Year-wise, in the peak year of 1989 BMA will spend Baht 236 million for the Project, which correspond to 8.8% of the projected capital expenditure in the same year.

3.2 Funding the Project

In the preceding section the comparative position of the Project in the overall infrastructure projects as well as in the total capital expenditure budget of BMA has been clarified. In this section specific sections of the BMA budget to be used to fund the project are designated and quantitatively analyzed.

In Table I.3 forecasted amount of the two major sources of BMA revenue increase is shown. It ranges from Baht 700 to 1,500 million over the period 1987 to 2000.

Case I

To meet capital, repayment and O/M costs over the 5 year implementation period 1987 to 1991, it is proposed that one fourth of the revenues to be generated by natural increase and the mobilization of existing local taxes will be appropriated. To recover repayment and O/M/R costs from 1992 onwards, one sixth (1992 to 2006) to one ninth (2007 to 2020) of the revenue by the mobilization of existing local taxes will be allotted to the Project. The result is as shown in Table I.10(1) or Figure I.3(1). Cumulative amount of capital, repayment and O/M/R costs over the repayment period for 34 years is estimated at Baht 3,351 million. It has been clarified that they can be fully met by using some of the expected yearly increase of BMA revenue.

Case II

To meet capital, repayment and O/M costs over the 5 year implementation period, it is proposed that 43% of the revenues to be generated by natural increase and the mobilization of existing local taxes during the same period will be appropriated. To recover repayment and O/M/R costs from 1992 onwards, one sixth (1992 to 2006)

TABLE I:10(1) CAPITAL RAISING & COST RECOVERY SCHEDULE

(at 1985 prices) (Baht million)

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
RQRD	11.8	211.2	283.9	289.9	126.0	80.2	78.3	76.6	75.0	73.4
N.ICR	97.1	102.9	109.1	115.7	122.6	0.0	0.0	0.0	0.0	0.0
MBLZ	75.5	80.0	84.8	89.9	95.3	67.4	71.4	75.7	80.2	85.0
TTL	172.6	183.0	193.3	205.6	217.9	67.4	71.4	75.7	80.2	85.0
BLNC	+160.8	-28.2	-89.9	-84.2	+91.9	-12.8	-6.8	-0.9	+5.2	+11.6
CM BLNC	+160.8	+132.6	+42.6	-41.5	+50.3	+37.5	+30.6	+29.7	+34.9	+46.5

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
RQRD	72.6	84.9	93.2	101.4	99.3	95.4	220.8	88.3	85.1	82.1
N.ICR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBLZ	90.1	95.6	101.3	107.4	107.4	107.4	107.4	107.4	107.4	107.4
TTL	90.1	95.6	101.3	107.4	107.4	107.4	107:4	107.4	107.4	107.4
BLNC	+17.5	+10.7	+8.1	+6.0	+8.1	+12.0	-113.4	+19.1	+22.3	+25.3
CM BLNC	+64.1	+74.7	+82.8	+88.8	+96.9	+108.8	-4.5	+14.5	+36.7	+62.0

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
RQRD	79.3	76.6	74.2	71.8	69.7	67.6	65.7	63.9	62.3	60.7
N.ICR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBLZ	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6
TTL	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6
BLNC	-7.7	-5.0	-2.6	-0.2	+1.9	+4.0	+5.9	+7.7	+9.3	+10.9
CM BLNC	+54.3	+49.3	+46.6	+46.4	+48.3	+52.3	+58.1	+65.8	+75.1	+86.0

Year	2017	2018	2019	2020
RQRD	59.0	181.4	47.5	42.8
N.ICR	0.0	0.0	0.0	0.0
MBLZ	71.6	71.6	71.6	71.6
TTL	71.6	71.6	71.6	71.6
BLNC	+12.6	-109.8	+24.1	+28.8
CM BLNC	+98.5	-11.2	+12.8	+41.6

NOTE: RQRD=required costs; N.ICR=natural increase of BMA revenue; MBLZ= revenue to be newly generated by mobilization of existing local taxes; TTL=total; BLNC=balance (=TTL-RQRD); CM BLNC=cumulative balance

TABLE I.10(2) CAPITAL RAISING & COST RECOVERY SCHEDULE

(at 1985 prices) (Baht million)

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
RQRD	23.8	398.2	519.9	505.8	172.0	80.2	78.3	76.6	75.0	73.4
N.ICR	167.0	177.0	187.7	198.9	210.9	0.0	0.0	0.0	0.0	0.0
MBLZ	129.9	137.7	145.9	154.7	164.0	67.4	71.4	75.7	80.2	85.0
TTL	296.9	314.7	333.6	353.6	374.8	67.4	71.4	75.7	80.2	85.0
BLNC	+273.1	-83.4	-186.3	-152.2	+202.8	-12.8	-6.8	-0.9	+5.2	+11.6
CM BLNC	+273.1	+189.6	+3.3	-148.9	+53.9	+41.0	+34.2	+33.2	+38.5	+50.1

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
RQRD	72.6	84.9	93.2	101.4	99.3	95.4	220.8	88.3	85.1	82.1
N.ICR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBLZ	90.1	95.6	101.3	107.4	107.4	107.4	107.4	107.4	107.4	107.4
TTL	90.1	95.6	101.3	107.4	107.4	107.4	107.4	107.4	107.4	107.4
BLNC	+17.5	+10.7	+8.1	+6.0	+8.1	+12.0	-113.4	+19.1	+22.3	+25.3
CM BLNC	+67.7	+78.3	+86.4	+92.4	+100.4	+112.4	-1.0	+18.0	+40.3	+65.6

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
RQRD	79.3	76.6	74.2	71.8	69.7	67.6	65.7	63.9	62.3	60.7
N.ICR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MBLZ	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6
TTL	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6
BLNC	-7.7	-5.0	-2.6	-0.2	+1.9	+4.0	+5.9	+7.7	+9.3	+10.9
CM BLNC	+57.8	+52.8	+50.2	+50.0	+51.9	+55.8	+61.7	+69.4	+78.7	+89.5

Year	2017	2018	2019	2020
RQRD	59.0	181.4	47.5	42.8
N.ICR	0.0	0.0	0.0	0.0
MBLZ	71.6	71.6	71.6	71.6
TTL	71.6	71.6	71.6	71.6
BLNC	+12.6	-109.8	+24.1	+28.8
CM BLNC	+102.1	-7.7	+16.4	+45.1

Note: RQRD=required costs; N.ICR=natural increase of BMA revenue; MBLZ= revenue to be newly generated by mobilization of existing local taxes; TTL=total; BLNC=balance (=TTL-RQRD); CM BLNC=cumulative balance to one ninth (2007 to 2020) of the revenue by the mobilization of existing local taxes will be allotted to the Project. The result is as shown in TAble I.10(2) or Figure I.3(2). Cumulative amount of capital, repayment and O/M/R costs over the repayment period is estimated at Baht 4,048 million. It has been made clear that the required cost during the implementation period can be fully met although it will occupy more than 40% of newly available resources. if it is felt difficult to set aside that much of newly available resources for the Project, then an alternative is to look for some means other than self-financing and govlernment subsidy to meet a part of the required cost. It will be floatation of BMA bond or introduction of a new charge or tax as described in (4) of 2.

3.3 Advisability of Project Implementation

The final judgement on whether the Project should be implemented or not is left to the economic evaluation. However, the advantages of implementing the Project will be treated here from financial standpoint.

As seen already, out of the project cost of Baht 2,655 million Baht 1,261 million (47.5%) will be financed by foreign loans. The lending terms of the loans are assumed to be soft as typified by the annual interest rate of 3.5%, which is not only by far less than the opportunity cost of capital (16%), but also less than the forecasted rate of price rise (5%). The implications are that even if the Project yields the return on the foreign component by far below the opportunity cost of capital it will still be all right, and also that the amount of repayment (Baht 1,078 million) will be in real terms less than the amount of the loans.

Regarding the local component including both capital cost (Baht 697 million in Case I) and O/M cost (annually Baht 42 million) to be self-financed by BMA, it can be stated that since the growth of BMA tax revenues will continue to be robust in the years to come, the yearly expenditure on the Project will growingly be felt lighter, or less burdensome as exemplified in Table I.8(1).

These things will provide solid grounds for supporting the early realization of the Project.

3.4 Introduction of "Beneficiaries Should Bear the Cost" Principle

So far as the Project is concerned, as has been seen, introduction of new charges or taxes to fund the project related cost is basically not considered because it can be covered within the BMA budget. In the Master Plan it is envisaged that Baht 6,280 million will be required to complete the flood protection and drainage by the year 2000 in the Eastern Suburban Area(Refer to Figure I.4.) To raise the funds of this scale within the existing framework of BMA budget will get increasingly difficult especially in view of the expected large scale expenditure of the flood control projects as a whole from 1992 onwards: the ADB Report estimates the total cost of Baht 25,800 million to control floods by 2000 in the entire BMA area.

Under such future prospects to implement Eastern Suburban Project Stage II and III successfully new measures of fund raising will have to be worked out.

(1) Two Views on "Who Bear the Cost"

There are two views regarding who bear the flood control cost. According to the first view direct beneficiaries should bear the cost in the same way that one pays for an umbrella. In contrast, the second one observes that flood control is an issue of national consequence as is the case with defence, medical care or education and as such it is under the responsibility of the government. In other words, the cost should be shouldered by the entire nation.

Bangkok yearly produces about one thirds of the economic value of the whole nation. It means that flood damage to the city greatly affects nation-wide economic activity. On the other hand, the main point of the argument of the first view is that beneficiaries are mostly rich people and if the second view is adopted it will create a situation where the poor comprizing the majority pay money to save a handful of the rich.

It is inadvisable to jump at one view to the exclusion of another. However, one should pay due consideration to the current trend in the government in favor of the first view.

(2) New methods of Fund Raising

As the first source of the funds for flood control projects the study team proposes a surcharge to developers. According to the team's projection, from 1985 to 2000 the average annual increase of population in the Project Area will be 64,500. So as an example, if an amount of Baht 1,000 is levied per newly arriving resident the yearly revenue from this source will be Baht 64 million. The charge will be paid by the developer, but the real bearer is the household buying or renting property from him. It is to be noted that the surcharge is not recurrent: it is paid only once.

The second alternative source of revenue will be the Urban Development Tax. In 1985 revenue from the development tax is estimated at Baht 110 million. It is projected that the revenue will increase to Baht 330 million in 2000. This local tax is based on the assessed value of land. The average existing rate of taxation is roughly calculated at 0.5%. If the rate of 0.1% is newly introduced to be applied to the assessed value of land as the Urban Development Tax, the annual revenue from this source will be Baht 66 million in 2000.

As the third alternative the measure proposed by ADB is taken up. It is a surcharge levied on landowners based on the location, size, type and use of land. The existing number of landowners in the BMA area is estimated at about one million. It is projected that the number will increase to around 1,300,000 in 2000. Supposing the number of landowners in the Project Area is 30% of the total number of them in the Bangkok Metropolis in 2000, it will be 390,000 in the same year. If Baht 200 is levied per landowner Baht 78 million will be annually raised.

Alternative 4 is based on the view that flood control is essentially a national matter to be taken care of by the central government. In this respect it differs from the preceding three which are grounded on the view that the beneficiaries should bear the related cost.

It is proposed in this alternative that business tax and vehicle tax will be increased. In 1985 the revenue from the two taxes is estimated at Baht 3,226 million, and it is projected that in 2000 the revenue will grow to Baht 6,434 million. If the taxes are increased so that the amount to be transferred to BMA shall be by 1% more than the existing level, the additional revenue of Baht 64 million will be expected in 2000.

Although this measure is based on the "public goods" principle, in substance it follows the "beneficiaries shoud bear the cost" view in that businesses and car owners are the major beneficiaries of flood control.

The taxation level of vehicle tax of the country is low (about one half) compared with that of Japan. Also, a raising of the tax will have an easing effect on the traffic congestion in Bangkok. These things reinforce the advisability of this alternative.

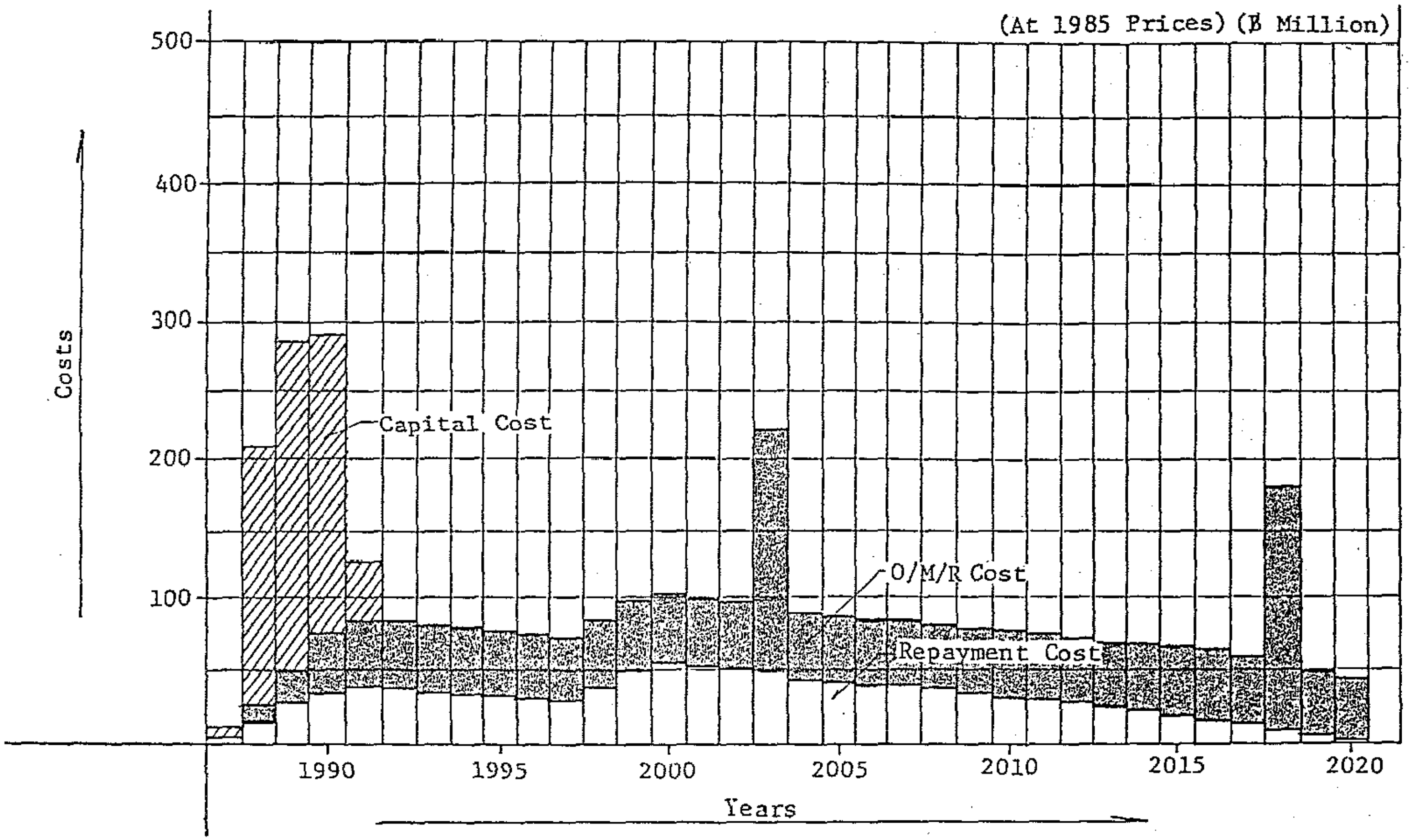

Fig. I.1 (1) ANNUAL COSTS FOR CAPITAL, REPAYMENT & O/M/R -CASE I-

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

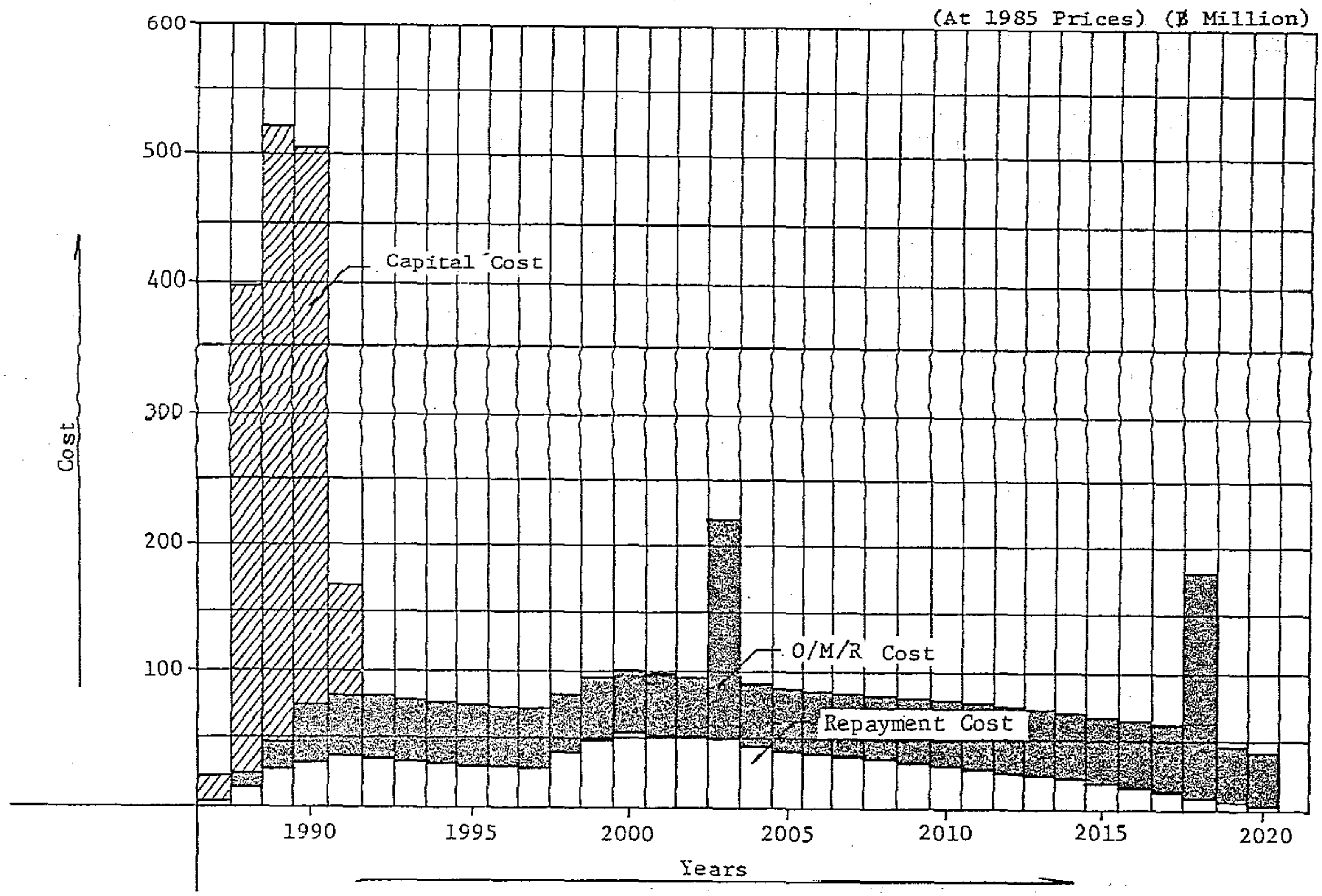

Fig. I.1 (2) ANNUAL COSTS FOR CAPITAL, REPAYMENT & O/M/R —CASE II—

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

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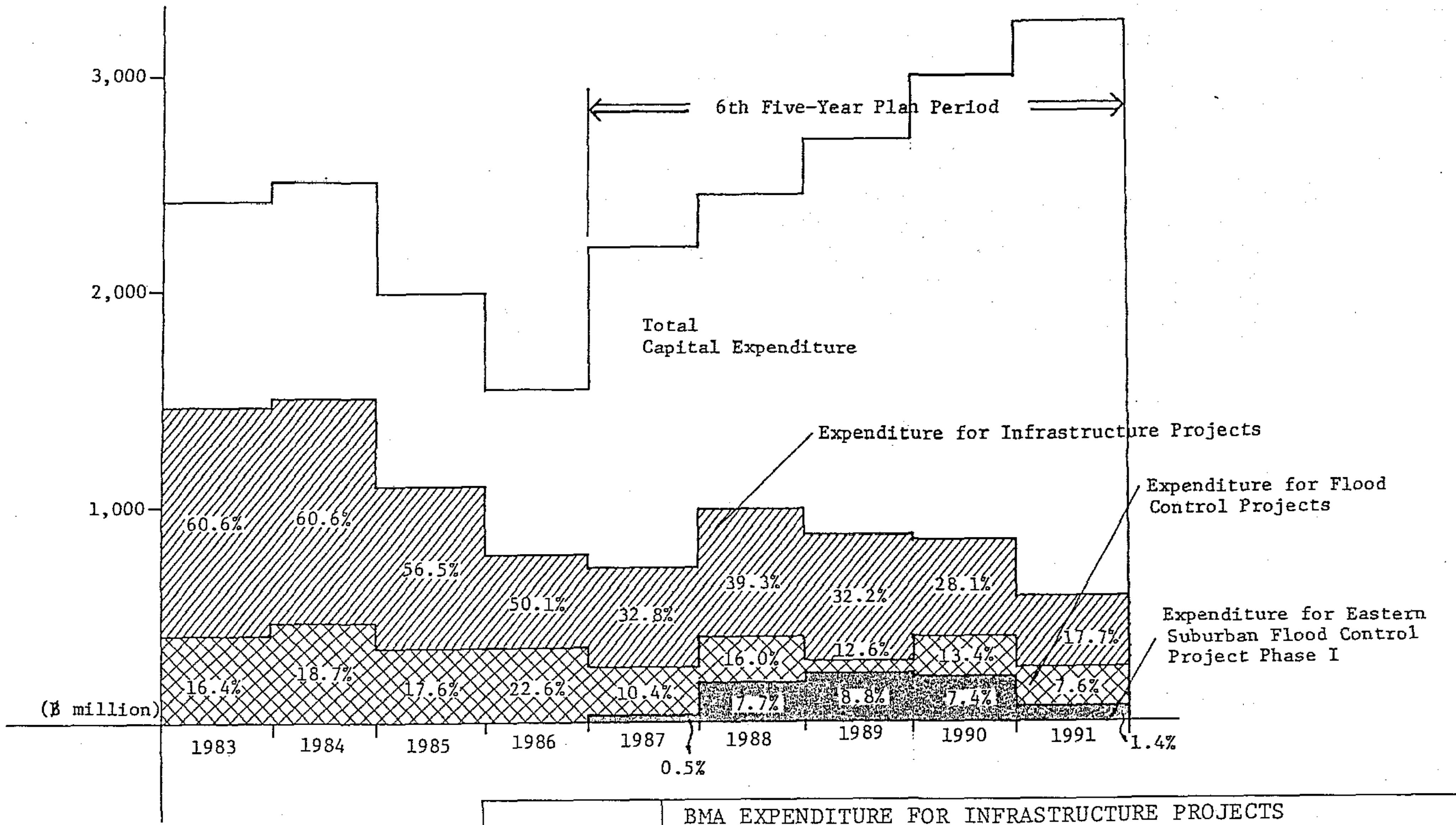

Fig. I.2	BMA EXPENDITURE FOR INFRASTRUCTURE PROJECTS IN 6TH FIVE-YEAR PLAN

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

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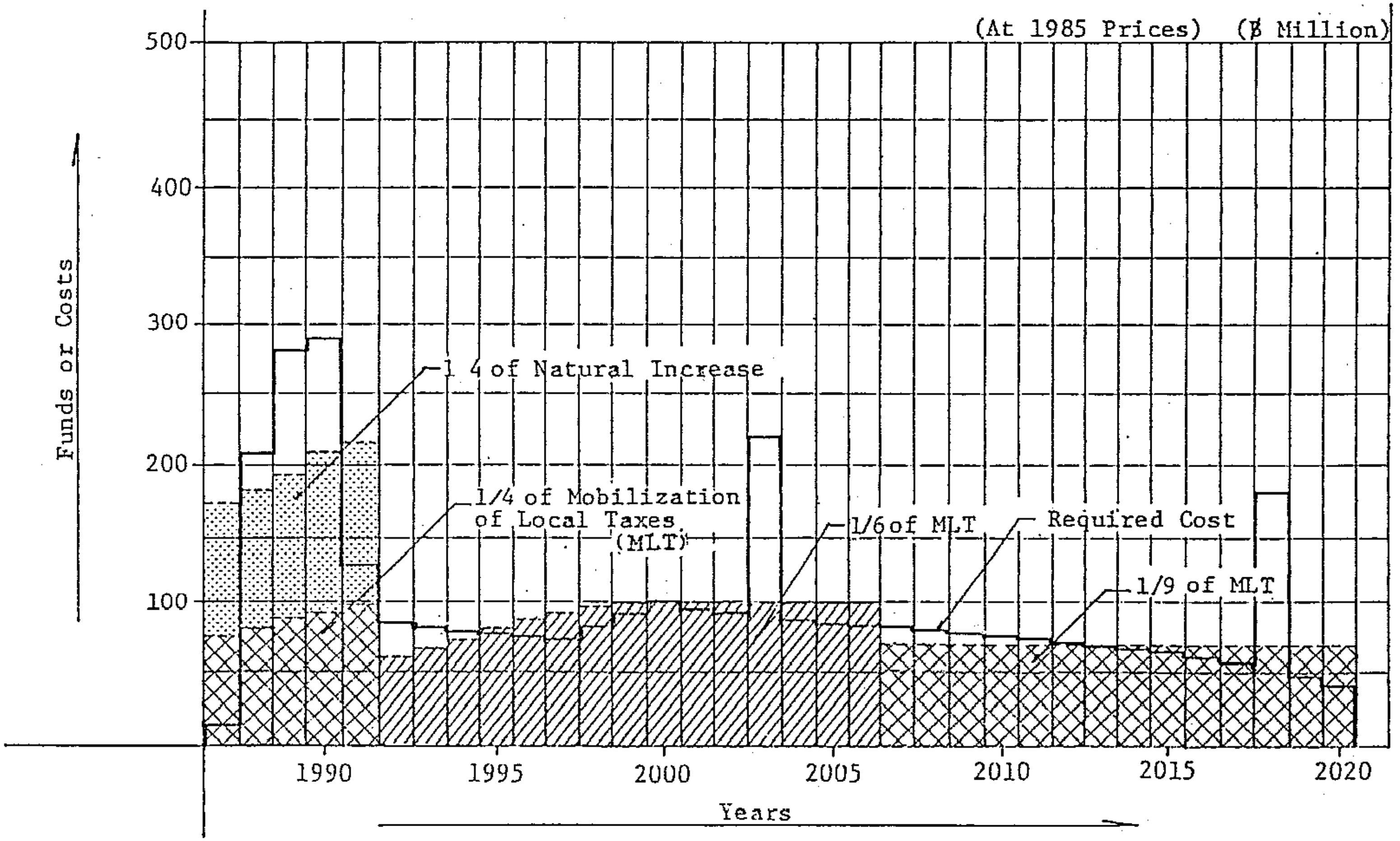


Fig. I.3 (1)	CAPITAL RAISING & COST RECOVERY SCHEDULE -CASE I-

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

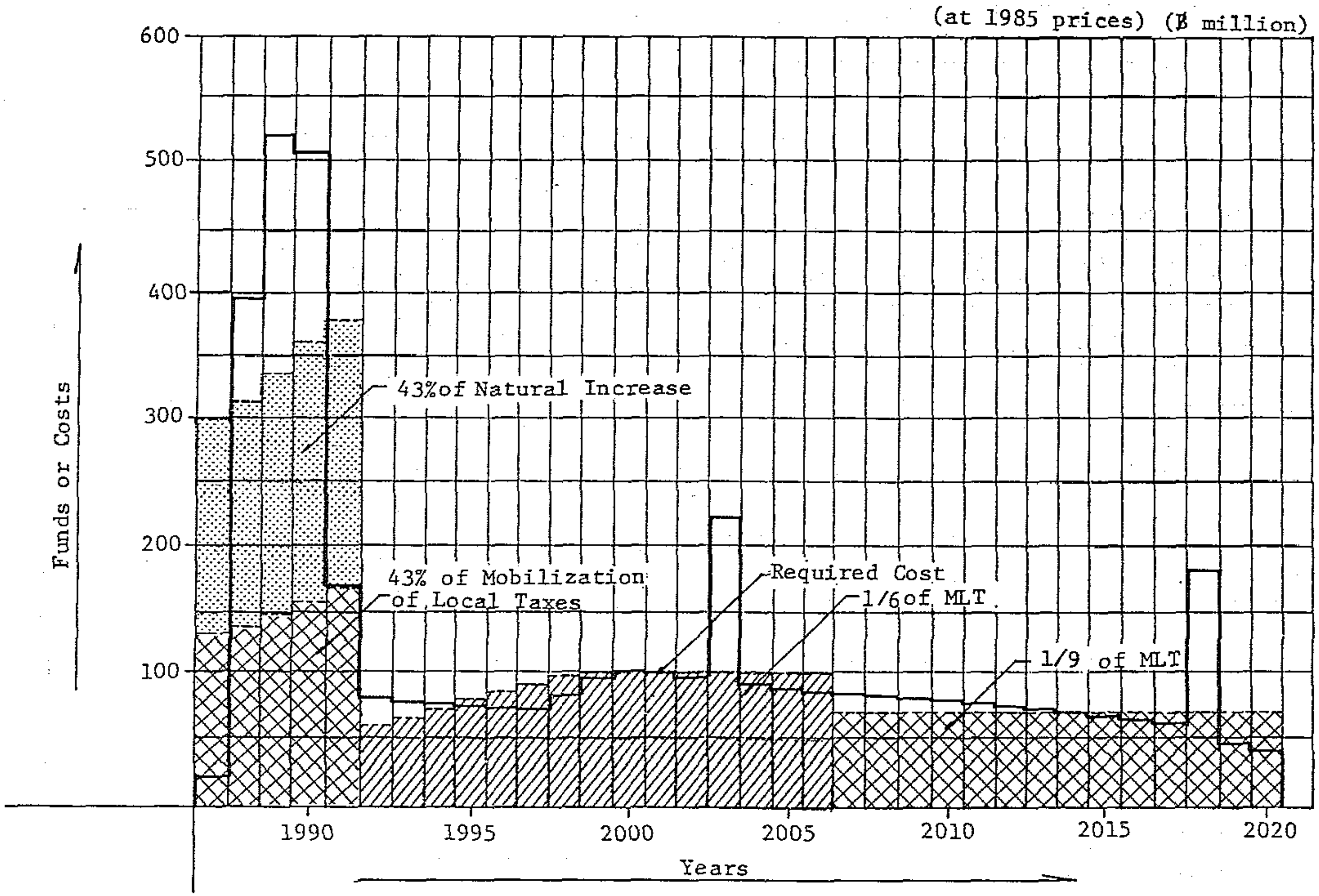
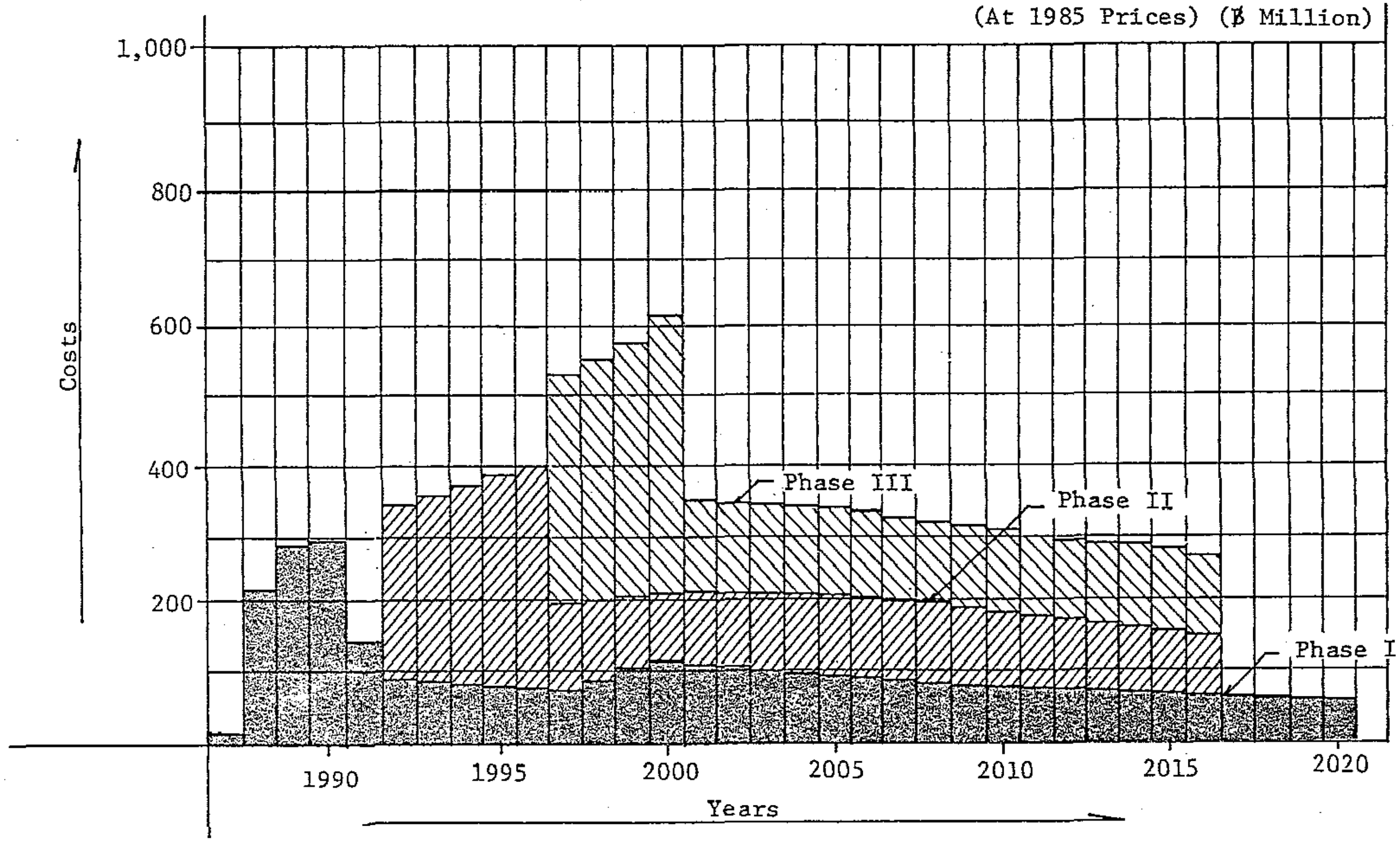


Fig. I.3 (2) CAPITAL RAISING & COST RECOVERY SCHEDULE -CASE II-

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



Note: Replacement cost for Phase I is levelled for the sake of convenience.

Fig. I.4	ANNUAL COSTS FOR EASTERN SUBURBAN-BANGKOK FLOOD PROTECTION & DRAINAGE PROJECT

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

APPENDIX J

ECONOMIC EVALUATION

APPENDIX J ECONOMIC EVALUATION

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APPENDIX J ECONOMIC EVALUATION

1. Estimation of Economic Cost

1.1 Economic Cost

To make economic analysis of the Project it is necessary to convert the project cost into economic cost. To do it the portions of transfer payment (tax, duty and subsidy) must be exempted from the project cost.

The project cost amounts to Baht 2,655 million, of which the local component including direct construction cost and contingency accounts for Baht 1,258 million. It is composed of cost and gross income from the contractor's standpoint. Gross income is supposed to be 30% of cost. Cost is made up of materials & equipment cost and labor cost. 7% of the materials and equipment cost is subtracted as business tax to producers. Also, 7% of labor cost is transferred as income tax. That is to say, Baht 68 million (= Baht 1,258 million/1.3 x 0.07) are excluded in calculating economic cost. Secondly, 3% of the project cost excluding engineering/supervision fees amounting to Baht 2,474 million is subtracted as business tax to contractors. It is Baht 74 million. Thirdly, business tax to real estate sellers by the rate of 3.5% is applied to the land acquisition cost of Baht 90 million, resulting in the reduction of Baht 3 million.
Lastly, income tax is levied to the foreign and local components of engineering/supervision fees amounting to Baht 46 million and Baht 45 million at the rate of 20% and 10%, respectively. That is to say, Baht 14 million will be cut.
The total amount of transfer payment to be subtracted from the project cost comes to Baht 159 million. (For details, refer to Table J.1.)

Shadow price of labor cost has not been considered because shadow wage rate is estimated to be near 100% on one hand and the weight of labor cost in the total cost will be not great on the other.
Usually, the price of imports contains a high percentage of duty nd taxes. However, the Project is a public project and therefore, such transfer payment has been basically exempted in calculating foreign component.

Table J.1 ECONOMIC COST

(Baht Million)

No.	Item	Code	Total	1987	1988	1989	1990	1991
1.	L/C Direct Construction Cost		1,154	0	315	384	391	64
2.	L/C Contingency		104	0	28	35	35	6
3.	Total	(A)	1,258	0	343	419	426	70
4.	(A) / 1.13 x 0.07	(B)	68	0	18	23	23	4
5.	Direct Construction Cost		2,270	0	719	704	726	121
6.	Contingency		204	0	65	63	65	11
7.	Total	(C)	2,474	0	784	767	791	132
8.	(C) x 0.03	(D)	74	0	23	23	24	4
9.	Land Acquisition	(E)	90	0	26	44	0	20
10.	(E) x 0.035	(F)	3	0	1	1	0	1
11.	F/C Engineering/Supervision	(G)	46	23	9	6	7	1
12.	(G) x 0.2	(H)	9	5	2	1	1	0
13.	L/C Engineering/Supervision	(I)	45	22	6	8	8	1
14.	(I) x 0.1	(J)	5	2	1	1	1	0
15.	(B) + (D) + (F) + (H) + (J)	(K)	159	7	45	49	49	9
16.	Project Cost (Financial)	(L)	2,655	46	825	825	805	154
17.	Economic Cost [(L) - (K)]	(M)	2,496	39	780	776	756	145
18.	Conversion Factor [(K) / (L)]	(N)	94.0%	84.5%	94.5%	94.1%	93.9%	94.2%

Since the Baht went afloat in 1984, it has become virtually unnecessary to consider shadow exchange rate in converting the Baht to a foreign currency or vice versa.

In conclusion the economic cost is Baht 2,496 million. Thus the conversion factor for the Project works out at 94.0%.

1.2 Operation and Maintenance Cost, and Replacement Cost

After the completion of the Project personnel, power, materials and other costs are annually required to maintain and operate the facilities.
According to the estimation, annual O/M cost amounts to Baht 42 million, which corresponds to 1.85% of the direct contruction cost of Baht 2,270 million.
During the project life, some items of equipment will lose their economic life and for such items the need of replacement arises. The prices of pumps and gates for the Project are estimated at Baht 47.0 million and Baht 19.0 million, respectively. When installation cost is added to them by 20%, the cost for the two items comes to Baht 79.2 million.
Further, electronic and other items of the equipment in the Flood Control Operation Center cost Baht 49.4 million.
The above items, costing Baht 129 million in total is assumed to be replaced once in 15 years.

2. Estimation of Economic Benefit

2.1 How to Estimate Economic Benefit

The economic benefit of flood protection and drainage derives from the reduction of damage resulting from flood protection measures. The damage includes physical damages to houses, household effects, commercial/industrial establishments and public facilities, interruption/stoppage of commercial/industrial and social activities, prevention cost and medical care.

Future damage is estimated under the concept of "Annual Average Flood Damage". The definition is as follows;

$$\overline{D} = {}_{Fo}\ Pr(F)D(F,Fo,S,Ls)dF$$

where

D	:	Flood damage
D	:	Average annual flood damage
F	:	Rainfall
Fo	:	Capacity of flood control facilities
S	:	Damage potential, e.g., population
Ls	:	Land subsidence
Pr(F)	:	Probability density function of F

The future amount of damage and losses caused by a flood will depend on such factors as depth, duration, and time of occurrence. These factors vary according to the amount of rainfall, rate of land subsidence, degree of flood protection/drainage facilities etc.

2.2 Estimation of Flood Damages

1) How to Estimate Flood Damages in Private Sector

According to the results of the flood damage survey, the relationship between the amount of flood damage per household or company and the inundation depth and duration can be estimated on the basis of the following equation:

$$D = a_0 + a_1H + a_2L$$

D : The amount of flood damages and losses per household or establishment

H : Flood depth (cm)

L : Flood duration (month)

a_0, a_1, a_2 : parameters

Table J.2 shows the estimated parameters for each item of the flood damages.

Table J.2 Estimated Parameters

Items of the flood damages		Constant a	Flood Depth a_1	Flood Duration a_2	Correlation Coefficient
Direct Damages to Houses, Buildings, etc.	Household	-1961.109	140.2839	909.8498	0.9451
	Commerce	8498.05	336.975	134.4	1.000
	Industry	-3413.925	2298.7875	5580.6	0.9909
Loss of Production and Services	Commerce		1115.628	11572.86	1.000
	Industry	310991.6	3125.0	53002.8	1.000
Loss of Transportation cost (Household)		-1.95318	0.17988	4.11992	0.8835
Medical Expenditure (Household)		10.1180	1.00779	57.6	0.9388
Expense for Permanent Prevention	Household	-48.353	2.27787	55.7333	0.8818
	Commerce	52.9178	5.2822	61.2329	0.9913
	Industry	455.45	40.475	47.6	0.9999
Expense for Temporary Prevention	Household	134.2896	14.02582	269.3333	0.9361
	Commerce	218.0	77.8	168.0	1.000
	Industry	1977.225	31.6625	239.8	0.9684

2) How to Estimate Flood Damages in Public Sector.

The survey for the damages and losses to the public sector is conducted on public offices, schools, and public corporation(BMTA). However, the result of the analysis for this survey is not sufficient from a statistical point of view. Therefore, the estimate of the flood damage (benefit) to public sector is not based on the aforementioned "Annual Average Flood Damage" but on the following method.

a) Public Expenditure for Flood

The public expenditure for flood such as direct damages to the buildings and extra medical expenditure is assumed to be 10 percent of total flood damages taking into account past flood surveys.

b) Public Corporation(BMTA)

Among the damage of public corporations, the flood damages to the Bangkok Mass Transit Authority (BMTA) is well recognized to be fairly large. In this project, the amount of this damage is estimated based on the BFCD (City Core) study. The method of this estimation is as follows:

(a) Repair and maintenance due to flood (D_1)
$D_1 = 1.0 \times 8{,}020 \times (4{,}285 \times r_1 \times 0.35 \times L)$

(b) Large repair cost and damage (D_2)
$D_2 = 0.5 \times 6{,}100 \times (4{,}285 \times r_1 \times 0.35 \times L)$

(c) Extra fuel cost (D_3)
$D_3 = 1{,}000 \times (4{,}285 \times r_1 \times 0.35 \times L)$

r_1, the percentage of buses, operational inside the Project Area, is assumed to be 0.25, which is based on the rate of population between core area and the Project Area. On the other hand, L represents the flood duration around Sukhumvit Road in Bang Na where buses became inaccessible due to flooding.

3) Estimation of Flood Damages

Flood damages for both "with project" and without project "cases in both the year 1985 and 2000 have been computed by employing the above mentioned formulas coupled with the estimated case-wise, year-wise, probability of rainfall-wise, mesh-wise input data of inundation depth and duration, and the year-wise input data of the number of households and commercial/industrial establishments. The results are as shown in Table J.3(1) to J.3(4).

2.3 Estimation of Economic Benefit

The economic benefit from the Project is estimated by subtracting the amount of annual flood damages for the "with project" case from the amount of annual flood damages for the "without project" case. It is done for both the year 1985 and 2000. The actual calculation of the yearly average benefit has been performed by the approximate method shown in Table J.4.

3. Project Justification

3.1 How to Make Economic Evaluation

There are three indices by which to evaluate the economic feasibility of a project. They are net present worth (NPW), benefit cost ratio (B/C) and economic internal rate of return (EIRR). They are mutually related with each other.

To get NPW and B/C of the Project, the annual benefits and costs are discounted by the prevailing opportunity cost of capital (around 16%) throughout the project life of 40 years.

NPW is the difference between cumulative benefit and cumulative cost discounted in that way, while B/C is the ratio between them.

At the same time, the discount rate equalizing cumulative benefit and cumulative cost is computed to determine EIRR.

TABLE J.3 (1) ANNUAL FLOOD DAMAGE BY SECTOR & BY PROBABILITY OF RAINFALL

A. The Year 1985, "Without Project"

(Baht million)

1. HOUSEHOLD

Probability of Rainfall	1. Direct Damage	2. Transportation Cost	3. Medical Payment	4. Permanent Protection	5. Temporary Protection	Total
2 Years	106	0	1	2	11	120
5 Years	360	0	3	6	37	406
10 Years	527	1	4	9	55	596
20 Years	650	1	5	11	67	734

2. COMMERCE

Probability of Rainfall	1. Direct Damage	2. Reduction of Revenue	3. Permanent Protection	4. Temporary Protection	Total
2 Years	18	60	0	4	82
5 Years	64	218	1	15	298
10 Years	90	306	1	21	418
20 Years	113	382	2	26	523

3. INDUSTRY

Probability of Rainfall	1. Direct Damage	2. Reduction of Revenue	3. Permanent Protection	4. Temporary Protection	Total
2 Years	9	13	0	0	22
5 Years	63	88	1	1	153
10 Years	89	125	2	1	217
20 Years	115	161	2	2	280

4. PUBLIC SECTOR

Probability of Rainfall	1. Flood Damages of BMTA 1) Repair & Mnt.	2) Large Repair	3) Extra Fuel	Sub-total	2. Public Expenditure	Total
2 Years	5	2	1	8	25	33
5 Years	5	2	1	8	95	103
10 Years	5	2	1	8	137	145
20 Years	6	2	1	9	171	180

TABLE J.3 (2) ANNUAL FLOOD DAMAGE BY SECTOR & BY PROBABILITY OF RAINFALL

B. The Year 1985, "With Project"

(Baht million)

1. HOUSEHOLD

Probability of Rainfall	1. Direct Damage	2. Transportation Cost	3. Medical Payment	4. Permanent Protection	5. Temporary Protection	Total
2 Years	15	0	0	0	2	17
5 Years	146	0	1	3	15	165
10 Years	262	0	2	5	27	296
20 Years	388	1	3	7	40	439

2. COMMERCE

Probability of Rainfall	1. Direct Damage	2. Reduction of Revenue	3. Permanent Protection	4. Temporary Protection	Total
2 Years	6	20	0	1	27
5 Years	30	102	0	7	139
10 Years	52	176	1	12	241
20 Years	75	254	1	17	347

3. INDUSTRY

Probability of Rainfall	1. Direct Damage	2. Reduction of Revenue	3. Permanent Protection	4. Temporary Protection	Total
2 Years	1	2	0	0	3
5 Years	31	44	1	0	76
10 Years	45	64	1	1	111
20 Years	75	106	1	1	183

4. PUBLIC SECTOR

Probability of Rainfall	1. Flood Damages of BMTA: 1) Repair & Mnt.	2) Large Repair	3) Extra Fuel	Sub-total	2. Public Expenditure	Total
2 Years	1	0	0	1	5	6
5 Years	1	0	0	1	42	43
10 Years	1	0	0	1	72	73
20 Years	1	0	0	1	108	109

TABLE J.3 (3) ANNUAL FLOOD DAMAGE BY SECTOR & BY PROBABILITY OF RAINFALL

C. The Year 2000, "Without Project"

(Baht million)

1. HOUSEHOLD

Probability of Rainfall	1. Direct Damage	2. Transportation Cost	3. Medical Payment	4. Permanent Protection	5. Temporary Protection	Total
2 Years	421	1	3	7	43	475
5 Years	1,042	1	9	18	108	1,178
10 Years	1,419	2	12	24	147	1,604
20 Years	1,916	3	16	33	198	2,166

2. COMMERCE

Probability of Rainfall	1. Direct Damage	2. Reduction of Revenue	3. Permanent Protection	4. Temporary Protection	Total
2 Years	84	285	1	19	389
5 Years	190	645	3	44	882
10 Years	245	835	4	57	1,141
20 Years	330	1,119	5	76	1,530

3. INDUSTRY

Probability of Rainfall	1. Direct Damage	2. Reduction of Revenue	3. Permanent Protection	4. Temporary Protection	Total
2 Years	23	32	0	0	55
5 Years	68	98	1	1	168
10 Years	106	150	2	1	259
20 Years	142	201	2	2	347

4. PUBLIC SECTOR

Probability of Rainfall	1. Flood Damages of BMTA 1) Repair & Mnt.	2) Large Repair	3) Extra Fuel	Sub-total	2. Public Expenditure	Total
2 Years	8	3	1	12	102	114
5 Years	9	3	1	13	248	261
10 Years	9	3	1	13	334	347
20 Years	10	4	1	15	449	464

TABLE J.3 (4) ANNUAL FLOOD DAMAGE BY SECTOR & BY PROBABILITY OF RAINFALL

D. The Year 2000, "With Project"

(Baht million)

1. HOUSEHOLD

Probability of Rainfall	1. Direct Damage	2. Transportation Cost	3. Medical Payment	4. Permanent Protection	5. Temporary Protection	Total
2 Years	158	0	1	3	17	179
5 Years	524	1	4	9	55	593
10 Years	868	1	7	15	91	982
20 Years	1,272	2	11	22	132	1,439

2. COMMERCE

Probability of Rainfall	1. Direct Damage	2. Reduction of Revenue	3. Permanent Protection	4. Temporary Protection	Total
2 Years	31	109	1	7	148
5 Years	106	361	2	25	494
10 Years	160	545	3	37	745
20 Years	227	772	4	53	1,056

3. INDUSTRY

Probability of Rainfall	1. Direct Damage	2. Reduction of Revenue	3. Permanent Protection	4. Temporary Protection	Total
2 Years	8	12	0	0	20
5 Years	29	42	1	0	72
10 Years	55	79	1	1	136
20 Years	89	127	2	1	219

4. PUBLIC SECTOR

Probability of Rainfall	1. Flood Damages of BMTA 1) Repair & Mnt.	2) Large Repair	3) Extra Fuel	Sub-total	2. Public Expenditure	Total
2 Years	0	0	0	0	39	39
5 Years	0	0	0	0	129	129
10 Years	0	0	0	0	207	207
20 Years	0	0	0	0	302	302

If a project is to be economically feasible, NPW must be more than 0, or B/C must be more than 1. Or EIRR must be more than the opportunity cost of capital.

3.2 Economic Evaluation

The annual benefit to be expected from the Project works out at Baht 254 million and Baht 632 million in 1985 and 2000, respectively as shown in Table J.4. Annual benefit, cost, cashflow and their respective aggregates throughout the project life of 40 years are as shown in Table J.5(1). When they are discounted by the opportunity cost of capital of 16%, the resultant flows are as presented in Table J.5(2). Resultant values of NPW and B/C are Baht 425 million and 1.24 respectively as seen in Table J.6.

Table J.6 also traces the process of arriving at the discount factor (= discount rate) equalizing cumulative benefit and cost, and shows the resultant EIRR of 20.2%.

The value of NPW is fairly above 0 and the value of B/C is by 24% more than the break even point of 1. The value of EIRR is by 4.2 points beyond the opportunity cost of capital. These figures of economic indices clarify a safely high economic viability of the Project.

The values of NPW, B/C and EIRR for the Master Plan Project are Baht 1,009 million, 1.5 and 26.5%, respectively. The reason that the study project, which is the Master Plan Project First Stage programme has lower evaluation values in spite of the fact that it is a priority project by its nature is that the flood protection facilities including pumping stations, gates and dykes that have been constructed up to the present under the urgent measures policy are estimated to be effective to a certain extent.

Table J.4 Estimation of Economic Benefit

1. The Year, 1985

(Baht Million)

			Without Project				With Project				
Probability of Rainfall	Frequency of Rainfall	$\overline{(B)}^{*}-(B)$	Total Damage	$\frac{\overline{(D_1)}^{*}+(D_1)}{2}$	(C)x(E_1)	Total Annual Average Damage	Total Damage	$\frac{\overline{(D_2)}^{*}+(D_2)}{2}$	(C)x(E_2)	Total Annual Average Damage	Benefit
(A)	(B)=1/(A)	(C)	(D_1)	(E_1)	(F_1)	$(G_1)=\Sigma(F_1)$	(D_2)	(E_2)	(F_2)	$(G_2)=\Sigma(F_2)$	$(H)=(G_1)-(G_2)$
1	1	-	-	-	-		-	-	-		
2	0.5	0.5	257	129	65		53	27	14		
5	0.2	0.3	960	608	182		423	238	71		
10	0.1	0.1	1,376	1,168	117		721	572	57		
20	0.05	0.05	1,717	1,547	77	441	1,078	899	45	187	254

2. The Year, 2000

(Baht Million)

			Without Project				With Project				
Probability of Rainfall	Frequency of Fainfall	$\overline{(B)}^{*}-(B)$	Total Damage	$\frac{\overline{(D_1)}^{*}+(D_1)}{2}$	(C)x(E_1)	Total Annual Average Damage	Total Damage	$\frac{\overline{(D_1)}+(D_1)}{2}$	(C)x(E_1)	Total Annual Average Damage	Benefit
(A)	(B)=1(A)	(C)	(D_1)	(E_1)	(F_1)	$(G_1)=\Sigma(F_1)$	(D_2)	(E_2)	(F_2)	$(G_2)=\Sigma(F_2)$	$(H)=(G_1)-(G_2)$
1	1	-	-	-	-		-	-	-		
2	0.5	0.5	1,033	517	259		386	193	97		
5	0.2	0.3	2,489	1,761	528		1,288	837	251		
10	0.1	0.1	3,351	2,920	292		2,078	1,683	168		
20	0.05	0.05	4,507	3,929	196	1,275	3,016	2,547	127	643	632

Note: (B), (D_1) and (D_2) are (B),(D_1) and (D_2) in the immediately above aolumn, respectively.

TABLE J.5(1) ECONOMIC BENEFIT AND COST FLOW
-DISCOUNT FACTOR=0%-

BNFIT=benefit; COST=cost; CSFL=cash flow (=BNFT-COST);
CM BNFT=cumulative benefit; CM COST=cumulative cost;
CM CSFL=cumulative cash flow

(Baht million)

Year	BNFT	COST	CSFL	CM BNFT	CM COST	CM CSFL
1987	0	39	-39	0	39	-39
1988	108	786	-678	108	825	-717
1989	226	795	-569	334	1,621	-1,286
1990	358	789	-430	693	2,410	-1,717
1991	405	185	219	1,098	2,596	-1,497
1992	430	42	388	1,529	2,638	-1,109
1993	455	42	413	1,984	2,680	-695
1994	481	42	439	2,465	2,722	-256
1995	506	42	464	2,972	2,764	207
1996	531	42	489	3,503	2,806	697
1997	556	42	514	4,060	2,848	1,212
1998	581	42	539	4,642	2,890	1,751
1999	607	42	565	5,249	2,932	2,317
2000	632	42	590	5,881	2,974	2,907
2001	632	42	590	6,514	3,016	3,497
2002	632	42	590	7,146	3,058	4,088
2003	632	171	461	7,778	3,229	4,549
2004	632	42	590	8,411	3,271	5,139
2005	632	42	590	9,043	3,313	5,730
2006	632	42	590	9,675	3,355	6,320
2007	632	42	590	10,308	3,397	6,910
2008	632	42	590	10,940	3,439	7,501
2009	632	42	590	11,572	3,481	8,091
2010	632	42	590	12,205	3,523	8,681
2011	632	42	590	12,837	3,565	9,272
2012	632	42	590	13,470	3,607	9,862
2013	632	42	590	14,102	3,649	10,452
2014	632	42	590	14,734	3,691	11,043
2015	632	42	590	15,367	3,733	11,633
2016	632	42	590	15,999	3,775	12,224
2017	632	42	590	16,631	3,817	12,814
2018	632	171	461	17,264	3,988	13,275
2019	632	42	590	17,896	4,030	13,866
2020	632	42	590	18,528	4,072	14,456
2021	632	42	590	19,161	4,114	15,046
2022	632	42	590	19,793	4,156	15,637
2023	632	42	590	20,425	4,198	16,227
2024	632	42	590	21,058	4,240	16,817
2025	632	42	590	21,690	4,282	17,408
2026	692	42	650	22,382	4,324	18,058

TABLE J.5(2) ECONOMIC BENEFIT AND COST FLOW
-DISCOUNT FACTOR=16%-

BNFIT=benefit; COST=cost; CSFL=cash flow (=BNFT-COST);
CM BNFT=cumulative benefit; CM COST=cumulative cost;
CM CSFL=cumulative cash flow

(Baht million)

Year	BNFT	COST	CSFL	CM BNFT	CM COST	CM CSFL
1987	0	33	-33	0	33	-33
1988	80	584	-504	80	618	-537
1989	145	509	-364	225	1,128	-902
1990	197	435	-237	423	1,563	-1,140
1991	193	88	104	616	1,652	-1,035
1992	176	17	159	793	1,669	-876
1993	161	14	146	954	1,684	-729
1994	146	12	133	1,101	1,697	-596
1995	133	11	122	1,234	1,708	-473
1996	120	9	110	1,354	1,717	-363
1997	108	8	100	1,463	1,726	-262
1998	98	7	90	1,561	1,733	-171
1999	88	6	82	1,649	1,739	-89
2000	79	5	73	1,728	1,744	-15
2001	68	4	63	1,797	1,749	48
2002	58	3	54	1,856	1,752	103
2003	50	13	37	1,906	1,766	140
2004	43	2	40	1,950	1,769	180
2005	37	2	35	1,988	1,772	216
2006	32	2	30	2,020	1,774	246
2007	28	1	26	2,048	1,776	272
2008	24	1	22	2,072	1,777	295
2009	20	1	19	2,093	1,779	314
2010	17	1	16	2,111	1,780	331
2011	15	1	14	2,127	1,781	345
2012	13	0	12	2,140	1,782	358
2013	11	0	10	2,151	1,782	369
2014	9	0	9	2,161	1,783	378
2015	8	0	7	2,170	1,784	386
2016	7	0	6	2,177	1,784	393
2017	6	0	5	2,184	1,785	399
2018	5	1	3	2,189	1,786	403
2019	4	0	4	2,194	1,786	407
2020	4	0	3	2,198	1,787	411
2021	3	0	3	2,201	1,787	414
2022	3	0	2	2,204	1,787	417
2023	2	0	2	2,207	1,787	419
2024	2	0	2	2,209	1,787	421
2025	1	0	1	2,211	1,788	423
2026	1	0	1	2,213	1,788	425

TABLE J.6 NPW, B/C AND IRR

(Unit of NPW: Baht million)

Item	NPW	B/C
Value	425	1.24

COMPUTATION OF IRR

DF=discount factor; CM BNFT=cumulative benefit; CM COST=cumulative cost; CM CSFL=cumulative cash flow

(Baht million)

DF	CM BNFT	CM COST	CM CSFL
1	17,954	3,895	14,059
2	14,590	3,553	11,037
3	12,005	3,275	8,729
4	9,997	3,046	6,950
5	8,420	2,855	5,565
6	7,167	2,691	4,475
7	6,162	2,551	3,611
8	5,346	2,427	2,919
9	4,679	2,318	2,360
10	4,126	2,220	1,905
11	3,665	2,132	1,533
12	3,277	2,052	1,225
13	2,948	1,978	969
14	2,666	1,910	756
15	2,424	1,847	576
16	2,213	1,788	425
17	2,029	1,732	297
18	1,868	1,680	187
19	1,725	1,631	94
20	1,599	1,585	14
21	1,486	1,540	-53

IRR = 20.2

3.3 Sensitivity Analysis

The purpose of the sensitivity analysis is to test the feasibility of the project by changing some factors that affect the results. In this study, the sensitivity test is conducted in such a way as shown in Table J.7.

Table J.7 CASES OF SENSITIVITY TEST

Test Case	Benefit	Cost
Test I	+10%	+10%
Test II	-10%	+10%
Test III	+20%	-20%
Test IV	-20%	+20%

The results of the sensitivity test are shown in Table J.8. In the sensitivity test IV, the Project shows the lower I.R.R. of 12.9 percent than the prime lending rate of 16 percent. However, even in this case, if the unquantifiable benefits such as environmental benefit and psychological relief are considered, this project might still prove to be viable for implementation.

Table J.8 RESULTS OF SENSITIVITY TEST

Sensitivity Test 1			Sensitivity Test 2			Sensitivity Test 3			Sensitivity Test 4		
Benefit +10% Cost -10%			Benefit -10% Cost +10%			Benefit +20% Cost -20%			Benefit -20% Cost +20%		
M.P.W.* (₱ Million)	B/C*	I.R.R. (%)	N.P.W.* (₱ Million	B/C*	I.R.R. (%)	N.P.W.* (₱ Million	B/C*	I.R.R. (%)	N.P.W.* (₱ Million	B/C*	I.R.R. (%)
823	1.51	25.1	22	10.1	16.2	1,223	1.85	31.6	-37.7	0.82	12.9

Note(*): NPW and B/C calculated under the condition of the opportunity cost of capital at 16%.

3.4 Other Benefit

In evaluating the feasibility of the project, it is necessary to evaluate the project not merely from the economic aspects based on the results of economic analysis, but comprehensively also from the technical, social, environmental, political, and financial aspects. In the former section, the study project is proved to be feasible economically. There are two important benefits which are not counted in the previous benefit.

1) Improvement of Environment

The benefits of environmental improvement will be enjoyed not only by residents living in the Project Area but also by visitors to the area. Its importance, however, depends mainly on public awareness and recognition of the benefits that stem from the flood protection system, which differs from person to person. Generally speaking, it is expected that the higher the public living standard, the higher the public recognition of benefits. Especially, the elimination of the present offensive odours from the drain and sludge accumulations will result in an improvement of environmental aesthetics, particularly for those living in or near the flood-prone atmosphere and unsightly environment. Then, the attractiveness of the enhanced environment should be conductive to the new commercial and industrial activities in the Project Area.

2) Increase in Land Value

The improved living environment through the flood protection project should obviously give spur for the development programme and the consequential large-scale financial transactions, which provide sufficient impetus for the increase of land value in the Project Area. Therefore, it is expected that BMA would obtain the additional revenue through this increase in value of private property.

3.5 Justification

There will be no doubt that the study project will produce the high social benefits such as upgrading the existing living environment and will develop the economy, and also contribute towards an elimination of the inconveniences of community life.

With the rising level of living standards, what once seemed as tolerable has come to be recognized as being intolerable. Also, if the flood protection project is not implemented, flooding will become more serious due to the anticipated land subsidence, and population inflow into the Project Area. Thus, the implementation of this project would make a big contribution to satisfactory living condition in the Project Area, therefore, the implementation of the proposed flood protection project is justified.

APPENDIX K

ENVIRONMENTAL IMPACT PERTAINING WATER QUALITY

APPENDIX K ENVIRONMENTAL IMPACT PERTAINING WATER QUALITY

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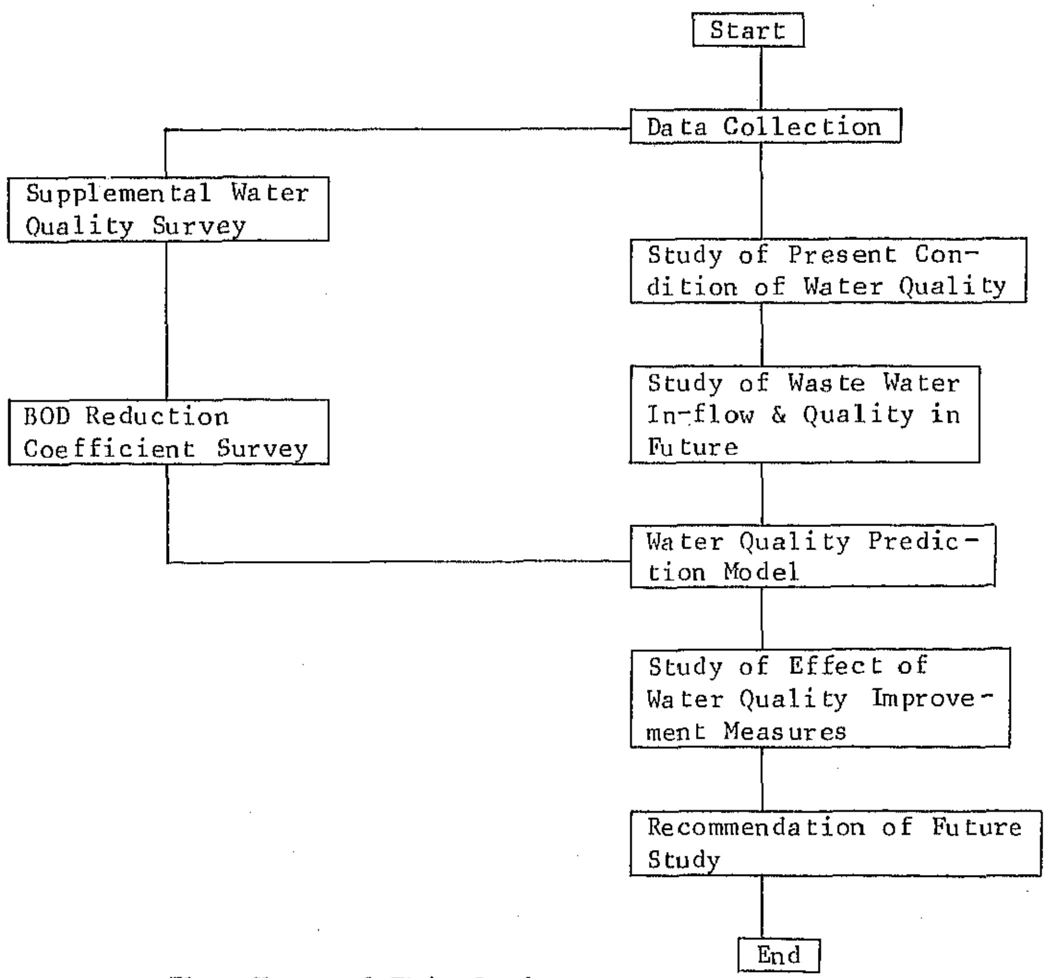
1. General

At present, water quality of klongs in the Master Plan Area is very poor throughout the year as recorded by 10 to 40 ppm in BOD. By the execution of the flood protection/drainage project, the klongs in the Master Plan Area will be enclosed by the barrier embankment and control gate and in rainy season the water level in klongs will be maintained in low by pumping up. Moreover, a progress of urbanization and land subsidence will aggravate water quality. In this study, the following investigation and analysis have been carried out for the purpose of a provision of basic information for the water quality control plan:

(1) Data Collection and Water Quality Survey
(2) Study of Present Condition of Water Quality
(3) Study of Wastewater Quantity and Quality in Future
(4) Water Quality Prediction Model
(5) Study of Effect of Water Quality Improvement Measures
(6) Recommendation of Future Study



Flow Chart of This Study

2. Data Collection and Water Quality Survey

2.1. Data Collection

Available data collected for this study is listed in Table K.1. to Table K.3.

Table K.1. Available Data Collected for Water Quality

Area	Source	Number of Station	Observed Year
Chao Phraya River	NEB Report	18	1983-1984
Core Area	NEDECO Report, DDS	30	1981-1985
Master Plan Area	DDS	38	1981-1985

Table K.2. Available Water Level Data Collected for Flushing Water

Area	Source	Number of Station	Observed Year
Chao Phraya River	PAT and RID	6	1980-1985
Green Belt Area	RID	10	1984-1985
Master Plan Area	JICA and DDS	12	1983-1985

Table K.3. Available Data Collected for Water Quality Improvement Plan

Name of Report	Date of Issue
Master Plan of Bangkok Sewerage System Project	1981 by JICA
Feasibility Study of Bangkok Sewerage System Project	1982 by JICA
The Improvement of Water Quality in Klongs by Flushing (First Phase)	1985 by DDS

2.2. Water Quality Survey

Field survey and chemical analysis shown in Table K.4. has been carried out for obtaining the supplemental data for klong's water quality in cooperation with DDS between July and September in 1985.

Table K.4. Field Survey and Chemical Analysis of Water Quality

Survey Item	Number of Sampling Points	Number of Sampling Times	Chemical Analysis
Water Quality Survey in Main Klong	12	3	Temp., PH, DO, COD BOD, SS, CL, H_2S Coliforms
BOD Reduction Coefficient Survey	5	3	Temp., PH, DO, COD BOD, SS
Water Quality Survey for Flushing Water	3	3	Temp., PH, DO, COD BOD, SS, CL, H_2S Coliforms

3. Present Condition of Water Quality in the Study Area

3.1. Chao Phraya River

NEB has monitored the water quality of the Chao Phraya River in many stations as shown in Fig. K.1.

According to the water quality survey in 1983 and 1984, the characteristics of water quality of the Chao Phraya River is as follows:

(1) The present situation of water quality is heavily polluted by the inflow of domestic, commercial and industrial wastewater.

(2) The distribution and seasonal changes in DO, BOD and COD along the Chao Phraya river are strongly influenced by three main factors; tidal effect, flow rate of the river and inflow of wastewater from Bangkok.

(3) DO, BOD and COD in the lower Chao Phraya river from river mouth to upstream 140 km vary from 1 to 5 mg/1, 1 to 3 mg/1 and 5 to 30 mg/1 respectively as shown in Fig. K.2.

(4) According to the monthly changes of DO, BOD and COD at Bangkok Port (mouth of Klong Phrakhanong), lower DO and higher BOD has been observed during hot and dry season and higher DO and lower BOD during rainy season as shown in Fig. K.3. These trends seem to be highly correlated with the flow rate of the river and the rainfall amount.

(5) It was considered that the river water in Bangkok area is polluted more than the upper-stream of the Chao Phraya River because of the coliform data as shown in Fig. K.2. and Fig. K.3.

3.2. Main Klongs in the City Core Area

The surface water quality in the City Core Area is very poor due to the discharge of sewers, which collect street drainage and household sullage, discharging directly into the canals while also the ground water draining towards canals is contaminated by overflow of septic tanks and leasheate from cess-pools.

From March through September 1980 the Department of Drainage and Sewerage (DDS) of BMA conducted a water sampling and testing survey in the canals.

The principal results of that survey are shown hereunder.

(1) Temperature varied from 28°C to 32°C

(2) Dissolved Oxygen content ranged from zero to 9.5 mg/l.

(3) Biochemical Oxygen Demand (BOD) averaged about 154 mg/l, with maximum in the order of 240 mg/l.

(4) Suspended Solids are usually high with values measured as high as 230 mg/l.

(5) High concentrations of Hydrogen Sulfide (H_2S) were observed in the heavily polluted canal waters during low tide. The average H_2S content reached to 0.5 to 0.6 mg/l in several canals.
H_2S is a main source of the odour nuisance from the polluted waters, and is toxic for human body and erosive for building materials.

(6) Coliforms were found in all canals, but reached high concentrations in Klong Maha Nak, Klong Padung Krung Kasem, Klong Bang Lam Phu, Klong Ong Ang and Klong Lord.
Coliforms are an indication of contamination with human fecal material. This indicates that the canal waters are hazardous for the public health. The maximum, found in Klong Padung Krung Kasem was an average of 5,400,000 MPN/100 ml. Fig. K.4. shows the locations of the various stations and Fig. K.5. and Fig. K.6. give a graphical display of concentrations measured.

3.3. Main Klongs in the Study Area

DDS had started surveying the water quality of the Klongs in the Study Area from 1982. At present, sampling stations shown in Fig. K.7. are less than forty, main of which are located in the urbanized area neighboring City Core Area.

The study of water pollution in the Study Area has been carried out based on the past data collected from DDS and supplemental data surveyed between July and September in 1985 in cooperated with DDS.

The Characteristics of water quality in the Study Area are shown hereunder.

(1) Temperature varied from 26°C to 32°C.

(2) Dissolved Oxygen (DO) content ranged from zero to 2.7 mg/l, especially DO of K. Sam Saen, K. Bang Sue and K. Lat Phrao is always zero mg/l.

(3) Biochemical Oxygen Demand (BOD) averaged about 15 mg/l, with maximum in order of 67 mg/l.
Average BOD value in dry and rainy season is not so different as shown in Fig. K.10.

(4) Chemical Oxygen Demand (COD) averaged approximately 40 mg/l, with maximum in order of 191 mg/l.
The relationship with COD and BOD is indicated in Fig. K.10.

(5) Suspended Solids (SS) are usually high with values measured as high as 30 mg/l.

(6) Coliforms are found in all klongs, but reached high concentrations in K. Prem Prachakon, K. Bang Sue, K. Lat Phrao, K. Huay Kwang and K. Kra Cha.

A graphical display for observed average value of water quality is shown in Fig. K.8. to K.10.

4. Wastewater Quantity and Quality

4.1. Per Capita Wastewater Flow and its Strength

According to the Master Plan report of "Bangkok Sewerage System Project" by JICA in 1981, present and future in 2000 per capita flow and its strength of domestic and commercial wastewater is presented in Table K.5.

Table K.5. Per Capita Wastewater Flow

Item	Present in 1980		Future in 2000	
	Domestic	Commercial	Domestic	Commercial
Per Capita Flow (1/day/cap)	184	*50	201	** 116
Per Capita BOD Load (g/day/cap)	48	13	52	*** 30

Note: *: Value of per capita correspondent
**: Estimated value to supplement dommestic wastewater for the central commercial area (m^3/day/ha)
***: ditto (kg/day/ha)

In view of water pollution control, industrial wastewater discharge is regulated by Ministry of Industry on the basis of the "Factory Act 2512. (1969)". Wastewater is prohibited to be discharged from any factory unless it satisfies the effluent quality standards for discharge, with necessary treatment as required, which can be discharged directly into the receiving water.

Under such condition, it is assumed that the factories scattered in the Study Area will undertake the required treatment of their own industrial wastes by their own individual treatment facilities prior to the completion of the proposed sewerage system. Accordingly, industrial wastewater is excluded in this study.

4.2. Wastewater Flow from Proposed Wastewater Treatment Plant

In JICA Sewerage Project, six wastewater treatment plants are proposed in the Mster Plan Area of this project as shown in Fig. K.11. The wastewater flow and BOD load from proposed treatment plants are listed in Table K.6.

Table K.6. Wastewater Flow from Proposed Treatment Plants

Treatment Plan	Flow m^3/day, (m^3/Sec)	BOD Load t/day
T_1 Sam Saen	* 68,700 (0.795)	* 3.64
T_5 Bang Khen	115,500 (1.336)	6.12
T_6 Lat Phrao	69,200 (0.801)	3.67
T_7 Saen Saeo	197,800 (2.289)	10.48
T_8 Phra Khanong	* 90,200 (1.044)	* 4.78
T_9 Khlet	* 76,300 (0.883)	* 4.07
Total	617,700 (7.148)	32.76

Note: The figures marked in * is convented into a value for the drainage area of this project.

4.3. Wastewater Quantity and Quality in the Master Plan Area

Present and future in 2000 wastewater flow in the Master Plan Area can be estimated on the basis of per capita wastewater flow and the population density as shown in Fig. K.12, which is studied in this project. These are summerized in Table K.7. and Fig. K.13.

Table K.7. Wastewater Flow and BOD Load in the Master Plan Area

Polder	Drainage Area	Flow m^3/day, (m^3/sec)		BOD Load t/day	
		1983	2000	1983	2000
Bang Khen -Bang Sue	Bang Khen-Bang Sue	113,180 (1.310)	247,060 (2.860)	27,470	63,510
Phra Khanong	Huay Khuang	60,050 (0.695)	117,000 (1.354)	15,670	32,250
	Lat Phrao	31,620 (0.366)	92,390 (1.069)	7,810	23,860
	Klong Chan	12,930 (0.150)	30,890 (0.358)	3,370	7,980
	Hua Mark	13,130 (0.152)	28,020 (0.324)	3,420	7,240
	Patterna Karn	4,950 (0.057)	19,370 (0.224)	1,290	5,000
Bang Na	Bang Na	34,590 (0.400)	87,650 (1.015)	9,020	22,640
	Total	270,450 (3.130)	622,380 (7.204)	68,050	162,480

Note: Total amount of wastewater flow in above table is more than that from proposed treatment plants shown in Table K.6, because of little difference of population density estimated in both studies.

5. Evaluation for Water Pollution in Klong

5.1 Objective of Evaluation

As mentioned before, the present condition of klong water quality in the Master Plan Area is very poor due to the domestic, commercial and industrial wastewater.

After execution of this Project, the Study Area will be enclosed by the polder embankments and gates, as flood protection facility. Klong water level in flood season will be maintained about 0.8 meter (1.8 meter in future 2000 due to land subsidence) lower than existing water level by the drainage facilities, in order to increase the storage capacity of klong. Moreover, considering the progress of urbanization in the Study Area, it is forecasted that the water pollution of klong will deteriorate year by year and water pollution control measures will be needed.

As the environmental impact pertaining water quality due to execution of this Project, the following studies have been carried out based on the previous study and sample calculations shown in Table K.8.

(1) Evaluation of water pollution due to execution of this Project.

(2) Estimation of water quality in future 2000.

(3) Evaluation of water pollution control measures.

Table K.8. Calculation Cases

Season	Land Use (Population) and Topography	Drainage Facility	Sewerage Facility	Rainfall	Flushing measure	Case No.
Rainy Season	Present	Without Present	Sanitary Sewerage	not consider	not consider	RP-001
				consider	"	RP-002
	Future in 2000	M/P Level	Without Sanitary Sewerage	"	"	RF-001
	"	"	With Planned Sanitary Sewerage	"	"	RF-002
Dry Season	Present	Present	Without Sanitary Sewerage	not consider	consider	DP-001
	Future in 2000	M/P Level	Without Planned Sanitary Sewerage	"	"	DF-001
	"	"	With Planned Sanitary Sewerage	"	"	DF-002

5.2. Water Quality Prediction Model

In order to grasp the water quality at main points in klong network, water quality prediction model will be adopted complete mixed flow type model under the basic data, such as klong water, flushing water, and operation of pumps and gates. Basic equations are consisted of the following flow and water quality formula;

(1) FLOW : Unsteady flow model

$$\frac{dQ}{dt} + \frac{d}{dx}\left(\frac{Q^2}{A}\right) + gA\frac{dZ}{dx} + g\frac{n^2 1010}{A.R4/3} = 0 \text{ ....(a)}$$

$$\frac{dZ}{dt} + \frac{dQ}{dx} = r + q \text{ ....(b)}$$

(2) Water Quality : Box mixing model

$$\frac{dc}{dt} + \frac{d}{dx}(uc) = -L\text{.............................(c)}$$

T: Time

u: Velocity

Q: Flow

A: Sectional flow area

Z: Water level

g: Cravity acceleration

R: Hydraulic radius

r: Rainfall

c: Water quality

q: Side inflow

L: Inflow loding of pollutant

5.3. Fundamental Conditions for Calculation

5.3.1 Topographic and Land Use Conditions

(1) Topography

Present: Ground elevation surveyed in M/P and F/S

Future : Assumed ground elevation in 2000

(2) Klong Section

Present: Existing section surveyed in M/P and F/S

Future : Improved section proposed in M/P and F/S

(3) Land Use and Population

Present: Land use and population in 1983

Future : Land use plan proposed in Master Plan and estimated population in 2000

5.3.2 Hydrological-Hydraulic Conditions

(1) Rainfall

Following average daily rainfall (R24) is considered in rainy season only.

$$R_{24} = \frac{\text{Average monthly rainfall in rainy season}}{\text{30 days}}$$

$$= \frac{150 \text{ mm}}{30 \text{ days}} = 5 \text{ mm/day}$$

Rainfall duration is assumed at 24 hours to estimate the average pollusion in klongs.

(2) Initial Water Level

Maintenance water level is adopted as initial water level condition.

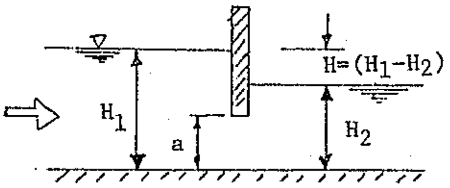
			Present	Future
Rainy season:	Bang Khen-Bang Sue Polder	:	-0.8 above MSL	-1.5 above MSL
	Phra Khanong, Bang Na Polder	:	-0.8	-1.8
Dry season :	Bang Khen-Bang Sue Polder	:	±0	-1.0
	Phra Khanong, Bang Na Polder	:	±0	-1.0

(3) Inflow from outer area as flushing water

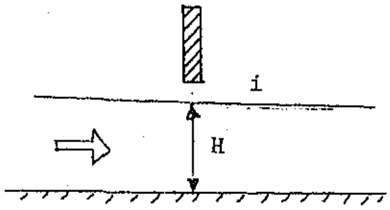
Inflow from outer area, Green Belt Area is estimated based on the recorded water level along the Green Belt embankment between 1984 and 1985 as shown in Fig. K.14.

<u>Table K.9 Inflow from Regulator along Green Belt</u>

Foundamental Equation



< Submerged Flow >



<Open Cannal>

$$Q = m \cdot a \cdot b \cdot \sqrt{2g\Delta H}$$

where.
- Q: Flow (m^3/sec)
- m: Coefficient of Gate
- a: Hight of Gate Opening (m)
- b: Width of Gate (m)
- g: Gravity Acceleration ($9.8^m/sec^2$)
- ΔH: Difference of Up and Down Water Level (m)

$$Q = \frac{1}{n} \cdot H \cdot b \cdot i \cdot R^{\frac{2}{3}}$$

- n: Coefficient of Roughness
- H: Water Hight (m)
- i: Hydraulic Gradient
- R: Hydraulic Radius (m)

Regulator	m	a (m)	b (m)	ΔH (m)	n	H (m)	i	R (m)	Q (m^3/sec)
K.Sai Tai	–	–	6.0	–	0.015	2.3	1/40,000	1.30	5.19
K.Moh Taak	–	–	4.0	–	"	2.1	"	1.02	2.84
K.Phraya Surain	–	–	6.0	–	"	2.0	"	1.20	4.52
K.Saen Saep	0.6	1.0	6.0	0.3	–	–	–	–	8.73
K.Phra Khanong	"	1.0	"	0.15	–	–	–	–	6.17

Note: Water level is based on the observed data in Feburuary, 1985.

Based on the esdtimated inflow from Green Belt Area to retarding area as shown in Table K.9, inflow from retarding area to Master Plan Area through main klongs is assumed as followings.

K.Song	:	5 m^3/sec
K. Chang	:	2
K. Lam Chala	:	2
K. Saen Saep	:	8
K. Phra Khanong	:	6
Total		23 m^3/sec

(4) Pump Operation

Considering the amount of inflow, rainfall and wastewater flow, the number and capacity of pump operation is considered as follows,

K. Bang Khen P.S.	:	1 unit	3 m^3/sec
K. Bang Sue P.S.	:	1	3
K. Phra Khanong P.S.	:	6	18
K. Bang Jek P.S.	:	1	3
K. Bang Oa P.S.	:	1	3
K. Bang Na P.S.	:	1	3
K. Kacha P.S.	:	1	3
K. Bang Na Chin P.S.	:	1	3
Total		13 units	39 m^3/sec

Each pumping station is operated to keep the needed maintenance water level discribed before.

5.3.3 Water Quality Conditions

(1) Initial water quality in klongs

Initial water quality (BOD) in klongs before excecution of sewerage project is adopted the average present value, 15 ppm, in the Master Plan Area. After completion of sewerage project, that is estimated 8 ppm based on the following assumption;

$$L = L_o \times \frac{L_A}{c \times L_B} = 15 \times \frac{32.76}{0.4 \times 162.48} = 8 \text{ ppm}$$

where L : Initial BOD after completion of sewerage project

L_o: Initial BOD before excecution of sewerage project

L_A: Total BOD load after completion of sewerage project

L_B: Total BOD load before excecution of sewerage project

C : Run-off coefficient of BOD load before excecution of sewerage project

(2) Water quality of inflow from outer area

Water quality of inflow is adopted the observed data, 4ppm, in the Green Belt.

(3) Wastewater flow and inflow points

Present and future wastewater flow and inflow points are shown in Fig. K.15 and Table K.10.

(4) Run-off coefficient of BOD load

In case of non sewerage system, run-off coefficient of BOD load before excecution of sewerage project is generally 0.1 to 0.6. In this study it is adopted in average rate 0.4 by the result of caliburation in present condition, calculation Case No. RP-002 and DP-001 shown in Table K.8.

5.4. Evaluation of Water Pollution due to Execution of This Project

As mentioned in Section 3, present average BOD value in the Study Area is approximately 15 ppm shown in Fig. K.8. After execution of this project, initial storage volume in the klongs will be almost 40% less than that at present, due to lower the maintenance water level from ±0 meter to -0.8 meter above MSL. As the result of the sample calculation, Case RP-001, average BOD value in worst case in the Study Area after execution of this project is estimated in 22 ppm, as shown in Table K.11 and Fig. K.16. Accordingly, water quality in the Study Area will be deteriorate by the execution of this project.

Table K.10 List of Wastewater Flow and BOD Load

Inflow Point	Area (Km^2)	Flow (m^3/sec)		BOD Load (t/day)		Inflow Point	Area (Km^2)	Flow (m^3/sec)		BOD Load (t/day)	
		1983	2000	1983	2000			1983	2000	1983	2000
1	6.3	0.034	0.063	0.773	1.399	33	2.3	0.014	0.018	0.307	0.406
2	9.3	0.043	0.058	0.970	1.290	34	1.1	0.001	0.009	0.024	0.192
3	3.1	0.024	0.082	0.533	1.820	35	3.3	0.006	0.032	0.139	0.707
4	6.8	0.077	0.185	1.733	4.134	36	1.2	0.009	0.027	0.192	0.608
5	3.5	0.056	0.233	1.272	5.200	37	6.5	0.021	0.051	0.466	1.128
6	6.0	0.225	0.520	5.078	11.31	38	1.3	0.016	0.063	0.360	1.404
7	5.8	0.097	0.221	2.174	4.940	39	0.9	0.013	0.030	0.298	0.660
8	6.5	0.134	0.224	0.302	5.002	40	4.8	0.127	0.281	2.851	6.261
9	8.6	0.068	0.204	1.540	4.560	41	3.3	0.044	0.131	0.979	2.922
10	1.1	0.023	0.038	0.514	0.848	42	1.7	0.008	0.010	0.173	0.213
11	7.8	0.161	0.269	3.634	6.001	43	2.2	0.013	0.051	0.293	1.144
12	6.0	0.124	0.207	2.794	4.618	44	7.6	0.109	0.201	2.453	4.482
13	10.3	0.273	0.555	6.153	12.39	45	1.8	0.016	0.056	0.360	1.238
14	2.8	0.083	0.151	1.872	3.359	46	1.9	0.018	0.045	0.408	1.004
15	5.2	0.033	0.171	0.754	3.806	47	3.2	0.019	0.079	0.437	1.736
16	7.6	0.456	0.593	10.28	15.48	48	3.1	0.018	0.069	0.408	1.550
17	3.2	0.023	0.102	0.528	2.278	R1	15.2	0.049	0.235	1.109	5.274
18	4.1	0.021	0.081	0.480	1.804	R2	13.8	0.041	0.120	0.931	2.673
19	1.9	0.005	0.037	0.105	0.816	R3	2.3	0.010	0.018	0.235	0.406
20	11.5	0.061	0.263	1.363	5.964	R4	11.8	0.019	0.067	0.427	1.498
21	2.9	0.011	0.026	0.250	0.572	R5	5.6	0.058	0.159	1.306	1.498
22	1.3	0.002	0.010	0.053	0.229	R6	3.5	0.015	0.061	0.346	1.362
23	5.2	0.033	0.171	0.754	3.806	R7	6.4	0.048	0.106	1.090	2.366
24	10.2	0.080	0.191	1.805	4.259	R8	5.8	0.022	0.059	0.504	1.326
25	1.9	0.082	0.180	1.838	4.025	R9	12.5	0.022	0.115	0.494	2.558
26	5.6	0.021	0.089	0.480	1.981	T1		---	0.795	---	3.640
27	1.9	0.014	0.045	0.307	1.004	T5		---	1.336	---	6.120
28	1.7	0.008	0.024	0.182	0.530	T6		---	0.801	---	3.670
29	2.1	0.009	0.020	0.211	0.452	T7		---	2.289	---	10.48
30	3.3	0.078	0.112	1.762	2.512	T8		---	1.044	---	4.780
31	2.4	0.034	0.066	0.768	1.482	T9		---	0.883	---	4.070
32	3.8	0.032	0.066	0.730	1.466						

Table K.11 Water Quality (BOD) in Drainage Area for Each Calculation Case

Case	Item \ Drainage Area	Bangkhen Bang Sue	Huay Kwang	Lat Phrao	Klong Chang	Hua Mark	Patterna Kham	Bang Na	Master Plan Area
RP-001	BOD Load (t)	26.1	15.7	11.2	6.8	16.3	5.70	6.50	88.3
	Storage Volume ($x10^6 m^3$)	1.06	0.65	0.46	0.29	0.93	0.36	0.25	4.00
	BOD (ppm)	25	24	24	17	17	16	26	22
RP-002	BOD Load (t)	19.0	12.6	5.6	3.2	14.5	4.4	4.2	63.7
	Storage Volume ($x10^6 m^3$)	1.06	0.65	0.46	0.29	0.93	0.36	0.25	4.0
	BOD (ppm)	18	19	12	13	16	12	17	16
RF-001	BOD Load (t)	39.1	45.1	20.4	12.0	29.4	13.5	10.2	169.7
	Storage Volume ($x10^6 m^3$)	1.66	2.14	1.12	0.78	1.88	0.90	0.55	9.02
	BOD (ppm)	24	21	18	15	16	15	19	19
RF-002	BOD Load (t)	20.1	24.6	15.8	9.50	18.0	8.0	7.3	103.3
	Storage Volume ($x10^6 m^3$)	1.66	2.14	1.12	0.78	1.88	0.90	0.55	9.02
	BOD (ppm)	12	12	14	12	10	9	13	9
DP-001	BOD Load (t)	20.8	24.4	6.9	3.3	18.4	3.0	7.1	83.9
	Storage Volume ($x10^6 m^3$)	1.40	1.00	0.60	0.50	1.30	0.50	0.40	5.59
	BOD (ppm)	15	24	11	7	15	6	18	15
DF-001	BOD Load (t)	44.6	46.8	18.8	7.4	28.6	6.1	11.7	163.9
	Storage Volume ($x10^6 m^3$)	2.19	2.15	1.12	0.78	1.83	0.69	0.71	9.46
	BOD (ppm)	20	22	17	9	16	9	16	17
DF-002	BOD Load (t)	24.1	28.1	16.9	5.8	16.6	6.7	8.7	106.8
	Storage Volume ($x10^6 m^3$)	2.19	2.15	1.12	0.78	1.86	0.69	0.72	9.46
	BOD (ppm)	11	13	15	7	9	10	12	11

5.5 Estimation of Water Quality in Future 2000

As the result of the rough calculation, Case No. RF-001, DF-002, even if klongs will be improved and initial storage volule in klongs will be increased in order of two times, water pollution in klongs will be deteriorate in order of almost 17 ppm in dry season and about 19 ppm in rainy season due to increasing of BOD load by urbanization (Table K.11, Fig. K.17).

5.6 Effect of Water Pollution Control Measures

Seven sample calculations for brief evaluation of water pollution control measures, such as flushing measures and Bangkok Sewerage Project, have been carried out by complete mixed flow model due to the foundamental conditions mentioned before. Table K.11 and Fig. K.16 and K.17 show BOD of each calculation cases in drainage area and inflow points respectively.

As the result of brief evaluation based on the sample calculation, Case No. RP-001 and DP-001, the effect of flushing measures can be expressed by BOD and BOD load decreasement in order of 15 to 40 percent as shown in Fig. K.18. Accordingly, after execution of this project, even if klong water level will be maintained in lower level, water quality in klongs will be improved by flushing up to same condition before

The effect of Bangkok Sewerage Project proposed by JICA in 1981 is estimated approximately 30 to 50 percent in condition of future 2000, as shown in Fig. K.18, based on the sample calculation, Case No. DF-001, DF-002, RF-001 and RF-002.

However, even if the above water pollution control measures will be executed, the water quality of klong in future 2000 will be forecasted almost as same as present conditions, because of rapid urbanization and water use. Accordingly, it will be necessary to be carried out the further study for water pollution control measure, i.e. increasing BOD reaction rate in klong by aeration, increasing flush water from outer area and providing high degree wastewater treatment harmonized economic condition.

6. BOD Reaction Coefficient

6.1 Field Survey of BOD Reaction Coefficient of Klong

6.1.1 Selection of Survey Field

For the survey of BOD reaction coefficient of klong, it is generally reasonable to select the survey field having the following conditions,

(1) The site condition of discharge observation and water sampling works is good for the implementation of survey.

(2) The variation of discharge flow, klong-bed slope and velocity in survey section are not to be so big.

(3) The variation of water quality in cross section at sampling section is uniform.

(4) BOD value of discharge at sampling station is to be at least more than 3 mg/l.

(5) Estimation of the inflow BOD load in the survey section is to be possible.

(6) Time of concentration in the survey section is to be more than 4 hours.

The Study Area is traversed by the extensive network of klong. The density of distribution of the klong is more than one kilometer per one square kilometer, moreover, there are many houses along the klongs. Accordingly, it can not find the klongs which satisfy the all survey conditions mentioned above.
In this Study, mainly considering the above items, (1), (3), (4), and (5), the down-stream section of K. Lat Phrao, approximately 3.0 kilometers in length, has been selected, as the reasonable survey section. Fig. K.19 to Fig. K.20 show the location map and profile of survey section, and cross section of five observation points including the blanch klongs.

6.1.2 Field Survey Items and Times

Field survey items and times are shown in Table K.12.

Table K.12 Field Survey Items and Times

Survey Item	Survey Times	Remarks
Discharge Flow Measurement	3	
Water Sampling	3	

6.1.3 Determination of Survey Interval

As shown in Fig. K.19,

Distance between Point C and Point B: L_1=1,600m
Distance between Point B and Point A: L_2=1,400m

Based on the pre-field investigation on 6, July, 1985, the average velocity (Vave) of survey section has been observed in approximately Vave=0.25 m/sec.
Accordingly, survey interval are estimated as follows,

Between Point C and B: $T_1 = \frac{L_1}{Vave} = \frac{1,600}{0.25} = 1.8^{hr}$

Between Point B and A: $T_2 = \frac{L_2}{Vave} = \frac{1,400}{0.25} = 1.6^{hr}$

However, the average velocity of klong will varied based on the discharge flow at the date of survey. In fact, survey interval should be everytimes estimated based on the result of practical velocity survey.

6.1.4 Water Sampling Point and Depth

Water smapling should be generally carried out at the center of the flow and in position of 20 percent water depth under the water surface. If the water depth is shallow, water smapling should be taken are not to muddle the bed soil.

6.1.5 Chemical Analysis

Chemical analysis for sampling has been carried out the following 6 items.

(1) Temperature
(2) PH
(3) Dissolved Oxygen (DO)
(4) Biochemical Oxygen Demand (BOD)
(5) Chemical Oxygen Demand (COD)
(6) Suspended Solids (SS)

6.1.6 Survey Result

The result of the field survey and chemical analysis, carried out three times between July and September in 1985, are shown in Table K.13.

6.2 Estimation of BOD Bottle Reaction Coefficient

The BOD has been classically formulated as a continuous first-order reaction of the form

$$y = L_o\,(1-10^{-kt})$$

where
- y = amount of oxygen consumed or BOD after any time t
- Lo = ultimate BOD or the total amount of oxygen consumed in the reaction
- k = average reaction coefficient
- t = time of incubation, days

Both k and Lo are generally unknown in the BOD reaction formula indicated above, so an indirect calculation must be used. Several procedures have been developed for this, for example,

(1) Method of moments
(2) Log-difference method
(3) Grophical method

of which the graphical method is employed in this study. $(t/y)^{1/3}$ is plotted as the ordinate vs.t as the abscissa, based on the BOD test data. For the plot,

$$k=2.61\frac{b}{a}, \qquad Lo=\frac{1}{2.3\ ka^3}$$

where b is the slope of the line and a is the intercept. Constant a and b can be calculated by means of least squares method.

Table K.13 Water Quality and Discharge of Survey Section

Station	Temp. (°c)	PH	SS (mg/l)	COD (mg/l)	BOD5 (mg/l)	DO (mg/l)	BOD1	BOD2	BOD3	BOD5	BOD7	Discharge (m^3/sec)	Average Velocity (m^3/sec)	Observation,Data
A	30.0	7.2	33	51	18	0.0	8	10	11	18	22	4.68	0.16	19, Jul. 1985
	29.5	7.3	19	66	11	0.0	4	9	10	11	19	3.52	0.13	30, Jul. 1985
	30.0	7.3	19	50	9	0.0	–	–	–	–	–	5.68		29, Aug. 1985
B	30.0	7.1	22	42	19	0.0	6	10	12	19	21	4.16	0.13	19, Jul. 1985
	29.5	7.3	19	92	13	0.0	10	10	10	13	15	4.00	0.17	30, Jul. 1985
	29.5	7.2	17	46	10	0.0	–	–	–	–	–	5.24		27, Aug. 1985
C	29.5	7.1	17	58	24	0.0	10	15	20	24	25	4.65	0.15	19, Jul. 1985
	29.5	7.4	17	70	12	0.0	6	10	11	12	13	4.60	0.15	30, Jul. 1985
	29.0	7.3	13	44	12	0.0	–	–	–	–	–	6.26		29, Aug. 1985
D	30.0	7.1	24	43	22	0.0	3	9	14	22	28	0.00	0.00	19, Jul. 1985
	30.0	7.5	18	58	6	0.0	6	8	9	10	12	0.48	0.05	30, Jul. 1985
	30.0	7.2	24	35	8	0.0	–	–	–	–	–	0.0		29, Aug. 1985
E	30.0	7.2	27	32	20	0.0	3	6	9	20	22	0.58	0.07	19, Jul. 1985
	30.0	7.6	22	64	16	0.0	5	6	15	16	18	0.39	0.04	30, Jul. 1985
	30.0	7.3	19	42	10	0.0	–	–	–	–	–	0.91		29, AUG. 1985

Table K.14 BOD Reaction Coefficient and Ultimate BOD

Station	Sample No.	a $\left(\frac{1}{2.3k\ Lo}\right)$	b $\left(\frac{(2.3k)^{\frac{2}{3}}}{6\ Lo^{\frac{1}{3}}}\right)$	Correlation Coefficient r	k $\left(\frac{2.616}{a}\right)$	Lo $\left(\frac{1}{2.3\ k\ a^3}\right)$
A	A1	0.521	0.026	0.846	0.130	23.6
	A2	0.599	0.022	0.796	0.096	21.1
B	B1	0.542	0.022	0.965	0.106	25.8
	B2	0.471	0.048	0.936	0.266	15.6
C	C1	0.440	0.031	0.996	0.184	27.7
	C2	0.504	0.046	0.995	0.238	14.3
D	D1	0.648	-0.006	0.362	-0.024	66.6
	D2	0.530	0.047	0.976	0.231	12.6
E	E1*	0.697	-0.005	0.463	-0.019	67.6
	E2	0.584	0.019	0.710	0.085	25.7
Aeverage		0.524	0.033	--	0.167	20.8

Note. Data presented in * are not available, so this is not considered in average.