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# Identifying Significant Tributaries from Human Impacted Sedimentary System, Lam Phachi Catchment, Western Thailand

**Tomomi Marutani, Tomohiro Furukawa, Norihito Endo**
Faculty of Agriculture, Shinshu University
Kami-ina, Nagano, 399-4598 Japan

**Masanobu Kimura, Mutsuki Higo**
Faculty of Regional studies, Faculty of Agriculture, Gifu University
Yanagido, Gifu, 501-11 Japan

**Hideji Maita**
Institute of Agricultural and Forest Engineering, University of Tsukuba
Tsukuba, Ibaraki, 305-8572 Japan

**Kosit Lorsirirat and Songpol Kumlungkeng**
Hydrology Division, Southern Regional Office, Royal Irrigation Department
Dusit, Bangkok, 10300, Muan, Pattalung, 93000 Thailand

***Abstract***

Lam Phachi catchment located in western Thailand is one of the human impacted sedimentary systems. Recent agricultural machinery in Thailand has much influenced on the link between hill-slope erosion and sediment delivery. Especially lots of reservoirs excavated by local peoples may bring huge influence on water resource and sediment of the catchment. To strategically mitigate the erosion-sedimentation linking caused by human impact, catchment scale study on sedimentary system is necessary. This study aims to the sedimentary cascades linking with discontinuity of hydrological processes changed by human impacted landscape management Gentle channel slope of tributary catchments is one of the reason why low water runoff does not increase downstream, because fine sediment and water flow from hill-slope stored in tributary catchments themselves. Reservoirs excavated by local farmers were resulted to intercept the water and suspended discharge from hill-slope into mainstream.

**Keywords: catchment scale, significant tributary, reservoir, sedimentary system**

## 1. INTRODUCTION

To mitigate sediment disaster and achieve sustainable landscape management, estimation of erosion rates of farmland is applied to many agricultural countries in the world. However the add and multiplication for calculating methods such as the United Soil Loss Equation (USLE) is already an old fashion, because not only more scientific insight related with discontinuity, intermittency and catastrophic changes (Fryirs *et al.*, 1998; Marutani *et al.*, 1999; Graf, 1988) but also new indices for time scale (Lu *et al.*, 2000; Pickup, 1988) are brought into the research of earth surface changes.

On the other hand human impact on landscape changes associated with sediment yield raise new interests rather than geomorphologic interest in natural landscape. Recently many earth scientist move their interest into the human impacted geomorphology (Ziegler *et al.*, 2000;

Reid et al., 1981; Reid et al., 1984 ). Road construction, logging and farmland reconstruction are addressed based on geomorphological and hydrological methods. To strategically analyze the erosion linking with sedimentation caused by human impact, catchment scale study on sedimentary system can be efficient (Marutani et al, 2000).

Rice (1998) proposed to identify significant tributaries disrupts downstream fining along the gravel bed rivers. Sediment supplied from lateral tributaries makes an important enrolment to control the discontinuity in main channel processes. Sedimentary systems of earth surface will changes the nature influenced by agricultural development in farmland. Therefore identifying significant lateral sources and associated sedimentary links is important for the human impacted sedimentary systems.

Lam Pachi catchment located in the western Thailand is also one of the human impacted sedimentary systems. Recent agricultural machinery in Thailand much influenced on the linking between erosion and sediment delivery. In this study, the sedimentary cascades linking with discontinuity of hydrological process changed by human impacted landscape management is aimed. Especially lots of reservoirs excavated by local peoples may bring huge influence on water resource and sediment transport along the main channel. In this paper, we identified significant tributaries controlling sedimentary cascades caused by reservoir excavating.

## 2. STUDY AREA

Lam Phachi catchment located in west Thailand has been intensely impacted by development of farmland since 1970's. Lam Phachi River drains a approximately 2620 $km^2$ basin bordered on the west by Myanmar. The main channel is 130km long and slope of riverbed averaged at 0.0042. Main channel of LanPhachi River joins into Mae Klong River at the downstream of Kancha Nabris City.

The Sedimentary rocks of Quaternary period are overlain igneous rocks of Mesozoic era and sedimentary rocks of Paleozoic era. Soil is mainly composed of three groups such as Slope Complex, Paleustults and Haplustalfs (Maita,1998). These geological components are weathered and crashed for long time, and the land surface today shows smooth and gentle slope. Sediment produced from hill-slope has extended in the valley floor by storms and developed huge flood plain.

Although the forest partly cutting by local peoples grew up the flood plain before 1970's, land-use changes from forest-dominated utilization to primitive farmland such as Sugar Cane and Pineapple has quickly extended into the entire flood plain. After 1970's, forest area keep decreasing and at last in 1999 more than 37% of the entire catchment area was cultivated (Maita, 1998, Maita 1999). Multiple use of the entire catchment by immigrants from the outside is out of the control for land-use guideline developed by RID.

Annual rainfall is ranged from 1500mm to 1200mm in the entire Mae Klong river basin, but in Lam Phachi catchment averaged annual rainfall is trend to decrease from 1200mm to 800mm since 1950's in this area (Kwanyuen et al., 1998). The lack in rainfall has caused the agricultural degradation in the entire catchment, and farmers settled in each tributary catchment started to construct reservoirs for personal use. Many reservoirs distributed in tributaries make an enrolment of temporally storage of water and sediment.

Catchment area and tributary divides are shown in Figure 1. Main channel of Lam Phachi sedimentary system incise flood plain with meandering. The lateral side of riverbank keeps recessing by excavation and attain to maximum 4m in height. Each number indicates tributary catchment. Totally 45 tributaries ranged from 573$km^2$ to 1.81$km^2$ in catchment area are identified and analyzed. The No.29 tributary is still covered deeply by tropical rain forest. Small squares along main channel are measuring and sampling points. Riverbed of main channel and tributary month were composed of sandy sediment and cobble-sized particles.

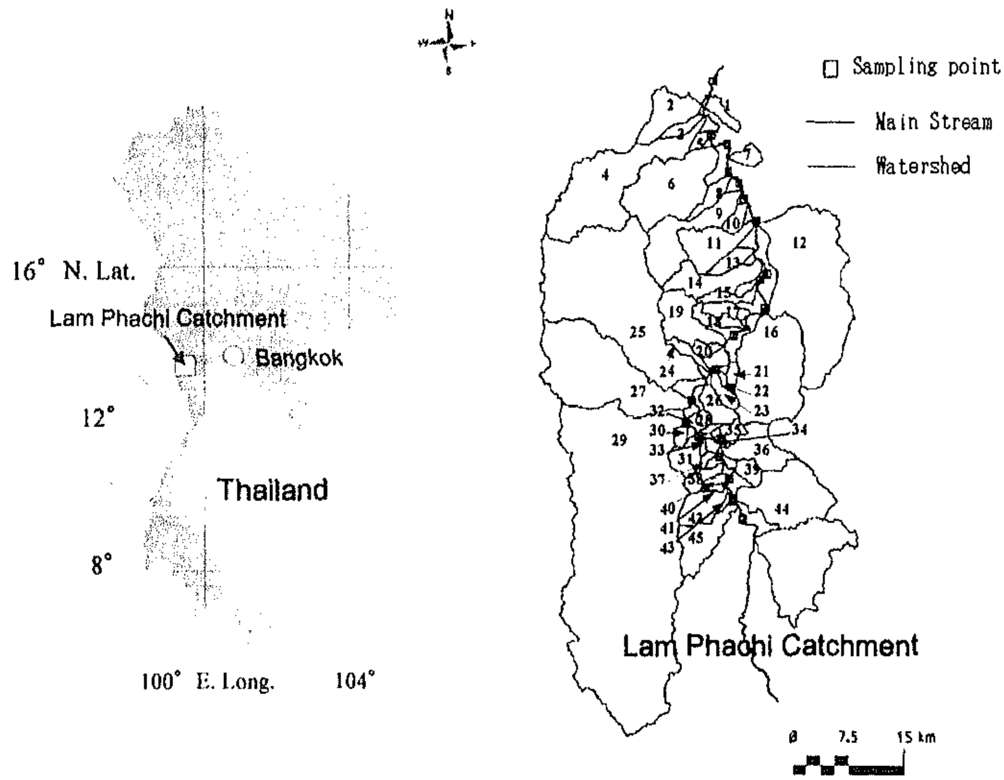


**Figure 1. Location of research site and the entire catchment map of Lam Phachi.**

## 3. METHODS

Totally 45 tributaries are identified from Lam Phachi catchment and geomorphic analyses have done by GIS method as follows. First topographic maps originated from Royal Thai Survey Department have imported to computer by the optical scanner, and after geometric correction using TNT Mips software the catchment topographic map has completed. Catchment area and averaged slope of identifying tributaries were analyzed.

The air photos taken in 1973, 1984, 1994 and 1998 by Royal Thai Survey Department were employed for analyzing reservoirs. Photographs were scanned and imported into computer. After geometric correction using TNT Mips software, the numbers and sizes of reservoirs were measured. As each air photo did not cover all catchment area, the total area of reservoirs per unit catchment area was calculated for each tributary catchment.

Cross section measuring, runoff measuring, suspended load and sedimentary particle samplings are conducted totally at 20 points along Lam Phachi River. Cross section measuring has been conducted in summer time of 2001 at 12 points. The other 8 cross section points were impossible to access because of deep bush cover. Laser distance meter and laser digital compass were used for field survey. The accuracy of laser distance mater is $\pm$5cm per 100m. Cross section lines were set on between both riverbanks. To calculate runoff at low water, flow velocity and flow-cross section were measured using measuring staff and laser distance meter. Water velocity was measured at the thalweg of cross section lines using automatic current meter.

Water samples (4 liter) including suspended load were drawn from 0.5m in water depth at each cross section line. and the samples were percolated using 5 $\mu$ m filter. Particle sizes deposited on the riverbed were sorted out using three sieves such as 1mm, 3mm and 20mm in diameter. Particles larger than 20mm in diameter were measured their size respectively.

**Table 1. Results of geomorphic properties of tributary catchments.**

| X-section number | Number of mesuring point | Distance from the river mouth (L, km) | Averaged slope of tributaries(I) | Catchment area(A, km2) | Channel slope of tributary | Indexes of stream power (AI) |
|---|---|---|---|---|---|---|
| XN | TN 1 | 4.98 | 0.01 | 8.37 | 0.0091 | 0.08 |
| | 2 | 6.78 | 0.01 | 31.62 | 0.0052 | 0.17 |
| | 3 | 8.91 | 0.01 | 7.46 | 0.0053 | 0.04 |
| 3 | 4 | 9.24 | 0.01 | 117.46 | 0.0100 | 1.17 |
| | 5 | 14.44 | 0.00 | 4.19 | 0.0048 | 0.02 |
| 4 | 6 | 16.01 | 0.02 | 84.35 | 0.0186 | 1.57 |
| 5 | 7 | 21.52 | 0.01 | 7.81 | 0.0086 | 0.07 |
| 6 | 8 | 24.39 | 0.01 | 10.35 | 0.0064 | 0.07 |
| 7 | 9 | 28.61 | 0.03 | 54.22 | 0.0263 | 1.43 |
| | 10 | 30.62 | 0.01 | 7.62 | 0.0082 | 0.06 |
| 8 | 11 | 33.45 | 0.01 | 35.46 | 0.0137 | 0.49 |
| | 12 | 34.33 | 0.04 | 183.03 | 0.0407 | 7.45 |
| | 13 | 39.08 | 0.01 | 10.74 | 0.0077 | 0.08 |
| 9 | 14 | 40.36 | 0.04 | 35.18 | 0.0361 | 1.27 |
| 10 | 15 | 45.28 | 0.02 | 9.99 | 0.0206 | 0.21 |
| | 16 | 50.49 | 0.00 | 111.86 | 0.0041 | 0.46 |
| | 17 | 52.64 | 0.02 | 9.76 | 0.0170 | 0.17 |
| 11 | 18 | 54.59 | 0.01 | 10.23 | 0.0098 | 0.10 |
| | 19 | 58.93 | 0.03 | 36.37 | 0.0334 | 1.21 |
| | 20 | 59.72 | 0.02 | 5.79 | 0.0234 | 0.14 |
| | 21 | 62.47 | 0.01 | 4.88 | 0.0083 | 0.04 |
| 12 | 22 | 64.61 | 0.01 | 1.86 | 0.0082 | 0.02 |
| | 23 | 64.89 | 0.00 | 8.39 | 0.0046 | 0.04 |
| | 24 | 65.46 | 0.06 | 6.60 | 0.0604 | 0.40 |
| | 25 | 66.66 | 0.02 | 241.27 | 0.0172 | 4.14 |
| 13 | 26 | 67.52 | 0.01 | 13.81 | 0.0114 | 0.16 |
| | 27 | 70.91 | 0.02 | 141.95 | 0.0182 | 2.59 |
| | 28 | 72.83 | 0.01 | 3.42 | 0.0147 | 0.05 |
| 14 | 29 | 75.35 | 0.01 | 573.68 | 0.0064 | 3.68 |
| | 30 | 75.60 | 0.07 | 4.23 | 0.0736 | 0.31 |
| 15 | 31 | 77.24 | 0.04 | 16.24 | 0.0383 | 0.62 |
| | 32 | 78.19 | 0.01 | 2.24 | 0.0098 | 0.02 |
| | 33 | 78.73 | 0.02 | 1.56 | 0.0204 | 0.03 |
| 16 | 34 | 79.89 | 0.01 | 0.96 | 0.0134 | 0.01 |
| | 35 | 81.71 | 0.02 | 7.13 | 0.0234 | 0.17 |
| | 36 | 83.21 | 0.01 | 32.51 | 0.0090 | 0.29 |
| 17 | 37 | 84.36 | 0.01 | 2.47 | 0.0108 | 0.03 |
| | 38 | 86.25 | 0.06 | 9.21 | 0.0598 | 0.55 |
| | 39 | 88.14 | 0.00 | 8.80 | 0.0046 | 0.04 |
| 18 | 40 | 89.47 | 0.02 | 3.58 | 0.0168 | 0.06 |
| | 41 | 91.21 | 0.07 | 2.07 | 0.0711 | 0.15 |
| | 42 | 91.76 | 0.09 | 21.04 | 0.0856 | 1.80 |
| | 43 | 92.95 | 0.03 | 1.81 | 0.0267 | 0.05 |
| 25 | 44 | 93.71 | 0.01 | 72.06 | 0.0073 | 0.53 |
| | 45 | 94.69 | 0.05 | 32.91 | 0.0488 | 1.60 |

## 4. RESULTS

The result of geomorphic analyses of tributary catchments was shown in Table 1. The first and second files are the number of cross sections and the number of tributary mouths respectively. The third file is the distance from the river mouth of Lam Phachi River to the tributary mouths. The fourth and fifth files indicate average slope and catchment area of tributaries respectively. The sixth file is the result from calculating stream power of each tributary.

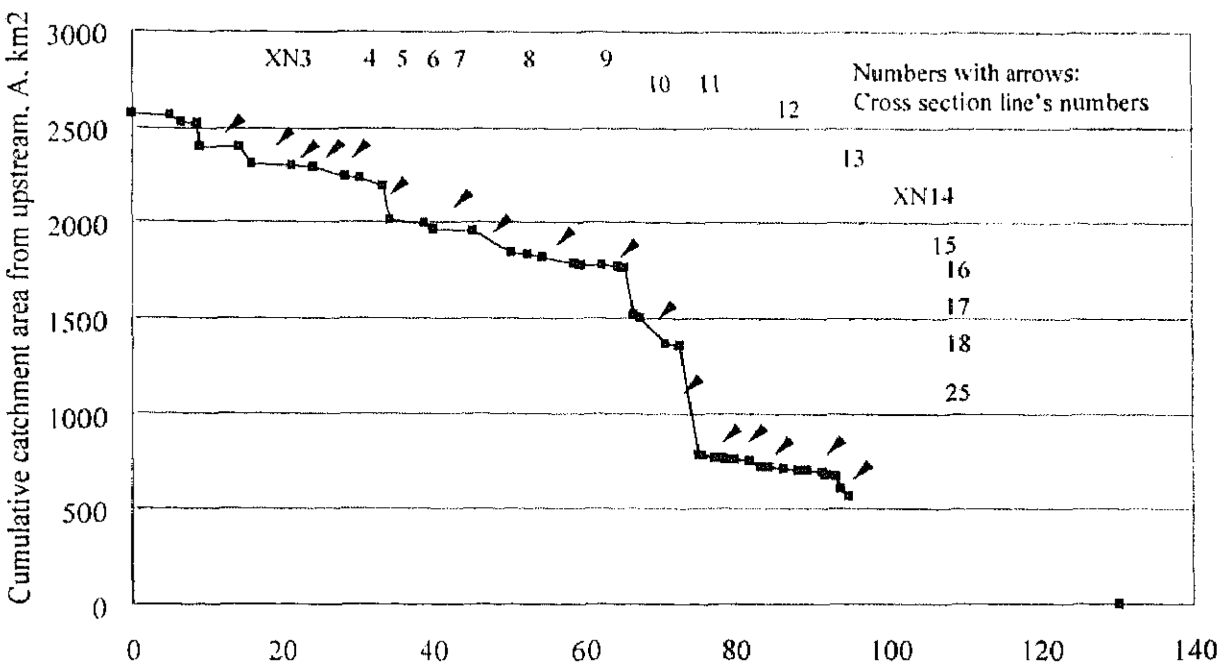


**Figure 2. Longitudinal changes in cumulative catchment area from upatream of Lam Phachi River.**

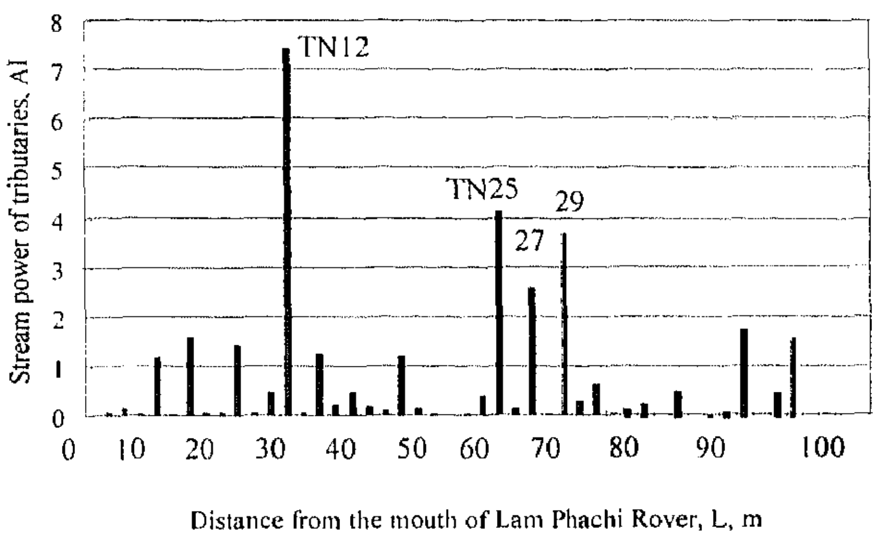


**Figure 3. Calculated stream power of each tributary.**

Figure 2 shows the longitudinal changes in cumulative catchment area from upstream. Tributary channel joined main channel causes not only sediment input but also stream power rising in main channel. Therefore tributary catchment sequences were overviewed from this figure. Numbers with allows are cross section lines. Cascade-like changes with increasing in catchment area are demonstrated at 10km (TN3 or XN3), 35km (TN12 or XN8), 65km (TN25 or XN12) and 70km (TN27 or XN13; TN29 or XN14) points.

Figure 3 shows the calculated stream power of each tributary. Indices of stream power, A·I, indicate large values at the joining points of tributaries, TN12, TN25, TN 27 and TN 29, respectively. Except for TN3, these points are coincident with the joining points with large catchment as shown in Figure 2. Therefore in Lam Phachi River, increasing in stream power yielded from tributaries can result to owe not to slope but to catchment size.

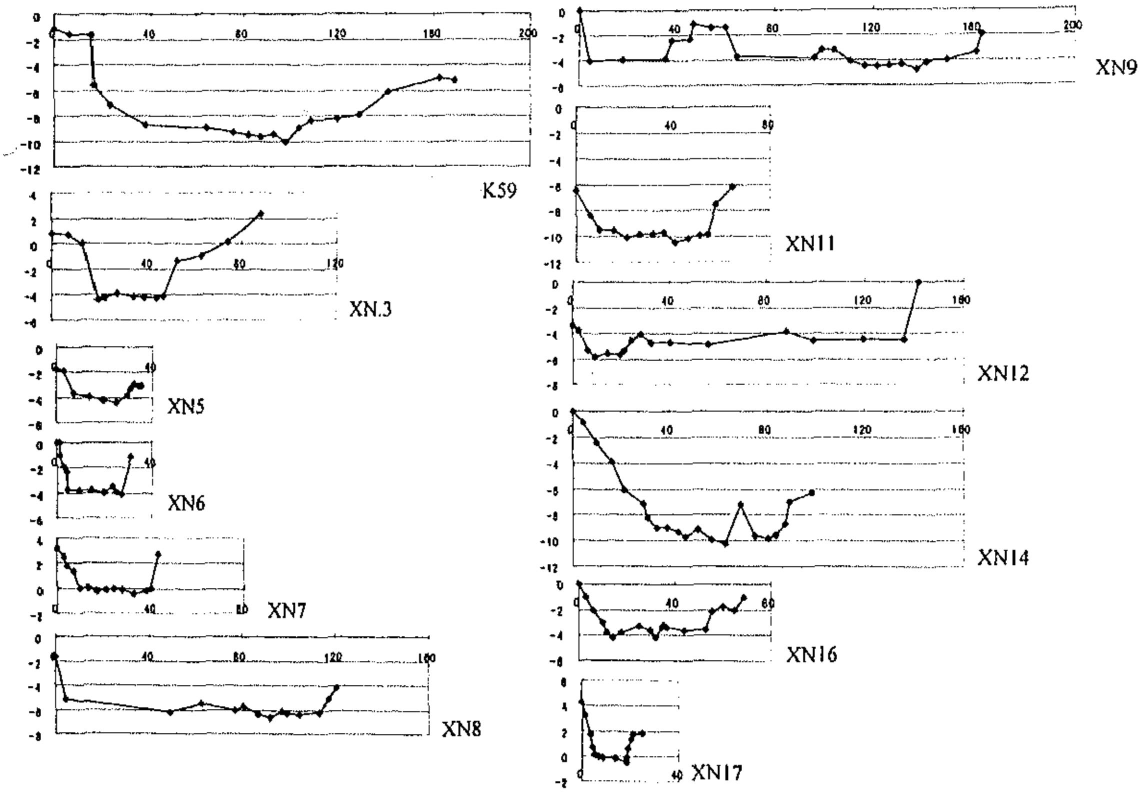


**Figure 4. Cross section along Lam Phachi main channel**

Cross sections measured in the summer of 2001 are shown in Figure 4. K59 point was mostly closed to the river mouth of Lam Phachi and XN17 was the highest points along the main channel. Bankful width of main channel is increasing from XN17 to XN12, and decreasing at the lower reach of XN9, at last increasing again from XN6 to the river mouth. From the observation of riverbed rough, the channel widening at XN9 in flooding time was between 60m point (bank on the mid river) and 160m point (left bank). As a result, the local widening in bankful width is dominated in XN12, No.8 and XN59 respectively. These points located in the downstream of junction with large tributary catchments (Fig. 2). On the other hand he bankful width at XN5, 6 and occasionally XN7 (TN7, 8, 9 and 10; 20-30km from the mouth) are relatively narrower than the upstream.

Runoff measuring at the low water was conducted twice in summer of 2001 and 2002 at the same water cross section. The results are shown in Figure 5. Both changes in runoff along the main channel are similar. After runoff, Q$m^3$/s, quickly increases at the junction, XN14, with large tributary, they keep going constantly or slightly decrease. The runoff begins to increase again at the lower reach from XN5 (TN7; 30km from the mouth). Although cumulative catchment area increase downstream of main channel (Fig. 2), changes in low water runoff are not affected by the geomorphologic nature.

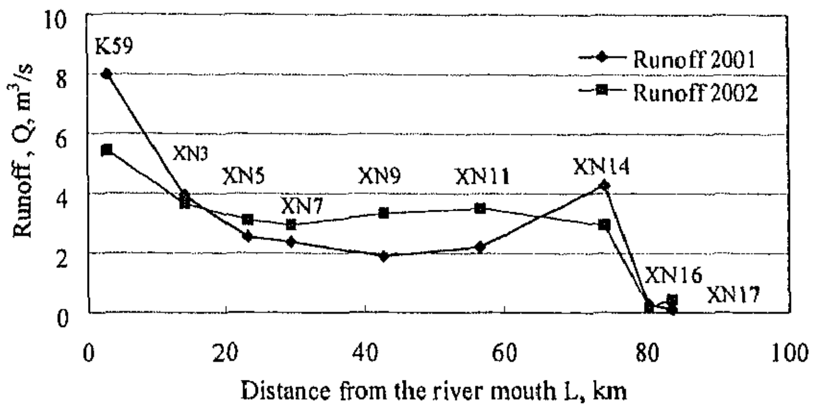


**Figure 5. Low water runoff along the main channel of Lam Phachi River.**
Water cross-section and flow velocity available for calculating runoff were collected at the cross section points of riverbed. Both measuring lines in 2001and 2002 were precisely identified at the field site.

Because changes in runoff along the main channel can reflect to changes in stream power downstream, sediment discharge at each point along the main channel can be affected by runoff changes. Riverbed slope is almost constant ranging within $0.005 \pm 0.002$ except for 0.019 at XN12 (TN22), and the bed slope may not a control factor of stream power. Although conductivity of suspended load in proportion to runoff squared is expected to increase downstream, changes in particle size distribution of bed load along main channel may be related with sediment input from tributaries. Therefore suspended load discharge and particle size of bed load should be compared with runoff respectively. Figure 6 shows longitudinal changes in suspended load conductivity and low water runoff, and Figure 7 shows longitudinal changes in mean diameter of particle size distribution of bed load and low water runoff respectively. Although suspended load conductivity is harmonized with low water runoff, mean diameter of particle size distribution of bed load is not coincident with the changes in low water runoff but contrast to suspended load conductivity.

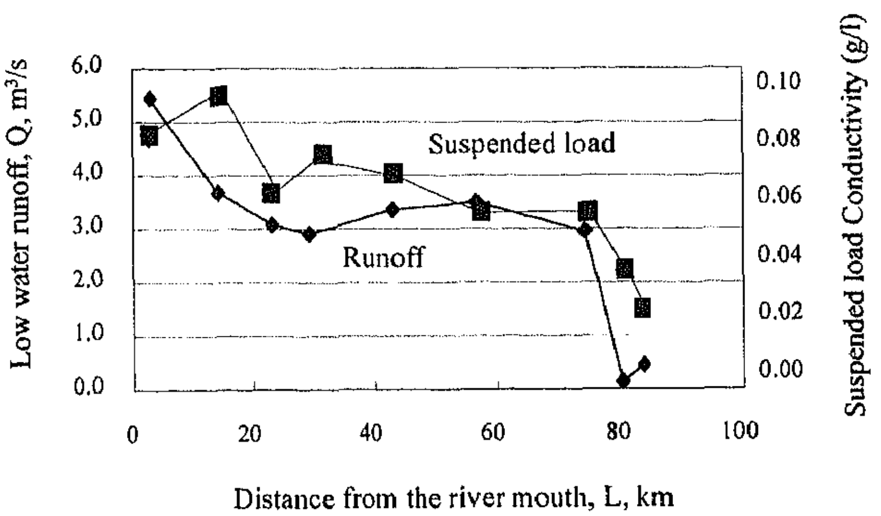


**Figure 6. Comparing suspended load conductivity with low water runoff along Lam Phachi River.**

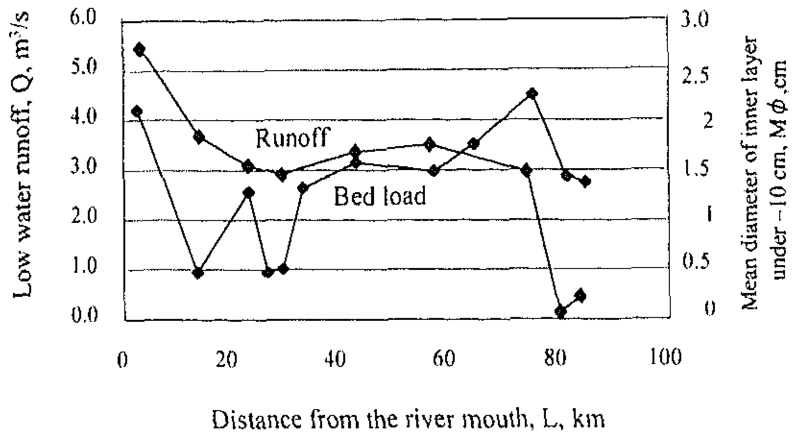


**Figure 7. Comparing mean diameter of bed load particle distribution with low water runoff along Lam Phachi River.**

Mean diameter of particle size was coarser at 75km and finer at 15km and 30km points from the mouth. Comparing with Fig.6, suspended load also slightly increase at the 15km and 30km points from the mouth. These result suggest that fine sediment may produced from the tributary channels joining at those points. From the result of Fig.2, those points show the cascades of catchment area increase, which are due to join with large tributaries.

One of the biggest impacts of human processes on sedimentary system of Lam Phachi catchment is expected to be temporally storage of water and sediment in reservoirs. Recent agricultural development substituted with forest dominated land use has disturbed the landscape management in the entire catchment. Among of many kinds of human-related earth surface changes, the reservoirs excavating at farmlands, which are available for personal use here, can affect to sedimentary system.

Figure 8 shows longitudinal changes in total area of reservoirs per unit catchment area of tributaries. Because the air photos does not always cover an entire tributary catchment and reservoir measuring was done in a part of catchment, the result surveyed should be calculated as totalized reservoir area per unit catchment area. Comparing air photos taken in 1994 with them in 1998, the area of reservoirs increased at any tributary catchments. In the upper reach of the 40km point from river mouth, area of reservoirs much more increased.

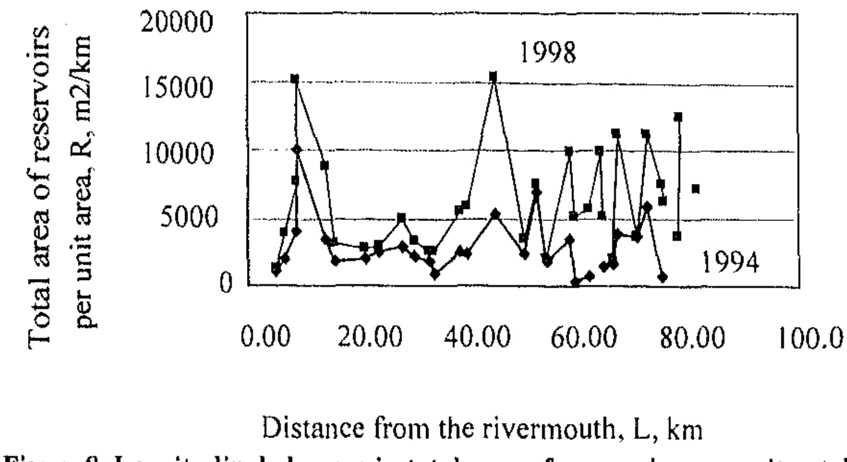


**Figure 8. Longitudinal changes in total area of reservoirs per unit catchment area, with comparing between 1998 and 1994 air photos.**

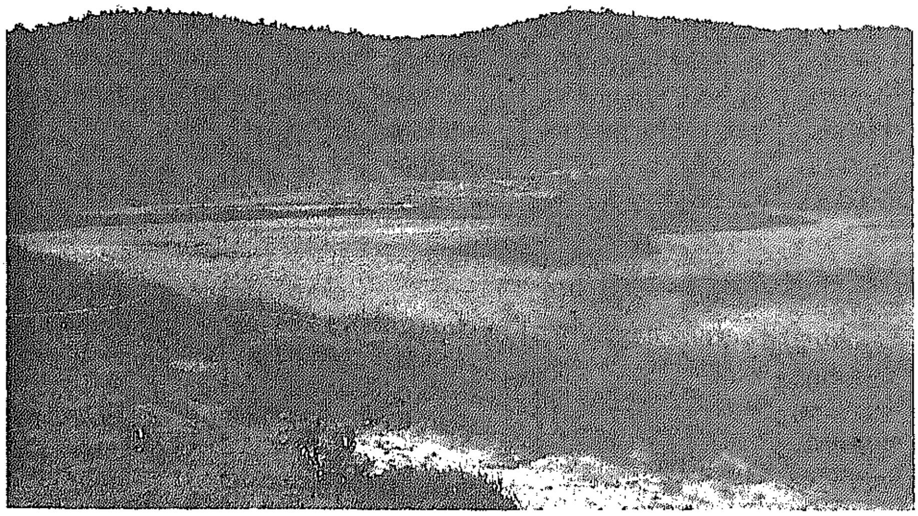

**Photo 1. Reservoir excavated in a tributary catchment by local farmers.**
Sediment and water from hill-slope were temporally stored in this reservoir and local farmers are used to sometimes deal illegally fine sediment excavated from the reservoir with local construction contractors.

At last, to characterize the significant tributaries, the relationship between magnitude and frequency analysis of reservoir distributions in tributary catchments is shown in Figure 9. Magnitude is defined as averaged area of reservoirs in each tributary catchment, and frequency is done by numbers of reservoirs per unit catchment area. The graph shows the hyperbolic relation between magnitude and frequency of reservoirs. That is, many reservoirs distribute with small size, and large-sized reservoirs distribute with isolating. The tendency of magnitude-frequency relation of reservoirs can be provided from the agricultural demand of water resource balance managed by local peoples.

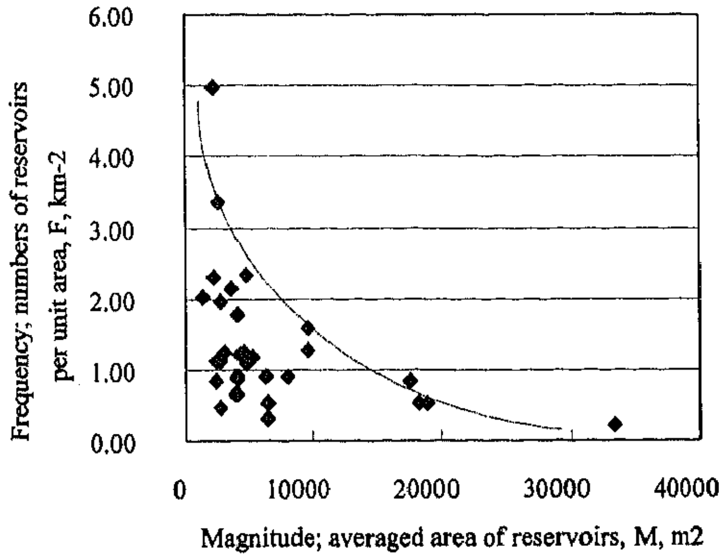


**Figure 9. Frequency-magnitude analysis of reservoirs**

Reservoirs may make an enrolment to temporally deposit of the water and fine sediment produced from hill-slope to tributary channels. As shown in table 1, channel slope of tributary channels ranged from 0.07 to 0.004 against 0.005±0.002 in main channel slope. Especially slopes of tributaries joining at the points of 15km and 30km from the mouth are 0.0048 and 0.0082 respectively. Branch channel in the mountainous area show steeper slope than the main channel, but in Lam Phachi catchment slope of tributary channels are rather gentler than main channel. In such flat catchments, the influence of reservoirs excavated by local farmer on water and sediment storage is much bigger than the mountainous catchment.

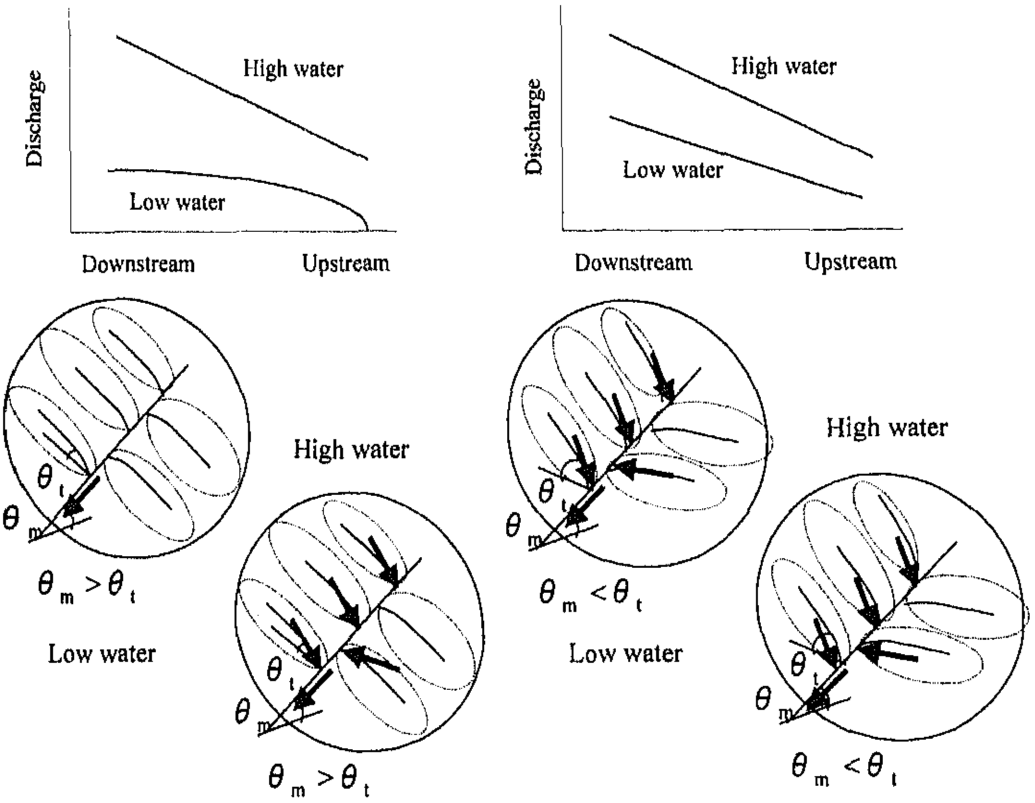


**Figure 10. Idealized model of sediment and water discharge from tributary cathments under geomorphic control.**

## 5. DISCUSSION

Figure 10 shows the idealized model of sediment and water discharge from tributary cathments under geomorphic control. From the result that low water runoff could not increase downstream accompanied with increasing in cumulative catchment area, water supply may be expected to be disturbed by geological and/or geomorphologic control. From the experiences of Waipaoa catchment, New Zealand, geomorphologic control, such as changes in stream order, gives much influence on sediment delivery ratio. However in the case study of the Lam Phachi catchment, because the slopes are more gentle in tributary catchment than in main stream, the model suggest that tributary storage of water and sediment during low flow and overflow from tributary catchment during flooding (left figure). Hydrological system of catchment, in common, develops the geo-system composed of steep-slope channel spaced in branch and gentle-sloped channel spaced in main channel (right figure).

In the case that reservoirs distribute in an entire tributary cathment, water supply during low water runoff will keep decreasing. This tendency is evidenced from the river located in dry area of the continent, such as Australia. On the contrary to low water runoff, high water will yield surplus water in tributary catchments according to their catchment area. Therefore reservoir may make a large enrolment to control water supply and sediment delivery, especially suspended sediment, through the dry season. Controlling magnitude and frequency of reservoirs in tributary cathments is ke issue for the human impacted sedimentary systems.

This study is subject to describe the longitudinal changes in geomorphic and hydrological features along Lam Phachi River. Rice (1998) implies identifying significant tributaries along main channel is important for analyzing downstream fining. Furthermore in this study, influence of catchment area and slope of tributaries on suspended load and runoff, especially for low water, is examined. Land use data such as reservoirs distributions in tributary catchments suggest that magnitude and frequency of reservoirs should be controlled in terms of degrading and reconstructing significant tributary cathments.

## ACKNOWLEDGEMENT

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