3. MASTER PLAN STUDY

3.1 Premises for Study

3.1.1 Target Year

In accordance with the Scope of Work, the target year for the Master Plan is defined as year 2010. Noteworthy here is that the year 2010 is only 12 years ahead of the present, and the Master Plan must therefore be formulated in strictly realistic considerations, especially on:

- Land use conditions at present and in year 2010;
- Present status and expected growth of the socioeconomic frame in the Study Area;
- Possible investments (national/local budgets and foreign aid amounts) in coming 12 years for the drainage improvement and flood control sector;
- Availability of land acquisition, house evacuation and preparation of adequate relocation sites for the actual implementation; and so on.

This understanding is a baseline for the formulation of the Master Plan.

<u>Land Use Conditions in 1998 and 2010</u>

The land use conditions in the Study Area at present (year 1998) and in future (year 2010) have been delineated in Section 2.3. The results are summarized in the following table:

Land Use Conditions in 1998 and 2010

Category	In 1998		In 2010		Variation
	Area (km^2)	Share (%)	Area (km^2)	Share (%)	(%)
A. Dense Urban Center	6.03	3.1	6.63	3.4	+ 10
B. Dense Residential Area	11.24	5.7	13.49	6.9	+ 20
C. Loose Residential Area	30.12	15.4	55.72	28.5	+ 85
D. Large-scale Developments	(10.80)	(5.6)	(20.17)	(10.3)	(+ 87)
D-1. Dense Activities	2.87	1.5	4.31	2.2	+ 50
D-2. Loose Activities	7.93	4.1	15.86	8.1	+ 100
E. Agricultural Land	119.19	60.9	81.30	41.5	- 32
F. Fishponds	0.70	0.4	0.77	0.4	+ 10
G. Green Space	2.09	1.1	2.09	1.1	0
H. Lakes and Ponds	15.54	7.9	15.54	7.9	0
Total	195.71	100.1	195.71	100.0	-

<u>Socioeconomic Frames in 1998 and 2010</u>

In addition, the socioeconomic frames in years 1998 and 2010 within the Study Area are estimated in Section 2.2 as follows:

Socioeconomic Frames in 1998 and 2010

Item		In 1998			In 2010			Growth Rate (% per annum)
		City Core	Suburbs	Total/ Average	City Core	Suburbs	Total/ Average	
Population (1,000 person)		545	272	817	795	397	1,192	3.2
GRDP	Per Capita (US $)	-	-	335	-	-	570	3.9
	Gross (US$ mill)	-	-	257	-	-	680	7.2

3.1.2 Protection Levels

Usually, determination of the protection level (design scale of facilities) depends on preceding practices in the similar projects. Table I3-1 shows such protection levels applied to the flood protection (flood control) and drainage improvement projects in capitals of Southeast Asian countries. In due consideration of these practices, we decided the protection level for each group of flood protection facilities, major drainage facilities (whose catchments are principally more than 1 km^2), and minor drainage facilities (whose catchments less than 1 km^2) as follows:

(a)	Flood protection facilities such as dikes, river walls, road heightening, etc.	:	30-year return period of water level (EL. 10 m) a little higher than the maximum water level since 1960 at Chaktomuk Station (EL. 9.96 m in 1961)
(b)	Major drainage facilities such as pumping stations, floodgates/sluiceways, regulation ponds, drainage mains (catchment area > approx. 1 km^2)	:	5-year return period of rainfall
(c)	Minor drainage facilities, meaning sewer systems (catchment area < approx. 1 km^2)	:	2-year return period of rainfall

3.2 Planning and Design Conditions

3.2.1 Planning Conditions

Prior to the study for the Master Plan, the planning conditions therefor have been established as stipulated below:

(1) To save the initial investments as well as operation and maintenance cost for structures/facilities, the non-physical measures will be incorporated as a major factor of the Master Plan. Among the non-physical measures, most essential are (a) flood defense activity for flood protection; and (b) land use control, comprising zoning control and development/building control, for assisting drainage improvement.

(2) Land acquisition and house evacuation must cause social conflicts in this area, so that the Master Plan should refrain from these as much as possible. For instance, when the existing sewer systems in the City Core are short in flow capacity, the installation of box culverts underneath main streets will be examined, in place of open channel construction in the house-congested area.

(3) Taking into account deteriorated environmental condition in the city of Phnom Penh, alternatives in this study will include not only those for flood protection and drainage improvement but for the environmental enhancement, like riverfront conservation, lake conservation, flush water introduction, "green" channel plan, etc.

(4) Most area of the City Core has been furnished with sewer networks of the combined system to collect both storm water and wastewater. The present Master Plan includes improvement of drainage situation in the Study Area, but excludes sewerage problem from its scope of work. In the Master Plan, the existing sewer networks will therefore be graded up to safely drain the storm water over the area; however it basically doesn't matter whether the improved networks would receive wastewater as they do, or a new separate system would be provided to take off the wastewater. (This is because the size of a sewer pipe is determined by the design discharge of storm water, not by that of wastewater.) As a matter of course, examination on the construction of sewage treatment plants or so is also out of scope. For such sewerage issues, another study should be formulated in the near future.

However, the Master Plan should incorporate a certain prediction on the possibility of the construction of sewage treatment plants and the like by its target year of 2010. The result affects the environment, especially water quality, along open drainage mains, in regulation ponds and at pumping stations all located downstream of the sewer networks. In this context, it is assumed in this Master Plan that:

(a) Sewage treatment plants and the like will not be provided by year 2010 since they incur huge costs for the construction and operation/maintenance, and hence the existing combined sewer system will remain in the City Core, and even develop outwards on newly urbanized areas; and

(b) As a result, the downstream facilities as listed above shall be planned and designed to cope not merely with storm water but with wastewater discharging from the combined sewer system.

(5) As for the future sewer network extension, on the other hand, the following two assumptions are applied to the Master Plan:

(a) Sewer networks be furnished publicly over A and B zones, with more than about 2 km^2 of catchment, on the 2010 land use condition. On practice, such areas are limited in the City Core.

(b) D zone in the 2010 land use "Large Scale Developments" may have similar sewer facilities, but they will be provided by the private sector under owner's responsibility and expense. Such plans and costs are ruled out from the Master Plan.

(6) There are nine pumping stations (one is not working) built mostly by the Inner Ring Dike for local drainage. However, an integrated pumping station are generally constructed at the final discharge point of the total catchment, not merely to save construction cost but to secure easy maintenance and low operation cost. This philosophy of planning in terms of the location of pumping stations is valid also for the present Master Plan, hence:

  (a) Existing intermediate pumping stations, such as Tum Nup Toek, Salang, Toek Laak, Olympic and Toul Kork I, II & III provided mostly along the Inner Dike, are ignored from the Master Plan and kept as they are just in case. The drainage for the relevant basin of each station above relies on gravity flow through a sluiceway to be installed under the Inner Dike. This has been proved to be hydraulically possible by the initial investigation of the topography and water stage balances inside and outside the dike during past floods.

  (b) On the contrary, the Master Plan will examine enhancement or new construction of the Trabek, Tompun and Svay Pak pumping stations to locate at the downstream ends of respective catchments.

3.2.2 Design Conditions

The design conditions enumerated in Table I3-2 will be applied to the preliminary design of facilities proposed in the Master Plan. The freeboards of dikes shown in the table are derived from an estimation presented in Table I3-3 which shows the basis of the determination of the high water level and freeboard of each section of dikes based on the water level records and considering the wave setup expected in the section of dike.

3.3 Alternative Studies on Flood Protection

3.3.1 Alternatives Suggested

The most essential issues on the flood protection in the Study Area are:

- The protection line, meaning on which line the Study Area should be protected from floods brought about by the Mekong river system; and
- Basic measures for the flood protection.

Primary discussions on the above issues are made in Table I3-4, and the alternatives on the protection line are depicted in Figure I3-1. These are looked into stretch by stretch hereinafter.

<u>Riverfront</u>

The Riverfront refers to the sections facing on the Tonle Sap and Tonle Bassac rivers, comprising the Sap Upstream (approx. 11.0 km), Sap Downstream (approx. 3.8 km) and Bassac (approx. 3.5 km) sections. Sap Downstream Section is further divided into the North (Chruoy Changvar Bridge to Street 108, approx. 1.7 km), Middle (Street 108 to Street 184, approx. 1.0 km) and South (Street 108 to Hotel Sofitel, approx. 1.1 km) sections.

(1) Sap Upstream and Bassac Sections

The Sap Upstream and Bassac sections are similar in nature. Trunk roads pass near both riverbanks: NR-5 in Sap Upstream Section and Samdach/Norodom blvds. in Bassac Section. The road surfaces are approximately 10 to 11 m in elevation, not lower than the high water level of the rivers (EL. 10 m) except several portions. However, between the roads and rivers are narrow strips with areas of 1.27 km^2 and 1.58 km^2 in the Sap Upstream and Bassac sections, respectively. The land of the strips is occupied by large-scale developments (factories, hotels, schools, embassies, etc.), housings and open spaces. The large-scale developments are in many cases established on the ground higher than the high water level, whilst most of the housings are built on lower elevations submergible during high water periods of floods. These conditions may suggest the following two alternatives on the flood protection along the Tonle Sap and Bassac sections:

- Alternative 1: Construction of dikes on the riverbank shoulders in necessary stretches in order to protect not solely inland areas behind the roads but housings in the narrow strips between the roads and rivers from being flooded.
- Alternative 2: Promotion of flood defense activity in lower portions of the trunk roads to protect the inland areas behind the roads only, and thus the riverine strips will be left as they are.

(2) Sap Downstream Section

The bank shoulder along Sap Downstream Section is as high as 10.5 m in elevation at lowest, with clearances of more than 0.5 m above the high water level, so that there is no possibility of spilling of floodwater due to the Mekong river system. In the Middle Section, however, the existing revetments have collapsed in places (whereas revetments or natural banks in the North and South sections are yet sound). This collapse not only jeopardizes the bank safety itself, but also damages aesthetics of the riverfront used as a park zone at present, further which is anticipated to be bettered in future. To solve the problem, the existing revetments should be reconstructed with a proper structure to be selected among the following two types of alternatives:

- Alternative 1: Stone pitching type of revetment
- Alternative 2: Concrete facing type of revetment

The alternatives suggested for the above two sections of the Riverfront are examined in the succeeding Subsections 3.3.2 and 3.3.3, respectively.

Existing Dike Sections

Along the perimeter of the Study Area, there exist two dike sections with considerably large heights, say more than 3 m: i. e. Kop Srov Dike and Tompun Dike (refer to Figure I3-1). The two dikes function as a part of the protection line of the Study Area against floods caused by the Mekong river system. In addition, the dike crests are increasingly used for traffic, especially transportation of heavy equipment and materials for industrial zones. (Such has been banned to cross the center of Phnom Penh City.) The features and dimensions of the dikes are as tabulated below:

Features of Kop Srov and Tompun Dikes

Description	Kop Srov Dike	Tompun Dike
(1) Length	9.0 km	4.4 km
(2) Existing Conditions		
(a) Crest Elevation	EL. 10.1 to 10.7 m	EL. 10.0 to 10.4 m
(b) Height above Land *	4 m	5 m
(c) Crest Width *	10 m	20 m
(d) Formation Width *	26 m	40 m
(e) Side Slopes	Approx. 1:2	Approx. 1:2
(f) Structural Conditions	- No pavement on the crest, undulated, and marshy in the rainy season. - Many holes found on the dike crest and even on the slopes that should be the traces of piping in the dike body. - Slopes eroded in places.	- No pavement on the crest, undulated, and marshy in the rainy season. - No holes found on the dike crest, however some piping reported in past flood times. - Slopes eroded in several places.
(g) Social Conditions	- Squatters live on both slopes in the east end portion.	- Squatters occupy on both slopes along the entire stretch.
(3) Design Conditions		
(a) High Water Level **	EL. 10.4 m	EL. 9.0 m
(b) Freeboard **	0.8 m	1.1 m
(c) Hydraulic Gradient of Seepage Water ***	1/8 (1/5)	1/8 (1/8)

* At a higher portion of the dike.

** Refer to Table I3-3.

*** Determined in consideration of practices in major foreign rivers, and the value in the bracket shows the existing condition.

(1) Kop Srov Dike

As can be seen in the table above, Kop Srov Dike is short in height by 1.1 m at maximum and is judged to be quite week against seepage phenomenon. Hence, heightening and widening the existing dike should be a component of the Master Plan. In view of the present conditions, the following two structural alternatives are suggested:

- Alternative 1: Triple Section (A dike on the riverside not only to prevent overtopping but also to reduce seepage with non-permeable material, and a berm on the land side to avoid piping with permeable material)
- Alternative 2: Single Section (Raising of the existing dike road up to the design dike height)

(2) Tompun Dike

With respect to Tompun Dike, on the other hand, the height is sufficient to confine the high water level (EL. 9.0 m). However, the dike body is supposed to be weak against seepage judging from the fact that piping was reported in past flood events (although the formation width of the dike is relatively large even compared to other practices). Some countermeasure should be taken to cope with such piping. Most effective, economical and practical may be the provision of a land side berm.

Alternative studies and detailed discussions on the reinforcement of the Kop Srov and Tompun dikes are made in Subsection 3.3.4.

On the other hand, in consideration of the importance of these dikes, the non-physical measure, especially flood defense activity, must carefully be prepared through the high water period of the Mekong river system even after the reinforcement of the dikes has been completed. Should there be some unordinary phenomena such as seepage through dike body, erosion on the dike slopes and deformation of the dike surface, immediate countermeasures shall be taken.

South Section

The land use condition in the South Area is mainly agriculture use with few developments and less urbanization at present and even in future. Moreover, the floods of the Prek Thnot River freely come into this area via existing three openings. This condition is rather beneficial for agricultural activity than hazardous to the assets in the area. In this case, the following two alternatives can be considered for the protection line along the South Area (see Figure I3-1):

- Alternative 1: On Prey Sar Road with the heightening of the road and the provision of a pumping station, a regulation pond, 3 floodgates and drainage mains to protect the South Area itself from flooding from the Prek Thnot River.
- Alternative 2: On the planned Tompun Extension Road in future to protect areas except S2 of the South Area (for the time being, on the BOT Road, with surface elevations of higher than 9.5 m, to protect areas except the whole South Area).

The alternative study results are presented in Subsection 3.3.5.

West Section

The West Section, totaling 9.2 km, corresponds to the southern portion of Kop Srov Road and Prey Pring Dike (a small dike connecting NR-3 to NR-4 on the border of the Study Area). Both are around 0.5 m high on the adjacent land with few crossing structures. The west of this section (outside the Study Area) is slightly hilly, and less water comes down to the section. Refer to Figure I3-1. On this condition, flood protection measures along the section will not be necessary.

3.3.2 Protection Line along Sap Upstream and Bassac Sections

Two alternatives suggested in Subsection 3.3.1 on the protection line along both Sap Upstream and Bassac sections are looked into herein: i. e. Alternative 1: Construction of dikes on the riverbank shoulders; and Alternative 2: Promotion of flood defense activity in lower portions of the trunk roads.

Shown in Table I3-5 is the costs and benefits when Alternative 1 is applied to the Sap Upstream and Bassac sections. The ratios of required cost per protected household, in the bottom row of the table, are as high as US$ 11,100/household and US$ 4,000/household for the Sap Upstream and Bassac sections, respectively, compared to US$ 900/household in Tompun Watershed. This indicates that the construction of dikes along the shoulders of the riverbanks of Sap and Bassac, only to protect shanties (large-scale factories/buildings are mostly located above the high water level), can be a quite costly and ineffective exercise.

In conclusion, most economical and reasonable measures for the flood protection in the sections is to promote flood defense activity along NR-5 for the Sap Upstream Section and along Samdach Sothearos/Norodom blvds. for the Bassac Section to protect the inland areas behind the roads. In addition, the flood defense activity is only limited to several portions and short time, because the road elevations are, basically, slightly higher than the high water level (EL. 10 m) of the rivers.

The riverside strips are thus left intact in front of the roads, so that the following basins are excluded from the succeeding drainage improvement study:

- C6: Bassac Riverside Basin (1.58 km^2); and
- E4: Sap Riverside Basin (1.27 km^2).

3.3.3 Riverfront Protection in Sap Downstream Middle Section

This work refers to the reconstruction of the existing revetments from Street 108 to Street 184 with a length of approximately 1.0 km to stabilize the riverbank and better the riverfront environment. The high water level along the section is EL. 10.0 m, and adding a freeboard of 0.9 m to cope with wave setup, the design bank height becomes 10.9 m (refer to Table I3-3). This elevation is generally correspondent to the present bank heights although in some places the design bank shoulder of the new revetment may be a little higher than the adjoining land formation (say, 20 to 30 cm at highest).

To protect the riverbank securely, the revetment should comprise slope protection and foot protection. Stone filling is suitable and economical for the foot protection, while as for the slope protection the following two structural alternatives are suggested: Alternative 1: Stone Pitching ; and Alternative 2: Concrete Facing. For the structure, see Figure I3-2. Taking into account the following points, it is recommended that Alternative 1 be applied to the slope protection for this section:

- The cost of Alternative 1 is a little lower than that of Alternative 2;
- Alternative 1 is, environmentally, superior to Alternative 2; and
- Maintenance of stone pitching is in wide meaning easier than the concrete facing.

The work shall incorporate reconstruction of three existing outlets all provided with pump facilities in 1998. Moreover, noted herewith is the prohibition of sand mining now carried out along the shoreline of the section that must jeopardize the stability of revetments existing and even newly reconstructed.

3.3.4 Reinforcement of Kop Srov and Tompun Dikes

The Master Plan, as determined in Subsection 3.3.1, includes the reinforcement of Kop Srov Dike located in the northern part of the Study Area with a length of 9.0 km and Tompun Dike in the southern part of 4.4 km. The height of the existing Kop Srov Dike is insufficient, by 1.1 m at maximum, safely to confine the design high water level (EL. 10.4 m) plus a wave setup (0.8 m). Moreover, the dike itself is judged to be structurally week to prevent piping through the dike body or its foundation. The Tompun Dike, on the other hand, has crest elevations enough to be free from overtopping, while the dike body, likewise in Kop Srov Dike, is in problem. The design requirements for both dikes are as follows:

Design Requirements of Kop Srov and Tompun Dikes

Item	Kop Srov Dike	Tompun Dike
Design High Water Level	EL. 10.4 m	EL. 9.0 m
Design Freeboard	0.8 m	1.1 m
Design Dike Height	EL. 11.2 m	EL. 10.1 m
Design Hydraulic Gradient of Seepage Water through Dike Body	1/8	

(1) Kop Srov Dike

Two alternatives are worked out with reference to the reinforcement of Kop Srov Dike: i. e. Alternative 1: Triple Section, and Alternative 2: Single Section. The detailed structure of each is presented in Figure I3-3. Alternative 2 is the idea of simply raising the existing dike, by 1.1 m at largest, across the full width, while Alternative 1 aims at cost saving and easy construction in the following manner:

(a) Constructing a dike, with a minimal crest width of 3 m and an elevation of 11.2 m, on the riverside of the existing dike to prevent overtopping and to reduce seepage with non-permeable material; and

(b) Providing a berm, with a width of 5.0 m and an elevation of 9.0 m, on the land side to avoid piping phenomenon at the toe of the dike by using permeable material.

Cost comparison between both clarifies that Alternative 1 can achieve an about 10 % cost reduction compared to Alternative 2. Taking into account the relative easiness of construction as well, Alternative 1 is selected as the optimal reinforcement method for Kop Srov Dike.

(2) Tompun Dike

As for Tompun Dike, the application of the land side berm method is recommended, similar to Kop Srov Dike, in view of economy and precedents in other countries. This method cannot stop seepage through the dike body or its foundation itself, but effective to avoid piping at the land side toe that might result in crucial failure of the dike. Completely to remove any seepage, concrete covering, sheet pile driving, etc. on the riverside of the dike are conceived, but these could be costly and unfeasible under the present condition of the Cambodian economy.

3.3.5 Protection of South Area

With respect to the flood protection line, in other words whether the South Area will be protected or not, two alternatives are suggested in Subsection 3.3.1: i. e. Alternative 1: On Prey Sar Road (to protect the whole South Area); and Alternative 2: On the planned Tompun Extension Road in future and on BOT Road for the time being (principally not to protect the South Area).

Naturally, Alternative 1 entails heightening of Prey Sar Road, and provision of a pumping station at the Prey Sar Bridge site, a regulation pond near the pumping station and three floodgates across the existing three outlets. This construction costs about US$ 24.3 million as estimated in Table 13-6. The economic efficiency of this flood protection work can be assessed using the cost per number of beneficiary. It is as high as around US$ 4,900/household as shown in the table. Comparing with US$ 900/household in Tompun Watershed for instance, this project is very costly and can be said unfeasible. The selection of Alternative 2 should be reasonable.

As a result, concerning the flood protection and drainage improvement in the South Area, it is concluded that:

(a) For the time being, the greater portion of the Study Area, except the South Area, is protected by the existing BOT Road, whose surface elevations are above 9.5 m so that it can prevent overtopping of floods due to the Prek Thnot River;

(b) In the future, the Study Area, inclusive of S1: BOT Road South Basin while still exclusive of S2: Prey Sar Basin both in the South Area, will be ensured form the floods by the planned Tompun Extension Road; and

(c) The Master Plan, in principle, does not apply physical measures to the South Area as mentioned above, but instead considers non-physical measures such as land use control and agricultural land conservation over the area.

3.4 Alternative Studies on Drainage Improvement

3.4.1 Alternatives Suggested

The alternative studies on drainage improvement, in turn, are made herein. The study principally covers the whole Study Area, however excepting the following three areas (43.45 km^2 in total) that are located outside the flood protection line as discussed in Section 3.3 above:

- C6: Bassac Riverside Basin in the City Core (1.58 km^2);
- E4: Sap Riverside Basin in the Northeast Area (1.27 km^2); and
- South Area comprising S1 and S2 (40.60 km^2).

The remaining area of 152.26 km^2 (Study Area, 195.71 km^2, minus the above excepted areas, 43.45 km^2) is hence subject to the drainage improvement study.

<u>Study Items Identified</u>

The most important matters on the drainage improvement study are:

- Drainage direction of each basin; and
- Basic measures for drainage in each basin.

Based on the above understanding, drainage direction and basic measures in each basin are examined as presented in Table I3-7 (refer to Figure I3-4). Most of the directions are naturally determined by the topography, land use and layout of the existing drainage facilities. As for the basic measures, on the other hand, several points still remain under further considerations. Moreover, Table I3-7 shows that E3 of the Northeast Area (1.25 km^2) and M4 in the Middle Area (0.70 km^2) can be omitted from the drainage improvement study for the reasons mentioned in the table. The study can thus focus on the area of 150.31 km^2 (152.26 km^2 above minus 1.25 km^2 and 0.70 km^2).

Summarizing the preliminary results in Table I3-7, main points in the drainage improvement study may be:

(a) Drainage direction of Pochentong East Basin;

(b) Economic optimization between the pump capacity and regulation pond volume at each site of Tompun, Trabek, Pochentong East pumping stations, etc.;

(c) Detailed comparison on the route, type, structure, etc. of drainage mains and other major facilities; and

(d) Possibility of the construction of Svay Pak Pumping Station.

Most fundamental among the above is Item (a) that dominates the boundaries of drainage areas. This will firstly be studied hereunder.

<u>Drainage Direction of Pochentong East Basin</u>

As for the drainage direction of Pochentong East Basin, which is expected to be developed as a commercial, industrial, educational and housing area, the following three alternatives have been suggested:

- Alternative 1: To the south over BOT Road;
- Alternative 2: To Tompun Basin through Meanchey Channel; and
- Alternative 3: To the north up to Boeng Poungpeay.

Mainly from the standpoint of difficulty of land acquisition for construction of a drainage channel connecting the basin to the outlet, Alternative 1, i.e. to the south over BOT Road, is judged to be advantageous over the others. Detailed discussions follow:

(a) Alternative 3 might require no pumping station at the outlet, however it entails an about 2.5 km drainage channel, with a width of 5 m or more, to connect the basin to Boeng Poungpeay through a house-congested area, even across NR-3 in between. Land acquisition for such construction could result in a serious social problem. This alternative is thus unfeasible.

(b) Alternative 2 could necessitate increase of pump capacity at Tompun Pumping Station and enlargement of the existing Meanchey Channel by a few meters over a stretch of about 4 km, which would also be unwelcome by the residents nearby.

(c) Compared to the above two, Alternative 1 has less problem, requiring no additional land for channel construction although a pumping station should be provided independently at the outlet.

Drainage Areas Subject to Study

As a result, the boundaries of drainage areas can be delineated dividing the objective area (150.31 km^2) into the following five:

- Tompun Watershed : 17.47 km^2
- Trabek Basin : 10.83 km^2
- City Core North Area : 6.57 km^2
- Pochentong East Basin : 15.35 km^2
- Northeast and Northwest Areas : 100.09 km^2

The studies on drainage improvement are conducted hereinafter area by area, in other word independently for the five areas, focussing mainly on Items (b) and (c) as well as Item (d) listed in Clause "Study Items Identified" in this Section.

3.4.2 Tompun Watershed

The drainage improvement in Tompun Watershed will comprise construction of a pumping station and regulation pond, improvement of Meanchey Channel (named Meanchey Drainage Main hereinafter), provision of underground drainage mains, and rehabilitation of existing sewers. The total catchment area is 17.47 km^2 consisting of:

- C8 : Salang Basin : 5.53 km^2
- C9 : Tum Nup Toek Basin : 0.68 km^2
- C10 : Toek Laak Basin : 0.10 km^2
- M1 : Tompun Basin : 11.16 km^2

Pumping Station and Regulation Pond

(1) Construction of New Pumping Station

There is an existing pumping station at the downmost of the watershed on the immediate land side of Tompun Dike, called Tompun Pumping Station built in 1972. Its present capacity has been rated at 5.9 m^3/sec on official base. In view of pump engineering, however, the pump capacity can be assessed nearly nil considering large volume of water leakage from the outlet pipes and deterioration of efficiency of pumps and motors/engines (maybe fabricated in 1950's and 1960's mostly). Moreover, the control panel in the station is now under quite dangerous condition, probably causing a short-circuit anytime during operation. On the other hand, it is technically difficult, and even economically unreasonable, not merely to repair such mechanical and electrical facilities but to rehabilitate the civil and architectural structure so aged and damaged in places. In this case, a new pumping station, with an adequate pump capacity, shall be constructed for sure and entire drainage of the watershed.

The new station is recommended to be provided on the west side of the existing station where less compensation is expected. The existing station will then be left intact just for emergency, and its capacity is not involved in the Master Plan.

(2) Construction of Regulation Pond

The pumping station is the key element of drainage in the watershed, however it is uneconomical to cope with all the peak discharge solely by pumps. Assistance of a regulation pond is essential. Fortunately, a large lake called Boeng Tompun is located just upstream of the pumping station (whose water surface area is 47.5 ha). Now, the lake is used only for aquiculture. This can function as a regulation pond, with a certain excavation of the lake bottom, to lighten the load of pump facilities, realizing an economical drainage plan for this watershed.

(3) Combination of Pump Capacity and Regulation Pond Volume

The following table shows the study results to seek the economically optimal combination of pump capacity and regulation pond volume based on the design hydrograph of Tompun Watershed, with a return period of 5 years, given in Subsection 2.4.6. Although there are no significant differences among Alternatives 1, 2 and 3 in construction cost, Alternative 2 is the most economical, and hence selected as the optimal combination. The pump capacity is 15 m^3/sec and the necessary regulation pond volume is 560,000 m^3.

Dimensions and Construction Costs of Alternatives on the Combination of Pump Capacity and Regulation Pond Volume

Alternative	Pump Capacity (m^3/sec)	Regulation Pond (47.5 ha) *			Construction Cost (US$ million)
		Necessary Volume (m^3)	Regulation Water Depth (m)	Low Water Level (EL. m)	
1	9	750,000	1.6	2.9	12.6
2	15	560,000	1.2	3.3	12.3
3	21	450,000	1.0	3.5	13.0
4	27	370,000	0.8	3.7	14.3
5	33	290,000	0.7	3.8	14.5

* The design surcharge water level is set at EL. 4.5 m on account of ground elevations around the lake.

<u>Meanchey Drainage Main</u>

Meanchey Drainage Main is an open channel running along outside of the Inner Ring Dike, and conveys all storm water from Tompun Watershed finally to discharge it to the Tompun Pumping Station site. The drainage main is divided into up- and downstream sections by Meanchey Bridge where the runoff from the western part of the City Core will join. Major points of the channel improvement are as follows:

Features of Meanchey Drainage Main

Description	Downstream Section	Upstream Section
Improvement Length (km)	Approx. 2.8	Approx. 2.1
Design Discharge (m^3/sec)	75	15 & 11
Longitudinal Profile	To be dug as deep as possible to ease drainage in the City Core area. 1/2,500.	To keep the existing profile not to affect riverine houses. 1/2,000 & 1/1,000.
Cross-section	Earth channel	Earth and revetted channels

Underground Drainage Mains

In the City Core portion of Tompun Watershed with a catchment area of 6.31 km^2, there is no open drains. This is very exceptional compared to other cases, e.g. in Hanoi City are open drains with densities of 1 km or more per km^2. Such lack of open drains is the main reason why the area suffers from repeated inundation even in small rains when the total rainfall becomes over approximately 50 mm. However, this area is completely congested with buildings, apartments and ordinary housing. No space is found for newly excavating open drains at all. Only the solution to be conceived, in this case, is the construction of underground drainage mains beneath major roads.

In the present area, on the other hand, a broad avenue, called Samdach Monireth Street, runs along the centerline of the area from the northeast to the southwest, joining several considerably wide streets. This structure of road network is favorable to provide underground drainage mains underneath. The drainage mains should be of the box culvert type in order to cope with the comparatively large design discharges (44, 20 and 8 m^3/sec). The profiles of such drainage mains established after preliminary examinations are enumerated in Subsection 3.6.1. Noted herein are the following:

(a) Samdach Monireth Drainage Main connects directly to Meanchey Drainage Main near Meanchey Bridge without pump facilities, but with a gated structure (stop logs) under the Inner Ring Dike just for emergency purpose (Jawaharlal Nehru Drainage Main is a branch of this main);

(b) Salang Drainage Main will be provided digging the existing Boeng Salang south lake, connecting to Meanchey Drainage Main in the same manner as above (Boeng Salang north lake will be left intact); and

(c) As for Tum Nup Toek Basin, a sluiceway across the Inner Ring Dike, furnished with stop logs, is designed to lead storm water in the basin to Meanchey Drainage Main.

Sewer Rehabilitation

The existing sewer network, of the combined system, will be rehabilitated by means of furnishing new pipeline networks because most existing pipes are largely short in capacity. The coverage area is 631 ha including Tum Nup Toek Basin. The size of each sewer pipe is determined by Manning Formula.

3.4.3 Trabek Basin

The drainage improvement in Trabek Basin comprises construction of a pumping station and regulation pond, provision of underground drainage mains along the existing Trabek and Toul Sen channels' alignments and so on, and rehabilitation of existing sewers. The total catchment area is 10.83 km^2.

Pumping Station and Regulation Pond

On the same considerations as applied to Tompun Watershed, a new pumping station will be provided on the west side of the existing one, and Boeng Trabek will be dug for regulation. The capacity of the new station has been set at 8 m^3/sec according to the ADB project, and the official capacity (4.2 m^3/sec) of the existing station is ignored. The regulation pond should hence store a volume remaining after subtracting the new pump capacity of 8 m^3/sec constantly from the hydrograph at the downmost of Trabek Basin, i.e. 350,000 m^3 (refer to Subsection 2.4.6). The major dimensions of the pumping station and regulation pond are as follows:

Major Dimensions of Trabek Pumping Station and Regulation Pond

Description	Dimensions	Remarks
(1) Pumping Station		
(a) Existing Station	4.2 m^3/sec (official)	Ignored in the Master Plan
(b) New Station (w/ Inlet Channel)	8.0 m^3/sec	According to the ADB project
(2) Regulation Pond		
(a) Area		
- Upper Pond	10.3 ha	
- Lower Pond	18.4 ha	
- Total	28.7 ha	
(b) Surcharge Water Level (SWL)	EL. 4.0 m	1.3 m of regulation depth
(c) High Water Level (HWL)	EL. 3.7 m	
(d) Low Water Level (LWL)	EL. 2.7 m	
(e) Bottom Height	EL. 2.4 m	
(f) Regulation Volume		
- Upper Pond	130,000 m^3	
- Lower Pond	220,000 m^3	
- Total	350,000 m^3	

The structure and detailed dimensions of the pumping station and regulation pond are tabulated in Subsection 3.6.1.

Drainage Mains

The following three drainage mains are conceived in Trabek Basin on the basis of the same strategy as in Tompun Watershed:

(a) Trabek Drainage Main, of the box culvert type, along the existing Trabek channel;

(b) Toul Sen Drainage Main along the existing Toul Sen channel, of the box culvert type in the downstream stretch while of the open channel type in the upstream stretch; and

(c) Norodom Drainage Main, of the box culvert type, on a new route along Street 360 and Norodom Blvd.

Sewer Rehabilitation

The existing sewer network, of the combined system, will be rehabilitated in the same way as in Tompun Watershed. The coverage area is 1,083 ha.

3.4.4 City Core North Area

The City Core North Area (6.57 km^2) is formed by the following five independent basins:

- C1: Wat Phnom Basin (0.89 km^2);
- C2: Kak Lakeshore Basin (0.51 km^2);
- C3: Boeng Kak Basin (1.14 km^2);
- C4: Tuol Kork Basin (3.32 km^2), which is further divided into separate three sub-basins such as: Tuol Kork I (2.64 km^2), Toul Kork II (0.43 km^2), and Toul Kork III (0.25 km^2); and
- C5: University Basin (0.71 km^2).

Major works in the City Core North Area are rehabilitation of existing sewers in C1, C2 and C4, incorporated with construction of drainage mains in C4 and provision of sluiceways in C3, C4 and C5.

Drainage Mains

Toul Kork Basin has a comparatively large catchment, hence requiring construction of drainage mains. In the same consideration in Tompun Watershed, two underground drainage mains are proposed along Streets 289 and 315. The features are summarized in Subsection 3.6.1. Both drainage mains discharge to the Northeast Area by gravity since the outlet water level is predicted to be EL. 7.0 m at maximum that is still lower than the ground elevation of 8.0 m on depressed lands in Toul Kork Basin.

Sluiceways

One sluiceway, with a single gate, will be installed at the discharge point of Boeng Kak to ensure drainage and to control water stage of the lake. In addition, similar sluiceway structures will be constructed in Toul Kork Basin (3 locations) and University Basin (2 locations).

Sewer Rehabilitation

In the same line as in Tompun Watershed, the existing sewers will be rehabilitated. The coverage areas are 89 ha in C1: Wat Phnom Basin, 51 ha in C2: Kak Lakeshore Basin, and 332 ha in Tuol Kork Basin, totaling 472 ha.

3.4.5 Pochentong East Basin

The Master Plan suggests for Pochentong East Basin, with a catchment area of 15.35 km^2, construction of a pumping station, regulation pond and drainage mains, open channel type, together with a closing gate to Tompun Watershed.

Pumping Station and Regulation Pond

One pumping station will be constructed near the existing pipe culvert across BOT Road. On the east side of the station site, there were two of slender lakes: north and south lakes. However, the south lake has been reclaimed so that the north lake, approximately 2 km away from the station site, can only be used as the regulation pond to assist the pump operation.

The water surface area of the north lake is 6.0 ha. The design low water level is set at EL. 6.0 m, equaling the bottom elevation of the drainage main (an existing channel) connecting the lake with the pumping station, while the surcharge water level at EL. 7.0 m considering adjacent land's elevations. As a result, 60,000 m^3 of regulation volume can be assured by the pond. Based on the hydrograph delineated in Subsection 2.4.6, this volume will achieve a peak cut of 5 m^3/sec, hence giving the pumping station a design capacity of 5 m^3/sec.

Features of the pumping station and regulation pond are presented in Subsection 3.6.1.

Drainage Mains and Closing Gate

Major part of Pochentong East Basin has been prepared for future developments furnished with a canal network. This network can be used as drainage mains in the Master Plan with only providing some revetment works. The design discharges are as small as 5 to 10 m^3/sec, so that no additional land acquisition might be necessary for construction of the drainage mains.

Moreover, there exists a gated structure at the outlet of the north lake (regulation pond) towards Tompun Watershed in order to control the discharge and water level of the lake. This gate is an important structure to protect Tompun Watershed from excess water generated in Pochentong East Basin and so on. The structure will be rehabilitated in the scope of the Master Plan.

3.4.6 Northeast and Northwest Areas

The Northeast Area is a huge swampy area with Boeng Poungpeay in its center, while the Northwest Area a large agricultural land. The total area is 100.09 km^2, sharing the northern half of the Study Area. The Master Plan incorporates some drainage measures for this area as well.

Svay Pak Drainage Sluiceway and Pumping Station

(1) Drainage Sluiceway

In the Northeast and Northwest areas, storm water from the catchment, 105.77 km^2 including a part of the City Core, is presently drained through a sluiceway (very old and damaged in places) provided under NR-5 to the Tonle Sap River when the river water stage is low, while in the reverse case it is just stored in the swampy area. The sluiceway is a crucial structure for flood protection and drainage improvement over the Study Area. Once that were broken down, the northern half of the Study Area should go under water. Taking into account its importance and present status, the drainage sluiceway will be rehabilitated under the Master Plan.

(2) Pumping Station

In the rainy season, as mentioned above, storm water simply accumulates, causing certain inundation over the area, then in the dry season stored water is drained through the sluiceway. This hydraulic annual cycle is roughly analyzed hereunder:

(a) Total runoff during the rainy season (7 months from May to November) is estimated at approx. 130 x 10^6 m^3 by multiplying the average rainfall amount, 1,230 mm, in the rainy season by the catchment area, 105.77 km^2;

(b) Total evaporation during the rainy season is approx. 85 x 10^6 m^3 taking the average annual evaporation height at 800 mm;

(c) The balance between the above two (approx. 45 x 10^6 m^3) is stored in E1 and E2 basins (37.71 km^2), the final inundation depth being approx. 1.2 m; and

(d) Assuming the water stage before the rainy season at EL. 5.8 m based on the field survey results, the final inundation water level may be EL. 7.0 m, which is well corresponding to the heights of flood marks in the area.

The water level of EL. 7.0 m less affects houses, fishponds, etc. in the area, resulting in minimal damage. However, there is an idea of providing pump facilities beside the said sluiceway to prevent such inundation. The operation cost of the pump facilities is calculated as follows:

(a) To maintain water level at EL. 5.8 m throughout the year, the pump capacity should be 2.5 m3/sec = 45 x 10^6 m^3 / 210 days / 86,400 sec;

(b) Necessary power is approx. 190 KW = 15 x 2.5 m3/sec x Head (5 m on average), annual energy to be consumed being 960,000 KWH = 190 KW x 210 days x 24 hr; and

(c) Taking the electric charge at US$ 0.1 per KWH, the annual operation cost becomes US$ 96,000.

The operation cost of US$ 96,000 per annum is quite expensive, and the economic effect is not high as mentioned above. In conclusion, the Master Plan excludes the construction of a pumping station at the Svay Pak site.

<u>Poungpeay Drainage Main</u>

This is only a drainage main in the Northeast and Northwest Areas. The major purpose is to convey to Boeng Poungpeay storm water in M3: Pochentong West Basin presently intruding into Pochentong Airport and even inflicting damage over Pochentong East Basin. Features of the drainage main are presented in Subsection 3.6.1.

<u>Drainage Sluiceways in Poungpeay East Basin</u>

Poungpeay East Basin is partitioned by several embankments for roads and railways. Some of the embankments are furnished with pipe culverts, whose sizes are however insufficient to drain storm water. This condition causes not merely inundation in the rainy season but deterioration of water quality in the dry season over the area of Poungpeay East Basin. To solve this, twelve (12) locations of sluiceway construction beneath said embankments are proposed in the Master Plan.

3.5 Studies on Environmental Enhancement

The Master Plan examines on environmental enhancement over the Study Area although it is, as a matter of course, limited within the scope of flood protection and drainage improvement. Shown in Figure I3-5 are such ideas, which are discussed item by item hereinafter.

(1) Riverfront Conservation: There is a series of existing revetments on the west bank of the Tonle Sap River in the approximately 1.5 km stretch from Chaktomuk (in front of the Royal Palace). A part of the revetments have been recommended to be rehabilitated under the present Master Plan. In this case, the works should incorporate some environmental considerations such as flower planting in-between the grids of the slope protection, and provision of promenades on the riverbank and/or berm with planting, installing benches, lighting, etc. These works are inclusive in the Riverfront Protection in Sap Downstream Middle Section described in Subsection 3.3.3.

(2) Lake Conservation: In the Study Area, there exist several lakes such as Boeng Poungpeay, Boeng Kak, Boeng Trabek, Boeng Tompun, Boeng Salang. Commonly, these lakes have been encroached on by housing and other developments, and the water has been contaminated with wastewater. This item is a measure to control such environmentally deteriorated condition by dredging sediments settling on the lake bottoms, by providing interceptors and/or environmental canals, by introducing flushing water, and by taking legislative action such as land use control. Following are works taken as the physical measures in the Master Plan:

   (a) Lake dredging in Boeng Tompun, Boeng Trabek, Boeng Salang (the north lake) and the north lake in Pochentong East Basin mainly for drainage improvement;

   (b) Provision of an interceptor, with a diameter of 600 mm, along the shoreline of Boeng Kak to prevent wastewater from flowing into the lake and to keep its water quality;

   (c) Rehabilitation of Svay Pak Sluiceway not only for flood protection but easy introduction of flushing water from the Tonle Sap River to the Poungpeay area when the river water stage is around EL. 6 to 7 m; and

   (d) Construction of an environmental canal, 1 m by 1m box culvert, between Meanchey and Poungpeay drainage mains to lead the flushing water introduced as above and excess water, if any, in the Poungpeay area towards the Tompun area in order to better water quality in channels/lakes therein.

   As for the non-physical measures pertaining to lake conservation, refer to Subsection 3.6.2.

(3) "Green" Channel Plan: There are very few open channels left in the Study Area, so that these remaining channels will play an important role in the city environment in the near future. The Master Plan may preserve two open channels, Meanchey and Poungpeay drainage mains, with sufficient widths of right of way, within which several environmental measures as described in 'Riverfront Conservation' above will be worked out.

3.6 Formulation of Master Plan

3.6.1 Features of Physical Measures

In accordance with the alternative studies on flood control, drainage improvement and environmental enhancement described in respective Sections 3.3, 3.4 and 3.5, preliminary designs for necessary facilities have been made, whose results are summarized hereunder packaging the facilities into the following eight components:

- Component 1: Riverfront Protection in Sap Downstream Middle Section
- Component 2: Reinforcement of Kop Srov and Tompun Dikes
- Component 3: Tompun Watershed Drainage Improvement
- Component 4: Trabek Basin Drainage Improvement
- Component 5: City Core North Area Drainage Improvement
- Component 6: Pochentong East Basin Drainage Improvement
- Component 7: Northeast and Northwest Areas Drainage Improvement
- Component 8: Environmental Enhancement

For the location of the above components and major facilities therein, refer to Figure I3-6.

<u>Component 1: Riverfront Protection in Sap Downstream Middle Section</u>

(See Figure I3-12)

(1)	Stretch	:	Street 108 to Street 184 with a length of 1.0 km
(2)	Design High Water Level	:	EL. 10.0 m
(3)	Design Bank Height	:	EL. 10.9 m (adding 0.9 m of freeboard)
(4)	Type of Revetment	:	Stone Pitching Type (see Figure I3-2)
(5)	Type of Foot Protection	:	Stone filling
(6)	Environmental Measures	:	Planting, Provision of promenade, etc.

<u>Component 2: Reinforcement of Kop Srov and Tompun Dikes</u>

(See Figure I3-7)

(1) Reinforcement of Kop Srov Dike

(a)	Stretch	:	9.0 km section southwestwards from the junction with NR-5
(b)	Design High Water Level	:	EL. 10.4 m (30-year return period)
(c)	Design Dike Height	:	EL. 11.2 m (adding 0.8 m of freeboard)

(d) Dike Structure : Earthfill of triple section with a 10 m wide asphalt-paved road (see Figure I3-3)

(2) Reinforcement of Tompun Dike

(a) Stretch : 4.4 km section between the junctions with the Inner Ring Dike and NR-303

(b) Design High Water Level : EL. 9.0 m (30-year return period)

(c) Design Dike Height : EL. 10.1 m (adding 1.1 m of freeboard)

(d) Dike Structure : Provision of toe drain with coarse material (see Figure I3-3)

Component 3: Tompun Watershed Drainage Improvement, 17.47 km^2

(See Figure I3-8)

(1) Tompun Pumping Station and Regulation Pond

(a) Pumping Station

- Location : On the Tompun Dike, adjoining the existing pumping station to the east (see Figure I3-9)
- Pump capacity : 15 m^3/sec (3 m^3/sec x 5 units)
- Type of Pumps : Submergible pump
- Structure : Pumping station of RC structure with foundation piles, two outlet sluiceways (one for natural drainage, the other for pump drainage), an inlet channel, an outlet channel outside the dike, and a control house.

(b) Regulation Pond

- Location : Existing Boeng Tompun (see Figure I3-9)
- Area : 47.5 ha (total of East and West ponds)
- Design Surcharge Water Level : EL. 4.5 m (at the maximum storage)
- Design High Water Level : EL. 3.7 m (at the peak discharge of Meanchey Drainage Main)
- Design Low Water Level : EL. 3.3 m (to be maintained through the year)
- Design Bottom Height : EL. 3.0 m
- Regulation Volume : 560,000 m^3 by which 60 m^3/sec of the peak discharge can be regulated.

(2) Meanchey Drainage Main, Downstream Stretch

(a) Stretch : From the regulation pond to Meanchey Bridge with a length of 2.76 km

(b) Design Discharge : 75 m^3/sec

(c) Channel Bed Gradient : 1/2,500

(d) Structure : Earth channel with a side slope of 1:2 and some environmental measures such as planting inclusive (see Figure I3-10)

(3) Meanchey Drainage Main, Upstream Stretch

(a) Stretch : From Meanchey Bridge to a road passing from the Salang area to Pochentong Airport with a length of 2.135 km

(b) Design Discharge : 15 & 11 m^3/sec

(c) Channel Bed Gradient : 1/2,000 & 1/1,000

(d) Structure : Earth and masonry-riveted channels with a side slope of 1: 2 & 1: 0.3 and some environmental measures such as planting inclusive (see Figure I3-10)

(4) Tum Nup Toek Drainage Sluiceway

(a) Location : On the Inner Ring Dike near the existing Tum Nup Toul Pumping Station

(b) Structure : 2 m by 2 m box culvert with a steel-made slide gate

(5) Samdach Monireth Drainage Main

(a) Stretch : Under Samdach Monireth Street from Meanchey Bridge to a road junction behind Olympic Stadium with a length of 2.36 km, at the outlet of which a sluiceway will be provided.

(b) Design Discharge : 44 & 20 m^3/sec

(c) Channel Bed Gradient : 1/2,000

(d) Structure (see Figure I3-11)

- Samdach Monireth 1 & 2 : Box culvert (4.25 m wide, 3.6 m high, 2 lanes)
- Samdach Monireth 3 : Box culvert (2.85 m wide, 3.6 m high, 2 lanes)

(6) Jawaharlal Nehru Drainage Main

(a) Stretch : Under Jawaharlal Nehru Street with a length of 1.16 km

(b) Design Discharge : 8 m^3/sec

(c) Channel Bed Gradient : 1/2,000

(d) Structure (see Figure I3-11) : Box culvert (2.25 m wide, 3.1 m high)

(7) Salang Drainage Main

(a) Stretch : Along the existing Boeng Salang south lake with a length of 1.4 km, at the outlet of which a sluiceway will be constructed.

(b) Design Discharge : 21 m^3/sec

(c) Channel Bed Gradient : 1/3,000

(d) Structure : Earth channel along the alignment of the Boeng Salang south lake with 1:2 of side slopes

(8) Sewer Rehabilitation (excluding Tum Nup Tock Basin)

(a) Area : 563 ha

(b) Total Pipe Length : 79,900 m

(9) Sewer Rehabilitation (Tum Nup Tock Basin)

(a) Area : 68 ha

(b) Total Pipe Length : 5,200 m

<u>Component 4: Trabek Basin Drainage Improvement, 10.83 km^2</u>

(See Figure I3-12)

(1) Trabek Pumping Station and Regulation Pond

(a) Pumping Station

- Location : On the Tompun Dike, adjoining the existing pumping station to the east (see Figure D3-13)
- Pump capacity : 8 m^3/sec (3 m^3/sec x 2 units plus 2 m^3/sec x 1 unit)
- Type of Pumps : Submergible pump
- Structure : Pumping station of RC structure with foundation piles, two outlet sluiceways (one for natural drainage, the other for pump drainage), an inlet channel, an outlet channel outside the dike, and a control house.

(b) Regulation Pond

- Location : Existing Boeng Trabek (see Figure I3-13)
- Area : 28.7 ha (Upper Pond 10.3 ha plus Lower Pond 18.4 ha)
- Design Surcharge Water Level : EL. 4.0 m (at the maximum storage)
- Design High Water Level : EL. 3.7 m (at the peak discharge of Trabek Drainage Main)
- Design Low Water Level : EL. 2.7 m (to be maintained through the year)
- Design Bottom Height : EL. 2.4 m
- Regulation Volume : 350,000 m^3 by which 62 m^3/sec of the peak discharge can be regulated.

(2) Trabek Drainage Main

(a)	Stretch	:	Along the existing Trabek Channel with a length of 1.604 km
(b)	Design Discharge	:	70, 38 & 27 m^3/sec
(c)	Channel Bed Gradient	:	1/2,000
(d)	Structure (see Figure I3-14)		
	- Trabek 1	:	Box culvert (6.0 m wide, 3.6 m high, 2 lanes)
	- Trabek 2	:	Box culvert (4.0 m wide, 3.6 m high, 2 lanes)
	- Trabek 3	:	Box culvert (5.0 m wide, 3.6 m high)

(3) Toul Sen Drainage Main

(a)	Stretch	:	Along the existing Toul Sen Channel with a length of 2.05 km
(b)	Design Discharge	:	8 & 5 m^3/sec
(c)	Channel Bed Gradient	:	1/2,000 & 1/1,500
(d)	Structure (see Figure I3-15)		
	- Toul Sen 1 & 2	:	Box culvert (2.5 m wide, 2.8 m high)
	- Toul Sen 3 & 4	:	Earth channel with retaining walls

(4) Norodom Drainage Main

(a)	Stretch	:	Under Street 360 and Norodom Blvd. with a length of 1.768 km
(b)	Design Discharge	:	18 & 10 m^3/sec
(c)	Channel Bed Gradient	:	1/1,500 & 1/1,000
(d)	Structure (see Figure I3-16)		
	- Norodom 1	:	Box culvert (3.4 m wide, 3.6 m high)
	- Norodom 2	:	Box culvert (2.75 m wide, 2.6 m high)

(5) Sewer Rehabilitation

(a)	Area	:	1,083 ha
(b)	Total Pipe Length	:	128,600 m

<u>Component 5: City Core North Area Drainage Improvement, 6.57 km^2</u>

(See Figure I3-17)

(1) C1: Wat Phnom Basin, Sewer Rehabilitation

(a)	Area	:	89 ha
(b)	Total Pipe Length	:	9,100 m

(2) C2: Kak Lakeshore Basin, Sewer Rehabilitation

(a) Area : 51 ha

(b) Total Pipe Length : 1,800 m

(3) C3: Boeng Kak Basin, Kak Drainage Sluiceway

(a) Location : Outlet of Boeng Kak under the Inner Ring Dike

(b) Structure : 2 m by 2 m one lane box culvert with steel-made slide gates

(4) C4: Tuol Kork Basin, Major Drainage Facilities

(a) Tuol Kork Drainage Main-I

- Stretch : Under Street 315 with a length of 1.887 km
- Design Discharge : 6, 4 & 3 m^3/sec
- Channel Bed Gradient : 1/2,000
- Structure (see Figure I3-18)
  + Tuol Kork-I 1 and 2 : Box culvert (3.75 m wide, 1.9 m high)
  + Tuol Kork-I 3 : Box culvert (2.75 m wide, 1.9 m high)
  + Tuol Kork-I 4 : Box culvert (2.2 m wide, 1.9 m high)

(b) Tuol Kork Drainage Main-II

- Stretch : Under Street 289 with a length of 0.577 km
- Design Discharge : 5 m^3/sec
- Channel Bed Gradient : 1/1,000
- Structure (see Figure I3-18) : Box culvert (2.5 m wide, 1.9 m high)

(c) Tuol Kork Drainage Sluiceway-I

- Location : Near the existing pumping station I
- Structure : 2m by 2 m one lane box culvert with a steel-made slide gate

(d) Tuol Kork Drainage Sluiceway-II

- Location : Near the existing pumping station II
- Structure : 2m by 2 m one lane box culvert with a steel-made slide gate

(e) Tuol Kork Drainage Sluiceway-III

- Location : Near the existing pumping station III
- Structure : 2m by 2 m one lane box culvert with a steel-made slide gate

(5) C4: Toul Kork Basin, Sewer Rehabilitation

(a) Area : 332 ha

(b) Total Pipe Length : 38,700 m

(6) C5: University Basin, Drainage Sluiceway

(a) Location : 2 locations under the Inner Dike and railway

(b) Structure : 2m by 2 m one lane box culvert with a steel-made slide gate

Component 6: Pochentong East Basin Drainage Improvement, 15.35 km^2

(See Figure I3-19)

(1) Pochentong Pumping Station and Regulation Pond

(a) Pumping Station

- Location : On BOT Road, adjoining the existing culvert to the west
- Pump capacity : 5 m^3/sec in total (3 m^3/sec x 1 unit plus 2 m^3/sec x 1 unit)
- Type of Pumps : Submergible pump
- Structure : Pumping station of RC structure with foundation piles, two outlet sluiceways (one for natural drainage, the other for pump drainage), and a control house

(b) Regulation Pond

- Location : An existing lake (North Lake) in front of the Salang area
- Area : 6.0 ha
- Design Surcharge Water Level : EL. 7.0 m (at the maximum storage)
- Design Low Water Level : EL. 6.0 m (to be maintained through the year)
- Regulation Volume : 60,000 m^3 by which 5 m^3/sec of the peak discharge can be regulated.

(2) Closing Gate Structure (Sluiceway)

(a) Location : Near the regulation pond

(b) Structure : 2 m by 2 m one lane box culvert with a steel-made slide gate

(3) Drainage Mains

(a) Stretch : 9.0 km

(b) Design Discharge : 5 & 10 m^3/sec

Component 7: Northeast and Northwest Areas Drainage Improvement, 100.09 km^2

(See Figure I3-20)

(1) Poungpeay Drainage Main

(a)	Stretch	: Along the northwest side of NR-3 and then the north side of the railway with a total length of 11.92 km
(b)	Design Discharge	: 20, 12 & 8 m^3/sec
(c)	Channel Bed Gradient	: 1/10,000, 1/2,000 & 1/1,000
(d)	Structure (see Figure I3-21)	
	- Poungpeay 1	: Earth channel with 1:2 side slopes (7 m wide at the bottom, 3 m of water depth)
	- Poungpeay 2	: Reveted channel with 1:0.3 side slopes (2.4 m wide at the bottom, 3 m of water depth)
	- Poungpeay 3	: Earth channel with 1:2 side slopes (1.5 m wide at the bottom, 2 m of water depth)
	- Poungpeay 4	: Earth channel with 1:2 side slopes (1.5 m wide at the bottom, 1.7 m of water depth)

(2) Svay Pak Drainage Sluiceway

(a)	Location	: Existing Svay Pak Drainage Sluiceway (PK #9) site
(b)	Structure	: 2-lane box culvert (each 2 m by 2 m with a steel-made slide gate)

(3) Drainage Sluiceways in Poungpeay East Basin

(a)	Location	: 12 locations under existing embankments in Poungpeay East Basin
(b)	Structure	: One-lane box culvert (2 m by 2 m with a steel-made slide gate)

Component 8: Environmental Enhancement

(See Figures I3-8 and I3-17)

(1) Environmental Canal

(a)	Stretch	: Along the Inner Dike between the origin of Meanchey Drainage Main and the vicinity of the outlet of Tuol Kork Drainage Sluiceway I with a length of 1.75 km
(b)	Structure	: One-lane box culvert (1 m by 1 m)

(2) Kak Interceptor

(a)	Stretch	: Along the eastern lakeshore of Boeng Kak with a length of 0.85 km
(b)	Structure	: 375 mm diameter of pipe

3.6.2 Features of Non-physical Measures

The Master Plan proposes construction of the facilities enumerated in Subsection 3.6.1 above. However, comprehensive flood protection and drainage improvement cannot be realized solely by such physical measures, but should incorporate the non-physical measures such as:

- Land use control (zoning control and development/building control);
- Flood defense activity with flood forecasting and warning;
- On-site storage;
- Public information and education; and
- Flood insurance.

Following are discussions on the land use control and flood defense activity that should be most applicable and effective among them as the non-physical measures in the flood protection and drainage improvement for the Study Area.

Land Use Control

The land use control is an essential component in the non-physical measures, comprising the following two aspects:

- Overall aspect : Zoning control; and
- Individual aspect: Development and building control.

The following discusses not just on the present constraints and improvement strategy but also on the concrete measures maybe applied to the Study Area.

(1) Present Constraints and Improvement Strategy

Zoning Control

Municipality of Phnom Penh has not yet established an authorized city development plan (zoning control) for its territory. This causes uncontrolled developments in many locations, not only destroying environments of the city but jeopardizing the function of flood protection and drainage facilities. Early establishment of a city development plan is strongly anticipated to better such condition. From the viewpoint of flood protection and drainage improvement, the following considerations should be made in the plan.

(a) Water Zone Conservation in the Northeast Area

The area is a large water zone with Boeng Poungpeay in its center. In addition, a lot of fishponds spread along the eastern perimeter of the lake. These lake and ponds play an important role in regulating runoff from the northern half of the Study Area, limiting inundation of the area within permissible range, and discharging the stored water safely through Svay Pak Sluiceway to the Tonle Sap River at the end of the rainy season.

However, presently, numbers of new developments for factories, housing, etc. are invading the water zone, making its area gradually narrower. This will result in decrease of its runoff control effect, causing serious inundation over the northern half of the Study Area. This trend must be controlled by the city development plan in which it is clearly stated that the water zone be preserved as it is, not merely for flood protection and drainage purpose but also for environmental conservation.

(b) Agricultural Land Conservation in the Northwest and South Areas

The areas are mostly shared by agricultural lands as of now, which function not only for runoff retention but better environment of the city. However, new developments are in progress in several places without authorized control. Such tendency may accelerate with city expansion.

Uncontrolled developments on the agricultural lands should produce increase of runoff, making severer inundation in the downstream reaches, moreover undermining the developments themselves by repeated flooding. In this context, the city development plan should incorporate a consideration for the conservation of agricultural lands in the Northwest and South areas.

Development and Building Control

The development and building control, likely, has not functioned well up to date. Indeed, land reclamation for developments and buildings is going on at many locations in the Study Area without any control of the municipal government. To avoid this situation, the following two should be considered:

(a) There is an old announcement by the MPP regarding the right-of-way of public facilities, however at present it is a dead letter in reality, resulting even in the encroachment of squatters on the governmental lands. To cope with this, the announcement should be effective legislatively.

(b) Establishment of a future land use plan or zoning as mentioned above; otherwise, the municipal government can hardly control such disordered developments.

(2) Concrete Measures

Concrete measures proposed for materializing appropriate land use control over the Study Area are as follows.

Zoning Control

The following activities are needed to remove the present constraints.

(a) Establish CATUC of the Municipality of Phnom Penh (or appoint responsible organization for land use planning) in accordance with the CNATUC Law. We considered CNATUC Law is still active even after the creation of Ministry of Construction.

(b) CATUC (or appointed organization) of the Municipality of Phnom Penh should establish "Land Use Master Plan" as soon as possible.

(c) In the "Land Use Master Plan", the following should be considered from the view point of flood protection and drainage improvement in the MPP.

(i) Agricultural Land Conservation Area

Large-scale development should be prohibited. Settlement of polluting activities should be prohibited in the following areas:

- Southern area from BOT Road; and
- Northern area from the railway and City Core.

(ii) Water Zone Conservation Area

Development that decreases water area should be prohibited especially in the following lakes:

- Boeng Poungpeay;
- Boeng Kak;
- Boeng Salang;
- Boeng Tompun;
- Boeng Trabek; and
- North Lake in the Pochentong East Basin.

Development and Building Control

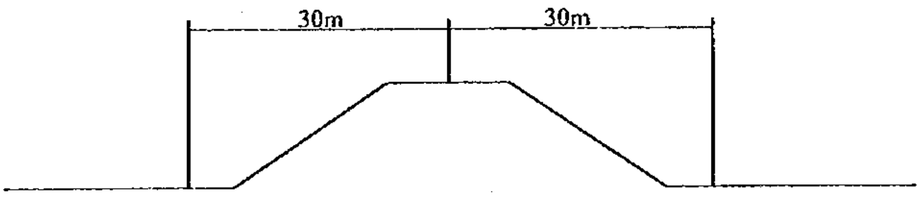
As for the development and building control that will be applied to individual developments and buildings, the following are suggested from the flood control and drainage point of view:

(a) Strict enforcement of "Sub-decree on Construction Permit" along with the reinforcement of land observations by Sangkat officials;

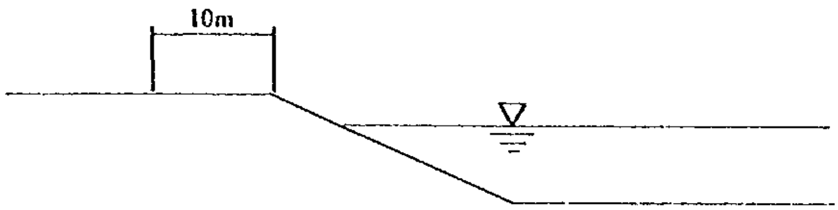
(b) Direction of reclamation heights and floor levels for new developments and buildings; and

(c) Re-setup of right-of-way (though there is an old announcement by the MPP regarding right-of-way, but presently is not functioning in reality) to prevent any people from encroaching on:

- Lake;
- River and waterway; and
- Structure (dike, sluiceway, pumping station, etc.).



Dikes and Roads



Lakes and Waterways

Flood Defense Activity

The flood defense activity is another important factor in the non-physical measures. In fact, Municipality of Phnom Penh, under coordination with Ministry of Public Works and other ministries concerned, forms an ad hoc committee for flood defense during high water stage of the Tonle Mekong river system, and makes great effort to protect Phnom Penh City from being flooded.

The Master Plan considers such effort still essential to reinforce and ensure the function of facilities to be provided under the plan, particularly along the Riverfront (Tonle Sap and Tonle Bassac), Kop Srov Dike and Tompun Dike. Following are the recommendations to the present system.

(1) Concerned Agencies and Responsibility

Present flow of the flood defense activity is basically well functioning and it will be continuously applied (for detail of the present activities and condition, refer to the Interim Report). Organization and flow of the activities are illustrated in Figure I3-22.

Observation of River Water Level

The Ministry of Water Resources (former GDIMH of MAFF) carries out observation of river water stage and announces them to the related agencies and to the public. Observation is presently at one station, Chaktomuk on the Tonle Mekong. It is recommended that observation at the mouth of the Prek Phnov on the Tonle Sap and at the NR 3 crossing of the Prek Thnot is added.

Flood Warning

When river water stage comes up to the warning level, Ministry of Water Resources announces flood warning. Presently one flood warning level is determined at Chaktomuk Station on the Tonle Mekong. Application of two stages, namely Level 1 and Level 2, is recommended as explained in the article of proposed flood defense activities.

Government Decision to Prepare and Protective to Disaster

Committee in charge of Disaster under the Council of Ministers decides when to prepare and protective to the disaster, and Minister of Interior informs it to all the related agencies.

Flood Defense Activities

The Municipality of Phnom Penh appoints the personnel for Committee and Sub-Committees for Flood Protection. General organizations and tasks assigned to the Committee and Sub-Committees for Flood Protection presently applied during flooding period will be continuously applied.

Namely, under the Committee for Flood Protection, there are four Sub-Committees:

- Technique to protect flood;
- Rescue and transport;
- Finding funds, supply and social affairs; and
- Security.

Recommendation to the present system is as follows:

(a) Flood Protection Division proposed to be newly created as an institutional improvement will act as the working group for the Sub-Committee in charge of technique to protect flood. Concrete activities are explained hereafter.

(b) Organization, tasks assigned, activities for District, Sangkat, and Commune should be more clearly described.

(2) Related Laws and Regulations

Actual activities are presently well functioning, but some activities have no legal background. Necessary laws and regulations should accordingly be prepared. The following would be taken into consideration for the preparation of laws and regulations:

- A basic law on disaster measures;
- An act for flood fighting;
- A law on fire defense system (the fire defense group could work for flood fighting);
- An act for the disaster relief (for the Ministry of Health);
- Review of disaster prevention related article for the police laws; and
- Review of disaster prevention related article for the national defense related laws.

(3) Flood Defense Activities and Necessary Facilities/Equipment

The concrete procedures for the flood defense activities will be as follows:

River water stage observation

(a) Station

- Chaktomuk on the Tonle Mekong (existing station)
- River mouth of the Prek Phnov on the Tonle Sap (newly proposed)
- NR 3 Crossing of the Prek Thnot (newly proposed)

(b) Observation Frequency: Twice a day

(c) Method of Data Transmission: Radio (wireless circuit)

Warning

(a) Flood Warning Level

- Level 1: prepare for flood defense activities
- Level 2: start operation of flood defense activities

(b) To the Public General: The Minister of Water Resources gives warning using:

- TV broadcast; and
- Radio broadcast.

(c) To the Critical Area: Public announcement by patrol/warning cars and boats by Flood Protection Division

Defense Activities

Technical skills for defense activities should be trained through actual practices and drills to the personnel of concerned agencies that include; Flood Defense Division, flood defense organizations in District, Sangkat, Commune, and MPWT, MAFF, police, military, NGOs and other related agencies.

- Protection of dikes from break by floodwater
- Evacuation of residents (determination of place for evacuation, evacuation method, support to the evacuee, etc.)
- Rescue (rescue works using equipment, assurance of hospitals, etc.)

Necessary Facilities/Equipment for Flood Defense Activities

The following are the major ones of the facilities and equipment for flood defense activities. It is recommended that the Flood Protection Division under the Municipality of Phnom Penh maintains the facilities and equipment in good condition.

- Warehouse for facilities and equipment
- Patrol/sound vehicle (4-wheel drive): 5-unit
- Patrol/sound motor boat: 3-unit
- Supplies for urgent works (including, sand sacks, plastic sheet, shovels, etc.)

3.6.3 Project Cost and O/M Cost

Project Cost

Eight components, as presented in the previous Subsection 3.6.1, compose the physical measures in the Master Plan for the flood protection and drainage improvement in the Municipality of Phnom Penh. The whole project cost over the Master Plan amounts approximately US$ 261.6 million (refer to Table I3-8). The project cost of each component is estimated in the following table at the price level as of July 1, 1998:

Project Costs of Eight Components in the Master Plan

Component	Project Cost (US$ million)
1: Riverfront Protection in Sap Downstream Middle Section	2.3
2: Reinforcement of Kop Srov and Tompun Dikes	17.8
3: Tompun Watershed Drainage Improvement	88.6
4: Trabek Basin Drainage Improvement	94.5
5: City Core North Area Drainage Improvement	32.0
6: Pochentong East Basin Drainage Improvement	11.9
7: Northeast and Northwest Areas Drainage Improvement	12.1
8: Environmental Enhancement	1.9
Total	261.6

O/M Cost

The operation and maintenance (O/M) cost should be taken into account for the economic evaluation of the Master Plan. Operation and maintenance for the Master Plan facilities will be done in line with the principle on the organization and institution described in Subsection 3.7.1. According to the principle, the annual O/M cost can be estimated by using a constant rate of 0.5 % to the total project cost of completed works at the time.

3.6.4 Implementation Schedule

The total project cost of the physical measures in the Master Plan reaches as high as US$ 261.6 million, so that the implementation must be achieved on a reasonable scheduling. Table I3-9 is an implementation schedule therefor prepared in the following considerations:

(a) Components with higher economy, commonly expressed in the economic internal rate of return (EIRR), should be implemented earlier than others. The individual EIRR of each component is as follows:

Individual EIRR and the Rank of Each Component

Component	EIRR (%)	Rank
1: Riverfront Protection in Sap Downstream Middle Section	- 0.5	6
2: Reinforcement of Kop Srov and Tompun Dikes	24.8	1
3: Tompun Watershed Drainage Improvement	11.0	2
4: Trabek Basin Drainage Improvement *	9.1	3
5: City Core North Area Drainage Improvement	5.3	4
6: Pochentong East Basin Drainage Improvement	4.8	5
7: Northeast and Northwest Areas Drainage Improvement	- 2.1	7
8: Environmental Enhancement	No tangible benefit	8
Total	12.9	-

* The construction of major facilities, Trabek pumping station and Trabek and Toul Sen drainage mains, will start in 1999 under the loan from ADB.

(b) Disbursement amounts in each year are assumed to be around US$ 15 million in accordance with the study result on financial affordability in Subsection 4.2.3.

(c) In Components 3, 4 and 5, the major drainage works such as construction of pumping stations, regulation ponds and drainage mains should be followed by the sewer rehabilitation works which entail considerably high costs. This is because most drainage benefit can be realized by the construction of the major drainage works, and without furnishing such major works sewer rehabilitation could technically be meaningless. In this context, it is premised that the major drainage works be completed by year 2010 while the sewer rehabilitation by year 2020.

3.7 Recommendation for Institutional Improvement

3.7.1 Organizational Improvement

The Executing Agency for the component projects of the Master Plan will be the Municipality of Phnom Penh. The Municipality of Phnom Penh will hold the final responsibilities for direction setting and decision making involved in proceeding the implementation of the project, with reference of important matters to the Government as may be necessary.

Within the MPP, Department of Public Works and Transport is the technical department in charge of the project. DPWT will be the implementing body. As one of subordinating organization under the management of DPWT, Drainage and Sewage Division (DSD) is the agency specifically responsible for the management and operation of drainage improvement issues in the master plan.

An organization responsible for flood protection is not clear in the present organizational structure. Accordingly, creation of Flood Protection Division under the DPWT is recommended. Flood Protection Division will be in charge of implementation of Kop Srov and Tompun Dikes Reinforcement in technical aspect. Proper operation and maintenance work is also important task.

(1) Creation of Flood Protection Division in DPWT

The duties assigned and the proposed organization of the Flood Protection Division are as follows:

(a) Duty

- In charge of construction of flood protection dikes and related facilities
- In charge of maintenance of flood protection dikes and related facilities and of flood protection function of roads
- Conduct activities e.g. patrol, give warning to isolated people, give technical advise for protecting dike from break

(b) Organization and Number of Staffs

The proposed organization and number of staffs are shown in Figure I3-23.

(2) Improvement in Drainage and Sewerage Division

Necessary staffs and their numbers for each construction, and operation and maintenance period are as discussed in the article of operation and maintenance plan.

3.7.2 Capacity Building for River Engineering and Flood Protection

Capacity building especially for basic knowledge for DPWT staffs is presently conducted through "Institutional Capacity Building Component and the Neighborhood Improvement Program" as a part of Phnom Penh Water Supply and Drainage Project Part B. After the creation of a division responsible for flood protection, capacity building in the river engineering field is necessary.

(1) Objective

The objective of the capacity building is to heighten the knowledge in the river engineering and disaster prevention fields, and use the knowledge for the construction, operation and maintenance of the flood protection facilities and to minimize flooding disaster.

(2) Courses

Field

- River engineering
- Design of flood protection dikes and riverine structures
- Construction supervision of flood protection works
- Operation and maintenance of riverine structures
- Flood defense activities
- Similar projects in the foreign countries
- Etc.

Possible Input

- Seminar or workshop with foreign experts and lecturers

- On-the-job training in the course of the project implementation
- Group training in foreign countries

3.7.3 Establishment of Laws and Regulations

Laws and Regulations

Various laws and regulations should be developed. The following will be taken into consideration.

- Water law or river law
- Law that regulates domestic and industrial wastewater disposal to rivers or sewerage systems
- Regulations for sewerage fee and its use
- Official development plan for MPP including a land use plan or a zoning plan
- Flood disaster crisis management
  - A basic law on disaster measures
  - An act for flood fighting
  - A law on fire defense system
  - An act for the disaster relief
  - Review of disaster prevention related article of the police laws
  - Review of disaster prevention related article for the national defense related laws

Of these, high priority should be given to the following:

- Decree for sewerage fee collection and its use, and,
- Preparation of the official land use plan for the MPP

Decree for sewerage fee collection and its use is closely related to secure sustainable operation and maintenance of the drainage system.

The "Land Use Master Plan" should be prepared as soon as possible following CNATUC Law. There found illegal and uncontrolled development at many locations and they destroy the water retention capacity of the suburban areas.

Guidelines

Technical guidelines that should be prepared include the following:

- Planning criteria and design manuals for flood control facilities
- Planning criteria and design manuals for drainage and sewerage works

Operation and Maintenance Manual

Operation and maintenance manuals should be prepared for each structure. Those for the structures of priority projects will be prepared in the detail design stage.

14. PROJECT EVALUATION

4.1 Economic Evaluation

4.1.1 Economic Benefit

Socioeconomic Framework

A socioeconomic framework is formulated for Phnom Penh City and the Study Area. The established socioeconomic framework provides basic conditions for forecasting land use characteristics for the year 2010. The following summarizes the established socioeconomic framework:

Socioeconomic Framework of Phnom Penh and Study Area

Item	Phnom Penh		Study Area		Growth Rate (%/year)
	1996/98 *1	2010	1996/98 *1	2010	
Population ($\times 10^3$) *2	1,000	1,451	817	1,192	3.2
GRDP (US$ 10^6) *3, *4	313.9	829.6	257.4	680.3	7.2
- Industry	(69.8)	(230.4)	(57.3)	(188.9)	(8.9)
- Service	(234.6)	(581.5)	(192.4)	(476.8)	(6.7)

Note: *1 Population in 1998, GRDP in 1996
*2 Population in Phnom Penh and the Study Area include both registered and non-registered population
*3 US$ = Riel 3,880 is applied
*4 GRDP (Gross Regional Domestic Product) in the Study Area is assumed to be 82% of the Phnom Penh's, applying the population proportion

Direct Benefit for Buildings and Assets

Direct benefit is calculated as the difference in flood and inundation damages with and without the project conditions. For the present project, inundation damage is divided into those for building properties and assets, and those for livestock, fish pond and agriculture.

(1) Building Properties and Assets

Values of flood and inundation damages on building properties and assets are obtained based on the following factors:

- Standard number of each building type in a mesh for respective land use type;
- Values of buildings and assets; and
- Damage ratio.

These values have been calculated as follows.

(a) Standard Number of Building in a Mesh by Land Use Type

The standard numbers of each building type are assumed for respective land use type as shown in Table I4-1. The number of meshes for each land use type are derived based on the analysis on land use pattern in 1998 and 2010 as presented in Section 2.3. The number of buildings by type in a mesh in 1998 are estimated based on an analysis on the existing land use characteristics and most likely pattern envisaged. The number of buildings in 2010 are set by adjusting the 1998 numbers, so that the total number of buildings in the Study Area to be derived are consistent with the population and economic growth rates worked out in the Socio-Economic Framework. The number of households is assumed to grow at the same rate as the population growth at 3.2 % per year. For other types of buildings than houses, an increase in the number of buildings and assets is assumed to contribute 50 % to an increase in the total values of building and assets. The remaining 50 % is assumed to result from a rise in the values per building and assets. The number of buildings is thus estimated as follows:

Number of Buildings in 1998 and 2010

Type	1998	2010
House	143,000	209,000
Shop	3,584	5,225
Factory	535	878
(Small)	(354)	(581)
(Large)	(181)	(297)
Warehouse	134	195
Office	438	639
School	105	153
Hospital	24	35

(b) Values of Buildings and Assets

The average values of buildings and assets are obtained based on the result of the Asset and Flood Damage Survey (hereafter " AFDS "), and information on the market prices of commodities. The average values on buildings and assets obtained by the AFD Survey are analyzed and partly adjusted to correct for the sample-based survey results. A coefficient of 0.79 is derived, meaning the level of average household income in Phnom Penh is 79 % of the income level of the households surveyed by AFDS. This coefficient is applied to the values of houses and households assets. The values of other types of buildings are taken from the results of AFDS without adjustment. The following values are applied to the present analysis:

Assets Values in 1998 and 2010

(Unit: $)

Type of Building	Building		Asset	
	1998	2010	1998	2010
House	3,008	3,400	890	1,000
Shop	4,800	7,100	800	1,100
Factory				
Small	9,000	15,200	11,300	19,100
Large	57,600	97,600	72,600	123,100
Warehouse	12,500	18,600	3,400	5,000
Office	10,000	14,900	8,800	13,100
School	100,000	100,000	7,800	7,800
Hospital	22,000	22,000	11,400	11,400

* Small: factories with workers less than 10
Large: factories with workers equal or more than 10 workers

(c) Damage Ratio

The damage ratios applied in Japan are applied to the present analysis. Table I4-2 shows the applied damage ratios.

The inundation damages estimated applying these damage ratios are cross-checked with the damage values declared by interviewees of AFDS in order to assess the appropriateness of the assumptions applied to estimating inundation damage. AFDS revealed the average floor levels and the levels of inundation depth in 1995 and 1996 floods. Based on these values, water levels are classified into inundation below floor level and that above floor level. The latter is further classified into ranges of depth above floor level. The average inundation levels reported were found to be either below floor inundation or inundation above floor level within 0.5 meter. The damage ratios applied in estimating damage values correspond to these reported inundation levels.

The following table presents the result of a comparison between the estimated and the surveyed average damage values per building. The surveyed damage values in the table below are the averages of those in 1995 flood and 1996 flood:

Comparison of Surveyed and Estimated Inundation Damage Values
to Building and Assets

(Unit: $/case)

Item	Compared Level of Inundation	a. Survey	b. Estimate	b/a
Household				
Building	<0.5 m above floor	348	277	0.80
Asset	<0.5 m above floor	161	129	0.80
Shop				
Building	below floor level	213	154	0.72
Asset	below floor level	60	26	0.43
School				
Building	below floor level	4,497	3,200	0.71
Asset	below floor level	4,844	3,482	0.72
Small factories				
Building	<0.5 m above floor	5,000	828	0.17
Asset	<0.5 m above floor	0	1,040	-
Other		768	0	0.00
Warehouse				
Building	<0.5 m above floor	0	1,150	-
Asset	<0.5 m above floor	0	313	-
Other		988	0	-
Office				
Building	<0.5 m above floor	5,000	920	0.18
Asset	<0.5 m above floor	0	810	-
Other		564	0	-

Note:
Survey : Values surveyed by Asset and Flood Damage Survey conducted by TEAM Consulting Engineers Co., Ltd. as part of the present study.
Estimate : Values estimated by the Study Team

Concerning household, shop and school, proportions of the estimated values to the surveyed values range from 0.43 to 0.80, indicating that the estimated values are on the conservative side. A comparison of the remaining three categories, small factories, warehouse and office, is constrained by limited numbers of samples. The average damage values to building for small factories and office are affected by a few special cases with high damage values. Damage values to asset for the three categories and that to building for warehouse are reported to be none. This would not reflect the reality in that there should be damages to buildings and assets in a long-run, if not felt immediately at the time of inundation. There also should be damages actually taking place, but not covered by the survey.

(d) Floor Level

Data on average floor levels were obtained by AFDS as follows:

Average Floor Levels by Building Type

(Unit: meter)

Item	Average Floor Level
Household	0.54
Shop	0.29
Office	0.39
Factory	0.18
Warehouse	0.12
School	0.72

The average floor levels for each building type obtained are weighed by the proportions of inundation damage values for respective land use category. This gives the average floor levels for respective land use type as follows:

Average Floor Levels by Land Use

(Unit: meter)

Land Use Type	Average Floor Level
1. Dense activities	0.19
2. Dense urban center	0.47
3. Dense residential	0.46
4. Loose residential	0.50
5. Loose activities	0.40
6. Agriculture land, unused land	0.50
7. Fishpond	0.54

(e) Total Damage to Buildings and Assets

The values of direct inundation damage are derived for a 200-meter by 200-meter mesh for each land use type and by level of inundation as presented in Table I4-3.

Indirect Benefit

AFD Survey revealed that there are a number of problems caused by inundation in addition to those on interviewees' buildings and assets such as inconvenience in transportation and water supply and health problems. There were many respondents who experienced no damage on their assets, but expressed their expectation for the improvement in inundation condition. This indicates that many people suffer form inundation apart from damages on their own property.

In the present analysis, various indirect benefits of inundation mitigation is assumed to be 30% of the direct benefit estimated above. There are no definite methods of calculating indirect benefits. In reality, however, there are a variety of damages caused by inundation such as those on inventory, infrastructure and utility facilities, sales activities and traffic, expenditure on mitigation and restoration measures, and psychological damages. In Japan, these damages in sum could well exceed 30 %, or even 100 %, of the direct damages. Table I4-4 shows a preliminary estimate of damage caused by degraded urban function due to inundation. This benefit is roughly equivalent to 8.3 % of the direct economic benefit, which is considered constituting a part of various indirect benefits.

Livestock, Fishpond and Agricultural Production

No damage is likely for livestock and fishpond operators judging from the finding of AFDS. There was a reported case of serious damage in fishpond. It was found that fish feed were damaged by inundation. This kind of damage can be avoided with sufficient precaution measure like most other fish pond operators are practicing.

Economic benefit in agriculture production is estimated for rice, since other crops such as vegetables and maize were found to be cultivated in the areas outside the Study Area in Phnom Penh City. Damages on agriculture production is estimated, therefore, for rice production in the meshes classified as "agricultural land" in the land use plan for 2010. The following assumptions and basic conditions are set in estimating agriculture benefit:

Assumptions for Rice Production Benefit Estimate

Item	Inundation by Dike Breach *	Inundation by Local Rainfall **	Remarks
1. Damage Ratio by Inundation Level			
a. Less than 0.5 m	0.50	0.21	MOCJ ***
b. 0.5 to 0.99 m	0.71	0.24	MOCJ
c. 1.0 m or more	0.74	0.37	MOCJ
2. Rice Production Value			
a. Per Hectare	US$ 136		AFDS ****
b. Per Mesh	US$ 544		a x 4 ha

* Damage ratios for inundation lasting 7 days or more
** Damage ratios for inundation lasting 1 to 2 days
*** Ministry of Construction, Japan
**** Asset and Flood Damage Survey

Result

Table I4-5 presents the direct damage values by inundation for 2-year, 5-year, 10-year and 30-year rainfall return period for with- and without-project condition. Economic benefit of inundation mitigation can be derived as the difference between the damage values in without-project and with-project condition.

Table I4-6 shows the conversion of economic benefits for selected rainfall return period to annual average benefits for the proposed Component 2 to Component 7. Indirect benefits are added to direct benefits at 30% of direct benefits. Table I4-7 gives average annual benefits for rice.

The following table summarizes the average annual benefit by component:

Estimated Economic Benefit of Master Plan

(Unit $ thousand / year)

Component	Economic Benefit		
	Direct & Indirect	Rice Production	Total
1	50	0	50
2	6,468	38	6,506
3	10,856	7	10,863
4	9,933	0	9,933
5	2,050	0	2,050
6	731	3	734
7	196	1	197
8	Environmental improvement		

Economic benefits are assumed to grow at a rate of 7.2 % per year, the GRDP growth rate set in Socioeconomic Framework, until 2010, the year in which a full scale benefit of each component is realized.

4.1.2 Economic Cost

Investment cost and operation and maintenance costs estimated are to be modified, where necessary, in economic analysis such that the costs reflect utilization of resources. The following aspects are analyzed:

- Transfer payments such as tax and subsidy;
- Cost of commodities domestically procured;
- Labor wage for unskilled labor; and
- Land cost.

The costs estimated do not include transfer payments such as tax and subsidy. No modification, therefore, is needed in this respect.

Costs of commodities domestically procured are converted to international prices by applying a standard conversion factor (SCF). SCF in Cambodia is estimated at 0.84 in 1996 and 0.85 in 1997. The present study applies 0.85 as SFC. The domestic currency portion of the investment and operation and maintenance costs is converted to international prices by multiplying them with 0.85.

It is often practiced that wages of unskilled labor are adjusted such that labor cost reflects production foregone of the labors. In the present analysis, unskilled labor costs constitute a negligibly small portion of the total cost. SCF at 0.85 is applied to labor costs.

An environmental impact assessment (EIA) was carried out in early 1999 for the two priority projects. The EIA revealed that most of the lands to be affected by the projects are either idle land, water body, or residential land. Almost no production activities seem to be practiced in the priority project area. Assuming that the condition is common for other areas planned in the master plan, no production foregone will result from the implementation of the master plan. The land acquisition costs estimated are included in the costs for economic evaluation applying a SCF of 0.85, judging them as reflecting costs for residents needed to resettle in other areas.

The economic costs thus estimated are shown with operation and maintenance costs and economic benefits in Table I4-8.

4.1.3 Economic Analysis

An economic evaluation of the proposed master plan and each component is carried out with the following principles:

(a) Benefit-cost ratio (B/C), net present value (NPV or B-C) and economic internal rate of return (EIRR) are derived for assessing the economic viability of Master Plan;

(b) The threshold EIRR, or opportunity cost of capital, is assumed at 10%, following the general practice in Cambodia; and

(c) An evaluation period is 50 years.

Table I4-8 shows flows of the costs and benefits for the Master Plan as a whole. Flows of costs and benefits are estimated following the implementation schedule of the Master Plan. The following results are obtained:

- EIRR : 12.9 %
- B/C ratio : 1.25
- Net present value (NPV) : 32,120 thousand US$

It is clarified that the master plan as a whole shows sufficiently high economic return, compared with the opportunity cost of capital at 10 %.

Table I4-9 shows the results of economic evaluation for each component of the master plan. For the purpose of comparison, construction of all the components is assumed to start in 2000. The following table summarizes the result:

Results of Economic Evaluation for Each Component of Master Plan

Component	EIRR (%)	B/C	NPV (US$ 10^3)
1	-0.5	0.18	-1,793
2	24.8	2.92	32,601
3	11.0	1.10	6,413
4	9.1	0.91	-5,880
5	5.3	0.57	-12,010
6	4.8	0.51	-5,544
7	-2.1	0.14	-9,878
8	N/A	N/A	N/A

Among the eight components, Component 2, Reinforcement of Kop Srov Dike, and Component 3, Tompun Watershed Drainage Improvement, show higher economic return. Their EIRRs are 24.8 % and 11.0 % respectively, higher than the opportunity cost of capital at 10 %.

4.2 Financial Affordability

4.2.1 Present Expenditure Levels of DPWT and DSD

Expenditures of Ministry of Public Works and Transport (MPWT), Municipality of Phnom Penh (MPP), Department of Public Works and Transport (DPWT) and Drainage and Sewerage Division (DSD) of DPWT are shown below for 1995, 1996 and 1997. Table I4-10 shows a detail for DPWT and DSD:

Expenditure of MPWT, MPP, DPWT and DSD

(Unit: Riel million)

Organization	1995	1996	1997
MPWT (Ministry of Public Works and Transport)	8,011	7,158	8,340
MPP (Municipality of Phnom Penh)	17,505	22,185	19,651
DPWT (Department of Public Works and Transport)	1,503	994	2,065
DSD (Drainage and Sewerage Division, DPWT)	313	330	383

The expenditures of DPWT and DSD do not include those for power payment. DPWT has been billed for power use for pumping and other facilities, but has not made payments due to lack of fund. The billed amount is about Riel 700 million per year for pumping facilities and Riel 400 to 500 million per year for other facilities. These combined account for from 52 % to 58 % of the DPWT's total expenditure in 1997. DPWT and MPP made a proposal to Electricité du Cambodge (EdC) to collect additional money from power users by imposing a surcharge at 3 % of power tariff as a way to compensate for the shortfall of DPWT's budget for power bill. The proposal has not been agreed by EdC.

From June 1997 to August 1998, MPP received Riel 1,576 million (US$0.41 million) from PPWSA, out of which Riel 1,326 million corresponds to the fund to be transferred during this period from PPWSA to MPP as the revenue generated by the wastewater surcharge at 10 % of water sale. The difference at Riel 250 million is counted as advance payment of the surcharge revenue and will be subtracted from future transfer. Out of this, about Riel 1,000 million (Riel 600 million in 1997 and Riel 400 million in 1998) or 63 % of Riel 1,576 million, was transferred to DPWT. This revenue has been used for various purposes, not limited to operation and maintenance of the sewerage and drainage facilities.

4.2.2 DPWT and DSD's Revenue Levels Projected for 2010

Tables I4-11 and I4-12 present a preliminary estimate of revenues for the central government, DPWT and DSD for 2010 and 2020. The estimate is made based on the following assumptions:

(a) Two cases are estimated as standard and low growth scenarios.

(b) Revenue of the central government is estimated for the year 2006, which is the last year of the World Bank's projection of a number of macroeconomic indicators, 2010, the target year of the present study and 2020 in which the last part of the proposed investment for the master plan is completed. Then the revenues of DPWT and DSD are estimated for 2010 and 2020, applying the growth rates estimated for the central government revenue until 2010 and 2020 for the two scenarios. The underlying idea is that a number of measures being currently implemented to strengthen and expand the taxation system will result in a rise of central government revenue and DPWT will proportionately enjoy an increase in budgetary allocation.

(c) GDP growth rates between 1997 and 2010 are set based on the established Socioeconomic Framework for the standard scenario. The rate for the low growth scenario is 3.6 % per year, half the standard scenario. GDP growth rates between 2010 and 2020 are set lower than the 1997-2010 period: 5.0 % per year and 2.0 % per year for the two scenarios. The growth rate between 1996 and 1997 is 2.0 % based on the actual performance.

(d) The proportion of the central government revenue to GDP is taken from the World Bank's projection. The target in 2006 is 16.9 %, whereas the proportion in 1996 was 9.1 %. This target is assumed to be maintained until 2010 for the standard scenario. The target for the low growth scenario is set at 9.1 % for 2010, assuming no increase in the proportion. The target for 2020 is set at 20 %, and 12 % for the standard scenario and low scenario respectively, considering the prevalent proportions in the neighboring Asian countries as shown in the table below:

Proportion of Government Revenue to GDP
in 1995 in Selected Asian Countries

(Unit: %)

Country	Tax Revenue	Other Revenue	Total
Nepal	9.1	4.3	13.4
Mongolia	20.3	5.0	25.3
Indonesia	16.4	6.2	22.6
Philippine	16.0	4.9	20.9
Thailand	17.1	7.4	24.5
Malaysia	20.6	6.6	27.2
Singapore	17.2	4.6	21.8
Japan	17.6	3.0	20.6

Source: World Development Report 1997, the World Bank

(e) The starting revenue levels of DPWT and DSD for projection are the averages of the revenues from 1995 to 1997 to minimize the impact of annual fluctuation of expenditure levels.

The following levels of revenue are estimated for DPWT and DSD for 2010 and 2020:

Estimated Revenues of DPWT and DSD in 2010 and 2020
Based on Increased Budget Allocation

(Unit : $ million)

Item	Scenario	
	Standard	Low
DPWT		
1997	0.39	0.39
2010	1.75	0.63
2020	3.38	1.01
DSD		
1997	0.09	0.09
2010	0.39	0.14
2020	0.76	0.23

Note : $: Riel 3,880 as mid-point level in October 1998

4.2.3 Comparison with Fund Requirement of Master Plan

Investment cost, depreciation cost and operation and maintenance costs for implementing the proposed master plan are estimated by local and foreign currency portion and by period as follows:

Investment Cost and Operation and Maintenance Costs
of the Master Plan

(Unit: $ million)

Item	By 2010	By 2020
Investment Cost		
Total	154.20	261.10
Local currency portion	61.60	95.50
Foreign currency portion	92.60	165.60
Depreciation *		
Total	3.08	5.22
Local currency portion	1.23	1.91
Foreign currency portion	1.85	3.31
Operation and Maintenance Cost	0.77	1.31

* Depreciation period of 50 years, 100% of investment cost to be depreciated, straight line method applied.

The DSD's revenue and the master plan's fund requirement thus estimated are compared as follows:

Comparison of DSD's Revenue by Increased Budget Allocation
and Master Plan's Fund Requirement

(Unit: $ million)

Item	2010	2020
Revenue		
Standard Scenario	0.39	0.76
Low Growth Scenario	0.14	0.23
Fund Requirement		
Depreciation (total cost)	3.08	5.22
Depreciation (only local currency portion)	1.23	1.91
Operation and Maintenance Costs	0.77	1.31

In 2010 the estimated revenue of DSD range from $ 0.14 million per year (low growth scenario) to $ 0.39 million per year (standard scenario). The cost of the master plan far exceed these revenue levels. Even operation and maintenance costs cannot be covered by increased budgetary revenue for DSD, let alone depreciation cost for the local currency portion. The same situation is foreseen for 2020. New sources of revenue in addition to the expected rise in the government budget allocation to DPWT need to be sought.

4.2.4 Revenue Enhancement Measures for DPWT and DSD

The existing wastewater charge system is an important tool for DPWT and DSD to generate revenues. Based on the system, PPWSA collected and transferred Riel 1,576 million to MPP during June 1997 to August 1998 period. DPWT received about 63 % or about Riel 1,000 million out of this. A projection by the World Bank estimates the PPWSA's revenue from water sale at Riel 53,091 million in 2007 in 1996 price level. Applying the rate of 10 % of water tariff, the currently applied rate, a revenue of Riel 5,309 million or $ 1.38 million per year will be generated in 2007. The projection by the World Bank is extrapolated to the years of 2010 and 2020, applying an annual growth rate at 3.2 % per year, the population growth rate set in the Socioeconomic Framework, assuming that the PPWSA's revenue will keep rising in proportion to the assumed population growth. The projected revenue for PPWSA and wastewater surcharge revenue at 10 % of water sale are estimated as follows:

<u>Water revenue</u>

- 2010 : 58.4 billion Riel ($ 15.1 million *)
- 2020 : 80.0 billion Riel ($ 20.6 million *)

<u>Wastewater surcharge revenue (10% of water revenue)</u>

- 2010 : $ 1.51 million
- 2020 : $ 2.06 million

* $1 = Riel 3,880 as the midpoint average in October 1998 applied

The revenue from the wastewater surcharge is added to the budget revenue and compared with the fund requirement as follows:

Comparison of Revenue from Budget Revenue and
Wastewater Surcharge and Master Plan's Fund Requirement

(Unit: $ million)

Item	2010	2020
Revenue		
Budget (standard scenario)	0.39	0.76
Wastewater Surcharge (10% of water sale)	1.51	2.06
Total	1.90	2.82
Fund Requirement		
Total Investment cost Depreciated	3.08	5.22
Local Currency Portion Depreciated	1.23	1.91
Operation and Maintenance Costs	0.77	1.31

The table above shows that the total revenue is larger by more than two times than the operation and maintenance cost of the master plan both in 2010 and 2020. The total revenue will come short of the fund requirement if the depreciation cost of the local currency portion is included in the fund requirement. In the event that foreign assistance be provided only for the foreign currency portion, the local currency portion of the master plan should be financed domestically. This matter is uncertain at this point. Supposing the need for domestic financing of the local currency portion, additional revenue sources become necessary to generate sufficient revenue for covering both operation and maintenance costs and depreciation costs of the local currency portion for the master plan implementation. At this point, it could be concluded that the projected revenue level including that from wastewater surcharge will be able to cover the minimum cost recovery target, that is to recover operation and maintenance costs, on the premise that investment cost be provided by the central government budget.

Theoretically speaking, wastewater surcharge is an appropriate measure for sewerage component, but not for rain water drainage component. The amount of wastewater is determined by the amount of water people use, but the amount of rainfall is determined by natural factors. The wastewater surcharge charged according to the amount of water supplied, therefore, is suited to sewerage component. The basis for applying the wastewater surcharge system to the sewerage and drainage component as currently practiced lie in the following two points:

- The sewerage and drainage system in Phnom Penh is a combined system. It is difficult to clearly divide sewerage and rain water drainage portions.
- Wastewater surcharge is realistically an efficient tool for generating fund.

In a medium- to long-run, introduction of land and property tax should be considered. At present, no tax is imposed as land and property tax in Cambodia. The World Bank Report ("Cambodia, Progress in Recovery and Reform", June 2 1997) points to the necessity of introducing land and property tax over the medium term. Land and property tax is a means for municipal governments to generate fund for providing various urban services. For such services as water supply, sewerage, power, telecommunications and gas, revenue can be generated by tariff in proportion to the amount of services provided from beneficiaries who can be clearly defined, those who are connected to water pipes, sewerage pipes, power lines, telephone lines and gas pipes. For other types of services such as urban drainage, road and various social services, on the contrary, land and property tax is an appropriate measure for recovering cost. For these types of services, it is impossible to clearly define beneficiaries and measure the amount of services received. For the present project, it would be desirable that the revenue expected from wastewater surcharge be gradually shifted to that by land and property tax in accordance with the reinforcement of the taxation system of the central and local governments.

4.3 Initial Environmental Examination

4.3.1 Initial Environmental Examination Matrix

A matrix was prepared to evaluate and identify important environmental components that can be affected by the Project, their present condition, their future condition without the project, and the impacts to be generated on them with the project implementation.

4.3.2 Criteria Used for Environmental Examination

The scale of importance given to the environmental elements is an arbitrary scale to evaluate the importance of each environmental element to the problem of flooding in the study area. The importance rating is given to each environmental element according to the following evaluation criteria:

Rating	Criteria
1 (not important)	un-related to or un-affected by flooding
2 (important)	affected to some extent by flooding
3 (very important)	affected significantly by flooding
x (not clear)	may/ may not be affected by flooding; further study necessary

The scale of present condition is an arbitrary measure to evaluate the current quality level of each environmental aspect determined to be important or very important in the importance rating above. The judgment is based on a comparison with conditions in the past. The scale of present condition evaluation in IEE Matrix was decided by comparing the present condition with the environmental state of the area 20 years ago as follows:

Rating	Criteria
1	worse quality than twenty years ago
2	almost same as 20 years ago
3	better quality than 20 years ago
x	rating not possible due to lack of data; further study needed

The next phase of the evaluation comprises an arbitrary scale determining what the future environmental condition would be "without " the proposed project. That is, what the environmental susceptibility to management is. Finally, potential environmental impacts to be generated by the project is predicted to preview the possible future environmental disruptions and benefits from the proposed project. The rating system for the predicted future condition and for the potential impacts in IEE Matrix is as follows:

Rating	"Without" Project/ Potential Impacts to be generated "With" the Project
-3	high significance (negative)
-2	medium significance (negative)
-1	low significance (negative)
0	no impact
x	impact not clear; further study needed
1	low significance (positive or beneficial)
2	medium significance (positive or beneficial)
3	high significance (positive or beneficial)

The ratings of these four phases have been judged based on the environmental pre-conditions in the project area presented in previous sections of this report. Those environmental elements receiving an importance rating of 2 or 3 or x, a present rating of 1 or x, and a future "Without" project rating of x or +/- 2 or 3 are important. They are indicative of environmental aspects whose existing conditions are not good and/or which would be affected if the Project were not implemented.

Considering the last phase of the Matrix, a negative rating of any environmental aspect due to a proposed structural alternative/option indicates negative impact caused by the alternative. A positive rating indicates project benefit. Those environmental elements receiving a rating of x or - 2 or -3 due to any proposed physical alternative need further study during subsequent project cycle stage.

4.3.3 Potential Alternatives and Options

Various physical alternative measures either individually or in combination are to be applied in each watershed area in the city core, northeast area, middle area, northwest area, and south area. These alternatives/options are summarized below. Non-physical measures in the form of land use/building control and farm/lake conservation need to be implemented in some watersheds. Their implementation and resulting impacts are positive in nature. Therefore, in the IEE, only impacts of physical measures are considered.

(1) Reinforcement of Ring Dikes

Flood protection dike would be developed by reinforcing the existing ring dikes comprising Kop Srov Dike on the north and Tompun Dike on the south of Phnom Penh. The road would be raised up by about 20-30 cm in average. The revetment would prevent damages from landslide and overflow from outside areas.

(2) Rehabilitation and Installation of Drainage Gates and Sluices

Existing drainage system would be improved. Drainage gates and sluices would be constructed crossing Kop Srov Dike, National Road No. 5, Tompun Dike, National Road No. 4 and inner dike.

(3) Rehabilitation & Closure of Existing Outlets

Revetment with stop gates would be rehabilitated on the right bank of the Tonle Sap near Chaktomuk and Royal Palace.

(4) Rehabilitation, Reinforcement, and/or Installation of Pumping Stations

Three pumping stations are expected to be rehabilitated and/or installed to facilitate flood draining from the area to the east of Pochentong Airport including Boeng Tompun and Boeng Trabek areas.

(5) Rehabilitation of Regulation Ponds

Boeng Poungpeay and Boeng Kak would be rehabilitated for higher efficiency in flood regulation and improving water quality.

(6) Rehabilitation and Installation of Main Drainage Pipes

The existing drainage culverts within the urban area would be improved for higher efficiency. Main drainage culverts are to be constructed along six roads comprising road No. 182, road No. 215 (Jawaharlal Nehru), road No. 217 (Samdach Monireth), road No. 245 (Mao Tse Toung), road No. 201 and road No. 315.

(7) Dredging and Improvement of Drainage Channels and Boengs

Existing drainage channels and Boengs would be excavated, i.e. drainage channels of Boeng Salang, Trabek and Tompun. This alternative needs permanent relocation of 855 households.

4.3.4 Potential Impacts to be Generated by the Alternatives/Options

A description of the impacts on each environmental aspect due to each of the proposed structural alternative measures is presented in Table I4-13. A "With Project" evaluation is presented in Table I4-14 for each environmental parameter due to proposed physical alternatives/options. Due to the differences of environmental characteristics, variation of project impacts can be expected (for more details see Table I4-14). A descriptive and comparative analysis of the impact of each proposed physical alternative on various environmental aspects is presented below.

Topography & Location: Most of the proposed project physical measures are improvements of existing features, e.g., dike enhancement, boeng and drainage channel excavation, and pump rehabilitation. Therefore, serious alterations of topographic aspects are not expected.

Flow Regime: Construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation/installation of main drainage channel would have no impact on the water balance. Other physical alternatives would cause some impact as they relate with inflow/outflow control, which affects flow regime.

Flooding & Surface Runoff: Construction of dike would be better than other alternatives in terms of flood protection since the dike structure would prevent flood and overflow along the total length of 30 km.

Eutrophication: Rehabilitation/installation of main drainage channel and flood protection revetment along the bank of the Tonle Sap would cause no impact since the sites are not within the waterways and water in Sap river would be diluted. Rehabilitation of boengs and dredging drainage channels and boengs would have positive impact since it would make water quality better.

Turbid/Polluted Water: Construction of dike would cause some minor adverse impact during construction phase. Construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation/installation of main drainage channel would cause no impact since water in the Tonle Sap will not be affected and it does not result in any waterway encroachment.

Dissolved Oxygen: Construction of dike would cause some minor adverse impact during construction. Construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation/installation of main drainage channels would cause no impact since water in the Tonle Sap will not be affected and waterways would not be encroached. The other remaining alternatives would also help in improving water quality by increasing DO.

Offensive Odor: Dike construction would cause some minor adverse impact during construction phase while construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation/installation of main drainage channels would cause no impact in the Tonle Sap and waterways would not be encroached. The other remaining alternatives would help in improving water quality.

Power and Water Supply: Most of alternatives would cause no impact on power and water supply. Construction of dike, rehabilitation of Boeng Poungpeay and Boeng Kak would cause some positive impact since it may induce power and water supply development opportunities in terms of expanding electrical and water supply services. The rehabilitated boengs could be a water source for communities around the boengs. Rehabilitation/installation of main drainage channel would cause some minor adverse impact during construction phase.

Sanitary Facilities: Most of alternatives would cause no impact due to the method and operation pattern. Rehabilitation/installation of main drainage channels would result in improved sanitation due to regular draining of storm sewers.

Drainage Network: Construction of dike, installation of regulators, construction of flood protection revetment along the bank of the Tonle Sap, installation of pumping station and rehabilitation/installation of main drainage channels would cause positive impact since they would improve drainage efficiency. The remaining two alternatives would cause no impact since they do not affect the drainage system.

Solid Waste Disposal: All seven alternatives would cause some minor adverse impacts during construction phase concerning which appropriate measures need to be implemented for waste disposal by construction contractors.

Spontaneous/Planned Settlements: Rehabilitation and installation of main drainage culverts would cause no impact since there would be no relocation of people. Rehabilitation and installation of main drainage channels would cause some impact since there would be relocation of people. Dike construction would cause medium impact since about 50 households have to be relocated. Dredging of drainage channels and boengs would cause serious impact since around 855 households need to be permanently relocated.

Squatters: The expected impacts are the same as those of spontaneous/planned settlements. Most of the households to be relocated are squatters. They only hope for a better living standard after relocation.

Fishery: Construction of dike would be beneficial in preventing damage to fish culture ponds. Most of the fishponds are within the dike especially near Kop Srov Dike and Boeng Poungpeay. Rehabilitation of boeng and dredging drainage channels/boengs would have some positive impact in improving aquaculture within the boengs.

Industry: Construction of flood protection revetment along the bank of the Tonle Sap, dike construction, installation of regulators and pumping station would cause moderate to high positive impact since they will prevent flooding of industrial plants within the project area. Rehabilitation and installation of main drainage channels would cause some minor negative impact during construction since business and transportation would be interrupted.

Tourism: Construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation and installation of main drainage channels would cause moderate positive impact since they would alleviate flood condition at main tourism sites such as the Royal Palace, the National Museum and the Russian Market. The other five alternatives would not cause any impact on tourism sites.

Land Transportation: Construction of dike would induce more convenience in transportation for people living along Kop Srov and Tompun roads since the road would be reinforced for flood protection resulting in better condition of roads. The other six alternatives would cause some impact on traffic during construction phase due to closing/diversion of traffic lanes, falling of construction material, residues/soil on roads causing traffic jams.

Waterborne Disease: All seven alternatives would be beneficial in decreasing prevalence of waterborne diseases due to control of flooding and drain waters and improvement in water quality. Environmental management of construction wastes and maintenance of sanitation and hygienic conditions during construction phase would result in minimal negative impact.

4.3.5 Conclusion

The main factors differentiating the significance and degree of impact of each proposed physical alternative are the natural environmental aspects comprising topography & location, flow regime (water balance), flooding and surface runoff and social environment aspects relating to spontaneous/planned settlements and squatters.

From the viewpoint of minimizing social impacts due to relocation, dike construction is the most appropriate. Second is construction of regulators, and third is installation of pumping stations. The least preferred option is dredging of drainage channel and boengs as they require permanent relocation of a large number of households. Dike construction would cause medium impact since 150 households have to be relocated. The only major significant negative impact is due to the physical alternative, dredging of drainage channel and boengs. This would cause serious impact since 855 households need to be relocated permanently and an appropriate relocation, resettlement and rehabilitation plan for affected persons needs to be formulated and implemented.

It can be concluded that the proposed project impacts are largely beneficial. Negative impacts of relocation can be controlled by formulation of mitigation measures. On the other hand, without the proposed project physical and non-physical measures, flooding in Phnom Penh would continue to cause considerable economic disruption and social hardship to a very large proportion of the population. Vulnerable social groups living in flood prone areas like in or near dikes, drainage channels and lakes, would be seriously affected, and could be further marginalized. Risk to health hazards and outbreak of water-borne diseases after floods would be higher.

4.4 Technical Evaluation

The construction of the Master Plan projects comprises the following work items:

- Dikes and Revetments : Embankment, asphalt pavement, stone pitching, stone filling
- Pumping Stations and Sluiceways : RC structure, foundation piles, electrical and mechanical works
- Regulation Ponds and Open Drainage Mains : Excavation, dredging
- Underground Drainage Mains : Temporary works (earth retaining), excavation, RC structure
- Sewers : Excavation and backfilling, fabrication and furnishing of PC pipes

Cambodia has experienced construction of dikes, revetments, pumping stations, open channels and sewers by himself or under foreign assistance. No difficulty would thus be encountered in the actual construction of Master Plan projects, except for (a) the electrical and mechanical works in pumping stations and sluiceways, (b) temporary works such as earth retaining in underground drainage mains, and (c) PC pipe fabrication in sewers. Pumps, gates and the appurtenance in Item (a) above shall be imported from a developed country, and the installation, operation and maintenance shall be supervised by engineers from such a country. Moreover, there might not be practices to date in earth retaining, with high sheet pile walls and H-beam struts, in Item (b), and fabrication of PC pipes in Item (c). Advanced technology therefor shall be introduced from neighboring countries.

15. IDENTIFICATION OF PRIORITY PROJECTS

The total Master Plan, either physical or non-physical measures, has been confirmed to be economically viable (EIRR 12.9 %), financially affordable, environmentally sound and technically possible in the relevant sectors. All projects proposed in the Master Plan can be materialized by year 2020 without serious constraints. Based on such overall understanding, this Section, as the final stage of the Master Plan study, attempts to identify one or some priority project(s) to be subject to the succeeding feasibility study.

The identification of priority projects, or components in the Master Plan, will be made in line with nearly same considerations as applied to the delineation of the implementation schedule in Subsection 3.6.4. The logic for the identification is as follows:

(a) Three components, Reinforcement of Kop Srov and Tompun Dikes, Tompun Watershed Drainage Improvement, and Trabek Basin Drainage Improvement, are of higher economic viability, namely 24.8 %, 11.0 % and 9.1 % of EIRR, respectively. The others are rather low in EIRR, say less than 6 %, which can naturally be out of the priority projects.

(b) As for Trabek Basin Drainage Improvement among the three, the construction of a new pumping station and drainage mains is on schedule starting in mid-1999 under the loan from ADB. This is also omitted from the priority projects.

(c) On the other hand, Kop Srov and Tompun dikes play an important role in protecting the Municipality of Phnom Penh from floods of the Mekong river system. Once these should breach, most part of the city would go under floodwater. Taking into account its high economy as well, Reinforcement of Kop Srov and Tompun Dikes must be a component of the priority projects. Moreover, Svay Pak Drainage Sluiceway with the same nature as the dikes shall be reconstructed under this component although it was included in Component 7 in the Master Plan.

(d) The eastern half of the urbanized area of Phnom Penh is being safe from inundation through the Trabek Project financed by ADB, however the western half will yet suffer from repeated inundation. To solve this, Tompun Watershed Drainage Improvement targeting said area shall be promoted as another component of the priority projects. In the same consideration as mentioned in Item (c) in Subsection 3.6.4, sewer rehabilitation in the drainage improvement is excluded from this component.

Summarizing the above, the priority projects to be examined in the succeeding feasibility studies are identified as follows:

- Project A: Reinforcement of Kop Srov and Tompun Dikes
(including reconstruction of Svay Pak Drainage Sluiceway)
Component 2 and a part of Component 7

- Project B: Tompun Watershed Drainage Improvement
(excluding sewer rehabilitation)
A part of Component 3

TABLES

Table I2-1 Related Studies and Projects

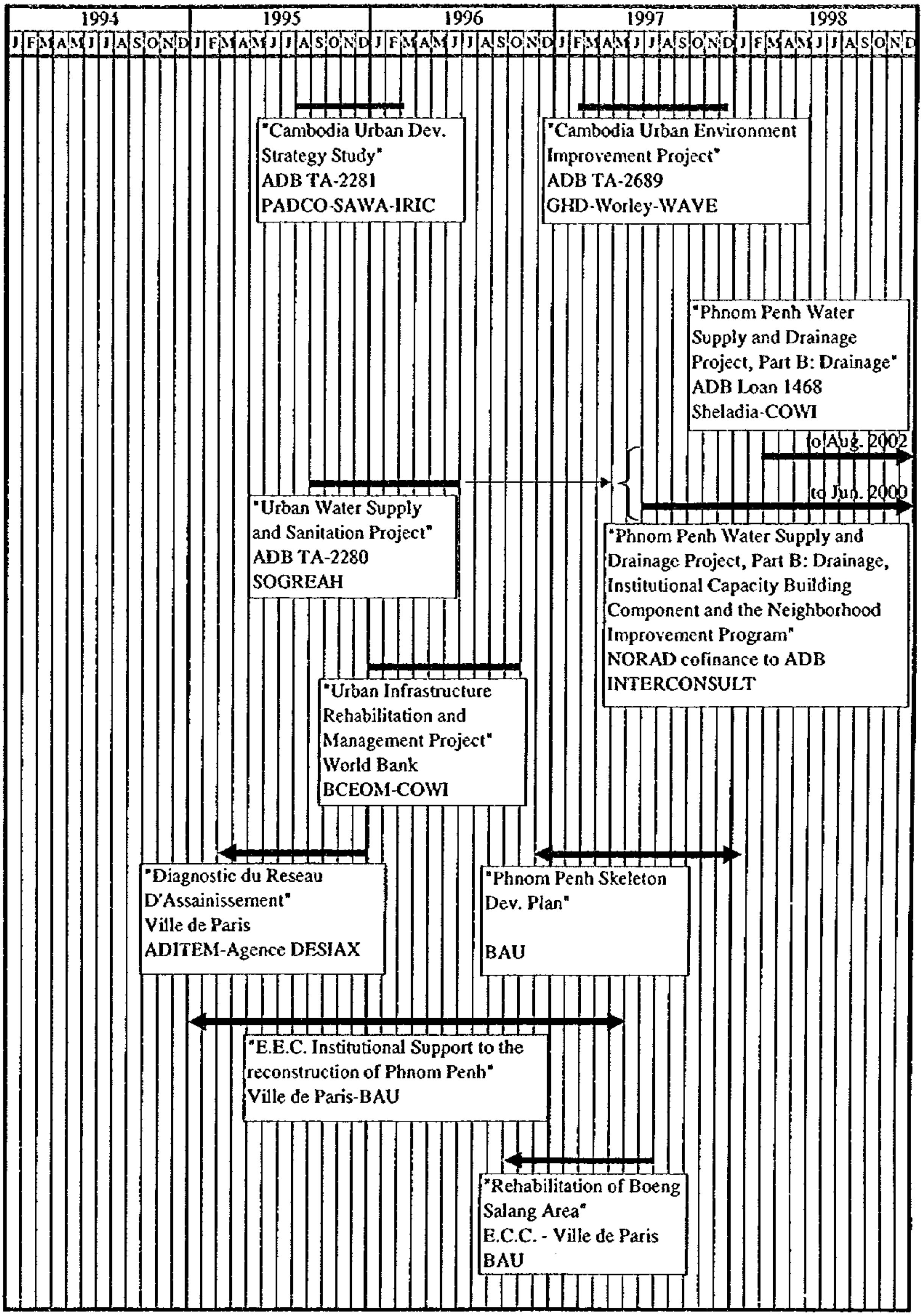


Table I2-2 Social and Economic Characteristics of Cambodia

Indicators	Unit	Cambodia	Laos	Vietnam	Thailand
a. Total population	million	10.0	4.9	73.5	58.2
b. GNP per capita	1995 US$	270	350	240	2,740
c. GDP in 1995	million US$	2,771	1,760	20,351	167,056
d. GDP composition in 1995					
Agriculture	%	51	52	28	11
Industry	%	14	18	30	40
(Manufacturing)	%	6	4	22	29
Service	%	34	30	42	49
e. GDP growth rate, 1990-1995	%/year	6.4	6.5	8.3	8.4
f. Illiterate population	%	35	43	6	6
g. Rate of population increase	1980-90, %/year	2.9	2.7	2.1	1.7
	1990-95, %/year	2.8	3.0	2.1	0.9
h. Infant mortality rate	per 1,000 births in 1995	108	90	41	35
I. Children going to primary school (1993)					
boy	%	48	123	111*	98
girl	%	46	92	106*	97

Source : World Development Report 1997, the World Bank

Note :

* Figures in 1980

** The figures in this table might not be consistent with those to appear in the tables to follow. In this table, the values in the source document are presented for the purpose of comparison with the other three countries.

Table I2-3 Gross Domestic Product (GDP) of Cambodia

Item	Unit	1991	1992	1993	1994	1995	1996	1997
GDP	10^9 Riel, current prices	1,336	2,509	5,414	6,131	7,200	8,200	9,132
	10^6 US$, current prices	1,634	1,506	1,923	2,385	2,923	3,113	3,177
GDP composition								
Agriculture	%	51.5	46.4	45.8	43.0	43.7	42.6	44.0
Industry	%	11.6	13.0	15.0	16.3	16.3	17.8	17.3
Services	%	36.9	40.6	39.2	40.7	40.0	39.6	38.7
Annual growth rates	(at 1989 prices)							
Agriculture	%/year	2.9	0.3	4.1	0.5	6.4	2.4	5.2
Industry	%/year	11.6	22.3	19.4	15.3	9.5	15.0	0.6
Services	%/year	12.2	9.6	7.3	11.9	8.2	7.3	-0.4
GDP	%/year	7.6	7.1	4.1	4.0	7.6	6.5	2.0
GDP by sector *								
Agriculture	10^9 Riel, current prices	688	1,164	2,480	2,636	3,146	3,493	4,018
Industry	10^9 Riel, current prices	155	326	812	999	1,174	1,460	1,580
Services	10^9 Riel, current prices	493	1,019	2,122	2,495	2,880	3,247	3,534

Source : Public Investment Programme 1998 - 2000, PIP Unit, Department of Investment, Ministry of Planning

Note :

(1) Average annual growth rates between 1990 and 1997

Agriculture 3.1 %/year
Industry 13.2 %/year
Services 7.9 %/year
GDP 5.5 %/year

(2) GDP growth rate in 1990 was 1.2% per year.

(3) GDP per capita in 1996 :

Population : 10,340 thousand (Table 2.2.3)
GDP : 3,113 million US$
GDP per capita : 301 US$

* Calculated based on GDP values and compositions.

Table I2-4 Estimated GRDP of Phnom Penh

Item	Unit	Sector			
		Agriculture	Industry	Service	Total
Cambodia					
GDP in 1996	10^9 Riel, current prices	3,493	1,460	3,247	8,200
Number of workforce in 1996	number	3,797,283	230,143	831,595	4,859,021
GDP per worker	Riel, current prices	919,868	6,343,882	3,904,545	1,687,583
Phnom Penh					
Number of workforce in 1996	number	40,271	42,781	233,029	316,081
GRDP per worker	Riel, current prices	919,868	6,343,882	3,904,545	1,687,583
GRDP	10^9 Riel, current prices	37	271	910	1,218
		3%	22%	75%	100%
GRDP/GDP	%	1.1	18.6	28.0	14.9

Note :

(1) GDP : Gross Domestic Product

(2) GRDP : Gross Regional Domestic Product

(3) Phnon Penh's GRDP is estimated assuming the same GRDPs per worker as GDPs per worker in Cambodia.

(4) Definition of sectors

Agriculurey : agriculture, forestry, fishing, livestock

Industry : mining and quarrying, manufacturing, power/gas/water and construction

Service : various services

Source :

(1) Number of workers : Socio Economic Survey of Cambodia 1996, National Institute of Statistics

(2) GDP : Table 2.2.2

Estimate of GRDP per capita in US$

a. Population in Phnom Penh 797 thousand in 1996

b. Exchange rate in December 1996 2,720 Riel / US$

c. GRDP in US$: US$ 448 million (1,218 billion Riel / 2,720 Riel / US$)

d. GRDP per capita of Phnom Penh : US$ 562 per capita in 1996

Estimate of annual growth rate of Phnom Penh's GRDP

Cambodia's GDP growth rates and weight for sectors

	GDP growth rate		Weight		
Agriculture	3.1 %/year	*	0.03	=	0.093
Industry	13.2 %/year	*	0.22	=	2.904
Services	7.9 %/year	*	0.75	=	5.925
			Total	=	8.922

GRDP growth of Phnom Penh (1990-97) = 8.9%/year

Table I2-5 Population of Study Area

District/sub-district	Total area in km²	Area in % in SA *	Area in % outside SA	Area in km² in SA	Area in km² outside SA	Population Total	Population in SA	Population outside SA
(Three suburban districts lying across study area boundary)								
Dang Kor								
1 Cheung Ek	11.6	0	100	0.0	11.6	5,081	0	5,081
2 Dang Kor	16.8	16	84	2.7	14.1	9,426	1,508	7,918
3 Prey Sar	10.6	53	47	5.6	5.0	4,037	2,140	1,897
4 Prey Veng	7.8	47	53	3.7	4.1	2,865	1,347	1,518
5 Sak Sampouv	6.3	0	100	0.0	6.3	1,951	0	1,951
6 Pong Toek	9.7	84	16	8.1	1.6	5,693	4,782	911
7 Kraing Prongor	8.6	0	100	0.0	8.6	2,288	0	2,288
8 Prateas Lang	8.6	0	100	0.0	8.6	3,789	0	3,789
9 Pleung Chhes Rotes	10.5	6	94	0.6	9.9	3,803	228	3,575
10 Chom Chao	28.0	100	0	28.0	0.0	15,673	15,673	0
11 Trapaing Krasaing	9.3	12	88	1.1	8.2	2,600	312	2,288
12 Samrong Krom	21.0	49	51	10.3	10.7	4,026	1,973	2,053
13 Kok Kokar	28.8	56	44	16.1	12.7	5,306	2,971	2,335
14 Kraing Thnong	9.4	100	0	9.4	0.0	2,773	2,773	0
15 Kakab	13.1	100	0	13.1	0.0	14,405	14,405	0
sub-total	*200.1*	*49*	*51*	*98.8*	*101.3*	*83,716*	*48,112*	*35,604*
Mean Chey								
1 Chbar Ampouv 1	0.513	0	100	0.0	0.5	10,304	0	10,304
2 Chbar Ampouv 2	1.938	0	100	0.0	1.9	24,000	0	24,000
3 Nirod	6.075	0	100	0.0	6.1	13,952	0	13,952
4 Prek Pra	5.313	0	100	0.0	5.3	11,161	0	11,161
5 Chak Angre Leu	2.250	0	100	0.0	2.3	16,033	0	16,033
6 Chak Angre Krom	8.463	0	100	0.0	8.5	19,775	0	19,775
7 Beung Toum Poun	4.125	100	0	4.1	0.0	28,930	28,930	0
8 Strung Meanchey	9.575	100	0	9.6	0.0	31,557	31,557	0
sub-total	38.252	*36*	*64*	*13.7*	*24.6*	*155,712*	*60,487*	*95,225*
Russey Keo								
1 Suay Pak	6.238	100	0	6.2	0.0	10,243	10,243	0
2 Chrang Chamres 1	3.163	100	0	3.2	0.0	7,898	7,898	0
3 Chrang Chamres 2	3.363	100	0	3.4	0.0	11,386	11,386	0
4 KM No 6	4.250	100	0	4.3	0.0	12,527	12,527	0
5 Russey Keo	3.563	100	0	3.6	0.0	17,666	17,666	0
6 Toul Sangke	3.713	100	0	3.7	0.0	22,020	22,020	0
7 Chroy Chang Var	8.375	0	100	0.0	8.4	13,744	0	13,744
8 Prek Leap	9.013	0	100	0.0	9.0	9,462	0	9,462
9 Prek Tasek	16.338	0	100	0.0	16.3	4,923	0	4,923
10 Toek Tla	5.825	100	0	5.8	0.0	26,143	26,143	0
11 Phnom Penh Thmey	17.113	100	0	17.1	0.0	17,866	17,866	0
12 Khmournh	13.388	100	0	13.4	0.0	5,890	5,890	0
sub-total	*94.342*	*64*	*36*	*60.6*	*33.7*	*159,768*	*131,639*	*28,129*
Total of three districts	*332.7*	*0.52*	*0.48*	*173.1*	*159.6*	*399,196*	*240,238*	*158,958*
							60.2%	*39.8%*
(Four downtown districts)								
Chamkarmon	9.8	100	0	9.8	0	148,432	148,432	0
Don Penh	6.2	100	0	6.2	0	110,727	110,727	0
Prampi Makara	2.3	100	0	2.3	0	92,463	92,463	0
Toul Kork	7.9	100	0	7.9	0	130,139	130,139	0
Total of four districts	*26.2*	*100*	*0*	*26.2*	*0*	*481,761*	*481,761*	*0*
GRAND TOTAL	**358.9**	**55.5**	**44.5**	**199.3**	**159.6**	**880,957**	**721,999**	**158,958**
							82.0%	**18.0%**

Note:

(1) * SA = Study Area

(2) Population figures for outlying three districts are based on the data provided by each district office. Those of downtown four districts are obtained at the Department of Planning of the Municipality of Phnom Penh.

(3) Areas of each district and sub-districts are measured by the JICA study team.

(4) The total area of the Study Area derived as sum of all the sub-districts and districts at 199.3 km² is slightly greater than the total area derived for land use analysis at 196.58 km². A deviation of this magnitude is judged negligible, especially because the objective of the analysis here is to derive a proportion of population living within the study area.

(5) The areas above include both land area and water surface.

Table I2-6 Characteristics of Each Basin (1/3)

Name of Basin	Area (km^2)	Characteristics
<u>CITY CORE</u>	(25.29)	
C1: Wat Phnom Basin	0.89	- Offices, hotels, houses, etc. densely located. - This area is the highest portion (over EL. 10.5 m) and local runoff drained to the Tonle Sap River by gravity.
C2: Kak Lakeshore Basin	0.51	- Offices, a hospital, French embassy, houses, etc. situated. - Local runoff drained to Boeng Kak.
C3: Boeng Kak Basin	1.14	- Lake area which will be a recreational zone in the city. - Water discharges northwards to B1 area.
C4: Tuol Kork Basin	3.32	- New housing area with high to medium density. - Runoff drained out by 2 pumping stations and by gravity.
C5: University Basin	0.71	- University zone and ponds/swamps of a slender shape. - Runoff reserved therein due to its low topography.
C6: Bassac Riverside Basin	1.58	- Hotels, offices, embassies, factories, etc. located and a lot of squatters spread in the river front. - Local runoff drained directly to the Tonle Bassac River.
C7: Trabek Basin	10.83	- Urban center shares its upstream reaches and dense residential area its downstream ones. - Local runoff drained out through open channels and by Trabek pumping station to Boeng Cheung Ek. A major watershed in the City Core.
C8: Salang Basin	5.53	- Urban center located upstream and dense residential area downstream with a new urban scheme in Salang area. - Local runoff drained by pumps and by gravity outside Inner Ring Dike, led to Tompun pumping station. Another important watershed in the City Core.
C9: Tum Nup Toek Basin	0.68	- Small but dense residential area inclusive. - Local runoff drained by pumps outside Inner Ring Dike.
C10: Toek Laak Basin	0.10	- ditto-

Table I2-6 Characteristics of Each Basin (2/3)

Name of Basin	Area (km^2)	Characteristics
NORTHEAST AREA	(40.23)	
E1: Poungpeay East Basin	13.53	- Many developments (mainly factories) found in the southern part, while fishponds still in the north. - This area divided into some ten portions by road/railway embankments with drain pipes. Runoff drained out to E2.
E2: Boeng Poungpeay Basin	24.18	- Lake/swamp area whose perimeter is already intruded by developments (factories, sand mining, etc.) in places. - All runoff from Northeast and Northwest areas gathers herein, discharging to the Tonle Sap River through a sluiceway at Syay Pek.
E3: Krom Sala Basin	1.25	- Farmland and fishponds occupy with some housing. - Local runoff directly led to the Tonle Sap River through a pipe culvert.
E4: Sap Riverside Basin	1.27	- Narrow strip facing the Tonle Sap River with factories, workshops, schools, shops, shanties, etc. located. - Local runoff drained directly to the Tonle Sap River.
NORTHWEST AREA	50.79	- Farmland with small villages scattering. - Rainfall mostly reserved in the paddy fields and storage ponds for irrigation, then less flow down into the Northeast Area.
MIDDLE AREA	(38.80)	
M1: Tompun Basin	11.16	- Many houses found on the highland and they encroach on the ex-swamp area around Boeng Tompun. - Flood prevented by Tompun dike and runoff from C8, C9, C10, M1, M2 & M3 areas drained here by pumps.
M2: Pochentong East Basin	15.35	- This is a newly developed area. The airport, factories, warehouses, offices, schools, shops and houses located with decreasing farmland left in the center. - Local runoff drained by gravity towards the east (to Tompun Basin) and by pumps towards the south.
M3: Pochentong West Basin	11.59	- Villages still scatter on farmland, however large-scale constructions (e.g. for a dry port) start in places. - Local runoff drained to the Pochentong Airport direction and to Northwest Area.
M4: Prey Pring Basin	0.70	- Village with farmland occupies. - Local runoff naturally drained outside the Study Area

Table I2-6 Characteristics of Each Basin (3/3)

Name of Basin	Area (km^2)	Characteristics
SOUTH AREA	(40.60)	
S1: BOT Road South Basin	6.46	- Factories rapidly develops with reclamation works. Along the southern border of this area, a road bypass planned (named Tompun extension). - Runoff drained to the south.
S2: Prey Sar Basin	34.14	- Farmland and villages spread with less development. - Flood enters through 3 openings from the outside of the Study Area (from the Prek Thnot River), and runoff drained through the openings.
Total	195.71	-

Table I2-7 Annual Water Levels of Mekong River System
(Chaktomuk Station)

Year	Highest (EL. m)		Mean (EL. m)	Loweat (EL. m)	Maximum Water Level Deference (m)
1960	8.93	(15)	3.68	0.20	8.73
1961	9.96	(1)	4.65	0.72	9.24
1962 *	9.14	(10)	4.34	0.69	8.45
1963 *	8.75	(23)	3.97	0.53	8.22
1964	9.04	(13)	4.06	0.70	8.34
1965	8.29	(28)	4.12	0.64	7.65
1966	9.91	(3)	4.33	0.62	9.29
1967	8.74	(24)	3.76	0.64	8.10
1968	8.66	(27)	3.46	0.64	8.02
1969	8.77	(22)	3.93	0.31	8.46
1970	9.14	(10)	4.22	0.58	8.56
1971	8.82	(19)	4.35	0.68	8.14
1972	9.16	(9)	4.18	0.64	8.52
1973	8.86	(18)	3.92	0.60	8.26
1974	8.82	(19)	3.82	0.78	8.04
1975	-	-	-	-	-
1976	-	-	-	-	-
1977	-	-	-	-	-
1978	-	-	-	-	-
1979	-	-	-	-	-
1980	9.19	(8)	-	-	-
1981	9.45	(7)	4.80	0.70	8.75
1982	8.92	(16)	4.06	0.90	8.02
1983	8.72	(25)	3.77	0.72	8.00
1984	9.61	(4)	4.46	0.76	8.85
1985	8.87	(17)	4.35	0.74	8.13
1986	8.70	(26)	4.20	0.67	8.03
1987	8.07	(29)	3.56	0.63	7.44
1988	7.30	(33)	3.46	0.74	6.56
1989	7.80	(32)	3.66	0.63	7.17
1990	8.80	(21)	4.35	0.60	8.20
1991	9.54	(5)	4.21	0.64	8.90
1992	7.99	(30)	3.53	0.68	7.31
1993	7.93	(31)	3.53	0.56	7.37
1994	9.51	(6)	4.33	0.64	8.87
1995	9.12	(12)	4.13	0.63	8.49
1996	9.92	(2)	4.51	0.89	9.03
1997	9.03	(14)	4.39	0.99	8.04
1998	6.90	(34)	-	0.67	6.23
Maximum	9.96		4.80	0.99	9.29
Minimum	6.90		3.46	0.20	6.23
Average	8.83		4.07	0.66	8.16

* At Changvar Station

Table I2-8 Flood Condition in Year 1995 and 1996

Item	Year 1995	Year 1996
Flood Characteristics		
(1) Peak Water Level at Chaktomuk	EL. 9.12 m (Sep. 18 & 19)	EL. 9.92 m (Oct. 02)
(2) Duration over EL. 8.5 m	47 days (Sep. 07 to Oct. 23)	44 days (Sep. 21 to Nov. 03)
(3) Type of Hydrograph	Flat	Sharp
Damage and Flood Defense Activity in the Year 1996 Flood		
(1) General	This flood is the second biggest in the last 38 years in terms of the water level. So, sever damage was inflicted on the municipality of Phnom Penh at many locations. However, the great effort for the flood defense activity by official /private organizations concerned could barely avoid fatal result.	
(2) Kop Srov Dike	- In the eastern approx. 6 km section of Kop Srov dike starting from NR-5, the flood stage reached nearly the dike crest whose elevations are 10.1 to 10.7 m (however, no spill-over occurred). - The head of 3 to 4 m (at the highest water stage) between the water levels inside and outside the dike generated more than 20 places of piping holes, most of which penetrated the dike body or its foundation entirely from the outside to the land side, water leaking through them. - Moreover, the dike slopes were damaged by local rainfall and wave action, jeopardizing the dike's stability. - To protect the dike from breaching due to the above phenomena, 92 trucks of soil were brought in the site to fill up the piping holes, and to cover the damaged dike slopes by using sand bags.	
(3) Tompun Dike	- Likewise, Tompun dike, whose crest elevations are 10.0 to 10.4 m, was suffered from serious danger during the flood. A lot of piping holes and slope erosion were found in places along the whole stretch, where the water balance between both sides reached nearly 5 m. - 119 tracks of soil were carried therein to repair such piping holes and dike slopes.	
(4) Tonle Sap and Bassac Riverfront	- In the lower portions of the Outer Ring Dike, the floodwater level had nearly exceeded their crests, whereas the construction of temporary embankments on the dike, with 30 trucks of soil, prevented overflowing at each location (see Figure B2-7). - A pipe culvert was broken in the event of the flood at the upstream portion. To prevent floodwater from entering through the culvert into the land side, sand bags were cast therein.	

Table I2-9 Inundation Condition in Year 1995 and 1996

Item	Year 1995	Year 1996
Rainfall Characteristics (1) Annual Rainfall	1,413 mm	1,639 mm
(2) Daily Rainfall (a) Over 50 mm	5 times Apr. 30 : 54 mm May 08 : 111 mm Sep. 02 : 55 mm Sep. 28 : 53 mm Oct. 06 : 51 mm	6 times Jun. 16 : 52 mm Aug. 08 : 62 mm Sep. 09 : 57 mm Nov. 03 : 58 mm Nov. 13 : 137 mm Nov. 23 : 58 mm
(b) Over 30 mm	16 times	15 times
Inundation Problems in the Year 1996		
(1) General	The description hereunder is with reference to the inundation problems in the year 1996. However, as almost every year very similar inundation problems take place in the Study Area, all the description may be valid for other years.	
(2) Natural Levee Area	This area runs along Tonle Sap and Bassac rivers, about 1 km wide, with elevations above 10 m, so that inundation in the area is slight in magnitude. It lasts only several hours with less than 25 cm of water depths mostly. However, it has repeated some ten times a year, interrupting traffic and in turn stagnating the economy, deteriorating the sanitation, then causing social issues, particularly in City Core.	
(3) Backswamp Area	This area lies behind the Natural Levee area above with widths of 2 to 3 km, whose elevations range from 6 to 8 m, which can be divided into the following two parts:	
(a) Northern Part	This is actually a swampy area, storing runoff from the northern half of the Study Area without problematic inundation.	
(b) Southern Part	The discharge of runoff from this part depends solely on mechanical drainage because of its low elevations. Inundation lasts for a longer time and comes to the peak at the end of the heavy rain period with a maximum water depth of more than 1 m at Trabek.	
(4) West Area Fringe	The area fringes the West Area, Item (5) below, with slightly high elevations, around 10 m, mostly formed by recent artificial fills. No serious inundation is hence observed therein.	
(5) West Area	Paddy fields spread over the area which declines at mild gradients from the west (EL. 13 m) to the east (EL. 9 m). Rainfalls are reserved in the paddy fields for planting/growing rice, of course, without causing damage.	
(6) South Area	This area (EL. 8 to 10 m) is considered a part of the floodplains of the Prek Thnot River, thus hydraulics are directly affected by the river through openings provided along the Prey Sar road. The inundation depth reaches more than 1 m at maximum.	

Table I2-10 Features of Existing Pumping Stations (1/2)

Pumping Station	1. Trabek	2. Tompon		3. Tum Nup Toek
Construction Year	1960	1972		1995
Motor Driven Pump				
Pump Type	horizontal-shaft centrifugal	vertical-shaft axial-flow	vertical-shaft centrifugal	horizontal-shaft centrifugal
Year Installed	1960	1972	1995	1995
No. of Unit	8	4	2	2
Power per Unit	80kW or 108HP	92.5kW or 125HP	25.8kW or 32HP	28.6kW or 38.6HP
Pumping Capacity per Unit (m^3/h)	2,350 (1,900)	2,500 (2,300)	720 (720)	900 (900)
Pumping Capacity (m^3/h)	18,800 (15,200)	11,440 (10,640)		1,800 (1,800)
Diesel Engine Driven Pump				
Pump Type		vertical-shaft axial-flow		
Year Installed		1998		
No. of Unit		5		
Power per Unit		90 kW or 120 HP		
Pumping Capacity per Unit (m^3/h)		2,100 (2,100)		
Pumping Capacity (m^3/h)		10,500 (10,500)		
Total				
No. of Unit	8	11		2
Pumping Capacity (m3/h)	18,800 (15,200)	21,940 (21,140)		1,800 (1,800)

Pumping Station	4. Salang	5. Toek Laak	6. Olympic	7. Toul Kork I
Construction Year	1970	1962	1965	1970
Motor Driven Pump				
Pump Type	vertical-shaft *1 centrifugal		vertical-shaft axial-flow	
Year Installed	1995		1965	
No. of Unit	2		3	
Power per Unit	25.8kW or 32HP		29.5kW or 40HP	
Pumping Capacity per Unit (m^3/h)	720 (720)		1,700 (0)	
Pumping Capacity (m^3/h)	1,440 (1,440)		5,100 (0)	
Diesel Engine Driven Pump				
Pump Type	vertical-shaft axial-flow	vertical-shaft axial-flow		vertical-shaft axial-flow
Year Installed	1970	1962		1970
No. of Unit	3	2		1
Power per Unit	90kW or 120HP	17.8kW or 24HP		92.5kW or 125HP
Pumping Capacity per Unit (m^3/h)	2,500 (2,100)	300 (300)		2,500 (2,100)
Pumping Capacity (m^3/h)	7,500 (6,300)	600 (600)		2,500 (2,100)
Total				
No. of Unit	5	2	3	1
Pumping Capacity (m3/h)	8,940 (7,740)	600 (600)	5,100 (0)	2,500 (2,100)

Table I2-10 Features of Existing Pumping Stations (2/2)

Pumping Station	8. Toul Kork II	9. Toul Kork III	10. Poung Peay *3	Grand Total
Construction Year	1970	1970		
Motor Driven Pump				
Pump Type				
Year Installed				
No. of Unit				21
Power per Unit				
Pumping Capacity per Unit (m^3/h)				
Pumping Capacity (m^3/h)				38,580 (29,080)
Diesel Engine Driven Pump				
Pump Type	vertical-shaft axial-flow	vertical-shaft *2 axial-flow		
Year Installed				
No. of Unit	1	1		13
Power per Unit	92.5kW or 125HP	92.5kW or 125HP		
Pumping Capacity per Unit (m^3/h)	2,500 (2,100)	2,500 (0)		
Pumping Capacity (m^3/h)	2,500 (2,100)	2,500 (0)		26,100 (21,600)
Total				
No. of Unit	1	1		34
Pumping Capacity (m3/h)	2,500 (2,100)	2,500 (0)		64,680 (50,680)

Note: Pumping capacities without ( ) show the condition when provided, while with ( ) the present conditions.

Remarks:

*1 This pump can be driven by motor (25.6kW or 32HP) and diesel engine (90kW or121HP).
*2 The pump was destroyed and no pump equipment is housed in Tuol Kork II.
*3 Information on Poung Peay pumping station is not available.

Table I2-11 Equipment Owned by DPWT

No.	Equipment	Quantity (unit)	Capacity	Donor Country/ Agency	Manufacturer	Present Conditions/ Remarks
Drainage and Sewerage Section						
1.	Vacuum truck with water jet cleaner	3	6m3	France	Renault	All units are in use.
2.	Vacuum truck	1	2m3	PADEK (NGO)	-	in use
3.	Vacuum truck with water jet cleaner	1	6m3	France	Ford	in use
4.	Vacuum truck with water jet cleaner	1	6m3	France	Fiat	out of order
5.	Vacuum Truck	1	6m3	France	Saviem	out of order
6.	Vacuum Truck	1	6m3	Russia	Zil	out of order
7.	Water tank lorry	1	12m3	Russia	Kamaz	out of order
8.	Dumptruck	1	4m3	China	-	in use
9.	Dumptruck	1	6m3	France	Ford	out of order
10.	Loader with backhoe	1	0.30m3	UK	Maseey F.	in use
11.	Grab bucket	1	0.50m3	Russia	-	in use
12.	Light lorry	1	-	Germany	Deutz	in use
13.	Dredger	1	-	-	-	no information
14.	Vacuum truck with water jet cleaner	3	6m3	Norway (NORAD)	IVECO (Italy)	brand-new donated in 1998
15.	Water tank lorry	1	8m3	Norway (NORAD)	HINO (Japan)	brand-new donated in 1998
16.	Caterpillar excavator	1	0.7m3	Norway (NORAD)	SAMSUNG (Korea)	brand-new donated in 1998
17.	Wheel excavator	1	-	Norway (NORAD)	SAMSUNG (Korea)	brand-new donated in 1998
18.	Dump truck	5	6.5m3 or 6t	Norway (NORAD)	TOYOTA (Japan)	brand-new donated in 1998
19.	Excavator loader (backhoe)	1	0.25 m3 & 0.88m3	Norway (NORAD)	New Holland (Netherlands)	brand-new donated in 1998
20.	Cargo crane (for pipe transportation)	1	load>5t, lift>2t	Norway (NORAD)	ISUZU (Japan)	brand-new donated in 1998
Road and Bridge Section						
1.	Dump truck	4	7m3	Russia	Kamaz	3 units are in use,1 unit is out of order
2.	Dump truck	1	4m3	Russia	Maz	out of order, not in use
3.	Truck crane	2	7m3	Russia	Kamaz	in use
4.	Water tank lorry	1	4m3	Russia	Maz	not in use
5.	Low loader	1	7m3	Russia	Kamaz	in use
6.	Grader	3	-	Russia	-	2 units are in use, 1 unit is out of order
7.	Loader	3	-	Russia	-	2 units are in use, 1 unit is out of order
8.	Roller	5	-	Russia	-	2 units are in use, 3 units are out of order
9.	Excavator	2	-	Russia	-	all units are out of order
10.	Excavator	1	-	Russia	-	in use
11.	Paint spraying machine	1	-	-	-	not in use
12.	Air compressor	2	-	Russia	-	not in use
13.	Bulldozer T130	2	-	Russia	-	1 unit is in use, the other is out of order

Table I2-12 (1/3) Descriptive Summary of Water Quality Analysis Results

St. No.	Location	General Site Description	Water	Water Characteristic (dry season) April 1998	Water Characteristic (dry season) May 1998	Water Characteristic (wet season) October 1998	Water Characteristic (wet season) November 1998
1	Tonle Sap at confluence with Phnou river	River is about 400 m wide with housing, shops, industries.	For washing, cleaning aquacultural purposes. The river is also mean of transportation.	Water is clear SS of 4.0 mg/ℓ, transparency of 1.8 m, DO is high at 5.2 mg/ℓ. Pollution level is quite low with COD at 6.7 mg/ℓ. Fecal coliform at 2,493 MPN/100 mℓ.	Water is soft indicating by low conductivity (<100 $x10^{-6}\Omega$/cm). DO is high at 6.4 mg/ℓ due to the high flow and neutral pH at 7.4.	High flow water; SS 40 mg/L; Transparency at 0.5 m; DO is 3.6 mg/L; BOD 13 mg/L and COD 16mg/L	High flow water, SS 44 mg/L with transparency at 0.4 m; BOD and COD similar to Oct. wet season sampling
2	Prek Phnou at river mouth close to N.R. No.5	Steep bank with low flow. Garbage dumping can be found around the place. Housing and industries are located on both banks.	No water uses due to its polluted nature.	Water is relatively clear (SS of 2 mg/ℓ). Quite low in DO (1.0 mg/ℓ). The waterway is heavily infested with water hyacinth and highly contaminated with human waste (Fecal Coliform of 42,625 MPN/100 mℓ).	There are drastically increased of conductivity from 200 to $1,800x10^{-6}\Omega$/cm detecting in April and May respectively. Other parameters, e.g., DO (0.8 mg/ℓ. and pH (7.6) are still at the same range as previous sampling period for dry season.	Water is relatively turbid (SS34 mg/L); transparency at 0.2 m; Low DO at 2.8 mg/L; Total coliform is very high at 460,000 MPN/100 ml	DO is 4.9 mg/L due to high flow with low BOD of 6 mg/L fecal coliform is high at 23,000 MPN/100ml
3	Tonle Sap at Chak Tomuk	River is about 500 m wide with housing, agricultural, business areas along both banks.	Washing, cleaning, and transportation.	Water is relatively clear (SS of 5.5 mg/ℓ). DO is 6.0 mg/ℓ with high flow. Aquatic weed (water hyacinth) can be found along the river.	DO is 6.8 mg/ℓ with low conductivity at $100x10^{-6}\Omega$/cm and pH of 8.4 which are similar to previous dry season sampling results.	SS is 83 mg/L with transparency at 0.2 m; DO is 3.4 mg/L but Fecal coliform is very high at 1,100,000 MPN/ 100ml	Water flow is still high with SS 78 mg/L; DO is 4 mg/L, BOD 7 mg/L and Fecal Coliform 43,000 MPN/ 100ml
4	Tonle Bassac at Monivong Bridge	River is about 200 m wide. Housing, floating rafts can be found along the river. Garbage dumping can be found along the banks.	Washing, cleaning, and transportation.	High DO at 6.6 mg/ℓ. SS at 21 mg/ℓ. COD at 6.68 mg/ℓ with high Fecal Coliform at 57,167 MPN/100 mℓ.	DO is relatively high at 5.8 mg/ℓ with pH on the base side of 8.9 and conductivity of $100x10^{-6}\Omega$/cm.	High flow water; DO is 3.2 mg/L; BOD at 8 mg/L and high Fecal Coliform at 75,000 MPN/ 100ml	Similar to October sampling period
5	Prek Thnot at river mouth near Tonle Bassac	The river is about 30 m wide with emergent and floating weeds. Housing, idle areas are scattered along river banks.	No water utilization other than transportation.	Water is very turbid (SS 458 mg/ℓ). DO is 3.8 mg/ℓ with high COD and Fecal Coliform 24.2 mg/ℓ and 86,000 MPN/100 mℓ.	The DO is similar to previous sampling to 3.7 mg/ℓ. Conductivity and pH are $600x10^{-6}\Omega$/cm and 8.9 which are in similar range to April samples.	High DO at 5.6 mg/L; BOD 35 mg/l, SS 119 mg/l	BOD and COD are low at 9 and 27 mg/l respectively; DO is high at 6.2 mg/l; conductivity is low at 100 x 10^{-6} Ω/cm
6	Phum Svay Pak at N.R. No.5	This river receives water from Boeng Poung Peay which is the industrial area. Along both banks are congested household and agricultural areas.	No water utilization in dry season.	DO is 0.1 mg/ℓ with turbid brownish color (SS= 440 mg/ℓ). COD is 105.2 mg/ℓ and Conductivity at $1,000x10^{-6}\Omega$/cm due to discharge from industrial area.	The algae bloom are detected at this site which obviously influences DO level to 6.4 mg/ℓ from 0.1 mg/ℓ (April).	Do is 2 mg/l, BOD 9 mg/l, COD 16 mg/l and fecal coliform high at 240,000 MPN/ 100ml	Water is turbid with transparency at 0.25 m; DO is low at 0.2 mg/l; BOD 11 mg/l and COD 27 mg/l
7	Boeng Kak Lake at guest house behind Mosque	Natural lake about 1.5 m deep surrounded by densed communities and shops.	Aquaculture and collect wastewater from nearby areas.	Water is greenish with SS of 12 mg/ℓ. DO is very high at 7.8 mg/ℓ due to photo-synthetic reaction. COD is high at 19.6 mg/ℓ with also high Fecal Coliform at 21,560 MPN/100mℓ.	DO is at 6.2 mg/ℓ, pH is 8.1 with conductivity at $900x10^{-6}\Omega$/cm.	Water has green color with high DO at 7 mg/l; SS 107 mg/l, BOD 15 mg/l and COD 97 mg/L	Water has green color with transparency at 0.65 m; Conductivity is high at 700 x 10^{-6} Ω/cm; DO is still high at 4.4 mg/l

Table I2-12 (2/3) Descriptive Summary of Water Quality Analysis Results

St. No.	Location	General Site Description	Water	Water Characteristic (dry season) April 1998	Water Characteristic (dry season) May 1998	Water Characteristic (wet season) October 1998	Water Characteristic (wet season) November 1998
8	Boeng Salang Lake at Intersection with Street No. 336	This natural lake is about 0.5 m deep; surrounded by congested housing & shops and totally covered by water hyacinth.	No water usage.	The water is highly polluted with black color (SS 25 mg/ℓ) and strong H2S smell. DO is only 0.1 mg/ℓ and Fecal Coliform of 460,000 MPN/100 mℓ.	Deteriorated water is still obvious with DO of 0.2 mg/ℓ, strong H_2S smell and conductivity of 1,000x10^{-6}Ω/cm.	Fecal Coliform is very high at 240,000 MPN/100 ml. Black color with strong H_2S smell. Low DO at 0.2 mg/l	DO is low at 0.3 mg/l. BOD is 46 mg/l. Fecal coliform is still high at 750,000 MPN/100 ml. Strong H_2S smell with black color
9	Meanchey drainage channel at Salang Pumping Station.	The channel is about 5 m wide fully covered with water hyacinth and surrounded by shops and housing.	No water utilization	Water is black (SS at 118 mg/ℓ) with very strong H_2S smell. DO is 0.1 mg/ℓ. COD is 61.6 mg/ℓ and very high Fecal Coliform of 221,600 MPN/100 mℓ.	Signed of polluted water is still obvious. Strong H_2S smell with DO of 0.1 mg/ℓ, conductivity of 1,400x10^{-6}Ω/cm, dark color and pH of 7.7.	Low DO at 0.2 mg/l, BOD is 25 mg/l; brown color with strong smell; very high fecal coliform (2,100,000 MPN/100ml)	Strong smell with black color; DO is 0.4 mg/l; BOD at 19 mg/l; fecal coliform 23,000 MPN/100ml
10	Toul Sen West drainage channel at the intersection with St. 310.	This drainage channel is about 2 m wide and is surrounded by housing and shops.	No water utilization	Water is black with strong H_2S smell. DO is only 0.1 mg/ℓ. Fecal coliform is 2,331,000 MPN/100 mℓ.	Similar quality of water is reported. DO is still very low at 0.2 mg/ℓ. Obvious pollutions are in the form of garbages and draining of wastewater into this channel.	Brown color with strong smell with extremely high fecal coliform (4,300,000 MPN/100ml); Do is low at 0.2 mg/l; BOD is 44 mg/l	BOD is high at 73mg/l; fecal coliform 460,000 MPN/100ml, DO is negligible at 0.2 mg/l; black color and strong smell
11	Toul Sen East drainage channel at intersection with St. 103	This drainage channel is about 2 m wide and surrounded by densed housing and shops.	No water utilization	Water is heavily polluted with DO of 0.1 mg/ℓ and black (SS of 36 mg/ℓ). COD is 39.8 mg/ℓ and Fecal Coliform at 2,840,000 MPN/100 mℓ.	This channel is highly polluted with indication from very low DO (0.2 mg/ℓ), strong H_2S smell, and high conductivity (800x10^{-6}Ω/cm).	Water is turbid brown, strong smell; transparency at 0.1 m, low DO at 0.3 mg/l; high BOD at 61 mg/l, COD 162 mg/l and fecal coliform 4,300,000 MPN/100ml	Black color, strong smell; DO is still low at 0.4 mg/l; BOD is 71 mg/l; Fecal coliform is extremely high at 2,400,000 MPN/100ml
12	Trabek drainage channel at intersection with St. 310	This drainage channel is about 2 m wide surrounded by dense housing and shops.	No water utilization	Water is heavily polluted with black color (SS 76 mg/ℓ) and strong H_2S smell. DO is only 0.1 mg/ℓ. Garbage dumping is all over the area. Fecal coliform is 462,308 MPN/100 mℓ.	Similar trend as previous sampling results can be found. DO is very low at 0.2 mg/ℓ. Water is black with strong H_2S odor. Conductivity is up from 700 (April) to 1,000x10^{-6}Ω/cm.	High BOD at 74 mg/l, low DO at 0.2 mg/l and high fecal coliform of 4,300,000 MPN/100 ml; turbid brown color and strong smell	BOD is high at 76 mg/l; DO is low at 0.2 mg/l; strong smell and black color; fecal coliform is high at 460,000 MPN/100 ml
13	Boeng Trabek Lake near pumping station	This swamp is surrounded by dense housing and hog raising can be found at some houses.	No water utilization. The lake is used for vegetable growing.	Water is heavily polluted with strong H_2S smell. DO is only 0.1 mg/ℓ. COD is quite high at 30.34 mg/ℓ and Fecal Coliform of 232,131 MPN/100 mℓ.	This swamp is highly polluted with wastewater from nearby communities and garbages. DO is 0.2 mg/ℓ, conductivity of 800x10^{-6}Ω/cm and Fecal Coliform of 2,633,333 MPN/100 mℓ.	Water color is black; strong H_2S smell, low DO at 0.2 mg/l; fecal coliform is high at 4,600,000 MPN/100ml	Black color with strong H_2S smell; low DO at 0.2 mg/l; fecal coliform is still high at 1,100,000 MPN/100 ml
14	Outside Trabek Pumping Station	The area receives wastewater from Trabek Pumping station.	Waterbody is covered by vegetable harvesting.	Water is heavily polluted with very strong smell of H_2S. DO is at 0.1 mg/ℓ. COD is very high at 26.65 mg/ℓ and Fecal Coliform at 384,000 MPN/100 mℓ.	Analysis of water sample from this station shows similar results as April's sample. DO is very low at 0.1 mg/ℓ with H_2S smell and dark in color (SS of 27.0 mg/ℓ) and Fecal Coliform at 2,323,388 MPN/100 mℓ.	Black color, strong smell, transparency at 0.2 m; SS of 22mg/l; fecal coliform is still high at 4,600,000 MPN/100 ml	DO is low at 0.3 mg/l; BOD is 20 mg/l, Fecal coliform iis 240,000 MPN/100 ml; black color and strong smell; transparency only 0.1 m

Table I2-12 (3/3) Descriptive Summary of Water Quality Analysis Results

St. No.	Location	General Site Description	Water	Water Characteristic (dry season) April 1998	Water Characteristic (dry season) May 1998	Water Characteristic (wet season) October 1998	Water Characteristic (wet season) November 1998
15	Boeng Tompun Lake 50 m north of Tompun pumping st.	Loosely surrounded by housing and agricultural area.	Waterbody is used mainly for wastewater collection and vegetable growing.	Water is highly polluted with highly contamination from human waste (DO = 0.0 mg/ℓ, SS =5.5 mg/ℓ and Fecal Coliform of 570,000 MPN/100 mℓ.)	Water quality is very poor with DO of 0.2 mg/ℓ, dark in color, very high Fecal Coliform of 40,080,000 MPN/100 mℓ.	Water has relatively green color with a lot of algae/ weeds. DO is high at 5 mg/L. Fecal coliform is 150,000 MPN/100ml	Green color; turbid with transparency at 0.25 m; high DO at 6.8 mg/L; fecal coliform is 150,000 MPN/100 ml
16	Boeng Tmai Lake South of Tompun pumping station on the other side of the road.	This low lying area receives water from Boeng Tompun Lake via pumping station.	Water is utilized for morning glory harvesting and cattle.	Water is highly polluted with DO of 0.1 mg/ℓ with very strong H_2S smell and Fecal Coliform of 530,000 MPN/100 mℓ.	Similar trend can still be observed. Storng H_2S odour, DO is very low at 0.2 mg/ℓ, Fecal Coliform of 1,844,444 MPN/100 mℓ and conductivity at $1{,}100 \times 10^{-6}$ Ω/cm.	Turbid brown color; transparency at 0.1 m; low DO at 1.7 mg/L; BOD 7 mg/L	DO is high at 3.2 mg/L (pump operating); BOD is 13 mg/L; transparency at 0.15 m
17	Phum Russey drainage canal 100 m upstream from Dangkao Bridge	The channel is about 80 m wide. Both banks are about 5 m high with scattered housing and rice mill.	The channel is covered by water hyacinth. The water is utilized for cattle only.	Water is quite turbid with SS at 270 mg/ℓ. DO is at 1.0 mg/ℓ. Fecal Coliform is 32,500 MPN/100 mℓ.	Sign of pollution is obvious. DO is at 1.2 mg/ℓ _ith high turbidity (SS of 360.0 mg/ℓ). Water is drained into the channel from surrounding community. Fecal Coliform is 3,636 MPN/100 mℓ.	High flow water; DO 3.8 mg/l; BOD 8 mg/l; fecal coliform 11,000 MPN/100ml	High flow water; high DO at 4.6 mg/l; Low BOD at 8 mg/l; fecal coliform is still high at 34,000 MPN/100 ml
18	Groundwater well #1 at Phum Dangkao Village	This well is about 12 m deep with cement castled and covered with wood plank.	Washing, cleaning, plant watering. Normally boiled before drinking.	The water is clear (SS 0.79 mg/ℓ, and relatively clean with Focal Coliform at 352 MPN/100 mℓ.	Water is soft and clear with conductivity at 800 mg/ℓ, SS at 0.0 mg/ℓ, Fecal Coliform of 82 MPN/100 mℓ.	Water is clear, SS 4 mg/l; fecal coliform low at 36 MPN/100 ml; conductivity at 900×10^{-6} Ω/cm	Water is still clear (SS 5 mg/l) and clean (Fecal coliform 36 MPN/100 ml); conductivity is also high at 1000×10^{-6} Ω/cm
19	Groundwater well #2 at Thnot Chrum Village	This well is about 36 m deep with cement casted.	Water is used for all domestic purposes (10 households).	Water is clean with no detection of Focal coliform and low SS of 1.0 mg/ℓ.	This is the new sampling station because pump for previous well is out of order. It is approximately 20 m from the April station. Many households use the well water for domestic use and boil before drinking. Water is clear and clean with SS of 0.0 mg/ℓ, conductivity of 900×10^{-6} Ω /cm and Fecal Coliform of 1 MPN/100 mℓ.	Water is very clean (SS 2 mg/l) and clean (Fecal coliform 30 MPN/100 ml); high conductivity at 1000×10^{-6} Ω/cm	Water is still very clear (SS 4 mg/l) and clean (Fecal coliform 30 MPN/100 ml), high conductivity at 1000×10^{-6} Ω/cm
20	Groundwater well #3 at Phum Chak Angre Kraom	This well is about 42 m deep with cement casted.	Water is utilized for all domestic purposes (cooking, cleaning, washing and drinking).	Water is relatively clean (Fecal coliform 178 MPN/100 mℓ), SS = 0 mg/ℓ with relatively high conductivity at 600×10^{-6} Ω/cm.	Water is clear with SS of 0.0 mg/ℓ and soft (conductivity at 700×10^{-6} Ω/cm). The Fecal Coliform of 11 MPN/100 mℓ is reported.	Water is clean and clear; conductivity is 600×10^{-6} Ω/cm	Water is clear (SS 4mg/l), coliform count 230 MPN/ 100 ml; conductivity 600 x 10^{-6} Ω/cm

Table 12-13 Average Contaminant's Concentrations in Benthic Material

Parameter		Natural Waterways	Lake / Swamp	Drainage Channels	Wells	Average
1. Cd	(ppm)	2.10	1.55	1.66	1.00	1.58
2. Total CN	(mg/kg)	0.99	0.64	0.44	0.45	0.63
3. Org. Phosphorus	(mg/kg)	132.50	149.30	168.25	232.00	170.51
4. Pb	(ppm)	36.03	90.43	96.22	26.96	62.41
5. Cr^{+6}	(ppm)	12.13	14.25	10.72	12.00	12.27
6. As	(ppm)	3.65	2.95	2.88	3.00	3.12
7. Total Hg	(ppb)	77.71	78.81	109.48	54.63	80.16
8. Alkyl Hg	(mg/kg)	0.99	0.26	0.73	0.41	0.59
9. PCB	(mg/kg)	ND	ND	ND	ND	ND

Selected Environmental Multimedia Goals and/or Quality Standards for Solid

Contaminants by Class	Concentration, mg/kg dry material		Concentration, mg/L
	Solid Waste DMEG[#A]	Soil AMEG[#B]	Water Quality (Drinking)[C]
Poly-chloride benzenes	0.001	0.0002	ND
Cyanide	3.6	-	ND
Phosphorous	200	-	ND (organic P)
Alkyl Mercury	0.6	0.002	ND
Total Mercury	0.4[D] (0.002 mg/L)	-	0.005
Arsenic	2[D] (0.05 mg/L)	-	0.05
Cadmium	0.3	0.08	0.01
Chromium	44	10	0.05
Lead	0.76	-	0.1

Notes:

ND: Not Detectable

: Source: Canter L.W., 1996, Environmental Impact Assessment, McGraw Hill, Second Edition

A : Discharge Multimedia Discharge Goals (DMEGs) prposed for use in USA. DMEGs represent approximate concentration maxima in source emissions to receiving water, atmosphere, or soil (through solid waste) which should be tolerable for short term exposure values based on acute human health effects and short term reversible effects on natural biological communities.

B: Ambient Level Multimedia Discharge Goals (AMEG) are appropriate levels of contaminants in water, air or soil below which unacceptable negative effects on human populations or in natural biological communities should not occur, even with continuous exposure

C : Source: Environmental Agency of Japan, 1990, Quality of the Environment, 1990

D : Estimated herein from the liquid emission values given in brackets using a simple leachate model whose assumptions are given below. These are the same used in deriving all DMEGs and AMEGs.

The MEGs for terrestrial environments (expressed in milligrams per kilogram) are based on a simple leachate model for solid waste (in this case DMEGs) and for contaminated soil (here, AMEGs are used). They are equal to the liquid emission MEGs (expressed : micrograms per liter) for the chemical of concern, multiplied by a factor of 0.2. This model assumes that all contaminants in 1 kg o soil or solid waste would be leached by 2L of water. The major human exposure route to contaminants from soil or solid waste is assumed to be consumption of contaminated drinking water. Similarly, the major exposure route for aquatic life is through leaching of contaminated soil or solid waste by surface waters. It is further assumed that the concentrated leachate entering a body of water (groundwater or surface water) will be diluted almost instantaneously by an arbitrary factor of 100. While this model is simplistic and in most situations very conservative (e.g. it considers almost no retention or attenuation of contaminants before reaching surfa water).

Table I2-14 Results of Leaching Test for Benthic Material

Parameter	Unit	Station*				EEC Surface Water Standard	Japan's Standard	
		1	2	3	4		Disposal to Dumping Site	Disposal to the Sea
Org.Phosphate	mg/ℓ	0.01	0.01	ND	0.01	0.03 (US.EPA)	1.0	ND
Cyanide (CN)	mg/ℓ	ND	ND	ND	ND	0.05	1.0	ND
Chromium(Cr)	mg/ℓ	ND	ND	0.020	ND	0.05	-	0.2
Cadmium (Cd)	mg/ℓ	0.005	ND	ND	0.004	0.005	0.3	0.01
Lead (Pb)	mg/ℓ	ND	ND	ND	0.0049	0.05	0.3	0.01
Arsenic (As)	mg/ℓ	0.0037	0.0012	0.0020	0.0018	0.05	0.3	0.01
Mercury (Hg)	mg/ℓ	ND	ND	0.0009	0.0006	0.001	0.005	0.0005

Note* Station 1 : Mean Chey Channel
Station 2 : Inside Tompun Pumping Station
Station 3 : Outside Tompun Pumping Station
Station 4 : Inside Trabek Pumping Station
ND = < 0.0001 mg/ℓ