Supplement of Hydrol. Earth Syst. Sci. Discuss., 12, 4997–5053, 2015
http://www.hydrol-earth-syst-sci-discuss.net/12/4997/2015/
doi:10.5194/hessd-12-4997-2015-supplement

Hydrology and Earth System Sciences
Open Access
Discussions

Supplement of

Integrated water system simulation by considering hydrological and biogeochemical processes: model development, parameter sensitivity and autocalibration

Y. Y. Zhang et al.

Correspondence to: Y. Y. Zhang (zhangyy003@igsnrr.ac.cn)

Supplementary material

1. Soil P cycle simulation (Neitsch *et al.*, 2011)

Mineralization: The mineralized P is added to solution P pool. The amount of active and stable organic P are calculated as

$$\begin{cases} orgP_{act} = orgP_{hum} \cdot orgN_{act} / (orgN_{act} + orgN_{sta}) \\ orgP_{sta} = orgP_{hum} \cdot orgN_{sta} / (orgN_{act} + orgN_{sta}) \end{cases} \quad \text{(S1)}$$

where $orgP_{act}$ and $orgP_{sta}$ are the amounts (kg/ha) of P in active organic pool and stable organic pool, respectively; $orgP_{hum}$ is the humic organic P in the layer (kg/ha); $orgN_{act}$ and $orgN_{sta}$ are the amounts of N in active organic pool and stable organic pool (kg/ha), respectively, which are simulated by DNDC.

The mineralized rate of humus active organic P pool (*RHP*) is calculated by

$$RHP = 1.4 \cdot \beta_{\min} \cdot (\gamma_{tmp} \cdot \gamma_{SW})^{1/2} \quad \text{(S2)}$$

where $\beta_{\min}$ is the mineralization rate of humus active organic P; γ_{tmp} and γ_{SW} are reduction factors of soil temperature and moisture.

The mineralized of the residue fresh organic P pool (*RRP*) is calculated as

$$\begin{cases} RRP = 0.8 \cdot \delta_P \\ \delta_P = \beta_{rsd} \cdot \gamma_P \cdot (\gamma_{tmp} \cdot \gamma_{SW})^{1/2} \end{cases} \quad \text{(S3)}$$

where δ_P and β_{rsd} are the residue decay rate and the mineralization rate of residue fresh organic P. γ_P is the P cycling residue composition factor.

Decomposition: The decomposition rate of the residue fresh organic P pool (*DRP*) is

$$DRP = 0.2 \cdot \delta_P \quad \text{(S4)}$$

Sorption: The P movement between soluble and active mineral pools ($P_{sol|act}$, kg/ha) and between active and stable mineral pools ($P_{act|sta}$, kg/ha) are

$$P_{sol|act} = \begin{cases} P_{sol} - \min P_{act} \cdot pai/(1-pai) & if \quad P_{sol} > \min P_{act} \cdot pai/(1-pai) \\ 0.1 \cdot [P_{sol} - \min P_{act} \cdot pai/(1-pai)] & if \quad P_{sol} < \min P_{act} \cdot pai/(1-pai) \end{cases} \quad \text{(S5)}$$

and

$$P_{act|sta} = \begin{cases} 0.0006 \cdot (4 \cdot \min P_{act} - \min P_{sta}) & if \quad \min P_{sta} < 4 \cdot \min P_{act} \\ 0.00006 \cdot \beta_{eqP} \cdot (4 \cdot \min P_{act} - \min P_{sta}) & if \quad \min P_{sta} > 4 \cdot \min P_{act} \end{cases} \quad \text{(S6)}$$

respectively, where P_{sol}, $minP_{act}$ and $minP_{sta}$ are soluble, mineral active and stable P (kg/ha), respectively; *pai* is P availability index.

2. Crop growth module

2.1 Crop yield (Williams *et al.*, 1989)

The crop growth process depends on the accumulation of daily heat (Sharpley and Williams, 1990). The accumulated heat (HU, ^{o}C) during a day and heat unit index (HUI) is calculated as:

$$\begin{cases} HU_K = (T_{mx,K} + T_{mn,K})/2 - T_{b,j} \\ HUI_i = \sum_{K=1}^{i} HU_K \Big/ PHU_j \end{cases} \quad \text{(S7)}$$

where $T_{mx,K}$ and $T_{mn,K}$ are the maximum and minimum temperatures (^{o}C) on the kth day, respectively; $T_{b,j}$ is the base temperature of the jth crop (^{o}C). PHU_j is the potential heat unit required for the jth crop maturity (^{o}C). The range of *HUI* is from 0.0 at the seeding time to 1.0 at the physiological maturity. *i* is the total days of crop growth.

The potential increased biomass for a day is estimated as follow:

$$\begin{aligned} \Delta B_{p,i} &= 0.001 \cdot BE_i \cdot PAR_i \cdot [1 + \Delta HRLT_i]^3 \\ &= 0.0005 \cdot BE_i \cdot RA_i \cdot [1 - \exp(-0.65 \cdot LAI)] \cdot [1 + \Delta HRLT_i]^3 \end{aligned} \quad \text{(S8)}$$

where ΔB_p is daily potential increased biomass (t/ha); *BE* is crop parameter for converting energy to biomass (kg·ha·m^2/MJ); *HRLT* and $\Delta HRLT$ are length of a day (hr) and its variation (hr/d); *PAR* is intercepted photosynthetic active radiation (MJ/m^2). *RA* is solar radiation (MJ/m^2) and *LAI* is leaf area index (m^2/m^2), which is a function of heat units, crop stress, and crop development stages.

From emergence to the start of leaf decline, *LAI* is estimated with the equation:

$$\begin{aligned} LAI_i &= LAI_{i-1} + \Delta LAI \\ &= LAI_{i-1} + (\Delta HUF)(LAI_{mx})(1 - \exp(5 \cdot (LAI_{i-1} - LAI_{mx}))) \cdot \sqrt{REG_i} \end{aligned} \quad \text{(S9)}$$

From the start of leaf decline to the end of the growing season,

$$LAI_i = LAI_0 \cdot \left(1 - HUI_i / 1 - HUI_0\right)^{ad_j} \quad \text{(S10)}$$

where *HUF* is heat unit factor. *REG* is minimum crop stress factor. *Ad* is a parameter controlled *LAI* decline rate for crop *j* and HUI_0 is *HUI* value when *LAI* begins to decline.

But the biomass growth is constrained by water, temperature, nutrient and aeration.

$$\Delta B = \Delta B_p \cdot REG = \Delta B_p \cdot \min(WS, TS, SN, SP, AS) \quad \text{(S11)}$$

where *REG* is the crop growth regulating factor.

The water stress: $WS_i = \sum_{l=1}^{M} u_{i,l} \Big/ E_{P,i}$ (S12)

The temperature stress: $TS_i = \sin[\pi \cdot (T_{g,i} - T_{b,j}) / 2(T_{o,j} - T_{b,j})] \quad 0 \le TS_i \le 1$ (S13)

The nitrogen stress: $\begin{cases} SN_{S,i} = 2[1 - \sum_{K=1}^{i} UN_K \Big/ (c_{NB,i} \cdot B_i)] \\ SN_i = 1 - SN_{S,i} / [SN_{S,i} + \exp(3.39 - 10.93 SN_{S,i})] \end{cases}$ (S14)

The phosphorus stress: $\begin{cases} SP_{S,i} = 2[1 - \sum_{K=1}^{i} UP_K \Big/ (c_{NP,i} \cdot B_i)] \\ SP_i = 1 - SP_{S,i} / [SP_{S,i} + \exp(3.39 - 10.93 SP_{S,i})] \end{cases}$ (S15)

The aeration stress: $\begin{cases} SAT = SW1 / PO1 - CAF_j \\ AS_{S,i} = 1 - SAT / [SAT + \exp(-1.291 - 56.1 \cdot SAT)] \quad SAT > 0.0 \end{cases}$

(S16)

where T_g and T_0 are average daily soil surface temperature and the optimal temperature (°C) for crop *j*, respectively; *SAT* is saturation factor; *SW1* and *PO1* are water moisture and porosity of the top 1m of soil (mm) , respectively; *CAF* is critical aeration factor for crop *j*; *AS* is aeration stress factor.

The crop yield is estimated using the harvest index, viz.:

$$YLD_j = HI_j \cdot B_{AG} \quad \text{(S17)}$$

where *YLD* is total amount yield harvested from the field (t/ha), and *HI* is harvest index; *BAG* is the above-ground biomass (t/ha). For non-stressed conditions, harvest index increases nonlinearly from zero at seedling to *HI* at maturity. Affected by water stress, the harvest index is calculated as following.

$$HIA_i = HIA_{i-1} - HI_j \cdot WSYF_j \cdot FHU_i \cdot (0.9 - WS_i) / [1 + WSYF_j \cdot FHU_i \cdot (0.9 - WS_i)] \quad \text{(S12)}$$

where HI_j is normal harvest index of crop *j*; *HIA* is adjusted harvest index; $WSYF_j$ is sensitivity parameter of harvest index to draught for crop *j*; *FHU* is a function of crop growth stage. The crop growth stage function is calculated as

$$FHU_i = \begin{cases} \sin[\pi \cdot (HUI_i - 0.3)/0.6] & 0.3 \le HUI_i \le 0.90 \\ 0. & HUI_i < 0.3, HUI_i > 0.9 \end{cases} \quad \text{(S18)}$$

2.2 Water use

The potential water use from surface soil to any root depth is calculated as

$$U_{p,i} = E_{p,i} \cdot [1 - \exp(-\Lambda \cdot Z / RZ)] / [1 - \exp(-\Lambda)] \quad \text{(S19)}$$

The potential water use ($U_{p,l}$, mm/day) in layer *l* is calculated by taking the difference between $U_{p,i}$ values at the layer boundaries, viz.,

$$U_{p,l} = E_{p,i} \cdot [\exp(-\Lambda \cdot Z_{l-1} / RZ) - \exp(-\Lambda \cdot Z_l / RZ))] / [1 - \exp(-\Lambda)] \quad \text{(S20)}$$

where *UP* is the total water used to depth *Z* m on day *i* (mm); *RZ* is the root zone depth (m); Λ is a water use distribution parameter.

Restricted by soil water content, the potential water use (U_l, mm/day) in layer *l* is calculated with the following equations when soil water content is less than 25% of plant available soil water (Jones and Kiniry, 1986).

$$U_l = \begin{cases} U_{p,l} \cdot \exp[20 \cdot (SW_{l,i} - WP_l)/(FC_l - WP_l) - 1] & \text{if } SW_{l,i} < (FC_l - WP)_l / 4 + WP_l \\ U_{p,l} & \text{if } SW_l \ge (FC_l - WP_l)/4 + WP_l \end{cases} \quad \text{(S21)}$$

2.3 Nutrient uptake

The daily crop nutrient uptake (*N* and *P*) is the difference between crop nutrient demand and ideal nutrient content for day *i*.

$$\begin{cases} UND_i = c_{NB,i} \cdot B_i - \sum_{K=1}^{i} UN_K \\ UPD_i = c_{PB,i} \cdot B_i - \sum_{K=1}^{i} UP_K \end{cases} \tag{S22}$$

where *UND* and *UNP* are *N* and *P* uptake amounts, rescpetively (kg/ha); *UN* and *UP* are the actual uptakes of *N* and *P* , rescpetively (kg/ha); c_{NB} and c_{NP} are the optimal *N* and *P* concentrations of the crop, rescpetively (kg/t); *B* is the accumulated biomass for day *i* (t/ha).

The soluble N (NO_3-N and NH_4-N) mass flow to the roots is used to distribute potential *N* uptake among soil layers.

$$\begin{cases} UN_{l,i} = u_{l,i} \cdot (WN_l / SW_l)_i \\ UNS_i = \sum_{K=1}^{M} UN_{l,i} \end{cases} \tag{S23}$$

where *WN* is NO_3^-N or NH_4-N amount in the soil (kg/ha). The total N available for uptake by mass flow *UNS* is estimated by summing *UN* of all layers.

The total *P* available for uptake is calculated using the equation.

$$\begin{cases} UPS_i = 1.50 \cdot UPD_i \cdot \sum_{l=1}^{M} LF_{u,l} \cdot (RW_l / RWT_i) \\ LF_{u,l} = 0.1 + 0.9 \cdot c_{LP,l} / [c_{LP,l} + 117 \cdot \exp(-0.283 \cdot c_{LP,l})] \end{cases} \tag{S24}$$

where *UPS* is the amount of *P* supplied by soil (kg/ha); *RW* and *RWT* are the root weights in layer *l* and in total, rescpetively (kg/ha); LF_u is the labile *P* factor for uptake (g/t).

A portion of uptake *N* will be fixed by legumes, viz.,

$$\begin{cases} WFX_i = FXR_i \cdot UND_i \qquad WFX \le 6.0 \\ FXR = \min(1.0, FXW, FXN) \cdot FXG \end{cases} \tag{S25}$$

where *FXG* is the growth stage factor; *FXW* and *FXN* are the factors of soil water and NO_3-*N*, respectively. All of these factors are calculated using the follow equations.

$$FXG_i = \begin{cases} 0.0 & HUI_i \le 0.15, HUI_i \ge 0.75 \\ 6.67 HUI_i - 1.0 & 0.15 < HUI_i \le 0.3 \\ 1.0 & 0.3 < HUI_i \le 0.55 \\ 3.75 - 5.0 HUI_i & 0.55 < HUI_i < 0.75 \end{cases} \tag{S26}$$

$$FXW_i = (SW_{0.3,i} - WP_{0.3}) / 0.85 \cdot (FC_{0.3} - WP_{0.3}) \quad SW_{0.3} < 0.85(FC_{0.3} - WP_{0.3}) + WP_{0.3} \quad \text{(S27)}$$

$$FXN_i = \begin{cases} 0.0 & WNO_3 > 300 kg \cdot ha^{-1} \cdot m^{-1} \\ 1.5 - 0.005 \cdot WNO_3 / RD & 100 < WNO_3 \leq 300 \\ 1.0 & WNO_3 \leq 100 \end{cases} \quad \text{(S28)}$$

where $SW_{0.3}$, $WP_{0.3}$ and $FC_{0.3}$ are the water contents in the top 0.3 m soil, at wilting point and field capacity (mm), respectively.

3. Soil erosion module (Onstad and Foster, 1975)

The soil erosion by precipitation is estimated using the improved USLE equation (Onstad and Foster, 1975), viz.,

$$Y = \begin{cases} (0.646EI + 0.45Q \cdot q_p{}^{0.333}) \cdot K \cdot CE \cdot PE \cdot LS & Q > 0. \\ 0 & Q = 0. \end{cases} \quad \text{(S29)}$$

where Y is the sediment yield (t/ha); Q is runoff volume (mm); q_p is peak runoff rate (mm/hr); K is soil erodibility factor determined by the soil type; PE is erosion control practice factor.

LS is the factor of slope length and steepness:

$$\begin{cases} LS = (\lambda / 22.1)^{\xi} (65.41S^2 + 4.56S + 0.065) \\ \xi = 0.6 \cdot [1 - \exp(-35.835S)] \end{cases} \quad \text{(S30)}$$

CE is the crop management factor:

$$CE = (0.8 - CE_{mn,j}) \exp(-0.00115CV) + CE_{mn,j} \quad \text{(S31)}$$

EI is the rainfall energy factor:

$$EI = R \cdot [12.1 + 8.9 \cdot (\log r_p - 0.434) \cdot r_{0.5}] / 1000 \quad \text{(S32)}$$

where S and λ are the land surface slope (m/m) and slope length (m), both of which are obtained during the procedure of preparing the spatial simulation units; ξ is a parameter dependent upon slop; $CE_{mn,j}$ is the minimum crop management factor of crop j; CV is soil cover (above ground biomass and residue) (kg/ha). R is daily rainfall amount (mm) and r_p, $r_{0.5}$ is the peak rainfall rate and maximum 0.5 h rainfall intensity (mm/hr). The value of r_p is obtained according to the exponential rainfall distribution.

4. Overland water quality module

4.1 Nutrient loss in urban and rural area

Generally, the inhabitant and industrial sewage in the urban area are collected, treated and discharged into river network from urban wastewater discharge outlets. Thus, this amount of nutrient flux is the input to the model directly as the point source pollutant load. The nonpoint source nutrient loss in urban area takes place along the overland flow and is estimated using the export coefficient model (Johnes, 1996).

$$V_{ur\_N} = 100 \cdot c_{ur\_N} \cdot Area_{urban} \qquad \text{(S33)}$$

where V_{ur_N}, c_{ur_N} and $Area_{urban}$ are the amount of nutrient loss in urban area (kg); the export coefficient (kg/ha/year) and urban area (km^2), respectively.

The farm manure of rural living and livestock farming is also considered as one of important nonpoint source of nutrient due to the deficiency of sewage treatment facilities in the rural area. The total loss is estimated using the following equations.

$$\begin{cases} V_{liv\_N} = c_{liv\_N} \cdot Pop_{rural} \\ V_{lst\_N} = c_{lst\_N} \cdot Pop_{stock} \end{cases} \qquad \text{(S34)}$$

where V_{liv_N} and V_{lst_N} are the amount of nutrient loss from living and livestock farming in the rural area, respectively (kg/year). c_{liv_N} and c_{lst_N} are the export coefficient of living (kg/day/person) and livestock (kg/day/animal), respectively; Pop_{rural} and Pop_{stock} are the population and the animal stock, respectively.

4.2 Nutrient loss of soil layer

The loss of soluble nutrient is considered to happen in both upper and lower layer of soil. The loss weight of NO_3^-N, NH_4-N and soluble P are calculated using the equation (Williams *et al.*, 1989), respectively.

$$\begin{cases} V_{N\_up} = W_{N\_up} \cdot [1 - \exp(-\frac{R_s + R_{ss}}{UL})] \\ V_{N\_low} = W_{N\_low} \cdot [1 - \exp(-\frac{R_g}{UL})] \end{cases} \quad \text{(S35)}$$

where W_{N_up} and W_{N_low} are the soluble nutrient weight in the upper and lower soil layer, respectively (kg/ha); *UL* is maximum soil water content (mm); V_{N_up} and V_{N_low} is soluble nutrient loss in the upper and lower soil layer, respectively (kg/ha); *Rs* and *Rss* are surface runoff, and interflow (mm), respectively, which are obtained from the hydrological cycle module.

The amount of insoluble nutrients migrated with the sediment is estimated using the equation (Neitsch *et al.*, 2011)

$$Y_{ON} = 0.001 \cdot Y \cdot c_{ON} \cdot ER \quad \text{(S36)}$$

where Y_{ON} is loss of organic *N* or *P* (kg/ha); c_{ON} is insoluble nutrient concentration in the soil layer (g/m^3); *ER* is enrich ratio.

4.3 Overland migration (Neitsch *et al.*, 2011)

$$N_{overl} = (N'_{overl} + N_{stor,i-1}) \cdot \left[1 - \exp(-T_{retain}/T_{route})\right] \quad \text{(S37)}$$

where N_{overl} is the overland pollutant discharged into main channel including sediment (tons), soluble and insoluble nutrient (kg); N'_{overl} and $N_{stor,i-1}$ are pollutant load generated in the subbasin, pollutant retained from the previous day (tons for sediment, kg for nutrient), respectively. T_{retain} and T_{route} are the retain time and routing time of flow(days), respectively.

5. Water quality module of water bodies

The basic equation of in-stream water quality module (Brown and Barnwell 1987) is

$$dC/dt = -(R_d + R_{set}) \cdot C + \sum S_{out} \quad \text{(S38)}$$

where C is the pollutant concentration (mg/L); K_d and K_{set} are degradation and settling coefficient of pollutant (day^{-1}), respectively; and $\sum S_{out}$ is the external source items (mg/L/day).

The equation of water quality module of water impounding is as follow.

$$\begin{cases} dh/dt = [Q_{in} - Q_{out}]/A + P - E \\ dC_L/dt = [C_{in}Q_{in} - C_L Q_{out}]/Ah - K_{set}C_L - K_d C_L + K_{scu}C_s \cdot d/h \\ dC_s/dt = h/d \cdot K_{set}C_L - K_{scu}C_s - K_{bur}C_s \end{cases} \quad \text{(S39)}$$

where h and d are water and sediment depth (m), respectively; Q_{in} and Q_{out} are inflow and outflow (m^3/s), respectively; C_{in} and C_{out} are pollutant concentration into and out of the water body (mg/L); P and E are precipitation and evapotranspiration (m/s); C_L and C_s are constituent concentration in the water body and the sediment (mg/L); K_{scu} and K_{bur} are resuspension and decay coefficient of pollutant in the sediment (day^{-1}), respectively; A is water surface area (km^2).

Table S1. All the parameters in the extended model

ID	Variables	Definition	Unit	Affected components
Subbasin parameters				
1	W_m	Minimum water content of soil	none	flow
2	Ww	Wilting water content of soil	none	flow
3	W_{fc}	Field capacity of soil	none	flow
4	$W_{sat,u}$	Saturated moisture capacity of upper soil layer	none	flow
5	$W_{sat,l}$	Saturated moisture capacity of lower soil layer	none	flow
6	g_1	Basic surface runoff coefficient	none	flow
7	g_2	Influence coefficient of soil moisture	none	flow
8	K_{ET}	Adjustment factor of evapotranspiration	none	flow
9	K_r	Interflow yield coefficient	none	flow
10	T_g	Delay time for aquifer recharge	day	flow
11	K_g	Baseflow yield coefficient	none	flow
12	K_{sat}	Steady state infiltration rate of soil	mm/hr	flow
13	kf_{mx}	Ratio of state infiltration rate to maximum rate in soil	none	flow
14	*DtoW*	Ratio of width to depth of channel	none	flow
15	*rch_k*	Infiltration rate of channel	mm/hr	sediment
16	*ch_cov*	Channel cover factor	none	sediment
17	*ch_erod*	Channel erodibility factor	cm/hr/Pa	sediment
18	R_{set}(algae)	Algae settling rate at 20 ^{0}C	mg/day	algae
19	R_{set}(solP)	Soluble P settling rate at 20 ^{0}C	mg/m^2/day	P
20	R_{set}(NH_4)	Settling rate of NH_4-N at 20 ^{0}C in channel	mg/m^2/day	N
21	R_{set}(orgN)	Settling rate of organic N at 20 ^{0}C in channel	day^{-1}	N
22	R_{set}(orgP)	Settling rate of organic P at 20 ^{0}C in channel	day^{-1}	P
23	R_d(COD)	COD deoxygenation rate at 20 ^{0}C in channel	day^{-1}	COD
24	Rch_k_1	Reaeration coefficients at 20 ^{0}C in channel	day^{-1}	DO
25	R_{set}(COD)	COD settling rate at 20 ^{0}C in channel	day^{-1}	COD
26	Rch_k_2	DO adsorption rate of sediment at 20 ^{0}C in channel	day^{-1}	DO
27	R_d(NH_4)	Bio-oxidation rate of NH_4-N at 20 ^{0}C in channel	day^{-1}	N
28	R_d(NO_2)	Oxidation rate of NO_2-N to NO_3-N at 20 ^{0}C in channel	day^{-1}	N
29	R_d(orgN)	Hydrolysis rate of organic N to NH_4-N at 20 ^{0}C in channel	day^{-1}	N
30	R_d(orgP)	Hydrolysis rate of organic P to soluble P at 20 ^{0}C in channel	day^{-1}	N
31	*CtoB*	Relationship between COD and BOD	none	COD
32	*res_k*	Infiltration rate in reservoir or sluice	mm/hr	flow
33	K_{set}(COD)	Settling rate of COD at 20 ^{0}C in reservoir or sluice	m/year	COD
34	K_{set}(NH_4)	Settling rate of NH_4-N at 20 ^{0}C in reservoir or sluice	m/year	N
35	K_{set}(NO_2)	Settling rate of NO_2-N at 20 ^{0}C in reservoir or sluice	m/year	N
36	K_{set}(NO_3)	Settling rate of NO_3-N at 20 ^{0}C in reservoir or sluice	m/year	N
37	K_{set}(orgN)	Settling rate of organic N at 20 ^{0}C in reservoir or sluice	m/year	N
38	K_{set}(orgP)	Settling rate of organic P at 20 ^{0}C in reservoir or sluice	m/year	P

39	K_{set}(solP)	Settling rate of soluble P at 20 ^{0}C in reservoir or sluice	m/year	P
40	K_{set} (DO)	Settling rate of DO at 20 ^{0}C in reservoir or sluice	m/year	DO
41	K_{set}(algae)	Settling rate of algae at 20 ^{0}C in reservoir or sluice	m/year	algae
42	K_{set}(TN)	Settling rate of TN at 20 ^{0}C in reservoir or sluice	m/year	N
43	K_{set}(TP)	Settling rate of TP at 20 0C in reservoir or sluice	m/year	P
44	K_d(COD)	COD deoxygenation rate in reservoirs at 20 ^{0}C	day^{-1}	COD
45	*res_k1*	Reaeration coefficients at 20 ^{0}C in reservoir or sluice	day^{-1}	DO
46	K_d(NH_4)	Bio-oxidation rate of NH_4-N in reservoir at 20 ^{0}C	day^{-1}	N
47	K_d(NO_2)	Oxidation rate of NO_2-N to NO_3-N at 20 ^{0}C in reservoir or sluice	day^{-1}	N
48	K_d(orgN)	Hydrolysis rate of organic N to NH_4-N at 20 ^{0}C in reservoir or sluice	day^{-1}	N
49	K_d(orgP)	Hydrolysis rate of organic P to soluble P at 20 ^{0}C in reservoir or sluice	day^{-1}	P
50	K_{scu}(COD)	Resuspension rate of COD at 20 ^{0}C in reservoir or sluice	m/year	COD
51	K_{scu}(NH_4)	Resuspension rate of NH_4-N at 20 ^{0}C in reservoir or sluice	m/year	N
52	K_{scu}(NO_2)	Resuspension rate of NO_2-N at 20 ^{0}C in reservoir or sluice	m/year	N
53	K_{scu}(NO_3)	Resuspension rate of NO_3-N at 20 ^{0}C in reservoir or sluice	m/year	N
54	K_{scu}(orgN)	Resuspension rate of organic N at 20 ^{0}C in reservoir or sluice	m/year	N
55	K_{scu}(orgP)	Resuspension rate of organic P at 20 ^{0}C in reservoir or sluice	m/year	P
56	K_{scu}(solP)	Resuspension rate of soluble P at 20 ^{0}C in reservoir or sluice	m/year	P
57	K_{scu}(DO)	Resuspension rate of DO at 20 ^{0}C in reservoir or sluice	m/year	DO
58	K_{scu}(algae)	Resuspension rate of algae at 20 ^{0}C in reservoir or sluice	m/year	algae
59	K_{scu}(TN)	Resuspension rate of TN at 20 ^{0}C in reservoir or sluice	m/year	N
60	K_{scu}(TP)	Resuspension rate of TP at 20 ^{0}C in reservoir or sluice	m/year	P
61	K_{bur}(COD)	Decay rate of COD at 20 ^{0}C in reservoir or sluice	m/year	COD
62	K_{bur}(NH_4)	Decay rate of NH_4-N at 20 ^{0}C in reservoir or sluice	m/year	N
63	K_{bur}(NO_2)	Decay rate of NO_2-N at 20 ^{0}C in reservoir or sluice	m/year	N
64	K_{bur}(NO_3)	Decay rate of NO_3-N at 20 ^{0}C in reservoir or sluice	m/year	N
65	K_{bur}(orgN)	Decay rate of organic N at 20 ^{0}C in reservoir or sluice	m/year	N
66	K_{bur}(orgP)	Decay rate of organic P at 20 ^{0}C in reservoir or sluice	m/year	P
67	K_{bur}(solP)	Decay rate of soluble P at 20 ^{0}C in reservoir or sluice	m/year	P
68	K_{bur}(DO)	Decay rate of DO at 20 ^{0}C in reservoir or sluice	m/year	DO
69	K_{bur}(algae)	Decay rate of algae at 20 ^{0}C in reservoir or sluice	m/year	algae
70	K_{bur}(TN)	Decay rate of TN at 20 ^{0}C in reservoir or sluice	m/year	N
71	K_{bur} (TP)	Decay rate of TP at 20 ^{0}C in reservoir or sluice	m/year	P
72	*usle_k*	Soil erodibility factor of USLE equation	none	sediment
73	*usle_p*	Erosion control practice factor of USLE equation	none	sediment
74	*MicrIn*	Microbe index	none	C, N
75	K_1	Decomposition rate of labile organic C	day^{-1}	C
76	μ_{CLAY}	Reduction factor of clay content on organic matter decomposition	none	C
77	μ_t	Reduction factor of soil temperature on growth of denitrifier or nitrifier	none	N
78	*S*	Labile fraction of organic C compounds	none	C
79	kr_{cvl}	Decomposition rate of very labile organic C in residue pool	day^{-1}	C
80	kr_{cl}	Decomposition rate of labile organic C in residue pool	day^{-1}	C
81	kr_{cr}	Decomposition rate of stable organic C in residue pool	day^{-1}	C

82	km_{sc}	Decomposition rate of stable organic C in microbial biomass pool	day^{-1}	C
83	km_{cl}	Decomposition rate of labile organic C in microbial biomass pool	day^{-1}	C
84	km_h	Decomposition rate of microbial biomass to humands	day^{-1}	C
85	K_C	Half velocity constant of organic C on denitrifier biomass growth	none	N
86	K_{NxOy}	Half velocity constant of NO_3-N, NO_2-N, NO and N_2O on denitrifier biomass growth	none	N
87	u_{NO3}	Maximum growth rate of NO_3-N denitrifier	day^{-1}	N
88	u_{NO2}	Maximum growth rate of NO_2-N denitrifier	day^{-1}	N
89	u_{NO}	Maximum growth rate of NO denitrifier	day^{-1}	N
90	u_{N2O}	Maximum growth rate of N_2O denitrifier	day^{-1}	N
91	M_C	Maintenance coefficient of C	hr^{-1}	C
92	Y_C	Maximum growth yield of soluble C	kg/ha/hr	C
93	M_{NO3}	Maintenance coefficient of NO_3-N	hr^{-1}	N
94	Y_{NO3}	Maximum growth yield of NO_3-N	kg/ha/hr	N
95	$CDR_{D:N}$	C:N ratio in bacteria	none	N
96	M_{NO2}	Maintenance coefficient of NO_2-N	hr^{-1}	N
97	Y_{NO2}	Maximum growth yield of NO_2-N	kg/ha/hr	N
98	M_{NO}	Maintenance coefficient of NO	hr^{-1}	N
99	Y_{NO}	Maximum growth yield of NO	kg/ha/hr	N
100	M_{N2O}	Maintenance coefficient of N_2O	hr^{-1}	N
101	Y_{N2O}	Maximum growth yield of N_2O	kg/ha/hr	N
102	$\mu_{SW,n}$	Soil water content adjusted factor for denitrification	none	C, N
103	β_{min}	Mineralization rate of humus active organic P	day^{-1}	P
104	β_{rsd}	Mineralization rate of residue fresh organic P	day^{-1}	P
Watershed parameters				
105	C_{ur}(COD)	Export coefficient of COD load in urban area	kg/ha/year	COD
106	$C_{ur}(NH_4)$	Export coefficient of NH_4-N load in urban area	kg/ha/year	N
107	C_{ur}(TN)	Export coefficient of TN load in urban area	kg/ha/year	N
108	C_{ur}(TP)	Export coefficient of TP load in urban area	kg/ha/year	P
109	C_{ur}(COD)	Export coefficient of COD load in unused area	kg/ha/year	COD
110	$C_{ur}(NH_4)$	Export coefficient of NH_4-N load in unused area	kg/ha/year	N
111	C_{ur}(TN)	Export coefficient of TN load in unused area	kg/ha/year	N
112	C_{ur}(TP)	Export coefficient of TP load in unused area	kg/ha/year	P
113	R_{ur}	Loss rate of non-point source load from soil layer	none	pollutant load
114	C_{liv}(COD)	Export coefficient of COD load from living in rural area	kg/year	COD
115	$C_{liv}(NH_4)$	Export coefficient of NH_4-N load from living in rural area	kg/year	N
116	C_{liv}(TN)	Export coefficient of TN load from living in rural area	kg/year	N
117	C_{liv}(TP)	Export coefficient of TP load from living in rural area	kg/year	P
118	C_{lst}(COD)	Export coefficient of COD load from livestock in rural area	kg/year	COD
119	$C_{lst}(NH_4)$	Export coefficient of NH_4-N load from livestock in rural area	kg/year	N
120	C_{lst}(TN)	Export coefficient of TN load from livestock in rural area	kg/year	N
121	C_{lst}(TP)	Export coefficient of TP load from livestock in rural area	kg/year	P
122	R_{liv}	Loss rate of non-point source load from living	none	pollutant load

123	R_{lst}	Loss rate of non-point source load from livestock	none	pollutant load
124	C_{pcp}(COD)	COD concentration in precipitation	mg/L	COD
125	$C_{pcp}(NH_4)$	NH_4-N concentration in precipitation	mg/L	N
126	C_{pcp}(TN)	TN concentration in precipitation	mg/L	N
127	C_{pcp}(TP)	TP concentration in precipitation	mg/L	P
128	SF_{tmp}	Snowfall temperature	^{0}C	flow
129	SM_{tmp}	Snow melt base temperature	^{0}C	flow
130	SMF_{mx}	Melt factor for snow on June 21	mm/day	flow
131	SMF_{mn}	Melt factor for snow on December 21	mm/day	flow
132	*TIMP*	Snow pack temperature lag factor	none	flow
133	*Coefrad*	Factor of maximum possible radiation to net radiation	none	flow
134	SC_{max}	Minimum snow water content that corresponds to 100% snow cover	mm	flow
135	SC_{50}	Fraction of snow volume represented by SCMX that corresponds to 50% snow cover	none	flow
136	SC_1	Coefficients that define shape of snow curve 95% coverage at 100% snow cover	none	flow
137	SC_2	Coefficients that define shape of snow curve 50% coverage at 100% snow cover	none	flow
138	*Surlag*	Surface runoff lag time	day	flow
139	*n_ch*	Roughness of Channel	none	flow
140	*msk_x*	Weighting factor in Muskingum equation	none	flow
141	*msk_k*	Storage time constant of channel in Muskingum equation	day	flow
142	AI_1	Fraction of algal biomass that is N	none	N
143	AI_2	Fraction of algal biomass that is P	none	P
144	AI_3	Adjusted rate of oxygen production per unit of algal photolysis	none	DO
145	AI_4	Adjusted rate of oxygen uptake per unit of algal respiration	none	DO
146	AI_5	Adjusted rate of oxygen uptake per unit of NH_4-N oxidation	none	N
147	AI_6	Adjusted rate of oxygen uptake per unit of NO_2-N oxidation	none	N
148	AI_7	Adjusted rate of NH_4-N oxidation to NO_2-N	none	N
149	g_{max}	Maximum specific algal growth rate at 20^{0}C	day^{-1}	algae
150	*RHOQ*	Algal respiration rate at 20^{0}C	day^{-1}	algae
151	*TFACT*	Fraction of solar radiation computed in temperature heat balance	none	algae
152	*K_1*	Half-saturation coefficient for light	kJ/m^2	algae
153	*K_N*	Michaelis-Menton half-saturation constant for N	mg/L	algae
154	*K_P*	Michaelis-Menton half-saturation constant for P	mg/L	algae
155	*Lec*	Non-algal portion of light extinction coefficient	m^{-1}	algae
156	Lec_1	Linear algal self-shading coefficient	$m^{-1\cdot}$ (μg/L)$^{-1}$	algae
157	Lec_2	Nonlinear algal self-shading coefficient	$m^{-1\cdot}$(μg /L)$^{-2/3}$)	algae
158	*P_N*	Algal preference factor for ammonia	none	N
159	*PRF*	Peak rate adjustment factor for sediment routing in channel	none	sediment
160	SP_{con}	Linear parameter for calculating maximum transport capacity of sediment in channel	none	sediment

161	*SPexp*	Exponent parameter for calculating maximum transport capacity of sediment in channel	none	sediment
162	*f_Ph*	Flood PH value	none	C, N
163	rcn_{rvl}	Ratio of C/N of very labile litter	none	C, N
164	rcn_{rl}	Ratio of C/N of labile litter	none	C, N
165	rcn_{rr}	Ratio of C/N of resistant litter	none	C, N
166	rcn_{b}	Ratio of C/N of labile biomass	none	C, N
167	rcn_{h}	Ratio of C/N of labile humus	none	C, N
168	rcn_{m}	Ratio of C/N of humads	none	C, N
169	*pavi*	P availability index	none	C, N
170	*TtoC*	Relationship between TOC and COD	none	COD
171-182	$rpnt_{01\sim 12}$	Ratio of point pollutant source from Jan. to Dec.	none	pollutant load