empirical dam aeration coefficient, h_{fall} is the height through which water falls (m), and $\bar{T}_{water}$ is the average water temperature (°C). The empirical water quality factor is assigned a value based on the condition of the stream: $coef_a$ = 1.80 in clean water $coef_a$ = 1.60 in slightly polluted water $coef_a$ = 1.00 in moderately polluted water $coef_a$ = 1.00 in moderately polluted water $coef_a$ = 0.65 in grossly polluted water The empirical dam aeration coefficient is assigned a value based on the type of structure: $coef_b$ = 0.70 to 0.90 for flat broad crested weir $coef_b$ = 1.05 for sharp crested weir with straight slope face $coef_b$ = 0.80 for sharp crested weir with vertical face $coef_b$ = 0.05 for sluice gates with submerged discharge

The format of the structure command is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
HYD_STOR	space 17-22	6-digit integer	i6
HYD_NUM	space 23-28	6-digit integer	i6
AERATION_COEF	space 41-46	decimal (xx.xxx)	f6.3

2.2.2.8 RECMON COMMAND (7)

The recmon command is one of five routing commands that reads in flow, sediment and chemical loading records from a file and routes the input through the watershed. The recmon command is used to read in data summarized by month. The recmon command requires two lines. Variables required on the recmon command lines are:

Variable name	Definition
COMMAND	The command code = 7 for the recmon command.
HYD_STOR	The hydrograph storage location number for data.
FILEMON_NUM	The file number. Unique file numbers should be used for each recmon command.
DRAINAGE_AREA	Drainage area associated with records (km^2) (optional)
FILE_MON	Name of the file containing the monthly records

The format of the recmon command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILEMON_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal (xx.xxx)	f6.3
FILE_MON	2	space 11-23	character	a13

2.2.2.9 RECYEAR COMMAND (8)

The recyear command is one of five routing commands that reads in flow, sediment and chemical loading records from a file and routes the input through the watershed. The recyear command is used to read in annual output. The recyear command requires two lines. Variables required on the recyear command lines are:

Variable name	**Definition**
COMMAND	The command code = 8 for the recyear command.
HYD_STOR	The hydrograph storage location number for data.
FILEYR_NUM	The file number. Unique file numbers should be used for each recyear command.
DRAINAGE_AREA	Drainage area associated with records (km^2) (optional)
FILE_YR	Name of file containing annual output.

The format of the recyear command lines is:

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILEYR_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal(xx.xxx)	f6.3
FILE_YR	2	space 11-23	character	a13

2.2.2.10 RECDAY COMMAND (10)

The recday command is one of four routing commands that reads in flow, sediment and chemical loading records from a file and routes the input through the watershed. This command is useful for reading in point source data or data from simulations of upstream areas. The recday command is used to read in data summarized on a daily basis. The recday command requires two lines. Variables required on the recday command lines are:

Variable name	**Definition**
COMMAND	The command code = 10 for the recday command.
HYD_STOR	The hydrograph storage location number for data.
FILEDAY_NUM	The file number. Unique file numbers should be used for each recday command.
DRAINAGE_AREA	Drainage area associated with records (km^2) (optional)
FILE_DAY	Name of file containing daily records.

The format of the recday command lines is:

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILEDAY_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal (xx.xxx)	f6.3
FILE_DAY	2	space 11-23	character	a13

2.2.2.11 RECCNST COMMAND (11)

The reccnst command is one of five routing commands that reads in flow, sediment and chemical loading records from a file and routes the input through the watershed. This command is useful for reading in point source data. The reccnst command is used to read in average annual data. The reccnst command requires two lines. Variables required on the reccnst command lines are:

Variable name	Definition
COMMAND	The command code = 11 for the reccnst command.
HYD_STOR	The hydrograph storage location number for data.
FILECNST_NUM	The file number. Unique file numbers should be used for each reccnst command.
DRAINAGE_AREA	Drainage area associated with records (km^2) (optional)
FILE_CNST	Name of file containing average annual records.

The format of the reccnst command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_STOR	1	space 17-22	6-digit integer	i6
FILECNST_NUM	1	space 23-28	6-digit integer	i6
DRAINAGE_AREA	1	space 41-46	decimal(xx.xxx)	f6.3
FILE_CNST	2	space 11-23	character	a13

2.2.2.12 SAVE COMMAND (9)

The save command allows the user to print daily SWAT output to the event output file specified in file.cio. This output file can then be read into another SWAT run using the recday command. Variables required on the save command line are:

Variable name	Definition
COMMAND	The command code = 9 for save command.
HYD_NUM	The hydrograph storage location number of the data to be printed to file.

The format of the save command line is:

Variable name	Position	Format	F90 Format
COMMAND	space 11-16	6-digit integer	i6
HYD_NUM	space 17-22	6-digit integer	i6

2.2.2.13 SAVECONC COMMAND (14)

The saveconc command saves flow, sediment and water quality indicator information from a specified point on the reach network to a file. The water quality information is reported as concentrations. This command is useful for isolating reach information at a particular point on the channel network. Up to 50 saveconc commands can be specified in the watershed configuration file.

The saveconc command requires two lines. Variables required on the saveconc command lines are:

Variable name	Definition
COMMAND	The command code = 14 for the saveconc command.
HYD_NUM	The hydrograph storage location number of the data to be printed to file.
FILECONC_NUM	The file number. Unique file numbers should be used for each saveconc command.
PRINT_FREQ	Printing frequency. For simulations using a sub-daily time step, water quality information may be summarized and printed for every hour or every day. Simulations using a daily time step will always print daily average values. 0 report daily averages 1 report hourly averages *(currently not operational)* If no printing frequency is specified, the model will print daily averages.
FILE_CONC	Name of file to which the water quality information is written.

The format of the saveconc command lines is:

Variable name	Line #	Position	Format	F90 Format
COMMAND	1	space 11-16	6-digit integer	i6
HYD_NUM	1	space 17-22	6-digit integer	i6
FILECONC_NUM	1	space 23-28	6-digit integer	i6
PRINT_FREQ	1	space 29-34	6-digit integer	i6
FILE_CONC	2	space 11-23	character	a13

2.3 REFERENCES

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CHAPTER 3

SWAT INPUT DATA: FILE.CIO

File management is performed with the control input/output file (file.cio). The control input/output file contains the name of files associated with the subbasins, database files, climate files and watershed-level input files accessed by SWAT during a simulation as well as the name of the files in which output will be stored. While the user may adopt any file naming scheme, we recommend that the file extensions listed in the manual are used to facilitate identification of the different file types.

Files required by the model that are not listed in the control input/output file include HRU files listed in the subbasin general input (.sub) file, reservoir and point source input files listed in the watershed configuration (.fig) file and "unique" files which contain input for uncommon or specialized processes not typically simulated.

The control input/output file can be divided into a number of different sections. Figure 3.1 illustrates the different groupings of files within file.cio.

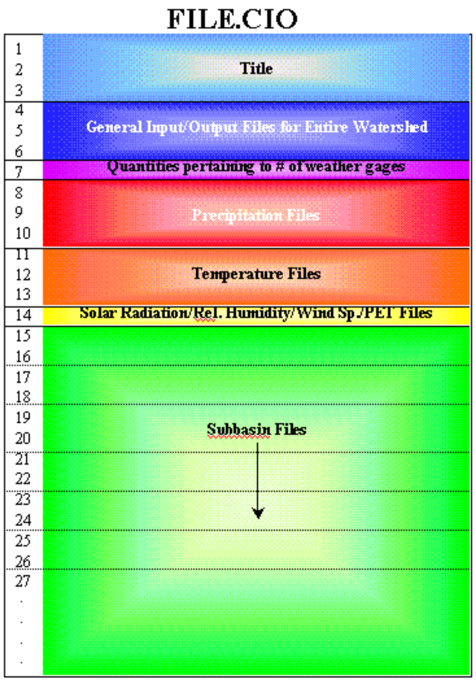

Figure 3.1: General organization of control input/output files

Following is a brief description of the variables in the control input/output file. They are listed in the order they appear within the file.

3.1 TITLE SECTION

Variable name	Definition
TITLE	The first three lines of 'file.cio' are reserved for a description of the simulation run. The description may take up to 80 spaces per line. The title given in file.cio is printed to every output file. (optional)

3.2 GENERAL INPUT/OUTPUT SECTION

Variable name	Definition
BIGSUB	Name of subbasin output file (**.bsb**). Loadings to the reach (water, sediment and nutrients) are summarized for each subbasin.
SBSOUT	Name of hydrologic response unit (HRU) output file (**.sbs**). Loadings to the reach (water, sediment and nutrients) and crop growth are summarized for each HRU.
RCHOUT	Name of main channel, or reach, output file (**.rch**). Summarizes the amount of water, sediment and pollutants entering and leaving the reach and provides data on in-steam processes (e.g. sediment deposition, evaporation occurring in the channel)
RSVOUT	Name of reservoir output file (**.rsv**). Summarizes the amount of water, sediment and pollutants entering and leaving the reservoir and quantifies processes occurring in the reservoir (e.g. sediment deposition).
WTROUT	Name of subbasin/HRU impoundment output file (**.wtr**). Summarizes the amount of water, sediment and pollutants entering and leaving ponds, wetlands and depressional areas (potholes) and quantifies processes occurring in the different impoundments.
PESTOUT	Name of pesticide output file (**.pso**). The movement and transformation of the different pesticides used in the simulation are summarized for each HRU.
EVENT	Name of event output file (**.eve**). When very large basins are being simulated, it is often easier to split them into several SWAT runs. This file writes daily output which can be read into a different SWAT run.
ROUTIN	Name of watershed configuration file (**.fig**). Contains the commands to add and route flows through the watershed.
CODEDAT	Name of input control code file (**.cod**). The input control code file summarizes information that affects the operation of SWAT (e.g. print codes, weather generator codes, number of years being simulated, number of subbasins being simulated)
BASNDAT	Name of basin input file (**.bsn**). Contains inputs for processes modeled at the watershed level.
WATQAL	Name of watershed water quality input file (**.wwq**)

Variable name	Definition
CROPDB	Name of land cover/plant growth database file (**crop.dat**). This file contains growth parameters for the different land covers.
TILLDAT	Name of tillage database file (**till.dat**). This file contains mixing efficiencies for different tillage implements.
PESTIDAT	Name of pesticide database file (**pest.dat**). This file contains parameters governing movement and degradation of pesticides.
FERTDAT	Name of fertilizer/manure database file (**fert.dat**). This file contains nutrient content data for fertilizers.
URBDAT	Name of urban land type database file (**urban.dat**). This file contains data required to model build-up/wash-off in urban areas.

3.3 CLIMATE INPUT SECTION

Variable name	Definition
NRGAGE	Number of precipitation gage (.pcp) files used in the simulation. Up to 18 files may be used.
NTGAGE	Number of temperature gage (.tmp) files used in the simulation. Up to 18 files may be used.
NRTOT	Total number of precipitation gage records used in the simulation. If each .pcp file contains only one precipitation gage record, NRTOT = NRGAGE. Otherwise, NRTOT > NRGAGE. A maximum of 5400 precipitation gage records may be used in a simulation.
NTTOT	Total number of temperature gage records used in the simulation. If each .tmp file contains only one temperature gage record, NTTOT = NTGAGE. Otherwise, NTTOT > NTGAGE. A maximum of 2700 temperature gage records may be used in a simulation.
NRGFIL	Number of precipitation gage records within each .pcp file. A maximum of 300 precipitation gage records may be placed in each .pcp file.
NTGFIL	Number of temperature gage records within each .tmp file. a maximum of 150 temperature gage records may be placed in each .tmp file

Variable name	Definition
NSTOT	Number of solar radiation records within the .slr file. A maximum of 300 solar radiation records may be placed in the .slr file.
NHTOT	Number of relative humidity records within the .hmd file. A maximum of 300 relative humidity records may be placed in the .hmd file.
NWTOT	Number of wind speed records within the .wnd file. A maximum of 300 wind speed records may be placed in the .wnd file.
RFILE(1)	Name of measured precipitation input file #1 (**.pcp**).
RFILE(2)	Name of measured precipitation input file #2 (**.pcp**).
RFILE(3)	Name of measured precipitation input file #3 (**.pcp**).
RFILE(4)	Name of measured precipitation input file #4 (**.pcp**).
RFILE(5)	Name of measured precipitation input file #5 (**.pcp**).
RFILE(6)	Name of measured precipitation input file #6 (**.pcp**).
RFILE(7)	Name of measured precipitation input file #7 (**.pcp**).
RFILE(8)	Name of measured precipitation input file #8 (**.pcp**).
RFILE(9)	Name of measured precipitation input file #9 (**.pcp**).
RFILE(10)	Name of measured precipitation input file #10 (**.pcp**).
RFILE(11)	Name of measured precipitation input file #11 (**.pcp**).
RFILE(12)	Name of measured precipitation input file #12 (**.pcp**).
RFILE(13)	Name of measured precipitation input file #13 (**.pcp**).
RFILE(14)	Name of measured precipitation input file #14 (**.pcp**).
RFILE(15)	Name of measured precipitation input file #15 (**.pcp**).
RFILE(16)	Name of measured precipitation input file #16 (**.pcp**).
RFILE(17)	Name of measured precipitation input file #17 (**.pcp**).
RFILE(18)	Name of measured precipitation input file #18 (**.pcp**).
TFILE(1)	Name of measured temperature input file #1 (**.tmp**).
TFILE(2)	Name of measured temperature input file #2 (**.tmp**).
TFILE(3)	Name of measured temperature input file #3 (**.tmp**).
TFILE(4)	Name of measured temperature input file #4 (**.tmp**).
TFILE(5)	Name of measured temperature input file #5 (**.tmp**).

Variable name	Definition
TFILE(6)	Name of measured temperature input file #6 (**.tmp**).
TFILE(7)	Name of measured temperature input file #7 (**.tmp**).
TFILE(8)	Name of measured temperature input file #8 (**.tmp**).
TFILE(9)	Name of measured temperature input file #9 (**.tmp**).
TFILE(10)	Name of measured temperature input file #10 (**.tmp**).
TFILE(11)	Name of measured temperature input file #11 (**.tmp**).
TFILE(12)	Name of measured temperature input file #12 (**.tmp**).
TFILE(13)	Name of measured temperature input file #13 (**.tmp**).
TFILE(14)	Name of measured temperature input file #14 (**.tmp**).
TFILE(15)	Name of measured temperature input file #15 (**.tmp**).
TFILE(16)	Name of measured temperature input file #16 (**.tmp**).
TFILE(17)	Name of measured temperature input file #17 (**.tmp**).
TFILE(18)	Name of measured temperature input file #18 (**.tmp**).
SLRFILE	Name of measured solar radiation input file (**.slr**).
RHFILE	Name of measured relative humidity input file (**.hmd**).
WNDFILE	Name of measured wind speed input file (**.wnd**).
PETFILE	Name of potential evapotranspiration input file (**.pet**).

3.4 SUBBASIN INPUT SECTION

Variable name	Definition
ISB	Subbasin number. Subbasins are numbered consecutively.
SUBDAT	Name of subbasin general input data file (**.sub**).
RTEDAT	Name of subbasin routing input data file (**.rte**). This file contains parameters for the main channel.
PNDDAT	Name of subbasin pond input data file (**.pnd**).
WUSDAT	Name of subbasin water use management data file (**.wus**).
WGNDAT	Name of subbasin weather generator data file (**.wgn**).
SWQDAT	Name of subbasin stream water quality data file (**.swq**).

Variable name	Definition
IRGAGE	Number of the measured precipitation record used within subbasin. Optional.
ITGAGE	Number of the measured temperature record used within the subbasin. Optional.
ISGAGE	Number of the solar radiation record used within the subbasin. Optional.
IHGAGE	Number of the relative humidity record used within the subbasin. Optional.
IWGAGE	Number of the wind speed record used within the subbasin. Optional.

The format of file.cio is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1-3	space 1-80	character	a80
BIGSUB	4	space 1-13	character	a13
SBSOUT	4	space 14-26	character	a13
RCHOUT	4	space 27-39	character	a13
RSVOUT	4	space 40-52	character	a13
empty location	4	space 53-65	character	a13
WTROUT	4	space 66-78	character	a13
PESTOUT	5	space 1-13	character	a13
EVENT	5	space 14-26	character	a13
ROUTIN	5	space 27-39	character	a13
CODEDAT	5	space 40-52	character	a13
BASNDAT	5	space 53-65	character	a13
WATQAL	5	space 66-78	character	a13
CROPDB	6	space 1-13	character	a13
TILLDAT	6	space 14-26	character	a13
PESTIDAT	6	space 27-39	character	a13
FERTDAT	6	space 40-52	character	a13
URBDAT	6	space 53-65	character	a13
NRGAGE	7	space 1-4	integer	i4
NTGAGE	7	space 5-8	integer	i4
NRTOT	7	space 9-12	integer	i4
NTTOT	7	space 13-16	integer	i4
NRGFIL	7	space 17-20	integer	i4
NTGFIL	7	space 21-24	integer	i4
NSTOT	7	space 25-28	integer	i4
NHTOT	7	space 29-32	integer	i4
NWTOT	7	space 33-36	integer	i4
RFILE(1)	8	space 1-13	character	a13
RFILE(2)	8	space 14-26	character	a13
RFILE(3)	8	space 27-39	character	a13
RFILE(4)	8	space 40-52	character	a13
RFILE(5)	8	space 53-65	character	a13

Variable name	Line #	Position	Format	F90 Format
RFILE(6)	8	space 66-78	character	a13
RFILE(7)	9	space 1-13	character	a13
RFILE(8)	9	space 14-26	character	a13
RFILE(9)	9	space 27-39	character	a13
RFILE(10)	9	space 40-52	character	a13
RFILE(11)	9	space 53-65	character	a13
RFILE(12)	9	space 66-78	character	a13
RFILE(13)	10	space 1-13	character	a13
RFILE(14)	10	space 14-26	character	a13
RFILE(15)	10	space 27-39	character	a13
RFILE(16)	10	space 40-52	character	a13
RFILE(17)	10	space 53-65	character	a13
RFILE(18)	10	space 66-78	character	a13
TFILE(1)	11	space 1-13	character	a13
TFILE(2)	11	space 14-26	character	a13
TFILE(3)	11	space 27-39	character	a13
TFILE(4)	11	space 40-52	character	a13
TFILE(5)	11	space 53-65	character	a13
TFILE(6)	11	space 66-78	character	a13
TFILE(7)	12	space 1-13	character	a13
TFILE(8)	12	space 14-26	character	a13
TFILE(9)	12	space 27-39	character	a13
TFILE(10)	12	space 40-52	character	a13
TFILE(11)	12	space 53-65	character	a13
TFILE(12)	12	space 66-78	character	a13
TFILE(13)	13	space 1-13	character	a13
TFILE(14)	13	space 14-26	character	a13
TFILE(15)	13	space 27-39	character	a13
TFILE(16)	13	space 40-52	character	a13
TFILE(17)	13	space 53-65	character	a13
TFILE(18)	13	space 66-78	character	a13
SLRFILE	14	space 1-13	character	a13
RHFILE	14	space 14-26	character	a13
WNDFILE	14	space 27-39	character	a13
PETFILE	14	space 40-52	character	a13

Variable name	Line #	Position	Format	F90 Format
The remaining lines provide input data for all of the subbasins. Two lines are devoted to each subbasin's input data. In the equation for the line number, *i* is the subbasin number.				
ISB	13 + 2*i*	space 1-5	integer	i5
SUBDAT	13 + 2*i*	space 7-19	character	a13
RTEDAT	13 + 2*i*	space 21-33	character	a13
PNDDAT	13 + 2*i*	space 35-47	character	a13
WUSDAT	13 + 2*i*	space 49-61	character	a13
WGNDAT	14 + 2*i*	space 7-19	character	a13
SWQDAT	14 + 2*i*	space 21-33	character	a13
IRGAGE	14 + 2*i*	space 49-52	integer	i4
ITGAGE	14 + 2*i*	space 53-56	integer	i4
ISGAGE	14 + 2*i*	space 57-60	integer	i4
IHGAGE	14 + 2*i*	space 61-64	integer	i4
IWGAGE	14 + 2*i*	space 65-68	integer	i4

CHAPTER 4

SWAT INPUT DATA:
.COD

The input control code file regulates the general operation of SWAT. In addition to setting output file formats, the input control code file defines which processes are/are not modeled in the SWAT simulation.

Following is a brief description of the variables in the input control file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .cod file is reserved for user comments. The comments may take up to 80 spaces. The title is never used by the model and is an optional input.
NBYR	Number of calendar years simulated. The number of years simulated in a SWAT run can vary from 1 to 9,999 years. If a simulation is begun on August 1st of the year 1995 and ends July 30th of the year 1997, the model will be simulating 3 calendar years (1995, 1996 and 1997).
IYR	Beginning year of simulation (for example, 1980). The value entered for this variable is not important unless measured data (e.g. weather) is used in the run. When measured data is used, the model uses this variable to locate the beginning year within the data file.
IDAF	Beginning julian day of simulation. With this variable, SWAT is able to begin a simulation at any time of the year. If the variable is left blank or set to zero, the model starts the simulation on January 1st.
IDAL	Ending julian day of simulation. With this variable, SWAT will end the simulation on the date specified. If the variable is left blank or set to zero, the model ends the simulation on December 31st.
IPD	Print code. This variable governs the frequency that model results are printed to output files. There are three options: 0 Monthly 1 Daily 2 Annually If you choose to print results on a daily basis, the number of years simulated should be limited and/or the variables printed to the output file should be restricted. If these precautions are not taken, the output files will be too large to view.

Variable name	Definition
NYSKIP	Number of years to ***not*** print output. The options are 0 print output for all years of the simulation 1 print output after the first year of simulation 2 print output after the second year of simulation ⇣ nbyr no output will be printed Some simulations will need a warm-up or equilibration period. The use of an equilibration period becomes more important as the simulation period of interest shortens. For 30-year simulations, an equilibrium period is optional. For a simulation covering 5 years or less, an equilibrium period is recommended. An equilibration period of one year is usually adequate to get the hydrologic cycle fully operational. NYSKIP allows the user to exclude data generated during the equilibration period from output summaries. In addition to not writing data to the output files, annual averages are not computed for the skipped years. Averages for the entire simulation period will also exclude data from the skipped years. The default value for NYSKIP is 0.
IPRN	Print code for input.std file. There are two options: 0 entire input.std file is printed 1 condensed version of input.std file is printed
ILOG	Streamflow print code. This variable allows the user to take the $\log_{10}$ of the flow prior to printing streamflow values to the .rch file. There are two options: 0 print streamflow in .rch file 1 print log of streamflow in .rch file In large basins (for example, the Mississippi River basin), streamflow values printed to the .rch file may exceed the range allowed by the file format statements. This variable will eliminate print errors caused by very large values.
IPRP	Print code for .pso file. There are two options: 0 do not print pesticide output (.pso file will be empty) 1 print pesticide output

Variable name	Definition
IGN	Random generator seed code. A set of random numbers is needed by SWAT to generate weather data. SWAT has a set of default random numbers embedded in the code. To use the default random numbers, the user should set IGN = 0. This is the default value for IGN. In some situations, a user may wish to vary the weather sequence between runs. This is done by setting IGN to a different number every time the model is run. This code will activate a random number generator, which will replace the default set of random numbers with a new set. The value to which IGN is set determines the number of times the random number generator is cycled before the simulation begins. The seeds produced by the random number generator are then utilized by the weather generator instead of the default values. Measured weather data read into the model is not affected by this variable. However, if the measured data contains missing values, the weather generator is activated to produce data to replace the missing values. The data produced to replace missing values will be affected by this variable.
PCPSIM	Rainfall input code. This variable identifies the method the model will use to process rainfall data. There are two options: 1 measured data read for each subbasin 2 rainfall generated for each subbasin If observed rainfall data is available for a watershed, the user should read in the measured data.
IDT	Time step used to report measured rainfall data (minutes). Required if IEVENT = 2 or 3. One of the following should be chosen: 1 min, 2 min, 3 min, 4 min, 5 min, 6 min, 10 min, 12 min, 15 min, 20 min, 30 min.
IDIST	Rainfall distribution code. There are two options: 0 skewed distribution 1 mixed exponential distribution
REXP	Value of exponent for mixed exponential rainfall distribution. A value for REXP is needed only if IDIST = 1. The model will set REXP = 1.3 if no value is entered.

Variable name	Definition
TMPSIM	Temperature input code. This variable identifies the method the model will use to process temperature data. There are two options: 1 measured date read for each subbasin 2 daily max/min generated for each subbasin If observed temperature data is available for the watershed, the user should read in the measured data.
SLRSIM	Solar radiation input code. This variable identifies the method the model will use to process solar radiation data. There are two options: 1 measured data read for each subbasin 2 solar radiation generated for each subbasin SWAT2000 is the first version that allows solar radiation data to be read into the model. This allows users to use recorded data or import values generated with an independent weather generator. The default or recommended option is #2—allow SWAT to generate solar radiation values.
RHSIM	Relative humidity input code. This variable identifies the method the model will use to process relative humidity data. There are two options: 1 measured data read for each subbasin 2 relative humidity generated for each subbasin SWAT2000 is the first version that allows relative humidity data to be read into the model. This allows users to use recorded data or import values generated with an independent weather generator. The default or recommended option is #2—allow SWAT to generate relative humidity values.
WNDSIM	Wind speed input code. This variable identifies the method the model will use to process wind speed data. There are two options: 1 measured data read for each subbasin 2 wind speed generated for each subbasin SWAT2000 is the first version that allows wind speed data to be read into the model. This allows users to use recorded data or import values generated with an independent weather generator.

Variable name	Definition
WNDSIM, cont.	The default or recommended option is #2—allow SWAT to generate wind speed values.
IPET	Potential evapotranspiration (PET) method. There are four options for potential ET calculations: 0 Priestley-Taylor method 1 Penman/Monteith method 2 Hargreaves method 3 read in potential ET values Numerous methods exist to calculate potential evapotranspiration. Three of the most popular or widely-used are included in SWAT. However, if a method other than Priestley-Taylor, Penman/Monteith, or Hargreaves is recommended for the area in which the watershed is located, the user can calculate daily PET values with the recommended method and read them into SWAT. A discussion of Priestley-Taylor, Penman-Monteith and Hargreaves PET methods is found in Chapter 7 of the theoretical documentation.
IEVENT	Rainfall/runoff/routing option: 0 daily rainfall/curve number runoff/daily routing 1 daily rainfall/Green & Ampt runoff/daily routing (sub-hourly rainfall required for Green & Ampt is generated from daily) *this option not yet operational* 2 sub-hourly rainfall/Green & Ampt runoff/daily routing 3 sub-hourly rainfall/Green & Ampt runoff/hourly routing Option 0 was the only active option in prior versions of the model and is the default. Option 3, hourly routing, should be considered in the testing phase.
ICRK	Crack flow code. There are two options: 0 do not model crack flow in soil 1 model crack flow in soil Crack, or bypass, flow is a newer feature in SWAT and has been tested on a limited basis in simulations of some areas in Texas. This type of flow should be modeled only on soils classified as Vertisols. The default option is to model the watershed without crack flow.

Variable name	Definition
IRTE	Channel water routing method: 0 variable storage method 1 Muskingum method The default option is IRTE=0. The Muskingum method is a new option available with SWAT2000. The user must be careful to define MSK_CO1, MSK_CO2 and MSK_X (in .bsn) when the Muskingum method is chosen.
IDEG	Channel degradation code. There are two options: 0 channel dimensions are not updated as a result of degradation (the dimensions remain constant for the entire simulation) 1 channel dimensions are updated as a result of degradation Traditionally, channel dimensions remain fixed, or constant, throughout the simulation. The change in channel dimensions with time is a new feature in SWAT that is still in the testing phase. The recommended option is to keep the channel dimensions constant.
IWQ	In-stream water quality code. The variable identifies whether in-stream transformation of nutrients using the QUAL2E algorithms is allowed to occur. 0 do not model in-stream nutrient transformations 1 model in-stream nutrient transformations The default option is IWQ=0.
ISPROJ	Special project flag. SWAT includes sections of code specific to particular projects. This variable flags the code used in the particular simulation. There are three options: 0 not a special project 1 HUMUS project 2 Missouri River climate change project A user will set this variable to something other than zero only if the SWAT programmers have told him to do so.

For long runs, the output files can get so large that the user may have difficulty in opening the files to look at output. The user has the option of customizing the output printed to the output files. Lines of the .cod file are used to specify the variables to be printed to the reach output file (.rch), the subbasin output file (.bsb), and the HRU output file (.sbs). If these lines contain only zeros, the model will print all the output variables to the file.

Variable name	**Definition**
IPDVAR(:)	Output variables printed to the .rch file. (up to 20 variables may be chosen in customized output.) The codes for the output variables are: 1 FLOW_IN: Average daily streamflow into reach (m^3/s) 2 FLOW_OUT: Average daily streamflow out of reach (m^3/s) 3 EVAP: Average daily loss of water from reach by evaporation (m^3/s) 4 TLOSS: Average daily loss of water from reach by transmission (m^3/s) 5 SED_IN: Sediment transported with water into reach (metric tons) 6 SED_OUT: Sediment transported with water out of reach (metric tons) 7 SEDCONC: Concentration of sediment in reach (mg/L) 8 ORGN_IN: Organic nitrogen transported with water into reach (kg N) 9 ORGN_OUT: Organic nitrogen transported with water out of reach (kg N) 10 ORGP_IN: Organic phosphorus transported with water into reach (kg P) 11 ORGP_OUT: Organic phosphorus transported with water out of reach (kg P) 12 NO3_IN: Nitrate transported with water into reach (kg N) 13 NO3_OUT: Nitrate transported with water out of reach (kg N) 14 NH4_IN: Ammonium transported with water into reach (kg N) 15 NH4_OUT: Ammonium transported with water out of reach (kg N) 16 NO2_IN: Nitrite transported with water into reach (kg N) 17 NO2_OUT: Nitrite transported with water out of reach (kg N) 18 MINP_IN: Mineral phosphorus transported with water into reach (kg P) 19 MINP_OUT: Mineral phosphorus transported with water out of reach (kg P) 20 CHLA_IN: Chlorophyll-a transported with water into reach (kg) 21 CHLA_OUT: Chlorophyll-a transported with water out of reach (kg) 22 CBOD_IN: Carbonaceous biochemical oxygen demand transported into reach (kg O_2) 23 CBOD_OUT: Carbonaceous biochemical oxygen demand transported out of reach (kg O_2) 24 DISOX_IN: Dissolved oxygen transported into reach (kg O_2) 25 DISOX_OUT: Dissolved oxygen transported out of reach (kg O_2) 26 SOLPST_IN: Soluble pesticide transported with water into reach (mg a.i.) 27 SOLPST_OUT: Soluble pesticide transported with water out of reach (mg a.i.) 28 SORPST_IN: Pesticide sorbed to sediment transported with water into reach (mg a.i.) 29 SORPST_OUT: Pesticide sorbed to sediment transported with water out of reach (mg a.i.)

Variable name	Definition
	continued from previous page: 30 REACTPST: Loss of pesticide from water by reaction (mg a.i.) 31 VOLPST: Loss of pesticide from water by volatilization (mg a.i.) 32 SETTLPST: Transfer of pesticide from water to river bed sediment by settling (mg a.i.) 33 RESUSP_PST: Transfer of pesticide from river bed sediment to water by resuspension (mg a.i.) 34 DIFFUSEPST: Transfer of pesticide from water to river bed sediment by diffusion (mg a.i.) 35 REACBEDPST: Loss of pesticide from river bed sediment by reaction (mg a.i.) 36 BURYPST: Loss of pesticide from river bed sediment by burial (mg a.i.) 37 BED_PST: Pesticide in river bed sediment (mg a.i.) 38 BACTP_OUT: Number of persistent bacteria transported out of reach 39 BACTLP_OUT: Number of less persistent bacteria transported out of reach 40 CMETAL#1: Conservative metal #1 transported out of reach (kg) 41 CMETAL#2: Conservative metal #2 transported out of reach (kg) 42 CMETAL#3: Conservative metal #3 transported out of reach (kg)
IPDVAB(:)	Output variables printed to the .bsb file (up to 15 variables may be chosen in customized output.) The codes for the output variables are: 1 PRECIP: Average total precipitation on subbasin (mm H_2O) 2 SNOMELT: Snow melt (mm H_2O) 3 PET: Potential evapotranspiration (mm H_2O) 4 ET: Actual evapotranspiration (mm H_2O) 5 SW: Soil water content (mm H_2O) 6 PERC: Amount of water percolating out of root zone (mm H_2O) 7 SURQ: Surface runoff (mm H_2O) 8 GW_Q: Groundwater discharge into reach (mm H_2O) 9 WYLD: Net water yield to reach (mm H_2O) 10 SYLD: Sediment yield (metric tons/ha) 11 ORGN: Organic N released into reach (kg/ha) 12 ORGP: Organic P released into reach (kg/ha) 13 NSURQ: Nitrate released into reach (kg/ha) 14 SOLP: Soluble P released into reach (kg/ha) 15 SEDP: Mineral P attached to sediment released into reach (kg/ha)
IPDVAS(:)	Output variables printed to the .sbs file (up to 20 variables may be chosen in customized output.) The codes for the output variables are: 1 PRECIP: Total precipitation on HRU (mm H_2O) 2 SNOFALL: Precipitation falling as snow, sleet, or freezing rain (mm H_2O) 3 SNOMELT: Amount of snow or ice melting (mm H_2O) 4 IRR: Amount of irrigation water applied to HRU (mm H_2O) 5 PET: Potential evapotranspiration (mm H_2O) 6 ET: Amount of water removed by evapotranspiration (mm H_2O)

Variable name	Definition
	continued from previous page:
	7 SW: Soil water content at end of time period (mm H_2O) 8 PERC: Amount of water percolating out of the root zone (mm H_2O) 9 GW_RCHG: Amount of water entering both aquifers (mm H_2O) 10 DA_RCHG: Amount of water entering deep aquifer from root zone (mm H_2O) 11 REVAP: Water in shallow aquifer returning to root zone (mm H_2O) 12 SA_IRR: Amount of water removed from shallow aquifer for irrigation (mm H_2O) 13 DA_IRR: Amount of water removed from deep aquifer for irrigation (mm H_2O) 14 SA_ST: Amount of water in shallow groundwater storage at end of time period (mm H_2O) 15 DA_ST: Amount of water in deep groundwater storage at end of time period (mm H_2O) 16 SURQ: Surface runoff contribution to reach (mm H_2O) 17 TLOSS: Amount of water removed from tributary channels by transmission (mm H_2O) 18 LATQ: Lateral flow contribution to reach (mm H_2O) 19 GW_Q: Groundwater discharge into reach (mm H_2O) 20 WYLD: Net amount of water contributed by the HRU to the reach (mm H_2O) 21 SYLD: Amount of sediment contributed by the HRU to the reach (metric tons/ha) 22 USLE: USLE soil loss (metric tons/ha) 23 N_APP: Amount of N fertilizer applied (kg N/ha) 24 P_APP: Amount of P fertilizer applied (kg P/ha) 25 NAUTO: Amount of N fertilizer applied automatically (kg N/ha) 26 PAUTO: Amount of P fertilizer applied automatically (kg P/ha) 27 NGRZ: Nitrogen applied to HRU in grazing operation during time step (kg N/ha) 28 PGRZ: Phosphorus applied to HRU in grazing operation during time step (kg P/ha) 29 NRAIN: Nitrate added in rainfall (kg N/ha) 30 NFIX: Amount of N fixed by legumes (kg N/ha) 31 F-MN: Transformation of N from fresh organic to mineral pool (kg N/ha) 32 A-MN: Transformation of N from active organic to mineral pool (kg N/ha) 33 A-SN: Transformation of N from active organic to stable organic pool (kg N/ha) 34 F-MP: Transformation of P from fresh organic to mineral pool (kg P/ha) 35 AO-LP: Transformation of P from organic to labile pool (kg P/ha) 36 L-AP: Transformation of P from labile to active mineral pool (kg P/ha) 37 A-SP: Transformation of P from active mineral to stable mineral pool (kg P/ha) 38 DNIT: Amount of N removed from soil by denitrification (kg N/ha) 39 NUP: Nitrogen uptake by plants (kg N/ha)

Variable name	Definition
	continued from previous page:
	40 PUP: Phosphorus uptake by plants (kg P/ha)
	41 ORGN: Organic N contributed by HRU to reach (kg N/ha)
	42 ORGP: Organic P contributed by HRU to reach (kg P/ha)
	43 SEDP: Mineral P attached to sediment contributed by HRU to reach (kg P/ha)
	44 NSURQ: NO_3 contributed by HRU in surface runoff to reach (kg N/ha)
	45 NLATQ: NO_3 contributed by HRU in lateral flow to reach (kg N/ha)
	46 NO3L: NO_3 leached below the soil profile (kg N/ha)
	47 NO3GW: NO_3 contributed by HRU in groundwater flow to reach (kg N/ha)
	48 SOLP: Soluble phosphorus contributed by HRU in surface runoff to reach (kg P/ha)
	49 P_GW: Soluble phosphorus contributed by HRU in groundwater flow to reach (kg P/ha)
	50 W_STRS: Number of water stress days.
	51 TMP_STRS: Number of temperature stress days
	52 N_STRS: Number of nitrogen stress days.
	53 P_STRS: Number of phosphorus stress days.
	54 BIOM: Total plant biomass (metric tons/ha)
	55 LAI: Leaf area index
	56 YLD: Harvested yield (metric tons/ha)
	57 BACTP: Number of persistent bacteria in surface runoff (count)
	58 BACTLP: Number of less persistent bacteria in surface runoff (count)

The input control code file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
NBYR	2	integer	free
IYR	3	integer	free
IDAF	4	integer	free
IDAL	5	integer	free
IPD	6	integer	free
NYSKIP	7	integer	free
IPRN	8	integer	free
ILOG	9	integer	free
IPRP	10	integer	free

Variable name	**Line #**	**Format**	**F90 Format**
IGN	11	integer	free
PCPSIM	12	integer	free
IDT	13	integer	free
IDIST	14	integer	free
REXP	15	real	free
TMPSIM	16	integer	free
SLRSIM	17	integer	free
RHSIM	18	integer	free
WNDSIM	19	integer	free
IPET	20	integer	free
IEVENT	21	integer	free
ICRK	22	integer	free
IRTE	23	integer	free
IDEG	24	integer	free
NO VARIABLE	25	integer	free
IWQ	26	integer	free
ISPROJ	27	integer	free
COMMENT LINE	28	character	a80
IPDVAR(1)	29	integer	free
IPDVAR(2)	29	integer	free
IPDVAR(3)	29	integer	free
IPDVAR(4)	29	integer	free
IPDVAR(5)	29	integer	free
IPDVAR(6)	29	integer	free
IPDVAR(7)	29	integer	free
IPDVAR(8)	29	integer	free
IPDVAR(9)	29	integer	free
IPDVAR(10)	29	integer	free
IPDVAR(11)	29	integer	free
IPDVAR(12)	29	integer	free
IPDVAR(13)	29	integer	free
IPDVAR(14)	29	integer	free
IPDVAR(15)	29	integer	free
IPDVAR(16)	29	integer	free
IPDVAR(17)	29	integer	free

Variable name	Line #	Format	F90 Format
IPDVAR(18)	29	integer	free
IPDVAR(19)	29	integer	free
IPDVAR(20)	29	integer	free
COMMENT LINE	30	character	a80
IPDVAB(1)	31	integer	free
IPDVAB(2)	31	integer	free
IPDVAB(3)	31	integer	free
IPDVAB(4)	31	integer	free
IPDVAB(5)	31	integer	free
IPDVAB(6)	31	integer	free
IPDVAB(7)	31	integer	free
IPDVAB(8)	31	integer	free
IPDVAB(9)	31	integer	free
IPDVAB(10)	31	integer	free
IPDVAB(11)	31	integer	free
IPDVAB(12)	31	integer	free
IPDVAB(13)	31	integer	free
IPDVAB(14)	31	integer	free
IPDVAB(15)	31	integer	free
COMMENT LINE	32	character	a80
IPDVAS(1)	33	integer	free
IPDVAS(2)	33	integer	free
IPDVAS(3)	33	integer	free
IPDVAS(4)	33	integer	free
IPDVAS(5)	33	integer	free
IPDVAS(6)	33	integer	free
IPDVAS(7)	33	integer	free
IPDVAS(8)	33	integer	free
IPDVAS(9)	33	integer	free
IPDVAS(10)	33	integer	free
IPDVAS(11)	33	integer	free
IPDVAS(12)	33	integer	free
IPDVAS(13)	33	integer	free
IPDVAS(14)	33	integer	free
IPDVAS(15)	33	integer	free

Variable name	Line #	Format	F90 Format
IPDVAS(16)	33	integer	free
IPDVAS(17)	33	integer	free
IPDVAS(18)	33	integer	free
IPDVAS(19)	33	integer	free
IPDVAS(20)	33	integer	free

CHAPTER 5

SWAT INPUT DATA:

.BSN

General watershed attributes are defined in the basin input file. These attributes control a diversity of physical processes at the watershed level. With the exception of the watershed area, all parameters contained in this file will be set to the "default" or recommended values listed in the variable documentation if left blank. Variables governing bacteria or pesticide transport need to be initialized only if these processes are being modeled in the watershed.

Following is a brief description of the variables in the basin input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line is reserved for a description. The description may take up to 80 spaces. The title line is not processed by the model and may be left blank.
DA_KM	Area of the watershed (km^2)
SFTMP	Snowfall temperature (ºC). Mean air temperature at which precipitation is equally likely to be rain as snow/freezing rain. The snowfall temperature should be between –5 ºC and 5 ºC. A default recommended for this variable is SFTMP = 1.0.
SMTMP	Snow melt base temperature (ºC). The snow pack will not melt until the snow pack temperature exceeds a threshold value, T_{mlt}. The snow melt base temperature should be between –5 ºC and 5 ºC. A default recommended for this variable is SMTMP = 0.50.
SMFMX	Melt factor for snow on June 21 (mm H_2O/ºC-day). If the watershed is in the Northern Hemisphere, SMFMX will be the maximum melt factor. If the watershed is in the Southern Hemisphere, SMFMX will be the minimum melt factor. SMFMX and SMFMN allow the rate of snow melt to vary through the year. The variables account for the impact of snow pack density on snow melt. In rural areas, the melt factor will vary from 1.4 to 6.9 mm H_2O/day-°C (Huber and Dickinson, 1988). In urban areas, values will fall in the higher end of the range due to compression of the snow pack by vehicles, pedestrians, etc. Urban snow melt studies in Sweden (Bengston, 1981; Westerstrom, 1981) reported melt factors ranging from 3.0 to 8.0 mm H_2O/day-°C. Studies of snow melt on asphalt (Westerstrom, 1984) gave melt factors of 1.7 to 6.5 mm H_2O/day-°C. If no value for SMFMX is entered, the model will set SMFMX = 4.5.

Variable name	Definition
SMFMN	Melt factor for snow on December 21 (mm H_2O/ºC-day). If the watershed is in the Northern Hemisphere, SMFMN will be the minimum melt factor. If the watershed is in the Southern Hemisphere, SMFMN will be the maximum melt factor. SMFMX and SMFMN allow the rate of snow melt to vary through the year. The variables account for the impact of snow pack density on snow melt. In rural areas, the melt factor will vary from 1.4 to 6.9 mm H_2O/day-°C (Huber and Dickinson, 1988). In urban areas, values will fall in the higher end of the range due to compression of the snow pack by vehicles, pedestrians, etc. Urban snow melt studies in Sweden (Bengston, 1981; Westerstrom, 1981) reported melt factors ranging from 3.0 to 8.0 mm H_2O/day-°C. Studies of snow melt on asphalt (Westerstrom, 1984) gave melt factors of 1.7 to 6.5 mm H_2O/day-°C. If no value for SMFMN is entered, the model will set SMFMN = 4.5.
TIMP	Snow pack temperature lag factor. The influence of the previous day's snow pack temperature on the current day's snow pack temperature is controlled by a lagging factor, ℓ_{sno}. The lagging factor inherently accounts for snow pack density, snow pack depth, exposure and other factors affecting snow pack temperature. TIMP can vary between 0.01 and 1.0. As ℓ_{sno} approaches 1.0, the mean air temperature on the current day exerts an increasingly greater influence on the snow pack temperature and the snow pack temperature from the previous day exerts less and less influence. As TIMP goes to zero, the snow pack's temperature will be less influenced by the current day's air temperature. If no value for TIMP is entered, the model will set TIMP = 1.0.
SNOCOVMX	Minimum snow water content that corresponds to 100% snow cover, SNO_{100}, (mm H_2O). Due to variables such as drifting, shading and topography, the snow pack in a subbasin will rarely be uniformly distributed over the total area. This results in a fraction of the subbasin area that is bare of snow. This fraction must be quantified to accurately compute snow melt in the subbasin.

Variable name	Definition
SNOCOVMX, cont.	The factors that contribute to variable snow coverage are usually similar from year to year, making it possible to correlate the areal coverage of snow with the amount of snow present in the subbasin at a given time. This correlation is expressed as an areal depletion curve, which is used to describe the seasonal growth and recession of the snow pack as a function of the amount of snow present in the subbasin (Anderson, 1976). The areal depletion curve requires a threshold depth of snow, SNO_{100}, to be defined above which there will always be 100% cover. The threshold depth will depend on factors such as vegetation distribution, wind loading of snow, wind scouring of snow, interception and aspect, and will be unique to the watershed of interest. If the snow water content is less than SNOCOVMX, then a certain percentage of ground cover will be bare. It is important to remember that once the volume of water held in the snow pack exceeds SNO_{100} the depth of snow over the HRU is assumed to be uniform, i.e. $sno_{cov} = 1.0$. The areal depletion curve affects snow melt only when the snow pack water content is between 0.0 and SNO_{100}. Consequently if SNO_{100} is set to a very small value, the impact of the areal depletion curve on snow melt will be minimal. As the value for SNO_{100} increases, the influence of the areal depletion curve will assume more importance in snow melt processes. If no value for SNOCOVMX is entered, the model will set SNOCOVMX = 1.00.
SNO50COV	Fraction of snow volume represented by SNOCOVMX that corresponds to 50% snow cover. SWAT assumes a nonlinear relationship between snow water and snow cover. SNO50COV can vary between 0.01 and 0.99. Example areal depletion curves for various fractions of SNO_{100} at 50% coverage are shown in the following figures. If no value for SNO50COV is entered, the model will set SNO50COV = 0.50, i.e. 50% of SNOCOVMX.

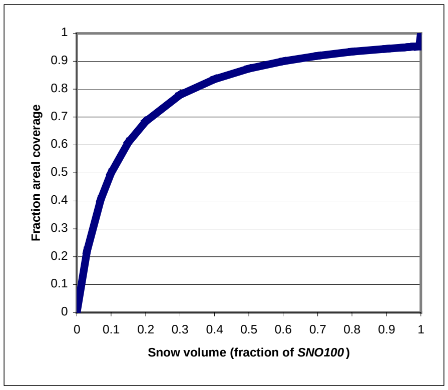

Figure 5-1:10% SNO_{100} = 50% coverage

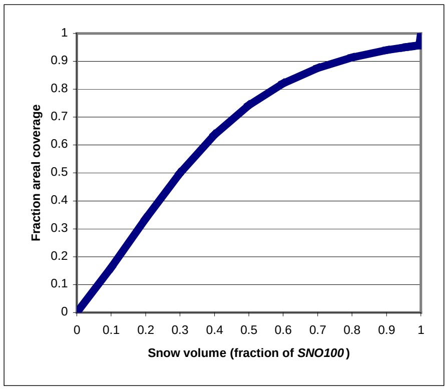

Figure 5-2: 30% SNO_{100} = 50% coverage

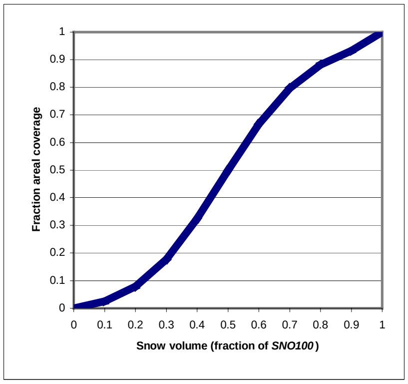

Figure 5-3: 50% SNO_{100} = 50% coverage

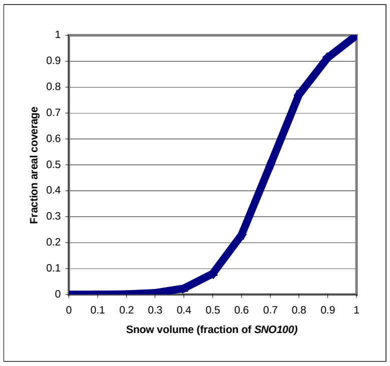

Figure 5-4: 70% SNO_{100} = 50% coverage

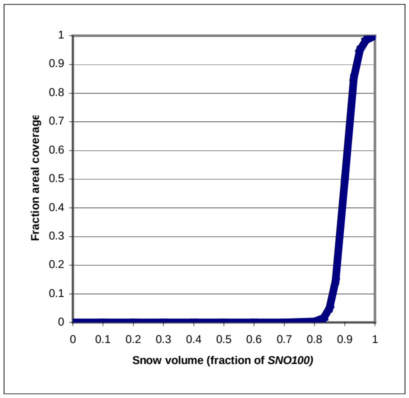

Figure 5-5: 90% SNO_{100} = 50% coverage

Variable name	Definition
RCN	Concentration of nitrogen in rainfall (mg N/L). If no value for RCN is entered, the model will set RCN = 1.0.
SURLAG	Surface runoff lag coefficient. In large subbasins with a time of concentration greater than 1 day, only a portion of the surface runoff will reach the main channel on the day it is generated. SWAT incorporates a surface runoff storage feature to lag a portion of the surface runoff release to the main channel. SURLAG controls the fraction of the total available water that will be allowed to enter the reach on any one day. Figure 5-6 plots the fraction of total available water entering the reach at different values for *surlag* and t_{conc}. Note that for a given time of concentration, as *surlag* decreases in value more water is held in storage. The delay in release of surface runoff will smooth the streamflow hydrograph simulated in the reach. If no value for SURLAG is entered, the model will set SURLAG = 4.0.

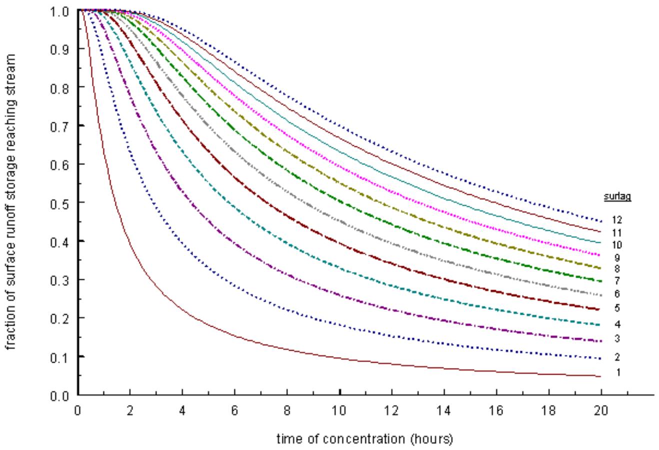

Figure 5-6: Influence of *surlag* and t_{conc} on fraction of surface runoff released.

Variable name	Definition
APM	Peak rate adjustment factor for sediment routing in the *subbasin (tributary channels)*. Sediment routing is a function of peak flow rate and mean daily flow. Because SWAT can not directly calculate the sub-daily hydrograph due to the use of precipitation summarized on a daily basis, this variable was incorporated to allow adjustment for the effect of the peak flow rate on sediment routing. This factor is used in the MUSLE equation and impacts the amount of erosion generated in the HRUs. If no value for APM is entered, the model will set APM=1.0.
PRF	Peak rate adjustment factor for sediment routing in the *main channel*. Sediment routing is a function of peak flow rate and mean daily flow. Because SWAT can not directly calculate the sub-daily hydrograph, this variable was incorporated to allow adjustment for the effect of the peak flow rate on sediment routing. This variable impacts channel degradation. If no value for PRF is entered, the model will set PRF = 1.0.
SPCON	Linear parameter for calculating the maximum amount of sediment that can be reentrained during channel sediment routing. The maximum amount of sediment that can be transported from a reach segment is calculated $conc_{sed,ch,mx} = c_{sp} \cdot v_{ch,pk}{}^{spexp}$ where $conc_{sed,ch,mx}$ is the maximum concentration of sediment that can be transported by the water (ton/m^3 or kg/L), c_{sp} is a coefficient defined by the user, $v_{ch,pk}$ is the peak channel velocity (m/s), and *spexp* is an exponent defined by the user. SPCON should be between 0.0001 and 0.01. If no value for SPCON is entered, the model will set SPCON = 0.0001.
SPEXP	Exponent parameter for calculating sediment reentrained in channel sediment routing The maximum amount of sediment that can be transported from a reach segment is calculated $conc_{sed,ch,mx} = c_{sp} \cdot v_{ch,pk}{}^{spexp}$ where $conc_{sed,ch,mx}$ is the maximum concentration of sediment that can be transported by the water (ton/m^3 or kg/L), c_{sp} is a coefficient defined by the user, $v_{ch,pk}$ is the peak channel velocity (m/s), and *spexp* is an exponent defined by the user. The exponent, *spexp*, normally varies between 1.0 and 2.0 and was set at 1.5 in the original Bagnold stream power equation (Arnold et al., 1995). If no value for SPEXP is entered, the model will set SPEXP = 1.0.

Variable name	Definition
EVRCH	Reach evaporation adjustment factor. The evaporation coefficient is a calibration parameter for the user and is allowed to vary between 0.0 and 1.0. This coefficient was created to allow reach evaporation to be dampened in arid regions. The original equation tends to overestimate evaporation in these areas. If no value for EVRCH is entered, the model will set EVRCH = 1.00.
EVLAI	Leaf area index at which no evaporation occurs from water surface. EVLAI is used in HRUs where a plant is growing in a ponded environment (e.g. rice). Evaporation from the water surface is allowed until the leaf area of the plant reaches the value specified for EVLAI. Chapter 27 in the Theoretical Documentation provides more detail on the use of this parameter. EVLAI should be set between 0.0 and 10.0. If no value for EVLAI is entered, the model will set EVLAI = 3.0.
FFCB	Initial soil water storage expressed as a fraction of field capacity water content. All soils in the watershed will be initialized to the same fraction. FFCB should be between 0.0 and 1.0. If FFCB is not set to a value, the model will calculate it as a function of average annual precipitation. The default method is to allow the model to calculate FFCB (set FFCB = 0.0).
CMN	Rate factor for humus mineralization of active organic nutrients (N and P). Chapters 10 and 11 of the Theoretical Documentation describe the use of this parameter in the mineralization calculations. If no value for CMN is specified, the model will set CMN = 0.0003.

Variable name	Definition
UBN	Nitrogen uptake distribution parameter. Root density is greatest near the surface, and plant nitrogen uptake in the upper portion of the soil will be greater than in the lower portion. The depth distribution of nitrogen uptake is controlled by β_n, the nitrogen uptake distribution parameter. The importance of the nitrogen uptake distribution parameter lies in its control over the maximum amount of nitrate removed from the upper layers. Because the top 10 mm of the soil profile interacts with surface runoff, the nitrogen uptake distribution parameter will influence the amount of nitrate available for transport in surface runoff. The model allows lower layers in the root zone to fully compensate for lack of nitrate in the upper layers, so there should not be significant changes in nitrogen stress with variation in the value used for β_n. If no value for UBN is entered, the model will set UBN = 20.0. Figure 5-7 illustrates nitrogen uptake as a function of depth for four different uptake distribution parameter values.

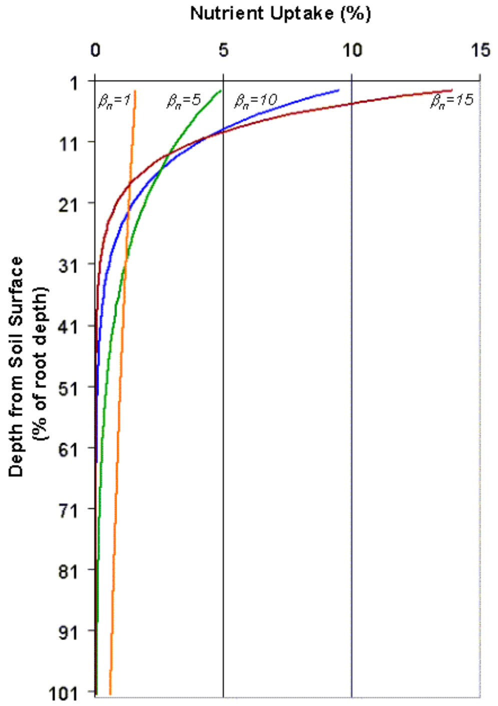

Figure 5-7: Depth distribution of nitrogen uptake

Variable name	Definition
UBP	Phosphorus uptake distribution parameter.
	This parameter controls plant uptake of phosphorus from the different soil horizons in the same way that UBN controls nitrogen uptake. The illustration of nitrogen uptake as a function of depth for four different uptake distribution parameter values in Figure 5-7 is valid for phosphorus uptake as well.
	Phosphorus removed from the soil by plants is taken from the solution phosphorus pool. The importance of the phosphorus uptake distribution parameter lies in its control over the maximum amount of solution P removed from the upper layers. Because the top 10 mm of the soil profile interacts with surface runoff, the phosphorus uptake distribution parameter will influence the amount of labile phosphorus available for transport in surface runoff. The model allows lower layers in the root zone to fully compensate for lack of solution P in the upper layers, so there should not be significant changes in phosphorus stress with variation in the value used for β_p.
	If no value for UBP is entered, the model will set UBP = 20.0.
NPERCO	Nitrate percolation coefficient.
	NPERCO controls the amount of nitrate removed from the surface layer in runoff relative to the amount removed via percolation.
	The value of NPERCO can range from 0.01 to 1.0. As NPERCO → 0.0, the concentration of nitrate in the runoff approaches 0. As NPERCO → 1.0, surface runoff has the same concentration of nitrate as the percolate.
	If no value for NPERCO is entered, the model will set NPERCO = 0.20.
PPERCO	Phosphorus percolation coefficient (10 m^3/Mg).
	The phosphorus percolation coefficient is the ratio of the solution phosphorus concentration in the surface 10 mm of soil to the concentration of phosphorus in percolate.
	The value of PPERCO can range from 10.0 to 17.5 If no value for PPERCO is entered, the model will set PPERCO = 10.0.

Variable name	Definition
PHOSKD	Phosphorus soil partitioning coefficient (m^3/Mg). The phosphorus soil partitioning coefficient is the ratio of the soluble phosphorus concentration in the surface 10 mm of soil to the concentration of soluble phosphorus in surface runoff. The primary mechanism of phosphorus movement in the soil is by diffusion. Diffusion is the migration of ions over small distances (1-2 mm) in the soil solution in response to a concentration gradient. Due to the low mobility of solution phosphorus, surface runoff will only partially interact with the solution P stored in the top 10 mm of soil. If no value for PHOSKD is entered, the model will set PHOSKD = 175.0.
PSP	Phosphorus availability index. Many studies have shown that after an application of soluble P fertilizer, solution P concentration decreases rapidly with time due to reaction with the soil. This initial “fast” reaction is followed by a much slower decrease in solution P that may continue for several years (Barrow and Shaw, 1975; Munns and Fox, 1976; Rajan and Fox, 1972; Sharpley, 1982). In order to account for the initial rapid decrease in solution P, SWAT assumes a rapid equilibrium exists between solution P and an “active” mineral pool. The subsequent slow reaction is simulated by the slow equilibrium assumed to exist between the “active” and “stable” mineral pools. The algorithms governing movement of inorganic phosphorus between these three pools are taken from Jones et al. (1984). Equilibration between the solution and active mineral pool is governed by the phosphorus availability index. This index specifies the fraction of fertilizer P which is in solution after an incubation period, i.e. after the rapid reaction period. A number of methods have been developed to measure the phosphorus availability index. Jones et al. (1984) recommends a method outlined by Sharpley et al. (1984) in which various amounts of phosphorus are added in solution to the soil as K_2HPO_4. The soil is wetted to field capacity and then dried slowly at 25°C. When dry, the soil is rewetted with deionized water. The soil is exposed to several wetting and drying cycles over a 6-month incubation period. At the end of the incubation period, solution phosphorus is determined by extraction with anion exchange resin.

Variable name	Definition
PSP, cont.	The P availability index is then calculated: $pai = \frac{P_{solution,f} - P_{solution,i}}{fert_{minP}}$ where pai is the phosphorus availability index, $P_{solution,f}$ is the amount of phosphorus in solution after fertilization and incubation, $P_{solution,i}$ is the amount of phosphorus in solution before fertilization, and $fert_{minP}$ is the amount of soluble P fertilizer added to the sample. If no value for PSP is entered, the model will set PSP = 0.40.
RSDCO	Residue decomposition coefficient. The fraction of residue which will decompose in a day assuming optimal moisture, temperature, C:N ratio and C:P ratio. If no value for RSDCO is entered, the model will set RSDCO = 0.05.
PERCOP	Pesticide percolation coefficient. PERCOP controls the amount of pesticide removed from the surface layer in runoff and lateral flow relative to the amount removed via percolation. The value of PERCOP can range from 0.01 to 1.0. As PERCOP → 0.0, the concentration of pesticide in the runoff and lateral flow approaches 0. As PERCOP → 1.0, surface runoff and lateral flow has the same concentration of pesticide as the percolate. If no value for PERCOP is entered, the model will set PERCOP = 0.50.
IRTPEST	Number of pesticide to be routed through the watershed channel network. This is the pesticide ID number from the pesticide database. While more than one type of pesticide may be applied to the HRUs, the model will monitor the movement of only one pesticide through the channel network.
WDPQ	Die-off factor for persistent bacteria in soil solution. (1/day)
WGPQ	Growth factor for persistent bacteria in soil solution. (1/day)
WDLPQ	Die-off factor for less persistent bacteria in soil solution. (1/day)
WGLPQ	Growth factor for less persistent bacteria in soil solution. (1/day)

Variable name	Definition
WDPS	Die-off factor for persistent bacteria adsorbed to soil particles. (1/day)
WGPS	Growth factor for persistent bacteria adsorbed to soil particles. (1/day)
WDLPS	Die-off factor for less persistent bacteria adsorbed to soil particles. (1/day)
WGLPS	Growth factor for less persistent bacteria adsorbed to soil particles. (1/day)
BACTKDQ	Bacteria partition coefficient. Partition coefficient for bacteria between soluble and sorbed phase in surface runoff. If no value for BACTKDQ is entered, the model will set BACTKDQ = 175.0.
THBACT	Temperature adjustment factor for bacteria die-off/growth. If no value for THBACT is entered, the model will set THBACT = 1.07.
MSK_CO1	Calibration coefficient used to control impact of the storage time constant (K_m) for normal flow (where normal flow is when river is at bankfull depth) upon the K_m value calculated for the reach. Required only if IRTE = 1 in .cod file.
MSK_CO2	Calibration coefficient used to control impact of the storage time constant (K_m) for low flow (where low flow is when river is at 0.1 bankfull depth) upon the K_m value calculated for the reach. Required only if IRTE = 1 in .cod file.
MSK_X	MSK_X is a weighting factor that controls the relative importance of inflow and outflow in determining the storage in a reach. The weighting factor has a lower limit of 0.0 and an upper limit of 0.5. This factor is a function of the wedge storage. For reservoir-type storage, there is no wedge and X = 0.0. For a full-wedge, X = 0.5. For rivers, X will fall between 0.0 and 0.3 with a mean value near 0.2. If no value for MSK_X is entered, the model will set MSK_X = 0.2. Required only if IRTE = 1 in .cod file.

Variable name	Definition
ESCO	Soil evaporation compensation factor. This coefficient has been incorporated to allow the user to modify the depth distribution used to meet the soil evaporative demand to account for the effect of capillary action, crusting and cracks. ESCO must be between 0.01 and 1.0. As the value for ESCO is reduced, the model is able to extract more of the evaporative demand from lower levels. The change in depth distribution resulting from different values of *esco* are graphed in Figure 5-8.

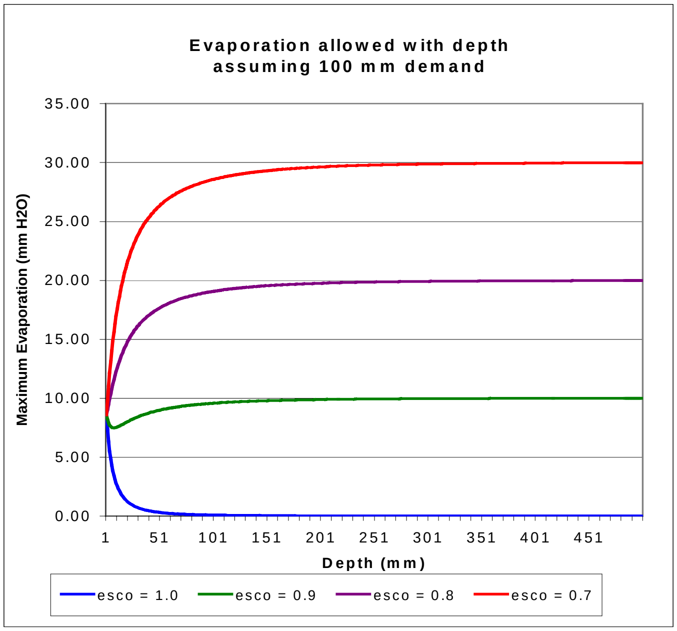

Figure 5-8: Soil evaporative demand distribution with depth

If no value for ESCO is entered, the model will set ESCO = 0.95. The value for ESCO may be set at the watershed or HRU level (ESCO in .hru).

Variable name	Definition
EPCO	Plant uptake compensation factor. The amount of water uptake that occurs on a given day is a function of the amount of water required by the plant for transpiration, E_t, and the amount of water available in the soil, *SW*. If upper layers in the soil profile do not contain enough water to meet the potential water uptake, users may allow lower layers to compensate. The plant uptake compensation factor can range from 0.01 to 1.00. As *epco* approaches 1.0, the model allows more of the water uptake demand to be met by lower layers in the soil. As *epco* approaches 0.0, the model allows less variation from the original depth distribution to take place. If no value for EPCO is entered, the model will set EPCO = 1.0. The value for EPCO may be set at the watershed or HRU level (EPCO in .hru).

The basin input file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
DA_KM	2	real	free
BLANK LINE	3	real	free
SFTMP	4	real	free
SMTMP	5	real	free
SMFMX	6	real	free
SMFMN	7	real	free
TIMP	8	real	free
SNOCOVMX	9	real	free
SNO50COV	10	real	free
RCN	11	real	free
SURLAG	12	real	free
APM	13	real	free
PRF	14	real	free
SPCON	15	real	free

Variable name	Line #	Format	F90 Format
SPEXP	16	real	free
BLANK LINE	17	real	free
BLANK LINE	18	real	free
BLANK LINE	19	real	free
BLANK LINE	20	real	free
BLANK LINE	21	real	free
EVRCH	22	real	free
EVLAI	23	real	free
FFCB	24	real	free
CMN	25	real	free
UBN	26	real	free
UBP	27	real	free
NPERCO	28	real	free
PPERCO	29	real	free
PHOSKD	30	real	free
PSP	31	real	free
RSDCO	32	real	free
PERCOP	33	real	free
IRTPEST	34	integer	free
WDPQ	35	real	free
WGPQ	36	real	free
WDLPQ	37	real	free
WGLPQ	38	real	free
WDPS	39	real	free
WGPS	40	real	free
WDLPS	41	real	free
WGLPS	42	real	free
BACTKDQ	43	real	free
THBACT	44	real	free
MSK_CO1	45	real	free
MSK_CO2	46	real	free
MSK_X	47	real	free
ESCO	48	real	free
EPCO	49	real	free

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CHAPTER 6

SWAT INPUT DATA:

.SUB

The subbasin general input file contains information related to a diversity of features within the subbasin. Data contained in the subbasin input file can be grouped into the following categories: properties of tributary channels within the subbasin, the amount of topographic relief within the subbasin and its impact on the climate, variables related to climate change, the number of HRUs in the subbasin and the names of HRU input files.

Following is a brief description of the variables in the subbasin general input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .sub file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
HRUTOT	Total number of HRUs modeled in the subbasin. Each subbasin must contain at least one HRU.
LATITUDE	Latitude of subbasin (degrees). The latitude is expressed as a real number with minutes and seconds converted to fractions of a degree.
ELEV	Elevation of subbasin (m).
ELEVB(band)	Elevation at the center of the elevation band (m). Orographic precipitation is a significant phenomenon in certain areas of the world. To account for orographic effects on both precipitation and temperature, SWAT allows up to 10 elevation bands to be defined in each subbasin. The only processes modeled separately for each individual elevation band are the accumulation, sublimation and melting of snow. As with the initial precipitation and temperature data, after amounts of sublimation and snow melt are determined for each elevation band, subbasin average values are calculated. These average values are the values that are used in the remainder of the simulation and reported in the output files. If the user wishes to simulate elevation bands in a subbasin, the elevation and fraction of the subbasin area contained in the elevation and must be specified.
ELEVB_FR(band)	Fraction of subbasin area within the elevation band. Values for ELEVB_FR should be between 0.0 and 1.0. Required only if elevation bands are being simulated in the subbasin.

Variable name	Definition
SNOEB(band)	Initial snow water content in elevation band (mm H_2O). The amount of snow in the elevation band is expressed as depth of water instead of depth of snow because the density of snow is highly variable. Optional.
PLAPS	Precipitation lapse rate (mm H_2O/km). A positive value denotes an increase in precipitation with an increase in elevation while a negative value denotes a decrease in precipitation with an increase in elevation. The lapse rate is used to adjust precipitation for elevation bands in the subbasin. To adjust the precipitation, the elevation of the recording station or the weather station is compared to the elevation specified for the elevation band. If no elevation bands are defined, the precipitation generated or read in from the .pcp file is used for the subbasin with no adjustment Required only if elevation bands are being simulated in the subbasin.
TLAPS	Temperature lapse rate (ºC/km). A positive value denotes an increase in temperature with an increase in elevation while a negative value denotes a decrease in temperature with an increase in elevation. The lapse rate is used to adjust temperature for elevation bands in the subbasin. To adjust the temperature, the elevation of the recording station or the weather station is compared to the elevation specified for the elevation band. If no elevation bands are defined, the temperature generated or read in from the .tmp file is used for the subbasin with no adjustment. If no value is entered for TLAPS, the model sets TLAPS = -6 ºC/km. Required only if elevation bands are being simulated in the subbasin.

Variable name	Definition
SNO_SUB	Initial snow water content (mm H_2O). The amount of snow in the subbasin is expressed as depth of water instead of depth of snow because the density of snow is highly variable. This value is not used if the subbasin is divided into elevation bands (see variables ELEVB, ELEVB_FR and SNOEB in this file). Optional.
CH_L(1)	Longest “tributary” channel length in subbasin (km). The channel length is the distance along the channel from the subbasin outlet to the most distant point in the subbasin.
CH_S(1)	Average slope of tributary channels (m/m). The average channel slope is computed by taking the difference in elevation between the subbasin outlet and the most distant point in the subbasin and dividing by CH_L.
CH_W(1)	Average width of tributary channels (m).
CH_K(1)	Effective hydraulic conductivity in tributary channel alluvium (mm/hr). This parameter controls transmission losses from surface runoff as it flows to the main channel in the subbasin.
CH_N(1)	Manning’s “n” value for the tributary channels.

Table 6-1: Values of Manning’s roughness coefficient, *n*, for channel flow (Chow, 1959).[1]

Characteristics of Channel	Median	Range
Excavated or dredged		
Earth, straight and uniform	0.025	0.016-0.033
Earth, winding and sluggish	0.035	0.023-0.050
Not maintained, weeds and brush	0.075	0.040-0.140
Natural streams		
Few trees, stones or brush	0.050	0.025-0.065
Heavy timber and brush	0.100	0.050-0.150

[1] Chow (1959) has a very extensive list of Manning’s roughness coefficients. These values represent only a small portion of those he lists in his book.

Variable name	Definition
CO2	Carbon dioxide concentration (ppmv). If no value for CO2 is entered the model will set CO2 = 330 ppmv (ambient CO_2 concentration). (Optional—used in climate change studies only)
RFINC(mon)	Rainfall adjustment (% change). Daily rainfall within the month is adjusted by the specified percentage. For example, setting RFINC = 10 will make rainfall equal to 110% of the original value. (Optional—used in climate change studies only).
TMPINC(mon)	Temperature adjustment (ºC). Daily maximum and minimum temperatures within the month are raised or lowered by the specified amount. (Optional—used in climate change studies only).
RADINC(mon)	Radiation adjustment (MJ/m^2-day). Daily radiation within the month is raised or lowered by the specified amount. (Optional—used in climate change studies only).
HUMINC(mon)	Humidity adjustment. Daily values for relative humidity within the month are raised or lowered by the specified amount. The relative humidity in SWAT is reported as a fraction. (Optional—used in climate change studies only).
HRUDAT	Name of HRU general input data file (**.hru**).
MGTDAT	Name of HRU land use management data file (**.mgt**).
SOILDAT	Name of HRU soil data file (**.sol**).
CHEMDAT	Name of HRU soil chemical data file (**.chm**).
GWDAT	Name of HRU groundwater data file (**.gw**).

The subbasin general input file is partially free format and partially fixed format. The variables that are free format will have *free* listed in the **F90Format** column and will not have a position defined. The variables that are fixed format will have a FORTRAN format and position specified.

The free format variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

The fixed format variables must be entered using the specified format and positioning on the line in order for the model to read them properly.

The format for the subbasin general input file is:

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
TITLE	1	space 1-80	character	a80
HRUTOT	2		integer	free
LATITUDE	3		real	free
ELEV	4		real	free
COMMENT LINE	5	space 1-80	character	a80
ELEVB(1)	6	space 1-8	decimal (xxxx.xxx)	f8.3
ELEVB(2)	6	space 9-16	decimal (xxxx.xxx)	f8.3
ELEVB(3)	6	space 17-24	decimal (xxxx.xxx)	f8.3
ELEVB(4)	6	space 25-32	decimal (xxxx.xxx)	f8.3
ELEVB(5)	6	space 33-40	decimal (xxxx.xxx)	f8.3
ELEVB(6)	6	space 41-48	decimal (xxxx.xxx)	f8.3
ELEVB(7)	6	space 49-56	decimal (xxxx.xxx)	f8.3
ELEVB(8)	6	space 57-64	decimal (xxxx.xxx)	f8.3
ELEVB(9)	6	space 65-72	decimal (xxxx.xxx)	f8.3
ELEVB(10)	6	space 73-80	decimal (xxxx.xxx)	f8.3
COMMENT LINE	7	space 1-80	character	a80
ELEVB_FR(1)	8	space 1-8	decimal (xxxx.xxx)	f8.3
ELEVB_FR(2)	8	space 9-16	decimal (xxxx.xxx)	f8.3
ELEVB_FR(3)	8	space 17-24	decimal (xxxx.xxx)	f8.3
ELEVB_FR(4)	8	space 25-32	decimal (xxxx.xxx)	f8.3
ELEVB_FR(5)	8	space 33-40	decimal (xxxx.xxx)	f8.3
ELEVB_FR(6)	8	space 41-48	decimal (xxxx.xxx)	f8.3
ELEVB_FR(7)	8	space 49-56	decimal (xxxx.xxx)	f8.3

Variable name	Line #	Position	Format	F90 Format
ELEVB_FR(8)	8	space 57-64	decimal (xxxx.xxx)	f8.3
ELEVB_FR(9)	8	space 65-72	decimal (xxxx.xxx)	f8.3
ELEVB_FR(10)	8	space 73-80	decimal (xxxx.xxx)	f8.3
COMMENT LINE	9	space 1-80	character	a80
SNOEB(1)	10	space 1-8	decimal (xxxx.xxx)	f8.3
SNOEB(2)	10	space 9-16	decimal (xxxx.xxx)	f8.3
SNOEB(3)	10	space 17-24	decimal (xxxx.xxx)	f8.3
SNOEB(4)	10	space 25-32	decimal (xxxx.xxx)	f8.3
SNOEB(5)	10	space 33-40	decimal (xxxx.xxx)	f8.3
SNOEB(6)	10	space 41-48	decimal (xxxx.xxx)	f8.3
SNOEB(7)	10	space 49-56	decimal (xxxx.xxx)	f8.3
SNOEB(8)	10	space 57-64	decimal (xxxx.xxx)	f8.3
SNOEB(9)	10	space 65-72	decimal (xxxx.xxx)	f8.3
SNOEB(10)	10	space 73-80	decimal (xxxx.xxx)	f8.3
PLAPS	11		real	free
TLAPS	12		real	free
SNO_SUB	13		real	free
CH_L(1)	14		real	free
CH_S(1)	15		real	free
CH_W(1)	16		real	free
CH_K(1)	17		real	free
CH_N(1)	18		real	free
CO2	19		real	free
COMMENT LINE	20	space 1-80	character	a80
RFINC(1)	21	space 1-8	decimal (xxxx.xxx)	f8.3
RFINC(2)	21	space 9-16	decimal (xxxx.xxx)	f8.3
RFINC(3)	21	space 17-24	decimal (xxxx.xxx)	f8.3
RFINC(4)	21	space 25-32	decimal (xxxx.xxx)	f8.3
RFINC(5)	21	space 33-40	decimal (xxxx.xxx)	f8.3
RFINC(6)	21	space 41-48	decimal (xxxx.xxx)	f8.3
COMMENT LINE	22	space 1-80	character	a80
RFINC(7)	23	space 1-8	decimal (xxxx.xxx)	f8.3
RFINC(8)	23	space 9-16	decimal (xxxx.xxx)	f8.3
RFINC(9)	23	space 17-24	decimal (xxxx.xxx)	f8.3
RFINC(10)	23	space 25-32	decimal (xxxx.xxx)	f8.3

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
RFINC(11)	23	space 33-40	decimal (xxxx.xxx)	f8.3
RFINC(12)	23	space 41-48	decimal (xxxx.xxx)	f8.3
COMMENT LINE	24	space 1-80	character	a80
TMPINC(1)	25	space 1-8	decimal (xxxx.xxx)	f8.3
TMPINC(2)	25	space 9-16	decimal (xxxx.xxx)	f8.3
TMPINC(3)	25	space 17-24	decimal (xxxx.xxx)	f8.3
TMPINC(4)	25	space 25-32	decimal (xxxx.xxx)	f8.3
TMPINC(5)	25	space 33-40	decimal (xxxx.xxx)	f8.3
TMPINC(6)	25	space 41-48	decimal (xxxx.xxx)	f8.3
COMMENT LINE	26	space 1-80	character	a80
TMPINC(7)	27	space 1-8	decimal (xxxx.xxx)	f8.3
TMPINC(8)	27	space 9-16	decimal (xxxx.xxx)	f8.3
TMPINC(9)	27	space 17-24	decimal (xxxx.xxx)	f8.3
TMPINC(10)	27	space 25-32	decimal (xxxx.xxx)	f8.3
TMPINC(11)	27	space 33-40	decimal (xxxx.xxx)	f8.3
TMPINC(12)	27	space 41-48	decimal (xxxx.xxx)	f8.3
COMMENT LINE	28	space 1-80	character	a80
RADINC(1)	29	space 1-8	decimal (xxxx.xxx)	f8.3
RADINC(2)	29	space 9-16	decimal (xxxx.xxx)	f8.3
RADINC(3)	29	space 17-24	decimal (xxxx.xxx)	f8.3
RADINC(4)	29	space 25-32	decimal (xxxx.xxx)	f8.3
RADINC(5)	29	space 33-40	decimal (xxxx.xxx)	f8.3
RADINC(6)	29	space 41-48	decimal (xxxx.xxx)	f8.3
COMMENT LINE	30	space 1-80	character	a80
RADINC(7)	31	space 1-8	decimal (xxxx.xxx)	f8.3
RADINC(8)	31	space 9-16	decimal (xxxx.xxx)	f8.3
RADINC(9)	31	space 17-24	decimal (xxxx.xxx)	f8.3
RADINC(10)	31	space 25-32	decimal (xxxx.xxx)	f8.3
RADINC(11)	31	space 33-40	decimal (xxxx.xxx)	f8.3
RADINC(12)	31	space 41-48	decimal (xxxx.xxx)	f8.3
COMMENT LINE	32	space 1-80	character	a80
HUMINC(1)	33	space 1-8	decimal (xxxx.xxx)	f8.3
HUMINC(2)	33	space 9-16	decimal (xxxx.xxx)	f8.3
HUMINC(3)	33	space 17-24	decimal (xxxx.xxx)	f8.3
HUMINC(4)	33	space 25-32	decimal (xxxx.xxx)	f8.3

Variable name	Line #	Position	Format	F90 Format
HUMINC(5)	33	space 33-40	decimal (xxxx.xxx)	f8.3
HUMINC(6)	33	space 41-48	decimal (xxxx.xxx)	f8.3
COMMENT LINE	34	space 1-80	character	a80
HUMINC(7)	35	space 1-8	decimal (xxxx.xxx)	f8.3
HUMINC(8)	35	space 9-16	decimal (xxxx.xxx)	f8.3
HUMINC(9)	35	space 17-24	decimal (xxxx.xxx)	f8.3
HUMINC(10)	35	space 25-32	decimal (xxxx.xxx)	f8.3
HUMINC(11)	35	space 33-40	decimal (xxxx.xxx)	f8.3
HUMINC(12)	35	space 41-48	decimal (xxxx.xxx)	f8.3
COMMENT LINE	36	space 1-80	character	a80
HRUDAT	37-END	space 1-13	character	a13
MGTDAT	37-END	space 14-26	character	a13
SOILDAT	37-END	space 27-39	character	a13
CHEMDAT	37-END	space 40-52	character	a13
GWDAT	37-END	space 53-65	character	a13

REFERENCES

Chow, V.T. 1959. Open-channel hydraulics. McGraw-Hill, New York.

CHAPTER 7

SWAT INPUT DATA: .PCP

SWAT requires daily precipitation. Values for precipitation may be read from records of observed data or they may be generated. This chapter describes the format of the file used to read in measured precipitation data.

Up to 18 precipitation files may be utilized in a simulation. The precipitation files are able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

The precipitation data may be read into the model in daily or sub-daily time increments. The following sections describe the format for a daily and a subdaily precipitation file.

7.1 DAILY PRECIPITATION DATA

Daily precipitation data is used when the SCS curve number method is chosen to model surface runoff (Set by IEVENT in the .cod file).

While the input file must contain data for the entire period of simulation, the record does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the file, saving editing time on the user's part. Once SWAT locates the record for the beginning day of simulation, it no longer processes the year and date. Because it does not check the subsequent dates, it is very important that the data for the remaining days in the simulation are listed sequentially. (If no year and date are entered for any of the records, the model assumes the first line of data corresponds to the first day of simulation.)

A negative 99.0 (-99.0) should be inserted for missing data. This value tells SWAT to generate precipitation for that day.

Following is a brief description of the variables in the precipitation input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the precipitation file is reserved for comments. The title line is not processed by the model and may be left blank.
LATITUDE	Latitude of precipitation recording gage location. This value is not used by the model and may be left blank.
LONGITUDE	Longitude of precipitation recording gage location. This value is not used by the model and may be left blank.
ELEVATION	Elevation of precipitation recording gage (m). The elevation of the recording gage is used to adjust precipitation values for elevation in subbasins where elevation bands and a precipitation lapse rate are defined.
YEAR	Year (4-digit)
DATE	Julian date
PRECIPITATION	Amount of precipitation falling during the day (mm).

The format of the daily precipitation file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
LATITUDE	2	space 8-12	free	unrestricted
LONGITUDE	3	space 8-12	free	unrestricted
ELEVATION	4	space 8-12	integer	i5
YEAR	5-END	space 1-4	integer	i4
DATE	5-END	space 5-7	integer	i3
PRECIPITATION	5-END	space 8-12	decimal(xxx.x)	f5.1

To place more than one data record within the .pcp file, repeat the original formatting for the recorded data to the right of the existing data. Simulations have been run with 200 records placed in the precipitation files.

For example, assume there are records for six different rain gages stored in the daily .pcp. The formatting of the .pcp file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
1	LATITUDE	2	space 8-12	free	unrestricted
2	LATITUDE	2	space 13-17	free	unrestricted
3	LATITUDE	2	space 18-22	free	unrestricted
4	LATITUDE	2	space 23-27	free	unrestricted
5	LATITUDE	2	space 28-32	free	unrestricted
6	LATITUDE	2	space 33-37	free	unrestricted
1	LONGITUDE	3	space 8-12	free	unrestricted
2	LONGITUDE	3	space 13-17	free	unrestricted
3	LONGITUDE	3	space 18-22	free	unrestricted
4	LONGITUDE	3	space 23-27	free	unrestricted
5	LONGITUDE	3	space 28-32	free	unrestricted
6	LONGITUDE	3	space 33-37	free	unrestricted
1	ELEVATION	4	space 8-12	integer	i5
2	ELEVATION	4	space 13-17	integer	i5
3	ELEVATION	4	space 18-22	integer	i5
4	ELEVATION	4	space 23-27	integer	i5
5	ELEVATION	4	space 28-32	integer	i5

Gage	Variable name	Line #	Position	Format	F90 Format
6	ELEVATION	4	space 33-37	integer	i5
ALL	YEAR	5-END	space 1-4	4-digit integer	i4
ALL	DATE	5-END	space 5-7	3-digit integer	i3
1	PRECIPITATION	5-END	space 8-12	decimal(xxx.x)	f5.1
2	PRECIPITATION	5-END	space 13-17	decimal(xxx.x)	f5.1
3	PRECIPITATION	5-END	space 18-22	decimal(xxx.x)	f5.1
4	PRECIPITATION	5-END	space 23-27	decimal(xxx.x)	f5.1
5	PRECIPITATION	5-END	space 28-32	decimal(xxx.x)	f5.1
6	PRECIPITATION	5-END	space 33-37	decimal(xxx.x)	f5.1

7.2 SUB-DAILY PRECIPITATION DATA

Sub-daily precipitation data is required if the Green & Ampt infiltration method is being used (Set by IEVENT in the .cod file). When the Green & Ampt infiltration method is used to calculate surface runoff, SWAT is unable to generate precipitation data. Because of this, PCPSIM in the .cod file must be set to 1 and negative 99.0 (-99.0) should ***not*** be inserted for missing data. An independent weather generator or extrapolation from adjacent weather stations should be used to fill in missing data.

While the input file must contain data for the entire period of simulation, the record does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the file, saving editing time on the user’s part. Unlike the daily precipitation data, SWAT verifies that the date is correct on all lines. If the model reads in an incorrect date, it will print an error message to the *input.std* file stating the day and year in the precipitation record where the inconsistency is located and the program will stop.

The number of lines of precipitation data per day is governed by the time step used (IDT in the .cod file). To save space, only one line is required for days with no rain at all. When SWAT reads a blank for the delimiter (see variable list below), it knows that all time steps on the day have no precipitation and that there are no more lines of precipitation data for that day.

Following is a brief description of the variables in the sub-daily precipitation input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the precipitation file is reserved for comments. The title line is not processed by the model and may be left blank.
LATITUDE	Latitude of precipitation recording gage location. This value is not used by the model and may be left blank.
LONGITUDE	Longitude of precipitation recording gage location. This value is not used by the model and may be left blank.
ELEVATION	Elevation of precipitation recording gage (m). The elevation of the recording gage is used to adjust precipitation values for elevation in subbasins where elevation bands and a precipitation lapse rate are defined.
YEAR	Year (4-digit)
DATE	Julian date
HOUR	Hour of day (0-23). The hour and minute are at the end of the time step.
DELIMITER	Space is allowed on the line for a colon to separate the hour and minute readings. The delimiter is used by the model to identify days where there is no rain and only one line is present for the day in the .pcp file. If a blank space is inserted instead of the colon, the model will assign zero precipitation to all time steps on the day.
MINUTE	Minute of hour (0-59). The hour and minute are at the end of the time step.
PRECIPITATION	Amount of precipitation falling in the time period (mm).

The format of the sub-daily precipitation file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
LATITUDE	2	space 13-17	free	unrestricted
LONGITUDE	3	space 13-17	free	unrestricted
ELEVATION	4	space 13-17	integer	i5
YEAR	5-END	space 1-4	integer	i4
DATE	5-END	space 5-7	integer	i3

Variable name	Line #	Position	Format	F90 Format
HOUR	5-END	space 8-9	integer	i2
DELIMITER	5-END	space 10	character	a1
MINUTE	5-END	space 11-12	integer	i2
PRECIPITATION	5-END	space 13-17	decimal(xxx.x)	f5.1

To place more than one data record within the .pcp file, repeat the original formatting for the recorded data to the right of the existing data. Simulations have been run with 200 records placed in the precipitation files.

For example, assume there are records for six different rain gages stored in the sub-daily .pcp. The formatting of the .pcp file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
1	LATITUDE	2	space 13-17	free	unrestricted
2	LATITUDE	2	space 18-22	free	unrestricted
3	LATITUDE	2	space 23-27	free	unrestricted
4	LATITUDE	2	space 28-32	free	unrestricted
5	LATITUDE	2	space 33-37	free	unrestricted
6	LATITUDE	2	space 38-42	free	unrestricted
1	LONGITUDE	3	space 13-17	free	unrestricted
2	LONGITUDE	3	space 18-22	free	unrestricted
3	LONGITUDE	3	space 23-27	free	unrestricted
4	LONGITUDE	3	space 28-32	free	unrestricted
5	LONGITUDE	3	space 33-37	free	unrestricted
6	LONGITUDE	3	space 38-42	free	unrestricted
1	ELEVATION	4	space 13-17	integer	i5
2	ELEVATION	4	space 18-22	integer	i5
3	ELEVATION	4	space 23-27	integer	i5
4	ELEVATION	4	space 28-32	integer	i5
5	ELEVATION	4	space 33-37	integer	i5
6	ELEVATION	4	space 38-42	integer	i5
ALL	YEAR	5-END	space 1-4	4-digit integer	i4
ALL	DATE	5-END	space 5-7	3-digit integer	i3
ALL	HOUR	5-END	space 8-9	integer	i2
ALL	DELIMITER	5-END	space 10	character	a1

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	MINUTE	5-END	space 11-12	integer	i2
1	PRECIPITATION	5-END	space 13-17	decimal(xxx.x)	f5.1
2	PRECIPITATION	5-END	space 18-22	decimal(xxx.x)	f5.1
3	PRECIPITATION	5-END	space 23-27	decimal(xxx.x)	f5.1
4	PRECIPITATION	5-END	space 28-32	decimal(xxx.x)	f5.1
5	PRECIPITATION	5-END	space 33-37	decimal(xxx.x)	f5.1
6	PRECIPITATION	5-END	space 38-42	decimal(xxx.x)	f5.1

CHAPTER 8

SWAT INPUT DATA: .TMP

SWAT requires daily maximum and minimum air temperature. Temperature data may be read from records of observed data or they may be generated. This chapter reviews the file used to store measured temperature data.

Up to 18 temperature files may be utilized in a simulation. The temperature files are able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

As with the precipitation file, the record in the temperature input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the temperature file and all the comments made for this feature in the discussion of the precipitation file pertain to the temperature file as well.

A negative 99.0 (-99.0) should be inserted for missing maximum or minimum temperatures. This value tells SWAT to generate the missing value(s).

Following is a brief description of the variables in the temperature input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the temperature file is reserved for comments. The title line is not processed by the model and may be left blank.
LATITUDE	Latitude of temperature recording gage location. This value is not used by the model and may be left blank.
LONGITUDE	Longitude of temperature recording gage location. This value is not used by the model and may be left blank.
ELEVATION	Elevation of temperature recording gage (m). The elevation of the recording gage is used to adjust temperature values for elevation in subbasins where elevation bands are defined.
YEAR	Year (4-digit)
DATE	Julian date
MAX TEMP	Daily maximum temperature (ºC).
MIN TEMP	Daily minimum temperature (ºC).

The format of the temperature file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
LATITUDE	2	space 8-17	free	
LONGITUDE	3	space 8-17	free	
ELEVATION	4	space 8-17	integer	i10
YEAR	5-END	space 1-4	4-digit integer	i4
DATE	5-END	space 5-7	3-digit integer	i3
MAX TEMP	5-END	space 8-12	decimal(xxx.x)	f5.1
MIN TEMP	5-END	space 13-17	decimal(xxx.x)	f5.1

To place more than one data record within the .tmp file, repeat the original formatting for the recorded data to the right of the existing data. Simulations have been run with 150 records placed in the temperature files.

For example, assume there are records for three different temperature gages stored in the .tmp. The formatting of the .tmp file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
1	LATITUDE	2	space 8-17	free	unrestricted
2	LATITUDE	2	space 18-27	free	unrestricted
3	LATITUDE	2	space 28-37	free	unrestricted
1	LONGITUDE	3	space 8-17	free	unrestricted
2	LONGITUDE	3	space 18-27	free	unrestricted
3	LONGITUDE	3	space 28-37	free	unrestricted
1	ELEVATION	4	space 8-17	integer	i10
2	ELEVATION	4	space 18-27	integer	i10
3	ELEVATION	4	space 28-37	integer	i10
ALL	YEAR	5-END	space 1-4	4-digit integer	i4
ALL	DATE	5-END	space 5-7	3-digit integer	i3
1	MAX TEMP	5-END	space 8-12	decimal(xxx.x)	f5.1
1	MIN TEMP	5-END	space 13-17	decimal(xxx.x)	f5.1
2	MAX TEMP	5-END	space 18-22	decimal(xxx.x)	f5.1
2	MIN TEMP	5-END	space 23-27	decimal(xxx.x)	f5.1
3	MAX TEMP	5-END	space 28-32	decimal(xxx.x)	f5.1
3	MIN TEMP	5-END	space 33-37	decimal(xxx.x)	f5.1

CHAPTER 9

SWAT INPUT DATA: .SLR

SWAT requires daily solar radiation values. These values may be read from records of observed data or they may be generated. This chapter reviews the file used to read in measured solar radiation data.

One solar radiation file may be used in a simulation. This file is able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

As with the precipitation file, the record in the solar radiation input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the solar radiation file and all the comments made for this feature in the discussion of the precipitation file pertain to the solar radiation file as well.

A negative 99.0 (-99.0) should be inserted for missing radiation values. This value tells SWAT to generate the missing value(s).

Following is a brief description of the variables in the solar radiation input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the solar radiation file is reserved for comments. The title line is not processed by the model and may be left blank.
YEAR	Year (4-digit)
DATE	Julian date
SOL_RAD	Daily total solar radiation (MJ/m^2).

The format of the solar radiation input file with one record is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	unrestricted	character	unrestricted
YEAR	2-END	space 1-4	4-digit integer	i4
DATE	2-END	space 5-7	3-digit integer	i3
SOL_RAD	2-END	space 8-15	decimal(xxxx.xxx)	f8.3

To place more than one data record within the .slr file, repeat the original formatting for the recorded data to the right of the existing data.

For example, assume there are records for six different solar radiation gages stored in the .slr. The formatting of the .slr file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
ALL	YEAR	2-END	space 1-4	4-digit integer	i4
ALL	DATE	2-END	space 5-7	3-digit integer	i3
1	SOL_RAD	2-END	space 8-15	decimal(xxxx.xxx)	f8.3
2	SOL_RAD	2-END	space 16-23	decimal(xxxx.xxx)	f8.3
3	SOL_RAD	2-END	space 24-31	decimal(xxxx.xxx)	f8.3
4	SOL_RAD	2-END	space 32-39	decimal(xxxx.xxx)	f8.3
5	SOL_RAD	2-END	space 40-47	decimal(xxxx.xxx)	f8.3
6	SOL_RAD	2-END	space 48-55	decimal(xxxx.xxx)	f8.3

CHAPTER 10

SWAT INPUT DATA: .WND

SWAT requires daily wind speed values when the Penman-Monteith method is selected to calculate potential evapotranspiration. Values for all these parameters may be read from records of observed data or they may be generated. This chapter reviews the input file used to read in measured daily wind speed values.

One wind speed input file may be used in a simulation. This file is able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

As with the precipitation file, the record in the wind speed input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the wind speed file and all the comments made for this feature in the discussion of the precipitation file pertain to the wind speed file as well.

A negative 99.0 (-99.0) should be inserted for missing wind speed values. This value tells SWAT to generate the missing value(s).

Following is a brief description of the variables in the wind speed input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line of the wind speed file is reserved for comments. The title line is not processed by the model and may be left blank.
YEAR	Year (4-digit)
DATE	Julian date
WND_SP	Daily average wind speed (m/s).

The format of the wind speed input file with one record is:

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
TITLE	1	unrestricted	character	unrestricted
YEAR	2-END	space 1-4	4-digit integer	i4
DATE	2-END	space 5-7	3-digit integer	i3
WND_SP	2-END	space 8-15	decimal(xxxx.xxx)	f8.3

To place more than one data record within the .wnd file, repeat the original formatting for the recorded data to the right of the existing data.

For example, assume there are records for ten different wind speed gages stored in the .wnd. The formatting of the .wnd file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
ALL	YEAR	2-END	space 1-4	4-digit integer	i4
ALL	DATE	2-END	space 5-7	3-digit integer	i3
1	WND_SP	2-END	space 8-15	decimal(xxxx.xxx)	f8.3
2	WND_SP	2-END	space 16-23	decimal(xxxx.xxx)	f8.3
3	WND_SP	2-END	space 24-31	decimal(xxxx.xxx)	f8.3
4	WND_SP	2-END	space 32-39	decimal(xxxx.xxx)	f8.3
5	WND_SP	2-END	space 40-47	decimal(xxxx.xxx)	f8.3
6	WND_SP	2-END	space 48-55	decimal(xxxx.xxx)	f8.3
7	WND_SP	2-END	space 56-63	decimal(xxxx.xxx)	f8.3
8	WND_SP	2-END	space 64-71	decimal(xxxx.xxx)	f8.3
9	WND_SP	2-END	space 72-79	decimal(xxxx.xxx)	f8.3
10	WND_SP	2-END	space 80-87	decimal(xxxx.xxx)	f8.3

CHAPTER 11

SWAT INPUT DATA: .HMD

SWAT requires daily relative humidity values when the Penman-Monteith or Priestley-Taylor method is used to calculate potential evapotranspiration. Values for relative humidity may be read from records of observed data or they may be generated. This chapter reviews the input file used to read relative humidity values into the model.

One relative humidity input file may be used in a simulation. This file is able to hold records for more than one gage, so there is not a limitation on the number of gages that can be used in a simulation.

As with the precipitation file, the record in the relative humidity input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the relative humidity file and all the comments made for this feature in the discussion of the precipitation file pertain to the relative humidity file as well.

A negative 99.0 (-99.0) should be inserted for missing relative humidity values. This value tells SWAT to generate the missing value(s).

Following is a brief description of the variables in the relative humidity input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line of the relative humidity file is reserved for comments. The title line is not processed by the model and may be left blank.
YEAR	Year (4-digit)
DATE	Julian date
RHD	Daily average relative humidity expressed as a fraction.

The format of the relative humidity input file with one record is:

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
TITLE	1	unrestricted	character	unrestricted
YEAR	2-END	space 1-4	4-digit integer	i4
DATE	2-END	space 5-7	3-digit integer	i3
RHD	2-END	space 8-15	decimal(xxxx.xxx)	f8.3

To place more than one data record within the .hmd file, repeat the original formatting for the recorded data to the right of the existing data.

For example, assume there are records for five different relative humidity gages stored in the .hmd. The formatting of the .hmd file is

Gage	Variable name	Line #	Position	Format	F90 Format
ALL	TITLE	1	unrestricted	character	unrestricted
ALL	YEAR	2-END	space 1-4	4-digit integer	i4
ALL	DATE	2-END	space 5-7	3-digit integer	i3
1	RHD	2-END	space 8-15	decimal(xxxx.xxx)	f8.3
2	RHD	2-END	space 16-23	decimal(xxxx.xxx)	f8.3
3	RHD	2-END	space 24-31	decimal(xxxx.xxx)	f8.3
4	RHD	2-END	space 32-39	decimal(xxxx.xxx)	f8.3
5	RHD	2-END	space 40-47	decimal(xxxx.xxx)	f8.3

CHAPTER 12

SWAT INPUT DATA: .PET

SWAT requires daily potential evapotranspiration values. If the user wishes to calculate potential evapotranspiration using a method other than Penman-Monteith, Priestley-Taylor, or Hargreaves, the potential evapotranspiration values can be read in using the .pet file. The potential evapotranspiration file holds only one record that is used for the entire watershed.

As with the precipitation file, the record in the potential evapotranspiration input file does not have to begin with the first day of simulation. SWAT is able to search for the beginning date in the potential evapotranspiration input file and all the comments made for this feature in the discussion of the precipitation file pertain to the potential evapotranspiration file as well.

Following is a brief description of the variables in the potential evapotranspiration input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line of the potential evapotranspiration file is reserved for comments. The title line is not processed by the model and may be left blank.
YEAR	Year (4-digit)
DATE	Julian date
PETMEAS	Daily potential evapotranspiration for watershed (mm H_2O).

The format of the potential evapotranspiration input file is:

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
TITLE	1	unrestricted	character	unrestricted
YEAR	2-END	space 1-4	4-digit integer	i4
DATE	2-END	space 5-7	3-digit integer	i3
PETMEAS	2-END	space 8-12	decimal(xxx.x)	f5.1

CHAPTER 13

SWAT INPUT DATA: .WGN

SWAT requires daily precipitation, maximum/minimum air temperature, solar radiation, wind speed and relative humidity. Values for all these parameters may be read from records of observed data or they may be generated.

The weather generator input file contains the statistical data needed to generate representative daily climate data for the subbasins. Ideally, at least 20 years of records are used to calculate parameters in the .wgn file. Climatic data will be generated in two instances: when the user specifies that simulated weather will be used or when measured data is missing.

Following is a brief description of the variables in the weather generator input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line of the .wgn file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
WLATITUDE	Latitude of weather station used to create statistical parameters (degrees). The latitude is expressed as a real number with minutes and seconds converted to fractions of a degree.
WLONGITUDE	Longitude of weather station (degrees). This variable is not used by the model and may be left blank.
WELEV	Elevation of weather station (m).
RAIN_YRS	The number of years of maximum monthly 0.5 h rainfall data used to define values for RAIN_HHMX(1,:) - RAIN_HHMX(12,:). If no value is input for RAIN_YRS, SWAT will set RAIN_YRS = 10.
TMPMX(mon)	Average or mean daily maximum air temperature for month (ºC). This value is calculated by summing the maximum air temperature for every day in the month for all years of record and dividing by the number of days summed: $\mu mx_{mon} = \frac{\sum_{d=1}^{N} T_{mx,mon}}{N}$ where μmx_{mon} is the mean daily maximum temperature for the month (°C), $T_{mx,mon}$ is the daily maximum temperature on record *d* in month *mon* (°C), and *N* is the total number of daily maximum temperature records for month *mon*.
TMPMN(mon)	Average or mean daily minimum air temperature for month (ºC).

Variable name	Definition
TMPMN(mon), cont.	This value is calculated by summing the minimum air temperature for every day in the month for all years of record and dividing by the number of days summed: $\mu mn_{mon} = \frac{\sum_{d=1}^{N} T_{mn,mon}}{N}$ where μmn_{mon} is the mean daily minimum temperature for the month (°C), $T_{mn,mon}$ is the daily minimum temperature on record *d* in month *mon* (°C), and *N* is the total number of daily minimum temperature records for month *mon*.
TMPSTDMX(mon)	Standard deviation for daily maximum air temperature in month (ºC). This parameter quantifies the variability in maximum temperature for each month. The standard deviation is calculated: $\sigma mx_{mon} = \sqrt{\left(\frac{\sum_{d=1}^{N} \left(T_{mx,mon} - \mu mx_{mon} \right)^2}{N-1} \right)}$ where σmx_{mon} is the standard deviation for daily maximum temperature in month *mon* (ºC), $T_{mx,mon}$ is the daily maximum temperature on record *d* in month *mon* (°C), μmx_{mon} is the average daily maximum temperature for the month (°C), and *N* is the total number of daily maximum temperature records for month *mon*.
TMPSTDMN(mon)	Standard deviation for daily minimum air temperature in month (ºC). This parameter quantifies the variability in minimum temperature for each month. The standard deviation is calculated: $\sigma mn_{mon} = \sqrt{\left(\frac{\sum_{d=1}^{N} \left(T_{mn,mon} - \mu mn_{mon} \right)^2}{N-1} \right)}$

Variable name	**Definition**
TMPSTDMN(mon), cont.	where σmn_{mon} is the standard deviation for daily minimum temperature in month *mon* (ºC), $T_{mn,mon}$ is the daily minimum temperature on record *d* in month *mon* (°C), μmn_{mon} is the average daily minimum temperature for the month (°C), and *N* is the total number of daily minimum temperature records for month *mon*.
PCPMM(mon)	Average or mean total monthly precipitation (mm H_2O). $\bar{R}_{mon} = \frac{\sum_{d=1}^{N} R_{day,mon}}{yrs}$ where $\bar{R}_{mon}$ is the mean monthly precipitation (mm H_2O), $R_{day,mon}$ is the daily precipitation for record *d* in month *mon* (mm H_2O), *N* is the total number of records in month *mon* used to calculate the average, and *yrs* is the number of years of daily precipitation records used in calculation.
PCPSTD(mon)	Standard deviation for daily precipitation in month (mm H_2O/day). This parameter quantifies the variability in precipitation for each month. The standard deviation is calculated: $\sigma_{mon} = \sqrt{\left(\frac{\sum_{d=1}^{N}\left(R_{day,mon} - \bar{R}_{mon}\right)^2}{N-1}\right)}$ where σ_{mon} is the standard deviation for daily precipitation in month *mon* (mm H_2O), $R_{day,mon}$ is the amount of precipitation for record *d* in month *mon* (mm H_2O), $\bar{R}_{mon}$ is the average precipitation for the month (mm H_2O), and *N* is the total number of daily precipitation records for month *mon*. (Note: daily precipitation values of 0 mm are included in the standard deviation calculation)
PCPSKW(mon)	Skew coefficient for daily precipitation in month. This parameter quantifies the symmetry of the precipitation distribution about the monthly mean. The coefficient of skewness is calculated:

Variable name	**Definition**
PCPSKW(mon), cont.	$g_{mon} = \frac{N \cdot \sum_{d=1}^{N}\left(R_{day,mon} - \overline{R}_{mon}\right)^3}{(N-1)\cdot(N-2)\cdot(\sigma_{mon})^3}$ where g_{mon} is the skew coefficient for precipitation in the month, N is the total number of daily precipitation records for month *mon*, $R_{day,mon}$ is the amount of precipitation for record *d* in month *mon* (mm H_2O), $\overline{R}_{mon}$ is the average precipitation for the month (mm H_2O), and σ_{mon} is the standard deviation for daily precipitation in month *mon* (mm H_2O). (Note: daily precipitation values of 0 mm are included in the skew coefficient calculation)
PR_W(1,mon)	Probability of a wet day following a dry day in the month. This probability is calculated: $P_i(W/D) = \frac{days_{W/D,i}}{days_{dry,i}}$ where $P_i(W/D)$ is the probability of a wet day following a dry day in month *i*, $days_{W/D,i}$ is the number of times a wet day followed a dry day in month *i* for the entire period of record, and $days_{dry,i}$ is the number of dry days in month *i* during the entire period of record. A dry day is a day with 0 mm of precipitation. A wet day is a day with > 0 mm precipitation.
PR_W(2,mon)	Probability of a wet day following a wet day in the month. This probability is calculated: $P_i(W/W) = \frac{days_{W/W,i}}{days_{wet,i}}$ where $P_i(W/W)$ is the probability of a wet day following a wet day in month *i*, $days_{W/W,i}$ is the number of times a wet day followed a wet day in month *i* for the entire period of record, and $days_{wet,i}$ is the number of wet days in month *i* during the entire period of record. A dry day is a day with 0 mm of precipitation. A wet day is a day with > 0 mm precipitation.

Variable name	Definition
PCPD(mon)	Average number of days of precipitation in month. This parameter is calculated: $\bar{d}_{wet,i} = \frac{days_{wet,i}}{yrs}$ where $\bar{d}_{wet,i}$ is the average number of days of precipitation in month i, $days_{wet,i}$ is the number of wet days in month i during the entire period of record, and yrs is the number of years of record.
RAINHHMX(mon)	Maximum 0.5 hour rainfall in entire period of record for month (mm H_2O). This value represents the most extreme 30-minute rainfall intensity recorded in the entire period of record.
SOLARAV(mon)	Average daily solar radiation for month (MJ/m^2/day). This value is calculated by summing the total solar radiation for every day in the month for all years of record and dividing by the number of days summed: $\mu rad_{mon} = \frac{\sum_{d=1}^{N} H_{day,mon}}{N}$ where μrad_{mon} is the mean daily solar radiation for the month (MJ/m^2/day), $H_{day,mon}$ is the total solar radiation reaching the earth's surface for day d in month mon (MJ/m^2/day), and N is the total number of daily solar radiation records for month mon.
DEWPT(mon)	Average daily dew point temperature in month (ºC). The dew point temperature is the temperature at which the actual vapor pressure present in the atmosphere is equal to the saturation vapor pressure. This value is calculated by summing the dew point temperature for every day in the month for all years of record and dividing by the number of days summed: $\mu dew_{mon} = \frac{\sum_{d=1}^{N} T_{dew,mon}}{N}$

Variable name	Definition
DEWPT(mon), cont.	where μdew_{mon} is the mean daily dew point temperature for the month (ºC), $T_{dew,mon}$ is the dew point temperature for day *d* in month *mon* (ºC), and *N* is the total number of daily dew point records for month *mon*.
WNDAV(mon)	Average daily wind speed in month (m/s). This value is calculated by summing the average or mean wind speed values for every day in the month for all years of record and dividing by the number of days summed: $\mu wnd_{mon} = \frac{\sum_{d=1}^{N} \mu_{wnd,mon}}{N}$ where μwnd_{mon} is the mean daily wind speed for the month (m/s), $\mu_{wnd,mon}$ is the average wind speed for day *d* in month *mon* (m/s), and *N* is the total number of daily wind speed records for month *mon*.

The format of the weather generator input file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
WLATITUDE	2	space 13-19	decimal(xxxx.xx)	f7.2
WLONGITUDE	2	space 32-38	decimal(xxxx.xx)	f7.2
WELEV	3	space 13-19	decimal(xxxx.xx)	f7.2
RAIN_YRS	4	space 13-19	decimal(xxxx.xx)	f7.2
TMPMX(1)	5	space 1-6	decimal(xxx.xx)	f6.2
TMPMX(2)	5	space 7-12	decimal(xxx.xx)	f6.2
TMPMX(3)	5	space 13-18	decimal(xxx.xx)	f6.2
TMPMX(4)	5	space 19-24	decimal(xxx.xx)	f6.2
TMPMX(5)	5	space 25-30	decimal(xxx.xx)	f6.2
TMPMX(6)	5	space 31-36	decimal(xxx.xx)	f6.2
TMPMX(7)	5	space 37-42	decimal(xxx.xx)	f6.2
TMPMX(8)	5	space 43-48	decimal(xxx.xx)	f6.2
TMPMX(9)	5	space 49-54	decimal(xxx.xx)	f6.2
TMPMX(10)	5	space 55-60	decimal(xxx.xx)	f6.2
TMPMX(11)	5	space 61-66	decimal(xxx.xx)	f6.2
TMPMX(12)	5	space 67-72	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
TMPMN(1)	6	space 1-6	decimal(xxx.xx)	f6.2
TMPMN(2)	6	space 7-12	decimal(xxx.xx)	f6.2
TMPMN(3)	6	space 13-18	decimal(xxx.xx)	f6.2
TMPMN(4)	6	space 19-24	decimal(xxx.xx)	f6.2
TMPMN(5)	6	space 25-30	decimal(xxx.xx)	f6.2
TMPMN(6)	6	space 31-36	decimal(xxx.xx)	f6.2
TMPMN(7)	6	space 37-42	decimal(xxx.xx)	f6.2
TMPMN(8)	6	space 43-48	decimal(xxx.xx)	f6.2
TMPMN(9)	6	space 49-54	decimal(xxx.xx)	f6.2
TMPMN(10)	6	space 55-60	decimal(xxx.xx)	f6.2
TMPMN(11)	6	space 61-66	decimal(xxx.xx)	f6.2
TMPMN(12)	6	space 67-72	decimal(xxx.xx)	f6.2
TMPSTDMX(1)	7	space 1-6	decimal(xxx.xx)	f6.2
TMPSTDMX(2)	7	space 7-12	decimal(xxx.xx)	f6.2
TMPSTDMX(3)	7	space 13-18	decimal(xxx.xx)	f6.2
TMPSTDMX(4)	7	space 19-24	decimal(xxx.xx)	f6.2
TMPSTDMX(5)	7	space 25-30	decimal(xxx.xx)	f6.2
TMPSTDMX(6)	7	space 31-36	decimal(xxx.xx)	f6.2
TMPSTDMX(7)	7	space 37-42	decimal(xxx.xx)	f6.2
TMPSTDMX(8)	7	space 43-48	decimal(xxx.xx)	f6.2
TMPSTDMX(9)	7	space 49-54	decimal(xxx.xx)	f6.2
TMPSTDMX(10)	7	space 55-60	decimal(xxx.xx)	f6.2
TMPSTDMX(11)	7	space 61-66	decimal(xxx.xx)	f6.2
TMPSTDMX(12)	7	space 67-72	decimal(xxx.xx)	f6.2
TMPSTDMN(1)	8	space 1-6	decimal(xxx.xx)	f6.2
TMPSTDMN(2)	8	space 7-12	decimal(xxx.xx)	f6.2
TMPSTDMN(3)	8	space 13-18	decimal(xxx.xx)	f6.2
TMPSTDMN(4)	8	space 19-24	decimal(xxx.xx)	f6.2
TMPSTDMN(5)	8	space 25-30	decimal(xxx.xx)	f6.2
TMPSTDMN(6)	8	space 31-36	decimal(xxx.xx)	f6.2
TMPSTDMN(7)	8	space 37-42	decimal(xxx.xx)	f6.2
TMPSTDMN(8)	8	space 43-48	decimal(xxx.xx)	f6.2
TMPSTDMN(9)	8	space 49-54	decimal(xxx.xx)	f6.2
TMPSTDMN(10)	8	space 55-60	decimal(xxx.xx)	f6.2
TMPSTDMN(11)	8	space 61-66	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
TMPSTDMN(12)	8	space 67-72	decimal(xxx.xx)	f6.2
PCPMM(1)	9	space 1-6	decimal(xxx.xx)	f6.2
PCPMM(2)	9	space 7-12	decimal(xxx.xx)	f6.2
PCPMM(3)	9	space 13-18	decimal(xxx.xx)	f6.2
PCPMM(4)	9	space 19-24	decimal(xxx.xx)	f6.2
PCPMM(5)	9	space 25-30	decimal(xxx.xx)	f6.2
PCPMM(6)	9	space 31-36	decimal(xxx.xx)	f6.2
PCPMM(7)	9	space 37-42	decimal(xxx.xx)	f6.2
PCPMM(8)	9	space 43-48	decimal(xxx.xx)	f6.2
PCPMM(9)	9	space 49-54	decimal(xxx.xx)	f6.2
PCPMM(10)	9	space 55-60	decimal(xxx.xx)	f6.2
PCPMM(11)	9	space 61-66	decimal(xxx.xx)	f6.2
PCPMM(12)	9	space 67-72	decimal(xxx.xx)	f6.2
PCPSTD(1)	10	space 1-6	decimal(xxx.xx)	f6.2
PCPSTD(2)	10	space 7-12	decimal(xxx.xx)	f6.2
PCPSTD(3)	10	space 13-18	decimal(xxx.xx)	f6.2
PCPSTD(4)	10	space 19-24	decimal(xxx.xx)	f6.2
PCPSTD(5)	10	space 25-30	decimal(xxx.xx)	f6.2
PCPSTD(6)	10	space 31-36	decimal(xxx.xx)	f6.2
PCPSTD(7)	10	space 37-42	decimal(xxx.xx)	f6.2
PCPSTD(8)	10	space 43-48	decimal(xxx.xx)	f6.2
PCPSTD(9)	10	space 49-54	decimal(xxx.xx)	f6.2
PCPSTD(10)	10	space 55-60	decimal(xxx.xx)	f6.2
PCPSTD(11)	10	space 61-66	decimal(xxx.xx)	f6.2
PCPSTD(12)	10	space 67-72	decimal(xxx.xx)	f6.2
PCPSKW(1)	11	space 1-6	decimal(xxx.xx)	f6.2
PCPSKW(2)	11	space 7-12	decimal(xxx.xx)	f6.2
PCPSKW(3)	11	space 13-18	decimal(xxx.xx)	f6.2
PCPSKW(4)	11	space 19-24	decimal(xxx.xx)	f6.2
PCPSKW(5)	11	space 25-30	decimal(xxx.xx)	f6.2
PCPSKW(6)	11	space 31-36	decimal(xxx.xx)	f6.2
PCPSKW(7)	11	space 37-42	decimal(xxx.xx)	f6.2
PCPSKW(8)	11	space 43-48	decimal(xxx.xx)	f6.2
PCPSKW(9)	11	space 49-54	decimal(xxx.xx)	f6.2
PCPSKW(10)	11	space 55-60	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
PCPSKW(11)	11	space 61-66	decimal(xxx.xx)	f6.2
PCPSKW(12)	11	space 67-72	decimal(xxx.xx)	f6.2
PR_W(1,1)	12	space 1-6	decimal(xxx.xx)	f6.2
PR_W(1,2)	12	space 7-12	decimal(xxx.xx)	f6.2
PR_W(1,3)	12	space 13-18	decimal(xxx.xx)	f6.2
PR_W(1,4)	12	space 19-24	decimal(xxx.xx)	f6.2
PR_W(1,5)	12	space 25-30	decimal(xxx.xx)	f6.2
PR_W(1,6)	12	space 31-36	decimal(xxx.xx)	f6.2
PR_W(1,7)	12	space 37-42	decimal(xxx.xx)	f6.2
PR_W(1,8)	12	space 43-48	decimal(xxx.xx)	f6.2
PR_W(1,9)	12	space 49-54	decimal(xxx.xx)	f6.2
PR_W(1,10)	12	space 55-60	decimal(xxx.xx)	f6.2
PR_W(1,11)	12	space 61-66	decimal(xxx.xx)	f6.2
PR_W(1,12)	12	space 67-72	decimal(xxx.xx)	f6.2
PR_W(2,1)	13	space 1-6	decimal(xxx.xx)	f6.2
PR_W(2,2)	13	space 7-12	decimal(xxx.xx)	f6.2
PR_W(2,3)	13	space 13-18	decimal(xxx.xx)	f6.2
PR_W(2,4)	13	space 19-24	decimal(xxx.xx)	f6.2
PR_W(2,5)	13	space 25-30	decimal(xxx.xx)	f6.2
PR_W(2,6)	13	space 31-36	decimal(xxx.xx)	f6.2
PR_W(2,7)	13	space 37-42	decimal(xxx.xx)	f6.2
PR_W(2,8)	13	space 43-48	decimal(xxx.xx)	f6.2
PR_W(2,9)	13	space 49-54	decimal(xxx.xx)	f6.2
PR_W(2,10)	13	space 55-60	decimal(xxx.xx)	f6.2
PR_W(2,11)	13	space 61-66	decimal(xxx.xx)	f6.2
PR_W(2,12)	13	space 67-72	decimal(xxx.xx)	f6.2
PCPD(1)	14	space 1-6	decimal(xxx.xx)	f6.2
PCPD(2)	14	space 7-12	decimal(xxx.xx)	f6.2
PCPD(3)	14	space 13-18	decimal(xxx.xx)	f6.2
PCPD(4)	14	space 19-24	decimal(xxx.xx)	f6.2
PCPD(5)	14	space 25-30	decimal(xxx.xx)	f6.2
PCPD(6)	14	space 31-36	decimal(xxx.xx)	f6.2
PCPD(7)	14	space 37-42	decimal(xxx.xx)	f6.2
PCPD(8)	14	space 43-48	decimal(xxx.xx)	f6.2
PCPD(9)	14	space 49-54	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
PCPD(10)	14	space 55-60	decimal(xxx.xx)	f6.2
PCPD(11)	14	space 61-66	decimal(xxx.xx)	f6.2
PCPD(12)	14	space 67-72	decimal(xxx.xx)	f6.2
RAINHHMX(1)	15	space 1-6	decimal(xxx.xx)	f6.2
RAINHHMX(2)	15	space 7-12	decimal(xxx.xx)	f6.2
RAINHHMX(3)	15	space 13-18	decimal(xxx.xx)	f6.2
RAINHHMX(4)	15	space 19-24	decimal(xxx.xx)	f6.2
RAINHHMX(5)	15	space 25-30	decimal(xxx.xx)	f6.2
RAINHHMX(6)	15	space 31-36	decimal(xxx.xx)	f6.2
RAINHHMX(7)	15	space 37-42	decimal(xxx.xx)	f6.2
RAINHHMX(8)	15	space 43-48	decimal(xxx.xx)	f6.2
RAINHHMX(9)	15	space 49-54	decimal(xxx.xx)	f6.2
RAINHHMX(10)	15	space 55-60	decimal(xxx.xx)	f6.2
RAINHHMX(11)	15	space 61-66	decimal(xxx.xx)	f6.2
RAINHHMX(12)	15	space 67-72	decimal(xxx.xx)	f6.2
SOLARAV(1)	16	space 1-6	decimal(xxx.xx)	f6.2
SOLARAV(2)	16	space 7-12	decimal(xxx.xx)	f6.2
SOLARAV(3)	16	space 13-18	decimal(xxx.xx)	f6.2
SOLARAV(4)	16	space 19-24	decimal(xxx.xx)	f6.2
SOLARAV(5)	16	space 25-30	decimal(xxx.xx)	f6.2
SOLARAV(6)	16	space 31-36	decimal(xxx.xx)	f6.2
SOLARAV(7)	16	space 37-42	decimal(xxx.xx)	f6.2
SOLARAV(8)	16	space 43-48	decimal(xxx.xx)	f6.2
SOLARAV(9)	16	space 49-54	decimal(xxx.xx)	f6.2
SOLARAV(10)	16	space 55-60	decimal(xxx.xx)	f6.2
SOLARAV(11)	16	space 61-66	decimal(xxx.xx)	f6.2
SOLARAV(12)	16	space 67-72	decimal(xxx.xx)	f6.2
DEWPT(1)	17	space 1-6	decimal(xxx.xx)	f6.2
DEWPT(2)	17	space 7-12	decimal(xxx.xx)	f6.2
DEWPT(3)	17	space 13-18	decimal(xxx.xx)	f6.2
DEWPT(4)	17	space 19-24	decimal(xxx.xx)	f6.2
DEWPT(5)	17	space 25-30	decimal(xxx.xx)	f6.2
DEWPT(6)	17	space 31-36	decimal(xxx.xx)	f6.2
DEWPT(7)	17	space 37-42	decimal(xxx.xx)	f6.2
DEWPT(8)	17	space 43-48	decimal(xxx.xx)	f6.2

Variable name	Line #	Position	Format	F90 Format
DEWPT(9)	17	space 49-54	decimal(xxx.xx)	f6.2
DEWPT(10)	17	space 55-60	decimal(xxx.xx)	f6.2
DEWPT(11)	17	space 61-66	decimal(xxx.xx)	f6.2
DEWPT(12)	17	space 67-72	decimal(xxx.xx)	f6.2
WNDAV(1)	18	space 1-6	decimal(xxx.xx)	f6.2
WNDAV(2)	18	space 7-12	decimal(xxx.xx)	f6.2
WNDAV(3)	18	space 13-18	decimal(xxx.xx)	f6.2
WNDAV(4)	18	space 19-24	decimal(xxx.xx)	f6.2
WNDAV(5)	18	space 25-30	decimal(xxx.xx)	f6.2
WNDAV(6)	18	space 31-36	decimal(xxx.xx)	f6.2
WNDAV(7)	18	space 37-42	decimal(xxx.xx)	f6.2
WNDAV(8)	18	space 43-48	decimal(xxx.xx)	f6.2
WNDAV(9)	18	space 49-54	decimal(xxx.xx)	f6.2
WNDAV(10)	18	space 55-60	decimal(xxx.xx)	f6.2
WNDAV(11)	18	space 61-66	decimal(xxx.xx)	f6.2
WNDAV(12)	18	space 67-72	decimal(xxx.xx)	f6.2

CHAPTER 14

SWAT INPUT DATA: CROP.DAT

Information required to simulate plant growth is stored by plant species in the plant growth database file. This database file is supplied with the model. The plant growth database distributed with SWAT include parameters for most of the common plant species. If a user needs to model a land use or plant not included in the database, please feel free to contact the SWAT development team for assistance in determining plant parameters. Appendix A documents the source of parameter values in the distributed database file.

Following is a brief description of the variables in the land cover/plant growth database file. They are listed in the order they appear within the file.

Variable name	**Definition**
ICNUM	Land cover/plant code. The different plants listed in crop.dat must have consecutive values for ICNUM. ICNUM is the numeric code used in the management file to identify the land cover to be modeled.
CPNM	A four character code to represent the land cover/plant name. The 4-letter codes in the plant growth and urban databases are used by the GIS interfaces to link land use/land cover maps to SWAT plant types. This code is printed to the output files. When adding a new plant species or land cover category, the four letter code for the new plant must be unique.
IDC	Land cover/plant classification: 1 warm season annual legume 2 cold season annual legume 3 perennial legume 4 warm season annual 5 cold season annual 6 perennial 7 trees Processes modeled differently for the 7 groups are: 1 warm season annual legume • simulate nitrogen fixation • root depth varies during growing season due to root growth 2 cold season annual legume • simulate nitrogen fixation • root depth varies during growing season due to root growth • fall-planted land covers will go dormant when daylength is less than the threshold daylength 3 perennial legume • simulate nitrogen fixation • root depth always equal to the maximum allowed for the plant species and soil • plant goes dormant when daylength is less than the threshold daylength

Variable name	**Definition**
IDC, cont.	4 warm season annual • root depth varies during growing season due to root growth 5 cold season annual • root depth varies during growing season due to root growth • fall-planted land covers will go dormant when daylength is less than the threshold daylength 6 perennial • root depth always equal to the maximum allowed for the plant species and soil • plant goes dormant when daylength is less than the threshold daylength 7 trees • root depth always equal to the maximum allowed for the plant species and soil • partitions new growth between leaves/needles (30%) and woody growth (70%). At the end of each growing season, biomass in the leaf fraction is converted to residue
DESCRIPTION	Full land cover/plant name. This description is not used by the model and is present to assist the user in differentiating between plant species.
BIO_E	Radiation-use efficiency or biomass-energy ratio ((kg/ha)/(MJ/m^2)). Radiation-use efficiency (RUE) is the amount of dry biomass produced per unit intercepted solar radiation. The radiation-use efficiency is assumed to be independent of the plant's growth stage. BIO_E represents the potential or unstressed growth rate (including roots) per unit of intercepted photosynthetically active radiation. Determination of RUE is commonly performed and a literature review will provide those setting up experiments with numerous examples. The following overview of the methodology used to measure RUE was summarized from Kiniry et al (1998) and Kiniry et al (1999).

Variable name	Definition
BIO_E, cont.	To calculate RUE, the amount of photosynthetically active radiation (PAR) intercepted and the mass of aboveground biomass is measured several times throughout a plant's growing season. The frequency of the measurements taken will vary but in general 4 to 7 measurements per growing season are considered to be adequate. As with leaf area determinations, the measurements should be performed on non-stressed plants. Intercepted radiation is measured with a light meter. Whole spectrum and PAR sensors are available and calculations of RUE will be performed differently depending on the sensor used. A brief discussion of the difference between whole spectrum and PAR sensors and the difference in calculations is given in Kiniry (1999). The use of a PAR sensor in RUE studies is strongly encouraged. When measuring radiation, three to five sets of measurements are taken rapidly for each plant plot. A set of measurements consists of 10 measurements above the leaf canopy, 10 below, and 10 more above. The light measurements should be taken between 10:00 am and 2:00 pm local time. The measurements above and below the leaf canopy are averaged and the fraction of intercepted PAR is calculated for the day from the two values. Daily estimates of the fraction of intercepted PAR are determined by linearly interpolating the measured values. The *fraction* of intercepted PAR is converted to an *amount* of intercepted PAR using daily values of incident total solar radiation measured with a standard weather station. To convert total incident radiation to total incident PAR, the daily solar radiation values are multiplied by the percent of total radiation that has a wavelength between 400 and 700 mm. This percent usually falls in the range 45 to 55% and is a function of cloud cover. 50% is considered to be a default value.

Variable name	Definition
BIO_E, cont.	Once daily intercepted PAR values are determined, the total amount of PAR intercepted by the plant is calculated for each date on which biomass was harvested. This is calculated by summing daily intercepted PAR values from the date of seedling emergence to the date of biomass harvest. To determine biomass production, aboveground biomass is harvested from a known area of land within the plot. The plant material should be dried at least 2 days at 65°C and then weighed. RUE is determined by fitting a linear regression for aboveground biomass as a function of intercepted PAR. The slope of the line is the RUE. Figure 14-1 shows the plots of aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass. (Note that the units for RUE values in the graph, as well as values typically reported in literature, are different from those used by SWAT. To obtain the value used in SWAT, multiply by 10.)

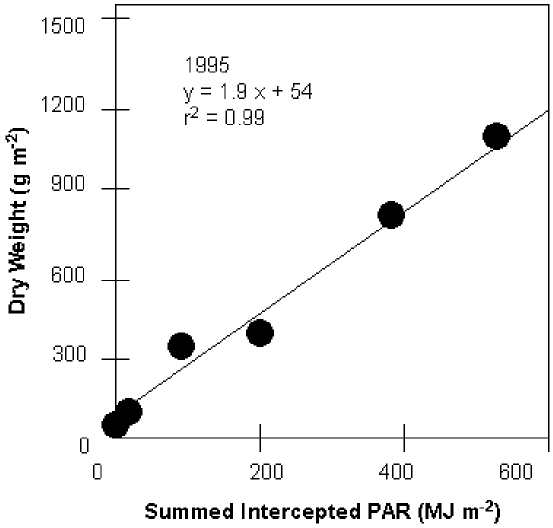

Figure 14-1: Aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass (After Kiniry et al.,1999).

Variable name	Definition
BIO_E, cont.	This parameter can greatly change the rate of growth, incidence of stress during the season and the resultant yield. This parameter should be one of the last to be adjusted. Adjustments should be based on research results. Care should be taken to make adjustments based only on data with no drought, nutrient or temperature stress.
HVSTI	Harvest index for optimal growing conditions. The harvest index defines the fraction of the aboveground biomass that is removed in a harvest operation. This value defines the fraction of plant biomass that is "lost" from the system and unavailable for conversion to residue and subsequent decomposition. For crops where the harvested portion of the plant is aboveground, the harvest index is always a fraction less than 1. For crops where the harvested portion is belowground, the harvest index may be greater than 1. Two harvest indices are provided in the database, the harvest index for optimal growing conditions (HVSTI) and the harvest index under highly stressed growing conditions (WSYF). To determine the harvest index, the plant biomass removed during the harvest operation is dried at least 2 days at 65°C and weighed. The total aboveground plant biomass in the field should also be dried and weighed. The harvest index is then calculated by dividing the weight of the harvested portion of the plant biomass by the weight of the total aboveground plant biomass. Plants will need to be grown in two different plots where optimal climatic conditions and stressed conditions are produced to obtain values for both harvest indices.
BLAI	Maximum potential leaf area index. BLAI is one of six parameters use to quantify leaf area development of a plant species during the growing season. Figure 14-2 illustrates the relationship of the database parameters to the leaf area development modeled by SWAT.

Variable name **Definition**

BLAI, cont.

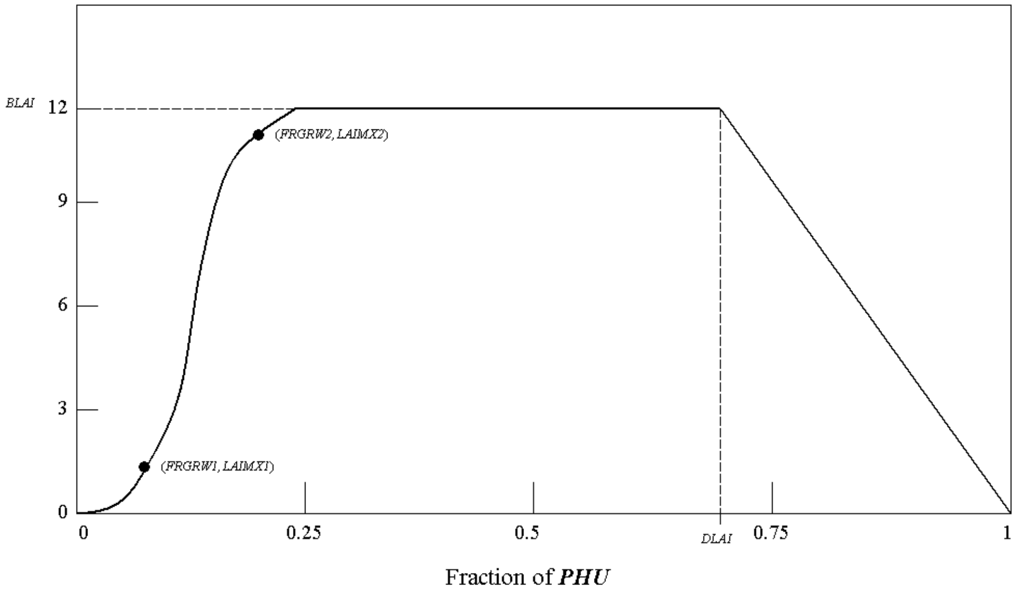

Figure 14-2: Leaf area index as a function of fraction of growing season for Alamo switchgrass

To identify the leaf area development parameters, record the leaf area index and number of accumulated heat units for the plant species throughout the growing season and then plot the results. For best results, several years worth of field data should be collected. At the very minimum, data for two years is recommended. It is important that the plants undergo no water or nutrient stress during the years in which data is collected.

The leaf area index incorporates information about the plant density, so field experiments should either be set up to reproduce actual plant densities or the maximum LAI value for the plant determined from field experiments should be adjusted to reflect plant densities desired in the simulation. Maximum LAI values in the default database correspond to plant densities associated with rainfed agriculture.

Variable name	Definition
BLAI, cont.	The leaf area index is calculated by dividing the green leaf area by the land area. Because the entire plant must be harvested to determine the leaf area, the field experiment needs to be designed to include enough plants to accommodate all leaf area measurements made during the year. Although measuring leaf area can be laborious for large samples, there is no intrinsic difficulty in the process. The most common method is to obtain an electronic scanner and feed the harvested green leaves and stems into the scanner. Older methods for estimating leaf area include tracing of the leaves (or weighed subsamples) onto paper, the use of planimeters, the punch disk method of Watson (1958) and the linear dimension method of Duncan and Hesketh (1968). Chapter 17 in the Theoretical Documentation reviews the methodology used to calculate accumulated heat units for a plant at different times of the year as well as determination of the fraction of total, or potential, heat units that is required for the plant database. The values for BLAI in the plant growth database are based on average plant densities in dryland (rainfed) agriculture. BLAI may need to be adjusted for drought-prone regions where planting densities are much smaller or irrigated conditions where densities are much greater.
FRGRW1	Fraction of the plant growing season or fraction of total potential heat units corresponding to the 1st point on the optimal leaf area development curve. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it.
LAIMX1	Fraction of the maximum leaf area index corresponding to the 1st point on the optimal leaf area development curve. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it.

Variable name	Definition
FRGRW2	Fraction of the plant growing season or fraction of total potential heat units corresponding to the 2nd point on the optimal leaf area development curve. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it.
LAIMX2	Fraction of the maximum leaf area index corresponding to the 2nd point on the optimal leaf area development curve. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it.
DLAI	Fraction of growing season when leaf area declines. Please see Figure 14-2 and the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it.
CHTMX	Maximum canopy height (m). Maximum canopy height is a straightforward measurement. The canopy height of non-stressed plants should be recorded at intervals throughout the growing season. The maximum value recorded is used in the database.
RDMX	Maximum root depth (m). To determine maximum rooting depth, plant samples need to be grown on soils without an impermeable layer. Once the plants have reached maturity, soil cores are taken for the entire depth of the soil. Each 0.25 meter increment is washed and the live plant material collected. Live roots can be differentiated from dead roots by the fact that live roots are whiter and more elastic and have an intact cortex. The deepest increment of the soil core in which live roots are found defines the maximum rooting depth.
T_OPT	Optimal temperature for plant growth (ºC). Both optimal and base temperatures are very stable for cultivars within a species. Optimal temperature for plant growth is difficult to measure directly. Looking at Figure 14-3, one might be tempted to select the temperature corresponding to the peak of the plot as the optimal temperature. This would not be correct.

Variable name	**Definition**
T_OPT, cont.	The peak of the plot defines the optimal temperature for leaf development—not for plant growth. If an optimal temperature cannot be obtained through a review of literature, use the optimal temperature listed for a plant already in the database with similar growth habits. Review of temperatures for many different plants have provided generic values for base and optimal temperatures as a function of growing season. In situations, where temperature information is unavailable, these values may be used. For warm season plants, the generic base temperature is ~8ºC and the generic optimal temperature is ~25ºC. For cool season plants, the generic base temperature is ~0ºC and the generic optimal temperature is ~13ºC.
T_BASE	Minimum (base) temperature for plant growth (ºC). SWAT uses the base temperature to calculate the number of heat units accrued every day. The minimum or base temperature for plant growth varies with growth stage of the plant. However, this variation is ignored by the model—SWAT uses the same base temperature throughout the growing season. Base temperature is measured by growing plants in growth chambers at several different temperatures. The rate of leaf tip appearance as a function of temperature is plotted. Extrapolating the line to the leaf tip appearance rate of 0.0 leaves/day gives the base or minimum temperature for plant growth. Figure 14-3 plots data for corn. (Note that the line intersects the x-axis at 8°C.)

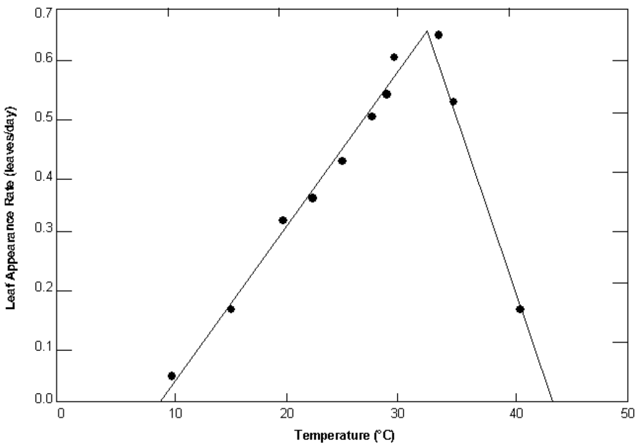

Figure 14-3: Rate of leaf tip appearance as a function of temperature for corn (After Kiniry et al, 1991)

Variable name	Definition
CNYLD	Normal fraction of nitrogen in yield (kg N/kg yield). In addition to the amount of plant biomass removed in the yield, SWAT needs to know the amount of nitrogen and phosphorus removed in the yield. The harvested portion of the plant biomass is sent to a testing laboratory to determine the fraction of nitrogen and phosphorus in the biomass. This value is estimated on a dry weight basis.
CPYLD	Normal fraction of phosphorus in yield (kg P/kg yield). In addition to the amount of plant biomass removed in the yield, SWAT needs to know the amount of nitrogen and phosphorus removed in the yield. The harvested portion of the plant biomass is sent to a testing laboratory to determine the fraction of nitrogen and phosphorus in the biomass. This value is estimated on a dry weight basis.
BN(1)	Nitrogen uptake parameter #1: normal fraction of nitrogen in plant biomass at emergence (kg N/kg biomass) In order to calculate the plant nutrient demand throughout a plant's growing cycle, SWAT needs to know the fraction of nutrient in the total plant biomass (on a dry weight basis) at different stages of crop growth. Six variables in the plant database provide this information: BN(1), BN(2), BN(3), BP(1), BP(2), and BP(3). Plant samples are analyzed for nitrogen and phosphorus content at three times during the growing season: shortly after emergence, near the middle of the season, and at maturity. The plant samples can be sent to testing laboratories to obtain the fraction of nitrogen and phosphorus in the biomass. Ideally, the plant samples tested for nutrient content should include the roots as well as the aboveground biomass. Differences in partitioning of nutrients to roots and shoots can cause erroneous conclusions when comparing productivity among species if only the aboveground biomass is measured.

Variable name	Definition
BN(2)	Nitrogen uptake parameter #2: normal fraction of nitrogen in plant biomass at 50% maturity (kg N/kg biomass) Please read the explanation for parameter BN(1) to obtain additional information about this parameter and methods used to measure it.
BN(3)	Nitrogen uptake parameter #3: normal fraction of nitrogen in plant biomass at maturity (kg N/kg biomass) Please read the explanation for parameter BN(1) to obtain additional information about this parameter and methods used to measure it.
BP(1)	Phosphorus uptake parameter #1: normal fraction of phosphorus in plant biomass at emergence (kg P/kg biomass) Please read the explanation for parameter BN(1) to obtain additional information about this parameter and methods used to measure it.
BP(2)	Phosphorus uptake parameter #2: normal fraction of phosphorus in plant biomass at 50% maturity (kg P/kg biomass) Please read the explanation for parameter BN(1) to obtain additional information about this parameter and methods used to measure it.
BP(3)	Phosphorus uptake parameter #3: normal fraction of phosphorus in plant biomass at maturity (kg P/kg biomass) Please read the explanation for parameter BN(1) to obtain additional information about this parameter and methods used to measure it.
WSYF	Lower limit of harvest index ((kg/ha)/(kg/ha)). The value between 0.0 and HVSTI which represents the lowest harvest index expected due to water stress. Please read the explanation for parameter HVSTI to obtain additional information about this parameter and methods used to measure it.

Variable name	Definition
USLE_C	Minimum value of USLE C factor for water erosion applicable to the land cover/plant. The minimum C factor can be estimated from a known average annual C factor using the following equation (Arnold and Williams, 1995): $C_{USLE,mn} = 1.463 \ln\left[C_{USLE,aa}\right] + 0.1034$ where $C_{USLE,mn}$ is the minimum C factor for the land cover and $C_{USLE,aa}$ is the average annual C factor for the land cover.
GSI	Maximum stomatal conductance at high solar radiation and low vapor pressure deficit (m·s^{-1}). Stomatal conductance of water vapor is used in the Penman-Monteith calculations of maximum plant evapotranspiration. The plant database contains three variables pertaining to stomatal conductance that are required only if the Penman-Monteith equations are chosen to model evapotranspiration: maximum stomatal conductance (GSI), and two variables that define the impact of vapor pressure deficit on stomatal conductance (FRGMAX, VPDFR). Körner et al (1979) defines maximum leaf diffusive conductance as the largest value of conductance observed in fully developed leaves of well-watered plants under optimal climatic conditions, natural outdoor CO_2 concentrations and sufficient nutrient supply. Leaf diffusive conductance of water vapor cannot be measured directly but can be calculated from measurements of transpiration under known climatic conditions. A number of different methods are used to determine diffusive conductance: transpiration measurements in photosynthesis cuvettes, energy balance measurements or weighing experiments, ventilated diffusion porometers and non-ventilated porometers. Körner (1977) measured diffusive conductance using a ventilated diffusion porometer. To obtain maximum leaf conductance values, leaf conductance is determined between sunrise and late morning until a clear decline or no further increase is observed. Depending on phenology, measurements are taken on at least three bright days in late spring and summer, preferably just after a rainy period. The means of

Variable name	**Definition**
GSI, cont.	maximum leaf conductance of 5 to 10 samples each day are averaged, yielding the maximum diffusive conductance for the species. Due to the variation of the location of stomata on plant leaves for different plant species, conductance values should be calculated for the total leaf surface area.
VPDFR	Vapor pressure deficit (kPa) corresponding to the second point on the stomatal conductance curve. (The first point on the stomatal conductance curve is comprised of a vapor pressure deficit of 1 kPa and the fraction of maximum stomatal conductance equal to 1.00.) As with radiation-use efficiency, stomatal conductance is sensitive to vapor pressure deficit. Stockle et al (1992) compiled a short list of stomatal conductance response to vapor pressure deficit for a few plant species. Due to the paucity of data, default values for the second point on the stomatal conductance vs. vapor pressure deficit curve are used for all plant species in the database. The fraction of maximum stomatal conductance (FRGMAX) is set to 0.75 and the vapor pressure deficit corresponding to the fraction given by FRGMAX (VPDFR) is set to 4.00 kPa. If the user has actual data, they should use those values, otherwise the default values are adequate.
FRGMAX	Fraction of maximum stomatal conductance corresponding to the second point on the stomatal conductance curve. (The first point on the stomatal conductance curve is comprised of a vapor pressure deficit of 1 kPa and the fraction of maximum stomatal conductance equal to 1.00.) Please read the explanation for parameter VPDFR to obtain additional information about this parameter and methods used to measure it.
WAVP	Rate of decline in radiation use efficiency per unit increase in vapor pressure deficit. Stockle and Kiniry (1990) first noticed a relationship between RUE and vapor pressure deficit and were able to explain a large portion of within-species variability in RUE values for sorghum and corn by plotting RUE values as a function of average daily vapor pressure deficit values. Since this first article, a number of other studies

Variable name	Definition
WAVP, cont.	have been conducted that support the dependence of RUE on vapor pressure deficit. However, there is still some debate in the scientific community on the validity of this relationship. If the user does not wish to simulate a change in RUE with vapor pressure deficit, the variable WAVP can be set to 0.0 for the plant. To define the impact of vapor pressure deficit on RUE, vapor pressure deficit values must be recorded during the growing seasons that RUE determinations are being made. It is important that the plants are exposed to no other stress than vapor pressure deficit, i.e. plant growth should not be limited by lack of soil water and nutrients. Vapor pressure deficits can be calculated from relative humidity (see Chapter 3 in Theoretical Documentation) or from daily maximum and minimum temperatures using the technique of Diaz and Campbell (1988) as described by Stockle and Kiniry (1990). The change in RUE with vapor pressure deficit is determined by fitting a linear regression for RUE as a function of vapor pressure deficit. Figure 14-4 shows a plot of RUE as a function of vapor pressure deficit for grain sorghum.

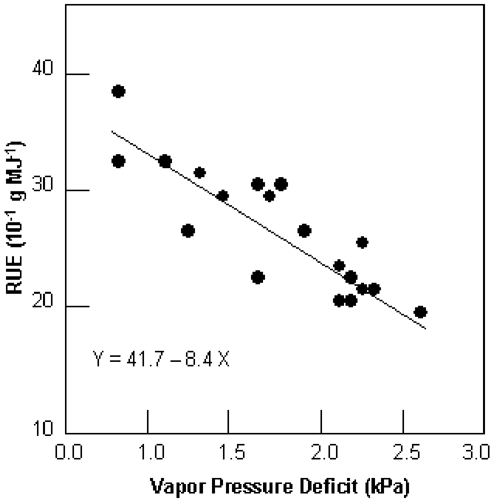

Figure 14-4: Response of radiation-use efficiency to mean daily vapor pressure deficit for grain sorghum (After Kiniry, 1999).

Variable name	**Definition**
WAVP, cont.	From Figure 14-4, the rate of decline in radiation-use efficiency per unit increase in vapor pressure deficit, Δrue_{dcl}, for sorghum is 8.4×10^{-1} g·MJ^{-1}·kPa^{-1}. When RUE is adjusted for vapor pressure deficit, the model assumes the RUE value reported for BIO_E is the radiation-use efficiency at a vapor pressure deficit of 1 kPa. The value of WAVP varies among species, but a value of 6 to 8 is suggested as an approximation for most plants.
CO2HI	Elevated CO_2 atmospheric concentration (µL CO_2/L air) corresponding the 2nd point on the radiation use efficiency curve. (The 1st point on the radiation use efficiency curve is comprised of the ambient CO_2 concentration, 330 µL CO_2/L air, and the biomass-energy ratio reported for BIO_E) In order to assess the impact of climate change on agricultural productivity, SWAT incorporates equations that adjust RUE for elevated atmospheric CO_2 concentrations. Values must be entered for CO2HI and BIOEHI in the plant database whether or not the user plans to simulate climate change. For simulations in which elevated CO_2 levels are not modeled, CO2HI should be set to some number greater than 330 ppmv and BIOEHI should be set to some number greater than BIO_E. To obtain radiation-use efficiency values at elevated CO_2 levels for plant species not currently in the database, plants should be established in growth chambers set up in the field or laboratory where CO_2 levels can be controlled. RUE values are determined using the same methodology described in the explanation of BIO_E.
BIOEHI	Biomass-energy ratio corresponding to the 2nd point on the radiation use efficiency curve. (The 1st point on the radiation use efficiency curve is comprised of the ambient CO_2 concentration, 330 µL CO_2/L air, and the biomass-energy ratio reported for BIO_E.) Please read the explanation for parameter CO2HI and BIO_E to obtain additional information about this parameter and methods used to measure it.

Variable name	Definition
RSDCO_PL	Plant residue decomposition coefficient. The plant residue decomposition coefficient is the fraction of residue that will decompose in a day assuming optimal moisture, temperature, C:N ratio, and C:P ratio. This variable was originally in the basin input file (.bsn), but was added to the crop database so that users could vary decomposition by land cover. A default value of 0.05 is used for all plant species in the database.

Four lines are required to store the plant growth parameters for a land cover/plant in the database (crop.dat) file. The plant growth database file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

Variable name	Line #	Format	F90 Format
ICNUM	1	integer	free
CPNM	1	character	a4
IDC	1	integer	free
BIO_E	2	real	free
HVSTI	2	real	free
BLAI	2	real	free
FRGRW1	2	real	free
LAIMX1	2	real	free
FRGRW2	2	real	free
LAIMX2	2	real	free
DLAI	2	real	free
CHTMX	2	real	free
RDMX	2	real	free
T_OPT	3	real	free
T_BASE	3	real	free
CNYLD	3	real	free
CPYLD	3	real	free
BN(1)	3	real	free
BN(2)	3	real	free

Variable name	Line #	Format	F90 Format
BN(3)	3	real	free
BP(1)	3	real	free
BP(2)	3	real	free
BP(3)	3	real	free
WSYF	4	real	free
USLE_C	4	real	free
GSI	4	real	free
VPDFR	4	real	free
FRGMAX	4	real	free
WAVP	4	real	free
CO2HI	4	real	free
BIOEHI	4	real	free
RSDCO_PL	4	real	free

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CHAPTER 15

SWAT INPUT DATA: TILL.DAT

SWAT uses five databases to store information required for plant growth, urban land characteristics, tillage, fertilizer components and pesticide properties. The tillage database distributed with SWAT contains mixing depth and mixing efficiency data for the most common tillage implements.

Tillage operations redistribute nutrients, pesticide and residue in the soil profile. Appendix A documents the source of parameter values in the distributed database.

Following is a brief description of the variables in the tillage database file. They are listed in the order they appear within the file.

Variable name	**Definition**
ITNUM	Tillage number. ITNUM is the numeric code used in the management file to identify the tillage practice to be modeled. The different tillage operations in till.dat must have consecutive values for ITNUM.
TILLNM	An eight-character code representing the tillage operation name.
EFFMIX	Mixing efficiency of tillage operation. The mixing efficiency specifies the fraction of materials (residue, nutrients and pesticides) on the soil surface which are mixed uniformly throughout the soil depth specified by DEPTIL. The remaining fraction of residue and nutrients is left in the original location (soil surface or layer).
DEPTIL	Depth of mixing caused by the tillage operation (mm).

The format of the tillage database file is:

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
ITNUM	ALL	space 1-4	4-digit integer	i4
TILLNM	ALL	space 9-16	character	a8
EFFMIX	ALL	space 25-32	decimal(xxxx.xxx)	f8.3
DEPTIL	ALL	space 41-48	decimal(xxxx.xxx)	f8.3

CHAPTER 16

SWAT INPUT DATA:
PEST.DAT

SWAT uses five databases to store information required for plant growth, urban land characteristics, tillage, fertilizer components and pesticide properties. The pesticide database contains parameters that govern pesticide fate and transport in the HRUs. Appendix A documents the source of parameter values in the distributed database.

Following is a brief description of the variables in the pesticide/toxin database file. They are listed in the order they appear within the file.

Variable name	**Definition**
IPNUM	Pesticide/toxin number. IPNUM is the numeric code used in the management file to identify the pesticide/toxin to be applied. The different toxins in pest.dat must have consecutive values for IPNUM.
PNAME	Name of pesticide/toxin. (up to 17 characters allowed)
SKOC	Soil adsorption coefficient normalized for soil organic carbon content (mg/kg)/(mg/L). Pesticide in the soil environment can be transported in solution or attached to sediment. The partitioning of a pesticide between the solution and soil phases is defined by the soil adsorption coefficient for the pesticide. The soil adsorption coefficient is the ratio of the pesticide concentration in the soil or solid phase to the pesticide concentration in the solution or liquid phase: $K_p = \frac{C_{solidphase}}{C_{solution}}$ where K_p is the soil adsorption coefficient ((mg/kg)/(mg/L) or m^3/ton), $C_{solidphase}$ is the concentration of the pesticide sorbed to the solid phase (mg chemical/kg solid material or g/ton), and $C_{solution}$ is the concentration of the pesticide in solution (mg chemical/L solution or g/ton). The definition of the soil adsorption coefficient in this equation assumes that the pesticide sorption process is linear with concentration and instantaneously reversible. Because the partitioning of pesticide is dependent upon the amount of organic material in the soil, the soil adsorption coefficient input to the model is normalized for soil organic carbon content. The relationship between the soil adsorption coefficient and the soil adsorption coefficient normalized for soil organic carbon content is: $K_p = K_{oc} \cdot \frac{orgC}{100}$

Variable name	Definition
SKOC, cont.	where K_p is the soil adsorption coefficient ((mg/kg)/(mg/L)), K_{oc} is the soil adsorption coefficient normalized for soil organic carbon content ((mg/kg)/(mg/L) or m^3/ton), and *orgC* is the percent organic carbon present in the soil.
WOF	Wash-off fraction. The wash-off fraction quantifies the fraction of pesticide on the plant canopy that may be dislodged. The wash-off fraction is a function of the nature of the leaf surface, plant morphology, pesticide solubility, polarity of the pesticide molecule, formulation of the commercial product and timing and volume of the rainfall event.
HLIFE_F	Degradation half-life of the chemical on the foliage (days). The half-life for a pesticide defines the number of days required for a given pesticide concentration to be reduced by one-half. The half-life entered for a pesticide is a lumped parameter that includes the net effect of volatilization, photolysis, hydrolysis, biological degradation and chemical reactions. For most pesticides, the foliar half-life is much less than the soil half-life due to enhanced volatilization and photodecomposition. If the foliar half-life is available for the pesticide this value should be used. If the foliar half-life is not available, the foliar half-life can be estimated using the following rules: 1) Foliar half-life is assumed to be less than the soil half-life by a factor of 0.5 to 0.25, depending on vapor pressure and sensitivity to photodegradation. 2) Foliar half-life is adjusted downward for pesticides with vapor pressures less than 10^{-5} mm Hg. 3) The maximum foliar half-life assigned is 30 days.
HLIFE_S	Degradation half-life of the chemical in the soil (days). The half-life for a pesticide defines the number of days required for a given pesticide concentration to be reduced by one-half. The soil half-life entered for a pesticide is a lumped parameter that includes the net effect of volatilization, photolysis, hydrolysis, biological degradation and chemical reactions.

Variable name	Definition
AP_EF	Application efficiency. The fraction of pesticide applied which is deposited on the foliage and soil surface (0.1-1.0). The remainder is lost. The application efficiency for all pesticides listed in the database is defaulted to 0.75. This variable is a calibration parameter.
WSOL	Solubility of the chemical in water (mg/L or ppm) The water solubility value defines the highest concentration of pesticide that can be reached in the runoff and soil pore water. While this is an important characteristic, researchers have found that the soil adsorption coefficient, K_{oc}, tends to limit the amount of pesticide entering solution so that the maximum possible concentration of pesticide in solution is seldom reached. Reported solubility values are determined under laboratory conditions at a constant temperature, typically between 20°C and 30°C.

The format of the pesticide/toxin database file is:

Variable name	Line #	Position	Format	F90 Format
IPNUM	ALL	space 1-3	integer	i3
PNAME	ALL	space 4-20	character	a17
SKOC	ALL	space 21-30	decimal(xxxxxxxx.x)	f10.1
WOF	ALL	space 31-35	decimal(xx.xx)	f5.2
HLIFE_F	ALL	space 36-43	decimal(xxxxxx.x)	f8.1
HLIFE_S	ALL	space 44-51	decimal(xxxxxx.x)	f8.1
AP_EF	ALL	space 52-56	decimal(xx.xx)	f5.2
WSOL	ALL	space 57-67	decimal(xxxxxxx.xxx)	f11.3

CHAPTER 17

SWAT INPUT DATA: FERT.DAT

SWAT uses five databases to store information required for plant growth, urban land characteristics, tillage, fertilizer components and pesticide properties. The fertilizer database summarizes the relative fractions of nitrogen and phosphorus pools in the different fertilizers. Information on levels of bacteria in manure is also stored in this file. Appendix A documents the source of parameter values in the distributed database.

Following is a brief description of the variables in the fertilizer database file. They are listed in the order they appear within the file.

Variable name	**Definition**
IFNUM	Number of fertilizer in database. This number is the reference number used in the management file to identify the fertilizer type being applied. This number should be equivalent to the line number in the file.
FERTNM	Name of fertilizer/manure (up to 8 characters allowed).
FMINN	Fraction of mineral N (NO_3 and NH_4) in fertilizer (kg min-N/kg fertilizer). Value should be between 0.0 and 1.0.
FMINP	Fraction of mineral P in fertilizer (kg min-P/kg fertilizer). Value should be between 0.0 and 1.0.
FORGN	Fraction of organic N in fertilizer (kg org-N/kg fertilizer). Value should be between 0.0 and 1.0.
FORGP	Fraction of organic P in fertilizer (kg org-P/kg fertilizer). Value should be between 0.0 and 1.0.
FNH3N	Fraction of mineral N in fertilizer applied as ammonia (kg NH_3-N/kg min-N). Value should be between 0.0 and 1.0.
BACTPDB	Concentration of persistent bacteria in manure/fertilizer (# bacteria/kg manure). Optional.
BACTLPDB	Concentration of less-persistent bacteria in manure/fertilizer (# bacteria/kg manure). Optional.
BACTKDDB	Bacteria partition coefficient. Value should be between 0.0 and 1.0. As the bacteria partition coefficient approaches 0.0, bacteria is primarily sorbed to soil particles. As the bacteria partition coefficient approaches 1.0, bacteria is primarily in solution. Optional.

The format of the fertilizer database file is:

Variable name	Line #	Position	Format	F90 Format
IFNUM	ALL	space 1-4	integer	i4
FERTNM	ALL	space 6-13	character	a8
FMINN	ALL	space 14-21	decimal(xxxx.xxx)	f8.3
FMINP	ALL	space 22-29	decimal(xxxx.xxx)	f8.3
FORGN	ALL	space 30-37	decimal(xxxx.xxx)	f8.3
FORGP	ALL	space 38-45	decimal(xxxx.xxx)	f8.3
FNH3N	ALL	space 46-53	decimal(xxxx.xxx)	f8.3
BACTPDB	ALL	space 54-61	decimal(xxxx.xxx)	f8.3
BACTLPDB	ALL	space 62-69	decimal(xxxx.xxx)	f8.3
BACTKDDB	ALL	space 70-77	decimal(xxxx.xxx)	f8.3

CHAPTER 18

SWAT INPUT DATA: URBAN.DAT

SWAT uses five databases to store information required for plant growth, urban land characteristics, tillage, fertilizer components and pesticide properties. The urban database summarizes parameters used by the model to simulate different types of urban areas. Appendix A documents the source of parameter values in the distributed database.

Following is a brief description of the variables in the urban database file. They are listed in the order they appear within the file.

Variable name	Definition
IUNUM	Number of urban land type. This value should be equivalent to the line number.
URBNAME	4-character code for urban land type. The 4-letter codes in the plant growth and urban databases are used by the GIS interfaces to link land use/land cover maps to SWAT plant types. This code is printed to the output files. When adding a new urban category, the four letter code for the new urban land type must be unique.
URBFLNM	Full description for urban land type—may take up to 54 characters. (not used by SWAT)
FIMP	Fraction total impervious area in urban land type. This includes directly and indirectly connected impervious areas. Urban areas differ from rural areas in the fraction of total area that is impervious. Construction of buildings, parking lots and paved roads increases the impervious cover in a watershed and reduces infiltration. With development, the spatial flow pattern of water is altered and the hydraulic efficiency of flow is increased through artificial channels, curbing, and storm drainage and collection systems.
FCIMP	Fraction directly connected impervious area in urban land type. Impervious areas can be differentiated into two groups: the area that is hydraulically connected to the drainage system and the area that is not directly connected. As an example, assume there is a house surrounded by a yard where runoff from the roof flows into the yard and is able to infiltrate into the soil. The rooftop is impervious but it is not hydraulically connected to the drainage system. In contrast, a parking lot whose runoff enters a storm water drain is hydraulically connected.

Variable name	Definition
FCIMP, cont.	When modeling urban areas the connectedness of the drainage system must be quantified. The best methods for determining the fraction total and directly connected impervious areas is to conduct a field survey or analyze aerial photographs.
CURBDEN	Curb length density in urban land type (km/ha). Curb length may be measured directly by scaling the total length of streets off of maps and multiplying by two. To calculate the density the curb length is divided by the area represented by the map.
URBCOEF	Wash-off coefficient for removal of constituents from impervious area (mm^{-1}) Wash off is the process of erosion or solution of constituents from an impervious surface during a runoff event. The original default value for urb_{coef} was calculated as 0.18 mm^{-1} by assuming that 13 mm of total runoff in one hour would wash off 90% of the initial surface load (Huber and Heaney, 1982). Using sediment transport theory, Sonnen (1980) estimated values for the wash-off coefficient ranging from 0.002-0.26 mm^{-1}. Huber and Dickinson (1988) noted that values between 0.039 and 0.390 mm^{-1} for the wash-off coefficient give sediment concentrations in the range of most observed values. This variable is used to calibrate the model to observed data.
DIRTMX	Maximum amount of solids allowed to build up on impervious areas (kg/curb km).
THALF	Number of days for amount of solids on impervious areas to build up from 0 kg/curb km to half the maximum allowed, i.e. 1/2 DIRTMX (days).
TNCONC	Concentration of total nitrogen in suspended solid load from impervious areas (mg N/kg sed).
TPCONC	Concentration of total phosphorus in suspended solid load from impervious areas (mg P/kg sed).
TNO3CONC	Concentration of nitrate in suspended solid load from impervious areas (mg NO_3-N/kg sed).

Every urban land type uses two lines in the urban.dat file to store input values. The format of every set of two lines is described below.

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
IUNUM	1	space 1-3	integer	i3
URBNAME	1	space 5-8	character	a4
URBFLNM	1	space 10-64	character	a54
FIMP	1	space 65-72	decimal(xxxx.xxx)	f8.3
FCIMP	1	space 73-80	decimal(xxxx.xxx)	f8.3
CURBDEN	2	space 5-12	decimal(xxxx.xxx)	f8.3
URBCOEF	2	space 13-20	decimal(xxxx.xxx)	f8.3
DIRTMX	2	space 21-28	decimal(xxxx.xxx)	f8.3
THALF	2	space 29-36	decimal(xxxx.xxx)	f8.3
TNCONC	2	space 37-44	decimal(xxxx.xxx)	f8.3
TPCONC	2	space 45-52	decimal(xxxx.xxx)	f8.3
TNO3CONC	2	space 53-60	decimal(xxxx.xxx)	f8.3

REFERENCES

Huber, W.C. and R.E. Dickinson. 1988. Storm water management model, version 4: user’s manual. U.S. Environmental Protection Agency, Athens, GA.

Huber, W.C. and J.P. Heaney. 1982. Chapter 3: Analyzing residual discharge and generation from urban and non-urban land surfaces. p. 121-243. *In* D.J. Basta and B.T. Bower (eds). Analyzing natural systems, analysis for regional residuals—environmental quality management. John Hopkins University Press, Baltimore, MD.

Sonnen, M.B. 1980. Urban runoff quality: information needs. ASCE Journal of the Technical Councils 106(TC1): 29-40.

CHAPTER 19

SWAT INPUT DATA:

.HRU

The HRU general input file contains information related to a diversity of features within the HRU. Data contained in the HRU input file can be grouped into the following categories: area contained in HRU, parameters affecting surface and subsurface water flow, parameters affecting erosion and management inputs related to the simulation of urban areas, irrigation, tile drains and potholes.

Following is a brief description of the variables in the HRU general input file. They are listed in the order they appear within the file.

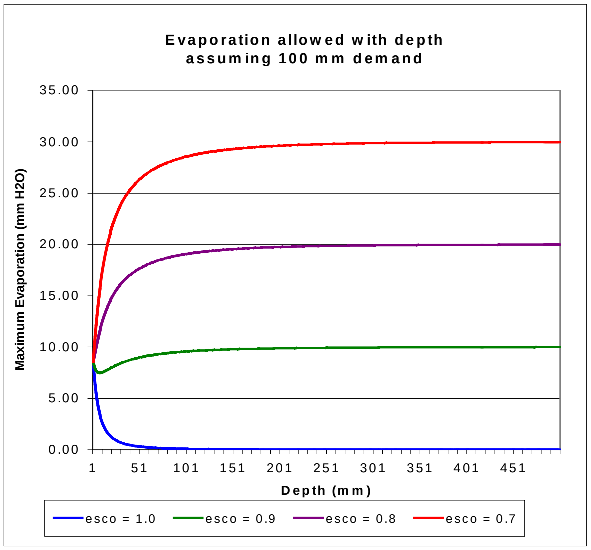
Variable name	**Definition**
TITLE	The first line of the .hru file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
HRU_FR	Fraction of total watershed area contained in HRU (km^2/km^2). If no value for HRU_FR is entered, the model will set HRU_FR = 0.0000001.
SLSUBBSN	Average slope length (m). This is the distance that sheet flow is the dominant surface runoff flow process. Slope length should be measured to the point that flow begins to concentrate. This length is easily observable after a heavy rain on a fallow field when the rills are well developed. In this situation, the slope length is the distance from the microwatershed divide to the origin of the rill. This value can also be determined from topographic maps. Terraces divide the slope of the hill into segments equal to the horizontal terrace interval. With terracing, the slope length is the terrace interval. For broadbase terraces, the horizontal terrace interval is the distance from the center of the ridge to the center of the channel for the terrace below. The horizontal terrace interval for steep backslope terraces is the distance from the point where cultivation begins at the base of the ridge to the base of the frontslope of the terrace below. Slope length is a parameter that is commonly overestimated. As a rule of thumb, 90 meters (300 ft) is considered to be a very long slope length. If no value for SLSUBBSN is entered, the model will set SLSUBBSN = 50. The GIS interfaces will assign the same value to this variable for all HRUs within a subbasin. However, some users like to vary this value by soil type and land cover.
SLOPE	Average slope steepness (m/m). The GIS interfaces will assign the same value to this variable for all HRUs within a subbasin. However, some users like to vary this value by soil type and land cover.

Variable name	Definition
OV_N	Manning's "n" value for overland flow.

Table 19-1: Values of Manning's roughness coefficient, *n*, for overland flow (Engman, 1983).

Characteristics of Land Surface	Median	Range
Fallow, no residue	0.010	0.008-0.012
Conventional tillage, no residue	0.090	0.060-0.120
Conventional tillage, residue	0.190	0.160-0.220
Chisel plow, no residue	0.090	0.060-0.120
Chisel plow, residue	0.130	0.100-0.160
Fall disking, residue	0.400	0.300-0.500
No till, no residue	0.070	0.040-0.100
No till, 0.5-1 t/ha residue	0.120	0.070-0.170
No till, 2-9 t/ha residue	0.300	0.170-0.470
Rangeland, 20% cover	0.600	
Short grass prairie	0.150	0.100-0.200
Dense grass	0.240	0.170-0.300
Bermudagrass	0.410	0.300-0.480

Variable name	Definition
LAT_TTIME	Lateral flow travel time (days). Setting LAT_TTIME = 0.0 will allow the model to calculate the travel time based on soil hydraulic properties. This variable should be set to a specific value only by hydrologists familiar with the base flow characteristics of the watershed.
LAT_SED	Sediment concentration in lateral and groundwater flow (mg/L). Sediment concentration in lateral and groundwater flow is usually very low and does not contribute significantly to total sediment yields unless return flow is very high.
SLSOIL	Slope length for lateral subsurface flow (m). If no value is entered for SLSOIL, the model sets SLSOIL = SLSUBBSN. The GIS interfaces will assign the same value to this variable for all HRUs within a subbasin. However, some users like to vary this value by soil type and land cover.
CANMX	Maximum canopy storage (mm H_2O). The plant canopy can significantly affect infiltration, surface runoff and evapotranspiration. As rain falls, canopy interception reduces the erosive energy of droplets and traps a portion of the rainfall within the canopy. The influence the canopy exerts on these processes is a function

Variable name	**Definition**
CANMX, cont.	of the density of plant cover and the morphology of the plant species.
	When calculating surface runoff, the SCS curve number method lumps canopy interception in the term for initial abstractions. This variable also includes surface storage and infiltration prior to runoff and is estimated as 20% of the retention parameter value for a given day (see Chapter 6). When the Green and Ampt infiltration equation is used to calculate surface runoff and infiltration, the interception of rainfall by the canopy must be calculated separately.
	SWAT allows the maximum amount of water that can be held in canopy storage to vary from day to day as a function of the leaf area index. CANMX is the maximum amount of water that can be trapped in the canopy when the canopy is fully developed (mm H_2O)
ESCO	Soil evaporation compensation factor.
	This coefficient has been incorporated to allow the user to modify the depth distribution used to meet the soil evaporative demand to account for the effect of capillary action, crusting and cracks. ESCO must be between 0.01 and 1.0. As the value for ESCO is reduced, the model is able to extract more of the evaporative demand from lower levels.
	The change in depth distribution resulting from different values of *esco* are graphed in Figure 19-1.
	 Figure 19-1: Soil evaporative demand distribution with depth

Variable name	Definition
ESCO, cont.	If no value for ESCO is entered, the model will set ESCO = 0.95. The value for ESCO may be set at the watershed or HRU level (ESCO in .bsn).
EPCO	Plant uptake compensation factor.
	The amount of water uptake that occurs on a given day is a function of the amount of water required by the plant for transpiration, E_t, and the amount of water available in the soil, SW. If upper layers in the soil profile do not contain enough water to meet the potential water uptake, users may allow lower layers to compensate. The plant uptake compensation factor can range from 0.01 to 1.00. As *epco* approaches 1.0, the model allows more of the water uptake demand to be met by lower layers in the soil. As *epco* approaches 0.0, the model allows less variation from the original depth distribution to take place.
	If no value for EPCO is entered, the model will set EPCO = 1.0. The value for EPCO may be set at the watershed or HRU level (EPCO in .bsn).
RSDIN	Initial residue cover (kg/ha).
	Optional
ERORGN	Organic N enrichment ratio for loading with sediment.
	As surface runoff flows over the soil surface, part of the water's energy is used to pick up and transport soil particles. The smaller particles weigh less and are more easily transported than coarser particles. When the particle size distribution of the transported sediment is compared to that of the soil surface layer, the sediment load to the main channel has a greater proportion of clay sized particles. In other words, the sediment load is enriched in clay particles. Organic nitrogen in the soil is attached primarily to colloidal (clay) particles, so the sediment load will also contain a greater proportion or concentration of organic N than that found in the soil surface layer.

Variable name	Definition
ERORGN, cont.	The enrichment ratio is defined as the ratio of the concentration of organic nitrogen transported with the sediment to the concentration in the soil surface layer. SWAT will calculate an enrichment ratio for each storm event, or allow the user to define a particular enrichment ratio for organic nitrogen that is used for all storms during the simulation. To calculate the enrichment ratio, the value for ERORGN is set to zero. The default option is to allow the model to calculate the enrichment ratio.
ERORGP	Phosphorus enrichment ratio for loading with sediment. The enrichment ratio is defined as the ratio of the concentration of phosphorus transported with the sediment to the concentration of phosphorus in the soil surface layer. SWAT will calculate an enrichment ratio for each storm event, or allow the user to define a particular enrichment ratio for phosphorus attached to sediment that is used for all storms during the simulation. If the value for ERORGP is set to zero, the model will calculate an enrichment ratio for every storm event. The default option is to allow the model to calculate the enrichment ratio.
FILTERW	Width of edge-of-field filter strip (m). Edge-of field filter strips may be defined in an HRU. Sediment, nutrient, pesticide and bacteria loads in surface runoff are reduced as the surface runoff passes through the filter strip. Optional.
IURBAN	Urban simulation code: 0 no urban sections in HRU 1 urban sections in HRU, simulate using USGS regression equations 2 urban sections in HRU, simulate using build up/wash off algorithm

Variable name	Definition
IURBAN, cont.	Most large watersheds and river basins contain areas of urban land use. Estimates of the quantity and quality of runoff in urban areas are required for comprehensive management analysis. SWAT calculates runoff from urban areas with the SCS curve number method or the Green & Ampt equation. Loadings of sediment and nutrients are determined using one of two options. The first is a set of linear regression equations developed by the USGS (Driver and Tasker, 1988) for estimating storm runoff volumes and constituent loads. The other option is to simulate the buildup and washoff mechanisms, similar to SWMM - Storm Water Management Model (Huber and Dickinson, 1988).
URBLU	Urban land type identification number from urban.dat.
IRR	Irrigation code. Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number. This variable, along with IRRNO, specifies the source of irrigation water applied in the HRU. Irrigation water may be diverted from anywhere in the watershed or outside the watershed. IRR tells the model what type of water body the irrigation water is being diverted from. The options are: 0 no irrigation 1 divert water from reach 2 divert water from reservoir 3 divert water from shallow aquifer 4 divert water from deep aquifer 5 divert water from unlimited source outside watershed

Variable name	Definition
IRRNO	Irrigation source location. Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number. The definition of this variable depends on the setting of IRR. IRR = 1: IRRNO is the number of the reach that water is removed from. IRR = 2: IRRNO is the number of the reservoir that water is removed from. IRR = 3 or 4: IRRNO is the number of the subbasin that water is removed from. IRR = 0 or 5: this variable is not used.
FLOWMIN	Minimum in-stream flow for irrigation diversions (m^3/s). If the source of the irrigation water is a reach, SWAT allows additional input parameters to be set. These parameters are used to prevent flow in the reach from being reduced to zero as a result of irrigation water removal. Users may define a minimum in-stream flow, a maximum irrigation water removal amount that cannot be exceeded on any given day, and/or a fraction of total flow in the reach that is available for removal on a given day. FLOWMIN may be set when IRR = 1. If FLOWMIN is defined by the user, irrigation water will be diverted from the reach only if flow in the reach is at or above FLOWMIN.
DIVMAX	Maximum daily irrigation diversion from the reach (If value entered for DIVMAX is positive the units are mm, if the value entered for DIVMAX is negative the units are 10^4 m^3) If the source of the irrigation water is a reach, SWAT allows additional input parameters to be set. These parameters are used to prevent flow in the reach from

Variable name	Definition
DIVMAX, cont.	being reduced to zero as a result of irrigation water removal. Users may define a minimum in-stream flow, a maximum irrigation water removal amount that cannot be exceeded on any given day, and/or a fraction of total flow in the reach that is available for removal on a given day. DIVMAX may be set when IRR = 1. If DIVMAX is defined by the user, the amount of water removed from the reach and applied to the HRU on any one day will never exceed the value assigned to DIVMAX.
FLOWFR	Fraction of available flow that is allowed to be applied to the HRU. Available flow is defined as the total flow in reach minus FLOWMIN. If FLOWMIN is left at zero, the fraction of available flow becomes the fraction of total flow in reach that is allowed to be applied to the reach. If the source of the irrigation water is a reach, SWAT allows additional input parameters to be set. These parameters are used to prevent flow in the reach from being reduced to zero as a result of irrigation water removal. Users may define a minimum in-stream flow, a maximum irrigation water removal amount that cannot be exceeded on any given day, and/or a fraction of total flow in the reach that is available for removal on a given day. FLOWFR may be set when IRR = 1. The value for FLOWFR should be between 0.01 and 1.00. The model will default FLOWFR = 1.0 if no value is entered or 0.00 is entered.
DDRAIN	Depth to subsurface drain (mm). If drainage tiles are installed in the HRU, the depth to the tiles is needed. A common depth for drain installation is 90 mm. To simulate tile drainage in an HRU, the user must specify the depth from the soil surface to the drains, the amount of time required to drain the soil to field capacity, and the amount of lag between the time water enters the tile till it exits the tile and enters the main channel. Tile drainage occurs when the soil water content exceeds field capacity.

Variable name	**Definition**
TDRAIN	Time to drain soil to field capacity (hours). The time required to drain the soil from saturation to field capacity. Most tile drains are designed to reduce the water content to field capacity within 48 hours. To simulate tile drainage in an HRU, the user must specify the depth from the soil surface to the drains, the amount of time required to drain the soil to field capacity, and the amount of lag between the time water enters the tile till it exits the tile and enters the main channel. Tile drainage occurs when the soil water content exceeds field capacity.
GDRAIN	Drain tile lag time (hours). The amount of time between the transfer of water from the soil to the drain tile and the release of the water from the drain tile to the reach. To simulate tile drainage in an HRU, the user must specify the depth from the soil surface to the drains, the amount of time required to drain the soil to field capacity, and the amount of lag between the time water enters the tile till it exits the tile and enters the main channel. Tile drainage occurs when the soil water content exceeds field capacity.
IPOT	Number of HRU with impounded water. In areas of low relief and/or young geologic development, the drainage network may be poorly developed. Watersheds in these areas may have many closed depressional areas, referred to as potholes. Runoff generated within these areas flows to the lowest portion of the pothole rather than contributing to flow in the main channel. Other systems that are hydrologically similar to potholes include playa lakes and fields that are artifically impounded for rice production. To define an HRU as a pothole, the user must set IPOT to the HRU number. To initiate water impoundment, a release/impound operation must be placed in the .mgt file.

Variable name	Definition
IPOT, cont.	If the HRU does not contain the pothole, but does contribute runoff to the pothole in another HRU, the user should set IPOT to the number of the HRU with the pothole. The pothole can accept water only from HRUs located within the subbasin.
POT_FR	Fraction of HRU area that drains into the pothole. Required if IPOT is set to a number other than zero.
POT_TILE	Average daily outflow to main channel from tile flow if drainage tiles are installed in the pothole (m^3/s). Required only for the HRU that is ponding water (IPOT = current HRU number) if drainage tiles are installed.
POT_VOLX	Maximum volume of water stored in the pothole (10^4 m^3 H_2O). Required only for the HRU that is ponding water (IPOT = current HRU number).
POT_VOL	Initial volume of water stored in the pothole (10^4 m^3 H_2O). Required only for the HRU that is ponding water (IPOT = current HRU number).
POT_NSED	Equilibrium sediment concentration in pothole (mg/L). Required only for the HRU that is ponding water (IPOT = current HRU number).
POT_NO3L	*Not currently active*. Nitrate decay rate in pothole (1/day). Required only for the HRU that is ponding water (IPOT = current HRU number).

The HRU general input file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format for the HRU general input file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
HRU_FR	2	real	free
SLSUBBSN	3	real	free
SLOPE	4	real	free
OV_N	5	real	free
LAT_TTIME	6	real	free
LAT_SED	7	real	free
SLSOIL	8	real	free
CANMX	9	real	free
ESCO	10	real	free
EPCO	11	real	free
RSDIN	12	real	free
ERORGN	13	real	free
ERORGP	14	real	free
FILTERW	15	real	free
IURBAN	16	integer	free
URBLU	17	integer	free
IRR	18	integer	free
IRRNO	19	integer	free
FLOWMIN	20	real	free
DIVMAX	21	real	free
FLOWFR	22	real	free
DDRAIN	23	real	free
TDRAIN	24	real	free
GDRAIN	25	real	free
NO VARIABLE	26	free	free
IPOT	27	integer	free
POT_FR	28	real	free
POT_TILE	29	real	free

Variable name	Line #	Format	F90 Format
POT_VOLX	30	real	free
POT_VOL	31	real	free
POT_NSED	32	real	free
POT_NO3L	33	real	free

REFERENCES

Engman, E.T. 1983. Roughness coefficients for routing surface runoff. Proc. Spec. Conf. Frontiers of Hydraulic Engineering.

CHAPTER 20

SWAT INPUT DATA: .MGT

A primary goal of environmental modeling is to assess the impact of anthropogenic activities on a given system. Central to this assessment is the itemization of the land and water management practices taking place within the system. The primary file used to summarize these practices is the HRU management file (.mgt). This file contains input data for planting, harvest, irrigation applications, nutrient applications, pesticide applications, and tillage operations.

20.1 GENERAL MANAGEMENT VARIABLES

The first two lines of the management input file contain general management variables. The remaining lines in the file list the sequence of management operations which occur at specific times during the simulation.

The general management variables define the status of plants growing in the HRU at the beginning of the simulation. Other parameters on this line initialize the curve number for the HRU, the USLE P factor for sediment erosion calculations, and the amount of biological mixing.

The general management variables are:

Variable name	**Definition**
TITLE	The first line of the .mgt file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
IGRO	Land cover status code. This code informs the model whether or not a land cover is growing at the beginning of the simulation. 0 no land cover growing 1 land cover growing
NROT	Number of years of rotation. This code identifies the number of years of management practices given in the .mgt file. (A blank line should be inserted between each different year of management.) If the management doesn't change from year to year, the management operations for only one year are needed. Two land covers/crops may not be grown simultaneously, but they may be grown in the same year. For two or more crops grown in the ***same*** year, NROT is equal to 1 for 1 year of management practices listed. NROT has nothing to do with the number of different crops grown.
NMGT	Management code. Used by SWAT/GRASS (GIS) interface. The model doesn't use this variable.

Variable name	Definition
NCRP	Land cover identification number. If a land cover is growing at the beginning of the simulation (IGRO = 1), this variable defines the type of land cover. The identification number is the numeric code for the land cover given in the plant growht database.
ALAI	Initial leaf area index. If a land cover is growing at the beginning of the simulation (IGRO = 1), the leaf area index of the land cover must be defined.
BIO_MS	Initial dry weight biomass (kg/ha). If a land cover is growing at the beginning of the simulation (IGRO = 1), the initial biomass must be defined.
PHU	Total number of heat units or growing degree days needed to bring plant to maturity. This value is needed only if a land cover is growing at the beginning of the simulation (IGRO = 1). Calculation of PHU is reviewed in Chapter 17 of the SWAT 2000 Theoretical Documentation.
BIO_MIN	Minimum plant biomass for grazing (kg/ha). This variable was created so that the plant cover in an HRU would not be reduced to zero when grazing was included in the list of management operations. Grazing will not be simulated unless the biomass is at or above BIO_MIN.
BIOMIX	Biological mixing efficiency. Biological mixing is the redistribution of soil constituents as a result of the activity of biota in the soil (e.g. earthworms, etc.). Studies have shown that biological mixing can be significant in systems where the soil is only infrequently disturbed. In general, as a management system shifts from conventional tillage to conservation tillage to no-till there will be an increase in biological mixing. SWAT allows biological mixing to occur to a depth of 300 mm (or the bottom of the soil profile if it is shallower than 300 mm).

Variable name	Definition
BIOMIX, cont.	The efficiency of biological mixing is defined by the user and is conceptually the same as the mixing efficiency of a tillage implement. The redistribution of nutrients by biological mixing is calculated using the same methodology as that used for a tillage operation. Biological mixing is performed at the end of every calendar year. If no value for BIOMIX is entered, the model will set BIOMIX = 0.20
CN2	Initial SCS runoff curve number for moisture condition II. The SCS curve number is a function of the soil's permeability, land use and antecedent soil water conditions. Typical curve numbers for moisture condition II are listed in the following tables for various land covers and soil types (SCS Engineering Division, 1986). These values are appropriate for a 5% slope. The curve number may be updated in plant, tillage, and harvest/ kill operations. If CNOP is never defined for these operations, the value set for CN2 will be used throughout the simulation. If CNOP is defined for an operation, the value for CN2 is used until the time of the operation containing the first CNOP value. From that point on, the model only uses operation CNOP values to define the curve number for moisture condition II. Values for CN2 and CNOP should be entered for pervious conditions. In HRUs with urban areas, the model will adjust the curve number to reflect the impact of the impervious areas.

Table 20-1: Runoff curve numbers for cultivated agricultural lands (from SCS Engineering Division, 1986)

Cover			Hydrologic Soil Group			
Land Use	**Treatment or practice**	**Hydrologic condition**	**A**	**B**	**C**	**D**
Fallow	Bare soil	- - - -	77	86	91	94
	Crop residue cover[*]	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row w/ residue	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured w/ residue	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced	Poor	66	74	80	82
		Good	62	71	78	81

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[*] Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

Variable name **Definition**

CN2, cont.

Table 20-1, cont.: Runoff curve numbers for cultivated agricultural lands

Cover			Hydrologic Soil Group			
Land Use	**Treatment or practice**	**Hydrologic condition**	**A**	**B**	**C**	**D**
	Contoured & terraced w/ residue	Poor	65	73	79	81
		Good	61	70	77	80
Small grains	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row w/ residue	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured w/ residue	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced w/ residue	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

Table 20-2: Runoff curve numbers for other agricultural lands (from SCS Engineering Division, 1986)

Cover		Hydrologic Soil Group			
Cover Type	**Hydrologic condition**	**A**	**B**	**C**	**D**
Pasture, grassland, or range—continuous forage for grazing[1]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay	- - - -	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element[2]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods—grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[3]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	- - - -	59	74	82	86

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[1] *Poor:* < 50% ground cover or heavily grazed with no mulch; *Fair:* 50 to 75% ground cover and not heavily grazed; *Good*: > 75% ground cover and lightly or only occasionally grazed

[2] *Poor:* < 50% ground cover; *Fair:* 50 to 75% ground cover; Good: > 75% ground cover

[3] *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning; *Fair:* Woods are grazed but not burned, and some forest litter covers the soil; *Good:* Woods are protected from grazing, and litter and brush adequately cover the soil.

Variable name **Definition**

CN2, cont.

Table 20-3: Runoff curve numbers for urban areas (from SCS Engineering division, 1986)[§]

Cover			**Hydrologic Soil Group**			
Cover Type	**Hydrologic condition**	**Average % impervious area**	**A**	**B**	**C**	**D**
Fully developed urban areas						
Open spaces (lawns, parks, golf courses, cemeteries, etc.)[†]	Poor		68	79	86	89
	Fair		49	69	79	84
	Good		39	61	74	80
Impervious areas:						
Paved parking lots, roofs, driveways, etc. (excl. right-of-way)	- - - -		98	98	98	98
Paved streets and roads; open ditches (incl. right-of-way)	- - - -		83	89	92	93
Gravel streets and roads (including right-of-way)	- - - -		76	85	89	91
Dirt streets and roads (including right-of way)	- - - -		72	82	87	89
Urban districts:						
Commercial and business		85%	89	92	94	95
Industrial		72%	81	88	91	93
Residential Districts by average lot size:						
1/8 acre (0.05 ha) or less (town houses)		65%	77	85	90	92
1/4 acre (0.10 ha)		38%	61	75	83	87
1/3 acre (0.13 ha)		30%	57	72	81	86
1/2 acre (0.20 ha)		25%	54	70	80	85
1 acre (0.40 ha)		20%	51	68	79	84
2 acres (0.81 ha)		12%	46	65	77	82
Developing urban areas:						
Newly graded areas (pervious areas only, no vegetation)			77	86	91	94

USLE_P USLE equation support practice factor.

The support practice factor, P_{USLE}, is defined as the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down slope culture. Support practices include contour tillage, stripcropping on the contour, and terrace systems. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

Contour tillage and planting provides almost complete protection against erosion from storms of low to moderate intensity, but little or no protection against occasional severe storms that cause extensive breakovers of contoured rows. Contouring is most effective on slopes of 3 to 8 percent. Values for P_{USLE} and slope-length limits for contour support practices are given in Table 20-4.

[§] SWAT will automatically adjust curve numbers for impervious areas when IURBAN and URBLU are defined in the .hru file. Curve numbers from Table 6-3 should ***not*** be used in this instance.

[†] *Poor:* grass cover < 50%; *Fair:* grass cover 50 to 75%; *Good:* grass cover > 75%

Variable name	Definition
USLE_P, cont.	

Table 20-4: P factor values and slope-length limits for contouring (Wischmeier and Smith, 1978).

Land slope (%)	P_{USLE}	Maximum length (m)
1 to 2	0.60	122
3 to 5	0.50	91
6 to 8	0.50	61
9 to 12	0.60	37
13 to 16	0.70	24
17 to 20	0.80	18
21 to 25	0.90	15

Stripcropping is a practice in which contoured strips of sod are alternated with equal-width strips of row crop or small grain. Recommended values for contour stripcropping are given in Table 20-5.

Table 20-5: P factor values, maximum strip width and slope-length limits for contour stripcropping (Wischmeier and Smith, 1978).

Land slope (%)	P_{USLE} values[1]			Strip width (m)	Maximum length (m)
	A	B	C		
1 to 2	0.30	0.45	0.60	40	244
3 to 5	0.25	0.38	0.50	30	183
6 to 8	0.25	0.38	0.50	30	122
9 to 12	0.30	0.45	0.60	24	73
13 to 16	0.35	0.52	0.70	24	49
17 to 20	0.40	0.60	0.80	18	37
21 to 25	0.45	0.68	0.90	15	30

[1] P values:

A: For 4-year rotation of row crop, small grain with meadow seeding, and 2 years of meadow. A second row crop can replace the small grain if meadow is established in it.

B: For 4-year rotation of 2 years row crop, winter grain with meadow seeding, and 1-year meadow.

C: For alternate strips of row crop and winter grain

Terraces are a series of horizontal ridges made in a hillside. There are several types of terraces. Broadbase terraces are constructed on gently sloping land and the channel and ridge are cropped the same as the interterrace area. The steep backslope terrace, where the backslope is in sod, is most common on steeper land. Impoundment terraces are terraces with underground outlets.

Terraces divide the slope of the hill into segments equal to the horizontal terrace interval. With terracing, the slope length is the terrace interval. For broadbase terraces, the horizontal terrace interval is the distance from the center of the ridge to the center of the channel for the terrace below. The horizontal terrace interval for steep backslope terraces is the distance from the point where cultivation begins at

Variable name	Definition
USLE_P, cont.	the base of the ridge to the base of the frontslope of the terrace below. Values for P_{USLE} for contour farming terraced fields are listed in Table 20-6. These values apply to broadbase, steep backslope and level terraces. Keep in mind that the values given in Table 20-6 do not account for all erosion control benefits of terraces. The shorter slope-length used in the calculation of the length-slope factor will produce additional reduction.

Table 20-6: P factor values for contour-farmed terraced fields (from Wischmeier and Smith, 1978)[1]

Land slope (%)	Farm planning		Computing sediment yield[3]	
	Contour P factor[2]	Stripcrop P factor	Graded channels sod outlets	Steep backslope underground outlets
1 to 2	0.60	0.30	0.12	0.05
3 to 8	0.50	0.25	0.10	0.05
9 to 12	0.60	0.30	0.12	0.05
13 to 16	0.70	0.35	0.14	0.05
17 to 20	0.80	0.40	0.16	0.06
21 to 25	0.90	0.45	0.18	0.06

[1] Slope length is the horizontal terrace interval. The listed values are for contour farming. No additional contouring factor is used in the computation.

[2] Use these values for control of interterrace erosion within specified soil loss tolerances.

[3] These values include entrapment efficiency and are used for control of offsite sediment within limits and for estimating the field's contribution to watershed sediment yield.

The format of the first two lines in the management file are:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
IGRO	2	space 1	1-digit integer	i1
NROT	2	space 2-4	3-digit integer	i3
NMGT	2	space 5-8	4-digit integer	i4
NCRP	2	space 9-12	4-digit integer	i4
ALAI	2	space 13-20	decimal (xxxxx.xx)	f8.2
BIO_MS	2	space 21-28	decimal (xxxxx.xx)	f8.2
PHU	2	space 29-36	decimal (xxxxx.xx)	f8.2
BIO_MIN	2	space 37-44	decimal (xxxxx.xx)	f8.2
BIOMIX	2	space 45-52	decimal (xxxxx.xx)	f8.2
CN2	2	space 53-60	decimal (xxxxx.xx)	f8.2
USLE_P	2	space 61-68	decimal (xxxxx.xx)	f8.2

20.2 SCHEDULED MANAGEMENT OPERATIONS

SWAT will simulate 14 different types of management operations. The first four variables on all management lines are identical while the remaining ten are operation specific. The variables for the different operations will be defined in separate sections. The type of operation simulated is identified by the code given for the variable MGT_OP.

The different codes for MGT_OP are:

1 **planting/beginning of growing season:** this operation initializes the growth of a specific land cover/plant type in the HRU

2 **irrigation operation:** this operation applies water to the HRU

3 **fertilizer application:** this operation adds nutrients to the soil in the HRU

4 **pesticide application:** this operation applies a pesticide to the plant and/or soil in the HRU

5 **harvest and kill operation:** this operation harvests the portion of the plant designated as yield, removes the yield from the HRU and converts the remaining plant biomass to residue on the soil surface. It also sets IGRO = 0 which allows the next crop to be planted.

6 **tillage operation:** this operation mixes the upper soil layers and redistributes the nutrients/chemicals/etc. within those layers

7 **harvest only operation:** this operation harvests the portion of the plant designated as yield and removes the yield from the HRU, but allows the plant to continue growing. (this operation is used for hay cuttings)

8 **kill/end of growing season:** this operation stops all plant growth and converts all plant biomass to residue. It also sets IGRO = 0 which allows the next crop to be planted.

9 **grazing operation:** this operation removes plant biomass at a specified rate and allows simultaneous application of manure.

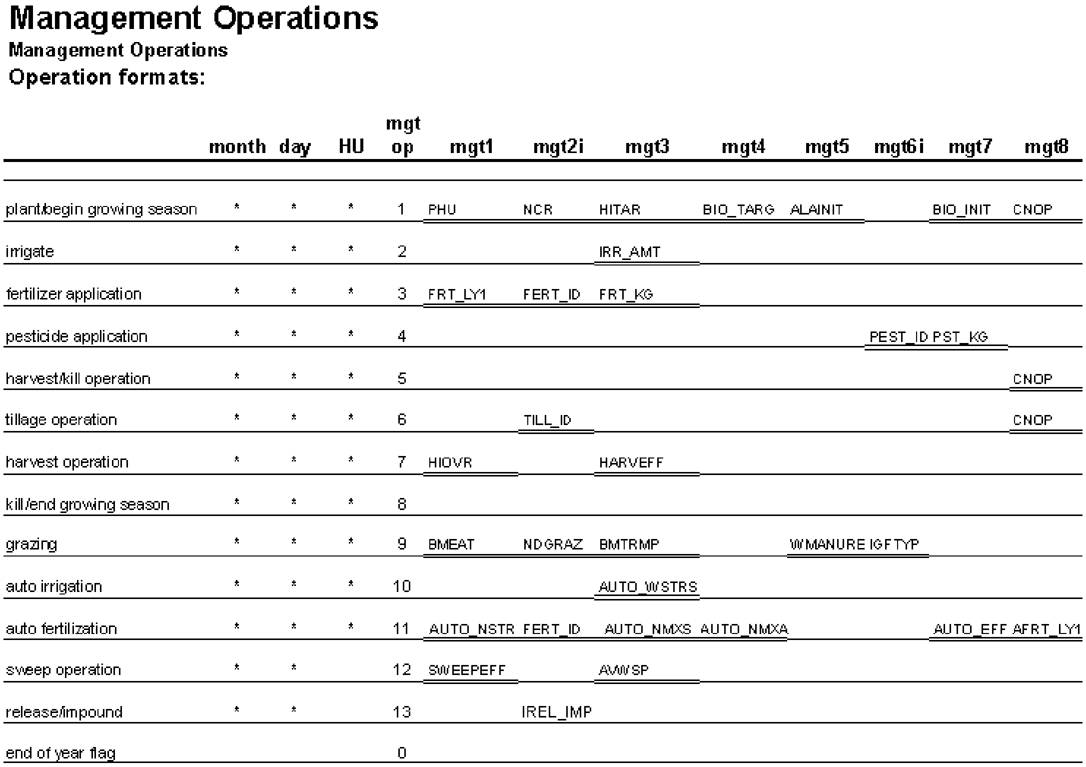
10 **auto irrigation initialization:** this operation initializes auto irrigation within the HRU. Auto irrigation applies water whenever the plant experiences a user-specified level of water stress.

11 **auto fertilization initialization:** this operation initializes auto fertilization within the HRU. Auto fertilization applies nutrients whenever the plant experiences a user-specified level of nitrogen stress.

12 **street sweeping operation:** this operation removes sediment and nutrient build-up on impervious areas in the HRU. This operation can only be used when the urban build up/wash off routines are activated for the HRU.

13 **release/impound:** this operation releases/impounds water in HRUs growing rice or other plants

0 **end of year rotation flag:** this operation identifies the end of the operation scheduling for the year.



Management Operations

Management Operations

Operation formats:

	month	day	HU	mgt op	mgt1	mgt2i	mgt3	mgt4	mgt5	mgt6i	mgt7	mgt8
plant/begin growing season	*	*	*	1	PHU	NCR	HITAR	BIO_TARG	ALAINIT		BIO_INIT	CNOP
irrigate	*	*	*	2			IRR_AMT					
fertilizer application	*	*	*	3	FRT_LY1	FERT_ID	FRT_KG					
pesticide application	*	*	*	4						PEST_ID	PST_KG	
harvest/kill operation	*	*	*	5								CNOP
tillage operation	*	*	*	6		TILL_ID						CNOP
harvest operation	*	*	*	7	HIOVR		HARVEFF					
kill/end growing season	*	*	*	8								
grazing	*	*	*	9	BMEAT	NDGRAZ	BMTRMP		WMANURE	IGFTYP		
auto irrigation	*	*	*	10			AUTO_WSTRS					
auto fertilization	*	*	*	11	AUTO_NSTR	FERT_ID	AUTO_NMXS	AUTO_NMXA			AUTO_EFF	AFRT_LY1
sweep operation	*	*		12	SWEEPEFF		AVWSP					
release/impound	*	*		13		IREL_IMP						
end of year flag				0								

Figure 20-1: Management operations.

For each year of management operations provided, the operations must be listed in chronological order starting in January.

20.2.1 PLANTING/BEGINNING OF GROWING SEASON

The plant operation initiates plant growth. This operation can be used to designate the time of planting for agricultural crops or the initiation of plant growth in the spring for a land cover that requires several years to reach maturity (forests, orchards, etc.).

The plant operation will be performed by SWAT only when no land cover is growing in an HRU. Before planting a new land cover, the previous land cover must be removed with a kill operation or a harvest and kill operation. If two plant operations are placed in the management file and the first land cover is not killed prior to the second plant operation, the second plant operation is ignored by the model.

Information required in the plant operation includes the timing of the operation (month and day or fraction of base zero potential heat units), the total number of heat units required for the land cover to reach maturity, and the specific land cover to be simulated in the HRU. If the land cover is being transplanted, the leaf area index and biomass for the land cover at the time of transplanting must be provided. Also, for transplanted land covers, the total number of heat units for the land cover to reach maturity should be from the period the land cover is transplanted to maturity (not from seed generation). Heat units are reviewed in Chapter 17 of the Theoretical Documentation.

The user has the option of varying the curve number in the HRU throughout the year. New curve number values may be entered in a plant operation, tillage operation and harvest and kill operation. The curve number entered for these operations are for moisture condition II. SWAT adjusts the entered value daily to reflect change in water content.

For simulations where a certain amount of crop yield and biomass is required, the user can force the model to meet this amount by setting a harvest index target and a biomass target. These targets are effective only if a harvest and kill operation is used to harvest the crop.

The variables which may be entered on the planting line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 1 for planting/beginning of growing season
HEAT UNITS	Total heat units for cover/plant to reach maturity. Calculation of HEAT UNITS is reviewed in Chapter 17 of the SWAT 2000 Theoretical Documentation.
NCR	Land cover/plant identification number from plant growth database.
HITAR	Harvest index target ((kg/ha)/(kg/ha)). This variable along with BIO_TARG allow the user to specify the harvest index and biomass produced by the plant every year. The model will then simulate plant growth to meet these specified values. If you are studying the effect of management practices on yields or you want the biomass to vary in response to different weather conditions, you would not want to use HITAR or BIO_TARG. Optional.
BIO_TARG	Biomass (dry weight) target (metric tons/ha). This variable along with HITAR allow the user to specify the harvest index and biomass produced by the plant every year. The model will then simulate plant growth to meet these specified values. If you are studying the effect of management practices on yields or you want the biomass to vary in response to different weather conditions, you would not want to use HITAR or BIO_TARG. Optional.
ALAINIT	Initial leaf area index. This variable would be used only for covers/plants which are transplanted rather than established from seeds. Optional.

Variable name	Definition
BIO_INIT	Initial dry weight biomass (kg/ha). This variable would be used only for covers/plants that are transplanted rather than established from seeds. Optional.
CNOP	SCS runoff curve number for moisture condition II Please read discussion for CN2 in Section 20.1 General Management Variables for more information on this variable. Optional.

The format of the planting operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
HEAT UNITS	space 21-28	decimal (xxxx.xxx)	f8.3
NCR	space 29-32	4-digit integer	i4
HITAR	space 33-40	decimal (xxxx.xxx)	f8.3
BIO_TARG	space 41-48	decimal (xxxx.xxx)	f8.3
ALAINIT	space 49-56	decimal (xxxx.xxx)	f8.3
BIO_INIT	space 61-66	decimal (xx.xxx)	f6.3
CNOP	space 67-72	decimal (xx.xxx)	f6.3

20.2.2 IRRIGATION OPERATION

Water applied to an HRU is obtained from one of five types of water sources: a reach, a reservoir, a shallow aquifer, a deep aquifer, or a source outside the watershed. In addition to the type of water source, the model must know the location of the water source (unless the source is outside the watershed). For the reach, shallow aquifer or deep aquifer, SWAT needs to know the subbasin number in which the source is located. If a reservoir is used to supply water, SWAT must know the reservoir number.

If the source of the irrigation water is a reach, SWAT allows additional input parameters to be set. These parameters are used to prevent flow in the reach from being reduced to zero as a result of irrigation water removal. Users may define a minimum in-stream flow, a maximum irrigation water removal amount that cannot be exceeded on any given day, and/or a fraction of total flow in the reach that is available for removal on a given day.

For a given irrigation event, SWAT determines the amount of water available in the source. The amount of water available is compared to the amount of water specified in the irrigation operation. If the amount available is less than the amount specified, SWAT will only apply the available water.

Water applied to an HRU is used to fill the soil layers up to field capacity beginning with the soil surface layer and working downward until all the water applied is used up or the bottom of the profile is reached. If the amount of water specified in an irrigation operation exceeds the amount needed to fill the soil layers up to field capacity water content, the excess water is returned to the source. For HRUs that are defined as potholes or depressional areas, the irrigation water is added to the ponded water overlying the soil surface.

The variables which may be entered on the irrigation line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 2 for irrigation operation
IRR_AMT	Depth of irrigation water applied on HRU (mm).

The format of the irrigation operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
IRR_AMT	space 33-40	decimal (xxxx.xxx)	f8.3

20.2.3 FERTILIZER APPLICATION

The fertilizer operation applies fertilizer or manure to the soil.

Information required in the fertilizer operation includes the timing of the operation (month and day or fraction of plant potential heat units), the type of fertilizer/manure applied, the amount of fertilizer/manure applied, and the depth distribution of fertilizer application.

SWAT assumes surface runoff interacts with the top 10 mm of soil. Nutrients contained in this surface layer are available for transport to the main channel in surface runoff. The fertilizer operation allows the user to specify the fraction of fertilizer that is applied to the top 10 mm. The remainder of the fertilizer is added to the first soil layer defined in the HRU .sol file. The weight fraction of different types of nutrients and bacteria are defined for the fertilizer In the fertilizer database,.

The variables which may be entered on the fertilization line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 3 for fertilizer application
FRT_LY1	Fraction of fertilizer applied to top 10mm of soil. The remaining fraction is applied to the 1st soil layer below 10 mm. If FRT_LY1 is set to 0, the model applies 20% of the fertilizer to the top 10mm and the remainder to the 1st soil layer below 10mm.

Variable name	Definition
FERT_ID	Fertilizer identification number. This corresponds to the line number of the fertilizer in fert.dat. If no identification number is provided, the model assumes 28-10-10 is being applied.
FRT_KG	Amount of fertilizer applied to HRU (kg/ha).

The format of the fertilizer application line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
FRY_LY1	space 21-28	decimal (xxxx.xxx)	f8.3
FERT_ID	space 29-32	4-digit integer	i4
FRT_KG	space 33-40	decimal (xxxx.xxx)	f8.3

20.2.4 PESTICIDE APPLICATION

The pesticide operation applies pesticide to the HRU.

Information required in the pesticide operation includes the timing of the operation (month and day or fraction of plant potential heat units), the type of pesticide applied, and the amount of pesticide applied.

Field studies have shown that even on days with little or no wind, a portion of pesticide applied to the field is lost. The fraction of pesticide that reaches the foliage or soil surface is defined by the pesticide's application efficiency.

The variables which may be entered on the pesticide application line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 4 for pesticide application
PEST_ID	Pesticide identification code from pesticide database.
PST_KG	Amount of pesticide applied to HRU (kg/ha).

The format of the pesticide application line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
PEST_ID	space 57-60	4-digit integer	i4
PST_KG	space 61-66	decimal (xx.xxx)	f6.3

20.2.5 HARVEST AND KILL OPERATION

The harvest and kill operation stops plant growth in the HRU. The fraction of biomass specified in the land cover’s harvest index (in the plant growth database) is removed from the HRU as yield. The remaining fraction of plant biomass is converted to residue on the soil surface.

The only information required by the harvest and kill operation is the timing of the operation (month and day or fraction of plant potential heat units). The user also has the option of updating the moisture condition II curve number in this operation.

The variables which may be entered on the harvest and kill line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 5 for harvest and kill operation
CNOP	SCS runoff curve number for moisture condition II Please read discussion for CN2 in Section 20.1 General Management Variables for more information on this variable. Optional.

The format of the harvest and kill line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
CNOP	space 67-72	decimal (xx.xxx)	f6.3

20.2.6 TILLAGE OPERATION

The tillage operation redistributes residue, nutrients, pesticides and bacteria in the soil profile. Information required in the tillage operation includes the timing of the operation (month and day or fraction of base zero potential heat units), and the type of tillage operation.

The user has the option of varying the curve number in the HRU throughout the year. New curve number values may be entered in a plant operation, tillage operation and harvest and kill operation. The curve number entered for these operations are for moisture condition II. SWAT adjusts the entered value daily to reflect change in water content.

The variables which may be entered on the tillage line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 6 for tillage operation
TILLAGE_ID	Tillage implement code from tillage database.
CNOP	SCS runoff curve number for moisture condition II Please read discussion for CN2 in Section 20.1 General Management Variables for more information on this variable. Optional.

The format of the tillage operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
TILLAGE_ID	space 29-32	4-digit integer	i4
CNOP	space 67-72	decimal (xx.xxx)	f6.3

20.2.7 HARVEST OPERATION

The harvest operation will remove plant biomass without killing the plant. This operation is most commonly used to cut hay or grass.

The only information required by the harvest operation is the date. However, a harvest index override and a harvest efficiency can be set.

When no harvest index override is specified, SWAT uses the plant harvest index from the plant growth database to set the fraction of biomass removed. The plant harvest index in the plant growth database is set to the fraction of the plant biomass partitioned into seed for agricultural crops and a typical fraction of biomass removed in a cutting for hay. If the user prefers a different fraction of biomass to be removed, the harvest index override should be set to the desired value.

A harvest efficiency may also be defined for the operation. This value specifies the fraction of harvested plant biomass removed from the HRU. The remaining fraction is converted to residue on the soil surface. If the harvest efficiency is left blank or set to zero, the model assumes this feature is not being used and removes 100% of the harvested biomass (no biomass is converted to residue).

After biomass is removed in a harvest operation, the plant’s leaf area index and accumulated heat units are set back by the fraction of biomass removed. Reducing the number of accumulated heat units shifts the plant’s development to an earlier period in which growth is usually occurring at a faster rate.

The variables which may be entered on the harvest line are listed and described below

Variable name	**Definition**
MONTH	Month operation takes place.
DAY	Day operation takes place.

Variable name	Definition
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 7 for the harvest only operation
HIOVR	Harvest index override ((kg/ha)/(kg/ha)) This variable will force the ratio of yield to total aboveground biomass to the specified value. The harvest index in the plant growth database (crop.dat) assumes only the seed is being harvested. If biomass is cut and removed (for example, in hay cuttings), HIOVR must be used to specify the amount of biomass removed. Optional.
HARVEFF	Harvest efficiency. The harvest efficiency defines the fraction of yield biomass removed by the harvesting equipment. The remainder of the yield biomass is converted to residue and added to the residue pool in the top 10 mm of soil. If the harvest efficiency is not set or a 0.00 is entered, the model assumes the user wants to ignore harvest efficiency and sets the fraction to 1.00 so that the entire yield is removed from the HRU. Optional.

The format of the harvest operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
HIOVR	space 21-28	decimal (xxxx.xxx)	f8.3
HARVEFF	space 33-40	decimal (xxxx.xxx)	f8.3

20.2.8 KILL OPERATION

The kill operation stops plant growth in the HRU. All plant biomass is converted to residue.

The only information required by the kill operation is the timing of the operation (month and day or fraction of plant potential heat units).

The variables which may be entered on the kill line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 8 for kill operation

The format of the kill line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4

20.2.9 GRAZING OPERATION

The grazing operation simulates plant biomass removal and manure deposition over a specified period of time. This operation is used to simulate pasture or range grazed by animals.

Information required in the grazing operation includes the time during the year at which grazing begins (month and day or fraction of plant potential heat units), the length of the grazing period, the amount of biomass removed daily, the amount of manure deposited daily, and the type of manure deposited. The amount of biomass trampled is an optional input.

Biomass removal in the grazing operation is similar to that in the harvest operation. However, instead of a fraction of biomass being specified, an absolute amount to be removed every day is given. In some conditions, this can result in a reduction of the plant biomass to a very low level that will result in increased erosion in the HRU. To prevent this, a minimum plant biomass for grazing may be specified (BIO_MIN in the second line of the management file). When the plant biomass falls below the amount specified for BIO_MIN, the model will not graze, trample, or apply manure in the HRU on that day.

If the user specifies an amount of biomass to be removed daily by trampling, this biomass is converted to residue.

Nutrient fractions of the manure applied during grazing must be stored in the fertilizer database. The manure nutrient loadings are added to the topmost 10 mm of soil. This is the portion of the soil with which surface runoff interacts.

After biomass is removed by grazing and/or trampling, the plant's leaf area index and accumulated heat units are set back by the fraction of biomass removed.

The variables which may be entered on the grazing line are listed and described below

Variable name	Definition
MONTH	Month grazing begins.
DAY	Day grazing begins.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 9 for grazing operation
BMEAT	Dry weight of biomass consumed daily ((kg/ha)/day).
NDGRAZ	Number of consecutive days grazing takes place in the HRU.
BMTRMP	Dry weight of biomass trampled daily ((kg/ha)/day) Trampling becomes significant as the number of animals grazed per hectare increases. This is a very subjective value which is typically set equal to BMEAT, i.e. the animals trample as much as they eat. Optional.
WMANURE	Dry weight of manure deposited daily ((kg/ha)/day).
IGFTYP	Manure identification code from fertilizer database

The format of the grazing operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
BMEAT	space 21-28	decimal (xxxx.xxx)	f8.3
NDGRAZ	space 29-32	4-digit integer	i4
BMTRMP	space 33-40	decimal (xxxx.xxx)	f8.3
WMANURE	space 49-56	decimal (xxxx.xxx)	f8.3
IGFTYP	space 57-60	4-digit integer	i4

20.2.10 AUTO IRRIGATION INITIALIZATION

Rather than specifying fixed amounts and time for irrigation, the user can allow the model to apply water as needed by the plant.

The variables which may be entered on the auto irrigation line are listed and described below

Variable name	Definition
MONTH	Month auto irrigation is initialized.
DAY	Day auto irrigation is initialized.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 10 for auto irrigation initialization
AUTO_WSTR	Water stress factor of cover/plant that triggers irrigation. When the user selects auto-application of irrigation water in an HRU, a water stress threshold must be specified. The water stress threshold is a fraction of potential plant growth. Anytime actual plant growth falls below this threshold fraction due to water stress the model will automatically apply water to the HRU. If enough water is available from the irrigation source, the model will add water to the soil until it is at field capacity. This factor ranges from 0.0 to 1.0 where 0.0 indicates there is no growth of the plant due to water stress and 1.0 indicates there is no reduction of plant growth due to water stress. The water stress threshold is usually set somewhere between 0.90 and 0.95.

The format of the auto irrigation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
AUTO_WSTR	space 33-40	decimal (xxxx.xxx)	f8.3

20.2.11 AUTO FERTILIZATION INITIALIZATION

Fertilization in an HRU may be scheduled by the user or automatically applied by SWAT. When the user selects auto-application of fertilizer in an HRU, a nitrogen stress threshold must be specified. The nitrogen stress threshold is a fraction of potential plant growth. Anytime actual plant growth falls below this threshold fraction due to nitrogen stress, the model will automatically apply fertilizer to the HRU. The user specifies the type of fertilizer, the fraction of total fertilizer applied to the soil surface, the maximum amount of fertilizer that can be applied during the year, the maximum amount of fertilizer that can be applied in any one application, and the application efficiency.

The variables which may be entered on the auto fertilization line are listed and described below.

Variable name	**Definition**
MONTH	Month initialization takes place.
DAY	Day initialization takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 11 for auto fertilization initialization
AUTO_NSTR	Nitrogen stress factor of cover/plant that triggers fertilization. The nitrogen stress factor is calculated by dividing the growth of the plant undergoing nitrogen stress by the growth of the plant if there was no nitrogen stress. This factor ranges from 0.0 to 1.0 where 0.0 indicates there is no growth of the plant due to nitrogen stress and 1.0 indicates there is no reduction of plant growth due to nitrogen stress. The nitrogen stress threshold is usually set somewhere between 0.90 and 0.95.

Variable name	Definition
FERT_ID	Fertilizer identification number. This corresponds to the number of the fertilizer in the fertilizer database. If this variable is left blank or set to zero, the model will apply the commercial fertilizer 28-10-10.
AUTO_NMXS	Maximum amount of mineral N allowed in any one application (kg N/ha). If this variable is left blank, the model will set AUTO_NMXS = 200.
AUTO_NMXA	Maximum amount of mineral N allowed to be applied in any one year (kg N/ha). If this variable is left blank, the model will set AUTO_NMXA = 300.
AUTO_EFF	Application efficiency. The amount of fertilizer applied in auto fertilization is based on the amount of nitrogen removed at harvest. If you set AUTO_EFF = 1.0, the model will apply enough fertilizer to replace the amount of nitrogen removed at harvest. If AUTO_EFF > 1.0, the model will apply fertilizer to meet harvest removal plus an extra amount to make up for nitrogen losses due to surface runoff/leaching. If AUTO_EFF < 1.0, the model will apply fertilizer at the specified fraction below the amount removed at harvest. If this variable is left blank, the model will set AUTO_EFF = 1.3.
AFRT_LY1	Fraction of fertilizer applied to top 10mm of soil. The remaining fraction is applied to the 1st soil layer below 10mm. If this variable is left blank, the model will set AFRT_LY1 = 0.2.

The format of the auto fertilization line is

Variable name	**Position**	**Format**	**F90 Format**
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
AUTO_NSTR	space 21-28	decimal (xxxx.xxx)	f8.3
FERT_ID	space 29-32	4-digit integer	i4
AUTO_NMXS	space 33-40	decimal (xxxx.xxx)	f8.3
AUTO_NMXA	space 41-48	decimal (xxxx.xxx)	f8.3
AUTO_EFF	space 61-66	decimal (xx.xxx)	f6.3
AFRT_LY1	space 67-72	decimal (xx.xxx)	f6.3

20.2.12 STREET SWEEPING OPERATION

Street cleaning is performed in urban areas to control buildup of solids and trash. While it has long been thought that street cleaning has a beneficial effect on the quality of urban runoff, studies by EPA have found that street sweeping has little impact on runoff quality unless it is performed every day (U.S. Environmental Protection Agency, 1983).

SWAT performs street sweeping operations only when the build up/wash off algorithm is specified for urban loading calculations. Street sweeping is performed only on dry days, where a dry day is defined as a day with less than 0.1 mm of surface runoff.

The variables which may be entered on the street sweeping line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 12 for street sweeping
SWEEPEFF	Removal efficiency of sweeping operation. The removal efficiency of street sweeping is a function of the type of sweeper, whether flushing is a part of the street cleaning process, the quantity of total solids, the frequency of rainfall events and the constituents considered. Removal efficiency can vary depending on the constituent being considered, with efficiencies being greater for particulate constituents. The removal efficiencies for nitrogen and phosphorus are typically less than the solid removal efficiency (Pitt, 1979).

Variable name	**Definition**
SWEEPEFF, cont.	Because SWAT assumes a set concentration of nutrient constituents in the solids, the same removal efficiency is in effect used for all constituents. Table 20-7 provides removal efficiencies for various street cleaning programs. SWEEPEFF is a fraction that ranges between 0.0 and 1.0. A value of 0.0 indicates that none of the built-up sediments are removed while a value of 1.0 indicates that all of the built-up sediments are removed.

Table 20-7: Removal efficiencies (fraction removed) from street cleaner path (from Pitt, 1979)

Street Cleaning Program and Street Surface Loading Conditions	**Total Solids**	**BOD$_5$**	**COD**	**KN**	**PO$_4$**	**Pesticides**
Vacuum Street Cleaner *(5.5-55 kg/curb km)*						
1 pass	.31	.24	.16	.26	.08	.33
2 passes	.45	.35	.22	.37	.12	.50
3 passes	.53	.41	.27	.45	.14	.59
Vacuum Street Cleaner *(55-280 kg/curb km)*						
1 pass	.37	.29	.21	.31	.12	.40
2 passes	.51	.42	.29	.46	.17	.59
3 passes	.58	.47	.35	.51	.20	.67
Vacuum Street Cleaner *(280-2820 kg/curb km)*						
1 pass	.48	.38	.33	.43	.20	.57
2 passes	.60	.50	.42	.54	.25	.72
3 passes	.63	.52	.44	.57	.26	.75
Mechanical Street Cleaner *(50-500 kg/curb km)*						
1 pass	.54	.40	.31	.40	.20	.40
2 passes	.75	.58	.48	.58	.35	.60
3 passes	.85	.69	.59	.69	.46	.72
Flusher	.30	*a*	*a*	*a*	*a*	*a*
Mechanical Street Cleaner followed by a Flusher	.80	*b*	*b*	*b*	*b*	*b*

a: efficiency fraction estimated .15 to .40
b: efficiency fraction estimated .35 to 1.00

Variable name	Definition
AVWSP	Fraction of curb length available for sweeping. The availability factor, fr_{av}, is the fraction of the curb length that is sweepable. The entire curb length is often not available for sweeping due to the presence of cars and other obstacles. AVWSP can range from 0.01 to 1.00. If no value is entered for AVWSP (AVWSP left blank or set to 0.0, the model will assume 100% of the curb length is available for sweeping.

The format of the street sweeping line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
SWEEPEFF	space 21-28	decimal (xxxx.xxx)	f8.3
AVWSP	space 33-40	decimal (xxxx.xxx)	f8.3

20.2.13 RELEASE/IMPOUND OPERATION

In areas of low relief and/or young geologic development, the drainage network may be poorly developed. Watersheds in these areas may have many closed depressional areas, referred to as potholes. Runoff generated within these areas flows to the lowest portion of the pothole rather than contributing to flow in the main channel. Other systems that are hydrologically similar to potholes include playa lakes and fields that are artifically impounded for rice production. The algorithms reviewed in this section are used to model these types of systems.

To define an HRU as a pothole, the user must set IPOT (.hru) to the HRU number. To initiate water impoundment, a release/impound operation must be placed in the .mgt file. The release/impound operation can be used only in the HRU designated as a depressional/impounded area in the subbasin (IPOT in .hru).

The variables which may be entered on the release/impound line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 17 of the SWAT 2000 Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value.
MGT_OP	Management operation number. MGT_OP = 13 for release/impoundment of water
IREL_IMP	Release/impound action code: 0 initiate water impoundment 1 initiate water release

The format of the release/impound line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
IREL_IMP	space 29-32	4-digit integer	i4

20.2.14 END OF YEAR OPERATION

SWAT requires a blank line to be inserted after all operations for a single year are listed. The blank line lets the model know that there will be no more operations in the year.

If a rotation is being simulated in which the land is left fallow for one of the years with no operations occurring, a blank line should be entered for the fallow year.

REFERENCES

Pitt, R. 1979. Demonstration of non-point pollution abatement through improved street cleaning practices. EPA-600/2-79-161 (NTIS PB80-108988), U.S. Environmental Protection Agency, Cincinnati, OH.

Soil Conservation Service Engineering Division. 1986. Urban hydrology for small watersheds. U.S. Department of Agriculture, Technical Release 55.

U.S. Environmental Protection Agency. 1983. Results of the nationwide urban runoff program; Volume 1 final report. NTIS PB84-185552, U.S. Environmental Protection Agency, Washington, D.C.

Wischmeier, W.H., and D.D. Smith. 1978. Predicting rainfall losses: A guide to conservation planning. USDA Agricultural Handbook No. 537. U.S. Gov. Print. Office, Washington, D. C.

CHAPTER 21

SWAT INPUT DATA: .WUS

Consumptive water use is a management tool that removes water from the basin. This file is used to simulate removal of water for irrigation outside the watershed or removal of water for urban/industrial use. Water removed for consumptive use is considered to be lost from the system. SWAT allows water to be removed from the shallow aquifer, the deep aquifer, the reach or the pond within any subbasin in the watershed. Water also may be removed from reservoirs for consumptive use.

Consumptive water use is allowed to vary from month to month. For each month in the year, an average daily volume of water removed from the source is specified.

Following is a brief description of the variables in the water use input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first three lines of the .wus file are reserved for user comments. The comments may take up to 80 spaces on each line. The title lines are not processed by the model and may be left blank.
WUPND(mon)	Average daily water removal from the pond for the month (10^4 m^3/day). Optional.
WURCH(mon)	Average daily water removal from the reach for the month (10^4 m^3/day). Optional.
WUSHAL(mon)	Average daily water removal from the shallow aquifer for the month (10^4 m^3/day). Optional.
WUDEEP(mon)	Average daily water removal from the deep aquifer for the month (10^4 m^3/day). Optional.

The format of the water use file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1-3	space 1-80	character	a80
WUPND(1)	4	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUPND(2)	4	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUPND(3)	4	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUPND(4:)	4	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUPND(5)	4	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUPND(6)	4	space 51-60	decimal (xxxxxxxx.x)	f10.1

Variable name	Line #	Position	Format	F90 Format
WUPND(7)	5	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUPND(8)	5	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUPND(9)	5	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUPND(10)	5	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUPND(11)	5	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUPND(12)	5	space 51-60	decimal (xxxxxxxx.x)	f10.1
WURCH(1)	6	space 1-10	decimal (xxxxxxxx.x)	f10.1
WURCH(2)	6	space 11-20	decimal (xxxxxxxx.x)	f10.1
WURCH(3)	6	space 21-30	decimal (xxxxxxxx.x)	f10.1
WURCH(4)	6	space 31-40	decimal (xxxxxxxx.x)	f10.1
WURCH(5)	6	space 41-50	decimal (xxxxxxxx.x)	f10.1
WURCH(6)	6	space 51-60	decimal (xxxxxxxx.x)	f10.1
WURCH(7)	7	space 1-10	decimal (xxxxxxxx.x)	f10.1
WURCH(8)	7	space 11-20	decimal (xxxxxxxx.x)	f10.1
WURCH(9)	7	space 21-30	decimal (xxxxxxxx.x)	f10.1
WURCH(10)	7	space 31-40	decimal (xxxxxxxx.x)	f10.1
WURCH(11)	7	space 41-50	decimal (xxxxxxxx.x)	f10.1
WURCH(12)	7	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUSHAL(1)	8	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUSHAL(2)	8	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUSHAL(3)	8	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUSHAL(4)	8	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUSHAL(5)	8	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUSHAL(6)	8	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUSHAL(7)	9	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUSHAL(8)	9	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUSHAL(9)	9	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUSHAL(10)	9	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUSHAL(11)	9	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUSHAL(12)	9	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUDEEP(1)	10	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUDEEP(2)	10	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUDEEP(3)	10	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUDEEP(4)	10	space 31-40	decimal (xxxxxxxx.x)	f10.1

Variable name	Line #	Position	Format	F90 Format
WUDEEP(5)	10	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUDEEP(6)	10	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUDEEP(7)	11	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUDEEP(8)	11	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUDEEP(9)	11	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUDEEP(10)	11	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUDEEP(11)	11	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUDEEP(12)	11	space 51-60	decimal (xxxxxxxx.x)	f10.1

CHAPTER 22

SWAT INPUT DATA: .SOL

The soils data used by SWAT can be divided into two groups, physical characteristics and chemical characteristics. The physical properties of the soil govern the movement of water and air through the profile and have a major impact on the cycling of water within the HRU. Inputs for chemical characteristics are used to set initial levels of the different chemicals in the soil. While the physical properties are required, information on chemical properties is optional. The soil input (.sol) file defines the physical properties for all layers in the soil.

Following is a brief description of the variables in the soil input file. They are listed in the order they appear within the file. The soil input file will hold data for up to 10 layers.

Variable name	**Definition**
TITLE/TEXT	The first line of the .sol file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
SNAM	Soil name. The soil name is printed in HRU summary tables.
HYDGRP	Soil hydrologic group (A, B, C, or D) This variable is required only by the SWAT ArcView interface. The U.S. Natural Resource Conservation Service (NRCS) classifies soils into four hydrologic groups based on infiltration characteristics of the soils. NRCS Soil Survey Staff (1996) defines a hydrologic group as a group of soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that impact the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to seasonally high water table, saturated hydraulic conductivity, and depth to a very slowly permeable layer. The definitions for the different classes are: A Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of sands or gravel that are deep and well to excessively drained. These soils have a high rate of water transmission (low runoff potential). B Soils having moderate infiltration rates when thoroughly wetted, chiefly moderately deep to deep, moderately well to well drained, with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission. C Soils having slow infiltration rates when thoroughly wetted, chiefly with a layer that impedes the downward movement of water or of moderately fine to fine texture and a slow infiltration rate. These soils have a slow rate of water transmission (high runoff potential).

Variable name	Definition
HYDGRP, cont.	D Soils having very slow infiltration rates when thoroughly wetted, chiefly clay soils with a high swelling potential; soils with a high permanent water table; soils with a clay pan or clay layer at or near the surface; and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission. Guidelines used by USDA Soil Survey to categorize soils into Hydrologic Groups are summarized in Table 22-1.

Table 22-1: Hydrologic Group Rating Criteria

	Hydrologic Soil Groups			
Criteria[*]	**A**	**B**	**C**	**D**
Final constant infiltration rate (mm/hr)	7.6-11.4	3.8-7.6	1.3-3.8	0-1.3
Mean permeability: surface layer (mm/hr)	> 254.0	84.0-254.0	8.4-84.0	< 8.4
Mean permeability: most restrictive layer below the surface layer to a depth of 1.0 m (mm/hr)	> 254.0	84.0-254.0	8.4-84.0	< 8.4
Shrink-swell potential: most restrictive layer[**]	Low	Low	Moderate	High, Very High
Depth to bedrock or cemented pan (mm)	> 1016	> 508	> 508	< 508
DUAL HYDROLOGIC GROUPS	**A/D**	**B/D**	**C/D**	
Mean depth to water table (m)	< 0.61	< 0.61	< 0.61	

[*] These criteria are guidelines only. They are based on the theory that the minimum permeability occurs within the uppermost 50 cm. If the minimum permeability occurs between a depth of 50 to 100 cm, then the Hydrologic Soil Group is increased one group. For example, C to B. If the minimum permeability occurs below a depth of 100 cm, the Hydrologic Soil Group is based on the permeability above 100 cm, using the rules previously given.

[**] Shrink-swell potential is assigned to a profile using the following guidelines:

Low: All soils with sand, loamy sand, sandy loam, loam or silt loam horizons that are at least 50 cm thick from the surface without a clay horizon within 100 cm of the surface.

Medium: All soils with clay loam horizons within 50 cm of the surface or soils with clay horizons from 50 to 100 cm beneath the surface.

High: All soils with clay horizons within 50 cm of the surface. Lower the shrink-swell potential one class when kaolinite clay is dominant.

Variable name	Definition
SOL_ZMX	Maximum rooting depth of soil profile (mm). If no depth is specified, the model assumes the roots can develop throughout the entire depth of the soil profile.

Variable name	Definition
ANION_EXCL	Fraction of porosity (void space) from which anions are excluded. Most soil minerals are negatively charged at normal pH and the net interaction with anions such as nitrate is a repulsion from particle surfaces. This repulsion is termed negative adsorption or anion exclusion. Anions are excluded from the area immediately adjacent to mineral surfaces due to preferential attraction of cations to these sites. This process has a direct impact on the transport of anions through the soil for it effectively excludes anions from the slowest moving portion of the soil water volume found closest to the charged particle surfaces (Jury et al, 1991). In effect, the net pathway of the anion through the soil is shorter than it would be if all the soil water had to be used (Thomas and McMahon, 1972). If no value for ANION_EXCL is entered, the model will set ANION_EXCL = 0.50
SOL_CRK	Potential or maximum crack volume of the soil profile expressed as a fraction of the total soil volume. To accurately predict surface runoff and infiltration in areas dominated by Vertisols, the temporal change in soil volume must be quantified. Bronswijk (1989, 1990) outlines methods used to determine the maximum crack volume. Optional.
TEXTURE	Texture of soil layer. This data is not processed by the model and the line may be left blank.
SOL_Z(layer #)	Depth from soil surface to bottom of layer (mm).
SOL_BD(layer #)	Moist bulk density (Mg/m^3 or g/cm^3). The soil bulk density expresses the ratio of the mass of solid particles to the total volume of the soil, $\rho_b = M_S / V_T$. In moist bulk density determinations, the mass of the soil is the oven dry weight and the total volume of the soil is determined when the soil is at or near field capacity. Bulk density values should fall between 1.1 and 1.9 Mg/m^3.

Variable name	Definition
SOL_AWC(layer #)	Available water capacity of the soil layer (mm H_2O/mm soil).
	The plant available water, also referred to as the available water capacity, is calculated by subtracting the fraction of water present at permanent wilting point from that present at field capacity, $AWC = FC - WP$ where AWC is the plant available water content, FC is the water content at field capacity, and WP is the water content at permanent wilting point.
	Available water capacity is estimated by determining the amount of water released between in situ field capacity (the soil water content at soil matric potential of -0.033 MPa) and the permanent wilting point (the soil water content at soil matric potential of -1.5 MPa).
SOL_K(layer #)	Saturated hydraulic conductivity (mm/hr).
	The saturated hydraulic conductivity, K_{sat}, relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. K_{sat} is the reciprocal of the resistance of the soil matrix to water flow.
SOL_CBN(layer #)	Organic carbon content (% soil weight).
	When defining by soil weight, the soil is the portion of the sample that passes through a 2 mm sieve.
CLAY(layer #)	Clay content (% soil weight).
	The percent of soil particles which are < 0.002 mm in equivalent diameter.
SILT(layer #)	Silt content (% soil weight).
	The percentage of soil particles which have an equivalent diameter between 0.05 and 0.002 mm.
SAND(layer #)	Sand content (% soil weight).
	The percentage of soil particles which have a diameter between 2.0 and 0.05 mm.
ROCK(layer #)	Rock fragment content (% total weight).
	The percent of the sample which has a particle diameter > 2 mm, i.e. the percent of the sample which does not pass through a 2 mm sieve.

Variable name	Definition
SOL_ALB(layer #)	Moist soil albedo. The ratio of the amount of solar radiation reflected by a body to the amount incident upon it, expressed as a fraction. The value for albedo should be reported when the soil is at or near field capacity.
USLE_K(layer #)	USLE equation soil erodibility (K) factor (units: 0.013 (metric ton m^2 hr)/(m^3-metric ton cm)). Some soils erode more easily than others even when all other factors are the same. This difference is termed soil erodibility and is caused by the properties of the soil itself. Wischmeier and Smith (1978) define the soil erodibility factor as the soil loss rate per erosion index unit for a specified soil as measured on a unit plot. A unit plot is 22.1-m (72.6-ft) long, with a uniform length-wise slope of 9-percent, in continuous fallow, tilled up and down the slope. Continuous fallow is defined as land that has been tilled and kept free of vegetation for more than 2 years. The units for the USLE soil erodibility factor in MUSLE are numerically equivalent to the traditional English units of 0.01 (ton acre hr)/(acre ft-ton inch). Wischmeier and Smith (1978) noted that a soil type usually becomes less erodible with decrease in silt fraction, regardless of whether the corresponding increase is in the sand fraction or clay fraction. Direct measurement of the erodibility factor is time consuming and costly. Wischmeier et al. (1971) developed a general equation to calculate the soil erodibility factor when the silt and very fine sand content makes up less than 70% of the soil particle size distribution. $K_{USLE} = \frac{0.00021 \cdot M^{1.14} \cdot (12 - OM) + 3.25 \cdot (c_{soilstr} - 2) + 2.5 \cdot (c_{perm} - 3)}{100}$ where K_{USLE} is the soil erodibility factor, M is the particle-size parameter, OM is the percent organic matter (%), $c_{soilstr}$ is the soil structure code used in soil classification, and c_{perm} is the profile permeability class. The particle-size parameter, M, is calculated $M = (m_{silt} + m_{vfs}) \cdot (100 - m_c)$

Variable name	Definition
USLE_K, cont.	where m_{silt} is the percent silt content (0.002-0.05 mm diameter particles), m_{vfs} is the percent very fine sand content (0.05-0.10 mm diameter particles), and m_c is the percent clay content (< 0.002 mm diameter particles). The percent organic matter content, *OM,* of a layer can be calculated: $OM = 1.72 \cdot orgC$ where *orgC* is the percent organic carbon content of the layer (%). Soil structure refers to the aggregation of primary soil particles into compound particles which are separated from adjoining aggregates by surfaces of weakness. An individual natural soil aggregate is called a ped. Field description of soil structure notes the shape and arrangement of peds, the size of peds, and the distinctness and durability of visible peds. USDA Soil Survey terminology for structure consists of separate sets of terms defining each of these three qualities. Shape and arrangement of peds are designated as type of soil structure; size of peds as class; and degree of distinctness as grade. The soil-structure codes for the equation are defined by the type and class of soil structure present in the layer. There are four primary types of structure, several of which are further roken down into subtypes: -Platy, with particles arranged around a plane, generally horizontal -Prismlike, with particles arranged around a verticle line and bounded by relatively flat vertical surfaces Prismatic: without rounded upper ends Columnar: with rounded caps -Blocklike or polyhedral, with particles arranged around a point and bounded by flat or rounded surfaces which are casts of the molds formed by the faces of surrounding peds Angular Blocky: bounded by planes intersecting at relatively sharp angles Subangular Blocky: having mixed rounded and plane faces with vertices mostly rounded

Variable name **Definition**

USLE_K, cont.

-Spheroidal or polyhedral, with particles arranged around a point and bounded by curved or very irregular surfaces that are not accomodated to the adjoining aggregates

Granular: relatively non-porous
Crumb: very porous

The size criteria for the class will vary by type of structure and are summarized in Table 22-2.

Table 22-2: Size classes of soil structure

	Shape of structure			
Size Classes	**Platy**	**Prismatic and Columnar**	**Blocky**	**Granular**
Very fine	< 1 mm	< 10 mm	< 5 mm	< 1 mm
Fine	1-2 mm	10-20 mm	5-10 mm	1-2 mm
Medium	2-5 mm	20-50 mm	10-20 mm	2-5 mm
Coarse	5-10 mm	50-100 mm	20-50 mm	5-10 mm
Very coarse	> 10 mm	> 100 mm	> 50 mm	> 10 mm

The codes assigned to $c_{soilstr}$ are:

1 very fine granular
2 fine granular
3 medium or coarse granular
4 blocky, platy, prismlike or massive

Permeability is defined as the capacity of the soil to transmit water and air through the most restricted horizon (layer) when moist. The profile permeability classes are based on the lowest saturated hydraulic conductivity in the profile. The codes assigned to c_{perm} are:

1 rapid (> 150 mm/hr)
2 moderate to rapid (50-150 mm/hr)
3 moderate (15-50 mm/hr)
4 slow to moderate (5-15 mm/hr)
5 slow (1-5 mm/hr)
6 very slow (< 1 mm/hr)

Williams (1995) proposed an alternative equation:

$$K_{USLE} = f_{csand} \cdot f_{cl-si} \cdot f_{orgc} \cdot f_{hisand}$$

where f_{csand} is a factor that gives low soil erodibility factors for soils with high coarse-sand contents and high values for soils with little sand, f_{cl-si} is a factor that gives low soil erodibility factors for soils with high clay to silt ratios, f_{orgc} is a factor that reduces soil erodibility for soils with high organic carbon content, and f_{hisand} is a factor that

Variable name	Definition
USLE_K, cont.	reduces soil erodibility for soils with extremely high sand contents. The factors are calculated: $f_{csand} = \left(0.2 + 0.3 \cdot \exp\left[-0.256 \cdot m_s \cdot \left(1 - \frac{m_{silt}}{100}\right)\right]\right)$ $f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}}\right)^{0.3}$ $f_{orgc} = \left(1 - \frac{0.25 \cdot orgC}{orgC + \exp[3.72 - 2.95 \cdot orgC]}\right)$ $f_{hisand} = \left(1 - \frac{0.7 \cdot \left(1 - \frac{m_s}{100}\right)}{\left(1 - \frac{m_s}{100}\right) + \exp\left[-5.51 + 22.9 \cdot \left(1 - \frac{m_s}{100}\right)\right]}\right)$ where m_s is the percent sand content (0.05-2.00 mm diameter particles), m_{silt} is the percent silt content (0.002-0.05 mm diameter particles), m_c is the percent clay content (< 0.002 mm diameter particles), and $orgC$ is the percent organic carbon content of the layer (%).
SOL_EC(layer #)	Electrical conductivity (dS/m). *Not currently active*

The format of the soil input file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
SNAM	2	space 13-28	character	a16
HYDGRP	3	space 25	character	a1
SOL_ZMX	4	space 29-35	decimal(xxxxxxxxx.xx)	f12.2
ANION_EXCL	5	space 52-56	decimal(x.xxx)	f5.3
SOL_CRK	6	space 34-38	decimal(x.xxx)	f5.3
COMMENT LINE	7	space 1-147	character	a80
SOL_Z(1)	8	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(2)	8	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(3)	8	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(4)	8	space 64-75	decimal(xxxxxxxxx.xx)	f12.2

Variable name	Line #	Position	Format	F90 Format
SOL_Z(5)	8	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(6)	8	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(7)	8	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(8)	8	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(9)	8	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_Z(10)	8	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(1)	9	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(2)	9	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(3)	9	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(4)	9	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(5)	9	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(6)	9	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(7)	9	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(8)	9	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(9)	9	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_BD(10)	9	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(1)	10	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(2)	10	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(3)	10	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(4)	10	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(5)	10	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(6)	10	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(7)	10	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(8)	10	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(9)	10	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_AWC(10)	10	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(1)	11	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(2)	11	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(3)	11	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(4)	11	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(5)	11	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(6)	11	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(7)	11	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(8)	11	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_K(9)	11	space 124-135	decimal(xxxxxxxxx.xx)	f12.2

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
SOL_K(10)	11	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(1)	12	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(2)	12	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(3)	12	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(4)	12	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(5)	12	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(6)	12	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(7)	12	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(8)	12	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(9)	12	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_CBN(10)	12	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
CLAY(1)	13	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
CLAY(2)	13	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
CLAY(3)	13	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
CLAY(4)	13	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
CLAY(5)	13	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
CLAY(6)	13	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
CLAY(7)	13	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
CLAY(8)	13	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
CLAY(9)	13	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
CLAY(10)	13	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SILT(1)	14	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SILT(2)	14	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SILT(3)	14	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SILT(4)	14	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SILT(5)	14	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SILT(6)	14	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SILT(7)	14	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SILT(8)	14	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SILT(9)	14	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SILT(10)	14	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SAND(1)	15	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SAND(2)	15	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SAND(3)	15	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SAND(4)	15	space 64-75	decimal(xxxxxxxxx.xx)	f12.2

Variable name	Line #	Position	Format	F90 Format
SAND(5)	15	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SAND(6)	15	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SAND(7)	15	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SAND(8)	15	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SAND(9)	15	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SAND(10)	15	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
ROCK(1)	16	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
ROCK(2)	16	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
ROCK(3)	16	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
ROCK(4)	16	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
ROCK(5)	16	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
ROCK(6)	16	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
ROCK(7)	16	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
ROCK(8)	16	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
ROCK(9)	16	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
ROCK(10)	16	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(1)	17	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(2)	17	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(3)	17	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(4)	17	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(5)	17	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(6)	17	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(7)	17	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(8)	17	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(9)	17	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_ALB(10)	17	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(1)	18	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(2)	18	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(3)	18	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(4)	18	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(5)	18	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(6)	18	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(7)	18	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(8)	18	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
USLE_K(9)	18	space 124-135	decimal(xxxxxxxxx.xx)	f12.2

Variable name	Line #	Position	Format	F90 Format
USLE_K(10)	18	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(1)	19	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(2)	19	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(3)	19	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(4)	19	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(5)	19	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(6)	19	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(7)	19	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(8)	19	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(9)	19	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_EC(10)	19	space 136-147	decimal(xxxxxxxxx.xx)	f12.2

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CHAPTER 23

SWAT INPUT DATA: .CHM

The soils data used by SWAT can be divided into two groups, physical characteristics and chemical characteristics. Inputs for chemical characteristics are used to set initial levels of the different chemicals in the soil.

Following is a brief description of the variables in the soil chemical input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .chm file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
NUTRIENT TITLE	The second line of the .chm file is reserved for the nutrient data title. This line is not processed by the model and may be left blank.
SOIL LAYER	Number of soil layer. This line is not processed by the model and may be left blank.
SOL_NO3(layer #)	Initial NO_3 concentration in the soil layer (mg/kg). Users may define the amount of nitrate for all soil layers at the beginning of the simulation. If the user does not specify initial nitrate concentrations, SWAT will initialize levels of nitrate using the equations reviewed in Chapter 10 of the SWAT 2000 Theoretical Documentation. Optional.
SOL_ORGN(layer #)	Initial organic N concentration in the soil layer (mg/kg). Users may define the amount of organic nitrogen contained in humic substances for all soil layers at the beginning of the simulation. If the user does not specify initial nitrogen concentrations, SWAT will initialize levels of organic nitrogen using the equations reviewed in Chapter 10 of the SWAT 2000 Theoretical Documentation. Optional.
SOL_SOLP(layer #)	Initial soluble P concentration in soil layer (mg/kg). Users may define the amount of solution P for all soil layers at the beginning of the simulation. If the user does not specify initial solution P concentrations, SWAT will initialize the concentration to 5 mg P/kg soil in all soil layers. Optional.

Variable name	Definition
SOL_ORGP(layer #)	Initial organic P concentration in soil layer (mg/kg). Users may define the amount of organic phosphorus contained in humic substances for all soil layers at the beginning of the simulation. If the user does not specify initial organic P concentrations, SWAT will initialize levels of organic phosphorus using the equations reviewed in Chapter 11 of the SWAT 2000 Theoretical Documentation. Optional.
PESTICIDE TITLE	Lines 8-11 are reserved for the pesticide data titles. These lines are not processed by the model and may be left blank.
PESTNUM	Number of pesticide from pesticide database. Required if pesticide amounts are given.
PLTPST	Initial pesticide amount on foliage (kg/ha). Optional.
SOLPST	Initial pesticide amount in soil (mg/kg). The pesticide is assumed to be found at this concentration in all soil layers. Optional.
PSTENR	Enrichment ratio for pesticide in the soil. As surface runoff flows over the soil surface, part of the water’s energy is used to pick up and transport soil particles. The smaller particles weigh less and are more easily transported than coarser particles. When the particle size distribution of the transported sediment is compared to that of the soil surface layer, the sediment load to the main channel has a greater proportion of clay sized particles. In other words, the sediment load is enriched in clay particles. The sorbed phase of pesticide in the soil is attached primarily to colloidal (clay) particles, so the sediment load will also contain a greater proportion or concentration of pesticide than that found in the soil surface layer.

Variable name	**Definition**
PSTENR, cont.	The enrichment ratio is defined as the ratio of the concentration of sorbed pesticide transported with the sediment to the concentration in the soil surface layer. SWAT will calculate an enrichment ratio for each storm event, or allow the user to define a particular enrichment ratio for sorbed pesticide that is used for all storms during the simulation. To calculate the enrichment ratio, the value for PSTENR is set to zero. The default option is to allow the model to calculate the enrichment ratio

The format of the soil chemical input file is:

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
TITLE	1	space 1-80	character	a80
NUTRIENT TITLE	2	space 1-80	character	a80
SOIL LAYERS	3	space 1-80	character	a80
SOL_NO3(1)	4	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(2)	4	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(3)	4	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(4)	4	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(5)	4	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(6)	4	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(7)	4	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(8)	4	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(9)	4	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_NO3(10)	4	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(1)	5	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(2)	5	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(3)	5	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(4)	5	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(5)	5	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(6)	5	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(7)	5	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(8)	5	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(9)	5	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGN(10)	5	space 136-147	decimal(xxxxxxxxx.xx)	f12.2

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
SOL_SOLP(1)	6	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(2)	6	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(3)	6	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(4)	6	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(5)	6	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(6)	6	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(7)	6	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(8)	6	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(9)	6	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_SOLP(10)	6	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(1)	7	space 28-39	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(2)	7	space 40-51	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(3)	7	space 52-63	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(4)	7	space 64-75	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(5)	7	space 76-87	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(6)	7	space 88-99	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(7)	7	space 100-111	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(8)	7	space 112-123	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(9)	7	space 124-135	decimal(xxxxxxxxx.xx)	f12.2
SOL_ORGP(10)	7	space 136-147	decimal(xxxxxxxxx.xx)	f12.2
PESTICIDE TITLE	8-11	space 1-80	character	a80
PSTNUM	12-END		integer	free
PLTPST	12-END		real	free
SOLPST	12-END		real	free
PSTENR	12-END		real	free

CHAPTER 24

SWAT INPUT DATA: .GW

SWAT partitions groundwater into two aquifer systems: a shallow, unconfined aquifer which contributes return flow to streams within the watershed and a deep, confined aquifer which contributes return flow to streams outside the watershed. The properties governing water movement into and out of the aquifers are initialized in the groundwater input file.

Following is a brief description of the variables in the groundwater input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .gw file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
SHALLST	Initial depth of water in the shallow aquifer (mm H_2O).
DEEPST	Initial depth of water in the deep aquifer (mm H_2O). If no value for DEEPST is entered, the model sets DEEPST = 1000.0 mm.
GW_DELAY	Groundwater delay time (days). Water that moves past the lowest depth of the soil profile by percolation or bypass flow enters and flows through the vadose zone before becoming shallow aquifer recharge. The lag between the time that water exits the soil profile and enters the shallow aquifer will depend on the depth to the water table and the hydraulic properties of the geologic formations in the vadose and groundwater zones. The delay time, δ_{gw}, cannot be directly measured. It can be estimated by simulating aquifer recharge using different values for δ_{gw} and comparing the simulated variations in water table level with observed values. Johnson (1977) developed a simple program to iteratively test and statistically evaluate different delay times for a watershed. Sangrey et al. (1984) noted that monitoring wells in the same area had similar values for δ_{gw}, so once a delay time value for a geomorphic area is defined, similar delay times can be used in adjoining watersheds within the same geomorphic province.
ALPHA_BF	Baseflow alpha factor (days). The baseflow recession constant, α_{gw}, is a direct index of groundwater flow response to changes in recharge (Smedema and Rycroft, 1983). Values vary from 0.1-0.3 for land with slow response to recharge to 0.9-1.0 for land with a rapid response. Although the baseflow recession constant may be calculated, the best estimates are obtained by analyzing measured streamflow during periods of no recharge in the watershed.

Variable name	Definition
ALPHA_BF	It is common to find the baseflow days reported for a stream gage or watershed. This is the number of days for base flow recession to decline through one log cycle. When baseflow days are known, the alpha facter can be calculated: $\alpha_{gw} = \frac{1}{N} \cdot \ln\left[\frac{Q_{gw,N}}{Q_{gw,0}}\right] = \frac{1}{BFD} \cdot \ln[10] = \frac{2.3}{BFD}$ where α_{gw} is the baseflow recession constant, and *BFD* is the number of baseflow days for the watershed
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_2O). Groundwater flow to the reach is allowed only if the depth of water in the shallow aquifer is equal to or greater than GWQMN.
GW_REVAP	Groundwater "revap" coefficient. Water may move from the shallow aquifer into the overlying unsaturated zone. In periods when the material overlying the aquifer is dry, water in the capillary fringe that separates the saturated and unsaturated zones will evaporate and diffuse upward. As water is removed from the capillary fringe by evaporation, it is replaced by water from the underlying aquifer. Water may also be removed from the aquifer by deep-rooted plants which are able to uptake water directly from the aquifer. This process is significant in watersheds where the saturated zone is not very far below the surface or where deep-rooted plants are growing. Because the type of plant cover will affect the importance of revap in the water balance, the parameters governing revap can be varied by land use. As GW_REVAP approaches 0, movement of water from the shallow aquifer to the root zone is restricted. As GW_REVAP approaches 1, the rate of transfer from the shallow aquifer to the root zone approaches the rate of potential evapotranspiration. The value for GW_REVAP should be between 0.02 and 0.20.

Variable name	Definition
REVAPMN	Threshold depth of water in the shallow aquifer for "revap" or percolation to the deep aquifer to occur (mm H_2O). Movement of water from the shallow aquifer to the unsaturated zone or to the deep aquifer is allowed only if the volume of water in the shallow aquifer is equal to or greater than REVAPMN.
RCHRG_DP	Deep aquifer percolation fraction. The fraction of percolation from the root zone which recharges the deep aquifer. The value for RCHRG_DP should be between 0.0 and 1.0.
GWHT	Initial groundwater height (m). Steady-state groundwater flow and the height of the water table are linearly proportional. The equations used to calculate the change in groundwater height with change in flow are included in SWAT. However, the groundwater height is not currently printed out in any of the output files. *This variable is not active*.
GW_SPYLD	Specific yield of the shallow aquifer (m^3/m^3). Specific yield is defined as the ratio of the volume of water that drains by gravity to the total volume of rock. Specific yield is required to calculate groundwater height fluctuations. *This variable is not active*
GWNO3	Concentration of nitrate in groundwater contribution to streamflow from subbasin (mg N/L). Optional.
GWSOLP	Concentration of soluble phosphorus in groundwater contribution to streamflow from subbasin (mg P/L). Optional.

The groundwater file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
SHALLST	2	real	free
DEEPST	3	real	free
GW_DELAY	4	real	free
ALPHA_BF	5	real	free
GWQMN	6	real	free
GW_REVAP	7	real	free
REVAPMN	8	real	free
RCHRG_DP	9	real	free
GWHT	10	real	free
GW_SPYLD	11	real	free
GWNO3	12	real	free
GWSOLP	13	real	free

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CHAPTER 25

SWAT INPUT DATA: .RTE

In order to simulate the physical processes affecting the flow of water and transport of sediment in the channel network of the watershed, SWAT requires information on the physical characteristics of the main channel within each subbasin. The main channel input file (.rte) summarizes the physical characteristics of the channel which affect water flow and transport of sediment, nutrients and pesticides.

Following is a brief description of the variables in the main channel input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line of the .rte file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
CH_W(2)	Average width of main channel at top of bank (m).
CH_D	Depth of main channel from top of bank to bottom (m).
CH_S(2)	Average slope of main channel along the channel length (m/m).
CH_L(2)	Length of main channel (km).
CH_N(2)	Manning's "n" value for the main channel.

Table 25-1: Values of Manning's roughness coefficient, *n*, for channel flow (Chow, 1959).[1]

Characteristics of Channel	**Median**	**Range**
Excavated or dredged		
Earth, straight and uniform	0.025	0.016-0.033
Earth, winding and sluggish	0.035	0.023-0.050
Not maintained, weeds and brush	0.075	0.040-0.140
Natural streams		
Few trees, stones or brush	0.050	0.025-0.065
Heavy timber and brush	0.100	0.050-0.150

[1] Chow (1959) has a very extensive list of Manning's roughness coefficients. These values represent only a small portion of those he lists in his book.

CH_K(2)	Effective hydraulic conductivity in main channel alluvium (mm/hr).

Streams may be categorized by their relationship to the groundwater system. A stream located in a discharge area that receives groundwater flow is a gaining or effluent stream (Figure 25-1a). This type of stream is characterized by an increase in discharge downstream. A stream located in a recharge area is a losing or influent stream. This type of stream is characterized by a decrease in discharge downstream. A losing stream may be connected to (Figure 25-1b) or perched above (Figure 25-1c) the groundwater flow area. A stream that simultaneously receives and loses groundwater is a flow-through stream (Figure 25-1d).

Variable name **Definition**

CH_K(2), cont.

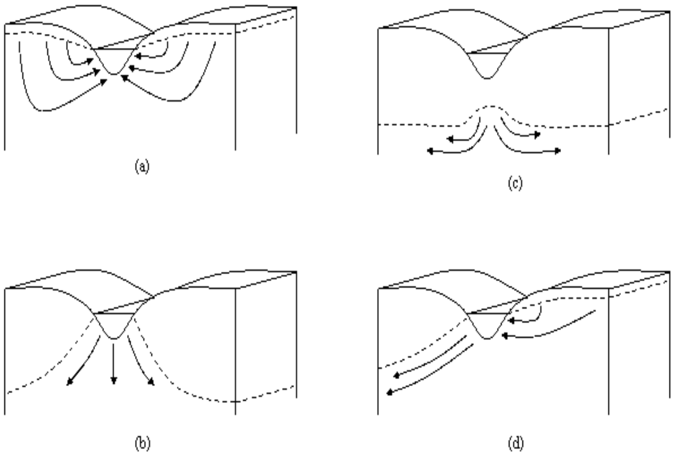

Figure 25-1: Stream-groundwater relationships: a) gaining stream receiving water from groundwater flow; b) losing stream connected to groundwater system; c) losing stream perched above groundwater system; and d) flow-through stream (After Dingman, 1994).

Typical values for K_{ch} for various alluvium materials are given in Table 25-2. For perennial streams with continuous groundwater contribution, the effective conductivity will be zero.

Table 25-2: Example hydraulic conductivity values for various bed materials (from Lane, 1983).

Bed material group	Bed material characteristics	Hydraulic conductivity
1 Very high loss rate	Very clean gravel and large sand	> 127 mm/hr
2 High loss rate	Clean sand and gravel, field conditions	51-127 mm/hr
3 Moderately high loss rate	Sand and gravel mixture with low silt-clay content	25-76 mm/hr
4 Moderate loss rate	Sand and gravel mixture with high silt-clay content	6-25 mm/hr
5 Insignificant to low loss rate	Consolidated bed material; high silt-clay content	0.025-2.5 mm/hr

Variable name	Definition
CH_EROD	Channel erodibility factor. The channel erodibility factor is conceptually similar to the soil erodibility factor used in the USLE equation. Channel erodibility is a function of properties of the bed or bank materials. Channel erodibility can be measured with a submerged vertical jet device. The basic premise of the test is that erosion of a vegetated or bare channel and local scour beneath an impinging jet are the result of hydraulic stresses, boundary geometry, and the properties of the material being eroded. Hanson (1990) developed a method for determining the erodibility coefficient of channels *in situ* with the submerged vertical jet. Allen et al. (1999) utilized this method to determine channel erodibility factors for thirty sites in Texas. A submerged, vertical jet of water directed perpendicularly at the channel bed causes erosion of the bed material in the vicinity of the jet impact area (Figure 25-2). Important variables in the erosion process are: the volume of material removed during a jetting event, elevation of the jet above the ground surface, diameter of the jet nozzle, jet velocity, time, mass density of the fluid and coefficient of erodibility.

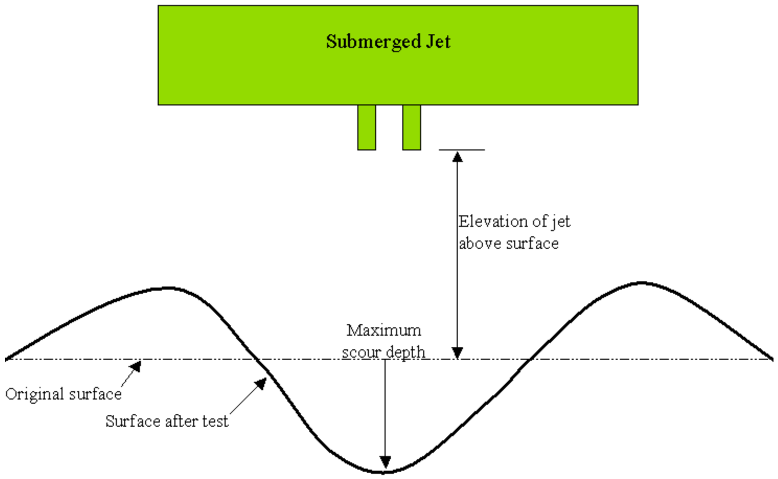

Figure 25-2: Simplified cross-section of submerged jet test (After Allen et al, 1999)

Variable name	**Definition**
CH_EROD, cont.	Hanson (1991) defined a jet index, J_i, to relate erodibility to scour created by the submerged jet. The jet index is a function of the depth of scour beneath the jet per unit time and the jet velocity. The jet index is determined by a least squares fit following the procedures outlined in ASTM standard D 5852-95.
	Once the jet index is determined, the channel erodibility coefficient is calculated:
	$K_{CH} = 0.003 \cdot \exp[385 \cdot J_i]$
	where K_{CH} is the channel erodibility coefficient (cm/h/Pa) and J_i is the jet index. In general, values for channel erodibility are an order of magnitude smaller than values for soil erodibility.
	CH_EROD is set to a value between 0.0 and 1.0. A value of 0.0 indicates a non-erosive channel while a value of 1.0 indicates no resistance to erosion.
CH_COV	Channel cover factor.
	The channel cover factor, C_{CH}, is defined as the ratio of degradation from a channel with a specified vegetative cover to the corresponding degradation from a channel with no vegetative cover. The vegetation affects degradation by reducing the stream velocity, and consequently its erosive power, near the bed surface.
	CH_COV is set to a value between 0.0 and 1.0. A value of 0.0 indicates that the channel is completely protected from degradation by cover while a value of 1.0 indicates there is no vegetative cover on the channel.
CH_WDR	Channel width-depth ratio (m/m).
	While sediment transport calculations have traditionally been made with the same channel dimensions throughout a simulation, SWAT will model channel downcutting and widening. When channel downcutting and widening is simulated, channel dimensions are allowed to change during the simulation period.
	Required only if channel degradation is being modeled (IDEG = 1 in .cod).

Variable name	**Definition**
ALPHA_BNK	Baseflow alpha factor for bank storage (days). Bank storage contributes flow to the main channel or reach within the subbasin. Bank flow is simulated with a recession curve similar to that used for groundwater.The baseflow alpha factor, or recession constant, characterizes the bank storage recession curve. This constant will be some number less than 1.0, and will be large (approach one) for flat recessions and small (approach zero) for steep recessions. If no value is entered for ALPHA_BNK, the variable will be set to the same value as ALPHA_BF from the groundwater (.gw) file.

The main channel file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the main channel input file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
CH_W(2)	2	real	free
CH_D	3	real	free
CH_S(2)	4	real	free
CH_L(2)	5	real	free
CH_N(2)	6	real	free
CH_K(2)	7	real	free
CH_EROD	8	real	free
CH_COV	9	real	free
CH_WDR	10	real	free
ALPHA_BNK	11	real	free

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CHAPTER 26

SWAT INPUT DATA: .WWQ

While water quality is a broad subject, the primary areas of concern are nutrients, organic chemicals—both agricultural (pesticide) and industrial, heavy metals, bacteria and sediment levels in streams and large water bodies. SWAT is able to model processes affecting nutrient, pesticide and sediment levels in the main channels and reservoirs. The data used by SWAT for in-stream water quality processes is contained in two files: the stream water quality input file (.swq) and the general water quality input file (.wwq).

Following is a brief description of the variables in the general water quality input file. The variables are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line is reserved for user comments. This line is not processed by the model and may be left blank.
LAO	Qual2E light averaging option. Qual2E defines four light averaging options. 1 Depth-averaged algal growth attenuation factor for light (FL) is computed from one daylight average solar radiation value calculated in the steady state temperature heat balance. 2 FL is computed from one daylight average solar radiation value supplied by the user. 3 FL is obtained by averaging the hourly daylight values of FL computed from the hourly daylight values of solar radiation calculated in the steady state temperature heat balance. 4 FL is obtained by averaging the hourly daylight values of FL computed from the hourly daylight values of solar radiation calculated from a single value of total daily, photosynthetically active, solar radiation and an assumed cosine function. The only option currently active in SWAT is 2.
IGROPT	Qual2E algal specific growth rate option. Qual2E provides three different options for computing the algal growth rate. 1 Multiplicative: the effects of nitrogen, phosphorus and light are multiplied together to calculate the net effect on the local algal growth rate 2 Limiting nutrient: the local algal growth rate is limited by light and one of the nutrients (nitrogen or phosphorus) 3 Harmonic mean: the local algal growth rate is limited by light and the harmonic mean of the nutrient interactions

Variable name	Definition
IGROPT, cont.	The multiplicative option multiplies the growth factors for light, nitrogen and phosphorus together to determine their net effect on the local algal growth rate. This option has its biological basis in the mutiplicative effects of enzymatic processes involved in photosynthesis. The limiting nutrient option calculates the local algal growth rate as limited by light and either nitrogen or phosphorus. The nutrient/light effects are multiplicative, but the nutrient/nutrient effects are alternate. The algal growth rate is controlled by the nutrient with the smaller growth limitation factor. This approach mimics Liebig's law of the minimum. The harmonic mean is mathematically analogous to the total resistance of two resistors in parallel and can be considered a compromise between the multiplicative and limiting nutrient options. The algal growth rate is controlled by a multiplicative relation between light and nutrients, while the nutrient/nutrient interactions are represented by a harmonic mean. The default option is the limiting nutrient option (2).
AI0	Ratio of chlorophyll-a to algal biomass (µg-chla/mg algae). Values for AI0 should fall in the range 10-100. If no value for AI0 is entered, the model will set AI0 = 50.0.
AI1	Fraction of algal biomass that is nitrogen (mg N/mg alg). Values for AI1 should fall in the range 0.07-0.09. If no value for AI1 is entered, the model will set AI1 = 0.08.
AI2	Fraction of algal biomass that is phosphorus (mg P/mg alg). Values for AI2 should fall in the range 0.01-0.02. If no value for AI2 is entered, the model will set AI2 = 0.015.
AI3	The rate of oxygen production per unit of algal photosynthesis (mg O_2/mg alg). Values for AI3 should fall in the range 1.4-1.8. If no value for AI3 is entered, the model will set AI3 = 1.6.
AI4	The rate of oxygen uptake per unit of algal respiration (mg O_2/mg alg). Values for AI4 should fall in the range 1.6-2.3. If no value for AI4 is entered, the model will set AI4 = 2.0.

Variable name	Definition
AI5	The rate of oxygen uptake per unit of NH_3-N oxidation (mg O_2/mg NH_3-N). Values for AI5 should fall in the range 3.0-4.0. If no value for AI5 is entered, the model will set AI5 = 3.5.
AI6	The rate of oxygen uptake per unit of NO_2-N oxidation (mg O_2/mg NO_2-N). Values for AI6 should fall in the range 1.00-1.14. If no value for AI6 is entered, the model will set AI6 = 1.07.
MUMAX	Maximum specific algal growth rate at 20º C (day^{-1}). Values for MUMAX should fall in the range 1.0-3.0. If no value for MUMAX is entered, the model will set MUMAX = 2.0.
RHOQ	Algal respiration rate at 20º C (day^{-1}). Values for RHOQ should fall in the range 0.05-0.50. If no value for RHOQ is entered, the model will set RHOQ = 0.30.
TFACT	Fraction of solar radiation computed in the temperature heat balance that is photosynthetically active. Values for TFACT should fall in the range 0.01-1.0. If no value for TFACT is entered, the model will set TFACT = 0.3.
K_L	Half-saturation coefficient for light (kJ/(m^2·min)). Values for K_L should fall in the range 0.2227-1.135. If no value for K_L is entered, the model will set K_L = 0.75.
K_N	Michaelis-Menton half-saturation constant for nitrogen (mg N/L). The Michaelis-Menton half-saturation constant for nitrogen and phosphorus define the concentration of N or P at which algal growth is limited to 50% of the maximum growth rate. Typical values for K_N range from 0.01 to 0.30 mg N/L. Values for K_N should fall in the range 0.01-0.30. If no value for K_N is entered, the model will set K_N = 0.02.

Variable name	Definition
K_P	Michaelis-Menton half-saturation constant for phosphorus (mg P/L). The Michaelis-Menton half-saturation constant for nitrogen and phosphorus define the concentration of N or P at which algal growth is limited to 50% of the maximum growth rate. Typical values for K_P will range from 0.001 to 0.05 mg P/L. If no value for K_P is entered, the model will set K_P = 0.025.
LAMBDA0	Non-algal portion of the light extinction coefficient (m^{-1}). The light extinction coefficient, k_ℓ, is calculated as a function of the algal density using the nonlinear equation: $k_\ell = k_{\ell,0} + k_{\ell,1} \cdot \alpha_0 \cdot algae + k_{\ell,2} \cdot (\alpha_0 \cdot algae)^{2/3}$ where $k_{\ell,0}$ is the non-algal portion of the light extinction coefficient (m^{-1}), $k_{\ell,1}$ is the linear algal self shading coefficient (m^{-1} (µg-chla/L)$^{-1}$), $k_{\ell,2}$ is the nonlinear algal self shading coefficient (m^{-1} (µg-chla/L)$^{-2/3}$), α_0 is the ratio of chlorophyll *a* to algal biomass (µg chla/mg alg), and *algae* is the algal biomass concentration (mg alg/L). This equation allows a variety of algal, self-shading, light extinction relationships to be modeled. When $k_{\ell,1} = k_{\ell,2} = 0$, no algal self-shading is simulated. When $k_{\ell,1} \neq 0$ and $k_{\ell,2} = 0$, linear algal self-shading is modeled. When $k_{\ell,1}$ and $k_{\ell,2}$ are set to a value other than 0, non-linear algal self-shading is modeled. The Riley equation (Bowie et al., 1985) defines $k_{\ell,1} = 0.0088 \text{ m}^{-1} \left(\mu\text{g - chla/L}\right)^{-1}$ and $k_{\ell,2} = 0.054 \text{ m}^{-1} \left(\mu\text{g - chla/L}\right)^{-2/3}$. If no value for LAMBDA0 is entered, the model will set LAMBDA0 = 1.0.
LAMBDA1	Linear algal self-shading coefficient (m^{-1}·(µg chla/L)$^{-1}$). See explanation for LAMBDA0 for more information on this variable. Values for LAMBDA1 should fall in the range 0.0065-0.065. If no value for LAMBDA1 is entered, the model will set LAMBDA1 = 0.03.

Variable name	**Definition**
LAMBDA2	Nonlinear algal self-shading coefficient ($m^{-1}\cdot(\mu g\ chla/L)^{-2/3}$). See explanation for LAMBDA0 for more information on this variable. The recommended value for LAMBDA2 is 0.0541. If no value for LAMBDA2 is entered, the model will set LAMBDA2 = 0.054.
P_N	Algal preference factor for ammonia. Values for P_N should fall in the range 0.01-1.0. If no value for P_N is entered, the model will set P_N = 0.5.

The watershed water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the general water quality input file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
LAO	2	integer	free
IGROPT	3	integer	free
AI0	4	real	free
AI1	5	real	free
AI2	6	real	free
AI3	7	real	free
AI4	8	real	free
AI5	9	real	free
AI6	10	real	free
MUMAX	11	real	free
RHOQ	12	real	free
TFACT	13	real	free
K_L	14	real	free
K_N	15	real	free
K_P	16	real	free
LAMBDA0	17	real	free

Variable name	Line #	Format	F90 Format
LAMBDA1	18	real	free
LAMBDA2	19	real	free
P_N	20	real	free

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CHAPTER 27

SWAT INPUT DATA: .SWQ

While water quality is a broad subject, the primary areas of concern are nutrients, organic chemicals—both agricultural (pesticide) and industrial, heavy metals, bacteria and sediment levels in streams and large water bodies. SWAT is able to model processes affecting nutrient, pesticide and sediment levels in the main channels and reservoirs. The data used by SWAT for in-stream water quality processes is contained in two files: the stream water quality input file (.swq) and the general water quality input file (.wwq).

Following is a brief description of the variables in the stream water quality input file. The variables are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line is reserved for user comments. This line is not processed by the model and may be left blank.
NUTRIENT TITLE	The second line is reserved for the nutrient section title. This line is not processed by the model and may be left blank.
RS1	Local algal settling rate in the reach at 20º C (m/day). Values for RS1 should fall in the range 0.15 to 1.82. If no value for RS1 is entered, the model sets RS1 = 1.0.
RS2	Benthic (sediment) source rate for dissolved phosphorus in the reach at 20º C (mg dissolved P/(m^2·day)). If no value for RS2 is entered, the model sets RS2 = 0.05.
RS3	Benthic source rate for NH_4-N in the reach at 20º C (mg NH_4-N/(m^2·day)). If no value for RS3 is entered, the model sets RS3 = 0.5.
RS4	Rate coefficient for organic N settling in the reach at 20º C (day^{-1}). Values for RS4 should fall in the range 0.001 to 0.10. If no value for RS4 is entered, the model sets RS4 = 0.05.
RS5	Organic phosphorus settling rate in the reach at 20º C (day^{-1}). Values for RS5 should fall in the range 0.001 to 0.1. If no value for RS5 is entered, the model sets RS5 = 0.05.
RS6	Rate coefficient for settling of arbitrary non-conservative constituent in the reach at 20º C (day^{-1}). If no value for RS6 is entered, the model sets RS6 = 2.5. *Not currently used by the model.*
RS7	Benthic source rate for arbitrary non-conservative constituent in the reach at 20º C (mg ANC/(m^2·day)). If no value for RS7 is entered, the model sets RS7 = 2.5. *Not currently used by the model.*

Variable name	Definition
RK1	Carbonaceous biological oxygen demand deoxygenation rate coefficient in the reach at 20º C (day^{-1}). Values for RK1 should fall in the range 0.02 to 3.4. If no value for RK1 is entered, the model sets RK1 = 1.71.
RK2	Oxygen reaeration rate in accordance with Fickian diffusion in the reach at 20º C (day^{-1}). Numerous methods have been developed to calculate the reaeration rate at 20°C, $\kappa_{2,20}$. A few of the methods are listed below. Brown and Barnwell (1987) provide additional methods. Using field measurements, Churchill, Elmore and Buckingham (1962) derived the relationship: $\kappa_{2,20} = 5.03 \cdot v_c^{0.969} \cdot depth^{-1.673}$ where $\kappa_{2,20}$ is the reaeration rate at 20°C (day^{-1}), v_c is the average stream velocity (m/s), and *depth* is the average stream depth (m). O'Connor and Dobbins (1958) incorporated stream turbulence characteristics into the equations they developed. For streams with low velocities and isotropic conditions, $\kappa_{2,20} = 294 \cdot \dfrac{\left(D_m \cdot v_c\right)^{0.5}}{depth^{1.5}}$ where $\kappa_{2,20}$ is the reaeration rate at 20°C (day^{-1}), D_m is the molecular diffusion coefficient (m^2/day), v_c is the average stream velocity (m/s), and *depth* is the average stream depth (m). For streams with high velocities and nonisotropic conditions, $\kappa_{2,20} = 2703 \cdot \dfrac{D_m^{0.5} \cdot slp^{0.25}}{depth^{1.25}}$ where $\kappa_{2,20}$ is the reaeration rate at 20°C (day^{-1}), D_m is the molecular diffusion coefficient (m^2/day), *slp* is the slope of the streambed (m/m), and *depth* is the average stream depth (m). The molecular diffusion coefficient is calculated $D_m = 177 \cdot 1.037^{\bar{T}_{water}-20}$

Variable name	Definition
RK2	where D_m is the molecular diffusion coefficient (m^2/day), and $\overline{T}_{water}$ is the average water temperature (°C). Owens et al. (1964) developed an equation to determine the reaeration rate for shallow, fast moving streams where the stream depth is 0.1 to 3.4 m and the velocity is 0.03 to 1.5 m/s. $\kappa_{2,20} = 5.34 \cdot \frac{v_c^{0.67}}{depth^{1.85}}$ where $\kappa_{2,20}$ is the reaeration rate at 20°C (day^{-1}), v_c is the average stream velocity (m/s), and *depth* is the average stream depth (m). Values for RK2 should fall in the range 0.01 to 100.0. If no value for RK2 is entered, the model sets RK2 = 50.0.
RK3	Rate of loss of carbonaceous biological oxygen demand due to settling in the reach at 20º C (day^{-1}). Values for RK3 should fall in the range -0.36 to 0.36. The recommended default for RK3 is 0.36 (not set by model).
RK4	Benthic oxygen demand rate in the reach at 20º C (mg O_2/(m^2·day)). If no value for RK4 is entered, the model sets RK4 = 2.0.
RK5	Coliform die-off rate in the reach at 20º C (day^{-1}). Values for RK5 should fall in the range 0.05 to 4.0. If no value for RK5 is entered, the model sets RK5 = 2.0. *Not currently used by the model*.
RK6	Decay rate for arbitrary non-conservative constituent in the reach at 20º C (day^{-1}). If no value for RK6 is entered, the model sets RK6 = 1.71. *Not currently used by the model*.
BC1	Rate constant for biological oxidation of NH_4 to NO_2 in the reach at 20º C in well-aerated conditions (day^{-1}). Values for BC1 should fall in the range 0.1 to 1.0. If no value for BC1 is entered, the model sets BC1 = 0.55.
BC2	Rate constant for biological oxidation of NO_2 to NO_3 in the reach at 20º C in well-aerated conditions (day^{-1}). Values for BC2 should fall in the range 0.2 to 2.0. If no value for BC2 is entered, the model sets BC2 = 1.1.

Variable name	Definition
BC3	Rate constant for hydrolysis of organic N to NH_4 in the reach at 20º C (day^{-1}). Values for BC3 should fall in the range 0.2 to 0.4. If no value for BC3 is entered, the model sets BC3 = 0.21.
BC4	Rate constant for mineralization of organic P to dissolved P in the reach at 20º C (day^{-1}). Values for BC4 should fall in the range 0.01 to 0.70. If no value for BC4 is entered, the model sets BC4 = 0.35.
PESTICIDE TITLE	This line is reserved for the pesticide section title. This line is not processed by the model and may be left blank.
CHPST_REA	Pesticide reaction coefficient in reach (day^{-1}). The rate constant is related to the aqueous half-life: $k_{p,aq} = \frac{0.693}{t_{1/2,aq}}$ where $k_{p,aq}$ is the rate constant for degradation or removal of pesticide in the water (1/day), and $t_{1/2,aq}$ is the aqueous half-life for the pesticide (days). If no value for CHPST_REA is entered, the model will set CHPST_REA = 0.007.
CHPST_VOL	Pesticide volatilization coefficient in reach (m/day). The volatilization mass-transfer coefficient can be calculated based on Whitman's two-film or two-resistance theory (Whitman, 1923; Lewis and Whitman, 1924 as described in Chapra, 1997). While the main body of the gas and liquid phases are assumed to be well-mixed and homogenous, the two-film theory assumes that a substance moving between the two phases encounters maximum resistance in two laminar boundary layers where transfer is a function of molecular diffusion. In this type of system the transfer coefficient or velocity is: $v_v = K_l \cdot \frac{H_e}{H_e + R \cdot T_K \cdot \left(K_l / K_g\right)}$ where v_v is the volatilization mass-transfer coefficient (m/day), K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), H_e is Henry's constant

Variable name	Definition
CHPST_VOL, cont.	(atm m^3 mole^{-1}), R is the universal gas constant (8.206 × 10^{-5} atm m^3 (K mole)$^{-1}$), and T_K is the temperature (K). For rivers where liquid flow is turbulent, the transfer coefficients are estimated using the surface renewal theory (Higbie, 1935; Danckwerts, 1951; as described by Chapra, 1997). The surface renewal model visualizes the system as consisting of parcels of water that are brought to the surface for a period of time. The fluid elements are assumed to reach and leave the air/water interface randomly, i.e. the exposure of the fluid elements to air is described by a statistical distribution. The transfer velocities for the liquid and gaseous phases are calculated: $K_l = \sqrt{r_l \cdot D_l} \qquad K_g = \sqrt{r_g \cdot D_g}$ where K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), D_l is the liquid molecular diffusion coefficient (m^2/day), D_g is the gas molecular diffusion coefficient (m^2/day), r_l is the liquid surface renewal rate (1/day), and r_g is the gaseous surface renewal rate (1/day). O'Connor and Dobbins (1956) defined the surface renewal rate as the ratio of the average stream velocity to depth. $r_l = \dfrac{86400 \cdot v_c}{depth}$ where r_l is the liquid surface renewal rate (1/day), v_c is the average stream velocity (m/s) and *depth* is the depth of flow (m). If no value for CHPST_VOL is entered, the model will set CHPST_VOL = 0.01.
CHPST_KOC	Pesticide partition coefficient between water and sediment in reach (m^3/g). The pesticide partition coefficient can be estimated from the octanol-water partition coefficient (Chapra, 1997): $K_d = 3.085 \times 10^{-8} \cdot K_{ow}$ where K_d is the pesticide partition coefficient (m^3/g) and K_{ow} is the pesticide's octanol-water partition coefficient ($\text{mg m}^{-3}_{\text{octanol}} \left(\text{mg m}^{-3}_{\text{water}}\right)^{-1}$).

Variable name	Definition
CHPST_KOC	Values for the octanol-water partition coefficient have been published for many chemicals. If a published value cannot be found, it can be estimated from solubility (Chapra, 1997): $\log\left(K_{ow}\right) = 5.00 - 0.670 \cdot \log\left(pst'_{sol}\right)$ where pst'_{sol} is the pesticide solubility (µmoles/L). The solubility in these units is calculated: $pst'_{sol} = \frac{pst_{sol}}{MW} \cdot 10^3$ where pst'_{sol} is the pesticide solubility (µmoles/L), pst_{sol} is the pesticide solubility (mg/L) and MW is the molecular weight (g/mole). If no value for CHPST_KOC is entered, the model will set CHPST_KOC = 0.
CHPST_STL	Settling velocity for pesticide sorbed to sediment (m/day). If no value for CHPST_STL is entered, the model will set CHPST_STL = 1.0.
CHPST_RSP	Resuspension velocity for pesticide sorbed to sediment (m/day). If no value for CHPST_RSP is entered, the model will set CHPST_RSP = 0.002.
CHPST_MIX	Mixing velocity (diffusion/dispersion) for pesticide in reach (m/day). The diffusive mixing velocity, v_d, can be estimated from the empirically derived formula (Chapra, 1997): $v_d = \frac{69.35}{365} \cdot \phi \cdot MW^{-2/3}$ where v_d is the rate of diffusion or mixing velocity (m/day), ϕ is the sediment porosity, and MW is the molecular weight of the pesticide compound. If no value for CHPST_MIX is entered, the model will set CHPST_MIX = 0.001.

Variable name	**Definition**
SEDPST_CONC	Initial pesticide concentration in reach bed sediment (mg/m^3 sediment).
SEDPST_REA	Pesticide reaction coefficient in reach bed sediment (day^{-1}). The rate constant is related to the sediment half-life: $k_{p,sed} = \frac{0.693}{t_{1/2,sed}}$ where $k_{p,sed}$ is the rate constant for degradation or removal of pesticide in the sediment (1/day), and $t_{1/2,sed}$ is the sediment half-life for the pesticide (days). If no value for SEDPST_REA is entered, the model will set SEDPST_REA = 0.05.
SEDPST_BRY	Pesticide burial velocity in reach bed sediment (m/day). If no value for SEDPST_BRY is entered, the model will set SEDPST_BRY = 0.002.
SEDPST_ACT	Depth of active sediment layer for pesticide (m). If no value for SEDPST_ACT is entered, the model will set SEDPST_ACT = 0.03.

The stream water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the stream water quality input file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
NUTRIENT TITLE	2	character	a80
NO DATA	3	real	free
NO DATA	4	real	free
NO DATA	5	real	free
NO DATA	6	real	free
NO DATA	7	real	free
NO DATA	8	real	free
NO DATA	9	real	free

Variable name	**Line #**	**Format**	**F90 Format**
NO DATA	10	real	free
QUAL2E TITLE LINE	11	real	free
RS1	12	real	free
RS2	13	real	free
RS3	14	real	free
RS4	15	real	free
RS5	16	real	free
RS6	17	real	free
RS7	18	real	free
RK1	19	real	free
RK2	20	real	free
RK3	21	real	free
RK4	22	real	free
RK5	23	real	free
RK6	24	real	free
BC1	25	real	free
BC2	26	real	free
BC3	27	real	free
BC4	28	real	free
PESTICIDE TITLE	29	character	a80
NO DATA	30	real	free
CHPST_REA	31	real	free
CHPST_VOL	32	real	free
CHPST_KOC	33	real	free
CHPST_STL	34	real	free
CHPST_RSP	35	real	free
CHPST_MIX	36	real	free
SEDPST_CONC	37	real	free
SEDPST_REA	38	real	free
SEDPST_BRY	39	real	free
SEDPST_ACT	40	real	free

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CHAPTER 28

SWAT INPUT DATA: .PND

Ponds and wetlands are impoundments located within the subbasin area. The .pnd file contains parameter information used to model the water, sediment and nutrient balance for ponds and wetlands.

Following is a brief description of the variables in the subbasin pond input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
POND SECTION TITLE	The second line of the file is reserved for a section title for the pond data. The title may take up to 80 spaces. The title line is not processed by the model and may be left blank.
PND_FR	Fraction of subbasin area that drains into ponds. The value for PND_FR should be between 0.0 and 1.0.
PND_PSA	Surface area of ponds when filled to principal spillway (ha).
PND_PVOL	Volume of water stored in ponds when filled to the principal spillway (10^4 m^3 H_2O).
PND_ESA	Surface area of ponds when filled to emergency spillway (ha).
PND_EVOL	Volume of water stored in ponds when filled to the emergency spillway (10^4 m^3 H_2O).
PND_VOL	Initial volume of water in ponds (10^4 m^3 H_2O).
PND_SED	Initial sediment concentration in pond water (mg/L).
PND_NSED	Equilibrium sediment concentration in pond water (mg/L).
PND_K	Hydraulic conductivity through bottom of ponds (mm/hr).
IFLOD1	Beginning month of non-flood season. Optional.
IFLOD2	Ending month of non-flood season. Optional.
NDTARG	Number of days needed to reach target storage from current pond storage. The default value for NDTARG is 15 days. Optional.
PSETL1	Phosphorus settling rate in pond for months IPND1 through IPND2 (m/year).

Variable name	Definition
PSETL1, cont.	The apparent settling velocity is most commonly reported in units of m/year and this is how the values are input to the model. For natural lakes, measured phosphorus settling velocities most frequently fall in the range of 5 to 20 m/year although values less than 1 m/year to over 200 m/year have been reported (Chapra, 1997). Panuska and Robertson (1999) noted that the range in apparent settling velocity values for man-made reservoirs tends to be significantly greater than for natural lakes. Higgins and Kim (1981) reported phosphorus apparent settling velocity values from –90 to 269 m/year for 18 reservoirs in Tennessee with a median value of 42.2 m/year. For 27 Midwestern reservoirs, Walker and Kiihner (1978) reported phosphorus apparent settling velocities ranging from –1 to 125 m/year with an average value of 12.7 m/year. ***A negative settling rate indicates that the reservoir sediments are a source of N or P; a positive settling rate indicates that the reservoir sediments are a sink for N or P***. Table 28-1 summarizes typical ranges in phosphorus settling velocity for different systems.

Table 28-1: Recommended apparent settling velocity values for phosphorus (Panuska and Robertson, 1999)

Nutrient Dynamics	Range in settling velocity values (m/year)
Shallow water bodies with high net internal phosphorus flux	$\nu \le 0$
Water bodies with moderate net internal phosphorus flux	$1 < \nu < 5$
Water bodies with minimal net internal phosphorus flux	$5 < \nu < 16$
Water bodies with high net internal phosphorus removal	$\nu > 16$

PSETL2	Phosphorus settling rate in pond for months other than IPND1-IPND2 (m/year). See explanation for PSETL1 for more information aout this variable.
NSETL1	Nitrogen settling rate in pond for months IPND1 through IPND2 (m/year). See explanation for PSETL1 for more information aout this variable.

Variable name	**Definition**
NSETL2	Nitrogen settling rate in pond for months other than IPND1-IPND2 (m/year). See explanation for PSETL1 for more information aout this variable.
CHLA	Chlorophyll *a* production coefficient for ponds. The user-defined coefficient, $Chla_{co}$, is included to allow the user to adjust the predicted chlorophyll *a* concentration for limitations of nutrients other than phosphorus. When $Chla_{co}$ is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for CHLA is 1.00, which uses the original equation.
SECCI	Water clarity coefficient for ponds. The clarity of the pond is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. The user-defined coefficient, SD_{co}, is included to allow the user to adjust the predicted secchi-disk depth for impacts of suspended sediment and other particulate matter on water clarity that are ignored by the original equation. When SD_{co} is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for SECCI is 1.00, which uses the original equation.
PND_NO3	Initial concentration of NO_3-N in pond (mg N/L).
PND_SOLP	Initial concentration of soluble P in pond (mg P/L).
PND_ORGN	Initial concentration of organic N in pond (mg N/L).
PND_ORGP	Initial concentration of organic P in pond (mg P/L).
COMMON VARIABLES SECTION TITLE	The 25th line of the file is reserved for a section title for data used for ponds and wetlands. The title may take up to 80 spaces. The title line is not processed by the model and may be left blank.
IPND1	Beginning month of mid-year nutrient settling “season”.
IPND2	Ending month of mid-year nutrient settling “season”.

Variable name	Definition
WETLAND SECTION TITLE	The 28th line of the file is reserved for a section title for the wetland data. The title may take up to 80 spaces. The title line is not processed by the model and may be left blank.
WET_FR	Fraction of subbasin area that drains into wetlands.
WET_NSA	Surface area of wetlands at normal water level (ha).
WET_NVOL	Volume of water stored in wetlands when filled to normal water level (10^4 m^3 H_2O).
WET_MXSA	Surface area of wetlands at maximum water level (ha).
WET_MXVOL	Volume of water stored in wetlands when filled to maximum water level (10^4 m^3 H_2O).
WET_VOL	Initial volume of water in wetlands (10^4 m^3 H_2O).
WET_SED	Initial sediment concentration in wetland water (mg/L).
WET_NSED	Equilibrium sediment concentration in wetland water (mg/L).
WET_K	Hydraulic conductivity of bottom of wetlands (mm/hr).
PSETLW1	Phosphorus settling rate in wetland for months IPND1 through IPND2 (m/year). See explanation for PSETL1 for more information aout this variable.
PSETLW2	Phosphorus settling rate in wetlands for months other than IPND1-IPND2 (m/year). See explanation for PSETL1 for more information aout this variable.
NSETLW1	Nitrogen settling rate in wetlands for months IPND1 through IPND2 (m/year). See explanation for PSETL1 for more information aout this variable.
NSETLW2	Nitrogen settling rate in wetlands for months other than IPND1-IPND2 (m/year). See explanation for PSETL1 for more information aout this variable.

Variable name	Definition
CHLAW	Chlorophyll *a* production coefficient for wetlands. The user-defined coefficient, $Chla_{co}$, is included to allow the user to adjust the predicted chlorophyll *a* concentration for limitations of nutrients other than phosphorus. When $Chla_{co}$ is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for CHLA is 1.00, which uses the original equation.
SECCIW	Water clarity coefficient for wetlands. The clarity of the wetland is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. The user-defined coefficient, SD_{co}, is included to allow the user to adjust the predicted secchi-disk depth for impacts of suspended sediment and other particulate matter on water clarity that are ignored by the original equation. When SD_{co} is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for SECCIW is 1.00, which uses the original equation.
WET_NO3	Initial concentration of NO_3-N in wetland (mg N/L).
WET_SOLP	Initial concentration of soluble P in wetland (mg P/L).
WET_ORGN	Initial concentration of organic N in wetland (mg N/L).
WET_ORGP	Initial concentration of organic P in wetland (mg P/L).

The pond input file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the pond input file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
POND SECT. TITLE	2	character	a80
PND_FR	3	real	free
PND_PSA	4	real	free
PND_PVOL	5	real	free
PND_ESA	6	real	free
PND_EVOL	7	real	free
PND_VOL	8	real	free
PND_SED	9	real	free
PND_NSED	10	real	free
PND_K	11	real	free
IFLOD1	12	integer	free
IFLOD2	13	integer	free
NDTARG	14	integer	free
PSETL1	15	real	free
PSETL2	16	real	free
NSETL1	17	real	free
NSETL2	18	real	free
CHLA	19	real	free
SECCI	20	real	free
PND_NO3	21	real	free
PND_SOLP	22	real	free
PND_ORGN	23	real	free
PND_ORGP	24	real	free
POND/WETLAND SECT. TITLE	25	character	a80
IPND1	26	integer	free
IPND2	27	integer	free
WETLAND SECT. TITLE	28	character	a80
WET_FR	29	real	free
WET_NSA	30	real	free

Variable name	Line #	Format	F90 Format
WET_NVOL	31	real	free
WET_MXSA	32	real	free
WET_MXVOL	33	real	free
WET_VOL	34	real	free
WET_SED	35	real	free
WET_NSED	36	real	free
WET_K	37	real	free
PSETLW1	38	real	free
PSETLW2	39	real	free
NSETLW1	40	real	free
NSETLW2	41	real	free
CHLAW	42	real	free
SECCIW	43	real	free
WET_NO3	44	real	free
WET_SOLP	45	real	free
WET_ORGN	46	real	free
WET_ORGP	47	real	free

REFERENCES

Chapra, S.C. 1997. Surface water-quality modeling. McGraw-Hill, Boston.

Higgins, J.M. and B.R. Kim. 1981. Phosphorus retention models for the Tennessee Valley Authority reservoirs. Wat. Resour. Res. 17:571-576.

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Walker, W.W. and J. Kiihner. 1978. An empirical analysis of factors controlling eutrophication in midwestern impoundments. Paper presented at the International Symposium on the Environmental Effects of Hydraulic Engineering Works, Univ. of Tenn., Knoxville.

CHAPTER 29

SWAT INPUT DATA: .RES

Reservoirs or lakes located on the main channel network of the watershed are modeled using input data stored in the reservoir input file (.res) and lake water quality file (.lwq).

29.1 RESERVOIR FILE

Following is a brief description of the variables in the reservoir input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the file is reserved for user comments. The comments may take up to 80 spaces. The title line is not processed by the model and may be left blank.
RES_SUB	Number of the subbasin with which the reservoir is associated. Weather for subbasin is used for the reservoir. If no subbasin number is assigned to RES_SUB, the model uses weather data from subbasin 1 to model climatic processes on the reservoir.
MORES	Month the reservoir became operational (0-12). If 0 is input for MORES and IYRES, the model assumes the reservoir is in operation at the beginning of the simulation.
IYRES	Year of the simulation the reservoir became operational (eg 1980). If 0 is input for MORES and IYRES, the model assumes the reservoir is in operation at the beginning of the simulation.
RES_ESA	Reservoir surface area when the reservoir is filled to the emergency spillway (ha)
RES_EVOL	Volume of water needed to fill the reservoir to the emergency spillway (10^4 m^3).
RES_PSA	Reservoir surface area when the reservoir is filled to the principal spillway (ha).
RES_PVOL	Volume of water needed to fill the reservoir to the principal spillway (10^4 m^3).
RES_VOL	Initial reservoir volume. If the reservoir is in existence at the beginning of the simulation period, the initial reservoir volume is the volume on the first day of simulation. If the reservoir begins operation in the midst of a SWAT simulation, the initial reservoir volume is the volume of the reservoir the day the reservoir becomes operational (10^4 m^3).

Variable name	Definition
RES_SED	Initial sediment concentration in the reservoir (mg/L).
RES_NSED	Equilibrium sediment concentration in the reservoir (mg/L).
RES_K	Hydraulic conductivity of the reservoir bottom (mm/hr).
IRESCO	Outflow simulation code: 0 compute outflow for uncontrolled reservoir with average annual release rate (if IRESCO=0, need RES_RR) 1 measured monthly outflow (if IRESCO=1, need RESOUT) 2 simulated controlled outflow—target release (if IRESCO=2, need STARG, IFLOD1R, IFLOD2D, and NDTARGR 3 measured daily outflow (if IRESCO=3, need RESDAYO)
OFLOWMX(mon)	Maximum daily outflow for the month (m^3/s). Set all months to zero if you do not want to trigger this requirement.
OFLOWMN(mon)	Minimum daily outflow for the month (m^3/s). Set all months to zero if you do not want to trigger this requirement.
RES_RR	Average daily principal spillway release rate (m^3/s). Required if IRESCO = 0.
RESMONO	Name of monthly reservoir outflow file. Required if IRESCO = 1.
IFLOD1R	Beginning month of non-flood season. Needed if IRESCO = 2.
IFLOD2R	Ending month of non-flood season. Needed if IRESCO = 2.
NDTARGR	Number of days to reach target storage from current reservoir storage. Needed if IRESCO = 2.
STARG(mon)	Monthly target reservoir storage (10^4 m^3). Needed if IRESCO = 2.

Variable name	**Definition**
RESDAYO	Name of daily reservoir outflow file. Required if IRESCO = 3.
WURESN(mon)	Average amount of water withdrawn from reservoir each day in the month for consumptive use (10^4 m^3). This variable allows water to be removed from the reservoir for use outside the watershed. Optional.
WURTNF	Fraction of water removed from the reservoir via WURESN that is returned and becomes flow out of reservoir (m^3/m^3). Optional.

The reservoir file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the reservoir input file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
RES_SUB	2	integer	free
MORES	3	integer	free
IYRES	4	integer	free
RES_ESA	5	real	free
RES_EVOL	6	real	free
RES_PSA	7	real	free
RES_PVOL	8	real	free
RES_VOL	9	real	free
RES_SED	10	real	free
RES_NSED	11	real	free
RES_K	12	real	free
IRESCO	13	integer	free
COMMENT LINE	14	character	a80
OFLOWMX(1)	15	real	free
OFLOWMX(2)	15	real	free
OFLOWMX(3)	15	real	free
OFLOWMX(4)	15	real	free

Variable name	Line #	Format	F90 Format
OFLOWMX(5)	15	real	free
OFLOWMX(6)	15	real	free
COMMENT LINE	16	character	a80
OFLOWMX(7)	17	real	free
OFLOWMX(8)	17	real	free
OFLOWMX(9)	17	real	free
OFLOWMX(10)	17	real	free
OFLOWMX(11)	17	real	free
OFLOWMX(12)	17	real	free
COMMENT LINE	18	character	a80
OFLOWMN(1)	19	real	free
OFLOWMN(2)	19	real	free
OFLOWMN(3)	19	real	free
OFLOWMN(4)	19	real	free
OFLOWMN(5)	19	real	free
OFLOWMN(6)	19	real	free
COMMENT LINE	20	character	a80
OFLOWMN(7)	21	real	free
OFLOWMN(8)	21	real	free
OFLOWMN(9)	21	real	free
OFLOWMN(10)	21	real	free
OFLOWMN(11)	21	real	free
OFLOWMN(12)	21	real	free
RES_RR	22	real	free
RESMONO	23	character (len=13)	a13
IFLOD1R	24	integer	free
IFLOD2R	25	integer	free
NDTARGR	26	integer	free
COMMENT LINE	27	character	a80
STARG(1)	28	real	free
STARG(2)	28	real	free
STARG(3)	28	real	free
STARG(4)	28	real	free
STARG(5)	28	real	free
STARG(6)	28	real	free

Variable name	Line #	Format	F90 Format
COMMENT LINE	29	character	a80
STARG(7)	30	real	free
STARG(8)	30	real	free
STARG(9)	30	real	free
STARG(10)	30	real	free
STARG(11)	30	real	free
STARG(12)	30	real	free
RESDAYO	31	character (len=13)	a13
COMMENT LINE	32	character	a80
WURESN(1)	33	real	free
WURESN(2)	33	real	free
WURESN(3)	33	real	free
WURESN(4)	33	real	free
WURESN(5)	33	real	free
WURESN(6)	33	real	free
COMMENT LINE	34	character	a80
WURESN(7)	35	real	free
WURESN(8)	35	real	free
WURESN(9)	35	real	free
WURESN(10)	35	real	free
WURESN(11)	35	real	free
WURESN(12)	35	real	free
WURTNF	36	real	free

29.2 DAILY RESERVOIR OUTFLOW FILE

When measured daily outflow is used for a reservoir, the name of the file containing the data is assigned to the variable RESDAYO. The daily outflow file contains the flow rate for every day of operation of the reservoir, beginning with the first day of operation in the simulation. The daily outflow file contains one variable:

Variable name	Definition
TITLE	The first line of the file is reserved for a description. The description may take up to 80 spaces. The title line is not processed by the model and may be left blank.
RES_OUTFLOW	The water release rate for the day (m^3/sec).

The format of the daily reservoir outflow file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
RES_OUTFLOW	2-END	space 1-8	decimal(xxxxx.xx)	f8.2

29.3 MONTHLY RESERVOIR OUTFLOW FILE

When outflow data summarized on a monthly basis is used for a reservoir, the name of the file containing the data is assigned to the variable RESMONO. The monthly outflow file contains the average daily flow rate for every month of operation of the reservoir, beginning with the first month of operation in the simulation. The monthly outflow file contains the following variables:

Variable name	Definition
TITLE	The first line of the file is reserved for a description. The description may take up to 80 spaces. The title line is not processed by the model and may be left blank.
RESOUT(mon,yr)	Measured average daily outflow from the reservoir for the month (m^3/s). Needed when IRESCO = 1. There must be a line of input for every year of simulation.

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80

If IRESCO = 1, the model will read the input data for RESOUT. There should be one line for data for RESOUT for each year of simulation beginning with the 1st year of simulation.

Variable name	Line #	Format	F90 Format
RESOUT(1,yr)	2-END	real	free
RESOUT(2,yr)	2-END	real	free
RESOUT(3,yr)	2-END	real	free
RESOUT(4,yr)	2-END	real	free
RESOUT(5,yr)	2-END	real	free
RESOUT(6,yr)	2-END	real	free
RESOUT(7,yr)	2-END	real	free
RESOUT(8,yr)	2-END	real	free
RESOUT(9,yr)	2-END	real	free
RESOUT(10,yr)	2-END	real	free
RESOUT(11,yr)	2-END	real	free
RESOUT(12,yr)	2-END	real	free

CHAPTER 30

SWAT INPUT DATA: .LWQ

While water quality is a broad subject, the primary areas of concern are nutrients, organic chemicals—both agricultural (pesticide) and industrial, heavy metals, bacteria and sediment levels in streams and large water bodies. SWAT is able to model processes affecting nutrient, pesticide and sediment levels in the main channels and reservoirs. The data used by SWAT for water quality in impoundments located on the main channel network is contained in the lake water quality input file (.lwq).

Following is a brief description of the variables in the lake water quality input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line is reserved for user comments. This line is not processed by the model and may be left blank.
NUTRIENT TITLE	The second line is reserved for the nutrient section title. This line is not processed by the model and may be left blank.
IRES1	Beginning month of mid-year nutrient settling period.
IRES2	Ending month of mid-year nutrient settling period.
PSETLR1	Phosphorus settling rate in reservoir for months IRES1 through IRES2 (m/year). The apparent settling velocity is most commonly reported in units of m/year and this is how the values are input to the model. For natural lakes, measured phosphorus settling velocities most frequently fall in the range of 5 to 20 m/year although values less than 1 m/year to over 200 m/year have been reported (Chapra, 1997). Panuska and Robertson (1999) noted that the range in apparent settling velocity values for man-made reservoirs tends to be significantly greater than for natural lakes. Higgins and Kim (1981) reported phosphorus apparent settling velocity values from –90 to 269 m/year for 18 reservoirs in Tennessee with a median value of 42.2 m/year. For 27 Midwestern reservoirs, Walker and Kiihner (1978) reported phosphorus apparent settling velocities ranging from –1 to 125 m/year with an average value of 12.7 m/year. ***A negative settling rate indicates that the reservoir sediments are a source of N or P; a positive settling rate indicates that the reservoir sediments are a sink for N or P*.** Table 30-1 summarizes typical ranges in phosphorus settling velocity for different systems.

Table 30-1: Recommended apparent settling velocity values for phosphorus (Panuska and Robertson, 1999)

Nutrient Dynamics	**Range in settling velocity values (m/year)**
Shallow water bodies with high net internal phosphorus flux	$\nu \leq 0$
Water bodies with moderate net internal phosphorus flux	$1 < \nu < 5$
Water bodies with minimal net internal phosphorus flux	$5 < \nu < 16$
Water bodies with high net internal phosphorus removal	$\nu > 16$

Variable name	**Definition**
PSETLR2	Phosphorus settling rate in reservoir for months other than IRES1-IRES2 (m/year). See explanation for PSETLR1 for more information about this parameter.
NSETLR1	Nitrogen settling rate in reservoir for months IRES1 through IRES2 (m/year). See explanation for PSETLR1 for more information about this parameter.
NSETLR2	Nitrogen settling rate in reservoir for months other than IRES1-IRES2 (m/year). See explanation for PSETLR1 for more information about this parameter.
CHLAR	Chlorophyll *a* production coefficient for reservoir. Chlorophyll *a* concentration in the reservoir is calculated from the total phosphorus concentration. The equation assumes the system is phosphorus limited. The chlorophyll *a* coefficient was added to the equation to allow the user to adjust results to account for other factors not taken into account by the basic equation such as nitrogen limitations. The default value for CHLA is 1.00, which uses the original equation.
SECCIR	Water clarity coefficient for the reservoir. The clarity of the reservoir is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. Because suspended sediment also can affect water clarity, the water clarity coefficient has been added to the equation to allow users to adjust for the impact of factors other than chlorophyll *a* on water clarity. The default value for SECCI is 1.00, which uses the original equation.
RES_ORGP	Initial concentration of organic P in reservoir (mg P/L).
RES_SOLP	Initial concentration of soluble P in reservoir (mg P/L).
RES_ORGN	Initial concentration of organic N in reservoir (mg N/L).
RES_NO3	Initial concentration of NO_3-N in reservoir (mg N/L).

Variable name	Definition
RES_NH3	Initial concentration of NH_3-N in reservoir (mg N/L).
RES_NO2	Initial concentration of NO_2-N in reservoir (mg N/L).
PESTICIDE TITLE	This line is reserved for the pesticide section title. This line is not processed by the model and may be left blank.
LKPST_CONC	Initial pesticide concentration in the reservoir water for the pesticide defined by IRTPEST (mg/m^3).
LKPST_REA	Reaction coefficient of the pesticide in reservoir water (day^{-1}) The rate constant is related to the aqueous half-life: $k_{p,aq} = \frac{0.693}{t_{1/2,aq}}$ where $k_{p,aq}$ is the rate constant for degradation or removal of pesticide in the water (1/day), and $t_{1/2,aq}$ is the aqueous half-life for the pesticide (days)
LKPST_VOL	Volatilization coefficient of the pesticide from the reservoir (m/day). The volatilization mass-transfer coefficient can be calculated based on Whitman’s two-film or two-resistance theory (Whitman, 1923; Lewis and Whitman, 1924 as described in Chapra, 1997). While the main body of the gas and liquid phases are assumed to be well-mixed and homogenous, the two-film theory assumes that a substance moving between the two phases encounters maximum resistance in two laminar boundary layers where transfer is a function of molecular diffusion. In this type of system the transfer coefficient or velocity is: $v_v = K_l \cdot \frac{H_e}{H_e + R \cdot T_K \cdot \left(K_l / K_g\right)}$ where v_v is the volatilization mass-transfer coefficient (m/day), K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), H_e is Henry’s constant (atm m^3 mole^{-1}), R is the universal gas constant (8.206×10^{-5} atm m^3 (K mole)$^{-1}$), and T_K is the temperature (K). For lakes, the transfer coefficients are estimated using a stagnant film approach: $K_l = \frac{D_l}{z_l} \qquad K_g = \frac{D_g}{z_g}$

Variable name	Definition
LKPST_VOL, cont.	where K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), D_l is the liquid molecular diffusion coefficient (m^2/day), D_g is the gas molecular diffusion coefficient (m^2/day), z_l is the thickness of the liquid film (m), and z_g is the thickness of the gas film (m). Alternatively, the transfer coefficients can be estimated with the equations: $K_l = K_{l,\mathrm{O_2}} \cdot \left(\frac{32}{MW}\right)^{0.25} \qquad K_g = 168 \cdot \mu_w \cdot \left(\frac{18}{MW}\right)^{0.25}$ where K_l is the mass-transfer velocity in the liquid laminar layer (m/day), K_g is the mass-transfer velocity in the gaseous laminar layer (m/day), $K_{l,\mathrm{O_2}}$ is the oxygen transfer coefficient (m/day), MW is the molecular weight of the compound, and μ_w is the wind speed (m/s). Chapra (1997) lists several different equations that can be used to calculate $K_{l,\mathrm{O_2}}$.
LKPST_KOC	Pesticide partition coefficient between water and sediment (m^3/g). The pesticide partition coefficient can be estimated from the octanol-water partition coefficient (Chapra, 1997): $K_d = 3.085 \times 10^{-8} \cdot K_{ow}$ where K_d is the pesticide partition coefficient (m^3/g) and K_{ow} is the pesticide's octanol-water partition coefficient ($\mathrm{mg\ m_{octanol}^{-3}} \left(\mathrm{mg\ m_{water}^{-3}}\right)^{-1}$). Values for the octanol-water partition coefficient have been published for many chemicals. If a published value cannot be found, it can be estimated from solubility (Chapra, 1997): $\log(K_{ow}) = 5.00 - 0.670 \cdot \log(pst'_{sol})$ where pst'_{sol} is the pesticide solubility (µmoles/L). The solubility in these units is calculated: $pst'_{sol} = \frac{pst_{sol}}{MW} \cdot 10^3$ where pst'_{sol} is the pesticide solubility (µmoles/L), pst_{sol} is the pesticide solubility (mg/L) and MW is the molecular weight (g/mole).

Variable name	**Definition**
LKPST_KOC, cont.	LKPST_KOC ranges between 10^{-4} to 10 m^3/g.
LKPST_STL	Settling velocity of pesticide sorbed to sediment (m/day)
LKPST_RSP	Resuspension velocity of pesticide sorbed to sediment (m/day).
LKPST_MIX	Pesticide diffusion or mixing velocity (m/day) The diffusive mixing velocity, v_d, can be estimated from the empirically derived formula (Chapra, 1997): $v_d = \frac{69.35}{365} \cdot \phi \cdot MW^{-2/3}$ where v_d is the rate of diffusion or mixing velocity (m/day), ϕ is the sediment porosity, and MW is the molecular weight of the pesticide compound.
LKSPST_CONC	Initial pesticide concentration in the reservoir bottom sediments. (mg/m^3)
LKSPST_REA	Reaction coefficient of pesticide in reservoir bottom sediment (day^{-1}) The rate constant is related to the sediment half-life: $k_{p,sed} = \frac{0.693}{t_{1/2,sed}}$ where $k_{p,sed}$ is the rate constant for degradation or removal of pesticide in the sediment (1/day), and $t_{1/2,sed}$ is the sediment half-life for the pesticide (days).
LKSPST_BRY	Burial velocity of pesticide in reservoir bottom sediment (m/day)
LKSPST_ACT	Depth of active sediment layer in reservoir (m)

The lake water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the lake water quality input file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
NUTRIENT TITLE	2	character	a80
IRES1	3	integer	free
IRES2	4	integer	free
PSETLR1	5	real	free
PSETLR2	6	real	free
NSETLR1	7	real	free
NSETLR2	8	real	free
CHLAR	9	real	free
SECCIR	10	real	free
RES_ORGP	11	real	free
RES_SOLP	12	real	free
RES_ORGN	13	real	free
RES_NO3	14	real	free
RES_NH3	15	real	free
RES_NO2	16	real	free
PESTICIDE TITLE	17	character	a80
LKPST_CONC	18	real	free
LKPST_REA	19	real	free
LKPST_VOL	20	real	free
LKPST_KOC	21	real	free
LKPST_STL	22	real	free
LKPST_RSP	23	real	free
LKPST_MIX	24	real	free
LKSPST_CONC	25	real	free
LKSPST_REA	26	real	free
LKSPST_BRY	27	real	free
LKSPST_ACT	28	real	free

REFERENCES

Chapra, S.C. 1997. Surface water-quality modeling. McGraw-Hill, Boston.

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Lewis, W.K. and W.G. Whitman. 1924. Principles of gas absorption. Ind. Eng. Chem. 16:1215-1220.

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Whitman, W.G. 1923. The two-film theory of gas adsorption. Chem. Metallurg. Eng. 29:146-148.

CHAPTER 31

SWAT INPUT DATA: MEASURED

SWAT directly simulates the loading of water, sediment and other constituents off of land areas in the watershed. To simulate the loading of water and pollutants from sources not associated with a land area (e.g. sewage treatment plants), SWAT allows point source information to be read in at any point along the channel network. The point source loadings may be summarized on a daily, monthly, yearly, or average annual basis.

Files containing the point source loads are created by the user. The loads are read into the model and routed through the channel network using recday, recmon, recyear, or reccnst commands in the watershed configuration file. SWAT will read in water, sediment, organic N, organic P, nitrate, soluble P, ammonium, nitrite, metal, and bacteria data from the point source files. Chapter 2 reviews the format of the command lines in the watershed configuration file while Chapter 31 reviews the format of the point source files.

31.1 DAILY RECORDS (RECDAY .DAT FILE)

The recday command in the watershed configuration (.fig) file requires a file containing SWAT input data summarized on a daily time step. An unlimited[*] number of files with daily flow data are allowed in the simulation. The file numbers assigned to the recday files in the watershed configuration file (.fig) must be ≥ 1 and numbered sequentially.

Following is a brief description of the variables in the recday input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first six lines of the file are reserved for user comments. The comments may take up to 80 spaces per line.
DAY	Julian date for record If the julian date and year are provided for the records, SWAT will search for the beginning day of simulation in the record. If the julian date and year are left blank, SWAT assumes that the first line of record corresponds to the first day of simulation. (SWAT uses the date and year to locate the record corresponding to the first day of simulation. From that point on, the day and year are ignored.)
YEAR	Four-digit year for record. See description of DAY for more information.
FLODAY	Contribution to streamflow for the day (m^3)
SEDDAY	Sediment loading to reach for the day (metric tons)
ORGNDAY	Organic N loading to reach for the day (kg N)
ORGPDAY	Organic P loading to reach for the day (kg P)
NO3DAY	NO_3 loading to reach for the day (kg N)
MINPDAY	Mineral P loading to reach for the day (kg P)
NH3DAY	NH_3 loading to reach for the day (kg N)
NO2DAY	NO_2 loading to reach for the day (kg N)
CMTL1DAY	Loading of conservative metal #1 to reach for the day (kg)

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[*] Please keep in mind that FORTRAN limits the total number of files that can be open at one time to something in the neighborhood of 250. The input files containing daily data (.pcp, .tmp, and recday) remain open throughout the simulation.

Variable name	Definition
CMTL2DAY	Loading of conservative metal #2 to reach for the day (kg)
CMTL3DAY	Loading of conservative metal #3 to reach for the day (kg)
BACTPDAY	Loading of persistent bacteria to reach for the day (# bact)
BACTLPDAY	Loading of less persistent bacteria to reach for the day (# bact)

One line of data is required for every day of the simulation period. The recday data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the recday data file is:

Variable name	Line #	Format	F90 Format
TITLE	1 - 6	character	a80
DAY	7-END	integer	free
YEAR	7-END	integer	free
FLODAY	7-END	real or exponential	free
SEDDAY	7-END	real or exponential	free
ORGNDAY	7-END	real or exponential	free
ORGPDAY	7-END	real or exponential	free
NO3DAY	7-END	real or exponential	free
MINPDAY	7-END	real or exponential	free
NH3DAY	7-END	real or exponential	free
NO2DAY	7-END	real or exponential	free
CMTL1DAY	7-END	real or exponential	free
CMTL2DAY	7-END	real or exponential	free
CMTL3DAY	7-END	real or exponential	free
BACTPDAY	7-END	real or exponential	free
BACTLPDAY	7-END	real or exponential	free

31.2 MONTHLY RECORDS (RECMON .DAT FILE)

The recmon command in the watershed configuration (.fig) file requires a file containing input data summarized on a monthly time step. SWAT will accept an unlimited number of data files with monthly flow data. The file numbers assigned to the files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the recmon data file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first 6 lines of the data file is reserved for user comments. The comments may take up to 80 spaces.
MONTH	Month of measured data.
	This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for January of the first year of simulation. The monthly data file must contain a line of data for every month of simulation in consecutive order.
YEAR	4-digit year of measured data.
	This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for January of the first year of simulation. The monthly data file must contain a line of data for every month of simulation in consecutive order.
FLOMON	Average daily water loading for month (m^3/day).
SEDMON	Average daily sediment loading for month (metric tons/day).
ORGNMON	Average daily organic nitrogen loading for month (kg N/day).
ORGPMON	Average daily organic phosphorus loading for month (kg P/day).
NO3MON	Average daily nitrate loading for month (kg N/day).
MINPMON	Average daily mineral (soluble) P loading for month (kg P/day).

Variable name	Definition
NH3MON	Average daily ammonia loading for month (kg N/day).
NO2MON	Average daily nitrite loading for month (kg N/day).
CMTL1MON	Average daily loading of conservative metal #1 for month (kg/day).
CMTL2MON	Average daily loading of conservative metal #2 for month (kg/day).
CMTL3MON	Average daily loading of conservative metal #3 for month (kg /day).
BACTPMON	Average daily loading of persistent bacteria for month (# bact/day).
BACTLPMON	Average daily loading of less persistent bacteria for month (# bact/day).

The file must contain one line of data for every month of simulation (Even if the simulation begins in a month other than January, the file must contain lines for every month of the first year.) The recmon data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the recmon data file is:

Variable name	Line #	Format	F90 Format
TITLE	1-6	character	a80
MONTH	7 – END	integer	free
YEAR	7 – END	integer	free
FLOMON	7 – END	real or exponential	free
SEDMON	7 – END	real or exponential	free
ORGNMON	7 – END	real or exponential	free
ORGPMON	7 – END	real or exponential	free
NO3MON	7 – END	real or exponential	free
MINPMON	7 – END	real or exponential	free
NH3MON	7 – END	real or exponential	free
NO2MON	7 – END	real or exponential	free
CMTL1MON	7 – END	real or exponential	free
CMTL2MON	7 – END	real or exponential	free
CMTL3MON	7 – END	real or exponential	free

Variable name	Line #	Format	F90 Format
BACTPMON	7 – END	real or exponential	free
BACTLPMON	7 – END	real or exponential	free

31.3 YEARLY RECORDS (RECYEAR .DAT FILE)

The recyear command in the watershed configuration (.fig) file requires a file containing SWAT input data summarized on an annual time step. SWAT will accept an unlimited number of data files with yearly flow data. The file numbers assigned to the recyear files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the recyear data file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first six lines of the data file are reserved for user comments. The comments may take up to 80 spaces per line.
YEAR	4-digit year of measured data. This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for the first year of simulation. The yearly data file must contain a line of data for every year of simulation in consecutive order.
FLOYR	Average daily water loading for year (m^3/day).
SEDYR	Average daily sediment loading for year (metric tons/day).
ORGNYR	Average daily organic nitrogen loading for year (kg N/day).
ORGPYR	Average daily organic phosphorus loading for year (kg P/day).
NO3YR	Average daily nitrate loading for year (kg N/day).
MINPYR	Average daily mineral (soluble) P loading for year (kg P/day).
NH3YR	Average daily ammonia loading for year (kg N/day).
NO2YR	Average daily nitrite loading for year (kg N/day).
CMTL1YR	Average daily loading of conservative metal #1 for year (kg/day).

Variable name	Definition
CMTL2YR	Average daily loading of conservative metal #2 for year (kg/day).
CMTL3YR	Average daily loading of conservative metal #3 for year (kg/day).
BACTPYR	Average daily loading of persistent bacteria for year (# bact/day).
BACTLPYR	Average daily loading of less persistent bacteria for year (# bact/day).

The recyear data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.The format of the recyear data file is:

Variable name	Line #	Format	F90 Format
TITLE	1 - 6	character	a80
YEAR	7 - END	integer	free
FLOYR	7 - END	real or exponential	free
SEDYR	7 - END	real or exponential	free
ORGNYR	7 - END	real or exponential	free
ORGPYR	7 - END	real or exponential	free
NO3YR	7 - END	real or exponential	free
MINPYR	7 - END	real or exponential	free
NH3YR	7 - END	real or exponential	free
NO2YR	7 - END	real or exponential	free
CMTL1YR	7 - END	real or exponential	free
CMTL2YR	7 - END	real or exponential	free
CMTL3YR	7 - END	real or exponential	free
BACTPYR	7 - END	real or exponential	free
BACTLPYR	7 - END	real or exponential	free

31.4 AVERAGE ANNUAL RECORDS (RECCNST .DAT FILE)

The reccnst command in the watershed configuration (.fig) file requires a file containing average annual SWAT input data. SWAT will accept an unlimited number of data files with average annual flow data. The file numbers assigned to the reccnst files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the reccnst data file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first six lines of the data file are reserved for user comments. The comments may take up to 80 spaces on each line.
FLOCNST	Average daily water loading (m^3/day)
SEDCNST	Average daily sediment loading (metric tons/day)
ORGNCNST	Average daily organic N loading (kg N/day)
ORGPCNST	Average daily organic P loading (kg P/day)
NO3CNST	Average daily NO_3 loading (kg N/day)
MINPCNST	Average daily mineral P loading (kg P/day)
NH3CNST	Average daily NH_3 loading (kg N/day)
NO2CNST	Average daily NO_2 loading (kg N/day)
CMTL1CNST	Average daily loading of conservative metal #1 (kg/day)
CMTL2CNST	Average daily loading of conservative metal #2 (kg/day)
CMTL3CNST	Average daily loading of conservative metal #3 (kg/day)
BACTPCNST	Average daily loading of persistent bacteria (# bact/day)
BACTLPCNST	Average daily loading of less persistent bacteria (# bact/day)

The format of the reccnst data file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1-6	character	a80
FLOCNST	7	real or exponential	free
SEDCNST	7	real or exponential	free
ORGNCNST	7	real or exponential	free
ORGPCNST	7	real or exponential	free
NO3CNST	7	real or exponential	free
MINPCNST	7	real or exponential	free
NH3CNST	7	real or exponential	free
NO2CNST	7	real or exponential	free
CMTL1CNST	7	real or exponential	free
CMTL2CNST	7	real or exponential	free
CMTL3CNST	7	real or exponential	free
BACTPCNST	7	real or exponential	free
BACTLPCNST	7	real or exponential	free

CHAPTER 32

SWAT OUTPUT DATA: PRIMARY OUTPUT FILES

A number of output files are generated in every SWAT simulation. These files are: the summary output file (output.std), the HRU output file (.sbs), the subbasin output file (.bsb), and the main channel or reach output file (.rch).

The detail of the data printed out in each file is controlled by the print codes in the input control code (.cod) file. Average daily values are always printed in the HRU, subbasin and reach files, but the time period they are summarized over will vary. Depending on the print code selected, the output files may include all daily values, daily amounts averaged over the month, daily amounts averaged over the year, or daily amounts averaged over the entire simulation period.

32.1 INPUT SUMMARY FILE (INPUT.STD)

The input summary file prints summary tables of important input values. This file provides the user with a mechanism to spot-check input values. All model inputs are not printed, but the file does contain some of the most important.

32.2 OUTPUT SUMMARY FILE (OUTPUT.STD)

The output summary file provides watershed average loadings from the HRUs to the streams. Tables are also included that present average annual HRU and subbasin values for a few parameters.

32.3 HRU OUTPUT FILE (.SBS)

The HRU output file contains summary information for each of the hydrologic response units in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the HRU output file.

Variable name	**Definition**
LULC	Four letter character code for the cover/plant on the HRU. (code from crop.dat file)
HRU	Hydrologic response unit number
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command.
SUB	Topographically-defined subbasin to which the HRU belongs.
MGT	Management number. This is pulled from the management (.mgt) file. Used by the SWAT/GRASS interface to allow development of output maps by landuse/management type.
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: four-digit year Average annual summary lines: total number of years averaged together
AREA	Drainage area of the HRU (km^2).
PRECIP	Total amount of precipitation falling on the HRU during time step (mm H_2O).
SNOFALL	Amount of precipitation falling as snow, sleet or freezing rain during time step (water-equivalent mm H_2O).
SNOMELT	Amount of snow or ice melting during time step (water-equivalent mm H_2O).
IRR	Irrigation (mm H_2O). Amount of irrigation water applied to HRU during the time step.
PET	Potential evapotranspiration (mm H_2O). Potential evapotranspiration from the HRU during the time step.
ET	Actual evapotranspiration (soil evaporation and plant transpiration) from the HRU during the time step (mm H_2O).

Variable name	Definition
SW	Soil water content (mm H_2O). Amount of water in the soil profile at the end of the time period.
PERC	Water that percolates past the root zone during the time step (mm H_2O). There is usually a lag between the time the water leaves the bottom of the root zone and reaches the shallow aquifer. Over a long period of time, this variable should equal groundwater recharge (PERC = GW_RCHG as time → ∞).
GW_RCHG	Recharge entering aquifers during time step (total amount of water entering shallow and deep aquifers during time step) (mm H_2O).
DA_RCHG	Deep aquifer recharge (mm H_2O). The amount of water from the root zone that recharges the deep aquifer during the time step. (shallow aquifer recharge = GW_RCHG - DA_RCHG)
REVAP	Water in the shallow aquifer returning to the root zone in response to a moisture deficit during the time step (mm H_2O). The variable also includes water uptake directly from the shallow aquifer by deep tree and shrub roots.
SA_IRR	Irrigation from shallow aquifer (mm H_2O). Amount of water removed from the shallow aquifer for irrigation during the time step.
DA_IRR	Irrigation from deep aquifer (mm H_2O). Amount of water removed from the deep aquifer for irrigation during the time step.
SA_ST	Shallow aquifer storage (mm H_2O). Amount of water in the shallow aquifer at the end of the time period.
DA_ST	Deep aquifer storage (mm H_2O). Amount of water in the deep aquifer at the end of the time period.
SURQ	Surface runoff contribution to streamflow in the main channel during time step (mm H_2O).
TLOSS	Transmission losses (mm H_2O). Water lost from tributary channels in the HRU via transmission through the bed. This water becomes recharge for the shallow aquifer during the time step. Net surface runoff contribution to the main channel streamflow is calculated by subtracting TLOSS from SURQ.
LATQ	Lateral flow contribution to streamflow (mm H_2O). Water flowing laterally within the soil profile that enters the main channel during time step.

Variable name	Definition
GW_Q	Groundwater contribution to streamflow (mm H_2O). Water from the shallow aquifer that enters the main channel during the time step. Groundwater flow is also referred to as baseflow.
WYLD	Water yield (mm H_2O). Total amount of water leaving the HRU and entering main channel during the time step. (WYLD = SURQ + LATQ + GWQ – TLOSS – pond abstractions)
SYLD	Sediment yield (metric tons/ha). Sediment from the HRU that is transported into the main channel during the time step.
USLE	Soil loss during the time step calculated with the USLE equation (metric tons/ha). This value is reported for comparison purposes only.
N_APP	Nitrogen fertilizer applied (kg N/ha). Total amount of nitrogen (mineral and organic) applied in fertilizer during the time step.
P_APP	Phosphorus fertilizer applied (kg P/ha). Total amount of phosphorus (mineral and organic) applied in fertilizer during the time step.
NAUTO	Nitrogen fertilizer auto-applied (kg N/ha). Total amount of nitrogen (mineral and organic) auto-applied during the time step.
PAUTO	Phosphorus fertilizer auto-applied (kg P/ha). Total amount of phosphorus (mineral and organic) auto-applied during the time step.
NGRZ	Nitrogen applied during grazing operation (kg N/ha). Total amount of nitrogen (mineral and organic) added to soil by grazing operation during the time step.
PGRZ	Phosphorus applied during grazing operation (kg P/ha). Total amount of phosphorus (mineral and organic) added to soil by grazing operation during the time step.
NRAIN	Nitrate added to soil profile by rain (kg N/ha).
NFIX	Nitrogen fixation (kg N/ha). Amount of nitrogen fixed by legumes during the time step.

Variable name	Definition
F-MN	Fresh organic to mineral N (kg N/ha). Mineralization of nitrogen from the fresh residue pool to the nitrate (80%) pool and active organic nitrogen (20%) pool during the time step. A positive value denotes a net gain in the nitrate and active organic pools from the fresh organic pool while a negative value denotes a net gain in the fresh organic pool from the nitrate and active organic pools.
A-MN	Active organic to mineral N (kg N/ha). Movement of nitrogen from the active organic pool to the nitrate pool during the time step.
A-SN	Active organic to stable organic N (kg N/ha). Movement of nitrogen from the active organic pool to the stable organic pool during the time step.
F-MP	Fresh organic to mineral P (kg P/ha). Mineralization of phosphorus from the fresh residue pool to the "active" mineral (80%) pool (P sorbed to soil surface) and the active organic (20%) pool. A positive value denotes a net gain in the active mineral and active organic pools from the fresh organic pool while a negative value denotes a net gain in the fresh organic pool from the active mineral and active organic pools.
AO-LP	Organic to labile mineral P (kg P/ha). Movement of phosphorus between the organic pool and the labile mineral pool during the time step. A positive value denotes a net gain in the labile pool from the organic pool while a negative value denotes a net gain in the organic pool from the labile pool.
L-AP	Labile to active mineral P (kg P/ha). Movement or transformation of phosphorus between the "labile" mineral pool (P in solution) and the "active" mineral pool (P sorbed to the surface of soil particles) during the time step. A positive value denotes a net gain in the active pool from the labile pool while a negative value denotes a net gain in the labile pool from the active pool.
A-SP	Active to stable P (kg P/ha). Movement or transformation of phosphorus between the "active" mineral pool (P sorbed to the surface of soil particles) and the "stable" mineral pool (P fixed in soil) during the time step. A positive value denotes a net gain in the stable pool from the active pool while a negative value denotes a net gain in the active pool from the stable pool.

Variable name	Definition
DNIT	Denitrification (kg N/ha). Transformation of nitrate to gaseous compounds during the time step.
NUP	Plant uptake of nitrogen (kg N/ha). Nitrogen removed from soil by plants during the time step.
PUP	Plant uptake of phosphorus (kg P/ha). Phosphorus removed from soil by plants during the time step.
ORGN	Organic N yield (kg N/ha). Organic nitrogen transported out of the HRU and into the reach during the time step.
ORGP	Organic P yield (kg P/ha). Organic phosphorus transported with sediment into the reach during the time step.
SEDP	Sediment P yield (kg P/ha). Mineral phosphorus sorbed to sediment transported into the reach during the time step.
NSURQ	NO_3 in surface runoff (kg N/ha). Nitrate transported with surface runoff into the reach during the time step.
NLATQ	NO_3 in lateral flow (kg N/ha). Nitrate transported by lateral flow into the reach during the time step.
NO3L	NO_3 leached from the soil profile (kg N/ha). Nitrate that leaches past the bottom of the soil profile during the time step. *The nitrate is not tracked through the shallow aquifer.*
NO3GW	NO_3 transported into main channel in the groundwater loading from the HRU (kg N/ha).
SOLP	Soluble P yield (kg P/ha). Soluble mineral forms of phosphorus transported by surface runoff into the reach during the time step.
P_GW	Soluble phosphorus transported by groundwater flow into main channel during the time step (kg P/ha).
W_STRS	Water stress days during the time step (days).
TMP_STRS	Temperature stress days during the time step (days).
N_STRS	Nitrogen stress days during the time step (days).
P_STRS	Phosphorus stress days during the time step (days).
BIOM	Biomass (metric tons/ha). Total biomass, i.e. aboveground and roots at the end of the time period reported as dry weight.
LAI	Leaf area index at the end of the time period.

Variable name	Definition
YLD	Harvested yield (metric tons/ha). The model partitions yield from the total biomass on a daily basis (and reports it). However, the actual yield is not known until it is harvested. The harvested yield is reported as dry weight.
BACTP	Number of persistent bacteria in surface runoff entering reach (count).
BACTLP	Number of less persistent bacteria in surface runoff entering reach (count).

The file format for the HRU output file (.sbs) is:

Variable name	Line #	Position	Format	F90 Format
LULC	All	space 1-4	character	a4
HRU	All	space 5-8	4-digit integer	i4
GIS	All	space 10-17	8-digit integer	i8
SUB	All	space 19-22	4-digit integer	i4
MGT	All	space 24-27	4-digit integer	i4
MON	All	space 29-32	4-digit integer	i4
AREA	All	space 33-42	decimal(xxxxxx.xxx)	f10.3
PRECIP	All	space 43-52	decimal(xxxxxx.xxx)	f10.3
SNOFALL	All	space 53-62	decimal(xxxxxx.xxx)	f10.3
SNOMELT	All	space 63-72	decimal(xxxxxx.xxx)	f10.3
IRR	All	space 73-82	decimal(xxxxxx.xxx)	f10.3
PET	All	space 83-92	decimal(xxxxxx.xxx)	f10.3
ET	All	space 93-102	decimal(xxxxxx.xxx)	f10.3
SW	All	space 103-112	decimal(xxxxxx.xxx)	f10.3
PERC	All	space 113-122	decimal(xxxxxx.xxx)	f10.3
GW_RCHG	All	space 123-132	decimal(xxxxxx.xxx)	f10.3
DA_RCHG	All	space 133-142	decimal(xxxxxx.xxx)	f10.3
REVAP	All	space 143-152	decimal(xxxxxx.xxx)	f10.3
SA_IRR	All	space 153-162	decimal(xxxxxx.xxx)	f10.3
DA_IRR	All	space 163-172	decimal(xxxxxx.xxx)	f10.3
SA_ST	All	space 173-182	decimal(xxxxxx.xxx)	f10.3
DA_ST	All	space 183-192	decimal(xxxxxx.xxx)	f10.3
SURQ	All	space 193-202	decimal(xxxxxx.xxx)	f10.3

Variable name	Line #	Position	Format	F90 Format
TLOSS	All	space 203-212	decimal(xxxxxx.xxx)	f10.3
LATQ	All	space 213-222	decimal(xxxxxx.xxx)	f10.3
GW_Q	All	space 223-232	decimal(xxxxxx.xxx)	f10.3
WYLD	All	space 233-242	decimal(xxxxxx.xxx)	f10.3
SYLD	All	space 243-252	decimal(xxxxxx.xxx)	f10.3
USLE	All	space 253-262	decimal(xxxxxx.xxx)	f10.3
N_APP	All	space 263-272	decimal(xxxxxx.xxx)	f10.3
P_APP	All	space 273-282	decimal(xxxxxx.xxx)	f10.3
NAUTO	All	space 283-292	decimal(xxxxxx.xxx)	f10.3
PAUTO	All	space 293-302	decimal(xxxxxx.xxx)	f10.3
NGRZ	All	space 303-312	decimal(xxxxxx.xxx)	f10.3
PGRZ	All	space 313-322	decimal(xxxxxx.xxx)	f10.3
NRAIN	All	space 323-332	decimal(xxxxxx.xxx)	f10.3
NFIX	All	space 333-342	decimal(xxxxxx.xxx)	f10.3
F-MN	All	space 343-352	decimal(xxxxxx.xxx)	f10.3
A-MN	All	space 353-362	decimal(xxxxxx.xxx)	f10.3
A-SN	All	space 363-372	decimal(xxxxxx.xxx)	f10.3
F-MP	All	space 373-382	decimal(xxxxxx.xxx)	f10.3
AO-LP	All	space 383-392	decimal(xxxxxx.xxx)	f10.3
L-AP	All	space 393-402	decimal(xxxxxx.xxx)	f10.3
A-SP	All	space 403-412	decimal(xxxxxx.xxx)	f10.3
DNIT	All	space 413-422	decimal(xxxxxx.xxx)	f10.3
NUP	All	space 423-432	decimal(xxxxxx.xxx)	f10.3
PUP	All	space 433-442	decimal(xxxxxx.xxx)	f10.3
ORGN	All	space 443-452	decimal(xxxxxx.xxx)	f10.3
ORGP	All	space 453-462	decimal(xxxxxx.xxx)	f10.3
SEDP	All	space 463-472	decimal(xxxxxx.xxx)	f10.3
NSURQ	All	space 473-482	decimal(xxxxxx.xxx)	f10.3
NLATQ	All	space 483-492	decimal(xxxxxx.xxx)	f10.3
NO3L	All	space 493-502	decimal(xxxxxx.xxx)	f10.3
NO3GW	All	space 503-512	decimal(xxxxxx.xxx)	f10.3
SOLP	All	space 513-522	decimal(xxxxxx.xxx)	f10.3
P_GW	All	space 523-532	decimal(xxxxxx.xxx)	f10.3
W_STRS	All	space 533-542	decimal(xxxxxx.xxx)	f10.3
TMP_STRS	All	space 543-552	decimal(xxxxxx.xxx)	f10.3

Variable name	Line #	Position	Format	F90 Format
N_STRS	All	space 553-562	decimal(xxxxxx.xxx)	f10.3
P_STRS	All	space 563-572	decimal(xxxxxx.xxx)	f10.3
BIOM	All	space 573-582	decimal(xxxxxx.xxx)	f10.3
LAI	All	space 583-592	decimal(xxxxxx.xxx)	f10.3
YLD	All	space 593-602	decimal(xxxxxx.xxx)	f10.3
BACTP	All	space 603-612	decimal(xxxxxx.xxx)	f10.3
BACTLP	All	space 613-622	decimal(xxxxxx.xxx)	f10.3

32.4 SUBBASIN OUTPUT FILE (.BSB)

The subbasin output file contains summary information for each of the subbasins in the watershed. The reported values for the different variables are the total amount or weighted average of all HRUs within the subbasin. The subbasin output file is written in spreadsheet format.

Following is a brief description of the output variables in the subbasin output file.

Variable name	Definition
SUB	Subbasin number.
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command.
MON	Daily time step: julian date Monthly time step: the month (1-12) Annual time step: four-digit year Average annual summary lines: total number of years averaged together
AREA	Area of the subbasin (km^2).
PRECIP	Total amount of precipitation falling on the subbasin during time step (mm H_2O).
SNOMELT	Amount of snow or ice melting during time step (water-equivalent mm H_2O).
PET	Potential evapotranspiration from the subbasin during the time step (mm H_2O).
ET	Actual evapotranspiration from the subbasin during the time step (mm).
SW	Soil water content (mm). Amount of water in the soil profile at the end of the time period.

Variable name	Definition
PERC	Water that percolates past the root zone during the time step (mm). There is potentially a lag between the time the water leaves the bottom of the root zone and reaches the shallow aquifer. Over a long period of time, this variable should equal groundwater percolation.
SURQ	Surface runoff contribution to streamflow during time step (mm H_2O).
GW_Q	Groundwater contribution to streamflow (mm). Water from the shallow aquifer that returns to the reach during the time step.
WYLD	Water yield (mm H_2O). The net amount of water that leaves the subbasin and contributes to streamflow in the reach during the time step. (WYLD = SURQ + LATQ + GWQ – TLOSS – pond abstractions)
SYLD	Sediment yield (metric tons/ha). Sediment from the subbasin that is transported into the reach during the time step.
ORGN	Organic N yield (kg N/ha). Organic nitrogen transported out of the subbasin and into the reach during the time step.
ORGP	Organic P yield (kg P/ha). Organic phosphorus transported with sediment into the reach during the time step.
NSURQ	NO_3 in surface runoff (kg N/ha). Nitrate transported by the surface runoff into the reach during the time step.
SOLP	Soluble P yield (kg P/ha). Phosphorus that is transported by surface runoff into the reach during the time step.
SEDP	Mineral P yield (kg P/ha). Mineral phosphorus attached to sediment that is transported by surface runoff into the reach during the time step.

The format of the subbasin output file (.bsb) is:

Variable name	Line #	Position	Format	F90 Format
SUB	All	space 7-10	4-digit integer	i4
GIS	All	space 12-19	8-digit integer	i8
MON	All	space 21-24	4-digit integer	i4
AREA	All	space 25-34	decimal(xxxxxx.xxx)	f10.3
PRECIP	All	space 35-44	decimal(xxxxxx.xxx)	f10.3
SNOMELT	All	space 45-54	decimal(xxxxxx.xxx)	f10.3
PET	All	space 55-64	decimal(xxxxxx.xxx)	f10.3
ET	All	space 65-74	decimal(xxxxxx.xxx)	f10.3
SW	All	space 75-84	decimal(xxxxxx.xxx)	f10.3
PERC	All	space 85-94	decimal(xxxxxx.xxx)	f10.3
SURQ	All	space 95-104	decimal(xxxxxx.xxx)	f10.3
GW_Q	All	space 105-114	decimal(xxxxxx.xxx)	f10.3
WYLD	All	space 115-124	decimal(xxxxxx.xxx)	f10.3
SYLD	All	space 125-134	decimal(xxxxxx.xxx)	f10.3
ORGN	All	space 135-144	decimal(xxxxxx.xxx)	f10.3
ORGP	All	space 145-154	decimal(xxxxxx.xxx)	f10.3
NSURQ	All	space 155-164	decimal(xxxxxx.xxx)	f10.3
SOLP	All	space 165-174	decimal(xxxxxx.xxx)	f10.3
SEDP	All	space 175-184	decimal(xxxxxx.xxx)	f10.3

32.5 MAIN CHANNEL OUTPUT FILE (.RCH)

The main channel output file contains summary information for each routing reach in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the .rch file.

Variable name	Definition
RCH	Reach number. The reach number is also the hydrograph number of the subbasin as defined in the .fig file.
GIS	GIS number reprinted from watershed configuration (.fig) file. See explanation of subbasin command.
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: 4-digit year Average annual summary lines: number of years averaged together
AREA	Area drained by reach (km^2).
FLOW_IN	Average daily streamflow into reach during time step (m^3/s).
FLOW_OUT	Average daily streamflow out of reach during time step (m^3/s).
EVAP	Average daily rate of water loss from reach by evaporation during time step (m^3/s).
TLOSS	Average daily rate of water loss from reach by transmission through the streambed during time step (m^3/s).
SED_IN	Sediment transported with water into reach during time step (metric tons).
SED_OUT	Sediment transported with water out of reach during time step (metric tons).
SEDCONC	Concentration of sediment in reach during time step (mg/L).
ORGN_IN	Organic nitrogen transported with water into reach during time step (kg N).
ORGN_OUT	Organic nitrogen transported with water out of reach during time step (kg N).
ORGP_IN	Organic phosphorus transported with water into reach during time step (kg P).
ORGP_OUT	Organic phosphorus transported with water out of reach during time step (kg P).

Variable name	Definition
NO3_IN	Nitrate transported with water into reach during time step (kg N).
NO3_OUT	Nitrate transported with water out of reach during time step (kg N).
NH4_IN	Ammonium transported with water into reach during time step (kg N).
NH4_OUT	Ammonium transported with water out of reach during time step (kg N).
NO2_IN	Nitrite transported with water into reach during time step (kg N).
NO2_OUT	Nitrite transported with water out of reach during time step (kg N).
MINP_IN	Mineral phosphorus transported with water into reach during time step (kg P).
MINP_OUT	Mineral phosphorus transported with water out of reach during time step (kg P).
ALGAE_IN	Algal biomass transported with water into reach during time step (kg).
ALGAE_OUT	Algal biomass transported with water out of reach during time step (kg).
CBOD_IN	Carbonaceous biochemical oxygen demand of material transported into reach during time step (kg O_2).
CBOD_OUT	Carbonaceous biochemical oxygen demand of material transported out of reach during time step (kg O_2).
DISOX_IN	Amount of dissolved oxygen transported into reach during time step (kg O_2).
DISOX_OUT	Amount of dissolved oxygen transported out of reach during time step (kg O_2).
While more than one pesticide may be applied to the HRUs, due to the complexity of the pesticide equations only the pesticide listed in .bsn is routed through the stream network.	
SOLPST_IN	Soluble pesticide transported with water into reach during time step (mg active ingredient)
SOLPST_OUT	Soluble pesticide transported with water out of reach during time step (mg active ingredient).

Variable name	Definition
SORPST_IN	Pesticide sorbed to sediment transported with water into reach during time step (mg active ingredient).
SORPST_OUT	Pesticide sorbed to sediment transported with water out of reach during time step (mg active ingredient).
REACTPST	Loss of pesticide from water by reaction during time step (mg active ingredient).
VOLPST	Loss of pesticide from water by volatilization during time step (mg active ingredient).
SETTLPST	Transfer of pesticide from water to river bed sediment by settling during time step (mg active ingredient).
RESUSP_PST	Transfer of pesticide from river bed sediment to water by resuspension during time step (mg active ingredient).
DIFFUSEPST	Transfer of pesticide from water to river bed sediment by diffusion during time step (mg active ingredient).
REACBEDPST	Loss of pesticide from river bed sediment by reaction during time step (mg active ingredient).
BURYPST	Loss of pesticide from river bed sediment by burial during time step (mg active ingredient).
BED_PST	Pesticide in river bed sediment during time step (mg active ingredient).
BACTP_OUT	Number of persistent bacteria transported out of reach during time step.
BACTLP_OUT	Number of less persistent bacteria transported out of reach during time step.
CMETAL#1	Conservative metal #1 transported out of reach (kg).
CMETAL#2	Conservative metal #2 transported out of reach (kg).
CMETAL#3	Conservative metal #3 transported out of reach (kg).

The format of the main channel output file (.rch) is:

Variable name	Line #	Position	Format	F90 Format
RCH	All	space 7-10	4-digit integer	i4
GIS	All	space 12-19	8-digit integer	i8
MON	All	space 21-25	5-digit integer	i5
AREA	All	space 26-37	exponential	e12.4
FLOW_IN	All	space 38-49	exponential	e12.4
FLOW_OUT	All	space 50-61	exponential	e12.4
EVAP	All	space 62-73	exponential	e12.4
TLOSS	All	space 74-85	exponential	e12.4
SED_IN	All	space 86-97	exponential	e12.4
SED_OUT	All	space 98-109	exponential	e12.4
SEDCONC	All	space 110-121	exponential	e12.4
ORGN_IN	All	space 122-133	exponential	e12.4
ORGN_OUT	All	space 134-145	exponential	e12.4
ORGP_IN	All	space 146-157	exponential	e12.4
ORGP_OUT	All	space 158-169	exponential	e12.4
NO3_IN	All	space 170-181	exponential	e12.4
NO3_OUT	All	space 182-193	exponential	e12.4
NH4_IN	All	space 194-205	exponential	e12.4
NH4_OUT	All	space 206-217	exponential	e12.4
NO2_IN	All	space 218-229	exponential	e12.4
NO2_OUT	All	space 230-241	exponential	e12.4
MINP_IN	All	space 242-253	exponential	e12.4
MINP_OUT	All	space 254-265	exponential	e12.4
CHLA_IN	All	space 266-277	exponential	e12.4
CHLA_OUT	All	space 278-289	exponential	e12.4
CBOD_IN	All	space 290-301	exponential	e12.4
CBOD_OUT	All	space 302-313	exponential	e12.4
DISOX_IN	All	space 314-325	exponential	e12.4
DISOX_OUT	All	space 326-337	exponential	e12.4
SOLPST_IN	All	space 338-349	exponential	e12.4
SOLPST_OUT	All	space 350-361	exponential	e12.4
SORPST_IN	All	space 362-373	exponential	e12.4
SORPST_OUT	All	space 374-385	exponential	e12.4
REACTPST	All	space 386-397	exponential	e12.4

Variable name	Line #	Position	Format	F90 Format
VOLPST	All	space 398-409	exponential	e12.4
SETTLPST	All	space 410-421	exponential	e12.4
RESUSP_PST	All	space 422-433	exponential	e12.4
DIFFUSEPST	All	space 434-445	exponential	e12.4
REACBEDPST	All	space 446-457	exponential	e12.4
BURYPST	All	space 458-469	exponential	e12.4
BED_PST	All	space 470-481	exponential	e12.4
BACTP_OUT	All	space 482-493	exponential	e12.4
BACTLP_OUT	All	space 494-505	exponential	e12.4
CMETAL#1	All	space 506-517	exponential	e12.4
CMETAL#2	All	space 518-529	exponential	e12.4
CMETAL#3	All	space 530-541	exponential	e12.4

32.6 HRU IMPOUNDMENT OUTPUT FILE (.WTR)

The HRU impoundment output file contains summary information for ponds, wetlands and depressional/impounded areas in the HRUs. The file is written in spreadsheet format.

Following is a brief description of the output variables in the HRU impoundment output file.

Variable name	Definition
LULC	Four letter character code for the cover/plant on the HRU. (code from crop.dat file)
HRU	Hydrologic response unit number
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command.
SUB	Topographically-defined subbasin to which the HRU belongs.
MGT	Management number. This is pulled from the management (.mgt) file. Used by the SWAT/GRASS interface to allow development of output maps by landuse/management type.
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: year Average annual summary lines: total number of years averaged together
AREA	Drainage area of the HRU (km^2).
PNDPCP	Precipitation falling directly on the pond during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
PND_IN	Pond inflow (mm H_2O). Surface runoff entering the pond during the time step. The depth of water is the volume divided by the area of the HRU.
PSED_I	Pond sediment inflow (metric tons/ha). Sediment transported into the pond during the time step. The loading is the mass divided by the area of the HRU.
PNDEVP	Evaporation from the pond surface during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
PNDSEP	Water that seeps through the bottom of the pond and recharges the shallow aquifer during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
PND_OUT	Pond outflow (mm H_2O). Water leaving the pond and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.
PSED_O	Pond sediment outflow (metric tons/ha). Sediment transported out of the pond and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
PNDVOL	Volume of water in pond at end of time step (m^3 H_2O).
PNDORGN	Concentration of organic N in pond at end of time step (mg N/L or ppm).
PNDNO3	Concentration of nitrate in pond at end of time step (mg N/L or ppm).
PNDORGP	Concentration of organic P in pond at end of time step (mg P/L or ppm).
PNDMINP	Concentration of mineral P in pond at end of time step (mg P/L or ppm).
PNDCHLA	Concentration of chlorophyll-a in pond at end of time step (mg chl-a/L or ppm).
PNDSECI	Secchi-disk depth of pond at end of time step (m).
WETPCP	Precipitation falling directly on the wetland during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
WET_IN	Wetland inflow (mm H_2O). Surface runoff entering the wetland during the time step. The depth of water is the volume divided by the area of the HRU.
WSED_I	Wetland sediment inflow (metric tons/ha). Sediment transported into the wetland during the time step. The loading is the mass divided by the area of the HRU.
WETEVP	Evaporation from the wetland during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
WETSEP	Water that seeps through the bottom of the wetland and recharges the shallow aquifer during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
WET_OUT	Wetland outflow (mm H_2O). Water leaving the wetland and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.
WSED_O	Wetland sediment outflow (metric tons/ha). Sediment transported out of the wetland and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
WET_VOL	Volume of water in wetland at end of time step (m^3 H_2O).
WETORGN	Concentration of organic N in wetland at end of time step (mg N/L or ppm).
WETNO3	Concentration of nitrate in wetland at end of time step (mg N/L or ppm).
WETORGP	Concentration of organic P in wetland at end of time step (mg P/L or ppm).
WETMINP	Concentration of mineral P in wetland at end of time step (mg P/L or ppm).
WETCHLA	Concentration of chlorophyll-a in wetland at end of time step (mg chl-a/L or ppm).
WETSECI	Secchi-disk depth of wetland at end of time step (m).
POTPCP	Precipitation falling directly on the pothole during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
POT_IN	Pothole inflow (mm H_2O). Surface runoff entering the pothole during the time step. The depth of water is the volume divided by the area of the HRU.
OSED_I	Pothole sediment inflow (metric tons/ha). Sediment transported into the pothole during the time step. The loading is the mass divided by the area of the HRU.
POTEVP	Evaporation from the pothole during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
POTSEP	Water that seeps through the bottom of the pothole and enters the underlying soil during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
POT_OUT	Pothole outflow (mm H_2O). Water leaving the pothole and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
OSED_O	Pothole sediment outflow (metric tons/ha). Sediment transported out of the pothole and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
POTVOL	Volume of water in pothole at end of time step (m^3 H_2O).
POT_SA	Surface area of pothole at end of time step (ha).
HRU_SURQ	Surface runoff contribution to streamflow in the main channel from entire HRU during the time step (mm H_2O).
PLANT_ET	Amount of water removed by transpiration from plants during the time step (mm H_2O).
SOIL_ET	Amount of water removed by evaporation from the soil during the time step (mm H_2O).

The format of the HRU impoundment output file (.wtr) is:

Variable name	Line #	Position	Format	F90 Format
LULC	All	space 1-4	character	a4
HRU	All	space 5-8	4-digit integer	i4
GIS	All	space 10-17	8-digit integer	i8
SUB	All	space 19-22	4-digit integer	i4
MGT	All	space 24-27	4-digit integer	i4
MON	All	space 29-32	4-digit integer	i4
AREA	All	space 33-42	decimal(xxxxxx.xxx)	f10.3
PNDPCP	All	space 43-52	decimal(xxxxxx.xxx)	f10.3
PND_IN	All	space 53-62	decimal(xxxxxx.xxx)	f10.3
PSED_I	All	space 63-72	decimal(xxxxxx.xxx)	f10.3
PNDEVP	All	space 73-82	decimal(xxxxxx.xxx)	f10.3
PNDSEP	All	space 83-92	decimal(xxxxxx.xxx)	f10.3
PND_OUT	All	space 93-102	decimal(xxxxxx.xxx)	f10.3
PSED_O	All	space 103-112	decimal(xxxxxx.xxx)	f10.3
PNDVOL	All	space 113-122	exponential	e10.4
PNDORGN	All	space 123-132	decimal(xxxxxx.xxx)	f10.3
PNDNO3	All	space 133-142	decimal(xxxxxx.xxx)	f10.3
PNDORGP	All	space 143-152	decimal(xxxxxx.xxx)	f10.3
PNDMINP	All	space 153-162	decimal(xxxxxx.xxx)	f10.3
PNDCHLA	All	space 163-172	decimal(xxxxxx.xxx)	f10.3
PNDSECI	All	space 173-182	decimal(xxxxxx.xxx)	f10.3

Variable name	Line #	Position	Format	F90 Format
WETPCP	All	space 183-192	decimal(xxxxxx.xxx)	f10.3
WET_IN	All	space 193-202	decimal(xxxxxx.xxx)	f10.3
WSED_I	All	space 203-212	decimal(xxxxxx.xxx)	f10.3
WETEVP	All	space 213-222	decimal(xxxxxx.xxx)	f10.3
WETSEP	All	space 223-232	decimal(xxxxxx.xxx)	f10.3
WET_OUT	All	space 233-242	decimal(xxxxxx.xxx)	f10.3
WSED_O	All	space 243-252	decimal(xxxxxx.xxx)	f10.3
WET_VOL	All	space 253-262	exponential	e10.4
WETORGN	All	space 263-272	decimal(xxxxxx.xxx)	f10.3
WETNO3	All	space 273-282	decimal(xxxxxx.xxx)	f10.3
WETORGP	All	space 283-292	decimal(xxxxxx.xxx)	f10.3
WETMINP	All	space 293-302	decimal(xxxxxx.xxx)	f10.3
WETCHLA	All	space 303-312	decimal(xxxxxx.xxx)	f10.3
WETSECI	All	space 313-322	decimal(xxxxxx.xxx)	f10.3
POTPCP	All	space 323-332	decimal(xxxxxx.xxx)	f10.3
POT_IN	All	space 333-342	decimal(xxxxxx.xxx)	f10.3
OSED_I	All	space 343-352	decimal(xxxxxx.xxx)	f10.3
POTEVP	All	space 353-362	decimal(xxxxxx.xxx)	f10.3
POTSEP	All	space 363-372	decimal(xxxxxx.xxx)	f10.3
POT_OUT	All	space 373-382	decimal(xxxxxx.xxx)	f10.3
OSED_O	All	space 383-392	decimal(xxxxxx.xxx)	f10.3
POTVOL	All	space 393-402	exponential	e10.4
POT_SA	All	space 403-412	decimal(xxxxxx.xxx)	f10.3
HRU_SURQ	All	space 413-422	decimal(xxxxxx.xxx)	f10.3
PLANT_ET	All	space 423-432	decimal(xxxxxx.xxx)	f10.3
SOIL_ET	All	space 433-442	decimal(xxxxxx.xxx)	f10.3

32.7 RESERVOIR OUTPUT FILE (.RSV)

The reservoir output file contains summary information for reservoirs in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the reservoir output file.

Variable name	Definition
RES	Reservoir number (assigned in .fig file)
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: four-digit year
VOLUME	Volume of water in reservoir at end of time step (m^3 H_2O).
FLOW_IN	Average flow into reservoir during time step (m^3/s H_2O).
FLOW_OUT	Average flow out of reservoir during time step (m^3/s H_2O).
PRECIP	Precipitation falling directly on the reservoir during the time step (m^3 H_2O).
EVAP	Evaporation from the reservoir during the time step (m^3 H_2O).
SEEPAGE	Water that seeps through the bottom of the reservoir and enters the shallow aquifer during the time step (m^3 H_2O).
SED_IN	Reservoir sediment inflow (metric tons). Sediment transported into the reservoir during the time step.
SED_OUT	Reservoir sediment outflow (metric tons). Sediment transported out of the reservoir during the time step.
ORGN_IN	Amount of organic nitrogen transported into reservoir during the time step (kg N).
ORGN_OUT	Amount of organic nitrogen transported out of reservoir during the time step (kg N).
ORGP_IN	Amount of organic phosphorus transported into reservoir during the time step (kg P).
ORGP_OUT	Amount of organic phosphorus transported out of reservoir during the time step (kg P).
NO3_IN	Amount of nitrate transported into reservoir during the time step (kg N).

Variable name	Definition
NO3_OUT	Amount of nitrate transported out of reservoir during the time step (kg N).
NO2_IN	Amount of nitrite transported into reservoir during the time step (kg N).
NO2_OUT	Amount of nitrite transported out of reservoir during the time step (kg N).
NH3_IN	Amount of ammonia transported into reservoir during the time step (kg N).
NH3_OUT	Amount of ammonia transported out of reservoir during the time step (kg N).
MINP_IN	Amount of mineral phosphorus transported into reservoir during the time step (kg P).
MINP_OUT	Amount of mineral phosphorus transported out of reservoir during the time step (kg P).
CHLA_IN	Amount of chlorophyll *a* transported into reservoir during the time step (kg chla).
CHLA_OUT	Amount of chlorophyll *a* transported out of reservoir during the time step (kg chla).
SECCHIDEPTH	Secchi-disk depth of reservoir at end of time step (m).
PEST_IN	Amount of pesticide transported into reservoir during the time step (mg pesticide active ingredient).
REACTPST	Loss of pesticide from water by reaction during time step (mg active ingredient).
VOLPST	Loss of pesticide from water by volatilization during time step (mg active ingredient).
SETTLPST	Transfer of pesticide from water to reservoir bed sediment by settling during time step (mg active ingredient).
RESUSP_PST	Transfer of pesticide from reservoir bed sediment to water by resuspension during time step (mg active ingredient).
DIFFUSEPST	Transfer of pesticide from water to reservoir bed sediment by diffusion during time step (mg active ingredient).
REACBEDPST	Loss of pesticide from reservoir bed sediment by reaction during time step (mg active ingredient).
BURYPST	Loss of pesticide from reservoir sediment by burial during time step (mg active ingredient).

Variable name	Definition
PEST_OUT	Amount of pesticide transported out of reservoir during the time step (mg pesticide active ingredient).
PSTCNCW	Average concentration of pesticide in reservoir water during time step (mg active ingredient/m^3 H_2O or ppb).
PSTCNCB	Average concentration of pesticide in reservoir bed sediment during time step (mg active ingredient/m^3 H_2O or ppb).

The format of the reservoir output file (.rsv) is:

Variable name	Line #	Position	Format	F90 Format
RES	All	space 7-14	integer	i8
MON	All	space 16-19	integer	i4
VOLUME	All	space 20-31	exponential	e12.4
FLOW_IN	All	space 32-43	exponential	e12.4
FLOW_OUT	All	space 44-55	exponential	e12.4
PRECIP	All	space 56-67	exponential	e12.4
EVAP	All	space 68-79	exponential	e12.4
SEEPAGE	All	space 80-91	exponential	e12.4
SED_IN	All	space 92-103	exponential	e12.4
SED_OUT	All	space 104-115	exponential	e12.4
ORGN_IN	All	space 116-127	exponential	e12.4
ORGN_OUT	All	space 128-139	exponential	e12.4
ORGP_IN	All	space 140-151	exponential	e12.4
ORGP_OUT	All	space 152-163	exponential	e12.4
NO3_IN	All	space 164-175	exponential	e12.4
NO3_OUT	All	space 176-187	exponential	e12.4
NO2_IN	All	space 188-199	exponential	e12.4
NO2_OUT	All	space 200-211	exponential	e12.4
NH3_IN	All	space 212-223	exponential	e12.4
NH3_OUT	All	space 224-235	exponential	e12.4
MINP_IN	All	space 236-247	exponential	e12.4
MINP_OUT	All	space 248-259	exponential	e12.4
CHLA_IN	All	space 260-271	exponential	e12.4
CHLA_OUT	All	space 272-283	exponential	e12.4
SECCHIDEPTH	All	space 284-295	exponential	e12.4
PEST_IN	All	space 296-307	exponential	e12.4

Variable name	Line #	Position	Format	F90 Format
REACTPST	All	space 308-319	exponential	e12.4
VOLPST	All	space 320-331	exponential	e12.4
SETTLPST	All	space 332-343	exponential	e12.4
RESUSP_PST	All	space 344-355	exponential	e12.4
DIFFUSEPST	All	space 356-367	exponential	e12.4
REACBEDPST	All	space 368-379	exponential	e12.4
BURYPST	All	space 380-391	exponential	e12.4
PEST_OUT	All	space 392-403	exponential	e12.4
PSTCNCW	All	space 404-415	exponential	e12.4
PSTCNCB	All	space 416-427	exponential	e12.4

CHAPTER 33

SWAT: CALIBRATION

Calibration of a model run can be divided into several steps:

- water balance and stream flow
- sediment
- nutrients

WATER BALANCE AND STREAM FLOW

To calibrate the water balance and stream flow you need to have some understanding of the actual conditions occurring in the watershed. Ideally, you have data from a stream gage located within or at the outlet of your watershed.

> The U.S. Geological Survey maintains a website (http://water.usgs.gov/) with daily records for all stream gages in the U.S. available for downloading.

Calibration for water balance and stream flow is first done for average annual conditions. Once the run is calibrated for average annual conditions, the user can shift to monthly or daily records to fine-tune the calibration.

The average annual observed and simulated results should be summarized in a manner similar to the following table:

	Total Water Yield	Baseflow	Surface Flow
Actual	200 mm	80 mm	120 mm
SWAT	300 mm	20 mm	280 mm

(When calibrating, we usually summarize data as depth of water in millimeters over the drainage area. Feel free to use whatever units you prefer.)

> If you are calibrating at the watershed outlet, the SWAT values for the table are provided in the .std file. These values are listed in the table titled "Ave Annual Basin Values" located near the end of the file.
>
> If you are calibrating a gage located within the watershed, the total water yield can be calculated from the FLOW_OUT variable in the reach (.rch) file. The values for Baseflow and Surface Flow have to be estimated from the HRU output (.sbs) file or the subbasin output file (.bsb). To estimate the contributions by baseflow and streamflow, the average annual values for GWQ, SURQ and WYLD need to be averaged so that an areally weighted value for the drainage area of interest is obtained. The surface flow and baseflow then need to be converted to fractions by dividing by the total water yield (WYLD). These fractions are then multiplied by the total water yield obtained from the reach output file. The values for GWQ and SURQ cannot be used directly because in-stream precipitation, evaporation, transmission losses, etc. will alter the net water yield from that predicted by the WYLD variable in the HRU or Subbasin Output files.

There are a number of methods available for partitioning observed stream flow into fractions contributed by baseflow and surface runoff. If daily steam flow is available, a baseflow filter program can be run which performs this analysis.

I. BASIC WATER BALANCE & TOTAL FLOW CALIBRATION

CALIBRATE SURFACE RUNOFF:

Step 1: Adjust the curve number (CN2 in .mgt) until surface runoff is acceptable. Appendix A contains tables of curve number values for a wide variety of land covers. Appendix B contains tables summarizing ranges for the general categories of land cover and lists the land cover category for all plants in the SWAT Land Cover/Plant database.

If surface runoff values are still not reasonable after adjusting curve numbers, adjust:
- -soil available water capacity (±0.04) (SOL_AWC in .sol) and/or
- -soil evaporation compensation factor (ESCO in .bsn or .hru).

CALIBRATE SUBSURFACE FLOW:

Step 2: Once surface runoff is calibrated, compare measured and simulated values of baseflow.

If simulated baseflow is too high:
- -increase the groundwater "revap" coefficient (GW_REVAP in .gw)—the maximum value that GW_REVAP should be set at is 0.20.
- -decrease the threshold depth of water in the shallow aquifer for "revap" to occur (REVAPMN in .gw)—the minimum value that REVAPMN should be set at is 0.0.
- -increase the threshold depth of water in the shallow aquifer required for base flow to occur (GWQMN in .gw)—the maximum value that GWQMN should be set at is left to user discretion.

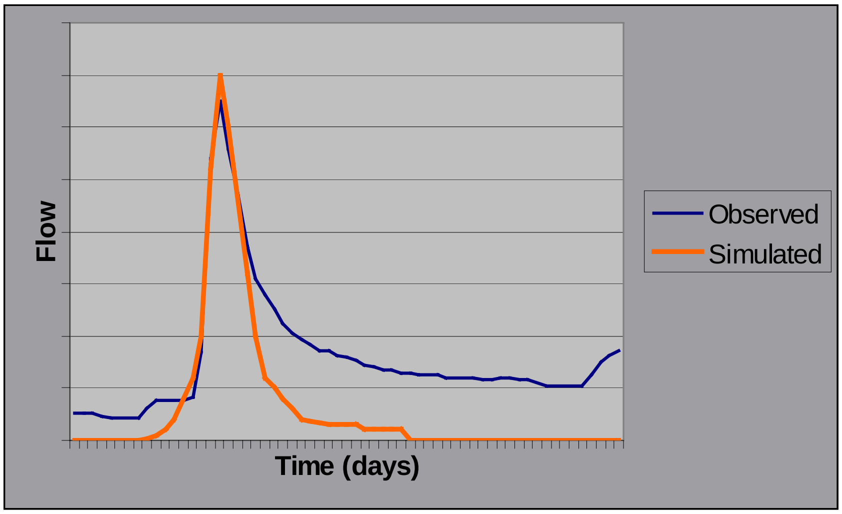
If simulated baseflow is too low, check the movement of water into the aquifer.

If groundwater recharge (GWQ in .sbs or .bsb) is greater than or equal to the desired baseflow:
- -decrease the groundwater "revap" coefficient (GW_REVAP in .gw)—the minimum value that GW_REVAP should be set at is 0.02.
- -increase the threshold depth of water in the shallow aquifer for "revap" to occur (REVAPMN in .gw).
- -decrease the threshold depth of water in the shallow aquifer required for base flow to occur (GWQMN in .gw)—the minimum value that GWQMN should be set at is 0.0.

Step 3: Repeat steps 1 and 2 until values are acceptable. It may take several reiterations to get the surface runoff and baseflow correct.

II. TEMPORAL FLOW CALIBRATION

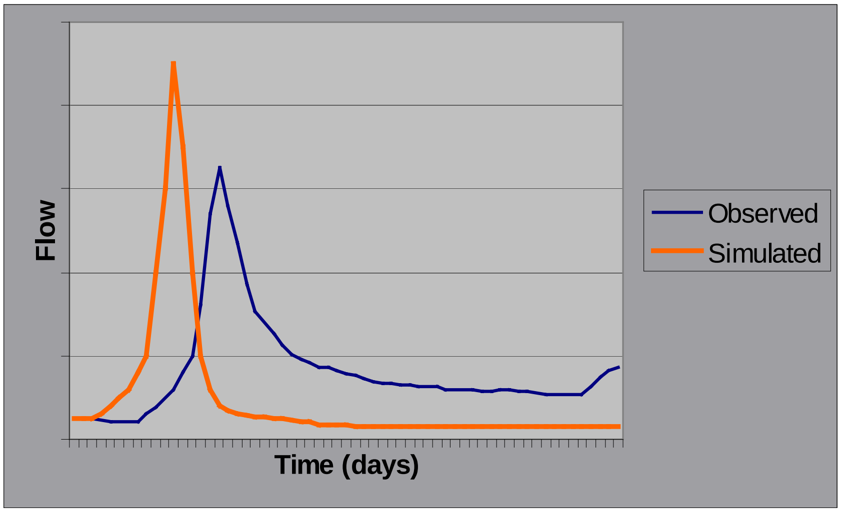
Once average annual and annual surface runoff and baseflow are realistic, the temporal flow should look reasonable as well. A few problems that may still be present include:



1) Peaks are reasonable, but the recessions "bottom out": Check the transmission losses/values for channel hydraulic conductivity (CH_K in .rte). The value for channel hydraulic conductivity is an *effective* hydraulic conductivity for movement of water **out** of the stream bed.

> For perennial streams receiving groundwater contribution to flow, the groundwater enters the stream through the sides and bottom of the stream bed, making the effective hydraulic conductivity of the channel beds to water losses equal to zero. The only time the channel hydraulic conductivity would be greater than zero is for ephemeral and transient streams that do not receive continuous groundwater contributions to streamflow.

A second variable that will affect the shape of the hydrograph is the baseflow alpha factor (ALPHA_BF in .gw).



2) In snow melt months, the peaks are too high and recessions are too low: Check the values for maximum and minimum melt rates for snow (SMFMX and SMFMN in .bsn). These values may need to be lowered. Another variable that will impact snow melt is the temperature lapse rate (TLAPS in .sub). These values may need to be increased. Finally, the baseflow alpha factor may need to be modified (ALPHA_BF in .gw).

III. SPATIAL FLOW CALIBRATION

If you are calibrating a watershed with multiple stream gages, calibrate streamflow for the gage furthest upstream. Once that gage is calibrated, move downstream to the next gage and calibrate for that area. It is important that, as you calibrate downstream gages, you do not change parameters within the files associated with the drainage area of the upstream gages already calibrated.

SEDIMENT

There are two sources of sediment in the SWAT simulation: loadings from HRUs/subbasins and channel degradation/deposition. Once the ratio of surface runoff to baseflow contribution to streamflow is being simulated correctly, the sediment contribution (loadings from HRUs/subbasins) should be close to measured values. In most situations, the user will probably have little information about channel degradation/deposition. For those unable to go out and assess the channel, we suggest that you adjust the loadings from the subbasins until they look reasonable and then assume that the remaining difference between actual and observed is due to channel degradation/deposition.

The average annual observed and simulated results should be summarized in a manner similar to the following table. A more detailed table which contains the loadings by land use on a given soil type may be used also.

	Sediment	
Loadings from mixed forest	187 metric tons/yr	0.14 metric tons/ha/yr
Loadings from bermuda pasture	354 metric tons/yr	0.23 metric tons/ha/yr
Loadings from range	1459 metric tons/yr	0.35 metric tons/ha/yr
Loading from HRUs/subbasins	2,000 metric tons/yr	0.28 metric tons/ha/yr
Amount of sediment leaving reach	2,873 metric tons/yr	
Actual	2,321 metric tons/yr	

Sediment loadings from the HRUs/subbasins can be calculated by summing values for SYLD in either the .sbs or .bsb file. The amount of sediment leaving the reach can be obtained from values reported for SED_OUT in the .rch file.

CHECK RESERVOIR/POND SIMULATION:

Reservoirs and ponds have a big impact on sediment loadings. If the amount of sediment being simulated in the watershed is off, first verify that you are accounting for all the ponds and reservoirs in the watershed and that they are being simulated properly.

CALIBRATE SUBBASIN LOADINGS:

While surface runoff is the primary factor controlling sediment loadings to the stream, there are a few other variables that affect sediment movement into the stream.

1) Tillage has a great impact on sediment transport. With tillage, plant residue is removed from the surface causing erosion to increase. Verify that the tillage practices are being accurately simulated.

2) USLE equation support practices (P) factor (USLE_P in the .mgt file): Verify that you have accurately accounted for contouring and terracing in agricultural areas. In general, agricultural land with a slope greater that 5% will be terraced.

3) USLE equation slope length factor (SLSUBBSN in .hru file): There is usually a large amount of uncertainty in slope length measurements. The slope length will also be affected by support practices used in the HRU.
4) Slope in the HRUs (SLOPE in .hru file): Verify that the slopes given for the subbasin are correct.
5) USLE equation cropping practices (C) factor (USLE_C in crop.dat): In some cases, the minimum C value reported for the plant cover may not be accurate for your area.

CALIBRATE CHANNEL DEGRADATION/DEPOSITION:

Channel degradation will be significant during extreme storm events and in unstable subbasins. Unstable subbasins are those undergoing a significant change in land use patterns such as urbanization. Variables that affect channel degradation/deposition include:
1) The linear and exponential parameters used in the equation to calculate sediment reentrained in channel sediment routing (SPCON and SPEXP in .bsn file). These variables affect sediment routing in the entire watershed.
2) The channel erodibility factor (CH_EROD in .rte)
3) The channel cover factor (CH_COV in .rte)

NUTRIENTS

The nutrients of concern in SWAT are nitrate, soluble phosphorus, organic nitrogen and organic phosphorus. When calibrating for a nutrient, keep in mind that changes made will have an effect all the nutrient levels.

Nutrient calibration can be divided into two steps: calibration of nutrient loadings and calibration of in-stream water quality processes.

CALIBRATE NUTRIENT LOADINGS (ALL NUTRIENTS):

1) Check that the initial concentrations of the nutrients in the soil are correct. These are set in the soil chemical input file (.chm):
    nitrate (SOL_NO3 in .chm)
    soluble P (SOL_MINP in .chm)
    organic N (SOL_ORGN in .chm)
    organic P (SOL_ORGP in .chm)
2) Verify that fertilizer applications are correct. Check amounts and the soil layer that the fertilizer is applied to. The fertilizer may be applied to the top 10mm of soil or incorporated in the first soil layer. The variable FRT_LY1 identifies the fraction of fertilizer applied to the top 10mm of soil. (If this variable is left at zero, the model will set FRT_LY1 = 0.20).
3) Verify that tillage operations are correct. Tillage redistributes nutrients in the soil and will alter the amount available for interaction or transport by surface runoff.
4) Alter the biological mixing efficiency (BIOMIX in .mgt file). Biological mixing acts the same as a tillage operation in that it incorporates residue and nutrients into the soil. This variable controls mixing due to biological activity in the entire watershed.

CALIBRATE NUTRIENT LOADINGS (NITRATE):

In addition to the variables mentioned above,
1) Modify the nitrogen percolation coefficient (NPERCO in .bsn file)

CALIBRATE NUTRIENT LOADINGS (SOLUBLE P):

In addition to the variables mentioned in the section for all nutrients,
1) Modify the phosphorus percolation coefficient (PPERCO in .bsn file)
2) Modify the phosphorus soil partitioning coefficient (PHOSKD in .bsn file).

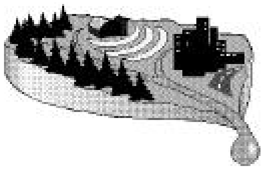
CALIBRATE NUTRIENT LOADINGS (ORGANIC N & P):

Organics are transported to the stream attached to sediment, so the movement of sediment will greatly impact the movement of organics.

CALIBRATE IN-STREAM NUTRIENT PROCESSES:

SWAT includes in-stream nutrient cycling processes as described in the QUAL2E documentation. Variables in the watershed water quality (.wwq) and stream water quality (.swq) files control these processes.

SWAT Calibration Techniques

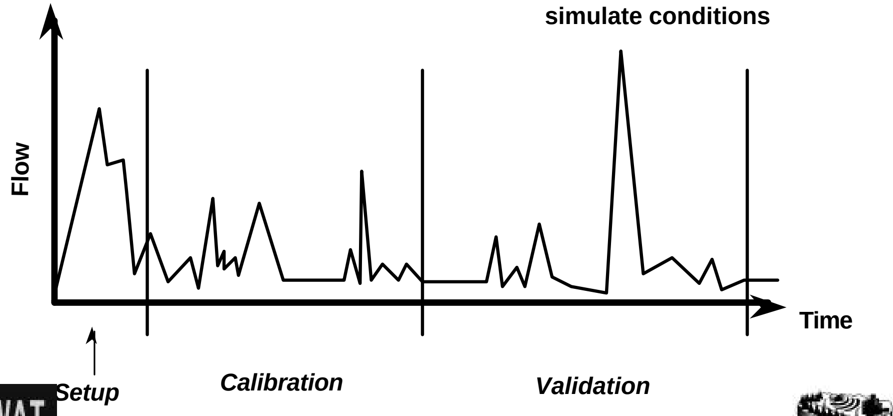


Calibration, Validation & Verification

- **CALIBRATION:** model testing with known input and output used to adjust or estimate factors
- **VALIDATION:** comparison of model results with an independent data set (without further adjustment).
- **VERIFICATION:** examination of the numerical technique in the computer code to ascertain that it truly represents the conceptual model and that there are no inherent numerical problems

Calibration/Validation Periods

- distinct time period
- similar range of conditions
- adequate time period to simulate conditions



Model Configuration

✦ Land use categories
  – land use types in watershed, existing and future land uses, management techniques employed, management questions

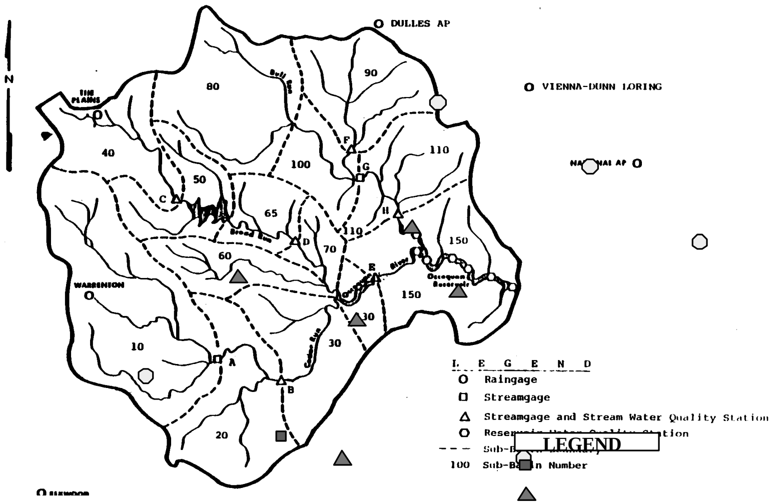
✦ Subwatersheds
  – location, physical characteristics/soils, gaging station locations, topographic features, management questions.

✦ Reaches
  – topographic features, stream morphology, cross-section data available

Calibration Issues:

- individual land use parameter determination
- location of gaging station data
- location of water quality monitoring information
- available information on stream systems

Model Configuration
Calibration Points Example



Calibration/Validation Procedures

- ✦ Hydrology - first and foremost
- ✦ Sediment - next
- ✦ Water quality - last (nitrogen, phosphorus, pesticides, DO, bacteria)

- ✦ Check list for model testing
  - water balance - is it all accounted for?
  - time series
  - annual total - stream flow & base flow
  - monthly/seasonal total
  - frequency duration curve
  - sediment and nutrients balance

Calibration Time Step

- Calibration sequence
  - annual water balance
  - seasonal variability
  - storm variability
    - time series plot
    - frequency duration curve
  - baseflow
  - overall time series

Calibration/Validation Statistics

- Mean and standard deviation of the simulated and measured data
- Slope, intercept and regression coefficient/coefficient of determination
- Nash-Suttcliffe Efficiency

Calibration/Validation Common Problems

- too little data - too short a monitoring period
- small range of conditions
  - only small storms
  - only storms during the spring...
- prediction of future conditions which are outside the model conditions
- calibration/validation does not adequately test separate pieces of model
  - accuracy of each land use category prediction
- calibration adjustments destroy physical representation of system by model
- adjustment of the wrong parameters

Calibration/Validation Suggested References

- Neitsch, S. L., J. G. Arnold, J. R. Kiniry and J. R. Willams. 2001. Soil and Water Assessment Tool – Manual, USDA-ARS Publications. pp: 341-354. http://www.brc.tamus.edu/swat/manual.

- Santhi, C., J. G. Arnold, J. R. Williams, W. A. Dugas, R. Srinivasan and L. M. Hauck. 2001. Validation of the SWAT Model on a Large River Basin with Point and Nonpoint Sources. J. American Water Resources Association 37(5): 1169-1188.

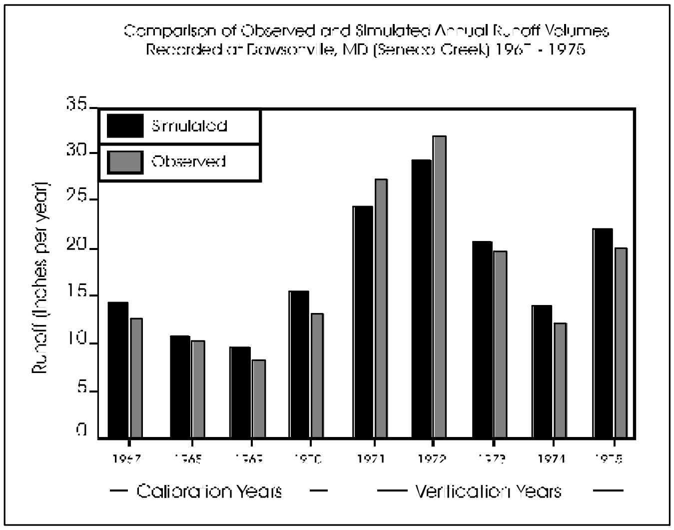
- Srinivasan, R., T. S. Ramanarayanan, J. G. Arnold and S. T. Bednarz. 1997. Large area hydrologic modeling and assessment: Part II - Model application. J. American Water Resources Association 34(1): 91-102.

- Arnold, J.G., R. S. Muttiah, R. Srinivasan and P. M. Allen. 2000. Regional estimation of baseflow and groundwater recharge in the upper Mississippi basin. J. Hydrology 227(2000): 21-40.

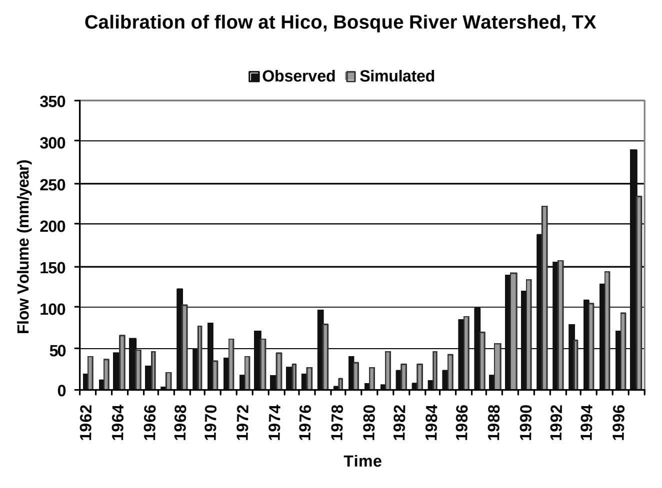
Hydrology Calibration Summary

- Key considerations
  - Water balance
    - overall amount
    - distribution among hydrologic components
  - Storm sequence
    - time lag or shifts
      - time of concentration, travel time
    - shape of hydrograph
      - peak
      - recession
      - consider antecedent conditions

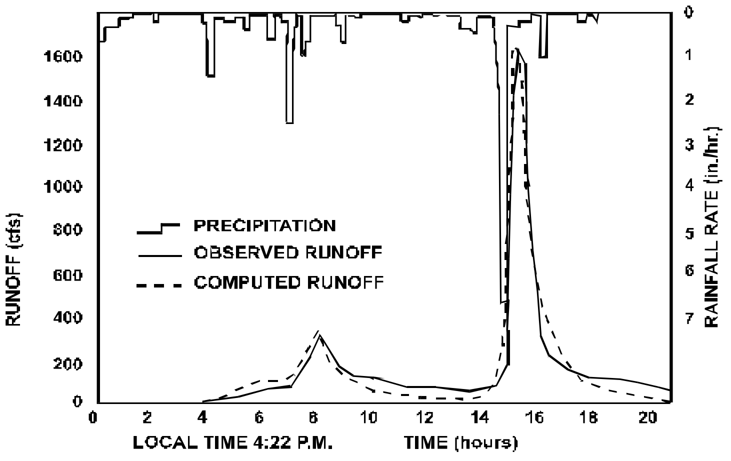
Example Calibration Plot



Example Calibration Plot

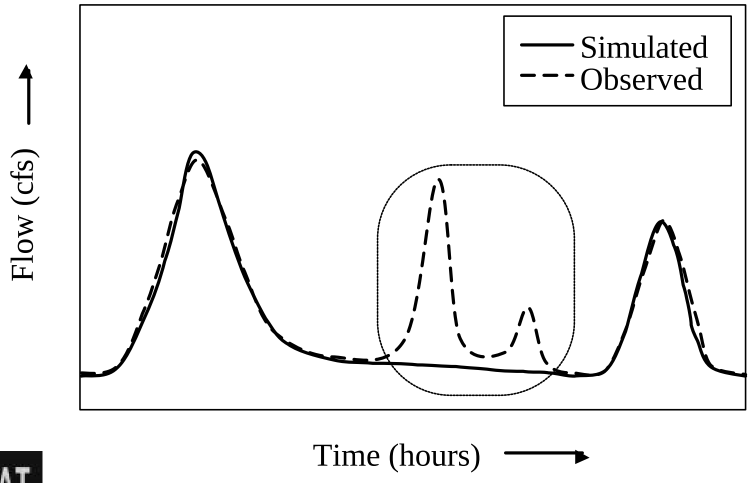

Calibration of flow at Hico, Bosque River Watershed, TX

Example Calibration Plot



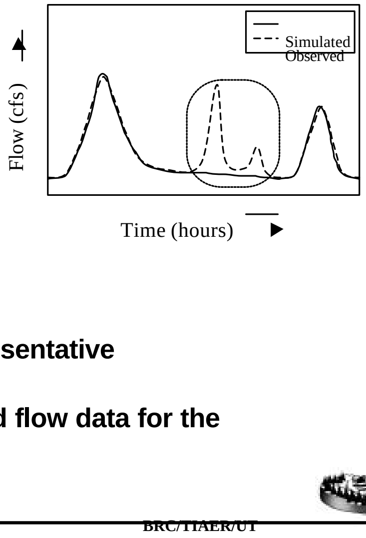
Comparison of Model Hydrograph (Using Interception-Infiltration Sub-models) with the Observed Hydrograph

Hydrologic Calibration
Scenario 1



Hydrologic Calibration
Model failed to simulate some peak flows

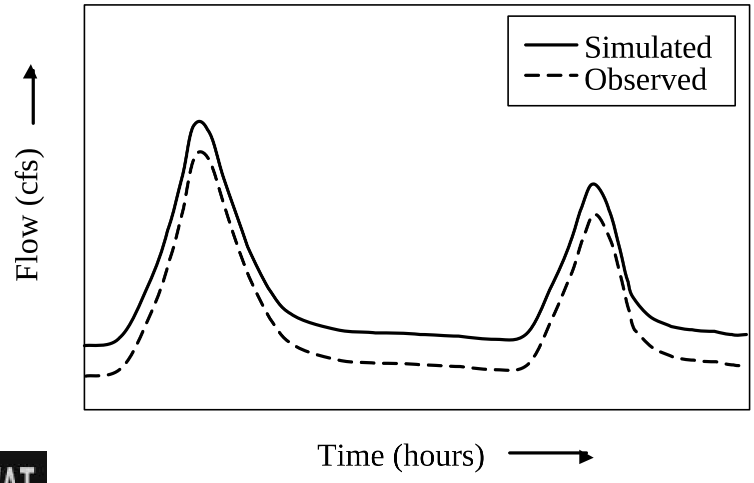
- Rainfall station is not representative
- Localized storm -no response
- Malfunctioning gages (precipitation or flow)



Solutions

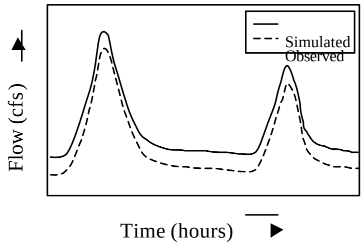
- Use precipitation data from representative meteorological stations
- Carefully review precipitation and flow data for the particular duration

Hydrologic Calibration
Scenario 2



Hydrologic Calibration
Model consistently over predicts the flow

- **High Surface flow**



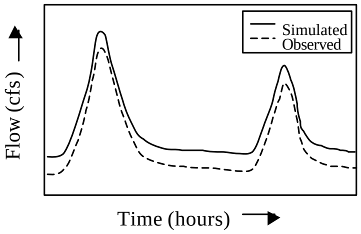
Solutions

- **Decrease curve number for different land uses (CN in .mgt)**
- **Soil available water (SOL_AWC in .sol)**
- **Soil evaporation compensation factor (ESCO in *.sub)**

Hydrologic Calibration

Model consistently over predicts the flow

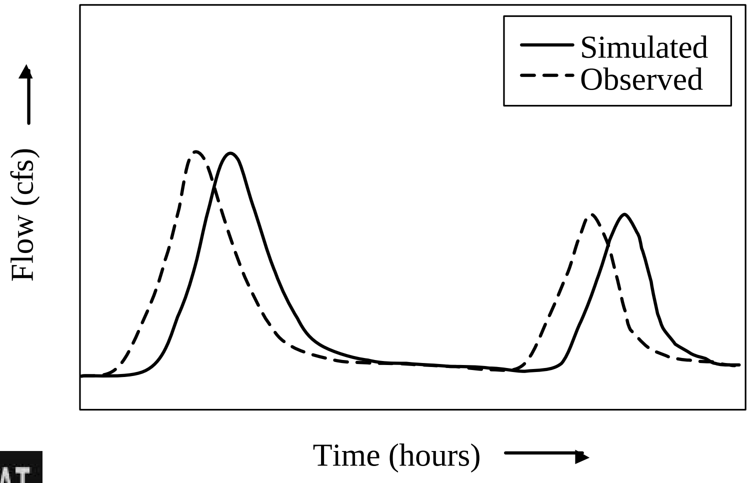
- ✦ **High base flow**
- ✦ **Too little evapotranspiration**



Solutions

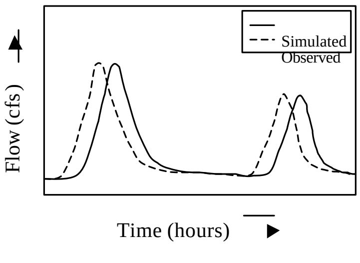
- ✦ **Increase deep percolation loss (Adjust threshold depth of water in shallow aquifer required for the base flow to occur) (GWQMN in .gw)**
- ✦ **Increase groundwater revap coefficient (GW_REVAP in .gw)**
- **Decrease theshold depth of water in shallow aquifer for revap to occur (REVAPMN in .gw)**

Hydrologic Calibration
Scenario 3



Hydrologic Calibration
Simulated flow follows the observed pattern but lags the actual flow consistently

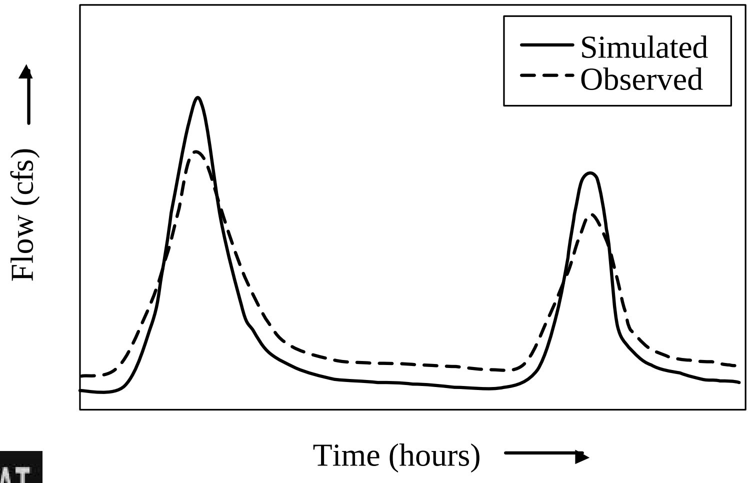
- **Time of concentration is too long**
- **Less than actual slope for overland flow**
- **Over estimated surface roughness**



Solutions

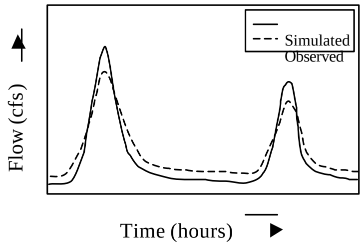
- **Adjust slope for over land flow (SLOPE)**
- **Adjust Manning's roughness coefficient (OV_N)**
- **Adjust the value of overland flow length (SLSUBBSN), if necessary**

Hydrologic Calibration
Scenario 4



Hydrologic Calibration
Simulated flow over predicts peak flows but under predicts all other times

- ✦ **Too little base flow**
- ✦ **Too high surface runoff**



Solutions

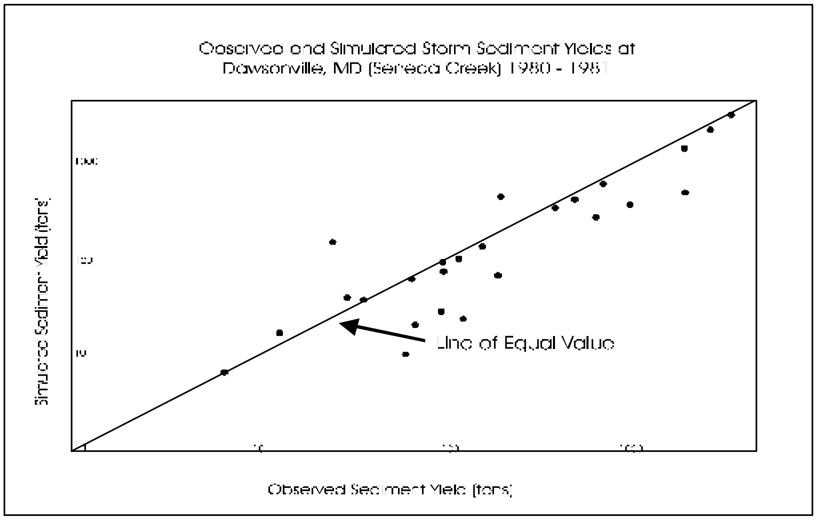
- ✦ **Adjust infiltration**
- ✦ **Adjust interflow**
- ✦ **Adjust base flow recession parameter**

Sediment Calibration Summary

- Key considerations
  - Sources of sediment loadings
    - Loadings from HRUs/Subbasins
    - Channel degradation/deposition
  - Sediment loading distribution
    - overall amount
    - Seasonal loading
      - distribution by storm sequence
        - rising and falling limb of hydrograph
        - peak concentration

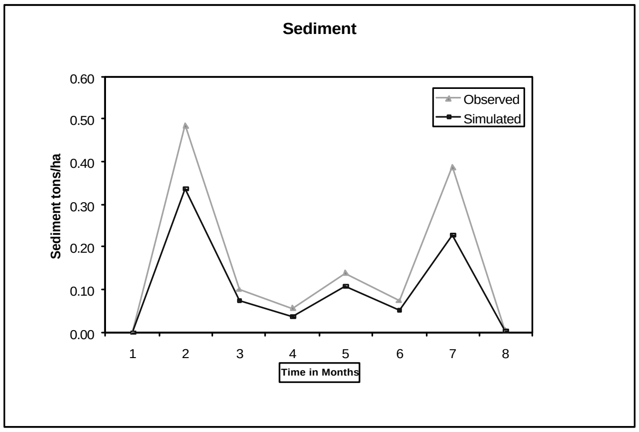
Srin@brc.tamus.edu BRC/TIAER/UT

Example Calibration Plot

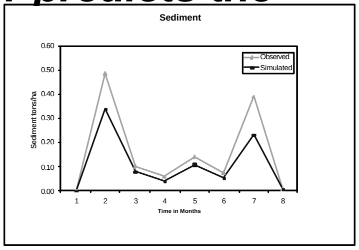


Srin@brc.tamus.edu BRC/TIAER/UT

Sediment Calibration
Scenario 1



Sediment Calibration
Model consistently under predicts the sediment

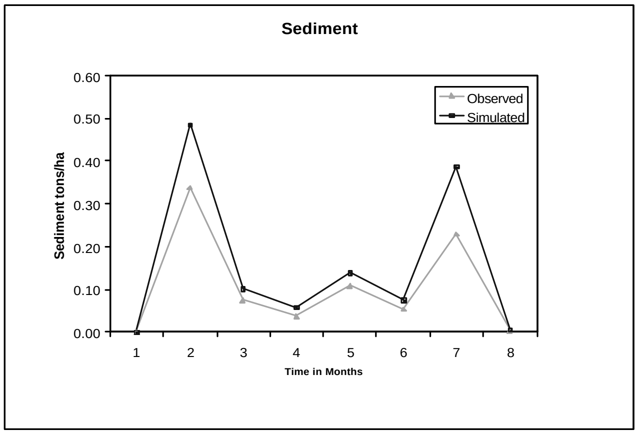


- **Low sediment yield**

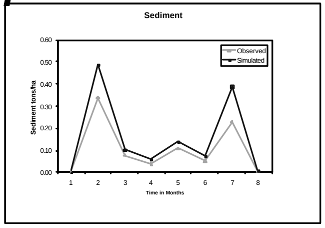
Solutions

- **Calibrate HRU/Subbasin Loadings**
  - **Adjust USLE crop management factor (P) (USLE_P in .sub)**
  - **Adjust USLE slope length factor (LS) (SLSUBBSN in .sub)**
  - **Adjust the slope of HRUs (SLOPE in .sub)**
  - **Adjust crop practice factor (C) for land use (USLE_C in crop.dat)**
  - **Verify tillage operations in *.mgt files and adjust crop residue coefficient (RSDCO) and bio-mixing efficiency (BIOMIX) in .bsn**
- **Calibrate Channel degradation/deposition**
  - **Linear and exponential parameters used for channel sediment routing (SPCON and SPEXP in .bsn)**
  - **Channel erodibility facor (CH_EROD in .rte)**
  - **Channel cover factor (CH_COV in .rte)**

Sediment Calibration
Scenario 2



Sediment Calibration
Model consistently over predicts the sediment



- **High sediment yield**

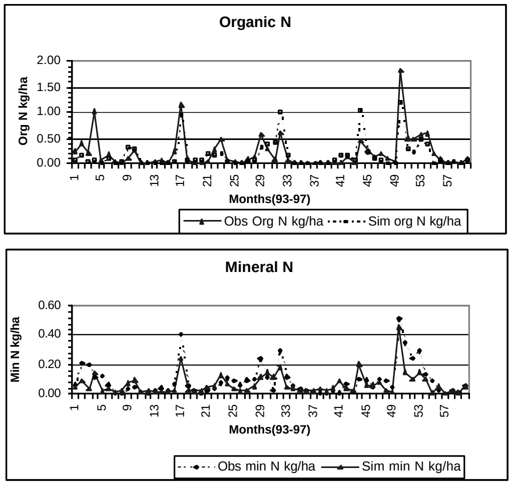
Solutions

- **Calibrate HRU/Subbasin Loadings**
  - **Adjust USLE crop management factor (P) (USLE_P in .sub)**
  - **Adjust USLE slope length factor (LS) (SLSUBBSN in .sub)**
  - **Adjust the slope of HRUs (SLOPE in .sub)**
  - **Adjust crop practice factor (C) for land use (USLE_C in crop.dat)**
  - **Verify tillage operations in *.mgt files and adjust crop residue coefficient (RSDCO) and bio-mixing efficiency (BIOMIX) in .bsn**
- **Calibrate Channel degradation/deposition**
  - **Linear and exponential parameters used for channel sediment routing (SPCON and SPEXP in .bsn)**
  - **Channel erodibility facor (CH_EROD in .rte)**
  - **Channel cover factor (CH_COV in .rte)**

Nutrients Calibration Summary

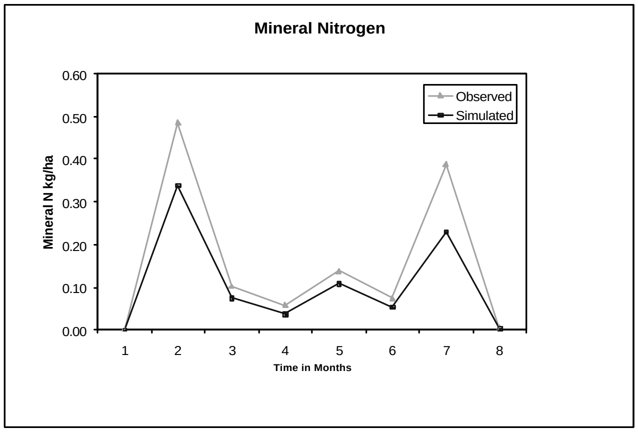
- ✦ Key considerations
  - – Sources of nutrients loadings
    - ◆ Loadings from HRUs/Subbasins
    - ◆ In-stream processes
  - – Nutrient loading distribution
    - ◆ overall amount
    - ◆ Seasonal loading
      - – distribution by storm sequence
        - • rising and falling limb of hydrograph
        - • peak concentration

Example Calibration Plot

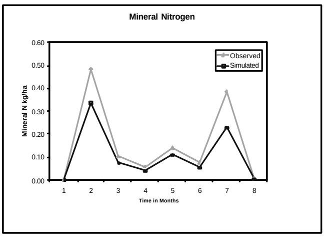


Monthly calibration of nitrogen at Hico, Bosque Watershed, TX

Mineral Nitrogen Calibration
Scenario 1



Mineral Nitrogen Calibration
Model consistently under predicts the mineral nitrogen

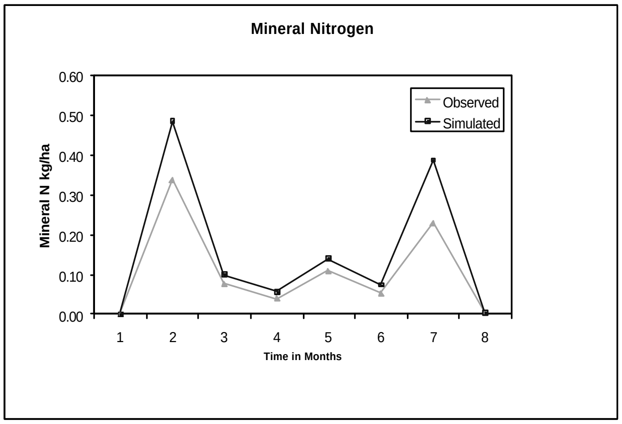


- ✦ Low mineral nitrogen loading

Solutions

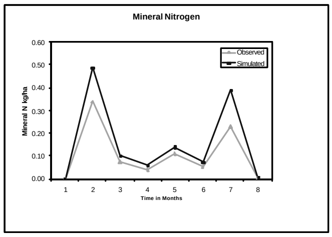
- ✦ Calibrate mineral nitrogen loadings
  - – Adjust initial concentration of the nutrient in soils (SOL_NO3 in .sol)
  - – Verify fertilizer application rates and adjust fertilizer application fraction to surface layer as 0.20 (FRT_LY1 in .mgt)
  - – Verify tillage operations in *.mgt files and adjust crop residue coefficient (RSDCO) and bio-mixing efficiency (BIOMIX) in .bsn
  - – Adjust nitrogen percolation coefficient (NPERCO in .bsn)
- ✦ Calibrate in-stream mineral nitrogen processes
  - – Adjust fraction of algal biomass that is as nitrogen for water quality (AI1 in.wwq)

Mineral Nitrogen Calibration Scenario 2



Mineral Nitrogen Calibration

Model consistently over predicts the mineral nitrogen

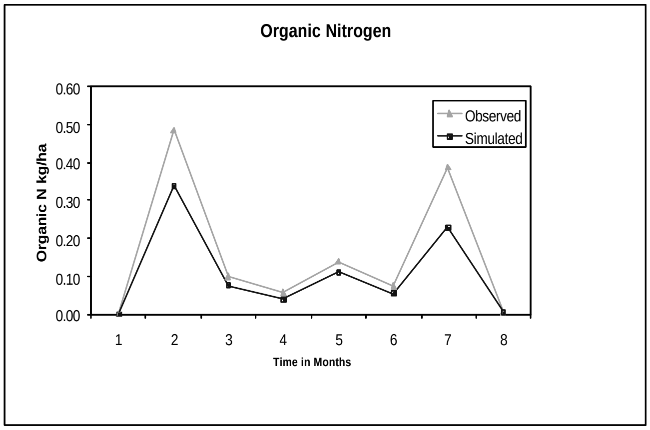


- **High mineral nitrogen loading**

Solutions

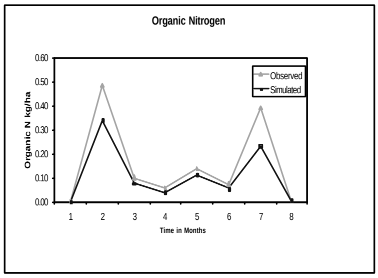
- **Calibrate mineral nitrogen loadings**
  - **Adjust initial concentration of the nutrient in soils (SOL_NO3 in .sol)**
  - **Verify fertilizer application rates and adjust fertilizer application fraction to surface layer as 0.20 (FRT_LY1 in .mgt)**
  - **Verify tillage operations in *.mgt files and adjust crop residue coefficient (RSDCO) and bio-mixing efficiency (BIOMIX) in .bsn**
  - **Adjust nitrogen percolation coefficient (NPERCO in .bsn)**
- **Calibrate in-stream mineral nitrogen processes**
  - **Adjust fraction of algal biomass that is as nitrogen for water quality (AI1 in.wwq)**

Organic Nitrogen Calibration Scenario 1



Organic Nitrogen Calibration

Model consistently under predicts the organic nitrogen

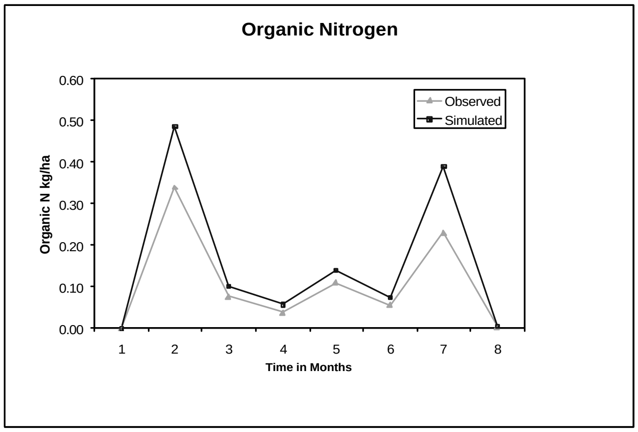


- ✦ **Low Organic nitrogen loading**

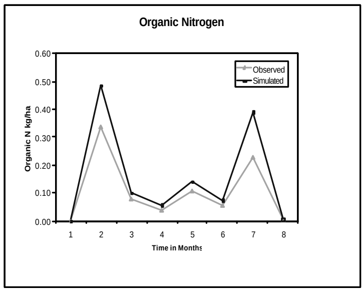
Solutions

- ✦ **Calibrate organic nitrogen loadings**
  - **Adjust initial concentration of the nutrient in soils (SOL_ORGN in .sol)**
  - **Verify fertilizer application rates and adjust fertilizer application fraction to surface layer as 0.20 (FRT_LY1 in .mgt)**
- ✦ **Calibrate in-stream organic nitrogen processes**
  - **Adjust fraction of algal biomass that is as nitrogen for water quality (AI1 in.wwq)**

Organic Nitrogen Calibration
Scenario 2



Organic Nitrogen Calibration
Model consistently over predicts the organic nitrogen

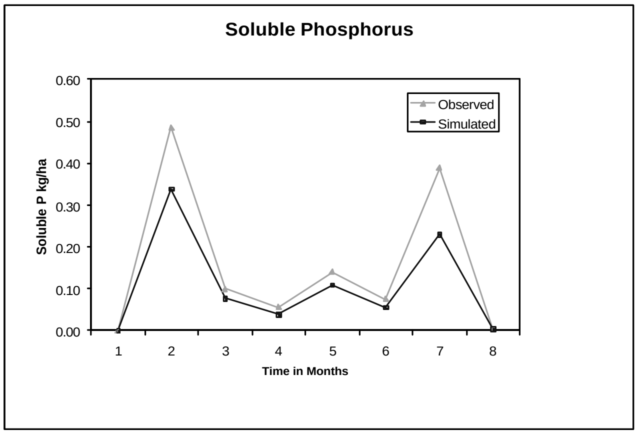


- **High Organic nitrogen loading**

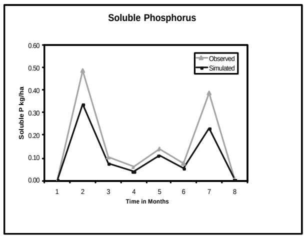
Solutions

- **Calibrate organic nitrogen loadings**
  - **Adjust initial concentration of the nutrient in soils (SOL_ORGN in .sol)**
  - **Verify fertilizer application rates and adjust fertilizer application fraction to surface layer as 0.20 (FRT_LY1 in .mgt)**
- **Calibrate in-stream organic nitrogen processes**
  - **Adjust fraction of algal biomass that is as nitrogen for water quality (AI1 in.wwq)**

Soluble Phosphorus Calibration
Scenario 1



Soluble Phosphorus Calibration
Model consistently under predicts the soluble phosphorus

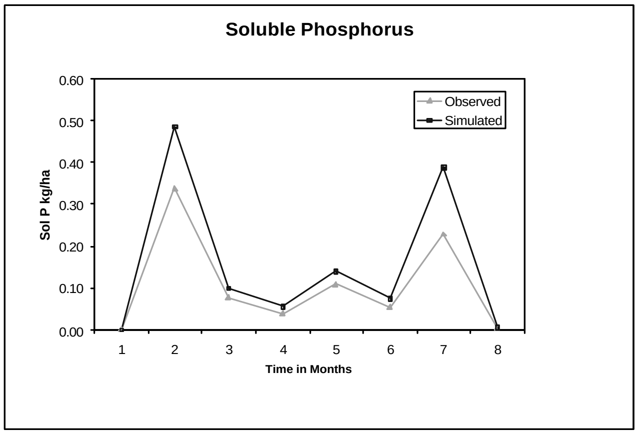


- ✦ **Low soluble phosphorus loading**

Solutions

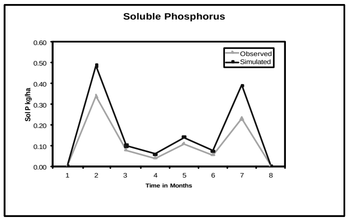
- ✦ **Calibrate soluble phosphorus loadings**
  - **Adjust initial concentration of the nutrient in soils (SOL_MINP in .sol)**
  - **Verify fertilizer application rates and adjust fertilizer application fraction to surface layer as 0.20 (FRT_LY1 in .mgt)**
  - **Verify tillage operations in *.mgt files and adjust crop residue coefficient (RSDCO) and bio-mixing efficiency (BIOMIX) in .bsn**
  - **Adjust phosphorus percolation coefficient (PPERCO in .bsn)**
  - **Adjust phosphorus soil partitioning coefficient (PHOSKD in .bsn)**
- ✦ **Calibrate in-stream soluble phosphorus processes**
  - **Adjust fraction of algal biomass that is as phosphorus for water quality (AI2 in.wwq)**

Soluble Phosphorus Calibration Scenario 2



Soluble Phosphorus Calibration

Model consistently over predicts the soluble phosphorus

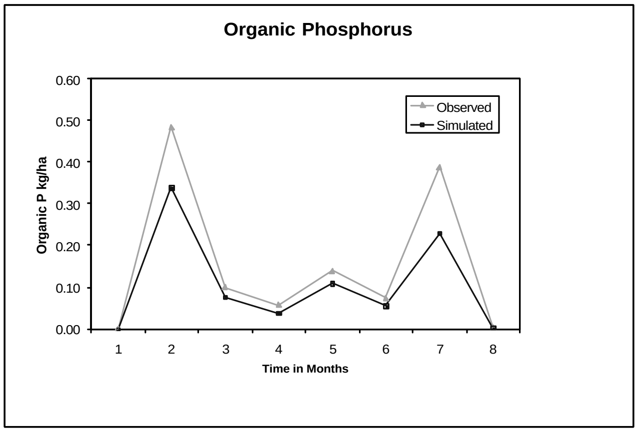


- High soluble phosphorus loading

Solutions

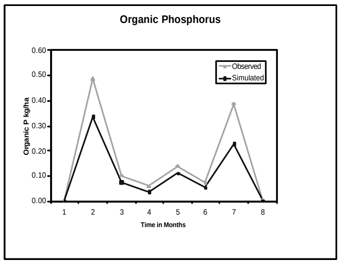
- Calibrate soluble phosphorus loadings
  - Adjust initial concentration of the nutrient in soils (SOL_MINP in .sol)
  - Verify fertilizer application rates and adjust fertilizer application fraction to surface layer as 0.20 (FRT_LY1 in .mgt)
  - Verify tillage operations in *.mgt files and adjust crop residue coefficient (RSDCO) and bio-mixing efficiency (BIOMIX) in .bsn
  - Adjust phosphorus percolation coefficient (PPERCO in .bsn)
  - Adjust phosphorus soil partitioning coefficient (PHOSKD in .bsn)
- Calibrate in-stream soluble phosphorus processes
  - Adjust fraction of algal biomass that is as phosphorus for water quality (AI2 in.wwq)

Organic Phosphorus Calibration Scenario 1



Organic Phosphorus Calibration

Model consistently under predicts the organic phosphorus

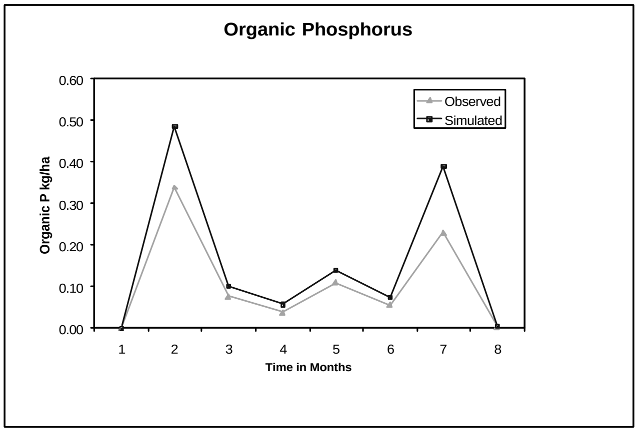


- Low organic phosphorus loading

Solutions

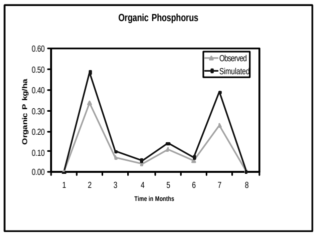
- Calibrate organic phosphorus loadings
  - Adjust initial concentration of the nutrient in soils (SOL_ORGP in .sol)
  - Verify fertilizer application rates and adjust fertilizer application fraction to surface layer as 0.20 (FRT_LY1 in .mgt)
- Calibrate in-stream organic phosphorus processes
  - Adjust fraction of algal biomass that is as phosphorus for water quality (AI2 in.wwq)

Organic Phosphorus Calibration Scenario 2



Organic Phosphorus Calibration

Model consistently over predicts the organic phosphorus



- **High organic phosphorus loading**

Solutions

- **Calibrate organic phosphorus loadings**
  - **Adjust initial concentration of the nutrient in soils (SOL_ORGP in .sol)**
  - **Verify fertilizer application rates and adjust fertilizer application fraction to surface layer as 0.20 (FRT_LY1 in .mgt)**
- **Calibrate in-stream organic phosphorus processes**
  - **Adjust fraction of algal biomass that is as phosphorus for water quality (AI2 in.wwq)**

Tables of Runoff Curve Number Values[‡]

Table 1: Runoff curve numbers for cultivated agricultural lands

Cover			Hydrologic Soil Group			
Land Use	**Treatment or practice**	**Hydrologic condition**	**A**	**B**	**C**	**D**
Fallow	Bare soil	- - - -	77	86	91	94
	Crop residue cover[*]	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row w/ residue	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured w/ residue	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced w/ residue	Poor	65	73	79	81
		Good	61	70	77	80
Small grains	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row w/ residue	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured w/ residue	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced w/ residue	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

[‡] These tables are reproduced from *Urban Hydrology for Small Watersheds*, USDA Soil Conservation Service Engineering Division, Technical Release 55, June 1986.

[*] Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

Table 2: Runoff curve numbers for other agricultural lands

Cover		**Hydrologic Soil Group**			
Cover Type	**Hydrologic condition**	**A**	**B**	**C**	**D**
Pasture, grassland, or range—continuous forage for grazing[1]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	- - - -	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element[2]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods—grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[3]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	- - - -	59	74	82	86

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[1] *Poor:* < 50% ground cover or heavily grazed with no mulch
Fair: 50 to 75% ground cover and not heavily grazed
Good: > 75% ground cover and lightly or only occasionally grazed

[2] *Poor:* < 50% ground cover
Fair: 50 to 75% ground cover
Good: > 75% ground cover

[3] *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 3: Runoff curve numbers for urban areas

Cover			**Hydrologic Soil Group**			
Cover Type	**Hydrologic condition**	**Average % impervious area**	**A**	**B**	**C**	**D**
Fully developed urban areas						
Open spaces (lawns, parks, golf courses, cemeteries, etc.)[4]	Poor		68	79	86	89
	Fair		49	69	79	84
	Good		39	61	74	80
Impervious areas:						
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	- - - -		98	98	98	98
Paved streets and roads; curbs and storm sewers (excluding right-of-way)	- - - -		98	98	98	98
Paved streets and roads; open ditches (including right-of-way)	- - - -		83	89	92	93
Gravel streets and roads (including right-of-way)	- - - -		76	85	89	91
Dirt streets and roads (including right-of way)	- - - -		72	82	87	89
Urban districts:						
Commercial and business		85%	89	92	94	95
Industrial		72%	81	88	91	93
Residential Districts by average lot size:						
1/8 acre (0.05 ha) or less (town houses)		65%	77	85	90	92
1/4 acre (0.10 ha)		38%	61	75	83	87
1/3 acre (0.13 ha)		30%	57	72	81	86
1/2 acre (0.20 ha)		25%	54	70	80	85
1 acre (0.40 ha)		20%	51	68	79	84
2 acres (0.81 ha)		12%	46	65	77	82
Developing urban areas:						
Newly graded areas (pervious areas only, no vegetation)			77	86	91	94

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[4] *Poor:* grass cover < 50%
Fair: grass cover 50 to 75%
Good: grass cover > 75%

Table 4: Runoff curve numbers for arid and semiarid rangelands

Cover		**Hydrologic Soil Group**			
Cover Type	**Hydrologic condition**[5]	**A**	**B**	**C**	**D**
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both: grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbrush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

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[5] *Poor:* < 30% ground cover (litter, grass, and brush overstory)
Fair: 30 to 70% ground cover
Good: > 70% ground cover

Curve Number Calibration

Table 1: Guideline runoff curve number ranges

	Hydrologic Soil Group			
Land Cover Category	**A**	**B**	**C**	**D**
Row crop	61-72	70-81	77-88	80-91
Small grain/close grown crop	58-65	69-76	77-84	80-88
Perennial grasses	30-68	58-79	71-86	78-89
Annual grasses (close-seeded legumes)	51-66	67-77	76-85	80-89
Range	39-68	61-79	74-86	80-89
Semiarid/arid range	39-74	62-80	74-87	85-93
Brush	30-48	48-67	65-77	73-83
Woods	25-45	55-66	70-77	77-83
Orchard/tree farm	32-57	58-73	72-82	79-86
Urban	46-89	65-92	77-94	82-95

APPENDIX A

DATABASES

The following sections describe the source of input for databases included with the model and any assumptions used in compilation of the database. Also, a methodology for appending additional information to the various databases is summarized.

A.1 LAND COVER/PLANT GROWTH DATABASE

The land cover/plant growth database contains information needed by SWAT to simulate the growth of a particular land cover. The growth parameters in the plant growth database define plant growth under ideal conditions and quantify the impact of some stresses on plant growth.

Table A-1 lists all the default plant species and Table A-2 lists all the generic land covers included in the database. When adding a new plant/land cover to the database, a review of existing literature should provide most of the parameter values needed to simulate plant growth. For users that plan to collect the data directly, the following sections briefly describe the methods used to obtain the plant growth parameters needed by SWAT.

Table A-1: Plants included in plant growth database.

Common Name	**Plant Code**	**Taxonomic Name**	**Plant type**
Corn	CORN	*Zea mays* L.	warm season annual
Corn silage	CSIL	*Zea mays* L.	warm season annual
Sweet corn	SCRN	*Zea mays* L. *saccharata*	warm season annual
Eastern gamagrass	EGAM	*Tripsacum dactyloides* (L.) L.	perennial
Grain sorghum	GRSG	*Sorghum bicolor* L. (Moench)	warm season annual
Sorghum hay	SGHY	*Sorghum bicolor* L. (Moench)	warm season annual
Johnsongrass	JHGR	*Sorghum halepense* (L.) Pers.	perennial
Sugarcane	SUGC	*Saccharum officinarum* L.	perennial
Spring wheat	SWHT	*Triticum aestivum* L.	cool season annual
Winter wheat	WWHT	*Triticum aestivum* L.	cool season annual
Durum wheat	DWHT	*Triticum durum* Desf.	cool season annual
Rye	RYE	*Secale cereale* L.	cool season annual
Spring barley	BARL	*Hordeum vulgare* L.	cool season annual
Oats	OATS	*Avena sativa* L.	cool season annual
Rice	RICE	*Oryza sativa* L.	warm season annual
Pearl millet	PMIL	*Pennisetum glaucum* L.	warm season annual
Timothy	TIMO	*Phleum pratense* L.	perennial
Smooth bromegrass	BROS	*Bromus inermis* Leysser	perennial
Meadow bromegrass	BROM	*Bromus biebersteinii* Roemer & Schultes	perennial
Tall fescue	FESC	*Festuca arundinacea*	perennial
Kentucky bluegrass	BLUG	*Poa pratensis*	perennial
Bermudagrass	BERM	*Cynodon dactylon*	perennial
Crested wheatgrass	CWGR	*Agropyron cristatum* (L.) Gaertner	perennial
Western wheatgrass	WWGR	*Agropyron smithii* (Rydb.) Gould	perennial
Slender wheatgrass	SWGR	*Agropyron trachycaulum* Malte	perennial

Common Name	Plant Code	Taxonomic Name	Plant type
Italian (annual) ryegrass	RYEG	*Lolium multiflorum* Lam.	cool season annual
Russian wildrye	RYER	*Psathyrostachys juncea* (Fisch.) Nevski	perennial
Altai wildrye	RYEA	*Leymus angustus* (Trin.) Pilger	perennial
Sideoats grama	SIDE	*Bouteloua curtipendula* (Michaux) Torrey	perennial
Big bluestem	BBLS	*Andropogon gerardii* Vitman	perennial
Little bluestem	LBLS	*Schizachyrium scoparium* (Michaux) Nash	perennial
Alamo switchgrass	SWCH	*Panicum virgatum* L.	perennial
Indiangrass	INDN	*Sorghastrum nutans* (L.) Nash	perennial
Alfalfa	ALFA	*Medicago sativa* L.	perennial legume
Sweetclover	CLVS	*Melilotus alba* Med.	perennial legume
Red clover	CLVR	*Trifolium pratense* L.	cool season annual legume
Alsike clover	CLVA	*Trifolium hybridum* L.	perennial legume
Soybean	SOYB	*Glycine max* L., Merr.	warm season annual legume
Cowpeas	CWPS	*Vigna sinensis*	warm season annual legume
Mung bean	MUNG	*Phaseolus aureus* Roxb.	warm season annual legume
Lima beans	LIMA	*Phaseolus lunatus* L.	warm season annual legume
Lentils	LENT	*Lens esculenta* Moench J.	warm season annual legume
Peanut	PNUT	*Arachis hypogaea* L.	warm season annual legume
Field peas	FPEA	*Pisum arvense* L.	cool season annual legume
Garden or canning peas	PEAS	*Pisum sativum* L. ssp. *sativum*	cool season annual legume
Sesbania	SESB	*Sesbania macrocarpa* Muhl [*exaltata*]	warm season annual legume
Flax	FLAX	*Linum usitatissum* L.	cool season annual
Upland cotton (harvested with stripper)	COTS	*Gossypium hirsutum* L.	warm season annual
Upland cotton (harvested with picker)	COTP	*Gossypium hirsutum* L.	warm season annual
Tobacco	TOBC	*Nicotiana tabacum* L.	warm season annual
Sugarbeet	SGBT	*Beta vulgaris (saccharifera)* L.	warm season annual
Potato	POTA	*Solanum tuberosum* L.	cool season annual
Sweetpotato	SPOT	*Ipomoea batatas* Lam.	warm season annual
Carrot	CRRT	*Daucus carota* L. subsp. *sativus* (Hoffm.) Arcang.	cool season annual
Onion	ONIO	*Allium cepa* L. var *cepa*	cool season annual
Sunflower	SUNF	*Helianthus annuus* L.	warm season annual
Spring canola-Polish	CANP	*Brassica campestris*	cool season annual
Spring canola-Argentine	CANA	*Brassica napus*	cool season annual
Asparagus	ASPR	*Asparagus officinalis* L.	perennial
Broccoli	BROC	*Brassica oleracea* L. var *italica* Plenck.	cool season annual
Cabbage	CABG	*Brassica oleracea* L. var *capitata* L.	perennial
Cauliflower	CAUF	*Brassica oleracea* L. var *botrytis* L.	cool season annual
Celery	CELR	*Apium graveolens* L. var *dulce* (Mill.) Pers.	perennial
Head lettuce	LETT	*Lactuca sativa* L. var *capitata* L.	cool season annual
Spinach	SPIN	*Spinacia oleracea* L.	cool season annual
Green beans	GRBN	*Phaseolus vulgaris*	warm season annual legume
Cucumber	CUCM	*Cucumis sativus* L.	warm season annual

Common Name	Plant Code	Taxonomic Name	Plant Type
Eggplant	EGGP	*Solanum melongena* L.	warm season annual
Cantaloupe	CANT	*Cucumis melo* L. Cantaloupensis group	warm season annual
Honeydew melon	HMEL	*Cucumis melo* L. Inodorus group	warm season annual
Watermelon	WMEL	*Citrullus lanatus* (Thunb.) Matsum and Nakai	warm season annual
Bell pepper	PEPR	*Capsicum annuum* L. Grossum group	warm season annual
Strawberry	STRW	*Fragaria* X *Ananassa* Duchesne.	perennial
Tomato	TOMA	*Lycopersicon esculentum* Mill.	warm season annual
Apple	APPL	*Malus domestica* Borkh.	trees
Pine	PINE	*Pinus*	trees
Oak	OAK	*Quercus*	trees
Poplar	POPL	*Populus*	trees
Honey mesquite	MESQ	*Prosopis glandulosa* Torr. var. *glandulosa*	trees

Table A-2: Generic Land Covers included in database.

Name	Plant Code	Origin of Plant Growth Values	Plant Type
Agricultural Land-Generic	AGRL	use values for Grain Sorghum	warm season annual
Agricultural Land-Row Crops	AGRR	use values for Corn	warm season annual
Agricultual Land-Close-grown	AGRC	use values for Winter Wheat	cool season annual
Orchard	ORCD	use values for Apples	trees
Hay[‡]	HAY	use values for Bermudagrass	perennial
Forest-mixed	FRST	use values for Oak	trees
Forest-deciduous	FRSD	use values for Oak	trees
Forest-evergreen	FRSE	use values for Pine	trees
Wetlands	WETL	use values for Alamo Switchgrass	perennial
Wetlands-forested	WETF	use values for Oak	trees
Wetlands-nonforested	WETN	use values for Alamo Switchgrass	perennial
Pasture[‡]	PAST	use values for Bermudagrass	perennial
Summer pasture	SPAS	use values for Bermudagrass	perennial
Winter pasture	WPAS	use values for Fescue	perennial
Range-grasses	RNGE	use values for Little Bluestem (LAI_{max}=2.5)	perennial
Range-brush	RNGB	use values for Little Bluestem (LAI_{max}=2.0)	perennial
Range-southwestern US	SWRN	use values for Little Bluestem (LAI_{max}=1.5)	perennial
Water[*]	WATR		not applicable

[‡] The Bermudagrass parameters input for Hay and Pasture are valid only in latitudes less than 35 to 37°. At higher latitudes, Fescue parameters should be used to model generic Hay and Pasture.

[*] Water was included in the plant growth database in order to process USGS map layers in the HUMUS project. This land cover should ***not*** be used as a land cover in an HRU. To model water bodies, create ponds, wetlands or reservoirs.

A.1.1 LAND COVER/PLANT TYPES IN DATABASE

When compiling the list of plants in the default database, we attempted to include the most economically important plants as well as those that are widely distributed in the landscape. This list is by no means exhaustive and users may need to add plants to the list. A number of generic land cover types were also compiled to facilitate linkage of land use/land cover maps to SWAT plant categories. Because of the broad nature of the some of the categories, a number of assumptions had to be made when compiling the plant growth parameter values. The user is strongly recommended to use parameters for a specific plant rather than those of the generic land covers any time information about plant types is available for the region being modeled.

Plant code (CPNM): The 4-letter codes in the plant growth and urban databases are used by the GIS interfaces to link land use/land cover maps to SWAT plant types. When adding a new plant species or land cover category, the four letter code for the new plant must be unique.

Land cover/plant classification (IDC): SWAT groups plants into seven categories: warm season annual legume, cold season annual legume, perennial legume, warm season annual, cold season annual, perennial and trees. (Biannual plants are classified as perennials.) The differences between the categories as modeled by SWAT are summarized in Chapter 17. Plant classifications can be easily found in horticulture books that summarize characteristics for different species. The classifications assigned to the plants in Table A-1 were obtained from Martin et al. (1976) and Bailey (1935).

A.1.2 TEMPERATURE RESPONSES

SWAT uses the base temperature (T_BASE) to calculate the number of heat units accrued every day. The minimum or base temperature for plant growth varies with growth stage of the plant. However, this variation is ignored by the model—SWAT uses the same base temperature throughout the growing season.

The optimal temperature (T_OPT) is used to calculate temperature stress for the plant during the growing season (temperature stress is the only calculation in which optimal temperature is used). Chapter 19 reviews the influence of optimal temperature on plant growth.

Base temperature is measured by growing plants in growth chambers at several different temperatures. The rate of leaf tip appearance as a function of temperature is plotted. Extrapolating the line to the leaf tip appearance rate of 0.0 leaves/day gives the base or minimum temperature for plant growth. Figure A-1 plots data for corn. (Note that the line intersects the x-axis at 8°C.)

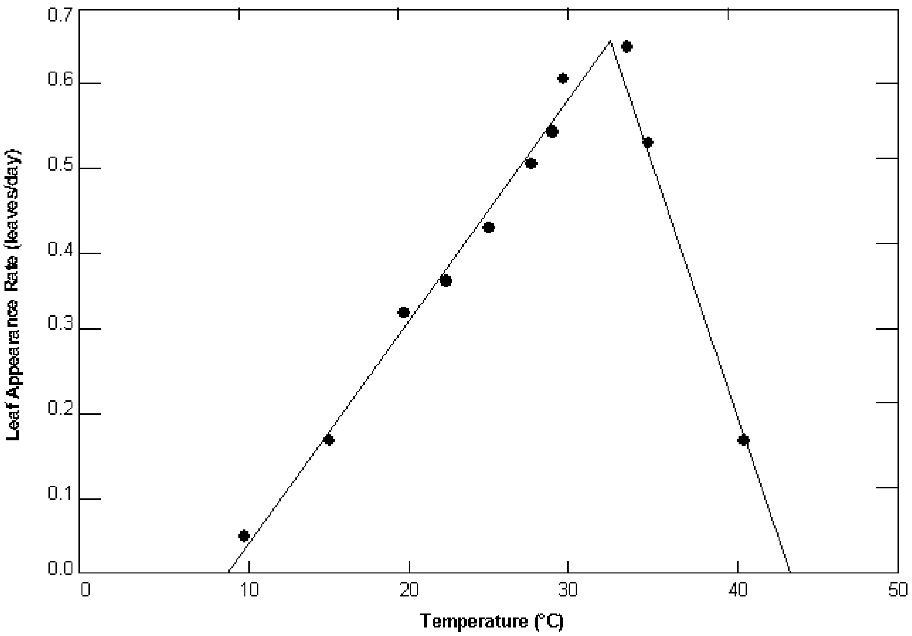

Figure A-1: Rate of leaf tip appearance as a function of temperature for corn (After Kiniry et al, 1991).

Optimal temperature for plant growth is difficult to measure directly. Looking at Figure A-1, one might be tempted to select the temperature corresponding to the peak of the plot as the optimal temperature. This would not be correct. The peak of the plot defines the optimal temperature for leaf development—not for plant growth. If an optimal temperature cannot be obtained through a review of literature, use the optimal temperature listed for a plant already in the database with similar growth habits.

Review of temperatures for many different plants have provided generic values for base and optimal temperatures as a function of growing season. In situations, where temperature information is unavailable, these values may be used. For warm season plants, the generic base temperature is ~8ºC and the generic optimal temperature is ~25ºC. For cool season plants, the generic base temperature is ~0ºC and the generic optimal temperature is ~13ºC.

Base and optimal temperatures for the plants included in the database are listed in Table A-3.

Table A-3: Temperature parameters for plants included in plant growth database.

Common Name	**Plant Code**	T_{base}	T_{opt}	**Reference**
Corn	CORN	8	25	(Kiniry et al, 1995)
Corn silage	CSIL	8	25	(Kiniry et al, 1995)
Sweet corn	SCRN	12	24	(Hackett and Carolane, 1982)
Eastern gamagrass	EGAM	12	25	(Kiniry, personal comm., 2001)
Grain sorghum	GRSG	11	30	(Kiniry et al, 1992a)
Sorghum hay	SGHY	11	30	(Kiniry et al, 1992a)
Johnsongrass	JHGR	11	30	(Kiniry et al, 1992a)
Sugarcane	SUGC	11	25	(Kiniry and Williams, 1994)
Spring wheat	SWHT	0	18	(Kiniry et al, 1995)
Winter wheat	WWHT	0	18	(Kiniry et al, 1995)
Durum wheat	DWHT	0	15	estimated
Rye	RYE	0	12.5	estimated
Spring barley	BARL	0	25	(Kiniry et al, 1995)
Oats	OATS	0	15	(Kiniry, personal comm., 2001)
Rice	RICE	10	25	(Martin et al, 1976)
Pearl millet	PMIL	10	30	(Kiniry et al, 1991)
Timothy	TIMO	8	25	estimated
Smooth bromegrass	BROS	8	25	estimated
Meadow bromegrass	BROM	6	25	(Kiniry et al, 1995)
Tall fescue	FESC	0	15	estimated
Kentucky bluegrass	BLUG	12	25	(Kiniry, personal comm., 2001)
Bermudagrass	BERM	12	25	(Kiniry, personal comm., 2001)
Crested wheatgrass	CWGR	6	25	(Kiniry et al, 1995)
Western wheatgrass	WWGR	6	25	(Kiniry et al, 1995)
Slender wheatgrass	SWGR	8	25	estimated
Italian (annual) ryegrass	RYEG	0	18	estimated
Russian wildrye	RYER	0	15	(Kiniry et al, 1995)
Altai wildrye	RYEA	0	15	(Kiniry et al, 1995)
Sideoats grama	SIDE	12	25	(Kiniry, personal comm., 2001)
Big bluestem	BBLS	12	25	(Kiniry, personal comm., 2001)
Little bluestem	LBLS	12	25	(Kiniry, personal comm., 2001)
Alamo switchgrass	SWCH	12	25	(Kiniry et al, 1996)
Indiangrass	INDN	12	25	(Kiniry, personal comm., 2001)
Alfalfa	ALFA	4	20	(Kiniry, personal comm., 2001)
Sweetclover	CLVS	1	15	estimated

Common Name	**Plant Code**	T_{base}	T_{opt}	**Reference**
Red clover	CLVR	1	15	estimated
Alsike clover	CLVA	1	15	estimated
Soybean	SOYB	10	25	(Kiniry et al, 1992a)
Cowpeas	CWPS	14	28	(Kiniry et al, 1991; Hackett and Carolane, 1982)
Mung bean	MUNG	15	30	(Hackett and Carolane, 1982)
Lima beans	LIMA	18	26	(Hackett and Carolane, 1982)
Lentils	LENT	3	20	(Hackett and Carolane, 1982)
Peanut	PNUT	14	27	(Hackett and Carolane, 1982)
Field peas	FPEA	1	15	estimated
Garden or canning peas	PEAS	5	14	(Hackett and Carolane, 1982)
Sesbania	SESB	10	25	estimated
Flax	FLAX	5	22.5	estimated
Upland cotton (harvested with stripper)	COTS	15	30	(Martin et al, 1976)
Upland cotton (harvested with picker)	COTP	15	30	(Martin et al, 1976)
Tobacco	TOBC	10	25	(Martin et al, 1976)
Sugarbeet	SGBT	4	18	(Kiniry and Williams, 1994)
Potato	POTA	7	22	(Hackett and Carolane, 1982)
Sweetpotato	SPOT	14	24	(estimated; Hackett and Carolane, 1982)
Carrot	CRRT	7	24	(Kiniry and Williams, 1994)
Onion	ONIO	7	19	(Hackett and Carolane, 1982; Kiniry and Williams, 1994)
Sunflower	SUNF	6	25	(Kiniry et al, 1992b; Kiniry, personal communication, 2001)
Spring canola-Polish	CANP	5	21	(Kiniry et al, 1995)
Spring canola-Argentine	CANA	5	21	(Kiniry et al, 1995)
Asparagus	ASPR	10	24	(Hackett and Carolane, 1982)
Broccoli	BROC	4	18	(Hackett and Carolane, 1982)
Cabbage	CABG	1	18	(Hackett and Carolane, 1982)
Cauliflower	CAUF	5	18	(Hackett and Carolane, 1982)
Celery	CELR	4	22	(Hackett and Carolane, 1982)
Head lettuce	LETT	7	18	(Hackett and Carolane, 1982)
Spinach	SPIN	4	24	(Kiniry and Williams, 1994)
Green beans	GRBN	10	19	(Hackett and Carolane, 1982)
Cucumber	CUCM	16	32	(Kiniry and Williams, 1994)
Eggplant	EGGP	15	26	(Hackett and Carolane, 1982)
Cantaloupe	CANT	15	35	(Hackett and Carolane, 1982; Kiniry and Williams, 1994)
Honeydew melon	HMEL	16	36	(Kiniry and Williams, 1994)
Watermelon	WMEL	18	35	(Kiniry and Williams, 1994)
Bell pepper	PEPR	18	27	(Kiniry and Williams, 1994)
Strawberry	STRW	10	32	(Kiniry and Williams, 1994)
Tomato	TOMA	10	22	(Hackett and Carolane, 1982)
Apple	APPL	7	20	(Hackett and Carolane, 1982)

Common Name	**Plant Code**	T_{base}	T_{opt}	**Reference**
Pine	PINE	0	30	(Kiniry, personal comm., 2001)
Oak	OAK	10	30	(Kiniry, personal comm., 2001)
Poplar	POPL	10	30	(Kiniry, personal comm., 2001)
Honey mesquite	MESQ	10	30	(Kiniry, personal comm., 2001)

A.1.3 LEAF AREA DEVELOPMENT

Leaf area development is a function of the plant's growing season. Plant growth database variables used to quantify leaf area development are: BLAI, FRGRW1, LAIMX1, FRGRW2, LAIMX2, and DLAI. Figure A-2 illustrates the relationship of the database parameters to the leaf area development modeled by SWAT.

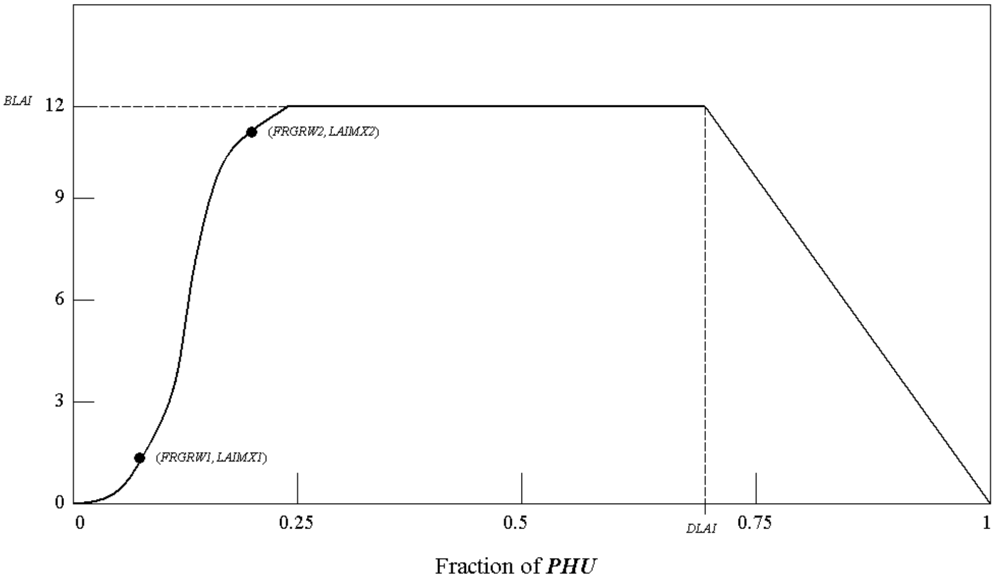

Figure A-2: Leaf area index as a function of fraction of growing season for Alamo switchgrass.

To identify the leaf area development parameters, record the leaf area index and number of accumulated heat units for the plant species throughout the growing season and then plot the results. For best results, several years worth of field data should be collected. At the very minimum, data for two years is recommended. It is important that the plants undergo no water or nutrient stress during the years in which data is collected.

The leaf area index incorporates information about the plant density, so field experiments should either be set up to reproduce actual plant densities or the maximum LAI value for the plant determined from field experiments should be adjusted to reflect plant densities desired in the simulation. Maximum LAI values in the default database correspond to plant densities associated with rainfed agriculture.

The leaf area index is calculated by dividing the green leaf area by the land area. Because the entire plant must be harvested to determine the leaf area, the field experiment needs to be designed to include enough plants to accommodate all leaf area measurements made during the year.

Although measuring leaf area can be laborious for large samples, there is no intrinsic difficulty in the process. The most common method is to obtain an electronic scanner and feed the harvested green leaves and stems into the scanner. Older methods for estimating leaf area include tracing of the leaves (or weighed subsamples) onto paper, the use of planimeters, the punch disk method of Watson (1958) and the linear dimension method of Duncan and Hesketh (1968).

Chapter 17 reviews the methodology used to calculate accumulated heat units for a plant at different times of the year as well as determination of the fraction of total, or potential, heat units that is required for the plant database.

Leaf area development parameter values for the plants included in the database are listed in Table A-4 (LAI_{mx} = BLAI; $fr_{PHU,1}$ = FRGRW1; $fr_{LAI,1}$ = LAIMX1; $fr_{PHU,2}$ = FRGRW2; $fr_{LAI,2}$ = LAIMX2; $fr_{PHU,sen}$ = DLAI).

Table A-4: Leaf area development parameters for plants included in plant growth database.

Common Name	**Plant Code**	LAI_{mx}	$fr_{PHU,1}$	$fr_{LAI,1}$	$fr_{PHU,2}$	$fr_{LAI,2}$	$fr_{PHU,sen}$	**Reference**
Corn	CORN	3	0.15	0.05	0.50	0.95	0.70	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Corn silage	CSIL	4	0.15	0.05	0.50	0.95	0.70	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Sweet corn	SCRN	2.5	0.15	0.05	0.50	0.95	0.50	(Kiniry, personal comm., 2001; Kiniry and Williams, 1994)
Eastern gamagrass	EGAM	2.5	0.05	0.18	0.25	0.90	0.40	(Kiniry, personal comm., 2001)
Grain sorghum	GRSG	3	0.15	0.05	0.50	0.95	0.64	(Kiniry, personal comm., 2001; Kiniry and Bockholt, 1998)
Sorghum hay	SGHY	4	0.15	0.05	0.50	0.95	0.64	(Kiniry, personal comm., 2001; Kiniry and Bockholt, 1998)

Common Name	**Plant Code**	LAI_{mx}	$fr_{PHU,1}$	$fr_{LAI,1}$	$fr_{PHU,2}$	$fr_{LAI,2}$	$fr_{PHU,sen}$	**Reference**
Johnsongrass	JHGR	2.5	0.15	0.05	0.57	0.95	0.50	(Kiniry, personal comm., 2001; Kiniry et al, 1992a)
Sugarcane	SUGC	6	0.15	0.01	0.50	0.95	0.75	(Kiniry and Williams, 1994)
Spring wheat	SWHT	4	0.15	0.05	0.50	0.95	0.60	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Winter wheat	WWHT	4	0.05	0.05	0.45	0.95	0.50	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Durum wheat	DWHT	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal communication, 2001; estimated)
Rye	RYE	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal communication, 2001; estimated)
Spring barley	BARL	4	0.15	0.01	0.45	0.95	0.60	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Oats	OATS	4	0.15	0.02	0.50	0.95	0.80	(Kiniry, personal comm., 2001)
Rice	RICE	5	0.30	0.01	0.70	0.95	0.80	(Kiniry, personal comm., 2001; estimated)
Pearl millet	PMIL	2.5	0.15	0.01	0.50	0.95	0.85	(Kiniry, personal comm., 2001; estimated)
Timothy	TIMO	4	0.15	0.01	0.50	0.95	0.85	(Kiniry, personal comm., 2001; estimated)
Smooth bromegrass	BROS	5	0.15	0.01	0.50	0.95	0.85	(Kiniry, personal comm., 2001; estimated)
Meadow bromegrass	BROM	3	0.45	0.02	0.80	0.95	0.85	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Tall fescue	FESC	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal comm, 2001; estimated)
Kentucky bluegrass	BLUG	2	0.05	0.05	0.30	0.70	0.35	(Kiniry, personal comm., 2001)
Bermudagrass	BERM	4	0.05	0.05	0.49	0.95	0.99	(Kiniry, personal comm, 2001)
Crested wheatgrass	CWGR	4	0.35	0.02	0.62	0.95	0.85	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Western wheatgrass	WWGR	4	0.50	0.02	0.89	0.95	0.85	(Kiniry et al, 1995; Kiniry, personal comm., 2001)
Slender wheatgrass	SWGR	4	0.15	0.01	0.50	0.95	0.85	(Kiniry, personal comm., 2001; estimated)
Italian (annual) ryegrass	RYEG	4	0.20	0.32	0.45	0.95	0.50	(Kiniry, personal comm., 2001; estimated)
Russian wildrye	RYER	3	0.35	0.02	0.62	0.95	0.80	(Kiniry et al, 1995)
Altai wildrye	RYEA	3	0.35	0.02	0.62	0.95	0.80	(Kiniry et al, 1995)
Sideoats grama	SIDE	1.7	0.05	0.05	0.30	0.70	0.35	(Kiniry, personal comm., 2001)
Big bluestem	BBLS	3	0.05	0.10	0.25	0.70	0.35	(Kiniry, personal comm., 2001)
Little bluestem	LBLS	2.5	0.05	0.10	0.25	0.70	0.35	(Kiniry, personal comm., 2001)
Alamo switchgrass	SWCH	6	0.10	0.20	0.20	0.95	0.70	(Kiniry, personal comm., 2001; Kiniry et al, 1996)
Indiangrass	INDN	3	0.05	0.10	0.25	0.70	0.35	(Kiniry, personal comm., 2001)
Alfalfa	ALFA	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001)
Sweetclover	CLVS	4	0.15	0.01	0.50	0.95	0.75	(Kiniry, personal comm., 2001; estimated)
Red clover	CLVR	4	0.15	0.01	0.50	0.95	0.75	(Kiniry, personal comm., 2001; estimated)
Alsike clover	CLVA	4	0.15	0.01	0.50	0.95	0.75	(Kiniry, personal comm., 2001; estimated)

Common Name	**Plant Code**	LAI_{mx}	$fr_{PHU,1}$	$fr_{LAI,1}$	$fr_{PHU,2}$	$fr_{LAI,2}$	$fr_{PHU,sen}$	**Reference**
Soybean	SOYB	3	0.15	0.05	0.50	0.95	0.60	(Kiniry, personal comm., 2001; Kiniry et al, 1992a)
Cowpeas	CWPS	4	0.15	0.01	0.50	0.95	0.80	(Kiniry, personal comm., 2001; estimated)
Mung bean	MUNG	4	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Lima beans	LIMA	2.5	0.10	0.05	0.80	0.95	0.90	(Kiniry and Williams, 1994)
Lentils	LENT	4	0.15	0.02	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Peanut	PNUT	4	0.15	0.01	0.50	0.95	0.75	(Kiniry, personal comm., 2001; estimated)
Field peas	FPEA	4	0.15	0.01	0.50	0.95	0.75	(Kiniry, personal comm., 2001; estimated)
Garden or canning peas	PEAS	2.5	0.10	0.05	0.80	0.95	0.60	(Kiniry and Williams, 1994)
Sesbania	SESB	5	0.15	0.01	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Flax	FLAX	2.5	0.15	0.02	0.50	0.95	0.90	(Kiniry, personal comm., 2001; estimated)
Upland cotton (harvested with stripper)	COTS	4	0.15	0.01	0.50	0.95	0.95	(Kiniry, personal comm., 2001; estimated)
Upland cotton (harvested with picker)	COTP	4	0.15	0.01	0.50	0.95	0.95	(Kiniry, personal comm., 2001; estimated)
Tobacco	TOBC	4.5	0.15	0.05	0.50	0.95	0.70	(Kiniry and Williams, 1994)
Sugarbeet	SGBT	5	0.05	0.05	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Potato	POTA	4	0.15	0.01	0.50	0.95	0.60	(Kiniry, personal comm., 2001; Kiniry and Williams, 1994)
Sweetpotato	SPOT	4	0.15	0.01	0.50	0.95	0.60	(Kiniry, personal comm., 2001; estimated)
Carrot	CRRT	3.5	0.15	0.01	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Onion	ONIO	1.5	0.15	0.01	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Sunflower	SUNF	3	0.15	0.01	0.50	0.95	0.62	(Kiniry, personal comm., 2001; Kiniry et al, 1992b)
Spring canola-Polish	CANP	3.5	0.15	0.02	0.45	0.95	0.50	(Kiniry et al, 1995)
Spring canola-Argentine	CANA	4.5	0.15	0.02	0.45	0.95	0.50	(Kiniry et al, 1995)
Asparagus	ASPR	4.2	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Broccoli	BROC	4.2	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Cabbage	CABG	3	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Cauliflower	CAUF	2.5	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Celery	CELR	2.5	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Head lettuce	LETT	4.2	0.25	0.23	0.40	0.86	1.00	(Kiniry and Williams, 1994)
Spinach	SPIN	4.2	0.10	0.05	0.90	0.95	0.95	(Kiniry and Williams, 1994)
Green beans	GRBN	1.5	0.10	0.05	0.80	0.95	0.90	(Kiniry and Williams, 1994)
Cucumber	CUCM	1.5	0.15	0.05	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Eggplant	EGGP	3	0.15	0.05	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Cantaloupe	CANT	3	0.15	0.05	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Honeydew melon	HMEL	4	0.15	0.05	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Watermelon	WMEL	1.5	0.15	0.05	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Bell pepper	PEPR	5	0.15	0.05	0.50	0.95	0.60	(Kiniry and Williams, 1994)

Common Name	**Plant Code**	LAI_{mx}	$fr_{PHU,1}$	$fr_{LAI,1}$	$fr_{PHU,2}$	$fr_{LAI,2}$	$fr_{PHU,sen}$	**Reference**
Strawberry	STRW	3	0.15	0.05	0.50	0.95	0.60	(Kiniry and Williams, 1994)
Tomato	TOMA	3	0.15	0.05	0.50	0.95	0.95	(Kiniry and Williams, 1994)
Apple	APPL	4	0.10	0.15	0.50	0.75	0.99	(Kiniry, personal comm., 2001; estimated)
Pine	PINE	5	0.15	0.70	0.25	0.99	0.99	(Kiniry, personal comm., 2001)
Oak	OAK	5	0.05	0.05	0.40	0.95	0.99	(Kiniry, personal comm., 2001)
Poplar	POPL	5	0.05	0.05	0.40	0.95	0.99	(Kiniry, personal comm., 2001)
Honey mesquite	MESQ	1.25	0.05	0.05	0.40	0.95	0.99	(Kiniry, 1998; Kiniry, personal communication, 2001)

A.1.4 ENERGY-BIOMASS CONVERSION

Radiation-use efficiency (RUE) quantifies the efficiency of a plant in converting light energy into biomass. Four variables in the plant growth database are used to define the RUE in ideal growing conditions (BIO_E), the impact of reduced vapor pressure on RUE (WAVP), and the impact of elevated CO_2 concentration on RUE (CO2HI, BIOEHI).

Determination of RUE is commonly performed and a literature review will provide those setting up experiments with numerous examples. The following overview of the methodology used to measure RUE was summarized from Kiniry et al (1998) and Kiniry et al (1999).

To calculate RUE, the amount of photosynthetically active radiation (PAR) intercepted and the mass of aboveground biomass is measured several times throughout a plant's growing season. The frequency of the measurements taken will vary but in general 4 to 7 measurements per growing season are considered to be adequate. As with leaf area determinations, the measurements should be performed on non-stressed plants.

Intercepted radiation is measured with a light meter. Whole spectrum and PAR sensors are available and calculations of RUE will be performed differently depending on the sensor used. A brief discussion of the difference between whole spectrum and PAR sensors and the difference in calculations is given in Kiniry (1999). The use of a PAR sensor in RUE studies is strongly encouraged.

When measuring radiation, three to five sets of measurements are taken rapidly for each plant plot. A set of measurements consists of 10 measurements above the leaf canopy, 10 below, and 10 more above. The light measurements should be taken between 10:00 am and 2:00 pm local time.

The measurements above and below the leaf canopy are averaged and the fraction of intercepted PAR is calculated for the day from the two values. Daily estimates of the fraction of intercepted PAR are determined by linearly interpolating the measured values.

The *fraction* of intercepted PAR is converted to an *amount* of intercepted PAR using daily values of incident total solar radiation measured with a standard weather station. To convert total incident radiation to total incident PAR, the daily solar radiation values are multiplied by the percent of total radiation that has a wavelength between 400 and 700 mm. This percent usually falls in the range 45 to 55% and is a function of cloud cover. 50% is considered to be a default value.

Once daily intercepted PAR values are determined, the total amount of PAR intercepted by the plant is calculated for each date on which biomass was harvested. This is calculated by summing daily intercepted PAR values from the date of seedling emergence to the date of biomass harvest.

To determine biomass production, aboveground biomass is harvested from a known area of land within the plot. The plant material should be dried at least 2 days at 65°C and then weighed.

RUE is determined by fitting a linear regression for aboveground biomass as a function of intercepted PAR. The slope of the line is the RUE. Figure A-3 shows the plots of aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass. (Note that the units for RUE values in the graph, as well as values typically reported in literature, are different from those used by SWAT. To obtain the value used in SWAT, multiply by 10.)

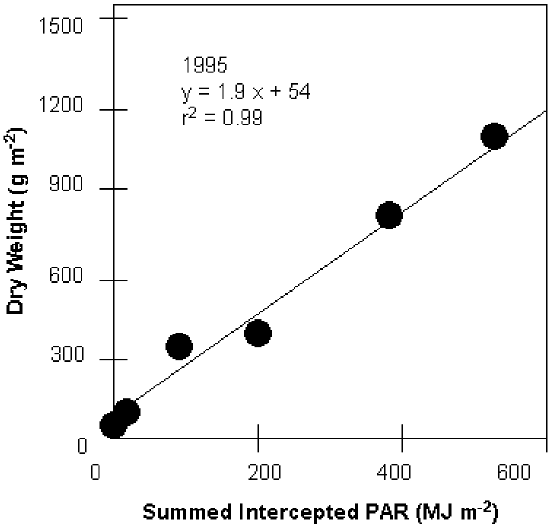

Figure A-3: Aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass (After Kiniry et al.,1999).

Stockle and Kiniry (1990) first noticed a relationship between RUE and vapor pressure deficit and were able to explain a large portion of within-species variability in RUE values for sorghum and corn by plotting RUE values as a function of average daily vapor pressure deficit values. Since this first article, a number of other studies have been conducted that support the dependence of RUE on vapor pressure deficit. However, there is still some debate in the scientific community on the validity of this relationship. If the user does not wish to simulate a change in RUE with vapor pressure deficit, the variable WAVP can be set to 0.0 for the plant.

To define the impact of vapor pressure deficit on RUE, vapor pressure deficit values must be recorded during the growing seasons that RUE determinations are being made. It is important that the plants are exposed to no other stress than vapor pressure deficit, i.e. plant growth should not be limited by lack of soil water and nutrients.

Vapor pressure deficits can be calculated from relative humidity (see Chapter 3) or from daily maximum and minimum temperatures using the technique of Diaz and Campbell (1988) as described by Stockle and Kiniry (1990). The change in RUE with vapor pressure deficit is determined by fitting a linear regression for RUE as a function of vapor pressure deficit. Figure A-4 shows a plot of RUE as a function of vapor pressure deficit for grain sorghum.

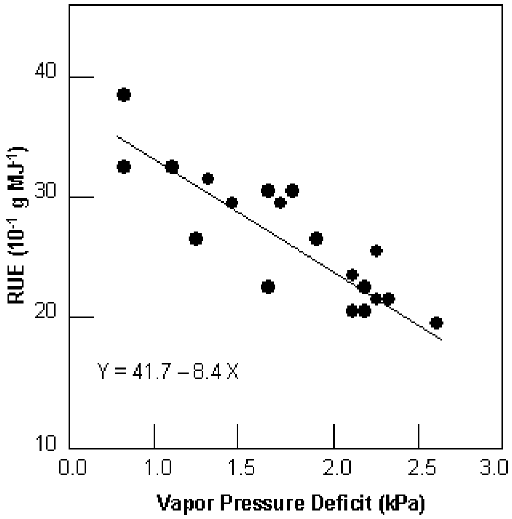

Figure A-4: Response of radiation-use efficiency to mean daily vapor pressure deficit for grain sorghum (After Kiniry, 1999).

From Figure A-4, the rate of decline in radiation-use efficiency per unit increase in vapor pressure deficit, Δrue_{dcl}, for sorghum is 8.4×10^{-1} g·MJ^{-1}·kPa^{-1}. When RUE is adjusted for vapor pressure deficit, the model assumes the RUE value reported for BIO_E is the radiation-use efficiency at a vapor pressure deficit of 1 kPa.

In order to assess the impact of climate change on agricultural productivity, SWAT incorporates equations that adjust RUE for elevated atmospheric CO_2 concentrations. Values must be entered for CO2HI and BIOEHI in the plant database whether or not the user plans to simulate climate change.

For simulations in which elevated CO_2 levels are not modeled, CO2HI should be set to some number greater than 330 ppmv and BIOEHI should be set to some number greater than BIO_E.

To obtain radiation-use efficiency values at elevated CO_2 levels for plant species not currently in the database, plants should be established in growth chambers set up in the field or laboratory where CO_2 levels can be controlled. RUE values are determined using the same methodology described previously.

Radiation-use efficiency parameter values for the plants included in the database are listed in Table A-5 (RUE = BIO_E; Δrue_{dcl} = WAVP; RUE_{hi} = BIOEHI; CO_{2hi} = CO2HI).

Table A-5: Biomass production parameters for plants included in plant growth database.

Common Name	**Plant Code**	RUE	Δrue_{dcl}	RUE_{hi}	CO_{2hi}	**Reference**
Corn	CORN	39	7.2	45	660	(Kiniry et al, 1998; Kiniry et al, 1997; Kiniry, personal communication, 2001)
Corn silage	CSIL	39	7.2	45	660	(Kiniry et al, 1998; Kiniry et al, 1997; Kiniry, personal communication, 2001)
Sweet corn	SCRN	39	7.2	45	660	(Kiniry and Williams, 1994; Kiniry et al, 1997; Kiniry, personal communication, 2001)
Eastern gamagrass	EGAM	21	10	58	660	(Kiniry et al, 1999; Kiniry, personal communication, 2001)
Grain sorghum	GRSG	33.5	8.5	36	660	(Kiniry et al, 1998; Kiniry, personal communication, 2001)
Sorghum hay	SGHY	33.5	8.5	36	660	(Kiniry et al, 1998; Kiniry, personal communication, 2001)
Johnsongrass	JHGR	35	8.5	36	660	(Kiniry et al, 1992a; Kiniry, personal communication, 2001)
Sugarcane	SUGC	25	10	33	660	(Kiniry and Williams, 1994; Kiniry, personal communication, 2001)
Spring wheat	SWHT	35	8	46	660	(Kiniry et al, 1992a; Kiniry, personal communication, 2001; estimated)
Winter wheat	WWHT	30	6	39	660	(Kiniry et al, 1995; estimated)
Durum wheat	DWHT	30	7	45	660	(estimated)
Rye	RYE	35	7	45	660	(estimated)
Spring barley	BARL	35	7	45	660	(Kiniry et al, 1995; estimated)
Oats	OATS	35	10	45	660	(Kiniry, personal communication, 2001)
Rice	RICE	22	5	31	660	(Kiniry et al, 1989; estimated)
Pearl millet	PMIL	35	8	40	660	(estimated)
Timothy	TIMO	35	8	45	660	(estimated)
Smooth bromegrass	BROS	35	8	45	660	(estimated)
Meadow bromegrass	BROM	35	8	45	660	(Kiniry et al, 1995; estimated)
Tall fescue	FESC	30	8	39	660	(estimated)
Kentucky bluegrass	BLUG	18	10	31	660	(Kiniry, personal communication, 2001)
Bermudagrass	BERM	35	10	36	660	(Kiniry, personal communication, 2001)
Crested wheatgrass	CWGR	35	8	38	660	(Kiniry et al, 1995; Kiniry, personal communication, 2001)
Western wheatgrass	WWGR	35	8	45	660	(Kiniry et al, 1995; estimated)
Slender wheatgrass	SWGR	35	8	45	660	(estimated)
Italian (annual) ryegrass	RYEG	30	6	39	660	(estimated)
Russian wildrye	RYER	30	8	39	660	(Kiniry et al, 1995; estimated)
Altai wildrye	RYEA	30	8	46	660	(Kiniry et al, 1995; Kiniry, personal communication, 2001)
Sideoats grama	SIDE	11	10	21	660	(Kiniry et al, 1999; Kiniry, personal communication, 2001)

Common Name	Plant Code	*RUE*	Δrue_{dcl}	RUE_{hi}	CO_{2hi}	Reference
Big bluestem	BBLS	14	10	39	660	(Kiniry et al, 1999; Kiniry, personal communication, 2001)
Little bluestem	LBLS	34	10	39	660	(Kiniry, personal communication, 2001)
Alamo switchgrass	SWCH	47	8.5	54	660	(Kiniry et al, 1996; Kiniry, personal communication, 2001)
Indiangrass	INDN	34	10	39	660	(Kiniry, personal communication, 2001)
Alfalfa	ALFA	20	10	35	660	(Kiniry, personal communication, 2001)
Sweetclover	CLVS	25	10	30	660	(estimated)
Red clover	CLVR	25	10	30	660	(estimated)
Alsike clover	CLVA	25	10	30	660	(estimated)
Soybean	SOYB	25	8	34	660	(Kiniry et al, 1992a; Kiniry, personal communication, 2001)
Cowpeas	CWPS	35	8	39	660	(estimated)
Mung bean	MUNG	25	10	33	660	(estimated)
Lima beans	LIMA	25	5	34	660	(Kiniry and Williams, 1994; estimated)
Lentils	LENT	20	10	33	660	(estimated)
Peanut	PNUT	20	4	25	660	(estimated)
Field peas	FPEA	25	10	30	660	(estimated)
Garden or canning peas	PEAS	25	5	34	660	(Kiniry and Williams, 1994; estimated)
Sesbania	SESB	50	10	60	660	(estimated)
Flax	FLAX	25	10	33	660	(estimated)
Upland cotton (harvested with stripper)	COTS	15	3	19	660	(estimated)
Upland cotton (harvested with picker)	COTP	15	3	19	660	(estimated)
Tobacco	TOBC	39	8	44	660	(Kiniry and Williams, 1994; estimated)
Sugarbeet	SGBT	30	10	35	660	(Kiniry and Williams, 1994; estimated)
Potato	POTA	25	14.8	30	660	(Manrique et al, 1991; estimated)
Sweetpotato	SPOT	15	3	19	660	(estimated)
Carrot	CRRT	30	10	35	660	(Kiniry and Williams, 1994; estimated)
Onion	ONIO	30	10	35	660	(Kiniry and Williams, 1994; estimated)
Sunflower	SUNF	46	32.3	59	660	(Kiniry et al, 1992b; Kiniry, personal communication, 2001)
Spring canola-Polish	CANP	34	10	39	660	(Kiniry et al, 1995; estimated)
Spring canola-Argentine	CANA	34	10	40	660	(Kiniry et al, 1995; estimated)
Asparagus	ASPR	90	5	95	660	(Kiniry and Williams, 1994; estimated)
Broccoli	BROC	26	5	30	660	(Kiniry and Williams, 1994; estimated)
Cabbage	CABG	19	5	25	660	(Kiniry and Williams, 1994; estimated)
Cauliflower	CAUF	21	5	25	660	(Kiniry and Williams, 1994; estimated)
Celery	CELR	27	5	30	660	(Kiniry and Williams, 1994; estimated)
Head lettuce	LETT	23	8	25	660	(Kiniry and Williams, 1994; estimated)
Spinach	SPIN	30	5	35	660	(Kiniry and Williams, 1994; estimated)
Green beans	GRBN	25	5	34	660	(Kiniry and Williams, 1994; estimated)
Cucumber	CUCM	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Eggplant	EGGP	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Cantaloupe	CANT	30	3	39	660	(Kiniry and Williams, 1994; estimated)

Common Name	**Plant Code**	***RUE***	**Δrue_{dcl}**	**RUE_{hi}**	**CO_{2hi}**	**Reference**
Honeydew melon	HMEL	30	3	39	660	(Kiniry and Williams, 1994; estimated)
Watermelon	WMEL	30	3	39	660	(Kiniry and Williams, 1994; estimated)
Bell pepper	PEPR	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Strawberry	STRW	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Tomato	TOMA	30	8	39	660	(Kiniry and Williams, 1994; estimated)
Apple	APPL	15	3	20	660	(estimated)
Pine	PINE	15	8	16	660	(Kiniry, personal communication, 2001)
Oak	OAK	15	8	16	660	(Kiniry, personal communication, 2001)
Poplar	POPL	30	8	31	660	(Kiniry, personal communication, 2001)
Honey mesquite	MESQ	16.1	8	18	660	(Kiniry, 1998; Kiniry, personal comm., 2001)

A.1.5 STOMATAL CONDUCTANCE

Stomatal conductance of water vapor is used in the Penman-Monteith calculations of maximum plant evapotranspiration. The plant database contains three variables pertaining to stomatal conductance that are required only if the Penman-Monteith equations are chosen to model evapotranspiration: maximum stomatal conductance (GSI), and two variables that define the impact of vapor pressure deficit on stomatal conductance (FRGMAX, VPDFR).

Körner et al (1979) defines maximum leaf diffusive conductance as the largest value of conductance observed in fully developed leaves of well-watered plants under optimal climatic conditions, natural outdoor CO_2 concentrations and sufficient nutrient supply. Leaf diffusive conductance of water vapor cannot be measured directly but can be calculated from measurements of transpiration under known climatic conditions. A number of different methods are used to determine diffusive conductance: transpiration measurements in photosynthesis cuvettes, energy balance measurements or weighing experiments, ventilated diffusion porometers and non-ventilated porometers. Körner (1977) measured diffusive conductance using a ventilated diffusion porometer.

To obtain maximum leaf conductance values, leaf conductance is determined between sunrise and late morning until a clear decline or no further increase is observed. Depending on phenology, measurements are taken on at least three bright days in late spring and summer, preferably just after a rainy period.

The means of maximum leaf conductance of 5 to 10 samples each day are averaged, yielding the maximum diffusive conductance for the species. Due to the variation of the location of stomata on plant leaves for different plant species, conductance values should be calculated for the total leaf surface area.

Körner et al (1979) compiled maximum leaf diffusive conductance data for 246 plant species. The data for each individual species was presented as well as summarized by 13 morphologically and/or ecologically comparable plant groups. All maximum stomatal conductance values in the plant growth database were based on the data included in Körner et al (1979) (see Table A-6).

As with radiation-use efficiency, stomatal conductance is sensitive to vapor pressure deficit. Stockle et al (1992) compiled a short list of stomatal conductance response to vapor pressure deficit for a few plant species. Due to the paucity of data, default values for the second point on the stomatal conductance vs. vapor pressure deficit curve are used for all plant species in the database. The fraction of maximum stomatal conductance (FRGMAX) is set to 0.75 and the vapor pressure deficit corresponding to the fraction given by FRGMAX (VPDFR) is set to 4.00 kPa. If the user has actual data, they should use those values, otherwise the default values are adequate.

A.1.6 CANOPY HEIGHT/ROOT DEPTH

Maximum canopy height (CHTMX) is a straightforward measurement. The canopy height of non-stressed plants should be recorded at intervals throughout the growing season. The maximum value recorded is used in the database.

To determine maximum rooting depth (RDMX), plant samples need to be grown on soils without an impermeable layer. Once the plants have reached maturity, soil cores are taken for the entire depth of the soil. Each 0.25 m increment is washed and the live plant material collected. Live roots can be differentiated from dead roots by the fact that live roots are whiter and more elastic and have an intact cortex. The deepest increment of the soil core in which live roots are found defines the maximum rooting depth. Table A-6 lists the maximum canopy height and maximum rooting depths for plants in the default database.

Table A-6: Maximum stomatal conductance ($g_{\ell,mx}$), maximum canopy height ($h_{c,mx}$), maximum root depth ($z_{root,mx}$), minimum USLE C factor for land cover ($C_{USLE,mn}$).

Common Name	**Plant Code**	$g_{\ell,mx}$	$h_{c,mx}$	$z_{root,mx}$	$C_{USLE,mn}$	**Reference**
Corn	CORN	.0071	2.5	2.0	.20	(Körner et al, 1979; Martin et al, 1976; Kiniry et al, 1995; Kiniry, personal comm., 2001)
Corn silage	CSIL	.0071	2.5	2.0	.20	(Körner et al, 1979; Martin et al, 1976; Kiniry et al, 1995; Kiniry, personal comm., 2001)
Sweet corn	SCRN	.0071	2.5	2.0	.20	(Körner et al, 1979, Kiniry and Williams, 1994; Kiniry, personal comm., 2001)
Eastern gamagrass	EGAM	.0055	1.7	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Grain sorghum	GRSG	.0050	1.0	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001)
Sorghum hay	SGHY	.0050	1.5	2.0	.20	(Körner et al, 1979; Martin et al, 1976; Kiniry, personal comm., 2001)
Johnsongrass	JHGR	.0048	1.0	2.0	.20	(Körner et al, 1979; Kiniry et al, 1992a)
Sugarcane	SUGC	.0055	3.0	2.0	.001	(Körner et al, 1979; Kiniry and Williams, 1994)
Spring wheat	SWHT	.0056	0.9	2.0	.03	(Körner et al, 1979; Kiniry, personal comm., 2001)
Winter wheat	WWHT	.0056	0.9	1.3	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Kiniry et al, 1995)
Durum wheat	DWHT	.0056	1.0	2.0	.03	(Körner et al, 1979; estimated; Kiniry, personal comm., 2001)
Rye	RYE	.0100	1.0	1.8	.03	(Körner et al, 1979; estimated; Martin et al, 1976; Kiniry, personal comm., 2001)
Spring barley	BARL	.0083	1.2	1.3	.01	(Körner et al, 1979; Kiniry and Williams, 1994; Kiniry et al, 1995)
Oats	OATS	.0055	1.5	2.0	.03	(Körner et al, 1979; Martin et al, 1976; Kiniry, personal comm., 2001)
Rice	RICE	.0078	0.8	0.9	.03	(Körner et al, 1979; Martin et al, 1976; estimated)
Pearl millet	PMIL	.0143	3.0	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; estimated)
Timothy	TIMO	.0055	0.8	2.0	.003	(Körner et al, 1979; estimated)
Smooth bromegrass	BROS	.0025	1.2	2.0	.003	(Körner et al, 1979; Martin et al, 1976; estimated)
Meadow bromegrass	BROM	.0055	0.8	1.3	.003	(Körner et al, 1979; estimated; Kiniry et al, 1995)
Tall fescue	FESC	.0055	1.5	2.0	.03	(Körner et al, 1979; Martin et al, 1976; estimated)
Kentucky bluegrass	BLUG	.0055	0.2	1.4	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Bermudagrass	BERM	.0055	0.5	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Crested wheatgrass	CWGR	.0055	0.9	1.3	.003	(Körner et al, 1979; Martin et al, 1976; Kiniry et al, 1995)
Western wheatgrass	WWGR	.0083	0.6	1.3	.003	(Körner et al, 1979; Martin et al, 1976; Kiniry et al, 1995; estimated)
Slender wheatgrass	SWGR	.0055	0.7	2.0	.003	(Körner et al, 1979; estimated)

Common Name	**Plant Code**	$g_{\ell,mx}$	$h_{c,mx}$	$z_{root,mx}$	$C_{USLE,mn}$	**Reference**
Italian (annual) ryegrass	RYEG	.0055	0.8	1.3	.03	(Körner et al, 1979; estimated)
Russian wildrye	RYER	.0065	1.0	1.3	.03	(Körner et al, 1979; estimated; Kiniry et al, 1995)
Altai wildrye	RYEA	.0055	1.1	1.3	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Kiniry et al, 1995)
Sideoats grama	SIDE	.0055	0.4	1.4	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Big bluestem	BBLS	.0055	1.0	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Little bluestem	LBLS	.0055	1.0	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Alamo switchgrass	SWCH	.0055	2.5	2.2	.003	(Körner et al, 1979; Kiniry, personal comm., 2001; Kiniry et al, 1996)
Indiangrass	INDN	.0055	1.0	2.0	.003	(Körner et al, 1979; Kiniry, personal comm., 2001)
Alfalfa	ALFA	.0100	0.9	3.0	.01	(Jensen et al, 1990; Martin et al, 1976; Kiniry, personal comm., 2001)
Sweetclover	CLVS	.0055	1.5	2.4	.003	(Körner et al, 1979; Kiniry, personal comm., 2001; Martin et al, 1976; estimated)
Red clover	CLVR	.0065	0.75	1.5	.003	(Körner et al, 1979; Martin et al, 1976; estimated)
Alsike clover	CLVA	.0055	0.9	2.0	.003	(Körner et al, 1979; Martin et al, 1976; estimated)
Soybean	SOYB	.0071	0.8	1.7	.20	(Körner et al, 1979; Kiniry et al, 1992a)
Cowpeas	CWPS	.0055	1.2	2.0	.03	(Körner et al, 1979; estimated)
Mung bean	MUNG	.0055	1.5	2.0	.20	(Körner et al, 1979; estimated)
Lima beans	LIMA	.0055	0.6	2.0	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Lentils	LENT	.0055	0.55	1.2	.20	(Körner et al, 1979; Martin et al, 1976; Maynard and Hochmuth, 1997)
Peanut	PNUT	.0063	0.5	2.0	.20	(Körner et al, 1979; estimated)
Field peas	FPEA	.0055	1.2	1.2	.01	(Körner et al, 1979; Martin et al, 1976; Maynard and Hochmuth, 1997; estimated)
Garden or canning peas	PEAS	.0055	0.6	1.2	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Sesbania	SESB	.0055	2.0	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; estimated)
Flax	FLAX	.0055	1.2	1.5	.20	(Körner et al, 1979; Martin et al, 1976; Jensen et al, 1990; estimated)
Upland cotton (harvested with stripper)	COTS	.0091	1.0	2.5	.20	(Monteith, 1965; Kiniry, personal comm., 2001; Martin et al, 1976)
Upland cotton (harvested with picker)	COTP	.0091	1.0	2.5	.20	(Monteith, 1965; Kiniry, personal comm., 2001; Martin et al, 1976)
Tobacco	TOBC	.0048	1.8	2.0	.20	(Körner et al, 1979; Martin et al, 1976; Kiniry and Williams, 1994)
Sugarbeet	SGBT	.0071	1.2	2.0	.20	(Körner et al, 1979; Kiniry and Williams, 1994)
Potato	POTA	.0050	0.6	0.6	.20	(Körner et al, 1979; Martin et al, 1976; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)

Common Name	**Plant Code**	$g_{\ell,mx}$	$h_{c,mx}$	$z_{root,mx}$	$C_{USLE,mn}$	**Reference**
Sweetpotato	SPOT	.0065	0.8	2.0	.05	(Körner et al, 1979; estimated; Maynard and Hochmuth, 1997)
Carrot	CRRT	.0065	0.3	1.2	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Onion	ONIO	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Sunflower	SUNF	.0077	2.5	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001)
Spring canola-Polish	CANP	.0065	0.9	0.9	.20	(Körner et al, 1979; estimated; Kiniry et al, 1995)
Spring canola-Argentine	CANA	.0065	1.3	1.4	.20	(Körner et al, 1979; estimated; Kiniry et al, 1995)
Asparagus	ASPR	.0065	0.5	2.0	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Broccoli	BROC	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Cabbage	CABG	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Cauliflower	CAUF	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Celery	CELR	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Head lettuce	LETT	.0025	0.2	0.6	.01	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Spinach	SPIN	.0065	0.5	0.6	.20	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Green beans	GRBN	.0077	0.6	1.2	.20	(Körner et al, 1979; Kiniry and Williams, 1994; Maynard and Hochmuth, 1997)
Cucumber	CUCM	.0033	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997)
Eggplant	EGGP	.0065	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Cantaloupe	CANT	.0065	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Honeydew melon	HMEL	.0065	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Watermelon	WMEL	.0065	0.5	2.0	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Bell pepper	PEPR	.0053	0.5	1.2	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Strawberry	STRW	.0065	0.5	0.6	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)

Common Name	Plant Code	$g_{\ell,mx}$	$h_{c,mx}$	$z_{root,mx}$	$C_{USLE,mn}$	Reference
Tomato	TOMA	.0077	0.5	2.0	.03	(Körner et al, 1979; Kiniry, personal comm., 2001; Maynard and Hochmuth, 1997; Kiniry and Williams, 1994)
Apple	APPL	.0071	3.5	2.0	.001	(Körner et al, 1979; estimated; Jensen et al, 1990)
Pine	PINE	.0019	10.0	3.5	.001	(Körner et al, 1979; Kiniry, personal comm., 2001)
Oak	OAK	.0020	6.0	3.5	.001	(Körner et al, 1979; Kiniry, personal comm., 2001)
Poplar	POPL	.0036	7.5	3.5	.001	(Körner et al, 1979; Kiniry, personal comm., 2001)
Honey mesquite	MESQ	.0036	6.0	3.5	.001	(Körner et al, 1979; Kiniry, personal comm., 2001)

A.1.7 PLANT NUTRIENT CONTENT

In order to calculate the plant nutrient demand throughout a plant's growing cycle, SWAT needs to know the fraction of nutrient in the total plant biomass (on a dry weight basis) at different stages of crop growth. Six variables in the plant database provide this information: BN(1), BN(2), BN(3), BP(1), BP(2), and BP(3). Plant samples are analyzed for nitrogen and phosphorus content at three times during the growing season: shortly after emergence, near the middle of the season, and at maturity. The plant samples can be sent to testing laboratories to obtain the fraction of nitrogen and phosphorus in the biomass.

Ideally, the plant samples tested for nutrient content should include the roots as well as the aboveground biomass. Differences in partitioning of nutrients to roots and shoots can cause erroneous conclusions when comparing productivity among species if only the aboveground biomass is measured.

The fractions of nitrogen and phosphorus for the plants included in the default database are listed in Table A-7.

Table A-7: Nutrient parameters for plants included in plant growth database.

Common Name	Plant Code	$fr_{N,1}$	$fr_{N,2}$	$fr_{N,3}$	$fr_{P,1}$	$fr_{P,2}$	$fr_{P,3}$	Reference
Corn	CORN	.0470	.0177	.0138	.0048	.0018	.0014	(Kiniry et al., 1995)
Corn silage	CSIL	.0470	.0177	.0138	.0048	.0018	.0014	(Kiniry et al., 1995)
Sweet corn	SCRN	.0470	.0177	.0138	.0048	.0018	.0014	(Kiniry and Williams, 1994)
Eastern gamagrass	EGAM	.0200	.0100	.0070	.0014	.0010	.0007	(Kiniry, personal communication, 2001)

Common Name	**Plant Code**	$fr_{N,1}$	$fr_{N,2}$	$fr_{N,3}$	$fr_{P,1}$	$fr_{P,2}$	$fr_{P,3}$	**Reference**
Grain sorghum	GRSG	.0440	.0164	.0128	.0060	.0022	.0018	(Kiniry, personal communication, 2001)
Sorghum hay	SGHY	.0440	.0164	.0128	.0060	.0022	.0018	(Kiniry, personal communication, 2001)
Johnsongrass	JHGR	.0440	.0164	.0128	.0060	.0022	.0018	(Kiniry et al., 1992a)
Sugarcane	SUGC	.0100	.0040	.0025	.0075	.0030	.0019	(Kiniry and Williams, 1994)
Spring wheat	SWHT	.0600	.0231	.0134	.0084	.0032	.0019	(Kiniry et al., 1992a)
Winter wheat	WWHT	.0663	.0255	.0148	.0053	.0020	.0012	(Kiniry et al., 1995)
Durum wheat	DWHT	.0600	.0231	.0130	.0084	.0032	.0019	estimated
Rye	RYE	.0600	.0231	.0130	.0084	.0032	.0019	estimated
Spring barley	BARL	.0590	.0226	.0131	.0057	.0022	.0013	(Kiniry et al., 1995)
Oats	OATS	.0600	.0231	.0134	.0084	.0032	.0019	(Kiniry, personal communication, 2001)
Rice	RICE	.0500	.0200	.0100	.0060	.0030	.0018	estimated
Pearl millet	PMIL	.0440	.0300	.0100	.0060	.0022	.0012	estimated
Timothy	TIMO	.0314	.0137	.0103	.0038	.0025	.0019	estimated
Smooth bromegrass	BROS	.0400	.0240	.0160	.0028	.0017	.0011	(Kiniry et al., 1995)
Meadow bromegrass	BROM	.0400	.0240	.0160	.0028	.0017	.0011	(Kiniry et al., 1995)
Tall fescue	FESC	.0560	.0210	.0120	.0099	.0022	.0019	estimated
Kentucky bluegrass	BLUG	.0200	.0100	.0060	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Bermudagrass	BERM	.0600	.0231	.0134	.0084	.0032	.0019	(Kiniry, personal communication, 2001)
Crested wheatgrass	CWGR	.0300	.0200	.0120	.0020	.0015	.0013	(Kiniry et al., 1995)
Western wheatgrass	WWGR	.0300	.0200	.0120	.0020	.0015	.0013	(Kiniry et al., 1995)
Slender wheatgrass	SWGR	.0300	.0200	.0120	.0020	.0015	.0013	estimated
Italian (annual) ryegrass	RYEG	.0660	.0254	.0147	.0105	.0040	.0024	estimated
Russian wildrye	RYER	.0226	.0180	.0140	.0040	.0040	.0024	(Kiniry et al., 1995)
Altai wildrye	RYEA	.0226	.0180	.0140	.0040	.0040	.0024	(Kiniry et al., 1995)
Sideoats grama	SIDE	.0200	.0100	.0060	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Big bluestem	BBLS	.0200	.0120	.0050	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Little bluestem	LBLS	.0200	.0120	.0050	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Alamo switchgrass	SWCH	.0350	.0150	.0038	.0014	.0010	.0007	(Kiniry et al., 1996)
Indiangrass	INDN	.0200	.0120	.0050	.0014	.0010	.0007	(Kiniry, personal communication, 2001)
Alfalfa	ALFA	.0417	.0290	.0200	.0035	.0028	.0020	(Kiniry, personal communication, 2001)
Sweetclover	CLVS	.0650	.0280	.0243	.0060	.0024	.0024	estimated
Red clover	CLVR	.0650	.0280	.0243	.0060	.0024	.0024	estimated
Alsike clover	CLVA	.0600	.0280	.0240	.0060	.0025	.0025	estimated
Soybean	SOYB	.0524	.0265	.0258	.0074	.0037	.0035	(Kiniry et al., 1992a)
Cowpeas	CWPS	.0600	.0231	.0134	.0049	.0019	.0011	estimated
Mung bean	MUNG	.0524	.0265	.0258	.0074	.0037	.0035	estimated
Lima beans	LIMA	.0040	.0030	.0015	.0035	.0030	.0015	(Kiniry and Williams, 1994)
Lentils	LENT	.0440	.0164	.0128	.0074	.0037	.0023	estimated
Peanut	PNUT	.0524	.0265	.0258	.0074	.0037	.0035	estimated
Field peas	FPEA	.0515	.0335	.0296	.0033	.0019	.0014	estimated
Garden or canning peas	PEAS	.0040	.0030	.0015	.0030	.0020	.0015	(Kiniry and Williams, 1994)
Sesbania	SESB	.0500	.0200	.0150	.0074	.0037	.0035	estimated
Flax	FLAX	.0482	.0294	.0263	.0049	.0024	.0023	estimated

Common Name	**Plant Code**	$fr_{N,1}$	$fr_{N,2}$	$fr_{N,3}$	$fr_{P,1}$	$fr_{P,2}$	$fr_{P,3}$	**Reference**
Upland cotton (harvested with stripper)	COTS	.0580	.0192	.0177	.0081	.0027	.0025	estimated
Upland cotton (harvested with picker)	COTP	.0580	.0192	.0177	.0081	.0027	.0025	estimated
Tobacco	TOBC	.0470	.0177	.0138	.0048	.0018	.0014	(Kiniry and Williams, 1994)
Sugarbeet	SGBT	.0550	.0200	.0120	.0060	.0025	.0019	(Kiniry and Williams, 1994)
Potato	POTA	.0550	.0200	.0120	.0060	.0025	.0019	(Kiniry and Williams, 1994)
Sweetpotato	SPOT	.0450	.0160	.0090	.0045	.0019	.0015	estimated
Carrot	CRRT	.0550	.0075	.0012	.0060	.0030	.0020	(Kiniry and Williams, 1994)
Onion	ONIO	.0400	.0300	.0020	.0021	.0020	.0019	(Kiniry and Williams, 1994)
Sunflower	SUNF	.0500	.0230	.0146	.0063	.0029	.0023	(Kiniry, personal communication, 2001)
Spring canola-Polish	CANP	.0440	.0164	.0128	.0074	.0037	.0023	(Kiniry et al., 1995)
Spring canola-Argentine	CANA	.0440	.0164	.0128	.0074	.0037	.0023	(Kiniry et al., 1995)
Asparagus	ASPR	.0620	.0500	.0400	.0050	.0040	.0020	(Kiniry and Williams, 1994)
Broccoli	BROC	.0620	.0090	.0070	.0050	.0040	.0030	(Kiniry and Williams, 1994)
Cabbage	CABG	.0620	.0070	.0040	.0050	.0035	.0020	(Kiniry and Williams, 1994)
Cauliflower	CAUF	.0620	.0070	.0040	.0050	.0035	.0020	(Kiniry and Williams, 1994)
Celery	CELR	.0620	.0150	.0100	.0060	.0050	.0030	(Kiniry and Williams, 1994)
Head lettuce	LETT	.0360	.0250	.0210	.0084	.0032	.0019	(Kiniry and Williams, 1994)
Spinach	SPIN	.0620	.0400	.0300	.0050	.0040	.0035	(Kiniry and Williams, 1994)
Green beans	GRBN	.0040	.0030	.0015	.0040	.0035	.0015	(Kiniry and Williams, 1994)
Cucumber	CUCM	.0663	.0075	.0048	.0053	.0025	.0012	(Kiniry and Williams, 1994)
Eggplant	EGGP	.0663	.0255	.0075	.0053	.0020	.0015	(Kiniry and Williams, 1994)
Cantaloupe	CANT	.0663	.0255	.0148	.0053	.0020	.0012	(Kiniry and Williams, 1994)
Honeydew melon	HMEL	.0070	.0040	.0020	.0026	.0020	.0017	(Kiniry and Williams, 1994)
Watermelon	WMEL	.0663	.0075	.0048	.0053	.0025	.0012	(Kiniry and Williams, 1994)
Bell pepper	PEPR	.0600	.0350	.0250	.0053	.0020	.0012	(Kiniry and Williams, 1994)
Strawberry	STRW	.0663	.0255	.0148	.0053	.0020	.0012	(Kiniry and Williams, 1994)
Tomato	TOMA	.0663	.0300	.0250	.0053	.0035	.0025	(Kiniry and Williams, 1994)
Apple	APPL	.0060	.0020	.0015	.0007	.0004	.0003	estimated
Pine	PINE	.0060	.0020	.0015	.0007	.0004	.0003	(Kiniry, personal communication, 2001)
Oak	OAK	.0060	.0020	.0015	.0007	.0004	.0003	(Kiniry, personal communication, 2001)
Poplar	POPL	.0060	.0020	.0015	.0007	.0004	.0003	(Kiniry, personal communication, 2001)
Honey mesquite	MESQ	.0200	.0100	.0080	.0007	.0004	.0003	(Kiniry, personal communication, 2001)

A.1.8 HARVEST

Harvest operations are performed on agricultural crops where the yield is sold for a profit. Four variables in the database provide information used by the model to harvest a crop: HVSTI, WSYF, CNYLD, and CPYLD.

The harvest index defines the fraction of the aboveground biomass that is removed in a harvest operation. This value defines the fraction of plant biomass that is "lost" from the system and unavailable for conversion to residue and subsequent decomposition. For crops where the harvested portion of the plant is aboveground, the harvest index is always a fraction less than 1. For crops where the harvested portion is belowground, the harvest index may be greater than 1. Two harvest indices are provided in the database, the harvest index for optimal growing conditions (HVSTI) and the harvest index under highly stressed growing conditions (WSYF).

To determine the harvest index, the plant biomass removed during the harvest operation is dried at least 2 days at 65°C and weighed. The total aboveground plant biomass in the field should also be dried and weighed. The harvest index is then calculated by dividing the weight of the harvested portion of the plant biomass by the weight of the total aboveground plant biomass. Plants will need to be grown in two different plots where optimal climatic conditions and stressed conditions are produced to obtain values for both harvest indices.

In addition to the amount of plant biomass removed in the yield, SWAT needs to know the amount of nitrogen and phosphorus removed in the yield. The harvested portion of the plant biomass is sent to a testing laboratory to determine the fraction of nitrogen and phosphorus in the biomass.

Table A-8 lists values for the optimal harvest index (HI_{opt}), the minimum harvest index (HI_{min}), the fraction of nitrogen in the harvested portion of biomass ($fr_{N,yld}$), and the fraction of phosphorus in the harvested portion of biomass ($fr_{P,yld}$).

Table A-8: Harvest parameters for plants included in the plant growth database.

Common Name	**Plant Code**	HI_{opt}	HI_{min}	$fr_{N,yld}$	$fr_{P,yld}$	**Reference**
Corn	CORN	0.50	0.30	.0140	.0016	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Corn silage	CSIL	0.90	0.90	.0140	.0016	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Sweet corn	SCRN	0.50	0.30	.0214	.0037	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984a)
Eastern gamagrass	EGAM	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Grain sorghum	GRSG	0.45	0.25	.0199	.0032	(Kiniry and Bockholt, 1998; Nutrition Monitoring Division, 1984b)

Common Name	Plant Code	HI_{opt}	HI_{min}	$fr_{N,yld}$	$fr_{P,yld}$	Reference
Sorghum hay	SGHY	0.90	0.90	.0199	.0032	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Johnsongrass	JHGR	0.90	0.90	.0200	.0028	(Kiniry, personal communication, 2001; Kiniry et al, 1992a)
Sugarcane	SUGC	0.50	0.01	.0000	.0000	(Kiniry and Williams, 1994)
Spring wheat	SWHT	0.42	0.20	.0234	.0033	(Kinry et al, 1995; Kiniry et al, 1992a)
Winter wheat	WWHT	0.40	0.20	.0250	.0022	(Kiniry et al, 1995)
Durum wheat	DWHT	0.40	0.20	.0263	.0057	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Rye	RYE	0.40	0.20	.0284	.0042	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Spring barley	BARL	0.54	0.20	.0210	.0017	(Kiniry et al, 1995)
Oats	OATS	0.42	0.175	.0316	.0057	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Rice	RICE	0.50	0.25	.0136	.0013	(Kiniry, personal communication, 2001; Nutrition Monitoring Division, 1984b)
Pearl millet	PMIL	0.25	0.10	.0200	.0028	(Kiniry, personal communication, 2001; estimated)
Timothy	TIMO	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001; estimated)
Smooth bromegrass	BROS	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Meadow bromegrass	BROM	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Tall fescue	FESC	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001; estimated)
Kentucky bluegrass	BLUG	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Bermudagrass	BERM	0.90	0.90	.0234	.0033	(Kiniry, personal communication, 2001)
Crested wheatgrass	CWGR	0.90	0.90	.0500	.0040	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Western wheatgrass	WWGR	0.90	0.90	.0500	.0040	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Slender wheatgrass	SWGR	0.90	0.90	.0500	.0040	(Kiniry, personal communication, 2001; estimated)
Italian (annual) ryegrass	RYEG	0.90	0.90	.0220	.0028	(Kiniry, personal communication, 2001; estimated)
Russian wildrye	RYER	0.90	0.90	.0230	.0037	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Altai wildrye	RYEA	0.90	0.90	.0230	.0037	(Kiniry, personal communication, 2001; Kiniry et al, 1995)
Sideoats grama	SIDE	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Big bluestem	BBLS	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Little bluestem	LBLS	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Alamo switchgrass	SWCH	0.90	0.90	.0160	.0022	(Kiniry et al, 1996)
Indiangrass	INDN	0.90	0.90	.0160	.0022	(Kiniry, personal communication, 2001)
Alfalfa	ALFA	0.90	0.90	.0250	.0035	(Kiniry, personal communication, 2001)
Sweetclover	CLVS	0.90	0.90	.0650	.0040	(Kiniry, personal communication, 2001; estimated)
Red clover	CLVR	0.90	0.90	.0650	.0040	(Kiniry, personal communication, 2001; estimated)

Common Name	**Plant Code**	HI_{opt}	HI_{min}	$fr_{N,yld}$	$fr_{P,yld}$	**Reference**
Alsike clover	CLVA	0.90	0.90	.0600	.0040	(Kiniry, personal communication, 2001; estimated)
Soybean	SOYB	0.31	0.01	.0650	.0091	(Kiniry et al, 1992a)
Cowpeas	CWPS	0.42	0.05	.0427	.0048	(estimated; Nutrition Monitoring Division, 1984c)
Mung bean	MUNG	0.31	0.01	.0420	.0040	(estimated; Nutrition Monitoring Division, 1984c)
Lima beans	LIMA	0.30	0.22	.0368	.0046	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Lentils	LENT	0.61	0.01	.0506	.0051	(estimated; Nutrition Monitoring Division, 1984c)
Peanut	PNUT	0.40	0.30	.0505	.0040	(estimated; Nutrition Monitoring Division, 1984c)
Field peas	FPEA	0.45	0.10	.0370	.0021	estimated
Garden or canning peas	PEAS	0.30	0.22	.0410	.0051	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Sesbania	SESB	0.31	0.01	.0650	.0091	estimated
Flax	FLAX	0.54	0.40	.0400	.0033	estimated
Upland cotton (harvested with stripper)	COTS	0.50	0.40	.0140	.0020	(Kiniry, personal communication, 2001; estimated)
Upland cotton (harvested with picker)	COTP	0.40	0.30	.0190	.0029	(Kiniry, personal communication, 2001; estimated)
Tobacco	TOBC	0.55	0.55	.0140	.0016	(Kiniry and Williams, 1994)
Sugarbeet	SGBT	2.00	1.10	.0130	.0020	(Kiniry and Williams, 1994)
Potato	POTA	0.95	0.95	.0246	.0023	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Sweetpotato	SPOT	0.60	0.40	.0097	.0010	(estimated; Nutrition Monitoring Division, 1984a)
Carrot	CRRT	1.12	0.90	.0135	.0036	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Onion	ONIO	1.25	0.95	.0206	.0032	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Sunflower	SUNF	0.30	0.18	.0454	.0074	(Kiniry et al, 1992b; Nutrition Monitoring Division, 1984d)
Spring canola-Polish	CANP	0.23	0.01	.0380	.0079	(Kiniry et al, 1995)
Spring canola-Argentine	CANA	0.30	0.01	.0380	.0079	(Kiniry et al, 1995)
Asparagus	ASPR	0.80	0.95	.0630	.0067	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Broccoli	BROC	0.80	0.95	.0512	.0071	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Cabbage	CABG	0.80	0.95	.0259	.0031	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Cauliflower	CAUF	0.80	0.95	.0411	.0059	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Celery	CELR	0.80	0.95	.0199	.0049	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Head lettuce	LETT	0.80	0.01	.0393	.0049	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Spinach	SPIN	0.95	0.95	.0543	.0058	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)

Common Name	Plant Code	HI_{opt}	HI_{min}	$fr_{N,yld}$	$fr_{P,yld}$	Reference
Green beans	GRBN	0.10	0.10	.0299	.0039	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Cucumber	CUCM	0.27	0.25	.0219	.0043	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Eggplant	EGGP	0.59	0.25	.0218	.0041	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Cantaloupe	CANT	0.50	0.25	.0138	.0017	(Kiniry and Williams, 1994; Consumer Nutrition Center, 1982)
Honeydew melon	HMEL	0.55	0.25	.0071	.0010	(Kiniry and Williams, 1994; Consumer Nutrition Center, 1982)
Watermelon	WMEL	0.50	0.25	.0117	.0011	(Kiniry and Williams, 1994; Consumer Nutrition Center, 1982)
Bell pepper	PEPR	0.60	0.25	.0188	.0030	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Strawberry	STRW	0.45	0.25	.0116	.0023	(Kiniry and Williams, 1994; Consumer Nutrition Center, 1982)
Tomato	TOMA	0.33	0.15	.0235	.0048	(Kiniry and Williams, 1994; Nutrition Monitoring Division, 1984a)
Apple	APPL	0.10	0.05	.0019	.0004	(estimated; Consumer Nutrition Center, 1982)
Pine	PINE	0.76	0.60	.0015	.0003	(Kiniry, personal communication, 2001)
Oak	OAK	0.76	0.01	.0015	.0003	(Kiniry, personal communication, 2001)
Poplar	POPL	0.76	0.01	.0015	.0003	(Kiniry, personal communication, 2001)
Honey mesquite	MESQ	0.05	0.01	.0015	.0003	(Kiniry, personal communication, 2001)

A.1.9 USLE C FACTOR

The USLE C factor is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow. This factor measures the combined effect of all the interrelated cover and management variables. SWAT calculates the actual C factor based on the amount of soil cover and the minimum C factor defined for the plant/land cover. The minimum C factor quantifies the maximum decrease in erosion possible for the plant/land cover. Because the USLE C factor is influenced by management, this variable may be adjusted by the user to reflect management conditions in the watershed of interest.

The minimum C factor can be estimated from a known average annual C factor using the following equation (Arnold and Williams, 1995):

$$C_{USLE,mn} = 1.463 \ln\left[C_{USLE,aa}\right] + 0.1034$$

where $C_{USLE,mn}$ is the minimum C factor for the land cover and $C_{USLE,aa}$ is the average annual C factor for the land cover. The minimum C factor for plants in the database are listed in Table A-6.

A.1.10 RESIDUE DECOMPOSITION

The plant residue decomposition coefficient is the fraction of residue that will decompose in a day assuming optimal moisture, temperature, C:N ratio, and C:P ratio. This variable was originally in the basin input file (.bsn), but was added to the crop database so that users could vary decomposition by land cover. A default value of 0.05 is used for all plant species in the database.

A.2 TILLAGE DATABASE

The tillage database contains information needed by SWAT to simulate the redistribution of nutrients and pesticide that occurs in a tillage operation. Table A-9 lists all the default tillage implements. This list was summarized from a farm machinery database maintained by the USDA Economic Research Service. Depth of tillage for each implement was also obtained from the USDA Economic Research Service. The fraction of residue mixed into the soil was estimated for each implement from a 'Residue Scorecard' provided by NACD's (National Association of Conservation Districts) Conservation Technology Information Center.

Table A-9: Implements included in the tillage database.

Implement	**Tillage Code**	**Mixing Depth**	**Mixing Efficiency**
Duckfoot Cultivator	DUCKFTC	100 mm	0.55
Field Cultivator	FLDCULT	100 mm	0.30
Furrow-out Cultivator	FUROWOUT	25 mm	0.75
Marker (Cultivator)	MARKER	100 mm	0.45
Rolling Cultivator	ROLLCULT	25 mm	0.50
Row Cultivator	ROWCULT	25 mm	0.25
Discovator	DISCOVAT	25 mm	0.50
Leveler	LEVELER	25 mm	0.50
Harrow (Tines)	HARROW	25 mm	0.20
Culti-mulch Roller	CULMULCH	25 mm	0.25
Culti-packer Pulverizer	CULPKPUL	40 mm	0.35
Land Plane-Leveler	LANDLEVL	75 mm	0.50
Landall, Do-All	LANDALL	150 mm	0.30
Laser Planer	LASRPLAN	150 mm	0.30
Levee-Plow-Disc	LEVPLDIS	25 mm	0.75
Float	FLOAT	60 mm	0.10
Field Conditioner (Scratcher)	FLDCDSCR	60 mm	0.10
Lister (Middle-Buster)	LISTRMID	40 mm	0.15
Roller Groover	ROLLGROV	60 mm	0.25
Roller Packer Attachment	ROLPKRAT	40 mm	0.05
Roller Packer Flat Roller	ROLPKRFT	40 mm	0.35
Sand-Fighter	SANDFIGT	100 mm	0.70
Seedbed Roller	SEEDROLL	100 mm	0.70
Crust Buster	CRUSTBST	60 mm	0.10
Roller Harrow	ROLLHRRW	60 mm	0.40
Triple K	TRIPLE K	100 mm	0.40
Finishing Harrow	FINHARRW	100 mm	0.55
Flex-Tine Harrow CL	FLEXHARW	25 mm	0.20
Powered Spike Tooth Harrow	SPIKETTH	75 mm	0.40
Spike Tooth Harrow	SPIKTOTH	25 mm	0.25
Springtooth Harrow	SPRGTOTH	25 mm	0.35
Soil Finisher	SOILFINS	75 mm	0.55

Implement	Tillage Code	Mixing Depth	Mixing Efficiency
Rotary Hoe	ROTHOE	5 mm	0.10
Roterra	ROTERRA	5 mm	0.80
Roto-Tiller	ROTOTILL	5 mm	0.80
Rotovator-Bedder	ROTBEDDR	100 mm	0.80
Rowbuck	ROWBUCK	100 mm	0.70
Ripper	RIPPER	350 mm	0.25
Middle Buster	MIDBST1R	100 mm	0.70
Rod Weeder	RODWEEDR	25 mm	0.30
Rubber-Wheel Weed Puller	RUBWHWPL	5 mm	0.35
Multi-Weeder	MULTIWDR	25 mm	0.30
Moldboard Plow Reg	MLDBOARD	150 mm	0.95
Chisel Plow	CHISPLOW	150 mm	0.30
Coulter-Chisel	CCHPLOW	150 mm	0.50
Disk Plow	DISKPLOW	100 mm	0.85
Stubble-mulch Plow	STUBMLCH	75 mm	0.15
Subsoil Chisel Plow	SUBCHPLW	350 mm	0.45
Row Conditioner	ROWCOND	25 mm	0.50
Hipper	HIPPER	100 mm	0.50
Rice Roller	RICEROLL	50 mm	0.10
Paraplow	PARAPLOW	350 mm	0.15
Subsoiler-Bedder Hip-Rip	SBEDHIPR	350 mm	0.70
Deep Ripper-Subsoiler	RIPRSUBS	350 mm	0.25
V-Ripper	VRIPPER	350 mm	0.25
Bed Roller	BEDROLLR	50 mm	0.25
Bedder (Disk)	BEDDER D	150 mm	0.55
Bedder Disk-Hipper	BEDDHIPR	150 mm	0.65
Bedder Disk-Row	BEDDKROW	100 mm	0.85
Bedder Shaper	BEDDER S	150 mm	0.55
Disk Border Maker	DSKBRMKR	150 mm	0.55
Disk Chisel (Mulch Tiller)	DKCHMTIL	150 mm	0.55
Offset Disk-Heavy Duty	OFFSETHV	100 mm	0.70
Offset Disk-Light Duty	OFFSETLT	100 mm	0.55
One-Way (Disk Tiller)	ONE-WAYT	100 mm	0.60
Tandem Disk Plow	TANDEMPL	75 mm	0.55
Tandem Disk Reg	TANDEMRG	75 mm	0.60
Single Disk	SINGLDIS	100 mm	0.45
Power Mulcher	PWRMULCH	50 mm	0.70
Blade 10 ft	BLADE 10	75 mm	0.25
Furrow Diker	FURWDIKE	100 mm	0.70
Beet Cultivator	BEETCULT	25 mm	0.25
Cultiweeder	CLTIWEED	100 mm	0.30
Packer	PACKER	40 mm	0.35

In addition to information about specific implements, the tillage database includes default information for the different crop residue management categories. Table A-10 summarizes the information in the database on the different residue management categories.

Table A-10: Generic management scenarios included in the tillage database.

Implement	Tillage Code	Mixing Depth	Mixing Efficiency
Generic Fall Plowing Operation	FALLPLOW	150 mm	0.95
Generic Spring Plowing Operation	SPRGPLOW	125 mm	0.50
Generic Conservation Tillage	CONSTILL	100 mm	0.25
Generic No-Till Mixing	ZEROTILL	25 mm	0.05

ASAE (1998b) categorizes tillage implements into five different categories—primary tillage, secondary tillage, cultivating tillage, combination primary tillage, and combination secondary tillage. The definitions for the categories are (ASAE, 1998b):

> **Primary tillage**: the implements displace and shatter soil to reduce soil strength and bury or mix plant materials, pesticides, and fertilizers in the tillage layer. This type of tillage is more aggressive, deeper, and leaves a rougher soil surface relative to secondary tillage. Examples include plows—moldboard, chisel, disk, bedder; moldboard listers; disk bedders; subsoilers; disk harrows—offset disk, heavy tandem disk; and powered rotary tillers.
>
> **Secondary tillage**: the implements till the soil to a shallower depth than primary tillage implements, provide additional pulverization, mix pesticides and fertilizers into the soil, level and firm the soil, close air pockets, and eradicate weeds. Seedbed preparation is the final secondary tillage operation. Examples include harrows—disk, spring, spike, coil, tine-tooth, knife, packer, ridger, leveler, rotary ground driven; field or field conditioner cultivators; rod weeders; rollers; powered rotary tillers; bed shapers; and rotary hoes.
>
> **Cultivating tillage**: the implements perform shallow post-plant tillage to aid the crop by loosening the soil and/or by mechanical eradication of undesired vegetation. Examples include row crop cultivators—rotary ground-driven, spring tooth, shank tooth; rotary hoes; and rotary tillers.
>
> **Combination primary tillage**: the implements perform primary tillage functions and utilize two or more dissimilar tillage components as integral parts of the implement.
>
> **Combination secondary tillage**: the implements perform secondary tillage functions and utilize two or more dissimilar tillage components as integral parts of the implement.

ASAE (1998b) provides detailed descriptions and illustrations for the major implements. These are very helpful for those who are not familiar with farm implements.

A.3 PESTICIDE DATABASE

The pesticide database file (pest.dat) summarizes pesticide attribute information for various pesticides. The pesticide data included in the database was originally compiled for the GLEAMS model in the early nineties (Knisel, 1993). The following table lists the pesticides included in the pesticide database.

Table A-11: SWAT Pesticide Database

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life		Water Solubility
				Foliar	Soil	
		(ml/g)		(days)		(mg/L)
2,4,5-TP	Silvex	2600	0.40	5.0	20.0	2.5
2 Plus 2	Mecoprop Amine	20	0.95	10.0	21.0	660000
Aatrex	Atrazine	100	0.45	5.0	60.0	33
Abate	Temephos	100000	0.65	5.0	30.0	0.001
Acaraben	Chlorobenzilate	2000	0.05	10.0	20.0	13
Accelerate	Endothall Salt	20	0.90	7.0	7.0	100000
Acclaim	Fenoxaprop-Ethyl	9490	0.20	5.0	9.0	0.8
Alanap	Naptalam Sodium Salt	20	0.95	7.0	14.0	231000
Alar	Daminozide	10	0.95	4.0	7.0	100000
Aldrin	Aldrin	300	0.05	2.0	28.0	0.1
Aliette	Fosetyl-Aluminum	20	0.95	0.1	0.1	120000
Ally	Metsulfuron-Methyl	35	0.80	30.0	120.0	9500
Amiben	Chloramben Salts	15	0.95	7.0	14.0	900000
Amid-Thin W	NAA Amide	100	0.60	5.0	10.0	100
Amitrol T	Amitrole	100	0.95	5.0	14.0	360000
Ammo	Cypermethrin	100000	0.40	5.0	30.0	0.004
Antor	Diethatyl-Ethyl	1400	0.40	10.0	21.0	105
A-Rest	Ancymidol	120	0.50	30.0	120.0	650
Arsenal	Imazapyr Acid	100	0.90	30.0	90.0	11000
Arsonate	MSMA	10000	0.95	30.0	100.0	1000000
Asana	Esfenvalerate	5300	0.40	8.0	35.0	0.002
Assert (m)	Imazamethabenz-m	66	0.65	18.0	35.0	1370
Assert (p)	Imazamethabenz-p	35	0.65	18.0	35.0	875
Assure	Quizalofop-Ethyl	510	0.20	15.0	60.0	0.31
Asulox	Asulam Sodium Salt	40	0.95	3.0	7.0	550000
Avenge	Difenzoquat	54500	0.95	30.0	100.0	817000
Azodrin	Monocrotophos	1	0.95	2.0	30.0	1000000
Balan	Benefin	9000	0.20	10.0	30.0	0.1
Banol	Propamocarb	1000000	0.95	15.0	30.0	1000000
Banvel	Dicamba	2	0.65	9.0	14.0	400000
Basagran	Bentazon	34	0.60	2.0	20.0	2300000
Basta	Glufosinate Ammonia	100	0.95	4.0	7.0	1370000
Bayleton	Triadimefon	300	0.30	8.0	26.0	71.5

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life		Water Solubility
				Foliar	Soil	
		(ml/g)		(days)		(mg/L)
Baytex	Fenthion	1500	0.65	2.0	34.0	4.2
Baythroid	Cyfluthrin	100000	0.40	5.0	30.0	0.002
Benlate	Benomyl	1900	0.25	6.0	240.0	2
Benzex	BHC	55000	0.05	3.0	600.0	0.1
Betamix	Phenmedipham	2400	0.70	5.0	30.0	4.7
Betanex	Desmedipham	1500	0.70	5.0	30.0	8
Bidrin	Dicrotophos	75	0.70	20.0	28.0	1000000
Bladex	Cyanazine	190	0.60	5.0	14.0	170
Bolero	Thiobencarb	900	0.70	7.0	21.0	28
Bolstar	Sulprofos	12000	0.55	0.5	140.0	0.31
Bordermaster	MCPA Ester	1000	0.50	8.0	25.0	5
Botran	DCNA (Dicloran)	1000	0.50	4.0	10.0	7
Bravo	Chlorothalonil	1380	0.50	5.0	30.0	0.6
Buctril	Bromoxynil Octan. Ester	10000	0.20	3.0	7.0	0.08
Butyrac Ester	2,4-DB Ester	500	0.45	7.0	7.0	8
Caparol	Prometryn	400	0.50	10.0	60.0	33
Carbamate	Ferbam	300	0.90	3.0	17.0	120
Carsoron	Dichlobenil	400	0.45	5.0	60.0	21.2
Carzol	Formetanate Hydrochlor	1000000	0.95	30.0	100.0	500000
Cerone	Ethephon	100000	0.95	5.0	10.0	1239000
Chem-Hoe	Propham (IPC)	200	0.50	2.0	10.0	250
Chlordane	Chlordane	100000	0.05	2.5	100.0	0.1
Chopper	Imazapyr Amine	100	0.80	30.0	90.0	500000
Classic	Chlorimuron-ethyl	110	0.90	15.0	40.0	1200
Cobra	Lactofen	100000	0.20	2.0	3.0	0.1
Comite	Propargite	4000	0.20	5.0	56.0	0.5
Command	Clomazone	300	0.80	3.0	24.0	1000
Cotoran	Fluometuron	100	0.50	30.0	85.0	110
Counter	Terbufos	500	0.60	2.5	5.0	5
Crossbow	Triclopyr Amine	20	0.95	15.0	46.0	2100000
Curacron	Profenofos	2000	0.90	3.0	8.0	28
Cygon	Dimethoate	20	0.95	3.0	7.0	39800
Cyprex	Dodine Acetate	100000	0.50	10.0	20.0	700
Cythion	Malathion	1800	0.90	1.0	1.0	130
Dacamine	2,4-D Acid	20	0.45	5.0	10.0	890
Dacthal	DCPA	5000	0.30	10.0	100.0	0.5
Dalapon	Dalapon Sodium Salt	1	0.95	37.0	30.0	900000
Dasanit	Fensulfothion	10000	0.90	4.0	24.0	0.01
DDT	DDT	240000	0.05	10.0	120.0	0.1
Dedweed	MCPA Amine	20	0.95	7.0	25.0	866000
DEF	Tribufos	5000	0.25	7.0	30.0	2.3
Dessicant L-10	Arsenic Acid	100000	0.95	10000.0	10000.0	17000
Devrinol	Napropamide	400	0.60	15.0	70.0	74

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Di-Syston	Disulfoton	600	0.50	3.0	30.0	25
Dibrom	Naled	180	0.90	5.0	1.0	2000
Dieldrin	Dieldrin	50000	0.05	5.0	1400.0	0.1
Dimilin	Diflubenzuron	10000	0.05	27.0	10.0	0.08
Dinitro	Dinoseb Phenol	500	0.60	3.0	20.0	50
Diquat	Diquat Dibromide	1000000	0.95	30.0	1000.0	718000
Dithane	Mancozeb	2000	0.25	10.0	70.0	6
Dowpon	Dalapon	4	0.95	37.0	30.0	1000
Dropp	Thidiazuron	110	0.40	3.0	10.0	20
DSMA	Methanearsonic Acid Na	100000	0.95	30.0	1000.0	1400000
Du-ter	Triphenyltin Hydroxide	23000	0.40	18.0	75.0	1
Dual	Metolachlor	200	0.60	5.0	90.0	530
Dyfonate	Fonofos	870	0.60	2.5	40.0	16.9
Dylox	Trichlorfon	10	0.95	3.0	10.0	120000
Dymid	Diphenamid	210	0.80	5.0	30.0	260
Dyrene	Anilazine	3000	0.50	5.0	1.0	8
Elgetol	DNOC Sodium Salt	20	0.95	8.0	20.0	100000
EPN	EPN	13000	0.60	5.0	5.0	0.5
Eradicane	EPTC	200	0.75	3.0	6.0	344
Ethanox	Ethion	10000	0.65	7.0	150.0	1.1
Evik	Ametryn	300	0.65	5.0	60.0	185
Evital	Norflurazon	600	0.50	15.0	90.0	28
Far-Go	Triallate	2400	0.40	15.0	82.0	4
Fenatrol	Fenac	20	0.95	30.0	180.0	500000
Fenitox	Fenitrothion	2000	0.90	3.0	8.0	30
Fruitone CPA	3-CPA Sodium Salt	20	0.95	3.0	10.0	200000
Fundal	Chlordimeform Hydroclo.	100000	0.90	1.0	60.0	500000
Funginex	Triforine	540	0.80	5.0	21.0	30
Furadan	Carbofuran	22	0.55	2.0	50.0	351
Fusilade	Fluazifop-P-Butyl	5700	0.40	4.0	15.0	2
Glean	Chlorsulfuron	40	0.75	30.0	160.0	7000
Goal	Oxyfluorfen	100000	0.40	8.0	35.0	0.1
Guthion	Azinphos-Methyl	1000	0.65	2.0	10.0	29
Harmony	Thifensulfuron-Methyl	45	0.80	3.0	12.0	2400
Harvade	Dimethipin	10	0.80	3.0	10.0	3000
Hoelon	Diclofop-Methyl	16000	0.45	8.0	37.0	0.8
Hyvar	Bromacil	32	0.75	20.0	60.0	700
Imidan	Phosmet	820	0.90	3.0	19.0	20
Isotox	Lindane	1100	0.05	2.5	400.0	7.3
Karate	Lambda-Cyhalothrin	180000	0.40	5.0	30.0	0.005
Karathane	Dinocap	550	0.30	8.0	20.0	4
Karmex	Diuron	480	0.45	30.0	90.0	42
Kelthane	Dicofol	180000	0.05	4.0	60.0	1

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Half-Life Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Kerb	Pronamide	200	0.30	20.0	60.0	15
Krenite	Fosamine Ammon. Salt	150	0.95	4.0	8.0	1790000
Lannate	Methomyl	72	0.55	0.5	30.0	58000
Larvadex	Cyromazine	200	0.95	30.0	150.0	136000
Larvin	Thiodicarb	350	0.70	4.0	7.0	19.1
Lasso	Alachlor	170	0.40	3.0	15.0	240
Limit	Amidochlor	1000	0.70	8.0	20.0	10
Lontrel	Clopyralid	6	0.95	2.0	30.0	300000
Lorox	Linuron	400	0.60	15.0	60.0	75
Lorsban	Clorpyrifos	6070	0.65	3.3	30.0	0.4
Manzate	Maneb	1000	0.65	3.0	12.0	6
Marlate	Methoxychlor	80000	0.05	6.0	120.0	0.1
Matacil	Aminocarb	100	0.90	4.0	6.0	915
Mavrik	Fluvalinate	1000000	0.40	7.0	30.0	0.005
Metasystox	Oxydemeton-Methyl	10	0.95	3.0	10.0	1000000
Milogard	Propazine	154	0.45	5.0	135.0	8.6
Miral	Isazofos	100	0.65	5.0	34.0	69
Mitac	Amitraz	1000	0.45	1.0	2.0	1
Modown	Bifenox	10000	0.40	3.0	7.0	0.4
Monitor	Methamidophos	5	0.95	4.0	6.0	1000000
Morestan	Oxythioquinox	2300	0.50	10.0	30.0	1
Nemacur	Fenamiphos	240	0.70	5.0	5.0	400
Nemacur Sulfone	Fenamiphos Sulfone	45	0.70	18.0	18.0	400
Nemacur Sulfoxide	Fenamiphos Sulfoxide	40	0.70	42.0	42.0	400
Norton	Ethofumesate	340	0.65	10.0	30.0	50
Octave	Prochloraz	500	0.50	30.0	120.0	34
Oftanol	Isofenphos	600	0.65	30.0	150.0	24
Orthene	Acephate	2	0.70	2.5	3.0	818000
Orthocide	Captan	200	0.65	9.0	2.5	5.1
Oust	Sulfometuron-Methyl	78	0.65	10.0	20.0	70
Pay-Off	Flucythrinate	100000	0.40	5.0	21.0	0.06
Penncap-M	Methyl Parathion	5100	0.90	3.0	5.0	60
Phenatox	Toxaphene	100000	0.05	2.0	9.0	3
Phosdrin	Mevinphos	44	0.95	0.6	3.0	600000
Phoskil	Parathion (Ethyl)	5000	0.70	4.0	14.0	24
Pipron	Piperalin	5000	0.60	10.0	30.0	20
Pix	Mepiquat Chlor. Salt	1000000	0.95	30.0	1000.0	1000000
Plantvax	Oxycarboxin	95	0.70	10.0	20.0	1000
Poast	Sethoxydim	100	0.70	3.0	5.0	4390
Polyram	Metiram	500000	0.40	7.0	20.0	0.1
Pounce	Permethrin	100000	0.30	8.0	30.0	0.006
Pramitol	Prometon	150	0.75	30.0	500.0	720
Prefar	Bensulide	1000	0.40	30.0	120.0	5.6

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Prelude	Paraquat	1000000	0.60	30.0	1000.0	620000
Prime	Flumetralin	10000	0.40	7.0	20.0	0.1
Princep	Simazine	130	0.40	5.0	60.0	6.2
Probe	Methazole	3000	0.40	5.0	14.0	1.5
Prowl	Pendimethalin	5000	0.40	30.0	90.0	0.275
Pursuit	AC 263,499	10	0.90	20.0	90.0	200000
Pydrin	Fenvalerate	5300	0.25	10.0	35.0	0.002
Pyramin	Pyrazon	120	0.85	5.0	21.0	400
Ramrod	Propaclor	80	0.40	3.0	6.0	613
Reflex	Fomesafen Salt	60	0.95	30.0	100.0	700000
Rescue	2,4-DB Sodium Amine	20	0.45	9.0	10.0	709000
Ridomil	Metalaxyl	50	0.70	30.0	70.0	8400
Ro-Neet	Cycloate	430	0.50	2.0	30.0	95
Ronstar	Oxadiazon	3200	0.50	20.0	60.0	0.7
Roundup	Glyphosate Amine	24000	0.60	2.5	47.0	900000
Rovral	Iprodione	700	0.40	5.0	14.0	13.9
Royal Slo-Gro	Maleic Hydrazide	20	0.95	10.0	30.0	400000
Rubigan	Fenarimol	600	0.40	30.0	360.0	14
Sancap	Dipropetryn	900	0.40	5.0	30.0	16
Savey	Hexythiazox	6200	0.40	5.0	30.0	0.5
Scepter	Imazaquin Ammonium	20	0.95	20.0	60.0	160000
Sencor	Metribuzin	60	0.80	5.0	40.0	1220
Sevin	Carbaryl	300	0.55	7.0	10.0	120
Sinbar	Terbacil	55	0.70	30.0	120.0	710
Slug-Geta	Methiocarb	300	0.70	10.0	30.0	24
Sonalan	Ethalfluralin	4000	0.40	4.0	60.0	0.3
Spectracide	Diazinon	1000	0.90	4.0	40.0	60
Spike	Tebuthiuron	80	0.90	30.0	360.0	2500
Sprout Nip	Chlorpropham	400	0.90	8.0	30.0	89
Stam	Propanil	149	0.70	1.0	1.0	200
Supracide	Methidathion	400	0.90	3.0	7.0	220
Surflan	Oryzalin	600	0.40	5.0	20.0	2.5
Sutan	Butylate	400	0.30	1.0	13.0	44
Swat	Phosphamidon	7	0.95	5.0	17.0	1000000
Tackle	Acifluorfen	113	0.95	5.0	14.0	250000
Talstar	Bifenthrin	240000	0.40	7.0	26.0	0.1
Tandem	Tridiphane	5600	0.40	8.0	28.0	1.8
Tanone	Phenthoate	250	0.65	2.0	40.0	200
Tattoo	Bendiocarb	570	0.85	3.0	5.0	40
TBZ	Thiabendazole	2500	0.60	30.0	403.0	50
Temik	Aldicarb	40	0.70	7.0	7.0	6000
Temik Sulfone	Aldicarb Sulfone	10	0.70	20.0	20.0	6000
Temik Sulfoxide	Aldicarb Sulfoxide	30	0.70	30.0	30.0	6000

Trade Name	Common Name	Koc	Wash-off Frac.	Half-Life Foliar	Half-Life Soil	Water Solubility
		(ml/g)		(days)		(mg/L)
Tenoran	Chloroxuron	3000	0.40	15.0	60.0	2.5
Terbutrex	Terbutryn	2000	0.50	5.0	42.0	22
Terrachlor	PCNB	5000	0.40	4.0	21.0	0.44
Terraneb	Chloroneb	1650	0.50	30.0	130.0	8
Terrazole	Etridiazole	1000	0.60	3.0	20.0	50
Thimet	Phorate	1000	0.60	2.0	60.0	22
Thiodan	Endosulfan	12400	0.05	3.0	50.0	0.32
Thiram	Thiram	670	0.50	8.0	15.0	30
Thistrol	MCPB Sodium Salt	20	0.95	7.0	14.0	200000
Tillam	Pebulate	430	0.70	4.0	14.0	100
Tilt	Propiconazole	1000	0.70	30.0	110.0	110
Tolban	Profluralin	2240	0.35	1.0	140.0	0.1
Topsin	Thiophanate-Methyl	1830	0.40	5.0	10.0	3.5
Tordon	Picloram	16	0.60	8.0	90.0	200000
Tralomethrin	Tralomethrin	100000	0.40	1.0	27.0	0.001
Treflan	Trifluralin	8000	0.40	3.0	60.0	0.3
Tre-Hold	NAA Ethyl Ester	300	0.40	5.0	10.0	105
Tupersan	Siduron	420	0.70	30.0	90.0	18
Turflon	Triclopyr Ester	780	0.70	15.0	46.0	23
Velpar	Hexazinone	54	0.90	30.0	90.0	3300
Vendex	Fenbutatin Oxide	2300	0.20	30.0	90.0	0.013
Vernam	Vernolate	260	0.80	2.0	12.0	108
Volck oils	Petroleum oil	1000	0.50	2.0	10.0	100
Vydate	Oxamyl	25	0.95	4.0	4.0	282000
Weedar	2,4-D amine	20	0.45	9.0	10.0	796000
Weed-B-Gon	2,4,5-T Amine	80	0.45	10.0	24.0	500000
Wedone	Dichlorprop Ester	1000	0.45	9.0	10.0	50
Zolone	Phosalone	1800	0.65	8.0	21.0	3

Knisel (1993) cites Wauchope et al. (1992) as the source for water solubility, soil half-life and K_{oc} values. Wash-off fraction and foliar half-life were obtained from Willis et al. (1980) and Willis and McDowell (1987).

A.3.1 WATER SOLUBILITY

The water solubility value defines the highest concentration of pesticide that can be reached in the runoff and soil pore water. While this is an important characteristic, researchers have found that the soil adsorption coefficient, K_{oc}, tends to limit the amount of pesticide entering solution so that the maximum possible concentration of pesticide in solution is seldom reached (Leonard and Knisel, 1988).

Reported solubility values are determined under laboratory conditions at a constant temperature, typically between 20°C and 30°C.

A.3.2 SOIL ADSORPTION COEFFICIENT

The pesticide adsorption coefficient reported in the pesticide database can usually be obtained from a search through existing literature on the pesticide.

A.3.3 SOIL HALF-LIFE

The half-life for a pesticide defines the number of days required for a given pesticide concentration to be reduced by one-half. The soil half-life entered for a pesticide is a lumped parameter that includes the net effect of volatilization, photolysis, hydrolysis, biological degradation and chemical reactions.

The pesticide half-life for a chemical will vary with a change in soil environment (e.g. change in soil temperature, water content, etc.). Soil half-life values provided in the database are “average” or representative values. Half-life values reported for a chemical commonly vary by a factor of 2 to 3 and sometimes by as much as a factor of 10. For example, the soil half-life for atrazine can range from 120 to 12 days when comparing values reported in cool, dry regions to those from warm, humid areas. Another significant factor is soil treatment history. Repeated soil treatment by the same or a chemically similar pesticide commonly results in a reduction in half-life for the pesticide. This reduction is attributed to the preferential build-up of microbial populations adapted to degrading the compound. Users are encouraged to replace the default soil half-life value with a site-specific or region-specific value whenever the information is available.

A.3.4 FOLIAR HALF-LIFE

As with the soil half-life, the foliar half-life entered for a pesticide is a lumped parameter describing the loss rate of pesticides on the plant canopy. For most pesticides, the foliar half-life is much less than the soil half-life due to enhanced volatilization and photodecomposition. While values for foliar half-life were available for some pesticides in the database, the majority of foliar half-life values were calculated using the following rules:

1) Foliar half-life was assumed to be less than the soil half-life by a factor of 0.5 to 0.25, depending on vapor pressure and sensitivity to photodegradation.
2) Foliar half-life was adjusted downward for pesticides with vapor pressures less than 10^{-5} mm Hg.
3) The maximum foliar half-life assigned was 30 days.

A.3.5 WASH-OFF FRACTION

The wash-off fraction quantifies the fraction of pesticide on the plant canopy that may be dislodged. The wash-off fraction is a function of the nature of the leaf surface, plant morphology, pesticide solubility, polarity of the pesticide molecule, formulation of the commercial product and timing and volume of the rainfall event. Some wash-off fraction values were obtained from Willis et al. (1980). For the remaining pesticides, solubility was used as a guide for estimating the wash-off fraction.

A.3.6 APPLICATION EFFICIENCY

The application efficiency for all pesticides listed in the database is defaulted to 0.75. This variable is a calibration parameter.

A.4 FERTILIZER DATABASE

The fertilizer database file (fert.dat) summarizes nutrient fractions for various fertilizers and types of manure. The following table lists the fertilizers and types of manure in the fertilizer database.

Table A-12: SWAT Fertilizer Database

Name	**Name Code**	**Min-N**	**Min-P**	**Org-N**	**Org-P**	**NH_3-N/ Min N**
Elemental Nitrogen	Elem-N	1.000	0.000	0.000	0.000	0.000
Elemental Phosphorous	Elem-P	0.000	1.000	0.000	0.000	0.000
Anhydrous Ammonia	ANH-NH3	0.820	0.000	0.000	0.000	1.000
Urea	UREA	0.460	0.000	0.000	0.000	1.000
46-00-00	46-00-00	0.460	0.000	0.000	0.000	0.000
33-00-00	33-00-00	0.330	0.000	0.000	0.000	0.000
31-13-00	31-13-00	0.310	0.057	0.000	0.000	0.000
30-80-00	30-80-00	0.300	0.352	0.000	0.000	0.000
30-15-00	30-15-00	0.300	0.066	0.000	0.000	0.000
28-10-10	28-10-10	0.280	0.044	0.000	0.000	0.000
28-03-00	28-03-00	0.280	0.013	0.000	0.000	0.000
26-13-00	26-13-00	0.260	0.057	0.000	0.000	0.000
25-05-00	25-05-00	0.250	0.022	0.000	0.000	0.000
25-03-00	25-03-00	0.250	0.013	0.000	0.000	0.000
24-06-00	24-06-00	0.240	0.026	0.000	0.000	0.000
22-14-00	22-14-00	0.220	0.062	0.000	0.000	0.000
20-20-00	20-20-00	0.200	0.088	0.000	0.000	0.000
18-46-00	18-46-00	0.180	0.202	0.000	0.000	0.000
18-04-00	18-04-00	0.180	0.018	0.000	0.000	0.000
16-20-20	16-20-20	0.160	0.088	0.000	0.000	0.000
15-15-15	15-15-15	0.150	0.066	0.000	0.000	0.000
15-15-00	15-15-00	0.150	0.066	0.000	0.000	0.000
13-13-13	13-13-13	0.130	0.057	0.000	0.000	0.000
12-20-00	12-20-00	0.120	0.088	0.000	0.000	0.000
11-52-00	11-52-00	0.110	0.229	0.000	0.000	0.000
11-15-00	11-15-00	0.110	0.066	0.000	0.000	0.000
10-34-00	10-34-00	0.100	0.150	0.000	0.000	0.000
10-28-00	10-28-00	0.100	0.123	0.000	0.000	0.000
10-20-20	10-20-20	0.100	0.088	0.000	0.000	0.000
10-10-10	10-10-10	0.100	0.044	0.000	0.000	0.000
08-15-00	08-15-00	0.080	0.066	0.000	0.000	0.000
08-08-00	08-08-00	0.080	0.035	0.000	0.000	0.000
07-07-00	07-07-00	0.070	0.031	0.000	0.000	0.000
07-00-00	07-00-00	0.070	0.000	0.000	0.000	0.000
06-24-24	06-24-24	0.060	0.106	0.000	0.000	0.000
05-10-15	05-10-15	0.050	0.044	0.000	0.000	0.000

Name	Name Code	Min-N	Min-P	Org-N	Org-P	NH_3-N/ Min N
05-10-10	05-10-10	0.050	0.044	0.000	0.000	0.000
05-10-05	05-10-05	0.050	0.044	0.000	0.000	0.000
04-08-00	04-08-00	0.040	0.035	0.000	0.000	0.000
03-06-00	03-06-00	0.030	0.026	0.000	0.000	0.000
02-09-00	02-09-00	0.020	0.040	0.000	0.000	0.000
00-15-00	00-15-00	0.000	0.066	0.000	0.000	0.000
00-06-00	00-06-00	0.000	0.026	0.000	0.000	0.000
Dairy-Fresh Manure	DAIRY-FR	0.007	0.005	0.031	0.003	0.990
Beef-Fresh Manure	BEEF-FR	0.010	0.004	0.030	0.007	0.990
Veal-Fresh Manure	VEAL-FR	0.023	***0.006***	0.029	***0.007***	0.990
Swine-Fresh Manure	SWINE-FR	0.026	0.011	0.021	0.005	0.990
Sheep-Fresh Manure	SHEEP-FR	***0.014***	0.003	***0.024***	0.005	0.990
Goat-Fresh Manure	GOAT-FR	***0.013***	***0.003***	***0.022***	***0.005***	0.990
Horse-Fresh Manure	HORSE-FR	***0.006***	0.001	***0.014***	0.003	0.990
Layer-Fresh Manure	LAYER-FR	0.013	0.006	0.040	0.013	0.990
Broiler-Fresh Manure	BROIL-FR	***0.010***	***0.004***	***0.040***	***0.010***	0.990
Turkey-Fresh Manure	TRKEY-FR	0.007	***0.003***	0.045	***0.016***	0.990
Duck-Fresh Manure	DUCK-FR	***0.023***	0.008	***0.025***	0.009	0.990

Values in bold italics are estimated (see section A.4.2)

A.4.1 COMMERCIAL FERTILIZERS

In compiling the list of commercial fertilizers in the database, we tried to identify and include commonly used fertilizers. This list is not comprehensive, so users may need to append the database with information for other fertilizers used in their watersheds.

When calculating the fractions of N and P for the database, it is important to remember that the percentages reported for a fertilizer are %N-%P_2O_5-%K_2O. The fraction of mineral N in the fertilizer is equal to %N divided by 100. To calculate the fraction of mineral P in the fertilizer, the fraction of P in P_2O_5 must be known. The atomic weight of phosphorus is 31 and the atomic weight of oxygen is 16, making the molecular weight of P_2O_5 equal to 142. The fraction of P in P_2O_5 is 62/142 = 0.44 and the fraction of mineral P in the fertilizer is equal to 0.44 (%P_2O_5 / 100).

A.4.2 MANURE

The values in the database for manure types were derived from manure production and characteristics compiled by the ASAE (1998a). Table A-13 summarizes the levels of nitrogen and phosphorus in manure reported by the ASAE. The data summarized by ASAE is combined from a wide range of published and unpublished information. The mean values for each parameter are determined by an arithmetic average consisting of one data point per reference source per year and represent fresh (as voided) feces and urine.

Table A-13: Fresh manure production and characteristics per 1000 kg live animal mass per day (from ASAE, 1998a)

			Animal Type[‡]										
Parameter			Dairy	Beef	Veal	Swine	Sheep	Goat	Horse	Layer	Broiler	Turkey	Duck
Total Manure	kg[†]	mean	86	58	62	84	40	41	51	64	85	47	110
		std dev	17	17	24	24	11	8.6	7.2	19	13	13	**
Total Solids	kg	mean	**12**	**8.5**	**5.2**	**11**	**11**	**13**	**15**	**16**	**22**	**12**	**31**
		std dev	2.7	2.6	2.1	6.3	3.5	1.0	4.4	4.3	1.4	3.4	15
Total Kjeldahl nitrogen[‖]	kg	mean	**0.45**	**0.34**	**0.27**	**0.52**	**0.42**	**0.45**	**0.30**	**0.84**	**1.1**	**0.62**	**1.5**
		std dev	0.096	0.073	0.045	0.21	0.11	0.12	0.063	0.22	0.24	0.13	0.54
Ammonia nitrogen	kg	mean	**0.079**	**0.086**	**0.12**	**0.29**	**	**	**	**0.21**	**	**0.080**	**
		std dev	0.083	0.052	0.016	0.10	**	**	**	0.18	**	0.018	**
Total phosphorus	kg	mean	**0.094**	**0.092**	**0.066**	**0.18**	**0.087**	**0.11**	**0.071**	**0.30**	**0.30**	**0.23**	**0.54**
		std dev	0.024	0.027	0.011	0.10	0.030	0.016	0.026	0.081	0.053	0.093	0.21
Ortho-phosphorus	kg	mean	**0.061**	**0.030**	**	**0.12**	**0.032**	**	**0.019**	**0.092**	**	**	**0.25**
		std dev	0.0058	**	**	**	0.014	**	0.0071	0.016	**	**	**

** Data not found.

[†] All values wet basis.

[‡] Typical live animal masses for which manure values represent are: dairy, 640 kg; beef, 360 kg; veal, 91 kg; swine, 61 kg; sheep, 27 kg; goat, 64 kg; horse, 450 kg; layer, 1.8 kg; broiler, 0.9 kg; turkey, 6.8 kg; and duck, 1.4 kg.

[‖] All nutrient values are given in elemental form.

The fractions of the nutrient pools were calculated on a Total Solids basis, i.e. the water content of the manure was ignored. Assumptions used in the calculations are: 1) the mineral nitrogen pool is assumed to be entirely composed of NH_3/NH_4^+, 2) the organic nitrogen pool is equal to total Kjeldahl nitrogen minus ammonia nitrogen, 3) the mineral phosphorus pool is equal to the value given for orthophosphorus, and 4) the organic phosphorus pool is equal to total phosphorus minus orthophosphorus.

Total amounts of nitrogen and phosphorus were available for all manure types. For manure types with either the ammonia nitrogen or orthophosphorus value missing, the ratio of organic to mineral forms of the provided element were used to partition the total amount of the other element. For example, in Table A-

13 amounts of total Kjeldahl N, ammonia N, and total P are provided for veal but data for orthophosphorus is missing. To partition the total P into organic and mineral pools, the ratio of organic to mineral N for veal was used. If both ammonia nitrogen and orthophosphorus data are missing, the ratio of the organic to mineral pool for a similar animal were used to partition the total amounts of element into different fractions. This was required for goat and broiler manure calculations. The ratio of organic to mineral pools for sheep was used to partition the goat manure nutrient pools while layer manure nutrient ratios were used to partition the broiler manure nutrient pools.

As can be seen from the standard deviations in Table A-13, values for nutrients in manure can vary widely. If site specific data are available for the region or watershed of interest, those values should be used in lieu of the default fractions provided in the database.

A.5 URBAN DATABASE

The urban database file (urban.dat) summarizes urban landscape attributes needed to model urban areas. These attributes tend to vary greatly from region to region and the user is recommended to use values specific to the area being modeled. The following tables list the urban land types and attributes that are provided in the urban database.

Numerous urban land type classifications exist. For the default urban land types included in the database, an urban land use classification system created by Palmstrom and Walker (1990) was simplified slightly. Table A-14 lists the land type classifications used by Palmstrom and Walker and those provided in the database.

Table A-14: Urban land type classification systems

Palmstrom and Walker (1990)	SWAT Urban Database
Residential-High Density	Residential-High Density
Residential-Med/High Density	Residential-Medium Density
Residential-Med/Low Density	Residential-Med/Low Density
Residential-Low Density	Residential-Low Density
Residential-Rural Density	Commercial
Commercial	Industrial
Industrial-Heavy	Transportation
Industrial-Medium	Institutional
Transportation	
Institutional	

The urban database includes the following information for each urban land type: 1) fraction of urban land area that is impervious (total and directly connected); 2) curb length density; 3) wash-off coefficient; 4) maximum accumulated solids; 5) number of days for solid load to build from 0 kg/curb km to half of the maximum possible load; 6) concentration of total N in solid loading; 7) concentration of total P in solid loading; and 8) concentration of total NO_3-N in solid loading. The fraction of total and directly connected impervious areas is needed for urban surface runoff calculations. The remaining information is used only when the urban build up/wash off algorithm is chosen to model sediment and nutrient loading from the urban impervious area.

A.5.1 DRAINAGE SYSTEM CONNECTEDNESS

When modeling urban areas the connectedness of the drainage system must be quantified. The best methods for determining the fraction total and directly connected impervious areas is to conduct a field survey or analyze aerial photographs. However these methods are not always feasible. An alternative approach is to use data from other inventoried watersheds with similar land types. Table A-15 contains ranges and average values calculated from a number of different individual surveys (the average values from Table A-15 are the values included in the database). Table A-16 contains data collected from the cities of Madison and Milwaukee, Wisconsin and Marquett, Michigan.

Table A-15: Range and average impervious fractions for different urban land types.

Urban Land Type	**Average total impervious**	**Range total impervious**	**Average connected impervious**	**Range connected impervious**
Residential-High Density (> 8 unit/acre or unit/2.5 ha)	.60	.44 - .82	.44	.32 - .60
Residential-Medium Density (1-4 unit/acre or unit/2.5 ha)	.38	.23 - .46	.30	.18 - .36
Residential-Med/Low Density (> 0.5-1 unit/acre or unit/2.5 ha)	.20	.14 - .26	.17	.12 - .22
Residential-Low Density (< 0.5 unit/acre or unit/2.5 ha)	.12	.07 - .18	.10	.06 - .14
Commercial	.67	.48 - .99	.62	.44 - .92
Industrial	.84	.63 - .99	.79	.59 - .93
Transportation	.98	.88 - 1.00	.95	.85 – 1.00
Institutional	.51	.33 - .84	.47	.30 - .77

Table A-16: Impervious fractions for different urban land types in Madison and Milwaukee, WI and Marquett, MI.

Urban Land Type	**Directly connected impervious**	**Indirectly connected impervious**	**Pervious**
Residential-High Density	.51	.00	.49
Residential-Medium Density	.24	.13	.63
Residential-Low Density	.06	.10	.84
Regional Mall	.86	.00	.14
Strip Mall	.75	.00	.25
Industrial-Heavy	.80	.02	.18
Industrial-Light	.69	.00	.31
Airport	.09	.25	.66
Institutional	.41	.00	.59
Park	.08	.06	.86

A.5.2 CURB LENGTH DENSITY

Curb length may be measured directly by scaling the total length of streets off of maps and multiplying by two. To calculate the density the curb length is divided by the area represented by the map.

The curb length densities assigned to the different land uses in the database were calculated by averaging measured curb length densities reported in studies by Heaney et al. (1977) and Sullivan et al. (1978). Table A-17 lists the reported values and the averages used in the database.

Table A-17: Measured curb length density for various land types

Location: Land type	Tulsa, OK km/ha	10 Ontario Cities km/ha	Average of two values km/ha	SWAT database categories using average value:
Residential	0.30	0.17	0.24	All Residential
Commercial	0.32	0.23	0.28	Commercial
Industrial	0.17	0.099	0.14	Industrial
Park	0.17	--	0.17	
Open	0.063	0.059	0.06	
Institutional	--	0.12	0.12	Transportation, Institutional

A.5.3 WASH-OFF COEFFICENT

The database assigns the original default value, 0.18 mm^{-1}, to the wash-off coefficient for all land types in the database (Huber and Heaney, 1982). This value was calculated assuming that 13 mm of total runoff in one hour would wash off 90% of the initial surface load. Using sediment transport theory, Sonnen (1980) estimated values for the wash-off coefficient ranging from 0.002-0.26 mm^{-1}. Huber and Dickinson (1988) noted that values between 0.039 and 0.390 mm^{-1} for the wash-off coefficient give sediment concentrations in the range of most observed values. This variable is used to calibrate the model to observed data.

A.5.4 MAXIMUM SOLID ACCUMULATION AND RATE OF ACCUMULATION

The shape of the solid build-up equation is defined by two variables: the maximum solid accumulation for the land type and the amount of time it takes to build up from 0 kg/curb km to one-half the maximum value. The values assigned to the default land types in the database were extrapolated from a study performed by Sartor and Boyd (1972) in ten U.S. cities. They summarized the build-up of solids over time for residential, commercial, and industrial land types as well as providing results for all land types combined (Figure A-5).

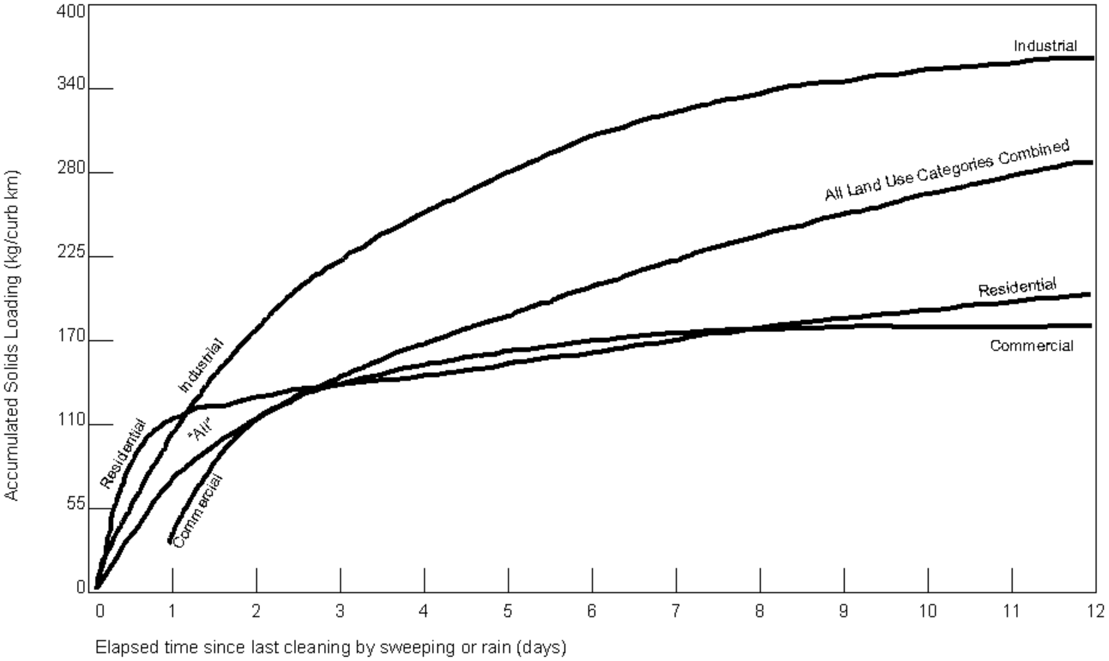

Figure A-5: Solid loading as a function of time (Sartor and Boyd, 1972)

The lines plotted in Figure A-5 were adapted for use in the database. Table A-18 lists maximum load values and time to accumulate half the maximum load that were derived from the graph. The assignment of values to the different land types is provided in the table also.

Table A-18: Maximum solid load and accumulation time (from Sartor and Boyd, 1972).

Land type	**Maximum loading kg/curb km**	**time to accumulate ½ maximum load days**	**SWAT database categories using value:**
Residential	225	0.75	All Residential
Commercial	200	1.60	Commercial
Industrial	400	2.35	Industrial
All land types	340	3.90	Transportation/Institutional

A.5.5 NUTRIENT CONCENTRATION IN SOLIDS

For the default land types in the database, nutrient concentrations in the solids were extrapolated from a nationwide study by Manning et al. (1977). The data published by Manning is summarized in Table A-19.

Three concentration values are required: total nitrogen (mg N/kg), nitrate nitrogen (mg NO_3-N/kg), and total phosphorus (mg P/kg). Manning provided total nitrogen values for all of his land use categories, nitrate values for one land use category and mineral phosphorus values for all the land use categories. To obtain nitrate concentrations for the other land use categories, the ratio of NO_3-N to total N for commercial areas was assumed to be representative for all the categories. The nitrate to total N ratio for commercial land was multiplied by the total N concentrations for the other categories to obtain a nitrate concentration. The total phosphorus concentration was estimated by using the ratio of organic phosphorus to orthophosphate provided by the Northern Virginia Planning District Commission (1979). Total phosphorus loads from impervious areas are assumed to be 75 percent organic and 25 percent mineral. Table A-20 summarizes the assignment of values to the default land types in the urban database.

Table A-19: Nationwide dust and dirt build-up rates and pollutant fractions (Manning et al., 1977)

Pollutant		**Land Use Category**				
		Single Family Residential	Mult. Family Residential	Commercial	Industrial	All Data
Dust & Dirt Accumulation	mean	17	32	47	90	45
(kg/curb km/day)	range	1-268	2-217	1-103	1-423	1-423
	# obs.	74	101	158	67	400
Total N-N	mean	460	550	420	430	480
(mg/kg)	range	325-525	356-961	323-480	410-431	323-480
	# obs.	59	93	80	38	270
NO_3	mean	--	--	24	--	24
(mg/kg)	range	--	--	10-35	--	10-35
	# obs.	--	--	21	--	21
PO_4-P	mean	49	58	60	26	53
(mg/kg)	range	20-109	20-73	0-142	14-30	0-142
	# obs.	59	93	101	38	291

Table A-20: Nutrient concentration assignments for default land types

	Manning et al (1977)	Modifications:	Final Value:	SWAT database categories using value:
Total Nitrogen-N				
Single Fam Res.	460 ppm	--	460 ppm	Residential: Med/Low & Low
Mult. Fam. Res.	550 ppm	--	550 ppm	Residential: Med. & High
Commercial	420 ppm	--	420 ppm	Commercial
Industrial	430 ppm	--	430 ppm	Industrial
All Data	480 ppm	--	480 ppm	Transportation/Institutional
Nitrate-N: multiply reported value by fraction of weight that is nitrogen to get NO_3-N				
Single Fam Res.	5.5 ppm	(5.5/420) x 460	6.0 ppm	Residential: Med/Low & Low
Mult. Fam. Res.		(5.5/420) x 550	7.2 ppm	Residential: Med. & High
Commercial		--	5.5 ppm	Commercial
Industrial		(5.5/420) x 430	5.6 ppm	Industrial
All Data		(5.5/420) x 480	6.3 ppm	Transportation/Institutional
Total Phosphorus-P: assume PO_4-P is 25% of total P				
Single Fam Res.	49 ppm PO_4-P	49/(.25)	196 ppm	Residential: Med/Low & Low
Mult. Fam. Res.	58 ppm PO_4-P	58/(.25)	232 ppm	Residential: Med. & High
Commercial	60 ppm PO_4-P	60/(.25)	240 ppm	Commercial
Industrial	26 ppm PO_4-P	26/(.25)	104 ppm	Industrial
All Data	53 ppm PO_4-P	53/(.25)	212 ppm	Transportation/Institutional

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APPENDIX B

EXAMPLE WATERSHED CONFIGURATIONS

The watershed configuration file defines the spatial relationship of objects within the watershed. The three techniques used to subdivide a watershed are the subwatershed discretization, the hillslope discretization, and the grid cell discretization. The following sections describe how to set up the watershed configuration file for each of the different discretization techniques.

B.1 SUBWATERSHED DISCRETIZATION

The subwatershed discretization divides the watershed into subbasins based on topographic features of the watershed. This technique preserves the natural flow paths, boundaries, and channels required for realistic routing of water, sediment and chemicals. **All of the GIS interfaces developed for SWAT use the subwatershed discretization to divide a watershed.**

The number of subbasins chosen to model the watershed depends on the size of the watershed, the spatial detail of available input data and the amount of detail required to meet the goals of the project. When subdividing the watershed, keep in mind that topographic attributes (slope, slope length, channel length, channel width, etc.) are calculated or summarized at the subbasin level. The subbasin delineation should be detailed enough to capture significant topographic variability within the watershed.

Once the subbasin delineation has been completed, the user has the option of modeling a single soil/land use/management scheme for each subbasin or partitioning the subbasins into multiple hydrologic response units (HRUs). Hydrologic response units are unique soil/land use/management combinations within the subbasin which are modeled without regard to spatial positioning. When multiple HRUs are modeled within a subbasin, the land phase of the hydrologic cycle is modeled for each HRU and then the loadings from all HRUs within the subbasin are summed. The net loadings for the subbasin are then routed through the watershed channel network. HRUs are set up in the subbasin general attribute file (.sub).

The following sections demonstrate how to create a SWAT watershed configuration file using the subwatershed discretization.

B.1.1 SUBWATERSHED DISCRETIZATION: 3 SUBBASINS

Assume we have a watershed with 3 subbasins as illustrated in Figure B-1.

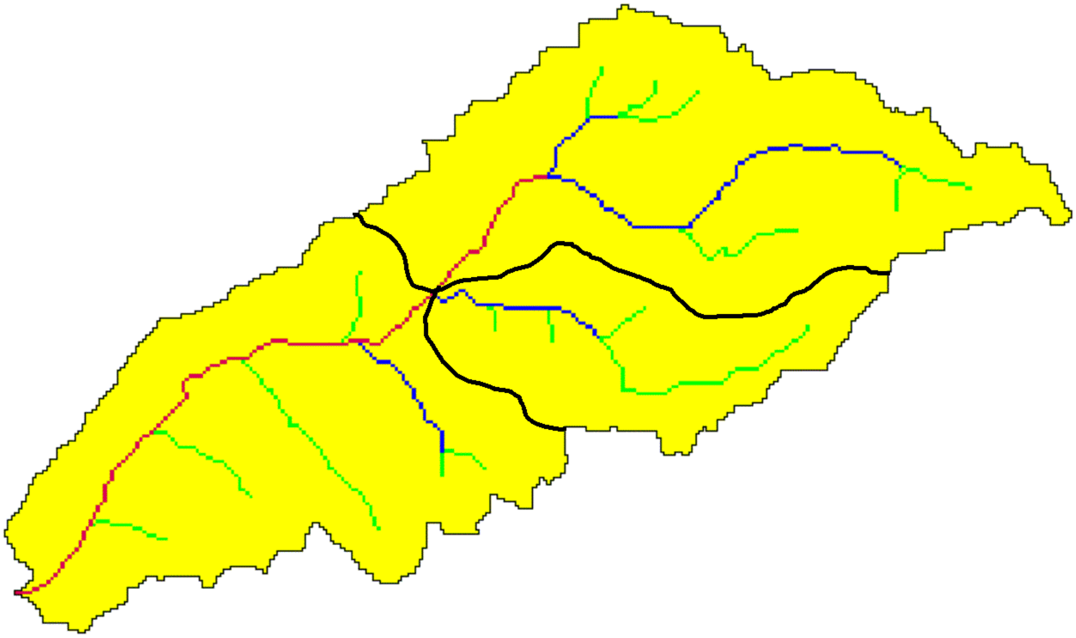

Figure B-1: Subwatershed delineation

Step 1: Write the subbasin command for each subbasin. (This command simulates the land phase of the hydrologic cycle.)

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				

Writing **subbasin** in space 1-10 is optional. The model identifies the configuration command by the code in column 1. The option of writing the command in space 1-10 is provided to assist the user in interpreting the configuration file.

Column 2 is the hydrograph storage location number (array location) where data for the loadings (water, sediment, chemicals) from the subbasin are stored.

Column 3 is the subbasin number. The subbasin number tells SWAT which input files listed in file.cio contain the data used to model the subbasin. Subbasin numbers are assigned sequentially in file.cio to each pair of lines after line 14. The files listed on lines 15 & 16 of file.cio are used to model subbasin 1, the files listed on lines 17 & 18 of file.cio are used to model subbasin 2, the files listed on lines 19 & 20 of file.cio are used to model subbasin 3, and so on.

Step 2a: Route the stream loadings through the reach network. Begin by routing the headwater subbasin loadings through the main channel of the respective subbasin. (Headwater subbasins are those with no subbasins upstream.) Referring to Figure B-1, assume that subbasins 1 and 2 are upstream of subbasin 3. This would make subbasins 1 and 2 headwater subbasins.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
route	**2**	**4**	**1**	**1**		**0.000**	
route	**2**	**5**	**2**	**2**		**0.000**	

As mentioned in the last step, column 1 is used to identify the command. Column 2 is the hydrograph storage location number identifying the location where results from the route simulation are placed.

Column 3 provides the number of the reach, or main channel, the inputs are routed through. The number of the reach in a particular subbasin is the same as the number of the subbasin.

Column 4 lists the number of the hydrograph storage location containing the data to be routed through the reach. The loadings from subbasin 1 are stored in hydrograph storage #1 and the loadings from subbasin 2 are stored in hydrograph storage #2.

Column 6 lists the fraction of overland flow. For the subwatershed discretization, this value will always be zero—flow is always considered to be channelized before entering the next subbasin.

Step 2b: Route the stream loadings through the reach network. Use the add and route commands to continue routing through the watershed. For this example, the water, sediment and chemicals flowing out of subbasins 1 and 2 and the loadings from subbasin 3 must be added together and routed through the main channel of subbasin 3. The loadings from the outlet of subbasin 1 are stored in hydrograph location #4; the loadings from the outlet of subbasin 2 are stored in hydrograph location #5; and the loadings from subbasin 3 are stored in hydrograph location #3.

	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
space 1-10							
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
route	**2**	**4**	**1**	**1**		**0.000**	
route	**2**	**5**	**2**	**2**		**0.000**	
add	**5**	**6**	**4**	**5**			
add	**5**	**7**	**6**	**3**			
route	**2**	**8**	**3**	**7**		**0.000**	

The add command is specified in column 1 by the number 5. The hydrograph storage location numbers of the 2 data sets to be added are listed in columns 3 and 4. The summation results are stored in the hydrograph location number given in column 2.

Step 3: Once the stream loadings have been routed to the watershed outlet, append a finish command line to signify the end of the watershed routing file.

	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
space 1-10							
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
route	**2**	**4**	**1**	**1**		**0.000**	
route	**2**	**5**	**2**	**2**		**0.000**	
add	**5**	**6**	**4**	**5**			
add	**5**	**7**	**6**	**3**			
route	**2**	**8**	**3**	**7**		**0.000**	
finish	**0**						

B.1.2 SUBWATERSHED DISCRETIZATION: SAVING SIMULATION RESULTS FOR DOWNSTREAM RUNS

If the watershed of interest is split up into subwatersheds that are modeled with separate SWAT runs, the outflow from the upstream subwatersheds must be saved in a file using the save command. This data will then be input into the SWAT simulation of the downstream portion of the watershed using a recday command.

In example B.1.1, the outflow from the watershed is stored in hydrograph location #8, so this is the data we need to store in a daily file for use in another SWAT simulation. The watershed configuration modified to store outflow data is:

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
route	**2**	**4**	**1**	**1**		**0.000**	
route	**2**	**5**	**2**	**2**		**0.000**	
add	**5**	**6**	**4**	**5**			
add	**5**	**7**	**6**	**3**			
route	**2**	**8**	**3**	**7**		**0.000**	
save	**9**	**8**					
finish	**0**						

The save command is specified in column 1 by the number 9. Column 2 lists the hydrograph storage location of the data to be saved in the event output file. The name of the event output file is listed in file.cio and usually possesses the .eve file extension. Only one save command is allowed in a simulation.

The event file output is described in Chapter 44.

B.1.3 SUBWATERSHED DISCRETIZATION: INCORPORATING POINT SOURCE/UPSTREAM SIMULATION DATA

Point source and upstream simulation data may be incorporated into a run using one of four record commands: recday, recmon, recyear, and reccnst. The recday command reads data from a file containing loadings of different constituents for each day of simulation. The recmon command reads data from a file containing average daily loadings for each month. The recyear command reads data from a file containing average daily loadings for each year. The reccnst command reads in average annual daily loadings. The record command chosen to read in the data is a function of the detail of data available. To read in upstream simulation data, the recday command is always used.

Assuming the subbasin delineation in Figure B-1 is used with one point source (sewage treatment plants) per subbasin, the watershed configuration file is:

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
recday	**10**	**4**	**1**				
	sub1.pnt						
add	**5**	**5**	**4**	**1**			
route	**2**	**6**	**1**	**5**		**0.000**	
recday	**10**	**7**	**2**				
	sub2.pnt						
add	**5**	**8**	**7**	**2**			
route	**2**	**9**	**2**	**8**		**0.000**	
add	**5**	**10**	**6**	**9**			
recday	**10**	**11**	**3**				
	sub3.pnt						
add	**5**	**12**	**11**	**10**			
add	**5**	**13**	**12**	**3**			
route	**2**	**14**	**3**	**13**		**0.000**	
finish	**0**						

All of the record commands require 2 lines. On the first line, column 1 contains the command code for the specific record command, column 2 contains the hydrologic storage location where the data from the file is stored, and column 3 contains the file number. A different file number must be used for each point source of a specific type (e.g., all recday commands must have unique file numbers). The second line lists the name of the file containing the input data.

A description of the four types of record files is given in Chapter 43.

B.1.4 SUBWATERSHED DISCRETIZATION: INCORPORATING RESERVOIRS

Water bodies located along the main channel are modeled using reservoirs. To incorporate a reservoir into a simulation, a routres command is used. There is no limitation on the number of reservoirs modeled.

Assuming the subbasin delineation in Figure B-1 is used with one reservoir located at the outlet, the watershed configuration file is:

space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
route	**2**	**4**	**1**	**1**		**0.000**	
route	**2**	**5**	**2**	**2**		**0.000**	
add	**5**	**6**	**4**	**5**			
add	**5**	**7**	**6**	**3**			
route	**2**	**8**	**3**	**7**		**0.000**	
routres	**3**	**9**	**1**	**8**	**3**		
	lakefork.res		**lakefork.lwq**				
finish	**0**						

The routres command requires 2 lines. On the first line, the routres command is identified with the number 3 in column 1. Column 2 gives the hydrograph storage location where outflow data from the reservoir is stored. Column 3 lists the reservoir number. Column 4 gives the hydrograph storage location of the data to be routed through the reservoir. Column 5 lists the subbasin with which the reservoir is associated. A different reservoir number must be assigned to each reservoir and the numbers should be sequential beginning with 1. The second line lists two file names, the reservoir input file (.res) and the reservoir water quality file (.lwq).

B.1.5 SUBWATERSHED DISCRETIZATION: SAVING SIMULATION RESULTS FOR ONE LOCATION

Users often need to compare streamflow, sediment, nutrient and/or pesticide levels predicted by the model with levels measured in the stream. To save daily or hourly model output data for a particular location on the stream, the saveconc command is used.

Assume there is a stream gage at the outlet of the watershed shown in Figure B-1 and that we want to compare simulated and measured streamflow for this location. Hydrograph storage location #8 stores the flow data for this location in the watershed, so this is the data we need to process to create the saveconc output file. The watershed configuration modified to process data for this location is:

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
route	**2**	**4**	**1**	**1**		**0.000**	
route	**2**	**5**	**2**	**2**		**0.000**	
add	**5**	**6**	**4**	**5**			
add	**5**	**7**	**6**	**3**			
route	**2**	**8**	**3**	**7**		**0.000**	
saveconc	**14**	**8**	**1**	**0**			
	strgage.out						
finish	**0**						

The saveconc command requires 2 lines. On the first line, the saveconc command is identified with the number 14 in column 1. Column 2 gives the hydrograph storage location of the data to be processed for the saveconc output file. Column 3 lists the file number. Column 4 gives the print frequency (daily or hourly). More than one saveconc command may be used in a simulation. A different file number must be assigned to each saveconc output file and the file numbers should be sequential beginning with 1. The second line lists the name of the saveconc output file.

The saveconc command differs from the save command in that it converts the mass amounts of water, sediment, and chemicals to units that are commonly used to report measured values. Output files produced by the saveconc command cannot be read into another SWAT run—the save command must be used to produce input for another simulation.

B.2 HILLSLOPE DISCRETIZATION

The hillslope discretization allows overland flow from one subbasin to flow onto the land area of another subbasin. As the name implies, this discretization allows SWAT to model hillslope processes.

The hillslope discretization incorporates more detail into the watershed configuration file than the subwatershed discretization. The number of subbasins chosen to model the watershed will depend on the size of the watershed, the spatial relationship of different land uses to one another, the spatial detail of available input data and the amount of detail required to meet the goals of the project. Because this discretization scheme places more emphasis on land use, the subbasins are delineated so that there is one land use and soil per subbasin.

The hillslope discretization can be combined with the subwatershed discretization to provide detailed modeling of particular land use areas while modeling the remaining land use areas with the more generalized approach.

Useful applications of this discretization include: watersheds with concentrated animal feeding operations, watersheds where detailed modeling of filter strips is desired, and microwatersheds where the scale of the simulation allows detail about relative land use positions to be incorporated.

B.2.1 HILLSLOPE DISCRETIZATION: MODELING A DAIRY OPERATION

Assume a microwatershed containing a concentrated animal feeding operation with several different areas of land use and management is being modeled. Milking cows are confined in stalls. All waste produced by the milking cows is collected and applied over manure application fields also located in the microwatershed. The dry cows are kept in pastures. The pastured cows keep the areas adjacent to the farm buildings denuded of grass. Runoff from the denuded areas flows onto the pasture. Runoff from the pasture flows into a filter strip or buffer zone. Runoff exiting the filter strip enters the stream. The manure application fields are isolated from the rest of the dairy operation. Runoff from the application fields flows into a filter strip, and then enters the steam. Figure B-2 illustrates the relationship of land areas in the dairy operation. Areas of the microwatershed outside of the daily operation are forested.

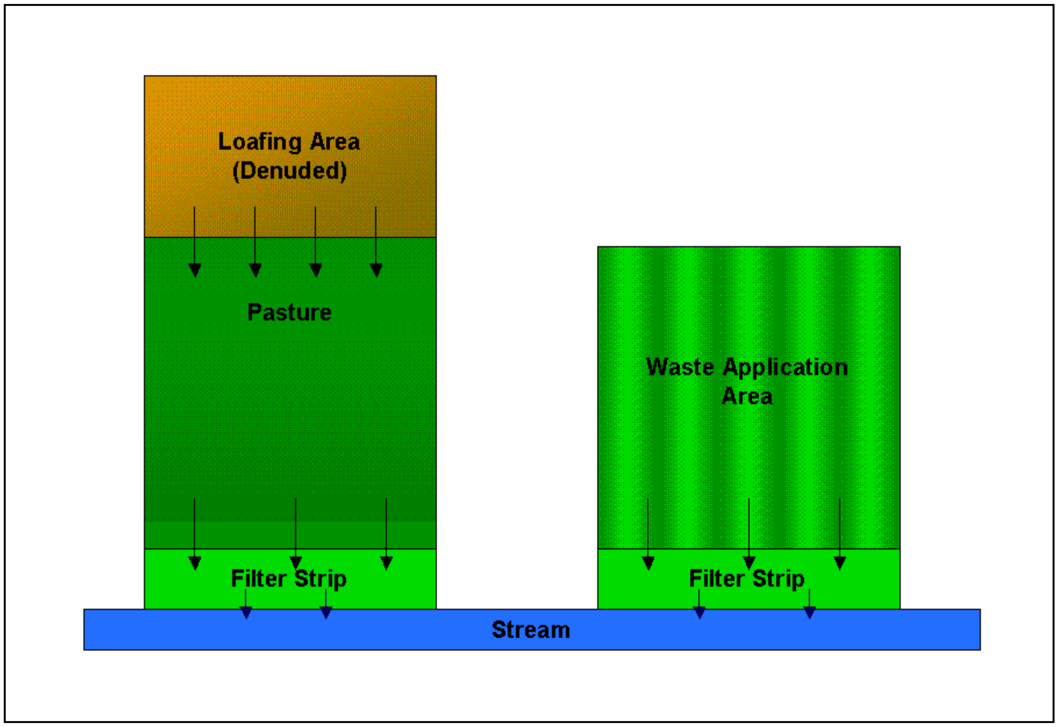

Figure B-2: Spatial positioning of land areas in dairy operation.

This microwatershed will be divided into 6 subbasins:

- Subbasin 1: loafing area
- Subbasin 2: pasture
- Subbasin 3: filter strip associated with pasture
- Subbasin 4: waste application area
- Subbasin 5: filter strip associated with waste application area
- Subbasin 6: completely channelized stream and forest in microwatershed

Step 1: Write the subbasin command for each subbasin. (This command simulates the land phase of the hydrologic cycle.)

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				

Writing **subbasin** in space 1-10 is optional. The model identifies the configuration command by the code in column 1. The option of writing the command in space 1-10 is provided to assist the user in interpreting the configuration file.

Column 2 is the hydrograph storage location number (array location) where data for the loadings (water, sediment, chemicals) from the subbasin are stored.

Column 3 is the subbasin number. The subbasin number tells SWAT which input files listed in file.cio contain the data used to model the subbasin. Subbasin numbers are assigned sequentially in file.cio to each pair of lines after line 14. The files listed on lines 15 & 16 of file.cio are used to model subbasin 1, the files listed on lines 17 & 18 of file.cio are used to model subbasin 2, the files listed on lines 19 & 20 of file.cio are used to model subbasin 3, and so on.

Step 2: Route the stream loadings.

The hillslope discretization differs from the subwatershed discretization primarily in the method used to route loadings through the watershed. Loadings from subbasins are not routed through the subbasin if the flow leaving the subbasin is not completely channelized. For our example, subbasin 6 is the only subbasin completely channelized.

Assume that runoff from the denuded areas (subbasin 1) is sheet flow, i.e. there are no rills, gullies or any other evidence of channelized flow in the denuded area. Runoff from the denuded area will be routed to the pasture (subbasin 2) using the route command:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
route	**2**	**7**	**2**	**1**		**1.000**	

As mentioned in the last step, column 1 is used to identify the command. Column 2 is the hydrograph storage location number identifying the location where results from the channelized portion of the route simulation are placed. In this instance, because there is no channelized flow, this storage location will contain no data.

Column 3 provides the number of the reach or subbasin the inputs are routed through. (The number of the reach in a particular subbasin is the same as the number of the subbasin.) The fraction of the loadings classified as overland flow are applied to the subbasin land area while the fraction of the loadings classified as channelized flow are routed through the main channel of the subbasin and are exposed to in-stream processes. Channelized flow has no interaction with the land area in the subbasin.

Column 4 lists the number of the hydrograph storage location containing the data to be routed through the reach. The loadings from subbasin 1 are stored in hydrograph storage #1.

Column 6 lists the fraction of overland flow. For completely channelized flow this fraction is zero. For 100% overland flow, this fraction is 1.00.

The entire watershed configuration to this point looks like:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
route	**2**	**7**	**2**	**1**		**1.000**	

Assume that runoff from the pasture is slightly channelized (10% channels). Flow from the pasture is routed to the filter strip (subbasin 3) using the next route command:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
route	**2**	**7**	**2**	**1**		**1.000**	
route	**2**	**8**	**3**	**2**		**0.900**	

As mentioned previously, hydrograph storage location #7 contains no data because none of the runoff entering subbasin 2 is channelized. Consequently, when routing runoff leaving subbasin 2, this hydrograph storage location can be ignored. For subbasin 3, however, there will be data in hydrograph storage location #8 from the 10% of flow that is channelized in that subbasin. Loadings from subbasin 3 will enter the main stream in subbasin 6. The total loadings from the denuded area/pasture/filter strip section of the microwatershed are determined by adding the runoff generated from subbasin 3 and the channelized flow routing results.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
route	**2**	**7**	**2**	**1**		**1.000**	
route	**2**	**8**	**3**	**2**		**0.900**	
add	**5**	**9**	**3**	**8**			

The loadings from simulation of the land phase of the hydrologic cycle in subbasin 3 are stored in hydrograph storage location #3 and the loadings from simulation of the channelized flow in subbasin 3 are stored in hydrograph location #8. The add command is specified in column 1 by the number 5. The hydrograph storage location numbers of the 2 data sets to be added are listed in columns 3 and 4. The summation results are stored in the hydrograph location number given in column 2. Net loadings from the denuded area/pasture/filter strip is stored in hydrograph location #9.

Assume that the manure application area (subbasin 4) is well managed and all runoff from this area is overland flow (no channelized flow). To route flow from the application area to the associated filter strip (subbasin 5) a route command will be appended to the end of the configuration:

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
route	**2**	**7**	**2**	**1**		**1.000**	
route	**2**	**8**	**3**	**2**		**0.900**	
add	**5**	**9**	**3**	**8**			
route	**2**	**10**	**5**	**4**		**1.000**	

Hydrograph storage location #10 contains no data because none of the runoff entering subbasin 5 is channelized. Consequently, when routing runoff leaving subbasin 5, this hydrograph storage location can be ignored. Net loadings from the waste application area/filter strip section of the watershed is stored in hydrograph location #5.

Flow through subbasin 6, which contains the stream, is completely channelized. All of the loadings for the stream must be summed together and then routed through the stream. There are 3 sources of loading to the stream: the denuded area/pasture/filter strip (hydrograph location #9), the waste application area/filter strip (hydrograph location #10), and the forest land area (hydrograph location #6). Add commands are used to sum the loadings.

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
route	**2**	**7**	**2**	**1**		**1.000**	
route	**2**	**8**	**3**	**2**		**0.900**	
add	**5**	**9**	**3**	**8**			
route	**2**	**10**	**5**	**4**		**1.000**	
add	**5**	**11**	**9**	**5**			
add	**5**	**12**	**6**	**11**			

Flow is routed through the stream using a route command:

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
route	**2**	**7**	**2**	**1**		**1.000**	
route	**2**	**8**	**3**	**2**		**0.900**	
add	**5**	**9**	**3**	**8**			
route	**2**	**10**	**5**	**4**		**1.000**	
add	**5**	**11**	**9**	**5**			
add	**5**	**12**	**6**	**11**			
route	**2**	**13**	**6**	**12**		**0.000**	

Step 3: Once the stream loadings have been routed to the watershed outlet, append a finish command line to signify the end of the watershed routing file.

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
route	**2**	**7**	**2**	**1**		**1.000**	
route	**2**	**8**	**3**	**2**		**0.900**	
add	**5**	**9**	**3**	**8**			
route	**2**	**10**	**5**	**4**		**1.000**	
add	**5**	**11**	**9**	**5**			
add	**5**	**12**	**6**	**11**			
route	**2**	**13**	**6**	**12**		**0.000**	
finish	**0**						

B.2.2 HILLSLOPE DISCRETIZATION: COMBINING WITH SUBWATERSHED DISCRETIZATION

The hillslope discretization is a very detailed discretization scheme and is suited to small watersheds. However, it can be used in combination with the subwatershed discretization to provide detailed simulation of certain land uses in a large watershed whose spatial relationships are important to the study.

As an example, assume that the dairy operation described in Section B.2.1 is located in a headwater region of the watershed example used in Section B.1. Figure B-3 illustrates the location of the dairy in the larger watershed. (Assume the microwatershed modeled in Section B.2.1 is subbasin B in Figure B-3.)

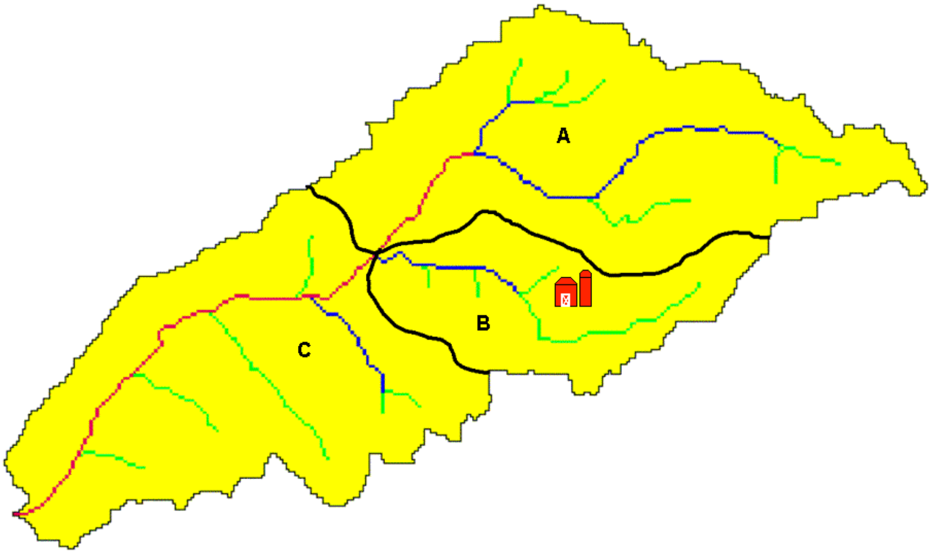

Figure B-3: Watershed with dairy operation

There are two options that may be used to combine the detailed modeling of the dairy with the less detailed modeling of the other land uses in the watershed. The first option is to model the dairy in a separate simulation and save the loadings from the microwatershed using the save command. These daily loadings will then be read into the simulation of the larger watershed using a recday command. The second option is to merge the watershed configuration given in Section B.2.1 with the watershed configuration given Section B.1.1

Option 1: Two separate runs.

The watershed configuration file for simulation of the microwatershed with the dairy will be modified to save the outflow data to an event file. The name of the event file is specified as “dairy.eve” in the file.cio for the microwatershed simulation.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
route	**2**	**7**	**2**	**1**		**1.000**	
route	**2**	**8**	**3**	**2**		**0.900**	
add	**5**	**9**	**3**	**8**			
route	**2**	**10**	**5**	**4**		**1.000**	
add	**5**	**11**	**9**	**5**			
add	**5**	**12**	**6**	**11**			
route	**2**	**13**	**6**	**12**		**0.000**	
save	**9**	**13**					
finish	**0**						

Because the area in subbasin B is modeled in the microwatershed simulation, the area will not be directly modeled in the large watershed simulation. Instead, the data in the file dairy.eve will be read in and routed.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
route	**2**	**3**	**1**	**1**		**0.000**	
recday	**10**	**4**	**1**				
	dairy.eve						
add	**5**	**5**	**3**	**4**			
add	**5**	**6**	**5**	**2**			
route	**2**	**7**	**2**	**6**		**0.000**	
finish	**0**						

In the above configuration, subbasin A is subbasin 1, subbasin C is subbasin 2 and outflow from subbasin B is read in with the recday command.

Option 2: A combined simulation.

In this simulation, the routing for the entire watershed is contained in one configuration file. We will include comment lines in this watershed configuration to identify the different portions of the watershed being simulated. Subbasin B will be divided into 6 separate subbasins numbered 1-6 with the same land use assignments listed in section B.2.1. Subbasin A is subbasin 7 in this simulation while subbasin C is subbasin 8.

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
*** land phase for subbasin B**							
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
*** land phase for subbasin A**							
subbasin	**1**	**7**	**7**				
*** land phase for subbasin C**							
subbasin	**1**	**8**	**8**				
*** route flow through subbasin A**							
route	**2**	**9**	**7**	**7**		**0.000**	
*** route flow through subbasin B**							
route	**2**	**10**	**2**	**1**		**1.000**	
route	**2**	**11**	**3**	**2**		**0.900**	
add	**5**	**12**	**3**	**11**			
route	**2**	**13**	**5**	**4**		**1.000**	
add	**5**	**14**	**12**	**5**			
add	**5**	**15**	**6**	**14**			
route	**2**	**16**	**6**	**15**		**0.000**	
*** add outflow from subbasin A and B to loadings from subbasin C**							
add	**5**	**17**	**9**	**16**			
add	**5**	**18**	**8**	**17**			
*** route flow through subbasin C**							
route	**2**	**19**	**8**	**18**		**0.000**	
finish	**0**						

Comment lines are denoted by an asterisk in the first space. When SWAT reads an asterisk in this location it knows the line is a comment line and does not process the line.

B.3 GRID CELL DISCRETIZATION

The grid cell discretization allows a user to capture a high level of spatial heterogeneity or variability in the simulation. The grid cells should be small enough to obtain homogenous land use, soil, and topographic characteristics for the area in each cell but large enough to keep the amount of data required for the run at a reasonable level.

The routing methodology for the grid cell discretization is the same as that for the subwatershed discretization. The difference between the two discretization schemes lies in the average size of the subbasin and the method used to define subbasin boundaries.

The GIS interfaces are currently not able to delineate a watershed using a grid cell discretization. However, there are plans to create a GIS tool capable of generating a grid cell discretization.

B.3.1 GRID CELL DISCRETIZATION: 9 CELLS

To illustrate the grid cell discretization, a simple nine-cell example will be used.

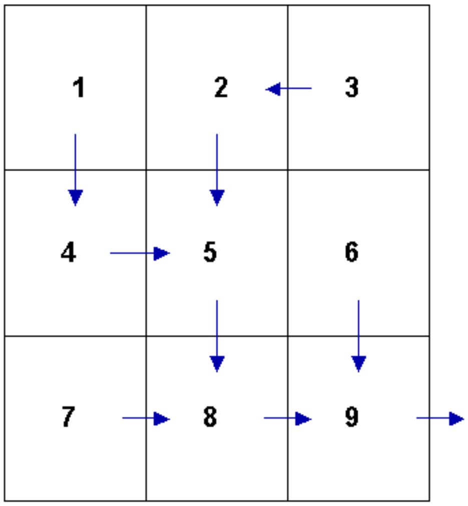

Figure B-4: Grid cell delineation with flow paths shown.

Step 1: Write the subbasin command for each cell. (This command simulates the land phase of the hydrologic cycle.)

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	1	1	1				
subbasin	1	2	2				
subbasin	1	3	3				
subbasin	1	4	4				
subbasin	1	5	5				
subbasin	1	6	6				
subbasin	1	7	7				
subbasin	1	8	8				
subbasin	1	9	9				

Writing **subbasin** in space 1-10 is optional. The model identifies the configuration command by the code in column 1. The option of writing the command in space 1-10 is provided to assist the user in interpreting the configuration file.

Column 2 is the hydrograph storage location number (array location) where data for the loadings (water, sediment, chemicals) from the subbasin are stored.

Column 3 is the subbasin number. The subbasin number tells SWAT which input files listed in file.cio contain the data used to model the subbasin. Subbasin numbers are assigned sequentially in file.cio to each pair of lines after line 14.

The files listed on lines 15 & 16 of file.cio are used to model subbasin 1, the files listed on lines 17 & 18 of file.cio are used to model subbasin 2, the files listed on lines 19 & 20 of file.cio are used to model subbasin 3, and so on.

Step 2a: Route the stream loadings through the flow path network. Begin by routing the headwater subbasin loadings through the main channel of the respective subbasin. (Headwater subbasins are those with no subbasins upstream.) Referring to Figure B-4, subbasins 1, 3, 6 and 7 are headwater subbasins.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
subbasin	**1**	**7**	**7**				
subbasin	**1**	**8**	**8**				
subbasin	**1**	**9**	**9**				
route	**2**	**10**	**1**	**1**		**0.000**	
route	**2**	**11**	**3**	**3**		**0.000**	
route	**2**	**12**	**6**	**6**		**0.000**	
route	**2**	**13**	**7**	**7**		**0.000**	

As mentioned in the last step, column 1 is used to identify the command. Column 2 is the hydrograph storage location number identifying the location where results from the route simulation are placed.

Column 3 provides the number of the reach, or main channel, the inputs are routed through. The number of the reach in a particular subbasin is the same as the number of the subbasin.

Column 4 lists the number of the hydrograph storage location containing the data to be routed through the reach.

Column 6 lists the fraction of overland flow. For the grid cell discretization, this value will always be zero.

Step 2b: Route the stream loadings through the reach network. Use the add and route commands to continue routing through the watershed.

First, add the outflow from subbasin 1 to the loadings from subbasin 4 and route the total through the channel in subbasin 4.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
subbasin	**1**	**7**	**7**				
subbasin	**1**	**8**	**8**				
subbasin	**1**	**9**	**9**				
route	**2**	**10**	**1**	**1**		**0.000**	
route	**2**	**11**	**3**	**3**		**0.000**	
route	**2**	**12**	**6**	**6**		**0.000**	
route	**2**	**13**	**7**	**7**		**0.000**	
add	**5**	**14**	**10**	**4**			
route	**2**	**15**	**4**	**14**		**0.000**	

The loadings from the outlet of subbasin 1 are stored in hydrograph location #10; the loadings from subbasin 4 are stored in hydrograph location #4.

The add command is specified in column 1 by the number 5. The hydrograph storage location numbers of the 2 data sets to be added are listed in columns 3 and 4. The summation results are stored in the hydrograph location number given in column 2.

Next, add the outflow from subbasin 3 to the loadings from subbasin 2 and route the total through the channel in subbasin 2.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
subbasin	**1**	**7**	**7**				
subbasin	**1**	**8**	**8**				
subbasin	**1**	**9**	**9**				
route	**2**	**10**	**1**	**1**		**0.000**	
route	**2**	**11**	**3**	**3**		**0.000**	
route	**2**	**12**	**6**	**6**		**0.000**	
route	**2**	**13**	**7**	**7**		**0.000**	
add	**5**	**14**	**10**	**4**			
route	**2**	**15**	**4**	**14**		**0.000**	
add	**5**	**16**	**11**	**2**			
route	**2**	**17**	**2**	**16**		**0.000**	

Next, add the outflow from subbasin 2 and 4 to the loadings from subbasin 5 and route the total through the channel in subbasin 5.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
subbasin	**1**	**7**	**7**				
subbasin	**1**	**8**	**8**				
subbasin	**1**	**9**	**9**				
route	**2**	**10**	**1**	**1**		**0.000**	
route	**2**	**11**	**3**	**3**		**0.000**	
route	**2**	**12**	**6**	**6**		**0.000**	
route	**2**	**13**	**7**	**7**		**0.000**	
add	**5**	**14**	**10**	**4**			
route	**2**	**15**	**4**	**14**		**0.000**	
add	**5**	**16**	**11**	**2**			
route	**2**	**17**	**2**	**16**		**0.000**	
add	**5**	**18**	**15**	**17**			
add	**5**	**19**	**18**	**5**			
route	**2**	**20**	**5**	**19**		**0.000**	

Next, add the outflow from subbasin 5 and 7 to the loadings from subbasin 8 and route the total through the channel in subbasin 8.

space 1-10	column 1 space 11-16	column 2 space 17-22	column 3 space 23-28	column 4 space 29-34	column 5 space 35-40	column 6 space 41-46	column 7 space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
subbasin	**1**	**7**	**7**				
subbasin	**1**	**8**	**8**				
subbasin	**1**	**9**	**9**				
route	**2**	**10**	**1**	**1**		**0.000**	
route	**2**	**11**	**3**	**3**		**0.000**	
route	**2**	**12**	**6**	**6**		**0.000**	
route	**2**	**13**	**7**	**7**		**0.000**	
add	**5**	**14**	**10**	**4**			
route	**2**	**15**	**4**	**14**		**0.000**	
add	**5**	**16**	**11**	**2**			
route	**2**	**17**	**2**	**16**		**0.000**	
add	**5**	**18**	**15**	**17**			
add	**5**	**19**	**18**	**5**			
route	**2**	**20**	**5**	**19**		**0.000**	
add	**5**	**21**	**20**	**13**			
add	**5**	**22**	**21**	**8**			
route	**2**	**23**	**8**	**22**		**0.000**	

Next, add the outflow from subbasin 8 and 6 to the loadings from subbasin 9, route the total through the channel in subbasin 9, and append a finish command line to signify the end of the watershed routing file.

	column 1	column 2	column 3	column 4	column 5	column 6	column 7
space 1-10	space 11-16	space 17-22	space 23-28	space 29-34	space 35-40	space 41-46	space 47-55
subbasin	**1**	**1**	**1**				
subbasin	**1**	**2**	**2**				
subbasin	**1**	**3**	**3**				
subbasin	**1**	**4**	**4**				
subbasin	**1**	**5**	**5**				
subbasin	**1**	**6**	**6**				
subbasin	**1**	**7**	**7**				
subbasin	**1**	**8**	**8**				
subbasin	**1**	**9**	**9**				
route	**2**	**10**	**1**	**1**		**0.000**	
route	**2**	**11**	**3**	**3**		**0.000**	
route	**2**	**12**	**6**	**6**		**0.000**	
route	**2**	**13**	**7**	**7**		**0.000**	
add	**5**	**14**	**10**	**4**			
route	**2**	**15**	**4**	**14**		**0.000**	
add	**5**	**16**	**11**	**2**			
route	**2**	**17**	**2**	**16**		**0.000**	
add	**5**	**18**	**15**	**17**			
add	**5**	**19**	**18**	**5**			
route	**2**	**20**	**5**	**19**		**0.000**	
add	**5**	**21**	**20**	**13**			
add	**5**	**22**	**21**	**8**			
route	**2**	**23**	**8**	**22**		**0.000**	
add	**5**	**24**	**23**	**12**			
add	**5**	**25**	**24**	**9**			
route	**2**	**26**	**9**	**25**		**0.000**	
finish	**0**						

As illustrated in section B.2.2 for the hillslope discretization, it is possible to combine the grid cell discretization with the subwatershed discretization to provide detailed modeling of portions of a large watershed while treating less significant areas in the more generalized approach used in the subwatershed discretization.