GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

SECTORAL REPORT

VOL. 5

RIVER CONDITIONS

OCTOBER 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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COMPOSITION OF THIS VOLUME

This Volume consists of two parts: Part 1 deals with the subject matters of Peninsular Malaysia and Part 2 is devoted to the States of Sabah and Sarawak.

ABBREVIATIONS

(1) Plan

FMP	:	First Malaysia Plan
SMP	:	Second Malaysia Plan
TMP	:	Third Malaysia Plan
4MP	:	Fourth Malaysia Plan
5MP	:	Fifth Malaysia Plan
6MP	:	Sixth Malaysia Plan
7MP	:	Seventh Malaysia Plan
NEP	:	New Economic Policy
OPP	:	Outline Perspective Plan
RESP	:	Rural Environmental Sanitation Program

(2) Domestic Organization

DID (JPT)	:	Drainage and Irrigation Department
DOA	:	Department of Agriculture
DOE	:	Division of Environment
DOF	:	Department of Forestry
DOFS	:	Department of Fishery
DOM	:	Department of Mines
DOS	:	Department of Statistics
EPU	:	Economic Planning Unit
FAMA	:	Federal Agricultural Marketing Authority
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
ICU	:	Implementation and Coordination Unit
MARDI	:	Malaysian Agricultural Research and Development Institute
MIDA	:	Malaysian Industrial Development Authority
MLRD	:	Ministry of Land and Regional Development
MMS	:	Malaysian Meteorological Service
MOA	:	Ministry of Agriculture
MOF	:	Ministry of Finance

MOH	:	Ministry of Health
MOPI	:	Ministry of Primary Industries
MRRDB	:	Malaysia Rubber Research and Development Board
NDPC	:	National Development Planning Committee
NEB (LLN)	:	National Electricity Board
PORIM	:	Palm Oil Research Institute of Malaysia
PWD (JKR)	:	Public Works Department
RDA	:	Regional Development Authority
RISDA	:	Rubber Industry Small-holders Development Authority
RRIM	:	Rubber Research Institute of Malaysia
SEB	:	Sabah Electricity Board
SEBC	:	State Economic Development Corporation
S(E)PU	:	State (Economic) Planning Unit
SESCO	:	Sarawak Electricity Supply Corporation
UDA	:	Urban Development Authority

(3) International or Foreign Organization

ADAA	:	Australian Development Assistance Agency
ADB	:	Asian Development Bank
ASCE	:	American Society of Civil Engineers
FAO	:	Food and Agriculture Organization of the United Nations
IBRD	:	International Bank for Reconstruction and Development
ILO	:	International Labour Organization
IMF	:	International Monetary Fund
IRRI	:	International Rice Research Institute
JICA	:	Japan International Cooperation Agency
JSCE	:	Japan Society of Civil Engineers
MOC	:	Ministry of Construction, Japan
OECD	:	Organization for Economic Cooperation and Development
OECF	:	Overseas Economic Cooperation Fund, Japan
UK	:	United Kingdom
UNDP	:	United Nations Development Program

UNSF	:	United Nations Special Fund
US or USA	:	United States of America
US/AID	:	United States Agency for International Development
USBR	:	United States Bureau of Reclamation
WHO	:	World Health Organization
WMO	:	World Meteorological Organization

(4) Others

B	:	Benefit
BOD	:	Biochemical Oxygen Demand
C	:	Cost
CIF	:	Cost, Insurance and Freight
COD	:	Chemical Oxygen Demand
D&I	:	Domestic and Industrial
dia	:	Diameter
EIRR	:	Economic Internal Rate of Return
El.	:	Elevation above mean sea level
Eq.	:	Equation
Fig.	:	Figure
FOB	:	Free on Board
FSL	:	Full Supply Level
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
H	:	Height, or Water Head
HWL	:	Reservoir High Water Level
LWL	:	Reservoir Low Water Level
O&M	:	Operation and Maintenance
Q	:	Discharge
Ref.	:	Reference
SITC	:	Standard International Trade Classification
SS	:	Suspended Solid
V	:	Volume
W	:	Width

ABBREVIATIONS OF MEASUREMENT

Length

mm = millimeter
cm = centimeter
m = meter
km = kilometer
ft = foot
yd = yard

Area

cm^2 = square centimeter
m^2 = square meter
ha = hectare
km^2 = square kilometer

Volume

cm^3 = cubic centimeter
l = lit = liter
kl = kiloliter
m^3 = cubic meter
gal. = gallon

Weight

mg = milligram
g = gram
kg = kilogram
ton = metric ton
lb = pound

Time

s = second
min = minute
h = hour
d = day
y = year

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt
GW = Gigawatt

Other Measures

% = percent
PS = horsepower
° = degree
' = minute
" = second
°C = degree in centigrade
10^3 = thousand
10^6 = million
10^9 = billion (milliard)

Derived Measures

m^3/s = cubic meter per second
cusec = cubic feet per second
mgd = million gallon per day
kWh = kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
kWh/y = kilowatt hour per year
kVA = kilovolt ampere
BTU = British thermal unit
psi = pound per square inch

Money

M$ = Malaysian ringgit
US$ = US dollar
¥ = Japanese Yen

CONVERSION FACTORS

	From Metric System	To Metric System
Length	1 cm = 0.394 inch 1 m = 3.28 ft = 1.094 yd 1 km = 0.621 mile	1 inch = 2.54 cm 1 ft = 30.48 cm 1 yd = 91.44 cm 1 mile = 1.609 km
Area	1 cm^2 = 0.155 sq.in 1 m^2 = 10.76 sq.ft 1 ha = 2.471 acres 1 km^2 = 0.386 sq.mile	1 sq.ft = 0.0929 m^2 1sq.yd = 0.835 m^2 1 acre = 0.4047 ha 1 sq.mile = 2.59 km^2
Volume	1 cm^3 = 0.0610 cu.in 1 lit = 0.220 gal.(imp.) 1 kl = 6.29 barrels 1 m^3 = 35.3 cu.ft 10^6 m^3 = 811 acre-ft	1 cu.ft = 28.32 lit 1 cu.yd = 0.765 m^3 1 gal.(imp.) = 4.55 lit 1 gal.(US) = 3.79 lit 1 acre-ft = 1,233.5 m^2
Weight	1 g = 0.0353 ounce 1 kg = 2.20 lb 1 ton = 0.984 long ton = 1.102 short ton	1 ounce = 28.35 g 1 lb = 0.4536 kg 1 long ton = 1.016 ton 1 short ton = 0.907 ton
Energy	1 kWh = 3,413 BTU	1 BTU = 0.293 Wh
Temperature	°C = (°F - 32)·5/9	°F = 1.8°C + 32
Derived Measures	1 m^3/s = 35.3 cusec 1 kg/cm^2 = 14.2 psi 1 ton/ha = 891 lb/acre 10^6 m^3 = 810.7 acre-ft 1 m^3/s = 19.0 mgd	1 cusec = 0.0283 m^3/s 1 psi = 0.703 kg/cm^2 1 lb/acre = 1.12 kg/ha 1 acre-ft = 1,233.5 m^3 1 mgd = 0.0526 m^3/s
Local Measures	1 lit = 0.220 gantang 1 kg = 1.65 kati 1 ton = 16.5 pikul	1 gantang = 4.55 lit 1 kati = 0.606 kg 1 pikul = 60.6 kg

Exchange Rate
(as average between July and December 1980)

$1 = M$2.22
¥100 = M$1.03

PART 1

PENINSULAR MALAYSIA

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1. INTRODUCTION

There are more than 100 river systems in Peninsular Malaysia. The rivers are used for many purposes such as inland navigation, tansportation of goods, irrigation, domestic water use and hydropower generation. While floods affect the human life, properties and public facilities almost every year and everywhere in Peninsular Malaysia. It is estimated that the flood prone area is 15,300 sq.km, which is 12% of the total area of 132,000 sq.km and 2.5 million people live in the flood prone area. Flood damage potential will increase according to the population growth and GDP growth. Bank erosions, sedimentation and salt water intrusion are also observed.

The objective of the river condition study is to make clear the constraints for water use and related land use arising from the inundation, sedimentation and erosion of rivers. The results will be used for the water resources planning especially for flood control and mitigation plannings.

The sectoral study comprises the following items:

(1) Review and observation of present river condition
(2) Review of flood records and characteristics
(3) Estimate of probable flood damage
(4) Formulation of flood mitigation plans, alternative study and the selection of recommended plan

Information was collected mainly from the state DID offices and also by visiting the field from July 1980 to December 1981. Chapter 2 describes the results of survey.

In Chapter 3, brief descriptions are given to the past flood events, flooding characteristics and existing flood control facilities.

Studies in Chapter 4 is the estimation of probable damages for some 50 flooding rivers. Annual average damage are calculated by river basin and also by state.

Discussed in Chapters 5, 6 and 7 are basic criteria and assumptions set out for plan formulation, cost estimate and benefit estimate, respectively. These criteria were applied uniformly to all the schemes studied, to aim at the comparison of the schemes on an equal basis.

Chapter 8 discusses the flood mitigation plans, inclusive of structural and non-structural measures. Through the screening of various proposed measures, 3 alternative development plans have been formulated for each state.

Chapter 9 describes the development schedule, budgetary and manpower requiremets for the implementation of the 3 alternative development plans. The economic evaluation of the plans is also contained in this chapter.

Presented in Chapter 10 is the recommended development plan for each state, which was selected through a comparison of the proposed 3 alternative plans. Technical review of the recommended plan is discussed in the latter part of this chapter.

Data and reports used for the study and analysis are summarized in the end of the text as reference.

A constraint experienced was that the study had to be based on the limited data and information, in particular hydrological data and river topographical data. It is hoped that the finding of this study would be ascertained based on further detailed data to be collected in subsequent studies which will be scheduled for the schemes recommended in this study.

2. PRESENT CONDITION OF RIVERS

2.1 River Basins

In this study, the Peninsular is divided into 41 river basins, which comprises 26 major rivers and 15 groups of medium to small river basins.

Tables 1 to 3 are the list of river basins, showing the basin area. The location of the rivers is shown in Fig. 1.

2.2 River Profiles

Figs 2 to 19 show the profile of major rivers. As the survey data are not available for most of the rivers, the figures were prepared based on information contained in 1:63,360 maps. Although the accuracy is limited (particularly as to riverbed levels), this information could be used for subsequent planning study.

As is observed on the profiles, the river gradient in the middle to lower reaches is very flat for most of the rivers. This is one of the reasons for flooding in these rivers.

2.3 River Condition and Behaviour

Present condition and noteworthy behaviour of rivers are described in tabular form in Tables 3 to 36 for each of the major river basins respectively. Owing to time constraint for field inspection and the limited accessibility to the sites, the Study could only achieve a general assessment of major problms inherent to the rivers.

The tables describe observations on river morphology, estuary condition, silting and flood problems. Water quality problem is discussed separately in Sectoral Report Water Quality.

3. FLOOD RECORDS AND EXISTING FACILITIES

3.1 Historical Flood Events

Tables 37 to 46 show the flood disasters recorded in Peninsular Malaysia during these several decades. Of those, the following flood events are of the severest kind and should be noted:

Year of Occurrence	Extent of flood (Source: Ref. 9)
1886	This, flood, called "Storm Forest Flood", caused very extenstive damages in the Kelantan plain. The flood was accompanied by gale force winds which destroyed several hundred square miles of forest in the low hilly terrain surrounding the flood plains of the Kelantan and Besut rivers.
1926	Biggest flood in living memory. The floods affected the most of Peninsular Malaysia, causing extensive damages to natural environment, as evidenced by the severe erosional scarring of hillside, silting up of river beds, creation of residual lakes, in the Pahang/Trengganu border region.
1931	Perak-Kelantan border region was assaulted by severe flooding, including the Kinta valley, in Perak.
1947	Severe flooding in North Perak including Krian District.
1954	Floods assaulted over a large area of Johor and some coastal area in Trengganu.
1957	Kelang valley in Selangor was severely affected by flooding. Although the flooded area is comparatively small, damages were significant due to the flooding in highly populated area.
1965	Extensive flooding in the Kelantan and Besut river basins.
1967	Most severe flood experienced in the Kelantan Trengganu and Perak basins with greater damages. (e.g. M$78 million in the Kelantan basin. Ref. Table 48)
1971	Most part of the Peninsular suffered losses and damages on an unprecedented scale. The worst hit area was the Pahang river basin (M$30 million, Ref. Table 48) and the Kuala Lumpur area (M$34 million, Ref. Table 49).

Of the above flood events, the 1967 and 1971 floods are of recent occurrence, for which flood behaviour records and some damage records have been made available. In the subsequent study, these two flood events are mainly evaluated to estimate the probable flood damages.

A noteworthy matter is that there were at least 2 disastrous flood events caused due to the failure of mining bunds; one is in Selangor (near Kuala Lumpur) in 1963 and the other in Perak (near Ipoh) in 1974.

3.2 Flood Vulnerable Areas

Flood vulnerable area in the Peninsular is shown on Fig. 20. Some 50 rivers are causing floods of varying severity.

As is shown in the figure, flood is occurring in almost every part of the Peninsular. Aerial pattern of flood occurrence is quite erratic and unpredictable year after year, depending on the course of monsoon flows.

3.3 Seasonal Pattern of Flood Occurrences

Seasonal pattern of flood occurrence was examined based on records in the DID's flood reports. The result is shown on Fig. 21, which indicates that the Peninsular can be divided broadly into 2 blocks, i.e. West Coast and East Coast areas, where the main flood season is occurring with a few month-time lag.

Paddy growing stage coinciding with the main flood period is as follows:

Area	Season	Paddy Growing Stage
East Coast/Johor	Dec.-Jan.	Heading to Ripening Stage
West Coast	Sep.-Nov.	Booting to Heading Stage

3.4 Flood Characteristics

Flood type is generally classified into the following 3 types:

(1) Overbank flow due to insufficient channel capacity.
(2) Tidal effect and back water effect, which causes floodings in the lower reaches and in the tributaries respectively.
(3) Inland flooding due to poor drainage.

The type of flood in each river basin is described in Tables 3 to 36.

Even in the case of flood due to overbank flow, the velocity of flood flow is in most cases of less significance to the damages because of wide flooding area and flat gradient of the rivers. Flood water is turbid in most of the cases. Subsequent flood damage estimate will be made assuming these flooding conditions, i.e. moderate to low flow velocity of the flood water and inundation by turbid water.

3.5 Flood Damage Records

(1) Flood damage statistics

Flood damage record is being collected by the related government departments and agencies. However, the survey and recording are not on regular basis and the data are not available in a form of statistical records. DID's flood report is only a comprehensive flood record made available for the Study. It contains much useful technical information, but the damage records cover only partial fields due to the difficulty of damage data collection by a single agency.

Limited availability of the actual records made the Study Team unable to prepare a flood damage statistics.

Table 47 is a flood damage record reported in the ESCAP water resources journal. As far as the table indicates, flood damage in Malaysia is of moderate extent as compared with other neighbouring countries. However, it is likely that this may partly be due to the underestimate of damages in the past flood events.

(2) Flood damage survey data

Other usable data are the flood damage survey data collected for major flood events in several river basins. The data is available in previous reports for the Kelantan, Kemasin/Semerak, Trengganu, Kuantan, Pahang and Kuala Lumpur floods. Tables 48 and 49 show the surveyed or estimated damage for these floods.

Damage-frequency relationship of those flood events can be expressed linearly on semi-leg coordinates as shown on Fig. 22.

3.6 Existing Flood Control and Warning Facilities

(1) Flood control facilities

Most of river facilities so far constructed are rather of ad-hoc basis, implemented mainly with the aim of protecting the irrigation and drainage schemes at localized places. In 1972, the flood mitigation work was assigned as an additional function of DID. Since then, overall plans of comprehensive river control purposes have been studied for several basins and some of them are under implementation.

Fig. 23 shows the location of major flood control and other related facilities so far constructed and under construction.

(2) Flood forecasting and warning facilities

Telemetric flood forecasting system has been installed for 4 river basins, i.e. the Kelantan, Trengganu, Pahang and Perak river basins.

In the Kelantan, Trengganu and Pahang river basins, real time data of rainfall and river water level are transmitted automatically by teleprinter to the State DID office located at the state capital. The data are further passed to Kuala Lumpur by teletype circuits for processing at the Flood Forecasting Center (FFC).

Computer programme for flood forecast for the Kelantan and Trengganu river basins is based on the Sacramento Model, while that for the Pahang basin is based on the unit hydrograph method. In preparing the forecast, observatory data from storm detection radars (operated by Malaysian Meteorological Services) are also assessed qualitatively. The forecast output is transmitted back to the State DID office who will distribute the information to the State Natural Disaster Relief Committee (SNDRC, commonly called State Flood Committee), for their issue of warning.

Flood forecast for the Perak river basin is prepared by the State DID office, independently from the DID Headquarters' centralized system. The forecast is principally based on stage correlation technique with input of water level records at the K.Kederong Station in Grik. The forecast output is informed to the State Flood Committee as well as to the DID Headquarter. This system provides forecast at downstream points with 15 to 18 hours warning time.

For other basins, telemetering system has not been installed yet. Flood level records observed at gauges are sent to the State DID through the use of voice communication either by telephone or VHF radio. The method of forecasting is based on stage correlation technique.

Existing flood forecasting and warning set-up for major river basins, including telemetric system, is shown in Tables 50 to 54. Fig. 24 illustrates the networks of flood forecast stations together with major flooding areas.

Details of flood warning and relief system (organization, warning dissemination, rescue operation) are discussed in Sectoral Report Water Resources Managemant.

4. ESTIMATE OF FLOOD DAMAGES

4.1 Method of Approach

The absence of flood damage statistical data has obliged the Study Team to carry out an elaborative work of flood damage estimate for each of 41 river basins.

In estimating the damages, proxy method had to be taken at each step of the study owing to the limited availability of data and records. The adopted method is described in 4.2 to 4.6 hereinafter.

Among others, a major difficulty was that no detailed topographic maps other than 1:63,360 maps were made available for most of the areas. Flood maps had to be prepared based on scarce contour information, 15 m (50 ft) intervals, contained in the 1:63,360 maps.

4.2 Preparation of Flood Maps

Flood map was prepared principally by assuming the largest flood recorded in each basin during these 17 years (1963 to 1979), as far as the flood record is made available in the DID's flood reports. The flood events selected for each basin are shown in Tables 88 to 89. The magnitude of the selected flood is varying by basins, 5 to 80-year floods, in terms of recurrence probability.

The mapping was made based on the following data and information:

(1) Peak flood levels recorded at gauges.
(2) Existing flood maps prepared by DID. They were particularly usable for mapping at places where flood level and ground height data are scarce.
(3) Information of spot flooding places (e.g. villages, padi schemes) recorded in the DID flood reports.
(4) Contour lines and spot ground heights shown on the 1:63,360 maps.

Flood maps were prepared for respective river basins as shown on Figs. 25 to 54.

Tables 55 and 56 summarize flood prone area by basin. The total flood prone area is 15.3 thousand sq.km, which is as large as 12% of the total Peninsular area (132 thousand sq.km).

4.3 Flood Area Statistics

(1) Land use areas

By superimposing the flood map on the latest-issued land use maps (1974), land area in the flood area was measured for 12 classified land use categories. The results are shown on Tables 58 to 68 (by basin) and also on Tables 69 to 71 (by state). The total flood area is summarized below.

1.	Urban Area	11,300 ha
2.	Mining	8,600 ha
3.	Mixed Horticulture	83,100 ha
4.	Rubber	227,000 ha
5.	Oil palm	38,800 ha
6.	Coconuts	57,700 ha
7.	Other tree crops	10,800 ha
8.	Paddy	150,200 ha
9.	Grassland	26,200 ha
10.	Forest lands	297,400 ha
11.	Swamps and unused lands	620,500 ha
	Total flood plain area	1,531,600 ha

There may have been some change of land use (probably more intensive use) since 1974 to the present (1980). Flood damage estimate in this Study will be slightly on a conservative side, since it is based on the 1974 land use data.

(2) Population in flood area

Population in flood areas was estimated by multiplying population density by residential areas (urban and mixed horticulture areas in the land use categories) in the flood prone area.

Population density was estimated for each state based on 1975 population data (Ref. Sectoral Reports Socio-economy and Domestic and Industrial Water Supply) and the 1974 land use maps. The details of the estimate are shown on Tables 72 to 74.

As to population growth from 1975 to the present (1980), the growth rate in the flood prone area was assumed to be half of the average rate for each state (See Table 75).

(3) Number of households

As presented in Table 76, number of persons per household is 5.5 on an average for the whole Peninsular with little difference among states. Although this figure is based on the 1970 population and housing census data, it was assumed that the figure has not changed much in the present.

The number of households in the flood area was calculated by dividing the population by 5.5 persons/household.

(4) Roads and railway

Lengths of roads and railway in the flood area was measured on the 1:63,360 maps. As road and railway are constructed at a higher elevation than the flood land levels, it does not imply that the whole lengths shown in Tables 58 to 68 are always submerged. The figures were worked out for reference purpose for assessing the damage potential of public facilities and utilities.

4.4 Flood Depths and Duration

As it was almost impossible to estimate the flooding depth on the 1:63,360 maps, the source of information only made available was the records contained in the DID flood reports.

Inundation depths reported in the DID's reports are mostly those at people-resided or damage-recorded areas like villages and paddy areas. Average flood depth assessed in this study (See Tables 88 to 89) therefore represents the depths in those people-resided/flood damageable lands, disregarding remote/unused lands (e.g. swamp land) where the depth record is usally not available and the damage value is nil.

4.5 Flood Damage Factors

(1) Crop damage factors

Damage factors were determined mostly by referring to the data and values analysed and recommended in previous studies. The adopted damage factors are shown in Tables 77 to 84 and Figs. 55 to 56.

Paddies:

- See Table 78 for damage factors. In determining the factors, plant height of local padi varieties and the damageability of crops by seasons were duly considered (See Table 74).

- Flood padi area was classified into 2 categories, i.e. irrigated and rainfed, in proportion to the padi areas ratio for the whole basin (See Tables 79 to 80).

Rubbers:

- Mortality: considered only for young rubber trees less than 3 years old. See Table 81 for mortality rates. No mortality for mature trees.

- Young trees: 9% of total planted area, assuming 3% replantation rate per annum. (3% x 3 year = 9%)

- Production loss: P = p x D
  where, P: production loss in dry rubber.
  p: production loss rate, 9.4 kg/ha/day, assuming 1,420 kg/ha of annual production (Ref. Sectoral Report Agriculture) and 150 tapping days per annum.
  D: 1/2 x flood duration (day) assuming the suspension of tapping for a half period of flood duration.

Oil palms:

- Mortality : only for young trees up to 3 years old. See Table 82 for mortality rates.

- Young tree: 9% of total planted area, assuming 3% replanting cycle.

Coconut palms:
- Mortality : only for young trees up to 3 years old. See Table 82 for mortality rates.

- Young trees: 6% of total planted area, assuming 2% replanting cycle.

Other tree crops:
- Damage factors was determined for fruit tree crops which represent the crops under this category.

-Mortality : only for young trees up to 3 years old. See Table 83 for mortality rates.

- Young trees: 10% of total planted area.

Mixed horticulture:
- See Table 84 for adopted damage factors.

(2) Livestock losses

Scarcity of actual damage records has obliged to derive the damage rates based on limited past records (See Table 85). Adopted loss rate is expressed per household affected by flood, as shown in Fig. 56.

(3) Housing/properties losses

Damage factors used in Japan were adopted. See Table 86.

(4) Public facilities and utilities

This category includes the damages to roads, railway, irrigation facilities, elctricity and telecommunication facilities, water supply works and other public facilities.

Information on 1:63,360 maps is not sufficient to estimate the damages under this category on a certain detailed basis. The damage was estimated to be 30% of building losses (both public and private housings). This assumed rate is rather conservative, if comparing with that of damage records shown on Tables 48 and 49 (mostly varying 30 to 50%, averagely 45% to the building losses).

(5) Public buildings

Damage factors are selected to be same as the housings.

(6) Industrial facilities

This damage was not estimated for floods occurring in rural areas, in consideration that industrial facilities are in most cases located in flood free areas.

Only for floods affecting some large urban areas or specific industrial areas, the estimate is made on a lump sum basis at 10% of the urban housing losses.

(7) Mining, grassland, forests and swamps

In view of minor or moderate damage potential in these areas, the damages were not estimate.

(8) Indirect damages

Damages under this category involves wages lost, commercial trade lost, industial production lost, transportation losses, losses from interruption of utility services and costs for rescue and relief operations.

The indirect damage can be usually estimated by multiplying a factor to direct damages. According to a survey conducted by US Corps of Engineers in New England areas, the following rates were worked out:

Category of Damage	Indirect Loss/Direct Loss
Residential/Public	1.5
Agricultural	0.2
Highways	1.0

In this study, a conservative rate of 30% is adopted in consideration that the majority of damage comes from agricultural or related activities. Actual damage records shown in Table 48 to 49 also agree to this adopted rate (average of 6 flood events in Tables 48 and 49: 32% to the direct damage).

4.6 Value of Crops and Buildings

The following values were used in the calculation of flood damages (1980 prices):

(1) Crop production values (Ref. Sectoral Report Agriculture).

Paddy:
- Irrigated: M$620-1,270/ha
- Rainfed: M$540-1,010/ha
  (Value varies by state. See Table 87).

Rubber:
- Replanting of young trees up to 2 years old: M$2,880/ha
- Production loss, dry rubber: M$2.73/kg

Oil palms:
- Replanting of young trees up to 2 years old: M$1,930/ha

Coconuts palms:
- Replanting of young trees up to 2 years old: M$3,440/ha

Other crops:
- Replanting of young cocoa and coconut trees up to 2 years old: M$3,540/ha

Mixed horticulture:
- Replanting cost of coconut in 75% of the area

and production loss value of orchard in 25% of that: M$2,900/ha

(2) Buildings/properties

Private housing,	urban:	M$7,500/household
	rural:	M$3,000/household
Public buildings	:	M$2 million/10,000 population (similar assumption to that made in Ref.19).

4.7 Estimate of Flood Damages

(1) Estimate of damage

Damage for flood events selected for each basin (See 4.2) were then calculated based on loss quantities (4.3), damage factors (4.4) and crops/properties values (4.6). The estimated damage amount is shown in Tables 88 to 89, together with flood event details assumed in the estimate.

The estimated damage amount represents the potential damage where the flood assaults the area under the present (1980) development conditions.

(2) Comparison with record/estimate in previous studies

The damage amount worked out in this study was compared with the actual records/estimate reported in previous studies. Flood events selected for the comparison are the 1967 Kelantan flood and the 1971 Pahang flood for which comparatively detailed damage survey was conducted.

The results of the comparison are summarized below. The breakdowned details are shown in Tables 90 and 91.

Unit: M$ million

	Kelantan 1967 Flood	Pahang 1971 Flood
(a) Record or estimate in previous studies (price level at study year)	78.9 (1976)	29.6 (1974)
(b) Estimate by applying the method used in this study (price level and quantity: same as for (a))	79.1 (1976)	28.6 (1974)
(c) Estimate in this study at 1980 price level and quantity	114.8 (1980)	86.0 (1980)

The above comparison indicates the following:

1) Estimate in this study (b) gives a slightly higher figure for the Kelantan flood and a lower figure for the Pahang flood at the same price level as for the previous studies. The difference in the estimated amount is within 4%.

2) Larger damage amount estimated in (c) is due to the following reasons:

- Increase in quantity of damage susceptible properties, e.g. more intensified use of land, increased population.

	Previous Studies	This Study
Land use data	1966	1974
Population	1971 & 76	1980

- Rise of crop and properties values

4.8 Annual Average Flood Damage

(1) Damage frequency curves

Damage frequency curve was then prepared on an assumption that damage-probability relationship is expressed linearly on semi-log coordinates (See 3.5). The curve was drawn by plotting the estimated damage for the selected flood events (See 4.7) and a point of recurrence probability of non-flooding year. The latter point was determined based on the information of non or minor flooding events contained in the DID's flood reports. This proxy method had to be adopted, since the bankful discharge could not be assessed due to lack of river cross sectional data.

Recurrence intervals of the selected flood events and non-flooding discharge are shown in Table 92. For river basins where hydrological records are not available or scarce, the recurrence probability of flood events was assumed to be similar to that in the neighbouring basins. The damage-frequency curves are shown on Figs. 57 and 58.

(2) Annual average flood damage

Annual average damage was then calculated on the basis of damage-frequency relationship worked out above.

The results are presented in Tables 93 to 95 (by basin) and also in Tables 69 to 71 (by state), together with the estimated number of people in the flood susceptible area.

Average flood damage potential for the whole Peninsular is estimated at M$72 million per annum. Approximately 2.2 million people are vulnerable to flood of varying probabilities.

5. PLANNING CRITERIA

This chapter describes the basic criteria and methodology of plan formulation study. The plan formulation is discussed in 8 hereinafter.

5.1 River Stretches and Design Flood

5.1.1 River stretches

To assess the viability of flood mitigation plans area by area, the flood area is divided into river stretches. The stretch division is made mainly in consideration of the distribution of flood areas, the layout of proposed flood protection schemes, the confluence of tributaries, and the land uses and damage potential of the areas.

5.1.2 Selection of design flood

(1) Design flood criteria

In planning the flood mitigation works, a primary requirement is to set out a hydrological design standard, i.e. hydrologic risk level allowed for the proposed plans. Reviewing the current local and overseas practices including the proposed criteria in the DID's Provisional Hydrological Procedure (Ref.41), the following basic criteria have been assumed in this study:

Design Flood (frequency of interval in year)	Damage Potential	Population
100-year	Large (M$20 thousand /km over)	Casuality in past floods Densely populated (500 people/km over)
50-year	Large (M$20 thousand /km over)	Densely populated (500 people/km over)
20-year	Moderate (M$20 thousand /km under)	Sparsely populated (500 people/km under)

Remarks: 1) km-length of improved river stretch
2) Damage expressed in terms of average annual damage.
3) Quantitative criteria expressed in the table (M$/km, people/km) are only tentative classifications assumed in this study to select the design flood on an equal basis for all the rivers.

Based on the above criteria, the design flood is to be selected for each river stretch. A consideration is given so that a consistent design flood is to be selected over a certain number of stretches to avoid the excessive variation of design flood stretch by stretch.

Design flood for flow regulation by dams is selected to be 50 or 100-year flood, depending on the design flood selected for the downstream improvement. Even if the protection level of the downstream area is at 20-year flood, the flood control function of the dam is designed for 50-year flood to preserve a larger flood control capacity in dam with a view to coping with the possible grade-up of the flood protection level in the downstream area in future.

(2) Estimate of design flood discharge

The design flood discharge is estimated from the regional flood frequency curves shown on Figs. 59 and 60 (reproduced from Sectoral Report Meteorology and Hydrology). The curves are constructed as the max. envelope curve of flood events recorded at various rivers under varied flow-routing conditions. The largest values read on the envelope curve should represent flood runoff with a lesser effect of flow routing, and hence they could be regarded to represent flood discharge under a confined condition.

5.2 Flood Mitigation - Structural Measures

Various alternative measures and their combinations are conceived for flood mitigation works. In this study, the following measures are mainly examined:

(a) Channel Improvement

This work is to increase the channel capacity by canalizing the river course and by bunding the river banks.

As to the cross-sectional improvement, composite-cross section is in principle proposed with a view to its favourable aspects of both hydraulic efficiency and channel stabilization. The channel section assumed is basically such that the present river channel is utilized as low-water channel, while the high-water channel is formed by river bunds constructed on the both banks.

In determining the sections, the following considerations were given:

- The selected section of low-water channel represents the typical cross sectional shape of the existing river channels. The present channel in most of the rivers has a capacity of accommodating 2 to 3-year flood discharges averagely, which corresponds approximately 25% of the selected design flood (50 to 100-year flood). Hence, an assumption is that 25% of flow is accommodated in the low-water channel, i.e. existing river channel.

- The width of high-water channel was selected in reference to the recommended width derived through experiences in Japan (See Table 96).

- The depth of high-water channel was then determined to pass 75% of flow. Where required, a minor adjustment was made to balance the excavation and embankment volumes by slightly varying the high-water channel bed level.

Single-cross section is also assumed, but limitedly for the river stretches described below.

- comparatively small rivers with design flood of less than 200 cu.m/s

- stretches with a gradient steeper than 1/500

- river in urban areas densely populated.

In actual implementation, there may be in some places a difficulty of acquiring lands sufficient for constructing a composite-section channel. Further, in some rivers, the construction of an excavated channel with low levels may be recommended in order not to excessively raise the flood flow level. These details should be examined through further detailed survey for each river system.

The length of river improvement is measured on 1:63,360 maps. The longitudinal gradient of river flow is assumed by referring to the stage records of the past major flood events or by reading ground heights appeared on 1:63,360 maps.

(b) Bypass Floodway

This plan will be considered where there is a constraint of improving the existing river channel and where the short-cut of the channel is topographically possible.

The channel cross section and longitudinal gradient were determined to be identical to (a) above. Flow diversion to the floodway was selected within a range of 50 to 100% (basically 75%) of the design flood at the floodway inlet, being varied depending on the estimated capacity of the downstream channel (basically assumed to be 25% of the design flood, unless otherwise known).

(c) Polder (Ring Bund)

This protection measure is conceived at the selected local areas where the damage potential is comparatively large. The work includes the construction of ring bund, drainage channels in the bunded area and drainage outlet facilities (e.g. pumping station).

The method of quantity estimate is described in 6.1 (3).

(d) Flood Control Dam

Potential dams having a comparatively large catchment were examined on 1:63,360 maps. In planning the flood control dams, the following assumptions were made:

-Flow regulation by dam:
Reservoir will regulate the design flood flow (50 to 100 year flood) and release 2 to 3-year flood discharge (approx. 25% of design flood). Flow cut ratio at the damsite (m) is therefore;

$$m = \text{outflow discharge/inflow discharge} = 0.25$$

In case of the existence of previous studies, the flow cut ratio recommended in the previous study was adopted.

-Peak inflow flood discharge:
As read on Fig.61 (reproduced from Sectoral Report Meteorology and Hydrology), where the base flow is assumed to be mean annual discharge.

-Inflow flood volume

$V = R. r. c. A$

where, V : Inflow flood volume
R : 3-day rainfall of given recurrence probability, at station located nearby the proposed damsite
r : Basin rainfall reduction ratio (Ref. Table 6 of Sectoral Report Meteorology and Hydrology)
c : Runoff coefficient (=0.8)
A : Catchment area

-Flood control storage
Duration of flood runoff is assumed to be 3 days. All excess water over the reservoir outflow is to be stored. An allowance of 20% in storage capacity is included to offset the uncertainties involved in reservoir capacity curve and inflow runoff.

-Flood routing effects at downstream point:

K = sq.root (1 - (1 - m2) x a/A)

where, K : Flood reduction ratio at downstream point
A : Catchment area of downstream point
a : Catchment area of dam
m : Flood reduction ratio at damsite

If a group of dams is proposed, (1 - m2) x a in the above equation shall be deemed to be the sum of (1 - m2) x a for all the dams.

In the first screening process of evaluating the flood control function of dams, the dams having a flood routing effect of less than 5% (i.e. $K > 0.95$) at downstream damage centers are discarded at the beginning of the study. Dams having K value of less than 0.95 are examined in further detail.

5.3 Flood Mitigation - Non-structural Measures

Detailed examination of these measures requires an extensive volume of study, which seems to be beyond the capability of this study. In this study, a very preliminary evaluation is attempted to compare the merits of the following non-structural measures:

(a) Restriction of development

In the flooding areas where structural improving measure is economically not justified, the following administrative controls could be enforced to suppress the future increase of damage potential in the area:

- flood area zoning and restriction of development
- public education
- flood risk mapping

This measure may be considered for all the flooding areas where the damage potential is comparatively large.

(b) Land use change and resettlement plan

A more positive measure is to reduce the damage potential in the present flood prone area by resettling the people to higher land and by converting paddy land to less damage-susceptible crop land (e.g. oil palm).

This plan is conceived for flood area having the following characteristics:

- paddy lands, but of small to medium scale, where the structural measure will not be justified.

- less population reasonable for resettlement

- severe flood condition with casuality (e.g. Pahang river basin.)

(c) Flood proofing

This measure comprises the structural change of buildings, elimination of opening, reorganization of spacing, higher structural elevation, and/or local ring dyke around buildings.

It is expected that, with the provision of this measure, most of the damages to buildings and properties can be reduced.

This protective measure will be conceived for flooding areas having the following characteristics:

- less populated at scattered places

- crop damages are not significant

- less severe flood condition, e.g. shallow inundation depth and low flow velocity

5.4 Flood Forecasting and Warning System

A certain portion of the damages to properties as well as the casuality could be reduced if the flood warning is given in due advanced (say 24 hrs) and the effective evacuation is succeeded.

As described in 3.6, flood forecasting and warning system is existing for most of the river systems (telemetric system for 4 major river basins and manual-reading stick gauge system for other basins). Nevertheless, for some of these rivers, the improvement or upgrading of the existing system could still be considered to attain faster forecasting and early dissemination of the warning.

As the improving and upgrading measures, the installation of telemetric forecasting system is proposed for the river basins where the following are expected:

- at least 24 hrs advanced warning attainable with telemetric system installation - more than 5,000 beneficiaries in the warning disseminated area

5.5 Other River Behaviour Problems

5.5.1 Estuary silting

In view of the absence of the detailed study data and the complicate nature of this problem, any proposal under this study seems premature.

Instead, the study estimates the amount of budget required for the allevation of impending problem arising at the places. An assumption made for the estimate of budget requirement is that river mouth dredging will be continued at such places at least up to 2000, until the ultimate measure is provided in long future.

- Rivers requiring dredging: 36 rivers incl. 18 major rivers (See Tables 3 to 36 for list of 18 major rivers).

- Dredging work by force-account system (dredging by the government force and equipment).

Other than the river mouth dredging, the construction of breakwater walls is proposed at the Kemasin and Peng Datu river mouths, following the recommendations of the existing study (Ref.20).

5.5.2 Erosion control

No specific projects are proposed for this purpose, assuming that the minor erosions at local places will be remedied by channel improvement proposed for flood mitigation works or by routine river maintenance projects for which the cost is separately estimated in 6.4 (3).

As for the bank erosion at Teluk Anson town in the Perak river basin, the protection of bank by rock riprap embankment will be proposed.

5.5.3 Sediment removal

Maintenance dredging will be needed to remove riverbed sediment for the rivers identified in Section 2.3. Cost thereof is to be included in the routine river maintenance projects for which the budget is estimated separately in 6.4 (3).

5.5.4 Salt water intrusion

Present problem is of minor extent, which could mostly be solved by discharging the 97% maintenance flow as proposed in Sectoral Report Water Resources Planning. No specific projects are proposed, unless new water supply intake is installed in the present saline reaches where tidal barrage will be considered. See Sectoral Report Water Resources Planning Study for the proposed tidal barrage schemes.

6. COST FUNCTIONS AND ESTIMATE

6.1 Flood Mitigation - Structural Measures

Basically, cost of the works was estimated based on quantities mostly measured on maps being multiplied by unit prices predetermined for each proposed work. The estimated cost represents financial cost at 1980 price level, comprising construction cost, physical contingencies (30% of construction cost) and engineering cost (10% of the former two). Land procurement and resettlement costs are estimated separately.

Cost functions and prices assumed in the estimate are described hereinbelow.

(1) Channel improvement

a. Length of improvement:

- measured on 1:63,360 maps. In principle, the length is measured along the present river course, in a manner to envelop small menders, but to short-cut excessive meanders.

b. Flow gradient

- determined based on flood stage records in the past flood events (shown on flood maps Fig. 25 to Fig. 54), to be supplemented by contour information appeared on 1:63,360 maps, River profiles shown in on Fig. 2 to Fig. 19 were also referred.

c. Cost per km:

- ref. to Table 97 for channel improvement cost

(2) Bypass flood way

a. Channel cross section:

- a single cross section is adopted.

b. Length of floodway:

- measured on 1:63,360 maps. In principle, straight channel route is selected.

c. Flow gradient:

- determined in a similar manner to (1) above. Outlet water level at the sea is selected at EL. 1.5 masl. which represents mean high spring-tide level.

d. Cost per km:

- ref. to Table 98.

(3) Polder

a. Layout and length of bund:

- planned and measured on 1:63,360 maps.

b. Height of bund:

- estimated based on information of average inundation depth in the past flood event. Basically, a freeboard of 1 m high is added.

c. Drainage works:

- drainage area is measured on 1:63,360 maps. Drainage requirement by pumping is assumed to be 1.2 cu.m per sq.km of drainage area.

d. Cost functions and prices:

- cost functions comprise the following:

- ref. to Table 99 for estimated unit prices.

(4) Flood control dam

a. Flood control storage:

- surchage capacity requirement for flood control is calculated for each proposed dam in a manner described in 5.2 (d),

b. Incremental dam volume:

- in case of multipurpose dams, incremental dam volume associated with the flood control surcharge capacity is estimated principally based on dam height - volume curve as far known or alternatively based on the following relationship:

$$V = \{(H22 - H12)/H12\} \times V1$$

where, V : incremental dam volume
H1 : height of dam without flood control
H2 : height of dam with flood control
V1 : volume of dam without flood control

- in case of flood control single-purpose dam, the dam volume is calculated independently based on the estimated sediment volume, flood storage volume, reservoir capacity curve and dam volume curve.

c. Cost for flood control storage

- if the previous cost estimate (at least of feasibility study grade) exists, the previous estimate is updated to the 1980 price level and the flood storage cost calculated in the following manners:

  $$C = V \times Co/Vo$$

  where,
  C : cost for flood control
  V : incremental dam volume due to flood control
  Co : updated cost of dam proposed in the previous study
  Vo : volume of dam proposed in the previous study

  The above implies that the cost for flood control is represented simply by the incremental cost due to flood control. No further detailed cost allocation was attempted in this study.

- for dams where no previous estimate exists, the unit prices per cu.m of dam volume are applied. See table 100 for the estimated unit prices.

(5) Land procurement and resettlement

a. Land area:

- land categories are extracted on 1:126,720 land use maps. Expropriated land area is estimated for each land use category by multiplying the lengths of structures (channel, polder dyke) by average occupying width of the structures, or otherwise by measuring the area on the maps (reservoir impounding area).

b. Resettlemenmt requirement:

- estimate is based on the area of mixed horticulture (village) and urban lands measured in a. above, being multiplied by population density (see Tables 72 to 74 for population density).

c. Prices of land and resettlement:

- ref. to Table 101.

6.2 Flood Mitigation - Non-structural Measures

As described in 5.3, the study only aims at very approximate evaluation of the non-structural measures. The cost estimate herein is based on the following bold assmuptions:

(1) Restriction of development

a. Expenditures for land management office:

- this cost covers salaries for the personnels of the management office, buildings, equipment, and all other expenditures related to land use management.

- once the land use control is enforced, this expenditure occurs continuously throughout the subsequent period.

- ref. to Table 102 for the assumed price.

b. Cost for flood risk mapping:

- this cost covers aero-photo surveys and mapping for production of 1:5,000 to 1:2,500 maps.

- the cost will be disbursed during the first 5 years.

- ref. to Table 102 for the estimated price.

(2) Land use change and resettlement plan

a. Plantation cost:

- this cost comprises (i) the cost for conversion of the presently flooded paddy land to oil palm dependent on flood condition and (ii) the cost for new plantation in the resettled area.

- ref. to Table 102 for the estimated prices.

b. Resettlement cost:

- this cost comprises (i) the cost for resettlement of people and (ii) the cost of new lands to be supplied to people at the resettled area.

- ref. to Table 102 for the estimated prices.

(3) Flood proofing

- various measures are conceived, but the cost assumed herein is the subsidy to household for rebuilding of the house or for construction of a local ring dyke around the house.

- ref. to Table 102 for the estimated price.

6.3 Flood Forecasting and Warning system

As a measure of upgrading the existing forecasting and warning system, the installation of telemetric systems is contemplated in this Study. The cost estimate is based on unit prices predetermined for each type of telemetric stations, to be multiplied by the number of stations proposed for each of the river basins.

Table 103 shows the unit prices by type of the telemetric station.

6.4 Other River Improvement Works

(1) Erosion control and river-mouth breakwater works

Erosion control work is proposed at Teluk Anson town and the construction of river-mouth breakwaters proposed in the Kemasin and Peng Datu river improvement plans, respectively. Table 104 shows the estimated unit prices for these rock embankment works.

(2) River mouth dredging

Departmental dredging by force-account work is conceived in this estimate. Cost for procurement and operation of one fleet of the dredger is estimated as shown in Table 104.

(3) Budget for routine river maintenance works

This item covers the cost requirement for small river improvement works carried out on ad hoc basis, river clearing, desilting works at local places and other routine river maintenance works.

In the DID's draft proposal for 4MP budget, a total amount of M$ 22 million is conceived for these work categories. Assuming that more or less the similar amount at 1980 price is required for 5MP period onward, the budget requirement by state is tentatively estimated as shown in Table 105.

6.5 Operation and Maintenance Costs

In order mainly to simplify the cost stream calculation, operation and maintenance (O&M) costs are expressed in percentage to the initial cost. Table 106 shows the rates of O&M costs for the proposed structural works, together with the estimated service life of the structures.

Replacement of structures/equipment is scheduled at the end of the service life assumed above.

7. BENEFIT ESTIMATE

7.1 Flood Mitigation Benefit - Structural Measures

The benefit of the flood mitigation project accrues from the reduction of flood damages and the benefit due to land enhancement effects. The details of the flood damage calculation are presented in 4. Only the basic principles are reproduced below.

(1) Estimate of present flood damage (1980 condition)

The damageable items and the principles of the damage estimate are as follows:

Agricultural crops: - production value x damage factor x flooded crop area
ti -5

Livestock:

- damage per household x number of households in flooded area

Housing and properties:

- housing properties value x damage factor x number of housings in flooded area

Public buildings:

- value of facilities in the flooded area x damage factor

Public facilities and utilities:

- 30% of building losses

Industrial facilities:

- 10% of urban housing damages

Indirect damages:

- 30% of the total direct damages

(2) Estimate of future damage potentials (2000 conditions)

Flood damage potential will increase in future due to more intensive use of land resources and the incremental value of assets and properties. To estimate the future damage, the following basic assumptions are made:

Corp damages:

- higher damage potential due to increased crop yield per area

Housing and properties incl.livestocks:

- increment of properties value and quantities per household at a rate of per-capita GDP growth.

Population:

- population increase in the flood prone area to be half of the growth rate for each state (a lower increased rate assumed in consideration of people's reluctance of residing in the flood affecting area).

Land use change:

- only new land development schemes proposed on project basis (e.g. DID's new irrigation schemes) taken into account.

(3) Land enhancement type benefit

Agricultural production in the flood-affected areas is normally less than that in the flood-free lands. Once the flood mitigation project is implemented, however, the production of the areas tends to increase to a level comparable to that of the flood-free area. In this study, this production increase is regarded as a land enhancement type benefit accrued from the flood mitigation project.

The implementation of flood mitigation project may also increase the value of urban lands. For conservative estimate, however, this land enhancement type benefit was not included in the benefit estimate of this study.

(4) Growth of damage potential

As described above, the flood damage potential is estimated for both the present (1980) and future (2000) year conditions. In the evaluation of the projects in 9.4, it is assumed that the damage potential will increase linearly from 1980 to 2000, and thereafter further increase at a half rate of per-capita GDP growth.

7.2 Flood Mitigation Benefit - Non-structural Measures

The estimation of these benefit is only attainable through an indepth study with the collection of supporting data and the examination of various alternatives. Without such detailed data, an attempt was made to estimate the benefits based on very rough assumptions described below.

(1) Restriction of development

(Conditions without the restriction of development)

- population will increase at a half rate of population growth in the state.

- Additional agricultural lands will be developed and private/public facilities expanded at an equal rate with the population growth, i.e. the damageability in the flood area will increase in proportionate to the population growth.

(Conditions with the restriction of development)

- No increase in population and no further development of land use in the flood area. Therefore, the damage potential will be remained almost same as the present level. All future development will be restricted in flood-free areas.

(Benefit)

- The benefit is deemed to be the difference in the damage potentials of the above 2 cases, which is calculated as,

  $B = D \times (P' - P)/P$

  where, B : benefit due to the restriction of development
  D : average annual damage in the area - 1980
  P : population in flood area - 1980
  P': population in flood area - 2000

(2) Land use change and resettlement plan

- Reduced damage to buildings/properties

  $B1 = Y (H + G)$

  where, H : annual damage to housing/properties - 1980
  G : annual damage to public buildings - 1980
  Y : a multiplication factor to include public facilities damage and indirect damage (= 1.69)

- Reduced damage to agricultural crops due to change of plantation (from paddy to oil palm):

  $B2 = Y \cdot (P - R) \cdot A$

  where, P : annual damage to paddy (M$/ha) - 1980
  R : annual damage to oil palm (M$/ha) - 1980
  A : paddy area in flood plain (ha)
  Y : a multiplication factor to include indirect damage

- Negative benefit due to loss of paddy production, for 7 years until maturity of the replanted oil palm:

  $B3 = Y \times P \times A$

  where, P: annual production of paddy under flood-affected condition (M$/ha/year)
  A: paddy area in flood plain (ha)
  Y: a coefficient to annualize the 7-year negative benefit over 50-year time span

- Increased net income from oil palm production over that from paddy, after 8th year onward:

  $B4 = Y \times (r - p) \times A$

  where, r : production value of oil palm (M$/ha)
  p : production value of paddy (M$/ha)

A : paddy area in flood plain (ha)
Y : a coefficient to annualize the benefit occurring after 8th year

- Total benefit:
  B = B1 + B2 - B3 + B4

(3) Flood proofing

- Reduced damages to housings/properties
  B = H
  where, H : damage to housing/properties
- Reduction in public facilities damage and indirect damage is not counted.

7.3 Flood Forecasting and Warning System

A very bold assumption may be proposed to evaluate the damage reduction owing to the advanced warning at 25% of the present properties losses (similar assumption to that made in Ref.19 - Kelantan River Basin Study). But no attempt was made to estimate the benefit for this item.

7.4 Other Project Benefits

No specific attempt was made to estimate the benefit from other improvement works such as river dredging and routine river maintenance works, in consideration that these works are more or less requisite to meet the public requirement and are to be evaluated from social well-being viewpoint.

The erosion control at Teluk Anson town and the river-mouth protection work in the Kemasin and Peng Datu rivers are proposed as a part of the flood mitigation project. No separate estimate of the benefit was attempted.

8. FLOOD MITIGATION PLANS

8.1 Design Flood by River Stretch

Following the criteria set out in 5.1, design flood was determined for each of 415 river stretches of 69 flooding rivers.

Design flood of 100-year occurrence probability was selected for the Perak, Kelang, Pahang and Kelantan rivers.

8.2 Flood Mitigation Benefit by River Stretch

Table 107 to 135 also show the estimated benefit by river stretch, which will accrue once the area is protected from flood inundation. The benefit comprises the damage reduction benefit and land enhancement benefit (Ref. 7.1). The damage reduction is expressed as average annual damage less residual damage at the given protection level.

The expressed amount in the tables is deemed to be flood mitigation benefit from structural measures. The benefit due to non-structural measures is to be estimated separately in a manner described in 7.2.

8.3 Plan Formulation

Also following the basic criteria described in 4.2 and 4.3, flood mitigation plan was formulated for both the structural and non-structural measures. The total number of plans studied is as follows:

Structural measures:	
- Channel improvement	415 stretches
- Bypass floodway	12 locations
- Polder	17 locations
- Flood control dam	64 dams
Non-structural measures:	415 stretches

For all the plans stated above, cost (C) and benefit (B) were estimated based on the prices and methods described in the foregoing chapters 6 and 7, and further the cost-benefit relation worked out in terms of (B - C) for comparison of the plans. Annual cost is calculated on the premises of 50-year evaluation horizon and 8.0%/a discount rate.

8.3.1 Structural Measures

(1) Channel improvement

Tables 107 to 135 show the outline and cost-benefit features of the river channel improvement proposed for all the 415 stretches.

(2) Bypass floodway

Tables 136 to 138 describe flood bypass plans examined in this study. In the case of the plans in the Kemasin-Semerak river basin, the cost and benefit was examined in integration of the downstream channel improvement as evaluated in Table 138.

(3) Polder

Polder plan was mainly considered for protection of urban areas as shown in Tables 139 to 144. Polder protection for the Rompin - Endau Irrigation Schemes are deemed as a part of the Irrigation Project, which are discussed in the Sectoral Report Irrigation Planning.

(4) Flood control dam

Firstly, flood flow reduction effect by dam at downstream points was examined as evaluated. Dams having only a lesser extent of flood reduction effect at the downstream points (less than 5% i.e. $K > 0.95$. Ref. 5.1.3 (d)) were ruled out from further study.

For 43 dams passed through from the above screening, flood control storage volume and cost for the storage were estimated. The results are summarized in Tables 145 to 151.

The viability of flood control dams was assessed in a manner to compare the total cost of dam and reduced channel improvement work with the benefits in the stretches downstream from the dam. In case that a group of dams is proposed, the best combination of the dams leading to a least total cost requirement (dams + downstream channel improvement) was selected for each river basin.

Tables 152 to 164 show the flood control dam plans finally selected, together with the plans of associated channel improvement.

8.3.2 Non-structural measures

By applying cost functions and benefit estimate formulae described in 6.2 and 7.2, cost and benefit of 3 conceived non-structural plans were estimated for all the stretches, irrespective of whether the plans are applicable to the area from techno-sociological viewpoint.

Of the plans, the land use change and resettlement plan will not be applicable in the areas where damages to paddy and people do not occur, and the flood proofing plan is also not applicable in the non-populated flood areas, respectively.

The estimated cost and benefit by stretch are not reproduced in this report, but only the evaluated B - C values presented in Tables 165 to 183.

8.4 Formulation of Development Alternatives

8.4.1 Alternatives setting criteria

As a function of formulating the National Water Resources Development and Use alternatives, three alternatives for flood mitigation development are proposed. Alternative F1 is the implementation of proposed measures to protect 90% of population in the flood prone area. Alternative F2 is the implementation of measures for 50% of population in the potential inundated area, and Alternative F3 is the implementation of only economically vialbe measures. The plans have been formulated for each state.

The strategies and alternatives setting criteria are as follows:

Alternative	Strategy and Target	Criteria for Formulation of Plans
F1: Total development alternative	Elimination of most part of flood hazards. Excepting very sparsely populated area, 90% of population in flood prone area to be relieved from flood hazard	Combination of least-costly structural measures. Improvement area/stretch to be selected in the order of damage potential and population thereat.
F2: Social well-being emphasized alternative	More than 50% of population presently in flood prone area to be relieved from flood hazard.	Combination of structural and non-structural measures. Improvedment area/ stretch to be selected in the order of population thereat.
F3: Economic-efficiency emphasized alternative	Implementation of only economically viable projects.	Combination of structural and non-structural measures assessed to have a positive B - C value.

8.4.2 Selection of alternatives

Following the alternatives setting criteria proposed in 8.4.1 above, the 3 alternatives are then formulated for each state through comparison of flood mitigation measures produced in 8.3 above. Tables 165 to 183 summarize the damage potential (in terms of average annual damage in 2000 condition) and population (in 2000) of each stretch and the B - C values of various measures for ease of comparison. As a result, the measures shown on the right-most column of the tables are selected for inclusion in the 3 development alternatives.

The selection of the measures is based on the following simplified process:

- All the structural measures having positive B - C value are included in Alt. F3, adopting more economical measure if more than 2 measures proposed in the same stretches.

- For formulating Alt. F2, the plan selection is extended to include the schemes proposed in large-populated stretches, until the population exceeds 50% of flood area population in the state.

- For formulating Alt. F1, the plan selection is further extended to other stretches, until the population to be relieved reaches more than 90%.

The selected alternatives are summarized in Tables 184 to 191, together with showing the estimated cost. The location of the proposed projects is shown in Figs. 62 to 82 by alternative selected for each state.

8.5 Flood Forecasting and Warning System

The installation of telemetric system is proposed for 23 river basins as indicated in Table 192.

Notwithstanding the benefit-cost estimated in the tables, this study recommends that all the proposed systems are to be implemented, as a part of social well-being program. The system will be requisite irrespective of whether other structural or non-structural measures are implemented simultaneously.

9. SCHEDULES AND EVALUATION

9.1 Development schedule

Development schedule of the flood mitigation alternatives has been prepared in consideration of the following:

- all the projects conceived in the alternatives are to be implemented towards the year 2000.

- for 4MP period, only the projects authorized in 4MP will be implemented. Other proposed projects are scheduled in 5MP period onward (1986 onward).

- the implementation period of a project is assumed basically to be 5 years. In case the annual expenditure exceeds M$ 20 million the period is extended to 10 or 15 years. Exceptions are 3 huge river improvement/floodway projects proposed in the Perak, Pahang and Kelantan rivers, which are scheduled for 15-year period with annual expenditure exceeding M$ 20 million

- projects accorded higher returns will be implemented at earlier period, to be followed by the next-evaluated projects. The scheduling is made to distribute the expenditures almost equally throughout a period from 1986 to 2000 or slightly increasingly in the latter period.

- non-structural measures will be scheduled to start in the 5MP period, irrespective of its economical return as compared with other proposed structural measures.

Figs. 62 to 85 show the proposed schedule for 3 flood mitigation alternatives formulated for each state.

9.2 Budgetary Schedule

Basing on the development schedules formulated in 9.1 above, budget requirement in the succedding 5-year plan periods is estimated as shown in Tables 193 to 198. Annual expenditure can be assumed almost equal for 5 years within the respective 5-year plan periods, on condition that the jobs are so scheduled. The budget for 4MP period is identical to the DID's schedule which is breakdowned in Table 199.

The budget requirement estimated in the tables includes the budgets for flood forecasting/warning system, river-mouth dredging, and also routine river maintenance works. See Tables 192, 200 and 105 for the estimated cost of those works, respectively.

9.3 Man-power Schedule

Man-power requirement is estimated by assuming a typical work force requirement by the size of the projects as shown in Table 201. Additional man-power requirement for each of the flood mitigation alternatives F1 to F3 is shown in Table 203 to 213.

Operating crew required for additional fleets of dredger is also estimated in Table 202. It is presumed that the flood forecasting/warning systems and routine river maintenance works could be managed basically by the present number of DID staff.

9.4 Economic Evaluation of Alternatives

To assess the economic viability of the flood mitigation alternatives F1 to F3, economic evaluation was made based on the following criteria:

Cost stream:

- Disbursement schedule is as per estimated in 9.2 above.
- Economic cost is assumed approximately to be 80% of financial cost. Cost for flood forecasting system is excluded in the evaluation.

Benefit stream:

- Damage potential (or damage reduction by flood control project) increases linearly from 1980 to 2000, and at a half rate of per-capita GDP growth thereafter.
- Project will progress stage-wise area by area. A part of damage reduction effect accrued from the portion completed in the 1st year is expected to occur from the middle of 2nd year after the commencement of the project. The damage reduction increases linearly thereafter and reaches at 100% at the completion of the project in 5th year.
- Land enhancement benefit is assumed to reach at 100% over a transition period of 5 years after the completion of the project.

Evaluation horizon: 50 years

Economic viability of the alternatives is compared in terms of economic internal rate of return. The result is presented in Tables 214 to 224.

The tables also show the assessments on social well-being account items.

10. RECOMMENDED PLAN

10.1 Selection of Recommended Plan

Through the studies in 9 above, the three flood mitigation alternatives are evaluated as summarized below.

Item	Alternative F1	Alternative F2	Alternative F3	
- EIRR (%)	4.5	9.1	8.7	
- Damage reduction (M$ mil.) /1	86.2	64.0	66.4	Ref. /3
- No. of people relieved (thou.)	2,661	1,590	2,017	Ref. /4
- Reduced flood area (sq.km)	8,220	2,950	4,440	Ref. /5
- Budget burden /2 (M$ mil.)	5,154	1,830	2,162	
- Additional man-power requirement	1,300	700	850	

Remarks:
- /1 Annual equivalent benefit.
- /2 5-year budget, average of 5MP - 7MP.
- /3 Total flood damage potential (without flood mitigation projects) over the Peninsular Malaysia is M$467. million.
- /4 Total population in flood prone area (without projects) 2,519 in 1980 and 2,958 thousand in 2000.
- /5 Total flood area (without projects) is 15,316 sq.km.

Recommendations from the above comparison are as follows:

(1) Alt. F1 will be most desirable from the view point of attainable reductions in flood damages, numbers. of flood victims and flood-affected land resources. However, a critical constraint is the heavy budgetary burden, which seems almost beyond a limit of budgetary capability at least up to year 2000. Employment of additional staff is also a major constraint to the selection of this alternative.

(2) Alt.F2 and F3 seem to be both acceptable with regards to the budget and people protected by the projects.

(3) Alt.F3 is to select the projects whose EIRR is more than 8%. Consequently the projects are concentrated on relatively populated and developed states. The projects for the states less populated would be left behind.

(4) Since 50% of the population of each state will be protected, Alt.F2 would be prefererable from regional and social well-being points of view.

(5) Alt. F2 relieves 1,590 thousand people or 54% of the present total victims from flood hazards and protect 19% of flood prone area. These attainments seem to be acceptable as a minimum target towards the year 2000.

(6) As a conclusion, the flood mitigation plan is formulated in a minimum scale, that is, hereby recommended is the implementation of Alt. F2.

Besides the budget for the recommended flood mitigation projects, the costs for flood forecasting system, river-mouth dredging and small-scale projects are also to be preserved in the public fund requirement for 5 to 7MP periods.

10.2 Description of Recommended Plans

The recommended plan for flood mitigation is summarized in Tables 225 to 231.

Basin 1 Perlis (Perlis)

The Perlis river, bifurcating into many tributaries, flooded 49 sq.km in 1976. Population in 1980 in the flooded area was estimated to be 28,000 including 9,000 in Kangar. The recommended plan is the multipurpose development of the proposed Timah-Tasoh dam and channel improvement of 34 km to protect paddy field and Kangar.

Basin 3 Kedah (Kedah)

Flooding in this river occurs locally at Alor Setar, Kg. Pai and Kuala Nerang. Muda Irrigation Office observes that there have been no serious flood inundation in this irrigation scheme for these 10 years. The inundation, even if occurs, will be of local nature, and it could be diminished by improving the drainage facilities as a part of rehabilitation work of the irrigation project.

Basin 5 Muda (Kedah/P. Pinang)

The Muda river flooded 99 sq.km in 1973. The recommended plan is channel improvement of 45 km along the Kechil river, a tributary where flush floods have endangered the inhabitants, and 27 km in the lower stretch of the main stream allowing flood retardation between the above-mentioned two river stretches. The plan also includes the on-going channel improvement to increase the discharge capacity in the lower reaches of the Tembus river which is a distributary of the Muda river.

Basin 6 Perai (P. Pinang)

The estuary area of the Perai river located in the south of Butterworth is densely populated. The recommended plan is to provide channel improvement in the lowermost stretch of the Perai river for 4 km below the Perai barrage which is under construction.

Basin 7 Pinang (P. Pinang)

The Pinang river flooded 1.4 sq.km in the south of Georgetown in 1980. The recommended plan is channel improvement of 2.5 sq.km below Scotland road including the widening of existing river course. Occasionl dredging of river-mouth mud will be necessary even after the recommended plan is implemented.

Basin 9 Kurau (Perak)

The Kurau river often innundate the land especially below the Bukit Merah dam. The recommended plan is to protect the Krian irrigation project from flooding by providing channel improvement for 13 km of river stretch which is located across the irrigation area.

Basin 10 Perak

The Perak river flooded 1,300 sq.km in 1967. The affected population was estimated to be 200,000 mostly in the downstream area. The same magnitude of flood if occurs in the future will still cause serious problem in the downstream areas, though the Temengor dam can largely decapitate the flood discharge. Teluk Anson, populated by 53,000, sometimes suffers from flooding due to high spring tide. Bank erosion is also significant near Teluk Anson. The recommended plan includes the construction of a 50 km long floodway to divert flood flow from the middle stretch of the Perak river to the estuary, construction of a low ring bund (polder) surrounding Teluk Anson and bank protection work in the river stretch near Teluk Anson.

Basin 15 Kelang (Selangor)

Flood problem is serious in the Kelang valley being densely populated. In 1971, the Kelang river flooded 142 sq.km affecting 177,000 people. The flood damage was estimated to be M$36 million at 1980 price. The Kelang Gates dam supplying domestic and industrial water to Kuala Lumpur was heightened to incorporate the flood mitigation purpose. The Batu dam was designed as a multipurpose project for water supply and flood control. The recommended plan includes 36 km of channel improvement and the multipurpose development of the proposed Batu and Gombak dams for water supply and flood mitigation.

Basin 18 Linggi (N. Sembilan/Melaka)

The Linggi river flooded 122 sq.km in 1971. The recommended plan includes channel improvement for 15 km in the upper stretch of the main stream to protect Seramban and its environs, 14 km in the upper stretch of the Sipur river, a tributary, and 12 km in the Bharu river which is southwest adjacent to the Linggi river to protect people and paddy field. Special attention should be paid not to cause sedimentation in the river in land development, because sedimentation has obviously deteriorated the channel discharge capacity.

Basin 18 Bharu (Melaka)

Channel improvement of 12 km is recommended from the estuary to Kg.Lbk Radah to protect the people and the paddy field. Some improvement work is scheduled for 4MP period.

Basin 19 Melaka/Seri Melaka (Melaka)

The Seri Melaka river flooded 82 sq.km including Melaka town in 1971. The recommended plan is the construction of a 5 km long bypass floodway to protect Melaka town by draining swamp which is developing upstream of the town.

Basin 19 Duyong

Channel improvement of this river is scheduled in the 4MP period. No further recommendation is made since the area is relatively less populated.

Basin 20 Kesang (Melaka/Johor)

The Kesang river flooded 114 sq.km in 1971. A preliminary channel improvement has been completed for the lower stretch up to the confluence between the Kesang river and Chohong river. The recommended plan is widening of the above-mentioned river strech and improvement of the Chohong river approximately as scheduled under 4MP.

Basin 21 Muar (N. Sembilan/Johor)

Flat valley of the Muar river is intensively utilized for paddy cultivation. Flood in 1971 inundated an area of 380 sq.km in which 50,000 people live. The recommended plan for protection of paddy field includes channel improvement for 20 km in the upper stretch of the Muar river, 16 km of the Jempol river and 17 km of the Gemanche river and integration of a flood control space of 24.4 million cu.m in the Muar dam which is proposed for balancing water demand and supply. The construction of ring bund is also recommended to protect a southwestern part of Segamat town.

Basin 22 Batu Pahat (Johor)

Rubber and oil palm farms in the Batu Pahat river basin are suffered from ill-dranage flooding. The Batu Pahat river bifarcating into the Simpang Kiri, Bekok and Semberong rivers flooded 350 sq.km where 30,000 people live. As a part of the West Johor Agricultual Development Project, the Semberong dam is being constructed and the Bekok dam has been planned for the purpose of flood mitigation. In addition to these, it is recommended to provide channel improvement of 32 km for the Simpang Kiri river, 40 km for the Bekok river and 21 km for the Semberong river and to construct a bypass floodway of 19 km by enlarging the Senggerang river between the confluent of the Bekok and Semberong rivers and the sea.

Basin 23 South-east Johor Rivers (Johor)

No specific study was attempted with a view that the most of flood problems in this area have been solved by the implementation of the South-west Johor Project including the Machap dam.

Basin 23 Sekudai/Tebrau (Johor)

Channel improvement of 25 km above the existing tidal gate to protect the area including Kulai town is recommended as a continuation of the on-going project.

Basin 24 Johor (Johor)

It is recommended to construct a ring bund to protect 4,700 people in Kota Tinggi.

Basin 26 Mersing (Johor)

The Mersing river flooded 42 sq.km and affected 16,000 people in 1971. It is recommended to protect Mersing town of 15,000 in population and agricultural lands by providing channel improvement for 6 km upstream of the town.

Basin 27 Endau (Johor)

The damage potential in the Endau river basin is small except the Mengkibol river, a tributary located in the southwest of the river basin and lower most stretch of the main stream where the Sawah Endau irrigation project is under construction. It is recommended to protect Keluang town of 55,000 in population and its vicinity by providing channel improvement for 11 km along the Mengkibol river. The Sawah Endau irrigation project should include necessary protection for the project area.

Basin 30 Pahang (Pahang)

Floods in the Pahang river is so large that they can significantly be mitigated by neither dam nor river improvement. The flood in 1971 inundated 3,000 sq.km in which population in 1980 was estimated to be 400,000 people. The recommended plan is to provide ring bunds to populated towns such as Pekan (2,000), Temerloh (15,000), Mentakab (9,000) and Kuala Lips (11,000). Some contribution on flood mitigation can be expected from the dams proposed for hydropower generation, though the effect is minor. It is recommended to provide flood control storage spaces to the Tekai, Tembeling, Telom and Jelai Kechil dams. Even with these measures, number of protected people will be only around 63,000, which is far below the target. Resettlement of people from the areas seriously affected by flood to the new towns of the Pahang Tenggara development project needs to be considered.

Basin 31 Kuantan (Pahang)

The Kuantan river flooded 230 sq.km in 1971. The affected population was estimated to be 30,000. Kuantan town located at the estuary of the Kuantan river was partly flooded. The recommended plan is to protect 20,000 people in 22 sq.km within Kuantan town by providing channel improvement of 6 km at the estuary and ring bund surrounding Batu Tiga/Paya Besar area.

Basin 32 Kemaman (Trengganu)

The Kemaman river flooded 265 sq.km in 1971. The recommended plan is to protect 14,000 people by providing a ring bund for Chukai town.

Basin 36 Ibai and Trengganu (Trengganu)

The Ibai river located to be south of Kuala Trengganu flooded 36 sq.km in 1967. Channel improvement of 12 km is recommended for the lowermost stretch of the river to protect 23,000 people in 20 sq.km.

Trengganu river flooded 290 sq.km in 1967, but no overbank flow will take place in the main stream under 50-year flood, if the Kenyir dam is complated. The recommended plan includes channel improvement of 12 km in the lowermost stretch of the main stream and 5 km in the Nerus river, a tributary, to protect Kuala Trengganu of 199,000 in population from flood coming from the Nerus river, and ring bund to protect 3,900 people in Kuala Brang from flood originating from the Brang river which is also a tributary of the Trengganu river.

Basin 37 Setiu (Trengganu)

The Setiu river inundated 252 sq.km in 1967. The recommendeed plan is to protect 6,600 people by providing channel improvement for 9 km as a continuation of the on-going project.

Basin 38 Keluang Besar and Besut (Trengganu)

The Keluang Besar and Besut rivers, running across the Besut irrigation project area of 5,058 ha, flooded 266 sq.km in 1967. The recommended plan is to protect the irrigation area and 57,000 people by providing channel improvement for 12 km of the Kuluang Besar river and 21 km of the Besut river.

Basin 40 Kelantan (Kelantan)

Severe flood occurred in 1926, 1931, 1965, 1967, 1969, 1972, 1973, 1975 and 1979. Of these the flood in 1967 is the biggest one. The damage potential and the number of people affected are estimated to be more than M$100 million and 625,000 respectively at 1980 level in the Kelantan plain. The flooding is caused by overbank from the Kelantan river.

The recommended flood mitigation program for the Kelantan river basin was worked out assuming that the Lebir and Dabong dams would be operational by 1995. It includes the river improvement for 65 km of river stretch between the Guillemard bridge and the estuary, construction of a polder (ring bund) for Kuala Kerai and provision of flood mitigation storage in the 2 dams, in order to protect 380,000 people in 78,000 ha. The construction cost was estimated to be M$400 million at 1980 constant price. An alternative if no dam would be constructed was also studied. The construction cost was estimated to be M$600 million. Although the estimated cost is very preliminary based on 1/63,360 map, this large difference in cost indicated that the proposed 2 dams are quite effective for the flood mitigation. The Lebir and Dabong dams together can regulate floods from almost 80% of the Kelantan river basin and they can reduce the flood discharge by 30%, beside generating a large hydropower. Furthermore, source development will, sooner or later, become necessary to support the growing water demand in the coastal plain. Early implementation of the Lebir and Dabong dams is worth for serious consideration from the viewpoint of integrated development of the Kelantan river basin.

11. PLAN IN CASE OF LOWER ECONOMIC GROWTH

11.1 Assumed GDP Growth Rate

The recommended plan in the foregoing chapter is bssed on an assumption that the growth rate of GDP is 7.7% in 1980 to 1985, 8.4% in 1985 to 1990, and 7.5% in 1990 to 2000, in accordance with 4MP and OPP.

For reference, a plan under a lower economic growth was prepared, assuming that Malaysia's economy might be affected by a long-lasting world-wide economic depression. The growth rate of GDP assumed was 7% in 1980 to 1985, 6% in 1985 to 1990, and 5% in 1990 to 2000.

11.2 Parameters Predominantly Related to GDP Per Capita

The parameters dominated by GDP per capita are the urbanization ratio and value of flood damage. These parameters under the condition of lower economic growth were estimated assuming a functional relationships with GDP per capita. Higher population growth rate is adopted in rural area and lower in urban than 4MP and OPP estimate.

11.3 Development Plan

The recommended flood mitigation plan under the condition of low economic growth does not change.

11.4 Beneficial and Adverse Effects

The beneficial and advers.e effects of the flood mitigation plan in the case of lower economic growth are summarized in the main report.

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TABLES

Table 1 LIST OF RIVER BASINS (1/2)

Basin No.	Name of Basin	River(s)	Basin Area (km^2)	State
1.	Perlis	- Perlis	790	Perlis/Kedah
2.	P. Langkawi	- Small rivers	475	Kedah
3.	Kedah	- Kedah - Salah, etc.	3,695	Kedah/Perlis
4.	Merbok	- Merbok, etc.	520	Kedah
5.	Muda	- Muda - Tembus	4,300	Kedah/P. Pinang
6.	Perai	- Perai - Juru - Jawi	895	P. Pinang/Kedah
7.	P. Pinang	- Pinang, etc.	300	P. Pinang
8.	Kerian	- Kerian	1,420	Kedah/P. Pinang/Perak
9.	Kurau	- Kurau - Beruas, etc.	3,255	Perak
10.	Perak	- Perak	14,700	Perak
11.	Bernam	- Bernam, etc.	3,335	Perak/Selangor
12.	Tengi	- Tengi, etc.	565	Selangor
13.	Selangor	- Selangor	1,820	Selangor
14.	Buloh	- Buloh, etc.	560	Selangor
15.	Klang	- Klang	1,425	Selangor
16.	Langat	- Langat	1,815	Selangor/N. Sembilan
17.	Sepang	- Sepang, etc.	640	Selangor/N. Sembilan
18.	Linggi	- Linggi - Bharu, etc.	1,420	N. Sembilan/Melaka
19.	Melaka	- Melaka - Duyong, etc.	1,010	Melaka/N. Sembilan
20.	Kesang	- Kesang	705	Melaka/N. Sembilan/ Johor
21.	Muar	- Muar, etc.	6,595	Johor/N. Sembilan/ Melaka/Pahang
22.	Batu Pahat	- Batu Pahat - Senggarang	2,600	Johor
23.	South-West Johor Rivers	- Benut, etc. - Pelai - Scudai - Tebrau	2,660	Johor
24.	Johor	- Johor, etc.	3,250	Johor

Table 2 LIST OF RIVER BASINS (2/2)

Basin No.	Name of Basin	River(s)	Basin Area (km^2)	State
25.	Sedili Besar	- Sedili Besar - Sedili Kechil, etc.	1,820	Johor
26.	Mersing	- Mersing - Teriang Besar - Tenglu, etc.	880	Johor
27.	Endau	- Endau	4,740	Johor/Pahang
28.	Rompin	- Rompin - Pontian	4,285	Pahang/Johor
29.	Bebar	- Merchong - Bebar	1,895	Pahang
30.	Pahang	- Pahang	29,300	Pahang/N. Sembilan
31.	Kuantan	- Kuantan, etc.	2,025	Pahang
32.	Kemaman	- Kemaman - Kemasik - Kartek	2,570	Trengganu
33.	Paka	- Peka	850	Trengganu
34.	Dungun	- Dungun	1,875	Trengganu
35.	Merchang	- Merchang - Marang	760	Trengganu
36.	Trengganu	- Trengganu - Ibai, etc.	4,650	Trengganu
37.	Setiu	- Setiu - Merang, etc.	1,035	Trengganu
38.	Besut	- Besut	1,230	Trengganu/Kelantan
39.	Kemasin/ Semerak	- Kemasin - Semerak, etc.	1,020	Kelantan/Trengganu
40.	Kelantan	- Kelantan	13,100	Kelantan
41.	Golok	- Golok, etc.	895	Kelantan/(Thailand)
-	Other islands not covered by above basins	-		-
	Peninsular Total:		131,680	

Remarks; Catchment area subject to minor correction.

Table 3 RIVER CHARACTERISTICS OF THE PERLIS RIVER (1/34)

	Item	Description	Source
1.	Location	Basin 1, Perlis State	
2.	Catchment Area	790 km^2 (Basin)	2
3.	Annual Basin Rainfall	1,900 mm	2
4.	Annual Mean Runoff		
5.	River Profile & Cross Sections	Surveyed in 1967. Natural trapezoidal cross section in lower reaches, bank incised U or V shape sections in upper reaches	2
6.	River Morphology	Meandering in tidal reaches, but generally in a stable regime with nippah and mangrove banks. Erosion appearing in upper reach, but the extent not serious due to hard banks.	2
7.	Estuary	No serious problem at present, but right banks and dune seems to be expanding. Future observation recommended.	1 & 2
8.	Sediment	Yield rate not studied so far. No impending problem at present, except silting in partial area due to sediment caused by the failure of mining bunds in 1980.	1 & 2
9.	Salt Water Intrusion	Up to 1 - 2 km upstream from Kangar Town. No adverse problem at present. Tidal control gates installed at almost all tributaries/ channel outlets in the lower reaches.	1 & 2
10.	Flood	Overbank flow occurs in Beseri area, passing over paddy area down to Kangar Town. Largest flood in 1976. For local people, flood is of nuissance nature, yet causing damages. Release of flood flow from Sg. Gial headwork also causes flooding in eastern area.	1 & Ref. 11
11.	Other Items		

Source; 1. Information from DID State Office
2. Observations on field visit and on 1 : 63,360 maps