Uncertainty in Runoff Estimation for a Catchment of the Tha Chin River's Upper Plain in Chai Nat Province, Thailand

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***Abstract*— Runoff production to the upstream of the Huai Khot Wang Man diversion canal with a catchment of the Huai Khun Kaew watershed in the upper part of the Tha Chin Basin was studied in 2006 – 2013. The soil and water assessment tool (SWAT) and the hydrological modeling system (HMS) using on the Climate Forecast System Reanalysis (CFSR) were applied to the simulation of the daily outflow. The results of both SWAT and HMS fitted to the observed data at the outlet during the calibration in 2010-2012 in the basis of monthly mean outflow according to the Nash and Sutcliffe efficiency (NSE), correlation (R^2), and the root mean square error (RSME) were 0.62 and 0.18, 0.66 and 0.46, and 14.3 and 18.1 m^3/s, respectively. These models show they are applicable enough for further efficient water management in the downstream area.**

Keywords—streamflow estimation; PUB; SWAT; HMS; CSFR

I. Introduction

The small to the medium watershed is usually a lack of hydrological data collection, which may consider as the Prediction in Ungauged Basin (PUB) [1]. The way of obtaining the quantity of surface flow by some modeling has been widely used such as the Hydrologic Modeling System (HMS) [2]. It is the rainfall-runoff model that user can apply with any transform method, loss rate, and base-flow methods in the component of the basin model manager. HMS components include meteorological, control specifications, time-series-paired or grid data manager, that can compute surface runoff, return flow, reservoir, diversion, source & sink, flow, reach routing, and etc. The production from HMS is the hydrograph for specific sub-basin and reach, that can be directly inputted to the worldwide 1 or 2-dimensional hydrodynamic model of the River Analysis System (RAS) [3]. The Soil and Water Assessment Tool (SWAT) [4], is a physical base or river basin scale model developed to quantify the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long periods of time. SWAT components include weather, surface runoff, return flow, percolation, evapotranspiration, losses, pond, crop growth and irrigation, groundwater flow, reach routing, and etc. Both HMS and SWAT production are the hydrograph for every sub-basin and in the river reaches as surface runoff model. RAS is designed to perform one and two-dimensional hydraulic calculations for a full network of natural and constructed channels with the graphical user interface (GUI). The system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed. Recently, the Japanese distributed hydrological model such as the Integrated Flood Analysis System (IFAS) developed by PWRI [5], which can be applied to the larger watershed. However, IFAS has taken long simulation time than others in comparing the result of the watershed.

Inefficient water resource management for the challenging of the flood and drought problems in the small to a medium watershed in Thailand was reported. The managing of the diversion channel seemed to be difficulty operated because of uncertainty streamflow runoff caused by the fluctuation of upstream runoff with none of any properly water storage systems as poor water management [6, 7]. The challenging of surface water problems in Nong Mamong district, Chai Nat province, Thailand had proposed to study. It included a diversion channel: Huai Khot – Wang Man canal to convey part of a flood from upstream and store in the proposed retention ponds [8]. Thus, this study aims to analyze the daily streamflow discharge produced from the upstream watershed of the Huai Khot - Wang Man diversion channel in the Nong

Mamong district using both HMS and SWAT as the comparative testing of the sensitivity from both models while compared to the observed data at an outlet of the basin.

II. Material and Method

A. Study Area

The study area: Huai Khun Kaew watershed locates in the upper part of the Tha Chin Basin, that situates between the southern part of the Sakae Krang river basin and the upper plain of the Tha Chin river basin in Uthai Thani and Chai Nat provinces, Thailand. The Huai Khun Kaew is a major stream and flows directly from west to east of the study area. The Huai Khot is the largest tributary stream with sub-watershed meets the lower plain of the Huai Khun Kaew stream. The overall drainage area watershed is approx.1,066 km^2 measured at the hydrological observation station at C.51 from the Royal Irrigation Department (RID). An existing diversion channel: Huai Khot - Wang Man conveys the water flow from the Huai Khot sub-basin in Ban Rain district, Uthai Thani province to Nong Mamong district in Chai Nat province. with the flow rate of 10 m^3/s [9]. The study area showed in Fig. 1.

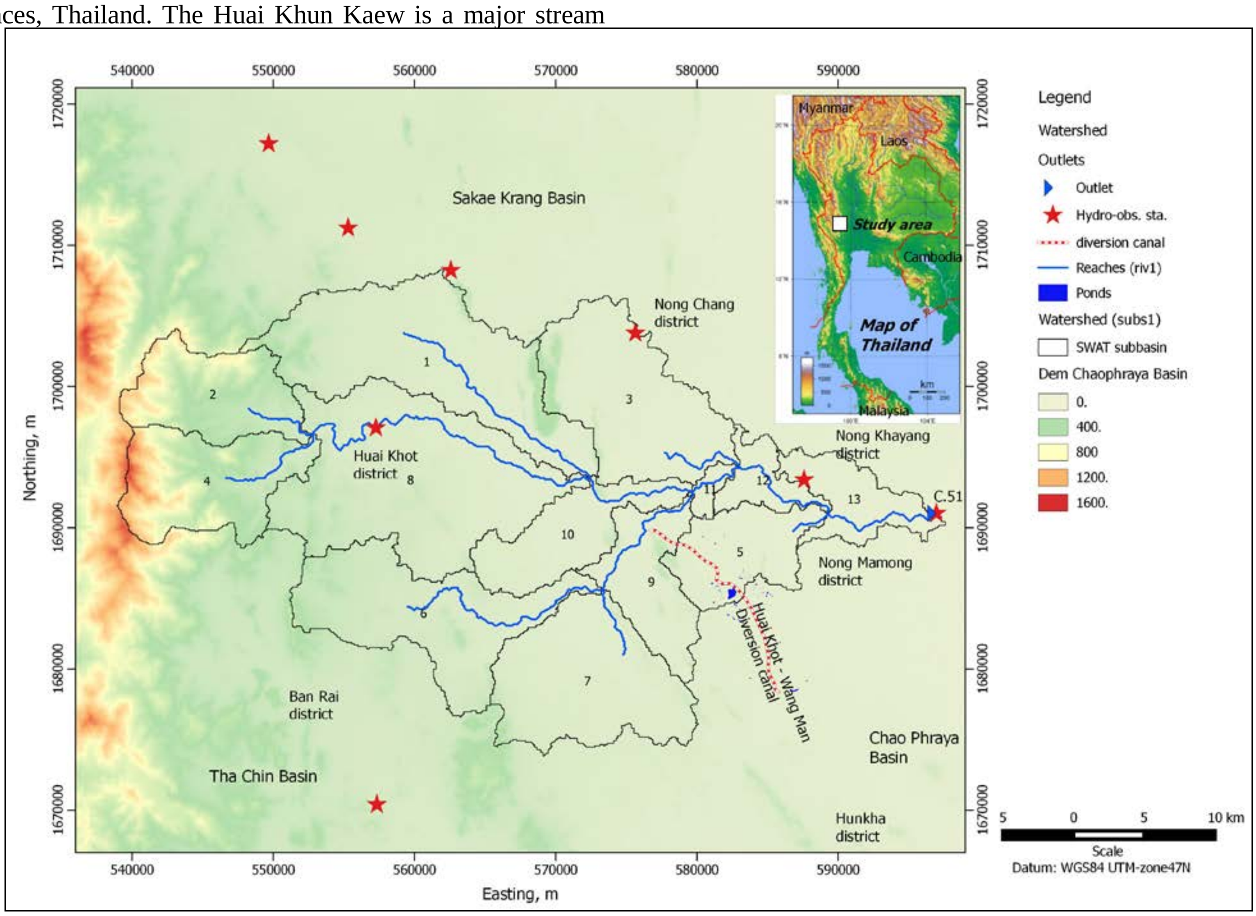

Fig. 1. Location of the study area located in the upper plain of the Tha Chin's river: Huai Khun Kaew watershed and its 13 sub-basins, stream networks, outlet, observed station, altitude (DEM 30m), and the Huai Khot – Wang Man diversion canal in Nong Mamong district, Chai Nat province

B. Models Application

The current study applied the SWAT as for the hydrological study and water balance using global soils map, land-use maps, and the Climate Forecast System Reanalysis (CFSR) from global weather data. In this study, SWAT was modeled using an open source geographic information system platform calling the Quantum GIS (QGIS) interface as QSWAT [10]. The comparative study applied HMS as for the calculation daily river outflow from each sub-basin using CSFR.

The first model applied by using SRTM-DEM [11] in the QSWAT as for the watershed delineation. There were 13 sub-basins included stream networks, and topographic slope, as well as the global land uses and soils maps via SWAT editor [12]. The full hydrological response unit (HRU) contained 6 land-use groups i.e. paddy field and upland crops (CRIR), other uplands (CRWO), mixed forest (FODB), forest (FOEB), grassland (SAVA), shrub tree (SHRB). Each HRUs contained soil, land-use, curve number (CN), soil-loss, and etc. These data resulted in sub-basin parameters that should be calibrated in order to ensure that the simulated result from the model fit to the observed data. These data were applied to HRUs in each sub-basin showed in Fig. 2.

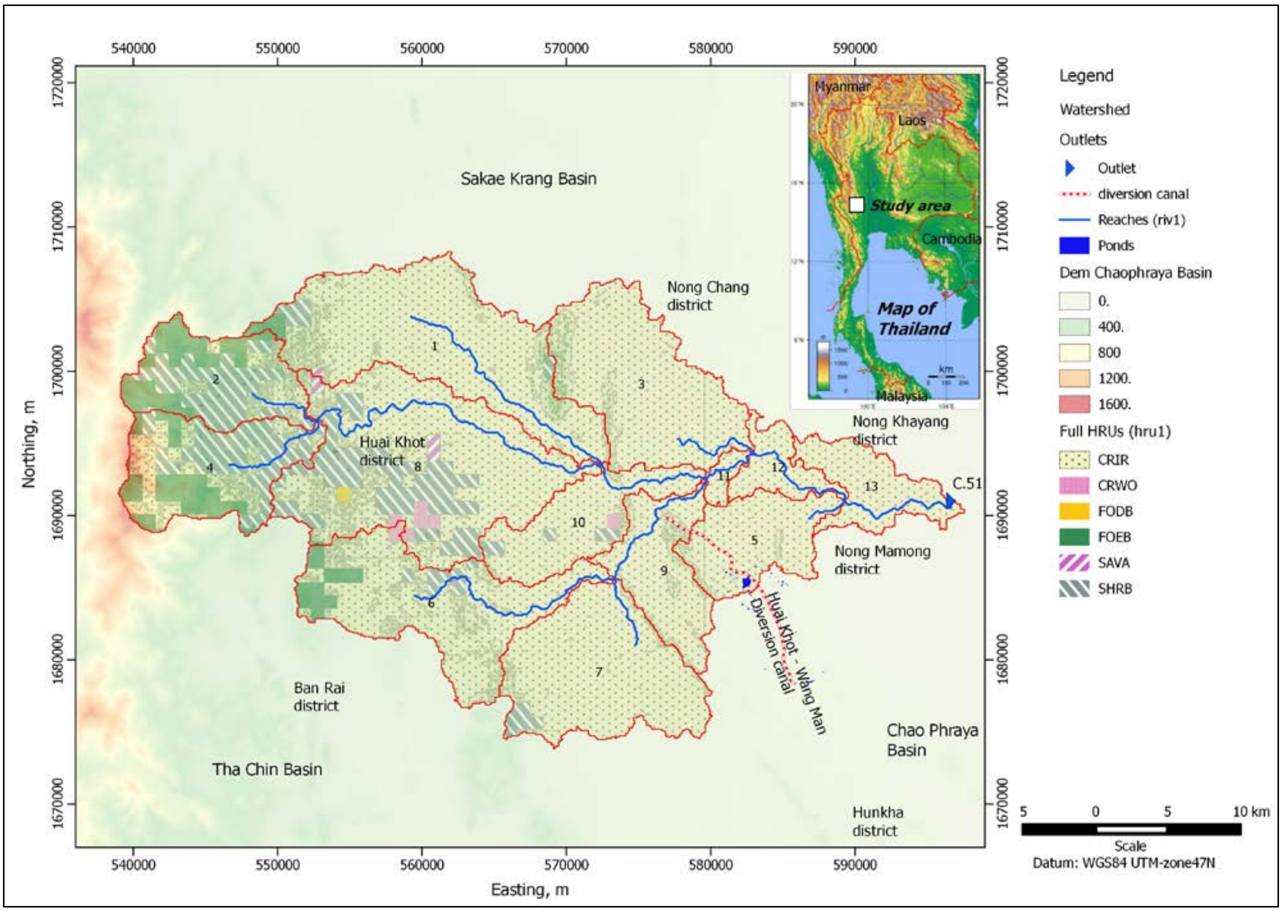

Fig. 2. The full 6- HRUs grouping resulted by using the global land use classes and soil types overlaying on the existing topographic map

The HMS modeled by overlaying with existing streamflow layouts layer. It included 6 sub-basins with each area of 408, 82, 282, 58, 112, and 123 km^2, respectively. In addition, the stream reaches and junctions were modeled as shown in Fig. 3. The basin parameters based on given the initial loss, constant loss late, and transformation by the Clark unit hydrograph.

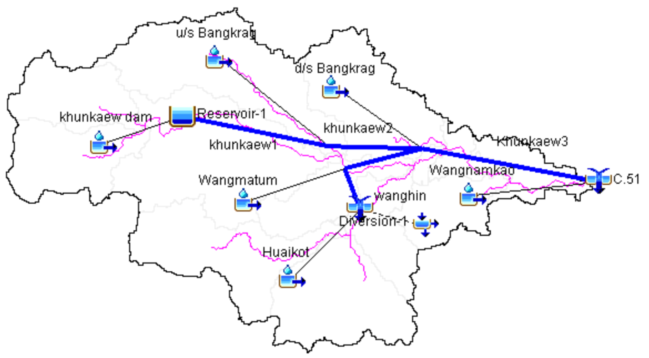

Fig. 3. The location of sub-basins, stream reaches, junctions, and outflow of was modeled for the Huai Khun Kaew based on the HMS.

C. Rainfall Data

The CSFR data had proved that it could be reliably applied to watershed modeling across a variety of hydro-climate regimes and watersheds with a good stream flow predictions particular for PUB [12]. CSFR data with 6 grid points in the basin were applied to both models and using the interpolation method as aerial rainfall based on Thiessen polygon and fitted to the observed data in 2007 – 2013 [11].

D. Model Sensitivity

The Nash and Sutcliffe efficiency (NSE) model [12], and the root mean square error (RSME) were used to test the model sensitivity while compared to the observed data particular with daily river flow discharge. NSE is computed as follows:

$$\mathrm{NSE} = 1 - \left[\frac{\sum_{i=1}^{n} (Y_i^{obs} - Y_i^{sim})^2}{\sum_{i=1}^{n} (Y_i^{obs} - Y^{mean})^2} \right] \tag{1}$$

where Y_i^{obs} is the i^{th} observation for the constituent being evaluated, Y_i^{sim} is the i^{th} simulated value of the constituent being evaluated, Y^{mean} is the mean of observed data for the constituent being evaluated, and n is the total number of observations. NSE ranges between $-\infty$ and 1.0 (1 inclusive), with NSE = 1 being the optimal value. Values between 0.0 and 1.0 are generally viewed as acceptable levels of performance, whereas values <0.0 indicates that the mean observed value is a better predictor than the simulated values, which indicates unacceptable performance.

The root mean square error (RSME) is computed as follows:

$$RSME = \sqrt{\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}{n}} \qquad (2)$$

RSME incorporates the benefits of error between simulated result and observed data.

The simulated production of daily and monthly streamflow in each reach was compared to the observed data based on the correlation (R^2).

III. RESULTS

The results of both HMS and SWAT models based on daily outflow discharge in 2010-2012 were plotted to the observation data at C.51 and CSFR from global rainfall as shown in Fig. 4.

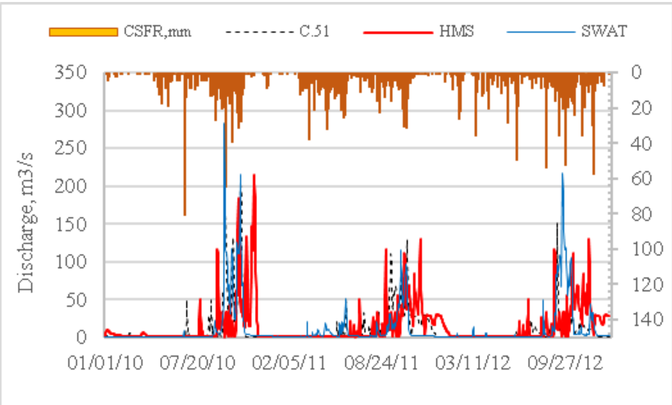

Fig. 4. Comparison of daily simulated and observed flow for SWAT and HMS outlet at C.51 during the model calibration in 2010-2012

The above results from SWAT showed that it incorporated to the calibrated parameters with the most effect by the average basin curve number (CN) of 61.6 and correlation fitted to the observation data with R^2 of 0.51, NSE of 0.42, and RSME of 22.68 m^3/s. However, the results from HMS was fair with R^2 of 0.09, NSE of -0.58, and RSME of 31.07 m^3/s, respectively. Instead of using daily calibration, the monthly basis of both simulated and observed from both models was applied to this study and the result from both HMS and SWAT outflow hydrographs were compared to the observed data at C.51 and CSFR global rainfall as shown in Fig. 5.

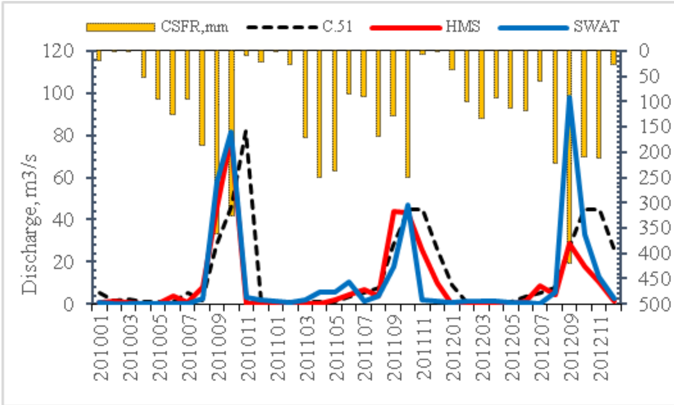

Fig. 5. Comparison of monthly simulated and observed flow for SWAT and HMS outlet at C.51 during the model calibration in 2010-2012

The results of both SWAT and HMS fitted to the observation data with NSE of 0.62 and 0.18, R^2 of 0.66 and 0.46, RSME 14.28 and 18.13 m^3/s, respectively. Those calibration results were good enough for the model validation. Table 1 showed the model sensitivity during the calibration in 2010-2012 of both SWAT and HMS models.

TABLE I. COMPARATIVE OF MODEL SENSITIVITY DURING THE CALIBRATION OF BOTH HMS AND SWAT IN 2010-2012

No.	Monthly calibration in 2010-2012		
	Model sensitivity	***HMS***	***SWAT***
1	RMSE (m^3/s)	18.13	14.28
2	NSE	0.18	0.62
3	R^2	0.46	0.66

Table 2, Fig. 6, and Fig. 7 showed model sensitivity during the verification in 2013 of both SWAT and HMS models. The results also fitted to the observation data with NSE of 0.71 and 0.46, R^2 of 0.76 and 0.58, RSME 9.73 and 13.25 m^3/s, respectively.

TABLE II. COMPARISON OF MODEL SENSITIVITY DURING THE VALIDATION STAGES BETWEEN HMS AND SWAT IN 2013

No.	Monthly validation in 2013		
	Model sensitivity	***HMS***	***SWAT***
1	RMSE (m^3/s)	13.25	9.73
2	NSE	0.46	0.71
3	R^2	0.58	0.76

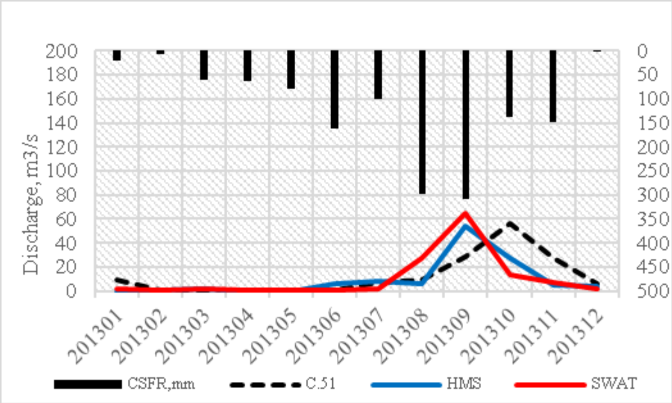

Fig. 6. Comparison of monthly simulated and observed flow for SWAT and HMS outlet at C.51 during the model validation in 2013

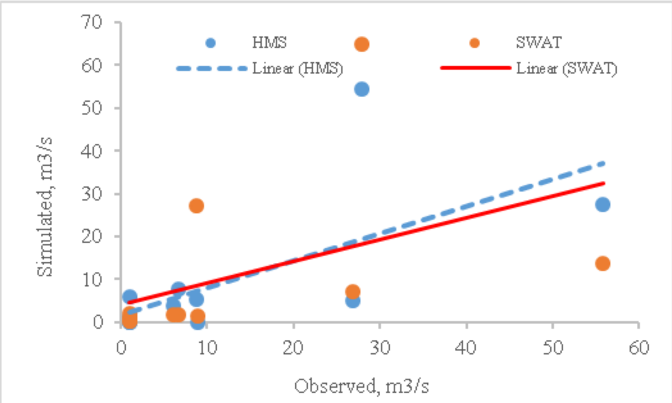

Fig. 7. Correlation of monthly simulation discharge and observation at C.51during the model verification from both SWAT and HMS in 2013

IV. DISCUSSION

The results of runoff production to the outlet of the Huai Khun Kaew watershed using both SWAT and HMS models in 2010 – 2013 showed the difference in model sensitivity of both during calibration and verification in 2010-2012 and 2013, respectively. The SWAT model seems to be very applicable and results are realized to the observed data. However, the complication of the calibration parameters of SWAT is more difficult than HMS with less parameter. The CFSR is the most convenient for applying in both models. The inspection on sensitivity should be carried out and compared to ground-based observation data.

V. CONCLUSION AND RECOMMENDATION

Both models of SWAT and HMS can be applied for an efficient downstream canal management such the Huai Khot - Wang Man diversion canal as well as the managing of the regulated structures by given the amount of inflow discharge to the canal from the model based on existing basin parameters. Recently, much global rainfall models produce the forecasted rainfall for coming 1 or 2 weeks. The amount of streamflow entering the gate can be estimated using either HMS or SWAT.

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