ASSESSMENT OF LOW HEAD, MICRO HYDROELECTRIC EQUIPMENT FOR USE ON SMALL TROPICAL ISLANDS

By

Dinshaw N. Contractor
Stephen J. Winter

UNIVERSITY OF GUAM

Water and Energy Research Institute
of the
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SURVEY OF MICRO HYDROELECTRIC SITES AND EQUIPMENT FOR USE IN UNDEVELOPED TROPICAL ISLANDS

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Principal Investigators: D. N. Contractor and S. J. Winter

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ABSTRACT

This project points out the suitability of micro hydroelectric equipment for application on undeveloped tropical islands. Two potential hydro sites on the island of Ponape were investigated. Manufacturers of hydro equipment suitable for installation at these sites were identified and price quotations were obtained.

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INTRODUCTION

Hydroelectric generation is a technology that has been used for many decades in developed countries. Even though the larger hydro sites in the U.S. have been developed, there is a resurgence of interest in developing the numerous, low-head, small-scale hydro sites that are still available. Hydroelectric generation on small tropical islands is a very attractive venture because of the following reasons: (1) The price of oil has been rising and the cost of delivery to the islands is rising just as fast. (2) Most of these tropical islands have an abundant annual rainfall and, consequently, stream flow that is always available. (3) There are many waterfalls on the islands that would provide the required head. (4) Many villages are too remote from urban areas to have municipal power delivered to them in the foreseeable future. (5) The electrical demand of these villages is modest, involving mainly the lighting needs of the village and perhaps some refrigeration. (6) Hydropower is independent of fuel-cost and is virtually maintenance-free.

For the reasons given above, it was decided to demonstrate the suitability of micro-hydroelectric generation on a typical Micronesian island. The demonstration unit would encourage other communities on the same or similar islands to meet their electrical needs using the same technology. The island chosen for this demonstration was Ponape.

This report will deal with the preliminary investigation of two sites on Ponape where such a demonstration hydro-unit can be installed. The size of the units will be discussed and the equipment manufacturers and the cost of the units will be presented.

SITE INVESTIGATIONS

Ponape island is located at 7° north latitude and 158° east longitude. The island is roughly circular in plan with a diameter of 10 miles and an area of 144 square miles. The annual rainfall at Kolonia, the capital, is approximately 192 inches, with rainfall in the interior mountains ranging from 350 to 400 inches. The streams on the island flow roughly radially from the center of the island out to sea. There are four rivers that have been gaged by the U.S. Geological Survey. They are presented in Table 1. There are, of course, numerous other rivers on the island. There are a number of sites on the island that have a potential for hydrogeneration. Two of the sites were selected for preliminary investigation.

The first site (site A) is on the Kiprohi River in Mand Village. There is a waterfall about 50 feet high and the village is about half a mile upstream of the falls. The watershed area at the falls is estimated to be about 1.3 square miles. The flow along this river is not gaged and so it is difficult to obtain a flow-duration curve directly at the waterfall. An approximate method of deriving an appropriate flow-duration curve is presented in the next section of this report.

The second site (site B) is a smaller waterfall that is located on an unnamed tributary of the Palikir River and is on the property of Mr. Fred Ramp.

Table 1. Gaged rivers in Ponape.

Name	USGS Gage #	Watershed Area (mi^2)	Gaging Period	Average Flow Rate	
				cfs.	cfs./mi^2
Nanpil River	16897600	2.93	'70 - Present	51.9	17.7
Lui River	16897900	0.47	'70 - "	5.59	11.9
Lui River at mouth	16898200	2.06	'70 - "	26.5	12.9
Lupwor River	16898600	1.12	'72 - "	8.92	7.96

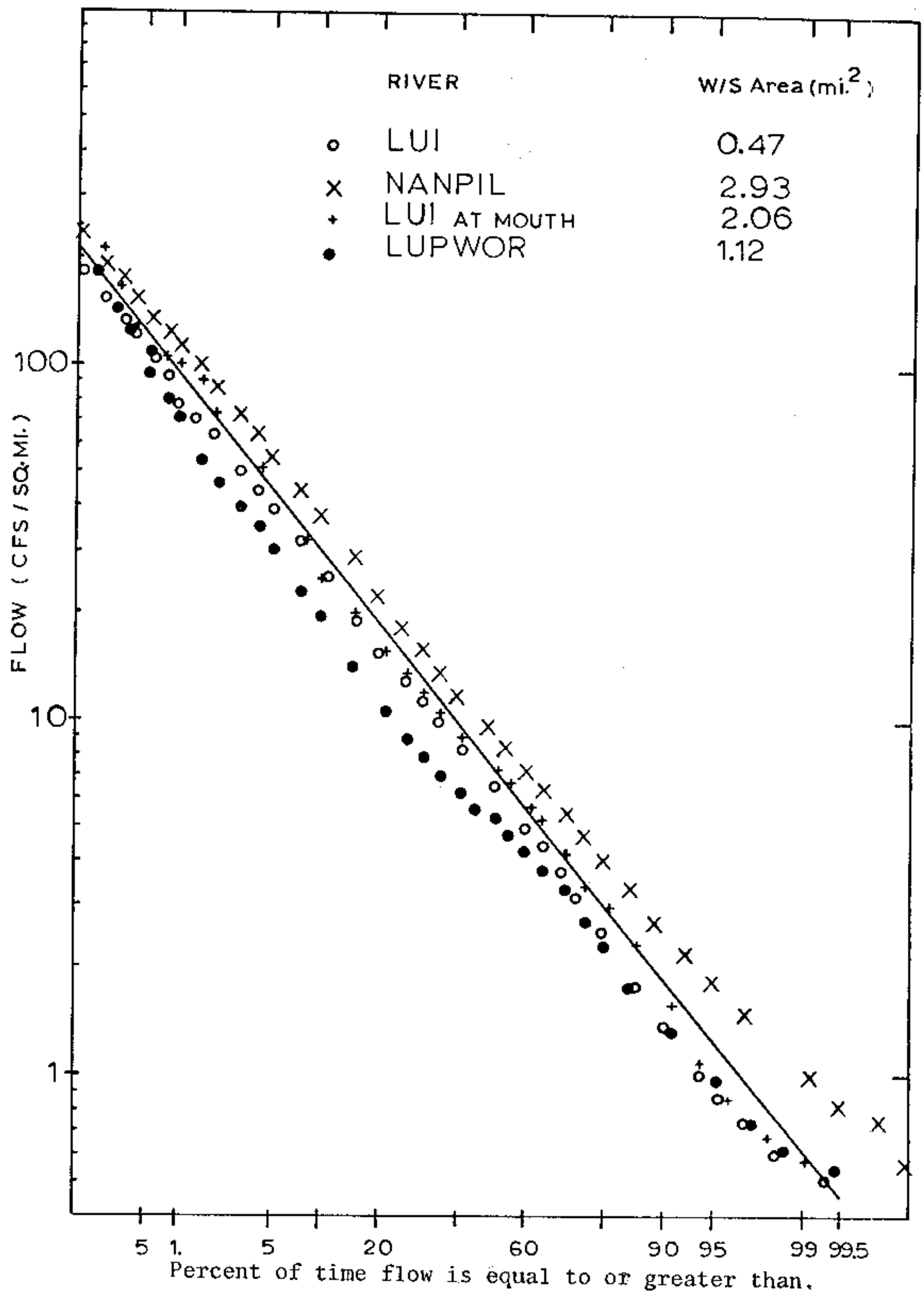

Figure 1. Flow-duration curves for gaged rivers in Ponape.

The waterfall is about 20 feet high and another 10 feet of head could be obtained 200 ft. downstream. The watershed area at the falls was estimated to be 0.3 square miles. Spot measurements of flows have been made on this stream but not enough to provide a flow-duration curve. A number of houses are to be built in the general vicinity and a hydro-unit will supply the electrical needs of these houses.

Both of these sites were visited and a qualitative impression of these sites obtained. Time did not allow any quantitative measurements to be made.

FLOW-DURATION CURVES

Daily discharge data (U.S.G.S., 1980) for the four rivers listed in Table 1 were used to obtain flow-duration curves. These curves are presented in Figure 1. The ordinate axis used is discharge per square mile. In this way, the four curves seem to fall close to one another and indicate that the hydrologic regimes of the rivers are not too different from one another. Because of this, an average line through the curves can be used as a predictive tool for other watersheds in the same general area of the rivers. The curve can be applied to the two sites concerned with in this report.

Flow-duration curves (Barrows, 1943) are helpful in the design and analysis of many water resources systems. In hydroelectric generation, they are used to determine the firm power provided by the stream and to study the probability of obtaining larger amounts of power. Thus, one can determine the power level that will be provided, say, 90% of the time or 80% of the time, etc.. Also, it can be seen that the average flow (or power) will be available only 30 to 40% of the time. If a storage reservoir can be built at the location, the firm power can be increased and the effect of storage on the flow duration curve can be studied. In the case of micro-hydro development, the cost of the storage structure would be unjustified and, so, micro-hydro must be a 'run of the river' development.

Figure 2 presents the estimated flow and power-duration curves for site A. The flow rates from Figure 1 were converted to power values by using the watershed area, the available head and a turbine efficiency of 60%. As more reliable data on the watershed area, available head and turbine efficiency become available, the conversion from flow rates to power will change and the power-duration curve must be re-evaluated. Figure 3 presents the corresponding flow and power-duration curves estimated for site B. It should be noted that the efficiency of small hydro units is less than the efficiency of large scale hydro units, which can be 80% or more.

EQUIPMENT

A list of small-turbine manufacturers was obtained from Moore (1979). Letters were mailed to these manufacturers asking them for quotes on turbines and control equipment for both sites A and B. The manufacturers and their replies are detailed below:

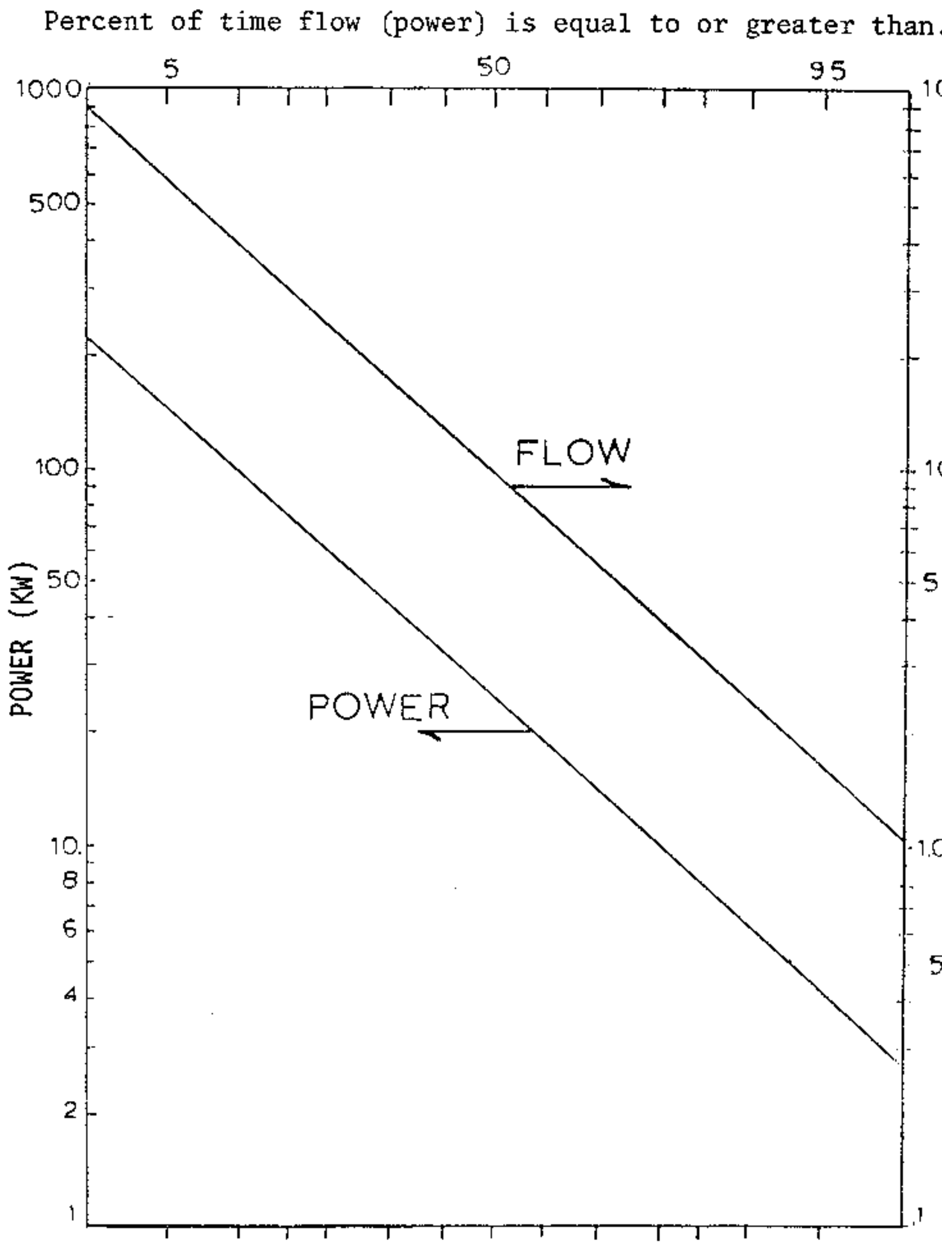

Figure 2. Flow and power-duration curves estimated for site A.

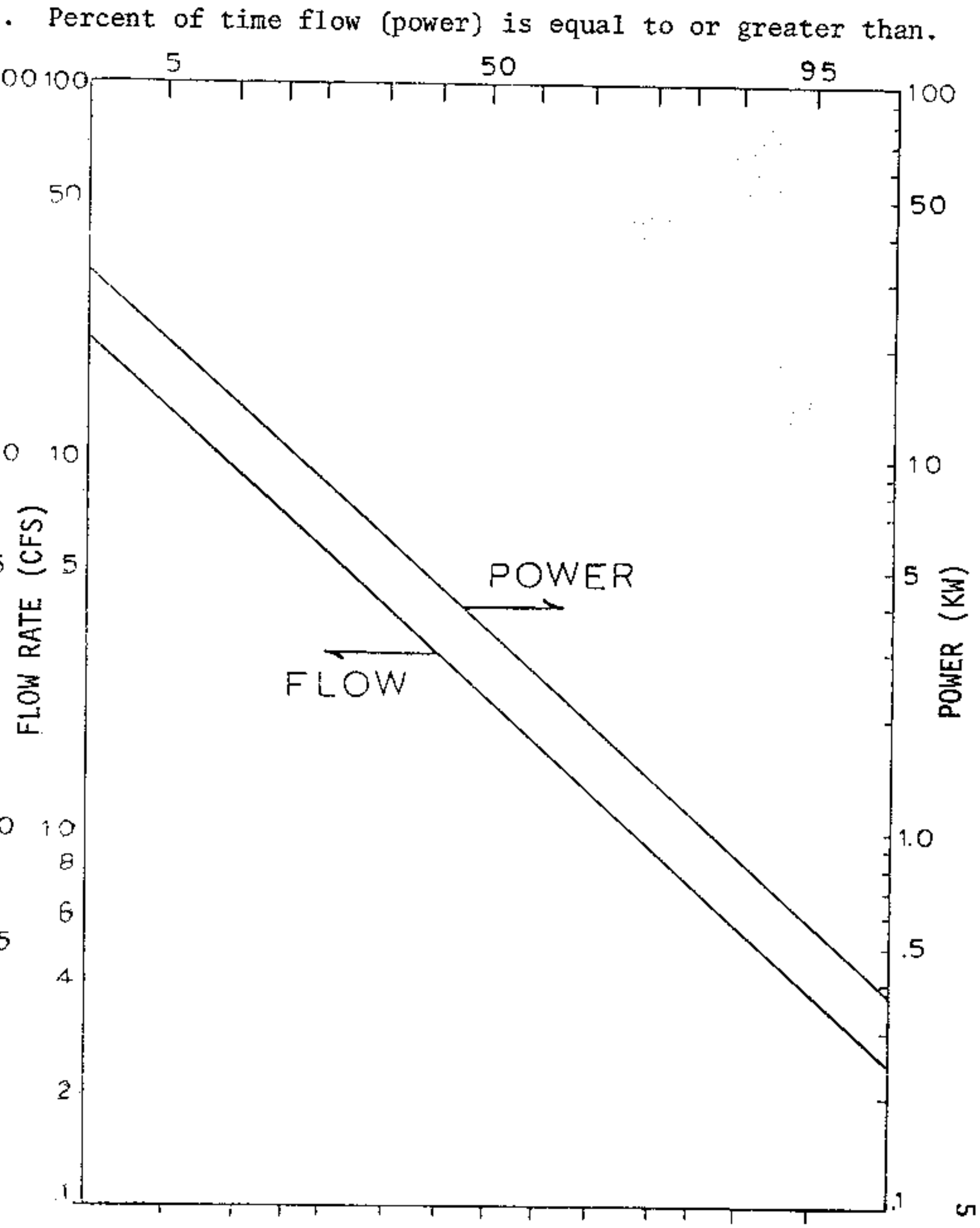

Figure 3. Flow and power-duration curves estimated for site B.

1) C. Dumont & Cie
Pont de St. Uze
26240 St. Vallier
Drome, France

The units required were much too small and out of their range of manufacture.

2) The James Leffel and Co.
426 East Street
Springfield, Ohio 45501

The units required are too small. The smallest turbine they manufacture is approximately 50 KW.

3) G. E. C. Machines Ltd.
Mill Road
Rugby, Warwickshire
England CV21 1BD

The company does not manufacture turbines but does manufacture generators and other electrical equipment that goes along with hydro turbines.

4) Jyoti Ltd.
International Division
Bombay Shopping Center
Vadodara, 390 005
India

This firm manufactures hydro sets down to 5 KW sizes. However, they manufacture only 3 phase generators and, for the application on Ponape, single phase generators would have been adequate. If three phase transmission lines do not involve a very large expense, quotations for their hydro-sets should be obtained, as they may be competitive.

5) MacKellar Engineering
Grantown-on-Spey
Morayshire,
Scotland

This firm was able to offer two of their turbines which would come close to the requirements for the two sites.

Site A.

500 mm propeller turbine; 6 m head; 28° blade angle (variable pitch); 31 cfs flow; 30 KW; Price: FOB $16,520. Electronic Box extra. The Electronic Box controls the voltage from the generator to the ballast load to domestic load. It is an on-load system where all electrical load is taken to the ballast load immersion heater, face heater, central heating, etc. and, as the domestic load is increased, the Electronic Box takes the load from the ballast and sends it to the domestic load and vice versa. If there is an electrical overload, then the overload switch at the generator-outlet trips and the turbine will shut down with the overspeed mechanism.

Site B.

300 mm turbine; 6 m head; 28° blade angle (variable pitch); 12 cfs flow; 11 KW; Price: FOB $13,720; Electronic Box extra.

6) Canyon Industries
   5346 Mosquito Lake Road
   Deming, Wash. 98244

A crossflow turbine was recommended for both sites. The turbine units would be custom-designed for the specific heads and flow rates of the sites. The runner is machined, polished, heat-treated and balanced. The runner is enclosed in a steel plate housing with internal water seals, external HD ball bearings and integrally-welded alternator support and turbine mounting base. The drive assemblies are multi-grooved V-belt components with a 20 service factor, protected with a safety shield. The flow of water is manually controlled with an infinitely variable control jet from maximum to minimum flow.

The alternator has the following specifications: Fidelity Electric; 27 KW; 1800 RPM; 120/240 volts AC; 60 cycles; single phase; brushless. It is industrially rated with patented HD bearing assemblies.

To maintain constant speed, frequency and voltage on the system, a Thompson and Howe load controller was recommended. This unit has been tested by Canyon Industries for two years and allows full use of all power produced, electronically shifting total available power from 'normal' load circuits.

Site A: $11,340.00

Site B: $13, 850.00

DISCUSSION

The data used in evaluating the power potential of each site were only first order estimates of the variables. More reliable (firm) estimates need to be obtained by engineering field work. Even after the field work, there will still remain the problem of selecting the size of the hydro units desirable at each site and matching it with the hardware that is available from manufacturers.

The power-duration curve estimated for a given site must be used to select the desirable size of the hydro unit. This selection is related to the degree of inconvenience that the users of the electrical power are willing to tolerate. If a power system is sized to provide the power level that is available all 24 hours of every day of every year (i.e. 100% firm or reliable power), then the units for both these sites would be very small and the power would not be very economical. Selecting a unit that is larger means that the unit will provide its rated power for part (say 90%) of the time and will provide less than its rated power for the remaining time (10%) depending on the flow in the river. The larger the unit, the greater will be the cost. This increase in cost has to be matched with the increase in power available (even though it is available with less reliability). If the increased available power can be utilized effectively, the increased cost of the unit may be justified. The specific size selected is dependent on the user's ability to gainfully utilize the extra power.

The desirable size of the hydro unit may or may not match the size of units made available by manufacturers. It will then be necessary to select the unit that comes closest to the desirable size. Once the unit is selected, then the efficiency of the unit can be used to determine the maximum power level that will be provided and the percent of time that it will be available.

CONCLUSIONS

The purpose of this project was to show the suitability of micro-hydro for use in small tropical islands. The technology for this development already exists and has been proven to be cost-effective in developed countries. To bring about its use in tropical islands, it was thought desirable to demonstrate its application and use to the local people.

Two sites were investigated on the island of Ponape where such a demonstration unit could be installed. Preliminary investigations were made to size the units. Quotations were obtained from two manufacturers on units for the sites. Further work would obviously need to be conducted before putting in a final order for either of the units. The cost of transportation of the units to the site, the cost of installation of the units and the cost of the electric transmission and distribution lines would have to be estimated and included in the total cost. However, the work reported in this study shows that a micro-hydro unit installed in either or both of the sites would fulfill the objectives of this study.

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