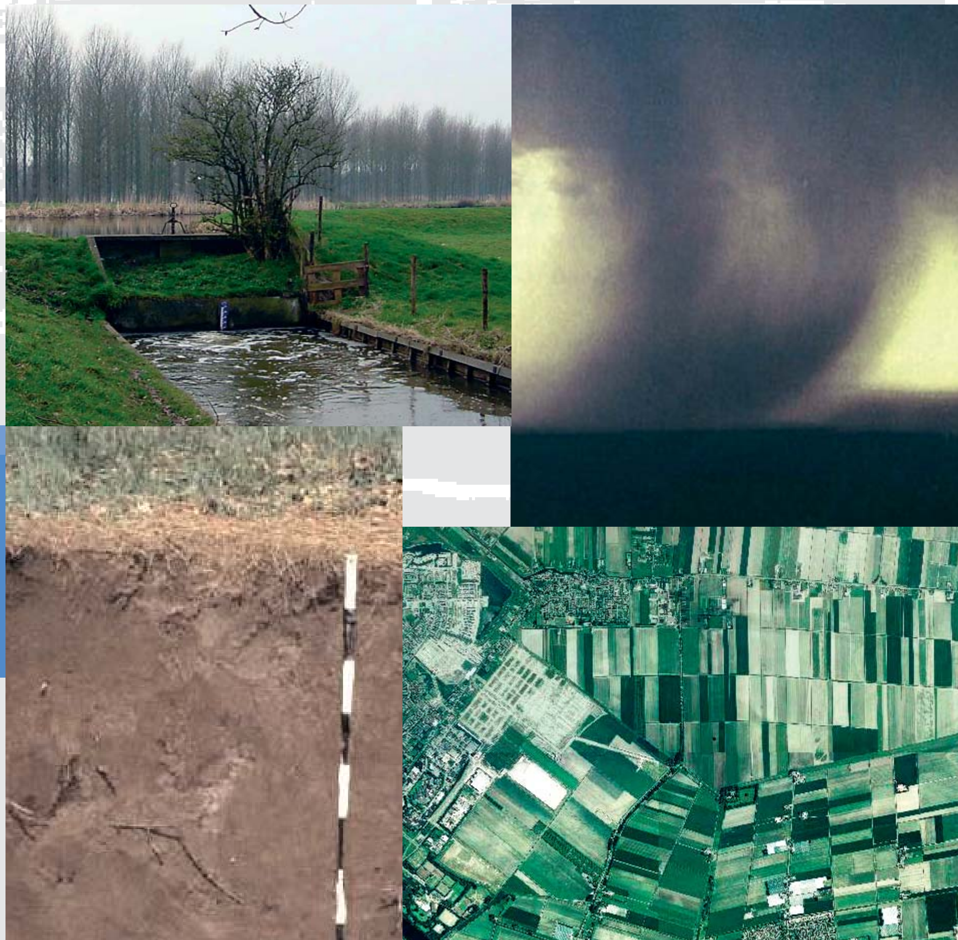
ALTERRA
WAGENINGEN UR

SIMGRO V7.1.4

Input and output reference manual

P.E.V. van Walsum



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ABSTRACT

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The regional hydrologic model SIMGRO is used for investigating various kinds of water management problems. The model implementation can include the crop growth model WOFOST, with feedback to the hydrologic parameters like root zone depth and leaf area index. SIMGRO is especially suited for modelling situations with shallow groundwater levels in relatively flat areas, like in delta regions. In such terrain the two-way interaction between groundwater and surface waters plays a crucial role. The offered modelling options include the simulation of drainage with feedback from surface water levels at the time step of the 'fast processes'. The SIMGRO package also includes a simplified model for the simulation of surface water processes. The user has furthermore the option of through-linking the surface water locations to a hydraulic model. The SIMGRO model assembly for the 'top system processes' is used in combination with MODFLOW for the groundwater. This document describes the input and output files.

Keywords: regional hydrology, simulation, water management, crop growth.

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PREFACE

In the past year the model has been made suitable for soils with deep groundwater levels; formerly the evapotranspiration of such soils was under¬estimated. The added extra 'aggregation layer' for the zone just below the root zone remedied that deficiency. The idea of using extra aggregation layers was first suggested by former colleague Pim Dik. This idea has now been implemented in a generalized form, involving N-layers forming a cascade of nonlinear reservoirs.

The second major enhancement of the last year was the coupling to the crop growth model WOFOST. This coupling has been implemented in a two-way fashion, including the (optional) feedback from the vegetation development to the hydrologic model. The used state variables for this feedback are the depth of the root zone, the crop height, the leaf area index, and the soil cover. For facilitating this feedback an option was included for dynamic development of the root zone layer in MetaSWAP. The coupling to WOFOST coincided with the enhancement of the SWAP-WOFOST coupling by SWAP developers Joop Kroes, Jos van Dam and the WOFOST expert Iwan Supit. They provided the information needed for realizing the coupling of WOFOST to SIMGRO.

The concept for the interception evaporation was reformulated, in collaboration with the SWAP developers. Furthermore, the SWAP-method for handling the partitioning between transpiration and soil evaporation was implemented. The Maas-Hoffman method was included for simulating the effect of salt stress on the transpiration uptake. The coupling to the TRANSOL model for simulating solute movements and processes in soils was implemented in collaboration with Joop Kroes. The program metaswap2transol also includes the temperature simulation of SWAP.

Low-cost parallel computing is now possible on multi-core pc's with 2 to 8 cores. And high-performance pc-clusters provide a further multiplication of computing power. To make use of these opportunities the codes of MetaSWAP and SIMGRO-drainage have been parallelized via the OpenMP-protocol in combination with a state-of-art 64bit-compiler (Intel Fortran 11.1).

SIMGRO has a history that goes back to the mid-eighties. The first and second versions were developed by Erik Querner in collaboration with Jan van Bakel. In the course of time, various other persons not belonging to the current team have contributed in one way or the other: Pim Dik, Robert Smit, and Frank van der Bolt.

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Wageningen, December 2009.

1 Introduction

This manual comprises the third of three documents describing the SIMGRO package:

1. SIMGRO Theory and model implementation;
2. SIMGRO User's guide;
3. SIMGRO Input and output reference manual.

The specification for the input file descriptions is tabulated below. In many cases, an example is included. If deemed necessary, descriptions are clarified through additional remarks.

Table 1.1 Input item characteristics

Item	description	
name	name of the parameter or variable	
format	input format in Fortran (see remarks below)	
col	column position of the data field (for tabular input only), given as beginning an ending position, e.g. 1-10.	
unit	unit of the input parameter or variable, e.g. m2	
description	brief description of the parameter or variable	
min.	minimum value allowed	
max.	maximum value allowed	
def.	default value	
type	req	: required
	opt	: optional
error-code	fatal	: error message, execution discontinued
	warning	: warning, execution continues
	set to min/max	: warning, variable set to min or max value

The formats of 'reals' are specified in the form of F*x*, where *x* is the total width of the available field (i.e. the number of ASCII characters, including the decimal dot). The user can specify any desired number of digits after the decimal dot, as long as it fits the available field. If the field can be in exponential notation, then the format is given as G*x*

The files listed in Table 1.2 are described in Section 2.

Table 1.2 Input files for SIMGRO. SVAT stands for Soil-Vegetation-Atmosphere Transfer module. SurfW is the simplified surface water model of SIMGRO

Input file	Req. /opt.	Module	Description
PARA_SIM.INP	req	param.	general input file
TIOP_SIM.INP	opt	output	specification of time-related output options
SEL_KEY_SVAT_PER/DTGW.INP	opt	output	specification of key variables for output to per/dtgw *bda* files (separate)
SEL_SVAT_PER/DTGW_BDA.INP	opt	output	specification of SVATs for output to per/dtgw bda-files (separate)
SEL_SVAT_CSV.INP	opt	output	specification of SVATs for output to csv files, both per and dtgw (same)
SEL_SWNR.INP	opt	output	specification of swnr's for output to *csv* files
MOD2SVAT.INP	req	coupling	linking of SVAT units to MODFLOW cells
SVAT2SWNR_ROFF.INP	opt	coupling	runoff routing of SVAT units to SIMGRO surface water locations
SVAT2SWNR_DRNG.INP	opt	coupling	drainage parameters of SIMGRO drainage links
SWNR2SWQN.INP	opt	coupling	through-linking of SIMGRO surface water locations to SWQN nodes
AREA_SVAT.INP	req	SVAT	area, soil surface elevation , soil unit, land use, thickness root zone, meteo station
INFI_SVAT.INP	req	SVAT	infiltration/exfiltration parameters of soil surface
LUSE_SVAT.INP	req	SVAT	set of land use options and their characteristics
FACT_SVAT.INP	req	SVAT	values of vegetation factors, interception characteristics
VG2CRP_SVAT.INP	opt	SVAT	coupling of *vg*-index to WOFOST crop files
UNSA_SVAT.BDA THSAT_SVAT.INP	req	SVAT	database with steady states of soil moisture profiles, file with saturated water contents
BETA2_SVAT.INP	req	SVAT	Boesten parameter for soil evaporation
FCWP_SVAT.INP GXG_GG_SVAT.INP	opt	SVAT	field capacity FC and wilting WP (pF's) groundwater levels for determining FC and WP
INIT_SVAT.INP	opt	SVAT	initial conditions of soil water
SCAP_SVAT.INP	opt	SVAT/ coupling	capacities of sprinkling links between SVAT units and SW and/or GW
FXSP_SVAT.INP	opt	SVAT	fixed sprinkling rates per time period
METE_STAT/SVAT.INP	req	SVAT	precipitation and evapotranspiration
METE_GRID.INP	opt	SVAT	meta-file for meteo-grids
SALT_SVAT.INP	opt	SVAT	salt effect parameters of soil physical units
SWNR_SIM.INP	opt	SurfW	list of SIMGRO surface water locations
MANA_RES.INP	opt	SurfW	surface water locations of SurfW model
GOTO_RESINP	opt	SurfW	network structure of SurfW model
DISH_RES.INP	opt	SurfW	discharge capacity per trajectory of SurfW
DISU_RES.INP	opt	SurfW	discharge capacity per trajectory (summer value)
RESV_RES.INP	opt	SurfW	supply links within SurfW model
TACL_RES.INP	opt	SurfW	target level lowering schemes of SurfW
TISW_RES.INP	opt	SurfW	time dependent water levels and discharges of SurfW model
INIT_RES.INP	opt	SurfW	initial conditions surface water in SurfW

2 Input files

2.1 General and IO-control

2.1.1 PARA_SIM.INP

The parameters in file PARA_SIM.INP are specified in a free format. Strings should be given between double quotes “...”.

Options for modelling of processes

Parameter format and description

name	format	unit	description
vegetation_mdl	I	-	vegetation model
evapotranspiration_mdl	I	-	evapotranspiration model
saltstress_mdl	I	-	salt stress model
surfacewater_mdl	I	-	surface water model
runoffconcept_swmdl1	I	-	runoff concept used for SVAT’s coupled to the SIMRES model
swmp_conf_file	A256	-	path-and-name string of file for mapping swnr’s to SOBEK id’s

Parameter characteristics

name	min.	max.	def.	type	error-code
vegetation_mdl	1	3	1	opt	fatal
evapotranspiration_mdl	1	2	1	opt	fatal
saltstress_mdl	0	1	0	opt	fatal
surfacewater_mdl	0	5	1	opt	fatal
runoffconcept_mdl1	-1	2	2	opt	fatal
swmp_conf_file	-	-	-	opt	fatal

Example

```
     evapotranspiration_mdl   =          1
     surfacewater_mdl         =          5
     swmp_conf_file           =    "D:\Sobek212\gw_sobek_conf.ini"
```

Options for vegetation model

vegetation_mdl	1	input of crop height and rooting depth via file FACT_SVAT.INP
	2	WOFOST; see VG2CRP_SVAT_INP, **no feedback** to ET simulation
	3	WOFOST; see VG2CRP_SVAT.INP, **with feedback** to ET simulation

Options for calculating evapotranspiration

evapotranspiration _mdl	1	input of Makkink reference crop evapotranspiration, crop factors
	2	Penman-Monteith, crop factors
	3	Penman-Monteith, crop-specific resistances

Options for stress model

saltstress_mdl	0	no simulation of salt stress
	1	Maas and Hoffman (1977); requires parameters c2eca, c2ecb, c2ecf (above) and two extra parameters in LUSE_SVAT.INP

Options for surface water model coupling

surfacewater_mdl	0	No SW coupling, even if SurfW files are present
	1	coupling to SurfW (optional, if files are present)
	2	coupling to SurfW (optional, if files are present) + SOBEK-CF
	5	coupling to SurfW (optional, if files are present) + SWQN

Options for runoff concept of SIMRES model

runoffconcept_swmdl1	-1	classic runoff concept for SVAT's coupled to the SIMRES model, using resistances
	2	integrated runoff concept (default)

Remarks

The use of the integrated runoff concept in combination with an external hydraulic model is not possible at this moment. Instead, only the "classic runoff" option is enabled, involving a linear resistance relationship with coefficient *crun* (see file SVAT2SWNR_ROFF.INP). The disadvantage of a resistance relationship is that the surface water model can can have strong level fluctuations during runon. (But the water balance is never violated.) The remedy is then to make the time step smaller, or choose a higher value for the resistance.

Calibration factor for bare soil evaporation simulation (Boesten)

Parameter format and description

name	format	unit	description
fact_beta2	R	-	calibration factor for beta2

Parameter characteristics

name	min.	max.	def.	type	error-code
fact_beta2	0.1	10.0	1.0	opt	-

Example

```
fact_svat            =   1.5
```

Remarks

The calibration factor is for taking into account the influence of short time intervals (< 1 day). See file BETA_SVAT.INP.

Location of soil physical database

Parameter format and description

name	format	unit	description
unsa_svat_path	A256	-	path of soil physical database files

Parameter characteristics

name	min.	max.	def.	type	error-code
unsa_svat_path	-	-	work directory	opt	-

Example

```
Unsa_svat_path            =   "D:\SoilPhysics\PAWN_cali03\"
```

Remarks

The path should include a backward slash at the end of the string. If the string is set to “ “ (or is not included altogether) the model assumes that the files are present in the work directory.

Time steps

Parameter format and description

name	format	unit	description
dtgw	F	d	time step for ground water (should be identical to MODFLOW)
dtsw	F	d	time step for fast processes (should be dtgw / N)

Parameter characteristics

name	min.	max.	def.	type	error-code
dtgw	1.0E-02	1.0E+02	1.00	opt	warning
dtsw	1.0E-03	1.0E+01	0.05	opt	warning

Example

```
       dtgw            =        1.00                 ! 1 day
       dtsw            =        0.416777777777       ! 1 hour
```

Begin/end time parameters

Parameter format and description

name	format	unit	description
tdbg	F	d	starting time of calculations, in days from beginning of year at 00:00:00
iybg	I	-	year number of starting time
tdbgsm	I	d	time of transition from “winter” to “summer”, in days from beginning of year at 00:00:00
tdedsm	I	d	time of transition from “summer” to “winter”, in days from beginning of year at 00:00:00

Parameter characteristics

name	min.	max.	def.	type	error-code
tdbg	0	365.	-	req	fatal
iybg	0	9999	-	req	fatal
tdbgsm	0	365.	91.	opt	fatal
tdedsm	0	365.	270.	opt	fatal

Example

```
       tdbg            =        0.00
       iybg            =        1989
       tdbgsm          =          91.
       tdedsm          =         274.
```

Remarks

The length of the simulation period is controlled by MODFLOW, using information from the *bas*-file. The starting time is needed by SIMGRO for knowing where to start with reading of the meteo-file.

If the time for start of summer season (*tdbgsm*) and end of summer season (*tdedsm*) are identical, then the model assumes that it is always “summer”.

Parameters for stabilisation of numerical schemes

Parameter format and description

name	format	unit	description
iterur1	I	-	maximum number of pcg-cycles without smoothing of storage coefficient
iterur2	I	-	maximum amount of pcg-cycles for which the storage coefficient is adjusted
dhmxsw	F	-	maximum change in surface water level over dtsw (SurfW)

Parameter characteristics

name	min.	max.	def.	type	error-code
iterur1	3	100	5	opt	fatal
iterur2	iterur1 + 1	101	7	opt	fatal
dhmxsw	0.	1.0E+01	0.25	opt	fatal

Example

```
      iterur1          =         5
      iterur2          =         7
       dhmxsw          =        0.05
```

Remarks

The iteration scheme for the convergence between MetaSWAP and MODFLOW would continue indefinitely if not some sort of smoothing operation is performed between the pcg-cycles; the latter are number by the variable *iter*. The iteration would never stop because – especially in a large model – there will always be a situation where the saturated flux is very sensitive to the specified storage coefficient of the phreatic layer. In order to use the computational resources efficiently we use the following smoothing scheme:

$$sc1(iter) = sc1new, \quad \text{for} \quad iter \leq iterur1$$
$$sc1(iter) = sc1new^{*}\,\omega + sc1(iter-1)^{*}(1-\omega), \quad \text{for} \quad iterur1+1 \leq iter \leq iterur2-1$$
$$sc1(iter) = sc1(iter-1) \quad \text{for} \quad iterur2 \leq iter$$

where *sc1new* is the new storage coefficient based on the latest information from MODFLOW and MetaSWAP, and ω is the under-relaxation factor defined as:

$$\omega = 1.0 - (iter - iterur1))/(iterur2 - iterur1)$$

The user should check the sensitivity of the model to the used parameters. At each iteration the model specifies the maximum deviation between MODFLOW and MetaSWAP. These can seem rather large (e.g. 0.2 m). But whether this is significant can best be judged from comparing the so-called GT-statistics using the MetaSWAP level and the MODFLOW level (see file SVAT_GT.BDA). A deviation of heads between the two submodels does not entail a water balance error. The consequence of such a deviation is just that the fluxes in MODFLOW are not computed with the same level as the phreatic level MetaSWAP. However, MetaSWAP does use *exactly* the same value of the saturated groundwater flux as computed within MODFLOW itself; this flux is outputted in the SVAT*.BDA files.

Parameters for output options

Parameter format and description

name	format	description
clocktime	I	writing of files with cpu/realtime per simulation module
svat_csvdigits	I	writing extra digits in svat*.csv output
svat_gt	I	writing bi-monthly output of groundwater levels per SVAT
svat_per	I	writing SVAT balances for periods to binary file
svat_per_csv	I	writing SVAT balances for periods to csv files
svat_dtgw	I	writing SVAT balances for dtgw time steps to binary file
svat_dtgw_csv	I	writing SVAT balances for dtgw time steps to csv files
svat2gw_dtgw	I	writing SVAT balances of groundwater as a system volume for
svatvg_per	I	writing SVAT vegetation state for periods to binary file
svatvg_per_csv	I	writing SVAT vegetation state for periods to csv files
svatvg_day	I	writing SVAT vegetation state day time steps to binary file
svatvg_day_csv	I	writing SVAT vegetation state day time steps to csv files
drng_per	I	writing drainage interactions for periods
sw_per	I	writing surface water balances for periods
sw_per_csv	I	writing surface water balances for periods to csv files
sw_dtgw	I	writing surface water balances for dtgw time steps
sw_dtgw_csv	I	writing surface water balances for dtgw time steps to csv files
sw_hq_dtgw	I	writing surface water level and flow for dtgw time steps
sw_dtsw	I	writing surface water balances for dtsw time steps
sw_hq_dtsw	I	writing surface water level and flow for dtsw time steps
svat_per_unf	I	writing file svat_per.unf for SVAT-disaggregation (periods)
modf_per_unf	I	writing file modf_per.unf for Modflow balances (periods)
sw_dtgw_unf	I	writing file sw_dtgw.unf for surface water quality (dtgw's)

Parameter options

Basically the parameters have two options:

- 0 = disable the output option
- 1 = enable the output option

In the case of *svat_per_unf* there is also the option '2' , which causes the output to be split into batches of 1000 units. This can be convenient if the output to *swatre*.** files is enabled in the *postmetaswap2transol* program, which can not handle more than a few thousand files at a time (Fortran limitation).

TIOP_SIM.INP

The file TIOP_SIM.INP defines the accumulation periods used for output to files SVAT_PER.BDA, DRNG_PER.BDA and SW_PER.BDA. The file can also be used for specifying changes of water management period (summer/winter).

Variable format and description

col	format	name	unit	description
1-15	F15	td	d	time from beginning of year at 00:00:00
16-21	I6	iy	-	year number
22-27	I6	io	-	option number
28-33	I6	ip	-	water management period (summer/winter)

Variable characteristics

name	min.	max.	def.	type	error-code
td	0	366	-	req	fatal
iy	1	9999	-	req	fatal
io	1	7	-	req	fatal
ip	1	2	-	opt	fatal

Options

io	description
1	change water management period (summer/winter)
7	save results for periodical water balance

ip	description
1	change to summer
2	change to winter

Example

```
       td           iy     io     ip
 <     F15        >< I6 >< I6 >< I6 >
       91.0000000  1989      1      1
       91.0000000  1989      7
       .     .          .    .
```

Remarks

A specification of season with *io*=1 and a value of *ip* over-rules the begin/end summer time parameters of PARA_SIM.INP. Once a specification *io*=1 has been given, the season will only change through a subsequent season specification.

For *io*=7 the *ip* parameter is not needed.

2.1.2 SEL_KEY_SVAT_PER/DTGW.INP

The optional file SEL_KEY_SVAT_PER.INP selects the variables for which output is written to the file SVAT_PER.BDA; this also requires activation of the option by *svat_per*=1 in PARA_SIM.INP. The optional file SEL_KEY_SVAT_DTGW.INP selects the variables for which output is written to the file SVAT_DTGW.BDA; this also requires activation of the option by *svat_dtgwr*=1 in PARA_SIM.INP.

Variable format and description

col	format	name	description
1-10	A10	key	name of variable
19-20	I1	ioptkey	option parameter (0/1)

Options

ioptkey	description
0	do not include variable in database
1	include variable in database

Remarks

The file should contain the ***full*** list of available variables, exactly in the ***order*** as given in Section 4.2.2. If a selection file is not present, all of the variables are selected. If the file is specified incorrectly, the program outputs the correct file to the work directory (with all options enabled!) and then stops execution.

2.1.3 SEL_SVAT_ PER/DTGW_ BDA.INP

The optional file SEL_SVAT_PER_BDA.INP selects the SVATs for which output is written to the file SVAT_PER.BDA; this also requires activation of the option by *svat_per*=1 in PARA_SIM.INP. The optional file SEL_SVAT_DTGW_BDA.INP selects the SVATs for which output is written to the file SVAT_DTGW.BDA; this also requires activation of the option by *svat_dtgwr*=1 in PARA_SIM.INP. The user can also use a file SEL_SVAT_BDA.INP for selecting both lists (which are then the same).

Variable format and description

col	format	name	unit	description
1-10	I10	svat	-	SVAT unit for which water balance data are saved per dtgw

Variable characteristics

name	min.	max.	def.	type	error-code
svat	1	999999	-	req	fatal

Remarks

If the file are not present *none* of the SVATs are selected.

2.1.4 SEL_SVAT_CSV.INP

The selection in SEL_SVAT_CSV.INP is used for generating optional csv-files SVAT_PER_<SVAT>.CSV and SVAT_DTGW_<SVAT>.CSV, if the respective option parameters are set to 1 (*svat_per_csv*=1 and *svat_dtgw_csv*=1). If a vegetation model is being used (*vegetation_mdl* ≥ 2), then the selection generates files SVATVG_PER_<SVAT>.CSV and SVATVG_DAY_<SVAT>.CSV, if the respective option parameters are set to 1 (*svatvg_per_csv*=1 and *svatvg_day_csv*=1), and if the respective vegetation of the SVAT is actually being simulated by the vegetation model, i.e. if the *vg*-index has been linked in the VG2CRP_SVAT.INP.

Variable format and description

col	format	name	unit	description
1-10	I10	svat	-	SVAT unit for which data are saved in csv-file

Variable characteristics

name	min.	max.	def.	type	error-code
svat	1	999999	-	req	fatal

Remarks
If the file SEL_SVAT_CSV.INP is not present *none* of the SVATs are selected.

2.1.5 SEL_SWNR_CSV.INP

The optional file SEL_SWNR_CSV.INP selects the *swnr*'s for generating optional csv-files SW_PER_<SWNR>.CSV and SW_DTGW_<SWNR>.CSV. (Also requires *sw_per_csv*=1 and *sw_dtgw_csv*=1).

Variable format and description

col	format	name	unit	description
1-10	I10	swnr	-	swnr location for output to csv files

Variable characteristics

name	min.	max.	def.	type	error-code
swnr	1	999999	-	req	fatal

Remarks
If the file is not present all of the *swnr*'s are selected that are coupled to SurfW. The results are then outputted to a single file, instead of to separate files per SWNR.

The selection does not influence the *swnr*'s used in de binary *bda*-files for surface water; these always include all of the surface water locations, also the ones not coupled to a surface water model

2.2 Coupling of modules

2.2.1 MOD2SVAT.INP

The file MOD2SVAT.INP contains the mapping of SVAT-units to MODFLOW-cells.

Variable format and description

col	format	name	unit	description
1-10	I10	modfcell	-	Modflow-cell number
11-12	2x	-	-	-
13-22	I10	svat	-	index of SVAT-unit
23-27	I5	ly	-	layer of SVAT-unit

Variable characteristics

name	min.	max.
modfcell	1	9999999
svat	1	9999999
ly	0	9999

Remarks
It is *not* anymore required that layer 1 of each SVAT is connected to a MODFLOW cell. The user has two options to deviate from the normal coupling:
- by leaving out the record for a certain SVAT;
- by specifying *ly*=0; the MODFLOW cell should be given a valid value.

The second method can be a way for the user to know where a certain SVAT is located in geographical terms, but it is not a way of georeferencing in the strict sense of the word: the model does not use the information of the linked MODFLOW cell in anyway; the *ly*=0 specification is the information that is used by the model.

Optionally, there can be more than one SVAT-unit coupled to a specific MODFLOW cell; these extra links should employ unique SVAT/ly combinations. If the SIMGRO model involves groundwater extractions for sprinkling, then the mapping should include entries for SVAT/layer combinations coupled to the specific MODFLOW cell identifier. If the extraction is from the phreatic layer, then no extra entry is needed. If the extraction is from a deeper layer, then the cell will have an identifier that is greater than NROW*NCELL of the MODFLOW model.

There are two options for the link between MetaSWAP and MODFLOW:
- *i*-link, which is a resistance-free link, meaning that the groundwater level of the SVAT unit and the head in MODFLOW cell are kept equal;
- *c*-link, which is a resistance link, involving a head difference.

The *i*-link is the most used type; the model uses *c*-link if the following two conditions are met:
- groundwater head above soil surface;
- presence of resistances *ctop_down* and *ctop_up* in the file INFI_SVAT.INP.

The layer 1 of a SVAT can be coupled to any layer of the MODFLOW model. This feature can be used for modelling surface water that occupies a significant areal percentage and that has a different level than the surrounding groundwater. If such an inundated SVAT is linked to a surface water location − via the mapping table in SVAT2SWNR.INP − the inundation water acts as a resistance-free surface water link. The combination of a *c*-link and a connection to a surface water location in SVAT2SWNR.INP is the SIMGRO method for modelling surface water interactions with deeper layers of MODFLOW, with feedback per *dtsw*.

2.2.2 SVAT2SWNR_ROFF.INP

The optional file SVAT2SWNR_ROFF.INP contains the runoff routing of SVAT units to SIMGRO surface water location id's.

Variable format and description

col	format	name	unit	description
1-10	I10	svat	-	SVAT unit
11-20	I10	swnr	-	surface water location identifier
21-28	F8	vxmu	m	micro-storage capacity, =sill of the runoff relationship
29-36	F8	crunoff	d	runoff resistance
37-44	F8	crunon	d	runon resistance

Variable characteristics

Name	min.	max.	def.	type	error-code
svat	1	99999999	-	key	fatal
swnr	0	99999999	0	req	fatal
vxmu	0.	1.0e+6	0.	opt	fatal
crunoff	dtsw	1.0e+6	dtsw	opt	fatal
crunon	dtsw	1.0e+6	crunoff	opt	fatal

Example

```
   svat    swnr     vxmu   crunoff crunon
 < I10 >< I10 ><  F8   ><  F8   ><  F8   >
       1       1   0.005   0.001   0.002
       2       1   0.005   0.001   0.002
      ..      ..     ...     ...     ...
```

Remarks

The file is optional. The specified surface water location identifier *swnr* is used by the model for:

- routing the surface runoff with a linear resistance relationship;
- determining the surface water level if the *swnr*-identifier is not present in file SVAT2SWNR_DRNG.INP

The parameter *vxmu* plays a crucial role in the simulation of runoff: *vxmu* acts as a sill for the runoff process. If it is set to zero, water can freely flow to surface water over the soil surface. Runoff is disabled by setting *vxmu* to 9999 m. Values of e.g. 1000 m should be avoided because this causes excess memory use.

For SVAT's coupled to a *swnr* of the SIMRES model the used simulation method depends on the option parameter *rc_swmdl1* that can be specified in PARA_SIM.INP. By default, *rc_swmdl1=-1*, meaning that the 'integrated method' is used: the ponding level and surface water level are made equal, unless the *vxmu* parameter acts as a barrier. For using the runoff/runon resistance method, the user should set *rc_swmdl1=2* in PARA_SIM.INP.

...continued on next page

If the file is not present (or if the record for a specific SVAT unit is not included) all SVATs are mapped to *swnr*=0; the surface runoff will be unconstrained. That will also apply to the drainage, unless a surface water level is explicitly specified in the SVAT2SWNR_DRNG.INP file. An unlimited supply of sprinkling water from surface water is enabled.

2.2.3 SVAT2SWNR_DRNG.INP

The optional file SVAT2SWNR_DRNG.INP contains drainage parameters of SIMGRO drainage links.

Variable format and description

col	format	name	unit	Description
1-10	I10	svat	-	SVAT unit
11-16	I6	sy	-	system index
17-24	F8	dpsw	m[1]	drain depth below soil surface
25-32	F8	wisw	m	drain width at bottom
33-40	F8	adsw	-	cotangent of slope
41-48	F8	ddsw	m	drain spacing
49-56	F8	lesw	m	length of drainage system
57-64	F8	redr	d	drainage resistance
65-72	F8	reen	d	entry resistance
73-80	F8	rein	d	infiltration resistance
81-88	F8	reex	d	exit resistance
89-98	I10	swnr	-	surface water location of the drainage link
99-106	F8	lvsw	m	surface water level for drainage/infiltration calculation

Variable characteristics

name	min.	max.	def.	type	error-code
svat	1	999999	-	req	fatal
sy	0	5	-	req	fatal
dpsw	-1.0E+05	1.0E+05	-	req	warning
wisw	0.	1.0E+05	-	req	warning
adsw	0.	1.0E+05	-	req	warning
ddsw	0.1	1.0E+05	-	req1	warning
lesw	0.01	1.0E+05	-	req2	warning
redr	2.0	1.0E+05	-1.0	req	set to min/max
reen	0	1.0E+05	0.0	req	set to min/max
rein	2.0	1.0E+05	redr	req	set to min/max
reex	0	1.0E+5	reen	req	set to min/max
swnr	0	999999	swnr in svat2swnr.inp	opt	-
lvsw	-1.0E+05	1.0E+05	-9999.	opt	-

Example

```
  7509     2    2.00    1.00    1.00   11.00         90000.00    0.0090000.00    0.00            1
  7489     4    1.50    0.10    0.00   11.00           100.00    0.00  100.00    0.00            1
  7490     4    1.50    0.10    0.00   11.00           100.00    0.00  100.00    0.00            1
  7491     4    1.50    0.10    0.00   11.00           100.00    0.00  100.00    0.00            1
  7492     4    1.50    0.10    0.00   11.00           100.00    0.00  100.00    0.00            1
  7493     4    1.50    0.10    0.00   11.00           100.00    0.00  100.00    0.00            1
```

Remarks
No specific ordering of the file is required. It is permitted to specify more than one record per SVAT-unit.

The ‘system’ index is described in the User’s Guide.

The role of the system index is *sy* is simply to classify the drainage link and then to provide model results as totals per system, as explained further in the User’s Guide. It is permitted to specify more than one drain at the same SVAT-unit with the same system number.

For field drains (usually given system index = 4) *wisw* should be given a nominal value (<0.1 m), and *adsw* should be zero. It can usually suffice to just specify *redr* and *rein*.

The parameters *dpsw*, *wisw*, *adsw*, *ddsw* and *lesw* are also used to calculate the surface water storage characteristics in a surface water location *swnr*.

Preferably, either *lesw* or *ddsw* should be given, not both because that can lead to confusion and errors. If both are given, then *lesw* has priority in the case that the data are not consistent. The parameters are related in the following manner:

$$lesw = \frac{A_{nod}}{ddsw} \quad \text{or} \quad ddsw = \frac{A_{nod}}{lesw}$$

with A_{nod} : SVAT area (m^2).

If no surface water location identifier is specified, the *swnr* specified in SVAT2SWNR_ROFF.INP is used.

The optional field for the surface water level is meant for situations where the surface water location is not connected to a model, not to SurfW and neither to an external model.

[1] ss : soil surface as defined in area_svat.inp

2.2.4 SWNR2SWQN.INP

The optional file SWNR2SWQN.INP contains the through-linking of SIMGRO surface water location id's to SWQN nodes.

Variable format and description

col	format	name	unit	description
1-10	I10	swnr	-	SIMGRO surface water location
11-20	I10	swqn_ node	-	node identifier of externally modelled surface water location in SWQN

Variable characteristics

name	min.	max.	def.	type
swnr	1	999999	-	req
swqn_node	1	999999	-	req

Remarks

The file is needed for *ioswmdl*=5, for coupling to the model SWQN. This optional file relates the identifiers of the SIMGRO surface water locations to node identifiers of the SWQN model. There can be more than one *swnr*-identifier coupled to a specific node.

The mapping file of the coupling to SOBEK is needed for *ioswmdl*=2. The format of this file is defined in the SOBEK documentation. Its location and name is specified by the string-parameter *swmp_conf_file* (see PARA_SIM.INP).

The (optional) mapping of the SIMGRO surface water location identifiers to the locations of the SurfW model is done with the file first column of file MANA_SIM.INP.

2.3 Soil-Vegetation-Atmosphere Transfer units (SVATs)

2.3.1 AREA_SVAT.INP

The file AREA_SVAT.INP contains the main parameters of the SVAT units.

Variable format and description

col	Format	name	unit	description
1-10	I10	svat	-	SVAT unit
11-20	F10	ark	m2	area
21-28	F8	glk	m+MSL	soil surface elevation
29-36	F8	tempCbotk	°C	temperature at bottom of soil profile
37-42	I6	slk	-	soil physical unit number
43-58	16x	-	-	blank
59-64	I6	luk	-	land use type
65-72	F8	dprzk	m	root zone thickness / maximum
73-82	I10	nm	-	meteorological region code number
83-90	F8	cfPm	-	local calibration factor for precipitation
91-98	F8	cfETref	-	local calibration factor for potential evapotranspiration of reference crop

Variable characteristics

name	min.	max.	def.	type
svat	1	99999999	-	key
ark	0.	999999.0	-	req
glk	-9999.0	9999.0	-	req
tempCbotk	-273	100.	12.0	opt
slk	1	999999	-	req
luk	1	999999	-	req
dprzk	0.	10.	-	req
nm	1	999999	1	opt
cfPm	0.1	10.	1	opt
cfETref	0.1	10.	1	opt

Remarks

The SVAT-units (column 1) should be numbered as an index with step 1, from 1.
The specified root zone depth is used in the following way:

- as the *maximum* depth within the SVAT if the root zone depth is specified dynamically via the FACT_SVAT.INP file for the vegetation types;
- as the default depth if the dynamic specification of root zone depths in FACT_SVAT.INP is missing.

If use is made of the option to input the meteorological data via grids and using the *evapotranspiration_mdl*=0 option, then the meteorological region does not have to be given.

2.3.2 INFI_SVAT.INP

The file INFI_SVAT.INP contains the infiltration parameters of the SVAT units. Optionally, resistance parameters of the soil surface can be specified.

Variable format and description

col	Format	name	unit	description
1-10	I10	svat	-	SVAT unit
11-18	F8	qinfbasic	m/d	infiltration capacity of soil surface
19-26	F8	ctop_down	d	downward flow resistance of soil surface
27-34	F8	ctop_up	d	upward flow resistance of soil surface
35-42	F8	sc2	m3/m2/m	storage coefficient of phreatic layer in case it becomes confined

Variable characteristics

name	min.	max.	def.	type
svat	1	99999999	-	key
qinfbasic	0.	1000.0	-	req
ctop_down	5/-9999.	999999	-	req
ctop_up	5/-9999.	999999	-	req
sc2	0.01	1.00	-	req

Remarks

The absence of a resistance at the soil surface should be indicated via the NoData value of -9999. . In that case the model assumes free movement of water in the case of inundation. The user should specify all three of *ctop_down*, *ctop_up* and *sc2*, or *none*. If a resistance is specified, low values (<5.) should be avoided, otherwise the iteration algorithm will fail. If the resistance is low, then it is better to choose the resistance-free option (-9999.).

In the case of ponding on the soil surface and a *non-saturated* soil profile, the infiltration rate gets computed with: *qinf = qinfbasic + Spd/ctop_down*, where *Spd* is the depth of the ponding layer.

In the case of ponding on the soil surface and a *saturated* soil profile and with downward flow, the rate gets computed with: *qinf = (Hpd-Hgwmodf)/ctop_down,* where *Hpd* is the head of the ponding water and *Hgwmodf* is the head of the groundwater model. In the case of upward flow *ctop_up* is used instead.

The computation is updated for each outer loop cycle of the PCG-solver. Since this iteration is not within the PCG scheme itself, the stability is not guaranteed. A small resistances in combination with a small storage coefficient should be avoided; a storage coefficient of e.g. 0.05 helps to stabilize without causing excessive buffering.

2.3.3 LUSE_SVAT.INP

The file LUSE_SVAT.INP contains the set of land use options and their data.

Variable format and description

col	format	name	unit	Description
1-6	I6	lu	-	index of land use type
7-26	A20	luna	-	name of land use type
27-32	I6	vglu	-	index of vegetation type
33-38	I6	alfafunclu	-	option for Feddes function
39-46	F8	p1fd	m	p1 Feddes function
47-54	F8	p2fd	m	p2 Feddes function
55-62	F8	p3hfd	m	p3h Feddes function
63-70	F8	p3lfd	m	p3l Feddes function
71-78	F8	p4fd	m	p4 Feddes function
79-86	F8	t3hfd	mm d^{-1}	t3 Feddes function
87-94	F8	t3lfd	mm d^{-1}	t3 Feddes function
95-102	F8	pbgsplu	m	pressure head begin sprinkling
103-110	F8	frevsplu	-	fraction evaporated sprinkling water
111-118	F8	gisplu	mm	gift in rotational period
119-126	F8	tigisplu	d	duration gift
127-132	F6	rpsplu	d	rotational period
133-138	F6	tdbgsplu	d	beginning of sprinkling period, from 00:00:00
139-144	F6	tdedsplu	d	end of sprinkling period
145-152	F8	fecmnlu	-	intercept of relationship for canopy evaporation, as a fraction of the potential value
153-160	F8	albedolu	-	albedo reflection coefficient
161-168	F8	rscdrylu	s/m	minimum dry canopy resistance
169-176	F8	rscwetlu	s/m	minimum dry canopy resistance
177-184	F8	ECmaxlu	dS/m	level of ECsat at which salt stress starts
185-192	F8	ECsloplu	%/dS/m	decline of root water uptake above critical salinity level ECmax

Variable characteristics

Name	min.	max.	def.	type error-code
lu	1	999	-	key
luna	-	-	-	opt
vglu	0	6	-	req
alfafunclu	1	2	-	req
p1fd	-160.0	0.0		req
p2fd	-160.0	0.0		req
p3hfd	-160.0	0.0		req
p3lfd	-160.0	0.0		req
p4fd	-160.0	0.0		req
t3hfd	0.1	10.0		req
t3lfd	0.1	10.0		req
pbgsplu	-160.0	0.0	-	req
frevsplu	0.0	1.0	-	req
gisplu	1.0	1000.0	-	req
tigisplu	0.01	1000.0	-	req
rpsplu	1.0	366.	-	req
tdbgsplu	0.0	366.	-	req
tdedsplu	0.0	366.	-	req
fecmn	0.0	1.0	-	req
albedolu	0.0	1.0	-	opt
rscdrylu	0.0	1E6	-	opt
rscwetlu	0.0	1E6	-	opt
ECmaxlu	0.0	20.0	-	opt
ECsloplu	0.0	40.0	-	opt

Remarks

In the implementation of the Feddes function in SIMGRO, the pressure head values for the reduction of ET due to **wet** conditions apply to the pressure head at the **soil surface**, not in the root zone itself. So to disable the reduction function for rice, for instance, values of p1 and p2 should be used that are higher than the maximum inundation depth in a paddy.

For the ‘Feddes function’ that relates the relative transpiration to the pressure head there are two options:

- 1 : original option, using a piece-wise linear trapezoidal function;
- 2: logarithmic option, using the pF instead of the pressure head for the dry side of the reduction function

For calculating the reduction due to **dry** conditions, the model first down-scales the pressure head in the root zone to separate values for equal fractions (‘slices’) of it. The reduction function is then applied to the separate fractions, and then averaged for the root zone as a whole.

The specification of the period for which sprinkling is enabled can also be used for situations that typically occur in the southern hemisphere, i.e. with *tdbgsplu* > *tdedsplu*.

The coefficients *albedolu, rscdrlu, rscwetlu* are only required for using the Penman-Monteith method to directly simulate vegetation evapotranspiration (*evapotranspiration_mdl* = 3).

In the option that Penman-Monteith is used via the reference vegetation method (*evapotranspiration_mdl* = 2), the used data for the reference vergetation are obtained from the code itself (i.e. hard-wired).

2.3.4 FACT_SVAT.INP

The file FACT_SVAT.INP contains values of vegetation factors and interception characteristics. These parameters are used for vegetations that are not modelled with the vegetation model WOFOST; they are also used if the feedback from the vegetation model has been disabled (*evapotranspiration_mdl* = 2)

Variable format and description

col	format	Name	unit	description
1-6	I6	vg	-	vegetation type
7-12	I6	dy	-	day number
13-20	F8	csvg	m2/m2	soil cover
21-28	F8	laivg	m2/m2	leaf area index
29-36	F8	vxicvg	m3/m2	interception capacity
36-44	F8	faevvg	-	vegetation factor
45-52	F8	faeivg	-	factor for interception evaporation
53-60	F8	faebsvg	-	factor for bare soil evaporation
61-68	F8	faepdvg	-	factor for ponding
69-76	F8	chvg	m	crop height
77-84	F8	drpzvg	m	dynamic root zone depth

Variable characteristics

name	min.	max.	def.	type	error-code
vg	0	999	-	key	fatal
dy	1	366	-	key	fatal
csvg	0.	1.0	-	req	fatal
laivg	0.	10.	-	opt	fatal
vxicvg	0.	0.1	-	req	fatal
faevvg	0.01	10.	-	opt	fatal
faeivg	0.01	10.	-	opt	fatal
faebsvg	0.01	10.	-	opt	fatal
faepdvg	0.01	10.	-	req	fatal
chvg	0.	100.	-	opt	fatal
dprzvg	0.	20.	-	opt	fatal

Remarks

If the leaf area index is not directly used by the model. The (optional) values in the file are just informative.

A non-zero interception capacity is only allowed if there is also a non-zero soil cover. With a soil cover of e.g. 0.7 (m^2/m^2) and an interception capacity of 0.010 m^3/m^2 the maximum storage per SVAT unit will be 0.007 m.

The vegetation factor *faevvg*, the interception evaporation factor *faeivg* and the bare soil factor *faeb*svg are only required for *evapotranspiration _mdl* ≤2.

The ponding factor *faepdvg* is always required, unless the vegetation model with feedback is being used (*vegetation_mdl=3*).

In the case of *evapotranspiration_mdl*=3 it is applied to E_{p0} obtained from Penman-Monteith; in other cases it is applied to the reference crop evapo-transpiration.

The *crop height* is only needed for if the Penman-Monteith method is used with crop-specific parameters (*evapotranspiration_mdl*=3). If Penman-Monteith is used for the reference crop method (*evapotranspiration_mdl*=2), the crop-height is obtained from a hard-wired value in the code.

The dynamic root zone depth *dprzvg* is optional; if it is not given, the value given in AREA_SVAT.INP is used for all days of the year, unless a vegetation model is being used with the feedback enabled (*vegetation_mdl=3*); in the latter case the value of the vegetation model overrule the ones in FACT_SVAT.INP.

When applying the model to the Southern hemisphere or to winter crops the standard file delivered along with the package should be adapted to the local conditions.

The SIMGRO code determines automatically what the maximum value *nxvg* is of the used index; *nxvg* is used for dimensioning of arrays, so 'wild' values should be avoided. It is not necessary to have entries for all values of *vg*=1...*nxvg*. Neither do they have to be ordered with increasing vg. However, if a certain index is used, it is mandatory that the number of entries is 366, covering all days of the year.

2.3.5 VG2CRP_SVAT.INP

This file is needed if the use of the crop growth model has been enabled via *vegetation_mdl*=2 in file PARA_SIM.INP. It contains the links between the vegetation index *vg* of the land use types (file LUSE_SVAT.INP) and the crop parameters of WOFOST.

Variable format and description

col	format	Name	unit	description
free	I	vg	-	vegetation type
free	string of max 80 characters enclosed in “”	pathcrop	-	day number
free	string of max 16 characters enclosed in “”	crpfile	-	soil cover
free	F	tdbeg	d	time of crop emergence
free	F	tdend	d	time of crop harvest

Remarks

The name of the crop file should *not* include the extension *.crp*. The format of these files is described in the SWAP documentation. Not all of the *vg*-index values that are listed in LUSE_SVAT.INP need to be linked, that is flexible.

Example

```
1,  "F:\S_tests\T-model\T-model_Basic_wofost_V6_7_1\" , "GrassG_16_2N_vg",   0.0,366.0
3,  "F:\S_tests\T-model\T-model_Basic_wofost_V6_7_1\" , "PotatoD_vg"           , 124.0,235.0
```

The *crp*-files of SWAP can be used, with the following changes:

- section with the crop parameters as a function of the leaf area index;
- root growth parameters involving the length unit **cm** (length unit in SWAP) should be converted to **m**; the *hlim*-data are not used from the *crp*-file;

Example of expanded section

```
* Part 1: Crop dependencies on the Leaf Area Index
* Crop height                    CH [0..100.0 m, R], as function of LAI [0..6 -,R]:
* Crop factor transpiration      CF [0.0..2.0,      R], as function of LAI [0..6 -,R]:
* Crop factor interception ev.  CFEIC [0.0..2.0, R], as function of LAI [0..6 -,R]:
* Crop factor bare soil ev.      CFEBS [0.0..2.0,R], as function of LAI [0..6 -,R]:
* Crop factor ponding ev.        CFEPD [0.0..2.0,R], as function of LAI [0..6 -,R]:

   LAI      CH     CF   CFEIC  CFEBS  CFEPD
  0.000  0.000  0.000  0.000  1.000  1.000
  0.001  0.000  0.000  0.000  1.000  1.000
  0.070  0.150  0.605  1.250  1.000  1.000
  0.230  0.300  0.871  1.250  1.000  1.000
  4.600  0.500  1.201  1.250  1.000  1.000
 10.000  0.500  1.201  1.250  1.000  1.000
* End of Table
*
* Dependency interception capacity VXIC on leaf area index LAI
  VXICLAI = 0.00025 ! Interception capacity coefficient [0.0..0.00100 m, R]
```

2.3.6 UNSA_SVAT.BDA, UNSA_SVAT.INP and THSAT_SVAT.INP

The file UNSA_SVAT.BDA contains the database with steady states of soil moisture profiles. File UNSA_SVAT.INP is the ASCII version. The file UNSA_POST.BDA contains extra information that is needed for the postprocessing with *postmetaswap2transol*..

Variable format and description of ASCII version
The first record of the file contains the pin-code of the database, format F9.7. This pin-code is also present in files THSAT_SVAT.INP. It should also be present in file BETA2_SVAT.INP. The model checks the consistency of the pin-codes.

The next section of the file is identical to the *premetaswap.key* file that is generated by *premetaswap*. This section is outputted by SIMGRO to disk at the start-up of each model run. That makes it easy for the user to check the content of the UNSA_SVAT.BDA database, by comparing the outputted *premetaswap.key* file to the one generated by *premetaswap*. The latter version should only differ from the one generated at runtime with respect to the information provided after the "!" symbol, which explains the contents of the records.

The third section contains the schematization of the aggregation layers of the subsoil, starting with a record containing the number of boxes that are used. In the database supplied along with the T-model this number is 18. Separate records are given for the different soil physical units, because the (calibrated) thickness of the second layer depends on the soil physical parameters.

The fourth section of the UNSA_SVAT.BDA file contains the actual database described below (next page)

Variable format and description of ASCII version (ctd.)

col	format	name	unit	description
1-6	I6	sl	-	soil number
8-13	I6	rz	-	root zone thickness number
15-21	F7.2	dprztb	m	thickness of rootzone
23-28	I6	ig	-	index of groundwater depth dpgwtb (of table in code)
30-35	I6	ip	-	index of root zone pressure head phrztb
36-47	F12.7	srtb	m3/m2	storage of water in rootzone
48-59	F12.7	s2tb	m3/m2	storage of water in box 2, relative to saturation (values ≤ 0.)
..	F12.7	..	m3/m2	…
..	F12.7	s*N*tb	m3/m2	storage of water in box *N*, relative to saturation (values ≤ 0.)
..	F12.7	qmtb	m/d	flux of steady state profile below root zone (+ = upwards)
..	F12.7	p2tb	m	mean pressure head in top SWAP-compartment of box 2
..	F10.3	phrztb(1)	m	mean pressure head of interval [0;0.1*dprztb]
..	F10.3	phrztb(2)	m	mean pressure head of [0.1*dprztb ;0.2*dprztb]
..	...	...	...	...
..	F10.3	phrztb(10)	m	mean pressure head of [0.9* dprztb; dprztb]
..	F10.6	theta(i)	m3/m3	water content of SWAP compartment *i*
..	F10.6	..	m3/m3	"
..	F10.6	prhead(i)	m	pressure head of SWAP compartment *i* (only in UNSA_POST.INP/BDA)

Remarks

If both unformatted and ASCII versions are present in the work directory the ASCII version is used.

The index *ig* of the groundwater level corresponds to the depths given in the *premetaswap.key* file. These values are given in cm's , since they are use for SWAP. For numerical reasons, the first value is set to 2 cm, but corresponds to a depth of 0 cm.

The index *ip* of the pressure head corresponds to the following pressure heads, ranging from +1.0 m to -160 m (pF=4.2):

- ip = -10–0 : *phrztb*(*ip*) = ip*0.1 (m)
- ip = 1–42 : *phrztb*(*ip*) = $-0.01*10^{(ip*0.1)}$ (m)

When making interpolations with the data for a certain ($ig + f_{ig}, ip + f_{ip}$) position (with the fractions f_{ig} and f_{ip} in the interval [0;1]) the interpolation should first be done for the groundwater depth, and only then for the pressure head.

THSAT_SVAT.INP

The file THSAT_SVAT.INP contains the saturated water contents and saturated conductivities that (together with other parameters) were used in generating the UNSA_SVAT.BDA. The saturated contents are needed for generating the SVAT2GWDTGW.BDA file. The file should not be modified manually.

Variable format and description

rec	format	name	unit	description
1	i6	nucp	-	number of compartments in SWAP schematization
2	-	dzcp (1..nucp)	m	compartment thicknesses of SWAP profile
3	nucp*F	theta_sat (1..nucp)	m3/m3	macropore of compartments, soil number **1**
4	nucp*F	theta_sat (1..nucp)	m3/m3	saturated water content of compartments, soil number **1**
5	nucp*F	k_sat (1...nucp)	m/d	saturated conductivity of compartments, soil number **1**
3	nucp*F	theta_sat (1..nucp)	m3/m3	macropores of compartments, soil number **1**
7	nucp*F	theta_sat (1..nucp)	m3/m3	saturated water content of compartments, soil number **2**
8	nucp*F	k_sat (1...nucp)	m/d	saturated conductivity of compartments, soil number **2**
...	..	..	..	..

Remarks
The actual data are preceded by a pin-code in F10.8 format. This pin-code should be the same as that of the files UNSA_SVAT.BDA. This is generated automatically by *premetaswap*.

2.3.7 BETA2_SVAT.INP

The file BETA2_SVAT.INP contains the parameter of the Boesten method for the simulation of bare soil evaporation.

Variable format and description

col	format	name	unit	description
1-6	I	sl	-	soil physical unit
7-12	F	beta2	$m^{1/2}$	Boesten-parameter bare soil evaporation

Variable characteristics

name	min.	max.	def.	type	error-code
beta2	0.0	0.1	-	req	

Remarks

The actual data are preceded by a pin-code in F10.8 format. This pin-code should be the same as that of the files UNSA_SVAT.BDA and THSAT_SVAT.INP. The BETA2_SVAT.INP file is created separately from the soil physical database. So the pincode has to be added via an ascii editor. The value can be taken from the ascii-file THSAT_SVAT.INP.

The standard value of *beta2* = 0.054 $m^{1/2}$ is used in SWAP. In that model also the conductiivity of the top layer can inhibit the soil evaporation. To compensate for the fact that MetaSWAP does not have the latter feature, a value of *beta2* = 0.038 $m^{1/2}$ is advised.

The mentioned values apply to simulations using precipitation data that have been averaged over *daily* time intervals. If the rainfall data are for shorter time intervals, e.g. hours, than the simulated bare soil evaporation tends to become lower. To compensate for this, the user can specify a calibration factor *fact_beta2* in file PARA_SIM.INP. For hourly rainfall data we found a value of 1.2 to give results that approximate those for daily data, though there are differences per land use type.

2.3.8 FCWP_SVAT.INP and GXG_GG_SVAT.INP

The optional files FCWP_SVAT.INP and GXG_GG_SVAT.INP are needed for generating information about the root-zone water content at field capacity and at wilting point. This information can e.g. be used for judging the validity of the soil physical database and for interpreting the results of the model.

Variable format and description FCWP_SVAT.INP

col	format	name	unit	description
1-6	F	FC	-	pF at field capacity
7-12	F	WP	-	pF at wilting point

Variable characteristics FCWP_SVAT.INP

name	min.	max.	def.	type	error-code
FC	1.0	2.7	-	req	-
WP	3.0	4.5	-	req	-

Variable format and description GXG_GG_SVAT.INP

col	format	name	unit	description
1-10	I	svat	-	SVAT unit
12-21	F	gg	m b.s.s	groundwater level

Variable characteristics GXG_GG_SVAT.INP

name	min.	max.	def.	type	error-code
svat	-	-	-	opt	-
gg	-100	100.	100.	opt	-

Remarks
The FC and WP characteristics depend on the assumed pressure head value and the depth of the groundwater level. If the default level of 100 m b.s.s. is used (by omitting the file GXG_GG_SVAT.INP), then lower bound values of FC and WP are calculated. The file GXG_GG_SVAT.INP has the same format as the output file GXG_GG.CSV of the postprocessing utility *bda2gt*, so it can be obtained by a simple rename operation.

Variable and format of output file FCWP_SVAT.CSV

col	format	name	unit	description
1-10	I	svat	-	SVAT unit
12-21	F	Srsat	m	root-zone water content at saturation
23-32	F	FCsd	m	saturation deficit of root zone at field capacity
34-43	F	WPsd	m	saturation deficit of root zone at wilting point
45-54	F	ASM	m	available soil moisture of root zone

2.3.9 INIT_SVAT.INP

The file INIT_SVAT.INP contains the initial conditions of soil water. The file is mandatory. There are four options for the initialization:

- *Equilibrium* : equilibrium profile
- *Rootzone_pF*: the pF-value of the root zone pressure head is given
- *MeteoInputP* : percolation flux initialization
- *Saved_State* : the initialization is from a saved state.

Variable format and description for initialization with Eqilibrium profile
The file consists just of the single keyword ***Equilibrium*** in the first record (position 1-11). Initialization from an equilibrium profile is handy for when comparisons are being made with the SWAP-model.

Variable format and description for initialization with pF of root zone
The file should contain keyword ***Rootzone_pF*** in the first record (position 1-11). The given pF is use for all units, all simulation layers. This entails that the flux is also the same for all layers, forming a continuous steady-state profile.

Col	format	name	unit	description
1-6	F	pFrzinit	-	pF of root zone

Variable format and description for initialization of percolation fluxes
The file consists just of the single keyword ***MeteoInputP*** in the first record (position 1-11). The precipitation intensity at the starting time (*iybg, tibg* in PARA_SIM.INP) is used for initializing the percolation flux in the profiles. This type of initialization is normally done separately from the actual run, using a specially prepared meteo-input file. After letting the model reach near equilibrium by letting it run for a number of years, the saved state is used for the initialization of subsequent runs (see below).

.. ctd

Variable format and description for initialization from saved state

The file INIT_SVAT.INP should contain keyword ***Saved_State*** in the first record (position 1-11).

Col	format	name	unit	description
1-10	I10	svat	-	SVAT unit
11-25	G15	lvgw	m+MSL	MetaSWAP groundwater level
26-40	G15	SumEbsact	m	Summation of Ebsact for Boesten method
41-55	G15	SumEbspot	m	Summation of Ebspot for Boesten method
56-70	G15	fretact	-	reduction factor of transpiration last time step
71-85	G15	plock12	-	logical for pressure head locking of boxes 1,2
86-100	G15	dprzk	m	root zone depth, rounded to table values
101-115	G15	dprzoldk	m	root zone depth, rounded to table values, old
116-130	G15	dprzvgk	m	root zone depth, according to crop model
131-145	G15	dprzvgoldk	m	root zone depth, according to crop model,old
146-160	G15	prz(1)	m	pressure head root zone box 1
..	G15	..	m	..
..	G15	prz(*N*)	m	pressure head (virtual) root zone box *N*
..	G15	Sic	m	storage interception reservoir
..	G15	Spd	m	storage ponding reservoir
..	G15	S01sd	m	saturation deficit of box 1
..	G15	..	m	
..	G15	S*N*sd	m	saturation deficit of box *N*
..	G15	S01sdold	m	saturation deficit of box 1, before rootzone update
..	G15	S02sdold	m	saturation deficit of box 2, before rootzone update
..	G15	S03sdold	m	saturation deficit of box 3, before rootzone update
..	G15	qinf	m/d	infiltration at soil soil surface
..	G15	qmv(1)	m/d	moisture flux at bottom of box 1
..	G15	..	m/d	..
..	G15	qmv(*N*)	m/d	moisture flux at bottom of box *N*
..	G15	qmodf	m/d	net flux of MODFLOW (+ = towards SVAT)
..	G15	lvgwmodf	m	groundwater level of MODFLOW

Variable characteristics

Name	min.	max.	type	error-code
svat	1	99999999	key	-
lvgw	-1.0E+05	1.0E+05	req	-
SumEbsact	0.	1.0e+5	req	-
SumEbspot	0.	1.0e+5	req	-
fretact	0.0	1.0	req	-
plock12	“F”	“T”	req	-
dprzk	0.	1.0E+2	req	-
dprzoldk	0.	1.0E+2	req	-
dprzvgk	0.	1.0E+2	req	-
dprzvgoldk	0.	1.0E+2	req	-
prz(*i*)	-1.0E+05	1.0E+05	req	-
Sic	0.0	1.0E+05	req	-
Spd	0.0	1.0E+05	req	-
S*i*sd	0.0	1.0E+05	req	-
S*i*sdold	0.0	1.0E+05	req	-
qinf	-1.0E+05	1.0E+05	req	-
qmv(*i*)	-1.0E+05	1.0E+05	req	-
qmodf	-1.0E+05	1.0E+05	req	-
lvgwmodf	-1.0E+05	1.0E+05	opt	-

Remarks

The file is generated as INIT_SVAT.OUT at the end of a run, ready to use (after renaming) for a hot start. The groundwater level of MODFLOW has only been included in the file for the convenience of the user. The model uses the value that is passed by MODFLOW via the model interface.

The ‘old’ values of the saturation deficit of the first there boxes are needed for ensuring that the administrated *decSi* values (changes form one time step to the next) are the same for a continuous run and for a run that is restarted. Tus is only relevant if there is a rootzone update at the end of the day.

2.3.10 INIT_SVATVG.INP

The file INIT_SVATVG.INP contains the initial conditions of the vegetation. The file can be obtained by renaming the output file INIT_SVATVG.OUT that is generated at the end of a run if the vegetation model is activated.

2.3.11 SCAP_SVAT.INP

The optional file SCAP_SVAT.INP contains the sprinkling capacities of links between SVAT units and groundwater/ surface water locations.

Variable format and description

Col	format	name	unit	description
1-10	I10	svat	-	SVAT unit
11-18	F8	fmmxabgw	mm/d	maximum abstraction from groundwater
19-26	F8	fmmxabsw	mm/d	maximum abstraction from surface water
27-34	F8	fxabgw	m3/d	maximum abstraction from groundwater
35-42	F8	fxabsw	m3/d	maximum abstraction from surface water
43-52	I10	svatab	-	SVAT unit from which groundwater is abstracted
53-58	I6	lyab	-	layer number for abstraction
59-68	I10	swnrab	-	trajectory from which surface water is abstracted

Variable characteristics

name	min.	max.	def.	type	error-code
svat	1	99999999	-	key	fatal
fmmxabgw	0.	40	0.0	opt	warning
fmmxabsw	0.	40	0.0	opt	warning
fxabgw	0.	1.0E+09	0.0	opt	warning
fxabsw	0.	1.0E+09	0.0	opt	warning
svatab	1	999999	svat	opt	fatal
lyab	1	nxly	-	key	fatal
swnrab	0	999999	swnr	opt	fatal

Remarks

The file only needs to contain records for SVAT's that really have a sprinkling capacity link.

Of the fields for *fmmxabgw* and *fxabgw* only one of them needs to be specified. If both *fmmxabgw* and *fxabgw* are specified, the abstraction of *fxabgw* is used (so when *fmmxabgw* = 1 and *fxabgw* is not specified the abstraction equals 1 mm/d and with *fxmmabgw* = 1 and *fxabgw* = 0 the abstraction will be zero). The same applies for surface water.

If sprinkling from both groundwater and surface water is enabled, sprinkling from surface water has priority. When the surface water does not have enough capacity to fulfil the demand, groundwater will complete the demand.

Surface water sprinkling from an unlimited source can be implemented by specifying *swnrab*=0 in combination with *fxabsw*=1.0e+9.

2.3.12 FXSP_SVAT.INP

The optional file FXSP_SVAT.INP contains fixed sprinkling rates per time period.

Variable format and description

Col	format	name	unit	description
1-15	F15	t	d	time
16-20	I5	iy	-	year number
21-30	I10	svat	-	SVAT unit
31-40	F10	fxspi	mm/d	intensity of sprinkling demand

Variable characteristics

name	min.	max.	def.	type
time	0.0	366.0	-	req
iy	0	9999	0.0	req
svat	1	99999999	0.0	req
fxspi	0.	1.0E+05	-1.0	req

Remarks

This file should be **sorted** chronologically. The values are specified **starting from a certain moment in time**. To end the sprinkling, a record with a **zero**-value is needed. If instead of a zero value a value of e.g. -1.0 is given, then the sprinkling demand that has not yet been realized will be handled as if it stems from sprinkling that is triggered by the pressure head.

The demand is read by the model per *dtgw*-interval (and then time-lumped), but applied per *dtsw*-interval. The capacities in file SCAP_SVAT.INP determine whether the sprinkling is from groundwater or from surface water, and also set upper bounds on the sprinkling rate. The capacities should be set at realistic values, to avoid excessively high application rates during the the *dtsw*-intervals, leading to runoff.

Options

fxspi	Description
> 0.0	a new fixed sprinkling demand intensity
= 0.0	zero new sprinkling demand intensity; the model still attempts to realize the nonrealized demand (if present)
< 0.0	revert to sprinkling depending on the rootzone pressure head, i.e. automatic sprinkling, which is the default option when no fixed intensity has yet been specified.

2.3.13 METE_STAT.INP and METE_SVAT.INP

METE_STAT.INP

The file METE_STAT.INP contains basic information about the meteorological stations. This file is only required for the options involving the Penman-Monteith method of calculating the evapotranspiration. In the case of *evapotranspiration_mdl =1* the model obtains the list of available station code numbers from the first records of file METE_SVAT.INP. In the case of *evapotranspiration_mdl* ≥2 the model checks that the meteo stations used in the time specifications have been listed in the METE_STAT.INP file. Not all of the listed stations have to be used in the METE_SVAT.INP file.

Variable format and description

Col	format	name	unit	description
1-10	I10	nmme	d	meteorological station
11-20	F10	lat	º	latititude
21-30	F10	alt	m +MSL	altititude of station
31-40	F10	zmeasw	m	height above soil surface of wind-speed measurement

Variable characteristics

name	min.	max.	def.	type	error-code
nmme	0	99999	-	req	fatal
lat	-60	60	-	req	fatal
alt	0	1.0E+04	-	req	fatal
altw	0	100	-	req	fatal

Remarks

The station numbers are handled as external identifiers in the model, so the numbers do not have to be in any specific order.

METE_SVAT.INP

The file METE_SVAT.INP contains the precipitation and evapotranspiration data per meteo station. Optionally (*evapotranspiration_mdl* ≥2), the file can also contain the variables needed for using the Penman-Monteith method. Alternatively, the meteorological data can be supplied in the form of grids, as documented in the next section.

Variable format and description

Col	format	name	unit	description
1-15	F15	td	d	time from beginning of year at 00:00:00
16-20	I5	iy	-	year number
21-30	F10	prec	mm/d	precipitation intensity
31-40	F10	etref	mm/d	reference evapotranspiration intensity
41-50	I10	nmme	-	meteorological station code number
51-60	F10	tempmn	ºC	minimum air temperature during day (24 hrs)
61-70	F10	tempmx	ºC	maximum air temperature during day (24 hrs)
71-80	F10	temp	ºC	mean air temperature during time interval
81-90	F10	Nrel	-	relative sunshine duration
91-100	F10	rad	kJ/m2/d	radiation intensity
101-110	F10	hum	kPa	humidity
111-120	F10	wind	m/s	wind speed at zmeasw(nmme) m (see METE_STAT.INP)

Variable characteristics

name	min.	max.	def.	type	error-code/ remarks
td	0	366	-	key	fatal
iy	0	9999	-	key	fatal
prec	0	1000.	-	req	warning
etref	0	50.	-	req	warning
nmme	1	99999	1	req	fatal
tempmn	-273	100	-	opt	needed for crop growth model
tempmx	-273	100	-	opt	needed for crop growth model
temp	-273	100	-	opt	needed for Penman-Monteith method and temperature simulation in PostMetaSWAP
Nrel	0.	1.0	-	opt	needed for Penman-Monteith method
rad	0	99999	-	opt	needed for Penman-Monteith method
hum	0	99999	-	opt	needed for Penman-Monteith method
wind	0.	99999	-	opt	needed for Penman-Monteith method

Example (for evapotranspiration_mdl = 1)

```
0.0000 1998       0.00       0.50          1
0.0400 1998       0.00       0.50          1
0.0800 1998       0.00       0.40          1
```

Remarks

The specified intensity should pertain to the value **starting from a certain moment in time**. So in the above example the intensity of the precipitation between *t*=0.0400 d and *t*=0.0800 d is 0.50 mm d^{-1}, and *not* 0.40 mm d^{-1}. The amount of precipitation during the time interval is 0.50*(0.08-0.04)=0.02 mm. The time increment can be less than 1 day. The data in this file should be in chronological order. When a new value is specified, new data for *all* the meteo-stations should be specified.

The time span of the data should be such that:

- there is at least one record (for each meteo-station number) with a time 'less than or equal to' to the start time as given in PARA_SIM.INP (*tdbg* and *idbg*);
- there is at least one record (for each meteo-station) with a time 'greater or equal than' the *beginning* of the last *dtgw* step of the MODFLOW run period

For the time interval of input data related to the evapotranspiration, we make the distinction between:

- input on a daily basis;
- input for shorter time intervals.

SWAP has a data-switch for these options. SIMGRO recognises the used option from the data: it is concluded that the day-interval option is used if the specified mean temperature of the interval does not differ more than 0.1 ^{o}C from the average of the minimum and maximum temperature of the *day*. The use of a day interval for the ET-data can be combined with shorter intervals for the precipitation data. In that case, the values relating to the ET-calculation should have the same value for all the shorter time intervals within a specific day.

Specification of the minimum and maximum day temperature is *not an alternative* for giving the 'mean temperature'. Daily minimum, daily maximum and mean should *all* be available for the Penman-Monteith method. The minimum and maximum day temperatures are also used in the crop growth model.

The humidity is required in kPa. These data should be handled with care, and not be mixed up with the relative humidity – the numerical values are similar. For input of data on a daily basis, the KNMI supplies daily averages for the major stations (column UG /100). These should be converted to kPa in a manner that is consistent with the method used in the (Meta)SWAP codes. In the case of short time intervals less than a day, the saturation vapour pressure e_s (in kPa) is found from (Tetens, 1930):

$$e_s = 0.611 * \mathbf{exp}(17.27 * temp/(temp + 237.3))$$

If a day interval is used for the ET-related data, it is found from:

$$e_s = 0.611 * [\ \mathbf{exp}(17.27 * tempmn/(tempmn + 237.3)) + \mathbf{exp}(17.27 * tempmx/(tempmx + 237.3))\ ]/2.$$

where the symbols are the same as given in the table above (*Variable format and description*). In the preprocessing of the meteorological data by the user, the same procedure should be followed as given here. The vapour pressure "*hum*" that should be entered in the METE_SVAT.INP file is then found from:

$hum = hum_{rel} * e_s$.

where hum_{rel} is a fraction ≤ 1.

The relative sunshine duration N_{rel} is needed for calculating the net longwave radiation (Appendix 1 of SWAP3.2 documentation). In SWAP it is calculated from the location parameters of the station and the specified net shortwave radiation. In SIMGRO this calculation is avoided in order to reduce the computational burden and to avoid the need of an option switch for short-interval/daily values of the meteorological data. It is important that the relative sunshine duration is consistent with the specified values of net shortwave radiation. The relative sunshine duration is *not* a substitute for inputting this net radiation. The relationship that SWAP uses for N_{rel} is given in the Appendix 1 of the SWAP3.2 documentation. If it is desired to have simulation that resembles that of SWAP as closely as possible, it is necessary to use that relationship. In other cases it is possible to use the directly measured values, as for instance given by the KNMI for the major weather stations of the Netherlands (column SP /100).

With respect to the wind speed measurement not only the vertical location is an important characteristic also the way in which the time-averaging is performed. For the calculation of r_{air} in the Penmon-Monteith equation the mean wind speed between 7.00 and 19.00 hrs is needed. If data are available as a 24 hours day average then the values should be corrected. For this correction the relationship given by Smith (1991; see appendix 1 in SWAP3.2 documentation) can be used:

$$u_{0,daytime} = 1.33 * u_{0,24hrs}$$

In SIMGRO this correction should be present in the *data*. In SWAP, this correction was formerly done in the code itself, but is now also done via the values in the input file (if relevant).

It is strongly advised to check that the input of data has been done correctly by taking a look at the echoed values in the output file SVAT_DTGW.BDA and/or the *.csv debug files; this can e.g. reveal errors with the column-position of data in METE_SVAT.INP.

2.3.14 METE_GRID.INP and SVAT2PREC/ETREFGRID.INP

METE_GRID.INP

The meteorological data can be supplied in the form of grids. The file METE_GRID.INP contains the meta-information about the location and time parameters of the meteo-grids. See also the remarks above (in Section 2.3.13). This input option is activated by the non-presence of file METE_SVAT.INP.

Variable format and description

Col	format	name	unit	description
free	F	td	d	time from 00:00:00
free	I	iy	-	year number
free	string (max 256 char's), enclosed in " "	precgrid	mm/d	path\name precipitation grid
free	string (max 256 char's), enclosed in " "	etrefgrid	mm/d	path\name evapotranspiration grid (reference crop values)
free	string (max 256 char's), enclosed in " "	tempmn grid	ºC	path\name min. **day** temperature grid
free	string (max 256 char's), enclosed in " "	tempmx grid	ºC	path\name max. **day** temperature grid
free	string (max 256 char's), enclosed in " "	tempgrid	ºC	path\name mean temperature grid
free	string (max 256 char's), enclosed in " "	Nrelgrid	ºC	path\name relative sunshine duration grid
free	string (max 256 char's), enclosed in " "	radgrid	kJ/m2/d	path\name radiation grid
free	string (max 256 char's), enclosed in " "	humgrid	kPa	path\name humidity grid
free	string (max 256 char's), enclosed in " "	windgrid	m/s	path\name wind speed grid

Variable characteristics

name	min.	max.	def.	type	remarks
td	0	366	-	key	
iy	0	9999	-	key	
precgrid	-	-	-	req	
etrefgrid	-	-	-	opt	use "NoValue" for et_mdl ≥2
tempmngrid	-	-	-	opt	required for vg_mdl ≥2, else use "NoValue"
tempmxgrid	-	-	-	opt	required for vg_mdl ≥2, else use "NoValue"
tempgrid	-	-	-	opt	optional for et_mdl=1, if not available use "NoValue" required for et_mdl ≥2
Nrelgrid	-	-	-	opt	required for et_mdl ≥2
radgrid	-	-	-	opt	required for et_mdl ≥2
humgrid	-	-	-	opt	required for et_mdl ≥2
windgrid	-	-	-	opt	required for et_mdl ≥2

Options for grid strings

value	description
path\filename	complete path name followed by file name, within “ “
filename	file name, and path set default to work directory, within “ “
“0.”	all values in the grid are set to zero
“-1”	use previous values
“NoValue”	no data available (only for optional temperature files)

Example for evapotranspiration_mdl=1 and no temperature data

```
79.00,2001,    "0.",           "F:\evap0.000","NoValue","NoValue","NoValue"
80.00,2001, "F:\precip0.001", "F:\evap0.001","NoValue","NoValue","NoValue"
81.00,2001, "F:\precip0.002", "-1"          ,"NoValue","NoValue","NoValue"
82.00,2001,    "0.",           "F:\evap0.003","NoValue","NoValue","NoValue"
```

Remarks

Spaces or commas can be used for the separation between data fields. Do not use tabs.

There must be at least one reference to an existing grid *precgrid* and *etrefgrid*.

SVAT2PRECGRID.INP and SVAT2ETREFGRID.INP

The files SVAT2PRECGRID.INP and SVAT2ETREFGRID.INP contain the mappings of the svat’s to the precipitation and evapotranspiration grids. The latter is also needed when the Penman-Monteith method with crop-specific resistances is used (*evapotranspiration_mdl*=3). The SVAT2ETREFGRID.INP mapping is used for all grids that are not precipitation.

Variable format and description

Col	format	name	unit	description
1-10	I10	svat	-	svat identifier
11-20	I10	row	-	row number of grid, with row 1 at the top of the grid
21-30	I10	column	-	column of grid

Especially when using grids for the input, it is strongly advised to check that the input of data has been done correctly by taking a look at the echoed values in the output file SVAT_DTGW.BDA and/or the *.csv debug files. This can reveal errors with the starting position of the grids, mixups of columns/rows, mirror images (e.g. upside down), etc.

2.3.15 SALT_SVAT.INP

The file SALT_SVAT.INP contains the salt simulation parameters of the soil units. These parameters are used together with the landuse- dependent parameters *ECmaxlu* and *ECsloplu* that are provided via file LUSE_SVAT.INP.

Variable format and description

col	Format	name	unit	description
1-6	I6	spu	-	soil physical unit
7-12	F6	c2eca	-	coefficient for converting concentration to EC (-)
13-18	F8	c2ecb	-	exponent for converting concentration to EC (-)
19-24	F8	c2ecf	-	factor for converting moisture contents from soil to saturated paste extract (-)

Variable characteristics

name	min.	max.	def.	type
spu	1	99999999	-	key
c2eca	0.	999999.0	-	req
c2ecb	-9999.0	9999.0	-	req
c2ecf	-273	100.	12.0	opt

Remarks

The file with the thicknesses of compartments COMP_POST.CSV should be available, which is also used in the MSW2TRANSOL routine.

Via the coupling to TRANSOL there should be a file with concentrations available, SOLUTE_COLIIT.CSV and the file THETAREL.CSV (Requires version 3.1.1 of MSW2TRANSOL).

The conversion from concentration to the electrical conductivity of the saturation extract is done with:

$$ECsat = c2eca*(conc(node)*theta(node)/(theta\_sat(node)*c2ecf(node)))^{c2ecb}$$

where:

conc : salt concentration (kg/m3)

ECsat : electrical conductivity of the saturation extract (dS/m)

For *ECsat*-values below *ECmax* there is no reduction of the transpiration. For values above *ECmax* the factor is found from:

α_{salt} = (100.0d0 - (*ECsat* - *ECmax*)**ECslop*) / 100.

α_{salt} = **max**(α_{salt} ,0)

where the landuse-dependent parameters (see LUSE_SVAT.INP) are

ECmax : level of ECsat at which salt stress starts (dS/m)

ECslop : decline of root water uptake above critical salinity level *ECmax* (%/dS/m)

2.4 Surface water

2.4.1 SWNR_SIM.INP

The optional file SWNR_SIM.INP contains the list of SIMGRO surface water location identifiers.

Variable format and description

col	format	name	unit	Description
1-10	I10	swnr	-	surface water location identifier

Variable characteristics

Name	min.	max.	def.	type	error-code
swnr	1	999999	0	key	fatal

Example

```
   swnr
 < I10 >
       1
       2
       3
      41
       5
 ...
```

Remarks

The file should contain all the identifiers that are used in the drainage module (SVAT2SWNR_DRNG.INP) and the runoff routing module (SVAT2SWNR.INP). Some (or all) of the identifiers can be mapped to a surface water model. The mapping to surface water models is done with:

- MANA_RES.INP (first column) for mapping to the simple SurfW model that comes along with the SIMGRO package;
- SWNR2SWQN.INP for mapping to the external surface water model SWQN, or with the *swmp_conf_file* as defined in PARA_SIM.INP for mapping TO SOBEK locations.

For the identifiers that are not mapped to any surface water model the model uses the following defaults:

- unrestricted runoff (except for the impediment due to the so-called macro-storage *vxmu*, see file AREA_SVAT.INP);
- no runon;
- drainage and infiltration simulation using the default water levels provided in SVAT2SWNR_DRNG.INP; if no such level is given, the default level of -9999. m is used, implying free drainage, but no infiltration;
- unlimited supply for sprinkling from surface water.

2.4.2 MANA_RES.INP

The optional file MANA_RES.INP contains the water management per surface water location of the (optional) SurfW-model.

Variable format and description

col	format	name	Unit	Description
1-10	I10	swnr	-	surface water location number
17-22	I6	ioma	-	option for weir/target in summer/winter
23-30	F8	lvtasm	m+MSL	summer target level (ioma = 1 or 3)
31-38	F8	lvtawt	m+MSL	winter target level (ioma = 3 or 4)
47-54	F8	dptasu	m	depth below target level for supply
55-62	F8	fxsuswsb	m3/d	maximum supply surface water
63-72	I10	ndta	-	SVAT unit for target level control on ground water level (ioma = 1, 3 or 4)
73-78	I6	iotasmnd	-	index target level control on summer ground water level (ioma = 1 or 3)
79-84	I6	iotawtnd	-	index target level control on winter ground water level (ioma = 3 or 4)
85-94	I10	swnrta	-	location used in target level control on surface water level (ioma = 1, 3 or 4)
95-100	I6	iotasmsb	-	index target level control on summer surface water level (ioma = 1 or 3)
101-106	I6	iotawtsb	-	index target level control on winter surface water level (ioma = 3 or 4)

Variable characteristics

Name	min.	max.	def.	type	error-code
swnr	1	999999	-	key	fatal
ioma	1	4	-	req	fatal
lvtasm	-1.0E+02	1.0E+04	-	req	warning
lvtawt	-1.0E+02	1.0E+04	-	req	warning
dptasu	-1.0E+02	10	0.0	opt	warning
fxsuswsb	0	1.0E+05	0.0	opt	warning
ndta	1	999999	-	opt	fatal
iotasmnd	0	nuta	0	req*	fatal
iotawtnd	0	nuta	0	req*	fatal
swnrta	1	999999	-	opt	fatal
iotasmsb	0	nuta	0	req*	fatal
iotawtsb	0	nuta	0	req*	fatal

** required when the weir level control is specified*

Example

```
    swnr   xxxx   ioma   lvtasm   lvtawt   xxxxx   dhtasu fxsuswsb
 < I10 >< 6x >< I6 ><   F8   ><   F8   ><  8x ><   F8   ><   F8   >
       1             1    1.20     1.20              0.20     0.00
       2             1    2.00     2.00              0.00     0.00
       3             1    2.00     2.00              0.10     0.00
       .      .      .      .        .        .        .        .
```

Remarks
The file serves the dual purpose of
- indicating whether a SIMGRO surface water location is within the domain of the SurfW model;
- supplying information about the water management in the location.

Weir/target levels may be specified as time dependent data.

When because of the implementation of more control levels several new weir levels are calculated the lowest level will be used.

The 'lowest possible weir level' (*lvwrlw* in GOTO_RES.INP) in combination with the stage-discharge relationships (DISH_RES.INP) always plays a role in determining the discharge *capacity* of a weir with an automated mechanism that tries to maintain a target level. In situations with a high discharge it can mean that the water level rises above the target level that is specified in MANA_RES.INP.

The depth below target level for supply, *dptasu*, can be given a negative value. In that case an outflow from the location will be generated, using part of the supplied water.

Locations that have been given a ' target level' can not not be linked to multiple locations in downstream direction.

Options
The *ioma* index determines how the SurfW model uses the target levels given in MANA_RES.INP and the weir levels in GOTO_RES.INP. If for instance *ioma* has been set to 3 then the weir levels in GOTO_RES.INP are in fact redundant.

The summer/winter weir level setting can be over-ruled by a setting in file TISW_RES.INP.

ioma

Ioma	Winter	Summer
1	Weir level	Target level
2	Weir level	Weir level
3	Target level	Target level
4	Target level	Weir level

2.4.3 GOTO_RES.INP

The optional file GOTO_RES.INP contains the network structure of links between surface water locations of the (optional) SurfW model.

Variable format and description

col	format	Name	unit	Description
1-10	I10	swnr	-	surface water location
11-20	I10	swnrgo	-	location in 'downstream direction'
21-28	F8	lvwrsm	m+MSL	summer weir level (ioma = 2 or 4)
29-36	F8	lvwrwt	m+MSL	winter weir level (ioma = 1 or 2)
37-44	F8	lvwrlw	m+MSL	lowest possible weir level
45-54	I10	ndwr	-	SVAT unit for weir level control on ground water level (ioma = 1, 2 or 4)
55-60	I6	iowrsmnd	-	index weir level control on summer ground water level (ioma = 2 or 4)
61-66	I6	iowrwtnd	-	index weir level control on winter ground water level (ioma = 1 or 2)
67-76	I10	swnrwr	-	location for weir level control on surface water level (ioma = 1, 2 or 4)
77-82	I6	iowrsmsb	-	index weir level control on summer surface water level (ioma = 2 or 4)
83-88	I6	iowrwtsb	-	index weir level control on winter surface water level (ioma = 1 or 2)
89-94	I6	iofwbk	-	option for backflow
95-102	F8	glnr	m+MSL	soil surface elevation next to weir construction
103-110	F8	lvcv	m+MSL	elevation of culvert
111-118	F8	alfa	$m^{(3-beta)}/s$	coefficient of discharge relationship
119-126	F8	beta	-	exponent of discharge relationship

Variable characteristics

Name	min.	Max.	def.	type	error-code
swnr	1	999999	-	key	fatal
swnrgo	1	999999	-	key	fatal
lvwrsm	-1.0E+02	1.0E+04	-	req	fatal
lvwrwt	-1.0E+02	1.0E+04	-	req	fatal
lvwrlw	-1.0E+02	1.0E+04	-	opt	fatal
ndwr	1	999999	-	opt	fatal
iowrsmnd	0	nuta	-	req*	fatal
iowrwtnd	0	Nuta	-	req*	fatal
swnrwr	1	999999	-	opt	fatal
iowrsmsb	0	nuta	-	req*	fatal
iowrwtsb	0	nuta	-	req*	fatal
iofwbk	-4	4	-	req	fatal
glnr	-1.0E+2	1.0E+4	1.0e+4	opt	fatal
lvcv	-1.0E+2	1.0E+4	1.0e+4	opt	fatal
alfa	0.0	1.0E+4	0.0	opt	fatal
beta	1.0E-3	2.5	1.0	opt	fatal

** required when the weir level control is specified*

Example

```
    swnr  swnrgo  lvwrsm  lvwrwt  lvwrlw
 < I10 >< I10 ><  F8  ><  F8  ><  F8  >
       1      0    1.80    1.20    2.00
       2      0    1.80    1.20    2.00
       .      .    .       .       .
```

Remarks
The file is not needed for *ioswmdl*=2 and *ioswmdl*=5, unless there are upstream locations that are modelled with the simplified concept. In that case the file should only contain records for the upstream locations.

There is a close relationship between the input files GOTO_RES.INP and MANA_RES.INP, so the files should be consistent. Locations that have been given a ‘ target level’ in MANA_RES.INP cannot at the same time be a bifurcation point with multiple branches. The code is dimensioned for a maximum of 5 branches from a bifurcation point.

The lowest possible weir level should be specified with care. In the case that for some reason the user does not include drainage records that extend to the full depth of the watercourse that is being modelled, then the *lvwrlw*-level is used as the zero level of the storage table. In such a case a nominal amount of storage (belonging to 1 m^2 area of water) is added above that level, to ensure that the model can complete the solution algorithm. The *lvwrlw*-level should of course not be higher than the lowest of the summer/winter weir level given in the GOTO_RES.INP file for the specific surface water connection It should also not be higher than the lowest of the weir levels that are dynamically specified in the file TISW_RES.INP.

The indexes *iowrsmnd*, *iowrwtnd*, *iowrsmsb*, *iowrwtsb*, *iowrsmfr*, *iowrwtfr* refer to the indexes in the file TACL_RES.INP.

Options iofwbk

iofwbk	description	
0	no influence of downstream level	(needed for pumps)
1	stop-flow	(-1 = with stabilisation)
2	equalizing backflow	(-2 = with stabilisation)
3	strong backflow	(-3 = with stabilisation)
4	mega backflow	(-4 = with stabilisation)

In case of the backflow options 3 and 4, one must realise that weirs are backwards permeable! It should also be realized that the functioning of options 2-4 is sensitive to the used surface water schematization. The presence of short trajectories will strongly impede the backflow. The backflow options 2-4 are only meant for simulating situations with a mild flow in the reverse direction (though the names of options suggest otherwise). *Whether or not a backflow option* *functions satisfactorily for the specific the situation should be verified by the model user.*

When the surface water location is pumped the backflow option should be set to 0 to avoid water to flow upstream, when the water level downstream rises above the target level.

For locations that connect to an external hydraulic model only the backflow options 0 and 1 are available.

The soil surface elevation parameter *glnr(nr,ng)* acts as a sill for resistance-free outflow to the downstream location; if the upstream water level rises above this level (and above the downstream level), then the water above the sill level is transferred in the downstream direction. At bifurcations, however, this parameter is *not* active. (Because the flow division over the branches could otherwise not be determined.)

The (optional) relationship for a culvert construction has the following form:

$$Q = alfa * \Delta h^{beta}$$

where Q is the discharge in $m^3 s^{-1}$, *alfa* is the discharge coefficient in $m^{3-beta} s^{-1}$, *beta* is the exponent of the relationship, and Δh is the head difference in m. For the relationship to be active, the water level *lvnr* has to be above the level of the culvert, *lvcv*. There are two cases:

- $\Delta h = lvnr - lvcv$ if the downstream level *lvnr_d* is below *lvcv*
- $\Delta h = lvnr - lvnr\_d$, if the downstream level *lvnr_d* is above *lvcv*

If such a relationship for a culvert is specified, then it is combined with the tables with discharge relationships given in files DISH_RES.INP (and DISU_RES.INP). The way the two types of relationships are combined depends on the prevailing situation, because the tables given in DISH_RES.INP are relative to the prevailing weir level; the latter can be modified by the transition from winter to summer, or dynamically on the basis of decision rules given in file TACL_RES.INP.

The relationship for a culvert is *not* used by the model if it involves one of the branches at a bifurcation. (The model simply does not read the parameters; so the presence of the parameters in the file does not do any harm.)

The relationship for the culvert is not used in any manner in the reverse flow direction in the backflow options.

2.4.4 DISH_RES.INP and DISU_RES.INP

The optional files DISH_RES.INP and DISU_RES.INP contain the discharge capacity per location of SurfW-model. The DISU_RES.INP file gives the values for the summer period; if it is not present, the values in DISH_SIM.INP are used.

Variable format and description

col	format	name	unit	description
1-10	I10	swnr	-	surface water location
11-18	F8	dhwr	m	energy head above weir crest
19-26	F8	fmwr	l/s/ha	discharge
27-34	F8	fswr	m^3/s	discharge
35-44	I10	swnrgo	-	"goto" location

Variable characteristics

name	min.	max.	def.	type	error-code
swnr	1	999999	-	key	fatal
dhwr	0.	1.0E+04	-	req	fatal
fmwr	0.	1.0E+06	-	req	fatal
fswr	0.	1.0E+06	-	opt	fatal
swnrgo	0	999999	-	key	fatal

Example

```
    swnr     dhwr     fmwr     fswr   swnrgo
  < I10 ><   F8   ><   F8   ><   F8   >< I10 >
        1   1.300    5.000              12
        1   1.000    4.000              12
        .     .        .        .        .
```

Remarks

The records can be missing for a certain location; in that case discharge can only take place in the two following ways:

- if the water level rises above *lvcv(nr,ng)*, the elevation of a culvert, if present (see file GOTO_RES.INP);
- if the water level rises above *glnr(nr,ng)*, the elevation of the soil surface next to the weir construction (see file GOTO_RES.INP).

No flow is assumed at *dhwr*=0.0 m. This level is the weir crest or the bottom height of the watercourse when there is no weir. It is not allowed to decrease the discharge capacity of a weir with increasing energy head above the weir crest.

If *fmwr* is specified instead of *fswr*, the discharge capacity is calculated in $m^3\ d^{-1}$ based on the ***entire*** area upstream of the weir. When both parameters are specified *fswr* is used.

The number of records in the optional file DISU_RES.INP should be ***exactly*** equal to the number of records in DISH_RES.INP. The levels (*dhwr*) do not have to be the same.

2.4.5 RESV_RES.INP

Theoptional file RESV_RES.INP contains the supply links within the SurfW-model.

Variable format and description

col	format	name	unit	Description
1-10	I10	swnrrviw	-	location for which water is supplied (in)
11-20	I10	swnrrvow	-	location of extraction reservoir (out)
21-28	F8	dptarv	m	allowed depletion depth below weir/target level in the extraction reservoir
29-36	F8	fltarv	m3/d	target flow at control location *swnrsbow*
37-44	F8	flcprv	m3/d	supply capacity
45-54	I10	swnrsbow	-	location for control
55-60	I6	iprv	-	season (*iprv*=1 for summer, 2 for winter) that the link should be active

Variable characteristics

Name	min.	max.	def.	type	error-code
swnrrviw	1	999999	-	key	fatal
swnrrvow	0	999999	-	key	fatal
dptarv	0.	100.	-	req	fatal
fltarv	0.	999999.	-	opt	fatal
flcprv	0.	999999.	-	req	fatal
swnrsbow	1	999999	-	opt	fatal
iprv	1	2	-	opt	fatal

Example

```
        48         0      0.00     864.0    100000        68
       216       161      0.30     864.0    100000       256
       159       171      0.30       0.0    100000         0
      2288       231      0.30       0.0    100000         0
       264       236      0.30     864.0    100000       445
      2291       245      0.30       0.0    100000         0
      2298       239      0.30       0.0    100000         0
```

Remarks

It is not allowed to specify supply from more than one reservoir to a location.
Supply from an unlimited source can be implemented with sw*nrrvow*=0.
The parameter *dptarv* is the depth below the actual weir/target level in the supply reservoir. When the water level is deeper than *dptarv*, supply is set to zero.

Supply to a location is triggered by *dptasu* (see MANA_RES.INP). It is not allowed to combine supply via RESV_RES.INP with the supply option of MANA_RES.INP.

By setting a <u>negative</u> *dptasu* (in MANA_RES.INP) the location where the water is sent (*swnrrviw*) to will start to have an outflow, of course only if there is enough supply capacity to satisfy all demands at the location. In this manner the supply link can generate flow that can then (optionally) be regulated by specifying the control location *swnrsbow* and a target outflow from *fltarv* it. The flow regulation is done in discrete steps, so there can be some variation around the target flow

2.4.6 TACL_RES.INP

The optional file TACL_RES.INP contains the target level lowering schemes of SurfW model.

Variable format and description

col	format	name	unit	description
1-6	I6	iota	-	index for level control
7-14	F8	dpgwlw	m	groundwater depth below soil surface or surface water level below reference level
15-22	F8	lwta	m	lowering target/weir level

Variable characteristics

name	min.	max.	def.	type	error-code
iota	1	nuta	-	key	fatal
dpgwlw	-1.0E+02	1.0E+02	-	req	fatal
lwta	-1.0E+02	1.0E+02	-	req	fatal

Example

```
   iota  dpgwlw    lwta
 < I6 ><  F8   ><  F8  >
      1    0.00    0.30
      1    0.10    0.20
      1    0.20    0.18
      1    0.30    0.15
      1    0.40    0.10
      .     .       .
      .     .       .
      .     .       .
```

Remarks

The summer is the period between *tdbgsm* and *tdedsm* (see PARA_SIM.INP).

The target level cannot fall below the lowest possible weir level.

The lowering values must be consistent with the groundwater depth: the shallower the groundwater table, the greater the associated target level lowering.

If the actual groundwater depth is lower (higher) than the lowest (highest) specified depths in this table, the lowering for the deepest (shallowest) groundwater level is used.

The lowering is interpolated: in the example table given above when looking for *dpgwlw* = 0.33, a value *lwta* = 0.135 is returned. Values for *lwta* are not extrapolated.

2.4.7 TISW_RES.INP

The optional file TISW_RES.INP contains the time dependent discharges of SurfW model, in the cases that fixed values from an externally determined boundary condition are to be specified.

Variable format and description

col	format	name	unit	Description
1-15	F15	td	d	time from beginning of year at 00:00:00
16-21	I6	iy	-	year number
22-31	I10	swnr	-	sw location identifier
42-51	F10	hhwrnw	m+MSL	new weir/target level
52-61	F10	flswnw	m3/d	new surface water inflow rate
62-71	I10	swnrgo	-	swnrgo link in case of new weir/target level

Variable characteristics

name	min.	max.	def.	type	error-code
td	0	366	-	req	fatal
iy	1	9999	-	req	fatal
swnr	1	999999	-	req	fatal
hhwrnw	-1.00E+03	1.00E+03	-	opt 2	warning
flswnw	0.00E+00	1.00E+08	-	opt 3	warning
swnrgo	1	999999	-	req	fatal

Example

```
         td         iy     swnr              hhwrnw     flswnw    swnrgo
<     F15      >< I6 ><    I10   ><   10x  ><  F10    ><    F10  ><  I10    >
      1.0000000  1985           3               10.40                      6
      1.0000000  1985           9                         554.00
```

Remarks

If a new weir/target level is introduced in the time-records, both the summer and winter weir/target levels are updated at the specified time, implying that the weir/target level of the specified subcatchment is to be controlled fully in this file.

If a new weir/target level is specified also the “goto” location should be given (*swnrgo*).

The new weir level should not be lower than “lowest possible weir level” (*lvwrlw*, see GOTO_RES.INP); otherwise a fatal error occurs. The *lvwrlw*-level should anticipate on dynamic changes of weir level made in TISW_RES.INP.

2.4.8 INIT_RES.INP

The optional file INIT_RES.INP contains the initial conditions surface water system of the SurfW model.

Variable format and description

col	format	name	unit	description
1-10	I10	swnr	-	surface water location
11-18	G15	lvsw	m	initial surface water level
19-26	G15	Qussw	m3	upstream* surface water inflow over surface water time step
27-34	G15	Qdssw	m3	downstream* surface water outflow over surface water time step
35-42	G15	VSurfWpk	m3	non-realized volume of SurfW

* definition of “upstream“ and “downstream” side according to GOTO_RES.INP; the used sign convention for the flow terms is: “+ = towards the surface water location”

Variable characteristics

name	min.	max.	def.	type	error-code
swnr	1	999999	-	key	fatal
lvsw	-1.0E+02	1.0E+04	see remarks	opt	fatal
Qussw	-	-	-	-	-
Qdssw	-	-	-	-	-
VSurfWpk	-	-	-	-	-

Remarks

If this files does not exist (or a record for a specific *swnr* is missing), the initial surface water levels are set to the lowest point in the storage table. That is at the lowest water course bottom level of the drainage links that refer to the surface water location. If there are no such drainage records, then the *lvwrlw*-level given in GOTO_RES.INP is used.

3 ASCII Output files

3.1 Run log

3.1.1 INFO_SIM.OUT and INFO_SVAT.out

The files contains all informative messages, warnings and error messages.

3.2 End states

3.2.1 INIT_SVAT.OUT

At the end of the SIMGRO calculations, SVAT state variables are written to the output file INIT_SVAT.OUT. This file can be used as input for a ‘hot start’ of a subsequent SIMGRO run. It suffices to rename the ".out" versions to ".inp" versions. A full description is given for INIT_SVAT.INP.

3.2.2 INIT_SVATVG.OUT

At the end of the SIMGRO calculations, WOFOST state variables are written to the output file INIT_SVATVG.OUT. This file can be used as input for a ‘hot start’ of a subsequent SIMGRO-WOFOST run. It suffices to rename the ".out" versions to ".inp" versions.

3.2.3 INIT_RES.OUT

At the end of the SIMGRO calculations, the surface water levels are written to the output file INIT_RES.OUT. This file can be used as input for a subsequent SIMGRO run. It suffices to rename the ".out" versions to ".inp" versions. A full description is given for INIT_RES.INP.

4 Binary Output files

4.1 Introduction

Binary output can be generated for:

- SVAT-units:
  - o phreatic level, written bimonthly for SVAT's (GT.*-files)
  - o state and balance variables for SVAT's (SVAT_PER.*-files, SVAT2GW_DTGW, SVAT_DTGW)
  - o vegetation state variables for SVATs (SVATVG_PER.* files and SVATVG_DAY.* files)
- Drainage interaction links:
  - o drainage and infiltration (DRNG_PER.*-files)
- Surface water locations:
  - o state and balance variables of surface water locations per groundwater time step *dtgw* and/or accumulation period (SW_DTGW.* and SW_PER.* files);
  - o state and aggregated balance variables per SIMGRO surface water time step *dtsw* (SW_DTSW.* files).

Binary output is specified with a set of three files::

- the **.key**-file (ASCII). The key-file describes the structure of the unformatted output-files.
- the **.tim**-file (ASCII) with the time information;
- the **.bda**-file containing the data in file format 'unformatted direct access' .

In the key-file the output-file is completely outlined. This is done by specifying the following parameters:

- OUTPUTFILE : name of BDA-file
- TIMERFILE : name of TIM-file
- FILETYPE : "SVAT" or "SWNR" (for surface water locations)
- FORMAT : for instance R4 for Real*4 or I4 for Integer*4
- PERIOD : 0/1 indicator; PERIOD=1, for a file containing water balance terms; PERIOD=0, for a file containing only state variables at certain moments in time
- NUMVAR : number of variables,
  - list with names of the variables, units, descriptions
- NUMPTS : number of SVAT-units/SWNR-locations
  - list with numpts-id, ground levels, areas and accumulated upstream areas (only relevant for FILETYPE "SWNR")

In the **tim**-file the output times are specified, with on each record the time (in days) from January 1 00:00:00 followed by the (Gregorian) year.

The **bda**-files are unformatted and direct-access, with a record length of reclen=1. The records are hierarchically structured with the following nested loops:

- periods/times;
- SVATs/subcatchments;
- items

For instance, the record number containing the value for the third period, for the sixth SVAT-unit out of 2000, for the fourth item out of 10 is equal to: (3-1)*2000*10 + (6-1)*10 + 4.
The files can be read using the utility programmes READ_BDA2TIME and READ_BDA2AREA, as described in the User's Guide.

Table 4.1 Output files, description and options. Option parameter values are set in PARA_SIM.INP

File	Opt. par. =1	Description
SVAT_GT	svat_gt	ground water level per 14 days
SVAT_PER [#]	svat_per	water balances of SVAT units per water balance period
SVAT_DTGW*,+	svat_dtgw	water balances of SVAT units per gr. water time step
SVAT2GW_DTGW*	svat2gw_dtgw	water balances of SVAT units for groundwater as a system volume, per gr. water time step
DRNG_PER	drng_per	drainage and infiltration of SIMGRO drainage links, water balance periods
SVATVG_PER	svat_vg_per	vegetation state variables, for periods
SVATVG_DAY	svat_vg_per	vegetation state variables, for days
SW_PER [@]	sw_per	water balances of surface water locations, per period
SW_DTGW[%]	sw_dtgw	water balances of surface water locations, per dtgw
SW_HQ_DTGW	sw_hq_dtgw	sw flows and water levels for plotting purposes, dtgw
SW_DTSW	sw_dtsw	water balances of surface water locations, per dtsw
SW_HQ_DTSW	sw_hq_dtsw	sw flows and levels for plotting purposes, per dtsw

** only for selected units specified in SEL_SVAT_BDA.INP;*
[#] also available in the form of csv-files for units in SEL_SVAT_CSV.INP, if svat_per_csv=1
[+] also available in the form of csv-files for units in SEL_SVAT_CSV.INP, if svat_dtgw_csv=1
[@] also available in the form of csv-file for units in SEL_SWNR_CSV.INP, if sw_per_csv=1
[%] also available in the form of csv-file for units in SEL_SWNR_CSV.INP, if sw_dtgw_csv=1

4.2 SVAT units

4.2.1 SVAT_GT

The SVAT_GT.BDA file contains the bimonthly values of the groundwater level, which in Dutch hydrology is used for deriving statistics of the phreatic regime.

key	Unit in out-file	item	Remarks
Hgw	m+MSL	groundwater level	groundwater level of MetaSWAP at the end of the groundwater time step
Hgwav	m+MSL	groundwater level	dtgw-averaged groundwater level of MetaSWAP
Hgwmodf	m+MSL	groundwater head	groundwater head of MODFLOW at the end of the groundwater time step
Hgwmodfav	m+MSL	groundwater head	dtgw-averaged groundwater head of MODFLOW

Remarks
For the convenence of the user the file contains information from both MetaSWAP and MODFLOW. For the svat's with a resistance-free link between MetaSWAP and MODFLOW the levels are the same if the iteration scheme has completely converged. Complete convergence for all svat's, however, requires a computational effort that is not in proportion to the achieved gain in accuracy. By providing the level information for both models the user can determine the degree to which the statistics of the groundwater regime differ between the models. In that way the tradeoff between the required computational effort and the achieved accuracy can be evaluated and the user can make a founded decision for setting the convergence parameters of the model.

For each of the models, two different values are given for the level: a momentaneous one and a time-averaged one. The best choice for determining the GT-statistics will depend on the used modelling options. If the MODFLOW drainage options are used, then the level at the end of the day is the most appropriate; that is because MODFLOW drainage is fully *implicitly* determined in the solution scheme. If the SIMGRO drainage is used, it can be judicious to use the average level; that is because the SIMGRO drainage is determined using an *explicit* time-averaging scheme with respect to the groundwater level (but has the advantage of using more up-to-date values of the surface water level in the drainage flux calculation).

4.2.2 SVAT_PER/SVAT_DTGW

The SVAT_PER.* and SVAT_DTGW.* files contain information about the state variables and water balance terms of the SVAT simulations. The files are activated by parameters in PARA_SIM.INP: *svat_per/svat_dtgw*=1.

key	unit	item	sign
decSic	m3/m2	decrease of interception storage	+/-
decSpdmac	m3/m2	decrease of 'macro' ponding storage	+/-
decSpdmic	m3/m2	decrease of 'micro' ponding storage'	+/-
decS1	m3/m2	decrease of water storage in rootzone, box 1	+/-
..	m3/m2	..	+/-
decS*N*	m3/m2	decrease of water storage in box *N*	+/-
Pm	m3/m2	measured precipitation	≥0.
Psgw	m3/m2	sprinkling precipitation, from groundwater	≥0.
Pssw	m3/m2	sprinkling precipitation, from surface water	≥0.
Esp	m3/m2	evaporation sprinkling water	≤0.
Eic	m3/m2	evaporation interception water	≤0.
Epd	m3/m2	evaporation ponding water	≤0.
Ebs	m3/m2	evaporation bare soil	≤0.
Tact	m3/m2	actual transpiration vegetation	≤0.
qrun	m3/m2	runon	+/-
qdr	m3/m2	net infltration of surface water, SIMGROdrainage	- =drn
qspgw	m3/m2	groundwater extraction for sprinkling	≤0.
qmodf	m3/m2	sum of all MODFLOW stresses on groundwater	+=in
vcr	m3/m2	water balance error (water creation)	+/-
qmodfbot	m3/m2	upward seepage of MODFLOW cell	+=in
qsim	m3/m2	sum of SIMGRO stresses on groundwater, including MODFLOW correction term	+/-
qsimcorrmf	m3/m2	correction term for realignment of MODFLOW in the case that there was not a full convergence during the last time step	+/i
dpvgrz	m	root zone depth, according to input or veg. model	>0.
dptbrz	m	root zone depth, table value of unsa database	>0.
vght	m	height of vegetation	≥0.
lai	m2/m2	leaf area index	≥0.
slcv	m2/m2	soil cover areal fraction	≥0.
Siccap	m3/m2	interception capacity of canopy	≥0.
fT	-	crop factor for transpiration	≥0.
fEic	-	factor for interception evaporation	≥0.
fEbs	-	factor for bare soil evaporation	≥0.
fEpd	-	factor for ponding evaporation below crop	≥0.
ETref	m3/m2	reference crop evapotranspiration	≤0.
Ebspot	m3/m2	potential evaporation bare soil	≤0.
Tpot	m3/m2	potential transpiration vegetation	≤0.
.. continued			

Trel	m3/m3	relative transpiration (=1.0 for Tpot=0.0)	≥0.
ETact	m3/m2	total actual transpiration	≤0.
qinf	m3/m2	infiltration on soil surface	+=down
qmr	m3/m2	flow through bottom of box1, root zone	+=up
key	unit	item (list continued)	sign
qmv(*2*)	m3/m2	flow through bottom of box *2*	+=up
..	m3/m2	..	+=up
qmv(*N*)	m3/m2	flow through bottom of box *N*	+=up
Sic	m3/m2	interception storage	≥0.
Spdmac	m3/m2	‘macro’ ponding storage	≥0.
Spdmic	m3/m2	‘micro’ ponding storage	≥0.
S01	m3/m2	soil water storage in rootzone, box 1	≥0.
Ssd01	m3/m2	soil water saturation deficit of box 1	≥0.
...	m3/m2	..	≥0.
Ssd*N*	m3/m2	soil water saturation deficit of box *N*	≥0.
Ssdtot	m3/m2	total soil water saturation deficit	≥0.
decStot	m3/m2	decrease of total storage	+/-
phrz01	m	mean root zone pressure head, box 1	+/-
..	m	..	+/-
phrz*N*	m	virtual mean root zone pressure head of box *N*	+/-
Hpd	m+MSL	MetaSWAP ponding water level	+/-
Hgw	m+MSL	MetaSWAP groundwater level	+/-
dHgw	m	MetaSWAP groundwater level change	+=rise
sc1	-	groundwater storage coefficient	0.< ≤1
Hgwmodf	m+MSL	MODFLOW groundwater head	+/-
dHgwmodf	m+MSL	MODFLOW groundwater head change	+/-
Hsw	m+MSL	surface water level	+/-
TempCmnday	^{o}C	minimum temperature during 24 hrs	+/-
TempCmxday	^{o}C	maximum temperature during 24 hrs	+/-
TempC	^{o}C	mean temperature	+/-
Nrel	-	mean relative sunshine duration	0.< ≤1
Rad	kJ/m2/d	mean shortwave radiation	≥0.
Hum	kPa	mean humidity	≥0.
wind	m/s	mean windspeed	≥0.
Rnt	kJ/m2/d	mean net radiation, discounting reflection (albedo effect) and long wave emission	+/-
HG	kJ/m2/d	mean rest term of energy balance, available for sensible (H) and ground (G) heat flux	+/-

The used sign convention for all water flow terms is: + = into the compartment

The above given list of items is written to two files, only for the SVAT-units specified in SEL_SVAT_BDA.INP:

- to file SVAT_PER.BDA per accumulation period as defined in TIOP_SIM.INP;
- to file SVAT_DTGW.BDA per groundwater time step *dtgw*..

The state variables are for the end of a period/time step. The number of variables that are written can be reduced by means of the optional files SEL_SVAT_PER_KEY.INP for SVAT_PER.BDA and/or SEL_SVAT_DTGW_KEY.INP for SVAT_DTGW.BDA.

Extra *csv* files with totals are created along with the *bda*-files:

- TOT_SWMDL*_SVAT_PER.CSV, with totals of the terms for *swnr*'s that are part of the domain:
  - SWMDL0 for the locations not coupled to surface water model
  - SWMDL1 for the locations coupled to SurfW
  - SWMDL2 for the locations coupled to SOBEK
  - SWMDL5 for the locations coupled to SWQN
- TOT_SWMDL*_SVAT_DTGW.CSV with totals per groundwater time step

For monitoring the progress of a run an extra facility is available that generates *csv*-files (with the water balance terms in **mm** instead of m^3/m^2) for the individual SVAT units selected in SEL_SVAT_CSV.INP. These files are generated by setting the following parameters in PARA_SIM.INP:

- *svat_per_csv* = 1 for obtaining files SVAT_PER_<SVAT>.CSV
- *svat_dtgw_csv* =1 for obtaining files SVAT_DTGW_<SVAT>.CSV

Remarks about variables

The Makkink-method for the evapotranspiration computes per day a *total* value during the growing season (soil cover is set to 1.0) even for when the crops have only just started growing. So during the growing season the "Transpiration" includes a certain amount of bare soil evaporation, which is not known in the model. Bare soil evaporation is only computed explicitly (separately) for the part of the season with *a soil cover that is less than 1.0.*

During the time fraction that interception evaporation is active, the model disables the transpiration. So the potential transpiration of the period is computed as [*Makkink reference transpiration*] X [*crop factor*] X [*1-fric*], where *fric* is the fraction of time with active interception evaporation.

The fraction of time that the vegetation does not have any moisture stress (i.e. the part of the time that the leaf pores are free to open and close determined by the need for CO_2) can be computed as:

$$r_{\mathrm{E}} = \frac{E_{\mathrm{ic}} + T_{\mathrm{act}}}{E_{\mathrm{ic}} + T_{\mathrm{pot}}}$$

The ponding storage on the soil surface is the summation of *Spdmic* and *Spdmac*. The former is the amount of 'micro-storage', which is less or equal to the micro-storage capacity on the soil surface (*vxmu* in AREA_SVAT.INP). The *Spdmac* variable represents the 'macro-storage'. This part of the ponding storage is also included in the storage of the surface water model if the 'unified' approach is used for the runoff simulation.

The ponding water level *Hpd* of MetaSWAP is set to the level of the soil surface when the ponding storage is empty.

Water balances of a SVAT colum and of its subsystems

The water balance error is calculated for the total SVAT column[1] by summating the terms listed in the table above *vcr* ; the opposite value of the sum is the water 'creation':

$$vcr = -[\, decSic + decSpdmac + decSpdmic + decS1 + decS2 + decS3 + Pm + Ps + Eic + Epd + Ebs + ETact + Esp + qrun + qdr + qspgw + qmodf \,]$$

The used symbols are explained in the table of key variables given above. All terms are defined according to the sign convention (+= in) given above.

Several partial water balances can be made. The water balance for the compartment above the soil surface surface[2] is given by:

$$vcr\_s = -[decSic + decSpdmac + decSpdmic + Pm + Ps + Eic + Epd + Esp + qrun - qinf\,]$$

The water balance for the rootzone[2] is given by:

$$vcr\_r = -[qinf + decS1 + Ebs + ETact + qmr]$$

For situations with the groundwater level in box 2, the water balance for this box is given by:

$$vcr\_2 = -[-qmr + decS2 + qdr + qspgw + qmodf\,]$$

With respect to the water balance of the groundwater it should be realized that the model is of the 'unified' type. So the recharge to the groundwater is partly taking place within the unsaturated zone. Thus the term 'recharge' is rather

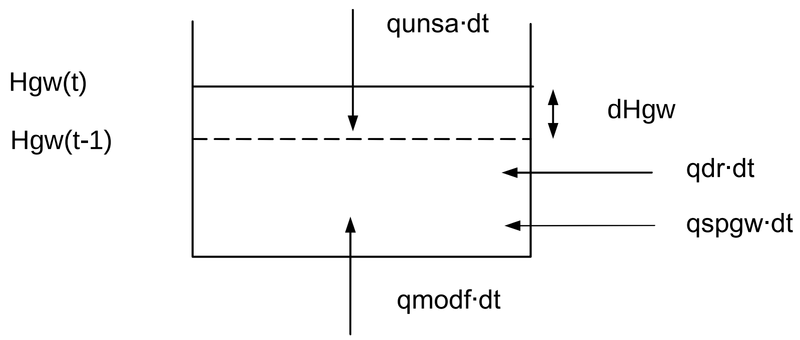

Figure 1 Definition of fluxes near the groundwater level. The 'recharge' of MODFLOW, qsim, can include saturated flow terms qdr for the SIMGRO drainage and qspgw for the SIMGRO extraction of groundwater for sprinkling: qsim = qunsa + qdr + qspgw. The arrows in the figure indicate the sign convention, which is based on '+ = to the saturated zone'. Thus the extraction for sprinkling is ≤0. The SIMGRO drainage term qdr is positive for infiltration from surface water.

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[1] = box 1, 2 and 3 defined in the Theory report, extending into the phreatic groundwater
[2] bare soil evaporation and transpiration are from the rootzone

misleading, since the unsaturated zone and the saturated zone form a continuum. In the iteration scheme for the *second* solution step of the model coupling, we use the sum of the SIMGRO stresses on the groundwater system *qsim* as the ‘recharge’ of the MODFLOW model. By way of example, we give the recharge for situations that the groundwater level at beginning and end of the time step is below the soil surface. In that case the value of *qsim* follows from the water balance of the total SVAT-system including phreatic groundwater:

$$qsim = qunsa + qdr + qspgw + qsimcorrmf$$

$$qunsa = qinf + Ebs + ETact + decS1^{\sim} + decS2^{\sim} + decS3^{\sim}$$

where *qsim* is the sum of the SIMGRO stresses, *qunsa* is the total of the unsaturated terms, and where the storage change terms appended with a “˜“ follow from intermediate updates of the soil moisture profile in the *first* solution step of the coupling scheme. (More details are given in the Theory report.)

Figure 1 shows the fluxes *qmodf* and the components of *qsim* in relation to the change of the groundwater level, *dlvgw*. To the MODFLOW model the water balance near the groundwater level appears in the form of:

$$sc1 \cdot dHgw = \left(qmodf + qsim\right) \cdot dt$$

where the storage coefficient *sc1* changes from time step to time step. Both the recharge and storage coefficient are merely *auxiliary* variables that are used in the coupling scheme.

For making explicit the amount of water that actually passes to the groundwater *body* (i.e. to the groundwater as a *system volume*) a different type of balance should be made, and a differently defined storage coefficient should be used. The terms for this balance are given in output file SVAT2GW.BDA.

A water balance for the complete system comprising the SVAT-columns, groundwater grids (MODFLOW) and surface water locations (SurfW model) is given Section in 4.4.1.

4.2.3 SVAT2GW_DTGW

The SVAT2GW_DTGW.* files contain information about the state variables and water balance terms of the groundwater perceived as a *system volume*, for the SVAT units, per time step of the groundwater model.

The file is activated by setting the parameter *svat2gw_dtgw*=1 in PARA_SIM.INP.

key	unit	item	sign
decSgw	m3/m2	decrease of groundwater storage	+/-
qsat	m3/m2	sum of saturated flow stresses on groundwater	+=in
qrecha	m3/m2	groundwater recharge from unsaturated zone	+/-
vcr	m3/m2	water balance error (water creation)	+/-
Hgw	m+MSL	MetaSWAP groundwater level	+/-
dHgw	m	MetaSWAP groundwater level change	+=rise
musat	m3/m3	groundwater storage coefficient	0.< ≤1
Hgwmodf	m+MSL	MODFLOW groundwater head	+/-

*** the used sign convention for all flow terms is: + = into the compartment**

Remarks
As indicated in the previous section the coupling of the soil water and ground-water is of the *integral* type. The meaning of the terms “recharge” and “storage coefficient” then depend on the specific interpretation that is given. Here we give the interpretation from the point of view of the groundwater modeller.

All terms are defined according to the sign convention (+= in) given above, as is the case for the computed balance error. Note that all flow terms are written as volumes to the output files, even though the used symbols start with a *‘q’.*

Water balance of groundwater as a system volume
The water balance terms are defined as in Figure 2. The main difference with Fig.1 lies in the interpretation of the storage coefficient *and* of the flux from the SIMGRO top-system model to the groundwater model. In this case we assume that the storage coefficient follows directly from the *saturated* water content profile of the groundwater column. It is calculated with:

$$\mu_{sat} = \frac{1}{Hgw(t+\Delta t) - Hgw(t)} \int_{Hgw(t)}^{Hgw(t+\Delta t)} [\theta_{sat}(z) + \theta_{mac}(z)] dz$$

where μ_{sat} is the storage coefficient of the groundwater system volume, *Hgw()* the groundwater level*,* θ_{sat} is the saturated water content used in the steady-state SWAP simulations, and θ_{mac} is the additional macro-pore porosity that has been added to the profile. Only the effect of this extra porosity on the water storage is taken into account, not on the flow.

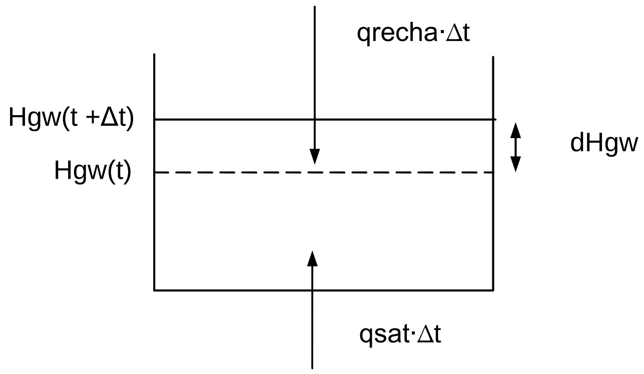

Figure 2 Definition of fluxes near the groundwater level for making a water balance of groundwater as a <u>*system volume*</u>*. The saturated flow term, qsat, can include flow terms modelled by SIMGRO: qsat = qmodf + qdr + qspgw, where: qmodf = net flux from MODFLOW(+/-), qdr = net SIMGRO drainage (+/-), qspgw = extraction for sprinkling (≤0.)*

The water balance of the groundwater as a system volume is given by

$$decSgw = -\mu_{sat} \cdot dHgw = -(qrecha + qsat) \cdot \Delta t$$

where the sign convention of all terms is given by "+ = to the system volume", including the term for the storage decrease, *decSgw*.

In the case of a rising groundwater level, the flux *qrecha* includes soil moisture that is being added to the groundwater because it is being 'eaten up' by the rising groundwater level. In the case of a falling groundwater level, the flux *qrecha* includes (as a negative term) soil water that is being lost because it is being 'left behind'. This transfer rate of water from the unsaturated system volume to the saturated system volume can be made explicit by rewriting the above equation as:

$$qrecha = \mu_{sat} \frac{d}{dt} Hgw - qsat$$

The above given representation of the flow at the interface between the soil moisture system volume and the groundwater system volume can be used for (simple) water quality modelling if the schematization assumes perfect mixing within the phreatic groundwater layer.

4.2.4 SVATVG_PER/DAY

The SVATVG_PER.* and SVATVG_DAY.* files contain information about the state variables of the vegetation, which are available if the vegetation model is being used (*vegetation_mdl* ≥1). The respective files are activated by setting the parameters *svatvg_per*=1 and *svatvg_day*=1 in PARA_SIM.INP.
Additionally, extra information can be outputted for selected SVATs (SEL_SVAT_CSV.INP) if the option parameters *svatvg_per_csv*=1 and *svatvg_day_csv*=1 are set. These files contain an expanded list of items; the full list is given below. The variables available in the bda files are indicated in the last column (B).

key	unit	item	B
dayvg	-	day number of active vegetation	√
dvs	-	development stage	√
htvg	m	height of vegetation	√
laipot	m^2/m^2	leaf area index, potential value	
lai	m^2/m^2	leaf area index, actual value	√
slcv	m^2/m^2	soil cover areal fraction	√
crt0	-	cumulative relative transpiration from start of crop	
crt1	-	cum. rel. tr. from start of generative phase (dvs ≥ 1.)	
dprzpot	m	depth of root zone, potential value	
dprz	m	depth of root zone, actual value	√
wrtpot	kg/ha	dry matter weight roots, potential value	
wrt	kg/ha	dry matter weight roots, actual value	
wstpot	kg/ha	dry matter weight stems, potential value	
wst	kg/ha	dry matter weight stems, actual value	
dwstpot	kg/ha	dry matter weight dead stems, potential value	
dwst	kg/ha	dry matter weight dead stems, actual value	
wlvpot	kg/ha	dry matter weight leaves, potential value	
wlv	kg/ha	dry matter weight leaves, actual value	
dwlvpot	kg/ha	dry matter weight dead leaves, potential value	
dwlv	kg/ha	dry matter weight dead leaves, actual value	
w**ag**ppot	kg/ha	dry weight of dead and living stems & leaves (**a**bove **g**round dry matter), potential value	
wagp	kg/ha	dry weight of dead and living stems&leaves, actual value	√
wagptpotyld	kg/ha	dry weight of harvested stems & leaves, potential value	
wagptyld	kg/ha	dry weight of harvested stems & leaves, actual value	√
wagptyldrel	-	relative yield of stems&leaves	√
wsopot	kg/ha	dry weight of storage organs, potential value	
wso	kg/ha	dry weight of storage organs, actual value	√
wsopotyld	kg/ha	dry weight of harvested storage organs, potential value	
wsoyld	kg/ha	dry weight of harvested storage organs, actual value	√
wsoyldrel	-	relative yield of harvested storage organs	√

Remarks
A number of the variables can also be outputted to the hydrological files, i.e. *htvg*, *lai, slcv,* and *dprz*. It should be noted that the values given in the output files of the vegetation model are the values *at the end of the day*, whereas the ones in the hydrological files contain the values *used for the calculations of that day*.

4.3 Drainage interaction links

4.3.1 DRNG_PER

The DRNG_PER.* files contain information about the SIMGRO drainage links modelled with parameters contained in file SVAT2SWNR_DRNG.INP.

The option is activated by parameter *drng_per*=1 in file PARA_SIM.INP.

key	unit	item	sign
Vdr_drng	m3	drainage	≥0.
Vif_drng	m3	infiltration	≥0.

The items are written to the output file for all the drainage records per period defined in TIOP_SIM.INP.

The key-file has a different format then the standard key-file. The key-file gives the number of the drainage record and its characteristics:
– NUMPTS-id (number of drainage record);
– SVAT unit
– number of layer, that is drained
– surface water location that the drainage record connects to
– system index
– drain depth below soil surface
– drain width at bottom
– cotangent of slope
– drain spacing
– length of watercourses of a drainage system in the SVAT unit
– drainage resistance
– entry resistance
– infiltration resistance
– exit resistance

4.4 Surface water locations

4.4.1 SW_PER/SW_DTGW

The SW_PER.* and SW_DTGW.* files give the complete water balance of the surface water system modelled by SurfW, for accumulation periods and for groundwater time steps. For the remaining surface water locations only the interaction terms are non-zero.

The writing of the files is activated by the following parameters in PARA_SIM.INP:

- *sw_per* = 1 for the SW_PER.* files
- *sw_dtgw* = 1 for the SW_DTGW.* files

key	unit	item	remarks	sign
Vusreg	m3	upstream* inflow from outside of region	SurfW	≥0.
Vusmdl	m3	upstream* inflow from outside sw-submodel part of domain, within region	All models (exc.SurfW)	≥0.
Vus	m3	upstream* inflow from inside sw-submodel part of domain	SurfW	+=in*
Vdsreg	m3	downstream* inflow from outside of region	SurfW	+=in*
Vdsmdl	m3	downstream* inflow from outside sw-submodel part of domain, within region	SurfW	+=in*
Vds	m3	downstream* inflow from inside sw-submodel part of domain	SurfW	+=in*
Vsurv	m3	supply from other reservoir (sw location)	SurfW	≥0.
Vexrv	m3	abstraction by other reservoir	SurfW	≤0.
Vsues	m3	supply from external source (“helicopter”)	SurfW	≥0.
Vexsp	m3	abstraction for sprinkling	All models	≤0.
Vru	m3	runoff/runon	All models	+=off
Vdrsy1+	m3	drainage to 1st system	All models	≥0.
Vifsy1	m3	infiltration from 1st system	All models	≤0.
Vdrsy2	m3	drainage to 2rd system	All models	≥0.
Vifsy2	m3	infiltration from 2nd system	All models	≤0.
Vdrsy3	m3	drainage to 3rd system	All models	≥0.
Vifsy3	m3	infiltration from 3rd system	All models	≤0.
Vdrsy4	m3	drainage to 4th system	All models	≥0.
Vifsy4	m3	infiltration from 4th system	All models	≤0.
Vdrsy5	m3	drainage to 5th system	All models	≥0.
Vifsy5	m3	infiltration from 5th system	All models	≤0.
decSsw	m3	decrease of storage in sw	SurfW	+/-
Vcrsw	m3	water balance error (creation)	SurfW	+/-
Ssw	m3	storage in surface water	SurfW	≥0.
Hsw	m+MSL	surface water level	All models	+/-
Hwr	m+MSL	weir level	SurfW	+/-
Hta	m+MSL	target level	SurfW	+/-

* definition of “upstream“ and “downstream” side according to GOTO_RES.INP; the used sign convention for the flow terms is: “+ = towards the surface water location”; flow towards non-coupled *swnr*’s is included in flow over region boundary

+ the classification into systems is according to SVAT2SWNR_DRNG.INP

The written data are:

– in SW_PER.BDA: for all the surface water locations in SWNR_SIM.INP per period as specified in TIOP_SIM.INP
– in SW_DTGW.BDA: for all the surface water locations in SWNR_SIM.INP, per groundwater time step;

The state variables are for the end of a period/time step.

Additional csv files can be generated by setting *sw_per_csv*=1 and/or *sw_dtgw_csv*=1, and also supplying a selection of *swnr*'s in file SEL_SWNR_CSV.INP. If there is such a selection then individual files are created; if the selection file is absent the data for all *swnr*'s are written to a single *csv*-file per region that is coupled to a certain surface water model. For instance, the results for non-coupled swnr's are collected in file SWMDL0_SW_PER.CSV and SWMDL0_SW_DTGW.CSV

Extra files with totals can be created by setting the option parameters to 2:

– *sw_per* = 2 for creating the files TOT_SWMDL1_SW_PER.CSV, with totals of the terms for *swnr*'s that are part of SurfW;
– *sw_dtgw* = 2 for creating the file TOT_SWMDL1_SW_DTGW.CSV files with totals per groundwater time step

Water balance of surface water system

The water balance of the surface water system modelled by SurfW is given by:

$$vcr = -\{ \sum_{swnr \in SIMRES} [decSsw + Vusreg + Vus + Vdsreg + Vdsmdl + Vds + Vsurv + Vexrv + Vsues + Vexsp + Vru + \sum_{sy=1,5} (Vdr_{sy} + Vif_{sy})]\}$$

where the symbols are explained in the table given above.

Water balance of total system

If both *sw_per* and *svat_per* are set to 2, then a file TOT_SWMDL*_PER.CSV is created with the water balance of the *total system,* comprising the *svat*'s coupled to the respective surface water model (*swmdl* = 1 for SurfW, 2 for SOBEK, 5 for SWQN), the phreatic layer of the MODFLOW model, and the *swnr*'s of the respective surface water model. If both *sw_dtgw* and *svat_dtgw* are set to 2, then a similar files TOT_SWMDL*_DTGW.CSV are created for the balances per *dtgw*-step.

Only in the case of SurfW does SIMGRO have all the information available for making the balance. For the part of the domain coupled to an external surface water as much as possible information is supplied. The rest should be obtained from the external models.

The water balance of the total system does not include any internal transfers of water. It just includes fluxes at the outer boundary of the system and the storage changes. With respect to the latter it is crucial to avoid double counting, especially in situations where the unified modelling approach is used. For the total system coupled to the SurfW model, we do not need any storage information from the MODFLOW model. That is because all the storage information is available in the SVAT-model. (Anyhow, the storage information available in the MODFLOW model is not complete, because it does not take the unsaturated storage into account.)

The flux along the boundary of the MODFLOW model is needed for the balance; but since the balance is only for the phreatic layer, the nett flux along the boundary of the model domain can be found by summating the *qmodf*-fluxes of the individual SVAT-columns (see Section 4.2.2). If the extraction from groundwater for sprinkling is from the phreatic layer, then this is an internal transfer within the defined 'total' system, and we do not have to take it into account here. But if it is from a deeper layer, it comes from outside the defined system, and thus it should be included.

The water balance error for the total system defined here is given by:

$$vcr = -\Big\{ \sum_{svat \in SIMRES} \big[decSic + decSpdmic + decStot + Pm - ETtot + qspgw_{deep} + qmodf \big] * a_{svat} + \sum_{swnr \in SIMRES} \big[decSsw + Vusbdsw + Vdsbdsw + decVspsw\_nr + decVpdmac\_nr \big] \Big\}$$

where:

vcr	= water creation within model domain coupled to SurfW (m^3)
a_{svat}	= area of a SVAT (m^2)
decSic	= decrease of interception storage (m)
decSpdmic	= decrease of 'micro' ponding storage (m)
decStot	= decrease of total storage in the soil column (<soil surface) (m)
Pm	= precipitation (m)
ETtot	= total evapotranspiration (m)
$qspgw_{deep}$	= sprinkling extraction from deep groundwater layers (m)
qmodf	= nett flux along the sides and bottom of the phreatic MODFLOW layer (m)
decSsw	= decrease of surface water storage, including water stored on the soil surface (m^3)
Vusbdsw	= upstream inflow of SurfW model (≥0.) (m^3)
Vdsbdsw	= downstream outflow of SurfW model (≤0.) (m^3)
Vspsw_nr	= sprinkling extraction from surface water, in transit (m^3)
decVpdmac_nr	= decrease of macro ponding storage in MetaSWAP not yet communicated to the surface water model (m^3)

The so-called macro storage on the soil surface (the ponding storage on the soil surface that is in excess of the micro storage capacity *vxmu*) is already included in the *decSsw* term fo the SurfW model; so the *decSpdmac* term of the SVAT-model is left out in order to avoid double counting. However, when making a balance for the domain coupled to an external hydraulic model in combination with the ‘classic’ runoff concept, the macro storage *should* be counted, because in that case a ‘compartment’ approach is used instead of the unified approach.

Ideally, the model initialization of groundwater and surface water is hydrologically consistent. In that case the specified ‘groundwater’ levels in lakes are equal to the specified surface water levels. But provisions have been made in the code so that the model does not derail if the surface water level initialization is left out, for instance. In that case it simply diagnoses a discrepancy between the groundwater mdoel and the surface water at the starting up time. This is then remedied by the simulation during the initial period.

Especially if the initialization of the model is not hydrologically consistent and with situations involving groundwater levels above soil surface, the initial amount of ‘non realized’ macro ponding storage (*Vpdmac_nr*) can be very large. In that case the ‘decrease’ value will also be very large during the first time step, because during this first step the volume is communicated to the surface water. That is not done in one single action during the first *dtsw* step, because the same mechanism of temporarily not communicating macro ponding storage is also used for the time-spreading of seepage to the soil surface. In situations with seepage to the soil surface the MODFLOW model causes the ponded water level of a MetaSWAP column to rise above its value at the end of the *dtgw*-step. If that water were to be communicated to the surface water in one go, then the model would simulate peaks of runoff at the first *dtsw*-step of each *dtgw*-cycle. In order to avoid this, the seepage to the soil surface is ‘fed’ in fractions of *dtsw*/*dtgw* to the surface water model, thus avoiding the simulation of artifical peaks.

4.4.2 SW_HQ_DTGW

For the convenience of the user (saving disk space) the SW_HQ_DTGW.* files can be written, containing just the level and the time-averaged flow rate per groundwater time step.

The file is activated by means of *sw_hq_dtgw*=1 in PARA_SIM.INP.

key	unit	item	remarks	sign
Qdssw	m3/s	downstream sw inflow rate	SurfW, mean flow over the groundwater time step dtgw	+=in*
Hsw	m+MSL	surface water level	level at the end of the groundwater time step	+/-

* definition of "downstream" side according to GOTO_RES.INP; the used sign convention for the flow terms is: "+ = towards the surface water location"

Remarks
This file includes the level at the initial time, which is convenient for making time plots.

For surface water locations not modelled by SurfW the surface water flow terms are given as zero.

4.4.3 SW_DTSW

The file SW_DTSW.BDA contains aggregated water balance terms per surface water time step *dtsw*.

The file is activated by *sw_dtsw*=1 in the PARA_SIM.INP file.

key	unit	item	remarks	sign
Vusbdsw	m3	upstream sw inflow from outside domain	All models	≥0.
Vussw	m3	upstream sw inflow from inside domain	All models	+=in*
Vdssw	m3	downstream sw inflow	SurfW	+=in*
Vsurv	m3	supply from other reservoir	SurfW	≥0.
Vexrv	m3	abstraction by other reservoir	SurfW	≤0.
Vsues	m3	supply from external source (“helicopter”)	SurfW	≥0.
Vexsp	m3	extraction for sprinkling	All models	≤0.
Vru	m3	surface runoff/runon	All models	+=off
Vdr	m3	drainage	All models	≥0.
Vif	m3	infiltration	All models	≤0.
decSsw	m3	decrease of sw in storage	SurfW	+/-
Vcrsw	m3	water balance error (creation)	SurfW	+/-
Vputsw	m3	flow request to surface water	All models: ‘put volumes’ in communication with surface water model; + = towards location	+/-
Vgetsw	m3	flow realization of flow request	All models: ‘get volumes’ in communication with surface water model; + = towards location	+/-
Ssw	m3	storage in sw	SurfW	≥0
Hsw	m+MSL	surface water level	All models	+/-

* definition of “upstream“ and “downstream” side according to GOTO_RES.INP; the used sign convention for the flow terms is: “+ = towards the surface water location”

For surface water locations not modelled by SurfW the storage and the surface water flow terms are given as zero, as are the target and weir levels.

The value of *Vcrsw* should be equal to the sum of volumes listed above it.

4.4.4 SW_HQ_DTSW

For the convenience of the user (saving disk space), file SW_HQ_DTSW.BDA just contains the water level and the flow rate per surface water time step *dtsw*.

The file is activated by *sw_hq_dtsw* = 1 in the PARA_SIM.INP file.

key	unit	item	remarks	sign
Qdssw	m3/s	downstream sw inflow rate	SurfW	+=in*
Hsw	m+MSL	surface water level	All models	+/-

* definition of "downstream" side according to GOTO_RES.INP; the used sign convention for the flow terms is: "+ = towards the surface water location"

Remarks
This file includes the level at the initial time, which is convenient for making time plots.

For surface water locations not modelled by SurfW the flow term is given as zero.

APPENDIX Output file for water quality simulation

The writing of file SW_DTGW.UNF is created by setting *sw_dtgw_unf*=1 in the PARA_SIM.INP file.

The used file format is the same as that of NuswaLite.

Rec	Field	Name	Description	Unit	Type
1	1	VersionID	Version id for water balance file	-	C40
	2	CalcID	Calculation identification message	-	C60
	3	StartYear	Day for start of calculation	day	I4
	4	StartMonth	Month for start of calculation	month	I4
	5	StartDay	Year for start of calculation	year	I4
	6	EndTime	Calculation length in days	day	I4
	7	TimestepsPerDay	Timesteps per day in water balance	1/day	I4
2	1	NOfNodes (N)	Number of nodes	-	I4
3*	1	NodeID	Node ID	-	I4
	2	BottomArea	Bottom area	m^2	R8
	3	InitialVolume	Initial volume	m^3	R8
	4	NOfConNodes (CN)	Number of connected nodes	-	I4
	5-CN	ConNodID	Connected node ID	-	I4
4**	1	VolAddAvg	Volume at middle of time step	m^3	R8
	2	VolAddEnd	Volume at end of time step	m^3	R8
	3	LevTimEnd	Water level at end of time step	m	R8
	4	Vel	Flow velocity	$m.d^{-1}$	R8
	5	FlwBndH	Level boundary discharge	$m^3.d^{-1}$	R8
	6	FlwBndQ	Flow boundary discharge	$m^3.d^{-1}$	R8
	7	FlwBndL	Link boundary discharge	$m^3.d^{-1}$	R8
	8	FlwBndP	Precipitation boundary discharge	$m^3.d^{-1}$	R8
	9	FlwBndE	Evaporation boundary discharge	$m^3.d^{-1}$	R8
	10-CN	FlwNodID1-CN	Internal flow discharges	$m^3.d^{-1}$	R8

** One record for every node*
*** One record for every node and then repeated for every day calculated*