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Original Research

The effects of Thailand's Great Flood of 2011 on river sediment discharge in the upper Chao Phraya River basin, Thailand

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ABSTRACT

Severe flooding that occurred during the 2011 monsoon season in Thailand was the heaviest flooding in the past 50 yr. The rainfall over the northern part of Thailand, especially during July–August 2011, was 150% higher than average. During the flooding period, river flows of the four major Chao Phraya River tributaries (Ping, Wang, Yom, and Nan rivers) increased in the range of 1.4–5 times the average discharge. This study examined the river sediment discharge of the four major rivers in the upper Chao Phraya River basin in Thailand. The four rivers are considered the main sources of sediment supply to the Chao Phraya Estuary. River surveys of the Ping, Wang, Yom, and Nan rivers were carried out in October 2011 (during the Great Flood) and October 2012 (one year after the flood). Survey data included river cross sections, flow velocities, suspended sediment concentrations, and bed load transport in each river. Analyses of these data indicated that total sediment transport rates for the four main rivers during the flooding of 2011 were 2.3–5.6 times higher than the average sediment discharge over 60 yr. The flood of 2011 significantly affected the sediment characteristics including the proportions of suspended and bed sediment loads in each river though in different ways. The rates of sediment transport per unit discharge for the Ping and Wang rivers dramatically increased during the 2011 flood, but the flooding had minimal effects on the sediment characteristics in the Yom and Nan rivers. The amount of total sediment discharge in each river caused by the 2011 flooding varied between 0.3 and 1.6 Mt. Additionally, the bed load transport in these rivers varied between ~0% and 26% of the suspended sediment discharge.

1. Introduction

In 2011, Thailand experienced the most severe flooding in the past 50 yr caused by excessive and continuous rainfall from consecutive, powerful monsoons and tropical storms. The floods started in June 2011 in the northern regions of Thailand with tropical storm Haima, which carried 128% of the average rainfall for June, followed rapidly by tropical storm Nock-Ten throughout parts of July and August. As a result, rainfall was more than 150% of the average for both months (July—176 mm/month, August—225 mm/month). Storms continued to hit the country from the north and the east and rainfall remained 135% and 116% above average throughout September and October, respectively. The above average precipitation from months of storms resulted in flooding of the central regions of Thailand. The flood covered more than 60,000 km^2 of land in 66 of the country's 77 provinces. The floods impacted heavily on the private sector, particularly manufacturing, tourism, housing, agriculture, and the financial sector. The largest impact came from losses in physical assets, products, raw materials, machinery, accommodations, transportation, food, and household goods. It had an effect on more than 13 million people from July to December 2011 (World Bank, 2012).

Flooding occurred in the downstream parts of the Nan and Yom rivers, which are present in the upper watershed of the Chao Phraya River (Fig. 1). All floodwaters in the upper watershed

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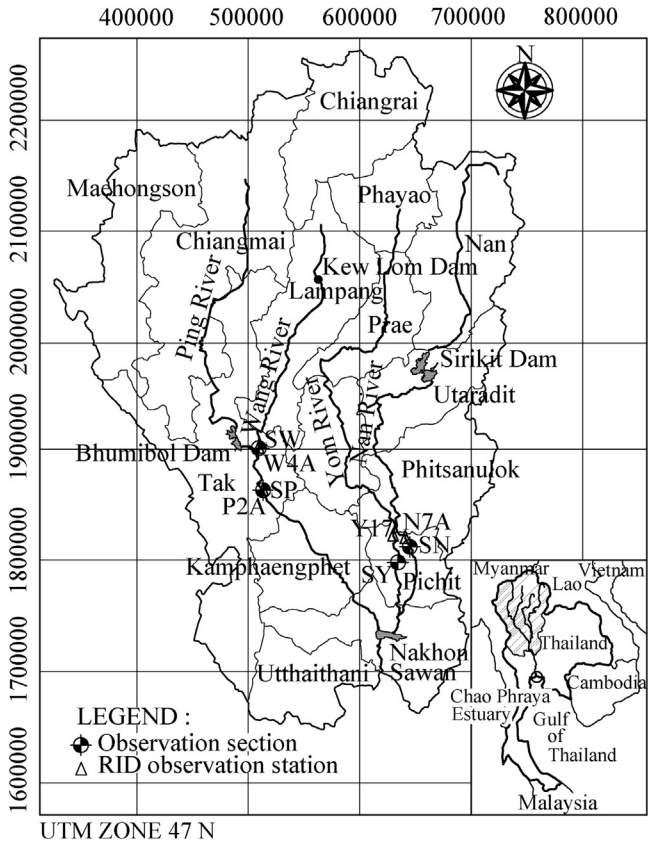

Fig. 1. Upper Chao Phraya River watershed study area and measurement stations.

including the Ping, Wang, Yom, and Nan rivers drain into the lower Chao Phraya River at Nakhon Sawan. The total discharge during the 2011 flood at Nakhon Sawan was 32.6 billion m^3, which was 232% of the average value for 1956–1999 (Komori et al., 2012).

The Chao Phraya River is the major drainage basin in Thailand, with a total surface area of approximately 180,000 km^2, 35% of the total surface area of the country. The river arises in the Central Cordillera near the Thai–Myanmar–Laos borders, and flows southward into the Gulf of Thailand (Alford, 1992). The Chao Phraya River basin is considered to be the main source of sediment supply to the Gulf of Thailand. Therefore, changes of flow characteristics in the upper watershed of the Chao Phraya River due to the flood in 2011 might be expected to directly affect the sediment process in those rivers and also affect the sediment supply to the Chao Phraya Estuary. The purpose of this study was to examine the effects of Thailand's Great Flood of 2011 on river sediment discharge in the four major rivers (Ping, Wang, Yom, and Nan rivers) that are the main sources of sediment supply to the Chao Phraya Estuary.

2. Study area

The Ping River basin, one of the largest sub-basins in the upper Chao Phraya basin, is located between latitudes 15°45′N and 19°45′N and longitudes 98°06′E and 100°12′E. The river basin is mainly characterized by terraced mountains with a catchment area of 34,453 km^2. It covers about 22% of the Chao Phraya River basin and contributes about 24% of the total average annual runoff. The climate of the basin is characterized by average annual rainfall of 1097 mm (Sharma et al., 2007). The Ping River length is approximately 740 km (Wuttichaikitcharoen & Babel, 2014) with the river slope varying from 1:40 to 1:2300 (Hydro and Agro Informatics Institute (Haii), 2014).

The Wang River basin is the smallest river sub-basin of the upper Chao Phraya River basin. It is located between 17°05′N and 19°30′N latitude and 98°54′E and 99°58′E longitude, and the topography is characterized by terraced mountains. The watershed area of the Wang River is 10,800 km^2 (Komori et al., 2012). The average annual precipitation is 1100 mm. The length of the Wang River is 460 km (Wuttichaikitcharoen & Babel, 2014), and the river gradient is between 1:60 and 1:1990 (Haii, 2014).

The Yom River basin is located between 17°30′N and 19°30′N latitude and 99°20′E and 100°40′E longitude, having a catchment area of 12,580 km^2. The topography of the basin varies from hilly areas in the northern part to lowland flat areas in the southern part. The climate of the basin is characterized by tropical monsoons, with a mean annual rainfall of 1250 mm. Rainfall distribution is generally uniform over the entire basin (Tingsanchali & Karim, 2010). The Yom River has a length of about 735 km (Wuttichaikitcharoen & Babel, 2014), and the river slope varies from 1:700 to 1:35,000 (Haii, 2014).

The Nan River basin is located between latitudes 15°42′N and 18°37′N and longitudes 99°51′E and 101°21′E with a watershed area of 34,682 km^2. The average annual rainfall in the basin is 1204 mm and the topography is characterized by mountains and floodplain areas (Amnatsan et al., 2009). The Nan River length is 770 km (Wuttichaikitcharoen & Babel, 2014) with the river gradient varying from 1:480 to 1:13,000 (Kitisuntorn, 1994).

3. Methods

Historical streamflow and sediment data collected by the Royal Irrigation Department (RID) were used for studying the average river flow conditions and sediment characteristics of the Ping, Wang, Yom, and Nan rivers. Unfortunately, sediment data in Thailand are insufficient for detailed studies, especially bed load which is generally not available in Thailand. Turowski et al. (2010) indicated that it has been frequently found that the bed load fraction is 10–20% in general, and sometimes 20–40% for mountainous rivers. For river sediment studies in Thailand, bed load discharge has been generally estimated as 30% of suspended load (Tae-Sombat, 1988). However, sediment transport processes are complicated and may vary due to local conditions such as climatic and geomorphological conditions, land use, etc. (Wuttichaikitcharoen & Babel, 2014). Kitisuntorn (1994) conducted 22 intervals of sediment sampling in the Nan River from June 1992 to December 1992 for assessing the sediment transport rate in the Nan River. He found that the bed load to suspended load ratios varied from 1% to 2% (September–December 1992). Additionally, Chanyotha and Chatchawan (1995) studied sediment transport characteristics on the Mae Kok River in Chiang Rai Province, and their results indicated that the bed load is approximately 38% of suspended load. Therefore, considering bed loads as 30% of suspended loads may not be appropriate for all rivers of the Chao Phraya basin. River surveys during the flood of 2011, and one year after the flood, were necessary for assessing effects of the flood of 2011 on sediment discharge.

River surveys were carried out as part of this study to quantify river discharge, flow depth, flow velocity, suspended sediment, and bed load in the Ping, Wang, Yom and Nan rivers at Stations SP, SW, SY, and SN, respectively (Fig. 1). Field measurements were conducted on October 17–24, 2011 (during the Thailand Great Flood of 2011) and on October 15–20, 2012 (one year after the flooding).

Flow velocities were measured using an AEM1-D in-situ portable single-axis current meter which was designed for simple and