The effect of flow discharge on suspended solids transport in the Nakhon-Nayok River

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Abstract

Suspended solid is one of the factors for water quality in the open channel. It affects various problems in waterways that can cause high sedimentation in the channels, leading to shallowness in the river. It is composed the organic and inorganic materials which can settle down anywhere along the open channel. Thus, depends on the solid amount and its composition, it occupies the water body capacity and causes the water quality problems simultaneously. However, the existing of suspended solid in the water column depends on the flow discharge (Q) and secchi depth (sec). This study aims to examine the effect of flow discharge (Q) and secchi depth (sec) on the suspended solids concentration in open channel and attempts to establish the formula that represents the relationship between flow discharges (Q), secchi depth (sec) and suspended solid concentration. The field samplings have been conducted in the Nakhon-Nayok River, during the wet season, September 15-16, 2014 and dry season, March 10-11, 2015. The samplings with five different locations are measured. The discharge has been measured onsite by floating techniques, the secchi depth has been measured by secchi disc and the water samples have been collected at the center of the water column. They have been analyzed in the laboratory for the suspended solids concentration. The results demonstrate that the decrease in suspended solids concentration is dependent on flow discharge, since the natural processes in erosion consists of routing of eroded material. Finally, an empirical equation to compute the suspended solids concentration that shows an equation (SS_{con} = 9.852 $(sec)^{-0.759}$ $Q^{0.0355}$) is developed. The calculated suspended solids concentration, with uses of empirical formula, show good agreement with the record data as the R^2 = 0.831. Therefore, the empirical formula in this study is clearly verified.

Keywords: suspended solids concentration, the Nakhon-Nayok River, secchi depth

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Introduction

Suspended solids represent the immediately response of a river system which influences ecosystem and it is cause of the problem in water quality. Suspended solids is composed the organic and inorganic materials which can settle down anywhere along the open channel. It consists of the fragments of coarse particulate matter (CPM) form the terrestrial area has entered open channel; it undergoes biological, chemical and mechanical degradation. Suspended solid is commonly range, 0.5 μm – 1.0 mm. Suspended solid is much easily transported because of them sizes. Thus, depends on the solid amount and its composition, it occupies the water body capacity and causes the water quality problems simultaneously.

The existing of suspended solid in the water column can be measured by the secchi disc and it has been studied for century, such as Secchi (1866). He is a pioneer physicist to use secchi disc in which the depth of disappearance of the disk is call secchi depth. Sauberer and Ruttner (1941) investigated the clarity of waters of the lake, estuary and coastline by using secchi disc. Medawar (1979) investigated the clarify water and the researcher observe the clarity water by binocle of eyeball optics. Wetzel (1983); Jorgensen and Johnsen (1989) studied the compound of particulate matter in the nature stream. Ostapenia (1989) analyzed the suspended particulate matter by secchi disc. Håkanson and Boulion (2002) investigated the lake food web by modeling predation. Hakanson *et al.* (2005) investigated the suspended particulate matter in open channels by the empirical data and models and Saiyudthong (2010) studied hydrodynamics and water quality of the Nakhon-Nayok River. Urantinon and Plailar (2011) investigated the estimation of the suspended solid concentration by using Secchi disc and equation of suspended solid concentration in the Nakhon-Nayok River. Many researchers developed an equation for calculation the suspended solid concentration in the open channel by using secchi disc but the site has not been clarified. The study area in literatures is the European site. These sites are different Thai site in the landscape, weather conditions and radiation and all reports make no clear in the tropical zone.

Thus, this study aims to examine the effect of flow discharge and seschi depth on the suspended solids concentration in the open channel and attempts to establish the formula that represents the relationship between flow related parameters on suspended solid concentration. A formula that represents the mechanisms of suspended solids transport in the open channel, with the concerning of related parameters effect, has been developed and verified.

Methodology

The field samplings have been conducted in the Nakhon-Nayok River, Nakhon-Nayok Province during the wet season, September 15-16, 2014 and dry season, March 10-11, 2015. The samplings with five different locations are measured (Figure 1-2) and the co-ordinate locations are shown in the (Table 1). The data are collected in the field for instance water. The samplings are collected at the mid-depth of depth water for the water quality analysis. All samplings is stored at 4°C in the icebox and transferred to analyze for suspended solids concentration under the laboratory condition. At any cross-section the samples are collected the three samples and the results are averaged. Others parameters such as the flow discharge has been measured onsite by floating technique and suschi depth has been measured onsite by secchi disc which is a circular black-white disk of 30-cm diameter (Figure 3). The procedure of collection, the secchi disc straight down into the water until the disk just disappears from the sight. Mark the rope at the water level with a clothespin. Slowly raise the disk up until it re-appears (Figure 4a-b). The distance from this point to the surface is measured by the tape measure. All related parameter are measured and recorded on data sheet. The details of experiments are as follows (Figure 5);

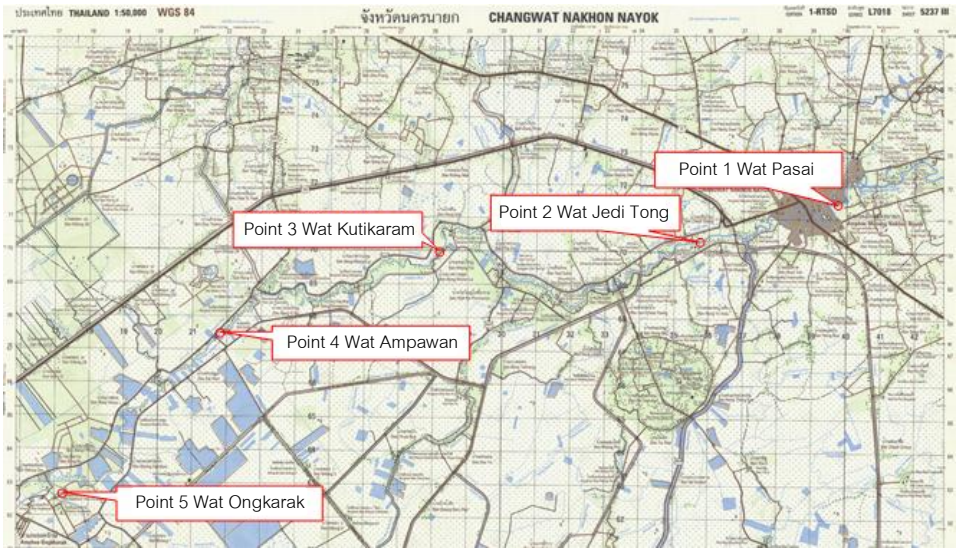

Figure 1 The Nakhon-Nayok River.

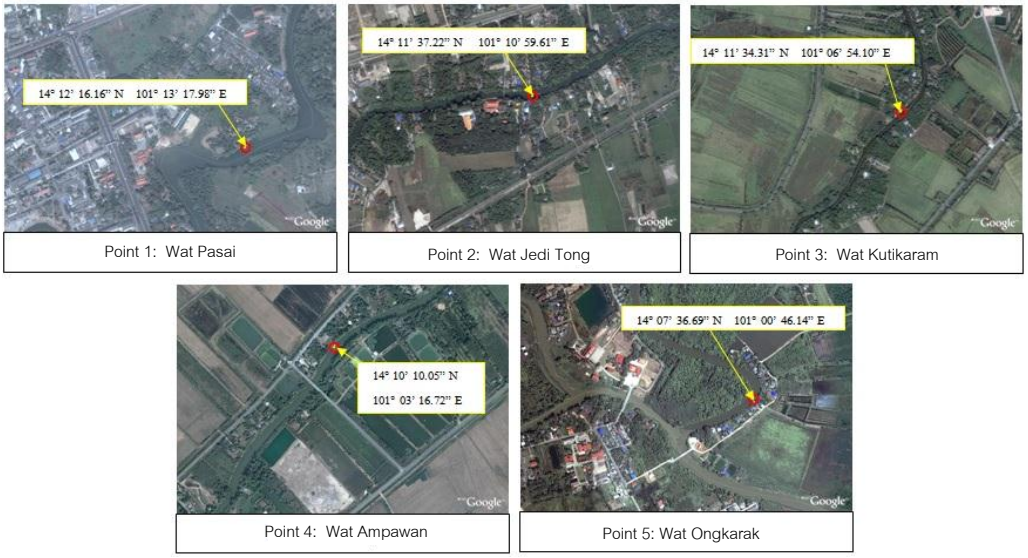

Figure 2 The measured sections.

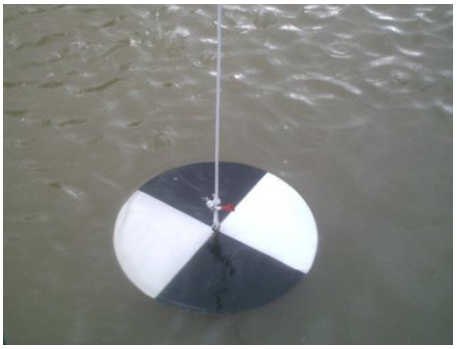

Figure 3 Secchi disc.

(a) (b)

Figure 4 The procedure of collection, the secchi disc.

Table 1 The co-ordinates of measured locations.

order	locations	co-ordinates
1	Wat Posai	14° 12' 16.16" N 101° 13' 17.98" E
2	Wat Jedi Thong	14° 11' 37.22" N 101° 10' 59.61" E
3	Wat Kutikaram	14° 11' 34.31" N 101° 06' 54.10" E
4	Wat Ampawan	14° 10' 10.05" N 101° 03' 16.72" E
5	Wat Ongkarak	14° 07' 36.69" N 101° 00' 46.14" E

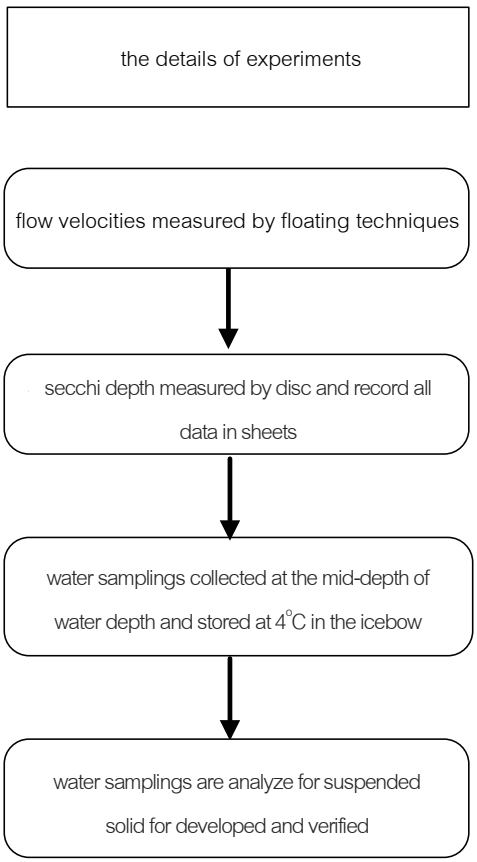

Figure 5 The steps of procedure.

Results and discussion

The relationship between the flow discharge and the suspended solids concentration

In this study, the Nakhon-Nayok River had been done by collected data on five points of the main stream since the suspended solids are increasingly from both sides of the river. Finally, in order to determine related parameters, all collected data sets are compared and analyzed. The days for collected samplers which are include wet season and dry season are good weather.

The record data (data on September 15-16, 2014) is compared with another case (data on March 10-11, 2015). The flow discharges and suspended solids concentration in 10 March 2015 (flow discharge = 13.09 m^3/s and suspended solids concentration = 23.18 mg/l) is lower, as compared with 15 Sep 2014 (flow discharge = 37.15 m^3/s and suspended solids concentration = 21.5 mg/l). In addition, the relationship

between the flow discharge and the suspended solids concentration is shown in (Figure 6). The suspended solids is seen to decrease with the flow discharge which indicates that suspended solids is continually lost from the water column as they settled down to the bed of river. The results demonstrate that the decreasing in suspended solids concentration is dependended on the flow discharge, since the natural processes in erosion consists of routing of eroded material and all record data are shown in (Table 2).

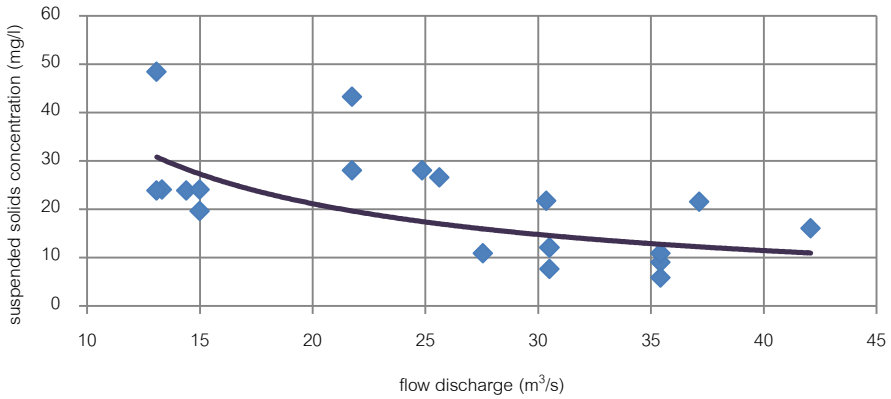

Figure 6 The relationship between the suspended solids v.s. the flow discharge.

Table 2 The measured data on site.

date	point	secchi depth (m)	discharge (m^3/s)	SS'con from laboratory experiment (mg/l)
15-Sep-14	1	0.65	42.08	16.0
	2	0.50	37.15	21.5
	3	0.50	30.37	21.7
	4	0.80	35.43	9.0
	5	0.35	25.63	26.5
16-Sep-14	1	1.00	35.43	5.8
	2	1.00	30.50	7.6
	3	0.20	13.09	48.4
	4	0.15	21.75	43.2
	5	0.30	15.00	19.6

Table 2 The measured data on site (cont).

date	point	secchi depth (m)	discharge (m^3/s)	SS'con from laboratory experiment (mg/l)
10-Mar-15	1	1.11	27.56	10.8
	2	1.29	30.50	12.0
	3	0.26	14.40	23.8
	4	0.33	24.86	28.0
	5	0.40	13.33	24.0
11-Mar-15	1	1.11	35.43	10.8
	2	1.29	30.50	12.0
	3	0.26	13.09	23.8
	4	0.33	21.75	28.0
	5	0.40	15.00	24.0

Development of empirical formula of the suspended solids concentration in the open channel

In order to establish the empirical formula of the suspended solids concentration in the open channel, the suspended solids concentration has been designated as SS_{con}. The empirical models describing relationships between the suspended solids concentration and the related parameters (secchi depth and flow discharge) are often used. The change of the suspended solids concentration is related to the change in the related parameters and the most common relationship is a relative curve that takes the form of a power function. A correction factor is introduced to the SS_{con} function as could be expressed as Equation (1):

$$SS_{con} = f^{n}(\sec, Q) \quad (1)$$

in which SS_{con} = suspendedsolids concentration (mg/l),

sec = secchi depth (m) and,

Q = flow discharge (m^3/s)

Then, $SS_{con}$is considered to be the function of secchi depth (sec) and the flow discharge (Q) by using PI theorem, White, (1976), SS_{con} function has been obtained; a correction factor is introduced to adjust the SS_{con}value as shown in Equation (2).

$$SS_{con} = 9.852(\sec)^{-0.759}\ (Q)^{0.0355} \quad (2)$$

Empirical suspended solids concentration formula verification

In order to verify the empirical formula of suspended solids concentration, the calculated suspended solids concentration with uses of Equation 2 have been compared with suspended solids concentration in August 19-24, 2014 and obtained from the field experiments. The comparison is shown in (Figure 7).

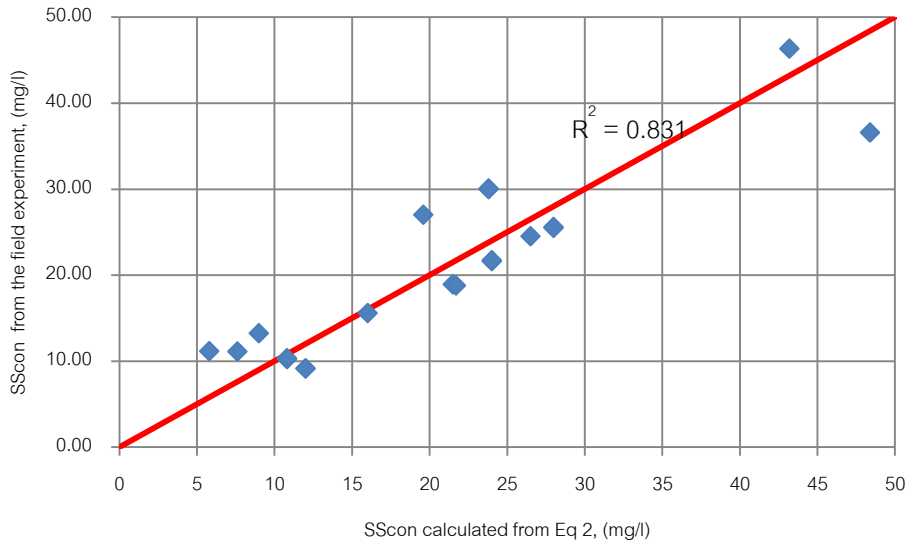

Figure 7 Comparison of the suspended solids concentration obtained from the calculation (using Eq 2) and the suspended solids concentration from the field experiments.

The calculated suspended solids concentration obtained from the empirical formula, Equation (2), presenting good relationship with suspended solids concentration which obtained from the field experiments since the comparison shows R^2 = 0.831. Therefore, the empirical formula of suspended solids concentration in this study is clearly verified.

Conclusions

The relationships between the flow discharge and the suspended solids concentration have been studied in the Nakhon-Nayok River. It is clearly seen that the flow discharges have significant effects on the suspended solids transport in theopen channel as follow:

(1) The high flow discharge affects suspended solids transport in the open channel and the suspended solids concentration in the water is continually reduced as the flow discharge,

(2) The decrease in suspended solids concentration is dependent on the flow discharge, since the natural processes in erosion consists of routing of eroded material and,

(3) The empirical formula of suspended solids concentration has been developed. Suspended solids concentration has been designated as SS_{con} and it is considered to be the function of flow discharge (Q) and secchi depth (sec).

Finally, an empirical equation to compute the suspended solids concentration to include the effect of flow discharge and secchi depth is developed. The calculated suspended solids concentration, with uses of empirical formula, show good agreement with the record data as the $R^2 = 0.831$. Therefore, the empirical formula in this study is clearly verified.

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