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Factors Affecting Hydrologic Characteristics in the Lam Phachi River Basin

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Abstract

Extraction of hydrologic characteristics in a watershed area having limited hydrologic data is needed for the conservation and sustainable use of soil and/or water resources. In this paper, hydrologic characteristics are extracted and discussed using data in the upper reach of the Lam Phachi River basin through the master recession and flow duration curves. The reliable baseflow contribution and lowflow regime aspect depend on the amount of annual rainfall. And the result of annual water balance means that the groundwater storage is consumed with the evapotranspiration function over the drought water year. Also the statistical analysis is used to determine whether climate change has occurred. Here we use rainfall data observed from 1952 to 2001 in the No.47022 site. Finally it is found that rainfall for a given non- exceedance (probability year) gradually decreases, and in addition the probability year for a given rainfall is larger than previously (1952-1976).

Keywords: water balance, climate change, water resources, Gumbel distribution

1. INTRODUCTION

In studying the conservation and the sustainable use of soil and/or water resources in a watershed area, it is fundamental to examine and discuss which factors affect hydrologic characteristics in a given area. Especially, in the case of discussing on the conservation and development of water resources, the relationship between climate change and hydrologic characteristics, and water balance have to be examined.

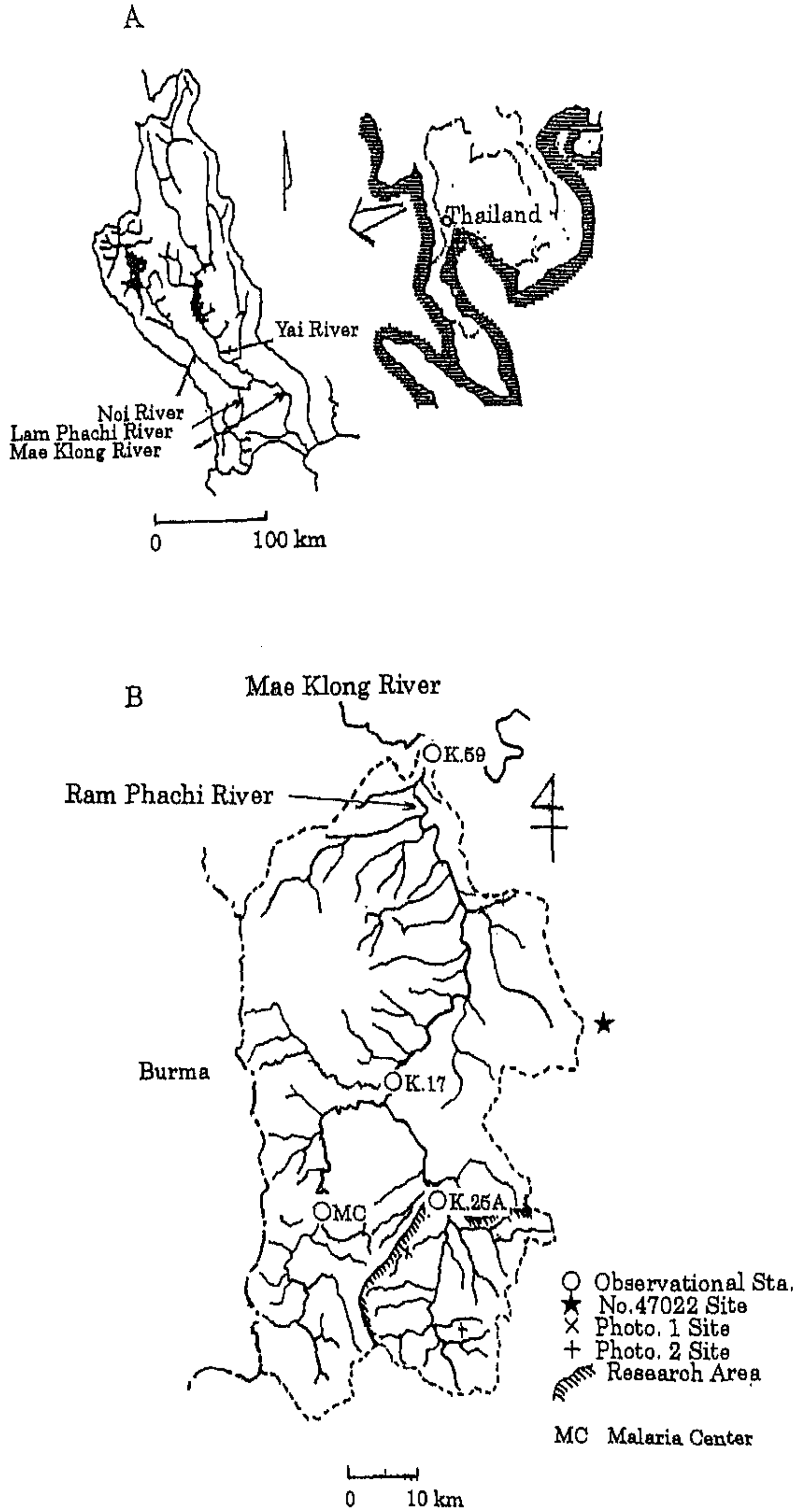


Figure 1. Location (top) and outline (bottom) in the research area.

It has been shown by many scientists that the potential storage capacity of water resources and drought and/or flood event characteristics in a watershed area may be changed with global climate change and forest deforestation in East –South Asia. So far various interesting reports have been shown on the climate change (for example, Hurd et al. (2000), Kanae et al.(2001), Chikamori & Nagai (2002)).

This paper focuses attention on the upper reaches in the Lam Phachi River, and addresses the following questions: (1) To what extent can the short term data be used to discuss water balance and hydrologic characteristics? (2) Does climate change occur in this study area?

2. DESCRIPTION OF THE RESEARCH WATERSHED AREA

2.1 Outline

The Lam Phachi river is a tributary of the Mae Klong river which is located in western Thailand and borders with Burma (Figure 1A). The watershed area is 2,590 km^2, and it is bordered by a mountain range with altitudes of about 1,000 m. The topography in the western part of the basin is mainly mountainous and hilly, and in addition several falls are found in the upper reaches (located by × site in Figure 1B, Photograph 1). In contrast, the land use in the eastern part of the basin is mostly low land, and there are a lot of ponds for irrigation and drinking from the upper reaches to the middle reaches of the basin area (located by + site in Figure 1B, Photograph 2) .

2.2 Data collection and observational system

The hydrologic observational locations used for analysis are shown in Figure 1B. The K.25A , K.59 and K.17 sites are managed by RID, and rainfall in the malaria center are observed by the Rajanagarindra Tropical Disease International Center (RTDIC). Water levels are observed at K.25A, K.17 and K.59, and record term at K.25A and K.17 sites are comparatively long. Evaporation is measured with the Class A-pan in K.59A and K.17 sites. Also the No.47022 rainfall station used for climatic change analysis (Section 5) has been managed by the Meteorological Department for over 50 years. The observed rainfall, flow, and evaporation are arranged using daily values.

The following analysis is mainly carried out by using hydrologic data in the K.25A watershed area (380 km^2). Table 1 gives record lists of hydrologic data used for the following hydrologic analysis.

Table 1. List of data used

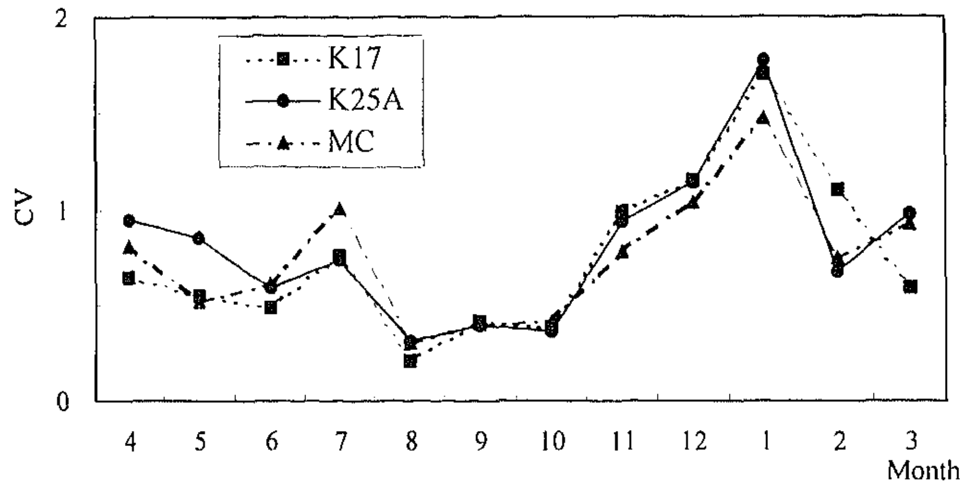
Station	Rainfall	Discharge	Evaporation*	Record length
K.25A	○	○	○	1995～2001
K.17	○	○	○	1995～2001
Malaria Cen.	○	×	×	1995～2001
No. 47022	○	×	×	1952～2001

* Observed with A Class Pan.

3. HYDROLOGIC CHARACTERISTICS

3.1 Spatial distribution of rainfall

The coefficient of variation (CV) for monthly average rainfall, calculated for the period of record, in K.25A, K.17 and Malaria Center is compared in Figure 2. Although the CV fluctuation for the three rainfall sites is similar from August to October, the CV values for other months are different respectively. This aspect suggests that the spatial distribution of rainfall in each site is homogeneous during the three months from August to October. On the other hand, during the dry season it is very heterogeneous.



3.2 Discharge time series

Figure 3 shows the autocorrelation function (ACF) for discharge time series in K.25A site. Examples of a droughty year* (solid line) and a heavy rainy year** (dotted line) are respectively compared. That comparative aspect indicates that the reliable baseflow contribution in the rainy year is stronger than that for the doughty year. From this respect, it is apparent that the reliable baseflow contribution depends on the amount of rainfall. Therefore, it is essential for water resources management and/or planning to examine how climatic change affects the rainfall situation. In section 5, this issue is discussed at length.

3.3 Extraction of droughty characteristics

It is important for the development and preservation of water resources how to extract useful information from the low flow data. The master recession curve and flow duration curves are very representative expressional forms for low flow recession characteristics. Then we discuss the characteristics of low flow with the above mentioned two curves.

The recession limb of the discharge hydrograph, if no recharge is taking place, is termed as the recession curve. This curve represents the total effect of various

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* water year annual rainfall is smallest during the given record term.

** water year annual rainfall is largest during the given record term.

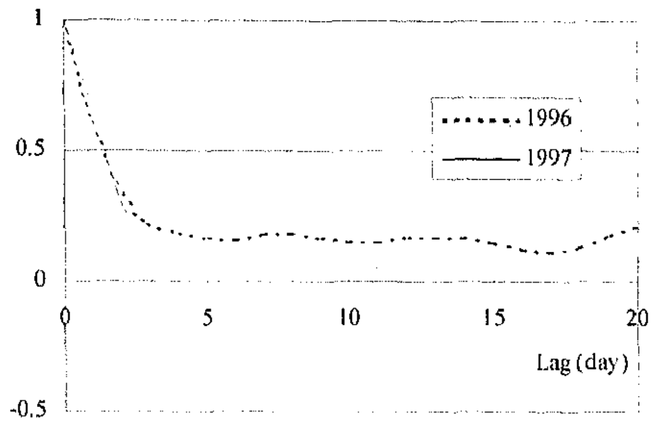


Figure 3. ACF of daily discharges

physical recession characteristics, and the curve constructed by combining individual recession limbs is usually termed the master recession curve. The recession constant may be defined as the total index of low flow characteristics.

The following equation is quoted by many hydrologists as the expressional equation that represents the recession limb during a long period without rain:

$$Q_t = Q_0 \exp(-\lambda t) \quad (1)$$

where Q_t is the discharge at time T, Q_0 is the initial discharge, and λ is the recession constant.

The recession constants were automatically and objectively estimated by the construction method presented by Sugiyama (1996) .

Figure 4 shows the master recession curve for K.25A site. The recession constant in this study area is 0.025 d^{-1}, and this value is larger than that in Srinagarind Dam basin area (0.013 d^{-1}), and is similar in value (0.024 d^{-1}) to Vajiralongkorn Dam (old name is Khao Leam Dam) (H. Sugiyama et al., 1999). This result indicates that the reliable baseflow contribution in K.25A basin area is a little less than that in the S Dam basin area.

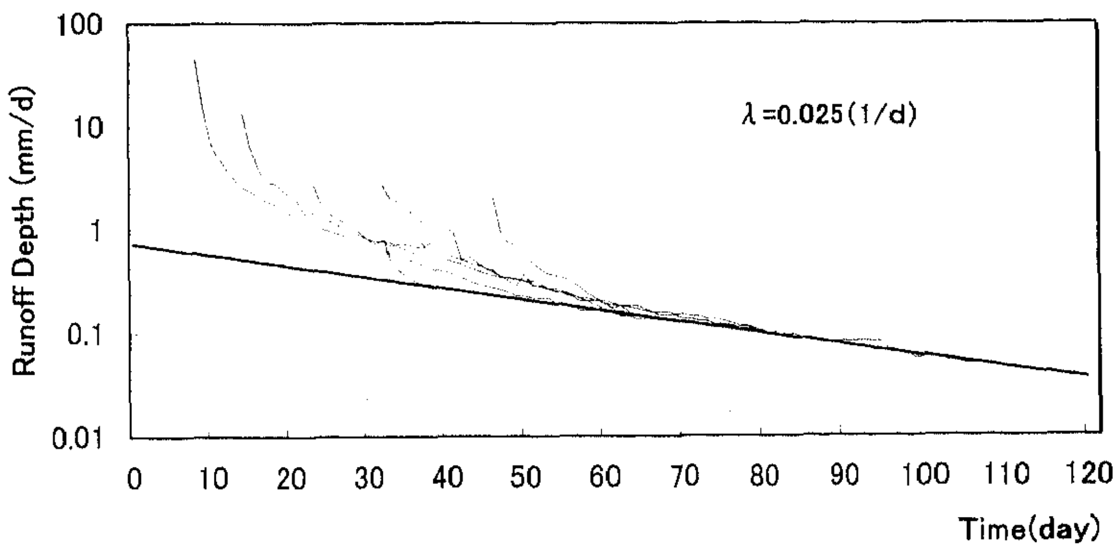


Figure 4. Master Recession Curre for the K.25A Site

The Flow duration curves for K.25A site are shown in Figure 5. This figure is drawn with discharge arranged in order of descending magnitude. The magnitude of stream discharge is plotted as ordinate against the corresponding percent of time, the probability that an arbitrary discharge will be equaled or exceeded, as abscissas. The average FD curve is constructed using daily discharge of successive years. From this figure, the runoff depth exceeded 80 percent of time, recognized as an index of low flows in Thailand, is 0.06 mm/d in rainy water year, 0.02 mm/d in drought year. These values are small because the persistence of flow in this study area is low (Figure 4, λ=0.025(d^{-1}). And that difference is about three times, demonstrating that flow regime is dependent on the amount of annual rainfall.

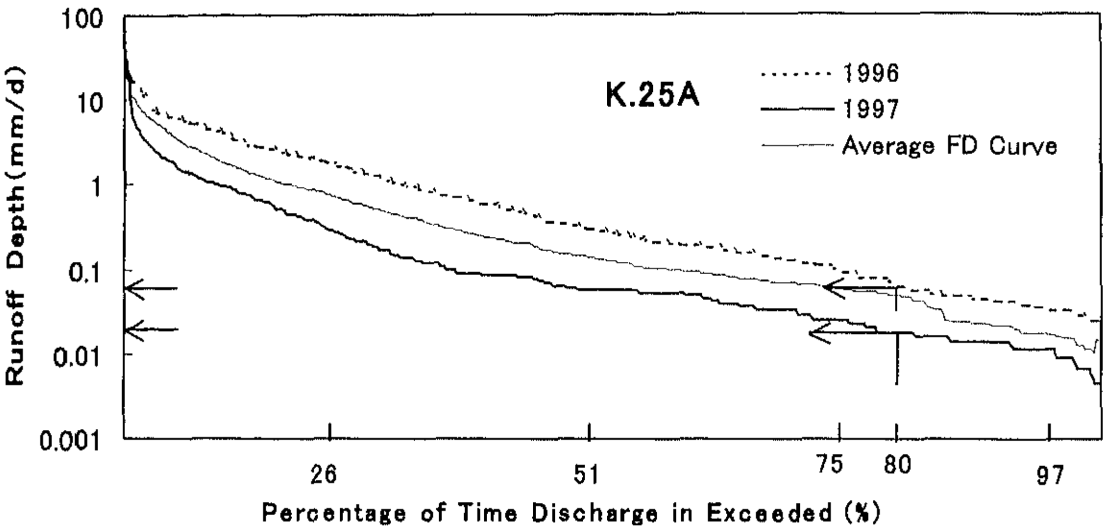


Figure 5.Flow duration curve for K.25A site.

4. WATER BALANCE

The water balance in the K.25A basin area was examined over 1996 and 1997 water years. Here we use average areal rainfall estimated by the Theisen method, and water level observed in K.25A site. Evapotranspiration is estimated multiplying evaporation observed in K.25A site by 0.7. Monthly water balance is given in Table 2 respectively. From the comparison of water years 1996 (annual rainfall 1,848 mm) and 1997 (annual rainfall 1,057 mm), it is understood that the percentage of evapotranspiration components to rainfall in July through November is low in 1996, high in 1997, and the percentage of runoff component is high in 1996, low in1997. Also the percentage of the change in storage components are almost similar to each water year.

The annual water balance is shown in Table 3. It is revealed comparing the result in water year 1996 that in water year 1997 the percentage of storage to annual rainfall is minus 36.7 %, and the value of evapotranspiration is over 100 %. And also it is indicated that although the change of storage is generally neglected in the estimation formula (Equation (2)) for annual water balance, the calculation of change in storage is especially needed in drought years. In other word, it means that the groundwater storage is consumed with the evapotranspiration function over the drought water year.

$$P = Q + Evap. \pm \triangle S \quad (2)$$

where, P is rainfall, Q runoff, Evap. evapotranspiration, $\triangle S$ change of storage.

Table 2. Monthly water balance in the K.25A basin area

Unit: mm

Water year / Month	1996				1997			
	P	Q	Evap	±⊿S	P	Q	Evap	±⊿S
Apr	110.2	2.9	121.3	-14.0	73.4	1.0	128.4	-56.0
May	266.7	12.0	139.5	115.2	27.4	0.9	122.1	-95.6
Jun	125.1	18.3	104.8	2.0	35.4	0.4	125.8	-90.8
Jul	348.9	52.5	64.9	231.5	103.1	0.6	95.9	6.6
Aug	124.2	27.4	89.2	7.6	151.0	1.6	107.9	41.5
Sep	357.7	173.6	69.8	114.3	257.2	16.7	72.8	167.7
Oct	295.4	188.4	63.2	43.8	175.6	39.5	81.8	54.3
Nov	175.3	95.1	61.6	18.6	226.6	135.0	67.3	24.3
Dec	9.4	13.1	64.2	-67.9	0.0	8.5	81.7	-90.2
Jan	0.8	3.7	84.1	-87.0	0.6	3.2	101.7	-104.3
Feb	13.3	1.5	95.5	-83.7	0.8	2.0	105.2	-106.4
Mar	20.9	1.1	130.4	-110.6	5.4	1.5	142.4	-138.5
Total	1847.9	589.6	1088.5	165.8	1056.5	210.9	1233.0	-387.4

Table 3. Annual water balance in the K.25A basin area

Water year	Rain fall	Discharge	Evap.	Change of storage
1996	1,847.9	589.6	1,088.5	165.8
1997	1,056.5	210.9	1,233.0	-387.4

Unit:mm/y

* Estimated by the Theisen meyhod.

5. DOES CLIMATE CHANGE OCCUR IN THIS STUDY AREA?

It is important for the preservation and management of water resources to examine how hydrologic characteristics are affected by global climate change. We attempted to extract information for climate change by examining rainfall data with statistical analysis. In this analysis, the daily rainfall record observed in the No. 47022 rainfall site (Figure 1B, ★) outside of the study area was used. We firstly defined rainfall during a series of rainy days as total rainfall, and secondly record length (from 1952 to 2001) was divided into 25 year terms respectively. Finally, the frequency and distribution of each given term was examined.

Although several extreme value distributions are presented, Gumbel distribution is applied for annual maximum of total rainfall and daily rainfall in each given term. The Gumbel distribution is given as follows.

$$F(x) = \exp(-e^{-y})$$

$$f(x) = a \cdot \exp(-y - e^{-y}) \qquad (3)$$

$$y = a(x - x_0), -\infty < x < \infty$$

where the notation F(x) and f(x) denote the probability cumulative function and density function, respectively, of the random variable x, and a and x_0 are parameters.

The relationship between annual maximum of total rainfall of a storm and non-exceedance probability for the two periods of 25 years is respectively shown in Figure 7. Non-exceedance probability is estimated with the following Weibull Plot (Equation (4)).

$$F_j = N+1-j \,/\, N+1 \qquad (4)$$

where F_j is non-exceedance probability, j order, N data number.

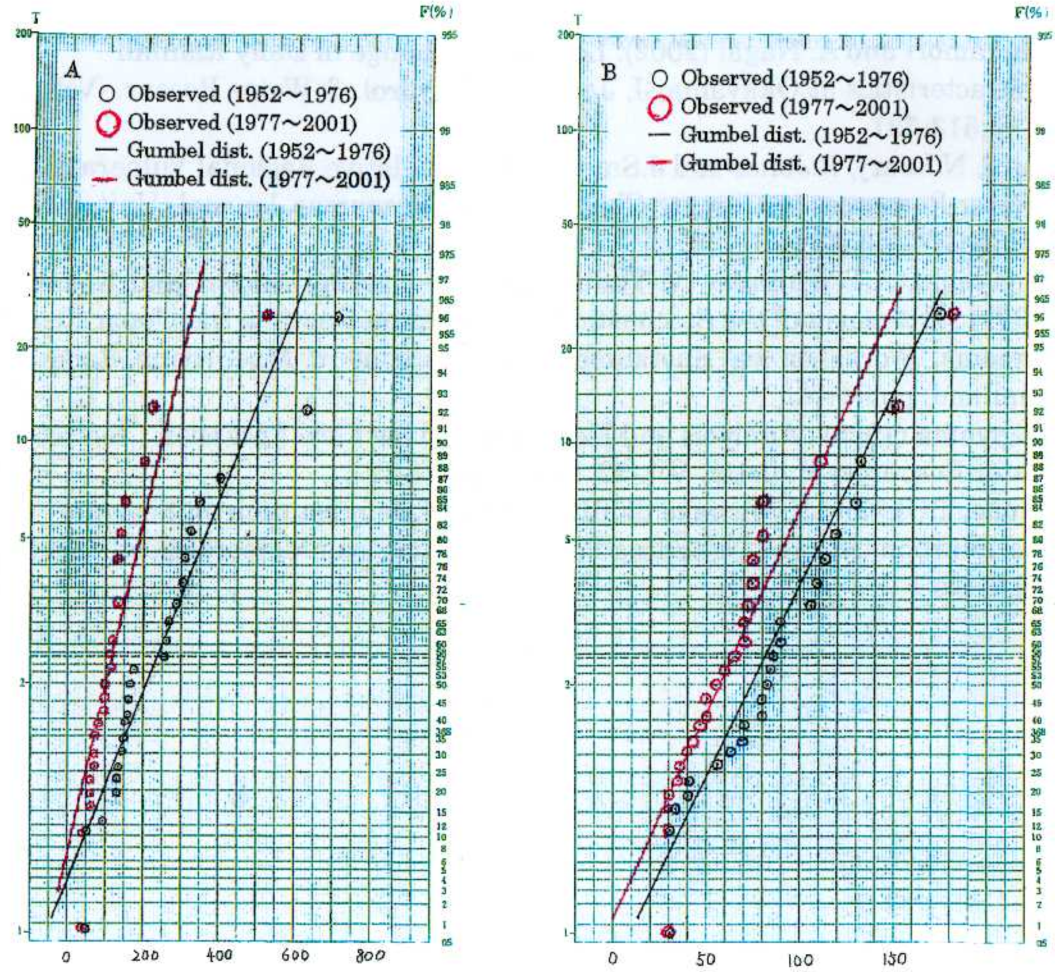
Figure 6A shows that plotting position for the recent 25 year term (1977-2001) moves to the left side. This aspect indicates that rainfall for a given non- exceedance (probability year) gradually decreases, and in addition the probability year for a given rainfall is larger than previously (1952-1976). Also the straight slope of the Gumbel distribution is larger than previously.

In Figure 6B, the distribution for the annual maximum daily rainfall is drawn with the same procedure. Although a changing trend of distribution is not so obvious as in the case of total rainfall, it is possible to conclude that the rainfall situation is inclined to change.

5. CONCLUSIONS

Hydrologic characteristics and climate change in the Lam Phachi River basin were discussed by using hydrologic data in K.25A site. By using hydrologic data of short record term, fundamental information for hydrologic characteristics can be extracted through the master recession curve and flow duration curve. It was shown that the reliable baseflow contribution depends on the amount of annual rainfall, and information for water resources can be extracted with the flow duration curve.

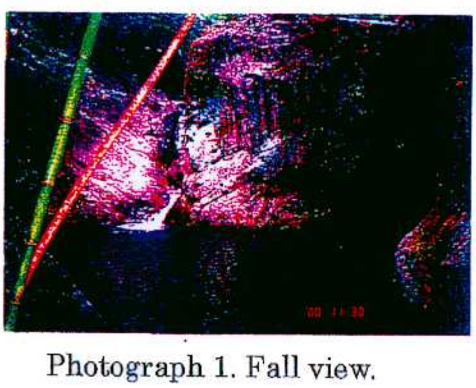
The annual maximum of total rainfall during a series of rainy days and daily rainfall for the same probability year decreases. So reconsidering magnitude of design floods and/or droughts for constructing hydraulics structures may be needed.



(a) Annual maximum of total rainfall (mm).

(b) Annual maximum of daily rainfall (mm/d).

Figure 6. Plotting on Double exponential distribution paper.



Photograph 1. Fall view.

Photograph 2. Pond view.

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