CHAPTER 6. FORMULATION OF THE MASTER PLAN

6.1 Selection of Applicable Measures

Based on the evaluation results, the applicable measures are selected for the formulation of the Master Plan.

6.1.1 Upper Central Plain and Nakhon Sawan Areas

Except the modification of reservoir operation rule, it seems to be not necessary to discuss the applicability of nonstructural measures in these areas, judging from the features and effectiveness. On the other hand, it is necessary to confirm the applicability of river improvement. The applicability of modification of reservoir operation rule and river improvement is therefore examined here in a quantitative manner.

(1) Modification of Reservoir Operation Rule

To evaluate the effectiveness in a quantitative manner, modification of the reservoir operation rules of the Bhumibol, Sirikit, Kwae Noi, Kaeng Sua Ten and Pasask dams was examined in three cases of flood control capacity: 7,400 million m^3, 10,700 million m^3 and 14,600 million m^3. This measure brings about the effectiveness in a manner of mitigation of flood discharge as the benefit, while it affects the reservoir operation for irrigation purposes and hydropower generation by the reduction of irrigation area and capacity for hydropower generation that must be compensated as the cost.

Since this measure has an effectiveness to mitigate the flood damage not only these areas, but also in the higher and lower delta in lower central plain, the applicability cannot be identified from the effectiveness in these areas alone. However, as shown in Table 5.3.1, the effectiveness of the measure is high, judging from the cost-effectiveness. Hence, the measure in case of 14,600 m^3 of flood control capacity was selected for the master plan.

(2) River Improvement

To identify the applicability of river improvement, the design discharge distribution in the river channel was examined in several cases of return period and also in case of with and without retarding effect situations. The design discharge distribution was obtained based on the simulation results for 45 floods as presented in Figs. 6.1.1 and 6.1.2. Fig. 6.1.1 is the caseswithout retarding, where the river improvement is solely applied. Fig. 6.1.2 shows the probable discharge distribution with harmless retarding to be attained by the flood distribution system improvement.

Comparing Figs. 6.1.1 (1/2) and (2/2), the adverse influences of river improvement in this area are understood. If the river improvement of 5-year return period flood in this area is made, the discharge at Chao Phraya Dam will increase from 3,100 m^3/s to 4,400 m^3/s. Hence, it is necessary to provide measures to absorb the increase of flood discharge. As the measures to absorb such influences, the artificial retarding basin and diversion channel are considered. However, they require a huge cost or huge sacrifice in the area downstream to absorb about 1,300 m^3/s of discharge increase. Therefore, it is not practically feasible to apply the river improvement together with the measures to absorb the adverse influence in these areas.

6.1.2 Higher Delta in Lower Central Plain

In this area, it is not necessary to discuss the necessity of nonstructural measures including the modification of reservoir operation rule. The applicability of the following structural measures was examined in a quantitative manner: river improvement, diversion channel, nd mitigation measure of damage in the paddy field.

(1) River Improvement

Based on the design discharge distribution shown in Fig. 6.1.2(2/2), the river improvement within an allowable extent so as not to cause serious adverse influence to the downstream is herein discussed.

As to the allowable extent, the flow capacity at Bangkok of about 3,600 m^3/s after construction of flood barrier is adopted as an indicator. The 10-year design discharge below Bang Sai coincides with the flow capacity of 3,600 m^3/s. This means that this 10-year river improvement with retarding might be the maximum development acceptable for the Bangkok metropolitan area. If the discharge distribution of the 10-year improvement is compared with the existing flow capacity in Fig. 3.3.2, it can be understood that a flow capacity increase of 800 m^3/s at the maximum is necessary at some portions below Bang Sai to upgrade the present capacity to the 10-year level.

Moreover, it is considered to further improve the river channel from 10-year to the 25-year level. In this case, it is also necessary to provide some measures to absorb the adverse influence in the downstream of about 300 m^3/s of discharge over the flow capacity at Bangkok by a diversion channel (Ayuthaya - East Bank - Sea route; refer to Fig. 5.1.2).

However, such diversion which aims to mitigate the flood damage only in agricultural areas is not so attractive from the economical point of view, while it may cause a huge social problem like house relocation. On the other hand, as discussed later, when such diversion is used to mitigate the flood damage in both the agricultural areas and Bangkok, it may be applicable even from an economical point of view.

(2) Diversion Channel

As an alternative to the river improvement, it is considered to apply only the diversion channel with a capacity of about 800 m^3/s to mitigate flood damage in agricultural areas. The route of the diversion channel is considered to be the Chianat-Pasak-Raphipat-Sea route.

Since the diversion channel is also effective to enhance the safety level at Bangkok, the effectiveness considering such aspect should be examined to identify the applicability. However, the applicability of the diversion channel may be low considering the cost and effectiveness compared with the case of river improvement (refer to Tables 6.1.1 and 6.1.2).

(3) Mitigation Measures of Flood Damage in Paddy Field

The agricultural areas contribute much to mitigation of the flood peak discharge in the Chao Phraya River as discussed in Subsection 5.3.3. On the other hand, the paddy fields suffer from habitual inundation, resulting in serious flood damage.

To mitigate such flood damage in paddy field, it is considered to improve the inundation water distribution system. Through the improvement of such system, about 30% of the present flood damage would be mitigated.

6.1.3 Lower Delta in Lower Central Plain

In this area, it is also not necessary to discuss the necessity of nonstructural measures and measures for flood damage mitigation in agricultural areas. The applicability of the following measures or options is discussed in a quantitative manner or qualitative manner.

(1) Mitigation of Adverse Influence due to Protection Works of Urban Areas

To assure the safety level at Bangkok, six (6) options are conceived (refer to Figs. 6.1.3 and 6.1.4). The advantage and disadvantage are as follows (refer to Table 6.1.3):

(b) Option-1: To maintain the present condition for Pathum Thani and Nontaburi (Not to implement protection works)

As noted from the title, the option is not to implement protection works for these urban areas. From this situation, the present safety level evaluated as about 2 to 3-year return period shall be maintained in the future, while the safety level at Bangkok would be about a 125-year return period because of the effectiveness of loop-cut. For this option, the following advantage and disadvantage are conceived:

- As the advantage, from economical and environmental points of view, there may be no issue derived from this option.
- However, from the social point of view, inhabitants in the urban areas of Pathum Thani and Nonthaburi will not accept to maintain the present safety level in the future.
- Besides, the option cannot cope with the situation to enhance the protection level of agricultural area in the upstream in the future. (Under this option, it is almost impossible to enhance the safety level of agricultural area from 10-year return period to 25-year return period.)

(b) Option-2: To enhance the safety level only up to the level in which an adverse influence to Bangkok is not expected so much

Since the protection level at Bangkok is slightly higher than a 100-year return period (125-year return period), it may be possible to enhance the safety level at Pathum Thani and Nonthaburi by lowering the safety level at Bangkok from 125-year return period to 100-year return period. According to rough estimation results, the safety level at Pathum Thani and Nonthaburi can be enhanced up to a 5-year return period from 2 to3-year return period, although that of Bangkok will be a 100-year return period. For this option, the advantage and disadvantage are the same as in Option-1.

(c) Option-3: To lower the safety level at Bangkok from 125-year return period to a certain level, e.g., 50-year return period, and slightly enhance the safety level for Pathum Thani and Nonthaburi

By lowering the safety level at Bangkok to a 50-year return period, that of Pathum Thani and Nonthaburi can be enhanced up to a 7-year return period. At this situation, however, the advantage and disadvantage are still similar to those of Option-1 and Option-2.

(d) Option-4: To narrow down the protection area for Pathum Thani and Nonthaburi

To narrow down the protection area to only a part of Nonthaburi, it is possible to protect the narrowed area with a 100-year return period without causing serious adverse influence to Bangkok. However, the remaining areas of Pathum Thani and Nonthaburi should maintain the present safety level in the future. From this situation, the advantage and disadvantage are still similar to those in the above options.

(e) Option-5: To heighten the flood barrier at Bangkok

To heighten the flood barrier at Bangkok for about 30 cm, it is possible to absorb the adverse influence due to protection works at Phatum Thani and Nonthaburi. The option involves the following advantage and disadvantage:

- From the technical point of view, this measure is to absorb the adverse influence of increase of flood discharge at Bangkok due to protection works for Pathum Thani and Nonthaburi. This alternative may enhance the protection level in the upstream area to a certain extent.
- From the economical point of view, the works can be done with relatively less cost compared with the diversion channel discussed later.
- From the environmental and social points of view, however, this option will cause serious issues judging from the difficulty of construction of the currently proposed flood barrier. (This option

will hamper the daily activities of inhabitants who fully use the Chao Phraya River for their daily life activities, and heightening of the barrier will prevent the inhabitants and tourists from enjoying the scenery of the Chao Phraya River.)

(f) Option-6: To provide a diversion channel

Through construction of a diversion channel with the capacity of 800 for Pathum Thani and Nonthaburi as shown in Table 6.1.4. For this option, the following advantage and disadvantage are conceived:

- From the technical point of view, this is the only alternative that can provide the opportunity for enhancement of protection level in the upstream area while satisfactorily protecting the downstream area.
- From the environmental point of view, issues derived from the works may be solved, although it may not be an easy work.
- From the economical point of view, however, the works will require a huge cost.
- Also from the social point of view, this option will cause issues on land acquisition and house evacuation.
- As for the enhancement of protection level for the agricultural area in the upstream in the future, this option can cope with the expanded capacity as discussed in Subsection 5.3.3. (To enhance safety level in agricultural areas in higher and lower deltas from a 10-year return period to the 25-year return period, it is necessary to further expand the capacity of the diversion channel from 800 to 1,100 m^3/s, as shown in Table 6.1.4.)
- Besides, the option can be used a large-scale multipurpose infrastructure for regional development such as transportation, water resources development, land and town planning, etc.

To select the suitable one among these options, it is necessary to thoroughly discuss it with the agencies concerned. In this study, Option-4 (partial protection of Pathum Thani and Nonthaburi) is proposed as Alternative-1, and Option-5 (heightening of flood barrier) and Pption-6 (diversion channel) are proposed as Alternative 2-1 and Alternative 2-2, respectively, from the following reasons:

- Considering the current urbanization and future development in these areas, it is necessary to assure the safety level for the protection of urban areas in the future, and it may be difficult to have varying protection levels among these urban areas. (For Option 1, 2 and 3)
- Although it may be difficult to delineate areas to be protected and not to be protected in Pathum Thani and Nonthaburi, this option can enhance the protection level of urban areas without serious adverse influence to the downstream and with less cost. (For Option 4)

- Although it is also difficult to implement the heightening of flood barrier from the social and environmental viewpoints, it may not involve serious issues from the economical and technical points of view. (For Option 5)
- Construction of diversion channel is not an easy work from the economical and social viewpoints. However, this measure can also be used to enhance the safety level for agricultural areas. This seems to be the ultimate solution to enhance the safety level for urban areas including Bangkok and the agricultural areas. (For Option 6)

(2) Further Comparison among Alternatives

As mentioned earlier, to select the suitable measures, it is necessary to thoroughly discuss it with the agencies concerned as well as the people concerned and it may not be an easy task due to social issues involved in each alternative.

Herein, further comparison among alternatives is made for further consultation among people concerned from the following viewpoints:

(a) Comparison from Technical, Economical, Environmental and Social Aspects

For the comparison from technical, economical, environmental and social aspects, the following sub-items are taken into consideration. Comparison results are shown in Table 6.1.5 and 6.1.6.

(i) Technical Aspect

- Technical difficulty of construction
- Influence to the enhancement of flood damage potential
- Influence to inland drainage in urban area
- Contribution to drainage system improvement in lower delta area (east bank area)
- Possibility to cope with the situation for enhancement of safety level in the upstream (river improvement in upstream)

(ii) Economic Aspect

- Construction cost
- Benefit

(iii) Environmental Aspect

- Natural environment

(iv) Social Aspect

- House evacuation and land acquisition
- People affected, who live and/or engage in business activities in riparian area

- People and assets which are not protected
- Influence to tourism industry
- Contribution to regional development

(v) Others

- Contribution to water resources development
- Contribution to transportation system improvement

(b) Comparison from Point of View of Affected and Beneficial Areas

Besides the above, the comparison was done from the point of affected and beneficial areas for the following areas: Ayuthaya, Pathum Thani, Nonthaburi, Bangkok, Samut Prakan and upstream of Ayuthaya to Chainat. The comparison results are shown in Table 6.1.7.

(3) Mitigation Measures of Flood Damage in Paddy Field

As in the higher delta, it is necessary to mitigate flood damage in the paddy fields. In this area, it is possible to mitigate the damage through drainage system improvement, although it may be difficult to further distribute the inundation water to mitigate the flood damage. Since the drainage to the Chao Phraya River in the flood season is substantially difficult, it is considered to drain the inundation water to the sea.

To identify the effectiveness of the drainage system improvement, several alternative cases of drainage system improvement by widening and deepening the present channels were examined applying the simulation model to the 1983, 1995 and 1996 floods (refer to Fig. 5.3.5).

According to the simulation results, the improvement of drainage system is considerably effective to mitigate inundation volume and duration, so that flood damage could be mitigated, although water depth is not drastically lowered in such a big flood as in 1983.

The longer channel can reduce inundation in the upper deep inundation areas. However, in terms of economic effectiveness expressed by the ratio of decrease of flood damage to cost, the shorter and smaller channel is advantageous.

Hence, the smallest capacity of 75 m^3/s is applied as the suitable case. By this drainage system improvement, about 30% of the damage in the area can be mitigated.

6.1.4 Summary of Measures Applied to the Master Plan

As a result, the following measures are applied to the Master Plan (refer to Tables 6.1.8 and 6.1.9 and Figs. 6.1.5, 6.1.6 and 6.1.7).

(1) Upper Central Plain and Nakhon Sawan Area

(a) Nonstructural Measures

The following nonstructural measures are applied to the Master Plan:

- Land use control and guidance
- Modification of reservoir operation rule
- Other nonstructural measures (flood forecasting and warning system, flood fighting, disaster recovery, subsidy, flood insurance, watershed management, and institution and organization)

(b) Structural Measurers

For this area, no structural measure is included in the Master Plan, except protection works for urban areas by PWD.

(2) Higher Delta in Lower Central Plain

(a) Nonstructural Measures

All nonstructural measures adopted in the higher central plain and Nakhon Sawan areas are applied to the Master Plan.

(b) Structural Measurers

For this area, river improvement and measures for damage reduction in paddy fields as well as protection works for urban areas are applied.

(i) River improvement

River improvement is undertaken in two (2) stages. Stage 1 is prompt implementation with a 10-year return period in combination with the improvement of floodwater distribution. The possibility to further enhance the safety level to the 25-year return period depends on the selection of options. In case of Alternative 1 and Alternative 2-1, river improvement to further enhance the safety level is not applicable. In case of Alternative 2-2, the river improvement is expanded in Stage 2 to the safety level of 25-year return period. However, the implementation of Stage 2 is proposed after the diversion channel is ready to absorb the adverse influence.

(ii) Damage Mitigation in Paddy Field

For the damage mitigation in paddy fields, the distribution system improvement for inundation water is considered.

(3) Lower Delta in Lower Central Plain

(a) Nonstructural Measures

All nonstructural measures adopted in the higher central plain and Nakhon Sawan areas are applied to the Master Plan and, furthermore, control of ground water extraction is added.

(b) Structural Measurers

In this area, the measures for damage reduction in paddy fields as well as protection works for urban areas are applied. As for the measures to absorb the influence of increase of discharge to Bangkok due to protection works for Pathum Thani and Nonthaburi, two options, Alternative 2-1 (heightening of flood barrier) and Alternative 2-2 (diversion channel) are considered. On the other hand, partial protection for these areas does not need the measures to absorb the influence.

In case of Alternative 2-2, diversion channel is to be implemented in two (2) stages. However, only Stage 1 is concerned in flood damage mitigation in this area, while Stage-2 is implemented to absorb the adverse influence of protection of agricultural areas by river improvement as aforementioned.

6.2 Alternatives of Master Plan

In this study, the Master Plan is formulated to consist of structural and nonstructural measures as shown in Fig. 6.1.5. In the Master Plan for flood mitigation in the urban areas of Phathum Thani, Nonthaburi and Bangkok, three (3) alternatives are provided; namely, Alternative 1, partial protection of Pathum Thani and Nonthaburi; Alternative 2-1, heightening of flood barrier at Bangkok; and Alternative 2-2, construction of diversion channel.

The difference in measures applied in these alternatives is only the way of flood mitigation in the urban areas. The other measures are commonly applied to these three options (refer to Fig. 6.1.5)

6.2.1 Alternative-1: Partial Protection of Pathum Thani and Nonthaburi

(1) Cost, Preliminary Design and Implementation Schedule

(a) Economic Cost and Benefit

It is possible to estimate only the economic cost and benefit. The other components are difficult to be evaluated in monetary term. Details of the costs are given in Table 6.2.1.

Project Component	Economic Cost (mil. Baht)		Benefit (mil. Baht)
	Initial	O&M	
Modification of Dam Operation Rule	40	394	3,268/year
Distribution and drainage system improvement	5,633	39	
River improvement	1,234	31	
Total	6,907	464	

(b) Preliminary Design and Implementation Schedule

(i) Preliminary Design

Among the project components, preliminary design is prepared for only the structural measures; i.e., river improvement and distribution and drainage system improvement. As for the distribution and drainage system improvement, only the area is shown in Figs.5.3.4 and 5.3.5.

Preliminary design of river improvement is made in the following manner:

Alignment

The alignment of the river improvement is set based on the existing channel. As for the alignment of dike for agricultural areas along the river channel, the following cases are conceived:

- Case-1: Alignment based on the bank of existing channel, in which PWD is to provide ring levee for protection of urban areas.
- Case-2: Alignment based on the dike of irrigation channel or road that play the role of dike, located in parallel with the existing channel.
- Case-3: Combination of Case-1 and Case-2.

The major differences among these 3 cases are the river widths, which influence the number of house relocation and the decision on design water height.

In this study, Case-2 is adopted to minimize the number of house relocation and social impact to inhabitants along the river course (refer to Fig. 6.2.1.).

Longitudinal Profile

The longitudinal profile is set based on that of the existing channel.

Design water level is set based on the water level calculated by non-uniform calculation applying the design discharge (refer to Fig. 6.2.2.).

Cross Section

The cross section is based on the dike of irrigation channel or road, but with heightening of dike up to the design dike height consisting of design water level and clearance (refer to Fig.6.2.1 and 6.2.3).

(ii) Implementation Schedule

In principle, the implementation schedule is prepared considering the following points:

- Flood damage in paddy fields can be mitigated with less cost if a detailed study is completed to prepare a guideline and an improvement plan of necessary facilities for floodwater distribution. Thus, a high priority is given to the implementation.
- River improvement can be implemented up to the level with 10-year return period by minimizing the adverse influence to Bangkok through the utilization of retarding effects. Thus it can be given a higher priority.
- The partial protection works of Pathum Thani and Nonthaburi should be undertaken considering the progress of loop-cut at Bangkok Port by RID.

Under the above considerations, the implementation schedule is prepared, as shown in Fig. 6.2.4.

(2) Evaluation of the Master Plan

(a) Economic Evaluation

The economic evaluation is made only for project components that can be evaluated in monetary term based on the economic cost and benefit mentioned above. The evaluation is made in a manner of EIRR, B-C and B/C, as shown below (refer to Table 6.2.2):

- EIRR= 21.1 % (excluding modification of reservoir operation rule)
- B-C= 5,875 million Baht
- B/C= 2.4

In the case of modification of reservoir operation rule, EIRR is not a suitable index to identify the economic viability. This is because the project brings about constant benefit and cost from the beginning (Bn and Cn are constant), so that EIRR shown in the following equation is infinite.

$$\Sigma[Bn / (1+i)] / \Sigma[Cn / (1+i)] = 1$$

Where,

Bn : Annual benefit of n-th year from the beginning

Cn : Annual cost of n-th year from the beginning

I : EIRR

Σ : Accumulation of benefit and cost for whole years in project life.

As identified, the economic viability evaluated by EIRR is high enough; over 12%. Thus, Alternative-1 is economically viable.

Also, the project involves many intangible benefits such as stabilization of people's living condition, decrease of waterborne diseases, increase of work opportunity and so on.

From the financial point of view, the source of the cost is assumed to be the government budget, which roughly amounts to the total annual budget of 96.5 billion bahts, i.e., 44.4 billion bahts for RID, 39.8 billion bahts for PWD and 12.3 billion bahts for BMA (Bangkok Metropolitan Authority). The annual cost assuming repayment period of 20 years roughly corresponds to 0.9% of the annual budget. The government budget will be fulfilled by increase of government income resulting from the increase of productivity in the river basin due to flood damage mitigation. (refer to Table 6.2.3).

(b) Technical Soundness and Social Acceptability

The project components are based on the conventional structural measures such as earth works. These measures do not face any technical difficulty.

On the other hand, river improvement may have social issues due to relocation of inhabitants in the areas where these measures are proposed. In this connection, it is natural to obtain a favorable public opinion through meetings and seminars for the decision on project implementation, so that the inhabitants can fully understand the significance and necessity of the project. By this method, it seems to be possible to receive social acceptability.

(c) Environmental Sustainability

Initial Environmental Examination (IEE) has been conducted for the structural measures of project components to confirm the environmental sustainability of the Master Plan; i.e., river improvement and distribution and drainage system improvement. IEE was conducted based on the customized parameters prepared in this study.

As the result, the IEE found that these measures may not bring significant impacts from the ecological point of view, but may have impacts on sites and the surroundings from the social point of view. Therefore, it is crucial to pay attention to the mitigation of such social impacts and it is assumed that the solution can be obtainable through continuous communication with affected people.

6.2.2 Alternative 2-1: Heightening of Flood Barrier at Bangkok

(1) Cost, Preliminary Design and Implementation Schedule

(a) Economic Cost and Benefit

It is possible to estimate the economic cost and benefit for only the following components. The other components are difficult to be evaluated in monetary term. Details of the costs are given in Table 6.2.4.

Project Components	Economic Cost (mil. Baht)		Benefit (mil. Baht)
	Initial	O&M	
Modification of Dam Operation Rule	40	394	4,838/year
Distribution and drainage system improvement	5,633	39	
River improvement	1,234	31	
Heightening of flood barrier	1,493	12	
Total	8,400	476	

(b) Preliminary Design and Implementation Schedule

(i) Preliminary Design

Among the project components, preliminary design is prepared for only the structural measures; i.e., river improvement. As for the distribution and drainage system improvement, only the area is shown in Fig. 5.3.4 and 5.3.5.

Preliminary design of river improvement is made in the following manner:

<u>Alignment</u>

The alignment of river improvement is set in the same manner as Alternative-1.

<u>Longitudinal Profile</u>

The longitudinal profile is set based on that of the existing channel.

Design water level is set based on the water level calculated by non-uniform calculation applying the design discharge (refer to Fig. 6.2.2.).

Cross Section

The cross section is set in the same manner as Alternative-1.

(ii) Implementation Schedule

In principle, the implementation schedule is prepared considering the following points:

- Flood damage in paddy fields can be mitigated with less cost if a detailed study is completed to prepare a guideline and an improvement plan of necessary facilities for the floodwater distribution. Thus, a high priority is given to the implementation.

- River improvement can be implemented up to the level with 10-year return period by minimizing the adverse influence to Bangkok through the utilization of retarding effect. Thus it can be given a higher priority.

- Currently proposed heightening of flood barrier is ongoing by BMA and is expected for completion by year 2002. Hence, further heightening should be undertaken after the current heightening of barrier is almost complete.

- In this connection, the protection works for Pathum Thanin and Nonthaburi should be undertaken considering the progress of heightening of flood barrier at Bangkok.

Under the above considerations, the implementation schedule is prepared, as shown in Fig. 6.2.5.

(2) Evaluation of the Master Plan

(a) Economic Evaluation

The economic evaluation is made only for project components that can be evaluated in monetary term based on the economic cost and benefit mentioned above. The evaluation is made in a manner of EIRR, B-C and B/C, as shown below (refer to Table 6.2.5):

- EIRR = 24.0% (excluding modification of reservoir operation rule)

- B-C = 9,014 million Baht

- B/C = 2.9

As identified, the economic viability evaluated by EIRR is high enough; over 12%. Thus, Alternative 2-1 is economically viable.

Also, the project involves many intangible benefits such as the stabilization of people's living condition, decrease of waterborne diseases, increase of work opportunities and so on.

From the financial point of view, the source of the cost is assumed to be the government budget, which roughly amounts to the total annual budget of 96.5 billion bahts, i.e., 44.4 billion bahts for RID, 39.8 billion bahts for PWD and 12.3 billion bahts for BMA (Bangkok Metropolitan Authority). The annual cost assuming repayment period of 20 years roughly corresponds to 0.9% of the annual budget. The government budget will be fulfilled by increase of government income resulting from the increase of productivity in the river basin due to flood damage mitigation (refer to Table 6.2.3).

(b) Technical Soundness and Social Acceptability

The project components are based on the conventional structural measures such as earth works and the piling of blocks on top of the present barrier. These measures do not face any technical difficulty.

On the other hand, the heightening of flood barrier may have social issues, since the works will hamper the activities of inhabitants who fully use the Chao Phraya River for their daily life activities. River improvement also may have social issues due to the relocation of inhabitants in the areas where these measures are proposed. In this connection, it is natural to obtain a favorable public opinion through the meetings and seminars for the decision on project implementation, so that the inhabitants can fully understand the significance and necessity of the project. By this method, it seems to be possible to receive social acceptability. (c)Environmental Sustainability

Initial Environmental Examination (IEE) has been conducted for the structural measures of project components to confirm the environmental sustainability of the Master Plan; i.e., river improvement, distribution and drainage system improvement and heightening of flood barrier. IEE was conducted based on the customized parameters prepared in this study.

As the result, the IEE found that these measures may not bring significant impacts from the ecological point of view, but may have impacts on sites and the surroundings from the social point of view. The heightening of flood barrier, which would interfere with the enjoyment by inhabitants and tourists of the nice landscape of the Chao Phraya River may bring serious impacts from the social point of view. Therefore, it is crucial to pay attention to the mitigation of such social impacts and it is assumed that the solution is obtainable through continuous communication with the affected people.

6.2.3 Alternative 2-2: Diversion Channel

(1) Cost, Preliminary Design and Implementation Schedule

(a) Economic Cost and Benefit

It is possible to estimate the economic cost and benefit for only the following components. The other components are difficult to be evaluated in monetary term. Details of the costs are given in Table 6.2.6.

Project Components	Economic Cost (mil. Baht)		Benefit
	Initial	O&M	(mil. Baht)
Modification of Dam Operation Rule	40	394	6,300/year
Distribution and drainage system improvement	5,633	39	
River improvement	2,821	71	
Diversion channel	31,402	167	
Total	39,896	671	

(b) Preliminary Design and Implementation Schedule

Among the project components, preliminary design is prepared for only the structural measures; i.e., diversion channel, river improvement and distribution and drainage system improvement.

(i) Preliminary Design

Among the project components, preliminary design is prepared for only structural measures; i.e., diversion channel and river improvement. As for the distribution and drainage system improvement, only the area is shown in Fig. 5.3.4 and 5.3.5.

Preliminary design of river improvement is made in the same manner as the case for agricultural area of Alternative-1.

Preliminary design of diversion channel is made in the following manner:

<u>Alignment</u>

The alignment of the diversion channel is set considering the following points:

- Utilization of existing channel passing through lowland area
- Minimization of house relocation

For the setting of alignment, photo mosaic map with a scale of 1/50,000 is used. The total length of diversion channel is approximately 96 km. The alignment is shown in Fig. 6.2.6.

Longitudinal Profile

The longitudinal profile is set based on that of ground height along the alignment. The ground height is obtained from the topographic map with the scale of 1/50,000 and 1/20,000.

Design water level at the river mouth adopts that of the Chao Phraya River: M.S.L+1.6m, while the design water level at diversion point is MSL+3.85m. The average gradient of high water level connecting two points is 1/43,000.

Standard Cross Section

The standard cross section is set considering the following points: stability and safety of channel and economic advantage. Hence, the compound cross section type is adopted:

Current area is mainly composed of excavated channel to have enough water depth, so that river width can be minimized.

(ii) Implementation Schedule

In principle, the implementation schedule is prepared considering the following points:

- Flood damage in paddy fields can be mitigated with less cost if a detailed study is completed to prepare a guideline and an improvement plan of necessary facilities for the floodwater distribution. Thus, a high priority is given to the implementation.
- River improvement can be implemented up to the level with 10-year return period by minimizing the adverse influence to Bangkok through the utilization of retarding effect. Thus it can be given a higher priority.
- However, to further enhance the protection level for agricultural areas, the river improvement should be implemented under the condition that the diversion channel is completed to absorb the adverse influence to the area downstream, especially the Bangkok metropolitan area.
- In this connection, the implementation of river improvement to enhance the protection level from 10-year to 25-year return period should be started after the diversion channel is ready to absorb the adverse influence.
- As for the protection works for Pathum Thani and Nonthaburi by PWD, they should be undertaken considering the progress of diversion channel Stage-1 to assure the safety level for Bangkok.

Under the above considerations, the implementation schedule is prepared, as shown in Fig. 6.2.7.

(2) Evaluation of the Master Plan

(a) Economic Evaluation

As well as Alternative-1, the economic evaluation is made only for project components that can be evaluated in monetary term based on the economic cost and benefit mentioned above. The evaluation is made in a manner of EIRR, B-C and B/C, as shown below (refer to Table 6.2.7):

- EIRR = 12.0% (excluding modification of reservoir operation rule)
- B-C = 1,427 million Baht
- B/C = 1.1

As identified, the economic viability is not so high, but the EIRR value is slightly over 12%, which is regarded as the minimum of project viability.

Also, the project involves many intangible benefits such as the stabilization of people's living condition, decrease of waterborne diseases, increase of work opportunities and so on.

From the financial point of view, the project requires about 2.6 billion bahts per annum for the implementation within 20 years, which roughly corresponds to 3.1% of the total annual government budget of 96.5 billion bahts for RID (44.4 billion bahts), PWD (39.8 billion bahts) and BMA (12.3 billion bahts). The government budget will be fulfilled by increase of government income resulting from the increase of productivity in the river basin due to flood damage mitigation (refer to Table 6.2.3).

(b) Technical Soundness and Social Acceptability

The project components are based on the conventional structural measures such as excavation and embankment. These measures do not face any technical difficulty.

On the other hand, the diversion channel and river improvement may have social issues due to relocation of inhabitants in the areas where these measures are proposed. In this connection, it is natural to obtain a favorable public opinion through the meetings and seminas for the decision on project implementation, so that the inhabitants can fully understand the significance and necessity of the project. By thismethod, it seems to be possible to receive social acceptability.

(c) Environmental Sustainability

Initial Environmental Examination (IEE) has been conducted for the structural measures of project components to confirm the environmental sustainability of the Master Plan; i.e., natural retarding basin, river improvement and diversion channel. IEE was conducted based on the customized parameters prepared in this study.

As the result, the IEE found that the natural retarding basin, river improvement and diversion channel may not bring significant impacts from the ecological point of view, but may have impacts on sites and the surroundings from the social point of view. Therefore, it is crucial to pay attention to the mitigation of such social impacts and it is assumed that the solution is obtainable through continuous communication with the affected people.

6.3 Selection of Project Components for the Feasibility Study

Priority projects were selected for the feasibility study. As shown in the implementation schedule in Figs. 6.2.4, 6.2.5 and 6.2.7, it is proposed to implement or adopt most of the project components of the Master Plan after this study. However, in the case of Alternative 2-1, heightening of flood barrier, and Alternative 2-2, diversion channel (Stage-1 and 2) and river improvement (Stage-2) are excluded due to time constraint and difficulty of selection of the optimum solution.

Among the project components that should be promptly implemented, some do not require a feasibility study, because they are now under the preparation stage for implementation by the Government or they should be studied in other projects judging from the project features.

Under such consideration, the following project components were selected for the Feasibility Study:

(1) Nonstructural Measures

Under the category of nonstructural measures, land use control and guidance based on flood risk map, modification of reservoir operation rule, and institution and organization are selected, because all these measures are essential to achieve the target of the comprehensive flood mitigation and they are necessary to promptly and further examine applicability.

(2) Structural Measures

Under the category of structural measures, river improvement (Stage-1) is selected from the following reasons:

- To promptly realize the flood mitigation in agricultural areas, river improvement is one of the essential measures.
- However, river improvement in the upstream may cause adverse influence to the downstream.
- In this connection, it is necessary to identify the allowable extent for river improvement as early as possible and to implement it within such an extent.

Regarding the partial protection of Phatum Thani and Nonthaburi, it is proposed that the project be conducted by PWD in the context of the currently ongoing study.

As for distribution and drainage system improvement, it is recommended that the the local government shall undertake the study for the following reasons:

- The distribution and drainage system improvement covers a wide area of more than 10,000 km^2. In this area, the irrigation and drainage system are composed of a tremendous number of channels and the paddy field is divided into a huge number of units.
- To further examine the effectiveness of distribution and drainage system improvement, it is necessary to prepare a detailed topographic map to include such irrigation and drainage systems.
- Furthermore, the hydraulic calculation model to reflect such area conditions needs to be newly developed.
- It will take a long time to cover such works including topographic survey and development of a new model but the scheduled study period is very limited, so that enough study was hardly undertaken.
- On the other hand, the effectiveness of distribution and drainage system improvement can be confirmed through daily practice of operation and management, and development of the system can be gradually promoted by confirming the effectiveness. For this purpose, the basic study by area should be conducted, but this is not included in the feasibility study.

6.4 Farmland Drainage Improvement

In the Master Plan, the study is conducted, putting more emphasis on flood mitigation of basin-wide flood. On the other hand, there are many areas that have flooding problems in the local areas due to local rainfall as well as overflow from the main rivers. In this section, discussion is made on the drainage system improvement for farmland in the Chao Phraya Delta to mitigate the flood damage in local areas.

6.4.1 Outline of the Study

The study procedure for the drainage system for farmland was in principle considered as follows:

- Confirmation of the study area
- Division of the study area
- Study on features of the area from drainage point of view considering topographic conditions and land use conditions
- Identification of main issues on flood in the drainage area
- Study on the measures to mitigate the flood damage
- Prioritization of the implementation of mitigation measures.

(1) Confirmation of Study Area

In the Chao Phraya River basin, the areas that have inland drainage problems widely spread in the whole basin. Among them, the drainage improvement study in areas located in the Chao Phraya River delta in the downstream is discussed herein, because covering the whole areas may not be realistic to reach a reasonable conclusion. The drainage improvement problem in the downstream seems to be more of economic considerations judging from the scale of such areas.

(2) Division of the Study Area

Judging from the river channel system and topographic conditions, the study area can be broadly divided into two areas; higher delta and lower delta, which are in turn divided into the following areas. These areas are further divided into several RID Project areas, as shown in Fig. 6.4.1.

(a) Higher Delta

- The northern part of the area surrounded by Tha Chin and Noi rivers
- The area surrounded by Noi and Chao Phraya rivers
- The area surrounded by Chao Phraya and Lop Buri rivers
- The area surrounded by Lop Buri and Pasak rivers

(b) Lower Delta

- The east bank areas of the Chao Phraya River
- The west bank areas of the Chao Phraya River

(2) Study on features of the divided areas from the drainage point of view considering topographic and land use conditions

The features of the divided areas were examined from the drainage point of view; i.e., catchment area, general slope of the areas, main drainage outlet, land use condition, etc. Features of the study area are shown in Table 6.4.1. According to this table, the features of the drainage area are emphasized as follows:

- The total drainage area is more than 10,000 km^2.
- The slope gradient is quite gentle, especially that of the lower delta. In the higher delta it is 1/4,000 to 1/5,000, while in lower delta, it is only 1/50,000 to 1/60,000.
- The main drainage outlets of these drainage areas are the rivers such as Chao Phraya, Tha Chin, Lop Buri and so on as well as the sea.
- At the drainage outlets of some drainage areas, drainage flume is provided with the total capacity of 467 m^3/s.
- These drainage areas, in general, receive overflow water from rivers.
- Flood damage magnitude may be much serious in the lower delta compared with that in the higher delta.
- Main land uses of the drainage areas are paddy with HYV, F/R and DWR and fruit tree.

(3) Identification of main issues on drainage

In the divided areas, the main issues on drainage from the aspects of main causes and drainage conditions were identified as below:

(a) Main Cause of Flood

From the aspect of main causes of flood, the following issues are considered:

- Heavy local rainfall
- Water from other project areas located upstream
- Overflow from rivers

(b) Drainage Condition

- Poor inland drainage channel capacities; i.e., the flood discharge by local rainfall cannot be collected in the drainage channel
- Flat plain; i.e., the inundation water is hardly transferred to the drainage outlet
- Continuation of the high water level of outlet; i.e., inland water cannot be drained out

Main drainage issues are shown in Table 6.4.2 and Fig. 6.4.2. Judging from the table, the main drainage issues are emphasized as follows:

- Local rainfall is the main drainage issue common to every drainage area.
- Furthermore, some drainage areas receive inundation water from other drainage areas located upstream.
- Also overflow from rivers deteriorate the drainage issues.
- In general, the drainage system is relatively in fair condition as long as the drainage channel is concerned.
- One of the serious issues is the difficulty to collect inland water to the outlet point due to very gentle gradient, especially in the lower delta.
- Also continuation of higher water level at outlet results in the difficulty of drainage.

(4) Study on Measures to Mitigate Flood Damage

After the identification of main issues, the measures to cope with the flood damage were examined. The conceivable measures are as follows:

- Improvement of drainage channel
- Installation of drainage pump
- Provision of retarding basin
- Construction of new drainage channel

- Drainage to the area in the downstream
- Heightening of dike to prevent overflow from the river channel

Possible conceivable measures for each project area are shown in Table 6.4.3 and Fig. 6.4.3.

From the table, the following points are specified:

- In principle, in accordance with the concept of the "Monkey Cheek", the preservation of present retarding effect will be a basis so as not to cause adverse influence to the other drainage areas.
- However, the development of certain drainage areas may be avoidable. To fulfill the reduction of retarding effect, the provision of retarding area and drainage channel improvement will be necessary.
- Further, to mitigate the present drainage issues, it is considered to improve the present drainage system in combination with the installation of drainage channel, heightenning of dike and construction of new drainage channel.

(5) Prioritization of Implementation of Drainage System Improvement

In general, prioritization is made considering the significance of issues, economic efficiency, etc. However, the area covered by this study is so large that the optimum measures as well as the construction cost and economic benefit cannot be identified. In this study, prioritization of implementation of drainage system improvement has been examined considering the drainage issues, and the implementation schedule according to priority has been prepared.

6.4.2 Consideration of Priority of Areas for Implementation

In this subsection, the priority of areas for implementation of the drainage system improvement is discussed. In such areas, the drainage problem is very severe and complicated, so that it is not an easy task to arrange the priority of implementation of drainage system improvement, unless a more detailed survey is undertaken. A rough evaluation of flood inundation was made as described below.

(1) Rough Evaluation based on Hydraulic Conditions

For the prioritization of divided areas, the hydraulic condition was roughly examined to evaluate the necessity of drainage system improvement in the following procedure:

- Comparison of ground height of the drainage areas and river water level at the drainage outlet point. (The difficulty of drainage was roughly identified through this comparison.)
- Rough evaluation of water balance in paddy field during high water level. (The inundation volume was roughly estimated through the examination of water balance in the paddy field.)
- Rough evaluation of inundation area based on the water balance

Since data are available to perform the above evaluation, the typical areas from among the divided areas were selected.

(a) Higher Delta

In the higher delta, following drainage conditions were identified:

- From the comparison between ground height and river water level, the area has difficulty in drainage to the Chao Phraya River for a relatively long period of time and very frequently.
- On the other hand, judging from the water balance during the period when water level is over the ground height, the maximum inundation volume and inundation water level is not severe.

Thus, the inundation condition by local rainfall in the area may not be so severe unless overflow from Chao Phraya River or the other rivers occur.

(b) Lower Delta

As for the lower delta, the area is broadly divided into two (2) areas: East Bank side and West Bank side. Since the drainage condition of both sides is similar, that of the East Bank was mainly examined.

As the result, the following drainage conditions were identified:

- From the comparison of ground height and river water level, gravity drainage in the area is difficult, as verified from the fact that drainage by pump is indispensable for the Bangkok metropolitan area during flood.
- Judging from the water balance, the inundation due to local rainfall may not be so severe as far as the local area is concerned. However, when the area receives additional floodwater from other areas such as the upstream area or the Chao Phraya River, the situation will be worst. Such a situation habitually emerges in the downstream area of the lower delta.

(2) Priority for Six (6) Divided Areas

As discussed earlier, the objective drainage areas are broadly divided into two (2) areas; higher delta and lower delta, which are further divided into four (4) areas in the higher delta and two (2) areas in the lower delta.

(a) Priority in Higher and Lower Delta

To compare priority in the higher and lower deltas, the following considerations were made:

- In general, the slope gradient in the lower delta is much more gentle, so that inundation water is hardly collected to the outlet points.

- Furthermore, the inundation water naturally flows down to the lower delta from the higher delta during a long-term inundation and is finally retained in the lower delta.
- In the relation between ground height in the drainage area and water level of the outlets, inundation water in higher delta is relatively easier to drain. That in the lower delta is quite difficult due to the continuation of higher water level of outlets compared with the ground height of drainage area.
- Thus, inundation condition from the hydraulic point of view seems to be more serious.
- Due to this situation, land development has been promoted from the lower delta where the land use condition is generally vulnerable to flood damage resulting in increased flood damage.

Under the above conditions, the drainage system improvement is more urgent in the lower delta than the higher delta.

(b) Comparison between East Bank and West Bank

There is not much difference in inundation condition between the east bank and the west bank. However, the following points are specified for comparison:

- Historically, land development in the east bank has been promoted earlier than the west bank, so that the retarding effect in the east bank has deteriorated resulting in the increase of flood damage potential.
- Also, damage in the economic aspect is more severe in the east bank.
- Furthermore, land subsidence caused by land development, which is remarkable in the east bank, has been aggravating the drainage condition.

Thus, a higher priority is given to the drainage system improvement in the east bank area.

In the east bank area, higher priority is given to the project area located in the most downstream where the inundation water from the upstream tends to concentrate. The drainage condition is worsened by the low ground height of the drainage area against high tide.

(c) Comparison among the Four (4) Divided Areas in Higher Delta

In the higher delta, the drainage condition of the four (4) areas is similar, but there may be a slight difference in the following points:

- As for the areas surrounded by irrigation channels such as Tha Chin and Noi rivers, regulators are provided at the diversion points from the Chao Phraya River, so that flood discharge can be controlled within the flow capacities. On the other hand, as for the areas surrounded by the Chao Phraya, Lop Buri and Pasak rivers, discharges over the flow capacity do occur, so that the areas receive damage by the overflow discharge.

- Furthermore, the condition under the higher water level lasts long in the Chao Phraya, Lop Buri and Pasak rivers, so that the drainage condition is worse than the areas surrounded by the irrigation channels of Tha Chin and Noi rivers.

Under these circumstances, the areas surrounded by the Chao Phraya, Lop Buri and Pasak rivers are given a higher priority. Inside these areas, those located in the downstream are given a higher priority, because the inundation water naturally flows down towards the downstream and is retained in the downstream areas.

The priority thus given to the areas is shown in Table 6.4.4.

6.4.3 Consideration on the Implementation Schedule

The implementation schedule, in general, is prepared considering work volumes and capabilities of contractors. However, work volumes are not identified in this study due to the difficulty of selecting the optimum measures to solve the drainage problem.

In this connection, the implementation schedule is prepared under the following premises:

- The entire drainage system project will be completed within the target year of the Master Plan, i.e., the year 2018.
- The implementation schedule is arranged based on the priority of project area mentioned above.
- The implementation period for each project area is assumed to be 7 years in the lower delta in addition to three years for F/S and D/D. The implementation period in the higher delta is 5 years in addition to two years for F/S and D/D considering the size of the project area and also the difficulty of drainage system improvement.

The implementation schedule based on the above premises has been prepared, as shown in Fig. 6.4.4.

6.5 Study on Possibility of Water Resources Development with the Use of Structures Proposed for Flood Mitigation

In this study, several measures are proposed for flood damage mitigation and some of them may be used also for water resources development purposes especially irrigation. Among the proposed measures, the preservation of natural retarding area with the capacity of 16 billion m^3 and the diversion channel have the potential for water resources development purposes. Since the water stored in the former measure is currently used for irrigation for practical purposes, new facilities for water resources development may not be required. As for the latter measure of diversion channel, it is a facility newly proposed.

In this connection, the effectiveness of diversion channel when used for water resources development is examined as follows:

(1) Storage Capacity of Diversion Channel

The storage capacity of diversion channel is roughly calculated by the following equations:

$$V_n = B_n \times L_n \times (h_{n1} + h_{n2}) / 2$$

$$V = \Sigma V_n$$

Where,

V_n, V (m^3): Storage volume of diversion channel in Section (n) and the whole Section

B_n , L_n (m): Width and length of diversion channel in Section (n)

h_{n1}, h_{n2}(m): Storage water height at both upper and lower terminal ends in Section (n)

As a result, the proposed diversion channel can store the volume of 55 million m^3.

(2) Benefit of Water Resources Development

The above storage water volume of 55 million m^3 will provide benefit in a manner of increase of rice production as shown below:

- Increase of Irrigation Area: 55 million m^3 divided by 21,000 m^3/s (unit irrigation water supply volume) = 2,600 ha
- Increase of Rice Production: 2,600 × 5,900 Bahts/ha (net benefit of rice production) = 15.3 million Bahts

Thus, the benefit of 15.3 million Bahts per year is expected through the water resources development using the diversion channel as the storage facility.

(3) Cost for Utilization of Diversion Channel as a Storage Facility

As the major additional facility for water resources development, only the pump to extract from the diversion channel is considered. The cost for installation of pump is estimated in the following manner:

- The required pump capacity is approximately 10 m^3/s, assuming that the volume of 55 million m^3 is extracted for 1,000 operation hours (100 days of irrigation days times 10 hours per day)
- The cost of pump is about 120 million Bahts, applying the unit cost of pump of 12 million Bahts/m^3.

(4) Economic Viability

Based on the above cost and benefit, EIRR is estimated to be 12%, assuming that the construction period is 2 years.

Thus, the utilization of diversion channel as the storage facility for water resources development is economically viable.

6.6 Recommendation on Comprehensive Operation of Drainage Pumps

6.6.1 The Problem of Increasing Urban Drainage Pumps

As discussed in Section 4.2, BMA and PWD have been making great efforts to mitigate flood damage in urban areas. Their principal measures consist of a combination of flood barriers/ring dikes and installation of drainage pumps. The barriers/ring dikes prevent flooding from rivers and adjacent higher areas. On the other hand, drainage pumps are to promptly drain inland floodwater in the areas surrounded by the barriers/ring dikes. Recently, in the metropolitan area including Pathum Thani, Nonthaburi, BMA and Samut Prakan, the increase of drainage pumps has been remarkable. The total pump capacity is as much as 818 m^3/s at present, and it is assumed to reach 1,343 m^3/s if all the future plans are realized.

Present and Future Pump Capacity (m^3/s)

Case	Pathum Thani	Nonthaburi	BMA	Samut Prakan	Total
Present	0	0	692	126	818
Future*	119	235	863	126	1,343

* Pump capacity after completion of PWD and BMA plans.

This increase of pump capacity will decrease inland inundation very much, but it will lead to the increase of river discharge. If the river water level is low enough, the influence of pump drainage will be negligible. During high water levels, however, the influence can be fatal. If pump drainage with full capacity is made while river water levels are critically high, the river water may surge over the flood barriers and ring dikes. In the worst case, the barriers and dikes may collapse and the metropolitan area may be submerged under the floodwater.

To avoid such a disaster, the drainage pumps should be operated carefully by monitoring the river water levels. When the water levels are critically high, the pump stations should refrain from pump operation. They should suspend the pump operation and allow inland inundation to some extent if necessary.

Hydraulic analysis was made for the metropolitan area, as described below, to obtain a clue for the pump operation during flood time.

6.6.2 Hydraulic Analysis

The following conditions were set and a schematic diagram of the applied simulation model was prepared, as presented in Fig. 6.6.1.

(1) River Model

A 120 km river stretch from the river mouth to Bang Sai with five (5) lateral inflow points was considered. These inflow points represent pump stations in Pathum Thani, Nonthaburi, Bangkok metropolitan area, Southern Bangkok metropolitan area and Samut Prakan. Pumps in the Bangkok metropolitan area were divided into two groups, upper and lower ones, from the Memorial Bridge.

(2) Boundary Condition

Observed tide levels at Pom Phracul in 1995 were given as the downstream end condition. At the upstream end, Bang Sai, a constant discharge of 3,000 m^3/s was given.

(3) Pump Capacity

Two (2) cases of the pump capacity, 818 m^3/s and 1,343 m^3/s, were considered as the present and future capacities.

(4) Pump Operation

Three (3) cases of pump operation were considered, namely, no operation, full operation during high tide, and full operation after high tide. In 1995 the maximum tide took place at 9:00 on October 28. In the case of operation during high tide, pump drainage with full pump capacity was made for six hours between 6:00 to 12:00 when the tide was at its highest. In the operation after high tide, the pump operation was assumed to start three hours later after the peak tide when the tide has subsided considerably and to continue for six hours from 12:00 to 18:00 as shown in Fig. 6.6.2.

The simulation results are presented in Fig. 6.6.2 and summarized as follows:

Maximum Water Level (m MSL) at Memorial Bridge (C.4)

Pump Operation	Pump Capacity (m^3/s)	
	Present (Q = 818)	Future (Q = 1,343)
No Pump Operation (Q = 0)	2.39	
During High Tide	2.47	2.54
After High Tide	2.39	2.39

The water level at the Memorial Bridge seems to be influenced very much by the tidal fluctuation. Even in the case of no pump operation, the water level fluctuates at the maximum range of 1.5 m. The peak water level takes place 1.5 hours later after the peak tide.

The pump operation causes water level rise. If the pump operation coincides with the peak tide, the maximum water level at Memorial Bridge is raised by 8 cm from 2.39 m to 2.47 m MSL under the present pump capacity. The future increase of pump capacity will further raise the water level by 7 cm from 2.47 m to 2.54 m MSL.

If the pumps are operated after the peak tide, the influence of pump operation to the water level is small. The maximum water level at Memorial Bridge will be the same as the case of no pump operation.

6.6.3 Recommendations

Based on the above hydraulic analysis, the following recommendations are made on the operation of the urban drainage pumps:

The drainage pumps should be operated carefully by monitoring the river water levels. When the water levels are critically high, the pump stations should refrain from pump operation. They should suspend the pump operation and allow inland inundation to some extent if necessary. It is said that river flood is generally more destructive than inland flood. River flood might be accompanied by collapse of barriers/dikes, resulting in catastrophic disaster in the metropolitan area. It is recommended that river flood should be prevented prior to inland flood. Fortunately, the high water levels do not last so long because of the tidal influence if the river discharge is not extremely large. The pump operation can be resumed a few hours later as the tide subsides.

CHAPTER 7. FEASIBILITY STUDY

7.1 General

7.1.1 Project Components for the Feasibility Study

In the Master Plan study, several project components were proposed for flood mitigation in the Chao Phraya River basin, consisting of structural and nonstructural measures. Among them, the following project components in which the necessity of urgent implementation was identified, were selected for the Feasibility Study:

(1) Nonstructural Measures

- Modification of Reservoir Operation Rule
- Land Use Control and Guidance
- Institution and Organization

(2) Structural Measures

- River Improvement for Protection of Agricultural Area

7.1.2 Basic Condition for the Feasibility Study

The Feasibility Study was in principle conducted in the following conditions:

(1) Project Components to identify Feasibility from the Economic Point of View

In general, project feasibility was identified from the economical, social and technical points of view. Among the above components, however, land use control and guidance and institution and organization were not identified from the economical point of view due to the difficulty of evaluating the cost and benefit in monetary term. Therefore, for these components, recommendation shall be done only after confirmation of feasibility from the technical and social points of view through a further study.

On the other hand, the feasibility of modification of reservoir operation rule and river improvement was identified from the economical as well as the technical and social points of view.

(a) Target Year

To identify the project feasibility from the economic point of view for the modification of reservoir operation rule and river improvement, it was necessary to set up the target year for project completion, based on which the cost and benefit were examined.

In the Master Plan study, it was proposed to complete the river improvement in 2005, while the modification of operation rule including planning of dams such as Kwae Noi and Keng Sua Teng shall be completed by the year 2018.

In the Feasibility Study, the target year was set at the year 2005, considering the following points:

- Feasibility of the modification of reservoir operation is examined only for the existing dams, Bhumibol and Sirikit, and the ongoing Pasak Dam, considering the necessity of feasibility study because of prompt realization of the projects.
- The realization of reservoir operation can be easily achieved within a short period, if the necessity and feasibility are fully identified.
- On the other hand, the completion of river improvement is expected to be around the year 2005, judging from the work quantities.

(2) Updating of Simulation Model

The flood simulation model established in the Master Plan Study was updated in the feasibility stage. The updated model was used for the feasibility studies on the modification of reservoir operation and the river improvement. Major modifications of the master plan model are as follows:

(a) New Cross Section Data

A river cross section survey was newly done for the Chao Phraya and Pasak rivers, Khlong Bang Kaeo, Khlong Bang Luang, and Khlong Bang Phra Mo. Old cross section data used in the flood simulation model for the Master Plan were replaced by the new data.

(b) Addition of Khlongs

To more precisely express water flow in the river and khlong network of the Chao Phraya River System, the Khlong Bang Bal, Khlong Bang Phra Mo, Khlong Bang Phra Khru and a shortcut channel at Pak Kret were additionally incorporated into the simulation model.

7.2 Study on Modification of Reservoir Operation Rule

7.2.1 General

In the Master Plan stage, the modification of reservoir operation rule for the Bhumibol and Sirikit dams was studied considering the current power generation during flood season. As the result, it was clarified that the proposed reservoir operation in the Master Plan Study has more effectiveness for flood mitigation compared with the operation under the present rule curve; i.e., the upper rule curve.

In the Feasibility Study stage, a further study was carried out putting more emphasis on the discharge released for hydropower generation during the flooding season to minimize the flood damage due to discharge released from the reservoir.

7.2.2 Strategy for the Study

(1) Principle of Proposed Reservoir Operation

The operation rule was modified under the following principles:

(a) Assurance of enough reservoir capacity at the beginning of flood season

To assure the reservoir operation considering flood mitigation, each dam should provide enough reservoir capacity to store the flood discharge at the beginning of the flood season.

(b) Minimization of discharge released from Dam

While flood damage is observed in the downstream, the discharge released from the dam should be fully controlled to minimize the flood damage.

(c) Prompt release of discharge to assure reservoir capacity for flood mitigation

While the river channel in the downstream has enough capacity to receive the flood discharge, the dam should promptly release the water stored in the reservoir in accordance with the hydropower requirement, so that the reservoir capacity for flood mitigation can be assured against the expected flood discharge.

(2) Objective Dams for Feasibility Study

The objective dams for the feasibility study were the Bhumibol, Sirikit and Pasak dams. The inflow of the Sirikit reservoir is under the situation that the Kok-Ing-Nan diversion project would not yet be in operation, considering that the target year of the Feasibility Study is 2005 while the proposed completion year of the Kok-Ing-Nan diversion project is 2012.

(3) Procedure of the Study

To set up the most appropriate operation rule for flood mitigation, the following procedures were applied:

(a) Selection of Reference Point

As mentioned earlier, the reservoir operation for flood mitigation has been carried out considering the flooding condition in the downstream. To identify the flooding condition in the downstream, it was necessary to select reference points that represent the critical flooding condition due to hydrological bottlenecks.

(b) Setting up of Rule Curves

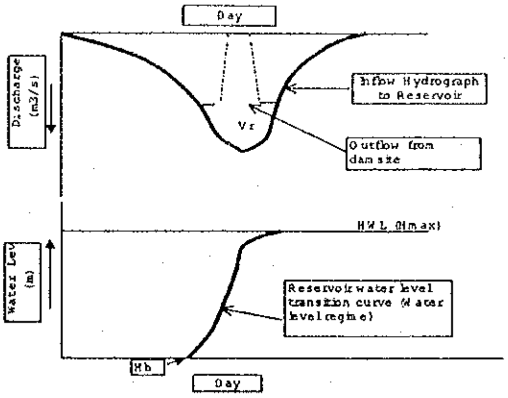
Due to the change of operation principle for flood mitigation, the rule curve was modified. The modification of rule curve was undertaken through some water balance simulation on major recorded floods as discussed below:

(i) Upper Rule Curve

The upper rule curves for the Bhumibol and Sirikit dams were set up in the following manner:

- While the river channel in the downstream still has enough capacity to receive the water released at the reference points from the reservoirs, the amount of water required for hydropower and irrigation is released from the reservoirs.
- On the other hand, when the river channel has no more capacity to receive the water released from the reservoirs, the release is stopped.
- Through the simulation applying the above principles to past floods, the reservoir water level transition curves (water level regime) are obtained.
- Also, the required volume (Vr) for flood mitigation can be obtained.
- Since the maximum storage water level (Hmax) is fixed for each reservoir, the upper rule curve to avoid the spill over the Hmax is naturally set, adjusting the storage water level at the beginning of the flood season. (Hb)
- The maximum required volume (Vmax) among the past floods is obtained in this process and the storage water level at the beginning of the flood season (Hbmax) is fixed for the flood with the maximum required volume.
- The water level transition curves for several floods are overplayed, starting with the fixed storage water level at the beginning of the flood season (Hbmax).
- Finally, the upper rule curve is set, enveloping the water level transition curves for several floods.

As for the Pasak Reservoir, three cases of upper rule curves were temporarily set up in the same manner as in the Master Plan Study.



(ii) Lower Rule Curve

The current lower rule curve of the Bhumibol reservoir is adopted as the proposed one. The curve for the Sirikit reservoir is the same as the one proposed in the Kok-Ing-Nan project.

(c) Evaluation of Proposed Operation Rule

The proposed operation rules would be effective for flood mitigation. On the other hand, they may cause some adverse influence on water utilization such as irrigation water supply and hydropower generation. Therefore, optimization of the scale of modification of reservoir operation rule was examined based on the economic evaluation. The economic benefit of the proposed operation rules was calculated by the reduction of flood damage, while the cost was counted for the reduction of rice production due to reduction of irrigation water supply and reduction of hydropower generation.

7.2.3 Modification of Operation Rule

In accordance with the aforementioned strategy, the modification of reservoir operation rule was examined as follows:

(1) Reference Points

(a) Bhumibol Dam

The reference point designated for the operation of Bhumibol Dam is at Nakhon Sawan, since the immediate downstream forms a bottleneck with the downstream of the Chao Phraya River before the river flows down to the Chao Phraya delta. The flooding condition in the downstream can be broadly identified at this point, and the flow capacity of the bottleneck is about 2,500 m^3/s.

(b) Sirikit Dam

Nakhon Sawan and Pitchit are selected as the reference points for the operation of Sirikit Dam, since the river channels near the points forms bottlenecks of the Chao Phraya and the Nan River. The flow capacities at the bottlenecks are about 2,500 m^3/s and 1,200 m^3/s, respectively.

(c) Pasak Dam

The reference points designated for reservoir operation of the Pasak Dam are at the Rama VI barrage and the Chao Phraya barrage. Flow capacities at these points are 1,000 m^3/s and 2,900 m^3/s, respectively.

(2) Modification of Operation Rule

According to the principle and procedure for modification of the rule curve, the upper and lower rule curves were set up as follows:

(a) Bhumibol Reservoir

According to the simulation for past floods, the required maximum capacity to store the flood discharge is approx. 3,500 million m^3 for the 1995 flood. On the other hand, the available capacity based on the present upper rule curve at the beginning of the flood season, Aug. 1st, is about 3,000 million m^3. Thus, the Bhumibol reservoir will face difficulty in flood mitigation in the 1995 flood situation. To cope with this condition, it was proposed to lower the present upper rule curve at the beginning of the flood season by 500 million m^3 . Starting with the water level on the upper rule curve, the water level transition curves of the reservoir were drawn for several floods through the water balance simulation.

The proposed upper rule curve was set up by enveloping the water level transition curves for several floods. The lower rule curve was based on the present rule curve. The proposed rule curves are shown in Figs. 7.2.1 and 7.2.2.

(b) Sirikit Reservoir

Likewise, the required maximum capacity for Sirikit reservoir is about 4,500 million m^3 for the 1995 flood. On the other hand, the available capacity at the beginning of the flood season, Aug. 1st, to the high water level is about 4,000 million m^3 according to rule curve studied under the Kok-Ing-Nan Study. Thus, the Sirikit reservoir will face difficulty in flood mitigation in the 1995 flood situation. To cope with this condition, it was proposed to lower the present upper rule curve at the beginning of the flood season by 500 million m^3. Starting with the water level on the upper rule curve, the water level transition curves of the reservoir were drawn for several floods through the water balance simulation.

The proposed upper rule curve was set up by enveloping the water level transition curves for several floods.

(c) Pasak Reservoir

As discussed in Subsection 7.2.2, the upper rule curve of Pasak reservoir was set up to secure flood mitigation functions by maintaining the vacant capacity when flood peak comes out. To set such a curve, the following three (3) cases of rule curves were examined considering the characteristics of the reservoir and the flood period of the reference points:

- Case-1: The maximum vacant volume on September 15th is 559 million m^3;
- Case-2: The maximum vacant volume on September 15th is 662 million m^3; and
- Case-3: The maximum vacant volume on September 15th is 772 million m^3.

Among these three cases, the rule curve based on Case-3 is selected as the suitable one from the following reasons through the comparison study on effectiveness and cost as shown below:

- The indices of B/C for Case-2 and Case-3 are quite large, while an index cannot be obtained in Case-1. This is because high benefit is expected, while cost is not high, as the features of nonstructural measures with least cost. Judging from the B/C indices, both cases are economically viable
- As to B-C, the value increases in proportion to the reservoir capacity.
- As identified in the Master Plan study, the modification of reservoir operation rule shows a higher economic viability compared with the other structural measures. Thus, maximization of the effectiveness of this measure is recommendable.
- Under the condition, it is recommendable to apply Case-3 as the suitable case to expect higher effectiveness for flood mitigation.

Case	Effectiveness		Influence		Economic Comparison	
	(Reduction of Inundation Volume)	Annual Benefit (B) (mil.baht)	(Reduction of Irrigation Area)	Cost (C) (mil.baht)	B-C (mil.baht)	B/C
Case-1	288 million m^3	232	0	0	230	-
Case-2	587	455	900 ha	6	450	76
Case-3	695	535	2,100 ha	15	520	36

The proposed rule curves for objective reservoirs are shown in Fig. 7.2.1.

7.2.4 Evaluation of Proposed Operation Rule

(1) Flood Mitigation Effect

The flood mitigation effects by the proposed reservoir operation rules were evaluated with the reduction of inundation volume of the reference points, from case of 'without', which was estimated as the volume stored in the reservoir while floodwater overflows at the reference point.

The flood mitigation effects for five (5) big floods are shown in Table 7.2.1 and summarized in the following table.

Reduction of Inundation Volume in Big Flood (Unit: million m^3)

Name of dam	Operation Case	1975 flood	1995 flood	Average of 5 big floods
Bhumibol	Without (Present Operation)	3,436	3,681	1,998
	Proposed Operation	4,477	3,773	2,232
Sirikit	Without (KIN project proposed)	2,323	2,725	1,180
	Proposed Operation	2,813	3,514	1,458
Pasak	Without (Without Rule Curve)	0	0	0
	Proposed Operation (Case-3)	438	695	252

* The 'without' operation cases are as follows:

- Bhumibol Reservoir : Actual operation
- Sirikit Reservoir : Operation with proposed Kok-Ing-Nan project
- Pasak Reservoir : Operation with non-upper rule curve

In this table, it is noted that the inundation volume of about 1,600 million m^3 is expected to be reduced in the 1995 flood situation through operation by the proposed rule curves for the three dams. The volume corresponds to 10% of the total inundation volume of the 1995 flood.

(2) Influence on Irrigation Water Supply and Power Generation

The reduction of water supply for irrigation and power generation is obtained through water balance simulation of 45 years (1952-1996). The release plan for irrigation water supply is shown in Table 7.2.2. The reduction of irrigation area in dry season and that of the annual power generation in each case are summarized in the following table:

Reduction of Irrigation Area and Power Generation

Item	Unit	Bhumibol Dam	Sirikit Dam	Pasak Dam
Reduced irrigation area from without	ha	-	5,400 (4%)	2,100 (4%)
Reduced power generation from without	Gwh	13 (1%)	40 (4%)	-

7.2.5 Establishment of Proposed Operation Rule Curve

As evaluated in Section 7.6, Economic Evaluation, the benefit of the annual average flood mitigation is about 13 times the annual compensation cost. Therefore, the proposed operation rule curves of the three reservoirs are justified as suitable.

The proposed operation rule curves are shown in the following table and the operation results for the three reservoirs are shown in Fig. 7.2.2.

Proposed Operation Curves (unit : million m^3)

Dam	Curve	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Bhumibl	Upper	13055	12250	11300	10500	10100	10000	9950	10000	10400	12750	13462	13460
Sirikit	Upper	8800	7800	6650	5700	5250	5100	5050	5100	7000	8900	9510	9300
Pasak	Upper	-	-	-	-	-	-	13	13	13	399	785	-

7.2.6 Benefit Estimation

The benefit of the proposed modification is expressed as the difference of flood damage amounts between the without and with-project situations.

(1) Flood Damage without Modification of Dam Operation

The following rules were applied as the rules before the modification, namely, the without-project situation:

Dam Reservoir	Rule before Modification
Bhumibol	Current Rule (Observed Outflow)
Sirikit	Rule proposed by JICA KIN Study
Pasak	Conventional Operation (Without rule curve operation)

Flood simulations were made for 33 years from 1964 to 1996 under the without-project condition. Descriptions and results of the flood simulations are given in Section 5.3 and Table 5.3.1 of Sector I, Hydrology, Vol. 3, Supporting Report (1/2), respectively. Flood damage amounts in all the flood events were estimated by using inundation depths and volumes obtained in the flood simulations, as shown in Table 7.2.3. The average annual damage amount is estimated at some 16 billion Baht.

(2) Flood Damage Amount with Modification of Dam Operation

To know flooding conditions under the with-project situation, flood simulations were made under the proposed dam operations too. In the combination case of the three dams, the flood simulations were conducted for all the 33 years, but only 10 representative floods in 1972, 1973, 1979, 1983, 1984, 1985, 1987, 1992, 1995 and 1996 were applied in the individual dam cases. Simulation results are given in Table 5.3.2 of Sector I in the Supporting Report. Using the obtained inundation depths and volumes, flood damage amounts in all the flood events were estimated, as presented in Table 7.2.3.

(3) Expected Benefit

The benefit, namely the reduction of the annual damage amount to be derived from the proposed modification was calculated by the following equation:

Benefit = Average Annual Damage Amount × (∑wop-∑wp) / ∑wop

Here;

∑wop = ∑ (damage amount of representative floods without-project)

∑wp = ∑ (damage amount of representative floods with-project)

In the combination case of the three dams, all the 33 floods are applied as the representative floods.

The estimated benefits are also presented in Table 7.2.3, and tabulated as follows:

Benefit of Modification of Dam Reservoir Operation (mil. baht/year)

Objective Dam	Bangkok	Other Areas	Total
Sirikit	171	253	424
Bhumibol	19	40	59
Pasak	103	440	543
Combination of above three dams	299	868	1,038

Note: The above benefits are under the future basin condition in 2001.

7.3. Study on Land Use Control and Guidance

7.3.1 Confirmation of Necessity of Land Use Control and Guidance

Effective land use control and guidance are essential for flood mitigation as pointed out in the Master Plan study as well as in many previous studies. This is emphasized with the following typical examples:

- Flood Damage Increase by land use change from 72 billion to 164 billion baht in the case of 1995 flood (refer to Fig. 4.2.6).
- Reduction of Retarding Function that results in the increase of water level at Samsen (C.12) by as much as 81 cm in the 1995 flood, if 2,700 km^2 of the flood plain is reclaimed.

The areas in the floodplain that are required more for land use control and guidance were identified and, furthermore, the strategy of land use control and guidance for such areas is proposed.

7.3.2 Identification of Areas for Land Use Control and Guidance

To identify such areas, the following approaches were taken:

(1) Historical Approach

As one of the general approaches, a flood risk map based on previous floods, 1983, 1995 and 1996 is prepared, as shown in Fig. 7.3.1, considering satellite image data, interview survey results and flood simulation results. Fig. 7.3.2 presents the maximum inundation depths in the three floods.

(2) Hydrological-hydraulic Approach

A map showing the potential flood risk area in case of a 5-year return period is prepared based on the flood inundation area by simulation results (refer to Fig. 7.3.3).

(3) Damage Approach

A map showing the magnitude of flood damage increase in the future is prepared based on the flood damage calculation results that were obtained in combination with the inundation water depth by flood simulation and the relation between inundation water depth and flood damage (refer to Fig. 7.3.4).

7.3.3 Realization of Land Use Control and Guidance

Based on the above study results, land use control and guidance could be realized in the following manner:

(1) Publication of Flood Risk Map

The flood risk map prepared by the historical approach should be published to caution on land use in the flood risk area. Accordingly, people and agencies concerned will consider land use in such a flood risk area in the following manner: utilization of the land by providing flood mitigation measures such as filling the land or avoiding the flood risks.

(2) Preparation of Land Use Plan

When the land use plan is prepared by agencies concerned, the above study results should be considered, such as preservation of the retarding function of the area.

(3) Preparation of Guideline for Construction of Public Facilities

When public facilities such as roads and airport are provided in the flood risk areas, the present retarding function in such areas should be preserved. For that purpose, it is necessary to prepare a guideline which stipulates the provision of measures for preservation of the present retarding function as well as mitigation of flood damage. Also, activities for the provision of public facilities should be registered with the agencies concerned, so that the adequacy of such activities can be confirmed.

7.4 Study on Institutional Arrangement

In the Master Plan study, several measures for flood mitigation were proposed. In this context, the following study regarding the institutional arrangement was undertaken:

- Study on the possibility of realization of measures proposed in the Master Plan study within the present institutional framework; and
- Study on additional institutional arrangement.

7.4.1 Possibility of Realization of Measures within the Present Framework

In the Master Plan study, the following measures were proposed:

- Nonstructural Measures: Land use control and guidance, modification of reservoir operation rule, control of ground water extraction, flood forecasting, flood fighting, disaster recovery, subsidy, flood insurance and watershed management.
- Structural Measures: Distribution system and drainage system improvement, river improvement and heightening of flood barrier at Bangkok or construction of diversion channel.

Most of these measures are currently being executed by agencies concerned, such as RID, BMA, PWD, DTCP and so on (refer to Table 7.4.1). Only the following measures are newly introduced: modification of operation rule, flood insurance and construction of diversion channel.

Judging from the current practices of the agencies concerned, the major issues for realization of these measures are emphasized as follows:

- It is necessary to strengthen or improve the present institutional arrangement.
- Coordination among agencies concerned is necessary, especially for flood mitigation works undertaken independently by agencies concerned: RID for agricultural area, PWD for major urban areas, and BMA for Bangkok.

Among these major issues, the former one will be somehow solved through strengthening the organization of agencies concerned. On the other hand, for the latter one, there is no existing organization except the National Water Resources Committee, which is too high level to cope with the issues on individual river basins.

In this connection, it is necessary to set up a River Basin Committee to coordinate these issues on flood mitigation.

7.4.2 Examples in Other Countries

To set up a new organization, it is desirable to refer to examples in other countries. The organization on river basin management in the other countries such as Japan, China, USA, UK, etc., are given in Tables 7.4.2 and 7.4.3 (for details, refer to Vol. 4, Supporting Report, Sector XI). Concerning these organizations, the following features are specified:

- Since the historical background of administration as well as river management is different among these countries, the organization for water management is also different.
- However, for management of large scale river basins, most of the countries such as China, USA and France have a committee for coordination or river management.
- In Europe, an international committee among the Netherlands, Germany, France and Belgium is to be set up for discussion on issues on flood mitigation in the Rhine river basin.

7.4.3 Setting up of a River Basin Committee in the Chao Phraya River Basin

As the study on additional institutional arrangement, the setting up of a river basin committee was examined on the following points:

- Scope of work to be included in the function of the River Basin Committee in terms of flood mitigation in the Chao Phraya River.
- Composition of the Committee and office of the Committee to handle the works.

(1) Major Issues in the Chao Phraya River Basin

In Thailand, there is no single organization to handle flood mitigation basin-widely and comprehensively. Issues on the current institution and organization in terms of flood mitigation originated from this situation, resulting in the following major issues:

- Due to this situation, a flood control plan from basin-wide and comprehensive viewpoints has hardly been provided. Plans for only the protection of urban areas or protection of agricultural areas are prepared individually by each responsible agency.
- Coordination among these plans and agencies concerned is sometimes not undertaken sufficiently.
- Under the circumstances, some conflicts or issues regarding flood mitigation emerged.

To cope with such conflicts or issues and to address the other issues concerned in the realization of comprehensive flood mitigation, it is necessary to set up an organization with functions for the formulation of basin-wide and comprehensive plans, coordination among the agencies concerned, and undertaking of activities to enhance the capability for flood mitigation.

(2) Present Status of Institutions and Organizations

As discussed above, the major issues for realization of a comprehensive flood mitigation plan are emphasized with the non-existence of a single agency to handle the flood mitigation comprehensively and basin-widely. So far the government is making efforts to set up a suitable organization to handle the issues, as described below.

(a) Establishment of the National Water Resource Committee

At the Cabinet Meeting on February 7, 1989, the regulation concerning the National Water Resources Management was endorsed by the Cabinet and published in Government Gazette 106. After that, on June 17, 1996, the Royal Decree on the organization of the Office of the Secretariat of the Prime Minister was announced and later on published in the Government Gazette.

(b) Preparation of Water Resources Act

In recognition of the current problems on water related situations such as shortage of water during dry season and flooding during rainy season, the preparation of a water resources act is ongoing. According to the latest version prepared by the Office of the National Water Resources Committee on 23 September 1997, the following statements are included in the draft of the Water Resources Act:

- Setting Up of the National Water Resources Committee
- Responsibilities and Functions of the National Water Resources Committee
- Designation of River Basin Committee

(c) Project of Study of Establishment of Chao Phraya Basin Organization

Recognizing the significance of prompt enactment of the Water Resources Act, the Office of National Water Resource Committee (ONWRC) put high priority on the works and the establishment of a river basin organization or a river basin committee as one of the contents.

The project of "Study of Establishment of Chao Phraya Basin Organization" has been submitted to World Bank with the support of Ausaid. At present ONWRC and NESDB are initiating related activities in two pilot areas: Ping River Basin and Pasak River Basin.

As the next step, it is expected that ONWRC will set up a river basin committee for each of these two rivers: the Ping River Basin Committee and the Pasak River Basin Committee. If their performance are acceptable, they will automatically turn into river basin commissions and perform their duties according to the law, when the draft Water Resources Act is enacted.

(3) Recommendation of Functions to be involved in the River Basin Committee in terms of Flood Mitigation

Considering the responsibilities and duties of the River Basin Committee, the functions to be involved in terms of flood mitigation are emphasized in the following points:

(a) Setting up of Strategy for Integrated Flood Mitigation

To successfully achieve the target of integrated flood mitigation in accordance with the national development policy, it is necessary to set up the strategy on short-term and long-term integrated flood mitigation considering the potential of development of the basin.

For that purpose, the river basin committee should have the function of formulation of a master plan for comprehensive and basin-wide flood mitigation in a manner of short term and long term and also execution of feasibility study. Such master plan and contents of the feasibility study are composed of structural and nonstructural measures.

(b) Nomination and Coordination among Agencies concerned for Implementation of Flood Mitigation Projects

In accordance with the Master Plan formulated, the flood mitigation projects are to be implemented. The River Basin Committee should have a function to nominate the implementation agency/agencies for the projects and to coordinate, follow up and evaluate the implementation of the projects.

As for the flood mitigation projects currently being implemented individually by agencies concerned according to their own responsibilities, the River Basin Committee should provide coordination among the agencies concerned. Besides, the Committee should coordinate the basin development plans, such as road projects and large-scale housing projects that may affect the flooding condition in the basin.

(c) Flood Disaster Management

Flood disaster management is currently being undertaken individually by each agency according to its own purposes. To achieve a more efficient flood disaster management basin-widely, it is desirable to integrate the flood disaster management function into one suitable organization. Thus, the River Basin Committee should function as the flood disaster management center in the following flooding stages:

- Pre-Flood Management and Preparedness
- Flood Management during Flood Time
- Flood Management, Post-Disaster Action

Among the work items for flood disaster management, the strengthening of flood fighting is essential. In this connection, it is recommended that the River Basin Committee should strengthen the current flood fighting activities through further participation of inhabitants along the river course. (Flood fighting activities in foreign countries are introduced in Table 7.4.4 and Vol. 4, Supporting Report, Sector XI.)

(d) Other Functions to Enhance the Flood Mitigation Capability

(i) Flood Information Center

In general, the existing information related to flood control is scattered and not uniform in format, and the dissemination of information is limited. To effectively promote the function of flood mitigation, it is essential to systematically collect the basin-wide information related to flood and establish a data network system. Thus, the River Basin Committee should play the role as flood information center.

In this connection, the flood forecasting system should be established in the River Basin Committee.

(ii) Training

To enhance the capability for flood mitigation works, it is essential to provide a training program for experts engaged in the work and the public affected by floods, although such a training program may involve several subjects.

(iii) Public Awareness

Needless to say, public awareness on flood risks isessential for the agencies concerned to smoothly promote the flood mitigation works and to receive support from the public for implementation of flood mitigation works in the following aspects:

- A good public knowledge and understanding of flood and vulnerabilities.
- Public awareness of the kind of mitigation measures which can be applied.
- Public participation in community preparedness program.

(iv) Research

To enhance the capability for flood mitigation works, it is necessary to pursue research work for mainly such items as meteorology and climatology, analysis of flood characteristics, identification of flood vulnerable areas and methodology to cope with the flood and so on.

(4) Recommendation of Organization of River Basin Committee

In principle, the organization for flood mitigation will be set up as a sub-committee in the River Basin Committee, as shown Fig. 7.4.1.

In case of the Chao Phraya River Basin, the following agencies should be included as members of the sub-committee:

- Office of National Water Resource Committee
- Royal Irrigation Department
- Bangkok Metropolitan Administration
- Public Works Department
- Harbor Department
- National Economics and Social Development Board

- Office of Environmental Policy and Planning
- Electricity Generating Authority of Thailand
- Department of Town and Country Planning
- Representative of Local Government Officials
- Representative of Local Organization
- Representative of Non-Governmental Organization
- Others

Most of the functions discussed in Subsection 4.2.4 will be handled in the sub-committee for decision making. However, to support and substantially pursue the functions, it is necessary to set up the Office of the River Basin Committee as well as the Office of the National Water Resources Committee.

The organization of the Office of the River Basin Committee shall be composed of similar divisions as the Office of National Water Resources Committee, as follows:

- Policy and Planning Division
- Coordination, Operation Division and Flood Disaster Management Division
- Flood Information Division
- Training, Research and Public Awareness Division
- Legal and General Administration Division

The organization chart of the River Basin Committee is shown in Fig. 7.4.1. To establish the organization, the number of necessary staffs and items of required equipment are as shown in Tables 7.4.5 and 7.4.6.

(5) Tentative Solution for the Period to Set Up the Committee

It may take a certain period to set up the River Basin Committee under the current situation where the restructuring of present government organization is being considered. In such a case, it may be necessary to set up an ad-hoc committee as a tentative solution to cope with the flood mitigation issues, referring to the current functions of the agencies concerned.

7.5 Study on River Improvement

The possibility of river improvement for the middle reaches of the Chao Phraya River System from Pathum Thani to Chainat to mitigate flood damage in the agricultural areas was examined in the Master Plan Study. It was concluded that it may be possible to enhance the flood protection level from 2-5 year return period to 10-year return period for the agricultural areas by river improvement in combination with the improvement of flood water distribution system and the planned three (3) dams, Pasak, Kwae Noi and Kaeng Sua Teng.

In the feasibility study stage, the possibility of river improvement was further examined to clarify the possible improvement scales and stretches. The project area is the midstream of the Chao Phraya River System from Chao Phraya Dam to Pathum Thani, including its tributary, the Pasak River, and the distributaries Noi and Lop Buri rivers and some major khlongs. Since the study on flood water distribution system was not included in the feasibility study, the possibility of river improvement was examined based on the assumption that the flood water distribution system improvement is not undertaken.

7.5.1 Basic Condition for River Improvement

The basic conditions for the feasibility study on river improvement were set up as follows:

(1) Target Year

The target completion year for the river improvement is set in 2005 in accordance with the implementation schedule proposed in the Master Plan, as mentioned in Subsection 7.1.2

(2) Project Scale

In the Master Plan, the agricultural areas in the Higher Delta is proposed to be protected with a return period of 10 years by a combination of river improvement, flood water distribution system and the planned three dam reservoirs. Among the three components, however, the river improvement is proposed to be implemented prior to the distribution system, and the completion of two of the three dams, Kwae Noi and Kaeng Sua Teng, by the target year 2005 is expected to be difficult. Thus, the project scale enhanced by the river improvement alone might be lower than a 10-year return period.

(3) Expected Future Basin Condition

The following conditions are taken into account as the future basin condition in the target year 2005.

(a) Land Use

The land use in the target year should be considered for the river improvement study. The future land use in 2005 is projected by applying the same annual growth rates of land use in the Master Plan Study.

(b) Related Works

To cope with the flooding problems, the agencies concerned are undertaking flood mitigation and protection works, which were taken into account in the formulation of the Master Plan. Some of them are planned to be completed by the target year 2005, and are incorporated in the future condition in the following manner:

(i) Construction of Flood Barrier by BMA

BMA is now constructing flood barriers along the Chao Phraya River. This work is scheduled to be completed in 2001, and the flood barriers are incorporated in the future condition.

(ii) Flood Protection Works for Major Urban Areas

PWD is planning to provide flood protection works for major urban areas in a manner of ring dikes with drainage pumps, of which tentative implementation schedules are as shown in Tables 7.5.1 and 7.5.2. All the protection works which are scheduled to be completed by 2005 in these tables are assumed to be existing in 2005. The locations of the urban ring dikes are shown in Fig. 7.5.1.

(iii) Loop-Cut at Bangkok Port by RID

To mitigate flood damage in agricultural areas, RID is going to implement a loop-cut near Bangkok Port, which is scheduled for completion in 2002. Thus, the loop-cut is also incorporated in the future condition in 2005.

(iv) Modification of Operation of Bhumibol, Sirikit and Pasak Dam Reservoirs

Modification of the reservoir operation rules of the three dams, Bhumibol, Sirikit and Pasak, is very effective for flood mitigation and is proposed to be implemented soon. The proposed optimum operation rules for the three dams are assumed to have been applied by the target year 2005.

(v) Regulators and Barrage

Four (4) regulators are now under construction by RID on the Lop Buri River and Khlongs Bang Kaeo and Bang Phra Khru, as shown in Fig. 7.5.2, and their completion is scheduled in 1999. In addition, RID is constructing some 30 regulators on khlongs joining the Chao Phraya River between Bang Sai and Pathum Thani, as shown in Fig. 7.5.3. The Harbor Department has a plan to construct two (2) barrages for navigation on the Chao Phraya River in Sing Buri and Nakhon Sawan Province by 2004. These control structures are also incorporated in the 2005 condition.

(3) River Improvement Works

Heightening of the existing dikes is considered the most economical among measures to increase the flow capacities of the Chao Phraya River System. Thus, this feasibility study is made under the condition that such dike heightening will be made as a basic work for the river improvement.

7.5.2 Existing Condition

In order to know the existing condition of the rivers and to identify problem areas, the flow capacities of rivers and khlongs were estimated, as follows:

(1) RID Embankment

Flood embankments were constructed along the Chao Phraya River and its tributaries from Chainat to Pathum Thani by the Royal Irrigation Department (RID), as shown in Fig. 7.5.4. According to RID, these embankments were designed to a standard of 1 in 25 years to prevent flooding of agricultural areas. These design water levels were obtained from a frequency analysis of the past observed water levels, however, influence of past and future probable developments such as confinement of floodwater by embankment and installation of regulators were not considered in the estimation of the 25-year design water levels. Thus the actual safety level seems to be a lot less than the 25-year return period level.

(2) Discharge Distribution in Chao Phraya River System

Prior to the flow capacity estimation, the discharge distribution in the Chao Phraya River System below the Chao Phraya Dam was estimated for several return periods, as shown in Fig. 7.5.5, assuming the future basin condition in 2005 which is the target year for the river improvement as described in the next section.

These discharges are based on probable discharges at all the stretches under the full confinement condition in which river water is confined in the rivers, not allowing any spillage. The discharge at the Chao Phraya Dam is distributed to the distributaries, Lop Buri River, Khlong Bang Phra Khru, Khlong Bang Kaeo, Noi River, Khlong Bang Luang, Khlong Ban Bal and Khlong Bang Phra Mo, then rejoined into the Chao Phraya River, receiving a discharge from the Pasak River.

(3) Existing Flow Capacity

Flow capacities of the rivers and khlongs were estimated in the Feasibility Study. The estimated flow capacities are compared with the discharge distribution under the full confinement condition in Fig. 7.5.5 and are presented in a form of return period as shown in Fig. 7.5.6.

The upper stretches of the Chao Phraya River from Khlong Bang Bal have comparatively large capacities greater than the 5-year discharge. The flow capacities of the lower stretches are very small. Several sections below Ayuthaya cannot accommodate even the 3-year discharge. Except for Khlong Bang Luang and Khlong Bang Phra Khru, the Pasak, Lop Buri and Noi rivers and the other khlongs have flow capacities, as small as the 3 to 5-year discharges or even less.

(a) Flow Capacity in Bangkok Metropolitan Area

The flow capacity at the design water level in the Bangkok metropolitan area was estimated at some 3,600 m^3/s, which corresponds to the 3-year discharge in an extreme case where all floodwaters are confined in the rivers from the Chao Phraya Dam to the Bangkok metropolitan area.

(b) Flow Capacity in Pathum Thani and Nonthaburi

The flow capacities in Pathum Thani and Nonthaburi were estimated at 3,700 m^3/s and 3,200 m^3/s which correspond to the 3.5 and 2.2-year discharges under the full confinement condition, respectively. These small capacities were estimated at the design water levels applied in the existing urban area protection plan by PWD.

(c) Discussion on Water Levels in Pathum Thani and Nonthaburi

According to the D/D Report of PWD, the design water levels are 100-year water levels obtained by the frequency analysis of water levels observed in the past. However, the design water levels seem to be too low when compared to the 100-year water levels obtained in the Master Plan Study. PWD's design water level at Pak Kret (C.22) is as low as 2.50 m MSL (the design dike level is 3.0 m MSL), while the 100-year water level after the confinement was estimated at 3.07 m MSL in the Master Plan Study.

Similar problems are pointed out in the Master Plan Study for BMA's flood barrier and in this Feasibility Study for the RID embankments. The gap between the PWD plan and this Study is generated from the different evaluations on the influence of the proposed dikes along the river. The PWD plan seems to have underestimated or neglected the influence, as understood from the fact that only the frequency of the past observed data were considered. On the other hand, this Study has taken the influence seriously into account, and the water level rise after confinement by the dikes has been closely examined.

The protection works are going to commence in 2001 according to the implementation schedule. On the other hand, the discussion on the Master Plan for the protection of the metropolitan areas including not only Pathum Thani and Nonthaburi but also the Bangkok metropolitan area has not been settled yet. Three alternative plans are proposed in the Master Plan Study. The water levels in these areas depend upon which alternative is applied, and the design water levels and dike levels should be determined considering the Master Plan. The 100-year water levels in the Master Plan are given in Table 7.5.3.

The flow capacities in Nonthaburi are smaller than in the Bangkok metropolitan area, but in this Feasibility Study the design water levels and dike levels in Nonthaburi are assumed to be raised high enough for the safety level of the Bangkok metropolitan area, the 3-year level at least.

(2) Problem Areas

Based on the flow capacities, problem areas where safety levels are lower than the 5-year return period level were identified by the JICA Study Team. The areas are divided into eight (8) areas by the river and major khlong dikes, and named Area-1 to Area-8 in order of distance from the river improvement stretches to the Bangkok metropolitan area, as shown in Fig. 7.5.7 and summarized in Table 7.5.4.

7.5.3 Determination of Project Scale and Target Stretches

The study on improvement scale and target stretches is presentedp in this Subsection as follows:

(1) Strategy

The river confinement works reduce the spillage discharge at the improvement section but increase the discharge to the downstream at the same time. This is a dilemma for the river improvement, and a conflict might arise between the area protected by the river improvement and the area downstream that will receive more water than the upstream. In addition, what makes the river improvement in the Chao Phraya River System more difficult and complicated is the small flow capacity at the downstream end of the Chao Phraya River, in the Bangkok metropolitan area. As discussed in the previous subsection, the flow capacity in Bangkok is as small as 3,600 m^3/s and constrains the extent of river improvement.

If all the stretches from Pathum Thani to the Chao Phraya Dam are improved at a unique level, such river improvement can be applied with a scale of the 3-year return period at the maximum. If the 5-year return period is applied as the scale of the river improvement, the discharge of 4,100 m^3/s will come down to the Bangkok metropolitan area even in a 5-year flood, and it will result in a terrible flood damage in Bangkok where the flow capacity is only 3,600 m^3/s as shown in Fig. 7.5.6. Thus, the whole stretch cannot be improved, and the improvement should be limited to only some selected stretches in case of the 5-year improvement.

Based on the above conditions, the following principles are made:

(a) Project Scale of River Improvement

As described in Subsection 7.5.1, the project scale of the river improvement is set up lower than the 10-year return period, and two cases, the 3-year and 5-year return periods are proposed.

(b) Maintaining of Safety Level at Bangkok Metropolitan Area

Bangkok is the capital of Thailand and is the center of political, economic and social activities in the country. Once this area is hit by flood, a disastrous damage to not only Bangkok but the country as a whole is inflicted. For planning the river improvement, therefore, special consideration should be made not to lower but maintain the safety level at the metropolitan area.

(c) Overall Improvement and Partial Improvement

The 5-year improvement is a partial improvement, and the river improvement should be limited to some selected areas. The 3-year improvement is overall improvement, and all the river stretches with a flow capacity of less than the 3-year discharge are allowed to be improved without increasing flood damage in the Bangkok metropolitan area.

(2) Conceivable Cases

In line with the above principles, five (5) cases of river improvement were conceived, namely, one (1) case for the 3-year improvement and four (4) cases for the 5-year improvement. Case-3 is the 3-year improvement, i.e., the overall improvement. As for the 5-year improvement, the four partial protection cases, Case 5-1 to 5-4, which will not increase flood damage in the Bangkok metropolitan area are conceived through a hydraulic analysis, as shown in Fig. 7.5.8.

Conceivable Cases of River Improvement

Case No.	Protection Level	Protection Area	Area (km2)
5-1	5-yr	Area-1	410
5-2	5-yr	Area-1 to 2	1,260
5-3	5-yr	Area-1 to 3	1,330
5-4	5-yr	Area-1 to 4	1,510
3	3-yr	Area-1,4,5,6,7 and 8	2,035

(2) Selection of Optimum Case

To select the optimum case among the five conceivable cases, an economic analysis was made as summarized in Table 7.5.5. In conclusion, Case 3, the 3-year river improvement, is selected from the following reasons:

The other 5-year cases, Cases 5-1 to 5-3, are economically viable, but would result in an imbalance of impacts. The partial improvement cases will considerably improve the protected areas but will significantly increase flood damage in the unprotected areas, although the increased damage will be balanced by benefits created by the proposed modification of dam reservoir operation rule when the combination with the reservoir operation is considered. The unprotected areas will be left in the lowest safety levels. On the other hand, the 3-year improvement is also economically feasible, and can upgrade all the problem areas of the lowest safety levels to the 3-year level. This overall improvement will lead to well-balanced development of the delta area.

7.5.4 Preliminary Design

(1) Design Discharge and Water Level

The 3-year discharges in Fig. 7.5.5 are applied as the design discharges of the river improvement. The design water levels were determined as shown in Fig. 7.5.9, based on the relation between water levels and discharges at every cross section obtained from hydraulic analysis. The design dike levels were determined by adding a freeboard of 30 cm to the design water levels in accordance with the current practice by RID.

(2) Cross Section

Heightening of the existing dikes which are generally forming roads is proposed as the most viable improvement work, as shown in Fig. 6.2.1. This improvement method was supported by a majority of the participants in the public consultation meetings that were held as a part of the EIA survey, as described in Subsection 7.5.8. The average dike heightening is about 50 cm with the maximum heightening of some 1.5 m.

(3) Dike Alignment

The proposed dike alignments are drawn as shown in Fig. 7.5.10, following the existing dikes or roads. The total length of the dike improvement is about 67 km. The number of house relocation is only four, and the land acquisition is also as small as 2.5 ha.

(4) Regulators

A total of 13 regulators are proposed to be additionally provided at the intersection of the existing/proposed dikes and khlongs which have been excluded from the RID plan in Fig. 7.5.3. The location of the additional regulators is also presented in Fig. 7.5.10.

7.5.5 Construction Plan

The construction plan for the proposed river improvement has been prepared, as shown in Fig. 7.5.11.

7.5.6 Work Quantity and Cost Estimate

The work quantities and cost of the proposed river improvement are summarized as follows:

Item	Chao Phraya R.	Lop Buri R.	Noi R.	K. Bang Bal	K. Bang Phro Mo	Total
Total Length of Dike Heightening Stretches (km)	41.8	14.0	6.6	2.5	2.1	67.0
Regulators (places)	10	3	-	-	-	13
Land Acquisition (m2)	12,600	12,200	-	-	-	24,800
House Relocation (houses)	3	1	-	-	-	1
Financial Cost (mil. Baht)	1,052	284	55	23	11	1,425

7.5.7 Benefit Estimation

The benefit expected from the proposed river improvement is expressed by the difference of flood damage amounts between the with- and without-project situations. The 3-year river improvement is effective for small floods of 3-year return period or less. Strictly speaking, the river improvement will reduce flood damage by small floods of from 1.3 to 3-year return period because the minimum flow capacity of the rivers in the project area corresponds to a 1.3-year discharge.

Flood simulation was made for both with and without river improvement conditions to grasp the inundation depths in the project area. The objective flood for the simulation is the 1957 flood that can be regarded as a 3-yr flood in terms of the discharge at the Chao Phraya Dam. Flood damage amounts of the two cases were estimated by using the obtained depths as shown in Table 7.5.6. Finally the annual flood damage reduction, the benefit of the 3-yearr river improvement is estimated at 221 million baht/year under the future basin condition in 2006 when the improvement will start to generate benefit, as shown in Table 7.5.7.

7.5.8 Environmental Consideration

An environmental impact assessment (EIA) for the river improvement project was conducted by TEAM Consulting Engineering Co., Ltd, and summarized as follows:

(1) Environmental Impact Assessment

Impacts of the proposed river improvement were assessed for both the construction and operation periods. Since the project scale of the improvement work is as small as the 3-year level, its adverse impacts are generally small. Although a water level rise of approximately 20 cm at the maximum by heightening of dikes is expected in the rivers during 3-year or less floods, the impacts to the people living on the river banks are considered not so serious because they are already accustomed to flooding situations that occur periodically. The required land acquisition and house evacuation are 1.8 ha and only one (1) house, respectively.

(2) Mitigation Measures

Quite a few measures are proposed to be undertaken to mitigate the assessed impacts. They include public relation activities, involvement of representatives from the related sectors and the affected people in the compensation committee, provision of small flood protection dikes for sensitive archaeological structures, and provision of efficient flood warning system.

(3) Environmental Monitoring Program

An environmental monitoring program is proposed to ensure the effectiveness of the proposed river improvement. The monitored items in the program include water levels, surface water quality, planktonic organisms and benthic organisms, flood duration, flood damage and changes of land use, etc.

(4) Public Consultation

A series of public consultations were made with sub-district headmen, village headmen, members of sub-district administrative organizations and villagers' representatives from concerned villages and sub-districts along the rivers. The government officials, community leaders and a portion of villagers are well aware of the river improvement projects because of the public consultation work. A majority of the meeting attendants agreed that the project is useful for agricultural lands and prefer heightening of existing dikes among the options including construction of new dikes.

7.6 Overall Evaluation for Project Components of Feasibility Study

In previous sections, the features of each project component were discussed. Here, the discussion is made on the overall evaluation for project components included in the feasibility study stage.

7.6.1 Effectiveness and Benefit of the Projects

The effectiveness and benefit of each project component are emphasized in the following points:

(1) Modification of Reservoir Operation Rule

The effectiveness and benefit derived from the modification of reservoir operation rule are flood mitigation in downstream areas at the dam site. On the other hand, this project component brings about an adverse influence in water use for irrigation and hydropower generation. The benefit and adverse influence are estimated as follows:

Name of Dam	Economic Benefit (mil. Baht/year)	Adverse Influence* (mil. Baht/year)		
		Irrigation	Hydro-power	Total
Bhumibol	59	0	23	23
Sirikit	424	17	24	41
Pasak	543	16	0	16
Total	1,038	33	47	80

* Adverse influence is estimated in a manner of financial compensation cost.

(2) Land Use Control and Guidance

The most essential benefit of land use control and guidance is the realization of the objective of preservation of natural retarding effect in the Chao Phraya River Basin. As a result, the future increase of flood damage caused by basin development is minimized. Theoretically, the future increase of flood damage is zero when the land use control and guidance is realized. However, it is not realistic to perfectly control and guide the future land use, while the extent of future land use control and guidance cannot be counted. Consequently, benefit derived from the land use control and guidance is not evaluated in monetary term, and thus, economic evaluation is not undertaken for this project component.

(3) Institution and Organization

For this project component, the study was done focusing on the setting up of the river basin committee together with the office of the committee. Needless to say, the benefits of setting up the river basin committee and the office of the committee are the realization of smooth and effective implementation of flood mitigation works through coordination among agencies concerned, so that economic and financial losses is remarkably mitigated.

However, as well as land use control and guidance, the benefit derived from setting up the river basin committee cannot be evaluated in monetary term and thus economic evaluation for the project component is not undertaken.

(4) River Improvement

The annual benefit derived from the river improvement is estimated to be 221 million baht/year, as discussed in Section 7.5.

Besides, it is expected that the river improvement bring about intangible benefits such as stability of living conditions, enhancement of living standards, increase of business opportunities, etc. Among these, the stability of living conditions and the enhancement of living standards derived from the alleviation of menace of flood are essential for the future development in the agricultural sector.

7.6.2 Cost of Projects

Among the project components, the modification of reservoir operation rule and the river improvement require costs for implementation. As for the others, land use control and guidance and institution and organization, the costs required can be hardly identified so that cost estimation was not undertaken.

The cost required for project implementation, which is expressed in terms of financial and economic costs, is as follows:

(1) Modification of Reservoir Operation Rule

In case of the modification of reservoir operation rule, it is not necessary to provide additional facilities. Therefore, this measure does not require cost for facilities. However, it is necessary to compensate the reduction of water use for irrigation and hydropower, which is assumed to be the cost.

The economic cost for compensation due to modification of the reservoir operation rule is as follows:

(Unit: million baht)

Name of Dam	Compensation for Irrigation	Compensation for Hydro-power	Total
Bhumibol	0	20	20
Sirikit	17	21	38
Pasak	16	0	16
Total	33	41	74

(2) River Improvement

As discussed in Section 7.4, River Improvement, the cost for river improvement is as follows:

(Unit: million baht)

Works	Financial Cost		Economic Cost	
	Initial Cost	O&M Cost	Initial Cost	O&M Cost
River Improvement	1,425	34	1,234	31

7.6.3 Economic Evaluation

The economic evaluation is made only for project components that can be evaluated in monetary term based on the economic cost and benefit discussed above. The evaluation is made in a manner of EIRR, B-C and B/C.

Table 7.6.1 shows the annual cash flow. EIRR, B-C and B/C are as given below:

Item	(1) River Improvement	(2) Modification of Reservoir Operation Rule	Combination of (1) and (2)
EIRR (%)	12.5	-	-
B-C (million Baht)	28	5,693	6,333
B/C	1.0	13.3	6.4

As identified in these figures, the economic viability is not so high, but the EIRR value is over 10%, which is regarded as the minimum of project viability. In case of modification of reservoir operation, EIRR is not a suitable index to identify the economic viability. This is because the project brings about constant benefit and cost from the beginning (Bn and Cn are constant), so that the EIRR shown in the following equation is not obtainable unless Bn = Cn.

$$\Sigma[Bn / (1+i)^n) / \Sigma(Cn / (1+i)^n] = 1$$

Where,

Bn : Annual benefit of n-th year from the beginning

Cn : Annual cost of n-th year from the beginning

i : EIRR

Σ : Accumulation of benefit and cost for whole years in project life.

Therefore, only B-C and B/C were used to evaluate the economic viability of the project component. Judging from the figures, the modification of reservoir operation rule will bring about a high economic return.

Also, the project involves many intangible benefits such as stabilization of people living conditions, decrease of waterborne diseases, increase of work opportunities and so on.

7.6.4 Financial Consideration

(1) Modification of Reservoir Operation Rule

The modification of reservoir operation rule requires the cost of 80 million baht per year. The source of the cost is assumed to be the government budget, which will be fulfilled by increase of government income resulting from the increase of productivity in the river basin due to flood damage mitigation.

(2) River Improvement

For implementation of river improvement, the initial financial cost of 1,425 million baht will be disbursed for the first 7 years, 339 million baht at the peak year in 2003 and 2004, and O&M cost of 34 million baht per year. The source of these costs is also assumed to be the government budget in the same reason as the case of modification of reservoir operation rule.

In case of RID, new projects are classified into three (3) categories depending on the project scale: large, medium or small. In these categories, a large scale project is defined as follows: project cost of more than 200 million baht and/or irrigation area of more than 80,000 rai and/or reservoir capacity of more than 100 million m^3.

Large scale projects are to be submitted to and approved by the Cabinet Council composed of all ministers and chaired by the Prime Minister. Once the approval is made by the Cabinet Council, the yearly budget is allocated to the ministry concerned. After the allocation to the ministry, the budget is set up independently of the ordinary budget and carried out under the administration and execution of that approved ministry.

7.6.5 Environment Assessment

As discussed before, an environment impact assessment (EIA) was made only for the river improvement. The EIA concludes that the river improvement will cause no serious environment impacts (refer to Subsection 7.5.8).

7.6.6 Implementation of the Project

(1) Organization for Implementation of the Project

In principle, each project component examined in the feasibility study is handled by the following executing agencies:

- Modification of Reservoir Operation Rule: EGAT and RID
- Landuse Control and Guidance: DTCP and LDD
- Institution and Organization (Establishment of River Basin Committee): Office of National Water Resources Committee
- River Improvement: RID

Among these, most of the project components can be undertaken by the present organization; however, it may be necessary to set up a project office for the implementation of river improvement, as discussed below:

- In case the river training works is implemented, the Project is generally under the direct responsibility of the Deputy Director General for Construction.
- After completion of the bidding procedures and the construction contractor and engineering consulting firm to supervise the construction works have been selected, the Project Field Office will be established and the Project Field Director will be appointed.
- The Project Field Office will work under the Office of Water Resources Development, which is under the Deputy Director General for Construction of RID.

- The Project Field Office, in general, is composed of: (1) administration and legal section, (2) planning and design section, (3) construction section, and (4) equipment and materials section.

The organization for project implementation is as shown in Fig. 7.6.1.

(2) Implementation Schedule

Most of the project components can be implemented after approval of the projects as discussed below:

(a) Modification of Reservoir Operation Rule

For the modification of reservoir operation rule, several processes will be taken for the implementation: nomination of section responsible for introduction of newly proposed operation rule; further detailed study on the proposed operation rule; approval of the proposed operation rule in EGAT and RID; confirmation of compensation system for reduction of water use and so on.

Although the necessary period for these processes was hardly identified, it is assumed that it will take about one (1) year to start the operation.

(b) Land Use Control and Guidance

The land use control and guidance is currently being implemented by the agencies concerned, and the information provided in the study such as flood risk map, flood potential map and damage map can be used for that purpose after the approval of the study. Thus, it does not take time to prepare the land use map considering the information provided.

(c) Institution and Organization

For official setting up of the River Basin Committee, it is necessary to enact the Water Resources Act, which is under consideration in the diet. Although the time of enactment of the Act is not presently clear, it is expected that the diet deliberations will be concluded within this year of 1999. After then, several processes for the establishment of the River Basin Committee will be taken. In this study, it is assumed that it will take a total of two (2) years for its establishment.

(d) River Improvement

As discussed earlier, it is assumed that it will take six (6) years for completion of the river improvement including detailed design.

The implementation schedule of these measures is shown in Fig. 7.6.2.

(3) Operation and Maintenance of Each Project Component

Most of the project components for nonstructural measures can be operated and maintained under the framework of the existing organization such as

EGAT, DTCP and LDD. As for the River Basin Committee, office running cost including manpower is necessary, although the amount is minimal.

As for the O&M cost for river improvement, the cost necessary for the administration, replacement of equipment, materials and structures is about 34 million baht per year as discussed in the previous section.