PRELIMINARY STUDY
OF

UPPER NAM PONG BASIN HYDRO - ELECTRIC PROJECT

THAILAND

August 1966

GOVERNMENT OF JAPAN

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FOREWORD

At the request of the government of Thailand to make the preliminary study for the Upper Nam Pong Basin hydro-electric project, the Overseas Technical Cooperation Agency, executive organization of the government of Japan for the technical cooperation, despatched its survey team to conduct the consulting services in connection with the project. The survey team consisted of two civil engineers, headed by Mr. H. Watanabe, and was engaged in the field investigation for about one month from 15th June 1966 at three proposed sites of Nam Phrom, Upper Nam Chern and Lower Nam Chern in order to study the priority for development of three sites. The results of the field investigation have been reviewed and compiled into this report.

I avail myself of this opportunity to express my great thanks to your government and organizations concerned for their invaluable coopelation and assistance extended to the survey team during its stay.

Nothing would be more gratifying to us if this report could be of any contribution to the hydro-electric project in your country as well as in the furtherance of the amity, friendship and economic relations between Thailand and Japan.

August, 1966

Shin-ichi Shibusawa

Director General,
Overseas Technical Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Shin-ichi Shibusawa
Director General
Overseas Technical Cooperation Agency
Tokyo

Dear Sir:

The undersigned, Head of the Japanese Government preliminary Survey Team on the Upper Nam Pong Basin Hydro-electric Project, take pleasure to communicate to you that the work assigned to the Team has been fulfilled and have the honor to submit herewith the report of our studies.

The Team visited Thailand from 15 June 1966 to 16 July 1966, and reconnoitered and investigated relevant areas and districts of Thailand in connection with the program with the cooperation of the Government of Thailand, the National Energy Authority (NEA) and the North-East Electricity Authority (NEEA). Upon return to Japan, the Team prepared this report of the studies under the direction of the Chief Engineer of and with the cooperation of engineers of the engineering departments of Electric Power Development Company.

In the performance of the studies, the Team constantly beared in mind the contribution of the program to the welfare and well-being of the people of Thailand.

Respectfully submitted,
H. Watanabe
Hiroshi Watanabe
Head of the Preliminary Survey Team
on the Upper Nam Pong Basin
Hydro-electric Projects.

Senior Civil Engineer
Electric Power Development Company

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CHAPTER 1.

INTRODUCTION

CHAPTER 1 INTRODUCTION

1-1 Authorization and History

The Government of Thailand in order to cope with the rapidly increasing demand of electricity in the north-east district has proposed the development of hydro-electric potentials of the Upper Nam Pong Basin. There are three probable projects. The Government of Thailand has requested the Government of Japan to determine the most economic project among the three and to conduct a feasibility study.

In response to the request the Government of Japan delegated the task to its agency the Overseas Technical Cooperation Agency (OTCA). OTCA in cooperation with the Overseas Electrical Industry Survey Institute, Inc. (OEISII) organized a team comprising of the undermentioned two civil engineers of Electric Power Development Company (EPDC). This team visited Thailand and made preliminary studies in order to determine the most economic project of the three proposed schemes.

Hiroshi Watanabe
Senior Civil Engineer

Tatsuo Hashimoto
Planning Engineer

The agency of the Government of Thailand responsible for and charged with the development of the hydro-electric potentials of the Upper Nam Pong Basin is the North-East Electricity Authority (NEEA), and the three projects it has under consideration are as follows:

Nam Phrom Project (installed capacity: 45 MW)
Upper Nam Chern Project (installed capacity: 13 MW)
Lower Nam Chern Project (installed capacity: 12 MW)

After studying reports related to or of reference to the projects, the Team visited Thailand for approximately one month from June 15, 1966 to July 16, 1966 and reconnoitered the project sites and collected available relevant data. This is a report of the preliminary studies of the three projects based on the results of studies of available reports, data collected in the field and field investigations made by the Team.

1-2 Scope of Report

The Government of Japan is anticipating to submit to the Government of Thailand by the end of April 1967, a feasibility report concerning one project from among the Nam Phrom, Upper Nam Chern and Lower Nam Chern Projects.

The purposes of this preliminary report are as follows.

(1) to study and examine which of these three proposed projects is the most economical, and then

(2) to define and recommend field investigations that NEEA will be required to preform of the project in order to conduct a feasibility study

Power market, hydrology, geology, topography and other data that were available for the present study were very limited. Therefore, it must be emphasized that more detail studies of load forecast, hydrology, scale of development, constructions costs and other factors must be made in the feasibility study.

This report comprises of the main report and appendix. The appendix contains figures and tables.

1-3 Existing Reports

In February, 1966, the first field survey was conducted on the Upper Nam Pong Basin by Mr. J. E. Kilpelainen, civil engineer, United Nations advisor and by NEEA engineers. In this survey, field investigation was carried out by helicopter flights over the site of Nam Phrom Project, while it was made by ground explorations on the site of Lower Nam Chern. On the site of Upper Nam Chern Project, however, no physical investigation was performed, but examination was limited to study of a topographical map to a scale of 1/50,000.

The results of this survey were prepared in a report by Planning Division, Engineering Department of NEEA and called:

"Nam Pong Basin Preliminary Report Concerning the Development by J. E. Kilpelainen, Civil Engineer, United Nations Advisor"

This preliminary report was augmented by a supplement dated April 7, 1966. Besides this report, there is no other report of survey concerning the projects in question. In the meantime, Mr. P. T. Tan, Chief, Water Resource Development Division of ECAFE made desk studies of the three projects. The results of his studies were published under the following title in May 24, 1966:

"Nam Phrom Financial Cost Analysis"

1-4 Basic Data

Basic data on rainfall, run-off, topography and load forecast were furnished to the Team by NEEA. In addition, during the course of the field investigation, the team collected data. However, data made available to or collected by the Team are limited and far from adequate.

"Nam Pong Project, Feasibility Report" by Rogers International Corporation dated March 29, 1962 and "Nam Pong Project, Engineering Report" which was later prepared by Salzgitter Industriebau GmbH include basic data which have relevance to the proposed projects.

1-5 Acknowledgement

The survey team expresses its profound gratitude to officials of the Government of Thailand, National Energy Authority and North-East Electricity Authority for the various conveniences and assistance received.

The Team wishes to acknowledge the valuable assistance received from Mr. S. Toranishi in connection with the market survey of the proposed projects.

The team also acknowledges the assistance and cooperation of the Government of Japan, Overseas Technical Cooperation Agency, Overseas Electrical Industry Survey Institute, and the Chief Engineer and engineering staff of Electric Power Development Co., Ltd.

CHAPTER 2. CONCLNSIONS AND RECOMMENDATIONS

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

2-1 Conclusions

Upon studying past reports and as a result of the field investigations and studies after return to Japan, it is the conclusion that:

(1) The Lower Nam Chern Project is not economical at the present stage. The geology of the dam site is limestone and there are geologic problems, and the cost of power of the project is extremely high. Moreover, this project includes the diversion of water from the headwaters of Nam Phrom to the Nam Chern, and unless this diversion is accomplished, the cost of power will be more expensive.

(2) There are no unusual engineering problems in the design and construction of Nam Phrom and Upper Nam Chern Projects. Both projects are economical. Comparative studies were made with a diesel plant as an alternative source. It was found that the cost of energy of both projects is less than the cost of energy of the alternative source, and that the benefit-cost ratio exceeds 1.

(3) It is not possible at the present stage to determine which of the two projects (Nam Phrom and Upper Nam Chern Projects) should be developed first.

The cost of energy and benefit-cost ratio of both projects were calculated, and it was found that the Nam Phrom Project is more favorable economically. However, on the basis of load forecasts for the 10-year period from 1966 to 1975, studies of the timing of development, supply capability against estimated demand and other factors revealed that whichever of the projects is developed first the economic merits are almost the same.

(4) It is essential that the project to be developed first should be started as early as practically possible because there will be a shortage of supply capability from 1968 according to the load forecast.

(5) Whether the Nam Phrom Project or the Upper Nam Chern Project is developed first, it is anticipated that the both projects will have to be developed by around 1977. According to the load forecast, if the Nam Phrom Project is developed first, it will be necessary to have the Upper Nam Chern Project ready for operation around 1977. Conversely, if the Upper Nam Chern Project is constructed first, it is anticipated that the Nam Phrom Project must

be completed and on the line in 1974.

(6) Data which were available are limited and far from adequate. Therefore, in order to determine the priority of development of the two projects, it is essential to ascertain whether or not there are discrepancies in the hydrological, topographical, geological and other data used in the present studies. For this purpose, it is essential that field studies of both projects be initiated immediately.

2-2 Recommendations

It is recommended that the following studies and investigations be conducted of the Nam Phrom Project and Upper Nam Chern Project before determining which of the two projects should be developed with priority.

(1) Ascertain the total storage capacity of the reservoir by traverse and cross-sectional surveying of the reservoir area, and check the accuracy of the 1/50,000 scale topographic map.

(2) Check the estimated costs of the projects. For this purpose geologic investigation of the dam site of Nam Phrom Project should be conducted by core boring, and the Upper Nam Chern Project by core boring of the dam site and along the right bank upstream of the dam site.

After determining which of the two projects should be developed with priority on the basis of the results of investigations (1) and (2) enumerated above, the following investigations should be carried out for the feasibility study.

(3) Aerial mapping of the reservoir area - map to scale of 1/10,000 with 5 m contour

Aerial mapping takes time and the map may not be ready in time for the feasibility study but it is eventually necessary and this work should be started as early as possible.

(4) Topographic survey and preparation of map to a scale of 1/1,000 with 1 m contour of the proposed dam site, intake, penstock and powerhouse sites (in case of the Upper Nam Chern Project, include the right bank upstream of the proposed dam site).

(5) Profile leveling along the center line of tunnel.

(6) Geologic survey by core boring of the proposed dam site (in case of Upper Nam Chern Project, include the right bank upstream of dam site)

(7) Investigation of dam embankment materials.

Preparation of the feasibility report will require 4 months after the results of the investigations enumerated above become available.

CHAPTER 3.

LOAD FORECAST

CHAPTER 3. LOAD FORECAST

3-1 Existing Conditions

The Upper Nam Pong Project area is situated in the north-east district of Thailand. The demand for electric power in the north-east district of Thailand is growing at a pace far exceeding estimates. This seems to be attributable to the fact that the government's policy for the development of industries in the north-east district is highly fruitful, that along with the development of industries, the living standard of the people is improving and that by the expansion of transmission and distribution lines Potential demands are being satisfied. Recently, several military bases of large scale have been established in this district which have accelerated the growth of the demand for electricity.

The 15 changwads in the north-east district have a population of 9,878,862 according to the census of 1964. Table 1 shows the breakdown of population and the power supply systems in the 13 changwads, namely, said 15 changwads less Loey and Buri-ram which are expected to remain isolated from the power supply systems for some time to come. The population in the supply area served by three supply systems reached 9,020,641 in 1964, which corresponds to about one third of the total population of Thailand. The concentration of population to cities is very low; the population living in cities is about 4% of the total population, and even if it is combined with the estimated population living in the outskirts of cities, the percentage is as small as 9%. In order to supply electric energy to sparcely settled population from the power supply systems in the future, it will be necessary to expand distribution facilities. The cost required for materializing this expansion will be enormous, so installation of isolated diesel generation plants may prove to be a more rational method of electrification.

In forecasting the demand for the power supply systems for the next 10 years or so, the urban population including inhabitants of the outskirts mentioned above should be considered. In this case, however, it must be taken into account that development of industries in cities has the possibility of accelerating the concentration of population from rural districts to cities.

3-2 Pattern of Supply

Table 2 shows existing power generation facilities and proposed power projects in the north-east district of Thailand. In this district, the Nam Pong and Nam Pung hydro-electric projects have been developed, and energy produced is supplied to principal cities in the district on 115 KV and 69 KV transmission lines. (See Fig. 3)

Ubolratana Power Station of the Nam Pong System has a maximum output of 18 MW, and energy produced is being supplied to Khon Kaen, Nakorn Ratsima, Udon Thani, Phol and Mahasarakham since February of this year. The maximum output of this power station is scheduled to be increased to 25 MW by the installation of a third unit in February of 1968.

Nam Pung Power Station has a maximum capacity of 6 MW, and energy generated is being supplied to Sakon Nakhon, Nakae, That Phanom since October 1965.

Electricity from these power stations is distributed to consumers by Provincial Electricity Authority (PEA). PEA is aggressively promoting the expansion of power distribution facilities and it is assumed that small cities which are now relying for supply of energy by diesel engines will be gradually connected to these supply systems. These two supply systems are scheduled to be interconnected in the autumn of 1967.

By the autumn of 1967, a 115 KV transmission line is scheduled to be completed connecting Udon Thani and Vientian, the capital of Laos. This transmission line will serve to supply electricity to Vientian and, at the same time, to supply power for the construction work of Nam Ngum Project which is scheduled to start soon. It is understood that upon completion of Nam Ngum Project, the transmission line will be used to send electricity from the Nam Ngum Project to Thailand. It is estimated that 8 MW of power will be delivered on this line.

In the southern region of this district where Ubol Rat Thani, Sri Saket and Su-rin are situated, hydro-electric power has not been developed. So these cities are served electricity from diesel generators. Lam Dom Noi Project which is expected to be started soon is scheduled to be completed by the end of 1969. When this project is completed, this region will receive supply of energy from the project which will have a maximum output of 15 MW.

3-3 Supply Territory:

The north-east district of Thailand consists of 15 changwads. Of these changwads, Loey will not benefit from either of the power systems and is anticipated to remain isolated for some time in the future. Similarly, Buri-ram will remain isolated from either of the supply systems for a considerable period, though it may receive supply of energy from Lam Dom Noi or Nakorn Ratsima in the future. Therefore, forecast of demand was made of 13 changwads, excluding the two changwads mentioned above.

As already mentioned in paragraph 3-2, there is also planned an interchange of power with the Nam Ngum System of Laos.

3-4 Load Forecast:

3-4-1 Period of forecast

Forecast for demand was made for the ten years beginning in 1967.

3-4-2 Annual mean rate of load growth

The annual mean rate of growth of power and energy demand in this district has recently reached 15 to 20%. Considering that both the Nam Pong System and Nam Pung System have not been in operation for a very long time, the demand for electricity is estimated to continue to grow rapidly within the next few years. Particularly, in 1967, in addition to the growth of demand within the district, it is anticipated that new demands will be created by the connection of new customers in the systems. But the growth rate of demand may not be high in the following years, if one takes into account the fact that, as stated in 3-1, the population of the outskirts of cities in the supply territory is not very large. With these factors taken into consideration, the annual mean rate of growth of KW demand for residential and commercial uses has been estimated at the values given in Table 3. Even if demand actually registers a high rate of growth temporarily, this will not necessarily mean that the high rate of growth will continue into the future. The annual mean rate of growth of 12 to 10% for the next 10 years is a conservative estimate and is not believed to be too small.

Special demands other than general demands will be described in 3-4-5.

3-4-3 Load factor

Fig. 6-1 through 6-8 show daily load curves for Ubolratana Power Station and sub-stations of the Nam Pong System. According to these curves, the peak load occurs around 1900 to 1930 hours, and the daily load factor is 39 to 53%.

A feature of this district is that substantially no fluctuation occurs in the load curves throughout the four seasons of the year. Fluctuation in load curves between week days and week ends is also small because the load is composed mostly of residential and commercial demands and there is no industrial load. That is the shape of load curve will remain substantially unchanged throughout the year, while only the size of load will continue to grow.

The 22-KV distribution lines operated by PEA cannot necessarily ensure steady transmission of electricity at all times. Records show occurrence of several hours of service interruption and occasional outage up to several tens of hours. Therefore, it is believed that the annual load factor is considerably lower than the daily load factor.

In consideration of this situation, the annual load factor for residential and commercial uses has been estimated at 44 to 45% for principal cities and at 34 to 38% for other minor cities as shown in Table 4-1.

3-4-4 Size of demand

For the size of demand, the demand at the consuming end at the end of 1966 has been estimated. In the estimation of this value, the actual loads on the substations in the Nam Pong and Nam Pung Systems in May 1966, the estimated growth of load up to the end of the year, the progress and scheduled construction of 22-KV distribution lines which would possibly create new demands from villages and cities connected to the systems were taken into account. The estimated demand was then corrected by referring to the values contained in "Electrical Energy Demand Investigation Report" prepared by a Committee of the Government of Thailand.

The demand in KW for future years has also been estimated on the basis of the estimated demand at the consuming end at the end of 1966 and the estimated annual growth rate mentioned earlier in this chapter. The annual energy demand has been estimated based on the KW demand and the estimated annual load factor. The power and energy demands at the sending end have been estimated by adding the transmission loss to the demand at the consuming end. Table 5-1 through 5-3 show the results of these estimations.

3-4-5 Special demand

The demand for electricity in this district includes cooperative demand, military base demand and demand from Laos in addition to general residential and commercial demands.

Cooperative demand is a type of demand which originates from the development plan for remote agricultural districts promoted by free countries for the purpose of maintaining order in the north-east district of Thailand and thereby preventing the infiltration of communization. This demand is mainly pumping stations operated for the irrigation of farmland in dry season, shipyards of small scale, and minor farm industries. This plan is said to start taking shape from 1967. The estimated KW demand for this load are the values provided by NEEA. It has been assumed that only a very small portion of this load coincides with the existing system peak loads and that only the lighting load which accounts for about 30% of the demand coincides with the system peak loads. The annual mean rate of growth of KW demand has been estimated as 10% as shown in Table 3. The load factor is expected to fluctuate appreciably according to season in consideration of the assumed operating time of irrigation pumps and the nature of small industries for processing of agricultural produces. Therefore, the annual load factor has been estimated at 25% as shown in Table 4-2.

As regards to the demand of military bases, those bases which have been formally decided to receive supply from the system and those which are expected to receive supply from the system have been considered. The KW demand has been estimated to reach the ultimate value between 1966 and 1968 and level off thereafter. For the load factor, the same value as that for residential and commercial demand has been adopted.

The demand from Laos has already been discussed in paragraph 3-2. In accordance with the agreement formally concluded between Thailand and Laos, it has been assumed that transmission to Laos of 2 MW of electricity will start in November 1967, which is the scheduled time of completion of the transmission line and thereafter gradually increase ultimately to 8 MW. The annual load factor has been assumed to be 40%.

3-5 Demand and Supply Capability

Fig. 4-1 and 4-2 and Table 6-1 and 6-2 show the balance between the demand estimated in paragraph 3-4 and the supply capability of existing plants and proposed projects described in paragraph 3-2. The supply capability in KW of hydro-electric power stations has been estimated to be the smallest at the end of June when the reservoir water level has been drawn down and the output will recover and reach maximum at the end of December with the rise of the reservoir water level. As regards KWH, the annual values and average monthly values for both demand and supply capability are given.

It will be noted from the figures that there will be a deficiency in energy supply capability in and after 1968, and that deficiency will be created in both power and energy supply capability in and after 1969. The shortage of energy supply capability will be particularly pronounced.

3-6 Order of Development

This paragraph concerns the problem of overcoming the shortage of supply capability described in the preceding paragraph by the development of the Upper Nam Pong. Of the three projects considered in the Upper Nam Pong basin, the Lower Nam Chern site is judged not feasible at the present time for the reasons described later. For the remaining two sites, namely, Nam Phrom and Upper Nam Chern, two methods of development are conceivable depending on which will be developed first. For the purpose of identification, the following designations will be used.

Case A: Develop the Nam Phrom site first.

Case B: Develop the Upper Nam Chern site first.

3-6-1 Case A

Fig. 5-1 and 5-2 and Table 7-1 and 7-2 show the balance between demand and supply capability if the Nam Phrom site is developed first. The assumed construction schedule for the Nam Phrom site is to start construction at the end of 1968 and have the first unit (16.5 MW) ready for operation in the early part of 1972. It will be difficult to start construction earlier than the time given above and even if the construction period is curtailed, it might be possible to have power from the project available about 3 months ahead of schedule.

The deficiency in supply capability existing before the Nam Phrom site enters into operation, namely, the deficiency in supply capability occurring during the period between 1968 and 1971, must be filled by diesel generators. Assuming that these diesel generators are operated in parallel in the system and that the annual load factor is 80%, these generators are required to have an output of 7.5 MW during 1968 and 1970 and of 12.0 MW in 1971.

All existing and newly installed diesel generators will no longer be needed after 1972, the year in which the first unit (16.5 MW) of Nam-Phrom Project will be put into operation. The second unit (16.5 MW) should be ready in 1975, the year in which a shortage of KW capability is expected.

The shortage of energy capability which may arise in and after 1977 can be satisfied by the construction of the Upper Nam Chern Project.

3-6-2 Case B

Fig. 5-3 and 5-4 and Table 7-3 and 7-4 show the balance between demand and Supply capability if the Upper Nam Chern site is developed first.

It is assumed that construction of the Upper Nam Chern site will begin toward the end of 1968, and the plant (10 MW) ready for operation in the early part of 1971.

The deficiency of supply capability before Upper Nam Chern site enters into operation, namely, during the period 1968 through 1970, must be made available from diesel generators. As in Case A, the required capacity of diesel generators is 7.5 MW.

In 1971, the year in which the Upper Nam Chern Project enters into operation, existing diesel stations can be retired from service but those diesel stations added newly must be retained in operation for some time. In 1974, shortage of supply capability will emerge again. To meet the shortage, the Nam Phrom site should be developed. In order to have No. 1 unit (16.5 MW) of Nam Phrom Project ready in 1974, it is necessary to commence construction of the Nam Phrom Project in 1971, immediately after completion of Upper Nam Chern Project around the end of 1970. When the first unit of Nam Phrom Project is put into operation, all the diesel stations will not be required. It may be around 1977 that No. 2 unit (16.5 MW) must be added to the Nam Phrom Project.

CHAPTER 4.

SCHEME OF DEVELOPMENT

CHAPTER 4 SCHEME OF DEVELOPMENT

4-1 General Description of Project Area:

The project area of Upper Nam Pong Basin occupies the southwestern portion of the drainage basin of Ubolratana Dam on the Nam Pong. The drainage area of the Ubolratana Dam is about 12,000 Km^2, while the Upper Nam Chern site is 158 Km^2, Nam Phrom site is 545 Km^2, and Lower Nam site is 535 Km^2. The Upper Nam Pong basin is a mountain region, and the western ridge and the southern ridge form the watershed of the drainage basin of Ubolratana Dam. In the upper basin there are mountains rising more than 1,000 meters above sea level. Upper Nam Chern site and Nam Phrom site are both situated at high level, and the elevation of the river bed above sea level are 740 m and 690 m respectively. Lower Nam site is situated where the Nam Chern descends from the mountain region and flows into a plain. This site is not very high above sea level. The elevation of the river bed is about 240 meters above sea level. Nam Phrom and Nam Chern merge to form Lam Chern which joins the Nam Pong immediately upstream of Ubolratana Dam.

According to available data, the annual mean rainfall in this area is 1,000 to 1,100 mm. The rainfall is particularly heavy in the area where the monsoon from the southwest strike the mountainous region. At a glance, one will note that the drainage basin of the upper stream of Nam Phrom is more densely covered with trees than the drainage basin of the upper stream of Nam Chern. This indicates that the drainage basin of Nam Phrom has more rainfall.

The water resources in this area have not been developed, with the exception of Ubolratana Power Station constructed on the dowstream of Nam Pong. A head of 360 to 390 m can be developed in the Nam Phrom Project by diverting the flow of Nam Phrom to Nam Chern, and also in the Upper Nam Chern Project by diverting the flow of Huai Chan to Nam Chern. These diversions can be accomplished by constructing a short tunnel of 1.5 Km to 1.8 Km long and therefore the undeveloped water resources can be effectively utilized for generation of electricity.

The geology of this area belongs to so-called Korat series. Accordingly, sandstone is distributed widely, generally in substantially horizontal formation. There are very little outcrops. Results of field investigation show that there are no major faults in the area. Besides sandstone, there limestone and some conglomerate. Peculiar shaped mountains of limestone are found in a considerable numbers. Lower Nam Chern site is in a limestone zone. Both abutments of the dam site are limestone with highly developed cavities. Especially in the ridge on the left bank where the river makes an oxbow bend there is a large cave extending to the otherside of the ridge. In view of the nature of the limestone, there will be foundation problems to construct a dam at this site.

4-2 Basic Assumption:

4-2-1 Run-off at project site

For the study on run-off at the project sites, the run-off record for the period of from 1963 to 1965 at Ban Song Kon (situated close to Lower Nam Chern) on the Nam Chern, the run-off record for the period of from 1957 to 1965 at the dam site of Ubolratana on the Nam Pong, and the calculated values for the period of from 1952 to 1956 were used. The calculated run-off at the dam site of Ubolratana were obtained from "Nam Pong Project Engineering Report" prepared by Salzgitter Industriebau GmbH. From the records of run-off for the period of from 1963 to 1965 at Ban Song Kon and at Ubolratana, the correlation of run-off between the two sites was found. Using this relationship, the run-off at Ubolratana for the period of from 1952 to 1962 was used to calculate the run-off at Ban Song Kon for the same period. As the next step, the run-off of each project site was calculated on the basis of the ratio of drainage area, with the calculated run-off for the period of 1952 to 1962 at Ban Song Kon and the recorded run-off for the period of from 1963 to 1965 used as basic values. It is, of course, problematic to calculate the run-off of Nam Phrom from the run-off of Nam Chern merely based on the ratio of drainage area. However, there is no alternative but to resort to such method, because no record of run-off is available for Nam Phrom at the present time. As already mentioned in 4-1, the run-off of Nam Phrom is estimated to be greater than that of Nam Chern. Therefore, errors, if any, arising from this method are considered to be on the safe side.

Analysis of hydrological data such as the correlation between rainfall and run-off within the drainage basin should be studied in detail at the time of feasibility study.

4-2-2 Available discharge for power

Using the run-off obtained in 4-2-1, mass curves at the project site for the period of from 1952 to 1965 have been prepared. Based on these curves, the assured volume of flow for the period of from 1952 to 1965 has been calculated in accordance with the effective storage capacity of each reservoir. In estimating the effective storage capacity of the respective reservoirs, a capacity was determined which can regulate flow so that the average powerhouse discharge is approximate, in so far as possible, to the average annual inflow of the 12 years aforementioned.

Then, taking into account the actual trend of load curves in this area, the powerhouse maximum discharge has been obtained at an annual load factor of 40%.

Further investigations concerning the optimum scale of development, including studies of the storage volume of reservoirs, powerhouse discharge, etc. will be carried out at the time of feasibility study.

4-2-3 Installed capacity, firm output and annual energy production

Based on the powerhouse maximum discharge and assured volume of flow mentioned above, the installed capacity and guaranteed output have been estimated.

The annual energy production has been estimated by using the annual mean inflow for the period of from 1952 to 1965.

4-3 Scheme of Development:

An outline of each project is shown in the following table.

Basic Data of Proposed Projects

Item	Units	Power Station		
		Nam Phrom	Upper Nam Chern	Lower Nam Chern
Method of Power Generation		Dam-Waterway type	Dam-Waterway type	Dam type
Catchment Area				
Proper Area	km^2	545	158	535
Additional Area	"	-	-	545
Total	"	545	158	1,080
Reservoir				
Annual Inflow	10^6m^3 (m^3/S)	157 (5.0)	44 (1.4)	305 (9.7)
Reservoir				
Normal High Water Surface Level	m	747	775	290
Water Surface Area	km^2	8	4	17
Total Storage Capacity	10^6m^3	180	79	385
Effective Storage Capacity	10^6m^3	105	42	200
Available Drawdown	m	22	14	15
Dam				
Type		Rock-fill	Rock-fill	Rock-fill
Height x Crest Length	m	60 x 930	45 x 480	60 x 500
Volume	10^6m^3	1.8	0.6	1.4
Waterway				
Headrace Diameter x Length	m	2.5 x 1,500	2.0 x 1,800	-

Basic Data of Proposed Projects (Continued)

Item	Units	Power Station		
		Nam Phrom	Upper Nam Chern	Lower Nam Chern
Power Production				
Standard Intake Level	m	740	772	285
Tailwater Level	m	380	380	240
Standard Effective Head	m	350	382	44
Powerhouse Discharge				
Maximum	m^3/S	12.0	3.5	26.0
Firm	m3/S	4.7	1.4	9.7
Output				
Installed Capacity	MW	33.0	10.0	0.9
Dependable Capacity	MW	30.0	10.0	0.7
Annual Energy Production	10^6KWH	120	38	30
Transmission Line				
Section		P.S.-Chumpae - Khon Kaen	P.S.-Chumpae - Khon Kaen	P.S.-Chumpae - Khon Kaen
Distance	Km	140	120	140
Voltage & (Number of Circuit)	KV(cct)	115 (1)	115 (1)	115 (1)

Basic Data of Proposed Projects (Continued)

Item	Units	Power Station		
		Nam Phrom	Upper Nam Chern	Lower Nam Chern
Substation				
Location		Chumpae	Chumpae	Chumpae
Capacity	MVA	3	3	3
Voltage	KV	115/22	115/22	115/22
Construction Cost				
Generating End	10^3 ฿	348,335	141,668	220,558
Transmission & Substation	10^3 ฿	42,778	42,222	36,112
Total Construction Cost	10^3 ฿	391,113	183,890	256,670
Cost of Energy	฿/KWH	0.270	0.391	0.680
Benefit-Cost Ratio		1.55	1.13	-

CHAPTER 5.

COMPARISON OF PROJECTS

CHAPTER 5 COMPARISON OF PROJECTS

5-1 Construction Schedule

Construction schedules of the respective projects are indicated on Fig. 7-1 and 7-2. Periods of time required for each project are as follows:

Nam Phrom Project - 36 months (3 dry seasons)

Upper Nam Chern - 26 months (2 dry seasons)

Provided that access roads are completed by the end of 1968.

5-2 Construction Costs

5-2-1 Basic assumptions

(1) Construction costs have been roughly calculated by the use of a map to a scale of 1/50,000, traverse section of proposed dam sites and by taking into consideration the results of the field survey.

(2) Estimated construction costs have been divided into foreign currency and local currency requirements.

(3) Interest rates on investments: 6% per annum for foreign currency borrowings and 7% per annum for domestic currency.

(4) Duty on imported machinery and equipment: 30% of purchase prices.

(5) Land acquisition costs and compensation are estimated to be a small percentage of total construction costs and they have been included in contingencies.

(6) Construction costs of access roads and installation costs of electric power facilities have been estimated based on the assumption that the respective projects will be constructed independently.

5-2-2 Summary of construction costs

A summary of the estimated construction costs of the respective projects is given on the following table and details are shown in Table 8.

	Foreign Currency	Domestic Currency	Total	
			Foreign Currency	Domestic Currency
	1,000 $	1,000 ฿	1,000 $	1,000 ฿
Nam Phrom Project	10,556	180,001	19,557	391,113
Upper Nam Chern Project	4,722	89,446	9,195	183,890
Lower Nam Chern Project	6,195	132,780	12,833	256,670

5-3 Economic Justification

5-3-1 Salable power and energy

Salable power and energy of the respective projects may be calculated based on the estimated demand and supply capability discussed in Chapter 3, 3-6 Order of Development. In other words, salable power and energy of the Nam Phrom Station are available in Fig. 5-1 and 5-2 and Table 7-1 and 7-2, and that of the Upper Nam Chern Station in Fig. 5-3 and 5-4 and Table 7-3 and 7-4. On the other hand, salable power and energy of the Lower Nam Chern Station may be roughly estimated based on the figure of the Nam Phrom Station. However, electric power and energy to be received from the Nam Ngum Station in Laos in accordance with the contract has been considered to be a constant value.

Salable power and energy of the respective stations estimated as described above are given in the following table.

Year	Nam Phrom		Upper Nam Chern		Upper Nam Chern	
	Salable Power MW	Salable Energy 10^3 MWH	Salable Power MW	Salable Energy 10^3 MWH	Salable Power MW	Salable Energy 10^3 MWH
1971	-	-	9.4	24	-	-
1972	4.6	34	4.6	34	4.6	30
1973	8.8	51	9.8	38	8.8	↓
1974	13.4	69	10.0	↓	9.0	
1975	18.6	89	↓		↓	
1976	24.3	120				
1977	30.0	↓				
1978	↓					
2020			10.0	38		
2021	30.0	120	-	-	9.0	30
Average during 50 Years	28.4	115	9.9	38	8.9	30
Loss (%)	10	5.5	10	5.5	10	5.5
Average at Load Center	25.8	109	9.0	36	8.1	28

5-3-2 Annual costs and costs of energy

Annual costs have been obtained on the following assumptions. As mentioned earlier, interest rate on construction fund are 6% per annum for foreign currency and 7% per annum for domestic currency.

Bases of Calculations

Maintenance and Operation

Dam — 0.0033 x (Construction cost of dam)

Power Generating Facilities — 0.012 x (Construction cost of power generating facilities)

Transmission Line — 0.016 x (Construction cost of transmission line)

Substation 0.026 x (Construction cost of Substation)

Replacement of Turbines and Generators at 35 years, 7%

0.0937 x 0.07246 x (Cost of turbines and generators)

Replacement of Substation Equipment at 25 years, 7%

0.1872 x 0.07246 x (Cost of Substation Equip.)

Amortization of Investment Costs

Foreign Currency Cost, 50 years, 6%

0.06344 x (Investment cost paid in foreign currency)

Local Currency Cost, 50 years, 7%

0.07246 x (Investment cost paid in domestic currency)

Annual Cost and Cost of Energy

Item	Unit	Nam Phrom	Upper Nam Chern	Lower Nam Chern
Maintenance & Operation				
Dam	10^3 ฿	481	139	493
Power Generating Facilities	10^3 ฿	1,486	622	359
Transmission Line	10^3 ฿	648	654	556
Substation	10^3 ฿	59	35	35
Sub-total	10^3 ฿	2,674	1,450	1,443
Replacement of Turbines & Generators	10^3 ฿	329	130	155
Replacement of Substation Equipment	10^3 ฿	18	11	11
Amortization of Investment Cost				
Foreign Currency Cost	10^3 ฿	13,043	6,481	8,977
Domestic Currency Cost	10^3 ฿	13,393	5,992	8,424
Sub-total	10^3 ฿	26,436	12,473	17,401
Total Annual Cost	10^3 ฿	29,457	14,064	19,010
Salable Energy at Load Center	10^6KWH	109	36	28
Cost per KWH at Load Center	฿/KWH	0.270	0.391	0.680

As described in the following paragraph 5-3-3, the unit cost of energy of an assumed alternate 5,000 KW diesel station is 0.452฿/KWH. Among the proposed three projects, the cost per KWH of the Lower Nam Chern Project is 0.680฿ and this is higher than the said alternate source. This fact evidently indicates that the Lower Nam Chern Project is not justified economically, and at the present time, it is not an economic project.

5-3-3 Alternate source

For the purpose of benefit-cost studies, a 5,000 KW diesel station built near the center of load was assumed as an alternative source. The unit costs of power and energy of the diesel station were calculated and the values were used as basic unit prices for the calculation of benefit of the proposed projects. Calculation of the basic unit prices are given in Table-10. Basic data and unit costs are as follows:

Basic data -	Rated output	5,000 KW
	Annual utilization factor	45%
	Investment cost	24,450,000 ฿
	Fuel cost	0.9 ฿/Liter
Annual costs -	Interest rate	7%
	Cost of energy	0.452 ฿/KWH
Fixed costs -	Fixed costs	3,680,000 ฿
	Cost per KW	736 ฿
Variable costs -	Variable cost:	5,160,000 ฿
	Cost per KWH	0.264 ฿

5-3-4 Benefit cost ratio

Annual benefits are obtained from the salable power and energy described under 5-3-1 and the basic unit prices of the alternate source mentioned in 5-3-3. In other words, annual benefits are calculated based on the annual salable power and energy and the annual benefits are converted into present worth at the time of operation, and then equally distributed over the life of the project by the capital recovery method. The benefits thus obtained are given in the table which follows. Benefit-cost studies of the Lower Nam Chern Project have been omitted as the project has been determined not to be economically justified under 5-3-2.

Item	Unit	Nam Phrom	Upper Nam Chern
Benefit of KW (V_1)	10^3 ฿	17,900	6,700
Benefit of KWH (V_2)	10^3 ฿	28,000	9,300
Benefit ($V = V_1 + V_2$)	10^3 ฿	45,900	16,000
Annual Cost (C)	10^3 ฿	29,500	14,100
Benefit-Cost Ratio (V/C)		1.55	1.13

On the basis of the benefit-cost ratio only, the Nam Phrom Project may be said more advantageous than the Upper Nam Chern Project. However, in the benefit-cost ratio, the factor of time of operation was not sufficiently taken into consideration. Therefore, it cannot be simply concluded that the Nam Phrom Project should be developed first because its benefit-cost ratio is greater. The influence of time of operation will be further studied under 5-4.

5-4 Order of Development

As described in paragraph 3-6 of Chapter 3 Load Forecast, for the purpose of coping with the anticipated deficiency of supply capability, there are two different means: one is to develop the Nam Phrom Project first (Case A) and the other one is to take up the Upper Nam Chern Project first (Case B). Difference between these two alternatives are described below. (See Fig. 5-1 to 5-4 and Table 7-1 to 7-4.)

(1) In the supply territory under consideration, shortage of energy supply capability is more acute than the shortage in KW supply capability. From this point of view, Case A which is the Nam Phrom Project that will produce approximately 120,000,000 KWH annually is considered more advantageous than Case B which is the Upper Nam Chern Project that will generate approximately 38,000,000 KWH annually.

(2) If Case A is adopted it will be possible to retire from service all diesel stations after the year 1972, but some diesel stations must be retained until the end of 1973 if Case B is adopted.

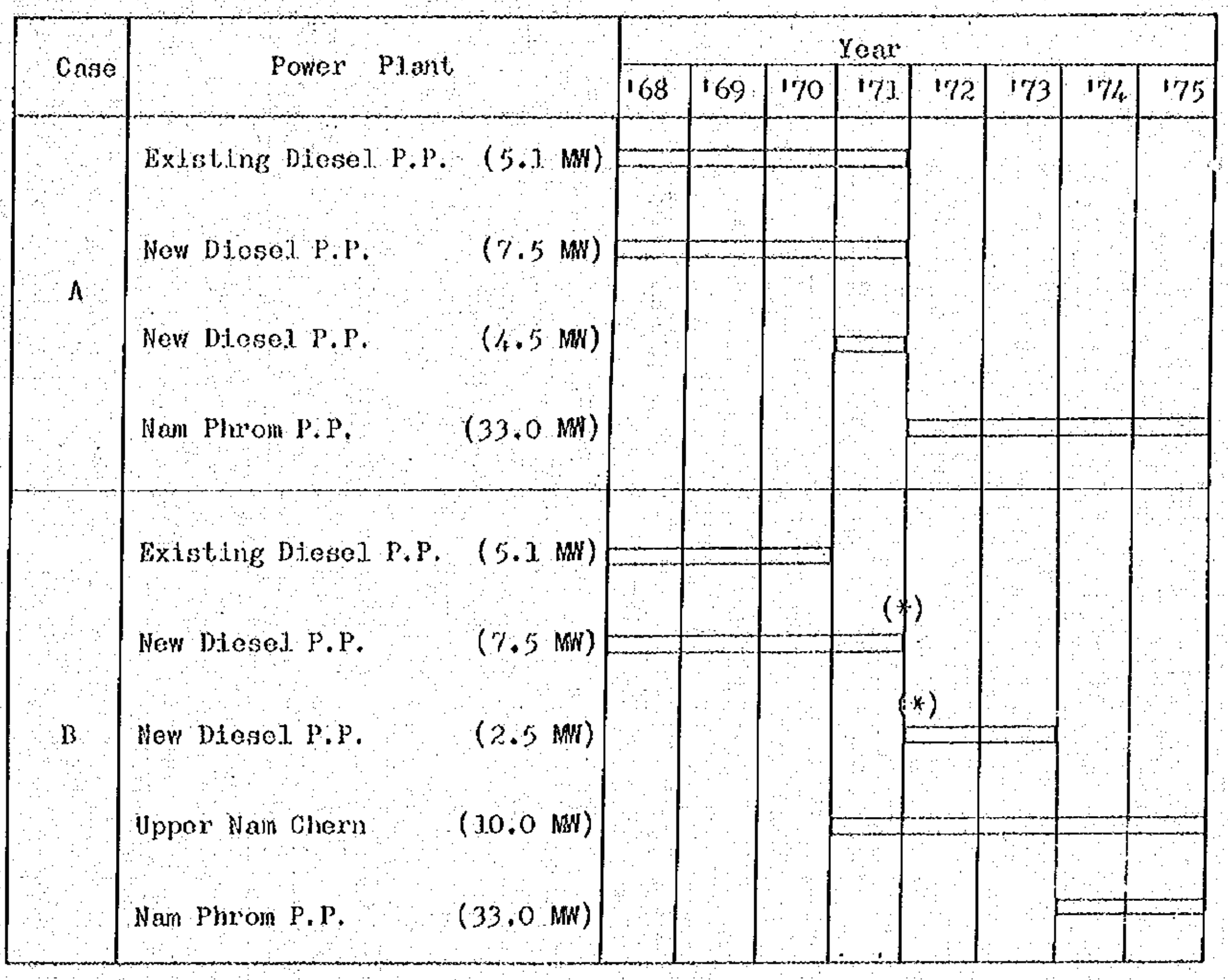
(3) If Case A is taken up, it will be possible to satisfy all demands until 1976 by constructing the Nam Phrom Project, while it will be required to construct the Nam Phrom Project immediately following the completion of the Upper Nam Chern Project if Case-B is adopted.

(4) The time of operation of Case A will be one year later than Case A. In Case A, due to this one year delay, it will be necessary to install approximately 4.5 MW of diesel capacity in 1971.

(5) In Case A, 5.1 MW of existing old diesel capacity cannot be retired from service until the end of 1971, but it may be retired at the end of 1970 in Case B.

(6) At the present time run-off records are not available for the Nam Phrom Project. Accordingly, if Case A is adopted and construction of the Nam Phrom Project is to commence at the end of 1968 it is evident that there will be a lack of run-off records. On the other hand, if Case B is adopted more run-off records will be available because construction of the Nam Phrom Project would get under way at the end of 1970.

Differences between Cases A and B have been described and now an attempt will be made to clarify in numerical values the better of the two projects. Let us first consider the eight-year period from 1968, when there will begin deficiency of supply capability, through to 1975 the last year of the load forecast. On the following chart is graphically indicated the generating installations of Case A and of Case B during this eight-year period. However, other hydro power generating facilities common to both Case A and Case B have been omitted.



Note: (*) 5.0 MW of 7.5 MW to be retired at the end of 1971 and 2.5 MW remains in service for two more years.

Then, annual costs of the respective power stations in Case A and Case B are calculated for each year and the values obtained are converted into 1968 present values. Annual costs of diesel stations may be obtained by using the criteria in Table-10 and by referring to the installed capacity and energy sales. The annual costs of Nam Phrom Project are calculated taking into account that the second unit is to be installed 3 years after the first unit. The total of said values is distributed uniformly over the said eight years by the capital recovery method in order to obtain annual costs.

On the other hand, salable energy in the respective years in Case A and Case B may be calculated from Table 6-2. And by averaging the figures thus obtained the average annual salable energy can be estimated.

Then the annual costs per unit of energy may be obtained from the annual costs and the annual salable energy. Details of the foregoing calculations are shown on Table-11 and the results are as follows:

Item		Case-A	Case-B
Annual Cost	(10^3 ฿)	27,100	26,900
Salable Energy at Substation	(10 KWH)	67.4	67.4
Cost per KWH at Substation	(฿)	0.45	0.45

It is obvious from the above that there is no difference in cost per unit of energy between Case A and Case B.

5-5 Technical Problems

The Lower Nam Chern site has an extremely serious geological problem. The bed rock of this dam site is limestone and there are a large number of cavities in both the right and left abutments. Especially in the left bank of the ridge formed by the oxbow bend of the river there is a huge cave that extends to the other side of the ridge. If a dam is constructed at this site, the load of the water stored behind the dam must be sustained by the ridge. This site is extremely unsuitable to construct a dam. At the present time, it is believed that this site is not economically feasible. This conclusion may be justified from the results of the economic evaluation.

It appears that there are no unusual engineering problems in the design and construction of the Upper Nam Chern and Nam Phrom Projects. However, it must be pointed out that there are 3 years run-off records available for the Nam Chern at the site of the Lower Nam Chern, but there are no run-off records for the Nam Phrom.

5-6 Conclusion

The following conclusions have been reached as a result of the comparative study of the projects.

(1) The Lower Nam Chern Project is not economical.

(2) At the present time it is difficult to make a decision as to which

project - the Nam Phrom or the Upper Nam Chern - should be developed with priority. It is therefore desirable to conduct further and detailed studies in order to make a sound decision. For this purpose it is necessary to continue investigations of the two sites.

CHAPTER 6.

FIELD INVESTIGATIONS FOR FEASIBILITY STUDY

CHAPTER 6 FIELD INVESTIGATIONS FOR FEASIBILITY STUDY

6-1 Items of Investigation

The decision to develop with priority either the Nam Phrom Project or the Upper Nam Chern Project will have close relation with the development of the Nam Ngum Project in Laos to be shortly commenced by the Mekong Committee and this decision will be made by the Government of Thailand and the NEEA. However, it is necessary to conduct the following field studies and study in detail the project plan in order to make feasibility studies of the projects.

6-1-1 Nam Phrom Project

a) Preparation of maps to a scale of 1/10,000 with 5 m contours of the reservoir area from aerial photographs. (for this purpose it is necessary to take aerial photographs to a scale of 1/10,000 to 1/20,000.)

b) Preparation of topographic maps to a scale of 1/1,000 covering the dam site, the penstock line and the powerhouse site.

c) Preparation of profile drawing of tunnel route.

d) Geological survey by core boring along the dam axis.

e) Exploratory shaft and core boring for material survey. Other additional investigations necessary will be instructed when EPDC engineers visit the site for feasibility studies.

6-1-2 Upper Nam Chern Project

a) Preparation of maps to a scale of 1/10,000 with 5 m contours of the reservoir area from aerial photographs. (for this purpose it is necessary to take aerial photographs to a scale of 1/10,000 to 1/20,000.)

b) Preparation of topographic maps to a scale of 1/1,000 covering the dam site, the penstock line and the powerhouse site.

c) Preparation of profile drawing of tunnel route.

d) Geological survey by core boring along the dam axis and along a ridge from the right abutment of the dam axis to about 3 km in a westerly direction.

e) Preparation of topographic map to a scale of 1/2000 with 1 m contour of the ridge from the right abutment dam axis to about 3 km in a westerly direction.

f) Exploratory shaft and core boring for material survey. Other additional investigations which may be necessary will be instructed when EPDC engineers visit the project site for feasibility studies.

Preparation of maps to a scale of 1/10,000 from aerial photographs of the reservoir areas of both projects will take considerable time, but such drawings are required to be completed as soon as possible for they will be extremely important in determining the storage capacities of the reservoirs of both projects. In order to prepare a feasibility report, which is scheduled to be submitted in April 1967 on either one of the projects, it is necessary to check the map to a scale of 1/50,000, Serial No. L708, prepared by the United States Army Map Service by traverse levelling along the main stream from the dam site in the reservoir area and by carrying out cross sectional surveying at 5 to 6 locations in the reservoir using the traverse line as the base line.

6-2 Items of Investigation and Schedule

Items of investigation and schedule are indicated on Table 11 and their locations are shown on Fig. 8.

Corresponding with the progress of the investigation, the items of investigation, schedule and locations may be modified depending on geological conditions. Such modifications, if required, will be made by EPDC engineers in the next field studies.