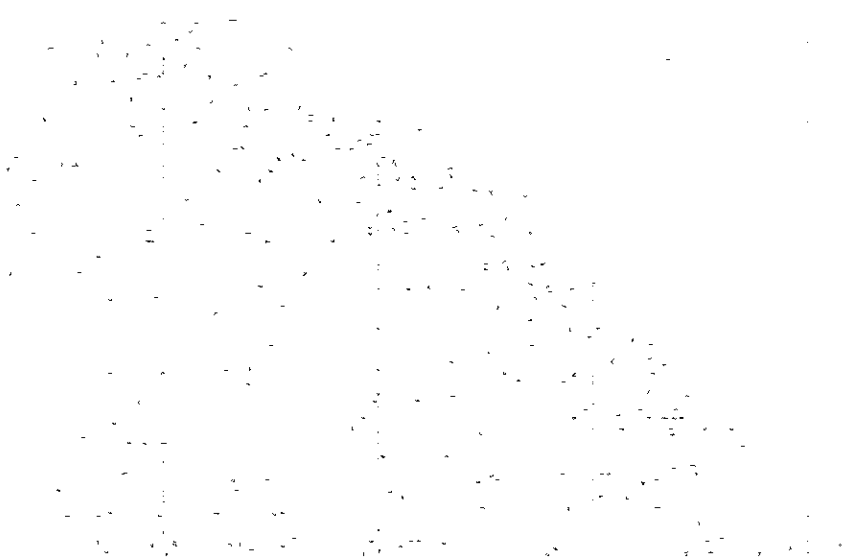
KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
ROYAL IRRIGATION DEPARTMENT

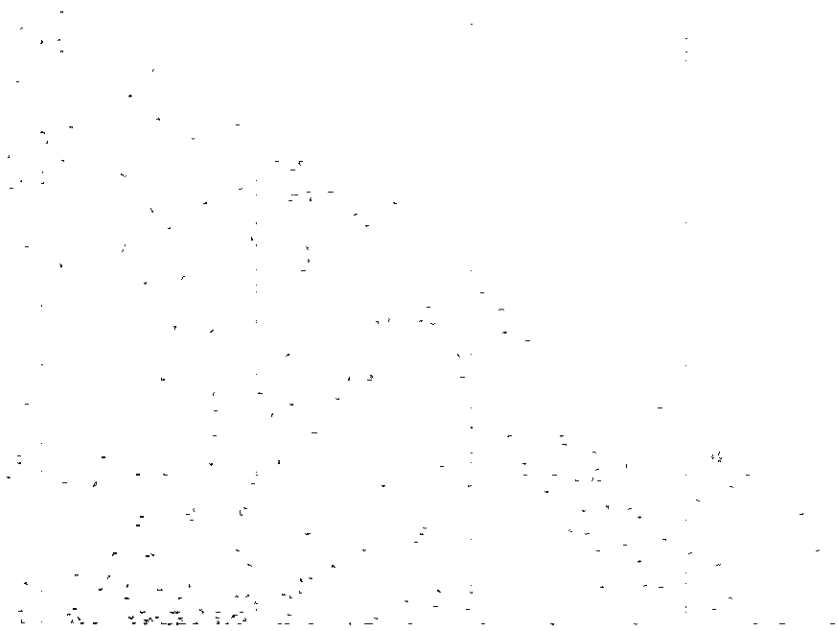
PRE-FEASIBILITY STUDY ON THE UPPER PASAK MEDIUM SCALE IRRIGATION PROJECT

FINAL REPORT
MAIN REPORT

MARCH 1982

JAPAN INTERNATIONAL
COOPERATION AGENCY





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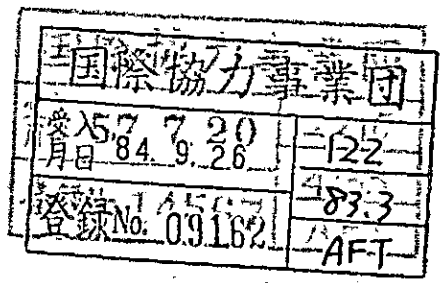


LETTER OF TRANSMITTAL

Mr. Keisuke ARITA
President
Japan International Cooperation Agency,
Tokyo Japan

Dear Sir,

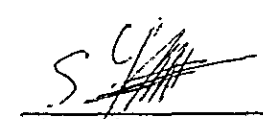
We are pleased to submit herewith forty-five (45) copies of the Pre-Feasibility Study Report on the Upper Pasak Medium Scale Irrigation Project in Thailand, in accordance with the terms of reference issued by your Agency.

This study was made to formulate the basic development plan for the selected four (4) projects i.e. Huai Saduang Yai, Huai Khon Kaen, Huai Yai and Khlong Chaliang Lab. Each project was basically formulated for the increase of agricultural production and the improvement of farmers' living standards in the project area through exploitation of irrigation water resources by constructing the storage dam in each tributary. All of dams were proposed as high as possible to exploit water resources to the maximum extent, as far as topographic and geological conditions are allowable. During this survey period, some data such as topographic maps, geological surveys, dam embankment material surveys, etc. were insufficient for the planning. To realize the basic plan formulated in this study, supplemental surveys and investigations would be required for the next stage of Feasibility Study.

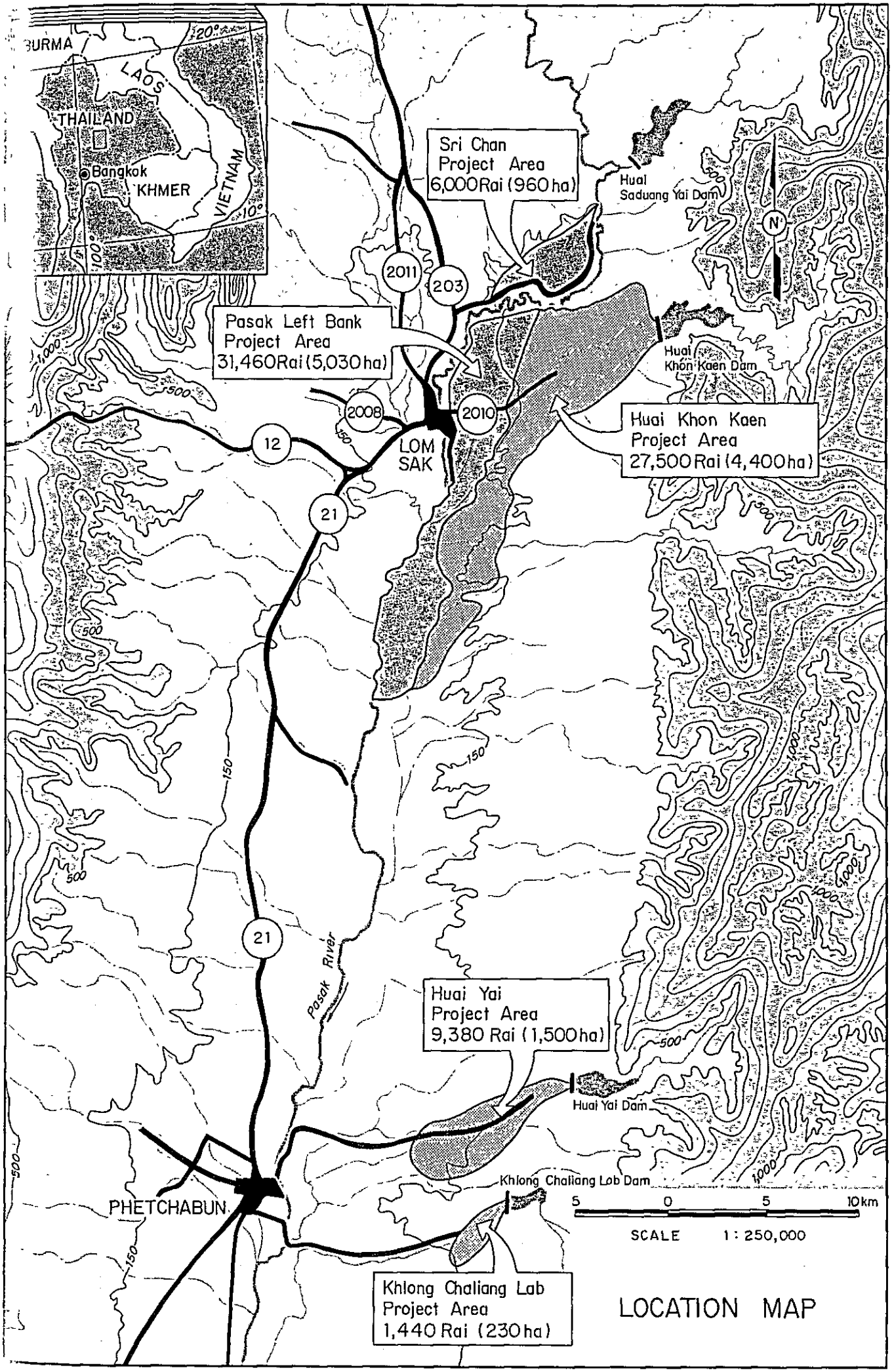
This study was commenced by the study team at the end of August 1981. The study team carried out the field surveys and studies in collaboration with the counterparts provided by Government of Thailand during two (2) months. Subsequently, the team made supplemental studies to fulfill the comments raised by the Thailand Authorities concerned as well as the advices and suggestions offered by the Supervisory Committee, and compiled herewith the Pre-Feasibility Study Report through the home office works in Japan

In submitting this report, we wish to express our sincere appreciation and gratitude to the personnel concerned of your Agency, the Embassy of Japan in Thailand and the Authorities concerned of Government of Thailand for the courtesies and cooperation extended us during our field surveys and studies.

Very truly yours,



Sinichi YANO
Leader of The Study Team
for The Upper Pasak Medium
Scale Irrigation Project


BURMA
LAOS
THAILAND
Bangkok
KHMER
VIETNAM
120°
100°
10°
Sri Chan
Project Area
6,000Rai (960 ha)
Huai
Saduang Yai Dam
Pasak Left Bank
Project Area
31,460Rai (5,030 ha)
Huai
Khon Kaen Dam
Huai Khon Kaen
Project Area
27,500 Rai (4,400 ha)
2011
203
2008
2010
12
21
LOM
SAK
Pasak River
Huai Yai
Project Area
9,380 Rai (1,500 ha)
Huai Yai Dam
PHETCHABUN
Khlong Chaliang Lob Dam
Khlong Chaliang Lab
Project Area
1,440 Rai (230 ha)
5 0 5 10km
SCALE 1 : 250,000
LOCATION MAP

SUMMARY, CONCLUSION AND RECOMMENDATION

BACKGROUND OF THE PROJECT

01. The recent economic growth of the Thailand has been impressive. The growth rate of GDP has been sustained at about 8% during the recent decade of 1970's. Such a rapid stride of the economic growth in Thailand causes serious and complex economic problems and social tensions. In order to overcome these problems and tensions, new strategy and approach have been envisaged and recently drafted out in the Fifth Development Plan, following the Fourth Development Plan which have successfully terminated in late 1981. The major targets and objectives are placed as follows in the development plan:

- to reduce absolute poverty and accelerate rural development in the backward area,

- to restructure the production process both in agriculture and industry in order to accelerate the expansion of exports, reduction of imports and creation of additional employment,

- to raise living standard of the people as well as to strive for more equitable distribution of welfare.

02. Agricultural sector is still a mainstay in the Thailand economy, and provides great contribution to the exports of goods accounting for about 52% of the total exports in 1977/78. The crops produced in Thailand comprise rice, maize, cassava, beans, and rubber, which share 83% of export amount of the agricultural products in 1978. In recent years, crop diversification has been rapidly accelerated particularly in the northern region. In order to achieve the development targets and objectives in the agricultural sector in the Fourth Development Plan, the Government put the more emphasis on raising productivity of agriculture through the development of irrigation system including on-farm development as well as water resources development, and conservation of forest and watershed.

03. Government of Thailand has recently recognized that the irrigation water resources development in the Upper Pasak river basin is to be urgently implemented in the light of basic strategy of the Fourth National Economic and Social Development Plan. Since 1970's, the Royal Irrigation Department (RID) has formulated eighteen (18) medium scale tank irrigation schemes in which RID picked out four schemes for feasibility study for urgent implementation. In response to the request of Government of Thailand to proceed to the feasibility study of the Project, the Government of Japan has decided to provide the technical services for the feasibility study of the Project as a part of the technical cooperation programme of the Government of Japan. Prior to proceed to the feasibility study, the Japan International Cooperation Agency (JICA) despatched the Scope of Works Mission headed by Mr. A. Kazama, Specialist of Agricultural Civil

Engineering Design Division, Department of Construction, Ministry of Agriculture, Forestry and Fishery, to the site in April 1981 to prepare the scope of works as well as the tentative work schedule for the feasibility study. Based on the said scope of works, JICA despatched the pre-feasibility team to Thailand from the end of August 1981 to the end of October 1981.

04. Objectives of the study are to carry out the pre-feasibility study on water resources development of four irrigation schemes i.e. Huai Saduang Yai, Huai Khon Kaen, Huai Yai and Khlong Chaliang Lab, with the following two major work programs:

- to identify the order of priority of implementation,
- to undertake on-the-job training of the counterpart personnel in the course of the study.

PROJECT AREA

05. The project area is extended over the Phetchabun Province situated at about 330 km north of Bangkok, capital of Thailand. Among the four schemes proposed, the Huai Saduang Yai and the Khon Kaen areas are located at eastern part of the Lom Sak District, about 45 km north of Phetchabun city, capital of the Province. The remaining two schemes of the Huai Yai and the Khlong Chaliang Lab areas are located at about 20 km east of Phetchabun municipality.

06. The population of the Phetchabun Province is about 755,000 as of 1978 of which about 292,000 dwell in both the Lom Sak and the Phetchabun Districts. The population in the Lom Sak area is approximately 39,000 and that in the Phetchabun area some 47,000. The working population is estimated at about 17,500 in the Lom Sak area and about 21,000 in the Phetchabun area.

07. The project area for irrigation development extends over the left bank of the Pasak river and are fairly flat with gentle sloping from east to west. The soils in the left bank areas of the Pasak river are broadly classified into three soil groups, i.e. Hydromorphic Alluvial Soil, Hydromorphic Non-calcic Brown Soil and Reddish Brown Lateritic Soil. Hydromorphic soil develops over flat alluvial plain along the Pasak river and is suitable for paddy cultivation. Hydromorphic Non-calcic Brown Soil mainly scatters over the alluvial fan shaped by the tributaries of the Pasak river and is well developed for both paddy and upland crops. Reddish Brown Lateritic Soil mainly develops over terrace and hillside and is moderately well drained and used for maize cultivation at present.

08. The climate in the Upper Pasak river basin is characterized by two distinct wet and dry seasons. The wet season lasts from May to October and the dry season from November to April. The annual mean temperature at the Phetchabun meteorological station is 27.6°C ranging from 33.2°C in maximum mean to 21.0°C in minimum mean. Annual mean rainfall is 1,177 mm at Phetchabun of which about 90% falls during the six months of wet season. Annual mean Pan evaporation is 1,808 mm in which the maximum evaporation occurs in April and the minimum in September. The relative humidity ranges narrowly throughout year, about 63% on an average during the dry season and about 79% during the wet season.

09. The Pasak river, one of the major tributaries of the Chao Phraya river, originates in high mountain ranges in the Loei and the Phetchabun Province, and flows down due southward about seventy (70) km to join the Phung river, the largest tributaries of the Pasak river. After their confluence in the vicinity of the Lom Sak municipality, the Pasak river take its course due southward and traverses the vicinity of the Phetchabun, the Lopburi, the Saraburi, and debouches into the Chao Phraya river in the vicinity of the Ayuthaya. The watershed of the Pasak river extends over to about 15,700 km^2, about nine (9)% of the entire Chao Phraya river basin, at the confluence of the Chao Phraya river. The annual mean runoff recorded at the Kaeng Khoi amounts to about 2,440 million m^3, about eight (8)% of the annual runoff of the entire Chao Phraya river basin.

10. The base rocks in the Upper Pasak river basin are mainly composed of sedimentary rocks originated in the Permian, the Triassic and the Tertiary, and usually covered with the Quarternary diluvial and alluvial deposits. In the skirt of eastern hilly ranges of the Upper Pasak river valley, the Nam Duk Formation originated in middle Permian extends with a strip of 20 to 30 km from north to south. The Khorat group originated in the Triassic of the Mesozoic Era broadly covers the eastern hilly ranges of the Upper Pasak river valley. The Nam Duk Formation has a strata of shale interbedded with sandstone, and discloses a fold structure with a axis extending from north to southward. The formation is supposedly bounded by the faults with NS-strike slip.

11. Irrigation development in the Upper Pasak river valley is relatively low. Only four small and medium scale irrigation projects have been implemented so far by the Central Government in the valley. The Pasak Left Bank project area of 31,460 rai (5,030 ha) is located eastward the Lom Sak municipality and slenderly extends north to south along the left bank of the Pasak river. The Huai Pa Daeng irrigation project area is located at about 15 km westward the Phetchabun municipality and it serves about 13,560 rai (2,170 ha) during only wet season and supplements the potable, domestic and industrial water supplies of the Phatchabun municipality. The wang Bon weir project area is located westward the Lom Sak municipality. The project area of about 2,000 rai (320 ha) is bounded by the National Highway Route 12 in the north and by the Chun river, a tributary of the Pasak river, in the south. The Sri Chan Irrigation Project area is located at about 10 km northeast the Lom Sak municipality. The area of about 6,000 rai (960 ha) extends north to south along the right bank of the Pasak river.

12. The present land use in both the Lom Sak and the Phetchabun Districts is tabulated below.

Category	Lom Sak Dist.		Phetchabun Dist.	
	(10^3 ha)	(%)	(10^3 ha)	(%)
Paddy land	30.0	48	32.4	30
Upland	28.2	45	44.0	41
Forest	0.2	-	16.3	15
Idle land	4.1	7	14.0	14
Total	62.5	100	106.7	100

13. Maize is the main crop grown in the both districts, followed by rice. Upland planting maize mainly extends over terraces and elevated alluvial fans along the skirt of hillside. Some of these maize lands are planted with beans as second crop after maize is harvested. The maize is mainly planted in the upland at onset of the southwestern monsoon, generally April thru May, and harvested in July thru August. After harvesting maize, farmer usually sows mungbeans, soy-beans, sorghum, etc., and harvests them in November at the cease of wet season. Paddy cultivation in the Phetchabun province is concentrated in the wet season because of extremely limited irrigation water resources during dry season. The cultivation pattern is directly affected by depth of annual rainfall. The hectarage planted and/or harvested sharply fluctuates year by year, depending on the available water throughout growing season.

14. The yields and productions widely fluctuate in the Phetchabun province year by year due to wide variation of annual rainfall and unexpected damages caused by flood, insect and diseases. The present crop yields and productions are, therefore, estimated at the average values from 1971 to 1980 as tabulated below:

Crops	Yield		Production
	kg/rai	(ton/ha)	($x10^3$ ton)
Paddy	434	(2.7)	325
Maize	389	(2.4)	483
Mungbeans	111	(0.7)	31
Soybeans	159	(1.0)	12

15. Average farm size in the Petchabun Province is about 30 rai in 1978 which correspond to about 1.14 times of that in the whole Thailand. Approximately 76% of farmers are within the range from 6 to 50 rais of land holding. Owner farmer in the Province is predominant amounting to about 84% in number and about 85% in area respectively.

PROSPECTIVE DEVELOPMENT PLAN

16. The development concepts for agricultural development would comprise:

1) increase of unit yield of wet season paddy through stable irrigation and extension of improved technology of irrigated agriculture,

2) stabilization of paddy cultivation in the wet season,

3) extensive agriculture with low cropping intensity from socio-logical view point,

4) encouragement of crop diversification,

5) extension of water saving cropping pattern, and

6) special attention to impacts on farm economy.

17. To realize the agricultural development concepts, the concepts for irrigation and water resources development would orientate

1) creation of medium scale reservoir by constructing dam,

2) the maximum exploitation of endowed water resources,

3) supplement of municipal water,

4) utilization of exploited water in the vicinity of the exploited site, and

5) full use of the existing irrigation system with proper restoration works.

18. In terms of the 20% recurrence of droughty year, annual yield amounts to 7.0 ℓ/sec/km^2 in the Lom Sak area and 7.8 ℓ/sec/km^2 in the Phetchabun area, resulting in annual runoff at the proposed site of each tributary as

Huai Saduang Yai	21.2	MCM
Huai Khon Kaen	71.0	MCM
Huai Yai	19.1	MCM
Khlong Chaliang Lab	18.9	MCM

19. The water resources at each dam site would be exploited to the maximum extent. The storage capacity of reservoir is determined by topographic and geologic conditions. The proposed storage capacity for each reservoir is:

Reservoir	Total Storage (MCM)	Dead Storage (MCM)	Useful Storage (MCM)
Huai Saduang Yai	15.0	0.96	14.04
Huai Khon Kaen	28.0	3.22	24.78
Huai Yai	7.9	0.78	7.12
Khlong Chaliang Lab	2.3	0.77	1.53

20. The optimal irrigable area for each reservoir is estimated as given below, by water balance study between inflow from tributary and demand of irrigation and municipal water.

Reservoir	Optimal Irrigable Area
Huai Saduang Yai	37,460 rai (5,990 ha)
Huai Khon Kaen	27,500 rai (4,400 ha)
Huai Yai	9,380 rai (1,500 ha)
Khlong Chaliang Lab	1,440 rai (230 ha)

21. The operation study on the proposed reservoir is made to clarify the efficient use of the installed capacity of reservoir operation. The outcomes of the study show that all of the proposed reservoirs are efficiently operated even in the 20% recurrence of droughty year.

22. Two cropping patterns are worked out in due consideration of exploitable amount of water resources in each watershed. Cropping intensity of 135% are proposed in the Lom Sak area comprising 100% of wet season paddy and 35% of dry season beans; cropping intensity of 125% are proposed in the Phetchabun area comprising 100% of wet season paddy and 25% of dry season beans.

23. The anticipated yields of paddy and beans are estimated under with-project condition, as follows:

	kg/rai	(t/ha)
Paddy		
High yield variety	800	(5.0)
Local variety	640	(4.0)
Beans	320	(2.0)

The annual crop productions at the full development stage are expected as tabulated below;

Crop	Huai Saduang Yai (ton)	Huai Khon Kaen (ton)	Huai Yai (ton)	Khlong Chaliang Lab (ton)
Paddy				
High yield variety	15,000	11,000	3,750	575
Local variety	12,000	8,800	3,000	460
Beans	4,200	3,080	750	116

24. The future economic farmgate prices of paddy and beans are estimated as follows on the basis of the Price Prospects for Major Commodities published by IBRD; they are estimated as of 1990 on the basis of 1980 constant dollars.

	฿/ton	($/ton)
Paddy		
High yield variety	7,700	(350)
Local variety	7,260	(330)
Beans	11,000	(500)

25. Annual irrigation requirement in depth amounts to 803.2 mm in the Lom Sak area and 712.1 mm in the Phetchabun area. Under the proposed cropping intensity, per 1,000 rai annual requirement amounts to 1.3 MCM and 1.1 MCM in the respective areas.

26. The exploited water in the Huai Saduang Yai reservoir would supplement irrigation water of the existing Sri Chan and Pasak Left Bank area which mainly depend their irrigation water resources upon the mainstream of the Pasak river. The storage water in the Huai Saduang Yai reservoir is released to the downstream of the Huai Saduang Yai and offtaken again at the Sri Chan Weir under construction and the Pasak diversion weir. No head race would be aligned to these service areas.

The land resources suitable for irrigated agriculture are limited at the lower basin of the Huai Khon Kaen. The service area for this reservoir would be delineated to southward along the eastern boundary of the Pasak Left Bank area. The irrigation water in the Khon Kaen area would be directly obtained from the reservoir and be conveyed by two main canals of about 42 km newly proposed. Nine (9) laterals and sub-laterals totalling 42.3 km would be aligned to distribute irrigation water to the field.

The exploited water resources are limited in the Huai Yai watershed compared with the potential lands suitable for irrigated agriculture. The irrigable area would be delineated from the upstream area to downstream area. The irrigation water would be directly offtaken from the outlet structures. The Huai Yai area would be supplied irrigation water by one main canal of 12.3 km and three laterals and sub-laterals of 16.3 km.

The exploited water resources are extremely limited in the Khlong Chaliang Lab watershed compared with the potential lands in the lower Chaliang Lab basin. The irrigable area is delineated over the limited upper area of the basin. The irrigation water would be directly offtaken from the outlet structures of the dam. The canal system comprises one main canal of 2.3 km and two laterals of 2.8 km in totals.

27. Various dam types might be technically eligible at four proposed dam sites. But in due consideration of geology of foundation, availability of materials, soil mechanical property of materials, etc., zoned type of earthfill dam would be selected for the four dam sites. Impervious core materials are sufficient and readily obtainable around each proposed dam site. Coarse materials suitable for semi-pervious zone must be borrowed from remote distance. Further survey would be made at the next stage.

28. The dam crest elevation would be determined by adding overflow depth of the spillway plus freeboard to the full water level in the reservoir. The width of dam crest is proposed to be 7.0 m to 10.0 m so as to provide a function of inspection road. The slope of upstream face is designed to be 1.0 to 3.0, vertical to horizontal; that of downstream to be 1.0 to 2.5. The foundation treatment would be made by grouting as required according to rock quality, permeability and height of dam.

The service spillway is proposed accounting flood discharge with return period of 100 years. Side channel spillway would be proposed without provision of any control gate in due consideration of the topographic condition at each dam site and safety of dam embankment. Emergency spillway would be provided to ensure stability of dam against extraordinary flooding discharge with return period of 500 years. Two types of the emergency spillway would be proposed according to the topographic condition at dam site, i.e. side channel type and overflow type.

The outlet structure of each dam comprises intake tower, conduit and operation bridge. The intake tower is of reinforced concrete and equipped with regulating gates. Water offtaken in the tower through regulator would be released into downstream through the conduit. The stepping to the operation deck from the dam would be spanned with operation bridge which would be mainly composed of steel.

29. The pre-feasibility level design of the irrigation canals is made on the basis of the maps of 1/10,000 and 1/50,000. The main canal is basically proposed to be concrete-lined, and the laterals and sub-laterals are unlined. All of the irrigation canals have a tropezoidal cross section with a side slope of 1 to 1.5, vertical to horizontal.

30. The general features of four projects proposed in this study are briefly tabulated as follows:

	Description	Name of Project: Huai Saduang Yai	Huai Khon Kaen	Huai Yai	Khlong Chaliang Lab
I.	Reservoir Plan				
(1)	Drainage Area (km^2)	96.0	322.0	78.0	77.0
(2)	Total Storage (MCM)	15.0	28.0	7.9	2.3
(3)	Useful Storage (MCM)	14.0	24.8	7.1	1.5
(4)	Dead Storage (MCM)	1.0	3.2	0.8	0.8
(5)	Full Water Level (m)	187.5	211.5	209.0	196.5
(6)	Reservoir Area at Full Water Level (km^2)	1.6	1.4	1.0	0.3
II.	Dam Plan				
(1)	Dam Type	----------	zoned earthfill type		----------
(2)	Dam Crest EL. (m)	191.0	216.0	212.5	200.0
(3)	Dam Height (m)	30.5	52.0	32.5	25.3
(4)	Dam Crest Length (m)	413.0	912.0	280.0	207.0
(5)	Dam Volume (MCM)	0.67	2.73	0.33	0.15
III.	Irrigation Plan				
(1)	Service Area (rai)	37,460	27,500	9,380	1,440
	(ha)	(5,990)	(4,400)	(1,500)	(230)
(2)	Crop Intensity (%)	135	135	125	125
(3)	Irrigation Water Requirement (MCM/year)	48.2	35.3	10.7	1.6
(4)	Canal Length (km)	-	84.3	28.6	5.1
IV.	Municipal Water Supply Plan (m^3/day)	4,000	4,000	-	-

31. The project costs are estimated on the basis of quantity-taking of project works and authorized unit prices at 1981 level. The costs for the implementation of each project are estimated as tabulated below:

(Unit: $x10^3$฿)

	Work Item	Name of Project: Huai Saduang Yai	Huai Khon Kaen	Hua Yai	Khlong Chaliang Lab
I.	Civil Works	155,390	406,010	88,210	44,670
II.	Engineering and Administration Cost	23,310	60,900	13,230	6,700
III.	Physical Contingency	35,740	93,380	20,290	10,270
	Total	214,440 ($9,747x10^3$$)	560,290 ($25,468x10^3$$)	121,730 ($5,533x10^3$$)	61,640 ($2,802x10^3$$)

Operation/maintenance cost mainly comprises personnel cost, depreciation cost of O/M equipment, vehicle, office and quarter, and consumable expenses. The O/M cost for each project are roughly estimated as follows:

Project	O/M Cost (10^3 ฿/annum)
Huai Saduang Yai	1,716
Huai Khon Kaen	4,482
Huai Yai	974
Khlong Chaliang Lab	493

ECONOMIC JUSTIFICATION AND SELECTION OF PRIORITY PROJECT

32. Economic evaluation is made in view of projects' impacts on national and regional economy. The project feasibility is evaluated in terms of economic internal rate of return. Two kinds of economic IRRs are estimated according to the direct benefits, and direct benefits plus secondary benefits, respectively. The impacts on the regional economy are assessed in terms of net present value (Benefit minus Cost). The estimated values are as summarized below:

Project	Economic Internal Rate of Return: Direct Benefit (%)	Direct Benefit plus Secondary Benefits (%)
Huai Saduang Yai	16.1	20.8
Huai Khon Kaen	14.2	17.9
Huai Yai	20.1	26.8
Khlong Chaliang Lab	7.4	10.1

Unit : 10^6฿ ($10^6$$)

Project	Net Present Value (Discount Rate: 12%) By Direct Benefit	By Direct Benefit plus Secondary Benefit
Huai Saduang Yai	60.13 (2.73)	143.75 (6.53)
Huai Khon Kaen	87.32 (3.97)	255.09 (11.60)
Huai Yai	81.20 (3.69)	143.90 (6.54)
Khlong Chaliang Lab	-16.96 (-0.77)	-7.30 (-0.33)

33. The priority projects would be selected on the basis of the following criteria:

Criteria - 1		Technical Soundness
	1.1	Stability of dam embankment
	1.2	Stability of dam foundation
	1.3	Present irrigation development
Criteria - 2		Economic viability
	2.1	Project economy
	2.2	Economic impacts caused by secondary benefits
	2.3	Associated benefits
Criteria - 3		Socio Economic Impacts
	3.1	Contribution to regional economy
	3.2	Administrative consideration
	3.3	Employment opportunity
	3.4	Impact on farm economy
	3.5	Other socio-economic factors

34. In accordance with each criteria, the project is assessed by four rankings as summarized below:

Criteria	Huai Saduang Yai	Huai Khon Kaen	Huai Yai	Khlong Chaliang Lab
Technical Soundness	1	3	4	2
Economic Viability	2	3	1	4
Socio-Economic Impacts	3	1	2	4

35. Among three criteria, the socio-economic impacts are highly regarded in the selection of priority project. While, technical soundness is less regarded, because this criteria are considerably evaluated in the economic viability. Therefore, the definite selection is made by weighting the criteria of socio-economic impacts and economic viability. The Huai Yai project would be given the first priority of implementation, followed by the Huai Khon Kaen project. The Huai Saduang Yai is also technically and economically as feasible as the Huai Khon Kaen project.

CONCLUSION

36. Among four projects, three projects i.e. Huai Yai, Huai Khon Kaen and Huai Saduang Yai, are verified herewith to be technically sound and economically feasible through this study. It is, therefore, recommended that some or all of these three projects should be proceeded to the next stage of Feasibility Study.

RECOMMENDATION

37. Although the economic viability of the Khlong Chaliang Lab project is not so high in this study, additional benefit can be expected from the fishery development using the proposed reservoir and irrigation canals. The fishery development would contribute to the local supplies of animal protein. The potential of fishery development in the project is proposed to be studied at the next stage.

38. Supplemental surveys and investigations as shown in ATTACHMENT-4 would be required for the next stage of the project. In order to carry out smoothly the feasibility study in the limited period, these surveys and investigations are recommended to be commenced as early as possible.

39. No meteoro-hydrological stations have been installed and operated in the watershed so far relevant to the project. Their networks are proposed to be established for the design works and O/M of the project.

40. Although the proposed dams in this study would be constructed mainly for the purpose of the irrigation water supply, the micro hydropower development would be considered as an associated scheme of the project.

41. Institutions for agricultural support services are essential to exploit the full potential for agricultural development. The study for those institutions would be made at the next stage of Feasibility Study.

42. The supply and demand of water resources are not sustainable in the entire Pasak river basin, unless decisive measures are adopted for water resources development as given in ATTACHMENT-1. To keep the stable balance of supply and demand, the following basic measures are recommendable for the entire Pasak river basin.

i) campaign and extension of water saving cultivation,

ii) betterment of water management,

iii) extension of irrigated agriculture of low intensity,

iv) further exploitation of deficient water resources through transbasin works, and

v) exploitation of groundwater for exclusive use for municipality and industry.

43. The watershed of each tributary is extremely small compared with the vast land resources extending in the lower basin of tributaries. The sprawl of land reclamation for shifting cultivation in the watershed has recently caused depletion of river flow in each tributary. The planless land reclamation should be strictly controlled by the administrations concerned. In addition, reforestration works are recommended to be formulated in respective tributaries and given high priority of implementation as well as irrigation works.

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GLOSSARY OF TERMS AND ABBREVIATION

1. Glossaries

Changwat	:	Province
Amphoe	:	District
Tambon	:	Township
Muban	:	Village
Muang	:	Administrative Center of Province
Mae Nam	:	River
Khwae	:	Main tributary of a river
Huai	:	Stream, creek or small tributary
Khlong	:	Canal
Baht	:	Unit of Thai Currency (US$1.00 = Baht 22)

2. Abbreviations

ACFT	:	Agricultural Cooperative Federation of Thailand
ALRO	:	Agricultural Land Reform Office
BAAC	:	Bank for Agriculture and Agricultural Cooperatives
DAE	:	Department of Agricultural Extension
EGAT	:	Electricity Generating Authority of Thailand
EL	:	Elevation above mean sea level
FMO	:	Farmers Marketing Organization
HYV	:	High Yielding Variety
JICA	:	Japan International Cooperation Agency
MOAC	:	Ministry of Agriculture and Cooperatives
NEA	:	National Energy Administration
NESDB	:	National Economic and Social Development Board
OAE	:	Office of Agricultural Economics
O&M	:	Operation and Maintenance
RID	:	Royal Irrigation Department

3. Area and Volume

rai	:	0.16 hectare
ha	:	hectare
m^2	:	square meter
km2	:	square kilometer
ℓ	:	liter
m^3	:	cubic meter
MCM	:	million cubic meter
kg	:	kilogram
t	:	ton

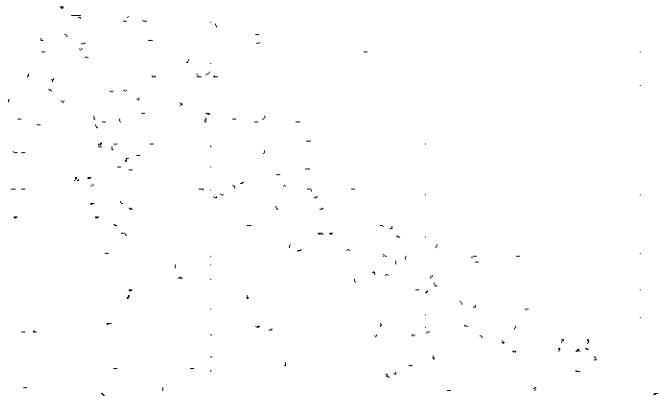
4. Derived Measures based on the Same Symbols

mm/day	:	millimeter per day
ℓ/sec/ha	:	liter per second per hectare
cm/sec	:	centimeter per second
km/sec	:	kilometer per second

m^3/sec	:	cubic meter per second
$m3/km2/year$	:	cubic meter per square kilometer per year
$kg/cm2$	:	kilogram per square centimeter
t/m^2	:	ton per square meter
t/ha	:	ton per hectare

5. Others

%	:	percent
No.	:	Number
Nos.	:	Numbers
HWL	:	High Water Level
FWL	:	Full Water Level
DWL	:	Dead Water Level
MSL	:	Mean Sea Level



CHAPTER I INTRODUCTION

1.1 AUTHORIZATION OF THE REPORT

This report is prepared in accordance with "Scope of Works" for the Pre-Feasibility Study on the Upper Pasak Medium Scale Irrigation Project agreed upon between the Government of Thailand (referred to as the Government, hereinafter) and the Government of Japan, in April, 1981.

This report presents the results of the field investigation and intensive study in Thailand and the subsequent study in Japan carried out by the Study Team on the basis of the comments raised by the Thailand Authorities concerned, and advices and suggestions offered by the Supervisory Committee of the Japan International Cooperation Agency (referred to as the JICA, hereinafter).

1.2 PROJECT HISTORY

Agricultural development in the Upper Pasak river valley has been left and never been focussed for a long time, owing to serious shortage of irrigation water resources. The committee for Reconciliation and Promotion of Water Resources Development under the Office of Prime Minister of the Government has recently recognized that the irrigation water resources development in the Upper Pasak river valley should be urgently implemented in the light of the basic strategy of the Fourth National Economic and Social Development Plan (referred to as the National Development Plan, hereinafter).

After much consultation with the Royal Irrigation Department (referred to as the RID, hereinafter), an executing body for irrigation water resources development, the Committee reached the conclusion that feasibility study should be promptly implemented for the first step to the water resources development in the valley. Meanwhile, since 1970's, the RID has envisaged medium scale irrigation water resources development in the tributaries of the Pasak river and formulated eighteen (18) medium scale tank irrigation projects in the valley, based on the detailed reconnaissance study.

In compliance with the conclusion of the Committee and the urgent request from the farmers concerned, the RID picked out the four projects for feasibility study in due consideration of their positions held in the overall development of the entire valley. While, the RID understood that one package implementation of these four projects would be beyond the capability of the RID in terms of both the budget and the technical manpower, and also concluded that these projects would be preferably implemented in two phases. To identify high priority projects for the Phase-I, the RID determined the policy for the implementation of these projects, as mentioned below.

A pre-feasibility study shall be undertaken for the first step of the water resources development in the valley and then, followed by the feasibility study on the eligible projects. These two-stage studies would be implemented at the Phase-I program. In accordance with the same procedures, the remaining projects would be subsequently implemented in the Phase-II program which will immediately follow the Phase-I program.

On the basis of the concept above-mentioned, the Government made a request to the Government of Japan to extend a technical cooperation for the pre-feasibility study on the four projects and the feasibility study on the selected projects as a series of the first phase technical cooperation program. In response to the request of the Government, the Government of Japan decided to offer the technical assistance for the pre-feasibility study on the said four projects as a part of the technical cooperation program for the Phase-I.

In early April, 1981, the JICA dispatched a scope of Works Mission for the Upper Pasak River Medium Scale Irrigation Project, headed by Mr. A. Kazama, Construction Department, the Bureau of Agricultural Structural Improvement, Ministry of Agriculture, Forestry and Fishery. The team discussed the scope of works for the pre-feasibility and the feasibility study on the said projects with the Authorities concerned. On the basis of the agreed "Scope of Works", the pre-feasibility study substantially commenced in early September, 1981, upon arrival of the first group of the study team.

1.3 OBJECTIVES OF THE STUDY AND SUMMARY OF THE SCOPE OF WORKS

As specified in the scope of works agreed upon between the Government and the Government of Japan, the pre-feasibility study contains two major work programs as presented below.

Program 1. To identify the priority of implementation among the selected four projects, and

Program 2. To undertake transfer-of-knowledge to the counterpart personnel in the course of the study.

The scope of works undertaken by the Team comprise the field works and office works in the project site and home office works. These works cover the following contents.

1) Field Works

- Reconnaissance of the project area,
- Collection and review of the relevant data and information,
- Meteoro-hydrological investigation,

- Dam foundation and material survey
- Topographic survey
- Inventory survey of the existing irrigation/drainage facilities
- Soil and land use survey
- Regional economic survey
- Agricultural and agro-economic survey
- Construction material and costs survey

2) Office Works at the Site

- Water resources development plan
- Agricultural development plan
- Irrigation development plan
- Dam plan

3) Home Office Work

- Review of the interim report which will be submitted before leaving the project site
- Preliminary design
- Identification of the priority to the proposed four projects
- Recommendation to the Government

1.4 ACTIVITIES IN THE FIELD

On the basis of the careful review of the previous studies and the findings through reconnaissance undertaken in advance of the commencement of the study, the Team envisaged technical approach to the project and practical plan of operation for the study, and compiled them in the Plan of Operation Report. The report was submitted to the Government immediately after the Team had arrived in Thailand. The discussion on the report was held at the RID office, Bangkok, on the beginning of September, at the presence of the Thailand Authorities concerned and the Supervisory Committee headed by Mr. Y. Sakamoto from Kinki Regional Bureau, the Ministry of Agriculture, Forestry and Fishery, Japan. The approach to the project and the plan of operation proposed in the Plan of Operation Report was basically approved by the Authorities concerned through the discussion.

In the course of the study, weekly meeting had been regularly held on every Monday morning between the Team and the Counterpart personnel to coordinate the field activities and to smoothly execute the field works. Work progress during previous week, work schedule during current week, and technical matters encountered in the course of the study had been mainly reported and discussed in the meeting. Furthermore, informal discussions had been frequently made on the specific technical matters, as required, between the personnel concerned.

On late October, 1981, the Team prepared the interim report and submitted it to the Government in accordance with the "Scope of Works". The discussion on the report was held at the RID office, Bangkok, on 28th of September, 1981 at the presence of the Thailand Authorities concerned and the Supervisory Committee headed by Mr. A. Kazama, Construction Department, the Bureau of Agricultural Structural Improvement, Ministry of Agriculture, Forestry and Fishery, Japan. Through the discussion, some comments were offered by the Thailand Authorities concerned. Subsequently, the Study Team made supplemental studies to fulfill the comments and compiled herewith the draft final report through the home office works in Japan.

CHAPTER II ECONOMIC AND AGRICULTURAL BACKGROUND

2.1 COUNTRY AND ITS CHARACTERISTICS

Thailand is located in the tropical monsoon zone occupying a territory of about 514,000 km^2 and having a population of about 45 million as of 1978, and average population growth rate of 2.7% per annum during the period of recent 8 years.

The Thailand has sustained an aggregate Gross Domestic Product (GDP) growth rate of nearly 8% during the recent decade of 1970's, in spite of negative impact of the oil crisis. The amount of GDP reached to 477 billions Baht (US$ 22.7 billions) as of 1978, corresponding to the per-capita GDP of 10,607 Baht (US$505).

The natural conditions in Thailand are much favourable for agriculture. About 114 million rai (18.2 million ha) or 35% equivalence of total land are being used for agriculture and nearly 76% of the total employment are engaged in agricultural sector which is still a mainstay of the Thailand economy.

Administratively, the country is divided into 72 Provinces (Changwat). Each Province is further devided into more or less 10 Districts (Amphoe). Each District is further subsegmented into several Townships (Tambon) which are a group of villages.

2.2 REGIONAL ECONOMY

The project areas are located in the northeastern part of the Northern Region. This region occupies about 170,000 km^2 or 33% of the entire territory of Thailand. The capable land resources is however equivalent to 42% of the total occupied area in the Northern Region, due mainly to its topography and vast natural reserved forests.

The population of the region is estimated to be 9.5 million, or 21% equivalence of the total population in Thailand. The annual population growth rate in the region has been recently decreased to 2.4%, which is lower than the rate of national average, because some amount of population is out-migrating year by year. The region is not fully capable of absorbing the increased population owing to shortage of land resources. Another reason for the out-migration in this region is due to the low income level. The region shares about 14% of the GDP because of the low aggregate productivity. The per-capita income of the region is ranked the second lowest, following the northeastern region; in 1978, the per-capita income still remains at 6,445 ฿ or 65% equivalence of the national average.

Administratively, the Northern Region has seventeen (17) provinces, 153 districts, 1,214 townships and 10,431 villages. The Petchabun province, within which the project areas are located, has nine (9) districts and 28 townships. The administrative map is given in Figure 2.1.

2.3 NATIONAL DEVELOPMENT PLAN

In 1977, the Royal Government launched the Fourth National Economic and Social Development Plan (referred to as National Development Plan, hereinafter) in order to follow the Third National Development Plan which have terminated by late 1976. Despite of the rapid strides of the development during the Fourth Development Plan, Thailand has been faced with more serious and complex economic problems and social tensions, such as rural poverty, income disparities, deterioration of external financial position and increase of national defense burden. In order to overcome these economic and social problems, new development strategy and approach have been envisaged by the Government. Following the Fourth Development Plan which have created various socio-economic problems and terminated in late 1981, the outlines of the Fifth National Development Plan was issued by the National Economic and Social Development Board in late 1981. The Plan mainly campaigns the major objectives as follows.

1) To reduce absolute poverty and accelerate rural development in backward areas,

2) To maintain the economic and financial stability by emphasizing "national austerity and expenditure control both in the public and private sectors,

3) To restructure the production process both in agriculture and industry in order to accelerate the expansion of exports, reduction of imports, and creation of additional employments,

4) To adjust social structure in order to make it more stable, fair and safe, as well as to provide more educational and employment opportunities for the poor, and

5) To coordinate consistently economic development activities with national security management.

During last two decades under the First through the Fourth Development Plan, Thailand has sustained high economic growth rate with structural changes in production, foreign trade, and the pattern of income distribution; the growth rate of the Thai economy is averaged at greater than 7 percent per annum. This was mainly attained by the expansion and diversification of production and exports of agricultural and industrial outputs. But the high growth rate has caused rapid deteriorations of forest, land, water and marine resources. While, the growth benefits have not been evenly spread over among various areas and economic sectors, and thus, this growth pattern has brought about greater income disparity.

In due consideration of the current confronting issues and the economic trends in Thailand to be anticipated in the coming five years, the Government sets forth the following development targets to alleviate the problems and to adjust the economic and social structure.

1) The quality of life of the rural population is highly developed, particularly of these in absolute poverty areas by channelling more financial and manpower resources of the Government to these depressed areas and by mobilizing the people's participation in the course of rural development. This Target receives the highest priority in the Fifth Development Plan,

2) The targets of both trade and current account deficits are set at less than 60 billion Baht and 42 billion Baht, respectively on an annual average,

3) The target of GDP growth rate is set at 6.9% per annum in real term. Special emphasis is placed on the expansion of the agricultural sector at 4.7% to generate more income in rural area. The growth of agricultural sector must mainly be brought about in the backward and depressed areas to improve income distribution,

4) Import target of oil is reduced to zero growth, and

5) In order to control the national aggregate spending to an appropriate level, the strict targets of revenue and expenditures are set forth.

2.4 GOVERNMENT POLICY FOR AGRICULTURAL DEVELOPMENT

Agricultural sector is still mainstay in the Thailand economy, and especially serves for the national economy through self sufficiency of staple food and employment absorption. Furthermore, the sector makes great contribution to the exports performance; share of agricultural exports accounts for 52% of the total exports in 1977/78.

Major crops produced in Thailand comprise rice, maize, cassava, beans, and rubber. These five crops share 63% of total added value of agricultural production in 1976, 90% of total planted area in 1977/78 and 83% of the export amount of agricultural crops in 1978. These leading shares are mainly caused by rapid expansion of uplands crops production in response to favourable world market for export crops.

In recent years, crop deversification has been rapidly accelerated in the northern region. The diversified crops comprise maize, rice, cassava, mungbeans, sugar cane, tobacco, soybeans, groundnuts, cotton, and sorghum. Among them, rice is still top-ranked in terms of shipment value in 1979, and followed by maize.

In order to achieve the shorter-run objectives of a rapid economic recovery and a greater degree of economic stability stipulated in the Fifth Development Plan, the following overall targets and supporting policy measures set forth in respect to agricultural sector.

1) To attain the target of about 7% increase in the GDP, the value in agricultural sector is projected to expand by about five (5) percent per annum,

2) The Government will put more emphasis on the conservation of forest and watershed. Hence, expansion of farmland will be limited over the 5 year period. In this connection, the strategy for agricultural development has to emphasize structural improvement within the sector; production increase through crop intensification and further agricultural diversification will be promoted,

3) In order to raise productivity of agriculture, the priority is given to development of irrigation system and expansion of on-farm facilities as well as water resources development. In addition, emphasis is placed on soil improvement and strengthening agricultural support services.

CHAPTER III PRESENT CONDITION IN AND AROUND THE PROJECT AREA

3.1 LOCATION

The four proposed projects under study scatteringly extend over the Phetchabun Province which is located at about 330 km north, remote from Bangkok, the capital of Thailand, along the National Highway Route-1 and -21. Among them, the Huai Saduang Yai and Huai Khon Kaen irrigation project areas are located at eastern part of the Lom Sak district, about 45 km north from the Phetchabun municipality, while the Huai Yai and Khlong Chaliang Lab irrigation project areas are located at about 20 km due east of the Phetchabun municipality, capital of the Province.

3.1.1 Lom Sak Area

The Sri Chan area is located at about 15 km northeast of the Lom Sak municipality and extends over the right bank along the Pasak river from the site of Sri Chan weir to the site of the Upper Pasak diversion weir. It is approximately bounded by the provincial road stretched out of the National Highway Route-203 on the east and the south, and by a natural creek on the north and the west. Administratively, the area comes under Tha Ibun township of the Lom Sak district.

The Upper Pasak Left Bank Area is located at 5 km due east of the Lom Sak municipality and extends over the left bank of the Pasak river. It is approximately bounded by the main stem of the Pasak river on the north and the west, by the existing main irrigation canal on the east and by the district boundary on the south. All of the area is fully covered by the Upper Pasak Left Bank Irrigation Project. It extends about 14 km from north to southward with an average width of 2 km. Administratively, the area comes under three townships of the Lom Sak district, i.e. Sak Long, Tan Diew and Ban Sok.

The Huai Khon Kaen area is located at about nine (9) km east of the Lom Sak municipality. It is approximately bounded by the main irrigation canal of the Pasak Left Bank Project on the west and by the Huai Nam Duk on the south. The northern and eastern boundaries are skirted with terrace lands extending along foots of eastern hilly ranges. The area extends about 15 km from north to southward and it is 2 km wide on an average. Administratively, the area comes under four townships of the Lom Sak district, i.e. Huai Rai, Ban Tiew, Ban Sok and Pak Chong.

3.1.2 Phetchabun Area

The Huai Yai area is located at due east of the Phetchabun municipality and slenderly extends about 14 km from the west to eastward with an average width of about 2 km astride the district road stretching out

from the Phetchabun municipality to Huai Yai village. It is approximately bounded by the Huai Yai on the north, by the Huai Nam Sai on the south, and by the Khlong Mai Daeng on the west. The eastern boundary is skirted by the existing paddy field extending close to the foot of eastern hill. Administratively, the area comes under four townships of the Phetchabun district; i.e. Huai Yai, Ban Khok, Dong Moon Laek, and Sadiang.

Khlong Chaliang Lab area is located at southeast of the Phetchabun municipality. In parallel with the Huai Yai area, it slenderly extends about 10 km from east to westward with an average width of 2 km, astride a district road aligned between the Phetchabun municipality and the Chaliang Lab village. It is approximately bounded by Khlong Chaliang Lab on the north, by low terrace land extending on the south and by the Khlong Kung on the west. The eastern boundary is extended to the foot of eastern hill. Administratively, the area comes under Na Pa township of the Phetchabun district.

3.2 NATURAL RESOURCES

3.2.1 Land Resources

About 845,000 rai (135,200 ha) of arable land resources are endowed in both the Lom Sak and the Phetchabun districts. Out of them, about 394,500 rai (63,100 ha) have been developed for paddy and upland crops cultivation. These lands slenderly extend from north to south along the both banks of the Pasak river.

In addition, about 450,000 rai (72,000 ha) of land resources extend along the skirt of hillsides and are scattered on the district boundary. These lands are mainly used for upland crop cultivation from the viewpoint of soil, topography and irrigation water availability.

Furthermore, about 215,500 rai (34,500 ha) of uncultivable lands extend over the both districts. These lands are presently covered with forest and bushes. In recent years some part of forests and bushes have been illegally reclaimed for shifting cultivation, in order to supplement limited land resources resulting in serious depletion of water resource in the tributaries of the Pasak river. Further extensive sprawl of reclamation in the watershed of tributaries causes serious water shortage all over the Pasak river valley. In view of water conservation, planless reclamation, particularly in the watershed area should be strictly prohibited and the maximum use of existing arable land should be firstly envisaged.

3.2.2 Water Resources

The Pasak river, one of the major tributaries of the Chao Phraya river, originates in high mountain ranges in the Loei and the Phetchabun Province, and flows down due southward about 70 km to join the Phung river, the largest tributaries of the Pasak river. After their

confluence in the vicinity of the Lom Sak municipality, the Pasak river takes its course due southward and traverses the vicinity of the Phetchabun, the Lopburi, the Saraburi, and debouches into the Chao Phraya river in the vicinity of the Ayuthaya.

The watershed of the Pasak river extends over to about 15,700 km^2, about nine (9)% of the entire Chao Phraya river basin, at the confluence of the Chao Phraya river. The annual mean runoff recorded at the Kaeng Khoi amounts to about 2,440 million m^3, about eight (8)% of the annual runoff of the entire Chao Phraya river basin. As given in Fig. 3.1, water gauging stations are installed in the mainstream of the Pasak river and operated by the Royal Irrigation Department. Furthermore, one water gauging station is installed at Kaen Sida to collect data for hydropower development. They provide considerably reliable data on runoff along the main reach of the Pasak river.

A number of tributaries confluences with the mainstream of the Pasak river. Eighteen (18) medium scale irrigation projects have been recently reconnoitred by the RID, depending their water resources on the major tributaries among them. Out of them four tributaries, i.e. Huai Saduang Yai, Huai Khon Kaen, Huai Yai, and Khlong Chaliang Lab are picked out to undertake a pre-feasibility study on the medium irrigation development in the upper Pasak river basin.

Huai Saduang Yai

The Huai Saduang Yai, a small tributary of the Pasak River, originates in the Mt. Phykok, Pnu and Bukpaen of about 700 m or so in altitude, and drifts down about 30 km from east to west to join the main reach of the Pasak river in the vicinity of the Fung Dorn Village.

The total watershed of this tributary extends over about 96 km^2 at the proposed dam site which is located at about 1.5 km upstream from the confluence of the mainstream of the Pasak river. The river channel totals about 28.5 km stretching from its origin to dam site. The river-bed gradient is relatively steep in the vicinity of the proposed dam site. No water gauging station has been installed so far in the watershed. No data is available on runoff at all.

Huai Khon Kaen

The Huai Khon Kaen, the largest tributary among the four selected water sources, originates in the ranges of Mt. Huai Koh, Huai Hi, Pu Mok, Pu Nam Rin, Pa Lob, etc., 900 m above MSL, locating in due east of the Lom Sak. It meanders about 72 km westward to join the main stem of the Pasak river at the left bank, at about 24 km downstream from the Upper Pasak diversion weir.

The watershed of the tributary is located at due south of the Huai Saduang Yai watershed, extending to about 322 km^2 at the proposed dam site which is proposed at about 19.5 km upstream from the confluence of the Pasak river. The river channel totals about 53 km stretching out

from its origin to the proposed dam site. The watershed is relatively better reserved even though sporadic land reclamation has been recently made by farmers for shifting farming in the hillside. No water gauging station has been installed so far in the watershed and no data is available on runoff at the dam site.

Huai Yai

The Huai Yai originates in the ranges of Mt. Hingumn, Ponthong, Suiroi, Saliang Tatard, etc. of about 1,200 m in altitude and drifts down about 47 km from northeast to southwestward joining many small rivulets, and debouches into the main reach of the Pasak river in the vicinity of the Phetchabun municipality.

The watershed of the tributary is located at due east of the Phetchabun municipality, extend over about 78 km^2 at the dam site which is proposed at about 25 km upstream from the confluence of the Pasak river. The river channel totals about 47 km stretching from its origin to the confluence of the Pasak river. The river-bed gradient is rather steep in the vicinity of the proposed dam site. Water and soils in the watershed are likely to be relatively better reserved.

Khlong Chaliang Lab

The Khlong Chaliang Lab originates in the ranges of Mt. None Yang, Huai Rong, None Sra, Ta Boh, etc. of about 1,300 m in altitude and meanders about 54 km from southeast to northwest joining many small rivulets and debouches into flat fan. Then, it splits into many distributaries developed across the fan.

The watershed of this tributary is located in due south of the Huai Yai watershed, extending to about 77 km^2 at the dam site which would be proposed at about 28 km upstream from the confluence with the Pasak river. The river channel of about 54 km stretches out its origin to the said confluence; about 26 km from its origin to the proposed dam site. The river-bed gradient is relatively steep in the vicinity of the proposed dam site.

The watersheds of these tributaries are demarcated as presented in Fig. 3.2. The Phetchabun district is a little more pluvious than the Lom Sak district. The mean annual rainfall in the Phetchabun is averaged at about 1,121 mm on the basis of the records from 1952 to 1977; that in the Lom Sak, at about 1,115 mm on the basis of the records from 1952 to 1977. Presuming the annual runoff coefficient of 26%, each watershed is endowed with the following mean annual runoff.

	Watershed	Drainage Area (km^2)	Endowed Mean Annual Runoff (MCM)
i)	Huai Saduang Yai	96	27.8
ii)	Huai Khon Kaen	322	93.3
iii)	Huai Yai	78	22.7
iv)	Khlong Chaliang Lab	77	22.4

3.3 HUMAN RESOURCES

The population of the Phetchabun province is about 755,000 as of 1978, out of which about 292,000 dwelt in both the Lom Sak and the Phetchabun districts. According to the population census undertaken in 1978, the Lom Sak area which covers eight townships relevant to both the Saduang Yai and the Khon Kaen irrigation project is populated by some 39,000, the Phetchabun area which covers five townships relevant to both the Yai and Chaliang Lab irrigation project is populated by some 47,000.

The number of household in the Lom Sak and the Phetchabun area is estimated at about 6,700 holds and 6,330 holds, respectively. Among them, the farm household accounts for about 5,760, 86% equivalence of the total household in the Lom Sak area and about 5,190, 82% equivalence of the total household in the Phetchabun area. The average family size is estimated to be seven (7) persons per household in the both areas.

Total working population is estimated at about 17,500 in the Lom Sak area and about 21,100 in the Phetchabun area which correspond to 45% of total population. Out of them, about 15,600 in the Lom Sak area and 19,000 in Phetchabun area are directly engaged in agricultural production.

3.4 PHYSICAL FEATURES

3.4.1 Topography

The Pasak river valley slenderly extends north to south along the Pasak river with an average width of about 45 km. The plain extending over the left bank of the Pasak river is broadly divided into terrace, alluvial fan and recent alluvial flat.

Low terraces are scattered over the elevated area near the eastern hillside and are mainly covered with forests and uplands. Many small scale alluvial fans have been created by the tributaries which originate in the eastern hilly ranges and join the Pasak river. The fan is gently sloping from northeast to southeast with a topographic gradient of nearly 0.4% and it has been developed mainly for upland cultivation. Its altitude ranges from 200 m to 170 m above MSL.

The recent alluvial flat shaped by fluvial action of the Pasak river slenderly extends along the bank of the Pasak river. The flat is topographically gentle and lowlying, and has been well-developed for paddy field. Its altitude varies between 160 m to 150 m above MSL.

3.4.2 Climate and Meteorology

Thailand belongs to the tropical monsoon. The climate in the Upper Pasak river valley is characterized by two distinctive season, i.e. wet and dry, according to the distribution of rainfall. The dry season is further subdivided into the cool winter and hot summer according to the fluctuation of temperature.

The humid southwest monsoon prevails over the Upper Pasak valley and the wet season starts in May, and it lasts until October. The dry season commences in the northeast monsoon and lasts until April. The first half of the dry season from November to January is so called cool winter. Both the temperature and the humidity considerably decline during this period. Whereas, the second half of the dry season from February to April is, so called, hot summer. The mean maximum temperature remains higher than 34°C throughout this period and sometimes rises as high as 37°C.

The project areas are blessed with favourable climatic conditions for the growth of various crops, excepting the uneven annual and seasonal distribution of rainfall. The seasonal trend of temperature in the project areas is characterized by its relatively wide variation compared with the central and southern region of Thailand.

The annual maximum mean, minimum mean and mean temperature are 33.2°C, 21.0°C and 27.6°C, respectively based on the records from 1951 to 1975 at the Phetchabun meteorological station. The maximum monthly mean temperature of 37.3°C occurs in April and the minimum monthly mean temperature of 14.7°C, in January.

The annual mean rainfall is estimated to be 1,177 mm and the annual mean rainy days are averaged to 120 days based on the records from 1951 to 1975. About 90% of the annual rainfall concentrates during the six months of wet season. The maximum consecutive drought of 185 days was recorded in Lom Sak in 1967. The consecutive drought frequently hampers a stable agricultural production in the valley.

Annual mean pan evaporation of 1,808 mm is estimated on the basis of the records at the Phetchabun meteorological station by AIT. The maximum monthly mean pan evaporation reads 219 mm in April and the minimum monthly mean, 113 mm in September. About 54% of annual evaporation occurs in dry season.

The relative humidity narrowly ranges throughout year, about 63% on an average during dry season and about 79% on an average during wet season. The maximum monthly mean relative humidity of 96.7% occurs in September and the minimum monthly mean humidity of 39.7%, in February.

The southwest wind is prevailing over the valley throughout wet season. On the contrary, the northeast wind is prevailing over the valley throughout dry season. The monthly mean wind velocity ranges from 3.2 knots (5.76 km/hr) to 4.6 knots (8.28 km/hr). The climatological data in the Phetchabun are summarized in Table 3.1.

3.4.3 Soil

Soil map is compiled as given in Fig. 3.3 on the basis of data prepared by Soil Survey Division, Department of Land Development, Ministry of Agriculture and Cooperatives, covering the both bank areas of the Pasak river. The Soils in the left bank area of the Pasak river are broadly classified into three soil groups, i.e. Hydromorphic Alluvial Soil, Hydromorphic Non-Calcic Brown Soil and Reddish Brown Lateritic Soil.

Hydromorphic Alluvial Soil develops over flat alluvial plain along the Pasak river. The effective soil depth is generally very deep. The color profiles are very dark gray to grayish brown over dark brown to dark yellowish brown and the textural profiles are silty clay to clay over clay. The soil structures of surface layer are weak moderate fine to medium sub-angular blocky and those of sub-surface layer are moderate to strong medium and coarse sub-angular blocky. This soil group is fully used for paddy cultivation.

Hydromorphic Non-Calcic Brown Soil mainly scatters over the alluvial fan shaped by tributaries of the Pasak river. The effective soil depth of the soil group is very deep. Its color of profiles are very dark grayish brown to dark brown over dark grayish brown to brown. Its textural profiles are clay loam or silty clay loam over silty clay or clay. The soil structures of surface layer are moderate fine and medium sub-angular blocky and those of sub-surface layer are moderate to strong medium sub-angular blocky. This soil group is somewhat poorly drained and it is well developed for both paddy field and upland.

Reddish Brown Lateritic Soil mainly develops over terrace and hillside. Its soil depth is very deep. Its color profiles are dark grayish brown to dark brown in the surface and reddish brown to yellowish brown in the sub-surface and its textural profiles are sandy clay loam to clay loam over clay loam to clay. The soil structures of surface layer are moderate fine to medium sub-angular blocky and these of sub-surface layer are moderate medium sub-angular blocky. This soil group is moderately well drained and broadly used for maize cultivation. The soils distributing in the Lom Sak and Phetchabun districts are broadly classified as given below.

	Soil Group	Lom Sak District (km^2)	Phetchabun District (km^2)	Total (km^2)
i)	Hydromorphic Alluvial Soil	327.7	277.4	605.1
ii)	Hydromorphic Non-Calcic Brown Soil	70.8	67.6	138.4
iii)	Reddish-Brown Lateritic Soils	294.3	695.0	989.3
	Total	692.8	1,040.0	1,732.8

3.4.4 Geology

As illustrated in the geological map (Fig. 3.4) and specified in the stratigraphy (Table 3.2), the base rocks in the Upper Pasak river valley are mainly composed of sedimentary rocks originated in the Permian, the Triassic and the Tertiary, and they are usually covered with the Quaternary diluvial and alluvial deposits. The younger and older sedimentary rocks in the stratum thereabout are structurally regarded as unconformity. Igneous rocks comprising Granite Diorite and Gabbroic Diorite are sporadically distributed as small stock or intrusive mass in the Permian Formation. The rocks typically crop out around the Huai Yai dam site.

In the skirt of eastern hilly ranges of the Upper Pasak river valley, the Nam Duk Formation originated in middle Permian extends with a strip of 20 to 30 km from north to south. The Khorat group originated in the Triassic of the Mesozic Era broadly covers the eastern hilly ranges of the Upper Pasak river valley. The Nam Duk Formation has alternate strata of shale interbedded with sandstone, and discloses a fold structure with a axis extending from north to southward. The formation is supposedly bounded by the faults with NS-strike slip.

While, at the skirt of western hilly ranges of the valley, the Pha Nok Khao Formation originated in the Lower Middle Permian extends about 20 km with a strip of about 600 m from north to south. The Formation mainly comprises limestone. The similar strata also develop at about 15 km south of the Phetchabun municipality.

The Tertiary system limitedly beds at about one km downstream of the Khlong Chaliang Lab dam site, as shown in the geological map. Actually however, the outcomes of geological survey at the Huai Yai dam site readily suggest that the Tertiary system more broadly beds under diluvial deposits.

3.5 INFRASTRUCTURES

3.5.1 Irrigation/Drainage

Irrigation development in the Upper Pasak river valley is relatively low. Only four small and medium scale irrigation projects, as shown in Fig. 3.5 have been implemented so far by the Central Government in the valley.

The Pasak Left Bank project area of 31,460 rai (5,030 ha) is located eastward the Lom Sak municipality and slenderly extends north to south along the left bank of the Pasak river. The project was completed in 1969. The major facilities of the project comprise a diversion weir constructed across the mainstream of the Pasak river and main/lateral irrigation canal system. The capacity of main canal at the head regulator is designed to be about 5.4 m^3/sec and the canal density is to be about 11.7 m/ha. The greater portion of the canal system is still unlined. No drainage system has been provided with the project. The irrigation water supply for the whole commanding area of 31,460 rai is basically limited within the wet season. During the dry season, the project can irrigate only the area of about 5,000 rai because of the depleted flow in the Pasak river. According to the operation records at the diversion weir site, about 24 MCM of irrigation water have been annually diverted into the commanding area on 20% recurrence drought.

The Huai Pa Daeng irrigation project area is located at about 15 km westward the Phetchabun municipality and it serves about 13,560 rai (2,170 ha) during only wet season and supplements the potable, domestic and industrial water supplies of the Phetchabun municipality. A medium scale reservoir of about 18.7 MCM has been created by construction earthfill dam for the stable irrigation and municipal water supplies. Main and lateral canal system is networked to irrigated the service area and to convey the municipal water with the canal density of about 16.4 m/ha. The greater part of the canal system is concrete-lined. The project was constructed in 1977. Since then, it has been operated for four years.

The Wang Bon weir irrigation project area is located westward the Lom Sak municipality. The project area of about 2,000 rai (320 ha) is bounded by the National Highway Route-12 in the north and by the Chun river, a tributary of the Pasak river, in the south. The irrigation water resources of the project depends on the Chun river by constructing a timber intake weir. The weir was washed away by intensive flood in 1975. In response to the request of farmers, the weir was reconstructed by the RID in 1978.

The Sri Chan Irrigation Project area is located at about 10 km northeast the Lom Sak municipality. The area of about 6,000 rai (960 ha) extends north to south along the right bank of the Pasak river. The primitive Sri Chan intake weir was initially constructed with timber by farmers themselves in 1940. Since then, the weir has been periodically washed away by flooding. In response to the strong request

of the beneficiary farmers, the Central Government decided to construct a perennial concrete weir in early 1981. The substantial construction works will start at the onset of dry season in 1982.

Small scale irrigation systems have been developed in the study area, depending their irrigation water resources on small tributaries. In the Huai Khon Kaen area, there exist five intake weirs. All of them are quite primitive structures constructed with local materials, and washed away by periodical flooding. Existing canal system in the area is unlined and deteriorated due to poor maintenance works. The section of canal is usually greater than that required for its commanding area. The density of the existing canal is estimated to be 10 m per ha; it is too low to better manage irrigation water.

In the Huai Yai and Khlong Chaliang Lab areas, there also exist many diversion weirs. Most of them have been perennially constructed with concrete by the district office concerned and relatively better maintained. The existing canal aligned in the both areas are almost unlined and much deteriorated. The density is extremely as low as 10 m/ha.

3.5.2 Transportation

Three national highways are networked in the Phetchabun province. The trunkline Route-21 extends about 220 km from Saraburi to Lom Sak by way of Witchanburi and Phetchabun after stretching out of the Route-1. The Route-203 further extends from Lom Sak and terminates at Loei. The Route-12 jointing Phitsanulok with Khon Kaen traverses the Phetchabun province from east to west and comes across the Route-21 in the vicinity of Lom Sak as shown in Fig. 3.6.

Many rural roads stretches out from the national highways and networked in and around the project area. Most of these roads have been constructed by the Accelerated Rural Development Office, aiming at the rural development. Some of the rural roads have been constructed by the Mobile Development Unit for the purpose of the security in northern part of the Province. The width of the rural roads constructed by the ARD varies from about six (6) meter to nine (9) meter; the width of the road constructed by the MDU is nearly six (6) meter.

Excepting the National Highway, greater parts of the existing roads are laterite-paved but these roads are considerably deteriorated due to insufficient maintenance works. After intensive rainfall, some of them are not jeepable. In the limited flood season, tentative boat services supplement the unpassable roads to cross over the Pasak river and its tributaries.

3.5.3 Municipal Water Supply

Each village in and around the project areas mainly depends its potable and domestic water resources on groundwater, ephemeral rivulets thereabout and rainfall. During dry season, the village people get

their drinking water from shallow well, since no rainfall is expected and all rivulets are completely depleted. The situation of potable water supply in the village is quite serious during dry season.

The urban areas of Phetchabun and Lom Sak have installed modernized municipal water supply system, depending its water resources on mainstream of the Pasak river which is rather exhausted during dry season. The situation of water supply in the both urban areas are also quite serious especially during dry season. To ease the serious situation, the Phetchabun municipality relys its municipal water of about 10,000 m^3 per day during four months of dry season upon the Huai Pa Daeng reservoir which has been operated since 1977. However, the situation of shortage of municipal water supply in the Lom Sak municipality has been deteriorating year by year according to the expansion of urban area. New water resources development for municipal water is therefore essential especially for the Lom Sak municipality.

3.6 PRESENT AGRICULTURE

3.6.1 Present Land Use

The present land use map of the study area covering the Lom Sak and Phetchabun districts is compiled, as illustrated in Fig. 3.7 on the basis of the land use map with a scale of 1/100,000, aerial photo of 1/15,000 shooted in late 1974, and minor revision after field survey. The present land use in the both districts is summarized as follows.

District	Category of Land	Area	Percentage
Lom Sak	Paddy field	187,500 rai (30,000 ha)	48
	Upland	176,250 rai (28,200 ha)	45
	Forest	1,250 rai (200 ha)	-
	Idle Land	25,630 rai (4,100 ha)	7
Sub-Total		390,630 rai (62,500 ha)	100
Phetchabun	Paddy field	202,500 rai (32,400 ha)	30
	Upland	275,000 rai (44,000 ha)	41
	Forest	101,880 rai (16,300 ha)	15
	Idle Land	87,500 rai (14,000 ha)	14
Sub-Total		666,880 rai(106,700 ha)	100

Paddy fields mainly extend over riverside which are covered with fertile alluvial soils. Most of these paddy fields are cultivated with only wet season paddy because no irrigation water is available throughout dry season. In the limited paddy field where all weather irrigation is stably practiced, paddy is usually planted twice a year.

Maize is the main crop grown in the both districts, followed by rice. Upland planting maize mainly extends over terraces and elevated alluvial fans along the skirt of hillside. Some of these maize lands are planted with beans as the second crop after maize is hervested.

The forest lands in the hilly area is not used for cultivation due to steep slope, sharp undulation, shallow soil depth, etc. It is basically maintained as a reserve land to protect erosion, ecological destruction, etc.

Most of the areas which the four projects would be implemented are covered with well-developed paddy field, planting only wet season paddy due to constraint of irrigation water during dry season.

3.6.2 Present Cropping Calendar

Phetchabun province is one of the corn granary in the northern Thailand. The present cropping calendar in Phetchabun province is presented in Fig. 3.8.

Paddy cultivation in the Phetchabun province is concentrated in the wet season because of extremely limited irrigation water resources during dry season. The cultivation pattern is directly affected by depth of annual rainfall. The area planted and/or harvested sharply fluctuates year by year, depending on the available water throughout growing season.

The wet season paddy is usually planted in June thru July. After harvesting the wet season paddy, farmer sows mungbeans, soybeans, tobacco and vegetables as second crops of paddy field and harvests them before commencement out of land preparation for wet season cropping. The paddy cultivation during dry season is quite rare in the province due mainly to shortage of water resources during the dry season.

The maize is mainly planted in the upland at onset of the southwestern monsoon, generally April thru May, and harvested in July thru August. After harvesting maize, farmer usually sows mungbeans, soybeans, sorghum, etc., and harvests them in November at the cease of wet season.

3.6.3 Crop Yield and Production

Major crops produced in the Phetchabun province comprise paddy, maize and beans. The yields of major crops under present condition

in the province are estimated on the basis of data obtained from "Agricultural Statistics of Thailand", as given in the following table.

(Unit: kg/rai)

Year	Paddy	Mungbean	Soybean	Groundnut	Maize
1971/72	407	250*	215*	343*	345
72/73	505*	126	144	169	279*
73/74	439	118	169	211	500*
74/75	442	158	180	252	426
75/76	461	99	157	261	411
76/77	427	91	168	196	441
77/78	326*	78*	98*	193	321
78/79	427	91	172	168	405
79/80	330*	93	126	148*	379

As shown in the above table, the yields widely fluctuate year by year due to wide variation of annual rainfall and unexpected damages caused by flood, insect and diseases. The present crop yields are therefore estimated at the average values neglecting the upper and lower extreme values marked with "*" in the above table, and the results are as follows.

Paddy	434 kg/rai (2.7 t/ha)
Mungbean	111 kg/rai (0.7 t/ha)
Soybean	159 kg/rai (1.0 t/ha)
Groundnut	207 kg/rai (1.3 t/ha)
Maize	389 kg/rai (2.4 t/ha)

The crop productions in the Phetchabun province are estimated at paddy of 325 x 10^3 ton, mungbean of 31 x 10^3 ton, soybean of 12 x 10^3 ton and maize of 483 x 10^3 ton as presented in Table 3.3.

3.6.4 Present Production Value

The present per-rai net production value of each crop is estimated on the basis of current farmgate price, crop yield and per-rai production cost. Farmgate prices for agricultural products fluctuate according to the FOB prices or local marketing condition. These prices are usually affected by the distance from producing arms to markets. According to the agricultural statistics in 1977, the trend of farmgate prices for paddy and maize in the Phetchabun province has got lower, while farmgate prices for beans have sharply increased in recent years. The extremely high prices of beans are due to shortage of production caused by extraordinary drought. In due consideration of such marketing condition in recent year as above-mentioned, the current averaged farmgate price of paddy, maize and beans is assessed to be 3.0, 2.0 and 5.4 Baht per rai, respectively.

The per-rai net production value of each crop is estimated as follows.

	Item	Paddy	Maize	Beans
(1)	Price (฿/kg)	3.0	2.0	5.4
(2)	Yield (kg/rai)	434	389	160
(3)	Per-rai gross production value (1) x (2) (฿/rai)	1,302	778	864
(4)	Per-rai production cost (฿/rai)	800	540	530
(5)	Per-rai net production value (3) - (4) (฿/rai)	502	238	334

3.6.5 Holding Size and Land Tenure

In the Phetchabun province, owner farmer is predominant accounting to about 84% in number and about 85% in area, respectively in 1978 as shown below.

Description	No. of Household		Area	
	(Number)	(%)	($x10^3$ rai)	(%)
Owner farmer (Owned)	69,690	84.2	2,098	85.0
Tenant (Rented)	6,890	8.3	138	5.6
Partial tenant	5,110	6.2	212	8.6
Others	1,080	1.3	21	0.8
Total	82,770	100.0	2,469	100.0

Average size of owner farmer is about 30 rai, while that of tenant is only about 20 rai. Partial tenants operate fairly large land of about 41 rai on an average. The following table shows average size of land holding classified into land ownership in the province and districts concerned with the project.

Description	Phetchabun Province	Phetchabun District	Lom Sak District
	(rai)	(rai)	(rai)
Owner farmer	30.1	28.0	21.0
Tenant	41.4	38.6	21.0
Partial tenant	20.0	18.3	8.6
Average size	29.9	28.5	20.5

The average farm size in the Phetchabun province increased substantially from about 19 rai in 1963 to about 30 rai in 1978 mainly due to rapid expansion of paddy land developed and uplands reclaimed from the forest. The following table shows the average farm size in the Phetchabun province in both 1963 and 1978, based on the Agricultural Census.

1963					1978				
Size of Farm Land (rai)	No. of Farm (10^3)	(%)	Area of Farm (10^3rai)	(%)	Size of Farm Land (rai)	No. of Farm (10^3)	(%)	Area of Farm (10^3rai)	(%)
					Under 2	0.9	1.1	0.2	0
2 - 6	7.2	15.5	27.1	3.1	2 - 6	5.8	7.0	22.4	0.9
6 - 15	17.1	36.7	165.9	18.8	6 - 15	17.3	20.7	172.2	7.0
15 - 30	13.9	29.8	283.1	32.0	15 - 30	26.7	32.0	553.3	22.4
30 - 45	5.0	10.7	172.6	19.5	30 - 50	19.3	23.1	694.7	28.1
45 - 60	2.0	4.3	99.7	11.3	50 - 60	4.9	5.9	253.7	10.3
60 -140	1.3	2.8	103.6	11.7	60 -140	7.8	9.4	618.9	25.1
Over 140	0.1	0.2	31.7	3.6	Over 140	0.7	0.8	154.0	6.2
Total	46.6	100.0	883.7	100.0	Total	83.4	100.0	2,469.4	100.0

The above table shows that approximately 76% of farmers are within the range from 6 to 50 rai of land holding which is rather even distribution of land. About 10% of large holding farmers, however, occupy still about 30% of the farm land in 1978.

CHAPTER IV AGRICULTURE CONSTRAINTS AND PROJECT NEEDS

4.1 SUMMARY ON CURRENT SITUATION

The project areas to be served by the four (4) proposed reservoirs are covered with relatively well developed paddy field. Paddy cultivation in the project areas is concentrated in the wet season and extremely limited in the dry season because the dependable water resources are completely exhausted and depleted during dry season. The cultivation is directly affected by total depth of annual rainfall. The planted area of paddy field widely fluctuates year by year depending on endowed rainfall and available river flow.

After harvesting wet season paddy at the cease of wet season, the farmers sow upland crops such as mungbeans, soybeans, tobacco, etc., in the limited paddy field in which irrigation water readily available throughout growing stage of upland crops. It is quite rare that dry season paddy is planted as a second crop of paddy field.

Some of paddy fields extending in and around the project areas are covered with village irrigation system depending their irrigation water resources on small rivulets. But most of the paddy field still remain under rainfed condition. The existing irrigation system mainly developed by farmers themselves are primitive. The intake weirs of village irrigation system have been constructed with timbers and cobbles. These weirs have been habitually washed away by intensive floods. While, perennial weirs have been also constructed with concrete along the Huai Yai and the Khlong Chaliang Lab by the district offices. These weirs have been relatively better maintained.

All of the irrigation canal aligned in the project areas are unlined. These canals are deteriorated due to poor maintenance. The density of the existing canal networked in each area is very low. Besides serious shortage of irrigation water, equitable water distribution has not been practiced because of the low canal density in the project area.

No technical drainage system has been developed so far in each project area. Most of the existing canals have dual function of irrigation/drainage. This substainally contributes to repeated use of limited water resources.

4.2 CONSTRAINTS

The project areas are graced with extended land resources quite suitable for agricultural production. Nevertheless, the land productivity thereabout are still low because of various constraints for agricultural development. The major constraints foreseen are as follows.

1) Serious shortage of irrigation water resources,

2) Annual fluctuation of rainfall depth,

3) Lack of perennial irrigation system,

4) Improper water management,

5) Improper application of agricultural inputs, and

6) Insufficient agricultural support services.

The decisive constraints among them are serious shortage of irrigation water resources and lack of perennial irrigation system which fully serves equitable water management.

4.3 THE PROJECT NEEDS

(1) Irrigation

Water resources are limitedly endowed in the Pasak river valley compared with the vast land resources thereabout. Existing irrigation projects under operation and construction in the valley cover about 893,000 rai (143,000 ha), corresponding to about 51% of total existing paddy field in the valley. Despite of the provision of irrigation system, most of them are still subject to serious shortage of irrigation water during dry season. Furthermore, the vast paddy field of about 840,000 rai (134,000 ha) still remains under rainfed condition, resulting in low land-productivity due mainly to shortage of irrigation water. Hence, irrigation development has recently become a pressing needs in the valley in order to improve the living standard of the rural population, most of which are engaged in agricultural production.

(2) Flood Mitigation

The Pasak river valley is slender and bounded by mountain ranges on the north, east and west. Flooding has periodically rushed into the valley every year and caused serious damages on agricultural crops and various infrastructures. Flood mitigation is therefore one of essential development sector in the valley. Creation of reservoir in the upper stream of the Pasak river and its tributaries would decisively contribute to the flood mitigation. Regardless of the scale of the project, the flood mitigation should be envisaged in this basin.

(3) Domestic and Municipal Water Supply

The domestic and municipal water supply in the Pasak river valley amounts to approximately 19 MCM per annum in total. This supply is extremely small compared with rural population in the valley (about 50 ℓ/day/capita equivalence). Most of rural population are depending their domestic and potable water on rainfall and natural river flow. Therefore, present situation on domestic

and municipal water supply is extremely aggravated during dry season. Water resources for the domestic and municipal water must be urgently developed especially in and around the urban areas of the valley.

(4) Navigation

The downstream of the Pasak river substantially functions inland navigation, jointing with the downstream of the Chao Phraya river. Some amount of maintenance flow must be habitually released from the upstream to the downstream of the Pasak river to stably maintain the river channel. Hence, in the water resources development in the Pasak river basin, special attention should be paid to the release of channel maintenance flows.

CHAPTER V PROSPECTIVE DEVELOPMENT PLAN

5.1 DEVELOPMENT CONCEPTS

In conformity with the objectives of the National Economic and Social Development Plan, the Government mainly aims at amendment of disparity of incomes and attainment of people's public peace with the implementation of irrigation project. To attain the major objectives, the project would aim at extension of stabilized irrigated agriculture through exploitation of new water resources in tributaries. The basic concepts for agricultural development, water resources development, and irrigation development are as described hereinafter.

Agricultural Development

1) Unit yield of wet season paddy would be increased through proper supplemental irrigation throughout wet season and introduction of improved technology of irrigated agriculture.

2) Total planted area of wet season paddy would be stabilized with stable water supply from newly exploited water sources.

3) The project must play a leading role for improvement of the living standards of extended rural population. In this context, extensive agriculture would be basically oriented as far as the economic feasibility of the project would be sustainable.

4) Special attention would be paid to crop diversification in conformity with the Governmental policy.

5) Paddy would be planted only in wet season due to limited exploitable water resources. During dry season, only upland crops would be planted to save and effectively use exploited water resources. Optimal cropping intensity would be proposed in due contemplation of agro and water economy.

6) Socio-aspects should be highly regarded in implementation of medium scale irrigation project. Therefore, the projects under study would be so formulated as to bring great impacts on farm economy in the backward areas.

In order to realize the concepts for agricultural development above mentioned, the following basic concepts for water resources development and irrigation development are envisaged.

1) The water resources endowed in the tributaries concerned would be developed by constructing storage dam.

2) Irrigation water resources is essential in the project areas. No water resources are dependable in the areas for the time being excepting ephemeral small tributaries. In this view, the maximum development of endowed water resources would be oriented as far as topographic and geological conditions are allowable. Thus, in these projects, no particular attention would be given to optimal water resources development.

3) Potable, domestic and industrial water resources for the municipality, Lom Sak and Phetchabun, would be considered if the exploited water resources are allowable.

4) In principle, the exploited water resources would be used for irrigation of the paddy fields extending the vicinity of the exploited sites; the project area would be delineated in the paddy field extending the vicinity of the exploited sites.

5) Existing irrigation canal system would be incorporated as they are. The existing intake weirs would be eliminated in principle, and instead, link canals would be aligned to connect the existing village irrigation system.

5.2 WATER RESOURCES DEVELOPMENT

5.2.1 Assessment of Endowed Water Resources

(1) Probable Annual Rainfall

The rainfall data records in the Lom Sak rainfall station would be applied for rainfall analysis in the Huai Saduang Yai and the Huai Khon Kaen watersheds, since no rainfall has ever been recorded. For a similar reason, the rainfall data recorded in the Phetchabun rainfall station would be applied for rainfall analysis in the Huai Yai and the Khlong Chaliang Lab watersheds. These applied rainfall data surely bring about conservative results for water resources development and irrigation planning since the basin rainfall in the hilly watershed is generally greater than that in the lowlying plain.

To obtain probable rainfalls in both drought year and pluvious year, two theoretical methods, i.e. Gumbel and Iwai, are applied and then, the results are cross-checked by the Thomas plotting. The estimated probable rainfalls are as given below, corresponding to respective recurrences.

Non-Excess Probability (Drought Year)

Recurrences (%)	Probable Annual Rainfall at Lom Sak	Probable Annual Rainfall at Phetchabun
10	787	868
20	885	938
50	1,040	1,040

Excess Probability (Pluvious Year)

Recurrences (%)	Probable Annual Rainfall at Lom Sak	Probable Annual Rainfall at Phetchabun
10	1,494	1,388
20	1,340	1,276

A probable rainfall pattern in each pluviometric station has been worked out in the "Rainfall and Evaporation Analysis of Thailand" issued by AIT. To figure out monthly distribution of probable rainfall, the AIT rainfall pattern in the Lom Sak and the Phetchabun area is applied after fully cross-checked by monthly rainfall records in the Lom Sak and the Phetchabun rainfall stations. The probable annual rainfall of each recurrence is monthly distributed as given in Fig. 5.1.

(2) Annual Runoff

Since no runoff data is available at all in the tributaries relevant to the projects, the rainfall records in the Phetchabun and Lom Sak rainfall stations are converted into runoffs by applying the runoff estimate chart which has been authorized in the RID. This chart has various lines corresponding to the condition of watershed, as shown in Fig. 5.2. The watershed of each tributary consists of rather steep area and open forest, which corresponds to line B in the chart. Therefore, the runoff of each tributary is estimated by using the line B. While, in the mainstream of the Pasak river, there exist two water gauging sites; one is located at Kaeng Sida covering the drainage area of 836 km^2 and the other is located at the Pasak diversion weir covering the drainage area of about 1,007 km^2. The annual runoff coefficients at these gauging stations are compared with estimated ones mentioned above. The estimated annual runoff coefficients are in the range of those recorded at the above two stations.

The monthly runoff is produced by multiplying monthly rainfall by the runoff coefficient which is read on the line B. The estimated runoff in each tributary is as summarized in Table 5.1. In terms of the 20% recurrence of droughty year, the annual runoff coefficient is assessed to be about 25% in the Lom Sak and about 26% in the Phetchabun area, specific annual yield amounts to 7.0 $\ell/sec/km^2$ in the Lom Sak area and 7.8 $\ell/sec/km^2$ in the Phetchabun area, and the annual runoff of 20% recurrence of droughty year at the proposed dam site of each tributary amounts to;

Tributary	Drainage Area (km^2)	Annual Runoff (MCM)
Huai Saduang Yai	96	21.2
Huai Khon Kaen	322	71.0
Huai Yai	78	19.1
Khlong Chaliang Lab	77	18.9

5.2.2 Proposed Dam Site

(1) Selection of Dam Site

To exploit the water resources endowed in the watershed to the maximum extent, the dam site is proposed to be selected close to the debouchment of the tributary so far as the topography and the geology of foundation are allowable. Among four proposed dams, the Huai Yai dam site is shifted to about 450 m upstream from the original dam site which is proposed by the RID at the debouchment of the Huai Yai, in due consideration of topographical and geological conditions at the site. At the original site, stable foundation is not obtainable unless an enormous expenditure is practiced for the foundation improvement. In addition, the embankment volume at the original site is roughly estimated at about 5 times larger than that of the proposed site in this study in order to create the same reservoir capacity.

(2) Topography

Huai Saduang Yai

The gorge at the proposed dam site is relatively symmetric, having a steep slope of 25° at its right abutment and relatively gentle slope of 20° at its left abutment. The lowest altitude of riverbed at the dam axis is about 164.0 m above MSL. A relatively lower saddle is extending from the left abutment with an altitude of about 195.0 m above MSL. The altitude of this saddle constitutes a decisive factor in determining the proposed dam crest. The proposed dam site has about 16 of the width-to-height ratio of dam and is blessed with much favourable topographic condition for construction of fill dam.

Huai Khon Kaen

The gorge at the proposed dam site comprises one dale and two saddles separated by two humps. The existing river channel is meandering toward the left-hand dale. The left-hand and the right-hand saddles are likely to be created by the fluvial action of the old river channels. The altitude of the left and right saddle is about 212.0 m, 213.0 m above MSL, respectively. A small rivulet is located adjacent to the right abutment of the gorge, and it is convenient for disposition of emergency spillway. The proposed dam site gives about 9 of the width-to-height ratio of dam at the main dale.

Huai Yai

The dam site is shifted to about 450 m upstream from the original site which is proposed at the debouchment of the Huai Yai. The shifted site has the narrowest gorge in the Huai Yai valley. The right abutment of gorge is relatively gently slanting with a slope of 15° and the left abutment is steeply slanting with a slope steeper than 25°. At the dam site, there exist a saddle at about 250 m upstream from the right abutment of dam axis. The gorge at the proposed site is about 100 m wide at the riverbed including lower terraces, and gives about 10 of the width-to-height ratio of dam. Therefore the site is much favourable for construction of fill dam.

Khlong Chaliang Lab

The dam site is proposed close to the debouchment of the Khlong Chaliang Lab. The gorge at the proposed dam site is relatively V-shaped. Its right abutment is slanting with a slope of about 25° and its left abutment is more steeply slanting with a slope of about 30°. The maximum altitude of ridge extending from the right abutment is about 200.0 m above MSL. The altitude of this ridge constitutes a decisive factor for determining the height of dam. The riverbed is about 20 m wide at the dam site. The gorge at the proposed site gives about 10 of the width-to-height ratio of dam and is much favourable for construction of fill dam.

(3) Geology of Dam Site

Huai Saduang Yai

The bedrock at the site consists of sandstone interbedded with shale originating from the Num Duk formation of the middle Permian period. The both abutments of the site are dominantly composed of sandstone; the riverbed of the site, of shale. The left abutment is subject to weathering of about 7 m thick, while the riverbed, of 10 to 14 m. The right abutment is highly weathered to about 22 m in depth.

Terrace deposits extend about 90 m and about 140 m wide from the periphery of river on the left bank and on the right bank, respectively. The base rock of the site is striking N3°E-N22°E and dipping 34°-50°W. In the light of the Lugeon value obtained at the site, both abutment and the riverbed are highly permeable to the depth of about 15 m to 20 m. Such a high permeability seems to be due to numerious cracks caused in the rock structure. According to inspection of drilling cores, there is no evidence for fractured zone and/or clay deposits in the strata which suggest presence of faults. But numerious joints develop in the rock texture and most of them are filled with clay and/or quartz stringer.

Huai Khon Kaen

The base rock of the site consists of hard sandstone interbedded with shale originating in the Permian Period Nam Duk formation, and is covered with terrace deposits of gravel strata. Base rock is striking N10°-15°W and dipping 70°-80°E. The base-rocks of the riverbed and both abutment are highly weathered to the depth of about 5 m to 10 m. But the base rock excluding weathered zone is fairly favourable for dam foundation.

The groundwater level at the site ranges from zero to about 7.0 m below the ground surface; it is broadly in conformity with topographic profile. Fault and fractured zone are not anticipated in the light of drilling cores obtained at the site.

According to permeability test, surface strata of the left abutment indicate rather high Lugeon value of 50, up to the depth of 16 m thereabout. But the value sharply decreases to the Lugeon 5 or so therebelow. The riverbed is relatively impermeable; the strata of about 5 m below indicate the value lower than 20. In the control portion of the site, the Lugeon value of 20 to 50 is gauged for the strata of 6 to 10 m below the ground surface. Hence, the permeability is relatively low thereabout. While, in the right bank, relatively high Lugeon value is recorded, but this is not attributable to fault and/or fractured rocks but due to weathering.

Huai Yai

The site is geologically similar to other sites where the base rocks comprise sandstone interbedded with shale as well as gabbroic diorite, belonging to the Nam Duk formation of the Permian period. The base rock is covered with silt and sandy gravel layer of approximately 6 m thick.

Some base rocks are sporadically outcropping on the left abutment which has a gentle slope of 25° and is covered with thin topsoil. While, there is no outcroppings on the right abutment which is also gently slanting and thickly covered with topsoil. Seeing that a number of loose sandstone boulders are scattered on the slope of both abutments, the base rock at the site is likely to be relatively shallow.

Khlong Chaliang Lab

The base rock of the site is nearly similar to that of the other sites; it is composed of sandstone interbedded with shale. According to the inspection of drilling cores, the base rock on the left bank seems to be highly weathered to about 6 m below the ground surface and slightly argillized. The base rock on the riverbed is thickly covered with sedimentary deposits of about 6 m thick, consisting clayey sand and silty sand of about 2 m and gravel of about 4 m. The base rock of the right abutment is weathered to 3 m to 4 m and geologically rather deteriorated. The rock strata below the weathered zone is fairly fresh and suitable for dam foundation.

The groundwater level at both abutments is recorded at about 12 m below the ground surface, and the level broadly fluctuates in conformity with topographic profile of the site. The Lugeon value at the site indicates that the base rock at the site is highly permeable. This is due mainly to cracks of rocks caused by weathering.

(4) Geology of Reservoir

Huai Saduang Yai

The area to be submerged by construction of the Huai Saduang Yai dam is geologically composed of sandstone interbedded with shale which belong to the Nam Duk formation. The strata thereabout generally strike north to south at N3°-22°E and dip 30° to 50°W.

Both banks of the river channel are covered with terrace deposits of about 400 m, the maximum wide. The strata of terrace is estimated at about 5 m thick, comprising clay interbedded with sand and weathered gravels. While, the terrace deposits extending along foot of hilly ranges are covered with talus consisting of clay intermixed with rocks fragments. There reveals no loose formation which causes structural collapse, after creation of reservoir in this area.

Huai Khon Kaen

The reservoir area consists of narrow and deep vale dissected by the Huai Khon Kaen, its periphery being bounded by steep foothills. The lineament of steep ridges extending north to south is composed of hard rocks, forming anticlinorium. The base rock of reservoir area geologically comprises shale interbedded with sandstone. The overall structure of the area is geologically characterized by north to south folding axis. The strike of folding strata is measured to be N15°W-N30°E with the dip of 60°-80° to both the west and the east.

An absence of tectonic lines or noticeable faults, as well as a presence of firm base rock afford abundant evidence that there never exist collapsible formation in the reservoir area. Furthermore, there exist no limestone deposits which potentially cause cavitations in the formation.

Huai Yai

The reservoir area is covered with hilly terrain of 200 to 250 m above MSL. The base rock of the area geologically comprises sandy shale interbedded with metamorphic sandstone belong to the middle Permian Nam Duk formation.

On the left side of the reservoir area, intrusion of gabbroic diorite is prevailingly observed. In terms of geological structure, the bedding generally reveals a strike of N7°W-N15°E north to south and a dip of 60°-65°E. This presents an evidence of the existence of folding structure over the area. The distribution of intrusive rocks is likely to be in conformity with the sedimentary structures. In the light of out crops thereabout, the intrusive rocks are relatively massive in texture. No rock failure and no loose formation of sedimentary materials are visible in the proposed reservoir area. Thus, no structural collapse is potentially caused even after the creation of reservoir.

Khlong Chaliang Lab

The area to be submarged by the dam construction is topographically slender, being founded by foothills. Due to absence of outcroppings in the reservoir area, geological condition of surface strata is not clearly confirmed. On the basis of the result of field inspection, the left part of the area consists of sandstone interbedded with shale belonging to the Nam Duk formation; the right part of the area, grayish green, fine grained sandstone. The strike of strata is roughly estimated at N30°W-N50°W; its dip, approximately 40°-60°NE. No unstable formation is disclosed after the creation of reservoir.

5.2.3 Storage Capacity

The optimum scale of the storage dam is determined in due consideration of the following conditions at the dam site;

(1) Topography,

(2) Geology,

(3) Storage capacity,

(4) Stability of dam body based on the embankment materials available in the vicinity of dam site, and

(5) Disposition of appurtenant structures.

Huai Saduang Yai

At the left abutment of the dam site, there exist a lower saddle with an altitude of about 195.0 m above MSL. This saddle constitutes a decisive factor in determining the proposed dam crest. The relation between dam height and storage capacity is studied based on the topographic maps with the scale of 1:4,000 and 1:50,000, and the result indicates that the dam crest elevation of 191.0 m above MSL has the best storage efficiency. From the viewpoint of dam stability, it is recommended that the toe of upstream embankment is put in the convex saddle extending over about 60 m upstream from the left abutment at the site. Therefore, the dam crest elevation is proposed to be 191.0 m above MSL.

Huai Khon Kaen

To secure stability of dam, the embankment should be made lower than the top of humps, since the high embankment which fully covers these humpers might cause unequal settlement of embanked materials. Actually however, such a low embankment can exploit only small amount of the water resources endowed in the development site. To conform with the basic concept for water resources development, the dam crest of 216.0 m above MSL would be proposed, paying special attention to embankment materials, cross section of dam embankment, optimal storage efficiency, disposition of appurtenant, etc.

Huai Yai

At the proposed dam site, no topographical and geological data are available. According to the site inspection, a saddle is found at about 250 m upstream from the right abutment of dam axis. This saddle constitutes a decisive factor for determining the height of dam. A emergency spillway can be easily constructed on this saddle. The dam crest elevation is determined to be 212.5 m above MSL in due consideration of the above conditions and storage efficiency.

Khlong Chaliang Lab

There exists a ridge extending from the right abutment at the dam site. The altitude of this ridge is about 200.0 m above MSL. The high dam over the altitude of 200.0 m requires a large amount of embankment volumes and the storage capacity become to be small. Therefore, the dam crest elevation is proposed to be 200.0 m above MSL in due consideration of above conditions and storage efficiency.

The storage capacity of each reservoir is estimated as shown below based on the proposed dam scale mentioned above. The elevation-storage and elevation-area curves are presented in Fig. 5.3. The useful storage is calculated by deducting the dead storage capacity from the total storage capacity. The dead storage capacity is estimated on the assumption that the sedimentation volume of the watershed is 200 m^3/km^2/year and the life of dam is 50 years.

Reservoir	Annual Inflow 1 (MCM)	Total Storage 2 (MCM)	Dead Storage 3 (MCM)	Useful Storage 4 (MCM)	Useful Storage Ratio(%) 5= 4 / 2	Regulated Inflow Ratio (%) 6 = 4 / 1
Huai Saduang Yai	21.16	15.00	0.96	14.04	94	66
Huai Khon Kaen	70.96	28.00	3.22	24.78	89	35
Huai Yai	19.14	7.90	0.78	7.12	90	37
Khlong Chaliang Lab	18.90	2.30	0.77	1.53	67	8

As clarified above, in regard to both the useful storage ratio and the regulated inflow ratio, the Huai Saduang Yai reservoir is provided with the highest percentage, followed by the Huai Yai reservoir. This indicates that both reservoirs are highly blessed with topographic and watershed conditions.

5.2.4 Optimal Irrigable Area

In the Huai Saduang Yai and Huai Khon Kaen areas, the demand of water resources comprises irrigation water requirement, municipal water supply and downstream maintenance flow. While, in the Huai Yai and Khlong Chaliang Lab areas, it comprises only irrigation water requirement and downstream maintenance flow. The Huai Khon Kaen, Huai Yai and Khlong Chaliang Lab reservoirs would fully serve irrigation water for newly delineated area. However, the Huai Saduang Yai reservoir would supplementary supply irrigation water for the existing Sri Chan and Pasak Left Bank Irrigation Project areas, the water resources of which mainly depend on the mainstream of the Pasak river.

To estimate an optimal irrigable area, the comparative study for crop intensity and the water balance study is made as given in Annex IV and VI on the basis of the supply and demand of water resources. The optimal irrigable area is estimated in the droughty year of 20% recurrence through the study as shown below.

Project	Supply	Exploited Water Resources	Irrigable Area	Crop Intensity
		(MCM)	(rai)	(%)
Huai Saduang Yai	Supplemental irrigation and municipal water	14.04	37,460 (5,990 ha)	135
Huai Khon Kaen	Full irrigation and municipal water	24.78	27,500 (4,400 ha)	135
Huai Yai	Full irrigation	7.12	9,380 (1,500 ha)	125
Khlong Chaliang Lab	Full irrigation	1.53	1,440 (230 ha)	125

5.2.5 Reservoir Operation

(1) General

To clarify the efficient use of the installed capacity of reservoir, an operation study is made on the basis of the long-range runoff data from 1952 to 1977 in accordance with the presumed set of operation rules as described below.

It is critically presumed that the reservoir operation would initially commence on the beginning of May, immediately after the completion of dam construction and then, the reservoir is completely vacant. The storage capacity in the reservoir would be adjusted by evaporation and precipitation in the reservoir site. Natural inflow would be balanced with total demand to clarify surplus or

deficit of water resources in the current month. The surplus water would be stored for the subsequent month. In case of the deficit of water resources, the storage water in the reservoir would be released to meet the deficit. Total amount of water exceeding the maximum storage capacity of reservoir would be unavailingly outspilled.

As previously discussed, the Huai Saduang Yai reservoir would be operated accounting for non-regulated runoff in the mainstream of the Pasak river. Specific operation rules are set forth for the Huai Saduang Yai reservoir as mentioned below.

The initial operation condition is presumed as same as the other three reservoirs. Where the runoff in the Pasak river exceeds irrigation demand for 37,500 rai (6,000 ha), no storage water in the Huai Saduang Yai reservoir would be released, excepting maintenance flow to the downstream. Otherwise, the storage water would be supplied for the 37,500 rai (6,000 ha) of service area to meet the deficit of irrigation water demand. As regards balance of supply and demand, and spilling out of reservoir, the same rules for other three reservoirs would be also applied for the Huai Saduang Yai reservoir.

(2) Supply and Demand

Monthly inflow into each reservoir is hydrologically produced on the basis of the rainfall records for 26 years from 1952 to 1977. The details are given in ANNEX-II. Water demand in the project area comprises irrigation requirement, municipal water and maintenance flow to downstream.

Irrigation requirement is calculated on monthly basis of meteorological data, recommendable cropping pattern, and proposed crop intensity as given in ANNEX-VI. Annual demand of irrigation requirement for each project is estimated as listed below, under the droughty year of 20% recurrence.

Project	Irrigation Demand (MCM)
Huai Saduang Yai	48.2
Huai Khon Kaen	35.3
Huai Yai	10.7
Khlong Chaliang Lab	1.6

Municipal water resources would be allocated for the Huai Saduang Yai and Huai Khon Kaen reservoirs. The water resources of 5,000 m^3/day including 20% of conveyance losses would be daily supplied for the Lom Sak municipality and its surroundings during dry season from November to April, from both reservoirs, respectively.

Forecasting water balance all over the Pasak river basin and taking into consideration the current riparian right of downstream population, maintenance flow of 1.0 ℓ/sec/km^2 would be released from each reservoir to downstream through a year. The annual released amount for maintenance flow is estimated as follows, according to the catchment area of each reservoir.

Project	Annual Release (MCM)
Huai Saduang Yai	3.0
Huai Khon Kaen	10.2
Huai Yai	2.5
Khlong Chaliang Lab	2.4

(3) Outcomes of Operation

The operation study on each proposed reservoir is made by use of the estimated supply and demand according to the operation rules abovementioned. The outcomes are as illustrated in Fig. 5.4 and the details are compiled in ANNEX-IV. The outcomes conclude that all of the proposed reservoirs are efficiently operated even in the 20% recurrence of droughty year.

5.3 AGRICULTURAL DEVELOPMENT

5.3.1 Recommendable Cropping Pattern

Supply of exploited irrigation water surely leads to increase of cropping intensity and/or change of crops and cropping calendar. The following principles would be applied for layout of cropping pattern.

(1) The cropping pattern must conform with the concept of the national development plan.

(2) The cropping pattern must meet social tradition in and around the area and must be willingly acceptable by farmers.

(3) The cropping pattern must be possibly of low-intensity to use the limited exploited water resources in the extended area.

(4) The cropping pattern must be practical with the limited farm labour and farm machinery.

On the basis of the above principles, paddy in wet season and beans in dry season would be recommended for the respective project areas. Dry season paddy is not proposed because it requires large amount of irrigation water, about 2 times of that of beans. In determining the optimum crop intensity, the comparative study is made in due consideration of exploitable water resources in the respective project areas. The explanation of this study is given in ANNEX VI and the result shows that the optimum crop intensity would be 135 percent for the Lom Sak area and 125 percent in the Phetchabun area, respectively.

The recommendable cropping pattern is determined as follows based on the above descriptions and is illustrated together with agro-climatic data in Fig. 5.5.

Description	Lom Sak Area	Phetchabun Area
Wet season		
Paddy		
Local variety	50%	50%
High yield variety	50	50
Dry season		
Beans	35	25
Crop Intensity	135%	125%

Note: Lom Sak Area - Huai Saduang Yai and Huai Khon Kaen Project area
Phetchabun Area - Huai Yai and Khlong Chaliang Lab area

Nursery for local variety of paddy is seeded in the beginning of May. Transplanting starts in the middle of June and lasts until the end of July. Harvesting commences in the middle of October and ends by the end of November when the dry season starts in the project area.

For high yielding variety, nursery is seeded in the beginning of June. Transplanting starts in the middle of July and lasts until the end of August. Harvesting is made in the same harvesting period of the local variety.

After the wet season paddy is harvested at the onset of the dry season, upland crops such as mungbean, soybean, groundnut, etc. are sown in the middle of January on 35 percent of total paddy field in case of Huai Saduang Yai and Huai Khon Kaen area and 25 percent of total paddy field in Huai Yai and Khlong Chaliang Lab area, and harvested by the end of April. The remaining 65 percent and 75 percent of paddy field in the respective areas are laid fallow throughout dry season owing to the limited water resources. The cultivation area for the dry season crops would be shifted in each project area by annual rotation.

In each project area, there is no constraints for germination of seeds of paddy and upland crops throughout year, blessed with relatively constant high temperature and high humidity. In the recommendable cropping pattern, the harvest season of paddy is laid out in the beginning of dry season so as to smoothly operate the harvesting and processing of paddy.

5.3.2 Anticipated Yield and Production

The present crop yields in the project areas are not so high with wide fluctuation year by year due to unstable irrigation water supply and unexpected damages caused by flood, insect and diseases. After completion of the project, the crop yields would be stabilized and increased through stable supply of irrigation water, improvement of irrigation practices and further expansion of agricultural support services.

The anticipated crop yields of paddy and beans recommended for the project are estimated on the basis of the information collected in the existing irrigation project areas in the study area and agricultural data in similar irrigation projects recently proposed in north Thailand.

Crop	Without Project		With Project	
Paddy	kg/rai	(t/ha)	kg/rai	(t/ha)
Local variety	434	(2.70)	640	(4.00)
High yield variety	640	(4.00)	800	(5.00)
Beans	160	(1.00)	320	(2.00)

Based on the above crop yields, the following annual crop productions at the full development stage are estimated for each project area.

Crop	Project			
	Huai Saduang Yai (6,000 ha)	Huai Khon Kaen (4,400 ha)	Huai Yai (1,500 ha)	Khlong Chaliang Lab (230 ha)
Paddy	(ton)	(ton)	(ton)	(ton)
Local variety	12,000	8,800	3,000	460
High yield variety	15,000	11,000	3,750	575
Beans	4,200	3,080	750	116

5.3.3 Price Forecast

Surplus paddy to be produced in the project areas after the completion of the project would be partly marketed in domestic markets and be mostly exported to foreign countries in shortage of food. Therefore, future economic price of paddy would be forecasted on the basis of the "Price Prospects for Major Primary Commodities" published by IBRD. The economic farmgate price of paddy is estimated at Baht 7,700 (US$350) per ton for high yield variety as of 1990. Future economic price of local variety is assumed to be about 5 percent lower than that of high yield variety.

The increased production of upland crops to be produced in the project areas would be locally marketed and consumed. Market prices of major upland crops have recently shooted up year by year. But no sufficient data are available for the forecast of future economic prices of respective upland crops. Therefore, the future economic price of beans, as well as that of paddy, would be forecast on the basis of the price prospects by IBRD and estimated at Baht 11,000 (US$500) per ton as of 1990.

5.3.4 Net Production Value Without and With Project

The net crop production value is estimated based on the forecast prices of crops and production costs. The unit net production values for paddy and beans without and with project are calculated as follows, and the details are given in ANNEX-V.

Crop	Unit Net Production Value			
	Without Project		With Project	
	฿/rai	($/ha)	฿/rai	($/ha)
Paddy				
Local variety	2,351	(668)	3,726	(1,059)
High yield variety	4,008	(1,139)	5,010	(1,423)
Beans	1,230	(349)	2,880	(818)

5.4 IRRIGATION DEVELOPMENT

5.4.1 Available Irrigation Water Resources

The irrigation water resources of the four projects would be dependent on four river systems, i.e. Huai Saduang Yai, Huai Khon Kaen, Huai Yai and Khlong Chaliang Lab, the tributaries of the Pasak river. The water resources endowed in each tributary would be exploited by construction of storage dam. The annual runoff and exploitable water resources at the proposed dam site are assessed as listed below, in view of hydrology, topography, and dam engineering.

Tributary	Catchment Area	Annual Runoff/1	Useful Storage Capacity
	(km^2)	(MCM)	(MCM)
Huai Saduang Yai	96	21.16	14.04
Huai Khon Kaen	322	70.96	24.78
Huai Yai	78	19.14	7.12
Khlong Chaliang Lab	77	18.90	1.53

/1: 20% recurrence of droughty year

5.4.2 Irrigation Water Requirement

Potential evapotranspiration is estimated by two empirical formula on the basis of the meteorological data recorded in the Phetchabun Meteorological Station and compared with the A class Pan evaporation recorded in the Phetchabun Station. The averaged value obtained by the both methods is applied for calculation of consumptive use after cross-checked by the records of the A class pan measured in the Phetchabun Station. The maximum potential evapotranspiration of 5.6 mm per day occurs in April and the minimum of 2.8 mm per day, in August.

No field data on percolation loss is available. On reference to the applied data in the similar projects and in due consideration of textural profiles of representative soil extending in the project areas, percolation loss of one (1) mm per day is incorporated in the calculation of irrigation requirement.

Effective rainfall during growing period of paddy and upland crops is estimated by the curve developed by RID and rainfall records in the year with the frequency of 20%. The annual effective rainfall is estimated at 686 mm in the Lom Sak area and 720 mm in the Phetchabun area. These are 74.1% and 76.3% equivalence of total annual rainfall, respectively.

The puddling water requirement of 150 mm is incorporated in irrigation requirement in due consideration of fine texture alluvial soils covering all over the project areas. Water requirements for nursery period of paddy are estimated at about 275 mm for local varieties and about 230 mm for high yield varieties according to the nursery period. The transplanting paddy field of 5% would be used for nursery bed.

The irrigation efficiency during the growing period is estimated to be 56% (70% of application efficiency and 80% of conveyance efficiency) for paddy and 48% (60% of application efficiency and 80% of conveyance efficiency) for upland crops.

As given in Table 5.2, the calculation of irrigation water requirement is made by monthly basis on the basis of the proposed cropping patterns and meteorological records in the Phetchabun Station. The annual irrigation requirement in depth amounts to 803.2 mm in the Lom Sak area and 712.1 mm in the Phetchabun area. The maximum unit diversion requirement is equivalent to 0.120 ℓ/sec/rai in the Lom Sak area and 0.115 ℓ/sec/rai in the Phetchabun area; these occur in October.

Under the proposed cropping intensity of 135% for Lom Sak area, annual requirement amounts to 1.3 MCM per 1,000 rai. While under the proposed cropping intensity of 125% for Phetchabun area, annual requirement amounts to 1.1 MCM per 1,000 rai. The details are explained in ANNEX-VI.

5.4.3 Delineation of the Project Area

(1) Criteria on Delineation

To delineate irrigable area specified in paragraph 5.2.4, criteria on delineation are laid down as below mentioned, taking into account of amount of exploited water resources, irrigable area, capable land resources, existing land use, river channel condition, etc.

Criteria - 1: Irrigable area would be delineated in the vicinity of the exploited site of water resources as far as possible

Criteria - 2: To quickly reap the project return and to save investment, irrigable area would be delineated in the existing paddy field, in principle, and

Criteria - 3: In case available water resources are allowable, delineation would be extended over existing upland and plantation area.

(2) Delineation

Huai Saduang Yai Area

The lower basin of the Huai Saduang Yai is sharply undulating and partly used for cultivation of upland crops. Land resources for irrigated agriculture are extremely limited and scattered. Therefore, against the criteria-1 mentioned above, the exploited water in the reservoir would be released in the original river channel and used in the remote area from the exploited site. The Sri Chan and Pasak Left Bank irrigation areas extend over the right and left bank of the Pasak river, respectively. The both areas depend their irrigation water resources on the unstable and non-regulated natural flow of the Pasak river and are subject to habitual drought damages. Supplemental irrigation water supply is essential for both areas to practice stable paddy cultivation. About 37,500 rai (6,000 ha) under both areas would be delineated for the service area of the Huai Saduang Yai reservoir.

Huai Khon Kaen Area

Land resources for irrigated agriculture are limited at the lower basin of the Huai Khon Kaen. In due consideration of reservoir planning, lands lower than 185 m contour lines would be delineated for the service area, including some extent of uplands and plantation areas. The service area would be extended to southward along the main canal of the Pasak Left Bank irrigation project so as to meet 27,500 rai (4,400 ha) of the irrigable area of the Huai Khon Kaen reservoir.

Huai Yai Area

The exploited water resources are extremely limited compared with the land resources suitable for irrigated agriculture in the Huai Yai basin. According to the criteria-1 and -2, the irrigable area of 9,380 rai (1,500 ha) would be delineated from the upper basin to the lower basin. Thus, some extent of the lowest basin is not incorporated in the irrigable area due to the shortage of the exploited water resources.

Khlong Chaliang Lab Area

This area also remains under similar condition to the Huai Yai area in view of the exploited water and the land resources. The same concepts contemplated for the delineation of the Huai Yai area would be also employed for the delineation of the irrigable area in the Khlong Chaliang Lab area. Only 1,440 rai (230 ha) of the irrigable area would be delineated from the upper area in the left bank of the Khlong Chaliang Lab.

5.4.4 Irrigation/Drainage System

The layout of the irrigation system is made by use of the available topographic maps of scale 1/10,000 and 1/50,000 together with site inspection in the course of the study. The proposed irrigation systems for four (4) projects are summarized as follows. With regard to the drainage systems, no technical drainage systems would be developed with the projects, since the project areas are rather steep, relatively better drained by natural creeks, and the limited water resources must be effectively used.

(1) Huai Saduang Yai Project

The storage water of the Huai Saduang Yai dam is proposed to be used as the supplementary supply for the Sri Chan Irrigation Project area and the Pasak Left Bank Irrigation Project area, since there are scarcely cultivable lands in the downstream of the dam due to the topographic condition.

The Sri Chan Irrigation Project area has 6,000 rai (960 ha) of irrigable area and at present, the irrigation water is supplied temporarily from the Pasak river by small pumps. In 1982, a perennial weir will be constructed by RID at about 3 km downstream from the confluence of the Pasak river and the Huai Saduang Yai.

The Pasak Left Bank Irrigation Project covering 31,460 rai (5,030 ha) of irrigable area has been operated by RID. This project was completed in 1969. The project facilities comprise an intake weir located at about 8 km downstream from the Sri Chan weir, and 59 km of the main and lateral irrigation canals.

As the existing irrigation facilities of the above two projects have been fully facilitated, no rehabilitation and/or up-grading work would be envisaged in these areas in relation to the development plan of the Huai Saduang Yai Project. The crop intensity would be increased from the existing 115 percent to 135 percent as more water supply is available.

The storage water of the Huai Saduang Yai dam is released to the river and conveyed to the above two project areas through the Huai Saduang Yai and the Pasak river. No canals would be newly proposed to be constructed, because the said existing areas are fairly provided with sufficient irrigation system well maintained.

The irrigation water for the Sri Chan Irrigation Project area and the Pasak Left Bank Irrigation Project area can be offtaken from the Pasak river involving the regulated flow of the Huai Saduang Yai dam through two intake weirs located at about 3 km and 11 km downstream from the confluence of the Pasak river and the Huai Saduang Yai, respectively. It can be distributed to the irrigable areas using the existing irrigation facilities. The irrigation plan of the Huai Saduang Yai Project is shown in Table 5.3(1) and Fig. 5.6(1).

(2) Huai Khon Kaen Project

The irrigable area of 27,500 rai (4,400 ha) is delineated with the proposed crop intensity of 135 percent comprising the existing paddy field of 15,000 rai (2,400 ha) and the existing plantation area and others of 12,500 rai (2,000 ha). The irrigation water is obtained directly from the Huai Khon Kaen dam and conveyed to the irrigable area through two main canals, namely right main canal (RMC) and left main canal (LMC). The main canals are planned to be constructed newly at the elevated area as far as possible in order to extend the irrigable area. The total length of the main canals is 42.0 km consisting of 6.9 km of RMC and 35.1 km of LMC. The right main canal is connected to the main canal of the Pasak Left Bank Irrigation Project for supplementary supply of irrigation water to the said project area in pluvious year and municipal water supply in future.

Nine laterals and sub-laterals are aligned to distribute the irrigation water to the field from the main canals and the canal length totals 42.3 km. Out of the total length, about 70 percent or 29.5 km are proposed along the existing canals with some improvement works. Table 5.3(2) shows the irrigation plan of the Huai Khon Kaen Project and Fig. 5.6(2) presents the irrigation canal system.

(3) Huai Yai Project

The irrigable area of 9,380 rai (1,500 ha) is delineated with the proposed crop intensity of 125 percent covering the existing paddy field. The area can be supplied the irrigation water by one main canal and three laterals and sub-laterals. The main canal would be directly stretched out from the outlet structure of the Huai Yai dam. The total length is 12.3 km, of which 5.6 km is aligned along the existing canals with some improvement works.

To distribute the irrigation water from the main canal to the field, 16.3 km of canal in total are proposed as the laterals and sub-laterals, and out of them, about 42 percent or 6.8 km are newly proposed and about 58 percent or 9.5 km of the existing canals would be improved. The irrigation plan of the Huai Yai Project is presented in Table 5.3(3) and Fig. 5.6(3).

(4) Khlong Chaliang Lab Project

The irrigation water is obtained directly from the dam and distributed to the irrigable area of 1,440 rai (230 ha) through one main canal and two laterals. The length of main canal extends to 2.3 km comprising the new canal of 0.8 km and the existing canal of 1.5 km. The laterals total 2.8 km of which the new canal is 0.4 km and the existing canal is 2.4 km. The existing canals are required to be improved to incorporate in the proposed irrigation system.

Table 5.3(4) shows the irrigation plan of the Khlong Chaliang Lab Project and Fig. 5.6(3) presents the proposed canal system.

5.5 ASSOCIATED DEVELOPMENT

5.5.1 Flood Mitigation

The proposed storage dams would be constructed mainly for the purpose of irrigation water supply. Based on the dam scale proposed in this study, the flood mitigation potential is estimated for floods of 10 year, 30 year and 50 year return period. The result is summarized as follows and details are given in ANNEX-II.

Dam	Return Period	Peak Inflow	Peak Outflow	Regulation Ratio
	(year)	(m^3/s)	(m^3/s)	(%)
Huai Saduang Yai	10	139	131	5.7
	30	202	192	4.6
	50	226	217	4.1
Huai Khon Kaen	10	370	367	0.8
	30	534	531	0.4
	50	598	596	0.2
Huai Yai	10	84	76	9.0
	30	126	114	8.9
	50	144	131	8.9
Khlong Chaliang Lab	10	75	75	0.3
	30	113	112	0.3
	50	129	128	0.3

Flood control effects of Huai Khon Kaen and Khlong Chaliang Lab dam are negligible small, indicating 0.2 - 0.8% decrease of peak discharge. While, the effects of Huai Saduang Yai and Huai Yai dam are comparatively bigger than the above two dams, but only 4.1 - 9.0% of peak inflows would be mitigated and cut-off discharges are to be 7.6 - 12.7 m^3/sec.

5.5.2 Hydropower

The hydropower potential is roughly estimated as mentioned hereinafter, making reference to the results of reservoir operation study. The following assumptions are made in this estimate that the water release from the reservoir would be made on the basis of water requirements for irrigation, municipal use, and river channel maintenance and thus, no special operation rule would be prepared for hydropower generation.

The available hydraulic head for power generation is estimated based on the following conditions proposed in dam design.

Dam	EL of Tailrace	Full Water Level	Dead Water Level
	(m)	(m)	(m)
Huai Saduang Yai	164.0	187.5	174.5
Huai Khon Kaen	186.5	211.5	186.5
Huai Yai	185.5	209.0	196.0
Khlong Chaliang Lab	180.0	196.5	190.0

The available monthly discharge widely ranges according to the reservoir operation. Using the monthly discharge in the average year of the reservoir operation study, the hydropower potential of each dam is estimated as shown in Table 5.4. The peak power generation and annual energy product of each dam is summarized as tabulated below.

Dam	Peak Power Generation (KW)	Annual Energy Product (10^3 KWh)
Huai Saduang Yai	267	893
Huai Khon Kaen	620	1,731
Huai Yai	203	612
Khlong Chaliang Lab	27	114

Generating Efficiency: 70%

As shown in the above table, the Huai Khon Kaen dam has relatively high hydropower potential comparing with other three dams, but annual energy product is expected to be 1,731 x 10^3 KWh only and in dry season, the peak power generation is extremely limited to be less than 200 KW.

CHAPTER VI PROPOSED PROJECT WORKS

6.1 STORAGE DAM

6.1.1 Dam Type and Embankment Materials

Various dam types might be technically eligible but concrete dam would be left out of consideration in view of project economy. Rockfill type of dam which offers relatively less embankment compared with earthfill type, seems to be suitable for each dam site. Actually however, the rockfill type is unfavourable for each dam site, since the information obtained from material surveys clarify that no quarry site required for rockfill dam can be found within the economic hauling distances. In this context, earthfill dam would be proposed for each site.

According to the outcomes of material survey, top soils in and around each site mainly comprise various fine materials, such as silty sand, clayed sand, sandy clay and silty clay. These materials are much suitable for the impervious zone. Coarse materials essential for semi-pervious or pervious zone are insufficient in the vicinity of each site but might be obtainable in hillside and/or deep layer under topsoils in the surroundings.

In the light of dam scale proposed at each site, zoned type of earthfill dam which is soil-mechanically more stable than homogeneous type would be recommendable in this study. The proposed zone typed earthfill dam would be composed of four zones, viz, impervious zone, semi-pervious or pervious zone, filters, and riprap for slope protection of upstream. Two filters are provided at both the upstream and downstream sides; the upstream filter is zoned behind the riprap and the downstream one, behind the semi-pervious zone. The riprap materials are obtainable from the limestone quarry site being located at Tham Kao Phra about 15 km southwest of the Lom Sak Municipality. This quarry site is located for exceeding the economic hauling distance from each dam site. Further investigations should be made at the next stage to quarry out more economical riprap materials in the vicinity of each dam site.

6.1.2 Preliminary Design of Dam

The dam crest elevation would be determined by adding overflow depth of the spillway plus freeboard to the full water level in the reservoir. The full water level, crest elevation and height of respective dams are proposed as given below.

Dam	Full Water Level	Dam Crest	Dam Height
	(m above MSL)	(m above MSL)	(m)
Huai Saduang Yai	187.50	191.00	30.5
Huai Khon Kaen	211.50	216.00	52.0
Huai Yai	209.00	212.50	32.5
Khlong Chaliang Lab	196.50	200.00	25.3

The width of dam crest is proposed to be 7.0 m to 10.0 m so as to provide a function of inspection road. The slope of upstream face is designed to be 1.0 to 3.0 (vertical to horizontal); that of downstream, to be 1.0 to 2.5 (vertical to horizontal). The central impervious core is embanked with a slope of 1.0 to 0.25 (vertical to horizontal) for both upstream and downstream side of the core, having the top width of 6.0 m. The filter of 2.0 m wide would be zoned along the downstream slope of the impervious core and connected to the downstream toe drain, to dissipate seepage water through the central core. The filter would be composed of sand and gravel to be collected at riverbed. The riprap of 1.0 m thick would be provided on the surface of upstream slope to prevent the slope from eroding caused by quick water surface fluctuation. Behind the riprap, the upstream filter of 0.5 m thick is proposed to serve function of transitional zone between the coarse riprap and the semi-pervious zone . The key trench would be excavated at the center of the core bottom and filled with fully impervious materials. The foundation treatment would be made by grouting as required according to rock quality, permeability and height of dam.

6.1.3 Preliminary Design of Appurtenant Structures

(1) Service Spillway

Service spillway is proposed accounting flood discharge with return period of 100 years. Side channel spillway would be proposed without provision of any control gate in due consideration of the topographic condition at each dam site and safety of dam embankment.

The service spillway of the Huai Saduang Yai dam would be aligned at the right abutment; that of the Huai Yai dam at the left abutment. The capacity of both spillways would be determined accounting for flood control effects which are estimated at flood mitigation study. The main features of both service spillways are as summarized below and the details are given in ANNEX-III.

Dam	Peak Inflow	Peak Outflow	Regulated Flow	Crest Length	Overflow Depth
	(m^3/sec)	(m^3/sec)	(m^3/sec)	(m)	(m)
Huai Saduang Yai	268.4	245.0	23.4	60.0	1.70
Huai Yai	168.4	149.0	19.4	40.0	1.60

While, the service spillway of the Huai Khon Kaen dam would be aligned at the left abutment; that of the Khlong Chaliang Lab dam, at the right abutment from the topographic condition at the dam site. Both reservoirs are provided with a relatively large watershed being compared with their reservoir areas, resulting in no substantial contribution to flood mitigation. Outflow through the spillway is regarded as being equal to inflow, and, thus, the capacity of each service spillway would be designed with the peak inflow of 100 year return period. The main features of both service spillways are as summarized below and the details are given in ANNEX-III.

Dam	Peak Outflow (m^3/sec)	Crest Length (m)	Overflow Depth (m)
Huai Khon Kaen	697.4	96.0	2.5
Khlong Chaliang Lab	150.0	40.0	1.6

(2) Emergency Spillway

Emergency spillway would be provided to ensure stability of dam against extraordinary floodings. Flooding discharge of 500 year return period would be applied for designing the emergency spillway. Two types of the emergency spillway would be proposed according to the topographic conditions at dam site, i.e. side channel type and overflow type. The side channel type would be installed together with service spillway, while the overflow type would be independently installed on the saddle extending from abutments. Emergency spillway would basically serve no function of flood mitigation at all. The capacity of emergency spillway would be supplementally provided, adding to the capacity of service spillway. The main feature of the emergency spillway of each dam is determined as summarized below on the basis of hydraulic calculation and the details are given in ANNEX-III.

Dam	Location	Design Discharge (m^3/sec)	Crest Length (m)	Overflow Depth (m)
Huai Saduang Yai	Left Abutment	354.0	30.0	0.45
Huai Khon Kaen	Left Abutment	940.0	34.0	0.50
Huai Yai	Right Abutment	218.0	25.0	0.40
Khlong Chaliang Lab	Right Abutment	193.0	40.0*	2.00*

* including capacity of service spillways

(3) Outlet Structure

The outlet structure of each dam comprises intake tower, conduit and operation bridge. The intake tower is of reinforced concrete and equipped with regulating gates. Water offtaken in the tower through regulator would be released into downstream through the conduit which is of reinforced concrete and laid

under each dam. The stepping to the operation deck from the dam would be spanned with operation bridge which would be mainly composed of steel. All of the bridges are long-spanned and supported by piers which would be composed of reinforced concrete.

The main features of dams and appurtenant structures proposed in the respective projects are as summarized in Table 6.1.

6.2 IRRIGATION FACILITIES

Pre-feasibility level design of the irrigation facilities is made on topographic maps with the scale of 1/10,000 and 1/50,000. Each project excepting the Huai Saduang Yai project would include the following main irrigation works.

(i) Concrete lined main irrigation canals,

(ii) Unlined lateral and sub-lateral irrigation canals, and

(iii) Structures related to main, lateral and sub-lateral irrigation canals.

The Huai Saduang Yai project commands the Pasak Left Bank and Sri Chan irrigation areas in which the irrigation systems have fairly developed so far. Thus, as regards the irrigation development of the Huai Saduang Yai, existing irrigation system would be up-graded by partial rehabilitation works.

The main canals are basically proposed to be concrete-lined and the laterals and sub-laterals are unlined. All of the irrigation canals are trapezoidal with a side slope of 1 to 1.5. Operation/ maintenance roads would be proposed on the canal bank along the canal alignment. The proposed typical canal sections are as illustrated in Fig. 6.1.

As regards irrigation canal system, a large number of structures are essential for full function of the canal systems. The following structures would be proposed.

i) Structures for destribution of irrigation water such as regulator and turnout

ii) Structures for regulation of water level such as check and drop

iii) Structures for conveyance of irrigation water over or under road, river, stream, etc. such as siphon, aqueduct culvert, and bridge

iv) Structures for protection of canal, such as canal spillway and cross drain.

The major structures proposed in each project are roughly accounted as summarized in Table 6.2.

CHAPTER VII COST ESTIMATE

7.1 PROJECT COST

The project cost mainly comprises direct construction costs and engineering/administration costs. All the construction costs are estimated on the basis of quantity-takings of project works and authorized unit prices issued by the RID in 1981. It is presumed that all the construction works would be executed by full contract basis.

The costs for the preparatory works such as construction of access roads, office and quarter, power-supply, are estimated to be 5% of the total direct construction cost.

The engineering/administration costs are roughly assumed to be 15% of the total direct construction cost, making reference to the criteria recently given in the similar projects. The physical contingency of 20% would be allowed on the total construction cost plus engineering/administration cost.

All the costs would be estimated at 1981 price level. The conversion rate is assumed at US$=Baht22. The project cost for the implementation of each project is thus estimated as tabulated below and the details are given in ANNEX-VII.

(Unit: $x10^3$฿)

Work Item	Name of Project			
	Huai Saduang Yai	Huai Khon Kaen	Huai Yai	Khlong Chaliang Lab
I. Civil Works	155,390	406,010	88,210	44,670
1. Preliminary Works	7,396	19,335	4,196	2,127
2. Dam Works	95,194	299,549	60,654	39,170
3. Irrigation Works	52,800	87,126	23,360	3,373
II. Engineering and Administration Cost	23,310	60,900	13,230	6,700
III. Physical Contingency	35,740	93,380	20,290	10,270
Total	214,440 ($9,747x10^3$$)	560,290 ($25,468x10^3$$)	121,730 ($5,533x10^3$$)	61,640 ($2,802x10^3$$)

7.2 OPERATION/MAINTENANCE COST

Operation/maintenance cost mainly comprises personnel cost, depreciation cost of O/M equipment, vehicle, office and quarter, and consumable expenses. Making reference to the criteria applied for similar projects and taking into consideration the characteristics of the project, about 1.0% of the total project cost would be applicable for the operation/maintenance cost as given below.

Project	O/M Cost (10^3 ฿/annum)
Huai Saduang Yai	1,716
Huai Khon Kaen	4,482
Huai Yai	974
Khlong Chaliang Lab	493

Among the proposed project works, amount of metal works and other materials to be replaced in future is almost negligibly small compared with the total project cost. The replacement cost, therefore, would not be accounted in the economic analysis.

CHAPTER VIII ECONOMIC JUSTIFICATION

8.1 GENERAL

Economic evaluation is made in view of projects' impacts on national and regional economy. The impacts on national economy would be made in terms of economic internal rate of return, while those on regional economy, in terms of net present value (Benefit minus Cost). Prior to the evaluation, the following assumptions are made.

(1) Project life is 50 years after completion of construction works.

(2) Construction period for each project is roughly estimated as follows, according to scale of each project.

i)	Huai Saduang Yai	4 years
ii)	Huai Khon Kaen	5 years
iii)	Huai Yai	3 years
iv)	Khlong Chaliang Lab	3 years

(3) Economic cost of each project is estimated by deducting transfer-payment from the project cost estimated at 1981 price level. The transfer-payment is equivalent to 20% of the total project cost. Price contingencies would not be incorporated.

(4) Direct benefit accrues from increased crop production with a provision of stable irrigation water supply. This benefit linearly increases year by year after commencement of partial operation of each project. Full development stage of the Huai Saduang Yai, Huai Yai and Khlong Chaliang Lab projects would be attained within 5 years after completion of the construction works since the existing irrigation systems thereabout have been well-developed; the Huai Khon Kaen would require the build-up period of 6 years, since the irrigation development in the area still remains low level.

(5) Secondary benefits such as stemming-from and induced-by benefits are also estimated for assessment of potential impacts on national economy. These benefits denote value added to activities influenced by the project through economic rather than technical linkages. The stemming-from benefits result from forward production linkages that increase net income of those who process project-outputs; the induced-by benefits result from backward production linkages which increase net income of those who provide goods and service to the project area. To estimate these secondary benefits, the criteria proposed by the USBR would be applicable.

8.2 ECONOMIC COST AND BENEFIT

8.2.1 Economic Project Cost

As abovementioned, the economic cost would be estimated by deducting transfer payment from the project cost on the assumption that the transfer payment is 20% equivalence of total project cost. The estimated economic cost of each project is summarized as belows.

Project	Economic Project Cost million ฿ (million $)
Huai Saduang Yai	171.55 (7.80)
Huai Khon Kaen	448.23 (20.37)
Huai Yai	97.38 (4.43)
Khlong Chaliang Lab	49.31 (2.24)

8.2.2 Incremental Direct Benefit

The incremental direct benefit is estimated as the difference of annual net crop production value under with and without production conditions. The direct benefit accrued from each project is as summarized below. The detailed estimates of direct benefit are given in ANNEX-V and VIII.

Project	Incremental Direct Benefit million ฿ (million $)
Huai Saduang Yai	44.02 (2.00)
Huai Khon Kaen	113.21 (5.15)
Huai Yai	32.41 (1.47)
Khlong Chaliang Lab	4.97 (0.23)

8.2.3 Secondary Benefits

Secondary benefits previously mentioned accrued from each project are also estimated based on the criteria recommended by the USBR as given below.

(1) Stemming-from benefits accrued from rice production are evaluated to be 18% of direct benefit.

(2) Stemming-from benefits accrued from production of beans are evaluated to be 28% of direct benefits.

(3) A uniform 18% of direct benefits are recommended for induced-by benefits for all crops.

According to the above criteria, the annual secondary benefits for each project are estimated as follows.

Unit: million ฿ (million $)

Project	Secondary Benefit		
	Stemming-from	Induced-by	Total
Huai Saduang Yai	10.52 (0.48)	7.92 (0.36)	18.44 (0.84)
Huai Khon Kaen	23.21 (1.06)	20.38 (0.93)	43.59 (1.99)
Huai Yai	6.51 (0.30)	5.83 (0.26)	12.34 (0.56)
Khlong Chaliang Lab	1.00 (0.05)	0.90 (0.04)	1.90 (0.09)

8.3 ECONOMIC INTERNAL RATE OF RETURN

Economic internal rate of return of each project is estimated on the basis of the economic cost and benefit previously mentioned. Two kinds of the economic IRR are estimated according to the two kinds of economic benefits, i.e. only direct benefit and the direct benefit plus secondary benefits. Prior to the economic evaluation, the project cost is yearly distributed according to the construction time schedule and the project benefit during build-up period is proportionally allotted until the attainment of full development stage. The detailed economic cost and benefit are given in ANNEX-VIII. The estimated economic internal rate of return is listed as follows.

Project	Economic Internal Rate of Return	
	Direct Benefit	Direct Benefit plus Secondary Benefits
Huai Saduang Yai	16.1 (%)	20.8 (%)
Huai Khon Kaen	14.2	17.9
Huai Yai	21.0	26.8
Khlong Chaliang Lab	7.4	10.1

8.4 NET PRESENT VALUE

The net present value of each project would be estimated to clarify the projects' impacts on regional economy. To obtain the present value of both benefit and cost, a discount rate would be assumed to be 12% which have recently been recommended by the World Bank for economic evaluation of irrigation projects in Thailand. Two kinds of net present value are estimated as given below, as well as the economic internal rate of return, according to the estimated two kinds of economic benefits.

Unit: million ฿ (million $)

Project	Net Present Value	
	By Direct Benefit	By Direct Benefit plus Secondary Benefit
Huai Saduang Yai	60.13 (2.73)	143.75 (6.53)
Huai Khon Kaen	87.32 (3.97)	255.09 (11.60)
Huai Yai	81.20 (3.69)	143.90 (6.54)
Khlong Chaliang Lab	-16.96 (-0.77)	-7.30 (-0.33)

8.5 SOCIO-ECONOMIC IMPACTS

Various socio-economic impacts are expected from the implementation of the project. They are:

(1) Increase of employment opportunity

It is expected that the present unemployment in and around the project areas is much improved by the project implementation. After completion of the project, the more intensive land use surely increases the employment opportunity. In addition, the people gains more experience, technical know-how and skillfulness in the various working fields. These up-graded human resources provide motive power for the future development in the Pasak River Basin.

(2) Improvement of farm products

The present quality of rice is much improved through sufficient irrigation water supplies which enable the crop damages minimize and assure the even maturing of rice. Such improved quality would increase the marketability of farm products.

(3) Environmental effects

The implementation of the project works would certainly leads to changes in rural economy. The local transportation system would be improved and contribute to the improvement of rural economic activities. The increased crop production in the project areas would stimulate the improvement of marketing system and also of agricultural support services.

(4) Improvement of operation and maintenance of existing irrigation schemes

Owing to temporary irrigation structures in the existing schemes, the farmers spend many days annually for the improvement and replacement of the facilities. After completion of the project, all these irrigation facilities would be changed into perennial structures, and the farmers would be released from such laborious works. The labour forces thus saved can be utilized for another productive works.

(5) Potential for fishery development

The proposed reservoirs and irrigation canals can be used for fishery development. Although further studies would be required, the fish culture has a future possibility for additional farm income. The fishery development would contribute to the local supplies of animal protein.