

Hydrology and Water Studies of Hydroelectric power plants of Huai Pa Law Reservoir, Muang District, Phetchabun Province

Anekpong Thammathiwat^a

^a *Department of Technology Industrial, Faculty of Agricultural Technology and Technology Industrial Phetchabun Rajabhat University, Phetchabun Province, 67100, Thailand*

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ABSTRACT

The paper presents the hydrological analysis of Huai Pa Law Reservoir and estimation of hydropower potential of Huai Pa Law Reservoir. The study involves estimation of design floods from extreme rainfall through convolution with unit hydrograph ordinates obtain from Snyder method. In order to determine available flow for generation, flow duration analysis was carried out. The analysis revealed that the flow of 50%, 75%, and 90% reliability that is available for energy generation from Huai Pa Law for the 75% and 90% reliability, the available flow is 0.70 m³/s, and 0.45 m³/s respectively and their corresponding hydropower potential is estimated as 52 KW and 34 KW.

1 Introduction

As long as the world needs energy to revolve around and people in the world have to face with decreasing fossil energy – a vital source of energy that drives our world for centuries – and fluctuation of energy market, we will remain undeniably threatened about energy shortage. It has already become a crisis that affects development and our lifestyle. Hence, people have looked for a number of solutions and explored alternative energy as it is believed to be a solution to ease the problem. To various groups; such as, the government, business and academicians, etc., energy has always been in the limelight. Members in energy community concur that energy is not something distant because everyone consumes energy more or less. At the same time, energy procurement and management for energy security is neither something out of our grasp nor a national mission.

Energy security has become an ultimate goal for every nation as a result of recurring energy crisis. In addition, all nations have come to realize that conventional fossil fuel is running out. Despite the fact that details of energy strategies of different nations may vary, they share the same commonalities. Namely, they support energy sufficiency plan and a utilization of alternative energy to ensure development and progress of the country. The need to tackle challenges such as energy security together with global warming caused by the combustion of petroleum fuel makes involvement from everyone to solve the energy problem crucial. Development of alternative energy – a source of renewable and clean energy for substitution of oil which is depleting, has thus become a topic of an international seminar. More than 48 countries in the world have already stipulated a policy, strategy and conducted research on alternative energy in a concrete manner.

According to the national power development plan, Thailand's dependence on imported energy supplies is expected to be 26% in 2015 and 28% in 2021 before reaching 30% in 2027. This indicates that the energy demand will be greater than the reserved generating capacity of the projected years. The study of development particularly hydropower from water reservoir is therefore crucial and necessary so as to find feasible alternative plans for the country's power development. The purpose of this research is to hydrology and water studies of hydroelectric power plants of Huai Pa Law reservoir, Muang district, Phetchabun province.

2 Study Area

The Huai Pa Law River Basin is located in the North and Central Regions of Thailand (Figure 1). The basin shape is long and narrow extending generally from North to South. The east boundary of the basin is confined by the mountain ridges dividing the North and Central Regions of the country from Northeast. The west boundary of the Huai Pa Law basin is also the high mountain ridges in its upper part in Loei and Petchabun Province. The long and narrow shape basin of Huai Pa Law contains an area of 15,700 km², with an average width of about 50 km and an approximate length of 300 km. The central strip of the basin is valley plain sloping from North to South following the Hui Pa Law water course.

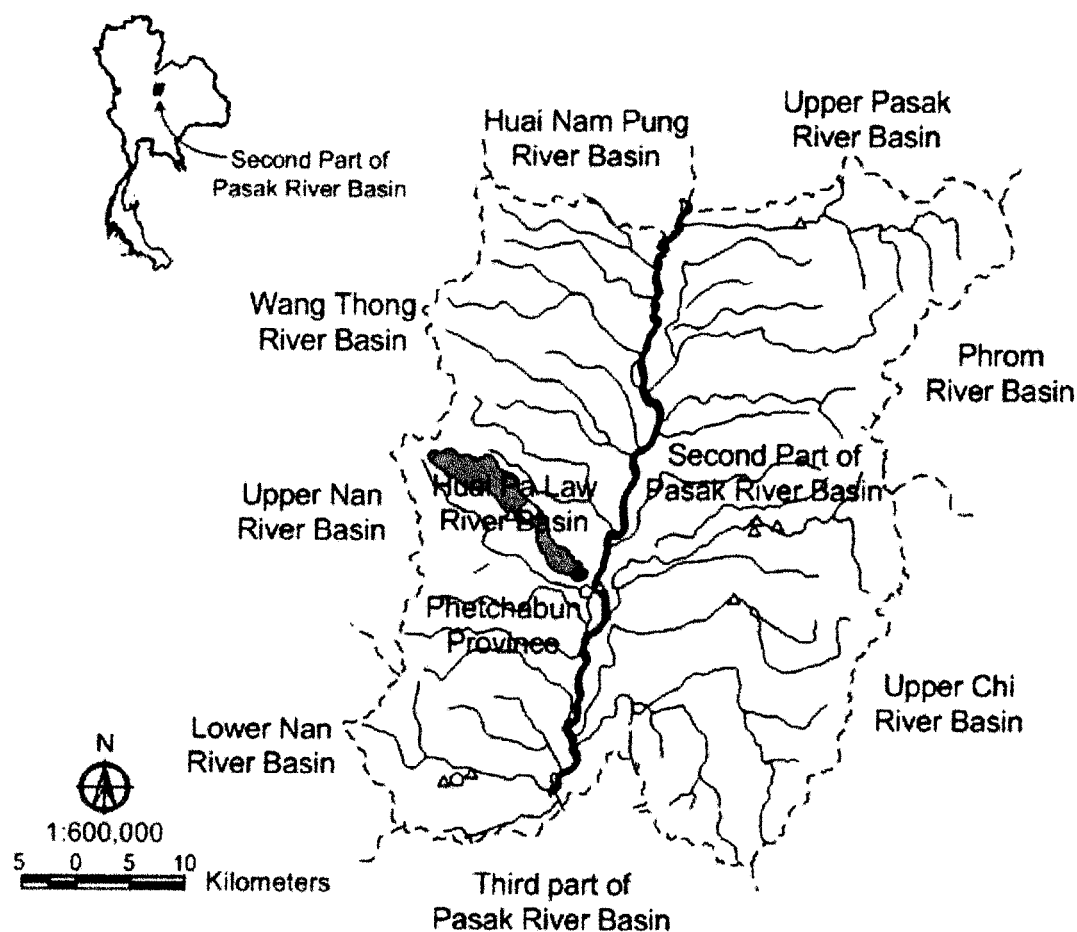


Figure 2: Geographic location of Huai Pa Law Catchment

3 Methodology

The unit hydrograph analysis for each gauging station were carried out by computing the unit hydrographs from various storm flood hydrographs and averaged for representative of the station. Two parameters of unit hydrograph, i.e., time to peak and peak discharge were calculated and used in constructing the dimensionless unit hydrograph which is the unit hydrograph having time scale and discharge scale

For the purpose of this study, there are several data that must be obtained, which includes the historical rainfall data, historical stream flow data, annual 7 days low flow and the water quality data of Sungai Pahang. Two rainfall stations and two stream flow stations were selected for this study. The selection criteria of the hydrological stations are to have more than 20 years of historical data. The historical rainfall data will be used to develop Intensity Duration Frequency (IDF) Curve. An IDF Curve is a tool that characterizes an area's design rainfall intensity.

US Soil Conservation Service method was used to develop dimensionless unit hydrograph for many drainage areas of varying sizes and different geographical locations. The peak discharge and the time to peak were determined in accordance to the standard method and the results are used to plot unit hydrographs, which was adopted in the establishment of storm hydrographs of desired return periods.

The estimation and prediction of extreme floods is a central theme in hydrologic engineering and dam safety (Swain et al., 2004). Mathematical watershed models are used to describe or simulate extreme floods. The watershed models that are extensively used to simulate extreme floods and Probable Maximum Floods (PMFs) are, in most cases, unit hydrograph or storage routing models. The meteorological criteria of this study that fulfill this requirement is maximizing the most severe storm rainfall from two critical monsoon season and also from critically-spaced typhoons or tropical cyclonic storm.

A Flow Duration Curve (FDC) will be developed using the stream flow historical data. FDC is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest. Meanwhile, low flow analysis will be conducted using analytical method i.e. Gumbel's Method and Log Pearson Type III Method and graphical method using Plotting position method. A flow-duration curves (FDC) represents the relationship between the magnitude and frequency of daily, weekly, monthly (or some other time interval of) streamflow for a particular river basin, providing an estimate of the percentage of time a given stream flow was equaled or exceeded over a historical

4 Results and Discussion

4.1 Synthesis of Monthly Streamflow

Huai Pa Law originates from the mountain range located on the west side of Muan district dividing territories between Phisanulok and Phetchabun Province. The available streamflow data recorded at Huai Pa Law station are of good quality, numerous discharge measurements have been taken since 1965. Those watersheds inclined toward the west, southwest and south flow was observed at the earliest data because it received rainfall from the south-west monsoon prior to other areas inclined to other direction. In dry period, the variation of flow date and flow interval was rather high depending upon the onset of rainy season and amount of annual rainfall.

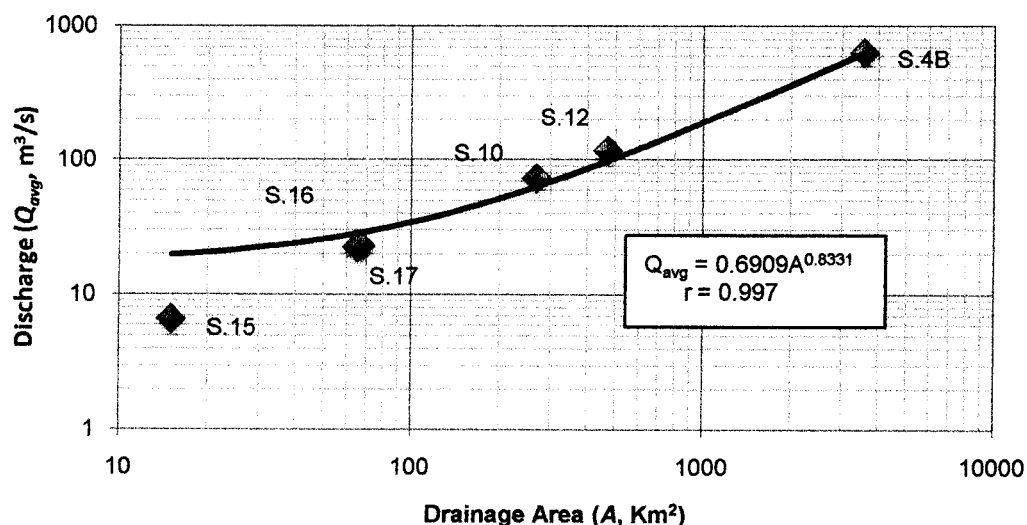


Figure 2 Relationship of mean annual flow and drainage area

In order to generate the reservoir inflow, the synthesis streamflow data which could represent the long-range natural streamflow at the selected stations would be done first. The HEC-4 Model was selected to accomplish this purpose. This model was prepared in the Hydrologic Engineering Center, Corps of Engineers, U.S.A. The model appropriated to predict flow quantity from watersheds in Huai Pa Law reservoirs is $Q_{ave} = 0.6909 A^{0.8331}$, where Q_{ave} was referred to quantity annual streamflow (m³/s); A is referred to watershed area (Km²); on which R^2 is 0.997 as shown in **Figure 2**.

4.2 Design Floods Hydrographs

The analysis of flood peak discharges of various frequencies of occurrence at Huai Pa Law gaging station is used as a basis for the estimation of flood hydrographs. The flood hydrographs of various return periods are of interest for the purpose of planning of diversion design during construction and also for evaluation of flood mitigation. To develop the unit hydrograph of any selected basin from this dimensionless unit hydrograph, two relationships, namely the relationship between time to peak of unit hydrograph and a function of length over square root of basin slope, and the relation of the peak unit discharge and time to peak of the unit hydrograph, are required.

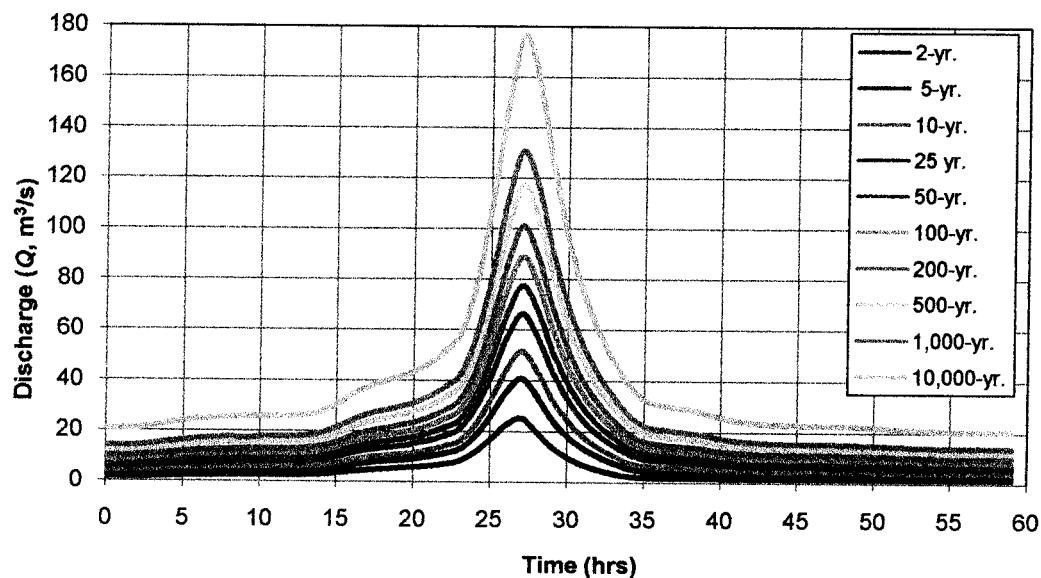


Figure 3 Flood hydrographs for various return periods at Huai Pa Law Reservoir

In this study, the hydrologic model called HEC-1 which was developed by the Hydrologic Engineering Center, Corps of Engineers, U.S.A., was applied. Figure 3 shows the flood hydrographs of various frequencies. Regarding to the diversion work during the construction period, the 20-year return period flood was considered for the design.

4.3 Probable Maximum Flood, PMF

In this study, the possibility of typhoon or decaying typhoon as tropical storm or depression reaching the Rub Roh basin was determined. Available records indicated that, between 1951-1978, no storm of full typhoon entered the peninsula of Thailand. Most of the storms carried a large-scale moisture from the sea causing widespread and heavy rainfall for several days over the eastern coast. Since the area along the east coast of southern Thailand and Malaysia and subjected to a similar type of tropical cyclonic storm disturbance, the derivation of PMP from this type in the area are considered.

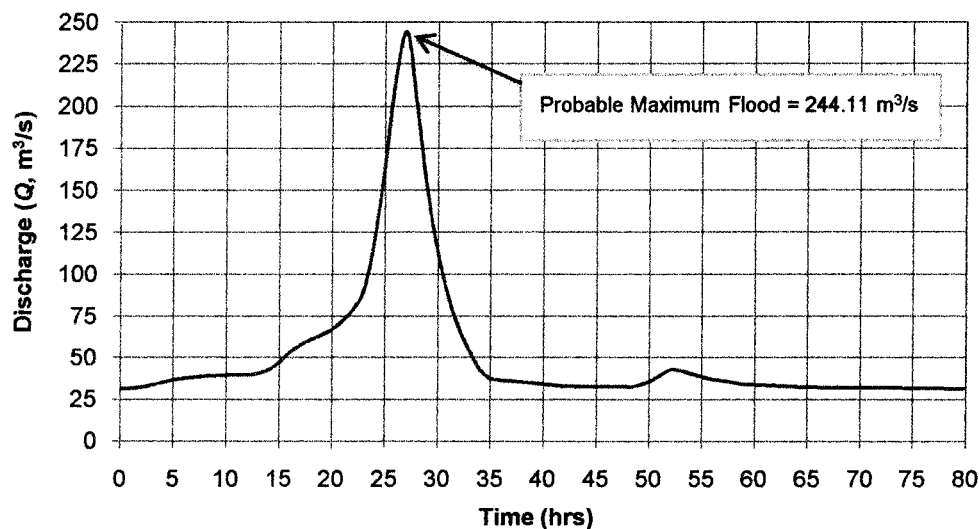


Figure 4 Probable Maximum Flood of Huai Pa Law Hydropower

In estimating the probable maximum flood it was assumed, based on experienced gained from the investigation of the selected storms, the 10 mm per day loss rate due to interception, depression storage, infiltration, etc. It was observed that the probable maximum flood storm pattern No.1 would produce higher flood peak, hence the probable maximum flood resulting from the probable maximum flood of this pattern was adopted for the Huai Pa Law project. The standard project flood or the design flood of the Huai Pa Law Project was adopted to be the flood that having discharges of 50 percent of the probable maximum flood. Base flow of 30 cms was also considered to be added for the direct runoff. The derived design flood for the Huai Pa Law project is shown in Figure 4.

4.4 Available Flow for Power Generation

The flow duration analysis was carried out in accordance to the method established by Quimpo et al. (1983), which can be referenced at <http://water.oregonstate.edu/streamflow/>. The method involves establishment of relationship between discharge and percent of time that the indicated discharge is equaled or exceeded (exceedence probability). The flow duration curve obtained is presented in Figure 6, the 50%, 60%, 75%, and 90% dependable flow for the Huai Pa Law Reservoir are obtained as 2.60 m³/s, 2.00m³/s, 1.20m³/s and 0.50m³/s respectively. Hence the estimated reservoir yield of 0.53 m³/s based on minimum flow corresponds to 90% reliable flow.

Table 1 Estimated energy potential

Reliability (%)	Flow (m ³ /s)	Available flow (m ³ /s)	Net head (m)	Turbine efficiency (%)	General or efficiency (%)	Power (KW)
25	2.60	0.5	12.5	0.95	90	105
30	2.00	0.6	12.5	0.95	92	105
35	1.20	0.7	12.5	0.95	93	105

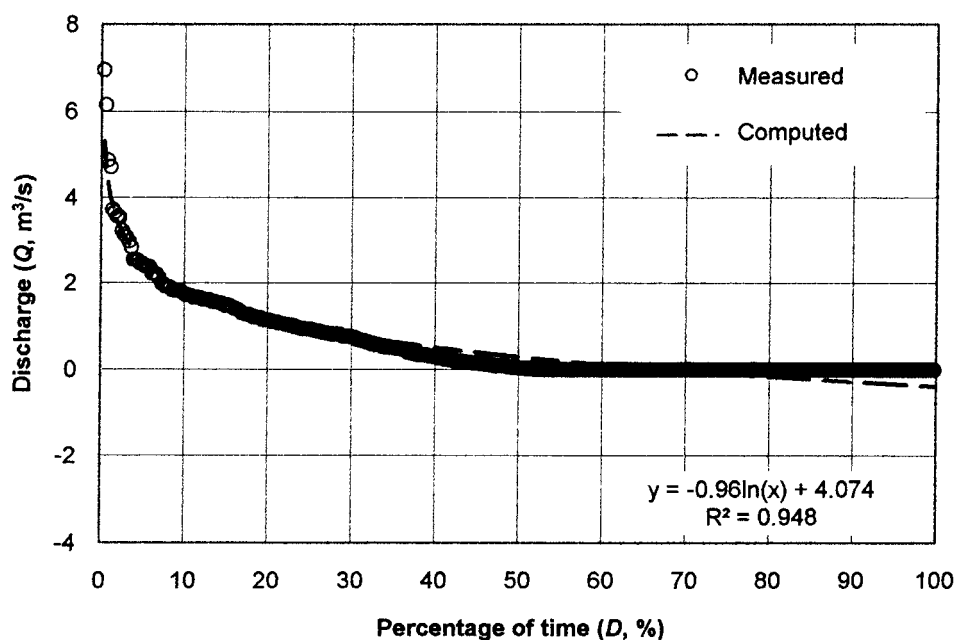


Figure 5 Flow Duration Curve for Huai Pa Law Reservoir

5 Conclusion

The Huai Pa Law Reservoir is ungaged, but there are inflow data at Oyun Dam in Offa, spanning from 1972 to 1981. This data was extended to year 2020 by modeling the inflow and the river flow at the Unilorin dam. These estimates were based on the procedural steps by Loucks et al (1981). The flow duration curve was established in accordance to the procedure developed by Oregon State University. For 50% reliability, the available flow for energy generation was obtained as $1.45 \text{ m}^3/\text{s}$ and the corresponding hydropower potential of the dam is estimated as 108 KW. While for the 75% and 90% reliability, the available flow is $0.70 \text{ m}^3/\text{s}$, and $0.45 \text{ m}^3/\text{s}$ respectively and their corresponding hydropower potential is estimated as 52 KW and 34 KW. Three units will be provided and their operation depends on the available flow into the dam.

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Anekpong Thammathiwat received his Bachelor in Civil Engineering from Thammasat University in 2000. He received his master degree in Structural Engineering from Thammasat University in 2003. Now he is currently working at the Phetchabun Rajabhat University.