Water management

Constructed wetlands

For an overview of basic assumptions and explanation of variables see the Basic assumptions section in the Rivers and lakes chapter.

The wetlands that are simulated are small artificial ponds. They have an area and depth (*dep*), but their area is not taken into account in terms of precipitation and evaporation. The water flow passes through the wetlands without being affected, so it's just as nutrient traps that the wetland model is significant. There are two types of wetlands, just as for the rivers and lakes. They are situated before the river in the calculation scheme. The local wetland (*lrwet*) receives a share of the local runoff (*part*) the rest passes by unaffected. Wetlands in main rivers (*mrwet*) receive a portion of the flow in the main river and the rest passes unaffected.

Wetland nutrient processes

In wetlands, retention of inorganic nitrogen is modelled (denitrification). For total phosphorus retention (sedimentation) and production (or release from sediments) of TP are modelled. The rates of these processes are constant coefficients (*teta*=1.2, *tkoeff*=20, *inpar*=2.3, *sedpar*= 0.09, and *uptpar*=0.1). The retention is limited to 99.9% of the substance in the wetland. The retention (*retIN, retTP, g/d*) depends on the rate parameter, the concentration in the wetland, wetland area, and for inorganic nitrogen also on 5-day-mean temperature. The production (*prodTP, g/d*) depends on a rate parameter, the concentration of the inflow to the wetland, wetland area, and a temperature function (30-day-mean temperature).

$$retIN = \frac{inpar \times INconc \times temp5 \times area}{1000.}$$

$$retTP = sedpar \times TPconc \times area$$

$$prodTP = uptpar \times TPin \times area \times teta^{\left(temp30 - tcoeff\right)}$$

Links to file reference

Parameter/Data	File
lrwet_area, lrwet_dep, lrwet_part	GeoData.txt
mrwet_area, mrwet_dep, mrwet_part	

Links to relevant modules in the code

Modules (file)	Procedures
npc_surfacewater_processes (npc_sw_proc.f90)	calculate_river_wetland
	calculate_wetland_np

References

Arheimer, B. and H.B. Wittgren, 2002. Modeling nitrogen removal in potential wetlands at the catchment scale, Ecol. Eng., 19: 63-80.

Tonderski, K.S., Arhemier, B. and Pers B.C., 2005. Modelling the Impact of Potential Wetlands on Phosphorus Retention in a Swedish Catchment, Ambio, 34(7): 544-551.

Irrigation

General principles

Irrigation constitutes a key water management activity in many parts of the world. Therefore, the HYPE model has a routine to simulate irrigation. The representation of irrigation in the model is based on a set of principles. Firstly, the irrigation water demand is assessed. Subsequently, the demanded water is withdrawn from the defined irrigation water sources. HYPE can either withdraw water from defined sub-basins in the model domain (subject to availability), or from unlimited sources outside the domain. Finally, the withdrawn water is applied onto the classes from which the demand originated. In addition, water losses between demand, withdrawal, and application are taken into account (for withdrawals within the model domain).

A class is irrigated if the crop type associated with it is irrigated (defined in GeoClass.txt). A crop is irrigated if the irrigation input variables in the CropData.txt file are defined and non-zero (*plantday, lengthini, kcbini, lengthdev, lengthmid, kcbmid, lengthlate, kcbend, dlref*). Irrigation also requires appropriate values in the MgmtData.txt file (*gw_part, regsrcid, irrdam, region_eff, local_eff, demandtype*) and the par.txt file (*pirrs, pirrg, sswcorr* etc.). See the File Reference for more details on each file and each parameter.

Irrigation water demand

The irrigation water demand ($W_{I,D}$) is calculated each day for each irrigated class (*j*) at the end of the soil water balance calculations. Two approaches to calculate $W_{I,D,j}$ are implemented in HYPE, one for submerged crops (e.g. paddy rice) and one for non-submerged crops. The input variables *imm_start* and *imm_end* in CropData.txt define (1) the beginning and end of the submerged season, and (2) if crops are submerged or not (zero is interpreted as a non-submerged crop).

Non-submerged crops

For non-submerged crops, the calculations are based on the FAO-56 crop coefficient methods (Allen et al., 1998). The dual crop coefficient method is used because it is more specific than the single crop coefficient method, and more suitable for daily water balance models. Since transpiration is of primary interest in estimating crop water demand, the irrigation routine focuses on estimating potential transpiration (T_P) with the basal crop coefficient (K_{CB}) and the reference potential crop

evapotranspiration (ET_0):

$$T_P = K_{CB} \square ET_0$$

ET0 follows the dynamics described above ($ET_0 = epot$ here following Wisser et al. (2008)). KCB depends on crop type and phenological stage, which is defined in CropData.txt. KCB is constant during the initial development stage, then increases linearly during the development stage until it reaches the mid-season stage during which it is again constant. Finally, K_{CB} decreases linearly from the end of the mid-season stage until the end of the season. The dynamics of ET_0 and K_{CB} produces a dynamic T_P profile (Figure 1). Allen et al. (1998) provide indicative values for K_{CB} (cf. their Table 17).

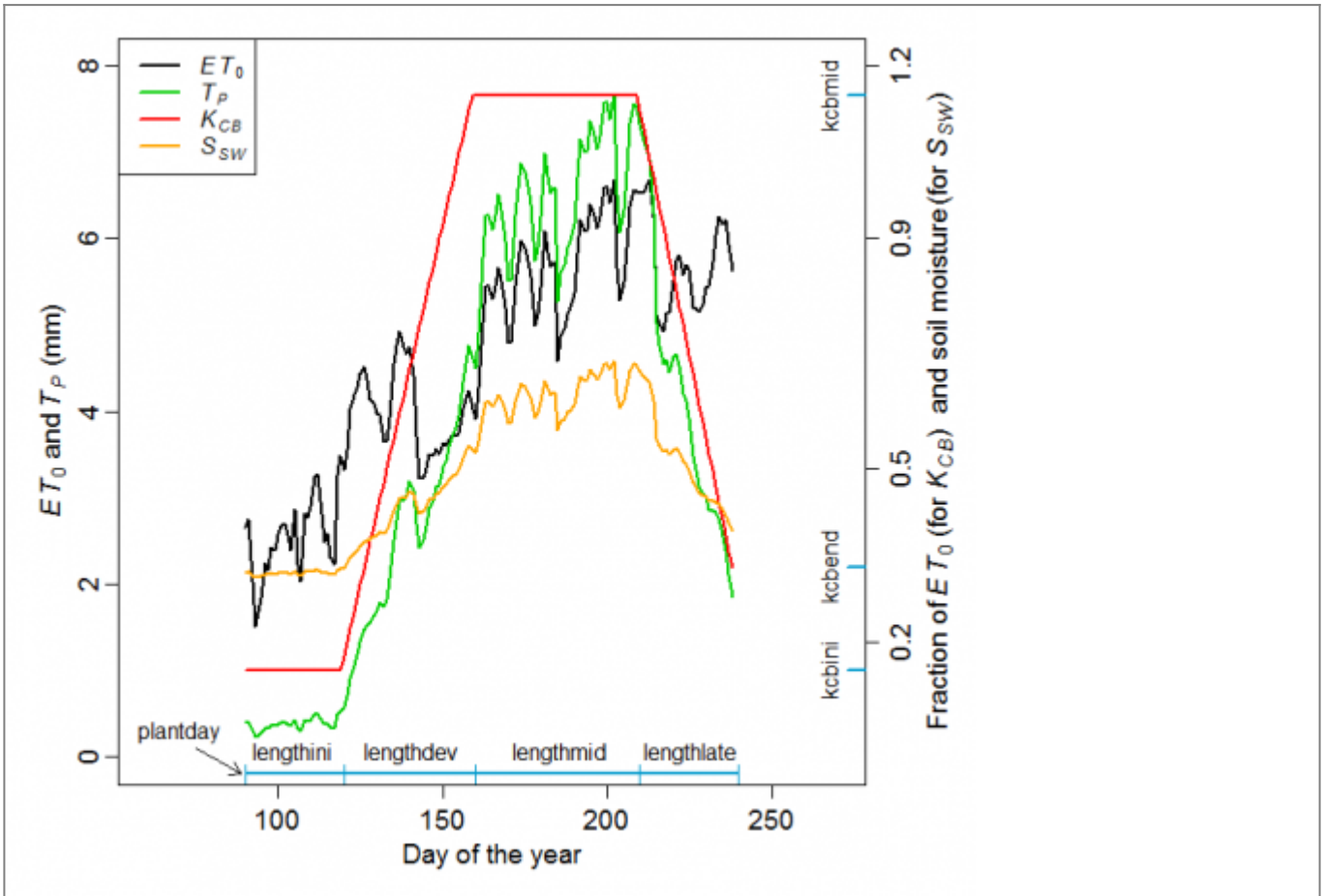


Figure 1 Illustration of ET_0, T_P, K_{CB}, and SSW for a typical maize crop on a medium coarse soil in southern Europe. Key input variables to define the K_{CB} profile are shown in blue.

On any given day, the model first calculates whether irrigation is needed, and then the amount required. The irrigation need is assessed by comparing the current soil water content (*H*) with a dynamic irrigation threshold (S_{SW}, the soil water stress threshold):

$$if\, H < \left(S_{SW} \square P_{SSWCORR} \square AWC \right) \rightarrow irrigate$$

H is the plant-available soil moisture (i.e. soil water above *wcwp1* and *wcwp2* in soil layers 1 and 2 respectively). *AWC* is the maximum plant-available water content in soil layers 1 and 2 (i.e. the sum of *fc1* and *fc2*). S_{SW} is a fraction of *AWC* (defined upwards from *wcwp*). Below S_{SW} the crop experiences water stress, creating a need for irrigation. S_{SW} varies from day to day and depends on the crop type and T_P:

$$S_{SW} = 1 - \left(DL_{ref} + 0.04 \cdot \left(5 - \frac{T_P}{0.95} \right) \right)$$

DL_{ref} is a crop-type specific reference depletion level (essentially the fraction of *AWC* that can be depleted before stress occurs, defined downwards from *wcfc*). Allen et al. (1998) provide indicative values for DL_{ref} (cf. their Table 22). The S_{SW} equation is a slightly modified form of the original FAO-56 equation to account for the fact that only T_P is used here. A typical S_{SW} profile is shown in Figure 3.1. By default, S_{SW} is limited to the range 0.2 – 0.9, but it can be further refined with the parameter $P_{SSWCORR}$ (*sswcorr* in par.txt) to maximum 1.

If irrigation is needed, the required irrigation amount ($W_{I,D,j}$) can be calculated with three alternative methods in HYPE (chosen by the demandtype variable in MgmtData.txt):

(1) A constant $W_{I,D,j}$ (defined by the *irrdemand* parameter in par.txt)

(2) Up to the field capacity: $W_{I,D,j} = AWC - H$

(3) Up to a defined fraction of S_{SW} ($P_{iwdfrac}$, *iwdfrac* in par.txt):

$$W_{I,D,j} = \min \left[\left(S_{SW} \cdot P_{SSWCORR} \cdot AWC - H \right) \cdot P_{iwdfrac}, \left(AWC - H \right) \right]$$

The fraction can be larger than 1. For example, to irrigate to a level 10% above S_{SW}, $P_{iwdfrac}$ =1.1. $W_{I,D,j}$ is, however, limited to AWC.

Submerged crops

The irrigation of submerged crops aims to satisfy a target flooding level above the soil surface (Wisser et al., 2008). The target flooding level is a constant input parameter ($P_{immdepth}$, *immdepth* in par.txt). Irrigation is required if the water level of the top soil layer (H1) falls below the target flooding level:

$$if\ H_1 < WP_1 + FC_1 + EP_1 + P_{immdepth} \rightarrow irrigate$$

The irrigation water demand is equal to the amount needed to reach the target flooding level:

$$W_{I,D,j} = WP_1 + FC_1 + EP_1 + P_{immdepth} - H_1$$

If the submerged season is shorter than the crop season, $W_{I,D}$ during the non-submerged period is calculated in the same way as for non-submerged crops. To maintain a desired flooding level and simulate terracing, for example, it may be necessary to adjust the soil and runoff parameters of the class with the submerged crops. When $W_{I,D,j}$ has been calculated for each irrigated class in the sub-basin, the total field-scale irrigation water demand for the sub-basin ($W_{I,D}$) is calculated:

$$W_{I,D} = \sum_{j=1}^{N} W_{I,D,j}$$

Irrigation water withdrawal

Irrigation water can be abstracted from a set of water sources (Figure 2). Within a given sub-basin, water can be abstracted from the olake, the ilake, the main river, and from groundwater in a deep aquifer. In addition, water can be withdrawn from the olake and the main river of another sub-basin. These sources can be used on their own or in combination. Alternatively, HYPE can withdraw water from an unlimited source outside the model domain. This is specified with the `irrunlimited` code word in info.txt, and applies to all irrigated sub-basins.

Withdrawals are calculated directly after the local discharge and the upstream discharge has been combined to flow into the main river of a given sub-basin.

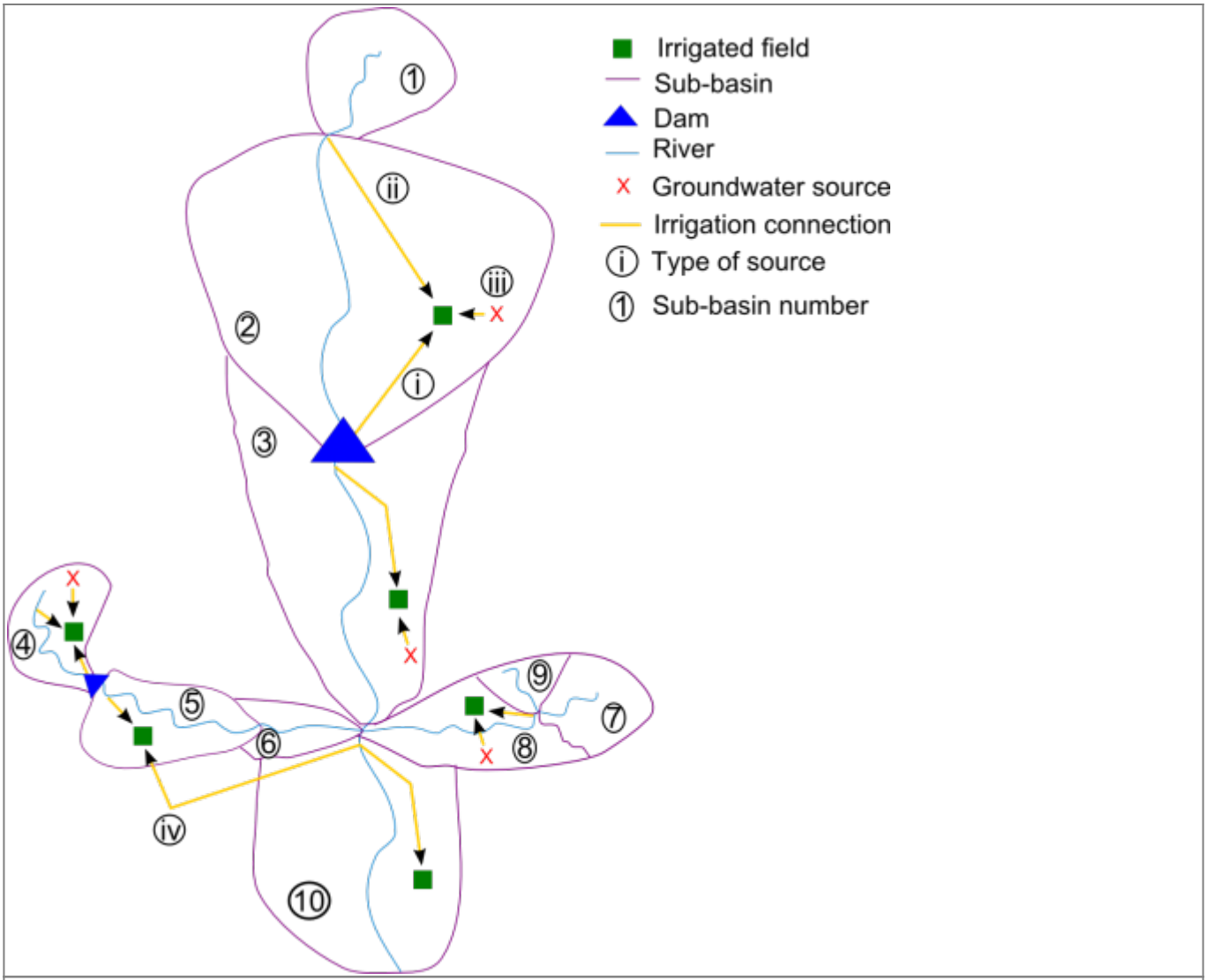


Figure 2: Schematic illustration of the available irrigation sources in HYPE. Irrigation water can be withdrawn from: (i) dams in the sub-basin (olake and ilake), (ii) the main river in the sub-basin, (iii) groundwater in a deep aquifer, and (iv) dams (olake) and main rivers in other sub-basins.

Irrigation inefficiencies within the sub-basin

Before any withdrawal occurs, the field-scale $W_{I,D}$ is scaled to sub-basin scale ($W_{L,D}$, the local sub-basin irrigation water demand). This is done in order to account for the often significant water losses between withdrawals and soil moisture replenishment. A simple user-provided scaling factor is applied:

$$W_{L,D} = \frac{W_{I,D}}{E_L}$$

The local efficiency (E_L, *local_eff* in MgmtData.txt) represents the fraction of the withdrawn water within the sub-basin that infiltrates the irrigated soil. E_L accounts for losses in irrigation canals, ponds etc. within the sub-basin, and for on-field losses from irrigation equipment (e.g. sprinkler systems). $W_{I,D}$ is not scaled if all withdrawals are from an unlimited source outside the model domain (i.e. $E_L = 1$ if `irrunlimited` is y).

Withdrawal from sources within the sub-basin

The model first attempts to withdraw water from sources within the sub-basin where the demand originated. The user specifies the proportion of water to be withdrawn from surface water and deep aquifer groundwater sources, respectively, in the MgmtData.txt file (*gw_part*). A *gw_part* value between 0 and 1 represents the long-term average proportion of surface and deep aquifer groundwater withdrawals for irrigation within the sub-basin. A *gw_part* value of 0 indicates that all irrigation water exclusively comes from surface water sources, while a *gw_part* value of 1 indicates that all irrigation water exclusively comes from deep aquifers. Based on *gw_part*, $W_{L,D}$ is split into the groundwater demand ($W_{L,D,g}$), and the surface water demand ($W_{L,D,s}$).

If any surface water demand exists, the model sequentially attempts to withdraw water from the olake, the ilake, and the main river. However, water withdrawal from olakes and ilakes is only calculated if the variable *irrdam* in MgmtData.txt is set to 1 for the sub-basin. Water withdrawals from the main river occur both from the inflow to the river reach and from the volume stored in the reach.

If the $W_{L,D,s}$ volume is available at the source, the demanded water is withdrawn. Otherwise, only the available volume (V_s) is withdrawn. The withdrawal can also be scaled with the user-defined parameter $P_{I,S}$ (*pirrs* in par.txt):

$$W_{L,A,s(1)} = \min\left(W_{L,D,s}, V_{s1}\right) \square P_{I,S}$$

$$W_{L,D,s2} = W_{L,D,s} - \frac{W_{L,A,s(1)}}{P_{I,S}}$$

where $W_{L,A,s(1)}$ is the abstracted water from the first surface water source in the sub-basin, and $W_{L,D,s2}$ is the residual surface water demand. The residual demands ($W_{L,D,s2}$ and below $W_{L,D,s,1}$, $W_{L,D,1}$ and $W_{R,D2}$) are calculated without the $P_{I,S}$ scaling in order to prevent erroneous source compensation due to scaling. If any demand remains, the next surface water source is probed in the same manner:

$$W_{L,A,s(2)} = \min\left(W_{L,D,s2}, V_{s2}\right) \square P_{I,S}$$

The total surface water withdrawal within the sub-basin ($W_{L,A,s}$), and the remaining surface water demand ($W_{L,D,s,1}$) is calculated accordingly, based on the abstractions from each source (k):

$$W_{L,A,s} = \sum_{k=1}^{N} W_{L,A,s(k)}$$

$$W_{L,D,s,l} = W_{L,D,s} - \frac{W_{L,A,s}}{P_{I,S}}$$

If any groundwater demand exists, the model withdraws a user-specified fraction of $W_{L,D,g}$ from an unlimited source outside the model domain or if an aquifer is simulated connected to the subbasin from this aquifer. The first case conceptually represents a large deep aquifer source, which is currently outside of the model domain. $W_{L,a,g}$ is the abstracted groundwater and $P_{I,G}$ (*pirrg* in par.txt) is the groundwater withdrawal fraction:

$$W_{L,A,g} = W_{L,D,g} \square P_{I,G}$$

To simulate a more dynamic conjunctive use of groundwater and surface water sources, the model allows for compensation of remaining surface water demands from the groundwater source. This compensation is only allowed if both groundwater and surface water sources are used (*0<gw_part<1*), and if the *irrcomp* parameter is >0. The *irrcomp* parameter defines the degree of compensation allowed, i.e. the fraction of the residual surface water demand which can be met through source compensation. The compensation algorithm is as follows: if any surface water demand remains ($W_{L,D,s,1} > 0$) and the groundwater is not depleted, the groundwater withdrawal cycle is calculated once more using the scaled residual surface water demand. Finally, after possible source compensation, the remaining (surface) water demand at the sub-basin scale ($W_{L,D,1}$) is calculated.

Withdrawal from another sub-basin

The model can also simulate withdrawal from another sub-basin in the model domain (D_R, defined with the *regsrcid* input variable in MgmtData.txt). This withdrawal is calculated when the model reaches D_R in the calculation order, after possible local irrigation water abstractions in D_R and only if any irrigation demand remains in the sub-basin(s) connected to the regional source ($W_{L,D,1} > 0$). For each connected sub-basin (i), $W_{L,D,l,i}$ is scaled to represent the regional-scale demand from that sub-basin ($W_{R,D,i}$). Again, a simple scaling factor is applied:

$$W_{R,D,i} = \frac{W_{L,D,l,i}}{E_{R,i}}$$

The regional efficiency ($E_{R,i}$, *region_eff* in MgmtData.txt) represents the fraction of the withdrawn water at the regional source that reaches the connected sub-basin. $E_{R,i}$ refers to the connected sub-basin. The regional scaling accounts for often significant water conveyance losses in large irrigation networks (in canals and dams etc.).

The total water demand from the regional source ($W_{R,D}$) is then calculated as the sum of the demand from each connected sub-basin, scaled by a parameter controlling the strength of the regional connection (P_{regirr}, *regirr* in par.txt):

$$W_{R,D} = \left(\sum_{i=1}^{N} W_{R,D,i} \right) \cdot P_{regirr}$$

The regional demand can be met from two sources in sub-basin D_R: the olake and the main river. If the regional source sub-basin has an olake, and if the *irrdam* input variable is set to 1 for that sub-basin, the model attempts to withdraw $W_{R,D}$ first from the olake and then the residual from the main river. If not, the model only attempts to withdraw $W_{R,D}$ from the main river. The regional abstraction ($W_{R,a}$) is limited by the volume available at the source (V_r) and the scaling parameter $P_{I,S}$:

$$W_{R,A1} = \min\left(W_{R,D}, V_{r1}\right) \cdot P_{I,S}$$

$$W_{R,D2} = W_{R,D} - \frac{W_{R,A1}}{P_{I,S}}$$

$$W_{R,A2} = \min\left(W_{R,D2}, V_{r2}\right) \cdot P_{I,S}$$

$$W_{R,A} = W_{R,A1} + W_{R,A2}$$

where $W_{R,A1}$ is the abstracted water from the first water source in D_R, V_{r1} the volume available at the first source, $W_{R,D2}$ the residual regional water demand after withdrawal from the first source (but prior to the $P_{I,S}$ scaling), $W_{R,A2}$ the abstracted water from the second water source in D_R, and V_{r2} the volume available at the second source.

Substance concentrations of irrigation water withdrawals

The concentrations of the withdrawn water are the same as that of the irrigation water source. If the water originates from several sources, the volume-weighted concentration is calculated. If desired, the model can simulate sedimentation tanks, in which a defined fraction of the particulate phosphorous (*pp*) and organic nitrogen (*on*) settles:

$$C_{a,pp} = C_{src,pp} \cdot \left(1 - P_{cirrsink}\right)$$

$$C_{a,on} = C_{src,on} \cdot \left(1 - P_{cirrsink}\right)$$

where $C_{,a}$ is the concentration of the abstracted water after settling, C_{src} is the concentration of the source, and $P_{cirrsink}$ is the concentration reduction fraction (*cirrsink* parameter in par.txt). To use sedimentation tanks in a region, the concentration reduction fraction needs to be set in par.txt ($0 < cirrsink \leq 1$).

Irrigation water application

In the calculation order, the irrigation water application occurs the next time step the model reaches the sub-basin from which the demand originated (typically the following day). The water is applied to the soils at the beginning of the soil balance calculations, before the calculation of the natural processes.

The regionally abstracted water ($W_{R,A}$) is first distributed to each connected sub-basin (i) according to their proportional demand, and then scaled to the local scale using the respective regional efficiency:

$$W_{R,A,i} = W_{R,A} \cdot \frac{W_{R,D,i} \cdot P_{regirr}}{W_{R,D}} \cdot E_{R,i}$$

For a given sub-basin, the total amount of abstracted water available at the local scale ($W_{L,A,i,tot}$) is calculated and then scaled, using the local efficiency, to represent the water applied to the soil ($W_{I,A,i}$):

$$W_{L,A,i,tot} = W_{L,A,i} + W_{R,A,i}$$

$$W_{I,A,i} = W_{L,A,i,tot} \cdot E_{L,i}$$

$W_{I,A,i}$ is then distributed onto each irrigated class in proportion to its water demand:

$$W_{I,A,j} = W_{I,A,i} \cdot \frac{W_{I,D,j}}{W_{I,D}}$$

$W_{I,A,j}$ is added to the soil water of class j as additional infiltration. $W_{I,A,j}$ is divided between the top two soil layers according to the epotdist function, beginning with the second layer. For unlimited irrigation: $W_{I,A,j} = W_{I,D,j}$, $P_{I,S} = 1$ and $P_{I,G} = 1$.

The water withdrawn from a regional source that does not reach connected sub-basins ($W_{R,L}$) evaporates at the regional source (D_R):

$$W_{R,L} = W_{R,A} - \sum_{i=1}^{N} W_{R,A,i}$$

Similarly, water losses due to local inefficiencies ($W_{L,L}$) evaporate within the sub-basin itself. This applies to local losses from abstractions both within the sub-basin and from the regional source (where applicable):

$$W_{L,L} = W_{L,A,i,tot} - W_{I,A,i}$$

Evaporation due to regional and local inefficiencies proportionally concentrates substances in the withdrawn water. The substance concentrations in the irrigation water applications are hence higher

than at the points of withdrawal (the mass remains the same while the volumes are reduced). However, if unlimited irrigation is simulated, the concentrations of the applied water are the same as in the layers to which water is added (i.e. causing no change in concentration).

Links to file reference

Section	Symbol	Parameter/Data	File
		cropid, reg	CropData.txt
		mgmttype=1, *subid*	MgmtData.txt
Irrigation water demand		*imm_start, imm_end*	CropData.txt
Non-submerged crops		*demandtype*	MgmtData.txt
	K_{CB} calculated from:	*plantday, lengthini, kcbini, lengthdev, lengthmid, kcbmid, lengthlate, kcbend*	CropData.txt
	DL_{ref}	*dlref*	
	$P_{SSWCORR}$	*sswcorr*	par.txt
	$P_{iwdfrac}$	*iwdfrac*	
	AWC	*wcfc1+wcfc2*	
Submerged crops	WP_1, FC_1, EP_1	*wcwp1, wcfc1, wcep1*	par.txt
	$P_{immdepth}$	*immdepth*	
Irrigation water withdrawal		*irrdam, gw_part*	MgmtData.txt
		irrunlimited	info.txt
	$P_{I,S}$	*pirrs*	par.txt
Irrigation inefficiencies within the sub-basin	$E_L, E_{L,i}$	*local_eff*	MgmtData.txt
Withdrawal from sources within the sub-basin		*irrcomp*	par.txt
	$P_{I,G}$	*pirrg*	
Withdrawal from another sub-basin	D_R	*regsrcid*	MgmtData.txt
	$E_{R,i}$	*region_eff*	
	P_{regirr}	*regirr*	par.txt
Substance concentrations of irrigation water withdrawals	$P_{cirrsink}$	*cirrsink*	par.txt

Links to relevant procedures in the code

Modules (file)	Procedures	Section
irrigation_module (irrigation.f90)	calculate_irrigation	irrigation water withdrawal
		irrigation water application
	apply_irrigation	irrigation water application
	irrigation_abstraction_sink	substance concentrations of irrigation water withdrawals
	calculate_irrigation_water_demand	irrigation water demand
	calculate_kcb	
	irrigation_season	
	immersion_season	

References

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith 1998. Crop Evapotranspiration (guidelines for computing crop water requirements), FAO Irrigation and Drainage Paper, No. 56, FAO, Rome, Italy, 300 pp.

Wisser, D., S. Frolking, E.M. Douglas, B.M. Fekete, C.J. Vörösmarty, and A.H. Schumann, 2008. Global irrigation water demand: Variability and uncertainties arising from agricultural and climate data sets, Geophysical Research Letters, Vol. 35, L24408, doi:10.1029/2008GL035296, 5 pp.

Point sources

Information on point sources is located in the file PointSourceData.txt.

Nutrient point sources

The model can handle up to three different types of point sources. They can used to simulate e.g. treatment plants, stormwater outlets, and industrial sources as separate types. All point sources have a constant flow, concentrations of total nitrogen and phosphorus, and fractions of IN and SP for a period of time. The time may be the whole simulation period, or different sources may be active during different parts of the simulation period. Point sources are added to the water in the main river.

Tracer T2 (water temperature) point sources

Water temperature may be added to the flow of nutrient point sources if T2 is simulated together with N and P. Water temperature point source may also be added on its own in the same way as nutrient point sources.

Tracer T1 point sources

Tracer T1 point source may be added in the same way as nutrient point sources. In addition, point sources of tracer T1 can be added to the local stream, the local lake, the main river or the outlet lake.

Negative point source

A point source with negative flow denotes an abstraction of water. The abstraction of water can be made from three different points in the river network. The default is to remove it from the main river volume (including the queue) after all river processes have been calculated except outflow from the river. Alternatives are to abstract the water from the outlet lake volume or from the main river inflow from upstream and from the river volume (and queue) proportionally. In the latter case the removal is done before any inflow to the main river is added (e.g. from upstream, point sources, or precipitation). The water is removed from the source, while the concentration is kept.

Links to file reference

Section	Parameter/Data	File
Nutrient point sources	*subid, ps_vol, ps_type, ps_tpconc, ps_tnconc, ps_infrac, ps_spfrac, fromdate, todate*	PointSourceData.txt
Tracer T2 (water temperature) point sources	*subid, ps_vol, ps_type, ps_t2, fromdate, todate*	
Tracer T1 point sources	*pstype=0*	
	subid, ps_vol, ps_t1, fromdate, todate, ps_source	
Negative point source	*subid, ps_vol, fromdate, todate, ps_source*	

Links to relevant procedures in the code

Modules (file)	Procedures
datamodule (data.f90)	load_pointsourcedata
	read_pointsourcedata
	get_current_pointsources
npc_surfacewater_processes (npc_sw_proc.f90)	add_point_sources_to_main_river
surfacewater_processes (sw_proc.f90)	point_abstraction_from_main_river
	point_abstraction_from_outlet_lake
tracer_processes (t_proc.f90)	add_tracer_point_source_to_river
	add_tracer_point_source_to_lake

Water transfer

Water transfer can be simulated by HYPE in different ways. One way is to represent abstraction by defining negative point source discharge. Another method is to use the bifurcation functionality that defines a branch through which the water is transferred to a downstream receiving subbasin. A third way is to define water transfer through water management (abstracting from subbasins with outlet lakes and transferring to any other subbasin). The negative point source method has the disadvantage that the water transfer is constant and with fixed concentrations specified by the user (although you can let it be constant at different values for different periods), but the abstraction can be located at different points throughout the catchment. The bifurcation method has the limitation that the receiving subbasin must be downstream. The management method can only take water from an outlet lake, and the water transfer will be delayed one time step. In all methods, the amount of water available on any given day will limit the amount that can be withdrawn or transferred.

Water transfer through bifurcation

Water transfer through bifurcation lets you divert a part of the outflow from a subbasin through a branch to another downstream subbasin specified in BranchData. The flow diverted may be defined by BranchData parameters (fraction, max-, or minflow). The water transfer can alternatively be given as a recorded time series of demanded water transfer (given as dwtr in Xobs). This water will then be taken from the ordinary simulated outflow of the subbasin if there is enough flow, the remaining flow will go through the main channel. A third method, if you have an outlet lake, is to use two outlets. The flow of outlet 2 can be defined as the flow given by dwtr.

See also the general description of bifurcations and Outlet lake with two outlets.

Water transfer through negative point source

Abstraction of water can be defined as a negative point sources. The abstracted water is constant (although it can be constant at different values for different periods), and thus the same amount of water is removed from the model every time step. The abstraction can be made from different points in the river network within the subbasin. The water is removed while the concentration is kept in the water remaining in the river. To simulate water transfer within the model domain, the same amount of water need to be added as a (positive) point source in another subbasin. This subbasin do not have to be downstream, since its (constant) flow and concentrations is defined in the file beforehand. However, there is no direct connection between the subbasins in which water is abstracted and released, respectively. In order to preserve the water balance, the user must define equally large flows abstracted and added. Since the concentration of the negative point source is defined in the file beforehand, the connection to the quality of the water abstracted water is not automatically preserved.

Water transfer through water management

Water transfer between two subbasins can be defined through water management (MgmtData.txt) if the source is an outlet lake. The source subid and subid of the receiving subbasin is defined together with a constant flow. The water is taken from the outlet lake of the source subbasin and is given the concentration of the lake. The water is then transported to the other subbasin's main river and arrive there the next time step. The delay in flow is necessary to handle transfer upstream within a catchment. Several water transfer can be specified for the same source or recieving subbasin.

Alternatively a demanded flow time series from Xobs can be used instead of a constant flow. In this case only one water transfer can be specified for each source lake.

Links to file reference

Section	Parameter/Data	File
Water transfer through bifurcation	*ALL*	BranchData.txt
	ldtype=5 and 6	LakeData.txt
	lakeid, rate, exp, deltaw0, qprod1, qprod2, datum1,datum2, qamp, qpha, regvol, maxQprod, minflow, obsflow	
	dwtr	Xobs.txt
Water transfer through negative point source	*ps_vol, fromdate, todate, ps_source*	PointSourceData.txt
Water transfer through water management	*mgmttype=2*	MgmtData.txt
	subid, receiver, flow	
	dwtr	Xobs.txt

Links to relevant procedures in the code

Modules (file)	Procedures	Section
datamodule (data.f90)	load_pointsourcedata	negative point source
	load_management_data	water management
npc_surfacewater_processes (npc_sw_proc.f90)	add_point_sources_to_main_river	negative point source
surfacewater_processes (sw_proc.f90)	calculate_outflow_from_outlet_lake	bifurcation
	point_abstraction_from_main_river	negative point source
	add_point_sources_to_main_river	
	point_abstraction_from_outlet_lake	
	add_water_transfer_to_main_river	water management
	water_transfer_from_outlet_lake	