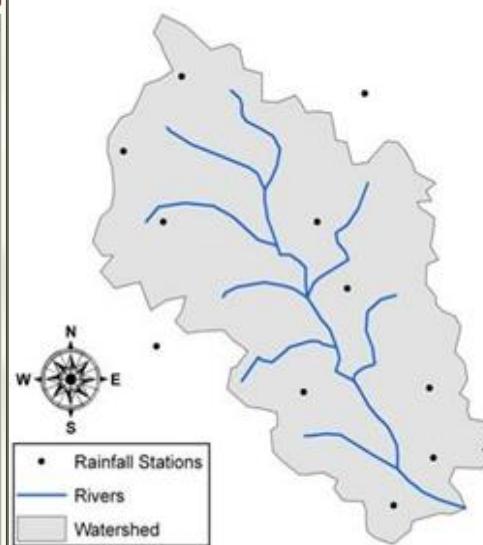


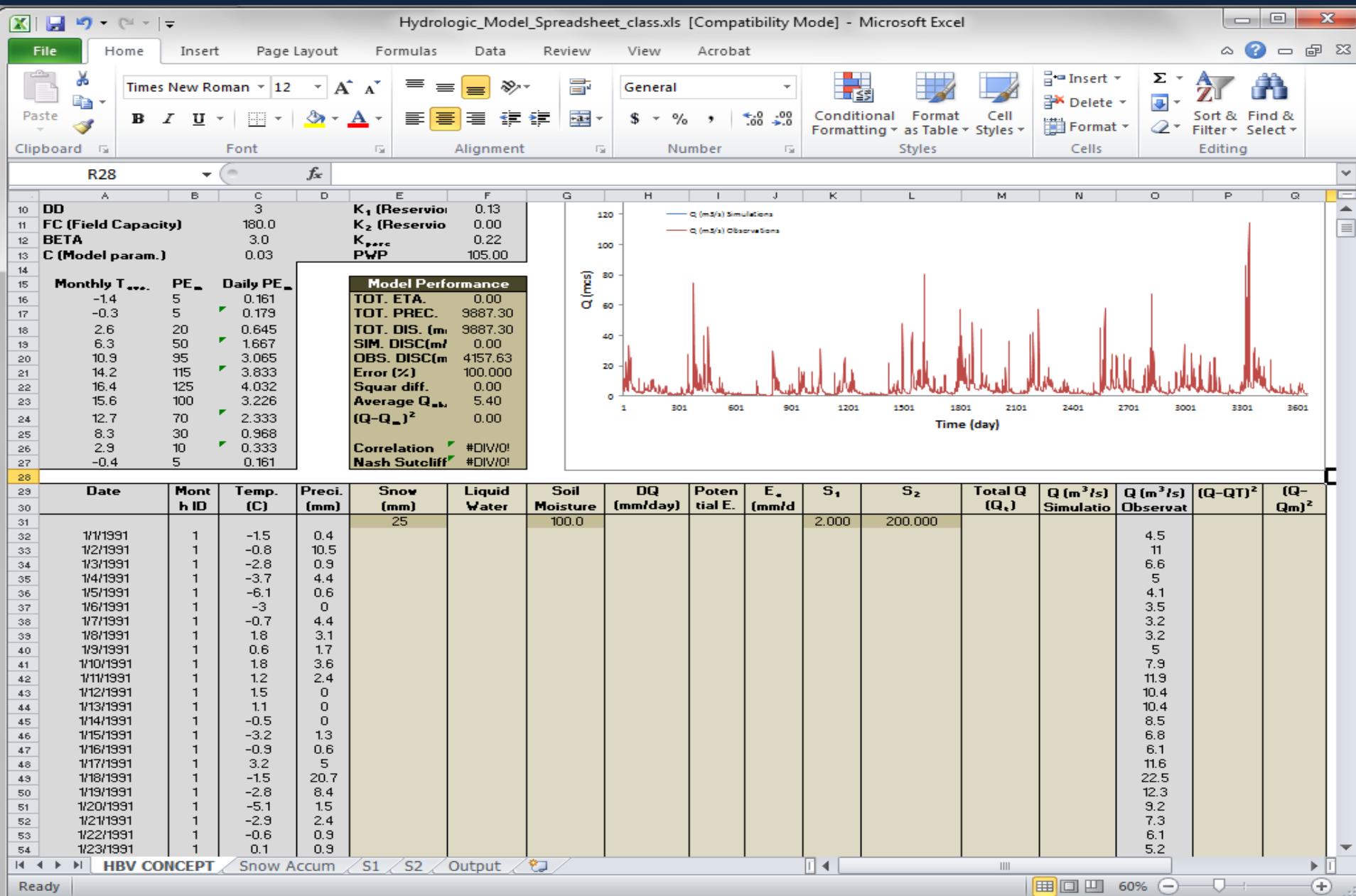
# WATERSHED MODELING

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Course Website:  
<http://amir.eng.uci.edu>



# Outline



# Outline

HBV\_EDU\_V2

Help

Contact  
HBV-EDU Ver. 2  
AghaKouchak & Emad Habib  
For questions and permissions contact:  
Dr. Amir AghaKouchak (amir.a@uci.edu)  
OR Dr. Emad Habib (habib@louisiana.edu)

Watershed Area & Snow Melt Thr.

Area	410
T_s	0

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
AghaKouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

Acknowledgment  
HBV-EDU is supported by the National Science Foundation (NSF) Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. DUE-0737073.

Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

Initial Values

Snow	0.0
Soil Moisture	100.0
S_1	2.0
S_2	200.0

Model Performance

Qrmse (Root Mean Square Error)	Correlation
Select Parameter to Plot	Plot
Select	Plot
Nash Sutcliffe	

Optimization Criteria

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

Load Input Files

Run

Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset # of simulations 50 Simulate Q

# Nonstationary Extreme Value Analysis (NEVA) Software Package

# GEV

# GPD

Prior Information

$$p(\beta) \quad \beta = (\mu_0, \mu_1, \sigma, \xi)$$

Data  $\vec{y}$  at Site  $s_i$  with  $N$  Time Points

$$y_{s_i,1} \dots y_{s_i,t} \dots y_{s_i,N_i}$$

Input for Bayesian inference

$$p(\beta | \vec{y}, x) \propto p(\vec{y} | \beta, x) p(\beta | x)$$

$$p(\vec{y} | \beta, x) = \prod_{t=1}^{N_i} p(y_t | \beta, x(t)) = \prod_{t=1}^{N_i} p(y_t | \mu(t), \sigma, \xi)$$

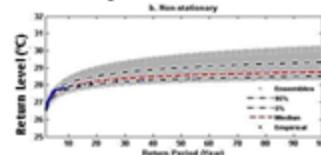
(1)

Input for Return  
Period

Return Level vs. Return Period

$$q_p = ((-\frac{1}{\ln p})^t - 1) \times \frac{\sigma}{\xi} + \tilde{\mu}$$

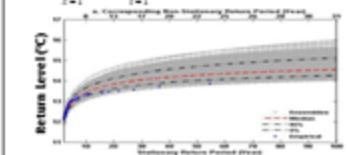
$$T = \frac{1}{1-p}$$



Non-stationary Return Period

$$q_p = 1 - \exp \left\{ - \left( 1 + \xi \left( \frac{z_{p_i} - \mu}{\sigma} \right) \right)^{-\frac{1}{\xi}} \right\}$$

$$\tilde{T} = \sum_{z=1}^{z_{\text{end}}} x q_z \prod_{t=1}^{z-1} (1 - q_t)$$



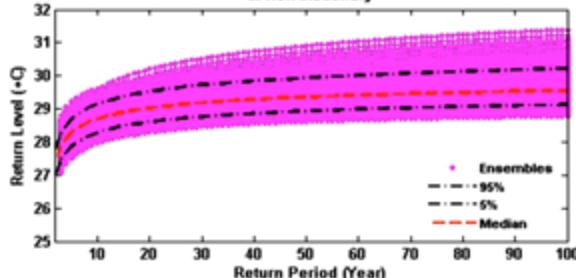
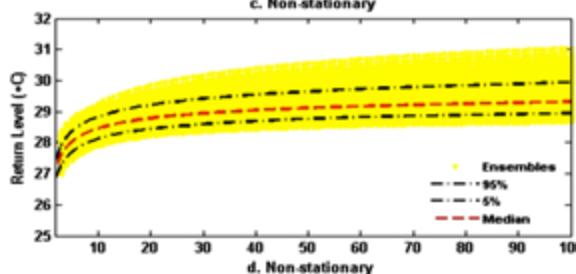
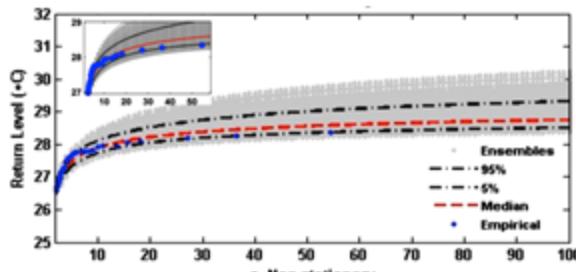
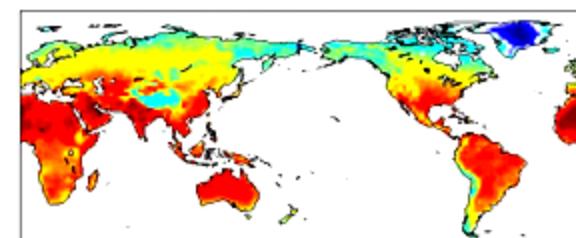
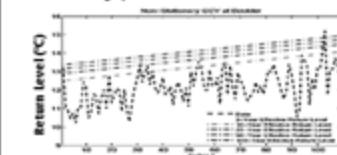
(2)

Input for Return  
Level Analysis

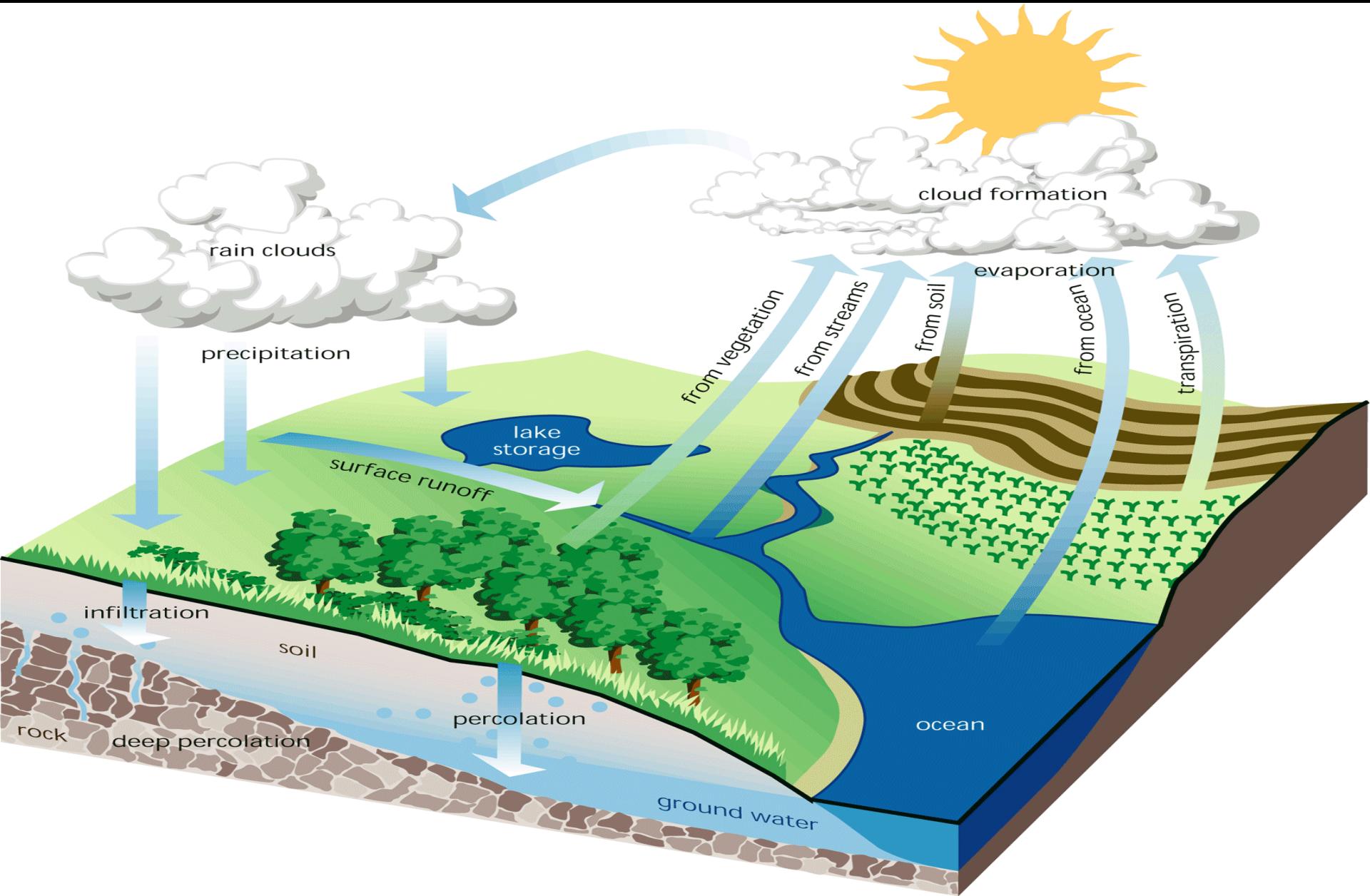
Effective Return Level vs. time t

$$q_p = ((-\frac{1}{\ln p})^t - 1) \times \frac{\sigma}{\xi} + \mu(t)$$

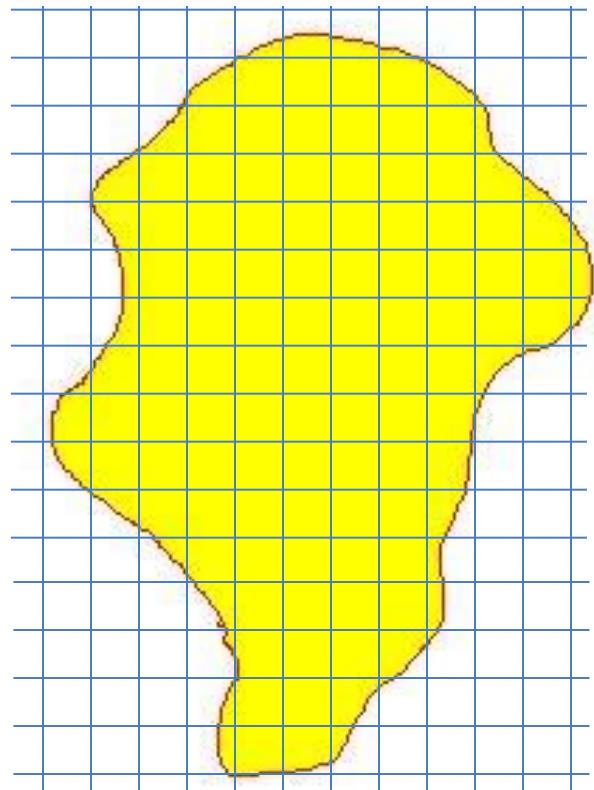
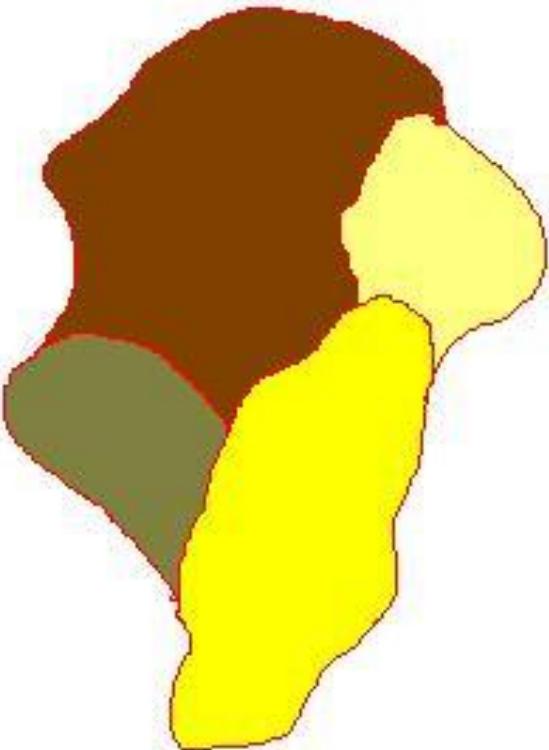
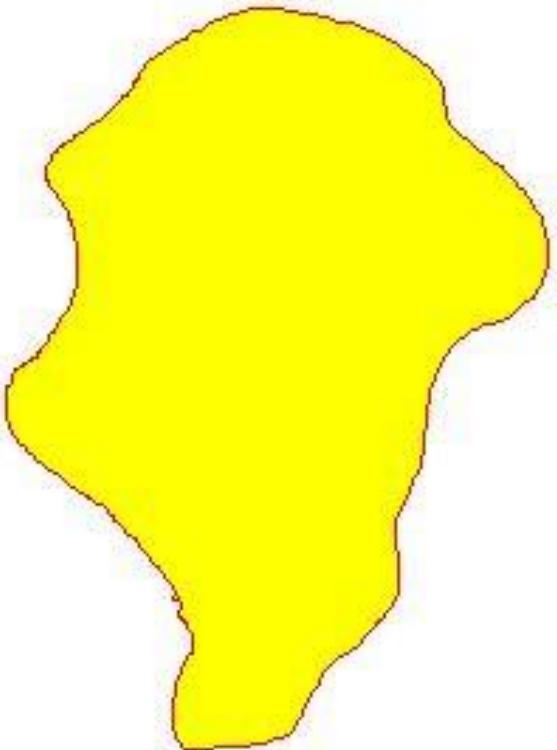
$$T = \frac{1}{1-p}$$



# Hydrologic Processes



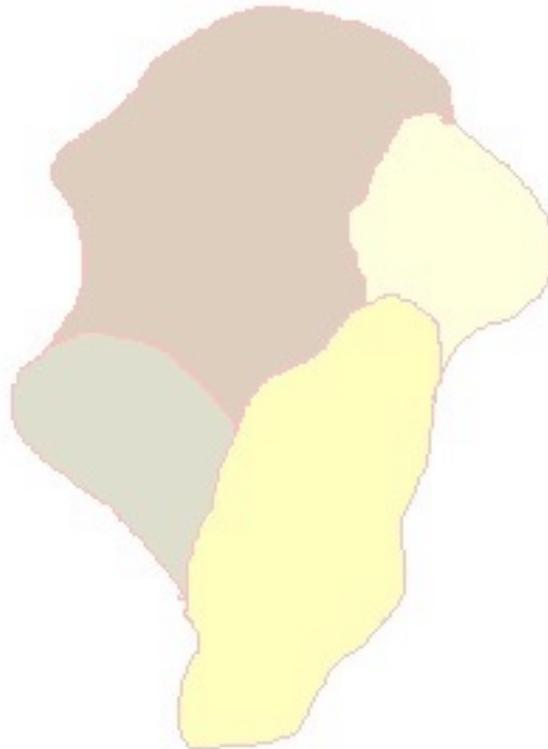
# Modeling Approaches



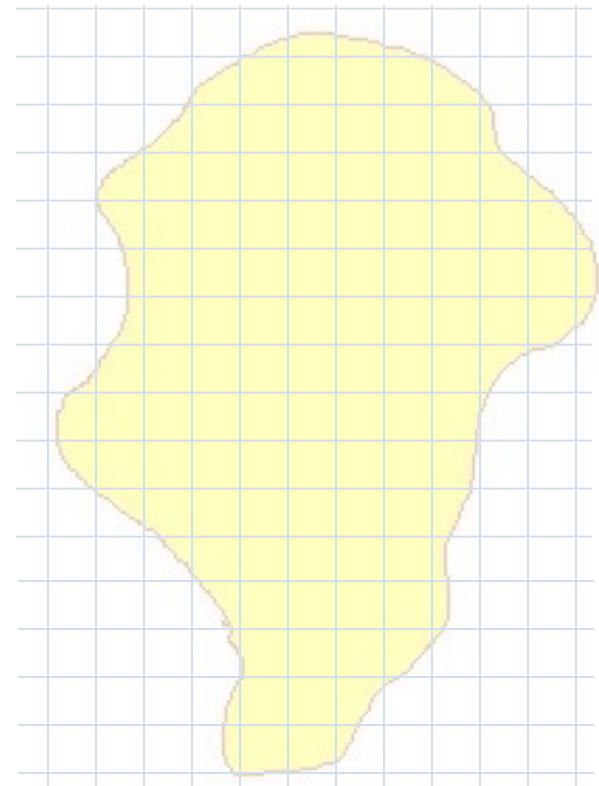
# Modeling Approaches



**Lumped**

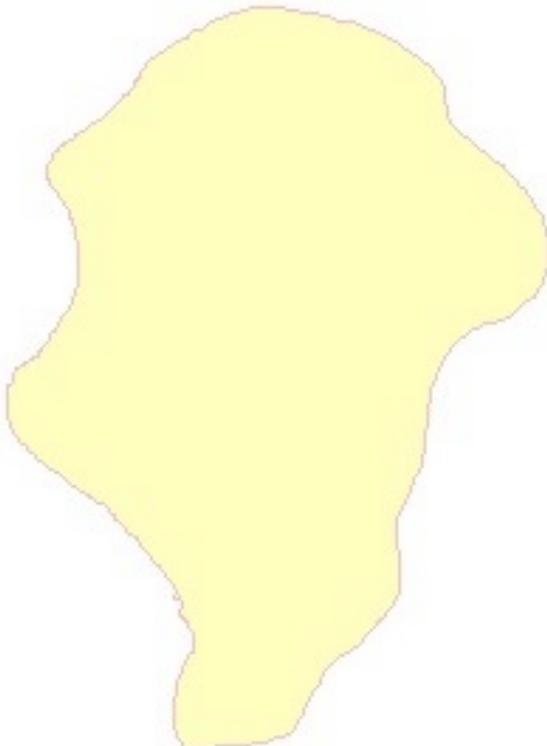


**Semi-Distributed**

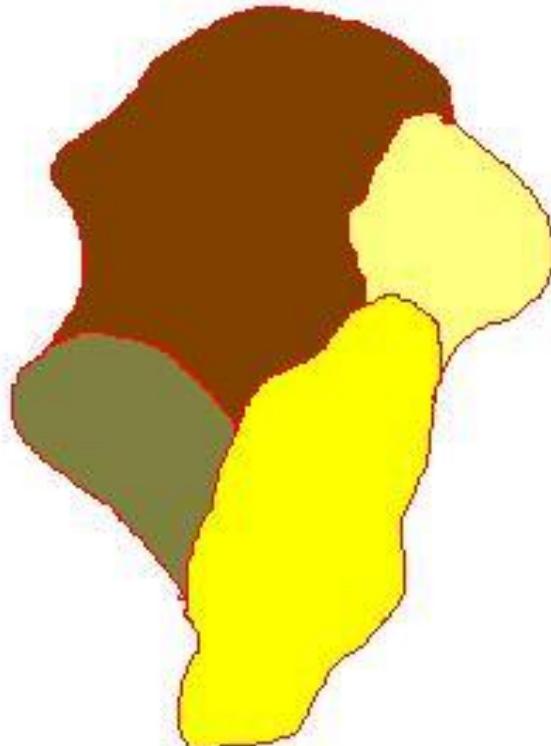


**Distributed**

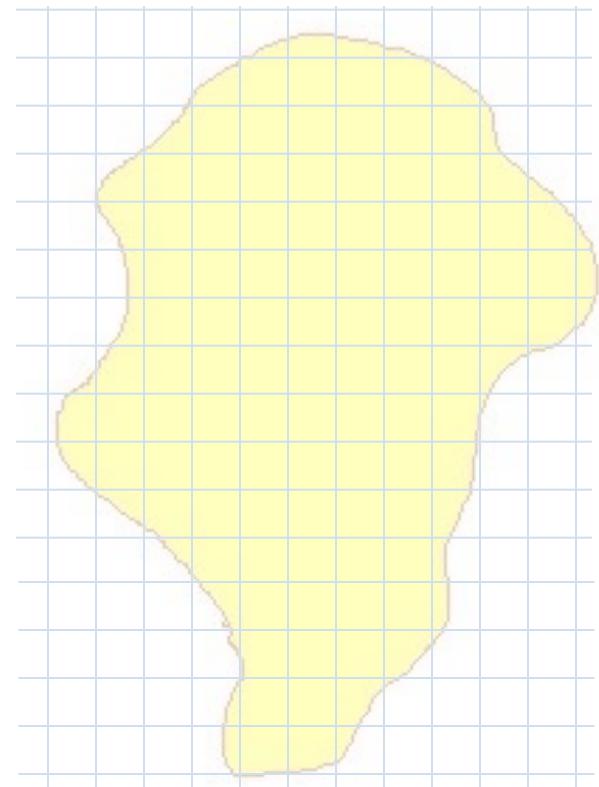
# Modeling Approaches



Lumped

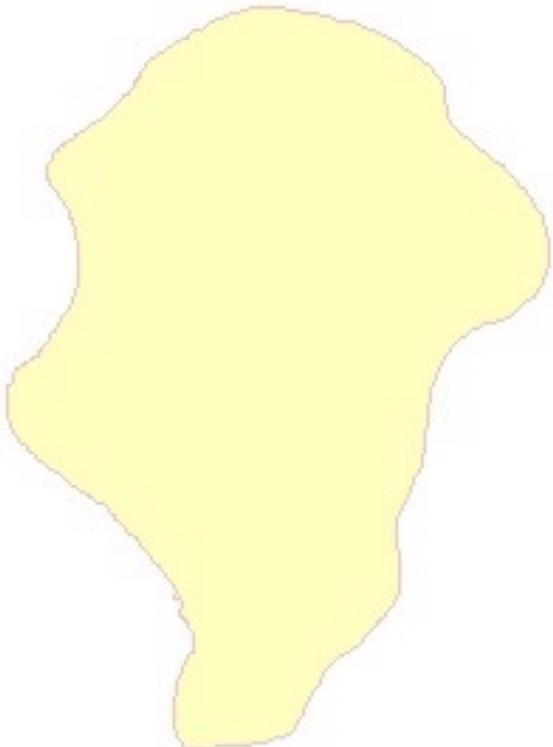


Semi-Distributed

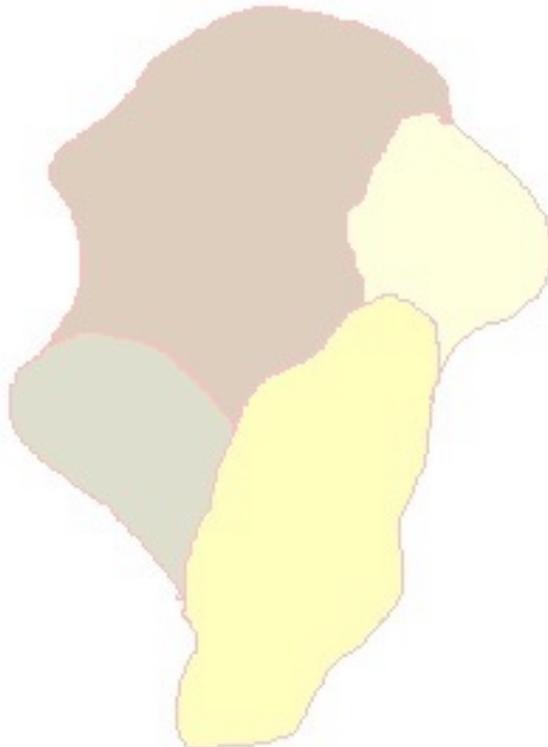


Distributed

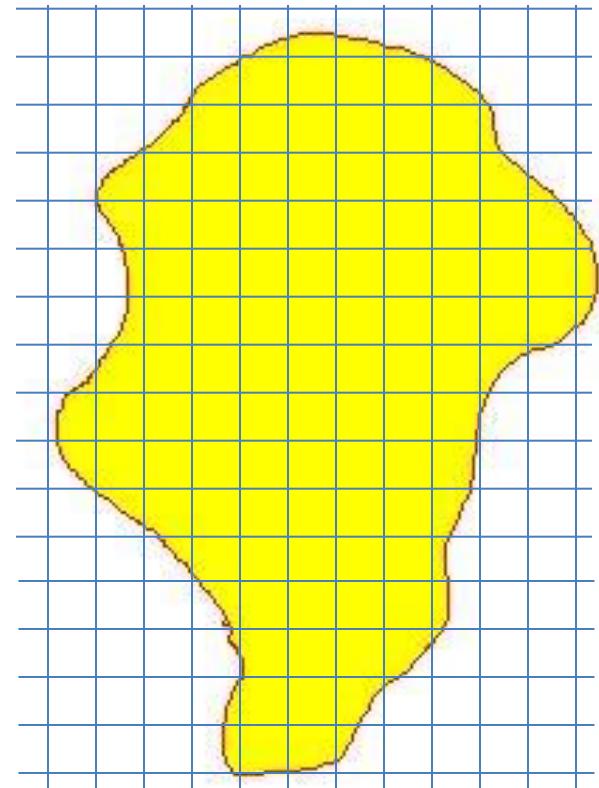
# Modeling Approaches



Lumped



Semi-Distributed



Distributed

# Types of Models

## Physically-Based Models

These models are based on governing equations such as conservation of mass, the momentum equation, etc. The disadvantage of physically based models is that they require complicated numerical solving techniques and large amount of input data.

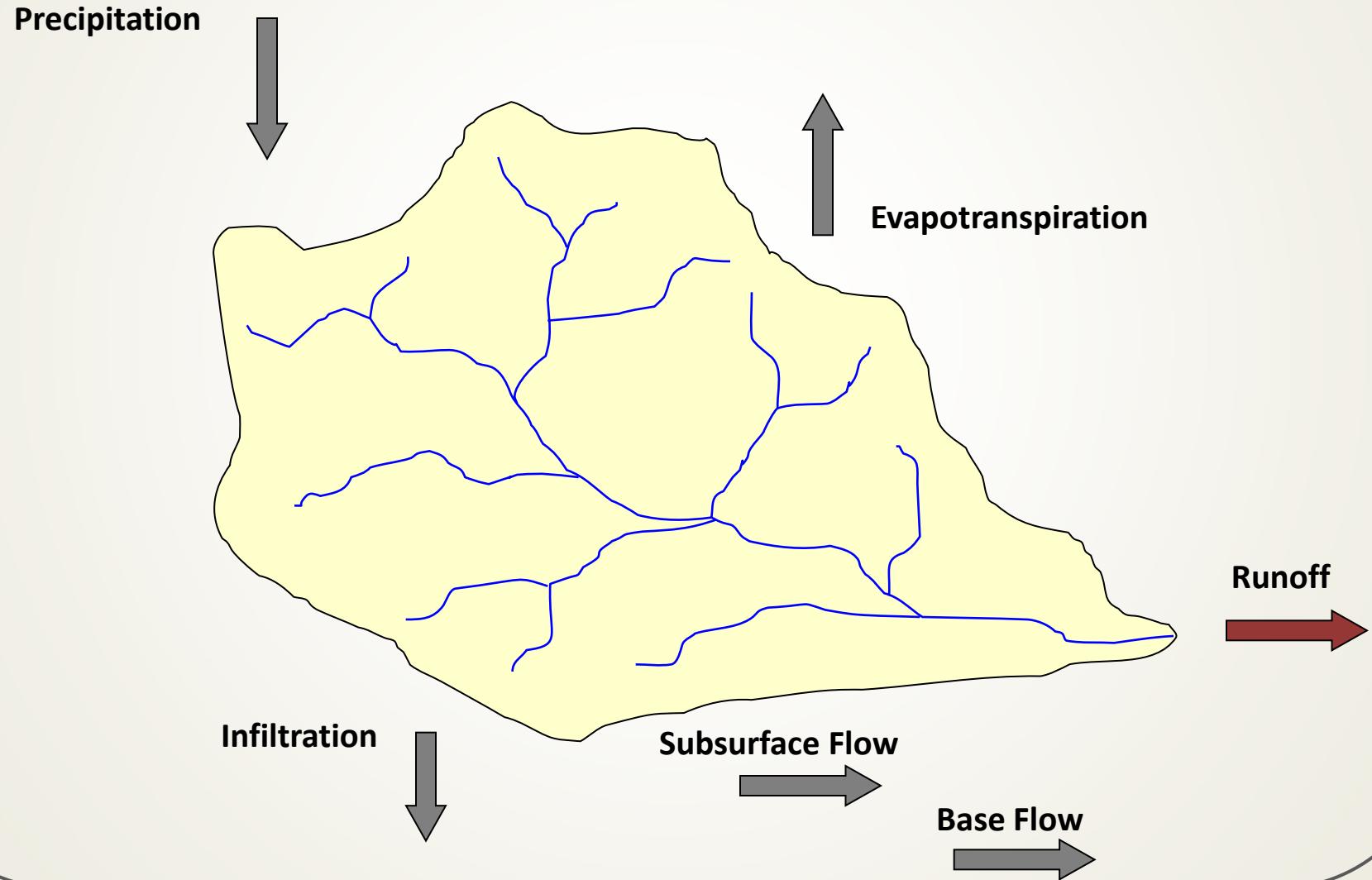
## Conceptual Models

Conceptual models describe the processes with simple (typically linear) mathematical equations. Conceptual models are much simpler than physically-based models from a mathematical viewpoint.

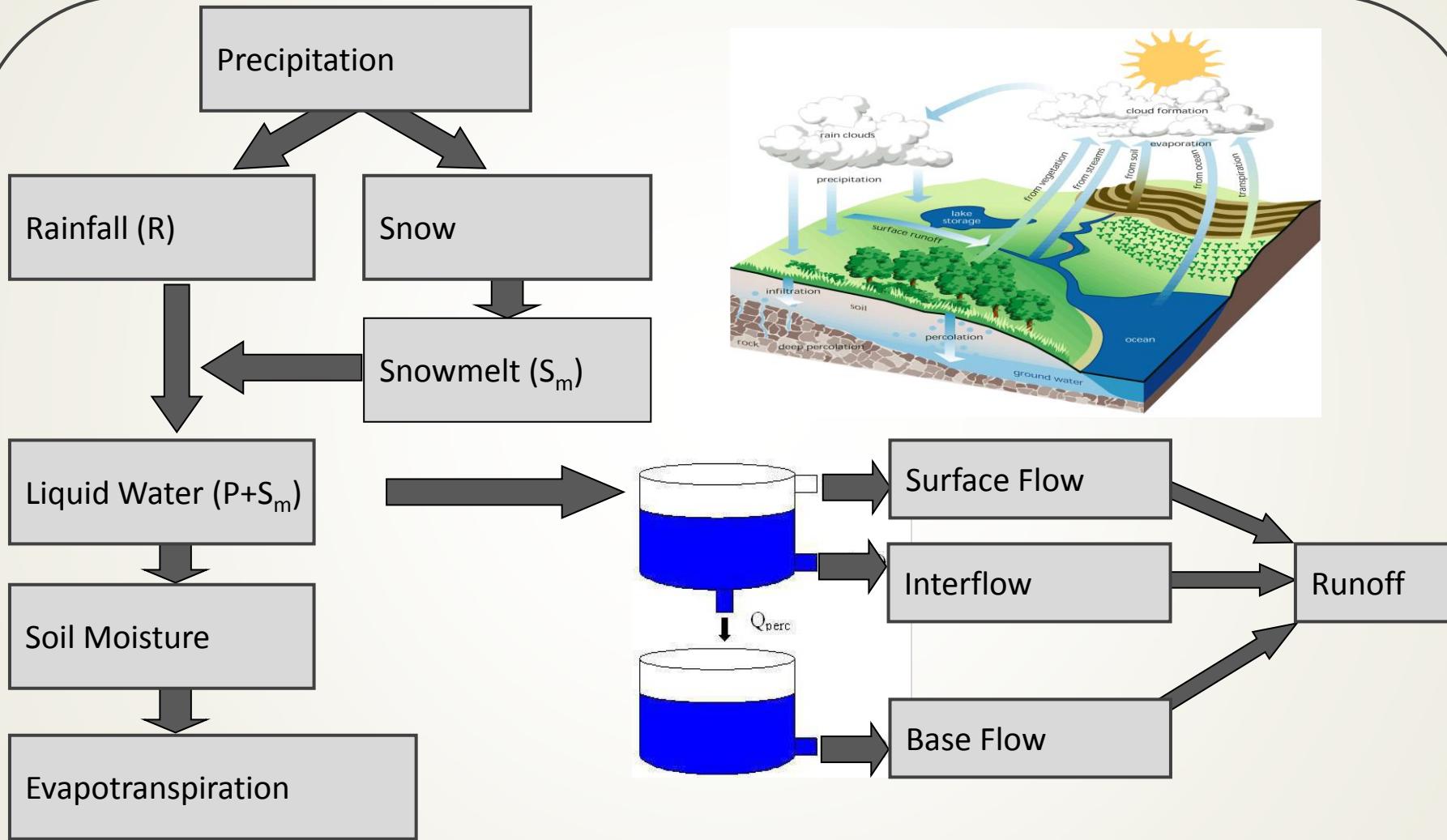
## Empirical Models

Empirical models are based on empirical analysis of observed input (e.g., rainfall) and output (discharge) data. The disadvantages of empirical models are: they are not transferable to other locations; understanding of the relevant physical processes can be difficult to ascertain; and the model is not valid if the study area experiences land use or climate change.

# Hydrologic Processes



# Model Structure



# Hydrologic Processes

Date	Temp. (C)	Preci. (mm)
1/1/1991	-1.5	0.4
1/2/1991	-0.8	10.5
1/3/1991	-2.8	0.9
1/4/1991	-3.7	4.4
1/5/1991	-6.1	0.6
1/6/1991	-3	0
1/7/1991	-0.7	4.4
1/8/1991	1.8	3.1
1/9/1991	0.6	1.7
1/10/1991	1.8	3.6
1/11/1991	1.2	2.4
1/12/1991	1.5	0
1/13/1991	1.1	0
1/14/1991	-0.5	0
1/15/1991	-3.2	1.3
1/16/1991	-0.9	0.6

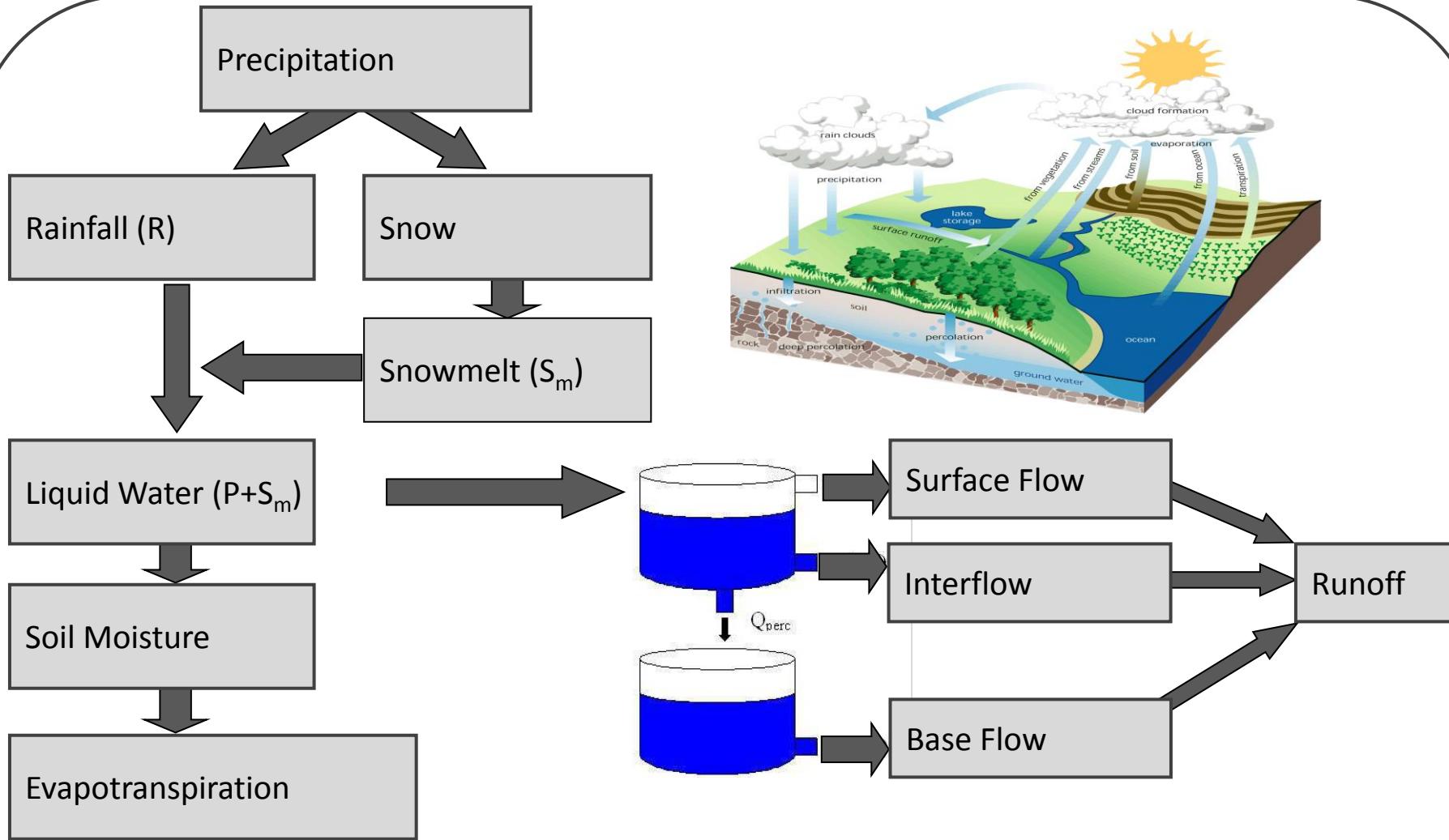
# Hydrologic Modeling

Date	Temp. (C)	Preci. (mm)
1/1/1991	-1.5	0.4
1/2/1991	-0.8	10.5
1/3/1991	-2.8	0.9
1/4/1991	-3.7	4.4
1/5/1991	-6.1	0.6
1/6/1991	-3	0
1/7/1991	-0.7	4.4
1/8/1991	1.8	3.1
1/9/1991	0.6	1.7
1/10/1991	1.8	3.6
1/11/1991	1.2	2.4
1/12/1991	1.5	0
1/13/1991	1.1	0
1/14/1991	-0.5	0
1/15/1991	-3.2	1.3
1/16/1991	-0.9	0.6



First  
Step?

# Model Structure



# Precipitation Separation: Rainfall & Snow



Rainfall

- Infiltration
- Direct Runoff

Snow

- Snowmelt
- Snow Accumulation

# Precipitation Separation: Rainfall & Snow

Precipitation separation into rainfall and snow based on ground temperature:

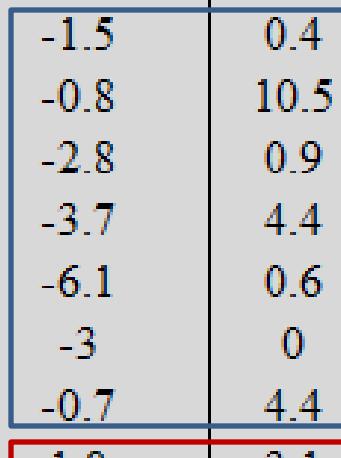
If  $T > T_t$  : Rainfall

If  $T \leq T_t$  : Snow

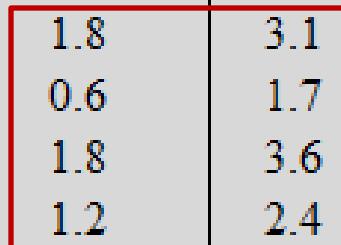
$T_t$  : Threshold temperature ( $0^{\circ}\text{C}$  /  $32^{\circ}\text{F}$ )

# Precipitation Separation: Rainfall & Snow

Date	Temp. (C)	Preci. (mm)
1/1/1991	-1.5	0.4
1/2/1991	-0.8	10.5
1/3/1991	-2.8	0.9
1/4/1991	-3.7	4.4
1/5/1991	-6.1	0.6
1/6/1991	-3	0
1/7/1991	-0.7	4.4
1/8/1991	1.8	3.1
1/9/1991	0.6	1.7
1/10/1991	1.8	3.6
1/11/1991	1.2	2.4
1/12/1991	1.5	0
1/13/1991	1.1	0
1/14/1991	-0.5	0
1/15/1991	-3.2	1.3
1/16/1991	-0.9	0.6



Snow



Rainfall

# Precipitation Separation: Rainfall & Snow

Snowmelt and accumulation is proportional to the temperature:

If  $T > T_t$  : snow melts

If  $T \leq T_t$  : snow accumulates

$T_t$  : Threshold temperature ( $0^{\circ}\text{C}$  /  $32^{\circ}\text{F}$ )

# Precipitation Separation: Rainfall & Snow

Date	Temp. (C)	Preci. (mm)
1/1/1991	-1.5	0.4
1/2/1991	-0.8	10.5
1/3/1991	-2.8	0.9
1/4/1991	-3.7	4.4
1/5/1991	-6.1	0.6
1/6/1991	-3	0
1/7/1991	-0.7	4.4
1/8/1991	1.8	3.1
1/9/1991	0.6	1.7
1/10/1991	1.8	3.6
1/11/1991	1.2	2.4
1/12/1991	1.5	0
1/13/1991	1.1	0
1/14/1991	-0.5	0
1/15/1991	-3.2	1.3
1/16/1991	-0.9	0.6

-1.5	0.4
-0.8	10.5
-2.8	0.9
-3.7	4.4
-6.1	0.6
-3	0
-0.7	4.4



1.8	3.1
0.6	1.7
1.8	3.6
1.2	2.4



# Precipitation Separation: Rainfall & Snow

Date	Temp. (C)	Preci. (mm)
1/1/1991	-1.5	0.4
1/2/1991	-0.8	10.5
1/3/1991	-2.8	0.9
1/4/1991	-3.7	4.4
1/5/1991	-6.1	0.6
1/6/1991	-3	0
1/7/1991	-0.7	4.4
1/8/1991	1.8	3.1
1/9/1991	0.6	1.7
1/10/1991	1.8	3.6
1/11/1991	1.2	2.4
1/12/1991	1.5	0
1/13/1991	1.1	0
1/14/1991	-0.5	0
1/15/1991	-3.2	1.3
1/16/1991	-0.9	0.6

-1.5	0.4
-0.8	10.5
-2.8	0.9
-3.7	4.4
-6.1	0.6
-3	0
-0.7	4.4



1.8	3.1
0.6	1.7
1.8	3.6
1.2	2.4



# Snowmelt

Estimation of Snowmelt:

$$\text{snowmelt} = DD.(T - T_t)$$

Snowmelt ( $[LT^{-1}]$ ): snowmelt rate as water equivalent

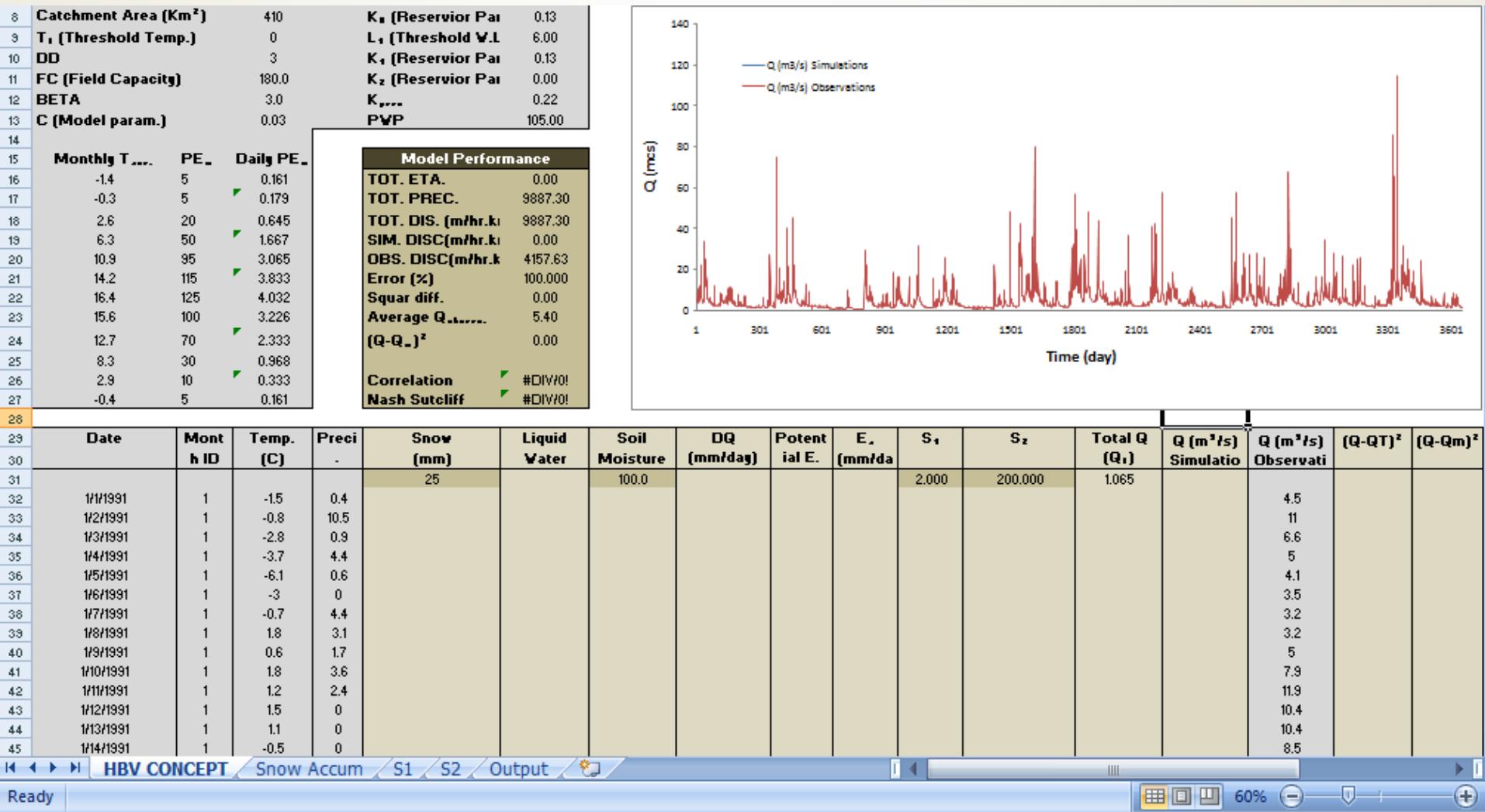
$DD$  ( $[L\theta^{-1}T^{-1}]$ ): degree-day factor

$T$  ( $[\theta]$ ): mean daily air temperature

$T_t$  ( $[\theta]$ ): threshold temperature

Download Model\_Spreadsheet.xls from:

[http://amir.eng.uci.edu/downloads/Model\\_Spreadsheet.xls](http://amir.eng.uci.edu/downloads/Model_Spreadsheet.xls)



# Snowmelt

If  $T \leq T_t$  :  $\text{Snow}_{t-1} + \text{Snow}_t$

If  $T > T_t$  :  $\text{Snow}_{t-1} - \text{DD.(T-T}_t\text{)}$

$T_t$  : Threshold temperature (0 °C / 32 °F)



=IF(C32>\$C\$9,MAX(E31-\$C\$10\*(C32-\$C\$9),0),E31+D32)

NOTE: The MAX function in the above statement is used to prevent negative values of snow height!

# Snowmelt

If  $T \leq T_t$  :  $\text{Snow}_{t-1} + \text{Snow}_t$

If  $T > T_t$  :  $\text{Snow}_{t-1} - \text{DD} \cdot (T - T_t)$

$T_t$  : Threshold temperature ( $0^{\circ}\text{C}$  /  $32^{\circ}\text{F}$ )



=IF(C32>\$C\$9,MAX(E31-\$C\$10\*(C32-\$C\$9),0),E31+D32)

$T > T_t$

$T \leq T_t$

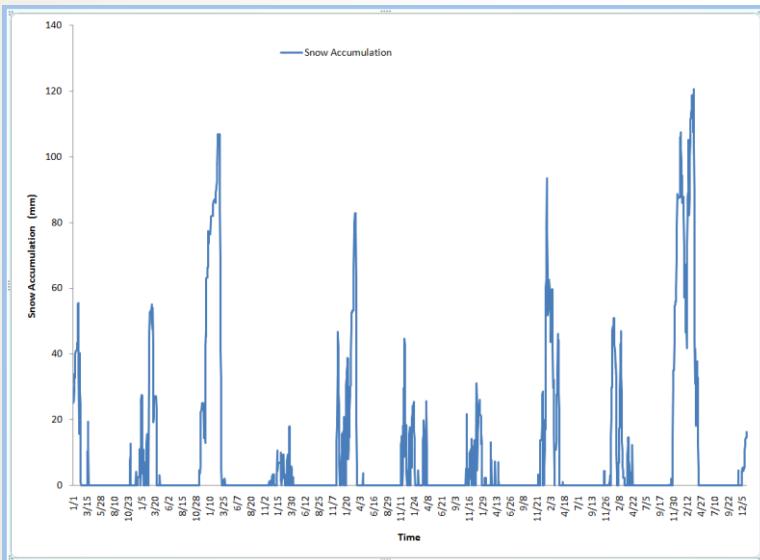
NOTE: The MAX function in the above statement is used to prevent negative values of snow height!

# Snowmelt

$$snowmelt = DD \cdot (T - T_t)$$

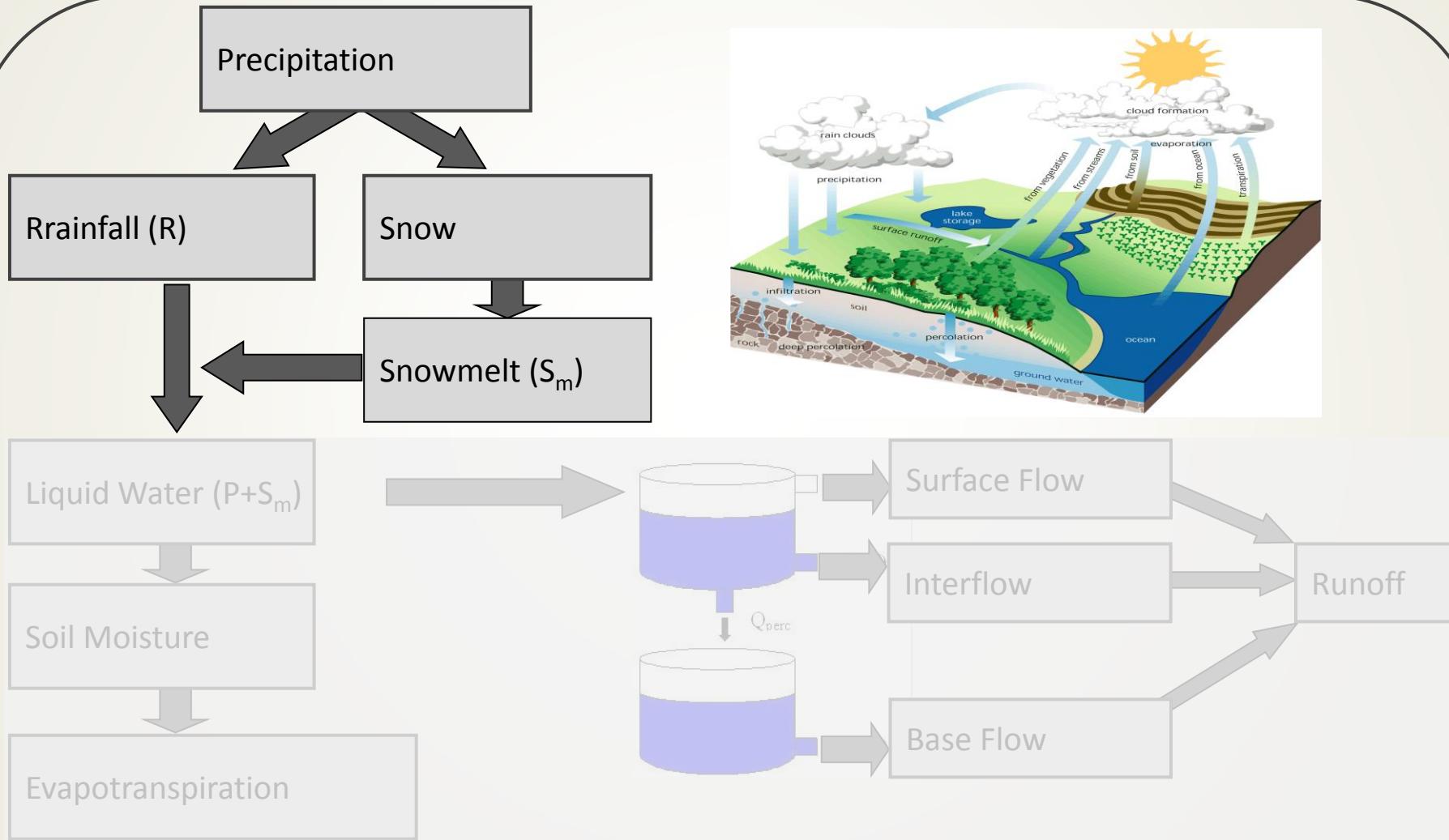
=IF(C32>\$C\$9,MAX(E31-\$C\$10\*(C32-\$C\$9),0),E31+D32)

NOTE: The MAX function in the above statement is used to prevent negative values of snow height!

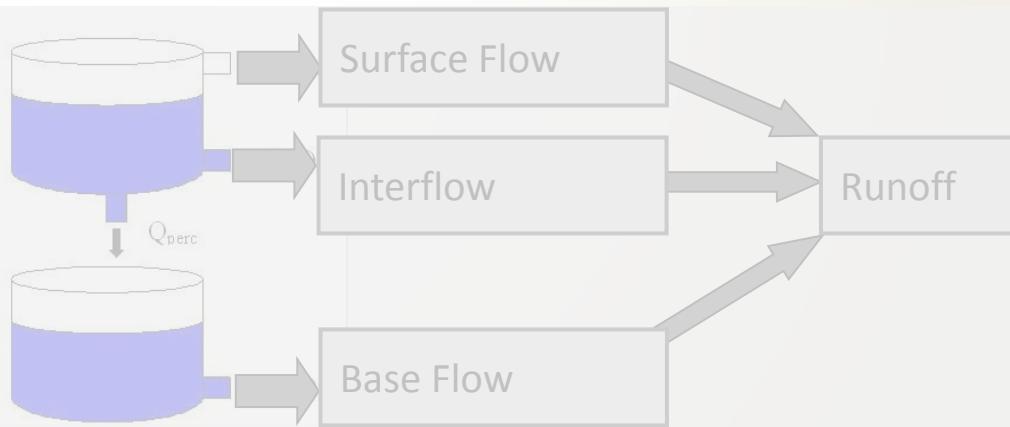
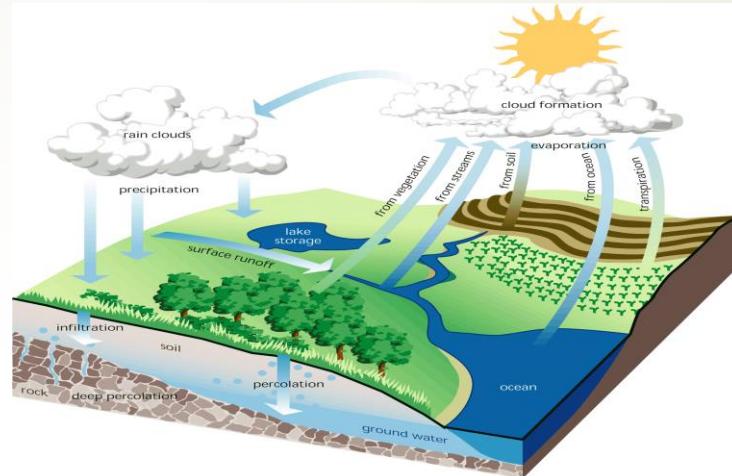
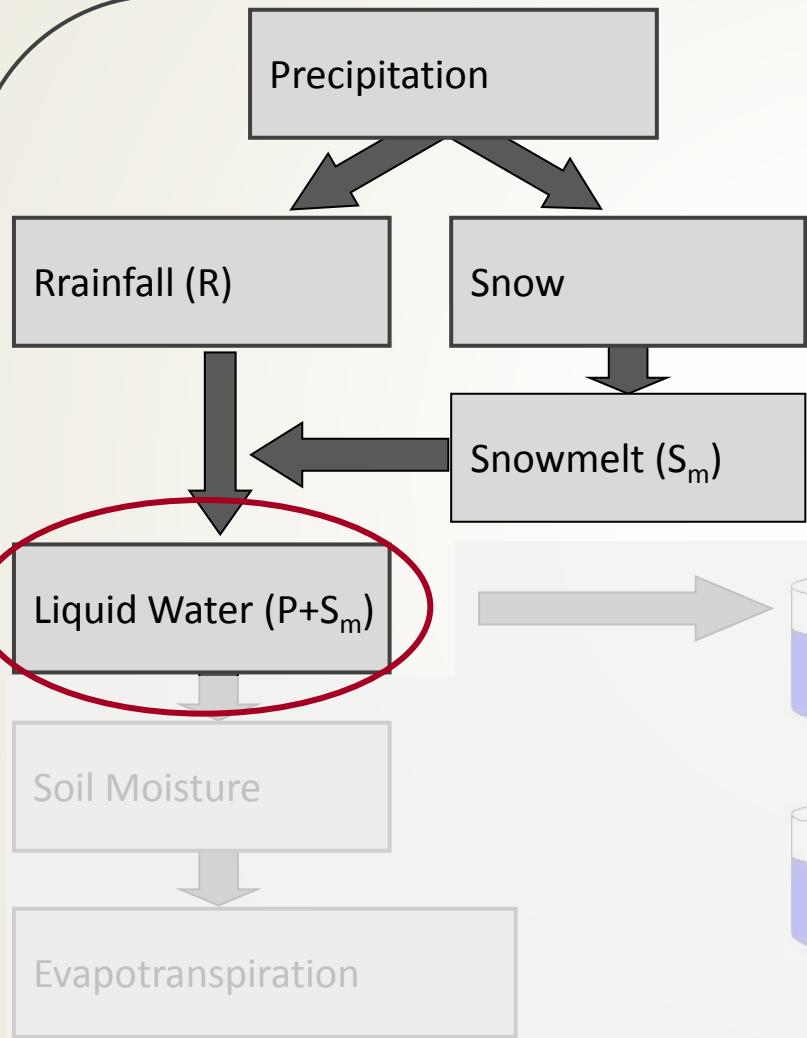


8 Catchment Area (Km <sup>2</sup> )	410	K <sub>0</sub> (Reservoir Par.)	0.13		
9 T <sub>t</sub> (Threshold Temp.)	0	L <sub>1</sub> (Threshold W.L.)	6.00		
10 DD	3	K <sub>1</sub> (Reservoir Par.)	0.13		
11 FC (Field Capacity)	180.000	K <sub>2</sub> (Reservoir Par.)	0.00		
12 BETA	5.400	K <sub>perc</sub>	0.22		
13 C (Model param.)	0.030	PWP	105.00		
14		Model Performance			
15 Monthly T <sub>ave.</sub>	PE <sub>m</sub>	TOT. ETA.	5761.39		
16 -1.4	5	TOT. PREC.	9887.30		
17 -0.3	5	TOT. DIS. (m/hr.km <sup>2</sup> )	4125.91		
18 2.6	20	OBS. DISC(m/hr.km <sup>2</sup> )	4132.27		
19 6.3	50	Sqr diff.	52292.14		
20 10.9	95	Average Q <sub>observ.</sub>	5.40		
21 14.2	115	(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78		
22 16.4	125	Correlation	0.84		
23 15.6	100	Nash Sutcliff	0.70		
24 12.7	70				
25 8.3	30				
26 2.9	10				
27 -0.4	5				
28					
29 Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water
30					
31				25	
32 1/1/1991	1	-1.5	0.4	25.4	0
33 1/2/1991	1	-0.8	10.5	35.9	0
34 1/3/1991	1	-2.8	0.9	36.8	0
35 1/4/1991	1	-3.7	4.4	41.2	0
36 1/5/1991	1	-6.1	0.6	41.8	0
37 1/6/1991	1	-3	0	41.8	0
38 1/7/1991	1	-0.7	4.4	46.2	0
39 1/8/1991	1	1.8	3.1	40.8	8.5
40 1/9/1991	1	0.6	1.7	39	3.5
41 1/10/1991	1	1.8	3.6	33.6	9
42 1/11/1991	1	1.2	2.4	30	6
43 1/12/1991	1	1.5	0	25.5	4.5

# Model Structure



# Model Structure



# Liquid Water Equivalent

$$\text{Liquid Water} = P + S_m$$

P= Precipitation

$S_m$ = Snowmelt

# Liquid Water Equivalent

$$\text{Liquid Water} = P + S_m$$

P= Precipitation

$S_m$ = Snowmelt



If  $T < T_t$  : Liquid Water = 0

If  $T > T_t$  : Liquid Water =  $P + S_m$

$T_t$  : Threshold temperature ( $0^\circ\text{C}$  /  $32^\circ\text{F}$ )

# Liquid Water Equivalent

$$\text{Liquid Water} = P + S_m$$

P = Precipitation

$S_m$  = Snowmelt



If  $T < T_t$  : Liquid Water = 0

If  $T > T_t$  : Liquid Water =  $P + S_m$

$T_t$  : Threshold temperature ( $0^\circ\text{C}$  /  $32^\circ\text{F}$ )



**IF(C32>\$C\$9,D32+MIN(E31,\$C\$10\*(C32-\$C\$9)),0)**

$T > T_t$

$T \leq T_t$

NOTE: The MIN function in the above statement is used to prevent negative values

# Liquid Water Equivalent

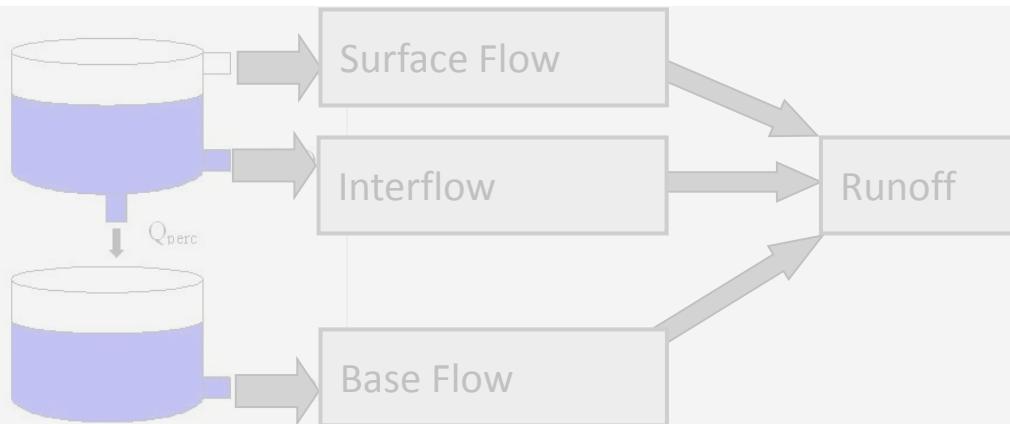
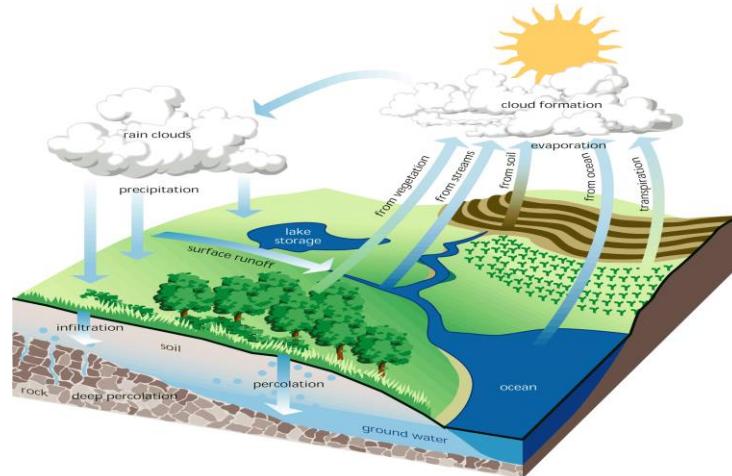
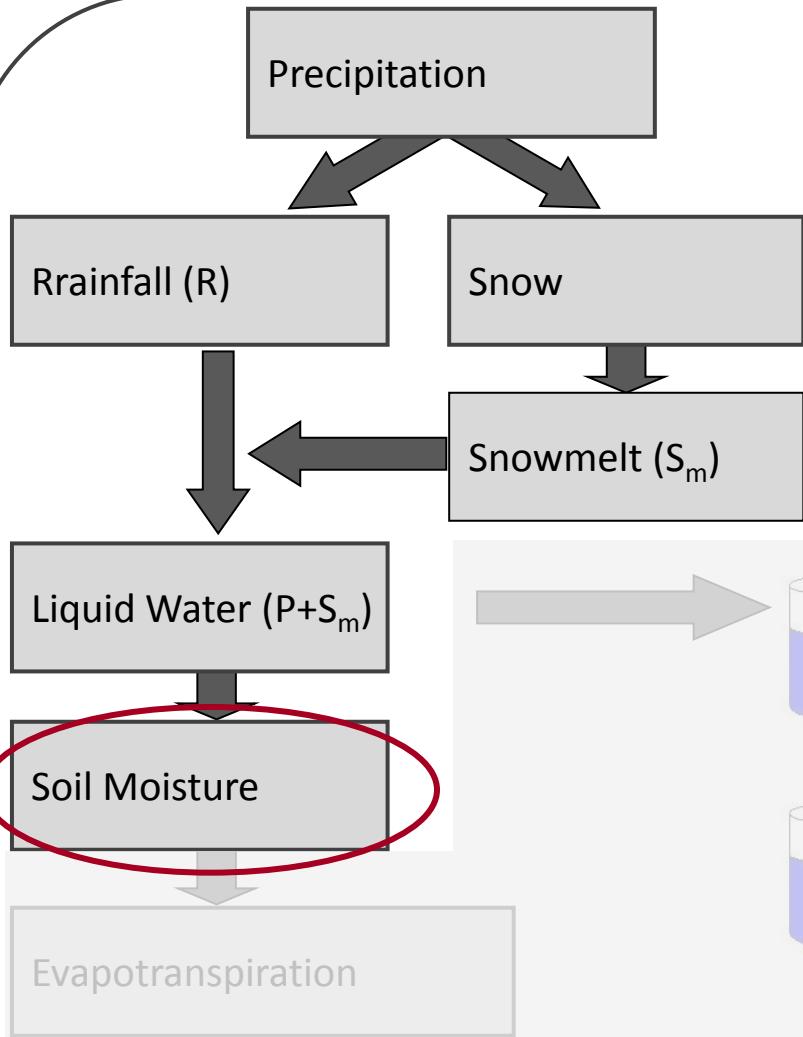
Liquid Water = P+S<sub>m</sub>

*IF(C32>\$C\$9,D32+MIN(E31,\$C\$10\*(C32-\$C\$9)),0)*

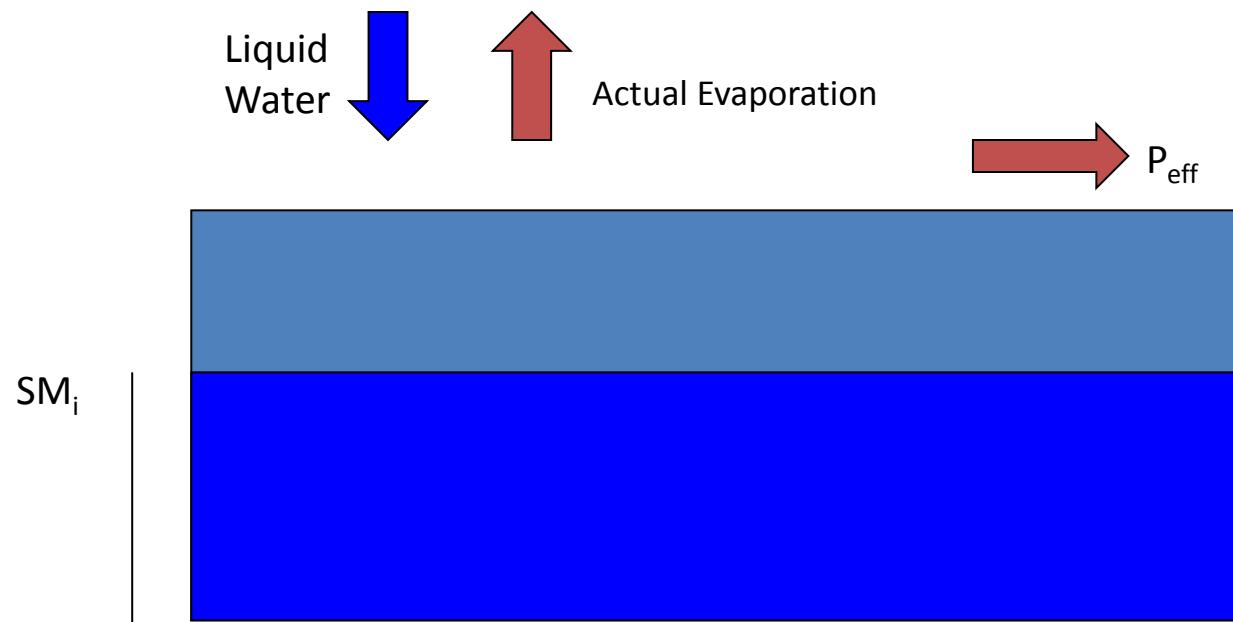
NOTE: The MIN function in the above statement is used to prevent negative values

29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water
30						
31					25	
32	1/1/1991	1	-1.5	0.4	25.4	0
33	1/2/1991	1	-0.8	10.5	35.9	0
34	1/3/1991	1	-2.8	0.9	36.8	0
35	1/4/1991	1	-3.7	4.4	41.2	0
36	1/5/1991	1	-6.1	0.6	41.8	0
37	1/6/1991	1	-3	0	41.8	0
38	1/7/1991	1	-0.7	4.4	46.2	0
39	1/8/1991	1	1.8	3.1	40.8	8.5
40	1/9/1991	1	0.6	1.7	39	3.5
41	1/10/1991	1	1.8	3.6	33.6	9
42	1/11/1991	1	1.2	2.4	30	6
43	1/12/1991	1	1.5	0	25.5	4.5
44	1/13/1991	1	1.1	0	22.2	3.3
45	1/14/1991	1	-0.5	0	22.2	0
46	1/15/1991	1	-3.2	1.3	23.5	0
47	1/16/1991	1	-0.9	0.6	24.1	0
48	1/17/1991	1	3.2	5	14.5	14.6

# Model Structure



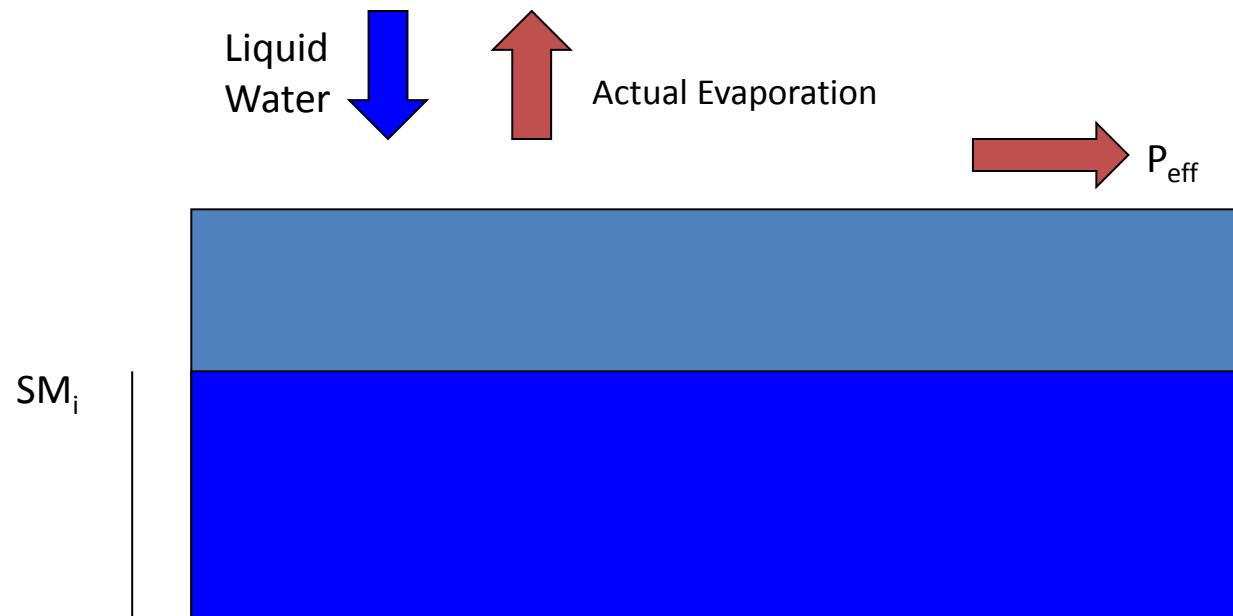
# Soil Moisture



# Soil Moisture

**Soil Moisture = Initial Soil Moisture ( $SM_i$ ) + Liquid Water – Effective Precipitation ( $P_{eff}$ ) – Actual Evapotranspiration**

In the following, Effective Precipitation and Actual Evapotranspiration are addressed.



# Effective Precipitation

$$P_{\text{eff}} = \left[ \frac{SM}{FC} \right]^\beta (P + SNOWMELT)$$

$P_{\text{eff}}$  ([L]) effective precipitation

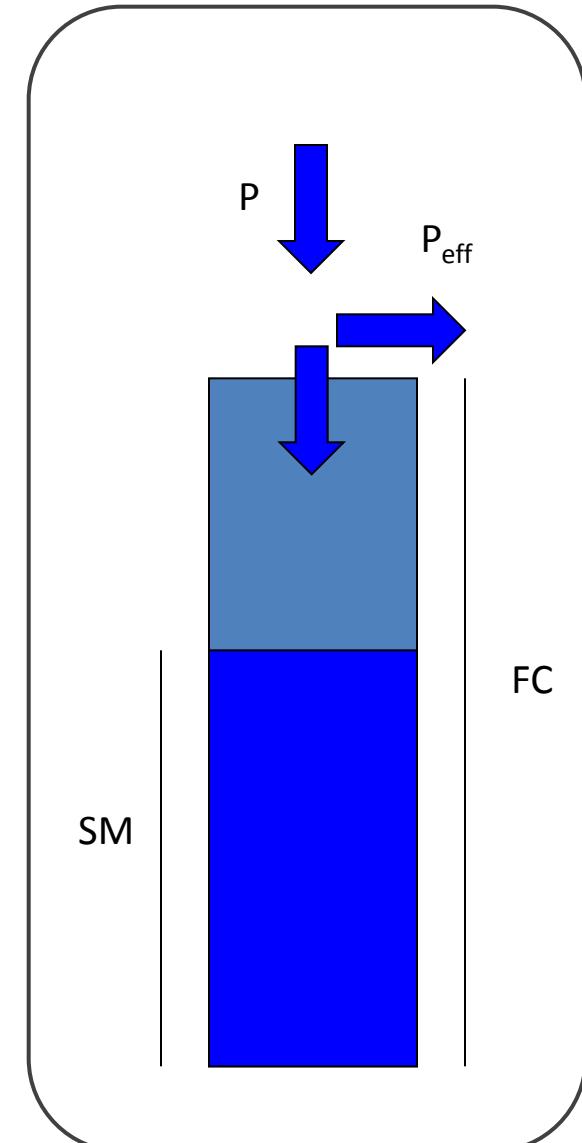
$SM$  [L] actual soil-moisture

$FC$  ([L]) maximum soil storage capacity

$\beta$  ([-]) model parameter

$P$  ([L]) depth of daily precipitation

Field capacity ( $FC$ ) : describes maximum soil moisture storage in the catchment. The higher the amount of soil moisture; the more precipitation contributes to runoff production.



# Effective Precipitation

$$P_{\text{eff}} = \left[ \frac{SM}{FC} \right]^{\beta} (P + \text{SNOWMELT})$$

Liquid Water

Runoff Coefficient

$P_{\text{eff}}$  ([L]) effective precipitation

$SM$  [L] actual soil-moisture

$FC$  ([L]) maximum soil storage capacity

$\beta$  [-] model parameter

$P$  ([L]) depth of daily precipitation

For a given soil-moisture deficit,  $\beta$  determines the amount of rain or snowmelt which contributes to runoff. The graph shows that for a specific soil moisture, the higher the  $\beta$ , the lower the runoff coefficient. Further, as the soil moisture ( $SM$ ) approaches the field capacity ( $FC$ ); the runoff coefficient increases.

# Effective Precipitation

$$P_{eff} = \left[ \frac{SM}{FC} \right]^\beta (P + SNOWMELT)$$

Liquid Water

Runoff Coefficient

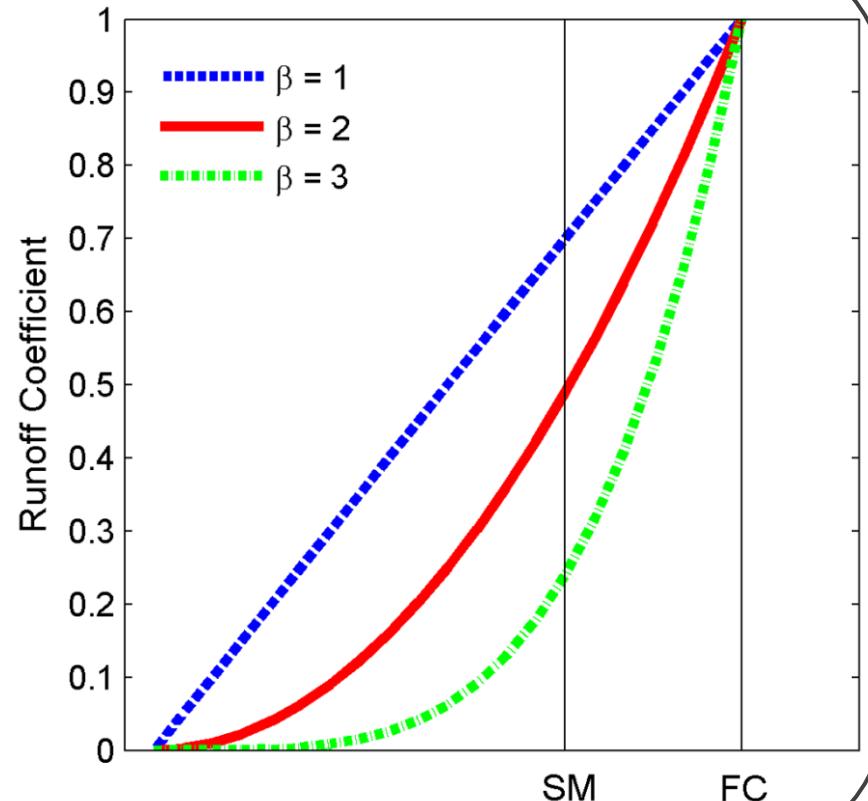
$P_{eff}$  ([L]) effective precipitation

$SM$  [L] actual soil-moisture

$FC$  ([L]) maximum soil storage capacity

$\beta$  ([-]) model parameter

$P$  ([L]) depth of daily precipitation

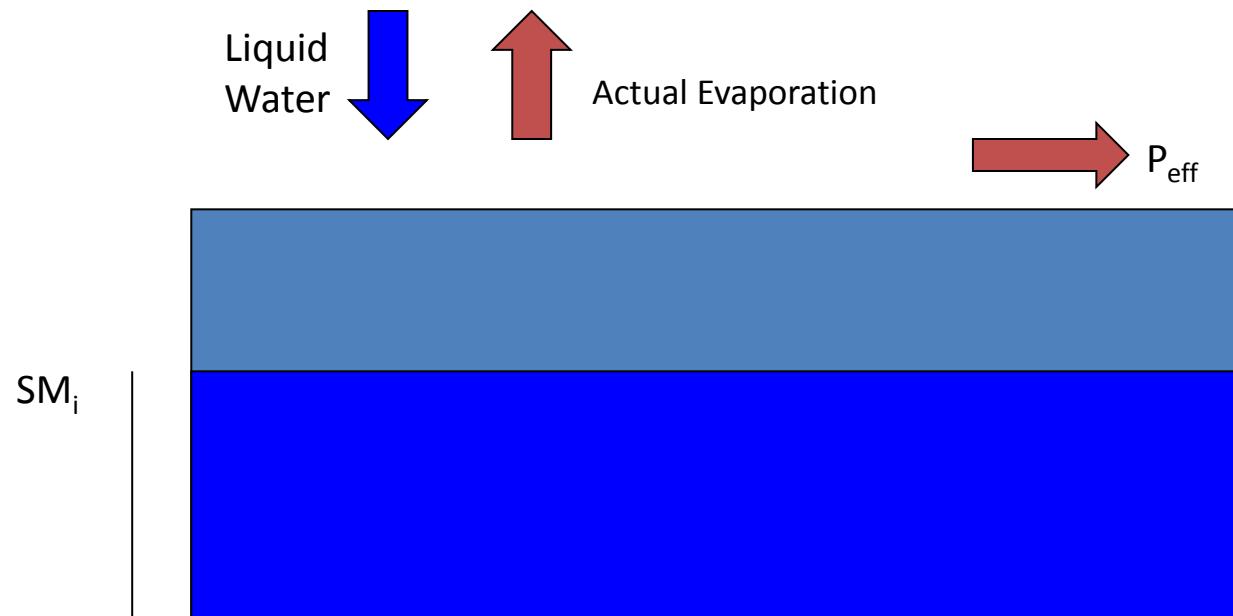


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# Soil Moisture

**Soil Moisture = Initial Soil Moisture ( $SM_i$ ) + Liquid Water – Effective Precipitation ( $P_{eff}$ ) – Actual Evapotranspiration**

In the following, Effective Precipitation and Actual Evapotranspiration are addressed.



# Effective Precipitation

$$P_{\text{eff}} = \left[ \frac{SM}{FC} \right]^{\beta} (P + SNOWMELT)$$



=(\$F32\*(G31/\$C\$11)^\$C\$12)

28	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>
29								
30								
31								
32	1/1/1991	1	-1.5	0.4	25	0	100.0	0.000
33	1/2/1991	1	-0.8	10.5	25.4	0	99.8	0.000
34	1/3/1991	1	-2.8	0.9	35.9	0	99.7	0.000
35	1/4/1991	1	-3.7	4.4	36.8	0	99.5	0.000
36	1/5/1991	1	-6.1	0.6	41.2	0	99.4	0.000
37	1/6/1991	1	-3	0	41.8	0	99.3	0.000
38	1/7/1991	1	-0.7	4.4	41.8	0	99.1	0.000
39	1/8/1991	1	1.8	3.1	46.2	0	99.0	0.000
40	1/9/1991	1	0.6	1.7	40.8	8.5	107.0	0.336
41	1/10/1991	1	1.8	3.6	39	3.5	110.1	0.211
					33.6	9	118.3	0.633

# Effective Precipitation

8	Catchment Area (Km <sup>2</sup> )	410	K <sub>0</sub> (Reservoir Par.)	0.13
9	T <sub>t</sub> (Threshold Temp.)	0	L <sub>1</sub> (Threshold W.L.)	6.00
10	DD	3	K <sub>1</sub> (Reservoir Par.)	0.13
11	FC (Field Capacity)	180.000	K <sub>2</sub> (Reservoir Par.)	0.00
12	BETA	5.400	K <sub>perc</sub>	0.22
13	C (Model param.)	0.030	PWP	105.00
14				

	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>
15	-1.4	5	0.161
16	-0.3	5	0.179
17	2.6	20	0.645
18	6.3	50	1.667
19	10.9	95	3.065
20	14.2	115	3.833
21	16.4	125	4.032
22	15.6	100	3.226
23	12.7	70	2.333
24	8.3	30	0.968
25	2.9	10	0.333
26	-0.4	5	0.161
27			
28			

Model Performance	
TOT. ETA.	5761.39
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4125.91
OBS. DISC(m/hr.km <sup>2</sup> )	4132.27
Square diff.	52292.14
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.84
Nash Sutcliff	0.70

	Date	Month	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day)	OR P <sub>eff</sub>
30		ID							
31					25		100.0		
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	
39	1/8/1991	1	1.8	3.1	40.8	8.5	107.0	0.336	
40	1/9/1991	1	0.6	1.7	39	3.5	110.1	0.211	
41	1/10/1991	1	1.8	3.6	33.6	9	118.3	0.633	
42	1/11/1991	1	1.2	2.4	30	6	123.5	0.621	
43	1/12/1991	1	1.5	0	25.5	4.5	127.2	0.588	
44	1/13/1991	1	1.1	0	22.2	2.2	120.8	0.507	

# Evapotranspiration

$$PE_a = (1 + C \cdot (T - T_m)) \cdot PE_m$$

$PE_a$  ([L]) : adjusted potential evapotranspiration (none negative)

$C$  ( $[\theta^{-1}]$ ) : model parameter

$T$  ( $[\theta]$ ) : mean daily air temperature

$T_m$  ( $[\theta]$ ) : long term mean monthly air temperature

$PE_m$  ([L]) : long term mean monthly potential evapotranspiration

The model parameter  $C$  is used to improve model performance when the mean daily temperature deviates considerably from its long-term mean. The soil moisture and the actual evapotranspiration are coupled through the use of the soil moisture limit, PWP.

# Evapotranspiration

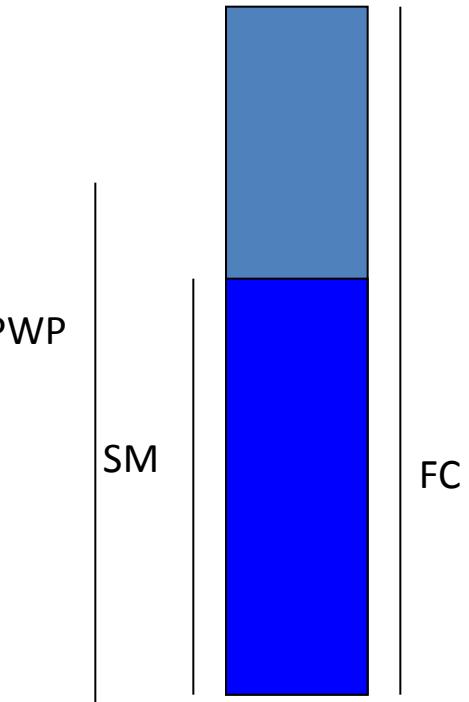
$$E_a = PE_a \cdot \frac{SM}{PWP} \quad \text{for } SM < PWP$$

$$E_a = PE_a \quad \text{for } SM \geq PWP$$

$E_a$  ([L]) Actual evapotranspiration

PWP ([L]) Soil Permanent Wilting Point

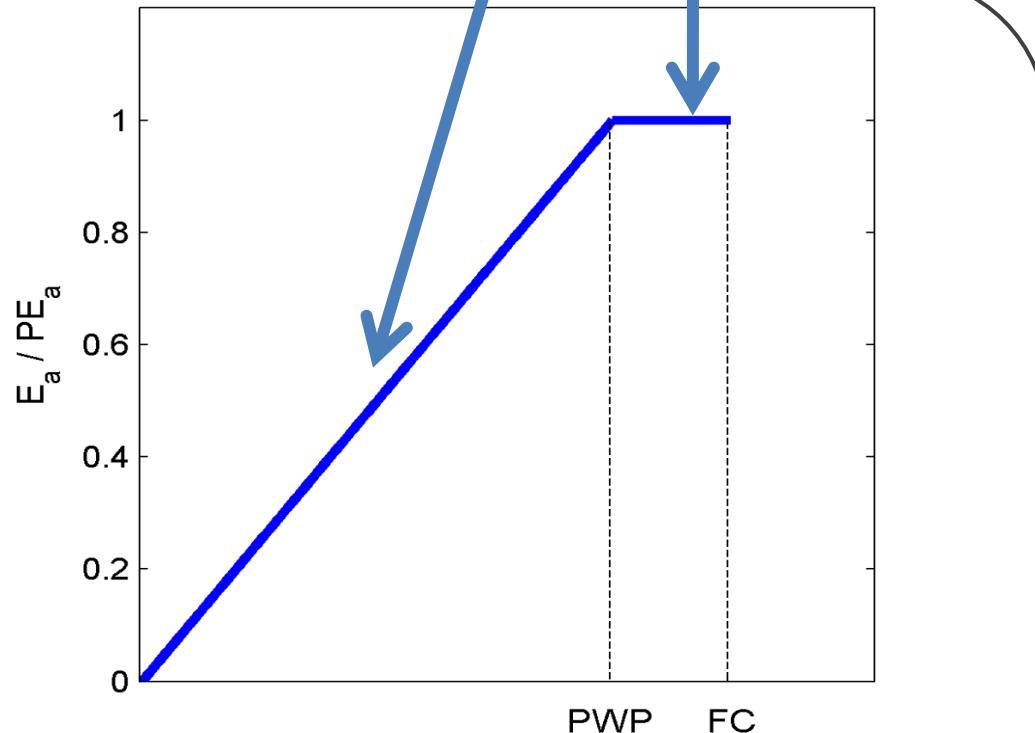
When the soil moisture is above the PWP, actual evapotranspiration occurs at the same rate as potential evapotranspiration. PWP is the soil-moisture limit for evapotranspiration decrease meaning that when the soil moisture is less than PWP, the actual evapotranspiration is less than the adjusted evapotranspiration.



# Evapotranspiration

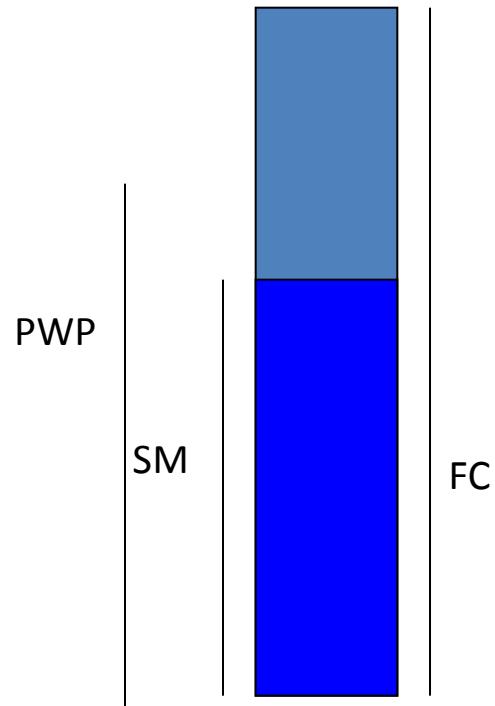
$$E_a = PE_a \cdot \frac{SM}{PWP} \quad \text{for } SM < PWP$$

$$E_a = PE_a \quad \text{for } SM \geq PWP$$



PEa ([L]) : adjusted potential evapotranspiration

Ea ([L]) : actual evapotranspiration



# Evapotranspiration

$$PE_a = (1 + C \cdot (T - T_m)) \cdot PE_m$$



=**(1+\$C\$13\*(C32-INDEX(\$A\$16:\$A\$27,B32)))\*INDEX(\$C\$16:\$C\$27,B32)**

29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)
30										
31										
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.161	0.156
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155
39	1/8/1991	1	1.8	3.1	40.8	8.5	107.0	0.336	0.177	0.167
40	1/9/1991	1	0.6	1.7	39	3.5	110.1	0.211	0.171	0.171
41	1/10/1991	1	1.8	3.6	33.6	9	118.3	0.633	0.177	0.177
42	1/11/1991	1	1.2	2.4	30	6	123.5	0.621	0.174	0.174
43	1/12/1991	1	1.5	0	25.5	4.5	127.2	0.588	0.175	0.175
44	1/13/1991	1	1.1	0	22.2	2.2	120.8	0.507	0.172	0.172

# Evapotranspiration

$$E_a = PE_a \cdot \frac{SM}{PWP} \quad \text{for } SM < PWP$$

$$E_a = PE_a \quad \text{for } SM \geq PWP$$



=IF(G31>=F\$13,I32,I32\*(G31/F\$13))

29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)
30										
31										
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.153
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155
39	1/8/1991	1	1.8	3.1	40.8	8.5	107.0	0.336	0.177	0.167
40	1/9/1991	1	0.6	1.7	39	3.5	110.1	0.211	0.171	0.171
41	1/10/1991	1	1.8	3.6	33.6	9	118.3	0.633	0.177	0.177
42	1/11/1991	1	1.2	2.4	30	6	123.5	0.621	0.174	0.174
43	1/12/1991	1	1.5	0	25.5	4.5	127.2	0.588	0.175	0.175
44	1/13/1991	1	1.1	0	22.2	2.2	120.8	0.507	0.172	0.172

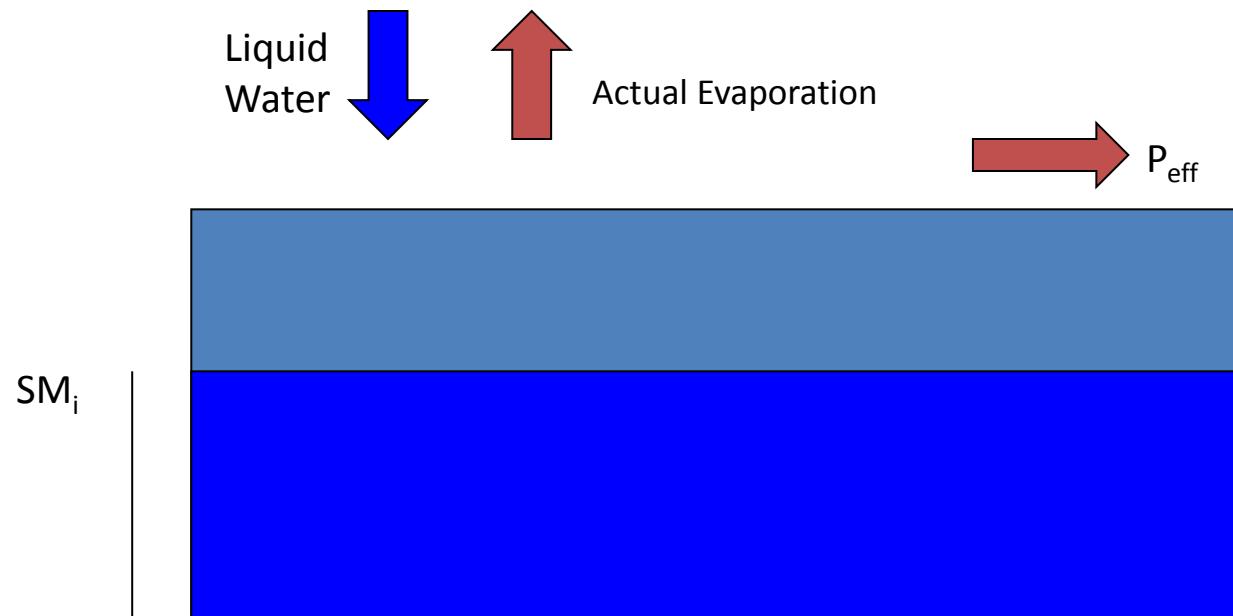
# Evapotranspiration

8	Catchment Area (Km <sup>2</sup> )	410	K <sub>0</sub> (Reservoir Par.)	0.13						
9	T <sub>t</sub> (Threshold Temp.)	0	L <sub>1</sub> (Threshold W.L.)	6.00						
10	DD	3	K <sub>1</sub> (Reservoir Par.)	0.13						
11	FC (Field Capacity)	180.000	K <sub>2</sub> (Reservoir Par.)	0.00						
12	BETA	5.400	K <sub>....</sub>	0.22						
13	C (Model param.)	0.030	PWP	105.00						
14										
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>							
16	-1.4	5	0.161							
17	-0.3	5	0.179							
18	2.6	20	0.645							
19	6.3	50	1.667							
20	10.9	95	3.065							
21	14.2	115	3.833							
22	16.4	125	4.032							
23	15.6	100	3.226							
24	12.7	70	2.333							
25	8.3	30	0.968							
26	2.9	10	0.333							
27	-0.4	5	0.161							
28										
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)
30										
31					25		100.0			
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155
39	1/8/1991	1	1.8	3.1	40.8	8.5	107.0	0.336	0.177	0.167
40	1/9/1991	1	0.6	1.7	39	3.5	110.1	0.211	0.171	0.171
41	1/10/1991	1	1.8	3.6	33.6	9	118.3	0.633	0.177	0.177
42	1/11/1991	1	1.2	2.4	30	6	123.5	0.621	0.174	0.174
43	1/12/1991	1	1.5	0	25.5	4.5	127.2	0.588	0.175	0.175
44	1/13/1991	1	1.1	0	22.2	2.2	120.8	0.507		

# Soil Moisture

**Soil Moisture = Initial Soil Moisture ( $SM_i$ ) + Liquid Water – Effective Precipitation ( $P_{eff}$ ) – Actual Evapotranspiration**

In the following, Effective Precipitation and Actual Evapotranspiration are addressed.



# Soil Moisture

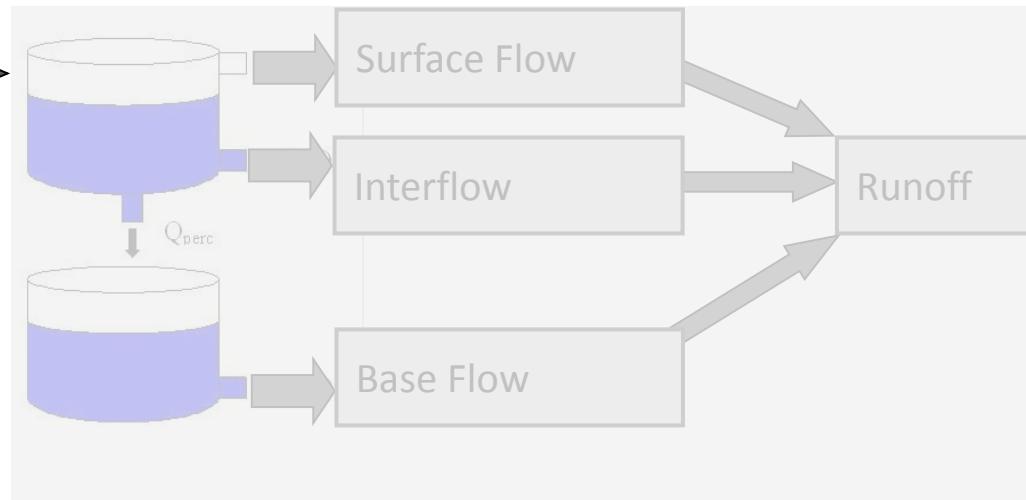
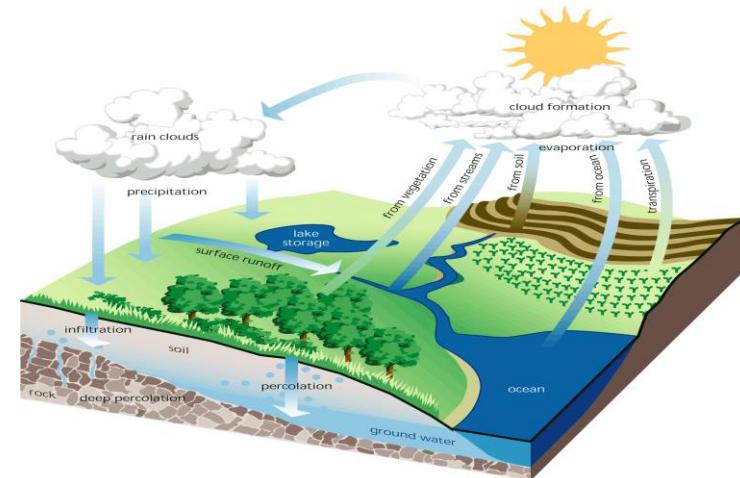
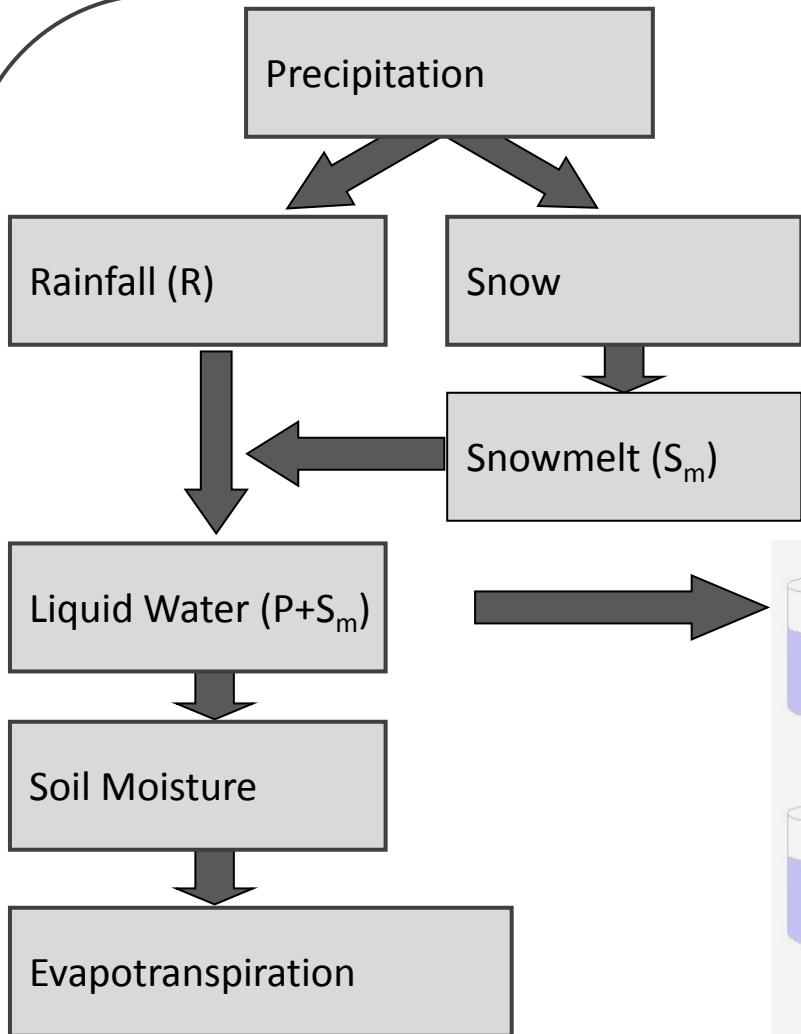
**Soil Moisture = Initial Soil Moisture ( $SM_i$ ) + Liquid Water – Effective Precipitation ( $P_{eff}$ ) – Actual Evapotranspiration**



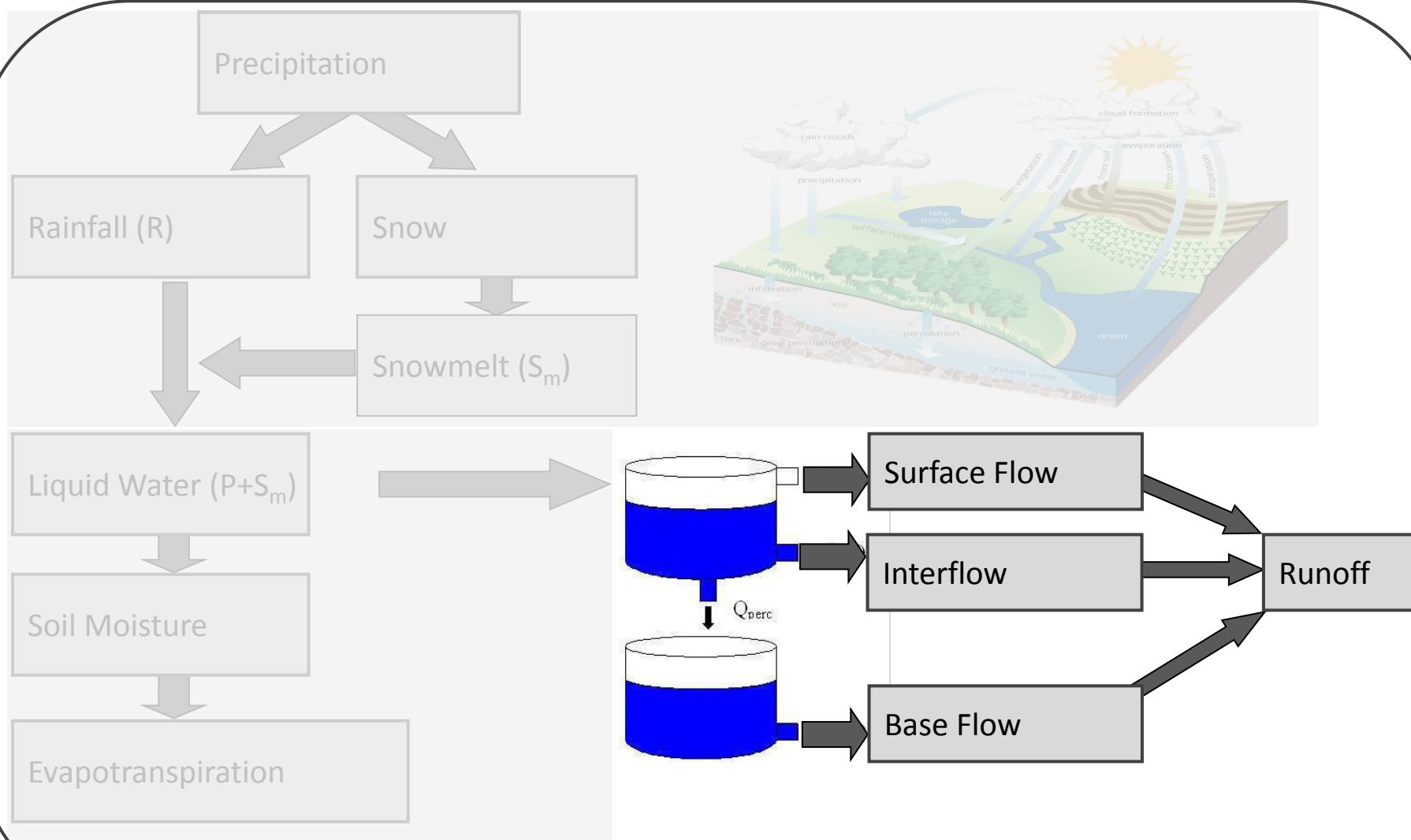
**=G31+F32-H32-J32**

	A	B	C	D	E	F	G	H	I	J
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR $P_{eff}$	Potential E. ( $PE_a$ )	$E_a$ (mm/day)
30										
31					25		100.0			
32	1/1/1991	1	-1.5	0.4	25.4	0	=G31+F32-H32-J32	0.000	0.161	0.153
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131

# Model Structure



# Model Structure

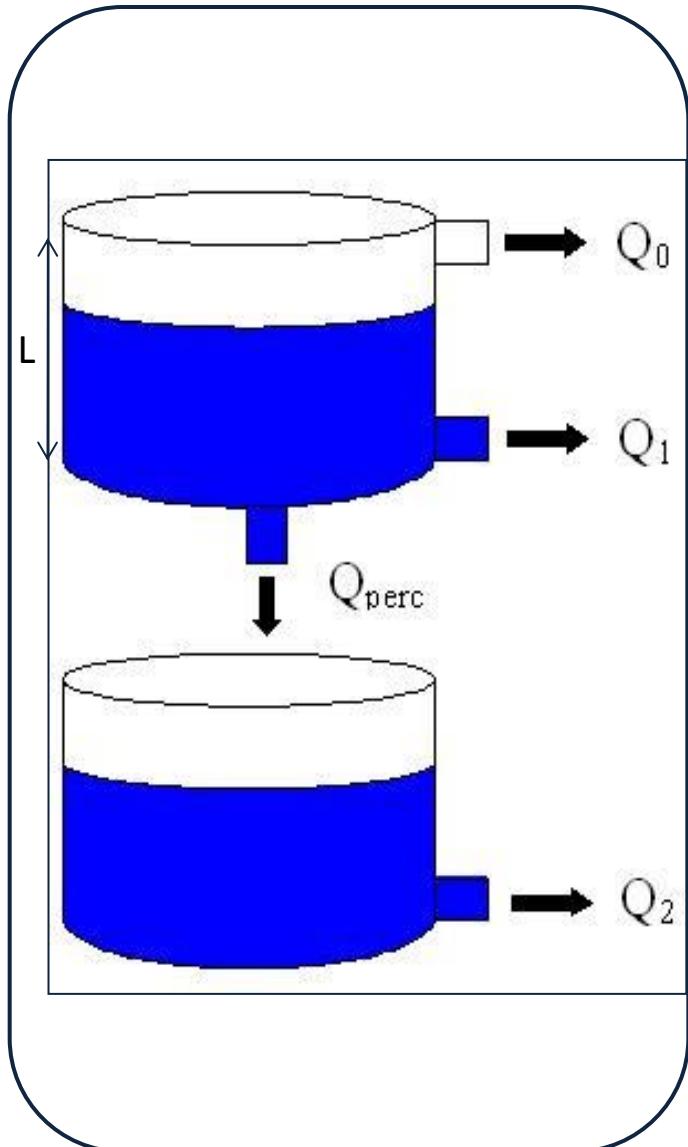


# Reservoir Concept

This module estimates the runoff at the catchment outlet based on the reservoir concept. The system consists of two conceptual reservoirs one above the other.

The first reservoir is used to model the near surface and sub-surface flow, and the second reservoir is used to simulate the base flow.

The reservoirs are directly connected to each other through the use of a constant percolation rate ( $Q_{\text{perc}}$ ).



# Reservoir Concept

$$Q_0 = \begin{cases} K_0 \cdot (S_i - L) \cdot A_{sc} & \text{for } S > L \\ 0 & \text{for } S \leq L \end{cases}$$

$$Q_1 = K_1 \cdot (S_i) \cdot A_{sc}$$

$$Q_{\text{perc}} = K_{\text{perc}} \cdot (S_i) \cdot A_{sc}$$

$$Q_2 = K_2 \cdot (S_b) \cdot A_{sc}$$

$Q_0$  ( $[L^3 T^{-1}]$ ) near surface flow

$Q_1$  ( $[L^3 T^{-1}]$ ) Interflow

$Q_{\text{perc}}$  ( $[L^3 T^{-1}]$ ) Percolation

$Q_2$  ( $[L^3 T^{-1}]$ ) base flow

$K_0$  ( $[T^{-1}]$ ) subsurface storage constant

$K_1$  ( $[T^{-1}]$ ) interflow storage constant

$K_{\text{perc}}$  ( $[T^{-1}]$ ) percolation storage constant

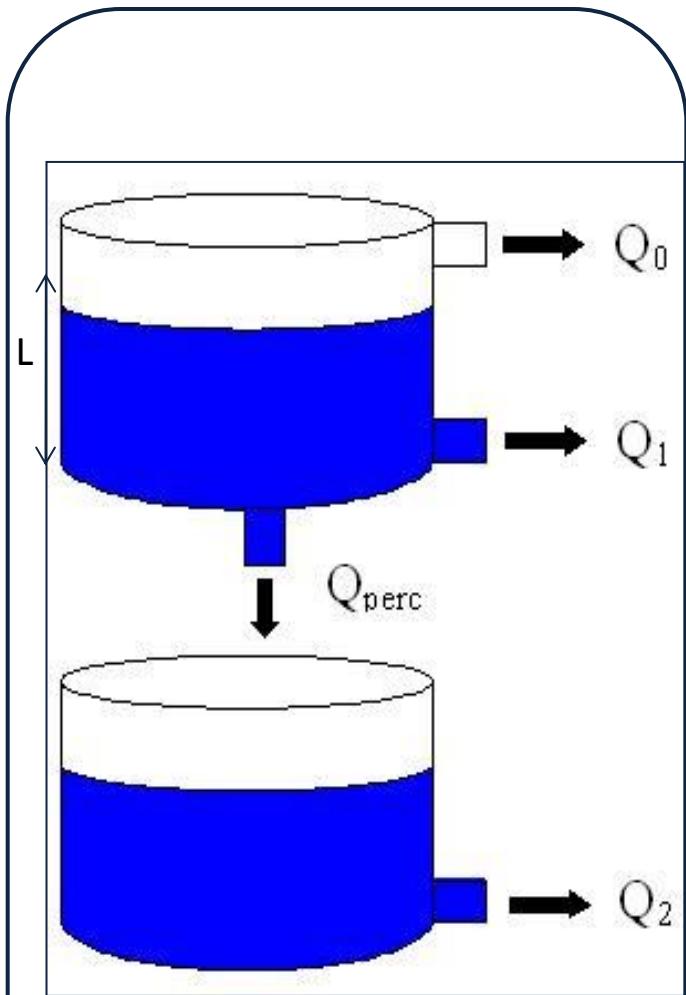
$K_2$  ( $[T^{-1}]$ ) base flow storage constant

$S_i$  ( $[L]$ ) upper reservoir water level (WL)

$S_b$  ( $[L]$ ) lower reservoir WL

$L$  ( $[L]$ ) threshold for subsurface flow

$A_{sc}$  [ $L^2$ ] Sub-catchment area



# Reservoir Concept

$$Q_0 = \begin{cases} K_0 \cdot (S_i - L) \cdot A_{sc} & \text{for } S > L \\ 0 & \text{for } S \leq L \end{cases}$$

$$Q_1 = K_1 \cdot (S_i) \cdot A_{sc}$$

$$Q_{\text{perc}} = K_{\text{perc}} \cdot (S_i) \cdot A_{sc}$$

$$Q_2 = K_2 \cdot (S_b) \cdot A_{sc}$$

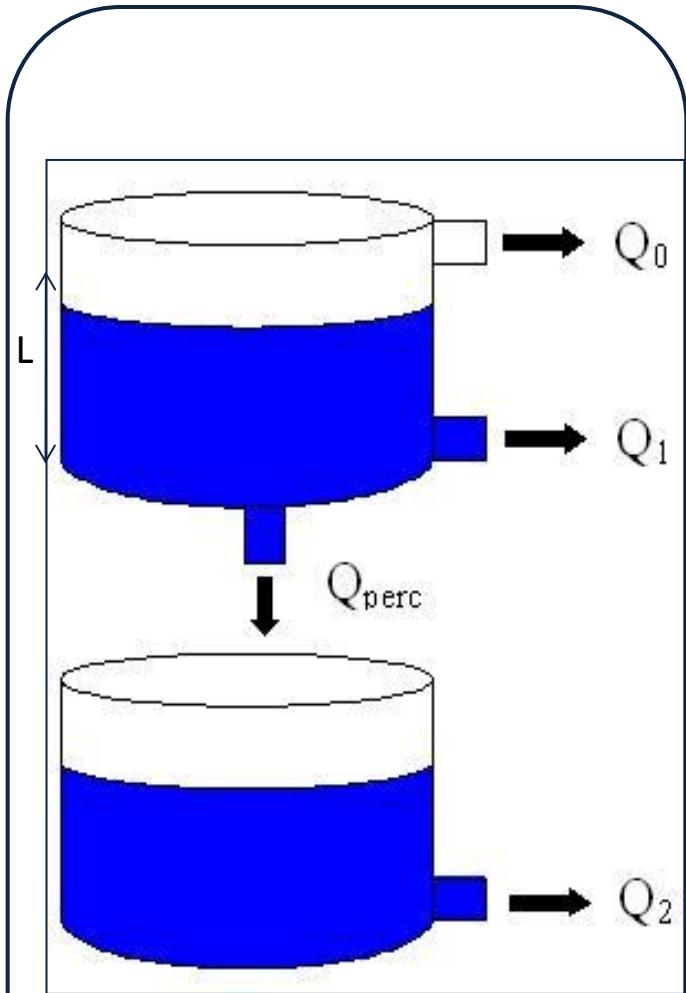
$K_0$  ( $[T^{-1}]$ ) subsurface storage constant

$K_1$  ( $[T^{-1}]$ ) interflow storage constant

$K_{\text{perc}}$  ( $[T^{-1}]$ ) percolation storage constant

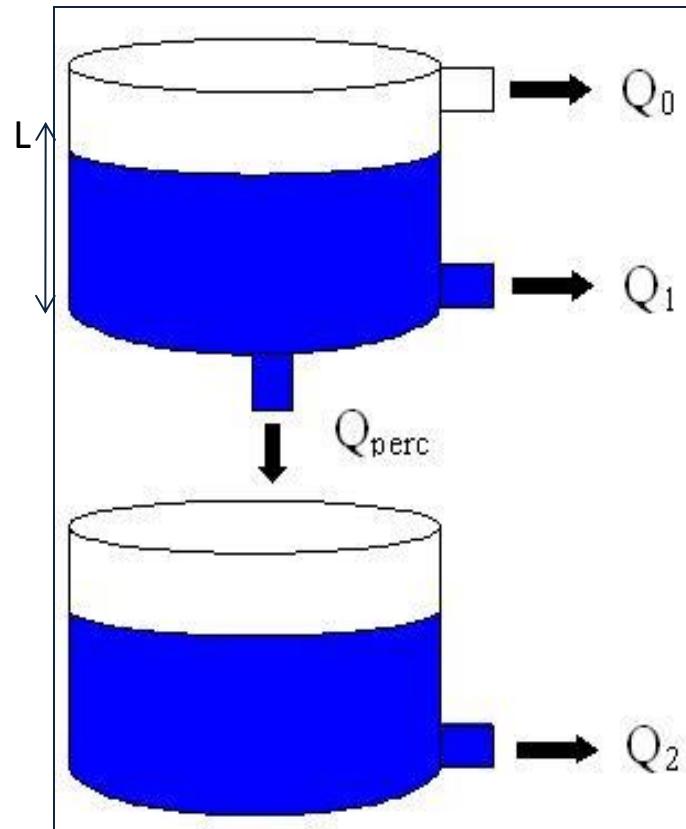
$K_2$  ( $[T^{-1}]$ ) base flow storage constant

When the water level in the upper reservoir exceeds the threshold value  $L$ , runoff quickly occurs from the upper reservoir. The flow response of its other two outlets is relatively slower. Recession coefficients  $K_0$ ,  $K_1$ ,  $K_2$ , represent the response function.



# Reservoir Concept

8	Catchment Area (Km <sup>2</sup> )	410	K <sub>0</sub> (Reservior Par.)	0.13
9	T <sub>t</sub> (Threshold Temp.)	0	L <sub>1</sub> (Threshold W.L.)	6.00
10	DD	3	K <sub>1</sub> (Reservior Par.)	0.13
11	FC (Field Capacity)	180.0	K <sub>2</sub> (Reservior Par.)	0.00
12	BETA	3.0	K <sub>perc</sub>	0.22
13	C (Model param.)	0.03	PWP	105.00
14				
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>	Model Performance
16	-1.4	5	0.161	TOT. ETA. 5493.37
17	-0.3	5	0.179	TOT. PREC. 9887.30
18	2.6	20	0.645	TOT. DIS. (m/hr.km <sup>2</sup> ) 4393.93
19	6.3	50	1.667	SIM. DISC(m/hr.km <sup>2</sup> ) 4399.65
20	10.9	95	3.065	OBS. DISC(m/hr.km <sup>2</sup> ) 4157.63
21	14.2	115	3.833	Error (%) 5.821
22	16.4	125	4.032	Square diff. 53933.17
23	15.6	100	3.226	Average Q <sub>observ.</sub> 5.40
24	12.7	70	2.333	(Q-Q <sub>m</sub> ) <sup>2</sup> 172559.78
25	8.3	30	0.968	Correlation 0.83
26	2.9	10	0.333	Nash Sutcliff 0.69
27	-0.4	5	0.161	

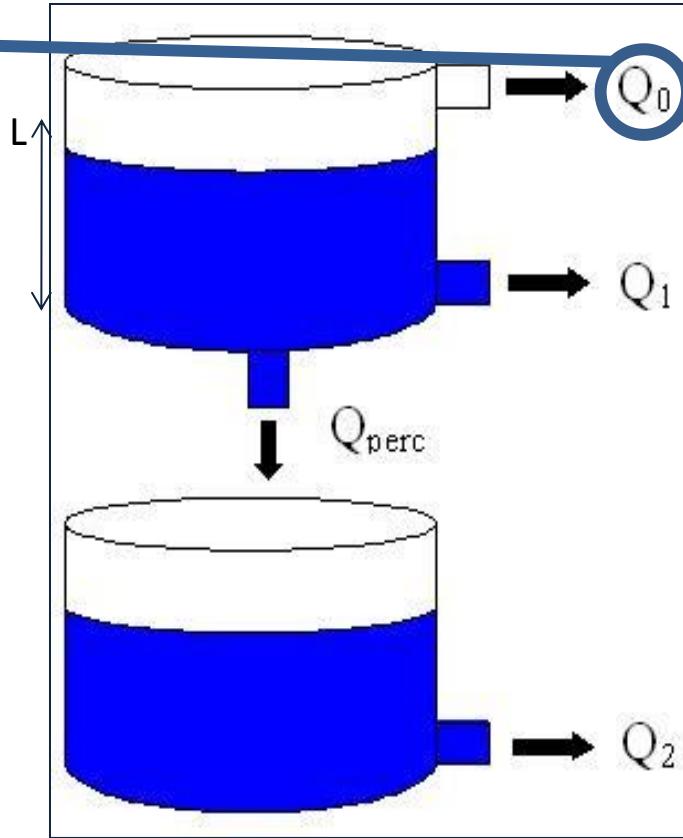


# Reservoir Concept

8	Catchment Area (Km <sup>2</sup> )	410	
9	T <sub>t</sub> (Threshold Temp.)	0	
10	DD	3	
11	FC (Field Capacity)	180.0	
12	BETA	3.0	
13	C (Model param.)	0.03	
14			
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>
16	-1.4	5	0.161
17	-0.3	5	0.179
18	2.6	20	0.645
19	6.3	50	1.667
20	10.9	95	3.065
21	14.2	115	3.833
22	16.4	125	4.032
23	15.6	100	3.226
24	12.7	70	2.333
25	8.3	30	0.968
26	2.9	10	0.333
27	-0.4	5	0.161

K <sub>0</sub> (Reservoir Par.)	0.13
L <sub>1</sub> (Threshold W.L.)	6.00
K <sub>1</sub> (Reservoir Par.)	0.13
K <sub>2</sub> (Reservoir Par.)	0.00
K <sub>perc</sub>	0.22
PWP	105.00

Model Performance	
<b>TOT. ETA.</b>	5493.37
<b>TOT. PREC.</b>	9887.30
<b>TOT. DIS. (m/hr.km<sup>2</sup>)</b>	4393.93
<b>SIM. DISC(m/hr.km<sup>2</sup>)</b>	4399.65
<b>OBS. DISC(m/hr.km<sup>2</sup>)</b>	4157.63
Error (%)	5.821
Square diff.	53933.17
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.83
Nash Sutcliff	0.69

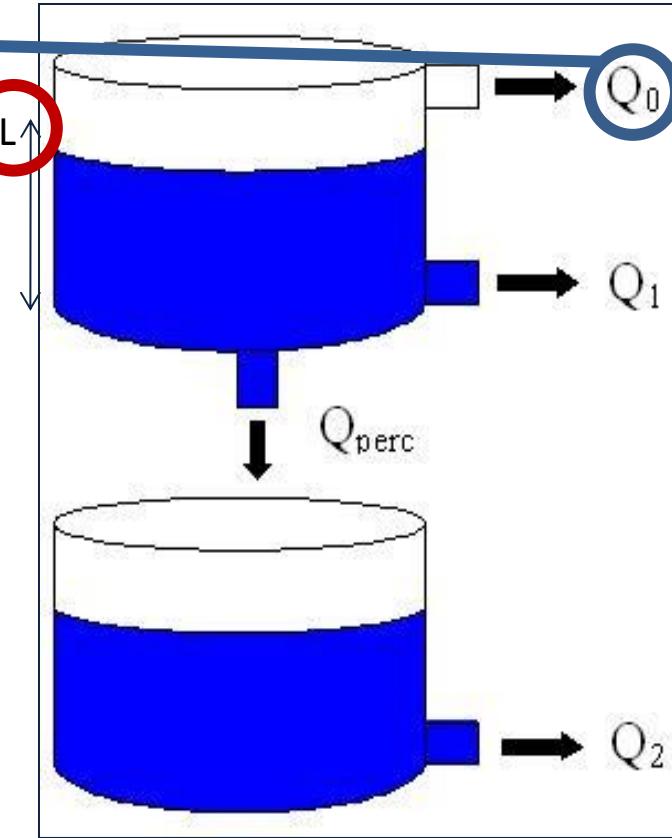


# Reservoir Concept

8	Catchment Area (Km <sup>2</sup> )	410	
9	T <sub>t</sub> (Threshold Temp.)	0	
10	DD	3	
11	FC (Field Capacity)	180.0	
12	BETA	3.0	
13	C (Model param.)	0.03	
14			
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>
16	-1.4	5	0.161
17	-0.3	5	0.179
18	2.6	20	0.645
19	6.3	50	1.667
20	10.9	95	3.065
21	14.2	115	3.833
22	16.4	125	4.032
23	15.6	100	3.226
24	12.7	70	2.333
25	8.3	30	0.968
26	2.9	10	0.333
27	-0.4	5	0.161

K <sub>0</sub> (Reservoir Par.)	0.13
L <sub>1</sub> (Threshold W.L.)	6.00
K <sub>1</sub> (Reservoir Par.)	0.13
K <sub>2</sub> (Reservoir Par.)	0.00
K <sub>perc</sub>	0.22
PWP	105.00

Model Performance	
TOT. ETA.	5493.37
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4393.93
SIM. DISC(m/hr.km <sup>2</sup> )	4399.65
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	5.821
Square diff.	53933.17
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.83
Nash Sutcliff	0.69

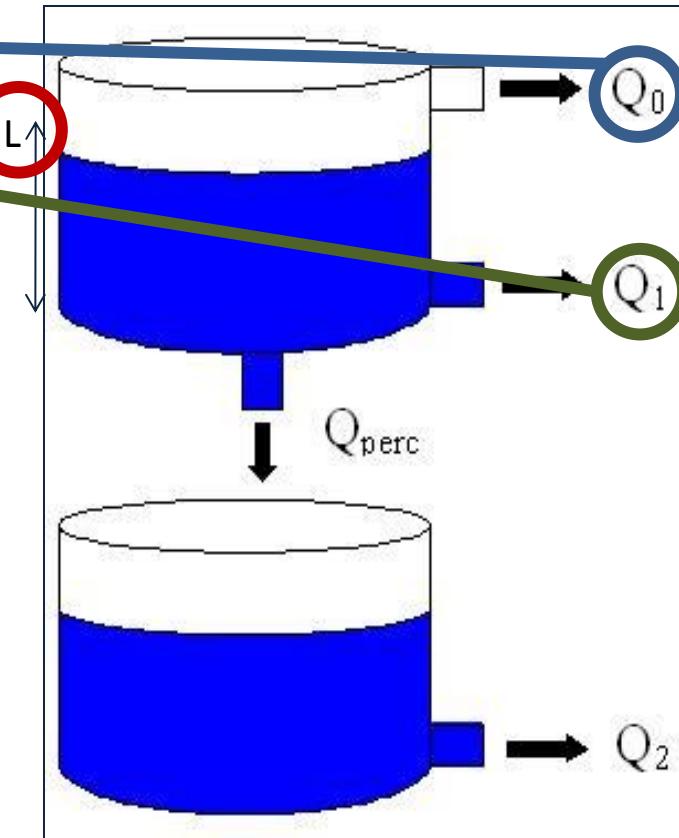


# Reservoir Concept

8	Catchment Area (Km <sup>2</sup> )	410	
9	T <sub>t</sub> (Threshold Temp.)	0	
10	DD	3	
11	FC (Field Capacity)	180.0	
12	BETA	3.0	
13	C (Model param.)	0.03	
14			
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>
16	-1.4	5	0.161
17	-0.3	5	0.179
18	2.6	20	0.645
19	6.3	50	1.667
20	10.9	95	3.065
21	14.2	115	3.833
22	16.4	125	4.032
23	15.6	100	3.226
24	12.7	70	2.333
25	8.3	30	0.968
26	2.9	10	0.333
27	-0.4	5	0.161

K <sub>0</sub> (Reservoir Par.)	0.13
L <sub>1</sub> (Threshold L.W.L.)	6.00
K <sub>1</sub> (Reservoir Par.)	0.13
K <sub>2</sub> (Reservoir Par.)	0.00
K <sub>perc</sub>	0.22
PWP	105.00

Model Performance	
TOT. ETA.	5493.37
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4393.93
SIM. DISC(m/hr.km <sup>2</sup> )	4399.65
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	5.821
Square diff.	53933.17
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.83
Nash Sutcliff	0.69

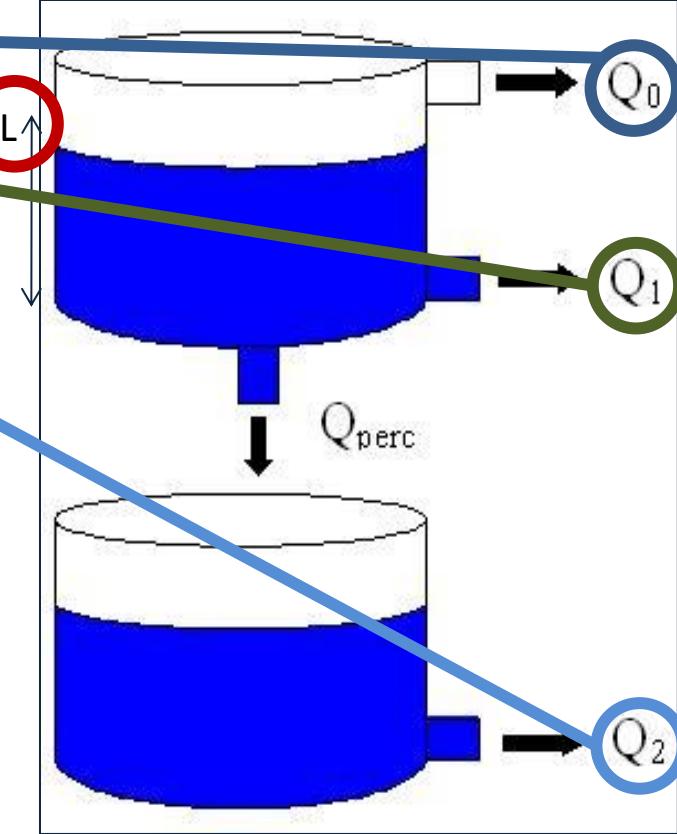


# Reservoir Concept

8	Catchment Area (Km <sup>2</sup> )	410	
9	T <sub>t</sub> (Threshold Temp.)	0	
10	DD	3	
11	FC (Field Capacity)	180.0	
12	BETA	3.0	
13	C (Model param.)	0.03	
14			
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>
16	-1.4	5	0.161
17	-0.3	5	0.179
18	2.6	20	0.645
19	6.3	50	1.667
20	10.9	95	3.065
21	14.2	115	3.833
22	16.4	125	4.032
23	15.6	100	3.226
24	12.7	70	2.333
25	8.3	30	0.968
26	2.9	10	0.333
27	-0.4	5	0.161

K <sub>0</sub> (Reservoir Par.)	0.13
L <sub>1</sub> (Threshold W.L.)	6.00
K <sub>1</sub> (Reservoir Par.)	0.13
K <sub>2</sub> (Reservoir Par.)	0.00
K <sub>perc</sub>	0.22
PWP	105.00

Model Performance	
TOT. ETA.	5493.37
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4393.93
SIM. DISC(m/hr.km <sup>2</sup> )	4399.65
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	5.821
Square diff.	53933.17
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.83
Nash Sutcliff	0.69

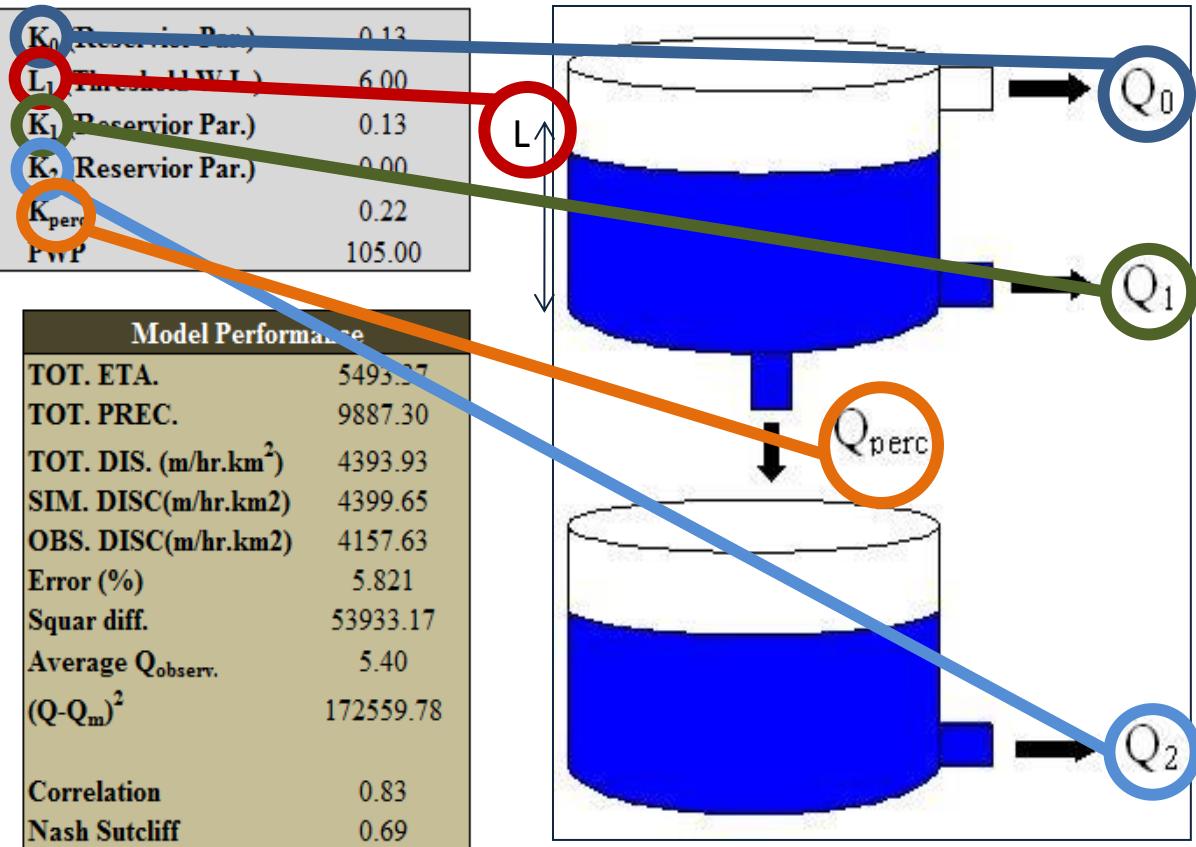


# Reservoir Concept

8	Catchment Area (Km <sup>2</sup> )	410	
9	T <sub>t</sub> (Threshold Temp.)	0	
10	DD	3	
11	FC (Field Capacity)	180.0	
12	BETA	3.0	
13	C (Model param.)	0.03	
14			
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>
16	-1.4	5	0.161
17	-0.3	5	0.179
18	2.6	20	0.645
19	6.3	50	1.667
20	10.9	95	3.065
21	14.2	115	3.833
22	16.4	125	4.032
23	15.6	100	3.226
24	12.7	70	2.333
25	8.3	30	0.968
26	2.9	10	0.333
27	-0.4	5	0.161

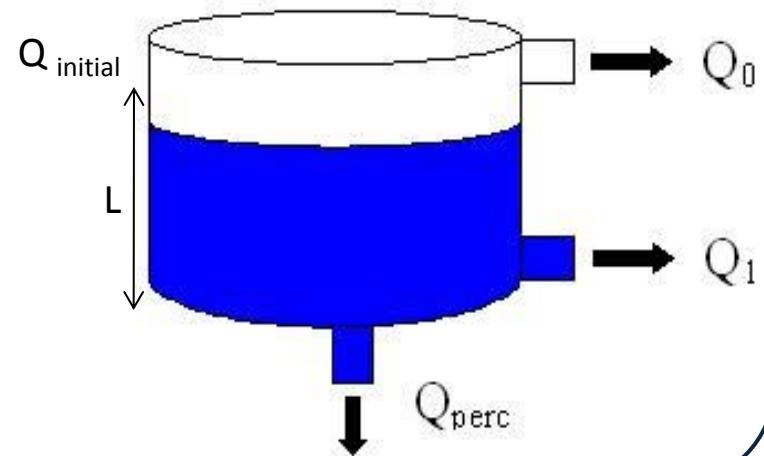
K <sub>0</sub> (Reservoir Par.)	0.13
L <sub>1</sub> (Threshold W.L.)	6.00
K <sub>1</sub> (Reservoir Par.)	0.13
K <sub>2</sub> (Reservoir Par.)	0.00
K <sub>perc</sub>	0.22
PWP	105.00

Model Performance	
TOT. ETA.	5493.37
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4393.93
SIM. DISC(m/hr.km <sup>2</sup> )	4399.65
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	5.821
Square diff.	53933.17
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.83
Nash Sutcliff	0.69



# Reservoir Concept

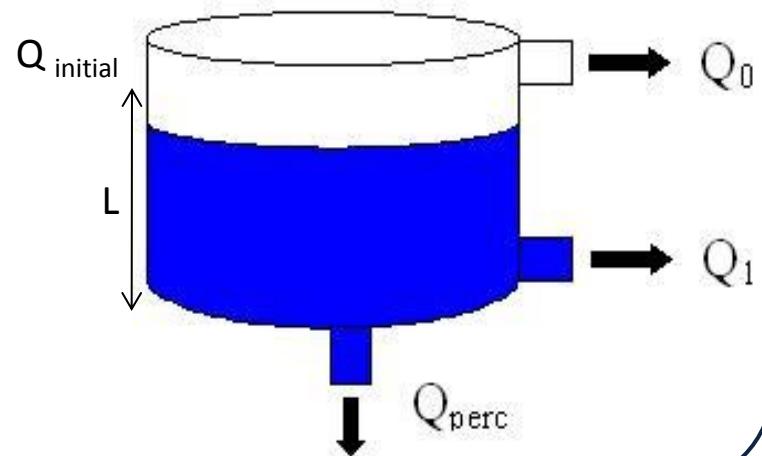
$$S_1 = Q_{\text{initial}} + Q_{\text{surface}} - Q_0 - Q_1 - Q_{\text{perc}}$$



$$=K31+H32-\text{MAX}(0,K31-$F$9)*$F$8-K31*$F$10 -K31*$F$12$$

# Reservoir Concept

$$S_1 = Q_{\text{initial}} + Q_{\text{surface}} - Q_0 - Q_1 - Q_{\text{perc}}$$



$$=K31+H32-\text{MAX}(0,K31-\$F\$9)*\$F\$8-K31*\$F\$10 -K31*\$F\$12$$

Initial  $S_1$

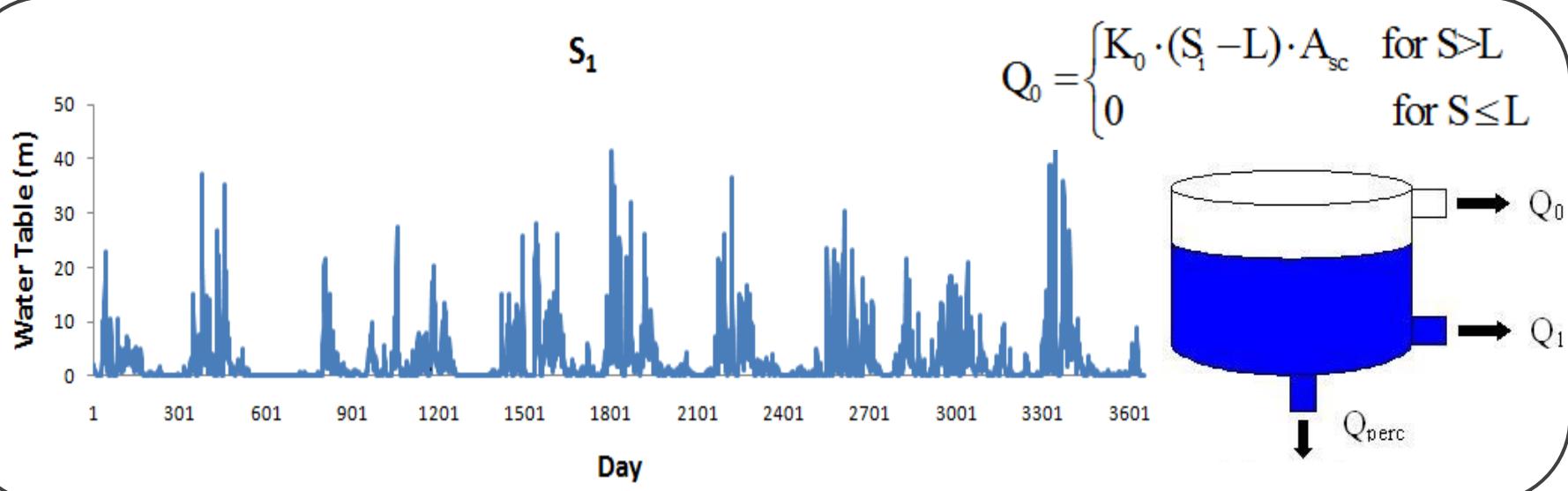
$P_{\text{eff}}$

$(S_1-L)* K_0$

$(S_1)* K_1$

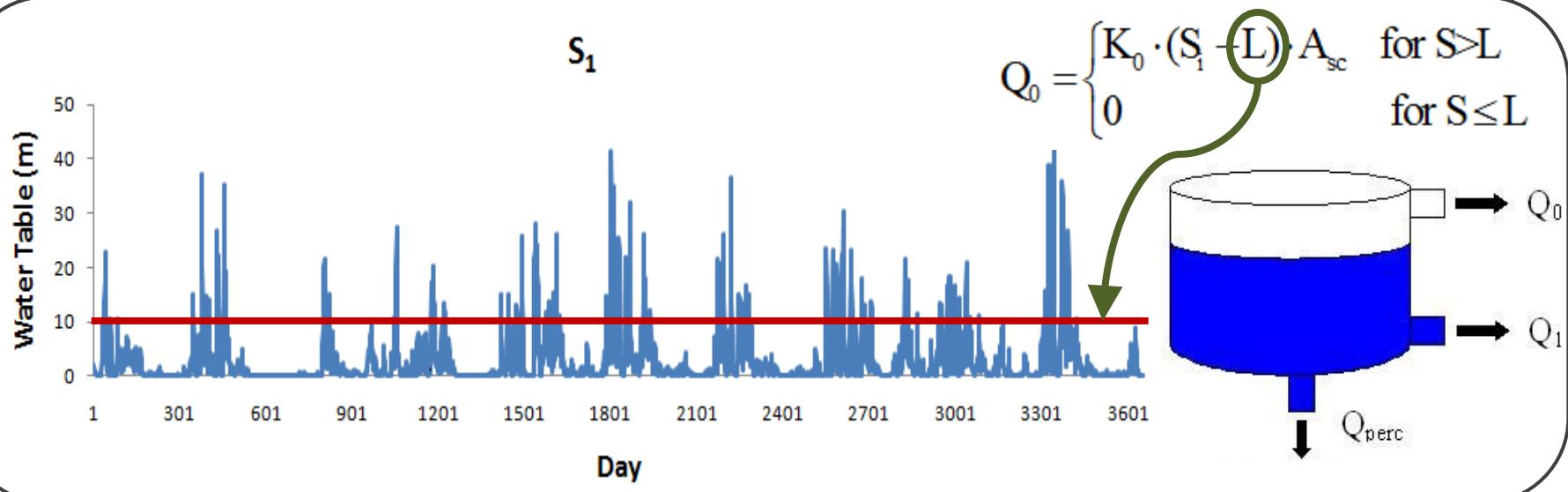
$(S_{\text{perc}})* K_{\text{perc}}$

# Reservoir Concept



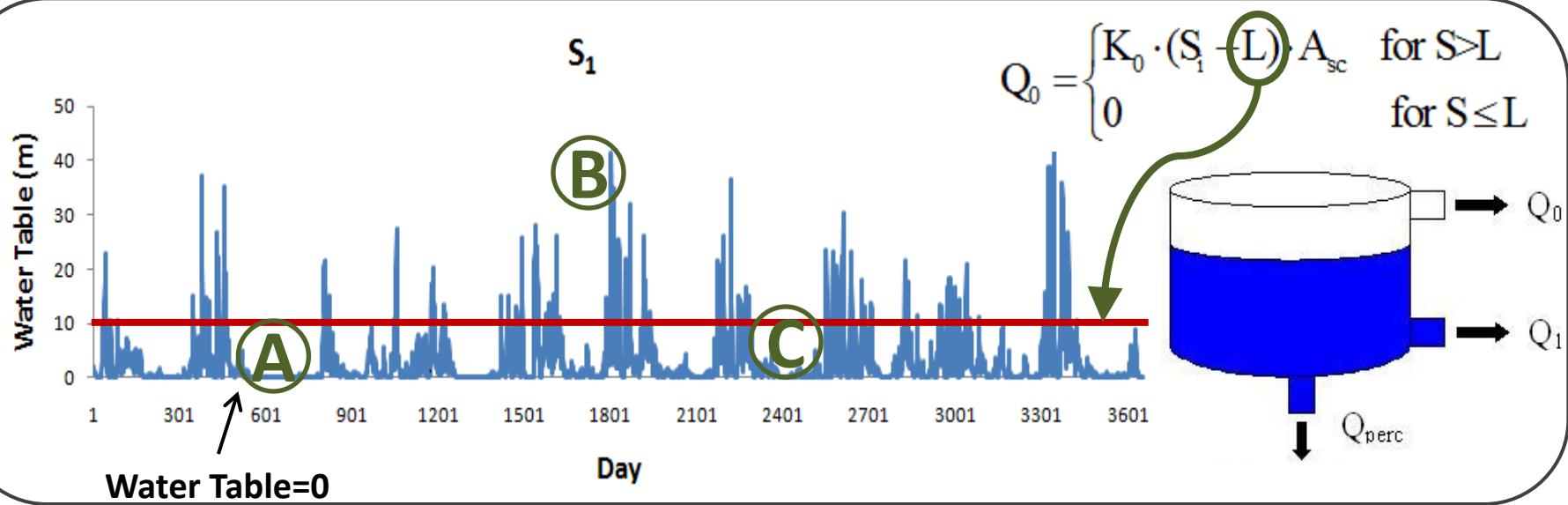
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ OR P <sub>eff</sub> (mm/day)	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>
30											
31					25		100.0				2.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093
39	1/8/1991	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473
40	1/9/1991	1	0.6	1.7	39	3.5	108.5	0.713	0.171	0.171	1.663
41	1/10/1991	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045
42	1/11/1991	1	1.2	2.4	30	6	119.6	1.579	0.174	0.174	3.545

# Reservoir Concept



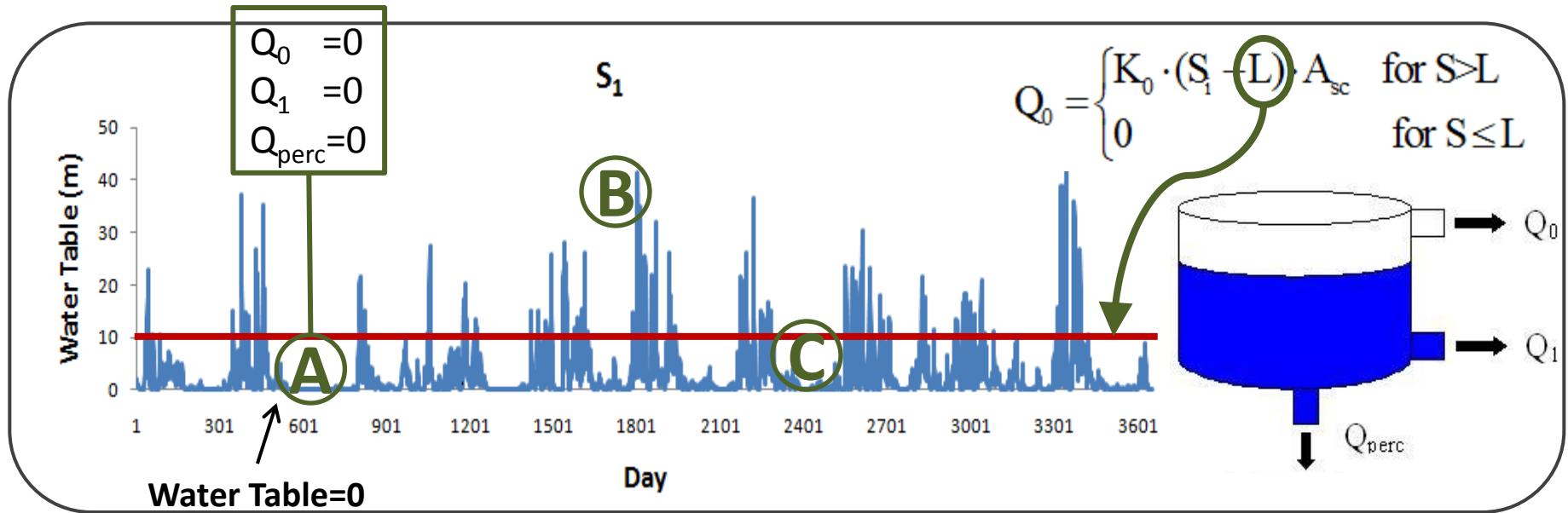
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ OR P <sub>eff</sub> (mm/day)	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>
30											
31					25		100.0				2.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538
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36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093
39	1/8/1991	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473
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41	1/10/1991	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045
42	1/11/1991	1	1.2	2.4	30	6	119.6	1.579	0.174	0.174	3.545

# Reservoir Concept



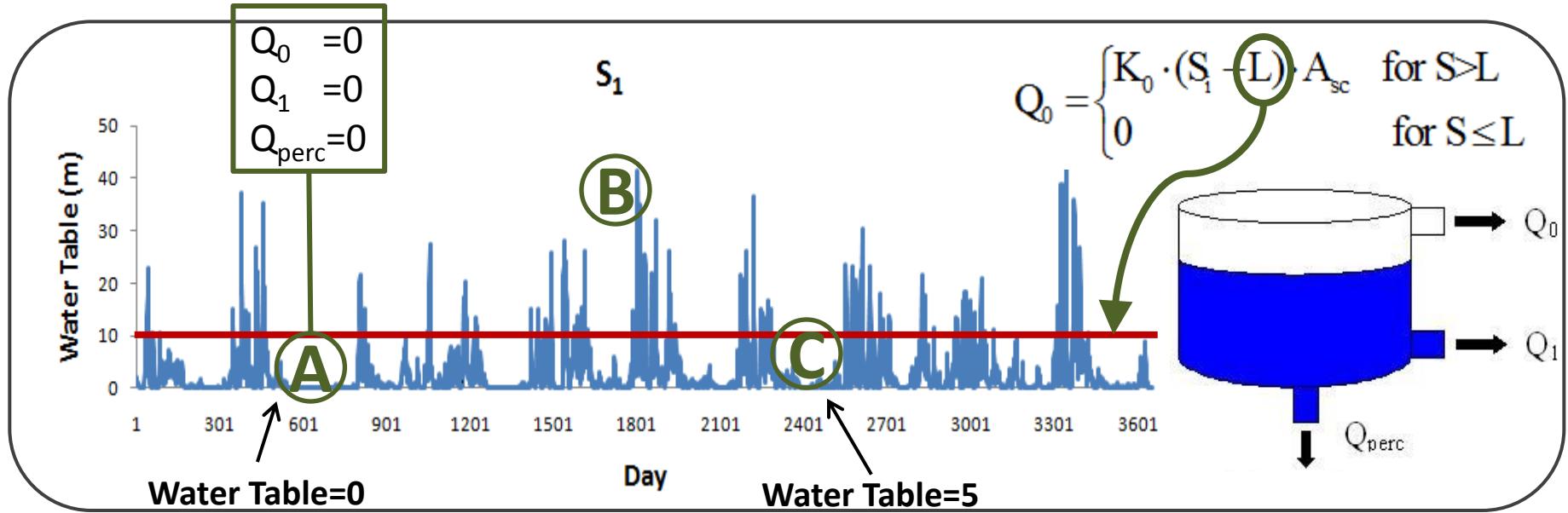
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ OR P <sub>eff</sub> (mm/day)	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>
30											
31					25		100.0				2.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833
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# Reservoir Concept



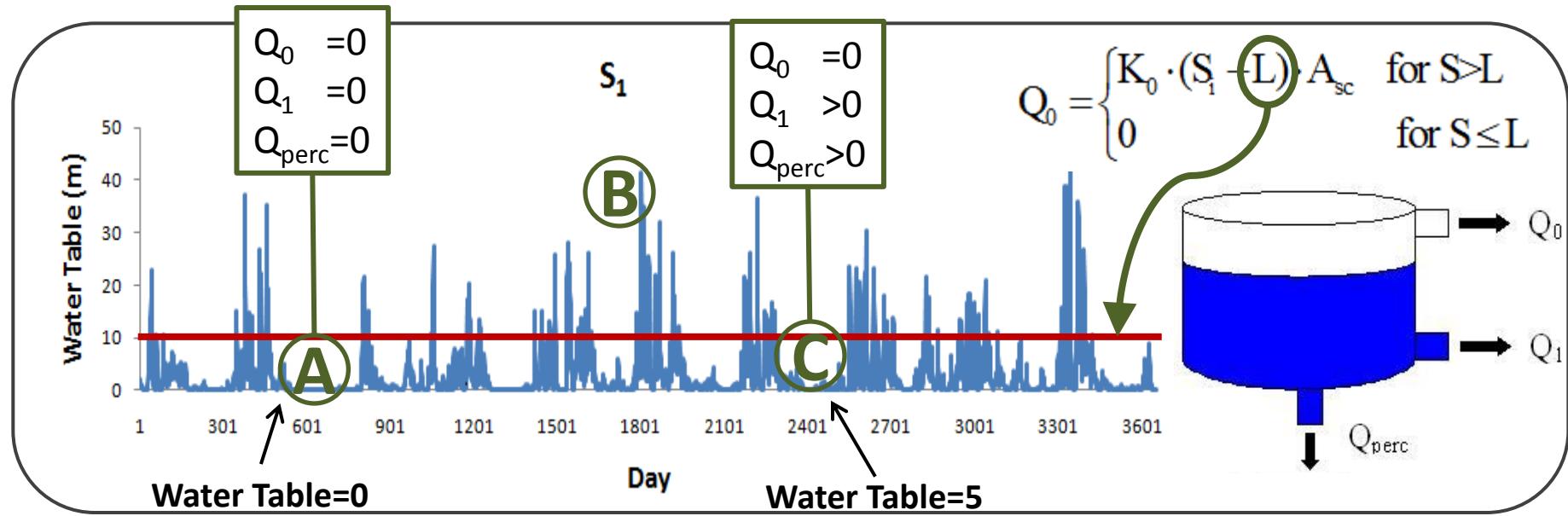
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ OR P <sub>eff</sub> (mm/day)	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>
30											
31					25		100.0				2.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291
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37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145
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39	1/8/1991	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473
40	1/9/1991	1	0.6	1.7	39	3.5	108.5	0.713	0.171	0.171	1.663
41	1/10/1991	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045
42	1/11/1991	1	1.2	2.4	30	6	119.6	1.579	0.174	0.174	3.545

# Reservoir Concept



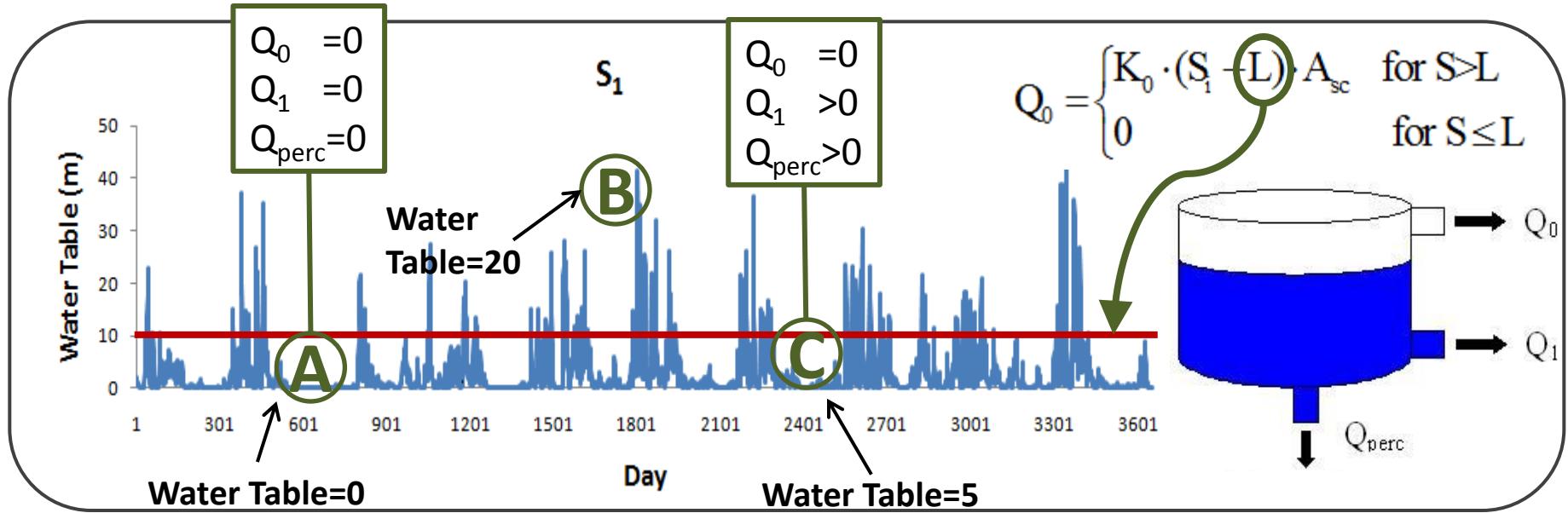
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ OR P <sub>eff</sub> (mm/day)	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>
30											
31					25		100.0				2.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093
39	1/8/1991	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473
40	1/9/1991	1	0.6	1.7	39	3.5	108.5	0.713	0.171	0.171	1.663
41	1/10/1991	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045
42	1/11/1991	1	1.2	2.4	30	6	119.6	1.579	0.174	0.174	3.545

# Reservoir Concept



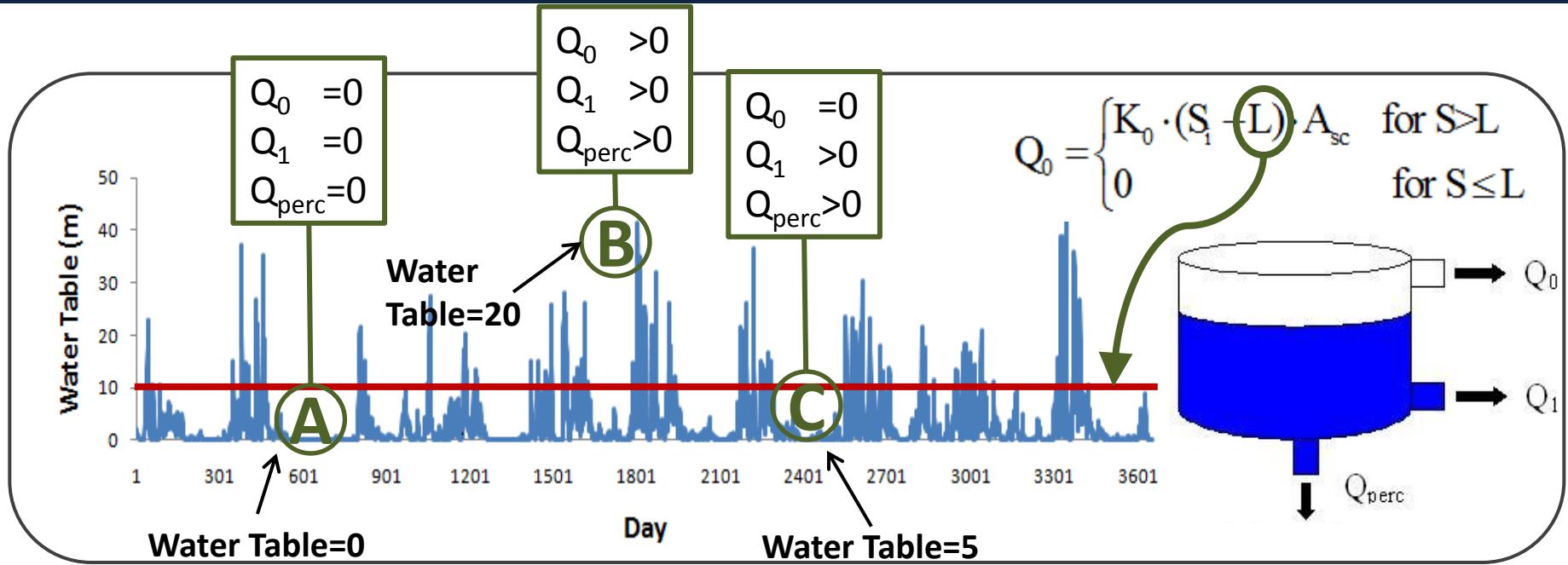
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ OR P <sub>eff</sub> (mm/day)	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>
30											
31					25		100.0				2.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093
39	1/8/1991	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473
40	1/9/1991	1	0.6	1.7	39	3.5	108.5	0.713	0.171	0.171	1.663
41	1/10/1991	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045
42	1/11/1991	1	1.2	2.4	30	6	119.6	1.579	0.174	0.174	3.545

# Reservoir Concept



29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>
30											
31					25		100.0				2.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093
39	1/8/1991	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473
40	1/9/1991	1	0.6	1.7	39	3.5	108.5	0.713	0.171	0.171	1.663
41	1/10/1991	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045
42	1/11/1991	1	1.2	2.4	30	6	119.6	1.579	0.174	0.174	3.545

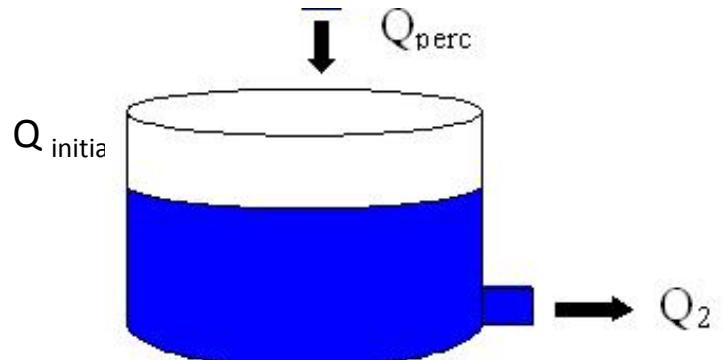
# Reservoir Concept



29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>i</sub>
30											
31					25		100.0				2.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093
39	1/8/1991	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473
40	1/9/1991	1	0.6	1.7	39	3.5	108.5	0.713	0.171	0.171	1.663
41	1/10/1991	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045
42	1/11/1991	1	1.2	2.4	30	6	119.6	1.579	0.174	0.174	3.545

# Reservoir Concept

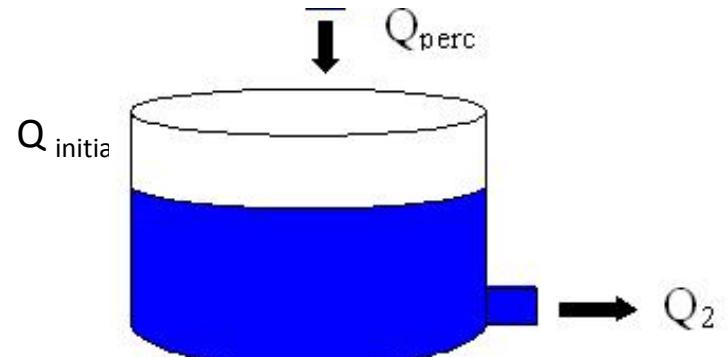
$$S_2 = Q_{\text{initial}} - Q_2 + Q_{\text{perc}}$$



$$=L31+K31*\$F\$12-L31*\$F\$11$$

# Reservoir Concept

$$S_2 = Q_{\text{initial}} - Q_2 + Q_{\text{perc}}$$



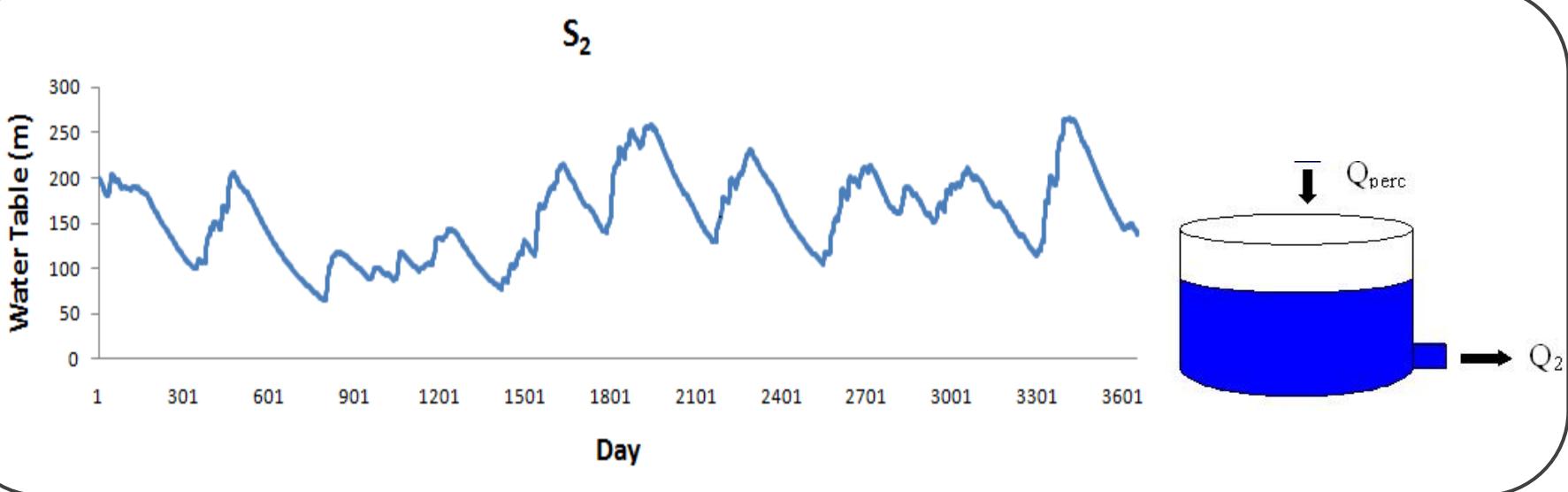
=L31+K31\*\$F\$12-L31\*\$F\$11

Initial  $S_2$

$(S_1) * K_{\text{perc}}$

$(S_2) * K_2$

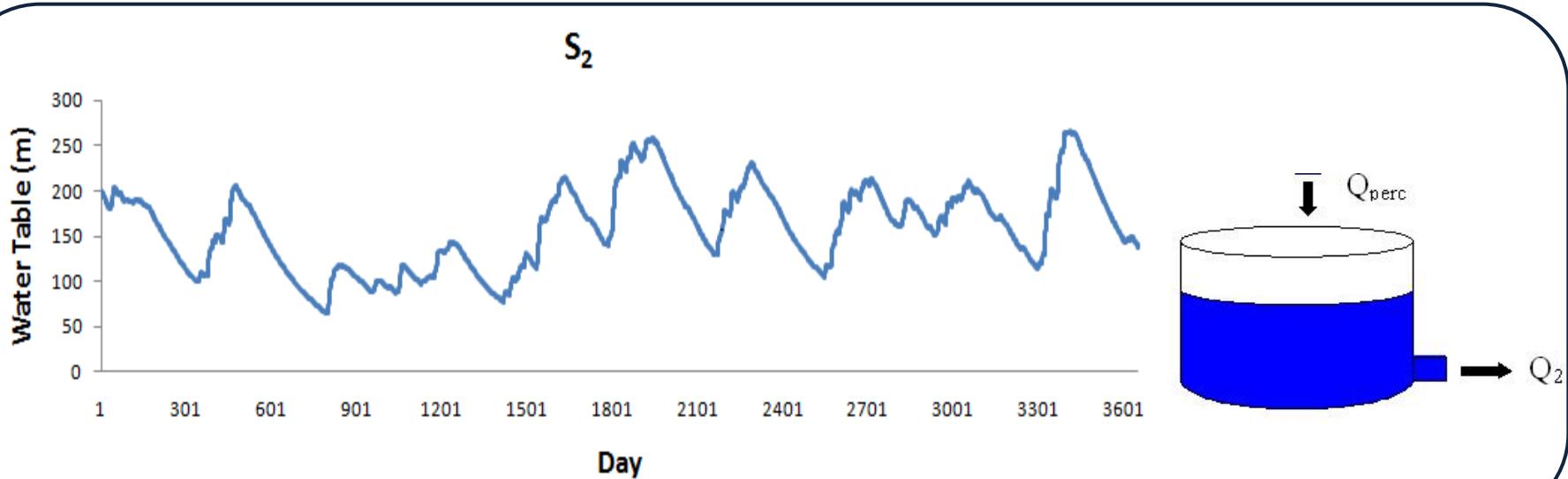
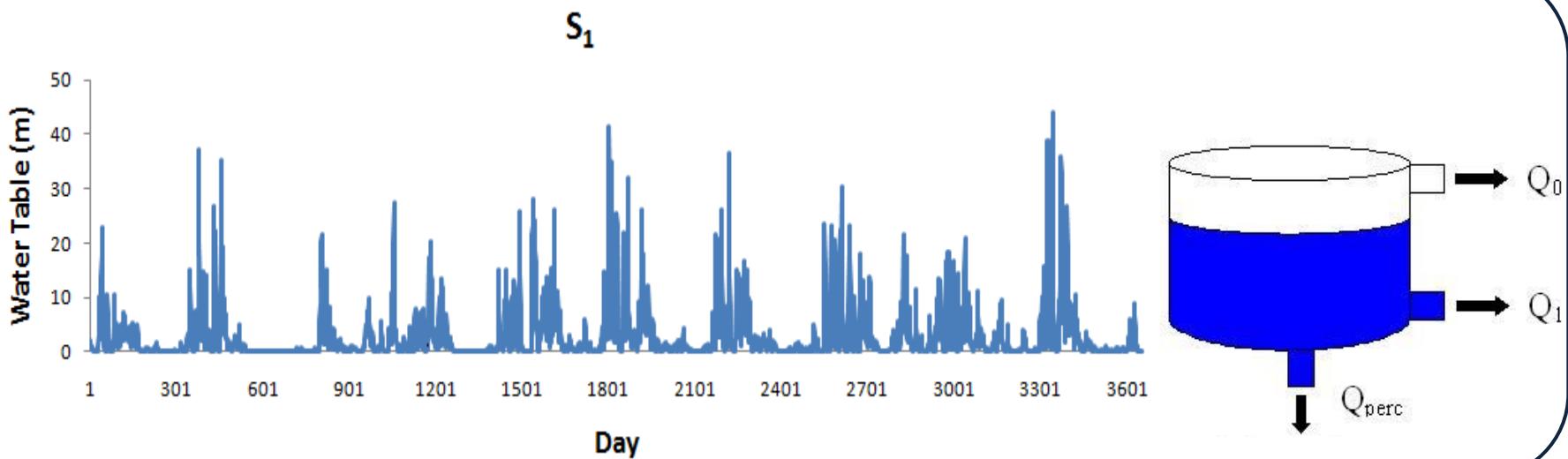
# Reservoir Concept



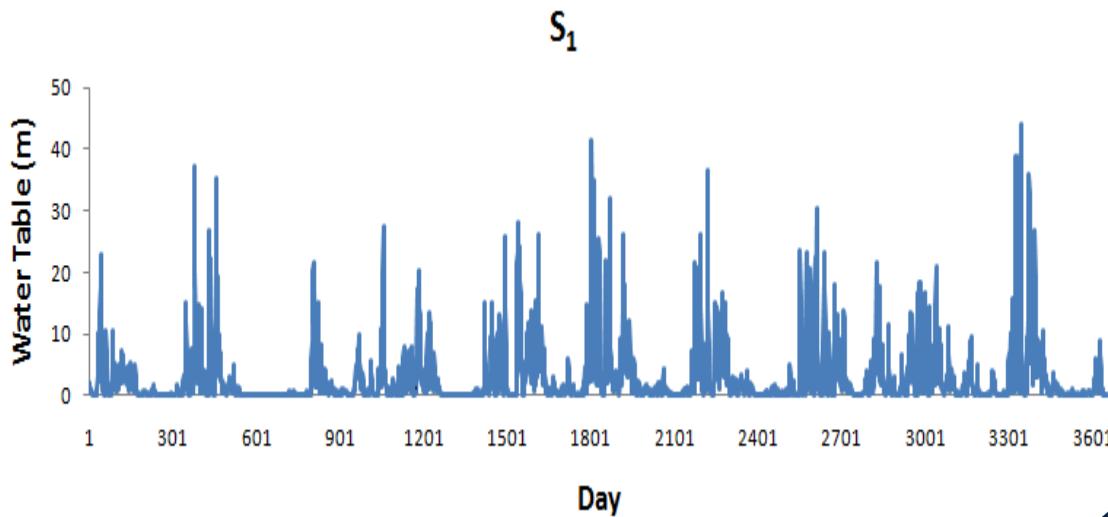
29	Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ OR P <sub>eff</sub> (mm/day)	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>	S <sub>2</sub>
30												
31					25		100.0				2.000	200.000
32	1/1/1991	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291	199.644
33	1/2/1991	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833	199.133
34	1/3/1991	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538	198.521
35	1/4/1991	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347	197.847
36	1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224	197.133
37	1/6/1991	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145	196.394
38	1/7/1991	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093	195.640
39	1/8/1991	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473	194.879
40	1/9/1991	1	0.6	1.7	39	3.5	108.5	0.713	0.171	0.171	1.663	194.426
41	1/10/1991	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045	194.018
42	1/11/1991											

HBV CONCEPT Snow Accum S1 S2 Output Ready

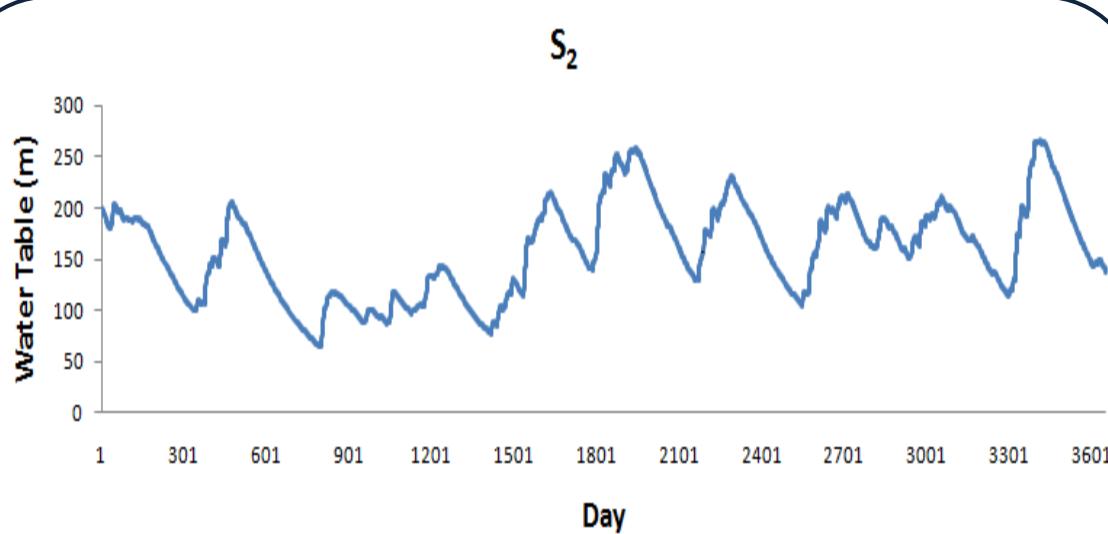
# Reservoir Concept



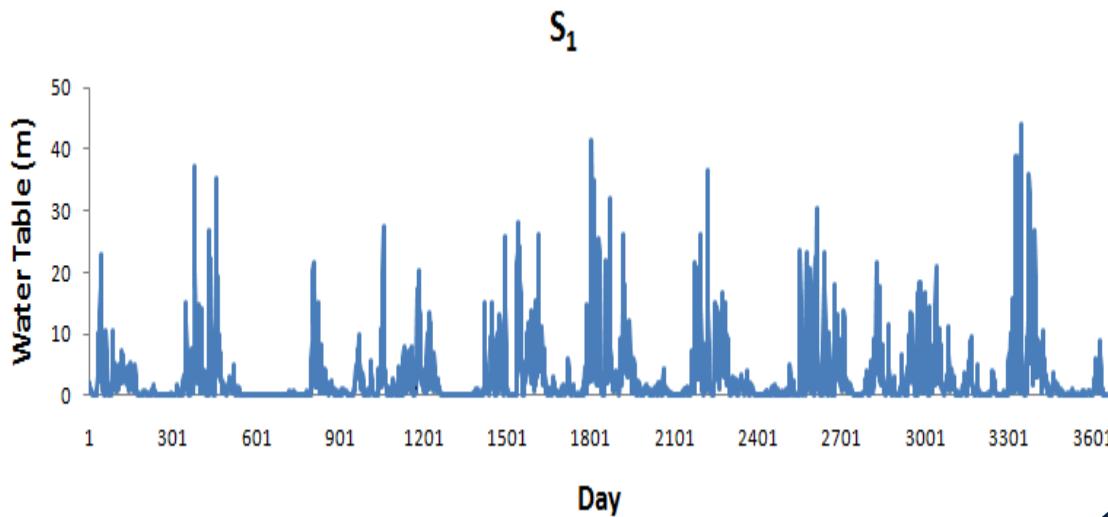
# Reservoir Concept



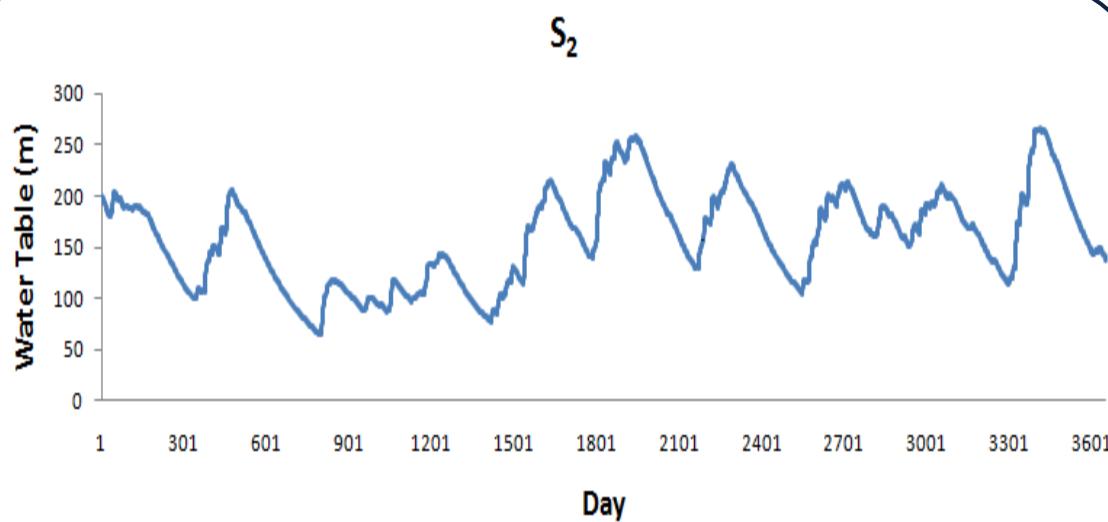
$$Q_0 = K_0 \cdot (S_1 - L) \cdot A$$
$$Q_1 = K_1 \cdot S_1 \cdot A$$
$$Q_2 = K_2 \cdot S_2 \cdot A$$



# Reservoir Concept



$$Q_0 = K_0 \cdot (S_1 - L) \cdot A$$
$$Q_1 = K_1 \cdot S_1 \cdot A$$
$$Q_2 = K_2 \cdot S_2 \cdot A$$



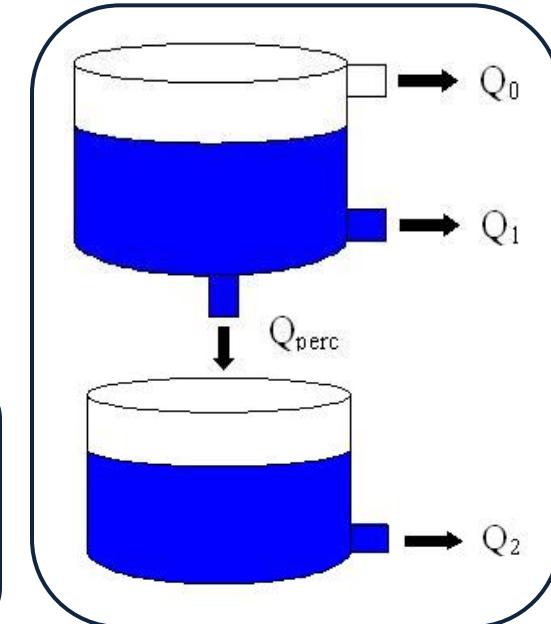
$$K_0 > K_1 > K_2$$

# Runoff Response

$$Q = Q_0 + Q_1 + Q_2$$



=MAX(0,K31-\$F\$9)\*\$F\$8+K31\*\$F\$10+L31\*\$F\$11



Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ OR P <sub>eff</sub> (mm/day)	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>	S <sub>2</sub>	Total Q (Q <sub>t</sub> ) (mm/day)	Q (m <sup>3</sup> /s) Simulations	Q (m <sup>3</sup> /s) Observations
		25		100.0				2.000	200.000	1.065		
-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291	199.644	0.969	4.600	4.5
-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833	199.133	0.907	4.303	11
-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538	198.521	0.865	4.106	6.6
-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347	197.847	0.837	3.973	5
-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224	197.133	0.818	3.883	4.1
-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145	196.394	0.805	3.819	3.5
-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093	195.640	0.795	3.772	3.2
1.8	3.1	40.8	8.5	107.0	0.336	0.177	0.167	0.396	194.879	0.832	3.948	3.2
0.6	1.7	39	3.5	110.1	0.211	0.171	0.171	0.467	194.187	0.838	3.979	5
1.8	3.6	33.6	9	118.3	0.633	0.177	0.177	0.934	193.514	0.898	4.259	7.9

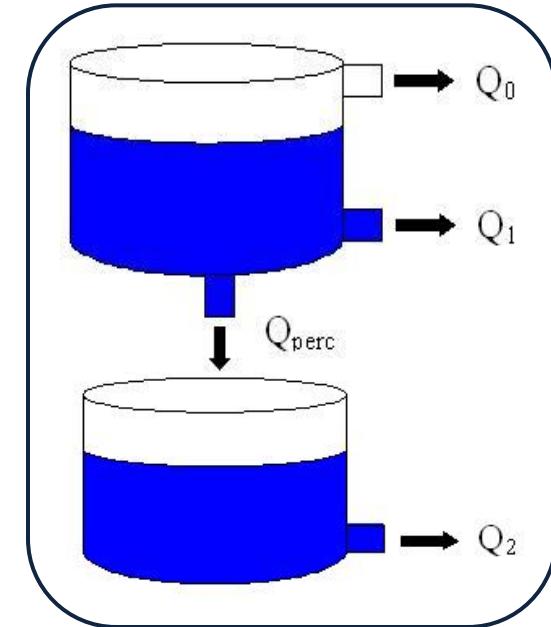
# Runoff Response

$$Q = Q_0 + Q_1 + Q_2$$



=MAX(0,K31-\$F\$9)\*\$F\$8+K31\*\$F\$10+L31\*\$F\$11

K<sub>0</sub> (S<sub>1</sub>-L)
K<sub>1</sub> (S<sub>1</sub>)
K<sub>2</sub> (S<sub>2</sub>)



Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>	S <sub>2</sub>	Total Q (Q <sub>t</sub> ) (mm/day)	Q (m <sup>3</sup> /s) Simulations	Q (m <sup>3</sup> /s) Observations
		25		100.0				2.000	200.000	1.065		
-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291	199.644	0.969	4.600	4.5
-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833	199.133	0.907	4.303	11
-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538	198.521	0.865	4.106	6.6
-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347	197.847	0.837	3.973	5
-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224	197.133	0.818	3.883	4.1
-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145	196.394	0.805	3.819	3.5
-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093	195.640	0.795	3.772	3.2
1.8	3.1	40.8	8.5	107.0	0.336	0.177	0.167	0.396	194.879	0.832	3.948	3.2
0.6	1.7	39	3.5	110.1	0.211	0.171	0.171	0.467	194.187	0.838	3.979	5
1.8	3.6	33.6	9	118.3	0.633	0.177	0.177	0.934	193.514	0.898	4.259	7.9

# Runoff Response

Convert Q (mm/d) to Q (m<sup>3</sup>/s)



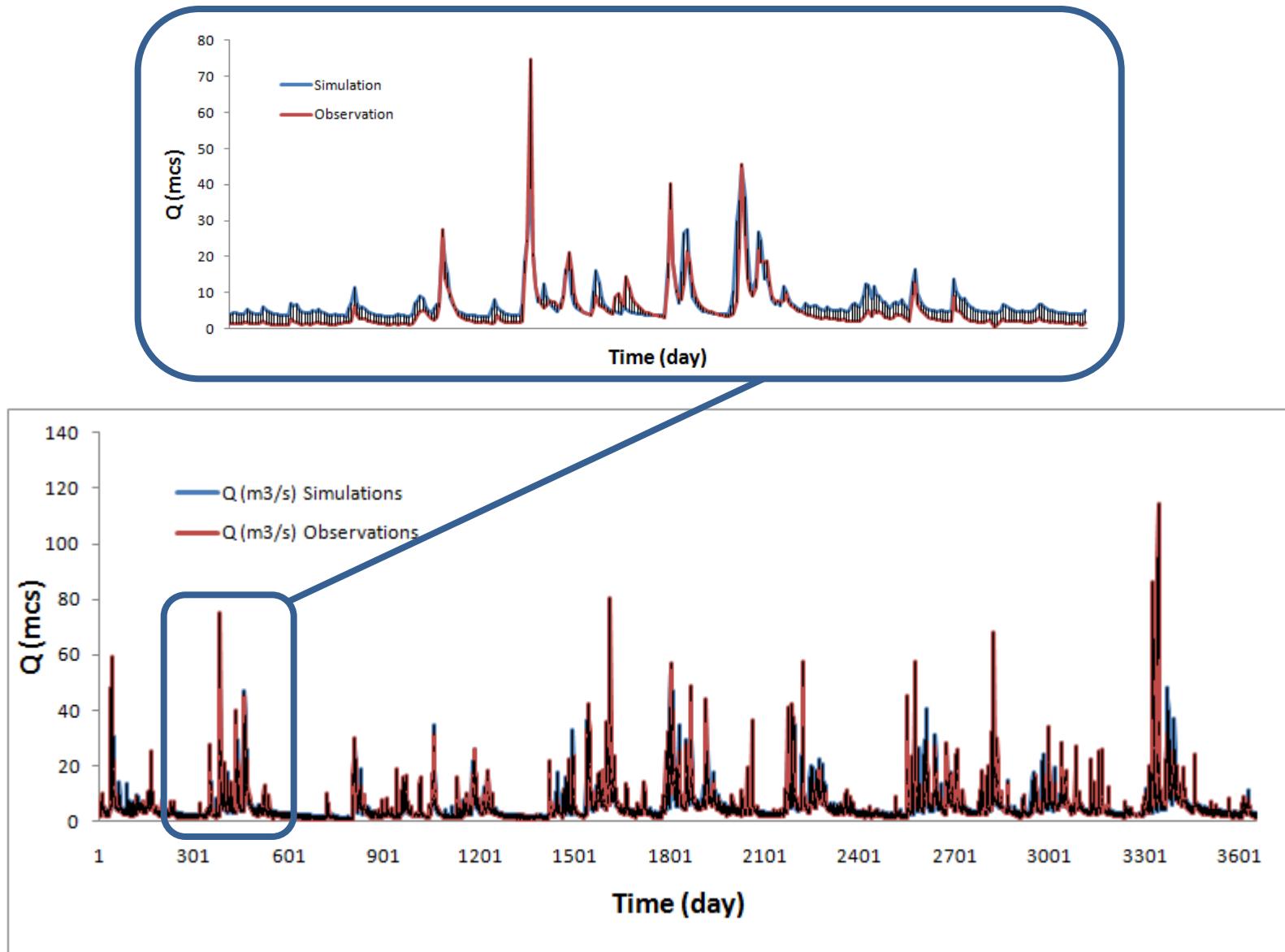
$$=M32*\$C\$8*1000/(24*3600)$$

Q (mm/day)

Watershed Area (km<sup>2</sup>)

Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>	S <sub>2</sub>	Total Q (Q <sub>t</sub> ) (mm/day)	Q (m <sup>3</sup> /s) Simulations	Q (m <sup>3</sup> /s) Observations
-1.5	0.4	25	0	99.8	0.000	0.161	0.153	1.291	199.644	0.969	4.600	4.5
-0.8	10.5	25.4	0	99.7	0.000	0.164	0.156	0.833	199.133	0.907	4.303	11
-2.8	0.9	35.9	0	99.5	0.000	0.155	0.147	0.538	198.521	0.865	4.106	6.6
-3.7	4.4	36.8	0	99.4	0.000	0.150	0.142	0.347	197.847	0.837	3.973	5
-6.1	0.6	41.2	0	99.3	0.000	0.139	0.131	0.224	197.133	0.818	3.883	4.1
-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145	196.394	0.805	3.819	3.5
-0.7	4.4	41.8	0	99.0	0.000	0.165	0.155	0.093	195.640	0.795	3.772	3.2
1.8	3.1	46.2	0	99.0	0.336	0.177	0.167	0.396	194.879	0.832	3.948	3.2
0.6	1.7	40.8	8.5	107.0	0.211	0.171	0.171	0.467	194.187	0.838	3.979	5
1.8	3.6	39	3.5	110.1	0.633	0.177	0.177	0.934	193.514	0.898	4.259	7.9

# Runoff Response



# Validation Criteria

## Correlation Coefficient

**Ideal  $R_p = 1$**

**$R_p = -1$  Negatively correlated**

**$R_p = 0$  Not correlated**

**$R_p = 1$  Correlated**

$$R_p = \frac{\sum_{i=1}^n (Q_o^i - \bar{Q}_o) \cdot \sum_{i=1}^n (Q_s^i - \bar{Q}_s)}{\sqrt{\sum_{i=1}^n (Q_o^i - \bar{Q}_o)^2} \cdot \sqrt{\sum_{i=1}^n (Q_s^i - \bar{Q}_s)^2}}$$

where:

$R_p$  Pearson correlation coefficient [-]

$\bar{Q}_s$  mean simulated discharge [ $L^3 T^{-1}$ ]

## Nash-Sutcliffe Coefficient

**Ideal  $R_{NS} = 1$**

**Negative  $R_{NS}$  means that the mean of observations is a better predictor than the model.**

$$R_{NS} = 1 - \frac{\sum_{t=1}^n (Q_s^t - Q_o^t)^2}{\sum_{t=1}^n (Q_o^t - \bar{Q}_o)^2}$$

where:

$R_{NS}$  Nash-Sutcliffe coefficient [-]

$Q_s$  simulated discharge [ $L^3 T^{-1}$ ]

$Q_o$  observed discharge [ $L^3 T^{-1}$ ]

$\bar{Q}_o$  mean observed discharge [ $L^3 T^{-1}$ ]

$n$  number of time steps

HBV

Home Insert Page Layout Formulas Data Review View Acrobat

Cut Copy Format Painter

Times New Rom 12 A A Wrap Text General

B I U Merge & Center \$ %

Font Alignment Number

K7 fuc

A	B	C	D	E	F		
7							
8	Catchment Area (Km <sup>2</sup> )	410	K <sub>0</sub> (Reservoir Par.)	0.13			
9	T <sub>t</sub> (Threshold Temp.)	0	L <sub>1</sub> (Threshold W.L.)	6.00			
10	DD	3	K <sub>1</sub> (Reservoir Par.)	0.13			
11	FC (Field Capacity)	180.0	K <sub>2</sub> (Reservoir Par.)	0.00			
12	BETA	3.0	K <sub>perc</sub>	0.22			
13	C (Model param.)	0.03	PWP	105.00			
14							
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>				
16	-1.4	5	0.161				
17	-0.3	5	0.179				
18	2.6	20	0.645				
19	6.3	50	1.667				
20	10.9	95	3.065				
21	14.2	115	3.833				
22	16.4	125	4.032				
23	15.6	100	3.226				
24	12.7	70	2.333				
25	8.3	30	0.968				
26	2.9	10	0.333				
27	-0.4	5	0.161				
28							
29	Date	Month	Temp.	Preci.	Snow	Liquid Water	
30	ID	(C)	(mm)	(mm)	(mm)	(mm)	
31					25		
32	1/1/1991	1	-1.5	0.4	25.4	0	
33	1/2/1991	1	-0.8	10.5	35.9	0	
34	1/3/1991	1	-2.8	0.9	36.8	0	
35	1/4/1991	1	-3.7	4.4	41.2	0	
36	1/5/1991	1	-6.1	0.6	41.8	0	
37	1/6/1991	1	-3	0	41.8	0	
38	1/7/1991	1	-0.7	4.4	46.2	0	
39	1/8/1991	1	1.8	3.1	40.8	8.5	
40	1/9/1991	1	0.6	1.7	39	3.5	
41	1/10/1991	1	1.8	3.6	33.6	9	
42	1/11/1991	1	1.0	0.4	28	6	

HBV CONCEPT Snow Accum S1 S2 Output

Ready

Model Performance

TOT. ETA.	5493.37
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4393.93
SIM. DISC(m/hr.km <sup>2</sup> )	4399.65
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	5.821
Squar diff.	53933.17
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.83
Nash Sutcliff	0.69

$$\sum_{i=1}^n Q_s$$

$$\sum_{i=1}^n Q_o$$

Error (%) of total runoff

# Nash-Sutcliff Coefficient

$$R_{NS} = 1 - \frac{\sum_{t=1}^n (Q_s^t - Q_o^t)^2}{\sum_{t=1}^n (Q_o^t - \bar{Q}_o)^2}$$

→ **= (O32-N32)^2**

where:

- $R_{NS}$  Nash-Sutcliffe coefficient [-]
- $Q_s$  simulated discharge [ $L^3 T^{-1}$ ]
- $Q_o$  observed discharge [ $L^3 T^{-1}$ ]
- $\bar{Q}_o$  mean observed discharge [ $L^3 T^{-1}$ ]
- $n$  number of time steps

29	Month	Temp.	Preci.	Snow	Liquid	Water	Soil Moisture	DQ (mm/day)	Potential	Ea	S1	S2	Total Q (Qo) (mm/day)	Q (m³/s) Simulations	Q (m³/s) Observations	(Q-QT)²	(Q-Qm)²
30	ID	(C)	(mm)	(mm)				OR P <sub>eff</sub>	E. (PE <sub>a</sub> )	(mm/day)							
31				25			100.0				2.000	200.000	1.065				
32	1	-1.5	0.4	25.4	0		99.8	0.000	0.161	0.153	1.291	199.644	0.969	4.600	4.5	0.010	0.817
33	1	-0.8	10.5	35.9	0		99.7	0.000	0.164	0.156	0.833	199.133	0.907	4.303	11	44.850	31.317
34	1	-2.8	0.9	36.8	0		99.5	0.000	0.155	0.147	0.538	198.521	0.865	4.106	6.6	6.221	1.431
35	1	-3.7	4.4	41.2	0		99.4	0.000	0.150	0.142	0.347	197.847	0.837	3.973	5	1.054	0.163
36	1	-6.1	0.6	41.8	0		99.3	0.000	0.139	0.131	0.224	197.133	0.818	3.883	4.1	0.047	1.700
37	1	-3	0	41.8	0		99.1	0.000	0.154	0.145	0.145	196.394	0.805	3.819	3.5	0.102	3.625
38	1	-0.7	4.4	46.2	0		99.0	0.000	0.165	0.155	0.093	195.640	0.795	3.772	3.2	0.327	4.857
39	1	1.8	3.1	40.8	8.5		105.9	1.413	0.177	0.167	1.473	194.879	0.974	4.624	3.2	2.028	4.857
40	1	0.6	1.7	39	3.5		108.5	0.713	0.171	0.171	1.663	194.426	0.998	4.735	5	0.070	0.163
41	1	1.8	3.6	33.6	9		115.4	1.971	0.177	0.177	3.045	194.018	1.179	5.595	7.9	5.314	6.231

# Nash-Sutcliff Coefficient

$$R_{NS} = 1 - \frac{\sum_{t=1}^n (Q_s^t - Q_o^t)^2}{\sum_{t=1}^n (Q_o^t - \bar{Q}_o)^2}$$

where:

- $R_{NS}$  Nash-Sutcliffe coefficient [-]
- $Q_s$  simulated discharge [ $L^3 T^{-1}$ ]
- $Q_o$  observed discharge [ $L^3 T^{-1}$ ]
- $\bar{Q}_o$  mean observed discharge [ $L^3 T^{-1}$ ]
- $n$  number of time steps

	Month	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>	S <sub>2</sub>	Total Q (Q <sub>t</sub> ) (mm/day)	Q (m <sup>3</sup> /s) Simulations	Q (m <sup>3</sup> /s) Observations	(Q-QT) <sup>2</sup>	(Q-Qm) <sup>2</sup>
29	ID															
30																
31				25		100.0										
32	1	-1.5	0.4	25.4	0	99.8	0.000	0.161	0.153	1.291	199.644	0.969	4.600	4.5	0.010	0.817
33	1	-0.8	10.5	35.9	0	99.7	0.000	0.164	0.156	0.833	199.133	0.907	4.303	11	44.850	31.317
34	1	-2.8	0.9	36.8	0	99.5	0.000	0.155	0.147	0.538	198.521	0.865	4.106	6.6	6.221	1.431
35	1	-3.7	4.4	41.2	0	99.4	0.000	0.150	0.142	0.347	197.847	0.837	3.973	5	1.054	0.163
36	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224	197.133	0.818	3.883	4.1	0.047	1.700
37	1	-3	0	41.8	0	99.1	0.000	0.154	0.145	0.145	196.394	0.805	3.819	3.5	0.102	3.625
38	1	-0.7	4.4	46.2	0	99.0	0.000	0.165	0.155	0.093	195.640	0.795	3.772	3.2	0.327	4.857
39	1	1.8	3.1	40.8	8.5	105.9	1.413	0.177	0.167	1.473	194.879	0.974	4.624	3.2	2.028	4.857
40	1	0.6	1.7	39	3.5	108.5	0.713	0.171	0.171	1.663	194.426	0.998	4.735	5	0.070	0.163
41	1	1.8	3.6	33.6	9	115.4	1.971	0.177	0.177	3.045	194.018	1.179	5.595	7.9	5.314	6.231



	A	B	C	D	E	F
7						
8	Catchment Area (Km <sup>2</sup> )	410	K <sub>0</sub> (Reservoir Par.)	0.13		
9	T <sub>t</sub> (Threshold Temp.)	0	L <sub>1</sub> (Threshold W.L.)	6.00		
10	DD	3	K <sub>1</sub> (Reservoir Par.)	0.13		
11	FC (Field Capacity)	180.0	K <sub>2</sub> (Reservoir Par.)	0.00		
12	BETA	3.0	K <sub>perc</sub>	0.22		
13	C (Model param.)	0.03	PWP	105.00		
14						
15	Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>			
16	-1.4	5	0.161			
17	-0.3	5	0.179			
18	2.6	20	0.645			
19	6.3	50	1.667			
20	10.9	95	3.065			
21	14.2	115	3.833			
22	16.4	125	4.032			
23	15.6	100	3.226			
24	12.7	70	2.333			
25	8.3	30	0.968			
26	2.9	10	0.333			
27	-0.4	5	0.161			
28						

Model Performance						
TOT. ETA.						5493.37
TOT. PREC.						9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )						4393.93
SIM. DISC(m/hr.km <sup>2</sup> )						4399.65
OBS. DISC(m/hr.km <sup>2</sup> )						4157.63
Error (%)						5.821
Squar diff.						53933.17
Average Q <sub>observ.</sub>						5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>						172559.78
Correlation						0.83
Nash Sutcliff						0.69

$$\sum_{t=1}^n (Q_s^t - Q_o^t)^2$$

$$\sum_{t=1}^n (Q_o^t - \bar{Q}_o)^2$$

$$R_{NS} = 1 - \frac{\sum_{t=1}^n (Q_s^t - Q_o^t)^2}{\sum_{t=1}^n (Q_o^t - \bar{Q}_o)^2}$$

	Date	Month	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Snow
	ID						
31					25		
32	1/1/1991	1	-1.5	0.4	25.4	0	
33	1/2/1991	1	-0.8	10.5	35.9	0	
34	1/3/1991	1	-2.8	0.9	36.8	0	
35	1/4/1991	1	-3.7	4.4	41.2	0	
36	1/5/1991	1	-6.1	0.6	41.8	0	
37	1/6/1991	1	-3	0	41.8	0	
38	1/7/1991	1	-0.7	4.4	46.2	0	
39	1/8/1991	1	1.8	3.1	40.8	8.5	
40	1/9/1991	1	0.6	1.7	39	3.5	
41	1/10/1991	1	1.8	3.6	33.6	9	
42	1/11/1991	1	1.0	0.4	28	6	

# Error Sources

## Error in Initial Conditions

- Error in the initial values of soil moisture, snow, field capacity, permanent wilting point

## Error in Model Processes

- Unrealistic model assumptions
- Unrepresentative conceptual description of the system

## Error in Observations

- Error in input data (e.g., precipitation, temperature, etc.)
- Error in observed discharge

## Error in Model Parameterization

- Inability to obtain the optimal set of parameters.
- Deficiencies in parameter estimation scheme

# Error Sources

## Error in Initial Conditions

- Error in the initial values of soil moisture, snow, field capacity, permanent wilting point

## Error in Model Processes

- Unrealistic model assumptions
- Unrepresentative

## Error in Observations

- Error in input data (e.g., precipitation, temperature, etc.)
- Unobserved

## Error in Model Parameterization

- Inability to obtain the optimal set of parameters.
- Deficiencies in parameter estimation scheme

### Conceptual

- BETA ( $\beta$ )
- C
- L
- $K_0$
- $K_1$
- $K_2$
- $K_{perc}$

### Conceptual & Measurable

- FC
- DD
- PWP
- $T_t$

# Model Parameters

## Conceptual

- BETA ( $\beta$ )
- C
- L
- $K_0$
- $K_1$
- $K_2$
- $K_{perc}$

## Conceptual & Measurable

- FC
- DD
- PWP
- $T_t$

## Initial Conditions

- Snow
- Soil Moisture
- $S_1$
- $S_2$

# Parameter Estimation

Excel ribbon showing the Data tab selected.

Cell F21 contains the formula:  $=+ABS((F20-F19))*100/F20$

	A	B	C	D	E	F	G	H	I	J	K	L
7												
8	<b>Catchment Area (Km<sup>2</sup>)</b>	410		<b>K<sub>0</sub> (Reservoir Par.)</b>	0.10							
9	<b>T<sub>t</sub> (Threshold Temp.)</b>	0		<b>L<sub>1</sub> (Threshold W.L.)</b>	6.00							
10	<b>DD</b>	3		<b>K<sub>1</sub> (Reservoir Par.)</b>	0.09							
11	<b>FC (Field Capacity)</b>	180.0		<b>K<sub>2</sub> (Reservoir Par.)</b>	0.00							
12	<b>BETA</b>	1.0		<b>K<sub>perc</sub></b>	0.07							
13	<b>C (Model param.)</b>	0.03		<b>PWP</b>	105.00							
14												
15	<b>Monthly T<sub>ave.</sub></b>	<b>PE<sub>m</sub></b>	<b>Daily PE<sub>m</sub></b>									
16	-1.4	5	0.161									
17	-0.3	5	0.179									
18	2.6	20	0.645									
19	6.3	50	1.667									
20	10.9	95	3.065									
21	14.2	115	3.833									
22	16.4	125	4.032									
23	15.6	100	3.226									
24	12.7	70	2.333									
25	8.3	30	0.968									
26	2.9	10	0.333									
27	-0.4	5	0.161									

Model Performance Data (highlighted in yellow):

Model Performance	
<b>TOT. ETA.</b>	4459.17
<b>TOT. PREC.</b>	9887.30
<b>TOT. DIS. (m/hr.km<sup>2</sup>)</b>	5428.13
<b>SIM. DISC(m/hr.km<sup>2</sup>)</b>	5500.67
<b>OBS. DISC(m/hr.km<sup>2</sup>)</b>	1157.03
<b>Error (%)</b>	32.303
<b>Square diff.</b>	59479.25
<b>Average Q<sub>observ.</sub></b>	5.40
<b>(Q-Q<sub>m</sub>)<sup>2</sup></b>	172559.78
<b>Correlation</b>	0.81
<b>Nash Sutcliffe</b>	0.60

Solver Parameters dialog box:

- Set Target Cell: \$F\$21
- Equal To: Min
- By Changing Cells: \$C\$11,\$C\$12,\$F\$13,\$F\$12,\$F\$11,\$F\$10,\$F\$9
- Subject to the Constraints:
  - \$F\$10 >= \$F\$11
  - \$F\$11 >= 0.004
  - \$F\$12 >= 0
  - \$F\$13 <= \$C\$11
  - \$F\$8 >= \$F\$10
  - \$F\$9 >= 0

# Parameter Estimation

Excel ribbon showing the Data tab selected.

Cell F21 contains the formula:  $=+ABS((F20-F19))*100/F20$

	A	B	C	D	E	F	G	H	I	J	K	L
7												
8	<b>Catchment Area (Km<sup>2</sup>)</b>	410		<b>K<sub>0</sub> (Reservoir Par.)</b>	0.10							
9	<b>T<sub>t</sub> (Threshold Temp.)</b>	0		<b>L<sub>1</sub> (Threshold W.L.)</b>	6.00							
10	<b>DD</b>	3		<b>K<sub>1</sub> (Reservoir Par.)</b>	0.09							
11	<b>FC (Field Capacity)</b>	180.0		<b>K<sub>2</sub> (Reservoir Par.)</b>	0.00							
12	<b>BETA</b>	1.0		<b>K<sub>perc</sub></b>	0.07							
13	<b>C (Model param.)</b>	0.03		<b>PWP</b>	105.00							
14												
15	<b>Monthly T<sub>ave.</sub></b>	<b>PE<sub>m</sub></b>	<b>Daily PE<sub>m</sub></b>									
16	-1.4	5	0.161									
17	-0.3	5	0.179									
18	2.6	20	0.645									
19	6.3	50	1.667									
20	10.9	95	3.065									
21	14.2	115	3.833									
22	16.4	125	4.032									
23	15.6	100	3.226									
24	12.7	70	2.333									
25	8.3	30	0.968									
26	2.9	10	0.333									
27	-0.4	5	0.161									

**Model Performance**

<b>TOT. ETA.</b>	4459.17
<b>TOT. PREC.</b>	9887.30
<b>TOT. DIS. (m/hr.km<sup>2</sup>)</b>	5428.13
<b>SIM. DISC(m/hr.km<sup>2</sup>)</b>	5500.67
<b>OBS. DISC(m/hr.km<sup>2</sup>)</b>	4157.03
<b>Error (%)</b>	32.303
<b>Square diff.</b>	59479.25
<b>Average Q<sub>observ.</sub></b>	5.40
<b>(Q-Q<sub>m</sub>)<sup>2</sup></b>	172559.78
<b>Correlation</b>	0.81
<b>Nash Sutcliffe</b>	0.60

**Solver Parameters**

- Set Target Cell: \$F\$21
- Equal To: Min
- By Changing Cells: \$C\$11,\$C\$12,\$F\$13,\$F\$12,\$F\$11,\$F\$10,\$F\$9
- Subject to the Constraints:

Constraints (Visible in screenshot):

- \$F\$10 >= \$F\$11
- \$F\$11 >= 0.004
- \$F\$12 >= 0
- \$F\$13 <= \$C\$11
- \$F\$8 >= \$F\$10
- \$F\$9 >= 0

# Parameter Estimation

## After Calibration

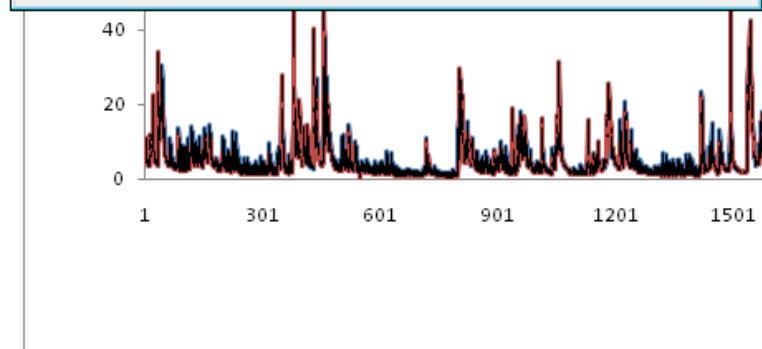
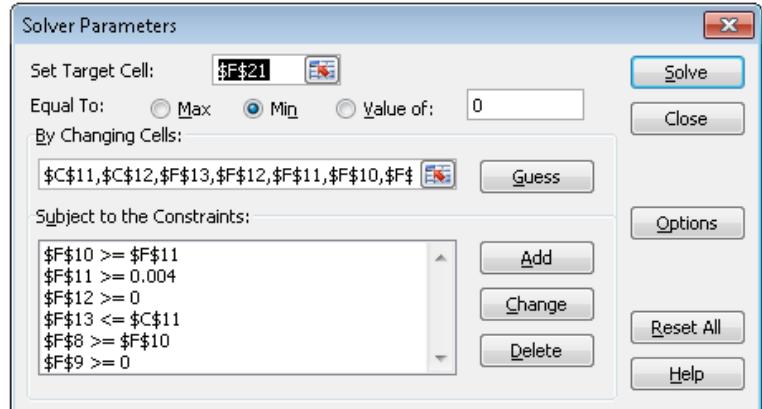
Model Performance		
TOT. ETA.	5625.87	
TOT. PREC.	9887.30	
TOT. DIS. (m/hr.km <sup>2</sup> )	4261.43	
SIM. DISC(m/hr.km <sup>2</sup> )	4157.63	
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63	
Error (%)	0.000	
Square diff.	153759.05	
Average Q <sub>observ.</sub>	5.40	
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78	
Correlation	0.27	
Nash Sutcliffe	0.07	

Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>
-1.4	5	0.161
-0.3	5	0.179
2.6	20	0.645
6.3	50	1.667
10.9	95	3.065
14.2	115	3.833
16.4	125	4.032
15.6	100	3.226
12.7	70	2.333
8.3	30	0.968
2.9	10	0.333
-0.4	5	0.161

Excel ribbon showing Data tab selected. A green checkmark points to the 'Sort & Filter' button in the Sort & Filter group.

K <sub>0</sub> (Reservoir Par.)	0.10
L <sub>1</sub> (Threshold W.L.)	6.00
K <sub>1</sub> (Reservoir Par.)	0.09
K <sub>2</sub> (Reservoir Par.)	0.00
K <sub>perc</sub>	0.07
PWP	105.00

Model Performance		
TOT. ETA.	4459.17	
TOT. PREC.	9887.30	
TOT. DIS. (m/hr.km <sup>2</sup> )	5428.13	
SIM. DISC(m/hr.km <sup>2</sup> )	5500.67	
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63	
Error (%)	32.303	
Square diff.	59479.25	
Average Q <sub>observ.</sub>	5.40	
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78	
Correlation	0.81	
Nash Sutcliffe	0.60	

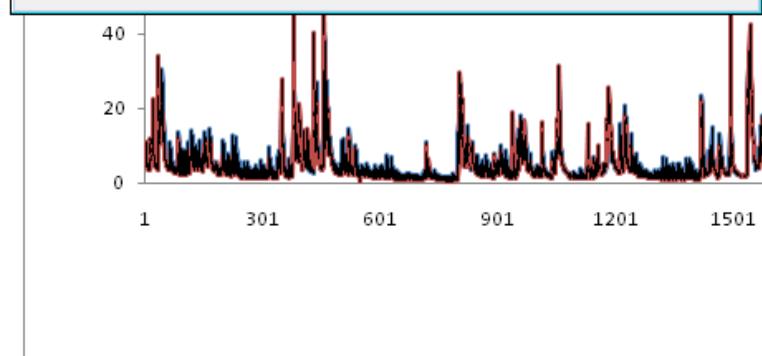
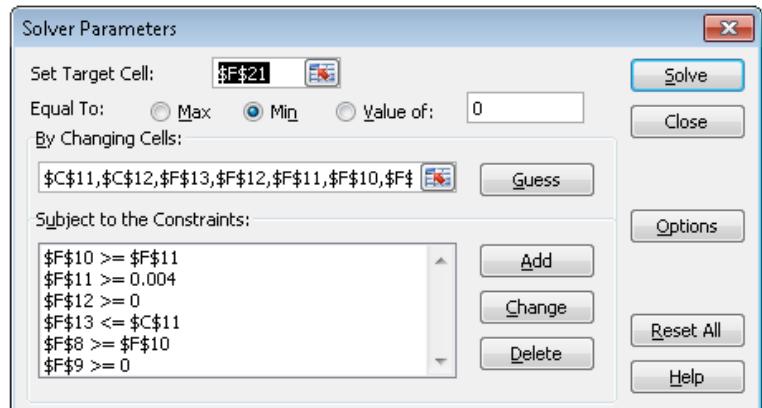
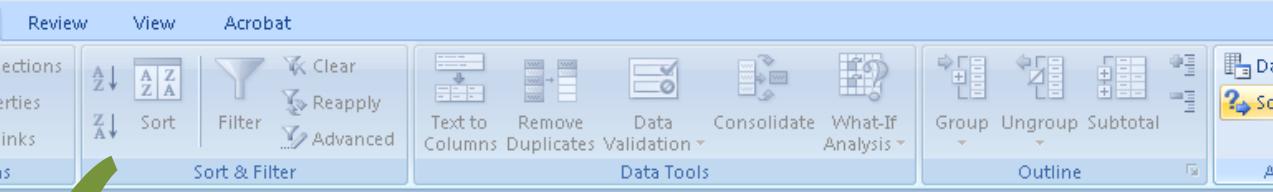


# Parameter Estimation

## After Calibration

Model Performance		
TOT. ETA.	5625.87	
TOT. PREC.	9887.30	
TOT. DIS. (m/hr.km <sup>2</sup> )	4261.43	
SIM. DISC(m/hr.km <sup>2</sup> )	4157.63	
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63	
Error (%)	0.000	
Square diff.	153759.05	
Average Q <sub>observ.</sub>	5.40	
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78	
Correlation	0.27	
Nash Sutcliffe	0.07	
Monthly T <sub>ave.</sub>		
PE <sub>m</sub>	Daily PE <sub>m</sub>	
-1.4	5	0.161
-0.3	5	0.179
2.6	20	0.645
6.3	50	1.667
10.9	95	3.065
14.2	115	3.833
16.4	125	4.032
15.6	100	3.226
12.7	70	2.333
8.3	30	0.968
2.9	10	0.333
-0.4	5	0.161

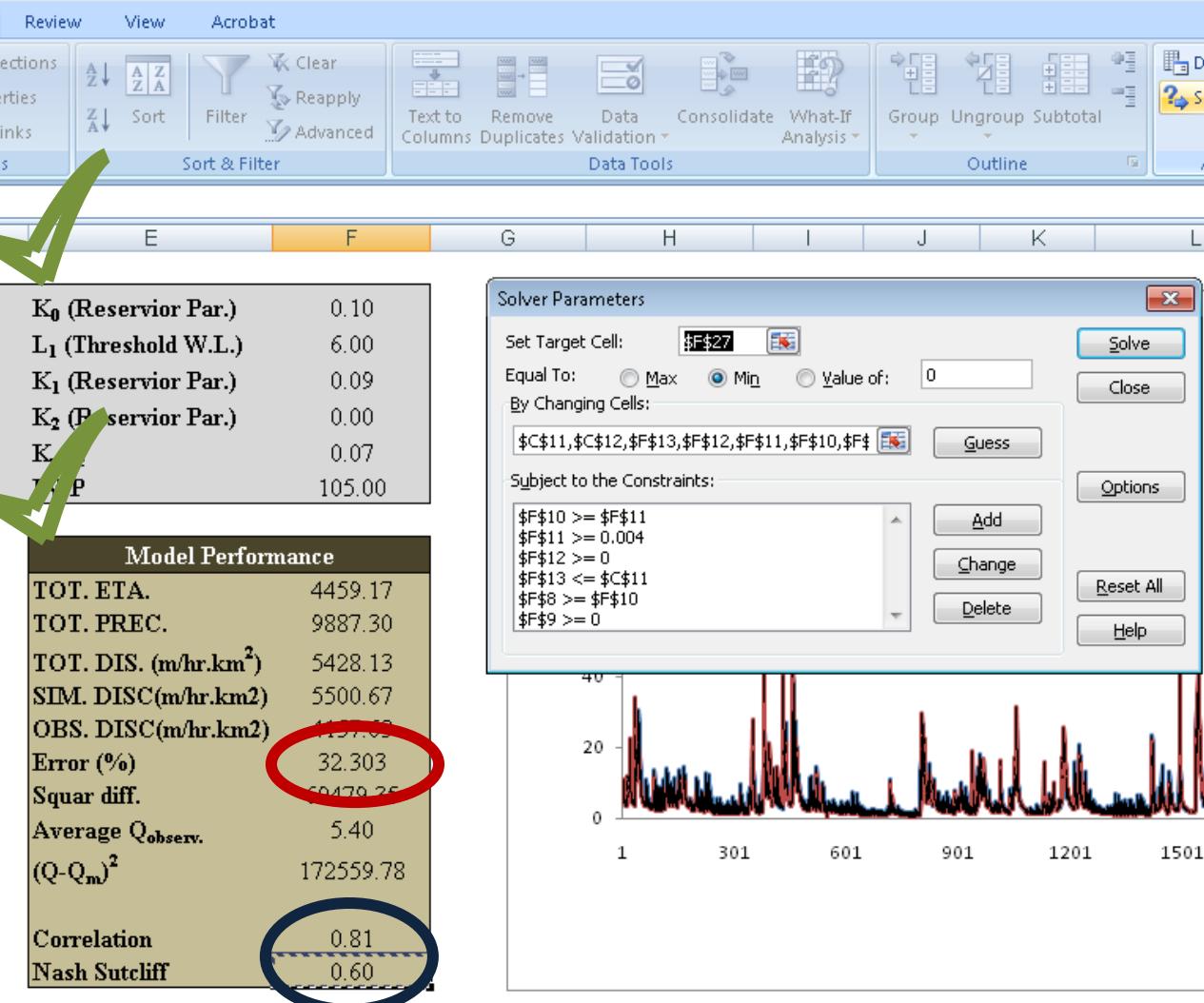
Model Performance		
TOT. ETA.	4459.17	
TOT. PREC.	9887.30	
TOT. DIS. (m/hr.km <sup>2</sup> )	5428.13	
SIM. DISC(m/hr.km <sup>2</sup> )	5500.67	
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63	
Error (%)	32.303	
Square diff.	59479.25	
Average Q <sub>observ.</sub>	5.40	
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78	
Correlation	0.81	
Nash Sutcliffe	0.60	



# Parameter Estimation

## After Calibration

Model Performance		
TOT. ETA.	5646.97	
TOT. PREC.	9887.30	
TOT. DIS. (m/hr.km <sup>2</sup> )	4240.33	
SIM. DISC(m/hr.km <sup>2</sup> )	4301.04	
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63	
Error (%)	3.449	
Square diff.	60701.52	
Average Q <sub>observ.</sub>	5.40	
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78	
Correlation	0.81	
Nash Sutcliffe	0.65	
Monthly T <sub>ave.</sub>	PE <sub>m</sub>	Daily PE <sub>m</sub>
-1.4	5	0.161
-0.3	5	0.179
2.6	20	0.645
6.3	50	1.667
10.9	95	3.065
14.2	115	3.833
16.4	125	4.032
15.6	100	3.226
12.7	70	2.333
8.3	30	0.968
2.9	10	0.333
-0.4	5	0.161



# Objective Function

**Objective Function 1:**

**Minimum total runoff error**

**Before Calibration**

Model Performance	
TOT. ETA.	4459.17
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	5428.13
SIM. DISC(m/hr.km <sup>2</sup> )	5500.67
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	32.303
Square diff.	69479.35
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.81
Nash Sutcliff	0.60

**After Calibration**

Model Performance	
TOT. ETA.	5625.87
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4261.43
SIM. DISC(m/hr.km <sup>2</sup> )	4157.63
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	0.000
Square diff.	159799.05
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.27
Nash Sutcliff	0.07

**Objective Function 2:**

**Maximum Nash-Sutcliff**

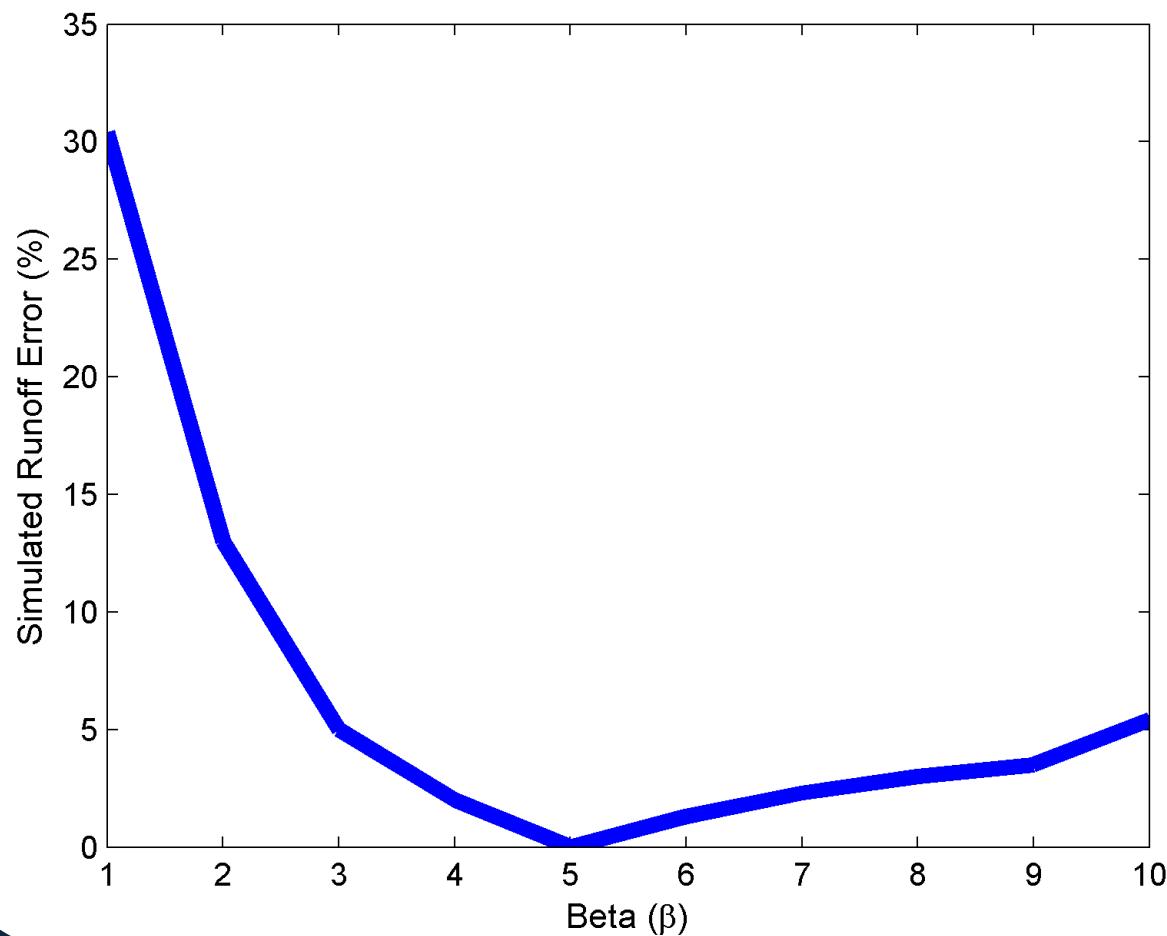
**Model Performance**

TOT. ETA.	4459.17
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	5428.13
SIM. DISC(m/hr.km <sup>2</sup> )	5500.67
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	32.303
Square diff.	69479.35
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.81
Nash Sutcliff	0.60

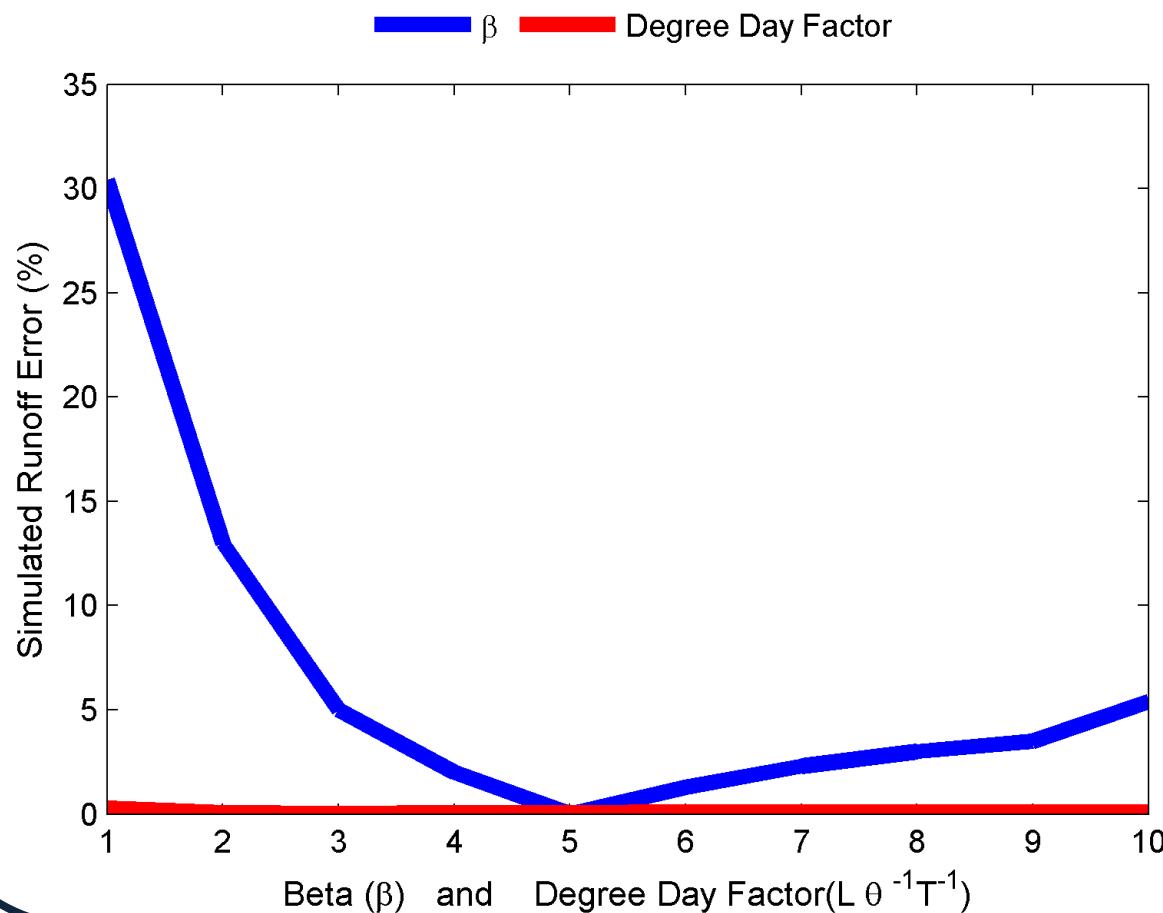
**Model Performance**

TOT. ETA.	5646.97
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4240.33
SIM. DISC(m/hr.km <sup>2</sup> )	4301.04
OBS. DISC(m/hr.km <sup>2</sup> )	4157.63
Error (%)	3.449
Square diff.	60701.52
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.81
Nash Sutcliff	0.65

# Parameter Sensitivity



# Parameter Sensitivity



# Error Sources

## Error in Initial Conditions

- Error in the initial values of soil moisture, snow, field capacity, permanent wilting point

## Error in Model Processes

- Unrealistic model assumptions
- Unrepresentative conceptual description of the system

## Error in Observations

- Error in input data (e.g., precipitation, temperature, etc.)
- Error in observed discharge

## Error in Model Parameterization

- Inability to obtain the optimal set of parameters.
- Deficiencies in parameter estimation scheme

## Initial Conditions

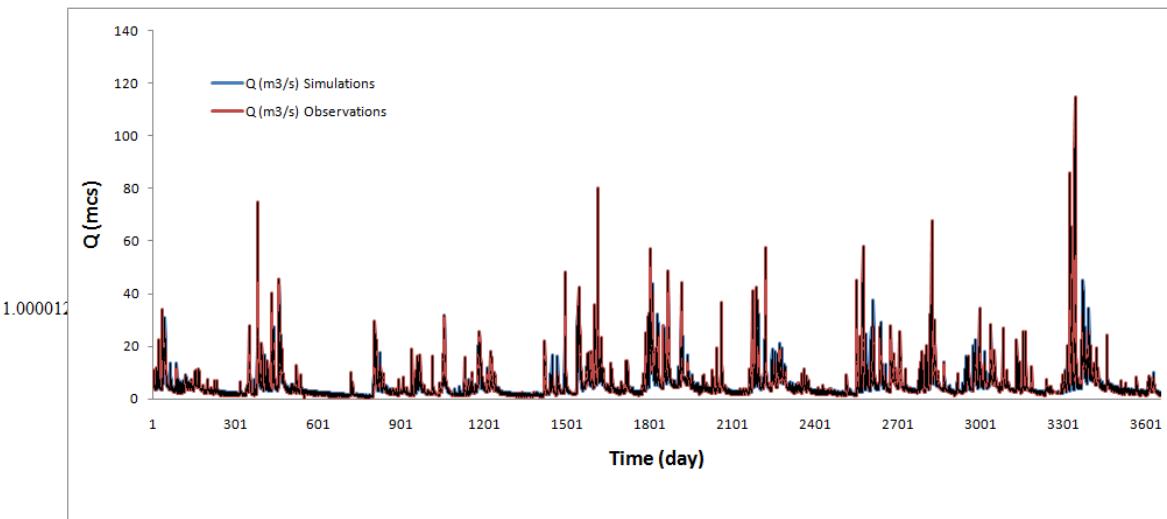
- Snow
- Soil Moisture
- $S_1$
- $S_2$

# Initial Condition Error

Catchment Area (Km <sup>2</sup> )	410	K <sub>0</sub> (Reservoir Par.)	0.13
T <sub>t</sub> (Threshold Temp.)	0	L <sub>1</sub> (Threshold W.L.)	6.00
DD	3	K <sub>1</sub> (Reservoir Par.)	0.13
FC (Field Capacity)	180.0	K <sub>2</sub> (Reservoir Par.)	0.00
BETA	5.0	K <sub>perc</sub>	0.22
C (Model param.)	0.03	PWP	105.00

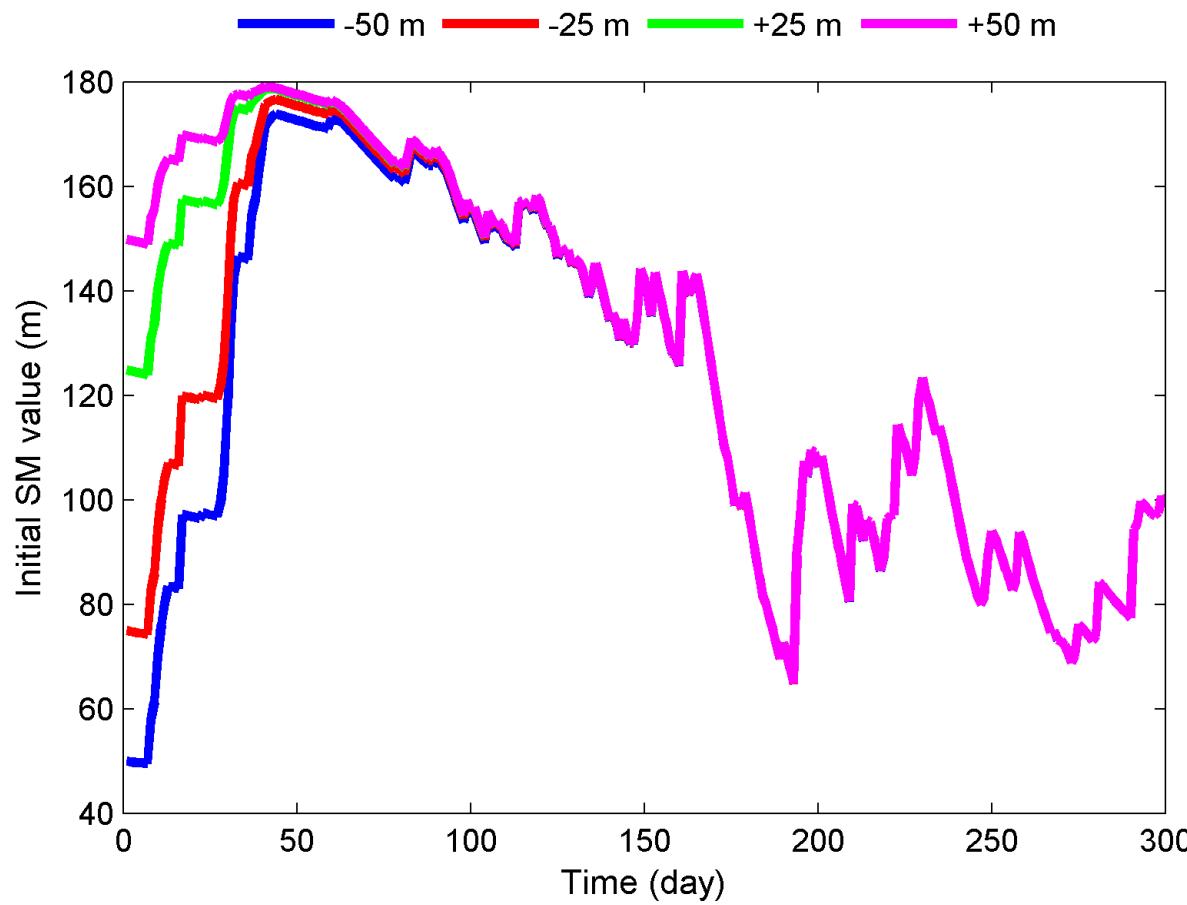
Monthly T <sub>ave.</sub>	PF <sub>m</sub>	Daily PE <sub>m</sub>
-1.4	5	0.161
-0.3	5	0.179
2.6	20	0.645
6.3	50	1.667
10.9	95	3.065
14.2	115	3.833
16.4	125	4.032
15.6	100	3.226
12.7	70	2.333
8.3	30	0.968
2.9	10	0.333
-0.4	5	0.161

Model Performance	
TOT. ETA.	5736.08
TOT. PREC.	9887.30
TOT. DIS. (m/hr.km <sup>2</sup> )	4151.22
SIM. DISC(m/hr.km2)	4157.68
OBS. DISC(m/hr.km2)	4157.63
Error (%)	0.001
Square diff.	52400.87
Average Q <sub>observ.</sub>	5.40
(Q-Q <sub>m</sub> ) <sup>2</sup>	172559.78
Correlation	0.84
Nash Sutcliffe	0.70



Date	Month ID	Temp. (C)	Preci. (mm)	Snow (mm)	Liquid Water	Soil Moisture	DQ (mm/day) OR P <sub>eff</sub>	Potential E. (PE <sub>a</sub> )	E <sub>a</sub> (mm/day)	S <sub>1</sub>	S <sub>2</sub>	Total Q (Q <sub>d</sub> ) (mm/day)	Q (m <sup>3</sup> /s) Simulations	Q (m <sup>3</sup> /s) Observations	(Q-QT) <sup>2</sup>	(Q-Qm) <sup>2</sup>
1/1/1991	1	-1.5	0.4	25.4	0	100.0	0.000	0.161	0.153	2.000	200.000	1.065	4.600	4.5	0.010	0.817
1/2/1991	1	-0.8	10.5	35.9	0	99.8	0.000	0.164	0.156	0.833	199.644	0.969	4.303	11	44.850	31.317
1/3/1991	1	-2.8	0.9	36.8	0	99.7	0.000	0.155	0.147	0.538	199.133	0.907	4.106	6.6	6.221	1.431
1/4/1991	1	-3.7	4.4	41.2	0	99.5	0.000	0.150	0.142	0.347	198.521	0.865	3.973	5	1.054	0.163
1/5/1991	1	-6.1	0.6	41.8	0	99.3	0.000	0.139	0.131	0.224	197.133	0.818	3.883	4.1	0.047	1.700

# Initial Condition Error



# Error Sources

## Error in Initial Conditions

- Error in the initial values of soil moisture, snow, field capacity, permanent wilting point

## Error in Model Processes

- Unrealistic model assumptions
- Unrepresentative conceptual description of the system

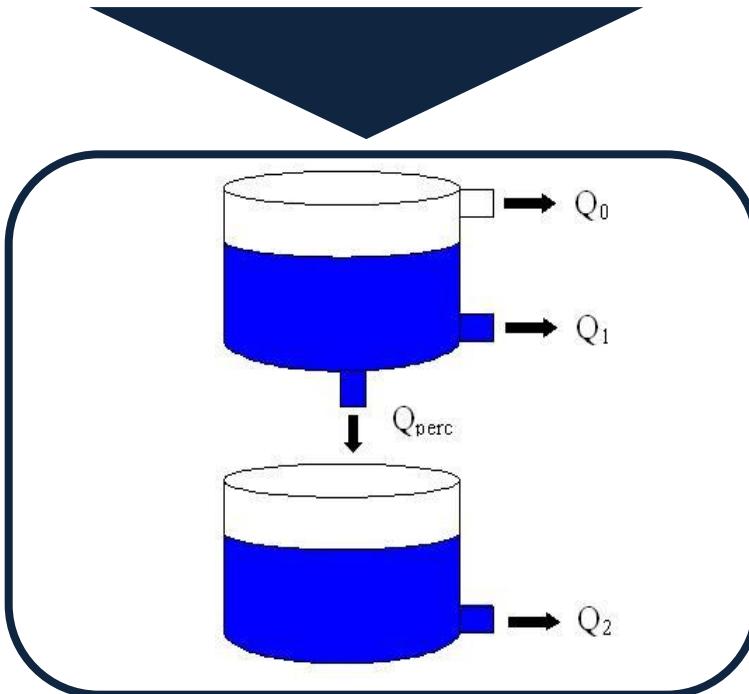
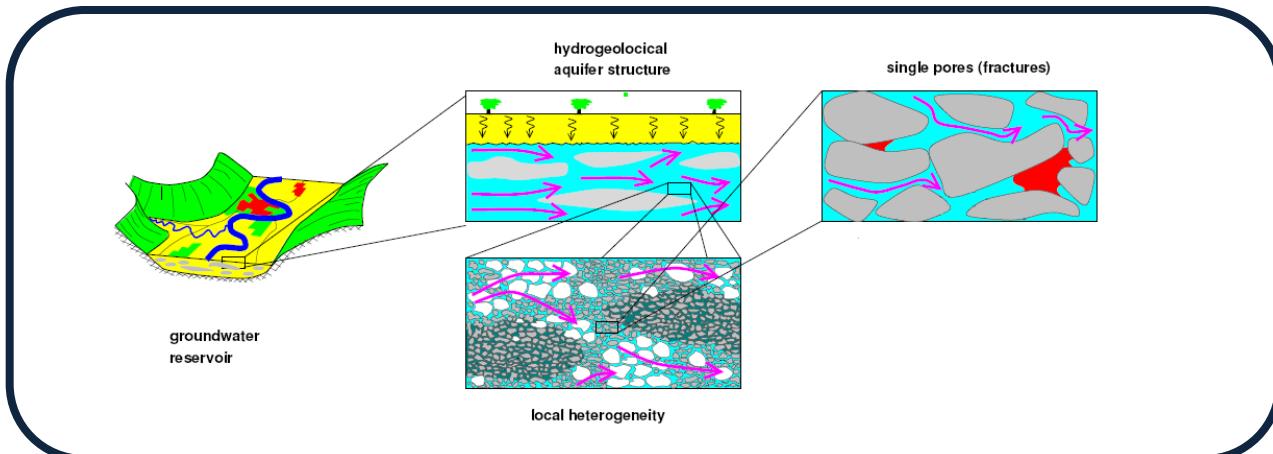
## Error in Observations

- Error in input data (e.g., precipitation, temperature, etc.)
- Error in observed discharge

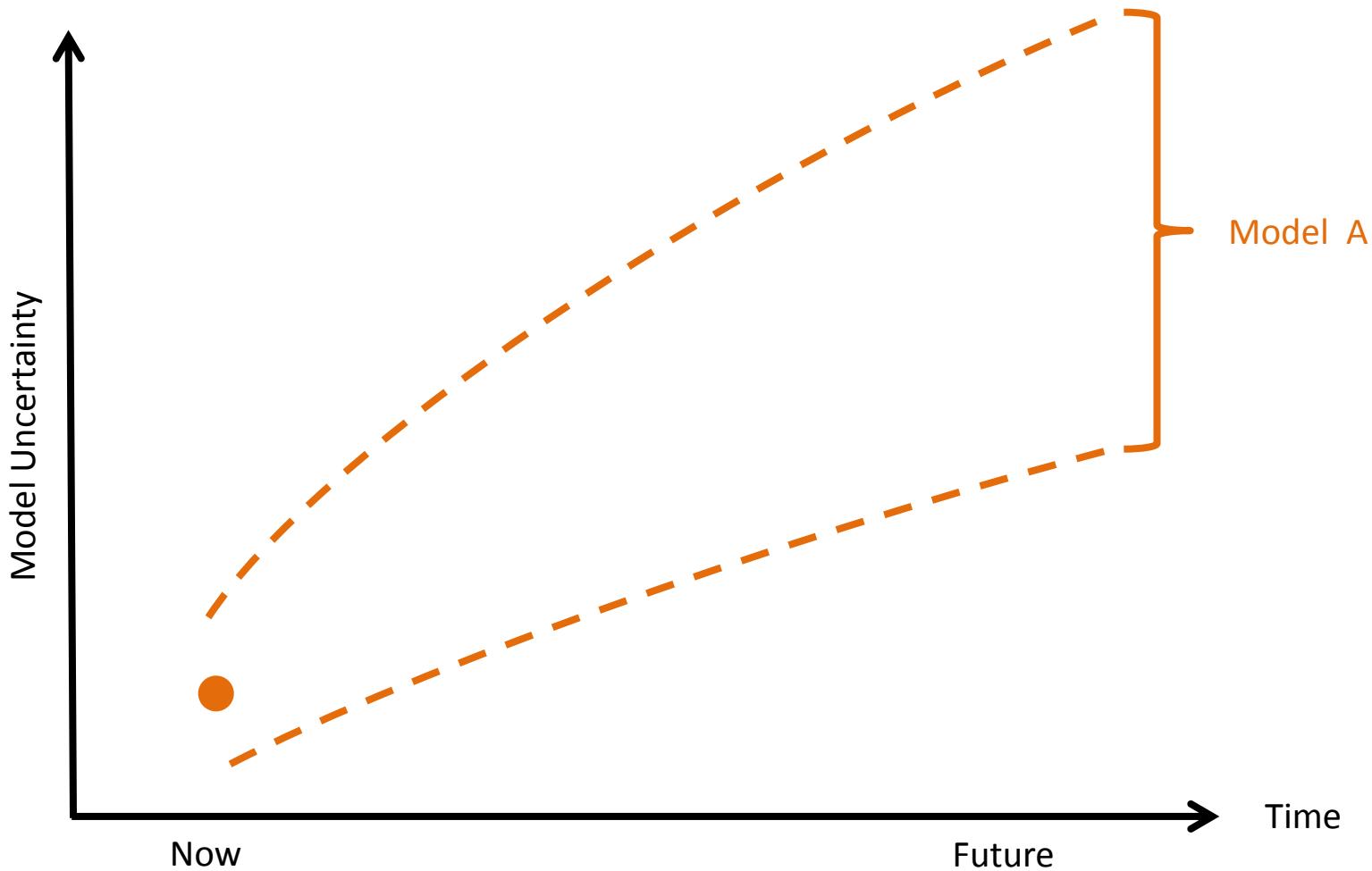
## Error in Model Parameterization

- Inability to obtain the optimal set of parameters.
- Deficiencies in parameter estimation scheme

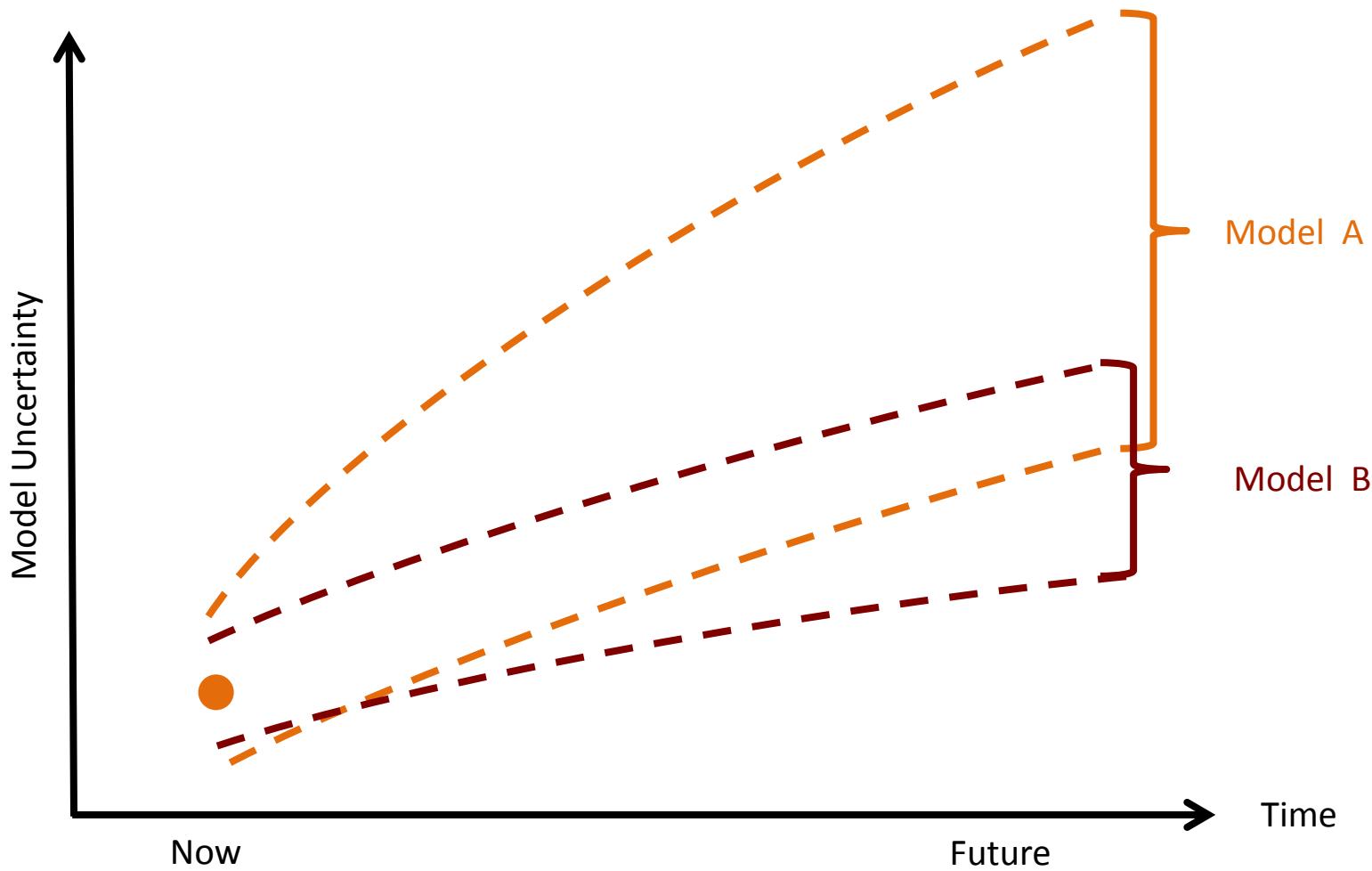
# Error in Model Processes



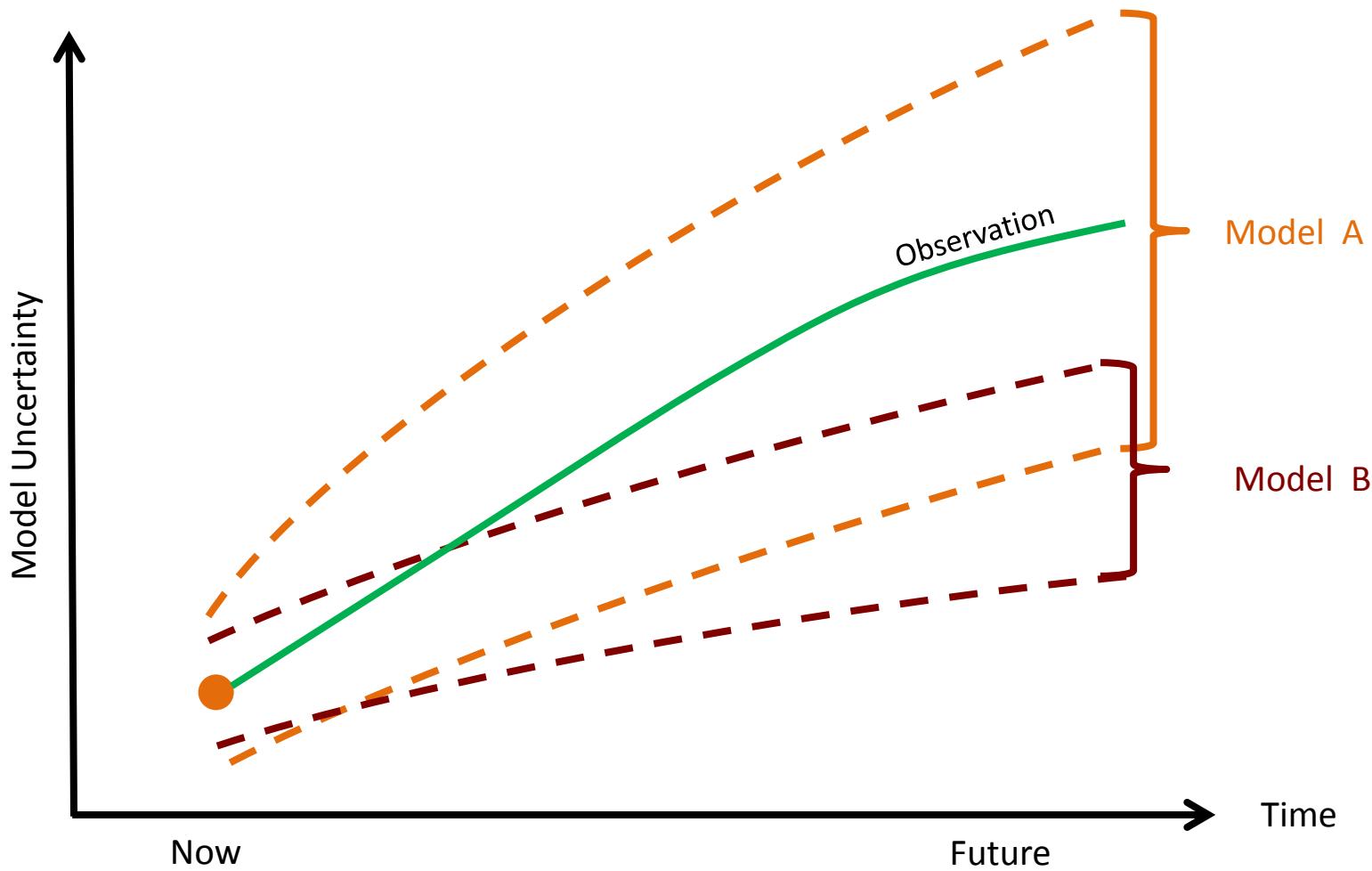
# Model Uncertainty



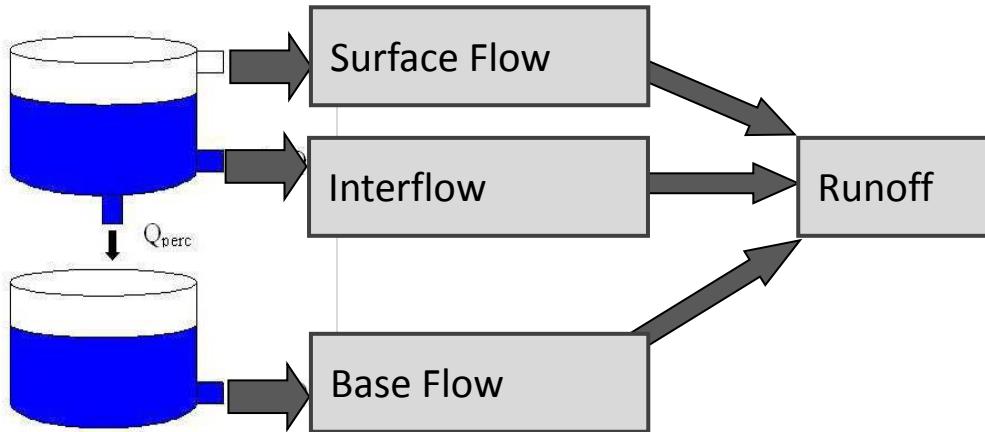
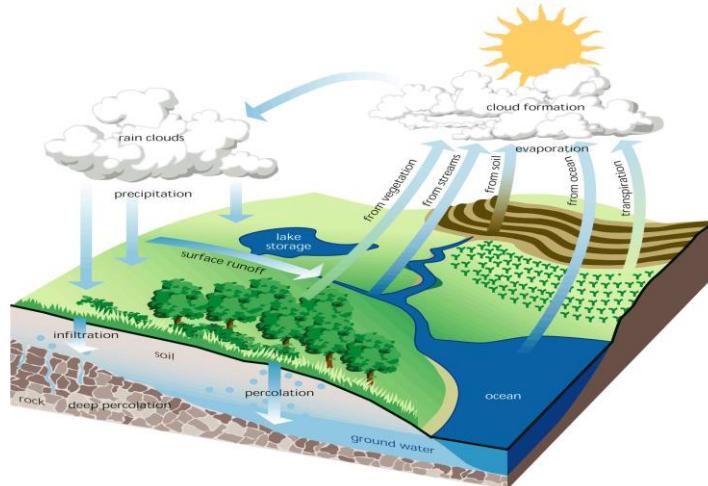
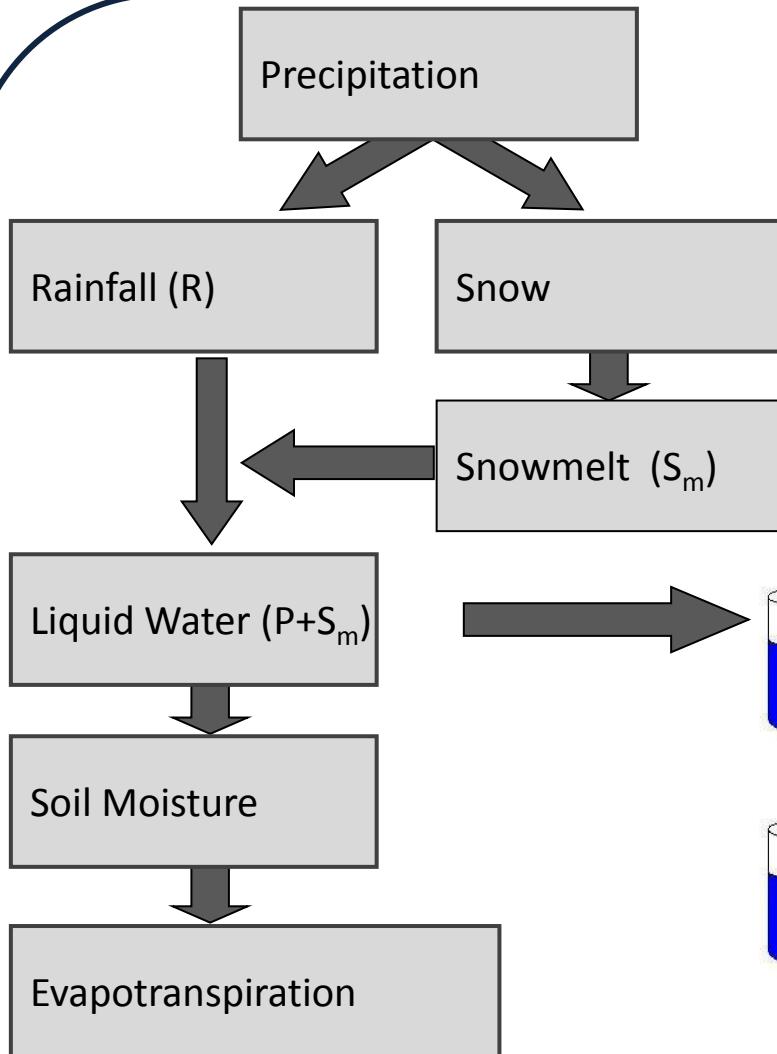
# Model Uncertainty



# Model Uncertainty



# Model Structure



# HBV-EDU

HBV\_EDU\_V2

Help

Contact  
**HBV-EDU Ver. 2**  
AghaKouchak & Emed Habib  
For questions and permissions contact:  
Dr. Amir AghaKouchak (amir.a@uci.edu)  
OR Dr. Emed Habib (habib@louisiana.edu)

Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

Watershed Area & Snow Melt Thr.

Area	410
T_s	0

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
AghaKouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

Acknowledgment  
HBV-EDU is supported by the National Science Foundation (NSF) Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. DUE-0737073.

Optimization Criteria

Qrmse (Root Mean Square Error)
--------------------------------

Select Parameter to Plot

Select	Plot
--------	------

Model Performance

Correlation
-------------

Nash Sutcliffe

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

MM	DD	YYYY	Temp.	Precip.	Snow	Liquid W.	Soil Moistu	Dq	Pot. Evap.	Evap.	S_1	S_2	Q obs	Q sim
List	List	Listbox	Tempar	Precip	Snow	Liquid W.	Soil Moistu	Dq	Pot. Evap.	Evap.	S1	S2	Q(obs)	Q(sim)

Load Input Files

Run

# of simulations 50

Simulate Q

Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset

# HBV-EDU

HBV\_EDU\_V2

Help

Contact  
HBV-EDU Ver. 2  
AghaKouchak & Emed Habib  
For questions and permissions contact:  
Dr. Amir AghaKouchak (amir.a@uci.edu)  
OR Dr. Emed Habib (habib@louisiana.edu)

Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

Watershed Area & Snow Melt Thr.

Area	410
T_s	0

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
AghaKouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

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Optimization Criteria

Qrmse (Root Mean Square Error)
--------------------------------

Select Parameter to Plot

Select	Plot
--------	------

Model Performance

Correlation
-------------

Nash Sutcliff
---------------

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

MM	DD	YYYY	Temp.	Precip.	Snow	Liquid Water	Soil Moisture	Dq	Pot. Evap.	Evap.	S <sub>1</sub>	S <sub>2</sub>	Q obs	Q sim
List	List	Listbox	Tempar	Precip	Snow	Liquid W	Soil Moistu	Dq	Pot. Evap.	Evap.	S1	S2	Q(obs)	Q(sim)

Load Input Files

Run

# of simulations 50

Simulate Q

Load Input Temp. & Precip.  
Load Monthly Temp. & Evap.  
Load Observed Q  
Reset

# HBV-EDU

HBV\_EDU\_V2

Help

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AghaKouchak & Emed Habib  
For questions and permissions contact:  
Dr. Amir AghaKouchak (amir.a@uci.edu)  
OR Dr. Emed Habib (habib@louisiana.edu)

Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

Watershed Area & Snow Melt Thr.

Area	410
T_s	0

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
AghaKouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

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Optimization Criteria

Qrmse (Root Mean Square Error)
--------------------------------

Select Parameter to Plot

Select	Plot
--------	------

Model Performance

Correlation
-------------

Nash Sutcliff
---------------

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

MM	DD	YYYY	Temp.	Precip.	Snow	Liquid Water	Soil Moisture	Dq	Pot. Evap.	Evap.	S <sub>1</sub>	S <sub>2</sub>	Q <sub>obs</sub>	Q <sub>sim</sub>
List	List	Listbox	Tempar	Precip	Snow	Liquid W	Soil Mois	Dq	Pot. Evap.	Evap.	S1	S2	Q(obs)	Q(sim)

Load Input Files

Run

# of simulations 50

Simulate Q

Load Input Temp. & Precip.  
Load Monthly Temp. & Evap.  
Load Observed Q  
Reset

**Source Code (only if you are interested to edit the source code):**  
**<http://amir.eng.uci.edu/downloads/HBV.zip>**

# HBV-EDU

HBV\_EDU\_V2

Help

Contact  
HBV-EDU Ver. 2  
Aghakouchak A., Emed Habib  
For questions and permissions contact:  
Dr. Amir Aghakouchak (amir.a@uci.edu)

## Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

Watershed Area & Snow Melt Thr.

Area	410
T_s	0

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
Aghakouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

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Optimization Criteria

Qrmse (Root Mean Square Error)
--------------------------------

Select Parameter to Plot

Select	Plot
--------	------

Model Performance

Correlation
-------------

Nash Sutcliffe

Nash Sutcliffe
----------------

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

MM	DD	YYYY	Temp.	Precip.	Snow	Liquid W.	Soil Moistu	Dq	Pot. Evap.	Evap.	S_1	S_2	Q obs	Q sim
List	List	Listbox	Tempar	Precip	Snow	Liquid W.	Soil Moistu	Dq	Pot. Evap.	Evap.	S1	S2	Q(obs)	Q(sim)

Load Input Files

Run

# of simulations 50

Simulate Q

Load Input Temp. & Precip.  
Load Monthly Temp. & Evap.  
Load Observed Q  
Reset

# HBV-EDU

HBV\_EDU\_V2

Help

Contact  
HBV-EDU Ver. 2  
Aghakouchak A., Emed Habib  
For questions and permissions contact:  
Dr. Amir Aghakouchak (amir.a@uci.edu)

## Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

### Initial Values

Snow	0.0
Soil Moisture	100.0
S_1	2.0
S_2	200.0

Watershed Area & Snow Melt Thr.

Area: 410

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
Aghakouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

Acknowledgment  
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Optimization Criteria

Qrmse (Root Mean Square Error)

Select Parameter to Plot

Plot

Model Performance

Correlation

Nash Sutcliffe

Load Input Files

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

List List Listbox Tempar Precip Snow Liquid W Soil Moistu Dq Pot. Evap. Evap. S1 S2 Q(obs) Q(sim)

Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset Run

# of simulations: 50

Simulate Q

# HBV-EDU

**HBV\_EDU\_V2**

**Model Parameters**

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_P	0.01 0.1	
PWP	90 180	

**Upper Bound of parameter**

**Watershed Area & Snow Melt Thr.**

Area	410
T_s	0

**Input Data Based on Monthly Climatological Data**

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

**Cite this program as:**  
Aghakouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

**Acknowledgment:**  
HBV-EDU is supported by the National Science Foundation (NSF) Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. DUE-0737073.

**Optimization Criteria:** Qrmse (Root Mean Square Error)

**Select Parameter to Plot:** Select Plot

**Model Performance:**

Correlation
Nash Sutcliffe

**Run:** # of simulations 50  
Simulate Q

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

Load Input Files: Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset Simulate Q

# HBV-EDU

HBV\_EDU\_V2

Help

Contact  
HBV-EDU Ver. 2  
Aghakouchak & Emad Habib  
For questions and permissions contact:  
Dr. Amin Aghakouchak (aaghakouchak@usgs.gov)

Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

Watershed Area & Snow Melt Thr.

Area	410
T_s	0

Initial Values

Snow	0.0
Soil Moisture	100.0
S_1	2.0
S_2	200.0

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
Aghakouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

Acknowledgment  
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Optimization Criteria

Qrmse (Root Mean Square Error)
--------------------------------

Select Parameter to Plot

Select	Plot
--------	------

Model Performance

Correlation
Nash Sutcliffe

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

Lower Bound of parameter

Run

# of simulations	50
Simulate Q	

[http://www.aghakouchak.com/\\_rsrcces/hm/hbv\\_edu/HBV\\_EDU\\_GUI.png](http://www.aghakouchak.com/_rsrcces/hm/hbv_edu/HBV_EDU_GUI.png)

Load Input Files

Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset Simulate Q

# HBV-EDU

**Model Parameters**

Parameters	Bounds	Optimal
DO	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

**Optimal Parameter (after calibration)**

**Watershed Area & Snow Melt Thr.**

Area	410
T_s	0

**Input Data Based on Monthly Climatological Data**

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

**Cite this program as:**  
Aghakouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

**Acknowledgment:**  
HBV-EDU is supported by the National Science Foundation (NSF) Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. DUE-0737073.

**Optimization Criteria**

ORMSE (Root Mean Square Error)
--------------------------------

**Select Parameter to Plot**

Select	Plot
--------	------

**Model Performance**

Correlation
-------------

**Nash Sutcliffe**

**Run**

# of simulations	50
------------------	----

**Load Input Files**

**Load Input Temp. & Precip.**   **Load Monthly Temp. & Evap.**   **Load Observed Q**   **Reset**   **Simulate Q**

# HBV-EDU

HBV\_EDU\_V2

Help

Contact  
**HBV-EDU Ver. 2**  
Aghakouchak & Emed Habib  
For questions and permissions contact:  
Dr. Amir Aghakouchak (amir.a@uci.edu)  
OR Dr. Emed Habib (habib@louisiana.edu)

Watershed Area & Snow Melt Thr.

Area	410
T <sub>f</sub>	0

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
Aghakouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

Acknowledgment  
HBV-EDU is supported by the National Science Foundation (NSF) Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. DUE-0737073.

Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K <sub>0</sub>	0.2 0.4	
L	2.0 5	
K <sub>1</sub>	0.01 0.2	
K <sub>2</sub>	0.01 0.1	
K <sub>P</sub>	0.01 0.1	
PWP	90 180	

Initial Values

Snow	0.0
Soil Moisture	100.0
S <sub>1</sub>	2.0
S <sub>2</sub>	200.0

Model Performance

Correlation	
Nash Sutcliffe	

Select Parameter to Plot

Select	Plot
--------	------

Input Precipitation and Temperature

Sample input in the package: inputPrecipTemp.txt -  
The file includes 4 columns: (I) date; (II) month | [http://www.aghakouchak.com/ces/hm/hbv\\_edu/HBV\\_EDU\\_GUI/](http://www.aghakouchak.com/ces/hm/hbv_edu/HBV_EDU_GUI/).  
Temperature (Celsius); and (IV) precipitation (mm/day)

Load Input Files:

Load Input Temp. & Precip. (highlighted)

Load Monthly Temp. & Evap.

Load Observed Q

Reset

Run

# of simulations: 50

Simulate Q

# HBV-EDU

HBV\_EDU\_V2

Help

Contact  
HBV-EDU Ver. 2  
Aghakouchak & Emed Habib  
For questions and permissions contact:  
Dr. Amir Aghakouchak (amir.a@uci.edu)  
OR Dr. Emed Habib (habib@louisiana.edu)

Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

Watershed Area & Snow Melt Thr.

Area	410
T_s	0

Input Data Based on Monthly Climatological Data

Monthly Temp.	Monthly PE	Daily PE
Temp.	Monthly PE	Daily PE

Cite this program as:  
Aghakouchak A., Habib E., 2010, Application of a Conceptual Hydrologic Model in Teaching Hydrologic Processes, International Journal of Engineering Education, 26(4), 963-973.

Acknowledgment  
HBV-EDU is supported by the National Science Foundation (NSF) Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. DUE-0737073.

Optimization Criteria

Qrmse (Root Mean Square Error)
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Select Parameter to Plot

Select	Plot
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Model Performance

Correlation
Nash Sutcliffe

Initial Values

Snow	0.0
Soil Moisture	100.0
S_1	2.0
S_2	200.0

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S\_1 S\_2 Q obs Q sim

Load Input Files

Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset Run

# of simulations 50 Simulate Q

**Input Long-Term Mean Temperature and Potential Evapotranspiration**

Sample input in the package: `inputMonthlyTempEvap.txt` - the file includes 3 columns: (I) Monthly Temperature (Celcius); (II) Monthly Potential Evapotranspiration; and (III) Mean Daily Potential Evapotranspiration (mm/day)



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Watershed Area & Snow Melt Thr.

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Input Data Based on Monthly Climatological Data

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Optimization Criteria

Model Performance

Observed Discharge

Sample input in the package: Qobs.txt -  
The file contains observed runoff (Q) in cubic meters per second (CMS)

Load Input Files

Run

Load Input Temp. & Precip.  
Load Monthly Temp. & Evap.  
Load Observed Q  
Reset  
# of simulations 50  
Simulate Q

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Watershed Area & Snow Melt Thr.: Watershed Area & Snow Melt Thr.: Input Data Based on Monthly Climatological Data

Area	410
T <sub>f</sub>	0

Initial Values

Snow	0.0
Soil Moisture	100.0
S <sub>-1</sub>	2.0
S <sub>-2</sub>	200.0

Model Parameters

Parameters	Bounds	Optimal
DD	4 7	
FC	100 200	
Beta	1 4	
C	0.03 0.07	
K <sub>0</sub>	0.2 0.4	
L	2.0 5	
K <sub>1</sub>	0.01 0.2	
K <sub>2</sub>	0.01 0.1	
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Optimization Criteria: Qrms (Root Mean Square Error)

Select Parameter to Plot: Select Plot

Model Performance: Correlation, Nash Sutcliffe

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S<sub>-1</sub> S<sub>-2</sub> Q obs Q sim

Optimization (Parameter Estimation) Criteria

The parameter estimation and uncertainty analysis is based on the GLUE concept using any of the following Objective functions:

- Qrms (Root mean square error)
- NSC (Nash-Sutcliff Coefficient)
- Corr (Correlation Coefficient)

Load Input

Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset # of simulations 50 Simulate Q

[http://www.aghakouchak.com/\\_rsrc/128ces/hm/hbv\\_edu/HBV\\_EDU\\_GUI.png](http://www.aghakouchak.com/_rsrc/128ces/hm/hbv_edu/HBV_EDU_GUI.png)

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Initial Values

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Soil Moisture	100.0
S_1	2.0
S_2	200.0

Optimization Criteria

Qrmse (Root Mean Square Error)

Select Parameter to Plot

Model Performance

Correlation

Nash Sutcliffe

Number of Simulations  
(Combinations of Parameters)

# of simulations 50

Load Input Files

Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset Simulate Q

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Watershed Area & Snow Melt Thr.

Area	410
T <sub>th</sub>	0

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Initial Values

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Soil Moisture	100.0
S <sub>1</sub>	2.0
S <sub>2</sub>	200.0

Optimization Criteria

Qrmse (Root Mean Square Error)
--------------------------------

Select Parameter to Plot

Select	Plot
--------	------

Model Performance

Correlation
Nash Sutcliffe

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S<sub>1</sub> S<sub>2</sub> Q obs Q sim

List	List	Listbox	Tempar	Precipi	Snow	Liquid W	Soil Mois	Dq	Pot. Evap.	Evap.	S1	S2	Q(obs)	Q(sim)	

Load Input Files

Run

# of simulations 50

Load Input Temp. & Precip. Load Monthly Temp. & Evap. Load Observed Q Reset Simulate Q

RUN

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Watershed Area & Snow Melt Thr.

Area	410
T <sub>th</sub>	0

Input Data Based on Monthly Climatological Data

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K <sub>P</sub>	0.01 0.1	
PWP	90 180	

Initial Values

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Soil Moisture	100.0
S <sub>1</sub>	2.0
S <sub>2</sub>	200.0

Model Performance

Qrmse (Root Mean Square Error)

Select Parameter to Plot

Select      Plot

Correlation

Nash Sutcliffe

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evap. S<sub>1</sub> S<sub>2</sub> Q(sim) Q(sim)

List List Listbo Temper Precip Snow Liquid W Soil Moistu Dq Pot. Evap. Evap. S1 S2 Q(s) Q(s) Q(sim) Q(sim)

Load Input Files

Load Input Temp. & Precip.    Load Monthly Temp. & Evap.    Load Observed Q    Reset    # of simulations 50    Simulate Q

Model Performance

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K_0	0.2 0.4	
L	2.0 5	
K_1	0.01 0.2	
K_2	0.01 0.1	
K_p	0.01 0.1	
PWP	90 180	

Initial Values

Snow	0.0
Soil Moisture	100.0
S_1	2.0
S_2	200.0

Optimization Criteria

Grmse (Root Mean Square Error)
--------------------------------

Model Performance

Correlation
Nash Sutcliff

Select      Plot

MM DD YYYY Temp. Precip. Snow Liquid Water Soil Moisture Dq Pot. Evap. Evi S\_1 S\_2 Q obs Q sim

Select Variable to Plot

Load Input Files

Load Input Temp. & Precip.    Load Monthly Temp. & Evap.    Load Observed Q    Reset

Run

# of simulations 50

Simulate Q

# HBV-EDU (Version 3)

