EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/ea/index.html
EnvironmentAsia 10(2) (2017) 33-42
DOI

# Dynamic Modeling of Water Storage Capacity for the Dilution of Waste Water of Land Utilization in the Upper Tha Chin Watershed, Thailand

Banchongsak Faksomboon [a], Surat Bualert [a], Narouchit Dampin [a] and Nipon Thangtham [b]

[a] *Department of Environmental Science, Faculty of Environment, Kasetsart University, Bangkok, Thailand*
[b] *Forestry Research Center, Faculty of Forestry, Kasetsart University, Bangkok, Thailand*

## Abstract

The objective of this study was to investigate the physical characteristics of watershed, water storage capacity, and dynamic modeling development for generating the water storage capacity necessary to dilute waste water from land utilization in the Upper Tha Chin Watershed (UTCW) within three scenarios: existing land use condition, expected land use change in the year 2020, and regulating water storage to dilute Biochemical Oxygen Demand (BOD). The Soil and Water Assessment Tool (SWAT) model was applied in order to estimate the amount of the streamflow, suspended sediment, soil loss, and BOD based on the observed land use and water release data from the reservoir, from January, 2013 to December, 2014 as presented in Scenario 1. The reliability of the model was calibrated with the observed data by adjusting the coefficient of the key parameters through SWAT calibration uncertainty procedures (SWAT-CUP) and validating the observed data from seven hydrologic stations. The goodness of the calibration results was assessed based on the coefficient of determination ($R^2$), Nash-sutcliffe efficiency coefficient (NSE), and mean squared error (MSE); along with simulating the impact of land utilization in the year 2020, and the drainage simulation of the Krasiao reservoir on BOD. The results obtained from the SWAT model found that the UTCW area was 5,253.96 km$^2$ with a stream length of 1,906 km, 14 sub-watersheds and 286 hydrological response units (HRUs). The application of the SWAT model in Scenario 1 indicated that the streamflow was 374.74 million cubic meter (MCM), suspended sediment was 1,854,720 tons/year, soil loss was 91.35 tons/ha/year, and BOD was 2.70 mg/L. The simulation of Scenario 2, forecasting the expected land use change in year 2020, showed that the amount of the streamflow decreased to 65.09 MCM, suspended sediment increased to 5,065,446 tons/year, soil loss increased to 240.96 tons/ha/year, and BOD was 2.70 mg/L; when compared with Scenario 1. The simulation of Scenario 3, regulating water storage for diluting waste water, found that BOD during the dry season of December, January, February, and March was 3.08, 3.24, 1.52, and 2.70 mg/L, respectively; and a decrease to 1.50 mg/L with an increased drainage of the Krasiao reservoir. This study shows that the SWAT model successfully stimulated and assessed the effects of land use activities on streamflow, sediment, and BOD; including the successful drainage of the Krasiao reservoir in both watershed and sub-watershed areas.

***Keyword:*** dynamic modeling; water storage capacity; dilution of waste water; land utilization

## 1. Introduction

As an important element in basic human life, water is a natural resource necessary for basic economic development; including agriculture, industry, public utilities, and transportation, as well as diluting waste human activity. Thailand has been facing the problems of water shortages and water quality, mainly due to increasing populations and changing lifestyles; especially in the central region, where the resident population, economic expansion, and housing have increased rapidly. Without proper water management and planning or in the event of the reckless usage of limited water resources, water yields will be affected in terms of quantity, quality, and the flow timing; leading to the degradation and pollution of water resources.

The UTCW, while having changed from its original condition, still provides a suitable ecosystem and environment. The land use or activities inside the watershed area rarely grows or expands. Water waste and pollution contamination entering the stream can be reconditioned or refreshed in equilibrium at certain levels. Current water quality problems are likely to continue to intensify and deteriorate, mainly due to human activities, such as the expansion of agricultural activities along the riparian river zones, including the encroachment of headwater for agricultural expansion. Such activities are the cause of soil erosion and pollution contamination of waste water, especially during the dry season flow, which induces the concentration of waste water greater than the carrying capacity. This directly and adversely effects water yields, in terms of quantity, quality, and timing of water flow to those people living along the river and surrounding areas.

The problems and impacts of management related to the degradation of natural resources, especially in the field of water resources, are important to all living things, and have inspired the authors to study the water storage capacity for the dilution of waste water from land utilization in the UTCW. This study hopes to provide systematic and sustainable concepts which will help prevent the deterioration of water yield problems to the ecology and environment, as well as to establish the guidelines of limited water resources, including land use in the UTCW. The main objective of this study was to investigate the physical characteristics of watershed, water storage capacity, and dynamic modeling development for generating the reservoir water storage capacity necessary to dilute waste water from land utilization in the UTCW for suitable, systematic, and sustainable development.

## 2. Materials and Methods

### *2.1 Study site*

The UTCW, located in central Thailand, is divided into 14 sub-watersheds, including the Krasiao reservoir in sub-watershed 8 (Fig. 1). The total watershed area is approximately 5,253.96 km$^2$ of lowland topography. The land north, east, and south of the UTCW area is predominantly agricultural, filled with crops and paddy fields. To the west are foothills, mostly covered with a deciduous forests and trees, with elevations rising to 1,538 meters above mean sea level. The climate of the UTCW area in terms of annual rainfall, averages of humidity, and daily temperature, observed from 2013 to 2014, were 1,115 mm, 72.80%, and 28.9°C, respectively. According to the Thai classification system, there are 32 soil groups present, and land use was classified into nine types.

### *2.2 Data collection*

The data used in this study to evaluate the amount of streamflow, suspended sediment, and BOD; including the digital elevation model (DEM), land use data, soil data, discharge data, suspended sediment data, BOD data, and meteorological data, were collected from the Land Development Department (LDD), Royal Irrigation Department (IRD), Pollution Control Department (PCD), and Thai Meteorological Department (TMD). The SWAT model and Geographic Information System (GIS) software were employed to simulate the hydrological characteristics and evaluate the impact of the land use activities affecting the amount of the streamflow, suspended sediment, and BOD within the UTCW. The work procedure flowchart is provided in Fig. 2.

### *2.3 Analysis and evaluation*

Data analysis and evaluation were divided into two main parts, as described below:

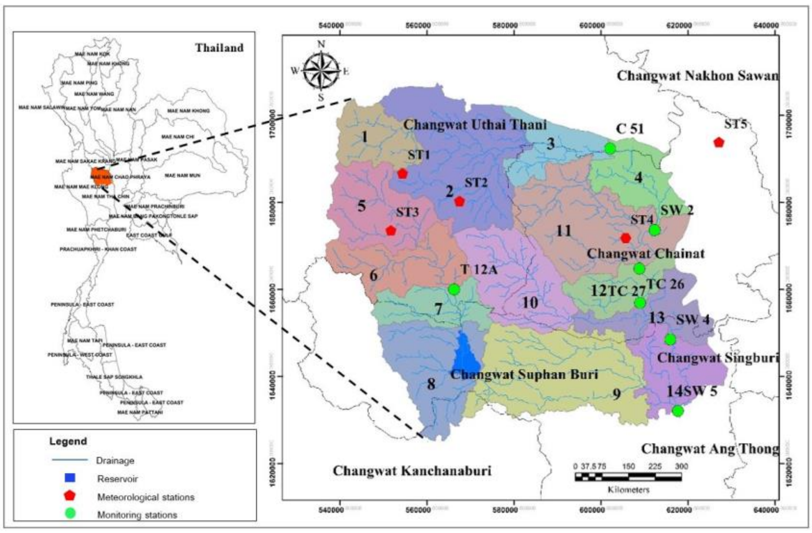


Figure 1. The location of the UTCW and 14 sub-watersheds

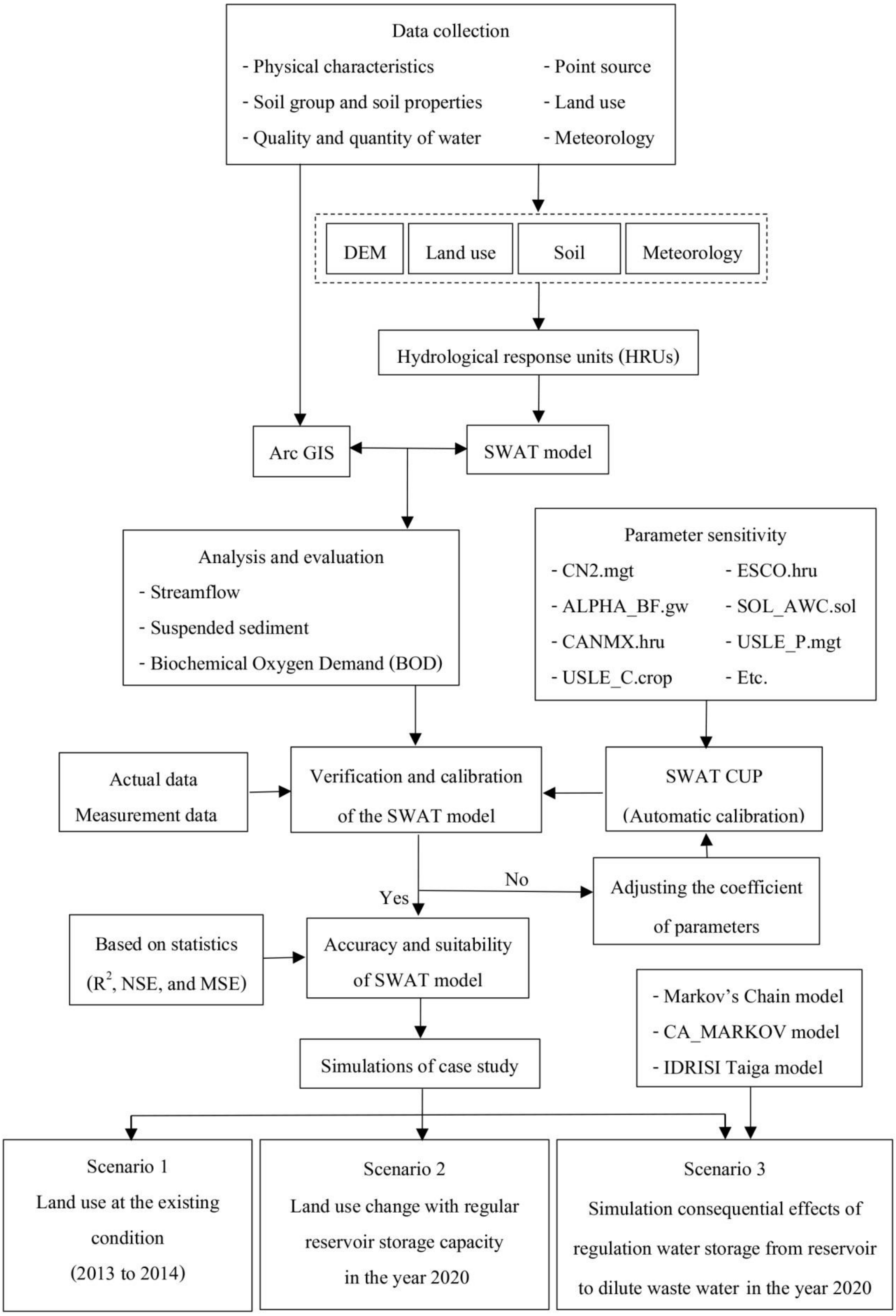


Figure 2. Work procedure flowchart

2.3.1 The data on streamflow, suspended sediment, and BOD in the UTCW; observed from January, 2013 to December, 2014, were analyzed in terms of mean monthly discharge, suspended sediment, and BOD in each station or measurement point, which were fed into the database for assessment verification/calibration by the SWAT model.

2.3.2 Calculations within the SWAT model were based on the premise that the simulation of the hydrology of a watershed can be separated into two major divisions. The first division is the land phase of the hydrologic cycle. The land phase of the hydrologic cycle controls the amount of water, sediment, nutrient, and pesticide loadings delivered to the main channel in each sub-watershed. The second division is the water or routing phase of the hydrologic cycle, which can be defined as the movement of water, sediments, etc., through the channel network of the watershed to the outlet (Neitsch *et al*., 2011). The land phase of the hydrologic cycle, modeled in the SWAT, was based on the water balance, as written in Equation 1. The erosion and sediment yields are estimated for each HRU with modified universal soil loss equation (MUSLE, Williams *et al*., 1984), as expressed in Equation 2. The carbonaceous biological oxygen demand (CBOD) defines the amount of oxygen required to decompose the organic matter transported in surface runoff, based upon the relationship of Thomann and Mueller, 1987; presented in Equation 3.

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \quad \text{Eq.1}$$

Where $SW_t$ is the final soil water content (mm), $SW_0$ is the initial soil water content (mm), $t$ is the time (days), $R_{day}$ is the amount of precipitation on day (mm), $Q_{surf}$ is the amount of surface runoff on day (mm), $E_a$ is the amount of evapotranspiration on day (mm), $W_{seep}$ is the amount of percolation and bypass flow exiting the soil profile bottom on day (mm), $Q_{gw}$ is the amount of return flow on day (mm).

$$sed = 11.8\left(Q_{surf} \,.\, q_{peak} \,.\, area_{hru}\right)^{0.56} \,.\, k_{usle} \,.\, c_{usle} \,.\, P_{usle} \,.\, LS_{usle} \,.\, CFRG \quad \text{Eq.2}$$

Where *sed* is the sediment yield on a given day (metric tons), $Q_{surf}$ is the surface runoff volume (mm $H_2O$/ha), $q_{peak}$ is the peak runoff rate ($m^3$/s), $area_{hru}$ is the area of the HRU, $k_{usle}$ is the USLE soil erodibility factor (0.013 metric ton $m^2$ hr/($m^3$ -metric ton cm)), $c_{usls}$ is the USLE cover and management factor, $P_{usls}$ is the USLE support practice factor, $LS_{usls}$ is the USLE topographic factor, *CFRG* is the coarse fragment factor.

$$cbod_{surq} = \frac{2.7 \,.\, orgC_{surq}}{Q_{surf} \,.\, area_{hru}} \quad \text{Eq.3}$$

Where $cbod_{surq}$ is the CBOD concentration surface runoff (mg CBOD/L), $orgC_{surq}$ is the organic carbon in surface runoff (kg orgC), $Q_{surf}$ is the surface runoff on a given day (mm $H_2O$), $area_{hru}$ is the area of the HRU ($km^2$).

However, the SWAT model is a continuous time model that operates on a daily time step, spatially semi-distributed, physically based model (Arnold *et al*., 1998; Baker and Miller, 2013; Brzozowski *et al*., 2011; Uzeika *et al*., 2012; Strauch *et al*., 2012; 2013; Andrade *et al*., 2013; Pinto *et al*., 2013). In this study, the surface runoff from daily rainfall was estimated using the modified SCS curve number (USDA-SCS, 1972). The peak runoff rate was calculated through a modified rational method (Neitsch *et al*., 2011), and the lateral sub-surface flow through a kinematic storage model (Sloan and Moore, 1984). The potential evapotranspiration (PET) was determined using a modified Penman-Monteith approach (Jensen *et al*., 1990). The basic file required by the SWAT model in order to delineate the watershed into sub-watershed and HRUs (including the DEM), was interpolated from topo to raster (spatial analyst), the soil data, and the meteorological data for the UTCW during January 2013 to December 2014.

### *2.4 Verification and calibration of the SWAT model*

The verification of the SWAT model examines the simulation results of the SWAT model with measurement data in the study area from designated monitoring stations or sampling points, from January, 2013 to December, 2014. The calibration model used in this study, SWAT CUP (Abbaspour *et al*., 2004; Abbaspour, 2007; Schuol *et al*., 2008; Yang *et al*., 2008; Oeurng *et al*., 2011; Arnold *et al*., 2012; Pinglot, 2012; Abbaspour *et al*., 2015), automatically calibrated the appropriate coefficients results of the parameter, before incorporation into the SWAT model. The criteria for calibration accuracy and appropriateness of the SWAT model employs a graph, coefficient of determination ($R^2$), nash-sutcliffe efficiency (NSE), and mean squared error (MSE).

*2.5 The simulation of land use impact on water, suspended sediment and BOD*

The results of the suspended sediment and BOD were incorporated into the management planning for the UTCW, and the verification and calibration of the drainage of the Krasiao model. The model was applied to assess the land use change and its effects on streamflow, and to determine suitable and sustainable land use and water storage regulation, through reservoir storage dilution of waste water caused by land utilization. The simulations were conducted given the three following scenarios:

*2.5.1 Scenario 1:* The land use at the existing condition in the UTCW from 2013 to 2014

This case describes the existing condition of land use and water drainage from the Krasiao reservoir, and their effect on streamflow, suspended sediment, and BOD.

*2.5.2 Scenario 2:* The land use change within the UTCW that is expected to occur in the year 2020, given regular reservoir storage capacity.

The databases of land use in years 2007 and 2014 were employed to predict land use for the year 2020 by applying the Markov's Chain model, CA_MARKOV model, and the IDRISI Taiga model; together with the creation of land use mapping. The GIS and the SWAT model were later applied to evaluate the streamflow, suspended sediment, and BOD that could occur in the year 2020.

*2.5.3 Scenario 3:* The simulated consequential effects of regulation water storage from the Krasiao reservoir considered necessary to dilute waste water caused by downstream land use activities on BOD within a sub-watershed in the year 2020.

**3. Results and Discussion**

*3.1 Hydrological Response Units (HRUs) of the UTCW*

The HRUs in the UTCW (Fig. 3) corresponding to the proportionate land use, soil group, and slope of the area were determined using land use over sub-basin at five percent (Fig. 2(a)); the percentage of soil class over soil group at ten percent (Fig. 2(b)), and the percentage of slope class over slope class at ten percent (Fig. 2(c)). The HRUs in the UTCW were determined at 286 HRUs.

*3.2 The parameter sensitivity of the streamflow, suspended sediment and BOD*

Sensitivity analysis of the SWAT model was performed in order to indicate uncertainties and the appropriate adjustment coefficient of various parameters. The results are detailed in Table 1, as follows:

*3.3 Calibration results of streamflow, suspended sediment, and BOD*

The calibration of the SWAT, through analyzed sensitivity (Section 3.2, Table 1), identified the formation of $R^2$, NSE, and MSE (Shi *et al*., 2013; Moriasi *et al*., 2015); beginning at the calibration of the upper sub-watershed to the sequential lower sub-watersheds. Streamflow is the first calibration parameter, followed by suspended sediment, and BOD. The seven monitoring stations within the UTCW (C 51, T12 A, SW 2, TC 27, TC 26, SW4, and SW5) were calibrated. The results depicting calibration accuracy are presented in Table 2.

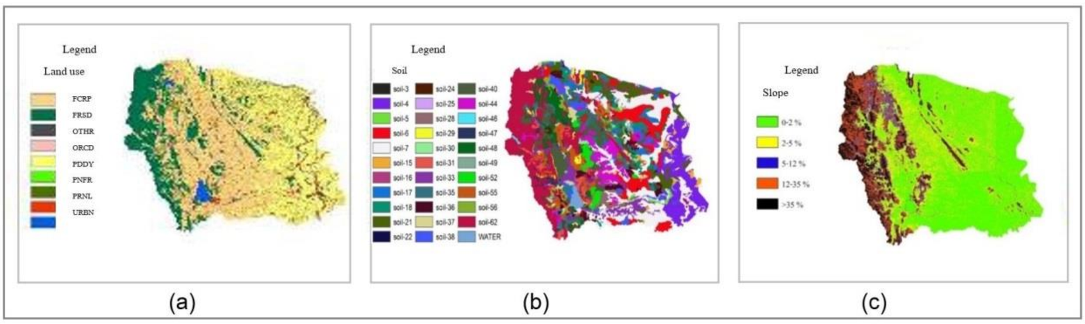


Figure 3. The HRUs of land use (a) soil group, (b) slope class and (c) in the UTCW

Table 1. Result of parameter sensitivity analysis for streamflow, suspended sediment, and BOD of UTCW

| Main parameters | Parameters in SWAT to be adjusted | Adjusted coefficient of parameters |
|---|---|---|
| Streamflow | - Base flow recession constant (ALPHA_BF) | 0.223 |
| | - Available water capacity (SOL_AWC) | 0.825 |
| | - Effective hydraulic conductivity of channel (CH_K2) | 162.433 |
| | - Manning's value for tributary channels (CH_N2) | 0.050 |
| | - Soil evaporation compensation coefficient (ESCO) | 0.025 |
| | - Maximum canopy storage (CANMX) | 42.500 |
| | - Potential maximum canopy height (BLAI) | 1.450 |
| | - SCS moisture condition 2 curve number for pervious areas (CN2) | 83.825 |
| Suspended sediment | - Sediment transport coefficient (SPCON) | 0.0008 |
| | - Exponent in sediment transport equation (SPEXP) | 1.0625 |
| | - Peak rate adjustment factor (PRF) | 0.2854 |
| | - Channel erodibility factor (CH_COV) | 0.7748 |
| | - Indicates resistance to erosion (CH_EROD) | 0.4212 |
| BOD | - Density of biomass (BIO_BD) | 925.0000 |
| | - BOD decay rate coefficient (COEFF_BOD_DC) | 3.8975 |
| | - Mortality rate coefficient (COEFF_MRT) | 0.7278 |
| | - Respiration rate coefficient (COEFF_RSP) | 0.1338 |
| | - A conversion factor representing the proportion of mass bacterial growth and mass BOD degraded in the STE (COEFF_BOD_CONV) | 0.2900 |

*3.4 Predicted streamflow, suspended sediment, and BOD in the UTCW*

Based on the adjusted calibration values and sensitivity analysis (Section 3.2, Table 1), the effects of land use change and dilution of waste water on the streamflow, suspended sediment, and BOD; including water drainage from the Krasiao reservoir, are described in the following three scenarios:

*3.4.1 Scenario 1:* Existing land use condition in the UTCW from January, 2013 to December, 2014 (Fig. 4)

The results confirmed that the total amount of streamflow from the UTCW was 374.74 MCM, with the highest value in September (126.27 MCM), due to the cumulative rainfall and soil water content of Thailand's rainy season; and the lowest in March (0.33 MCM), due to our anticipated dry season (Fig. 4(a)). The total amount of suspended sediment from

Table 2. The results of calibration accuracies based on $R^2$, NSE, and MSE on streamflow, suspended sediment, and BOD for the UTCW via SWAT model analysis with adjusted parameter coefficients (Table 1)

| Parameter | Station code | $R^2$ | NSE | MSE | Period of observed data |
|---|---|---|---|---|---|
| Streamflow | C 51 | 0.83 | 0.80 | 7.32 | Jan 2013 - Mar 2014 |
| | T12 A | 0.85 | 0.78 | 13.96 | Jan 2013 - Dec 2014 |
| Suspended sediment | SW 2 | 0.77 | 0.57 | 12.08 | Nov 2013, Jan 2014, May 2014 |
| | T12 A | 0.80 | 0.84 | -10.25 | Jan 2013 - Dec 2014 |
| | TC 27 | 0.92 | 0.30 | 2.30 | Feb, May, Aug, Nov 2013<br>Mar, Aug 2014 |
| | TC 26 | 0.90 | 0.75 | 10.92 | Feb, May, Aug, Nov 2013<br>Mar, May, Aug, Nov 2014 |
| | SW 4 | 0.88 | -0.18 | 35.76 | Nov 2013, Jan 2014, May 2014 |
| | SW 5 | 0.94 | 0.86 | 9.03 | Nov 2013, Jan 2014, May 2014 |
| BOD | SW 2 | 0.72 | 0.70 | -2.88 | Nov 2013, Jan 2014, May 2014 |
| | TC 27 | 0.94 | 0.85 | 9.23 | Feb, May, Aug, Nov 2013<br>Mar, Aug 2014 |
| | TC 26 | 0.91 | 0.76 | 14.14 | Feb, May, Aug, Nov 2013<br>Mar, May, Aug, Nov 2014 |
| | SW4 | 0.49 | -1.39 | 16.89 | Nov 2013, Jan 2014, May 2014 |
| | SW5 | 0.90 | 0.86 | -4.51 | Nov 2013, Jan 2014, May 2014 |

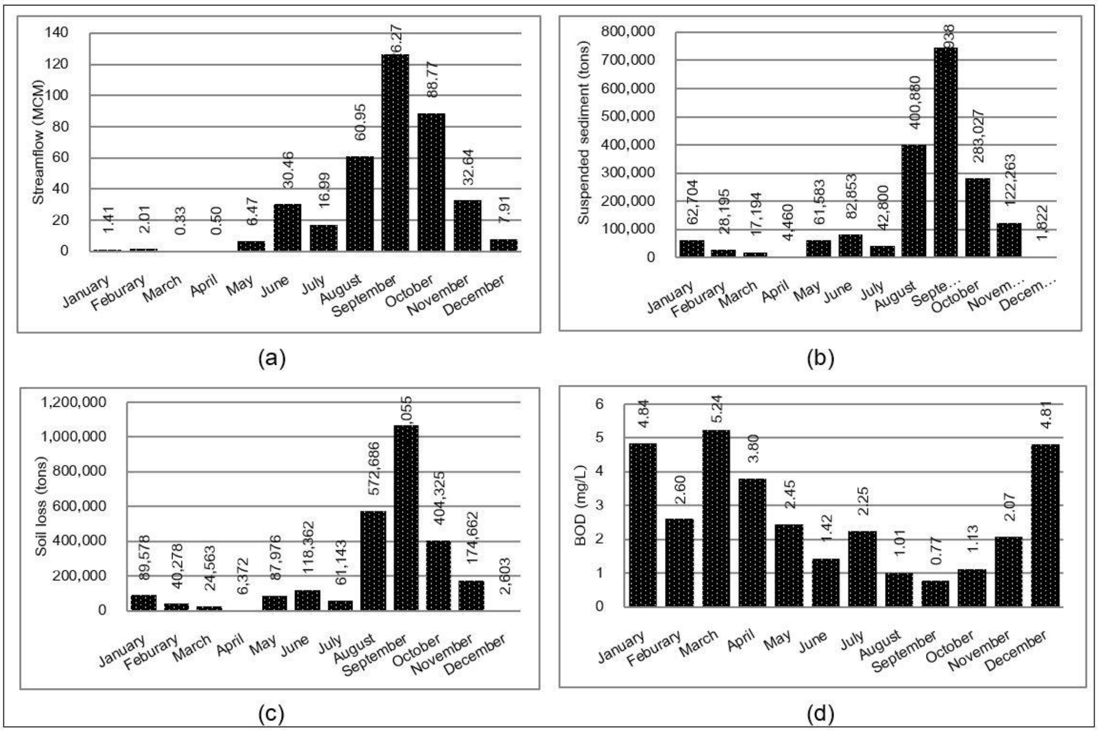


Figure 4. The results of the (a) streamflow, (b) suspended sediment, (c) soil loss and (d) BOD; in Scenario 1.

the UTCW was 1,854,720 tons/year, with the highest value in September (746,938 tons), and the lowest of 1,822 tons in December (Fig. 4(b)). The total amount of soil loss from the UTCW was 2,649,600 tons/year, with the highest value in September (1,067,055 tons) corresponding to the period of largest streamflow, and the lowest in December (2,603 tons), (Fig. 4(c)). The average BOD of the UTCW was 2.70 mg/L, with the highest value in March (up to 5.24 mg/L). When water discharge is at its lowest water level, in September, the BOD was 0.77 mg/L; due to the excessive dilution of high water discharge (Fig. 4(d)).

*3.4.2 Scenario 2:* Anticipated land use condition of the UTCW in the year 2020 (Fig. 5)

The results in this study found that when the ratio of land use changes (from Scenario 1 to Scenario 2, as shown in Table 3), the orchard and urban areas displayed a decreasing trend from year 2014 to 2020, due to changes in the field crops. The total amount of streamflow of the UTCW was 309.02 MCM, a decrease of 65.72 MCM, when compared to Scenario 1. The highest value (89.00 MCM, in September), and the lowest (0.55 MCM, in March) were a result of surface water drainage as groundwater, without rainfall (Fig. 5(a)).

Table 3. The land use change ratio of the UTCW from 2013 to 2014 (Scenario 1), and in year 2020 (Scenario 2)

| Order | Type of land use | Scenario 1 | | Scenario 2 | | Land use change | |
|---|---|---|---|---|---|---|---|
| | | km$^2$ | % | km$^2$ | % | km$^2$ | % |
| 1 | Field crop (FCRP) | 2,006.86 | 38.20 | 2,087.92 | 39.74 | 81.06 | 1.54 |
| 2 | Forest area (FRSD) | 967.30 | 18.41 | 939.93 | 17.89 | -27.37 | -0.52 |
| 3 | Other (OTHR) | 91.60 | 1.74 | 102.14 | 1.94 | 10.54 | 0.20 |
| 4 | Orchard (PRCD) | 79.85 | 1.52 | 68.28 | 1.30 | -11.57 | -0.22 |
| 5 | Paddy field (PDDY) | 1,520.91 | 28.95 | 1,478.45 | 28.14 | -42.46 | -0.81 |
| 6 | Planted forest (PNFR) | 3.85 | 0.07 | 3.27 | 0.06 | -0.58 | -0.01 |
| 7 | Perennial land (PRNL) | 150.11 | 2.86 | 152.50 | 2.90 | 2.39 | 0.04 |
| 8 | Urban area (URBN) | 269.99 | 5.14 | 240.95 | 4.59 | -29.04 | -0.55 |
| 9 | Water area (WATR) | 163.49 | 3.11 | 180.62 | 3.44 | 17.13 | 0.33 |
| | Total | 5,253.96 | 100 | 5,253.96 | 100 | - | - |

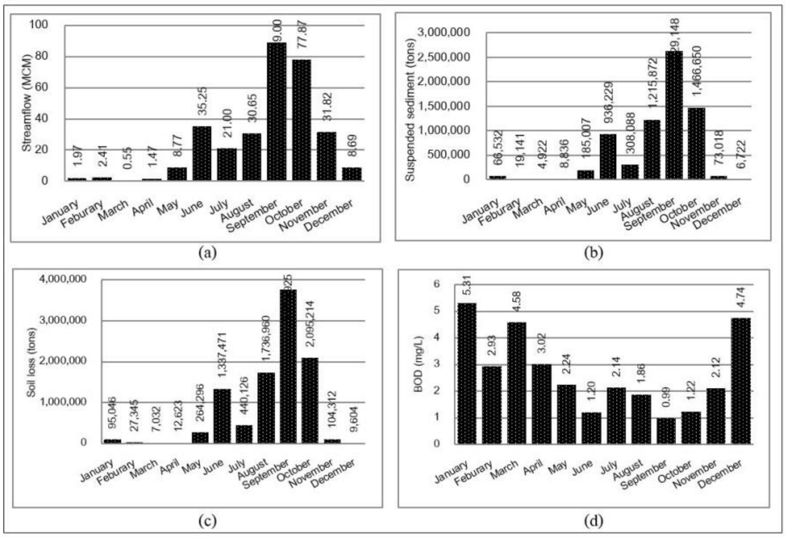


Figure 5. The result of the (a) streamflow, (b) suspended sediment, (c) soil loss and (d) BOD; in Scenario 2.

The total amount of suspended sediment from the UTCW was 6,920,166 tons/year, with the highest value in September (2,629,148 tons), due to the decrease in forest area (FRSD) and increase in field crops (FCRP); and the lowest value in March (4,922 tons), as shown in Fig. 5(b). The total amount of soil loss in the UTCW was 9,885,952 tons/year, increasing 7,236,352 tons/year when compared with Scenario 1 (2,649,600 tons/year), with the highest value in September (3,755,925 tons), and the lowest in December (7,032 tons), illustrated in Fig. 5(c). The average BOD of the UTCW was only slightly changed (2.70 mg/L), in which highest value occurred in January (at 5.31 mg/L), and lowest in September (at 0.99 mg/L), shown in Fig. 5(d).

*3.4.3 Scenario 3:* The simulation of storage water released from the Krasiao reservoir for diluting waste water, caused by land use activities on downstream areas on BOD (Fig. 6).

Scenario 3 investigates the drainage of the Krasiao reservoir on monthly BOD in sub-watershed No 8 and land use in the year 2020 (Fig. 6(a)), in which the normal and proposed dilution of waste water were compared. The BOD met the higher water quality standard of surface water, Class 2 (Note, that to conserve aquaculture: BOD < 1.5 mg/L; Pollution Control Department, 1994). In normal water regulation, the average drain out of the Krasiao reservoir was at 239.25 MCM/year, with the highest drainage

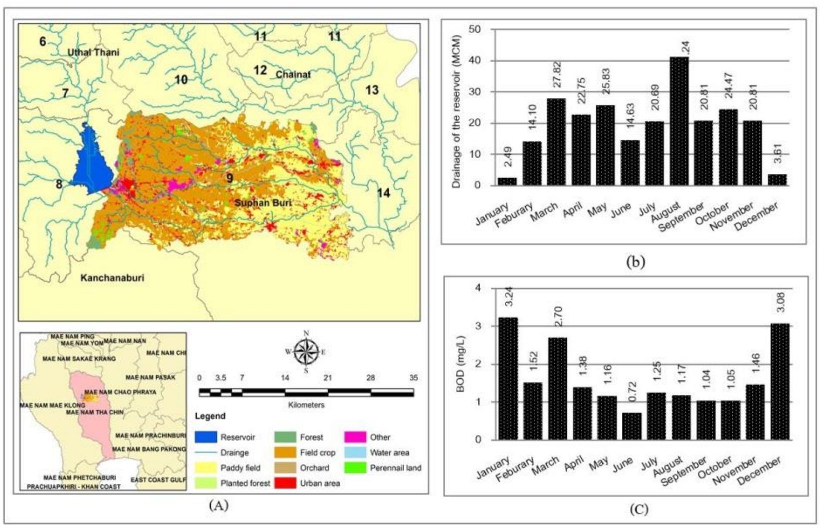


Figure 6. The amount of drainage and BOD of the Krasiao reservoir in sub-watershed No 8, in Scenario 3

Table 4. The BOD derived at normal and proposed water drainage of the Krasiao reservoir.

| Period | Normal drainage of the Krasiao reservoir [1*] | | | Proposed drainage of the Krasiao reservoir [2*] | | |
|---|---|---|---|---|---|---|
| | Flow rates (CM/sec) | Water volume (MCM) | BOD (mg/L) | Flow rates (CM/sec) | Water volume (MCM) | BOD (mg/L) |
| January | 28.78 | 2.49 | 3.24 | 82.15 | 7.10 | 1.50 |
| February | 163.21 | 14.10 | 1.52 | 175.00 | 15.12 | 1.50 |
| March | 321.98 | 27.82 | 2.70 | 386.73 | 33.41 | 1.50 |
| April | 263.32 | 22.75 | 1.38 | 263.32 | 22.75 | 1.38 |
| May | 298.96 | 25.83 | 1.16 | 298.96 | 25.83 | 1.16 |
| June | 169.30 | 14.63 | 0.72 | 169.30 | 14.63 | 0.72 |
| July | 239.41 | 20.69 | 1.25 | 239.41 | 20.69 | 1.25 |
| August | 477.27 | 41.24 | 1.17 | 477.27 | 41.24 | 1.17 |
| September | 240.90 | 20.81 | 1.04 | 240.90 | 20.81 | 1.04 |
| October | 283.24 | 24.47 | 1.05 | 283.24 | 24.47 | 1.05 |
| November | 240.85 | 20.81 | 1.46 | 240.85 | 20.81 | 1.46 |
| December | 41.84 | 3.61 | 3.08 | 216.23 | 18.68 | 1.50 |
| Average | 230.76 | 19.94 | 1.65 | 256.11 | 22.13 | 1.27 |
| Total | - | 239.25 | - | - | 265.54 | - |

Remark: [1*]Observed values; [2*]Simulated value by SWAT model

in August, at 41.24 MCM; and the lowest in January, at 2.49 MCM (Fig. 6(b)). The BOD during the four month dry season (December, January, February, and March) proved higher than the standard surface water quality, estimated by SWAT at 3.08, 3.24, 1.52, and 2.70 mg/L, respectively (Fig. 6(c)). In order to reduce BOD to meet the standard surface water quality (Class 2 BOD < 1.5 mg/L), the monthly water drained from the Krasiao reservoir during the dry season would be need to be increased form 2.49, 14.10, 27.82, and 3.61 MCM to 7.10, 15.12, 33.41, and 18.68 MCM. The flow rate in January decreased from the previous month due to the reduction of the Krasiao reservoir storage, shown in Table 4.

## 4. Conclusion

The dynamic modeling of the water storage capacity of waste water dilution from land utilization in the UTCW was formulated through the application of the SWAT model to indicate both existing and expected conditions of land use from 2013 to 2014 (Scenario 1), land use change within the UTCW expected to occur in the year 2020 with regular reservoir storage capacity (Scenario 2), and simulation of storage water released from the Krasiao reservoir for diluting waste water caused by land use activities of downstream areas on BOD (Scenario 3). Study results of Scenario 1 found the amount of streamflow at 374.74 MCM, suspended sediment at 1,854,720 tons/year, soil loss at 91.35 tons/ha/year, and BOD at 2.70 mg/L. In scenario 2, the amount of the streamflow decreased to 65.09 MCM, suspended sediment increased to 5,065,446 tons/year, soil loss increased to 240.96 tons/ha/year, and BOD was 2.70 mg/L; when compared with the first scenario. In Scenario 3, given normal reservoir drainage, BOD during the dry season of December, January, February, and March was 3.08, 3.24, 1.52, and 2.70 mg/L, respectively. A decrease of 1.50 mg/L occurred with a concurrent drainage increase of the Krasiao reservoir from 3.61, 2.49, 14.10, and 27.82 MCM, to 18.68, 7.10, 15.12, and 33.41 MCM, respectively.

The study determined that with an increase in the drainage of the Krasiao reservoir, specifically during dry season, the amount of water in the stream regulated from the reservoir would help BOD return to the Class 2 of the standard of surface water quality (BOD < 1.5 mg/L). The SWAT model herein was applied to simulate and assess the effects of land use activities on streamflow, sediment, BOD, and drainage of the Krasiao reservoir in both watershed and sub-watershed areas.

### Acknowledgements

The researchers would like to thank Kasetsart University, Bangkok, Thailand; and Professor Nipon Thangtham, our research project advisor, whose wisdom and expertise guided our efforts; and to all others whose participation and assistance made this research possible.

**References**

Abbaspour KC, Johnson CA, Van Genuchten MT. Estimating uncertain flow and transport parameters using a sequential uncertainty fitting procedure. Vadose Zone Journal 2004; 3(4): 1340-52.

Abbaspour KC. User nanual for SWAT-CUP, SWAT calibration and uncertainty analysis programs. Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland. 2007.

Abbaspour KC, Rouholahnejad E, Vaghefi S, Srinivasan R, Klove B. A continental-scale hydrology and water quality model for Europe: Calibration and uncertainty of a high-resolution large-scale SWAT model. Journal of Hydrology 2015; 524: 733-52.

Andrade MA, de Mello CR, Beskow S. Hydrological simulation in a watershed with predominance of Oxisol in the Upper Grande river region, MG-Brazil. Revista Brasileira de Engenharia Agrícola e Ambiental 2013; 17(1): 69-76.

Arnold JG, Moriasi DN, Gassman PW, Abbaspour KC, White MJ, Srinivasan R, Santhi C, Harmel RD, van Griensven A, Van Liew MW, Kannan N, Jha MK. SWAT: model use, calibration, and validation. Transactions of the ASABE 2012; 55(4): 1491-508.

Arnold JG, Srinivasan R, Muttiah RS, Williams JR. Large-area hydrologic modeling and assessment Part I: Model development. Journal of the American Water Resources Association 1998; 34(1): 73-89.

Baker TJ, Miller SN. Using the soil and water Assessment tool (SWAT) to assess land use impact on water resources in an East African watershed. Journal of Hydrology 2013; 486: 100-11.

Brzozowski J, Miatkowski Z, Śliwiński D, Smarzyńska K, Śmietanka M. Application of SWAT model to small agricultural catchment in Poland. Journal of Water and Land Development 2011; 15: 157-66.

Jensen ME, Burman RD, Allen RG. Evapotranspiration and irrigation water requirements. ASCE Manuals and Reports on Engineering Practice No.70, ASCE. 1990; 322.

Moriasi D, Gitau MW, Pai N, Daggupati P. Hydrologic and water quality models: performance measures and evaluation criteria. Transactions of the ASABE 2015; 58(6): 1763-85.

Neitsch SL, Arnold JG, Kiniry JR, Williams JR. Soil and water assessment tool theoretical documentation (Version 2009). 2011.

Oeurng C, Sauvage S, Sánchez-Pérez JM. Assessment of hydrology, sediment and particulate organic carbon yield in a large agricultural catchment using the SWAT model. Journal of Hydrology 2011; 401(3-4): 145-53.

Pinglot F. Mountainous river stream flow modeling Via ArcSWAT: a challenge, Toulouse. 2012.

Pinto DBF, da Silva AM, Beskow S, de Mello CR, Coelho G. Application of the soil and water assessment tool (SWAT) for sediment transport simulation at a headwater watershed in Minas Gerais state, Brazil. Transactions of the ASABE 2013; 56(2): 697-709.

Pollution Control Department. Classification of water resources for each region. Notification of Pollution Control Department. Published in the Royal Government Gazette. 1994.

Schuol J, Abbaspour KC, Srinivasan R, Yang H. Estimation of freshwater availability in the West African sub-continent using the SWAT hydrologic model. Journal of Hydrology 2008; 352(1-2): 30-49.

Shi ZH, Ai L, Li X, Huang XD, Wu GL, Liao W. Partial least-squares regression for linking land-cover patterns to soil erosion and sediment yield in watersheds. Journal of Hydrology 2013; 498: 165-76.

Sloan PG, Moore ID. Modeling subsurface stormflow on steeply sloping forested watersheds. Water Resource Research 1984; 20(12): 1815-22.

Strauch M, Bernhofer C, Koide S, Volk M, Lorz C, Makeschin F. Using precipitation data ensemble for uncertainty analysis in SWAT streamflow simulation. Journal of Hydrology 2012; 414-415: 413-24.

Strauch M, Lima JEFW, Volk M, Lorz C, Makeschin F. The impact of best management practices on simulated streamflow and sediment load in a Central Brazilian catchment. Journal of Environmental Management 2013; 127: S24-S36.

Thomann RV, Mueller JA. Principles of surface water quality modeling and control. Harper & Row Publishers. 1987.

USDA Soil Conservation Service (USDA-SCS). National Engineering Handbook Section 4 Hydrology. 1972. Chapters 4-10.

Uzeika T, Merten GH, Minella JPG, Moro M. Use of the SWAT model for hydro-sedimentologic simulation in a small rural watershed. Revista Brasileira de Ciência do Solo 2012; 36(2): 557-65.

Williams JR, Jones CA, Dyke PT. A modeling approach to determining the relationship between erosion and soil productivity. Transactions of the ASABE 1984; 27(1): 129-44.

Yang J, Reichert P, Abbaspour KC, Xia J, Yang H. Comparing uncertainty analysis techniques for a SWAT application to the Chaohe Basin in China. Journal of Hydrology 2008; 358(1-2): 1-23.

---

*Received 23 March 2017*
*Accepted 1 May 2017*

**Correspondence to**
Mr. Banchongsak Faksomboon
Department of Environmental Science,
Faculty of Environment,
Kasetsart University,
Bangkok, 10900
Thailand
Tel: +668-7258-0010
E-mail: banchongsakf@gmail.com;
gently_noteza@hotmail.com