THE HYDROLOGICAL ROLE OF KHAO YAI NATIONAL PARK

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บทคัดย่อ

อุทยานแห่งชาติเขาใหญ่ นอกเหนือจากจะเป็นอุทยานแห่งชาติแห่งแรกของประเทศและเป็นมรดกสำคัญในการศึกษาด้านนิเวศวิทยาป่าไม้ของโลกแห่งหนึ่ง ซึ่งอุดมสมบูรณ์ด้วยพรรณไม้และสัตว์ป่านานาชนิด อันเป็นประโยชน์ต่อการทัศนศึกษาและพักผ่อนหย่อนใจของประชาชนทั่วไปแล้ว อุทยานแห่งชาติแห่งนี้ยังมีบทบาทสำคัญยิ่งต่อการเอื้ออำนวยน้ำต่อพื้นที่เกษตรกรรมและราษฎรโดยรอบ

การศึกษาบทบาททางอุทกวิทยาของอุทยานแห่งชาติเขาใหญ่ ในที่นี้ได้ดำเนินการภายใต้โครงการศึกษาระบบนิเวศน์ของเขาใหญ่ โดยคณะวนศาสตร์ ทั้งนี้ได้ใช้ข้อมูลน้ำฝน น้ำท่า และการเปลี่ยนแปลงการใช้ที่ดินในพื้นที่ลุ่มน้ำภายในอุทยานฯ ที่เก็บบันทึกไว้โดยกรมชลประทาน การพลังงานแห่งชาติ การไฟฟ้าฝ่ายผลิต และกรมป่าไม้ ที่บันทึกไว้ในช่วงปี พ.ศ. 2507–2529 จากพื้นที่ลุ่มน้ำทั้งหมด 13 ลุ่มน้ำ

จากการวิเคราะห์ลักษณะทางอุทกวิทยาของลุ่มน้ำต่าง ๆ ดังกล่าวพบว่า ขณะที่อุทยานแห่งชาติเขาใหญ่ยังมีป่าปกคลุมอยู่ 89 เปอร์เซ็นต์นั้น จะมีฝนตกเฉลี่ยทั้งพื้นที่ประมาณปีละ 1,600 มม. โดยจะให้น้ำท่าลงสู่ลุ่มน้ำตอนล่างรอบ ๆ เขาใหญ่ประมาณ 0.87 ล้าน ลบ.ม./ตร.กม./ปี ลุ่มน้ำใดที่ยังมีป่าไม้ปกคลุมมากกว่า 70 เปอร์เซ็นต์ขึ้นไปจะมีคุณภาพทางกายภาพดีกว่าลุ่มน้ำที่มีป่าเหลืออยู่น้อยกว่า สัดส่วนของน้ำท่าในช่วงฤดูน้ำหลากต่อฤดูแล้งเฉลี่ย 10 : 1 ลุ่มน้ำที่มีป่าเหลืออยู่น้อยจะมีน้ำไหลในช่วงฤดูแล้งน้อยกว่าลุ่มน้ำที่มีป่าอยู่มาก เนื่องจากน้ำส่วนใหญ่ได้หลากลงไปมากในช่วงฤดูฝน การเปลี่ยนสภาพป่าเพื่อทำการเกษตรและพัฒนารูปแบบต่าง ๆ บริเวณรอบ ๆ อุทยานเท่าที่ผ่านมา จะทำให้มีน้ำท่าลดน้อยลงประมาณ 47 ล้าน ลบ.ม. ทุก ๆ 10 เปอร์เซ็นต์ของพื้นที่ป่าในเขตอุทยานฯ ที่ถูกบุกรุก อย่างไรก็ตามตะกอนแขวนลอยที่พัดพามาจากพื้นที่ลุ่มน้ำในเขตอุทยานฯ ยังอยู่ในระดับต่ำคือประมาณ .05 มม./ปี

ABSTRACT

The hydrolgical role of Khao National Park as a function of watershed ecosystems was investigated using historical data of runoff and sediment discharges recorded during 1964 – 1986 by the Roayl Irrigation Department, National Energy Authority and Electricity Generating Authority of Thailand. The specific yield, seasonal distribution, water budget, flow timing (flow dates and flow intervals) including sediment yield and some physical water qualities contributed from eight catchments having their headwater source in Khao Yai National Park were analysed. Probable impacts of deforestation in those watersheds on flow magnitude, erosion and sedimentation were also attempted to determine. It was found that at the time of the study (1982) when Khao Yai was covered by 89 percent forest and average annual rainfall of 1600 mm,

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the runoff discharge was generated at 0.87 mcm/sq.km/yr. The catchments with less than 70 percent forest cover contained streams with higher values of pH, turbidity, color, electrical conductivity, total dissolved solids and hardness. The bulk of surface water from Khao Yai takes place during the rainy season (May to October) with peak flows from August to October. Overall, the ratio between wet and dry flows is 10 : 1. The basin with the least amount of forest cover was shown to have the shortest half – flow and quarter – flow intervals of all basins, indicating rapid runoff during high rainfall periods. Regression analysis indicated that for every 10 percent decrease in forest area of Khao Yai, runoff will decrease by about 47 mcm/yr. The present catchment erosion rates of Khao Yai average 0.05 mm/yr. (0.65 ton/ha/yr).

INTRODUCTION

In the past decades, the ecosystem of forested and agricultural land has been studied extensively in America, Europe, and in some Asian Countries. General and specific studies have reached the widely accepted conclusion that the understanding of ecosystem concepts can aid in developing plans for wiser and even more intensive use of the natural resources. Cooper (1969) stated that "an uncultivated watershed is an intergrated system that transforms precipitation, solar radiation, other environmental variables, labor and capital into wood products, livestock products, wildlife, recreational and esthetic satisfactions and water. The forest management subsystem, the grazing subsystem, the recreation use and development subsystem, and the water management subsystem interact to produce the vegetation, animal and soil conditions that govern the yield and quality of its products and services. The only level of ecological theory that can effectively guide management of such a complex system is a theory of ecosystem".

The term "ecosystem" was proposed by Tanslay (1935) as "a system resulting from the integration of all living and nonliving factors of the environment". Odum (1963) defined "ecosystem" as a basic functional unit of nature which includes both organisms and their nonliving environment, each interacting with the other and influencing each other's properties and both necessary for the maintenance and development of the system. Similarly, Vaissere (1972) explained that "an ecological system or ecosystem possesses its own organization which is represented by plant-animal groups in continual interaction and existing in a physico – chemical environment where exchange occurs".

In its fundamental aspects, an ecosystem involves the circulation, transformation and accumulation of energy and matter through the medium of living things and their activities. Photosynthesis, decomposition, herbivory, predation, parasitism and other symbiotic activities are among the principal biological processes responsible for the transport and storage of materials and energy. The interactions of the organisms engaged in these activities provide the pathways of distribution. In the nonliving part of the ecosystem, circulation of energy and matter is completed by such physical processes as evaporation, precipitation, erosion and deposition (Tansley, 1935). An ecosystem, then, may be visualized as a series of components, such as species populations, organic debris, available nutrients, primary and secondary minerals and atmoshperic gases, linxed together by food webs, nutrient flow and energy flow (Bormann and Likens, 1969).

In recent years, the watershed approach to the study of ecosystems is being used extensively in studying ecosystem. Cooper (1969) stated that "a watershed is occupied at any given time by a particular grouping of plants and animals." This is almost a rewording of the classic definition of an ecosystem. As such, a catchment of convenient size is useful for studying interactions among plants and animals and their nonliving environments.

Among three main functions of forest ecosystems, i.e., hydrologic cycle, nutrient cycling and energy flow, the hydrological function is the one that can be visualized by people not only in terms of its physical process but also its benefits contribute to people. It is thus the main aim of this paper to present herein the hydrological role of Khao Yai National Park.

Khao Yai National Park has been considered to be very essential forested ecosystems which was proposed to be one of the world heritage. Besides recognizing as the first national park in Thailand which is popularly known as a place for recreation and tourism, it is also a superative source of streamwater for downstream areas of the northeastern and eastern provinces. This paper intents to present the benefits of Khao Yai National Park in terms of its hydrological role to downstream people. The specific objectives are (1) to describe, in general, the benefits of Khao Yai National Park as a forest ecosystems. (2) to present its hydrological role in forms of the contribution on flow quantity, quality and regimen to the surrounding downstream areas and (3) to determine the impact of deforestation of this ecosystems on those hydrological characteristics.

It is hoped that the results obtained from this study could be a part of knowledge leading to ecosystem rehabilitation in the comming decades so that environmental condition not only in Thailand but also of the world be recieved more attention in better management and improvement which will be consequently beneficial to the quality of life of all mankinds.

KHAO YAI NATIONAL PARK
The Last Forest Resources in the Northeast-Central Region

The General View

Khao Yai, Thailand's first national park, is located at the southwest edge of the khorat Plateau in northeast Thailand (Figure 1). Its 2168 km^2 extend into four provinces: Prachinburi, Nakhon Nayok, Saraburi, an Nakhon Rachasima. Located about 160 km northeast of Bangkok, Khao Yai has been one of Thailand's most popular parks since its establishment in 1962 and is one of ten Asean Heritage parks and Reserves (NPD 1986).

It is located at the western edge of the Dongrek mountain range and most of its terrain is mountainous. Limestone peaks dominate its western side while the eastern side is primarily low, undulating hills. Evergreen forests cover most of the park along with smaller areas of deciduous forest and grassland. Average rainfall is more than 2000 mm per year, with most of this occurring during the rainy season from July to October.

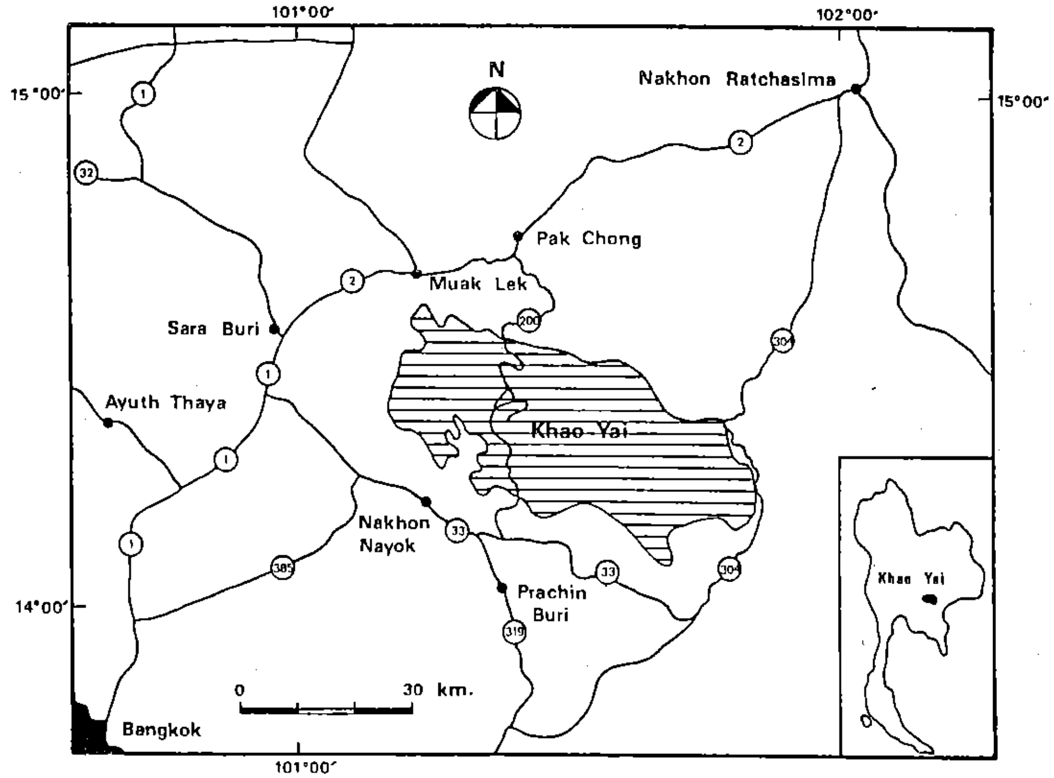

Figure 1. Location of Khao Yai National Park
Source : Santiapillai et al. (1987).

The northeast region of Thailand has the smallest proportion of forested area of any of the country's regions. Between 1961 and 1985, the region's percentage of forest declined from 42 to 14.4 percent (TDRI 1987). In the vicinity of Khao Yai, almost all forests outside of the national park system have been degraded or totally cleared for agriculture and settlements. Deforestation within Khao Yai is much lower than in the surrounding areas. However, even with its protected status, forest cover in Khao Yai decreased from 94 percent in 1961 to 85 percent of land area in 1985 (RFD various years).

Khao Yai provides a number of benefits both to the surrounding region and the nation. It is a premier tourist destination in the region with between 250,000 and 400,000 visits per year. Since it contains most of the remaining forest in the region, it is of critical importance for wildlife and also profoundly affects the hydrology of the region. Four major river basins have their headwaters in Khao Yai, and two major reservoirs are dependent on water from the park.

The main threats to Khao Yai are of human origin. Clearing of forests in side the park's border for agricultural land. Poaching of timber, wildlife, and other forest products degrade the park.

Benefits of Khao Yai National Park.

This part briefly describes the benefits of Khao Yai in particular to biodiversity, ecological processes and tourism.

Maintenance of Biodiversity and Ecological Processes

Khao Yai contains one of the largest remaining areas of rain forest in mainland Asia (Dobias 1982). More than 60 percent of the park is considered tropical rain forest (NPD 1986), mostly between the 400-m and 1000-m elevation level. This type of forest is multistoried with many epiphytes. Within this category, different stands contain quite different vegetation communities (Kasetsart University, 1982).

Dry evergreen forest is the second most common vegetation type, covering approximately 26 percent of the park. These forest, found mostly between the 100-and 400-m elevation level, occur in the west, north, and south of the park. Because of their valuable timber species, many have been disturbed by timber poaching (NPD, 1986).

Areas above 1000-m elevation are covered with hill evergreen forest. These forests only cover approximately 2.2 percent of Khao Yai's area. The National Parks Division (1986) has called for special protection of these areas. There are also small areas of dry, mixed deciduous forest. Only isolated patches of this forest type remain due to past disturbances.

Khao Yai's size and diversity of habitats make it a valuable storehouse of plant genetic diversity. MacKinnon and MacKinnon (1986) note that Khao Yai is considered a plant conservation priority site, the only such area in Thailand.

Overall, Khao Yai is estimated to have more than 2000 plant species (NPD, 1986). Cumberlege and Cumberlege (1964) reported finding 121 species of orchids in a series of visits between 1962 and 1963. Eighteen of these species had not been previously report in Thailand, and three were believed to be new species, previously unrecorded anywhere.

The diverse habitats harbor a rich variety of wildlife. More than 60 species of mammals live in the park including larger species such as elephant, tiger, gaur, serow, sambar deer, plieated gibbon, white-handed gibbon, and pig-tailed macaque. The park also contains 18 species of amphibians and 35 species of reptiles (Kasetsart University, 1982). For all of these species, the protected areas remain their last refuge in the area. Even within the park, few of the larger species are abundant outside of the headquarters area of the park due to widespread poaching (NPD, 1986).

Khao Yai is the only known area where the ranges of pileated and white-handed gibbons overlap. This zone of contact is considered an important research area, and the hybrid offspring between the two species are of great interest to scientists (Dobias, 1982; Brockelman, 1975). Borckelman, a professor at Mahidol University, goes as far as saying that Khao Yai could become the most important gibbon study area in the world.

Khao Yai is also considered a key site for forest bird preservation (Round, 1985). More than 295 species of birds have been recorded (NPD, 1986). This includes four species of hornbills--species that require large areas of mature forest to survive. As one of the largest protected areas in Thailand, Khao Yai provides the best chance for long-term survival of hornbills in the region.

Overall, Khao Yai's rich diversity of plants and animals makes it an important conservation area for maintenance of biological diversity. There are few places in Thailand

where such a large area of forest has remained intact. These few remaining reserves are critical to maintaining viable populations of wild species. Khao Yai may harbor a much as 10 percent of Thailand's total population of elephant, guar, tiger, and pileated gibbon (Kasetsart University, 1985).

Tourism

In addition to being the oldest national park in Thailand, Khao Yai is also one of the most popular and well-developed parks for recreation. Located approximately 3 hours away from Bangkok by car, Khao Yai attracts large numbers of both Thais and foreigners.

Tourism in Khao Yai has increased dramaticially during the last decade. Between 1977 and 1985 (the peak year), the number of visits tripled, reaching more than 460,000 in 1985. The number of visits has dropped in the last two years, but was still more than 400,000 in 1987. (Sherman and Dixon, 1989)

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The Headwater Sources

Khao Yai plays an extremely important role in regulating the water resources of the surrounding region. The headwaters of four major river basins are located within the park's boundary.

Figure 2 shows the location of the major watersheds in Khao Yai. The two watersheds on the western edge, Muag Lek and Huai Yai, are mostly outside of the park's boundaries and are not considered further. The remaining four watersheds--Prachin Buri, Lam Phra Phloeng, Lam Takhong, and Nakhon Nayok--are all of considerable importance.

The west are southwest part of Khao Yai contains the headwaters of the Nakhon Nayok River. Most of this watershed is located on the windward side of the park and has an average rainfall of 2350 mm/yr (Tangtham 1988). Three streams--Khlong Tha Dan, Khlong Nang Rong, and Khlong Wang Takhrai--originate in Khao Yai and merge just south of the boundary to form the Nakhon Nayok River. The Khlong Tha Dan Irrigation Project is located in this watershed.

The largest watershed in Khao Yai, the prachinburi, includes streams which eventually drain into the Prachinburi River. These streams include the Sai Yai River, Sai Noi River, and Lam Phraya Thun River, which flow into the Hanuman River, and Khlong Nong Kaeo which flows to the Prachantakham River. These rivers both flow into the Prachinburi River

In the northern part of the park on the leeward side of the mountains is the Lam Takhong watershed. This watershed covers a relatively small area of the park (201 km^2), and the water flows to the Mun River in Nakhon Ratchasima Province. There is a reservoir on the Lam Takhong River in Sikhiu District, Nakhon Ratchasima, approximately 166 km downstream from the headwaters of the river.

Another tributary of the Mun River, Lam Phra Phloeng, also originates in Khao Yai. Its watershed covers 114 km^2 in the northeast part of the park. There is also a reservoir on this river at Pak Thong Chai District, Nakhon Ratchasima, Approximately 60 km downstream from the headwater source.

At present, the major areas of forest loss are around the perimeter of the park though as

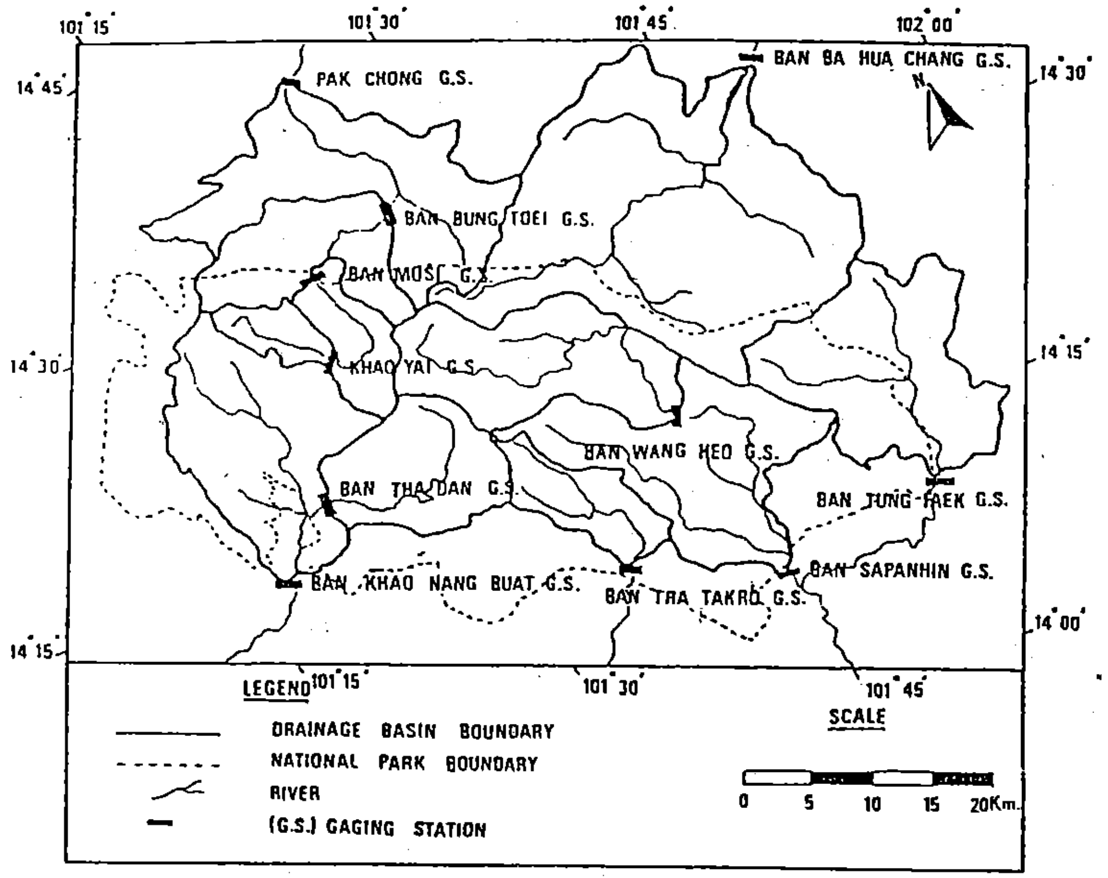

Figure 2. Location and drainage basins of Khao Yai National Park

time continues, deforestation is moving farther inward (NPD 1986). The areas suffering the greates losses in forest cover are in the northeast (from Pak Thong Chai District west to Pak Chong District), the southeast (Nadi District and Prachantakham District), the northwest (from Pak Chong District to Muak Lek District), and in the west (Khaeng Khoi District) (NPD, 1986).

The Hydrological Role Investigation

In order to evaluate the hydrological role of Khao Yai National Park, the following methods and procedures were employed.

1) The study area was divided into 3 main river basins namely: Nakhon Nayok River Basin, Prachinburi River Basin and Nam Mun Basin.

2) In each river basin, it was divided into subdrainage areas basing on availability of historic hydrometeorological record (Figure 2.)

3) The watershed areas within and outside the National Park boundary were separately measured for the purpose of estimating water yield contributed by National Park area and those by areas outside the National Park.

4) The historic-hydrometeorological data were mainly obtained from the reports published by Royal Irrigation Department (RID), National Energy Authority (NEA), and Electricity Generating Authority of Thailand (EGAT) including some parts from the Meteorological Department.

5) Monthly water--quality data were obtained from water samples taken at the eight assigned sampling stations from November 1981 to October 1982 (Tongtub, 1985). Some water-quality characteristics such as water temperature, pH and DO were measured at the sites. The duplicated water samples were taken and preserved and analysed immediately after the samples reached the laboratory in Bangkok.

6) Streamflow characteristics in the following categories were investigated and discussed:

(1) Water yields in terms of annual and seasonal flows.

(2) Specific yield-the volume of annual stream-flow per unit area of drainage basin (mcm/sq.km) and runoff potential-the ratio of annual runoff and mean annual basin rainfall (in percent).

(3) Monthly and seasonal distribution of runoff of each drainage area.

(4) Water budget of each drainage area and for the Khao Yai National Park area.

(5) Regression models of the runoff-rainfall relationships for each drainage area.

(6) Regression equation for predicting deforestation effect on runoff discharge.

(7) Streamflow timing in terms of half-flow dates, half-flow intervals, quarter-flow dates and intervals for each drainage area.

(8) Impact of forest destruction on suspended sediment yield.

Rusults of Investigation:

Results of this investigation are divided into 3 parts

PART I: The Role on Water Quantity Contribution

I-1: Water Contributed to Downstreams

The summary of mean annual runoff discharge, seasonal flow and specific yield for all drainage basins employed in this study are shown in Table 1. and can be briefly described as follows:

1) The average annual rinfall over drainage areas where their head-watershed originate in Khao Yai National Park ranged from 1300 mm for Nam Mun Basin to 4000 mm at the upstream of Nakhon Nayok River basin. The areal weighted average of annual rainfall over these drainage basins is about 2000 mm.

2) Generally the Nakhon Nayok and Prachinburi River Basins which locate on the windward side of Khao Yai National Park have higher annual rainfall than the Lam Thakong and Lam Phra Phloeng watershed which locate on the leeward side.

The mean annual rainfall of the windward basins, the Nakhon Nayok and Prachinburi are 2,351 and 2,337 mm respectively. The Mun River Basin which locates in the leeward side has about 1900 mm of annual rainfall.

3) By average, runoff of about 1680 mm (or 70% of annual rainfall) for Nakhon Nayok Basin and about 845 mm (or 40% annual rainfall) for Prachinburi Basin are also greater than that of 426 mm (or about 25% of rainfall) of the Nam Mun Basin. On the contrary the evapotranspiration (Et) calculated for both of the windward basins are less than that of

Table 1. The hydrological characteristics of Khao Yai National Park : Mean annual runoff discharge, seasonal flow and specific water – yield for drainage basins within and around Khao Yai National Park

River Basin and Watershed Name	Drainage Area in sq.km.	Annual Basin Rainfall, mm	Mean Runoff Discharge: Annunal Flow – Volume mcm	Volume mm	Yield mcm/km^2	% Runoff Rainfall	Wet Flow mcm	Wet Flow %	Dry Flow mcm	Dry Flow %	Period of Runoff Record
Nakhon Nayok Basin :											
– Tha Dan Catchment	192	2652	357	1859	1.86	70	345	97	12	3	1965–78
– Khao Karieng	520	2051	779	1498	1.50	73	766	98	13	2	1973–80
Prachinburi Basin :											
Sai Yai Tributary at											
– Ban Wang Heo	314	2328	260	828	0.83	36	241	93	19	7	1965–71
– Ban Saphan Hin	636	2387	581	914	0.91	38	542	93	39	7	1963–80
Lam Phaya Thun at											
– Ban Tung Faek	366	2006	141	385	0.39	19	132	94	9	6	1966–86
Phrachunthakham at											
– Ban Tha Takro	121	2627	164	1355	1.36	52	158	96	8	4	1971–85
Nam Mun Basin :											
Lam Phra Phloeng at											
– Ban Bu Hua Chang	822	2000	122	148	0.15	7	144	94	8	6	1955–64
Lam Tha Kong at											
– Khao Yai	60.5	2070	46	755	0.75	36	41	89	5	11	1964–76
– Ban Musi	235	2127	118	502	0.50	24	101	86	17	14	1965–83
– Ban Bung Toi	329	1303	156	473	0.47	36	133	85	23	15	1964–76
– Pak Chong	699	1584	215	307	0.31	19	165	77	50	23	1970–86
Weigted average by drainage area	–	2021	–	–	0.68	32	–	91	–	9	–

the leeward basins. The Et of these three basins i.e., Nakhon Nayok, Prachinburi and Nam Mun are 695, 1492 and 1519 mm which is equivalent to about 30, 60 and 75% of annual rainfall respectively.

4) The Tha Dan Basin in the windward side containing 97% of forest cover has the highest specific yield of runoff (1.86 million cubic meters, mcm, per sq.km) while the Bu Hua Chang watershed in the leeward side which having only 22% of forest cover has only 0.15 mcm/sq.km of specific yield. The weighted average of this parameter was calculated at 0.68 mcm/sq.km (Table 1).

5) In general, peak flow occurs during the month of August, September and October depending upon topographic location (windward or leeward side) forest coverage and land use practices. About 77 to 98 percent of total annual runoff occurs in the wet season (May to October), the rest of 2 to 26 percent occurs in the dry season. By average the wet flow-dry flow ratio is about 10 : 1 for the streamflow from Khao Yai National Park.

I-2: Effect of Forest Conversion on water Quantity

1) The study of effect of topography and landuse on water balance of Khao Yai National Park (Kaeochada, 1984) indicated that deforestation has caused the higher water loss especially in the area converted from forest land to agricultural practices. For instance, the Nakhon Nayok Basin which was covered by 97% of forest has only 30% of water loss (evapotranspiration and leakage) from the basin while about 81% of water loss has been observed for the Lam Phraya Thun Basin which locates in the same windward side and covered by only 63% of forest (see also Table 2).

2) In order to abtain quantitative impact of land use change on amount of water downstream, the multiple regression analysis based on the historical runoff discharge and annual rainfall which were recorded during 1966 to 1980 together with existing forest and drainage area was determined to find out their ralationships (Ruangpanit and Tangtham, 1982). The equation and its statistical parameters are:

$$RD(mcm) = -905.63 + 0.9627DA + 0.2099RAIN + 4.5856EFA;$$

$$R^2 = 0.6129,$$

$$\text{multiple } R = 0.7829$$

$$\text{with F-ratio} = 36.42$$

where

RD = predicted annual runoff discharge in million cubic meters (mcm),

DA = drainage area in sq.km,

RAIN = observed basin average of annual rainfall in mm,

EFA = existing forest cover in the basin, in percent of total drainage area,

R^2 = Coefficient of determination.

Although regression analysis resulted in not very high of R^2, this statistical parameter and the positive coefficient of EFA indicate some effect of forest destruction on downstream flood. In general, it can be said for all drainage areas within and around Khao Yai National Park that conversion of forest landuse into conventional agricultural practices has resulted in decreasing annual flow downstream. The magnitude of impact depends upon the drainage area, topographic effect, amount of annual rainfall and type of agricultural practices. The decreasing annual flow downstream runoff is perhaps

Table 2. Land use patterns and water budget of all basins around Khao Yai National Park.

River Basin	Land Use Pattern, km² [1]							Water Budget (mm)		
	Area within Khao Yai	Area out of Khao Yai	Total Area	Reservoir Area	Agricultural Area	Grass Land	Forest Land' 81	Annual Rainfall	Annual Runoff	Annual Et
1. Nokhon Nayok River Basin										
Ban Khao Nang Buat	481.88	37.12	519.0	–	36.49	9.44	473.07	2,050	1,500	500
	(92.85)	(7.15)			(7.03)	(1.82)	(91.15)		(73)	(27)
Ban Tha Dan	192.00	–	192.0	–	0.62	4.97	168.41	2,652	1,859	840
	(100)				(0.32)	(2.59)	(97.09)		(70)	(30)
2. Prachinburi River Basin										
Sai Yai at Ban Wang Heo	314.00	–	314.0	–	–	–	–	2,328	829	1,499
	(100)								(36)	(64)
Sai Yai at Ban Saphan Hin	632.08	3.92	636.0	–	2.62	5.89	627.49	2,387	925	1,462
	(99.38)	(0.62)			(0.41)	(0.93)	(98.66)		(39)	(61)
Lam Phaya Than at	155.17	214.83	366.0	–	138.98	5.13	221.89	2,006	384	1,622
Ban Tung Faek	(41.30)	(58.70)			(37.97)	(1.40)	(60.63)		(19)	(81)
Prachantakham at	121.00	–	121.0	–	12.81	1.42	106.77	2,627	1,240	1,387
Ban Tha Takro	(100)				(53)	(10.59)	(1.17)		(88.24)	(47)
3. Mun River Basin										
Lam Phra Phleong at	123.43	698.57	822.0	7.48	628.28	1.87	184.37	2,000	148	1,852
Ban Bu Hua Chang	(15.02)	(84.98)		(0.91)	(76.43)	(0.23)	(22.43)		(7)	(93)
Lam Takhong at Pak Chong	220.53	478.47	688.0	–	452.80	13.55	232.65	1,633	327	1,306
	(31.55)	(68.45)			(64.78)	(1.94)	(33.28)		(20)	(80)
Lam Takhong at Ban Bung Toei	192.71	136.29	329.0	–	123.61	13.31	192.08	1,830	425	1,405
	(58.57)	(41.43)			(37.57)	(4.05)	(58.38)		(23)	(77)
Lam Takhong at Ban Musi	220.53	14.47	235.0	–	54.89	13.31	166.80	2,127	474	1,666
	(93.84)	(6.16)			(23.36)	(5.56)	(70.98)		(22)	(78)
Lam Takhong at Khao Yai	60.50	–	60.50	–	–	5.65	54.85	2,071	755	1,364
	(100)					(9.34)	(90.66)		(36)	(64)

1 Obtained from Markov's Chain Model based on land use data from Landsat Imageries detected in 1965, 1976, and 1981. Figures in parentheses are areal distribution in percent.

due to the higher loss of water diverted from stream channels and stored for horticultural and agronomic purpose.

3) Since statistical parameters of the derived equations show highly significant impact of land-use change in the study area, the equations are therefore applied for predicting impact of forest destruction on downstream flood for Khao Yai National Park, It can be interpreted based on the equation that for every 10 percent decrease in forest area for Khao Yai National Park, runoff discharge produces by this area will decrease about 1.5 cms (or about 47 mcm/annum). At present (1985) when existing forest area is about 1918 sq.km or about 89% and given basin average of annual rainfall about 1600 mm/yr. the runoff discharge produced by Khao Yai National Park is about 2000 million cubic meters per year (cal. at 1993 mcm/yr).

PART II: The Role on Flow Regimen

Background and Definition

In order to evaluate the impact of land use evolution within and around the Khao Yai National Park on flow regimen, streamflow timing defined by Court (1961, 1962), Saterlund and Eschner (1965), and Sopper and Lull (1970) is employed in this study.

According to the previous literatures, indicator of streamflow timing can be categorized into two main parameters, i.e., the "Flow Dates" and the "Flow Intervals". The first one can be defined as the date on which a given flow volume of a year has passed and it can be further designed as:

Half-flow date (HFD):-The date on which half of the streamflow of a year has passed.

First (1QFD) and Third (3QFD) quartile flow dates-A dates on which one-fourth (1/4) and three-fourth (3/4), respectively, of the year's flow has passed.

For the "Flow interval" parameters it was defined as the shortest number of consecutive days that accounts for high flow and the longest number of consecutive days that accounts for low flows.

The "high-flow intervals" in this study are defined as follows:

Half-flow interval (HFI):-The shortest rainy season period that includes one-half of the annual runoff.

Quarter-flow interval (QFI):-The shortest rainy season period that includes one quarter of the annual runoff.

For "low flows", runoff-flow intervals can be defined for this study as follows:

Five percent-flow interval (5FI):-The longest period, usually in dry season, that accounts for 5 percent of annual flow.

One percent-flow interval (1FI):-The longest period, mainly in dry season, that accounts for one percent of annual flow.

II-2: Method of Determination

Since the change of flow dates and flow-intervals can be altered by various factors such as the month that highest rainfall occurs, the amount of annual rainfall, amount of rainfall in each month and the changes of land use within the watershed, variations of momentary peak date, half-flow dates and any particular flow interval are therefore difficult to detect which factor or factors significantly affected on. The study on the impact of land use changes on streamflow timing here thus based on the assumption that within a given period of consecutive years, e.g., 5 year period, i.e., the average of flow volumes of each of those given periods can be assumed

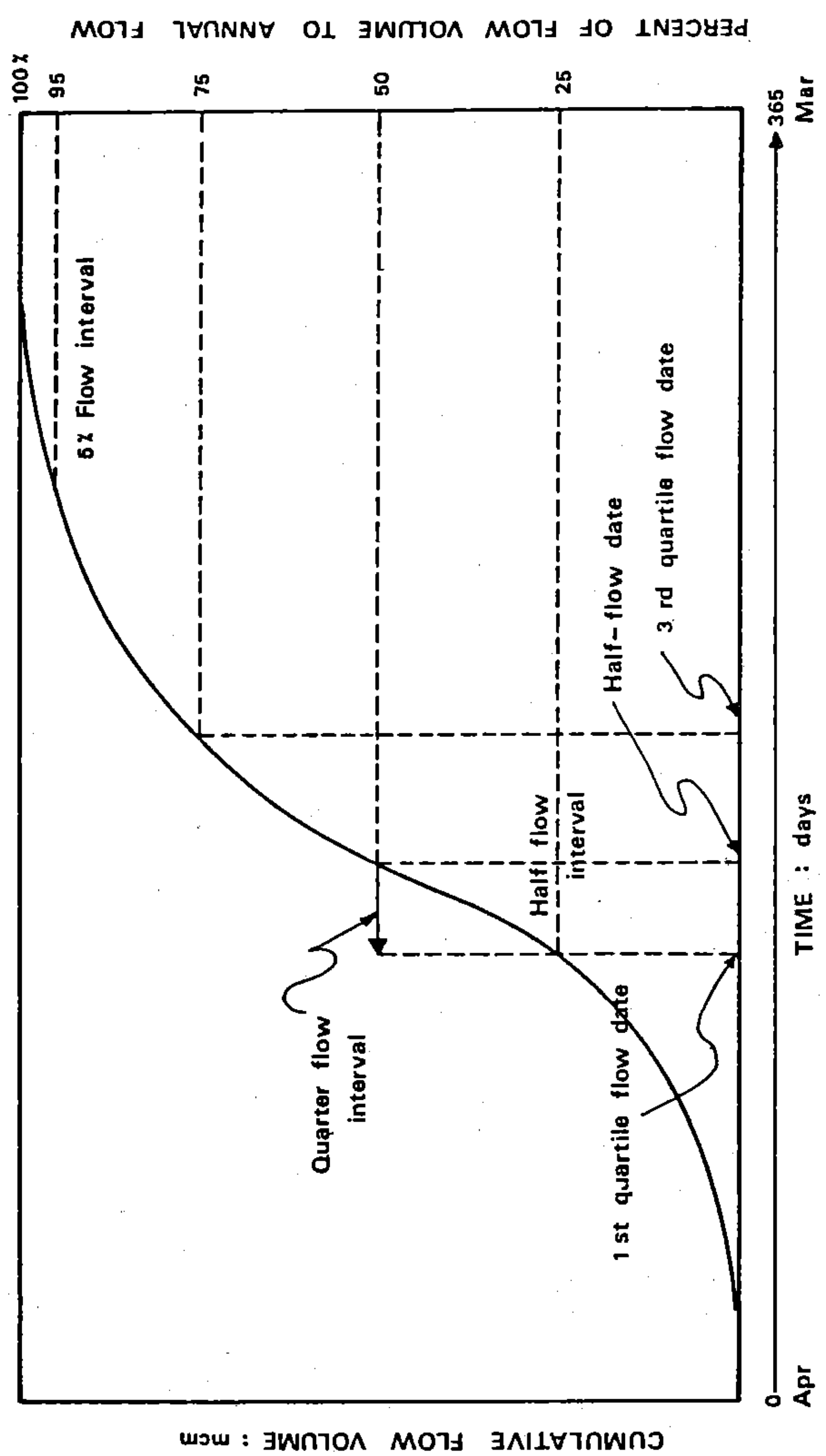

Figure 3. Hypothetical curve of cumulative flow volume for deriving streamflow timing parameters

Table 3. Streamflow regimen indicated by "flow dates" and "flow intervals" of given flow volume in water-year basis for watersheds within and around Khao Yai National Park

Name of River Basin and Studied watersheds	Basin annual rainfall mm	Existing forest area %	Flow Interval, days			Flow Dates, date of Year			Given period of flow regimen
			QFI	HFI	5FI	1QFD	HFD	3QFD	
Nakhon Nayok Basin :	–	100	24	49	197	119	144	168	1958–1960
– at Ban Tha Dan	–	100	18	41	218	106	124	147	1961–1965
(192 sq.km)	2732	99	22	54	204	107	129	161	1966–1970
	2570	97	32	69	184	112	114	181	1971–1975
		96	26	60	198	107	133	167	1976–1977
– at Khao Karieng	–	96	26	54	184	127	153	181	1955–1960
and									
Khao Nang Buat	–	95	36	76	179	110	146	186	1961–1965
(520 sq.km)	2054	93	28	64	188	113	141	177	1966–1970
	2048	91	31	68	186	111	142	179	1971–1975
	–	90	28	60	194	111	139	171	1976–1980
Prachinburi Basin :									
– Nam Sai Yai at									
Ban Saphan Hin	–	100	32	70	176	119	157	189	1964–1965
(636 sq.km)	2340	99	23	53	191	121	144	174	1966–1970
	2436	98	28	61	182	122	150	183	1971–1975
	–	97	25	61	182	122	147	183	1976–1978
– Lam Phaya Thun at	1969	99	18	36	195	131	152	170	1966–1970
Ban Tung Fack	2043	87	29	58	179	128	157	186	1971–1975
(366 sq. km)	2028	82	26	52	185	128	154	180	1976–1979
– Prachuntakham	2558	90	24	48	202	115	139	163	1971–1975
at Ban Tha Takro	2194	85	20	44	203	118	138	162	1976–1979
(121 sq.km)									
Mun River Basin :									
– Lam Takhong	2044	88	22	77	183	105	127	182	1966–1970
at Khao Yai	2098	89	31	70	171	124	163	194	1971–1975
(60.5 sq.km)									
– Lam Takhong at	2100	94	34	74	185	106	146	180	1966–1970
Ban Mu Si	2163	70	30	69	176	120	159	189	1971–1975
(235 sq.km)	–	65	37	75	171	119	156	194	1976–1980
– Lam Takhong at	1779	98	40	86	172	107	153	193	1964–1965
Ban Bung Toi	1881	90	41	86	173	106	147	192	1966–1970
(329 sq.km)									
– Lam Takhong at	1633	35	33	70	153	142	179	212	1971–1975
Pak Chong	–	30	43	89	151	125	171	214	1976–1980
(699 sq.km)									
– Lam Phra Phloeng			35	76	163	126	167	202	1955
at Ban Bu Hua Chang			10	27	166	172	189	199	1956–1960
(822 sq.km)			25	60	159	146	181	204	1961–1964

Notes :

Table 4. Mean annual of approximated flow timing in terms of flow intervals in relation to forest cover and drainage area of studied watersheds

Name of Watershed	Drainage area	Existing forest area	Flow Intervals, days			Flow Date, date of water year		
	sq.km	%	quarter flow	half flow	5% flow	1st quarter flow date	half flow date	3rd quarter flow date
Forested watersheds :								
– Nam Sai Yai at Ban Saphan Hin	636	98.7	28	59	186	120	148	179
– Lam Si Sook at Ban Tha Dan	192	97.1	26	58	204	103	129	161
– Nakhon Nayok at Khao Nang Buat	520	91.2	31	66	189	110	141	176
– Lam Takong at Khao Yai	60.5	90.7	35	75	176	114	153	189
– Prachuntakham at Ban Tha Takro	121	88.2	21	61	184	122	141	181
– Lam Takhong at Ban Musi	235	71.0	37	77	176	112	149	189
Average for forested watersheds	–	–	29.7	49.5	185.8	113.5	143.5	179.2
Agricultural watersheds :								
– Lam Phaya Thun at Ban Tung Fack	366	60.6	26	56	187	112	148	158
– Lam Takhong at Ban Bung Toei	329	58.4	37	74	178	113	150	187
– Lam Takhong at Pak Chong	699	33.3	36	84	152	129	146	213
– Lam Phra Phloeng at Ban Bu Hua Chang	822	22.4	36	78	171	156	191	204
Average for agricultural watersheds	–	–	33.7	73.0	171	12.5	158.7	190.5

to be treated by the same rainfall characteristics. Only the changes in land use within a given period is then presumed to be a main factor causing the change in streamflow timing.

With the above assumption, cumulative flow volume of each month is calculated starting with April as the first month of the water-year. Cumulative flow volume of the last month (March) is assigned as 100 percent. Cumulative flow-volumes of each month average for the given period (generally 5 yr--period in this study except any of particular one that its consecutive years is less than 5) are then plotted in graphic paper. Lines representing cumulative values of each period are adjusted for determining flow dates and flow--intervals. The method of deriving those streamflow timing is illustrated in Figure 3. Mean annual flow intervals and flow dates were calculated for given periodical intervals and for the whole recording periods of each drainage basin are shown in Table 3 and Table 4.

II-3: The results

In general, streamflow timing intervals for each studied watershed can be briefly described as follows:

1) High-flow Intervals:

The mean and range of high-flow intervals for three main river basins are given in Table 3. High-flow intervals of Nakhon Nayok Basin are almost the same as that of Prachinburi Basin but much more concentrated in watersheds locate in the windward side than the leeward side of Lam Takhong Basin. Lam Phra Phloeng has quite different flow-interval patterns from those mentioned basins. On average, halflow interval was as much as 18 days shorter in the Nakhon Nayok Basin and Prachinburi Basin than the Nam Mun Basin excepts in the Lam Phra Phloeng where its half-flow intervals is about 48 days-the shortest among watersheds in studied area.

For the quarter flow interval, watersheds in the windward side have about 8 to 10 days shorter than the leewardside basins. Lam Phra Phloeng where having the lowest percentage of forest cover again shows the shortest quarter-flow interval, i.e., 23 days.

2) Low-flow Intervals:

The longest interval for 5-percent (about 197 days on average) occurred in all studied drainage areas of Nakhon Nayok Basin, followed by watersheds in Prachinburi Basin (about 185 days) and the shortest on (~171 days) in watersheds of Lam Thakong Basin. As expected, Lam Phra Phloeng, where it had lowest percentage of forest cover, has the shortest 5 percent flow interval among the Mun Rive Basin.

3) Streamflow Timing in Relation to Lan-use Changes:

Based on the relevant data of flow timing in concurrence of land use changes, variation of annual rainful and the difference in drainage area as shown in Table 3, the regression analysis using stepwise method yielded the following equations:

When annual rainfall in each drainage area is treated as low variation among the given periods, i.e., only percentage of existing forest area (EFA) and the size of watershed or drainage area (DA) were considered as factor influencing flow regimen, the following results are obtained:

Flow timing parameters and equation derived by stepwise analysis :	R^2	R	F-ratio
QFI = 49.43 - 0.0098 RAIN	0.19	-.44	3.75
HFI = 105.94 - 0.0498 RAIN	0.17	-.41	3.41
5FI = 117.58 + 0.031 RAIN	0.47	+.69	14.46
1QFD = 153.39 - 0.407 EEA	0.35	-.59	8.79
HFD = 195.38 - 0.538 EFA	0.44	-.66	12.55
3QFD = 247.42 - 0.031 RAIN	0.47	-.69	14.46

Flow timing parameters and equation derived by stepwise analysis :	R^2	R	F-ratio
QFI = no variable meets criteria			
HFI = no variable meets criteria			
5FI = 137.99 + 0.53 EFA	0.39	+.62	10.04
1QFD = 153.39 - 0.407 EFA	0.35	-.59	8.79
HFD = 195.38 - 0.538 EFA	0.44	-.66	12.8
3QFD = 227.01 - 0.523 EFA	0.39	-.62	10.4

Parameters and Equations	R^2	R	F-ratio
QFI = 39.53 - 0.116 EFA	0.30	-0.55	3.39
HFI = 85.80 - 0.239 EFA	0.42	-0.64	5.82
5FI = 154.28 + 0.366 EFA	0.53	+0.73	9.06
1QFD = 147.66 - 0.401 EFA	0.54	-0.73	9.31
HFD = 178.77 - 0.410 EFA	0.49	-0.69	7.32
3QFD = 212.70 - 0.407 EFA	0.42	-0.65	5.81

Again, when the mean annual of approximated flow-timing parameters in relation to the most recent forest cover of each watershed as shown in Table 4 was analysed by stepwise regression analysis, the influence of forest cover on flow-timing was indicated as follows:

Regarding the dynamic factors influencing flow regimen of watersheds within and around Khao Yai National Park, regression analysis indicates that annual rainfall is a main factor that meets statistical criteria in explaining flow regimen. Only two streamflow timing parameters, i.e., first quarter flow-date and half-flow date are affected by forest cover.

If the drainage area (DA) and existing forest cover (EFA) are considered as factors influencing flow timing, only EFA meets statistical criteria for explaining 5FI and all flow-date parameters. The general equation derived for representing the effect of EFA on streamflow timing also indicates significant role of EFA on almost all flow-timing parameters excepts QFI and HFI. The equations indicate that besides the 5 percent flow interval, forest cover and annual rainfall decrease the flow

intervals and flow-dates due to the negative sign in the coefficeint of parameter RAIN and EFA.

One may be interested in 5FI in which it should be the only parameter that could be affected by RAIN and EFA because of its prime importance in supplying summer flow. Prediction equation for 5FI in all cases indicates that EFA and RAIN increase longer interval of this low-flow parameter. It could be said that the greater portion of forest cover in the watershed and higher amount of rainfall the longer 5% flow-interval is occurred.

PART III: The role on Water Quality

III-1: Streamflow Sediment Observation

Although there are 13 streamflow gaging stations installed in and around Khao Yai National Park, only seven of drainage areas namely : Tha Dan at Ban Khlong SiSook, SaiYai at Ban Saphan Hin, Lam Phraya Thun at Ban Tung Faek, Lam Phra phloeng at Ban Bu Hua Chang, Lam Takhong at Khao Yai, Lam Takhong at Pak Chong and Lam Takhong at Damsite observed the suspended sediment discharge. The streamflow sediment measured at different period of the mentioned stations is thus employed to determine the role of Khao Yai National Park on sediment contribution. The measured suspended sediment yield and estimated erosion rate of each basin are shown in Table 5.

III-2: Sediment Yield and Erosion Rate

The observed suspended sediment and calculated sediment yield data in Table 5 indicate that the mean annual suspended sediment produced by watershed within and around Khao Yai National park is about 48 tons per sq.km. The sediment yield or total sediment load, which is estimated based on the assumption that bed load is about 30% of annual suspended sediment and sediment density is equivalent to 1.303 tons/cubic meter, equals to about 65 tons/sq.km or equivalent to the catchment area erosion rate of about 0.05 mm/yr. This amount is quite low compared to those watersheds in the North and the South of Thailand.

III-3: Impact of Land-use Change on Sediment Discharge

Based on the historical records of runoff discharge and suspended sediment data together with estimated precentage of existing forest areas as shown in Table 5, a regression equation representing relational function between annual suspended sediment (ASS in tons) and drainage area (DA in sq.km), annual rainfall (RAIN in mm), mean annual runoff discharge (RD in cms) together which percent of existing forest area (EFA, %) of each year was derived for the purpose of landuse impact determination. The equation is:

$$ASS = e^{(1.714 + 0.0118RD + 0.003DA + 0.0015RAIN + 0.0321EFA)}$$

with

$r_{ASS.RD} = 0.73$; $r_{ASS.DA} = 0.66$

$r_{ASS.RAIN} = 0.53$; $r_{ASS.EFA} = 0.58$

and multiple R = 0.80

Table 5. Sediment yield and basin erosion rate estimated from available data of study watershed

Name of watershed :	Drainage area sq.km.	Recorded period	Existing forest cover,%	Mean annual suspended sediment, tons	Estimated annual bed load[1] tons	Sediment yield Total load[2] tons/yr	Sediment yield Total load[2] tons/km^2/yr	Erosion[3] rate mm/yr
Nakhon Nayok River Basin :								
– Tha Dan at Ban Khlong Si Sook	192	1967–1971	99–97	21,315 (111)	6,394	27,709	144	0.14
Prachinburi River Basin :								
– Sai Yai at Ban Saphan Hin	636	1967–1975	99–98	28,963 (46)	8,687	37,654	59	0.05
– Lam Phaya thun at Ban Tung Fack	366	1967–1983	100–50	21,726 (59)	6,578	28,244	77	0.06
Mun River Basin :								
– Lam Phra Phloeng at Ban Bu Hua Chang	822	1957–1963*	22	43,164 (53)	12,949	56,118	68	0.05
– Lam Takhong at Khao Yai	60.5	1967–1975	87–90	1,562 (26)	469	2,031	36	0.03
– Lam Takhong at Pak Chong	699	1978–1985	34–25	36,121 (52)	10,836	46,957	67	0.05
– Lam Takhong at Ban Khlong Phai	1,293	1962–1966**	20	41,238	12,371	53,609	42	0.03
Areal weighted average		–	–	35,552 (48)	–	–	65	0.05

Notes :
1 Bed load is assumed to be about 30% of annual suspended sediment (EGAT, 1982)
2 Equals mean annual suspended sediment + estimated annual bed load
3 sediemnt density is assumed equivalent to 1.303 tons/m^3 (EGAT, 1982)
* Lam Phra Phlong Reservoir operated in 1970
** Lam Takhong Reservoir operated in 1969

Table 6. Water quality in relation to forest coverage and flow quantity of watersheds originated in Khao Yai National Park.

Name of Watershed	Drainage area (sq.Km)	% For (EFA)	Mean specific yield mcm/km^2	Temp. (°C)	DO (mg/l)	pH	Turb (JTU.)	Color (unit)	EC μmoh/cm	TDS mg/l	Acid mg/l $CaCO_3$	Alka mg/l $CaCO_3$	Hard mg/l $CaCO_3$
				Annual average of water quality parameters									
1. Nam Sai Yai – Ban Saphan Hin	636	98.7	0.91	25.9	6.7	6.2	9.6	31.4	28.2	19.4	9.6	9.6	10.1
2. Lam Si Sook – Ban Tha Dan	192	97.1	1.86	24.8	7.8	6.9	14.9	41.2	46.8	31.2	9.8	20.1	15.4
3. Nakhon Nayok – Khao Nang Buat	530	91.2	1.50	25.3	6.7	6.7	16.2	50.4	48.3	32.2	9.3	18.2	15.7
4. Lam Takhong – Khao Yai	60.5	90.7	0.75	21.3	6.1	6.5	15.2	56.3	47.2	31.4	11.1	17.4	10.5
5. Prachantakham – Tha Takro	121	88.2	1.36	–	–	–	–	–	–	–	–	–	–
6. Lam Takhong – Mu Si	235	71.0	0.50	22.5	6.9	7.0	17.5	54.7	58.2	38.8	10.2	16.5	17.0
Average for forested watershed	–	–	1.15	23.9	6.8	6.7	14.7	35.9	45.7	30.6	10.0	16.4	13.7
7. Lam Phaya Than – Tung Fack	366	60.6	0.39	25.7	6.0	7.6	55.8	173.8	184.9	123.3	13.7	84.0	77.6
8. Lam Takhong – Bung Toei	329	58.4	0.47	–	–	–	–	–	–	–	–	–	–
9. Lam Takhong – Pak Chong	699	33.3	0.31	24.4	7.9	8.1	18.6	66.3	381.8	254.5	10.9	178.7	162.3
10. Lam Phra Phloeng – Ban Bu Hua Chang	822	22.4	0.15	24.9	7.2	8.3	74.6	253.4	359.3	239.4	19.3	134.1	136.7
Average for agricultural watershed	–	–	0.33	25.0	7.0	8.0	49.7	164.5	308.7	205.7	17.9	132.3	125.5
RATIO between Forest and Agric. Watershed :			3.5 : 1	1 : 1.04	1 : 1.03	1 : 1.9	1 : 3.4	1 : 4.6	1 : 6.7	1 : 6.7	1 : 1.8	1 : 8.1	1 : 9.2

Statistical analysis indicated that all parameters exist in the equation have positive impact on suspended sediment yield. However the T-test indicates insignificant effect EFA on ASS exceptes those three parameters, i.e., RD, DA and RAIN. It might be possible that forest cover in the range of 70 to 80 percent of drainage area can maintain equally of watershed ecosystem in controlling erosion and downstream sedimentation. The data of ASS employed in this study were available only in the watersheds that have forest cover greater than 80 percent. The equation obtained herein is therefore not recommended for future prediction.

It could be however interpreted that ASS produced by watersheds of Khao Yai National Park sofar was dependent on the magnitude of streamflow power rather than the effect of forest destruction. That is the greater the streamflow power the large the amount of ASS be produced by Khao Yai Watershed.

III-4: Impact of Land-use on Physical Water Quality

The study was carried out by Thontab (1985) under the Khao Yai Ecosystem project. Numbers of watershed employed in this study were the same as that used in studying stream water quantity. The purpose of study was to determine the impact of land use practices in watershed on water quality such as temperature, DO, pH, turbidity, color, electrical conductivity (EC), total disolved solid (TDS), acidity, alkalinity and hardness. To meet the objectives, five watersheds having forest cover more than 70% are considered as forested watershed. Those remaining watersheds with 22 to 60 percent forest cover were classified as agricultural watershed. Stream water of these selected watersheds as their names listed in Table 6 was randomly sampled during Novermber 1981 to October 1982 and laboratory analysed immediately after sampling.

The summary of investigation is shown in Table 6. In general, it can be concluded that the water temperature difference was rather small ranging from 21.3 to 25.9°C. The DO in all selected watersheds range from 6.0 to 7.9 mg/l. The average values of pH, turbidity and color of water range from 6.2-8.3; 9.6-74.6 J.T.U.; and 31.4-253.4 units respectively. The EC ranges from 28.2 umhos/cm at Sai Yai (98% forest cover) to maximum of 526.6 umhos/cm at Lam Takhong at Pak Chong (33% forest cover). The TDS, acidity, and alkalinity in all studied watersheds range from 19.4 to 254.5 mg/l, 9.3 to 23.9 mg/l as $CaCO_3$ and 9.6-128.7 mg/l as $CaCO_3$ respectively. The water in the streams of these watersheds can be classified as a soft to moderate hard water as their average hardness range from 10.1 to 162.3 mg/l as $CaCO_3$.

The results confirm that watersheds in Khao Yai National Park and its vicinity which most of the land were covered less than 70 percent of forest (agricultural watershed) such as Lam Phaya Thun, Lam Phra Phloeng and Lam Takhong at Pak Chong have the higher values of pH, turbidity, color, EC, TDS, acidity alkalinity and hardness. In the contrary, the rest of studied watersheds whereas most of the land still cover with dense forest (minimal disturbance from agricultural activities) are normally low in value of those mentioned parameters. It could be said that the ratios of water temperature, DO, pH, turbidity

color, Ec, TDS, acidity, alkalinity and hardness between forested watershed and agricultural watershed are 1:1.04, 1:1.03, 1:1.2, 1:3.4, 1:4.6, 1:6.7, 1:6.7, 1:1.8, 1:8 and 1:9 respectively.

An attempt to determine the impact of forest conversion of these watersheds on those water quality parameters was also done by using simple regression analysis. The relation between the mentioned water quality parameters and percentage of existing forest area was analysed. The resulted equations are as follows :

There is insignificant effect of land use change on water temperature and DO. The decrease of forest cover tends to significantly increase in pH, turbidity, color, EC, TDS, acidity, alkalinity and water hardness.

These results indicate the adverse effects of changing land use from forest land to agricultural land on stream water quality. However, water quality produced by the studied watershed was not seriousely contaminated and is still acceptable for public water supply and usages.

SUMMARY AND CONCLUSION

The investigation on the hydrological role of Khao Yai National Park as a part of ecosystematic function was carried out using historic-hydrometeorological data during 1961 to 1986 collected by RID, NEA and EGAT together with the recent forest map and water quality observation. The results can be summarized as follows:

1) The windward side of Khao Yai National Park recieved higher rainfall than the leeward side. The annual rainfall ranged from 1300 mm at the leeward uplands to 4000 mm at higher altitudes of windward side.

2) The runoff coefficient indicating percentage of rainfall becomes runoff ranged from 23 in the leeward side to 70 in the windward side.

3) Peak flow of all basins usually occurs during the month of August, September and October depending on the peak of ranfall. About 74 to 98 percent of total annual runoff occurs in the rainy season (May to October. The rest (2 to 26 percent) occurs in the dry period.

1) Temp (°C) $= 24.68 - 0.0047EFA$ (%) ; $r^2 = 0.0074$; $F = 0.044^n$
2) Do (mg/1) $= 7.43 - 0.0073EFA$; $r^2 = 0.09$; $F = 0.631^n$
3) pH $= 8.90 - 0.0246EFA$; $r^2 = 0.92$; $F = 70.18^{**}$
4) TURB (J.T.U.) $= 68.58 - 0.5774EFA$; $r^2 = 0.52$; $F = 6.42^{**}$
5) COLOR (unit) $= 232.27 - 2.012EFA$; $r^2 = 0.56$; $F = 7.57^{*}$
6) EC (μmho/cm) $= 483.22 - 4.7984EFA$; $r^2 = 0.92$; $F = 70.22^{**}$
7) TDS (mg/l) $= 321.94 - 3.1953EFA$; $r^2 = 0.92$; $F = 69.86^{**}$
8) ACID (mg/l) $= 23.36 - 0.1469EFA$; $r^2 = 0.88$; $F = 46.32^{**}$
9) ALKA (mg/l) $= 203.12 - 122.0298EFA$; $r^2 = 0.85$; $F = 33.77^{**}$
10) HARD (mg/l) $= 196.09 - 1.9885EFA$; $r^2 = 0.89$; $F = 48.54^{**}$

4) At the time that Khao Yai National Park covered by 89 percent of forest (in 1982), it yielded about 1,888 mcm or about 0.87 mcm/sq.km per year when average annual rainfall of 1600 mm is given.

5) Converting forest on Khao Yai National Park into conventional agricultural crops has resulted in decreasing annual runoff discharge at downstreams. Small reservoir development and diversion of streamwater for agricultural purposes are believed to be the main cause.

6) The average suspended sediment produced by Khao Yai National Park during 1960-1985 is estimated at about 58 tons/sq.km/yr. or equivalent to 0.05 mm/yr. This amount is quite low compared to those watersheds in other regions.

7) During the mentioned period when forest cover in Khao Yai is reduced from 94 to 85 percent, there was insignificant impact of deforestation on suspended sediment.

8) The catchment with least amount of forest cover was shown to have the shortest half-flow and quarter-flow interval of all basins, indicating rapid runoff during high rainfall period. Forest of Khao Yai also prolongs the 5 percent-flow interval which is a prime need when considered from the watershed management point of view.

9) The catchments with less than 70 percent forest cover produced streamwater with higher value of almost all physical water qualities except temperature and Do.

10) Although the above results indicate the adverse effects of deforestation on stream water quality, the water quality within the vicinity of Khao Yai National Park is still within the acceptable range of water quality criteria for public water supply and usages.

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