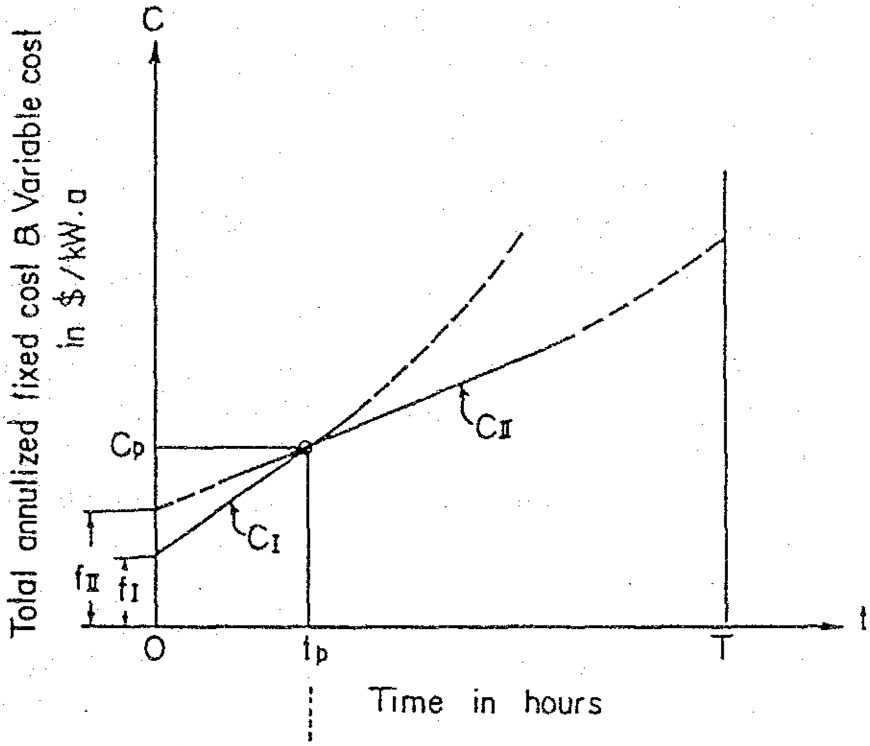


Fig. 9–2 Unit Cost Lines of Thermal Power Plants

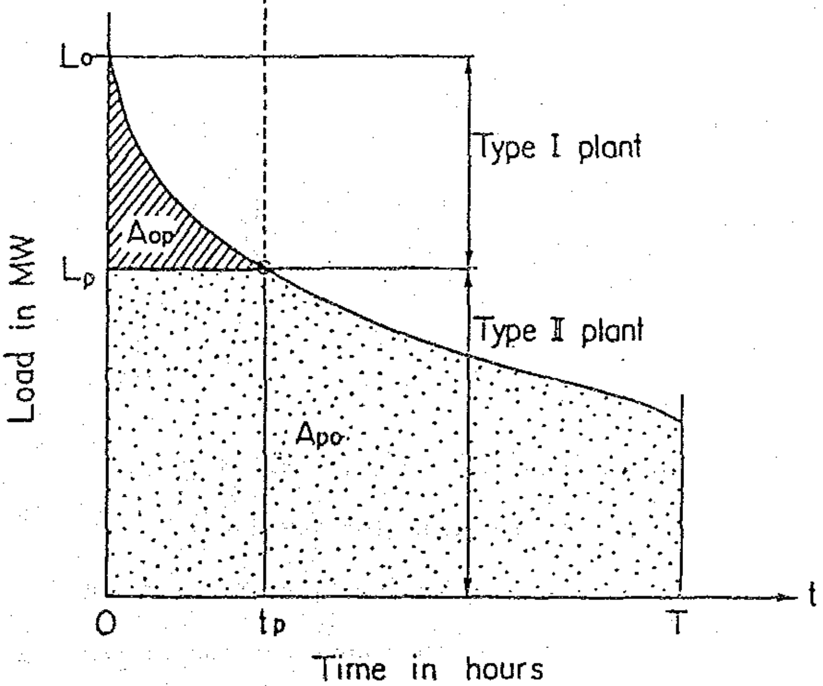


Fig. 9–3 Load Duration Curve Divided into Two Portions

Suppose that the load duration curve of the average demand day is given as illustrated on Fig. 9-3. The peak demand is L_o KW and the total energy requirement in this day is E (A_{op} + A_{po}) KWH.

The point t_p as above obtained is plotted on the time axis and a vertical line is drawn passing through this point and the intersection of this line with the load duration curve is then established. The horizontal line passing through this intersection divides the whole area under the load duration curve into two portions, the lower portion (dotted area) and the upper portion (hatched area). The height of the lower portion is denoted by L_p KW and that of the upper portion is (L_o - L_p) KW. The area of the former is represented by A_{po} KWH and that of the latter by A_{op} KWH.

It is obvious from the above reasoning that the lower portion should be supplied by the type II plant and the upper portion by the type I plant respectively.

Consequently, the total cost C_1 required to supply the thermal powers and energies to this demand can be calculated by the following formula:

$$c_1 = c_{1p} + c_{1e} \quad (7)$$

where,

$$c_{1p} = f_I (L_o - L_p) + f_{II} Lp$$
$$c_{1e} = v_I A_{op} + v_{II} A_{po} \quad (8)$$

and where,

c_1 : total cost

c_{1p} : capacity cost (or KW cost)

c_{1e} : energy cost (or KWH cost)

A_{op} : area of the upper portion in KWH

A_{po} : area of the lower portion in KWH

4) Benefit of Hydro Power Plant

As we have seen in Section 2, the power and energy generated by the hydro power plant occupy the unique portion under the given load duration curve. This is schematically reproduced on Fig. 9-4. The hatched area A_{12} represents the firm energy and the dotted area E_{24} shows the secondary energy of the hydro power plant. The firm capacity P_f takes the height $(L_1 - L_2)$ of the load interval. In addition, the dividing line L_p between type I and type II thermal teritories is superposed too.

It is seen that the area $A_{12} + E_{24}$ which was supplied previously by the thermal plants, has now been replaced by the energies of the hydro power plant.

The conventional method of evaluating the benefit of the hydro power plant is to equate the costs of the thermal power plants thus replaced by the hydro power plant to the benefit of this hydro power plant. Hence it is expressed as following:

$$B_o = B_p + B_{e1} + B_{e2} \qquad (9)$$

where

$$\begin{aligned} B_p &= f_I(L_1 - L_p) + f_{II}(L_p - L_2) \\ B_{e1} &= v_I A_{1p} + v_{II} A_{p2} \qquad (10) \\ B_{e2} &= v_{II} E_{24} \end{aligned}$$

and where,

B_o: benefit of the hydro power plant evaluated by the conventional method,

A_{1p}: area under the load duration curve between load levels L_p and L_1 in KWH,

A_{p2}: area under the load duration curve between load levels L_p and L_2 in KWH,

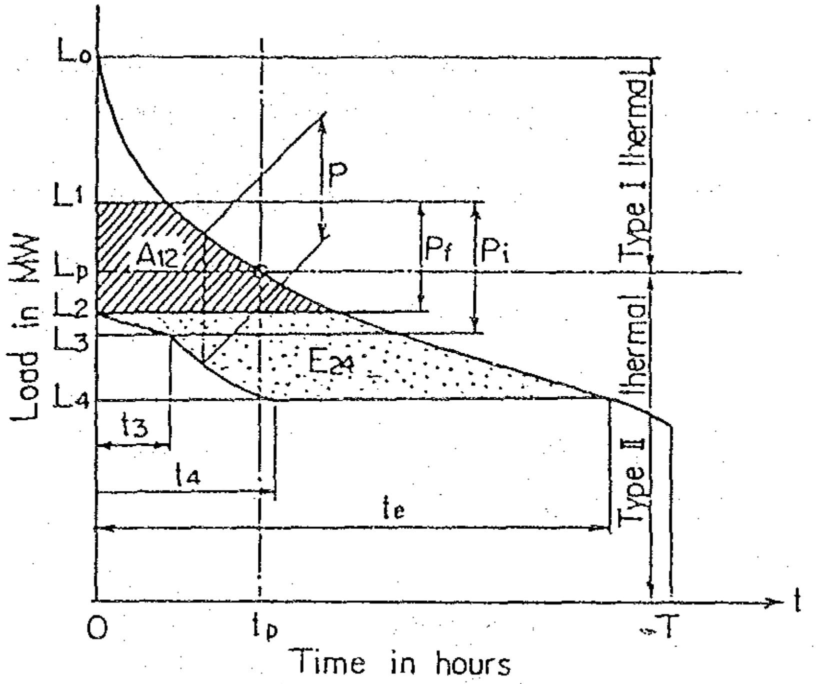
E_{24}: partial area under the load duration curve between load levels L_2 and L_4 occupied by the secondary energy of the hydro power plant in KWH.

Note that, according to the conventional method, the capacity benefit is evaluated only for the firm capacity (i.e. $L_1 - L_2$ KW) and other capacity benefits, if any, associated with the secondary energy are neglected. This is a very conservative way of evaluation because, as has been discussed in section 2, the hydro power plant can output more power than the firm capacity during most of the days in the entire period.

On Fig. 9-5, the area in which the hydro power and energy had occupied, has been eliminated (but is shown with the dotted line), and only the lower portion and the small top triangle portion remains. This remaining portion of the curve will be called a residual load duration curve.

Suppose now that a new load duration curve which is identical to the residual load duration curve is given.

Since the hydro portion has been eliminated, a new intersection L_u can be established between the same vertical line t_p and the residual load duration curve at the lower level than L_p. As the result, the lower portion of the residual demand, which is lower than the newly established load level L_u will now be supplied by the type II plant and the new upper portion by the type I plant.



for $0 < t < t_3$: $P_f \leq P < P_i$,

for $t_3 \leq t \leq t_4$: $P = P_i$,

for $t_4 < t < t_e$: $P < P_i$,

Fig. 9–4 Fitting Hydro Power & Energy under Load Duration Curve

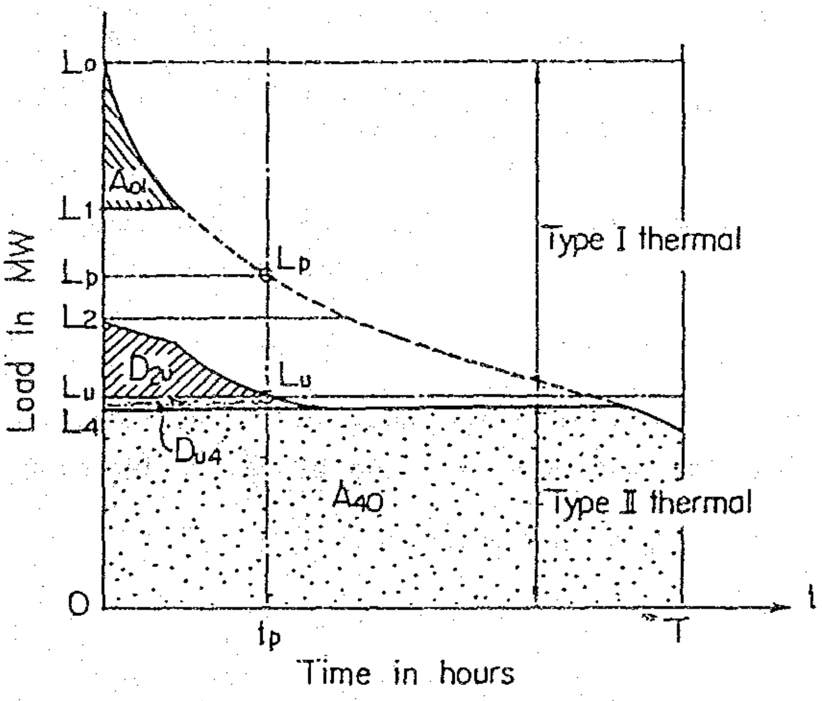


Fig. 9–5 Residual Load Duration Curve Supplied by Thermal Plants

The new cost C_2 of supplying the residual demand by the thermal power plants only is then calculated as follows:

$$C_2 = C_{20} + C_{2p} + C_{2e1} + C_{2e2} \qquad (11)$$

where,

$$\begin{aligned} C_{20} &= f_I(L_0 - L_1) + v_I A_{01} \\ C_{2p} &= f_I(L_2 - L_u) + f_{II} L_u \\ C_{2e1} &= v_I D_{2u} + v_{II} D_{u4} \\ C_{2e2} &= v_{II} A_{40} \end{aligned} \qquad (12)$$

where,

C_{2p} : capacity cost,

C_{2e1}: energy cost corresponding to the load range between L_2 and L_4,

C_{2e2}: energy cost corresponding to the load range less than L_4,

and where,

D_{2u}: area under the residual load duration curve between load levels L_2 and L_u in KWH,

D_{u4}: area under the residual load duration curve between load levels L_u and L_4 in KWH, and

A_{40}: area under the residual load duration curve below L_4 load level in KWH.

Now the benefit B of the hydro power plant must be the difference between the costs C_1 and C_2 as following:

$$B = C_1 - C_2 \qquad (13)$$

Upon substitution of the equations (7) and (11) for (13) and by taking the expression (10) into account, it follows:

$$B = B_p + B_{e1} + B_{e2} + \Delta B \qquad (14)$$

where,

$$B_p = f_I(L_1 - L_p) + f_{II}(L_p - L_2)$$

$$B_{e1} = v_I A_{1p} + v_{II} A_{p2} \qquad (15)$$

$$B_{e2} = v_{II} E_{24}$$

$$\triangle B = (v_I - v_{II}) \left\{ t_p(L_2 - L_u) - D_{2u} \right\} \qquad (16)$$

where we used the relation (6) to derive the equation (16). Note that the first three terms in the right side of the equation (14) add up to the benefit B_o as has been obtained by the equation (9).

Hence,

$$B = B_o + \triangle B \qquad (17)$$

But from Fig. 9-5 it is easily seen that $L_2 > L_u$ and $t_p(L_2 - L_u) > D_{2u}$, hence by considering the inequality relationship (4), it is concluded that

$$\triangle B > 0 \qquad (18)$$

In words, the incremental benefit of the hydro power plant over the benefit evaluated by the conventional method is positive.

In the above development, we have focussed on the case where the intersection L_p is positioned between load levels L_1 and L_2 as shown on Fig. 9-4 and Fig. 9-5. However, by the similar reasoning, the same conclusions could be obtained for all the cases of the positions of L_p varying from L_1 through L_4, although the detailed presentation is omitted here.

The incremental benefit, however, will not be adopted for the benefit evaluation of the hydropower plants in the following sections of economic analysis. Therefore, the calculated benefit will give a conservative result and the actual benefit will be larger than the value calculated there.

9.2 Alternative Thermal Power Plants

Combination of the following three types of thermal power plants were adopted as the appropriate alternative thermal plants for the evaluation of the benefit of the hydro power plant:

i) Gas turbine plant

fuel: natural gas for the first 25 years and diesel oil for the second 25 years

ii) Steam thermal power plant

fuel: natural gas for the first 25 years and imported coal for the second 25 years

iii) Lignite thermal power plant

fuel: lignite for the whole 50 years

Basic economic criteria and basic costs of these thermal plants are as shown on Table 9-1 for base case.

Based on these criteria, the annuitized fixed cost and variable cost for each of these thermal plants were calculated using the annual cost method as shown on Table 9-2 through Table 9-4.

The results for the base case are summarized as follows:

	kW-cost ฿/kW.a	kWh-cost ฿/kWh
Gas turbine	1810.1	1.0285
Steam thermal	3062.9	0.7190
Lignite	4735.8	0.5171

(price level: 1986)

Since these unit costs give the intercept and slopes of the unit cost lines as described in clause 9.1, these lines were determined and were plotted as shown on the Fig. 9-6.

Then the intersection points among these lines were established as shown on Table 9-5 for the base case.

It is seen from these results that the boundary time point between gas turbine and steam thermal is 46.2% (i.e. 11.1 hrs on daily base) and that between steam thermal and lignite thermal is 83.3% (i.e. 20.0 hrs on daily base).

Note the extremely high value 46.2% of the boundary point between gas turbine and steam thermal. This means that in order for the system to be operated most economically under the given fuel costs, the gas turbine should be operated at the plant factor of 46.2%.

The standard capacity factor of gas turbine adopted by EGAT is less than 5% (See EGAT data given on Oct. 7, 1985) and world wide standard is 10% as shown on Table 9-6. Compared with these standard capacity factors, more than 8 times (for EGAT standard) or 4 times (for world wide standard) of actual operation hours are expected to the above proposed gas turbine. This will result in the actual shortening of the economic life length of the gas turbine.

It is therefore reasonable to adopt the shorter life length of the gas turbine for the economic evaluation of the hydropower project which is assumed to be replaced by this heavy duty gas turbine.

For the base case, 10 years of the life length is adopted as shown on Table 9-2 and Table 9-7. This is only a half length of the EGAT standard of 20 years. (See EGAT data op. cit.)

The effect of fuel cost reduction on the capacity factor of the thermal power plant is not so severe as that of the gas turbine, but still exist to some degree. Therefore, the life length of the thermal power plant also shortened from 25 years to 20 years for the base case as shown on Table 9-3 and Table 9-7.

Now these boundary points were plotted on the load duration curves which were forecast in clause 2-7 for the years 2000 shown on Fig. 9-6 and Fig. 9-7.

As can be seen from these results the areas under the load duration curves are divided into three portions, i.e. gas turbine, steam thermal and lignite portion, so that for each of them, the respective unit costs as above estimated should be applied.

Among these curves, the one for the year 2000 was selected for the ensuing study as the load duration curve of the target year.

The underlying assumption is that at least two projects in the basin will come into the commercial operation by the year 2000.

Table 9–1 Economic Criteria and Basic Cost of Thermal Power Plants Case 0 (Base Case)

3rd stage study

		Unit	Hydro power plant	Gas turbine		Thermal		Lignite (50 years)	
				Natural gas (1st 25 years)	Diesel Oil (2nd 25 years)	Natural gas (1st 25 years)	Imported coal (2nd 25 years)		
	Installed capacity	MW	H	G	G	T	T	L	
a	Standard unit capacity	MW		25	25	600	600	600	EGAT data given on Oct.7,1985
b	Standard capacity factor	%		$X_g \leq 5$	$X_g \leq 5$	$40 \leq X_t \leq 85$	$40 \leq X_t \leq 85$	$40 \leq X_t \leq 85$	- ditto -
c	Economic life length adopted	years	50	10	10	20	25	25	
d	Station service rate	%	1	2	2	7	7	7	
e	Scheduled outage rate	%		2	2	13	13	13	
f	Forced outage rate	%		4	4	4	4	4	
g	Annual fixed O&M rate	%	1	3	3	2.5	2.5	2.5	
h	Unit construction cost w/o IDC	$/KW		320	320	580	957	957	
	ditto	฿/KW		8640	8640	15660	25839	25839	1 US$ = 27 ฿
	(Fuel)			Natural gas	Diesel oil	Natural gas	Imported coal	Lignite	
i	Fuel calorific value			1000Btu/cu.ft	8959.6Kcal/Lit	1000Btu/Cu.ft	5796Kcal/kg	2648.8Kcal/kg	EGAT data given on July 3,1986
j					= 35558Btu/Lit				
k	Thermal efficiency	%		25	25	36	36	36	
l	Energy equivalence	Kcal/KWH		3440Kcal/KWH	3440Kcal/KWH		2388.9Kcal/KWH	2388.9Kcal/KWH	- ditto -
m	= Plant heat value	Btu/KWH		13650.8Btu/KWH		9479.7Btu/KWH			
n	Fuel consumption			13.6508cu.ft/KW	0.3839Lit/KWH	9.4797cu.ft/KWH	0.4122kg/KWH	0.9019kg/KWH	- ditto -
o	Unit fuel price			71.0947฿/MBtu	3.68฿/Lit	71.0947฿/MBtu	1.484฿/kg	0.5332฿/kg	- ditto -
p	Unit fuel cost	฿/KWH		0.9705	1.4128	0.6740	0.6117	0.4809	- ditto - (Base case)
q	Effective capacity	MW		0.94G	0.94G	0.83T	0.83T	0.83L	(1-(e+f)/100fxInstalled capa.
r	Send-out capacity	MW	0.99H	0.92G	0.92G	0.77T	0.77T	0.77L	q x (1-a/100)
s	Energy production	MWH		GX_gH_r	GX_gH_r	TX_tH_r	TX_tH_r	LX_LH_r	
t	Send-out energy	MWH		$0.98GX_gH_r$	$0.98GX_gH_r$	$0.93TX_tH_r$	$0.93TX_tH_r$	$0.93LX_LH_r$	
u	Capital investment cost	฿		8640G	8640G	15660T	25839T	25839L	h x installed capacity
v	Annual O&M cost	฿		259.2G	259.2G	391.5T	646.0T	646.0L	u x g
w	Daily O&M cost	฿		0.7101G	0.7101G	1.0726T	1.7698T	2.1238L	v/365
x	Fuel cost	฿		$0.9705GX_gH_r$	$1.4128GX_gH_r$	$0.6740TX_tH_r$	$0.6117TX_tH_r$	$0.4809LX_LH_r$	s x p

Table 9–2 Cost Stream of Alternative Gas Turbine (Natural Gas – Diesel Oil) Case 0 (Base Case)

3rd stage study

Year	Single payment worth factor 1)	Capital investment cost						O&M	Fuel Cost		
		Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Total		for the 1st 25 years	for the 2nd 25 years	Total
n	i = 10%										
0	1.000	8640G									
1								259.2G	$0.9705GXgH_r$		
10	0.385543		8640G								
20	0.148644			8640G							
25										$1.4128GXgH_r$	
30	0.057308				8640G						
40	0.022095					8640G					
50	0.008519										
Present value factor		1.000	0.385543	0.148644	0.057308	0.022095			9.077040 3)	0.8377745 4)	
Present value		8640G	3331.1G	1284.3G	495.1G	190.9G	13941.4G		$8.8093GXgH_r$	$1.1836GXgH_r$	$9.9929GXgH_r$
Capital recovery factor		0.10085917 5)									
Annuitized cost							1406.1G	259.2G			$1.0079GXgH_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	1406.1G	
O&M	฿	259.2G	
Fuel	฿		$1.0079GXgH_r$
Total	฿	1665.3G	$1.0079GXgH_r$

	Unit	Cost	
KW-benefit	฿/KW	1810.1	1665.3G/0.92G
KWH-benefit	฿/KWH	1.0285	$1.0079GXgH_r/0.98GXgH_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... Yg = 1810.1 + 1.0285 x 8760 Xg

Daily cost ...... Yg = 1810.1/365 + 1.0285 x 24 Xg = 4.9592 + 24.6840Xg

Table 9–3 Cost Stream of Alternative Steam Thermal (Natural Gas – Imported Coal) Case 0 (Base Case)

3rd stage study

Year	Single payment worth factor 1)	Capital investment cost: Plant 1 Natural gas	Capital investment cost: Plant 2 Natural gas	Capital investment cost: Plant 3 Imported coal	Capital investment cost: Total	O&M cost: Plant 1 & Plant 2	O&M cost: Plant 3	O&M cost: Total	Fuel cost: for the 1st 25 years	Fuel cost: for the 2nd 25 years	Fuel cost: Total
n	i = 10%	T MW	T MW	T MW							
0	1.000	15660T									
1						391.5T ↓			$0.674TX_tH_r$ ↓		
20	0.148644		15660T								
25	0.092296		$-\frac{15}{20}$ 15660T	25839T							
							646.0T ↓			$0.6117TX_tH_r$ ↓	
50	0.008519										
Present value factor i = 10%		1.000	0.148644 0.092296	0.092296		9.07704 3)	0.83777 4)		9.07704 3)	0.83777 4)	
Present value		15660T	2327.8T -1084.0T	2384.8T	19288.6T	3553.7T	541.2T	4094.9T	$6.118TX_tH_r$	$0.512TX_tH_r$	$6.630TX_tH_r$
Capital recovery factor		← 0.10085917 5) →									
Annuitized cost					1945.4T			413.0T			$0.6687TX_tH_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	1945.4T	
O&M	฿	413.0T	
Fuel	฿		$0.6687TX_tH_r$
Total	฿	2358.4T	$0.6687TX_tH_r$

	Unit	Cost	
KW-benefit	฿/KW	3062.9	2358.4T/0.77T
KWH-benefit	฿/KW	0.7190	$0.6687TX_tH_r/0.93TX_tH_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... $Y_t = 3062.9 + 0.7190 \times 8760X_t = 3062.9 + 6298.4X_t$

Daily cost ...... $Y_t = 3062.9/365 + 0.7190 \times 24X_t = 8.392 + 17.256X_t$

Table 9–4 Cost Stream of Alternative Steam Thermal (Lignite) Case 0 (Base Case)

3rd stage study

Year	Single payment worth factor 1)	Capital investment cost			O&M cost			Fuel cost		
		Plant 1	Plant 2	Total	Plant 1	Plant 2	Total	for the 1st 25 years	for the 2nd 25 years	Total
n	i = 10%	L MW	L MW					Lignite	Lignite	
0	1.0	25839L								
1 ↓					646.0L ↓		646.0L ↓	$0.4809LX_1H_r$ ↓		$0.4809LX_1H_r$ ↓
25 ↓	0.092296		25839L			646.0L ↓			$0.4809LX_1H_r$ ↓	
50										
Present value factor i = 10%		1.0	0.092296					9.077043)	0.837774)	
Present value		25839L	2384.8L	28223.8L						
Capital recovery factor		← 0.100859175) →								
Annuitized cost				2846.6L			646.0L			$0.4809LX_1H_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	2846.6L	
O&M	฿	646.0L	
Fuel	฿		$0.4809LX_1H_r$
Total	฿	3492.6L	$0.4809LX_1H_r$

	Unit	Cost	
KW-benefit	฿/KW	4535.8	3492.6L/0.77L
KWH-benefit	฿/KW	0.5171	$0.4809LX_1H_r/0.93LX_1H_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... $Y_1 = 4535.8 + 0.5171 \times 8760Y_1 = 4535.8 + 4529.8X_1$

Daily cost ...... $Y_1 = 4535.8/365 + 0.5171 \times 24X_1 = 12.4268 + 12.4104X_1$

Table 9–5 Intersection Points of Cost Curves (Base Case)

Cost curves of gas turbine

$$y_g = 4.9592 + 24.6840\ X_g \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

Cost curves of thermal

$$y_t = 8.392 + 17.256\ X_t \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

Cost curves of lignite

$$y = 12.4268 + 12.4104\ X \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (3)$$

Intersection point of (1) and (2),

$$X_{g,t} = \frac{8.392 - 4.9592}{24.6840 - 17.256} = 0.4621$$

for daily base, 0.4621 x 24 hr = 11.1 hr

Intersection point of (2) and (3)

$$X_{t,\ell} = \frac{12.4268 - 8.392}{17.256 - 12.4104} = 0.8327$$

for daily base, 0.8327 x 24 hr = 20.0 hr

Table 9–6 Plant Characteristics

Dury cycle	Nominal annual capacity factor	Cost factors	Performance factor	Typical Power plant type
Base	65%	Low fuel cost; high capital cost	Designed for high reliability and high efficiency	Hydroelectric, nuclear, large coal- or oil-fired units
Intermediate	30%	Intermediate to high capital cost; intermediate fuel cost	Flexible performance	Small coal-fired unit; oil-fired; large gas-fired units
Peaking	10%	Low capital cost; high fuel cost	Flexible performance; quick starting; short construction lead time	Small gas- or oil-fired boilers; gas- or oil-fired combustion turbines; diesel generators

Source: "Expansion Planning for Electrical Generating Systems", International Atomic Energy Agency, Vienna, 1984, Table 9.1, p.344.

Table 9–7 Additional Study, Variations of Fuel Cost, Capacity Factors and Economic Life Lengths of Alternative Thermals

Daily plant factor of hydro power plant at max. demand day = 0.15, discount rate = 10%

Additional study

	Unit	Case 0 Base Case	Case 1	Case 2	Case 3
[1] Alternative thermal plants					
a) Unit fuel cost					
Gas turbine (natural gas)	฿/KWH	0.9705 1)	1.0560	1.1415	1.2270
Gas turbine (diesel oil)	฿/KWH	1.4128 1)	1.6638	1.9149	2.1659
Gas turbine (natural gas - diesel oil)	฿/KWH	1.0092			
Thermal (natural gas)	฿/KWH	0.6740 1)	0.6974	0.7208	0.7442
Thermal (imported coal)	฿/KWH	0.6117 1)	0.6254	0.6392	0.6529
Thermal (natural gas - imported coal)	฿/KWH	0.6687			
Lignite(lignite)	฿/KWH	0.4809 1)	0.4843	0.4877	0.4912
b) Estimated ranges of capacity factors					
Gas turbine, X_g	%	0 - 37.5			
Thermal, X_t	%	37.5 - 83.3			
Lignite, X_l	%	83.3 - 100			
c) Standard ranges of capacity factors					
Gas turbine, X_{go}	%	$X_{go} \leqq 5$ 2)			
Thermal, X_{to}	%	$40 \leqq X_{to} \leqq 85$ 2)			
Lignite, X_{lo}	%				
d) Estimated economic life length					
Gas turbine	year	10	12	14	16
Thermal (natural gas)	year	20	21	22	23
Thermal (imported coal, lignite)	year	25	25	25	25

1) Given by EGAT on July 3, 1986.

2) Given by EGAT on Oct. 7, 1985.

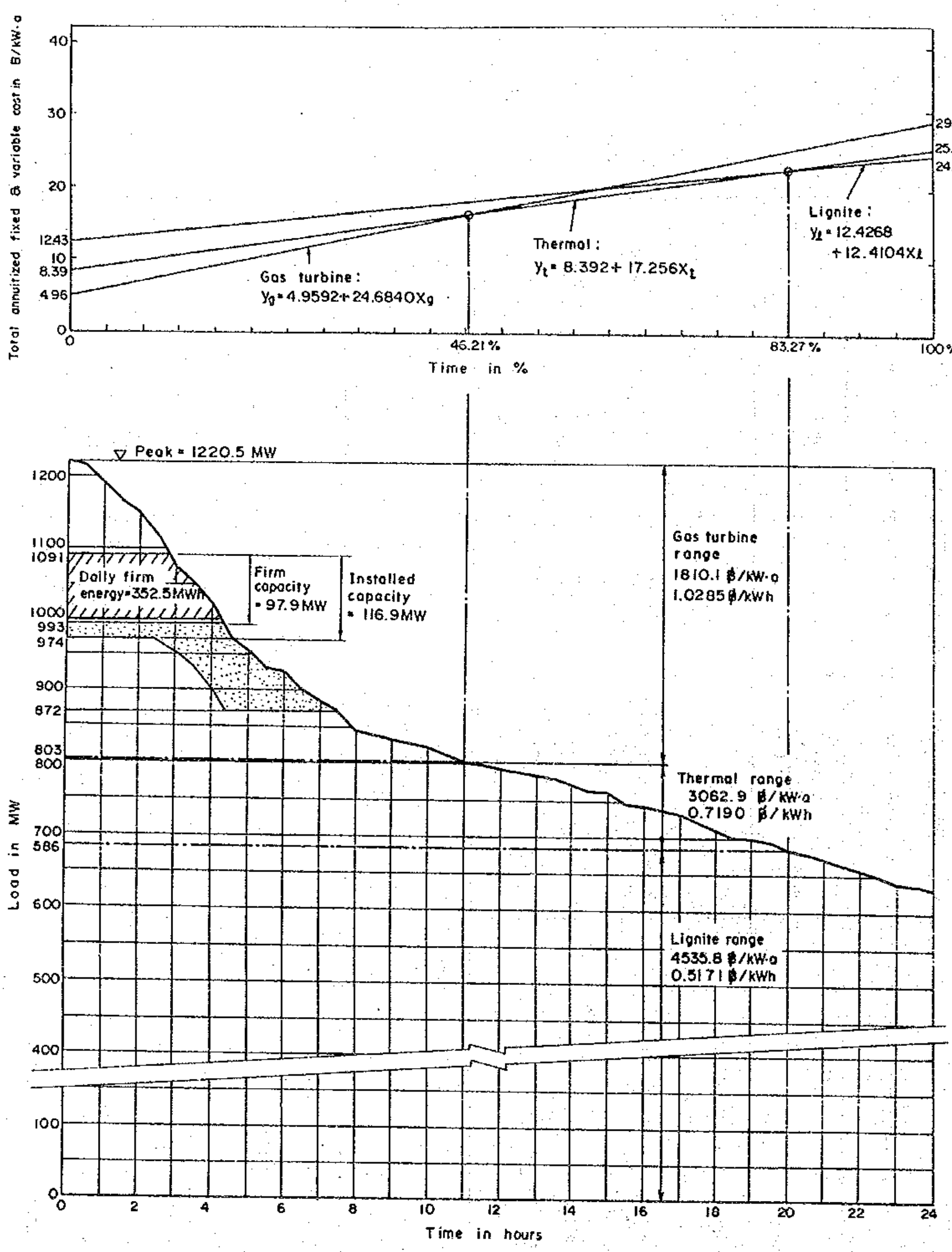


Fig. 9–6 Load Durations Curve of Northern Region 2000 with Nam Mae Ngao No. 2 (N02A 260.25b) fitted

fitted and replaced the portion of demand which otherwise might be supplied by the optimal combination of thermal plants obtained by screening curve method (Case O)

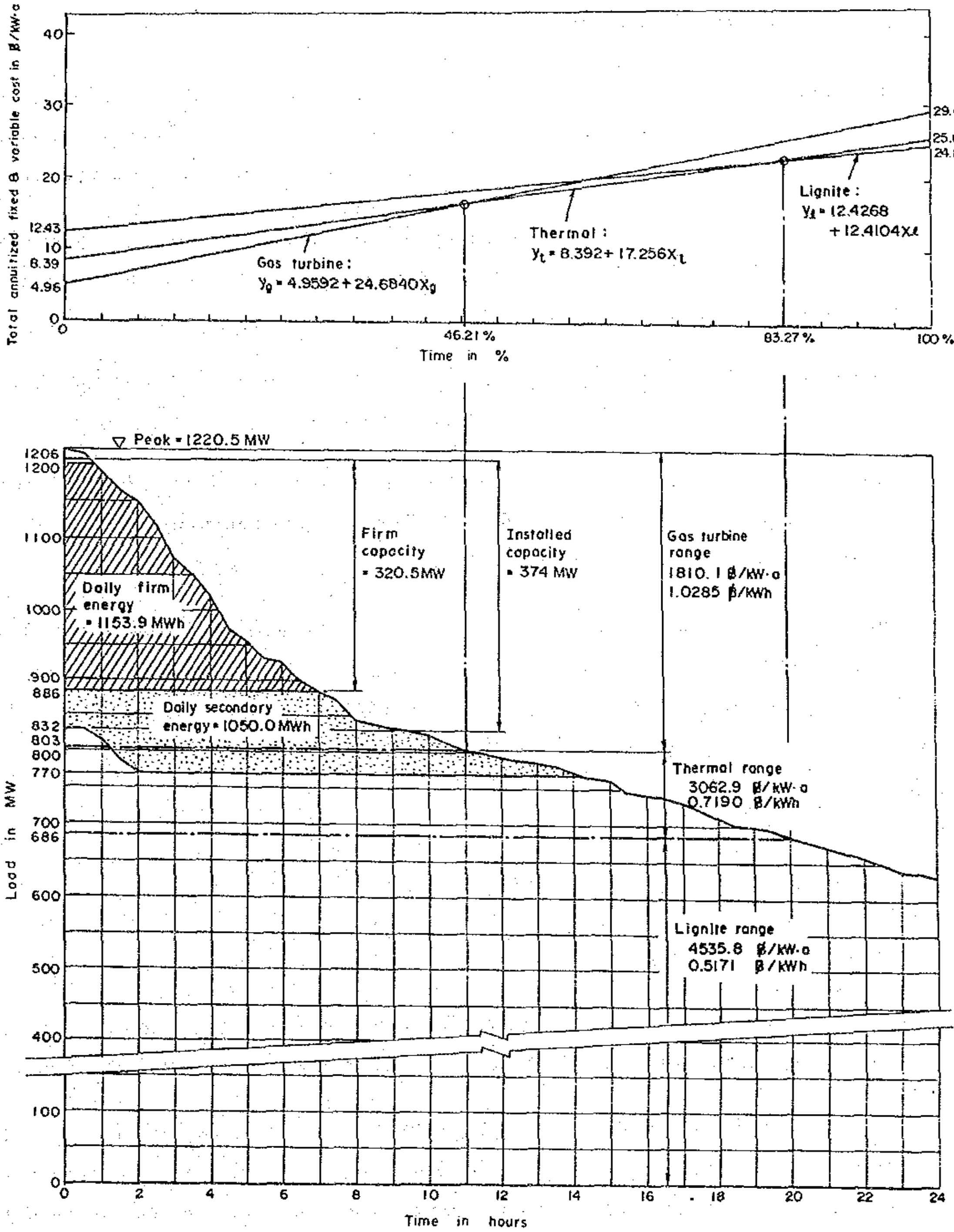


Fig. 9–7 Load Durations Curve of Northern Region 2000 with Nam Mae Ngao + Lower Yuam fitted

fitted and replaced the portion of demand which otherwise might be supplied by the optimal combination of thermal plants obtained by screening curve method (Case O)

9.3 Benefits of the Hydro Power Projects

The capacity and energy of each hydro power project which were calculated by the reservoir operation study for each case of variations as described in clause 5.4, were fitted under the load duration curve.

Since the capacities and energies estimated by the reservoir operation vary case by case, the positions that these capacities and energies occupy under the load duration curve differ correspondingly.

Consequently, the thermal costs that were replaced by these hydro power projects are different from case to case.

Thus the benefits of all the cases of the variations of the hydro power projects were calculated. Of these, the representative one is shown in Table 9-8, Table 9-9 and Table 9-10.

These tables show the economic evaluations of Nam Mae Ngao individual development, Lower Yuam individual development and Nam Mae Ngao & Lower Yuam integrated development respectively.

Fig. 9-6 shows the fitting of the output of Nam Mae Ngao project under the load duration curve.

As can be seen from this plotting, the power and energy of Nam Mae Ngao No.2 project (case (3) NO2A260.25b) are entirely situated within the gas turbine range.

Fig. 9-7 shows the fitting of the output of Nam Mae Ngao and Lower Yuam integrated project under the same load duration curve as above.

It is seen in this case, although both the firm capacity and firm energy are suited for the gas turbine range, a part of the secondary energy falls in the gas turbine range and the rest of the secondary energy comes in the thermal range.

Therefore, for the Nam Mae Ngao individual development, the unit costs of the gas turbine (i.e. 1810.1 ฿/kW for firm capacity and 1.0285 ฿/kWh for firm energy) can be applied directly, but for Nam Mae Ngao and Lower Yuam integrated development the unit cost of the gas turbine and that of the thermal should be averaged (weighted average in proportion to the shares of the respective ranges).

The averaged unit energy cost in this case is then calculated at 0.9228 ฿/kWh as shown on Table 9-10.

Table 9–8–1 Additional Study, Economic Evaluation of Nam Mae Ngao Individual Development for Various Cases of Fuel Cost

Additional study — Discount rate = 10%

	Unit	Case 0	Case 1	Case 2	Case 3
Simulation Case No.		N02A260.25b			
a) Project features					
Catchment area	km^2	835			
Annual flow	MCM	1272			
HWL	m	260			
NIWL	m	248.4			
LWL	m	235			
TWL	m	163			
Effective head	m	82.5			
Daily plant factor at max. demand day	%	15			
Capacity factor	%	23.9			
Firm discharge (95% probability)	cms	24.9			
Max. turbine discharge	cms	166.2			
Installed capacity	MW	116.9			
Firm capacity	MW	97.9			
Annual energy production	GWH	245.2			
Annual firm energy	GWH	128.6			
Annual secondary energy (97%)	GWH	116.5			
b) Project economy					
Construction Cost					
for generating facilities	M฿	3081.3	3081.3	3081.3	3081.3
for transmission facilities	M฿	89.5	89.5	89.5	89.5
Annual cost					
for generating facilities, n=50, O&M 1%	M฿	342.0	342.0	342.0	342.0
for transmission facilities, n=40,O&M1%	M฿	10.1	10.1	10.1	10.1
for transmission loss, see next page	M฿	0.7	0.7	0.7	0.7
Total annual cost, C	M฿	352.8	352.8	352.8	352.8
Annual benefit					
for firm capacity	M฿	@1810.1 177.2	@1660.7 162.6	@1557.9 152.5	@1482.6 145.1
for firm energy	M฿	@1.0285 132.3	@1.1300 145.4	@1.2315 158.4	@1.333 171.5
for secondary energy	M฿	@1.0285 119.8	@1.1300 131.6	@1.2315 143.5	@1.331 155.0
Total annual benefit, B	M฿	429.3	439.6	454.4	471.6
c) B–C	M฿	76.5	86.8	101.6	118.8
B/C		1.22	1.25	1.29	1.34
Annual energy cost	฿/KWH	1.439	1.439	1.439	1.439

Table 9–8–2 Additional Study, Transmission Loss for Nam Mae Ngao Individual Development (116.9 MW)

Additional study

		Unit	Case 0	Case 1	Case 2	Case 3
Capacity loss	(A)	MW	0.311	0.311	0.311	0.311
Average capacity cost	(B)	฿/KW	1810.1	1660.7	1557.9	1482.6
(A) x (B)		M฿	0.563	0.516	0.485	0.461
Annual energy loss	(C)	MWH	165.6	165.6	165.6	165.6
Average energy cost	(D)	฿/KWH	1.0285	1.1300	1.2315	1.332
(C) x (D)		M฿	0.170	0.187	0.204	0.221
Total transmission loss		M฿	0.733 ≑ 0.7	0.703 ≑ 0.7	0.689 ≑ 0.7	0.682 ≑ 0.7

Table 9–9–1 Additional Study, Economic Evaluation of Lower Yuam Individual Development for Various Cases of Fuel Costs

Additional study

Discount rate = 10%

	Unit	Case 0	Case 1	Case 2	Case 3
Simulation Case No.		YOV170.20o			
a) Project features					
Catchment area	km^2	592.0			
Annual flow	MCM	2818			
HWL	m	170			
NIWL	m	161.7			
LWL	m	150			
TWL	m	73.2			
Effective head	m	85.6			
Daily plant factor at max. demand day	%	14.8			
Capacity factor	%	38.0			
Firm discharge (95% probability)	cms	32.5			
Max. turbine discharge	cms	219.5			
Installed capacity	MW	162.0			
Firm capacity	MW	139.9			
Annual energy production	GWH	538.9			
Annual firm energy	GWH	181.6			
Annual secondary energy (97%)	GWH	357.3			
b) Project economy					
Construction Cost					
for generating facilities	M฿	4352	4352	4352	4352
for transmission facilities	M฿	550	550	550	550
Annual cost					
for generating facilities, n=50, i=0.1	M฿	483.1	483.1	483.1	483.1
for transmission facilities, n=40, i=0.1	M฿	62.2	62.2	62.2	62.2
for transmission loss, see next page	M฿	8.3	7.8	7.6	7.3
Total annual cost, C	M฿	553.6	553.1	552.9	552.6
Annual benefit					
for firm capacity	M฿	@1810.1 253.2	@1660.7 232.3	@1557.9 218.0	@1482.6 207.4
for firm energy	M฿	@1.0285 186.8	@1.1300 205.2	@1.2315 223.6	@1.333 242.1
for secondary energy	M฿	@0.9349 334.0	@0.9566 341.8	@0.99606 355.8	@0.98877 353.2
Total annual benefit, B	M฿	774.0	779.3	797.4	802.7
c) B–C	M฿	220.4	226.2	244.5	250.1
B/C		1.40	1.41	1.44	1.45
Annual energy cost	฿/KWH	1.027	1.026	1.026	1.025

Table 9–9–2 Additional Study, Transmission Loss for Lower Yuam Individual Development (162 MW)

Additional study

		Unit	Case 0	Case 1	Case 2	Case 3
Capacity loss	(A)	MW	3.55	3.55	3.55	3.55
Average capacity cost	(B)	฿/KW	1810.1	1660.7	1557.9	1482.2
(A) x (B)		M฿	6.426	5.895	5.531	5.263
Annual energy loss	(C)	MWH	1888	1888	1888	1888
Average energy cost	(D)	฿/KWH	0.9664	1.0150	1.0752	1.1047
(C) x (D)		M฿	1.825	1.916	2.030	2.086
Total transmission loss		M฿	8.251 ≑ 8.3	7.811 ≑ 7.8	7.561 ≑ 7.6	7.349 ≑ 7.3

Table 9–10–1 Additional Study, Economic Evaluation of Nam Mae Ngao + Lower Yuam Integrated Development for Various Cases of Fuel Costs

Additional study — Discount rate = 10%

	Unit	Case 0	Case 1	Case 2	Case 3
Simulation Case No.		N02A260.25b+Y0A170.20c			
a) Project features					
Catchment area	km^2	5920			
Annual flow	MCM	2825			
HWL	m	260 & 170			
NIWL	m	248.4 & 161.4			
LWL	m	235 & 150			
TWL	m	163 & 73.2			
Effective head	m	82.5 & 85.3			
Daily plant factor at max. demand day	%	15			
Capacity factor	%	23.9 & 24.8			
Firm discharge (95% probability)	cms	24.9 & 52.4			
Max. turbine discharge	cms	166.2 & 349.3			
Installed capacity	MW	116.9 + 257.1 = 374.0			
Firm capacity	MW	97.9 + 222.6 = 320.5			
Annual energy production	GWH	245.2 + 559.3 = 804.4			
Annual firm energy	GWH	128.6 + 292.5 = 421.1			
Annual secondary energy (97%)	GWH	116.5 + 266.8 = 383.3			
b) Project economy					
Construction Cost					
for generating facilities	M฿	8250.1*1)	8250.1	8250.1	8250.1
for transmission facilities	M฿	660.0*2)	660.0	660.0	660.0
Annual cost					
for generating facilities, n=50, i=0.1	M฿	915.8	915.8	915.8	915.8
for transmission facilities, n=40, i=0.1	M฿	74.6	74.6	74.6	74.6
for transmission loss, see next page	M฿	21.7	20.5	19.8	19.2
Total annual cost, C	M฿	1012.1	1010.9	1010.2	1009.6
Annual benefit					
for firm capacity	M฿	@1810.1 580.1	@1660.7 532.3	@1557.9 499.3	@1482.6 475.2
for firm energy	M฿	@1.0285 433.2	@1.1300 475.9	@1.2315 518.7	@1.333 561.4
for secondary energy	M฿	@0.9228 353.7	@0.9143 350.4	@0.92537 354.6	@0.84142 322.5
Total annual benefit, B	M฿	1367.0	1358.6	1372.6	1359.1
c) B-C	M฿	354.9	347.7	362.4	349.5
B/C		1.35	1.34	1.36	1.35
Annual energy cost	฿/KWH	1.258	1.257	1.256	1.255

Generating f.	
Ngao	3081.3
Lower Yuam	5168.8
Total	8250.1*1)
Transmission f.	
Ngao	89.5
Lower Yuam	570.5
Total	660.0*2)

Table 9–10–2 Additional Study, Transmission Loss for Nam Mae Ngao + Lower Yuam Integrated Development (116.9 + 257.1)

Additional study

		Unit	Case 0	Case 1	Case 2	Case 3
Capacity loss	(A)	MW	9.3	9.3	9.3	9.3
Average capacity cost	(B)	฿/KW	1810.1	1660.7	1557.9	1482.6
(A) x (B)		M฿	16.834	15.445	14.488	13.788
Annual energy loss	(C)	MWH	4924	4924	4924	4924
Average energy cost	(D)	฿/KWH	0.9782	1.0272	1.0857	1.0988
(C) x (D)		M฿	4.817	5.058	5.346	5.410
Total transmission loss		M฿	21.651 ≑ 21.7	20.503 ≑ 20.5	19.834 ≑ 19.8	19.198 ≑ 19.2

9.4 Costs of the Hydro Power Projects

The construction costs of all the cases of the variation of the hydro power projects were estimated.

The annuitized capital costs then were calculated basing upon the construction cost using the same discount rate (10%) as adopted in the calculation of the benefits described in the foregoing sections.

Thus the capital recovery factor, CRF is 0.10086 for the assumed project life of 50 years for the generation facilities and 40 years for the transmission facilities.

The operation and maintenance costs for the hydro power project and transmission line are estimated at 1% of the construction costs.

Thus the annuity factor of 0.111 is applied for the annuity costs or the generation facilities and 0.113 for the transmission facilities.

The results are shown on Table 9-8 through 9-10.

9.5 B-C and B/C

Using the results of benefits and costs as above obtained, B-C and B/C were calculated for all the cases of the study and the results were included in the same tables as explained above.

It is seen that the case N02A260.25b of Nam Mae Ngao No.2 project is the most economical one in case of the individual development (B/C=1.22) and case No.2A260.25b of Nam Mae Ngao plus case YOA170.20c of Lower Yuam is most preferable (B/C=1.35) in case of integrated development even if the fuel price goes down to the lowest level.

The "scope of work" on the present study preclude the study of Lower Yuam project except the study on the incremental benefit which will accrue from Lower Yuam project due to the regulation effect of the Nam Mae Ngao project.

The evaluation result of this incremental benefit is shown on Table 9-11. It is seen that the annual benefit of Lower Yuam project will be increased as much as 58 million baht.

This amounts to about 13.5% of the annual benefit of Nam Mae Ngao individual development, 429.3 million Baht (see Table 9-8).

The virtual B/C ratio of Nam Mae Ngao project is higher than 1.22 as estimated previously.

Table 9–11

3rd Stage Study, Incremental Benefit of Lower Yuam due to Effect of Nam Mae Ngao Development (Lower Nam Yuam: Dam is fixed at F/S, installed capacity is optimized)

3rd stage study

Base Case

		Individual development			Integrated development Nam Mae Ngao & Lower Yuam	Increase
		Nam Mae Ngao	Lower Yuam	Total (1) + (2)		(4) - (3)
Simulation Case No.		3 N02A260.25b	1 YOV170.20o		Case VI	
	Unit	(1)	(2)	(3)	(4)	(5)
Installed capacity	MW	116.9	162.0	278.9	374.0	95.1
Firm capacity	MW	97.9	139.9	237.8	320.5	82.7
Annual energy product						
Firm energy	GWH	128.6	181.6	310.2	421.1	110.9
Secondary energy	GWH	116.5	357.3	473.8	383.3	-90.5
Total	GWH	245.1	538.9	784.0	804.4	20.4
Construction cost						
Generating f.	M฿	3081.3	4352	7433.3	8250.1	816.8
Transmission f.	M฿	89.5	550	639.5	660.0	20.5
Total	M฿	3170.8	4902	8072.8	8910.1	837.3
Annual cost						
for generating f.	M฿	342.0	483.1	825.1	915.8	90.7
for transmission f.	M฿	10.1	62.2	72.3	74.6	2.3
for transmission loss	M฿	0.7	8.3	9.0	21.7	12.7
Total	M฿	352.8	553.6	906.4	1012.1	105.7
Annual benefit						
for firm capacity	M฿	177.2	253.2	430.4	580.1	149.7
for firm energy	M฿	132.3	186.8	319.1	433.2	114.1
for secondary energy	M฿	119.8	334.0	453.8	353.7	-100.1
Total	M฿	429.3	774.0	1203.3	1367.0	163.7
B - C	M฿	76.5	220.4	296.9	354.9	58.0
B/C		1.22	1.40	-	1.35	-
Energy cost	฿/KWH	1.439	1.027			
Incremental benefit	M฿					58.0
EDR	%	10.64			11.68	

9.6 Equalizing Discount Rate (EDR)

In order to determine a priority or development order among various projects proposed and to obtain optimum development scales of these projects, comparison study has been carried out by using annual cost method in the previous sections.

Furthermore, in this section, the equalizing discount rates (EDR) have been calculated on Nam Mae Ngao individual development and Nam Mae Ngao + Lower Yuam integrated development.

The results are shown in Fig. 9-12 and 9-13.

The results will make it possible to evaluate the economical efficiency of these projects through comparison with other national projects. In calculation of EDR, the same criteria and data as those used in the calculation of B/C were employed, and actual disbursement schedules of construction cost, which were ignored in the calculation of B/C, have been taken into account.

Table 9-12 Cost and Benefit Stream of Nam Mae Ngao Individual Development

Equalizing discount rate 10.64(%)
(without shadow price factor)

Case: 0
unit: Mill Bahts

Serial Number	Number After Completion	Costs: Investment Cost	Costs: O & M Cost	Costs: Total	Costs: Discounted Cost Flow	Benefits: Investment Cost	Benefits: O & M Cost	Benefits: Fuel Cost	Benefits: Total	Benefits: Discounted Benefit Flow
1		0.00		0.00	0.00				0.00	0.00
2		329.70		329.70	269.33				0.00	0.00
3		704.30		704.30	520.02				0.00	0.00
4		903.70		903.70	603.08	362.50			362.50	241.91
5		986.70		986.70	595.14	453.20			453.20	273.35
6		246.40		246.40	134.32	90.60			90.60	49.39
7	1		31.70	31.70	15.61		27.20	240.20	267.40	131.75
8	2		31.70	31.70	14.11		27.20	240.20	267.40	119.08
9	3		31.70	31.70	12.75		27.20	240.20	267.40	107.63
10	4		31.70	31.70	11.53		27.20	240.20	267.40	97.28
11	5		31.70	31.70	10.42		27.20	240.20	267.40	87.92
12	6		31.70	31.70	9.42		27.20	240.20	267.40	79.47
13	7		31.70	31.70	8.51		27.20	240.20	267.40	71.82
14	8		31.70	31.70	7.69	362.50	27.20	240.20	629.90	152.93
15	9		31.70	31.70	6.95	453.20	27.20	240.20	720.60	158.12
16	10		31.70	31.70	6.28	90.60	27.20	240.20	358.00	71.00
17	11		31.70	31.70	5.68		27.20	240.20	267.40	47.93
18	12		31.70	31.70	5.13		27.20	240.20	267.40	43.32
19	13		31.70	31.70	4.64		27.20	240.20	267.40	39.15
20	14		31.70	31.70	4.19		27.20	240.20	267.40	35.39
21	15		31.70	31.70	3.79		27.20	240.20	267.40	31.98
22	16		31.70	31.70	3.42		27.20	240.20	267.40	28.91
23	17		31.70	31.70	3.09		27.20	240.20	267.40	26.13
24	18		31.70	31.70	2.80	362.50	27.20	240.20	629.90	55.63
25	19		31.70	31.70	2.53	453.20	27.20	240.20	720.60	57.52
26	20		31.70	31.70	2.28	90.60	27.20	240.20	358.00	25.83
27	21		31.70	31.70	2.06		27.20	240.20	267.40	17.43
28	22		31.70	31.70	1.86		27.20	240.20	267.40	15.76
29	23		31.70	31.70	1.68		27.20	240.20	267.40	14.24
30	24		31.70	31.70	1.52		27.20	240.20	267.40	12.87
31	25		31.70	31.70	1.37		27.20	240.20	267.40	11.63
32	26		31.70	31.70	1.24		27.20	349.70	376.90	14.82
33	27		31.70	31.70	1.12		27.20	349.70	376.90	13.40
34	28		31.70	31.70	1.01	362.50	27.20	349.70	739.40	23.76
35	29		31.70	31.70	0.92	453.20	27.20	349.70	830.10	24.11
36	30		31.70	31.70	0.83	90.60	27.20	349.70	467.50	12.27
37	31		31.70	31.70	0.75		27.20	349.70	376.90	8.94
38	32		31.70	31.70	0.67		27.20	349.70	376.90	8.08
39	33		31.70	31.70	0.61		27.20	349.70	376.90	7.30
40	34		31.70	31.70	0.55		27.20	349.70	376.90	6.60
41	35		31.70	31.70	0.50		27.20	349.70	376.90	5.96
42	36		31.70	31.70	0.45		27.20	349.70	376.90	5.39
43	37		31.70	31.70	0.41		27.20	349.70	376.90	4.87
44	38		31.70	31.70	0.37	362.50	27.20	349.70	739.40	8.64
45	39		31.70	31.70	0.33	453.20	27.20	349.70	830.10	8.77
46	40	22.40	31.70	54.10	0.51	90.60	27.20	349.70	467.50	4.46
47	41		31.70	31.70	0.27		27.20	349.70	376.90	3.25
48	42		31.70	31.70	0.24		27.20	349.70	376.90	2.94
49	43		31.70	31.70	0.22		27.20	349.70	376.90	2.65
50	44		31.70	31.70	0.20		27.20	349.70	376.90	2.40
51	45		31.70	31.70	0.18		27.20	349.70	376.90	2.17
52	46		31.70	31.70	0.16		27.20	349.70	376.90	1.96
53	47		31.70	31.70	0.14		27.20	349.70	376.90	1.77
54	48		31.70	31.70	0.13		27.20	349.70	376.90	1.60
55	49		31.70	31.70	0.12		27.20	349.70	376.90	1.44
56	50		31.70	31.70	0.11		27.20	349.70	376.90	1.30
		3193.20	1585.00	4778.20	2283.51	4531.50	1360.00	14747.50	20639.00	2284.47

Table 9-13 Cost and Benefit Stream of Nam Mae Ngao + Lower Yuam

Integrated Development

Equalizing discount rate 11.68(%)
(without shadow price factor)

Case: 0
unit: Mill Bahts

Serial Number	Number After Completion	Costs: Investment Cost	Costs: O & M Cost	Costs: Total	Costs: Discounted Cost Flow	Benefits: Investment Cost	Benefits: O & M Cost	Benefits: Fuel Cost	Benefits: Total	Benefits: Discounted Benefit Flow
1		610.60		610.60	546.74				0.00	0.00
2		826.80		826.80	662.90				0.00	0.00
3		1743.60		1743.60	1251.75				0.00	0.00
4		2874.10		2874.10	1847.56	1156.40			1156.40	743.37
5		2363.90		2363.90	1360.66	1445.40			1445.40	831.97
6		491.10		491.10	253.11	289.10			289.10	149.00
7	1		89.10	89.10	41.11		86.70	749.50	836.20	385.90
8	2		89.10	89.10	36.81		86.70	749.50	836.20	345.54
9	3		89.10	89.10	32.96		86.70	749.50	836.20	309.40
10	4		89.10	89.10	29.52		86.70	749.50	836.20	277.04
11	5		89.10	89.10	26.43		86.70	749.50	836.20	248.07
12	6		89.10	89.10	23.66		86.70	749.50	836.20	222.12
13	7		89.10	89.10	21.19		86.70	749.50	836.20	198.89
14	8		89.10	89.10	18.97	1156.40	86.70	749.50	1992.60	424.38
15	9		89.10	89.10	16.99	1445.40	86.70	749.50	2281.60	435.11
16	10		89.10	89.10	15.21	289.10	86.70	749.50	1125.30	192.15
17	11		89.10	89.10	13.62		86.70	749.50	836.20	127.85
18	12		89.10	89.10	12.19		86.70	749.50	836.20	114.48
19	13		89.10	89.10	10.92		86.70	749.50	836.20	102.51
20	14		89.10	89.10	9.78		86.70	749.50	836.20	91.79
21	15		89.10	89.10	8.75		86.70	749.50	836.20	82.19
22	16		89.10	89.10	7.84		86.70	749.50	836.20	73.59
23	17		89.10	89.10	7.02		86.70	749.50	836.20	65.89
24	18		89.10	89.10	6.28	1156.40	86.70	749.50	1992.60	140.60
25	19		89.10	89.10	5.62	1445.40	86.70	749.50	2281.60	144.16
26	20		89.10	89.10	5.04	289.10	86.70	749.50	1125.30	63.66
27	21		89.10	89.10	4.51		86.70	749.50	836.20	42.36
28	22		89.10	89.10	4.04		86.70	749.50	836.20	37.93
29	23		89.10	89.10	3.61		86.70	749.50	836.20	33.96
30	24		89.10	89.10	3.24		86.70	749.50	836.20	30.41
31	25		89.10	89.10	2.90		86.70	749.50	836.20	27.23
32	26		89.10	89.10	2.59		86.70	1039.90	1126.60	32.85
33	27		89.10	89.10	2.32		86.70	1039.90	1126.60	29.41
34	28		89.10	89.10	2.08	1156.40	86.70	1039.90	2283.00	53.37
35	29		89.10	89.10	1.86	1445.40	86.70	1039.90	2572.00	53.84
36	30		89.10	89.10	1.67	289.10	86.70	1039.90	1415.70	26.53
37	31		89.10	89.10	1.49		86.70	1039.90	1126.60	18.90
38	32		89.10	89.10	1.33		86.70	1039.90	1126.60	16.93
39	33		89.10	89.10	1.19		86.70	1039.90	1126.60	15.16
40	34		89.10	89.10	1.07		86.70	1039.90	1126.60	13.57
41	35		89.10	89.10	0.96		86.70	1039.90	1126.60	12.15
42	36		89.10	89.10	0.86		86.70	1039.90	1126.60	10.88
43	37		89.10	89.10	0.77		86.70	1039.90	1126.60	9.74
44	38		89.10	89.10	0.69	1156.40	86.70	1039.90	2283.00	17.68
45	39		89.10	89.10	0.61	1445.40	86.70	1039.90	2572.00	17.83
46	40	165.00	89.10	254.10	1.57	289.10	86.70	1039.90	1415.70	8.79
47	41		89.10	89.10	0.49		86.70	1039.90	1126.60	6.25
48	42		89.10	89.10	0.44		86.70	1039.90	1126.60	5.60
49	43		89.10	89.10	0.39		86.70	1039.90	1126.60	5.02
50	44		89.10	89.10	0.35		86.70	1039.90	1126.60	4.49
51	45		89.10	89.10	0.31		86.70	1039.90	1126.60	4.02
52	46		89.10	89.10	0.28		86.70	1039.90	1126.60	3.60
53	47		89.10	89.10	0.25		86.70	1039.90	1126.60	3.22
54	48		89.10	89.10	0.22		86.70	1039.90	1126.60	2.89
55	49		89.10	89.10	0.20		86.70	1039.90	1126.60	2.58
56	50		89.10	89.10	0.18		86.70	1039.90	1126.60	2.31
		9075.10	4455.00	13530.10	6315.37	14454.50	4335.00	44735.00	63524.50	6319.46

9.7 Sensitivity Analysis

(1) First, the sensitivity analysis to the variation of the fuel prices for the alternative thermal power plant is performed. All together 4 cases of the variation as shown in Table 9-7 were tested of which Case 0 was adopted as the base case as already described in the preceding section. The procedures and the results for all the cases are included in Table 9-7 through Table 9-10.

The results are also plotted on Fig. 9-8. It is seen from these results that the B/C ratio of Nam Mae Ngao No.2 increases from 1.22 for the base case to 1.34 for the case 3 as the fuel price goes up.

At the same time, the B/C ratio of Nam Mae Ngao No.2 + Lower Yuam integrated project remains at the same level of 1.35.

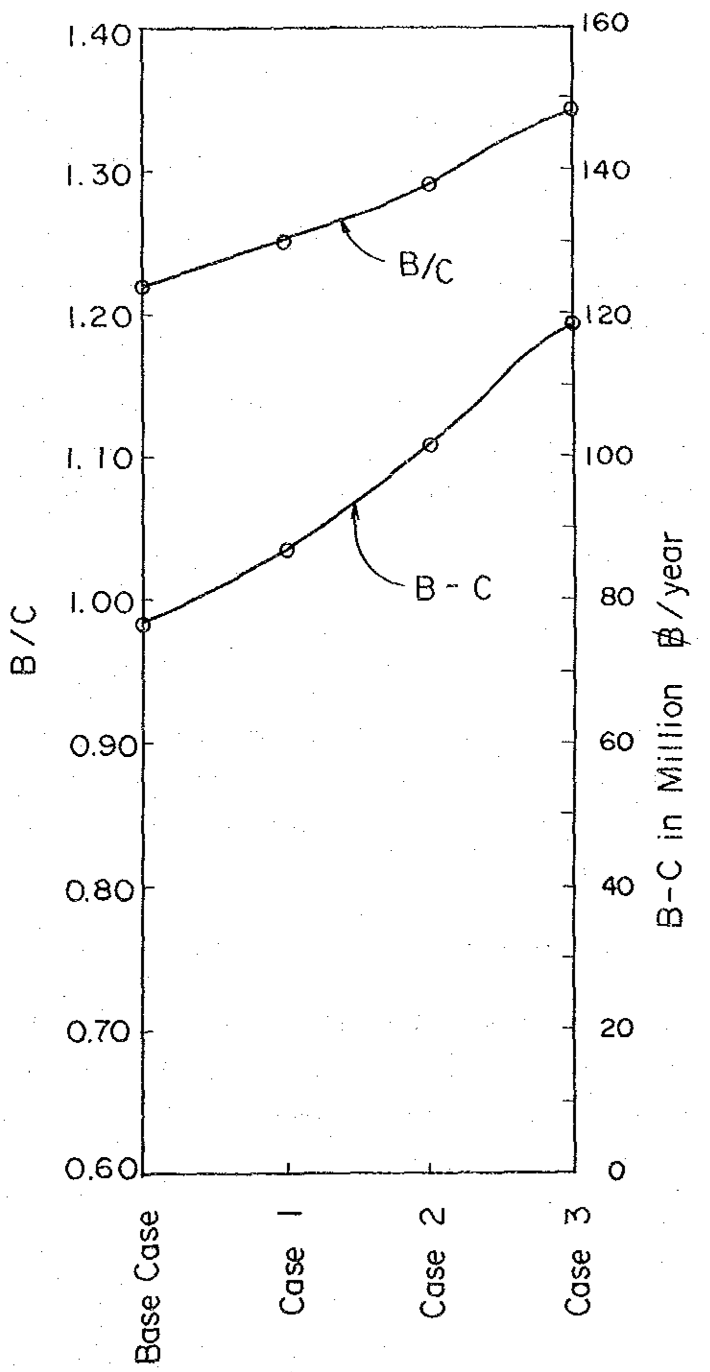


Fig. 9–8 Variation of B - C & B/C for Nam Mae Ngao Individual Development

(2) The second sensitivity analysis concerns with a variation of a discount rate

In this test, a discount rate of 12% is adopted for the base case. Assuming that all other conditions are equal, the procedures and results are shown on Table 9-14 through 9-24.

It is seen that the B/C ratio of 1.06 and 1.20 are obtained for Nam Mae Ngao individual development and Nam Mae Ngao + Lower Yuam integrated development respectively.

The result shows that even in the case of discount rate at 12% the projects are economically feasible, and in particular, the B/C ratio of the integrated development exceeds 1.20.

(3) The third sensitivity analysis is concerned with the transmission line of Nam Mae Ngao Project.

In this case, the 2 circuits 230 KV transmission line is constructed directly from the project to Lamphun 2 substation (the length of the line: 197 km) as against the original plan where the transmission line only from the project to Lower Yuam was considered. (see Chapter 7).

The results of analysis are contained in Table 9-26-1 and 9-26-2.

It is seen that the B/C ratios of Nam Mae Ngao Project vary from 1.08 for base case of fuel price to 1.18 for case 3 of fuel price indicating still the economic superiority of the project.

Table 9–14 Additional Study, Economic Criteria and Basic Costs of Thermal Power Plants Case 0 (Base Case)

Additional study

		Unit	Hydro power plant	Gas turbine		Thermal		Lignite (50 years)	
				Natural gas (1st 25 years)	Diesel Oil (2nd 25 years)	Natural gas (1st 25 years)	Imported coal (2nd 25 years)		
	Installed capacity	MW	H	G	G	T	T	L	
a	Standard unit capacity	MW		25	25	600	600	600	EGAT data given on Oct.7,1985
b	Standard capacity factor	%		$X_g \leq 5$	$X_g \leq 5$	$40 \leq X_t \leq 85$	$40 \leq X_t \leq 85$	$40 \leq X_t \leq 85$	- ditto -
c	Economic life length adopted	years	50	10	10	20	25	25	
d	Station service rate	%	1	2	2	7	7	7	
e	Scheduled outage rate	%		2	2	13	13	13	
f	Forced outage rate	%		4	4	4	4	4	
g	Anual fixed O&M rate	%	1	3	3	2.5	2.5	2.5	
h	Unit construction cost w/o IDC	$/KW		320	320	580	957	957	
	ditto	฿/KW		8640	8640	15660	25839	25839	1 US$ = 27 ฿
	(Fuel)			Natural gas	Diesel oil	Natural gas	Imported coal	Lignite	
i	Fuel calorific value			1000Btu/cu.ft	8959.6Kcal/Lit	1000Btu/Cu.ft	5796Kcal/kg	2648.8Kcal/kg	EGAT data given on July 3,1986
j					= 35558Btu/Lit				
k	Thermal efficiency	%		25	25	36	36	36	
l	Energy equivalence	Kcal/KWH		3440Kcal/KWH	3440Kcal/KWH		2388.9Kcal/KWH	2388.9Kcal/KWH	- ditto -
m	= Plant heat value	Btu/KWH		13650.8Btu/KWH		9479.7Btu/KWH			
n	Fuel consumption			13.6508cu.ft/KWH	0.3839Lit/KWH	9.4797cu.ft/KWH	0.4122kg/KWH	0.9019kg/KWH	- ditto -
o	Unit fuel price			71.0947฿/MBtu	3.68฿/Lit	71.0947฿/MBtu	1.484฿/kg	0.5332฿/kg	- ditto -
p	Unit fuel cost	฿/KWH		0.9705	1.4128	0.6740	0.6117	0.4809	- ditto - (Base case)
q	Effective capacity	MW		0.94G	0.94G	0.83T	0.83T	0.83L	(1-(e+f)/100fxInstalled capa.
r	Send-out capacity	MW	0.99H	0.92G	0.92G	0.77T	0.77T	0.77L	q x (1-a/100)
s	Energy production	MWH		GX_gH_r	GX_gH_r	TX_tH_r	TX_tH_r	LX_LH_r	
t	Send-out energy	MWH		$0.98GX_gH_r$	$0.98GX_gH_r$	$0.93TX_tH_r$	$0.93TX_tH_r$	$0.93LX_LH_r$	
u	Capital investment cost	฿		8640G	8640G	15660T	25839T	25839L	h x installed capacity
v	Annual O&M cost	฿		259.2G	259.2G	391.5T	646.0T	646.0L	u x g
w	Daily O&M cost	฿		0.7101G	0.7101G	1.0726T	1.7698T	2.1238L	v/365
x	Fuel cost	฿		$0.9705GX_gH_r$	$1.4128GX_gH_r$	$0.6740TX_tH_r$	$0.6117TX_tH_r$	$0.4809LX_LH_r$	s x p

Table 9–15 Additional Study, Sensitivity Analysis for Discount Rate = 12% Cost Stream of Alternative Gas Turbine (Natural Gas – Diesel Oil)

Case 0 (Base Case)

Additional study

Year	Single payment worth factor 1)	Capital investment cost						O&M	Fuel Cost		
		Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Total		for the 1st 25 years	for the 2nd 25 years	Total
n	i = 12%										
0	1,000	8640G									
1								259.2G	$0.9705GXgH_r$		
10	0.321973		8640G								
20	0.103667			8640G							
25										$1.4128GXgH_r$	
30	0.033378				8640G						
40	0.010747					8640G					
50	0.003460										
Present value factor		1.000	0.321973	0.103667	0.033378	0.010747			7.8431393)	0.4613594)	
Present value		8640G	2781.8G	895.7G	288.4G	92.9G	12698.8G		$7.6117664GXgH_r$	$0.651808GXgH_r$	$8.263574GXgH_r$
Capital recovery factor		0.1204167									
Annuitized cost							1529.1G	259.2G			$0.9951GXgH_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	1529.1G	
O&M	฿	259.2G	
Fuel	฿		$0.9951GXgH_r$
Total	฿	1788.3G	$0.9951GXgH_r$

	Unit	Cost	
KW-benefit	฿/KW	1943.8	1788.3G/0.92G
KWH-benefit	฿/KW	1.0154	$0.9951GXgH_r/0.98GXgH_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... Yg = 1943.8 + 1.0154 x 8760 Xg

Daily cost ...... Yg = 1943.8/365 + 1.0154 x 24 Xg
= 5.3255 + 24.3696Xg

1) Present worth factor $1/(1+i)^n$

3) Annuity cost factor = $\frac{(1+i)^n-1}{i(1+i)^n}$

i = 0.12 n = 25 7.843139

4) $\frac{(1+i)^{50}-1}{i(1+i)^{50}} - \frac{(1+i)^{25}-1}{i(1+i)^{25}}$

= 8.304498 - 7.843139 = 0.461359

5) Annuity factor $\frac{i(1+i)^n}{(1+i)^n-1}$

Table 9–16 Additional Study, Sensitivity Analysis for Discount Rate = 12%
Cost Stream of Alternative Steam Thermal (Natural Gas – Imported Coal)

Additional study

Case 0 (Base Case)

Year	Single payment worth factor 1)	Capital investment cost				O&M cost			Fuel cost		
		Plant 1 Natural gas	Plant 2 Natural gas	Plant 3 Imported coal	Total	Plant 1 & Plant 2	Plant 3	Total	for the 1st 25 years	for the 2nd 25 years	Total
n	i = 12%	T MW	T MW	T MW							
0	1.000	15660T									
1						391.5T			$0.674TX^{t}H^{r}$		
20	0.103667		15660T								
25	0.058823		$-\frac{15}{20}$ 15660T	25839T							
							646.0T			$0.6117TX_tH_r$	
50	0.003460										
Present value factor i = 12%		1.000	0.103667 0.058823	0.058823		7.843139[3)]	0.461359[4)]		7.843139[3)]	0.461359[4)]	
Present value		15660T	1623.4T	1519.9T		3070.6T	298.0T		$5.286TX_tH_r$	$0.282TX_tH_r$	
			-690.9T		18112.4T			3368.6T			$5.568TX_tH_r$
Capital recovery factor		0.1204167[5)]									
Annuitized cost					2181.0T			405.6T			$0.6705TX_tH_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	2181.0T	
O&M	฿	405.6T	
Fuel	฿		$0.6705TX_tH_r$
Total	฿	2586.6T	$0.6705TX_tH_r$

	Unit	Cost	
KW-benefit	฿/KW	3359.2	2586.6T/0.77T
KWH-benefit	฿/KW	0.7210	$0.6705TX_tH_r/0.93TX_tH_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... $Y_t = 3359.2 + 0.7210 \times 8760X_t = 3359.2 + 6316.0X_t$

Daily cost ...... $Y_t = 3359.2/365 + 0.7210 \times 24X_t = 9.203 + 17.304X_t$

Table 9–17 Additional Study, Sensitivity Analysis for Discount Rate = 12% Cost Stream of Alternative Steam Thermal (Lignite)

Case 0 (Base Case)

Additional study

Year	Single payment worth factor 1)	Capital investment cost			O&M cost			Fuel cost		
		Plant 1	Plant 2	Total	Plant 1	Plant 2	Total	for the 1st 25 years	for the 2nd 25 years	Total
n	i = 12%	L MW	L MW					Lignite	Lignite	
0	1.0	25839L								
1					646.0L		646.0L	$0.4809LX_1H_r$		$0.4809LX_1H_r$
25	0.058823		25839L			646.0L			$0.4809LX_1H_r$	
50	0.003460									
Present value factor i = 12%		1.0	0.058823					7.843139 3)	0.461359 4)	
Present value		25839L	1519.9L	27358.9L						
Capital recovery factor		0.1204167 5)								
Annuitized cost				3294.5L			646.0L			$0.4809LX_1H_r$

Cost	Unit	Fixed	Variable
Capital investment	฿	3294.5L	
O&M	฿	646.0L	
Fuel	฿		$0.4809LX_1H_r$
Total	฿	3940.5L	$0.4809LX_1H_r$

	Unit	Cost	
KW-benefit	฿/KW	5117.5	3940.5L/0.77L
KWH-benefit	฿/KWH	0.5171	$0.4809LX_1H_r/0.93LX_1H_r$

Total annuitized fixed & variable cost in ฿/KW: Annual cost ...... $Y_1 = 5117.5 + 0.5171 \times 8760Y_1$

Daily cost ...... $Y_1 = 5117.5/365 + 0.5171 \times 24X_1 = 14.0205 + 12.4104X_1$

Table 9–18 Sensitivity Test for Discount Rate
Nam Mae Ngao Individual Development

Nam Mae Ngao individual development

	Unit	Case B1 Discount rate = 12%	
Simulation Case No.		NO2A260.25b	
a) Project features			
Catchment area	km^2	835	
Annual flow	MCM	1272	
HWL	m	260	
NIWL	m	248.4	
LWL	m	235	
TWL	m	163	
Effective head	m	82.5	
Daily plant factor at max. demand day	%	15	
Capacity factor	%	23.9	
Firm discharge (95% probability)	cms	24.9	
Max. turbine discharge	cms	166.2	
Installed capacity	MW	116.9	
Firm capacity	MW	97.9	
Annual energy production	GWH	245.2	
Annual firm energy	GWH	128.6	
Annual secondary energy (97%)	GWH	116.5	
b) Project economy			
Construction cost			
for generating facilities	M฿	3081.3	
for transmission facilities	M฿	89.5	
Annual cost			
for generating facilities	M฿	401.8	0.1304
for transmission facilities	M฿	11.8	0.1313
for transmission loss	M฿	0.8	
Total annual cost, C	M฿	414.4	
Annual benefit			
for firm capacity	M฿	@1943.8 190.3	
for firm energy	M฿	@1.0154 130.6	
for secondary energy	M฿	@1.0154 118.3	
Total annual benefit, B	M฿	439.2	
c) B - C	M฿	24.8	
B/C		1.06	
Annual energy cost	฿/KWH	1.690	

Table 9–19 Sensitivity Test for Discount Rate
Transmission Loss for Nam Mae Ngao Individual Development

Transmission loss for Nam Mae Ngao individual development

		Unit	Case B1 Discount rate = 12%
Capacity loss	(A)	MW	0.311
Average capacity cost	(B)	฿/KW	1943.8
(A) x (B)		M฿	0.605
Annual energy loss	(C)	MWH	165.6
Average energy cost	(D)	฿/KWH	1.0154
(C) x (D)		M฿	0.168
Total transmission loss		M฿	0.773 ≒ 0.8

Table 9-20 Sensitivity Test for Discount Rate
Lower Yuam Individual Development

Lower Nam Yuam individual development

	Unit	Case B2 Discount rate = 12%	
Simulation Case No.		YOV170.20o	
a) Project features			
Catchment area	km^2	5920	
Annual flow	MCM	2818	
HWL	m	170	
NIWL	m	161.7	
LWL	m	150	
TWL	m	73.2	
Effective head	m	85.6	
Daily plant factor at max. demand day	%	14.8	
Capacity factor	%	38.0	
Firm discharge (95% probability)	cms	32.5	
Max. turbine discharge	cms	219.5	
Installed capacity	MW	162.0	
Firm capacity	MW	139.9	
Annual energy production	GWH	538.9	
Annual firm energy	GWH	181.6	
Annual secondary energy (97%)	GWH	357.3	
b) Project economy			
Construction cost			
for generating facilities	M฿	4352	
for transmission facilities	M฿	550	
Annual cost			
for generating facilities	M฿	567.5	0.1304
for transmission facilities	M฿	72.2	0.1313
for transmission loss	M฿	8.8	
Total annual cost, C	M฿	648.5	
Annual benefit			
for firm capacity	M฿	@1943.8 271.9	
for firm energy	M฿	@1.0154 184.4	
for secondary energy	M฿	@0.9666 345.3	
Total annual benefit, B	M฿	801.6	
c) B - C	M฿	153.1	
B/C		1.24	
Annual energy cost	฿/KWH	1.203	

Table 9–21 Sensitivity Test for Discount Rate
Transmission Loss for Lower Yuam Individual Development

Transmission loss for Lower Nam Yuam Individual development

		Unit	Case B2 Discount rate = 12%
Capacity loss	(A)	MW	3.55
Average capacity cost	(B)	฿/KW	1943.8
(A) x (B)		M฿	6.900
Annual energy loss	(C)	MWH	1888
Average energy cost	(D)	฿/KWH	0.9829
(C) x (D)		M฿	1.856
Total transmission loss		M฿	8.756 ≑ 8.8

Table 9–22 Sensitivity Test for Discount Rate
Nam Mae Ngao + Lower Yuam Integrated Development

Nam Mae Ngao + Lower Nam Yuam integrated development

	Unit	Case B3 Discount rate = 12%	
Simulation Case No.		NO2A260.25b+YOA170.20C	
a) Project features			
Catchment area	km^2	5920	
Annual flow	MCM	2825	
HWL	m	260 & 170	
NIWL	m	248.4 & 161.4	
LWL	m	235 & 150	
TWL	m	163 & 73.2	
Effective head	m	82.5 & 85.3	
Daily plant factor at max. demand day	%	15	
Capacity factor	%	23.9 & 24.8	
Firm discharge (95% probability)	cms	24.9 & 52.4	
Max. turbine discharge	cms	166.2 & 349.3	
Installed capacity	MW	116.9+257.1 = 374.0	
Firm capacity	MW	97.9+222.6 = 320.5	
Annual energy production	GWH	245.1+559.3 = 804.4	
Annual firm energy	GWH	128.6+292.5 = 421.1	
Annual secondary energy (97%)	GWH	116.5+266.8 = 383.3	
b) Project economy			
Construction cost			
for generating facilities	M฿	8250.1	
for transmission facilities	M฿	660	
Annual cost			
for generating facilities	M฿	1075.8	0.1304
for transmission facilities	M฿	86.7	0.1313
for transmission loss	M฿	23.0	
Total annual cost, C	M฿	1185.5	
Annual benefit			
for firm capacity	M฿	@1943.8 623.0	
for firm energy	M฿	@1.0154 427.7	
for secondary energy	M฿	@0.9712 372.2	
Total annual benefit, B	M฿	1422.9	
c) B - C	M฿	237.4	
B/C		1.20	
Annual energy cost	฿/KWH	1.474	

Table 9-23 Sensitivity Test for Discount Rate
Transmission Loss for Nam Mae Ngao + Lower Yuam Integrated Development

Transmission loss for Nam Mae Ngao + Lower Nam Yuam integrated development

		Unit	Case B3 Discount rate = 12%
Capacity loss	(A)	MW	9.3
Average capacity cost	(B)	฿/KW	1943.8
(A) x (B)		M฿	18.077
Annual energy loss	(C)	MWH	4924
Average energy cost	(D)	฿/KWH	0.9944
(C) x (D)		M฿	4.896
Total transmission loss		M฿	22.973 ≑ 23.0

Table 9–24 Sensitivity Test for Discount Rate (=12%) Incremental Benefit of Lower Yuam

fuel price: base case

		Individual development			Integrated development	Increase
		Nam Mae Ngao	Lower Yuam	Total (1) + (2)	Nam Mae Ngao & Lower Yuam	(4) - (3)
Simulation Case No.		3 N02A260.25b	1 YOV170.20б		Case VI	
	Unit	(1)	(2)	(3)	(4)	(5)
Installed capacity	MW	116.9	162.0	278.9	374.0	95.1
Firm capacity	MW	97.9	139.9	237.8	320.5	82.7
Annual energy product						
Firm energy	GWH	128.6	181.6	310.2	421.1	110.9
Secondary energy	GWH	116.5	357.3	473.8	383.3	-90.5
Total	GWH	245.1	538.9	784.0	804.4	20.4
Construction cost						
Generating f.	M฿	3081.3	4352	7433.3	8250.1	816.8
Transmission f.	M฿	89.5	550	639.5	660.0	20.5
Total	M฿	3170.8	4902	8072.8	8910.1	837.3
Annual cost						
for generating f.	M฿	401.8	567.5	969.3	1075.8	106.5
for transmission f.	M฿	11.8	72.2	84.0	86.7	2.7
for transmission loss	M฿	0.8	8.8	9.6	23.0	13.4
Total	M฿	414.4	648.5	1062.9	1185.5	122.6
Annual benefit						
for firm capacity	M฿	190.3	271.9	462.2	623.0	160.8
for firm energy	M฿	130.6	184.4	315.0	427.7	112.7
for secondary energy	M฿	118.3	345.3	463.6	372.2	-91.4
Total	M฿	439.2	801.6	1240.8	1422.9	182.1
B - C	M฿	24.8	153.1	177.9	237.4	59.5
B/C		1.06	1.24	-	1.20	-
Energy cost	฿/KWH	1.690	1.203		1.474	
Incremental benefit	M฿					59.5

Table 9–25 Cost and Benefit Stream of Nam Mae Ngao Individual Development

Equalizing discount rate 11.13(%)
(with shadow price factor) 1.000

Case: 0
unit: Mill Bahts

Serial Number	Number After Compl-etion	Costs: Investment Cost	Costs: O & M Cost	Costs: Total	Costs: Discounted Cost Flow	Benefits: Investment Cost	Benefits: O & M Cost	Benefits: Fuel Cost	Benefits: Total	Benefits: Discounted Benefit Flow
1		0.00		0.00	0.00				0.00	0.00
2		314.70		314.70	254.82				0.00	0.00
3		708.70		708.70	516.37				0.00	0.00
4		904.20		904.20	592.84	396.00			396.00	259.63
5		996.00		996.00	587.62	495.20			495.20	292.16
6		254.20		254.20	134.95	99.00			99.00	52.55
7	1		31.80	31.80	15.19		29.70	240.20	269.90	123.93
8	2		31.80	31.80	13.67		29.70	240.20	269.90	116.02
9	3		31.80	31.80	12.30		29.70	240.20	269.90	104.40
10	4		31.80	31.80	11.06		29.70	240.20	269.90	93.94
11	5		31.80	31.80	9.96		29.70	240.20	269.90	84.53
12	6		31.80	31.80	8.96		29.70	240.20	269.90	76.07
13	7		31.80	31.80	8.06		29.70	240.20	269.90	68.45
14	8		31.80	31.80	7.25	396.00	29.70	240.20	665.90	151.97
15	9		31.80	31.80	6.53	495.20	29.70	240.20	765.10	157.12
16	10		31.80	31.80	5.87	99.00	29.70	240.20	368.90	68.17
17	11		31.80	31.80	5.28		29.70	240.20	269.90	44.88
18	12		31.80	31.80	4.75		29.70	240.20	269.90	40.38
19	13		31.80	31.80	4.28		29.70	240.20	269.90	36.34
20	14		31.80	31.80	3.85		29.70	240.20	269.90	32.70
21	15		31.80	31.80	3.46		29.70	240.20	269.90	29.42
22	16		31.80	31.80	3.11		29.70	240.20	269.90	26.47
23	17		31.80	31.80	2.80		29.70	240.20	269.90	23.82
24	18		31.80	31.80	2.52	396.00	29.70	240.20	665.90	52.90
25	19		31.80	31.80	2.27	495.20	29.70	240.20	765.10	54.69
26	20		31.80	31.80	2.04	99.00	29.70	240.20	368.90	23.72
27	21		31.80	31.80	1.84		29.70	240.20	269.90	15.62
28	22		31.80	31.80	1.65		29.70	240.20	269.90	14.05
29	23		31.80	31.80	1.49		29.70	240.20	269.90	12.65
30	24		31.80	31.80	1.34		29.70	240.20	269.90	11.38
31	25		31.80	31.80	1.20		29.70	240.20	269.90	10.24
32	26		31.80	31.80	1.08		29.70	349.70	379.40	12.95
33	27		31.80	31.80	0.97		29.70	349.70	379.40	11.65
34	28		31.80	31.80	0.87	396.00	29.70	349.70	775.40	21.44
35	29		31.80	31.80	0.79	495.20	29.70	349.70	874.60	21.76
36	30		31.80	31.80	0.71	99.00	29.70	349.70	478.40	10.71
37	31		31.80	31.80	0.64		29.70	349.70	379.40	7.64
38	32		31.80	31.80	0.57		29.70	349.70	379.40	6.87
39	33		31.80	31.80	0.51		29.70	349.70	379.40	6.18
40	34		31.80	31.80	0.46		29.70	349.70	379.40	5.56
41	35		31.80	31.80	0.42		29.70	349.70	379.40	5.01
42	36		31.80	31.80	0.37		29.70	349.70	379.40	4.51
43	37		31.80	31.80	0.34		29.70	349.70	379.40	4.05
44	38		31.80	31.80	0.30	396.00	29.70	349.70	775.40	7.46
45	39		31.80	31.80	0.27	495.20	29.70	349.70	874.60	7.57
46	40	23.00	31.80	54.80	0.42	99.00	29.70	349.70	478.40	3.72
47	41		31.80	31.80	0.22		29.70	349.70	379.40	2.66
48	42		31.80	31.80	0.20		29.70	349.70	379.40	2.39
49	43		31.80	31.80	0.18		29.70	349.70	379.40	2.15
50	44		31.80	31.80	0.16		29.70	349.70	379.40	1.93
51	45		31.80	31.80	0.14		29.70	349.70	379.40	1.74
52	46		31.80	31.80	0.13		29.70	349.70	379.40	1.56
53	47		31.80	31.80	0.11		29.70	349.70	379.40	1.41
54	48		31.80	31.80	0.10		29.70	349.70	379.40	1.27
55	49		31.80	31.80	0.09		29.70	349.70	379.40	1.14
56	50		31.80	31.80	0.08		29.70	349.70	379.40	1.02
		3200.80	1590.00	4790.80	2237.71	4951.00	1485.00	14747.50	21183.50	2237.82

Table 9–26–1 Economic Evaluation of Nam Mae Ngao Individual Development for Various Cases of Fuel Costs Sensitivity Test (Transmission Line from Nam Mae Ngao to Lamphun 2 included)

Discount rate = 10%

	Unit	Case 0	Case 1	Case 2	Case 3
Simulation Case No.		NO2A260.25b			
a) Project features					
Catchment area	km^2	835			
Annual flow	MCM	1272			
HWL	m	260			
NIWL	m	248.4			
LWL	m	235			
TWL	m	163			
Effective head	m	82.5			
Daily plant factor at max. demand day	%	15			
Capacity factor	%	23.9			
Firm discharge (95% probability)	cms	24.9			
Max. turbine discharge	cms	166.2			
Installed capacity	MW	116.9			
Firm capacity	MW	97.9			
Annual energy production	GWH	245.2			
Annual firm energy	GWH	128.6			
Annual secondary energy (97%)	GWH	116.5			
b) Project economy					
Construction Cost					
for generating facilities	M฿	3081.3	3081.3	3081.3	3081.3
for transmission facilities	M฿	476.0	476.0	476.0	476.0
Annual cost					
for generating facilities, n=50, O&M 1%	M฿	342.0	342.0	342.0	342.0
for transmission facilities, n=40, O&M1%	M฿	53.3	53.3	53.3	53.3
for transmission loss, see next page	M฿	3.4	3.3	3.2	3.2
Total annual cost, C	M฿	398.7	398.6	398.5	398.5
Annual benefit					
for firm capacity	M฿	@1810.1 177.2	@1660.7 162.6	@1557.9 152.5	@1482.6 145.1
for firm energy	M฿	@1.0285 132.3	@1.1300 145.4	@1.2315 158.4	@1.333 171.5
for secondary energy	M฿	@1.0285 119.8	@1.1300 131.6	@1.2315 143.5	@1.331 155.0
Total annual benefit, B	M฿	429.3	439.6	454.4	471.6
c) B−C	M฿	30.6	41.0	55.9	73.1
B/C		1.08	1.10	1.14	1.18
Annual energy cost	฿/KWH	1.626	1.626	1.625	1.625

Table 9–26–2 Transmission Loss for Nam Mae Ngao Individual Development (116.9 MW) Sensitivity Test (Transmission Line from Nam Mae Ngao to Lamphun 2 included)

		Unit	Case 0	Case 1	Case 2	Case 3
Capacity loss	(A)	MW	1.45	1.45	1.45	1.45
Average capacity cost	(B)	฿/KW	1810.1	1660.7	1557.9	1482.2
(A) x (B)		M฿	2.62	2.41	2.26	2.15
Annual energy loss	(C)	MWH	772	772	772	772
Average energy cost	(D)	฿/KWH	1.0285	1.1300	1.2315	1.332
(C) x (D)		M฿	0.79	0.87	0.95	1.03
Total transmission loss		M฿	3.41 ≒ 3.4	3.28 ≒ 3.3	3.21 ≒ 3.2	3.18 ≒ 3.2

CHAPTER 10. IMPACT ON IRRIGATION PROJECTS

CHAPTER 10 IMPACT ON IRRIGATION PROJECTS

CONTENTS

Figure List

CHAPTER 10. IMPACT ON IRRIGATION PROJECTS

10.1 Purpose of Field Investigation

Upper Mae Yuam 1 Project is located in the upstream reach of the Yuam river basin and the project site is situated in the upstream of Lower Yuam Project, the feasibility study of which was completed in March 1984 by JICA. There are several irrigation projects using the water resource of the main and tributaries of the Yuam river in the investigation area extending between No.1 dam site of the Upper Mae Yuam Hydro Power Project and the upstream end of Lower Yuam reservoir.

It will be necessary for Upper Mae Yuam Project to study its power scheme by taking into consideration the impact on the existing and future irrigation projects in the said investigation area.

The purpose of field investigation is to examine the impact on the downstream irrigation projects which will be caused by Upper Mae Yuam Project. Major study items of the field investigation are summarized below.

(1) Existing condition and operation works of the irrigation projects which have been constructed by Royal Irrigation Department (referred to as RID) and Rural Acceleration Development by the Ministry of Interior (referred to as RAD).

(2) Possibility of future irrigation projects in the Mae Sariang Plain.

(3) Various agriculture information on cropping schedule, yield and price etc. in the existing RID Irrigation Project in the Mae Sariang Plain.

10.2 Result of Field Investigation

JICA-Team collected the data and/or information of agriculture and irrigation by means of interview to villagers, RID office and Agriculture office etc., as well as observation of topographic feature and agricultural condition in the investigation area. The results of investigation are summarized as follows.

(1) The right bank area of the Yuam river in the Mae Sariang plain (Approximately 12,500 rai) has been brought into irrigation by Large-medium Scale Irrigation Project of RID and used the river water of the Yuam river through the year.

(2) There is little possibility of land to economically develop new irrigation areas by the Yuam river because of topographical constraint within the investigation area.

(3) Irrigation requirement at the RID diversion weir is maximum 2.94 cu.m/sec for the existing RID irrigation project at present and in future.

(4) In case that the river run-off in the dry season would be improved by Upper Mae Yuam Project, cropping intensity in the dry season will increase within the existing RID Irrigation Project area. Incremental net benefit thereby is estimated to be 5.4 million Baht per year.

(5) There is no impact on the existing small irrigation projects constructed by RID and RAD after completion of Upper Mae Yuam Project to be built on the main river because those projects use the tributary water for irrigation purpose.

10.3 RID Nam Yuam Irrigation Project (existing)

Nam Yuam Irrigation Project was completed in 1976 by RID and the operation of the project has been also undertaken by RID. Irrigation water is diverted at the RID diversion weir which is located at approximately 25 km downstream of Upper Mae Yuam 1 Project.

The project description is as follows:

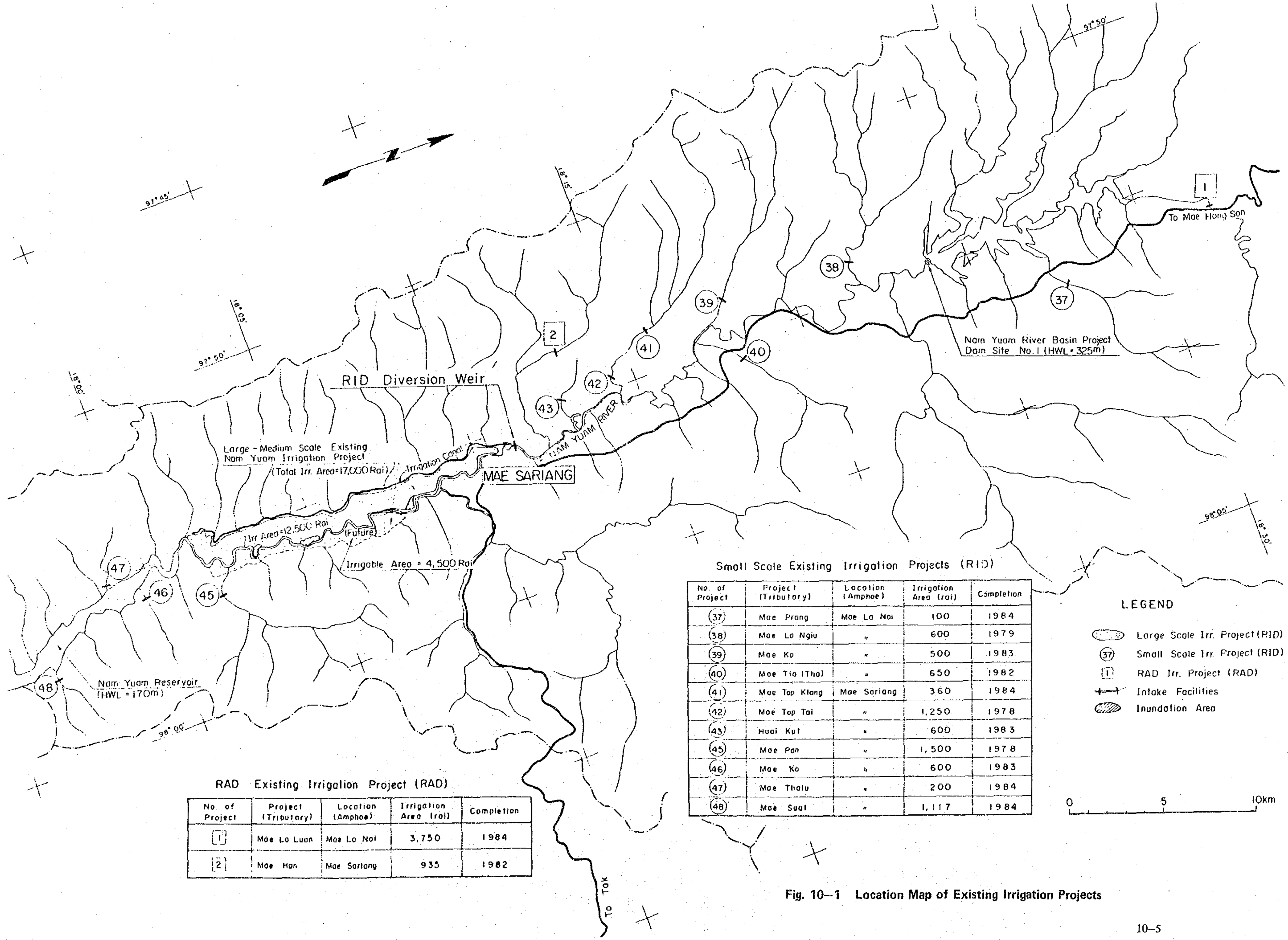
Irrigation Area	:	12,500 Rai in the right bank, 4,500 Rai in the left bank (not completed as of the end of 1985)
Water Requirement at Diversion Site	:	Maximum 2.94 cu.m/sec
Diversion Weir	:	Height 2.5 m Length 110 m in concrete 870 m in embankment
Main Canal	:	22.58 km of concrete lining canal
Household	:	Approximately 5,000
Major Crop	:	Paddy in wet season (approximately 100%) Soybean in dry season (approximately 60%)

10.4 Incremental Benefit

Impact and/or benefit can be expected to increase by intensifying the land-use in the dry season from 60% (7,500 Rai) to 100% (12,500 Rai) within the RID irrigation area. Because the minimum discharge to be released at Upper Mae Yuam 1 Project is estimated to be more than 12 cu.m/sec, which results in improvement of run-off condition of the Yuam river in the dry season.

Incremental benefit due to the said increasing cropping intensity in the dry season can be evaluated in terms of increased production of soybean which is major dry season crop and estimated to be 5.4 million Baht per annum in the value of net profit.

Yield of Soybean	:	300 kg/rai
Farm-gate Price	:	6 Baht/kg
Gross Value	:	1,800 Baht/rai
Net Profit	:	1,080 Baht/rai
Incremental Area	:	5,000 rai
Incremental Benefit	:	5.4 million Baht per annum



RAD Existing Irrigation Project (RAD)

No. of Project	Project (Tributary)	Location (Amphoe)	Irrigation Area (rai)	Completion
1	Mae Lo Luan	Mae La Noi	3,750	1984
2	Mae Han	Mae Sariang	935	1982

Small Scale Existing Irrigation Projects (RID)

No. of Project	Project (Tributary)	Location (Amphoe)	Irrigation Area (rai)	Completion
37	Mae Prang	Mae La Noi	100	1984
38	Mae La Ngiu	"	600	1979
39	Mae Ko	"	500	1983
40	Mae Tio (Tha)	"	650	1982
41	Mae Top Klang	Mae Sariang	360	1984
42	Mae Top Tai	"	1,250	1978
43	Huai Kut	"	600	1983
45	Mae Pan	"	1,500	1978
46	Mae Ko	"	600	1983
47	Mae Thalu	"	200	1984
48	Mae Suat	"	1,117	1984

Fig. 10–1 Location Map of Existing Irrigation Projects

CHAPTER 11. ENVIRONMENTAL PROBLEM

CHAPTER 11 ENVIRONMENTAL PROBLEM

CONTENTS

Table List

CHAPTER 11. ENVIRONMENTAL PROBLEM

11.1 Environmental Background

11.1.1 Physical Resource

1) Meteorology

The average annual rainfall at Amphoe Mae Sariang in 30 years period is 1,245.3 mm. The average maximum monthly rainfall in August of 253.4 mm and the average minimum monthly rainfall in February of 5.1 mm were also recorded. The average annual relative humidity in 30 years period at Amphoe Mae Sariang is 74%. The record showed an annual mean temperature of 26.2°C.

2) Surface Water Hydrology

Hydrological stations in the Yuam river comprise 2 stations, Ban Tha Rua station and Sop Han station. The prediction of average annual flow at many located sub-projects are shown as follows; 2,816 MCM at lower Yuam sub-project, 395 MCM at Nam Mae Rit sub-project; 1,292 MCM at Nam Mae Ngao sub-project and 570 MCM at Upper Mae Yuam 1 sub-project.

3) Water Quality

The analytical results show that physical and chemical water quality characteristics of the Yuam, the Rit, the Ngao river are suitable for aquatic esosystem. The concentration of dissolved oxygen ranges from 5.5 to 8.8 mg/ℓ. The pH values varies from 7.0 to 7.7. The alkalinity of the water at Ban Nam Rit are considered high in value of 142 mg/ℓ, at other points have the value from 74 to 100 mg/ℓ. The vlaue of hardness of the water is in values ranging from 76 to 108 mg/ℓ, varies from 115 to 292.5 mg/ℓ.

4) Geology

The geologic structure of the Lower Yuam consists of pre-cambrian to quaternary about 600 million years to recent age.

11.1.2 Ecological Resource

1) Forestry and Wildlife

The proposed reservoir area of hydroelectric development in Nam Yuam basin project consists of 3 forest types, namely, mixed deciduous forest, tropical evergreen forest and dry dipterocarpus forest. Many wild animal species live in the project area, for examples: Common Barking Deer, Sambar deer, Common Wild Pig, Hog Deer, Elephant, etc. including many species of birds, reptiles. Presently the hunting for food is the reason of wildlife's destruction.

2) Fisheries

Generally species of fish existing in the Yuam river are striped snake-head fish (Pla Chon), climbing fish (Pla Mor), walking catfish (Pla Duk Dan), common silver barb (Pla Ta Pien).

11.1.3 Human Uses Value

1) Soil and Land Uses

The study of soil characteristic and land potential in the project area are shown that the proper area for agriculture covers a small size and is limited at the riverbank plain in Amphoe Mae Sariang and Amphoe Mae La Noi. The regions which can be used for cultivation are the area at Tambon Mae La Luang, Tambon Mae Yuam and Tambon Mae Na Tuan from the area of 70,529 rai, 32,593 rai and 25,695 rai serially.

2) Water Utilization

Water utilizations from the Yuam river in the project area are classified as follows:

a. For agriculture and irrigation
b. For water supply at Amphoe Mae Sariang and Amphoe Mae La Noi

3) Mineral Resource

In Amphoe Mae Sariang and Amphoe Mae La Noi area, there are several economic mineral occurrences. Tungsten, tin, fluorite, barite, lead zinc, iron and manganese are found in this area. The important mineral resources in Amphoe Mae Sarieng are in the south of amphoe near the domain with Amphoe Tha Song Yang and in the east of amphoe at Amphoe Mae La Noi, there are 9 mineral resources.

11.1.4 Quality of Life

1) Socio-economic

There are many differences in ethnic composition of the people in Amphoe Mae Sariang and Amphoe Mae La Noi, for examples the local northern people, Thai Yai and the hill-tribe of 65%. The average density of population from size of household of 5.5 persons per household is 16.24 persons per sq.km.

The majority of population who are in Amphoe Mae Sariang and Amphoe Mae La Noi obtained education level of Prathom. Urban residents finished higher education.

Main occupation of people is agriculture, they cultivate rice, soybean, peanut, garlic and tobacco. Many of them considered wage earning as their occupation.

Land holding document occur with the few at the riverside of the Yuam river. About less than 10,000 cases have the legal document with the average plot size of 5 rai per household.

Important existing land transportation to the project area consists of Highway No.108 from Chiangmai to Mae Hong Son, highway No. 1085 from Amphoe Mae Sariang to Amphoe Mae Sod.

2) Compensation

From preliminary study, hydroelectric development in Nam Yuam basin project, resettling of 3,962 persons in 846 households will be required.

3) Public Health

For health care service in the project area, a number of health centers are enough for the demand of people. But the ratio of physician and population is not sufficient. Contagious disease in the project area are gastro-intestinal tract disease, respiratory tract disease and malaria. The disease in this area is generally, can be controlled.

4) Archaeology

From the preliminary study, the proposed reservoir area is unlikely to have any archaeological or historical significants. But there are 2 monasteries in this area. Wat Mae Su in Ban Mae Su, Amphoe Mae La Noi may be effected from Upper Mae Yuam 1 subproject and Wat Ban Maei in Ban Maie, Amphoe Mae Sariang may be effected from Lower Yuam sub-project.

5) Tourism

In general, no important tourist attractions will be lost because the implementation of hydroelectric development in the Yuam river basin project. But the important benefit of tourism development caused by the proposed reservoir will be increased.

11.2 Environmental Implication

11.2.1 Land Feature and Uses

Hydropower sources in the Yuam river basin may be considered as a system or a package to develop consecutively providing maximized benefit obtained from indigenous resources. But the implementation of Lower Yuam sub-project and Upper Mae Yuam 1 sub-project may be significant caused of the effect upon the Yuam riverbank plain. This area which is rich agricultural land will be the proposed reservoir area. Land uses in the project area will change from agricultural uses for people in Amphoe Mae Sariang to the inundated area. For the effect from the Nam Mae Rit sub-project and Nam Mae Ngao sub-project will be trivial impacts because the most of the area is the mountain and the steep area.

11.2.2 Air Environment

The hydroelectric development in the Yuam river basin is the hydro-power project. Air Quality of the proposed power plant and the proposed area project will not change. The total proposed project area is about 70.6 sq.km. which is considered as the small size area. So the construction and the operation of the project will effect to the meteorological characteristics insignificantly.

11.2.3 Water Environment

The construction of the Upper Mae Yuam 1 sub-project may be the cause of changing in flow of the downstream region significantly. Because the people in Amphoe Mae La Noi and Amphoe Mae Sariang use the water for irrigation, agriculture and other water supply. The water quality may be changed during the construction period.

11.2.4 Species and Ecosystem

Local forests will be disturbed by logging, cleaning and filling the reservoir. The changes to the environment caused by the project are likely to result in the reducing number of local nature flora and fauna in forest ecosystem and fresh-water ecosystem. The species diversity and the density of flora and fauna in the project area will change because of the construction.

11.2.5 Social and Economic Environment

The Lower Yuam project will have impacts upon the socio-economics of the Yuam river basin including the resettlement in the proposed reservoir area. The loss of the rich agricultural land beside the Yuam river will occur because of the reservoir of the Lower Yuam sub-project and Upper Mae Yuam 1 sub-project. Highway No. 1085 at Tambon Sop Moie and Tambon Mae Ta Cuan in Amphoe Mae Sariang will be inundated.

Table 11–1 Resettlement and Evaluation of Structural Property Compensation Cost and Fruit Tree Compensation Cost

	Nam Yuam Sub-project	Nam Yuam 1 Sub-project	Nam Ngao Sub-project	Mae Rit Sub-project
Normal High Water Level (m. MSL)	170	325	240	332
Effected area	A.Mae Sariang T.Sob Moie T.Mae Ka Cuan T.Mae Yuam	A.Mae La Noi T.Mae La Noi T.Mae La Luang	A.Mae Sariang T.Mae Yuam	- -
Resettled Household (Households)	506	365	15	-
Resettler (persons)	2,305	1,582	75	-
Structural Property Compensation Cost (Baht)	8,296,000	5,339,550	189,050	-
Fruit Tree Compensation Cost (Baht)	705,364	453,050	20,910	-
Total Compensation Cost Except Land Compensation (Baht)	9,001,364	5,792,600	209,960	-

Average fruit-tree compensation cost per household = 1394 Baht

JICA