

CHAPTER FILE.CIO

SWAT+ INPUT DATA:

File management is performed with the master watershed file (file.cio). The master watershed file contains the file names for the simulation run.

The master watershed file is divided into several sections. A brief description of the variables in the master watershed file follows. They are grouped by section and listed in the order they appear within the file.

Over the past 20 years, the Soil and Water Assessment Tool (SWAT) has become widely used across the globe. The large numbers of applications across the globe have also revealed limitations and identified model development needs. Numerous additions and modifications of the model and its individual components have made the code increasingly difficult to manage and maintain. In order to face present and future challenges in water resources modeling SWAT code has undergone major modifications over the past few years, resulting in SWAT+, a completely revised version of the model. Even though the basic algorithms used to calculate the processes in the model have not changed, the structure and organization of both the code (object based) and the input files (relational based) have undergone considerable modification. This is expected to facilitate model maintenance, future code modifications, and foster collaboration with other researchers to integrate new science into SWAT modules. SWAT+ provides a more flexible spatial representation of interactions and processes within a watershed.

Descriptions of the SWAT+ input data files are listed and described in this document.

| Variable name | Definition |
|---------------|--|
| TITLE | The first line of ‘file.cio’ is reserved for a description of the simulation run. The description may take up to 80 spaces. The description is optional, the line is required. |

SIMULATION – The simulation section of file.cio contains filenames for the entire simulation run. The list of the filenames are listed below with a brief description of the inputs within each file.

[illegible]

TIME.SIM

The time simulation file includes the number of years to run the simulation and time step and is space delimited. Below is a sample TIME.SIM file:

| | | | | |
|-----------|-----------|---------|---------|------|
| time.sim: | | | | |
| DAY_START | YRC_START | DAY_END | YRC_END | STEP |
| 0 | 2006 | 0 | 2007 | 0 |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the time.sim file (may be blank) |
| HEADER | |
| DAY_START | 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 1 st . Required. |
| YRC_START | 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 YR_START to locate the beginning year within the data file. Required. |
| DAY_END | Ending Julian day of simulation. With this variable, SWAT is able to end a simulation at any time of the year. If the variable is left blank or set to zero, the model ends the simulation on December 31 st . Required. |
| YRC_END | Ending year of simulation |
| STEP | Timestep of the simulation. 0 = daily; 1=increment (12 hrs); 24=hourly; 96-15 mins; 1440 = minute) Required. |

PRINT.PRT

The print file controls the occurrence of the output files and is space delimited. Below is a sample PRINT.PRT file. Some pointers:

- The user will input the actual start and stop julian day for daily printing.
- NYSKIP will not print until NYSKIP is over.
- When time crosses the end of the year, the print will continue to increment the print INTERVAL.
- Daily printing of all files could cause very large output files (exceeding hard drive capabilities)

| print.prt: | Output | print | settings | | |
|---------------|-----------|-----------|----------|---------|----------|
| NYSKIP | DAY_START | YRC_START | DAY_END | YRC_END | INTERVAL |
| 0 | 0 | 0 | 0 | 0 | 1 |
| AA_NUMINT | | | | | |
| 0 | | | | | |
| CSV | DB | NETCDF | | | |
| n | n | n | | | |
| SOIL | MGT | HYDCON | FDC | | |
| n | n | n | n | | |
| OBJECTS | DAILY | MONTHLY | YEARLY | AVANN | |
| basin_wb | y | n | n | y | |
| basin_nb | n | n | y | n | |
| basin_ls | y | n | n | n | |
| basin_pw | n | y | n | n | |
| basin_aqu | n | n | n | n | |
| basin_res | n | n | n | n | |
| basin_cha | n | n | n | n | |
| basin_sd_cha | y | n | n | y | |
| basin_psc | n | n | n | n | |
| region_wb | n | n | n | n | |
| region_nb | n | n | n | n | |
| region_ls | n | n | n | n | |
| region_pw | n | n | n | n | |
| region_aqu | n | n | n | n | |
| region_res | n | n | n | n | |
| region_cha | n | n | n | n | |
| region_sd_cha | n | n | n | n | |
| region_psc | n | n | n | n | |
| lsunit_wb | n | n | n | n | |
| lsunit_nb | n | n | n | n | |
| lsunit_ls | n | n | n | n | |
| lsunit_pw | n | n | n | n | |
| hru_wb | n | n | y | n | |
| hru_nb | n | y | n | n | |
| hru_ls | n | y | n | n | |
| hru_pw | n | n | n | y | |
| hru-lte_wb | n | n | n | n | |
| hru-lte_nb | n | n | n | n | |
| hru-lte_ls | n | n | n | n | |
| hru-lte_pw | n | n | n | n | |
| channel | n | n | n | n | |
| channel_sd | y | n | n | n | |
| aquifer | n | n | n | n | |

| | | | | | |
|-----------|---|---|---|---|--|
| reservoir | n | n | n | n | |
| recall | n | n | n | n | |
| hyd | y | n | n | n | |
| ru | n | n | n | n | |
| pest | n | n | n | n | |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the print.prt file |
| HEADER | Headings |
| NYSKIP | <p>Number of years to not print output.</p> <p>The options are</p> <p>0 print output for all years of the simulation</p> <p>1 print output after the first year of simulation</p> <p>2 print output after the second year of simulation</p> <p>↓</p> <p>nbyr no output will be printed</p> <p>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.</p> <p>Examples: If NYSKIP =2, the model will skip printing the first two years regardless of the starting year. In other words, if YRC_START = 2000, we start printing in 2002. If YRC_START = 2005, printing starts in 2007.</p> <p>Notes: The daily print start and end time has nothing to do with NYSKIP. If the daily print time is skipped, it simply won't print the daily output.</p> <p>The start year of printing is $\max(\text{YRC_START} + \text{NYSKIP})$.</p> |
| DAY_START | Beginning Julian day of simulation to start printing output files for daily printing only |
| YRC_START | Beginning year of simulation to start printing files. |
| DAY_END | Ending Julian day of simulation to stop printing output files for daily printing only |
| YRC_END | Ending year of simulation to stop printing output files. |

| | |
|-------------|---|
| INTERVAL | Daily print within the period Specifies the interval within the specified printing time (i.e., INTERVAL =2) will print every other day. |
| HEADER | Headings |
| AA_NUMINT | Number of print intervals for ave annual output Example: If AA_NUMINT = 1955 1965 1975, Average annual results will be printed for the time periods ending in 1955, 1965, 1975. Leaving the first number zero on this line will print average annual for the entire period (after NYSKIP). |
| AA_YEARS | End years for ave annual output |
| HEADER | Header |
| CSVOUT | Code to print .csv files n=no print; y = print |
| DBOUT | Code to print database (db) files n=no print; y = print (not currently active) |
| CDFOUT | Code to print netcdf (cdf) files n=no print; y = print (not currently active) |
| HEADER | Header |
| SNUTC | Soil nutrients carbon output file; input should be character - d(daily; m(monthly); y(yearly); aa(ave annual); |
| MGTOUT | Management output file (print codes apply) (mgt.out) |
| HYDCON | Hydrograph connect output file (hydcon.out) |
| FDCOUT | Flow duration curve output file n=no print; avann=print |
| HEADER | Header. All of the following codes are entered as : 'y' (yes) or 'n' (no) to print on a daily, monthly, yearly or avann timestep. |
| WB_BSN | Water balance BASIN output variables |
| NB_BSN | Nutrient balance BASIN output variables |
| LS_BSN | Losses BASIN output variables |
| PW_BSN | Plant weather BASIN output variables |
| AQU_BSN | Aquifer BASIN output variables |
| RES_BSN | Reservoir BASIN output file variables |
| CHAN_BSN | Channel BASIN output file variables |
| SD_CHAN_BSN | CHANDEG BASIN output file variables |
| RECALL_BSN | Point source BASIN output file variables |
| WB_REG | Water balance REGION output variables |
| NB_REG | Nutrient balance REGION output variables |
| LS_REG | Losses REGION output variables |
| PW_REG | Plant weather REGION output variables |
| AQU_REG | Aquifer REGION output variables |

| | |
|-------------|--|
| RES_REG | Reservoir REGION output variables |
| CHAN_REG | Channel REGION output variables |
| SD_CHAN_REG | SWATDEG Channel REGION output variables |
| RECALL_REG | Point source REGION output variables |
| WB_SUB | Water balance ROUTING UNIT output variables |
| NB_SUB | Nutrient balance ROUTING UNIT output variables |
| LS_SUB | Losses ROUTING UNIT output variables |
| PW_SUB | Plant weather ROUTING UNIT output variables |
| WB_HRU | Water balance HRU output variables |
| NB_HRU | Nutrient balance HRU output variables |
| LS_HRU | Losses HRU output variables |
| PW_HRU | Plant weather HRU output variables |
| WB_SD | Water balance HRU-LTE output variables |
| NB_SD | Nutrient balance HRU-LTE output variables |
| LS_SD | Losses HRU-LTE output variables |
| PW_SD | Plant weather HRU-LTE output variables |
| CHAN | Channel output variables |
| SD_CHAN | SWAT DEG (lte) channel output variables |
| AQU | Aquifer output variables |
| RES | Reservoir output variables |
| RECALL | Recall output variables |
| HYD | Hydin output and hydout output variables |
| RU | Routing Unit output variables |
| PEST | Pesticide constituents outputs |

OBJECT.PRT

The object print file allows the user to define output and is space delimited. Below is a sample OBJECT.PRT file:

| | | | | |
|-------------|-------|---------|--------|---------------|
| object.prt: | | | | |
| NUMB | OBTYP | OBTYPNO | HYDTYP | FILENAME |
| 1 | sdc | 1 | tot | two_stage.out |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the object print file |
| HEADER | Header |
| NUMB | The sequential number |
| OBTYP | Type of object to print (cha, res...) |
| OBTYPNO | Object type number |
| HYDTYP | Hydrograph type to print |
| FILENAME | Filename of output file (user defined). |

OBJECT.CNT

The object count file contains the total counts for the watershed simulation and is space delimited. Below is a sample OBJECT.CNT file:

| | | | | | | | | | | | | | | | | | | |
|-------------|------------|------------|-----|-----|-----|----|---------|-----|-----|-----|-----|------|----|-------|------|-----|---------|-------|
| object.cnt: | | | | | | | | | | | | | | | | | | |
| NAME | AREA_LS_HA | REA_TOT_HA | OBJ | HRU | LTE | RU | MODFLOW | AQU | CHA | RES | REC | EXCO | DR | CANAL | PUMP | OUT | CHANDEG | 2DAQU |
| 2_stage | 30 | 33 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the object count file |
| HEADER | Header to describe the following inputs; Not used in model; |
| NAME | Name of the watershed |
| AREA_LS_HA | Area of the landscape units (ha) |
| AREA_TOT_HA | Total area of the watershed (ha) |
| OBJS | Total number of objects (sum of all following objects) |
| HRU | Total number of HRU's |
| HRU_LTE | Total number of HRU LTE (SWAT-DEG) |
| RU | Total number of routing units |
| MODFLOW | Total number of modflow |
| AQU | Total number of aquifers |
| CHAN | Total number of channels |
| RES | Total number of reservoirs |
| RECALL | Total number of reccdays |
| EXCO | Total number of export coefficients |
| DR | Total number of delivery ratios |
| CANAL | Total number of canals |
| PUMP | Total number of pumps |
| OUTLET | Total number of outlets |
| CHANDEG | Total number of LTE channels (SWAT-DEG) |
| AQU2D | Total number of 2D aquifers |
| HERD | Total number of herds (not used at this time) |
| WRO | Total number of water right objects (not used at this time) |

SETTING PESTICIDES IN SWAT+

C:\data\modular_datasets_60.2\pesticides.docx

1. **LIST ALL PESTICIDES USED IN THE SIMULATION IN THE CONSTITUENTS.CS FILE (INCLUDE NAME IN PESTICIDES.PST FILE)**

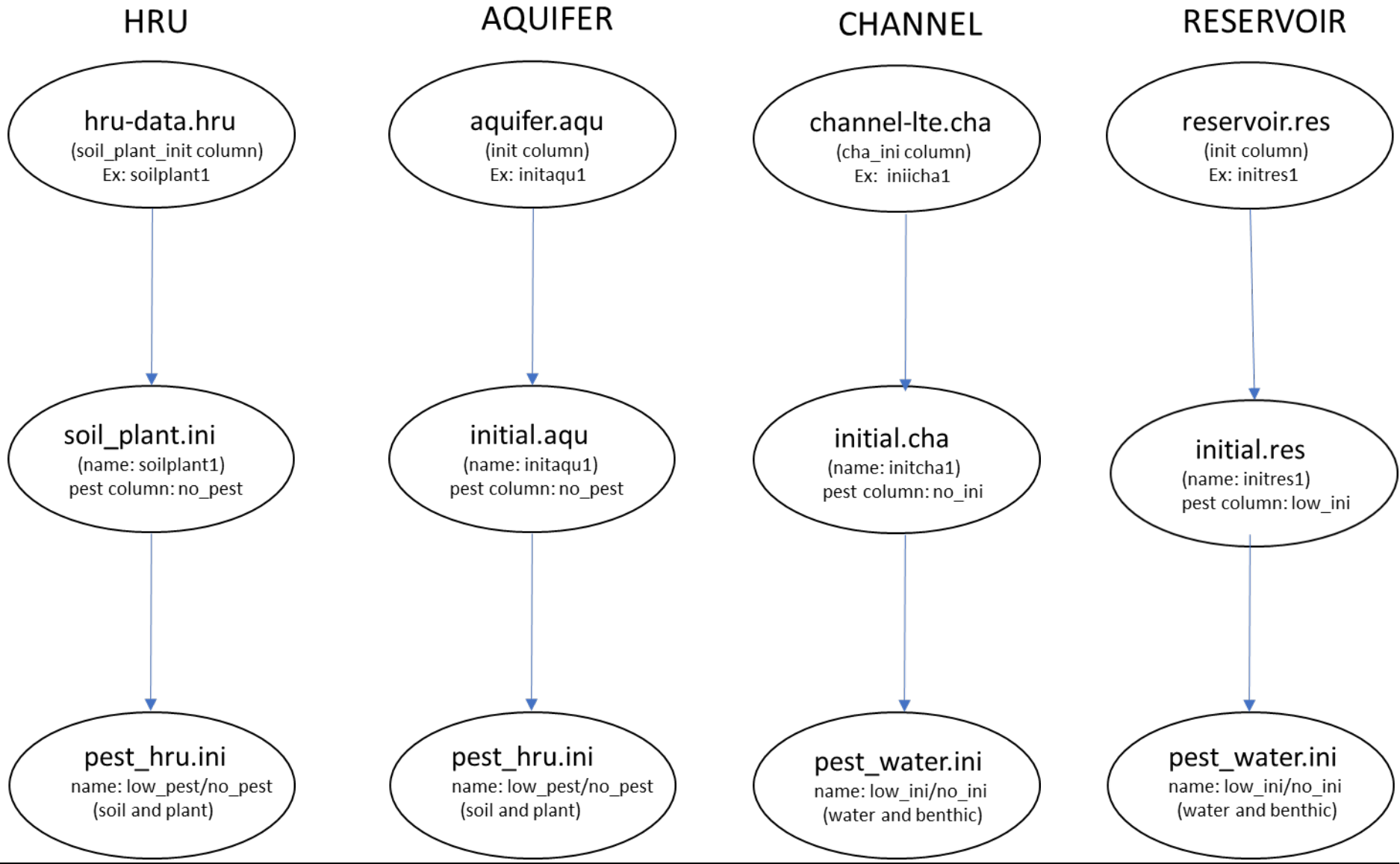
PESTICIDES.PST

| | | | | | | | | | | | | | | | |
|-----------------|----------|-----------|------------|---------|--------|----------|----------|--------|----------|-----------|-----------|----------|-----------|-------------|--|
| pesticide.pst | | | | | | | | 12:02 | | | | | | | |
| name | soil_ads | frac_wash | hl_foliage | hl_soil | solub | aq_hlife | aq_volat | mol_wt | aq_resus | aq_settle | n_act_dep | ben_bury | ben_hlife | description | |
| aatrex | 171 | 0.05 | 5 | 61 | 33 | 201 | 0.00001 | 215.68 | 0.002 | 0.5 | 0.3 | 0.002 | 201 | Atrazine | |
| dacamine | 20 | 0.45 | 5 | 10 | 890 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | 2,4-D | |
| roundup | 24000 | 0.6 | 2.5 | 47 | 900000 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Glyphosate | |

CONSTITUENTS.CS

| | | | |
|-----------------|---------------|-----------------|----------------|
| constituents.cs | | | |
| | 3 | !pesticides | |
| | aatrex | dacamine | roundup |

2. INITIALIZING THE PESTICIDES AT THE START OF THE SIMULATION FOR ANY OF THE FOLLOWING OOBJECTS:



HRU**HRU DATA.HRU**

| | | | | | | | | | |
|--------------|--------|------------|--------|---------|----------|------------------------|-----------|---------|-------|
| hru-data.hru | | | | | | | | | |
| id | name | topo | hydro | soil | lu_mgt | soil_plant_init | surf_stor | snow | field |
| 1 | hru001 | topohru001 | hyd001 | Kenyon | corn_lum | soilplant1 | null | snow001 | null |
| 2 | hru002 | topohru002 | hyd002 | Cresken | corn_lum | soilplant1 | null | snow001 | null |
| 3 | hru003 | topohru003 | hyd003 | Clyde | corn_lum | soilplant1 | null | snow001 | null |
| 4 | hru004 | topohru004 | hyd004 | Bassett | corn_lum | soilplant1 | null | snow001 | null |
| 5 | hru005 | topohru005 | hyd005 | Sparta | corn_lum | soilplant1 | null | snow001 | null |
| 6 | hru006 | topohru006 | hyd006 | Donnan | corn_lum | soilplant1 | null | snow001 | null |

SOIL PLANT.INI

| | | | | | | |
|-------------------|---------|-----------|----------------|------|------|------|
| soil_plant.ini | | | | | | |
| name | sw_frac | nutrients | pest | path | hmet | salt |
| soilplant1 | 1 | soilnut1 | no_pest | null | null | null |

PEST HRU.INI

| | | |
|----------------|--------------|----------|
| pest_hru.ini | | |
| NAME | aatrex | |
| low_pest | | |
| | soil | 0 |
| | plant | 0 |
| no_pest | | |
| | soil | 0 |
| | plant | 0 |

AQUIFER**AQUIFER.AQU**

| | | | | | | | | | | | | | | | | | |
|-------------|-----------|----------|--------|---------|--------|-------|-------|--------|----------|--------|----------|-------|---------|----------|---------|---------|----------|
| aquifer.aqu | | | | | | | | | | | | | | | | | |
| id | name | init | gw_flo | dep_bot | dep_wt | no3_n | sol_p | carbon | flo_dist | bf_max | alpha_bf | revap | rchg_dp | spec_yld | hl_no3n | flo_min | evap_min |
| 1 | aqu10 | initaqu1 | 0.05 | 10 | 3 | 0 | 0 | 0.5 | 50 | 1 | 0.0635 | 0.02 | 0.05 | 0.05 | 0 | 3 | 500 |
| 2 | aqu20 | initaqu1 | 0.05 | 10 | 3 | 0 | 0 | 0.5 | 50 | 1 | 0.0635 | 0.02 | 0.05 | 0.05 | 0 | 3 | 500 |
| 3 | aqu30 | initaqu1 | 0.05 | 10 | 3 | 0 | 0 | 0.5 | 50 | 1 | 0.0635 | 0.02 | 0.05 | 0.05 | 0 | 3 | 500 |
| 4 | aqu40 | initaqu1 | 0.05 | 10 | 3 | 0 | 0 | 0.5 | 50 | 1 | 0.0635 | 0.02 | 0.05 | 0.05 | 0 | 3 | 500 |
| 5 | aqu50 | initaqu1 | 0.05 | 10 | 3 | 0 | 0 | 0.5 | 50 | 1 | 0.0635 | 0.02 | 0.05 | 0.05 | 0 | 3 | 500 |
| 6 | aqu_deep2 | initaqu1 | 0 | 100 | 20 | 0 | 0 | 0.5 | 50 | 1 | 0.01 | 0 | 0 | 0.03 | 0 | 0 | 0 |

INITIAL.AQU

| | | | | | | |
|-------------|---------|---------|------|------|------|-------------|
| initial.aqu | | | | | | |
| name | org_min | pest | path | hmet | salt | description |
| initaqu1 | no_init | no_pest | null | null | null | null |

PEST_HRU.INI

| | | |
|--------------|--------|---|
| pest_hru.ini | | |
| NAME | aatrex | |
| low_pest | | |
| | soil | 0 |
| | plant | 0 |
| no_pest | | |
| | soil | 0 |
| | plant | 0 |

CHANNEL**CHANNEL-LTE.CHA**

| | | | | | |
|-----------------|------|-----------------|---------|---------|---------|
| channel-lte.cha | | | | | |
| id | name | cha_ini | cha_hyd | cha_sed | cha_nut |
| 1 | cha1 | initcha1 | hydcha1 | null | nutcha1 |
| 2 | cha2 | initcha1 | hydcha2 | null | nutcha1 |
| 3 | cha3 | initcha1 | hydcha3 | null | nutcha1 |
| 4 | cha4 | initcha1 | hydcha4 | null | nutcha1 |
| 5 | cha5 | initcha1 | hydcha5 | null | nutcha1 |

INITIAL.CHA

| | | | | | | |
|-----------------|---------|---------------|------|------|------|-------------|
| initial.cha | | | | | | |
| name | org_min | pest | path | hmet | salt | description |
| initcha1 | no_init | no_ini | null | null | null | null |

PEST WATER.INI

| | | |
|----------------|----------------|----------|
| pest_water.ini | | |
| NAME | aatrex | |
| low_ini | | |
| | water | 0 |
| | benthic | 0 |
| no_ini | | |
| | water | 0 |
| | benthic | 0 |

RESERVOIR**RESERVOIR.RES**

| | | | | | | |
|---------------|----------|---------|------|------|------|------|
| reservoir.res | | | | | | |
| NUMB | NAME | INIT | HYD | REL | SED | NUT |
| 1 | initres1 | low_ini | null | null | null | null |

INITIAL.RES

| | | | | | | |
|-------------|---------|---------|------|------|------|-------------|
| initial.res | | | | | | |
| name | org_min | pest | path | hmet | salt | description |
| initres1 | no_init | low_ini | null | null | null | null |

PEST WATER.INI

| | | |
|----------------|---------|---|
| pest_water.ini | | |
| NAME | aatrex | |
| low_ini | | |
| | water | 0 |
| | benthic | 0 |
| no_ini | | |
| | water | 0 |
| | benthic | 0 |

3. APPLYING THE PESTICIDES
MANAGEMENT.SCH

| | | | | | | |
|------------|------------|---|---|------|----------|---------|
| corn_hu_hr | 5 | 1 | | | | |
| | fert_rot_1 | | | | | |
| | till | 0 | 0 | 0.1 | sprgplow | null |
| | plnt | 0 | 0 | 0.15 | corn | null |
| | pest | 0 | 0 | 0.35 | aatrex | foliar |
| | hvkl | 0 | 0 | 1.2 | corn | grain |
| | till | 0 | 0 | 1.3 | fallplow | null |
| | | | | | | 1.12085 |

LUM.DTL

| | | | | | | | | | |
|-----------------|------|----------|------------|-----------|-----------|--------|---------------|------|------|
| pst_timing_unif | 3 | 2 | 1 | | | | | | |
| COND_VAR | OBJ | OBJ_NUMB | LIM_VAR | LIM_OP | LIM_CONST | | | ALT1 | ALT2 |
| land_use | hru | 0 | corn_lum | - | 0 | | | = | = |
| prob_unif | null | 127 | null | - | 151 | | | = | - |
| jday | null | 0 | null | - | 151 | | | - | = |
| ACT_TYP | OBJ | OBJ_NUM | ACT_NAME | CT_OPTION | CONST | CONST2 | FILE_POINTER | OUT1 | OUT2 |
| pest_apply | hru | 0 | aatrex_app | aatrex | 2 | 1 | aerial_liquid | y | y |

CONSTITUENTS.CS

The CONSTITUENTS.CS file contains the input variables for the pesticide constituents. Below is a sample CONSTITUENTS.CS file:

| | | | | |
|-----------------|-------------|-------|---------|--|
| constituents.cs | | | | |
| 4 | !pesticides | | | |
| aatrex | banvel | prowl | roundup | |
| 2 | !pathogens | | | |
| fecal_col_form | e_coli | | | |
| 1 | !metals | | | |
| mercury | | | | |
| 2 | !salts | | | |
| sodium | magnesium | | | |

| 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. |
| NUM_PESTS | Number of pesticides simulated |
| NAME | Pesticide names (for each NUM_PESTS) |
| NUM_PATHS | Number of pathogens simulated |
| NAME | Pathogen names (for each NUM_PATHS) |
| NUM_METALS | Number of heavy metals simulated |
| NAME | Heavy metal names (for each NUM_METALS) |
| NUM_SALTS | Number of salts simulated |

BASIN – General watershed attributes are defined in the basin input file. These attributes control a diversity of physical processes at the watershed level. The interfaces will automatically set these parameters to the “default” or recommended values listed in the variable documentation. Users can use the default values or change them to better reflect what is happening in a given watershed. Variables governing bacteria or pesticide transport need to be initialized only if these processes are being modeled in the watershed. Even if nutrients are not being studied in a watershed, some attention must be paid to these variables because nutrient cycling impacts plant growth which in turn affects the hydrologic cycle.

CODES.BSN

Below is a partial sample CODES.BSN FILE:

| codes.bsn: | | | | | | | | | | Watershed | | | | | | | | | | | | |
|------------|----------|-----|-------|-----|-------|---------|-----|-----|-------------|-----------|------|-------|--------|------|--------|------|------|---------|-------|------|------|----------|
| PETFILE | WWQFILE | PET | EVENT | CRK | SUBWQ | SED_DET | RTE | DEG | WQ_NOSTRESS | CN | CFAC | CSWAT | BF_FLG | UHYD | SED_CH | TDRN | WTDN | P_MODEL | ABSTR | ATMO | SMAX | I_SUBHWQ |
| test.pet | test.wwq | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

| | |
|---------|---|
| TITLE | <p>The first line is reserved for user comments. This line is not processed by the model and may be left blank.</p> <p>Optional.</p> |
| HEADER | Headers for the codes.bsn file. |
| PETFILE | Potential ET filename |
| WWQFILE | Watershed stream water quality filename |
| PET | <p>Potential evapotranspiration (PET) method.</p> <p>There are four options for potential ET calculations:</p> <ul style="list-style-type: none"> 0 Priestley-Taylor method 1 Penman/Monteith method 2 Hargreaves method 3 read in potential ET values <p>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 import them into SWAT. A discussion of Priestley-Taylor, Penman-Monteith and Hargreaves PET methods is found in Chapter 2:2 of the theoretical documentation.</p> <p>Required.</p> |
| EVENT | <p>Rainfall/runoff/routing option:</p> <ul style="list-style-type: none"> 0 daily rainfall/curve number runoff/daily routing 1 sub-daily rainfall/Green & Ampt infiltration/sub-daily routing <p>Option 0 is the default option.</p> <p>Required.</p> |
| CRK | <p>Crack flow code.</p> <p>There are two options:</p> <ul style="list-style-type: none"> 0 do not model crack flow in soil 1 model crack flow in soil <p>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.</p> <p>The default option is to model the watershed without crack flow.</p> <p>Required.</p> |

| | |
|---------|--|
| SUBWQ | <p>Subbasin water quality code.</p> <p>The algorithms used to calculate loadings of algae, organic carbonaceous biological oxygen demand and dissolved oxygen to the stream network (see Chapter 4:4 in Theoretical Documentation) were derived from results of limited studies and are still in the testing phase. ISUBWQ allows the user to choose to apply or not apply the algorithms.</p> <ul style="list-style-type: none"> 0 do not calculate algae/CBOD loadings and set dissolved oxygen to saturated oxygen concentration 1 calculate algae/CBOD/dissolved oxygen loadings using algorithms documented in Theoretical Documentation <p>The default option is ISUBWQ=0. Required.</p> |
| SED_DET | <p>Code governing calculation of daily maximum half-hour rainfall value:</p> <ul style="list-style-type: none"> 0 generate daily value using triangular distribution 1 use monthly maximum half-hour rainfall value for all days in month <p>The user has the option of using the monthly maximum half-hour rainfall for all days in the month. The randomness of the triangular distribution used to generate daily values causes the maximum half-hour rainfall value to jump around. For small plots or microwatersheds in particular, the variability of the triangular distribution is unrealistic. Required.</p> |
| RTE | <p>Channel water routing method:</p> <ul style="list-style-type: none"> 0 variable storage method 1 Muskingum method <p>The user must be careful to define MSK_CO1, MSK_CO2 and MSK_X when the Muskingum method is chosen.</p> <p>The default option is RTE=0. Required.</p> |
| DEG | <p>Channel degradation code.</p> <p>There are two options:</p> <ul style="list-style-type: none"> 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 <p>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. Required.</p> |

| | |
|----------|---|
| WQ | <p>In-stream water quality code.</p> <p>The variable identifies whether in-stream transformation of nutrients using the QUAL2E algorithms and in-stream transformation of pesticides is allowed to occur.</p> <p>0 do not model in-stream nutrient and pesticide transformations 1 model in-stream nutrient and pesticide transformations</p> <p>The default option is IWQ=0. Required.</p> |
| NOSTRESS | <p>STRESS codes:</p> <p>0 = (all stresses applied) 1 = (turn off all plant stress) 2 = (turn off nutrient plant stress only)</p> |
| CN | <p>Daily curve number calculation method:</p> <p>0 calculate daily CN value as a function of soil moisture 1 calculate daily CN value as a function of plant evapotranspiration 2 use traditional SWAT method which bases CN on soil moisture but retention is adjusted for mildly-sloped tiled-drained watersheds</p> <p>Option 0 was the only method used to calculate the daily CN value in versions of SWAT prior to SWAT2012. Calculation of the daily CN value as a function of plant evapotranspiration was added because the soil moisture method was predicting too much runoff in shallow soils. By calculating daily CN as a function of plant evapotranspiration, the value is less dependent on soil storage and more dependent on antecedent climate. Required.</p> |
| CFAC | <p>CFAC = 0 for C-factor calculation using Cmin. = 1 for new C-factor calculation. (0-1)</p> |
| CSWAT | <p>Code for new carbon routines:</p> <p>0 = original routines 1 = new carbon routines</p> |
| BF_FLG | <p>Baseflow distribution factor during the day for subdaily runs.</p> <p>0 = baseflow evenly distributed to each time step during the day 0.5 = even weights between even distribution and rainfall pattern 1 = profile of baseflow in a day follows rainfall pattern</p> |
| UHYD | <p>Unit hydrograph method:</p> <p>1 = triangular UH 2 = gamma function UH</p> |
| SED_CH | <p>Instream sediment model, 0=Bagnold model, 1=Brownlie model, 2=Yang model</p> |

| | |
|-------|---|
| EVLAI | <p>Leaf area index at which no evaporation occurs from water surface.</p> <p>EVLAI is used in HRUs where a plant is growing in a ponded environment (e.g. rice). Currently, this is simulated only in HRUs defined as depressional areas/potholes.</p> <p>Evaporation from the water surface is allowed until the leaf area of the plant reaches the value specified for EVLAI. Chapter 8:1 in the Theoretical Documentation provides more detail on the use of this parameter.</p> <p>EVLAI should be set between 0.0 and 10.0. If no value for EVLAI is entered, the model will set $EVLAI = 3.0$.</p> <p>Required if depressional areas/potholes are modeled in the watershed.</p> |
| FFCB | <p>Initial soil water storage expressed as a fraction of field capacity water content.</p> <p>All soils in the watershed will be initialized to the same fraction.</p> <p>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 $FFCB = 0.0$).</p> <p>We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for FFCB is not going to impact model results.</p> <p>Required.</p> |

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 4-7 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.

Required.

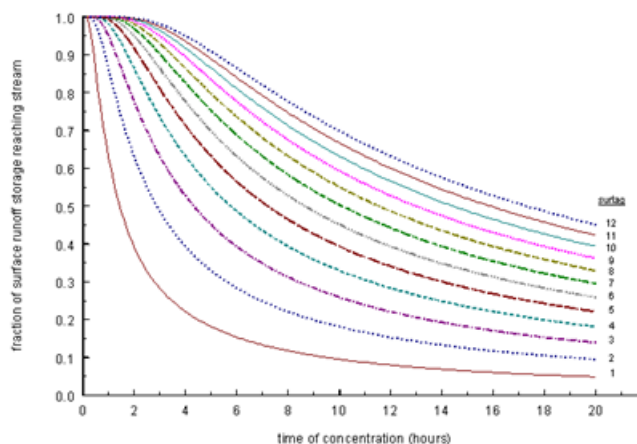


Figure 4-7: Influence of *surlag* and t_{conc} on fraction of surface runoff released.

ADJ_PKR

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 originally could 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 ADJ_PKR is entered, the model will set ADJ_PKR=1.0.

Required.

| | |
|-------|--|
| PRF | <p>Peak rate adjustment factor for sediment routing in the main channel.</p> <p>Sediment routing is a function of peak flow rate and mean daily flow. Because SWAT originally could 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.</p> <p>If no value for PRF is entered, the model will set PRF = 1.0.</p> <p>Required.</p> |
| SPCON | <p>Linear parameter for calculating the maximum amount of sediment that can be reentrained during channel sediment routing.</p> <p>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 concsed,ch,mx is the maximum concentration of sediment that can be transported by the water (ton/m³ or kg/L), csp is a coefficient defined by the user, vch,pk is the peak channel velocity (m/s), and spexp is an exponent defined by the user.</p> <p>SPCON should be between 0.0001 and 0.01. If no value for SPCON is entered, the model will set SPCON = 0.0001.</p> <p>Required.</p> |
| SPEXP | <p>Exponent parameter for calculating sediment reentrained in channel sediment routing</p> <p>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 concsed,ch,mx is the maximum concentration of sediment that can be transported by the water (ton/m³ or kg/L), csp is a coefficient defined by the user, vch,pk is the peak channel velocity (m/s), and spexp is an exponent defined by the user.</p> <p>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.</p> <p>Required.</p> |

CMN

Rate factor for humus mineralization of active organic nutrients (N and P).

Chapters 3:1 and 3:2 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.

Required.

N_UPDIS

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 N_UPDIS is entered, the model will set N_UPDIS = 20.0.

Figure 4-9 illustrates nitrogen uptake as a function of depth for four different uptake distribution parameter values.

Required.

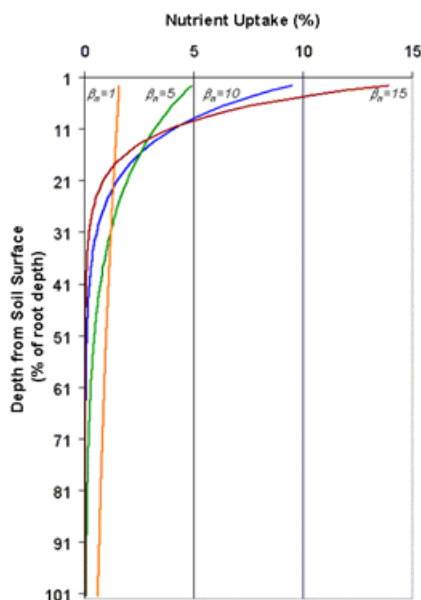


Figure 4-9: Depth distribution of nitrogen uptake

P_UPDIS

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 4-9 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 P_UPDIS is entered, the model will set P_UPDIS = 20.0.

Required.

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 \rightarrow 0.0, the concentration of nitrate in the runoff approaches 0. As NPERCO \rightarrow 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.

Required.

PPERCO

Phosphorus percolation coefficient ($10 \text{ m}^3/\text{Mg}$).

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.

Required.

PHOSKD

Phosphorus soil partitioning coefficient (m³/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.

Required.

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.

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 $PSP = 0.40$.

Required.

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 $RSDCO = 0.05$.

Required.

| | |
|---------|---|
| PERCOP | <p>Pesticide percolation coefficient.</p> <p>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 $\text{PERCOP} \rightarrow 0.0$, the concentration of pesticide in the runoff and lateral flow approaches 0. As $\text{PERCOP} \rightarrow 1.0$, surface runoff and lateral flow has the same concentration of pesticide as the percolate.</p> <p>If no value for PERCOP is entered, the model will set $\text{PERCOP} = 0.50$.</p> <p>Required if pesticide transport is of interest.</p> |
| MSK_CO1 | <p>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.</p> <p>Required only if $\text{IRTE} = 1$.</p> |
| MSK_CO2 | <p>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.</p> <p>Required only if $\text{IRTE} = 1$.</p> |
| MSK_X | <p>MSK_X is a weighting factor that controls the relative importance of inflow and outflow in determining the storage in a reach.</p> <p>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.</p> <p>If no value for MSK_X is entered, the model will set $\text{MSK}_X = 0.2$.</p> <p>Required only if $\text{IRTE} = 1$.</p> |
| TRNSRCH | <p>Fraction of transmission losses from main channel that enter deep aquifer. The remainder if the transmission losses enter bank storage.</p> <p>In arid watersheds, transmission losses from the main channel network may be permanently lost due to transmission to aquifers that do not contribute flow back to the stream network. This variable allows the user to specify the fraction of transmission losses from the channel network that is permanently lost.</p> <p>TRNSRCH varies between 0.00 and 1.00. The default value for TRNSRCH is 0.00.</p> <p>Required.</p> |

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.

Required.

SCOEF

Channel storage coefficient (0-1) (default =1)

CDN

Denitrification exponential rate coefficient.

This coefficient allows the user to control the rate of denitrification.

Acceptable values for CDN range from 0.0 to 3.0. If no value for CDN is specified, the model will set CDN = 1.4.

Required.

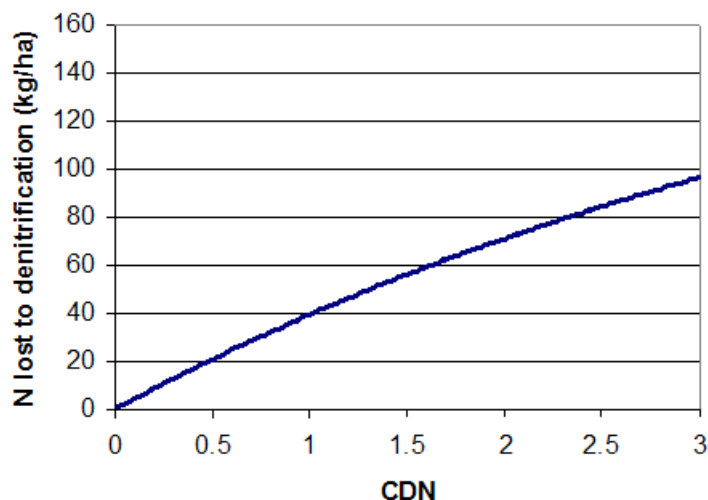


Fig 4-8: Impact of **CDN** value on amount of nitrogen lost to denitrification assuming initial nitrate content in layer is 200 kg/ha, temperature of layer is 10 °C, and organic carbon content of layer is 2%.

| | |
|------------|--|
| SDNCO | <p>Denitrification threshold water content.</p> <p>Fraction of field capacity water content above which denitrification takes place.</p> <p>Denitrification is the bacterial reduction of nitrate, NO_3^-, to N_2 or N_2O gases under anaerobic (reduced) conditions. Because SWAT does not track the redox status of the soil layers, the presence of anaerobic conditions in a soil layer is defined by this variable. If the soil water content calculated as fraction of field capacity is \geq SDNCO, then anaerobic conditions are assumed to be present and denitrification is modeled. If the soil water content calculated as a fraction of field capacity is $<$ SDNCO, then aerobic conditions are assumed to be present and denitrification is not modeled.</p> <p>If no value for SDNCO is specified, the model will set SDNCO = 1.10.</p> <p>Required.</p> |
| BACT_SWF | <p>Fraction of manure applied to land areas that has active colony forming units.</p> <p>If no value for BACT_SWF is specified, the model will set BACT_SWF = 0.15.</p> <p>Required if bacteria processes are of interest.</p> |
| TB_ADJ | <p><i>New variable in testing.</i></p> <p><i>Adjustment factor for subdaily unit hydrograph basetime.</i></p> |
| CN_FROZ | <p>Parameter for frozen soil adjustment on infiltration/runoff.</p> <p>If no value for CNFROZ_BSN is entered, the model will set CNFROZ_BSN = 0.000862.</p> <p>Optional.</p> |
| DORM_HR | <p>Time threshold used to define dormancy (hours). The maximum day length minus DORM_HR is equal to when dormancy occurs.</p> <p>Optional.</p> |
| OPENVAR2 | <p>This input variable currently not being used (formerly smxco).</p> |
| FIXCO | <p>Nitrogen fixation coefficient. (0.0 – 1.0)</p> <p>1.0 = fixes 100% of nitrogen demand. 0.0 = fixes none of nitrogen demand.</p> |
| NFIXMX | <p>Maximum daily-n fixation (kg/ha). (1.0 – 20.0)</p> |
| DECR_MIN | <p>Minimum daily residue decay (fraction 0.0 – 0.05)</p> |
| RSD_COVCO | <p>Residue cover factor for computing fraction of cover. (0.1 – 0.5)</p> |
| VCRIT | <p>Critical velocity</p> |
| RES_STR_CO | <p>Reservoir sediment settling coefficient (0.09 – 0.27)</p> |

| | |
|-----------|--|
| UHALPHA | Alpha coefficient for gamma function unit hydrograph. Required if iuh = 2 is selected |
| EROS_SPL | Splash erosion coefficient (0.9 – 3.1) |
| RILL_MULT | Rill erosion coefficient – multiplier to USLE_K for soil susceptible to rill erosion (0.5-2.0) |
| EROS_EXPO | Exponential coefficient for overland flow – (1.5-3.0) |
| C_FACTOR | Scaling parameter for cover and management factor for overland flow erosion (0.03/0.001/0.45) |
| CH_D50 | Median particle diameter of main channel (mm) (50/10/100) |
| SIG_G | Geometric standard deviation of particle size (1.57/1.0/5.0) |
| OPENVAR3 | This input variable currently not being used (formerly r2adj). |
| IGEN | Random generator code 0 = use default number; 1 = generate new numbers in every simulation |

CLIMATE – The CLIMATE section of file.cio contains filenames for the entire simulation run. The list of the filenames are listed below with a brief description of the inputs within each file.

WEATHER-STA.CLI

The weather station climate file contains the weather stations that will be included in the simulation and is space delimited. Below is a sample WEATHER-STA.CLI file:

| | | | | | | | | |
|-----------------|--------|-------------|-------------|-------|-------|-------|-------|---------|
| weather-sta.cli | | | | | | | | |
| NAME | WGN | PGAGE | TGAGE | SGAGE | HGAGE | WGAGE | WNDIR | ATMODEP |
| wea1 | wgn001 | mentone.pcp | mentone.tmp | sim | sim | sim | null | atmo_2 |
| wea2 | wgn001 | warsaw.pcp | warsaw.tmp | sim | sim | sim | null | atmo_3 |

Variable name Definition

| | |
|----------|--|
| TITLE | title of the weather station. |
| HEADER | Headings |
| WST_NAME | The weather station name |
| WGN | The weather generator station name (from the weather-wgn.cli file) |
| PGAGE | The precipitation station name (from pcp.cli file). If precipitation is generated, 'sim' should be input. |
| TGAGE | The temperature station name (from tmp.cli file). If temperature will be generated, 'sim' should be input. |

| | |
|---------|--|
| SGAGE | The solar radiation station name (from slr.cli file). If solar radiation will be generated, 'sim' should be input. |
| HGAGE | The relative humidity station name (from hmd.cli file). If relative humidity will be generated, 'sim' should be input. |
| WGAGE | The wind station name (from wnd.cli file). If wind will be generated, 'sim' should be input. |
| WNDIR | The wind direction name (from wind-dir.cli file). If wind direction will be generated, 'sim' should be input. |
| ATMODEP | The atmospheric deposition file name. If no atmospheric deposition file is used, 'null' should be input. |

WEATHER-WGN.CLI

The weather generator climate file contains the weather generator stations that will be included in the simulation and is space delimited. Below is a sample WEATHER-WGN.CLI file:

| weather-w | Weather | | | | | | | | | | | | |
|-----------|---------|--------|--------|-------|--------|--------|-------|-------|------|---------|---------|--------|--------|
| wgn001 | 43.07 | -94.3 | 374.9 | 31 | | | | | | | | | |
| TMPMX | TMPMN | TMPSTD | TMPDMM | PCPMM | PCPSTD | PCPSKW | PR_WD | PR_WW | PCPD | RAINHMX | SOLARAV | DEWPT | WINDAV |
| -3.9 | -13.52 | 6.76 | 7.5 | 18.5 | 4.01 | 2.09 | 0.12 | 0.32 | 4.48 | 3.35 | 7.12 | -11.06 | 5.61 |
| -1.22 | -10.79 | 7.04 | 7.72 | 18 | 4.6 | 2.72 | 0.12 | 0.25 | 3.83 | 4.43 | 10.81 | -8.92 | 5.59 |
| 5.8 | -4.3 | 7.36 | 6.22 | 43.4 | 8.24 | 1.81 | 0.15 | 0.33 | 5.6 | 6.5 | 15 | -3.91 | 5.8 |
| 14.81 | 2.12 | 7.32 | 4.87 | 80.4 | 9.58 | 1.69 | 0.22 | 0.39 | 7.83 | 18.45 | 17.93 | 0.87 | 6.04 |
| 21.53 | 8.87 | 5.64 | 4.55 | 107.3 | 11.83 | 2.31 | 0.25 | 0.46 | 9.9 | 24.11 | 20.78 | 4.12 | 5.47 |
| 26.52 | 14.38 | 4.49 | 3.74 | 128.6 | 17.15 | 2.84 | 0.28 | 0.39 | 9.47 | 40.11 | 22.84 | 6.66 | 4.78 |
| 28.12 | 16.55 | 3.58 | 3.16 | 107.4 | 12.61 | 1.59 | 0.25 | 0.32 | 8.37 | 35.16 | 23.21 | 15.92 | 3.89 |
| 26.69 | 15.22 | 3.67 | 3.48 | 105.3 | 18 | 4.34 | 0.21 | 0.36 | 7.77 | 39.17 | 20.41 | 15.27 | 3.57 |
| 23.15 | 10.25 | 5.33 | 4.86 | 72.6 | 12.77 | 2.61 | 0.2 | 0.33 | 6.8 | 15.72 | 15.92 | 5.13 | 4.22 |
| 15.74 | 3.41 | 6.44 | 5.13 | 59.2 | 9.29 | 1.59 | 0.15 | 0.41 | 6.44 | 12.93 | 11.1 | 1.54 | 4.9 |
| 6.07 | -3.99 | 7.17 | 5.86 | 39.8 | 8.97 | 2.6 | 0.13 | 0.36 | 5.17 | 5.93 | 7.16 | -3.25 | 5.42 |
| -2.17 | -11.12 | 7.07 | 7.4 | 24.6 | 4.88 | 1.77 | 0.13 | 0.23 | 4.62 | 3.21 | 5.66 | -8.88 | 5.48 |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the weather-wgn.cli file |
| WGN_NAME | The weather station name (to be referenced in weather-sta.cli file). |
| LATITUDE | 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. |
| LONGITUDE | Longitude of weather station (degrees). |
| ELEV | Elevation of weather station (m). Required if elevation bands are modeled in watershed. |

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.

Required.

TMPMX(MON) Average or mean daily maximum air temperature for month (°C).

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 .

Required.

TMPMN(MON) Average or mean daily minimum air temperature for month (°C).

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 .

Required.

TMPSTDMX(MON) Standard deviation for daily maximum air temperature in month (°C).

This parameter quantifies the variability in maximum temperature for each month. The standard deviation is calculated:

$$\sigma mx_{mon} = \sqrt{\frac{\sum_{d=1}^N (T_{mx,mon} - \mu mx_{mon})^2}{N - 1}}$$

where σmx_{mon} is the standard deviation for daily maximum temperature in month mon (°C), $T_{mx,mon}$ 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 .

Required.

TMPSTDMN_(MON) Standard deviation for daily minimum air temperature in month (°C).

This parameter quantifies the variability in minimum temperature for each month. The standard deviation is calculated:

$$\sigma_{mn_{mon}} = \sqrt{\frac{\sum_{d=1}^N (T_{mn,mon} - \mu_{mn_{mon}})^2}{N-1}}$$

where $\sigma_{mn_{mon}}$ is the standard deviation for daily minimum temperature in month mon (°C), $T_{mn,mon}$ is the daily minimum temperature on record d in month mon (°C), $\mu_{mn_{mon}}$ is the average daily minimum temperature for the month (°C), and N is the total number of daily minimum temperature records for month mon .

Required.

PCPMM_(MON) Average or mean total monthly precipitation (mm H₂O).

$$\bar{R}_{mon} = \frac{\sum_{d=1}^N R_{day,mon}}{yrs}$$

where \bar{R}_{mon} is the mean monthly precipitation (mm H₂O), $R_{day,mon}$ is the daily precipitation for record d in month mon (mm H₂O), 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.

Required.

PCPSTD_(MON) Standard deviation for daily precipitation in month (mm H₂O/day).

This parameter quantifies the variability in precipitation for each month. The standard deviation is calculated:

$$\sigma_{mon} = \sqrt{\left(\frac{\sum_{d=1}^N (R_{day,mon} - \bar{R}_{mon})^2}{N - 1} \right)}$$

where σ_{mon} is the standard deviation for daily precipitation in month *mon* (mm H₂O), $R_{day,mon}$ is the amount of precipitation for record *d* in month *mon* (mm H₂O), \bar{R}_{mon} is the average precipitation for the month (mm H₂O), 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).

Required.

PCPSKW_(MON) Skew coefficient for daily precipitation in month.

This parameter quantifies the symmetry of the precipitation distribution about the monthly mean. The skew coefficient is calculated:

$$g_{mon} = \frac{N \cdot \sum_{d=1}^N (R_{day,mon} - \bar{R}_{mon})^3}{(N - 1) \cdot (N - 2) \cdot (\sigma_{mon})^3}$$

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 H₂O), \bar{R}_{mon} is the average precipitation for the month (mm H₂O), and σ_{mon} is the standard deviation for daily precipitation in month *mon* (mm H₂O). (Note: daily precipitation values of 0 mm are included in the skew coefficient calculation).

Required.

PR_WD_(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.

Required.

PR_WW_(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.

Required.

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.

Required.

RAINHMX_(MON)

Maximum 0.5 hour rainfall in entire period of record for month (mm H₂O).

This value represents the most extreme 30-minute rainfall intensity recorded in the entire period of record.

Required.

SOLARAV_(MON) Average daily solar radiation for month (MJ/m²/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/m²/day), $H_{day,mon}$ is the total solar radiation reaching the earth's surface for day d in month mon (MJ/m²/day), and N is the total number of daily solar radiation records for month mon .

Required.

DEWPT_(MON) Average daily dew point temperature for each month (°C) or relative humidity (fraction) can be input.

If all twelve months are less than one, the model assumes relative humidity is input. Relative humidity is defined in equation 1:3.5.1 in the SWAT Theoretical documentation as the amount of water vapor in the air as a fraction of saturation humidity. If any month has a value greater than 1.0, the model assumes dewpoint temperature is input.

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:

$$\mu dew_{mon} = \frac{\sum_{d=1}^N T_{dew,mon}}{N}$$

where μdew_{mon} is the mean daily dew point temperature for the month (°C), $T_{dew,mon}$ is the dew point temperature for day d in month mon (°C), and N is the total number of daily dew point records for month mon . Dew point is converted to relative humidity using equations 1:3.5.1 and 1:3.5.2 in the Theoretical Documentation.

Required for Penman-Monteith potential evaporation equation.

WINDAV_(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 $\mu_{wnd_{mon}}$ 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 .

Required.

WIND-DIR.CLI

This file contains the wind direction values that will be included in the simulation and is space delimited. Below is a sample WIND-DIR.CLI file:

| | | | | | | | | | | | | |
|-------------|------|------|-----|------|------|------|------|------|------|-----|------|--|
| wind-dir.cl | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| AL_BAN | | | | | | | | | | | | |
| 0 | 0 | | | | | | | | | | | |
| 3.46 | 3.47 | 3.64 | 3.3 | 2.55 | 2.26 | 2.09 | 2.06 | 2.44 | 2.37 | 2.8 | 3.11 | |
| 10 | 10 | 8 | 7 | 8 | 7 | 6 | 9 | 13 | 14 | 12 | 11 | |
| 4 | 5 | 4 | 4 | 4 | 4 | 4 | 6 | 9 | 8 | 6 | 5 | |
| 4 | 4 | 4 | 4 | 6 | 6 | 6 | 8 | 9 | 8 | 6 | 5 | |
| 3 | 4 | 4 | 4 | 5 | 6 | 6 | 7 | 9 | 8 | 5 | 4 | |
| 5 | 6 | 5 | 5 | 6 | 8 | 8 | 9 | 12 | 10 | 6 | 7 | |
| 5 | 5 | 5 | 4 | 5 | 6 | 6 | 5 | 7 | 6 | 4 | 7 | |
| 9 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 7 | 6 | 8 | 8 | |
| 9 | 7 | 8 | 9 | 7 | 7 | 7 | 5 | 5 | 5 | 6 | 7 | |
| 12 | 9 | 11 | 13 | 11 | 10 | 12 | 8 | 6 | 5 | 7 | 8 | |
| 7 | 6 | 7 | 9 | 8 | 8 | 9 | 5 | 4 | 3 | 5 | 4 | |
| 3 | 4 | 4 | 5 | 6 | 6 | 7 | 5 | 3 | 2 | 3 | 3 | |
| 2 | 3 | 3 | 4 | 4 | 5 | 5 | 4 | 2 | 2 | 3 | 3 | |
| 3 | 4 | 5 | 4 | 5 | 5 | 6 | 5 | 2 | 3 | 4 | 5 | |
| 6 | 7 | 7 | 7 | 5 | 5 | 4 | 4 | 2 | 4 | 7 | 6 | |
| 9 | 8 | 8 | 7 | 6 | 6 | 4 | 6 | 4 | 7 | 10 | 8 | |
| 7 | 8 | 8 | 7 | 6 | 5 | 4 | 6 | 7 | 9 | 9 | 8 | |

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

| | |
|-------|---|
| TITLE | Description of the wind direction file (may be blank) |
|-------|---|

| | |
|-----------|--|
| MWIND_DIR | The maximum number of wind direction stations in the file. |
|-----------|--|

| | |
|------|-------------------|
| NAME | Wind Station name |
|------|-------------------|

| | |
|------|---|
| SKIP | Next 2 lines are not read in by the model |
|------|---|

| | |
|----------|--|
| WIND_DIR | The monthly wind directions input data (16 lines/directions) |
|----------|--|

PCP.CLI

This file contains the information on the precipitation gages included in the simulation and is space delimited. A path has been added to file.cio to enable the daily files to be present in another folder; if path is null daily is in same project folder as other data. Below is a sample PCP.CLI file:

| |
|-------------|
| pcp.cli |
| FILENAME |
| mentone.pcp |
| warsaw.pcp |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the precipitation climate file (may be blank) |
| HEADER | The header information for the pcp.cli file |
| PCP_FILENAME | The name of the precipitation file containing daily precipitation input data (description of the pcp_filename data follows) |

PCP_FILENAME

The pcp_filename is input in the pcp.cli file. The description of the 'pcp_filename' contains the daily precipitation amounts for the simulation and is space delimited. A path has been added to file.cio to enable the daily files to be present in another folder; if path is null daily is in same project folder as other data. Below is a sample of the file (partial listing):

| mentone.pcp | | | | |
|-------------|-------|-------|--------|------|
| NBYR | TSTEP | LAT | LONG | ELEV |
| 114 | 0 | 41.14 | -85.98 | 268 |
| 1900 | 1 | 0.3 | | |
| 1900 | 2 | 0 | | |
| 1900 | 3 | 0 | | |
| 1900 | 4 | 0 | | |
| 1900 | 5 | 0 | | |
| 1900 | 6 | 0.6 | | |
| 1900 | 7 | 0.5 | | |
| 1900 | 8 | 0 | | |
| 1900 | 9 | 3.6 | | |
| 1900 | 10 | 3.5 | | |
| 1900 | 11 | 2.3 | | |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the precipitation file (may be blank) |
| HEADER | |
| NBYR | The header information for the file |
| TSTEP | Timestep of the simulation |
| LAT | Latitude of the precipitation gage |
| LONG | Longitude of the precipitation gage |
| ELEV | Elevation of the precipitation gage |
| IYR | The year of the precipitation amount |
| ISTEP | The step (day, sub-daily) of the precipitation amount |
| PCP | The amount of precipitation amount (mm) for istep (enter -99.0 for missing days) |

TMP.CLI

This file contains information on the maximum and minimum temperatures included in the simulation and is space delimited. A path has been added to file.cio to enable the daily files to be present in another folder; if path is null daily is in same project folder as other data. Below is a sample TMP.CLI file:

| |
|-------------|
| tmp.cli |
| FILENAME |
| mentone.tmp |
| warsaw.tmp |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the maximum and minimum temperature file (may be blank) |
| HEADER | The header information for the tmp.cli file |
| TMP_FILENAME | The name of the temperature file containing daily maximum and minimum temperatures. |

TMP_FILENAME

The tmp_filename is input in the tmp.cli file. The description of the 'tmp_filename' contains the daily maximum and minimum temperatures for the simulation and is space delimited. Below is a sample of the file:

| | | | |
|-------------|-------|--------|-------|
| mentone.tmp | | | |
| NBYR | LAT | LONG | ELEV |
| 114 | 41.14 | -85.98 | 268 |
| 1900 | 1 | -99 | -99 |
| 1900 | 2 | -99 | -11.5 |
| 1900 | 3 | -99 | -7.5 |
| 1900 | 4 | 3.1 | -9.4 |
| 1900 | 5 | 5.7 | -0.2 |
| 1900 | 6 | 6.8 | -0.1 |
| 1900 | 7 | 11.2 | 2.6 |
| 1900 | 8 | 7.7 | -99 |
| 1900 | 9 | 8 | -3.4 |
| 1900 | 10 | 4.9 | 1.3 |
| 1900 | 11 | -99 | -1.2 |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the temperature file (may be blank) |
| HEADER | Headings |
| NBYR | The header information for the file |
| LAT | Latitude of the temperature gage |
| LONG | Longitude of the temperature gage |
| ELEV | Elevation of the temperature gage |
| IYR | The year of the temperature data |
| ISTEP | Timestep |
| TMP_MAX | The maximum temperatures for istep (enter -99.0 for missing days) |
| TMP_MIN | The minimum temperatures for istep (enter -99.0 for missing days) |

SLR.CLI

This file contains the information on the solar radiation daily data included in the simulation and is space delimited. A path has been added to file.cio to enable the daily files to be present in another folder; if path is null daily is in same project folder as other data. Below is a sample SLR.CLI file:

| | |
|---------|-----------|
| slr.cli | |
| NUMB | FILENAME |
| 1 | gage1.slr |

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

| | |
|--------------|---|
| TITLE | Description of the solar radiation file (may be blank) |
| HEADER | The header information for the slr.cli file |
| SLR_FILENAME | The name of the solar radiation file containing values of solar radiation |

SLR_FILENAME

The slr_filename is input in the slr.cli file. The description of the 'slr_filename' contains the daily solar radiation values for the simulation and is space delimited. Below is a sample of the file (partial listing):

| | | | |
|-----------|-----|------|------|
| gage1.slr | | | |
| NBYR | LAT | LONG | ELEV |
| 25 | 0.0 | 0.0 | 0.0 |
| 1988 | 1 | 12.9 | |
| 1988 | 2 | 27.4 | |
| 1988 | 3 | 22.7 | |
| 1988 | 4 | 0 | |
| 1988 | 5 | 9.7 | |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the solar radiation file (may be blank) |
| HEADER | Headings |
| NBYR | The header information for the file |
| LAT | Latitude of the solar radiation gage |
| LONG | Longitude of the solar radiation gage |
| ELEV | Elevation of the solar radiation gage |
| IYR | The year of the solar radiation data |
| ISTEP | Timestep |
| SLR | The solar radiation value for istep (MJ/m ² ; -99.0 to generate missing days) |

HMD.CLI

This file contains the information on the relative humidity stations included in the simulation and is space delimited. A path has been added to file.cio to enable the daily files to be present in another folder; if path is null daily is in same project folder as other data. Below is a sample HMD.CLI file:

| | |
|---------|-----------|
| HMD.CLI | |
| NUMB | FILENAME |
| 1 | gage1.hmd |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the relative humidity file (may be blank) |
| HEADER | The header information for the hmd.cli file |
| HMD_FILENAME | The name of the relative humidity file containing daily relative humidity input data |

HMD_FILENAME

The hmd_filename is input in the hmd.cli file. The description of the 'hmd_filename' contains the daily relative humidity values for the simulation and is space delimited. Below is a sample of the file (partial listing):

| | | | |
|-----------|-----|------|------|
| gage1.HMD | | | |
| NBYR | LAT | LONG | ELEV |
| 25 | 0.0 | 0.0 | 0.0 |
| 1988 | 1 | 1 | |
| 1988 | 2 | 0.8 | |
| 1988 | 3 | 0.7 | |
| 1988 | 4 | 1 | |
| 1988 | 5 | 0.5 | |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the relative humidity file (may be blank) |
| HEADER | Headings |
| NBYR | The header information for the file |
| LAT | Latitude of the relative humidity gage |
| LONG | Longitude of the relative humidity gage |
| ELEV | Elevation of the relative humidity gage |
| IYR | The year of the relative humidity data |
| ISTEP | Timestep |
| RELHUM | The relative humidity value for istep (-99.0 to generate missing days) |

WND.CLI

This file contains the information on the windspeed input data included in the simulation and is space delimited. A path has been added to file.cio to enable the daily files to be present in another folder; if path is null daily is in same project folder as other data. Below is a sample WND.CLI file (partial listing):

| | |
|---------|-----------|
| WND.CLI | |
| NUMB | FILENAME |
| 1 | gage1.wnd |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the wnd.cli file (may be blank) |
| HEADER | The header information for the wnd.cli file |
| WND_FILENAME | The name of the precipitation file containing daily windspeed input data |

WND_FILENAME

The wnd_filename is input in the wnd.cli file. The description of the 'wnd_filename' contains the daily wind values for the simulation and is space delimited. Below is a sample of the file (partial listing):

| | | | |
|-----------|-----|------|------|
| gage1.WND | | | |
| NBYR | LAT | LONG | ELEV |
| 25 | 0.0 | 0.0 | 0.0 |
| 1988 | 1 | 3.8 | |
| 1988 | 2 | 4.4 | |
| 1988 | 3 | 2.8 | |
| 1988 | 4 | 2 | |
| 1988 | 5 | 3.1 | |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the windspeed file (may be blank) |
| HEADER | Headings |
| NBYR | The header information for the file |
| LAT | Latitude of the windspeed gage |
| LONG | Longitude of the windspeed gage |
| ELEV | Elevation of the windspeed gage |
| IYR | The year of the windspeed data |
| ISTEP | Timestep |
| WNDSPD | The windspeed value for istep (-99.0 to generate missing days) |

ATMO.CLI

The ATMO.CLI file contains the input variables for atmospheric deposition. The atmospheric deposition input file contains annual average atmospheric nitrogen deposition values including ammonium, nitrate, dry ammonium and dry nitrate and can be read in as average annual, yearly or monthly. This file is optional. An example annual file is listed below:

ATMO_ANNUAL.TXT:

```

Atmodep_file example - annual
NUM_STA  Timestep  MO_INIT  YR_INIT  NUM_AA
      2      aa      0      0      0

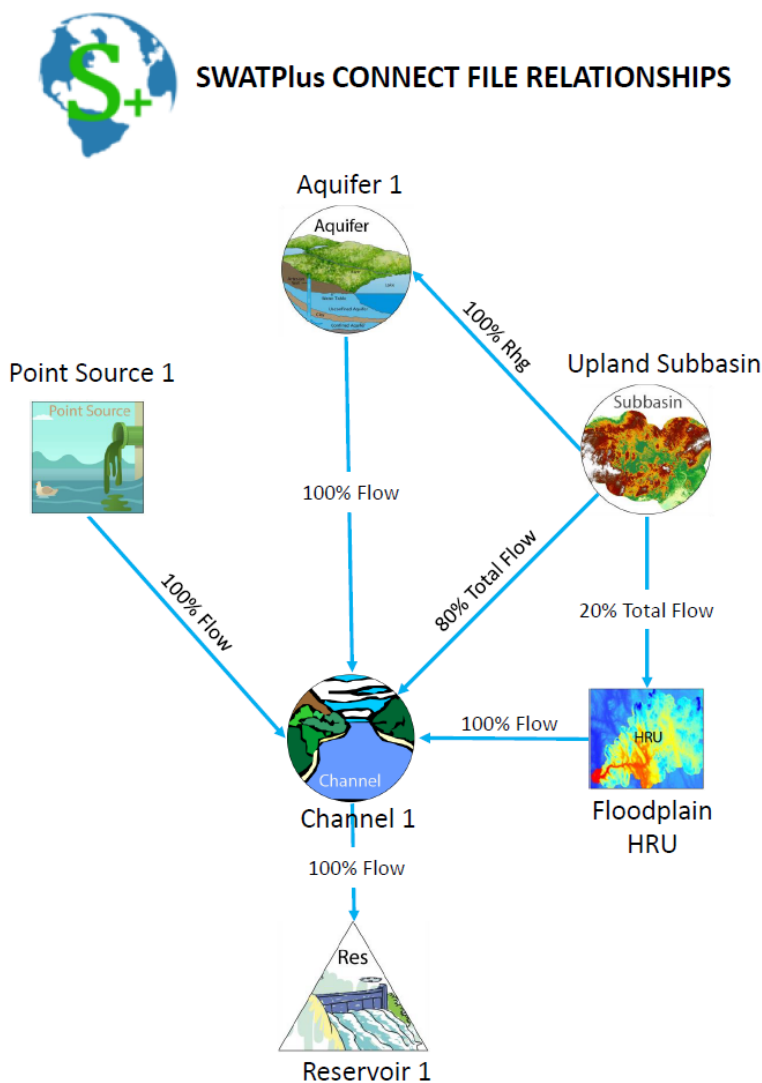
atmo_1
0.35      (NH4_RF)
3.24      (NO3_RF)
0.13      (NH4_DRY)
0.12      (NO3_DRY)

atmo_2
0.35      (NH4_RF)
3.24      (NO3_RF)
0.13      (NH4_DRY)
0.12      (NO3_DRY)

```

| Variable name | Definition |
|---------------|---|
| TITLE | The first line is reserved for user comments. The title line is not processed by the model and may be left blank. |
| HEADER | The second line is the header for the inputs. This line is not processed by the model. |
| NUM_STA | Total number of deposition stations in the file |
| TIMESTEP | There are three different timesteps for the file to be read and should be character. ‘aa’ = annual average (constant) ‘mo’ = monthly ‘yr’ = yearly |
| MO_INIT | Initial month of the input data (applies to month option only) input 0 for other options; |
| YR_INIT | Initial year of the input data (applies to year and monthly option only) input 0 for annual; |
| NUM_AA | Number of average annual values in file; |
| NAME | Initial month of the input data (applies to month option only) input 0 for other options; |
| NH4_RF | Ammonia in rainfl (mg/l) |
| NO3_RF | Nitrate in rainfall (mg/l) |
| NH4_DRY | Ammonia deposition (kg/ha/yr) |
| NO3_DRY | Nitrate dry deposition (kg/ha/yr) |

CONNECT – The CONNECT section of file.cio contains the filenames for the object connectivity for the simulation run. All connect (.con) files read in the same input variables, only differing in the connect units (HRU, HRU-LTE, ROUT_UNIT, modflow, aquifer, aquifer2d, channel, reservoir, recall, exco, delivery ratio, outlet and chandeg).



EXPLANATION OF SPATIAL OBJECTS

SUBBASIN

The subbasin is defined by the DEM in the GIS interface as it always has been. All flow within the subbasin drains to the subbasin outlet.

LANDSCAPE UNIT

A landscape unit is defined as a collection of HRU's and can be defined as a subbasin, or it could be a flood plain or upland unit, or it could be a grid cell with multiple HRU's. The landscape unit is not routed, it only used for output. The landscape unit output files (waterbal, nutbal, losses, and plant weather) are output for HRU's, landscape units, and for the basin. Two input files are required: 1) landscape elements and, 2) landscape define. The elements file includes HRU's and their corresponding LSU fraction and basin fractions. The define file specifies which HRU's are contained in each LSU.

ROUTING UNIT

A routing unit is a collection of hydrographs that can be routed to any spatial object. The routing unit can be configured as a subbasin, then total flow (surface, lateral and tile flow) from the routing unit can be sent to a channel and all recharge from the routing unit sent to an aquifer. This is analogous to the current approach in SWAT. However, SWAT+ gives us much more flexibility in configuring a routing unit. For example, in CEAP, we are routing each HRU (field) through a small channel (gully or grass waterway) before it reaches the main channel. In this case, the routing unit is a collection of flow from the small channels. We also envision simulating multiple representative hillslopes to define a routing unit. Also, we are setting up scenarios that define a routing unit using tile flow from multiple fields and sending that flow to a wetland.

The routing unit is the spatial unit SWAT+ that allows us to lump outputs and route the outputs to any other spatial object. It gives us considerably more flexibility than the old subbasin lumping approach in SWAT, and will continue to be a convenient way of spatial lumping until we can simulate individual fields or cells in each basin.

HRU.CON

The HRU.CON file contains the connectivity for the HRU spatial objects within the watershed that will be included in the simulation and is space delimited. Below is a sample HRU.CON file:

```

hru.con
NUMB NAME GIS_ID AREA LAT LONG ELEV HRU WST CONST_TYPE OVERFLOW RULESET OUT_TOT OBJ_TYP1 OBJ_ID1 HYDRO_TYP1 FRAC!
1 bench 1 0.480 0.000 0.000 0.000 1 wea1 0 0 0 0 0 0 0
2 field 2 495.27 0.000 0.000 0.000 2 wea2 0 0 0 0 0 0 0

```

| Variable name | Definition |
|------------------|---|
| TITLE | Description of the connect file |
| HEADER | The header information for the HRU connect file |
| NUMB | Number of object unit |
| NAME | Name of the object connect |
| GIS_ID | ID number (used for GIS_ID number for manipulating databases) |
| AREA_HA | Area of the object (ha) |
| LAT | Latitude of the object |
| LONG | Longitude of the object |
| ELEV | Elevation of the object |
| PROPS | Object properties number (Spatial objects for PROPS abbreviations - HRU, HLT, RU, MFL, AQU, CHA, RES, REC, EXC, DR, OUT, SDC) |
| WST | Weather station number ('weather-sta.cli' file) |
| CONSTIT | Constituent data pointer (pesticides, pathogens, heavy metals, salts) |
| PROPS2(OVERFLOW) | Overbank connectivity pointer to landscape units |
| RULESET | Ruleset pointer for flow fraction of hydrograph |
| SRC_TOT | Total number of incoming (source) objects |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------|--|--|--|-----|--------------------------|-----|----------|-----|--------------|-----|---------|-----|---------|-----|---------|-----|-----------|-----|--------|-----|---------------------|----|----------------|-----|-------|-----|------|-----|--------|-----|------------------|
| OBTYP_OUT | Outflow object type ('hru'; 'hlt'; 'ru'; 'mfl'; aqu'; 'cha'; 'res'; 'exc'; 'dr'; 'out'; 'sdc') (default == 'null') | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | <div><div>SPATIAL OBJECTS</div><table><tr><td>HRU</td><td>HYDROLOGIC RESPONSE UNIT</td></tr><tr><td>HLT</td><td>HRU LITE</td></tr><tr><td>RU</td><td>ROUTING UNIT</td></tr><tr><td>MFL</td><td>MODFLOW</td></tr><tr><td>AQU</td><td>AQUIFER</td></tr><tr><td>CHA</td><td>CHANNEL</td></tr><tr><td>RES</td><td>RESERVOIR</td></tr><tr><td>REC</td><td>RECALL</td></tr><tr><td>EXC</td><td>EXPORT COEFFICIENTS</td></tr><tr><td>DR</td><td>DELIVERY RATIO</td></tr><tr><td>CAN</td><td>CANAL</td></tr><tr><td>PUM</td><td>PUMP</td></tr><tr><td>OUT</td><td>OUTLET</td></tr><tr><td>SDC</td><td>SWAT DEG CHANNEL</td></tr></table></div> | | | HRU | HYDROLOGIC RESPONSE UNIT | HLT | HRU LITE | RU | ROUTING UNIT | MFL | MODFLOW | AQU | AQUIFER | CHA | CHANNEL | RES | RESERVOIR | REC | RECALL | EXC | EXPORT COEFFICIENTS | DR | DELIVERY RATIO | CAN | CANAL | PUM | PUMP | OUT | OUTLET | SDC | SWAT DEG CHANNEL |
| HRU | HYDROLOGIC RESPONSE UNIT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HLT | HRU LITE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| RU | ROUTING UNIT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MFL | MODFLOW | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| AQU | AQUIFER | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CHA | CHANNEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| RES | RESERVOIR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| REC | RECALL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| EXC | EXPORT COEFFICIENTS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DR | DELIVERY RATIO | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CAN | CANAL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PUM | PUMP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| OUT | OUTLET | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SDC | SWAT DEG CHANNEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| OBTYPNO_OUT | Outflow object type name | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HTYP_OUT | Outflow hydrograph (1='tot'; 2='rhg';3='sur';4='lat';5='til'; (default = 'null') <div><div>OUTFLOW HYDROGRAPHS</div><table><tr><td>TOT</td><td>TOTAL</td></tr><tr><td>RHG</td><td>RECHARGE</td></tr><tr><td>SUR</td><td>SURFACE</td></tr><tr><td>LAT</td><td>LATERAL</td></tr><tr><td>TIL</td><td>TILLAGE</td></tr></table></div> | | | TOT | TOTAL | RHG | RECHARGE | SUR | SURFACE | LAT | LATERAL | TIL | TILLAGE | | | | | | | | | | | | | | | | | | |
| TOT | TOTAL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| RHG | RECHARGE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SUR | SURFACE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LAT | LATERAL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TIL | TILLAGE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| FRAC_OUT | Fraction of hydrograph | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

CHANNEL – The CHANNEL section of file.cio contains the filenames for simulation of a channel in the model. 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 channel input files summarizes the physical characteristics of the channel which affect water flow and transport of sediment, nutrients and pesticides.

INITIAL.CHA

The INITIAL.CHA file contains the input variables for the initialization of a channel. Below is a sample INITIAL.CHA file:

| | | | | | |
|-------------|-----------|------------|-----------|--------------|-------|
| initial.cha | | | | | |
| NAME | ORG-MIN | PESTICIDES | PATHOGENS | HEAVY_METALS | SALTS |
| low_init | low_init | no_ini | no_ini | null | null |
| high_init | high_init | low_ini | low_ini | null | null |

| Variable name | Definition |
|---------------|--|
| TITLE | Title of the initial channel file |
| HEADER | The header information for the initial channel file |
| NAME | Name of the initial channel |
| ORG-MIN | Organic mineral in channel (points to OM_WATER.INI file) |
| PESTICIDES | Pesticides initialization in channel (points to PEST_WATER.INI file) |
| PATHOGENS | Pathogens initialization in channel (points to PATH_WATER.INI file) |
| HEAVY METALS | Heavy metals initialization in channel (points to HMET_WATER.INI file) |
| SALTS | Salts initialization in channel (points to SALT_WATER.INI file) |

CHANNEL.CHA

The CHANNEL.CHA file contains the input variables for the initialization of a channel. Below is a sample CHANNEL.CHA file:

| | | | | | | | | |
|-------------|----------|----------|----------|----------|----------|----------|------------|-----------|
| channel.cha | | | | | | | | |
| CHA_NUMB | CHA_NAME | CHA_INI | CHA_HYD | CHA_SED | CHA_NUT | CHA_PST | CHA_LS_LNK | A_AQU_LNK |
| 1 | cha1 | cha_ini1 | cha_hyd1 | cha_sed1 | cha_nut1 | cha_pst1 | null | null |
| 2 | cha2 | cha_ini2 | cha_hyd2 | cha_sed2 | cha_nut2 | cha_pst2 | null | null |
| 3 | cha3 | cha_ini3 | cha_hyd3 | cha_sed3 | cha_nut3 | cha_pst3 | null | null |
| 4 | cha4 | cha_ini4 | cha_hyd4 | cha_sed4 | cha_nut4 | cha_pst4 | null | null |
| 5 | cha5 | cha_ini5 | cha_hyd5 | cha_sed5 | cha_nut5 | cha_pst5 | null | null |
| 6 | cha6 | cha_ini6 | cha_hyd6 | cha_sed6 | cha_nut6 | cha_pst6 | null | null |
| 7 | cha7 | cha_ini7 | cha_hyd7 | cha_sed7 | cha_nut7 | cha_pst7 | null | null |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the channel file |
| HEADER | The header information for the channel file |
| NUMB | Number of the channel |
| NAME | Name of the channel |
| INIT | Initial data (points to initial.cha) |
| HYD | Channel hydrology inputs (points to hydrology.cha) |
| SED | Channel sediment inputs (points to sediment.cha) |
| NUT | Channel nutrient inputs (points to nutrients.cha) |
| PST | Channel pesticide inputs (points to pesticide.cha) |
| LS_LNK | Landscape linkage (points to chan-surf.lin) |
| AQU_LNK | Aquifer linkage (points to chan-aqu.lin) |

HYDROLOGY.CHA

The HYDROLOGY.CHA file contains the input variables for the hydrology inputs of a channel. Below is a sample HYDROLOGY.CHA file:

| | | | | | | | | | |
|---------------|------|--------|-------|--------|-------|------|-----|-----------|------|
| hydrology.cha | | | | | | | | | |
| NAME | W | D | S | L | N | K | WDR | ALPHA_BNK | SIDE |
| cha_hyd1 | 3.45 | 0.3556 | 0.009 | 0.1116 | 0.014 | 0.01 | 9.7 | 0.1 | 2 |

| Variable name | Definition |
|---------------|---|
| HEADER | Description of the channel hydrology file |
| NAME | The header information for the channel hydrology file |
| W | Name of the channel hydrology |
| D | Average width of the main channel (m) |
| S | Average depth of the main channel (m) |
| L | Average slope of the main channel (m/m) |
| N | Main channel length (km) |
| K | Manning's "n" value for the main channel |
| WDR | Effective hydraulic conductivity of main channel alluvium (mm/hr) |
| ALPHA_BNK | Channel width to depth ratio (m/m) |
| SIDE | Alpha factor for bank storage recession curve (days) |
| | Change in horizontal distance per unit |

SEDIMENT.CHA

The SEDIMENT.CHA file contains the input variables for the sediment inputs of a channel. Below is a sample SEDIMENT.CHA file:

| | | | | | | | | | | | | | |
|--------------|-----|------|------|--------|--------|--------|--------|---------|---------|--------|--------|-------|-----------|
| sediment.cha | | | | | | | | | | | | | |
| NAME | EQN | COV1 | COV2 | BNK_BD | BED_BD | BNK_KD | BED_KD | BNK_D50 | BED_D50 | TC_BNK | TC_BED | EROD1 | ...EROD12 |
| cha_sed1 | 0 | 0.5 | 0.5 | 1.5 | 1.5 | 0.5 | 0.5 | 1.5 | 1.5 | 0.05 | 0.05 | 1 | 1 |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the sediment channel file |
| HEADER | The header information for the sediment channel file |
| NAME | Name of the sediment channel |
| EQN | Sediment routine methods: 0 = original SWAT method; 1 Bagnold's 2 Kodatie 3 Molinas WU 4 Yang |
| COV1 | Channel erodibility factor (0.0-1.0) |
| COV2 | Channel cover factor (0.0-1.0) |
| BNK_BD | Bulk density of channel bank sediment (g/cc) |
| BED_BD | Bulk density of channel bed sediment (g/cc) |
| BNK_KD | Erodibility of channel bank sediment by jet test |
| BED_KD | Erodibility of channel bed by jet test |
| BNK_D50 | D50 (median) particle size diameter of channel bank |
| BED_D50 | D50 (median) particle size diameter of channel bed |
| TC_BNK | Critical shear stress of channel bank (N/m ²) |
| TC_BED | Critical shear stress of channel bed (N/m ²) |
| EROD1-12 | Value of 0.0 indicates a non-erosive channel while a value of 1.0 indicates no resistance to erosion |

NUTRIENTS.CHA

The NUTRIENTS.CHA file contains the input variables for the nutrients of a channel. Below is a sample partial NUTRIENTS.CHA file:

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------|------|------|-----|------|-----|------|------|-----|-----|------|-----|-----|-----|------|------|------|-----|------|------|-----|--------|----|------|------|-----|----|-----|-------|------|-------|----------------|----------------|----------------|---------|---------|---------|----------------|
| NAME | ONCO | OPCO | RS1 | RS2 | RS3 | RS4 | RS5 | RS6 | RS7 | RK1 | RK2 | RK3 | RK4 | RK5 | RK6 | BC1 | BC2 | BC3 | BC4 | LAO | IGROPT | A0 | A2 | A3 | A4 | A5 | A6 | MUMAX | RHOQ | TFACT | K ₁ | K ₂ | K ₃ | LAMBDA0 | LAMBDA1 | LAMBDA2 | P _N |
| nut_cha1 | 0 | 0 | 1 | 0.05 | 0.5 | 0.05 | 0.05 | 2.5 | 2.5 | 1.71 | 1 | 2 | 0 | 1.71 | 1.71 | 0.55 | 1.1 | 0.21 | 0.35 | 2 | 2 | A1 | 0.08 | 0.01 | 1.6 | 2 | 3.5 | 1.07 | 2 | 2.5 | 0.4 | 0.75 | 0.02 | 0.025 | 1 | 0.03 | 0.054 |

| 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. Optional. |
| HEADER | Headers for the nutrients.cha file. |
| NAME | Name of the nutrients channel |
| ONCO | Channel organic N concentration (ppm) |
| OPCO | Channel organic P concentration (ppm) |
| RS1 | Local algal settling rate in the reach at 20° C (m/day). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS1 are converted to m/hr by the model. Values for RS1 should fall in the range 0.15 to 1.82 m/day. If no value for RS1 is entered, the model sets RS1 = 1.0 m/day. Required if in-stream nutrient cycling is being modeled. |
| RS2 | Benthic (sediment) source rate for dissolved phosphorus in the reach at 20° C (mg dissolved P/(m ² ·day)). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS2 are converted to mg dissolved P/(m ² ·hr) by the model. If no value for RS2 is entered, the model sets RS2 = 0.05 mg dissolved P/(m ² ·day). Required if in-stream nutrient cycling is being modeled. |
| RS3 | Benthic source rate for NH ₄ -N in the reach at 20° C (mg NH ₄ -N/(m ² ·day)). If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS3 are converted to mg NH ₄ -N/(m ² ·hr) by the model. If no value for RS3 is entered, the model sets RS3 = 0.5 mg NH ₄ -N/(m ² ·day). Required if in-stream nutrient cycling is being modeled. |

| Variable name | Definition |
|---------------|--|
| RS4 | <p>Rate coefficient for organic N settling in the reach at 20° C (day^{-1}).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS4 are converted to hr^{-1} by the model. Values for RS4 should fall in the range 0.001 to 0.10 day^{-1}. If no value for RS4 is entered, the model sets $\text{RS4} = 0.05 \text{ day}^{-1}$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| RS5 | <p>Organic phosphorus settling rate in the reach at 20° C (day^{-1}).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RS5 are converted to hr^{-1} by the model. Values for RS5 should fall in the range 0.001 to 0.1 day^{-1}. If no value for RS5 is entered, the model sets $\text{RS5} = 0.05 \text{ day}^{-1}$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| RS6 | <p>Rate coefficient for settling of arbitrary non-conservative constituent in the reach at 20° C (day^{-1}).</p> <p>If no value for RS6 is entered, the model sets $\text{RS6} = 2.5$.</p> <p><i>Not currently used by the model.</i></p> |
| RS7 | <p>Benthic source rate for arbitrary non-conservative constituent in the reach at 20° C ($\text{mg ANC}/(\text{m}^2 \cdot \text{day})$).</p> <p>If no value for RS7 is entered, the model sets $\text{RS7} = 2.5$.</p> <p><i>Not currently used by the model.</i></p> |
| RK1 | <p>Carbonaceous biological oxygen demand deoxygenation rate coefficient in the reach at 20° C (day^{-1}).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RK1 are converted to hr^{-1} by the model. Values for RK1 should fall in the range 0.02 to 3.4 day^{-1}. If no value for RK1 is entered, the model sets $\text{RK1} = 1.71 \text{ day}^{-1}$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |

| Variable name | Definition |
|---------------|--|
| RK2 | <p>Oxygen reaeration rate in accordance with Fickian diffusion in the reach at 20° C (day⁻¹).</p> <p>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.</p> <p>Using field measurements, Churchill, Elmore and Buckingham (1962) derived the relationship:</p> $\kappa_{2,20} = 5.03 \cdot v_c^{0.969} \cdot depth^{-1.673}$ <p>where $\kappa_{2,20}$ is the reaeration rate at 20°C (day⁻¹), v_c is the average stream velocity (m/s), and <i>depth</i> is the average stream depth (m).</p> <p>O'Connor and Dobbins (1958) incorporated stream turbulence characteristics into the equations they developed. For streams with low velocities and isotropic conditions,</p> $\kappa_{2,20} = 294 \cdot \frac{(D_m \cdot v_c)^{0.5}}{depth^{1.5}}$ <p>where $\kappa_{2,20}$ is the reaeration rate at 20°C (day⁻¹), D_m is the molecular diffusion coefficient (m²/day), v_c is the average stream velocity (m/s), and <i>depth</i> is the average stream depth (m). For streams with high velocities and nonisotropic conditions,</p> $\kappa_{2,20} = 2703 \cdot \frac{D_m^{0.5} \cdot slp^{0.25}}{depth^{1.25}}$ <p>where $\kappa_{2,20}$ is the reaeration rate at 20°C (day⁻¹), D_m is the molecular diffusion coefficient (m²/day), <i>slp</i> is the slope of the streambed (m/m), and <i>depth</i> is the average stream depth (m). The molecular diffusion coefficient is calculated</p> $D_m = 177 \cdot 1.037^{\bar{T}_{water} - 20}$ <p>where D_m is the molecular diffusion coefficient (m²/day), and \bar{T}_{water} is the average water temperature (°C).</p> |

| Variable name | Definition |
|---------------|--|
| RK2, cont. | <p>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.</p> $\kappa_{2,20} = 5.34 \cdot \frac{v_c^{0.67}}{depth^{1.85}}$ <p>where $\kappa_{2,20}$ is the reaeration rate at 20°C (day⁻¹), v_c is the average stream velocity (m/s), and <i>depth</i> is the average stream depth (m).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RK2 are converted to hr⁻¹ by the model. Values for RK2 should fall in the range 0.01 to 100.0 day⁻¹. If no value for RK2 is entered, the model sets RK2 = 50.0 day⁻¹.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| RK3 | <p>Rate of loss of carbonaceous biological oxygen demand due to settling in the reach at 20° C (day⁻¹).</p> <p>Values for RK3 should fall in the range -0.36 to 0.36 day⁻¹. The recommended default for RK3 is 0.36 day⁻¹ (not set by model).</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| RK4 | <p>Benthic oxygen demand rate in the reach at 20° C (mg O₂/(m²·day)).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of RK4 are converted to (mg O₂/(m²·hr)) by the model. If no value for RK4 is entered, the model sets RK4 = 2.0 mg O₂/(m²·day).</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| RK5 | <p>Coliform die-off rate in the reach at 20° C (day⁻¹).</p> <p>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.</p> <p><i>Not currently used by the model.</i></p> |
| RK6 | <p>Decay rate for arbitrary non-conservative constituent in the reach at 20° C (day⁻¹).</p> <p>If no value for RK6 is entered, the model sets RK6 = 1.71.</p> <p><i>Not currently used by the model.</i></p> |

| Variable name | Definition |
|---------------|--|
| BC1 | <p>Rate constant for biological oxidation of NH_4 to NO_2 in the reach at 20° C in well-aerated conditions (day^{-1}).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of BC1 are converted to hr^{-1} by the model. Values for BC1 should fall in the range 0.1 to 1.0 day^{-1}. If no value for BC1 is entered, the model sets $\text{BC1} = 0.55 \text{ day}^{-1}$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| BC2 | <p>Rate constant for biological oxidation of NO_2 to NO_3 in the reach at 20° C in well-aerated conditions (day^{-1}).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of BC2 are converted to hr^{-1} by the model. Values for BC2 should fall in the range 0.2 to 2.0 day^{-1}. If no value for BC2 is entered, the model sets $\text{BC2} = 1.1 \text{ day}^{-1}$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| BC3 | <p>Rate constant for hydrolysis of organic N to NH_4 in the reach at 20° C (day^{-1}).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of BC3 are converted to hr^{-1} by the model. Values for BC3 should fall in the range 0.2 to 0.4 day^{-1}. If no value for BC3 is entered, the model sets $\text{BC3} = 0.21 \text{ day}^{-1}$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| BC4 | <p>Rate constant for mineralization of organic P to dissolved P in the reach at 20° C (day^{-1}).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), the units of BC4 are converted to hr^{-1} by the model. Values for BC4 should fall in the range 0.01 to 0.70 day^{-1}. If no value for BC4 is entered, the model sets $\text{BC4} = 0.35 \text{ day}^{-1}$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |

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.

Required if in-stream nutrient cycling is being modeled.

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. | <p>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.</p> <p>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.</p> <p>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.</p> <p>The default option is the limiting nutrient option (2).</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| AI0 | <p>Ratio of chlorophyll-a to algal biomass ($\mu\text{g-chla}/\text{mg algae}$).</p> <p>Values for AI0 should fall in the range 10-100. If no value for AI0 is entered, the model will set $\text{AI0} = 50.0$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| AI1 | <p>Fraction of algal biomass that is nitrogen ($\text{mg N}/\text{mg alg}$).</p> <p>Values for AI1 should fall in the range 0.07-0.09. If no value for AI1 is entered, the model will set $\text{AI1} = 0.08$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| AI2 | <p>Fraction of algal biomass that is phosphorus ($\text{mg P}/\text{mg alg}$).</p> <p>Values for AI2 should fall in the range 0.01-0.02. If no value for AI2 is entered, the model will set $\text{AI2} = 0.015$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| AI3 | <p>The rate of oxygen production per unit of algal photosynthesis ($\text{mg O}_2/\text{mg alg}$).</p> <p>Values for AI3 should fall in the range 1.4-1.8. If no value for AI3 is entered, the model will set $\text{AI3} = 1.6$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |

| Variable name | Definition |
|---------------|--|
| AI4 | <p>The rate of oxygen uptake per unit of algal respiration (mg O₂/mg alg).</p> <p>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.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| AI5 | <p>The rate of oxygen uptake per unit of NH₃-N oxidation (mg O₂/mg NH₃-N).</p> <p>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.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| AI6 | <p>The rate of oxygen uptake per unit of NO₂-N oxidation (mg O₂/mg NO₂-N).</p> <p>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.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| MUMAX | <p>Maximum specific algal growth rate at 20° C (day⁻¹).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), MUMAX is converted to (hr⁻¹) by the model. 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.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| RHOQ | <p>Algal respiration rate at 20° C (day⁻¹).</p> <p>If routing is performed on an hourly time step (see IEVENT in .bsn file), RHOQ is converted to (hr⁻¹) by the model. 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.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| TFACT | <p>Fraction of solar radiation computed in the temperature heat balance that is photosynthetically active.</p> <p>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.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |

| Variable name | Definition |
|---------------|--|
| K_L | <p>Half-saturation coefficient for light ($\text{kJ}/(\text{m}^2 \cdot \text{min})$).</p> <p>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 $K_L = 0.75$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| K_N | <p>Michaelis-Menton half-saturation constant for nitrogen (mg N/L).</p> <p>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.</p> <p>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 $K_N = 0.02$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| K_P | <p>Michaelis-Menton half-saturation constant for phosphorus (mg P/L).</p> <p>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.</p> <p>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 $K_P = 0.025$.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| LAMBDA0 | <p>Non-algal portion of the light extinction coefficient (m^{-1}).</p> <p>The light extinction coefficient, k_ℓ, is calculated as a function of the algal density using the nonlinear equation:</p> $k_\ell = k_{\ell,0} + k_{\ell,1} \cdot \alpha_0 \cdot \text{algae} + k_{\ell,2} \cdot (\alpha_0 \cdot \text{algae})^{2/3}$ <p>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 ($\text{m}^{-1} (\mu\text{g-chla/L})^{-1}$), $k_{\ell,2}$ is the nonlinear algal self shading coefficient ($\text{m}^{-1} (\mu\text{g-chla/L})^{-2/3}$), α_0 is the ratio of chlorophyll <i>a</i> to algal biomass ($\mu\text{g chla/mg alg}$), and <i>algae</i> is the algal biomass concentration (mg alg/L).</p> |

| Variable name | Definition |
|----------------|--|
| LAMBDA0, cont. | <p>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 $k_{\ell,1} = 0.0088 \text{ m}^{-1} (\mu\text{g - chl}a/\text{L})^{-1}$ and $k_{\ell,2} = 0.054 \text{ m}^{-1} (\mu\text{g - chl}a/\text{L})^{-2/3}$.</p> <p>If no value for LAMBDA0 is entered, the model will set LAMBDA0 = 1.0.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| LAMBDA1 | <p>Linear algal self-shading coefficient ($\text{m}^{-1} \cdot (\mu\text{g chl}a/\text{L})^{-1}$).</p> <p>See explanation for LAMBDA0 for more information on this variable.</p> <p>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.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| LAMBDA2 | <p>Nonlinear algal self-shading coefficient ($\text{m}^{-1} \cdot (\mu\text{g chl}a/\text{L})^{-2/3}$).</p> <p>See explanation for LAMBDA0 for more information on this variable.</p> <p>The recommended value for LAMBDA2 is 0.0541. If no value for LAMBDA2 is entered, the model will set LAMBDA2 = 0.054.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |
| P_N | <p>Algal preference factor for ammonia.</p> <p>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.</p> <p>Required if in-stream nutrient cycling is being modeled.</p> |

PATHOGENS.CHA

The PATHOGENS.CHA file contains the input variables for the nutrients of a channel. Below is a sample partial PATHOGENS.CHA file: (no file included in this revision)

| 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. Optional. |
| HEADER | Headers for the channel-lte file. |
| NAME | Name of the nutrients channel lte |
| CHA_INI | Channel lte initial file (points to initial.cha file) |
| CHA_HYD | Channel lte hydrology file (points to hyd-sed-lte.cha file) |
| CHA_SED | Channel lte sediment file (points to hyd-sed-lte.cha file) |
| CHA_NUT | Channel lte nutrient file (points to nutrient.cha file) |
| CHA_PST | Channel lte pesticide file (points to pesticide.cha file) |
| CHA_PATH | Channel lte pathogen file (points to pathogen.cha file) |
| CHA_HMET | Channel lte heavy metals file (points to hmet.cha file) |
| CHA_SALT | Channel lte salt file (points to salt.cha file) |
| CH_TEMP | Channel lte temperature file (points to temperature.cha file) |

HYD-SED-LTE.CHA

The HYD-SED-LTE.CHA file contains the input variables for the nutrients of a channel. Below is a sample HYD-SED-LTE.CHA file:

| | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------|-------|--------|-----|------|-------|-----|------|-----|--------|-------|--------|-------|-----|------|--------|-----|------|-------|-----|----------|-------|--------|--------|
| hyd-sed-lte.cha | | | | | | | | | | | | | | | | | | | | | | | |
| NAME | ORDER | RTE_DB | CHW | CHD | CHS | CHL | CHN | CHK | CHEROD | CHCOV | HC_COV | CHSEQ | D50 | CLAY | CARBON | BD | CHSS | BEDLD | TC | SHEAR_BN | HC_KH | HC_HGT | HC_INI |
| 1st_stage | ditch | nut1 | 4 | 0.5 | 0.005 | 0.6 | 0.1 | 1 | 0.01 | 0.005 | 0.005 | 0.001 | 12 | 30 | 0.04 | 1.5 | 0.5 | 0.5 | 120 | 0.75 | 0.2 | 0 | 0 |
| Gully_hru2 | gully | nut1 | 5.5 | 0.71 | 0.007 | 8 | 0.05 | 1 | 0.01 | 0.005 | 0.005 | 0.001 | 12 | 30 | 0.04 | 1.5 | 0.5 | 0.5 | 120 | 0.75 | 0.2 | 0.4 | 0 |
| First_Ord1 | first | nut1 | 6.5 | 0.71 | 0.007 | 8 | 0.05 | 1 | 0.01 | 0.005 | 0.005 | 0.001 | 12 | 30 | 0.04 | 1.5 | 0.5 | 0.5 | 120 | 0.75 | 0.05 | 0.5 | 0 |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the time.sim file (may be blank) |
| HEADER | Headers for variables |
| NAME | Channel lte name |
| ORDER | Stream order |
| RTE_NUT | Pointer to routing nutrient data in nutrients.cha file |
| CHW | Channel lte width (m) |
| CHD | Channel lte depth (m) |
| CHS | Channel lte slope (m/m) |
| CHL | Channel lte length (km) |
| CHN | Channel lte Manning's N |
| CHK | Channel lte bottom conductivity (mm/day) |

| | |
|-----------|---|
| CHEROD | Channel lte erodibility factor (0=non-erosive channel; 1=no resistance to erosion) |
| CHCOV | Channel lte cover factor (0=channel is completely protected from erosion; 1=no vegetative cover on channel) |
| WD_RTO | Width-Depth ratio (0.5-100.0) |
| CHSEQ | Channel lte equilibrium channel slope (m/m) |
| D50 | Channel lte median sediment size (%) |
| CLAY | Channel lte clay percent of bank and bed (%) |
| CARBON | Carbon percent of bank and bed (%) |
| BD | Channel lte dry bulk density (t/m ³) |
| CHSS | Channel lte side slope |
| BED_LOAD | Percent of sediment entering the channel lte that is bed material (%) |
| TC | Channel lte time of concentration |
| SHEAR_BNK | Channel lte bank shear coefficient – fraction of bottom shape |
| HC_KH | Channel lte headcut erodibility |
| HC_HGT | Channel lte headcut height (m) |
| HC_INI | Initial channel lte length for gullies |

TEMPERATURE.CHA

The TEMPERATURE.CHA file contains the input variables for the nutrients of a channel. Below is a sample TEMPERATURE.CHA file:

| | | | | | |
|-----------------|---------|------|---------|---------|---------|
| temperature.cha | | | | | |
| NAME | SNO_MLT | GW | SUR_LAT | BULK_CO | AIR_LAG |
| CHA1 | 1.0 | 0.97 | 1.0 | 0.0025 | 6.0 |

| Variable name | Definition |
|----------------------|--|
| TITLE | Description of the time.sim file (may be blank) |
| HEADER | Headers for variables |
| NAME | Channel lte name |
| SNO_MLT | Coefficient influencing snowmelt temperature contributions |
| GW | Coefficient influencing groundwater temperature contributions |
| SUR_LAT | Coefficient influencing surface and lateral flow temperature contributions |
| BULK_CO | Bulk coefficient of heat transfer (1/hour) |

AIR_LAG Average air temperature lag (days)

RESERVOIR – The RESERVOIR section of file.cio contains the filenames for simulation of a reservoirs in the model. Reservoirs are impoundments located on the main channel network of the watershed. Reservoirs receive loadings from all upstream subbasins. The reservoir input file (.res) contains input data to simulate water and sediment processes.

INITIAL.RES

The INITIAL.RES file contains the input variables for the initialization of a channel. Below is a sample partial INITIAL.RES file: (this file will change in Rev54)

initial.res: Reservoir data file - asdf.lj

| NAME | VOL | SED | ORGN | NO3 | NO2 | NH3 | ORGP | SOLP | SECI | SAN | SIL | CLA | SAG | LAG |
|--------------|------|--------|-------|------|------|------|------|------|------|------|------|------|------|------|
| reservoir001 | 0.90 | 200.00 | 10.00 | 2.00 | 0.20 | 0.10 | 1.00 | 0.10 | 1.00 | 0.00 | 1.00 | 9.00 | 0.00 | 0.00 |

| 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. Optional. |
| HEADER | Headers for the initial_res file. |
| NAME | Initial name of the reservoir |
| 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). |
| SED | Initial sediment concentration in the reservoir (mg/L). If the reservoir is in existence at the beginning of the simulation period, the initial sediment concentration is the concentration on the first day of simulation. If the reservoir begins operation in the midst of a SWAT simulation, the initial sediment concentration is the concentration the day the reservoir becomes operational (mg/L). |
| ORGN | Amount of organic N in reservoir |
| NO3 | Initial concentration of $\text{NO}_3\text{-N}$ in reservoir (mg N/L). |
| NO2 | Initial concentration of $\text{NO}_2\text{-N}$ in reservoir (mg N/L). |
| NH3 | Initial concentration of $\text{NH}_3\text{-N}$ (ammonia) in reservoir (mg N/L). |

| | |
|------|--|
| ORGP | Initial concentration of organic P in reservoir (mg P/L). We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for ORGP is not going to be important if the reservoir is in operation at the beginning of the simulation. However, if the reservoir starts operation in the middle of a simulation, this value needs to be reasonably accurate. |
| SOLP | Amount of soluble phosphorus in the reservoir (read in as mg/L and converted to kg/L) See comment for ORGP. |
| SECI | Secchi-disk depth(m) |
| SAN | Amount of sand in the reservoir (read in as mg/L and converted to kg/L) |
| SIL | Amount of silt in the reservoir (read in as mg/L and converted to kg/L) |
| CLA | Amount of clay in the reservoir (read in as mg/L and converted to kg/L) |
| SAG | Amount of small aggregates in the reservoir (read in as mg/L and converted to kg/L) |
| LAG | Amount of large aggregates in the reservoir (read in as mg/L and converted to kg/L) |
| GRA | Amount of gravel in the reservoir (read in as mg/L and converted to kg/L) |
| CHLA | Amount of chlorophyll-s in the reservoir (read in as mg/L and converted to kg/L) |

RESERVOIR.RES

The reservoir input file (.res) contains input data to simulate water and sediment processes while the lake water quality file (.lwq) contains input data to simulate nutrient and pesticide cycling in the water body.

Below is a sample RESERVOIR.RES file:

```

reservoir.res
RES_NUMB  RES_NAME  RES_INI  RES_HYD  RELEASE  RES_SED  RES_NUT  RES_PST
1         pnd1     res001   pnd1     lrew_sm_res  res001   res001   res001
2         pnd2     res001   pnd2     lrew_sm_res  res001   res001   res001
3         pnd3     res001   pnd3     lrew_sm_res  res001   res001   res001
4         pnd4     res001   pnd4     lrew_sm_res  res001   res001   res001
5         pnd5     res001   pnd5     lrew_sm_res  res001   res001   res001
6         pnd6     res001   pnd6     lrew_sm_res  res001   res001   res001
7         pnd7     res001   pnd7     lrew_sm_res  res001   res001   res001

```

| 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. Optional. |
| HEADER | Headers for the reservoir.res file. |
| NUMB | The number of the reservoir |
| NAME | The name of the reservoir |
| VARIABLE | The initial data points to 'initial.res' file. |
| NAME | |
| INIT | The initial data (points to initial.res file) |
| HYD | Hydraulic conductivity of the reservoir bottom (mm/hr). If seepage occurs in the water body, the hydraulic conductivity must be set to a value other than 0. (points to hydrology.res file) |
| RELEASE | Average daily principal spillway release rate (m ³ /s). The name for this variable is slightly misleading. SWAT uses this variable when the volume of water in the reservoir is between the principal and emergency spillway volumes. If the amount of water exceeding the principal spillway volume can be released at a rate \leq REL, then all of the water volume in excess of the principal spillway volume is released. Otherwise the release rate, REL is used. (points to release.res file) |
| SED | Initial sediment concentration in the reservoir (mg/L). If the reservoir is in existence at the beginning of the simulation period, the initial sediment concentration is the concentration on the first day of simulation. If the reservoir begins operation in the midst of a SWAT simulation, the initial sediment concentration is the concentration the day the reservoir becomes operational (mg/L). (points to sediment.res file) |
| NUT | Nutrient inputs (points to nutrients.res file) |
| PST | Pesticide inputs (points to pesticide.res file) |

HYDROLOGY.RES

Reservoirs are impoundments located on the main channel network of the watershed. Reservoirs receive loadings from all upstream subbasins. The reservoir input file (.res) contains input data to simulate water and sediment processes while the lake water quality file (.lwq) contains input data to simulate nutrient and pesticide cycling in the water body.

Below is a sample HYDROLOGY.RES file:

| | | | | | | | | | | |
|---------------|-------|--------|---------|--------|---------|--------|-------|---------|----------|----------|
| hydrology.res | | | | | | | | | | |
| RES_HYD_NAM | YR_OP | MON_OP | AREA_PS | VOL_PS | AREA_ES | VOL_ES | RES_K | EVAP_CO | SHP_CO_1 | SHP_CO_2 |
| pnd1 | 0 | 0 | 4.95 | 12.375 | 5.445 | 13.613 | 0 | 1 | 0 | 0 |
| pnd2 | 0 | 0 | 4.41 | 11.025 | 4.851 | 12.128 | 0 | 1 | 0 | 0 |
| pnd3 | 0 | 0 | 3.06 | 7.65 | 3.366 | 8.415 | 0 | 1 | 0 | 0 |
| pnd4 | 0 | 0 | 8.55 | 21.375 | 9.405 | 23.513 | 0 | 1 | 0 | 0 |
| pnd5 | 0 | 0 | 2.16 | 5.4 | 2.376 | 5.94 | 0 | 1 | 0 | 0 |
| pnd6 | 0 | 0 | 2.52 | 6.3 | 2.772 | 6.93 | 0 | 1 | 0 | 0 |
| pnd7 | 0 | 0 | 0.63 | 1.575 | 0.693 | 1.733 | 0 | 1 | 0 | 0 |
| pnd8 | 0 | 0 | 5.76 | 14.4 | 6.336 | 15.84 | 0 | 1 | 0 | 0 |

| 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. Optional. |
| HEADER | Headers for the hydrology.res file. |
| NAME | The name of the reservoir |
| IYRES | Year 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. Required. |
| 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. Required. |
| PSA | Reservoir surface area when the reservoir is filled to the principal spillway (ha). See comment for ESA. Required. |
| PVOL | Volume of water needed to fill the reservoir to the principal spillway (10^4 m ³). See comment for RES_ESA. Required. |

ESA Reservoir surface area when the reservoir is filled to the emergency spillway (ha).

For SWAT to calculate the reservoir surface area each day the surface area at two different water volumes must to be defined. Variables referring to the principal spillway can be thought of as variables referring to the normal reservoir storage volume while variables referring to the emergency spillway can be thought of as variables referring to maximum reservoir storage volume.
Required.

EVOL Volume of water needed to fill the reservoir to the emergency spillway (10^4 m^3).

See comment for RES_ESA.

Required.

K Hydraulic conductivity of the reservoir bottom (mm/hr).

If seepage occurs in the water body, the hydraulic conductivity must be set to a value other than 0.

Required.

EVRSV Lake evaporation coefficient.

Default = 0.6

Required.

BR1 Vol_surface area coefficient for reservoirs (model estimates if zero)

BR2 Vol_surface area coefficient for reservoirs (model estimates if zero)

NUTRIENTS.RES

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.

Below is a sample partial NUTRIENTS.RES file:

| | | | | | | | | | | | | | |
|----------------|---------|---------|-----------|-------|-----------|-------|---------|----------|---------|---------|-----------|-----------|--|
| nutrients.res: | | | | | | | | | | | | | |
| RES_NUT_NAM | MID_BEG | MID_END | MID_N_STL | N_STL | MID_P_STL | P_STL | CHLA_CO | SECCI_CO | THETA_N | THETA_P | CONC_NMIN | CONC_PMIN | |
| res001 | 4 | 10 | 0.5 | 2 | 1 | 0.5 | 1 | 1 | 1 | 1 | 0.1 | 0.01 | |

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

| | |
|----------------|---|
| TITLE | <p>The first line is reserved for user comments. This line is not processed by the model and may be left blank.</p> <p>Optional.</p> <hr/> |
| HEADER NAME | <p>Headers for the nutrients.res file.</p> <hr/> <p>The name of the reservoir</p> <hr/> |
| IRES1 | <p>Beginning month of mid-year nutrient settling period.</p> <p>The model allows the user to define two settling rates for each nutrient and the time of the year during which each settling rate is used. A variation in settling rates is allowed so that impact of temperature and other seasonal factors may be accounted for in the modeling of nutrient settling. To use only one settling rate for the entire year, both variables for the nutrient may be set to the same value. Setting all variables to zero will cause the model to ignore settling of nutrients in the water body.</p> <p>Required.</p> <hr/> |
| IRES2 | <p>Ending month of mid-year nutrient settling period.</p> <p>See comment for IRES1.</p> <p>Required.</p> |

| | |
|---------|--|
| NSETLR1 | <p>Nitrogen settling rate in reservoir for months IRES1 through IRES2 (m/year).</p> <p>See explanation for PSETLR1 for more information about this parameter.</p> <p>Required if nutrient cycling is being modeled.</p> |
| NSETLR2 | <p>Nitrogen settling rate in reservoir for months other than IRES1-IRES2 (m/year).</p> <p>See explanation for PSETLR1 for more information about this parameter.</p> <p>Required if nutrient cycling is being modeled.</p> |
| PSETLR1 | <p>Phosphorus settling rate in reservoir for months IRES1 through IRES2 (m/year).</p> <p>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.</p> <p>Table 30-1 summarizes typical ranges in phosphorus settling velocity for different systems.</p> <p>Required if nutrient cycling is being modeled.</p> <p>Table 30-1: Recommended apparent settling velocity values for phosphorus (Panuska and Robertson, 1999)</p> |

| Nutrient Dynamics | Range in settling velocity values (m/year) |
|---|--|
| Shallow water bodies with high net internal phosphorus flux | $v \leq 0$ |
| Water bodies with moderate net internal phosphorus flux | $1 < v < 5$ |
| Water bodies with minimal net internal phosphorus flux | $5 < v < 10$ |
| Water bodies with high net internal phosphorus removal | $v > 10$ |

| | |
|---------|--|
| PSETLR2 | <p>Phosphorus settling rate in reservoir for months other than IRES1-IRES2 (m/year).</p> <p>See explanation for PSETLR1 for more information about this parameter.</p> <p>Required if nutrient cycling is being modeled.</p> |
|---------|--|

| Variable name | Definition |
|---------------|---|
| CHLAR | <p>Chlorophyll <i>a</i> production coefficient for reservoir.</p> <p>Chlorophyll <i>a</i> concentration in the reservoir is calculated from the total phosphorus concentration. The equation assumes the system is phosphorus limited. The chlorophyll <i>a</i> 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.</p> <p>The default value for CHLAR is 1.00, which uses the original equation.</p> <p>Required if nutrient cycling is being modeled.</p> |
| SECCIR | <p>Water clarity coefficient for the reservoir.</p> <p>The clarity of the reservoir is expressed by the secchi-disk depth (m) which is calculated as a function of chlorophyll <i>a</i>. 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 <i>a</i> on water clarity.</p> <p>The default value for SECCIR is 1.00, which uses the original equation.</p> <p>Required if nutrient cycling is being modeled.</p> |
| THETA_N | Temperature adjustment for nitrogen loss (settling) |
| THETA_P | Temperature adjustment for phosphorus loss (settling) |
| CONC_NMIN | Minimum nitrogen concentration for settling (ppm) |
| CONC_PMIN | Minimum phosphorus concentration for settling (ppm) |

PATHOGENS.RES

The PATHOGENS.RES file contains the input variables for the nutrients of a channel. Below is a sample partial PATHOGENS.RES file:

| Variable name | Definition |
|---------------|---|
| TITLE | This line is reserved for the pesticide section title. This line is not processed by the model and may be left blank. |
| HEADER | Headings |
| NAME | Name of the pathogens reservoir |

METALS.RES

The METALS.CHA file contains the input variables for the nutrients of a channel. Below is a sample partial METALS.CHA file:

| Variable name | Definition |
|---------------|---|
| TITLE | This line is reserved for the pesticide section title. This line is not processed by the model and may be left blank. |
| HEADER | Headings |
| NAME | Name of the metals reservoir |

SALT.RES

The SALT.RES file contains the input variables for the nutrients of a channel. Below is a sample partial SALT.RES file:

| Variable name | Definition |
|---------------|---|
| TITLE | This line is reserved for the pesticide section title. This line is not processed by the model and may be left blank. |
| HEADER | Headings |
| NAME | Name of the salt reservoir |

SEDIMENT.RES

Reservoirs are impoundments located on the main channel network of the watershed. Reservoirs receive loadings from all upstream subbasins. The reservoir input file (.res) contains input data to simulate water and sediment processes while the lake water quality file (.lwq) contains input data to simulate nutrient and pesticide cycling in the water body. Below is a sample SEDIMENT.RES file:

| | | | | | | |
|--------------|------|-----|--------|-----------|-----------|----------|
| sediment.res | | | | | | |
| NAME | NSED | D50 | CARBON | BULK_DENS | SED_SETLR | VELSETLR |
| sw_us_med | 100 | 20 | 0.04 | 0.8 | 0.15 | 0.0002 |

| 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. Optional. |
| HEADER | Headers for the sediment.res file. |
| NAME | The name of the reservoir |
| NSED | Equilibrium sediment concentration in the reservoir (mg/L). The amount of suspended solid settling that occurs in the water body on a given day is calculated as a function of concentration. Settling occurs only when the sediment concentration in the water body exceeds the equilibrium sediment concentration specified by the user. Required. |

D50

Median particle diameter of sediment (μm).

| Sediment Class | Size (μm) | Approx. Size |
|----------------|------------------------|-------------------------------|
| Boulders | > 256,000 | > Volley ball |
| Cobbles | > 64,000 | > Tennis ball |
| Pebbles | > 2,000 | > Match Head |
| Sand | | |
| V. Course | 1,500 | |
| Medim | 375 | |
| V. Fine | 94 | |
| Silt | | |
| V. Coarse | 47 | |
| Medium | 11.7 | No longer visible to the huma |
| V. Fine | 4.9 | |
| Clay | 1.95 | |

SWAT calculates the median sediment particle diameter for impoundments located within a subbasin using the equation:

$$d_{50} = \exp\left(0.41 \cdot \frac{m_c}{100} + 2.71 \cdot \frac{m_{silt}}{100} + 5.7 \cdot \frac{m_s}{100}\right)$$

where d_{50} is the median particle size of the sediment (μm), m_c is percent clay in the surface soil layer, m_{silt} is the percent silt in the surface soil layer, m_s is the percent sand in the surface soil layer.

Because reservoirs are located on the main channel network and receive sediment from the entire area upstream, defaulting the sand, silt, and clay fractions to those of a single subbasin or HRU in the upstream area is not appropriate. Instead the user is allowed to set the median particle size diameter to a representative value.

If no value is defined for the median particle diameter, the model will set RES_D50 = 10 μm .
Required.

CARBON

Organic carbon in suspended and benthic sediment (%)

BD

Bulk density of benthic sediment (t/m^3)

SED_STLR

Sediment settling rate

VELSETLR

Sediment settling velocity (m/d)

WEIR.RES

Below is a sample WEIR.RES file:

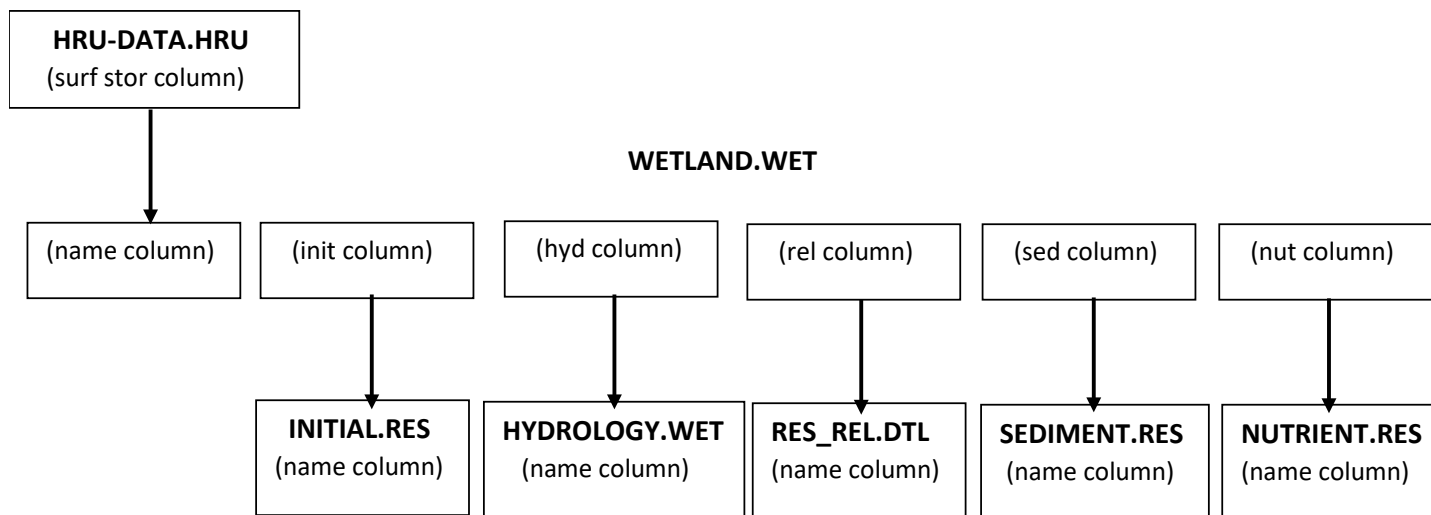
| | | | | | | |
|-----------|-----------|---|-------|---|-------|-------|
| weir.res: | | | | | | |
| WEIR_NAME | NUM_STEPS | C | K | W | BCOEF | CCOEF |
| shape001 | 24 | 1 | 15000 | 2 | 1.75 | 1 |

| 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. Optional. |
| HEADER | Headers for the weir.res file. |
| NAME | The name of the reservoir |
| NUM_STEPS | The number of time steps in day for weir routing |
| C | Weir discharge coefficient |
| K | Energy coefficient (broad_crested=147,000' sharp crested=153,000) |
| W | The width of the weir (m) |
| BCOEF | Velocity exponent coefficient for bedding material |
| CCOEF | Depth exponent coefficient for bedding material |

WETLAND.WET

A figure for crosswalking the wetland.wet file:

(d:\modular_datasets_rev59_3_freeze\documentation\wetland_crosswalked.docx)



Below is a sample WETLAND.WET file:

| wetland.wet | | | | | | | |
|-------------|-----------|------------|------|---------|--------|--------|--------|
| NUMB | NAME | INIT | HYD | RELEASE | SED | NUT | PST |
| 1 | wetland1 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 2 | wetland2 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 3 | wetland3 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 4 | wetland4 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 5 | wetland5 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 6 | wetland6 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 7 | wetland7 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 8 | wetland8 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 9 | wetland9 | wetland001 | pnd1 | null | res001 | res001 | res001 |
| 10 | wetland10 | wetland001 | pnd1 | null | res001 | res001 | res001 |

| 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. Optional. |
| HEADER | Headers for the wetland.wet file. |
| NAME | The name of the wetland |
| INIT | Initial data (points to initial.res) |
| HYD | Hydrology inputs (points to hydrology.res) |
| RELEASE | 0 = simulated; 1 = measured outflow |
| SED | Sediment inputs (points to sediment.res) |
| NUT | Nutrient inputs (points to nutrient.res) |
| PST | Pesticide inputs (points to pesticide.res) |

HYDROLOGY.WET

Below is a sample HYDROLOGY.WET file:

| hydrology.wet | | | | | | | | | | |
|---------------|-----|----------|-----|----------|------|-------|------|------|------|------|
| NAME | PSA | PVOL | ESA | EVOL | K | EVRSV | ACOE | BCOE | CCOE | FRAC |
| pnd1 | 0.5 | 12.25125 | 0.9 | 14.82401 | 0.02 | 0.6 | 0 | 0 | 1 | 0.5 |

| 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. Optional. |
| HEADER | Headers for the hydrology.wet file. |
| NAME | The name of the hydrology |

| | |
|-------|--|
| PSA | Fraction of hru area at principal spillway (ie: when surface inlet riser flow starts) (frac) |
| PVOL | Average depth of water at principal spillway (mm) |
| ESA | Fraction of hru area at emergency spillway (ie: when starts to spill into ditch) |
| EVOL | Average depth of water at emergency spillway (mm) |
| K | Hydraulic conductivity of the res bottom (mm/hr) |
| EVRSV | Lake evap coeff |
| ACOE | Vol-surface area coefficient for hru impoundment |
| BCOE | Vol-depth coefficient for hru impoundment |
| CCOE | Vol-depth coefficient for hru impoundment |
| FRAC | Fraction of hru that drains into impoundment |

ROUTING UNIT

A routing unit is a collection of hydrographs that can be routed to any spatial object. The routing unit can be configured as a subbasin, then total flow (surface, lateral and tile flow) from the routing unit can be sent to a channel and all recharge from the routing unit sent to an aquifer. This is analogous to the current approach in SWAT. However, SWAT+ gives us much more flexibility in configuring a routing unit. For example, in CEAP, we are routing each HRU (field) through a small channel (gully or grass waterway) before it reaches the main channel. In this case, the routing unit is a collection of flow from the small channels. We also envision simulating multiple representative hillslopes to define a routing unit. Also, we are setting up scenarios that define a routing unit using tile flow from multiple fields and sending that flow to a wetland.

The routing unit is the spatial unit SWAT+ that allows us to lump outputs and route the outputs to any other spatial object. It gives us considerably more flexibility than the old subbasin lumping approach in SWAT, and will continue to be a convenient way of spatial lumping until we can simulate individual fields or cells in each basin.

ROUT_UNIT.DEF

The rout_unit.def file contains data that defines HRU's in the subbasin.

Below is a sample rout_unit.def file:

| RTU_NUMB | RTU_NAME | ELEM_TOT | ELEM1 | ELEM2 |
|----------|----------|----------|-------|-------|
| 1 | sub1 | 2 | 1 | -21 |
| 2 | sub2 | 2 | 22 | -28 |
| 3 | sub3 | 2 | 29 | -39 |
| 4 | sub4 | 2 | 40 | -42 |
| 5 | sub5 | 2 | 43 | -62 |
| 6 | sub6 | 2 | 63 | -67 |

Variable name

Definition

| | |
|-----------|--|
| TITLE | The title of the rout_unit.def file |
| HEADER | Headers for the rout_unit.def file. |
| NUMB | Routing unit number |
| NAME | The name of the routing unit |
| ELEM_TOT | Total number of total elements to follow |
| ELEM_CNT1 | Starting routing unit |
| ELEM_CNT2 | Ending routing unit |

ROUT_UNIT.ELE

Below is a sample ROUT_UNIT.ELE file:

| | | | | | |
|---------------|------|--------|----------|------|------|
| rout_unit.ele | | | | | |
| NUMB | NAME | OBTYPE | OBTYPENO | FRAC | DR |
| 1 | hru1 | hru | 1 | 0.5 | 0.00 |
| 2 | hru2 | hru | 2 | 0.5 | 0.00 |

| Variable name | Definition |
|---------------|---|
| TITLE | The title of the rout_unit.ele file |
| HEADER | Headers for the rout_unit.ele file. |
| NUMB | The number of the connect (routing) unit |
| NAME | The name of the connect (routing) unit |
| OBTYPE | Outflow object type (1=hru;2=hru_lte,3=subbasin;5=aquifer;6=channel; 11=export coefficients; 12=delivery ratios; outlet=15) |
| OBTYPENO | Number of HRU_LTE's or 1 st HRU lte command. Points to the exco_connect.dat object. |
| FRAC | Fraction of element in the subbasin (expansion factor -1.0 = 100%) |
| IDR | Delivery ratio through the aquifer. The subsurface flow that is delivered through the aquifer. Points to del_ratio.dat file. |

ROUT_UNIT.RTU

Below is a sample ROUT_UNIT.RTU file:

| rout_unit.rtu | | | | | |
|---------------|----------|------------|---------|---------|-------|
| RTU_NUMB | RTU_NAME | RTU_DEFINE | ELEM_DR | SUBTOPO | FIELD |
| 1 | sub1 | sub1 | null | top1 | fld1 |
| 2 | sub2 | sub2 | null | top2 | fld2 |
| 3 | sub3 | sub3 | null | top3 | fld3 |
| 4 | sub4 | sub4 | null | top4 | fld4 |
| 5 | sub5 | sub5 | null | top5 | fld5 |
| 6 | sub6 | sub6 | null | top6 | fld6 |
| 7 | sub7 | sub7 | null | top7 | fld7 |

| Variable name | Definition |
|---------------|-------------------------------------|
| TITLE | The title of the rout_unit.rtu file |
| HEADER | Headers for the rout_unit.rtu file. |
| NUMB | Number of the subbasin |
| NAME | The name of the parm unit |
| RTU_DEFINE | Points to define.sub |
| ELEM_DR | Delivery ratio definition |
| SUBTOOP | Topography link |
| FIELD | Field database definition |

ROUT_UNIT.DR

Below is a partial sample ROUT_UNIT.DR file:

| rout_unit.dr | | | | | | | | | | | | | | | | | |
|--------------|-----|------|------|-----|------|------|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|------|
| flo | sed | orgn | sedp | no3 | solp | chla | nh3 | no2 | cbod | dox | san | sil | cla | sag | lag | grv | temp |
| 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 3 | 0 | 0.1 | 0.2 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 3 | 0 | 0.1 | 0.2 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Variable name | Definition |
|---------------|--|
| TITLE | The title of the rout_unit.dr file |
| HEADER | Headers for the rout_unit.dr file. |
| FLO | Volume of water (m ³) |
| SED | sediment (metric tons) |
| ORGN | Organic N (kg N) |
| SEDP | Organic P (kg P) |
| NO3 | NO3-N (kg N) |
| SOLP | Mineral (soluble P) (kg P) |
| CHLA | Chlorophyll-a (kg) |
| NH3 | NH3 (kg N) |
| NO2 | NO2 (kg N) |
| CBOD | Carbonaceous biological oxygen demand (kg) |
| DOX | Dissolved oxygen (kg) |
| SAN | Detached sand (tons) |
| SIL | Detached silt (tons) |
| CLA | Detached clay (tons) |
| SAG | Detached small ag (tons) |

| | |
|------|--------------------------|
| LAG | Detached large ag (tons) |
| GRV | gravel (tons) |
| TEMP | Temperature (deg c) |

HRU – HRU's are now defined by weather, topography, soil, landuse, operational management, potholes, subsurface drainage, structural operations, septic systems, plant community, initial soil chemistry, pesticides, bacteria, impoundments, snow and atmospheric deposition. Each HRU points to objects in each of the associated data files. HRU's consist of plants and soils on the landscape and now are not associated with aquifers and ponds and wetlands. HRUs are defined as contiguous areas (ie fields or grid cells) and a delivery from edge-of-field to subbasin outlet is computed in the subbasin module. This is not necessary when landscape units or grid cells are used. Several inputs for each HRU are required in addition to pointing to data files, including drainage area. These variables may be moved to a calibration file.

HRU-DATA.HRU

Below is a sample HRU-DATA.HRU file:

| hru-data.hru: | | | | | | | | | | |
|---------------|------------|----------|------------|-------|--------------|----------------|-----------|---------|-------|-----------|
| NUMB | NAME | TOPO | HYD | SOIL | LAND_USE_MGT | SOIL_NUTR_INIT | SURF_STOR | SNOW | FIELD | SCHED_UPD |
| 1 | hru0010104 | hru00101 | hru0010104 | IN025 | agriculture | low_init | null | snow001 | null | null |
| 2 | hru0010104 | hru00101 | hru0010104 | IN025 | agriculture | no_init | null | snow001 | null | null |

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.

Optional.

HEADER

Headers for the hru-data.hru file.

NUMB

HRU Number

NAME

Name of the HRU

TOPO

Topographic data (points to topography.hyd)

HYD

Hydrologic data (points to hydrology.hyd)

SOIL

Soil name (points to soils.sol)

LAND_USE_MGT

Landuse database name (points to landuse.lum)

SOIL_NUTR_INIT

Initial soil chemical properties name (points to nutrients.sol)

SURF_STOR

Pothole database name (points to NAME column in WETLAND.WET file)

SNOW

Snow database name (points to snow.sno)

FIELD

Field database name (points to field.fld)

HRU-LTE.HRU

Below is a sample HRU-LTE.HRU file:

| hru-lte.hru | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------|----------|--------|-----|------|---------|---------|--------|----------|------|-------|-------|--------|-------|-----|------|--------|--------|------|-------|-------|----------|--------|--------|--------|------|-----|-------|--------|-------|-------|-------|--------|
| NUMB | NAME | DAKM2 | CN2 | TC | SOILDEP | DEP_IMP | SLOPE | SLOPELEN | ETCO | SY | ABF | REVAPC | PERCC | SW | GW | GWFLOW | GWDEEP | SNOW | XLAT | ITEXT | TROPICAL | IGROW1 | IGROW2 | IPLANT | IPET | IRR | IRRSC | TDRAIN | USLEK | USLEC | USLEP | USLELS |
| 1 | N6289890 | 36.741 | 79 | 1200 | 760 | 6000 | 0.063 | 75 | 1 | 0.003 | 0.048 | 0.02 | 0.05 | 0.8 | 1000 | 0.1 | 1000 | 0 | 36.96 | 4 | 0 | 60 | 201 | mge | 2 | 0 | 2 | 0 | 0.29 | 0.003 | 1 | 1.18 |
| 2 | N6289890 | 18.717 | 70 | 1200 | 760 | 6000 | 0.0824 | 45 | 1 | 0.003 | 0.048 | 0.02 | 0.05 | 0.8 | 1000 | 0.1 | 1000 | 0 | 36.96 | 4 | 0 | 60 | 201 | frse | 2 | 0 | 2 | 0 | 0.29 | 0.001 | 1 | 1.74 |
| 3 | N6289890 | 11.785 | 74 | 1200 | 760 | 6000 | 0.0482 | 75 | 1 | 0.003 | 0.048 | 0.02 | 0.05 | 0.8 | 1000 | 0.1 | 1000 | 0 | 36.96 | 4 | 0 | 60 | 201 | rnge | 2 | 0 | 2 | 0 | 0.29 | 0.003 | 1 | 0.942 |
| 4 | N6289890 | 1.386 | 92 | 1200 | 760 | 6000 | 0.0114 | 90 | 1 | 0.003 | 0.048 | 0.02 | 0.05 | 0.8 | 1000 | 0.1 | 1000 | 0 | 36.96 | 4 | 0 | 60 | 201 | watr | 2 | 0 | 2 | 0 | 0.29 | 0 | 1 | 0.184 |
| 5 | N6289900 | 45.296 | 79 | 1200 | 760 | 6000 | 0.0549 | 75 | 1 | 0.003 | 0.048 | 0.02 | 0.05 | 0.8 | 1000 | 0.1 | 1000 | 0 | 36.96 | 4 | 0 | 60 | 201 | mge | 2 | 0 | 2 | 0 | 0.29 | 0.003 | 1 | 0.926 |

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.

Optional.

HEADER

Headers for the hru-lte.hru file.

NUMB

Number

NAME

Name of the SWAT-DEG hru file

DAKM2

Drainage area (km²)

CN2

Condition II curve number

CN3_SWF

Soil water factor for cn3 (used in calibration) 0 =fc; 1=saturation (porosity)

TC

Time of concentration (min)

SOILDEP

Soil profile depth (mm)

SLOPE

Land surface slope (m/m)

SLOPELEN

Land surface slope length (m)

SY

Specific yld of the shallow aquifer

ABF

Alpha factor groundwater

REVAPC

Revap coefficient-amt of et from shallow aquifer

PERCC

Percolation coeff from shallow to deep

SW

Initial soil water (frac of awc) (fraction)

GW

Initial shallow aquifer storage (mm)

GWFLOW

Initial shallow aquifer flow (mm)

GWDEEP

Initial deep aquifer flow (mm)

SNOW

Initial snow water equivalent (mm)

XLAT

Latitude

TEXT

Soil texture (character):

sand; loamy_sand; sandy_loam; loam; silt_loam; silt;
silty_clay; clay_loam; sandy_clay_loam; sandy_clay;
silty_clay; clay;

TROPICAL

Tropics (character):

'non_trop' = non-tropical

'trop' = tropical

| | |
|--------|--|
| IGROW1 | Start of growing season (character – from dtable.dtl file): ‘pl_grow_sum’ ‘pl_end_sum’ ‘pl_grow_win’ ‘pl_end_win’ |
| IGROW2 | End of growing season ‘pl_grow_sum’ ‘pl_end_sum’ ‘pl_grow_win’ ‘pl_end_win’ |
| PLANT | Plant type (as listed in plant.plt) |
| STRESS | Plant stress – pest, root restriction, soil quality, nutrient, (non water, temp) |
| IPET | Potential evapotranspiration (PET) method (character): ‘harg’ = Hargreaves method ‘p_t’ = Priestley-Taylor method 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 import them into SWAT. A discussion of Priestley-Taylor, Penman-Monteith and Hargreaves PET methods is found in Chapter 2:2 of the theoretical documentation. Required. |

IRR

Irrigation code (character):

(See WATER_ALLOCATION below)

‘no_irr’ = no irrigation

‘irr’ = irrigation

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

divert water from unlimited source outside watershed

IRRSRC

Irrigation source (character):

‘outside_bsn’ = outside basin

‘shal_aqu’ = shallow aquifer

‘deep_aqu’ = deep aquifer

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

| | |
|--------------|--|
| | <p>The definition of this variable depends on the setting of IRR.</p> <p>IRR = 1: IRRSRC is the number of the reach that water is removed from.</p> <p>IRR = 2: IRRSRC is the number of the reservoir that water is removed from.</p> <p>IRR = 3 or 4: IRRSRC is the number of the subbasin that water is removed from.</p> <p>IRR = 0 or 5: this variable is not used.</p> <p>Required if $1 \leq \text{IRR} \leq 4$</p> |
| TDRAIN | Design subsurface tile drain time (hr) |
| USLEK | <p>USLE equation soil erodibility (K) factor (units: 0.013 (metric ton m² hr)/(m³-metric ton cm)).</p> <p>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</p> |
| USLEK, cont. | <p>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).</p> <p>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.</p> <p>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.</p> |
| USLEK, cont. | $K_{USLE} = \frac{0.00021 \cdot M^{1.14} \cdot (12 - OM) + 3.25 \cdot (c_{soilstr} - 2) + 2.5 \cdot (c_{perm} - 3)}{100}$ |

USLEK, cont.

where KUSLE is the soil erodibility factor, M is the particle-size parameter, OM is the percent organic matter (%), csoilstr is the soil structure code used in soil classification, and cperm is the profile permeability class.

The particle-size parameter, M, is calculated

$$M = (m_{silt} + m_{vfs}) \cdot (100 - m_c)$$

where msilt is the percent silt content (0.002-0.05 mm diameter particles), mvfs is the percent very fine sand content (0.05-0.10 mm diameter particles), and mc 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 (%).

USLEK, cont.

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.

Angular Blocky: bounded by planes intersecting at relatively sharp angles

Subangular Blocky: having mixed rounded and plane faces with vertices mostly rounded

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 broken 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

-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.

USLEK, cont.

Definition

Table 22-2: Size classes of soil structure

| Size Classes | Shape of structure | | | |
|--------------|--------------------|------------------------|----------|----------|
| | 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 |

USLEK, cont.

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

- | | |
|---|-------------------------------------|
| 1 | very fine granular |
| 2 | fine granular |
| 3 | medium or coarse granular |
| 4 | blocky, platy, prismatic 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 reduces soil erodibility for soils with extremely high sand contents.

The factors are calculated:

$$f_{csand} = \left(0.2 + 0.3 \cdot \exp \left[-0.256 \cdot m_s \cdot \left(1 - \frac{m_{silt}}{100} \right) \right] \right)$$

$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}} \right)^{0.3}$$

USLEK, cont.

USLEK, cont.

$$f_{orgc} = \left(1 - \frac{0.0256 \cdot orgC}{orgC + \exp[3.72 - 2.95 \cdot orgC]} \right)$$

$$f_{hisand} = \left(1 - \frac{0.7 \cdot \left(1 - \frac{m_s}{100} \right)}{\left(1 - \frac{m_s}{100} \right) + \exp[-5.51 - 0.001 \cdot m_{silt} - 0.001 \cdot m_c]} \right)$$

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 (%).

Required.

USLEC

USLE cover factor

USLEP

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.

USLEP, cont.

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

| Land slope (%) | P_{USLE} |
|----------------|------------|
| 1 to 2 | 0.60 |
| 3 to 5 | 0.50 |
| 6 to 8 | 0.50 |
| 9 to 12 | 0.60 |
| 13 to 16 | 0.70 |
| 17 to 20 | 0.80 |
| 21 to 25 | 0.90 |

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.

USLEP, cont.

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 | | |
|----------------|--------------------------------|------|------|
| | A | B | C |
| 1 to 2 | 0.30 | 0.45 | 0.60 |
| 3 to 5 | 0.25 | 0.38 | 0.50 |
| 6 to 8 | 0.25 | 0.38 | 0.50 |
| 9 to 12 | 0.30 | 0.45 | 0.60 |
| 13 to 16 | 0.35 | 0.52 | 0.70 |
| 17 to 20 | 0.40 | 0.60 | 0.80 |
| 21 to 25 | 0.45 | 0.68 | 0.90 |

¹P 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

USLEP, cont.

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.

USLEP, 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.

USLEP, cont.

Table 20-6: P factor values for contour-farmed terraced fields¹

| Land slope (%) | Farm planning | | Con |
|----------------|-------------------------------|--------------------|------------------|
| | Contour P factor ² | Stripcrop P factor | Grac chan sod ou |
| 1 to 2 | 0.60 | 0.30 | 0.1 |
| 3 to 8 | 0.50 | 0.25 | 0.1 |
| 9 to 12 | 0.60 | 0.30 | 0.1 |
| 13 to 16 | 0.70 | 0.35 | 0.1 |
| 17 to 20 | 0.80 | 0.40 | 0.1 |
| 21 to 25 | 0.90 | 0.45 | 0.1 |

¹Slope 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.

USLELS

USLE equation length slope (LS) factor

C:\Data\modular_datasets_rev60.2\documentation\water_allocation.docx

Water Allocation

There are 2 objects needed to model water allocation:

- 1) Water demand objects and
- 2) Water source objects.

There are currently 3 water demand objects:

- 1) HRU
- 2) Channel
- 3) Water rights object

An individual HRU can demand water for irrigation which is set daily. The demand can be set by specific date in the management.sch file or can be automatically triggered by plant stress or soil moisture in a decision table (lum.dtl). The first decision table triggers irrigation demand when plant stress is less the 0.8, applying 25.4mm using a drip system. The source will be set in the irrigation action associated with the appropriate source object. The second table also uses plant stress to trigger demand, however, it specifies an unlimited source which does not require a source object. The third table triggers irrigation demand when soil moisture falls 75mm below field capacity, applying 50mm using a sprinkler system. The final table is similar, except an unlimited source is specified.

| NAME | CONDS | ALTS | ACTS | | | | | | |
|----------------|-------|---------|-----------|----------------|---------|--------|-------|--|----------|
| irr_str8 | 1 | 1 | 1 | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | | ALT1 |
| w_stress | hru | 0 | null | - | 0.8 | | | | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | | OUTCOMES |
| irr_demand | hru | 0 | drip_high | drip | 25.4 | 0 | null | | y |
| | | | | | | | | | |
| NAME | CONDS | ALTS | ACTS | | | | | | |
| irr_str8_unlim | 1 | 1 | 1 | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | | ALT1 |
| w_stress | hru | 0 | null | - | 0.8 | | | | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | | OUTCOMES |
| irr_demand | hru | 0 | drip_high | drip | 25.4 | 0 | unlim | | y |
| | | | | | | | | | |
| NAME | CONDS | ALTS | ACTS | | | | | | |
| irr_sw75 | 2 | 1 | 1 | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | | ALT1 |
| soil_water | hru | 0 | fcap_mm | - | 75 | | | | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | | OUTCOMES |
| irr_demand | hru | 0 | sprinkler | sprinkler_high | 50 | 0 | null | | y |
| | | | | | | | | | |
| NAME | CONDS | ALTS | ACTS | | | | | | |
| irr_sw75_unlim | 2 | 1 | 1 | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | | ALT1 |
| soil_water | hru | 0 | fcap_mm | - | 75 | | | | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | | OUTCOMES |
| irr_demand | hru | 0 | sprinkler | sprinkler_high | 50 | 0 | unlim | | y |

A channel can also be a water demand object that has rights to a minimum flow or a fraction of flow. A water rights object is a collection of demand objects (HRU and channel) and includes priority rights for each object and a ruleset for allocating water within the water rights object.

Water Source Objects

There are 3 water source objects:

- 1) Reservoir
- 2) Aquifer
- 3) Channel

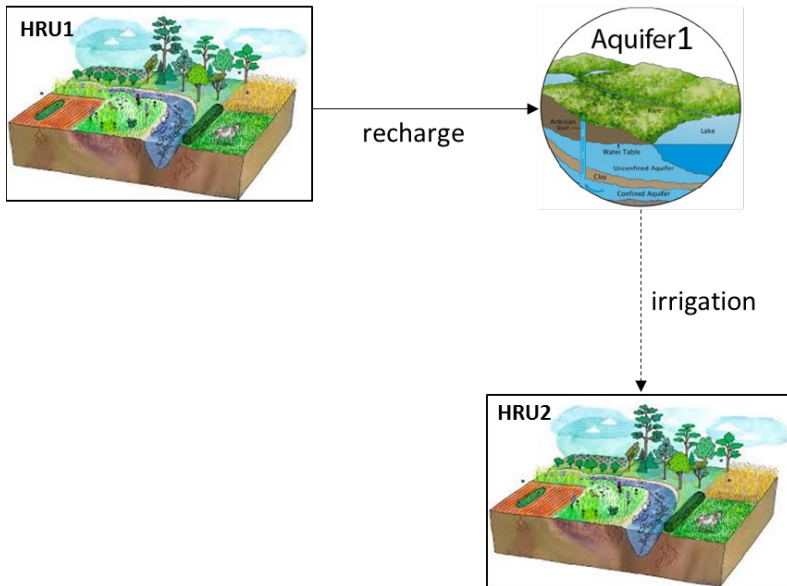
The source objects set supply constraints and have associated decision tables. The decision tables are contained in the connect file for each source object (flo_con.dtl). Actions from these decision tables include irrigating a single HRU, setting the amount of water allocated to a water rights object, and diverting water to multiple outflow channels. Potential outflow channels are identified in the connect file, however, the fractions are set at zero and the fractions are set each day based on the rules included in the decision table.

Water Allocation Examples

1. Water Source Object with one HRU
 1a. Aquifer Source

Two conditions are used to schedule irrigation withdrawal from the aquifer. Condition 1 checks the aquifer level to ensure it is less than 30m from the ground surface. If the conditions are not met, HRU 2 is irrigated from aquifer 1 using the irrigation parameters set by the HRU in the irr.ops file. CONST2 will override the application amount if greater than zero.

Aquifer Only

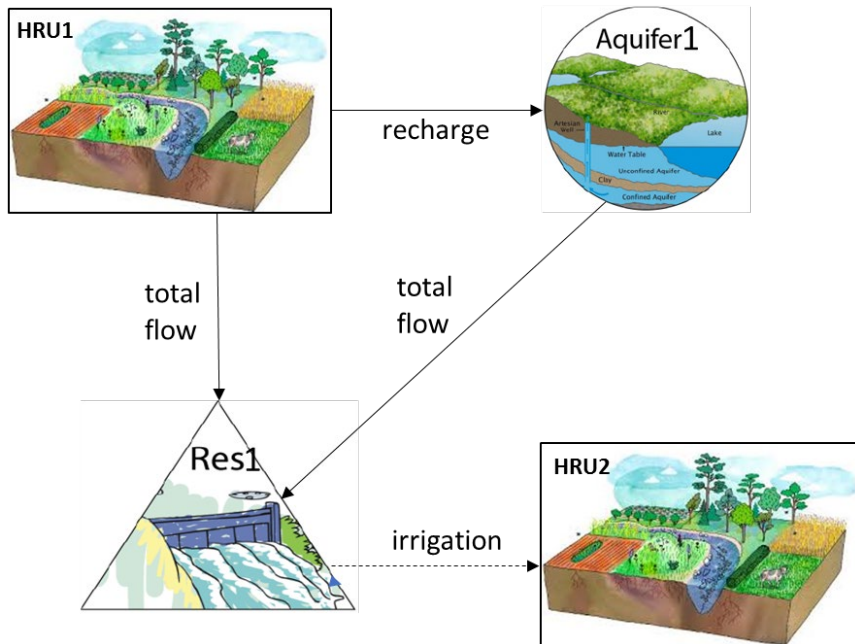


| NAME | CONDS | ALTS | ACTS | | | | | |
|------------|-------|---------|--------------|--------|---------|--------|------|----------|
| aqu_only | 2 | 1 | 1 | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 |
| irr_demand | hru | 2 | null | - | 0 | | | > |
| aqu_dep | aqu | 1 | null | - | 30 | | | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES |
| irrigate | hru | 2 | aquifer_only | null | 0 | 0 | null | y |

1b. Reservoir Source

The decision table using a reservoir as a source object is similar to the aquifer source. The second condition constrains supply when the reservoir drops below 70% (0.7) of the principal spillway volume (pvol).

Reservoir Only

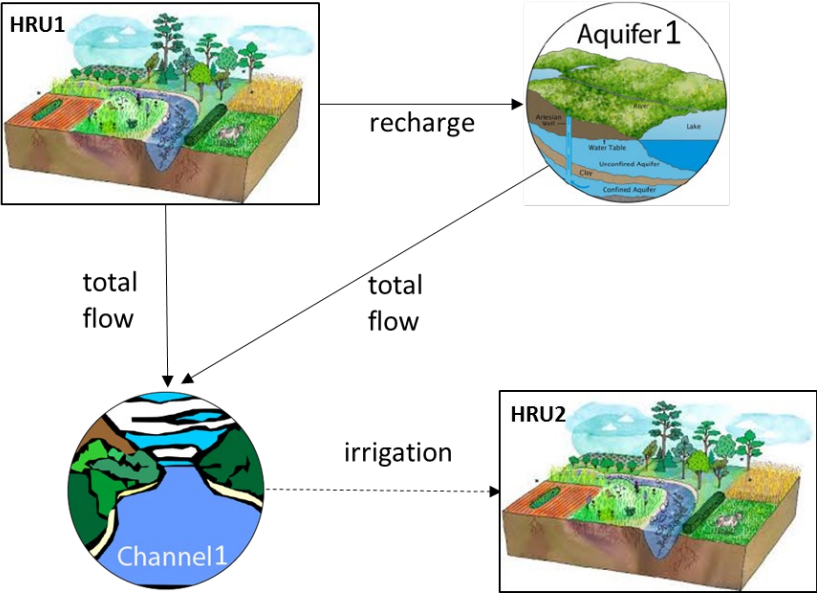


| NAME | CONDS | ALTS | ACTS | | | | | |
|------------|-------|---------|----------------|--------|---------|--------|------|----------|
| res_only | 2 | 1 | 1 | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 |
| irr_demand | hru | 2 | null | - | 0 | | | > |
| vol | res | 1 | pvol | * | 0.7 | | | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES |
| irrigate | hru | 2 | reservoir_only | null | 0 | 0 | null | y |

1c. Channel Source

Again, the decision table using a channel is similar. Flow in the channel must be 0.8 times the demand to trigger irrigation.

Channel Only



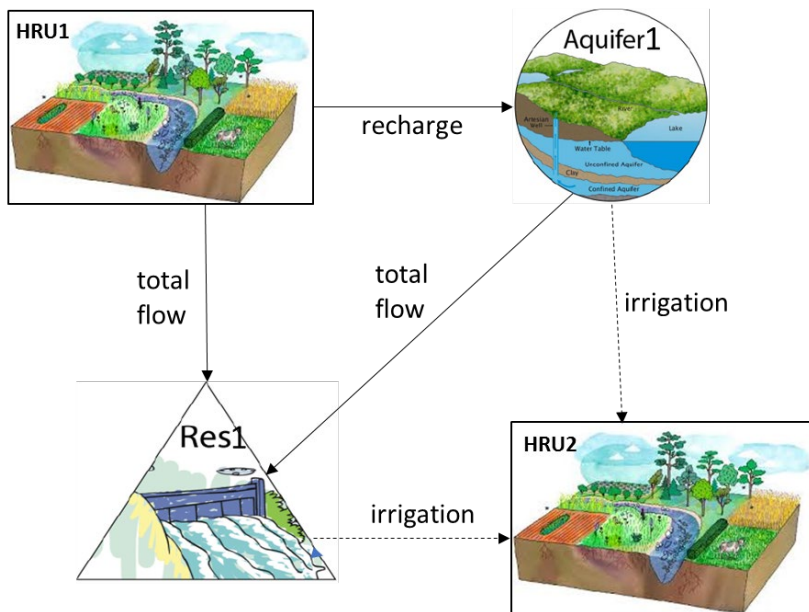
| NAME | CONDS | ALTS | ACTS | | | | | |
|------------|-------|---------|--------------|--------|---------|--------|------|----------|
| cha_only | 2 | 1 | 1 | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 |
| irr_demand | hru | 2 | null | - | 0 | | | > |
| cha_flo | cha | 2 | demand | - | 0.8 | | | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES |
| irrigate | hru | 2 | channel_only | null | 0 | 0 | null | y |
| | | | | | | | | |

2. Water Source Backup

2a. Reservoir with Aquifer Backup

This scenario has 3 conditions and will withdraw water from the reservoir as long as reservoir volumes stay above 0.7 times the principal spillway volume. If reservoir volumes drop below that level, water is withdrawn from aquifer 1 as long as the aquifer level stays within 30m of the surface. If aquifer levels exceed 30m depth and reservoir levels drop below $0.7 \times \text{pvol}$, no irrigation is applied.

Reservoir with Aquifer Backup

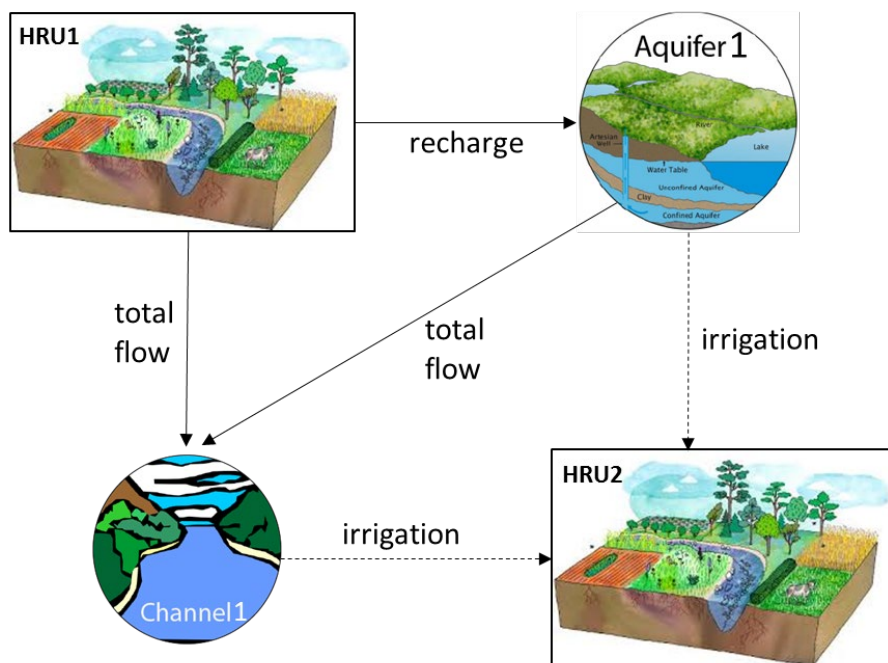


| NAME | CONDS | ALTS | ACTS | | | | | | |
|----------------|-------|---------|-----------|--------|---------|--------|------|----------|------|
| res_aqu_backup | 2 | 2 | 2 | | | | | | |
| VAR | OBJ | OBJ_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 |
| irr_demand | hru | 2 | null | - | 0 | | | > | > |
| vol | res | 1 | pvol | * | 0.7 | | | > | < |
| aqu_dep | cha | 2 | aqu_dep | - | 30 | | | - | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | |
| irrigate | hru | 2 | reservoir | null | 0 | 0 | null | y | n |
| irrigate | hru | 2 | aquifer | null | 0 | 0 | null | n | y |

2b. Channel with Aquifer Backup

If flow in the channel exceeds 0.8 times demand, all flow will be taken from the channel, not to exceed total demand. If the channel flow does not meet the condition, the irrigation water is taken from aquifer1, assuming the aquifer level is within 30m of the surface.

Channel with Aquifer Backup



| NAME | CONDS | ALTS | ACTS | | | | | | |
|----------------|-------|---------|---------|--------|---------|--------|------|----------|------|
| cha_aqu_backup | 3 | 2 | 2 | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 |
| irr_demand | hru | 2 | null | - | 0 | | | > | > |
| cha_flo | cha | 2 | demand | - | 0.8 | | | > | < |
| aqu_dep | cha | 2 | aqu_dep | - | 30 | | | - | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | |
| irrigate | hru | 2 | channel | null | 0 | 0 | null | y | n |
| irrigate | hru | 2 | aquifer | null | 0 | 0 | null | n | y |

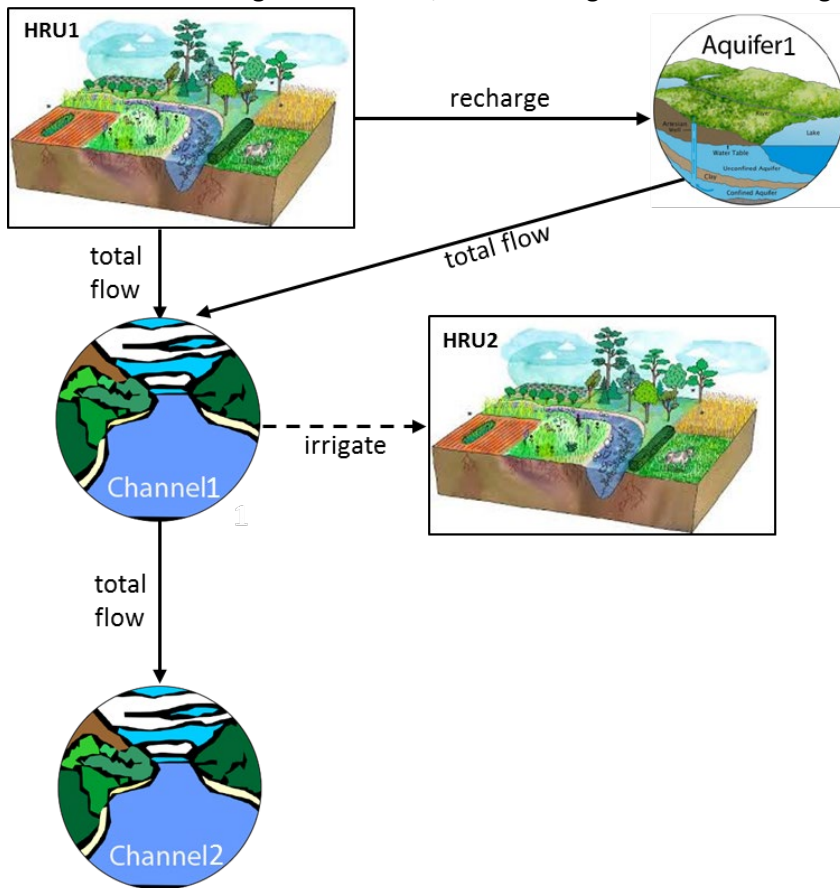
3. Channel Diversions

3a. Divert Direct to HRU for Irrigation and Leave Minimal Flow

Two conditions are established in the decision table. First, irrigation demand from the HRU is determined. The second condition compares flow in channel 1 to minimum flow+irrigation demand.

Alternative 1 – if flow is less than minimum flow required+irrigation demand, the action is to send all flow to the first outflow object in the connect file (channel 1).

Alternative 2 – if there is an irrigation demand and the flow in channel 1 is greater than the minimum flow+irrigation demand, HRU 2 is irrigated and remaining flow (OPTION_rest_flo) is sent to channel 2.

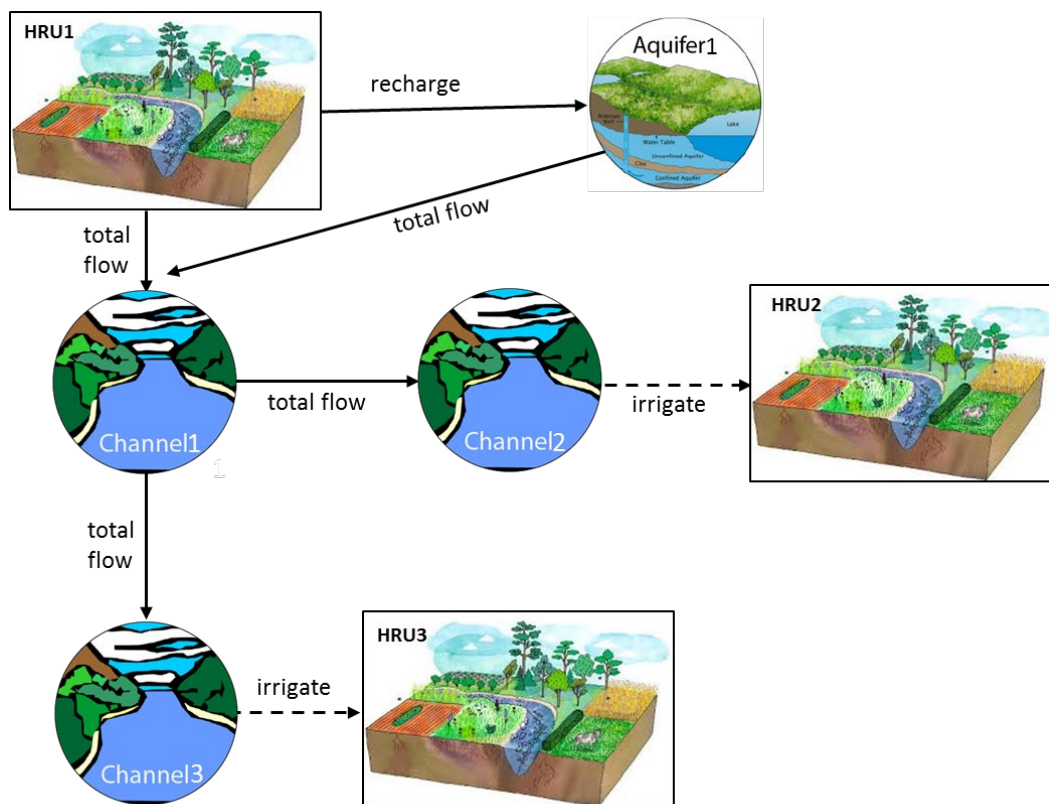


| NAME | CONDS | ALTS | ACTS | | | | | | |
|------------------|-------|---------|----------|----------|---------|--------|------|----------|------|
| ch_diver_min_flo | 3 | 2 | 3 | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 |
| irr_demand | hru | 2 | null | - | 0 | | | - | > |
| cha_flo | cha | 3 | min+dmd | * | 1 | | | < | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | |
| irrigate | hru | 2 | irrigate | null | 0 | 0 | null | n | y |
| flow_control | cha | 1 | all_min | all_flo | 0 | 0 | null | y | n |
| flow_control | cha | 2 | all_min | rest_flo | 0 | 0 | null | n | y |

3b. Partition Flow Between Two Channels Based on Irrigation Demand

The first two conditions establish irrigation demand from HRU's 2 and 3. The third condition compares flow in channel 2 with the total irrigation demand from HRU's 2 and 3. If flow is less than total demand, the action is to partition flow between the first 2 outflow channels in the connect file based on demand. For example, if demand from HRU 2 is 1.0 ha-m and HRU 3 is 0.5 ha-m, then 2/3 of flow is sent to channel 2 and 1/3 to channel 3. If there is no demand from HRU 2, all flow is sent to channel 3. If there is no demand from HRU 3, all flow is sent to channel 2.

3b-e Partition Flow Between Two Channels



| NAME | CONDS | ALTS | ACTS | | | | | | | |
|-----------------|-------|---------|---------|----------|---------|--------|------|----------|------|------|
| ch_div_part_dmd | 3 | 3 | 3 | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 | ALT3 |
| irr_demand | hru | 2 | cha | - | 1 | | | - | > | = |
| irr_demand | hru | 3 | cha | - | 2 | | | - | = | > |
| cha_flo | cha | 1 | dmd_tot | - | 0 | | | < | > | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | |
| flow_control | cha | 2 | channel | part_dmd | 0 | 0 | null | y | n | n |
| flow_control | cha | 2 | channel | all_flo | 0 | 0 | null | n | y | n |
| flow_control | cha | 3 | channel | all_flo | 0 | 0 | null | n | n | y |

3c. Channel with Highest Irrigation Demand Receives All Demand First

The only differences between the Highest Demand and Partitioning in 3.2 is the option for Action 1. In this case, we use the high_dmd, which sends available water to the highest demand first, and sends all remaining water to the object with the lowest demand. If either object has zero demand on a given day, all flow is sent to the other object.

| NAME | CONDS | ALTS | ACTS | | | | | | | |
|-----------------|-------|---------|---------|----------|---------|--------|------|----------|------|------|
| ch_div_high_dmd | 3 | 3 | 3 | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 | ALT3 |
| irr_demand | hru | 2 | cha | - | 1 | | | - | > | = |
| irr_demand | hru | 3 | cha | - | 2 | | | - | = | > |
| cha_flo | cha | 1 | dmd_tot | - | 0 | | | < | > | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | |
| flow_control | cha | 2 | channel | high_dmd | 0 | 0 | null | y | n | n |
| flow_control | cha | 2 | channel | all_flo | 0 | 0 | null | n | y | n |
| flow_control | cha | 3 | channel | all_flo | 0 | 0 | null | n | n | y |

3d. Partition Flow Between Two Channels Based on Water Rights

The part_right action option partitions flow based on the water right for each object. If the water right for HRU 2 is 100 and the water right for HRU 3 is 50, then 66% of the flow would to HRU 2 and the remaining 33% goes to HRU 3.

| NAME | CONDS | ALTS | ACTS | | | | | | | |
|-------------------|-------|---------|---------|------------|---------|--------|------|----------|------|------|
| ch_div_part_right | 3 | 3 | 3 | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 | ALT3 |
| irr_demand | hru | 2 | null | - | 0 | | | > | > | = |
| irr_demand | hru | 3 | null | - | 0 | | | > | = | > |
| cha_flo | cha | 2 | dmd_tot | - | 0 | | | > | > | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | |
| flow_control | cha | 2 | channel | part_right | 0 | 0 | null | y | n | n |
| flow_control | cha | 2 | channel | all_flo | 0 | 0 | null | y | y | n |
| flow_control | cha | 3 | channel | all_flo | 0 | 0 | null | y | n | y |

3e. Channel with Highest Irrigation Demand Receives all Demand First

In this situation, the high-right option is specified in the first action (when both demands are greater than 0.0).

| NAME | CONDS | ALTS | ACTS | | | | | | | |
|-------------------|-------|---------|---------|------------|---------|--------|------|----------|------|------|
| ch_div_high_right | 3 | 3 | 3 | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 | ALT3 |
| irr_demand | hru | 2 | null | - | 0 | | | > | > | = |
| irr_demand | wro | 1 | null | - | 0 | | | > | = | > |
| cha_flo | cha | 2 | dmd_tot | - | 0 | | | > | > | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | |
| flow_control | cha | 2 | channel | high_right | 0 | 0 | null | y | n | n |
| flow_control | cha | 2 | channel | all_flo | 0 | 0 | null | y | y | n |
| flow_control | cha | 3 | channel | all_flo | 0 | 0 | null | y | n | y |

Water Rights Objects

If more than one field or channel are managed together as a demand object, a water right object needs to be defined in water_rights.wro. Each water rights object contains a name, rule type, right and number of objects.

There are currently two rule types:

- 1) high_right_first_serve
- 2) partition_by_right

The high_right_first_serve gives priority to the object with the highest right and works down by right until all water is used. Partition_by_right uses the objects right as a ratio and partitions to each object based on the ration. The right of the water rights object is also input for use in the flo_con.dtl file references in the previous section.

The options for demand type for each element are irr_demand for HRU's and min_flo for channels. Irrigation demand is calculated every day for HRU's while minimum flow and flow fractions are applied every day when the channel is simulated. The minimum flow amount (ha-m) and fraction (0-1) are input as AMOUNT. The water right is also input for each object.

For simple irrigation examples, each HRU can specify an unlimited source in either the operations file (management.sch) or in the irrigation demand decision table (lum.dtl) by inputting unlimited in the FP column.

| | | | | | |
|------------------|------------------------|--------|------------|--------|-------|
| water_rights.wro | | | | | |
| 4 | | | | | |
| | | | | | |
| NAME | RULE_TYP | RIGHT | NUM_OBJS | | |
| Irr_District_1 | high_right_first_serve | 100 | 2 | | |
| NUM | OB_TYP | OB_NUM | DEMAND_TYP | AMOUNT | RIGHT |
| 1 | hru | 2 | irr_demand | 0 | 100 |
| 2 | hru | 3 | irr_demand | 0 | 50 |
| | | | | | |
| NAME | RULE_TYP | RIGHT | NUM_OBJS | | |
| Irr_District_2 | partition_by_right | 75 | 2 | | |
| NUM | OB_TYP | OB_NUM | DEMAND_TYP | AMOUNT | RIGHT |
| 1 | hru | 2 | irr_demand | 0 | 100 |
| 2 | hru | 3 | irr_demand | 0 | 50 |
| | | | | | |
| NAME | RULE_TYP | RIGHT | NUM_OBJS | | |
| min_down_stream | high_right_first_serve | 100 | 1 | | |
| NUM | OB_TYP | OB_NUM | DEMAND_TYP | AMOUNT | RIGHT |
| 1 | cha | 2 | min_flo | 2 | 100 |
| 2 | hru | 2 | irr_demand | 0 | 50 |
| | | | | | |
| NAME | RULE_TYP | RIGHT | NUM_OBJS | | |
| frac_down_stream | partition_by_right | 100 | 1 | | |
| NUM | OB_TYP | OB_NUM | DEMAND_TYP | AMOUNT | RIGHT |
| 1 | cha | 2 | min_frac | 0.2 | 100 |
| 2 | hru | 2 | irr_demand | 0 | 50 |

EXCO – Export Coefficient

EXCO.EXC

The EXCO.EXC file contains the input variables for the nutrients of a channel. Below is a sample EXCO.EXC file:

| | | | | | |
|----------|----------|------------|------------|------------|------------|
| exco.exc | | | | | |
| NAME | OM | PEST | PATH | HMET | SALT |
| exco1 | exco_om1 | exco_pest1 | exco_path1 | exco_hmet1 | exco_salt1 |
| exco2 | exco_om2 | exco_pest2 | exco_path2 | exco_hmet2 | exco_salt2 |

| Variable name | Definition |
|---------------|--|
| TITLE | The title of the exco.exc file |
| HEADER | Headers for the exco.exc file |
| NAME | Name of the export coefficient (points to exco.con file) |
| OM_NAME | Name of the organic matter (points to exco_om.exc file) |
| PEST_NAME | Name of the pesticides (points to exco_pest.exc file) |
| PATH_NAME | Name of the pathogens (points to exco_path.exc file) |
| SALT_NAME | Name of the salt (points to exco_salt.exc file) |

EXCO_OM_EXC

The EXCO_OM_EXC file contains the input variables for the nutrients of a channel. Below is a sample EXCO_OM_EXC file:

| | | | | | | | | | | | | | | | | | | |
|----------|------|-----|------|------|-----|------|------|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|------|
| exco_om | | | | | | | | | | | | | | | | | | |
| | flo | sed | orgn | sedp | no3 | solp | chla | nh3 | no2 | cbod | dox | san | sil | cla | sag | lag | grv | temp |
| exco_om1 | 12.5 | 100 | 90 | 80 | 70 | 60 | 30 | 20 | 10 | 9 | 8 | 2 | 1 | 100 | 90 | 80 | 70 | 60 |
| exco_om2 | 22.5 | 110 | 99 | 88 | 77 | 66 | 33 | 22 | 11 | 19 | 28 | 82 | 91 | 190 | 98 | 87 | 76 | 65 |

| Variable name | Definition |
|---------------|--|
| TITLE | The title of the exco_om.exc file |
| HEADER | Headers for the exco_om.exc file |
| NAME | Name of the organic matter (exco.exc file) |

| | |
|------|--|
| FLO | Volume of water (m ³) |
| SED | sediment (metric tons) |
| ORGN | Organic N (kg N) |
| SEDP | Organic P (kg P) |
| NO3 | NO3-N (kg N) |
| SOLP | Mineral (soluble P) (kg P) |
| CHLA | Chlorophyll-a (kg) |
| NH3 | NH3 (kg N) |
| NO2 | NO2 (kg N) |
| CBOD | Carbonaceous biological oxygen demand (kg) |
| DOX | Dissolved oxygen (kg) |
| SAN | Detached sand (tons) |
| SIL | Detached silt (tons) |
| CLA | Detached clay (tons) |
| SAG | Detached small ag (tons) |
| LAG | Detached large ag (tons) |
| GRV | gravel (tons) |
| TEMP | Temperature (deg c) |

EXCO_PEST.EXC

| exco_pest.exc | | | | | | | | |
|---------------|------------|------------|------------|------------|-----------|-----------|-------------|-------------|
| | aatrex_sol | aatrex_sor | banvel_sol | banvel_sor | prowl_sol | prowl_sor | roundup_sol | roundup_sor |
| exco_pest1 | 12.5 | 100 | 90 | 80 | 70 | 60 | 50 | 40 |
| exco_pest2 | 22.5 | 110 | 99 | 88 | 77 | 66 | 55 | 44 |

The EXCO_PEST.EXC file contains the input variables for the nutrients of a channel. Below is a sample EXCO_PEST.EXC file:

| Variable name | Definition |
|---------------|---------------------------------------|
| TITLE | The title of the exco_pest.exc file |
| HEADER | Headers for the exco_pest.exc file |
| NAME | Name of the pesticide (exco.exc file) |
| EXCO_PEST_SOL | Pesticide soluble constituent mass |
| EXCO_PEST_SOR | Pesticide sorbed constituent mass |

EXCO_PATH.EXC

The EXCO_PATH.EXC file contains the input variables for the nutrients of a channel. Below is a sample EXCO_PATH.EXC file:

| | | | | |
|---------------|------------|------------|------------|------------|
| exco_path.exc | | | | |
| | fecals_sol | fecals_sor | e_coli_sol | e_coli_sor |
| exco_path1 | 12.5 | 100 | 90 | 80 |
| exco_path2 | 22.5 | 110 | 99 | 88 |

| Variable name | Definition |
|---------------|---------------------------------------|
| TITLE | The title of the exco_path.exc file |
| HEADER | Headers for the exco_path.exc file |
| NAME | Name of the pathogens (exco.exc file) |
| EXCO_PATH_SOL | Pathogen soluble constituent mass |
| EXCO_PATH_SOR | Pathogen sorbed constituent mass |

EXCO_HMET.EXC

The EXCO_HMET.EXC file contains the input variables for the nutrients of a channel. Below is a sample EXCO_HMET.EXC file:

| | | |
|---------------|-------------|-------------|
| exco_hmet.exc | | |
| | mercury_sol | mercury_sor |
| exco_hmet1 | 12.5 | 100 |
| exco_hmet2 | 22.5 | 110 |

| Variable name | Definition |
|---------------|--|
| TITLE | The title of the exco_hmet.exc file |
| HEADER | Headers for the exco_hmet.exc file |
| NAME | Name of the heavy metals (exco.exc file) |
| EXCO_HMET_SOL | Heavy metal soluble constituent mass |
| EXCO_HMET_SOR | Heavy metal sorbed constituent mass |

EXCO_SALT.EXC

The EXCO_SALT.EXC file contains the input variables for the nutrients of a channel. Below is a sample EXCO_SALT.EXC file:

| | | | | |
|---------------|------------|------------|---------------|---------------|
| exco_salt.exc | | | | |
| | sodium_sol | sodium_sor | magnesium_sol | magnesium_sor |
| exco_salt1 | 12.5 | 100 | 90 | 80 |
| exco_salt2 | 22.5 | 110 | 99 | 88 |

| Variable name | Definition |
|---------------|-------------------------------------|
| TITLE | The title of the exco_salt.exc file |
| HEADER | Headers for the exco_salt.exc file |
| NAME | Name of salt (exco.exc file) |
| EXCO_HMET_SOL | Salt soluble constituent mass |
| EXCO_HMET_SOR | Salt sorbed constituent mass |

RECALL

The recall data have the option to read measured data in a daily, monthly or yearly timestep described in the recall.rec file.

An option to read constant (average annual) data has been added as an export coefficient. Review section **RECCNST** Example below for examples to set up a reccnst scenario using the recall.rec and export coefficient files.

RECALL.REC

The RECALL.REC file contains the input variables for the nutrients of a channel. Below is a sample RECALL.REC file:

| | | | |
|------------|-------|-----|----------------|
| recall.rec | | | |
| NUMB | NAME | TYP | FILENAME |
| 1 | daily | 1 | recall_day.rec |

| Variable name | Definition |
|---------------|---|
| TITLE | This line is reserved for the recall record title. This line is not processed by the model and may be left blank. |
| HEADER | Headers |
| NUMB | Sequential number of recall |
| NAME | Daily, monthly, annual |
| TYP | 1==daily; 2=monthly; 3=annual; 4=reccnst; |
| FILENAME | Name of recall file to be read (for TYP 1,2,3) (4 TYP name is crosswalked with NAME column in the EXCO.EXC file. |

EXAMPLE RECALL DAY.REC FILE:

| recall_day.rec | | | | | | | | | | | | | | | | | | | | |
|----------------|-------|---------|-----|------|------|-----|------|------|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|------|--|
| IYR | ISTEP | flo | sed | orgn | sedp | no3 | solp | chla | nh3 | no2 | cbod | dox | san | sil | cla | sag | lag | grv | temp | |
| 2006 | 1 | 10167.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 2006 | 2 | 10059.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 2006 | 3 | 9233.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 2006 | 4 | 7760.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

| Variable name | Definition |
|---------------|---|
| TITLE | This line is reserved for the recall daily, monthly or annual title. This line is not processed by the model and may be left blank. |
| NBYR | Number of years of recall data |
| IYR | Current year of input data |
| ISTEP | Current day of input data |
| FLO | Volume of water (m ³) |
| SED | sediment (metric tons) |
| ORGN | Organic N (kg N) |
| SEDP | Organic P (kg P) |
| NO3 | NO3-N (kg N) |
| SOLP | Mineral (soluble P) (kg P) |
| CHLA | Chlorophyll-a (kg) |
| NH3 | NH3 (kg N) |
| NO2 | NO2 (kg N) |
| CBOD | Carbonaceous biological oxygen demand (kg) |
| DOX | Dissolved oxygen (kg) |
| SAN | Detached sand (tons) |
| SIL | Detached silt (tons) |
| CLA | Detached clay (tons) |
| SAG | Detached small ag (tons) |
| LAG | Detached large ag (tons) |
| GRV | gravel (tons) |
| TEMP | Temperature (deg c) |

RECCNST Example

The 'object.cnt' file should contain a RECALL object.

RECALL.REC (NAME cross walked with name in EXCO.EXC file)

| | | | |
|------------|--------|-----|--------------|
| recall.rec | | | |
| NUMB | TNAME | TYP | NAME |
| 1 | aveann | 4 | exco1 |

EXCO.EXC (exco_om1 cross walked with EXCO_OM.EXC)

| | | | | | |
|--------------|-----------------|------|------|------|-------|
| exco.exc | | | | | |
| name | om | pest | path | hmet | salts |
| exco1 | exco_om1 | null | null | null | null |
| exco2 | exco_om2 | null | null | null | null |

EXCO_OM.EXC

| | | | | | | | | | | | | | | | | | | |
|-----------------|------|-----|------|------|-----|------|------|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|------|
| exco_om.exc | | | | | | | | | | | | | | | | | | |
| name | flo | sed | orgn | sedp | no3 | solp | chla | nh3 | no2 | cbod | dox | san | sil | cla | sag | lag | grv | temp |
| exco_om1 | 12.5 | 100 | 90 | 80 | 70 | 60 | 30 | 20 | 10 | 9 | 8 | 2 | 1 | 100 | 90 | 80 | 70 | 60 |
| exco_om2 | 22.5 | 110 | 99 | 88 | 77 | 66 | 33 | 22 | 11 | 19 | 28 | 82 | 91 | 190 | 98 | 87 | 76 | 65 |

DR –Delivery Ratio

DELRATIO.DEL

The DELRATIO.DEL file contains the input variables for the nutrients of a channel. Below is a sample DELRATIO.DEL file:

| | | | | | |
|--------------|-----------|-------------|-------------|-------------|-------------|
| delratio.del | | | | | |
| NAME | OM_FILE | PEST_FILE | PATH_FILE | HMET_FILE | SALTS_FILE |
| dr01 | dr_om.del | dr_pest.del | dr_path.del | dr_hmet.del | dr_salt.del |

Variable name

Definition

TITLE

The title of the delratio.del file

HEADER

Headers for the delratio.del file

NAME

Name of the export coefficient (points to delratio.con)

OM_NAME

Name of the organic matter (points to dr_om.del)

PEST_NAME

Name of the pesticides (points to dr_pest.del)

PATH_NAME

Name of the pathogens (points to dr_path.del)

SALT_NAME

Name of the salt (points to dr_salt.del)

DR_OM.DEL

The DR_OM.DEL file contains the input variables for the nutrients of a channel. Below is a sample DR_OM.DEL file:

| dr_om.del | | | | | | | | | | | | | | | | | | |
|-----------|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | flo | sed | orgn | sedp | no3 | solp | chla | nh3 | no2 | cbod | dox | san | sil | cla | sag | lag | grv | temp |
| dr_om1 | 0.125 | 0.9 | 0.9 | 0.8 | 0.7 | 0.6 | 0.3 | 0.2 | 0.1 | 0.9 | 0.8 | 0.2 | 1 | 0.1 | 0.9 | 0.8 | 0.7 | 0.6 |
| dr_om2 | 0.225 | 0.11 | 0.99 | 0.88 | 0.77 | 0.66 | 0.33 | 0.22 | 0.11 | 0.19 | 0.28 | 0.82 | 0.91 | 0.19 | 0.98 | 0.87 | 0.76 | 0.65 |

| Variable name | Definition |
|---------------|--|
| TITLE | The title of the dr_om.del file |
| HEADER | Headers for the dr_om.del file |
| NAME | Name of the organic matter (delratio.del file) |
| FLO | Volume of water (m ³) |
| SED | sediment (metric tons) |
| ORGN | Organic N (kg N) |
| SEDP | Organic P (kg P) |
| NO3 | NO3-N (kg N) |
| SOLP | Mineral (soluble P) (kg P) |
| CHLA | Chlorophyll-a (kg) |
| NH3 | NH3 (kg N) |
| NO2 | NO2 (kg N) |
| CBOD | Carbonaceous biological oxygen demand (kg) |
| DOX | Dissolved oxygen (kg) |
| SAN | Detached sand (tons) |
| SIL | Detached silt (tons) |
| CLA | Detached clay (tons) |
| SAG | Detached small ag (tons) |
| LAG | Detached large ag (tons) |
| GRV | gravel (tons) |
| TEMP | Temperature (deg c) |

DR_PEST.DEL

The DR_PEST.DEL file contains the input variables for the nutrients of a channel. Below is a sample DR_PEST.DEL file:

| | | | | | | | | |
|-------------|------------|------------|------------|------------|-----------|-----------|-------------|-------------|
| dr_pest.del | | | | | | | | |
| | aatrex_sol | aatrex_sor | banvel_sol | banvel_sor | prowl_sol | prowl_sor | roundup_sol | roundup_sor |
| dr_pest1 | 0.125 | 0.1 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 |
| dr_pest2 | 0.225 | 0.11 | 0.99 | 0.88 | 0.77 | 0.66 | 0.55 | 0.44 |

The DR_PEST.DEL file contains the input variables for the nutrients of a channel. Below is a sample partial DR_PEST_DEL file:

| Variable name | Definition |
|---------------|------------------------------------|
| TITLE | The title of the DR_PEST.DEL file |
| HEADER | Headers for the DR_PEST.DEL file |
| NAME | Name of the pesticide |
| DR_PEST_SOL | Pesticide soluble constituent mass |
| DR_PEST_SOR | Pesticide sorbed constituent mass |

DR_PATH.DEL

The DR_PATH.DEL file contains the input variables for the nutrients of a channel. Below is a sample DR_PATH.DEL file:

| | | | | |
|-------------|------------|------------|------------|------------|
| dr_path.del | | | | |
| | fecals_sol | fecals_sor | e_coli_sol | e_coli_sor |
| dr_path1 | 0.125 | 0.1 | 0.9 | 0.8 |
| dr_path2 | 0.225 | 0.11 | 0.99 | 0.88 |

| Variable name | Definition |
|---------------|---|
| TITLE | The title of the dr_path.del file |
| HEADER | Headers for the dr_path.del file |
| NAME | Name of the pathogens (delratio.del file) |
| DR_PATH_SOL | Pathogen soluble constituent mass |
| DR_PATH_SOR | Pathogen sorbed constituent mass |

DR_HMET.DEL

The DR_HMET.DEL file contains the input variables for the nutrients of a channel. Below is a sample DR_HMET.DEL file:

| | | |
|-------------|-------------|-------------|
| dr_hmet.del | | |
| | mercury_sol | mercury_sor |
| dr_hmet1 | 0.125 | 0.1 |
| dr_hmet2 | 0.225 | 0.11 |

| Variable name | Definition |
|---------------|--|
| TITLE | The title of the dr_hmet.exc file |
| HEADER | Headers for the dr_hmet.exc file |
| NAME | Name of the heavy metals (delratio.del file) |
| DR_HMET_SOL | Heavy metal soluble constituent mass |
| DR_HMET_SOR | Heavy metal sorbed constituent mass |

DR_SALT.DEL

The DR_SALT.DEL file contains the input variables for the nutrients of a channel. Below is a sample EXCO_DR_SALT.DEL file:

| | | | | |
|-------------|------------|------------|---------------|---------------|
| dr_salt.del | | | | |
| | sodium_sol | sodium_sor | magnesium_sol | magnesium_sor |
| dr_salt1 | 0.125 | 0.1 | 0.9 | 0.8 |
| dr_salt2 | 0.225 | 0.11 | 0.99 | 0.88 |

| Variable name | Definition |
|---------------|-----------------------------------|
| TITLE | The title of the dr_salt.del file |
| HEADER | Headers for the dr_salt.del file |
| NAME | Name of salt (delratio.del file) |
| DR_HMET_SOL | Salt soluble constituent mass |
| DR_HMET_SOR | Salt sorbed constituent mass |

AQUIFER

INITIAL.AQU

| | | | | | |
|-------------|-----------|------------|-----------|--------------|-------|
| initial.aqu | | | | | |
| NAME | ORG-MIN | PESTICIDES | PATHOGENS | HEAVY_METALS | SALTS |
| low_init | low_init | no_ini | no_ini | null | null |
| high_init | high_init | low_ini | low_ini | null | null |

| Variable name | Definition |
|---------------|--|
| TITLE | Title of the initial aquifer file |
| HEADER | The header information for the initial aquifer file |
| NAME | Name of the initial aquifer |
| ORG-MIN | Organic mineral in aquifer (points to OM_WATER.INI file) |
| PESTICIDES | Pesticides initialization in aquifer (points to PEST_WATER.INI file) |
| PATHOGENS | Pathogens initialization in aquifer (points to PATH_WATER.INI file) |
| HEAVY METALS | Heavy metals initialization in aquifer (points to HMET_WATER.INI file) |
| SALTS | Salts initialization in aquifer (points to SALT_WATER.INI file) |

AQUIFER.AQU

Below is a sample AQUIFER.AQU file:

| | | | | | | | | | | | | | | | | | |
|-------------|------|----------|---------|---------|--------|-------|-------|--------|----------|--------|----------|-------|---------|----------|---------|---------|-----------|
| aquifer.aqu | | | | | | | | | | | | | | | | | |
| id | name | aqu_init | aqu_flo | dep_bot | dep_wt | no3_n | sol_p | carbon | flo_dist | bf_max | alpha_bf | revap | rchg_dp | spec_yld | hl_no3n | flo_min | revap_min |
| 1 | aqu1 | low_init | 0.05 | 100 | 3 | 0 | 0 | 0.5 | 50 | 1 | 1 | 0.02 | 0.06 | 0.05 | 0 | 5 | 3 |

| 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. Optional. |
| HEADER | Headings for the aquifer.aqu file. |
| NUMB | Number |
| AQUNM | Name |

| | |
|----------|---|
| FLO | Initial depth of water in the shallow aquifer (mm H ₂ O). |
| | We recommend using a 1 year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for FLO is not that important. |
| DEP_BOT | Depth to the bottom - mid-slope surface to bottom of aquifer (m) |
| DEP_WT | Depth – mid-slope surface to water water table (initial) (m). |
| NO3 | Initial concentration of nitrate in shallow aquifer. (mg N/L or ppm). Nitrate levels in the shallow aquifer are modeled, allowing for variation in nitrate concentration and groundwater loadings of nitrate contributed to streamflow in the subbasin. Optional. |
| SOL_P | Concentration of soluble phosphorus in groundwater contribution to streamflow from subbasin (mg P/L or ppm). This is a fixed concentration used throughout the entire period of simulation. Optional. |
| CARBON | Carbon default = 0.5 Optional. |
| FLO_DIST | FLO_DIST default =50.0 Optional. |
| BF_MAX | Baseflow rate when the entire area is contributing to baseflow (mm) default = 1.00 |

ALPHA_BF

Baseflow alpha factor (1/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.

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 factor 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.

Required.

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 REVAP approaches 0, movement of water from the shallow aquifer to the root zone is restricted. As REVAP approaches 1, the rate of transfer from the shallow aquifer to the root zone approaches the rate of potential evapotranspiration. The value for REVAP should be between 0.02 and 0.20.

This variable, along with REVAPMN, is the reason a different groundwater file is created for each HRU rather than each subbasin.

Required.

RCHG_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.

Required.

SPEC_YLD

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

HL_NO3

Half-life of nitrate in the shallow aquifer (days).

Nitrate in the shallow aquifer may be removed by uptake by bacteria present in the aquifer or by chemical conversion to other compounds in regions of the aquifer that are depleted in oxygen (reduced environment). The half-life, as for half-life values reported for pesticides, is the time period required for the concentration of nitrate to drop to one-half its original value. The reduction is a net reduction by all processes occurring in the shallow aquifer.

Optional.

FLO_MIN

Minimum aquifer storage to allow return flow [m]

REVAP_MIN

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 is allowed only if the volume of water in the shallow aquifer is equal to or greater than REVAPMN.

This variable, along with GW_REVAP, is the reason a different groundwater file is created for each HRU rather than each subbasin.

Required.

HERD –

ANIMAL.HRD

Below is a sample ANIMAL.HRD FILE:

HERD.HRD

Below is a sample HERD.HRD FILE:

RANCH.HRD

Below is a sample RANCH.HRD FILE:

WATER RIGHTS –

DEFINE.WRO

Below is a sample DEFINE.WRO FILE:

ELEMENT.WRO

Below is a sample ELEMENT.WRO FILE

WATER_RIGHTS.WRO

Below is a sample WATER_RIGHTS.WRO FILE:

LINK –

CHAN-SURF.LIN

Below is a sample CHAN_SURF.LIN FILE:

| | | | | | | | |
|------------|-------|------|-------|----------|-------|----------|--|
| chan-surf. | | | | | | | |
| 1 | | | | | | | |
| NUMB | NAME | NSPU | OBTYP | OBTYP_NO | OBTYP | OBTYP_NO | |
| 1 | chan1 | 1 | hru | 1 | | | |
| 2 | chan2 | 1 | sub | 1 | | | |
| 8 | chan3 | 2 | sub | 3 | sub | 4 | |
| 9 | chan4 | 2 | hru | 5 | hru | 6 | |

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

| | |
|-------|--|
| TITLE | The title line for the chan-surf.lin file (optional) |
|-------|--|

| | |
|---------|---------------------------------------|
| MCHA_SP | Total number of channel links in file |
|---------|---------------------------------------|

| | |
|--------|-------------------------------------|
| HEADER | Headings for the chan-surf.lin file |
|--------|-------------------------------------|

| | |
|------|--|
| NUMB | The sequential number of the channel links |
|------|--|

| | |
|------|-------------------------------------|
| NAME | The unique name of the channel link |
|------|-------------------------------------|

| | |
|---------|--|
| NUM | The total objects following |
| OBTYP | The object type (1=hru; 2=hru_lte; 11=export coeff; |
| OBTYPNO | Number of hru_lte's or 1 st hru_lte command |

CHAN-AQU.LIN

Below is a sample CHAN-AQU.LIN FILE:

| | | | | | |
|--------------|-------|------|------|------|------|
| CHAN-AQU.LIN | | | | | |
| 4 | | | | | |
| NUMB | NAME | NSPU | AQU1 | AQU2 | AQU3 |
| 1 | CHAN1 | 3 | 1 | 2 | 3 |
| 2 | CHAN2 | 1 | 4 | | |
| 8 | CHAN3 | 2 | 5 | 6 | |
| 9 | CHAN4 | 2 | 8 | 9 | |

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

| | |
|---------|---|
| TITLE | The title line for the chan-aqu.lin file (may be blank) |
| MCHA_SP | Total number of channel aquifer links in file |
| NUMB | The sequential number of the channel aquifer links |
| NAME | The unique name of the channel link |
| NUM | The total objects following |
| AQU_NO | The aquifer number |

HYDROLOGY –**HYDROLOGY.HYD**

Data contained in the hydrology.dat data file can be grouped into the following categories: topographic characteristics, water flow, erosion, land cover, and depressional storage areas.

Below is a partial sample HYDROLOGY.HYD FILE:

| | | | | | | | | | | | | | | | |
|---------------|----------|---------|-------|------|------|--------|--------|---------|--------|-------|----------|----------|----------|--------|--|
| hydrology.hyd | | | | | | | | | | | | | | | |
| NAME | LAT_TIME | LAT_SED | CANMX | ESCO | EPCO | ERORGN | ERORGP | CN3_SWF | BIOMIX | PERCO | LAT_ORGN | LAT_ORGP | HARG_PET | CNCOEF | |
| hru0010104 | 0 | 0 | 0 | 0.95 | 1 | 0 | 0 | 0 | 0.2 | 1 | 0 | 0 | 0.0023 | 0.3 | |
| HRU0010105 | 0 | 0 | 0 | 0.95 | 1 | 0 | 0 | 0 | 0.2 | 1 | 0 | 0 | 0.0023 | 0.3 | |
| HRU0010108 | 0 | 0 | 0 | 0.95 | 1 | 0 | 0 | 0 | 0.2 | 1 | 0 | 0 | 0.0023 | 0.3 | |
| HRU0010109 | 0 | 0 | 0 | 0.95 | 1 | 0 | 0 | 0.5 | 0.2 | 1 | 0 | 0 | 0.0023 | 0.3 | |
| HRU0010110 | 0 | 0 | 0 | 0.95 | 1 | 0 | 0 | 0.5 | 0.2 | 1 | 0 | 0 | 0.0023 | 0.3 | |
| HRU0010112 | 0 | 0 | 0 | 0.95 | 1 | 0 | 0 | 0.5 | 0.2 | 1 | 0 | 0 | 0.0023 | 0.3 | |

| Variable name | Definition |
|---------------|------------|
| NAME | Name |

| | |
|-----------|---|
| TITLE | <p>The first line is reserved for user comments. This line is not processed by the model and may be left blank.</p> <p>Optional.</p> |
| HEADER | Headers for the nutrients.res file. |
| NAME | Name |
| LAT_TTIME | <p>Lateral flow travel time (days).</p> <p>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.</p> <p>Required.</p> |
| LAT_SED | <p>Sediment concentration in lateral and groundwater flow (mg/L).</p> <p>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.</p> <p>Optional.</p> |
| CANMX | <p>Maximum canopy storage (mm H₂O).</p> <p>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 of the density of plant cover and the morphology of the plant species.</p> <p>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 2:1). When the Green and Ampt infiltration equation is used to calculate infiltration, the interception of rainfall by the canopy must be calculated separately.</p> <p>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 H₂O).</p> <p>Required.</p> |

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.

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, see Chapter 4).

Required.

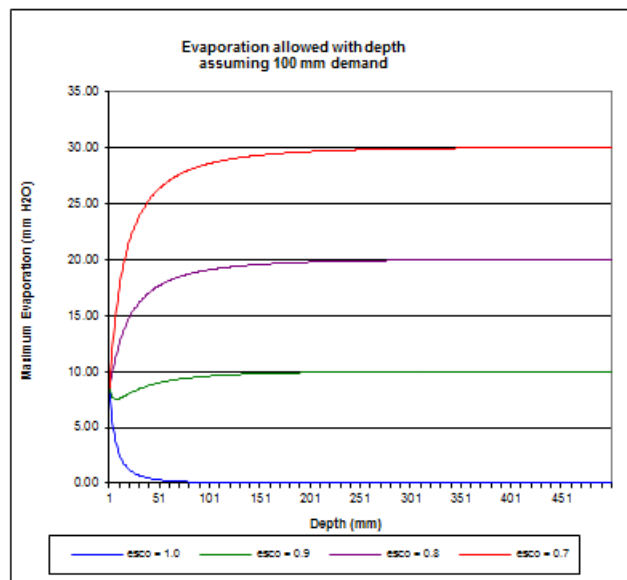


Figure 19-1: Soil evaporative demand distribution with depth

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, see Chapter 4).

Required.

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.

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.

Required.

| | |
|----------|---|
| ERORGP | <p>Phosphorus enrichment ratio for loading with sediment.</p> <p>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.</p> <p>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.</p> |
| CN3_SWF | <p>Required.</p> <p>Pothole evaporation coefficient</p> |
| BIOMIX | <p>Biological mixing efficiency.</p> <p>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).</p> <p>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.</p> <p>If no value for BIOMIX is entered, the model will set BIOMIX = 0.20.</p> <p>Optional.</p> |
| PERCO | <p>Percolation coefficient - adjusts soil moisture for perc to occur (1.0 = fc)</p> |
| LAT_ORGP | <p>Organic P in the base flow (mg/L) (range 0.0 – 200.0) default = 0.0</p> <p>Optional.</p> |
| HARG_PET | <p>Coefficient related to radiation used in Hargreaves equation</p> |

CNCOEF

Plant ET curve number coefficient.

ET weighting coefficient used to calculate the retention coefficient for daily curve number calculations dependent on plant evapotranspiration.

This value can vary between 0.5 and 2.0. If no value is entered for CNCOEF, the model will set CNCOEF = 1.0.

Required if ICN = 1.

TOPOGRAPHY.HYD

Data contained in the topo.dat data file can be grouped into the following categories: topographic characteristics, water flow, erosion, land cover, and depressional storage areas.

Below is a sample TOPOGRAPHY.HYD FILE:

| | | | | | |
|----------------|-------|---------|---------|------------|--------|
| topography.hyd | | | | | |
| HRU | SLP | SLP_LEN | LAT_LEN | DIS_STREAM | DEP_CO |
| top1 | 0.047 | 50 | 50 | 100 | 1 |
| top2 | 0.035 | 50 | 50 | 100 | 1 |
| top3 | 0.148 | 50 | 50 | 100 | 1 |
| top4 | 0.033 | 50 | 50 | 100 | 1 |
| top5 | 0.118 | 50 | 50 | 100 | 1 |
| top6 | 0.064 | 50 | 50 | 100 | 1 |

| 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. Optional. |
| HEADER | Headers for the topography.hyd file. |
| NAME | Sequential number of topo in file |
| SLOPE | Average slope steepness in HRU (m/m) |
| SLOPE_LEN | Average slope length for erosion (m) |
| LAT_LEN | Slope length for lateral subsurface flow (m) |
| DIS_STREAM | Average distance to stream (m) |
| DEP_CO | Deposition coefficient |

FIELD.FLD

Below is a sample FIELD.FLD FILE:

| | | | |
|-----------|--------|-------|-------|
| field.fld | | | |
| NAME | LENGTH | WIDTH | ANGLE |
| fld1 | 600 | 20 | 30 |
| fld2 | 600 | 20 | 30 |
| fld3 | 600 | 20 | 30 |
| fld4 | 600 | 20 | 30 |
| fld5 | 600 | 20 | 30 |
| fld6 | 600 | 20 | 30 |

| 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. Optional. |
| HEADER | Headers for the field.fld file. |
| NAME | Name of the field |
| LENGTH | Field length for wind erosion (m) |
| WID | Field width for wind erosion (m) |
| ANG | Field angle for wind erosion (m) |

STRUCTURAL –

TILEDRAIN.STR

Tile drains remove excess water for an area to optimize plant growth. Drains may be added at the beginning of the simulation in the .mgt file. To account for the installation of tile drains mid-simulation, the option was included as a schedulable operation.

Below is a sample TILEDRAIN.STR FILE:

| | | | | | | | | |
|---------------|-------|------|-----|--------|------|----------|---------|---------|
| tiledrain.str | | | | | | | | |
| NAME | DEPTH | TIME | LAG | RADIUS | DIST | DRAIN_CO | PUMPCAP | LATKSAT |
| mw24_1000 | 1000 | 24 | 96 | 100 | 30 | 10 | 1 | 2 |

| 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. |
| HEADER | Headings for variables |

TYP The type of septic system

| Type | Definition |
|------|---|
| 1 | Generic type conventional system |
| 2 | Generic type advanced system |
| 3 | Septic tank with conventional drainfield |
| 4 | Septic tank with SAS ^a type 1 |
| 5 | Septic tank with SAS type 2 |
| 6 | Septic tank with in-tank N removal and SAS |
| 7 | Septic tank with effluent N removal recycle |
| 8 | Septic tank with corrugated plastic trickling Filter |
| 9 | Septic tank with open-cell form trickling filter |
| 10 | Single pass sand filter 1 |
| 11 | Single pass sand filter 2 |
| 12 | Single pass sand filter 3 |
| 13 | Single pass sand filter 4 |
| 14 | At grade recirculating sand filter |
| 15 | Maryland style RSF ^b |
| 16 | RSF |
| 17 | Septic tank w/ constructed wetland and surface water discharge |
| 18 | Municipal wastewater w/ constructed wetland and surface water discharge 1 |
| 19 | Municipal wastewater w/ constructed wetland and surface water discharge 2 |
| 20 | Municipal wastewater w/ constructed wetland |
| 21 | Municipal wastewater w/ lagoon and constructed wetland |
| 22 | Waterloo biofilter (plastic media) 1 |
| 23 | Waterloo biofilter (plastic media) 2 |
| 24 | Peat biofilter |
| 25 | Recirculating textile filter |
| 26 | Foam or textile filter effluent |
| 27 | Septic, recirculating gravel filter, UV disinfection |
| 28 | Untreated Effluent - Texas A&M reference |

YR

Year the septic system became operational (eg 1980).

If 0 is input for *isep_ylr*, the model assumes the septic system is in operation at the beginning of the simulation

Required.

OPT Initial septic HRU operational condition. User can define the default condition of a septic HRU as either active (*sep_opt*=1), failing (*sep_opt*=2), or non-septic (*sep_opt*=0). An active system automatically becomes failing as biozone layer gets clogged over time. A failing system turns to an active system after user specified “number of days for rehabilitation” defined by *isep_tfail*.

Required.

CAP Number of permanent residents in the house. *SEP_cap* for a typical US residence is 2.5 and ranges 1~10000.

Required.

AREA Average area of drainfield of individual septic systems (m^2).
Typically recommended drainfield area per person is about 40 to 70 (m^2). This varies from state to state in the United States. For a household with 2.5 people, generally a drainfield area of 100 (m^2) is recommended. User can modify the *bz_area* based on the number of people in a household. The *bz_area* and *sep_cap* may be modified appropriately to study the effects of larger population size using septic systems.

Required

TFAIL Time until failing systems gets fixed (days). An active system becomes failing as the biozone gets clogged and hydraulic failure occurs. A failing system automatically turns active during the simulation and septic parameters are re-initialized to default values after the user specified number of days (days assigned for *isep_tfail*) for rehabilitation. The default value for *isep_tfail* is 70 days but it can range between 10~100000 days. For testing long term failure, *isep_tfail* can be increased as per the failing duration. *isep_opt* should be set at 2 for simulating failing conditions..

Required.

Z Depth to the top of biozone layer from the ground surface (mm). The thickness includes top soil layer and septic tank effluent (STE) distribution chamber including perforated pipe. The default is 500mm and the depth typically ranges between 10-10000mm.

Required.

| | |
|-----------|--|
| THK | Thickness of the biozone layer (mm). The biozone layer is thin soil layer underneath the STE distribution chamber where pollutants are degraded by naturally existing live biomass bacteria. The default thickness is 50mm and ranges 5~100mm. |
| | Required. |
| STRM_DIST | Distance to the stream from the septic HRU (km) |
| | Currently not available. |
| DENSITY | Number of septic systems per square kilometer. |
| | Currently not available. |
| BD | Density of biomass (kg/m^3), typically in the range of 900~1100 kg/m^3 . The default is 1000 kg/m^3 . |
| | Required. |
| BOD_DC | BOD decay rate coefficient. Biozone BOD coefficient is normalized by the volume of biomass in the formula. The default value is 0.5 and the value ranges 0.1~ 5. |
| | Required. |
| BOD_CONV | A conversion factor representing the proportion of mass bacterial growth and mass BOD degraded in the STE. The default value is 0.32 and the value ranges 0.1~ 0.5. |
| | Required. |
| FC1 | Linear coefficient for calculation of field capacity in the biozone. The default value is 30 and the value ranges 0~ 50. |
| | Required. |
| FC2 | Exponential coefficient for calculation of field capacity in the biozone. The default value is 0.8 and the value ranges 0.5~ 1. |
| | Required. |
| FECAL | Fecal coliform bacteria decay rate coefficient. Biozone fecal coliform coefficient is normalized by the volume of biomass in the formula. The default value is 1.3 and the value ranges 0.5~ 2. |
| | Required. |

| | |
|----------|--|
| PLQ | Conversion factor for plaque from total dissolved solids. The default value is 0.1 and the value ranges 0.08~ 0.95. |
| | Required. |
| MRT | Mortality rate coefficient. The default value is 0.5 and the value ranges 0.01~ 1. |
| | Required. |
| RSP | Respiration rate coefficient. The default value is 0.16 and the value ranges 0.01~ 1. |
| | Required. |
| SLG1 | Linear coefficient for calculating the rate of biomass sloughing. The default value is 0.3 and the value ranges 0.01~ 0.5. |
| | Required. |
| SLG2 | Exponential coefficient for calculating the rate of biomass sloughing. The default value is 0.5 and the value ranges 0.1~ 2.5. |
| | Required. |
| NITR | Nitrification rate coefficient. Biozone nitrification rate coefficient is normalized by the volume of biomass in the formula. The default value is 1.5 and the value ranges 0.1~ 300. |
| | Required. |
| DENITR | Denitrification rate coefficient. Biozone denitrification rate coefficient is normalized by the volume of biomass in the formula. The default value is 0.32 and the value ranges 0.1~50. |
| | Required. |
| PDISTRB | Linear P sorption distribution coefficient (L/kg). The default value is 128 and the value ranges 1.4~478. |
| | Required. |
| PSORPMAX | Maximum P sorption capacity (mg P/kg Soil). The default value is 850 and the value ranges 0~17600. |
| | Required. |

SOLPSLP Slope of the linear effluent soluble P equation. The default value is 0.04 and the value ranges 0~0.3.

Required.

SOLPINTC Intercept of the linear effluent soluble P equation. The default value is 3.1 and the value ranges 0~10.

Required.

FILTERSTRIP.STR

A filter strip is a strip of dense vegetation located to intercept runoff from upslope pollutant sources and filter it. Filter strips remove contaminants by reducing overland flow velocity which results in the deposition of particulates. The filter strip area also acts as an area of increased infiltration, reducing both the runoff volume and non-particulate contaminants. The filter strip used algorithm used in SWAT was derived from White and Arnold (2009). Filter strips reduce sediment, nutrients, bacteria, and pesticides, but do not affect surface runoff in SWAT. The variables which may be entered on the pesticide application line are listed and described below.

Below is a sample FILTERSTRIP.STR FILE:

| | | | | | | | |
|-----------------|----------|--------|-------|-----------------------------------|--|--|--|
| filterstrip.str | | | | | | | |
| NAME | VFSRATIO | VFSCON | VFSCH | | | | |
| field_border | 0.1 | 0.003 | 0.2 | Field_border | | | |
| high_engineered | 0.1 | 0.001 | 0.05 | Highly_engineered_low_channelized | | | |

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.

HEADER Headings for variables

NAME Name

VFSI Flag for the simulation of filter strips (VFSI = 1/0 active/inactive).

VFSRATIO Ratio of field area to filter strip area (unitless). Ranges from 0 to 300 with values from 30-60 being most common. Default value is 40

VFSCON Fraction of the HRU which drains to the most concentrated ten percent of the filters strip area. Runoff generated upslope a filter strip is not uniformly distributed across the entire length of the strip. Ten percent of the filter strip can receive between 0.25 and 0.75 of the runoff from the entire filed. Default value is 0.5.

VFSCH

Fraction of the flow within the most concentrated ten percent of the filter strip which is fully channelized (dimensionless). Flow which is fully channelized is not subject to filtering or infiltration effects. Default value is 0.0

GRASSEDWW.STR

Grassed waterways are vegetated channels which transport runoff from a field. Vegetation within the waterways reduces flow velocities, and protects the waterway from the scouring potential of concentrated flow. These are generally broad and shallow channels; the channel simulated in SWAT has a side slope of 8:1. Grasses waterways trap sediment and other contaminants by reducing flow velocities which increases deposition of particulate contaminates.

Below is a sample GRASSEDWW.STR FILE:

| grassedww.str | | | | | | | |
|---------------|-------|-------|-------|-------|--------|-------|-----------|
| NAME | MAN_N | SPCON | DEPTH | WIDTH | LENGTH | SLOPE | DESC |
| grwway_high | 0.05 | 0.02 | 1 | 4 | 0.5 | 0.1 | Slope_>8 |
| grwway_med | 0.05 | 0.02 | 0.75 | 3 | 0.75 | 0.035 | Slope_2-5 |
| grwway_low | 0.05 | 0.02 | 0.5 | 2 | 1 | 0.01 | Slope_0-2 |

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.

HEADER

Headings for variables

NAME

Name

GRWAT_I

On/off Flag for waterway simulation

GRWAT_N

Mannings's n for grassed waterway

GRWAT_SPCON

sediment transport coefficient defined by user

GRWAT_D

depth of Grassed waterway (m)

GRWAT_W

width of grass waterway

GRWAT_L

length of Grass Waterway (km)

GRWAT_S

slope of grass waterway (m/m)

BMPUSER.STR

There are many conservation practices for which approximate removal efficiencies have been established which are unsupported by SWAT or any other existing model. To allow these practices to be included, this generic conservation practice operation allows fixed removal efficiencies to be specified by constituent.

Below is a sample BMPUSER.STR FILE:

| bmpuser.str - Little River Experimental Watershed | | | | | | | |
|---|----------|---------|--------|--------|--------|--------|---------|
| NAME | BMP_FLAG | BMP_SED | BMP_PP | BMP_SP | BMP_PN | BMP_SN | BMP_BAC |
| bmpusr1 | 1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

| 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. |
| HEADER | Headings for variables |
| NAME | User BMP Name |
| BMP_FLAG | Code to turn on/off user BMP (range 0-1)(mgtli) |
| BMP_SED | Sediment removal by BMP (%) (range 0-100) |
| BMP_PP | Particulate (Organic) phosphorous removal by BMP (%) (range 0-100) |
| BMP_SP | Soluble phosphorous removal by BMP (%) (range 0-100) |
| BMP_PN | Particulate (Organic) nitrogen removal by BMP (%) (range 0-100) |
| BMP_SN | Soluble nitrogen removal by BMP (%) (range 0-100) |
| BMP_BAC | Bacteria removed by BMP (%) (range 0-100) |

HRU PARM DB– The parameters database files are supplied with the model containing Input parameters for most of the common plants, fertilizers, pesticides, urban, are included in the database files with the option for the user to add new parameters to each file.

PLANTS.PLT

HEAT UNITS TO MATURITY

We took the PHU program and incorporated it directly into SWAT+ (currently in subroutine plants_init). Only one input change was required. In the plants.plt file, we changed the heat units to maturity (phu_mat) to days to maturity (days_mat). The concept of heat units to maturity was developed for annual crops and we use heat units for the entire growing season for native perennials and native annuals. By inputting days to maturity, we can include different crop varieties as defined by length of growing season (for example, corn varieties for 120, 110, 100 and 90 day varieties). The heat units to maturity calculation in the model first computes base zero heat units for the entire year and assumes a planting date when heat units exceed $0.15 \times \text{base zero}$. Then, the model calculates heat units from planting date through the days to maturity, using the crops base temperature as input in plants.plt. If the maximum days for a crop are input (120 days for corn) and the growing season is less than 120 days, the model essentially sums heat units for the entire growing season which represents (and estimates) the maximum days to maturity. This is the exact procedure used in the phu program.

The algorithm currently uses monthly weather generator parameters but could be modified to alternatively use daily temperature inputs. The model provides heat unit estimates in both the northern and southern hemispheres.

There are several advantages to incorporating the heat unit program into SWAT+ including:

1) Eliminates the need for running an external program when developing inputs, 2) allows input of a commonly understood variable (days) instead of a variable that is not commonly known at every location (heat units), 3) allows the model to calculate heat units for native perennials and annuals that are location dependent, 4) a database (plants.plt) can be maintained and supported that includes different crop seasonal varieties, and 5) by inputting the maximum growing season for a crop, the model will calculate appropriate heat units for that crop anywhere in the northern or southern hemisphere.

Additional notes on days to maturity:

The number after the crop name is days to maturity. Since the heat unit program is included in the SWAT+ model, the days to maturity for “corn” is 120 (the maximum for corn) and SWAT+ adjusts for climate. You could also choose a shorter variety in Texas for example, corn90.

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 includes 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. Below is a partial sample PLANTS.PLT file (see plants.plt in example input dataset directory for complete file):

| name | plnt_typ | gro_trig | nfix_co | days_mat | bm_e |
|---------|-------------|----------|---------|----------|------|
| corn | warm_annual | temp_gro | 0 | 120 | 39 |
| corn100 | warm_annual | temp_gro | 0 | 100 | 39 |
| corn110 | warm_annual | temp_gro | 0 | 110 | 39 |
| corn120 | warm_annual | temp_gro | 0 | 120 | 39 |
| corn90 | warm_annual | temp_gro | 0 | 90 | 39 |

| 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. |
| HEADER | Headings for variables |
| PLANTNM | 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. Required. |

| | |
|----------|---|
| PLNT_TYP | Land cover/plant classification (read in as character): perennial warm_annual cold_annual fall-planted land covers will go dormant when daylength is less than the threshold daylength |
| NFIX_CO | N fixation coefficient (0.5 =legume; 0=non-legume) |

| Variable name | Definition |
|---------------|--|
| PHU | Total number of heat units to bring crop to maturity |
| BIO_E | <p>Radiation-use efficiency or biomass-energy ratio ((kg/ha)/(MJ/m²)).</p> <p>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.</p> |

| Variable name | Definition |
|---------------|---|
| BIO_E, cont. | <p>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).</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p> |

| Variable name | Definition |
|---------------|---|
| BIO_E, cont. | <p>The <i>fraction</i> of intercepted PAR is converted to an <i>amount</i> 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 nm. 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.</p> <p>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.</p> <p>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.</p> <p>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.)</p> <p>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.</p> <p>Required.</p> |

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

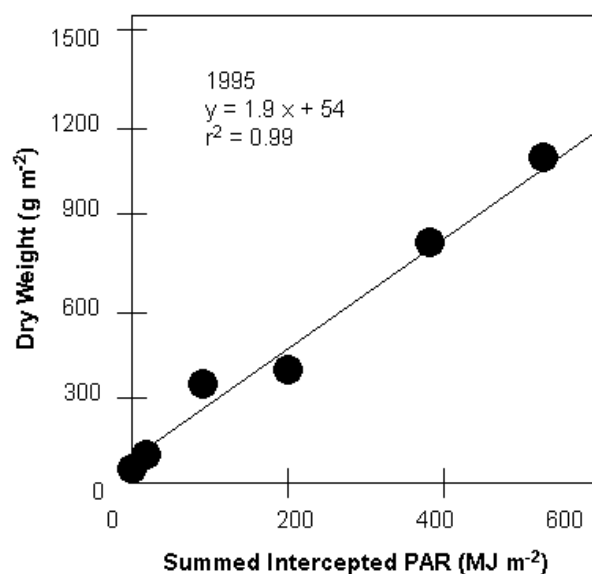


Figure 14-1: Aboveground biomass and summed intercepted photosynthetically active radiation for Eastern gamagrass (after Kiniry et al., 1999).

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).

| Variable name | Definition |
|---------------|--|
| HVSTI, cont. | 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. Required. |
| 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. |

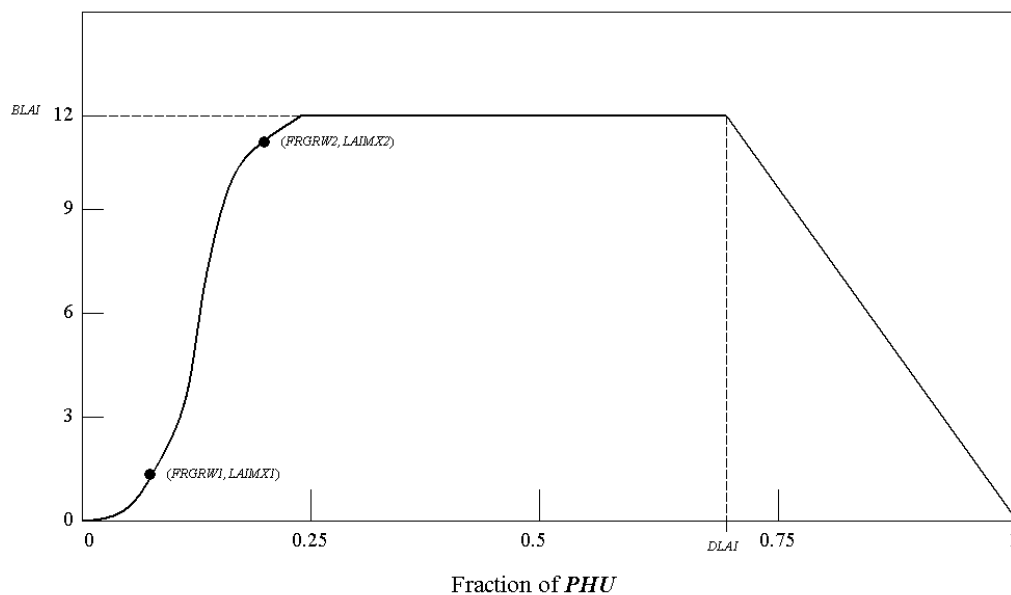


Figure 14-2: Leaf area index as a function of fraction of growing season for Alamo switchgrass

| Variable name | Definition |
|---------------|--|
| BLAI, cont. | <p>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.</p> <p>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.</p> <p>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.</p> <p>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).</p> <p>Chapter 5:1 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.</p> |

| Variable name | Definition |
|---------------|---|
| BLAI, cont. | <p>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.</p> <p>Required.</p> |
| FRGRW1 | <p>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.</p> <p>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.</p> <p>Required.</p> |
| LAIMX1 | <p>Fraction of the maximum leaf area index corresponding to the 1st point on the optimal leaf area development curve.</p> <p>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.</p> <p>Required.</p> |
| FRGRW2 | <p>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.</p> <p>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.</p> <p>Required.</p> |
| LAIMX2 | <p>Fraction of the maximum leaf area index corresponding to the 2nd point on the optimal leaf area development curve.</p> <p>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.</p> <p>Required.</p> |

| Variable name | Definition |
|---------------|---|
| DLAI | <p>Fraction of growing season when leaf area begins to decline.</p> <p>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.</p> <p>Required.</p> |
| CHTMX | <p>Maximum canopy height (m).</p> <p>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.</p> <p>Required.</p> |
| RDMX | <p>Maximum root depth (m).</p> <p>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.</p> <p>Required.</p> |
| T_OPT | <p>Optimal temperature for plant growth (°C).</p> <p>Both optimal and base temperatures are very stable for cultivars within a species.</p> <p>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.</p> |

| Variable name | Definition |
|---------------|---|
| T_OPT, cont. | <p>The peak of the plot defines the optimal temperature for leaf development—not for plant growth.</p> <p>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.</p> <p>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 $\sim 8^{\circ}\text{C}$ and the generic optimal temperature is $\sim 25^{\circ}\text{C}$. For cool season plants, the generic base temperature is $\sim 0^{\circ}\text{C}$ and the generic optimal temperature is $\sim 13^{\circ}\text{C}$.</p> <p>Required.</p> |
| T_BASE | <p>Minimum (base) temperature for plant growth ($^{\circ}\text{C}$).</p> <p>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.</p> <p>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.)</p> <p>Required.</p> |

| Variable name | Definition |
|---------------|------------|
| T_BASE, cont. | |

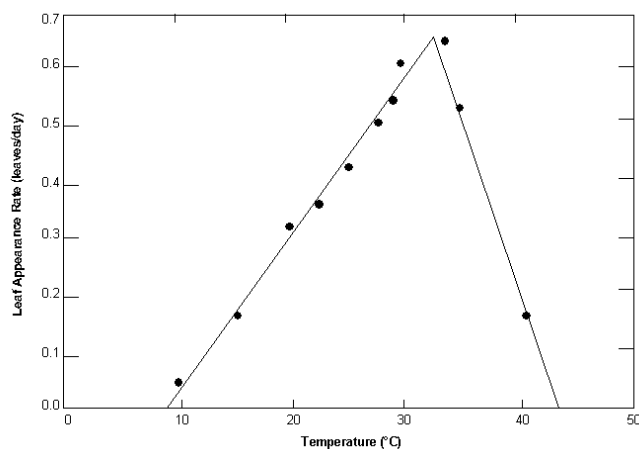


Figure 14-3: Rate of leaf tip appearance as a function of temperature for corn (after Kiniry et al, 1991)

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.

Required.

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.

Required.

| Variable name | Definition |
|---------------|--|
| PLTNFR1 | <p>Nitrogen uptake parameter #1: normal fraction of nitrogen in plant biomass at emergence (kg N/kg biomass)</p> <p>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: PLTNFR(1), PLTNFR(2), PLTNFR(3), PLTPFR(1), PLTPFR(2), and PLTPFR(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.</p> <p>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.</p> <p>Required.</p> |
| PLTNFR2 | <p>Nitrogen uptake parameter #2: normal fraction of nitrogen in plant biomass at 50% maturity (kg N/kg biomass)</p> <p>Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |
| PLTNFR3 | <p>Nitrogen uptake parameter #3: normal fraction of nitrogen in plant biomass at maturity (kg N/kg biomass)</p> <p>Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |

| Variable name | Definition |
|---------------|---|
| PLTPFR1 | <p>Phosphorus uptake parameter #1: normal fraction of phosphorus in plant biomass at emergence (kg P/kg biomass)</p> <p>Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |
| PLTPFR2 | <p>Phosphorus uptake parameter #2: normal fraction of phosphorus in plant biomass at 50% maturity (kg P/kg biomass)</p> <p>Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |
| PLTPFR3 | <p>Phosphorus uptake parameter #3: normal fraction of phosphorus in plant biomass at maturity (kg P/kg biomass)</p> <p>Please read the explanation for parameter PLTNFR(1) to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |
| WSYF | <p>Lower limit of harvest index ((kg/ha)/(kg/ha)).</p> <p>The value between 0.0 and HVSTI which represents the lowest harvest index expected due to water stress.</p> <p>Please read the explanation for parameter HVSTI to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |

| Variable name | Definition |
|---------------|--|
| USLE_C | <p>Minimum value of USLE C factor for water erosion applicable to the land cover/plant.</p> <p>The minimum C factor can be estimated from a known average annual C factor using the following equation (Arnold and Williams, 1995):</p> $C_{USLE,mn} = 1.463 \ln[C_{USLE,aa}] + 0.1034$ <p>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.</p> <p>Required.</p> |
| GSI | <p>Maximum stomatal conductance at high solar radiation and low vapor pressure deficit ($m \cdot s^{-1}$).</p> <p>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).</p> <p>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 CO₂ 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.</p> |

| Variable name | Definition |
|---------------|--|
| GSI, cont. | <p>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.</p> |
| VPDFR | <p>Required.</p> <hr/> <p>Vapor pressure deficit (kPa) corresponding to the second point on the stomatal conductance curve.</p> <p>(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.)</p> <p>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.</p> |
| | <p>Required.</p> <hr/> |

| Variable name | Definition |
|---------------|--|
| GMAXFR | <p>Fraction of maximum stomatal conductance corresponding to the second point on the stomatal conductance curve.</p> <p>(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.)</p> <p>Please read the explanation for parameter VPDFR to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |
| WAVP | <p>Rate of decline in radiation use efficiency per unit increase in vapor pressure deficit.</p> <p>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.</p> <p>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.</p> <p>Vapor pressure deficits can be calculated from relative humidity (see Chapter 1:2 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.</p> |

| Variable name | Definition |
|---------------|------------|
| WAVP, cont. | |

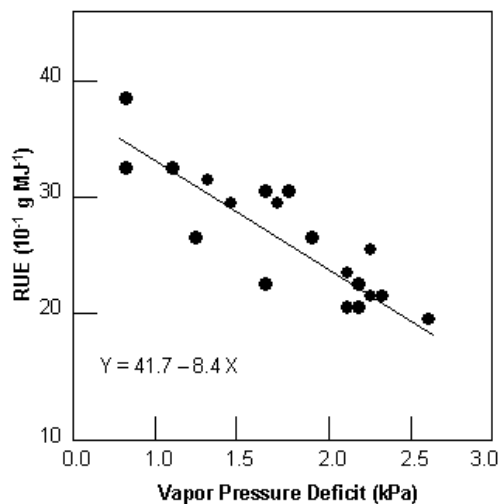


Figure 14-4: Response of radiation-use efficiency to mean daily vapor pressure deficit for grain sorghum (after Kiniry, 1999).

From Figure 14-4, the rate of decline in radiation-use efficiency per unit increase in vapor pressure deficit, Δrue_{dcl} , for sorghum is $8.4 \times 10^{-1} \text{ g} \cdot \text{MJ}^{-1} \cdot \text{kPa}^{-1}$. 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.

Required.

CO2HI

Elevated CO₂ atmospheric concentration ($\mu\text{L CO}_2/\text{L air}$) corresponding the 2nd point on the radiation use efficiency curve.

(The 1st point on the radiation use efficiency curve is comprised of the ambient CO₂ concentration, 330 $\mu\text{L CO}_2/\text{L air}$, and the biomass-energy ratio reported for BIO_E)

| Variable name | Definition |
|---------------|---|
| CO2HI, cont. | <p>In order to assess the impact of climate change on agricultural productivity, SWAT incorporates equations that adjust RUE for elevated atmospheric CO₂ concentrations. Values must be entered for CO2HI and BIOEHI in the plant database whether or not the user plans to simulate climate change.</p> <p>For simulations in which elevated CO₂ 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.</p> <p>To obtain radiation-use efficiency values at elevated CO₂ levels for plant species not currently in the database, plants should be established in growth chambers set up in the field or laboratory where CO₂ levels can be controlled. RUE values are determined using the same methodology described in the explanation of BIO_E.</p> <p>Required.</p> |
| BIOEHI | <p>Biomass-energy ratio corresponding to the 2nd point on the radiation use efficiency curve.</p> <p>(The 1st point on the radiation use efficiency curve is comprised of the ambient CO₂ concentration, 330 µL CO₂/L air, and the biomass-energy ratio reported for BIO_E.)</p> <p>Please read the explanation for parameter CO2HI and BIO_E to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |
| RSDCO_PL | <p>Plant residue decomposition coefficient.</p> <p>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.</p> <p>This variable was originally in the basin input file (.bsn), but was added to the crop database so that users could vary decomposition by plant species. A default value of 0.05 is used for all plant species in the database.</p> <p>Required.</p> |

| Variable name | Definition |
|---------------|--|
| ALAI_MIN | <p>Minimum leaf area index for plant during dormant period (m^2/m^2).</p> <p>This variable pertains to perennials and trees only. (The value is never used for other types of plants.) In versions of SWAT prior to SWAT2012, the minimum leaf area index for plants during the dormant period was always set to 0.75. Because this value was not ideal for all plants (trees in particular), users are now allowed to vary the minimum LAI for dormancy.</p> <p>Please see the explanation given for parameter BLAI to obtain additional information about this parameter and methods used to measure it.</p> <p>Required.</p> |
| LAIXCO_TREE | <p>Fraction of tree biomass accumulated each year that is converted to residue during dormancy.</p> <p>This variable pertains to trees only. (The value is never used for other types of plants.) BIO_LEAF governs the amount of biomass that falls off the tree and is converted to residue when the plant goes dormant in the winter. In versions of SWAT prior to SWAT2012, the fraction of biomass converted to residue at the beginning of dormancy was always defined as 0.30.</p> <p>Required if land cover is classified as a tree (see IDC).</p> |
| MAT_YRS | <p>Number of years required for tree species to reach full development (years).</p> <p>This variable pertains to trees only. (The value is never used for other types of plants.)</p> <p>Required if land cover is classified as a tree (see IDC).</p> |
| BMX_PEREN | <p>Maximum biomass for a forest (metric tons/ha).</p> <p>This variable pertains to trees only. (The value is never used for other types of plants.)</p> <p>The maximum biomass for a mature forest stand generally falls in the range of 30-50 metric tons/ha.</p> <p>Required if land cover is classified as a tree (see IDC).</p> |
| EXT_COEF | <p>Light extinction coefficient.</p> <p>This coefficient is used to calculate the amount of intercepted photosynthetically active radiation. In versions of SWAT prior to SWAT2012, the light extinction coefficient was always defined as 0.65.</p> |

EXT_COEF
(CONT)

Differences in canopy structure for a species are described by the number of leaves present (leaf area index) and the leaf orientation. Leaf orientation has a significant impact on light interception and consequently on radiation-use efficiency. More erect leaf types spread the incoming light over a greater leaf area, decreasing the average light intensity intercepted by individual leaves (Figure 14-5). A reduction in light intensity interception by an individual leaf favors a more complete conversion of total canopy-intercepted light energy into biomass.

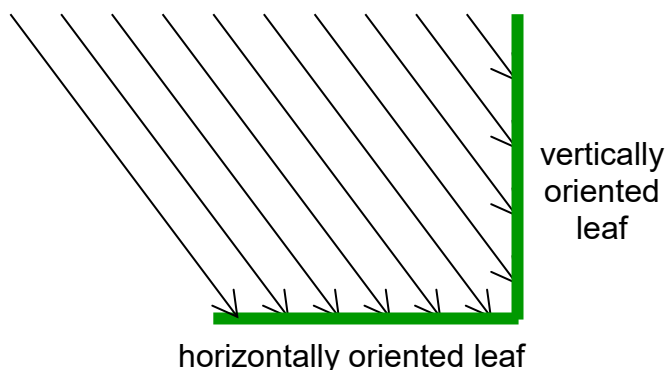


Figure 14-5: Light intensity interception as a function of leaf orientation. The vertically oriented leaf intercepts 4 units of light while a horizontally oriented leaf of the same length intercepts 6 units of light.

Using the light extinction coefficient value (k_ℓ) in the Beer-Lambert formula (equation 5:2.1.1) to quantify efficiency of light interception per unit leaf area index, more erect leaf types have a smaller k_ℓ .

To calculate the light extinction coefficient, the amount of photosynthetically active radiation (PAR) intercepted and the mass of aboveground biomass (LAI) is measured several times throughout a plant's growing season using the methodology described in the previous sections. The light extinction coefficient is then calculated using the Beer-Lambert equation:

$$\frac{TPAR}{PAR} = (1 - \exp(-k_\ell \cdot LAI)) \quad \text{or} \quad k_\ell = -\ln\left(\frac{TPAR}{PAR}\right) \cdot \frac{1}{LAI}$$

where $TPAR$ is the transmitted photosynthetically active radiation, and PAR is the incoming photosynthetically active radiation.

| | |
|--------------|---|
| LEAF_TOV_MIN | Perennial leaf turnover rate with minimum stress (months) |
| LEAF_TOV_MAX | Perennial leaf turnover rate with maximum stress (months) |

| | |
|-----------|--|
| BM_DIEOFF | Biomass dieoff fraction. This coefficient is the fraction above ground biomass that dies off at dormancy. Default value = 0.10. |
| RSR1 | Initial root to shoot ration at the beginning of the growing season. Default = 0.40. |
| RSR2 | Root to shoot ration at the end of the growing season. Default = 0.20. |
| POP1 | Plant population corresponding to the 1st point on the population lai curve (plants/m ²) |
| FRLAI1 | Frac of max leaf area index corresponding to the 1st point on the leaf area development curve (frac) |
| POP2 | Plant population corresponding to the 2nd point on the population lai curve (plants/m ²) |
| FRLAI2 | Frac of max leaf area index corresponding to the 2nd point on the leaf area development curve (frac) |
| FRSW_GRO | Frac of field capacity to initiate growth of tropical plants during monsoon season - pcom()%(plcur())%(iseason (frac) |
| WIND_STL | Wind erosion factor for standing live biomass |
| WIND_STD | Wind erosion factor for standing dead residue |
| WIND_FLAT | Wind erosion factor for flat residue |

FERTILIZER.FRT

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 database file provided with the model. Below is a partial listing of the fertilizer.frt file.

| fertilizer.frt | | | | | | | |
|----------------|-------|-------|-------|-------|-------|-----------|----------------------|
| FERTNM | FMINN | FMINP | FORGN | FORGP | FNH3N | Pathogens | Description |
| elem_n | 1 | 0 | 0 | 0 | 0 | null | ElementalNitrogen |
| elem_p | 0 | 1 | 0 | 0 | 0 | null | ElementalPhosphorous |
| anh_nh3 | 0.82 | 0 | 0 | 0 | 1 | null | AnhydrousAmmonia |
| urea | 0.46 | 0 | 0 | 0 | 1 | null | Urea |
| 46_00_00 | 0.46 | 0 | 0 | 0 | 0 | null | 46_00_00 |
| 33_00_00 | 0.33 | 0 | 0 | 0 | 0 | null | 33_00_00 |
| 31_13_00 | 0.31 | 0.057 | 0 | 0 | 0 | null | 31_13_00 |

| 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. Optional. |
| HEADER | Headers for the fertilizer.frt file. |
| FERTNM | Name of fertilizer/manure (up to 8 characters allowed). Required. |
| 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. Required. |
| FMINP | Fraction of mineral P in fertilizer (kg min-P/kg fertilizer). Value should be between 0.0 and 1.0. Required. |
| FORGN | Fraction of organic N in fertilizer (kg org-N/kg fertilizer). Value should be between 0.0 and 1.0. Required. |
| FORGP | Fraction of organic P in fertilizer (kg org-P/kg fertilizer). Value should be between 0.0 and 1.0. Required. |
| 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. Required. |
| PATHOGENS | |

TILLAGE.TIL

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

Below is a partial listing of the tillage.til file.

| | | | | | | | | | |
|--------------|--------|--------|--------|----------|----------|--|-------------------------------|--|--|
| tillage.til: | | | | | | | | | |
| TILLNM | EFFMIX | DEPTIL | RANRNS | RIDGE_HT | RIDGE_SP | | Description | | |
| fallplow | 0.95 | 150 | 75 | 0 | 0 | | genericfallplowingoperation | | |
| sprgplow | 0.5 | 125 | 50 | 0 | 0 | | genericspringplowingoperation | | |
| constill | 0.25 | 100 | 40 | 0 | 0 | | genericconservationtillage | | |
| zerotill | 0.05 | 25 | 10 | 0 | 0 | | genericno-tillmixing | | |
| duckftc | 0.55 | 100 | 15 | 0 | 0 | | duckfootcultivator | | |
| fldcult | 0.3 | 100 | 20 | 0 | 0 | | fieldcultivator | | |
| furowout | 0.75 | 25 | 15 | 0 | 0 | | furrow-outcultivator | | |
| marker | 0.45 | 100 | 15 | 0 | 0 | | marker(cultivator) | | |
| rollcult | 0.5 | 25 | 15 | 0 | 0 | | rollingcultivator | | |
| rowcult | 0.25 | 25 | 15 | 0 | 0 | | rowcultivator | | |
| discovat | 0.5 | 25 | 15 | 0 | 0 | | discovator | | |
| leveler | 0.5 | 25 | 15 | 0 | 0 | | leveler | | |

| 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. Optional. |
| HEADER | Headers for the tillage.til.res file. |
| TILLNM | Name of fertilizer/manure (up to 8 characters allowed). Required. |
| 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). Required. |
| DEPTIL | Depth of mixing caused by the tillage operation (mm). Required. |
| RANRNS | Random roughness (mm) Required. |
| RIDGE_HT | Ridge height (mm) Required. |
| RIDGE_SP | Ridge interval (mm) Required. |

PESTICIDE.PST

The pesticide database contains parameters that govern pesticide fate and transport in the HRUs. Appendix A documents the source of parameter values in the database file provided with the model. Below is a partial listing of the pesticide.pst file:

| pesticide.pst | | | | | | | | | | | | | | |
|---------------|--------|---------|-----------|---------|--------|---------|---------|-------|----------|---------|---------|---------|----------|------------------------------|
| PEST_NAME | KOC | WASHOFF | FOLIAR_HI | SOIL_HL | SOLUB | AQ_REAC | AQ_VOLA | AQ_MW | AQ_RESUS | AQ_SETL | BEN_ACT | BEN_BUR | BEN_REAC | Description |
| 245-tp | 2600 | 0.4 | 5 | 20 | 2.5 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Silvex_Amine |
| 2plus2 | 20 | 0.95 | 10 | 21 | 660000 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Mecoprop |
| aatrex | 171 | 0.45 | 5 | 60 | 33 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Atrazine |
| abate | 100000 | 0.65 | 5 | 30 | 0 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Abate |
| acaraben | 2000 | 0.05 | 10 | 20 | 13 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Chlorobenzilate_Salt |
| accelera | 20 | 0.9 | 7 | 7 | 100000 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Endothall |
| acclaim | 9490 | 0.2 | 5 | 9 | 0.8 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Fenoxaprop-Ethyl_Sodium_Salt |
| alanap | 20 | 0.95 | 7 | 14 | 231000 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Naptalam |
| alar | 10 | 0.95 | 4 | 7 | 100000 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Daminozide |
| aldrin | 300 | 0.05 | 2 | 28 | 0.1 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Aldrin |
| aliette | 20 | 0.95 | 0.1 | 0.1 | 120000 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Fosetyl-Aluminum |
| ally | 35 | 0.8 | 30 | 120 | 9500 | 0.007 | 0.00001 | 0.1 | 0.002 | 0.5 | 0.3 | 0.002 | 0.05 | Metsulfuron-Methyl_Salts |

| Variable name | Definition |
|---------------|---|
| TITLE | <p>The first line is reserved for user comments. This line is not processed by the model and may be left blank.</p> <p>Optional.</p> |
| HEADER | <p>Headers for the pesticide.pst file.</p> |
| PESTNM | <p>Name of pesticide/toxin. (up to 17 characters allowed)</p> <p>Required.</p> |
| SKOC | <p>Soil adsorption coefficient normalized for soil organic carbon content (mg/kg)/(mg/L).</p> <p>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:</p> $K_p = \frac{C_{solidphase}}{C_{solution}}$ <p>where K_p is the soil adsorption coefficient ((mg/kg)/(mg/L) or m³/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.</p> <p>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:</p> $K_p = K_{oc} \cdot \frac{orgC}{100}$ |

| Variable name | Definition |
|---------------|---|
| SKOC, cont. | <p>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 m³/ton), and $orgC$ is the percent organic carbon present in the soil.</p> <p>Required.</p> |
| PST_WOF | <p>Wash-off fraction.</p> <p>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.</p> <p>Required.</p> |
| HLIFE_F | <p>Degradation half-life of the chemical on the foliage (days).</p> <p>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.</p> <p>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:</p> <ol style="list-style-type: none"> 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. <p>Required.</p> |

| Variable name | Definition |
|---------------|---|
| HLIFE_S | <p>Degradation half-life of the chemical in the soil (days).</p> <p>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.</p> <p>Required.</p> |
| PST_WSOL | <p>Solubility of the chemical in water (mg/L or ppm)</p> <p>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.</p> <p>Reported solubility values are determined under laboratory conditions at a constant temperature, typically between 20°C and 30°C.</p> <p>Required.</p> |
| AQ_REAC | Aquatic pesticide reaction coefficient (1/day) |
| AQ_VOLAT | Aquatic volatilization coefficient (m/day) |
| MOL_WT | Molecular weight to calculate mixing velocity |
| AQ_RESUS | Aquatic resuspension velocity for pesticide sorbed to sediment (m/day) |
| AQ_SETTLE | Aquatic settling velocity for pesticide sorbed to sediment (m/day) |
| BEN_ACT_DEP | Depth of active benthic sediment (m) |
| BEN_BURY | Burial velocity in benthic sediment (m/day) |
| BEN_REAC | Reaction coefficient in benthic sediment (1/day) |

PATHOGENS.PTH

Below is a sample partial PATHOGENS.PTH:

| | | | | | | | | | | | | | | | | | | |
|---------------|---------|---------|---------|---------|------|-------|---------|---------|---------|--------|-------|----------|---------|---------|--------|--------|------|---------|
| pathogens.pth | | | | | | | | | | | | | | | | | | |
| BACTNM | DO_SOLN | GR_SOLN | DO_SORB | GR_SORB | KD | T_ADJ | WASHOFF | DO_PLNT | GR_PLNT | MANURE | PERCO | T_THRSHD | STREAM1 | STREAM2 | DO_RES | GR_RES | SWF | ONC_MIN |
| Example | 10 | 5 | 12 | 6 | 0.05 | 1.05 | 0.1 | 100 | 1 | 0.9 | 10 | 100 | 0 | 0 | 0 | 0 | 0.15 | 100 |

| 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. Optional. |
| HEADER | Headers for the bacteria.bac file. |
| BACTNM | Name of bacteria |
| DO_SOLN | Die-off factor for persistent bacteria in soil solution at 20°C. (1/day) SWAT allows two different bacteria types to be modeled in a given simulation. In the input/output files these two types are referred to as 'persistent' and 'less persistent'. These terms are purely descriptive and are used solely to differentiate between the two types. The bacteria input variables in the .bsn file govern the actual persistence of the two bacteria types. The user may choose to model no, one, or two types of bacteria. Required if bacteria processes are of interest. |
| GR_SOLN | Growth factor for persistent bacteria in soil solution at 20°C. (1/day) Required if bacteria processes are of interest. |
| DO_SORB | Die-off factor for persistent bacteria adsorbed to soil particles at 20°C. (1/day) Required if bacteria processes are of interest. |
| GR_SORB | Growth factor for persistent bacteria adsorbed to soil particles at 20°C. (1/day) Required if bacteria processes are of interest. |
| KD | Bact part coeff bet sol and sorbed phase in surf runoff |
| T_ADJ | Temperature adjustment factor for bacteria die-off/growth. If no value for THBACT is entered, the model will set THBACT = 1.07. Required if bacteria processes are of interest. |
| WASHOFF | Wash-off fraction for persistent bacteria. Fraction of persistent bacteria on foliage that washes off during a rainfall event. Required if bacteria processes are of interest. |
| DO_PLNT | Die-off factor for persistent bacteria on foliage at 20°C. (1/day) Required if bacteria processes are of interest. |
| GR_PLNT | Growth factor for persistent bacteria on foliage at 20°C. (1/day) Required if bacteria processes are of interest. |

| | |
|------------|---|
| FR_MANURE | Fraction of manure applied to land areas that has active colony forming units. If no value for SWF is specified, the model will set SWF = 0.15. Required if bacteria processes are of interest. |
| PERCO | Bacteria percolation coefficient (10 m ³ /Mg). The bacteria percolation coefficient is the ratio of the solution bacteria concentration in the surface 10 mm of soil to the concentration of bacteria in percolate. The value of BACTMIX can range from 7.0 to 20.0. If no value for BACTMIX is entered, the model will set BACTMIX = 10.0. Required if bacteria processes are of interest. |
| DET_THRSHD | Threshold detection level for less persistent bac when bacteria levels drop to this amount the model considers bacteria in the soil to be insignificant and sets the levels to zero |
| DO_STREAM | Die-off factor for persistent bacteria in streams (moving water) at 20°C. (1/day) Required if bacteria processes are of interest. |
| GR_STREAM | growth factor for persistent bacteria in streams |
| DO_RES | Die-off factor for less persistent bacteria in streams (moving water) at 20°C. (1/day) Required if bacteria processes are of interest. |
| GR_RES | growth factor for less persistent bacteria in reservoirs |
| SWF | fraction of manure containing active colony forming units |
| CONC_MIN | |

METALS.MTL**SALTS.STL****URBAN.URB**

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 database file provided with the model. Below is a listing of the urban.urb file:

| | | | | | | | | | | | | |
|------------------|------|-------|---------|---------|--------|-------|--------|--------|----------|--------|----------------|---------|
| urban.urb: | | | | | | | | | | | | |
| urbnm | fimp | fcimp | curbden | urbcoef | dirtmx | thalf | tnconc | tpconc | tno3conc | urbcn2 | Description | |
| residen_high_den | 0.6 | 0.44 | 0.24 | 0.18 | 225 | 0.75 | 550 | 223 | 7.2 | 98 | Residentia | Density |
| residen_med_den | 0.38 | 0.3 | 0.24 | 0.18 | 225 | 0.75 | 550 | 223 | 7.2 | 98 | Residentia | Density |
| residen_ml_den | 0.2 | 0.17 | 0.24 | 0.18 | 225 | 0.75 | 460 | 196 | 6 | 98 | Residentia | Density |
| residen_low_den | 0.12 | 0.1 | 0.24 | 0.18 | 225 | 0.75 | 460 | 196 | 6 | 98 | Residentia | Density |
| commercial | 0.67 | 0.62 | 0.28 | 0.18 | 200 | 1.6 | 420 | 240 | 5.5 | 98 | Commercial | |
| industrial | 0.84 | 0.79 | 0.14 | 0.18 | 400 | 2.35 | 430 | 104 | 5.6 | 98 | Industrial | |
| transportation | 0.98 | 0.95 | 0.12 | 0.18 | 340 | 3.9 | 480 | 212 | 6.3 | 98 | Transportation | |
| institutional | 0.51 | 0.47 | 0.12 | 0.18 | 340 | 3.9 | 480 | 212 | 6.3 | 98 | Institutional | |
| residential | 0.38 | 0.3 | 0.24 | 0.18 | 225 | 0.75 | 550 | 223 | 7.2 | 98 | Residential | |

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.

HEADER

Headings for the variables

URBNM

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.

Required.

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.

Required.

FCIMP

Fraction directly connected impervious area in urban land type.

| Variable name | Definition |
|---------------|--|
| FCIMP, cont. | <p>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.</p> <p>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.</p> <p>Required.</p> |
| CURBDEN | <p>Curb length density in urban land type (km/ha).</p> <p>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.</p> <p>Required.</p> |
| URBCOEF | <p>Wash-off coefficient for removal of constituents from impervious area (mm^{-1}).</p> <p>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 $0.002\text{--}0.26 \text{ mm}^{-1}$. 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.</p> <p>Required.</p> |
| DIRTMX | <p>Maximum amount of solids allowed to build up on impervious areas (kg/curb km).</p> <p>Required.</p> |

| Variable name | Definition |
|---------------|---|
| 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). Required. |
| TNCONC | Concentration of total nitrogen in suspended solid load from impervious areas (mg N/kg sed). Required. |
| TPCONC | Concentration of total phosphorus in suspended solid load from impervious areas (mg P/kg sed). Required. |
| TNO3CONC | Concentration of nitrate in suspended solid load from impervious areas (mg NO ₃ -N/kg sed). Required. |
| URBCN2 | Curve number for moisture condition II in impervious areas of urban land type. Required. |

URBAN in HRU-LTE1. Adjust CN₂

$$CN_{urb} = Fr_{imp} * 98 + (1 - Fr_{imp}) * CN_{non-imp}$$

Fr_{imp} = fraction impervious

$CN_{non-imp}$ = CN₂ of non-impervious land use

2. Adjust tc

$$tc = tc * [0.1 * Fr_{imp} + (1 - Fr_{imp})]$$

3. Adjust USLE parameters

$$K_{usle} = K_{soil} * (1 - Fr_{imp})$$

SEPTIC.SEP

Information of water quality or effluent characteristics required to simulate different types of Onsite Wastewater Systems (OWSs) is stored in the septic water quality database. The database file distributed with SWAT includes water quality data for most of conventional, advanced, and failing septic systems. Information contained in the septic water quality database is septic tank effluent flow rate for per capita and effluent characteristics of various septic systems. The database is developed based on the field data summarized by

Siegrist et al. (2005), McCray et al. (2005) and OWTS 201 (2005). Below is a partial listing of the septic.sep file:

| septic.sep | | | | | | | | | | |
|------------|-------|---------|----------|---------|---------|---------|---------|-------|-------|----------|
| SEPNM | QS | BODCONC | TSSCONCS | NH4CONC | NO3CONC | NO2CONC | ORGNCON | MINPS | ORGPS | FCOLIS |
| GCON | 0.227 | 170 | 75 | 42.4 | 0 | 0 | 10 | 6 | 1 | 10000000 |
| GADV | 0.227 | 22 | 14 | 18.9 | 9.6 | 0 | 3 | 5.1 | 0.9 | 543 |
| COND | 0.227 | 170 | 75 | 58 | 0.2 | 0 | 14 | 9 | 1 | 10000000 |
| SAS1 | 0.227 | 170 | 75 | 60 | 0 | 0 | 10 | 8.5 | 1.5 | 10000000 |
| SAS2 | 0.227 | 170 | 75 | 0 | 0 | 0 | 0 | 9 | 1 | 10000000 |
| SAS3 | 0.227 | 170 | 80 | 0 | 20 | 0 | 0 | 8.5 | 1.5 | 1000000 |
| SAS4 | 0.227 | 100 | 65 | 0 | 0 | 0 | 0 | 8.5 | 1.5 | 10000000 |
| SAS5 | 0.227 | 20 | 10 | 2.4 | 7.1 | 0 | 0 | 0 | 0 | 0 |
| SAS6 | 0.227 | 18 | 17 | 5.6 | 4.1 | 0 | 1.3 | 0 | 0 | 0 |

| 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. Optional. |
| HEADER | Headers for the septic.sep file. |

SEPNM

| Abridged name of a septic system | |
|----------------------------------|---|
| sptname | Definition |
| GCON | Generic type conventional system |
| GADV | Generic type advanced system |
| COND | Septic tank with conventional drainfield |
| SAS1 | Septic tank with SAS ^a type 1 |
| SAS2 | Septic tank with SAS type 2 |
| SAS3 | Septic tank with in-tank N removal and SAS |
| SAS4 | Septic tank with effluent N removal recycle |
| SAS5 | Septic tank with corrugated plastic trickling Filter |
| SAS6 | Septic tank with open-cell form trickling filter |
| SPF1 | Single pass sand filter 1 |
| SPF2 | Single pass sand filter 2 |
| SPF3 | Single pass sand filter 3 |
| SPF4 | Single pass sand filter 4 |
| RCF1 | At grade recirculating sand filter |
| RCF2 | Maryland style RSF ^b |
| RCF3 | RSF |
| CWT1 | Septic tank w/ constructed wetland and surface water discharge |
| CWT2 | Municipal wastewater w/ constructed wetland and surface water discharge 1 |
| CWT3 | Municipal wastewater w/ constructed wetland and surface water discharge 2 |
| CWT4 | Municipal wastewater w/ constructed wetland |
| CWT5 | Municipal wastewater w/ lagoon and constructed wetland |
| BFL1 | Waterloo biofilter (plastic media) 1 |
| BFL2 | Waterloo biofilter (plastic media) 2 |
| BFL3 | Peat biofilter |
| TXF1 | Recirculating textile filter |
| TXF2 | Foam or textile filter effluent |
| GFL1 | Septic, recirculating gravel filter, UV disinfection |
| USPT | Untreated Effluent - Texas A&M reference |

a: Sand absorption system

b: Recirculating sand filter

Optional.

QS

Septic tank effluent (STE) flow rate (m³/capita/day). McCray et al. (2005) proposed 0.227 m³/capita/day as the median value for USA based on the data collected from various sources.

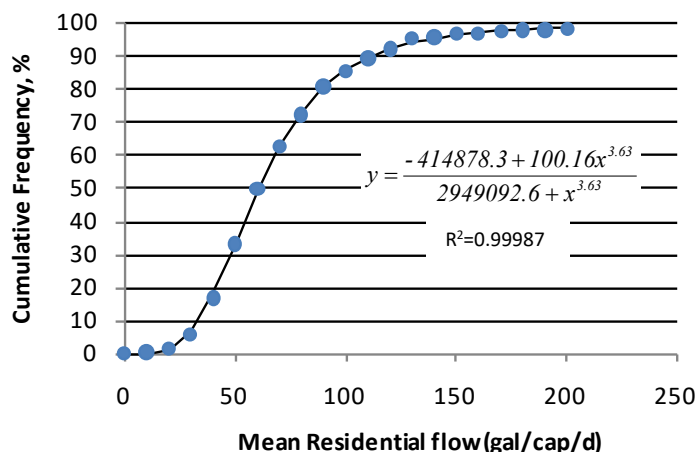


Figure 34.1 Cumulative frequency distribution for residential septic tank effluent flow rate (after McCray et al., 2005)

BODCONCS

7 day Biochemical oxygen demand in STE (mg/L). BOD for a conventional system is typically 170 mg/L. The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005).

Required.

TSSCONCS

Total suspended solids in STE (mg/L). TSS for a conventional system is typically 75 mg/L. The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005).

Required.

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

| | |
|----------|--|
| NH4CONCS | Ammonium nitrogen in STE (mg-N/L). NH ₄ for a conventional system is typically 60 mg-N/L (ranging 17~78 mg-N/L). The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005). |
|----------|--|

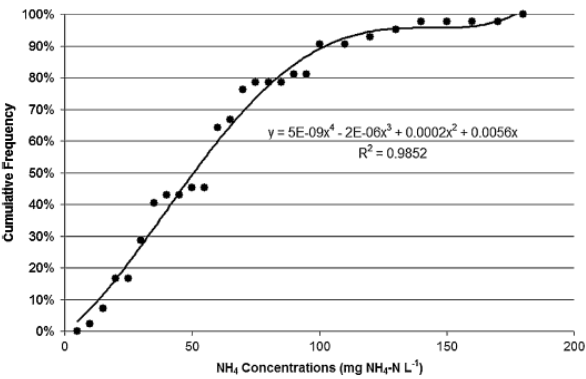


Figure 34.2 Cumulative frequency distribution for ammonium concentration in the septic tank effluent flow rate (after McCray et al., 2005)

Required.

| | |
|----------|--|
| NO3CONCS | Nitrate nitrogen in STE (mg-N/L). NO ₃ for a conventional system ranges 0~1.94 mg-N/L. The value varies for different types of septic systems (See Table A-1 of Siegrist et al., 2005). |
|----------|--|

Required.

| | |
|----------|--|
| NO2CONCS | Nitrite nitrogen in STE (mg-N/L). NO ₂ for a conventional system is typically very low. |
|----------|--|

Required.

| | |
|-----------|--|
| ORGNCONCS | Organic nitrogen in STE (mg-N/L). ORGN for a conventional system ranges 9.4~15 mg-N/L. |
|-----------|--|

Required.

| Variable name | Definition |
|---------------|--|
| MINPS | Concentration of mineral phosphorus in the septic tank effluent (mg/L). Required. |
| ORGPS | Organic phosphorus in STE (mg-P/L). ORGP for a conventional system is typically 1 mg-p/L. Required. |
| FCOLIS | Total number of fecal coliform in STE (cfu/100mL). FCOLI for a conventional system is typically 1E7 cfu/100mL. The value varies greatly for different types of septic systems (See Table A-1 of Siegrist et al., 2005). Required. |

SNOW.SNO

The SNOW.SNO file contains the input variables for snow. Below is a partial listing of the snow.sno file.

| | | | | | | | | |
|----------|---------|---------|--------|--------|------|-------|-------|---------|
| snow.sno | | | | | | | | |
| NAME | FALLTMP | MELTTMP | MELTMX | MELTMN | TIMP | COVMX | COV50 | INIT_MM |
| snow001 | 1.0 | 2.0 | 6.0 | 3.0 | 1.0 | 0.0 | 0.0 | 0.0 |

| 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. Optional. |
| HEADER | Headers for the snow.sno file. |
| NAME | Name of the snow parameters |
| FALLTMP | Snowfall temperature (°C). Mean air temperature at which precipitation is equally likely to be rain as snow/freezing rain. The snowfall temperature should be between –5 °C and 5 °C. A default recommended for this variable is SFTMP = 1.0. Required in watersheds where snowfall is significant. |
| MELTTMP | Snow melt base temperature (°C). The snow pack will not melt until the snow pack temperature exceeds a threshold value, T_{melt} . The snow melt base temperature should be between –5 °C and 5 °C. A default recommended for this variable is SMTMP = 0.50. Required in watersheds where snowfall is significant. |

MELTMX

Melt factor for snow on June 21 (mm H₂O/°C-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 H₂O/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 H₂O/day-°C. Studies of snow melt on asphalt (Westerstrom, 1984) gave melt factors of 1.7 to 6.5 mm H₂O/day-°C.

If no value for SMFMX is entered, the model will set SMFMX = 4.5.

Required in watersheds where snowfall is significant.

| Variable name | Definition |
|---------------|---|
| MELTMN | <p>Melt factor for snow on December 21 (mm H₂O/°C-day).</p> <p>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.</p> <p>In rural areas, the melt factor will vary from 1.4 to 6.9 mm H₂O/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 H₂O/day-°C. Studies of snow melt on asphalt (Westerstrom, 1984) gave melt factors of 1.7 to 6.5 mm H₂O/day-°C.</p> <p>If no value for SMFMN is entered, the model will set SMFMN = 4.5.</p> <p>Required in watersheds where snowfall is significant.</p> |
| TIMP | <p>Snow pack temperature lag factor.</p> <p>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.</p> <p>If no value for TIMP is entered, the model will set TIMP = 1.0.</p> <p>Required in watersheds where snowfall is significant.</p> |
| COVMX | Minimum snow water content (mm H ₂ O) |
| COV50 | Fraction of COVMX |
| INIT_MM | Initial snow water content at start of simulation |

OPS– The OPS files contain management operations for fertilizer, pesticide, grazing, harvest, irrigation and sweep.

HARV.OPS

The inputs for grazing are found in the HARV.OPS file. 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. A sample HARV.OPS file is listed below:

| | | | | |
|--------------|---------|--------|------|--------|
| harv.ops | | | | |
| NAME | TYP | HI_OVR | EFF | BM_MIN |
| grain | grain | 0 | 0.95 | 0 |
| grass_mulch | biomass | 0.5 | 0 | 2000 |
| grass_bag | biomass | 0.5 | 1 | 2000 |
| silage | biomass | 0.9 | 0.95 | 0 |
| forest_cut | tree | 0.95 | 0.99 | 0 |
| stover_high | residue | 0.9 | 1 | 1000 |
| stover_med | residue | 0.6 | 1 | 2000 |
| stover_los | residue | 0.3 | 1 | 3000 |
| hay_cut_high | biomass | 0.8 | 1 | 3000 |
| hay_cut_low | biomass | 0.8 | 1 | 1000 |
| potatoes | tuber | 1.1 | 0.95 | 0 |
| peanuts | tuber | 1.1 | 0.95 | 0 |

| <u>Variable name</u> | <u>Definition</u> |
|-----------------------------|---|
| 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. |
| HEADER | Headings for variables |

| | |
|--------|--|
| NAME | Name of harvest operation |
| TYP | grain;biomass;residue;tree;tuber; |
| 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. |
| EFF | 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. |
| BM_MIN | minimum biomass to allow harvest (kg/ha) |

GRAZE.OPS

The inputs for grazing are found in the GRAZE.OPS file. This operation removes plant biomass at a specified rate and allows simultaneous application of manure. A sample GRAZE.OPS file is listed below:

| | | | | | | |
|-----------|----------|------|-----|-------|--------|---------|
| graze.ops | | | | | | |
| NAME | FERTNM | DAYS | EAT | TRAMP | MANURE | BIO_MIN |
| fr_gr | dairy_fr | 365 | 10 | 5 | 5 | 500 |
| fr_congr | dairy_fr | 365 | 10 | 5 | 5 | 4000 |

| <u>Variable name</u> | <u>Definition</u> |
|----------------------|---|
| 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. |
| HEADER | Headings for variables |

| | |
|---------|--|
| NAME | Name of grazing operation |
| FERTNM | Name of grazing operation from fertilizer database |
| EAT | Dry weight of biomass consumed daily ((kg/ha)/day) |
| TRAMP | 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. |
| MANURE | Dry weight of manure deposited daily ((kg/ha)/day). |
| BIO_MIN | Minimum plant biomass for grazing (kg/ha) |

IRR.OPS

The inputs for irrigation are found in the IRR.OPS file. This operation applies water to the HRU on the specified day. A sample IRR.OPS file is listed below:

| | | | | | | |
|-------------|---------|------------|-------|----------|---------|---------|
| irr.ops | | | | | | |
| IRR_OP_NAME | IRR_EFF | SURQ_RATIO | DEPTH | IRR_SALT | IRR_NO3 | IRR_PO4 |
| surface | 0.5 | 0.4 | 0 | 0 | 0 | 0 |
| sprinkler | 0.7 | 0.1 | 0 | 0 | 0 | 0 |
| drip | 0.9 | 0 | 0 | 0 | 0 | 0 |
| subsurface | 1 | 0 | 150 | 0 | 0 | 0 |

| 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. |
| HEADER | Headings for variables |
| NAME | Name of irrigation operation |
| EFF | Irrigation in-field efficiency (0-1). |
| SURQ | Surface runoff ratio (0-1). (.1 is 10% surface runoff) (fraction) |
| DEP_MM | Depth of irrigation water applied on HRU (mm). Required. |
| SALT | Concentration of salt in irrigation (mg/kg). Not currently operational. |
| NO3 | Concentration of nitrate in irrigation (mg/kg) |
| PO4 | Concentration of phosphate in irrigation |

CHEM_APP.OPS

The inputs for sweeping operations are found in the CHEM_APP.OPS file. A sample CHEM_APP.OPS file is listed below:

| chem_app.ops | | | | | | | | |
|---------------|--------|-----------|---------|------------|------------|-----------|-----------|-------------|
| PEST_OP_NAME | FORM | OPERATION | APP_EFF | FOLIAR_EFF | INJECT_DEP | SURF_FRAC | DRIFT_POT | AERIAL_UNIF |
| broadcast | solid | spread | 0.9 | 0 | 0 | 1 | 0 | 1 |
| band | solid | spread | 0.9 | 0 | 0 | 1 | 0 | 0.5 |
| foliar | liquid | spray | 0.8 | 0.7 | 0 | 1 | 0 | 1 |
| inject | liquid | inject | 0.95 | 0 | 150 | 0.2 | 0 | 1 |
| aerial_liquid | liquid | spray | 0.7 | 0.7 | 0 | 1 | 0.5 | 1 |
| aerial_solid | solid | spread | 0.9 | 0 | 0 | 1 | 0.1 | 1 |
| drill | solid | inject | 0.95 | 0 | 50 | 0.05 | 0 | 1 |
| side_dress | solid | spread | 0.9 | 0 | 0 | 1 | 0 | 0.5 |
| fertigate | liquid | spray | 0.9 | 0.5 | 0 | 1 | 0.2 | 1 |
| basal | liquid | spread | 0.9 | 0 | 0 | 1 | 0 | 0.1 |
| rope_wick | liquid | direct | 1 | 0.95 | 0 | 1 | 0 | 1 |
| tree_inject | liquid | inject | 0.95 | 0 | 300 | 0 | 0 | 0.01 |

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.

HEADER

Headings for variables

NAME

Name of chemical application operation

FORM

solid; liquid

OP_TYP

operation type-spread; spray; inject; direct

APP_EFF

application efficiency

FOLIAR_EFF

foliar efficiency

INJECT_DEP

injection depth (mm)

SURF_FRAC

surface fraction-amount in upper 10 mm

DRIFT_POT

drift potential

AERIAL_UNIF

aerial uniformity

FIRE.OPS

The inputs for sweeping operations are found in the FIRE.OPS file. A sample FIRE.OPS file is listed below:

| fire.ops | | |
|--------------|---------|-----------|
| NAME | CN2_UPD | FRAC_BURN |
| grass | 8 | 1 |
| tree_intense | 8 | 0.9 |
| tree_low | 6 | 0.7 |

| 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. |
| HEADER | Headings for variables |
| NAME | Name of fire operation |
| CN2_UPD | change in SCS curve number II value |
| FR_BURN | fraction burned |

SWEEP.OPS

The inputs for sweeping operations are found in the SWEEP.OPS file. A sample SWEEP.OPS file is listed below.

| | | |
|-------------|---------|---------|
| sweep.ops | | |
| SWP_OP_NAME | SWP_EFF | FR_CURB |
| high_eff | 0.8 | 0.9 |

| 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. |
| HEADER | Headings for the variables |
| NAME | Street sweeping operation name |
| EFF | <p>Removal efficiency of sweeping operation</p> <p>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).</p> <p>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.</p> <p>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.</p> <p>Required.</p> |
| FR_CURB | <p>Fraction of curb length available for sweeping.</p> <p>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.</p> <p>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.</p> <p>Required.</p> |

LUM – 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 (.sch). 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.

LANDUSE.LUM

Below is a sample LANDUSE.LUM FILE:

| Variable name | Definition |
|----------------------|--|
| TITLE | The first line of the landuse.lum 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. |
| HEADER | Headings for landuse.lum variables |
| NAME | Name of land use treatments/practice/conditions |
| CAL_GRP | Calibration group |
| PLANT_COV | Plant cover (points to plant.ini file) |
| MGT_OPS | Management operation (points to management.sch file) |

CN_LU

(points to cntable.lum file)

Landuse curve number identifier (from table)

Table 19d-1: Runoff Curve Numbers for Cultivated Agricultural Lands

| CN_LU | COVER | |
|-------|------------------------|--------------------------------|
| | LANDUSE | TREATMENT/PRACTICE |
| 1 | Fallow | Bare soil |
| 2 | 6677 | Crop residue cover* |
| 3 | 6677 | |
| 4 | Row crops Straight row | |
| 5 | 6677 | |
| 6 | 6677 | Straight row w/residue |
| 7 | 6677 | |
| 8 | 6677 | Contoured |
| 9 | 6677 | |
| 10 | 6677 | Contoured w/residue |
| 11 | 6677 | |
| 12 | 6677 | Contoured & Terraced |
| 13 | 6677 | |
| 14 | 6677 | Contoured & Terraced w/residue |
| 15 | 6677 | |
| 15 | Small grains | Straight Row |
| 16 | 6677 | |
| 17 | 6677 | Straight Row w/residue |
| 18 | 6677 | |
| 19 | 6677 | Contoured |
| 20 | 6677 | |
| 21 | 6677 | Contoured w/residue |
| 22 | 6677 | |
| 23 | 6677 | Contoured & Terraced |
| 24 | 6677 | |
| 25 | 6677 | Contoured & Terraced w/residue |
| 26 | 6677 | |

Runoff Curve Numbers for Other Agricultural Lands

| CN_LU | COVER | | HYDROLOGIC COND | AVERAGE % IMPERVIOUS AREA | Hydrologic Soil Group |
|-------|---|--|--------------------|------------------------------|-----------------------|
| | COVER TYPE | | | | |
| 27 | Pasture, grassland or range | | | | |
| 28 | continuous forage for grazing ¹ | | | | |
| 29 | 6677 | | | | |
| 30 | Meadow-continuous grass, protected from grazing | | | | |
| | and general mowed for hay | | | | |
| 31 | Brush—brush-weed-grass mixture with brush | | | | |
| | the major element ² | | | | |
| 32 | 6677 | | | | |
| 33 | 6677 | | | | |
| 34 | Woods-grass combination | | | | |
| | (orchard or tree farm) | | | | |
| 35 | 6677 | | | | |
| 36 | 6677 | | | | |
| 37 | Woods ³ | | | | |
| 38 | 6677 | | | | |
| 39 | 6677 | | | | |
| 40 | Farmsteads-building, lanes, driveways | | | | |
| | and surrounding lots | | | | |

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

¹ *Poor*: < 50% ground cover or heavily grazed with no mulch; *Fair*: 50 to 75% ground cover and lightly or only occasionally grazed² *Poor*: < 50% ground cover; *Fair*: 50 to 75% ground cover; *Good*: > 75%³ *Poor*: Forest litter, small trees, and brush are destroyed by heavy grazing or burned, and some forest litter covers the soil; *Good*: Woods are protected from soil.

| | |
|-----------|--|
| CONS_PRAC | USLE equation support practice (P) factor (points to cons_practice.lum file) |
| URB_LU | Urban land use (points to urban.urb file) |
| URB_RO | usgs_reg buildup_washoff Urban simulation runoff code: USGS_REG - simulate using USGS regression equations Build up/wash off – simulate using build up washoff 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). |
| OVN | Manning’s “n” value for overland flow (points to ovn_table.lum) |
| TILEDRAIN | Tile drain file name (points to tiledrain.str) |
| SEPTIC | Septic tank file name (points to septic.str) |
| FSTRIP | Filter strip file name (points to filterstrip.str) |
| GRASSWW | Grassed waterways file name (points to |
| BMPUSER | Best management practices file name |

MANAGEMENT.SCH

The inputs management operations are found in the MANAGEMENT.SCH file. A sample MANAGEMENT.SCH file is listed below:

| | | | | | | | | | |
|----------------|---------|----|-----|-----|------|---------|---------|---------|------------------|
| management.sch | | | | | | | | | |
| NAME | NUM_OPS | OP | MON | DAY | HUSC | OP_DATA | OP_METH | OP_OVER | |
| csoy_ai_nt | 7 | 1 | | | | | | | |
| autoirr_str.8 | | | | | | | | | |
| fert | | | 0 | 0 | 0.14 | anh-nh3 | inject | 200 | FERTILIZER |
| plnt | | | 0 | 0 | 0.15 | corn | null | 0 | PLANT CORN BEGIN |
| hvkl | | | 10 | 30 | 1.2 | corn | grain | 0 | HARVKILL |
| skip | | | 0 | 0 | 0 | null | null | 0 | SKIP_YEAR |
| plnt | | | 0 | 0 | 0.15 | soyb | null | 0 | PLANT SOYBEANS |
| hvkl | | | 10 | 30 | 1.2 | soyb | grain | 0 | HARVKILL |
| skip | | | 0 | 0 | 0 | null | null | 0 | SKIP_YEAR |
| canary_nomgt | | | 0 | 0 | | | | | |

SWAT will simulate different types of management operations. 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:

| | |
|------|---|
| PCO | plant community: this operation initializes the plant community in the HRU |
| PLNT | planting/beginning of growing season: this operation initializes the growth of a specific land cover/plant type in the HRU |
| HARV | 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. |
| HVKL | 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. |
| TILL | tillage operation: this operation mixes the upper soil layers and redistributes the nutrients/chemicals/etc. within those layers |
| IRRM | irrigation operation: this operation applies water to the HRU on the specified day. (IRROPS.DAT) |
| FERT | fertilizer application: this operation adds nutrients to the soil in the HRU on the specified day (FERTOPS.DAT) |
| PEST | pesticide application: this operation applies a pesticide to the plant and/or soil in the HRU on the specified day |
| GRAZ | grazing operation: this operation removes plant biomass at a specified rate and allows simultaneous application of manure. |
| BURN | burn operation: the burn operation records the biomass, residue and phosphorus that is burned. |
| SWEP | 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). |
| SKIP | skip operation: this operation skips to the end of the year. |

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

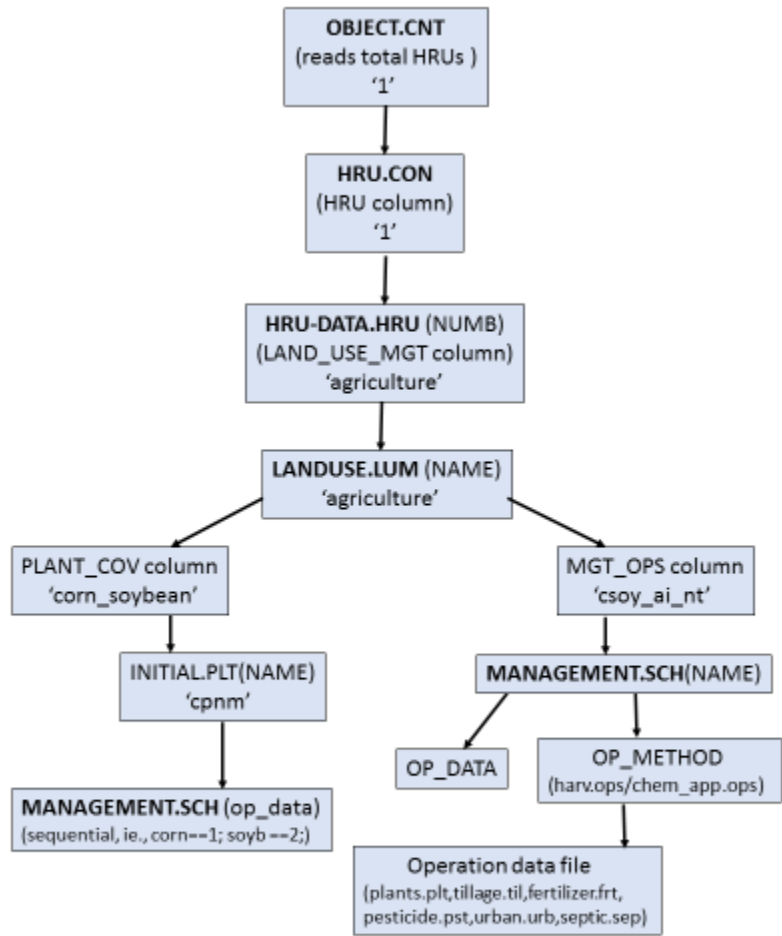
For simulations where a certain amount of crop yield and biomass is required, the user can force the model to meet this amount by setting a harvest index target and a biomass target. These targets are effective only if a harvest and kill operation is used to harvest the crop. Variables are listed below.

| Variable name | Definition |
|---------------|--|
| TITLE | Title for the management.sch file. Optional (may be blank) |
| HEADER | Header for the management.sch variables |
| NAME | Name of the operations |
| NUM_OPS | Number of operations following |
| NUM_AUTOS | Number of auto schedule |
| OP | <p>Management operation name:</p> <p>pcom = plant community</p> <p>plnt = beginning of growing season</p> <p>harv = harvests the portion of the plant designated as yield and removes the yield from the HRU, but allows the plant to continue to grow.</p> <p>hvk1 = 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.</p> <p>till = mixed the upper soil layers and redistributes the nutrients/chemicals, etc within those layers</p> <p>irrm = applies water to the HRU on the specified day</p> <p>fert = adds nutrients to the soil in the specified day</p> <p>pest = applies a pesticide to the plant and/or soil in the HRU on a specified day</p> <p>graz = removes plant biomass at a specified rate and allows simultaneous application of manure</p> <p>burn = burning</p> <p>swep = 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)</p> <p>skip</p> |
| MON | <p>Month operation takes place.</p> <p>Either MONTH/DAY or HUSC is required.</p> |
| DAY | <p>Day operation takes place.</p> <p>Either MONTH/DAY or HUSC is required.</p> |
| HUSC | <p>Fraction of total base zero heat units at which operation takes place.</p> <p>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.</p> <p>Either MONTH/DAY or HUSC is required.</p> |

| | |
|-----------|--------------------------|
| OP_DATA | Operation type character |
| OP_METHOD | Plant name in community |
| OP_OVER | Harvest index override |

Further explanation of management.sch file:

| management.sch | | | | |
|----------------|------------------------|----------------|--------------------------|--------------|
| OP | OP_DATA from file ---> | | OP_METHOD from file ---> | |
| plnt | cots | initial.plt | null | |
| harv | corn | initial.plt | grain | harv.ops |
| kill | | | | |
| hvk1 | soyb | initial.plt | grain | harv.ops |
| till | riprsubs | tillage.til | | till.ops |
| irrm | | | drip | irr.ops |
| fert | anh-nh3 | fertilizer.frt | broadcast | chem_app.ops |
| pest | aatrex | pesticide.pst | inject | chem_app.ops |
| graz | | | | graze.ops |
| burn | | | | fire.ops |
| swep | | | | sweep.ops |
| skip | | | | |
| mons | | | | |
| dwm | | | | |



OBJECT.CNT FILE

object.cnt: Spatial object counts – (2-stage)

| OBJ | HRU | LTE | SUB | MODFL | AQU | CHA | RES | REC | EXCO | DR | CANAL | PUMP | OUT | CHDEG | 2DAQU | |
|-----|-----|-----|-----|-------|-----|-----|-----|-----|------|----|-------|------|-----|-------|-------|---|
| 4 | 1 | 0 | 0 | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |

HRU.CON FILE

hru.con (2-stage)

| NUMB | NAME | AREA | LAT | LONG | ELEV | HRU | WST | CON_TYP | OVERFLOW | RULESET | OUT_TOT |
|------|-------|-------|-------|-------|-------|-----|------|---------|----------|---------|---------|
| 1 | bench | 0.480 | 0.000 | 0.000 | 0.000 | 1 | wea1 | 0 | 0 | 0 | 0 |

HRU-DATA.HRU

hru-data.hru: HRU properties – (2-stage)

| NUM | NAM | TOPO | HYD | SOIL | LU_MGT | SOLN_INI | SURF_STOR | SNOW | FLD | SCH_UPD |
|-----|------------|----------|------------|-------|--------------------|----------|-----------|--------|------|---------|
| 1 | hru0010104 | hru00101 | hru0010104 | IN025 | agriculture | IN025 | null | snow01 | null | null |

LANDUSE LUM: General land use properties (2-stage - partial file)

| NAME | CAL_GRP | PLNT_COV | MGT_OPS | CN_LU | CONS_PRAC |
|--------------------|---------|---------------------|-------------------|---------------|---------------|
| forestmixed | null | frst_mixed | null | wood_f | up_down_slope |
| pasture | null | pasture | null | pasth | up_down_slope |
| agriculture | null | corn_soybean | csoy_ai_nt | rc_strowres_p | up_down_slope |
| urban | null | urban_residential | null | urban | up_down_slope |
| fpbench | null | canary_grass | canary_nomgt | pasth | up_down_slope |

MANAGEMENT.SCH: Management schedules – (2-stage)

| NAME | NUM_OPS | OP | MON | DAY | HUSC | OP_DATA | OP_METHOD | OP_OVER |
|-------------------|---------|---------------|-----|-----|-------|---------|-----------|-----------------|
| csoy_ai_nt | 7 | 1 | | | | | | |
| | | autoirr_str.8 | | | | | | |
| | | fert | 0 | 0 | 0.140 | anh-nh3 | inject | 200. FERTILIZER |
| | | plnt | 0 | 0 | 0.150 | corn | null | 0.0 PLNT CORN |
| | | hvkl | 10 | 30 | 1.200 | corn | grain | 0.0 HARVKILL |
| | | skip | 0 | 0 | 0.000 | null | null | 0.0 SKIP_YEAR |
| | | plnt | 0 | 0 | 0.150 | soyb | null | 0.0 PLNT SOYB |
| | | hvkl | 10 | 30 | 1.200 | soyb | grain | 0.0 HARVKILL |
| | | skip | 0 | 0 | 0.000 | null | null | 0.0 SKIP_YEAR |
| canary_nomgt | 0 | | 0 | | | | | |

CNTABLE.LUM

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.

Below is the CNTABLE.LUM FILE:

| cntable.lum | | | | | | | |
|----------------|------|------|------|------|--|--------------------------------|----------|
| LANDUSE | CN_A | CN_B | CN_C | CN_D | LANDUSE_DESCRIPTION | TREATMENT | CONDITIO |
| fal_bare | 77 | 86 | 91 | 94 | Fallow | Bare_soil | ---- |
| fal_res_p | 76 | 85 | 90 | 93 | Fallow | Crop_residue_cover | Poor |
| fal_res_g | 74 | 83 | 88 | 90 | Fallow | Crop_residue_cover | Good |
| rc_strow_p | 72 | 81 | 88 | 91 | Row_crops | Straight_row | Poor |
| rc_strow_g | 67 | 78 | 85 | 89 | Row_crops | Straight_row | Good |
| rc_strowres_p | 71 | 80 | 87 | 90 | Row_crops | Straight_row_w_residue | Poor |
| rc_strowres_g | 64 | 75 | 82 | 85 | Row_crops | Straight_row_w_residue | Good |
| rc_cont_p | 70 | 79 | 84 | 88 | Row_crops | Contoured | Poor |
| rc_cont_g | 65 | 75 | 82 | 86 | Row_crops | Contoured | Good |
| rc_contres_p | 69 | 78 | 83 | 87 | Row_crops | Contoured_w_residue | Poor |
| rc_contres_g | 64 | 74 | 81 | 85 | Row_crops | Contoured_w_residue | Good |
| rc_contter_p | 66 | 74 | 80 | 82 | Row_crops | Contoured_&_terraced | Poor |
| rc_contter_g | 62 | 71 | 78 | 81 | Row_crops | Contoured_&_terraced | Good |
| rc_conterres_p | 65 | 73 | 79 | 81 | Row_crops | Contoured_&_terraced_w_residue | Poor |
| rc_conterres_g | 61 | 70 | 77 | 80 | Row_crops | Contoured_&_terraced_w_residue | Good |
| sg_strow_p | 65 | 76 | 84 | 88 | Small_grains | Straight_row | Poor |
| sg_strow_g | 63 | 75 | 83 | 87 | Small_grains | Straight_row | Good |
| sg_strowres_p | 64 | 75 | 83 | 86 | Small_grains | Straight_row_w_residue | Poor |
| sg_strowres_g | 60 | 72 | 80 | 84 | Small_grains | Straight_row_w_residue | Good |
| sg_cont_p | 63 | 74 | 82 | 85 | Small_grains | Contoured | Poor |
| sg_cont_g | 61 | 73 | 81 | 84 | Small_grains | Contoured | Good |
| sg_contres_p | 62 | 73 | 81 | 84 | Small_grains | Contoured_w_residue | Poor |
| sg_contres_g | 60 | 72 | 80 | 83 | Small_grains | Contoured_w_residue | Good |
| sg_contter_p | 61 | 72 | 79 | 82 | Small_grains | Contoured_&_terraced | Poor |
| sg_contter_g | 59 | 70 | 78 | 81 | Small_grains | Contoured_&_terraced | Good |
| sg_conterres_p | 60 | 71 | 78 | 81 | Small_grains | Contoured_&_terraced_w_residue | Poor |
| sg_conterres_g | 58 | 69 | 77 | 80 | Small_grains | Contoured_&_terraced_w_residue | Good |
| legr_strow_p | 66 | 77 | 85 | 89 | Close-seeded_or_broadcast_legumes_or_rotation | Straight_row | Poor |
| legr_strow_g | 58 | 72 | 81 | 85 | Close-seeded_or_broadcast_legumes_or_rotation | Straight_row | Good |
| legr_cont_p | 64 | 75 | 83 | 85 | Close-seeded_or_broadcast_legumes_or_rotation | Contoured | Poor |
| legr_cont_g | 55 | 69 | 78 | 83 | Close-seeded_or_broadcast_legumes_or_rotation | Contoured | Good |
| legr_contter_p | 63 | 73 | 80 | 83 | Close-seeded_or_broadcast_legumes_or_rotation | Contoured_&_terraced | Poor |
| legr_contter_g | 51 | 67 | 76 | 80 | Close-seeded_or_broadcast_legumes_or_rotation | Contoured_&_terraced | Good |
| pastg_p | 68 | 79 | 86 | 89 | Pasture_grassland_or_range-continuous_forage_for_grazing | ---- | Poor |
| pastg_f | 49 | 69 | 79 | 84 | Pasture_grassland_or_range-continuous_forage_for_grazing | ---- | Fair |
| pastg_g | 39 | 61 | 74 | 80 | Pasture_grassland_or_range-continuous_forage_for_grazing | ---- | Good |
| pasth | 30 | 58 | 71 | 78 | Meadow-continuous_grass_protected_from_grazing_mowed_for_hay | ---- | ---- |
| brush_p | 48 | 67 | 77 | 83 | Brush-brush-weed-grass_mixture_with_brush_the_major_element | ---- | Poor |
| brush_f | 35 | 56 | 70 | 77 | Brush-brush-weed-grass_mixture_with_brush_the_major_element | ---- | Fair |
| brush_g | 30 | 48 | 65 | 73 | Brush-brush-weed-grass_mixture_with_brush_the_major_element | ---- | Good |
| woodgr_p | 57 | 73 | 82 | 86 | Woods-grass_combination_(orchard_or_tree_farm) | ---- | Poor |
| woodgr_f | 43 | 65 | 76 | 82 | Woods-grass_combination_(orchard_or_tree_farm) | ---- | Fair |
| woodgr_g | 32 | 58 | 72 | 79 | Woods-grass_combination_(orchard_or_tree_farm) | ---- | Good |
| wood_p | 45 | 66 | 77 | 83 | Woods | ---- | Poor |
| wood_f | 36 | 60 | 73 | 79 | Woods | ---- | Fair |
| wood_g | 30 | 55 | 70 | 77 | Woods | ---- | Good |
| farm | 59 | 74 | 82 | 86 | Farmsteads-buildings_lanes_driveways_and_surrounding_lots | ---- | ---- |
| open_p | 68 | 79 | 86 | 89 | Open_spaces_(lawns_parks_golfcourses_cemeteries_etc.) | ---- | Poor |
| urban | 98 | 98 | 98 | 98 | Paved_parking_lots_roofs_driveways_etc_(excl_right-of-way) | ---- | ---- |
| paveroad | 83 | 89 | 92 | 93 | Paved_streets_and_roads;_open_ditches_(incl_right-of-way) | ---- | ---- |
| gravroad | 76 | 85 | 89 | 91 | Gravel_streets_and_roads_(including_right-of-way) | ---- | ---- |
| dirtroad | 72 | 82 | 87 | 89 | Dirt_streets_and_roads_(including_right-of-way) | ---- | ---- |

| Variable name | Definition |
|----------------------|--|
| TITLE | The first line of the cntable.lum 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. |
| HEADER | Headings for cntable.lum variables |
| NAME | Name of land use treatments/practice/conditions |
| CNA | Land use curve number A |
| CNB | Land use curve number B |
| CNC | Land use curve number C |
| CND | Land use curve number D |
| | Land use description follows (not read by model) |

CONS PRACTICE.LUM

Below is a sample CONS_PRACTICE.LUM FILE:

| | | | |
|-------------------|----------|---------------|--|
| cons_practice.lum | | | |
| NAME | P_FACTOR | SLOPE_LEN_MAX | DESCRIPTION |
| up_down_slope | 1 | 121 | Up_and_down_slope |
| cross_slope | 0.75 | 121 | Cross_slope_tillage |
| contour_farming | 0.5 | 121 | Contour_tillage |
| strip_cros_slope | 0.37 | 121 | Strip_cropping_cross_slope |
| strip_contour | 0.25 | 121 | Strip_cropping_contour |
| contour_1-2 | 0.3 | 121 | Contour_tillage_1-2%_slopes |
| contour_3-5 | 0.5 | 91 | Contour_tillage_3-5%_slopes |
| contour_6-8 | 0.5 | 61 | Contour_tillage_6-8%_slopes |
| contour_9-12 | 0.6 | 36 | Contour_tillage_9-12%_slopes |
| contour_13-16 | 0.7 | 24 | Contour_tillage_13-16%_slopes |
| contour_17-20 | 0.8 | 18 | Contour_tillage_17-20%_slopes |
| contour_21-25 | 0.9 | 15 | Contour_tillage_21-25%_slopes |
| strip_1-2_past | 0.3 | 244 | Strip_cropping_1-2%_slopes_with-pasture |
| strip_1-2_row | 0.6 | 244 | Strip_cropping_1-2%_slopes_with-rowcrops |
| strip_3-5_past | 0.25 | 183 | Strip_cropping_3-5%_slopes_with-pasture |
| strip_3-5_row | 0.5 | 183 | Strip_cropping_3-5%_slopes_with-rowcrops |
| strip_6-8_past | 0.25 | 122 | Strip_cropping_6-8%_slopes_with-pasture |
| strip_6-8_row | 0.5 | 122 | Strip_cropping_6-8%_slopes_with-rowcrops |
| strip_9-12_past | 0.3 | 73 | Strip_cropping_9-12%_slopes_with-pasture |
| strip_9-12_row | 0.6 | 73 | Strip_cropping_9-12%_slopes_with-rowcrops |
| strip_13-16_past | 0.35 | 49 | Strip_cropping_13-16%_slopes_with-pasture |
| strip_13-16_row | 0.7 | 49 | Strip_cropping_13-16%_slopes_with-rowcrops |
| strip_17-20_past | 0.4 | 36 | Strip_cropping_17-20%_slopes_with-pasture |
| strip_17-20_row | 0.8 | 36 | Strip_cropping_17-20%_slopes_with-rowcrops |
| strip_21-25_past | 0.45 | 30 | Strip_cropping_21-25%_slopes_with-pasture |
| strip_21-25_row | 0.9 | 30 | Strip_cropping_21-25%_slopes_with-rowcrops |
| ter_1-2_sodout | 0.12 | 121 | terraces_1-2%_slopes_sod-outlet |
| ter_1-2_undout | 0.05 | 121 | terraces_1-2%_slopes_underflow-outlet |
| ter_3-8_sodout | 0.5 | 76 | terraces_3-8%_slopes_sod-outlet |
| ter_3-8_undout | 0.25 | 76 | terraces_3-8%_slopes_underflow--outlet |
| ter_9-12_sodout | 0.6 | 61 | terraces_9-12%_slopes_sod-outlet |
| ter_9-12_undout | 0.3 | 61 | terraces_9-12%_slopes_underflow--outlet |
| ter_13-16_sodout | 0.7 | 45 | terraces_13-16%_slopes_sod-outlet |
| ter_13-16_undout | 0.35 | 45 | terraces_13-16%_slopes_underflow--outlet |
| ter_17-20_sodout | 0.8 | 45 | terraces_17-20%_slopes_sod-outlet |
| ter_17-20_undout | 0.4 | 45 | terraces_17-20%_slopes_underflow--outlet |
| ter_21-25_sodout | 0.9 | 30 | terraces_21-25%_slopes_sod-outlet |
| ter_21-25_undout | 0.45 | 30 | terraces_21-25%_slopes_underflow--outlet |

| Variable name | Definition |
|---------------|--|
| TITLE | The first line of the cons_practice.lum 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. |
| HEADER | Headings for cons_practice.lum variables |
| NAME | Name of conservation practice |
| PFAC | Usle P factor |
| SL_LEN_MX | Maximum slope length (m) |

OVN_TABLE.LUM

Below is a sample OVN_TABLE.LUM FILE:

| ovn_table.lum: | | | | |
|-----------------|--------|-------|-------|---------------------------------|
| OVN_ID | MANN_N | MIN | MAX | DESCRIPTION |
| fallow_nores | 0.01 | 0.008 | 0.012 | Fallow_no_residue |
| convtill_nores | 0.09 | 0.06 | 0.12 | Conventional_tillage_no_residue |
| convtill_res | 0.19 | 0.16 | 0.22 | Conventional_tillage_residue |
| chisplow_nores | 0.09 | 0.06 | 0.12 | Chisel_plow_no_residue |
| chisplow_res | 0.13 | 0.1 | 0.16 | Chisel_plow_residue |
| falldisk_res | 0.4 | 0.3 | 0.5 | Fall_disking_residue |
| notill_nores | 0.07 | 0.04 | 0.1 | No_till_no_residue |
| notill_0.5-1res | 0.12 | 0.07 | 0.17 | No_till_0.5-1_t/ha_residue |
| notill_2-9res | 0.3 | 0.17 | 0.47 | No_till_2-9_t/ha_residue |
| range_sparse | 0.13 | 0.13 | 0.13 | Rangeland_sparse_cover |
| range_20cover | 0.6 | 0.6 | 0.6 | Rangeland_20%_cover |
| shortgrass | 0.15 | 0.1 | 0.2 | Short_grass_prairie |
| densegrass | 0.24 | 0.17 | 0.3 | Dense_grass |
| bermudagrass | 0.41 | 0.3 | 0.48 | Bermudagrass |
| forest_light | 0.4 | 0.3 | 0.5 | Forest_light_fair |
| forest_med | 0.6 | 0.5 | 0.7 | Forest_medimum_good |
| forest_heavy | 0.8 | 0.7 | 0.9 | Forest_heavy |
| urban_asphalt | 0.11 | 0.11 | 0.11 | Urban_asphalt |
| urban_concrete | 0.012 | 0.012 | 0.012 | Urban_concrete |
| urban_rubble | 0.024 | 0.024 | 0.024 | Urban_rubble |

| Variable name | Definition |
|---------------|--|
| TITLE | The first line of the ovn_table.lum 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. |
| HEADER | Headings for ovn_table.lum variables |
| NAME | Name of conservation practice |
| OVN | Overland flow mannings n – mean |
| OVN_MIN | Overland flow mannings n – min |
| OVN_MAX | Overland flow mannings n - max |

CHG – The change section includes the files for calibration simulation runs in SWAT+.

SOFT CALIBRATION:

The soft calibration requires 10-12 simulations and is a simple, heuristic, one-at-a-time procedure. Each process has one or two parameters and each is looped through a couple of times. After the soft calibration is complete, the hard (daily gage) calibration should only require some adjustments of the peaks and recessions. Three files are needed for soft calibration of the water balance:

1) codes.sft

You can turn the water balance soft calibration on (“y”) and off (“n”) in the HYD_HRU column. The others are still a work in progress.

| | | | | | | | |
|-----------|------------|-----|-----|-----|-------|-------|-----|
| codes.sft | | | | | | | |
| HYD_HRU | HYD_HRULTE | PLT | SED | NUT | CHSED | CHNUT | RES |
| n | n | n | n | n | n | n | n |

2) wb_parms.sft

Shows all the parameters that can be used with max/min ranges and max/min absolute values. It is fixed and you shouldn't have to change it.

| | | | | | | |
|--------------|---------|------|-----|--------|-----|------|
| wb_parms.sft | | | | | | |
| 10 | | | | | | |
| NAME | CHG_TYP | NEG | POS | LO | UP | |
| cn2 | abschg | -8 | 8 | 35 | 95 | |
| esco | abschg | -1 | 1 | 0 | 1 | |
| lat_len | pctchg | -30 | 30 | 5 | 200 | m |
| k_lo | pctchg | -99 | 30 | 0.0001 | 500 | mm/h |
| slope | pctchg | -25 | 25 | 0.0001 | 0.9 | m/m |
| tconc | pctchg | -30 | 30 | 5 | 960 | min |
| etco | abschg | -0.4 | 0.4 | 0.8 | 1.2 | |
| perco | abschg | -0.8 | 0.8 | 0 | 1 | |
| revapc | abschg | -0.4 | 0.4 | 0 | 0.4 | |
| cn3_swf | abschg | -1.2 | 1.2 | -0.2 | 1 | |

3) water_balance.sft

gives each component of the water balance we are soft calibrating as a fraction of precipitation.

| | | | | | | | | | | | |
|-------------------|------|------|------|-----|-----|-----|------|------|-----|------|--|
| water_balance.sft | | | | | | | | | | | |
| 1 | | | | | | | | | | | |
| NAME | NLUM | | | | | | | | | | |
| basin | 1 | | | | | | | | | | |
| NAME | SRR | LFR | PCR | ETR | TFR | SED | ORGN | ORGP | NO3 | SOLP | |
| null | 0.1 | 0.05 | 0.05 | 0.7 | 0.1 | 0.1 | 0 | 0 | 0 | 0 | |

CAL_PARMS.CAL

The CAL_PARMS.CAL file contains the input variables for the characteristics of the calibration update properties. Below is a partial sample CAL_PARMS.CAL file:

| | | | | |
|---------------|---------|--------|--------|--------|
| cal_parms.upd | | | | |
| 187 | | | | |
| NAME | OBJ_TYP | ABSMIN | ABSMAX | UNITS |
| cn2 | hru | 25 | 98 | null |
| usle_p | hru | 0 | 1 | null |
| ovn | hru | 0.01 | 30 | null |
| elev | hru | 0 | 5000 | m |
| slope | hru | 0 | 1 | m/m |
| slope_len | hru | 10 | 150 | m |
| lat_ttime | hru | 0 | 180 | days |
| lat_sed | hru | 0 | 5000 | g/L |
| lat_len | hru | 0 | 150 | m |
| canmx | hru | 0 | 100 | mm/H2O |
| esco | hru | 0 | 1 | null |
| epco | hru | 0 | 1 | null |
| erorgn | hru | 0 | 5 | null |
| erorgp | hru | 0 | 5 | null |
| dis_stream | hru | 0 | 100000 | m |
| biomix | hru | 0 | 1 | null |

Variable name**Definition**

| | |
|----------|--|
| TITLE | The first line of the cal_parms.cal 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. |
| MCHG_PAR | Maximum number of calibration parm changes |
| HEADER | Headings for cal_parms.cal variables |
| NAME | cn2, esco, awc, etc. |
| OB_TYP | object type the parameter is associated with (hru, chan, res, basin, etc) |
| ABSMIN | minimum range for variable |
| ABSMAX | maximum change for variable |
| UNITS | units used for each parameter |

CALIBRATION.CAL

The CALIBRATION.CAL file contains the input variables for the characteristics of the calibration update properties. Below is a partial sample CALIBRATION.CAL file:

| | | | | | | | | | | | | | | | | | |
|-----------------|----------|-----|-------|------|------|-------|-------|------|------|---------|---|----|---|----|----|-----|--|
| calibration.cal | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | |
| NAME | CHG_TYPE | VAL | CONDS | LYR1 | LYR2 | YEAR1 | YEAR2 | DAY1 | DAY2 | OBJ_TOT | | | | | | | |
| k | pctchg | 25 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| k | pctchg | 20 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| k | pctchg | 20 | 0 | 4 | 6 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| k | pctchg | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| k | pctchg | 25 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| hsg | = | 0 | D | | | | | | | | | | | | | | |
| k | pctchg | 25 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| texture | = | 0 | fsl | | | | | | | | | | | | | | |
| k | pctchg | 25 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| texture | = | 0 | fsl | | | | | | | | | | | | | | |
| landuse | = | 0 | past | | | | | | | | | | | | | | |
| k | pctchg | 25 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 6 | 1 | -3 | 4 | -8 | 12 | -15 | |
| texture | = | 0 | FSL | | | | | | | | | | | | | | |
| landuse | = | 0 | past | | | | | | | | | | | | | | |
| k | pctchg | 25 | 1 | 1 | 10 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| slope | < | 10 | | | | | | | | | | | | | | | |
| t_opt | abschg | 12 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| plant | = | 0 | corn | | | | | | | | | | | | | | |

calibration.cal file continued:

| | | | | | | | | | | | | | | | | |
|---------|--------|-------|--------|---|---|------|------|-----|-----|---|---|----|--|--|--|--|
| pltnfr1 | absval | 0.003 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | |
| plant | = | 0 | grsg | | | | | | | | | | | | | |
| wsol | pctchg | -50 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | |
| pest | = | 0 | 245-tp | | | | | | | | | | | | | |
| pcp | pctchg | 10 | 0 | 0 | 0 | 1977 | 1977 | 300 | 300 | 1 | 1 | | | | | |
| pcp | pctchg | 10 | 0 | 0 | 0 | 1977 | 1977 | 300 | 300 | 2 | 1 | -3 | | | | |
| pcp | pctchg | 10 | 0 | 0 | 0 | 1977 | 1977 | 300 | 301 | 0 | | | | | | |
| pcp | pctchg | 10 | 0 | 0 | 0 | 1977 | 1977 | 1 | 361 | 0 | | | | | | |
| pcp | pctchg | 10 | 0 | 0 | 0 | 1978 | 1978 | 1 | 365 | 0 | | | | | | |
| pcp | pctchg | 10 | 0 | 0 | 0 | 1979 | 1979 | 3 | 3 | 0 | | | | | | |
| tmp | pctchg | 5 | 0 | 0 | 0 | 1977 | 1977 | 1 | 1 | 1 | 1 | | | | | |
| tmp | pctchg | 5 | 0 | 0 | 0 | 1977 | 1977 | 2 | 7 | 1 | 2 | | | | | |
| tmp | pctchg | 5 | 1 | 0 | 0 | 1977 | 1977 | 2 | 7 | 0 | | | | | | |

| | |
|----------|--|
| TITLE | The first line of the calibration.cal 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. |
| MCAL | Total number of calibration updates in the file |
| NAME | Name of SWAT+ variable (NAME column from cal_parms.upd file) |
| CHG_TYPE | Type of change ('absval', 'abschg', 'pctchg') <ol style="list-style-type: none"> 1. "absval" changes the value of the parameter to the specified value (VAL) 2. "abschg" changes the value of the parameter by abschg. For example, if VAL = -3 under abschg conditions, a condition II curve number of 80 would be changed to 77. 3. "pctchg" changes the parameter by a percentage. For example, if VAL = 5%, a condition II curve number of 80 would be changed to 84. |
| VAL | Value of change |
| CONDS | Calibration parameters can be conditioned on several variables to determine which hru's to apply the changes. Conditions include hydrologic soil group ("hsg"), "texture", "landuse" and "region". Each hru is checked to determine if they match the condition and the change is made to the parameter. Multiple conditions can be applied to each variable. |
| LYR1 | Soil variables can be conditioned by soil layer. For example, if only the first two layers are updated, LYR1=1 and LYR2=2. To make changes applicable to soils with variable number of layers, LYR1=0 assumes layer 1 and LYR2 assumes the last layer. |
| LYR2 | (see definition for LYR1) |
| YEAR1 | These variables are used to update climate data. For example, YEAR1=1977, YEAR2=1978, DAY1=1 and DAY2=365. Precipitation or temperature values will be changed by the specified amount for every day from January1, 1977 through December 31, 1978. |
| YEAR2 | (see definition for YEAR1) |
| DAY1 | (see definition for YEAR1) |
| DAY2 | (see definition for YEAR1) |

| | |
|-----------|---|
| OBJ_TOT | The objects to apply the changes can be set using conditions, or they can be specified using OBJ_TOT. the first number in OBJ_TOT is the total number of objects to read. If OBJ_TOT=0, then all objects (ie: hru) are changed. The example shown in the calibration.cal file: 6 1 -3 4 -8 12 -15 would change hru's 1,2,3,4,5,6,7,8,12,13,14 and 15. This allows the changing of specific hru's or easily change all the hru's in a particular subbasin. |
| ELEM_CNT1 | Elements modified |

CODES.SFT

The CODES.SFT file contains the input variables for the characteristics of the calibration update properties. Below is a sample CODES.SFT file:

| | | | | | | | |
|-----------|------------|-----|-----|-----|-------|-------|-----|
| codes.sft | | | | | | | |
| HYD_HRU | HYD_HRULTE | PLT | SED | NUT | CHSED | CHNUT | RES |
| n | n | n | n | n | n | n | n |

| Variable name | Definition |
|---------------|--|
| TITLE | The first line of the codes.sft 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. |
| HEADER | Headings for codes.sft variables |
| HYD_HRU | if y, calibrate hydrologic balance for hru by land use in each region |
| HYD_HRU1 | if y, calibrate hydrologic balance for hru_lte by land use in each region |
| PLT | if y, calibrate plant growth by land use (by plant) in each region |
| SED | if y, calibrate sediment yield by land use in each region |
| NUT | if y, calibrate nutrient balance by land use in each region |
| CHSED | if y, calibrate channel widening and bank accretion by stream order |
| CHNUT | if y, calibrate channel nutrient balance by stream order |
| RES | if y, calibrate reservoir budgets by reservoir |

WB_PARMS.SFT

The WB_PARMS.SFT file contains the input variables for the characteristics of the calibration parameter properties. Below is a sample WB_PARMS.SFT file:

| | | | | | | |
|--------------|---------|------|-----|--------|-----|------|
| wb_parms.sft | | | | | | |
| 10 | | | | | | |
| NAME | CHG_TYP | NEG | POS | LO | UP | |
| cn2 | abschg | -8 | 8 | 35 | 95 | |
| esco | abschg | -1 | 1 | 0 | 1 | |
| lat_len | pctchg | -30 | 30 | 5 | 200 | m |
| k_lo | pctchg | -99 | 30 | 0.0001 | 500 | mm/h |
| slope | pctchg | -25 | 25 | 0.0001 | 0.9 | m/m |
| tconc | pctchg | -30 | 30 | 5 | 960 | min |
| etco | abschg | -0.4 | 0.4 | 0.8 | 1.2 | |
| perco | abschg | -0.8 | 0.8 | 0 | 1 | |
| revapc | abschg | -0.4 | 0.4 | 0 | 0.4 | |
| cn3_swf | abschg | -1.2 | 1.2 | -0.2 | 1 | |

| Variable name | Definition |
|---------------|---|
| TITLE | The first line of the ls_parms.cal 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. |
| MLSP | Total number of parameter updates in the file |
| NAME | Name of SWAT+ variable (NAME column from cal_parms.upd file) |
| CHG_TYPE | Type of change ('absval', 'abschg', 'pctchg') |
| NEG | Negative limit of change |
| POS | Positive limit of change |
| LO | Lower limit of parameter |
| UP | Upper limit of parameter |

WATER_BALANCE.SFT

The WATER_BALANCE.SFT file contains the input variables for the characteristics of land use regions parameter properties for HRUs. Below is a sample WATER_BALANCE.SFT file:

| | | | | | | | | | | |
|-------------------|------|------|------|-----|-----|-----|------|------|-----|------|
| water_balance.sft | | | | | | | | | | |
| 1 | | | | | | | | | | |
| NAME | NLUM | | | | | | | | | |
| basin | 1 | | | | | | | | | |
| NAME | SRR | LFR | PCR | ETR | TFR | SED | ORGN | ORGP | NO3 | SOLP |
| null | 0.1 | 0.05 | 0.05 | 0.7 | 0.1 | 0.1 | 0 | 0 | 0 | 0 |

| Variable name | Definition |
|---------------|---|
| TITLE | The first line of the ls_regions.cal 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. |
| MLSCAL | Total number of regions updates in the file |
| NAME | Regions calibration name |
| LUM_NUM | Total number of land use regions in following lines |
| NUM_REG | The number of elements in following lines |
| REG | Elements count |
| NAME2 | Name of the land use management regions |
| SRR | Surface runoff ratio – surface runoff/precip |
| LFR | Lateral flow ratio – soil lat flow/precip |
| PCR | Percolation ratio – perc/precip |
| ETR | ET ratio – ET/precip |
| TFR | Tile flow ratio – tile flow/total runoff |
| SED | Sediment yield (t/ha or t) |
| ORGN | Organic N yield (kg/ha or kg) |
| ORGP | Organic P yield (kg/ha or kg) |
| NO3 | Nitrate yield (kg/ha or kg) |
| SOLP | Soluble P yield (kg/ha or kg) |

CH SED BUDGET.SFT

The CH_SED_BUDGET.SFT file contains the input variables for the characteristics of channel orders parameter properties for

SWAT HRUs. Below is a sample CH_SED_BUDGET.SFT file:

| | | | | |
|-----------------|--------------|------|----------|-----|
| chan_orders.cal | | | | |
| 1 | | | | |
| NAME | ORD_NUM | NPSU | ELEM_CNT | |
| region_1 | 8 | 0 | | |
| | ORDER | CHW | CHD | FPD |
| | gully | 100 | 100 | 0.0 |
| | tributary | 25 | 10 | 0.0 |
| | main_upper_c | 10 | 10 | 0.0 |
| | main_lower_c | 5 | 5 | 0.0 |
| | gully_c | 0 | 0 | 0.0 |
| | tributary_c | 1 | 1 | 0.0 |
| | main_upper_c | 1 | 1 | 0.0 |
| | main_lower_c | 0.58 | 0 | 0.0 |

| Variable name | Definition |
|---------------|---|
| TITLE | The first line of the chn_orders.cal 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. |
| MREG | Total number of stream order updates in the file |
| NAME | Regions calibration name |
| ORD_NUM | Total number of stream orders in following lines |
| NSPU | The number of elements in following lines |
| ELEM_CNT | |
| NAME2 | Order name |
| CHW | Channel widening (mm/yr) |
| CHD | Channel down cutting or accretion (mm/yr) |
| HC | Head Cut advance (m/yr) |
| FPD | Flood plain accretion (mm/yr) |

CH SED PARMS.SFT

The CH_SED_PARMS.SFT file contains the input variables for the characteristics of land use parameter properties for SWAT HRUs. Below is a sample CH_SED_PARMS.SFT file:

| Variable name | Definition |
|----------------------|---|
| TITLE | The first line of the chan_parms.cal 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. |
| MCHP | Total number of stream order updates in the file |
| HEADER | Heading |
| NAME | Regions calibration name |
| CH_TYP | Type of change ('absval', 'abschg', 'pctchg') |
| NEG | Negative limit of change |
| POS | Positive limit of change |
| LO | Lower limit of parameter |
| UP | Upper limit of parameter |

PLANT_PARMS.SFT

The PLANT_PARMS.SFT file contains the input variables for the characteristics of land use parameter properties for SWAT HRUs. Below is a sample PLANT_PARMS.SFT file:

PLANT_GRO_SFT

The PLANT_GRO.SFT file contains the input variables for the characteristics of land use parameter properties for SWAT HRUs. Below is a sample PLANT_GRO.SFT file:

INIT – The initial files includes initialization data for organic matter, pesticide, pathogens, heavy metals and salts.

PLANT.INI

The PLANT.INI file contains the input variables for the characteristics of the plant community properties. The PLANT_COV input in the landuse.lum file points to the name in the plant.ini file. Plant initialization files can be constructed to allow decision tables for planting and harvesting to be used in both northern and southern hemispheres. Below is a sample PLANT.INI file:

| | | | | | | | | | | |
|----------------|--------|-------|------|------|-----|-------|--------|-----|-------|-------|
| plant.ini: | | | | | | | | | | |
| NAME | PL_COM | ROTYR | CPNM | IGRO | LAI | BIOMS | PHUACC | POP | YRMAT | RSDIN |
| corn_sb_1 | 2 | 1 | | | | | | | | |
| | | | corn | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| | | | soyb | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| corn_sb_2 | 2 | 2 | | | | | | | | |
| | | | corn | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| | | | soyb | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| corn_sb_shemi1 | 2 | 1 | | | | | | | | |
| | | | corn | y | 2 | 8000 | 0.3 | 0 | 0 | 2000 |
| | | | soyb | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| corn_sb_shemi2 | 2 | 2 | | | | | | | | |
| | | | corn | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| | | | soyb | y | 2 | 4000 | 0.3 | 0 | 0 | 2000 |
| corn_con | 1 | 1 | | | | | | | | |
| | | | corn | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| soyb_con | 1 | 1 | | | | | | | | |
| | | | soyb | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| corn_con_shemi | 1 | 1 | | | | | | | | |
| | | | corn | y | 2 | 8000 | 0.3 | 0 | 0 | 2000 |
| soyb_con_shemi | 1 | 1 | | | | | | | | |
| | | | soyb | y | 2 | 4000 | 0.3 | 0 | 0 | 2000 |
| canary_grass | 1 | 1 | | | | | | | | |
| | | | cang | y | 1 | 1000 | 0 | 0 | 0 | 2000 |

In the example above, corn_sb_1 initializes a corn-soybean rotation with corn growing the first year. This can be used in the northern hemisphere when starting the simulation on January 1 or in the southern hemisphere starting the simulation on July 1. The corn_sb_2 example initializes a corn-soybean rotation with soybeans growing the first year (ROT_YR=2). The corn_sb_shemi1 and corn_sb_shemi2 examples can be used in the southern hemisphere when starting the simulation on January 1 with summer crops growing.

The corn_con and soyb_con examples are for continuous corn and soybeans starting in the cold season (January 1 in northern hemispheres and July 1 in southern hemispheres) and corn_con_shemi1 and soyb_con_shemi are for continuous corn and soybeans in the southern hemisphere starting on January 1.

The canary_grass example is typical of any native perennial plant.

| 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. |
| HEADER | Headers for the variables |
| NAME | Name of plant community (from PLANT_COV column in the landuse.lum file) |
| PLANTS_COM | Number of plants in the community |
| ROTYR | Beginning year of rotation. For example, in a corn-soybean rotation, setting ROTYR=1 will start operations in the second or soybean year of rotation. |
| CPNM | <p>Plant name (from plants.plt file)</p> <p>A four character code to represent the land cover/plant name.</p> <p>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.</p> <p>When adding a new plant species or land cover category, the four letter code for the new plant must be unique. Required.</p> |
| IGRO | <p>Land cover status code (character)</p> <p>This code informs the model whether or not a land cover is growing at the beginning of the simulation.</p> <p>‘n’ = no land cover growing</p> <p>‘y’ = land cover growing</p> <p>Required.</p> |

| | |
|--------|---|
| LAI | <p>Initial leaf area index.</p> <p>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.</p> <p>Required if IGRO = 1.</p> |
| BIOMS | <p>Initial dry weight biomass (kg/ha).</p> <p>If a land cover is growing at the beginning of the simulation (IGRO = 1), the initial biomass must be defined.</p> <p>Required if IGRO = 1.</p> |
| PHUACC | <p>Total number of heat units or growing degree days needed to bring plant to maturity.</p> <p>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.</p> <p>Required if IGRO = 1.</p> |
| POP | <p>Plant population</p> |
| YRMAT | <p>Years to maturity</p> |
| RSDIN | <p>Initial residue cover (kg/ha)</p> |

SOIL_PLANT.INI

(see CONSTITUENTS.CS section for pesticide input to soil_plant.ini/pest_hru.ini/pest_water.ini)

| | | | | | | |
|----------------|---------|----------|-------------|--------------|--------------|-------|
| soil_plant.ini | | | | | | |
| NAME | SW_FRAC | NUTRIENT | PESTICIDES | PATHOGENS | HEAVY_METALS | SALTS |
| no_init | 0.2 | in25 | no_ini_pst | no_ini_path | null | null |
| low_init | 0.7 | in25 | low_ini_pst | low_ini_path | null | null |

OM_WATER.INI

| | | | | | | | | | | | | | | | | | | |
|--------------|-----|------|------|------|-----|------|------|-----|-----|------|-----|-----|-----|------|-----|-----|-----|------|
| om_water.ini | | | | | | | | | | | | | | | | | | |
| | flo | sed | orgn | sedp | no3 | solp | chla | nh3 | no2 | cbod | dox | san | sil | cla | sag | lag | grv | temp |
| om_low_init | 0.8 | 1000 | 90 | 80 | 70 | 60 | 30 | 20 | 10 | 9 | 8 | 2 | 1 | 1000 | 90 | 80 | 70 | 60 |
| om_high_init | 0.9 | 1100 | 99 | 88 | 77 | 66 | 33 | 22 | 11 | 19 | 28 | 82 | 91 | 1900 | 98 | 87 | 76 | 65 |

PEST_HRU.INI

| | |
|---------|--|
| TITLE | The first line of the initial.pst 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. |
| HEADER | Heading of file |
| NAME | Name of pesticide in community |
| NUM | Number of pesticides in community |
| EXCO_DF | Name of export coefficient file for pesticide community |
| DR_DF | Name of delivery ratio file for pesticide community |
| NAME2 | Name in pesticide community |
| PLT | Amount of pesticide on plant at start of simulation (kg/ha) |
| SOIL | Amount of pesticide in soil at start of simulation (kg/ha) |
| ENR | Pesticide enrichment ratio |

PEST_WATER.INI (ENTIRE FILE NEEDS ATTENTION)

| <u>Variable name</u> | <u>Definition</u> |
|----------------------|--|
| 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. |
| HEADER | Headings for the variables |

PATH HRU.INI (ENTIRE FILE NEEDS ATTENTION)

| 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. Optional. |
| MBAC_DB | |
| HEADER | Headings for the initial.bac file |
| NUM | Total number of initial bacteria in file |
| NUM_DB | Number of bacteria to follow |
| PLT | Bacteria on plants at beginning of simulation (#cfu/m ²) |
| SOL | Soluble bacteria in soil at beginning of simulation (#cfu/m ²) |
| SOR | Sorbed bacteria in soil at beginning of simulation (#cfu/m ²) |

PATH WATER.INI (ENTIRE FILE NEEDS ATTENTION)

| 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. |
| HEADER | Headings for the variables |

HMET_HRU.INI (ENTIRE FILE NEEDS ATTENTION)

| <u>Variable name</u> | <u>Definition</u> |
|-----------------------------|--|
| 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. |
| HEADER | Headings for the variables |

HMET_WATER.INI**SALT_HRU.INI** (ENTIRE FILE NEEDS ATTENTION)

| <u>Variable name</u> | <u>Definition</u> |
|-----------------------------|--|
| 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. |
| HEADER | Headings for the variables |

SALT_WATER.INI (ENTIRE FILE NEEDS ATTENTION)

| <u>Variable name</u> | <u>Definition</u> |
|-----------------------------|--|
| 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. |
| HEADER | Headings for the variables |

SOILS – 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.

SOILS.SOL

The SOILS.SOL file contains the input variables for the characteristics of the soil properties. Below is a partial sample SOILS.SOL file (four layer soil):

| | | | | | | | | | | | | | | | | | | | | |
|-----------|-----|---------|------|----------|-----|------------|--------|-----|------|-----|------|------|-------|-------|------|------|--------|----|-----|----|
| soils.sol | | | | | | | | | | | | | | | | | | | | |
| SNAM | NLY | HYD_GRP | ZMX | ANION_EX | CRK | TEXTURE | DEPTH | BD | AWC | K | CBN | CLAY | SILT | SAND | ROCK | ALB | USLE_K | EC | CAL | PH |
| IN025 | 4 | B | 1524 | 0.5 | 0.5 | sandy-loam | | | | | | | | | | | | | | |
| | | | | | | | 355.6 | 1.6 | 0.13 | 83 | 1.74 | 15 | 19.09 | 65.91 | 1.52 | 0.01 | 0.2 | 0 | 0 | 0 |
| | | | | | | | 812.8 | 1.7 | 0.1 | 65 | 0.35 | 12.5 | 19.65 | 67.85 | 1.62 | 0.12 | 0.2 | 0 | 0 | 0 |
| | | | | | | | 1219.2 | 1.8 | 0.07 | 180 | 0.15 | 7.5 | 9.02 | 83.48 | 1.71 | 0.17 | 0.15 | 0 | 0 | 0 |
| | | | | | | | 1524 | 1.8 | 0.04 | 300 | 0.05 | 6 | 1.88 | 92.11 | 1.71 | 0.21 | 0.15 | 0 | 0 | 0 |

| | |
|--------|--|
| TITLE | 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. |
| HEADER | |
| SNAM | Soil name |
| NLY | Number of layers in the soil |
| HYDGRP | <p>Soil hydrologic group (A, B, C, or D).</p> <p>Required only for the SWAT ArcView interface.</p> <p>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:</p> <p>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).</p> <p>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.</p> |

| Variable name | Definition |
|---------------|--|
| HYDGRP, cont. | <p>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).</p> <p>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.</p> |

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

| Criteria* | Hydrologic Soil Groups | | | |
|---|------------------------|------------|----------|-----------------|
| | 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 |
|---------------|--|
| ZMX | <p>Maximum rooting depth of soil profile (mm).</p> <p>If no depth is specified, the model assumes the roots can develop throughout the entire depth of the soil profile.</p> |
| ANION_EXCL | <p>Fraction of porosity (void space) from which anions are excluded.</p> <p>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.</p> <p>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).</p> <p>If no value for ANION_EXCL is entered, the model will set ANION_EXCL = 0.50.</p> |
| CRK | <p>Potential or maximum crack volume of the soil profile expressed as a fraction of the total soil volume.</p> <p>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.</p> |
| TEXTURE | <p>Texture of soil layer.</p> <p>This data is not processed by the model and the line may be left blank.</p> |

| Variable name | Definition |
|---------------|--|
| Z(layer #) | Depth from soil surface to bottom of layer (mm). |
| BD(layer #) | <p>Moist bulk density (Mg/m^3 or g/cm^3).</p> <p>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.</p> |
| AWC(layer #) | <p>Available water capacity of the soil layer (mm $\text{H}_2\text{O/mm}$ soil).</p> <p>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.</p> <p>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).</p> |
| K(layer #) | <p>Saturated hydraulic conductivity (mm/hr).</p> <p>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.</p> |
| CBN(layer #) | <p>Organic carbon content (% soil weight).</p> <p>When defining by soil weight, the soil is the portion of the sample that passes through a 2 mm sieve.</p> |

| Variable name | Definition |
|-------------------|--|
| CLAY(layer #) | <p>Clay content (% soil weight).</p> <p>The percent of soil particles which are < 0.002 mm in equivalent diameter.</p> |
| SILT(layer #) | <p>Silt content (% soil weight).</p> <p>The percentage of soil particles which have an equivalent diameter between 0.05 and 0.002 mm.</p> |
| SAND(layer #) | <p>Sand content (% soil weight).</p> <p>The percentage of soil particles which have a diameter between 2.0 and 0.05 mm.</p> |
| ROCK(layer #) | <p>Rock fragment content (% total weight).</p> <p>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.</p> |
| ALB(top layer) | <p>Moist soil albedo.</p> <p>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.</p> |
| USLE_K(top layer) | <p>USLE equation soil erodibility (K) factor (units: 0.013 (metric ton m² hr)/(m³-metric ton cm)).</p> <p>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</p> |

| Variable name | Definition |
|---------------|---|
| USLE_K, cont. | <p>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).</p> <p>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.</p> <p>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.</p> <hr/> $K_{USLE} = \frac{0.00021 \cdot M^{1.14} \cdot (12 - OM) + 3.25 \cdot (c_{soilstr} - 2) + 2.5 \cdot (c_{perm} - 3)}{100}$ <hr/> <p>where KUSLE is the soil erodibility factor, M is the particle-size parameter, OM is the percent organic matter (%), csoilstr is the soil structure code used in soil classification, and cperm is the profile permeability class.</p> <p>The particle-size parameter, M, is calculated</p> $M = (m_{silt} + m_{vfs}) \cdot (100 - m_c)$ <p>where msilt is the percent silt content (0.002-0.05 mm diameter particles), mvfs is the percent very fine sand content (0.05-0.10 mm diameter particles), and mc is the percent clay content (< 0.002 mm diameter particles).</p> <p>The percent organic matter content, OM, of a layer can be calculated:</p> $OM = 1.72 \cdot orgC$ <p>where orgC is the percent organic carbon content of the layer (%).</p> <hr/> |

| Variable name | Definition |
|---------------|--|
| USLE_K, cont. | <p>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.</p> <p>Angular Blocky: bounded by planes intersecting at relatively sharp angles</p> <p>Subangular Blocky: having mixed rounded and plane faces with vertices mostly rounded</p> <p>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 broken down into subtypes:</p> <ul style="list-style-type: none"> <li>-Platy, with particles arranged around a plane, generally horizontal <li>-Prismlike, with particles arranged around a verticle line and bounded by relatively flat vertical surfaces <ul style="list-style-type: none"> <li>Prismatic: without rounded upper ends <li>Columnar: with rounded caps <li>-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 <li>-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 <ul style="list-style-type: none"> <li>Granular: relatively non-porous <li>Crumb: very porous <p>The size criteria for the class will vary by type of structure and are summarized in Table 22-2.</p> |

Variable name**Definition**

USLE_K, cont.

Table 22-2: Size classes of soil structure

| Size Classes | Shape of structure | | | |
|--------------|--------------------|------------------------|----------|----------|
| | 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:

- 5 very fine granular
- 6 fine granular
- 7 medium or coarse granular
- 8 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:

- 7 rapid (> 150 mm/hr)
- 8 moderate to rapid (50-150 mm/hr)
- 9 moderate (15-50 mm/hr)
- 10 slow to moderate (5-15 mm/hr)
- 11 slow (1-5 mm/hr)
- 12 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 reduces soil erodibility for soils with extremely high sand contents. The factors are calculated:

$$f_{csand} = \left(0.2 + 0.3 \cdot \exp \left[-0.256 \cdot m_s \cdot \left(1 - \frac{m_{silt}}{100} \right) \right] \right)$$

| Variable name | Definition |
|---------------|------------|
|---------------|------------|

USLE_K, cont.

$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}} \right)^{0.3}$$

$$f_{orgc} = \left(1 - \frac{0.0256 \cdot orgC}{orgC + \exp[3.72 - 2.95 \cdot orgC]} \right)$$

$$f_{hisand} = \left(1 - \frac{0.7 \cdot \left(1 - \frac{m_s}{100} \right)}{\left(1 - \frac{m_s}{100} \right) + \exp \left[-5.51 + 22.9 \cdot \left(1 - \frac{m_s}{100} \right) \right]} \right)$$

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 (%).

| | |
|-------------|---------------------------------|
| EC(layer #) | Electrical conductivity (dS/m). |
|-------------|---------------------------------|

| | |
|--------------|---------------------------|
| CAL(layer #) | Soil CaCo3 (%). (0 – 50%) |
|--------------|---------------------------|

| | |
|-------------|----------------|
| PH(layer #) | Soil Ph (3-10) |
|-------------|----------------|

NUTRIENTS.SOL

The NUTRIENTS.SOL file Soil nutrient parameters.

Below is a sample NUTRIENTS.SOL file (one layer soil):

| nutrients.sol: | | | | | | | | | | | |
|----------------|--------|--------|--------|------|--------|--------|------|------------|-------|-----------|---------------|
| NAME | EXP_CO | TOTALN | INORGN | ORGN | TOTALP | INORGP | ORGP | WATERSOL_P | H3A_P | MEHLICH_P | BRAY_STRONG_P |
| in25 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew02 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew03 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew04 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew05 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew06 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew07 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew08 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew09 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew10 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew11 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |
| lrew12 | 0.001 | 13 | 6.85 | 3.34 | 3.22 | 3.66 | 0.39 | 0.16 | 0.26 | 1.22 | 0.85 |

| | |
|------------|--|
| TITLE | The first line of the nutrients.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. |
| HEADER | |
| NAME | Nutrient name |
| EXP_CO | Depth coefficient to adjust concentrations for depth |
| TOTALN | Total N in soil (ppm) |
| INORGN | Inorganic N in soil surface (ppm) |
| ORGN | Organic N in soil surface (ppm) |
| TOTALP | Total P in soil surface (ppm) |
| INORGP | Inorganic P in soil surface (ppm) |
| ORGP | Organic P in soil surface (ppm) |
| WATERSOL_P | Water soluble P in soil surface (ppm) |
| H3A_P | H3a P in soil surface (ppm) |
| MEHLICH_P | Mehlich P in soil surface (ppm) |
| | Bray P in soil surface (ppm) |

SOILS_LTE.SOL - The SOILS_LTE.SOL file parameters for LTE watershed . Below is a sample SOILS_LTE.SOL file.

| | | | |
|-----------------|-------|------|------|
| soils_lte.sol | | | |
| NAME | AWC | POR | SCON |
| sand | 0.56 | 0.4 | 105 |
| loamy_sand | 0.116 | 0.4 | 60 |
| sandy_loam | 0.115 | 0.4 | 0.26 |
| loam | 0.114 | 0.4 | 13.2 |
| silt_loam | 0.186 | 0.43 | 6.8 |
| silt | 0.254 | 0.47 | 5.6 |
| silty_clay | 0.141 | 0.43 | 4.3 |
| clay_loam | 0.138 | 0.4 | 2.3 |
| sandy_clay_loam | 0.113 | 0.4 | 1.5 |
| sandy_clay | 0.13 | 0.4 | 1.2 |
| silty_clay | 0.132 | 0.48 | 0.9 |
| clay | 0.113 | 0.47 | 1.5 |

| | |
|--------------|--|
| TITLE | The first line of the soils_lte.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. |
| HEADER | Headings for variables |
| NAME/TEXTURE | Texture description (cross walked from TEXTURE column in HRU-LTE.HRU file) |
| AWC | Available water capacity for LTE soil (mm/mm) |
| POR | Porosity for LTE soil (mm/mm) |
| SCON | Saturated conductivity for LTE soil (mm/hr) |

D TABLE – Decision tables are a precise yet compact way to model complex rule sets and their corresponding actions.

Decision tables, like flowcharts and if-then-else and switch-case statements, associate conditions with actions to perform, but in many cases do so in a more elegant way (see Wikipedia – ‘Decision table’)

STRUCTURE OF DECISION TABLES

- I. Conditions
- II. Condition alternatives
- III. Actions
- IV. Action entries

Each decision corresponds to a variable, relation or predicate whose possible values are listed among the condition alternatives. Each action is a procedure or operation to perform, and the entries specify whether (or in what order) the action is to be performed for the set of condition alternatives the entry corresponds to. Many decision tables include in their condition alternatives the ‘don’t care’ symbol, a hyphen. Using ‘don’t cares’ can simplify decision tables, especially when a given condition has little influence on the actions to be performed. In some cases, entire conditions thought to be important initially are found to be irrelevant when none of the conditions influence which actions are performed.

Decision tables, especially when coupled with the use of a domain-specific language, allow developers and policy experts to work from the same information, the decision tables themselves.

Tools to render nested if statements from traditional programming languages into decision tables can also be used as a debugging tool.

Decision tables have proven to be easier to understand and review than code, and have been used extensively and successfully to produce specifications for complex systems.

Quadrant I. Number of conditions, alternatives and actions

1. Conditional variables
2. Limit variables (each conditional variable has predefined limit variables)

| CHAR NAME | TYPE | DESCRIPTION | UNITS | LIMIT VAR |
|------------------|-------------|--------------------|--------------|------------------|
|------------------|-------------|--------------------|--------------|------------------|

| | | |
|--------------|------------|------------|
| soil_water | soil | wp, fc, ul |
| w_stress | plant | |
| month | time | |
| jday | time | |
| hu | plant | |
| n_stress | plant | |
| soil_n | soil | |
| soil_p | soil | |
| n_applied | mgt | |
| plant | plant | |
| rot_yr | mgt | |
| biomass | plant | |
| cover | plant/soil | |
| lai | | |
| stir_tillage | mgt | |
| vol | res | pvol, evol |
| flow | chan | |

Quadrant II. Condition alternatives

1. Condition rules – all alternatives met (<, >, =, -)

Quadrant III. Actions

| ACTION | OPTIONS |
|----------------|----------------------|
| irrigate | amt, file → irr.ops |
| release | rate, day, weir |
| plant | name from plants.plt |
| harvest | file → harv.ops |
| tillage | file → till.ops |
| fire | file → fire.ops |
| (structures) | |
| (herd) | |
| (water-rights) | |

Quadrant IV. Action Entries

1. 'y' (yes)
2. 'n' (no)

D_TABLE.DTL

The D_TABLE.DTL file contains the input variables for the nutrient characteristics of the soil properties. Below is a sample D_TABLE.DTL file:

d_table.dtl - Little River Watershed

```

2
NAME  CONDS  ALTS  ACTS
autoirr_str.8      1      1      1
VAR              OBJ      OB_NUM      LIM_VAR      LIM_OP      LIM_CONST      ALT1
w_stress plant      1      null      -      0.7      <
ACT_TYP      NAME      OPTION CONST      FILE_POINTER      OUTCOME
irrigate drip_high      file      0      drip      y

```

| | | | | | | | | |
|--------------|----------------|------|------|--------------|----------------|--------------|--------|----------------|
| NAME | CONDS | ALTS | ACTS | | | | | |
| sw_deficit75 | 1 | 1 | 1 | | | | | |
| VAR | | OBJ | | OB_NUM | LIM_VAR | | LIM_OP | LIM_CONST ALT1 |
| soil_water | | hru | | 0 | fcap_mm - | 75. | < | |
| ACT_TYP | | NAME | | OPTION CONST | | FILE_POINTER | | OUTCOME |
| irrigate | sprinkler_high | rate | | 0 | sprinkler_high | | y | |

| 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. |
| MDTBL | Total number of decision tables in the file |
| HEADER | Header |
| NAME | Name of decision table |
| CONDS | Number of conditions |
| ALTS | Number of alternatives |
| ACTS | Number of actions |
| VAR | Condition variable (vol, sw, time, etc) |
| OB | Object variable (res, hru, canal, etc) |
| OB_NUM | Object number |
| LIM_VAR | Limit variable (evol, pvool, fc, ul, etc) |
| LIM_OP | Limit operator (*,+, -) |
| LIM_CONST | Limit constant |
| ALT | Condition alternatives |
| TYP | Type of action (reservoir, irrigate, fertilizer, etc) |
| NAME | Name of action |
| OPTION | Action option-specific to type of action (ie for reservoir, option to input rate, days of drawdown, weir equation pointer, etc) |
| CONST | Constant used for rate, days, etc |
| FILE_POINTER | Pointer for option (ie weir equation pointer) |
| ACT_OUTCOMES CONST | Action outcomes ('y' to perform action; 'n' to not perform action) |

Example decision table for continuous corn and explanation:

| NAME | CONDS | ALTS | ACTS | | | | | | | | | | |
|--------------|-------|---------|------------|----------|-----------|--------|-------|----------|------|---|---|---|--|
| pl_hv_corn | 6 | 4 | 3 | | | | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | LIM_CONST | ALT1 | ALT2 | ALT3 | ALT4 | | | | |
| soil_water | hru | 0 | fc | * | 1.05 | < | < | - | - | | | | |
| phu_base0 | hru | 0 | null | - | 0.15 | > | - | - | - | | | | |
| phu_plant | hru | 0 | phu_mat | - | 1.15 | - | > | - | - | | | | |
| year_rot | hru | 0 | null | - | 1 | = | = | = | - | | | | |
| jday | hru | 0 | null | - | 350 | - | - | = | - | | | | |
| year_rot | hru | 0 | null | - | 1 | - | - | - | - | | | | |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | | | | |
| plant | hru | 0 | plant_corn | corn1500 | 0 | 1 | null | y | n | n | n | n | |
| harvest_kill | hru | 0 | grain_harv | corn1500 | 0 | 1 | grain | n | y | y | y | n | |
| rot reset | hru | 0 | reset 1 | null | 1 | 0 | null | n | n | n | n | y | |

In the above table, there are 6 conditions, 4 alternatives and 3 actions.

Description of the conditions:

1. soil_water – if soil water is too high ($> 1.05 \times \text{field capacity}$), it will be too wet to operate machinery
2. phu_base0 – (0.15) when the sum base zero heat units for the year (starting Jan 1) exceeds 0.15, indicating it's warm enough to plant
3. phu_plant – (1.15) harvest is scheduled when the sum of the heat units for the crop exceed 1.15 (if the heat units to maturity for the crop = 1500, then harvest would be scheduled at $1.15 \times 1500 = 1725$).
4. year_rot – needed to identify the current year of rotation. In this example, corn is grown in year 1.
5. jday – julian day (350) – if heat units are not met by this day, the plants are harvested regardless of heat units. This ensures the crop is harvested.
6. year_rot – need to reset the year of rotation

Description of the alternatives:

If all of the conditions for each alternative are met, outcomes are checked for 'y' to take action. Alternatives with dash ('-') are not checked.

1. plant corn based on heat units:
if soil_water < 1.05 and
if phubase0 > 0.15 and
if year_rot = 1 and
then
check outcomes for 'y' and if 'y', take that action
2. Harvest corn based on crop accumulated heat units
If soil_water < 1.05 and
If phu_plant > 1.15 and
If year_rot = 1 and
then
check outcomes for 'y' and if 'y', take that action
3. Harvest corn based on day of year
If year_rot = 1 and
If jday = 350

then

check outcomes for 'y' and if 'y', take that action

4. Reset rotation year

If year_rot > 1

then

check outcomes for 'y' and if 'y', take that action

Description of the actions:

1. Plant – corn1500 – cross walked to plant name in plants.plt file
2. Harvest_kill – corn1500 – cross walked to plant name in plants.plt file
grain – relates to harvest type in harv.ops file
3. CONST2 set = 1 signifies that only 1 action (operation) is allowed in the calendar year.
4. rot_reset- rotation reset – for continuous corn (1 year rotation). The rotation year is reset to 1 at the end of every year.

Fertilizer (will work for Corn and Corn/Soybean rotation):

| NAME | CONDS | ALTS | ACTS | | | | | | |
|------------|-------|---------|------------------|---------|-----------|--------|-----------|----------|------|
| fert_rot_1 | 5 | 2 | 2 | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | LIM_CONST | | | ALT1 | ALT2 |
| phu_base0 | hru | 0 | null | - | 0.12 | | | > | - |
| year_rot | hru | 0 | null | - | 1 | | | = | = |
| n_stress | hru | 0 | null | - | 0.9 | | | - | < |
| plant_gro | hru | 0 | y (or crop name) | - | 1 | | | - | = |
| phu_plant | hru | 0 | phu_mat | - | 1.05 | | | - | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | |
| fertilize | hru | 0 | ammonia_spring | anh_nh3 | 160. | 1 | inject | y | n |
| fertilize | hru | 0 | side_dress | urea | 50. | 2 | broadcast | n | y |

In the above table, there are 5 conditions, 2 alternatives and 2 actions.

Description of the conditions:

1. phu_base0 – schedule spring and anhydrous ammonia application when base zero heat units exceed 0.12
2. year_rot – checks for year 1 of rotation. This table will work for continuous corn and corn-soybean rotation when corn is planted in the first year.
3. n_stress – used to check side dress urea application. If n-stress is less than 0.9, the side dress application will occur.
4. plant_gro – the side dress occurs while the plant is growing (entered as '1' or crop name e.g., corn)
5. phu_plant – to ensure the side dress application occurs before the plant reaches maturity

Description of the alternatives:

If all of the conditions for each alternative are met, outcomes are checked for 'y' to take action. Alternatives with dash ('-') are not checked.

1. Apply spring anhydrous ammonia
If phu_base0 > 0.12 and
If year_rot = 1
Then

- Apply anhydrous ammonia (anh_nh3)
2. Apply urea
 - If year_rot = 1 and
 - If n_stress < 0.9 and
 - If plant_gro = 1 (plant growing) or can be entered as crop name e.g., corn and
 - If phu_plant < 1.0
 - Then
 - Apply side_dress (urea)

Descriptions of the Actions:

1. Apply 160 kg/ha of anh-nh3 (fertilizer name in fertilizer.frt file) - one time
2. Apply 50 kg/ha of urea (fertilizer name in fertilizer.frt file) a maximum of two times

| NAME | CONDS | ALTS | ACTS | | | | | | | |
|--------------|-------|---------|------------|----------|-----------|--------|-------|----------|------|-----------|
| pl_hv_corn | 9 | 4 | 3 | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | LIM_CONST | | | ALT1 | ALT2 | ALT3 ALT4 |
| soil_water | hru | 0 | fc | * | 1.05 | | | < | < | - - |
| phu_base0 | hru | 0 | null | - | 0.15 | | | > | - | - - |
| phu_base0 | hru | 0 | null | - | 0.50 | | | < | - | - - |
| phu_plant | hru | 0 | phu_mat | - | 1.15 | | | - | > | - - |
| year_rot | hru | 0 | null | - | 1 | | | = | = | = - |
| plant_gro | hru | 0 | n | - | 1 | | | = | - | - - |
| plant_gro | hru | 0 | y | - | 1 | | | - | = | = - |
| jday | hru | 0 | null | - | 350 | | | - | - | = - |
| year_rot | hru | 0 | null | - | 1 | | | - | - | - > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | |
| plant | hru | 0 | plant_corn | corn1500 | 0 | 0 | null | y | n | n n |
| harvest_kill | hru | 0 | grain_harv | corn1500 | 0 | 0 | grain | n | y | y n |
| rot_reset | hru | 0 | reset_1 | null | 1 | 0 | null | n | n | n y |

In the above table, there are 9 conditions, 4 alternatives and 3 actions.

Description of the conditions:

7. soil_water – if soil water is too high ($> 1.05 \times \text{field capacity}$), it will be too wet to operate machinery
8. phu_base0 – (0.15) when the sum base zero heat units for the year (starting Jan 1) exceeds 0.15, indicating it's warm enough to plant
9. phu_base0 – (0.50) this prevents planting late in the year after the previous crop has been harvested
10. phu_plant – (1.15) harvest is scheduled when the sum of the heat units for the crop exceed 1.15 (if the heat units to maturity for the crop = 1500, then harvest would be scheduled at $1.15 \times 1500 = 1725$).
11. year_rot – needed to identify the current year of rotation. In this example, corn is grown in year 1.
12. plant_gro – 'n' – needed to allow planting only when a crop is not growing
13. plant_gro – 'y' – needed to allow harvesting only when a plant is growing
14. jday – julian day (350) – if heat units are not met by this day, the plants are harvested regardless of heat units. This ensures the crop is harvested.
15. year_rot – need to reset the year of rotation

Description of the alternatives:

If all of the conditions for each alternative are met, outcomes are checked for 'y' to take action. Alternatives with dash ('-') are not checked.

5. plant corn based on heat units:
if soil_water < 1.05 and
if phubase0 > 0.15 and
if phubase0 < 0.50 and
if year_rot = 1 and
if plant_gro = 1 (plant growing) or can be entered as crop name, e.g., corn)
then
check outcomes for 'y' and if 'y', take that action
6. Harvest corn based on crop accumulated heat units
If soil_water < 1.05 and
If phu_plant > 1.15 and
If year_rot = 1 and
If plant_gro = 1 (plant growing) or can be entered as crop name, e.g., corn) and
Then
7. check outcomes for 'y' and if 'y', take that action

8. Harvest corn based on day of year
If year_rot = 1 and
If plant_gro = 1 (plant growing) or can be entered as crop name, e.g., corn and
If jday = 350
then
9. check outcomes for 'y' and if 'y', take that action
10. Reset rotation year
If year_rot > 1
then
check outcomes for 'y' and if 'y', take that action

Description of the actions:

5. Plant – corn1500 – cross walked to plant name in plants.plt file
6. Harvest_kill – corn1500 – cross walked to plant name in plants.plt file
grain – relates to harvest type in harv.ops file
7. rot_reset-year. rotation reset – for continuous corn (1 year rotation). The rotation year is reset to 1 at the end of every year.

Example decision table for fertilizer and explanation:

Fertilizer Example:

| NAME | CONDS | ALTS | ACTS | | | | | | |
|------------|-------|---------|----------------|---------|-----------|-----------|-----------|----------|---|
| fert_rot_1 | 5 | 2 | 2 | | | | | | |
| VAR | OBJ | OBJ_NUM | LIM_VAR | LIM_OP | LIM_CONST | ALT1 ALT2 | | | |
| phu_base0 | hru | 0 | null | - | 0.12 | > | | - | |
| year_rot | hru | 0 | null | - | 1 | = | | = | |
| n_stress | hru | 0 | null | - | 0.9 | - | | < | |
| plant_gro | hru | 0 | y | - | 1 | - | | = | |
| phu_plant | hru | 0 | phu_mat | - | 1.05 | - | | < | |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | |
| fertilize | hru | 0 | ammonia_spring | anh_nh3 | 160. | 1 | inject | y | n |
| fertilize | hru | 0 | side_dress | urea | 50. | 2 | broadcast | n | y |

In the above table, there are 5 conditions, 2 alternatives and 2 actions.

Description of the conditions:

6. phu_base0 – schedule spring and anhydrous ammonia application when base zero heat units exceed 0.12
7. year_rot – checks for year 1 of rotation. This table will work for continuous corn and corn-soybean rotation when corn is planted in the first year.
8. n_stress – used to check side dress urea application. If n-stress is less than 0.9, the side dress application will occur.
9. plant_gro – the side dress occurs while the plant is growing
10. phu_plant – to ensure the side dress application occurs before the plant reaches maturity

Description of the alternatives:

If all of the conditions for each alternative are met, outcomes are checked for 'y' to take action. Alternatives with dash ('-') are not checked.

3. Apply spring anhydrous ammonia
If phu_base0 > 0.12 and
If year_rot = 1
Then
Apply anhydrous ammonia (anh_nh3)
4. Apply urea
If year_rot = 1 and
If n_stress < 0.9 and

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If plant_gro = 1 (plant growing) or can be entered as plant name, e.g., corn and

If phu_plant < 1.0

Then

Apply side_dress (urea)

Descriptions of the Actions:

3. Apply 160 kg/ha of anh-nh3 (fertilizer name in fertilizer.frt file) - one time
4. Apply 50 kg/ha of urea (fertilizer name in fertilizer.frt file) a maximum of two times

1) Decision tables for planting and harvesting.

Warm season annual crops (continuous corn example). This decision table will work with any warm season annual.

| NAME | CONDS | ALTS | ACTS | | | | | | | | |
|--------------|-------|---------|------------|--------|---------|--------|-------|----------|------|------|------|
| pl_hv_corn | 6 | 4 | 3 | | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 | ALT3 | ALT4 |
| soil_water | hru | 0 | fc | * | 1.5 | | | < | < | - | - |
| plant_gro | hru | 0 | n | - | 0 | | | = | - | - | - |
| phu_base0 | hru | 0 | null | - | 0.15 | | | > | - | - | - |
| phu_plant | hru | 0 | phu_mat | - | 1.15 | | | - | > | - | - |
| year_rot | hru | 0 | null | - | 1 | | | = | = | = | > |
| days_plant | hru | 0 | null | - | 200 | | | - | - | = | - |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | | |
| plant | hru | 0 | plant_corn | corn | 0 | 1 | null | y | n | n | n |
| harvest_kill | hru | 0 | grain_harv | corn | 0 | 1 | grain | n | y | y | n |
| rot_reset | hru | 0 | reset_1 | null | 1 | 0 | null | n | n | n | y |

In the above table, there are 6 conditions, 4 alternatives and 3 actions.

Description of the conditions:

16. soil_water – if soil water is too high ($> 1.50 \times \text{field capacity}$), it will be too wet to operate machinery
17. plant_gro – (“n”) Planting allowed if plant is not growing.
18. phu_base0 – (0.15) when the sum base zero heat units for the year (starting Jan 1) exceeds 0.15, indicating it’s warm enough to plant
19. phu_plant – (1.15) harvest is scheduled when the sum of the heat units for the crop exceed 1.15 (if the heat units to maturity for the crop = 1500, then harvest would be scheduled at $1.15 \times 1500 = 1725$).
20. year_rot – needed to identify the current year of rotation. In this example, corn is grown in year 1.
21. days_plant – days since last plant (200) to ensure harvest occurs before next crop is planted.

Description of the alternatives:

If all of the conditions for each alternative are met, outcomes are checked for ‘y’ to take action. Alternatives with dash (‘-’) are not checked.

11. plant corn based on heat units:
if soil_water < $1.50 \times \text{fc}$ and
if phubase0 > $0.15 \times \text{phu_mat}$ and
if year_rot = 1 and
then
check outcomes for ‘y’ and if ‘y’, take that action (plant)
12. Harvest corn based on crop accumulated heat units
If soil_water < $1.50 \times \text{fc}$ and
If phu_plant > $1.15 \times \text{phu_mat}$ and

```

If year_rot = 1 and
then
  check outcomes for 'y' and if 'y', take that action (plant)
13. Harvest corn based on days since planting
  If year_rot = 1 and
  If days_plant =200
  then
    check outcomes for 'y' and if 'y', take that action (harvest)
14. Reset rotation year
  If year_rot > 1
  then
    check outcomes for 'y' and if 'y', take that action (rot_reset)

```

Description of the actions:

- 8. plant – corn – cross walked to plant name in plants.plt file
- 9. harvest_kill – corn – cross walked to plant name in plants.plt file
grain – relates to harvest type in harv.ops file
- 10. rot_reset- rotation reset – for continuous corn (1 year rotation). The rotation year is reset to 1 at the end of every year.

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2) Cool season annual crops (continuous winter wheat example).

| | | | | | | | | | | | | |
|--------------|-----|---------|------------|--------|---------|--------|-------|----------|------|------|------|---|
| pl_hv_wwht | 6 | 4 | 3 | | | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 | ALT3 | ALT4 | |
| soil_water | hru | 0 | fc | * | 1.5 | | | < | < | - | - | |
| plant_gro | hru | 0 | n | - | 0 | | | = | - | - | - | |
| phu_base0 | hru | 0 | null | - | 0.85 | | | > | - | - | - | |
| phu_plant | hru | 0 | phu_mat | - | 1.15 | | | - | > | - | - | |
| year_rot | hru | 0 | null | - | 1 | | | = | = | = | > | |
| days_plant | hru | 0 | null | - | 200 | | | - | - | = | - | |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | | | |
| plant | hru | 0 | plant_wwht | wwht | 0 | 1 | null | y | n | n | n | n |
| harvest_kill | hru | 0 | grain_harv | wwht | 0 | 1 | grain | n | y | y | n | n |
| rot_reset | hru | 0 | reset_1 | null | 1 | 0 | null | n | n | n | n | y |

The cool season annual decision table is similar to the warm season except for the heat units to schedule planting. Planting is triggered when base zero heat units exceed 0.85 of the total annual base zero heat units.

3) Warm season annual crops with 2-year rotation.

| | | | | | | | | | | | | | |
|---------------|-------|---------|------------|--------|---------|--------|-------|----------|------|------|------|------|------|
| NAME | CONDS | ALTS | ACTS | | | | | | | | | | |
| pl_hv_corn_sb | 7 | 7 | 5 | | | | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 |
| soil_water | hru | 0 | fc | * | 1.5 | | | < | < | < | < | - | - |
| plant_gro | hru | 0 | n | - | 0 | | | = | = | - | - | - | - |
| phu_base0 | hru | 0 | null | - | 0.15 | | | > | > | - | - | - | - |
| phu_plant | hru | 0 | phu_mat | - | 1.15 | | | - | - | > | > | - | - |
| year_rot | hru | 0 | null | - | 1 | | | = | - | = | - | = | - |
| year_rot | hru | 0 | null | - | 2 | | | - | = | - | = | - | = |
| days_plant | hru | 0 | null | - | 200 | | | - | - | - | - | = | = |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | | | | | |
| plant | hru | 0 | plant_corn | corn | 0 | 1 | null | y | n | n | n | n | n |
| plant | hru | 0 | plant_soyb | soyb | 0 | 1 | null | n | y | n | n | n | n |
| harvest_kill | hru | 0 | grain_harv | corn | 0 | 1 | grain | n | n | y | n | y | n |
| harvest_kill | hru | 0 | grain_harv | soyb | 0 | 1 | grain | n | n | n | y | n | y |
| rot_reset | hru | 0 | reset_2 | null | 1 | 0 | null | n | n | n | n | n | n |

The 2-year rotation, warm season annual decision is identical to the continuous corn warm season, with the addition of a condition to check for second year of rotation. In the first year of rotation, corn is planted and harvested, while soybeans are grown in the second year. An action for resetting the rotation year is triggered when the rotation year exceeds two.

4) Warm and cool season annuals in rotation (4-year rotation is corn-corn-soybeans-winter wheat-soybeans).

| NAME | CONDS | ALTS | ACTS | | | | | | | | | | | | | | | |
|--------------|-------|---------|------------|--------|---------|--------|-------|---------|------|------|------|------|------|------|------|-------|-------|---|
| pl_hv_ccsws | 10 | 11 | 7 | | | | | | | | | | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | ALT1 | ALT2 | ALT3 | ALT4 | ALT5 | ALT6 | ALT7 | ALT8 | ALT9 | ALT10 | ALT11 | |
| soil_water | hru | 0 | fc | * | 1.5 | | < | < | - | < | < | < | < | - | - | - | - | |
| phu_base0 | hru | 0 | null | - | 0.15 | | > | > | - | - | - | - | - | - | - | - | - | |
| days_harv | hru | 0 | null | - | 7 | | - | - | = | = | - | - | - | - | - | - | - | |
| phu_plant | hru | 0 | phu_mat | - | 1.15 | | - | - | - | - | > | > | > | - | - | - | - | |
| year_rot | hru | 0 | null | - | 3 | | < | - | - | - | < | - | - | < | - | - | - | |
| year_rot | hru | 0 | null | - | 2 | | - | - | - | - | - | > | - | - | - | > | - | |
| year_rot | hru | 0 | null | - | 3 | | - | = | - | = | - | - | - | - | - | - | - | |
| year_rot | hru | 0 | null | - | 4 | | - | - | = | - | - | - | = | - | - | - | = | |
| days_plant | hru | 0 | null | - | 200 | | - | - | - | - | - | - | - | = | = | = | = | |
| year_rot | hru | 0 | null | - | 4 | | - | - | - | - | - | - | - | - | - | - | - | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | UTCOMES | | | | | | | | | | |
| plant | hru | 0 | plant_corn | corn | 0 | 1 | null | y | n | n | n | n | n | n | n | n | n | n |
| plant | hru | 0 | plant_soyb | soyb | 0 | 1 | null | n | y | y | n | n | n | n | n | n | n | n |
| plant | hru | 0 | plant_wwht | wwht | 0 | 1 | null | n | n | n | y | n | n | n | n | n | n | n |
| harvest_kill | hru | 0 | grain_harv | corn | 0 | 1 | grain | n | n | n | n | y | n | n | y | n | n | n |
| harvest_kill | hru | 0 | grain_harv | soyb | 0 | 1 | grain | n | n | n | n | y | n | n | y | n | n | n |
| harvest_kill | hru | 0 | grain_harv | wwht | 0 | 1 | grain | n | n | n | n | n | y | n | n | y | n | n |
| rot_reset | hru | 0 | reset_4 | null | 1 | 0 | null | n | n | n | n | n | n | n | n | n | n | n |

Adding the winter crop to the rotation required a change in the planting of the winter wheat. Winter wheat planting is scheduled using the days_harv condition. When days since the last harvest = 7, and soil water is below 1.5*fc, and in rotation year 3, winter wheat is planted.

- 5) Perennial grass and range. If there is no management of native grass or range, no management file is needed and “null” can be entered in the MGT_OPS column in landuse.lum file. In plants.ini, the plants can be growing at the start of the simulation (IGRO=“y”) and initial leaf area, biomass, residue etc. on the first day of the simulation can be input.

a) Hay cutting (continuous alfalfa)

| NAME | CONDS | ALTS | ACTS | | | | | | |
|-------------|-------|---------|----------|--------|-----------|--------|---------|----------|------|
| hay_cutting | 3 | 1 | 1 | | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | LIM_CONST | | | | ALT1 |
| soil_water | hru | 0 | fc | * | 1.5 | | | | < |
| phu_plant | hru | 0 | phu_mat | - | 0.5 | | | | > |
| biomass | hru | 0 | null | - | 3000 | | | | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | |
| harvest | hru | 0 | hay_harv | alfa | 0 | 3 | biomass | y | |

Hay cuttings are scheduled when soil water is below 1.5*fc, heat units exceed 0.5*phu_mat and above ground biomass exceeds 3,000 kg/ha. In this case, no additional conditions are needed since heat units are reset during a cutting operation. The “harvest” action harvests “alfa” “biomass” with a maximum of 3 harvests per year (CONST2).

b) Grazing

| | | | | | | | | |
|--------------|-----|---------|-------------|-----------|---------|--------|------|----------|
| graze_summer | 3 | 1 | 1 | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 |
| jday | hru | 0 | null | - | 120 | | | > |
| jday | hru | 0 | null | - | 200 | | | < |
| biomass | hru | 0 | null | - | 3000 | | | > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES |
| graze | hru | 0 | summer_high | beef_high | 0 | 0 | null | y |

| | | | | | | | | |
|--------------|-----|---------|------------|----------|-----------|--------|------|-----------|
| graze_winter | 3 | 2 | 1 | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | LIM_CONST | | | ALT1 ALT2 |
| jday | hru | 0 | null | - | 295 | | | > - |
| jday | hru | 0 | null | - | 85 | | | - < |
| biomass | hru | 0 | null | - | 3000 | | | > > |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES |
| graze | hru | 0 | winter_low | beef_low | 0 | 0 | null | y y |

These decision tables schedule grazing by dates for summer and winter grazing schedules. The winter grazing allows razing between day 295 and 85 when biomass is above 3,000 kg/ha. The tables can be easily modified to use heat units instead of dates and also to include different grazing management schedules.

- 6) Forest. When a native forest it not managed, no management file is needed and “null” can be entered in the MGT_OPS column in landuse.lum. Initial LAI, biomass, residue and initial years to maturity will need to be input in plants.ini. When forests are cut, a simple decision table can be used.

| | | | | | | | | |
|-------------|-----|---------|-----------|--------|---------|--------|------------|----------|
| forest_cut | 2 | 1 | 1 | | | | | |
| VAR | OBJ | OB_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 |
| cur_yrs_mat | hru | 0 | null | - | 20 | | | = |
| jday | hru | 0 | null | - | 295 | | | = |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES |
| harvest | hru | 0 | tree_harv | frsd | 0 | 0 | forest_cut | y |

In the 20th year of growth, on julian day 295, the forest is harvested. The “forest_cut” operation in harv.ops specifies the harvest index and efficiency used in the operation.

- 7) Wetland. When a wetland it not managed, no management file is needed and “null” can be entered in the MGT_OPS column in landuse.lum.

Fertilizer decision table:

| NAME | CONDS | ALTS | ACTS | | | | | | |
|---------------|-------|---------|----------------|---------|---------|--------|-----------|----------|------|
| fert_sprg_sic | 5 | 2 | 2 | | | | | | |
| VAR | OBJ | OBJ_NUM | LIM_VAR | LIM_OP | M_CONST | | | ALT1 | ALT2 |
| phu_base0 | hru | 0 | null | - | 0.12 | | | > | - |
| year_rot | hru | 0 | null | - | 1 | | | = | = |
| n_stress | hru | 0 | null | - | 0.9 | | | - | < |
| plant_gro | hru | 0 | y | - | 1 | | | - | = |
| phu_plant | hru | 0 | phu_mat | - | 1.05 | | | - | < |
| ACT_TYP | OBJ | OBJ_NUM | NAME | OPTION | CONST | CONST2 | FP | OUTCOMES | |
| fertilize | hru | 0 | ammonia_spring | anh_nh3 | 160 | 1 | inject | y | n |
| fertilize | hru | 0 | side_dress | urea | 50 | 2 | broadcast | n | y |

PLANT.INI file:

| plant.ini: | | | | | | | | | | |
|----------------|--------|-------|------|------|-----|-------|--------|-----|-------|-------|
| NAME | PL_COM | ROTYR | CPNM | IGRO | LAI | BIOMS | PHUACC | POP | YRMAT | RSDIN |
| corn_sb_1 | 2 | 1 | | | | | | | | |
| | | | corn | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| | | | soyb | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| corn_sb_2 | 2 | 2 | | | | | | | | |
| | | | corn | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| | | | soyb | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| corn_sb_shemi1 | 2 | 1 | | | | | | | | |
| | | | corn | y | 2 | 8000 | 0.3 | 0 | 0 | 2000 |
| | | | soyb | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| corn_sb_shemi2 | 2 | 2 | | | | | | | | |
| | | | corn | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| | | | soyb | y | 2 | 4000 | 0.3 | 0 | 0 | 2000 |
| corn_con | 1 | 1 | | | | | | | | |
| | | | corn | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| soyb_con | 1 | 1 | | | | | | | | |
| | | | soyb | n | 0 | 0 | 0 | 0 | 0 | 2000 |
| corn_con_shemi | 1 | 1 | | | | | | | | |
| | | | corn | y | 2 | 8000 | 0.3 | 0 | 0 | 2000 |
| soyb_con_shemi | 1 | 1 | | | | | | | | |
| | | | soyb | y | 2 | 4000 | 0.3 | 0 | 0 | 2000 |
| canary_grass | 1 | 1 | | | | | | | | |
| | | | cang | y | 1 | 1000 | 0 | 0 | 0 | 2000 |

REGIONS**LS_UNIT.ELE**

The LS_UNIT.ELE file contains the input variables

Below is a sample LS_UNIT.ELE

```
ls_unit.ele
NUMB  NAME  OB_TYP  OB_TYPNO  BSN_FRAC  SUB_FRAC  REG_FRAC
  1    hru1    hru        1      0.500      0.5      0
  2    hru2    hru        2      0.500      0.5      0
```

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the LS_UNIT.ELE file |
| HEADER | |
| NUMB | The sequential number of the LS_UNIT.ELE |
| NAME | Name |
| OB_TYP | Type of object to print (cha, res, etc) |
| OB_TYPNO | Object type number |
| BSN_FRAC | fraction of element in basin (expansion factor) |
| SUB_FRAC | fraction of element in sub (expansion factor) |

LS_UNIT.DEF

The LS_UNIT.DEF file contains the input variables

Below is a sample LS_UNIT.DEF

```
ls_unit.def  Subbasin
2
NUMB  NAME  AREA_HA  NSPU  ELEM1  ELEM2
  1    lcu1    493.38    1      1      2
```

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the LS_UNIT.DEF file |
| MLSU | Number of regions |
| HEADER | |
| NUMB | The sequential number of the LS_UNIT.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

LS_REG.DEF

The LS_REG.DEF file contains the input variables

Below is a sample LS_REG.DEF

ls_reg.def Subbasin

2

| | | | | | |
|------|------|---------|------|-------|-------|
| NUMB | NAME | AREA_HA | NSPU | ELEM1 | ELEM2 |
| 1 | lcu1 | 493.38 | 1 | 1 | 2 |

| Variable name | Definition |
|------------------|---|
| TITLE | Description of the LS_REG.DEF file |
| MREG | Number of regions |
| MLUG | Number of landuse groups |
| HEADER | |
| NUMB | The sequential number of the LS_REG.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

CH_CATUNIT.DEF

The CH_CATUNIT.DEF file contains the input variables

Below is a sample CH_CATUNIT.DEF

Ch_catunit.def Subbasin

2

| | | | | | |
|------|------|---------|------|-------|-------|
| NUMB | NAME | AREA_HA | NSPU | ELEM1 | ELEM2 |
| 1 | lcu1 | 493.38 | 1 | 1 | 2 |

| Variable name | Definition |
|------------------|---|
| TITLE | Description of the CH_CATUNIT.DEF file |
| MREG | Number of regions |
| HEADER | |
| NUMB | The sequential number of the CH_CATUNIT.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

CH_REG.DEF

The CH_REG.DEF file contains the input variables

Below is a sample CH_REG.DEF

Ch_reg.def Subbasin
2

| | | | | | |
|------|------|---------|------|-------|-------|
| NUMB | NAME | AREA_HA | NSPU | ELEM1 | ELEM2 |
| 1 | lcu1 | 493.38 | 1 | 1 | 2 |

| Variable name | Definition |
|---------------|---|
| TITLE | Description of the CH_REG.DEF file |
| MREG | Number of regions |
| HEADER | |
| NUMB | The sequential number of the CH_REG.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

AQU_CATUNIT.ELE

Below is a sample AQU_CATTUNIT.ELE

| aqu_catunit.ele | id | name | obj_typ | obj_typ_no | bsn_frac | ru_frac | reg_frac |
|-----------------|----|-------|---------|------------|----------|---------|----------|
| 1 | | aqu01 | aqu | 1 | 0.025111 | 0 | 0 |
| 2 | | aqu02 | aqu | 2 | 0.031975 | 0 | 0 |
| 3 | | aqu03 | aqu | 3 | 0.559743 | 0 | 0 |
| 4 | | aqu04 | aqu | 4 | 0.484497 | 0 | 0 |
| 5 | | aqu05 | aqu | 5 | 0.44563 | 0 | 0 |
| 6 | | aqu06 | aqu | 6 | 0.394218 | 0 | 0 |
| 7 | | aqu07 | aqu | 7 | 0.352965 | 0 | 0 |
| 8 | | aqu08 | aqu | 8 | 0.340873 | 0 | 0 |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the AQU_CATUNIT.ELE file |
| HEADER | |
| NUMB | The sequential number of the AQU_CATUNIT.ELE |
| NAME | |
| OBTYP | Type of object to print (cha, res, etc) |
| OBTYPNO | Object type number |
| BSN_FRAC | fraction of element in basin (expansion factor) |
| RU_FRAC | fraction of element in routing unit (expansion factor) |
| REG_FRAC | fraction of element in calibration region (expansion factor) |

AQU_CATUNIT.DEF

The AQU_CATUNIT.DEF file contains the input variables

Below is a sample AQU_CATUNIT.DEF

Aqu_catunit.def Subbasin

2

| | | | | | |
|------|------|---------|------|-------|-------|
| NUMB | NAME | AREA_HA | NSPU | ELEM1 | ELEM2 |
| 1 | lcu1 | 493.38 | 1 | 1 | 2 |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the AQU_CATUNIT.DEF file |
| MREG | Number of regions |
| HEADER | |
| NUMB | The sequential number of the AQU_CATUNIT.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

AQU_REG.DEF

The AQU_REG.DEF file contains the input variables

Below is a sample AQU_REG.DEF

aqu_reg.def Subbasin

2

| | | | | | |
|------|------|---------|------|-------|-------|
| NUMB | NAME | AREA_HA | NSPU | ELEM1 | ELEM2 |
| 1 | lcu1 | 493.38 | 1 | 1 | 2 |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the AQU_REG.DEF file |
| MREG | Number of regions |
| HEADER | |
| NUMB | The sequential number of the AQU_REG.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

RES_CATUNIT.ELE

The RES_CATUNIT.ELE file contains the input variables

Below is a sample RES_CATTUNIT.ELE

res_catunit.ele

| NUMB | NAME | OBTYP | OBTYPNO | BSN_FRAC | SUB_FRAC | REG_FRAC |
|------|------|-------|---------|----------|----------|----------|
| 1 | hru1 | hru | 1 | 0.500 | 0.5 | 0 |
| 2 | hru2 | hru | 2 | 0.500 | 0.5 | 0 |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the RES_CATUNIT.ELE file |
| HEADER | |
| NUMB | The sequential number of the RES_CATUNIT.ELE |
| NAME | |
| OBTYP | Type of object to print (cha, res, etc) |
| OBTYPNO | Object type number |
| BSN_FRAC | fraction of element in basin (expansion factor) |
| SUB_FRAC | fraction of element in sub (expansion factor) |
| REG_FRAC | fraction of element in calibration region (expansion factor) |

RES_REG.DEF

The RES_REG.DEF file contains the input variables

Below is a sample RES_REG.DEF

res_reg.def Subbasin

| NUMB | NAME | AREA_HA | NSPU | ELEM1 | ELEM2 |
|------|------|---------|------|-------|-------|
| 1 | lcu1 | 493.38 | 1 | 1 | 2 |

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the RES_REG.DEF file |
| MREG | Number of regions |
| HEADER | |
| NUMB | The sequential number of the RES_REG.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

RES_CATUNIT.DEF

The RES_CATUNIT.DEF file contains the input variables

Below is a sample RES_CATUNIT.DEF

```
res_catunit.def  Subbasin
2
NUMB      NAME      AREA_HA      NSPU      ELEM1      ELEM2
1          lcu1      493.38        1          1          2
```

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the RES_CATUNIT.DEF file |
| MREG | Number of regions |
| HEADER | |
| NUMB | The sequential number of the RES_CATUNIT.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

REC_CATUNIT.ELE

The REC_CATUNIT.ELE file contains the input variables

Below is a sample REC_CATTUNIT.ELE

```
rec_catunit.ele
NUMB  NAME  OBTPY  OBTPYNO  BSN_FRAC  SUB_FRAC  REG_FRAC
1     hru1   hru      1        0.500     0.5       0
2     hru2   hru      2        0.500     0.5       0
```

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the REC_CATUNIT.ELE file |
| HEADER | |
| NUMB | The sequential number of the REC_CATUNIT.ELE |
| NAME | |
| OBTPY | Type of object to print (cha, res, etc) |
| OBTPYNO | Object type number |
| BSN_FRAC | fraction of element in basin (expansion factor) |
| SUB_FRAC | fraction of element in sub (expansion factor) |
| REG_FRAC | fraction of element in calibration region (expansion factor) |

REC_CATUNIT.DEF

The REC_CATUNIT.DEF file contains the input variables

Below is a sample REC_CATUNIT.DEF

```
rec_catunit.def Subbasin
2
NUMB      NAME      AREA_HA      NSPU      ELEM1      ELEM2
  1         lc1         493.38         1         1         2
```

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the REC_CATUNIT.DEF file |
| MREG | Number of regions |
| HEADER | |
| NUMB | The sequential number of the REC_CATUNIT.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

REC_REG.DEF

The REC_REG.DEF file contains the input variables

Below is a sample REC_REG.DEF

```
rec_reg.def Subbasin
2
NUMB      NAME      AREA_HA      NSPU      ELEM1      ELEM2
  1         lc1         493.38         1         1         2
```

| Variable name | Definition |
|---------------|--|
| TITLE | Description of the REC_REG.DEF file |
| MREG | Number of regions |
| HEADER | |
| NUMB | The sequential number of the REC_REG.DEF |
| NAME | |
| AREA_HA | Surface area |
| NSPU | |
| ELEM_CNT | |

PATH_PCP/PATH_TMP/PATH_SLR/PATH_HMD/PATH_WND

The PATH weather files contain the daily values for the simulation run. The data files can be present in the same directory as the other input data OR in a separate sub-directory. If they are copied to a sub-directory, the following should be input so the model will read from the files during runtime.

In the following example, the data directory is: c:\LREW and the weather will be read from c:\LREW\weather.

Example: CLIMATE_PCP weather\\
 CLIMATE_TMP weather\\
 CLIMATE_SLR weather\\
 CLIMATE_HMD weather\\
 CLIMATE_WND weather\\

(d:\swatplus_code\water_bal_plant_wx_sums_or_avgs.xlsx)

Basin Outputs – The following table defines whether the water balance and plant weather variables are averaged or summed in the output file. All losses and nutrients are summed.

| <u>WATER BAL - AVERAGE</u> | <u>WATER BAL - SUM</u> | | <u>PLANT WX - AVERAGE</u> | <u>PLANT WX - SUM</u> |
|------------------------------------|------------------------|--|---------------------------|-----------------------|
| cn | precip | | lai | yield |
| sw | snofall | | bioms | strsw |
| sw_300 | snomlt | | residue | strsa |
| snopack | surq_gen | | sol_tmp | strstmp |
| | latq | | npInt | strsn |
| | wateryld | | ppInt | strsp |
| | perc | | tmx | percn |
| | et | | tmn | |
| | tloss | | tmpav | |
| | eplant | | solrad | |
| | esoil | | wndspd | |
| | surq_cont | | rhum | |
| | pet | | phubase0 | |
| | qtile | | | |
| | irr | | | |
| | surq_runon | | | |
| | latq_runon | | | |
| | overbank | | | |
| | surq_cha | | | |
| | surq_res | | | |
| | surq_ls | | | |
| | latq_cha | | | |
| | latq_res | | | |
| | latq_ls | | | |
| | | | | |
| <u>LOSSES and NUTRIENTS</u> | | | | |
| (all sums) | | | | |

OUTPUT FILES:

The following output files print the same variables for all time steps (day, mon, yr and aa) for the following:

WB = Water Balance

BASIN_WB_*.TXT (Basin)

LSUNIT_WB_*.TXT (Landscape Units)

HRU_WB_*.TXT (HRU)

HRU-LTE_WB_*.TXT (HRU lite; SWAT Deg)

| | | |
|-------------------------|---------|---|
| real :: precip = 0. | !mm H20 | prec falling on they HRU during timestep |
| real :: snofall = 0. | !mm H20 | amt of prec falling as snow/sleet/freezing rain during ts |
| real :: snomlt = 0. | !mm H20 | amt of snow or ice melting during timestep |
| real :: surq_gen = 0. | !mm H20 | amt of surf runoff to main channel |
| real :: latq = 0. | !mm H20 | amt of lat flow contrib to main channel during HRU during mo |
| real :: wateryld = 0. | !mm H20 | water yld(tot amt water entering main chan)from HRU during mo |
| real :: perc = 0. | !mm H20 | amt of water perc out of the soil profile & into the vadose |
| zone in HRU during mon | | |
| real :: et = 0. | !mm H20 | actual ET in HRU during mon |
| real :: tloss = 0. | !mm H20 | amt of trans losses from trib channels in HRU for mon |
| real :: eplant = 0. | !mm H20 | actual amt of transpiration that occurs during mon in HRU |
| real :: esoil = 0. | !mm H20 | actual amt of evap (from soil) that occurs during mon in HRU |
| real :: surq_cont = 0. | !mm H20 | amt of surf runoff gen during mon in HRU |
| real :: cn = 0. | !none | CN values during mon in HRU |
| real :: sw_init = 0. | !mm H20 | initial soil water content of entire profile |
| real :: sw_final = 0. | !mm H20 | final soil water content of entire profile |
| real :: sw = 0. | !mm H20 | average soil water content of entire profile |
| real :: sw_300 = 0. | !mm H20 | soil water content of upper 300 mm |
| real :: snopack = 0. | !mm | snow pack |
| real :: pet = 0. | !mm H20 | pot et on current day in HRU |
| real :: qtile = 0. | !mm H20 | drainage tile flow contrib to main channel from HRU in mon |
| real :: irr = 0. | !mm H20 | amount of water applied to HRU |
| real :: surq_runon = 0. | !mm H20 | surface runoff from upland landscape units |
| real :: latq_runon = 0. | !mm H20 | lateral soil flow from upland landscape units |
| real :: overbank = 0. | !mm H20 | overbank flooding from channels |
| real :: surq_cha = 0. | !mm H20 | surface runoff flowing into channels |
| real :: surq_res = 0. | !mm H20 | surface runoff flowing into reservoirs |
| real :: surq_ls = 0. | !mm H20 | surface runoff flowing into a landscape element |
| real :: latq_cha = 0. | !mm H20 | lateral soil flow into channels |
| real :: latq_res = 0. | !mm H20 | lateral soil flow into reservoirs |
| real :: latq_ls = 0. | !mm H20 | lateral soil flow into a landscape element |

The following output files print the same variables for all time steps (day, mon, yr and aa) for the following:

NB = Nutrient balance

BASIN_NB_*.TXT (Basin)

LSUNIT_NB_*.TXT (Landscape Units)

HRU_NB_*.TXT (HRU)

| | | |
|---------------------------|----------|--|
| real :: grazn = 0. | !kg N/ha | amt of nit added to soil in grazing on the day in HRU |
| real :: grazp = 0. | !kg P/ha | amt of phos added to soil in grazing on the day in HRU |
| real :: lab_min_p = 0. | !kg P/ha | amt of phos moving from the labile min pool to the |
| active min pool | | |
| | | in the soil profile on the current day in |
| the HRU | | |
| real :: act_sta_p = 0. | !kg P/ha | amt of phos moving from the active min pool to the |
| stable min pool | | |
| | | in the soil profile on the current day in |
| the HRU | | |
| real :: fertn = 0. | !kg N/ha | tot amt of nit applied to soil in HRU on day |
| real :: fertp = 0. | !kg P/ha | tot amt of phos applied to soil in HRU on day |
| real :: fixn = 0. | !kg N/ha | amt of nit added to plant biomass via fixation on the |
| day in HRU | | |
| real :: denit = 0. | !kg N/ha | amt of nit lost from nitrate pool by denit in soil |
| profile | | |
| | | on current day in HRU |
| real :: act_nit_n = 0. | !kg N/ha | amt of nit moving from active org to nitrate pool in |
| soil profile | | |
| | | on current day in HRU |
| real :: act_sta_n = 0. | !kg N/ha | amt of nit moving from active org to stable org pool |
| in soil | | |
| | | profile on current day in HRU |
| real :: org_lab_p = 0. | !kg P/ha | amt of phos moving from the org to labile pool in soil |
| profile | | |
| | | on current day in HRU |
| real :: rsd_nitorg_n = 0. | !kg N/ha | amt of nit moving from the fresh org (residue) to the |
| nitrate(80%) | | |
| | | and active org(20%) pools in soil profile |
| on current day in HRU | | |
| real :: rsd_laborg_p = 0. | !kg P/ha | amt of phos moving from the fresh org (residue) to the |
| labile(80%) | | |
| | | and org(20%) pools in soil profile on |
| current day in HRU | | |
| real :: no3atmo = 0. | !kg N/ha | nitrate added to the soil from atmospheric deposition |
| (rainfall+dry) | | |
| real :: nh4atmo = 0. | !kg N/ha | ammonia added to the soil from atmospheric deposition |
| (rainfall+dry) | | |

The following output files print the same variables for all time steps (day, mon, yr and aa) for the following:

LS = Losses

BASIN_LS_*.TXT (Basin)

LSUNIT_LS_*.TXT (Landscape Units)

HRU_LS_*.TXT (HRU)

HRU-LTE_*.TXT (HRU lite; SWAT Deg)

| | | |
|-----------------------|-----------------|---|
| real :: sedyld = 0. | !metric tons | daily soil loss caused by water erosion |
| real :: sedorgn = 0. | !kg N/ha | amt of org nit in surf runoff in HRU for the day |
| real :: sedorgp = 0. | !kg P/ha | amt of org phos in surf runoff in HRU for the day |
| real :: surqno3 = 0. | !kg N/ha | amt of NO3-N in surf runoff in HRU for the day |
| real :: latno3 = 0. | !kg N/ha | amt of NO3-N in lat flow in HRU for the day |
| real :: surqsolp = 0. | !kg P/ha | amt of soluble phos in surf runoff in HRU for the |
| day | | |
| real :: usle = 0. | !metric tons/ha | daily soil loss predicted with USLE equation |
| real :: sedmin = 0. | ! | |
| real :: tileno3 = 0. | !kg N/ha | NO3 in tile flow |

The following output files print the same variables for all time steps (day, mon, yr and aa) for the following:

PW = Plant weather

BASIN_PW_*.TXT (Basin)

LSUNIT_PW_*.TXT (Landscape Units)

HRU_PW_*.TXT (HRU)

HRU-LTE_PW_*.TXT (HRU lite; SWAT Deg)

| | | |
|-----------------------|------------|---|
| real :: lai = 0. | !m**2/m**2 | leaf area index |
| real :: bioms = 0. | !kg/ha | land cover/crop biomass |
| real :: yield = 0. | !kg/ha | yield (dry weight) by crop type |
| real :: residue = 0. | !kg/ha | initial residue cover |
| real :: sol_tmp = 0. | !deg C | daily average temperature of soil layer |
| real :: strsw = 0. | !0-1 | water (drought) stress |
| real :: strsa = 0. | !0-1 | water (aeration) stress |
| real :: strstp = 0. | !0-1 | temperature stress |
| real :: strsn = 0. | !0-1 | nitrogen stress |
| real :: strsp = 0. | !0-1 | phosphorus stress |
| real :: nplnt = 0. | !kg N/ha | plant uptake of nit in HRU for the day |
| real :: percn = 0. | !kg N/ha | NO3-N leached from soil profile |
| real :: pplnt = 0. | !kg P/ha | plant uptake of phos in HRU for the day |
| real :: tmx = 0. | !deg C | maximum temperature for the day in HRU |
| real :: tmn = 0. | !deg C | minimum temperature for the day in HRU |
| real :: tmpav = 0. | !deg C | average air temperature on current day in HRU |
| real :: solrad = 0. | !MJ/m^2 | solar radiation for the day in HRU |
| real :: wndspd = 0. | !m/s | windspeed |
| real :: rhum = 0. | !none | relative humidity |
| real :: phubase0 = 0. | !deg c | base zero potential heat units |

The following output file prints the same variables for all time steps (day, mon, yr and aa) for the following:

BASIN_AQU_*.TXT (Basin Aquifer)

AQUIFER_*.TXT (Aquifer)

| | | |
|----------------------|------------|---|
| real :: flo = 0. | !mm | flow from aquifer in current time step |
| real :: dep_wt = 0. | !m | depth to water table |
| real :: stor = 0. | !mm | total water storage in aquifer |
| real :: rchrg = 0. | !mm | recharge |
| real :: seep = 0. | !kg N/ha | seepage to next object |
| real :: revap = 0. | !mm | revap |
| real :: no3 = 0. | !ppm NO3-N | nitrate-N concentration in aquifer |
| real :: minp = 0. | !kg | mineral phosphorus from aquifer on current timestep |
| real :: cbn = 0. | !percent | organic carbon in aquifer (initial) |
| real :: orgn = 0. | !kg/ha | organic nitrogen |
| real :: rchrg_n = 0. | ! | amount of nitrate getting to the shallow aquifer |
| real :: nloss = 0. | !kg/ha | nitrogen loss |
| real :: no3gw | !kg N/ha | nitrate loading to reach in groundwater |
| real :: seepno3 = 0. | !kg | seepage of no3 to next object |
| real :: flo_cha = 0. | !mm H2O | surface runoff flowing into channels |
| real :: flo_res = 0. | !mm H2O | surface runoff flowing into reservoirs |
| real :: flo_ls = 0. | !mm H2O | surface runoff flowing into a landscape element |

The following output file prints the same variables for all time steps (day, mon, yr and aa) for the following:

BASIN_RES_*.TXT (Basin Reservoir)

RESERVOIR_*.TXT (Reservoir)

| | | |
|------------------------|---------------|---|
| real :: area_ha = 0. | ! ha | water body surface area |
| real :: precip = 0. | ! ha-m | precip on the water body |
| real :: evap = 0. | ! ha-m | evaporation from the water surface |
| real :: seep = 0. | ! ha-m | seepage from bottom of water body |
| real :: flo_stor = 0. | ! m^3 | volume of water storage |
| real :: sed_stor = 0. | ! metric tons | sediment in |
| real :: orgn_stor = 0. | ! kg N | organic N storage |
| real :: sedp_stor = 0. | ! kg P | organic P storage |
| real :: no3_stor = 0. | ! kg N | NO3-N storage |
| real :: solp_stor = 0. | ! kg P | mineral (soluble P) storage |
| real :: chla_stor = 0. | ! kg | chlorophyll-a storage |
| real :: nh3_stor = 0. | ! kg N | NH3 storage |
| real :: no2_stor = 0. | ! kg N | NO2 storage |
| real :: cbod_stor = 0. | ! kg | carbonaceous biological oxygen demand storage |
| real :: dox_stor = 0. | ! kg | dissolved oxygen storage |
| real :: san_stor = 0. | ! tons | detached sand storage |
| real :: sil_stor = 0. | ! tons | detached silt storage |
| real :: cla_stor = 0. | ! tons | detached clay storage |
| real :: sag_stor = 0. | ! tons | detached small ag storage |
| real :: lag_stor = 0. | ! tons | detached large ag storage |
| real :: grv_stor = 0. | ! tons | gravel storage |
| real :: temp_stor = 0. | ! deg c | temperature storage |
| real :: flo_in = 0. | ! m^3 | volume of water in |
| real :: sed_in = 0. | ! metric tons | sediment in |
| real :: orgn_in = 0. | ! kg N | organic N in |
| real :: sedp_in = 0. | ! kg P | organic P in |
| real :: no3_in = 0. | ! kg N | NO3-N in |
| real :: solp_in = 0. | ! kg P | mineral (soluble P) in |
| real :: chla_in = 0. | ! kg | chlorophyll-a in |
| real :: nh3_in = 0. | ! kg N | NH3 in |
| real :: no2_in = 0. | ! kg N | NO2 in |
| real :: cbod_in = 0. | ! kg | carbonaceous biological oxygen demand in |
| real :: dox_in = 0. | ! kg | dissolved oxygen in |
| real :: san_in = 0. | ! tons | detached sand in |
| real :: sil_in = 0. | ! tons | detached silt in |
| real :: cla_in = 0. | ! tons | detached clay in |
| real :: sag_in = 0. | ! tons | detached small ag in |
| real :: lag_in = 0. | ! tons | detached large ag in |
| real :: grv_in = 0. | ! tons | gravel in |
| real :: temp_in = 0. | ! deg c | temperature in |
| real :: flo_out = 0. | ! m^3 | volume of water out |
| real :: sed_out = 0. | ! metric tons | sediment out |
| real :: orgn_out = 0. | ! kg N | organic N out |
| real :: sedp_out = 0. | ! kg P | organic P out |
| real :: no3_out = 0. | ! kg N | NO3-N out |
| real :: solp_out = 0. | ! kg P | mineral (soluble P) out |
| real :: chla_out = 0. | ! kg | chlorophyll-a out |
| real :: nh3_out = 0. | ! kg N | NH3 out |
| real :: no2_out = 0. | ! kg N | NO2 out |
| real :: cbod_out = 0. | ! kg | carbonaceous biological oxygen demand out |
| real :: dox_out = 0. | ! kg | dissolved oxygen out |
| real :: san_out = 0. | ! tons | detached sand out |
| real :: sil_out = 0. | ! tons | detached silt out |
| real :: cla_out = 0. | ! tons | detached clay out |
| real :: sag_out = 0. | ! tons | detached small ag out |

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| | | |
|-----------------------|---------|-----------------------|
| real :: lag_out = 0. | ! tons | detached large ag out |
| real :: grv_out = 0. | ! tons | gravel out |
| real :: temp_out = 0. | ! deg c | temperature out |

The following output file prints the same variables for all time steps (day, mon, yr and aa) for the following:

BASIN_CHA_*.TXT (Basin Channel)

CHANNEL_*.TXT (Channel)

| | | |
|--------------------------|---------------|---|
| real :: flo_in = 0. | ! (ha-m) | streamflow into reach during time step |
| real :: flo_out = 0. | ! (ha-m) | streamflow out of reach during time step |
| real :: evap = 0. | ! (m^3/s) | daily rate of water loss from reach by evaporation |
| real :: tloss = 0. | ! (m^3/s) | rate of water loss from reach by transmission through |
| the streambed | | |
| real :: sed_in = 0. | ! (tons) | sediment transported with water into reach |
| real :: sed_out = 0. | ! (tons) | sediment transported with water out of reach |
| real :: sed_conc = 0. | ! (mg/L) | concentration of sediment in reach |
| real :: orgn_in = 0. | ! (kg N) | organic nitrogen transported with water into reach |
| real :: orgn_out = 0. | ! (kg N) | organic nitrogen transported with water out of reach |
| real :: orgp_in = 0. | ! (kg P) | organic phosphorus transported with water into reach |
| real :: orgp_out = 0. | ! (kg P) | organic phosphorus transported with water out of reach |
| real :: no3_in = 0. | ! (kg N) | nitrate transported with water into reach |
| real :: no3_out = 0. | ! (kg N) | nitrate transported with water out of reach |
| real :: nh4_in = 0. | ! (kg) | ammonium transported with water into reach |
| real :: nh4_out = 0. | ! (kg) | ammonium transported with water out of reach |
| real :: no2_in = 0. | ! (kg) | nitrite transported with water into reach |
| real :: no2_out = 0. | ! (kg) | nitrite transported with water out of reach |
| real :: solp_in = 0. | ! (kg P) | soluble pesticide transported with water into reach |
| real :: solp_out = 0. | ! (kg P) | soluble pesticide transported with water out of reach |
| real :: chla_in = 0. | ! (kg) | amount of chlorophyll a transported into reach |
| real :: chla_out = 0. | ! (kg) | amount of chlorophyll a transported out of reach |
| real :: cbod_in = 0. | ! (kg) | carbonaceous biochemical oxygen demand of material |
| transported into reach | | |
| real :: cbod_out = 0. | ! (kg) | carbonaceous biochemical oxygen demand of material |
| transported out of reach | | |
| real :: dis_in = 0. | ! (kg) | amount of dissolved oxygen transported into reach |
| real :: dis_out = 0. | ! (kg) | amount of dissolved oxygen transported out of reach |
| real :: solpst_in = 0. | ! (mg pst) | soluble pesticide transported with water into reach |
| real :: solpst_out = 0. | ! (mg pst) | soluble pesticide transported with water out of reach |
| real :: sorbpst_in = 0. | ! (mg pst) | pesticide sorbed to sediment transported with water |
| into reach | | |
| real :: sorbpst_out = 0. | ! (mg pst) | pesticide sorbed to sediment transported with water out |
| of reach | | |
| real :: react = 0. | ! (mg pst) | loss of pesticide from water from reaction |
| real :: volat = 0. | ! (mg) | loss of pesticide from water by volatilization |
| real :: setlpst = 0. | ! (mg pst) | transfer of pesticide from water to river bed sediment |
| by settling | | |
| real :: resuspst = 0. | ! (mg) | transfer of pesticide from river bed sediment to water |
| by resuspension | | |
| real :: difus = 0. | ! mg | transfer of pesticide from water to river bed sediment |
| by diffusion | | |
| real :: reactb = 0. | ! (mg) | loss of pesticide from river bed sediment by reaction |
| real :: bury = 0. | ! (mg) | loss of pesticide from river bed sediment by burial |
| real :: sedpest = 0. | ! mg | pesticide in river bed sediment |
| real :: bacp = 0. | ! # cfu/100mL | number of persistent bacteria transported out of reach |
| real :: baclp = 0. | ! # cfu/100mL | number of less persistent bacteria transported out of |
| reach | | |
| real :: met1 = 0. | ! kg | conservative metal #1 transported out of reach |
| real :: met2 = 0. | ! kg | conservative metal #2 transported out of reach |
| real :: met3 = 0. | ! kg | conservative metal #3 transported out of reach |
| real :: sand_in = 0. | ! tons | sand in |
| real :: sand_out = 0. | ! tons | sand out |
| real :: silt_in = 0. | ! tons | silt_in |
| real :: silt_out = 0. | ! tons | silt_out |

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| | | |
|-----------------------|--------|---|
| real :: clay_in = 0. | ! tons | clay_in |
| real :: clay_out = 0. | ! tons | clay_out |
| real :: smag_in = 0. | ! tons | small aggregates transported into reach |
| real :: smag_out = 0. | ! tons | small aggregates transported out of reach |
| real :: lag_in = 0. | ! tons | large aggregates transported into reachlg ag in |
| real :: lag_out = 0. | ! tons | large aggregates transported out of reach |
| real :: grvl_in = 0. | ! tons | gravel in |
| real :: grvl_out = 0. | ! tons | gravel out |
| real :: bnk_ero = 0. | ! tons | bank erosion |
| real :: ch_deg = 0. | ! tons | channel degradation |
| real :: ch_dep = 0. | ! tons | channel deposition |
| real :: fp_dep = 0. | ! tons | flood deposition |
| real :: tot_ssed = 0. | ! mg/L | total suspended sediments |

The following output file prints the same variables for all time steps (day, mon, yr and aa) for the following:

BASIN_SD_CHA_*.TXT (Basin SWAT Deg Channel)

CHANNEL_SD_*.TXT (SWAT Deg Channel)

| | | |
|-----------------------|---------------|---|
| real :: area_ha = 0. | ! ha | water body surface area |
| real :: precip = 0. | ! ha-m | precip on the water body |
| real :: evap = 0. | ! ha-m | evaporation from the water surface |
| real :: seep = 0. | ! ha-m | seepage from bottom of water body |
| real :: flo_in = 0. | ! m^3 | volume of water in |
| real :: sed_in = 0. | ! metric tons | sediment in |
| real :: orgn_in = 0. | ! kg N | organic N in |
| real :: sedp_in = 0. | ! kg P | organic P in |
| real :: no3_in = 0. | ! kg N | NO3-N in |
| real :: solp_in = 0. | ! kg P | mineral (soluble P) in |
| real :: chla_in = 0. | ! kg | chlorophyll-a in |
| real :: nh3_in = 0. | ! kg N | NH3 in |
| real :: no2_in = 0. | ! kg N | NO2 in |
| real :: cbod_in = 0. | ! kg | carbonaceous biological oxygen demand in |
| real :: dox_in = 0. | ! kg | dissolved oxygen in |
| real :: san_in = 0. | ! tons | detached sand in |
| real :: sil_in = 0. | ! tons | detached silt in |
| real :: cla_in = 0. | ! tons | detached clay in |
| real :: sag_in = 0. | ! tons | detached small ag in |
| real :: lag_in = 0. | ! tons | detached large ag in |
| real :: grv_in = 0. | ! tons | gravel in |
| real :: temp_in = 0. | ! deg c | temperature in |
| real :: flo_out = 0. | ! m^3 | volume of water out |
| real :: sed_out = 0. | ! metric tons | sediment out |
| real :: orgn_out = 0. | ! kg N | organic N out |
| real :: sedp_out = 0. | ! kg P | organic P out |
| real :: no3_out = 0. | ! kg N | NO3-N out |
| real :: solp_out = 0. | ! kg P | mineral (soluble P) out |
| real :: chla_out = 0. | ! kg | chlorophyll-a out |
| real :: nh3_out = 0. | ! kg N | NH3 out |
| real :: no2_out = 0. | ! kg N | NO2 out |
| real :: cbod_out = 0. | ! kg | carbonaceous biological oxygen demand out |
| real :: dox_out = 0. | ! kg | dissolved oxygen out |
| real :: san_out = 0. | ! tons | detached sand out |
| real :: sil_out = 0. | ! tons | detached silt out |
| real :: cla_out = 0. | ! tons | detached clay out |
| real :: sag_out = 0. | ! tons | detached small ag out |
| real :: lag_out = 0. | ! tons | detached large ag out |
| real :: grv_out = 0. | ! tons | gravel out |
| real :: temp_out = 0. | ! deg c | temperature out |

The following output file prints the same variables for all time steps (day, mon, yr and aa) for the following:

BASIN_SD_CHAMORPH_*.TXT (Basin SWAT Deg Channel Morphology)

CHANNEL_SDMORPH_*.TXT (SWAT Deg Channel Morphology)

| | | |
|-------------------------|-----------------------|-------------------|
| real :: flo_in = 0. | ! (m ³ /s) | !ave flow rate |
| real :: aqu_in = 0. | ! (m ³ /s) | !ave flow rate |
| real :: flo = 0. | ! (m ³ /s) | !ave flow rate |
| real :: peakr = 0. | ! (m ³ /s) | !peak runoff rate |
| real :: sed_in = 0. | ! (tons) | !total sed in |
| real :: sed_out = 0. | ! (tons) | !total sed out |
| real :: washld = 0. | ! (tons) | !wash load |
| real :: bedld = 0. | ! (tons) | !bed load |
| real :: dep = 0. | ! (tons) | !deposition |
| real :: deg_btm = 0. | ! (tons) | !bottom erosion |
| real :: deg_bank = 0. | ! (tons) | !bank erosion |
| real :: hc_sed = 0. | ! (tons) | !headcut erosion |
| real :: width = 0. | ! m | !channel width |
| real :: depth = 0. | ! m | !channel depth |
| real :: slope = 0. | ! m/m | !channel slope |
| real :: deg_btm_m = 0. | ! (m) | !downcutting |
| real :: deg_bank_m = 0. | ! (m) | !widening |
| real :: hc_m = 0. | ! (m) | !headcut retreat |

The following output file prints the same variables for all time steps (day, mon, yr and aa) for the following:

BASIN_PSC_*.TXT (Basin Point Source)

RECALL_*.TXT (Recall)

| | | |
|-------------------|----------------|---------------------------------------|
| real :: flo = 0. | !! m^3 | volume of water |
| real :: sed = 0. | !! metric tons | sediment |
| real :: orgn = 0. | !! kg N | organic N |
| real :: sedp = 0. | !! kg P | organic P |
| real :: no3 = 0. | !! kg N | NO3-N |
| real :: solp = 0. | !! kg P | mineral (soluble P) |
| real :: chla = 0. | !! kg | chlorophyll-a |
| real :: nh3 = 0. | !! kg N | NH3 |
| real :: no2 = 0. | !! kg N | NO2 |
| real :: cbod = 0. | !! kg | carbonaceous biological oxygen demand |
| real :: dox = 0. | !! kg | dissolved oxygen |
| real :: san = 0. | !! tons | detached sand |
| real :: sil = 0. | !! tons | detached silt |
| real :: cla = 0. | !! tons | detached clay |
| real :: sag = 0. | !! tons | detached small ag |
| real :: lag = 0. | !! tons | detached large ag |
| real :: grv = 0. | !! tons | gravel |
| real :: temp = 0. | !! deg c | temperature |