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

by

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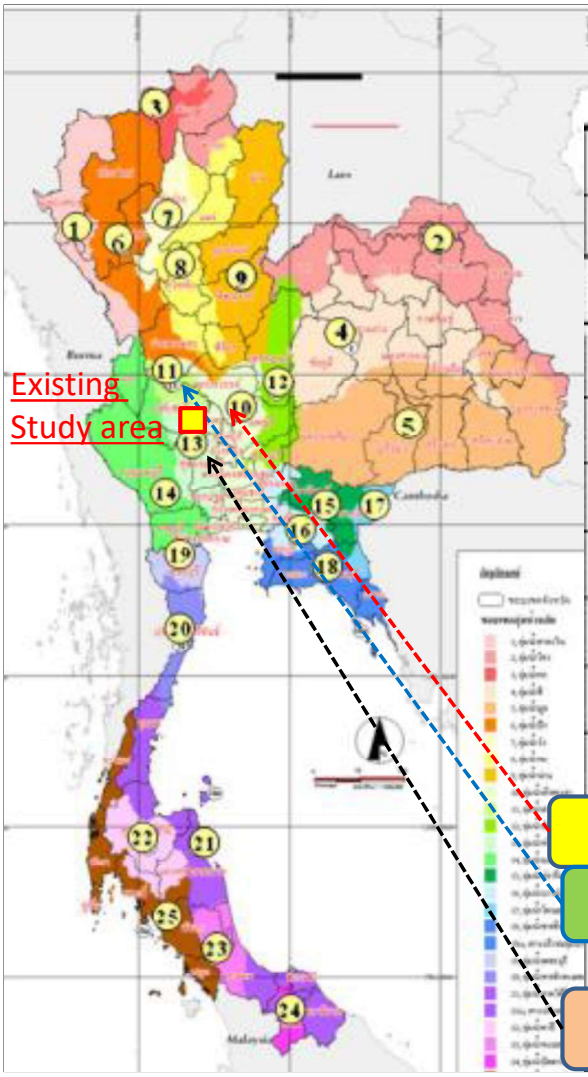
INTRODUCTION

- The small river basin is usually a lack of hydrological data collection from the field and difficulty in flood estimation which can be considered as Prediction in Ungauged Basin (PUB). Accurate estimates of stream runoff and other hydrologic quantities are needed for numerous purposes of water resources planning and management.
- The way of obtaining such estimates by modeling methods such as the Rational Method and the index-flood method have been widely used i.e. the Hydrologic Modeling System (HMS) for the synthesis streamflow hydrograph productions from all catchments over the basin. It corporates to the River Analysis System (RAS) in order to perform 1-2D water surface profiles along the river reaches.

INTRODUCTION (CON'D)

- Worldwide physical based model: Soil and Water Assessment Tool (SWAT) developed by USDA, is a 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 main components include weather, surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, and water transfer.
- HEC-HMS determines the flow values corresponding to different amounts of rain fallen in a given area. The model divides a watershed into sub-basins. It converts an amount of rain into runoff at the exist of each sub-basin, and routes this runoff along the reaches until the outlet of the watershed.



River Basins Man. in Thailand

25 Main Basins	
1.Salawin	14.Meklong
2.Mekong	15.Prachin
3.Kok	16.Bangpakong
4.Chi	17.Tonle Sap
5.Mun	18.East Coast
6.Ping	19.Phetchaburi
7.Wang	20.West Coast
8.Yom	21.South East Coast
9.Nan	22.Ta Pi
10 Chaophraya	23.Songkhla Lake
11 Sakae Krang	24.Pattani
12.Pasak	25.South West COast
13 Tha Chin	

Background & Objective of the Study

- Challenge drought problem in many sub-basin upstream of Thailand's central plain rice-bowl i.e. in Nong Mamong district, Chai Nat province has been conducted by the construction of a diversion channel: Huai Khot – Wang Man canal in order to take part of flood water from upstream sub-basin to this area during drought.
- However, the managing of the diversion channel seemed to be difficulty operated because of the fluctuation of surface runoff with none of any properly water storage systems in the upstream yet as poor water management.
- Thus, this study aims to analyze daily & monthly discharge from upstream of existing diversion canal using SWAT combine to global soils & land-use maps, and the Climate Forecast System Reanalysis (CFSR) as global weather data via Quantum GIS (QGIS) platform interface as QSWAT and compare to HMS model.

MATERIAL AND METHOD: Study area

- The Huai Khun Kaew watershed locates between the southern part of the Thap Salao (major sub-basin of Sakae Krang) and the northern part of the Tha Chin basins in Uthai Thani and Chai Nat provinces. Huai Khun Kaew is main stream and flows direction to the Tha Chin and Chaophraya rivers. The total drainage area of its watershed is 1,066 km^2 measured at the hydrological observation station at C.51.
- Huai Khot is main tributary sub-basin and stream joining the Huai Khun Kaew river in the lower part upstream of C.51.
- Existing Huai Khot - Wang Man is a diversion canal to convey a flow from Uthai Thani to Chai Nat with the flow rate of 10 m^3/s connected to storage ponds with total capacity of 3 million m^3 in order to use during the drought period.

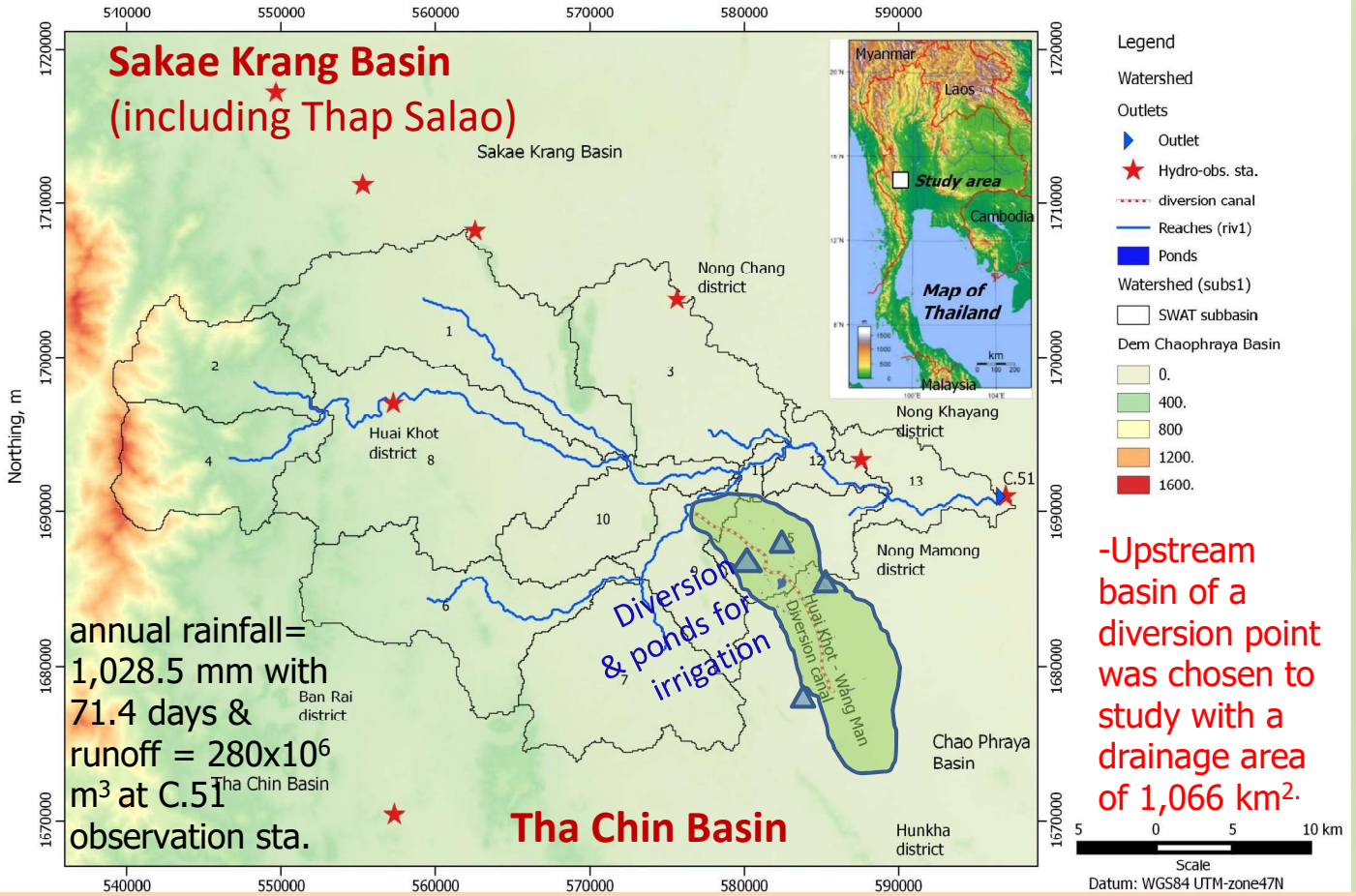


Fig 1. Location of Huai Khun Kaew watershed, sub-basins, stream networks, outlet, RID's observation station (C.51) using QSWAT with SRTM-DEM 30m , and existing diversion canal

Methodology: SWAT Hydrological Model

- Water balance eq:

$$SW_t = SW_o + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - w_{seep} - Q_{qw})_i$$

SW_t, SW_o= final, initial soil water content, R_{day}= daily precipitation, Q_{surf}= surface runoff, E_a=evapotranspiration, W_{seep}= seepage to vadose zone, Q_{gw}=return flow (all unit in mm)

- SWAT + QGIS = QSWAT for the simulation of the hydrological response unit systems and head flow discharge to the outlet and a diversion point & create many map layers. The topography using Digital Elevation Model (DEM) with 30 m resolution from SRTM (USGS's Earth Explorer Web). Land use & soil data, slope were generated to smaller sub-basins as 13-hydrologic response units (HRUs).
- Existing global weather data based on Climate Forecast System Reanalysis (CFSR) were obtained automatically via SWAT editor. CSFR data had proved & applied to many watershed across a variety of hydro-climate regimes and watersheds with a good stream flow predictions.

Method con'd: HMS Hydrologic Modeling Systems

- HMS by HEC determines the flow values corresponding to different amounts of rain fallen in a given area. The model divides a watershed into sub-basins. It converts an amount of rain into runoff at the exist of each sub-basin, and routes this runoff along the reaches until the outlet of the watershed.
- The model supports different methods for calculating infiltration/runoff, transforming this runoff into a flow at the exit of each sub-basin, and routing this flow. The required parameters were obtained from GIS. Watersheds and reaches are attributed with hydrologic parameters and stored in tables.
- The model also requires information related to the precipitation (100 year hypothetical storm) and some to specify the duration of the simulation and also the time interval of the calculations.

Methodology: Model Sensitivity Tests

- Nash and Sutcliffe Efficiency (NSE) model 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 =1.0 being the optimal value.
- =0.0 - 1.0 acceptable levels of performance,
- <0.0 unacceptable performance (mean observed is better predictor than simulated value).

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

Methodology: model test con'd

- Root Mean Square Error (RSME) used for incorporates the benefits of error between simulated result and observed data.

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

- The correlation (R^2) applied to test and compare between the daily simulation of streamflow and observation data at outlet from the basin.
- The output of daily streamflow at the outlet were compared at RID's C.51 observation station.

Results: Hydrologic Response Units from QSWAT

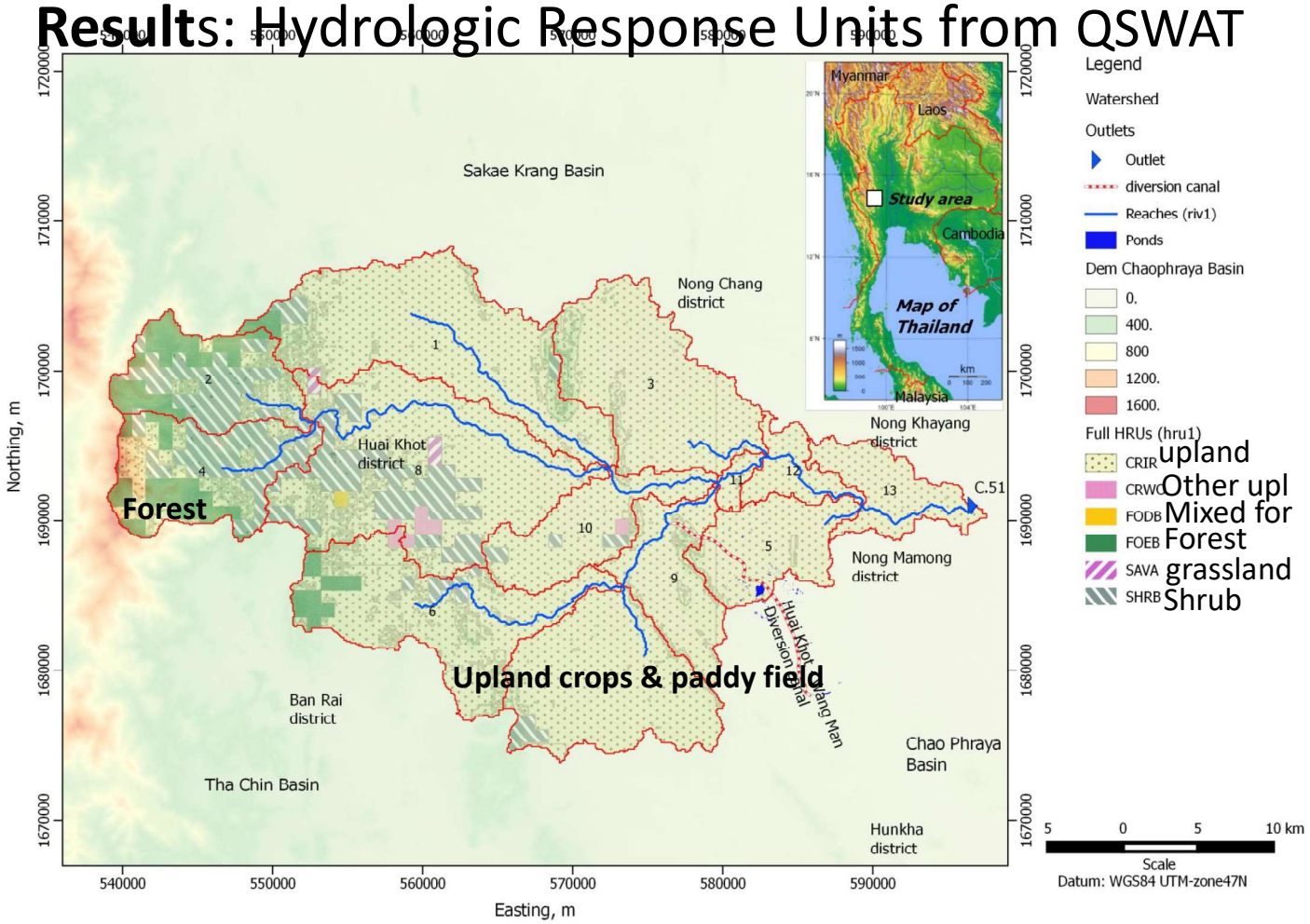
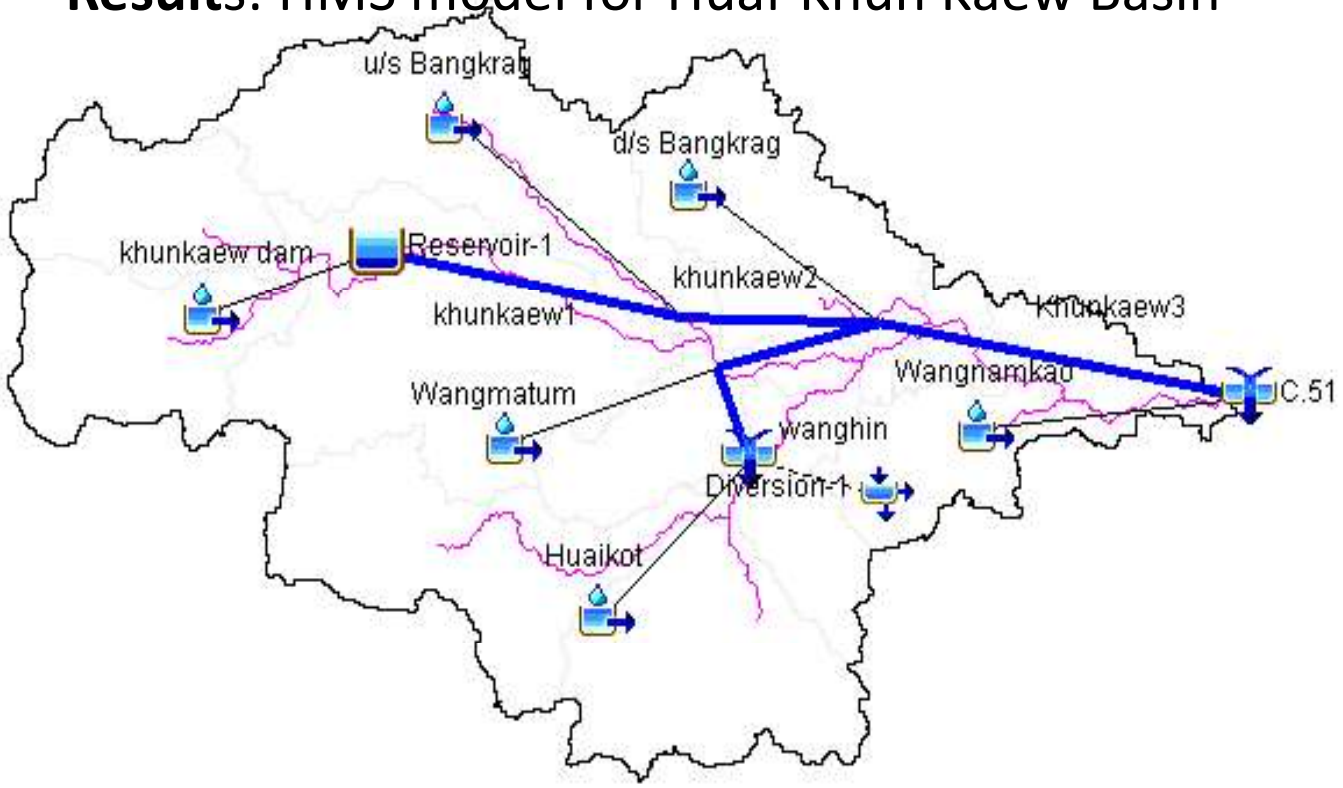


Fig 2. The full HRUs results of global land use types over DEM 30m.

Results: HMS model for Huai-Khun Kaew Basin



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

Average monthly CSFR (6-grids) & ground-based rainfall

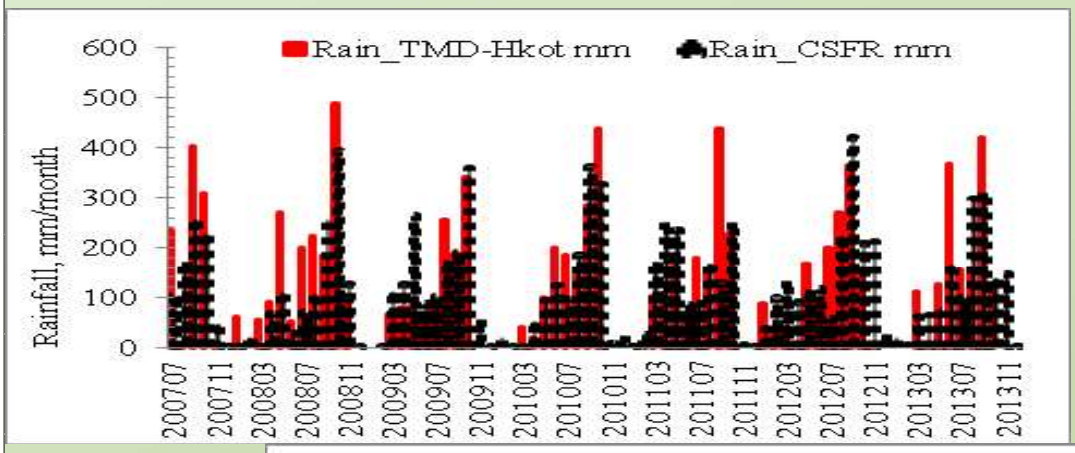


Fig.3. Comparison the mean monthly CFSR fitted to observation rainfall by TMD in 2007 – 2013 with R^2=0.56

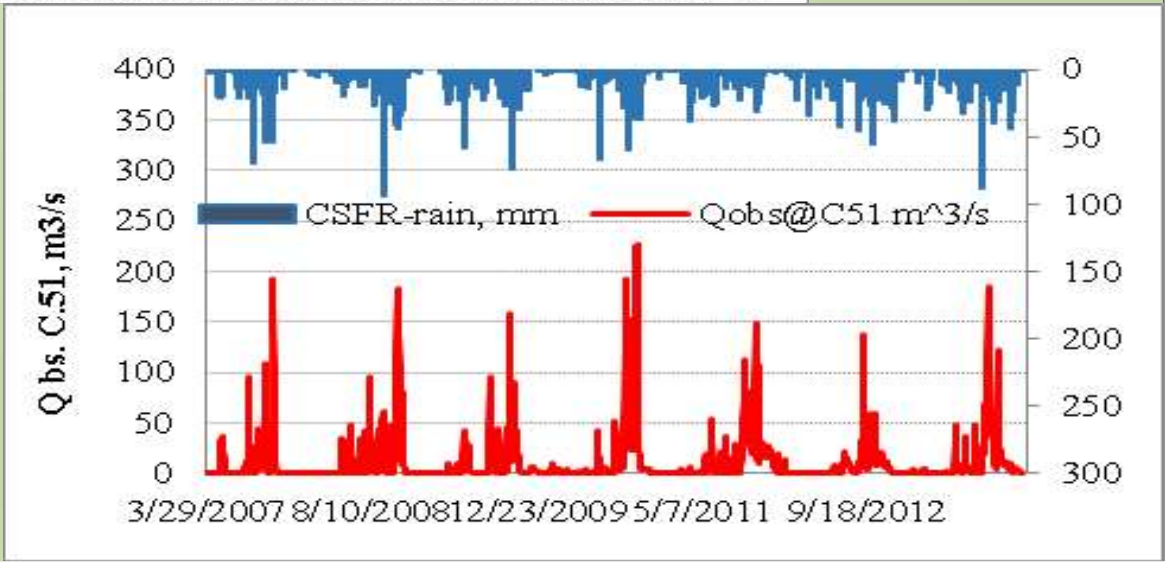
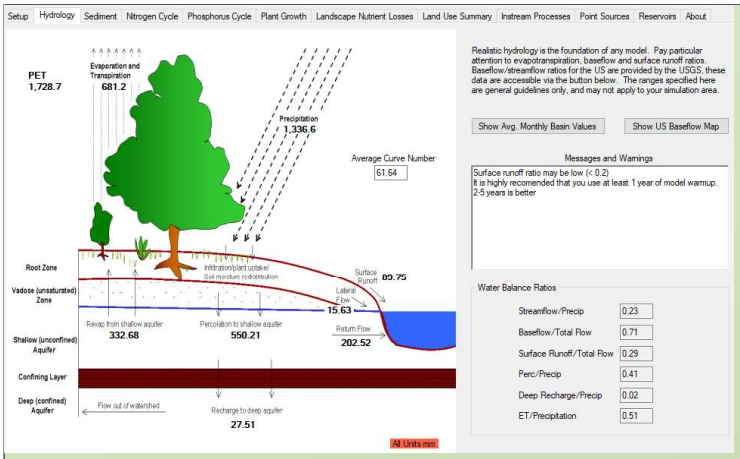


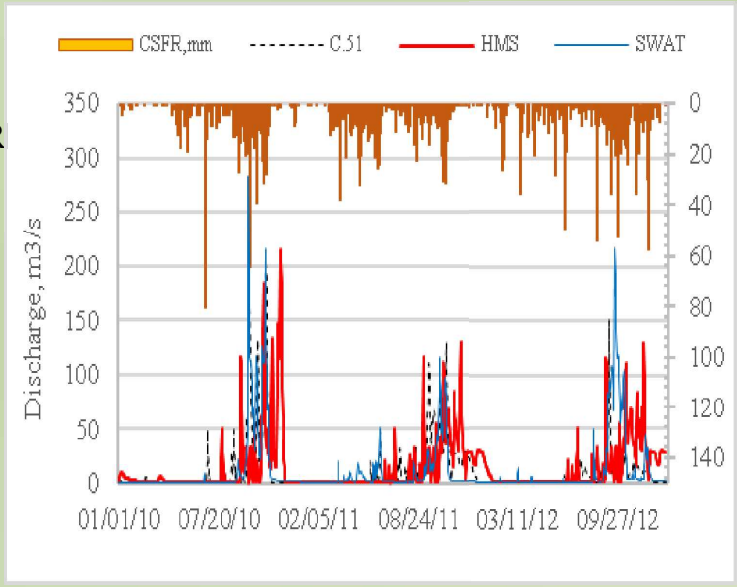
Fig.4. Mean daily of CFSR-rainfall and observation streamflow in 2007 – 2013



The overall results of annual water balance of the Huai Khun Kaew watershed using SWAT-check in 1994 - 2013 incorporated to the calibrated parameters such CN of 61.6 and resulted to rainfall, evapotranspiration, surface runoff, lateral flow, and return flow of 1336.6, 681.2, 89.8, 15.6, and 202.2 mm,

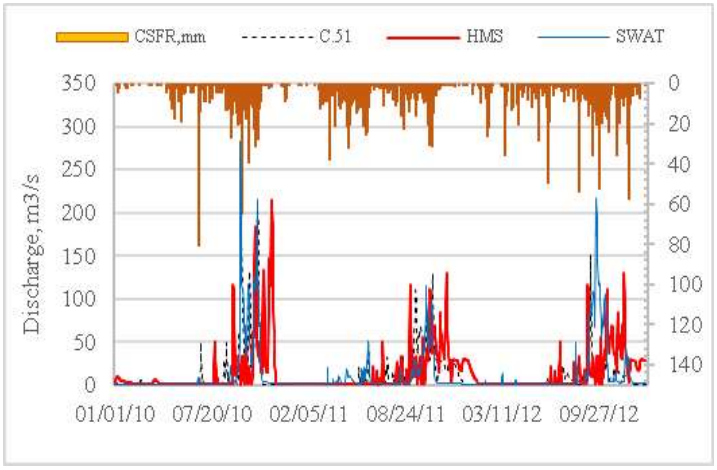
Results both HMS & SWAT models based on daily outflow discharge in 2010-2012 were plotted to the observation data at C.51 & CSFR

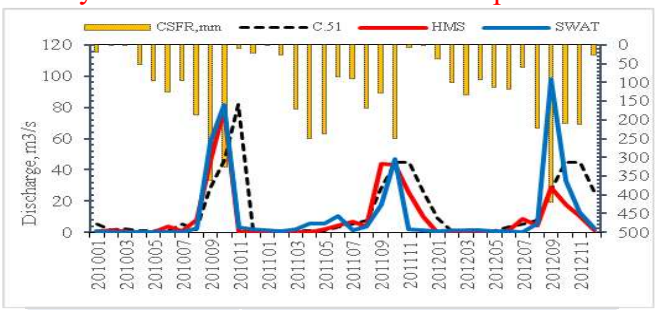
Daily simulation results from SWAT showed incorporated to the calibrated parameters with the most effect by the average basin curve number (CN) = 61.6, correlation fitted to the observed data with R^2 =0.51, NSE = 0.42, RSME = 22.68 m^3/s. However, the results from HMS was fair with R^2 = 0.09, NSE=-0.58, RSME= 31.07 m^3/s, respectively.



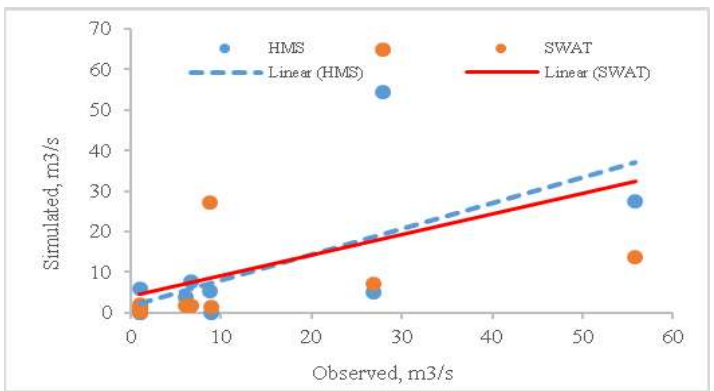
Results con'd [compared Qsim & Qobs]

Monthly basis of HMS & SWAT & compare to C.51.

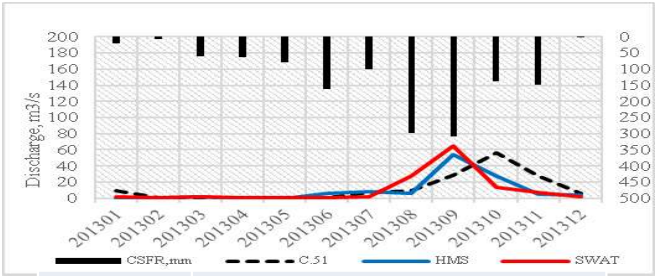




No.	Monthly calibration in 2010-2012		
	Model sensitivity	HMS	SWAT
1	RMSE (m^3/s)	18.13	14.28
2	NSE	0.18	0.62
3	R^2	0.46	0.66



Correlation of monthly simulation discharge and observation at C.51during the model verification of SWAT and HMS 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

CONCLUSION

- The calibration and verification results showed good enough for this watershed and each sub-basin which can be applied to the discharge estimation to the diversion canal.
- The model errors were come from the regulated flow in the watershed, sub-basins, and streams reach via many small-scale irrigation projects and obstruction structures including dams, farm-ponds, weirs, regulators, turn-outs, road-structures, and etc. Those structures did not provide any information on managing data.
- Moreover, the change of land uses and others impact has widely seen in the watershed and effect to the outflow hydrograph i.e. higher base flow, longer time in basin-lag, and etc.
- 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-Sutcliffe efficiency (NSE) =0.62 and 0.18, correlation (R^2) =0.66 and 0.46, and RSME = 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.

RECOMMENDATION

- The results of runoff production to the outlet of the Huai Khun Kaew watershed from both SWAT and HMS during 2010 – 2013 showed the difference in models 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.

Thank you very much for your kind attention !