SWQN

Manual Version 3.0

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SWQN

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ABSTRACT

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The SWQN model is a simplified hydraulic model which computes flows and water levels in watercourses. SWQN and its predecessor SURFACEWATER has proven to be widely applicable, fast and accurate. This manual describes the input, execution and output of the SWQN model. Directions are given how to use SWQN in an adequate way. Example files are included of the application of SWQN to the Vansjø-Hobøl catchment (Norway). Furthermore the coupling to the water quality model NUSWALITE and the online coupling to the regional hydrologic model SIMGRO is described.

Keywords: SWQN, Hydraulic model, St. Venant equations, surface water quantity, water management.

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Contents

Preface

This report describes the input, execution and output of the SWQN model, which computes flows and water levels in watercourses. The SWQN model is frequently used in combination with the water quality model NUSWALITE. The need for a more substantial documentation grew linearly with the use of the model.
Directions are given how to use SWQN in an adequate way. As an example the SWQN model is applied to the Vansjø-Hobøl catchment (Norway). Furthermore the online coupling to the regional hydrologic model SIMGRO is described. A detailed description of the concepts behind the model is provided by the process description (Smit et al., 2009).

For questions about the contents of this report the reader is referred to the co-author mr. L. van Gerven (luuk.vangerven@wur.nl).

Wageningen, September 2009

Summary

This manual provides the necessary help in using SWQN on an adequate way and is based on version 3.0. It describes the data model, the schematization, the parameterization of the conduits and weirs/pumps/etc., the initial and boundary conditions and the general options. In the appendix an example is given. As an example the SWQN model is applied to the Vansjø-Hobøl catchment (Norway). Furthermore the coupling to the water quality model NUSWALITE and the online coupling to the regional hydrologic model SIMGRO is described.

1 Introduction

SWQN computes flows and water levels in a network of nodes labelled as 'volumes' and segments labelled as 'connectors'. Water levels are calculated in the nodes and determine the one-dimensional flows in the connectors between the volumes. The model is pseudo-dynamical in time, based on the assumption that steady-state conditions prevail during a time step. A connector can be specified as an open water course or a structure like a weir, underflow, pump, etc. It is assumed that the flow between 2 nodes is linear dependent on the difference in water level, the wetted profile and a given resistance. Each structure, on the other hand, has its own specific stage-discharge relation and is linearized using a number of intervals. More information on the concepts behind SWQN can be found in the process description (Smit et al., 2009).

The latest version allows for large network configurations up to thousands of nodes, depending on the internal memory of the computer used. The computational time step is usually set from 1 to several hours, but strongly depends on the water storage capacity associated with the volumes and the dynamic behaviour of the modelled system.

This report describes the input, execution and output of the current version of the model. Chapter 2 describes the functionalities and their definition in the SWQN input files. Per subsection we give:

- the organization of files involved in defining a certain functionality;
- a short description of the functionality;
- a specification of the input files.

The specifications are given as formatted tables of the involved parameters and the key variables (e.g. the node number) that are used for accessing them. Key variables, also called independent variables, are marked in bold. That helps to understand the structure of the input files.

In Chapter 3 we first describe the program execution and the hard- and software that is needed for actually running the model, the running itself and finally the output. In the appendices an overview of the input and output files is given, a list of warnings and error messages is provided and the model is applied to the Vansjø-Hobøl catchment (Norway). In addition the principals and the usage of the online coupling of SWQN and SIMGRO is described.

2 Input

2.1 Input filenames

The SWQN input is divided over a set of thirteen different files (Table 1). Only three of the files are obligatory, the other are optional.

Table 1 Overview filenames

File	Description
SWQN_RUNTIMEOPTIONS.IN	Calculation period and input/output type options
SWQN_NODESDEFINITION.CSV	X and Y coordinates, bottom level, etc.
SWQN_SECTIONSDEFINITION.CSV	Nodes, dimensions (length, etc.)
SWQN_WEIRSDEFINITION.CSV*	Definition of weirs
SWQN_WEIRSCONTROLS.CSV*	Management for weirs
SWQN_GATESDEFINITION.CSV*	Definition of gates
SWQN_GATESCONTROLS.CSV*	Management for gates
SWQN_CULVERTSDEFINITION.CSV*	Definition of culverts
SWQN_PUMPSDEFINITION.CSV*	Definition of pumps
SWQN_PUMPSCONTROL.CSV*	Management for pumps
SWQN_FLOWBOUNDARY.CSV*	Boundary discharges (5 different boundary discharges can be defined)
SWQN_LEVELBOUNDARY.CSV*	Fixed level boundary condition
SWQN_PRECEVAP.CSV*	open water precipitation and evaporation

**optional*

2.2 Network definition

Organisation

The network definition and the location of the structures are the basis for the water quantity calculations. The network and location of the structures is defined in six files (Table 2).

Table 2 Input files

Input file	**Description**
SWQN_NODESDEFINITION.CSV	X and Y coordinates
SWQN_SECTIONSDEFINITION.CSV	Connected nodes
SWQN_WEIRSDEFINITION.CSV*	Location
SWQN_GATESDEFINITION.CSV*	Location
SWQN_CULVERTSDEFINITION.CSV*	Location
SWQN_PUMPSDEFINITION.CSV*	Location

**optional: only needed if (this type of) structures exist*

Description

The water courses are schematised in a network of nodes and sections (Table 3 and Table 4). The numbering of the nodes and sections may be at random.

The nodes are the basic computational elements with a water level variable in time depending on the storage capacity and driven by in- and outgoing flows and boundary conditions, such as drainage, precipitation, etc. Water levels are calculated in these nodes and determine the one-dimensional flows in the connectors (sections) between the nodes.

It is important to realise that the program assigns a volume to a node on base of the dimensions of the connected sections. The actual water volume of a node is calculated based on the wetted profile of the linked sections times half the section length. The method of assigning volumes to nodes is shown in Figure 1.

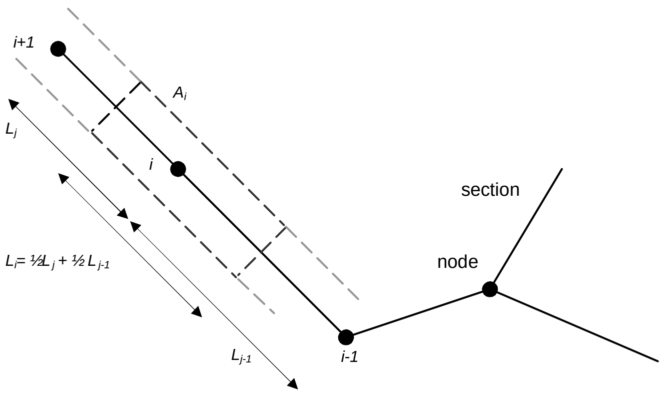


Figure 1 Schematization in nodes and sections

The coordinates of the nodes are used to check the length of the sections. When the distance between the nodes is greater than the given length in SWQN_SECTIONSDEFINITION.CSV, the calculated distance is used as length.

During the calculation a section will be regarded as a connector between nodes. This connector can be specified as an open water course or a structure: a weir, a gate, a culvert or a pump. The structures are linked to a section by referring to the section number (see Table 5 till Table 8).

It is assumed that the flow between 2 nodes is linear dependent on the difference in water level and a given resistance. Each structure, on the other hand, has its own specific stage-discharge relation and is linearized using a number of intervals. When a section contains a structure it is assumed that the flow resistance in the water course is negligible compared to the resistance of the water course. Therefore we advise to keep sections with structures short.

The latest version allows for large network configurations up to thousands of nodes and sections, depending on the internal memory of the computer used. The maximum number of connections of a node with other nodes equals 10.

Specification

Table 3 Input parameters in SWQN_NODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID***	**Node identifier**	**-**	**I**
3	NodeX	X coordinate	m	R
4	NodeY	Y coordinate	m	R

** Maximum NodeID = 6000*

Table 4 Input parameters in SWQN_SECTIONSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**SectionID**	**Section identifier**	**-**	**I**
2	BeginNodeID	Begin node	-	I
3	EndNodeID	End node	-	I

Table 5 Input parameters in SWQN_WEIRSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**WeirID**	**Weir identifier**	**-**	**I**
2	SectionID	ID of the section where the weir is located	-	I

Table 6 Input parameters in SWQN_GATESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**GateID**	**Gate identifier**	**-**	**I**
2	SectionID	ID of the section where the gate is located	-	I

Table 7 Input parameters in SWQN_CULVERTSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**CulvertID**	**Culvert identifier**	**-**	**I**
2	SectionID	ID of the section where the culvert is located	-	I

Table 8 Input parameters in SWQN_PUMPSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**PumpID**	**Pump identifier**	**-**	**I**
2	SectionID	ID of the section where the pump is located	-	I

2.3 Parameterization

2.3.1 Open conduits

Organisation

Table 9 Input files

File	Description
SWQN_RUNTIMEOPTIONS.IN	Specification resistance type (Manning, Chezy)
SWQN_NODESDEFINITION.CSV	Bottom level
SWQN_SECTIONSDEFINITION.CSV	Watercourse profile and resistance

Description

The watercourse profile should be specified as a trapezoid.
The dimensions have to be defined in SWQN_SECTIONDEFINITION.CSV (Table 12):

- LENGTH
  The length of the section;
- BOTTOMWIDTHBEGIN
  Bottom width at the begin node;
- BOTTOMWIDTHEND
  Bottom width at the end node;
- SLOPEBEGIN
  Side slope at the begin node;
- SLOPEEND
  Side slope at the end node.

The bottom level is defined at the nodes (SWQN_SECTIONDEFINITION.CSV ,Table 13)

- BOTTOMLEVEL
  Bottom level at the node.

In previous versions of SWQN the bottom level could also be defined at the begin and the end of a section. Using this approach different bottom levels of the sections can come together at a node. This may lead to model instabilities since the open water surface (corresponding with the nodal water volume) is discontinuous with the water height in such a situation. Therefore we chose to define the bottom level at the nodes so that all connected sections have the same bottom level (for their half-length). Be careful with tributaries connected to the main stream. It is advised to keep the section of the tributary that connects to the main stream small, to prevent extra water storage of the main stream in the half-section of the connected tributary, which has the same bottom level as the main stream.

The flow resistances are specified as Manning or Chezy values. The option is specified in SWQN_RUNTIMEOPTIONS.IN (Table 11) by the following parameter:

- RESISTANCETYPE = 1, use Chezy resistance coefficient;
- RESISTANCETYPE = 2, use Manning resistance coefficient. In this case the Manning resistance coefficient will be recomputed every time step dependent on the water level of the previous time step .

Table 10 Manning coefficients in different situations, assuming normal maintenance (CTV, 1988)

Size of the watercourse	**Manning coefficient K_m ($m^{1/3}$ s^{-1})**	
	winter	**summer**
small (0,4 < h < 0,8 m)	35 – 25	20 – 15
middle (0,7 < h < 1,5 m)	40 – 30	30 – 20
large (h > 1,5 m)	50 - 40	50 – 40

When the resistance formula of Manning is chosen the resistance depends on the water level, which is not the case when the Chezy formula is used. The consequence is that using the Manning formula leads to better calculation results for dry falling water courses. Table 10 gives a lead for the resistance value of different watercourses.

The flow resistances are specified in SWQN_SECTIONDEFINITION.CSV (Table 12).

- RESISTBEGINPOS
  Resistance at the begin node, when the flow is directed from begin node to end node;
- RESISTBEGINNEG
  Resistance at the begin node, when the flow is directed from end node to begin node;
- RESISTENDPOS
  Resistance at the end node, when the flow is directed from begin node to end node;
- RESISTENDNEG
  Resistance at the end node, when the flow is directed from end node to begin node.

Specification

Table 11 Input parameters in SWQN_RUNTIMEOPTIONS.IN

Section/Name	**Description**	**Default**	**Unit**	**Type**
ResistanceType	Resistance coefficient of: 1 = Chezy 2 = Manning	2	-	I

Table 12 Input parameters in SWQN_SECTIONDEFINITION.CSV

Col	**Name**	**Description**	**Unit**	**Type**
1	**SectionID**	**Section identifier**	**-**	**I**
4	Length	Length	m	R
5	BottomWidthBegin	Bottom width begin node	m	R
6	BottomWidthEnd	Bottom width end node	m	R
7	SlopeBegin	Slope begin node: ratio between width and height	-	R
8	SlopeEnd	Slope end node: ratio between width and height	-	R
9	ResistBeginPos	Chezy/Manning resistance coefficient begin node pos. direction	$m^{1/2}.s^{-1}$ $m^{1/3}.s^{-1}$	R
10	ResistBeginNeg	Chezy/Manning resistance coefficient begin node neg. direction	$m^{1/2}.s^{-1}$ $m^{1/3}.s^{-1}$	R
11	ResistEndPos	Chezy/Manning resistance coefficient end node pos. direction	$m^{1/2}.s^{-1}$ $m^{1/3}.s^{-1}$	R
12	ResistEndNeg	Chezy/Manning resistance coefficient end node neg. direction	$m^{1/2}.s^{-1}$ $m^{1/3}.s^{-1}$	R

Table 13 Input parameters in SWQN_NODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node identifier**	**-**	**I**
5	Bottomlevel	Bottom level	m f.r.l.	R

2.3.2 Weirs

Organisation

Table 14 Input files

File	Description
SWQN_WEIRSDEFINITION.CSV*	Weir dimensions, flow characteristics.
SWQN_WEIRSCONTROL.CSV*	Weir control parameters

**optional: only needed if this type of structures exist.*

Description

Weirs are predominantly used for upstream water level control, but can also be applied for water distribution and flow measurements. The model differentiates between free and submerged flow over weirs.

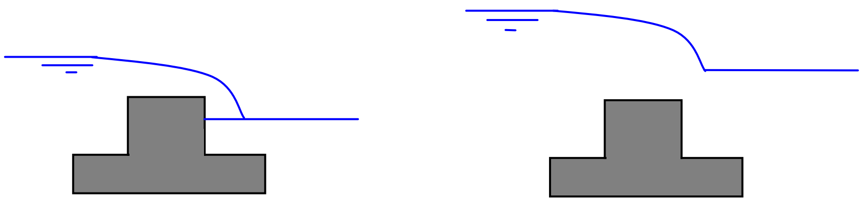


Figure 2 Free flow (left) and submerged flow (right) over a weir

Level control is usually exercised by adjusting the crest of the weir between a minimum and a maximum level. The model allows for the following controls:

- Target upstream water level, set for a given period in time;
- Target downstream water level, set for a given period in time;
- Fixed crest level, set for a given period in time.

For the first 2 control settings a new crest level is determined based on the old level plus the difference in level between the given target level and the actual water level. A fixed crest level can be supplied directly to the model.

The maximum water level, which is defined by the parameter MAXLEVEL in SWQN_NODESDEFINITION.CSV, determines the linearization trajectories for the structures (Smit et al., 2009).
It is important that the trajectory BOTTOMLEVEL – MAXLEVEL covers the range of calculated water levels. Usually the soil surface level is taken as a good approximation for the maximum water level. This parameter is also used for the calculation of the precipitation and evaporation amounts on the water surface (paragraph 2.4.1).

The characteristics of the weir have to be specified in SWQN_WEIRSDEFINITION.CSV:

- MAXCRESTWIDTH
  The maximum crest width of the weir. It is used as an upper limit for when the crest width is varied in the control settings (SWQN_WEIRSCONTROL.CSV);
- INITIALCRESTWIDTH
  The crest width at the start of the calculation.
- MAXCRESTLEVEL
  The maximum crest level of the weir. It is used as an upper limit for when the crest level is varied in the control settings (SWQN_WEIRSCONTROL.CSV);
- MINCRESTLEVEL
  The minimum crest level of the weir. It is used as a lower limit for when the crest level is varied in the control settings (SWQN_WEIRSCONTROL.CSV);
- INITIALCRESTLEVEL
  The crest level at the start of the calculation.
- MUPOS
  Weir coefficient (formula 2) in the positive direction (from begin node to end node).
- MUNEG
  Weir coefficient (formula 2) in the negative direction (from end node to begin node).

MUPOS and MUNEG are coefficients in the weir formula (CTV, 1988):

$$Q_{weir,t} = \mu_{weir} W_{crest} \left(h_{up,t} - h_{crest,t}\right)^{1.5} \tag{1}$$

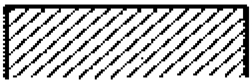
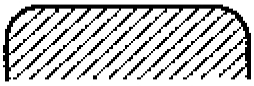
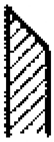
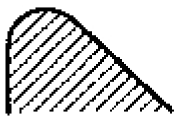
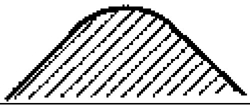
With the weir coefficient (see Table 15 for its value for differently shaped weirs):

$$\mu_{weir} = \tfrac{2}{3}\sqrt{\tfrac{2}{3} g}\, C_d C_v \tag{2}$$

where:

$Q_{weir,t}$	weir discharge at time t	[m^3 s^{-1}]
μ_{weir}	weir coefficient	[$m^{0.5}$ s^{-1}]
W_{crest}	crest width	[m]
$h_{up,t}$	upstream water level	[m]
$h_{crest,t}$	crest level	[m]
C_d	discharge efficiency coefficient	[-]
C_v	velocity correction coefficient	[-]
g	gravity constant	[m s^{-2}]

Table 15 Weir coefficients (μ_{weir}) for different kinds of rectangular weirs (CTV, 1988)

	Type	$C_d \cdot C_v$ [-]	μ_{weir} [$m^{0.5}$ s^{-1}]
	Broad crested weir I	0,85 – 0,88	1,45 – 1,50
	Broad crested weir I	0,87 – 0,95	1,48 – 1,62
	Sharp crested weir	1,11	1,89
	Short crested weir I	1,30	2,22
	Short crested weir II	1,37	2,34

The control settings are specified in the file SWQN_WEIRSCONTROL.CSV for a date and a weir identifier for the following parameters:

- SELECTCONTROLWEIR
  This parameter selects, which control will be used:
  - 1 = Crest width;
  - 2 = Crest level;
  - 3 = Target level for begin node;
  - 4 = Target level for end node
- CRESTWIDTH
  When SELECTCONTROLWEIR = 1, the value in this column will be used until a new date is encountered;
- CRESTLEVEL
  When SELECTCONTROLWEIR = 2, the value in this column will be used until a new date is encountered;
- TARGETLEVELBEGIN
  When SELECTCONTROLWEIR = 3, the value in this column will be used until a new date is encountered. When possible the CRESTLEVEL will be lowered or raised according to the difference in the upstream surface water level and the target level upstream.
- TARGETLEVELEND
  When SELECTCONTROLWEIR = 4, the value in this column will be used from that date on. When possible the CRESTLEVEL will be lowered or raised according to the difference in the downstream surface water level and the target level downstream.

Specification

Table 16 Input parameters in SWQN_NODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node identifier**	**-**	**I**
6	MaxLevel	Maximum water level	m f.r.l.	R

Table 17 Input parameters in SWQN_WEIRSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**WeirID**	**Weir identifier**	**-**	**I**
3	MaxCrestWidth	Maximum crest width	m	R
4	InitialCrestWidth	Initial crest width	m	R
5	MaxCrestLevel	Maximum crest level	m f.r.l.	R
6	MinCrestLevel	Minimum crest level	m f.r.l.	R
7	InitialCrestLevel	Initial crest level	m f.r.l.	R
8	MuPos	Weir coefficient μ in pos. direction (begin to end node)	$m^{1/2} s^{-1}$	R
9	MuNeg	Weir coefficient μ in neg. direction (end to begin node)	$m^{1/2} s^{-1}$	R

Table 18 Input parameters in SWQN_WEIRSCONTROL.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date for change of setting**	**date**	**C10**
2	**WeirID**	**ID used in structure definition**	**-**	**I**
3	SelectControlWeir	1 = Crest width 2 = Crest level 3 = Target level for begin node 4 = Target level for end node	-	I
4	CrestWidth	Crest width	m	R
5	CrestLevel	Crest level	m f.r.l.	R
6	TargetlevelBegin	Target level begin node	m f.r.l.	R
7	TargetlevelEnd	Target level end node	m f.r.l.	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*

2.3.3 Pumps

Organisation

Table 19 Input files

File	Description
SWQN_PUMPSDEFINITION.CSV*	Pump capacity.
SWQN_PUMPSCONTROL.CSV*	Control levels, etc.

**optional: only needed if this type of structures exist.*

Description

A pump replaces water from the upstream part of the section (begin node) to the downstream part of the section (end node). The pump can be used to prevent that the upstream water level becomes too high. On the other hand the pump can be used to prevent low water levels in the downstream section. Both applications can be implemented. It is also possible to define a certain amount of pumping (from upstream tot downstream). This amount can be changed in time and is independent of the water levels (in the upstream and downstream part).

When the pump is activated the capacity of the pump is determined by the specifications in SWQN_PUMPSDEFINITION.CSV:

- PUMPCHARACTERISTICA
  Level dependent pump capacity *(A_{pump})*
- PUMPCHARACTERISTICB
  Level independent pump capacity *(B_{pump})*

The total discharge of the pump equals:

$$Q_{pump} = A_{pump} (h_{up} - h_{down}) + B_{pump} \qquad (3)$$

with:

Q_{pump}	Pump capacity [m^3/s]
A_{pump}	Level dependent pump capacity [m^2/s]
B_{pump}	Level independent pump capacity [m^3/s]
h_{up}	Upstream (node begin) water level (m f.r.l.)
h_{down}	Downstream (node end) water level (m f.r.l.)

The file SWQN_PUMPSCONTROL.CSV defines under which conditions the pump has to be activated. The following settings can be applied per pump and per date:

- SELECTCONTROLPUMP
  This parameter selects, which control will be used:
  - 1 = Level independent capacity;
  - 2 = Start and stop level for begin node;
  - 3 = Start and stop level for end node;
- DISCHARGE
  When SELECTCONTROLPUMP = 1, this value determines the level independent pump capacity, which determines the total pump capacity (level dependent part is zero in this mode).
- STARTLEVELBEGIN and STOPLEVELBEGIN
  Works if SELECTCONTROLPUMP = 2. When the upstream level (node begin) exceeds the STARTLEVELBEGIN the pump starts working. When the level becomes lower than the STOPLEVELBEGIN the pump stops working. The STOPLEVELEND should be lower than the STARTLEVELBEGIN
- STARTLEVELEND AND STOPLEVELEND
  Applies when SELECTCONTROLPUMP = 3. When the downstream level (node end) is lower than the STARTLEVELEND the pump starts working. The pump stops working when the downstream level exceeds the STOPLEVELEND. The STOPLEVELEND should be higher than the STARTLEVELBEGIN

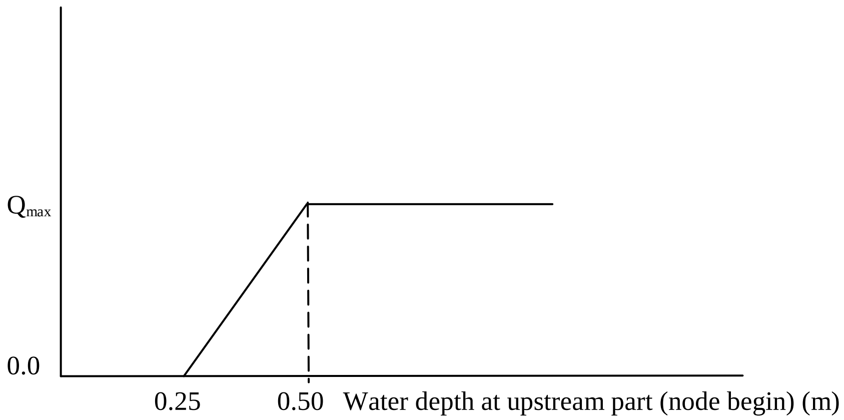


Figure 3 Reduction of the pumped discharge depending on the upstream water level

To prevent that the upstream part (node begin) falls dry the pumping capacity reduces or becomes zero when the upstream water level is low. When the upstream water depth is less than 0.50 m the pumping discharge will be reduced. When the upstream water depth is less than 0.25 the discharge is set to zero (Figure 3). If the pumping capacity has to be reduced a warning is written to the log-file, see warning 24 in Appendix 3.

Specification

Table 20 Input parameters in SWQN_PUMPSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**PumpID**	**Pump identifier**	**-**	**I**
3	PumpCharacteristicA	Level dependent capacity (see formula 3)	$m^2\ s^{-1}$	R
4	PumpCharacteristicB	Level independent capacity (see formula 3)	$m^3\ s^{-1}$	R

Table 21 Input parameters in SWQN_PUMPSCONTROL.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date for change of control setting**	**date**	**C10**
2	**PumpID**	**ID used in structure definition**	**-**	**I**
3	SelectControlPump	1 = Level independent capacity 2 = Start and stop level for begin node 3 = Start and stop level for end node	-	I
4	Discharge	Level independent capacity	$m^3\ s^{-1}$	R
5	StartLevelBegin	Start level for begin node	m f.r.l.	R
6	StoplevelBegin	Stop level for begin node	m f.r.l.	R
7	StartlevelEnd	Start level for end node	m f.r.l.	R
8	StoplevelEnd	Stop level for end node	m f.r.l.	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*

2.3.4 Gates

Organisation

Table 22 Input files

File	Description
SWQN_GATESDEFINITION.CSV*	Gate dimensions, flow characteristics.
SWQN_GATESCONTROL.CSV*	Gate control parameters

**optional: only needed if (this type of) structures exist.*

Description

Undershot gates are classified as an opening in a plate or a bulkhead of which the top is placed below the upstream water level. Gates are used for water regulation. Figure 4 shows four situations having different stage-discharge relations.

Level control is implemented by adjusting the vertical gate opening between a given minimum and a maximum level. In the model 4 types of control can be set for a defined period in time:

- Opening level;
- Upstream target water level;
- Downstream target water level;
- Upstream and downstream target water level simultaneously.

The parameter MAXLEVEL in SWQN_NODESDEFINITION.CSV defines the linearization trajectories of the gate's stage-discharge relation (Smit et al., 2009). It is important that the trajectory BOTTOMLEVEL – MAXLEVEL covers the range of calculated water levels. Usually the soil surface level is taken as a good approximation.

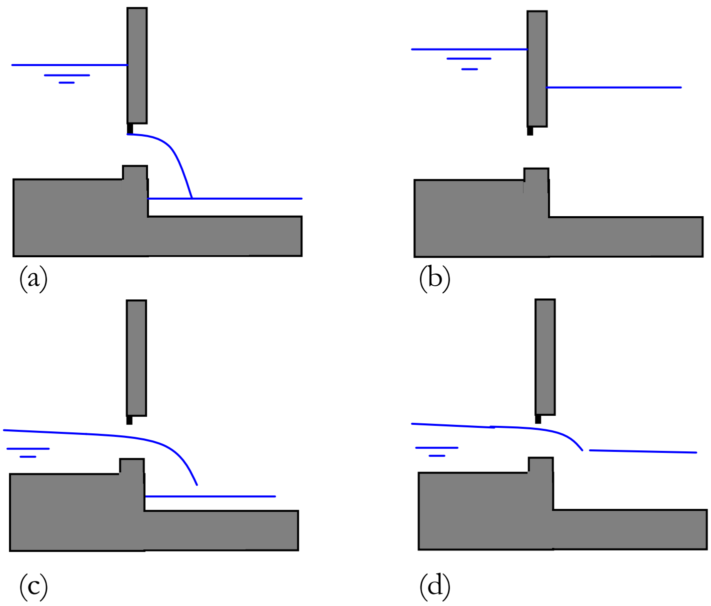


Figure 4 Freely discharging underflow (a), submerged underflow (b), weir type of flow (c) and submerged weir type of flow (d)

A gate has several characteristics that are specified in SWQN_GATESDEFINITION.CSV:

- SILLEVEL
  The bottom level of the gate opening (see Figure 5);
- INITIALOPENINGLEVEL
  Top level of the gate opening at the start of the period (see Figure 5);
- MAXOPENINGLEVEL
  The maximum opening level. It is used as an upper limit if the opening level is changed by control settings (SWQN_GATESCONTROL.CSV);

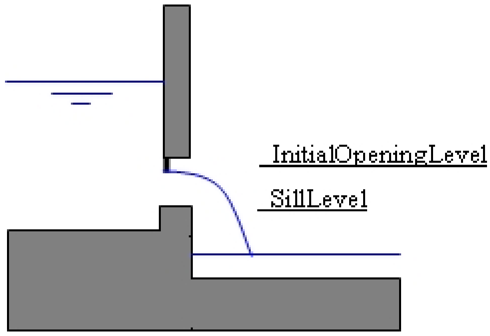


Figure 5 Definition of gate levels

- INITIALOPENINGWIDTH
  The width of the gate opening at the start of the simulation period.
- MAXOPENINGWIDTH
  The maximum opening width. It is used as an upper limit if the opening width is changed due to the control settings (SWQN_GATESCONTROL.CSV);
- MUPOS
  The coefficient for submerged gates (formula 5) in the positive direction (from begin node to end node).
- MUNEG
  The coefficient for submerged gates (formula 5) in the negative direction (from end node to begin node).

MUPOS and MUNEG are coefficients in the gate formula which reads for a submerged orifice (Gelok, 1969):

$$Q_{undershot,t} = \mu_{undershot} A_{undershot,t} \left(h_{up,t} - h_{down,t}\right)^{0.5} \quad (4)$$

With the gate coefficient

$$\mu_{undershot} = C_d C_v \sqrt{(2g)} \quad (5)$$

where:

$Q_{undershot,t}$	gate discharge at time t	[m^3 s^{-1}]
$\mu_{undershot}$	gate coefficient	[$m^{0.5}$ s^{-1}]
$A_{undershot,t}$	gate opening	[m^2]
$h_{up,t}$	upstream water level	[m]
$h_{down,t}$	downstream water level	[m]
C_d	discharge efficiency coefficient	[-]
C_v	velocity correction coefficient	[-]
g	gravity constant	[m s^{-2}]

For submerged orifices C_d=0.61 and C_v=1.035 (Bos, 1978). This results in $\mu_{undershot}$=2.80 $m^{0.5}s^{-1}$. This value has to be entered in SWQN_GATESDEFINITION.CSV. When SWQN notices that the gate is freely discharging, SWQN adjusts the gate coefficient since the value for C_d changes to 0.85 for a freely discharging orifice (Bos, 1978).

The control settings are specified in the file SWQN_GATESCONTROL.CSV for a date and a gate identifier for the following parameters:

- SELECTCONTROLGATE
  This parameter selects which control will be used:
  - 1 = Opening level;
  - 2 = Opening width;
  - 3 = Target level for begin node;
  - 4 = Target level for end node;
  - 5 = Target level for begin and end node;
- OPENINGLEVEL
  When SELECTCONTROLGATE = 1, the value in this column will be used from that date on;
- OPENINGWIDTH
  When SELECTCONTROLGATE = 2, the value in this column will be used from that date on;
- TARGETLEVELBEGIN
  When SELECTCONTROLGATE = 3 or 5, the value in this column will be used from that date on;
- TARGETLEVELEND
  When SELECTCONTROLGATE = 4 or 5, the value in this column will be used from that date on.

Specification

Table 23 Input parameters in SWQN_NODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node identifier**	**-**	**I**
6	MaxLevel	Maximum water level	m f.r.l.	R

Table 24 Input parameters in SWQN_GATESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**GateID**	**Gate identifier**	**-**	**I**
3	SillLevel	Sill level	m f.r.l.	R
4	InitialOpeningLevel	Initial opening level	m f.r.l.	R
5	MaxOpeningLevel	Maximum opening level	m f.r.l.	R
6	InitialOpeningWidth	Initial opening width	m	R
7	MaxOpeningWidth	Maximum opening width	m	R
8	MuPosSub	Coefficient μ for submerged gates in pos. direction (begin to end node)	$m^{1/2} s^{-1}$	R
9	MuNegSub	Coefficient μ for submerged gates in neg. direction (end to begin node)	$m^{1/2} s^{-1}$	R

Table 25 Input parameters in SWQN_GATESCONTROL.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date for change of setting**	**date**	**C10**
2	**GateID**	**Gate identifier**	**-**	**I**
3	SelectControlGate	1 = Opening level 2 = Opening width** 3 = Target level begin node 4 = Target level end node 5 = Both 3 and 4	-	I
4	OpeningLevel	Opening level	m	R
5	OpeningWidth	Opening width	m	R
6	TargetlevelBegin	Target level begin node	m f.r.l.	R
7	TargetlevelEnd	Target level end node	m f.r.l.	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*
*** not functional yet*

2.3.5 Culverts

Organisation

Table 26 Input files

File	Description
SWQN_CULVERTSDEFINITION.CSV*	Culvert dimensions, flow characteristics.

**optional: only needed if (this type of) structures exist.*

Description

Culverts are used to cross other infrastructure, such as roads, waterways, railroads, etc. The model assumes that no water level or flow control mechanisms are present. Various shapes exist and culverts are built with different construction materials.

The parameter MAXLEVEL in de file SWQN_NODESDEFINITION.CSV defines the linearization trajectories for the culvert (Smit et al., 2009). It is important that the trajectory BOTTOMLEVEL – MAXLEVEL covers the range of calculated water levels. Usually the surface level is a good approximation for the MAXLEVEL.

The characteristics of a culvert are specified in SWQN_CULVERTSDEFINITION.CSV:

- SELECTTYPE
  This parameter selects the type of culvert:
  - 1 = circular;
  - 2 = square;
- NUMBER
  The number of parallel identical culverts should be specified. Usually the value 1 is assigned;
- LENGTH
  The length of the culvert;
- DIMENSION
  In case of an circular culvert the values represents the radius. In case of a rectangular culvert it represents the width and height;

- BOTTOMLEVEL
  The bottom level of the culvert;
- KMPOS
  The Manning resistance coefficient (Table 27) for flow in the positive direction (from begin node to end node);
- KMNEG
  The Manning resistance coefficient (Table 27) for flow in the negative direction (from end node to begin node).

Table 27 Manning values for culverts made of different materials (design values) (CTV, 1988)

Material	Manning coefficient K_m ($m^{1/3}$ s^{-1})
Concrete	75
Asbestos concrete	90
Steal	80 (range 30-90 dependent on the type and corrosion state)
PVC	100

Specification

Table 28 Input parameters in SWQN_NODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node identifier**	**-**	**I**
6	MaxLevel	Maximum water level	m f.r.l.	R

Table 29 Input parameters in SWQN_CULVERTSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**CulvertID**	**Culvert identifier**	**-**	**I**
3	SelectType	1 = Circular 2 = Square	-	I
4	Number	Number of parallel identical culverts	-	I
5	Length	Length	m	R
6	Dimension	Radius (if SelectType = 1) Width/height (if SelectType = 2)	m	R
7	Bottomlevel	Bottom level	m f.r.l.	R
8	KmPos	Manning resistance coefficient in pos. direction (from begin node to end node)	$m^{1/3}.s^{-1}$	R
9	KmNeg	Manning resistance coefficient in neg. direction (from end node to begin node)	$m^{1/3}.s^{-1}$	R

2.4 Boundary and initial conditions

2.4.1 Precipitation and evaporation

Organisation

Table 30 Input files

File	Description
SWQN_NODESDEFINITION.CSV	Meteorological region, maximum water level (surface level
SWQN_PRECEVAP.CSV*	direct precipitation and evaporation per meteorological region

**optional*

Description

Open water precipitation and evaporation can be significant terms in the water balance, especially in polder areas with large water surfaces. In SWQN the precipitation and evaporation have to be specified in volume per areal unit per time step. Multiplying this term with the open water area leads to the total precipitation and evaporation volume per time step. It is important to keep in mind that the area at the MAXLEVEL (surface level) is taken as the open water surface (Figure 6). The precipitation in this area will end up directly in the watercourse. The open water evaporation may be overestimated in case of low water depths.

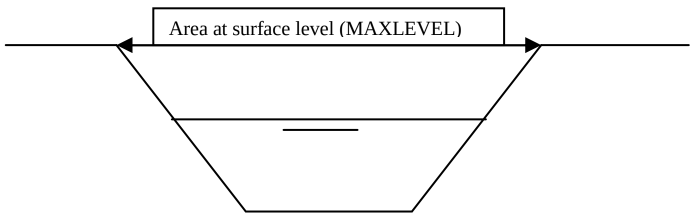


Figure 6 Catchment area for precipitation and evaporation

The amount of precipitation and evaporation has to be specified per meteorological region, which has to be assigned to a node.

Specification

Table 31 Input parameters in SWQN_NODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node ID**	**-**	**I**
2	**PrecEvapID***	**ID for meteorological region**	**-**	**I**
6	MaxLevel	Maximum water level	m f.r.l.	R

** the amount of unique ID's can be defined in SWQN_RUNTIMEOPTIONS.IN (default = 10)*

Table 32 Input parameters in SWQN_PRECEVAP.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date**	**date**	**C10**
2	**PrecEvapID****	**ID for meteorological region**	**-**	**I**
3	Precipitation	(open water) precipitation***	$m.d^{-1}$	R
4	Evaporation	open water evaporation***	$m.d^{-1}$	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*
*** the amount of unique ID's can be defined in SWQN_RUNTIMEOPTIONS.IN (default = 10)*
**** Values are sustained in time until a new value is given*

2.4.2 Flow boundary

Organisation

Table 33 Input files

File	Description
SWQN_FLOWBOUNDARY.CSV*	boundary discharges
SWQN_FLOWBOUNDARY1.CSV*	boundary discharges, 1st type
SWQN_FLOWBOUNDARY2.CSV*	boundary discharges, 2nd type
SWQN_FLOWBOUNDARY3.CSV*	boundary discharges, 3rd type
SWQN_FLOWBOUNDARY4.CSV*	boundary discharges, 4th type

**optional*

Description

Water can be added to the watercourse or extracted from it. These sink and source terms are usually considered as boundary conditions and may represent:

- Drainage from and infiltration into the subsoil;
- Run-off from the topsoil and/or subsurface drainage;
- Leakage to and seepage from the groundwater;
- Irrigation discharges.

The user can distinct between the water flow of up to four different pathways, using four different flow boundary files (SWQN_FLOWBOUNDARY1.CSV up to SWQN_FLOWBOUNDARY4.CSV). It is also possible to sum all water flows and use only one flow boundary file (SWQN_FLOWBOUNDARY.CSV). When dealing with water quality issues it is recommended to separate the different pathways since they will each have a different water quality.

The flow boundary files have certain properties:

- When a discharge is specified for a certain day, this value will be sustained in time until a new value is given;
- If several values for the same day and the same node are specified they will be added;
- It is not necessary to sort the records in the file on date.

Specification

Table 34 Input parameters in SWQN_FLOWBOUNDARY.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date**	**date**	**C10**
2	**NodeID**	**Node ID**	**-**	**I**
3	Discharge	Inflow or outflow discharge**	$m^3.s^{-1}$	R

* *date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*

*** Multiple discharges on same node and day add up. Values are sustained in time until a new value for the node is given. Positive value means inflow, negative values corresponds with outflow*

2.4.3 Level boundary

Organisation

Table 35 Input files

File	Description
SWQN_LEVELBOUNDARY.CSV*	Level boundaries

**optional*

Description

It is recommended to fix the water level at the outlets of the modelled network. Such a fixed level boundary has to be defined in SWQN_LEVELBOUNDARY.CSV. If there is no level boundary (or flow boundary) at the outlets the modelled water network will drown since the water cannot leave the network.

The flow boundary files has certain properties:

- When a fixed water level is specified for a certain day, this value will be sustained in time until a new value is given;
- It is not necessary to sort the records in the file on date.

Specification

Table 36 Input parameters in SWQN_LEVELBOUNDARY.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date**	**date**	**C10**
2	**NodeID**	**Node ID**	**-**	**I**
3	Level	Fixed level boundary condition **	m f.r.l.	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*
*** Values are sustained in time until a new value is given*

2.4.4 Initial conditions

Organisation

Table 37 Input files

File	Description
SWQN_NODESDEFINITION.CSV	Initial water level

Description

The initial water level per node is specified in the file SWQN_NODESDEFINITION.CSV.

Specification

Table 38 Input parameters in SWQN_NODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node ID**	**-**	**I**
7	InitialWaterlevel	Initial water level	m f.r.l.	R

2.5 Options and switches

2.5.1 Runtime options

Organisation

Table 39 Input files

File	Description
SWQN_RUNTIMEOPTIONS.IN	Options and switches

Description

In the file SWQN_RUNTIMEOPTIONS.IN the computational time step, the simulation period and the calculation ID can be set. Furthermore there is an option to initialize the model for a certain period (given the boundary conditions on the first day) to account for wrongly chosen initial conditions.

The time step is usually set from one to several hours, but strongly depends on the water storage capacity associated with the volumes and the dynamic behaviour of the modelled system. The Courant number can be used to calculate the desired time step. Ideally the Courant number does not exceed the value of one. This means that the distance travelled by a water particle during a time step does not exceed the section length. By making an estimation of the flow velocity the desired time step can be calculated, given the section length. When the Courant number is bigger than one this could lead to model instabilities. However SWQN is equipped with smart solutions to prevent instabilities to a certain extent.

Specification

Table 40 Input parameters in SWQN_RUNTIMEOPTIONS.IN

Name	Description	Default	Unit	Type
CalculationID*	Calculation identification message**	-	-	C60
StartDay	Day for start of calculation	-	day	I
StartMonth	Month for start of calculation	-	month	I
StartYear	Year for start of calculation	-	year	I
EndDay	Day for end of calculation	-	day	I
EndMonth	Month for end of calculation	-	month	I
EndYear	Year for end of calculation	-	year	I
InitiatioNrDays*	Number of days for initial calculation***	0	day	I
MaxPrecEvapSets*	Maximum number of meteorological zones (with different precipitation and evaporation)	10	-	I
SWQNTimestepsPerDay*	Calculation time step (must be a full divisor of 86400; number of seconds in one day)	24	-	I
NuswaLiteTimestepsPerDay*	Time step at which output to the water quality model NUSWALITE is generated (must be a full divisor of SWQNTimestepsPerDay)	1	-	I

**optional*

***written to SWQN_OUT(TOTAL)BALANCE.CSV and NUSWALITE_WATERBALANCE.BIN*

****boundary conditions at the start of the calculation period will be applied during this period*

2.5.2 Switches

Organisation

Table 41 Input files

File	Description
SWQN_RUNTIMEOPTIONS.IN	Options and switches

Description

There is one switch. It concerns the flow resistance type for water courses:

- Switch for the use of the Chezy coefficient (RESISTANCETYPE = 1) or Manning coefficient (RESISTANCETYPE = 2). See also paragraph 2.3.1.

Specification

Table 42 Input parameters in SWQN_RUNTIMEOPTIONS.IN

Name	Description	Default	Unit	Type
ResistanceType*	Resistance formula of: 1 = Chezy 2 = Manning	2	-	I

**optional*

2.5.3 Output specification

Organisation

Table 43 Input files

File	Description
SWQN_RUNTIMEOPTIONS.IN	Options and switches

Description

Some choices can be made concerning the output (see Table 44 and Table 45):

- switch OUTLAYOUT: Produces file (SWQN_OUTLAYOUT.CSV) with model network. This option can be handy to check the schematization.
- switch OUTBALANCEALL: Write all balance output (1) or only deviations (2) This switch influences the output that is written to SWQN_OUTBALANCE.CSV.
- switch OUTECHOBOUNDS: Produces file with a summary of all boundary conditions (SWQN_OUTECHOBOUNDS.CSV). This option is handy to have an overview of all boundary fluxes, with regard to water quality modelling.
- switch OUTBALANCENL: Produces file with the network layout and the water balance terms (NUSWALITE_WATERBALANCE.BIN) needed to run the water quality model NUSWALITE (Siderius et al., 2008).
- OUTPUTNODE: Selection of the nodes for which output will be generated in SWQN_OUTDEPTHS.CSV, SWQN_OUTLEVELS.CSV + SWQN_OUTBALANCE.CSV;
- OUTPUTSECTION: selection of the nodes for which output will be generated in SWQN_OUTDISCHARGES.CSV.
- switch WATERDEPTHTYPE: Defines how the water depths are written to NUSWALITE_WATERBALANCE.BIN. Choose between a profile averaged or a maximum water depth.

Table 44 Overview of output files and the influence of the output options

	OUTLAYOUT	OUTBALANCEALL	OUTECHOBOUNDS	OUTBALANCENL	WATERDEPTHTYPE	OUTPUTNODE	OUTPUTSECTION
SWQN_OUTDEPTHS.CSV*						**V**	
SWQN_OUTLEVELS.CSV*						**V**	
SWQN_OUTDISCHARGES.CSV*							**V**
SWQN_OUTBALANCE.CSV*		**V**				**V**	
SWQN_OUTBALANCEYEARLY.CSV*							
SWQN_OUTTOTALBALANCE.CSV*							
SWQN_OUTTOTALBALANCEYEARLY.CSV*							
SWQN_OUTLAYOUT.CSV*	**V**						
SWQN_OUTECHOBOUNDS.CSV			**V**				
NUSWALITE_WATERBALANCE.BIN				**V**	**V**		
SWQN.LOG*							
SWQN_OUTNODESDEFINITION.CSV*							

** generated by default*

Specification

Table 45 Output options in SWQN_RUNTIMEOPTIONS.IN

Name	Description	Default	Unit	Type
OutLayout	Produce SWQN_OUTLAYOUT.CSV with schematization: 0 = no 1 = yes	1	-	I
OutBalanceAll	1 = Write all balance output 2 = only deviations	1	-	I
OutEchoBounds	Produce SWQN_OUTECHOBOUNDS.CSV: 0 = no 1 = yes	0	-	I
OutBalanceNL	Produce NUSWALITE_WATERBALANCE.BIN: 0 = no 1 = yes	0	-	I
WaterdepthType	Type of water depth that is written to NUSWALITE_WATERBALANCE.BIN: 1 = (water depth = water volume / open water surface) 2 = (water depth = water level - bottom level)	1	-	I
OutputNode	Nodes (list of comma separated nodes)	all	-	I
OutputSection	Sections (list of comma separated sections)	all	-	I

3 Execution and output

3.1 Hardware requirements

To run you are advised to use at least the following system configuration:

- IBM compatible PC with a Pentium processor (≥ 2 GHz);
- 512 MB RAM;
- Hard disk with at least 2 GB free space;
- Windows NT, XP or 2000.

When running the model with huge schematizations (more than 500 nodes) and small time steps at least 2 GB RAM and more space at the hard disk is required.

3.2 Program execution

The program consists of two parts:

- SurfaceWater.dll;
- SWQN.exe.

The program starts by activating the executable. The input files should be in the same folder as the executable. An example of a SWQN run is given in Appendix 4.

3.3 Potential problems during execution

A user may encounter problems during execution of the model. To determine the cause of these problems the following steps should be taken:

- check if input files are used by other programs. If this is the case, close the files;
- inspect the reported errors in the logfile SWQN.LOG. Open this file, read the (last) lines in the file and try to determine if there is a mistake in the input file;
- check if all the input files (SWQN_*CONTROLS.CSV, SWQN_PRECEVAP.CSV, SWQN_FLOWBOUNDARY.CSV and SWQN_LEVELBOUNDARY.CSV) cover the calculation period;
- check the amount of free memory (RAM) on your PC;
- check the size of the paging file, which is used as virtual memory when the RAM is fully allocated. For extended schematizations this size should be set to at least 1500 MB. The file size can be changed in the Windows Help menu -> paging files;
- check the amount of free space on the hard disk;
- check if the node-, section- and ID's do not exceed 6000, the maximum number that can be handled in the current SWQN version;

3.4 Output: depths, levels and discharges

There are three output files describing the water depths, levels and discharges:

- SWQN_OUTDEPTHS.CSV: Daily averaged water depth (= water level – bottom level) for every node;
- SWQN_OUTLEVELS.CSV: Daily averaged water level for every node;
- SWQN_OUTDISCHARGES.CSV: Daily averaged discharge for every section. The discharge is positive when the water flows from node begin to node end.

The results are written to these files for all nodes on each day. It is also possible to specify nodes and sections for output (see paragraph 2.5.3).

The format of the output files is given in Appendix 2.

3.5 Output: balances

There are four output files describing the water balance. They differ in the aggregation level for time and area (Table 46).

Table 46 Aggregation levels of the water balance files

	Per node	Whole network
Daily	SWQN_OUTBALANCE.CSV	SWQN_OUTTOTALBALANCE.CSV
Yearly	SWQN_OUTBALANCEYEARLY.CSV	SWQN_OUTTOTALBALANCEYEARLY.CSV

The format of the output files is given in Appendix 2.

3.6 Output: other

There are five other output files with special characteristics:

- SWQN_OUTLAYOUT.CSV: This file describes the network layout and provides an easy check on the schematization;
- SWQN_OUTECHOBOUNDS.CSV: This file gives an overview of all boundary fluxes. Handy as an input check and helpful with regard to water quality modelling;
- NUSWALITE_WATERBALANCE.BIN: This binary file can be used as an input for the water quality model NUSWALITE (Siderius et al., 2008). It contains the network layout and water balances;
- SWQN.LOG: This file contains the logs of the model run, including warnings and error messages (Appendix 3).
- SWQN_OUTNODESDEFINITION.CSV: This file has exactly the same format as the input file SWQN_NODESDEFINITION.CSV but now contains the water levels at the end of the calculation period. This file can be used as an input for a follow-up calculation period.

The format of the output files is given in Appendix 2.

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Appendix 1 Input files

Overview of input files

File	Description
SWQN_RUNTIMEOPTIONS.IN	calculation settings and output options
SWQN_NODESDEFINITION.CSV	x and y coordinates, bottom level, etc.
SWQN_SECTIONSDEFINITION.CSV	connected nodes, length, etc.
SWQN_WEIRSDEFINITION.CSV*	definition of weirs
SWQN_WEIRSCONTROLS.CSV*	management for weirs
SWQN_GATESDEFINITION.CSV*	definition of gates
SWQN_GATESCONTROLS.CSV*	management for gates
SWQN_CULVERTSDEFINITION.CSV*	definition of culverts
SWQN_PUMPSDEFINITION.CSV*	definition of pumps
SWQN_PUMPSCONTROL.CSV*	management for pumps
SWQN_FLOWBOUNDARY.CSV*	flow boundary discharges
SWQN_FLOWBOUNDARY1.CSV*	flow boundary discharges, 1st type
SWQN_FLOWBOUNDARY2.CSV*	flow boundary discharges, 2nd type
SWQN_FLOWBOUNDARY3.CSV*	flow boundary discharges, 3rd type
SWQN_FLOWBOUNDARY4.CSV*	flow boundary discharges, 4th type
SWQN_LEVELBOUNDARY.CSV*	fixed level boundary condition
SWQN_PRECEVAP.CSV*	open water precipitation and evaporation

**optional*

SWQN_RUNTIMEOPTIONS.IN

Section/Name	Description	Default	Unit	Type
[CalculationSettings]	Head of the file (obligatory)			
CalculationID*	Calculation identification message**	-	-	C60
StartDay	Day for start of calculation	-	day	I
StartMonth	Month for start of calculation	-	month	I
StartYear	Year for start of calculation	-	year	I
EndDay	Day for end of calculation	-	day	I
EndMonth	Month for end of calculation	-	month	I
EndYear	Year for end of calculation	-	year	I
InitiatioNrDays*	Number of days for initial calculation***	0	day	I
MaxPrecEvapSets*	Maximum number of meteorological zones (with different precipitation and evaporation)	10	-	I
SWQNTimestepsPerDay*	Calculation time step (must be a full divisor of 86400; number of seconds in one day)	24	-	I
NuswaLiteTimestepsPerDay*	Time step at which output to the water quality model NUSWALITE is generated (must be a full divisor of SWQNTimestepsPerDay)	1	-	I
MaxPrecEvapSets*	Maximum number of precipitation- and evaporation sets	10	-	I
ResistanceType*	Resistance formula of: 1 = Chezy 2 = Manning	2	-	I
OutLayout*	Produce SWQN_OUTLAYOUT.CSV with model network: 0 = no 1 = yes	1	-	I
OutBalanceAll*	1 = Write all balance output 2 = only deviations	1	-	I
OutEchoBounds*	Produce SWQN_OUTECHOBOUNDS.CSV: 0 = no 1 = yes	0	-	I
OutBalanceNL*	Produce NUSWALITE_WATERBALANCE.BIN: 0 = no 1 = yes	0	-	I
WaterdepthType*	Type of water depth that is written to NUSWALITE_WATERBALANCE.BIN: 1 = (water depth = water volume / open water surface) 2 = (water depth = water level - bottom level)	1	-	I
OutputNode*	Nodes (list of comma separated nodes)	all	-	I
OutputSection*	Sections (list of comma separated sections)	all	-	I

**optional*
***written to SWQN_OUT(TOTAL)BALANCE.CSV and NUSWALITE_WATERBALANCE.BIN*
****boundary conditions at the start of the calculation period will be applied during this period*

SWQN_NODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node ID**	**-**	**I**
2	PrecEvapID	Precipitation and evaporation region	-	I
3	NodeX	X coordinate	m	R
4	NodeY	Y coordinate	m	R
5	Bottomlevel	Bottom level	m f.r.l.	R
6	MaxLevel	Maximum water level	m f.r.l.	R
7	InitialLevel	Initial water level	m f.r.l.	R

SWQN_SECTIONSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**SectionID**	**Section ID**	**-**	**I**
2	BeginNodeID	Node ID of begin node	-	I
3	EndNodeID	Node ID of end node	-	I
4	Length	Length	m	R
5	BottomWidthBegin	Bottom width begin node	m	R
6	BottomWidthEnd	Bottom width end node	m	R
7	SlopeBegin	Slope begin node: ratio between width and height	-	R
8	SlopeEnd	Slope end node: ratio between width and height	-	R
9	ResistBeginPos	Chezy/Manning resistance coefficient begin node pos. direction	$m^{1/2}\ s^{-1}$ $m^{1/3}\ s^{-1}$	R
10	ResistBeginNeg	Chezy/Manning resistance coefficient begin node neg. direction	$m^{1/2}\ s^{-1}$ $m^{1/3}\ s^{-1}$	R
11	ResistEndPos	Chezy/Manning resistance coefficient end node pos. direction	$m^{1/2}\ s^{-1}$ $m^{1/3}\ s^{-1}$	R
12	ResistEndNeg	Chezy/Manning resistance coefficient end node neg. direction	$m^{1/2}\ s^{-1}$ $m^{1/3}\ s^{-1}$	R

SWQN_WEIRSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**WeirID**	**Weir identifier**	**-**	**I**
2	SectionID	ID of the section where the weir is located	-	I
3	MaxCrestWidth	Maximum crest width	m	R
4	InitialCrestWidth	Initial crest width	m	R
5	MaxCrestLevel	Maximum crest level	m f.r.l.	R
6	MinCrestLevel	Minimum crest level	m f.r.l.	R
7	InitialCrestLevel	Initial crest level	m f.r.l.	R
8	MuPos	weir coefficient μ in pos. direction (begin to end node) (see paragraph 0)	$m^{1/2}\ s^{-1}$	R
9	MuNeg	weir coefficient μ in neg. direction (end to begin node) (see paragraph 0)	$m^{1/2}\ s^{-1}$	R

SWQN_WEIRSCONTROL.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date for change of control setting**	**date**	**C10**
2	**WeirID**	**Weir identifier**	**-**	**I**
3	SelectControlWeir	1 = Crest width 2 = Crest level 3 = Set target level for begin node 4 = Set target level for end node	-	I
4	CrestWidth	Crest width	m	R
5	CrestLevel	Crest level	m f.r.l.	R
6	TargetlevelBegin	Target level begin node	m f.r.l.	R
7	TargetlevelEnd	Target level end node	m f.r.l.	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*

SWQN_GATESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**GateID**	**Gate identifier**	**-**	**I**
2	SectionID	ID of the section where the gate is located	-	I
3	SillLevel	Sill level	m f.r.l.	R
4	InitialOpeningLevel	Initial opening level	m f.r.l.	R
5	MaxOpeningLevel	Maximum opening level	m f.r.l.	R
6	InitialOpeningWidth	Initial opening width	m	R
7	MaxOpeningWidth	Maximum opening width	m	R
8	MuPos	Coefficient μ for submerged gates in pos. direction (begin to end node) (see paragraph 2.3.4)	$m^{1/2} s^{-1}$	R
9	MuNeg	Coefficient μ for submerged gates in neg. direction (end to begin node) (see paragraph 2.3.4)	$m^{1/2} s^{-1}$	R

SWQN_GATESCONTROL.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date for change of setting**	**date**	**C10**
2	**GateID**	**Gate identifier**	**-**	**I**
3	SelectControlGate	1 = Opening level 2 = Opening width** 3 = Target level begin node 4 = Target level end node 5 = Both 3 and 4	-	I
4	OpeningLevel	Opening level	m	R
5	OpeningWidth	Opening width	m	R
6	TargetlevelBegin	Target level begin node	m f.r.l.	R
7	TargetlevelEnd	Target level end node	m f.r.l.	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*
*** not functional yet*

SWQN_CULVERTSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**CulvertID**	**Culvert identifier**	**-**	**I**
2	SectionID	ID of the section where the culvert is located	-	I
3	SelectType	1 = Circular 2 = Square	-	I
4	Number	Number of parallel identical culverts	-	I
5	Length	Length	m	R
6	Dimension	Radius (if SelectType = 1) Width/height (if SelectType = 2)	m	R
7	Bottomlevel	Bottom level	m f.r.l.	R
8	KmPos	Manning resistance coefficient in pos. direction (begin to end node) (see paragraph 2.3.5)	$m^{1/3}.s^{-1}$	R
9	KmNeg	Manning resistance coefficient in neg. direction (end to begin node) (see paragraph 2.3.5)	$m^{1/3}.s^{-1}$	R

SWQN_PUMPSDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**PumpID**	**Pump identifier**	**-**	**I**
2	SectionID	ID of the section where the pump is located	-	I
3	PumpCharacteristicA	Level dependent capacity*	$m^2\ s^{-1}$	R
4	PumpCharacteristicB	Level independent capacity*	$m^3\ s^{-1}$	R

**Total discharge* $Q_{pump} = A\ (H_{beg} - H_{end}) + B$ *[*$m^3\ s^{-1}$*]*

SWQN_PUMPSCONTROL.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date for change of control setting**	**date**	**C10**
2	**PumpID**	**Pump identifier**	**-**	**I**
3	SelectControlPump	1 = Level independent capacity 2 = Start and stop level for begin node 3 = Start and stop level for end node	-	I
4	Discharge	Level independent capacity	$m^3\ s^{-1}$	R
5	StartLevelBegin	Start level for begin node	m f.r.l.	R
6	StoplevelBegin	Stop level for begin node	m f.r.l.	R
7	StartlevelEnd	Start level for end node	m f.r.l.	R
8	StoplevelEnd	Stop level for end node	m f.r.l.	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*

SWQN_FLOWBOUNDARY.CSV

SWQN_FLOWBOUNDARY1.CSV - SWQN_FLOWBOUNDARY4.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date**	**date**	**C10**
2	**NodeID**	**Node ID**	**-**	**I**
3	Discharge	Inflow or outflow discharge**	$m^3\ s^{-1}$	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*
*** Multiple discharges on same node and day add up. Values are sustained in time until a new value for the node is given. Positive values mean inflow, negative values correspond with outflow*

SWQN_LEVELBOUNDARY.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date**	**date**	**C10**
2	**NodeID**	**Node ID**	**-**	**I**
3	Level	Fixed level boundary condition**	m	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*
*** Values are sustained in time until a new value is given.*

SWQN_PRECEVAP.CSV

Col	Name	Description	Unit	Type
1	**Date***	**Date**	**date**	**C10**
2	**PrecEvapID****	**ID for meteorological region**	**-**	**I**
3	Precipitation	(open water) precipitation***	$m.d^{-1}$	R
4	Evaporation	open water evaporation***	$m.d^{-1}$	R

** date formats 'yyyy-m-d' and 'd-m-yyyy' are both accepted*
*** the amount of unique ID's can be defined in SWQN_RUNTIMEOPTIONS.IN (default = 10)*
**** Values are sustained in time until a new value is given*

Appendix 2 Output files

Overview of output files

File	Description
SWQN.LOG	Logging of the model run, including errors and warnings
SWQN_OUTDEPTHS.CSV	Daily averaged water depth (= water level - bottom level) for every node
SWQN_OUTLEVELS.CSV	Daily averaged water level for every node
SWQN_OUTDISCHARGES.CSV	Daily averaged discharge for every section (positive when water flows from begin node to end node)
SWQN_OUTBALANCE.CSV	Daily water balance for every node
SWQN_OUTBALANCEYEARLY.CSV	Yearly water balance for every node
SWQN_OUTTOTALBALANCE.CSV	Daily water balance for whole network
SWQN_OUTTOTALBALANCEYEARLY.CSV	Yearly water balance for whole network
SWQN_OUTLAYOUT.CSV	Network layout
SWQN_OUTECHOBOUNDS.CSV	Overview of all daily boundary fluxes for every node
NUSWALITE_WATERBALANCE.BIN	Binary file with network layout and water balance for the water quality model NUSWALITE (Siderius et al., 2008). Output given per Nuswalite time step (=NuswaLiteTimestepsPerday).
SWQN_OUTNODESDEFINITION.CSV	Can be used as SWQN_NODESDEFINITION.CSV for a follow-up calculation period. This files contains the water levels at the end of the calculation period (as the initial levels)

SWQN_OUTDEPTHS.CSV

Col	Name	Description	Unit	Type
1	**Date**	**Date**	**date**	**Y-m-d**
2	**NodeID**	**Node ID**	**-**	**I**
3	Depth	Daily averaged water depth (water level - bottom level)	m	R

SWQN_OUTLEVELS.CSV

Col	Name	Description	Unit	Type
1	**Date**	**Date**	**date**	**Y-m-d**
2	**NodeID**	**Node ID**	**-**	**I**
3	Level	Daily averaged water level	m	R

SWQN_OUTDISCHARGES.CSV

Col	Name	Description	Unit	Type
1	**Date**	**Date**	**date**	**Y-m-d**
2	**SectionID**	**Section ID**	**-**	**I**
3	Discharge	Daily averaged flow discharge (positive when water flows from begin node to end node of the section)	$m^3 s^{-1}$	R

SWQN_OUTBALANCE.CSV

Col	Name	Description	Unit	Type
1	**Date**	**Date**	**date**	**Y-m-d**
2	**Node**	**Node ID**	**-**	**I**
3	LevTimEnd	Water level at end of the day	m	R
4	VolAddStrt	Water volume at start of the day	m^3	R
5	VolAddEnd	Water volume at end of the day	m^3	R
6-15	FlwNodID1-10	Internal flow discharges*	$m^3\ s^{-1}$	R
16	FlwBndH	Level boundary discharge*	$m^3\ s^{-1}$	R
17	FlwBndQ	Flow boundary discharge*	$m^3\ s^{-1}$	R
18	FlwBndL	Link boundary discharge**	$m^3\ s^{-1}$	R
19	FlwBndP	Precipitation boundary discharge*	$m^3\ s^{-1}$	R
20	FlwBndE	Evaporation boundary discharge*	$m^3\ s^{-1}$	R
21	AbsErr	Absolute water balance error	m^3	R
22	RelVErr	Water balance error relative to daily averaged water volume	%	R
23	RelQErr	Water balance error relative to daily water discharge	%	R
24	Calculation ID	Calculation ID	-	C60

SWQN_OUTBALANCEYEARLY.CSV

Col	Name	Description	Unit	Type
1	**Year**	**Year**	**-**	**I**
2	**Node**	**Node ID**	**-**	**I**
3	InternalFlowDischarge	Sum of internal flow discharges*	$m^3\ y^{-1}$	R
4	LevelBoundaryDischarge	Level boundary discharge*	$m^3\ y^{-1}$	R
5	FlowBoundaryDischarge	Flow boundary discharge*	$m^3\ y^{-1}$	R
6	LinkBoundaryDischarge	Link boundary discharge**	$m^3\ y^{-1}$	R
7	PrecipitationBoundaryDischarge	Precipitation boundary discharge*	$m^3\ y^{-1}$	R
8	EvaporationBoundaryDischarge	Evaporation boundary discharge*	$m^3\ y^{-1}$	R
9	StorageChange	Change in water storage***	m^3	R
10	BalanceError	Water balance error	m^3	R

SWQN_OUTTOTALBALANCE.CSV

Col	Name	Description	Unit	Type
1	**Date**	**Date**	**date**	**Y-m-d**
2	VolAddStrt	Water volume at start of the day	m^3	R
3	VolAddEnd	Water volume at end of the day	m^3	R
4-13	FlwNodID1-10	Internal flow discharges*	$m^3\ s^{-1}$	R
14	FlwBndH	Level boundary discharge*	$m^3\ s^{-1}$	R
15	FlwBndQ	Flow boundary discharge*	$m^3\ s^{-1}$	R
16	FlwBndL	Link boundary discharge**	$m^3\ s^{-1}$	R
17	FlwBndP	Precipitation boundary discharge*	$m^3\ s^{-1}$	R
18	FlwBndE	Evaporation boundary discharge*	$m^3\ s^{-1}$	R
19	AbsErr	Absolute water balance error	m^3	R
20	RelVErr	Water balance error relative to daily averaged water volume	%	R
21	Calculation ID	Calculation ID	-	C60

* *positive value = incoming flow, negative value = outgoing flow*
** *not functional yet*
*** *positive value = increase in water storage*

SWQN_OUTTOTALBALANCEYEARLY.CSV

Col	Name	Description	Unit	Type
1	**Year**	**Year**	**-**	**I**
2	LevelBoundaryDischarge	Level boundary discharge*	$m^3 y^{-1}$	R
3	FlowBoundaryDischarge	Flow boundary discharge*	$m^3 y^{-1}$	R
4	LinkBoundaryDischarge	Link boundary discharge**	$m^3 y^{-1}$	R
5	PrecipitationBoundaryDischarge	Precipitation boundary discharge*	$m^3 y^{-1}$	R
6	EvapirationBoundaryDischarge	Evaporation boundary discharge*	$m^3 y^{-1}$	R
7	StorageChange	Change in water storage***	m^3	R
8	BalanceError	Water balance error	m^3	R

* *positive value = incoming flow, negative value = outgoing flow*
** *not functional yet*
*** *positive value = increase in water storage*

SWQN_OUTLAYOUT.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node ID**	**-**	**I**
2	BottomArea	Bottom area	m^2	R
3	MaxWaterArea	Open water area at maximum water level	m^2	R
4	NOfConNodes	Number of connected nodes (CN)	-	I
5-CN	ConNodID	Connected node ID	-	I

SWQN_OUTECHOBOUNDS.CSV

Col	Name	Description	Unit	Type
1	**Date**	**Date**	**date**	**Y-m-d**
2	**NodeID**	**Node ID**	**-**	**I**
3	HBnd	Level boundary discharge*	$m^3 s^{-1}$	R
4	FlwBnd	Flow boundary discharge (from SWQN_FLOWBOUNDARY.CSV)*	$m^3 s^{-1}$	R
5	FlwBnd1	Flow boundary discharge 1 (from SWQN_FLOWBOUNDARY1.CSV)*	$m^3 s^{-1}$	R
6	FlwBnd2	Flow boundary discharge 2 (from SWQN_FLOWBOUNDARY2.CSV)*	$m^3 s^{-1}$	R
7	FlwBnd3	Flow boundary discharge 3 (from SWQN_FLOWBOUNDARY3.CSV)*	$m^3 s^{-1}$	R
8	FlwBnd4	Flow boundary discharge 4 (from SWQN_FLOWBOUNDARY4.CSV)*	$m^3 s^{-1}$	R
9	FlwBndP	Precipitation boundary discharge*	$m^3 s^{-1}$	R
10	FlwBndE	Evaporation boundary discharge*	$m^3 s^{-1}$	R

* *positive value = incoming flow, negative value = outgoing flow*

NUSWALITE_WATERBALANCE.BIN

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	**NrDays**	**Number of calculation days**	**day**	**I4**
	7	**TimestepsPerDay**	**Time steps per day at which output is generated (=NuswaLiteTimestepsPerDay)**	**1/day**	**I4**
2	**1**	**NOfNodes**	**Number of nodes**	**-**	**I4**
3*	**1**	**NodeID**	**Node ID**	**-**	**I4**
	2	BottomArea	Bottom area	m^2	R8
	3	InitialVolume	Initial water volume	m^3	R8
	4	NOfConNodes	Number of connected nodes (CN)	-	I4
	5-CN	ConNodID1-CN	Connected node ID	-	I4
4**	1	VolAddAvg	Average water volume per time step	m^3	R8
	2	VolAddEnd	Volume at end of time step	m^3	R8
	3	DepthAvg	Averaged water depth per time step	m	R8
	4	Vel	Flow velocity averaged over time step	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 NuswaLite time step (=NuswaLiteTimestepsPerDay)*
**** positive value = incoming flow, negative value = outgoing flow*
***** not functional yet*

SWQN_OUTNODESDEFINITION.CSV

Col	Name	Description	Unit	Type
1	**NodeID**	**Node ID**	**-**	**I**
2	PrecEvapID	Precipitation and evaporation region	-	I
3	NodeX	X coordinate	m	R
4	NodeY	Y coordinate	m	R
5	Bottomlevel	Bottom level	m f.r.l.	R
6	MaxLevel	Maximum water level	m f.r.l.	R
7	InitialLevel	Initial water level (level at the end of calculation period)	m f.r.l.	R

Appendix 3 Warnings and error messages

Warnings and error messages during the model run are written to SWQN.LOG. Only their number ends up in the log file. The table below gives information on each warning number and error number.

Nr	Type*	Description
8	W	underflow discharge cannot be linearized within working range for water depths for submerged and freely discharging structures (remedy: increase maximum water depth)
9	W	underflow discharge cannot be linearized within working range for water depths for structures acting as weir (remedy: increase maximum water depth)
10	W	weir discharge cannot be linearized within working range for water depths for freely discharging structures (remedy: increase maximum water depth)
11	W	weir discharge cannot be linearized within working range for water depths for submerged structures (remedy: increase maximum water depth)
13	W	max. rel. nodal balance deviation exceeds 0.1% for internal time step
14	W	max. rel. nodal balance deviation exceeds 1% for internal time step
15	W	max. rel. nodal balance deviation exceeds 0.1% for output time step
16	W	wetted perimeter equals zero
17	W	surface area equals zero
18	W	water level below bottom level in a linked section
19	W	dryfall in node
20	W	coefficient matrix is numerically singular
21	W	growth factor is too large to continue
22	W	matrix is too ill-conditioned for iterative refinement
23	W	max. rel. nodal balance deviation exceeds 0.1% for output time step
24	W	pump discharge reduced because of low water depth
25	W	Boundary condition Q-h: flow reduced due to low water depth
103	E	Time step outside range <=1 or >=86400 sec
107	E	section length zero
108	E	more than 10 connections with other nodes
109	E	water surface approaching zero, probably input error
110	E	iteration time step became too small (less than 5 seconds)
111	E	matrix solver failed
112	E	linearization bottom boundary for seepage/leakage failed
113	E	too many error messages
114	E	correction for water level (because of wrong storage term) failed
115	E	negative water depth occurred

** W=Warning, E=Error (calculation stops)*

Appendix 4 Example: Vansjø-Hobøl catchment (Norway)

Introduction

The application of SWQN to the Vansjø-Hobøl catchment is used as one of the cases in the EUROHARP project (J.M. Terres, P.Campling, S. Vandewall, J. van Orshoven, *Calculation of Agricultural Nitrogen Quantity for EU River Basins, Final Report: EUR 20256 EN*, 2006). EUROHARP includes nine different contemporary methodologies for quantifying diffuse losses of N and P, and a total of 17 study catchments across gradients in European climate, soils, topography, hydrology and land use. In the Dutch methodology the surface water flow was simulated using the SWQN model. In this example only the simulation of the surface water of the Norwegian subcatchment is presented for a time stretch of only 2 years.

Successively the characteristics of the catchment, the schematization, the parameterization, and the model results are described.

General

The catchment is 690 km^2 in size and situated in the south of Norway, in the neighbourhood of the capital Oslo. The outlet of the catchment is located in the city of Moss. The dominant land use is forest (Figure 7). The average precipitation in the area is 810 mm. The soil type is predominantly clay. There is ca. 120 km^2 of agricultural land, of which more than two thirds is used to produce grains.

The runoff of the catchment flows through 959 km of streams and 48 km^2 of lakes in which two measurements stations are located (Figure 8). One station is located in the Hobøl River, and has an upstream catchment of almost half the entire catchment. The other is located just after the biggest lake in the catchment, Lake Vansjø, at a dam in Moss.

During the process modelling choices have been made on parameter settings and interpretation of data. These choices will be described here, as well as the final results.

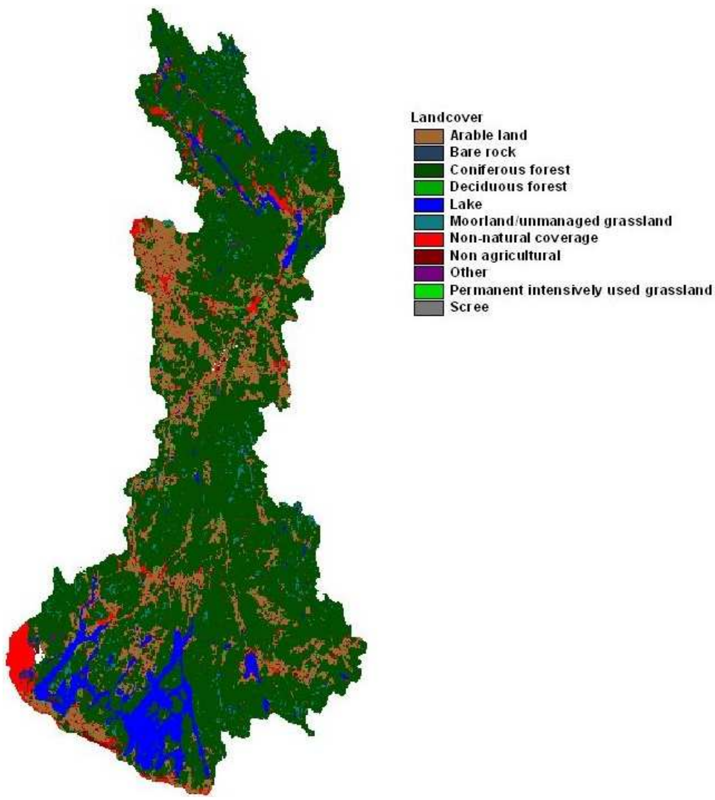

Figure 7 Map showing land cover of the Vansjø-Hobøl catchment

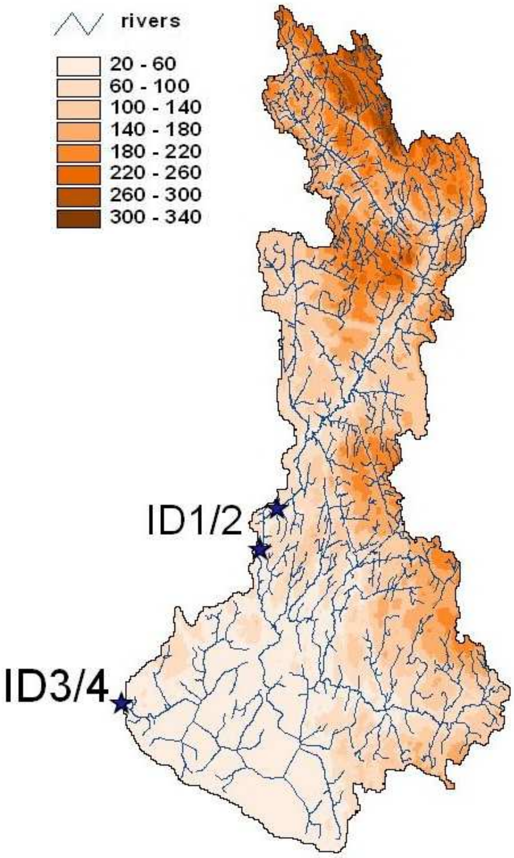

Figure 8 Rivers, DEM and the location of the surface water measurement stations

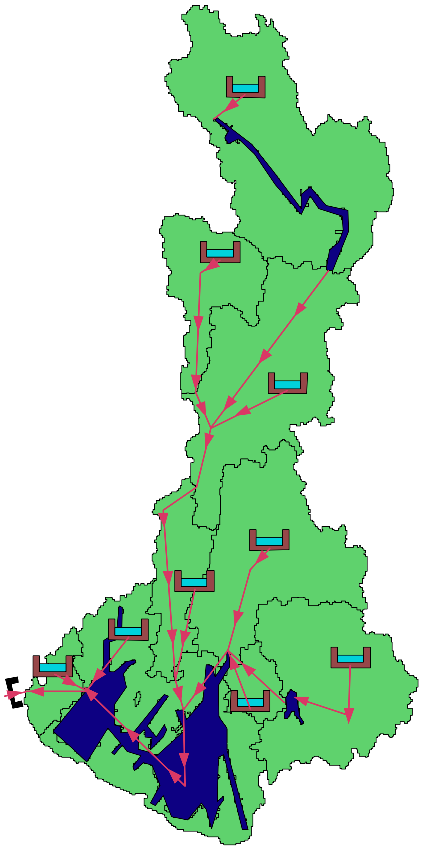

Figure 9 The schematized surface water system

Schematisation

The watercourses are schematized in a network of nodes and sections. This schematization should be based on the catchment characteristics and the purpose of the project.

Lake Vansjø makes up 75% of the entire surface water in the catchment, and 85% of the total volume. With an annual average discharge of $304 \cdot 10^6$ m^3 (from 1991 until 1995), the residence time is circa 10½ months in Lake Vansjø, but only 2½ days for rivers and streams.

For the case of the EUROHARP project the great influence of Lake Vansjø on the retention of nutrients made a coarse schematization possible. Therefore the main rivers and lakes of the surface water system were schematized into larger sections. The remaining river sections were aggregated per subcatchment into added storage basins to represent the finer watercourses. For each subcatchment a boundary flow is calculated and is connected to the added storage sections. The schematization is shown in Figure 9.

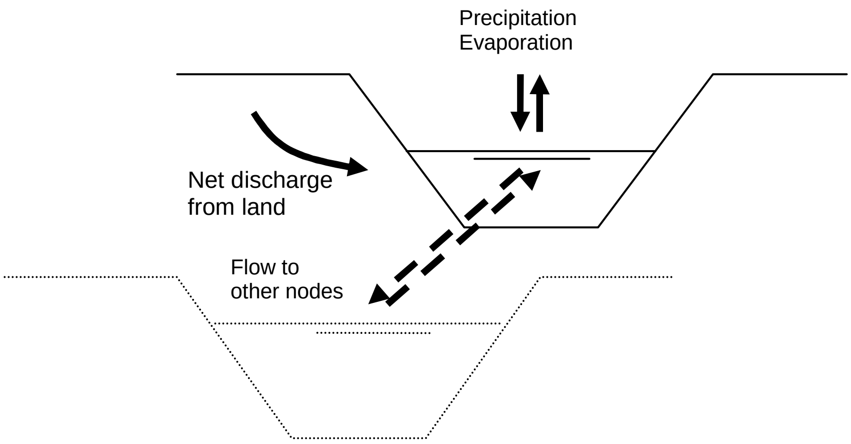

Figure 10 Fluxes per node

Figure 10 shows the fluxes per node that are taken into account:

- Precipitation and evaporation;
- Discharge from the soil: drainage and runoff;
- Interaction fluxes with other sections (or boundaries).

The first two are boundary fluxes, the third is calculated by the model. In this example the derivation of the boundary fluxes will not be described. In the EUROHARP project these fluxes were calculated using a one dimensional, non stationary soil model.

There are several structures in the water system. An important one is the power plant downstream of Lake Vansjø, which is modelled as a series of pumps. There are also several weirs. Both the power plant and the weirs are connected to sections.

Parameterisation

Watercourses

The parameterization was based on the provided information by the catchment owner. The provided river map contained 959 km of streams divided into 2846 sections. There was also a map with 34 lakes. All river segments had a classified width and depth, except streams through lakes (128 km). The width of these sections was determined by dividing the total area of each lake by the total length of streams within it. Lakes for which no depth was given were considered to be 0.50 m deeper than the connecting streams. The parameters for the schematized sections and nodes are given in Table 47 and Table 48. As can be concluded from the length and bottom width the sections 29 and 30 represent Lake Vansjø. The sections with the higher resistances represents the added storage, e.g. section 6. These section do have a very big length.

Table 47 Definition of surface water sections (SWQN_SECTIONSDEFINITION.CSV)

SectionID	Begin NodeID	End NodeID	Length	Bottom Width Begin	Bottom WidthEnd	SlopeBegin	SlopeEnd	Resist BeginPos	Resist BeginNeg	Resist EndPos	Resist EndNeg
1	1*	2	271959	17.6	17.6	4	4	8023	8023	8023	8023
2	2	3	25	8.8	8.8	0	0	20	20	20	20
3	3	4	18000	221.2	139.6	0	0	20	20	20	20
4	4	5	25	9.6	9.6	0	0	20	20	20	20
5	5	6	20152	9.6	9.6	0	0	20	20	20	20
6	7	8	5191	20	20	4	4	21	21	21	21
7	8	9	25	5.3	5.3	0	0	20	20	20	20
8	9	10	9091	5.3	5.3	0	0	20	20	20	20
9	10	6	3661	10	10	0	0	20	20	20	20
10	11	12	123880	5	5	4	4	2466	2466	2466	2466
11	12	6	25	1	1	0	0	20	20	20	20
12	6	13	4531	10	10	0	0	20	20	20	20
13	13	14	17141	21.4	21.4	0	0	20	20	20	20
14	15	16	31492	5	5	4	4	316	316	316	316
15	16	14	25	2.5	2.5	0	0	20	20	20	20
16	14	21	2868	62.6	62.6	0	0	20	20	20	20
17	18	19	139563	9.4	9.4	4	4	2949	2949	2949	2949
18	19	20	25	4.7	4.7	0	0	20	20	20	20
19	20	21	6465	11.9	11.9	0	0	20	20	20	20
20	22	23	93259	11.2	11.2	4	4	1611	1611	1611	1611
21	23	24	25	5.6	5.6	0	0	20	20	20	20
22	24	25	5034	6.8	6.8	0	0	20	20	20	20
23	25	26	25	6.8	6.8	0	0	20	20	20	20
24	26	27	756.3	2040.7	2040.7	0	0	20	20	20	20
25	27	28	25	22.8	22.8	0	0	20	20	20	20
26	28	21	5904	22.8	22.8	0	0	20	20	20	20
27	29	30	8254	11.2	11.2	4	4	42	42	42	42
28	30	21	25	5.6	5.6	0	0	20	20	20	20
29	21	17	6000	6043.6	6043.6	0	0	20	20	20	20
30	17	31	18300	1732.9	1732.9	0	0	20	20	20	20
31	32	33	9842	11.8	11.8	4	4	55	55	55	55
32	33	31	25	5.9	5.9	0	0	20	20	20	20
33	34	35	9842	16.4	16.4	4	4	55	55	55	55
34	35	31	25	8.2	8.2	0	0	20	20	20	20
35	31	36	25	50	50	0	0	20	20	20	20
36	36	37	6328	50	50	0	0	20	20	20	20
37	41	38	100	500	500	0	0	20	20	20	20
38	37	39	100	500	500	0	0	20	20	20	20
39	37	40	100	500	500	0	0	20	20	20	20
40	39	41	100	500	500	0	0	20	20	20	20
41	40	41	100	500	500	0	0	20	20	20	20
42	37	42	100	500	500	0	0	20	20	20	20
43	42	41	100	500	500	0	0	20	20	20	20
44	37	43	100	500	500	0	0	20	20	20	20
45	43	41	100	500	500	0	0	20	20	20	20

* *in red the nodes on which the flows from the land system are set*

Table 48 Definition of surface water nodes (SWQN_NODESDEFINITION.CSV)

NodeID	Meteo region	X (m)	Y (m)	Bottom level(m f.r.l.)	Max level (m f.r.l.)	Initial level (m f.r.l.)
1	10	607314	6628272	131.96	153.06	132.46
2	10	607314	6628272	131.96	153.06	132.46
3	10	607314	6628272	105.88	153.06	112.48
4	10	614911	6618239	105.88	132.48	112.48
5	10	614911	6618239	111.48	132.48	111.98
6	10	607096	6607773	53.54	74.54	54.54
7	10	606393	6618046	96.83	117.13	97.13
8	10	606393	6618046	96.83	117.13	97.13
9	10	606393	6618046	76.33	117.13	76.83
10	10	616237	6588650	60.08	117.13	60.58
11	10	607096	6607773	55.24	74.54	55.74
12	10	607096	6607773	55.24	74.54	55.74
13	10	606105	6603836	51.06	72.06	52.06
14	7	604725	6591023	23.5	45	25
15	7	604725	6591023	24.4	45	24.9
16	7	604725	6591023	24.4	45	24.9
17	7	605259	6589007	17.6	45	25
18	8	609727	6598324	57.61	78.31	58.31
19	8	609727	6598324	57.61	78.31	58.31
20	8	609727	6598324	22.31	78.31	22.81
21	7	608227	6592958	17.6	45	25
22	8	616237	6588650	68.51	89.21	69.21
23	8	616237	6588650	68.51	89.21	69.21
24	8	616237	6588650	68.41	89.21	69.21
25	8	612842	6589763	46.7	67.5	47.5
26	8	612842	6589763	39.7	67.5	47.5
27	8	611936	6589491	39.7	67.5	47.5
28	8	611936	6589491	24.7	67.5	25.2
29	8	608227	6592958	23.7	45	25
30	8	608227	6592958	23.7	45	25
31	7	598891	6590270	17.6	45	25
32	7	598891	6590270	23.75	45	25
33	7	598891	6590270	23.75	45	25
34	7	598891	6590270	23.75	45	25
35	7	598891	6590270	23.75	45	25
36	7	594804	6590213	23	45	25
37	7	592042	6589798	22.66	44.66	24.66
38	7	592040	6589798	0	22	2
39	7	592041	6589797	0	22.5	2.5
40	7	592041	6589799	0	22.5	2.5
41	7	592041	6589798	0	22.5	2.5
42	7	592041	6589799	0	22.5	2.5
43	7	592041	6589799	0	22.5	2.5

Weirs and power plants

On several locations in the water system weirs are build, which are connected to sections (Table 49). The crest height and crest width are provided by the catchment owner (is that true or is a spacious crest width chosen). As can be seen in Table 49 weir 1 and 2 are assigned zero values for the resistances in negative (upstream) direction. This means that water can only flow in downstream direction.

The discharges downstream of Lake Vansjø are clearly influenced by the management strategies of the electric power plant at the dam in Moss. Due to trade secret, no information on management was provided. At first only a dam was modelled at the end of the lake, but a closer look learned that the discharges are more or less discrete around ca. 1 m^3/s, ca. 8 m^3/s, and ca. 15 m^3/s.

This behaviour is not characteristic for a normal dam, so it was imitated by a combination of three pumps (Table 50 and Table 51) and a weir at the outlet point of the catchment. First there is a pump with a capacity of 1 m^3/s, which starts pumping if the level in the lake reaches 24.51m. If the runoff of the catchment is higher than 1 m^3/s, the water level will rise, and at first run over a weir with a crest level of 25.00m. If the runoff is high enough and the level still raises, at 25.01m a second pump starts with an extra discharge of 7 m^3/s. If even this doesn't stop the raising of the water, a third pump will start with another extra discharge of 7 m^3/s. The most extreme runoff peeks will just run over the weir. If the runoff lowers and the water level drops below 24.96, the third pump stops pumping. At 24.95m the second pump stops, and eventually if levels drop to 24.50m even the first pump stops but this does seldom happen.

Table 49 Definition of weirs (SWQN_WEIRSDEFINITION.CSV)

Weir	Section	Max Crest Width (m)	Initial Crest Width (m)	Max Crest Level (m f.r.l.)	Min Crest Level (m f.r.l.)	Initial Crest Level (m f.r.l.)	MuPos ($m^{0.5}$ s^{-1})	MuNeg ($m^{0.5}$ s^{-1})
1	38	50	50	25	25	25	2	0
2	2	50	50	132.46	132.46	132.46	2	0
3	7	50	50	97.33	97.33	97.33	2	2
4	11	50	50	55.74	55.74	55.74	2	2
5	15	50	50	24.9	24.9	24.9	2	2
6	18	50	50	58.11	58.11	58.11	2	2
7	21	50	50	69.01	69.01	69.01	2	2
8	28	50	50	25	25	25	2	2
9	32	50	50	25	25	25	2	2
10	34	50	50	25	25	25	2	2
11	25	50	50	47.2	47.2	47.2	2	2
12	4	50	50	112.48	112.48	112.48	2	2

Table 50 Definition of pumps (SWQN_PUMPSDEFINITION.CSV)

PumpID	SectionID	PumpCharacteristicA (m^2/s)	PumpCharacteristicB (m^3/s)
1	39	0	1
2	42	0	7
3	44	0	7

Table 51 Control of pumps (SWQN_PUMPSCONTROL.CSV)

Date	PumpID	SelectControlPump	Discharge (m^3/s)	StartLevelBegin (m f.r.l.)	StopLevelBegin (m f.r.l.)
01/01/1990	1	2	1	24.51	24.5
01/01/1990	2	2	7	25.01	24.95
01/01/1990	3	2	7	25.02	24.96

Inflow from land system

The watercourses receive water from the land system. These fluxes are defined in the file SWQN_FLOWBOUNDARY.CSV (Table 52).

Table 52 Inflow from land system (SWQN_FLOWBOUNDARY.CSV)

Date	NodeID	Discharge (m^3/s)
01/01/1990	1	0.0404
02/01/1990	1	0.0423
03/01/1990	1	0.0409
04/01/1990	1	0.0379
05/01/1990	1	0.0378
06/01/1990	1	0.0438
07/01/1990	1	7.9808
08/01/1990	1	10.5468
09/01/1990	1	13.6445
10/01/1990	1	14.0020
11/01/1990	1	9.0998
12/01/1990	1	1.5104
13/01/1990	1	0.1623
14/01/1990	1	0.1437
15/01/1990	1	9.1374
16/01/1990	1	2.1470
17/01/1990	1	5.1456
18/01/1990	1	0.8385
19/01/1990	1	0.1600
20/01/1990	1	5.4944
21/01/1990	1	1.4954
22/01/1990	1	0.2639
23/01/1990	1	1.4343
24/01/1990	1	27.4645

Precipitation and evaporation
The precipitation and evaporation is defined in SWQN_PRECEVAP.CSV (Table 53).

Table 53 Precipitation and evaporation (SWQN_PRECEVAP.CSV)

Date	PrecEvapID	Prec (m/d)	Evap (m/d)
01/01/1990	7	0.00000	0.00010
02/01/1990	7	0.00000	0.00009
03/01/1990	7	0.00030	0.00009
04/01/1990	7	0.00120	0.00009
05/01/1990	7	0.00040	0.00003
06/01/1990	7	0.00060	0.00004
07/01/1990	7	0.00650	0.00006
08/01/1990	7	0.00010	0.00015
09/01/1990	7	0.00000	0.00013
10/01/1990	7	0.00400	0.00006
11/01/1990	7	0.00000	0.00009
12/01/1990	7	0.00010	0.00009
13/01/1990	7	0.00000	0.00014
..	..	..	..

Level boundary
At the outlet a fixed water level is used as boundary condition (Table 54). In this way the discharge flows over the border of the model. Without this boundary condition the water level would have build up (with the sky as the limit).

Table 54 Water level boundary at the outlet (SWQN_LEVELBOUNDARY.CSV)

Date	NodeID	Level (m f.r.l.)
01/01/1990	38	2.5

Simulation results

Calibration

The calibration of the model for this example was done on the measured discharges at the outlet point for the years 1991 and 1992. Flow was mainly calibrated by:

- adjusting the boundary conditions, that is the inflow (from the land/soil);
- adjusting the simulation of the power plant by the structures. As described the influence of the power plant on the discharges downstream Lake Vansjø showed to be important and had to be modelled in detail.

Results after calibration

The yearly water balances are presented in Table 55. The results of the calibration on discharges can be found in Figure 11. Results are presented on both a normal and a logarithmic scale. On a normal scale peaks can be seen more clearly, and on a logarithmic scale it is possible to see the 'background' flow. The results are very reasonable.

Discharges at the catchment outlet were very difficult to model in detail. The approach with structures representing the power plant did not always result in simulated discharges at the same moments as in the measurements, but the result is satisfying.

Table 55 Surface water balances for 1991 and 1992

Surface water balances for 1991

Water balance			*10^6 m^3*
Input		Output	
Runoff	285.2	Outflow	323.7
Precipitation	63.5	Evaporation	31.1
Storage change	6.2		
	354.8		354.8

Surface water balances for 1992

Water balance			*10^6 m^3*
Input		Output	
Runoff	267.8	Outflow	281.2
Precipitation	68.0	Evaporation	31.0
		Storage change	23.7
	335.8		335.8

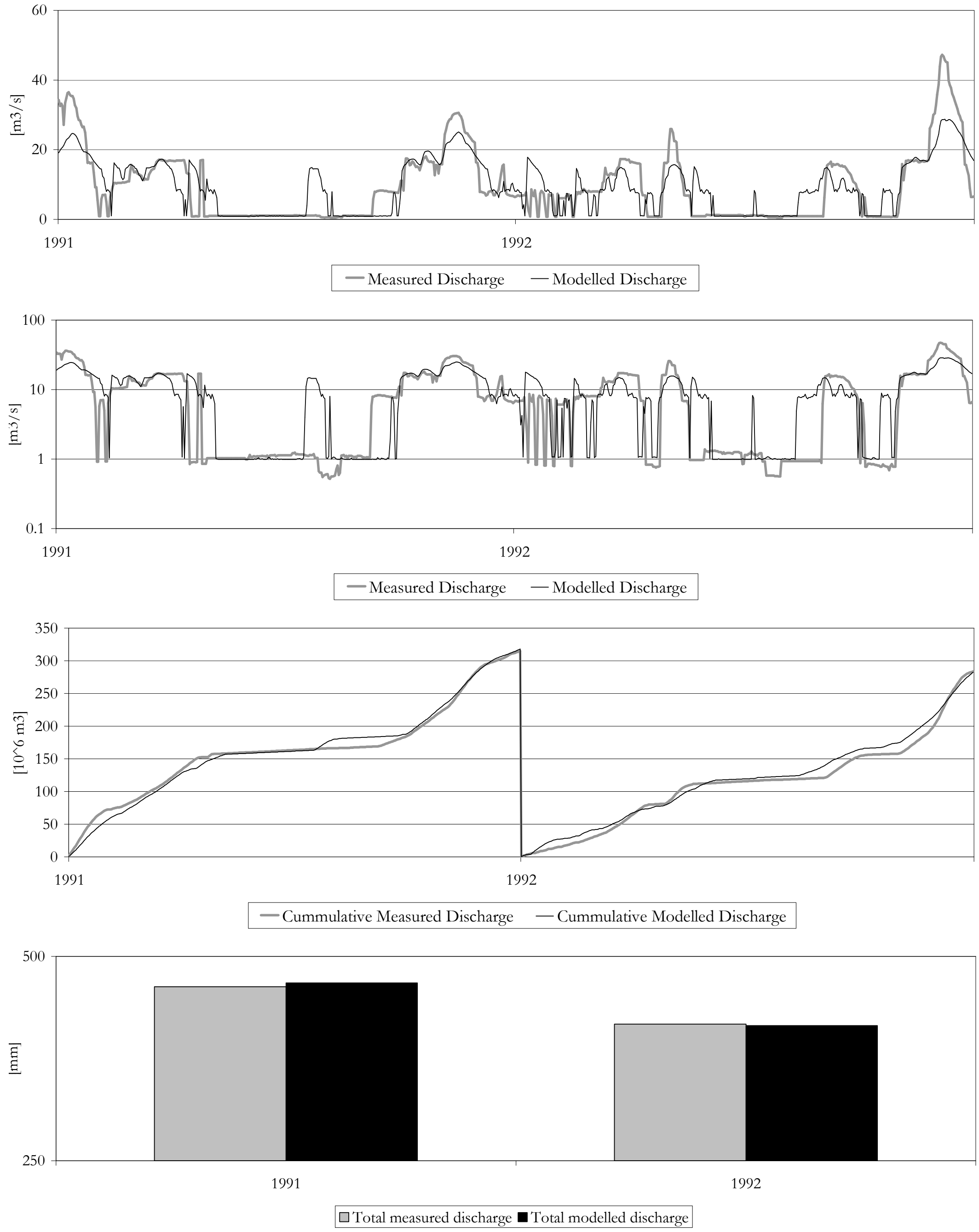

Figure 11 Calibrated discharges from total catchment

Appendix 5 Coupling of SWQN to Simgro

Introduction

This section describes the theory and usage of the online coupling of SWQN with SIMGRO. The models interact for a user defined exchange time step, and exchange data through the internal memory (RAM) or through a file. First the spatial domains of the models and the data that are exchanged by the models will be described. Secondly the technical implementation of the online coupling is explained. In the end the input file is described to run the model coupling.

Spatial domains of the models

The SIMGRO model covers the whole hydrological system. The model integrates the saturated zone, the unsaturated zone and the surface water. The surface water part of SIMGRO has its limitations, and in some situations it can be useful to use a specialised surface water model for a part of the catchment, especially when modelling polder areas where the flow direction can alter. In SIMGRO-SWQN parts of the surface water system are taken over by SWQN (Figure 12).

Water is exchanged between SWQN and SIMGRO. SIMGRO supplies drainage water (groundwater) to SWQN, as well as water from the surface water system that is not modelled in SWQN (for example ditches). In case of infiltration SIMGRO demands water from SWQN. Water supply from SIMGRO is always realised in SWQN. When SIMGRO demands water SWQN looks if it can give the desired amount of water. In case of dryfall the realised demand is smaller than the demand put by SIMGRO. To maintain the feedback mechanisms that SIMGRO is noted for, the coupling needs to be bidirectional, and SWQN has to return the resulting water levels as well. Figure 13 gives an example of the spatial relation between SWQN and SIMGRO.

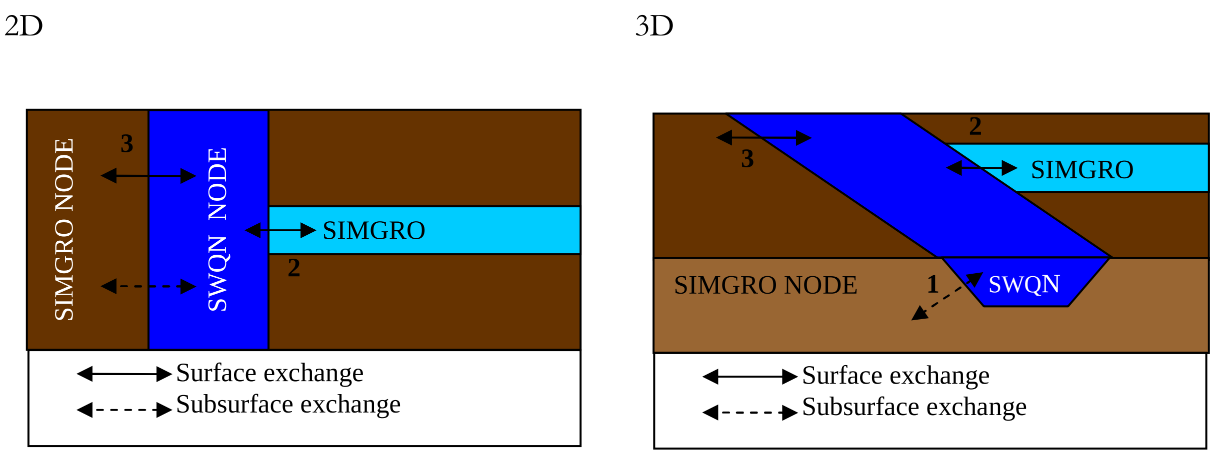

Figure 12 The spatial relation between SIMGRO and SWQN.

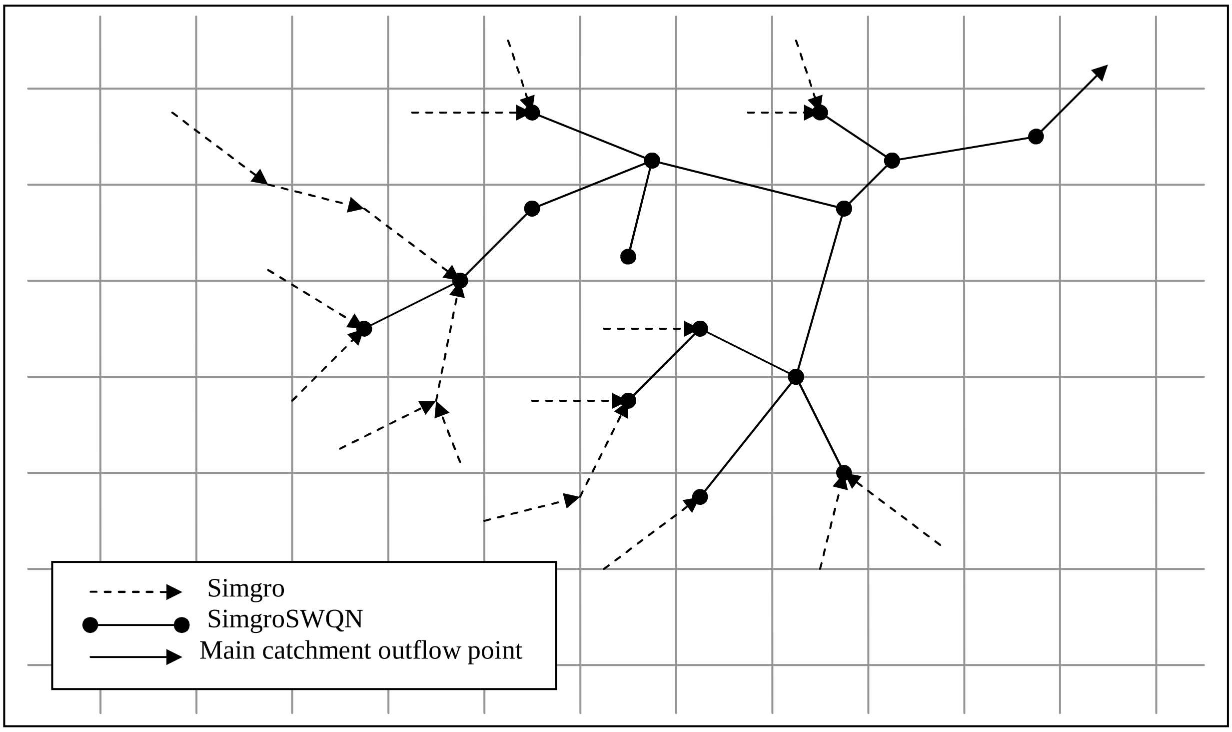

Figure 13 Example of the spatial relation between SIMGRO and SWQN. SWQN can receive supplies and demands from multiple SIMGRO segments

Data to exchange

Before the first time step SIMGRO passes the model ID (=SIMGRO in this case), the schematisation ID, the number of exchange nodes, the exchange time step, and the SWQN-IDs of the nodes to SWQN. SWQN replies with confirmation of the existence of the nodes in the SWQN schematisation, and the initial water levels. After the initiation, for every exchange time step SIMGRO passes the supply and demand to SWQN and SWQN replies with realised supply and demand and water levels from the nodes.

SWQN allows more than one connection to a node. When the total of the demands can not be realised, SWQN limits all demands proportionate to the original damns. Supplies to a node always contribute to demands on the same node.

Implementation

Exchange of data through the internal memory (RAM) is supposed to be the fastest way to exchange data. The amount of exchange data is limited. Even with one million exchange segments in double precision, SWQN returns with three values (realised flow and water levels at the begin and end of the segment), which takes a maximum of 3 x 8 bytes x one million = 24 MB of data. Total integration of the models (as a subroutine or dll) makes exchange through memory and signalling possible easily, but this has the disadvantage that the included model has to be maintained in two forms: as part of the combined model and as an independent model.

The solution for RAM-exchange comes from the CreateFileMapping-function. This function is part of the Windows SDK (Software Development Kit), and is included in Fortran Visual Studio 6. In Fortran the function can be made available with 'Use DFWIN'. The function is also available in other programming languages supporting Windows SDK. This function can label a part of the memory outside the application of a specified size with a unique name. With the MapViewOfFile-function any application can connect to this memory when it uses the same unique name. MapViewOfFile returns a pointer to the start of the memory. With CopyMemory it is possible to send or receive data from this location for a specified number of bytes. The first four bytes can be used as an integer-flag giving the status of the calculation. If both models monitor this flag, they will know if they have to wait for the other model to send its data, or that the other model has already placed its data in the shared memory.

Currently the models wait for 1 ms (sleep-function) before checking the flag again. Otherwise the checking loop will consume 50% of the CPU-time, slowing down the other process. A more elegant way to realise this would have been the use of the WaitForSingleObject function. It is possible to create a 'mutex' with a unique name (which can easily be based on the name of the shared memory). This mutex can only be 'owned' by one of processes. With the WaitForSingleObject function a process goes into an efficient wait state until the other process releases the mutex. However, in the current version of the model coupling this is not built in yet. WaitForSingleObject will not always wait for the object to become available, and will not always take ownership of the object. On the other hand ReleaseMutex will not always release the object. It is also difficult to monitor the state of the mutex with the debugger. Therefore, it was decided to stay put with the sleep function, which looses 1 ms at maximum for every exchange time step.
Figure 14 shows a flow chart of the process.

Running the model coupling (with SIMGRO-SWQN)

Both models only have to know that they are part of a system of models, and need to communicate, and they have to receive the name of the shared memory. A mini application (SIMGRO-SWQN) was created to establish the start-up of both models. The user supplies the (maximum) number of exchange segments, the location of both executables, and the working directories of both models.

The parameters of SIMGRO-SWQN are placed in a small ini-file. The user gives the name of this file (e.g. SIMGROSWQN.INI) as an argument to the SIMGROSWQN - executable. An example of this file is:

```
[General]
NExchangeSegments = 1000

[Simgro]
Simgro_Path = 'D:\SimgroSWQN\m16_test5\'
Simgro_Cmd = 'D:\SimgroSWQN\Simgro\modmsw.exe aa 1'

[SWQN]
SWQN_Path='D:\SimgroSWQN\TestSWQN\'
SWQN_Cmd='D:\SimgroSWQN\SWQN.exe D:\SimgroSWQN\TestSWQN\'
```

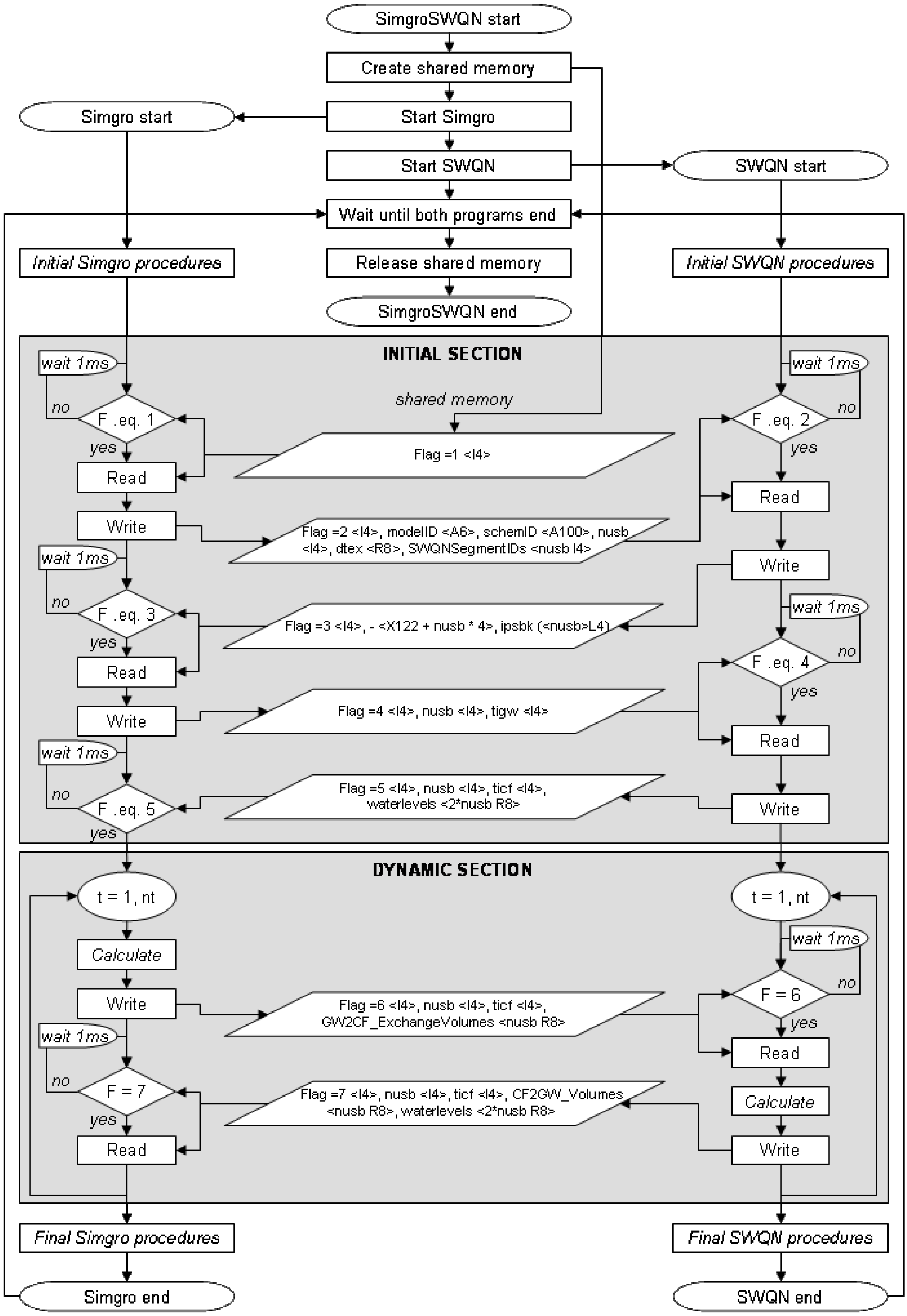

Figure 14 Flow chart of SIMGRO and SWQN interaction