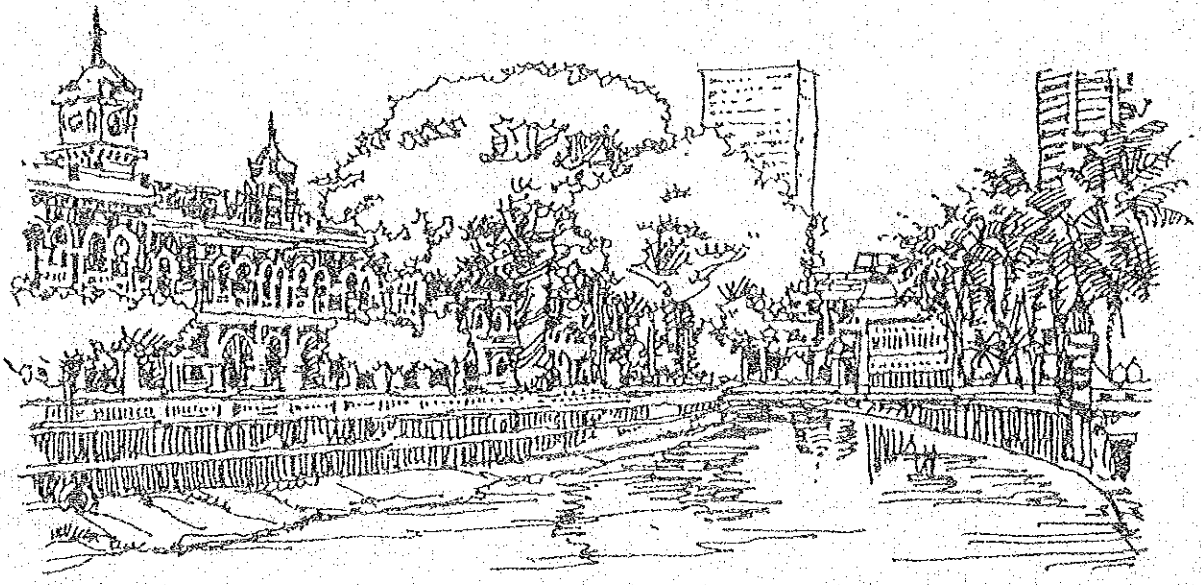
GOVERNMENT OF MALAYSIA

THE STUDY ON THE FLOOD MITIGATION OF THE KLANG RIVER BASIN

MAIN REPORT



JANUARY 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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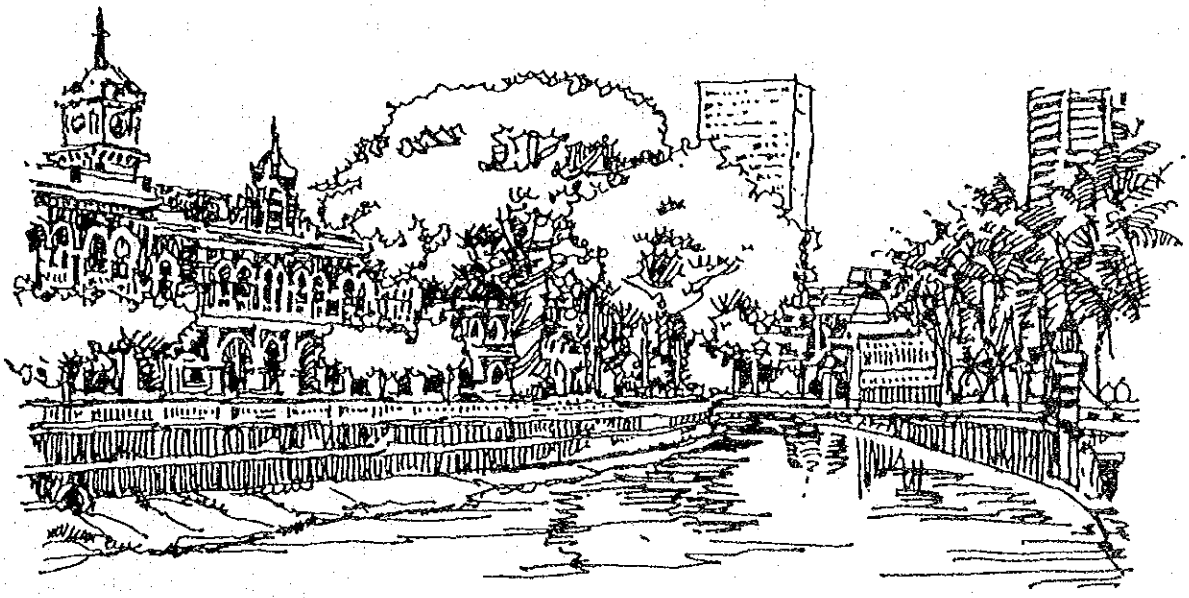


JANUARY 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of Malaysia, the Government of Japan decided to conduct a Study on the Flood Mitigation of the Klang River Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Malaysia a study team headed by Mr. Saburo FUKAGAWA of Pacific Consultants International, from October to December, 1987 and from May to June, 1988.

The team held discussions with concerned officials of the Government of Malaysia, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the development of the project and to the promotion of the friendly relations between our two countries.

I wish to express my sincerest appreciation to concerned officials of the Government of Malaysia for their close cooperation extended to the team.

January, 1989

Kensuke Yanagiya

Kensuke YANAGIYA
President
Japan International Cooperation Agency

THE STUDY

ON

THE FLOOD MITIGATION OF THE KLANG RIVER BASIN

Mr. Kensuke YANAGIYA
President
Japan International
Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

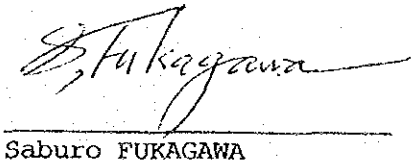
We are pleased to submit to you the final report entitled "THE STUDY ON THE FLOOD MITIGATION OF THE KLANG RIVER BASIN". This report has been prepared by the Study Team in accordance with the contract signed on 19 September 1987 and 18 May 1988 between the Japan International Cooperation Agency and the consortium of consultants comprising Pacific Consultants International and Nippon Koei Co., Ltd.

The report examines the feasible flood mitigation measures in the basin, presents a flood mitigation master plan and the results of a feasibility study on an urgent project comprising river improvement works, retention ponds, and drainage works in lowlying areas.

The report consists of the Executive Summary, Main Report, and Supporting Reports. The Summary summarises the results of all studies. The Main Report contains background conditions, flood mitigation Master Plan, urgent flood mitigation plan, conclusions and recommendations. The Supporting Report includes data and technical details. In addition, a Data Book has been prepared and is submitted herewith.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Malaysia, and also to officials and individuals of the Government of Malaysia for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the socio-economic development and well-being of the Klang River basin.

Yours faithfully,



Saburo FUKAGAWA
Team Leader

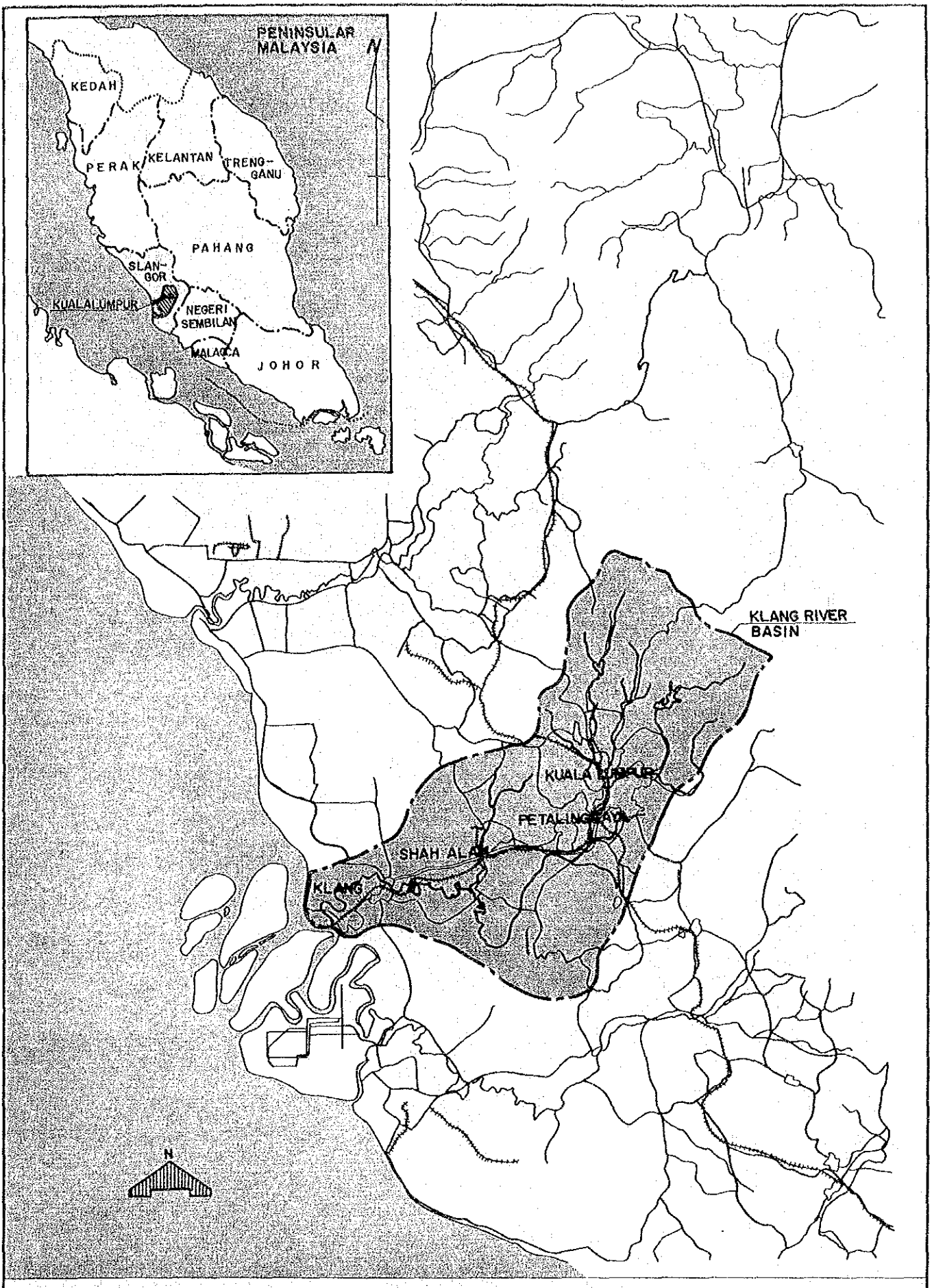
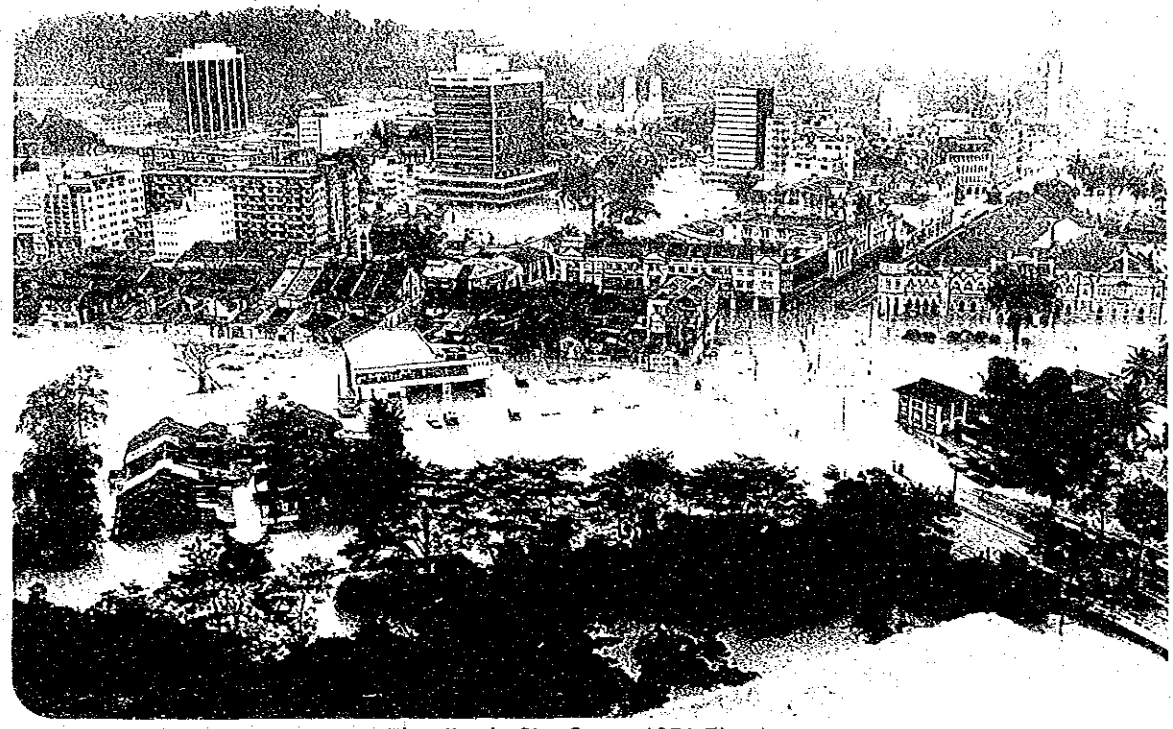


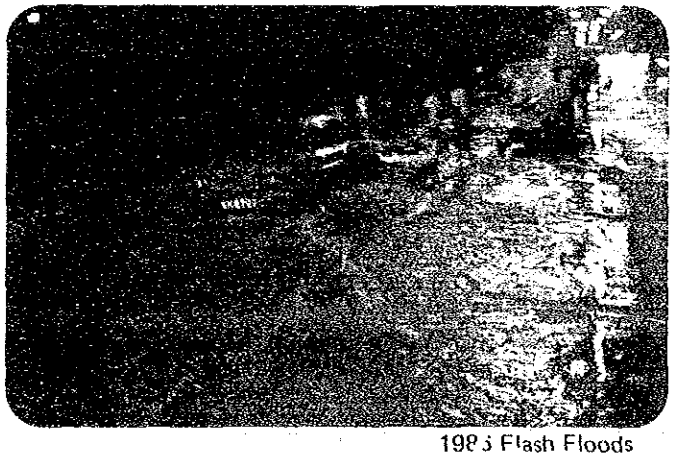
Fig. I LOCATION MAP OF THE STUDY AREA

THE STUDY ON THE FLOOD MITIGATION OF THE KLANG RIVER BASIN

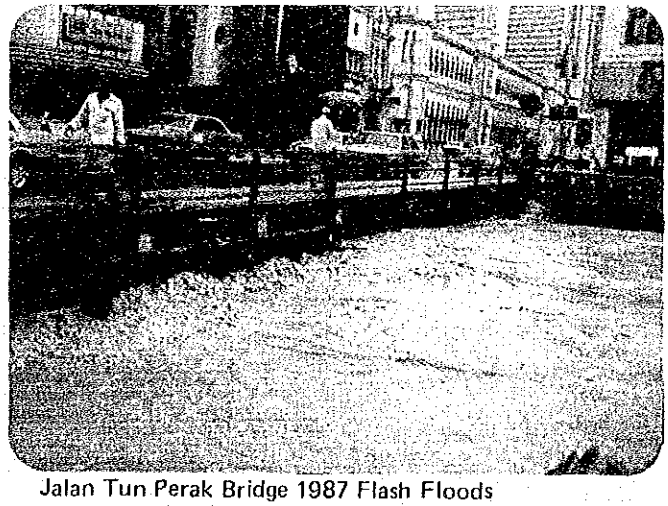
JICA



Flooding in City Centre 1971 Floods



1983 Flash Floods



Jalan Tun Perak Bridge 1987 Flash Floods

	Discription	Unit	Q'ty	Short Term					Mid Term					Long Term				
				93	94	95	96	97	98	99	2000	2001	2002	2003	2004	2005	2006	2007
PHASE -1 (Urgent Project)	1. Batu retention pond	ha	113.4															
	2. Diversion channel	km	3.3															
	3. River Improvement																	
	- Batu river																	
	B2 (R2, 3.4) Windening & Deepening	km	3.4															
	B1	km	3.2															
	- Gombak river																	
	G4 (R7) Widening & Deepening	km	2.5															
	- Klang river																	
	K9 (R10, 11) Widening & Deepening	km	4.1															
	4. Inner water Drainage	m3/sec	2.0															
PHASE -2	1. River Improvement																	
	- Klang river																	
	K7 Widening	km	4.4															
	K6 Widening	km	10.1															
	K2 Widening & Deepening	km	9.4															
	K10 Widening & Deepening	km	3.3															
	K4 Widening & Deepening	km	9.1															
	K5 Widening & Deepening	km	5.4															
	K3 Embankment	km	13.5															
PHASE -3	1. Puchong Drop Removal																	
	2. River Improvement																	
	- Klang river																	
	K6 Deepening	km	10.1															
	K7 Deepening	km	4.4															
	K8 Deepening	km	5.7															
	- Gombak river																	
	G1 Deepening	km	2.4															
	G2 Widening & Deepening	km	2.8															
	G3 Widening & Deepening	km	2.2															
	- Klang river																	
	K1 Widening & Deepening	km	11.4															
	K3 Widening & Deepening	km	13.5															
	K11 Widening & Deepening	km	6.2															
	- Batu river																	
	B1 Deepening	km	1.4															

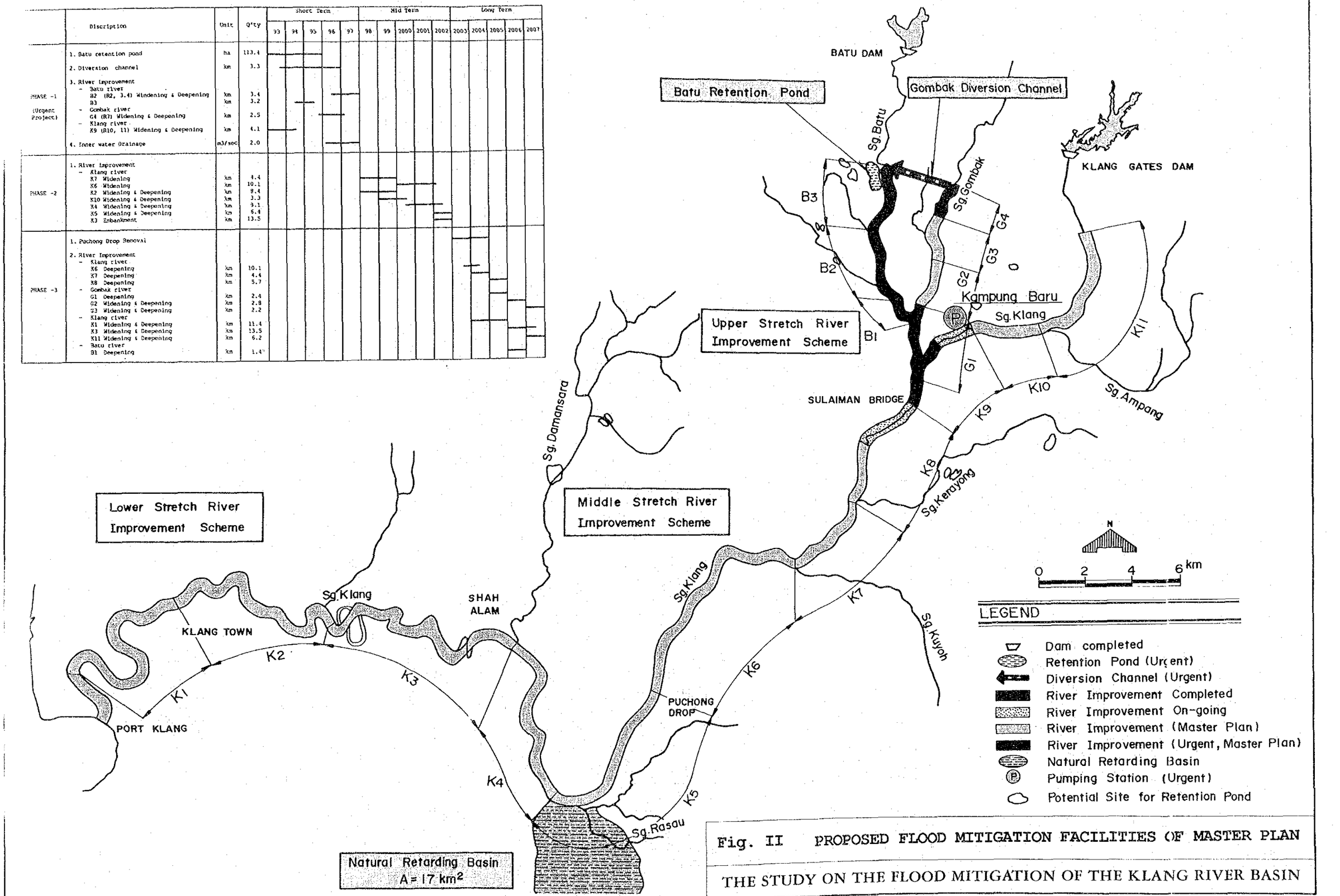
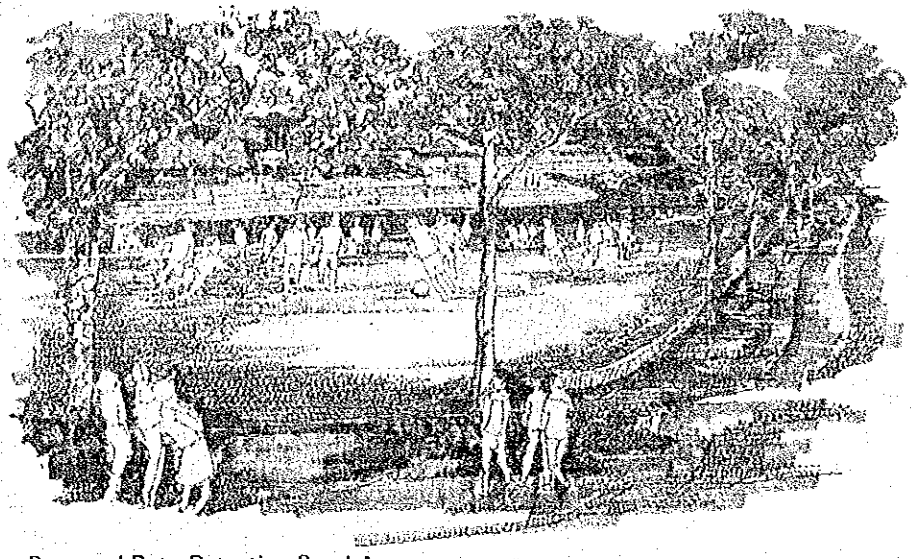


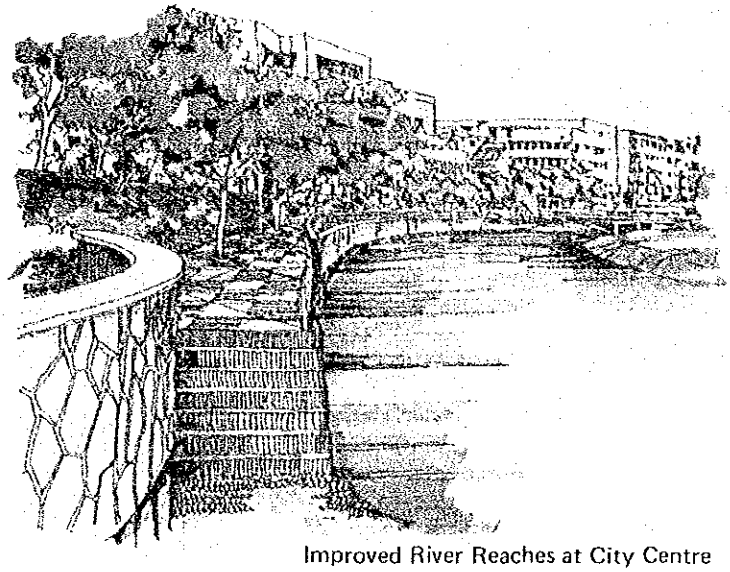
Fig. II PROPOSED FLOOD MITIGATION FACILITIES OF MASTER PLAN

THE STUDY ON THE FLOOD MITIGATION OF THE KLANG RIVER BASIN

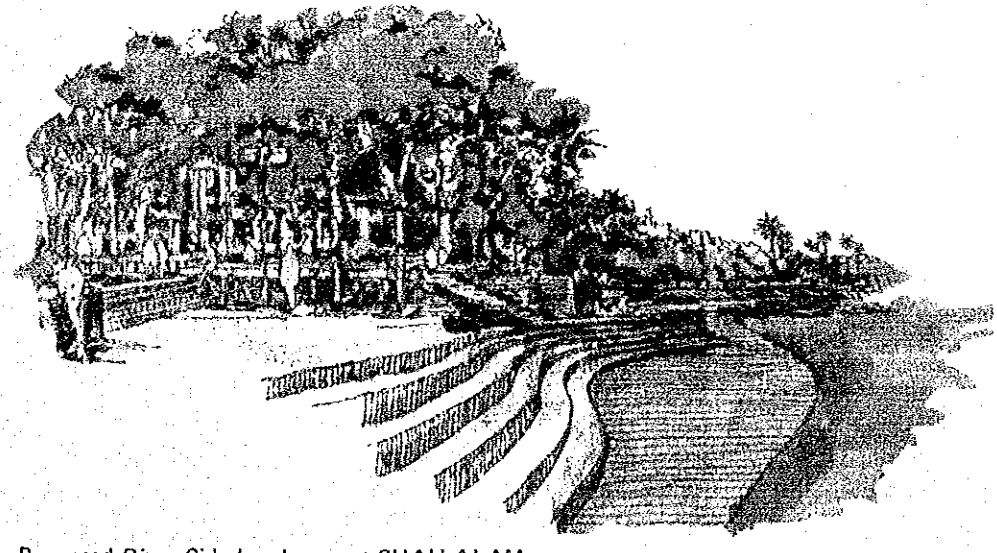
JICA



Proposed Batu Retention Pond Area



Improved River Reaches at City Centre



Proposed River Side Landscape at SHAH ALAM

SUMMARY

SUMMARY

1. Introduction

The Klang river basin (the Study Area) is located towards the west coast of Peninsular Malaysia, in the central part of Selangor state, as shown in Fig. I. The basin consists of the most urbanized and still rapidly urbanizing regions including the nations' Federal Capital of Kuala Lumpur, and is affected by recurrent flooding of Klang River and its tributaries. This necessitated the mitigation of flood damage in the basin, and hence the identification of this project, "The Study on the Flood Mitigation of the Klang River Basin".

This study was carried out by the Study Team of the Japan International Cooperation Agency (JICA) in collaboration with the officials concerned of the Federal Government of Malaysia from October 1987 to January 1989.

2. Study Area

The study area is the whole drainage basin (Area of Basin is 1,288 sq. km) of the Klang river with a mainstream length of 120 km and its tributaries, the Batu river, Gombak river, Kerayong river and others. The river reaches, and also the respective river sub-drainage basins, are divided into upper, middle and lower reaches as shown in Fig. II.

The annual mean rainfall in the Basin is about 2,300 mm. The rainfall is maximum during the northeast monsoon season in October ~ November and the southwest monsoon season in April.

The total population in the Klang river basin (Study Area) has increased from 1,266,000 people in 1970 to 2,020,000 people by 1980. The average annual population growth rate of the region during this decade was 4.8%. According to the Klang Valley Perspective Plan, the population is estimated to reach 4,760,000 people by 2000.

The present land-use pattern of the Study Area is urbanized area of 27.5%, agricultural area of 41.8%, forest reserve/swamp area of 27.4% and mining area of 3.3%. The urbanized area is expected to increase up to 43.9% in 2005, while that of agricultural area would decrease to 20.1%.

The projected rates of increase in urbanized area for the upper, middle and lower basins from 1985 to 2005 are 30.3%, 32.3% and 146.5% respectively.

3. Objectives of the Study

The objectives of the study are:

(a) To review the existing flood mitigation plan for Kuala Lumpur
(b) To formulate a master plan of flood mitigation for the whole Klang River Basin, and
(c) To conduct a feasibility study for an urgent flood mitigation project selected in the master plan.

4. Floods and Flood Damage

4.1 Rainfall

Flooding in the Klang River Basin is caused by both depression-type monsoon storms and thunderstorms.

Depression storms

- Wide spread over the whole Basin
- Are of long duration (3 - 5 days) with low intensity
- Cause flooding in mainstream of Klang River with large catchment areas

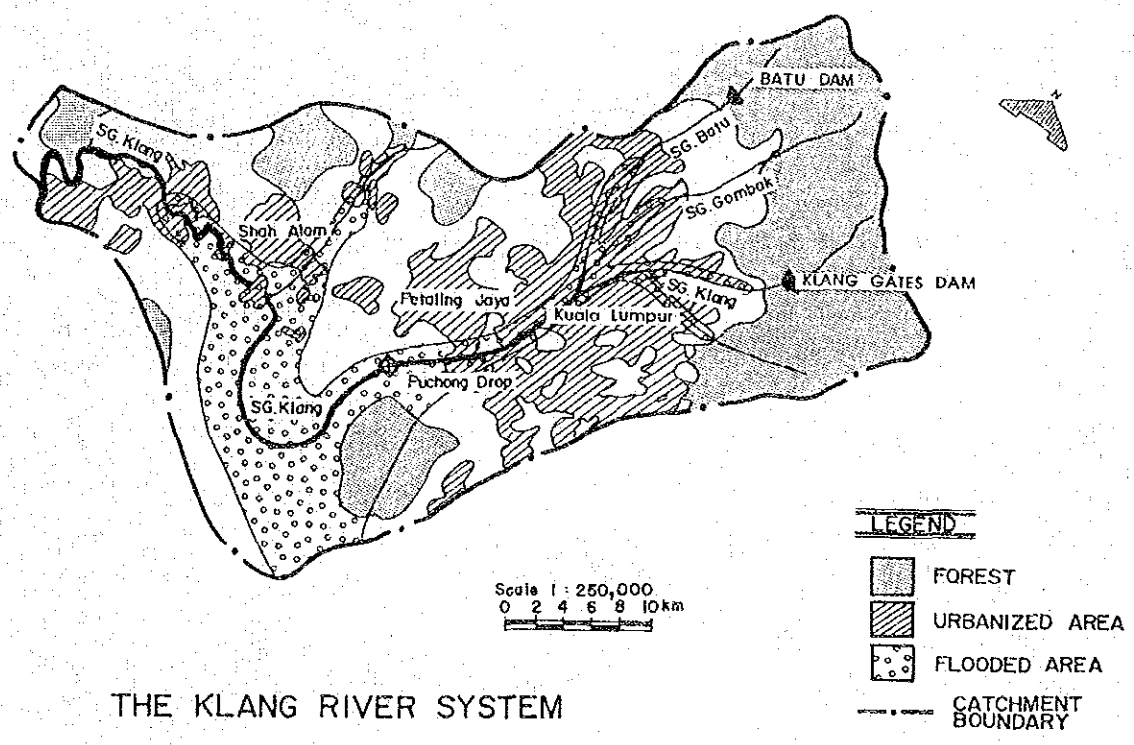
Thunder storms

- Occurance is very frequent but highly localized.
- Are of short duration (3 - 5 hrs) with high intensity.
- Cause flooding in tributaries

4.2 Flood history

Over the period 1949 - 1988, eleven occurrence of significant flooding of the Klang River were recorded at Sulaiman Bridge in Kuala Lumpur. The most severe floods ever recorded was in January 1971 which persisted for 5 days.

The Klang River System along with the affected area by this floods is illustrated below. This flood area is demarcated as the flood vulnerable area in this study.



THE KLANG RIVER SYSTEM

4.3 Cause of flooding

The cause of flooding in the Klang River Basin is summarized below.

(a) Increase in Storm Run-off

- Increase of run-off coefficient of the Basin due to rapid urbanization.
- Loss of ex-mining ponds as potential retention ponds due to refilling for land developments.

- Improvement of drainage at upstream or tributaries to an excessive scale compared to the discharge capacity of downstream stretch.
- Flowing down of floating logs in the river channel during floods.
- Sediment run-off into the trunk drainage or river due to soil erosion caused by land development.

(b) Problem of Drainage Facilities

- Inadequate flow capacity of river channel or trunk drainage.
- Existence of lowlying area.
- Insufficient clearance at bridge crossings.
- Tidal effect in the downstream reaches.

5. Master Plan

5.1 Basic Considerations

The basic considerations in formulating the comprehensive flood mitigation Master Plan are as follows:

- It is impossible to realize an economically viable perfect flood mitigation plan for the whole River Basin
- Both the structural and non-structural measures will be considered to limit the flood damage to an acceptable level in the whole River Basin. (Comprehensive flood mitigation plan)
- The master plan is formulated under the conditions of a design rainfall of 100 year frequency and the projected land-use pattern in the year 2005.
- The formulated master plan is in compatible with the existing ongoing Kuala lumpur flood mitigation plan.

5.2 Master Plan Alternatives

Five possible alternative protective measures of flood mitigation are evaluated for the selection of most suitable alternative as the master plan. Each of these alternatives consist of a combination of

several structural measures, which include both the existing two dams, that are capable in limiting the discharge in the Klang River at Sulaiman Bridge to the permissible maximum of 730 m^3/s. The optimum alternative was selected as the master plan based on both technical and economic considerations.

5.3 Structural Measures of Master Plan

The structural measures of flood mitigation are as follows:

(1) Construction of multipurpose Batu Retention Pond with a total area of 113.4 ha
(2) Construction of the Gombak Diversion Channel with 3.2 km length
(3) Use of the Natural Retarding Basin
(4) Removal of the Puchong Drop
(5) Channel improvement of 94.7 km in length for the Klang, the Gombak and the Batu Rivers
(6) Construction of pumping station in Kampung Baru
(7) Reconstruction of 10 bridges

Plan of the flood mitigation facilities of the master plan is shown in Fig. II.

5.4 Non-structural Measures of Master Plan

A major nonstructural measure incorporated in the Master Plan is the natural retarding area at Sg.Rasau. In addition the following non-structural measures are also recommended.

1) Institutional Framework
2) Establishment of Comprehensive Flood Mitigation Committee
3) Effective Management and Monitoring of the Basin Land Use
4) Identification and Publicizing of Flood Prone Area
5) Encouragement of Individual Flood-proofing Measures
6) Control of Discharge of Tributaries
7) Soil Erosion and Run-off Control
8) Formulation of Design Criteria for River and Related Structures
9) Flood Forecasting and Warning System

5.5 Implementation Program

Implementation of the master plan is divided into three phases, with a total period of fifteen years, considering the scale of investment, the extent of economic effectiveness, and degree of urgency.

i) Phase I (Urgent Project)

The urgent project is discribed in the proceeding chapter.

ii) Phase II (Mid-term Plan)

The mid-term plan consists of river improvement works in the middle and lower reaches of the Klang River, mainly at downstream of the Puchong Drop.
The flood protection levels after completion of these river improvement works in this stage will become about a 30-year return period for the middle reach and a 100-year return period for the Kland town reach.

iii) Phase III (Long-term Plan)

Initially at Phase III the Puchong Drop will be removed to facilitate river improvement works at its upstream stretches. Then the widening and/or deepening of the remaining stretches of main Klang river, Gombak and Batu rivers will be executed. Thereby the required design target, provision of a river discharge capacity for 100 year frequency floods, will be achieved in the whole river stretches of the Klang River Basin. The overall implementation schedule of the Master Plan is shown in Fig. II.

5.6 Flood Protection Level of Master Plan

The degree of flood protection level that will be achieved for each stretch of the rivers by the implementation of each of the three (3) project phases is as follows:

Stretch \ Phase	Present	Phase I	Phase II	Phase III
Upper Stretch				
Klang River				
K9	1/10~1/25	1/100	1/100	1/100
K10	~1/10	~1/10	1/100	1/100
K11	1/10~1/100	1/10~1/100	1/10~1/100	1/100
Gombak River				
G1	1/25	1/35	1/35	1/100
G2	1/10	1/10~1/25	1/10~1/25	1/100
G3	1/10~1/30	1/30	1/30	1/100
G4	1/5~1/10	1/100	1/100	1/100
Batu River				
B1	1/5~1/10	1/35	1/35	1/100
B2	~1/5	1/100	1/100	1/100
B3	1/10~1/20	1/100	1/100	1/100
Middle stretch				
klang River				
K6	~1/10	~1/10	1/35	1/100
K7	~1/10	~1/10	1/35	1/100
K8	~1/10	1/35	1/35	1/100
Lower Stretch				
K1	1/100~	1/100~	1/100~	1/100~
K2	1/100~	1/100~	1/100~	1/100~
K3	~1/10	~1/10	1/30	1/100
K4	~1/10	~1/10	1/100	1/100
K5	~1/10	~1/10	1/100	1/100

Note: Also refer Fig. II for details on river stretches.

5.7 Project Cost of Master Plan

The total project cost of the Master Plan is estimated to be 619 million M$ in 1988 financial price. The cost breakdown for each of the three phases is as follows:

	Million M$
Phase I	193.1
Phase II	172.4
Phase III	253.3

5.8 Economic Evaluation of Master Plan

The economic evaluation of the master plan was made in terms of the Internal Rate of Return (IRR), Net Present Value (NPV) and Benefit-Cost Ratio (B/C), based on the following assumptions:

1) The annual operation and maintenance costs are assumed to be 1.0% of economic construction cost.

2) The project benefits are assumed to be realized from 5 years after the beginning of the project implementation, in 1998.

3) The opportunity cost of capital is 13.0%.

4) Evaluation period is set at 50 years.

The results of this Economic Evaluation is as follows:

1) IRR = 19.5%
2) B/C = 1.66
3) NPV = 193,145 (M$1000)

6. Urgent Flood Mitigation Plan

6.1 Priority Area

The existing urban area of Kuala Lumpur City often suffers flood damage and requires immediate attention. Hence, an "urgent flood mitigation plan", the Urgent Project of Phase I, based on the master plan is formulated by demarcating a priority project area.

6.2 Urgent Flood Mitigation Facilities

The flood mitigation facilities of the Urgent Project are as follows:

- River improvement works of 10.4 km in length for the stretches of the Klang, Gombak and Batu Rivers.
- The Batu Retention Pond and the Gombak Diversion Channel.
- Drainage works for Kampung Baru low lying area.

River Improvement

Klang River - A stretch of 1.3 km in length between Tun Perak Bridge and Jln. Sultan Ismail Bridge is to be widened and deepened.

Gombak River - A stretch of 2.5 km in length between Sg. Belongkong confluence and Gombak Diversion Channel is to be widened and deepened to facilitiate in diverting the design discharge into diversion channel.

Batu River - A stretch of 6.6 km in length at downstream of Batu retention pond is to be widened and deepened to obtain the necessary water depth for retention pond operation.

Batu Retention Pond

The Batu Retention Pond is to be constructed using the ex-mining area as shown in Fig. II.

Capacity of the Retention Pond is 2,700,000 cubic meters with a total area (including park) of 113.4 ha. The maximum effective depth for flood mitigation is 7.3 m.

The central portion of the pond is permanently filled with water and the surrounding portion is planned as a temporary pond.

The entire temporary pond area will be sub-divided into several portions to meet the retention capacity required for various levels of probable floods.

Gombak Diversion Channel

The diversion channel of 3250 m length will pass through the original ex-mining area. Major related structures are two box culverts which cross K.L.-Karak Highway and urban planning road near the Batu Retention Pond, and five bridges.

The overflow weir of 55 meters long and 2.60 meter high will be constructed at the entrance of the diversion channel.

Drainage Plan and Kampung Baru Area

About 35 ha of Kampung Baru Area will be lower than the design flood level of the Klang River after completion of all improvement works. The inner water problem caused by frequent inundation due to flash floods in this area is to be solved by a pumped drainage system with underground pondage as given below:

Design recurrence intervals : 5-years

Pump capacity : 2 m^3/s

Underground pondage capacity : 32,700 m^3

Trunk drainage : Box culvert 2,050 m

6.3 Project Cost

The construction cost of the Urgent Project is estimated based on the price prevailed in 1988. The cost breakdown is given below:

Unit: Mx10^3$

	Foreign Currency	Local Currency	Total
Direct construction cost	29,791	60,454	90,245
Land acquisition/ compensation	-	62,138	62,138
Administration cost	-	4,422	4,422
Engineering cost	3,095	1,326	4,421
Contingency	6,377	25,506	31,883
Total	39,263	153,846	193,109

Note: Exchange rate: US$1 = M$2.55 = ¥125

6.4 Economic Evaluation

The economic evaluation of the urgent project was made based on the assumption that the benefit increases exponentially between 1988 to 2005, and remains constant after 2005.

The results of evaluation are as follows:

EIRR = 15.7%

B/C = 1.24

NPV = 32,576 million M$

Sensitivity analysis was carried out on the above economic indicators. Accordingly, the Urgent Project is found to be economically feasible even if the cost increased by 20% or the benefit decreased by 10%.

7. Conclusion and Recommendations

(1) The master plan on flood mitigation of the Klang River Basin is proposed consisting of both structural and non-structural measures. The protective measures proposed are river improvement works, retention pond, diversion channel, retarding areas and others. The proposed plan is both technically and economically feasible, and also socially justifiable.

(2) Immediate implementation of the urgent project, Phase I of the 3 Phases of Master Plan, is extremely important, because of the presence of flood prone built-up areas and low-lying areas undergoing frequent flood damage caused by flash floods.

(3) The required land acquisition shall be completed before the commencement of construction works in order to ensure a smooth implementation of the Project.
It is also recommended to reserve immediately the required land area for the natural retarding basin at Sg.Rasau.

(4) It is very important to control the discharges from the tributaries. The existing ex-mining ponds in the Klang River Basin serve as retention ponds of flood mitigation.
Hence, it is strongly recommended to preserve these ponds for flood mitigation.

(5) It is strongly recommended to institute the Klang River Comprehensive Flood Mitigation Committee under the Klang Valley Planning Secretariat chaired by DID.

(6) It is necessary to publicize the importance of flood mitigation. In this regard, especially, it is recommended to publicize the flood risk maps to enhance the awareness and concern of the residents on the required flood protection measures and the available evacuation systems, in case of emergency.

(7) It is recommended to formulate the creteria to institute new retention ponds inaccordance with land development activities in the basins of the tributaries.

(8) Instituting the Radar Raingauge system of rainfall measurement is a very important step towards modernizing the existing flood forecasting and warning system of the Klang River basin. Further detailed study on this Radar Raingauge system requirement is recommended to be carried out, if necessary, utilizing international expertise.

(9) It seems to be possible to improve the Klang River water quality by dilution water from the two existing dams. However, it is necessary to conduct further detailed studies by taking into account other conflicting future benefitial water demand such as water supply and the resulting increase in wastewater generation.

(10) It is recommended to institute a training centre of river engineering to train local technical personnel on advanced techniques of flood mitigation, drainage and coastal engineering.

ABBREVIATION

(1) Organization

BAS	:	Bekalan Air Selangor
DID (JPT)	:	Drainage and Irrigation Department
DOA	:	Department of Agriculture
DOE	:	Department of Environment
DOS	:	Department of Statistic
EPU	:	Economic Planning Unit
FELD	:	Federal Land Development Authority
FMD	:	Federal Marine Department
HICOM	:	Heavy Industry Corporation of Malaysia
JICA	:	Japan International Cooperation Agency
KTM	:	Keretapi Tanah Melayu
KVPS	:	Klang Valley Planning Secretariat
KVRPC	:	Klang Valley Regional Planning Council
MOA	:	Ministry of Agriculture
MOC	:	Ministry of Construction, Japan
NEB (LLN)	:	National Electricity Board
OECF	:	Overseas Economic Cooperation Fund, Japan
PWD (JKR)	:	Public Works Department
SEPU	:	State Economic Planning Unit
STM	:	Syarikat Telekom Malaysia
USBR	:	United States Bureau of Reclamation

(2) Plan

KVEIP	:	Klang Valley Environmental Improvement Project
KVPP	:	Klang Valley Perspective Plan
KLFMP	:	Kuala Lumpur Flood Mitigation Plan
FMP	:	Fifth Malaysia Plan

(3) Others

B	:	Benefit
BOD	:	Biochemical Oxygen Demand
C	:	Cost
CBD	:	Central Business District
CCC	:	Central Control Center
COD	:	Chemical Oxygen Demand
DL	:	Datum Level
DO	:	Dissolved Oxygen
EIRR	:	Economic Internal Rate of Return
FC	:	Forign Currency
FT	:	Federal Territory
GDP	:	Gross Domestic Product
GRP	:	Gross Regional Product
GNP	:	Gross National Product
ISO	:	Intercepter Sea Outfall
IWPS	:	Industrial Waste Permit System
Jln.	:	Jalan
Kg.	:	Kampung
KL	:	Kuala Lumpur
LC	:	Local Currency
LSD	:	Land Survey Datum
MMS	:	Malaysian Meteorological Service
NPV	:	Net Present Value
Sg.	:	Sungai
M$	:	Malaysian ringgit

MAIN REPORT

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CHAPTER 1. INTRODUCTION

1.1 Background of the Study

The Klang River has a main stream of 120 km, and drains a watershed of 1,288 square kilometers. The River basin is the most developed area in Malaysia and is rapidly urbanizing. It consists of four major urban areas: the federal capital, Kuala Lumpur; Petaling Jaya; Shah Alam (capital of Selangor State); and the Klang / Port Klang conurbation, one of the nation's largest trading ports.

The total population of these four areas was 1.8 million in 1985 and is projected to increase to 3.6 million by 2005. The 300 square kilometers of existing urbanized area in the entire basin is expected to expand to 500 square kilometers within the next 20 years.

The Klang River often floods and damages property and crops over a wide area. The most severe floods in 1971 inundated a total area of 140 square kilometers, causing an estimated total damage of M$36 million (1980 price level) with nearly 180 thousand people affected as a result. The latest incidents took place in December, 1985 and October, 1986 in which ten thousand people in total were evacuated from various parts of Kuala Lumpur.

An existing flood mitigation program has been established with the aim of protecting Kuala Lumpur from heavy floods by providing an adequate retention capacity to mitigate floodwaters of the same scale as the 1971 floods.

In the original flood mitigation assessment in 1973, a rather static approach was taken with the 1971 land use and flood conditions as the basis. The intensity and extent of future urban development was not taken into consideration. Since then, the rapid progress of urban development has further reduced the retention capacity of rain water in the catchment area, especially by housing development encroaching into abandoned tin mines that functioned as retention ponds.

The Gombak Dam Project, which was proposed as one of the three flood mitigation dams, has been recently cancelled, and, at the moment, river channel improvements has been completed only in certain sections in the central part of Kuala Lumpur.

In the lower reaches, the future expansion of urban areas in Shah Alam and Klang is expected to take place in the low-lying flood prone areas; and sound flood mitigation measures will be required to support this potential development.

In view of this situation, updating of the existing flood mitigation program is now an obvious requirement. The Government of Malaysia has therefore requested technical assistance for this Project study on the Flood Mitigation of the Klang River Basin from the Japanese Government.

In response to this request of the Government of Malaysia, the Government of Japan has decided to conduct the Study and commissioned the Japan International Cooperation Agency (JICA). In March 1987, JICA dispatched a mission headed by Mr. Takayuki Inoue to Malaysia for the preliminary survey as well as discussions on the scope of work for the Study.

The scope of work was agreed upon between the Government of Malaysia and JICA on March 11, 1987.

In accordance with the scope of work, the JICA Study Team commenced the Study on the Flood Mitigation of the Klang River Basin in Malaysia.

1.2 Objectives and Area of the Study

The objectives of the study are:

(1) To review the existing flood mitigation plan

(2) To formulate a master plan of flood mitigation for the Klang River Basin, and

(3) To conduct a feasibility study for an urgent flood mitigation project selected in the master plan.

The study area will cover the whole Klang River Basin (area: 1,288.4 km^2) as shown in Fig. I.

1.3 Implementation of the Study

The Drainage and Irrigation Department (DID) was assigned as the counterpart agency for the Japanese Study Team and the Economic Planning Unit as the main coordination body to other relevant organizations for the smooth implementation of the Study, the organizations representing Malaysia, while JICA was assigned to be reprezentative organization of Japan.

The Study was carried out by the Japanese consultant team retained by JICA and counterpart staff of DID and DOE. The JICA Advisory Committee acted as advisors to the JICA Study Team.

The Study was conducted from October 1987 to October 1988. The members involved in the Study are listed below.

(1) JICA Study Team

Mr. S. Fukagawa	(PCI)	:	Team Leader/Flood Mitigation
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Mr. Y. Kobayashi	(PCI)	:	Hydrologist (I)
Mr. S. Ito	(PCI)	:	Hydrologist (I)
Mr. Y. Nabeta	(NK)	:	Drainage Engineer
Mr. T. Kameyama	(PCI)	:	Hydrologist (II)
Mr. T. Kikuta	(NK)	:	Survey Expert
Mr. F. Watanabe	(NK)	:	Survey Expert
Mr. K. Kotoo	(NK)	:	Geographic Expert/Geologist
Mr. H. Ichihara	(NK)	:	Structural Engineer
Mr. H. Onodera	(NK)	:	Construction Engineer
Mr. M. Honma	(PCI)	:	Socio Economist

Mr. H. Tanaka	(PCI)	:	Environment Expert

(2) JICA Advisory Committee

Mr. T. Tomaru	(MOC)	:	Chairman
Mr. Y. Taka	(MOC)	:	Member
Mr. E. Sazawa	(MOC)	:	Member

(3) Steering Committee

Mr. Helmi bin Mohd Noor	EPU	:	Chairperson
Dr. Zainal Aznam bin Yusof	EPU	:	Chairperson
Dr. Mohd Noor bin Hj Harun	EPU	:	Chairperson
Ms. Rosmah bt Hj Jentra	EPU	:	Chairperson
Ir. Ho Kee Chai	EPU		
Mr. Arisfadilah bin Sariat	EPU		
Ms. Lin Mui Kiang	EPU		
Mr. Thomas Mathew	Ministry of Agriculture		
Mr. Mohammed Khusrin bin Hj Munawi	Selangor State		
Mr. Ismail bin Hashim	Selangor State		
Mr. Nazirruddin bin Abd. Rahman	Prime Minister's Dept.		
Ir. D.N.Welch	DID HQ		
Ir. Quah Tek Hoe	DID HQ		
Ir. Tan Hoe Tim	DID HQ		
Ir. Lim Teik Keat	DID HQ		
Ir. Liew Chin Loong	DID HQ		
Mr. Jalaluddin Ismail	DOE		
Ir. Zulkifli bin Yahya	MOH LG		
Mr. Tadatoshi Matsuishi	DID HQ		
Ir. Abd. Rashid bin Abd. Rahman	City Hall		
Mr. Prem Kumar	Prime Minister's Dept		
Mr. A. Latib Markom	EPU		
Mr. Ahmad Zubir bin Abdul Ghani	EPU		
Mr. Hee Hoi Leng	Prime Minister's Dept		
Ir. Nawam bin Abdul	MOH LG		

	Datuk Yaacob b Abdul Hamid	KVPS
Ms.	Norasiah bt Hj Yahya	KVPS
Mr.	Abdul Majid bin Abdul Hamid	Survey Dept.
Mr.	Ismail bin Mohamed	EPU
Ms.	Wong Peg Har	EPU
Mr.	Ramli bin Hassan	EPU
Mr.	Misran bin Basir	EPU

(4) Technical Committee

Ir.	D.N. Welch	DID HQ	Chairperson at 1st stage
Ir.	Tan Hoe Tim	DID HQ	Chairperson at 2nd stage
Ir.	Quah Tek Hoe	DID HQ	
Ir.	Lim Teik Keat	DID HQ	Secretary
Mr.	Ismail Hashim	Selangor State	
Mr.	Jalaluddin Ismail	D.O.E	
Ms.	Zaniah Ahmad	KVPS	
Ir.	Awangku Hidup bin Awangku Hosain	KVPS	
Mr.	Jebasingam Issac	Jabatan Perancang Bandar dan Desa	
Mr.	Zulkifli Yahya	MOH LG	
Mr.	Samad bin Haji Abu	Survey Dept.	
Mr.	Abd. Rashid bin Abd. Rahman	City Hall	
Ir.	Lau Kim Paik	DID Selangor	
Ir.	Low Peng Weng	DID Selangor	
Ir.	Poh Thuan Poon	DID Wilayah Persekutuan	
Ir.	Ferng Meow Chong	DID RTB	
Ir.	Julian Putra	DID HQ	
Ir.	Lee Chock Seng	DID HQ	
Ir.	Tadatoshi Matsuishi	DID HQ	
Ir.	Liew Chin Loong	DID RTB	Chief Counterpart
Ir.	Poh Thuan Poon	DID Wilaya Persekutuan	
Ir.	Ferng Meow Chong	DID RTB	
Ir.	Sardar Ali	DID HQ	
Ir.	Sea Ching Hoo	DID HQ	

(5) DID and DOE Counterparts

Ir. Liew Chin Loong	(DID)	:	Chief Counterpart
Mr. Ong Siew Heng	(DID)	:	Counterpart
Mr. Jamal bin Abdullah	(DID)	:	Counterpart
Mr. Tan Yong Long	(DID)	:	Counterpart
Mr. Ng Kim Hoy	(DID)	:	Counterpart
Mr. Ziauddin Abdul Latif	(DID)	:	Counterpart
Mr. Jalaluddin bin Ismail	(DOE)	:	Counterpart

Special Abbreviations:

MOC : Ministry of Construction
PCI : Pacific Consultants International
NK : Nippon Koei

1.4 Composition of Report

This report consists of three (3) volumes: Main Report, Supporting Report, and Data Book.

The Main Report presents the summarized results of all the studies. In Chapters 2 through 3, the basic information for the Study are described. In Chapter 4, master plan for the whole Klang River Basin is presented. In Chapters 5 through 8, feasibility study of the urgent project is described. In Chapter 9, environmental aspect, and in Chapters 10 and 11, supplementary studies and recommendations are presented.

The Supporting Report consists of the following studies;

A: Topographical Survey
B: Meteo-Hydrological Condition
C: Topography and Geology
D: Socioeconomic and Land Use Study
E: Present Conditions of the Klang River and the Basin
F: Flood Run-off and Flooding Mechanism
G: Floods and Flood Damage

H: Review of Existing Flood Mitigation Project

I: Formulation of Master Plan

J: Urgent Flood Mitigation Plan

K: Construction Plan and Cost Estimate

L: Economic Evaluation for Urgent Flood Mitigation Project

M: Operation and Maintenance Plan for Urgent Project

N: Environmental Aspect

O: Consideration on Water Quality Improvement

P: Run-off Study of Tributaries

The Data Book contains the data of the following surveys;

I: Data of River Survey

II: Flood Risk Map

1.5 Acknowledgement

In undertaking the Study, the Study Team has attached great importance to be incorporation of the views of departments and agencies of the Government of Malaysia relating to the various aspects covered by the Study. The contributions to the Study by the officials of Economic Planning Unit, Drainage and Irrigation Department, and other individuals who have provided information and data, participated in discussions, given valuable advices, and provided other forms of assistance to the Study are greatfully acknowledged.

A heartfelt gratitude is also extended to the officials of the Embassy of Japan in Malaysia, the Ministry of Foreign Affairs and Ministry of Construction of the Government of Japan who gave advice and provided various supports during the performance of the Study. In reality, the Study can be regarded as a joint effort by the Malaysian and Japanese officials and individuals concerned and the Japanese Study Team. The Study Team sincerely hopes that this effort will contribute to the future development of flood mitigation of the Klang River Basin in particular, and to its socio-economic development and well-being in general.

CHAPTER 2. STUDY AREA

2.1 Natural Conditions

2.1.1 Topography

The Klang River Basin with a catchment area of 1,288.4 square kilometers occupies the central parts of Selangor State on the west coast of Peninsular Malaysia. The Basin is bounded by latitudes of 2°55'N and 3°25'N and longitudes of 101°20'E and 101°50'E. Roughly extending 55 km from east to west, the seaward edge of the Basin faces the Straits of Malacca to the west.

The Klang River originates in the Main Range at an altitude of 1,330 m in the east of the Basin. The upper basin above the existing dams is mountainous with fairly steep slopes as shown in Fig. 2-1. A major part of the mountains is covered by tropical jungle.

The metropolitan area of Kuala Lumpur is situated between the elevations of 30 m and 60 m downstream of the dam sites where the basin is 20 kilometers wide.

In the lower stretch at downstream of Kuala Lumpur, the land is low and rolling. The hills in this area are mostly covered by rubber and oil palm plantation. The lowest stretch of the basin near the river mouth is occupied by flat coastal plains.

2.1.2 Meteorology

The climatic characteristics of the study area are its almost uniform temperature, high humidity, and heavy rainfall.

Meteorological observations in the study area have been carried out at Petaling Jaya and Subang Airport. Table 2-1 shows the monthly meteorological data at Petaling Jaya.

The average maximum daily temperature is 32°C and the corresponding minimum is 23°C. Annual mean relative humidity is 81%. The annual mean rainfall in the Basin is about 1,840 mm at JPT. Klang and 2,700 mm in the mountainous area.

The maximum amount of precipitation generally occurs in October and November preceding the northeast monsoon season and in April preceding the southwest monsoon season.

The basin mean annual evaporation amount is estimated at around 1,070 mm.

2.1.3 Geology and Soil Mechanics

(1) Geology

The study area is roughly classified into plain and mountainous regions. The plain region is further classified into coastal plain and fluvial plain. The geological structures of these regions are as follows: (Fig. 2-2)

a. Coastal plain (less than 5 m in elevation)

Sand & gravel layer is found under the 15 m ~ 20 m thick clayey and sandy soil layer.

b. Fluvial plain (from 5 m to 50 m in elevation)

Sand & gravel or weathered rock is found under the 5 ~ 15 m thick clayey & sandy soil layer.

c. Mountainous region (above 150 m in elevation)

Granitic rock and vein quartz schist, limestone

(2) Soil Profile and Bearing Capacity

The soil profile in the coastal and fluvial plain is characterized by 3 distinct layers i.e., 1 ~ 5 m thick clayey soil, 5 ~ 10 m thick sandy soil, and sand and gravel layers from the ground surface.

The first layer is not found in the ex-mining area.

The third layer, sand and gravel or weathered rock, has enough bearing capacity with N-value more than 30.

The following foundation treatment measures are recommended for designing the structures.

a. Pile foundation borne by the 3rd layer for the heavy structures such as bridge, sluice gate, box culvert under the road and pumping station.

b. Foundation directly on the 1st layer for embankment of levee and bank around the retention pond.

(3) Embankment Materials

According to the site reconnaissance and bed material sampling, the river bed and bank materials are of suitable quality for usage as embankment materials of levees.

These materials are mainly sandy soil but no liquefaction is expected. Embankment materials for retention pond are expected to be sand which has high permeability due to washing during mining operations. Hence, the bank at retention pond is recommended to have the enough width with more than 50 m.

2.2 Hydrology

2.2.1 Rainfall

The mean annual rainfall in the Basin is about 2,300 mm.

The recorded maximum daily rainfall is 171.5 mm at JPT Ampang station and 176.3 mm at Pemasekan Ampang station. The mean monthly rainfall observed at ten stations in the Basin are shown in Fig. 2-3. Probable area rainfall for the upstream catchments of Sulaiman bridge, Puchong Drop and river mouth are estimated by means of Gumbel method and shown in Table 2-2.

The 100 year two days area rainfall for the upstream catchments of Sulaiman bridge and river mouth are 181.5 mm and 154.9 mm respectively.

2.2.2 River Discharge

The annual maximum discharges at five gauging stations, Sulaiman, Market Street, Jln. Jun Razak, Sentul and Kg. Sg. Tua are shown in Table 2-3. The maximum discharge is 667.9 m^3/s at Market Street in January 1971.

The monthly discharge in these stations are illustrated in Fig. 2-4. It could be recognized from the figures that the basins experience a high discharge in May and in the period from October through December, and low discharge in February, July and August.

2.2.3 Tidal Water Level

The tide is recorded at the Port Klang by Department of Survey and Mapping since 1983.

The various datum relationship at Port Klang is as follows:

Extreme High Water (Oct. 1985)	-----	+4.97 m
Mean High Water Spring	-----	+4.22 m
Mean High Water Neap	-----	+2.91 m
Land Survey Datum	-----	+2.30 m
Mean Low Water Neap	-----	+1.62 m
Mean Low Water Spring	-----	+0.06 m
Extreme Low Water (March 1985)	-----	-0.85 m

All values are above Chart Datum Level.

2.2.4 Sediment

The annual rate of sedimentation observed at the Klang Gates Dam is 580 $m^3/km^2/year$. According to the sediment concentration records on suspended load in the Klang River at Sulaiman, the annual sediment discharge was about 380 x 10^3 tonnes in 1985. A rating table of the discharge versus suspended sediment is prepared by DID.

2.3 Socioeconomy

2.3.1 Population

The total population in the Klang Valley Region has increased from 1,266,000 in 1970 to 2,020,000 in 1980. The average annual population growth rate of the region during this decade was 4.8%. Among these areas, the population growth rates of Gombak and Petaling Districts were conspicuously higher than that of the remaining areas.

The population density in the Federal Territory was 40.1 persons per ha in 1980. This was much higher than the average population density of 7.1 persons per ha for the whole of the Klang Valley Region.

According to the Klang Valley Perspective Plan (KVPP), the population in the Klang Valley is estimated to reach a total of 4,760,000 by 2000. Based on this KVPP projection, the population in the

Klang River basin 1985-2005 is estimated to be 2,249,000 in 1985 and 4,744,000 in 2005.

The population in the flood prone area is roughly estimated to be about 474,000 (21% of the Basin) in 1985.

2.3.2 Regional Economy

According to the Fifth Malaysia Plan, Gross Regional Product (GRP) of the Federal Territory and Selangor State amounted to M$18,014 million in 1985 at the 1978 price, which accounted for 30.4% of the total GDP of the nation. Among the GRP of the above region, 9.6% was contributed by the primary sector, 32.2% by the secondary sector and 58.2% by tertiary sector.

The annual growth rate of the GRP during 1980-1985 was 7.5% in the Federal Territory and 5.2% in the Selangor State.

The per capita GRP was M$7,783 in the Federal Territory and M$4,963 in the Selangor State in 1985, which corresponded to 2.07 times and 1.32 times respectively of the national average of the per capita GDP of M$3,758.

In the Klang Valley Region itself, the GRP is estimated to be M$15,511 million in 1985 and M$48,842 million in 2005 at the 1978 price according to the Klang Valley Transportation Study (KVTS) carried out by JICA.

2.3.3 Regional Infrastructure

In the Klang Valley Region, there are four major expressways radiating from Kuala Lumpur: Federal Route 1, Federal route 2, Kuala Lumpur-Seremban Highway and Karak Highway. The Federal Route 2 connects Kuala Lumpur to Klang through Petaling Jaya and Shah Alam, which lies across the study area from east to west along the Klang River.

The Subang International Airport, located in the Klang Valley Region, plays an important role in international as well as domestic air transportation activities.

Port Klang, located at the mouth of the Klang River, is a focal point of cargo transportation for international as well as domestic shipment.

2.4 Land Use

2.4.1 Present Land Use in the Basin

A present land use pattern in the Klang River basin in 1985 is shown in Fig. 2-5. The area and composition of land use of three subdivided areas are summarized below.

PRESENT LAND USE IN THE KLANG RIVER BASIN, 1985

Landuse Category	Upper Basin (ha)	Middle Basin (ha)	Lower Basin (ha)	Basin Total (ha)	(%)
Urbanized Area	12,810	15,390	7,230	35,430	27.5
Mining Area	420	1,140	2,650	4,210	3.3
Agricultural Area	10,410	7,310	36,190	53,910	41.8
Forest Reserve/ Swamp Area	22,180	1,540	11,570	35,290	27.4
Total	45,820	25,380	57,640	128,840	100.0

Urbanized areas account for 35,430 ha or 27.5 % of the whole basin. Most of those urbanized areas are concentrated in the Federal Territory of Kuala Lumpur and the three municial areas of Petaling Jaya, Shah Alam and Klang. The mining areas are mostly ex-mining lands and some of these play the role of retention ponds for flood mitigation.

2.4.2 Present Land Use in Flood Prone Area

The flood prone area estimated on the basis of the past severest flood of 1971 covers the area along the Klang River, the Gombak, the Batu, the Ampang, the Kerayong and the Damansara river.

The present land use pattern of these flood prone areas is shown in Fig. 2-6 using 500 m x 500 m mesh map, and their land use composition are shown below.

PRESENT LAND USE IN THE FLOOD PRONE AREA 1985

Landuse Category	Area (ha)	(%)
Urbanized Area	6,068	33.0
Agriculture	5,642	30.6
Mining	2,425	13.2
Forest Reserve/Swamp	4,260	23.2
Total	18,395	100.0

2.4.3 Future Land Use Plan

A future land use plan proposed for the Basin, in the target year of 2005, is shown in Fig. 2-7 taking into account of the basic development strategies in the Klang Valley Perspective Plan (KVPP).

The land use composition for the upper, middle and lower basins are shown below. The urbanized area will increase from 35,430 ha (27.5%) in 1985 to 56,540 ha (43.9%) in 2005. The most extensive urbanization during this period is expected to be more concentrated in the lower basin. These urbanization will be due to the growth centers Shah Alam, Petaling Jaya and Klang in the lower basin. A future land use pattern envisaged in the flood prone area (2005) is shown in Fig. 2-8.

FUTURE LAND USE IN THE KLANG RIVER BASIN, 2005

Landuse Category	Upper Basin (ha)	Middle Basin (ha)	Lower Basin (ha)	Basin Total (ha)	(%)
Urbanized Area	18,380	20,360	17,820	56,540	43.9
Mining Area	170	450	2,380	3,000	2.3
Agricultural Area	4,410	2,490	18,990	25,890	20.1
Forest Reserve/ Swamp Area	22,910	2,080	18,450	43,440	33.7
Total	45,820	25,380	57,640	128,840	100.0

The rates of increase of urbanized area for the upper, middle and lower basins from 1985 to 2005 are 30.3%, 32.3% and 146.5% respectively. This future urbanization trend is illustrated in Fig. 2-9.

2.5 Present River Conditions and River Characteristics

2.5.1 Klang River and Tributaries

The Klang River and its two main tributaries, the Gombak and Batu rivers are characterized by relatively smooth bed slopes, as illustrated in Fig. 2-10. It drains a total catchment area of 1,288.4 square kilometers. Broadly speaking, the Klang River can be classified into three stretches, namely, an upstream stretch with steep slope, a middle stretch between confluence with the Gombak River and a point at about 10 km downstream of the Puchong Drop, where a slope transition occurs, and a lower stretch downstream with relatively gentle slopes. In the upstream steep slope portion, the bed slope decreases from approximately 1/400 to 1/2300, and from the slope transition portion to the river mouth, the bed slope further decreases gradually from 1/2300 to 1/10000.

The Gombak and Batu Rivers possess only a single upstream stretch, with characteristics similar to that of the upstream of the Klang River.

Longitudinal river profiles and cross sections have been obtained throughout the entire length of the Klang River, with no reports of active meanders.

Local erosion occurs at meanders along the middle stretch. The bank erosion in the lower river stretches are probably due to tidal action. Soils loosened from banks in the lower river stretch may be the cause of siltation at the river mouth, while the formation of sand bars and shoals in the upper and middle river stretches are largely affected by sediment deposits caused by soil erosion due to housing development. Recently, some sections of the river in the upper stretches had been canalized as shown in Fig. 3-1.

The river width, bed slope and discharge capacity in the rivers are shown in Table 2-4 and Fig. 2-11 ~ 2-14.

2.5.2 River and Related Structures

In the Klang River and its main tributaries there exist the following river and related structures besides two existing dams.

River Improvement Structures .. The improved structural elements are with concrete lining, vertical concrete retaining walls and parapet walls. The location of improved stretches is shown in Fig. 3-1.

Gabion ..... In certain stretches of the Gombak River Gabions were installed to restore the eroded river banks.

Drop Structure ..... In the Batu and Gombak Rivers, two small drop structures were constructed for maintaining the river bed. In the middle stretch of the Klang River there exists a drop structure of 3 m height named Puchong Drop.

Dyke ..... As river channels are principally excavated type, there exist only short stretches with dyke at the Kampung Baru Region and the middle stretch of the Klang River. In the downstream, for the protection against high tidal waters, a dyke of 3 m in height and about 30 km in length is in existence.

Sluice Gate ..... In the low-lying areas of the Kampung Baru and some other regions, some sluice gates are installed. Also in the lower stretch of the Klang River, about 30 tidal sluice gates are installed. Location of these tidal gates are shown in Fig. 2-15.

Drainage ..... There are many drainage pipes along the river in and around the city areas the klang Gates and Batu dams.

Bridge ..... Along the downstream of the damsites of the Klang, and Batu Rivers and the shelved damsite of the Gombak river, there are 58 bridges. Most of these are concrete highway bridges. There are also 3 railway bridges. Location of these bridges are shown in Fig. 2-16.

The bridges in the middle and lower stretches are expected to cause no severe reduction in the flow capacity of the river because of comparatively large river width.

In the upper stretches, there exist 42 bridges.

The results of the overall evaluation of these bridges are presented in Table 2-5.

Among these bridges, 6 bridges are recommended to be replaced urgently and other 4 bridges along with the river improvement.

These bridges are shown in Fig. 4-9.

2.5.3 Existing Ex-Mining Pond

As of 1986, in the basin, total active mining area is about 1,400 ha and existing ex-mining areas amounts to some 6,900 ha. The ex-mining areas developed into housing schemes is some 4,100 ha. The total area of ex-mining ponds, located in the Klang River basin at upstream of the Puchong Drop, is about 650 ha. From the view-point of flood mitigation, these ponds are greatly useful as retarding ponds. Distribution of ex-mining ponds for each catchment area is shown in Fig. E-10 of APPENDIX-E. The sizes of these ponds differ quite substantially, ranging from 0.5 ha to 90 ha. Most of these ex-mining ponds have been ear-marked for potential housing or industrial development. Though there are many ponds in existence, only those deeper ones, existing along the Batu River, the Jinjang River and the Kerayong River, would remain without being slated for refilling.

2.6 Flood Problem

2.6.1 Features of Flood

In the Klang River Basin, flooding is caused both by depression-type monsoon storms and thunderstorms. Depression-type monsoon storms are of long duration (3 to 5 days), and are widespread over the whole Klang River Basin. These storms have rainfall intensity of only about 20 mm and do not usually cause serious damage to small tributaries, but may heavily damage the main stream due to its large catchment.

Thunderstorms are typically of short duration (3 ~ 5 hrs) with high intensity rainfall and can cause serious damage to small catchment streams. This flash flooding occur through the year and may inundate the low-lying area or riverine of tributaries which have inadequate flow capacity several times each year. Fig. 2-17 shows the inundation status caused by flash floods in the Federal Territory.

2.6.2 Past Major Floods

Over the period 1949 ~ 1988, eleven occurrence of flooding of the Klang River were recorded at Sulaiman Bridge. The most severe flood ever recorded was in January 1971, and it continued for 5 days, covering the whole Basin. Approximately 122 square kilometers on 9.5% of the Klang River Basin was inundated as shown in Fig. 2-18. The recorded maximum hourly rainfall was 18 mm/hr at Hospital KAJANG Selangor and the total recorded rainfall at JPT. Ampang for this storm period was 320.3 mm. The mean rainfall in the basin in 2 days and 3 days are estimated to be 188.3 mm and 230.5 mm respectively.

The peak flood discharge is estimated to be 540 m^3/s at Sulaiman Bridge.

2.7 Flood Damage

Flood damage is estimated, in principle, from properties in the flooding area multiplied by the damage ratio depending on the flooding conditions. The damage is estimated for general properties such as house and household effects, shops, warehouses and agricultural crops, public properties such as roads, railways, electricity and telecommunication, and indirect flood damages.

The flooding conditions, such as area, depth and duration of flooding or inundation, are obtained on the calculation results by the flood simulation model in APPENDIX F.

(1) Probable Flood Damage

The flood damage is estimated for respective return periods and for three subdivided area of the Basin.

The flood damages under the conditions of the year 2005 are summarized as follows.

Return Period (Year)	Flood Damages (M10^6)			
	Upper Reach	Middle Reach	Lower Reach	Total
100	440	1,518	328	2,286

Flood Damages (M10^6)	Return Period (Year)					
	10	30	50	80	100	200
Total	957	1,343	1,929	2,190	2,286	2,503

(2) Annual Average Flood Damage

The annual average flood damage is estimated as a sum of flood damage segments derived from the probability of flood damage multiplied by the corresponding probability of occurrence, from non-damageable runoff up to 100-year probable flood.

The annual average flood damage is estimated at 179.1 million M$ under the land use conditions in the year of 2005.

2.8 Present Environmental Conditions of the Klang River

The Klang River has various aspects for natural resources and human activities as its environmental conditions.

(1) Characteristics of Riverine Environment

The upstream rivers are generally clear and rich in ecological resources. However, in the immediate downstream reaches of the forest reserve, the water becomes turbid due to erosion. The river banks in both areas are generally covered with native grass, shrubs, and trees.

At the central district of Kuala Lumpur, recently completed revetments with pedestrian walkways and plazas are part of a new harmony in the urban riverine landscape. Downstream of Kuala Lumpur, the river once again features the grassy banks and native vegetation. After

Puchong Drop, most of the vegetation is of salt-tolerant; Nipa being a common example of such a plant. At the estuarine area, the river meanders gently through mangrove colonies.

(2) The Wild Life, Birds and Fishes

Many kinds of wild life, birds, and fish are still observed on the upper stream adjacent to the natural forest areas. In the urbanized area, approximately 20 kinds of birds are in abundance, among which some are state protected species.

(3) Squatter Area

Many squatters have settled along the river side. Within the Federal Territory alone, approximately 1,300 squatter huts are present along over 14.2 km length of river fringes. These squatter areas are environmentally degraded and produce unmanaged solid wastes, floating debris, and also some sanitary sewers discharge to the river.

(4) Water Quality of the River

According to the KVEIP report, the water quality in the Klang River System is critical during low flow conditions in the dry season. The BOD (Biochemical Oxygen Demand) upstream of the Klang Gates Dam is 2-4 mg/l, while the DO (Dissolved Oxygen) in the same area is 7-8 mg/l. The BOD increases gradually to 6 mg/l in the urbanized area and reaches a peak condition of 11 mg/l near the Damansara confluence. In the further downstream reaches, it decreases due to dilution by tidal intrusion. The DO level reaches a 1.6 mg/l in the city center but at the Puchong Drop, it improves to over 2 mg/l due to aeration effect with the weir. However, these conditions might have changed due to change of flow regime since the completion of Batu Dam.

(5) Erosion and Siltation

The tin mining activities, rubber plantation, urbanization, and especially large scale housing development works have excessively

stripped the ground surface of its natural vegetation, resulting in severe soil erosion. The eroded soil causes siltation and reduction of the flow capacity of the river.

(6) Floating Debris and Screening Management

The floating debris such as paper, plastic containers, and driftwood further degrade river water quality. For screening and removals of floating debris, screening equipment and a log boom are installed and operated by the City Hall at Batu, Gombak and Klang Rivers. The amount of collected trash daily comes to about 10 tons.

CHAPTER 3. REVIEW OF EXISTING FLOOD MITIGATION PROJECT AND WORKS

3.1 Existing Flood Mitigation Project

The existing flood mitigation plan for the Klang River Basin covering the stretch upstream of Puchong Drop, was formulated by DID in 1981. This plan is called the "Kuala Lumpur Flood Mitigation Plan" (KLFMP), which covers a catchment of 712 square kilometers. The planned flood control measures were as follows:

(1) Raising the existing crest of the Klang Gates Dam by 3.05 m. Thereby an approximately 6.2 million cubic meters of capacity would be provided for flood control storage.

(2) Construction of a new Batu Dam with a 4.8 million cubic meters storage capacity for flood control.

(3) Construction of a second new dam on the Gombak River with a 7.8 million cubic meters storage capacity for flood control.

(4) River improvement works including channelization of 47.3 km of river course along the Klang, Gombak and Batu Rivers. This river improvement plan consists of the following elements of works.

Design Characteristics	Length Involved (km)	Final Width after Widening (m)	Average Deepening (m)
Klang River	33.7 (From Ulu Klang Bridge to Puchong Drop)	Upstream 30 Downstream 70	2.0
Gombak River	8.1 (From Kg. Tangut to confluence with Klang River)	Upstream 25 Downstream 30	2.5
Batu River	5.5 (From Ipoh Road Bridge to confluence with Gombak River)	30	3.0

3.2 Present Status of Project Implementation

(1) Works with Respect to the Kuala Lumpur Flood Mitigation Project

As of December 1987, the following works have been completed: the enlargement of the Klang Gates Dam, the construction of the Batu Dam, and the river improvement works covering 4.85 km length along the Klang river and its tributaries in the city center. The completed river improvement works are shown in Fig. 3-1.

As of June, 1988, projects covering 4.85 km of the Klang river are in progress. The proposed Gombak Dam, however, was cancelled due to problems in land acquisition. As the Urban Drainage improvement works, the works are being carried out at Sg. Bunus, Sg. Batong Tolak, Sg. Kerayong, Sg. Penchala, Sg. Keroh and Sg. Kuyoh and etc. Periodic desilting works are carried out for Sg. Keroh and Sg. Kerayong and in the Klang River, Gombak River and Batu River.

(2) Planning and Program of Implementation

The total cost of the project was estimated at M$ 385.5 million at 1979 prices, and at the end of the 4th Malaysian Plan (1981 ~ 1985), some M$ 111.0 million has been expended.

The Kuala Lumpur Flood Mitigation Plan was originally scheduled to be completed over a period of 20 years (1976-1995). However, in view of the current depressed national economy, the program is expected to be extended beyond 1995.

(3) Problems in Project Implementation

The problems commonly encountered during Project Implementation are as follows:

a. Socio-political problems are associated with land acquisition in developed urban areas.

b. Squatters must be relocated before proceeding with construction works. In the projected river improvement for stretches upstream of the City Center, there exist squatter areas in the stretch for 17.3 km along the river banks. The implementation program must be coordinated with programs to relocate squatters by the relevant authorities.

c. Technical problems encountered on site, such as the existence of uncharted rock formation and old structures, insufficient working space, restricted working hours, and the prevalence of various public utilities.

CHAPTER 4. FORMULATION OF MASTER PLAN

4.1 General

When an inundation occurs in the Klang River Basin, it takes place over a vast expanse of the basin along the Klang River and several of its tributaries. It is therefore impractical from the viewpoints of both economic effectiveness and budgetary demand, to realize a perfect flood mitigation facility for each and every reach of such a large river system. As such, it is prudent to limit the flood damage to an acceptable level by the combination of both structural and non-structural measures.

The structural measures adopted will be evaluated on the basis of their economic effectiveness, lack of deleterious influence on the health of the riparian settlers and the ability to be completed within the shortest possible time period in view of the urgent need for the provision of such measures.

In the application of structural measures, higher target levels of protection capable of mitigating floods of longer return periods are intuitively more desirable, as this will minimize the damage to facilities in the flood prone areas and would confer long term stability to the livelihood of the riparian settlers in the flood prone areas. However, a much larger expenditure for construction cost and a much longer construction period will be required to effect structural measures of high target level plans. In order to realize the benefits of the flood mitigation project as early as possible and to satisfy the urgent need for such measures, the proposed flood mitigation plan shall be amenable for a stage wise implementation.

Non-structural measures are to be considered as an indispensable means for supplementing the structural measures. In areas where no effective structural measures are suitable, mitigation of flood damage solely by means of non-structural measures will be considered.

The concept of the comprehensive flood mitigation system is shown in Fig. 4-1.

4.2 Cause of Inundation and Countermeasures

In the Klang River Basin, flooding is caused both by depression-type monsoon storms and thunderstorms. Depression-type monsoon storms are of long duration, and are widespread over the whole Klang River Basin. These storms have rainfall intensity of only about 20 mm and do not usually cause serious damage to small tributaries, but may heavily damage the main stream due to its large catchment. The countermeasures against these flooding should be contemplated considering the existing conditions of flood prone areas and river features.

The cause of flooding in the Klang River Basin is summarized as follows:

(a) Cause of Increase in Storm Run-off

- Increase of run-off coefficient of the Basin due to rapid unbanization.
- Loss of ex-mining ponds as potential retention ponds due to refilling for housing developments.
- Improvement of trunk drainage or tributaries to an excessive scale compared to the discharge capacity of downstream stretch.
- Flowing down of floating logs in the river channel during floods.
- Sediment run-off into the trunk drainage or river due to soil erosion caused by land development.

(b) Problem of Drainage Facilities

- Inadequate flow capacity of river channel or trunk drainage.
- Existence of lowlying area.
- Insufficient clearance at bridge crossings.
- Tidal effect in the downstream reaches.

Table 4-1 shows the causes of flooding and the respective countermeasures for each river stretch in the Klang, Gombak and Batu Rivers.

4.3 Alternative Protective Measures

Five possible alternative protective measures of flood mitigation are considered for the selection of most suitable alternative. These alternatives are shown in Table 4-2 and Figs. 4-2~4-4. Each of these alternatives consist of a combination of several structural measures, that include both the existing two dams, and are capable of regulating the discharge in the main stream of the Klang River at Sulaiman Bridge not to exceed the permissible maximum discharge of 730 m^3/s. The necessary structural measures of these five alternatives differ only in the upper reaches of the Klang River Basin, and are the same in the middle and lower reaches.

A major nonstructural measure considered in all alternatives, except Alternative II-2, is the reservation of an area of about 12 km^2 of natural forests and swampy lands at Sg. Rasau in the middle reach as a natural retarding basin, as illustrated in Fig. 4-5.

(1) Alternative I-1

Upper reaches of this Alternative I consist of the construction of two retention ponds (Gombak and Batu Retention Pond), and river improvements.

The Gombak Retention Pond is to be constructed in the open space of the Malay Reservation area. The Batu retention pond is an ex-mining pond. The middle reaches consist of river improvement works to be executed in between Sulaiman Bridge and confluence of Sg. Damansara, which is of about 35.7 km in length including completed 4.1 km stretch.

A 17 km^2 area of natural forests and swampy lands at 6.5 km downstream of the Puchong Drop in Sg.Rasau is to be reserved as a retarding basin.

In the lower reaches, river improvement work is necessary for almost the whole length of the Klang River, which consists of deepening, widening and cut-off works of the river course and the construction of levees.

(2) Alternative I-2

The Upper Gombak Dam was considered as an alternative instead of the Gombak Retention Pond. The rest is the same as Alternative I-1. The Upper Gombak Dam is located at the 21.9 km of the Gombak River and has a nominal volume of 3,300,000 cubic meters.

(3) Alternative II-1

In the upper reaches, this alternative consists of the construction of the Batu Retention Pond and a diversion channel with a flow capacity of 60 m^3/s. The rest is the same as Alternative I-1.

(4) Alternative II-2

For the upper reach, the structural measures are the same as Alternative II-1. For the middle and lower reaches, the river improvement works are considered as an alternative instead of the natural retarding basin.

(5) Alternative III

The Alternative III consists of Batu Retention Pond, Ampang Diversion Channel, Kerayong Retention Pond and river improvements.

(6) Alternative IV

The Alternative IV consists of the Batu Retention Pond, and the proposed but shelved Gombak Dam. For the middle and lower reaches, the same structural measures as Alternative I-1 are adopted.

(7) Alternative V

This alternative is the case without two retention ponds, Gombak and Batu. A diversion channel from the Ampang to the Kerayong Rivers is considered. Kerayong Retention Pond is also necessary.

4.4 Establishment of Flood Protection Level

The degree of protection with respect to flood mitigation is determined by the adoption of a suitable design storm return period. Generally speaking, as an international standard, a design storm return period of 50 - 100 years is adopted for long term measures of flood mitigation for large scale important rivers. Some examples of design storm return period adopted in certain selected countries are given in APPENDIX I. For this study of the Klang River Basin, a design storm return period of 100 years was selected, based on the considerations given below;

Considerations

i) The previous flood mitigation study, The Flood Mitigation Plan of Kuala Lumpur, was carried out by adopting a discharge return period of approximately 100 years.

ii) According to a rainfall frequency analysis in this study, rainfall of 1971 floods is estimated as about 100 year return period for the upstream reaches.

iii) For a degree of protection level higher than a 100 years of storm return period, the construction of Gombak Dam, which has been shelved, would become necessary.

iv) The planned river channels of the upper and middle stretches will be excavated water ways. The design flow capacity was determined with an allowance of 0.9 m freeboard. Hence the maximum flow capacity of these stretches would be about 120% of the design flow capacity. Hence, at the state of bankful flow capacity the effective storm return period would be higher than the design storm return period of 100 years.

4.5 Comparison of Alternatives

The cost of civil works, land acquisition, and compensation required were estimated for each alternative. The direct construction cost is composed of cost for civil works and costs required for land acquisition and compensation. The cost required for civil works is calculated by multiplying work quantity by unit cost.

The estimated construction cost is summarized below (Ref. APPENDIX I).

Alternative	Construction Cost (M10^3)	Flood Protection Level
A-I-1	353,371	1/100
A-I-2	389,096	1/50
A-II-1	372,708	1/100
A-II-2	486,794	1/100
A-III	385,817	1/100
A-IV	387,831	1/100
A-V	357,071	1/80

Note: Construction cost includes both that of Civil Works and land acquisition.

These alternative schemes were studied by adopting a design flood frequency of 100 years, except for Alternatives I-2 and V.

As the optimum scheme, Alternative II-1 was selected for the Master Plan, based on an overall comparative study in relation to technical, economic and social aspects.

- Alternative I-1 is the most economical scheme as evident from the above Table. However the site of the proposed Gombak Retention Pond falls within the area of Malay Reservation. This is expected to cause much difficulities in relation to the land acquisition for this retention pond, a social problem.

- Alternative I-2 is comparatively expensive with a flood protection level only againt a 50 years return period of flood frequency. The upper Gombak Dam, a project component of this alternative, is not effective againt flash floods as it is located too far from the area to be protected.

- Alternative II-1 is the second most economical one with a flood prection level of 100 years, second only to Alternative I-1 which has the problem of land acquisition. However this Alternative encounters no problem of land acquisition for the construction of Batu Retention Pond, as this pond is to be constructed in an area of ex-mining pond. Operation and Maintenance of this single pond is rather easy in comparision to the two (2) pond alternative, Alternative I-1.
  Hence this Alternative II-1 was selected as the Master Plan alternative.

- Alternative II-2 is more expensive mainly due to the requirement of river improvement works in the downstream stretches of Sg. Resau, though this eleminates the requirement of the natural retarding basin adjoining it.
  Also this alternative is expected to encounter land acquisition problem for river improvement works at Klang town reach.

- In Alternative III further improvement of the Gombak river in the City Centre involving further widening of the already improved channel sections would be necessary.
  This is practically infeasible in consideration to the existing riverine land use conditions.
  The project construction cost is also comparatively expensive.
  Land acquisition for Ampang / Kerayong diversion channel is also expected to be difficult.

  Alternative IV includes the Gombak dam, construction of which is already shelved due to the problem of land acquisition in the Malay Reserve area.
  The project construction cost is also more expensive than Alternative II-1.

- Even though Alternative V is the second most economical one, it has a flood protection level of only 80 years.

This Alternative also requires further river improvement works of Gombak river at City Centre, which is practically infeasible in consideration to the existing reverine land use conditions.

4.6 Master Plan

4.6.1 Distribution of Design Flood Discharge

Fig. 4-6 shows the distribution of the design flood discharge determined based on the land use conditions in the year of 2005. Also taken into account were flood mitigation effects of the two existing dams and the proposed retention pond and retarding basin.

The resulting design discharge at Sulaiman Bridge is 730 m^3/sec. The probable flood hydrograph at this station in the year 2005 is shown in Fig. 4-7.

4.6.2 Proposed Flood Mitigation Plan

The proposed flood mitigation plan consists of the following countermeasures;

(1) Construction of the Batu Retention Pond
(2) Construction of the Gombak Diversion Channel with 3.2 km in length
(3) Use of the Natural Retarding Basin
(4) Removal of the Puchong Drop
(5) Channel improvement of 94.7 km long for the Klang, the Gombak and the Batu Rivers
(6) Construction of pumping station in Kampung Baru
(7) Reconstruction of 10 bridges

Plan of the flood mitigation facilities for the Klang River is shown in Fig. 4-8. General descriptions of these facilities for each river are as follows;

(1) The Klang River

The total length of channel improvement of the main stream of the Klang River is 76.8 km. Two bridge crossings across the river must be reconstructed as shown in Fig. 4-9.

Pumping stations are to be constructed in Kampung Baru area, and also along the Klang river stretch between Sg. Kerayong and Sg. Kuyoh, for the purpose of inner drainage of low-lying areas along the Klang River. No development activities will be permitted in the natural retarding basin. Existing Puchong Drop structures will be removed after the completion of river improvement works at its (Puchong Drop) downstream river reaches..

(2) The Gombak River

River improvement of 9.9 km will be executed, including the excavation of the river bed in the already improved stretches. Three bridges will be reconstructed. The diversion channel connecting the Gombak River to the Batu River will be constructed including five bridges and two box culverts.

(3) The Batu River

River improvements for 8.0 km of the Batu River will be executed, including the reconstruction of five bridges. (Ref. Fig. 4-9)

A multi-purpose retention pond with a capacity of 2.7 million cubic meters for flood control will be constructed along the Batu River. The total area of this pond, including the park area, is about 113 ha.

The construction works for this retention pond include a sluice gate for maintenance water, the primary regulation pond, an overflow weir, and outlet gates.

4.6.3 Implementation Program

(1) General

Basically, the construction works for the comprehensive flood mitigation project were contemplated as divided into three phases with a total of fifteen years, taking into account the scale of investment, the extent of economic effectiveness, and degree of urgency based on social requirements.

Fig. 4-10 shows the required project cost for flood mitigation and present and future flood damages, in each stretch of the Klang River and its tributaries. As shown in this figure, in the upper reach the flood damages under present land use conditions is very high, and is described in APPENDIX G. There are also many places frequently affected by flash floods. In these upper stretches, the river improvement works have been partially completed by DID and in some stretches is now on-going. Hence, the upper reach has the first priority to be improved.

In the middle reach, only upstream stretches of Puchong Drop have a high potential for damage at present. However, in future, as the assets in the flood prone area increase, it will be necessary to protect these developing areas from floods.

In the lower reach, only the Klang town stretch is subject to heavy flood damage under present land use conditions. The river channel in the lower reach has a comparatively large section, and is not so urgent to widen the channel. However, these areas are continuous, flat lowlying areas affected by high tides along the length of the Klang River. Therefore, it will be necessary to construct a continuous and long levee, at first.

In general, the lower and middle reaches of the flood prone areas along the main river, except the upper portion of the middle reach, are rarely affected by flash floods and have low priority of improvement compared with the upper reach.

(2) Outline of the Proposed Flood Mitigation Projects

The outline and purpose of the proposed flood mitigation facilities are summarized in Table 4-3, and described below:

i) Phase I (Provisional Plan)

In order to realize the flood mitigation plan as soon as possible and to meet the urgent social requirement, a provisional plan (urgent project) was introduced, and a 35-year probable flood was applied as the design flood considering the existing flow capacity of the river channel in the central part of Kuala Lumpur, and quantities of work for flood mitigation.

During this phase the necessary land area of about 12 km^2 for the Natural Retarding Basin in Sg. Rasau area shall be reserved.

For the upstream stretches of the Sulaiman Bridge, the following works will be executed:

- The Batu Retention Pond is to be constructed to reduce the discharge in the Batu, Gombak and Klang Rivers. This is the most effective measure to decrease the discharge passing through the Sulaiman Bridge which has a discharge capacity of only 520 m^3/s conesponding to a 25year return period at present. The Gombak Diversion Channel to divert the flood water from the Gombak River to the Batu River will be also constructed at this stage.

- The river improvement works will be limited to the central portion of the City. The stretches with squatter settlements along their banks are not to be executed at this stage because of the problem of land acquisition.

- For the Batu River, the B2 and B3 stretches at downstream of the proposed retention pond are to be widened and deepened for carrying the release of discharge from the Batu Retention Pond.

- For the Gombak River, the G4 stretch of 2.5 km in length is to be widened and deepened to divert the discharge effectively to the diversion channel.

- The K9 stretch of the Klang River is to be widened and deepened. The inner water drainage works in Kampung Baru along the Klang River is to be executed. Six bridges (B3, B4, B5, B6, B7 and K22 as shown in Fig. 4-9) are also to be reconstructed.

ii) Phase II (Mid-term Plan)

In order to complete the long-term plan, extensive construction cost will be incurred and a long construction period will be needed. Thus, in order to attain various targets of the flood mitigation plan as soon as possible, a staged flood mitigation plan was designed and this mid-term plan was introduced as Phase II. In this stage, the improvement works are executed mainly in the middle and lower reaches of the Klang River.

The K7 stretch between 3rd Mile Bridge and confluence of Sg. Kuyoh, and the K6 stretch between Sg. Kuyoh and Puchong Drop are to be widened. The deepening of these stretches is not possible before deepening the K4 and K5 stretches and removal of Puchong Drop. The K7 and K6 stretches suffer from heavy flood damage at present. The K10 stretch between Circular Road Bridge and confluence of Sg. Ampang is also to be widened and deepened. The Klang Town stretch K2 is to be improved by widening and deepening in order to reduce the flood damage in this area. K4 and K5 stretches can be widened and deepened to make the removal of Puchong Drop

possible. For the K3 stretch, only the construction of the levee will be executed for the effective use of the natural retarding basin in Rasau area.

The flood protection levels after completion of these river improvement works in this stage will become about a 30-year return period for the middle reach and a 100-year return period for the Klang town reach.

iii) Phase III (Long-term Plan)

To ensure the safety of the facility and long term stability, and also the safety of livelihood of the riparian people concerned, a long-term plan was introduced as a target plan for future phase of flood mitigation, and a 100-year probable flood was applied as the design flood. This was chosen due to the reason that if the river improvement work is designed to cope with a 100 year probable flood, a flood peak discharge with the same scale as that in 1971 can be safely handled throughout the whole river channel of the Klang River.

In this stage, the Puchong Drop structure will be removed and the K6, K7 and K8 stretches in the middle reach are to be deepened. For the Gombak River, the G1 stretch is to be deepened while the G2 and G3 stretches are to be widened and deepened.

In the upper reach of the Klang River, the K11 stretch is to be widened and deepened.

In the lower reach of the Klang River, the K1 stretch near the river mouth and the K3 stretch are to be widened and deepened. For the Batu River, deepening of the B1 stretch will be necessary.