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DEVELOPMENT OF KAM PONG, MAE TON LUANG, HUAI PUI, AND BO KAEO MICRO-HYDROPOWER PROJECTS

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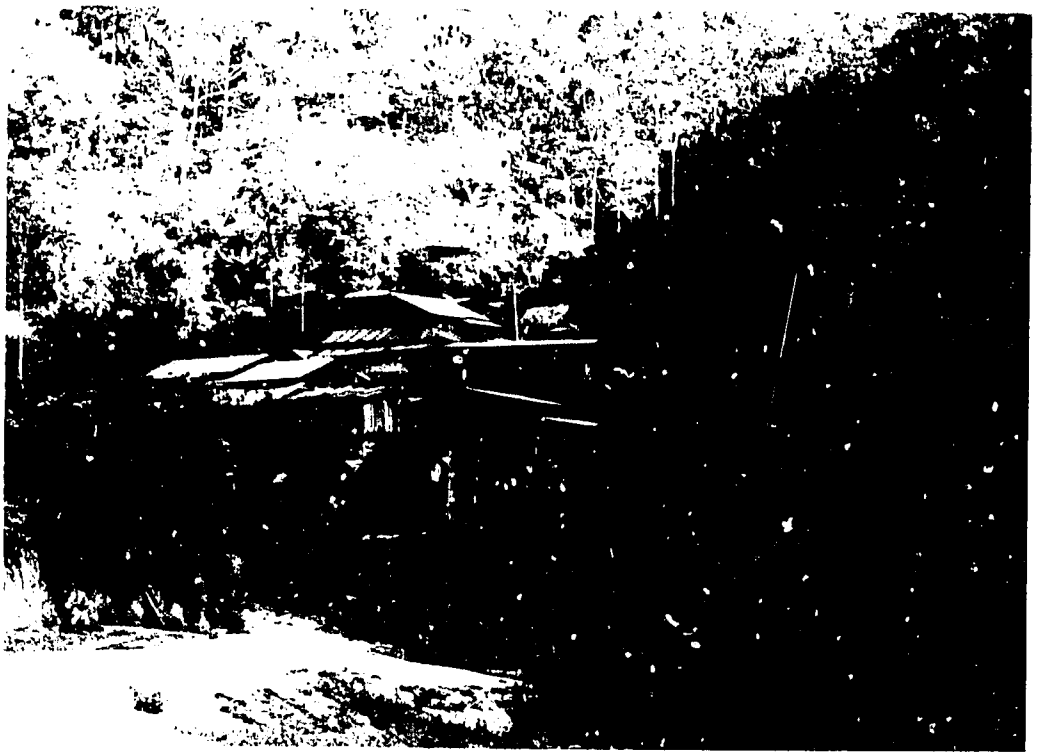

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TERMS AND ABBREVIATIONS

AC	=	Alternating Current
AIT	=	Asian Institute of Technology
ARE	=	Accelerated Rural Electrification
B/C	=	Benefit-Cost Ratio
DC	=	Direct Current
EGAT	=	Electricity Generating Authority of Thailand
MSL	=	Mean Sea Level
NEA	=	National Energy Administration
PEA	=	Provincial Electricity Authority
PVC	=	Polyvinyl Chloride
TEAM	=	TEAM Consulting Engineers Co.,Ltd.
USAID	=	U.S. Agency for International Development
A	=	ampere
AT	=	ampere-turn
GWh	=	giga-watt-hour
Hz	=	Hertz
kV	=	kilo-volt
kW	=	kilo-watt
KVA	=	kilo-volt-ampere
kWh	=	kilo-watt-hour
km	=	kilometer
MB	=	million baht
m	=	meter
rpm	=	revolution per minute

EXECUTIVE SUMMARY

In this study the results from the implementation of four micro-hydropower projects in Chiang Mai are presented. These four projects are Kam Pong, Mae Ton Luang, Huai Pui, and Bo Kaeo Projects. These projects were implemented with financial assistance from the United States Agency for International Development (USAID).

In studying the project features, socio-economic characteristics, project organization and construction works, the following conclusions can be made.

1. The micro-hydro component is the only one of the technology components for which the technology was actually installed, operated, and maintained by the local villagers. This provided an opportunity to conduct a baseline survey, transitional surveys and evaluation surveys -- although the evaluation surveys were very limited because the hydropower had been operated and used by the villagers for only a few months.

2. The hydropower component demonstrated very clearly that village participation can be successfully utilized in rural development projects.

3. The hydropower component has not yet completely demonstrated the economic feasibility of this source of renewable energy because the governmental agency has provided free of charge all of the materials and hardware which are unavailable in the villages being served.

4. There is a need for basic designs of micro-hydro plants and systems to be developed specifically for micro-hydro which are suited to the PARED technique so that there can be even greater involvement of the villagers, and so that micro-hydro plants and systems can be set up in the future without such heavy input from the governmental agency, especially with regard to the input of materials and hardware from outside. In other words, such projects can and must be made economically feasible to the villagers (who should pay all costs) at some point in the near future.

In evaluating the results of the implementation of these four projects, the following recommendations are given.

1. A permanent unit in the NEA should be established for a rapid and systematic expansion of the micro-hydro program in the remote areas of Thailand which are sufficiently far removed from the national electric grid that it will be several years, at the earliest, before the grid reaches them.

2. Careful study should be given to simpler and less expensive designs of all the components for micro-hydro projects in the future--in order to reduce still further the overall cost of each project.

3. Detailed study, with the villagers, should be given to ways for the villagers to pay more and more of the total costs of a micro-hydro project--including the materials and the mechanical and electrical equipment brought in from outside.

4. Greater care should be given to utilizing the participation of the villagers for every step of project development all the way from situation assessment and problem identification to operation and maintenance, monitoring and evaluation.

5. The staff and program for the development of micro-hydro projects should be a part of, and be very closely tied and linked to, each of the nearby Regional Energy Centers.

CONCLUSIONS

This chapter summarizes the results of the implementation of the four micro-hydropower projects in Chiang Mai Province, the Kam Pong project, the Mae Ton Luang project, the Huai Pui Project, and the Bo Kaeo project. All four projects have received financial support from USAID, and the National Energy Administration (NEA) is the government authority responsible for the implementation.

A. THE KAM PONG PROJECT

The Kam Pong project is located in Kam Pong village, Tambon Huai Kao, Amphoe San Kampaeng, Chiang Mai Province. The catchment area at the weir site is approximately 6 km^2. The main features of the project include :

1. A concrete gravity weir, 2 m high and 15 m long, with intake structure and spillway.

2. An asbestos cement pipe headrace 0.30 m in diameter and 470 m long.

3. A penstock consisting of an asbestos cement pipe 0.30 m in diameter and 50 m in length and a 50-m long steel pipe of the same diameter.

4. A powerhouse equipped with two sets of turbines, generators, and switchboards. The installed capacity is 40 kW with the design discharge of 0.12 m^3/s and effective head of 60 m.

5. Transmission line and distribution system together with step-up and step-down transformers.

The electricity generated from Kam Pong powerhouse is supplied to 118 households in Kam Pong village. The construction cost of the Kam Pong project is 2,656,500 Baht (US $ 115,500), excluding the labor cost and some local materials contributed by the villagers of Kam Pong. The grant from USAID to the Kam Pong project is 1,438,519 Baht (US $ 62,544). As compared with the diesel power plant of the same capacity, the benefit-cost ratio of the Kam Pong project is 1.98:1, that is, the project is considered economically feasible.

Besides the direct benefit from energy production, there exist some indirect benefits as a result of villager participation in construction work. These indirect benefits include :

1. Increasing villagers' income and upgrading their standard of living.

2. Initiating a rule of cooperatives in rural development.

3. Fostering close cooperation between local people and the government in rural development.

4. Transferring an appropriate technology to rural people.

B. THE MAE TON LUANG PROJECT

The Mae Ton Luang micro-hydropower project is located in Tambon Pa Miang, Amphoe Doi Saket, Chiang Mai Province. The catchment area of the basin at the weir site is about 19 km^2. Most parts of the terrain are steeply sloping and are covered with dense forests. The main features of the Mae Ton Luang project include :

1. An concrete gravity weir, 2.20 m high and 19 m long with intake structure and sluice gate for sediment release.

2. An asbestos cement pipe headrace 0.30 m in diameter and 1,255 m long.

3. An asbestos cement penstock 0.30 m in diameter and 140 m long.

4. A steel surge tank, 1.2 m in diameter and 15.0 m high.

5. A powerhouse equipped with a set consisting of one turbine, generator, and switchboard. The installed capacity is 35 kW at the design discharge of 0.1 m^3/s and effective head of 60 m.

6. Transmission line system including transformers, high-voltage and low-voltage lines.

The electricity generated is supplied to 230 households in three villages of Tambon Pa Miang. The total construction cost is 2,577,150 Baht (US $ 112,050), in which 1,275,731 Baht (US$ 55,467) is a grant from USAID. Besides this budget, the villagers in the Mae Ton Luang project area also contributed to the project by providing part of the labor force and some local construction materials.

When considering the installation, operation, and fuel costs of the diesel power plant of the same capacity as the benefit of the Mae Ton Luang micro-hydropower project, the economic analysis shows that the benefit-cost ratio of the Mae Ton Luang project is 1.82:1. That is, the project is economically feasible.

Similar to the Kam Pong project, the participation of the villagers in the construction work of Mae Ton Luang project also yielded indirect benefits as mentioned in Chapter 4, Section G.

The main difficulty arising in the implementation of Mae Ton Luang project was the delay in the purchase and delivery of the generating equipment. This led to the delay in the operation schedule.

C. THE HUAI PUI PROJECT

The Huai Pui project is located in Tambon Long Khod, Amphoe Prao, Chiang Mai Province. The catchment area is approximately 11.6 km^2. The main features of the Huai Pui project include :

1. A concrete gravity weir, 3 m high and 16 m long with intake structure and sluice gate at the right abutment.

2. An asbestos cement headrace 0.30 m in diameter and 1,450 m long. The design discharge is 0.1 m^3/sec.

3. A steel penstock 0.30 m in diameter and 165 m long.

4. A powerhouse equipped with a set of turbine, generator and switchboard. The installed capacity is 50 kW at the design discharge of 0.1 m^3/s and design head of 85 m.

5. Transmission line system consisting of step-up and step-down transformers, high-voltage and low-voltage lines.

The electricity produced from the Huai Pui powerhouse is supplied to 250 households in Tambon Long Khod. The total construction cost is approximately 2,972,000 Baht (US $ 129,217) in which 1,030,921 Baht (US $ 44,823) is a grant from USAID. Similar to the Kam Pong and Mae Ton Luang projects, the villagers in Huai Pui project area also contributed in the form of supplying labor force and some local construction materials. With a benefit-cost ratio of 2.09:1, the Huai Pui project is considered to be economically feasible.

Besides the benefit from electric power generation, the implementation of the Huai Pui project also has some indirect benefits as a result of villagers' participation.

The main problems encountered in the implementation of Huai Pui project result from the mountainous topography of the project area. This caused great difficulty in the installation of the headrace and resulted in the delay in project operation.

D. THE BO KAEO PROJECT

The Bo Kaeo project is located in Tambon Bo Kaeo, Amphoe Samoeng, Chiang Mai Province. The main features of the project include:

1. A concrete weir 2 m high and 15 m long with intake structure and sluice gate for sediment release.

2. A steel headrace, 200 m long and 0.40 m in diameter.

3. A steel penstock, 0.40 m in diameter and 600 m long.

4. A powerhouse equipped with two sets of turbines, generators and switchboards, each of which has an installed capacity of 100 kW. That is, the total installed capacity of Bo Kaeo project is 200 kW.

The electricity generated from the Bo Kaeo project is mainly supplied to the Tin Mine of the Mining Industrial Organization. However, four small villages situated near Bo Kaeo powerhouse will also be served by the Bo Kaeo project. Since most electricity from the Bo Kaeo powerhouse would be supplied to the Tin Mine, the construction work was carried out by a contractor without villagers' participation.

The construction cost of the Bo Kaeo project is approximately 6,142,500 Baht (US $ 267,065), of which 1,500,000 Baht (US $ 65,217) is contributed by USAID. The economic analysis reveals that the benefit-cost ratio of Bo Kaeo project is as high as 3.64:1. That is, the project is considered economically feasible.

The major problem encountered during the construction phase of the Bo Kaeo project was the poor accessibility to the project area, and the contractor had to construct a new access road to the site. Another problem was the delay in the purchase and delivery of a transformer which resulted in a delay in project operation.

RECOMMENDATIONS

In investigating the implementation of the four micro-hydropower projects mentioned above, the following recommendations can be made.

1. All the data necessary for the project design and planning should be carefully collected and recorded prior to the approval for the implementation of the project. The collected data should include :

- Topographic map of the project area in an appropriate scale showing the sites for a weir and a powerhouse as well as the location of the villages that will receive the electricity generated from the project.

- Detailed profile along the routes of the headrace and the penstock.

- Geologic structures at the weir site, the routes of the headrace and the penstock, as well as the site for the powerhouse.

- Socio-economic structure of the nearby villages, emphasizing the requirement of electricity for productive use.

- Hydrological data of the stream where the weir will be constructed.

2. With respect to hydrological study, an appropriate method should be adopted in order to obtain as reliable data as possible. More field observation and data collection should be conducted to obtain the most suitable value of the design discharge. Detailed investigation of hydrological characteristics of the region with consideration of several potential sites for micro-hydropower development should be conducted by the responsible agency.

3. Since most of the potential sites for micro-hydropower development are located in a remote area where the accessibility is rather poor, operation and maintenance problems should be carefully considered in the design stage.

4. The implementation schedule should take into consideration the time period needed for each task, including the purchase and delivery of construction materials, and equipment, the available manpower, the nature of the project area, and project features.

5. Villagers' participation should be maintained since valuable indirect benefits result. In addition, some training program should be offered for those staff who are responsible for projects with this kind of work organization.

Chapter 1

Introduction

INTRODUCTION

This report summarizes all information related to the development of four micro-hydropower projects in Chiang Mai Province. These four, the Kam Pong, Mae Ton Luang, Huai Pui and Bo Kaeo Projects, were implemented with financial support from the United States Agency for International Development (USAID) and with technical assistance from the National Energy Administration (NEA)

A. HISTORICAL BACKGROUND

A sharp increase in the amount of fuel oil consumed and increases in the price of fuel oil during the past decade has greatly affected the economic situation in Thailand. A major use of fuel oil has been to produce electricity. There are approximately 20 fuel oil plants distributed throughout various parts of Thailand and 83% of all imported crude oil has been used in electricity generation (Elliott,1981). In order to relieve the nation's dependency on this imported oil for power generation, considerable effort has been made to locate other natural resources available within the country. Several large-scale hydropower projects have been implemented. However, potential sites for these large-scale hydropower projects are limited. Therefore, small-scale hydropower projects are now being considered.

The National Energy Administration (NEA), which is the governmental organization responsible for all aspects of energy planning and development, has included an Energy Master-Plan in the Fifth 5-Year (1982-1986) National Economic and Social Development Plan, in which small-scale hydropower projects are emphasized in connection with development of rural communities in remote areas. In total 25 projects ranging in size from 275 kW to 6,000 kW have been identified by NEA as the most promising small-scale hydropower projects for the first 5-year Plan.

In addition to the above mentioned small-scale hydropower projects, NEA has currently planned for developing several micro-hydropower projects in various parts of the country. Among these, 300 sites in the Ping River Basin in Northern Thailand were identified. In a recent study by TEAM (1983), on the "Master Plan of Mini/Micro Hydropower to Replace Diesel Power Plants", 40 potential mini/micro hydropower sites were considered. The TEAM study revealed 29 sites which are economically suited for further detailed study for engineering works. An economic analysis of the projects shows the benefit-cost ratio (B/C) ranges from 1.094 to 2.568.

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Since most of these projects are located in relatively isolated areas, and due to the imited budget for development of these projects, it was decided to have local people participate in the construction, operation, and maintenance as much as possible. A number of the micro-hydropower projects were implemented with financial support from USAID, technical assistance provided by the NEA and the cooperation of the local people. In addition, information concerning construction cost, problems in construction, operation and maintenance, etc., could also be collected.

The results obtained from the development of the four micro-hydropower projects in Chiang Mai Province, the center of Northern Thailand, are presented in this report. These four projects are the Bo Kaeo Project, the Kam Pong Project, the Huai Pui Project and the Mae Ton Luang Project.

B. NEED FOR THE PROJECT

Due to a rapid expansion of rural electrification, the demand for electricity in Thailand has greatly increased. According to the records of the Electricity Generating Authority of Thailand (EGAT), the demand for electric power consumption has increased from 748.35 MW in 1970 to 2838.00 MW in 1982 and has been forecasted to be as high as 6,217 MW in 1991. Similarly, the energy demand has increased from 4,095.32 GWh in 1970 to 16,881.95 GWh in 1982 and is expected to reach 36,929 GWh in 1991 (Table 1.1)

At present, the energy and power supply in Thailand comes primarily from fuel oil which must be imported. In the past decade, the price of this fuel oil has increased sharply. Therefore, in preparing electric power development plans to fulfil this increasing demand, emphasis has been placed on hydropower which is an available natural resource of Thailand. A number of large hydropower projects have been implemented recently. The electric power generated from these projects are connected to existing transmission systems in order to cope with the requirements from various regions of Thailand. However, due to limited water resources for large-scale hydropower development for rural communities in remote areas, these small-scale hydropower projects have been included in the Fifth 5-year National Economic and Social Development Plan. These projects are needed to help develop remote rural villages. They will be helpful in encouraging the local populace to participate in the planning, decision making and construction of the development projects which will improve the living standard of their own village. Electricity generated from these projects would be utilized for lighting, pumping water for irrigation purposes, driving motors for domestic industries, etc.

TABLE 1.1 EGAT'S TOTAL GENERATING REQUIREMENTS (EGAT, 1983)

Fiscal Year	Peak Generation		Energy Generation		Load Factor %
	MW	% Increase	GWh	% Increase	
		ACTUAL			
1970	748.35	17.26	4,095.32	21.32	62.47
1971	872.70	16.62	4,792.88	17.03	62.69
1972	1,028.80	17.89	5,711.16	19.16	63.20
1973	1,199.30	16.57	6,872.84	20.34	65.42
1974	1,256.30	4.75	7,258.62	5.61	65.96
1975	1,406.60	11.96	8,211.57	13.13	66.64
1976	1,652.10	17.45	9,414.48	14.65	64.87
1977	1,873.40	13.40	10,950.62	16.32	66.73
1978	2,100.60	12.13	12,371.67	12.98	67.23
1979	2,255.00	7.35	13,964.56	12.88	70.69
1980	2,417.40	7.20	14,753.73	5.65	69.48
1981	2,588.70	7.09	15,959.97	8.18	70.38
1982	2,838.00	9.63	16,881.95	5.78	67.91
		FORECAST			
1983	3,292.00	13.87	19,330.00	10.52	67.03
1984	3,708.00	12.64	21,530.00	11.38	66.28
1985	4,070.00	9.76	23,761.00	10.36	66.64
1986	4,415.00	8.48	26,017.00	9.49	67.27
1987	4,750.00	7.59	28,048.00	7.81	67.41
1988	5,114.00	7.66	30,245.00	7.83	67.51
1989	5,469.00	6.94	32,384.00	7.07	67.60
1990	5,837.00	6.73	34,611.00	6.88	67.69
1991	6,217.00	6.51	36,929.00	6.70	67.81

C. OBJECTIVES OF THE STUDY

The main objectives of the four micro-hydropower projects in Chiang Mai can be outlined as follows :

1. To study the cooperation of local people in construction, operation and maintenance of micro-hydropower development projects;

2. To establish local organizations which are most suitable for implementating other micro-hydropower projects in Thailand;

3. To have local people in remote rural areas participate in development projects which are aimed at improving their standard of living;

4. To generate electric power for the rural communities by making use of available natural resources which will in turn reduce the need to import fuel oil from foreign countries.

D. SCOPE OF THE STUDY

The development of the four micro-hydropower projects in Chiang Mai Province includes the following tasks :

1. To conduct an investigation into the suitability of the sites, taking into consideration location and topography, available water resources, demand for electricity, existing electrical supply and distribution of the electrical system, etc.;

2. To conduct the planning, design and specification for each project;

3. To establish local organizations for project development;

4. To carry out the construction work and to purchase and install the mechanical and electrical equipment;

5. To conduct an economic analysis and cost estimation;

6. To identify problems encountered during construction, operation and maintenance of the projects and to provide suggestions for solving these problems; and

7. To conduct socio-economic studies, scrutinize the cooperation of local people concerning project development, and evaluate the suitability and effectiveness of the established organization and the overall impact of the project on the villages and people involved.

E. OUTLINE OF THE REPORT

This report summarizes all available information relating to the development of the Kam Pong, Mae Ton Luang, Huai Pui, and Bo Kaeo micro-hydropower projects, all of which are located in Chiang Mai Province. The report is divided into 10 chapters. In Chapter 2, the existing documents and previous studies relating to micro-hydropower projects are reviewed and summarized. Chapter 3 states the concepts and criteria used in the design of these four micro-hydropower projects. Chapters 4, 5, 6 and 7 present the data concerning design, construction, cost estimation, socio-economic aspects, operation and maintenance of the projects at Kam Pong, Mae Ton Luang, Huai Pui and Bo Kaeo villages, respectively. The discussion and evaluation of the results of the development of these four projects are presented in Chapter 8. Conclusions and recommendations are presented in Chapter 9 and 10, respectively.

F. SIGNIFICANCE OF THE STUDY

There are many constraints in developing micro-hydropower projects. These constraints include the high cost of the project and problems in operation and maintenance. Many projects are not economically feasible. In order to lower the construction cost of the project, participation of the villagers is needed to reduce the labor cost. Use of locally made equipment, including turbine, generator, transformer, switchboard, etc., will also reduce the project cost since most locally made products are cheaper than those from foreign countries. The study of the four micro-hydropower projects in Chiang Mai Province will provide information on the cooperation of local people in the implementation of the project, which will in turn lead to the selection of an organization of the other micro-hydropower projects. In addition, more information concerning actual construction cost, as well as problems encountered in construction, operation and maintenance will be gained. This will be very useful in the planning and design of other micro-hydropower projects.

Chapter 2

Review of the Literature

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REVIEW OF THE LITERATURE

In this chapter, existing documents and reports related to mini and micro-hydropower development projects in Thailand are reviewed and summarized. Most of these projects are planned by NEA, the organization responsible for all energy development programs in Thailand.

A. SMALL HYDROPOWER PROJECTS IN THE RENEWABLE ENERGY ACCELERATION PLAN (NEA, 1981)

The NEA has currently planned to develop several small hydropower projects to cope with the increasing energy demand in the rural area. According to the first five-year Renewable Energy Acceleration Plan (1982-1986), twenty-five small hydropower projects are planned to be constructed by the end of fiscal year 1986. Most of these projects are located in Northern Thailand. A list of these 25 projects and their installed capacity is shown in Table 2.1. Total installed capacity is 55,385 kW with annual energy production of 217.51 GWh. These 25 small hydropower projects include 19 newly proposed hydropower projects of NEA and 6 turbine installation projects of EGAT. Total construction cost of these projects is estimated to be 2,295.34 M฿ (about US$ 99.8 M). About 1,823.74 M฿ (US$ 79.29 M) will be from NEA's annual budget and the remaining 461.60 M฿ (US$ 20.07 M) will be from EGAT. The installed capacity of these projects varies from 275 kW to 6,000 kW whereas the construction cost varies from 25 to 307 M฿ (US$ 1.09-13.35 M). On the average, the construction cost per kW of the installed capacity is 53,362 Baht (US$ 2,320). The average energy production cost is estimated to be 1.66 Baht (US$ 0.07) per kWh. This is much cheaper than the energy production cost of the diesel and crude oil power plants of the same capacity which is about 2.82 Baht (US$ 0.12) per kWh (NEA, 1981).

B. THE PLANNING OF MINI/MICRO-HYDROPOWER PROJECTS IN THAILAND (MONGA,1981)

This paper was presented in the Workshop on Small-Scale Hydropower Technology Applications in Asian Rural Setting which was held at the Asian Institute of Technology, Bangkok, during June 8-12,1981. It summarizes the present state of hydropower facilities in Thailand, and the country's total potential and development plan. An outline of technological considerations in the planning process is provided, together with a discussion of the economic aspects involved and the availability of funding sources for small hydropower development.

TABLE 2.1 TWENTY FIVE SMALL HYDROPOWER PROJECTS OF NEA (NEA,1981)

No.	Project	Location	Installed Capacity (kW)	Annual Energy (GWh)	Estimated [1] Construction [2] Cost (MB)	Estimated Benefit-Cost Ratio (B/C)
1	Nam Mae Sa Nga	Mae Hong Son	2,000	8.20	82.93	2.12
2	Huai Mae Suk	Chiang Mai	400	2.46	80.31	1.83
3	Pranburi Dam [3]	Prachuob Kirikhan	2,500	11.59	67.50	2.47
4	Nam Mae Serin	Mae Hong Son	275	1.80	24.88	1.73
5	Lam Ta Kong Dam [3]	Nakhon Rachasima	2,500	11.56	82.50	1.97
6	Nam Mae Khong	Mae Hong Son	400	2.58	50.53	1.18
7	Huai Mae Tho	Chiang Rai	2,200	9.05	74.84	2.46
8	Nam Mae Sap	Chiang Mai	2,100	6.10	79.29	2.00
9	Nam Mae Mao	Chiang Mai	6,000	17.30	269.29	1.34
10	Klong Ra	Phang Nga	1,040	4.37	54.62	1.96
11	Nom Un Dam [3]	Sakol-Nakhon	1,120	4.91	60.15	1.17
12	Klong Ae	Surat Thani	2,700	11.12	111.69	1.73
13	Lam Pa Fueng Dam [3]	Nakhon Rachsima	930	4.07	53.45	1.09
14	Nam Mae Ya	Chiang Mai	1,500	6.22	61.10	1.77
15	Nam Mae Wang	Chiang Mai	6,000	27.85	178.53	2.63
16	Nam Mae Rim	Chiang Mai	2,800	11.02	88.97	2.21
17	Huai Wang Kiang	Kanchanaburi	1,000	6.46	55.39	2.56
18	Phitsanulok Dam [3]	Phitsanulok	3,530	15.44	90.00	2.80
19	Klong La Un	Ranong	500	4.15	40.33	1.84
20	Nam Mae Suai	Chiang Rai	5,600	16.16	306.96	1.11
21	Nam Mae Klang	Chiang Mai	3,000	11.28	101.17	2.03
22	Nam Mae Ngat	Chaing Mai	1,120	5.00	117.00	1.08
23	Mae Kueng Dam [3]	Chiang Mai	4,800	12.02	108.00	2.06
24	Klong Na	Phang Nga	970	4.08	67.75	1.16
25	Nam Mae Tun	Chiang Mai	400	2.70	27.66	2.21
Total			55,385	217.51	2,285.34	-

Remark
[1] Cost estimated in 1981
[2] 23 Baht = 1 US.$
[3] Turbine installation projects of EGAT.

According to this paper, in 1981 there were about 276 diesel generating plants throughout the country with about 90 MW capacity. These plants consumed about 33 million liters of oil a year. Many of them were operated for only a few hours a day and since a large number of them were rather old, the reliability of supply could not be guaranteed. Therefore, mini and micro-hydropower projects were considered to replace these diesel plants in the areas where the development of mini-and micro plants were proved feasible.

Since there is no clear definition regarding the terminology of micro, mini, medium or large hydropower projects, the following definitions were proposed in this paper.

Type of Plant	Installed Capacity (kW)
Micro	less than 100
Mini	100 - 6,000
Medium	6,000 - 20,000
Large	more than 20,000

References to small hydropower projects usually mean micro- or mini-hydropower projects, i.e. hydropower projects with installed capacity lower than 6,000 kW.

C. ENERGY NEEDS IN RURAL DEVELOPMENT : THE CASE FOR MINI-HYDROPOWER (CHULLAKESA,1981)

This paper was presented in the Workshop on Small-Scale Hydropower Technology Applications in Asian Rural Settings. It viewed the role of mini-hydropower in serving the energy needs of rural regions from the perspective of the current efforts of the Provincial Electricity Authority (PEA) to provide electricity to 95 percent of all villages in Thailand by 1990. Most of the villages will be connected to the national grid, except for very remote villages which will be served by other means. It is thought that mini-hydropower offers the best means to serve this purpose. PEA has initiated its mini-hydro program with two pilot facilities as examined in this paper.

According to this paper, the PEA has set up a Mini Hydro Generation (MHG) Subprogram which is integrated with the Accelerated Rural Electrification (ARE) Program (as shown in Table 2.2). The MHG program will, over a period of 14 years, cover about 500 potential stations with 1-MW

and below at a total investment cost of about US$ 500 million. The PEA's MHG program is intended to be a simple system, using a standardized design, and runoff type systems suitable for operation in remote areas. The PEA policy of MHG development is to install an alternative source of supply to the ARE Program, instead of simply expanding from the grid system, and to replace the existing diesel generating plants wherever it is proved to be feasible from a least-cost calculation estimate.

TABLE 2.2 INVESTMENT PROGRAM FOR ACCELERATED RURAL ELECTRIFICATION AND MINI-HYDROPOWER PROJECTS OF PEA

Subprogram	Time	Number of Villages	Estimated Investment (M฿)		
			Total Project	Foreign Component	Local Component
ARE Project-First Stage	1977-82	5,200	2,195.0	941.0	1,254.0
ARE Project-Second Stage	1981-85	8,000 (+MHG)	5,524.6	2,138.6	3,386.0
ARE Project-Third Stage	1984-88	3,700 (+MHG)	5,130.0	2,250.0	2,880.0
ARE Project-Fourth Stage	1987-91	(MHG)	6,070.0	2,700.0	3,370.0
ARE Project-Fifth Stage	1990-94	(MHG)	1,340.0	596.0	744.0
Total Program	18 Years	16,900 (+MHG)	20,259.6 (US$880.8M)	8,625.6 (US$375.0M)	11,634.0 (US$505.8M)

Remarks :
1. Total ARE Villages in Stage 1,2,3 = 16,900 villages
2. Total MHG Stations in Stage 2,3,4,5 = 500 stations
3. Total Investment For ARE Villages = 10,275.5 Million Baht (US$446.8M)
4. Total Investment For MHG Stations = 9,985.0 Million Baht (US$434.1M)
5. ARE = Accelerated Rural Electrification Project
6. MHG = Mini Hydro Generation Project
7. Use Exchange Rate of US$ 1.00 = 23.00 Baht.

D. SMALL HYDRO IN THAILAND (MCCLENNAN, SEONI, AND RATNARAK, 1984)

This paper was presented in the First International Conference on Small Hydro organized by International Water Power & Dam Construction in Singapore in February 1984. It summarizes the results of the studies carried out by the Electricity Generating Authority of Thailand (EGAT) and its consultants to develop the hydroelectric potential of a number of irrigation dams in the country. The purpose of the paper was to document the analyses carried out for six of these sites, both to illustrate a general approach and to identify some of the key considerations for constructing hydro plants at existing irrigation facillities. The common elements among projects and the factors which made them unique were identified.

The six sites mentioned in this paper include Chao Phraya Dam, Mae Ngat Dam, Lam Ta Kong Dam, Vajiralongkorn Dam, Phitsanulok Dam and Uttaradit Dam. Each of these six projects was briefly described. The elements of the reconnaissance level analysis were mentioned which included (a) walkover investigation, (b) calculation of benefits, and (c) calculation of costs. Finally, the elements of the feasibility level analysis were described which included (a) general approach, (b) selection of equipment, (c) calculation of benefits, (d) calculation of costs, and (f) economic evaluation.

With these six irrigation projects selected for the feasibility study of adding power generation, three projects were rejected on the basis of reconnaissance level analysis. The remaining three -- Chao Phraya, Mae Ngat and Lam Ta Kong -- were picked for feasibility level analysis. Economic evaluation revealed that the internal rates of return for Chao Phraya, Mae Ngat and Lam Ta Kong Projects were 18.7, 15.2 and 13.8 percent, respectively.

The outcome of the studies is that Lam Ta Kong was shelved for the time being, Mae Ngat is under construction, and Chao Phraya is awaiting final approval from the Government of Thailand.

E. MASTER PLAN OF MINI/MICRO HYDROPOWER TO REPLACE DIESEL POWER PLANTS (TEAM, 1983)

This master plan study was carried out by TEAM Consulting Engineer Co.,Ltd. and submitted to NEA in August 1983. The purpose of the study is to identify promising mini/micro-hydropower projects to replace the existing diesel power plants scattered throughout rural Thailand. The aim of the study is to find a long-term solution to the costly electricity generation by the diesel power plants which depend on imported oil.

Altogether, there are 40 potential mini/micro hydropower sites considered in this master plan study. Among these, 29 sites were justified economically suitable for further detailed feasibility study and engineering works.

The selection of the sites was done primarily based on 1:50,000 topographic maps prepared by the Royal Thai Survey Department and then was checked by field surveys. Layout of project components was made for each selected site. These project components include a low head diversion weir, an intake to the conveyance channel, a penstock and a powerhouse.

The hydrologic study was carried out on the basis of regional approach. Regional flow duration curves for the Northern, Northeastern and Southern regions were developed from available streamflow records.

Cost estimation of each selected mini/micro hydropower project was based on the quantity estimates of the typical layout with key dimensions varied from site to site.

In conducting economic justification of the hydropower projects, two bases were considered. For the isolated system, comparison with the diesel power plant was made. Only one project was evaluated with this basis. In case of interconnected system, the economic justification was undertaken on the basis of comparison between the system which would be supplied by the national power system of EGAT alone and the system which would be supplied by the national power system of EGAT with power reinforcement by the mini/micro hydropower project.

It was recommended that the 29 sites which were considered economically feasible should be subjected for further work and detailed engineering layouts and designs should be undertaken together with the revision of the economic feasibility study with more accurate cost estimates. For those remaining sites, it was still recommended that those load centers be hooked-up to the national transmission grid because they would be more economical than utilizing existing diesel plants.

Chapter 3

Design Considerations

DESIGN CONSIDERATIONS

In this chapter, the criteria used in selecting a suitable site plus the basic design concepts for micro-hydropower development are described. The methodology used in hydrological study, designs of civil works, mechanical works and electrical works, as well as an economical analysis of the micro-hydropower projects are also included.

A. CRITERIA FOR SITE SELECTION

The selection of an appropriate site for micro-hydropower development requires consideration of several factors which can be outlined as follows (Elliott, 1981 ; TEAM, 1983) :

1. Access to the site should not be too difficult, so that plant construction, operation, and maintenance can be attained with low transportation cost.

2. The powerhouse should be located at a reasonable distance, (preferably not more than 5 km) from the consumers.

3. The project should be located in a remote area which is some distance from the existing distribution system, but still be close enough to be easily connected into the existing distribution system. This will serve people in the rural areas and will also prevent the introduction of a diesel generating plant.

4. The project should be located in an area where the existing electric supply is through diesel generating plants. This will help replace old and inefficient diesel generating plants and will also reduce oil consumption.

5. The project should be situated in an area where there are promising uses of electricity, such as the use of electric pumps for irrigation and local industries.

6. The project should be connected with one which already exists, i.e., an irrigation project currently considering the possibilities of installing turbines and generators for its own expansion.

7. The project should be located in an area where local residents are willing to co-operate in the planning, construction, operation and maintenance of the project.

8. The project should correspond with the development plan of the village, and the effects of the project on village development should be taken into consideration. The selected site should not present any adverse effects on the usual practices of the local people.

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9. The province where the project is situated should be responsible for project implementation, including the construction and installation phase as well as operation and maintenance of the project, provided that NEA has given technical and financial assistance for supporting material and equipment costs which are not available in the local area.

10. The selected site should have a catchment area greater than 20 km^2 so that the stream discharge will exist all year round.

11. To keep project cost low, sites which require a long power canal and massive excavation should be avoided.

B. BASIC CONCEPTS USED IN MICRO-HYDROPOWER DEVELOPMENT

In this section the basic concepts for the designs and general layout, as well as the organizational plan for micro-hydropower development are described.

Basic Design Concepts

In the development of a micro-hydropower project, the following aspects should be considered during the design stage (Appleby and Kenneally, 1984)

Reliability

Reliability of the power plant is of utmost importance. Since most small hydropower projects are located in remote areas, it is rather difficult to get a well-trained engineer to repair the equipment or to find spare parts. Therefore, the small hydropower plant should be carefully designed and the installed equipment should be reliable and require very few spare parts and a minimum of out of service time for repairing.

Simplicity of construction and installation

As mentioned in the organization plan, the construction of the small hydropower plant will be carried out by local residents with supervision by a NEA engineer. Therefore it is recommended that the designs of the plant should be simple to avoid difficulties in construction.

Simplicity of operation and maintenance

This aspect must be considered together with the reliability of the plant. Automatic control of the machines can reduce the skills needed in its operation. At the same time, replaceable plug-in modules will make maintenance operations less complex.

Availability of repair facilities, skills, and spare parts

These factors are very essential for the small hydropower project which is located in a rural area. It is recommended that adequate workshop facilities be provided in areas where there are several micro-hydro power plants in operation to ensure the plants can return to operation quickly whenever difficulties occur.

Safety

The safety of operating personnel, of the plant and of the environment should all be considered in the design. The layout should be planned to provide safe access to operational areas of the plant and to prevent unauthorized access into high voltage areas. The prevention of high voltage and fire hazards must be considered carefully. Flooding conditions must be taken into consideration locating the various electrical and mechanical equipment, including the powerhouse.

Use of local materials and equipment

In the design, the availability of local materials for construction should be considered in order to reduce transportation cost. In addition, locally made equipment, including the turbine, generator and pipe, should be used.

Familiar specifications and standards

The use of familiar specifications will avoid a cost penalty that may be expected when contractors or suppliers are asked to bid for construction, installation, or equipment. Current standards used in Thailand should be utilized.

Criteria for General Layout

For the selected sites for micro-hydropower development, the layout of each project component (Fig. 3.1) should be made with the following criteria in mind (Inversin, 1981 ; TEAM, 1983) :

Weir

A weir is a structure placed across a stream to increase the upstream water level so that water can be diverted, via an intake structure, into a headrace at a determined rate. Its height should be as low as practicable to minimize construction cost. It must be designed to be adequately stable when subjected to large floods. Large variations in stream flow must be considered in the design. Selection of the site for the weir is very important. Topographic and geologic conditions are significant factors to be considered in locating the weir on the stream.

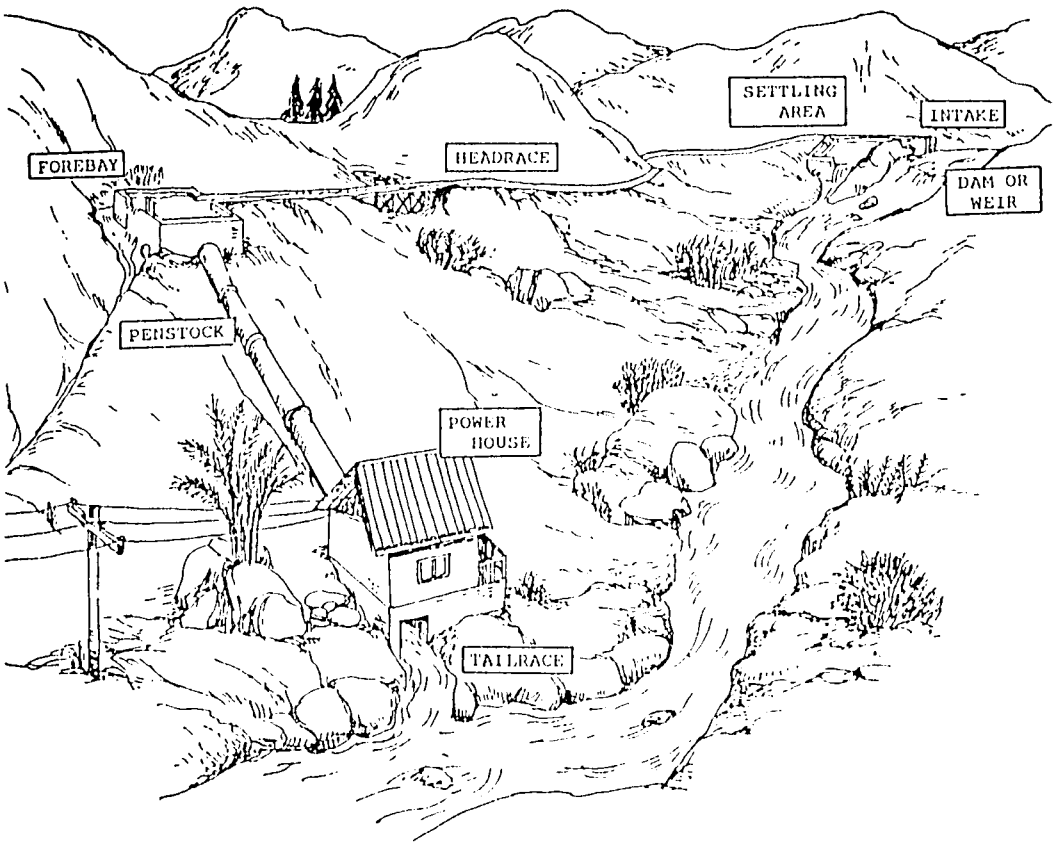

FIGURE 3.1 COMPONENTS OF A MICRO-HYDROPOWER SCHEME

(AFTER INVERSIN, 1981)

Intake

An intake is a structure to divert water, with controlled flow, from the stream into the headrace while it minimizes the intake of heavy bed-load and floating debris. The intake should be designed so that enough water can pass through to keep the pipeline full and to prevent air from being drawn into the pipeline. The intake should be installed with a good trashrack to prevent floating debris and stones from entering the pipeline. It should be properly located, taking into consideration the natural tendency of the deposition of river sediment which will alter the profile of the river bed. As part of the intake structure, a gate should be provided to cut off flow when maintenance or repair work is necessary.

Headrace

A headrace is a pipeline or power canal conveying water from the intake to the forebay. The pipeline is more advantageous when ground slope is too steep to construct a power canal. A pipeline can also prevent sedimentation deriving from hillside slope cut or from falling debris. On the other hand, the installation of a pipeline normally needs both heavy construction equipment and the need to transport the pipes to the project area.

Soil conditions and geological formations along the alignment of the headrace must be stable enough so that the pipeline or power canal will not be damaged by landslides. The headrace should have as shallow a slope as economically possible in order to maximize the head remaining between the forebay and the turbine. Its cross-sectional dimensions must be large enough to carry the required flow.

Forebay

A forebay is a final settling area, with trashrack, just before the water enters the penstock. The forebay may be equipped with a gate to prevent water from entering the penstock. As part of the forebay, a spillway should be provided to safely remove excess water. The forebay depth must be sufficient to prevent the formation of a vortex at the penstock entrance.

Penstock

A penstock is a pipe used to convey water from the forebay to the turbine. Soil conditions and geological formations along the alignment of the penstock must be considered during installation. The size of the penstock and its strength must be carefully selected to prevent problems during operation. At those places where bending is necessary, a properly-designed foundation structure is needed.

Powerhouse

A powerhouse is a shelter to house the turbine, generator, and associated control and electrical equipment. Generally, after performing a

field investigation, a powerhouse can be suitably located. Topographic features and the flooded level of the stream must be considered in located the powerhouse.

Tailrace

A tailrace is a canal used to carry the spent water from the turbine back to the river. The tailrace should be elevated from the river in order to prevent a backlash of debris for the river during flooding periods.

Organization Plan

Due to inadequate financial support, micro-hydropower development will rely on commmunity participation and promotion by the productive use of electricity. With this concept, the NEA has set the following plan for micro-hydropower development.

Socio-economic survey

The NEA will conduct the socio-economic survey with emphasis being placed upon the demand for electricity, existing electric supply, community participation, and available water resources for hydropower development.

Promotion of community participation and decision making

This involves discussions with village leaders and villagers to ensure their participation prior to implementation and to create a sense of ownership where appropriate.

Detailed design

The NEA will conduct the field survey, site selection, and carry out the detailed design and cost estimates, as well as prepare the financial plan for implementation.

Construction

The construction of the project will be carried out by the local residents in the area with close supervision by NEA's officials.

Budget

Part of the budget should be supported by the province or from the electricity consumers, while the NEA will provide money for equipment which is not available in the local area.

Establishment of co-operatives

The NEA will assist and advise in the establishment of co-operatives of the electricity consumers. The contract should be signed prior

to construction so that community participation can be derived from the beginning.

Training

The NEA will conduct a training program for the selected employees to operate the plant and to run the co-operatives.

C. HYDROLOGICAL STUDY

Most of the selected sites for micro-hydropower stations are located on small streams where streamflow records are rarely available. Therefore, some calculation methods must be developed to estimate the streamflow parameters in order to determine the power potential of the site. Two hydrologic parameters are normally required for micro-hydropower development. These are flow-duration data and peak flow. Flow duration data are needed in evaluating the installed capacity of the plant, whereas the peak flow is used in the design of the weir, the spillway, and in placing equipment so that it will not be damaged during a flood.

Regional Flow-duration Curves

Regional flow-duration curves can be constructed by using the available streamflow data recorded at other existing gauging stations in the same region. The monthly streamflow records of these gauging stations are collected and used in the analysis. TEAM (1983) has developed flow-duration curves for the northern part of Thailand as shown in Fig. 3.2. The ratio of streamflow to mean annual streamflow is plotted against time percentage with exceeding flow. If a mean annual flow of the proposed site can be estimated, its streamflow at any time percentage can be determined from this curve.

Mean Annual Streamflow

The mean annual streamflow of an ungauged site can be estimated by various methods. Two methods of estimation are presented here.

Area ratio method

In case there exists a gauging station on the same stream the annual streamflow at the site can be calculated proportionally to its respective catchment area by the equation :

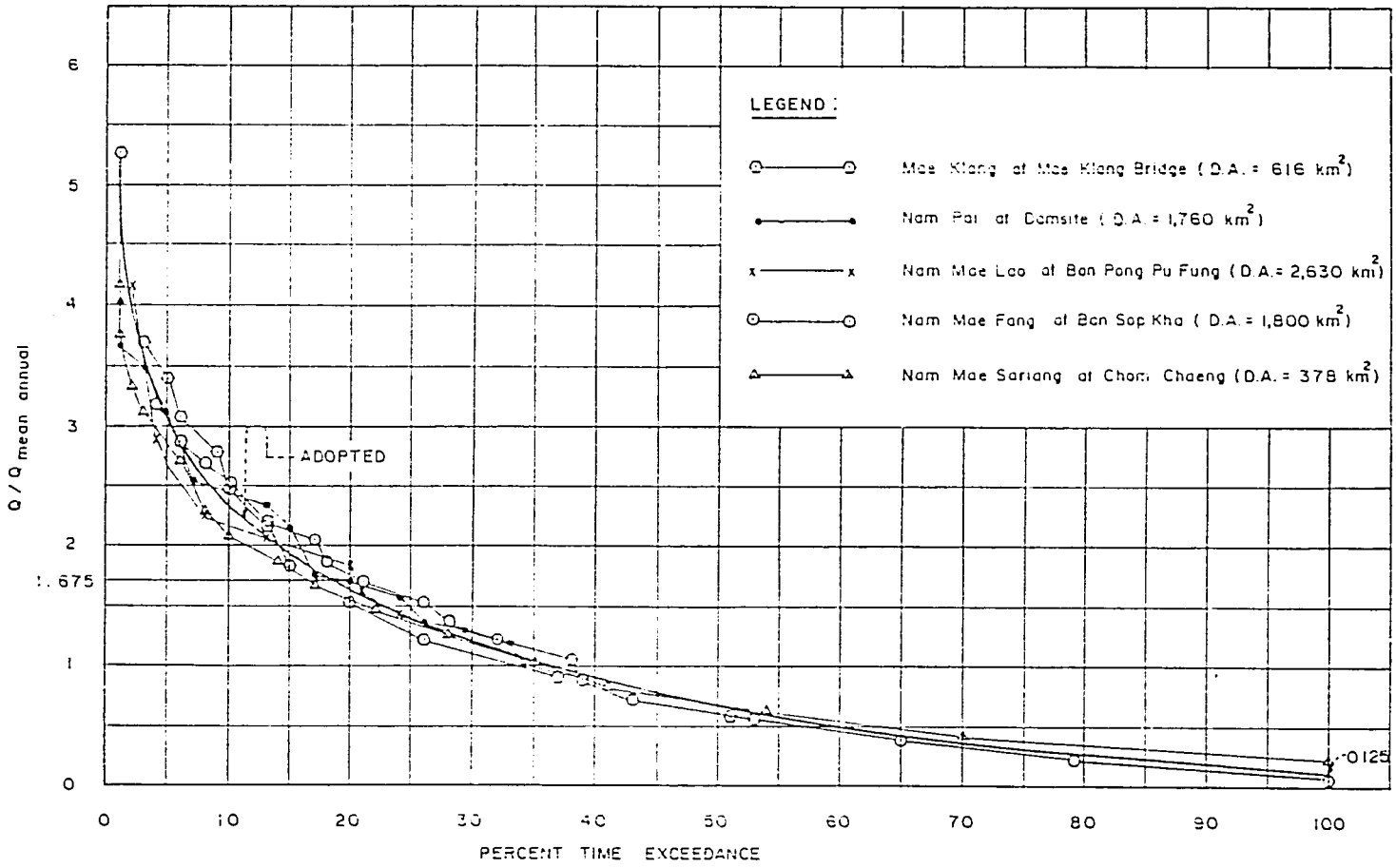

FIGURE 3.2 FLOW DURATION CURVE FOR NORTHERN PART OF THAILAND (TEAM,1983)

$$Q_2 = Q_1 (A_2/A_1)$$

Where

Q_1 is the mean annual streamflow at the gauging station

Q_2 is the mean annual streamflow at the site

A_1 is the catchment area at the gauging station

A_2 is the catchment area at the site

Specific yield method

When there is no gauging station on the stream at all, the mean annual flow at the ungauged site can be calculated by the specific yield method. The run-off factor of a nearby gauged basin can be applied to the ungauged basin in association with the mean annual rainfall as follows :

For gauged basin : $F = Y1/1000\ R1$

For ungauged basin : $Y2 = 1000\ F.\ R2$

and $Q = A.Y2$

Where

F = run-off

Y1 = mean annual yield of the gauged basin, m^3/km^2

Y2 = mean annual yield of the ungauged basin, m^3/km^2

R1 = mean annual rainfall of the gauged basin, mm

R2 = mean annual rainfall of the ungauged basin, mm

Q = annual streamflow of the ungauged stream

A = catchment area of the ungauged basin

Design Discharge and Number of Generating Units

The adopted flow duration curve of the stream is used in determining the design discharge. For a dam or weir with storage reservoir of adequately high capacity, the design discharge can be close to the mean annual streamflow. For the run-off river development project, the pondage capacity is rather low, and during some months of the year the dis-

charge will be much lower than the mean annual value. In selecting the design discharge for such installation the time percentage with exceeding flow must be specified, taking into consideration flow characteristics, etc. For the four micro-hydropower projects being studied, the minimum flow in the dry season was considered in determining the design discharge. In other words, 100 percent of time with exceeding flow is used in the design.

Another solution for a run-off river development with variational streamflow is to provide at least two or more sets of turbines and generators and controllable gate valves. Only one turbine unit will be operated during the dry season, and two or more units will be operated in the wet season when more water is available. However, the load characteristics must be carefully studied in this case.

Design Flood

The value of the design flood is used in determining weir height, foundation structure, and spillway capacity. There are several methods in determining the design flood. In this section, three methods which are applicable to the small hydropower project with no streamflow gauging stations are presented.

Envelope curve method

The envelope curve derived from hydrologic data recorded at existing gauging stations situated in the region is very useful in estimating the design floods of a hydropower project. This curve relates the values of peak unit discharge (in $m^3/s/km^2$) with the drainage area (in km^2). The regional envelope curves derived for the Northern Thailand are shown in Fig. 3.3, which include the envelope curves derived by the Royal Irrigation Department (RID) and the curve adopted for mini/micro-hydropower projects by TEAM (1983).

Rational formula

The rational formula is widely used in estimating the peak flow from a given drainage area. This equation is written as

$$Q = CiA$$

where

Q is the designed peak flow

C is the runoff coefficient

i is rainfall intensity

A is the catchment area

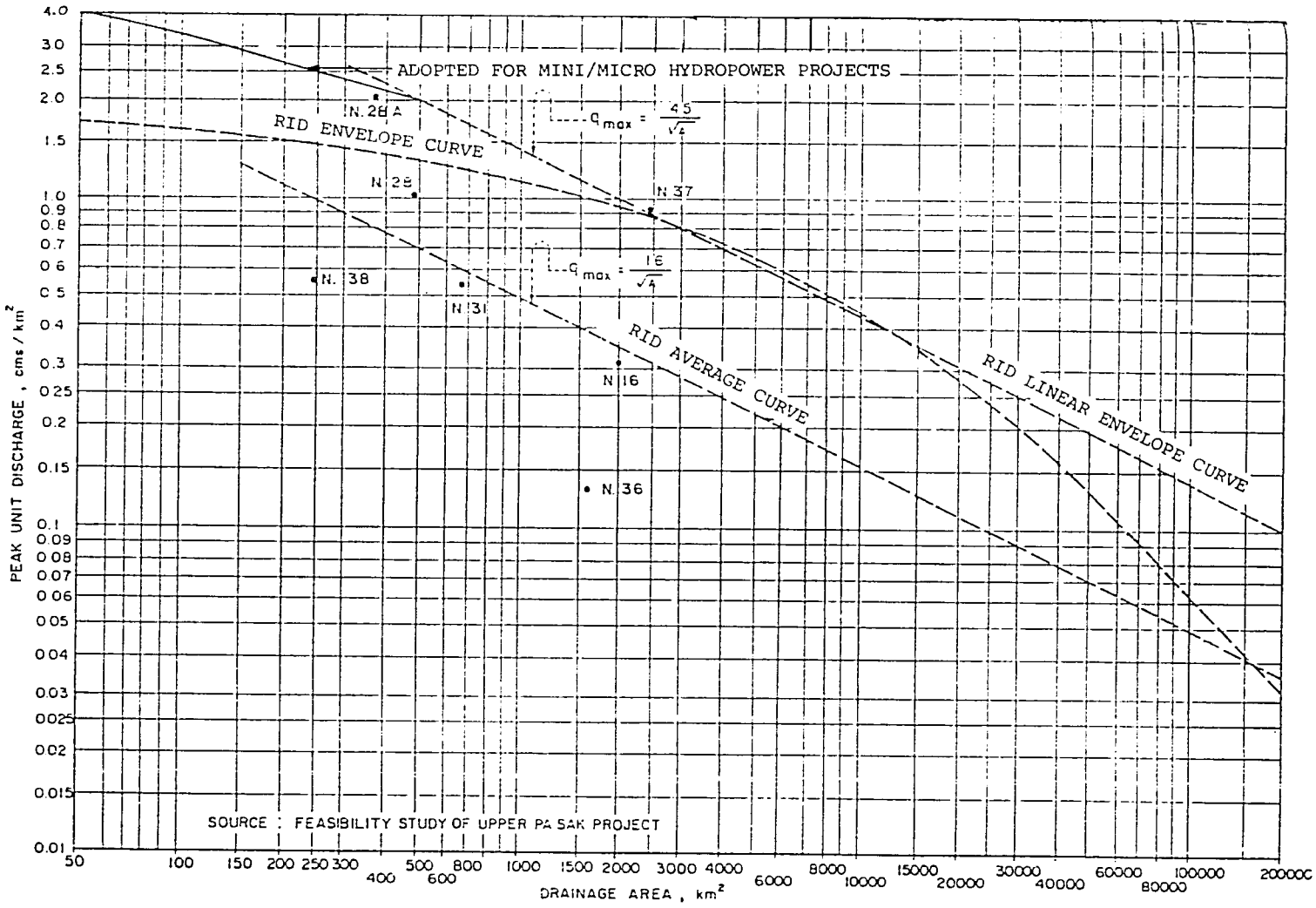

FIGURE 3.3 REGIONAL ENVELOPE CURVES FOR THE NORTHERN THAILAND (TEAM, 1983)

The value of the rainfall intensity to be used in this equation is obtained from the rainfall-duration curve at the identified recurrence interval which is normally in the range of 30-50 years for a micro-hydropower project. For the forest area, the value of C is approximately 0.15.

Empirical formula

Besides the above two methods, an empirical formula relating the value of peak discharge to the catchment area of the basin is sometimes used in estimating the design flood. This empirical formula is obtained from the analysis of streamflow records at some existing gauging stations in the region. In estimating the design floods of the Kam Pong and Mae Ton Luang projects, the empirical formula derived by Bunchob (1980) is used. This equation is written

$$Q_p = 6.58\ A^{0.178}$$

where Q_p is the value of the design flood (m^3/s)

A is the catchment area (km^2)

Effective Head

The effective head can be computed by subtracting losses from gross available head. These losses include entrance loss at an intake structure, head loss on water conveyance through a power canal, head loss in a penstock, and other losses at valves and gates. For the study based on 1:50,000 scale maps, these losses can be simplified by taking into account just two major losses, i.e., conveyance and flow through a penstock. The gross head can be assumed to be equal to the difference between elevations of weir crest and tailwater. Since most of the selected sites are run-off river type, the gross head can be considered constant all year.

Installed Capacity and Energy Generation

The installed capacity of the hydropower plant can be calculated from the following expression :

$$P = \eta \frac{\gamma QH}{102}$$

P	=	the installed capacity, kW
η	=	the total plant efficiency
γ	=	the specific weight of water, 1,000 kg/m^3
Q	=	the design discharge, m^3/s
H	=	the effective water head, m

The total plant efficiency can be determined by taking into consideration hydraulic losses in the pipe line, valves, bending, etc. and losses within the turbines, bearing, and generator. Normally, the value of total efficiency ranges from 0.6-0.8.

The annual energy generation of any plant can be obtained by multiplying the ratio of average/design discharge by the product of installed capacity and annual operating hours of the plant.

D. CIVIL WORKS

In this section basic design considerations for civil works of micro-hydropower development are summarized. Detailed design can be undertaken only after field investigation has been conducted at the site and the study of hydrological characteristics of the stream is complete.

Weir

In order to minimize the construction cost, the weir height must be properly selected. Selection of optimum weir height requires the study of the relationship between construction cost and effective head which will vary from site to site.

The material for weir construction can be masonry, concrete, earth, or rocks. In selecting material for weir construction several factors must be considered, e.g. availability of the material at the project area or vicinity, characteristics of streamflow, river bed and stream cross-section,size of weir to be constructed, etc.

The energy of the water flowing over the weir must be dissipated, possibly by forming a deep stilling pond just downstream of the weir or by placing a bed of sufficiently large stones there. If the river bed is wide and the dry season flow is low, it might be desirable to slightly slope the crest of the weir towards the intake in order to divert the flow in that direction.

The design flood of the site is used in determining a weir height. The relationship between the design flood, crest length of the weir, and flood surcharge above the crest of a rectangular weir can be written as follows (Chao, 1959) :

$$Q = \frac{2}{3} C_d . L \sqrt{2g} \; . \; H^{\frac{3}{2}}$$

where Q = the design flood, m^3/s
L = the crest length of the weir, m
H = the flood surcharge above weir crest, m
g = the gravitational acceleration, m/s^2
C_d = the coefficient of discharge

When the effects of end contraction, channel side slopes, shape of the weir crest, etc. are included, the following relationship can be adopted :

$$Q = \alpha L H^{\frac{3}{2}}$$

where
- Q = the design flood, m^3/s
- L = the crest length of the weir, m
- H = the flood surcharge above the weir crest, m
- α = an empirical coefficient

For a trapezoidal weir having a side slope of 1:4, the value of α is 1.85 (Khurmi, 1976).

Intake

The removal of sediment and debris which enters the headrace and penstock is the principal operation and maintenance task assigned to the civil works section. Therefore, it is recommended that as much silt, bed-load, and debris be removed from the water as possible as it enters the intake. A trashrack to keep out floating debris and stones is often included. Usually, this consists of vertical steel bars embedded across the intake channel.

Several factors are to be considered in designing the intake. These include direction and magnitude of flow, normal and flooded water levels, bed-load characteristics, etc. In order to minimize the inflow of bed-load, the intake should be placed as nearly perpendicular to the direction of stream flow as possible and it should avoid any location within the stream where a natural sediment deposition tendency exists. The bottom of the intake channel should be raised above the river bed to prevent the heavier bed-load from being washed directly into the intake.

In order to halt the flow of water into the headrace and penstock during maintenance work, a gate should be provided. This gate will also enable water flow to the turbine to be controlled. A sliding gate is normally used in for micro-hydropower projects. The discharge through the gate opening can be computed from (Creager and Justin, 1950) :

$$Q = CA\sqrt{2gH}$$

Where
- Q = the discharge
- A = the opening area of the gate
- g = the gravitational acceleration
- H = the head of water on the center line of the flow
- C = the coefficient of discharge

The value of C depends on the shape of the sluice and the velocity of approach and can be found in some literature (e.g. Creager and Justin, 1950; Chow, 1959).

Headrace

The headrace is a canal or pipeline conveying water, often for a relatively long distance, from the intake to the forebay. Topographic features and geological foundations are the major factors used in the layout and design of the headrace. Normally, the headrace should have as shallow a slope or as low a head loss as economically possible in order to maximize the head remaining between the forebay and the turbine. Flow through the headrace is related to the slope or head loss per unit length and the cross-sectional area of the canal or pipeline as follows :

For open-channel flow in a canal (Manning Equation)

$$Q = \frac{A}{n} (R^{\frac{2}{3}} S^{\frac{1}{2}})$$

where
- Q = the discharge in m^3/s
- A = the cross-sectional area of the flow, m^2
- n = Manning's coefficient
- R = hydraulic radius, m
- S = slope of the canal

The value of n depends on the roughness of the canal bed. For concrete lined canals, values ranging from 0.010 - 0.016 are applicable (WPCF & ASCE, 1970).

For pressure flow in closed conduit (Darcy-Weisbach Equation)

$$S = f \frac{L(Q/A)^2}{8gR}$$

where
- S = head loss per unit length
- f = the resistance coefficient
- L = the length of the conduit, m
- Q = the discharge through the conduit, m^3/s
- A = the cross-sectional area of the conduit, m^2
- g = the gravitational acceleration, m/s^2
- R = hydraulic radius, m

The value of f depends on the flow condition (indicated by the Reynolds number) and the relative roughness of the conduit (Fig. 3.4).

In addition to the loss of head in the conduit or to the slope of the canal, the stability of the canal bed (especially for an earth canal) and the strength of the conduit will have to be considered in the design of the headrace. Soil conditions and geological foundation along the alignment of the headrace must be stable in order to ensure that the

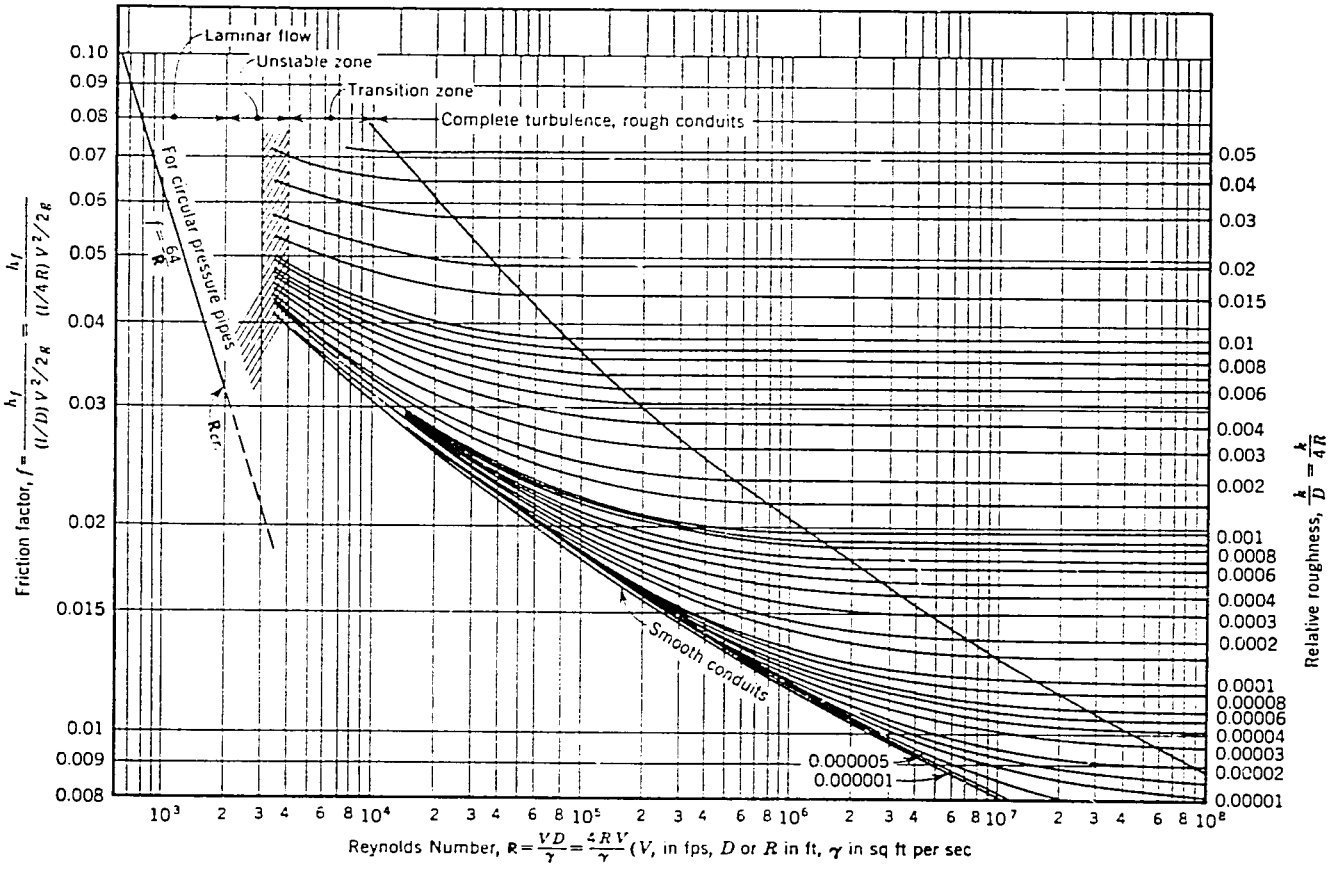

FIGURE 3.4 FRICTION FACTORS AS A FUNCTION OF REYNOLDS NUMBER AND RELATIVE ROUGHNESS (AFTER WPCF & ASCE, 1970)

canal will not be damaged by landslides. The velocity of flow through the headrace should not be too low (otherwise sediment carried by the water will deposit) nor too high (or the bed of the headrace will be eroded). Normally, a flow velocity ranging from 0.6-1.5 m/s is used for an earthen headrace. For a concrete-lined canal or a pipe conduit, a higher flow velocity can be used in the design if it does not cause too much loss in water head.

Forebay

The forebay is the enlarged body of water just before the water enters the penstock. It is normally equipped with a gate for cutting off water to the penstock during maintenance work and it has a spillway for releasing excess water not desired in the penstock.

The forebay is generally constructed of concrete. Its size should not be too large otherwise its cost will be higher than necessary. The size of the forebay can be determined from the demand of the turbine and from fluctuations of flow through the headrace. For a micro-hydro-power project which is a runoff-river plant, the flow through the intake can be adjusted to provide the maximum flow required by the turbine. During times when less power is used, excess water would overflow the forebay spillway. The forebay will also act as a settling area; therefore, appropriate gates and trashracks should be provided to drain the deposited sediment and to prevent the debris from entering the penstock. Otherwise the turbine could be damaged.

Penstock

The penstock is a pipe used to convey the water from the forebay to the turbine. Several types of materials can be used in the construction of penstock pipe, e.g. asbestos-cement, prestressed concrete, polyvinyl chloride (PVC), polyethylene, fiberglass, wood or steel. Selection of the material depends on several factors including cost, local availability, required construction equipment, required strength, etc.

Head loss in the penstock can be computed using the equation of flow in a closed conduit (Darcy-Weisbach Equation) as mentioned in the section on "Headrace".

Powerhouse

The purpose of the powerhouse is to support and house the hydraulic and electric equipment. It can be divided into two sections (Creager and Justin, 1955) as follows :

a) The substructure used to support the equipment and to provide the necessary waterways
b) The substructure or building used to house and protect the equipment.

The powerhouse of a micro-hydropower plant can be constructed of a variety of materials, e.g., wood, brick, or concrete. There should be ample clearance in the powerhouse between different pieces of apparatus. The foundation of the substructure which support the heavy equipment must be properly designed in order to avoid uneven settlement which might result in non-alignment of the turbine-generator set.

Tailrace

Normally, the tailrace has received less attention than other features of the hydroelectric plant. This has resulted in an increase in operation and maintenance work at some plants. Therefore, a careful study of tailrace should be undertaken at any site where a plant is being considered. The records on the fluctuation in tailwater elevations at different discharges are necessary for the layout and design of the tailrace.

E. MECHANICAL WORKS

In this section, various factors to be considered in the design, selection, and installation of the mechanical works of the small hydropower plants are described. These mechanical works include the pipeline and turbine.

The Pipeline

The pipeline is of great importance to the performance of a micro-hydropower plant. The design of the pipeline should receive adequate attention; otherwise, operational difficulties could occur.

The pipeline should be installed in such a manner as to avoid any adjustments of the pipeline in the future. It should be installed away from the stream so that it will not be damaged by floods. It should also be buried at least 0.6 m in depth (Kitching, 1981).

The pipeline should be installed with a revent pipe located both near the intake and wherever air can get trapped in the pipeline; otherwise, the effective head will be decreased, resulting in the turbine's power output being drastically reduced.

The Turbine

There are two basic types of hydraulic turbines, namely the impulse type and the reaction type. The impulse turbine utilizes the kinetic energy of a high-velocity jet which acts upon only a small part of the

circumference at any instant. The reaction turbine develops power from the combined action of the pressure and velocity of the water that completely fills the runner and water passages. The reaction group is divided into two general types, the Francis and the propeller type.

In this study four well-known types of turbines will be briefly described. These include the Pelton turbine, the cross-flow turbine, the Francis turbine, and the propeller turbine.

The Pelton Turbine

The Pelton turbine is a modern impulse type which is usually restricted to relatively high head applications. One or more jets of water will impinge on a wheel containing many curved buckets, producing a force on the buckets and resulting in a torque on the shaft. All of the available head is converted to kinetic energy at the nozzle and any kinetic energy leaving the runner is lost. It is therefore essential that the buckets are designed in such a manner that exit velocities are at a minimum. (Arndt,1981).

The Cross-Flow Turbine

The cross-flow turbine, also known as the Banki-Mitchell turbine, is another type of impulse turbine. In the cross-flow turbine, the flow passes through the blade row twice, first at the upper portion of the wheel and again at the lower portion. The flow exits the blade in the opposite direction from the first pass. (Arndt,1981).

The Francis Turbine

The Francis turbines are of the reaction type. The water enters from a casing or flume with a relatively low velocity, passes through guide vanes or gates located around the circumference, and flows through the runner, from which it discharges into a draft tube which is sealed below the tailwater level. All the water passages are completely filled with water, which acts upon the whole circumference of the runner. Only a portion of the power is derived from the dynamic action obtained by water velocity. A large portion of the power is obtained from the differences in pressures acting on the front and back of the runner buckets (Pfau and White, 1955). The Francis turbines are of the radial or mixed-flow type, depending on the design specific speed. The radial-flow type is a low specific speed design, whereas the mixed-flow type achieves peak efficiency at considerably higher specific speed (Arndt, 1981).

The Propeller Turbine

This type of turbine is inherently suitable for low-head applications. The higher speed of this type of turbine results in a lower-

cost generator and somewhat smaller powerhouse substructure. The propeller turbine is further subdivided into two types; namely the fixed-blade type and the adjustable-blade type. The fixed-blade propeller type unit has a high efficiency at a point near full load, but the efficiency drops off rapidly as the load decreases. The installation of the fixed-blade propeller type runner should therefore be limited to developments where the units may be operated at a point near maximum efficiency. The adjustable-blade propeller type is an evolution of the fixed-blade propeller type. One of the best known units of this type is the Kaplan unit, in which the blades may be rotated to the most efficient angle by a hydraulic servomotor. By reasons of its high efficiency at all gate openings, the adjustable-blade propeller-type unit is particularly applicable to low-head developments where conditions are such that the units must be operated at varying load and varying head.(Pfau and White, 1955).

Performance Comparison

Performance characteristics of various types of turbines depend on the designs. It is obvious that the configuration changes with speed and head. This can be expressed in terms of peak efficiency versus specific speed. Impulse turbines are efficient over a relatively narrow range of specific speeds, whereas the Francis turbines have a wider useful range. Variable geometry is an important consideration when a turbine is required to operate over a wide range of loads. Fig. 3.5 shows the range of application of various types of turbines (Arndt,1981).

F. ELECTRICAL WORKS

The electrical works of a micro-hydropower project start at the couplings which drive the generators and include the generators, control switch-boards and wiring, transformers and distribution system. This section briefly reviews basic considerations for the design and selection of electrical equipment for the micro-hydropower project. More details are available in the paper written by B. Jackson which is presented in the Workshop on Small-Scale Hydropower Technology held at A.I.T. in 1981.

The Generators

The generator is a machine that transforms mechanical energy into electrical energy. The essential features of the generator are (1) a field or assembly of magnets arranged to produce a magnetic flux, and (2) an armature or assembly of electric conductors arranged across the path of the magnetic flux. The field and armature are so mounted that by the application of mechanical force a relative motion is produced between the magnetic flux and the electric conductors, and this motion induces an electromotive force in the conductors.

Two major types of alternating current (AC) generators for electricity supply are (1) synchronous generators, and (2) induction generators.

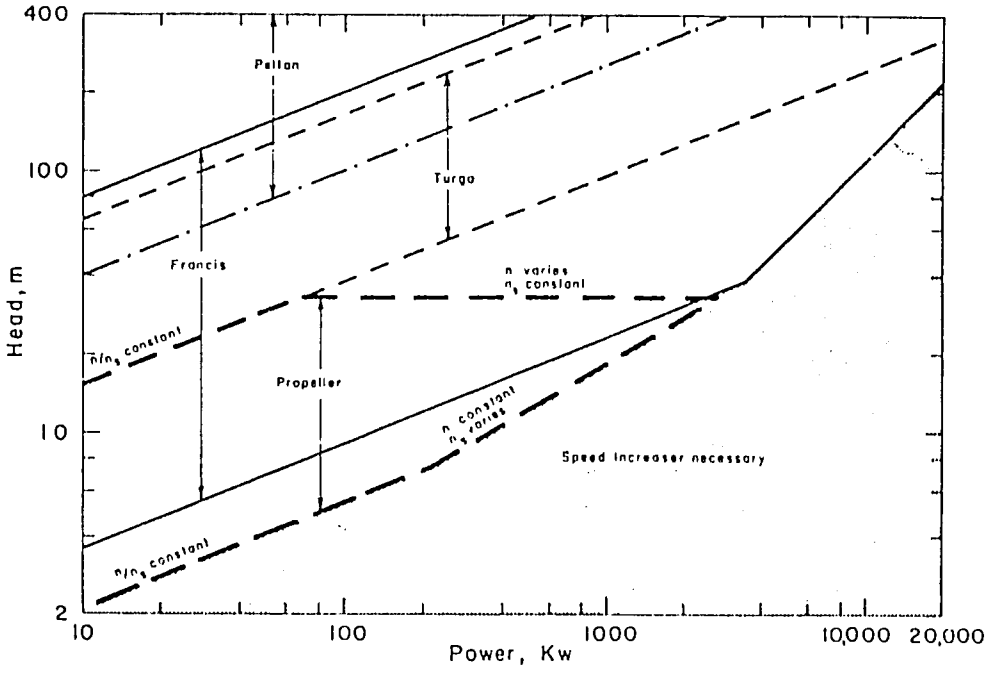

FIGURE 3.5 RANGE OF APPLICATION OF VARIOUS TYPES OF TURBINES (AFTER ARNDT, 1981)

The Synchronous Generator

In the synchronous generator the magnetic flux is achieved by applying a direct current (DC) source across the rotor field coils. When the mechanical torque through the shaft of the turbine moves the rotor, the rotating magnetic flux will induce a voltage potential in the stator coils. The synchronous generator is very common in micro-hydropower development. It is normally required for isolated operation, high capacity installation and power factor improvement.

The Induction Generator

An induction generator is normally used in conjunction with a large system, at an installation with low capacity and high generator speed and for those applications which do not require power factor correction.

Performance Comparison

In evaluating whether or not an induction generator or a synchronous generator should be used, it is important to establish not only the effect upon the system of absorbing excitation but its cost. Some locations may not be suitable for supplying the reactive power, such as a remote location or one near the end of a distribution line. In general, the power factor and the efficiency of induction generators are higher for high-speed than for low-speed machines. A rule of thumb guide, which may be conservative for the induction generators, is that they should be used in applications below 600 HP and above 600 r.p.m. (Jackson, 1981).

Generator Selection

In selecting the generators for the micro-power development, the following factors should be considered (Jackson, 1981).

1. The generator should be able to handle the load without unnecessary apparatus for staggered load switching ;
2. It should be able to maintain the voltage during all expected power factor loads, thereby reducing the need for high efficiency motors and/or oversized transmission cables;
3. It should be able to generate the electric power efficiently under all load conditions; and
4. It should have proper insulation for local climate and use.

The Transformers

The transformer is a device used in transferring electrical energy from one AC circuit to another AC circuit, usually of a different voltage. The essential features are (1) a primary winding which receives energy from the supply circuit, (2) a secondary winding which delivers energy to the receiving circuit, and (3) an iron core common to both windings. The windings are so arranged on the core that an alternating current in the primary (from the supply circuit) induces a magnetic flux in the core, which in turn induces an alternating current in the secondary.

Besides the above mentioned essential features, the power transformers will also include a cooling system to prevent excessive temperature rise.

Control Systems

The regulation of the frequency and voltage of alternating current electricity permits the use of this energy with maximum efficiency. That is, electrical motors work best at their design voltage and frequency. The controlled frequency and voltage of energy provides protection of the user's equipment against failures arising from insulation breakdown, overheating and burnout.

Governors

The system frequency is regulated by the turbine's governor. The governor senses the systems operating conditions, compares this to the desired conditions, and adjusts system controls accordingly.

Governors can either regulate the input flow to the turbine or the output load on the generator, and they can either sense the system load or the generator speed.

Most governors sense generator speed and regulate the flow to the turbine runner. In broad classifications, speed controllers can be categorized as :

- All electric;
- All mechanical;
- Electro-mechanical;
- Electro-hydraulic;
- Mechano-hydraulic; or,
- Electro-mechano-hydraulic.

In the last four classifications, the prefix term refers to the type of speed sensing and the suffix term refers to the type of actuation or servomotor. There are nine parameters for evaluating the governor needs of small and micro-hydro installations :

- Cost;
- Output work;
- Speed control;
- Stability;
- Droop;
- Maintainability;
- Cold start;
- Local manufacturing capability; and
- Load sense control.

An essential function of a governor is to insure that all of the rotating parts are designed to withstand prolonged runaway under maximum head conditions with the gates wide open.

A constant load system is another type of governor. The regulator keeps the sum of the system demand load constant and constantly keeps the load dissipated into ballast resistors. This constant generator load, with a constant turbine head, will give a constant shaft speed. The advantages associated with this type of control are : (1) The electronic current sensing and load switching is very quick; (2) The magnitude of frequency changes in the rotating equipment is very small; (3) There are fewer moving parts and thus a reduced probability for mechanical malfunctioning; (4) Instantaneous inductive load, such as motor starting, is reduced because of the availabiligy of excess power in the ballast. These constant load governors are generally less expensive than flow regulating governors for single phase generators.

The disadvantages associated with constant load regulation are keyed to resource utilization. Capacity based on a high percentage availability of stream flow wastes the flow with lower availability. The constant load system has no droop capability or partgate regulating capability. Without droop, the synchronizing of two or more small turbines will not be possible. Load sharing modules are available for electric speed governors and may be adapted to constant load controllers.

Switchgear

For single unit small hydroelectric installation, the switchgear will consist of the generator circuit breaker, plus a disconnect switch, a line circuit breaker and metering equipment.

Breakers

Breakers are classified by type, voltage class, continuous rated current and interrupting capacity. In packaged small turbine-generator units, the generator circuit breakers are usually provided by the manufacturers.

Packaged units usually include indicating meters to provide information on voltage levels, current levels, watts, and frequency. It is recommended that watt-hour meters be added to this standard package so that the total energy output of an installation can be evaluated.

Protection Systems

When planning a protection scheme, one usually starts by dividing the electrical system into zones of protection. Protection devices are then specified to "see" all faults or other abnormal conditions in its zone. Zones should overlap to provide back-up protection in case the primary protection device fails to operate.

The level of protection planned for an electrical installation is a function of the investment being protected. Even though the basic problems associated with protecting large generators also applies to small generators, it is not cost effective to require the same degree of sophistication.

Generators are rarely damaged when they are provided with reasonable protection. Yet failures do occur and with very serious consequences.

Obviously, one has to protect against faults and lightning. Additionally, if the generator voltage becomes too high, it indicates that the voltage regulator may not be functioning correctly and the unit should be shut down before the insulation is damaged. The over-voltage relay is also back-up protection for overspeed.

Protection of induction generators

A general rule-of-thumb guide concerning protecting induction generators is to use the same protection as you would for the same size induction motor.

An induction machine draws an in-rush current 7 to 10 times its rated current. Consequently, the overcurrent protection must be set very high for starting. Instantaneous overcurrent relays should be set above the minimum in-rush current, and thermal (time delayed) overcurrent settings should be at least 120% of the rated output current.

One characteristic of an induction generator is that the output will delay within a few cycles after the machine has been short circuited. For a three-phase machine, this means a fault on one or two phases will cause the machine to operate in an unbalanced way. Single-phasing of three-phase induction generators by the operation of single-phase protective devices (a practice commonly used on rural distribution systems) can damage an induction generator. Hence, single-phasing protection should only be used on systems with single-phase protection devices.

Protection of synchronous generators

The protection of a small synchronous generator is similar to induction generator protection, but there are some significant differences.

- For the synchronous generator possible synchronizing surges will be smaller than the in-rush currents in induction machines. The maximum current output will only occur as a result of a fault in the system;

- The synchronous generator can supply a continuous fault current. Unlike the small induction generator, the synchronous generator fault current must be interrupted by an overload or undervoltage device; and circuit breakers with shorter closing time;
- Finer three pole operation are preferred to achieve better synchronizing control.

For large generators (over 100 kW) protection against the following hazards should be considered :

- Faults in windings (differential relays);
- Overheating of windings or bearings;
- Failure or loss of field for synchronous machines;
- Monitoring of generator (requires from 0.2 to 2.0% of rated kW depending upon the type of turbine);
- Single-phase or unbalanced current operation;
- Out-of-step relays for interconnected synchronous units;
- Synchronizing check relays.

Distribution System

The AC electric power from a micro-hydropower plant is usually transformed to a higher distribution (primary) voltage, transferred to system loads over the distribution lines, then transformed down to the service (secondary) voltage where it is used by consumers. The cost for distribution facilities will be a major part of the hydroelectric project, unless a distribution system presently exists with some other power source. Distribution costs can account for about 50% of the capital cost required to serve rural consumers. Hence, a good understanding of the distribution system as part of a mini or micro-hydropower project is essential for a sound feasibility study.

A well-designed distribution system minimizes the initial capital cost, the annual energy losses, the operating cost, and the future capital cost when building for system growth. The planner is initially faced with several different combinations of design voltages, line conductor sizes, and system configurations which all could perform adequately. In addition, the planner must consider factors such as reliability, safety, and land use impacts which are not easily quantified. Mathematical expression can be used to determine the most economical choice; but the number of factors is so high that the expressions become complicated, difficult and unsatisfactory. Therefore, NRECA offers the following general guides for approaching a distribution system plan.

Interconnection with an existing distribution system

Interconnecting a small hydroelectric generator to an existing distribution system must be done with regard to the safety, electrical protection, and service quality of the existing system.

Many existing distribution lines are protected by reclosers which respond to faults by briefly de-energizing the line, and then reclosing to restore service in the likely event that the fault was temporary. This operation may be repeated up to three times before the recloser "locks out", leaving the line de-energized. If a hydro unit feeds directly into a line protected by a recloser, the alternate disconnecting and reconnecting may result in damage to the generator because of excess current or abrupt torque changes. Whenever a recloser is used near a small generator, the effects of the recloser operation on the generator should be investigated.

When interconnecting with a small isolated distribution system that may have an existing small generating unit, the operating characteristics of the new and existing units must be examined to ensure that the units can be operated simultancously. Speed droop characteristics must be coordinated to ensure that one generator will not "monopolize" the other.

When a small hydro unit is interconnected with an existing system, and in the event of a fault in the existing system, the hydro unit will supply a portion of the fault current. Hence, the protective devices must be recalculated and set to account for the additional fault current. Before workers can go out to repair the faulted line, it must be ensured that the generating unit cannot feed back into the faulted line, thus endangering the public and line crews. Generally, it is recommended that the hydro unit be de-energized and kept out of service until a faulted line is repaired or safely isolated from the system.

Voltage selection

Generally, a higher voltage has greater construction costs and gives less reliable service. A lower voltage design has greater energy losses and requires a larger conductor to distribute the same quantity of power. As these factors tend to balance each other, the most important consideration in voltage selection is a national standard. A standard national distribution voltage will offer the following advantages :

- Standardized designs;
- Less spare parts inventory;
- Isolated systems will be easier to interconnect into a national grid in the future;
- Neighboring systems can share spare parts, mobile transformers, etc; and,
- Markets will develop for possible local manufacturing of hardware.

The development of national distribution voltage standards should be encouraged where they do not presently exist.

Conductor size selection

Various charts and graphs for determining the optimum conductor size for given voltage levels, future loads, conductor lengths, and desired voltage regulation are given in distribution handbooks. However, to reduce a multiplicity of conductor sizes, warehouse items, and overall operation and maintenance procedures, the following guidelines are recommended :

- For main three-phase feeders, a conductor with plenty of excess capacity (such as a 1/10 ACSR) should be used. Main feeders affect all consumers. Therefore, a cost slightly in excess of the most economical wire is justified;
- For all taps, one conductor size (such as a 4 ACSR) for both the primary and neutral conductors should be used. This will simplify warehousing operations and maintenance procedures;
- For secondary lines, a 1/10 ACSR and a 4 ACSR should be matched with the distribution transformer capacity;
- A standard insulated conductor for service drops should be used.

By minimizing the number of conductor sizes, one also minimizes the number of connector sizes, splices, and maintenance activities.

Pole structure selection

Where suitable timber products are available, a full pressure treated wood pole may be produced for 50% less than equivalent concrete support structures. Although spun, pre-stressed concrete poles can be produced to any desired specification, an average concrete pole of comparable size is twice the weight of a wood pole and has one-third less tensile strength.

Breakage in transportation over country roads is minimal for wood poles but becomes a measurable factor with concrete poles. Wood pole attachments are simple, which simplifies field framing. The attachments for concrete poles are more expensive and have reduced insulation levels. A wood pole can be handled more easily in the field with simple equipment and requires no special foundations.

Long-lasting wood poles can be produced locally in many areas at appreciable savings, thereby contributing to the advance of rural electrification and to the development of new small businesses.

Route selection

The following criteria should be considered in selecting routes for distribution lines :

- The existence of all-weather roads for main three-phase feeders;

- The existence of at least seasonal roads for single-phase taps; and,
- Comsumer density.

During the first phase of electrification through a rural area, high consumer densities will yield maximum returns from initial investments. This is always a desirable approach. Next, one should solicit potential consumers in or near existing facilities in the following order :

1. Those who may be connected directly from existing secondary facilities;
2 Those who may be connected through the extension of existing secondary facilities;
3. Those who may be served from existing lines with the addition of a transformer to the secondary facilities; and,
4. Extensions of primary lines of no more than two spans.

Systems maps should be developed indicating consumers, single-phase, and three-phase distribution lines.

Meters

Customer meters add to the overall cost of the project and some rural systems have elected to operate without them. In such cases, each system consumer pays a standard monthly rate regardless of the amount of energy used. Eventually, a few large consumers have used most of the system energy and, in effect, are subsidized by the other consumers. To prevent this inequity, consumer meters should be installed on larger loads.

G. PROJECT COST AND ECONOMIC EVALUATION

All four micro-hydropower projects under investigation are isolated hydropower projects which only serve the demand in the project area. The economic analysis is made by comparing the hydropower plant with a diesel power plant of the same capacity. That is the construction and operational costs of the diesel power plant are considered the benefit of micro-hydropower project.

Project Cost

Construction cost, equipment cost, as well as the administration, operation and maintenance costs are all considered parts of the project cost. In this study, the operation and maintenance cost of the civil works is estimated to be 1.0 percent of the construction cost. For the electricity transmission system, the value amounts to 5 percent of the investment cost (NEA,1982).

Project Benefit

As mentioned above, the construction cost and the operational cost of an equivalent diesel power plant are considered as the benefit of the development project in economic analysis. The cost of the diesel power plant includes plant installation cost, cost of the transmission system, operation and maintenance cost, and fuel cost. The amount of fuel used is considered proportional to the units of energy produced. The amount of 0.33 liter of diesel oil is estimated to be used for each kWh of electric energy production (NEA, 1982). The unit price of diesel oil of 6.70 Baht (US$ 0.29) per liter is considered in estimating the fuel cost.

Economic Analysis

The following assumptions are made in an economical feasibility study of the micro-hydropower projects.

1. The service life of all civil structures in the project is 30 years, the service life of turbines and generators is 25 years, the service life of the diesel plant is 15 years, and the service life of the transmission and distribution system is 15 years.

2. The investment in the transmission and distribution system (including the transformers of the diesel plant installation) is the same as those of the micro-hydropower development project.

3. The interest rate is 12 percent per year.

Based on the above assumptions, the annual equivalent costs of the micro-hydropower plant and the diesel power plant are determined, taking into account the annual depreciation, operation and maintenance cost, and fuel cost. The benefit-cost ratio of the micro-hydropower project is then obtained by dividing the annual equivalent cost of the diesel plant by the annual equivalent cost of the micro-hydropower plant.

H. OPERATION AND MAINTENANCE

Operation and maintenance works are very essential in micro-hydropower development. In this section, operation and maintenance of four main components of micro-hydropower development (as discussed by Gary Kitching in the Workshop on Small-Scale Hydropower Technology Applications in Asian Rural Settings) are presented. The four components to be mentioned include the pipeline, turbine, generator and the turbine-generator combination.

Pipeline

The maintenance of a pipeline should be very minimal. The important consideration is the intake. One must ensure that as little silt as possible goes down the line.

The pipeline must be flushed after construction and before the turbine is connected. All debris should be totally flushed out so that there is nothing left in the line that could damage the turbine runner. There have been cases where, after the turbine has been started, a rock or piece of wood comes down the line, plugs the nozzle, and blows up the pipeline. The pipeline, in this circumstance, would not have blown up if it had been flushed out prior to operation.

As previously mentioned, the pipeline should have a revent pipe near the intake, and anywhere else the air can get trapped in the pipeline. The accumulation of air in the pipeline will reduce the effective head and thus lower the power output of the turbine. The plant operator must release the trapped air with the revent pipe from time to time.

The Turbine

The operation and maintenance of the turbine are often concerned with its bearings, shafts, wheel or runner. Also, problems associated with various types of turbines will be discussed in this section.

There are several types of bearings that can be used on a turbine. There are heavy-duty tapered bearings, spherical bearings, regular ball bearings, and sleeve-oil bearings. The heavy-duty tapered bearings are probably the best to use with small hydroelectric plants because of their high thrust-carrying ability and their radial load capability. These are also the safest bearings to use. The outside of the roller is extremely hard but the center is soft, which prevents the roller from shattering. These bearings work exceptionally well for turbines that are left unattended for long periods of time.

Spherical roller bearings also have a high radial and thrust-carrying capability, but not as high as heavy-duty tapered bearings. These bearings are often used when a shaft is misaligned, and are suitable provided the bearings are properly sized.

Regular ball bearings can be the most problematic because of the small contact area of the ball in the cone. These bearings have very little thrust-carrying capability and can shatter easily because the balls are hardened all the way through. These bearings are not practical when a turbine is to be left unattended for a long time.

Lastly, the sleeve-oil bearings are probably the most efficient bearings to use. One hindrance is that the bearings require an oil pump which must be watched. If neglected, the bearings could lose their oil and destroy the entire system.

A second factor to consider when selecting a bearing is the type of seal that is required. Rubber seals should be avoided. These can be blown off with a high pressure grease gun which will totally destroy any sealing capability of the bearing. The best type of seal to use on a bearing is one with a labyrinth seal. Bearings with this type of seal will not be blown out because they allow excess grease to weep out of the bearing. This type of seal will also have a longer life-span than other seals.

The shaft is another very important part of the turbine. It can create some of the biggest problems for the turbine operator. If the shaft becomes bent, it can destroy the bearings and possibly the runner. The best protection against bending is to be very generous with shaft sizes. It is the shaft size, not the type of metal used, that determines bending moment.

One other area to look at when selecting the shafting is how well it fits the bearings. If a shaft is several thousandths of an inch undersize when the set is screwed on the bearings it could run eccentrically and cause vibrations.

The wheel, which is also referred to as the runner, requires very careful selection. There are several types of runners available : impulse, Turgo, Francis, propeller and cross-flow runners. The impulse runner (Pelton type) is about the easiest to operate because the turbine housing is not pressurized. The construction of an impulse wheel is very important in order to increase both its lifetime and its safety. The best runner is a one-piece casting of either stainless steel or manganese bronze. Cast iron should not be used as it is very brittle and could fracture with explosive force.

The Turgo runner is similar to the impulse runner except that the jet of water striking the Turgo wheel hits the wheel at an angle which creates a very complicated bearing arrangment.

The Francis runner is usually used on medium and high heads with large flows of water. This runner suffers from cavitation because the entire runner is covered with water all the time. This turbine is also under pressure inside the housing. Therefore the water seal is more of a problem.

The propeller turbine operates very well with low head and high flows. Unfortunately these turbines also suffer from cavitation eventually. If the proper stainless steel is used in the runner it will greatly increase the turbine's life span. In most cases the propeller runner will require less maintenance than the Francis runner.

The cross-flow turbine will also suffer from some cavitation, and care should be taken in the selection of the turbine so that it will suit the site. This type of turbine can work well if used properly, as it is best used with low heads.

The maintenance of different types of turbines can be as different as the turbines themselves. The impulse and Turgo both need very little maintenance after they are in operation. About the only tasks that are necessary are greasing the bearings and operating the valves once a month. With other types of turbines such as the propeller, Francis and cross-flow, it is important to check with the manufactures. They will know the exact maintenance required to maintain peak efficiency.

The impulse type of turbine will require much less maintenance than any other type because it is designed so that the runner is operated in a large chamber with a generous amount of room surrounding it. If the bearings should work themseleves loose, the runner will not strike anything. With the propeller, Francis and cross-flow type of turbines the runners have a very close tolerance between the runner and the turbine housing. In some cases this spacing can be as small as just a few thousandths of an inch. If something were to happen to the bearings or the shaft, the turbine could be destroyed very quickly.

The Generator

Maintenance of the generator should entail very little except normal greasing. The bearings in the generator are usually good for several years but the manufacturer should be consulted for any special maintenance that may be required.

The generator can be regulated by either internal transformer regulation, which can maintain the voltage within 5 percent without any external regulation, or by external electronic regulation, which can maintain the voltage to within 1 percent. This is very good for the operation of delicate instruments, whereas the internally regulated generator is very good for motor starting.

The Turbine-Generator

The turbine-generator combination can use three types of drives. They include belt drives, gearboxes and direct drives. The need for overspeed protection will be explained.

In most cases the belt drive is the best choice because it is easily maintained and requires little knowledge to install. Gear drives can be very expensive and create enormous problems due to their complexity in construction. Gear drives should only be used when there is no other choice. When the drive is over 200 HP, a direct drive is not possible.

It is usually best to choose a direct drive if the turbine speed can be matched with the speed of the generator (The wheel size may have to be altered to match the speeds). This is worthwhile in turbine sets of over 125 kW, due to the fact that belt drive in that power range is not really feasible.

Overspeed is one of the biggest dangers to the operation of the generator, since most generators can only withstand about 25 percent overspeed and runaway on a turbine is 100 percent of operating speed. Runaway can be avoided by simply having a deflector to deflect the water away from the runner. However, this can only be accomplished with impulse turbines. With turbines such as the propeller and Francis types, it is very difficult to control overspeed, since the water cannot be diverted away from the runner. Consequently, overspeed control becomes very expensive as a water bypass needs to be used on these types of turbines.

Chapter 4

Design and Construction

of Kam Pong Micro-Hydropower Project

DESIGN AND CONSTRUCTION OF KAM PONG MICRO-HYDROPOWER PROJECT

The Kam Pong micro-hydropower project is one of the projects with financial assistance from USAID. It is located in the Chiang Mai Province. The construction of civil works started in February 1983 and was completed in December 1983. The installed capacity is 40 kW. It is now operational and the electric power is distributed to the users in Kam Pong village. In this chapter, the details of the design and construction of the Kam Pong project are described.

A. LOCATION AND TOPOGRAPHY

The Kam Pong micro-hydropower project is located at Kam Pong village, Tambon Huai Kao, Amphoe San Kampaeng, Chiang Mai Province at a distance of approximately 50 km northeast of the city of Chiang Mai. The terrain in this area is very rugged. The project is situated on a small stream that originates in the mountainous part of the area. The catchment area at the weir site is about 6 km^2. Most of the area is covered with dense forests. Agricultural lands are limited due to very steep slopes in the area. Fig. 4.1 shows the location and topography of the Kam Pong project area.

B. SOCIOLOGY AND COMMUNITY STRUCTURE

In this section, the characteristics of Kam Pong village are described Most of the data presented here were retrieved from the survey report of the Energy Economics Division, NEA. The survey was conducted in April 1983. About 38 percent of the total households were randomly selected for interviewing during the field survey.

Households and Population

Kam Pong village consists of 7 small groups; namely Pang Nai, Pang Tone, Pang Khon, Pang Klang, Pang Nok, Pang Kae and Pang Pueng. The households and population in each of these groups are tabulated in Table 4.1. Altogether, there are 118 households with 490 inhabitants (in April,1983).

Village Characteristics

Kam Pong village has existed for more than 100 years. The first group of residents here migrated from the northern part of the Democratic

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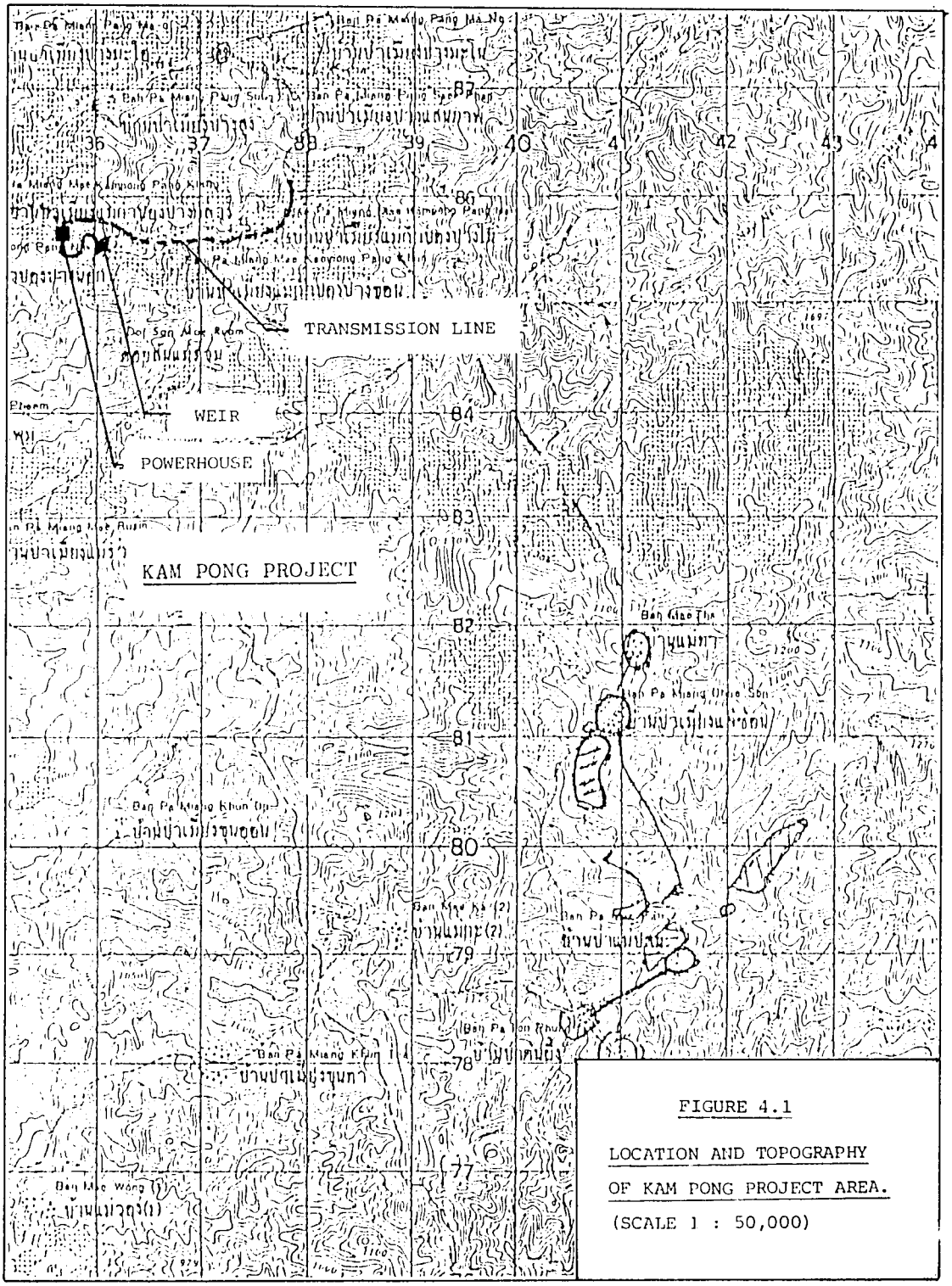


FIGURE 4.1

LOCATION AND TOPOGRAPHY OF KAM PONG PROJECT AREA.

(SCALE 1 : 50,000)

TABLE 4.1 NUMBER OF HOUSEHOLDS AND POPULATION

Village	Number of Households	Number of Population
Pang Nai	34	153
Pang Tone	10	42
Pang Khon	12	49
Pang Klang	17	65
Pang Nok	18	73
Pang Kae	12	48
Pang Pueng	15	60
Total	118	490

People's Republic of Laos. They came to settle at Pang Tone. When the population increased, the settlement was expanded to Pang Khon. After that, the northern people from nearby districts moved into the area to occupy lands for agriculture and set up other groups. At present, there are 7 groups, each group is approximately 1 km apart. These are :

Pang Nai This group is located in the northern most part of the village.

Pang Tone This group is located south of Pang Nai. The headman of the village and his assistant live here. There is a Buddhist temple in this group.

Pang Khon This group is located beyond Pang Tone. There is a school here.

Pang Klang This group is located beyond Pang Tone. There is a school here.

Pang Nok This is the center of Kam Pong village and the Kam Pong Micro-hydropower project is located here.

Pang Kae This group is situated south of Pang Nok.

Pang Pueng This is the southernmost group located next to Pang Kae and is the latest group established.

The dwelling units in Kam Pong village were simply constructed using construction materials available in the local area. However, some new houses were constructed with materials from the city of Chiang Mai. Photos 4.1 through 4.6 illustrate the characteristics of Kam Pong village.

PHOTO 4.1 THE ACCESS ROAD VIA PONG DIN ENTRANCE

PHOTO 4.2 A BIRD'S-EYE VIEW OF THE KAM PONG VILLAGE

PHOTO 4.3 KAM PONG VILLAGE AT THE WEIR SITE

PHOTO 4.4 ROAD IN KAM PONG VILLAGE

PHOTO 4.5 ACCESS ROAD TO THE POWERHOUSE

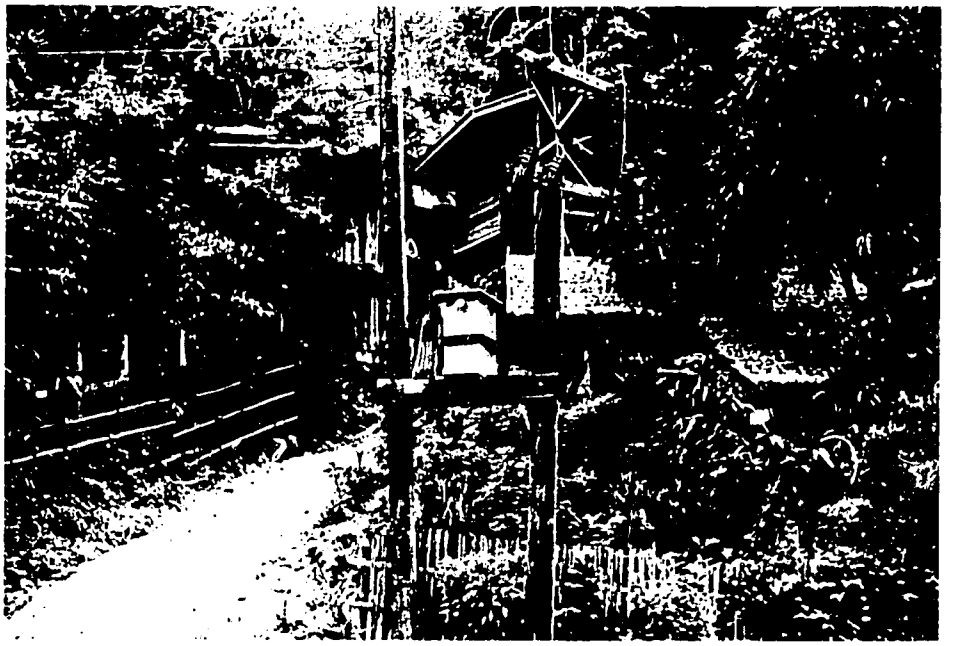


PHOTO 4.6 ELECTRICITY DISTRIBUTION NETWORK IN KAM PONG VILLAGE

Education

Formerly there was no school in Kam Pong village since transportation was very poor. Those who wanted to enter the school had to travel to Tambon Huai Kao which is approximately 10 km from Kam Pong village. The first primary school (Prathom 1 - Prathom 6) of Kam Pong village was built in 1981 at Pang Khon. At present there are about 60 students and 7 teachers in this school.

Data obtained from the socio-economic survey conducted by the Energy Economics Division, NEA, revealed that 65.3 percent of the residents of Kam Pong village could read and write. Most (92 percent) finished Prathom 1 - Prathom 4 level, 3.2 percent finished Prathom 5 - Prathom 6 level and only 4.7 percent studied beyond Prathom 6.

Occupation

With the exception of the Pang Pueng group, most of the residents of Kam Pong village (more than 80 percent) earn their living from growing chewing tea. In Pang Pueng, 80 percent of the residents work as laborers in the Forest Plantation Office. Other major occupations of households include trading, dress-making, etc. Table 4.2 tabulates percentages of the household heads in Kam Pong village who are engaged in each type of occupation. Besides these main occupation, more than 50 percent of the household heads in Kam Pong Village are also engaged in secondary occupations.

TABLE 4.2 MAIN OCCUPATION OF THE HEADS OF HOUSEHOLD

Village \ Occupation	Growing Chewing tea	Laborers in Forest Plantation Office	Trading	Dress-making	Others
Pang Nai	100.0	-	-	-	-
Pang Tone	80.0	-	-	-	20.0
Pang Khon	75.0	-	25.0	-	-
Pang Klang	87.5	-	-	12.5	-
Pang Nok	100.0	-	-	-	-
Pang Kae	80.0	-	-	-	20.0
Pang Pueng	20.0	80.0	-	-	-
Overall Average	82.2	9.0	2.2	2.2	4.4

Land Use and Land Holdings

The Kam Pong village is located within the Forest Reserve area and therefore there are no ownership documents for the occupied lands in this village. The villagers are, however, allowed to occupy lands for cultivation and they have to pay tax for the occupied lands. About 80 percent of the occupied lands are used for growing chewing tea. Another 4 percent is used for residential purposes. The remainder is used for upland crop cultivation.

The average land holding in Kam Pong village is about 14.6 rai per household. Pang Tone is highest (approximately 24 rai per household) whereas the amount of land holding at Pang Pueng is lowest (about 3.6 rai per household).

Agriculture

As previously mentioned, the main occupation of most residents in Kam Pong village is growing chewing tea. In addition, mushroom growing has recently received much attention and some villagers consider it as their secondary occupation.

Chewing tea growing

The chewing tea growing areas occupy the hilly area surrounding the village. The height of the chewing tea is 2-5 m. The chewing tea leaves are harvested during the day and these leaves are heated by steam during the night. Chewing-tea harvesting usually lasts for 100-150 days each year.

Table 4.3 tabulates the chewing tea planting area per household and its production in Kam Pong village. On the average, each household has 10.0 rai of chewing tea planting area, and the annual production is 425.08 kg per rai or 4,675 kg per household. The chewing tea is sold to a merchant for 5-7 Baht (US$ 0.22-0.30) per kg. That is, each household will earn about 30,386 Baht (US$ 1,321.13) each year from growing chewing tea.

Table 4.4 shows the expenses in chewing tea production. On the average, the overall cost is about 555 Baht (US$ 24.13) per rai. Taking into account the average growing area of 10.0 rai per household, this outlay costs about 5,550 Baht (US$ 241.30) per household. Therefore, the net annual income from growing chewing tea is about 24,836 Baht (US$ 1,079.83) per household.

Mushroom growing

This occupation has received much attention recently since there exists a mushroom growing center near the village. The villagers who want to buy mushroom seeds must be a member of this center. The price of the seed is 5 Baht (US$ 0.22) per piece of wood. The center will buy the mushrooms from the villagers at 60 Baht (US$ 2.61) per kilogram.

Table 4.5 tabulates the mushroom production in Kam Pong village. The overall average is 6.01 kg per household. About 0.76 kg is collected for household consumption. With a selling price of 60 Baht per kg, the average income from mushroom growing is 315 Baht (US$ 13.70) per household each year.

TABLE 4.3 CHEWING TEA GROWING AND PRODUCTION

Production / Village	Chewing tea planting area (rai/household)	Production		Income per household * (Baht/year)
		kg/rai	kg/household	
Pang Nai	14.29	601.87	8,600	55,900.00
Pang Tone	15.80	240.22	3,795	24,667.50
Pang Khon	7.94	591.04	4,693	30,504.50
Pang Klang	8.88	457.39	4,062	26,403.00
Pang Nok	9.29	357.34	3,320	21,580.00
Pang Kae	6.40	446.49	2,858	18,577.00
Pang Pueng	3.00	42.34	127	825.50
Overall Average	10.00	425.08	4,675	30,385.50

* Calculated on a selling price of 6.50 Baht per kg.

TABLE 4.4 EXPENSES FOR CHEWING TEA PRODUCTION

Village	Planting Area (rai/household)	Labor Cost (Baht/rai)	Fuel Cost (Baht/rai)	Maintenance Cost (Baht/rai)	Total Cost	
					Baht/rai	Baht/house-hold
Pang Nai	14.29	681.80	67.00	60.00	808.80	11,557.75
Pang Tone	15.80	250.60	7.60	34.00	292.20	4,616.75
Pang Khon	7.94	242.50	2.20	21.80	266.50	2,116.00
Pang Klang	8.88	609.20	45.00	58.50	712.70	6,328.75
Pang Nok	9.29	281.60	31.40	43.70	356.70	3,313.75
Pang Kae	6.40	312.50	25.00	44.00	381.50	2,441.60
Pang Pueng	3.00	16.70	-	2.70	19.40	58.20
Overall Average	10.00	468.20	39.30	47.50	555.00	5,550.00

TABLE 4.5 MUSHROOM GROWING AND PRODUCTION

Village \ Production	Production (kg/household)	Household Consumption (kg/household)	Annual Income (Baht/household)
Pang Nai	1.11	0.17	56.40
Pang Tone	4.40	0.40	240.00
Pang Khon	11.25	1.25	600.00
Pang Klang	17.50	1.88	937.20
Pang Nok	-	-	-
Pang Kae	10.00	2.00	480.00
Pang Pueng	-	-	-
Overall Average	6.01	0.76	315.00

Household Economy

Household income

Besides incomes from growing chewing tea and mushrooms, the residents in Kam Pong Village still earn some money from other occupations, such as household industry, trading, land rentals, farming vegetable crops and laborers. Table 4.6 shows household incomes derived from these occupations in Kam Pong village. On the average, the total annual income is 36,043 Baht (US$ 1,567.00) per household.

Household expense

Besides agricultural expenses (as shows in Table 4.4) the remaining household expenditures in Kam Pong village can be classified into 3 categories, i.e. regular expenses, irregular expenses and investment expenses (Table 4.7). The regular expenses, which are the expenses for household consumption, are the biggest category accounting for 20,639 Baht (US$ 897.35) per household per year. The irregular expenses which are the expenses for house repairs, etc., account for 5,693 Baht (US$ 247.52) per household annually. The investment expenses,which were mainly the outlay for merchandise, account for 572 Baht (US$ 24.87) per household. Totally, these three categories of household expenses account for 26,904 Baht (US$ 1,169.74) per household per annum.

TABLE 4.6 HOUSEHOLD INCOME OF KAM PONG VILLAGE

Baht/household/year

Village	Chewing-tea growing	Mushroom growing	Vegetable crops	Household industry	Trading	Rentals	Laborer	Total
Pang Nai	55,900.00	56.40	-	25.00	-	-	483.30	56,464.70
Pang Tone	24,667.50	240.00	-	472.00	-	1,000.00	-	26,379.50
Pang Khon	30,504.50	600.00	-	62.50	3,887.50	-	4,825.00	39,879.50
Pang Klang	26,403.00	937.20	-	437.50	1,750.00	-	4,720.25	34,247.95
Pang Nok	21,580.00	-	416.70	166.70	125.00	-	666.70	22,955.10
Pang Kae	18,577.00	480.00	480.00	-	-	-	6,384.00	25,921.00
Pang Pueng	825.50	-	160.00	-	-	-	18,642.40	19,627.40
Overall Average	30,385.50	315.00	126.70	164.70	673.30	111.10	4,266.50	36,042.80

TABLE 4.7 HOUSEHOLD EXPENSES OF KAM PONG VILLAGE

Baht/household/year

Village	Regular	Irregular	Investment	Total Expenses
Pang Nai	25,755.90	13,671.25	-	39,427.15
Pang Tone	17,774.40	650.00	-	18,424.40
Pang Khon	21,000.25	6,925.00	2,500.00	30,425.25
Pang Klang	25,009.25	606.25	1,250.00	26,865.85
Pang Nok	16,645.00	5,666.70	83.30	22,395.00
Pang Kae	18,636.80	1,822.00	-	20,458.80
Pang Pueng	10,736.40	2,640.00	44.00	13,420.40
Overall Average	20,639.00	5,693.00	572.00	26,904.00

Use of Fuel

For cooking

Like other villages in remote areas in Chiang Mai province, the residents of Kam Pong village have sticky rice as a staple food. Cooking sticky rice usually requires more fuel than other foods. Almost all households in this village use firewood for cooking sticky rice. The amount of firewood used in cooking during the period of chewing tea harvesting is more than that normally used, since during that period more food is prepared for the hired laborers. Table 4.8 shows the amount of firewood used for cooking in Kam Pong village. On the average, about 2,120 kg. or 5.30 m^3 of firewood is used by each household annually.

For lighting

About 97.5 percent of total households in Kam Pong village use kerosene for lighting. The rest use electric generators. During the non-harvesting period, a lamp will be lit for 1-3 hours a day. In the harvesting period, it will be lit for 3-5 hours a day. Each house has approximately 3 lamps. On the average, the amount of kerosene used is 69.75 litres per household per year. The total amount of kerosene used in Kam Pong village is estimated about 3,231 litres per annum (Table 4.9). For those households with electric generators, the total amount of diesel oil used is about 260 litres per annum and the total amount of benzene used is about 400 litres per annum.

TABLE 4.8 THE AMOUNT OF FIREWOOD USED IN COOKING

Village	Harvesting period		Non-harvesting period		Total	
	kg/H.H.	m^3/H.H.	kg/H.H.	m^3/H.H.	kg/H.H.	m^3/H.H.
Pang Nai	552	1.38	1,892	4.73	2,444	6.11
Pang Tone	400	1.00	1,568	3.92	1,968	4.92
Pang Khon	294	0.74	1,882	4.71	2,176	5.45
Pang Klang	399	1.00	1,389	3.47	1,788	4.47
Pang Nok	179	0.45	2,222	5.56	2,401	6.01
Pang Kae	209	0.52	1,773	4.43	1,982	4.95
Pang Pueng	10	0.03	1,583	3.96	1,593	3.99
Overall Average	330	0.83	1,790	4.47	2,120	5.30

TABLE 4.9 THE AMOUNT OF KEROSENE USED FOR LIGHTING

Village	Kerosene used (lt/H.H./year)	Total number of households	Total amount of kerosene used (litres)
Pang Nai	92.85	34	3,157
Pang Tone	54.60	10	546
Pang Khon	120.78	12	1,449
Pang Klang	39.53	17	672
Pang Nok	68.61	18	1,235
Pang Kae	41.00	12	492
Pang Pueng	45.33	15	680
Overall Average	69.75	118	8,231

For chewing tea processing

The amount of firewood required for processing 1 kg of chewing is approximately 0.65 kg. Based on the data on chewing tea production (Table 4.3), the amount of firewood used can be estimated as shown in Table 4.10. Totally, about 358,592 kg (896 m^3) of firewood is used annually.

TABLE 4.10 THE AMOUNT OF FIREWOOD USED IN PROCESSING CHEWING TEA

Village	No.of Households	Chewing Tea Production (kg/household)	Total Amount of Firewood Used	
			Kg	m^3
Pang Nai	34	8,600	190,060	475
Pang Tone	10	3,795	24,668	62
Pang Khon	12	4,693	36,605	92
Pang Klang	17	4,062	44,885	112
Pang Nok	18	3,320	38,844	97
Pang Kae	12	2,858	22,292	56
Pang Pueng	15	127	1,238	3
Total	118	4,675	358,592	896

For heating

During the winter, additional amounts of firewood are used for heating. It is estimated that each household uses about 430 kg of firewood for such purpose annually. The total amount of firewood used for heating in Kam Pong village is about 50,740 kg or 127 m^3.

For transportation

A public bus is normally used by the villagers in travelling between the village and the town. Only 2 households in Kam Pong village have their own pick-up truck. The amount of benzene used by these two trucks is about 3,640 litres per annum.

Total amount of fuel used

Table 4.11 summarizes the total amounts of fuel used for various purposes in Kam Pong village. Totally, about 1,648 m^3 of firewood, 8,231 litres of kerosene, 260 litres of diesel and 4,040 litres of benzene are used annually.

TABLE 4.11 TOTAL AMOUNT OF FUEL USED

Purpose \ Fuel	Firewood (m^3)	Kerosene (lt)	Diesel (lt)	Benzene (lt)
Cooking	625	-	-	-
Lighting	-	8,231	260	400
Chewing-tea processing	896	-	-	-
Heating	127	-	-	-
Transportation	-	-	-	3,640
Total	1,648	8,231	260	4,040

C. HYDROLOGICAL STUDY

The catchment area of the Kam Pong micro-hydropower project is about 6 km^2. The area is mountainous and covered with dense forests. The weir is located at Pang Nok which is the center of Kam Pong village.

There is no gauging station on this stream. Therefore, in determining the design flood which is used in the design of the weir, and empirical formula developed by Bunchob (1980) which is formulated for the Northern part of Thailand is used. This empirical formula is

$$Q_p = 6.58\ A^{0.718}$$

where Q_p = the design flood with 50-year recurrence interval, m^3/s

A = the catchment area, km^2

For the catchment area of 6 km^2, the design flood of 23.8 m^3/s was obtained. This value was used in designing the weir of the Kam Pong project.

For the design discharge, the value of minimum flow in the stream was used because there is no pondage. A minimum flow of 0.12 m^3/s was the recorded during the dry season by NEA officials. This value was then used in the design of the headrace, penstock and turbines.

The available water head of the Kam Pong project was at first determined from the topographic map of 1:50,000 scale. Field survey was then conducted to determine more accurate information. The value of approximately 60 m was obtained as the design head.

With the obtained design discharge of 0.12 m^3/s and design head of 60 m, the installation capacity of 40 kW was estimated.

D. CIVIL WORKS

Civil works at the Kam Pong micro-hydropower project include a weir, a headrace, a forebay, a penstock and a powerhouse. The details of these works are discussed in this section.

Weir

The weir of the Kam Pong micro-hydropower project is located at Pang Nok of Kam Pong village. It is constructed of gravity type concrete, 2 m high and 15 m long. The crest elevation is at 885.0 m MSL. The upstream face slope is 1:1 whereas the downstream face is curved with a radius of 2.08 m. At the left abutment there is an intake structure and a sluice gate for draining the trapped sediment. Fig. 4.2 shows the detailed cross section of the Kam Pong weir. Photo 4.7 illustrates the constructed Kam Pong weir whereas the intake and the sluice gate are shown in Photo 4.6.

Headrace

The headrace at the Kam Pong project is constructed with an asbestos cement pipe 0.30 m in diameter and 470 m in length. The headrace begins at the left abutment of the weir and is buried along the side of the hill to the forebay.

Forebay

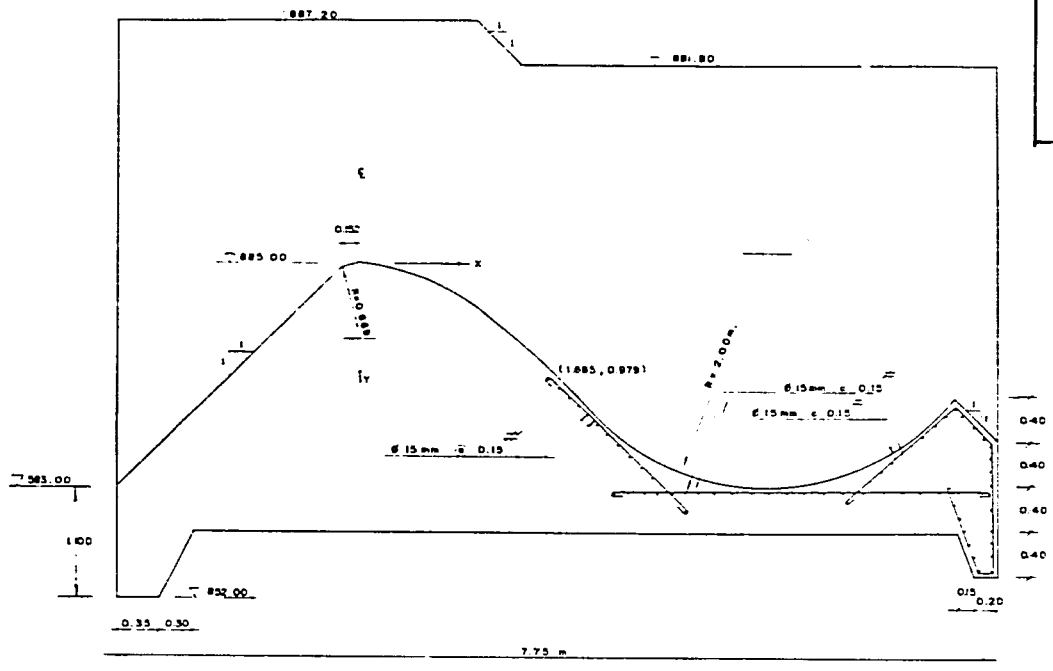
The forebay of the Kam Pong project is a rectangular concrete tank, approximately 3 m long, 1.5 m wide and 1.5 m high. The forebay receives the diverted water from the headrace before discharging it to the turbine via the penstock. The forebay of the Kam Pong Project is also constructed with an overflow spillway to drain the excess water.

Penstock

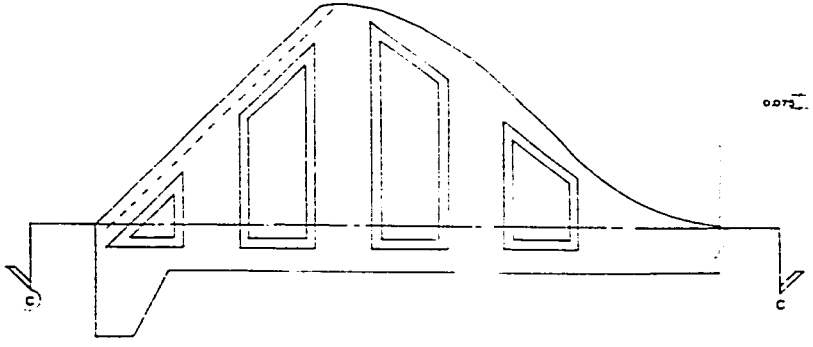
The penstock of the Kam Pong project consists of an asbestos cement pipe 0.30 m in diameter and 50 m in length, and a 50 m long steel pipe of the same diameter. The penstock extends from the forebay to the powerhouse. Photo 4.9 illustrates the steel section of the penstock.

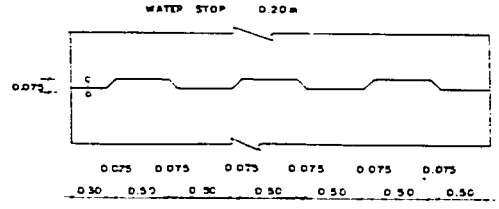
FIGURE 4.2

WEIR OF THE KAM PONG PROJECT



X	Y
0	0
0.1	0.006
0.2	0.022
0.3	0.043
0.4	0.076
0.5	0.113
0.6	0.158
0.7	0.205
0.8	0.260
0.9	0.321
1.0	0.383
1.1	0.457
1.2	0.586
1.3	0.618
1.4	0.705
1.5	0.718
1.6	0.815
1.673	0.979





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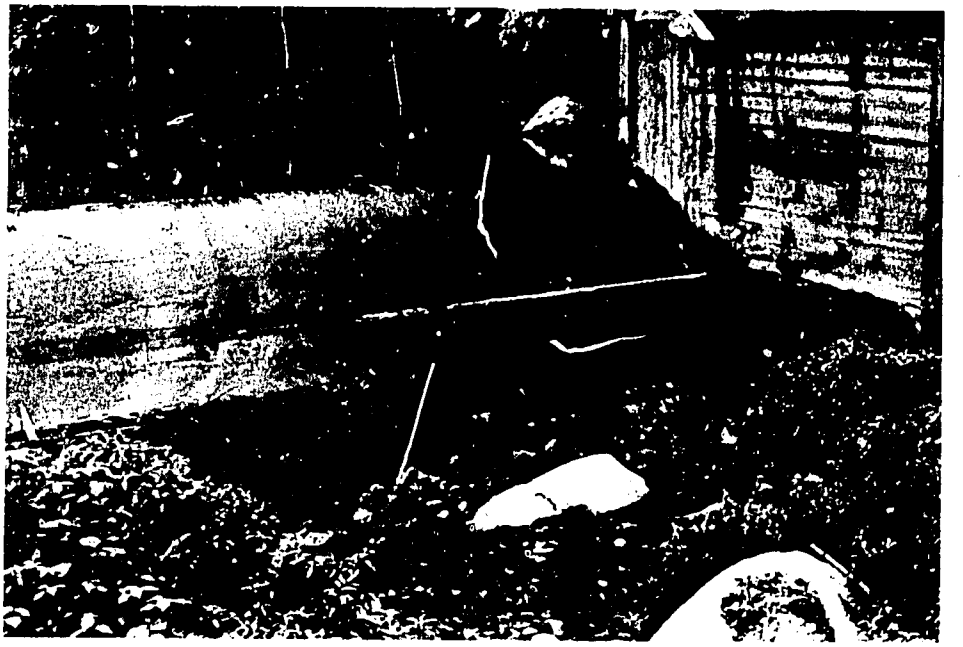


PHOTO 4.7 WEIR AT THE KAM PONG PROJECT

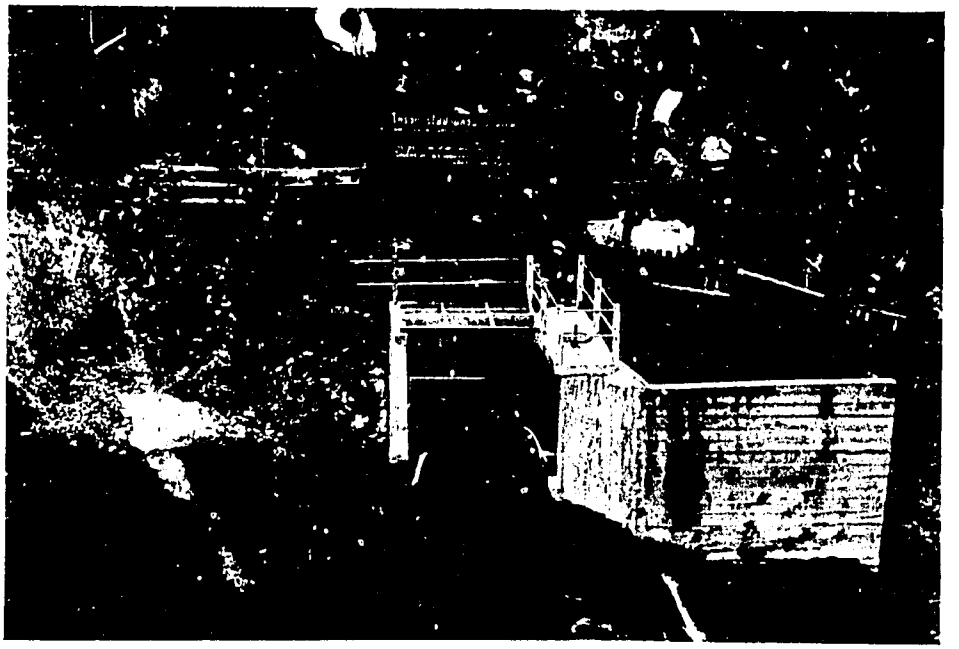


PHOTO 4.8 INTAKE STRUCTURE AND SLUICE GATE FOR SEDIMENT RELEASE

PHOTO 4.9 STEEL SECTION OF KAM PONG PENSTOCK

Powerhouse

The powerhouse of the Kam Pong project is located at an elevation of 824 m MSL approximately 61 m below the weir crest level. It is approximately 500 m downstream of the weir. It is constructed of wooden plank floors and walls and a galvanized steel roof (Photo 4.10). The useful floor area is approximately 18 m^2. It is equipped with 2 sets of turbines, generators and switchboards. The installed capacity is 40 kW.

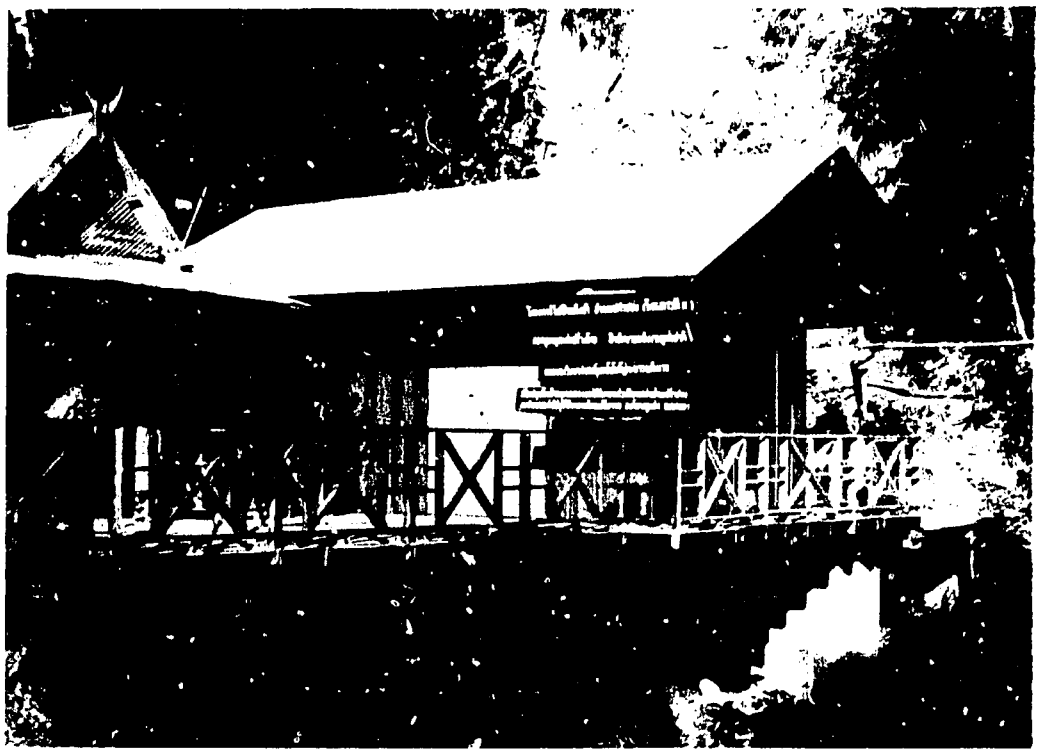


PHOTO 4.10 POWERHOUSE OF KAM PONG PROJECT

E. MECHANICAL WORKS

Two sets of turbines were installed in the Kam Pong powerhouse. They are a pelton type with double fixed area nozzles. The designed head is 60 m and the designed discharge is 60 litres per second. The speed is 1500 rpm. Power output of each unit is approximately 20 kW. It is designed by NEA and locally manufactured. Details of these turbines are as follows :

Runner

The runner consists of disks and buckets. The disks are made of JIS SS 41-steel whereas the buckets are made of cast steel. The shaft of the runner is horizontally connected with the generator.

Nozzle

The nozzle and the flow-straightening vanes are made of stainless steel. The remaining auxiliary parts are made of JIS SS 41-steel.

Flow Deflector

The flow deflector is made of stainless steel with smoothed surface.

Shaft

The shaft of the turbine is made of carbon steel (C 10400). Flexible coupling is used in connecting the turbine's and the generator's shafts.

Casing and Hood

The casing and the hood of the turbine is made of JIS SS 41-steel welded to the designed shapes and fixed together with bolts and nuts.

F. ELECTRICAL WORKS

The electrical works of the Kam Pong micro-hydropower project include a generator, a switchboard, a speed controller, a transformer and a transmission line system. The details are briefly described in this section.

Generator

The generator at the Kam Pong project is a 3-phase, 380-V alternating current, synchronous generator with horizontal shaft, self-ventilation and brushless excitation. The frequency of the electricity generator is 50 Hz at the synchronous speed of 1500 rpm. The number of poles is 4. The stator connection is a star type. The rating is 25 kVA and the power output is about 20 kW.

Speed Controller

The speed controller used in the Kam Pong powerhouse is an electronic load controller manufactured by NEA.

Switchboard

The switchboard for the Kam Pong project is 0.55 m wide, 1.80 m high and 0.50 m deep. It is equipped with the following electrical equipment :

- 1 set of circuit breakers, 3-phase, 380-V, 4-wire 75 amperes with over-current relay and under-voltage relay;
- 6 pilot lamps;
- 1 AC ammeter, 40-A full scale 240°;
- 3 sets of current transformers, ratio 40/5 A;
- 1 AC voltmeter, 0-400 V full scale 240°;
- 1 Frequency meter, range 45-55 Hz;
- 1 power factor meter, range -0.5 to +0.5;
- 1 wattmeter, 3-phase, 4-wire unbalanced load, range 0-20 kW, 5A, 380 V;
- 1 ampere selector; and,
- 1 voltage selector;

Transformers

Step-up transformer

One 25-kVA step-up transformer is installed at the Kam Pong powerhouse. It is an outdoor type with 3 phases, oil immersed and self cooling. The nominal voltage is 400/250 V at the primary and 3,500 V at the secondary. The winding connection is a delta type at the primary and a star type at the secondary.

Step-down transformers

Three 10-kVA and two 5-kVA step-down transformers are installed at Kam Pong village. They are the 3-phase, oil immersed, self-cooling types. The nominal voltage is 3,500 V at the primary, 400/230 V at the secondary. The primary winding is a delta-connection whereas the secondary is a star-connection.

Transmission Line System

The transmission line system of the Kam Pong project consists of a 3,500 V transmission line from Kam Pong powerhouse to the village groups, a distance of approximately 5.5 km. with a 380-V distribution line connected to the step-down transformer. The total length of the low voltage line is approximately 4 km.

G. PROJECT COST AND ECONOMIC EVALUATION

In this section the costs of the Kam Pong micro-hydropower project are discussed together with project benefits. These consequently lead to the economic justification of the project.

Project Cost

The details of the project cost are summarized in Table 4.12. The total project cost is 2,656,500 Baht (US $ 115,500), of which 1,438,519 Baht (US $ 62,544) is a grant from USAID.

In addition to the above mentioned cost items, the villagers of Kam Pong were also involved in the construction work and they contributed some locally available construction materials such as gravel, sand, wood poles, planks and wood for framework.

Project Benefits

The benefits to be derived from the Kam Pong micro-hydropower project can be separated into 2 items, i.e. direct and indirect benefits.

Direct benefit

The direct benefit of the Kam Pong micro-hydropower project, which is an isolated project, can be considered as that equivalent to the investment and operational cost of a diesel power plant which has the same capacity. It has been estimated that if a diesel power plant of this capacity is operated, approximately 77,220 liters of diesel oil would be used annually. Thus, the annual benefit of the Kam Pong project can be considered as the cost of this diesel oil, which is approximately 517,374 Baht (US $ 22,495) plus the depreciation and operating cost of the diesel power plant.

Indirect benefit

Besides the above mentioned direct benefit, there exist some indirect benefits resulting from the development of the Kam Pong micro-hydropower project with villager participation. These indirect benefits include :

- Increasing villagers income and upgrading their living standard;
- Initiating the role of cooperation in rural development;
- Fostering close cooperation between local people and the government in rural development; and
- Transferring an appropriate technology to the rural people

Economic Evaluation

The Kam Pong micro-hydropower project is an isolated project, i.e., a project which is not connected to another power transmission network. The economic analysis is made in comparison with a diesel power plant of the same capacity.

The main characteristics and costs of the diesel power plant which will be compared with the Kam Pong micro-hydropower plant are summarized in Table 4.13. About 600,000 Baht (US $ 26,087) is required for plant installation and another 982,000 Baht (US $ 42,696) is needed for the transmission line system and transformer (the same as that used in the Kam Pong micro-hydropower project). The operation and maintenance cost is approximately 5 percent of the installation cost, i.e., 79,100 Baht (US $ 3,439) per year and the fuel cost is approximately 517,374 Baht (US $ 22,495) per year.

Based on the assumptions mentioned in Chapter 3, section G, the annual equivalent cost of the Kam Pong micro-hydropwer plant (including the

TABLE 4.12 COST OF THE KAM PONG PROJECT

Item	Cost	
	Baht	US$
1. Weir with intake structure and sluice gate	350,000	15,217
2. Headrace	516,500	22,457
3. Penstock and concrete support	95,000	4,150
4. Powerhouse	60,000	2,609
5. Turbine, generation and switchboard	405,000	17,522
6. Transmission line system	700,000	30,435
7. Transformers	282,000	12,260
8. Administration and services of construction equipments	250,000	10,870
Total	2,656,500	115,500

TABLE 4.13 DETAILS OF A DIESEL POWER PLANT EQUIVALENT TO THE KAM PONG MICRO-HYDROPOWER PLANT

Item	Value	
1. Installation capacity	40	kW.
2. Number	1	
3. Annual energy production	0.234	GWh
4. Plant factor	65	%
5. Service life	15	years
6. Installation cost	600,000	Baht
7. Amount of diesel used per unit	0.33	liter/kWh
8. Annual diesel oil consumption	77,220	liters
9. Unit price of diesel oil	6.70	Baht/liter
10. Fuel cost	517,374	Baht/year
11. Transmission line cost	982,000	Baht
12. Operation & maintenance cost	79,100	Baht/year

annual depreciation, operation and maintenance costs) are summarized in Table 4.14 whereas the annual equivalent cost of the equivalent diesel power plant is shown in Table 4.15 The annual equivalent cost of the Kam Pong micro-hydropower plant is 419,180 Baht (US$ 18,225), or 1.79 Baht (US$ 0.08) per kWh, and the annual equivalent cost of the diesel power plant is 828,746 Baht (US$ 36,032), or 3.54 Baht (US$ 0.15) per kWh. Thus, the benefit-cost ratio of the Kam Pong project is 1.98:1. That is the Kam Pong project is considered economically feasible.

H. CONSTRUCTION AND OPERATION

The implementation of the Kam Pong project was carried out with co-operation between technical staff from NEA and the villagers of Kam Pong, and with financial support from USAID. In this section, a brief discussion on construction and project organization is made.

Work Organization

Fig. 4.3 illustrates the work organization for the Kam Pong micro-hydropower development. The project is under the responsible of the Micro-hydropower Development Section of NEA.

Villagers' Participation

Most of the residents of Kam Pong village have participated in the construction words of the Kam Pong micro-hydropower project. Altogether, 105 households (89 percent) have been involved in the construction. Besides working as laborers, they also supplied local construction materials such as gravel and sand, wood poles, planks and wood for framework, etc.

Construction Schedule

Fig. 4.4 illustrates the planned schedule and the actual work period for the construction of the Kam Pong micro-hydropower project. The actual work period lagged behind the planned schedule due to some unexpected problems, including climatic and topographic conditions. The construction works were completed in September 1983.

Co-operatives of Electricity Users

In operating the Kam Pong micro-hydropower plant, the Kam Pong villagers have planned to manage as a co-operative. At present, a committee

TABLE 4.14 ANNUAL EQUIVALENT COST OF KAM PONG MICRO-HYDROPOWER PLANT

in Baht

Item \ Annual Equivalent Cost	Civil Works [1]	Power Generating Equipment [2]	Transmission Line System [3]	Total Annual Cost
1. Depreciation	157,780	51,380	144,180	353,340
2. Operation and Maintenance	12,710	4,030	49,100	65,840
Total	170,440	55,410	193,280	419,180

Note : [1] The investment cost for civil works is 1,271,000 Baht (US$ 55,260)

[2] The investment cost for power generating equipment is 403,000 Baht (US$ 17,522)

[3] The investment cost for a transmission line system is 982,000 Baht (US$ 42,696)

TABLE 4.15 ANNUAL EQUIVALENT COST OF THE DIESEL POWER PLANT

in Baht

Item \ Annual Equipment Cost	Power Plant [1]	Transmission Line System [2]	Total Annual Cost
1. Depreciation	88,092	144,180	232,272
2. Operation & Maintenance	30,000	49,100	79,100
3. Fuel Cost	517,374	-	517,374
Total	635,466	193,280	828,746

Note : [1] The investment cost for the power plant is 600,000 Baht (US$ 26,087)

[2] The investment cost for a transmission line system and transformer is 982,000 Baht (US$ 42,686)

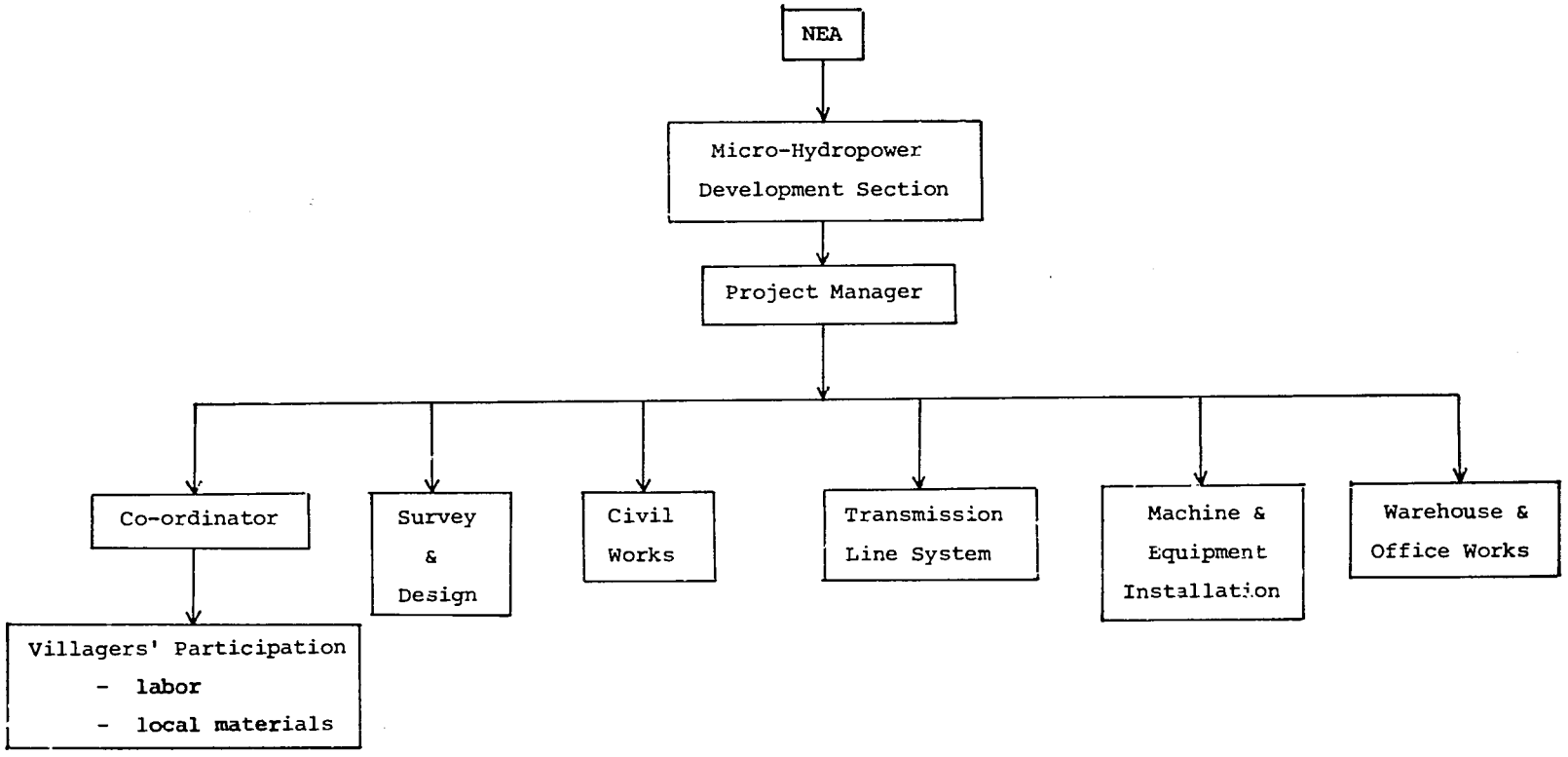
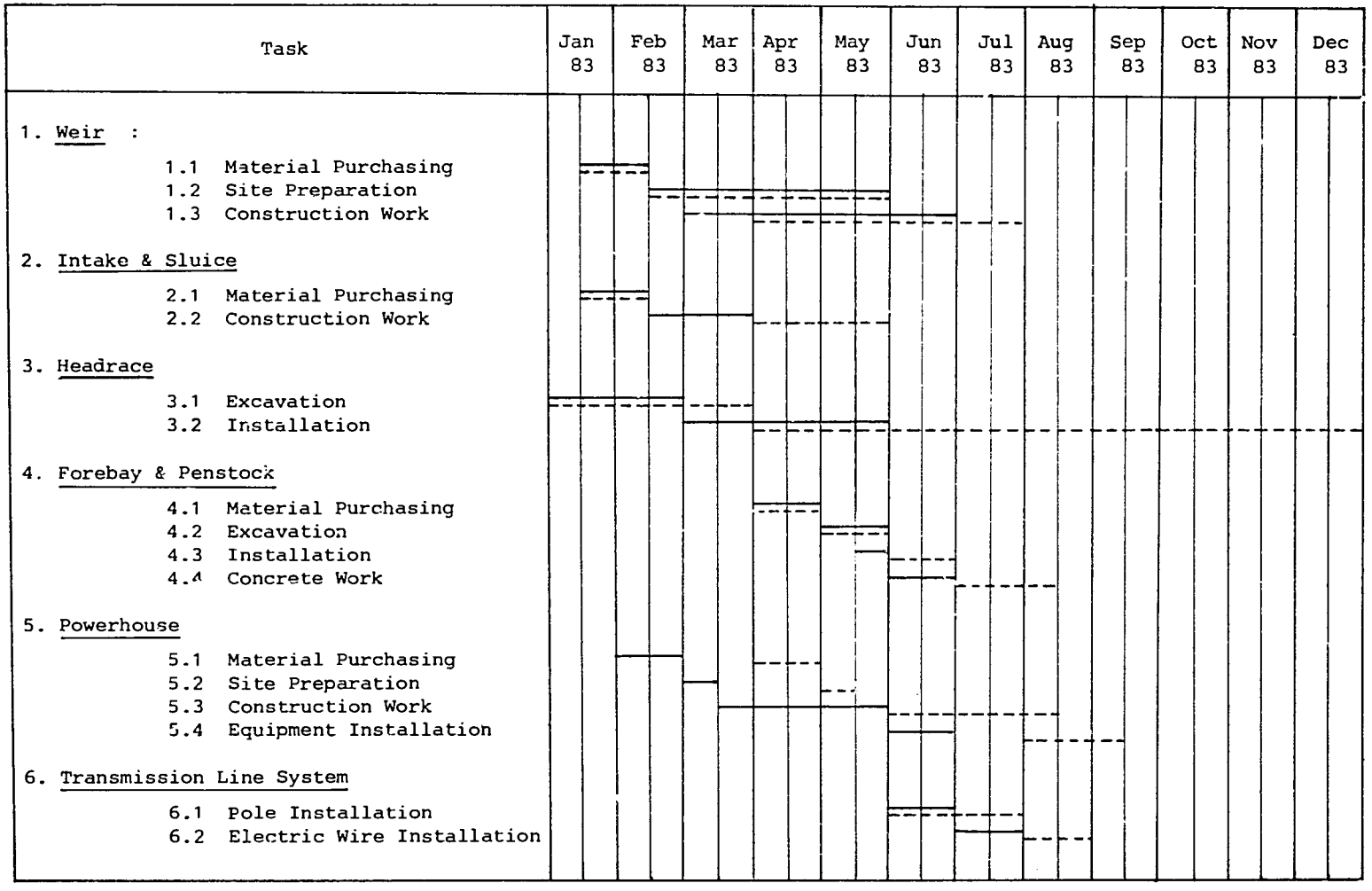


FIGURE 4.3 WORK ORGANIZATION CHART FOR MICRO-HYDROPOWER DEVELOPMENT

FIGURE 4.4 CONSTRUCTION SCHEDULE FOR THE KAMPONG MICRO-HYDROPOWER PROJECT



has been established with representatives from each group (Pang) of the Kam Pong Village. The main activities of this committee include control and setting up regulation for electricity users, collecting a charge for electricity use, coordinating with the NEA personnel when there occur some problems in operation and maintenance, etc.

Problems Encountered in the Implementation

In the implementation of the Kam Pong micro-hydropower development project, there existed a number of difficulties resulted from several factors which can be concluded as follows:

Topography and transportation

The Kam Pong village is situated in the mountainous area and the access road is rather poor especially in the rainy season; therefore, transportation of construction equipment and materials to the project area was rather difficult.

Social problem

Since the Kam pong village is separated into several groups and communication between these groups is inconvenient, there were some difficulties in the coordination and sometimes conflicts between the villagers from different groups.

Unskilled laborer

Most of the villagers who participated in the construction were lacking experience in such a work this caused some delay and the construction work was not so neat. There was some leakage in the pipeline during testing and re-construction and/or repairing works had to be made.

Chapter 5

Design and Construction

of Mae Ton Luang Micro-Hydropower Project

DESIGN AND CONSTRUCTION OF MAE TON LUANG MICRO-HYDROPOWER PROJECT

The Mae Ton Luang micro-hydropower project one of the projects requiring financial assistance from USAID and was constructed with participation of local villagers. The civil work was started in April 1983 and completed in March 1984. Its installed capacity is 35 kW. The Mae Ton Luang micro-hydropower project has been planned to serve about 230 household in 3 villages in Tambon Pa Miang, Amphoe Doi Saket. In this chapter, the details of the design and construction of the Mae Ton Luang project are described.

The electricity generated from Mae Ton Luang powerhouse is planned to be transmitted to 3 villages in Tambon Pa Miang. namely :

- Ban Mae Wan Pang Klang (Moo 6)
- Ban Pa Pan (Moo 7)
- Ban Mae Ton Luang (Moo 8)

A. LOCATION AND TOPOGRAPHY

The Mae Ton Luang micro-hydropower project is located in Tambon Pa Miang, Amphoe Doi Saket, Chiang Mai Province. It is situated in a high mountainous area about 50 km northeast of the city of Chiang Mai. Most parts of the terrain have steep slopes and are covered with forests. An overflow weir was constructed on Mae Ton stream nearby the village. The catchment area at the weir site is approximately 19 km^2. Fig. 5.1 shows the location and topography of Mae Ton Luang project area.

B. SOCIOLOGY AND COMMUNITY STRUCTURE

In this section, the characteristics of those villages in Tambon Pa Miang which receive electricity from Mae Ton Luang powerhouse are described. The data presented here are summarized from the survey report of the Energy Economics Division, NEA. The survey was conducted in December 1983. About 43 percent of the total households in Ban Mae Wan Pang Klang, Ban Pa Pan and Ban Mae Ton Luang were randomly selected for the socio-economic study.

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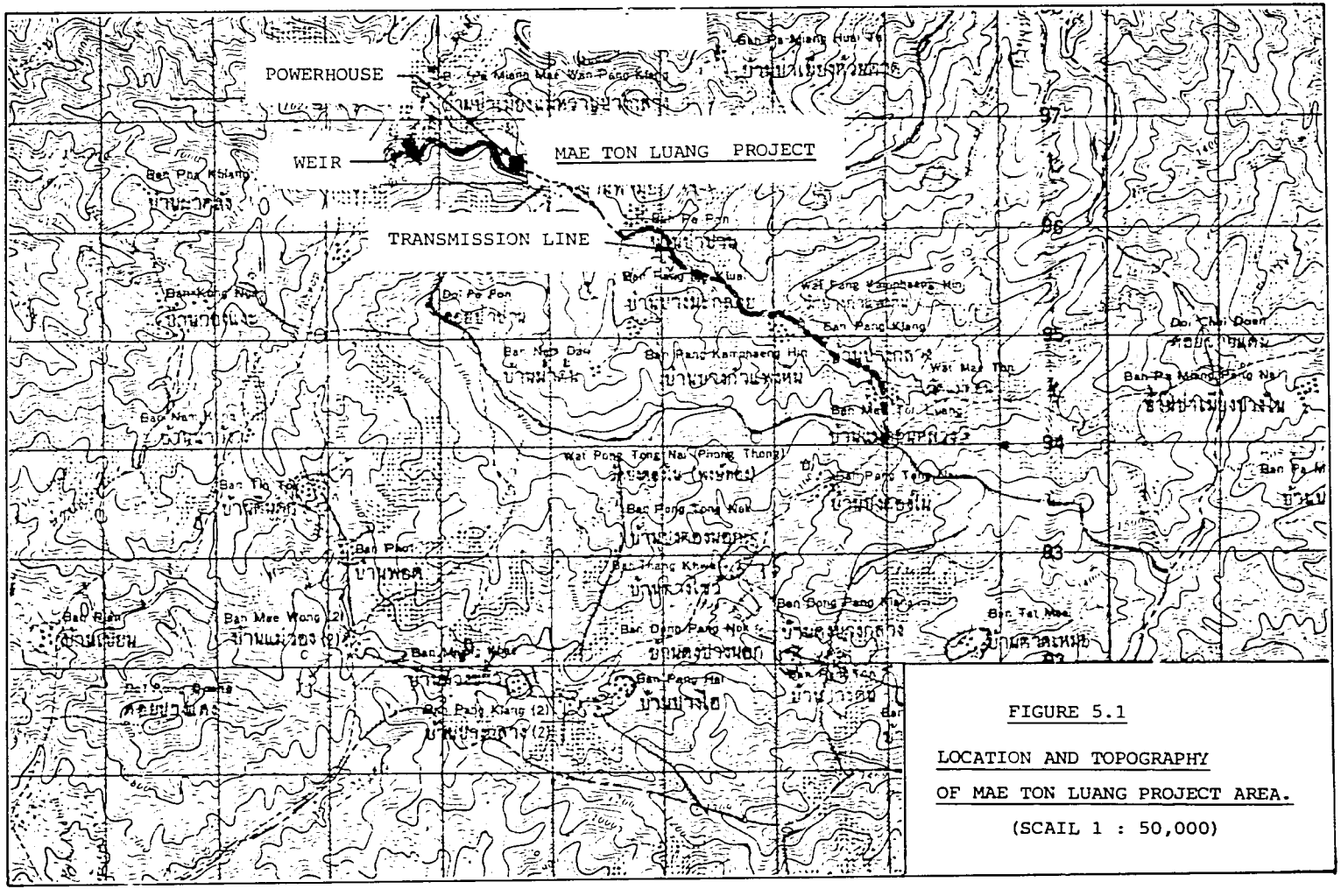


FIGURE 5.1

LOCATION AND TOPOGRAPHY

OF MAE TON LUANG PROJECT AREA.

(SCAIL 1 : 50,000)

Households and Population

The number of households and population in the three villages where electricity from Mae Ton Luang project will be distributed is shown in Table 5.1. Altogether, there are 230 households with 1,011 inhabitants. Among these villages, the number of households and population in Ban Mae Ton Luang is the greatest.

TABLE 5.1 NUMBER OF HOUSEHOLDS AND POPULATION IN MAE TON LUANG PROJECT AREA

Village	Number of Households	Number of Population
Ban Mae Wan Pang Klang	51	295
Ban Pa Pan	54	326
Ban Mae Ton Luang	125	392

Village Characteristics

The villages in Mae Ton Luang project area have existed for more than 200 years. The first group of residents were the "Kamu" who migrated from Chiang Rai Province and cultivated lands for growing chewing tea. Later, the Thai people from Amphoe Doi Saket and Amphoe San Kampaeng moved into this area and the "Kamu" people migrated to other places.

This area is officially called Tambon Pa Miang and consists of 12 villages, one of which is Mae Ton Luang village. However, since Mae Ton Luang village is the largest village and is the center of Tambon Pa Miang, the whole area is sometimes referred to as "Ban Mae Ton Luang".

Most parts of Tambon Pa Miang are covered with dense forests and chewing tea growing areas. The terrain is very rugged. There are some small streams passing through each village which are the main sources of water supply.

The villagers in this area are situated in groups, most of which are small since the terrain is hilly and there is no large plain for a populous settlement. Houses are simply constructed, using local materials : most of them are one-storied with elevated floor.

There are four Buddhist monasteries in Tambon Pa Miang. However, there are no monks who are permanently living in these monasteries, so from time to time the villagers have to invite monks from temples in Amphoe Doi Saket or Amphoe San Kamphaeng for religious activities.

Photos 5.1-5.5 illustrate general characteristics of Mae Ton Luang project area.

PHOTO 5.1 ACCESS ROAD TO MAE TON LUANG PROJECT AREA

PHOTO 5.2 ACCESS ROAD TO MAE TON LUANG WEIR SITE

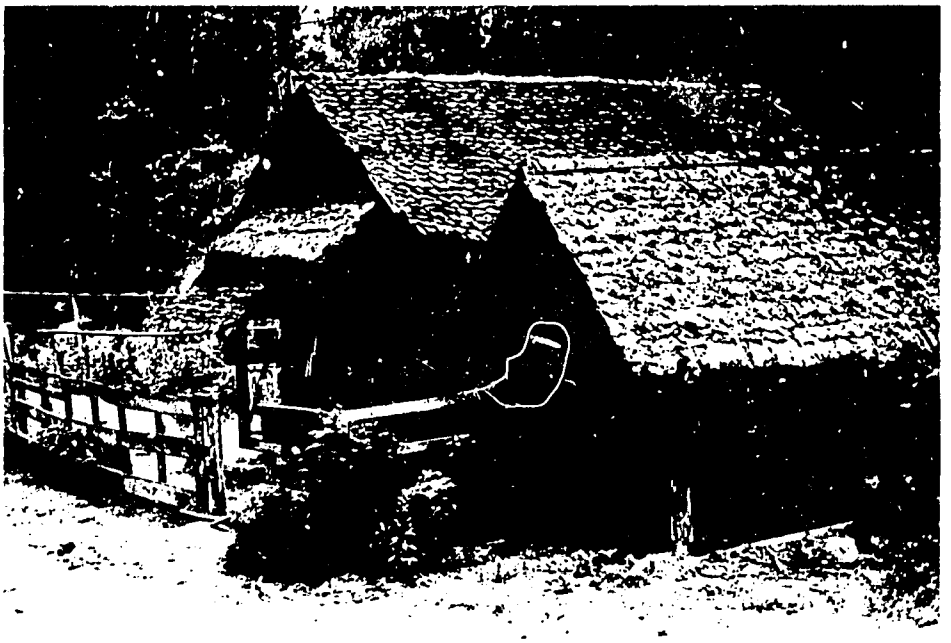


PHOTO 5.3 A POOR CONDITION HOUSE IN MAE TON LUANG VILLAGE

PHOTO 5.4 MAE TON LUANG VILLAGE NEAR THE POWERHOUSE

PHOTO 5.5 HOUSES IN BAN MAE WAN PANG KLANG

There are two health centers located at Ban Pong Din and Ban Huai Mo of Tambon Pa Miang. However, the villagers prefer to go to the hospitals in Amphoe Doi Saket or in the city of Chiang Mai.

The villagers normally use their own native language which is similar to the Northern Thai dialect and always refuse to speak the Central Thai dialect with visitors. All of the local people are Buddhists.

The project area is accessible via two routes, the Pang Fan entrance and the Pong Din entrance. The Pang Fan route is a branch road from the Doi Saket-Chiang Rai highway at 28 km from Doi Saket. This branch road is a lateritic road. The total distance from the highway to Mae Ton Luang project area is approximately 20 km. The Pong Din route is a branch road, also lateritic from the Doi Saket-Chiang Rai highway at 12 km from Doi Saket. The total distance from the highway to the project area is 23 km.

There is no regular bus travelling between the villages and the town. The villagers must use pick-up trucks which transport the chewing tea produce from the villages to the markets in the town. The access roads to the villages are in good condition during the dry season only. During the rainy season accessibility is difficult since the roads are muddy and very slippery.

Education

About 60.69 percent of the villagers in the project area (Moo 6, 7 and 8) finished primary or secondary school, 14.04 percent are currently in school and the remainder (25.27 percent) have never attended school. Table 5.2 shows the level of education of the villagers in this area.

TABLE 5.2 EDUCATION LEVEL OF THE VILLAGERS IN MAE TON LUANG PROJECT AREA

Village	Studying				Finished				No Education
	Primary School		Secondary School		Primary School		Secondary School		
	P.1-4	P.5-7	MS.1-3	MS.4-5	P.4	P.7	MS.3	MS.5	
Ban Mae Wan Pang Klang	8.75	-	-	-	66.25	3.75	-	-	21.25
Ban Pa Pan	11.57	4.95	0.83	0.83	47.93	4.13	0.83	-	28.93
Ban Mae Ton Luang	5.73	6.87	0.76	0.38	50.76	6.11	3.05	1.53	24.81
Overall Average	7.78	5.18	0.65	0.43	52.70	5.18	1.94	0.87	25.27

Occupation

Most of the villagers in the project area are farmers, producing such dominant crops as chewing tea and rice. Besides agriculture, which is considered as the main occupation, about 43 percent of the sampled households have subsidiary occupations, as mushroom growers, laborers, traders, etc. Tables 5.3 and 5.4 show the records of the main and subsidiary occupations of the household heads in this area.

TABLE 5.3 MAIN OCCUPATIONS OF HOUSEHOLD HEADS IN MAE TON LUANG PROJECT AREA

Percent of Total

Village	Agriculture	Laborer	Trading	Others
Ban Mae Wan Pang Klang	100.00	-	-	-
Ban Pa Pan	91.67	8.33	-	-
Ban Mae Ton Luang	94.44	3.71	1.85	-
Overall Average	94.90	4.08	1.02	-

TABLE 5.4 SUBSIDIARY OCCUPATIONS OF HOUSEHOLD HEADS IN MAE TON LUANG PROJECT AREA

Percent of Total

Village	Households with Subsidiary Occupations				Households without Subsidiary Occupation
	Agriculture	Laborers	Trading	Others	
Ban Mae Wan Pang Klang	10.00	25.00	5.00	5.00	55.00
Ban Pa Pan	8.33	20.84	8.33	4.17	58.33
Ban Mae Ton Luang	12.96	16.67	11.11	1.85	57.41
Overall Average	11.23	19.39	9.18	3.06	57.14

Land Use and Land Holding

As previously mentioned, the villagers in this area earn their living by farming. Besides growing chewing tea, some of them grow rice, coffee, and/or mushrooms. Table 5.5 shows the land use patterns in the three villages in the project area. The residential areas are usually located in a patch of flat plain in the valleys surrounded by agricultural lands.

TABLE 5.5 LAND USE PATTERNS IN MAE TON LUANG PROJECT AREA

Village	Chewing Tea Growing Areas		Coffee Growing Areas		Rice Growing Areas	
	Total (rai)	Av./HH (rai)	Total (rai)	Av./HH (rai)	Total (rai)	Av./HH (rai)
Ban Mae Wan Pang Klang	277	5.43	140	2.75	408	8.00
Ban Pa Pan	416	7.71	117	2.17	135	2.50
Ban Mae Ton Luang	900	7.21	250	2.00	1,375	11.00
Total	1,593	6.93	507	2.20	1,918	8.34

Agriculture

The main crops cultivated in this area are chewing tea, rice, coffee and mushrooms. Details about the production and required monetary input of these crops are as follows :

Chewing tea

Similar to the village of Kam Pong, chewing tea in Tambon Pa Miang is grown on a hilly area surrounding the villages. Harvesting of chewing tea leaves is done in the daytime and heated with steam during the night. The production and income from chewing tea in this area is shown in Table 5.6, whereas the required monetary input is summarized in Table 5.7. About 41,980 Baht (US$ 1,825.22) per household is earned annually from chewing tea production while approximately 9,259 Baht (US$ 402.57) is required for expenditures.

TABLE 5.6 PRODUCTION AND INCOME FROM CHEWING TEA GROWING

Village	Planting Area (rai/house-hold)	Production		Household Consumption (kg/HH)	Annual Income (Baht/house-hold)
		kg/rai	kg/HH		
Ban Mae Wan Pang Klang	5.43	821.54	4,460	47	28,685
Ban Pa Pan	7.71	1,014.02	7,818	40	50,557
Ban Mae Ton Luang	7.21	939.66	6,775	51	43,706
Average	6.93	939	6,506	47.5	41,980

Note : Consider the selling price of 6.50 baht/kg

TABLE 5.7 EXPENSES FOR CHEWING-TEA PRODUCTION

Village	Planting Area (rai/HH)	Labor Cost (Baht/rai)	Fuel Cost (Baht/rai)	Mainte-nance Cost (Baht/rai)	Total Cost	
					(Baht/rai)	(Baht/rai)
Ban Mae Wan Pang Klang	5.43	1,288.15	68.30	201.80	1,558.25	8,461.30
Ban Pa Pan	7.71	1,014.75	94.70	189.10	1,298.55	10,011.80
Ban Mae Ton Luang	---------- no data ----------					
Average	6.60	1,124.40	84.20	194.25	1,420.85	9,259

Rice

Rice is also a popular crop in this area. The rice fields cover about 1,918 rai or 48 percent of the total agricultural area. The production is also very high, amounting to 671 kg per rai. The production and income from rice farming in this area is summarized in Table 5.8 and the expenses in planting and harvesting are shown Table 5.9. On the average, about 6,512 Baht (283.13 US$) must be paid in expenses. Most of the rice produced is for household consumption.

TABLE 5.8 PRODUCTION AND INCOME FROM RICE

Village	Planting Area (rai/household)	Production		Household consumption (kg/HH)	Annual income (baht/household)
		kg/rai	kg/HH		
Ban Mae Wan Pang Klang	8.0	875	7,000	5,530	3,675
Ban Pa Pang	2.5	648	1,620	1,620	-
Ban Mae Ton Luang	11.0	736	8,096	3,900	10,490
Average	8.34	759	6,330	3,726	6,512

Note : Consider the selling price of 2.50 baht/kg.

TABLE 5.9 EXPENSES FOR RICE PRODUCTION

Village	Planting area (rai/HH)	Fertilizer (Baht/rai)	Labor cost (Baht/rai)	Machinery (Baht/rai)	Operation & Maintenance (Baht/rai)	Total Expenses	
						Baht/rai	Baht/rai
Ban Mae Wan Pang Klang	8.0	150.00	250.00	-	18.75	418.75	3,350
Ban Pa Pan	2.5	----------	----------	no data	----------	----------	----------
Ban Mae Ton Luang	11.0	13.65	386.35	109.10	22.75	531.82	5,850
Overall Average	8.13	45.00	355.00	84.00	21.80	505.80	5,275

Coffee

The planting of coffee is not so popular in this area. The planting area is only 2.47 rai per household and the average income earned from the coffee harvest is approximately 1,078 Baht (US$ 46.87) per household per annum (Table 5.10). The expenses for the planting and harvesting of coffee are shown in Table 5.11. On the average, about 581 Baht (US$ 25.26) per household is paid in these expenses.

TABLE 5.10 PRODUCTION AND INCOME FROM COFFEE

Village	Planting Area (rai/HH)	Production		Annual Income (Baht/HH)
		kg/rai	kg/HH	
Ban Mae Wan Pang Klang	2.75	8.20	22.55	1,353
Ban Pa Pan	2.17	14.77	32.05	1,923
Ban Mae Ton Luang	2.00	5.00	10.00	600
Overall Average	2.21	8.13	17.96	1,078

Note : Consider the selling price of 60 Baht/kg.

TABLE 5.11 EXPENSES FOR COFFEE PRODUCTION

Village	Planting Area (rai/HH)	Insecticide (Baht/rai)	Fertilizer (Baht/rai)	Operation & Maintenance (Baht/rai)	Total Expenses	
					Baht/rai	Baht/rai
Ban Mae Wan Pang Klang	2.75	----------	no data	----------		
Ban Pa Pan	2.17	-	50.80	22.30	73.10	158.60
Ban Mae Ton Luang	2.00	25.00	350.00	6.50	381.50	763.00
Overall Average	2.78	17.00	254.25	11.55	282.80	580.65

Mushrooms

Similar to the village of Kam Pong, mushroom growing has recently been promoted in this area. The villagers buy the mushroom spawn at the price of 5 Baht (US$ 0.22) per piece of wood and they sell the harvested mushrooms at the price of 60 Baht (US$ 2.61) per kg. Mushroom growing in the Mae Ton Luang project area is more popular than that in the village of Kam Pong. The production is about 21.16 kg per household. That is about 1,270 Baht (US$ 55.22) per household that is earned from mushroom growing annually (Table 5.12). However, about 358 Baht (US$ 15.57) per household must be paid for the spawn and other expenses (Table 5.13).

TABLE 5.12 PRODUCTION AND INCOME FROM MUSHROOMS

Village	Production (kg/HH)	Household Consumption (kg/HH)	Annual Income/HH	
			kg	Baht
Ban Mae Wan Pang Klang	21.67	-	21.67	1,300
Ban Pa Pan	20.50	5.67	14.83	890
Ban Mae Ton Luang	21.27	3.58	17.69	1,060
Overall Average	21.16	4.28	17.90	1,074

Household Economy

Household income

Most of the income of the villagers is earned from farming. As previously analyzed, the income gained per household annually from chewing tea is approximately 41,980 Baht (US$ 1,825.22), from rice 6,512 Baht (US$ 283.13), from coffee 1,078 Baht (US$ 46.37), and from mushrooms 1,270 Baht (US$ 55.22). Altogether, the total income derived from agricultural activities in this area amounts to 50,840 Baht (US$ 2,210.43) per household annually.

TABLE 5.13 EXPENSE FOR MUSHROOM PRODUCTION

Village	Expenses (Baht/HH)
Ban Mae Wan Pang Klang	no data
Ban Pa Pang	500
Ban Mae Ton Luang	297
Overall Average	358

Besides the income derived from agricultural, these villagers still earn some money from other subsidiary occupations, such as laborer, household industry, trading, animal husbandry, etc. The total average income from these subsidiary occupations is approximately 9,824 Baht (US$ 427.13) per household (Table 5.14). Thus, the total annual income of the villagers in Mae Ton Luang project area is estimated about 60,664 Baht (US$ 2,637.57) per household.

TABLE 5.14 ANNUAL INCOME FROM SUBSIDIARY OCCUPATIONS

Baht/household

Village	Laborer	Household Industry	Trading	Animal Husbandary	Others	Total
Ban Mae Wan Pang Klang	456	-	1,020	450	459	2,385
Ban Pa Pan	1,873	217	3,025	269	2,023	7,407
Ban Mae Ton Luang	2,037	51	8,737	1,002	972	12,799
Average	1,674	81	5,764	710	1,895	9,824

Household expenditure

Besides expenses for agricultural input (Table 5.7, 5.9, 5.11 and 5.13), remaining household expenditures of the villagers in Mae Ton Luang project area can be categorized as follows :

(i) Regular expenses which include all expenses for household consumption,

(ii) irregular expenses, which are those expenses for house repairing, etc. and

(iii) investment expenses which are mainly the input for merchandise.

These three categories account for 21,503, 2,500 and 13,094 Baht per household annually (Table 5.15). Taken into account the agricultural input the total household expenses in this area are as high as 52,570 Baht (US$ 2,285.65) per household annually.

TABLE 5.15 HOUSEHOLD EXPENDITURE IN MAE TON LUANG PROJECT AREA

baht/household

Village	Agricultural Inputs	Regular Expenses	Irregular Expenses	Investment Expenses	Total
Ban Mae Wan Pang Klang	↓	14,372	1,995	4,582	↓
Ban Pa Pan		26,447	2,680	7,380	
Ban Mae Ton Luang		22,276	2,630	19,035	
Overall Average	15,473	21,503	2,500	13,094	52,570

Use of Fuel

The use of fuel in Mae Ton Luang project area is mainly for cooking, processing chewing tea, lighting, and heating. For cooking, heating and processing chewing tea, firewood is used. For lighting, kerosene lamps are used. Details about the amount of fuel used for each purpose are summarized in the following paragraphs.

For cooking

All households in the Mae Ton Luang project area use firewood for cooking sticky rice which is their staple food. The amount of firewood used is approximately 1,594 kg (4.0 m^3) per household per year (Table5.16)

TABLE 5.16 AMOUNT OF FIREWOOD USED FOR COOKING

Village	Number of Households	Amount of Firewood Used		
		kg/HH/year	kg/year	m^3/year
Ban Mae Wan Pang Klang	51	1,150	58,650	146.6
Ban Pa Pan	54	2,422	130,788	326.9
Ban Mae Ton Luang	125	1,418	177,250	443.1
Total	230	1,594	366,688	916.6

For heating

Similar to the village of Kam Pong, firewood is used for heating in the winter. On the average, about 1,880 kg (4.7 m^3) of firewood is used for each household annually. Totally, the amount of firewood used for heating in this area amounts to 432,400 kg (1,081 m^3) each year.

For chewing tea processing

The amount of firewood required for processing 1 kg of chewing tea is approximately 0.65 kg. The production of chewing tea in the Mae Ton Luang project area is approximately 6,506 kg per household. Therefore, the amount of firewood used in processing chewing tea is about 4,228.9 kg (10.6 m^3) per household. Totally, taken into account 230 households in this area, the overall amount of firewood required for chewing tea processing is 972,647 kg (2,431.6 m^3) per annum.

For lighting

For lighting, most of the villagers (80 percent) in the Mae Ton Luang project area use kerosene lamps. The rest use batteries. The amount of kerosene used for lighting in each village in this area is shown in Table 5.17. Totally, about 17,696 liters of kerosene are used annually.

TABLE 5.17 AMOUNT OF KEROSENE USED FOR LIGHTING

Village	Number of Lamps/HH	period of Lighting (hr)	Amount of Kerosene Used	
			liter/HH/year	liter/year
Ban Mae Wan Pang Klang	3.15	4.43	81.49	4,156
Ban Pa Pan	3.42	5.35	107.23	5,790
Ban Mae Ton Luang	3.00	3.54	62.00	7,750
Average/Total	3.13	4.16	76.94	17,696

Total amount of fuel used

Table 5.18 summarized the total amount of firewood and kerosene used for each purpose in the Mae Ton Luang project area. Totally, about 4,430 m^3 of firewood and 17,696 liters of kerosene are used annually.

TABLE 5.18 TOTAL AMOUNT OF FUEL USED

Purpose \ Fuel	Firewood (m^3)	Kerosene (liter)
Cooking	917	-
Heating	1,081	-
Chewing tea processing	2,432	-
Lighting	-	17,696
Total	4,430	17,696

C. HYDROLOGICAL STUDY

Since there is no gaging station on Huai Mae Ton stream, some estimation methods were adopted to determine the values of design discharge, and design flood of the project. In addition, the value of effective head was calculated by subtracting the estimated head loss in the pipe lines from the total static head of water. The values of design discharge and effective head lead to the computation of installation capacity of the plant.

The minimum flow in the dry period was used as the design discharge of Mae Ton Luang project. This minimum flow was obtained by field measurement in April 1982, the value of 0.1 m^3/sec was used as the design discharge.

With respect to the design flood, the empirical formula developed by Bunchob (1980) was used. This empirical formula was developed for the northern region of Thailand. For a 50-year recurrence interval, this equation is as follows :

$$Q_p = 6.58\ A^{0.178}$$

Where Q_p is the value of the design flood (m^3/s)

A is the catchment area (km^2)

The catchment area of Mae Ton Luang project at the weir site is 19 km^2, thus the value of 11.1 m^3/s is obtained for the design flood.

The effective head is computed by subtracting the estimated value of head loss in the pipe line from the total static head. The total static head was obtained from a topographic map. For Mae Ton Luang project, the effective head of 50 m was estimated.

The installation capacity of the plant is estimated from the design discharge, effective head, and overall plant efficiency. With the design discharge of 0.1 m^3/s, the effective head of 60 m and the overall plant efficiency of 60 percent, the estimated installation capacity is 35 kW.

D. CIVIL WORKS

The civil works of Mae Ton Luang micro-hydropower development project include the construction of a diversion weir, installation of a headrace and a penstock, and construction and installation of a surge tank and a powerhouse. The details of these structures are discussed in this section.

Weir

The weir of the Mae Ton Luang micro-hydropower project is of concrete gravity type, 2.20 m high and 19 m long. The crest elevation is at 94 m MSL. The upstream face is vertical, whereas the downstream face is inclined with a slope of 1:1. The intake structure and the sluice gate for sediment release are located at the right abutment of the weir. Fig. 5.2 and 5.3 show the details of the Mae Ton Luang weir. Photos 5.6 and 5.7 illustrate the constructed weir and its associated structures.

Headrace

The headrace of the Mae Ton Luang project is an asbestos cement pipe, 0.35 m in diameter and 1,253 m in length. It extends from the intake at the right abutment of the weir along the hill side to the surge tank located approximately 1.2 km downstream of the weir site.

Surge Tank

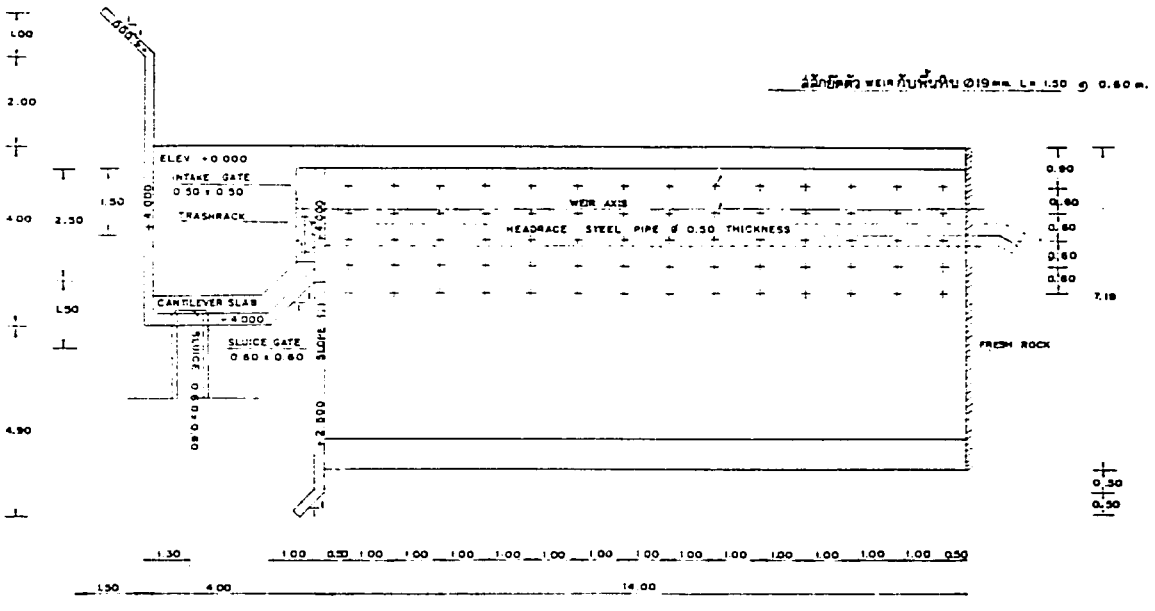
A steel surge tank was constructed at the end of the headrace. The diameter of the surge tank is 1.20 m and the height is 15.00 m. It was installed vertically. Fig. 5.4 shows the details of Mae Ton Luang surge-tank.

Penstock

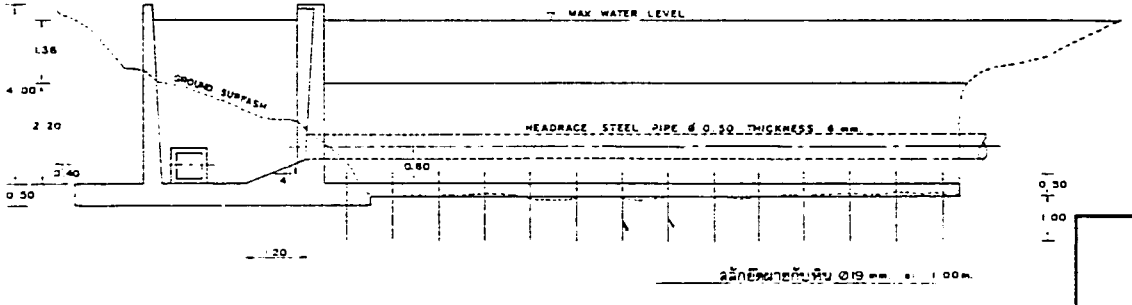
The penstock of the Mae Ton Luang micro-hydropower project is a steel pipe, 0.30 m in diameter and 140 m long. It extends from the surge tank to the powerhouse (Photo 5.8).

Powerhouse

The powerhouse of the Mae Ton Luang project is located at the elevation of 30 m MSL, approximately 1.2 km downstream from the weir site. The floor is made of concrete, whereas the walls are made of wooden plank. The roof is also made of wood. The useful floor area is approximately 15 m^2 (Photo 5.9). The Mae Ton Luang powerhouse is equipped with a set of turbine, generator, switchboard and speed controller. The installed capacity is 35 kW.



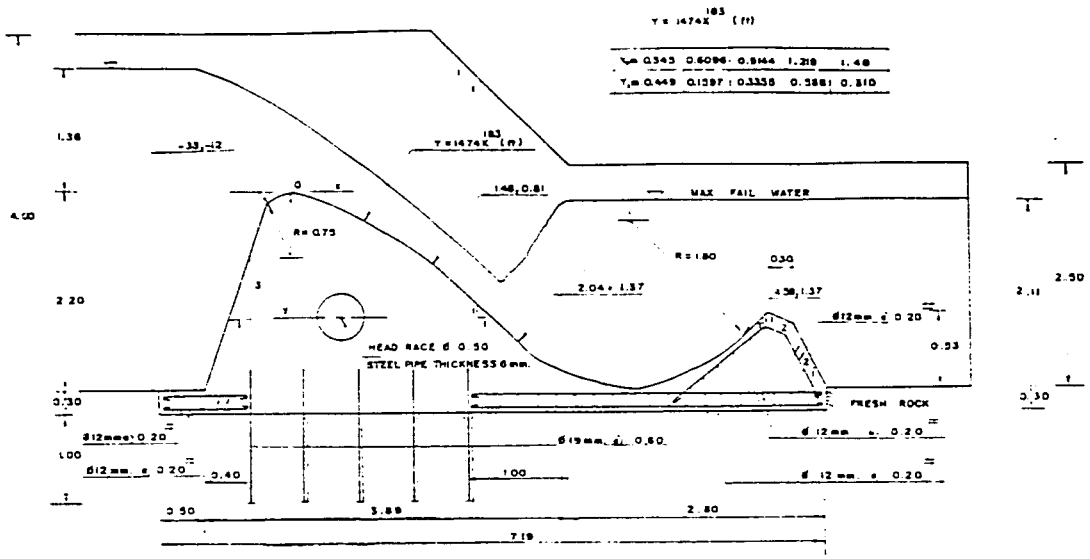
Plan



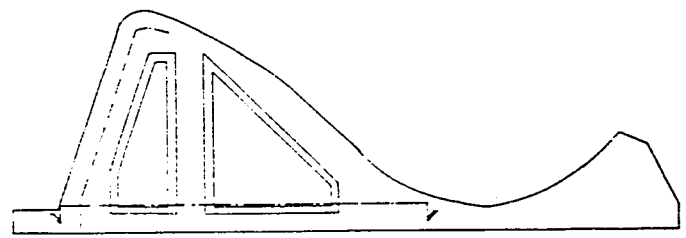
Section

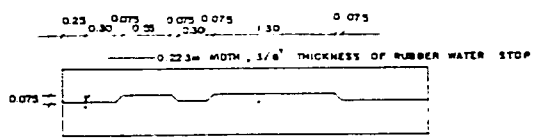
FIGURE 5.2

MAE TON LUANG WEIR (1)



WEIR SECTION





CONNECTION JOINT @ 3.00 M.

FIGURE 5.3

MAE TON LUANG WEIR (2)

PHOTO 5.6 WEIR OF MAE TON LUANG PROJECT

PHOTO 5.7 INTAKE AND SLUICE GATE

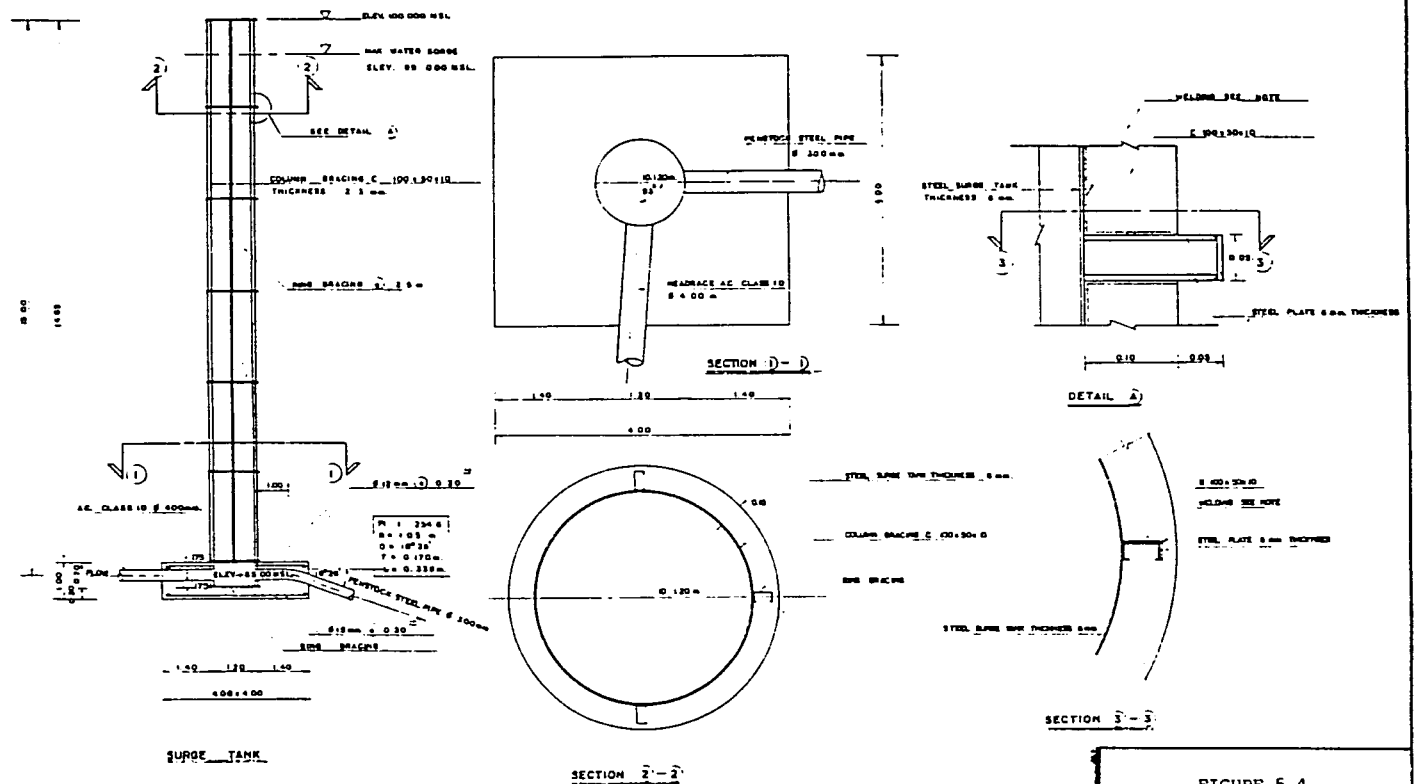


FIGURE 5.4

MAE TON LUANG SURGE TANK

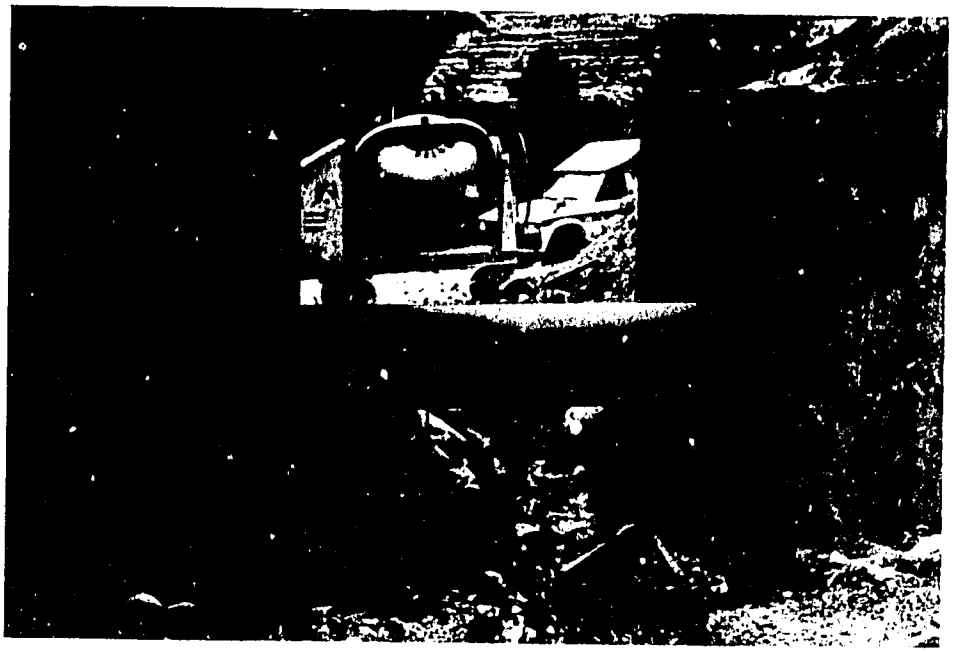


PHOTO 5.8 PENSTOCK OF MAE TON LUANG PROJECT

PHOTO 5.9 MAE TON LUANG POWERHOUSE

E. MECHANICAL WORKS

The turbine of the Mae Ton Luang micro-hydropower plant is of the cross-flow type, 35 kW in capacity. The designed head is 60 m and the designed discharge is 100 liters per second. The synchronous speed is 1,500 rpm. The details of each component are as follows :

Casing and Base

The casing and the base are made of SS 41 steel welded to the designed shapes and fixed together with bolts and nuts.

Runner

The runner of the turbine is constructed of SS 41 steel welded with a carbon steel shaft.

Inlet Valve

The inlet valve is stainless steel, installed with bronze bushing and sealed to prevent water leakage.

Flywheel

The flywheel is of the heavy rim type, made of cast steel. The flywheel was tested for dynamic balance.

Photos 5.10 and 5.11 illustrate the cross-flow turbine and the governor installed at Mae Ton Luang powerhouse.

F. ELECTRICAL WORKS

The electrical works of Mae Ton Luang micro-hydropower plant include a generator, a switchboard, a transformer, and a transmission line system. The details of these equipments are as follows :

Generator

The generator of Mae Ton Luang project is a 3-phase, alternating current, synchronous generator with horizontal shaft. It is a self-ventilated type with brushless excitation. The rating output is 35 kW. The generated electric power has of frequency of 50 Hz at the synchronous speed of 1,500 rpm. The number of poles is 4 and the power factor is 0.80 lagging. The stator winding connection is a star type.

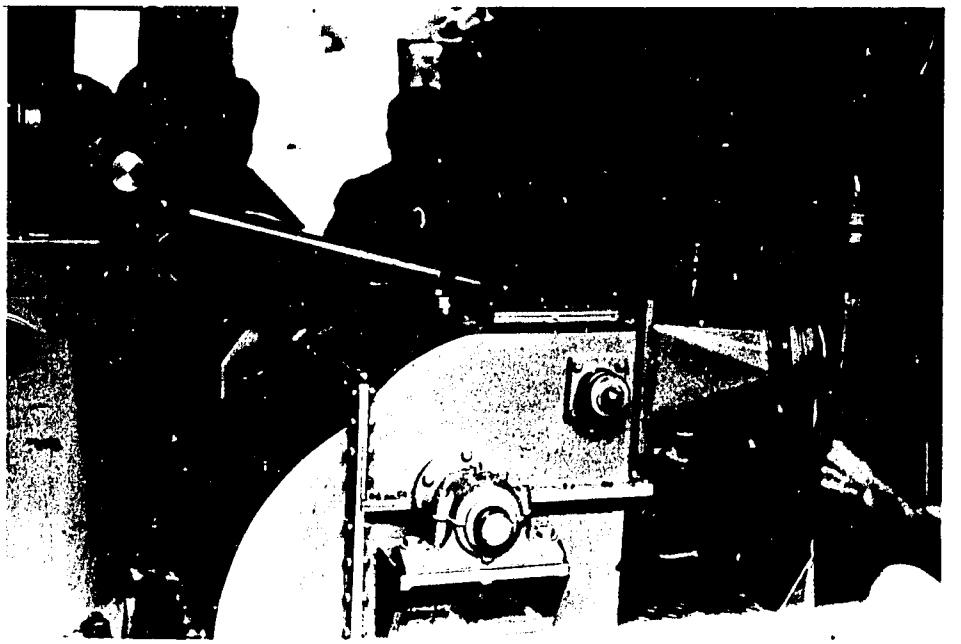


PHOTO 5.10 THE CROSS-FLOW TURBINE OF MAE TON LUANG PROJECT

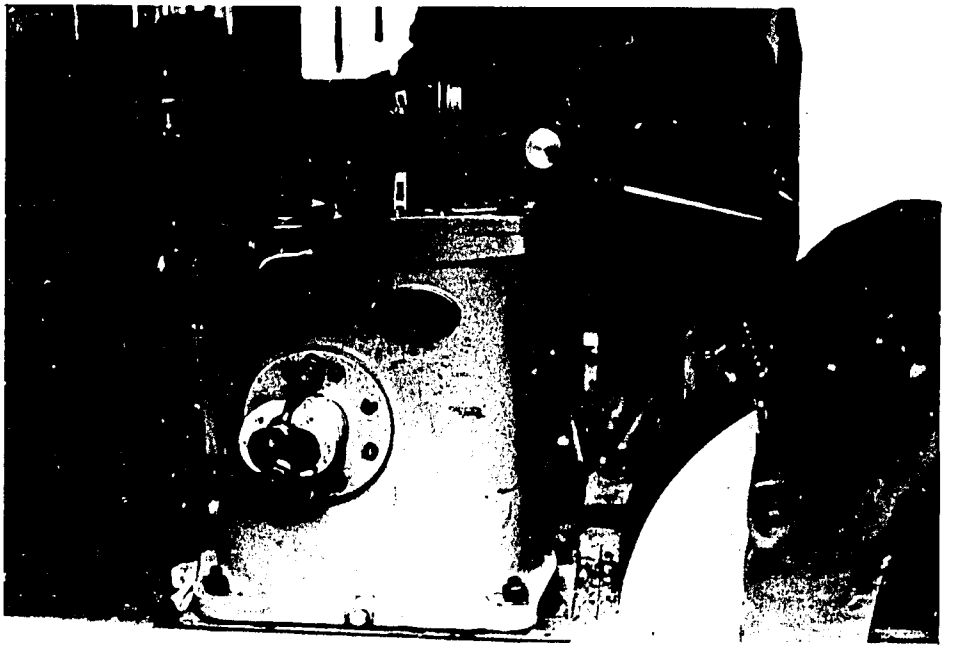


PHOTO 5.11 THE GOVERNOR OF MAE TON LUANG PROJECT

Switchboard

The switchboard of the Mae Ton Luang project is equipped with the following electrical equipments :

- 1 set of AC ammeters for 380-V circuit (0-100 A).
- 1 set of ampere selector switches.
- 1 set of AC voltmeters for 380-V circuit (0-500) V).
- 1 set of volt selector switches.
- 1 set of frequency meters (45-55 Hz).
- 1 set of 3-phase wattmeters for 380-V circuit unbalanced load (0-50 kW).
- 1 set of 3-phase kilowatt-hour meters for 380-V circuit unbalanced load.
- 3 sets of 1-phase, dry type current transformers for 380-V circuit.
- 2 sets of moulded case circuit breakers, 3-phase, 3-pole, 100 AF, 600 V, setting range 60-100 A, with voltage trip coil and indicator operation.
- 2 sets of signal lamps, red and green.
- 1 set of no-fuse circuit breakers, 30 AF, 10 AT.
- 1 set of no-fuse circuit breakers, 30 AF, 20 AT.
- 1 set of no-fuse circuit breakers, 30 AF, 15 AT.
- 1 set of test terminal and test switches.

Transformers

The transformers of the Mae Ton Luang project include one 50-KVA step-up transformer, three 10-KVA, and one 20 KVA step-down transformers. All of these transformers are an outdoor type, 3-phase, oil immersed and self-cooled. For the step-up transformer, the nominal voltage is 400/230 V at the primary and 3,500 V at the secondary. For the step-down transformers, the nominal voltage at the primary is 3,500 V and the voltage at the secondary is 400/230 V. The primary connection is a delta type and the secondary connection is a star type.

Transmission Line System

The transmission line system of the Mae Ton Luang project includes a 3,500-V transmission line from the powerhouse to the villages with a total length of 5.5 km and a 380-V distribution line connected from the step-down transformers to the electricity consumers. The total length of the low voltage line is approximately 5.0 km.

G. PROJECT COST AND ECONOMIC EVALUATION

In this section, project cost, benefits, and economic evaluation of the Mae Ton Luang project are presented. The benefit of the project is considered equivalent to the cost of the diesel power plant of the same capacity.

Project Cost

Table 5.19 summarizes the cost of each component of the Mae Ton Luang project. The total project cost is 2,577,150 Baht (US$ 112,050), of which 1,275,731 Baht (US$ 55,467) was contributed by USAID.

Besides those items tabulated in Table 5.19, the villagers of Mae Ton Luang also contributed some local construction materials such as wood poles, etc. and were involved in the construction activities.

TABLE 5.19 COST OF MAE TON LUANG PROJECT

Item	Cost	
	Baht	US$
1. Weir, intake & sluice gate	328,900	14,300
2. Headrace	538,200	23,400
3. Penstock and concrete support	170,000	7,391
4. Powerhouse	39,100	1,700
5. Generating equipment	278,300	12,100
6. Transmission line system	818,800	35,600
7. Transformers	188,600	8,200
8. Administration and services of construction equipment	215,250	9,359
Total	2,577,150	112,050

Project Benefits

Similar to the Kam Pong project, the benefits of the Mae Ton Luang project can be classified into two categories, i.e. direct benefit and the indirect benefit.

Direct benefit

The direct benefit of the Mae Ton Luang project is considered to be equivalent to the cost of the diesel power plant of the same capacity. Using the same assumptions as those mentioned in Chapter 4,Section G, the development of the Mae Ton Luang micro-hydropower plant will result in the saving of 65,770 liters of diesel oil annually over the installation of a diesel power plant of the same capacity.

Indirect benefit

The indirect benefits of the development of a micro-hydropower plant at the Mae Ton Luang project area are similar to those of the Kam Pong project as mentioned in Chapter 4, Section G.

Economic Evaluation

The evaluation of economic feasibility of the Mae Ton Luang project is undertaken with the same approach and assumptions as those used for the Kam Pong project. That is, the cost of the diesel power plant of the same capacity is considered as equally beneficial to Mae Ton Luang micro-hydropower project.

The main features and costs of the diesel power plant to be compared with the Mae Ton Luang project are tabulated in Table 5.20. It is estimated that the installation of the diesel power plant will cost 525,000 Baht (US$ 22,826) and another 1,007,400 Baht (US$ 43,800) for the installation of the transmission line system and transformers. The operation and maintenance cost is estimated about 76,620 Baht (US$3,331) per year. The fuel cost is approximately 442,200 Baht (US$19,226) per year.

With the same assumptions as mentioned in Chapter 3, Section B, the annual equivalent costs of the Mae Ton Luang micro-hydropower plant and the equivalent diesel power plant are determined as tabulated in Tables 5.21 and 5.22, respectively. In conclusion, the annual equivalent cost of the Mae Ton Luang micro-hydropower plant is 409,777 Baht (US$ 17,816) or 2.05 Baht (US$ 0.09) per kWh and the annual equivalent cost of the diesel power plant is 743,806 Baht (US$ 32,339) or 3.72 Baht (US$ 0.16) per kWh. The benefit-cost ratio of the Mae Ton Luang micro-hydropower development is 1.82: 1 . So, the Mae Ton Luang project is economically feasible.

TABLE 5.20 DETAILS OF A DIESEL POWER PLANT EQUIVALENT TO THE MAE TON LUANG MICRO-HYDROPOWER PLANT

	Item	Value	
1	Installation capacity	35	kW
2	Number	1	
3	Annual energy production	0.20	GWh
4	Plant Factor	65	%
5	Service life	15	year
6	Installation cost	525,000	Baht
7	Amount of diesel used per unit	0.33	liter/kWh
8	Annual diesel oil consumption	66,000	liters
9	Unit price of diesel oil	6.70	Baht/liter
10	Fuel cost	442,200	Baht
11	Transmission line cost	1,007,400	Baht
12	Operation & maintenance cost	76,620	Baht/year

TABLE 5.21 ANNUAL EQUIVALENT COST OF MAE TON LUANG MICRO-HYDROPOWER PLANT

Item \ Annual Equivalent Cost	Civil Works [1]	Power Generating Equipments [2]	Trans-mission Line System [3]	Total Annual Cost
1. Depreciation	160,320	35,483	147,906	343,709
2. Operation and Maintenance	12,915	2,783	50,370	66,068
Total	173,235	38,266	198,276	409,777

Note : [1] : The investment cost for civil works is 1,291,450 Baht (US$ 56,150).

[2] : The investment cost for power generating equipment is 278,300 Baht (US$ 12,100)

[3] : The investment cost for transmission line system is 1,007,400 Baht (US$ 43,800)

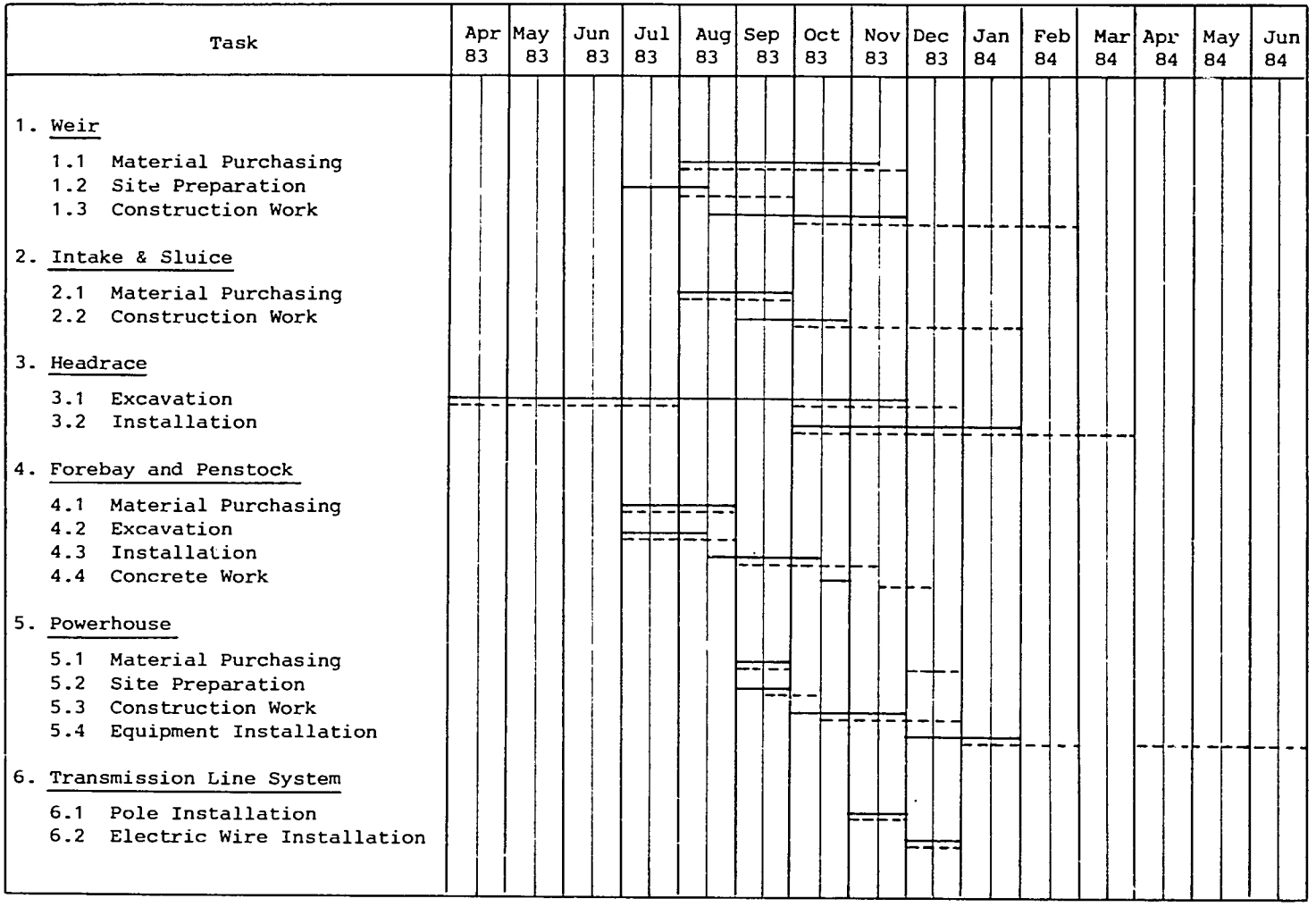
TABLE 5.22 ANNUAL EQUIVALENT COST OF THE DIESEL POWER PLANT

Item \ Annual Equivalent Cost	Power Plant [1]	Trans-mission Line System [2]	Total
1. Depreciation	77,080	147,906	224,986
2. Operation and Maintenance	26,250	50,370	76,620
3. Fuel Cost	442,200	-	442,200
Total	545,530	198,276	743,806

Note : [1] The investment cost for the power plant is approximately 525,000 Baht (US$ 22,826).

[2] The investment cost for the transmission line system and transformers is 1,007,400 Baht (US$ 43,800).

FIGURE 5.5 CONSTRUCTION SCHEDULE OF MAE TON LUANG MICRO-HYDROPOWER PROJECT



H. CONSTRUCTION AND OPERATION

Similar to the Kam Pong project, the implementation of Mae Ton Luang micro-hydropower project was carried out with cooperation between technical staff from NEA and the villagers in Mae Ton Luang project area and with financial support from USAID. In this section, a brief discussion of construction and project organization is presented.

Work Organization

The same group of personnel was responsible for the construction of the Mae Ton Luang micro-hydropower project as for the Kam Pong project. Therefore, the work organization is the same as that mentioned previously in the section on the Kam Pong project.

Villager Participation

The villagers in three villages in Mae Ton Luang project area have participated in the construction activities. They worked mostly as laborers. Besides, some local materials such as wood poles, plank and wood for framework, etc. were contributed by the villagers.

Construction Schedule

The planned schedule and the actual work done in the implementation of Mae Ton Luang micro-hydropower project are shown in Fig. 5.5. The installation of turbines and generators lagged greatly behind the planned schedule. This is due to the delay in supplying the equipments.

Problems Encountered in the Implementation

The problems encountered in the implementation of the Mae Ton Luang project are similar to those of the Kam Pong project. In addition, one main problem which postponed the operation schedule of the project was the delay in delivery of the turbines and the generators. The installation of this equipment was just completed at the end of June 1984.

Chapter 6

DESIGN AND CONSTRUCTION OF HUAI PUI MICRO-HYDROPOWER PROJECT

Design and Construction of Huai Pui Micro-Hydropower Project

The Huai Pui micro-hydropower project is one of the projects constructed with financial assistance from USAID. It is located in Tambon Long Khod, Amphoe Prao, Chiang Mai Province. Its installed capacity is 50 kW and it can generate electric energy to 250 households in the project area. In this chapter, the details of the design and construction of Huai Pui project are described.

A. LOCATION AND TOPOGRAPHY

The Huai Pui project is located in Tambon Long Khod, Amphoe Prao, Chiang Mai Province. It is a run-off-river project constructed on Huai Pui stream located about 31 km from the town of Amphoe Prao. The weir site is at the latitude 19° 6' 56.8" N and the longitude 99° 8' 4.5" E.

The catchment area at the weir site is approximately 11.6 km². The area is mountainous and covered with forests. The annual streamflow at the weir site is approximately 7.67 MCM. A concrete weir is constructed on the Huai Pui stream. The weir is approximately 3.0 m high and 16 m long. The weir crest is at 532 m MSL. From the intake at the right abutment of the weir , an asbestos cement pipe 0.30 m in diameter and 1,450 m in length is laid along the hillside to a forebay. From the forebay a steel penstock 0.30 m in diameter and 165 m in length is connected to the powerhouse. The elevation of the tailrace at the powerhouse is approximately 439 m MSL. A 22-KV transmission line is then connected to the villages in Tambon Long Khod which are situated about 2.5 km from the powerhouse. Fig.6.1 illustrates the location and topography of Huai Pui project area.

B. SOCIOLOGY AND COMMUNITY STRUCTURE

In the section, the characteristics of those villages in Tambon Long Khod which receive electricity from Huai Pui micro-hydropower plant are described. The information presented here is obtained from the field survey undertaken by staff from the Energy Statistics Section of NEA. The survey was conducted in May 1984.

Households and Population

Though the Huai Pui micro-hydropower project was planned to serve 250 households in 7 villages the total number of households is as high as

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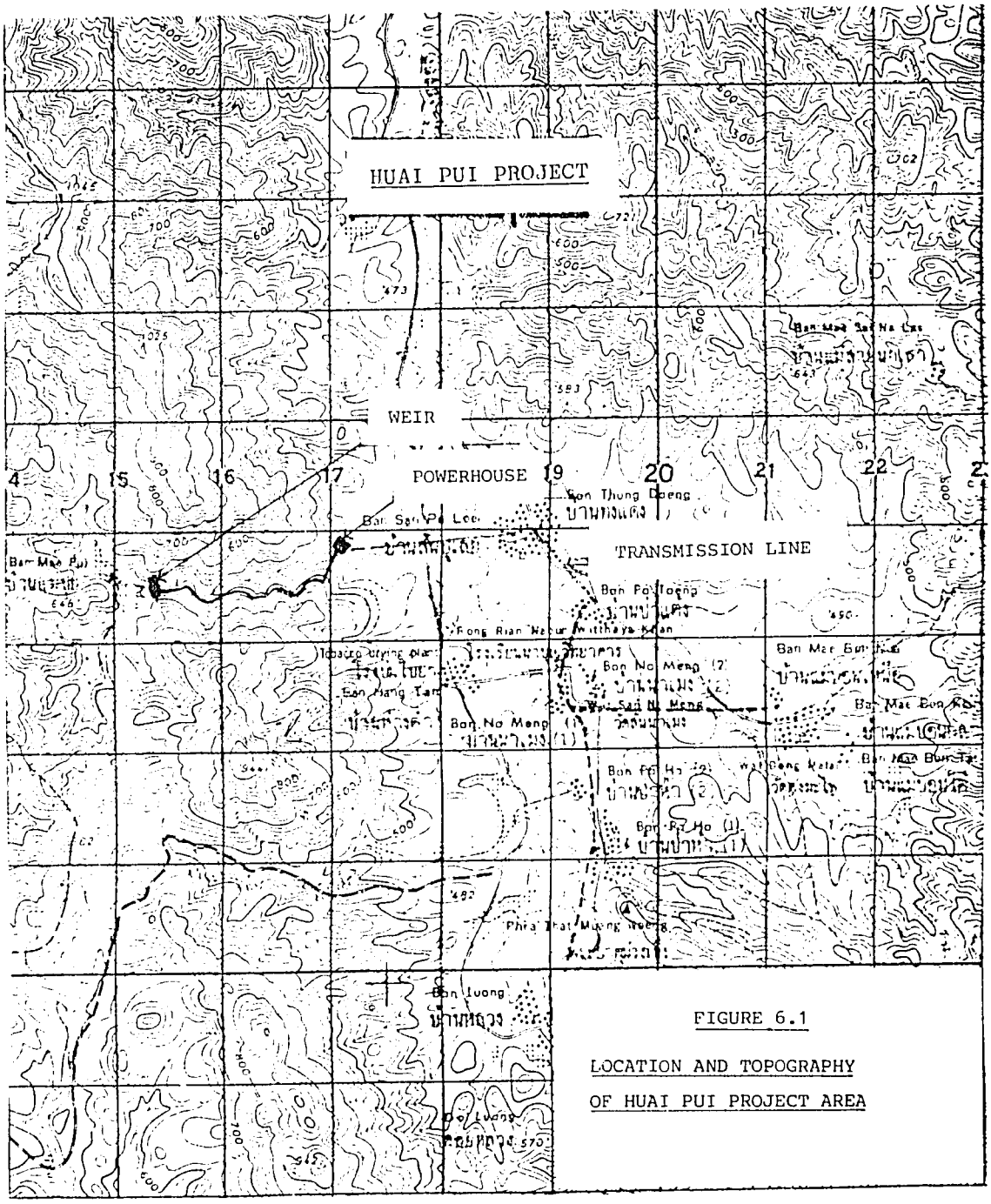


FIGURE 6.1

LOCATION AND TOPOGRAPHY OF HUAI PUI PROJECT AREA

1,094. Some of these households are situated at a remarkable distance on the hill far from the distribution network. The number of households and population in these 7 villages is shown in Table 6.1. In total, there are 1,094 households with 4,261 residents in these 7 villages. About 30 percent of these households were selected randomly for socio-economic study.

TABLE 6.1 NUMBER OF HOUSEHOLDS AND POPULATION

Village	Number of Households	Number of Population
Ban Tung Daeng	192	695
Ban Pa Taeng	158	526
Ban Na Meng	44	196
Ban Mae Mon	91	356
Ban Pa Ha	160	679
Ban Luang	336	1,287
Ban Chang Tam	113	452
Total	1,094	4,261

Village Characteristics

Tambon Long Khod is located in Amphoe Prao, Chiang Mai Province. Most parts of the area are flat terrain cultivated for rice growing. The villages are located not far from each other with easy accessibility to all villages. These villages are located near the Chiang Mai-Prao highway and there are lateritic roads connecting the villages and the highway. Roads within the villages are in good condition. The dwelling units are located together and surrounded by rice fields. There is a school in each village except Ban Pa Taeng. There are two health centers in this area, one at Ban Na Meng, the other at Ban Luang. Photos 6.1-6.8 illustrate general characteristics of Tambon Long Khod.

PHOTO 6.1 ACCESS ROAD TO THE VILLAGES

PHOTO 6.2 SERVICE ROAD IN A VILLAGE

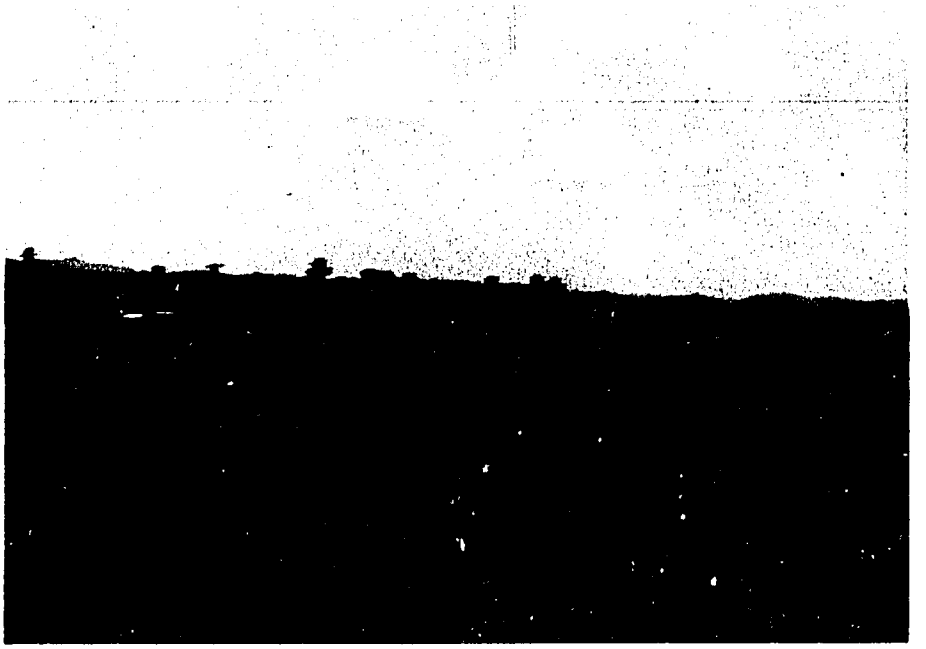


PHOTO 6.3 PADDY FIELD IN THE VILLAGE AREA

PHOTO 6.4 HOUSE COMPOUND WITH ORCHARD LAND

PHOTO 6.5 TOBACCO CURING PLANT NEAR THE VILLAGES

PHOTO 6.6 ACCESS ROAD TO HUAI PUI WEIR SITE

PHOTO 6.7 INSTALLATION OF HUAI PUI HEADRACE (1)

PHOTO 6.8 INSTALLATION OF HUAI PUI HEADRACE (2)

Education

Approximately 12 percent of the sampled household members are studying in a primary school in the village, the other 66 percent have finished studying and the remaining 22 percent have never attended a school. (Table 6.2)

Among those who have finished studying, most of them (93 percent) finished the primary school level and the remaining 5.7 percent finished higher than the primary school level. Among those members who are studying in a school, 75 percent are in the primary school level, the other 25 percent are in the secondary school level. (Table 6.3)

TABLE 6.2 CLASSIFICATION OF HOUSEHOLD MEMBERS BY EDUCATION STATUS

Village	Percent of Total Household Member		
	Finished studying	Being studying	No education
Ban Tung Daeng	73.69	7.52	18.80
Ban Pa Taeng	65.25	7.99	26.76
Ban Na Meng	69.23	3.08	27.69
Ban Mae Mon	70.64	11.93	17.43
Ban Pa Ha	62.35	14.20	23.48
Ban Luang	65.62	14.18	20.21
Ban Chang Tam	59.28	19.28	21.42
Overall Average	66.43	11.82	21.75

TABLE 6.3 EDUCATION LEVEL OF HOUSEHOLD MEMBERS

Village	Finished			Study	
	primary	secondary	higher	primary	secondary
Ban Tung Daeng	93.88	4.59	1.53	70.00	30.00
Ban Pa Taeng	95.68	2.88	1.44	82.34	17.66
Ban Na Meng	75.55	20.00	4.45	50.00	50.00
Ban Mae Mon	100.00	-	-	84.62	15.38
Ban Pa Ha	90.26	7.80	1.94	71.42	28.58
Ban Luang	93.60	6.00	0.40	59.25	40.75
Ban Chang Tam	95.17	3.61	1.22	77.78	22.22
Overall Average	93.22	5.51	1.27	74.51	25.49

Occupation

Most of the household heads in Tambon Long Khod are farmers. Rice is the dominant crop in this area. Raising of animals such as pigs, cattle, buffaloes, etc. is also popular. Besides agriculture other occupations which are considered a main occupation of some household heads are working as a laborer and trading (Table 6.4).

Besides the main occupation, about 40 percent of the sampled household heads also engage in some subsidiary occupations, mostly as a laborer, and trading (Table 6.5).

Present Land Use and Land Holding

Most parts of the area in each village of Tambon Long Khod are cultivating area. Table 6.6 shows the distribution of land use in this area. Table 6.7 summarizes the amount of land holding in these villages.

TABLE 6.4 MAIN OCCUPATION OF THE SAMPLED HOUSEHOLD HEADS

Village	Percent of Total Sampled Households			
	Agriculture	Trading	Laborer	Others
Ban Tung Daeng	85.00	1.25	8.75	5.00
Ban Pa Taeng	76.67	5.00	16.60	1.67
Ban Na Meng	89.47	-	10.53	-
Ban Mae Mon	100.00	-	-	-
Ban Pa Ha	75.86	6.90	15.20	2.00
Ban Luang	76.00	6.00	18.00	-
Ban Chang Tam	65.71	5.71	26.7	1.83
Overall Average	79.58	4.19	14.40	1.83

TABLE 6.5 SUBSIDIARY OCCUPATION OF THE SAMPLED HOUSEHOLD HEADS

Village	Households without Subsidiary Occupations	Households with Subsidiary Occupations	Subsidiary Occupation			
			Agri-culture	Trading	Laborer	Others
Ban Tung Daeng	66.25	33.75	14.81	7.41	66.67	11.11
Ban Pa Taeng	35.00	65.00	-	10.26	79.48	10.26
Ban Na Meng	73.68	26.32	-	20.00	80.00	-
Ban Mae Mon	53.33	46.67	-	14.29	50.00	35.71
Ban Pa Ha	56.90	43.10	-	4.00	84.00	12.00
Ban Luang	38.00	62.00	19.35	11.30	56.45	12.90
Ban Chang Tam	54.25	45.71	-	12.50	68.75	18.75
Overall Average	49.21	50.79	8.51	10.11	67.55	13.83

TABLE 6.6 LAND USE PATTERN IN TAMBON LONG KHOD

Village	Total Area (Rai)	Cultivating Area		Forests		Public Area	
		Rai	%	Rai	%	Rai	%
Ban Tung Daeng	2,000	1,950	97.5	-	-	50	2.5
Ban Pa Taeng	3,500	3,000	85.7	400	11.4	100	2.9
Ban Na Meng	400	380	95.0	10	2.5	10	2.5
Ban Mae Mon	918	918	100.0	-	-	-	-
Ban Pa Ha	2,660	2,600	97.7	25	1.0	35	1.3
Ban Luang	8,600	5,820	67.7	1,780	20.7	1,000	11.6
Ban Chang Tam	150	148	98.7	-	-	2	1.3
Total	18,228	14,816	81.3	2,215	12.2	1,197	6.5

Source : Provincial Statistics Office of Chiang Mai

TABLE 6.7 AMOUNT OF LAND HOLDING

Village	Average Land Holding (rai/household)
Ban Tung Daeng	10.5
Ban Pa Taeng	19.2
Ban Na Meng	8.8
Ban Mae Mon	10.6
Ban Pa Ha	14.5
Ban Luang	17.0
Ban Chang Tam	1.3
Overall Average	13.4

Source : Provincial Statistics Office of Chiang Mai

Agriculture

Several types of crops are grown in this village area, including paddy rice, upland rice, peanut, garlic, chilli, tobacco, many bean, etc. Rice is the most dominant crop in this area. Table 6.8 summarizes the cultivated area and production of rice in each village of Tambon Long Khod.

TABLE 6.8 CULTIVATED AREA AND PRODUCTION OF RICE

Village	Cultivating Area (rai)	Production (kg/rai)
Ban Tung Daeng	1,000	600
Ban Pa Taeng	2,000	300
Ban Na Meng	100	400
Ban Mae Mon	813	350
Ban Pa Ha	2,000	300
Ban Luang	5,203	300
Ban Chang Tam	30	250
Total/Average	11,146	330

Household Economy

Household income

The household income in this area can be classified into 2 categories, i.e. agricultural income and non-agricultural income. The agricultural income includes those incomes derived from farming and animal husbandry. The non-agricultural income includes those incomes from trading, hired laborer, etc. Table 6.9 shows the average annual income of each village in Tambon Long Khod. On the average, the annual income of each household is approximately 19,092 Baht (US$ 830).

TABLE 6.9 ANNUAL HOUSEHOLD INCOME

Village	Annual Income (Baht/Household)		
	Agricultural	Non-agricultural	Total
Ban Tung Daeng	9,659	9,007	18,666
Ban Pa Taeng	8,833	11,552	20,385
Ban Na Meng	9,904	12,084	21,988
Ban Mae Mon	7,029	2,891	9,920
Ban Pa Ha	7,847	10,999	18,846
Ban Luang	7,952	12,100	20,052
Ban Chang Tam	4,724	17,080	21,804
Overall Average	8,161	10,931	19,092

Household Expenditure

In the same manner, the household expenditure in Tambon Long Khod area can be classified as agricultural expenditure and non-agricultural expenditure. The average annual expenditure of each village in Tambon Long Khod is shown in Table 6.10, the total annual expenditure of each household is approximately 18,859 Baht (US$ 820)

TABLE 6.10 ANNUAL HOUSEHOLD EXPENDITURE

Village	Annual Household Expenditure (Baht/Household)		
	Agricultural	Non-agricultural	Total
Ban Tung Daeng	2,126	13,149	15,275
Ban Pa Taeng	2,478	13,567	16,045
Ban Na Meng	3,830	16,019	19,849
Ban Mae Mon	4,351	13,409	20,280
Ban Pa Ha	3,303	17,176	20,479
Ban Luang	4,316	19,377	23,693
Ban Chang Tam	2,184	17,815	19.999
Overall Average	3,198	15,661	18,859

Use of Fuel

The fuel used in this area includes firewood, charcoal, kerosene, benzene and diesel oils, and batteries. Firewood and charcoal are mostly used in cooking. Kerosene and batteries are used for lighting. Benzene and diesel oils are used for transportation or some diesel machines. Table 6.11 shows the amount of fuel used in each village in Tambon Long Khod.

TABLE 6.11 AMOUNT OF FUEL USED

Village	Average Annual Use Per Household					
	Firewood (kg)	Charcoal (kg)	Kerosene (liter)	Benzene (liter)	Diesel (liter)	Batteries (Baht)
Ban Tung Daeng	1,294	93	28.6	77.3	70.1	275
Ban Pa Taeng	1,332	49	35.7	1.3	175.8	247
Ban Na Meng	1,464	47	37.9	23.1	63.2	410
Ban Mae Mon	1,764	24	39.0	20.7	60.8	170
Ban Pa Ha	1,193	108	30.9	71.3	47.8	260
Ban Luang	1,440	68	36.0	67.6	115.1	334
Ban Chang Tam	1,406	169	45.3	20.7	133.5	325
Overall Average	1,379	190	34.8	49.6	99.8	287
Cost (Baht)	30	39	306	56.3	831	287

C. HYDROLOGICAL STUDY

Since there is no gagging station on Huai Pui stream, the hydrological study was made by using the streamflow data of Nam Mae Ngat at Ban Teen That which is also located in Chiang Mai Province. The catchment area at the gauging station of Nam Mae Ngat is approximately 80.7 km^2, whereas the catchment area of Huai Pui stream at the weir site is about 11.6 km^2. The area-ratio method is then applied to obtain the approximate streamflow data of Huai Pui. The obtained results are shown in Tables 6.12and 6.13and Fig. 6.2. Table 6.6 summarizes the estimated monthly flows of Huai Pui at the weir site whereas Table 6.7 tabulates the value of the minimum flow each month. Fig. 6.2 is the adopted flow duration curve of Huai Pui as correlated from Nam Mae Ngat at Ban Teen That.

The results from the hydrological study show that the annual streamflow at Huai Pui weir site is approximately 7.76 MCM. The minimum flow varies from 0.04 m^3/sec to 0.33 m^3/sec. With this analysis, the flow value of 0.10 m^3/sec was used as the design discharge of the Huai Pui project.

The effective head of the project is obtained by substracting the estimated head loss from the static head. From the topographic map the static head, which is the head difference between the upstream water level and the powerhouse elevation, is approximately 100 m. The value of 85 m is considered the effective head of Huai Pui project.

Regarding the design flood, the estimation is based on the rational formula, i.e. $Q = CiA$. The value of C used in the calculation is 0.15 and the rainfall duration curve for 50 years recurrence interval of Chiang Mai Province is used. The estimated design flood of Huai Pui project is 24 m^3/s. This design flood value is used in the design of a weir and in specifying the powerhouse location and tailrace level.

TABLE 6.12 MEAN MONTHLY FLOW AT HUAI PUI WEIR SITE

Unit : $x10^6$ m^3

Year \ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1977	0.34	0.22	0.20	0.21	0.40	0.13	0.31	0.49	1.20	0.84	0.64	0.46	5.45
1978	0.37	0.22	0.17	0.16	0.33	0.40	2.40	1.88	2.31	1.61	0.77	0.44	11.17
1979	0.37	0.20	0.18	0.16	0.25	0.38	0.22	0.88	0.58	0.52	0.31	0.22	4.25
1980	0.12	0.08	0.10	0.07	0.15	0.37	0.52	1.01	2.19	0.79	0.48	0.38	6.27
1981	0.31	0.23	0.22	0.23	0.28	0.46	1.81	2.14	1.62	1.52	1.31	1.06	11.20
Average	0.30	0.19	0.18	0.17	0.28	0.35	1.06	1.28	1.58	1.06	0.70	0.53	7.67

TABLE 6.13 MINIMUM FLOW AT HUAI PUI WEIR SITE

Unit : m^3/sec

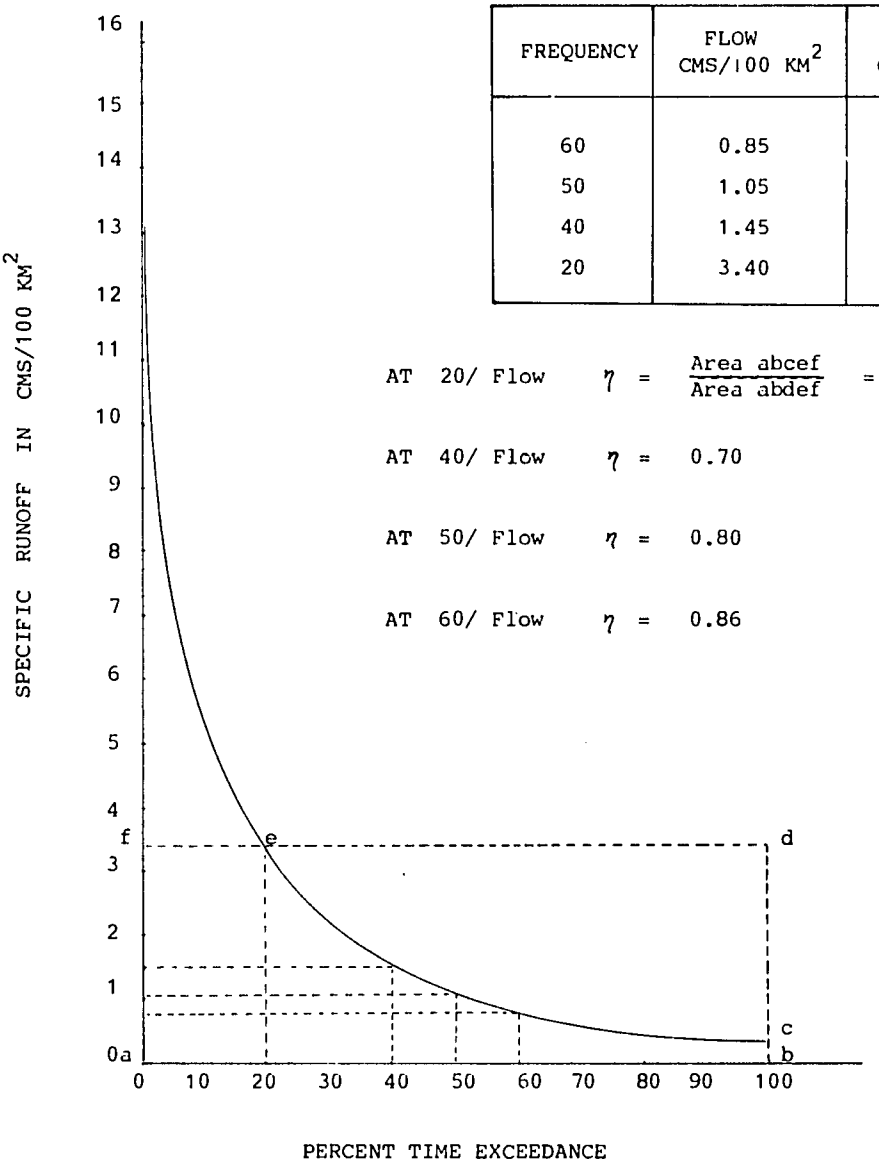
Year \ Month	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
1977	0.07	0.08	0.06	0.04	0.04	0.02	0.03	0.07	0.25	0.15	0.17	0.11
1978	0.07	0.07	0.04	0.04	0.05	0.06	0.18	0.44	0.58	0.35	0.24	0.16
1979	0.11	0.06	0.04	0.04	0.04	0.04	0.05	0.07	0.11	0.14	0.10	0.05
1980	0.04	0.02	0.02	0.02	0.02	0.06	0.03	0.08	0.26	0.21	0.14	0.11
1981	0.10	0.07	0.07	0.06	0.06	0.12	0.12	0.51	0.47	0.39	0.43	0.31
Average	0.08	0.06	0.05	0.04	0.04	0.06	0.08	0.23	0.33	0.25	0.22	0.15

Source : Survey and Planning Division, NEA.

HUAI PUI AT DAMSITE (C.A. 11.6 KM^2)

(CORRELATED FROM NAM MAE NGAT AT BAN TEEN THAT C.A. 807 KM^2)

FREQUENCY	FLOW CMS/100 KM^2	FLOW CMS/11.6 KM^2
60	0.85	0.099
50	1.05	0.122
40	1.45	0.168
20	3.40	0.394



AT 20/ Flow $\eta = \frac{\text{Area abcef}}{\text{Area abdef}} = 0.46$

AT 40/ Flow $\eta = 0.70$

AT 50/ Flow $\eta = 0.80$

AT 60/ Flow $\eta = 0.86$

FIGURE 6.2 FLOW DURATION CURVE FOR HUAI PUI PROJECT

D. CIVIL WORKS

The civil works of the Huai Pui micro-hydropower project include the construction of a weir, a powerhouse, a forebay, excavation and installation of a headrace, and a penstock. The details of each item are discussed in the following sections.

Weir

The weir of the Huai Pui project is a concrete type, 3.0 m high and 16 m long. The weir crest is at 532 m MSL. An intake structure and a sluice gate are constructed at the right abutment of the weir. Photos 6.9 and 6.10 illustrate the characteristics of Huai Pui weir under construction.

Headrace

The headrace of Huai Pui project is an asbestos cement pipe, 0.30 m in diameter. For those areas where the headrace must be installed unburied, a steel pipe of the same diameter is used instead. The total length of the headrace is approximately 1,450 m. At the bending, a concrete anchorage is constructed to support the headrace. Photo 6.11 illustrates the installation of a steel section of the headrace at the weir site whereas Photo 6.12 illustrates the installed asbestos cement headrace along the hill side.

Forebay

The forebay of the Huai Pui project is a rectangular concrete tank, 2.0 m long, 1.5 m wide, and 1.5 m high. It is constructed at the end of the headrace. An overflow weir with natural spillway is also provided to drain the excess water into the original stream.

Penstock

A steel penstock 0.30 m in diameter is installed from the forebay to the powerhouse. The total length of this penstock is approximately 165 m.

PHOTO 6.9 WEIR OF HUAI PUI PROJECT

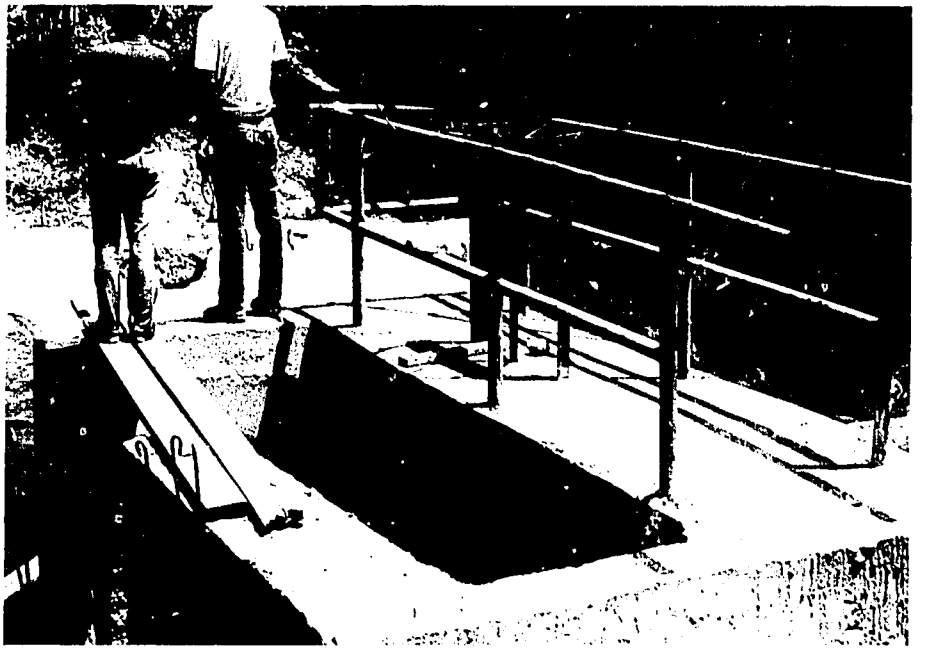


PHOTO 6.10 INTAKE AND SLUICE STRUCTURE

PHOTO 6.11 STEEL HEADRACE OF HUAI PUI PROJECT

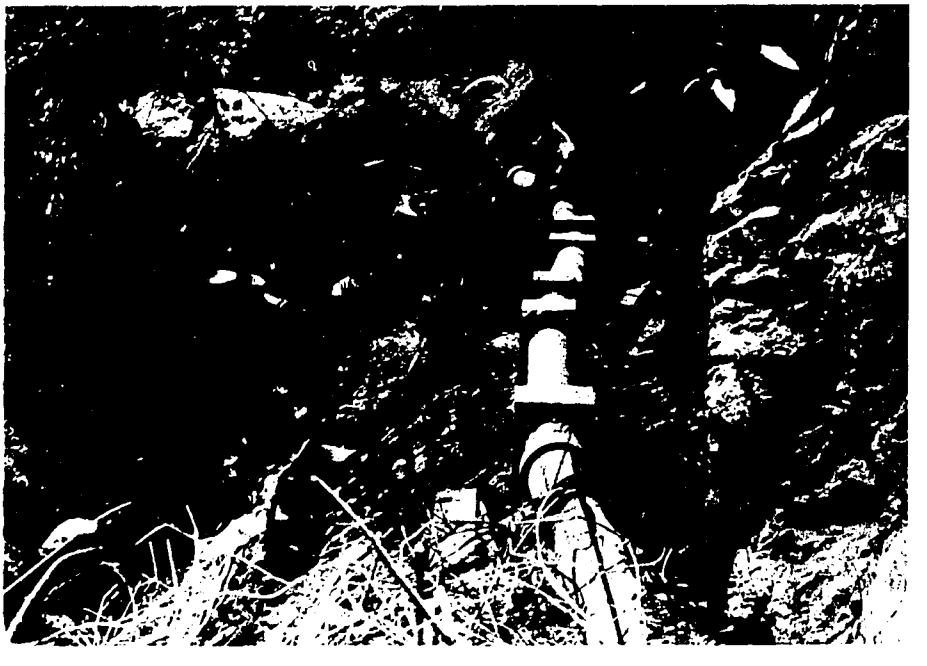


PHOTO 6.12 ASBESTOS CEMENT HEADRACE ALONG THE HILL SIDE

Powerhouse

The powerhouse of the Huai Pui project is located at the elevation of 439 m MSL, approximately 1.5 km downstream from the weir site. It has a reinforced concrete floor, concrete block walls, and galvanized steel roof (Photo 6.13). The Huai Pui powerhouse is equipped with a turbine, generator and switchboard. Its installed capacity is 50 kW. The water discharged from the turbine is drained into the origiral stream via a concrete-lined tailrace.

PHOTO 6.13 HUAI PUI POWERHOUSE

PHOTO 6.14 THE CROSS-FLOW TURBINE OF HUAI PUI PROJECT

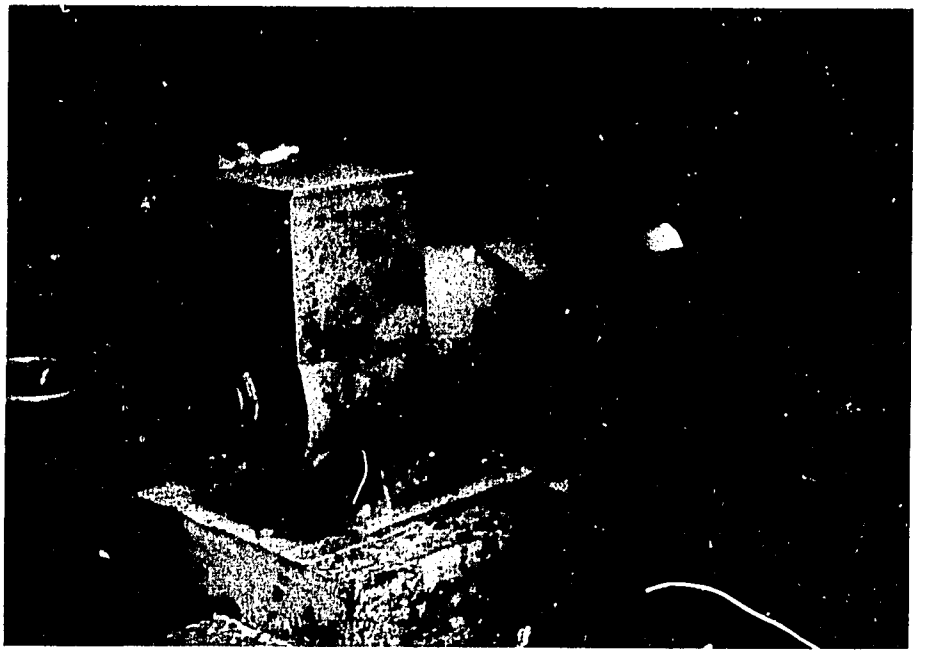


PHOTO 6.15 A TURBINE-GENERATOR SET

E. MECHANICAL WORKS

The turbine of the Huai Pui project is a cross-flow type with output rating of 50 kW. The designed head is 85 m and the designed discharge is 0.10 m^3/s. The synchronous speed is 1,500 rpm. The details of the main components of the turbine are as follows :

Casing and Base

The casing and the base are made of SS 41 steel, welded to the designed shapes, and fixed together with bolts and nuts.

Runner

The runner of the turbine is made of SS 41 steel welded with the steel shaft. The shaft is made of AISI 4,140 steel. The runner was tested for dynamic balance.

Inlet Valve

The inlet valve is stainless steel with bronze bushing and sealed to prevent water leakage.

Photo 6.14 and 6.15 illustrate the turbine installed at Huai Pui powerhouse.

F. ELECTRICAL WORKS

The electrical works of the Huai Pui project include a generator, a switchboard, transformers, and transmission line system. The details of these electrical equipment are as follows :

Generator

The generator of Huai Pui project is a 3-phase, 380 V, alternating current, synchronous generator with horizontal shaft, self-ventilation and brushless excitation. The rating output is 50 kW. The generated electricity has a frequency of 50 Hz at the synchronous speed of 1,500 rpm. The number of poles is 4 and the power factor is 80 percent lagging. The stationary winding connection is a star type.

Speed Controller

The speed controller used in Huai Pui powerhouse is an electronic load controller manufactured by NEA.

Switchboard

The switchboard installed in the Huai Pui powerhouse is equipped with the following instruments.

- 1 set of circuit breakers, 3-phase, 380-V, 4-wire, with operating indicator and over-current relay and under-voltage relay.
- 1 set of AC ammeters.
- 1 set of AC voltmeters (0-400 V).
- 1 set of watt-meters, 3-phase, 4-wire,unbalanced load.
- 1 set of power factor meters,range -0.5 to +0.5.
- 1 set of frequency meters, range 45-55 Hz.
- 3 sets of current transformers.

Transformers

The transformers installed at Huai Pui project area include one 62.5-KVA step-up transformer, two 20-KVA and three 10-KVA step-down transformers. The specification of these transformers are the same as those installed at Mae Ton Luang project, except for the KVA rating.

G. PROJECT COST AND ECONOMIC EVALUATION

In this section the cost of the Huai Pui project and the benefits based on the installation cost of a diesel power plant of the same capacity are discussed. The results of economic analysis based on the same approach and assumptions as described in Chapter 4 , Section G are also presented.

Project Cost

Details of the cost items of Huai Pui project are shown in Table 6.14. The cost of civil works amounts to 1,546,500 Baht (US$ 67,239). The cost of the electricity generating equipments is 240,000 Baht (US$ 10,435) and the cost of transformers and transmission line system is 868,500 Baht (US$ 37,761). About 317,000 Baht (US$ 13,783) is used for administration and services of construction equipments. The total cost of the project excluding the labor cost is equal to 2,972,000 Baht (US$ 129,217) of which 1,030,921 Baht (US$ 44,823) is contributed from USAID.

In addition to the above-mentioned cost items, the villagers in Tambon Long Khod, recipients of the electricity generated from the Huai Pui project, were involved in construction work as laborers and supplied Some local construction materials such as wood poles, sand, gravel, etc.

TABLE 6.14 CONSTRUCTION COST OF HUAI PUI PROJECT

Item	Cost	
	Baht	US$
1. Weir with intake and sluice gate	291,500	12,674
2. Headrace	788,000	34,261
3. Penstock with concrete support	427,000	18,565
4. Powerhouse	40,000	1,739
5. Electricity generating equipment	240,000	10,435
6. Transformers	218,500	9,500
7. Transmission line system	650,000	28,261
8. Administration and services of construction equipment	317,000	13,783
Total	2,972,000	129,217

Project Benefits

The Huai Pui micro-hydropower project is also an insulated power generation project, i.e. the electricity project is not connected to other distribution networks. The benefits of the project are then considered as the installation cost of a diesel power plant of the same capacity. Table 6.15shows the characteristics and installation cost of such a diesel plant. It is estimated that the installation of this diesel power plant will cost 750,000 Baht (US$ 32,609) excluding the cost of transformers and the transmission line system. The operation and maintenance cost (about 5 percent of the investment cost) amounts to 80,925 Baht (US$ 3,518) a year. With 65 percent plant factor and the rate of fuel requirement of 0.33 liter of diesel oil per kWh of energy produced, the total amount of diesel oil consumption is 94,050 liters per year. If the unit price of diesel is 6.70 Baht (US$ 0.29) per liter, the fuel cost is 630,135 Baht (US$ 27,397) annually. This fuel cost will be saved if the Huai Pui micro-hydropower plant is operated and thus it is considered as a direct benefit of the Huai Pui project.

In addition to the above direct benefit, there exist some indirect benefits as a result of villagers' participation. The indirect benefits of such project organization were already mentioned in Chapter 4, Section G.

TABLE 6.15 DETAILS OF DIESEL POWER PLANT EQUIVALENT TO THE HUAI PUI MICRO-HYDROPOWER PLANT

Item	Value	
1. Installation Capacity	50	kW
2. Number	1	
3. Annual Energy Production	0.285	GWh
4. Plant Factor	65	percent
5. Service Life	15	years
6. Installation Cost	750,000	Baht
7. Amount of Diesel Oil Used per kWh	0.33	liter/kWh
8. Annual Diesel Oil Consumption	94,050	liters
9. Unit Price of Diesel Oil	6.70	Baht/liter
10. Fuel Cost	630,135	Baht
11. Transmission Line and Transformer	868,500	Baht
12. Operation & Maintenance Cost	80,925	Baht/year

Economic Evaluation

Based on the assumptions given in Chapter 3, Section G and the cost-benefit data shown in the preceding sections, the annual equivalent costs of the Huai Pui micro-power plant and the equivalent diesel power plant are determined as shown in Tables 6.16 and 6.17. In conclusion, the annual equivalent cost of the Huai Pui micro-hydropower plant is 453,908 Baht (US$ 19,735) or 1.59 Baht (US$ 0.07) per kWh, while the annual equivalent cost of the diesel power plant is 948,688 Baht (US$ 41,247) or 3.23 Baht (US$ 0.14) per kWh. Thus, the benefit-cost ratio of the Huai Pui project is 2.09 : 1. Therefore, the Huai Pui project is considered economically feasible.

TABLE 6.16 ANNUAL EQUIVALENT COST OF HUAI PUI MICRO-HYDROPOWER PLANT

Annual Equivalent Cost / Item	Civil Work (Baht) [1]	Power Generating Equipment (Baht) [2]	Transmission Line System (Baht) [3]	Total Annual Cost (Baht)
1. Depreciation	231,335	30,600	127,513	389,448
2. Operation and Maintenance	18,635	2,400	43,425	74,060
Total	249,970	33,000	170,938	453,908

Note :

[1] The investment cost for civil works including the administration and services is 1,863,500 Baht (US$ 81,022)

[2] The investment cost for power generating equipment is 240,000 Baht (US$ 10,435)

[3] The investment cost for transmission line system is 868,500 Baht (US$ 37,761)

TABLE 6.17 ANNUAL EQUIVALENT COST OF THE DIESEL POWER PLANT

Item \ Annual Equivalent Cost	Power Plant[1]	Transmission Line System[2]	Total
1. Depreciation	110,115	127,513	237,628
2. Operation & Maintenance	37,500	43,425	80,925
3. Fuel Cost	630,135	-	630,135
Total	777,750	170,938	948,688

Note :

1. The investment cost for the diesel power plant is 750,000 Baht (US$ 32,609)

2. The investment cost for transmission line system and transformers is 868,500 Baht (US$ 37,761)

H. CONSTRUCTION AND OPERATION

Similar to the Kam Pong and Mae Ton Luang projects, the construction work of Huai Pui project was performed with cooperation between the villagers in Tambon Long Khod and NEA's technical staff, with financial support from USAID. In this section the construction and operation of Huai Pui project is discussed.

Work Organization

The same group of NEA's staff as those for the Kam Pong and Mae Ton Luang projects was responsible for the implementation of Huai Pui project. Therefore, the organization chart is the same as that shown in Chapter 4, Section H.

Villagers' Participation

Most of the residents in Tambon Long Khod have participated in the project, working as laborers in the construction work. Besides, they also contributed some local materials such as wood poles, gravel, sand, plank, and wood for formwork.

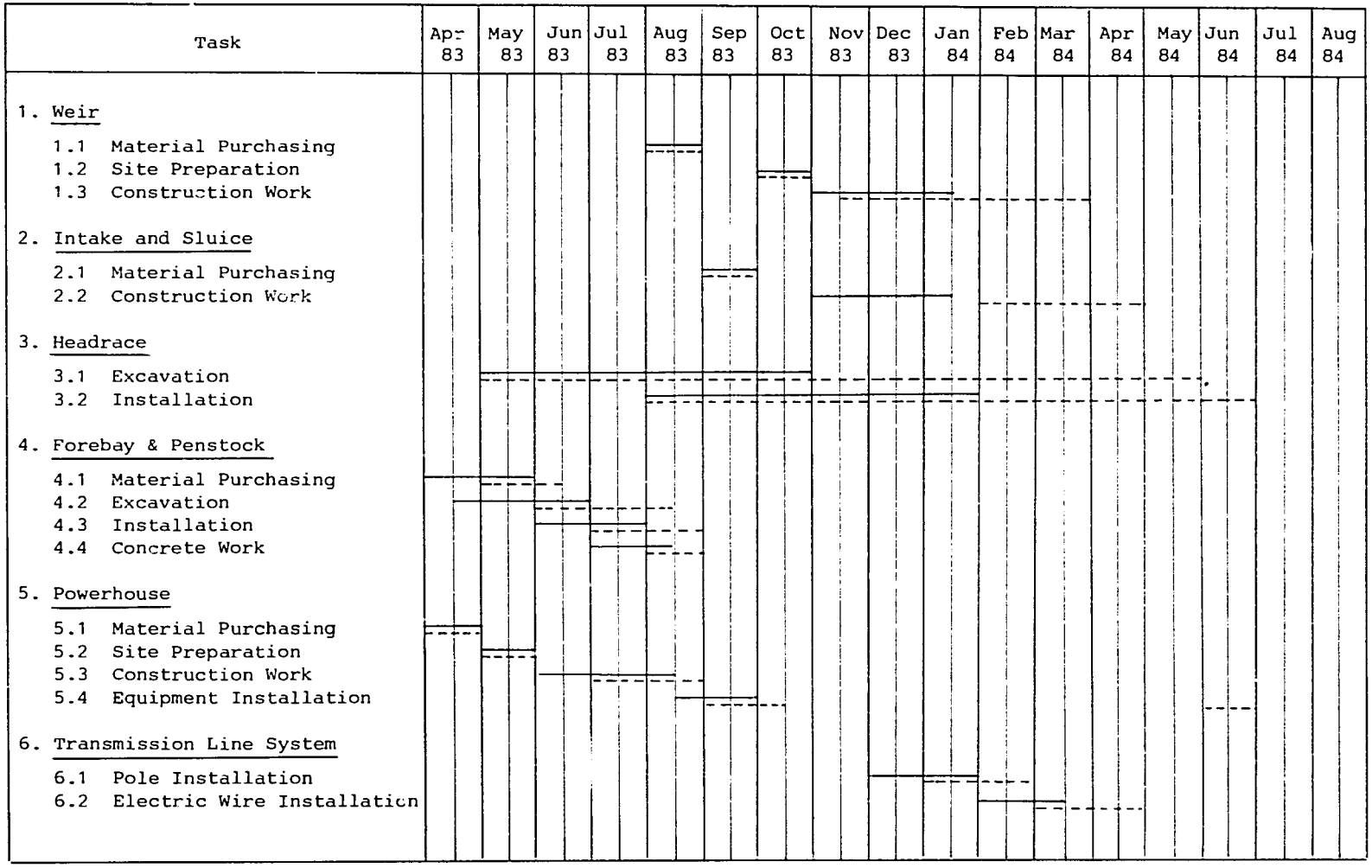
Construction Schedule

Fig.6.3 illustrates the planned schedule and actual work done of the Huai Pui project. Due to unfavorable topographic features, the installation of a headrace was rather difficult. This resulted in a delay in the civil work program and as a result, the operation schedule of the plant had to be postponed.

Problems Encountered in the Implementation

The major problem which resulted in a delay in project operation is the mountainous topographic feature of the project area. Several sections of the headrace had to be installed across the creeks and an asbestos cement pipe must be replaced by a steel pipe which required considerable time period in purchasing. Moreover, most villagers who had participated in the construction activities felt unhappy when they faced such difficult work. At the present time of reporting, the construction work of the Huai Pui project has just been completed and the test run is being undertaken.

FIGURE 6.3 CONSTRUCTION SCHEDULE OF HUAI PUI MICRO-HYDROPOWER PROJECT



——— Planned Schedule - - - - - Actual Work Period

Chapter 7

Design and Construction of Bo Kaeo Micro-Hydropower Project

DESIGN AND CONSTRUCTION OF BO KAEO MICRO-HYDROPOWER PROJECT

Bo Kaeo micro-hydropower project is one of the projects constructed with financial assistance from USAID. It is located in Tambon Bo Kaeo, Amphoe Samoeng, Chiang Mai Province. Its installed capacity is 200 kW. The electricity generated from this plant will be supplied to the Bo Kaeo Tin Mine of the Mining Industrial Organization, and to the nearby villages. In this chapter, the details of the Bo Kaeo project are described.

A. LOCATION AND TOPOGRAPHY

The Bo Kaeo micro-hydropower project is located in Tambon Bo Kaeo, Amphoe Samoeng, Chiang Mai Province. The project area is approximately 20 km west of the city of Chiang Mai. A concrete weir is constructed on Mae Bo Kaeo stream at the original site of the storage weir of the Mining Industrial Organization. Water is then diverted along a steel headrace and penstock to a powerhouse located about 800 m from the weir site. The project area is very rugged and is covered with dense forests. Fig. 7.1 illustrates the location and topographic feature of Bo Kaeo project area.

B. SOCIOLOGY AND COMMUNITY STRUCTURE

The electricity generated from the Bo Kaeo micro-hydropower project is supplied to the Tin Mine of the Mining Industrial Organization at Ban Bo Kaeo, Tambon Bo Kaeo. In addition, some nearby villages such as Ban Bo Kaeo, Ban Pang Kia, Ban King Mai Yang Ha, and Ban Huai Fan Nua could receive electricity from this project. In the following paragraphs, the sociology and community structure of these villages are described. This information was obtained from the Provincial Statistics Office of Chiang Mai and the reports of Socio-Economic Survey of Highland Units of northern Thailand for Community Development prepared by the Social Research Institute (CMU).

Households and Population

The number of households and population in Ban Bo Kaeo, Ban Pang Kia, Ban King Mai Yang Ha, and Ban Huai Fan Nua is shown in Table 7.1. There are 226 households with 1,723 inhabitants in all.

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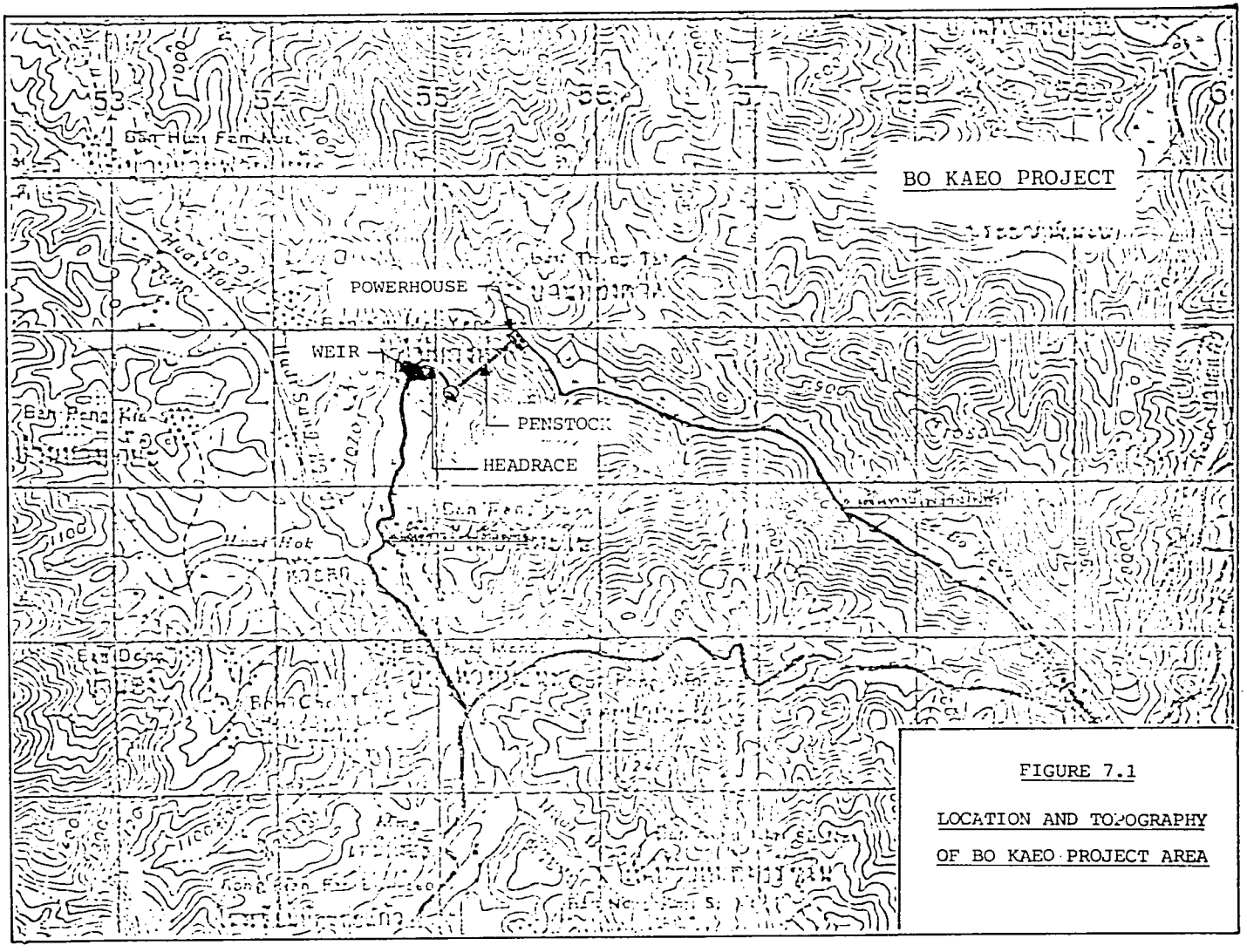


FIGURE 7.1

LOCATION AND TOPOGRAPHY OF BO KAEO PROJECT AREA

TABLE 7.1 NUMBER OF HOUSEHOLDS AND POPULATION

Village	Number of Households	Number of Population
Ban Bo Kaeo	25	140
Ban Pang Kia	144	1,260
Ban King Mai Yang Ha	44	240
Ban Huai Fan Nua	13	83
Total	226	1,723

Village Characteristics

The four villages mentioned above are located in a hilly area, covered with dense forests. Some parts with less slope and moderate soil fertility are cultivated for growing rice, ground nuts, soy beans, and garlic. Almost all residents of these villages are Karen.

There are a few streams flowing through these villages. These streams are the main source of water supply; however, a number of sprinkle wells were drilled for drinking water.

There are three primary schools in this area located at Ban Bo Kaeo, Ban Pang Kia and Ban King Mai Yang Ha. Besides, there is one health center and one police station at Ban Bo Kaeo.

Ban Bo Kaeo is the center of Tambon Bo Kaeo, the other three villages are located nearby. There is a lateritic road connecting these villages with the center of Tambon Bo Kaeo and some other villages. However, this road is in poor condition during the rainy season.

The tin mine of the Mining Industrial Organization, a receiver of electricity generated from the Bo Kaeo micro-hydropower plant, is located at Ban Bo Kaeo in the center of Tambon Bo Kaeo.

Photo 7.1-7.8 illustrate the characteristics of Ban Bo Kaeo village, Bo Kaeo tin mine, and surrounding area.

PHOTO 7.1 ACCESS ROAD TO BAN BO KAEO VILLAGE

PHOTO 7.2 GENERAL CHARACTERISTICS OF BAN BO KAEO VILLAGE

PHOTO 7.3 BO KAEO POLICE STATION

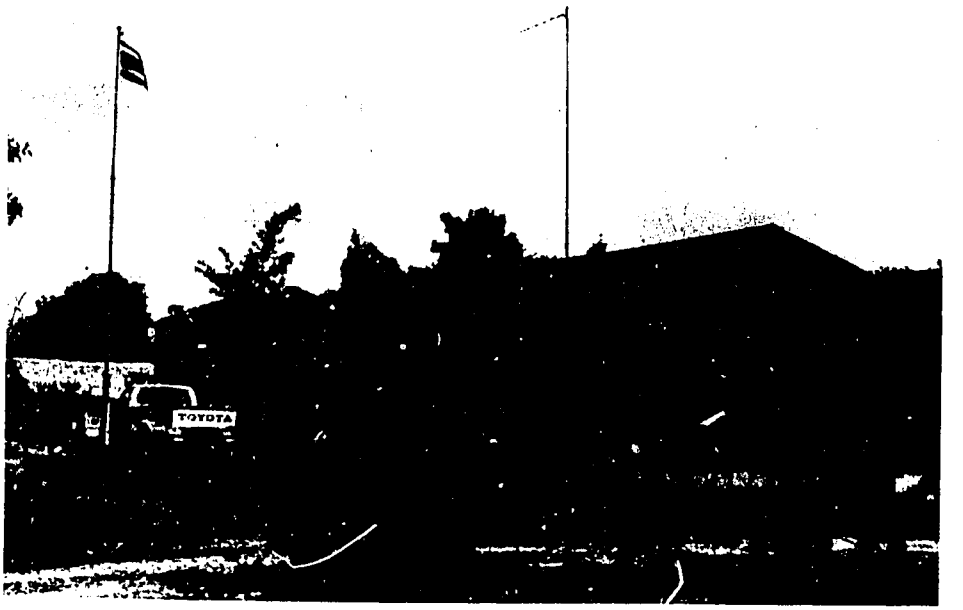


PHOTO 7.4 BO KAEO PUBLIC HEALTH OFFICE

PHOTO 7.5 A TIN MINE NEAR BO KAEO WEIR SITE

PHOTO 7.6 BO KAEO TIN MINE

PHOTO 7.7 ACCESS ROAD TO BO KAEO POWERHOUSE

PHOTO 7.8 ACCESS ROAD TO BO KAEO WEIR SITE

Occupation

Almost all household heads in these three villages are farmers. The major crop grown in this area is rice. At Ban King Mai Yang Ha ground nuts, soy beans, gartlic are also grown. Besides this main occupation some villagers also engaged in subsidiary occupations such as working as a laborer, trader, or in cottage industries.

Land Use and Land Holding

Table 7.2 summarizes the percent distribution of land use of the four villages in the project area. It is found that most parts of the area are still left as forest land. The average cultivating area per household in these villages is shown in Table 7.3. The household heads of Ban Pang Kia hold about 14.6 rai per household; while the average land holding of Ban Bo Kaeo households is 2.8 rai per household.

TABLE 7.2 PERCENT DISTRIBUTION OF LAND USE

Village	Type of Land Use			
	Residence	Cultivating	Forest	Public
Ban Bo Kaeo	0.8	11.2	88.0	-
Ban Pang Kia	0.6	16.8	70.6	12.0
Ban King Mai Yang Ha	0.9	6.3	92.7	0.1
Ban Huai Fan Nua	0.9	5.6	92.9	0.6
Overall Average	0.7	13.3	78.1	7.9

TABLE 7.3 AVERAGE CULTIVATING LAND HOLDING

Village	Average Cultivating Area (rai/household)
Ban Bo Kaeo	2.8
Ban Pang Kia	14.6
Ban King Mia Yang Ha	6.1
Ban Huai Fan Nua	6.9
Overall Average	12.2

Agriculture

As previously mentioned, most household heads in these villages earn their living from agriculture. The main crops cultivated here are rice, ground nuts, soy beans, garlic, and the opium poppy. The cultivated areas and production of these crops are shown in Table 7.4.

TABLE 7.4 CULTIVATING AREAS AND AGRICULTURAL PRODUCTION

Village / Crop	Ban Bo Kaeo		Ban Pong Kia		Ban King Mai Yang Ha		Ban Huai Fan Nua	
	Area (rai)	Product (kg/rai)	Area (rai)	Product (kg/rai)	Area (rai)	Product (kg/rai)	Area (rai)	Product (kg/rai)
Paddy Rice	30	500	100	700	70	450	50	900
Upland Rice	40	200	900	300	95	200	35	300
Ground Nut	-	-	-	-	15	120	-	-
Soy Bean	-	-	-	-	20	120	-	-
Garlic	-	-	-	-	60	1,000	-	-
Opium Poppy	-	-	1,100	0.8	-	-	-	-

C. HYDROLOGICAL STUDY

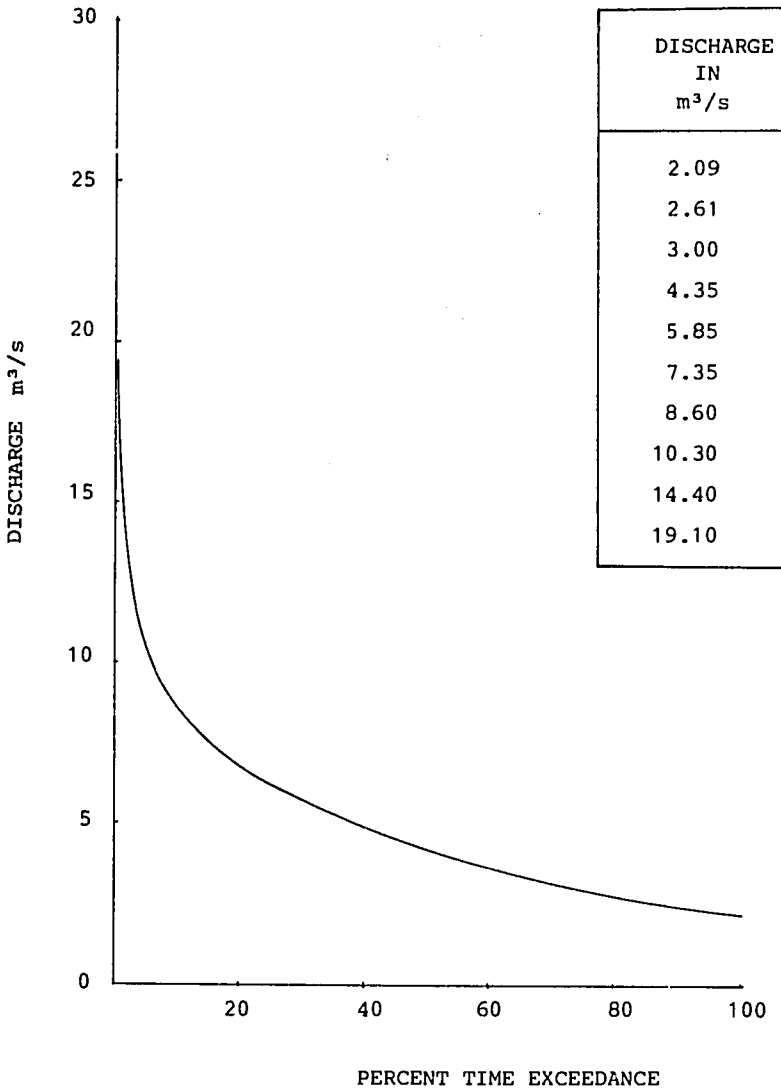
Since there is no gauging station at Huai Bo Kaeo stream, the data recorded from the other basin was adopted to estimate the value of design discharge and design flood of Bo Kaeo project.

For the design discharge flow duration curve of Huai Mai Sao at Ban Mae Sao was considered. The Huai Mae Sao is a tributary of the Fang River, one main river in the northern part of Chiang Mai Province. The flow-duration curve of Huai Mae Sao is shown in Fig. 7.2. The catchment area of this basin at the gaging station is approximately 111 km^2. From the value of discharge at 60 percent of time with exceeding flow and by applying the area-ratio method, the value of the design discharge of 0.2 m^3/s was computed. This value was used in the designed of the headrace, penstock and power generating units.

For the design flood the rational formula, $Q = CiA$, was used in calculation. The rainfall intensity i for a 50-year recurrence interval of the northern Thailand is used. For the Bo Kaeo basin which is considered as forest land, the value of 0.15 is used for runoff coefficient C. By using this formula, the value of 140 m^3/s was computed and used as the design flood of Bo Kaeo project.

The value of the effective head is computed by subtracting the estimated head loss from the static head. The value of 200 m is obtained for the effective head of the Bo Kaeo project.

The design discharge together with the effective head lead to the computation of the installation of the plant. For the Bo Kaeo project, the value of 200 kW is estimated.



DISCHARGE IN m^3/s	PERCENT OF TIME
2.09	100
2.61	85
3.00	69
4.35	47
5.85	30
7.35	17
8.60	6.8
10.30	3.3
14.40	0.8
19.10	0.3

FIGURE 7.2 FLOW DURATION CURVE OF UPPER MAE SAO PROJECT

D. CIVIL WORKS

The civil works of Bo Kaeo micro-hydropower project include the construction of a weir and its associated components, a headrace, a forebay, a penstock, and a powerhouse. The main features of these components are as follows :

Weir

The weir of Bo Kaeo micro-hydropower project is a concrete weir constructed on Mae Bo Kaeo stream at the same location as the original storage weir of the Mining Industrial Organization. The constructed weir is 2 m high and 15 m long. The power intake and the sluice gate for sediment release are constructed on the right abutment of the weir. Details of the Bo Kaeo weir and its associated components are shown in Fig. 7.3 and illustrated in Photos 7.9-7.11.

Headrace

A steel headrace of 400 mm in diameter and 200 m in length is laid along the sloping terrain from the intake to the forebay. The headrace of Bo Kaeo micro-hydropower project was designed as an open-channel flow with flow depth of 70 percent at the design discharge. Photo 7.12shows the installation of the headrace of the Bo Kaeo project.

Forebay

The forebay of the Bo Kaeo project is constructed as a rectangular concrete tank. It is approximately 2.0 m long, 1.5 m wide and 1.50 m high. A spillway is also provided to remove the excess water. In addition, a gate valve was installed at the outlet to control the flow to the powerhouse through the penstock (Photo 7.13).

Penstock

The penstock of the Bo Kaeo project is a steel pipe 600 m in length and 400 mm in diameter. It is connected between the concrete forebay and the powerhouse (Photo 7.14).

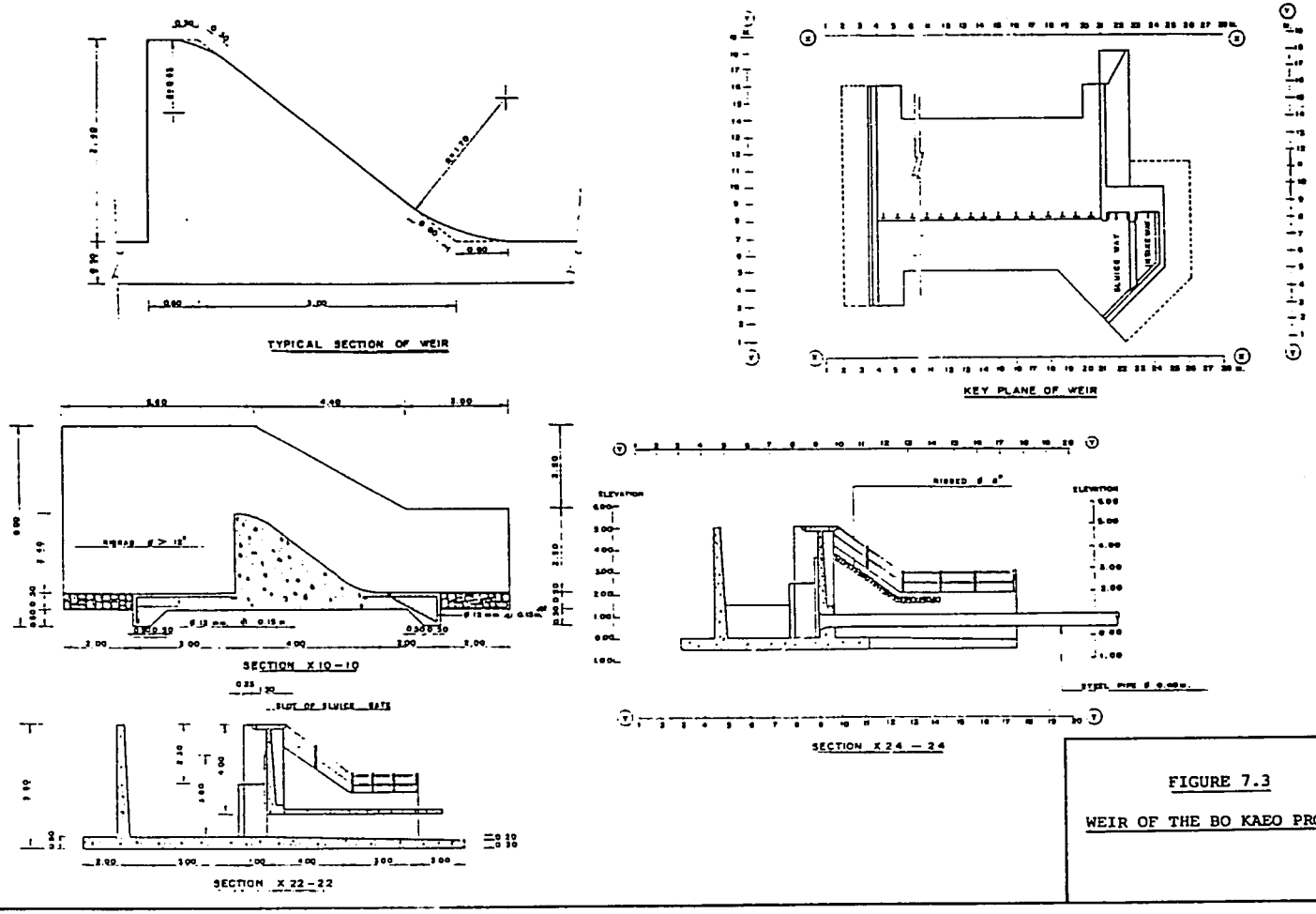


FIGURE 7.3

WEIR OF THE BO KAEO PROJECT

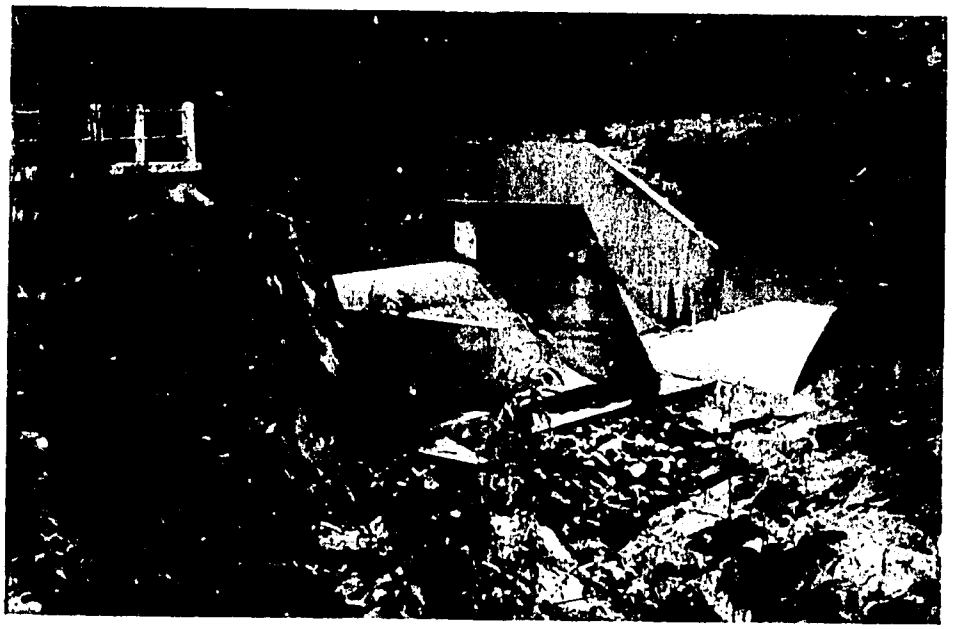


PHOTO 7.9 BO KAEO WEIR (1)

PHOTO 7.10 BO KAEO WEIR (2)

PHOTO 7.11 POWER INTAKE AND SLUICE FOR SEDIMENT RELEASE

PHOTO 7.12 STEEL HEADRACE

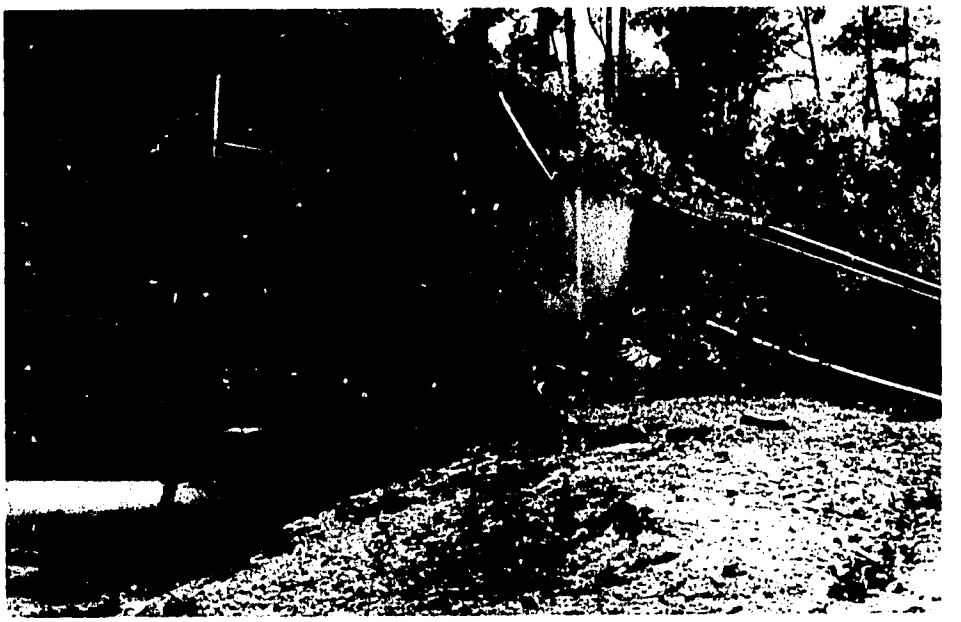


PHOTO 7.13 CONCRETE FOREBAY SHOWING SPILLWAY AND GATE VALVE

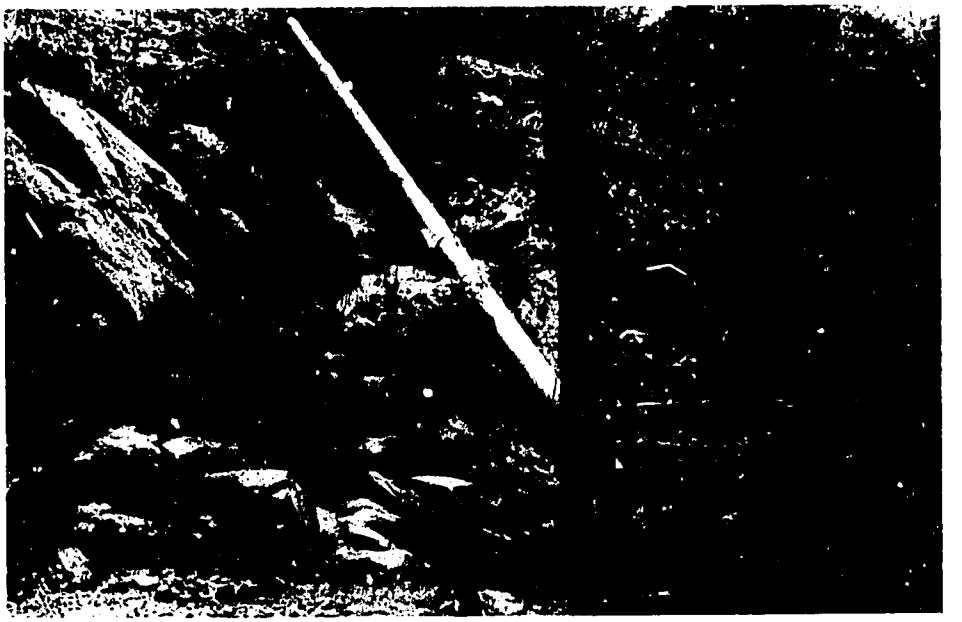


PHOTO 7.14 THE STEEL PENSTOCK CONNECTING TO THE POWERHOUSE

The powerhouse of the Bo Kaeo project is located about 800 m from the weir site. It is a one storey house with reinforced concrete floor and corrugated asbestos cement roof (Photo 7.15). The powerhouse is equipped with two sets of turbines, generators, and switchboards. A step-up transformer is located at the outside space near the powerhouse. In addition, a tailrace channel is constructed to discharge the water from the turbines to the original stream.

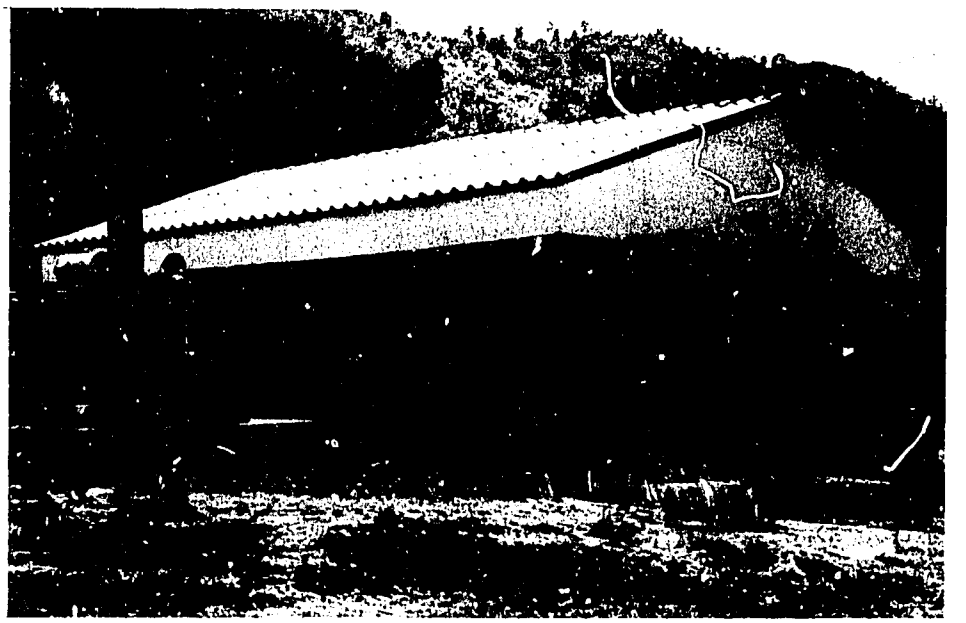


PHOTO 7.15 THE POWERHOUSE OF BO KAEO PROJECT

E. MECHANICAL WORKS

Two units of Pelton turbines were installed in the powerhouse of Bo Kaeo micro-hydropower project. These turbines were coupled to a horizontal shaft, three-phase synchronous generator. Details of the installed turbines are as follows :

Type	Pelton type
Net head	200 meters
Flow	100 liters/second
Output	100 kW
Speed	1,000 rpm
Number of units	2 units

Photo 7.16 illustrates the feature of the installed Pelton turbine

PHOTO 7.16 THE CROSS-FLOW TURBINE OF THE BO KAEO PROJECT

F. ELECTRICAL WORKS

The electrical works of Bo Kaeo project include generators, transformers, switchboard and switchgear. In the following paragraphs, details of these equipments are described.

The Generators

The generators of Bo Kaeo project are a horizontal shaft, three-phase synchronous generator. Two sets of generators were installed, each with an installed capacity of 100 kW. Totally, the installation capacity of the Bo Kaeo project amounts to 200 kW. The details of the installed generators are as follows :

Number of units :	2 units
Type :	3 phase, 400/230 volts, alternating current, brushless exiting synchronous generator, horizontal shaft, self-ventilated type, totally enclosed and completed with automatic voltage regulator.
Service condition :	Usual service condition
Rating :	
Operating duty :	Continuous
Output :	125 KVA
Voltage	400/230 volts
Current	190 amperes
Power factor	0.8 (lagging)
Frequency	50 Hz
Speed	1,000 rpm
Prime mover :	Coupled to the hydraulic turbine
Stator winding connection :	Star-type connection
Design :	All the parts of the generator are so designed and constructed as to withstand safety to the stress due to runaway speed and short circuit fault as well as normal continuous operation.

Photo 7.17 illustrates the installed generator in the Bo Kaeo powerhouse.

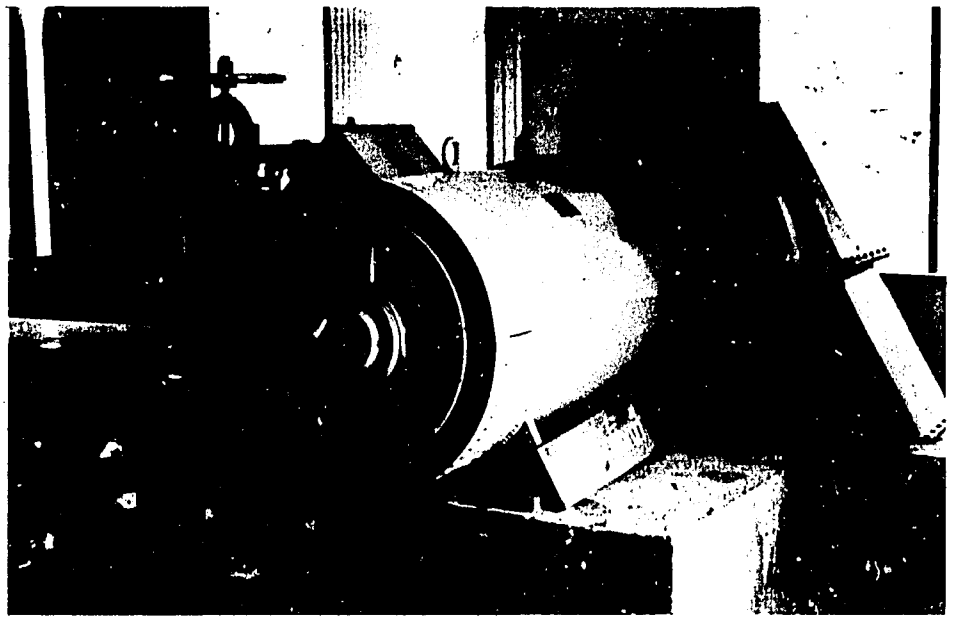


PHOTO 7.17 THE GENERATOR OF THE BO KAEO PROJECT

The Transformers

One three-phase, step up transformer with the rating of 315 KVA was installed at the powerhouse to raise the voltage of the electric power before transmittal to the transmission line to the consumers. The details of this step-up transformer are as follows :

Number of unit :	1 unit
Type :	Outdoor, 3-phase, oil immersed, self-cooled
Service condition :	Usual service condition

Rating :

Operating duty :	Continuous
Output :	315 KVA
Nominal voltage :	
- primary	400/230 volts
- secondary	3,500 volts
Frequency :	50 Hz
Connection :	Delta (primary) - Star (secondary)

The neutral point is directly grounded, off load tap changer, at least four positions.

Photo 7.18 illustrates the features of the installed step up transformer at the powerhouse of Bo Kaeo micro-hydropower project.

In addition to the above-mentioned step up transformer, NEA has purchased two three-phase step down transformers, each with a rating of 20 KVA. The purpose of these step down transformers is to decrease the voltage of the transmitted electricity from 3,500 volts to be 400/230 volts before it is distributed to the consumers in the serviced villages. For the Bo Kaeo Tin Mine of the Mining Industrial Organization, the transmission line network(including the step down transformer) is purchased and installed by the mine itself. The details of the step down transformers purchased by NEA are as follows :

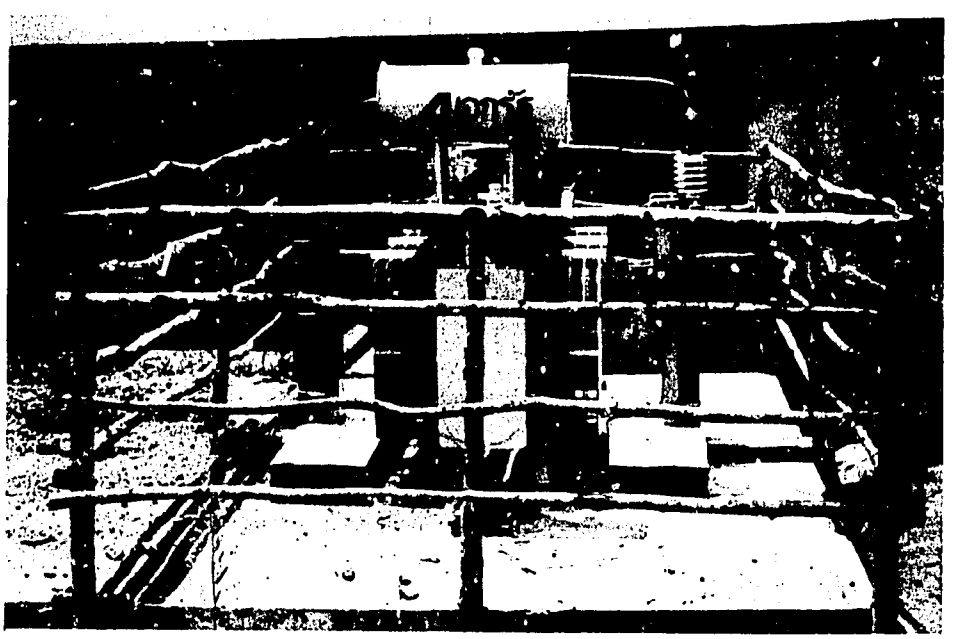


PHOTO 7.18 THE STEP-UP TRANSFORMER AT THE BO KAEO POWERHOUSE

Number of units :	2 units
Type :	Outdoor, 3-phase, oil immersed, self cooled
Service condition :	Usual service condition
Rating :	
Operating duty :	Continuous
Output :	20 KVA
Nominal voltage :	
- primary	3,500 volts
- secondary	400/380 volts
Frequency :	50 Hz
Connection :	Delta (primary) - Star (secondary)

The neutral point is directly grounded, off load tap changer, at least four positions.

Switchboard

The switchboard for controlling and operating the generators was installed in the powerhouse of the Bo Kaeo micro-hydropower project. The equipment arranged on the front panel or inside the switchboard include :

Incoming panel board

1. AC ammeter, for 380-volt circuit (0-200 A)
2. Ampere selector switch, 2 sets
3. AC voltmeter, for 380-volt circuit (0-500 V)
4. Volt selector switch, 2 sets
5. Power factor meter, for 380-volt, circuit, 2 sets
6. Kilowatt meter, 3 phase, for 380-volt circuit, 2 sets
7. Frequency meter, 2 sets
8. Current transformer 200 /5 A, for 380-V circuit, 6 sets
9. Potential transformer, 380/110/(110/53) volts, 1-phase, 6 sets
10. Over- and under-voltage relay, adjustable trip-range 80-120% of excitation voltage, 2 sets

11. Inverse time power relay, 2 sets
12. Synchronizing measuring instrument with double voltmeter and double frequency meter, 1 set
13. Auxiliary relay and reset push button
14. Control fuse
15. Fault indicating and operating lamp
16. Alarm devices
17. Circuit breaker 250-AF, 660-V, 3-phase, 4-pole. Overload relay setting 160-200 A, with motor operating or magnetic contractor. Adjustable thermal and magnetic release trip with shunt trip and auxiliary switch, 2 sets.
18. Power and control wiring

Outgoing panel board

1. AC ammeter, for 380-volt circuit, 1 set
2. AC ammeter, for 3.5-KV circuit, 1 set
3. Amp selector switch, 2 sets
4. AC voltmeter, for 380-volt circuit, 1 set
5. AC voltmeter, for 3.5-KV circuit, 1 set
6. Volt selector switch, 2 sets
7. Kilowatt meter, 3-phase, for 380-volt circuit, 1 set
8. Power factor meter for 380-volt circuit, 1 set
9. Kilowatt-hour meter, 3-phase for 3.5-KV circuit, 1 set
10. Current transformer, for 380-volt circuit, 3 sets
11. Potential transformer, 300/110/(110/53), 3 sets
12. Circuit breaker 500 AF, 660-volt, 3-phase, 4-poles Overload relay setting range 320-400 A. Adjustable thermal and electromagnetic release trip with shunt trip and auxiliary switch, 1 set.
13. No-fuse circuit breaker 500 V, 3 poles, 50 Hz, 30 AT, 100 AF.
14. No-fuse circuit breaker, 500 V, 2 poles, 20 AT, 1 set
15. Circuit breaker, on-off lamp
16. Power and control wiring

Photo 7.19 illustrates the switchboard of the Bo Kaeo micro-hydropower project.

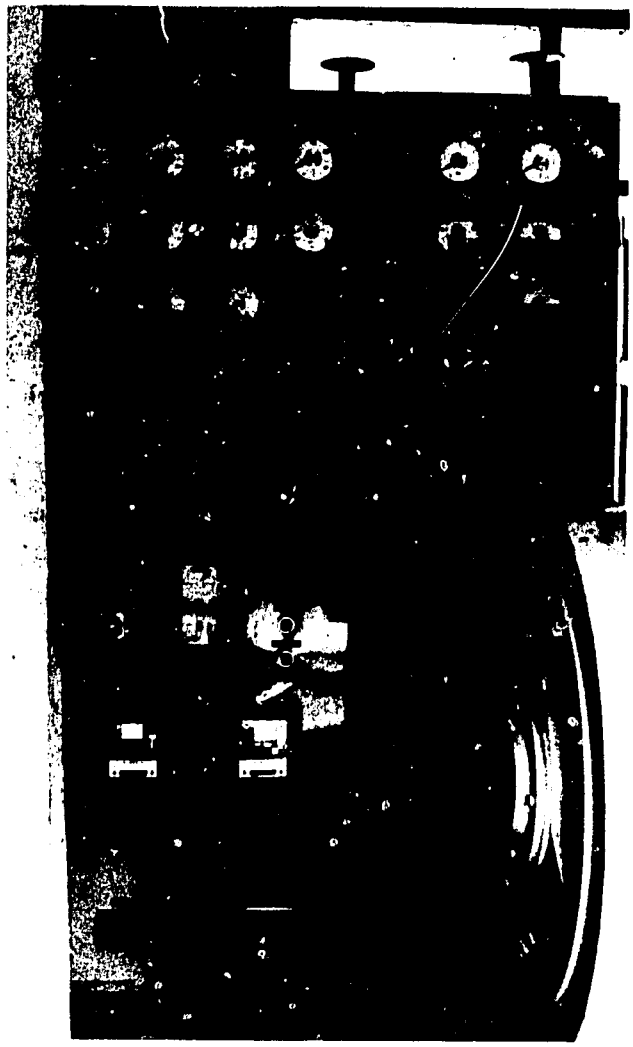


PHOTO 7.19 SWITCHBOARD OF THE BO KAEO PROJECT

G. PROJECT COST AND ECONOMIC EVALUATION

In this section the construction cost of Bo Kaeo project is shown together with the expected benefits as compared to installation and operation cost of the diesel power plant with the same capacity. The economic analysis is also undertaken to determine the feasibility of the project on economic point of view.

Project Cost

The construction cost of the Bo Kaeo project is shown in Table 7.5. The total cost is 6,142,500 Baht (US$ 267,065). The cost of civil works is 3,614,410 Baht (US$ 157,148). The cost of electricity generating equipment is 1,583,000 Baht (US$ 68,826). The cost of the transmission line system is 833,000 Baht (US$ 36,217) and the administration cost is 112,090 Baht (US$ 4,873). About 1,500,000 Baht (US$ 65,217) is contributed by USAID.

Project Benefits

The benefits of the Bo Kaeo project are estimated by considering the installation and operation cost of a diesel power plant of the same capacity. Details of such a plant are shown in Table 7.6. The installation cost is approximately 3,000,000 Baht (US$ 130,435) and 1,043,000 Baht still has to be paid for the transmission line system. The operation and maintenance cost as well as fuel cost amount to 2,720,480 Baht (US$ 118,282) per year.

TABLE 7.5 COST OF BO KAEO MICRO-HYDROPOWER PROJECT

Item	Cost
1. Weir with intake and sluice gate	360,000
2. Headrace	306,220
3. Forebay	128,195
4. Penstock	1,840,000
5. Powerhouse	400,000
6. Access road	580,000
7. Electricity generating equipment	1,373,000
8. Transmission line system and transformer	1,043,000
9. Administration	112,085
Total	6,142,500

TABLE 7.6 DETAILS OF THE DIESEL POWER PLANT EQUIVALENT TO BO KAEO MICRO-HYDROPOWER PLANT

Item	Cost	
1. Installation Capacity	200	kW
2. Number of Units	1	unit
3. Annual Energy Production	1.139	GWh
4. Plant Factor	65	percent
5. Service Life	15	years
6. Installation Cost	3,000,000	Baht
7. Amount of Diesel Oil Used/kWh	0.33	liter/kWh
8. Annual Diesel Oil Consumption	375,870	liters
9. Unit Price of Diesel Oil	6.70	Baht/liter
10. Fuel Cost	2,518,330	Baht/year
11. Transmission Line and Transformers	1,043,000	Baht
12. Operation and Maintenance	202,150	Baht/year

Economic Evaluation

Based on the same assumptions as those mentioned in Chapter 3, an estimate is made of the annual equivalent costs of Bo Kaeo micro-hydropower project and the equivalent diesel power plant. The details are respectively shown in Tables 7.7 and 7.8. It is found that the annual equivalent cost of Bo Kaeo micro-hydropower plant is 893,944 Baht (US$ 38,867), whereas that of the equivalent diesel power plant is as high as 3,256,113 Baht (US$ 141,570). The benefit-cost ratio of Bo Kaeo project is then equal to 3.64 : 1. The unit price of electric energy produced is 0.51 Baht (US$ 0.02) per kWh. Thus, the Bo Kaeo project is considered excellent from the economic point of view.

TABLE 7.7 ANNUAL EQUIVALENT COST OF BO KAEO MICRO-HYDROPOWER PLANT

Item \ Annual Equivalent Cost	Civil Works (Baht) [1]	Power Generating Equipment (Baht) [2]	Transmission Line System (Baht) [3]	Total Annual Cost (Baht)
1. Depreciation	462,608	175,058	153,133	790,799
2. Operation and Maintenance	37,265	13,730	52,150	103,145
Total	499,873	188,788	205,283	893,944

Note : [1] The investment cost for civil works including administration work is 3,726,500 Baht (US$ 162,022)

[2] The investment cost for power generating equipments is 1,373,000 Baht (US$ 59,696)

[3] The investment cost for transmission line system is 1,043,000 Baht (US$ 45,348)

TABLE 7.8 ANNUAL EQUIVALENT COST OF THE DIESEL POWER PLANT

Item \ Annual Equivalent Cost	Power Plant (Baht) [1]	Transmission Line System (Baht) [2]	Total (Baht)
1. Depreciation	382,500	153,133	535,633
2. Operation & Maintenance	150,000	52,150	202,150
3. Fuel Cost	2,518,330	-	2,518,330
Total	3,050,830	205,283	3,256,113

Note : [1] The investment cost for the diesel power plant is 3,000,000 Baht (US$ 130,435)

[2] The investment cost for transmission line system is 1,043,000 Baht (US$ 45,348)

H. CONSTRUCTION AND OPERATION

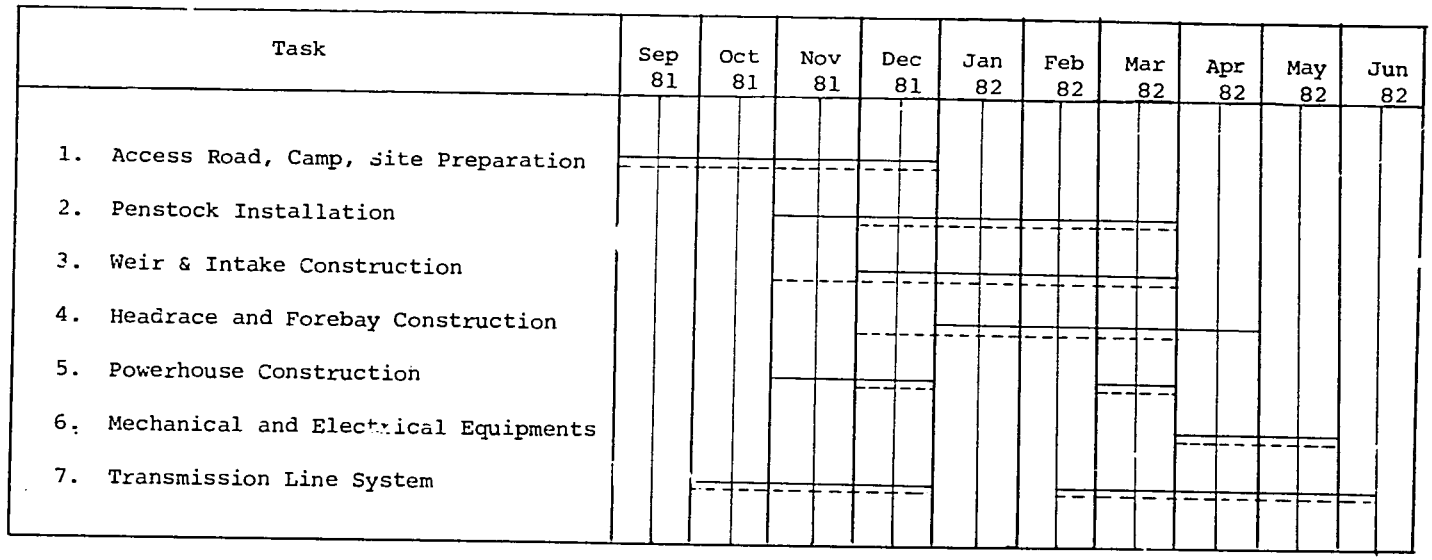
Construction Work

Since most of the electricity produced by the Bo Kaeo micro-hydropower plant will be supplied to the Tin Mine of the Mining Industrial Organization, the villagers in the project area did not participate in the construction activities and did not contribute materials like the other three projects previously mentioned. The construction work was mainly conducted by the contractors with supervision by NEA's staff. Fig. 7.4 shows the planned schedule and the actual work done in the implementation of Bo Kaeo project.

Problems Encountered in the Implementation

A number of unexpected problems were faced in the implementation of Bo Kaeo micro-hydropower project. One main problem is the poor access road to the project area and lack of an access road to the site for powerhouse. Consequently, the contractors had to build the road in order to have access to the site. The total length of this access road is approximately 5 km.

FIGURE 7.4 CONSTRUCTION SCHEDULE OF BO KAEO MICRO-HYDROPOWER PROJECT



——— Planned Schedule - - - - - Actual Work Period

Chapter 8

Discussion and Evaluation of Results

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DISCUSSION AND EVALUATION OF RESULTS

This chapter contains a general discussion of various aspects in the development of the four micro-hydropower projects in Chiang Mai Province. The discussed topics include site selection, work organization, hydrological study, civil works, mechanical works, electrical works, construction cost, and operation and maintenance.

A. SITE SELECTION

Several factors have been considered in the selection of the sites for the micro-hydropower development in Chiang Mai Province. It seems that one of the most important factors leading to the choice of the site is the request from the villagers for electricity in their village. The four sites mentioned in this report are, however, also suitable from an engineering point of view. Although, the catchment areas are rather small, the areas are still covered with dense forests and there exist some base flows in the streams twelve months of the year.

The topographic features are one of the most important factors which must be taken into consideration in the selection of the site for micro-hydropower development, not only for obtaining high head, but also for the suitability for construction. For example, the installation of the headrace for the Huai Pui project experienced great difficulty resulting in excessive labor costs.

B. WORK ORGANIZATION

The three micro-hydropower projects, namely Kam Pong, Mae Ton Luang, and Huai Pui, were constructed with participation of the villagers. The NEA's staff had conducted the site investigation and the hydrological study, and had also designed the project. The NEA, with financial assistance from USAID, then supplied those materials and equipment which were not available at the project site. The villagers contributed some local materials such as wood poles, gravel and sand, as well as wood for the formwork. The villagers were also involved in the construction activities, mostly as laborers, with supervision by the NEA's officials. This resulted in valuable indirect benefits, which include :

1. Involving the villagers as participants at the begining of the project.

2. Demonstrating the rule of a cooperative approach in rural development.

3. Fostering close cooperation between local people and the government in rural development.

4. Transferring an appropriate technology to rural people.

5. Creating the sense of ownership of the project by the villagers.

The problems encountered in this work organization include :

1. Most villagers were unskilled and so the work done was not so neat. Sometimes, this resulted in considerable repair work to be done after the test run.

2. Since most villagers had their own work to do, mostly as farmers, during the cultivating and harvesting seasons there was some loss of the labor force.

3. There were some conflicts between the villagers who participated in the project and those villagers who did not participate in the project.

The remaining site, the Bo Kaeo project, was built by a contractor since the electricity produced from this plant would be mainly supplied to the Tin Mine of the Mining Industrial Organization. Therefore, the villagers in the project area did not participate in the construction activities.

C. HYDROLOGICAL STUDY

The hydrological study is very important in the planning and design of a micro-hydropower development project. It is required for the identification of the design discharge and the installed capacity of the plant as well as the reliability of power generation, especially at those sites without pondage (runoff-river).

Since no streamflow gauging stations exist on the four streams developed for hydropower, some approximation methods were adopted to determine the values of the design discharge and design flood. For the design discharge, field measurements at the sites were conducted during the dry season. The values obtained, which were considered as minimum flows, were used as the design discharge of the project. For the design flood some empirical formula which were developed for the basins in Northern Thailand, or the rational formula, were used in calculation.

The use of the empirical formulae and flow measurement for one dry season period may not be adequate for hydropower development planning. However, it was all the data that were available. Detailed field observation of the basin characteristics are also required. More information on streamflow characteristics should be collected either by asking the villagers or by field measurements for longer periods of time. However, the latter approach is usually restricted by the time factor.

D. CIVIL WORKS

The civil works of the micro-hydropower project include a weir, a headrace, a forebay, a penstock, and a powerhouse building. The weir type used in the four projects is a concrete weir. Most of the headraces and penstocks are asbestos cement pipes which are cheaper in price. The installation of these pipes must be done carefully and they should be buried under ground to prevent the damage caused by falling stones from the hill.

Most of the construction works were carried out with villagers' participation except for the Bo Kaeo project. The main problem in this work organization is that most of the villagers are unskilled, so the work done was not neat and sometimes repairs were needed. A training program should be offered and classification of the workers should be made to put the right man in the right place.

E. MECHANICAL AND ELECTRICAL WORK

All of the turbines and generators installed in the powerhouses of these four micro-hydropower projects were designed and manufactured by NEA. Moreover, most of other equipment, including transformers and transmission lines, are made within the country. All of the mechanical and electrical equipment was installed by the technical staff of NEA who had a lot of experience in such installation work. The only problem arising was the delay in the delivery of this equipment.

F. OPERATION AND MAINTENANCE

The participation of the villagers in construction work is beneficial to the operation and maintenance of the plant since the villagers then understand the function of every part of the project. As previously mentioned, the villagers in each project area have set up a committee to take care of this electricity, for collecting the electricity charge from the consumers, and for operation and maintenance work. One villager is hired for operating the plant. The following tasks have to be done for the operation and maintenance of the micro-hydropower plant.

1. Start and stop the electricity generating equipments daily.

2. Lubricate the machines and observe the performance of each apparatus periodically.

3. Release the sediment by opening the sluice gate from time to time.

4. Remove the debris from the screen of the intake structure.

5. Survey the routes of the headrace and penstock to observe any potential cause of damage to the pipelines, e.g. erosion of soil underneath the pipelines, etc.

6. Read the consumers' meters for computing the electricity charge.

Chapter 9

Conclusions

CONCLUSIONS

This chapter summarizes the results of the implementation of the four micro-hydropower projects in Chiang Mai Province, the Kam Pong project, the Mae Ton Luang project, the Huai Pui Project, and the Bo Kaeo project. All four projects have received financial support from USAID, and the National Energy Administration (NEA) is the government authority responsible for the implementation.

A. THE KAM PONG PROJECT

The Kam Pong project is located in Kam Pong village, Tambon Huai Kao, Amphoe San Kampaeng, Chiang Mai Province. The catchment area at the weir site is approximately 6 km^2. The main features of the project include :

1. A concrete gravity weir, 2 m high and 15 m long, with intake structure and spillway.

2. An asbestos cement pipe headrace 0.30 m in diameter and 470 m long.

3. A penstock consisting of an asbestos cement pipe 0.30 m in diameter and 50 m in length and a 50-m long steel pipe of the same diameter.

4. A powerhouse equipped with two sets of turbines, generators, and switchboards. The installed capacity is 40 kW with the design discharge of 0.12 m^3/s and effective head of 60 m.

5. Transmission line and distribution system together with step-up and step-down transformers.

The electricity generated from Kam Pong powerhouse is supplied to 118 households in Kam Pong village. The construction cost of the Kam Pong project is 2,656,500 Baht (US $ 115,500), excluding the labor cost and some local materials contributed by the villagers of Kam Pong. The grant from USAID to the Kam Pong project is 1,438,519 Baht (US $ 62,544). As compared with the diesel power plant of the same capacity, the benefit-cost ratio of the Kam Pong project is 1.98:1, that is, the project is considered economically feasible.

Besides the direct benefit from energy production, there exist some indirect benefits as a result of villager participation in construction work. These indirect benefits include :

1. Increasing villagers' income and upgrading their standard of living.

2. Initiating a rule of cooperatives in rural development.

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3. Fostering close cooperation between local people and the government in rural development.

4. Transferring an appropriate technology to rural people.

B. THE MAE TON LUANG PROJECT

The Mae Ton Luang micro-hydropower project is located in Tambon Pa Miang, Amphoe Doi Saket, Chiang Mai Province. The catchment area of the basin at the weir site is about 19 km^2. Most parts of the terrain are steeply sloping and are covered with dense forests. The main features of the Mae Ton Luang project include :

1. An concrete gravity weir, 2.20 m high and 19 m long with intake structure and sluice gate for sediment release.

2. An asbestos cement pipe headrace 0.30 m in diameter and 1,255 m long.

3. An asbestos cement penstock 0.30 m in diameter and 140 m long.

4. A steel surge tank, 1.2 m in diameter and 15.0 m high.

5. A powerhouse equipped with a set consisting of one turbine, generator, and switchboard. The installed capacity is 35 kW at the design discharge of 0.1 m^3/s and effective head of 60 m.

6. Transmission line system including transformers, high-voltage and low-voltage lines.

The electricity generated is supplied to 230 households in three villages of Tambon Pa Miang. The total construction cost is 2,577,150 Baht (US $ 112,050), in which 1,275,731 Baht (US$ 55,467) is a grant from USAID. Besides this budget, the villagers in the Mae Ton Luang project area also contributed to the project by providing part of the labor force and some local construction materials.

When considering the installation, operation, and fuel costs of the diesel power plant of the same capacity as the benefit of the Mae Ton Luang micro-hydropower project, the economic analysis shows that the benefit-cost ratio of the Mae Ton Luang project is 1.82:1. That is, the project is economically feasible.

Similar to the Kam Pong project, the participation of the villagers in the construction work of Mae Ton Luang project also yielded indirect benefits as mentioned in Chapter 4, Section G.

The main difficulty arising in the implementation of Mae Ton Luang project was the delay in the purchase and delivery of the generating equipment. This led to the delay in the operation schedule.

C. THE HUAI PUI PROJECT

The Huai Pui project is located in Tambon Long Khod, Amphoe Prao, Chiang Mai Province. The catchment area is approximately 11.6 km^2. The main features of the Huai Pui project include :

1. A concrete gravity weir, 3 m high and 16 m long with intake structure and sluice gate at the right abutment.

2. An asbestos cement headrace 0.30 m in diameter and 1,450 m long. The design discharge is 0.1 m^3/sec.

3. A steel penstock 0.30 m in diameter and 165 m long.

4. A powerhouse equipped with a set of turbine, generator and switchboard. The installed capacity is 50 kW at the design discharge of 0.1 m^3/s and design head of 85 m.

5. Transmission line system consisting of step-up and step-down transformers, high-voltage and low-voltage lines.

The electricity produced from the Huai Pui powerhouse is supplied to 250 households in Tambon Long Khod. The total construction cost is approximately 2,972,000 Baht (US $ 129,217) in which 1,030,921 Baht (US $ 44,823) is a grant from USAID. Similar to the Kam Pong and Mae Ton Luang projects, the villagers in Huai Pui project area also contributed in the form of supplying labor force and some local construction materials. With a benefit-cost ratio of 2.09:1, the Huai Pui project is considered to be economically feasible.

Besides the benefit from electric power generation, the implementation of the Huai Pui project also has some indirect benefits as a result of villagers' participation.

The main problems encountered in the implementation of Huai Pui project result from the mountainous topography of the project area. This caused great difficulty in the installation of the headrace and resulted in the delay in project operation.

D. THE BO KAEO PROJECT

The Bo Kaeo project is located in Tambon Bo Kaeo, Amphoe Samoeng, Chiang Mai Province. The main features of the project include:

1. A concrete weir 2 m high and 15 m long with intake structure and sluice gate for sediment release.

2. A steel headrace, 200 m long and 0.40 m in diameter.

3. A steel penstock, 0.40 m in diameter and 600 m long.

4. A powerhouse equipped with two sets of turbines, generators and switchboards, each of which has an installed capacity of 100 kW. That is the total installed capacity of Bo Kaeo project is 200 kW.

The electricity generated from the Bo Kaeo project is mainly supplied to the Tin Mine of the Mining Industrial Organization. However, four small villages situated near Bo Kaeo powerhouse will also be served by the Bo Kaeo project. Since most electricity from the Bo Kaeo powerhouse would be supplied to the Tin Mine, the construction work was carried out by a contractor without villagers' participation.

The construction cost of the Bo Kaeo project is approximately 6,142,500 Baht (US $ 267,065), in which 1,500,000 Baht (US $ 65,217) is contributed by USAID. The economic analysis reveals that the benefit-cost ratio of Bo Kaeo project is as high as 3.64:1. That is, the project is considered economically feasible.

The major problem encountered during the construction phase of the Bo Kaeo project was the poor accessibility to the project area, and the contractor had to construct a new access road to the site. Another problem was the delay in the purchase and delivery of a transformer which resulted in a delay in project operation.

Chapter 10

Recommendations

RECOMMENDATIONS

In investigating the implementation of the four micro-hydropower projects mentioned above, the following recommendations can be made.

1. All the data necessary for the project design and planning should be carefully collected and recorded prior to the approval for the implementation of the project. The collected data should include :

- Topographic map of the project area in an appropriate scale showing the sites for a weir and a powerhouse as well as the location of the villages that will receive the electricity generated from the project.

- Detailed profile along the routes of the headrace and the penstock.

- Geologic structures at the weir site, the routes of the headrace and the penstock, as well as the site for the powerhouse.

- Socio-economic structure of the nearby villages, emphasizing the requirement of electricity for productive use.

- Hydrological data of the stream where the weir will be constructed.

2. With respect to hydrological study, an appropriate method should be adopted in order to obtain as reliable data as possible. More field observation and data collection should be conducted to obtain the most suitable value of the design discharge. Detailed investigation of hydrological characteristics of the region with consideration of several potential sites for micro-hydropower development should be conducted by the responsible agency.

3. Since most of the potential sites for micro-hydropower development are located in a remote area where the accessibility is rather poor, operation and maintenance problems should be carefully considered in the design stage.

4. The implementation schedule should take into consideration the time period needed for each task, including the purchase and delivery of construction materials, and equipment, the available manpower, the nature of the project area, and project features.

5. Villagers' participation should be maintained since valuable indirect benefits result. In addition, some training program should be offered for those staff who are responsible for projects with this kind of work organization.

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