CHAPTER 5
CONCEPTUAL PLAN FOR PROJECT FACILITY

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5.1 Proposed Water Diversion Route

(1) Proposed Water Diversion Plan

The proposed Kok-Ing-Nan water diversion plan is summarized as follows based on the study result as mentioned in the preceeding chapter 4.

(a) The surplus wet season water of the Kok river is taken at the Kok diversion damsite and diverted to the Ing diversion damsite by the Kok-Ing diversion canal with the discharge capacity of 125 cu.m/sec. The canal system consists of the open canal, syphon, culvert, tunnel and pumping station.

(b) At the Ing diversion damsite, the surplus wet season water of the Ing river and the diverted water from the Kok is regulated and then diverted to the Ing-Yot tunnel with the gravity flow of 175 cu.m/sec.

(c) The water conveyed by the Ing-Yot tunnel is released to the Yao flood control dam which controls the flood in the Yao upper basin.

(d) In order to release the bulk discharge of more than 200 cu.m/sec. through the Yao river, the river training works are required along the Yao river for the approximate length of 40 km.

(2) Alternative Routes

Three alternative water diversion routes of A, B and C as shown in the Database map have been studied by the Thai side, as the result, the route B plan is recommended to be suitable and viable for conducting the Feasibility Study.

JICA Team has reviewed carefully the above three alternative route plans and judged that the route C plan is not suitable for the project, because the Ing-Yot tunnel route along the southern mountain in the Lao basin is placed at unsuitable geological condition for tunnel construction causing the high construction cost.

While, it is rather difficult at present stage to confirm the relative merits of the A and B route plans as discussed below,

(a) Difference of A and B Route Plans

A route

- A new diversion dam is proposed at 3.3 km. downstream of the existing Chiang Rai Weir.
- Open canal with the short distance crosses the agricultural area and reaches the inlet of the tunnel between the Kok and Ing basins.
- Two tunnels with the total length of 13.5 km are required at the mountain between the Kok and Ing basin which is located under the poor geological condition with many fault zones requiring high construction cost.
- There will be less environmental impact along the route consisting of canal passing through agricultural field in the Kok basin and tunnels crossing the mountains.

B route

- The existing Chiang Rai Weir is to be used as the diversion dam of the project, so that the construction cost for diversion dam is not required.
- An open canal is passing through the agricultural area neighboring Chiang Rai urban area, thus resulting in more social environmental impact and land acquisition cost will be higher than those of the A route plan.
- The culvert with long distance of 13.5 km and deep excavation of more than 25 m depth is required at the reaches between the Nong Luang lake and the Kok-Ing tunnel inlet, so that the high construction cost is required and the larger social environmental impact takes place.
- However, tunnel passing through the mountain between the Kok and Ing basin is planned with the short distance of 5.5 km and placed at the good geological condition for construction.

Both A and B route plans have the same route in the Ing basin after passing through the route between the Kok river and outlet of the Kok-Ing tunnel and reaches to the Ing diversion damsite. Namely, the difference of A and B route plan is only the route section passing through the Kok basin, where especially the big difference is in between the culvert with long distance with deep excavation in case of the B route and the tunnel with long distance and passing through the poor geological condition in case of the A route.

(b) Additional Alternative Route for Plan B

In order to minimize the construction cost and mitigate the social environmental impact for the culvert works in the B route plan, JICA Team has studied the following additional two route plans.

- B-J route starts off at the existing Chiang Rai Weir and passes through the area between the route A and B in order to escape the culvert reaches of long distance.
- B-P route is the same route as the proposed B but is planned with pumping station at the Nong Luang swamp site to lift up the diverted water of 125 cu.m/sec. with 10 to 15 m head.

The above alternative route plans are as shown in the Database map. In accordance with the study result, B-J plan has some advantage to minimize the culvert length as compared with the plan B, while the pumping system in the B route could minimize the construction cost and mitigate the social environmental impact but requires the additional pump operation cost.

(c) Additional Alternative Route for Plan A-R

It is rather difficult to select the plan A as mentioned in the above, because tunnel AT1 route with the length of 5.8 km is lying on the very weak geological condition consisting of fault zones of more than 10 places and thin overburden depth of 30 to 50 m along the route.

In accordance with the above tunnel condition, RID proposed the A-R route which starts at the new diversion damsite and reaches the B-J tunnel inlet in order to avaid the tunnel AT1 route.

This alternative route will be studied additionally in F/S stage.

(d) Recommendation and Conclusion

The comparison study for the above alternative routes has been made on the conceptional plan level within a short period and without the detailed map of 1 to 10,000 in the B plan and the geological investigation works for tunnel route in all route plans.

Accordingly it is very difficult to discuss definitely the relative merits of the alternative routes at this stage. JICA Team recommends to carry out the detailed topographical survey and geological investigation works and to perform the comparison study of alternative routes at the basic plan study stage under the Feasibility Study.

JICA Team has no objection to the other water diversion routes proposed by Thai Side Study such as the route of diversion canal route in the Ing basin, Ing diversion damsite, route of Ing-Yot tunnel, Yao flood control damsite, etc., although some modifications and improvement will be required for each structure.

JICA Team however recommends to set up the plan to use the Nong Luang wet land being located along the B route for the fishery and irrigated agriculture and to provide the regulating pond at the Kok-Ing tunnel outlet to distribute the diverted water from the Kok to the Ing river and irrigation area in the Ing basin.

(3) Overall hydraulic condition

Overall hydraulic condition along the route designed by Thai side is reviewed by JICA Team and found mostly acceptable. The overall hydraulic condition designed along the route is summarized as follows ;

- Diversion water level at the Kok diversion dam is 389 m at the existing Chiang Rai Weir in the B plan and 385 m at the proposed new dam.
- In the water diversion canal, the hydraulic gradient of 1/2,500 to 1/3,000 is adopted for the tunnel and culvert reaches in order to minimize the hydraulic section area of structure and construction cost.
- In the Ing diversion damsite, the high water level of 367 m for the design flood and the retention water level of 363.5 m to divert the water of 175 cu.m/sec. to the Ing and Yot tunnel is adopted. JICA Team recommends to study the possibility to set up the full water level of 365 m to provide the regulating reservoir at the site so as to regulate the peak flood in the Ing basin and diverted water from the Kok river.
- In the Ing-Yot tunnel, the hydraulic gradient of 1 to 2,500 is adopted instead of the gradient of 1 to 4,000 proposed by Thai Side Study in order to reduce the tunnel hydraulic section area and construction cost. Accordingly the water level of the tunnel outlet is placed at 339 m which is sufficient water head to release the tunnel water to the reservoir of the Yao flood control dam with the full water level of 310 m.

5.2 General Topography and Geology of Proposed Diversion Route

(1) Topography

(a) Kok Alluvial Plain

The Kok alluvial plain is lying along the Kok river basin with elevation of 390 to 380 m and with five to seven km. width from the Kok river to mountains or low hilly area. The diversion canal route is planned to cross this alluvial plain. There are many marshy grounds and swamps on the upper stream of the Sakoen river. The typical one is Nong Luang marsh. The diversion canal route B is planned to cross these marshy areas. The elevation of marshy ground is 397 m to 398 m (above sea level on topographical map of scale 1/50,000).

(b) Mountains between Kok and Ing Alluvial plain

The mountains are lying between the Kok and Ing alluvial plain along the Tak river. Mountains consist of the west and east one and the west mostly of lower mountain with elevation of less than 500 meter, while the east with 500 to 650 meter. The width of each mountains is 7 km along the tunnel alignment A. The tunnel alignment B is selected to approach to the most narrow part of this mountains after passing through the above mentioned Nong Luang marshy area.

(c) Ing alluvial plain and Chiang Kham Basin

The alluvial plain of the Ing river has a width of 9 km to 11 km with the elevation of 365 m to 370 m . There are small mountains with the elevation of 500 m near the Ing diversion damsite.

Along the river Lao which is a tributary of the Ing river, a wide Chiang Kham basin is formed with the alluvial plain of elevation of 390 to 400 m and terrace of 400 to 450 m. There are existing a number of low hills and small mountains between Chiang Kham and Ing alluvial plain.

(d) Mountains surrounding Chiang Kham Basin

There are high and steep mountain ranges stretching from north to south along the border of Laos. This mountains are divided into the river basins of Ing and Nan and Ing and Yom. There are also formed with low hills and small mountain of ground height 500 m to 600 m on the northern part and the southern part around the Chiang Kham basin. In accordance with the Thai side study, two alignments of Ing-Yot diversion tunnel A and B are proposed to cross North and East mountain area of Chiang Kham basin and another alternative C alignment to cross southern low hill and mountain area.

(e) Mountain area of Yao river basin

This mountain area is formed with elevation of 500 m to 600 m and there are many tributaries distributed dense cutting mountain. The both tunnel alignments reach to the Yot river which is uppermost stream of Yao river. Yao river is one of the tributaries of Nan river and Yao flood control dam is planned on the upper stream.

(f) Limestone Mountain

Some unique topographies are found in the limestone area, of which mount Doi Pha Deang on the Ing-Yot diversion tunnel alignments A and B and nearby Ban Sakoen village of the Ing - Yot tunnel alignment C are remarkable. Another small and steep limestone mountains are found also on the Kok-Ing tunnel alignment A in the valley of Tak river and neighborhood of outlet of the Ing-Yot tunnel.

(2) Geology

The general geology of the area is shown in database map of scale 1/250,000.

Geological characteristic of each formation is shown in Table 5.1. There are two geological maps with the scale of 1/50,000 and 1/250,000 prepared by DMR. The different giological formation name is used in the above maps and compared in Table 5.1. The geological characteristics are explained below;

Table 5.1 Stratigraphical Classification

Geological Age	Formation	Acronym of 1/50,000	Rock Facies	Acronym of 1/250,000
Holocene	Alluvial deposit	(Qa)	unconsolidated Sand,Silt & Gravel	q
Pleistocene	Terrace deposit	(Qt)	unconsolidated Red Soil Sand Silt Gravel	q
Tertiary	Hai Sieo fm.	(Ths)	Semiconsolidated Clay,Silt with Sand st.	ng
Jurassic	Mae Tam fm.	(Jmt)	Shale ,Sand st.	ms5
	ms-5	(ms5-3)	Tuff,Shale and Sand st.	ms5-3
	Phu Kham fm.	(Jpk)	Quartzitic Sand st. Shale	ms4
	Na Ngan fm.	(Jnn)	Sand st.,Shale,Conglomarate	ms3
Upper Triassic	Mae Phong fm.	(TRmp)	Sand st.,Shale, Tuff & Lapilly tuff	ms1
	Huai Sarian fm.	(TRhs)	fin alternation of Shale and Sand st. associated tuff	t-p
	Pha Chik fm.	(TRpc)	Lime st.	h
Permian	Ban Tham fm.	(Pbt)	Lime st.	p2-1
Permian-Carboniferous	Phu Rang Ka fm.	(CPpr)	alternation of Phyllite,Slate & Sand st.associated Quartzite,Tuff & Calcareous shale	p-h

Igneous Rocks

Tertiary	Basalt	(Bs)	Basalt	B-ng
Upper Triassic	Doi Mon Yao Volcanic fm.	(TRv)	Rhyolitic & Andesitic tuff, Rhyolite & Andesite	Lms-2 L-tp
Triassic-Permian	Andesite-Rhyolite	(An)	Andesite,Rhyolite & Tuff	L-tp
Triassic	Granite	(Gr)	Granite,Granodiorite porphyry	Gt

< Carboniferous - Permian >

1) Phu Ran Ka formation (CPpr) or p-h formation

This formation is the oldest one of Carboniferous - Permian which is located in the diversion canal route area. CPpr characterized with low grade metamorphosed rock such as Phyllite and consist of alternation of Phyllite, slate and sandstone, and is associated with quartzite, tuff and calcareous and siliceous shale. This formation is located on the border area of Thai and Laos making high and steep mountains.

< Triassic >

2) Huai Sarian formation (TRhs) or t-p

Continuously, CPpr has been overlain by Triassic formation by t-p or Huai Sarian formation (TRhs). This formation is characterized by fin alternation of shale and sand stone, and tuff is located nearby outlet of Ing-Yot tunnel. This formation is located also on the area of watershed of Ing and Nan river basin, making high mountain and mountains between Kok and Ing river basin.

3) Doi Mon Yao volcanic formation (TRv) or Ltp and An

Some volcanic formations are located as contemporaneous heterotopic facies of TRhs formation. These are Ltp or Doi Mon Yao volcanic formation (TRv) which consist of Rhyolite and Andesite, Ryoritic and Andesitic tuff and Andesite, Rhyolite (An)

4) Pha Chik formation (TRpc) or h

Some Limestone formations are located making unique land form. One of them is Pha Chik formation (TRpc) or h formation is located on Doi Pha Daeng on Ing-Yot diversion tunnel alignment A, B nearby Ban Pong Tham village.

5) Ban Tham formation (Pbc) or p2-1

Another Limestone formation is Ban Tham formation (Pbc) or p2-1 located nearby Ing-Yot tunnel alignment C on Ban Sakoen village and nearby the outlet of Ing-Yot tunnel on Ban Yot and Ban pha Lak village.

6) Mae Phong formation (TRmp) or ms1

Upper most formation of Triassic sedimentary basin is Mae Phong formation (TRmp) or ms1 which consist of shale and sand stone associated with out and Lapilly tuff. This formation is located making lower hills between Ing alluvial plain and Chiang Kham basin, and margin of the higher mountain on northern part of Chiang Kham basin nearby inlet of Ing-Yot tunnel A and B route.

7) Granite (Gr) or Gt

The Granite is located on the mountains between Kok alluvial plain and Ing alluvial plain nearby the axis of anticline. The Kok-Ing tunnel B route pass through near the granite.

< Jurassic >

As a result of new transgression in Jurassic, a series of formation is formed on the basement rocks which is older than Triassic. These Jurassic sedimentary basins were formed on the Chiang Rai plain ,the Ing plain and the Chiang Kham basin. These series are Na Ngan formation to Mae Tam formation. These formation is located on the Ing-Yot tunnel alignment C.

8) Na Ngan formation (Jnn) or ms3

The Jnn formation consist of sand stone, shale and conglomerate.

9) Phu Kham formation (Jpk) or ms4

The Jkp formation consist of quartzitic sand stone and shale.

10) Mae Tam formation (Jmt) or ms5

The Jmt formation consist of silt stone and sand stone.

11) ms5-3 formation

This formation is only mentioned in 1/250,000 map about on the mountain top on the Ing-Yot tunnel A,B and C route but not mentioned in the geological map of Ï Ban Waen KlongÓ on the Ing-Yot tunnel C route. In addition the ms5-3 formation is mentioned to be located nearby planed the Yao flood control dam in 1/250,000 map. The former has not been confirmed. The latter consist of tuff, sand stone and shale.

12) Lms-2

The Lms-2 formation is mentioned in 1/250,000 map which was formed during same age of the above mentioned Jurassic. On the other hand, there is mentioned as the formation which was formed as a result of Upper Triassic volcanic activity in the 1/50,000 map 釘an Waen Klongî and 鄭mphoe Chunî.

< Tertiary >

13) Hai Sieo formation (Ths) or ng

Tertiary formation is located making gentle slope or flat plain. This formation consist of semiconsolidated clay, silt and sand.

14) Basalt (Bs) or B-ng

The Basalt is located partly on the ridge of mountains between the Kok plain and the Ing plain and which is underlain t-p formation. The rock facies of the Basalt is lava. The Ing-Yot tunnel B alignment is planned to pass through under the Basalt but it is supposed that bottom of basalt will be higher than the top of tunnel.

< Pleistocene >

15) Terrace deposit (Qt) or q

The Terrace is located around the Chiang Rai alluvial plain and the Chiang Kham basin. This consists of unsolicited clay, silt, sand , gravel and Laterite.

< Holocene >

16) Alluvial deposit (Qa) or q

The alluvial deposit consist of loose clay, silt, sand and gravel.

(3) Geological structure

The general structural trend is north-east to south-west in the area. So the repetitive axis of anticline and syncline , and major fault trend also follows this direction.

5.3 Kok Diversion Dam

The Kok diversion dam (weir) will regulate water level of the Kok river for the water diversion at the design discharge of 125 m^3/s.

(1) Alternative Study of Diversion Damsite

The Thai side study made the alternative study on Kok diversion dam and set up the following two alternatives.

(a) Alternative 1: Existing Chiang Rai Weir

Alternative 1: Existing Chiang Rai Weir was selected in connection with the water diversion route of alternativee "B". The Chiang Rai weir was constructed in 1994 by DEA for the purposes of irrigation about 78,000 rais, water supply for the Chiang Rai City and water conservation of the Kok river and Korn river, a tributary, for river transportation and tourism. The weir is located on the Kok river at Ban Pa Yang Mon, Amphoe Muang, Chiang Rai Province and it is about 7 km downstream from the Chiang Rai City. The irrigation facilities are under construction at present and the intake facility will be constructed from December 1996 or early 1997.

(b) Alternative 2: New Kok Diversion Dam

Alternative 2: New Kok Diversion Dam was selected in connection with the water diversion route of alternative. "A". The new diversion dam is planned at downstream of Ban Farm, Muang District, Chiang Rai Province or about 3.3 km downstream of the existing Chiang Rai weir.

Principal features of the Alternatives are shown in Table 5.2. The Thai side study recommended the Alternative 1: existing Chiang Rai weir as the Kok diversion dam with the following reason.

(It is desired to select Chiang Rai weir as the diversion dam site because; it was already constructed, and the control water level is high enough for diverting water to a diversion canal. Besides, this can reduce the construction cost of new diversion structures.)

Table 5.2 Principal Features of Alternative Diversion Dams

Principal Features	Unit	Alternative 1 Existing Chiang Rai Weir	Alternative 2 New Kok Diversion Dam
Hydrology and Reservoir			
- Catchment area	km^2	6,220	9,330
- Average annual Inflow	MCM	3,645	
- Peak discharge in 100 year return period	m^3/s	890	1,105
- Maximum water level in 100 year return period	m MSL	390.50	386.70
- Backwater level at upstream	m MSL	389.00	386.98
- Control water level	m MSL	389.00	385.00
Length of reservoir		at 389.00 m MSL	at 385.00 m MSL
- Kok river	km	9.1	
- Kom river	km	3.1	
- Surface area of reservoir	km^2	2.77	
- Gross storage	MCM	2.95	
Dam facilities			
- Type of dam		Concrete dam of Ogee type	Concrete dam of Ogee type
- Type of gate		Radial gate	Radial gate
- Height of steel gate pane	m	4.0	3.80
- Width of steel gate pane	m	8.0	10.00
- Numbers of steel gate	nos.	11	10
- Cut-off channel bed elevation at upstream and downstream	m MSL	384.75	381.50
- Gate sill elevation	m MSL	385.75	381.50
- Pier top elevation	m MSL	392.00	389.00
Dike			
- Crest level	m MSL	390.50	
- Height	m	0 ~ 3	
- Length	km	10.7	

Source : Thai side study

The JICA Study Team reviewed the Thai side study and prepared the additional comments as follows:

	Alternative 1 Existing Chiang Rai Weir	Alternative 2 New Kok Diversion Dam
Advantage		
1)	The utilization of the existing weir as the Kok diversion dam does not make additional environmental problem.	The operation would be more simple.
2)	The utilization of the existing weir would save the Project cost.	Water resource of the Kok-Lao river is available.
Disadvantage		
1)	It shall monitor the flood condition in the Chiang Rai city more carefully.	It might make a problem crossing the new irrigation canals.
2)	Joint operation by the both DEDP (mainly in dry season) and RID (wet season) is required.	It might make a problem of land acquisition in the value added paddy field by the new irrigation system.
3)		It might increase the dimension of water diversion facilities due to the lower head between the dam and the Ing diversion dam.

If the above items 1), 2) and 3) in disadvantage of Alternative 2; New Kok Diversion Dam are not serious problem or the cost increase is not so much compared with the total project cost, the new diversion dam might be considerable for the safety of the Chiang Rai city.

The site selection of the Kok diversion dam might not be the major issue to select the optimum route alignment from the technical, environmental and economical point of view. The selection of optimum route will depend on the diversion canal and tunnel alignment since the cost and environmental condition of them will affect to the Project much more. It is recommended to decide the suitable location of the Kok diversion dam based on the optimum route between the Kok river basin and the Ing river basin.

(2) Proposed Intake Water Level at Diversion Site

The Thai side study recommended the control water level at diversion structures in order to define the optimum dimension of head regulator of diversion canal which can operate without

any effect on the downstream water requirement. The control water level at diversion structures was recommended as follows:

Control Water Level = 389.00 m. MSL for Alternative 1: Existing Chiang Rai Weir
Control Water Level = 385.00 m. MSL for Alternative 2: New Kok Diversion Dam

The crest length of intake facility will be about 125 m assuming that approach velocity is 0.5 m/s and overflow depth is 2 m in case of the design water diversion discharge at 125 m^3/s.

Design intake water level of the Kok diversion dam shall be determined taking into consideration the maintenance flow to the downstream of Kok river, stable water diversion and safety of the Chiang Rai city against floods. Judging from the rating curve and water level fluctuation, the design discharge of 125 m^3/s could be diverted within some drawdown. It is recommended to study the possibility of the intake water level as follows:

Alternative 1: Existing Chiang Rai Weir	Normal High WL = 389.00 m MSL
	Low WL = 388.00 m MSL
Alternative 2: New Kok Diversion Dam	Normal High WL = 385.00 m MSL
	Low WL = 384.50 m MSL

(3) Particular Attention for Water Operation and Flood Releasing

The Thai side study made the preliminary hydrological analysis. Probable flood at the alternative diversion site on the Kok river was estimated as follows:

Probable Flood and Water Level at Kok Diversion Dam

Return Periods (yrs)	Alternative 1 Existing Chiang Rai Weir		Alternative 2 New Kok Diversion Dam	
	Flow (m^3/s)	WL (m MSL)	Flow (m^3/s)	WL (m MSL)
2	486.85	389.25	638.86	385.55
5	595.50	389.52	761.54	385.90
10	673.05	389.92	852.15	386.10
20	741.74	390.10	932.11	386.25
50	828.41	390.35	1,033.25	386.50
100	890.20	390.50	1,105.26	386.70
500	1,043.82	390.75	1,286.32	387.05
1,000	1,109.86	390.85	1,364.29	387.15
10,000	1,330.30	391.25	1,625.09	387.65

Source : Thai side study

As the hydrological analysis are the basis for the design of diversion structures, it is recommended to study the hydrological analysis more carefully.

Alternative 1: Existing Chiang Rai Weir (catchment area = 6,220 km^2)

Peak discharge in 100 year return period = 890 m^3/s (q = 0.14 $m^3/s/km^2$)

Maximum WL in 100 year return period = 390.5 m MSL

Alternative 2: New Kok Diversion Dam (catchment area = 9,330 km^2)

Flood discharge in 100 year return period = 1,100 m^3/s (q = 0.12 $m^3/s/km^2$)

Maximum WL in 100 year return period = 386.7 m MSL

According to the map on a scale of 1/10,000, the elevation of low land area in the Chiang Rai city is about 390.8 m MSL. The Chiang Rai city may be safe against flood from the Kok river. However, it is recommended to establish an operation rule for reliable regulation of the diversion water and for the safety of the Chiang Rai city against flood due to the mistake of gate operation.

(4) Additional Study Items to be required for F/S

i) Flood analysis and flood routing shall be made to confirm the safety of the operation rule.

ii) Operating rule for the Kok diversion dam shall be studied in collaboration with flood forecasting system, telemetering system, etc. for the safety of the Chiang Rai city and for the reliable regulation of the diversion water.

iii) Influence of back water from the diversion dam shall be studied.

iv) Necessity of the emergency spillway besides the Kok dam shall be studied to avoid flood by mistake of gate operation and the design shall be made if necessary.

v) Basin and river management system shall be studied as well as monitoring system.

vi) Possibility of water diversion from the Kok-Lao river shall be studied.

vii) Following study shall be made for design.

1) Review of design data, design criteria and design standards
2) Determination of design loads and safety factors
3) Stability analysis of dam and bank
4) Foundation treatment in accordance with geologic condition
5) Design of mechanical and electrical equipment
6) Quantity survey and cost estimate

viii) Topographic maps are required for the facility design of F/S. Survey area shall be from 5 km upstream of the Chiang Rai weir to 3.5 km downstream and 500 m width of both side from the river.(If Kok diversion dam can be fixed at the existing weir, survey area shall be 5 km upstream from the Chiang Rai weir to 1 km downstream), including 1/1,000 with 1 m (to 5 m) contour for the area of intake and emergency spillway.

5.4 Kok-Ing Diversion Canal

(1) Proposed Canal Route

The proposed canal route by Thai Side Study is reviewed by JICA Team dividing into two sections, one is planned with the canal length of about 30 km for the section from the Kok diversion damsite to outlet of the Kok-Ing tunnel, while the other is for the above tunnel outlet to the Ing diversion damsite with the length of about 24 km. The former route is very complicated one consisting of the open canal, syphon, culvert, tunnel and pumping station but the latter is simple one running through the Ing basin by the open canal only. The proposed canal route is as shown in the Database Map.

As mentioned in 5.1 Proposed Water Diversion Route, five alternative routes of A, A-R, B, B-J and B-P are studied by JICA Team at the canal section between the Kok river and outlet of Kok-Ing tunnel.

- A and A-R route start the Kok diversion dam newly constructed in the river, cross the flat paddy field lying on the right bank of the Kok river with elevation of 380 to 385 m, pass through the mountain area by tunnel and reach the tunnel outlet located at the north of Ban San Khong in the basin.
- A-R route is planned with the open canal approching the tunnel inlet proposed by B-J plan and with tunnel and culvert proposed by B-J plan passing through the mountains between the Kok and Ing basin.
- The other three routes start the existing Chiang Rai Weir, run through the paddy field near the Chiang Rai urban district by the open canal and culvert, cross the mountain by tunnel and reach the outlet of Kok-Ing tunnel which is the same as proposed in A route. However B route crosses the high land and mountain by the culvert with long distance of 13.5 km and a short tunnel of 5.5 km, B-J route by two tunnels with long distance and B-P route by pumping up and tunnel with short distance.
- The regulating pond will be provided at the outlet of Kok-Ing tunnel near Ban San Khong in order to regulate the fluctuated discharge diverted from the Kok river, supply the irrigation water to the downstream beneficial area in the Ing basin, provide the recreation place for local inhabitant, use for fishery pond, etc. The regulating pond is planned with the dike of 2 km, the depth of 2 to 3 m and the pond area of about 1.5 sq.km.
- After passing through the regulating pond, five alternative canals take the same route, cross the paddy field in the Ing basin and reach the Ing diversion damsite.

The outline of five routes is summarized in the following table ;

Item	Alternative Route				
	A	A-R	B	B-J	B-P
1. Kok Diversion Dam	New	New	Existing	Existing	Existing
2. Open Canal with Concrete Lining (m)	13,746	15,112	14,063	18,589	23,507
3. Culvert (m)	1,050	3,011	17,994	1,861	3,856
4. Tunnel No.1 (m)	5,800	3,114	5,506	3,114	4,200
Tunnel No.2 (m)	7,240	7,775	-	7,775	-
S.Total (m)	13,040	10,889	5,506	10,889	4,200
5. Open Canal in Ing Basin (m)	21,750	21,750	21,750	21,750	21,750
Total	49,586	50,762	59,313	53,089	53,313

Advantage and disadvantage for five alternatives are as follows ;

A route ; Tunnel with the long distance and passing through the poor geological condition is required but social environmental impact is small.

A-R route ; The culvert length is short but tunnel length is long. Environmental impact is relatively small.

B route ; Culvert with deep excavation and long distance is required and large social environmental impact takes place. Tunnel length is short.

B-J route ; Tunnel with the long distance but less social environmental impact.

B-P route ; No culvert, short distance tunnel and less social environmental impact but high pump operation cost.

Outline for each canal route and additional study items to be required for F/S are described as follows ;

(2) A Route Canal

(a) Outline

- The open canal between the Kok diversion dam and inlet of Kok-Ing tunnel shall pass through the paddy field where a number of irrigation canal systems are provided by DEA and the existing people irrigation area so that many crossing structures such as syphon, cross drain, bridge, etc. are required for construction of the open canal in the project.
- The open canal route shall cross small villages, paddy field, provincial roads and several rivers such as the Mae Hong river.
- The open canal is constructed mostly with excavation with the depth of 4 m, accordingly, the huge spoil bank of about 2 million cum. will be required.
- No.1 and No.2 tunnels with the length of 5,800 m and 7,240 m respectively are required to cross the mountain between the Kok and Ing basin, where is formed with poor geological conditions such as shallow overburden of 30 to 50 m above tunnel, weathered shale, tuff and sand stone with compression strength of less than 100 kg/cm^2, 20 fault zones, etc. Accordingly tunnel will be designed mostly by type D and E to be supported by strong steel support of H-150 ~ H-200 and to be lined with the reinforced concrete of 50 to 60 cm thickness.

  Tunnel type and its distance to be applied for the A route is estimated as follows in accordance with reconnaissance geological survey at the site and the preliminary study.

Classification of Tunnel Type

Tunnel Type	No.1 Tunnel		No.2 Tunnel		Total	
	Length (m)	Rate (%)	Length (m)	Rate (%)	Length (m)	Rate (%)
C1	25	1	716	10	741	6
C2	354	6	1,790	25	2,144	16
D1	732	12	1,390	19	2,122	16
D2	1,432	25	1,180	16	2,612	20
E1	1,244	21	660	9	1,904	15
E2	2,013	35	1,500	21	3,513	27
Ewr	(805)	-	(600)	-	-	-
Total	5,800	100	7,240	100	13,040	100

(b) Additional Study Required for F/S

The following additional study for the Thai side study is made by JICA Team but will be required in F/S stage to confirm the technical viability and estimate the accurate construction cost.

- Design of the open canal taking into account the balance of excavation and fill volume in order to minimize the spoil bank volume.
- Concrete lining in the open canal is designed with thickness of 10 cm which will be thin for the canal with large discharge of 125 cum./sec. The lining thickness of 15 to 20 cm will be applied for canal lining.
- Hydraulic gradient of open canal is designed with steep slope of 1 to 2,400 , accordingly the large excavation is required at the end of canal because the water head of about 4 m is lost at the canal of 9 km as a result the canal with deep excavation of more than 4 m is required at the end of canal section.

  It is desirable to apply the gentle hydraulic gradient of more than 1 to 5,000 for the open canal running the flat topographical area.
- Tunnel type shall be studied carefully in accordance with the geological investigation result.

  Tunnel passing through A route consists of shallow and weathered overburden above tunnel, so that the particular attention shall be paid for water leakage by rain and ground water through overburden into the tunnel.
- The canal in the A route can access the Nong Luang Wet Land which is lying on the east high land of Chiang Rai city and has been used for fishery pond. However the wet land has been dried up always in dry season due to less inflow from the surrounding drainage area. Chiang Rai provincial office requests strongly the water resources development of the wet land by supplying the diverted water from the Kok river.

  It is necessary accordingly to study the water supply method to the Nong Luang wet land from the other water resources in the A route plan.

  The water resources development plan to pump up the water which is diverted from the Lao river and flowing down in the Nam Mae Sokoen may be studied in the A route plan.

(3) A-R Route Canal

(a) Outline

- The open canal passes through the same paddy field as the proposed one in the A route canal but approches to the tunnel inlet proposed by B-J route plan in order to avoide the AT1 tunnel route consisting of the poor geological condition and the long distance of 5.8 km. Accordingly the open canal length of 3.3 km will increase as compared with the canal length in A route plan.
- As No.1 tunnel is planned at the same route proposed by B-J route plan, the tunnel length of 2.2 km will reduce compared with the length in A route plan.

(b) Additional Study Required for F/S

Additional study as mentioned in A route plan and B-J route plan will be required for A-R route plan.

(4) B Route Canal

(a) Outline

- The open canal started at the intake of diversion damsite with the water level of 389 m runs toward the Nong Luang wet land in the high land with elevation of 390 to 400 m.

  This open canal also is designed with the steep hydraulic gradient of 1 to 2,400 in Thai side study. The hydraulic head of 5.5 m is lost at the end of canal, as a result the deep excavation with depth of more than 10 m is required at the end of canal located near the wet land and its excavation volume reaches 3.5 million cum., which will give large social environmental impact in the area.
- The canal is designed with the culvert structure after passing the wet land. In accordance with Thai side study, the culvert is designed with the length of 13 km and the deep depth of 25 to 30 m, because the culvert route is placed at the high land with the elevation of 395 to 400 m between the Nong Luang and inlet of Kok-Ing tunnel. Accordingly, the culvert construction for the length of 13 km is consisting of the cross section with the top width of 100 m and bottom width of 30 m, depth of 25 to 30 m and the huge excavation volume of 18 million cum. which will cause the large social environmental problem such as the compensation for the area divided by the culvert construction with 100 m width, preparation of spoil bank to treat the

huge excavation volume, provision of drainage system to drain the rain and seepage water during culvert construction works, etc.

- Although the Kok-Ing tunnel is planned with the length of 4.0 km by Thai Side Study, the length of 5.5 km will be required by the careful study by JICA Team. Tunnel passes through the mountain with a little favourable geological condition for construction such as the overburden of more than 200 m above tunnel, six small fault zones, etc. except the inlet site with the length of 1.5 km which is originally designed with the culvert and consists of poor geological condition.

Tunnel type and its distance to be applied for the B route is estimated as follows.

Tunnel Type	Tunnel Length (m)	Rate (%)
C1	480	9
C2	790	14
D1	620	11
D2	660	12
E1	750	14
E2	2,210	50
Ewr	(880)	-
Total	**5,510**	**100**

(b) Additional Study Required for F/S

The following alternative and additional study will be required for the B canal route in F/S.

- The open canal will be designed with the gentle hydraulic gradient of more than 1 to 5,000 to reduce the excavation volume in the high land and with the concrete lining thickness of 15 to 20 cm.
- It is necessary to study the possibility to use the existing Nam Mae Sokoen river which starts at the weir at the Lao river and reaches to the Nong Luang wet land, for the water diversion canal by upgrading the above river.
- It is necessary for the Nong Luang wet land to study the possibility to construct the polder dike, store the wet season water by pumping up the diverted water from the Kok river and use it for irrigation in the beneficial area of 1,500 ha along the Mae Tak and the Nam Hong Luk rivers and at the area surrounding the Nong Luang wet land.

The reservoir will be planned with the area of 10 sq.km, effective storage depth of 3 m at the proposed water level of 395 m and the active storage capacity of 20 to 25 million cum..

Fish culture at the Nong Luang will be accelerated.

- The culvert design will be reviewed in order to minimize the deep excavation and mitigate the social environmental impact, taking into account the leveling up of the hydraulic gradient, adoption of horse shoe type culvert instead of the box culvert, etc. The geological investigation works along the culvert route are required in order to confirm the earth or rock foundation. It is necessary also to carry out the environmental impact assessment for the area along the culvert route.
- The spoil bank to treat the huge excavation material is to be selected and studied.
- The geological investigation works are required for the tunnel route to design the tunnel type to be applied by the geological condition.

(5) B-J Route Canal

(a) Outline

B-J route is proposed by JICA to avoid the culvert route with deep excavation.

- The open canal route starts the same Kok intake proposed in the B route and passes through the paddy field with elevation of 385 to 390 m which does not require the culvert and reaches No.1 tunnel inlet. The gentle hydraulic gradient of more than 1 to 5,000 will be applied for the canal design to minimize the excavation volume along the canal.
- No.1 and No.2 tunnels with the length of 3,110 m and 7,780 m respectively are provided to cross the mountain with poor geological conditions between the Kok and Ing basin.
- Tunnel type and its length to be applied for B-J route is estimated as follows ;

Tunnel Type	No.1 Tunnel		No.2 Tunnel		Total	
	Length (m)	Rate (%)	Length (m)	Rate (%)	Length (m)	Rate (%)
C1	130	4	760	10	890	8
C2	340	1	1,890	24	2,230	20
D1	320	10	1,400	18	1,720	16
D2	420	13	1,190	16	1,610	15
E1	800	26	660	9	1,460	13
E2	1,100	35	1,880	23	2,980	28
Ewr	(440)	ñ	(750)	ñ	ñ	ñ
Total	3,110	100	7,780	100	10,890	100

(b) Additional Study Required in F/S

Additional study as mentioned in the A and B routes will be required for the B-J route. The particular attention for No.1 tunnel study is paid, because the No.1 tunnel route will be set up at the area with very complicated topographical and geological conditions.

(6) B-P Route

(a) Outline

The B-P canal route is almost same as the B canal route but its water level and canal bottom are placed at the higher elevation than that of the B route by pumping of the diverted water of 125 cum./sec in order to avoide the culvert construction section with the huge excation volume. The outline of pumping station to be required for the B-P route is as follows ;

-	Pumping capacity	125 cum./sec, 12 m head
-	No of pumps	11 units with one stand-by
-	Pump Bore	2,300 mm
-	Pump Capacity/unit	12.5 cum./sec (750 cum./min)
-	Motor Output	2,000 kW/unit
-	Pumping Water/year	2,200 MCM
-	Operation Hours	3,490 hr/year/unit
-	Electrical charge for operation ;	138 million Baht/year

In accordance with pumping plan in the B-P route, the huge excavation volume in the B route could be reduced and the construction cost for the B route is decreased as compared with the other plan. However, the high pumping operation cost is required.

(b) Additional Study Required for F/S

It is necessary to carry out the careful study for construction and operation cost of pumping station and minimized construction cost for civil works.

(7) Diversion Canal from Kok-Ing Tunnel Outlet to Ing Diversion Damsite.

(a) Outline

The water released from the Kok-Ing tunnel is guided by the culvert and open canal connecting with the tunnel outlet and then reaches to the regulation pond. The pond is planned at the tunnel outlet to regulate the water released from the tunnel. The outline of regulation pond is as follows ;

-	Reservoir Area	1.5	Sq.km.
-	Effective Reservoir Depth	3.0	m
-	Reservoir Capacity	4	million cum.
-	Full Water Level	374	±
-	Low Water Level	371	±
-	Polder Dike Length	2.0	km

The diversion canal started from the above pond is designed by the open canal with the length of 21.8 km which passes through the paddy field and reaches to the Ing diversion damsite.

The canal route selected by Thai Side Study is acceptable except the route passing through the hilly area at Ban Huai Kang Rat near the proposed reservoir. The above route will require the large excavation and give the large social environmental impact to village.

The open canal runs through in the Ing basin crossing many tributaries flowing down from the western mountains. Accordingly, many crossing structures such as pipe and box culvert are required along the diversion canal.

(b) Additional Study Required for F/S

- Land acquisition for regulating pond is to be surveyed
- Outlet facility of regulating pond for the water diversion canal to Ing diversion dam and irrigation canal to the downstream beneficial area is to be studied.
- The design flood capacity in the tributaries flowing down from the western mountain and empties into the Ing river is to be analized in order to design the allowable flood discharge of the crossing structures for the diversion canal.
- Inventory survey is required for the existing rivers and canals which cross the proposed diversion canal route. Inventry survey for rivers and canals include the

drainage area, past flood condition such as water level and discharge, profile of 500 m and cross section with interval of 50 m, the existing structures such as weir, intake, bridge, pond, etc., the flow condition in wet and dry season.

- The regulator and turn out points for the irrigation canal started from the diversion canal to the beneficial area in the Ing basin are to be selected at the route of the diversion canal.
- Canal will be designed with the fill type and require the huge fill materials, so that the borrow area shall be surveyed at the Ing basin.

(8) Topographical and Geological Condition

(a) Kok-Ing Tunnel Alignment A

A-1 Tunnel

* The tunnel passes through low hills where ground height is maximum 510 m and generally about 420 m to 440m, so that tunnel overburden is very shallow (about 35 m to 60m). Especially these hill areas are eroded by many small and shallow valleys of ground height 405 m to 410 m formed with the weak geology along fault zone. Under this valleys, tunnel overburden is only 20 m to 30 m (the geological profile is shown in the Database map).

* From inlet to 6.0 km

The tunnel passes through the t-p formation of Permian-Triassic which consists of Shale, Sandstone and Tuff. After that, from 2.0 km to 2.6 km and from 3.2 km to 5.4 km passes through the Lms-2 formation of Upper Triassic which consists of Rhyolite and Rhyolitic Tuff. After that, from 5.2 km to 6.0 km passes through p3 formation which consists of Shale, Sandstone and Tuff.

* 6.0 km to outlet

After 6.0 Km point, the tunnel passes through Limestone mountain Pha Kiu Klai (EL 520 m) consisting of p2 formation of Permian where limestone cave can be found.

* Generally on such lower hills, t-p, p3 and Lms-2 formations are deeply and highly weathered, so grade of rock mass is classified E1 to E2 type.

* About 11 faults are assumed to exist by topographic analysis, and there is a trend of extending NE to SW.

* It is assumed that during tunnel excavation ground water discharge will be increased when crossing these faults situated under small river courses and Limestone caves.

* Therefore, this alignment is not recommendable from geological condition view point.

Alignment A-2

The tunnel route mainly passes through under mountain of ground height 450 m to 500 m, crossing three rows of mountains and two small valleys. Maximum height of these mountains is about 600 m (the geological profile is shown in the Database map).

* From inlet to 2 km

Near inlet, passes through the **L-tp** formation which consist of Rhyolite and Rhyolitic tuff. After that pass through steep and high mountain of ground height maximum 620 m underlain by **Granite**.

* 2.0 to 7.1 km

Passes through **p3** formation which consists of Shale, Sandstone and Tuff. After that the geology change to **t-p** formation which is almost similar to **p3** formation. Between 2.4 km to 2.6 km, passes through under river valley of ground height 430 m formed along fault.

* 7.1 km to outlet

Last 900 m passes through under very gentle slope of ground height 380 m to 400 m underlain by Talus and highly weathered rocks.

* Nine (9) faults are supposed to exist by topographic feature along the small valleys which have a trend extending NE to SW. Along these fault, rocks are deeply and highly weathered, so rock mass is classified E to D type.

*: It is supposed that during tunnel excavation ground water discharge will be increased when crossing these faults situated under small river courses.

* Rock mass is classified under **Granite** mountain **D1** to **C1** type and **p3** and **t-p** formation is classified under higher mountain **D1** to **C1** type, and under lower mountain **D2** to **D1** type without fault zone. Under shallow overburden section underlain by Tulas and highly weathered rock near inlet and outlet is classified **E2** type.

(b) Kok-Ing Tunnel Alignment BJ

Alignment BJ-1

The tunnel route passes through under Doi Ung mountains of maximum ground height of maximum 580 m, after that from 2.1 km passes through lower hill of ground height less than 450 m (the geological profile is shown in the Database map).

* From inlet to 2.1 km

From inlet to 2.0 km is underlain by Lms-2 formation which consists of Rhyolite and tuff. Near 1.3 km, crosses under small stream valley of ground height 440 m formed along fault.

* 2.1 km to outlet

Passes through under small and low hill of ground height 395 m to 450 m. Last 0.5 km near outlet is underlain by t-p formation.

* Six (6) fault are supposed to exist along small river valley.

Alignment BJ-2

This alignment is planned to pass through about 2.5 km south of alignment A. So topographical and geological condition are similar to that of alignment A-2.

From inlet lower hill which is underlain by Shale and Sandstone of t-p formation, and then continue Lhyolitic tuff of L-tp formation. From 1.5 km to 3.4 km passes through Granite which make Doi Om mountain with maximum height on the tunnel route of 560 m. After that, passes through small valley of Mon Hac river (ground height is 420 m) and passes through mountains which underlain by Shale, Sandstone and Tuff of p3 and t-p formation.

(c) Kok-Ing Tunnel Alignment B

The tunnel route is planned to pass through under the mountains with the ground height of maximum 640m and generally 480m to 540m. The tunnel route is designed along the mountain ridge which extends north-west to south-east (the geological profile is shown in the Database map).

* From inlet to 1 km

The tunnel passes through under very gentle slope of ground height 400 m to 420 m underlain by highly weathered Rhyolite and Rhyolitic tuff of L-tp formation and Talus.

* 1 km to 4.7 km

Passes through under narrow ridge of ground height 460 m to 640 m which is underlain by Basalt and t-p formation consisting of Shale and Tuff, and L-tp formation.

* The Basalt is located on mountain ridge at 1.1 km to 3.9 km. The Basalt lava is exposed at inlet side at the elevation higher than 460m and outlet side higher than 560m. So, it is supposed that the basement of Basalt will be higher than tunnel crown, and geology of near tunnel elevation may be alternation of Shale and Tuff of t-p formation.

- About five (5) faults are supposed to exist crossing the tunnel route.
-

Rock mass is classified E2 type on shallow overburden section of near inlet and outlet which is underlain by Talus and highly weathered rock and major section which is covered by enough overburden classified C1 and C2 type. Fault zone is classified D and E type.

* Groundwater from cracky Basalt lava is supposed to supply through cracky rock of fault zone. but the volume is not so much because the mountain ridge is narrow and is separated to another ridge by deep valley.

(d) Additional geological investigation required for F/S

* To make clear geological condition of every alternatives for alignment A-1, A-2, B and BJ-1, such as depth of weathered zone, rock facies of each geological unit, geological investigation is required including seismic prospecting, core drilling accompanied by on site test such as permeability test and geological logging and rock test.

* Especially, investigation is required to make clear rock condition of fault zone and shallow overburden section as found in alignment A-1.

* To make clear geology of inlet and outlet such as depth of Talus and highly weathered rock.

* To make clear bottom the Basalt lava on alignment B, TDEM (Time Domain Electro-Magnetic method) is required.

5.5 Ing Diversion Dam

The Ing diversion dam will regulate water level of the Ing river for the water diversion to the Nan river basin at the design discharge of 175 m^3/s.

(1) Proposed Damsite

The Thai side study set up the following two damsites in accordance with the alternative diversion route alignment.

(a) Lower Site

The lower site plan was prepared for the alternative Ing-Yot diversion alignment ﾉA and ﾉB. The lower site of Ing diversion weir is located on the Ing river at the foot of Mon Kong Khao hill about 2.8 km upstream of the Thoeng bridge. This site is selected to avoid the rise of flood water level at Thoeng District due to the weir construction.

The design of diversion dam with radial gates is not applicable since the pin bearing elevation 364.00 m MSL will be lower than 367.6 m MSL which is the maximum water level in 100 year probable flood. A rubber weir on a reinforced concrete floor was recommended by the Thai side study.

(b) Upper Site

The upper site plan was prepared for the alternative Ing-Yot diversion alignment ﾉC. The upper weir site is located on the Ing river about 3.5 km southwest of Ban Huai Luang. Bank elevation at the weir site is at 366.00 m MSL while low water control level upstream of the weir is at 365.50 m MSL. This weir will also be of rubber type. Since hydrological data at the weir site is still unavailable at present, the weir size will be the same as the lower site.

The alternative Ing-Yot diversion alignment ﾉC was not recommended by the both Thai side and JICA Study Team, since the Ing-Yot tunnel work along this route might be more dangerous and costly due to the poor geological condition. The lower site is recommended as the Ing diversion damsite from the technical, environmental and economical point of view.

(2) Regulating Capacity and Design Water Level

The lower site is located on the flood plain and its catchment area is 2,210 km^2. The upstream of the lower site spreads as swamp and paddy field. The diversion water of 125 m^3/s from the Kok river will flow into the Ing river and increase water level at the damsite above 364 m MSL.

It is predicted that cultivation lands on this elevation will be inundated continuously in wet season especially from August to October due to the diversion water of 125 m^3/s from the Kok river. In addition, it is required to stop and store the diversion water volume from the Kok-Ing diversion canal (about 3 MCM) in accordance with flood condition in the Nan basin.

The maximum discharge of 784 m^3/s ($q = 0.226$ $m^3/s/km^2$), which was equivalent to 100 year probable flood, was recorded at the Thoeng bridge in September 1980 for the recent 20 years. The recent flood in 1995 marked at 367.45 m MSL, 700 m^3/s, which was equivalent to 50 year probable flood. Probable flood at the Thoeng bridge on the Ing river was estimated as follows:

Probable Flood and Water Level at Thoeng Bridge

Return Periods (yrs)	Flow (m^3/s)	WL (m MSL)
2	293.65	365.60
5	413.07	366.60
10	509.50	367.10
20	579.73	367.25
50	700.47	367.50
100	779.89	367.60
500	963.13	367.80
1,000	1,046.46	368.00
10,000	1,311.69	368.20

Source : Thai side study

The extraordinary floods exceeding 50 year and 100 year probable flood occurred for 20 years. The preliminary hydrological analysis by Thai side is questionable. Since the results of hydrological analysis are used as basic data for the design of diversion facilities, it is recommended to study the hydrological analysis more carefully.

The JICA Study Team recommend a flood retention/regulating pond with the Ing diversion dam, taking into consideration that the site area is frequently flooded and that the

diversion water of 125 m^3/s will increase water level of the Ing river in wet season. The flood retention/regulating pond has the following functions.

- to store the diversion water volume from the Kok river,
- to regulate the water level fluctuation for the stable water diversion to the Nan river basin and
- to protect paddy field from the ordinary floods.

The regulating pond will be provided by the embankment of polder dike along the boundary of swamp. High water level of the regulating pond will be set at 365 m MSL and low water level at 363.5 m MSL. The storage volume is estimated at 6 MCM at HWL 365 m.

It is also recommended to construct a flood diversion canal from the Lao river into the flood retention/regulating pond for the following purposes.

- to protect downstream of the Lao river from floods and
- to utilize flood excess water for the water diversion to the Nan river basin.

(3) Layout of Diversion Dam Structure

The Ing diversion dam is recommended as combined type dam which is composed of reinforced concrete dam with regulating gates and rubber dam. The regulating gates are recommended for the regulation of water level. The intake high water level will be set at 365 m MSL and low water level at 363.5 m MSL. Principal features of the conceptual plan of the weir is shown in Table 5.3.

Table 5.3 Principal Features of Ing Diversion Dam

Principal Features	Unit	Recommended by Thai Side Study	Recommended by JICA Study Team
Regulating Pond		none	
- High water level	m MSL		365
- Low water level	m MSL		363.5
- Reservoir surface area	km^2		5
- Gross storage	MCM		6
Dam facilities			
- Type of dam		Rubber dam	Reinforced concrete dam and rubber dam
- Type of gate		none	Radial gate
- Height of gate (weir)	m		7
- Width of gate (crest length)	m		10
- Numbers of gate	nos.		1
- River bed elevation at upstream and downstream	m MSL	approximately 358	approximately 359
- Weir sill elevation	m MSL	359.00	359.0
- Weir crest elevation	m MSL	363.50	363.5 (concrete dam) 365.0 (rubber dam)
- Control water level	m MSL	363.50	HWL 365.0 LWL 363.5
- Maximum water level before the rubber weir deflated	m MSL	364.40	
Intake/Dike			
- Peak discharge in 100 year return period	m^3/s	780	780
- Maximum water level in 100 year return period	m MSL	367.6	367.6
- Crest level	m MSL	369.13	368.6
- Original bank elevation	m MSL	364	364
- Length	km		7

(4) Additional Study Items to be required for F/S

i) Hydrological analysis on the Ing and Lao basins such as low flow analysis, flood analysis and sedimentation.

ii) Water diversion from the Ing-Lao river shall be studied considering water availability, potential amount of diversion, available space of the Sirikit reservoir, water demand as well as economic point of view.

iii) Following study shall be made for design.

1) Review of design data, design criteria and design standards
2) Preliminary design of the diversion dam, intake, polder dike, Ing-Lao flood diversion canal and drainage system for the inland water. It shall be designed taking into consideration the regulation of water level and the safety of the lower Ing-Lao, Yao and Nan basins against floods.
3) Determination of design loads and safety factors
4) Stability analysis of dam and dike
5) Foundation treatment in accordance with geological condition
6) Operating rule in collaboration with basin and river management system, monitoring system, etc.
7) Quantity survey and cost estimate

iv) Design of mechanical and electrical equipment and operating rule for gates.

v) Back water influence from the Mekong river and from the regulating pond shall be checked.

vi) Survey on land acquisition and compensation for the construction of facilities.

vii) Following topographic maps are required for the facility design of F/S.

1) 1/1,000 with 1 m (to 5 m) contour for the area of diversion dam and flood protection dike (boundary of swamp area), and 200 m width of both side from the dam and dike axis
2) Dam axis, Ing and Lao river profiles with horizontal scale of 1/1,000 and vertical scale of 1/100
3) Dam axis cross section with horizontal scale of 1/200, vertical scale of 1/100 and 200 m interval
4) Ing and Lao river cross section with horizontal scale of 1/200, vertical scale of 1/100 and 200 m interval up to the river bed El. 367 m

5.6 Lao Diversion Canal to Ing-Yot Tunnel

(1) Outline of Lao Diversion Canal

(a) Proposed Route

Lao diversion canal starts off at the Ing diversion damsite and reaches to the inlet of the Ing-Yot tunnel. In accordance with the Thai Side Study, the diversion canal route is selected along the Lao river which empties into the Ing river at the Ing diversion damsite and consists of the open canal, tunnel, syphon and culvert. The canal route proposed by Thai Side Study is modified slightly by JICA study taking into account the difficulty for culvert construction of 1.0 km proposed with the deep excavation of more than 40 m depth and social environmental impact for the route running through the areas near villages. The outline of the diversion canal is summarized as follows ;

Items	Thai Side Study	JICA Revised
Open Canal Length (m)	2,430	1,130
Culvert A (Depth 40 m)	1,000	-
Culvert B (Depth 20 m)	9,670	10,310
Tunnel (m)	-	1,000
River Improvement (m)	-	1,300

Remarks : Total length of Lao canal between Thai Side Study and JICA Revised is different due to the route difference.

- Open canal is placed at the right bank of Ing diversion damsite to convey the diversion water of 175 cum./sec to the tunnel inlet.
- The route of 1.0 km from the end of open canal to the Lao river is originally planned with the culvert with deep excavation of the depth of more than 40 m which is difficult for construction and changed to tunnel by JICA study.
- The route from the tunnel outlet to the inlet of Ing-Yot tunnel crosses the Lao river and passes through the high land with the elevation of 380 m, therefore the route is designed with the culvert with deep excavation of about 20 m.

It is rather difficult to set up the proper diversion canal route between the Ing diversion dam and the inlet of the Ing-Yot tunnel, because the profile and cross section survey along the Lao river is not done yet, though the same will be carried out by RID in the dry season in 1997.

(2) Additional Study Required for F/S

- Profile with the length of 15 km along the Lao river and its cross section survey with interval of 100 m are required.
- The definitive route is to be studied based on the above topographical map and taking into consideration the flood water level at the Lao river.
- The Lao runoff in wet season including the flood is to be introduced to the Ing diversion damsite, so that the river training of the Lao is to be studied in parallel with the diversion canal route.
- Since the proposed culvert route running through the high land lying on the right bank of the Lao is covered with rock formation, the geological investigation works shall be carried out along the culvert route.
- As the culvert works require a huge excavation, the spoil bank area is to be surveyed.

5.7 Ing River Training

(1) Present River Condition

(a) River course and river bank

In the Upper Ing River, a number of small tributaries in the mountainous area flow into the Ing River that drains into the Phayao Lake. The outflows from the lake are regulated by a weir that is serving for flood protection downstream.

In the Nam Phung River, a number of waterways are scattered in the alluvial plain. The main stream, Nam Phung River collects water from the waterways and drains into the Middle Ing River near Ban San Makha just upstream the location of a rubber weir for irrigation in dry season.

In the Middle Ing River, three major tributaries, such as Huai Rong Khui, Rong Chang and Nam Chun flow into the Ing River. There exist some waterways near Ban Mae Ing that are serving for flood protection and irrigation. After passing an irrigation rubber weir, it becomes a meandered stream with wide flood plain area.

In the Lao River, a number of small tributaries in the steep mountainous area flow into the Lao River that flows in the alluvial plain with some waterways that are serving for flood protection and irrigation near Amphoe Chiang Kham.

In the Lower Ing River, after the confluence of the Ing and Lao River, the Ing River becomes heavily meandered with wider flood plains, finally draining into the Mekong River. A number of freshwater ponds are constructed for fishery in the flood plains along the meandering Ing River.

The river bank with riprap for flood protection and erosion protection was constructed only at the left bank just downstream of a bridge in Amphoe Thoeng in the whole Ing River basin.

The man-made waterway (channel width = about 20 m) was constructed at the lower part of the Nam Rong Chae that is one of the tributaries of the Ing River, joining at Ban Rong Chae to drain the inundated internal flood water from the low-lying area into the Ing River.

(b) Mekong backwater

The water level fluctuation of the Mekong River at the river mouth of the Ing River is estimated to be from a maximum of 350 m.MSL. to a minimum of 340 m.MSL. The river is at its deepest in August and reaches its lowest depth in April.

The Ing River is affected by the backwater from the Mekong River at Ban Sop Ing up to about 50 km from the river mouth, without reaching to Amphoe Thoeng.

(c) Inundation area in wet season

In the Ing River, main flood plains that are inundated by floods of a short return period in wet season are as follows:

Kwai Phayao Flood Plain is located in the area of Amphoe Muang Phayao, covering 250 km^2, having the mean elevation of about 390 m.MSL.

The causes of the inundation in the area around the Phayao Lake are considered as follows:

- Shortage of flood control space for the Phayao Lake
- Shortage of flood outflow volume from the Phayao Weir
- Shortage of bankfull flow capacity of the main stream of downstream area after the Phayao Lake
- Disturbance of flood flow in the main stream by a number of small irrigation weirs located downstream of the Phayao Lake

Ing Flood Plain is situated in the area of Amphoe Thoeng, covering 400 km^2, having the mean elevation of about 360 m.MSL.

The causes of the inundation in the area are considered as follows:

- Shortage of bankfull flow capacity of the main stream and tributaries
- Low-lying area near the confluence of the Ing and Lao Rivers

Lower Ing Flood Plain is located in the area of Amphoe Chiang Khong near the river mouth, covering 100 km2, having the mean elevation of about 340 m.MSL.

The causes of the inundation in the area are considered as follows:

- Shortage of bankfull flow capacity of the main stream
- Disturbance of flood flow by backwater effects from the Mekong River

(d) Number of existing weirs at the upstream

In the Middle Ing River basin after passing the Phayao Lake, a number (about 17) of small scaled irrigation weirs was installed in the main stream and minor streams flowing in the alluvial plain near Ban Mae Ing and other villages.

(e) Assumed flood capacity

The bankfull flow capacity of the Ing River varies between streams, from a few times each year to once every few years in terms of its frequency of occurrence, reflecting on a situation where no man-made dikes were constructed along the streams. Most of the river bank in the Ing River is a sand and/or shingle ones in natural condition.

(2) Layout plan of river training

The river training plan in the Ing River is categorized into the following :

- River training plan directly related to the Kok-Ing-Nan Water Diversion Project
- Associated river training plan for the entire Ing River basin

(a) Widening of river width

River training plan directly related to the Kok-Ing-Nan Water Diversion Project includes the following:

- River training for the upstream and downstream of the Ing Diversion Weir
- River training of the heavily meandering Lao River near the confluence to the Ing River

A river training plan for both the Ing and Lao River near the confluence is fully related to a layout plan of the Ing Diversion Weir and Retaining Pond. Tentatively, the design flood for the river training is recommended to be 20 year flood, based on the design standard of RID.

To investigate the bankfull capacity of both the Ing and Lao River near the confluence, river profile and river cross section survey are required for plan and feasibility grade design of river training.

(b) Flood protection bank

Flood protection both for right and left banks of the Ing and Lao River, (1) near the confluence, (2) upstream and downstream of the Ing Diversion Weir, and (3) upstream of the Lao River is required to improve the river condition for flood events. The earth embankment can be adopted in principle for the construction of the earth dikes.

The dimension, such as, length and width of the river bank and dike shall be determined by the Feasibility Study with additional river profile and cross section data and detailed flood hydrological study.

The layout of the river bank and dike for each river section is recommended as follows:

- Downstream of the Ing Diversion Weir shall be protected only by the higher river bank suitable for the 20 year flood without changing the present meandering stream channel.
- Upstream of the Ing Diversion Weir (The length of the river training shall be determined by the design high water level of the Ing Diversion Weir.) shall be protected by new earth dikes constructed along the flood plain outside the meandering stream channel suitable for the 20 year flood with maintaining the present stream channel. Tentatively, HWL is set to be 365 m.MSL.
- At the lowest point of the Lao River, flood flows from the Lao River are planned to be diverted directly into the Ing Diversion Weir by a side overflow structure, and downstream part of the Lao River is to be naturally remained with no improvement.

For further study, it is recommended that additional profile and cross section survey be carried out for upstream of the Ing and Lao River from the confluence by 200 m interval.

(c) Integration of existing weirs

A number (about 17) of existing small scaled irrigation weirs in the main stream and minor streams flowing in the alluvial plain near Ban Mae Ing and other villages in the Middle Ing River after passing the Phayao Lake is recommended to be integrated since those small weirs exacerbate the inundation of flood flows in the main and minor waterways frequently in wet season. The location and dimension of the integrated weir and improved main and minor waterways shall be determined by a careful irrigation and drainage plan and community development plan in the alluvial plain during the Feasibility Study.

(d) Erosion protection at river bank (riprap)

The river bank and new dikes related to the Ing Diversion Weir and Regulation Pond shall be fully covered by riprap to protect the bank and dike from the erosion in flood events.

(e) Flood mitigation swamp

Next to the man-made waterway (channel width = about 20 m) at the lower part of the Nam Rong Chae that is one of the tributaries of the Ing River, joining at Ban Rong Chae to drain the inundated internal flood water from the low-lying area into the Ing River, the comb-shaped waterway was constructed along the Nam Rong Chae River mainly for fishery and also for flood mitigation pond providing a flood buffering effect.

The concept of the flood mitigation swamp with a function of the fishery pond is fully adopted presently in the low-lying flood plains in the Middle and Lower Ing River basins. During the Feasibility Study, the integration of small ponds, which are usually inundated only in wet season, shall be planned for the purpose of the higher efficiency of flood mitigation and fishery.

Most of the nearby villages in the Lower Ing River are located in flood fringe area, outside flood plain or flood storage area, which is beyond the regulatory flood limits.

5.8 Tunnel

The major project facility involved in the Kok-Ing-Nan water diversion plan consists mainly of the following large scale tunnel works ;

- Kok-Ing tunnel with the length of more than 5 km and the hydraulic section area of 60 sq.m. to divert the discharge of 125 cu.m/sec
- Ing-Yot tunnel with the length of 51 km with hydraulic section area of 70 sq.m. to divert the discharge of 175 cu.m/sec and with Inclined shaft of 17.4 km at 7 sites.

The above Ing-Yot tunnel will be the largest scale water diversion tunnel in the world. The tunnel construction cost in the project shares about 60 percent of total construction cost. It is necessary, therefore to verify carefully technical viability for implementing such huge tunnel works in Thailand smoothly and safely, otherwise this project could not be realized.

Although the tunnel works are fairly studied in the conceptual plan by Thai side, JICA Team has carried out further detailed study to verify further the technical and financial viability of tunnel works. The study result by JICA Team is described as below ;

(1) Alternative Tunnel Route

(a) Kok-Ing Tunnel

As mentioned in the above paragraph 5.4 Kok-Ing Diversion Canal, five alternative canal routes including three tunnel routes of A, B and B-J are proposed and studied by JICA Team. It is rather difficult, however, to decide the best canal route at the conceptual plan stage because each canal has the different advantage and disadvantage for construction and water management and requires further detailed survey and study based on the topographical survey and geological investigation works. Especially the geological investigation works for the tunnel route of A, B and B-J shall be required.

(b) Ing-Yot Tunnel

In accordance with Thai side study for the Ing-Yot tunnel, two alternative routes are proposed, one is the northern route (A and B route) and the other is the southern route (C route). The southern tunnel route, however, have no viability to implement the tunnel works with the following reasons, as the result, further study in the Feasibility Study stage is not required.

- The tunnel route of 28.5 km from the tunnel inlet in the southern tunnel is composed of such very poor geological condition as shallow overburden depth of less than 60 m above tunnel, weathered rock formation consisting of crushed shale, tuff and sandstone with compression strength of only 100 to 150 kg/cm^2, highly permeable overburden to bring about water leakage into tunnel during construction, etc., as a result the tunnel structure is mostly designed with type D and E requiring the strong steel support and the lining with reinforced concrete. Tunnel construction cost for the southern route, therefore, will be estimated at the huge amount of 29,300 million Baht which is about 1.4 times of the northern tunnel cost of 20,600 million Baht. Accordingly the southern tunnel route is not recommendable in the project.

- In order to access the southern tunnel inlet, the Kok-Ing diversion open canal in the Ing basin requires the canal length of 36.5 km which is longer than 23.5 km in the A and B route plan, because the inlet of the southern tunnel is located at about 8 km upstream of the canal route in A and B.
  In accordance with the longer tunnel length in the southern route (C route), the construction cost is naturally increased.

- In order to access to the inlet of the C route, the open canal shall cross the upstream basin in the Ing river where the large paddy field is existed and many creeks for irrigation and drainage are developed. Accordingly, the open canal construction cost will be higher than that in the A and B route because the open canal shall cross a number of creeks and tributaries and require many bridges, crossing structures, etc.

- It is also difficult from the engineering aspect to provide the Ing diversion dam at the upstream basin because the Ing river becomes small section and can not pass through the design diversion capacity of 175 cu.m/sec without expansion of the river hydraulic section. This river improvement also requires additional construction cost.

The proposed northern tunnel route (the A and B route) by Thai Side Study is mostly suitable in accordance with the geological and engineering aspect reviewed by JICA Team. Only the location of tunnel outlet has been slightly changed taking into account the social environmental impact for Yot Village located near the original tunnel route and for provincial road to be replaced.

The northern route tunnel is planned mostly to pass through the consolidated and firm rock formation with the high overburden of 200 to 1,000 m above tunnel except the tunnel inlet

section and fault zone section. The definitive northern tunnel route is as shown in the Database Map.

(2) Topographical and Geological Condition

(a) Proposed alignment (North route alignments)

The geological map, the profile of proposed Ing-Yot tunnel route, and the geological logging of core drilling which was carried out by Thai said, is shown in the Database map.

* Inlet - 3.2 km

From inlet to 1 km, tunnel is planned to pass through under lower hills of ground height 390m-420m underlain by Mae Phong formation (TRmp) which consists of shale ,tuff and lapilly tuff. Shale is not so hard and easily be separated along the lamina, and because of weathering becames cracky and changed to some kinds of clay mineral. Rock mass is classified E type.

* 3.2 km - 28.7 km

After 3.2 km , the tunnel passes through under lower mountains (EL.500-550m) which are underlain by Huai Sarian formation (Trhs). After that, along the tunnel route Phu Rang Ka formation (CPpr) continuing for about 25 km . CPpr consists of metamorphosed phillitic slate and sandstone, and sometime associated with quartzite band being hard and compact in intact condition, on the other hand Phyllitic sate contain graphite and has a characteristic to be easily separated with hammer blow along the lamina. Some faults are found along bedding plain and usually quartzite is dragged along the fault. Tunnel crosses under river course where supposed to be formed by erosion along fault sheared zone. Rock mass is classified B to C1 type under thick overburden section while D to E type on the fault zone.

* 28.7 - 29.8 km

Tunnel alignment changes the course from 24.4 km point to south east and passes through Limestone of Pha Chick formation (TRpc) from 28.7 km to 29.8 km which make high and unique form mountains called Doi pha Dam (1000-1300m height). Limestone cave are found near Ban Phang Tham village on both sides of river Yuan, and water is flowing out from the cave of right bank. It is supposed that Limestone formation is underlain by CPpr formation however the base of the Limestone has not been confirmed deeper than tunnel basement not yet. It is supposed that the Limestone contact with CPpr and TRhs formation with fault and continue to south crossing the river Yuan

forming steep mountains. Rock mass is classified D and E type considering groundwater discharge when crossing Limestone caves.

* 29.8 km - 45 km

Then, tunnel passes through under high mountains which is underlain by Huai Sarian formation (TRhs fm.) which consists of fine and rhythmical alternation of Shale and Sand stone and this rock is hard and compact in intact condition. The overburden of the tunnel become thick and reach to maximum 1360 m. This formation is exposed along the river Yuan but any outcrop of major fault has not been confirmed. General strike and dip of the formation are NS - N 15 W and 10 - 30 degree to E. Rock mass is classified B and C1 under high mountain rigs and D to E type on fault zone.

* 45 km - Outlet

Nearby the Yot village, from 45 km to 45.5 km, the tunnel passes through small Limestone mountain which is called Pbt formation. The limestone is inclined about 30 degree to 45 degree toward west, and it is supposed that on the west boundary, the Limestone contact TRhs with fault.

The tunnel passes under mountain of bellow 700m which is underlain by Tuff of TRhs formation. From 49.9 km to 50.4 km passes through Limestone mountain again near Ban Pha Lak village. After that then to outlet, passes through lower hill on which ground height is bellow 390 m and underlain by deeply and highly weathered tuff, and. Rock mass is classified D and E type under Limestone ,another Tuff and Sandstone is classified C2 to D type and near outlet highly weathered section is classified E2 type.

Problems for groundwater with tunnel excavation are pointed out as follows.

* Groundwater discharge from limestone cave of TRpc on the Doi Pha Deang mountain.
* Groundwater discharge from limestone cave of Pbt on the Yot valley.
* Influence for hot spring of Phu Sang water fall.

(b) Tunnel alignment C (South route)

The profile of the tunnel alignment is shown in Database Map

* Inlet - 18.9 km

From inlet to 18.9 km the tunnel passes through under low hills, terrace and alluvial plain with the ground height of 400 m to 450 m, so overburden of tunnel are mostly less than 60 m . The geology near tunnel elevation is shale and sandstone of

Triassic and Jurassic formation called TRmp , Na Ngan (Jnn), Phu Kham (Jpk) and Mae Tam (Jmt) formation. These rock are generally reddish brown color and not so strong. Especially Shale easily deteriorate as caused by water and become clayey. Rock strength of Sandstone is 100 kg/cm^2 according to the result of uniaxial compression test.

Groundwater discharge during tunnel excavation is expected to be mainly caused by overlain loose and permeable formation of Quaternary sediment and highly weathered rock.

So rock mass classification is estimated very low type of E1or E2 mostly.

* 18.9 km to 26.4 km

The tunnel route is planned under narrow width ridge extending from north-west to south-east as underlain by Andesite and Rhyolite of TRv or Lms-2 formation and ground height is 600 m to 700 m with having faults parallel to ridge. The rock of TRv formation of hard in intact but will become cracky along these fault. Rock mass is classified D and E type.

* 26.4 km to 34 km

A fault zone is supposed to exist at 26.4 km which make boundary between Jurassic formations and CPpr formation which is major fault on the tunnel route. So it is supposed that Phyllite of CPpr formation become cracky and clayey nearby the fault zone, and rock mass is classified D and E type mainly. After that, overburden of the tunnel become thick (ground height 600 m to 800 m) , so rock of Cppr formation become hard, compact and massive. Rock mass is classified C1 and C2 type.

* 34 km to Outlet

The tunnel passes through high mountain of ground height 800 m to 1600 m which is underlain by fin alternation of shale and sand stone of TRhs formation being very hard, compact and massive in intact.

There supposed to be the limestone of Pbt or p2-1 formation between 42 km to 44 km. The northern boundary has not been confirmed yet, so the tunnel route is selected to avoid this limestone.

After that, the tunnel route is connected to the proposed tunnel alignment/B.

(c) Additional geological investigation required for F/S

* To make clear geological condition such as depth of weathered rock of shallow overburden section near inlet and outlet, Seismic prospecting and Core drilling accompanied with on site test such as Permeability test, Electrical and Density logging are required.

* To confirm rock facies of fault zone supposed to be on river valley, Seismic prospecting and TDEM, and Core drilling are required, especially for deeper drilling high core recovery is required. On site test accompanied with drilling following test is required; Permeability, Water pressure, Electrical and Density Logging, and following laboratory test for drilling core sample is required; Uniaxial compression test, X ray analysis for clay mineral and observation by Optical microscope.

* To confirm basement of Limestone of mount Doi Pha Deang, TDEM which is suitable to sound deeper part is required.

* To investigate rock condition under thick overburden on high mountain area, TDEM for deeper part is also required on upper basin of Yuan river.

* To evaluate influence with tunnel excavation for spring of Phu Sang water fall making clear mechanism of hydro-geological feature, Seismic prospecting, Core drilling and TDEM is required near No. 2 adits.

* To make clear geological condition of adits especially for depth of Talus and weathered rock facies Seismic prospecting and Core drilling is required.

(3) Tunnel Hydraulic Section

(a) Alternative Tunnel Section

Alternative tunnel sections of circle, standard horseshoe and widened horseshoe type are studied and the widened horseshoe section is applied for the project with the following reason ;

- Tunnel designed with circle section is generally applied for the pressure tunnel to ensure the inner water pressure. The standard or widened horseshoe section is generally applied for the gravity flow tunnel. If the circle section is applied for the gravity flow tunnel, the circle portion at the tunnel invert shall be filled up with

concrete in order to provide the flat area in the invert to haul the tunnel excavation material and concrete material during construction and to drive the inspection car during O&M period. Accordingly, tunnel requires the larger hydraulic section area for the circle section than that for widened horseshoe section. Widened horseshoe section have the wider width at the invert which can be used for transportation in the tunnel easily and smoothly.

(b) Hydraulic Gradient of Tunnel

In Thai side study, tunnel was designed with the ordinary hydraulic gradient of 1 to 2,500 for the Kok-Ing route with the discharge capacity of 125 cu.m/sec. but with the gentle gradient of 1 to 4,000 for the Ing-Yot route.

JICA Team studied the hydraulic condition such as discharge velocity and tunnel section area as follows based on the different hydraulic gradient of 1 to 2,500 and 1 to 4,000

Items	Discharge Capacity cu.m/sec				
	100	125	150	175	200
1 Gradient of 1 to 4,000					
Radius of Upper Harf (m)	4.85	5.25	5.60	5.95	6.25
Total Height of Inner Section (m)	7.28	7.88	8.40	8.93	9.38
Velocity (m/sec)	1.91	2.05	2.14	2.23	2.30
Inner Section Area (sq.m)	57.20	68.10	77.50	87.60	96.60
2 Gradient of 1 to 2,500					
Radius of upper Half (m)	4.40	4.80	5.15	5.45	5.75
Total Height of Inner Section (m)	6.60	7.20	7.73	8.18	8.63
Velocity (m/sec)	2.31	2.48	2.56	2.66	2.75
Inner Section Area (sq.m)	47.80	56.90	65.50	73.40	81.80

As is clear in the above table, the tunnel inner section area by the gradient of 1 to 2,500 is about 20 percent smaller than that of 1 to 4,000 , as a result the tunnel construction cost is naturally reduced. JICA Team, accordingly designed the Ing-Yot tunnel with the gradient of 1 to 2,500 changing the location of tunnel outlet to the site with the low elevation.

(4) Tunnel Structural Section

(a) Tunnel Type

Tunnel structural section is designed in accordance with tunnel type classifying into B, C1, C2, D1, D2, E1, and E2 which is decided by geological condition along the tunnel route.

Tunnel type and its length for A, B and B-J route in the Kok-Ing Diversion canal is as shown in 5.4 , while the type for Ing-Yot tunnel in the northern route and the southern route is classified as follows based on the geological analysis along the tunnel route.

Tunnel Type	Northern Route		Southern Route	
	Tunnel Length (m)	Rate (%)	Tunnel Length (m)	Rate (%)
B	2,680	5	770	1
C1	8,910	18	3,850	7
C2	14,790	29	7,090	14
D1	12,090	24	5,540	11
D2	7,810	15	5,740	11
E1	2,870	6	6,330	12
E2	1,730	3	23,130	44
(Ewr)	(690)	-	-	-
Total	50,880	100	52,450	100

As is indicated in the above table, tunnel length of about 80% out of the total length of the Southern Route is occupied by type of D and E, which requires the high tunnel construction cost.

The distribution of tunnel type is shown in the Database Map.

(b) Standard Support Pattern for Tunnel Type

The standard support pattern for tunnel type such as rock bolting, steel supporting, shotcreting, concrete lining, etc. is as shown in Table 5.4 and Database Map. The outline of excavation and concrete lining for each tunnel type is described as follows ;

- B and C1 type is excavated by the full-face-attack method with auxiliary bench and reinforced with only rock bolt but without steel support. Concrete lining thickness is 30 cm for arch and side wall and 40 cm for invert.
- C2 type is excavated by the full-face-attack method with auxiliary bench and reinforced with rock bolt and steel support of H-125. Concrete lining thickness is 30 cm in arch and side wall, 40 cm in invert.
- D and E type is excavated by the upper-half-attack method due to poor geological formation which could not allow the full-face-attack method and reinforced with rock bolt and strong steel support of H-150 and H-200. Reinforced concrete lining is required and its thickness is 50 cm in arch and side wall and 60 cm in invert.

Table 5.4 Standard Support Patterns for Kok-Ing-Nan Water Diversion Tunnels

Grade of ground	Excavation method	Standard round length (upper half) (m)	Rock bolt			Steel arch supporting			Shotcrete thickness (cm)	Welded metal net		Lining		
			Length (m)	Installation pitch		Upper half	Lower half	Standard pitch (m)		Upper half	Lower half	thickness (cm)		Rein-forcement
				Circumferential (m)	Longitudinal (m)							Arch and side wall	Invert	
B	Full face method with auxiliary bench	2.0	3.0	1.5 (upper half only)	2.0	None	None	-	5	-	-	30	40	-
C I	Full face method with auxiliary bench	1.5	3.0	1.5	1.5	None	None	-	10	-	-	30	40	-
C II	Full face method with auxiliary bench	1.2	3.0	1.5	1.2	H-125	None	1.2	10	-	-	30	40	-
D I	Upper half method	1.0	4.0	1.2	1.0	H-125	H-125	1.0	15	○	-	40	50	○
D II	Upper half method	1.0	4.0	1.2	1.0	H-150	H-150	1.0	20	○	○	40	50	○
E I	Upper half method	1.0	4.0	1.2	1.0	H-200	H-200	1.0	20	○	○	50	60	○
E II	Upper half method	1.0 or less	forepiling 3.0	0.6	1.0	H-200	H-200	1.0	25	○	○	50	60	○
			4	1.2	1.0									

(5) Tunnel Construction Plan

(a) Construction Division

The Kok-Ing and Ing-Yot tunnels are constructed dividing into the following divisions.

Items	Kok-Ing Tunnel							Ing-Yot Northern Route
	A Route		A-R Route		B Route	B-J Route		
	No.1	No.2	No.1	No.2	No.2	No.1	No.2	
Tunnel Length Construction Divisions	5,800 2	7,240 2	3,114 1	7,775 2	5,510 2	3,110 1	7,780 2	50,880 9

The Kok-Ing tunnel could be driven with two construction divisions from the inlet and outlet due to the tunnel length of less than 8 km.

The Ing-Yot tunnel, however, requires construction divisions by the tunnel inlet and outlet and 7 inclined shafts. In the Ing-Yot tunnel, the tunnel length of about 6 km including the shaft length is planned to be carried out at one construction division. The tunnel construction period is planned with 6 and harf years at each construction division.

(b) Quantity for Tunnel Construction

Quantity for excavation, shotcrete, rock bolt, steel support, concrete lining, etc per meter for Kok-Ing and Ing-Yot tunnel is estimated as follows ;

Quantity per meter for Kok-Ing Tunnel

Item		C I	C II	D I	D II	E I	E II
1 Tunnel Excavation	(m^3/m)	74.00	73.60	76.70	77.80	81.00	82.10
2 Shotcrete	(m^2/m)	19.60	19.60	20.00	20.00	20.30	20.30
3 Rock Bolt	(Nos./cycle)	14	14	17	17	17	8/18 Forepiling
4 Steel Arch Supporting	(ton/cycle)	-	0.38	0.48	0.63	1.01	1.02
5 Tunnel Lining	(m^3/m)	14.00	13.20	15.30	15.30	18.40	18.40
6 Reinforcement	(ton.m)	-	-	0.92	0.92	1.10	1.10

Quantity per meter for Ing-Yot Tunnel

Item		B	C I	C II	D I	D II	E I	E II
1 Tunnel Excavation	(m^3/m)	92.20	92.70	92.20	95.70	96.90	100.50	101.70
2 Shotcrete	(m^2/m)	22.10	22.10	22.10	22.40	22.40	22.70	22.70
3 Rock Bolt	(Nos./cycle)	12	16	16	19	19	19	8/22 Forepiling
4 Steel Arch Supporting	(ton/cycle)	-	-	0.43	0.53	0.71	1.13	1.14
5 Tunnel Lining	(m^3/m)	16.70	15.80	14.90	17.20	17.20	20.70	20.70
6 Reinforcement	(ton.m)	-	-	-	1.03	1.03	1.24	1.24

(c) Inclined Adit in Ing-Yot Tunnel

In the Ing-Yot tunnel with total length of 50.9 km, seven inclined adit shall be constructed to access the construction of main tunnel. The planned adit location is as shown in Database Map and the outline of the adit is as follows ;

No.of Inclined Adit	Distance Remark m	Inv.El. of Crossing Point m	El.on Portal of Inclined Adit El.m	Difference Height m	Length of Inclined Adit m	Gradient %
(Inlet)	0.0	(352)				
1	5,727	350	457.5	107	1,980	5.4
2	10,919	347	460.0	112	1,790	6.3
3	18,442	344	506.0	161	2,190	7.3
4	25,510	342	510.0	167	3,170	5.3
5	31,958	339	508.0	168	2,470	6.8
6	38,156	337	570.0	232	3,340	7.0
7	44,870	334	430.0	95	2,430	3.9
(Outlet)	50,875	(331)				

(d) Tunnel Construction Method

Tunnel Construction is planned to be executed with NATM as proposed by Thai Side Study.

The major construction equipment by NATM for Ing-Yot tunnel of 51 km is listed up as shown in Table 5.5.

(e) Construction Progress

The construction progress of tunnel will be about 100 m/month for good geological condition and about 60 to 70 m/month for poor geological condition which are proposed by Thai Side Study and judged by JICA Team to be suitable.

(6) Additional Survey and Study Required in F/S

Additional survey and study required for tunnel in F/S is as follows ;

(a) Geological investigation works by seismic prospecting and core drilling with deep depth of 100 to 200 m will be required. The investigation quantity is already proposed by Thai Side and will be considered to be sufficient.

(b) Comparison study for tunnels of A, B and B-J routes in Kok-Ing Diversion Canal shall be made and the best route shall be proposed.

(c) Tunnel length in accordance with tunnel type of B, C, D and E is to be studied based on the geological investigation result.

(d) Route of access road and inclined adit is to be studied by the detailed topographical map and taking into account the environmental impact along the route.

(e) Tunnel construction plan by NATM and by possibility to use T.B.M. is to be studied.

Table 5.5 Major Construction Machines for Ing-Yot Tunnel of 51 km

(Blasting Exacavation Method/1 face)

Operations	Items	Description	Unit	No's.	Remarks
Excavation (Drilling and Blasting) and Mucking	Hydraulic jambo (3-Boom)	Wheel Type/Oil-Pressure Dorifuta : 150 kg class	set	1	use with drilling of rockbolt countermeasure for fumes
	Hydraulic breaker (kosoku)	Oil-Pressure: 600-800kg class	set	1	base machine:back hoe Oil-Pressure:0.4m3 class
	Side dump shovel	Wheel Type/Side Dump 2.3 m3 class	set	1	muck loading countermeasure for fumes
	Back Hoe	Crawler Type/Oil-Pressure 0.4 m3 class	set	1	assist for muck loading countermeasure for fumes
	Dump Truck	Diesel 11 ton	set	16	carring out of muck
	Pick-hammer	CA-7	set	2	
	Leg-hammer	40 kg class	set	-	
	Dump Truck	Diesel 4 ton	set	-	
	Tracter Shovel	Crawler Type 1.4 m3 class	set	-	
Supporting, Shotcrete and Rock bolt	Shotcrete-robot	Shotcrete-range: 8 m class	set	1	
	Shotcrete machine	10 - 15 m3 / hr	set	1	
	Mortar pump mixer	5.5 kw	set	1	
	Mixed concrete car	4.4 - 4.5 m3 class	set	2	
	Back Hoe	Crawler Type/Oil-Pressure 0.4 m3 class	set	1	base machine for shotcrete -robot
	Truck	Diesel 4 ton / crane 2.9 ton	set	1	
	Grouting mixer	Vertical type : single, 5.5 kw	set	1	
	Grouting pump	Horizonntal type : single 15-30 m3/min class	set	1	
	Dusting machine	Vacuum : 300 m3/hr,30 kw	set	1	
	Air compressor	fixed type/screw : 12 m3/min 7kg/cm2 , 75 kw	set	2	per 1.2 km
	Shotcrete plant	fixed type/mixer : 25 m3/hr	set	1	cement silo: 30t/day aggregate hoppa:15m3*3
	Lift car		set	1	
Sheeting and Concrete Lining	Concrete pump car	pressed pipe , 55 m3/hr	set	1	
	Concrete vibrator	electrical stick type dia.60mm	set	2	
	Working frame for sheeting	frame-range:4-6m , L=4.5m	set	1	
	Sliding form for lining	1 barrel=10.5m	set	1	

(f) Location and area of the spoil bank for tunnel muck and its utilization are to be studied.

(g) Operation and maintenance method including inspection method for tunnel is to be studied.

5.9 Flood Control Dam

(1) Necessity of Flood Control Dam

The diversion water at 175 m3/s from the Kok and Ing rivers will flow into the Nan river through its sub-basins; Yot river and Yao river. In spite that the present monthly mean discharge is estimated less than 20 m3/s at the damsite, the Yot and Yao rivers shall carry the diversion water and local flow about 195 m3/s in wet season. Therefore the diversion water will change the flow condition of Yot and Yao rivers completely.

The flow capacity of the Yot river at the Ing-Yot tunnel outlet is estimated about 150 m^3/s and the flow capacity of the Yao river is in the range between 160 and 300 m^3/s. In order to avoid the impact by the diversion water during flood and to protect the villages downstream of the dam from flooding, it is necessary to construct a flood control dam.

(2) Proposed Damsite

The flood control damsite is recommended on the Yao river, about 3 km downstream from the confluence with the Yot river or about 2 km upstream from King Amphoe Song Khwae, Changwat Nan based on the map study on scale of 1:10,000 and 1:50,000 and site reconnaissance. The catchment area is 372 km^2. The damsite foundation consists of shale, sandstone, tuff and lapilly tuff.

The Thai side study recommended the flood control dam as zone type dam. The storage capacity was determined in relation with the improved flow capacity of the Yot and Yao rivers. They recommended the storage capacity of 14.4 MCM at the flood control level 306.3 m MSL in case of the flow capacity of the downstream at 200 m^3/s. The regulated flow of 200 m^3/s will be discharged through the river outlet under the dam. It was assumed that the diversion water would stop at a flood time and the remaining water in the Ing-Yot tunnel, about 3.8 MCM, would be stored in the reservoir. However it might not be practical operation since it is difficult to judge the timing when the flood begins and the diversion water shall stop.

The JICA Study Team recommend the flood control dam as concrete gravity dam since the reservoir water level will fluctuate frequently about 10 m in maximum. The dam foundation may be applicable for a concrete gravity dam based on our field reconnaissance, although it is reported that there are faults along the Yao river.

(3) Flood Control Plan

(a) Design Flood to be Controlled

Design flood of 20 year return period for 3 day duration is applied for the purpose of flood control. The peak flood is estimated about 250 m^3/s tentatively based on the flood records of the gauging station N.51 at the Yao river, though the estimate by the Thai side study is 520 m^3/s.

(b) Daily Control Plan

The flood control dam will release the diversion water and local flow at 200 m^3/s continuously in rainy season through the diversion outlet of 2.8 m in diameter. The normal water level of the reservoir to discharge 200 m^3/s is set at 302.1 m MSL and the tail race water level is estimated about 278.5 m MSL. The local flow which exceeds 25 m^3/s will be stored in the reservoir.

Flood volume is estimated at 27 MCM as shown below and will be stored in the reservoir of the flood control dam. The reservoir water level will reach at 312 m MSL in case of 20 year probable flood to store the flood volume of 27 MCM.

In case that there is flood in the Nan lower basin or the reservoir storage of the Sirikit dam is full, the intake gate of the Kok and Ing diversion dams will be closed to stop water diversion. Extraordinary floods from the Yot and Yao river basin will be discharged over the spillway.

(4) Dam Conceptual Layout

Principal feature of the Yao flood control dam is shown in Table 5.6.

Table 5.6 Principal Features of Yao Flood Control Dam

Principal Features	Unit	Recommended by Thai Side Study	Recommended by JICA Study Team
Reservoir			
- Peak discharge in 20 year return period	m^3/s	520	250
- Flood water level	m MSL	306.30	312.0
- Reservoir surface area at FWL	km^2	2.26	3.2
- Gross storage	MCM	14.42	35
- Flood control volume	MCM	7.10	27
- Nonnal (retention) water level	m MSL	302.00	302.1
- Low water level	m MSL	299.00	295.0
Dam facilities			
- Type of dam		Zone fill	Concrete gravity
- Dam crest elevation	m MSL	310.00	313.0
- River bed elevation	m MSL	275.79	276.0
- Dam height from river bed	m	34.2	37
- Crest length	m	140	120
- Crest width	m	10	6

(5) Additional Study Items to be required for F/S

i) Hydrological analysis such as low flow analysis, flood analysis and sedimentation.

ii) Following study shall be made for design.

1) Review of design data, design criteria and design standards for dam, outlet and spillway
2) Determination of design loads and safety factors
3) Stability analysis
4) Foundation treatment in accordance with geologic condition
5) Study on possible damage from flooding to life and property upstream and downstream of dam
6) Study on safety measures, adequate spillway operation scheme and flood routing
7) Reservoir operation study to confirm availability of flood control volume as irrigation and water supply in dry season
8) Quantity survey and cost estimate

iii) Design of mechanical and electrical equipment.

iv) Geological investigation and material survey to select type of dam.

v) Environmental analysis of reservoir and protection measures on dissemination of waterborne diseases, degradation of water quality, endangered species, etc.

vi) Following topographic maps are required for the facility design of F/S.

1) 1/1,000 for the damsite area with 1 m (to 5 m) contour and 200 m width of both side from the dam axis
2) 1/10,000 for the reservoir area of alternative damsites
3) Dam axis profile with horizontal scale of 1/1,000 and vertical scale of 1/100
4) Dam axis cross section with horizontal scale of 1/200, vertical scale of 1/100 and 200 m interval
5) Yao river cross section with horizontal scale of 1/200, vertical scale of 1/100 and 500 m interval up to the river bed El. 400 m

5.10 Yao River Training

(1) Present river condition

(a) Division of sub-basins

The Yao River basin is mainly divided into the following sub-basins up to a confluence to the Nan River by the location of the Yao Flood Control Dam.

- Yot River basin
- Upper Yao River basin (upstream of the Yao flood control dam)
- Lower Yao River basin (downstream of the Yao flood control dam)

In the lower Yao River basin, four major side flows, such as, the Mong, Rak, Ki and Haen Luang River join from the right bank of the Yao River up to the confluence of the Nan River. No major side flows exist from the left bank. Side flows from four tributaries shall be modeled in the flood hydrological analysis in the Feasibility Study.

(b) River profile and cross section

Available profile and cross section data in the Yao River are as follows:

- River profile and cross section data of the Yot River from upstream of the Ing-Yot Diversion Tunnel to the confluence of the Yao River by 500 m interval, (totally 14 km)
- River profile and cross section data of the Yao River from upstream of the confluence of the Yot River to the confluence of the Nan River by 500 m interval (totally 54 km)

JICA Study Team considered that for further study, additional profile and cross section survey are needed by 200 m interval at village areas.

(c) Present flood condition (water level and discharge, etc.)

Actual flood conditions regarding flood water level and its discharge in the past are not known because no water level gauging stations are not installed in the Yao River basin except for one stream gauge (N51) located near the confluence of the Nan River.

The Yot River has a steep slope of about 1:200. The river channel bankfull capacity from the tunnel outlet to the confluence of the Yao River varies from about 40 to 100 m^3/s.

The river slope of the Yao River varies from 1:300 to 1:1,000. The river channel capacity from the confluence of the Yot River to the confluence of the Nan River varies about 150 to 300 m^3/s.

(d) Village, public facility and farm land along the river

There exist thirteen (13) villages to be affected and therefore protected from flood events in the Yao River downstream of the Yao Flood Control Dam as follows :

As one of the important public facilities, the existing bridges are heavily affected by flood events in the Yao River. There exist six (6) bridges along the Yao River from downstream of the Yao Flood Control Dam to the confluence of the Nan River.

Farm land along the upper and middle Yao River is limited to the small flood plains accessible from nearby villages. In the lower Yao River near the confluence, paddy fields are developed widely. The detailed present land use in the Yao River basin is shown in the environmental study report.

(2) River training plan

A river training plan in the Yao River basin is fully related to the Kok-Ing-Nan Water Diversion Project.

The total river length of about 50 km up to the confluence of the Nan River is to be studied for the river training and improvement plan.

The optimum river training plan is to be studied with a suitable combination of the flood control dam plan in the upstream of the Yao River. For instance, a river training plan for the Yot River, downstream of the Ing-Yot Water Diversion Tunnel, shall be carefully examined on the basis of the design high water level of the Yao Flood Control Dam, and a river training plan for the Yao River, downstream of the Yao Flood Control Dam, shall be studied on the basis of the regulation of flood peak by the Yao Reservoir.

The basic concept for the river training of the Yao River is summarized as follows:

- To thoroughly control the artificial flood within the river channel
- To maintain the river channel and river course as much as possible
- To sustain the visual amenity and safety
- To facilitate the river suitable for community development

(a) Analysis of design flood at control point along the river

The preliminary analysis of the design flood at the following control points along the Yao River was made by Thai side study:

The flood peaks at the control points were simply estimated by general regional flood peak and catchment relationship for the upper Nan river basin as follows:

Control Point	2-Year Return Period (m^3/s)	5-Year Return Period (m^3/s)	20-Year Return Period (m^3/s)
Diversion Outlet (Yot River)	42	82	133
Yot & Yao Confluence (before confluence)	98	183	290
Yot & Yao Confluence (after confluence)	149	273	427
Yao & Nan Confluence (before confluence)	289	507	780
Yao & Nan Confluence (after confluence)	475	811	1,231

To check the probable floods in the Yao River, an attempt was made by the JICA Study Team to estimate the probable floods using site specific flood data in the Yao River.

Probable flood peaks at N51 stream gauging station located just before the confluence of the Nan River (catchment area = 774 km^2) were estimated using 13-year records (1979 - 91). Results of the calculation are summarized below:

Location	2-Year Return Period (m^3/s)	5-Year Return Period (m^3/s)	20-Year Return Period (m^3/s)
N51 (Ca = 774 km^2) (before confluence)	210	280	360

As a reference value, probable flood peaks at the Yao Flood Control Dam (Ca = 372 km^2) were estimated using the empirical equation as follows:

$$Q \text{ at Yao Dam} = Q \text{at N51} \times (372/774)^{0.5}$$

Location	2-Year Return Period (m^3/s)	5-Year Return Period (m^3/s)	20-Year Return Period (m^3/s)
Yao Dam (Ca = 372 km^2)	150	190	250

The estimated flood peak values by Thai side study using regional flood curve are much higher than those by JICA Study Team using site specific flood records (1.7 to 2.2 times in 20-year return period).

It is recommended by JICA Study Team that design flood at each control point shall be newly estimated during the Feasibility Study by suitable rainfall runoff model and flood routing model, such as, HEC-1 or Storage Function Model, taken into consideration several side flows in the Yao River basin and the regulation by the Yao Flood Control Dam.

(b) Study on river reaches to be improved

The preliminary study on river reaches to be improved was made by Thai side study based on the above flood hydrological study and water surface profile calculation by HEC-2.

The river channel capacities at control points in the Yot and Yao River were analyzed in the following conditions:

a) Present condition without project and river training
b) Future condition with project and without river training
c) Future condition with project and river training

In water surface profile calculation by HEC-2, design floods at considered points (located at river front villages) were linearly allocated by design flood values at the control points without considering flood flows from the side streams.

Therefore, it is also recommended that HEC-2 calculation shall be made during the Feasibility Study by revised control points at side flows with design flood values estimated by HEC-1 or Storage Function Model.

(3) Countermeasures of river improvement

The several countermeasures of the river improvement for the Yao River are considered to minimize the effects of the artificial flood from the Ing-Yot Water Diversion Tunnel into the Yao River.

The following countermeasures were conceptually studied by JICA Study:

- Optimum river cross sections of the Yao River to be improved
- Weirs and drops to dissipate flood flow energy
- Protection of river bank and river bed
- Replacement of existing roads and bridges

(a) River cross sections

Three alternative river training types were proposed by Thai side study as follows:

a) Construction of dike without expanding the river channel (Method 1)
b) Construction of enlarged river channel (Method 2)
c) Construction of dike and enlarged river channel (Method 3)

Three methods were compared by preliminary cost analysis as follows:

Maximum Released Water from Yao Dam	Construction Cost (Mil. Baht)		
(m^3/s)	Method 1	Method 2	Method 3
160	77.1	155.0	149.8
210	84.8	185.6	171.4
260	89.7	213.9	182.3

Method 1 was recommended by Thai side study for the river training plan in the Yao River as a least cost alternative.

Based on the review of the study by Thai side study and site investigation in the Yao River, JICA Study Team recommends the following:

- From the viewpoint of the visual amenity and safety of the river, Method 3 (with dike and enlarged channel) is recommendable since the Yao River is composed of the different topography such as valley area in the mountain and flat area used for paddy fields and villages.
- The installment of the weirs or falling works to dissipate the flow energy is needed to protect river banks and river beds from erosion.
- The total length (about 42 km) of the Yao River has to be protected by riprap and/or gabion in stead of partial river training recommended by TEAM (river training length is about 13 km).

- The optimum river cross sections shall be selected both by technical ,economical and environmental feasibility by setting the allowable flow velocity for water diversion

If the total length of the Yao River is trained by Method 3, construction cost will be around 510 Million Baht in case that the maximum released water from the Yao Flood Control Dam is set to be 200 m^3/s.

(b) Weir and drops to dissipate flow energy

To dissipate flood flow energy and resultantly to protect river bank and river bed from erosion by continuous artificial flood caused by water diversion, a number of weirs are to be installed along the river course. Weirs are considered to be more efficient than drops (falling works) in terms of accessibility to the river and safety. Small pond or pool structure can be conceived for a rest area of fish habitat at downstream of the weir or falling works.

The location, size and number of the weirs are to be determined by the Feasibility Study.

(c) Protection of river bank and bed

Protection of river bank along the river is assumed to be made only by riprap since river flow is expected to be fully dissipated by the construction of weirs.

River bed along the river can also be maintained and protected by a number of ground sill installed at the weirs.

(d) Replacement of existing road and bridge

The existing bridges and roads to be affected by the river training works shall be replaced suitable for the design flood in the Yao River.

The existing road along the river course will not be affected by the river training, therefore, roads to be replaced will be only ones which access to bridges across the river.

For villages developed in both sides of the river, a suitable community bridge shall be planned taken into consideration needs of the community.

(4) Problems

The associated social and environmental problems relating to the river training of the Yao River are considered as follows:

(a) Land acquisition and compensation

Land acquisition and compensation for residential area and tillable paddy fields related to the river training in the Yao River have to be carefully made since a land for resettlement is limited specially in the middle and upper river basins. The necessary river width for river training is fully influenced by the flow velocity for water diversion.

The resettlement of houses and paddy fields can be realized by new land development near the problem areas probably in the mountain side.

(b) Water supply facility for village

Based on site investigation by the JICA, a water supply facility for each village is already installed, diverting from nearby branch stream. Therefore, water supply facilities are not to be considered for river training plan in the Yao River.

(c) Visual amenity of the river

Visual amenity of the river and surrounding natural and social environment shall be utmostly maintained and restored and enhanced by the river training works.

Therefore, a planing of the river training in the Feasibility Study shall be made with full supports by several environmentalists, such as, sociologist, botanical specialist, fishery/aquaculture specialist, landscape planner, etc.

(d) Safety of river channel

Safety measures for people living near the river and fully depending on water front of the river shall be planned. JICA Study Team recommends, as one of the counter measures, to construct a suitable sized pond situated near villages as a facility for community use with an inlet and an outlet to the river bank. And, to better design the suitable river related structures, the relationship between people along the Yao River and river both in wet and dry seasons should be carefully studied by community development specialist.

Also, a flood warning system with a siren or other means shall be properly planned and installed for each village in case for the emergency of extreme flood from the Flood Control Dam.