GOVERNMENT OF MALAYSIA

# NATIONAL WATER RESOURCES STUDY MALAYSIA
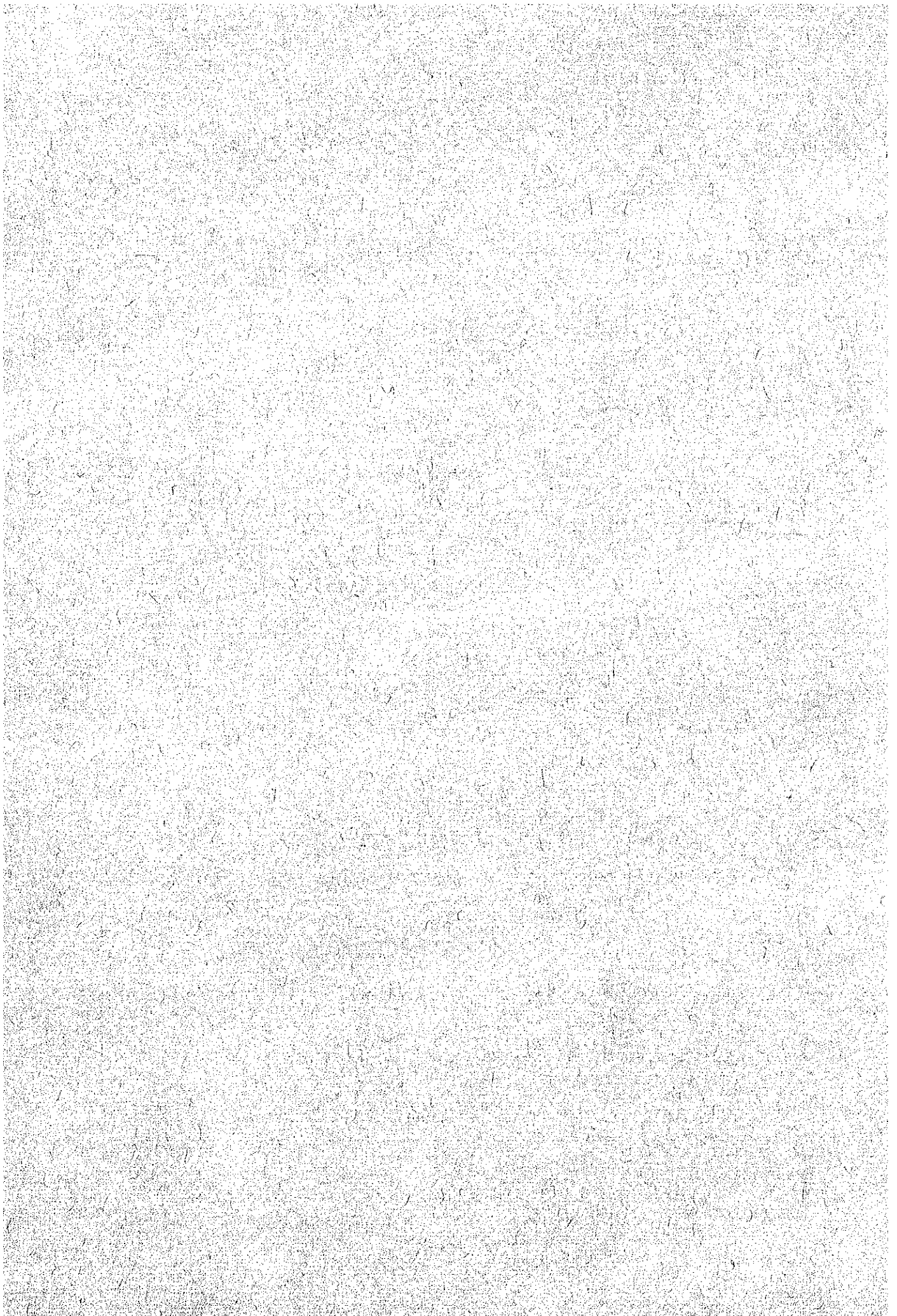
## SECTORAL REPORT

GOVERNMENT OF MALAYSIA

# NATIONAL WATER RESOURCES STUDY, MALAYSIA

## SECTORAL REPORT

## VOL. 14

## WATERSHED MANAGEMENT

OCTOBER 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

# LIST OF REPORTS

MAIN REPORT

STATE REPORT

SECTORAL REPORT

## 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) <u>International or Foreign Organization</u>

| | | |
|---|---|---|
| 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<br>1 m = 3.28 ft = 1.094 yd<br>1 km = 0.621 mile | 1 inch = 2.54 cm<br>1 ft = 30.48 cm<br>1 yd = 91.44 cm<br>1 mile = 1.609 km |
| Area     | 1 cm$^2$ = 0.155 sq.in<br>1 m$^2$ = 10.76 sq.ft<br>1 ha = 2.471 acres<br>1 km$^2$ = 0.386 sq.mile | 1 sq.ft = 0.0929 m$^2$<br>1sq.yd = 0.835 m$^2$<br>1 acre = 0.4047 ha<br>1 sq.mile = 2.59 km$^2$ |
| Volume   | 1 cm$^3$ = 0.0610 cu.in<br>1 lit = 0.220 gal.(imp.)<br>1 kl = 6.29 barrels<br>1 m$^3$ = 35.3 cu.ft<br>$10^6$ m$^3$ = 811 acre-ft | 1 cu.ft = 28.32 lit<br>1 cu.yd = 0.765 m$^3$<br>1 gal.(imp.) = 4.55 lit<br>1 gal.(US) = 3.79 lit<br>1 acre-ft = 1,233.5 m$^2$ |
| Weight   | 1 g = 0.0353 ounce<br>1 kg = 2.20 lb<br>1 ton = 0.984 long ton<br>= 1.102 short ton | 1 ounce = 28.35 g<br>1 lb = 0.4536 kg<br>1 long ton = 1.016 ton<br>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<br>1 kg/cm$^2$ = 14.2 psi<br>1 ton/ha = 891 lb/acre<br>$10^6$ m$^3$ = 810.7 acre-ft<br>1 m$^3$/s = 19.0 mgd | 1 cusec = 0.0283 m$^3$/s<br>1 psi = 0.703 kg/cm$^2$<br>1 lb/acre = 1.12 kg/ha<br>1 acre-ft = 1,233.5 m$^3$<br>1 mgd = 0.0526 m$^3$/s |
| Local Measures | 1 lit = 0.220 gantang<br>1 kg = 1.65 kati<br>1 ton = 16.5 pikul | 1 gantang = 4.55 lit<br>1 kati = 0.606 kg<br>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

The watershed management study has been carried out to evaluate the influence of development activities in the watershed region to the sediment yield and flow regime, and to make recommendation on the watershed management if necessary from the viewpoint of river management and water use.

## 2. OUTLINE OF FOREST IN PENINSULAR MALAYSIA

### 2.1 Present Situation of Forested Land

According to the "Annual Report on Forestry in Peninsular Malaysia, 1979" prepared by the Federal Forestry Department, the total area of forested land in Peninsular Malaysia was 64,500 km$^2$ at the end of 1979, corresponding to 49% of the whole Peninsular Malaysia (Ref. 1). "The Present Land Use of Peninsular Malaysia" states that the total area of forested land occupied 96,400 km$^2$ or 73% of the whole Peninsular Malaysia in 1966 and 88,100 km$^2$ or 69% in 1974 (Ref. 2).

During the period between 1966 and 1979 as shown in Table 1, the total area of forested land reduced from 300 km$^2$ to 200 km$^2$ in Perlis, 5,300 km$^2$ to 3,800 km$^2$ in Kedah, 200 km$^2$ to 100 km$^2$ in Pulau Pinang, 14,800 km$^2$ to 10,300 km$^2$ in Perak, 4,300 km$^2$ to 2,400 km$^2$ in Selangor, 3,900 km$^2$ to 2,000 km$^2$ in Negeri Sembilan, 300 km$^2$ to 100 km$^2$ in Melaka, 11,600 km$^2$ to 5,500 km$^2$ in Johor, 32,200 km$^2$ to 24,000 km$^2$ in Pahang, 11,200 km$^2$ to 6,600 km$^2$ in Trengganu, and 12,300 km$^2$ to 9,500 km$^2$ in Kelantan.

### 2.2 Institutions

Under the Federal Constitution of Malaysia, the State Government is responsible for forest resources development and use. The Federal Forestry Department, which is a component of the Ministry of Primary Industries, Federal Government, has the responsibility of the conduct of research, the provision and maintenance of experimental stations, the giving advice and technical assistance to the Forestry Department of any State within Peninsular Malaysia, and the provision of education and demonstrations for the people and forestry officers of any State. The Federal Forestry Department has two Divisions, Forest Operations Division and Research and Industrial Development Division. The former Division is responsible for the management and development of the forest resource, regulation of exploitation, special functions, forest administration, training and manpower development. For these operations, this Division has five units such as Forest Management, Silviculture, Forest Engineering, Forestry Education and Training, and Special Functions. The latter Division is responsible for the planning of resource, economic studies, industrial development, utilization and industrial extension and forestry research. For this purpose, this Division has four units such as Forest Economic, Forest Planning, Industrial Development, and Forest Research.

State Forest Departments are established integratively in Kedah/ Pulau Pinang and Negeri Sembilan/Melaka and individually in other seven States. The responsibilities of the State Forest Department are to administrate and regulate forest exploitation, to collect forest revenue, to manage and develop the State's forest resources, and to plan and co-ordinate the development of wood-based industries. Usually, the State Forest Department consists of two organization components, Forest Operations and Forest Development, and several District Forest Offices.

## 2.3 National Forestry Policy

The National Forestry Policy was adopted by the National Forestry Council, of which function is to coordinate and to uniform forestry practices, in August, 1977. This Policy was made as the basis for the formulation of technical development policies and strategies specially for forest management, for forest development, for forest research and for forest industry developments (Ref. 3).

The Forest Policy for Peninsular Malaysia is:

(1) to dedicate as Permanent Forest Estate sufficient areas of land strategically located throughout the country,

(2) to manage the Permanent Forest Estate with the object of maximizing social, economic and environmental benefits for the Nation and its people in accordance with the principles of sound forest management,

(3) to pursue a sound program of forest development through regeneration and rehabilitation operations in accordance with approved silvicultural practices in order to achieve maximum productivity from the Permanent Forest Estate,

(4) to ensure through and efficient utilization of the forest resources on land not included in the Permanent Forest Estate, prior to the alienation of such land, by means of proper co-ordinated planning by land development agencies in order to obtain maximum benefits for the people through complete harvesting and processing of such resources adhering strictly to the optimum need of local processing industries,

(5) to promote efficient harvesting and utilization of all forms of forest produce and to stimulate the development of appro-priate wood-based industries with determined capacities commensurate with the resource flow in order to achieve maximum resource utilization, create employment opportunities and earn foreign exchange,

(6) to ensure the sound development of trade and commerce in and to promote the exportation of forest products,

(7) to promote effective Bumiputra participation in forest and wood-based industries consistent with Government policy,

(8) to undertake and support an intensive research program in forest development aimed at achieving maximum yield from the Permanent Forest Estate, maximum direct and indirect benefits from harvesting and utilization and, above all maximum financial return on investment in forest development activities,

(9) to undertake and support a comprehensive program of forestry training at all levels in the public sector in order to ensure an adequate supply of trained manpower to meet the requirements of forestry and wood-based industries,

(10) to encourage private sector's involvement in forestry research and training at all levels with a view to accelerate industrial development and enhance the quality of professionalism in forestry and forest industrial practices,

(11) to foster, by education and publicity, a better understanding among the community of the multiple value of the forests to them and their descendants, and

(12) to foster close cooperation among all in order to achieve optimum utilization of the valuable natural resources of the country.

## 2.4  Legal and Administrative Status of Forested Land

Forest Reserves are set up for the management of forest land in Peninsular Malaysia. The status of the forested land existed in 1979 was that 29,300 km$^2$ or 46% of the total area of forested land was constituted as Forest Reserves, 6,100 km$^2$ or 9% as Wildlife and Other Reserves, and 29,100 km$^2$ or 45% as Stateland. The constitution of forested land by State is also as shown in Table 1. The State having the largest area of Forest Reserve is Perak followed by the States of Pahang, Johor, Kedah, Kelantan, Selangor, Trengganu and Negeri Sembilan in order. The area ranges from 6,800 km$^2$ to 1,800 km$^2$ and the total area amounts to 29,100 km$^2$, while the Forest Reserves occupy less than 100 km$^2$ in the States of Perlis, Melaka and Pulau Pinang.

The Forest Reserves are further classified into the following three categories: (1) Productive Forest Reserves aiming at the supply in perpetuity of reasonable rates of all forms of forest produce which can be economically produced within Peninsular Malaysia and are required for agricultural domestic and industrial purposes, and for export, (2) Unproductive Forest Reserves purposing the sound climatic and physical condition of Peninsular Malaysia, the safeguarding of water supplies, soil fertility and environmental quality and the minimization of damage by floods and erosion to rivers and agricultural land, and (3) Wildlife and Other Reserves having an objective of the conservation of adequate forest areas for recreation, education, research and the protection of the country's unique flora and fauna.

The distribution of three types of Forest Reserves by State is as shown in Table 2. Among the Forest Reserves totalling 29,300 km$^2$, the share of Productive Forest Reserves was 72% in Peninsular Malaysia. The State with the share over the above 72% is Perlis of 73%, Selangor of 86%, Melaka of 88%, Johor of 82%, Pahang of 86%, Trengganu of 85% and Kelantan of 78%, while the States of Pulau Pinang and Negeri Sembilan have the share of less than 50%.

In the State of Pahang, a total of 7,200 km$^2$ was preliminarily notified as Proposed Reserves from the Stateland forest of 14,700 km$^2$ at the beginning of 1979.  In addition, 1,100 km$^2$ was also notified in the States of Kedah, Johor, Trengganu and Kelantan at the same time.

2.5  Forest Reserve Allocated for Exploitation

The State Forest Departments are responsible for preparation and implementation of Working Plans and Annual Felling Plans covering Forest Reserves.  Of the total area of Forest Reserves, 27,200 km$^2$ was under the Working Plans and the balance, 2,100 km$^2$, was not under the Working Plans as of 1979.  The latter area comprised 1,900 km$^2$ of area for which the Working Plans were required during next 10 years and 200 km$^2$ of area for which the Working Plans were not required during next 10 years.

## 3. LOGGING AND REFORESTING ACTIVITIES IN FORESTED LAND

### 3.1 Logging Activities

From physiographical viewpoint, the Forest Reserves are divided into two groups, *Inland Forest Reserves* and *Mangrove Forest Reserves*. The distribution of both groups by State is as shown in Table 3. In the States of Perak, Johor, Selangor and Kedah, a total of 980 km$^2$ or 93% of the whole Mangrove Forest Reserves was concentrated as of 1979.

Among the Inland Forest Reserves of 28,300 km$^2$ in Peninsular Malaysia, forest exploitation was completed in an area of 6,800 km$^2$ up to the end of 1979 and there remained 11,700 km$^2$ of unexploited forests. During 1979, it was reported that annual coupe area was 350 km$^2$, annual opened area was 780 km$^2$ and final telling area was 1,040 km$^2$. Naturally regenerated forest totaled 1,590 km$^2$, while artificially regenerated forest was only 100 km$^2$ including the area under treatment. The progress of forest exploitation by State is as shown in Table 4.

The total production in 1979 was 11.1 x 10$^6$ m$^3$ comprising logs of 10.4 x 10$^6$ m$^3$, poles of 0.1 x 10$^6$ m$^3$, firewood of 0.1 x 10$^6$ m$^3$ and charcol 0.5 x 10$^6$ m$^3$. Among the total log production, 3.6 x 10$^6$ m$^3$ was produced in the State of Pahang being a major contributor followed by Johor with a volume of 1.9 x 10$^6$ m$^3$, Perak with 1.6 x 10$^6$ m$^3$, and Perak and Kelantan with 1.0 x 10$^6$ m$^3$ each.

The remaining area of unexploited forests in the Inland Forest Reserves as of 1979 was 22 km$^2$ in Perlis, 854 km$^2$ in Kedah, 4 km$^2$ in Pulau Pinang, 1,676 km$^2$ in Perak, 532 km$^2$ in Selangor, 702 km$^2$ in Negeri Sembilan, 6 km$^2$ in Melaka, 2,212 km$^2$ in Johor, 3,167 km$^2$ in Pahang, 1,411 km$^2$ in Trengganu and 1,156 km$^2$ in Kelantan.

### 3.2 Silviculture

Throughout the year of 1979, silviculture operations were carried out on a relatively small area compared to the area actually harvested. Silviculture practices consist of two types: (1) treatment to release regeneration by poison girdling of weed species, over matured relics and climing cutting was undertaken in the exploited forests where natural regeneration of commercial species was adequate, and (2) enrichment planting with seedlings of selected indigeneous species was done where natural regeneration of commercial species was inadequate. As of 1979, there existed untreated forests of 4,500 km$^2$, while the area silviculturally treated during 1979, was 220 km$^2$, increasing the accumulated total area treated to about 2,300 km$^2$. The progress of natural regeneration and artificially regeneration in the Inland Forest Reserves is as shown in Tables 5 and 6.

Forest plantation of quick growing species was concentrated in two plantation project areas, Kemasul Forest Reserve in Pahang and Ulu Sedili in Johor. The total area planted in 1979 was around 50 km$^2$.

## 3.3  Research on Forest Hydrology

The Forestry Research Institute under the Federal Forestry Department has established a Forestry Hydrology Section to study the effect of logging on the environment particulary in the hill forests in Peninsular Malaysia.  For undertaking a long-term field observation, two areas have been selected in the Jengka river basin in the State of Pahang and in the Bukit Berembun river basin in the State of Negeri Sembilan (Ref. 4).

The main objectives in the observation is to study the effect of different methods of logging on (1) stream flow quantities, (2) physical, chemical and biological water quality, (3) soil erosion and sediment yields, and (4) soil water regimes.

The hydrological measurement work  under pre-logging condition was carried out until the end of 1981.  The measurements under post logging condition will be commenced at the beginning of 1983.

A preliminary research was conducted in two forested catchments, Gunon Jerai Forest Reserve in Kedah and Ulu Gombak Forest Reserve in Selangor during the period from 1974 to 1978 (Refs. 5 & 6).  Observation records regarding rainfall and suspended sediment in both the catchments are as shown in Tables 7 and 8.

According to the above preliminary study, stream flow from undisturbed forest is generally clear and contains low sediment except during periods of intense rainfall.  In another word, except for landslides or slumpings of stream banks into stream channels, sedimentation from undisturbed forest is low and does not adversely affect water quality. On the other hand, a greater sediment was still observed, even though logging operations were stopped during rainy season.  The main cause of this phenomenon is greater surface runoff generated by disturbed soil surface and the greater ease with which soil is washed away over the disturbed soil surfaces.  It is very difficult to separate specific effects of logging operations including road construction, skidding and logging through field observation, because the contributions by each of these activities to sedimentation are invariably measured together.


## 3.4  Soil Conservation Unit of National Extension Project

As a component of the National Extension Project financed by IBRD, soil conservation study has been undertaking in MOA.  For solving any particular field problems in soil conservation, "A Training Handbook" was prepared aiming at proper training of the departmental staff which is a primary and basic necessary (Ref. 7).

Under the Project, a soil conservation plan is being drawn on micro-watershed basis taking into account the results of ground works in various sectors in accordance with specific designs.  For this purpose, a national watershed framework was set up for the whole area of Peninsular Malaysia. The framework consists of two conservation resource region, nine conservation resource basins, 72 catchments units for catchment area master plans,

266 sub-catchments and 66 watersheds, being expressed from higher to lower categories.

In order to identify problems in quantitative terms and to prepare watershed development and conservation plans, soil conservation surveys in the following sectors will be conducted for the above-mentioned framework; (1) aerial photo-interpretation with ground reconnaissance, (2) detailed soil survey and land use capability study for selected watersheds, (3) collection of additional information on specific sites, being required along with socio-economic data to prepare the soil conservation plans on watershed basis, and (4) detailed contour surveys for designs and working plans for conservation treatment.

A total of 50,000 km$^2$ was proposed as a target for this soil conservation survey till the year 2000.

# 4. EVALUATION OF SOIL EROSION POTENTIAL

## 4.1 General

As described in the previous Chapters, logging activities in Peninsular Malaysia have formed a contributory cause of surface soil loss in watershed regions. Aiming at quantitative evaluation of the impact of such development activities on watershed regions, various factors concerned are analyzed by using a computer model for evaluation of soil erosion potential. A flow chart of this model is illustrated in Fig. 1. Basic input factors for the above model comprise land use, elevation, slope degree, soil, surface geology, river basin division based on major river systems, river basin sub-division based on tributary system and hydrological observation records. Each input information is assessed and classified into several categories and ranges. Representative input information is schematized on a map with a square or mesh divided by grid system of 2'30" x 2'30".

As a result of application of grid system, the whole area of Peninsular Malaysia is divided into 6,334 meshes for peninsular including the Langkawi and Pinang islands and 19 meshes for other small islands. The total area is 131,680 km² for the former and 220 km² for the latter.

## 4.2 Outline of Input Data

### 4.2.1 Land use classification

In Peninsular Malaysia, 19 land use categories are identified as a category with one mesh or more. These land use categories are combined into a more simplified system consisting of 10 categories, i.e. settlements and associated non-agricultural land, horticultural land, rubber land, other tree crop land, paddy land, shifting cultural land, improved permanent pasture and grass land, forest land, swamp and wet forest land, and unused land. Distribution of simplified land use categories by Basin is as shown in Table 9 and illustrated in Fig. 2.

### 4.2.2 Ground elevation and slope degree classifications

Ground elevation is classified into every 100 m intervals and, above El. 801 m, into 801 to 1,000 m, 1,001 to 1,500 m, 1,501 to 2,000 m and over 2,001 m as shown in Table 10 and Fig. 3. Slope degree is divided into five ranges; i.e., 0° to 2°, 3° to 6°, 7° to 12°, 13° to 20° and more than 21° as shown in Table 11 and Fig. 4.

Out of the total area in Peninsular Malaysia, about 60% is classified into a range with the elevation below El. 100 m and 65% is almost flat land with the slope degree of 0° to 2°.

The correlation between the land use category and the ground elevation and that between the land use category and slope degree ranges are as shown in Tables 12 and 13.

In Peninsular Malaysia, inland forest distributes with wide range of elevation. Tree crop development activities are mostly undertaken in areas with the elevation below El. 100 m and the slope degree of less than 2°.

4.2.3  Soil classification

In Peninsular Malaysia, soils are divided into 51 soil associations. For simplification these 51 soil associations are combined into eight units, i.e. alluvial soils on coastal plains; alluvial soils on coastal plains and/or riverine; alluvial soils on riverine, flood plains and/or low riverine terrace; alluvial soils on intermediate and high terrace; sedentary soils on undulating plains to rolling land; sedentary soils on rolling and low hilly land; sedentary soils on hills and mountains; and urban and mined land as shown in Table 14 and Fig. 5.

In Peninsular Malaysia, a unit of sedentary soils on hills and mountains shares 37% of the total, followed by a unit of sedentary soils on undulating plains to rolling land sharing 26%, sedentary soils on rolling and low hilly land having a share of 12% and alluvial soils on coastal plains and/or riverine having a share of 8%.

The correlation between the land use category and the soil unit is as shown in Table 15.

4.2.4  Surface geology classification

Surface geology is classified into 15 categories. For simplification, these 15 categories are combined into 10 groups. Those distribution by Basin is as shown in Table 16 and Fig. 6.

In Pensular Malaysia, a category of Igneous Instrusive occupies 30% of the whole area. Other prevailing categories are Quaternary and Jurassic Triassic with a share of 20% each and Permian with a share of 10%.

4.2.5. Basin division, catchment area and hydrological records

By referring to the Basin division established for water resources engineering studies, schematic Basin division map is reproduced as illustrated in Fig. 7. This Basin indicates a watershed of main stream of each river. The catchment area, Basin rainfall and surface runoff records are given by the hydrological assessment in the Study as shown in Table 17.

Total catchment area covered by a randomized mesh selected on a main river stream and its tributaries is portrayed with some ranges in Fig. 8. Combined with data on Basin rainfall and runoff ratio, stream flow discharge at the randomized mesh mentioned in the above is obtained as schematically pictured in Fig. 9.

4.3 Evaluation

4.3.1 Soil loss under different land use pattern

Some soil loss monitoring works have been undertaking in recent
years in Malaysia, but there has been no establishment of systematic
monitoring network under the national level coordination.   In the
"Soil Conservation, A Training Handbook, Volume 1", prepared under the
National Extension Project financed by IBRD, experimental data pre-
viously made on soil loss under different land use patterns are
compiled as shown in Table 18.   In these data, however, soil loss born
in regenerating forests after exploitation and in rubber areas extending
over lands with non-erodable soils are not included.   With some
modifications and amendments, therefore, the unit soil loss is set up
for soil erosion potential study as shown in Table 19.


4.3.2 Soil erosion potential under past and present conditions

Annual volume of soil loss by Basin can be obtained by multiplying
the unit soil loss by hectareage of the respective land use patterns.

The result of computation for the present land use pattern is as
shown in Table 20.   As it means the total annual soil loss in each
Basin under the present land use pattern, the average annual soil loss
is assumed to indicate a soil erosion potential.   In Table 20, this
potential is also tabulated by Basin.

For clarifying effect of the past forest exploitation activities
on the present soil erosion potential, the average annual soil
loss is estimated under the following assumption of land use pattern:
(1) urban, (2) mixed horticulture, (3) paddy, (4) forest and (5) swamp.
All the present diversified crop field, shifting cultivation area,
grassland, scrub forest and newly cleared land are included into
natural forest area.   Among perennial crop areas, coconut and sago
areas are included into swamp, while all the other tree crops are
considered as natural forest area.   The result of estimate and the
increase in soil erosion potential are as shown in Table 20.


4.3.3 Soil erosion potential under future condition

As described in Section 3.1, the existing forest unexploited will
be opened up to large extent for the purposes of logging and agricultural
land development scheme.   Thus, the increase in soil erosion potential ·
caused by the future exploitation of forest is estimated on the basis of
the following cases including the case of reforestation which can be
greatly expected to reduce the existing soil erosion potential;

Case 1 :   Reforestation is carried out in the presently shifting
          cultivation are and artificial regeneration is conducted
          in the presently scrub forest.

Case 2 :   Forest exploitation for logging purpose is conducted
           in the presently unexploited forest extending over lands
           with a slope degree of 0° to 2°.

Case 3 :   Forest exploitation for logging purpose is conducted in
           the presently unexploited forest extending over lands
           with a slope degree of 3° to 6°.

Case 4 :   Agricultural land development scheme for rubber planting
           purpose is conducted in the presently unexploited forest
           extending over lands with a slope degree of 0° to 2°.

     The results of estimate for the increase in total annual soil loss
by Case by Basin are as shown in Table 21. The increase in soil erosion
potential by Case by Basin is as shown in Table 22.

     To identify problem areas with high soil erosion potential, the
following four alternatives are reviewed by estimating the annual
average surface soil loss; Alternative 1 : same as Case 1, Alternative 2 :
Case 2 plus Case 3, Alternative 3 : same as Case 3, Alternative 4 : same
as Case 4 and Alternative 5 : Case 3 plus Case 4.   The results of
estimate are as shown in Table 23.


4.3.4  Suspended solid concentration

     The average suspended solid concentration at each estuary of 41
Basins is estimated by dividing the total annual soil loss by the total
surface runoff.   For this estimate, the following assumptions are made:
(1) the whole volume of soil loss occurred in a Basin was delivered into
a stream by surface runoff, (2) the soils delivered were throughly
drifted down to the estuary and (3) specific gravity of soil is 1.00.
In another word, both the delivery ratios on a slope and in a river are
assumed to be 1.0 and also no attention is paid to sediment load and
bed load due to lack of useful and accurate hydrological observation data.
The results of estimates for the five Alternatives and for the present
land use pattern are as shown in Table 24.

     The simulation analysis is carried out to visualize the change of
suspended solid concentration in the respective river stretches.   The
results are schematically illustrated in Fig. 10 for the present land
use pattern and Fig. 11 for the future land use pattern under the
Alternative 5.

## 4.3.5 Effect of forest exploitation on low flow

It is well known that a part of rainfall is restored to the atomosphere through evaporation and transpiration and the remainder becomes surface runoff and groundwater. In the field of forest hydrology, the correlation between low flow and change in vegetation has not been quantitatively grasped in all over the world.

In Malaysia, as described in Section 3.3, some experimental works on forest hydrology have been undertaking in two study areas being located in the Gunong Jerai Forest Reserve in Kedah and the Ulu Gombak Forest Reserve in Selangor. The main objective of these experimental works is to study the effect of logging on sediment yield. According to the experimental results up to date, the study shows considerably good progress in grasping the difference of sediment yield under logging and undisturbed conditions of forest in both catchments.

The difference of low flows from natural forest and tree crop plantations has, however, not been studied yet under the above experiments. It has been believed that forest clearing results in reduction of low river flow and increase of flood discharge. Experimental records in this respect in other countries are inadequate to draw conclusions applicable to Malaysia. This aspect accordingly has not been analysed, but this does not mean that the importance of forest conservation in water resources conservation can be neglected. In this Study, therefore, discussions are concentrated into the identification of problem areas having high potential of soil erosion.

# 5. PROBLEM AREAS AND NEEDS

## 5.1 Identification of Problem Areas

Throughout the soil erosion potential evaluation under present land use pattern, the following Basins are recognized as the Basin having the annual average surface soil loss of more than 500 tons/km$^2$/y and the suspended solid concentration of more than 700 mg/lit at estuary; Pulau Pinang, Langat, Melaka, Muar and Johor. The Basins with the annual average surface soil loss of more than 500 tons/km$^2$/y and the suspended soil concentration of less than 700 mg/lit at estuary area Merbok, Perai, Kerian, Selangor, Sepang, Pontian Kechil, Sedili Besan, Kemasin and Golok. On the other hand, the Batu Pahat Basin has the suspended solid concentration at estuary of more than 700 mg/lit, though its annual average surface soil loss is less than 500 tons/km$^2$/y.

Reforestation in the disturbed forest can reduce erosion in a long run. In Peninsular Malaysia, however, substantial reduction in erosion is generally not expected from reforestation in the disturbed forest, because agricultural land occupying a large area is the major contributor to erosion. The annual average surface soil loss in Peninsular Malaysia will decrease to 300 tons/km$^2$/y compared with the value of 350 tons/km$^2$/y under the present land use pattern. The suspended solid concentration at estuary will be over 700 mg/lit in the Pulan Pinang, Langat, Melaka, Muar, Batu Pahat and Johor Basins.

If all natural forest including unexploited and regenerated ones on slope of less than 6° are disturbed, the annual average surface soil loss will increase to 500 to 3,200 tons/km$^2$/y in all Basins except for the Tengi and Buloh Basins, where natural forest has already converted to other land to a large extent. The suspended solid concentration at estuary will be over 700 mg/lit in all the Basins except for Merbok, Kurau, Bernam, Tengi, Buloh, Sepang, Setiu and Kemasin.

If natural forest exploitation activities are restricted to a land on slope of less than 2°, the annual average surface soil loss in Peninsular Malaysia will reduce from 1,700 tons/km$^2$/y in the above case to 1,300 tons/km$^2$/y. The Basins of which annual average surface soil loss will be above 1,300 tons/km$^2$/y are Pulan Pinang, Kerian, Selangor, Muar, Johor, Sedili Besar, Mersing, Endau, Rompin, Pahang, Kemaman, Paka, Dungun, Marang and Trengganu. The suspended solid concentration at estuary will be less than 700 mg/lit in the Merbok, Perai, Kurau, Bernam, Tengi, Buloh, Sepang, Linggi, Bebar, Setiu, Besut and Kemasin Basins.

If all natural forests on slope of less than 2° are cleared and then converted to rubber farm, the annual average surface soil loss will further decrease to 800 tons/km$^2$/y in Peninsular Malaysia. The Pulau Langkawi, Muda, Perai, Pulan Pinang, Kerian, Selangor, Langat, Melaka, Johor, Sedili Besar, Endau, Pahang, Kemaman, Paka, Trengganu and Golok Basins will have still the annual average surface soil loss of higher than 800 tons/km$^2$/y. The suspended solid concentration at estuary will be over 700 mg/lit in the Pulan Langkawi, Muda, Pulan Pinang, Kerian, Perak, Selangor, Kelang, Langkat, Melaka, Muar, Batu Pahat, Johor, Sedili Besar, Endau, Rompin and Pahang Basins.

As a result, the following Basins are identified as problem area, because these Basins are presently subject to soil erosion in those catchments; Perai, Pulau Pinang, Kerian, Selangor, Langat, Johor and Gombak. The future forest development will increase soil erosion potential in the Pulau Langkawi, Kedah, Muda, Perak, Kelang, Melaka, Muar, Sedili Besar, Endau, Rompin, Pahang, Kemaman, Peka, Dungun, Trengganu and Kelantan Basins.

Soil erosion potential by state is as shown in Table 25.


5.2  Needs and Provisional Countermeasures

Based on these considerations, the following conclusions are pre-liminarily drawn:

(1)  Forest clearing should be limited within the land of 2° in slope.

(2)  After clearing forest, such land use as appropriately protect-ing soils against erosion should be undertaken.

(3)  As a long-term program for preservation of productive forest and soil conservation, reforestation should be undertaken in the disturbed forest.

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# TABLES

Table 1    PRESENT STATUS OF FORESTED LAND BY STATE

Unit : km$^2$

| State | 1966 Total Forested Land | 1974 Total Forested Land | 1979 Total Forested Land | 1979 Forest Reserves | 1979 Wildlife & Other Reserves | 1979 State-land |
|---|---|---|---|---|---|---|
| Perlis | 301 | 253 | 211 | 101 | 2 | 108 |
| Kedah | 5,306 | 4,517 | 3,845 | 3,402 | 49 | 394 |
| P. Pinang | 185 | 178 | 74 | 61 | 8 | 5 |
| Perak | 14,786 | 13,920 | 10,336 | 6,756 | 37 | 3,543 |
| Selangor | 4,275 | 3,928 | 2,366 | 2,139 | 68 | 159 |
| N. Sembilan | 3,921 | 3,280 | 1,949 | 1,845 | – | 104 |
| Melaka | 289 | 253 | 87 | 67 | 6 | 14 |
| Johor | 11,554 | 9,749 | 5,496 | 4,831 | 442 | 223 |
| Pahang | 32,229 | 29,695 | 23,991 | 5,732 | 3,521 | 14,738 |
| Trengganu | 11,184 | 10,504 | 6,608 | 1,997 | 817 | 3,794 |
| Kelantan | 12,328 | 11,860 | 9,488 | 2,398 | 1,088 | 6,002 |
| Total | 96,358 | 88,137 | 64,451 | 29,329 | 6,038 | 29,084 |

Source; Refs. 1 & 2


Table 2    PRESENT STATUS OF FOREST RESERVES BY
STATE AS OF 1979

Unit : km$^2$

| State | Productive F.R. | Unproductive F.R. | Total F.R. | F.R. during 1979 Added | F.R. during 1979 Excluded | F.R. during 1979 Proposed |
|---|---|---|---|---|---|---|
| Perlis | 74 | 27 | 101 | – | – | – |
| Kedah | 1,932 | 1,470 | 3,402 | – | 1 | 44 |
| P. Pinang | 22 | 39 | 61 | – | – | – |
| Perak | 3,950 | 2,806 | 6,756 | – | 6 | – |
| Selangor | 1,834 | 304 | 2,138 | – | – | – |
| N. Sembilan | 840 | 1,006 | 1,846 | – | 0 | – |
| Melaka | 59 | 8 | 67 | – | – | – |
| Johor | 3,954 | 877 | 4,831 | – | 0 | 91 |
| Pahang | 4,914 | 818 | 5,732 | – | – | 7,209 |
| Trengganu | 1,701 | 296 | 1,997 | 174 | 659 | 798 |
| Kelantan | 1,860 | 538 | 2,398 | – | – | 195 |
| Total | 21,140 | 8,189 | 29,329 | 174 | 666 | 8,337 |

Source; Ref. 1

Remarks; F.R. : Forest Reserves

Table 3    PRESENT STATUS OF INLAND AND MANGROVE
FOREST RESERVES BY STATE

Unit : $km^2$

| State | Inland F.R. | | | Mangrove F.R. | | |
|---|---|---|---|---|---|---|
| | Productive | Unproductive | Total | Productive | Unproductive | Total |
| Perlis | 74 | 27 | 101 | -- | -- | -- |
| Kedah | 1,854 | 1,458 | 3,312 | 77 | 13 | 90 |
| P. Pinang | 18 | 39 | 57 | 4 | - | 4 |
| Perak | 3,603 | 2,747 | 6,350 | 347 | 59 | 406 |
| Selangor | 1,611 | 302 | 1,913 | 223 | 2 | 225 |
| N. Sembilan | 831 | 1,001 | 1,832 | 9 | 5 | 14 |
| Melaka | 58 | 8 | 66 | 1 | -- | 1 |
| Johor | 3,773 | 802 | 4,575 | 181 | 75 | 256 |
| Pahang | 4,890 | 818 | 5,708 | 24 | 1 | 25 |
| Trengganu | 1,679 | 288 | 1,967 | 22 | 8 | 30 |
| Kelantan | 1,861 | 537 | 2,398 | - | 0 | 0 |
| Total | 20,252 | 8,027 | 28,279 | 888 | 163 | 1,051 |

Source; Ref. 1


Table 4    PRESENT STATUS OF PROGRESS IN FOREST
EXPLOITATION DURING 1979

Unit : $km^2$

| State | Annual Coupe | Opened During 1979 | Under Final Telling | Exploitation Completed | | Unexploited Forests |
|---|---|---|---|---|---|---|
| | | | | Not yet treated | Girdled to date | |
| Perlis | 1 | 23 | 34 | 17 | - | 22 |
| Kedah | 25 | 59 | 58 | 245 | 493 | 854 |
| P. Pinang | 0 | - | - | 0 | 9 | 4 |
| Perak | 130 | 160 | 100 | 692 | 456 | 1,676 |
| Selangor | 19 | 30 | 53 | 443 | 186 | 532 |
| N. Sembilan | 10 | 73 | 28 | 250 | 224 | 702 |
| Melaka | - | 6 | 1 | 3 | 8 | 6 |
| Johor | 44 | 137 | 101 | 705 | 399 | 2,212 |
| Pahang | 61 | 132 | 75 | 1,252 | 245 | 3,167 |
| Trengganu | 34 | 57 | 451 | 455 | 219 | 1,411 |
| Kelantan | 27 | 105 | 136 | 429 | 41 | 1,156 |
| Total | 351 | 782 | 1,037 | 4,491 | 2,280 | 11,742 |

Source; Ref. 1

Table 5　　　PRESENT STATUS OF NATURAL REGENERATION
IN INLAND FOREST RESERVES

Unit : km$^2$

| State | Total Regenerated Forest | Age of Class of Regenerated Forest | | | | |
|---|---|---|---|---|---|---|
| | | 10-20 | 20-30 | 30-40 | 40-50 | 50-70 |
| Perlis | – | – | – | – | – | – |
| Kedah | 315 | 287 | 17 | 11 | – | – |
| P. Pinang | 4 | – | 3 | 1 | – | – |
| Perak | 225 | 111 | 76 | 31 | 7 | – |
| Selangor | 227 | 110 | 82 | 35 | 0 | – |
| N. Sembilan | 67 | 45 | 9 | 9 | 4 | – |
| Melaka | 35 | 3 | 7 | 18 | 7 | – |
| Johor | 508 | 361 | 147 | – | – | – |
| Pahang | 87 | 76 | 11 | – | – | – |
| Trengganu | 4 | 4 | – | – | – | – |
| Kelantan | 116 | 96 | 20 | – | – | – |
| Total | 1,588 | 1,093 | 372 | 105 | 18 | – |

Source; Ref. 1

Table 6　　　PRESENT STATUS OF PROGRESS IN ARTIFICIAL
REGENERATION IN INLAND FOREST RESERVES
DURING 1979

Unit : km$^2$

| State | Enrichment Planting | | | | Regular Planting | | | |
|---|---|---|---|---|---|---|---|---|
| | REP | Formed in 1979 | Under Treatment | PAR | DRR | Formed in 1979 | Under Treatment | TAR |
| Perlis | – | – | – | – | – | – | 1.3 | – |
| Kedah | 23.0 | 0.4 | 18.8 | – | 8.8 | – | 0 | 1.5 |
| P. Pinang | – | – | – | – | 0.2 | – | 0.1 | 0.2 |
| Perak | 70.8 | 3.0 | 35.8 | – | 26.9 | – | – | – |
| Selangor | 62.3 | 0.2 | 15.2 | – | 2.8 | – | 3.5 | – |
| N. Sembilan | – | – | – | – | – | 0.3 | 7.9 | – |
| Malaka | 29.7 | 0.8 | 0.1 | – | – | – | – | – |
| Johor | 0.7 | – | – | – | 105.7 | – | 2.6 | 0.1 |
| Pahang | 293.8 | 0.5 | 11.4 | 11.8 | – | – | – | – |
| Trengganu | – No Activity – | | | | | | | |
| Kelantan | – | 0.4 | 0.3 | – | – | – | – | – |
| Total | 480.3 | 5.3 | 81.6 | 11.8 | 144.4 | 0.3 | 15.4 | 1.8 |

Source; Ref. 1

Table 7    MEAN MONTHLY SUSPENDED SEDIMENT AND
           RAINFALL FOR GUNONG JERAI CATCHMENT
           FROM 1975 TO 1978

| Month | Railfall (mm) | Suspended Sediment (mg/lit) | | | |
|-------|---------------|-----------------------------|---|---|---|
| | | Low flow | | Storm flow | |
| | | Control Area | Logging Area | Control Area | Logging Area |
| Jan. | 41 | 2.4 | 3.2 | – | 25.2 |
| Feb. | 65 | 1.6 | 3.7 | – | – |
| Mar. | 53 | 1.8 | 3.1 | – | 37.2 |
| Apr. | 199 | 3.5 | 23.1 | – | 156.8 |
| May | 450 | 9.6 | 45.0 | – | 172.4 |
| June | 235 | 2.6 | 3.9 | – | 122.0 |
| July | 226 | 2.1 | 4.3 | – | 94.3 |
| Aug. | 225 | 4.1 | 11.1 | – | 133.9 |
| Sept. | 425 | 14.4 | 44.8 | – | 67.2 |
| Oct. | 492 | 7.2 | 53.9 | – | 46.4 |
| Nov. | 312 | 3.3 | 9.6 | – | 88.8 |
| Dec. | 169 | 2.1 | 4.4 | – | – |
| Total | 2,892 | 54.7 | 210.1 | – | 944.2 |
| Mean | 241 | 4.5 | 17.5 | – | 94.4 |

Source; Ref. 5

Table 8    MEAN MONTHLY SUSPENDED SEDIMENT AND
           RAINFALL FOR ULU GOMBAK CATCHMENT
           FROM 1976 TO 1978

| Month | Railfall (mm) | Suspended Sediment (mg/lit) | | | | | |
|-------|---------------|-----------------------------|---|---|---|---|---|
| | | Low flow | | | Storm flow | | |
| | | Control Area | Logging Area | Logged Area | Control Area | Logging Area | Logged Area |
| Jan. | 99 | 5 | 10 | 8 | 159 | 1,117 | 311 |
| Feb. | 61 | 11 | 8 | 17 | 22 | 126 | 140 |
| Mar. | 107 | 2 | 6 | 3 | 117 | 1,212 | 1,072 |
| Apr. | 224 | 34 | 70 | 31 | 250 | 5,958 | 1,022 |
| May | 158 | 11 | 6 | 11 | 15 | 1,873 | 1,132 |
| June | 201 | 5 | 7 | 9 | 39 | 2,554 | 797 |
| July | 86 | 5 | 28 | 8 | 65 | 805 | 255 |
| Aug. | 236 | 5 | 3 | 9 | 11 | 834 | 625 |
| Sept. | 409 | 19 | 8 | 31 | 118 | 1,464 | 976 |
| Oct. | 371 | 19 | 10 | 8 | 388 | 1,556 | 733 |
| Nov. | 259 | 7 | 24 | 3 | 138 | 1,115 | 854 |
| Dec. | 135 | 6 | 7 | 8 | 52 | 525 | 236 |
| Total | 2,346 | 118 | 187 | 146 | 1,374 | 19,139 | 8,153 |
| Mean | 196 | 9.9 | 15.6 | 12.2 | 115 | 1,595 | 679 |

Source; Ref. 5

Table 9    DISTRIBUTION OF LAND USE CATEGORY BY BASIN

Unit:  No. of mesh

| Basin No. | Name of Basin | Land Use Category | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SA | HL | RC | TC | PL | CL | GL | FL | SW | UL | Total |
| 1 | Perlis | -- | 1 | 4 | 6 | 26 | - | - | 11 | -- | -- | 48 |
| 2 | Pulau Langkawi | - | 1 | -- | -- | 3 | - | -- | 19 | 2 | - | 25 |
| 3 | Kedah | - | - | 49 | - | 53 | - | 2 | 67 | - | - | 171 |
| 4 | Merbok | 2 | 1 | 15 | -- | 3 | -- | - | 5 | 4 | - | 30 |
| 5 | Muda | -- | 1 | 76 | - | 6 | - | - | 120 | -- | - | 203 |
| 6 | Perai | 2 | 1 | 24 | 6 | 4 | - | -- | 3 | -- | -- | 40 |
| 7 | Pulau Pinang | 3 | 5 | 3 | 1 | 1 | - | -- | 6 | 1 | - | 20 |
| 8 | Kerian | -- | -- | 27 | 3 | 3 | - | -- | 27 | 3 | - | 63 |
| 9 | Kurau | 4 | 1 | 45 | 6 | 20 | 3 | - | 41 | 41 | - | 161 |
| 10 | Perak | 43 | 5 | 102 | 27 | 7 | 7 | -- | 499 | 44 | - | 734 |
| 11 | Bernam | 1 | -- | 12 | 43 | 9 | - | - | 42 | 48 | -- | 155 |
| 12 | Tengi | -- | -- | -- | 5 | 3 | - | - | 1 | 18 | - | 27 |
| 13 | Selangor | 5 | - | 25 | 9 | - | - | - | 42 | 6 | - | 87 |
| 14 | Buloh | 1 | 1 | 5 | 14 | - | - | - | 7 | 3 | - | 31 |
| 15 | Kelang | 14 | - | 19 | 4 | - | - | - | 21 | 9 | - | 67 |
| 16 | Langat | - | -- | 43 | 24 | - | -- | - | 17 | 34 | - | 118 |
| 17 | Sepang | 2 | - | 13 | 14 | -- | - | - | 1 | 9 | - | 39 |
| 18 | Linggi | 1 | 2 | 52 | 1 | -- | -- | -- | 17 | 2 | - | 75 |
| 19 | Melaka | 3 | 3 | 39 | - | 3 | -- | -- | 9 | 2 | - | 59 |
| 20 | Kesang | -- | -- | 27 | -- | - | -- | -- | 3 | 4 | -- | 34 |
| 21 | Muar | 2 | 3 | 131 | 18 | - | - | - | 136 | 5 | - | 295 |
| 22 | Batu Pahat | 1 | -- | 62 | 26 | - | - | 1 | 24 | 12 | - | 126 |
| 23 | Pontian Kechil | 5 | 1 | 69 | 37 | - | -- | - | 21 | 19 | - | 152 |
| 24 | Johor | - | 1 | 26 | 40 | - | - | 2 | 54 | 13 | -- | 136 |
| 25 | Sedili Besar | - | - | - | 1 | -- | - | - | 74 | 20 | - | 95 |
| 26 | Mersing | 2 | - | 4 | 1 | -- | - | 1 | 37 | 16 | -- | 61 |
| 27 | Endau | - | 1 | 16 | 16 | - | - | - | 159 | 30 | -- | 222 |
| 28 | Rompin | - | - | - | 10 | -- | - | - | 166 | 26 | - | 202 |
| 29 | Bebar | - | - | - | - | - | -- | -- | 24 | 68 | - | 92 |
| 30 | Pahang | 1 | 5 | 189 | 60 | 1 | - | 1 | 1,092 | 57 | - | 1,406 |
| 31 | Kuantan | 3 | 1 | 10 | 6 | - | - | 1 | 50 | 15 | - | 86 |
| 32 | Kemaman | - | 2 | 4 | 7 | - | - | - | 97 | 19 | - | 129 |
| 33 | Paka | 1 | - | 3 | 1 | - | - | - | 36 | 4 | - | 45 |
| 34 | Dungun | 1 | 1 | 1 | 1 | - | -- | 1 | 74 | 3 | - | 82 |
| 35 | Marang | - | 4 | 3 | 5 | - | -- | 1 | 15 | 19 | - | 47 |
| 36 | Trengganu | 1 | 4 | 16 | 4 | 6 | - | 3 | 195 | -- | - | 229 |
| 37 | Setiu | - | - | 4 | 1 | -- | - | - | 20 | 25 | - | 50 |
| 38 | Besut | - | 5 | 5 | - | 6 | - | 3 | 31 | 2 | - | 52 |
| 39 | Kemasin | - | 9 | 4 | 1 | 15 | - | 4 | 3 | 5 | - | 41 |
| 40 | Kelantan | - | 9 | 67 | 2 | 16 | -- | 1 | 465 | - | - | 560 |
| 41 | Golok | -- | - | 14 | - | 6 | -- | -- | 14 | 5 | -- | 39 |
| | Total | 98 | 68 | 1,208 | 400 | 191 | 10 | 21 | 3,745 | 593 | - | 6,334 |
| | Small Islands | -- | -- | - | - | - | - | -- | 16 | 3 | - | 19 |
| | Peninsular Malaysia | 98 | 68 | 1,208 | 400 | 191 | 10 | 21 | 3,761 | 596 | - | 6,353 |

Remarks;  SA:  Settlements and associated non-agricultural land,
HL:  Horticultural land,  RC:  Rubber land,  TC:  Other tree
crop land,  PL:  Paddy land,  CL:  Upland crop field,
GL:  Improved permanent pasture and grass land,  FL:  Forest
land,  SW:  Swamp and wet forest land, and UL:  Unused land

Table 10    DISTRIBUTION OF ELEVATION RANGE BY BASIN

Unit : No. of mesh

| Basin No. | Name of Basin | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Perlis | 42 | 5 | – | 1 | – | – | – | – | – | 48 |
| 2. | Pulau Langkawi | 12 | 5 | 3 | 2 | 1 | 2 | – | – | – | 25 |
| 3. | Kedah | 130 | 24 | 4 | 7 | 1 | 5 | – | – | – | 171 |
| 4. | Merbok | 27 | 1 | – | – | 1 | 1 | – | – | – | 30 |
| 5. | Muda | 81 | 50 | 8 | 12 | 19 | 30 | 2 | 1 | – | 203 |
| 6. | Perai | 32 | 8 | – | – | – | – | – | – | – | 40 |
| 7. | Pulau Pinang | 14 | 4 | – | 1 | 1 | – | – | – | – | 20 |
| 8. | Kerian | 40 | 3 | 1 | 3 | 2 | 11 | 3 | – | – | 63 |
| 9. | Kurau | 138 | 8 | – | 2 | 4 | 8 | 1 | – | – | 161 |
| 10. | Perak | 247 | 67 | 16 | 63 | 67 | 176 | 80 | 18 | – | 734 |
| 11. | Bernam | 128 | 4 | 3 | 2 | 3 | 9 | 5 | 1 | – | 155 |
| 12. | Tengi | 27 | – | – | – | – | – | – | – | – | 27 |
| 13. | Selangor | 59 | 7 | 1 | 6 | 3 | 11 | – | – | – | 87 |
| 14. | Buloh | 31 | – | – | – | – | – | – | – | – | 31 |
| 15. | Kelang | 50 | 8 | – | 2 | 4 | 2 | 1 | – | – | 67 |
| 16. | Langat | 97 | 10 | – | 5 | 3 | 3 | – | – | – | 118 |
| 17. | Sepang | 39 | – | – | – | – | – | – | – | – | 39 |
| 18. | Linggi | 59 | 6 | 1 | – | 4 | 5 | – | – | – | 75 |
| 19. | Melaka | 54 | 3 | – | 1 | 1 | – | – | – | – | 59 |
| 20. | Kesang | 33 | 1 | – | – | – | – | – | – | – | 34 |
| 21. | Muar | 243 | 26 | 14 | 4 | 4 | 4 | – | – | – | 295 |
| 22. | Batu Pahat | 116 | 7 | – | 3 | – | – | – | – | – | 126 |
| 23. | Pontian Kechil | 148 | 3 | – | – | – | 1 | – | – | – | 152 |
| 24. | Johor | 129 | 4 | – | 2 | 1 | – | – | – | – | 136 |
| 25. | Sedili Besar | 81 | 13 | – | 1 | – | – | – | – | – | 95 |
| 26. | Mersing | 51 | 9 | 1 | – | – | – | – | – | – | 61 |
| 27. | Endau | 151 | 14 | 7 | 28 | 9 | 13 | – | – | – | 222 |
| 28. | Rompin | 149 | 38 | 7 | 6 | 1 | 1 | – | – | – | 202 |
| 29. | Bebar | 80 | 9 | 1 | 1 | 1 | – | – | – | – | 92 |
| 30. | Pahang | 633 | 310 | 75 | 100 | 81 | 133 | 59 | 14 | 1 | 1,406 |
| 31. | Kuantan | 61 | 10 | 3 | 7 | 2 | 2 | 1 | – | – | 86 |
| 32. | Kemaman | 89 | 19 | 8 | 4 | 4 | 5 | – | – | – | 129 |
| 33. | Paka | 38 | 4 | 1 | 2 | – | – | – | – | – | 45 |
| 34. | Dungun | 47 | 11 | 1 | 3 | 4 | 8 | 8 | – | – | 82 |
| 35. | Marang | 45 | 2 | – | – | – | – | – | – | – | 47 |
| 36. | Trengganu | 94 | 36 | 12 | 26 | 22 | 35 | 4 | – | – | 229 |
| 37. | Setiu | 45 | – | 1 | 2 | 1 | 1 | – | – | – | 50 |
| 38. | Besut | 33 | 4 | – | 2 | 1 | 12 | – | – | – | 52 |
| 39. | Kemasin | 37 | 1 | – | 1 | 2 | – | – | – | – | 41 |
| 40. | Kelantan | 232 | 104 | 25 | 57 | 50 | 57 | 31 | 3 | 1 | 560 |
| 41. | Golok | 33 | 3 | – | – | 2 | 1 | – | – | – | 39 |
| | Total | 3,875 | 841 | 193 | 356 | 299 | 536 | 195 | 37 | 2 | 6,334 |
| | Small Islands | 4 | 10 | 2 | 1 | 1 | 1 | – | – | – | 19 |
| | Peninsular Malaysia | 3,879 | 851 | 195 | 357 | 300 | 537 | 195 | 37 | 2 | 6,353 |

Remarks;   (1): 1 to 100m,   (2): 101 to 200m,   (3): 201 to 300m,
(4): 301 to 400m,  (5): 401 to 500m,  (6): 501 to 1,000m,
(7): 1,001 to 1,500m,   (8): 1,501 to 2,000m, and
(9): above 2,001m above sea level

Table 11     DISTRIBUTION OF SLOPE DEGREE RANGE BY BASIN

Unit:   Number of mesh

| Basin No. | Name of Basin | (1) | (2) | (3) | (4) | (5) | Total |
|---|---|---|---|---|---|---|---|
| 1. | Perlis | 42 | 5 | 1 | – | – | 48 |
| 2. | Pulau Langkawi | 14 | 6 | 2 | 2 | 1 | 25 |
| 3. | Kedah | 137 | 23 | 5 | 4 | 2 | 171 |
| 4. | Merbok | 26 | 2 | – | 1 | 1 | 30 |
| 5. | Muda | 116 | 36 | 24 | 17 | 10 | 203 |
| 6. | Perai | 32 | 8 | – | – | – | 40 |
| 7. | Pulau Pinang | 14 | 4 | 1 | 1 | – | 20 |
| 8. | Kerian | 40 | 4 | 6 | 7 | 6 | 63 |
| 9. | Kurau | 139 | 8 | 2 | 7 | 5 | 161 |
| 10. | Perak | 330 | 111 | 129 | 106 | 58 | 734 |
| 11. | Bernam | 127 | 7 | 10 | 5 | 6 | 155 |
| 12. | Tengi | 27 | – | – | – | – | 27 |
| 13. | Selangor | 59 | 9 | 14 | 3 | 2 | 87 |
| 14. | Buloh | 31 | – | – | – | – | 31 |
| 15. | Kelang | 52 | 7 | 5 | 1 | 2 | 67 |
| 16. | Langat | 99 | 9 | 7 | 3 | – | 118 |
| 17. | Sepang | 39 | – | – | – | – | 39 |
| 18. | Linggi | 60 | 6 | 2 | 3 | 4 | 75 |
| 19. | Melaka | 55 | 2 | 1 | 1 | – | 59 |
| 20. | Kesang | 33 | 1 | – | – | – | 34 |
| 21. | Muar | 244 | 38 | 5 | 7 | 1 | 295 |
| 22. | Batu Pahat | 115 | 8 | 3 | – | – | 126 |
| 23. | Pontian Kechil | 145 | 6 | – | – | 1 | 152 |
| 24. | Johor | 129 | 4 | 2 | 1 | – | 136 |
| 25. | Sedili Besar | 80 | 14 | 1 | – | – | 95 |
| 26. | Mersing | 49 | 11 | 1 | – | – | 61 |
| 27. | Endau | 162 | 20 | 27 | 10 | 3 | 222 |
| 28. | Rompin | 151 | 41 | 8 | 2 | – | 202 |
| 29. | Bebar | 81 | 8 | 2 | 1 | – | 92 |
| 30. | Pahang | 821 | 274 | 153 | 93 | 65 | 1,406 |
| 31. | Kuantan | 61 | 16 | 6 | 1 | 2 | 86 |
| 32. | Kermaman | 92 | 25 | 4 | 5 | 3 | 129 |
| 33. | Paka | 38 | 5 | 2 | – | – | 45 |
| 34. | Dungun | 48 | 14 | 3 | 7 | 10 | 82 |
| 35. | Marang | 45 | 2 | – | – | – | 47 |
| 36. | Trengganu | 115 | 40 | 32 | 22 | 20 | 229 |
| 37. | Setiu | 45 | – | 4 | 1 | – | 50 |
| 38. | Besut | 33 | 4 | 2 | 9 | 4 | 52 |
| 39. | Kemasin | 37 | 1 | 2 | 1 | – | 41 |
| 40. | Kalantan | 281 | 124 | 79 | 42 | 34 | 560 |
| 41. | Golok | 34 | 2 | – | 2 | 1 | 39 |
| | Total | 4,278 | 905 | 545 | 365 | 241 | 6,334 |
| | Small Islands | 15 | 2 | 1 | 1 | – | 19 |
| | Peninsular Malaysia | 4,293 | 907 | 546 | 366 | 241 | 6,353 |

Remarks;  (1): 0° to 2°,  (2): 3° to 6°,  (3): 7° to 12°,
(4): 13° to 20°, and (5): over 21°

Table 12    CORRELATION BETWEEN LAND USE
            CATEGORY AND GROUND ELEVATION

Unit: No. of mesh

| Range of Elevation | Land Use Category | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA | HL | RC | TC | PL | CL | GL | FL | SW | UL | Total |
| 1 – 100 m | 96 | 67 | 1,096 | 385 | 189 | 10 | 21 | 1,422 | 593 | – | 3,879 |
| 101 – 200 m | 2 | 1 | 95 | 11 | 2 | – | – | 737 | 3 | – | 851 |
| 201 – 300 m | – | – | 6 | 3 | – | – | – | 186 | – | – | 195 |
| 301 – 400 m | – | – | 7 | – | – | – | – | 350 | – | – | 357 |
| 401 – 500 m | – | – | 4 | – | – | – | – | 296 | – | – | 300 |
| 501 – 1,000 m | – | – | – | – | – | – | – | 537 | – | – | 537 |
| 1,001 – 1,500 m | – | – | – | 1 | – | – | – | 194 | – | – | 195 |
| 1,501 – 2,000 m | – | – | – | – | – | – | – | 37 | – | – | 37 |
| Above 2,000 m | – | – | – | – | – | – | – | 2 | – | – | 2 |
| Total | 98 | 68 | 1,208 | 400 | 191 | 10 | 21 | 3,761 | 596 | – | 6,353 |

Remarks;   SA, HL, RC, TC, PL, CL, GL, FL, SW & UL:   See remarks in
           Table 9.


Table 13    CORRELATION BETWEEN LAND USE
            CATEGORY AND SLOPE DEGREE

Unit: No. of mesh

| Range of Slope Degree | Land Use Category | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA | HL | RC | TC | PL | CL | GL | FL | SW | UL | Total |
| 0° – 2° | 96 | 67 | 1,133 | 383 | 189 | 10 | 21 | 1,800 | 594 | – | 4,293 |
| 3° – 6° | 2 | 1 | 66 | 15 | 2 | – | – | 819 | 2 | – | 907 |
| 7° – 12° | – | – | 6 | 2 | – | – | – | 538 | – | – | 546 |
| 13° – 20° | – | – | 3 | – | – | – | – | 363 | – | – | 366 |
| 21° – | – | – | – | – | – | – | – | 241 | – | – | 241 |
| Total | 98 | 68 | 1,208 | 400 | 191 | 10 | 21 | 3,761 | 596 | – | 6,353 |

Remarks;   SA, HL, RC, TC, PL, CL, GL, FL, SW & UL:   See remarks in
           Table 9.

Table 14    DISTRIBUTION OF SOIL UNIT BY BASIN

Unit: No. of mesh

| Basin No. | Name of Basin | AC | AR | AF | AT | SR | SH | SM | UM | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Perlis | 16 | - | 7 | 17 | 3 | - | 5 | - | 48 |
| 2 | Pulau Langkawi | 3 | - | 2 | - | 1 | - | 19 | - | 25 |
| 3 | Kedah | 34 | - | 25 | - | 76 | - | 36 | - | 171 |
| 4 | Merbok | 9 | - | 1 | - | 16 | - | 4 | - | 30 |
| 5 | Muda | 3 | - | 6 | 3 | 80 | - | 111 | - | 203 |
| 6 | Perai | 10 | - | - | 9 | 14 | 1 | 6 | - | 40 |
| 7 | Pulau Pinang | 2 | - | 1 | - | - | 1 | 12 | 4 | 20 |
| 8 | Kerian | 3 | 9 | 1 | 4 | 15 | 8 | 23 | - | 63 |
| 9 | Kurau | 42 | 25 | 10 | 36 | 3 | 11 | 31 | 3 | 161 |
| 10 | Perak | 17 | 30 | 35 | 52 | 45 | 63 | 455 | 37 | 734 |
| 11 | Bernam | 39 | 48 | 9 | - | 29 | 2 | 28 | - | 155 |
| 12 | Tengi | 7 | 17 | - | - | 3 | - | - | - | 27 |
| 13 | Selangor | 10 | 9 | 2 | - | 20 | 8 | 33 | 5 | 87 |
| 14 | Buloh | 16 | 2 | 2 | - | 9 | - | 1 | 1 | 31 |
| 15 | Kelang | 16 | 4 | 1 | - | 10 | 4 | 17 | 15 | 67 |
| 16 | Langat | 41 | 18 | 3 | - | 32 | 4 | 20 | - | 118 |
| 17 | Sepang | 12 | 10 | - | - | 12 | 4 | - | 1 | 39 |
| 18 | Linggi | 3 | 2 | - | - | 51 | - | 18 | 1 | 75 |
| 19 | Melaka | 8 | - | - | - | 38 | - | 10 | 3 | 59 |
| 20 | Kesang | 2 | 7 | 2 | - | 21 | - | 2 | - | 34 |
| 21 | Muar | 14 | 46 | 10 | 6 | 160 | 14 | 44 | 1 | 295 |
| 22 | Batu Pahat | 40 | 24 | 3 | 1 | 45 | - | 12 | 1 | 126 |
| 23 | Pontian Kechil | 34 | 39 | 2 | 15 | 55 | 1 | 4 | 2 | 152 |
| 24 | Johor | 12 | 6 | 5 | 20 | 79 | 7 | 7 | - | 136 |
| 25 | Sedili Besar | 5 | 15 | - | - | 40 | 23 | 12 | - | 95 |
| 26 | Mersing | 8 | 10 | 1 | 2 | 34 | - | 6 | - | 61 |
| 27 | Endau | 4 | 31 | 11 | 18 | 84 | 3 | 71 | - | 222 |
| 28 | Rompin | 9 | 26 | 4 | 14 | 77 | 47 | 24 | 1 | 202 |
| 29 | Bebar | 10 | 57 | - | - | 8 | 17 | - | - | 92 |
| 30 | Pahang | 10 | 45 | 38 | 28 | 388 | 233 | 662 | 2 | 1,406 |
| 31 | Kuantan | 8 | 7 | 5 | 4 | 8 | 33 | 21 | - | 86 |
| 32 | Kemaman | 8 | 10 | 4 | - | 29 | 41 | 37 | - | 129 |
| 33 | Paka | 1 | - | 9 | - | 13 | 15 | 6 | 1 | 45 |
| 34 | Dungun | 2 | 1 | 7 | - | 11 | 22 | 39 | - | 82 |
| 35 | Marang | 7 | 12 | 5 | - | 11 | 9 | 2 | 1 | 47 |
| 36 | Trengganu | 6 | 4 | 18 | - | 17 | 48 | 135 | 1 | 229 |
| 37 | Setiu | 13 | 9 | 2 | - | 12 | 7 | 7 | - | 50 |
| 38 | Besut | 7 | - | 12 | - | 10 | 2 | 21 | - | 52 |
| 39 | Kemasin | 9 | 3 | 22 | - | 5 | - | 2 | - | 41 |
| 40 | Kelantan | 3 | - | 29 | 6 | 47 | 111 | 364 | - | 560 |
| 41 | Golok | - | - | 9 | 7 | 19 | 1 | 3 | - | 39 |
| | Total | 503 | 526 | 303 | 242 | 1,630 | 740 | 2,310 | 80 | 6,334 |
| | Small Islands | - | - | - | - | - | - | 19 | - | 19 |
| | Peninsular Malaysia | 503 | 526 | 303 | 242 | 1,630 | 740 | 2,329 | 80 | 6,353 |

Remarks; AC: Alluvial soils on coastal plains, AR: Alluvial soils on
coastal plains and/or riverine, AF: Alluvial soils on
riverine, flood plains and/or low riverine terrace,
AT: Alluvial soils on intermeidate and high terraces,
SR: Sedentary soils on undulating plains to rolling land,
SH: Sedentary soils on rolling and low hilly land,
SM: Sedentary soils on hills and mountains, and UM: Urban
and mined land

Table 15      CORRELATION BETWEEN LAND USE CATEGORY AND SOILS

Unit:  No. of mesh

| Soil Unit | SA | HL | RC | TC | PL | CL | GL | FL | SW | UL | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alluvial Soils on Coastal Plains | 7 | 11 | 66 | 128 | 85 | - | 16 | 14 | 176 | - | 503 |
| Alluvial Soils on Coastal Plains and/or Riverine | 5 | 2 | 80 | 56 | 17 | 1 | 1 | 51 | 313 | - | 526 |
| Alluvial Soils on Riverine, Flood Plains and/or Low Riverine Terrace | 2 | 32 | 89 | 9 | 72 | 1 | - | 52 | 46 | - | 303 |
| Alluvial Soils on Intermediate and High Terrace | 10 | 2 | 102 | 17 | 12 | 6 | - | 76 | 17 | - | 242 |
| Sedentary Soils on Undulating Plains to Rolling Land | 8 | 13 | 623 | 145 | 3 | - | 4 | 808 | 26 | - | 1,630 |
| Sedentary Soils on Rolling and Low Hilly Land | 4 | 3 | 167 | 39 | - | 1 | - | 518 | 8 | - | 740 |
| Sedentary Soils on Hills and Mountains | 2 | 4 | 67 | 5 | 2 | - | - | 2,240 | 9 | - | 2,329 |
| Urban and Mined Land | 60 | 1 | 14 | 1 | - | 1 | - | 2 | 1 | - | 80 |
| Total | 98 | 68 | 1,208 | 400 | 191 | 10 | 21 | 3,761 | 596 | - | 6,353 |

Remarks;  SA, HL, RC, TC, PL, CL, GL, FL, SW & UL:  See remarks in Table 9.

Table 16    DISTRIBUTION OF SURFACE GEOLOGICAL CATEOGRY BY BASIN

Unit:   No. of mesh

| Basin No. | Name of Basin | Surface Geological Category | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | QT | TT | CJ | JT | PR | CB | DV | SL | OR | CR | IG | |
| 1 | Perlis | 22 | 1 | – | – | – | 19 | – | – | 6 | – | – | 48 |
| 2 | Pulau Langkawi | 4 | – | – | – | – | 5 | – | – | 6 | 4 | 6 | 25 |
| 3 | Kedah | 72 | 1 | – | 44 | – | 38 | – | 8 | – | 1 | 7 | 171 |
| 4 | Merbok | 6 | – | – | – | – | – | – | 19 | – | 4 | 1 | 30 |
| 5 | Muda | 10 | – | – | 64 | – | – | – | 34 | – | – | 95 | 203 |
| 6 | Perai | 20 | – | – | 2 | – | – | – | 1 | – | – | 17 | 40 |
| 7 | Pulau Pinang | 1 | – | – | – | – | – | – | – | – | – | 19 | 20 |
| 8 | Kerian | 14 | – | – | 10 | – | – | – | 9 | – | – | 30 | 63 |
| 9 | Kurau | 107 | – | – | 12 | – | – | – | – | – | – | 42 | 161 |
| 10 | Perak | 101 | – | – | – | 13 | 45 | 62 | 149 | – | – | 364 | 734 |
| 11 | Bernam | 85 | – | – | – | – | – | 41 | 5 | – | – | 24 | 155 |
| 12 | Tengi | 21 | – | – | – | – | – | 6 | – | – | – | – | 27 |
| 13 | Selangor | 11 | – | – | – | – | 3 | 23 | 23 | – | – | 27 | 87 |
| 14 | Buloh | 15 | – | – | – | – | 13 | – | 1 | – | – | 2 | 31 |
| 15 | Kelang | 10 | – | – | – | – | 21 | 1 | 12 | – | – | 23 | 67 |
| 16 | Langat | 56 | – | – | – | – | 5 | 18 | 2 | – | – | 37 | 118 |
| 17 | Sepang | 23 | – | – | – | – | – | 14 | – | – | – | 2 | 39 |
| 18 | Linggi | – | – | – | – | – | – | 52 | – | – | – | 23 | 75 |
| 19 | Melaka | 1 | – | – | – | – | – | 29 | – | – | – | 29 | 59 |
| 20 | Kesang | 8 | – | – | – | – | – | 10 | – | – | – | 16 | 34 |
| 21 | Muar | 43 | 7 | – | 169 | – | – | 17 | – | – | – | 59 | 295 |
| 22 | Batu Pahat | 46 | – | – | 66 | – | – | – | – | – | – | 14 | 126 |
| 23 | Pontian Kechil | 86 | – | – | 30 | – | – | – | – | – | – | 36 | 152 |
| 24 | Johor | 40 | 5 | 5 | – | 28 | – | – | – | – | – | 58 | 136 |
| 25 | Sedili Besar | 20 | – | 1 | – | 47 | – | – | – | – | – | 27 | 95 |
| 26 | Mersing | 18 | – | – | 2 | 41 | – | – | – | – | – | – | 61 |
| 27 | Endau | 62 | – | 22 | 14 | 45 | – | – | – | – | – | 79 | 222 |
| 28 | Rompin | 37 | – | 12 | 39 | 43 | – | – | – | – | – | 71 | 202 |
| 29 | Bebar | 67 | – | 4 | 1 | 18 | – | – | – | – | – | 2 | 92 |
| 30 | Pahang | 57 | – | 4 | 611 | 245 | 37 | 41 | 51 | – | – | 360 | 1,406 |
| 31 | Kuantan | 19 | 8 | 3 | 3 | – | 34 | – | – | – | – | 19 | 86 |
| 32 | Kemaman | 17 | 1 | – | 2 | – | 63 | – | – | – | – | 46 | 129 |
| 33 | Paka | 8 | – | – | 2 | – | 19 | – | – | – | – | 16 | 45 |
| 34 | Dungun | 9 | – | – | – | – | 39 | – | – | – | – | 34 | 82 |
| 35 | Marang | 27 | – | – | 5 | – | 5 | – | – | – | – | 10 | 47 |
| 36 | Trengganu | 22 | – | 2 | 2 | 17 | 88 | – | – | – | – | 98 | 229 |
| 37 | Setiu | 23 | – | – | – | – | 12 | – | – | – | – | 15 | 50 |
| 38 | Besut | 17 | – | 1 | 1 | – | 14 | – | – | – | – | 19 | 52 |
| 39 | Kemasin | 32 | – | – | – | – | – | – | – | – | – | 9 | 41 |
| 40 | Kelantan | 28 | – | 2 | 177 | 158 | – | – | 19 | – | – | 176 | 560 |
| 41 | Golok | 12 | – | – | 2 | 17 | – | – | – | – | – | 8 | 39 |
| Total | | 1,277 | 23 | 56 | 1,258 | 672 | 460 | 314 | 333 | 12 | 9 | 1,920 | 6,334 |
| Small Islands | | – | – | – | – | 10 | – | – | – | – | – | 9 | 19 |
| Peninsular Malaysia | | 1,277 | 23 | 56 | 1,258 | 682 | 460 | 314 | 333 | 12 | 9 | 1,929 | 6,353 |

Remarks;  QT:  Quaternary,  TT:  Tertiary,  CJ:  Cretaceous Jurassic,
ST:  Jurassic Triassic,  PR:  Permian,  CB:  Carboniferous,
DV:  Devonian,  SL:  Silurian,  OR:  Ordorician,
CR:  Cambrian and IG:  Igneous Instrusive

Table 17    SURFACE RUNOFF BY BASIN

| Basin No. | Name of Basin | Catchment Area (km$^2$) | Annual Rainfall (10$^9$ m$^3$/y) | Total Surface Runoff (10$^9$ m$^3$/y) | Unit Surface Runoff (10$^6$ m$^3$/y/km$^2$) |
|---|---|---|---|---|---|
| 1 | Perlis | 790 | 1.50 | 0.84 | 1.06 |
| 2 | Pulau Langkawi | 475 | 0.93 | 0.52 | 1.09 |
| 3 | Kedah | 3,695 | 8.40 | 4.71 | 1.27 |
| 4 | Merbok | 520 | 1.27 | 0.71 | 1.37 |
| 5 | Muda | 4,300 | 10.87 | 6.09 | 1.42 |
| 6 | Perai | 895 | 2.49 | 1.39 | 1.55 |
| 7 | Pulau Pinang | 300 | 0.70 | 0.39 | 1.30 |
| 8 | Kerian | 1,420 | 3.96 | 2.22 | 1.56 |
| 9 | Kurau | 3,255 | 8.57 | 4.80 | 1.47 |
| 10 | Perak | 14,700 | 34.43 | 15.05 | 1.02 |
| 11 | Bernam | 3,335 | 8.30 | 4.39 | 1.32 |
| 12 | Tengi | 565 | 1.21 | 0.59 | 1.04 |
| 13 | Selangor | 1,820 | 4.55 | 2.23 | 1.23 |
| 14 | Buloh | 560 | 1.16 | 0.57 | 1.02 |
| 15 | Kelang | 1,425 | 3.20 | 1.57 | 1.10 |
| 16 | Langat | 1,815 | 4.01 | 1.97 | 1.09 |
| 17 | Sepang | 640 | 1.39 | 0.68 | 1.06 |
| 18 | Linggi | 1,420 | 2.96 | 0.96 | 0.68 |
| 19 | Melaka | 1,010 | 1.93 | 0.63 | 0.62 |
| 20 | Kesang | 705 | 1.25 | 0.40 | 0.57 |
| 21 | Muar | 6,595 | 11.84 | 3.10 | 0.47 |
| 22 | Batu Pahat | 2,600 | 5.43 | 1.42 | 0.55 |
| 23 | Pontian Kechil | 2,660 | 6.71 | 2.12 | 0.80 |
| 24 | Johor | 3,250 | 7.78 | 2.90 | 0.89 |
| 25 | Sedili Besar | 1,820 | 4.61 | 1.72 | 0.95 |
| 26 | Mersing | 880 | 2.46 | 0.92 | 1.05 |
| 27 | Endau | 4,740 | 12.33 | 4.59 | 0.97 |
| 28 | Rompin | 4,285 | 10.04 | 3.73 | 0.87 |
| 29 | Bebar | 1,895 | 5.04 | 1.87 | 0.99 |
| 30 | Pahang | 29,300 | 62.32 | 26.66 | 0.91 |
| 31 | Kuantan | 2,025 | 5.32 | 3.08 | 1.52 |
| 32 | Kemaman | 2,570 | 7.96 | 4.61 | 1.79 |
| 33 | Paka | 850 | 2.48 | 1.44 | 1.69 |
| 34 | Dungun | 1,875 | 6.20 | 3.60 | 1.92 |
| 35 | Marang | 760 | 2.59 | 1.50 | 1.97 |
| 36 | Trengganu | 4,650 | 16.50 | 9.56 | 2.06 |
| 37 | Setiu | 1,035 | 3.39 | 1.96 | 1.89 |
| 38 | Besut | 1,230 | 3.98 | 2.31 | 1.88 |
| 39 | Kemasin | 1,020 | 2.85 | 1.63 | 1.60 |
| 40 | Kelantan | 13,100 | 33.51 | 19.15 | 1.46 |
| 41 | Golok | 895 | 2.65 | 1.52 | 1.70 |
| Total | | 131,680 | 319.07 | 150.10 | 1.14 |

Table 18    ANNUAL SOIL LOSS UNDER DIFFERENT LAND
USES IN MALAYSIA

Unit:    ton/ha/y

| Land Use | Annual Soil Loss | Remarks |
|---|---|---|
| 1.  Natural Forest | 0.33 | P.G.D. Shallow, Tech. Comm. 3 Central Elec. Board (1956) Cameron Highlands |
| 2.  Tea | 6.73 | – do – |
| 3.  Vegetables | 10.09 | – do – |
| 4.  Rubber | | |
| (a)  Mature rubber under soil series Rengam on slopes of 7 to 9% and rainfall of 2,920 mm | | Rubber Research Institute: Soil Erosion & Conservation in Peninsular Malaysia (1980) |
| Bare | 103 | |
| Grass | 44 | |
| Nephrolepis | Negligible | |
| (b)  The same conditions as above but under soil series Serdang on slopes of 5 to 7% and rainfall of 3,250 mm | | RRIM |
| Bare | 132 | |
| Grass | 117 | |
| Neophrolepis | 59 | |
| 5.  Oil Palm | | |
| Harvesting Path | 14.9 | L.M. Maene, K.C. Thong, T.S. Ong and A.M. Mokhtaruddin-Surface Wash Under Natural Oil Palm – Dept. of Agriculture, Kuala Lumpur (1979) |
| Tree Row | 7.5 | |
| Frond Row | 1.1 | |
| Mixed Row | 4.2 | |
| Average for the Whole Area | 7.7 | |
| 6.  Pepper | | |
| Up and Down Cultivation | 64 | Dept. of Agri. Sarawak (1980) |
| Bench Terraced | 0.9 | – do – |
| 7.  Grass with Spray of Natural Rubber Formulation on the Soil | 35 to 62 | RRIM Experiments Handbook of Soil Erosion and Conservation in Peninsular Malaysia (1980) |

Source;    Ref. 7

Table 19　　ASSUMED SOIL LOSS FOR EROSION POTENTIAL
EVALUATION IN MALAYSIA

Unit:　ton/ha/y

| Land Use Pattern | Slope | Soil Erodability | | |
| --- | --- | --- | --- | --- |
| | | None | Light | Heavy |
| Forest | | | | |
| - Natural hill | 0° - | 0.33 | 0.33 | 0.33 |
| - Natural wet | 0° - | 0 | 0 | 0 |
| - Scrub | 0° - | 35 | 35 | 35 |
| - Newly cleared | 0° - | 62 | 62 | 62 |
| Tree Crops | | | | |
| - Rubber | 0° - 2° | 2 | 6 | 36 |
| | 3° - 6° | 2 | 12 | 72 |
| | 7° - 12° | 6 | 18 | 108 |
| | 13° - 20° | 12 | 24 | 144 |
| - Oil palm & others | 0° - 2° | 2 | 2 | 6 |
| | 3° - 6° | 2 | 6 | 12 |
| | 7° - 12° | 2 | 12 | 18 |
| | 13° - 20° | 6 | 18 | 24 |
| - Coconut & sago | 0° - 20° | 0 | 0 | 0 |
| Annual Crops | | | | |
| - Paddy | 0° - | 0 | 0 | 0 |
| - Upland crops | 0° - | 10.09 | 10.09 | 10.09 |
| - Shifting area | 0° - | 62 | 62 | 62 |
| Grass Land | | | | |
| - Improved | 0° - | 35 | 35 | 35 |
| - Wild | 0° - | 62 | 62 | 62 |

Table 20    ANNUAL SURFACE SOIL LOSS BY BASIN UNDER
PRESENT AND PAST LAND USE PATTERNS

| Basin No. | Name of Basin | CA (km$^2$) | Present Land Use Pattern | | Past Land Use Pattern | |
|---|---|---|---|---|---|---|
| | | | TASSL ($10^3$ton/y) | AASSL (ton/km$^2$/y) | TASSL ($10^3$ton/y) | AASSL (ton/km$^2$/y) |
| 1 | Perlis | 790 | 277 | 350 | 13 | 17 |
| 2 | Pulau Langkawi | 475 | 85 | 179 | 12 | 25 |
| 3 | Kedah | 3,695 | 1,533 | 415 | 75 | 20 |
| 4 | Merbok | 520 | 326 | 627 | 13 | 25 |
| 5 | Muda | 4,300 | 1,928 | 448 | 124 | 29 |
| 6 | Perai | 895 | 815 | 911 | 18 | 20 |
| 7 | Pulau Pinang | 300 | 380 | 1,267 | 6 | 20 |
| 8 | Kerian | 1,420 | 1,428 | 1,006 | 36 | 25 |
| 9 | Kurau | 3,255 | 955 | 293 | 59 | 18 |
| 10 | Perak | 14,700 | 5,507 | 375 | 393 | 27 |
| 11 | Bernam | 3,335 | 1,299 | 390 | 45 | 13 |
| 12 | Tengi | 565 | 17 | 3 | 2 | 0.4 |
| 13 | Selangor | 1,820 | 1,320 | 725 | 46 | 25 |
| 14 | Buloh | 560 | 160 | 29 | 15 | 3 |
| 15 | Kelang | 1,425 | 578 | 406 | 28 | 20 |
| 16 | Langat | 1,815 | 1,535 | 846 | 51 | 28 |
| 17 | Sepang | 640 | 363 | 567 | 16 | 25 |
| 18 | Linggi | 1,420 | 373 | 263 | 44 | 31 |
| 19 | Melaka | 1,010 | 536 | 531 | 30 | 30 |
| 20 | Kesang | 705 | 255 | 362 | 19 | 27 |
| 21 | Muar | 6,595 | 3,385 | 513 | 175 | 27 |
| 22 | Batu Pahat | 2,600 | 1,157 | 445 | 61 | 23 |
| 23 | Pontian Kechil | 2,660 | 1,407 | 529 | 74 | 28 |
| 24 | Johor | 3,250 | 2,406 | 740 | 76 | 23 |
| 25 | Sedili Besar | 1,820 | 982 | 540 | 47 | 26 |
| 26 | Mersing | 880 | 171 | 194 | 27 | 31 |
| 27 | Endau | 4,740 | 1,357 | 286 | 120 | 25 |
| 28 | Rompin | 4,285 | 1,138 | 266 | 111 | 26 |
| 29 | Bebar | 1,895 | 15 | 8 | 15 | 8 |
| 30 | Pahang | 29,300 | 8,269 | 282 | 848 | 29 |
| 31 | Kuantan | 2,025 | 398 | 197 | 42 | 21 |
| 32 | Kemaman | 2,570 | 214 | 83 | 68 | 26 |
| 33 | Paka | 850 | 367 | 432 | 25 | 29 |
| 34 | Dungun | 1,875 | 259 | 138 | 49 | 26 |
| 35 | Marang | 760 | 320 | 421 | 14 | 18 |
| 36 | Trengganu | 4,650 | 2,042 | 439 | 137 | 29 |
| 37 | Setiu | 1,035 | 140 | 135 | 16 | 15 |
| 38 | Besut | 1,230 | 432 | 351 | 25 | 20 |
| 39 | Kemasin | 1,020 | 579 | 568 | 7 | 7 |
| 40 | Kelantan | 13,100 | 1,803 | 138 | 337 | 26 |
| 41 | Golok | 895 | 794 | 887 | 18 | 20 |
| | Total | 131,680 | 47,305 | 359 | 3,337 | 25 |

Table 21　　　INCREASE IN TOTAL SURFACE SOIL LOSS BY BASIN
UNDER FUTURE LAND USE PATTERN

Unit:　$10^3$ ton/y

| Basin No. | Name of Basin | Present Land Use | Future Land Use Pattern | | | |
|---|---|---|---|---|---|---|
| | | | Case 1 | Case 2 | Case 3 | Case 4 |
| 1 | Perlis | 277 | -219 | 365 | 146 | 233 |
| 2 | Pulau Langkawi | 85 | -73 | 512 | 438 | 526 |
| 3 | Kedah | 1,533 | -585 | 2,046 | 1,535 | 1,326 |
| 4 | Merbok | 326 | 0 | 0 | 73 | 0 |
| 5 | Muda | 1,928 | -146 | 2,996 | 1,973 | 2,543 |
| 6 | Perai | 815 | 0 | 0 | 219 | 0 |
| 7 | Pulau Pinang | 380 | -73 | 73 | 146 | 75 |
| 8 | Kerian | 1,428 | 0 | 438 | 146 | 173 |
| 9 | Kurau | 955 | 0 | 1,242 | 585 | 676 |
| 10 | Perak | 5,507 | -585 | 6,942 | 7,161 | 6,039 |
| 11 | Bernam | 1,299 | -73 | 1,096 | 365 | 778 |
| 12 | Tengi | 17 | 0 | 73 | 0 | 75 |
| 13 | Selangor | 1,320 | 0 | 1,023 | 658 | 838 |
| 14 | Buloh | 160 | 0 | 512 | 0 | 463 |
| 15 | Kelang | 578 | 0 | 585 | 365 | 538 |
| 16 | Langat | 1,535 | 0 | 146 | 438 | 150 |
| 17 | Sepang | 363 | 0 | 73 | 0 | 12 |
| 18 | Linggi | 373 | 0 | 146 | 438 | 150 |
| 19 | Melaka | 536 | 0 | 438 | 73 | 325 |
| 20 | Kesang | 255 | 0 | 146 | 73 | 24 |
| 21 | Muar | 3,385 | -146 | 5,700 | 2,485 | 1,387 |
| 22 | Batu Pahat | 1,157 | -146 | 877 | 438 | 195 |
| 23 | Pontian Kechil | 1,407 | -146 | 731 | 219 | 53 |
| 24 | Johor | 2,406 | 0 | 2,631 | 146 | 521 |
| 25 | Sedili Besar | 982 | 0 | 3,873 | 950 | 977 |
| 26 | Mersing | 171 | 0 | 1,900 | 731 | 165 |
| 27 | Endau | 1,357 | 0 | 7,015 | 1,315 | 2,635 |
| 28 | Rompin | 1,138 | -73 | 7,892 | 2,923 | 2,025 |
| 29 | Bebar | 15 | 0 | 1,023 | 512 | 75 |
| 30 | Pahang | 8,269 | -1,023 | 37,413 | 17,757 | 19,147 |
| 31 | Kuantan | 398 | 0 | 1,827 | 1,169 | 759 |
| 32 | Kemaman | 214 | -73 | 4,458 | 1,681 | 2,164 |
| 33 | Paka | 367 | 0 | 1,973 | 365 | 522 |
| 34 | Dungun | 259 | -73 | 2,850 | 1,023 | 1,605 |
| 35 | Marang | 320 | -146 | 804 | 146 | 119 |
| 36 | Trengganu | 2,042 | -1,023 | 4,677 | 2,923 | 3,076 |
| 37 | Setiu | 140 | -73 | 1,023 | 0 | 202 |
| 38 | Besut | 432 | 0 | 877 | 292 | 275 |
| 39 | Kemasin | 579 | 0 | 0 | 0 | 0 |
| 40 | Kelantan | 1,803 | -292 | 13,373 | 8,988 | 8,304 |
| 41 | Golok | 794 | -365 | 292 | 0 | 31 |
| Peninsular Malaysia | | 47,305 | -5,333 | 120,061 | 58,895 | 59,181 |

Remarks;　Case 1:　Reforestation of all existing forest disturbed.
　　　　　　Case 2:　All natural forests on slope of less than 2° are
　　　　　　　　　　　disturbed.
　　　　　　Case 3:　All natural forests on slope of 3° - 6° are
　　　　　　　　　　　disturbed.
　　　　　　Case 4:　All natural forests on slope of less than 2° are
　　　　　　　　　　　disturbed and then converted to rubber farm.

Table 22    INCREASE IN ANNUAL AVERAGE SURFACE SOIL LOSS
            BY BASIN UNDER FUTURE LAND USE PATTERN

Unit:  ton/km$^2$/y

| Basin No. | Name of Basin | Present Land Use | Future Land Use Pattern | | | |
|---|---|---|---|---|---|---|
| | | | Case 1 | Case 2 | Case 3 | Case 4 |
| 1 | Perlis | 350 | −277 | 463 | 185 | 295 |
| 2 | Pulau Langkawi | 179 | −154 | 1,078 | 922 | 1,107 |
| 3 | Kedah | 415 | −158 | 554 | 415 | 359 |
| 4 | Merbok | 627 | 0 | 0 | 140 | 0 |
| 5 | Muda | 448 | −34 | 697 | 459 | 591 |
| 6 | Perai | 911 | 0 | 0 | 245 | 0 |
| 7 | Pulau Pinang | 1,267 | −243 | 243 | 487 | 250 |
| 8 | Kerian | 1,006 | 0 | 308 | 103 | 122 |
| 9 | Kurau | 293 | 0 | 382 | 180 | 208 |
| 10 | Perak | 375 | −40 | 472 | 487 | 411 |
| 11 | Bernam | 390 | −22 | 329 | 109 | 233 |
| 12 | Tengi | 3 | 0 | 13 | 0 | 13 |
| 13 | Selangor | 725 | 0 | 562 | 362 | 460 |
| 14 | Buloh | 29 | 0 | 91 | 0 | 83 |
| 15 | Kelang | 406 | 0 | 411 | 256 | 378 |
| 16 | Langat | 846 | 0 | 80 | 241 | 83 |
| 17 | Sepang | 567 | 0 | 114 | 0 | 19 |
| 18 | Linggi | 263 | 0 | 103 | 308 | 106 |
| 19 | Melaka | 531 | 0 | 434 | 72 | 322 |
| 20 | Kesang | 362 | 0 | 207 | 104 | 34 |
| 21 | Muar | 513 | −22 | 864 | 377 | 210 |
| 22 | Batu Pahat | 445 | −56 | 337 | 168 | 75 |
| 23 | Pontian Kechil | 529 | −55 | 275 | 82 | 20 |
| 24 | Johor | 740 | 0 | 810 | 45 | 160 |
| 25 | Sedili Besar | 540 | 0 | 2,128 | 522 | 537 |
| 26 | Mersing | 194 | 0 | 2,159 | 831 | 188 |
| 27 | Endau | 286 | 0 | 1,480 | 277 | 556 |
| 28 | Rompin | 266 | −17 | 1,842 | 682 | 473 |
| 29 | Bebar | 8 | 0 | 540 | 270 | 40 |
| 30 | Pahang | 282 | −35 | 1,277 | 606 | 653 |
| 31 | Kuantan | 197 | 0 | 902 | 577 | 375 |
| 32 | Kemaman | 83 | −28 | 1,735 | 654 | 842 |
| 33 | Paka | 432 | 0 | 2,321 | 429 | 614 |
| 34 | Dungun | 138 | −39 | 1,520 | 546 | 856 |
| 35 | Marang | 421 | −192 | 1,058 | 192 | 157 |
| 36 | Trengganu | 439 | −220 | 1,006 | 629 | 662 |
| 37 | Setiu | 135 | −71 | 988 | 0 | 195 |
| 38 | Besut | 351 | 0 | 713 | 237 | 224 |
| 39 | Kemasin | 568 | 0 | 0 | 0 | 0 |
| 40 | Kelantan | 138 | −22 | 1,021 | 686 | 634 |
| 41 | Golok | 887 | −407 | 326 | 0 | 35 |
| | Peninsular Malaysia | 359 | −40 | 912 | 447 | 449 |

Remarks;  Case 1:  Reforestation of all existing forest disturbed.
          Case 2:  All natural forests on slope of less than 2° are
                   disturbed.
          Case 3:  All natural forests on slope of 3° − 6° are
                   disturbed.
          Case 4:  All natural forests on slope of less than 2° are
                   disturbed and then converted to rubber farm.

Table 23    ANNUAL AVERAGE SURFACE SOIL LOSS BY BASIN
UNDER ALTERNATIVES OF LAND USE PATTERN

Unit: ton/km²/y

| Basin No. | Name of Basin | Catchment Area (km²) | Present Land Use | Alternatives 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| 1 | Perlis | 790 | 350 | 73 | 998 | 813 | 645 | 830 |
| 2 | Pulau Langkawi | 475 | 179 | 25 | 2,179 | 1,257 | 1,286 | 2,208 |
| 3 | Kedah | 3,695 | 415 | 257 | 1,384 | 969 | 774 | 1,189 |
| 4 | Merbok | 520 | 627 | 627 | 767 | 627 | 627 | 767 |
| 5 | Muda | 4,300 | 448 | 414 | 1,604 | 1,145 | 1,039 | 1,498 |
| 6 | Perai | 895 | 911 | 911 | 1,156 | 911 | 911 | 1,156 |
| 7 | Pulau Pinang | 300 | 1,267 | 1,024 | 1,997 | 1,510 | 1,517 | 2,004 |
| 8 | Kerian | 1,420 | 1,006 | 1,006 | 1,417 | 1,314 | 1,128 | 1,231 |
| 9 | Kurau | 3,255 | 293 | 293 | 855 | 675 | 501 | 681 |
| 10 | Perak | 14,700 | 375 | 335 | 1,334 | 847 | 786 | 1,273 |
| 11 | Bernam | 3,335 | 390 | 368 | 828 | 719 | 623 | 732 |
| 12 | Tengi | 565 | 3 | 3 | 16 | 16 | 16 | 16 |
| 13 | Selangor | 1,820 | 725 | 725 | 1,649 | 1,287 | 1,185 | 1,547 |
| 14 | Buloh | 560 | 29 | 29 | 120 | 120 | 112 | 112 |
| 15 | Kelang | 1,425 | 406 | 406 | 1,073 | 817 | 784 | 1,040 |
| 16 | Langat | 1,815 | 846 | 846 | 1,167 | 926 | 929 | 1,170 |
| 17 | Sepang | 640 | 567 | 567 | 681 | 681 | 586 | 586 |
| 18 | Linggi | 1,420 | 263 | 263 | 674 | 366 | 369 | 677 |
| 19 | Melaka | 1,010 | 531 | 531 | 1,037 | 965 | 853 | 925 |
| 20 | Kesang | 705 | 362 | 362 | 673 | 569 | 396 | 500 |
| 21 | Muar | 6,595 | 513 | 491 | 1,754 | 1,377 | 723 | 1,100 |
| 22 | Batu Pahat | 2,600 | 445 | 389 | 950 | 782 | 520 | 688 |
| 23 | Pontian Kechil | 2,660 | 529 | 474 | 886 | 804 | 549 | 631 |
| 24 | Johor | 3,250 | 740 | 740 | 1,550 | 1,595 | 900 | 945 |
| 25 | Sedili Besar | 1,820 | 540 | 540 | 3,190 | 2,668 | 1,077 | 1,599 |
| 26 | Mersing | 880 | 194 | 194 | 3,184 | 2,353 | 382 | 1,213 |
| 27 | Endau | 4,740 | 286 | 286 | 2,043 | 1,766 | 842 | 1,119 |
| 28 | Rompin | 4,285 | 266 | 249 | 2,108 | 948 | 739 | 1,421 |
| 29 | Bebar | 1,895 | 8 | 8 | 818 | 548 | 48 | 318 |
| 30 | Pahang | 29,300 | 282 | 247 | 2,165 | 1,559 | 935 | 1,541 |
| 31 | Kuantan | 2,025 | 197 | 197 | 1,676 | 1,099 | 572 | 1,149 |
| 32 | Kemaman | 2,570 | 83 | 55 | 2,472 | 1,818 | 925 | 1,579 |
| 33 | Paka | 850 | 432 | 432 | 3,182 | 2,753 | 1,046 | 1,475 |
| 34 | Dungun | 1,875 | 138 | 99 | 2,204 | 1,658 | 994 | 1,540 |
| 35 | Marang | 760 | 421 | 229 | 1,671 | 1,479 | 578 | 770 |
| 36 | Trengganu | 4,650 | 439 | 219 | 2,074 | 1,445 | 1,101 | 1,730 |
| 37 | Setiu | 1,035 | 135 | 64 | 1,123 | 1,123 | 330 | 330 |
| 38 | Beaut | 1,230 | 351 | 351 | 1,301 | 1,064 | 575 | 812 |
| 39 | Kemasin | 1,020 | 568 | 568 | 568 | 568 | 568 | 568 |
| 40 | Kelantan | 13,100 | 138 | 116 | 1,845 | 1,159 | 772 | 1,458 |
| 41 | Golok | 895 | 887 | 480 | 1,213 | 1,213 | 922 | 922 |
| | Peninsular Malaysia | 131,680 | 359 | 319 | 1,718 | 1,271 | 808 | 1,255 |

Remarks;  Alternative 1: Reforestation of all existing forest disturbed.
Alternative 2: All natural forests on slope of less than 6°
are disturbed.
Alternative 3: All natural forests on slope of less than 2°
are disturbed.
Alternative 4: All natural forests on slope of less than 2°
are disturbed and then converted to rubber farm.
Alternative 5: All natural forest on slope of less than 6° are
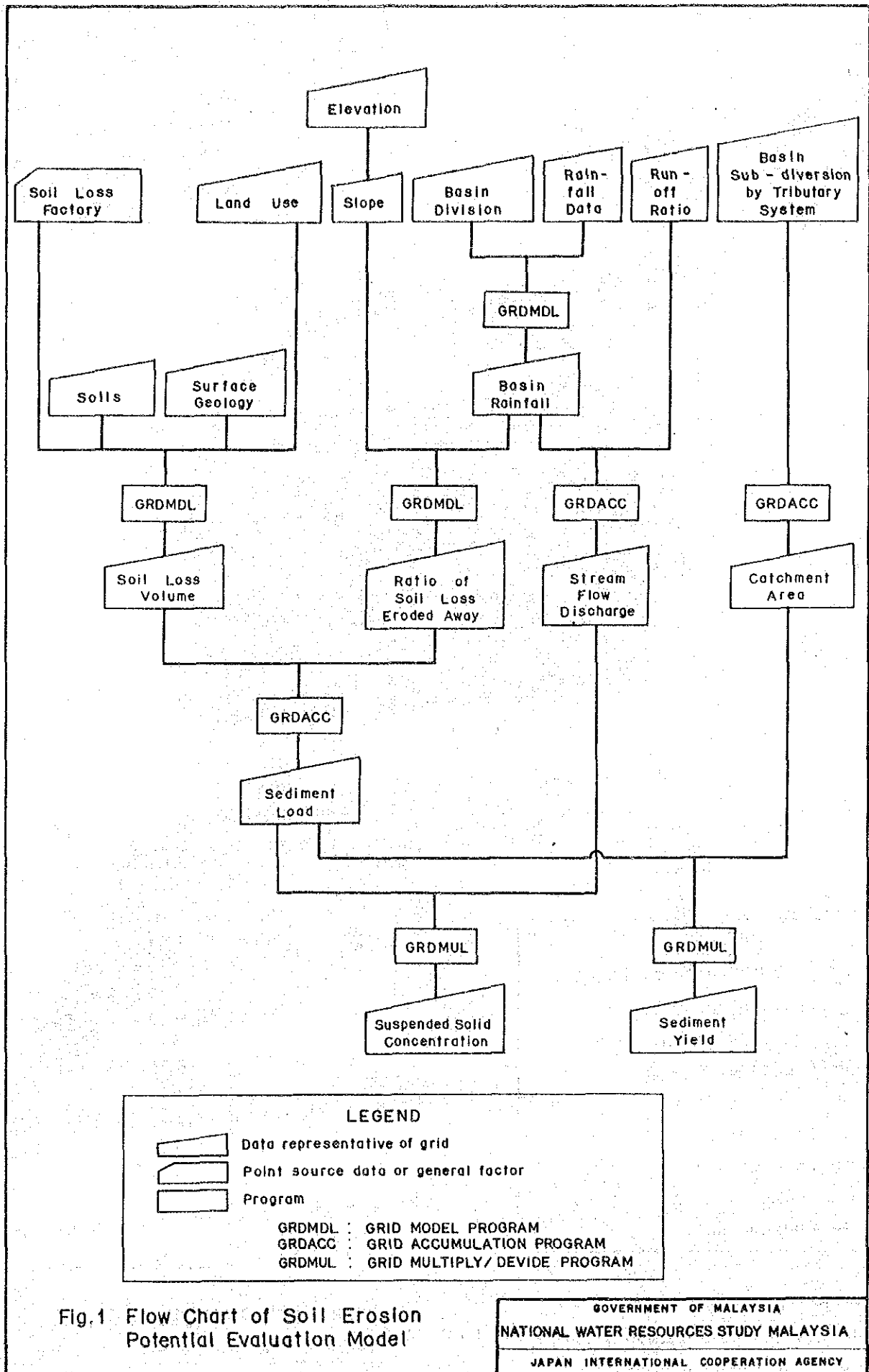disturbed and then converted to rubber farm on
slope of less than 2°.

Table 24    ESTIMATE OF SUSPENDED SOLID CONCENTRATION
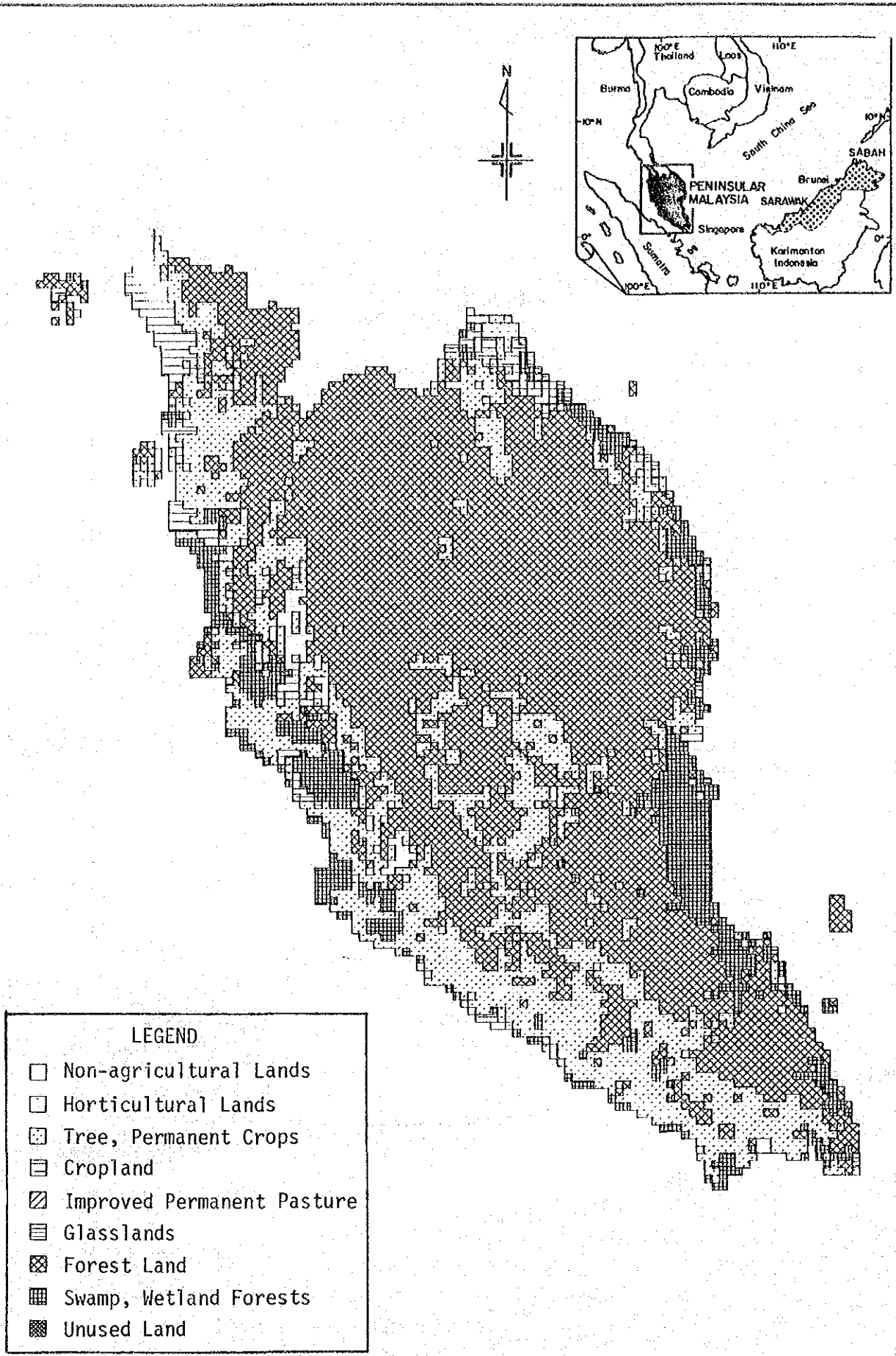            AT ESTUARY BY BASIN

Unit:    mg/lit

| Basin No. | Name of Basin | Present Land Use Pattern | Alternatives 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| 1 | Perlis | 330 | 69 | 942 | 767 | 608 | 783 |
| 2 | Pulau Langkawi | 164 | 23 | 1,999 | 1,153 | 1,180 | 2,026 |
| 3 | Kedah | 327 | 202 | 1,090 | 763 | 609 | 936 |
| 4 | Merbok | 458 | 458 | 560 | 458 | 458 | 560 |
| 5 | Muda | 315 | 292 | 1,130 | 806 | 732 | 1,055 |
| 6 | Perai | 588 | 588 | 746 | 588 | 588 | 746 |
| 7 | Pulau Pinang | 975 | 788 | 1,536 | 1,162 | 1,167 | 1,542 |
| 8 | Kerian | 645 | 645 | 908 | 842 | 723 | 789 |
| 9 | Kurau | 199 | 199 | 582 | 459 | 341 | 463 |
| 10 | Perak | 368 | 328 | 1,308 | 830 | 771 | 1,248 |
| 11 | Bernam | 295 | 279 | 627 | 545 | 472 | 555 |
| 12 | Tengi | 3 | 3 | 15 | 15 | 15 | 15 |
| 13 | Selangor | 589 | 589 | 1,341 | 1,046 | 963 | 1,258 |
| 14 | Buloh | 28 | 28 | 118 | 118 | 110 | 110 |
| 15 | Kelang | 369 | 369 | 975 | 743 | 713 | 945 |
| 16 | Langat | 776 | 776 | 1,071 | 850 | 852 | 1,073 |
| 17 | Sepang | 535 | 535 | 642 | 642 | 553 | 553 |
| 18 | Linggi | 387 | 387 | 991 | 538 | 543 | 996 |
| 19 | Melaka | 856 | 856 | 1,673 | 1,556 | 1,376 | 1,492 |
| 20 | Kesang | 635 | 635 | 1,181 | 998 | 695 | 877 |
| 21 | Muar | 1,091 | 1,045 | 3,732 | 2,930 | 1,538 | 2,340 |
| 22 | Batu Pahat | 809 | 707 | 1,727 | 1,422 | 945 | 1,251 |
| 23 | Pontian Kechil | 661 | 593 | 1,108 | 1,005 | 686 | 789 |
| 24 | Johor | 831 | 831 | 1,742 | 1,792 | 1,011 | 1,062 |
| 25 | Sedili Besar | 568 | 568 | 3,358 | 2,808 | 1,134 | 1,683 |
| 26 | Mersing | 185 | 185 | 3,032 | 2,241 | 364 | 1,155 |
| 27 | Endau | 295 | 295 | 2,106 | 1,821 | 868 | 1,154 |
| 28 | Rompin | 306 | 286 | 2,423 | 3,207 | 849 | 1,633 |
| 29 | Bebar | 8 | 8 | 826 | 554 | 48 | 321 |
| 30 | Pahang | 310 | 271 | 2,379 | 1,713 | 1,027 | 1,693 |
| 31 | Kuantan | 130 | 130 | 1,103 | 723 | 376 | 756 |
| 32 | Kemaman | 46 | 31 | 1,381 | 1,016 | 517 | 882 |
| 33 | Paka | 256 | 256 | 1,883 | 1,629 | 619 | 873 |
| 34 | Dungun | 72 | 52 | 1,148 | 864 | 518 | 802 |
| 35 | Marang | 214 | 116 | 848 | 751 | 293 | 391 |
| 36 | Trengganu | 213 | 106 | 1,007 | 701 | 534 | 840 |
| 37 | Setiu | 71 | 34 | 594 | 594 | 175 | 175 |
| 38 | Besut | 187 | 187 | 692 | 566 | 306 | 432 |
| 39 | Kemasin | 355 | 355 | 355 | 355 | 355 | 355 |
| 40 | Kelantan | 95 | 79 | 1,264 | 794 | 529 | 999 |
| 41 | Golok | 522 | 282 | 714 | 714 | 542 | 542 |
| | Peninsular Malaysia | 315 | 280 | 1,507 | 1,115 | 709 | 1,101 |

Remarks;  Alternative 1:  Reforestation of all existing forest disturbed.
          Alternative 2:  All natural forests on slope of less than 6°
                          are disturbed.
          Alternative 3:  All natural forests on slope of less than 2°
                          are disturbed.
          Alternative 4:  All natural forests on slope of less than 2°
                          are disturbed and then converted to rubber farm.
          Alternative 5:  All natural forests on slope of less than 6° are
                          disturbed and then converted to rubber farm on
                          slope of less than 2°.

Table 25    SOIL EROSION POTENTIAL BY STATE

Unit:   ton/km$^2$/y

| State | Present Condition | Future Condition | | | |
|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) |
| Perlis | 274 | 57 | 779 | 635 | 504 |
| Kedah | 511 | 434 | 1,493 | 1,090 | 952 |
| P. Pinang | 946 | 888 | 1,288 | 1,003 | 1,005 |
| Perak | 351 | 321 | 1,138 | 771 | 690 |
| Selangor | 520 | 520 | 1,066 | 856 | 817 |
| N. Sembilan | 306 | 306 | 581 | 398 | 374 |
| Melaka | 404 | 404 | 776 | 702 | 582 |
| Johor | 475 | 455 | 1,741 | 1,467 | 734 |
| Pahang | 261 | 232 | 2,136 | 1,541 | 846 |
| Trengganu | 283 | 179 | 2,012 | 1,531 | 879 |
| Kelantan | 236 | 187 | 1,917 | 1,250 | 854 |
| Peninsular Malaysia | 359 | 319 | 1,718 | 1,271 | 808 |

Remarks; (1): Reforestation of all existing forests disturbed.

(2): All natural forests on slope of less than 6° are disturbed.

(3): All natural forests on slope of less than 2° are disturbed.

(4): All natural forests on slope of less than 2° are disturbed and then converted to rubber farm.

*FIGURES*

Fig.1 Flow Chart of Soil Erosion
Potential Evaluation Model

**LEGEND**

Data representative of grid

Point source data or general factor

Program

GRDMDL : GRID MODEL PROGRAM
GRDACC : GRID ACCUMULATION PROGRAM
GRDMUL : GRID MULTIPLY/ DEVIDE PROGRAM

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

LEGEND
☐ Non-agricultural Lands
☐ Horticultural Lands
☒ Tree, Permanent Crops
☐ Cropland
▨ Improved Permanent Pasture
☰ Glasslands
⊠ Forest Land
▦ Swamp, Wetland Forests
▩ Unused Land

Fig. 2   Distribution of Land Use Pattern

LEGEND

| | | |
|---|---|---|
| ☐ | – | 99 (m) |
| ☐ | 100 – | 199 |
| ☐ | 200 – | 299 |
| ☐ | 300 – | 399 |
| ▨ | 400 – | 499 |
| ☰ | 500 – | 599 |
| ⊠ | 600 – | 699 |
| ▦ | 700 – | 799 |
| ▓ | 800 – | 999 |
| ▤ | 1000 – | 1499 |
| ■ | 1500 – | 1999 |
| ■ | 2000 – | |
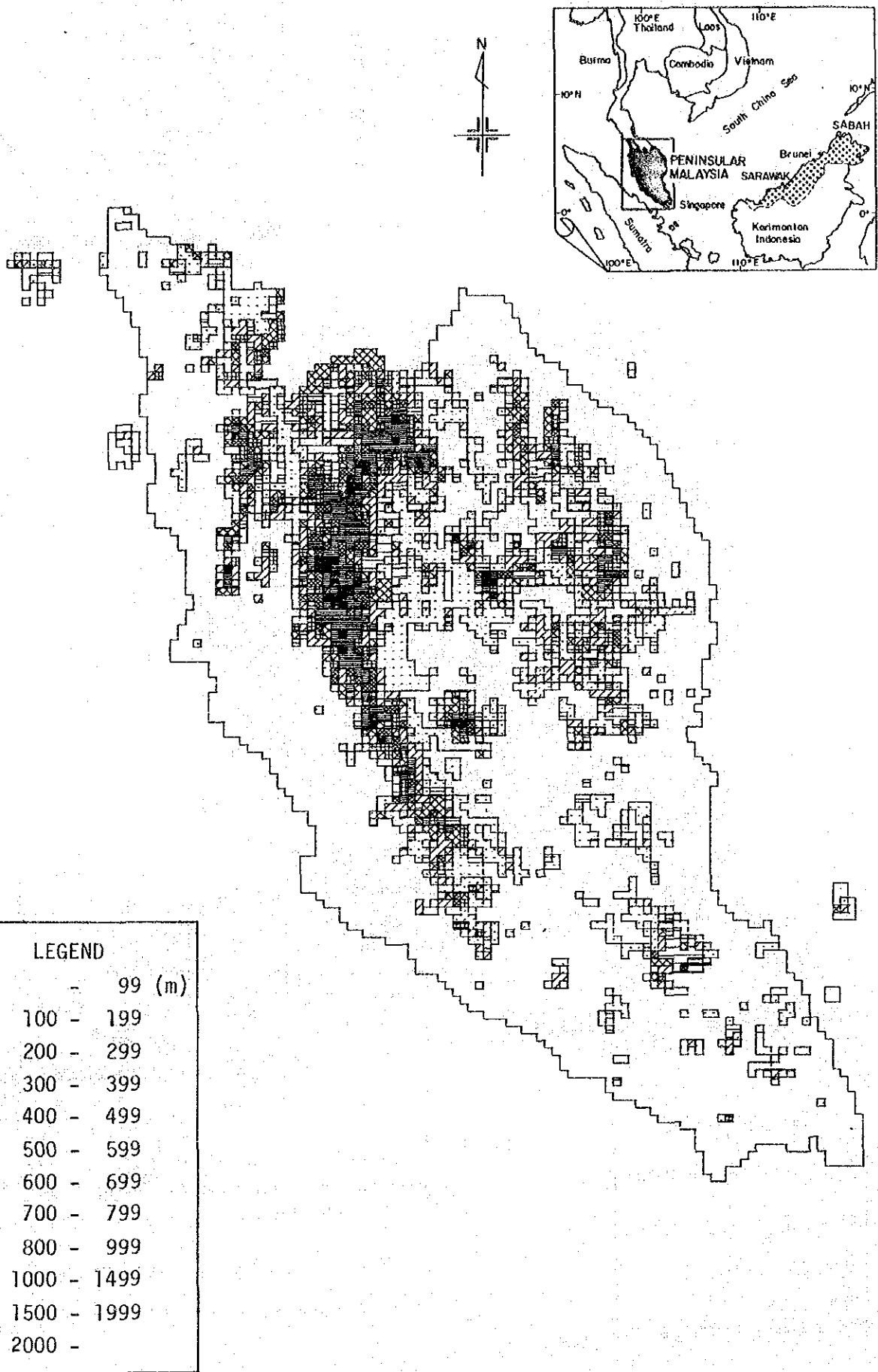
Fig. 3   Distribution of Ground Elevation
        Pattern

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN   INTERNATIONAL   COOPERATION   AGENCY
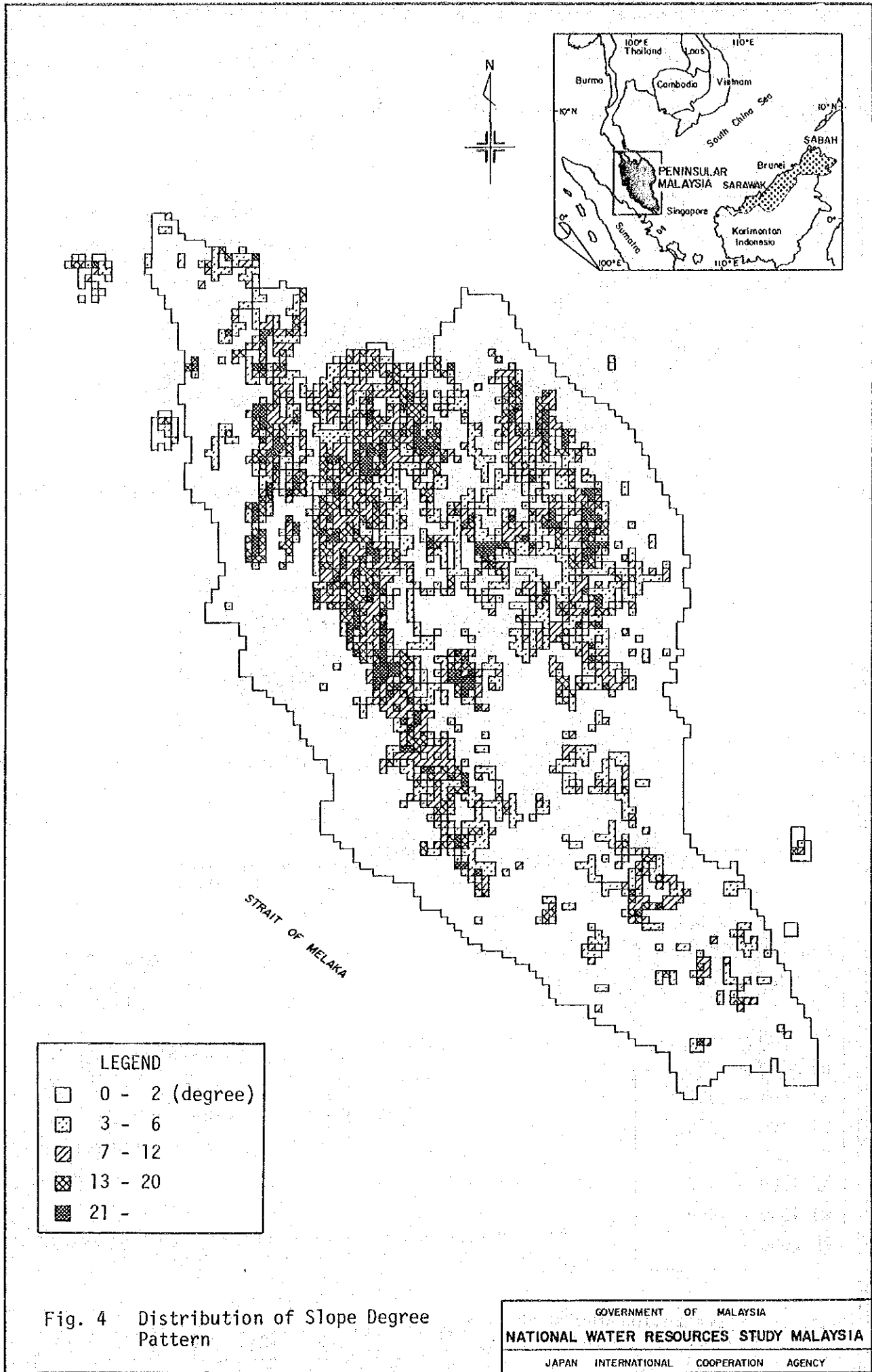
LEGEND
☐ 0 - 2 (degree)
▨ 3 - 6
▨ 7 - 12
▨ 13 - 20
▨ 21 -

Fig. 4    Distribution of Slope Degree
           Pattern

GOVERNMENT   OF   MALAYSIA
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LEGEND

Alluvial on Coastal Plains
Alluvial on Coastal Plains and/or Riverine
Alluvial on Riverine Flood Plains and/or
Low Riverine Terrace
Alluvial on Intermediate and Higher Terrace
Sedentary on Undulating Plains to Rolling Land
Sedentary on Rolling and Low Hilly Land
Sedentary on Hills and Mountains
Urban and Mined Land

Fig. 5  Distribution of Soil Pattern

LEGEND
- ▣ Quaternary
- ▨ Tertiary
- ▤ Cretaceous-Jurassic
- ▨ Jurassic-Triassic
- ▤ Permian
- ▧ Carboniferous
- ▦ Devonian
- ▨ Silurian
- ▤ Ordovician
- ◼ Cambrian
- ▢ Igneous Intrusives

Fig. 6    Distribution of Surface
          Geological Pattern

GOVERNMENT   OF   MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
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Fig. 7   Schematic Basin Division

GOVERNMENT   OF   MALAYSIA
**NATIONAL WATER RESOURCES STUDY MALAYSIA**
JAPAN   INTERNATIONAL   COOPERATION   AGENCY

## LEGEND

| | | | |
|---|---|---|---|
| ☐ | | – 200 | (km²) |
| ☐ | 201 | – 500 | |
| ⊟ | 501 | – 1000 | |
| ▨ | 1001 | – 2000 | |
| ▤ | 2001 | – 4000 | |
| ▨ | 4001 | – 8000 | |
| ▦ | 8001 | – 16000 | |
| ▩ | 16001 | – 32000 | |
| ■ | 32001 | – | |
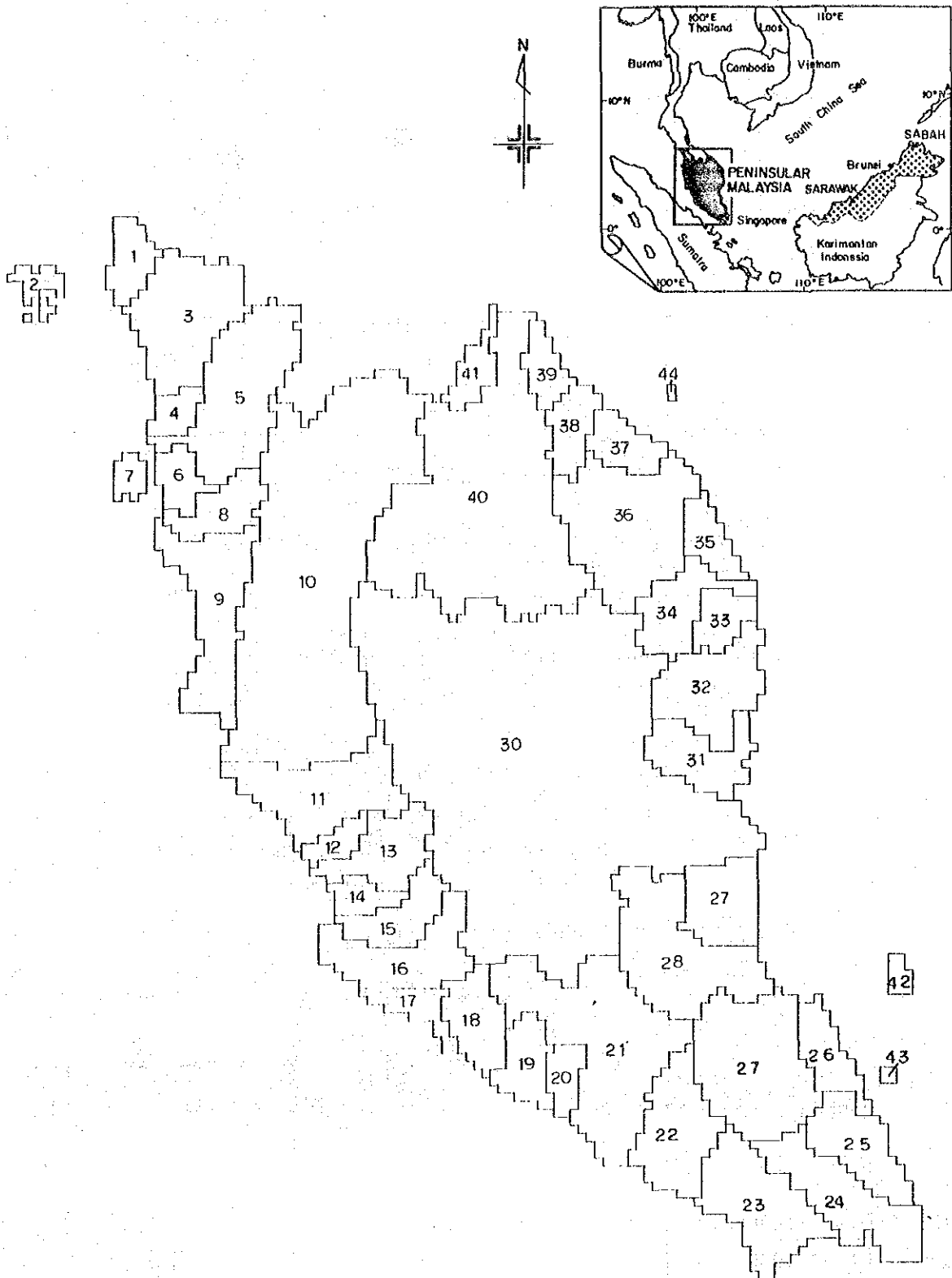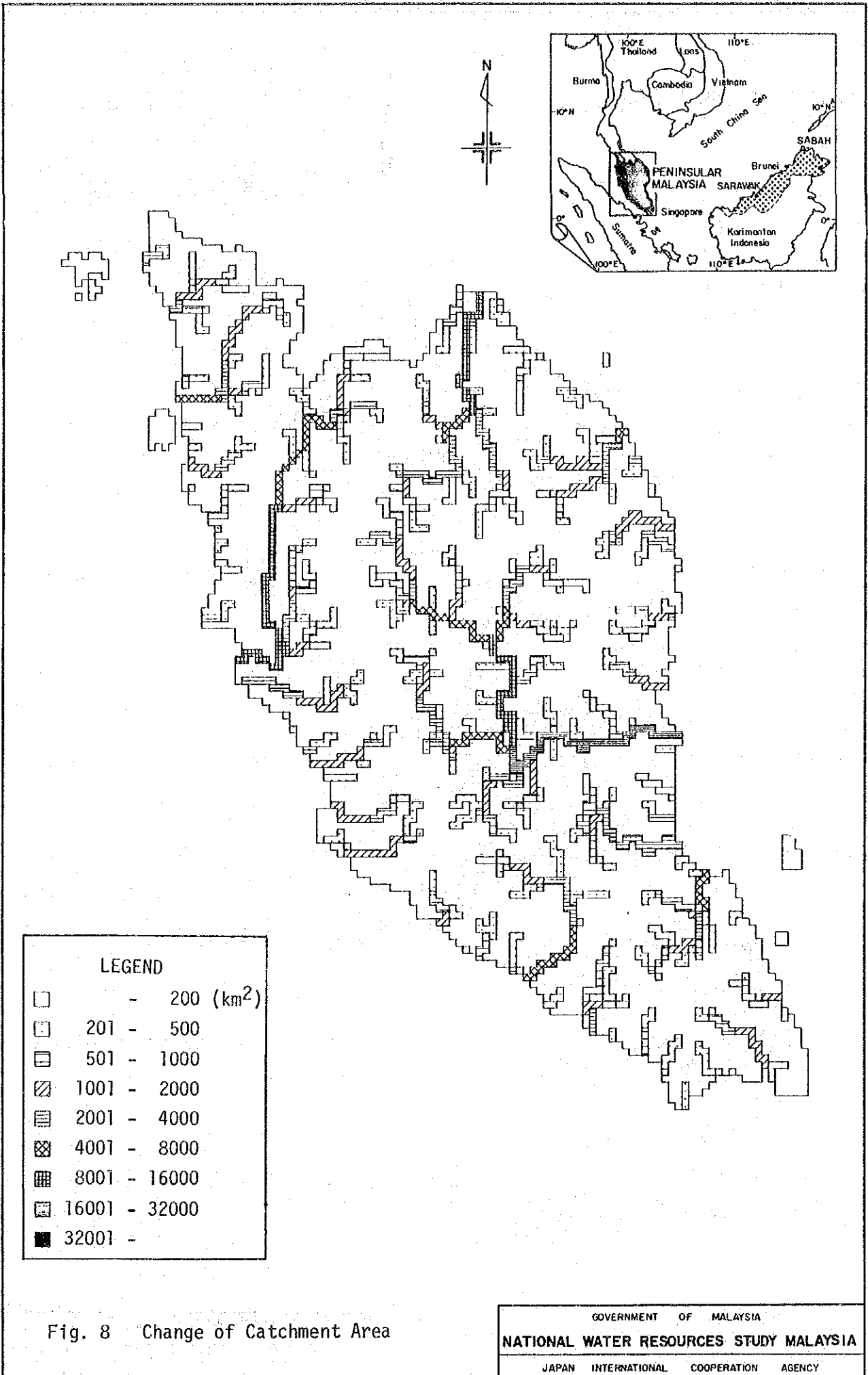
Fig. 8   Change of Catchment Area

LEGEND

| | | |
|---|---|---|
| ☐ | – | 99 (10$^6$ m$^3$) |
| ☐ | 100 – | 199 |
| ☐ | 200 – | 499 |
| ▨ | 500 – | 999 |
| ☐ | 1000 – | 1999 |
| ⊠ | 2000 – | 4999 |
| ▥ | 5000 – | 9999 |
| ▧ | 10000 – | 19999 |
| ☰ | 20000 – | 49999 |
| ■ | 50000 – | |
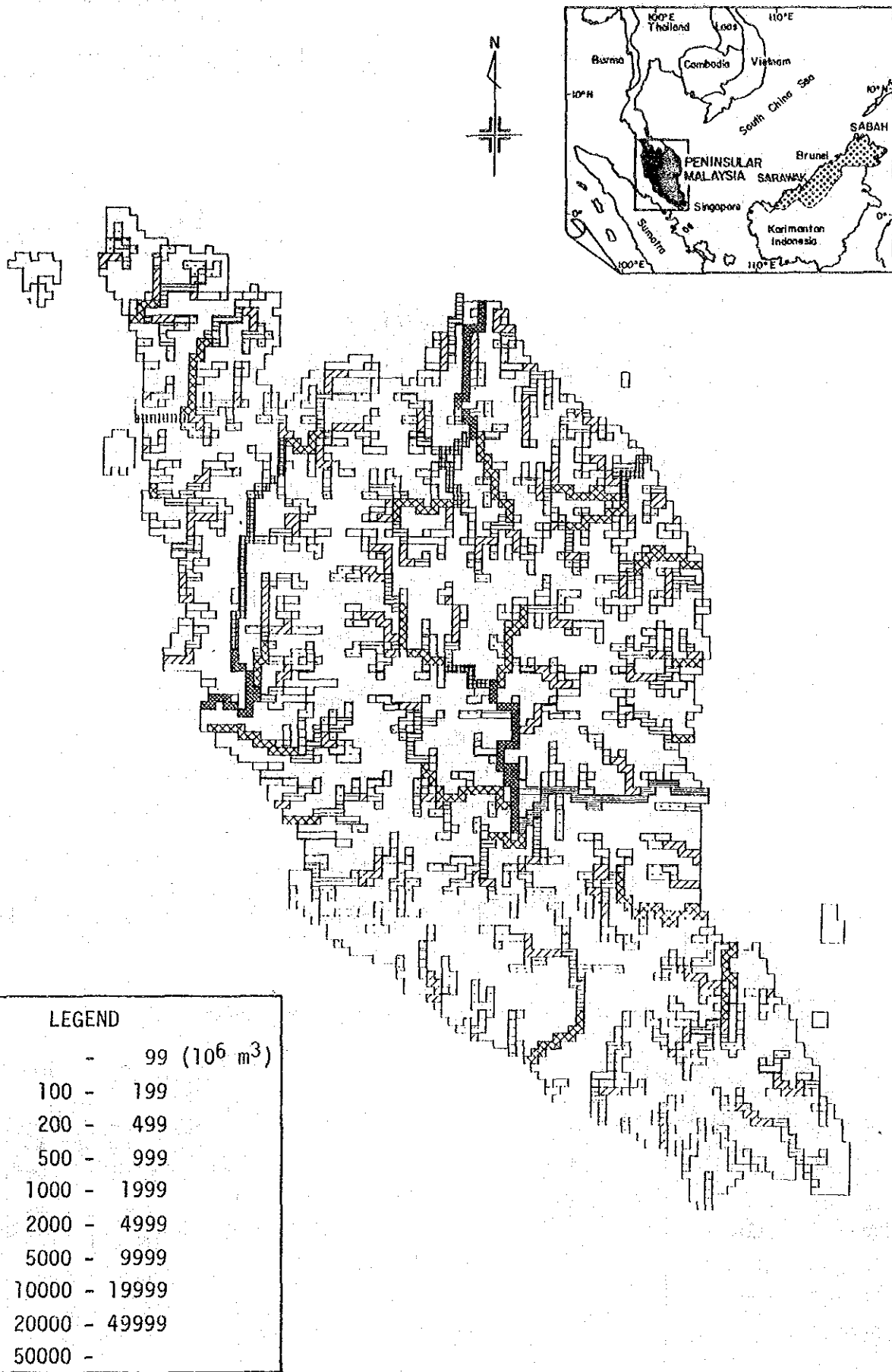
Fig. 9   Change of Stream Flow Discharge

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN   INTERNATIONAL   COOPERATION   AGENCY
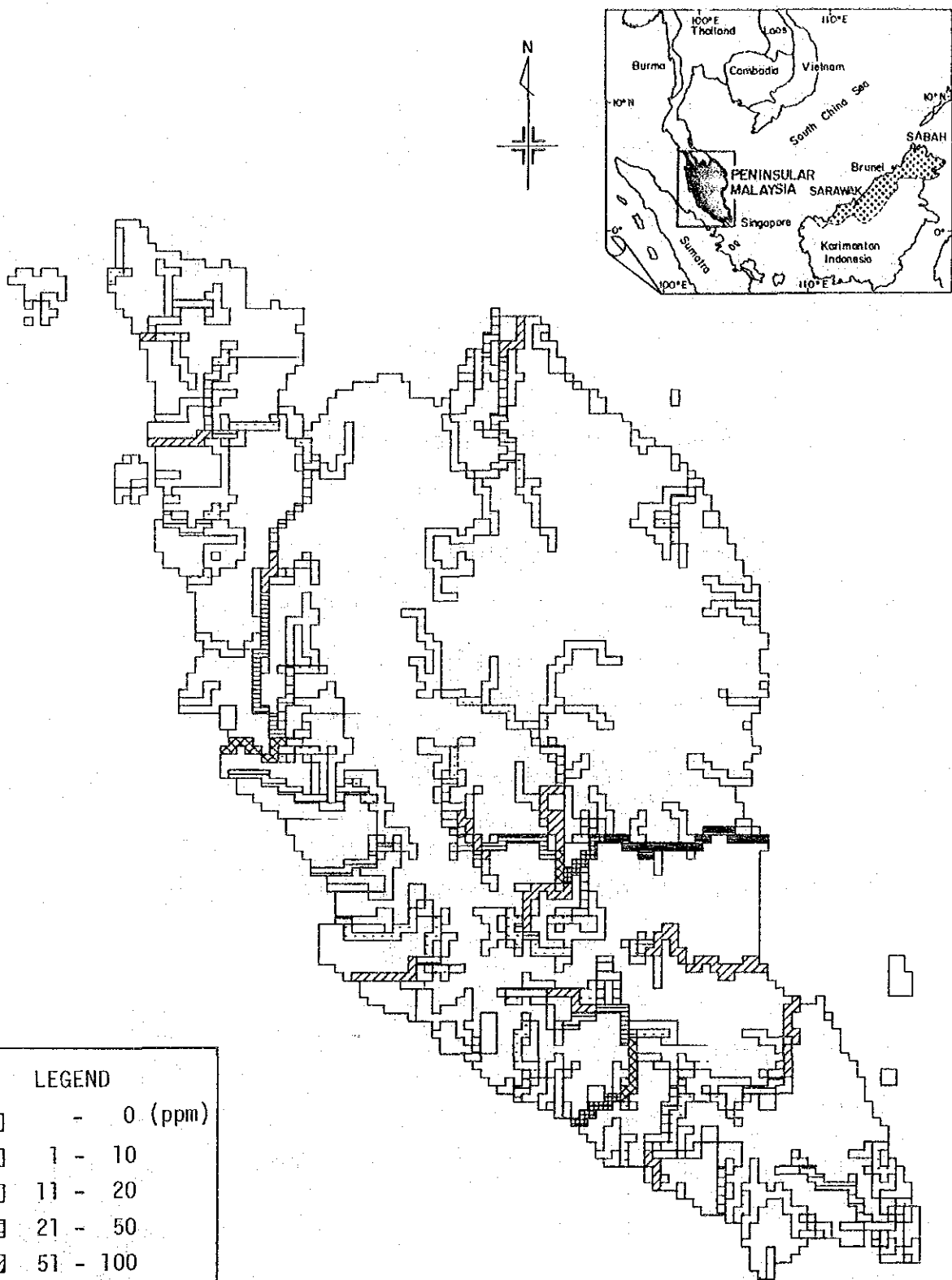
LEGEND

| | |
|---|---|
| ☐ | – 0 (ppm) |
| ☐ | 1 – 10 |
| ☐ | 11 – 20 |
| ☐ | 21 – 50 |
| ▨ | 51 – 100 |
| ▤ | 101 – 200 |
| ▩ | 201 – 300 |
| ▦ | 301 – 400 |
| ▤ | 401 – 500 |
| ■ | 501 – |

Fig. 10　Change of Suspended Solid
　　　　Concentration under Present
　　　　Land Use Pattern

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY
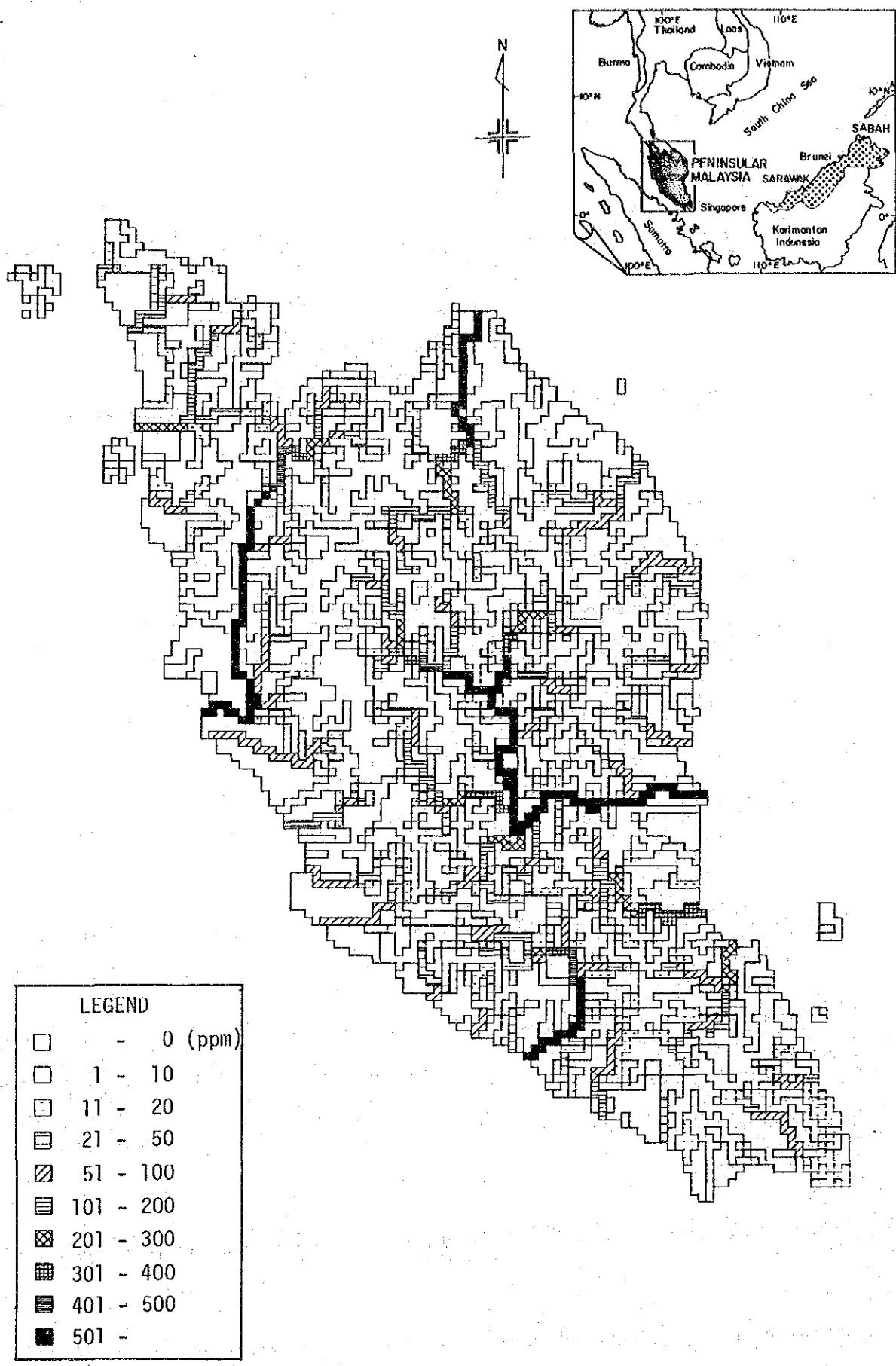
LEGEND

| | | |
|---|---|---|
| ☐ | – | 0 (ppm) |
| ☐ | 1 – | 10 |
| ☐ | 11 – | 20 |
| ☐ | 21 – | 50 |
| ▨ | 51 – | 100 |
| ▤ | 101 – | 200 |
| ☒ | 201 – | 300 |
| ▦ | 301 – | 400 |
| ▤ | 401 – | 500 |
| ■ | 501 – | |

Fig. 11    Change of Suspended Solid
           Concentration under Future
           Land Use Pattern

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# PART 2
# SABAH AND
# SARAWAK

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# 1. INTRODUCTION

The watershed management study has been carried out to evaluate the influence of development activities in the watershed region to the sediment yield and flow regime, and to make recommendation on the watershed management if necessary from the viewpoint of river management and water use.

## 2. OUTLINE OF FOREST IN SABAH AND SARAWAK

### 2.1 Present Situation of Forest Land in Sabah

#### 2.1.1 Forest resources in Sabah

According to the Forest Department of Sabah, forest resources as of 1980 total 39,300 $km^2$ corresponding to 53% of the whole territory, 74,400 $km^2$, of Sabah (Refs. 1 to 3). The "Report of the Forest Inventory" states that the total forest land in 1971/72 occupied 63,600 $km^2$ or 86% of the State's territory. Among the existing forest resources, undisturbed high forest has decreased from 45,200 $km^2$ in 1971/72 to 20,200 $km^2$ in 1980 as a result of logging activities which have gained more than half of the State's export earnings. The reminder of forest resources consists of montane forest, mangrove, transitional beach and freshwater swamp, and immature and disturbed forest. The composition of each forest type to the total forest area in 1978 is 47% for undisturbed high forest, 28% for immature and disturbed forest, 14% for montane forest, 7% for mangrove and 4% for transitional beach and freshwater swamp.

#### 2.1.2 Institutions in Sabah

The Government and statutory bodies concerned with forestry are composed of the State Forest Department, Sabah Foundation, Sabah Forestry Development Authority (SAFODA) and Sabah Marketing Corporation (SAMA) (Refs. 4 & 5).

The State Forestry Department has responsibilities for the management of forest reserves and forested State land. Its responsibilities cover licensing and renewal of forest activities, revenue collection from forest activities, research work, the scaling and grading of export logs, wildlife management, monitoring of all forest exploitations and so on. Under the Headquarter of State Forest Department, the Research Section conducts experimental and trial works on timber and pulp plantations, ecology/silviculture, botany, entomology and timber utilization. The forest land in Sabah is divided into three main regions, termed Forest Circles of Sandakan, Tawau and West Coast, each under the supervision of a Circle Forest Officer. These Forest Circles are sub-divided into 10 Forest Districts in total under the day-to-day administration of District Forest Officers.

The Sabah Foundation is undertaking timber exploitation in its concession area of 8,547 $km^2$ with a licence agreement for a period of 100 years. Timber operations are one of the Foundation's roles and play an important part in obtaining fund resource for provision of finance to its own educational, social, commercial and industrial activities. The Foundation also establishes joint ventures with local and foreign companies in wood processing and production.

SAFODA was established in 1976 and its main objectives are as follows (Ref. 6):

(a)  to convert waste lands to productive use,

(b)  to supplement timber production of the natural forests with
     timber coming from man-made forests,

(c)  to encourage the active participation of the rural people in
     reforestation work and provide mass employment, and

(d)  to uplifit the standard of living of the people through forest
     settlement scheme, and the introduction of forestry-oriented
     agricultural development schemes.

SAMA commenced operation of its Timber Marketing Unit from 1978.
The Unit carries out the export marketing of timber products in the EEC
countries, Australia, West Asia, Thailand, Hong Kong and USA on behalf of
private timber companies and the Sabah Foundation's joint venture enter-
prise.


2.1.3  Sabah's policy on forest conservation, utilization and development

The State Government officially fixed export quota over nine years
from 1977 for conservation of commercial natural forest resource in the
State. During 4MP period, the annual export quota is fixed at a volume
of $4.7 \times 10^6$ m$^3$.

The State Government encourages the Sabah Foundation to conduct
reforestation projects with its joint ventures over logged area of about
600 km$^2$. The State Government is practising a concept of agro-forestry
by planting of cocoa under the regenerating forest.

Execution of reafforestation and reforestation works throughout the
State has been programed through SAFODA in denuded land, grassland,
scrubland and forest land with fast growing species.


2.1.4  *Legal and administrative status of forest land in Sabah*

The Forest Department sets up a forest reserve for the management
of forest land in the State. Forest land in Sabah is categorized into
five classes from the viewpoint of forest utilization; i.e., Inland
Forest Reserves with Protection Forest as Class I reserve, Commercial
Forest as Class II reserve, Domestic Forest as Class III reserve and
Amenity Forest as Class IV: Mangrove Forest Reserves with Commercial/ .
Domestic Forest as Class V: Virgin Jungle Reserves: National Parks:
and Water Catchment. The distribution of each category alters continually
as new reserved are formed and old ones degazetted every year. The areal
distribution of Forest Reserves by the above category/class as of 1980
is as shown in Table 1. The total Forest Reserves cover an area of
38,755 km$^2$ or 99% of the total forest land and 52% of the whole area of
the State of Sabah. Some forests outside of the Forest Reserve scatter
in the State land.

## 2.1.5  Forest reserve allocated for exploration in Sabah

Among the categories set up for the Forest Reserve, the Class II Commercial Forest Reserves and the Class V Mangrove Forest Reserves as well as forest of the State land are available for logging.  Exploitation of forest in Sabah is done with the provision of concession or licence under the following three ways; Concession Agreement, Special Licence and Form I Licence.  As of 1980, there were 11 Concessions with the total licensed area of 12,665 km$^2$, 106 Special Licences for timber with the total licensed area of 10,805 km$^2$ and two Special Licences for mangrove with the total licensed area of 851 km$^2$.

## 2.2  Present Situation of Forest Land in Sarawak

### 2.2.1  Forest resources in Sarawak

Land use measurement by the Land and Survey Department of Sarawak indicates that forest resources reduced from 101,700 km$^2$ or 81% of the total land area, 124,400 km$^2$, in the early 1970's to 94,300 km$^2$ or 77% in 1979.  This decrease in forest resources in Sarawak is caused by logging activities.  However, the Forest Department of Sarawak has recently estimated that the existing forested area actually reduced to 82,800 km$^2$ in total as of 1980 on the basis of its preliminary studies using maps and other available data (Ref. 7).  The balance may show realities of shifting cultivation and illegal felling undertaken in virgin forest areas.  The forest areas in 1979 comprised 74,200 km$^2$ of hill forests, 3,700 km$^2$ of forest on sandy podosolic soil area, 11,700 km$^2$ of mixed swamp forest, 1,700 km$^2$ of mangrove swamp forest and 3,000 km$^2$ of other swamp forests.

### 2.2.2  Institutions in Sarawak

In Sarawak, the State Forest Department is responsible for overall forest management activities covering forest licensing and renewal, collection of royalty and export duty, management of gazetted forest areas, timber research works, operation of forest technical training school, wildlife protection and management, and establishment, development and management of national parks.

### 2.2.3  Sarawak's policy on forest conservation, utilization and development

According to 4MP of Sarawak, the State Government entrusts the Forest Department with the responsibility for implementation of the following State's policies towards forest resources in Sarawak (Ref. 8):

(a)  to conserve, expand and develop the forest resources for earning the maximum benefits to the State, and

(b)  to integrate the development of the forestry sector with other sectors of the State economy.

In order to achieve these two policies, the Forest Department of Sarawak would:

(a) enlarge the Permanent Forest Estate over forest land, not required for other forms of land development,

(b) plan for multiple use management for timber production and protection, recreation and wildlife sanctuaries, wherever possible,

(c) undertake reforestation and rehabilitation of denuded land and shifting cultivation areas,

(d) strengthen the protection of Forest Estates and Reserves against encroachment, and

(e) improve the institutional frame-work through upgrading professional and technical skills and increasing the manpower of the Department.


2.2.4 Legal and administrative status of forest land in Sarawak

The Forest Ordinance of Sarawak provides for three types of Permanent Forest; Forest Reserve, Protected Forests and Communal Forests. The main objectives in establishing Permanent Forests are to reserve permanently forest areas for the benefit of the present and future inhabitants of Sarawak.

The Forest Reserves are normally productive forests which are destined to be the principal permanent sources of the country's supplies of timber and other forest produce. In the Protected Forests, only the people of Sarawak are admitted to exercise their rights such as taking forest produce for their own domestic use, hunting and fishing, and pasturing cattle. The Communal Forests are constituted only where they are clearly the desire of settled communities to set aside a convenient area of woodland for provision of communities' domestic needs of forest produce. The area of Permanent Forest amounted to 31,700 $km^2$ in 1979 corresponding to 34% of the total forest land in Sarawak. This included 7,480 $km^2$ of the Forest Reserve, 23,920 $km^2$ of the Protected Forest and 300 $km^2$ of the Communal Forest. There exist five national parks occupying 700 $km^2$ in total. The remaining 61,900 $km^2$ is other forest lands which have not been gazetted as the Permanent Forest. The areal distribution of each category in the above is as shown by District in Table 2.


2.2.5 Forest reserve allocated for exploitation in Sarawak

At the end of 1979, there were 367 timber licences, comprising 88 long term licences, 190 annual licences and 89 short term licences. All the licences are requested to write the Management and Felling Plans for registration of their activities in each licensed area to the Forest Department of Sarawak. In 1979, the management plans area totaled 38,800

km$^2$ consisting of the Working Plans area of 23,500 km$^2$ in the Permanent Forest areas and the Felling Plans area of 15,300 km$^2$ in the other forest lands.

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