

The potential micro-hydropower projects in Nakhon Ratchasima province, Thailand

Preeyaphorn Kosa^a, Thanatchai Kulworawanichpong^b, Rerkchai Srivoramas^c, Avirut Chinkulkijniwat^a, Suksun Horpibulsuk^{a,*}, Neung Teaumroong^d

^a School of Civil Engineering, Institute of Engineering, Suranaree University of Technology, 111 University Avenue, Muang District, Nakhon Ratchasima 30000, Thailand

^b School of Electrical Engineering, Institute of Engineering, Suranaree University of Technology, 111 University Avenue, Muang District, Nakhon Ratchasima 30000, Thailand

^c Department of Civil Engineering, Ubon Ratchathani University, P.O. Box 3, Warin Chamrap, Ubon Ratchathani 34190, Thailand

^d Research Department, Institute of Agricultural Technology, Suranaree University of Technology, 111 University Avenue, Muang District, Nakhon Ratchasima 30000, Thailand

ARTICLE INFO

Article history:

Received 25 December 2009

Accepted 8 September 2010

Available online 14 October 2010

Keywords:

Micro-hydropower

Run-of-the-river

Reservoir scheme

ABSTRACT

At present, fossil fuel energy is commonly used in developing countries, including Thailand. The tendency to use fossil fuel energy is continuously increasing, and the price of fossil fuels is rising. Thus, renewable energy is of interest. Hydropower is one of the oldest renewable energy forms known and one of the best solutions for providing electricity to rural communities. The present paper aims to determine the potential micro-hydropower sites that could provide more than 50 kW but not over 10 MW in Nakhon Ratchasima Province, Thailand. Both reservoir and run-of-the-river schemes are considered for the assessment of potential micro-hydropower sites. For the reservoir scheme, the discharge in the reservoir is employed for generating micro-hydropower electricity. This installation can be carried out without major modifications to the dam. The run-of-the-river scheme diverts water flow from the river mainstream to the intake via a pressure pipe or an open canal, which is then conveyed to the turbine via a penstock to generate electricity. The results showed that there are 6 suitable projects for the reservoir scheme and 11 suitable projects for the run-of-the-river. The maximum power load was 6000 kW and 320 kW for the reservoir and the run-of-the-river schemes, respectively. Hydropower from the run-of-the-river scheme is more suitable than hydropower from the reservoir scheme because of the many mountains in this province. The designed head for the run-of-the-river scheme is thus generally higher than that for the reservoir scheme. Because stream flow during the dry season is very low, electricity can only be produced in the wet season. This research is a pilot study to determine the potential sites of micro-hydropower projects.

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1. Introduction

Many of the developed countries in the world rarely consume their own fossil fuel energy (it is mostly imported from overseas), while developing countries, including Thailand, commonly consume their own fossil fuel energy. Each year, a large amount of the national budget is expended for fossil fuel energy, and the tendency to use fossil fuel energy use is continuously increasing. The prices of fossil fuels are increasing, while the Thai Baht is becoming devalued. The increase in the fuel price might cause a decrease in many development activities in Thailand.

To manage the situation, many types of renewable energy, such as solar, wind, biomass, hydropower, and geothermal, are of interest. The energy from water (hydropower) has been shown to

be economical and clean for electricity generation. It is one of the oldest energy forms known to mankind and one of the best solutions for providing electricity for rural communities, hence improving the quality of life. The present paper aims to determine potential micro-hydropower sites of more than 50 kW but not over 10 MW in Nakhon Ratchasima Province, Thailand.

Nakhon Ratchasima is one of the north-eastern provinces of Thailand and is the largest province in Thailand, with an area of around 20,494 km². The neighboring provinces are Chaibaphum, Khon Kaen, Buriram, Sa Kaeo, Prachinburi, Nakhon Nayok, Saraburi, and Lopburi. The province is located on the western end of the Khorat Plateau, separated from the Chao Phraya river valley by the Phetchabun and Dong Phrayayen mountain ranges. There are two national parks in the province: Khao Yai in the west and the Thab Lan in the south. There are 340 water resource projects developed in this province that are financially supported mainly by the Royal Irrigation Department, Thailand.

* Corresponding author. Tel.: +66 (0) 4422 4420 1.

E-mail address: suksun@sut.ac.th (S. Horpibulsuk).

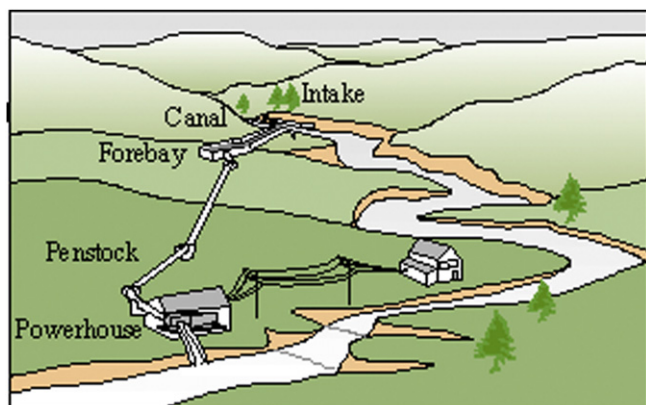


Fig. 1. Run-of-the-river scheme (<http://www.pnwwaterweb.com/images/RofR.jpg>).

2. Methodology

A micro-hydropower plant project aims to produce alternative energy to be used for powering local communities, with a surplus of renewable hydropower energy to potentially sell on the grid. There are various schemes to convert the potential energy of a mass of water flowing in a stream with a certain fall to the turbine into electric energy at the lower end of the scheme. The power output of the scheme is proportional to the flow and the head. In this paper, two schemes, (i) the run-of-the-river scheme and (ii) the reservoir scheme, are explored.

The run-of-the-river scheme, as shown in Fig. 1, generates electricity when the water in the river is sufficient. This scheme diverts water flow from the river mainstream to the intake via a pressure pipe or an open canal. It is then conveyed to the turbine via a penstock to generate electricity.

The advantage of this micro-hydropower scheme is that it does not need its own large reservoir. The discharge for fundamental use or the ecological flow from reservoirs built for any other purposes, such as flood control, irrigation, or recreation, can be employed for generating micro-hydropower electricity. The installation of this micro-hydropower scheme can be carried out without major modifications to the dam, as is illustrated in Fig. 2. Several reservoirs storing enough water for irrigation purposes are available in Nakhon Ratchasima.

For this research, both the run-of-the-river and the reservoir schemes were considered. The stream flow of the river and the

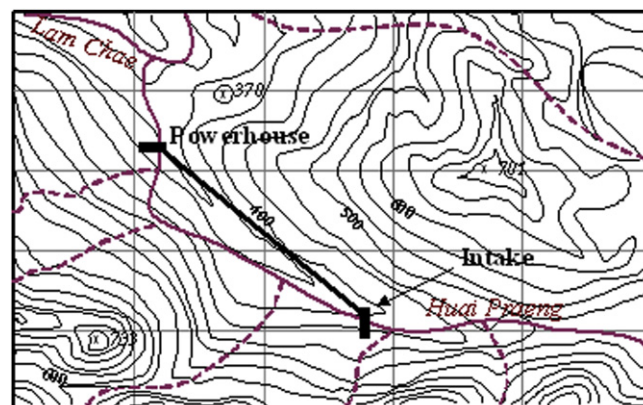


Fig. 3. Positions of the intake and powerhouse at Lumtakong sub-river point C.

contour line around the river were used to compute the power. If the capacity is sufficient, the run-of-the-river scheme is considered for this site. For the reservoir scheme, the water in the reservoirs was used to estimate the load of electricity before release for irrigation activities and water supply. Water to support the irrigation area and water supply will not be impacted by the electrical generation. The characteristics of reservoirs were also data for the power output. In this case, there is not a new reservoir or a new dam. If the reservoirs have the capacity to produce power, the reservoir scheme will be applied for them.

To estimate the power for the run-of-the-river and reservoir schemes, the head and stream flow are important data. Head is defined as the vertical distance that the water falls. It is a function of the characteristics of the channel or pipe through which water flows. When determining head, it is important to consider both gross head and net head. Gross head is the vertical distance between the top of the penstock that conveys the water under pressure and the point where the water is discharged from the turbine. The net head is the difference between the gross head and the losses due to friction and turbulence in piping. Stream flow is the quantity of water falling in gallons per minute, cubic feet per

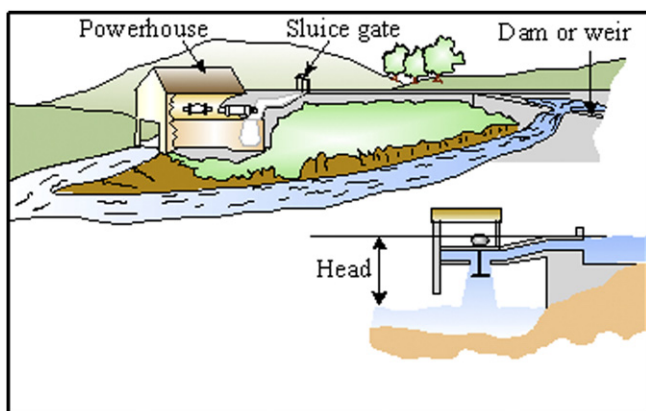


Fig. 2. Reservoir scheme (<http://www.rise.org.au/info/Tech/hydro/image019.jpg>).



Fig. 4. Runoff stations at Nakhon Ratchasima.

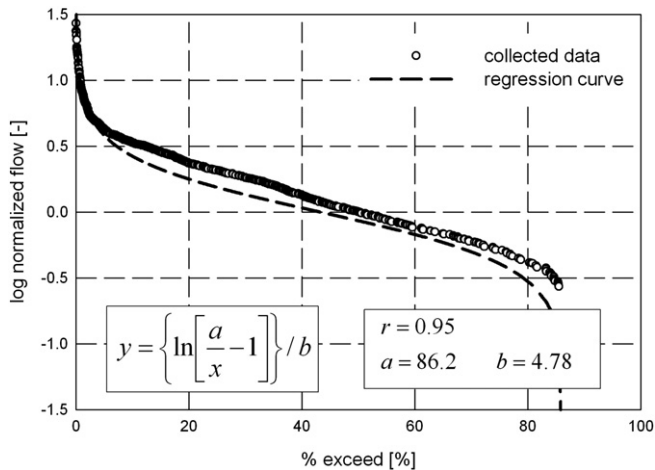


Fig. 5. Flow duration curve at Lumtakong sub-river point C.

second, or liters per second. Both head and stream flow were used for power estimation based on the run-of-the-river and reservoir schemes.

For decisions involving the designed discharge and head for each irrigation project, the crop calendar, the frequency of flooding and drying, the storage in reservoir, the inflow and outflow of the reservoir, the daily rainfall, the infrastructures of the irrigation project, the drainage discharge, the evaporation and infiltration in the reservoir, the discharge calendar for other purposes of the irrigation project, and the distance between the reservoir and electric lines were also taken into consideration.

2.1. Run-of-the river

To select the potential site, the positions of the intake and powerhouse were first located using topographic maps with scales of 1:50000 and 1:4000. The differential elevation between the positions of the intake and powerhouse should be more than 20 m, while the distance between them should be less than 3 km to minimize head loss. Fig. 3 presents the positions of the intake and powerhouse at Lumtakong Sub-river Point C. The differential elevation between the positions of intake and powerhouse is 90 m, while the distance between them is 2.5 km.

Having selected the potential sites, the stream flow or runoff was considered from the nearby runoff station. Thereafter, the selected potential sites were surveyed to determine accurate head and stream flow. The runoff stations studied are shown in Fig. 4.

The runoff data from these stations were used to calculate the designed stream flow using the concept of a flow duration curve (FDC). The FDC presents the relationship between the normalized stream flow and the percent exceeded. The normalized stream flow

Table 1
Designed characteristics for power estimation.

Title			Note
Head	5.00	m	1-m Diameter
Flow rate	2.00	m ³ /s	
Head loss	0.72	m	with head loss
Power output	49.05	kW	
Power output	41.99	kW	

was determined by dividing stream flow by the median discharge of the non-zero flow days. From the analysis of the runoff data, it was found that the FDC for this study can be represented by the logarithmic function, as previously shown by some researchers [1–4]. The logarithm of the normalized stream flow crosses the axis at the median stream of the non-zero flow days. The FDC is calculated using the following equation:

$$y = \ln\left(\left(\frac{a}{x}\right) - 1\right) / b, \quad (1)$$

where y is the log (normalized stream flow), x is the percent exceeded, a is the percent exceeded in the case of the flow value and b is a constant controlling the slope of the FDC.

Fig. 5 shows an FDC at Lumtakong Sub-river Point C, which was one potential site. The runoff stations used included M.38C, M.43A, M.89 and M.177. It was found that the predicted FDC was in very good agreement with the measured one, which reinforces the application of Eq. (1) for predicting the FDC in Nakhon Ratchasima province, Thailand.

Finally, the head and stream flow were used to compute the power output. The power generated is presented as follows:

$$P = \frac{\eta \gamma Q H}{1000}, \quad (2)$$

where P is the electric power output in kW, η is the station efficiency, γ is the specific weight of water in N/m³, H is the net head of water in m and Q is the design flow in m³/s.

An η value of 0.5 was taken for this calculation, which is typical for small hydropower systems in Thailand. This value was also used for some hydropower projects in other countries [5,6], possibly because the hydropower systems are generally constructed from similar materials. Additionally, head loss (major and minor head loss) must be taken into consideration. They can be approximated by the following equations:

$$H_{\text{major}} = \frac{f \times L_p \times 0.08 Q^2}{d^5} \quad (3)$$

$$H_{\text{minor}} = \xi \frac{v^2}{2g}, \quad (4)$$

Table 2
Power estimation at Subpradu Reservoir.

Left main channel, LMC						
Discharge (m ³ /day)	76896.0	57024.0	13824.0	8640.0		
Energy (kWh/day)	523.8	388.4	94.2	58.9		
Operating hour per day	12.5	9.3	2.2	1.4		
Duration (day)	20	14	5	3		
Right main channel, RMC						
Discharge (m ³ /day)	93312.0	57024.0	56180.0	49248.0	43200.0	7776.0
Energy (kWh/day)	635.67	388.5	382.7	335.5	294.3	52.9
Operating hour per day	15.1	9.3	9.1	8.0	7.0	1.23
Duration (day)	7	17	7	14	8	15

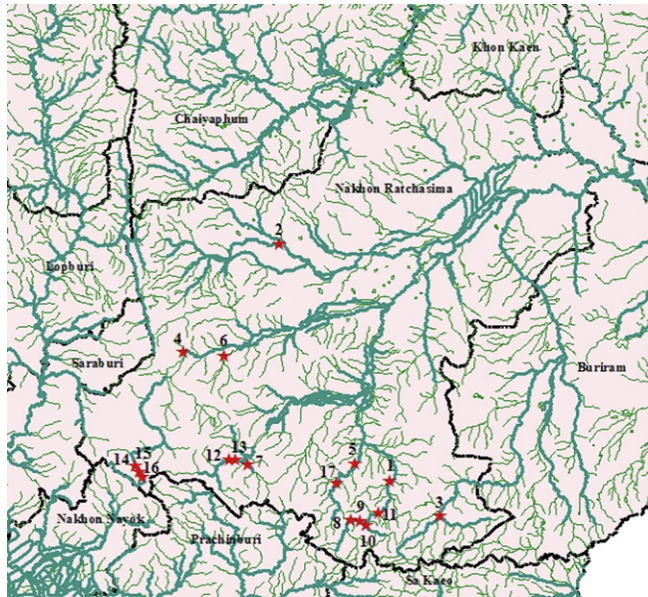


Fig. 6. Positions for hydropower in Nakhon Ratchasima.

where f is the friction coefficient, Q is the discharge in m^3/s , d is the diameter in m, v is the velocity in m/s and ξ is the minor loss coefficient.

2.2. Reservoir type

From topographic maps with scales of 1:50,000 and 1:4000, surveying and reservoir characteristics were considered to determine the designed head. The daily discharge of the reservoir was considered to determine the designed discharge based on the method of FDC. Normally, there are two main channels in a reservoir, the right main channel (RMC) and the left main channel (LMC), so the head and discharge from both the RMC and LMC were used for the estimation of power. The power was estimated by Equations (2) to (4). To explain the calculation of power, Subpradu Reservoir is taken as an example. Table 1 presents the designed head, design discharge and designed installation capacity. Table 2 presents the

details of the power estimation at both the RMC and LMC. Thus, the designed installation capacity of the RMC and LMC are 50 kW each, and the duration of power generation is 103 days in a year. The total power output in a year is 38142.23 kW.

3. Results

For the reservoir type, there are 6 projects suitable for generating electricity. They are Lumcha Reservoir, Lumchaikai Reservoir, Lumpraymas Dam, Lumtakong Dam, Munbon Dam, Subpradu Reservoir, as shown in Fig. 6. The maximum power load of 6000 kW was determined for the Lumpraymas Dam, while the minimum power load of 50 kW was determined for Subpradu reservoir (see Table 3).

For the run-of-the-river scheme, there are 11 suitable projects for generating power, as presented in Fig. 6. The maximum power load of 320 kW was calculated for Lumcha Point C, while the minimum power load of 75 kW was determined for Klongpai, Lumcha Point D, Lumprapreang Point A and Lumprapreang Point B, as shown in Table 3.

4. Conclusion

It can be concluded that Nakhon Ratchasima has potential to produce micro-hydropower using both the reservoir and the run-of-the-river schemes. The designed head is important for power generation because a designed discharge for each site had a low of about 0.25–0.75 m^3/s . Hydropower from the run-of-the-river scheme is more suitable than hydropower from the reservoir scheme because of the many mountains in this province. The designed head for the run-of-the-river scheme is thus generally higher than that for reservoir scheme. Because stream flow during dry season is very low, electricity can only be produced during the wet season. This research was a pilot study to determine the potential sites of micro-hydropower projects based on the reservoir scheme and the run-of-the-river scheme.

Acknowledgements

This research was funded by the National Research Council of Thailand. The authors are grateful to the Suranaree University of Technology for facilities and equipment provided. The stream flows

Table 3
Hydropower sites.

No	Project	Powerhouse (UTM)		Designed head	Scheme	Power load (kW)		
		E	N					
1	Lumcha Reservoir	205,342	1,596,225	5	Reservoir Scheme	1800		
2	Lumchaikai Reservoir	166,790	1,685,177	5		300		
3	Lumpraymas Dam	223,370	1,582,900	5		500		
4	Lumtakong Dam	129,894	1,646,223	10		6000		
5	Munbon Dam	192,499	1,603,180	5		300		
6	Subpradu Reservoir	145,040	1,64,4405	5		50		
		Powerhouse (UTM)		Intake (UTM)				
7	Klongpai	152,611	1,603,816	153507	1602272	20	Run-off-the-river	75
8	Lumcha Point A	190,527	1582304	188746	1581618	50		200
9	Lumcha Point B	193747	1581771	191527	1582604	55		180
10	Lumcha Point C	196046	1580406	197689	1578253	90		320
11	Lumcha Point D	200821	1584903	198485	1584663	20		75
12	Lumprapreang Point A	146020	1606040	145219	1606314	20		75
13	Lumprapreang Point B	148391	1605989	146984	1605766	20		75
14	Lumtakong Sub-river Point A	110892	1604636	112216	1602647	25		100
15	Lumtakong Sub-river Point B	112529	1602334	113363	1600672	50		200
16	Lumtakong Sub-river Point C	113532	1600328	113521	1599918	50		200
17	Mun River	185596	1596179	183753	1594417	25		90

from the Royal Irrigation Department and topographic maps from the Royal Thai Survey Department are appreciated.

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