CHAPTER 20

SWAT INPUT DATA: .MGT

A primary goal of environmental modeling is to assess the impact of human 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. Information regarding tile drains and urban areas is also stored in this file.

The management file can be divided into two sections. The first section summarizes inputs for initial conditions or management practices that never change during the simulation. The second section lists the schedule of management operations occurring at specific times.

20.1 GENERAL MANAGEMENT VARIABLES

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. Optional.
NMGT	Management code. Used by SWAT/GRASS (GIS) interface. The model doesn't use this variable. Optional.

20.1.1 INITIAL PLANT GROWTH PARAMETERS

Variable name	Definition
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 Required.
PLANT_ID	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 growth database (Chapter 14). Required if IGRO = 1.

Variable name	Definition
LAI_INIT	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. Required if IGRO = 1.
BIO_INIT	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. Required if IGRO = 1.
PHU_PLT	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_PLT is reviewed in Chapter 5:1 of the Theoretical Documentation. Required if IGRO = 1.

20.1.2 GENERAL MANAGEMENT PARAMETERS

Variable name	Definition
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). 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.

Variable name	Definition
BIOMIX, cont.	If no value for BIOMIX is entered, the model will set BIOMIX = 0.20. Optional.
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. Required.

Table 20-1: 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

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

Variable name	**Definition**

CN2, cont.

Cover			**Hydrologic Soil Group**			
Land Use	**Treatment or practice**	**Hydrologic condition**	**A**	**B**	**C**	**D**
	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

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

[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[§]

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.

Variable name	Definition
USLE_P, cont.	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.
	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.
	Required.

Table 20-6: P factor values for contour-farmed terraced fields[1]

	Farm planning		**Computing sediment yield[3]**	
Land slope (%)	**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.

Variable name	Definition
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.
	Required if grazing occurs in HRU.

Variable name	Definition
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.

20.1.3 URBAN MANAGEMENT PARAMETERS

Variable name	Definition
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 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). Required.
URBLU	Urban land type identification number from the urban database (see Chapter 18). Required if IURBAN > 0.

20.1.4 IRRIGATION MANAGEMENT PARAMETERS

Variable name	Definition
IRRSC	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. IRRSC 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
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.

Variable name	Definition
IRRNO, cont.	The definition of this variable depends on the setting of IRRSC. IRRSC = 1: IRRNO is the number of the reach that water is removed from. IRRSC = 2: IRRNO is the number of the reservoir that water is removed from. IRRSC = 3 or 4: IRRNO is the number of the subbasin that water is removed from. IRRSC = 0 or 5: this variable is not used. Required if 1 ≤ IRRSC ≤ 4.
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 IRRSC = 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. Optional. Used only if IRRSC = 1.
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 104 m3) 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.

Variable name	Definition
DIVMAX, cont.	DIVMAX may be set when IRRSC = 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. Optional. Used only if IRRSC = 1.
FLOWFR	Fraction of available flow that is allowed to be applied to the HRU. 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. Available flow is defined as the total flow in the reach minus FLOWMIN. If FLOWMIN is left at zero, the model assume all flow in the reach is available for application as irrigation water. FLOWFR may be set when IRRSC = 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. Required if IRRSC = 1.

20.1.5 TILE DRAIN MANAGEMENT PARAMETERS

Variable name	Definition
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 900 mm.

Variable name	Definition
DDRAIN	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. Required if drainage tiles are modeled in HRU.
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 until it exits the tile and enters the main channel. Tile drainage occurs when the soil water content exceeds field capacity. Required if drainage tiles are modeled in HRU.
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. Required if drainage tiles are modeled in HRU.

20.1.6 MANAGEMENT OPERATIONS

The first section of the management file is free format. 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 first section of the management file is:

Variable name	**Line #**	**Format**	**F90 Format**
TITLE	1	character	a80
NMGT	2	integer	Free
Comment line	3	character	a80
IGRO	4	integer	Free
PLANT_ID	5	integer	Free
LAI_INIT	6	real	free
BIO_INIT	7	real	free
PHU_PLT	8	real	free
COMMENT LINE	9	character	a80
BIOMIX	10	real	free
CN2	11	real	free
USLE_P	12	real	free
BIO_MIN	13	real	free
FILTERW	14	real	free
Comment line	15	character	a80
IURBAN	16	integer	free
URBLU	17	integer	free
Comment line	18	character	a80

Variable name	Line #	Format	F90 Format
IRRSC	19	integer	free
IRRNO	20	integer	free
FLOWMIN	21	real	free
DIVMAX	22	real	free
FLOWFR	23	real	free
Comment line	24	character	a80
DDRAIN	25	real	free
TDRAIN	26	real	free
GDRAIN	27	real	free
Comment line	28	character	a80
Comment line	30	character	a80

20.2 SCHEDULED MANAGEMENT OPERATIONS

SWAT will simulate 15 different types of management operations. The first four variables on all management lines are identical while the remaining nine 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 on the specified day

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

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

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.

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.
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 (see IURBAN).
13	**release/impound:** this operation releases/impounds water in HRUs growing rice or other plants
14	**continuous fertilization:** this operation applies fertilizer/manure to the soil surface on a continuous basis
15	**continuous pesticides:** this operation applies pesticides to the soil surface on a continuous basis
0	**end of year rotation flag:** this operation identifies the end of the operation scheduling for a year.

	mon	day	HU	mgt op	mgt1i	mgt2i	mgt3i	mgt4	mgt5	mgt6	mgt7	mgt8	mgt9
plant/begin growing season	*	*	*	1	PLANT_ID		CURYR_MAT	HEAT_UNITS	LAI_INIT	BIO_INIT	HI_TARG	BIO_TARG	CNOP
irrigate	*	*	*	2				IRR_AMT					
fertilizer application	*	*	*	3	FERT_ID			FRT_KG	FRT_SURFACE				
pesticide application	*	*	*	4	PEST_ID			PST_KG					
harvest/kill operation	*	*	*	5				CNOP					
tillage operation	*	*	*	6	TILL_ID			CNOP					
harvest operation	*	*	*	7				HARVEFF	HI_OVR				
kill/end growing season	*	*	*	8									
grazing	*	*	*	9	GRZ_DAYS	MANURE_ID		BIO_EAT	BIO_TRMP	MANURE_KG			
auto irrigation	*	*	*	10	WSTRS_ID			AUTO_WSTRS					
auto fertilization	*	*	*	11	AFERT_ID			AUTO_NSTRS	AUTO_NAPP	AUTO_NYR	AUTO_EFF	AFRT_SURFACE	
sweep operation	*	*		12				SWEEPEFF	FR_CURB				
release/impound	*	*		13	IMP_TRIG								
continuous fertilization	*	*	*	14	FERT_DAYS	CFRT_ID	IFRT_FREQ	CFRT_KG					
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 5:1 of the Theoretical Documentation. If the transplanted land cover is a type of tree, the age of the plants in years at the time of transplanting must be provided.

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. Variables are listed below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 1 for planting/beginning of growing season. Required.
PLANT_ID	Land cover/plant identification number from plant growth database (see Chapter 14). Required.
CURYR_MAT	Current age of trees (years). If the land cover planted/transplanted is a type of tree, the age of the seedlings in years is required. For other types of land covers, this input is not required.
HEAT UNITS	Total heat units for cover/plant to reach maturity. Calculation of HEAT UNITS is reviewed in Chapter 5:1 of the Theoretical Documentation. Required.
LAI_INIT	Initial leaf area index. This variable is used only for covers/plants which are transplanted rather than established from seeds. Optional.
HI_TARG	Harvest index target ((kg/ha)/(kg/ha)). This variable along with BIO_TARG allows 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 HI_TARG or BIO_TARG. Optional.

Variable name	Definition
BIO_INIT	Initial dry weight biomass (kg/ha). This variable is used only for covers/plants that are transplanted rather than established from seeds. Optional.
BIO_TARG	Biomass (dry weight) target (metric tons/ha). This variable along with HI_TARG allows 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 HI_TARG or BIO_TARG. 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 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
PLANT_ID	space 20-23	4-digit integer	i4
CURYR_MAT	space 29-30	2-digit integer	i2
HEAT UNITS	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
LAI_INIT	space 45-50	decimal (xxx.xx)	f6.2
BIO_INIT	space 52-62	decimal (xxxxx.xxxxx)	f11.5
HI_TARG	space 64-67	decimal (x.xx)	f4.2
BIO_TARG	space 69-74	decimal (xxxxx.xx)	F6.2
CNOP	space 76-80	decimal (xx.xx)	f5.2

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. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 2 for irrigation operation. Required.
IRR_SC	Irrigation source 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 IRR_NO, 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_SC 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

IRR_NO	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_SC. IRRSC = 1: IRR_NO is the number of the reach that water is removed from. IRRSC = 2: IRR_NO is the number of the reservoir that water is removed from. IRRSC = 3 or 4: IRR_NO is the number of the subbasin that water is removed from. IRR_SC = 0 or 5: this variable is not used. Required if 1 ≤ IRR_SC ≤ 4.
IRR_AMT	Depth of irrigation water applied on HRU (mm). Required.
IRR_SALT	Concentration of salt in irrigation (mg/kg). Not currently operational.
IRR_EFM	Irrigation efficiency (0-1).
IRR_SQ	Surface runoff ratio (0-1). (.1 is 10% surface runoff) (fraction)

The format of the irrigation operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
IRR_SC	space 25-27	3-digit integer	i3
IRR_NO	space 29-30	2-digit integer	i2
IRR_AMT	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
IRR_SALT	space 45-50	decimal (xxx.xx)	f6.2
IRR_EFM	space 52-62	decimal (xxxxx.xxxxx)	f11.5
IRR_SQ	space 64-67	decimal (x.xx)	f4.2

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. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 3 for fertilizer application. Required.

Variable name	Definition
FERT_ID	Fertilizer identification number from fertilizer database (see Chapter 17). Required.
FRT_KG	Amount of fertilizer applied to HRU (kg/ha). Required.
FRT_SURFACE	Fraction of fertilizer applied to top 10mm of soil. The remaining fraction is applied to the 1st soil layer below 10 mm. If FRT_SURFACE is set to 0, the model applies 20% of the fertilizer to the top 10mm and the remainder to the 1st soil layer. Required.

The format of the fertilizer application line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
FERT_ID	space 20-23	4-digit integer	i4
FRT_KG	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
FRT_SURFACE	space 45-50	decimal (xxx.xx)	f6.2

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. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 4 for pesticide application. Required.
PEST_ID	Pesticide identification code from pesticide database (see Chapter 16). Required.
PST_KG	Amount of pesticide applied to HRU (kg/ha). Required.
PST_DEP	Depth of pesticide incorporation in the soil (mm) If = 0, assumes surface apply.

The format of the pesticide application line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
PEST_ID	space 20-23	4-digit integer	i4
PST_KG	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
PST_DEP	space 45-50	decimal (xxx.xx)	f6.2

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, see Chapter 14) 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. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 5 for harvest and kill operation. Required.
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.
HI_OVR	Harvest index override ((kg/ha)/(kg/ha)) This variable will force the ratio of yield to total aboveground biomass to the specified value. For grain harvest, the harvest index in the plant growth database (plant.dat) is used that assumes that only the seed is being harvested (HI_OVR is not used in grain harvest). If biomass is cut and removed (for example, in hay cuttings), HIOVR must be used to specify the amount of biomass cut. Optional.
FRAC_HARVK	Stover fraction removed (0-1)

The format of the harvest and kill line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
CNOP	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
HI_OVR	space 45-50	decimal (xxx.xx)	f6.2
FRAC_HARVK	space 52-62	decimal (xxxxx.xxxxx)	f11.5

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 also has the option of updating the moisture condition II curve number in this operation.

The variables for the tillage operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 6 for tillage operation. Required.
TILL_ID	Tillage implement code from tillage database (see Chapter 15). Required.
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 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
TILL_ID	space 20-23	4-digit integer	i4
CNOP	space 32-43	decimal (xxxxxx.xxxxx)	f12.5

20.2.7 HARVEST OPERATION

The harvest operation will remove grain or plant biomass without killing the plant. A code (IHV_GBM) is used to specify if the harvest is for grain or biomass. Grain harvest was developed so the user could harvest grain and then harvest biomass for biofuel or feed. Biomass harvest 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.

For grain harvest, a harvest index in the plant growth database is set to the optimum fraction of the plant biomass partitioned into seed for agricultural crops. The harvest index override is not used for grain harvest (see harvest index target). A typical fraction of biomass removed in a cutting for hay is included in the plant growth database. 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. When harvesting grain, the efficiency accounts for losses from the harvesting machine. For example, if an efficiency of 0.95 is used for grain, yield is cut by 5 percent and the nutrients and carbon in the lost grain is not returned to the soil. For biomass harvest, the efficiency 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). For grass mowing, an efficiency of one assumes that all clippings are removed from the HRU while an efficiency of zero leaves all clippings on the ground.

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 for the harvest-only operation are listed and described below:

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 7 for the harvest only operation. Required.
IHV_GBM	Grain or biomass harvest code A value of 0 specifies a biomass harvest while a value of 1 specifies a grain harvest.
HARVEFF	Harvest efficiency. For grain harvest, the harvest efficiency defines the fraction of yield biomass removed by the harvesting equipment, with the remaining yield lost. For biomass harvest, if HARVEFF is close to zero, the cutting or clipping are left on the ground and if HARVEFF is 1.0, all cut biomass (yield) is removed. If the harvest efficiency is not set or 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.
HI_OVR	Harvest index override ((kg/ha)/(kg/ha)) This variable will force the ratio of yield to total aboveground biomass to the specified value. For grain harvest, the harvest index in the plant growth database (plant.dat) is used that assumes that only the seed is being harvested (HI_OVR is not used in grain harvest). If biomass is cut and removed (for example, in hay cuttings), HIOVR must be used to specify the amount of biomass cut. Optional.

The format of the harvest operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
IHV_GBM	space 25-27	3-digit integer	I3
HARVEFF	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
HI_OVR	space 45-50	decimal (xxx.xx)	f6.2

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 entered for the kill operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 8 for kill operation. Required.

The format of the kill line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2

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 first section 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 are stored in the fertilizer database (see Chapter 17). 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 entered for the grazing operation are listed and described below.

Variable name	Definition
MONTH	Month grazing begins. Either MONTH/DAY or HUSC is required.
DAY	Day grazing begins. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 9 for grazing operation. Required.
GRZ_DAYS	Number of consecutive days grazing takes place in the HRU. Required.
MANURE_ID	Manure identification code from fertilizer database (see Chapter 17). Required.
BIO_EAT	Dry weight of biomass consumed daily ((kg/ha)/day). Required.
BIO_TRMP	Dry weight of biomass trampled daily ((kg/ha)/day) Trampling becomes significant as the number of animals grazing per hectare increases. This is a very subjective value which is typically set equal to BIO_EAT, i.e. the animals trample as much as they eat. Optional.
MANURE_KG	Dry weight of manure deposited daily ((kg/ha)/day). Required.

The format of the grazing operation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
GRZ_DAYS	space 20-23	4-digit integer	i4
MANURE_ID	space 25-27	3-digit integer	i3
BIO_EAT	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
BIO_TRMP	space 45-50	decimal (xxx.xx)	f6.2
MANURE_KG	space 52-62	decimal (xxxxx.xxxxx)	f11.5

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 entered for auto-irrigation initialization are listed and described below.

Variable name	Definition
MONTH	Month auto irrigation is initialized. Either MONTH/DAY or HUSC is required.
DAY	Day auto irrigation is initialized. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 10 for auto irrigation initialization. Required.
WSTRS_ID	Water stress identifier. SWAT allows automatic irrigation to be triggered by plant water demand or by soil water content. WSTRS_ID identifies the process the user wishes to use to trigger automatic irrigation. WSTRS_ID may be set to: 1 plant water demand 2 soil water content Required.

Variable name	Definition
IRR_SCA	Auto Irrigation source 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 IRR_NOA, 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_SCA tells the model what type of water body the irrigation water is being diverted from. The source 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
IRR_NOA	Auto 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 IRRSC. IRR_SCA = 1: IRR_NOA is the number of the reach that water is removed from. IRR_SCA = 2: IRR_NOA is the number of the reservoir that water is removed from. IRR_SCA = 3 or 4: IRR_NOA is the number of the subbasin that water is removed from. IRR_SCA = 0 or 5: this variable is not used. Required if 1 ≤ IRR_SCA ≤ 4.
AUTO_WSTRS	Water stress threshold that triggers irrigation. When the user selects auto-application of irrigation water in an HRU, a water stress threshold must be specified. When water stress is based on plant water demand (WSTRS_ID=1), 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.

Variable name	Definition
AUTO_WSTRS, cont.	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 for plant water demand is usually set somewhere between 0.90 and 0.95. When water stress is based on soil water deficit (WSTRS_ID=2), the water stress threshold is the soil water deficit below field capacity (mm H_2O). Anytime the water content of the soil profile falls below *FC – AUTO_WSTR*, 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. Required.
IRR_EFF	Irrigation efficiency (0.0 – 100.0).
IRR_MX	Amount of irrigation water applied each time auto irrigation is triggered (mm) (0.0 – 100.0).
IRR_ASQ	Surface runoff ratio (0-1) (.1 is 10% surface runoff) (fraction)

The format of the auto irrigation line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
WSTRS_ID	space 20-23	4-digit integer	i4
IRR_SCA	space 25-27	3-digit integer	i3
IRR_NOA	space 29-30	2-digit integer	i2
AUTO_WSTRS	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
IRR_EFF	space 45-50	decimal (xxx.xx)	f6.2
IRR_MX	space 52-62	decimal (xxxxx.xxxxx)	f11.5
IRR_ASQ	space 64-67	decimal (x.xx)	f4.2

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 entered for auto-fertilization initialization are listed and described below.

Variable name	Definition
MONTH	Month initialization takes place. Either MONTH/DAY or HUSC is required.
DAY	Day initialization takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 11 for auto fertilization initialization. Required.
AFERT_ID	Fertilizer identification number from the fertilizer database (see Chapter 17). Required.
NSTRESS	Code for approach used to determine amount of nitrogen to HRU. 0=nitrogen target approach; 1=annual max approach.

Variable name	Definition
AUTO_NSTRS	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. Required.
AUTO_NAPP	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. Required.
AUTO_NYR	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. Required.
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. Required.

Variable name	Definition
AFRT_SURFACE	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. Required.

The format of the auto fertilization line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
AFERT_ID	space 20-23	4-digit integer	i4
AUTO_NSTRS	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
AUTO_NAPP	space 45-50	decimal (xxx.xx)	f6.2
AUTO_NYR	space 52-62	decimal (xxxxx.xxxxx)	f11.5
AUTO_EFF	space 64-67	decimal (x.xx)	f4.2
AFRT_SURFACE	space 69-74	decimal (xxxxx.xx)	F6.2

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 entered for the street sweeping operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 12 for street sweeping. Required.
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

Variable name	**Definition**
SWEEPEFF, cont.	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). 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. Required.

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
FR_CURB	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. FR_CURB can range from 0.01 to 1.00. If no value is entered for FR_CURB (FR_CURB left blank or set to 0.0, the model will assume 100% of the curb length is available for sweeping. Required.

The format of the street sweeping line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
SWEEPEFF	space 32-43	decimal (xxxxxx.xxxxx)	f12.5
FR_CURB	space 45-50	decimal (xxx.xx)	f6.2

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.

One HRU in each subbasin can be defined as a pothole. 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.

The variables entered for the release/impound operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 13 for release/impoundment of water. Required.
IMP_TRIG	Release/impound action code: 0 initiate water impoundment 1 initiate water release Required.

The format of the release/impound line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
IMP_TRIG	space 20-23	4-digit integer	i4

20.2.14 CONTINUOUS FERTILIZER OPERATION

When manure is being distributed across land areas as part of waste management for intensive animal operations, the continuous fertilizer operation provides the user with a convenient method to set up the multiple fertilizer applications.

The variables entered for the continuous fertilizer operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 14 for continuous fertilizer operation. Required.
FERT_DAYS	Duration or length of period (days) the continuous fertilizer operation takes place in the HRU. Required.
CFRT_ID	Fertilizer/manure identification number from fertilizer database (see Chapter 17). Required.
IFRT_FREQ	Application frequency (days). This variable allows the user to set the frequency at which fertilizer applications take place during the application period. For example, fertilizer can be applied every day (IFRT_FREQ = 1), every other day (IFRT_FREQ = 2), etc. Required.
CFRT_KG	Amount of fertilizer/manure applied to ground in each application (kg/ha). Required.

The format of the continuous fertilization line is

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
FERT_DAYS	space 20-23	4-digit integer	i4
CFRT_ID	space 25-27	3-digit integer	i3
IFRT_FREQ	space 29-30	2-digit integer	i2
CFRT_KG	space 32-43	decimal (xxxxxx.xxxxx)	f12.5

20.2.15 CONTINUOUS PESTICIDE OPERATION

A constant pesticide application operation can be used to periodically apply pesticide. A fixed amount of pesticide is applied repeatedly at user defined intervals for the duration specified.

The variables entered for the continuous pesticide operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 14 for continuous pesticide operation. Required.
CPST_ID	Pesticide identification number from pesticide database (see Chapter 16). Required.
PEST_DAYS	Number of days continuous pesticide will be simulated Required.
IPEST_FREQ	Number of days between applications. Required.
CPST_KG	Amount of pesticide applied to HRU on a given day (kg/ha). Required.

The format of the continuous pesticide line is:

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
CPST_ID	space 20-23	4-digit integer	i4
PEST_DAYS	space 25-27	3-digit integer	i3
IPEST_FREQ	space 29-30	2-digit integer	i2
CPST_KG	space 32-43	decimal (xxxxxx.xxxxx)	f12.5

20.2.16 BURN OPERATION

The variables entered for the burn operation are listed and described below.

Variable name	Definition
MONTH	Month operation takes place. Either MONTH/DAY or HUSC is required.
DAY	Day operation takes place. Either MONTH/DAY or HUSC is required.
HUSC	Fraction of total base zero heat units at which operation takes place. Heat unit scheduling is explained in Chapter 5:1 of the Theoretical Documentation. If MONTH and DAY are not provided, HUSC must be set to a value. Either MONTH/DAY or HUSC is required.
MGT_OP	Management operation number. MGT_OP = 16 for burn operation. Required.
BURN_FRLB	Fraction of biomass, plant nitrogen and phosphorus, surface residue, soil surface organic nitrogen and phosphorus that remains after a burn (fraction).

The format of the burn operation line is:

Variable name	Position	Format	F90 Format
MONTH	space 2-3	2-digit integer	i2
DAY	space 5-6	2-digit integer	i2
HUSC	space 8-15	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-18	2-digit integer	i2
BURN_FRLB	space 32-43	decimal (xxxxxx.xxxxx)	f12.5

20.2.17 SKIP A YEAR OPERATION

This operation code skips to January 1 in the northern hemisphere and July 1 in the southern hemisphere. There can be as many skips as needed to skip years. For example, if you start with forest growing, you may enter nine 17's to skip 9 years and harvest in the 10^{th} year.

*A note about scheduling management operations in the northern and southern hemispheres. In the southern hemisphere, if you start the simulation on July 1, you can use the exact same management file as you did for the northern hemisphere.

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