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Research Paper

Assessment of water balance using SWAT – A case study of the Nakhon Ratchasima Province

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ABSTRACT

In the dry season, the Nakhon Ratchasima province is facing a water scarcity problem in every year due to the gap between demand and supply of the water system. However, there are the high rainfall and runoff during rainy season. Then, the purposes of this study are to analyze the water balance and to manage the water resources in Nakhon Ratchasima province using SWAT. The study can be presented that, during dry season, the total amount of water demand is higher than the amount of runoff for the Lam Takhlong basin, Lam Phra Phloeng basin, Lam Sae basin, Lam Plai Mat basin, and Lam Chakkarat basin. However, this water demand can be supported by the maximum water storage in the reservoir. On the other hand, the total amount of water demand is less than the amount of runoff for Lam Choengkrai basin, Upper part of Lam Nam Mun basin, Lam Sa Thaet basin, and Second part of Lam Nam Mun basin. The excess water runoff from Lam Choengkrai basin should be diverted to Lam Takhlong basin and water diversion from Upper part of Lam Nam Mun basin should be considered for Lam Phra Phloeng basin and Lam Sae basin.

1. Introduction

In Thailand, the flooding in rainy season and the drought in dry season are the cycle of a common feature of life in a year. There is flooding in every year and it usually occurs during September to October (Petchprayoon et al., 2010). The main causes of flooding are the heavy rain in monsoon season and the overload capacity of dam and river. Moreover, urbanization in the flood-plain areas, used to be the area for retaining water, were developed by unwell plan expansion and it is then a block of the natural drainage mechanism. Even though Thailand has an average annual rainfall of over 1,500 mm, the drought problem occurs in some parts of the country because of the uneven distribution of rainfall and the water shortage. Drought normally occurs in summer or when rainfall is delayed in the early part of the rainy season or July. It had a negative effect on crops and agriculture in Thailand. Some areas have been experienced the both of flooding and drought in a year, because of temporal and spatial uncertainties in the monthly rainfall or the poor management of the conveyance infrastructure.

In 2010, there was a heavy rainfall in the Khao Yai National Park where is the upper basin of the Nakhon Ratchasima province and there was flooding in this area. During 14-16 Oct 2010, the maximum 3-day rainfall in the upstream of Nakhon Ratchasima province was 180.3 mm, while in the downstream was 211.6 mm. The reservoir volume roses very quickly and downstream was flooded at very wild scale. The city area was seriously flooded.

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However, there was droughts in every year (Kosa et al, 2017). Therefore, managing flood and drought problem is becoming increasingly important as a result of natural uncertainty.

The water management has been supported by the principle of hydrological cycles and it is based on the framework of water balance. To consider water balance, the understanding of partition of rainfall into runoff and evapotranspiration is so importance (Yang et al. 2008 and Zhang et al., 2004). The water balance can be derived from the concept of mass conservation and it is the most fundamental aspect of global and regional water cycle (Oki and Musiake, 2005). The water planners and managers has been applied the water balance to optimize human water uses based on the constraints of water extraction capacity. The purposes of this study are to analyze the water balance and to manage water resources in Nakhon Ratchasima province using SWAT. The SWAT is a hydrological model which continuously simulates time model and operates on a daily time step at basin scale. To achieve the objective, land use map on 2008, DEM, topographical data, soil map and daily weather data during January 1, 1981 to December 31, 2009 were mainly input data to SWAT.

2. Materials and methods

2.1 The study area :Nakhon Ratchasima

Nakhon Ratchasima in Thailand forms study area .It locates in the northeastern of Thailand. Latitude and longitude coordinates are: 14.979900 N, 102.097771 E. It is at the west end of the Khorat Plateau, separated from the Chao Phraya river valley by the Phetchabun and Dong Phaya Yen mountain ranges. There are two national parks in the province: Khao Yai in the west and Thap Lan in the south. A large province on the northeastern plateau and acts as a gateway to other provinces in the northeast is Nakhon Ratchasima. It has an area of around 20,494 square kilometer (7,913 square mile) and it is in Mun river basin. There are included nine sub-basins and five large reservoirs shown in Fig .1 and Table 1.

Inhabitants of the province are mainly engaged in agricultural activities that include farming of rice and other crops such as sugar cane, tapioca, corn, jute, peanuts, sesame and fruits. There are more than 100 savings and agricultural cooperatives in the province, 35 irrigation projects and 7,122 industrial factories. Most of the factories are rice mills, tapioca product manufacturers, and industrial factories.

The climate in Nakhon Ratchasima is tropical .There are generally three seasons in the region: Hot (February – May), Rainy (May – October), Cold (October – February). It have a good deal of rainfall, while the winters have very

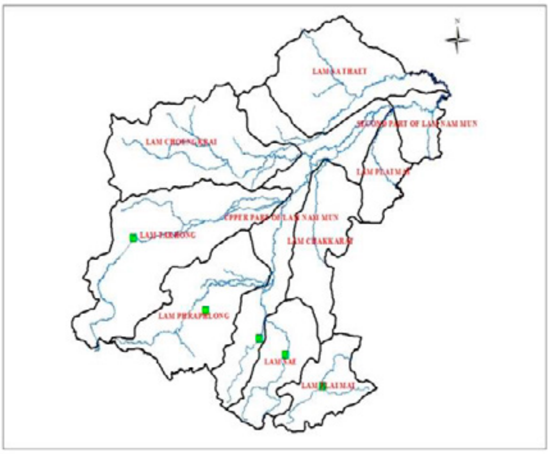

Fig. 1. The nine sub-basins and five large reservoirs

Table 1. The reservoirs and water storage in nine sub-basins.

Sub-basin	**Reservoirs**			**Storages)million (m^3)**
	Large	**Medium**	**Small**	
Lam Takhlong	1	2	278	439.11
Lam Phra Phloeng	1	5	115	331.59
Lam Choengkrai		4	553	190.71
Upper part of Lam Nam Mun	1	1	30	357.1
Lam Sae	1	1	20	336.87
Lam Chakkarat		1	79	34.18
Lam Sa Thaet		2	618	84.22
Lam Plai Mat	1	5	71	166.15
Second part of Lam Nam Mun			298	216.45
Total	5	21	2062	2156.38

little. The average annual temperature is 27.4 °C. About 1019 mm of rainfall falls annually.

2.2 Soil and Water Assessment Tool (SWAT)

To understand the hydrological cycle change and the associated potential of runoff and evapotranspiration, this study applied SWAT model to estimate the runoff and evapotranspiration in the Nakhon Ratchasima province. SWAT is hydrological model which continuously simulates time model and operates on a daily time step at basin scale. SWAT are consisted of the main components such as weather, hydrology, sedimentation, crop growth, nutrients, pesticides, agricultural management, and stream routing (Arnold et al., 1998). However, this study focuses only on weather, hydrology, agricultural management, and stream routing to estimate surface runoff and evapotranspiration.

Nakhon Ratchasima province is the large scale spatial heterogeneity, considering information from the elevation map (DEM), the soil map and land use map. It can be divided into sub-basins and each sub-basin is also discriminated into a series of hydrologic response units or HRUs. HRUs are consisted of unique soil, land use, slope, reach dimensions, and climate data. In each HRUs, water is stored in rainfall, soil profile (0-2 m), shallow aquifer (typically 2-20 m) and deep aquifer. The routing through the river system is concerned using the variable storage or Muskingum method (Abbaspour et al., 2007).

The most fundamental input of hydrological model like SWAT is weather data. The daily data of rainfall and minimum/maximum temperature are required. However, the weather station network is not very dense and data duration is quite short. Moreover, there are many missing data and erroneous data. To simulate missing data, the weather generator program WXGEN was concerned in SWAT model. The WXGEN program fills data gap and extends time series of daily data based on monthly statistics. (Schuol et al., 2008)

The soil profile is subdivided into multilayer and it supports the process of infiltration, evaporation, plant uptake, lateral flow, and percolation to lower layers. To estimate flow to soil layer in root zone, the percolation is applied using the method of water storage capacity. When field capacity of soil layer is exceeded and layer below is not saturated, the percolation to lower layers occurs. Moreover, there is not percolation to lower layer when temperature in soil layer is less than or equal 0°C. Groundwater flow contribution to total stream flow is simulated by routing a shallow aquifer storage component to the stream (Abbaspour et al., 2007; Arnold and Allen, 1996).

Thereafter, the framework of water balance is considered using the elements of water cycle. There are two major division of hydrologic cycle for the watershed. Firstly, to control the amount of water loading to the main channel in each sub-watershed, the land phase of the hydrological cycle is concerned. Secondary, the water phase of the water cycle is considered for the movement of water through the channel network of the watershed to the outlet. The water balance equation simulated in hydrologic cycle is presented as [1]

$$S_f = S_i + \sum_{i=1}^{t} (P - Q_s - ET - w - Q_g) \qquad [1]$$

The surface runoff is calculated using the SCS runoff method. The SCS curve method which estimates runoff based on land use, soil type, and antecedent moisture condition is applied in SWAT model to calculate surface runoff from daily rainfall. The SCS curve number equation is (Soil Conservation Service, 1972)

$$Q_s = \frac{(P - I_a)^2}{(P - I_a + S)^2} \qquad [2]$$

The retention parameter varies spatially due to changes in soil, land use, management and slope and temporally due to changes in soil water content.

To estimate potential soil water evaporation, the function of potential evapotranspiration and leaf area index are applied while, to calculate actual soil evaporation, the exponential function of soil depth and water content is concerned. Plant water evaporation is simulated using the linear function of potential evapotranspiration, leaf area index, and root depth (Williams et al., 1984; Williams et al., 1985; Leonard et al., 1987).

Potential evapotranspiration is computed using Penman-Monteith equation (Monteith, 1965; Allen, 1986; Allen, 1989). The components of this equation are included the energy required to sustain evaporation and the mechanism needed to remove the water vapor and aerodynamic and surface resistance terms. The Penman-Monteith equation is:

$$\lambda E = \frac{\Delta(H_{net} - G) + \rho_{air} \cdot c_p \left(e_z^o - e_z\right)/r_a}{\Delta + \gamma(1 + r_c / r_a)} \qquad [3]$$

2.3 SWAT Model Sensitivity Analysis

The sensitivity analysis was conducted to concern the influence of parameters that had on estimating sediment. Parameters were analyzed for the sensitivity analysis of calibration and validation parameters shown in Table 2.

2.4 Calibration and Validation

The calibration and validation were focused on the periods of January 2004 – December 2008 and January 2009 – March 2010, respectively. The calibration and validation were completed by comparing time series model results to gaged monthly runoff at station M89. Two criteria for the goodness of fit - the graphical comparison and the Nash-Sutcliffe efficiency (NSE) coefficient - were used for calibration and validation (Table 3). Graphical comparison is extremely useful for judging the results of model calibration and model validation. It is overlooked by coefficient of determination (R^2). In addition, the Nash-

Sutcliffe efficiency (NSE) coefficient is an indicator of a model ability to predict about the 1:1 line. The closer the value is to 1.0, the more accurate the model. These results relate to the study of Arnold, 2000 (R^2 = 0.63), Benham et al., 2006 (R^2 = 0.70), Cerucci and Conrad, 2003) R^2 = 0.72), Chaplot et al., 2004 (R^2 = 0.73), Chu and Shirmohammadi, 2004 (R^2 = 0.66), Gitau et al., 2004 (R^2 =0.76), Jha et al., 2006 (R^2 = 0.74) and Kalin and Hantush, 2006 (R^2 = 0.77).

3. Results

Nakhon Ratchasima is consisted of nine sub-basins and they are classified to 232 HRUs depended on DEM, land use, soil type and slope shown in Table 4. Thereafter, the daily runoff and daily evapotranspiration during January 1, 1981 to December 31, 2009 were computed by SWAT. Water consuming (WC) was estimated base on the number of people in these nine sub-basins with the rate of 200 lit/person/day. The results of water balance (WB) in each sub-basin are presented in Table 5. Also, it can be presented as following:

Lam Takhlong sub-basin, a mean annual runoff is 570.50 million cubic meters and a mean annual evapotranspiration is 851.03 million cubic meters. The water consuming for 448,755 person (in 2011) is 32.76 million cubic meters. Then, there is a water shortage during November to August. The water demand is higher than runoff about 2.73 million cubic meters per month or 313.29 million cubic meters per year.

Lam Phra Phloeng sub-basin, a mean annual runoff is 295.89 million cubic meters and a mean annual evapotranspiration is 560.21 million cubic meters. The water consuming for 162,132 person (in 2011) is 11.84 million cubic meters. Then, there is a water shortage during November to August. The water demand is higher than runoff about 23.01 million cubic meters per month or 276.16 million cubic meters per year.

Lam Choengkrai sub-basin, a mean annual runoff is 1234.55 million cubic meters and a mean annual evapotranspiration is 527.16 million cubic meters. The water consuming for 271,617 person (in 2011) is 19.83 million cubic meters. Then, there is an excess water during March to October. The water demand is lower than runoff about 48.58 million cubic meters per month or 582.96 million cubic meters per year.

Upper part of Lam Nam Mun sub-basin, a mean annual runoff is 1339.30 million cubic meters and a mean annual evapotranspiration is 707.48 million cubic meters. The water consuming for 304,315 persons (in 2011) is 22.21 million cubic meters. Then, there is an excess water during May to December. The water demand is lower than

Table 2. The calibration and validation parameters for sensitivity analysis.

Parameter	Value
GWQMN :Threshold depth of water in the shallow aquifer required for return flow to occur	300
REVAPMN :Threshold depth of water in the shallow aquifer for "revap "to occur	60
GW_REVAP :Groundwater "revap "coefficient	0.10
CN2 :SCS runoff curve number for moisture condition 2	35-98
SOL_AWC :Available water capacity of the soil layer	0.03-0.11
ESCO :Soil evaporation compensation factor	0.70

Table 3. The calibration and validation of mean monthly runoff.

	Mean monthly Runoff (m^3/s)	Difference (%)	R^2	NSE
<u>**Calibration**</u>				
Runoff Station M89.	4.21	11.38	0.85	0.62
SWAT Model	3.78			
<u>**Validation**</u>				
Runoff Station M89.	2.91	5.84	0.95	0.73
SWAT Model	3.08			

Table 4. The HRUs for nine basins.

Sub-basin	HRUs
Lam Takhlong	HRU #- 41 #44, HRU #- 45 #59, HRU #83- #109
Lam Phra Phloeng	HRU #65- #82, HRU #- 115 #138
Lam Choengkrai	HRU #- 25 #30
Upper part of Lam Nam Mun	HRU #- 16 #20, HRU #- 21 #24, HRU #- 60 #64, HRU #- 139 #162
Lam Sae	HRU #- 110 #114, HRU #- 163 #183
Lam Chakkarat	HRU #- 31 #35, HRU #- 36 #40
Lam Sa Thaet	HRU #- 1#3
Lam Plai Mat	HRU #- 10 #15, HRU #- 184 #211, HRU #- 212 #232
Second part of Lam Nam Mun	HRU #4- #9

runoff about 50.80 million cubic meters per month or 609.60 million cubic meters per year.

Lam Sae sub-basin, a mean annual runoff is 158.83 million cubic meters and a mean annual evapotranspiration is 357.45 million cubic meters. The water consuming for 56,723 person (in 2011) is 4.14 million cubic meters. Then, there is a water shortage during January to December. The water demand is higher than runoff about 16.90 million cubic meters per month or 202.76 million cubic meters per year.

Lam Chakkarat sub-basin, a mean annual runoff is 256.44 million cubic meters and a mean annual evapotranspiration is 268.85 million cubic meters. The water consuming for 158,806 person (in 2011) is 11.59 million cubic meters. Then, there is a water shortage during November to July. The water demand is only higher than runoff about 2.00 million cubic meters per month or 24.00 million cubic meters per year.

Table 5 The monthly water balance in nine sub-basins

Unit :million m^3

Sub-basin		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Lam Takhlong	Runoff	1.6	3.7	14.1	45.4	86.4	52.9	42.1	55.2	134.9	111.0	21.5	1.8	570.5
	ET	30.5	32.0	58.7	87.7	106.7	89.5	87.9	94.8	79.9	83.1	63.3	36.9	851.0
	WC	2.8	2.5	2.8	2.7	2.8	2.7	2.8	2.8	2.7	2.8	2.7	2.8	32.8
	WB	-31.7	-30.8	-47.4	-45.0	-23.1	-39.3	-48.6	-42.4	52.3	25.0	-44.5	-37.8	-313.3
Lam Phra Phloeng	Runoff	0.4	2.1	5.3	18.4	40.3	23.0	27.4	35.3	77.5	60.2	5.7	0.3	295.9
	ET	24.3	24.9	34.8	53.8	66.9	58.2	62.3	61.1	53.1	55.7	41.5	23.5	560.2
	WC	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	11.8
	WB	-24.9	-23.7	-30.5	-36.4	-27.6	-36.1	-36.0	-26.8	23.4	3.4	-36.7	-24.2	-276.2
Lam Choengkrai	Runoff	3.5	13.5	45.6	105.9	193.9	108.3	117.0	127.3	251.4	217.6	45.1	5.3	1234.5
	ET	19.3	18.6	40.9	63.3	79.3	57.3	62.9	69.6	66.1	74.1	51.4	29.0	631.8
	WC	1.7	1.5	1.7	1.6	1.7	1.6	1.7	1.7	1.6	1.7	1.6	1.7	19.8
	WB	-17.5	-6.6	3.1	41.0	112.9	49.4	52.4	56.0	183.7	141.8	-7.9	-25.4	583.0
Upper part of Lam Nam Mun	Runoff	16.1	12.6	28.9	62.4	152.4	143.6	148.0	174.2	242.3	224.9	96.0	37.9	1339.3
	ET	23.3	24.5	45.8	69.6	91.6	68.0	73.1	78.0	73.5	76.5	53.3	30.2	707.5
	WC	1.9	1.7	1.9	1.8	1.9	1.8	1.9	1.9	1.8	1.9	1.8	1.9	22.2
	WB	-9.0	-13.7	-18.8	-9.1	59.0	73.8	73.0	94.4	166.9	146.5	40.9	5.8	609.6
Lam Sae	Runoff	0.1	2.0	3.2	6.6	18.0	25.4	24.7	21.7	32.1	22.4	2.6	0.1	158.8
	ET	16.2	18.5	23.5	29.7	39.3	39.1	40.9	41.0	35.5	34.6	24.3	14.8	357.4
	WC	0.4	0.3	0.4	0.3	0.4	0.3	0.4	0.4	0.3	0.4	0.3	0.4	4.1
	WB	-16.5	-16.9	-20.7	-23.4	-21.7	-14.1	-16.6	-19.7	-3.7	-12.5	-22.0	-15.1	-202.8
Lam Chakkarat	Runoff	0.4	2.6	4.0	13.5	34.5	30.1	32.2	40.9	56.5	34.6	6.9	0.2	256.4
	ET	7.2	7.9	16.5	27.6	35.1	28.6	31.6	31.2	27.9	26.9	18.2	10.1	268.8
	WC	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	11.6
	WB	-7.8	-6.2	-13.5	-15.1	-1.6	0.6	-0.4	8.8	27.7	6.6	-12.2	-10.9	-24.0
Lam Sa Thaet	Runoff	5.4	23.2	58.9	93.7	178.6	215.0	196.9	231.9	327.9	211.1	68.8	8.7	1620.2
	ET	6.3	5.1	13.7	26.6	39.1	25.8	34.2	41.4	43.6	41.1	24.7	12.0	313.7
	WC	1.7	1.5	1.7	1.6	1.7	1.6	1.7	1.7	1.6	1.7	1.6	1.7	20.0
	WB	-2.5	16.5	43.6	65.5	137.8	187.6	161.0	188.8	282.6	168.4	42.4	-5.0	1286.6
Lam Plai Mat	Runoff	1.3	5.6	8.8	18.4	45.6	51.2	51.6	59.8	82.1	58.5	9.9	0.8	393.6
	ET	13.0	15.3	24.8	39.9	55.3	48.1	50.0	49.5	44.5	41.3	27.0	14.4	423.0
	WC	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	9.4
	WB	-12.5	-10.4	-16.8	-22.3	-10.5	2.3	0.8	9.5	36.9	16.4	-17.9	-14.4	-38.8
Second part of Lam Nam Mun	Runoff	1.1	2.2	11.7	27.0	47.8	55.3	56.2	72.0	87.9	66.3	18.9	3.0	449.2
	ET	2.5	2.3	5.9	11.6	17.3	13.1	14.3	15.3	15.1	13.6	7.4	4.0	122.2
	WC	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	5.1
	WB	-1.8	-0.5	5.4	15.0	30.0	41.8	41.4	56.3	72.4	52.3	11.1	-1.4	321.9

Lam Sa Thaet sub-basin, a mean annual runoff is 1620.33 million cubic meters and a mean annual evapotranspiration is 313.66 million cubic meters. The water consuming for 273,999 persons (in 2011) is 20.00 million cubic meters. Then, there is an excess water during February to November. The water demand is lower than runoff about 107.21 million cubic meters per month or 1286.56 million cubic meters per year.

Table 6. The comparison of maximum storage, water demand and runoff.

Million m^3 per year

Sub-basins	Max storage	Water demand > Runoff	Water demand < Runoff
Lam Takhlong	439.11	313.29	-
Lam Phra Phloeng	331.59	276.16	-
Lam Choengkrai	190.71	-	582.96
Upper part of Lam Nam Mun	357.10	-	609.60
Lam Sae	336.87	202.76	-
Lam Chakkarat	34.18	24.00	-
Lam Sa Thaet	84.22	-	1,286.56
Lam Plai Mat	166.15	38.78	-
Second part of Lam Nam Mun	216.45	-	321.94

Lam Plai Mat sub-basin, a mean annual runoff is 393.59 million cubic meters and a mean annual evapotranspiration is 423.01 million cubic meters. The water consuming for 128,279 persons (in 2011) is 9.36 million cubic meters. Then, there is a water shortage during November to May. The water demand is only higher than runoff about 3.23 million cubic meters per month or 38.78 million cubic meters per year.

Second part of Lam Nam Mun sub-basin, a mean annual runoff is 449.21 million cubic meters and a mean annual evapotranspiration is 122.22 million cubic meters. The water consuming for 69,191 persons (in 2011) is 5.05 million cubic meters. Then, there is an excess water during March to November. The water demand is lower than runoff about 26.83 million cubic meters per month or 321.94 million cubic meters per year.

4. Discussion

As the result of water balance in nine sub-basins, it can be divided to two scenarios that are (1) water demand higher than runoff and (2) water demand lower than runoff. There are five sub-basins where occurs shortage water and there are four sub-basins where happen excess water shown Table 6.

In the case of water demand higher than runoff, the maximum water storages of all five sub-basin are more than the shortage water so it is important to manage water in the reservoirs to support the water demand for a year. At the end of rainy season, the maximum water storage should be concerned to support water demand in the dry season.

For Lam Choengkrai sub-basin, Upper part of Lam Nam Mun sub-basin, Lam Sa Thaet sub-basin, and Second part of Lam Nam Mun sub-basin, the water demand is lower than runoff. There is the outflow (392.25 million cubic meters) from Lam Choengkrai sub-basin to the Upper part of Lam Nam Mun where is the urban area of Nakhon Ratchasima and there is the outflow about 252.50 million cubic meters from Upper part of Lam Nam Mun sub-basin to the Second part of Lam Nam Mun. It is important to be considered for flooding. The new reservoirs should be developed to reserve this outflow and to protect flooding.

In addition, there are the out flow from Lam Sa Thaet sub-basin (1202.34 million cubic meters) and from Second part of Lam Nam Mun sub-basin (216.45 million cubic meters) to Burirum province.

5. Conclusions

As water balance analysis, the overall of runoff in Nakhon Ratchasima is higher than water demand and this water demand can be supported by the storage of reservoirs during dry season. However, it is important to manage water resources in each sub-basin because of the excess water and shortage water.

For the Lam Takhlong sub-basin, Lam Phra Phloeng sub-basin, Lam Sae sub-basin and Lam Chakkarat sub-basin, the reservoirs should be concerned for maximum capacity to support the water shortage during dry season. Also, crop type in agricultural area should relative with the water storage so the good cooperation between the staffs of Royal Irrigation Department and the famer is so importance.

Moreover, the excess water from Lam Choengkrai sub-basin should be diverted to Lam Takhlong sub-basin and water diversion from Upper part of Lam Nam Mun sub-basin should be considered for Lam Phra Phloeng sub-basin and Lam Sae sub-basin. The new reservoirs in the Lam Sa Thaet sub-basin and Second part of Lam Nam Mun sub-basin should be developed to storage excess water and to protect flooding.

The dredging canals and the channel networks in sub-basin and between sub-basins are significance to plan for effectively water management in Nakhon Ratchasima. The hydraulic structures should be also operated to the efficient water management.

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References

Abbaspour, K.C., Yang, J., Maximov, I., Siber, R., Bogner, K., Mieleitner, J., Zobrist, J. and Srinivasan R., 2007. Modelling hydrology and water quality in the pre-alpine/alpine Thur watershed using SWAT, Journal of Hydrology, **333**: 413–430.

Allen, R.G., 1986. A Penman for all season .Journal of Irrigation and Drainage Engineering,112 (4): 348-368.

Allen, R .G., Jensen, M .E., Wright, J .L .and Burman, R . D., 1989. Operational estimates of reference evapotranspiration .Agronomy Journal, **81**: 650–662.

Arnold, J .G .and Allen, P .M., 1996. Estimating hydrologic budgets for three Illinois watersheds .Journal of Hydrology, **176**: 57–77.

Arnold, J .G., Srinivasan, R., Muttiah, R .S . and Williams, J .R., 1998. Large area hydrologic modeling and assessment Part I Model development .Journal of the American Water Resources Association **34**: 73–89.

Arnold, J .G., Muttiah, R .S., Srinivasan, R .and Allen, P . M., 2000 .Regional estimation of base floe and groundwater recharge in the upper Mississippi basin . Journal of Hydrology, **227**: 21–40 .

Benham, B .L., Baffaut, C., Zeckoski, R .W., Mankin, K .R., Pachepsky Y .A., Sadeghi A .M., Brannan K .M., Soupir M .L., and Habersack. M .J., 2006. Modeling Bacteria fate and transport in watershed model to support TMDLs .Transactions of the ASAE, **49**: 987–1002.

Cerucci, M .and Conrad, J .M., 2003. The use of binary optimization and hydrologic models to form riparian buffers .Journal of the American Water Resources Association, **39**: 1167–1180.

Chaplot, V., Saleh, A., Jaynes, D .B., and Arnold, J., 2004. Predicting water, sediment, and NO_3-N loads under scenarios of land-use and management practices in a flat watershed .Water Air Soil Pollution, **154**: 271–293.

Chu, T .W .and Shirmohammadi, A., 2004. Evaluation of the SWAT model's hydrology component in the Piedmont physiographic region of Maryland . Transactions of the ASAE, **47**: 1057–1073.

Gitau, M .W., Veith, T .L .and Gburek, W .J., 2004. Farm-level optimization of BMP placement for cost-effective pollution reduction .Transactions of the ASAE, 47)6(: 1923–1931.

Jha, M., Arnold, J .G., Gassman, P .W., Giorgi, F .and Gu, R., 2006. Climate change sensitivity assessment on upper Mississippi river basin steamflows using SWAT . Journal of the American Water Resources Association, 42 (4): 997–1015.

Kalin, L .and Hantush, M .H., 2006. Hydrologic modeling of an eastern Pennsylvania watershed with NEXRAD and rain gauge data .Journal of Hydrology Engineering, 11: 555–569.

Kosa, P., Teekabunya, P. and Sukwimolseree,. T., 2017. Evaluation of Flood Area in Lam Taklong River Basin with MIKE FLOOD **.**4TH EIT-WRE, January 23-24, 2017, Chonburi, Thailand.

Leonard, R .A., Knisel, W .G .and Still, D .A., 1987. Groundwater loading effects on agricultural management systems .Transactions of the ASAE, 30: 1403–1428.

Monteith, J.L., 1965 .Evaporation and the environment .P . 205-234 .The state and movement of water in living organisms, XIXth Symposium Soc .For Ex .Biol., Swansea, Cambridge university Press.

Oki, T .and Musiake, K., 1995. Global atmospheric water balance and runoff from large river basins, Hydrology Process 9; 655–678.

Petchprayoon, P., Blanken, P .D., Ekkawatpanit C .and Hussein K., 2010. Hydrological impacts of land use/land cover change in a large river basin in central-nortnern Thailand .International Journal Climate, 30: 1917–1930.

Schuol, J., Abbaspour, K.C., Srinivasan, R .and Yang, H., 2008. Estimation of freshwater availability in the West African sub-continent using the SWAT hydrologic model, Journal of Hydrology, 352: 30–49.

Soil Conservation Service, 1972. Section 4 :Hydrology . National Engineering Handbook .SCS.

Williams, J .R., Jones, C .A .and Dyke, P .T., 1984. A modeling approach to determining the relationship between erosion and soil productivity .Transactions of the ASAE, 27(1): 129–144.

Williams, J .R., Nicks A .D . and Arnold, J .G., 1985. Simulator for water resources in rural basins .Journal of Hydraulic Engineering, **111**: 970–986.

Yang, H., Yang, D., Lei, Z., and Sun, F., 2008. New analytical derivation of the mean annual water-energy balance equation .Water Resources Research .44: W03410 doi:10.1029/2007WR006135.

Zhang, L., Hickel, K., Dawes, W .R., Chiew, F .H .S., Western A .W., and Briggs P .R., 2004. A rational function approach for estimating mean annual evapotranspiration .Water Resources Research;40, W02502, doi:10.1029/2003WR002710.

Symbols and abbreviations

S_f	Final soil water content (mm H_2O)
S_i	Initial soil water content (mm H_2O)
t	Time (days)
P	Precipitation on day i (mm H_2O)
Q_s	Surface runoff on day i (mm H_2O)
ET	Evapotranspiration on day i (mm H_2O)
w	Water entering the vadose zone from the soil profile on day i (mm H_2O),
Q_g	Return flow on day i (mm H_2O)
Q_s	Accumulated runoff or rainfall excess (mm H_2O)
P	Rainfall depth for the day (mm H_2O)
I_a	Initial abstractions which is included surface storage, interception and infiltration prior to runoff (mm H_2O)
S	Retention parameter (mm H_2O)
λE	Latent heat flux density (MJ/m^2/d)
E	Depth rate evaporation (mm/d)
Δ	Slope of the saturation vapor pressure-temperature curve, (MJ/m^2/d)
de/dT	kPa/ C
H_{net}	Net radiation (MJ/m^2/d)
G	Heat flux density to the ground)MJ/m^2/d(
ρ_{air}	Air density (kg/m^3)
C_p	Specific heat at constant pressure (MJ/kg/ C)
e_z^o	Saturation vapour pressure of air at height z (kPa)
e_z	Water vapor pressure of air at height z (kPa)
γ	Psychrometric constant (kPa/ C)
r_c	Plant canopy resistance (s/m)
r_a	Diffusion resistance of the air lay aerodynamic resistance (s/m)